SEDIMENTOLOGY OF THE SNOWBLIND BAY FORMATION CORNWALLIS ISLAND, NORTHWEST TERRITORIES

by

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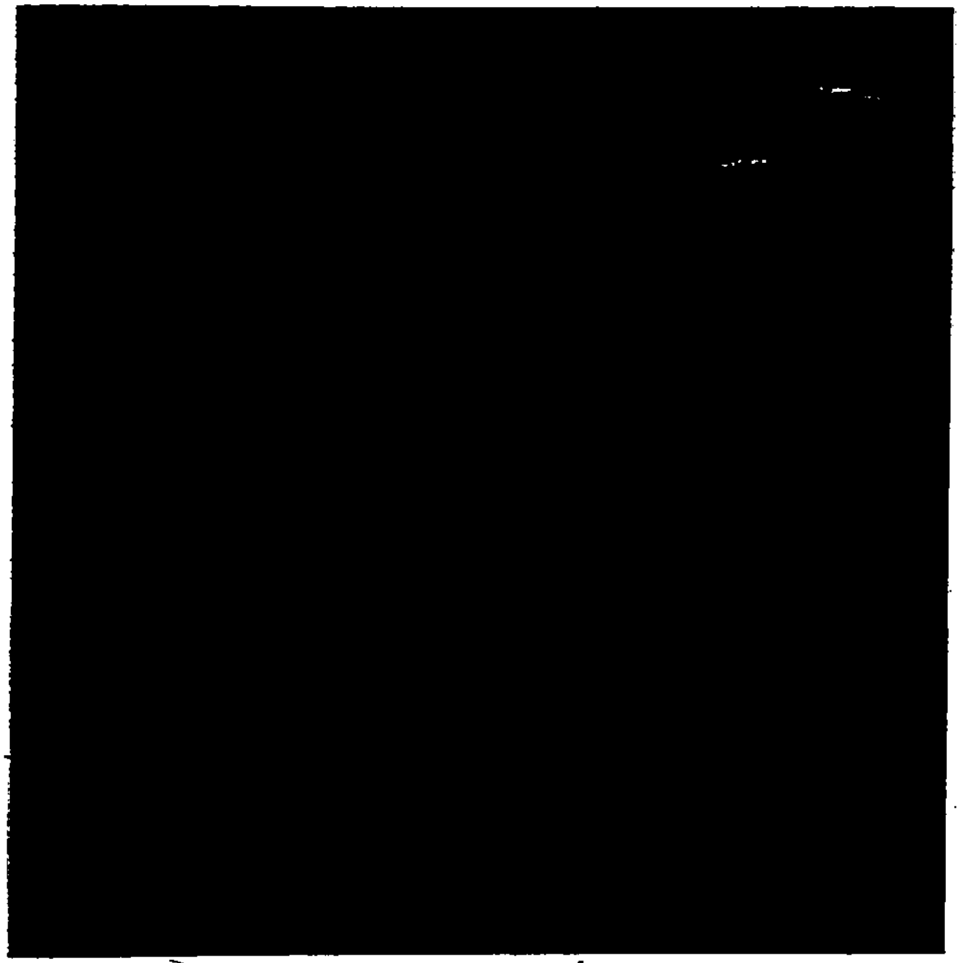

Frontispiece

View of the present erosional surface marking the top of the Snowblind Bay Formation, in the vicinity of section 03.

COLOURED PICTURES

ABSTRACT

During Late Silurian - Early Devonian time, vertical movement of the north-south trending Boothia Uplift affected regional sedimentation in the central Arctic Islands. Syn- and post-orogenic clastic wedges, which include the Peel Sound Formation (Prince of Wales Is., Somerset Is.), Prince Alfred Formation (Devon Is.) and Snowblind Bay Formation (Cornwallis Is.) were derived from the uplift and deposited in flanking basins.

The Snowblind Bay Formation (578 m thick) has been divided into three facies associations based on constituent lithologies, sedimentary structures and biota.

The capping conglomerate facies association (210 - 240 m thick) contains more than 90% horizontally bedded framework - supported conglomerates, which display good bed thickness: mean particle size correlation; clast grading at various scales; sheet-form geometry; and radiating sediment dispersal patterns. The depositional environment is interpreted as the mid-reaches of an alluvial fan complex.

The underlying conglomerate-sandstone facies association (120 - 300 m thick) contains 10 - 90% conglomerate. Lithofacies display sheet-form geometry and are arranged into two major types of fluvial cycles. The sand-dominated, sheet-braided

cycle (3.0 m thick) contains abundant erosional surfaces and trough cross-stratified sandstone units. The gravel-dominated, sheet flood cycle (3.7 m thick) formed from higher discharge, less confined braided stream flow. Paleocurrent directions are consistent with those determined in the conglomerate facies association and the overall decreased particle size, increased sandstone component, and decreased sedimentary unit thickness indicate a distal alluvial fan-braided stream environment.

The lower association is the fine-grained facies association (70 - 220 m thick) and contains less than 10% conglomerate. The noncyclic sequence shows evidence for an intertidal depositional environment, including a probable Skolithos ichnofauna, abundant soft sediment deformation structures, pinstripe bedding and rare resedimented conglomerate units. A nearshore mud flat facies assemblage can be grossly distinguished from a more offshore sand flat - tidal flat facies assemblage by the presence of terrestrial conglomerate units, scarcity of faunal elements, higher mud content, and relatively higher abundance of low energy bedforms and stratification. Geochemical evidence (Sr/Ca) reflects the progradational nature of the clastic wedge by indicating increased fresh water influence on the tidalite assemblage.

The Snowblind Bay Formation was derived from a north-northwest source, possibly from reactivated fault scarps that may have controlled the Ordovician - Silurian basin (Cape

Phillips Formation) to shelf (Allen Bay Formation, Read Bay Group) facies change in the Laura Lakes district.

The Snowblind Bay, Peel Sound, and Prince Alfred Formations are coarsening-upward coastal fan complexes which contain internal evidence that documents the episodic nature of the tectonic movement. Source - area climate for the Boothia Uplift clastic wedges was seasonally wet to semi-arid, based on the absence of calcrete and debris flow units, and the presence of fluvial cyclicity and sheet-like sedimentation units.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF ILLUSTRATIONS

Con't | Page

Con't		Page

Plates

Chapter I

INTRODUCTION

1.1 LOCATION AND ACCESS

The Snowblind Bay Formation outcrops along the central-east coast of Cornwallis Island, N.W.T. (Figs. 1,2). Exposures are principally restricted to the sea coast and stream gorges draining into Sophia Lake.

Logistic support was provided by the Polar Continental Shelf Project in Resolute, 65km southwest of the study area. The use of two Honda 90 all-terrain vehicles facilitated access to all exposures from a centrally located base camp near Sophia Lake.

1.2 GENERAL GEOLOGY

The geologic evolution of the Arctic Islands has been summarised by several authors including: Thorsteinsson and Tozer (1970); Churkin (1973); Drummond (1974); Herron, Dewey and Pitman (1974); Embry and Klovan (1976); Kerr (1977); Trettin and Balkwill (1979); and Christie (1980). The reader is referred to these papers for a more regional description of Canadian Arctic geology.

The study area is situated near the eastern boundary of the Boothia Uplift on the east coast of Cornwallis Island (Fig. 1).

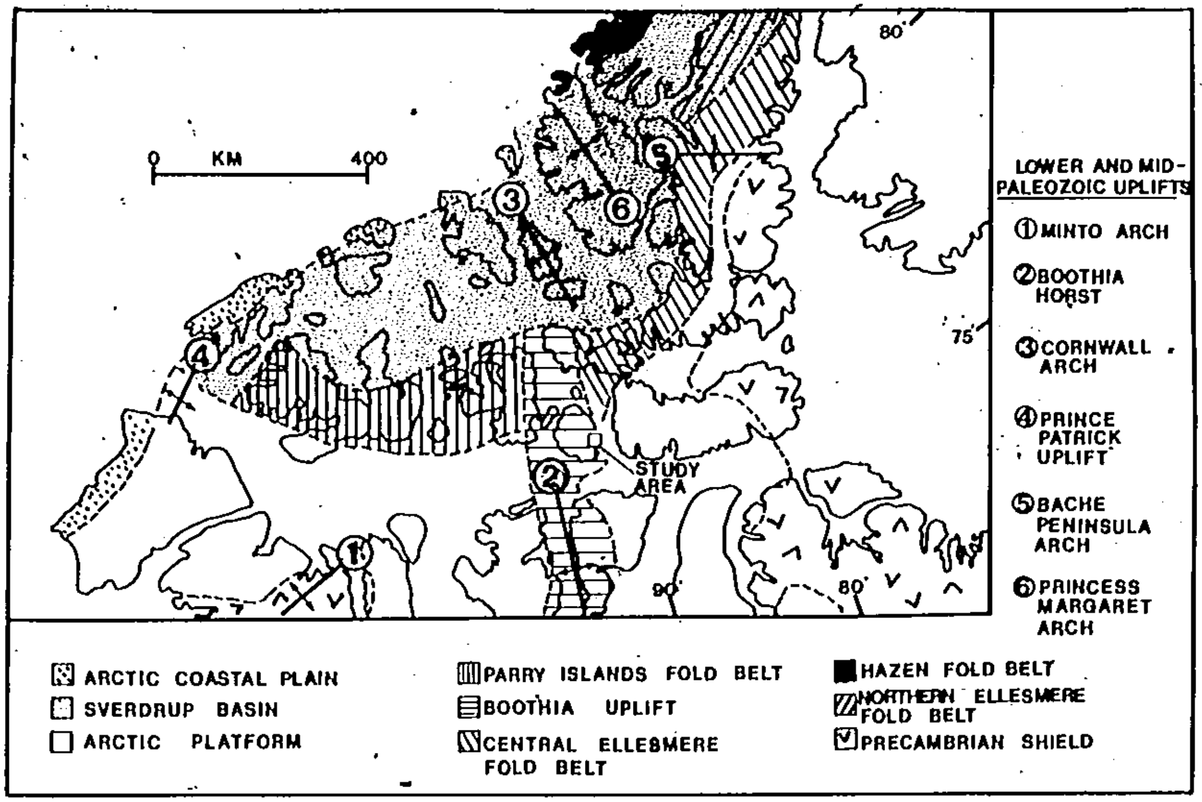

Fig. 1: Geologic provinces of the Canadian Arctic (modified after Trettin and Balkwill, 1979 and other maps).

The Boothia Uplift includes the following structural elements:

1. The Boothia Horst consists of Proterozoic igneous and metamorphic rocks which make up a basement structure that plunges north beneath younger parts of the uplift. The uplift itself extends across the Arctic Platform and geographically divides the Parry Islands and Central Ellesmere Fold Belts. The horst was periodically uplifted along north-trending near vertical basement faults, deforming the overlying strata. The basement structure consists of felsic and mafic gneisses, granitic rocks and minor ultramafic intrusions metamorphosed to the amphibolite to granulite grade (Brown et al., 1969). The horst was uplifted by deep-seated vertical forces, although the genesis of the structure is not fully understood (Kerr and Christie, 1965). Similar basement uplifts occur elsewhere in the Arctic (Fig. 1).
2. The Cornwallis Fold Belt represents the deformed overlying Paleozoic sedimentary cover affected by movement along basement structures in the Boothia Horst. The fold belt is a faulted anticlinorium more than 650 km long and up to 160 km wide (Kerr, 1977). Evidence of uplift and erosion of the Boothia Uplift is demonstrated by unconformities which occur within the Cornwallis Fold Belt and by the fact that the Boothia Uplift periodically provided a source of terrigenous clastic sediments.

3. Cretaceous to Tertiary Strata constitute the youngest cover rocks, unconformably overlying the Paleozoic and older rocks. The sediments are predominantly nonmarine and are preserved as small fault-bounded outliers which range in thickness from 60 to 310 m (Dineley and Rust, 1968; Brown et.al., 1969; Miall and Kerr 1977).

During Late Silurian - Early Devonian time, movement occurred along predominantly north-south trending structures in the Boothia Uplift. Kerr (1977) termed this event Pulse 2 of the Cornwallis Disturbance. Syn-orogenic and post-orogenic clastic wedges were derived from the exposed fold belt during the disturbance, and include the Peel Sound Fm. (Miall, 1969; Gibling, 1978), Prince Alfred Fm. (Morrow and Kerr, 1978; Thorsteinsson, 1980) and the Snowblind Bay Fm. (Thorsteinsson, 1958).

Kerr (1977) suggested that the horst consists of a number of subparallel blocks which moved upwards during each pulse. There is some evidence that the disturbance may have progressed northwards along the tectonic element (Gibling, 1978). However, precise ages cannot be assigned to these clastic wedges due to the scarity of biostratigraphic data (Gibling and Narbonne, 1977).

The Peel Sound Fm., Prince Alfred Fm., and Snowblind Bay Fm. will be compared in both stratigraphic and sedimentological contexts in Chapter 5.

1.3 DISTRIBUTION AND AGE OF THE SNOWBLIND BAY FORMATION

The Snowblind Bay Fm. outcrops on Cornwallis Island (Fig.2)

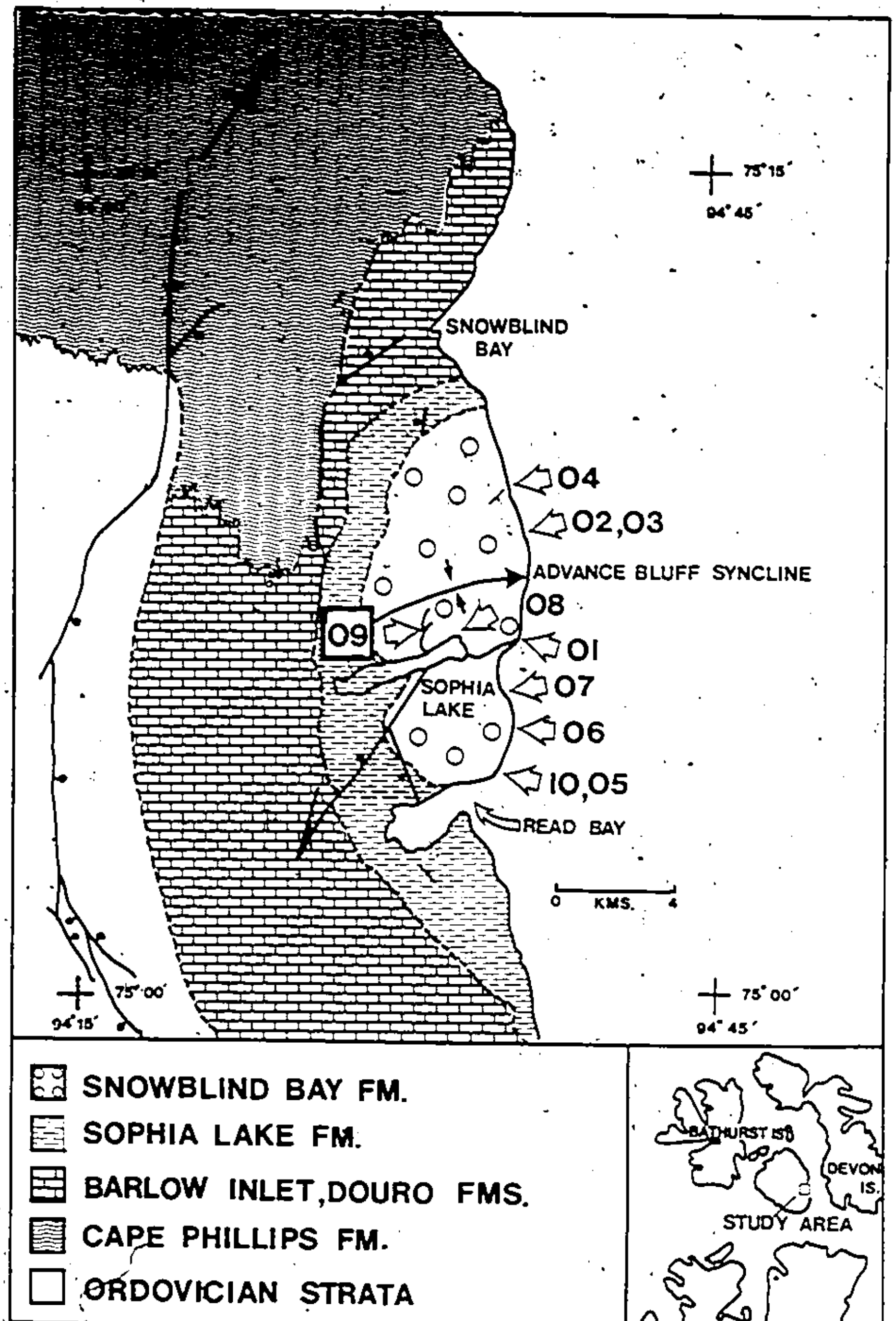

Fig.2: Simplified regional geology and location of study sections.
Solid dots on the downthrown sides of faults where direction of movement is known. Anticlines (diverging arrows) and synclines (converging arrows) plunge in the direction designated by larger arrows.

(Modified after Thorsteinsson, 1980 and Thorsteinsson and Kerr, 1968.)

and is named for a sequence consisting predominantly of conglomerate, sandstone and minor siltstone exposed between Snowblind Bay and Read Bay (Thorsteinsson, 1958).

The underlying Sophia Lake Fm. is an approximately 560 m thick sequence of planar-bedded limestones and dolostone with minor siltsone, sandstone and shale (Thorsteinsson, 1980). The lower contact is sharp and conformable with the Barlow Inlet Fm, as resistant, thick-bedded limestone units pass upwards into thin-bedded, less resistant, interbedded sandstone and impure limestone (Thorsteinsson, 1980). Low diversity of faunal elements (leperditicopid ostracodes, acanthodian scales, conodonts, heterostracan fragments) and sedimentological characteristics including desiccation cracks, vugs, and salt casts support an intertidal origin for the Sophia Lake Fm. (Gibling, 1978; Thorsteinsson, 1980). Thorsteinsson (1980) suggested that shallow water conditions may have prevailed for the upper half of the sequence. The Sophia Lake Fm. is Gedinnian in age, based on conodonts (Uyeno, 1980).

The base of the Snowblind Bay Fm. is established as the lowest conglomerate unit (Thorsteinsson, 1980) and is exposed only at Read Bay, where it conformably overlies the Sophia Lake Fm. Sections 10 and 05 represent the basal portion of the type section for the Snowblind Bay Fm. as established by Thorsteinsson (1958). The estimated thickness of the sequence preserved in the Advance Bluff Syncline is 578 m (Fig. 2,3). An unknown thickness of the uppermost beds has been removed by

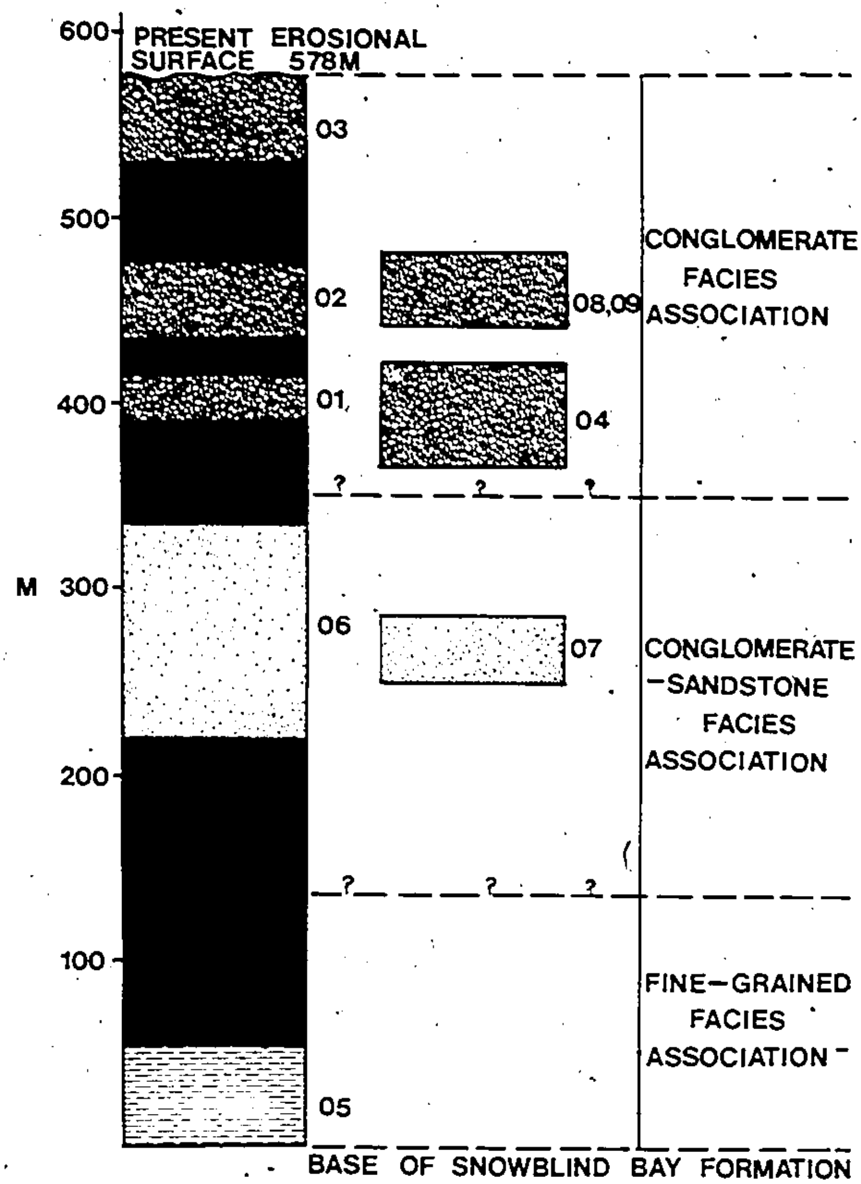

Fig. 3: Location of measured sections in the Snowblind Bay Fm. Section 10 represents the uppermost 13 m of the Sophia Lake Fm. Black areas indicate covered intervals.

erosion. The clastic wedge has been divided into three facies associations:

1. Fine-grained facies association (reference sections 10, 05 located at 75° 04'N, 93° 33'W)

2. Conglomerate-sandstone facies association (reference section 06 located at 75° 05'N, 93° 28'W)

3. Conglomerate facies association (reference sections 02, 03 located at 75° 08'N, 93° 28'W)

The sedimentological and paleogeographic significance of these three gross subdivisions will be discussed in the following chapters.

The age of the Snowblind Bay Fm., based on a pteraspidid fauna 25.3 m above the base of the type section, is Gedinnian (Thorsteinsson, 1980). A sample containing a well-preserved spore assemblage was obtained from a dolarenite unit in the conglomerate-sandstone facies association (section 07), approximately 275 m above the base. The sedimentology of this unit is discussed in Chapter 3. McGregor (pers.comm., 1981) identified rare acritarchs indicating marine influence at the site of deposition. Spores identified by Dr. D.C. McGregor include:

> Apiculatisporis sp., Apiculiretusispora? plicata, A. spicula, Cymbosporites senex, Dibolisporites n. sp., D. cf. D. echinaceus, Emphanisporites micrornatus, E. sp., Retusotriletes sp., Streelisporites Newportensis, Tholisporites chulus McGregor var. nanus

Although the assemblage is relatively low in species diversity, it is sufficient to indicate that the age is Lower Devonian, probably Siegenian (McGregor; pers.comm., 1981). It is therefore concluded that the age of the Snowblind Bay Fm. is Early Devonian (Gedinnian - Siegenian).

1.4 AIMS OF STUDY

A detailed sedimentological study of the Snowblind Bay Formation represents an extension of geologic studies of Upper Silurian - Lower Devonian strata in the Boothia Uplift by the University of Ottawa Geology Dept.

Regressive clastic wedges of the Peel Sound Fm. on Prince of Wales and the Somerset Island and Peel Sound Fms. on Somerset Island were examined by Miall (1969), and Gibling (1978), among others. Although Gibling (1978) and Thorsteinsson (1958, 1980) made cursory reconnaissance observations for the basal portion of the Snowblind Bay Fm., the sequence has not been studied in detail.

The main objectives of the project were: 1) systematic study of the sedimentology; 2) establishment of process-response relationships to source areas during tectonic uplift; 3) paleogeographic reconstructions and comparison with other regressive clastic wedges along the Boothia Uplift during the Late Silurian and Early Devonian.

1.5 METHODS

Field data were obtained from 10 detailed stratigraphic sections, and 27 paleocurrent stations. Units were measured on a graduated measuring rod to the nearest 0.1 m. Beds were described using a sedimentary unit card modified from that of the Geological Survey of Canada. The unit card offers the obvious advantage of rapid recording of observations represented by numerals. The numerals may be stored under specific types of observations which are keyed into a computer data bank. Not all data can be entered on a unit card, hence qualitative description is referenced by section number and unit number in a field notebook.

The unit card is broken down into five fields. Field 1 identifies the section number, lithofacies type, unit number and percentage of the unit exposed. A unit is a sedimentary package composed of one or more lithologies interpreted to reflect a particular depositional event. Each lithology is described by a separate unit card under Field 2 observations. These observations include: the number of lithologies within the unit; identification and lateral persistence of each specific lithology; lithology basal contact type; relative percentage of lithology in unit; sample (if taken); bedding mode, minimum and maximum thickness; internal stratification type; weathering style.

The distribution and spatial relationship of the composite lithologies were noted in a field book. Each lithology falls either into the clastic subfield or carbonate subfield of Field 3. In the clastic subfield, characters include detailed clastic lithology type; average grain size (or average framework clast size in a conglomerate); matrix grain size in a conglomerate; maximum apparent clast size (average 10 largest clasts); number of clast lithotypes (lithotypes and respective percentages estimated visually and entered in a field book);

sorting and rounding. The carbonate subfield was rarely applicable in the Snowblind Bay Fm. and corresponding units were described in a field book.

Field 4 refers to miscellaneous characteristics that require qualitative description including sedimentary structures, biogenic structures and fossils. Paleocurrent measurements were recorded under Field 5.

Computer printouts generated from these data include, where applicable: mean, minimum and maximum lithofacies thickness; mean clast size; proportions of lithofacies in each facies association, relative abundance of sedimentary structures, bedding style, clast lithotype etc., which permit a semi-quantitative appraisal of the depositional environments for the Snowblind Bay Fm.

These data were supplemented by sandstone petrography, paleocurrent analyses, and trace element geochemistry to construct a paleogeographic interpretation of the clastic wedge. The methods are described in relevant portions of the thesis.

1.6 GENERAL DESCRIPTION OF THE LITHOFACIES IN THE SNOWBLIND BAY FORMATION

Lithofacies refer to rock units with specific characteristics chosen to represent products of different environmental processes. Although a rock unit may bear a specific bedding style and suite of sedimentary structures, it can be formed by various processes in different environments (eg. horizontally laminated siltstone in fluvial overbank, lacustrine and intertidal depositional environments).

As a result, lithofacies are interpreted in terms of facies associations which are considered to be genetically or environmentally related. Lithofacies will be described in this context for the facies associations composing the Snowblind Bay Fm.

Each lithofacies is assigned a two-part code as described by Miall and Gibling (1978). All lithofacies are listed in Table 1.

1.7 ACKNOWLEDGEMENTS

I am particularly grateful to my thesis advisor, Dr. B.R. Rust, for initiating this project and for subsequent stimulating discussions on many aspects of clastic sedimentology. I would also like to thank Dr. O.A. Dixon, Dr. G. Narbonne, and J. Packard for constructive criticism on portions of this study and for their much needed expertise on Arctic logistics.

Dr. G. Narbonne kindly identified ichnofossils and Dr. D.C. McGregor listed spore elements from the Snowblind Bay Fm. Unpublished paleomagnetic data were obtained from P. Lapointe, Earth Physics Branch. Logistic support was provided by the Polar Continental Shelf Project; financial aid by Dept. of Indian and Northern Affairs, and the University of Ottawa Northern Research Group. Additional financial support

Table 1 Lithofacies observed in the Snowblind Bay Fm. (modified after Miall and Gibling, 1978)

C -	limestone
Cf -	silty dolostone
Fl -	laminated siltstone, fine-grained sandstone
Fm -	massive and/or mottled siltstone
Sh -	horizontally laminated sandstone
Sl -	low angle stratified sandstone
Sr -	rippled sandstone
St -	trough cross-stratified sandstone
Gm -	horizontally bedded, clast-supported conglomerate, commonly imbricate
Gt -	trough cross-bedded conglomerate
Gp -	planar cross-bedded conglomerate
ES -	laterally extensive (>50 m) erosional surfaces treated as lithofacies for purposes of Markov chain analysis

came from Dr. B.R. Rust (N.S.E.R.C. Grant) and an Ontario Graduate Scholarship awarded in 1980 - 81.

Sage advice from M. Jackson (administrative officer), the secretarial staff and my fellow graduate students was most appreciated. I am particularly indebted to B. Zaitlin, M. Wadleigh, and H. Majid who clarified many problems pertaining to the thesis.

Finally, I wish to thank L. Adams who typed the study; A. Muir for his friendship and able assistance on Cornwallis Island; and my wife, Nancy, whose enthusiastic support never failed during the course of the thesis.

Chapter II

CONGLOMERATE FACIES ASSOCIATION

2.1 INTRODUCTION

The conglomerate facies association contains more than 90% conglomerate lithofacies. Relative percentages and ranges in unit thicknesses for the major lithofacies are summarized in Fig. 4. Location of sections 01, 02, 03, 04, 08, 09 are given in Figs. 2, 3. The conglomerate facies association stratigraphically overlies its finer, distal equivalent (conglomerate-sandstone facies association; Chapt. 3). The minimum thickness for the assemblage ranges from 210 - 240 m. The present day erosional surface marks the top of the association and the Snowblind Bay Formation. The remainder of this chapter will provide evidence for alluvial fan deposition for lithofacies composing the conglomerate facies association.

2.2 STRATIFICATION

The conglomerate lithofacies are laterally extensive (>400 m; Pl.1, fig.1) with units displaying very little change in their sheet-like geometry.

Conglomerate lithofacies are separated into discrete units on the basis of differential weathering, usually reflecting grain size variations; vertical variations in clast size; and as

LITHOFACIES	%	UNIT THICKNESS (M)		
		MIN.	MEAN	MAX.
Gm, Gp	96.7	0.30	2.30	5.60
Sh	1.8	0.03	0.15	0.31
Sl, St	1.5	0.04	0.15	0.35
Sr	0.02	0.03	0.03	0.03
	100			

LITHOFACIES IN THE CONGLOMERATE FACIES ASSOCIATION

Fig. 4: Data taken from sections 01, 02, 03, 04, 08, 09. Gp lithofacies are minor (<1%) and change laterally into Gm lithofacies.

Gm-Sh 'couplet units' where horizontally laminated sandstone bodies were observed to cap the conglomerate units. Approximately 60% of all bed contacts observed in the conglomerate facies association are sharp and flat.

Horizontal stratification is predominant (Pl.1, fig.2; Pl.2) but in many cases it is poorly defined in the coarse conglomerate units. The lack of channels and cross-stratified units is indicative of relatively unconfined flow on the depositional surface (Sykes and Brand, 1976). Solitary Gp lithofacies (Table 1) changes laterally to Gm and represents bar edge avalanche deposits (Rust, 1979). These units are usually finer-grained conglomerates. The general lack of evidence for reworking and scouring demonstrates rapid aggradation rates (Miall, 1980), presumably from sheet floods which rarely deposit cross-stratified units (Allen, 1981). Sheet floods in modern alluvial fans are characterized by low bars and wide, shallow braided channels as streams emerge on to the fan surface downslope of the intersection point (Bull, 1977).

2.3 LITHOFACIES

Gm, Gp These two lithofacies are grouped together because Gp appears to be genetically related to bar development as minor (<1%) avalanche deposits. Gp wedges into Gm over a distance of less than 3 m (max. 10 m) oblique to the depositional slope and may be difficult to recognize in sections normal to the slope or in crudely bedded coarse conglomerates. Gm is the predominant conglomerate lithology and constitutes nearly 97% of the lithofacies observed in sections 01, 02, 03, 04, 08, 09. Individual units range in thickness from 0.3 m (Gp) to 5.6 m (Gm), but average 2.0 - 2.5 m (Gm). Basal contacts are predominantly planar, signifying that there is little local scouring of the depositional surface. The framework-supported conglomerates are generally well to crudely horizontally bedded.

Clasts average 5 - 10 cm in long axis, with maximum lengths approaching 50 cm in sections 08, 09 (Pl.3, fig.1). Approximately 350 imbrication measurements taken at nine stations (Appendix 3) show that the average clast AB plane dips at 25° - 30°, with the A axis subparallel to AB strike (Pl.3, fig.2). This is a characteristic fabric of alluvial conglomerates. Imbrication is poorly defined in some units, which may be in part due to the orientation of the cliff exposures, the spheroidal nature of the clasts or general horizontal to shallow imbricate orientation of the clasts. Shallow dip of imbricate pebbles may be caused by very shallow flow although this remains to be verified (Rust, pers.comm., 1981). Paleocurrent studies in the conglomerate facies association reveal a radiating dispersal pattern which points to a source in the north, northwest (Fig. 5). This illustration may support other evidence that the conglomerate facies association was deposited in an alluvial fan environment.

The conglomerates are polymodal and consist of four extraformational clast lithotypes: chert (subangular),

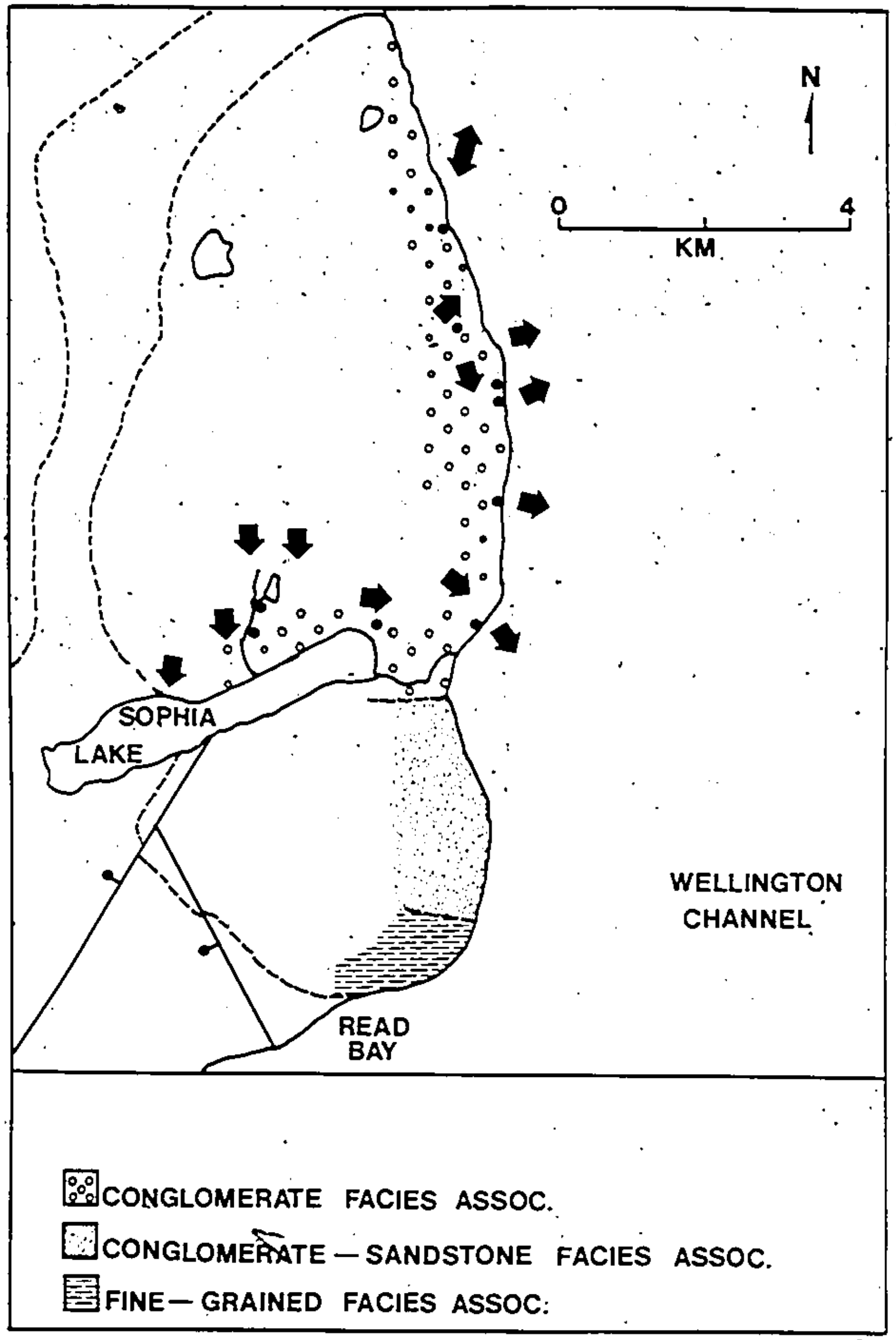

Fig. 5: Paleocurrent directions in the conglomerate facies association. Each arrow represents a mean paleocurrent direction at a specific station. The paleocurrent data are provided in Appendix 3.

limestone (subrounded), dolostone (subrounded) and siltstone (subrounded-subangular). Intraformational siltstone clasts could be identified where they outlined scours (Pl.4, fig.2) or showed little evidence of abrasion (e.g. desiccated, angular Fl clasts). Siltstone clasts were not differentiated on the basis of an extraformational or intraformational origin during clast lithotype counts. Fig. 6 summarizes the distribution of clast lithotypes in the conglomerate and conglomerate-sandstone facies associations. Chert clast content shows a weak antithetic relationship with the siltstone clast content. Thorsteinsson (1980), suggested that erosion of the uplifted Cape Phillips Fm., presently exposed to the north and northwest of the Snowblind Bay Fm., provided most of the chert clasts. Several siltstone clasts containing Monograptus sp., including one found in situ in section 03, unit 003, were presumably derived from the graptolitic calcareous siltstones of the Cape Phillips Fm. (Thorsteinsson, 1980). Silicified fossil debris, primarily consisting of Favosites sp. 'heads' (Pl.4, fig.1), stromatoporoid and crinoid fragments, constitutes only trace amounts of the conglomerate clasts. The probable source is the carbonate lithologies of the Barlow Inlet Fm.

The conglomerate matrix is very poorly sorted (medium-grained sand to granules) and the paucity of silt and clay grains may reflect effective winnowing and removal of fines by sheet flow. Quartz (35%) and feldspars (10%) represent significant components of the matrix but were not observed as

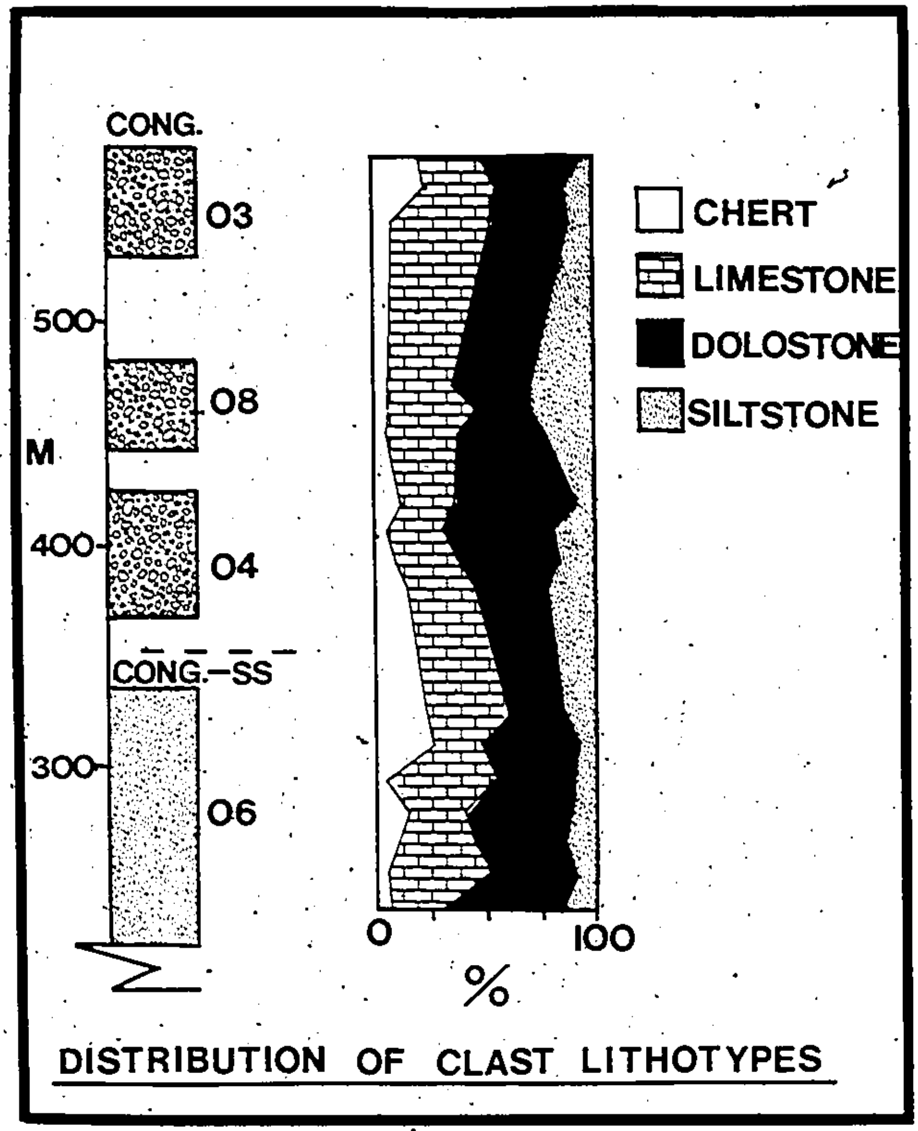

Fig. 6: Note weak antithetic relationship between chert and siltstone clast content.

discrete clast lithotypes. Quartz and feldspar grains are probably multi-cyclic in origin, derived from the pre-existing quartzose siltstones of the Sophia Lake Fm., Cape Phillips Fm., and lower Snowblind Bay Fm. Although there are no apparent sources in the carbonate platform sediments exposed on Cornwallis Island, the primary source for the siliciclastic detritus was probably the uplifted Boothia Horst that was exposed in the vicinity of Somerset Island. Thorsteinsson (1980) observed that the quartz content in the Sophia Lake Fm. increased southwards towards the Boothia Horst.

Bed thickness and maximum clast size data display positive correlation, particularly in the coarser units of sections 08, 09 (Figs 7, 8). This implies little or no erosion of tops prior to deposition. Fining-upward (FU) and coarsening-upward then fining-upward (CUFU) trends based on clast size variations were frequently observed (Pl.2, 5, 6) in the conglomerate units.

Sh, Sl, St, Sr

Thin lenses of sandstone averaging 0.1 - 0.2 m in thickness are discontinuous along depositional strike for more than 400 m, however individual lenses rarely extend beyond 10 m. Basal contacts are planar, sharp and frequently gradational with the subjacent conglomerate units. Primary current lineation (Pl.7, fig.1), intraclasts and rare tool marks in Sh, Sl denote upper flow regime conditions. Lateral transitions in the sandstone lithofacies are primarily Sh → Sl, representing upper flow regime conditions transitional from a flat depositional surface

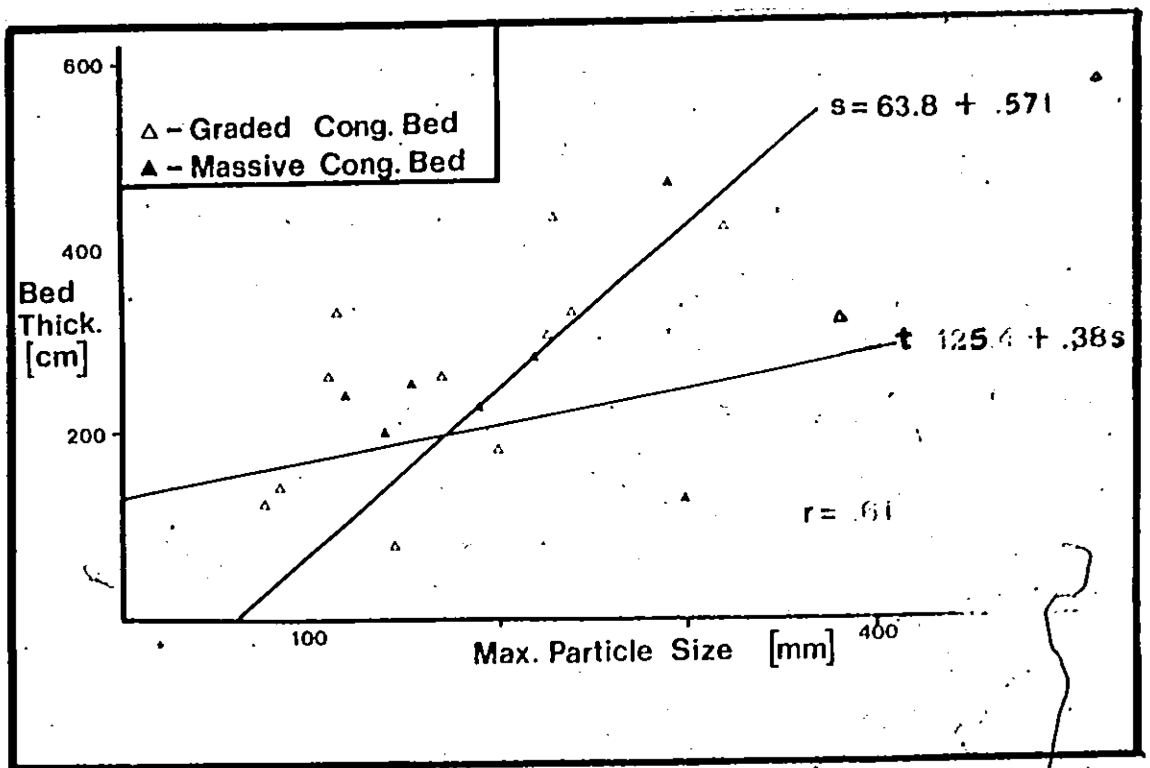

Fig. 7: Data on bed thickness and maximum particle size in the conglomerate facies association - sections 08, 09. t = bed thickness, s = maximum particle size, r = correlation coefficient. Units are interpreted to have been deposited just downslope from the fan intersection point. Bed thickness and maximum particle size data are provided in Appendix 4.

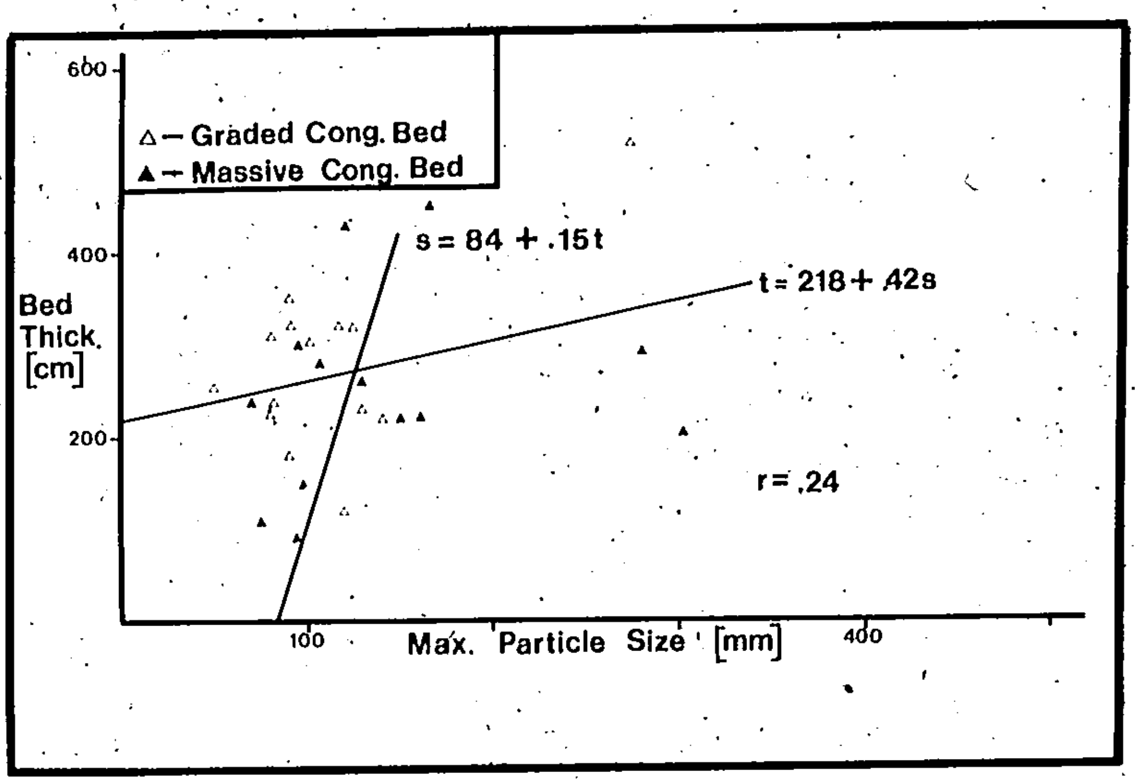

Fig. 8: Data on bed thickness and maximum particle size in the conglomerate facies association - sections 03, 04. t = bed thickness, s = maximum particle size, r = correlation coefficient. Poor correlation (as compared to Fig. 7) may be attributed to recording bed thicknesses of composite units as a result of several episodes of flow. Bed thickness and maximum particle size data are provided in Appendix 4.

into low-relief scours (Rust, 1979). St is locally present where scour relief was sufficiently great (10 - 15 cm) to permit dune formation, but cross-stratified sandstone units are rare (St lithofacies < 1%).

Fine-grained Sr caps Sh, Sl and there is normal grading in most units which display the vertical transition, reflecting waning current flow.

2.4 VERTICAL DISTRIBUTION OF LITHOFACIES AND DEPOSITIONAL ENVIRONMENT

The paucity of channel-fill structures, cross-stratified units and erosional basal contacts may be explained by relatively unconfined flow. Laterally extensive clast-supported conglomerate units are frequently capped by thin, moderately sorted Sh, Sl lithofacies (Fig. 9). Each Gm-Sh couplet is interpreted to have been deposited by a major flood episode, probably as sediment-charged sheet flow (very shallow braided channels), using the following criteria:

1. Regular, sheet-like geometry of the conglomerate units with only minor shallow scouring of the underlying lithofacies. Fabric was formed by fluvial traction currents.
2. Common gradational contact of Sh, Sl lenses with the underlying Gm unit, indicating a continuous depositional process (Wilson, 1980)
3. Occurrence of grading in the conglomerate units (CUFU,

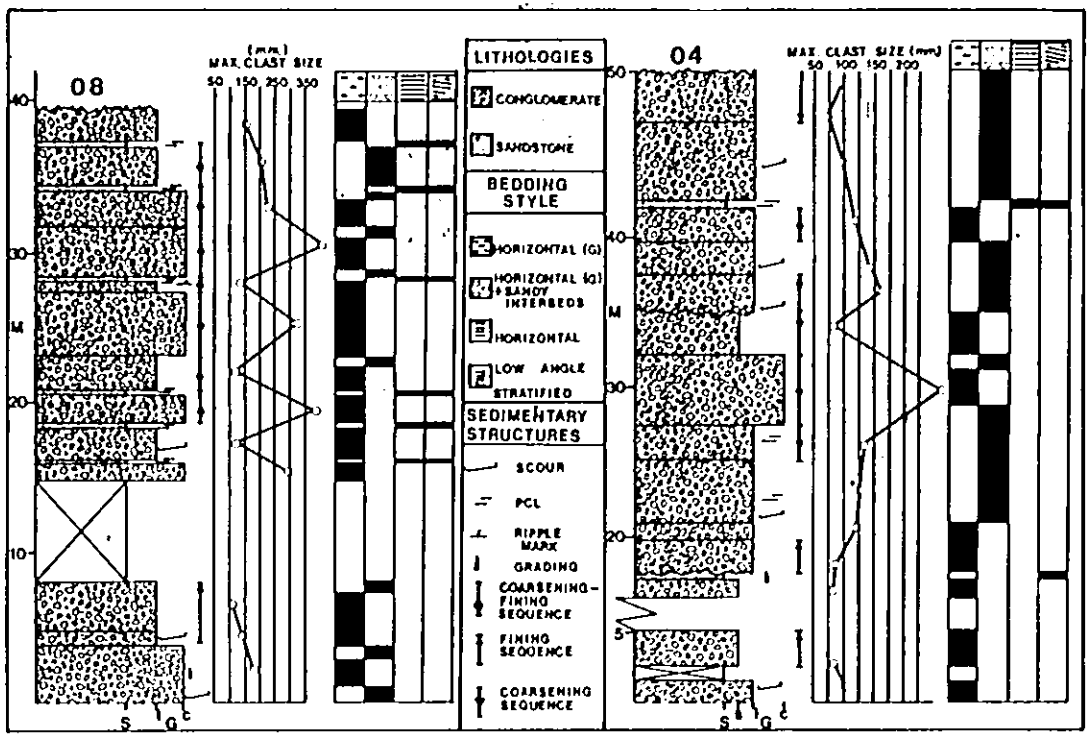

Fig. 9: Detailed sections 08, 04 in the conglomerate facies association. Column width reflects grain size. S = sand; G - gravel, s = small pebble, l = large pebble, c - cobble, PCL = primary current lineation.

FU trends) and minor normal grading in the overlying Sh, Sl beds; suggestive of waning flood conditions (Pl.7, fig.2).

4. Significant positive correlation between the maximum particle size and bed thickness in sections 08, 09. According to Bluck (1967), this correlation records a direct relationship between competency and discharge.

During the waning stages of the flood episodes, increasingly finer fractions of the gravel were 'frozen', no longer entrained by the weaker currents (FU). At this time suspended sand and fines were carried downstream, but as the competency of the flood waters decreased by infiltration, widening and shallowing of waning sheet floods down the depositional slope, sand was deposited under upper flow regime conditions. The final stage in the flood episode was under lower flow régime conditions, in which rippled sandstone and thin (<1 cm) mud drapes were deposited. However the sand and mud facies have low preservation potential in these cycles.

Waxing then waning flood conditions and/or lateral shifting of the locus of maximum discharge (i.e. the point where entrenched channels emerge onto the fan surface) could result in a CUFU cycle.

The conglomerate beds are multistory units representing coalesced longitudinal bars and diffuse gravel sheets. Rust (1978) suggested that the low ratio of water depth to mean particle diameter suppresses development of slip faces and hence accumulation of facies Gp. Evidence for bar-edge deposits was rarely observed in the Snowblind Bay Fm.

Positive correlation between the bed thickness and maximum particle size is obtained irrespective of the type of grading in the units (Figs. 7, 8). Beds are approximately 12 times thicker than their maximum particle size in sections 08, 09. However downslope trends indicate the beds diminish in thickness at a much lesser rate than their corresponding maximum particle sizes. Bed thicknesses are 22 times their maximum clast size at sections 03, 04 and 32 times their maximum clast size in section 06 of the conglomerate-sandstone facies association. Nemac et al., (1980) stated that any decrease in flow capacity will probably take place less rapidly than the accompanying drop in competence. This is probably the case for sheet floods, as flow shallows and widens from entrenched source stream channels on the fan complex. It is also likely that bed thickness is an overestimate of current capacity. Flood episodes were flashy and episodic in nature and may have been closely spaced. In some cases, the measured bed thickness could represent a composite of several episodes of flow (Larsen and Steel, 1978).

A thick conglomerate unit in section 09 (Pl.8) is interpreted as a surge deposit, possibly in a fanhead entrenchment environment. Lateral berms or terraces were constructed by flood surges of the Rubicon River in the head canyon feeder (Scott and Gravlee, 1968). These terraces were observed to be as much as 8 m above the channel thalweg.

Coarsening-upward cycles were attributed by Scott and Gravlee (1968) to possible dispersive stresses forcing larges particles to the surface. Differences in surge velocity of tractionally moved particles may account for stranding of the entrained boulders as they were bypassed by the surge peak. Although in Plate 8 there is no CU trend, it is evident that there is a parallel alignment of the apparent long axes of the largest clasts (0.4 - 0.6 m). The lower unit contact is sharp and parallel stratification is well-defined. The largest clasts were presumably oriented with their maximum projection planes normal to dispersive pressure by impacts of smaller clasts (Lewis et al., 1980). The clast concentrations which define the stratification possibly represent amalgamated beds deposited by periodic surges. Entrained bed load layers froze as clasts interlocked. The high concentration of debris would also serve to create a clast support mechanism as excess porefluid pressures were created (Lewis et al., 1980). Fluid pressure exerted by water and debris finer than the largest clasts carried, would be sustained because of the weight of the overlying debris.

Debris flow environments are optimized by the following conditions (Bull, 1972):

1. steep slopes and insufficient vegetation.
2. source rocks which weather to produce a substantial proportion of fine debris.
3. intensive rainfall at irregular intervals.

It may be that some of these conditions were absent during Snowblind Bay deposition, or debris flow deposits were removed by subsequent erosional episodes. The possibility that some of Bull's conditions were not operative during deposition is discussed in the paleogeographic reconstruction of the Snowblind Bay Fm. in Chapt. 5.

Two minor Fl units (0.7 m, 0.8 m thick) were observed in the lower portion of section 02. The beds are laterally extensive but thin northwards between sandwiching Gm lithofacies over a distance of 300 m. Both units consist of alternating, very thinly bedded green and red siltstone. The red siltstone is dominant towards the tops of both beds. Sedimentary structures include: raindrop impressions?, halite casts, mudcracks, normal grading on a 1.0 cm scale, minor rippled horizons, and thin mudstone breccias. The alternation of dark and light hues reflects periodic changes in water chemistry as the water level fluctuated (Van Dijk et al., 1978). The absence of faunal elements, unusual thickness, common evidence of emergence, good lateral continuity and stratigraphic bounding by terrestrial sheet flood deposits suggests an ephemeral lake depositional environment based on other studies (Bartow, 1978; Collinson, 1978; Van Dijk et al., 1978).

Shallow topographic lows on the inactive portions of the fan or areas between active prograding fan lobe toes are possible areas of accumulation. Preservation of ephemeral lacustrine deposits would be favoured on a low gradient slope.

In summary, the conglomerate facies association was deposited in an alluvial fan environment. Depositional processes were largely related to sheet flood cycles, with only minor scouring and channelized aggradation.

It will be shown in the following chapters how the intensity of the sheet floods influenced the style of deposition in both the conglomerate-sandstone facies association and fine-grained facies association.

2.5 NATURE OF CYCLIC SEDIMENTATION

Cyclicity in the conglomerate facies association may be a response to allocyclic and/or autocyclic controls. Allocyclic controls are represented by variations in discharge, load and slope caused by climatic or tectonic processes outside the sedimentary basin (Miall, 1980). Autocyclic mechanisms operate as processes originating within the fan complex (Rust, 1979).

Cyclicity will be discussed in terms defined by Heward (1978a).

1. cycle is an arrangement of related beds (1-6 m thick).
2. sequence is an arrangement of related cycles (10-30 m thick).
3. megasequence is an arrangement of related sequences (10's-100's m thick)

The cyclic nature of the sheet floods was discussed in the previous section. They are postulated to be entirely autocyclic in origin. Grouped cycles are superimposed on a large scale to constitute 7 - 30 m (avg. 10 - 15 m) thick CUFU sequences

(Fig. 9). These are attributed to fault movement which triggered periods of increased mass movement (CU as proximal deposits prograded across more distal deposits) by oversteepening slope profiles. The stability threshold was exceeded by sediment buildup at the fan apex (Heward, 1978a), and the resulting steep slopes and tectonic activity could have flushed large volumes of water and sediment downfan. The fining-upwards portion of the sequence reflects a return to equilibrum between fault movements (Daily et al., 1980). The CUFU or FU sequences may also have documented the shifting of small fans to more stable topographic lows on the fan complex surface. However the scale of the CUFU complex sequence (10 - 30 m) suggests that an allocyclic mechanism is more likely responsible for the stacked arrangement of cycles. The alternating coarse and fine CUFU cycles in section 08 (Fig. 9) may result from rapid fan lobe migration on the upper reaches of the fan complex. Bowman (1978) stated that local depositional lobes are commonly formed at the intersection points of modern alluvial fans. The embryonic fans shift laterally and downfan without migrating significantly beyond mid-fan. These lobe-like features are localized at the exits of gullies as a result of severe floods, and subsequent migration would be reflected in alternating fine and coarse flood cycles. Both sections 08 and 09 are proximal to a fan head entrenchment environment, but the geometry of these confined channels cannot be ascertained due to the lack of exposure.

Section 09 is a 30 m coarsening-upward sequence demonstrating increased energy conditions during depositon. Progradation of the fan lobe may have resulted in an asymmetrical coarsening-upward sequence. A 6 m thick Gm unit interpreted as a fanhead surge deposit caps the section. The present erosional surface marks the top of the sequence.

The sediments of the fine-grained, conglomerate-sandstone, and overlying conglomerate facies associations constitute a CU megasequence. This is substantiated by the following observations:

1. mean unit thickness and maximum particle size is greatest in the conglomerate facies association
2. sandstone and siltstone lithologies constitute less than 5% of all observed lithofacies in the conglomerate facies association.

'Nested' CUFU sequences and related cycles record the progradation of fan lobes as the alluvial fan complex built outward over its equivalents. These depositional events document the overall increasing rate of tectonic uplift as sediments of the Snowblind Bay Fm. formed a regressive clastic wedge.

In summary, the three cycle orders observed in the Snowblind Bay Fm. are:

1. cycle - autocyclic
2. sequence - allocyclic; individual fault movements
3. megasequence - allocyclic; major uplift

Cyclicity in alluvial fan deposits has been reported elsewhere in the literature. The Devonian Hornelen basin is a small (50 x 20 km) late orogenic basin in Norway containing a succession of sandstone and conglomerate lithofacies. The succession is nearly 25 km thick and is organized into 200 basinwide CU cyclothems, each in the order of 150 m thickness (Steel and Aasheim, 1978). Steel and Aasheim (1978) interpreted each cyclothem as a response to episodes of basin floor subsidence as proximal deposits came to be deposited above their distal equivalents.

The term 'cyclothem' is used in the same connotation as 'megasequence' for the Snowblind Bay, i.e. an arrangement of cycles and sequences (10's - 100's m) controlled by allocyclic processes associated with major uplift and/or basin subsidence. The poorly exposed conglomeratic proximal deposits are frequently observed as conglomerate-sandstone 'couplets' (1 - 6 m). These flood units (Steel and Aasheim, 1978) are similar to the Gm - Sh flood cycles observed in the conglomerate facies association in the Snowblind Bay Fm. The conglomeratic proximal deposits do not appear to be organized into sequences. However the proximal sandy alluvium (downslope of the cong. proximal deposits) display CU units (10 - 22 m) which are approximately the same order of scale as the CUFU sequences observed in the Snowblind Bay Fm. The CU sequences indicate inadequate time for the uplifted source to be worn down and the fan returned to equilibuium (Rust, 1979). Steel and Aasheim (1978) suggested that the coarsening-upwards nature of the sequence documented the rapid abandonment of fan lobes in the proximal reaches of the fan complex. They may also represent truncated sequences by means of tectonic rejuvenation of the source and intraformational erosion of the proximal fan sediments.

Local debris-flow dominated fanglomerates flank the margins of the Hornelen Basin. Unlike the proximal conglomeratic basinal deposits, these fans are arranged in 10 to 25 m CU sequences. The subcycles were attributed to the recurrence of rapid faulting at the basin margin followed by fan progradation (Steel and Aasheim, 1978).

Thus, the alluvial fan deposits in both the Snowblind Bay Fm., and in the Hornelen Basin are the result of repeated source area rejuvenation by faulting. The cyclic sediments record the history of uplift and erosion of the adjacent highlands.

Plate 1

Fig.1. Laterally extensive (>120 m) conglomerate lithofacies in the conglomerate facies association. The cliff section (03) is approximately 40 m high.

Fig. 2. Horizontal stratification in conglomerate units at section 02. Thin (0.2 - 0.5 m), dark, recessive Fl units are less abundant towards the top of the section. Vertical section is approximately 40 m high.


1

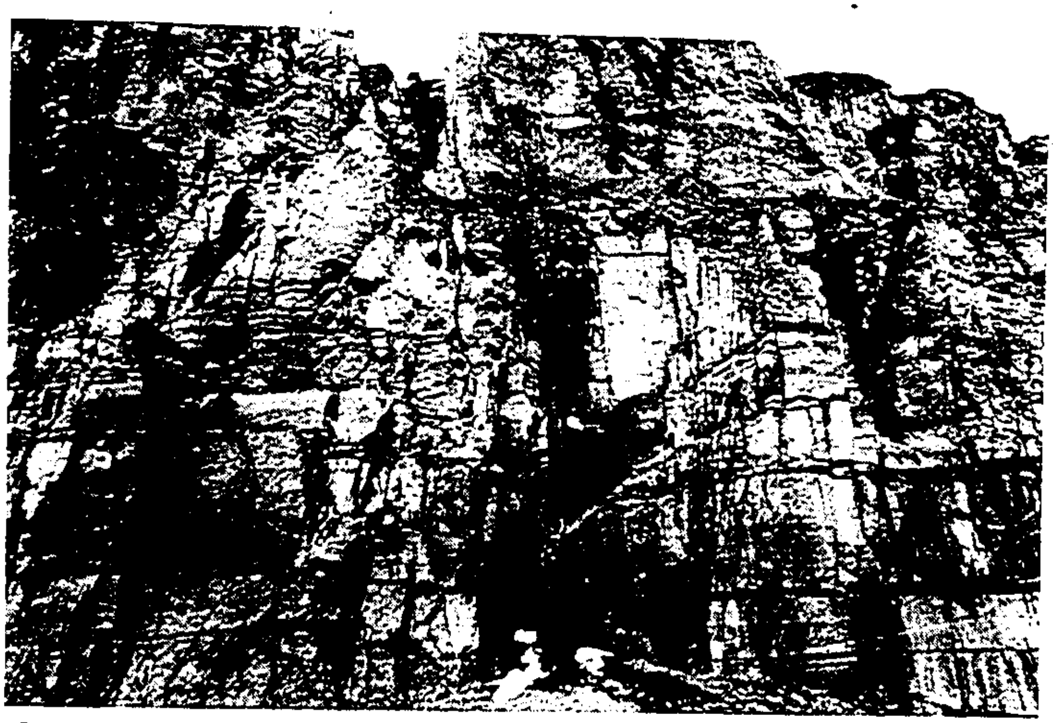
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Plate 2

Horizontally stratified Gm units. The basal unit adjacent to figure (1.9 m) displays a weak CUFU trend for clast size. Fl units (dark, recessive units) pinch out to the right of the photograph (northwards). Exposure is approximately 500 m south of section 02.

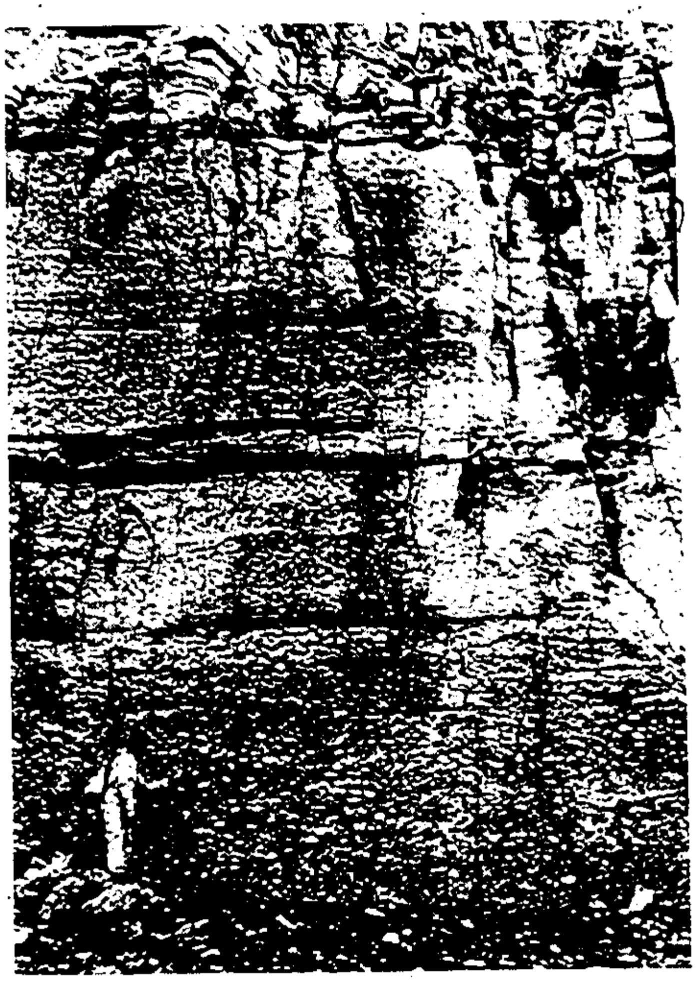


Plate 3

Fig. 1. Maximimum clast size observed in the conglomerate facies association (section 09; unit 010). Scale is in decimeters.

Fig. 2. Imbricated clasts (20° - 30°) in Gm unit at section 03. Note low angle cross-stratification in overlying Sp/Sl unit. Lens cap diameter is 6 cm.


1


2

Plate 4

Fig. 1. Well-rounded, silicified favositid 'head' probably derived from the Barlow Inlet Fm. Scale is 15 cm; location at top of section 03.

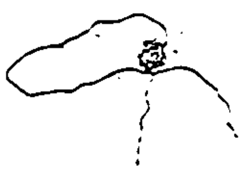
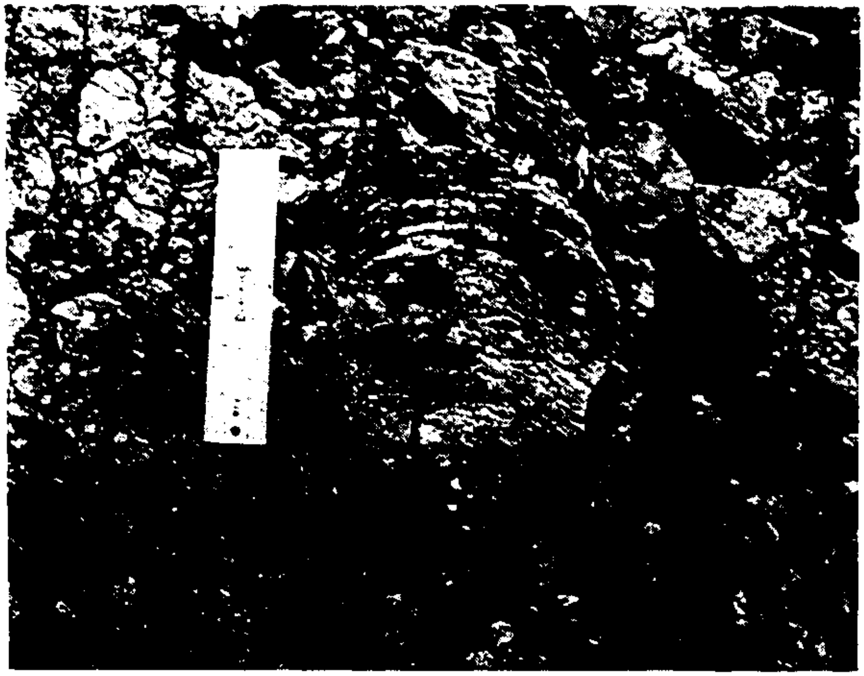


Fig. 2. Intraclasts of the Fl facies derived from the erosion of cohesive ephemeral lake deposits in the conglomerate facies association (section 02; unit 008). Hammer handle is 25 cm long.



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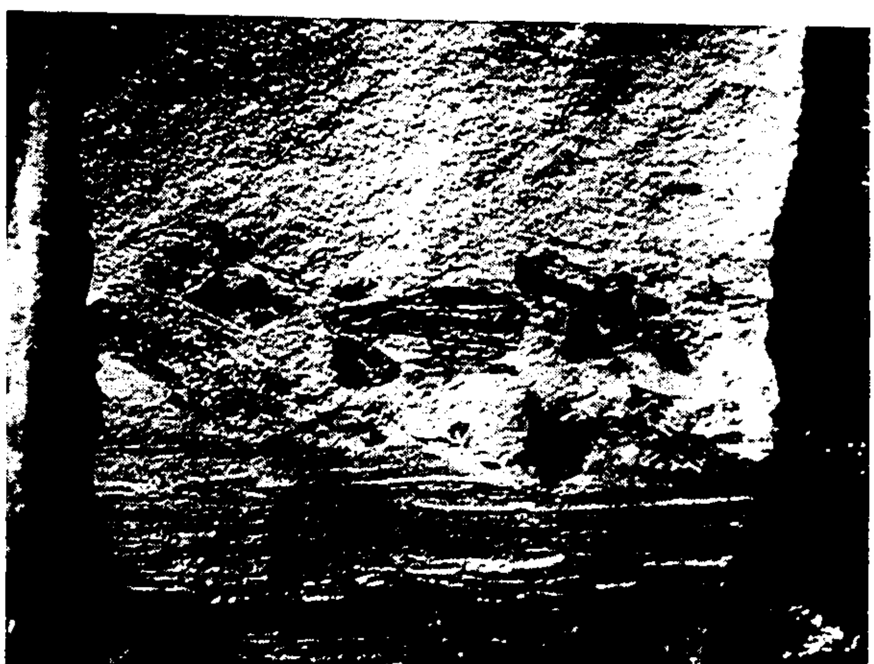

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Plate 5

Gm unit displaying CUFU clast size trend and capped by a thin discontinuous Sh unit. Rifle is 1 m long. Exposure is located approximately 800 m south of section 02.

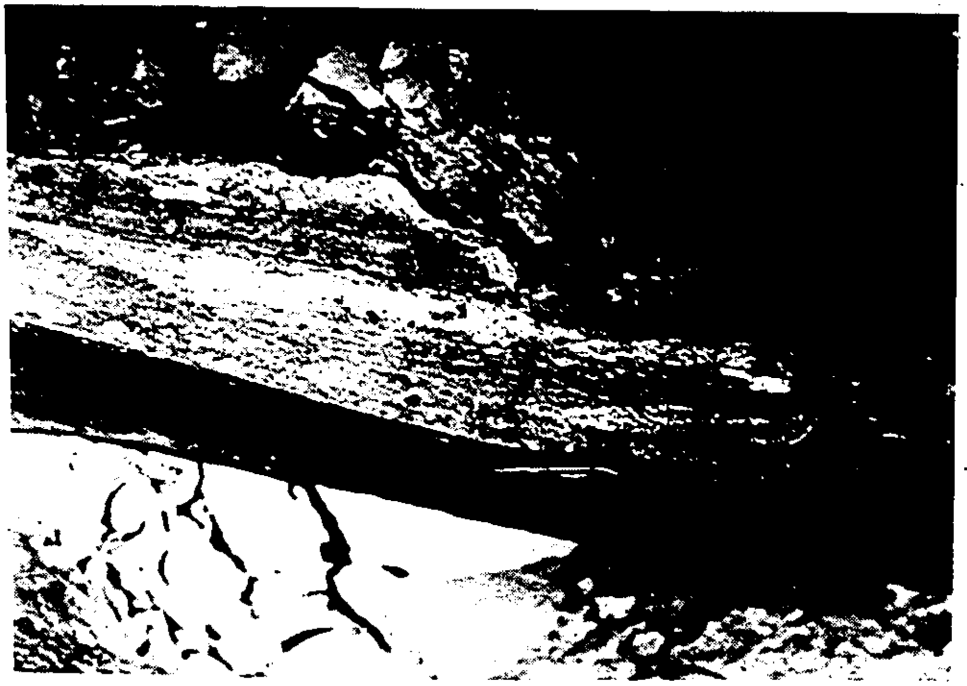
Plate 6

CUFU clast size trend in Gm unit. The conglomerate lithology is capped sharply by a Sh unit. Figure is 1.7 m tall. Location at section 02; unit 004.

Plate 7

Fig. 1. Pebbly Sl/Sh unit showing primary current lineation (PCL) parallel to the ruler (15 cm). Note vertical transition from Sl to Sh. Location at section 04; unit 022.

Fig. 2. Gradational basal contact of Sh unit overlying an imbricate Gm unit. Note normal grading in the sandstone unit. Scale is 15 cm. Location is approximately 500 m south of section 02.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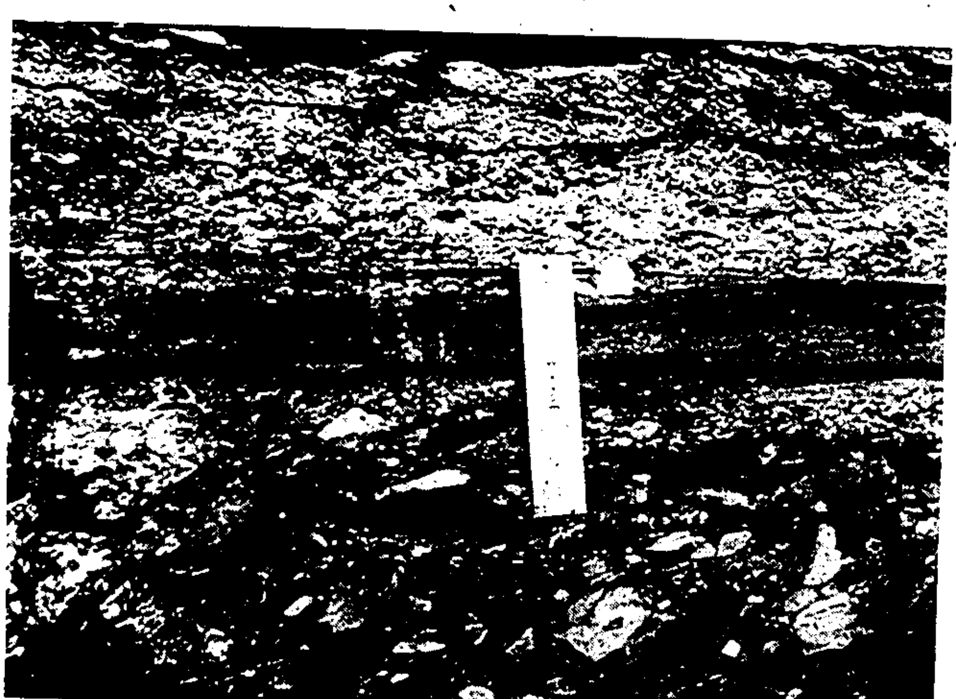
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Plate 8

Scale (1.5 m) marks a coarse imbricate Gm unit which underlies a Gm surge deposit capping section 09. Note bimodal distribution of clast sizes, parallel stratification and parallel alignment of apparent long axes for the largest clasts (0.4 - 0.6 m) in the surge deposit. (see text for explanation)

Chapter III

CONGLOMERATE-SANDSTONE FACIES ASSOCIATION

INTRODUCTION

This facies association includes all sequences which contain 10 - 90% conglomerate. The lithofacies of the conglomerate-sandstone facies association display sheet-form geometry and were measured in sections 06 and 07 (Fig. 2). Markov chain analysis shows that the suite of rocks is a product of cyclic fluvial processes (see 3.4). Fig. 10 summarizes the relative proportions of the constituent lithofacies and their respective thicknesses. The distribution of sedimentary structures, lithologies, and stratification types for section 06 is illustrated in Fig. 11.

The assemblage stratigraphically overlies the fine-grained facies association and is subjacent to the conglomerate facies association. Total thickness ranges from approximately 120 m to 300 m. Covered intervals prevent a more precise estimate. Fig. 11 displays an upward increase in coarse-grained lithologies (sandstone, conglomerate), decrease in fine-grained lithologies (siltstone, mudstone) and weak trend towards an increasing proportion of high energy over low energy bedforms. This indicates an overall coarsening-upwards trend for the conglomerate-sandstone facies association.

LITHOFACIES	%	UNIT THICKNESS (M)		
		MIN.	MEAN	MAX.
Gm	43.9	0.30	1.55	4.75
St	17.8	0.16	1.03	2.13
Sh	22.7	0.07	0.63	1.90
Sl	3.0	0.20	0.48	0.86
Sr	5.7	0.09	0.42	0.84
Fl, Fm	7.1	0.02	0.52	1.30
	100			

LITHOFACIES IN THE CONGLOMERATE – SANDSTONE FACIES ASSOCIATION

Fig. 10: Data taken from sections 06, 07.

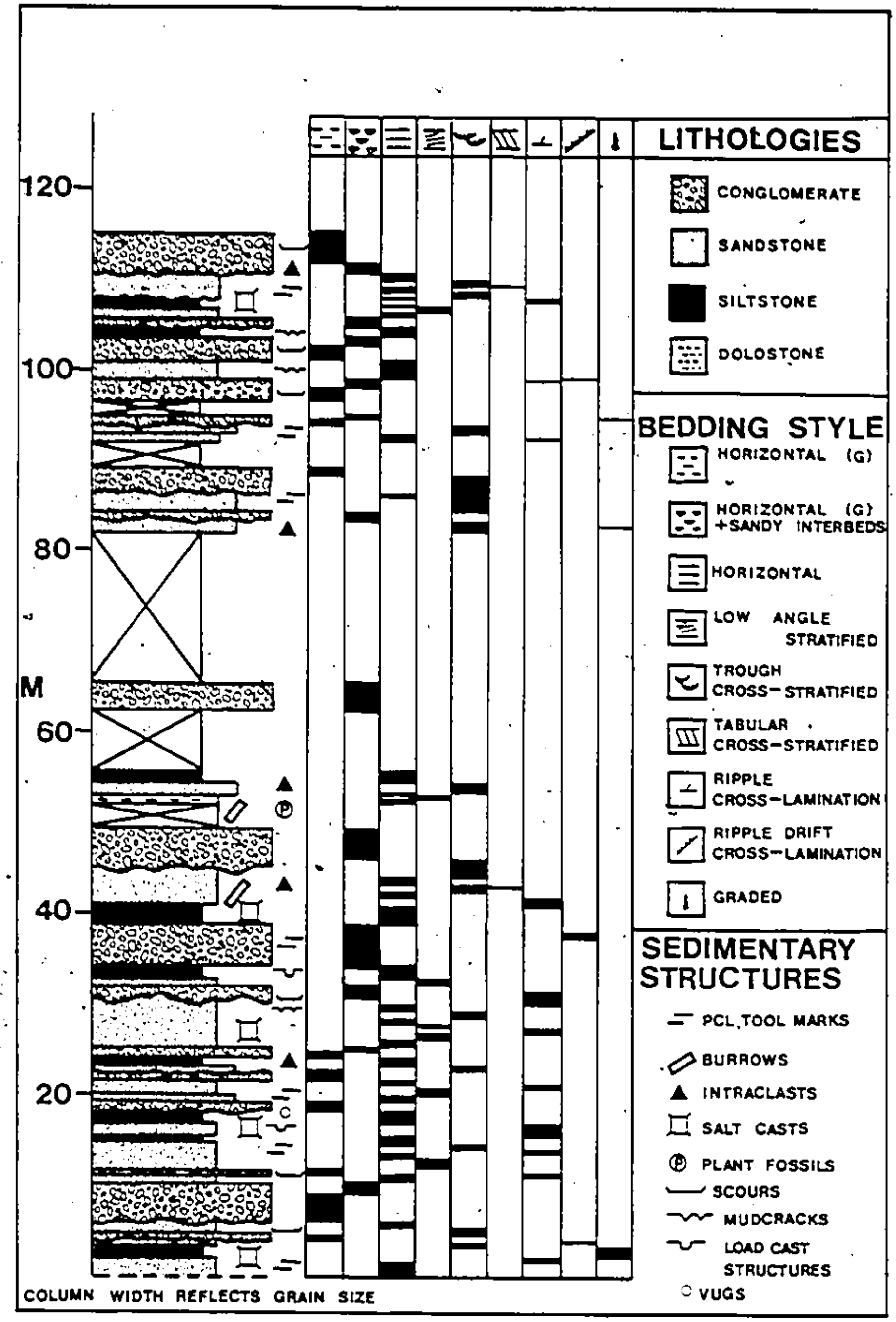


Fig. 11: Detailed section 06 in the conglomerate-sandstone facies association. FU, CUFU cycles in the conglomerate units are not displayed in this diagram. PCL = primary current lineation.

STRATIFICATION

Parallel to low-angle stratification is the dominant bedding style (approximately 70%). Units may be traced laterally in excess of 400 m (Pl. 9). The absence of well-defined channel morphologies may be explained by relatively unconfined flow on the depositional surface (Sykes and Brand, 1976). In measured sections 06 and 07, the bed contacts are mainly sharp and flat (49%), although slightly erosional, irregular bed contacts constitute the second most abundant grouping (33%). Unit thicknesses range from 0.4 m (Fl, Sr) to 1.6 m (Gm) with minimum and maximum thickness of 0.1 m and 4.8 m respectively.

The genetic implications of the stratification types will be discussed later in the chapter.

LITHOFACIES

Gm Conglomerate units average 1.6 m in thickness (range: 0.3 - 4.8 m) and exhibit lateral continuity in excess of 400 m. Bedding is horizontal, although minor ($<1\%$), isolated, low-angle stratification was observed in several units (Pl. 10). The framework of facies Gm is clast-supported, with a well-developed fabric consisting of ab planes dipping at 25-30°.

Sandstone lenses are present in some units. Miall (1977) interpreted similar interbedded sand/silt lenses as the products of low-water accretion processes.

The deposition of the gravels probably took place under upper flow regime conditions in the form of broad, low amplitude bars (Miall, 1977). FU and CUFU trends (Pl. 10) in several of the conglomerate units indicate flood-stage discharge fluctuations. These sequences rarely display a corresponding upward decrease in bed thickness with smaller scale fining in each bed.

ES

Laterally extensive (>50 m) erosional surfaces are treated as a distinct lithofacies for Markov chain analysis. The low relief (<15 cm) scours were commonly observed to be lined with extraformational and intraformational (Fl, Fm) clasts. The erosional surfaces were probably formed by local eddies associated with flow over low relief bars.

Other types of scours were recorded in the conglomerate-sandstone association but were not included in Markov chain analysis because of their limited extent (<5 m). Few large cut and fill structures were observed (Pl. 11, fig. 1). Inclined stratification in these scours resulted from back-filling, as flood waters receded (Picard and High, 1973). Reactivation surfaces were observed in the St, Sl lithofacies and may have resulted from bar dissection phenomena during slow falling water conditions (Miall, 1977).

St

Trough cross-stratified pebbly sandstone (Pl. 11, fig. 2) constitutes nearly 18% of all observed lithofacies in the conglomerate-sandstone facies association. The mean coset thickness is 1.0 m (range: 0.2 - 2.1 m). The depth of the trough sets is generally 5 - 10 cm and the width and length averages 30 - 50 cm, 50 - 100 cm respectively. The sets commonly decrease in thickness upwards in the units. Troughs are shallow and spoon-shaped in geometry. Foresets are strongly tangential to the enclosing surfaces and maximum dips average 15° - 20°.

Paleocurrent data is remarkably consistent (see Appendix 3) and indicate low trough set variance, although the scoops are rarely exposed in plan, leading to difficulties in measuring axial orientations. Williams (1971) recognized similar phenomena in trough cross-stratified flood deposits of shallow sand-bed ephemeral streams in central Australia.

The St sets arose from simultaneous scour and fill. Current eddies migrating downstream of advancing shallow linguoid dunes resulted in erosional-based bedforms (Gibling, 1978). Minor gravel lags and scattered green and red siltstone intraclasts derived from the Fl, Fm lithofacies were observed at the bases of the troughs.

Lateral transitions from St to Sh, Sl indicate fluctuating changes in current velocity and/or depth of the fluvial system.

Sh, Sl

Horizontal and low angle stratified sandstone units constitute 25% of the lithofacies in section 06, 07. The laterally extensive (>400 m) sandstone bodies average 0.5 - 0.6m in thickness (range 0.1 - 1.9 m). Sh, Sl lithofacies are present as lenses with sharp and gradational bases in Gm (Pl. 12). The lenses generally display a lenticular-planar base and planar top, and average 1.0 - 10.0 m in width and 10 cm in thickness. Sl is dominant where lenses in the conglomerate units are thickest. The lateral transition Sh → Sl represents deposition in shallow hollows of the depositional surface (Rust, 1978).

Facies Sh, Sl commonly display current crescents which record local scour around scattered pebbles (Pl. 13, fig. 1). This structure is always associated with primary current lineation and indicates high flow regime conditions. Minor tool marks were observed in fine-grained Sh and may have been formed by saltating pebbles. Minor siltstone intraclasts (max. size = 2 cm) were probably derived from indurated fine-grained bar top deposits.

Horizontal parallel stratification also forms in lower flow regime conditions (Picard and High, 1973). Sh formed under both lower and upper flow regimes is interbedded with Sr and frequently passes upwards in section to Fl, Fm lithofacies. Thin beds are alternately hematized at 1 - 3 cm intervals, reflecting a fluctuating water table level.

Sr

Ripple cross-stratified units appear to be a minor component (6%) in the facies association. Units of this lithofacies average 0.4 m thickness, with an observed range of 0.1 - 0.8 m. Sr frequently overlies Sh, St or Sl and passes vertically into Fl or Fm lithofacies in a gradational interstratified manner.

In a plan view, linguoid ripple marks are the most commonly observed form. The ripples are 1 - 2 cm in amplitude and are generally asymmetric. Minor sinuous asymmetric ripple marks and smoothed, irregular 'basin and dome' interference ripples are also present. The interference ripples were probably formed as water drained from bar tops during falling flood stage, washing out existing rippled surfaces. In section, this feature is common in the Snowblind Bay Fm., in the form of ripple crests that are 'planed off' by units of Sh lithofacies indicating fluctuating flow conditions.

Minor climbing ripple lamination, which climbs at 5 - 10° from horizontal is also present in the Sr lithofacies and suggests rapid sedimentation rates.

Fl, Fm

Mudstone and siltstone units constitute 7% of the lithofacies observed in section 06, 07. Average thickness of these lithofacies is 0.5 m (0.1 - 1.3 m range).

The laminated siltstone lithofacies contains thin (1 cm) sandstone horizons indicating fluctuations in sediment supply and/or flood conditions. The Fl units generally show sharp basal contacts with Gm or St lithofacies and gradational interbedded contacts with Sh or Sr lithofacies.

Green siltstone is a minor component of the Fl lithofacies and alternates with red siltstone (1 - 2 cm), demonstrating changes in the water table level, which controlled the prevalence of oxidizing or reducing conditions. Convolute lamination, load casts, flaser bedding, flame structures, climbing ripple lamination, minor normal grading (laminae scale) and syneresis cracks (Pl. 13, fig. 2) suggest periods of high sedimentation rates for the Fl lithofacies. The laminated to massive lithologies likely accumulated as suspension fallout in slowly moving or ponded water during low flood stage (Leeder, 1973).

Fl and Fm units represent accretion deposits which were repeatedly drained and desiccated, as indicated by runzel marks (Pl. 14, fig. 1); sand-filled, v-shaped polygonal desiccation cracks with subsidiary polygons; rare plant debris; and abundant siltstone intraclasts (Pl. 14, fig. 2) including those exhibiting curled (desiccated) edges.

Proximity to marine influence is indicated by the presence of <u>Polarichnus</u>, horizontal burrows (<u>Planolites?</u>), and rare oxidized plant debris. Marine fauna may have invaded mud beds after terrestrial flood waters receded, possibly at abandoned channel sites (Dixon, 1979). Evaporite minerals may have formed from the evaporation of saline ponded water as capillary action drew dissolved ion species from the Fl and Fm deposits and concentrated them in shallow ponds. Wrinkled films possibly record the withdrawal of interstitial water to topographically higher areas (Picard and High, 1973). Alternatively saline water may have accumulated from sea spray blown across the flood basin (Winston, 1978) or in shallow lagoons during low energy marine incursions.

Calcareous soil profiles did not develop, probably because of the coarseness of sediment and restricted time of exposure. Leeder (1975) suggested that at least 10^3 years are required for the initial development of a calcrete profile. However, mottled, hematized, laterally discontinuous siltstone units (Fm lithofacies) contain minor plant debris? and disrupted wavy bedding, possibly indicating incipient soil development.

Cf

A single 2 - 3 m thick, fine-grained dolarenite unit (Fig. 12) can be traced from section 06 (50 m above base of section) for 1.7 km northwards to section 07 (14 m above base of section). This unique lithofacies has a sharp, erosional lower contact and planar, abrupt upper contact with bounding Fl lithofacies. The Cf facies was probably deposited by an exceptional event which did not significantly alter the depositional environment (Reading, 1978). The adjacent Fl units (units 1, 5 in Fig. 12) contain large halite casts (approx. 1 cm^2), 'basin and dome' interference ripples, symmetrical wave ripples, unidentified burrows, Fl intraclasts and oxidized plant

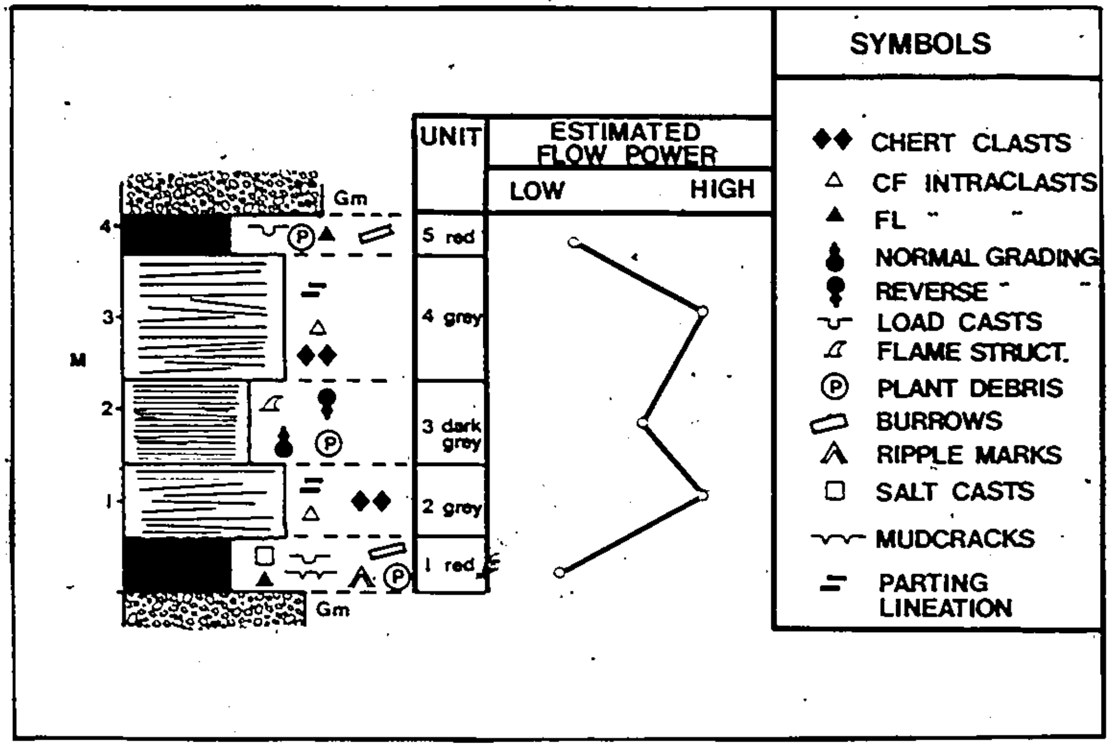


Fig. 12: Detailed log of the Cf unit in the conglomerate-sandstone facies association, section 07 (as in text). Column width reflects grain size. Units 1, 5 are Fl lithofacies. Units 2, 3, 4 are Cf lithofacies. Low angle stratification and horizontal stratification are the major bedding styles in units 2, 3, 4.

debris. The load casts, thin (2 - 3 cm) interbedded Cf units, and Fl intraclasts in unit 5 indicate periodic fluctuations in wave energy. Units 1 and 5 are the only Fl lithofacies which display burrows and plant debris in the conglomerate-sandstone facies association.

Thin to medium-bedded units 2 and 4 show horizontal stratification and low angle stratification. Primary current lineation; depositional, and erosional-based inclined laminae are common. The predominant inclination (5 - 10°) of laminae is down the depositional slope (i.e. towards the paleoshoreline). The units contain small (1 - 3 cm), angular extrabasinal chert clasts and abundant buff-coloured dolosiltite intraclasts (Pl. 15, fig. 1) which commonly display syneresis cracks.

Unit 3 differs from its enclosing lithologies by the following characteristics:

1. horizontal stratification is the prevalent bedding style
2. thinly bedded to thickly laminated
3. darker grey colour imparted by its higher carbonaceous debris content
4. fine-grained
5. abundant reverse grading (Pl. 15, fig. 2) and less common normal grading on a 1 - 2 cm scale
6. general absence of chert clasts and Cf intraclasts
7. contains abundant, well-preserved plant fragments, spore elements and rare acritarchs

The sequence is interpreted as a storm surge deposit, formed on the submerged part of the coastal fan complex, presumably in an area not affected by terrestrial floods or during a period when terrestrial floods were inactive. The sharp lower and upper contacts; lack of bioturbation in the Cf lithofacies, evidence of high energy flow power (PCL, chert clasts, Cf intraclasts); rapid deposition (reverse grading, load casts); and subsequent return to mud deposition (Fl lithofacies) indicate a sudden surge of sediment followed by rapid deposition resulting from storm waves.

During severe coastal storms, large sections of barrier islands and sandflats may be flattened to form extensive washover flats (Leatherman, et al., 1977). Coalescing washover fans may exhibit sheet-like geometry in the order of kms width, normal to the shoreline (Reinson, 1979). Washover flat sediments generally consist of only medium to fine-grained Sh lithofacies where flow is across a subaerial surface (Leatherman, et al., 1977). The Cf units were deposited under upper flow regime conditions by swash action associated with breaking waves. Inverse and normal grading, primary current lineation and seaward inclined laminae are common characteristics of swash sediments (Reinson, 1979). Material in washover fans tends to be well sorted (Leatherman, et al., 1977) and chert clasts in units 2 and 4 represent the most resistant clast lithotype that would be found in the offshore sediments.

A vertical arrangement of lithofacies in the storm surge deposit is unpredictable because of non-uniform, unsteady flow conditions. Many overwash surges can be counted in a specific time period. Leatherman et al (1977) documented 121 surge events during a 4 hr. 40 min. period for a March 19-20, 1975 storm at Assateague Island Maryland. Depth, velocity and direction of flow changes constantly during swash action.

Fig. 12 only documents gross changes in flow power for the storm surge deposit as indicated by bedding style and sedimentary structures.

3.4 VERTICAL DISTRIBUTION OF LITHOFACIES

Lithofacies were chosen to represent distinct rock types that formed under certain environmental processes. If a vertical succession of facies does not have any major 'breaks', an analysis of facies sequences provides an approximation of the changing environmental conditions (Reading, 1980)

Markov chain analysis deals with the relationship between a given bed and the preceding bed. In this study, a first-order embedded chain method is employed. This form of analysis considers sequential pairs of beds which are in contact, recording vertical facies changes regardless of bed thickness (Miall, 1977). The major problems encountered with Markov chain analysis include the following points:

1. Reduction of the number of lithofacies for purposes of statistical simplification may take away important hydrodynamic information (Reading, 1980).
2. Periods of nondeposition are not considered.

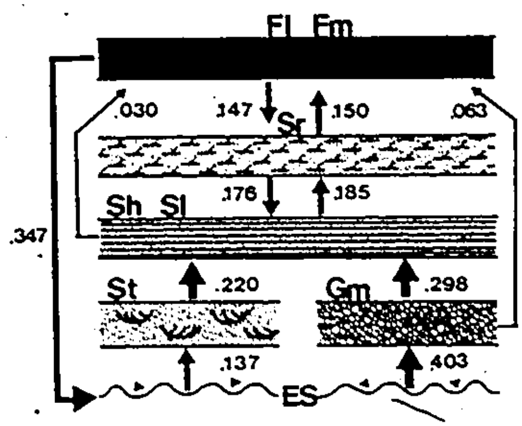
However, Markov chain analysis does allow comment on principal cyclic relationships. Fig. 13 represents the major path successions of lithofacies observed in the conglomerate-sandstone facies association. A chi-square test indicates that the vertical succession was derived by nonrandom variations in the depostional mechanisms.

Two major types of fining-upward cycle are distingushed by the following criteria:

DIFFERENCE MATRIX

	ES	Gm	St	Sh,Sl	Sl	Fl,Fm
ES	0.000	.403	.137	-.304	-.133	-.103
Gm	-.110	0.000	-.167	.298	-.085	.063
St	-.026	-.017	0.000	.220	-.136	-.040
Sh, Sl	-.019	-.027	-.168	0.000	.185	.030
Sr	-.067	-.155	-.104	.176	0.000	.150
Fl, Fm	.347	-.057	-.156	-.281	.147	0.000

PATH DIAGRAM



$\chi^2 = 185.7$ [HARBAUGH AND BONHAM-CARTER 1970]

No. of transitions = 146 Limiting value = 30.1 [95 % CONFIDENCE LEVEL]

Fig. 13: Markov chain analysis of lithofacies transitions in the conglomerate-sandstone facies association at section 06.

1. <u>Sheet-braided cycle</u> (Fig. 14)
   a) sheet-like geometry of constituent lithofacies
   b) sand dominated; ES → St → Sh,Sl. → Sr → Fl,Fm
   c) ES are abundant
   d) average cycle thickness of 3.0 m

2. <u>Sheet flood cycle</u> (Fig. 15)
   a) sheet-like geometry of constituent lithofacies
   b) gravel dominated;(ES) → Gm → Sh,Sl. → Sr → Fl,Fm
   c) sharp, flat basal contacts are abundant
   d) average cycle thickness of 3.7 m

Both cycles are representative of braided alluvial deposits however, the sheet-flood cycle is coarser and was probably formed by less confined flood events of higher discharge.

The <u>sheet-braided cycle</u> in Fig. 14 was observed in 10 fining-upward cycles from section 06. Plate 16 displays an incomplete cycle (base is obscured by scree): Sp?, St → Sl → Sh → Fl.

The channel deposits commenced with an erosional surface (ES) that was generally outlined by a layer of intraclasts. This was formed by the scouring and reworking of the underlying fine-grained deposits during flood conditions.

Coarse, poorly sorted pebbly sand was primarily transported as dunes within wide, shallow channels. The dunes gave rise to shallow trough cross-stratification, as observed in facies St (Fig. 14). Minor lateral lithofacies variations, for example St → Gm, St → Sl, document differences in velocity, depth and load at any given stage during flood conditions (McKee et.al., 1967). Localized scouring and lateral facies changes reflect the episodic nature of the flood conditions. The relatively low angles (10 - 20°) of the trough foresets in the St facies are attributed to strong currents during deposition (McKee et al.,

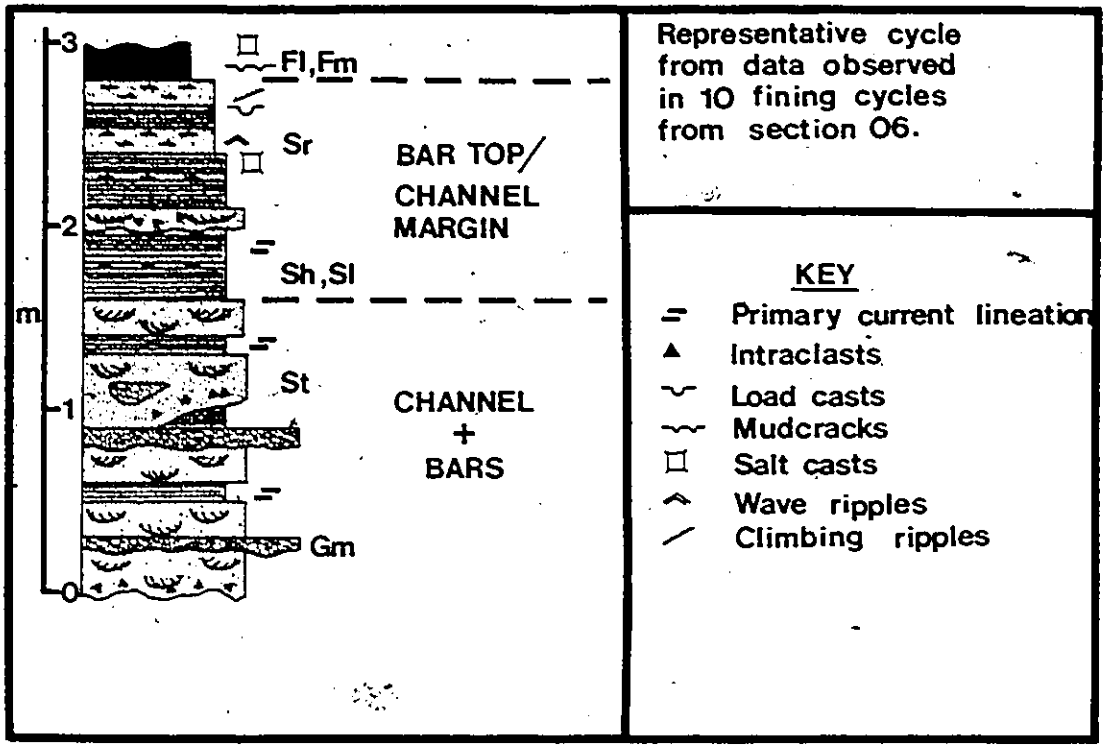


Fig. 14: Sheet-braided fluvial cycle in the conglomerate-sandstone facies association. Column width reflects grain size. The fining-upward cycle is attributed to waning flood conditions and/or migration from deep to shallow portions of the braided complex.

1967).

As the water level dropped, either by waning flood conditions or channel migration, the dunes were modified (Collinson, 1978). During this phase, interbar depressions functioned as channels where currents reworked dune slipfaces.

After planation of the bar tops by shallow, rapidly flowing water, Sh was deposited under upper flow regime conditions. The presence of primary current lineation, sharp basal contacts and intraclasts (Pl. 14, fig. 2) substantiate this interpretation. The fine-grained intraclasts may have been derived from abandoned channel segments (Rust, pers.comm., 1981) or mud drapes deposited on bar tops by much shallower ponded water (Blodgett and Stanley, 1980). Bar relief is unlikely to be smoothed over as a result of shallow flow and the lateral transition Sh → Sl takes place in bar top depressions or shallow channel segments (Rust, 1978).

As the velocity and depth of the floodwaters decreased, finer sediment was mainly deposited by vertical accretion processes. Rippled sands and interbedded mud drapes were deposited on the inactive portions of the stream tract (bar top and channel margins).

Thicker fine-grained deposits may accumulate on alluvial islands and low lying inactive areas of terraces. The siltstone (Fl,Fm lithofacies) either lies abruptly over the bar top/channel margin deposits or is intercalated with thin Sh,Sr lithofacies. Although these sediments reflect intervening periods of subaerial exposure between flood cycles (see section 3.3, Fl and Fm lithofacies), the exposure was not prolonged enough to permit calcrete development (Leeder 1973, 1975). The massive to mottled siltstone (Fm) observed in some cycles probably resulted from drainage, and the associated oxidation/reduction effects caused by moisture fluctuations during the initial development of a soil profile (Gibling, 1978). The fine-grained accretion deposits (Fl,Fm) were eroded by the initiation of a new fluvial cycle.

The coarser, generally thicker sheet flood cycle (Fig. 15) displays a fining-upward sequence with sharp, flat basal contacts and diminishing bed thicknesses; cycles averaging 3.7 m in thickness based on 12 sequences observed in section 06. Beds were superimposed under progressively decreasing energy conditions (Miall, 1977).

The channel deposits consist of Gm with minor Sh,Sl lenses. The conglomerate units have a lateral extent of more than 400 m and represent coarse bed load transported when flood competency was greatest. Crude stratification may be related to flood stage discharge fluctuations or migration of shallow channels and longitudinal bars. Common FU, and CUFU clast size trends in the conglomerate units indicate waning or waxing-waning flood cycles. The coarse gravel was transported as diffuse gravel sheets and longitudinal bars. Hein and Walker (1977) stated that if the water discharge levels were high, then the diffuse gravel sheet would lengthen

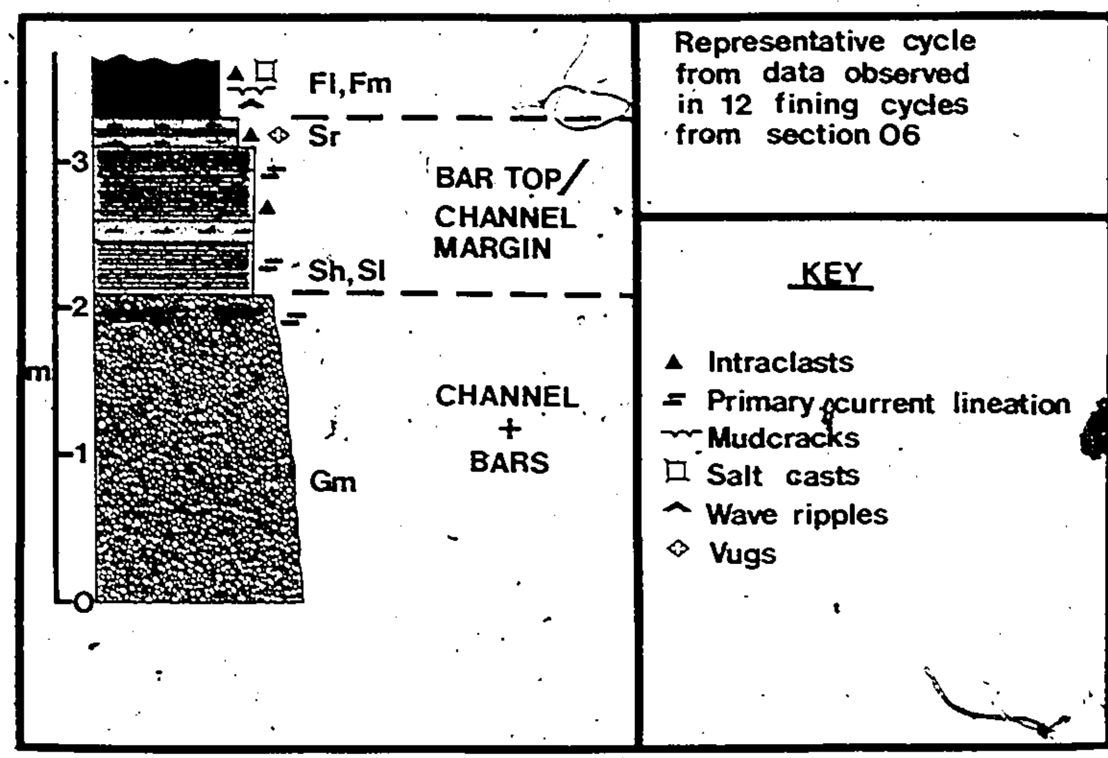


Fig. 15: Sheet flood fluvial cycle in the conglomerate-sandstone facies association. The gravel dominated fluvial cycle generally do not show undulating basal erosional surfaces. However the underlying depositional surface may have been bevelled by the high discharge flood event.

downstream faster than it aggraded and no angle-of-repose slipface would develop. A low water depth to mean particle size ratio may have also suppressed development of slipfaces (Rust, 1975).

Waning flood conditions may have been caused by decreased flood energy and/or decreased competency as sheet floods thinned and spread on the fan surface. When coarse gravel ceased to move, bars were built upward by the addition of finer material still in transport. Sh,Sl lenses are preserved in bar top depressions (Collinson, 1978). These sandstone bodies probably had increasingly higher preservation potential as the flood cycle waned, and for this reason are more frequently observed in the upper portion of the channel deposit.

Flood waters continued to decrease in flow power below the level of competency to move pebbles, and a carpet of sand was transported across the tops of gravel bars. Both gradational and sharp basal contacts were observed for the sheet-like sand bodies. Upper flow regime conditions produced plane bedding with minor low angle stratification as the sand moved into bar top depressions.

Continued falling water levels deposited interbedded low flow regime sand and silt lithofacies (Sr, Sh, Fl). Laminated siltstone (Fl) represents the distal or terminal segments of the flood cycle, deposited from suspension in stagnant or slowly moving water. Although these sediments were periodically exposed, there are no calcrete units in the Snowblind Bay Fm.

The sheet flood cycles are downfan equivalents to the flood cycles of the conglomerate facies association based on similar bedding style, constituent lithofacies, and unit geometry. This aspect is discussed in the following section.

3.5 DEPOSITIONAL ENVIRONMENT

The style of deposition in the conglomerate-sandstone facies association may be summarized under the following headings:

1. sandstone, conglomerate unit geometry
2. coarse member - fine member ratio
3. paleocurrent patterns
4. relationship of lithofacies deposited by sheet-flood versus sheet-braided cycles

Geometry High continuity of conglomerate beds is common for wave reworked gravels. Evidence for marine incursions onto the fan complex was discussed in the Fl, Cf lithofacies descriptions. However Long (1978) stated that extensive conglomerate beds may also be evidence for alluvial processes as sheet-flood or shallow braided stream deposits. Lack of restricting cohesive banks could have permitted braided channels to move laterally across the fan complex with little incision into the fan surface during Snowblind Bay depositon. The resultant sheet geometry reflects changes from channel complex centers (St, Gm, Sh) to channel complex margins (Fl, Fm, Sr, Sh) as well as vertical accretion processes (waning flood cycles). Cotter (1978) introduced the term 'sheet-braided' for those channels with a width: depth ratio of greater than 20:1. However the ratio of most braided channels is much greater than this proposed figure (Rust, 1978).

Sheet flow processes are prevalent in the upper reaches of fan complexes, usually just downslope of the erosion/deposition intersection points (Bull, 1964). Description of the nature of deposition in this zone is not well described in the literature. Flow is in broad, shallow channels which pinch and swell on the fan surface (Bull, 1977). Consequently, geometry does not serve to distinguish sheet-braided and sheet flood cycles but simply reflects small changes in thickness normal to the depositional strike for both types.

Graded conglomerate units display positive bed thickness: maximum clast size correlation (Fig. 16). This relationship may directly reflect the competency of the flood events. The predominance of sheet-style sedimentation over the presence of channel scours is suggestive of rapid aggradation with only minor reworking processes (Miall, 1980). Reworking would tend to disrupt the correlation by removing the upper portions of the units.

<u>Coarse member : fine member ratio</u> At the highest discharge levels, gravel was transported as bed load and constitutes the coarse member of the conglomerate-sandstone lithofacies association. The fine member includes all sandstone and siltstone lithofacies which were deposited at relatively lower discharge.

Coarse member : fine member ratios are dependent on

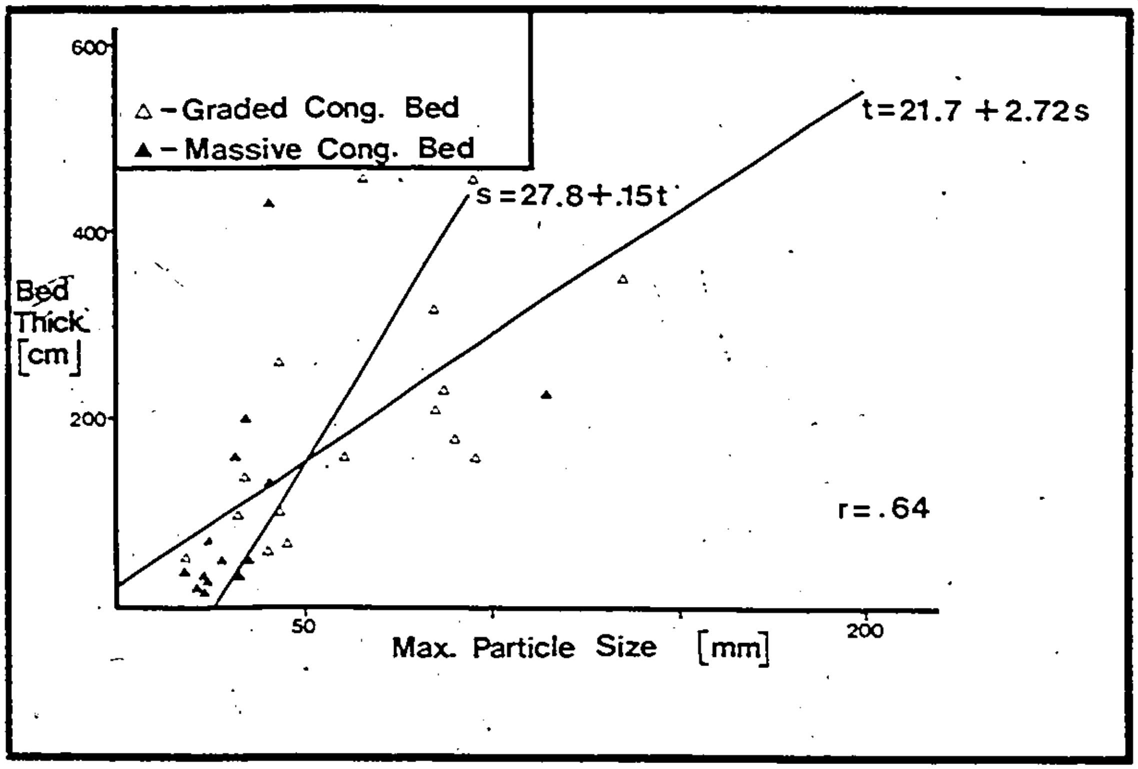


Fig. 16: Data on bed thickness and maximum particle size in the conglomerate-sandstone facies association. t = bed thickness, s = maximum particle size, r = correlation coefficient. Bed thickness and maximum particle size data are provided in Appendix 4.

sediment supply, manner of channel migration and the overall subsidence of the depositional surface (Long, 1978). A high ratio (Fig. 24) characterizes the conglomerate-sandstone facies association and indicates the braided stream environment was the major operative depositional system. Bed load was transported by shallow, wide streams and the instability of the banks was increased by the absence of an extensive vegetation root system (Cotter, 1978). Hence fine-grained accretion deposits were very susceptible to reworking and constitute only a minor percentage of the conglomerate-sandstone facies association.

Paleocurrent patterns Paleocurrent azimuths in the conglomerate-sandstone facies association are strongly unidirectional (Fig. 17; Appendix 3). The unimodal distribution of paleocurrents for trough axes is consistent with the mean directional vectors obtained from imbrication studies (AB plane imbrication; current normal A-axis orientation). Measurements obtained from both conglomerate and sandstone lithofacies have low directional variances with significance levels of $<10^{-8}$ and vector magnitudes $>70\%$. This implies a uniform paleoslope. The data support the interpretation that the fan complex was developed by braided stream depositional processes.

The average clast imbrication angle for the AB plane is $25° - 30°$, whereas beach gravels are imbricated at much shallower angles (Daily et al., 1980). Structures produced by fluvial traction currents (stratified conglomerates, trough cross-stratification, 'fluvial type' clast imbrication) negate a

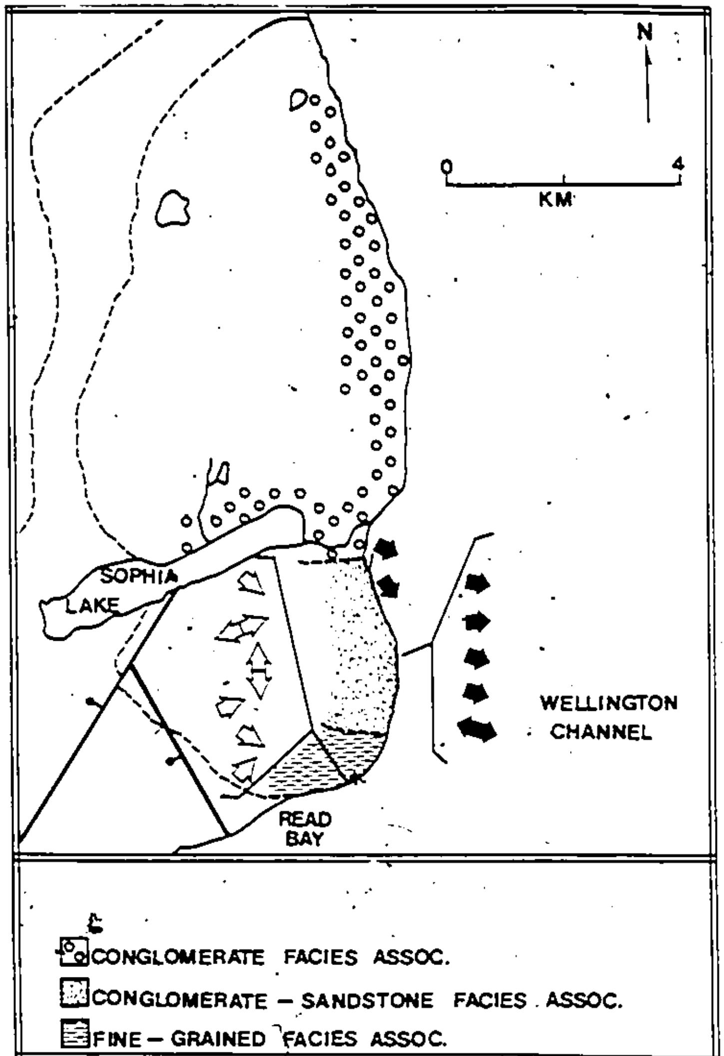


Fig. 17: Paleocurrent directions in the conglomerate-sandstone, and the fine-grained facies associations. Each arrow represents a mean paleocurrent direction at a specific station. The paleocurrent data are provided in Appendix 3.

mass flow interpretation for the deposition of the conglomerate-sandstone facies association.

Relationship of lithofacies deposited by sheet flood cycles versus sheet-braided cycles The obvious difference between the sheet flood and sheet-braided cycle is that the latter is sand-dominated and the former is gravel-dominated (see section 3.4). The thickness of both types of fluvial cycles (3-4 m), common FU trends, and sheet-form geometry show that large volumes of sediment were involved in their accumulation (Heward, 1978b). Although the cycles reflect minor differences in transport and accumulation processes, they are probably related to the same flood events (i.e. sheet flood cycles are transitional to sheet-braided cycles).

During higher discharge flood events, sheet flood sedimentation processes prograded downfan. A series of diffuse gravel sheets and large low amplitude longitudinal bars were deposited in response to flood conditions. The FU, CUFU conglomerate units display a positive correlation between unit thickness and associated clast size. Following this reasoning, each unit was the result of a single flood event (Bluck, 1967). A decrease in competency was associated with thinning and widening of flow downfan (Bull, 1977). This response is recorded by a rapid decrease in grain size for each flood cycle. Loss of competence and deposition of bed load was also related to the waning stage of each flood event (Deegan, 1973).

During lower discharge flood events, sheet flood sediment accumulated up slope of the area for deposition in the conglomerate-sandstone facies association. Thus the sheet flood cycle passes distally to the sheet-braided cycle and is a reflection of lesser flood events between major sheet flood (higher discharge) events. Periodic increases in discharge are reflected by the presence of thin Gm units. Sheet-braided deposition was probably controlled by higher discharge bed forms. The toes of modern alluvial fans are frequently characterized by the collection of sheet flow into broad swales (Bull, 1977). Bull (1977) attributed this phenomenon to decreasing sediment concentration and incipient erosion of well-defined channels in the finer-grained distal portion of the fan complex. Evidence of reworking is demonstrated by the abundance of erosional surfaces and better sorting of the thin conglomerate beds which may be present in the sheet-braided cycle.

Bryhni (1978) observed extensive sandstone units in the flood deposits of the Devonian Hornelen Basin, W. Norway. He concluded that the finer-grained braided stream deposits are reworked sheet flood deposits with lower mean clast size, better sorting and no clast size: bed thickness correlation. Fig. 16 shows massive to faintly horizontally stratified conglomerate units which have lower mean clast size and weak clast size: bed thickness correlation. These beds could represent reworked sheet flood deposits.

The sheet-braided cycle displays evidence to suggest that the low and high flow regime conditions were frequently episodic. Small, rapid changes in flow depth and velocity would have enhanced braiding and subsequent erosion of low energy bedforms.

As discussed for the conglomerate facies association, slope may be related to tectonic and/or climatic events (allocyclic processes) and/or autocyclic controls such as fan lobe migration and crevassing (Miall, 1980). It is sometimes difficult to distinguish between these two major controls on distal fluvial deposits. A general statement summarizing possible cyclic sedimentation processes in the conglomerate-sandstone association is outlined below:

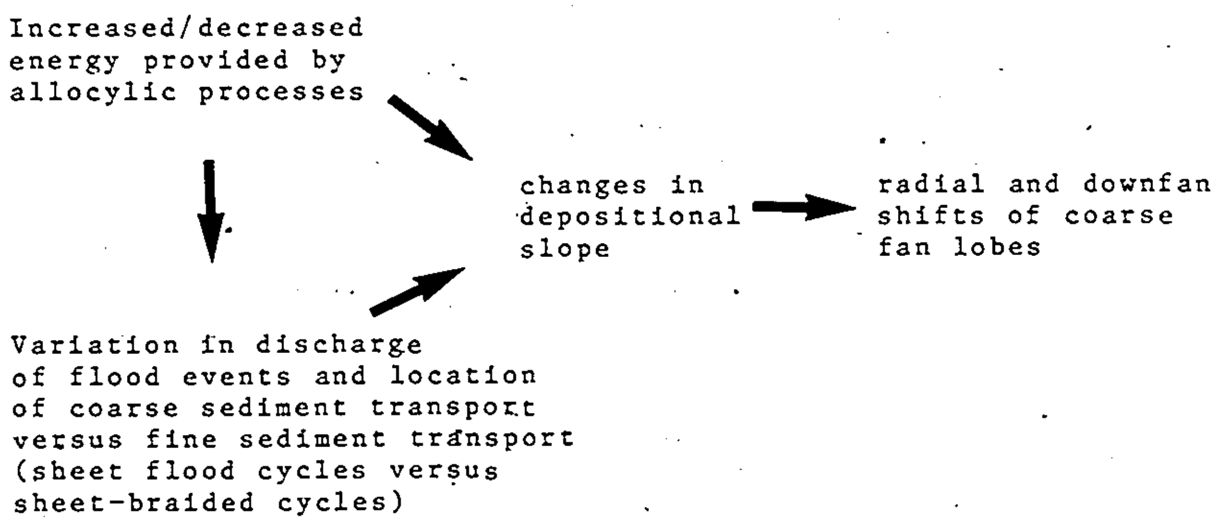


Plate 9

Aerial photograph of the conglomerate-sandstone facies association in the vicinity of section 06. Vertical exposure is approximately 70 m. Units are laterally continuous in excess of 400 m

Plate 10

Horizontally stratified sheet flood cycles in the conglomerate facies association. Note the CUFU clast trend (indicated by diamond symbol) in the first Gm unit and isolated cross-stratification in the second Gm unit above the figure (1.7 m tall). Recessive units are Sh and Fl lithofacies. Location is at section 06.

Plate 11

Fig. 1. Rare cut-and-fill structure 200 m south of section 06. Note inclined beds within structure. Fl, Sh, Sr units cap the feature. Notebook is 18 cm long.

Fig. 2. Shallow, trough cross-stratification in the pebbly St lithofacies. The scale is divided into decimeters. Location at section 06.


1


2

Plate 12

Sh unit abruptly overlying a Gm unit. Overlying Gm unit displays an erosional, undulating basal contact (arrows). Vertical variations in grain size indicate waxing/waning flood control. Note clast imbrication in the mid-part of the CUFU Gm unit. Pencil is 10 cm long. Location at section 06, unit 050.

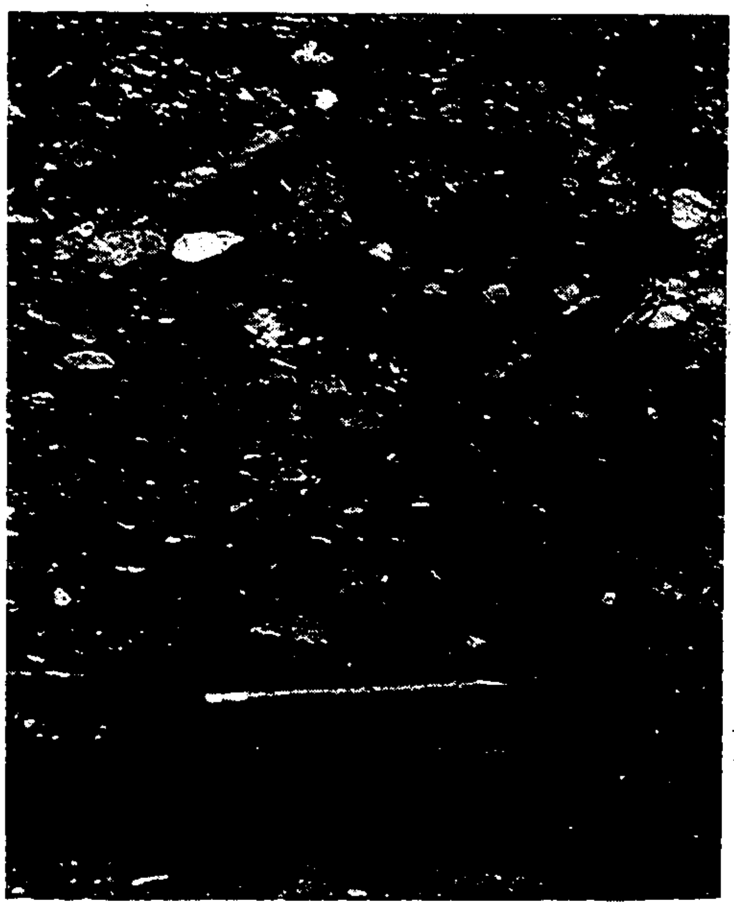
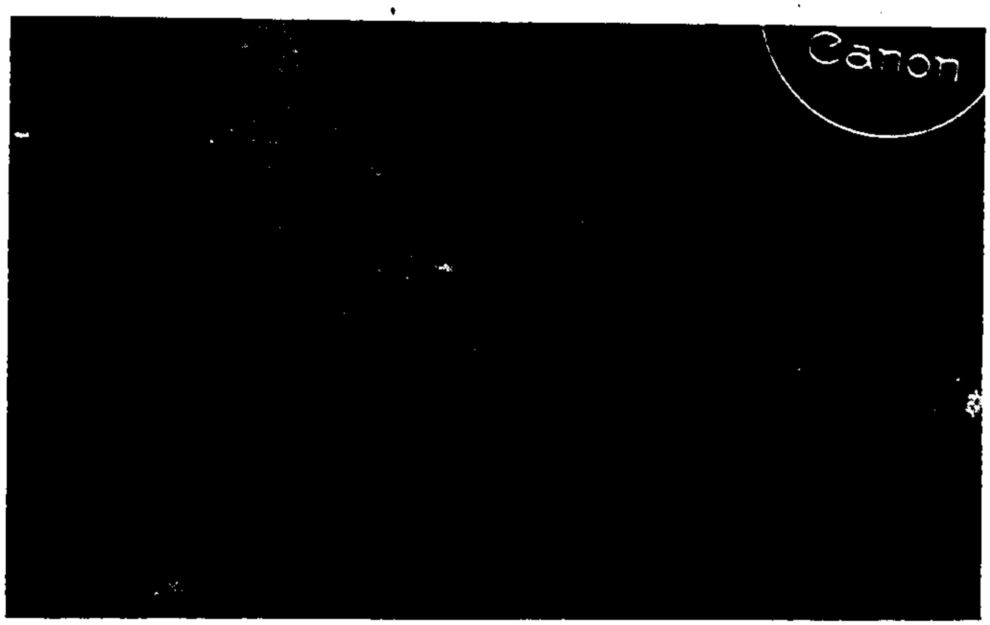


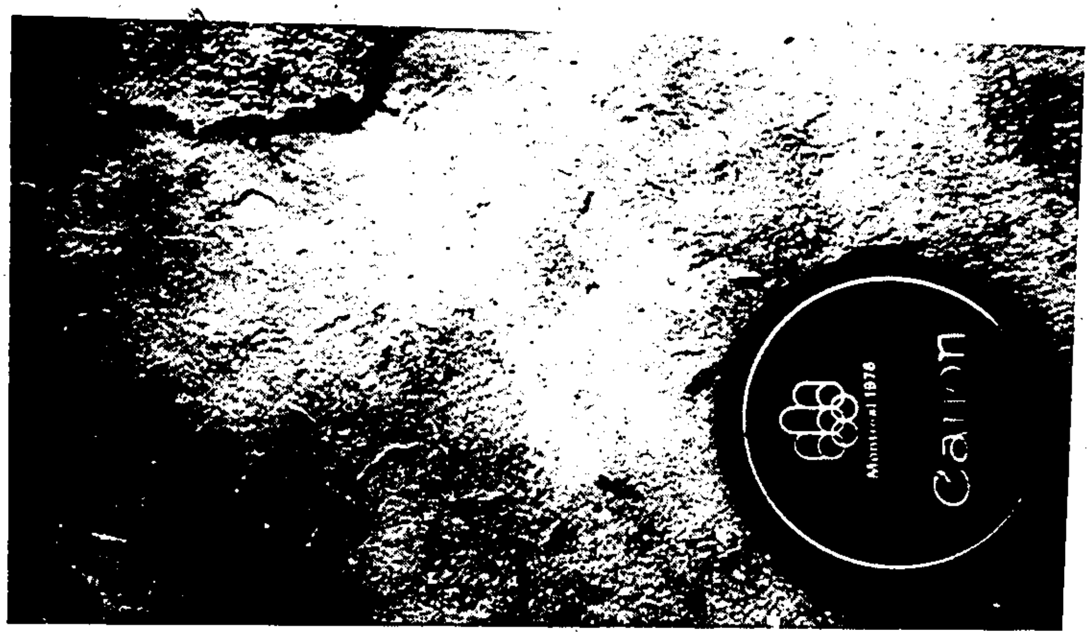
Plate 13

Fig. 1. Current crescents and primary current lineation on the sole of a Sh bed. Lens cap is 6 cm diameter. Location at section 06; unit 055.

Fig. 2. Syneresis cracks in an Fl unit. Lens cap is 6 cm diameter. Location at section 06; unit 024.



1

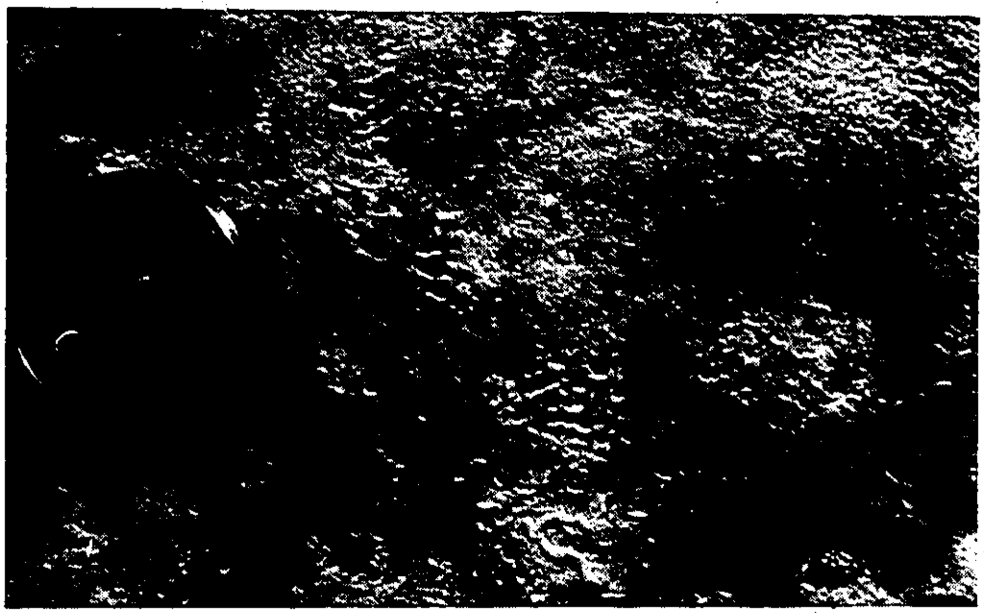


2

Plate 14

Fig. 1. Runzel marks on top of a Fl unit. Lens cap is 6 cm diameter. Location at section 06; unit 024.

Fig. 2. Angular siltstone intraclasts on the sole of Sh, Sr bed. Intraclasts are probably derived from desiccated Fl lithofacies. Scale is 15 cm long. Location at section 06; unit 049.

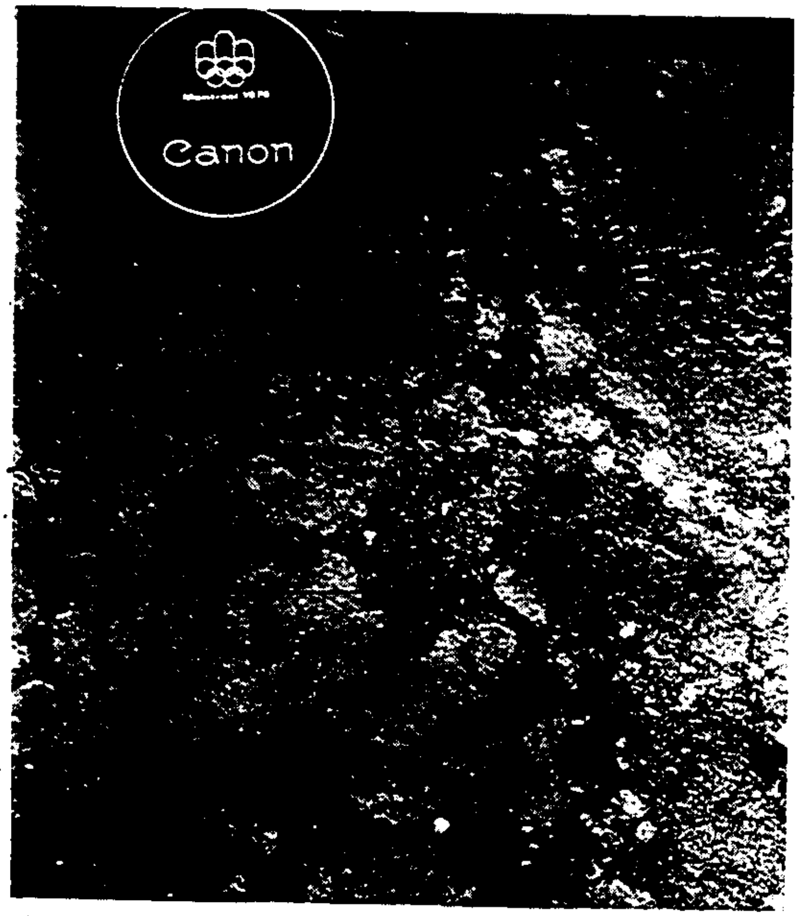

1


2

Plate 15

Fig. 1. Irregular-shaped dolosiltite rip-up intraclasts (grey) and small, subangular chert clasts (white) in dolarenite unit. Lens cap is 6 cm diameter. Location at section 07; unit 011.

Fig. 2. Reverse grading in a fine-grained dolarenite unit with flame structures at the base. Lens cap is 6 cm diameter. Slab removed from outcrop. Location at section 07; unit 011.

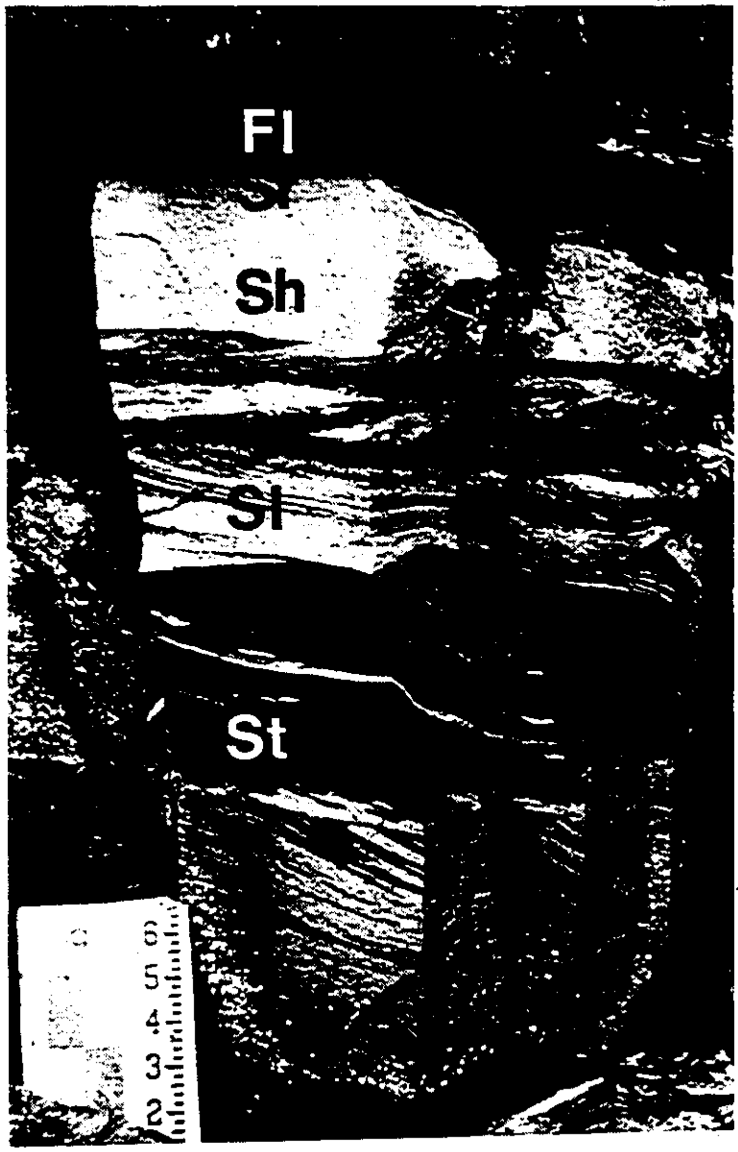


1

2

Plate 16

Sheet-braided fluvial cycle (basal portion obscured by scree). Vertical transition of lithofacies: Sp? St → Sl → Sh → Sr → Fl. Notebook is 18 cm long. Location at section 06.


Fl
Sh
Sl
St

Chapter IV

FINE-GRAINED FACIES ASSOCIATION

4.1 Introduction

The fine-grained facies association contains more than 90% sandstone and siltstone lithofacies with less than 10% conglomerate. The association is a distinct assemblage of spatially arranged lithofacies possessing sedimentary and paleobiologic evidence for an intertidal depositional environment. Tidal traction currents, slack water sedimentation, late-stage emergence flow prior to subaerial exposure, terrestrial floods derived from the adjacent alluvial fan complex and wind-driven waves were the major operating agents of deposition. Stratigraphic sections 10 and 05 represent the uppermost portion of the Sophia Lake Fm. and the overlying lower Snowblind Bay Fm. (Fig. 2, 3). The proportion and range of thicknesses for the major lithofacies present in these sections are displayed in Fig. 18. The thickness of the sequence is uncertain because of covered intervals, but ranges from a minimum of 70 m to a maximum of 220 m.

4.2 Stratification

The predominantly horizontally stratified units display lateral continuity in excess of 400 m (Pl. 17, fig. 1). Unit

LITHOFACIES	%	UNIT THICKNESS (M.)		
		MIN.	MEAN	MAX.
Cf	29.9	0.20	0.70	1.20
Fl	21.6	0.18	1.17	4.60
Fm	2.9	0.33	0.52	0.63
Sh,Sl	40.9	0.04	1.17	3.70
Gm,Gt	4.6	0.30	0.50	0.80
	100			
LITHOFACIES IN THE FINE-GRAINED FACIES ASSOCIATION				

Fig. 18: Data from sections 05, 10.

thicknesses vary from 4 cm to 4.6 m but generally average between 0.5 and 1.0 m (Fig. 18). Bed contacts are mainly sharp and planar (46%) or gradational (37%). Approximately 10% of the beds display loaded contacts. Erosional or irregular bed contacts are relatively minor (10%) and mainly restricted to Gm, Gt, Sh and Sl lithofacies.

4.3 Lithofacies

Sh,Sl Horizontally stratified and low angle stratified sandstone units constitute over 40% of the observed lithofacies. The laterally extensive units (>400 m) show little variation in thickness across depositional strike. Sedimentary structures include primary current lineation, reactivation surfaces and minor micro-cross lamination and may signify deposition by tide-influenced traction currents (Klein, 1970).

Green siltstone intraclasts, groove and prod marks, and chevron structures are typical of these lithofacies (Pl. 17, fig. 2). Minor soft sediment deformation structures and climbing ripple lamination record locally high sedimentation rates. Sh was frequently observed to pass laterally into Sl, possibly representing infill of shallow hollows and scours in the depositional surface. The overall sheet geometry and sharp, planar basal contacts suggest that these sandstone units are probably tidal and wave reworked products of alluvial floods. Sh,Sl may be derived from distal extensions of fan lobes onto the tidal flats. Storm surge ebb currents would be effective transporting agents for moving sand offshore from these fan lobes.

A bioturbated, thick coarsening-upward Sl → Sh unit at the top of the Sophia Lake Fm. (Fig. 19), displays open-space structures (gas escape structures?, Pl. 22), green Fl intraclasts, disarticulated ostracoderm fragments, horizontal burrows and <u>Diplocraterion</u>. Although stratification has been partially obliterated by bioturbation and post-depositional diagenesis, the presence of primary current lineation, intraclasts and ostracoderm fragments, and minor groove casts indicate that most of the unit was deposited under upper flow regime conditions. Load casts, convolute lamination and bioturbated horizons are common towards the top of the unit. The sequence is anomalously thick (7 m) for typical Sh, Sl lithofacies and may represent an overwash surge deposit (Leatherman, et.al., 1977).

<u>Cf</u>

A brief petrographic description for several of the sandy dolostone units is summarized in section 4.5 and Appendix 1. Cf lithofacies are the second most abundant lithofacies observed in sections 10, 05 (30%). Basal contacts are mainly sharp and planar. Most sedimentary structures are similar to those exhibited by the Sh, Sl lithofacies (shallow scours outlined by intraclasts, reactivation surfaces, minor low angle and trough cross-stratification, wave and current ripple marks, micro-cross

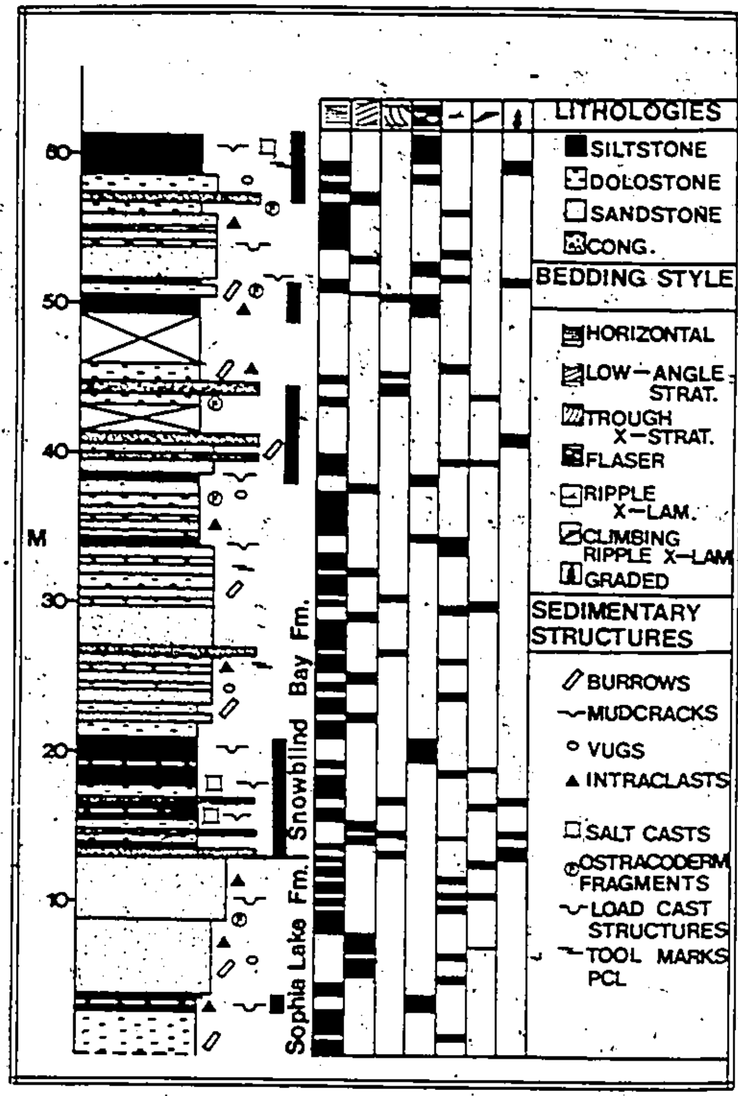


Fig. 19: Detailed section (10, 05) in the fine-grained facies association. Extension of stratigraphic column to right reflects mean grain size. Nearshore mud flat facies are indicated by adjacent vertical bars. Sand flat - tidal flat facies represent the other major grouping in the fine-grained association (see text for explanation).

lamination and minor groove sole markings). Sedimentary structures formed by processes other than traction currents include: soft sediment deformation structures (Pl. 18, fig. 1), solution cavities and normal grading. The solution cavities probably resulted from the dissolution of evaporite nodules formed under hypersaline conditions (Gibling, 1978). Rare fossils observed in this lithofacies include ostracoderm fragments (Pl. 18, fig. 2) and Ostracoda.

Ichnofossils recovered in the fine-grained facies association (predominantly in Cf lithofacies) indicate the presence of a Skolithos ichnofacies (Narbonne, pers.comm., 1981). Diplocraterion (Pl. 19, fig. 1) is restricted to high energy marine environments (Seilacher, 1968; Narbonne, pers.comm.). Polarichnus (Pl. 19, fig. 2) is apparently restricted to intertidal environments (Narbonne et al., 1979). Arenicolites and Lingulichnus may be observed over a broad range of environments but are most common in the Skolithos and Cruziana ichnofacies (Narbonne, pers.comm.). Unidentified vertical and horizontal burrows (Skolithos?, Planolites?) as well as arthropod walking trails proved to be environmentally non-diagnostic. However, the low diversity Skolithos ichnofacies suggests harsh environmental conditions such as those exhibited in the intertidal zone.

Fl

The laminated siltstone lithofacies represents approximately 22% of the observed lithofacies in the fine-grained facies association. Unit thicknesses range from 18 cm to 4.6 m (mean = 1.2 m). Fl facies contain sandy-silty laminae alternating with clayey laminae and is termed 'pinstripe bedding' (Pl. 20, fig. 1). Flaser, lenticular and wavy bedding are the abundant stratification types. Reif and Slatt (1979) suggested that pinstripe bedding is formed in response to moderately fast flowing water with high suspension load. These currents may be related to the distal phases of terrestrial floods; wave activity and/or tidal influence. Pulsations of current energy in response to tidal cycles may account (in part) for the bedding style.

After a period of current activity when sand is no longer transported as traction load, suspension sedimentation buries the substrate under a layer of cohesive mud. Lenticular bedding is an example of pinstripe bedding where traction load sediments are represented by discontinuous small-scale current ripples.

Convolute laminations, small-scale slump folds, water escape structures, load casts and flame structures are soft sediment deformation structures which are particularly abundant in the Fl lithofacies. Evidence for shallow water conditions include mudcracks (Pl. 20, fig. 2); mudchips which have been incorporated within traction load deposits; halite and gypsum casts (Pl. 21, fig. 1); interference ripples (Pl. 21, fig. 2); rounded and double crested ripple marks; gas escape structures (dimpled bedding surfaces); and rare 'chaotic' mudstone. The disruption of the laminated siltstone may have been caused by interfering growth and subsequent dissolution of evaporite minerals in the muds.

Fm

Mottled red-green siltstone is a minor lithofacies (<3%) associated with Fl. Bedding contacts are sharp and planar. The units are generally massive, although faint distorted laminae are present in some cases. Flattened (parallel to bedding) vugs 10 - 15 mm long and green siltstone intraclasts are ubiquitous. The lithofacies probably represents suspension sedimentation in small ponds on the tidal flats. The mottled appearance may reflect subsequent drying and movement of moisture in the muds (Gibling, 1978) or bioturbation.

Gm

Thin, extensive (>400 m) conglomerate units contain extraformational clasts (dolostone, limestone, chert, siltstone) suggestive of a fluvial influence. Thick units (0.4 - 0.6 m) display scour and fill structures; minor low angle clast imbrication; isolated trough cross-bedding; and interbedded horizontally stratified to low angle stratified sandstone lenses. The basal contacts are sharp-planar to slightly erosional. The conglomerate is generally framework-supported and well sorted although several units display normal grading and matrix-supported fabrics near the tops of the beds. Low level reworking by waves and tidal currents could have partially liquified the gravel beds. At slack water stage fines may have infiltrated the gravel surface.

The sheet-like, poorly channelized conglomerate units represent the distal portions of terrestrial floods derived from the fan complex. Minor, isolated cross-bedding may be due to the aggradation of dunes during the waning stages of flood conditions.

4.4 Vertical Distribution of Lithofacies

The representative section (Fig. 19) displays the interdigitating nature of the constituent lithologies in the fine-grained facies association. It appears that the lithofacies fall into two broad groups.

In the first group, Fl is the major rock type with subordinate Cf, Sh, Sl and Gm lithofacies. The association of Gm beds indicates relative proximity to a terrestrial source. Low energy bed forms and stratification types characterize this assemblage, including normal grading, climbing ripple lamination, ripple marks and pinstripe bedding. Periods of current bedload during mid-tide cycles and/or terrestrial flood episodes and high wave activity fluctuate with periods dominated by suspension sedimentation (high/low tide, low wave activity, limited terrestrial floods) and is responsible for the pinstripe bedding (Pl. 20, fig. 1).

An impoverished fauna and deep U-shaped burows (>13 cm) indicate high environmental stresses (Seilacher, 1967). Rare unit packages show a mudstone/sandstone ratio increasing upwards in a gradational interbedded manner. Loaded and gradational basal contacts are suggestive of variable sedimentation rates. Rapid changes in water depth are reflected by variations in paleocurrent data, interference ripples, double-crested ripples and rounded symmetrical ripples (Klein, 1975). Evidence of repeated drainage and subaerial exposure of the sediments is recorded by wrinkly marks, salt casts, intraclasts, desiccation and syneresis cracks, and gas escape structures.

The assemblage probably formed in the mid to high intertidal zone as mixed mud flats, where there were widely varying conditions of sediment supply. The prograding low energy intertidal flat sequences were repeatedly interrupted by terrestrial sheet floods and storm activity. Fig. 19 illustrates proposed sequences deposited in a mixed mud flat environment.

Sediments in the second group were deposited by higher energy bed load transport processes (Fig. 19). Sedimentary structures indicative of shallow, fluctuating water depth are minor components compared to those exhibited in the mixed mud flat facies. Stronger currents associated with terrestrial flood episodes, high energy wave activity and asymmetric tidal cycles, transported sand derived from the fan complex and high intertidal flats into the intertidal to subtidal zone. The general absence of thick (2.0 m) winnowed sand bodies may indicate a small tidal range. Sh,Sl lithofacies alternate with Cf lithofacies in the second grouping or sand flat - tidal flat facies, and documents the spasmodic nature of terrigenous influx into the carbonate tidal flat environment. Detrital carbonate was provided by reworking of tidal flat sediments and terrestrial input. Emergence of the sand flats and tidal flats allowed thin mud drapes to form on stagnant depressions as the area drained. Current velocity fluctuations, and shoaling processes were primary factors in determining changes in flow regimes in the sand flat - tidal flat zone. Flat lamination, low angle stratification, abundant intraclasts lining shallow erosional scours, primary current lineation and rare tool marks are predominant sedimentary structures in this assemblage (Fig. 19). The Skolithos ichnofacies is mainly restricted to the sand flat - tidal flat facies and is an indicator of a high energy, marine depositional environment.

Subordinate Fl, Fm, Sr lithofacies reflect sedimentological evidence for shallowing to subaerially exposed conditions (closely spaced mudcracks; branching and linear syneresis cracks; normal grading; flattened, low amplitude wave ripple marks, minor wavy bedding; gas escape structures; flaser bedding).

The grouping of lithofacies into mixed mud flat facies and sand flat - tidal flat facies cannot be further subdivided, because the vertical succession of lithofacies is unpredictable. Deposition may have been affected by a number of processes, which interrupted cyclic sedimentation to produce random sequences. These include terrestrial flood episodes, major shifts of the depocentres of fan lobes shifted across the fan complex, and storm and normal wave activity. Random sequences may be enhanced on low depositional slopes, and where subsidence and sedimentation are approximately in balance (Daily et al., 1980).

4.5 Petrography and geochemistry of the dolostones

4.5.1 Aims and Methods

In this study, attempts are made to interpret depositional environments based on trace element studies published by several authors (Kinsman, 1969; Bathurst, 1975; Dunham and Olson, 1980; Gibling, 1978; Sibley, 1980; Veizer, 1977; Veizer and Demovic, 1974; Land et al., 1975).

The aims of this portion of the study were to answer the following questions:

1. How does the Sr^{+2} distribution reflect the lateral variation of facies as well as timing of the dolomitization events?
2. Are there any geochemical differences between lithofacies constituting the low intertidalite assemblage or sand flat - tidal flat package and the high intertidalite assemblage or mixed mudflat package?

Gross petrographic, sedimentological and paleontological descriptions of the samples taken from the tidalite sequence are summarized in Appendix 1. It is clear that there are no distinguishing characteristics in the dolostone lithofacies to separate the mixed mud flat facies assemblage from the sand flat - tidal flat facies assemblage.

Care was taken in selecting samples with little (30 - 60%) siliciclastic material and no carbonate clasts. Thin sections were stained in a solution of 0.2% hydrochloric acid, 0.5% potassium ferrocyanide and 0.2% alizarin red S. Resulting stained minerals included: Fe^{2+}-free calcite (red), Fe^{2+}-rich calcite (purple), Fe^{2+}-free dolomite (colourless, and Fe^{2+}-rich dolomite (dark blue - turquoise).

The corresponding rock samples were powdered using the jaw crusher, plate crusher and shatter box. Approximately 1 g of each sample was treated with 8% (v/v) HCI overnight. The solutions were filtered into 50 ml. volumetric flasks. Insoluble residue (I.R.) was determined gravimetrically after ashing the filter paper at 900°C for two hours. Average reproducibility was 11 relative %. Mg, Ca, Sr concentrations were determined on a VARIAN-TECHTRON AAS-GR. Mg and Ca were processed through an air-acetylene flame, and Sr in a nitrous oxide flame. $Sr(NO_3)_2$ was added to samples and calibration solutions for Ca and Mg determinations. Concentrations were recalculated on a total carbonate basis. Average accuracy of element determinations compared to standard rock samples was 8.3 relative %.

4.5.2 Petrography

Examination of the thirteen thin sections revealed petrographic evidence for "late diagenetic" replacement textures and mineral transformations. Dolomitization proceeded along sequential steps:

1. Replacement of fine-grained matrix, probably in a near surface environment (Folk, 1974). Finely crystalline, subhedral dolomite rhomb cores contain cryptocrystalline inclusions, giving the crystals a cloudy-centered appearance. Folk and Land (1975) suggested that in solutions of high salinity, rapidly formed dolomite incorporates a variety of ion species which are 'hastily' crammed into the crystal lattice. Several of these cores appear rounded, implying local reworking on the tidal flats by traction currents. The high siliciclastic content (30 - 60%) indicates that detrital dolomite is probably a significant component of these rocks. Whether the dolomite was predominantly from the erosion of older source rocks or formed within the depositional basin is unknown. Reworking of early formed dolomite in landward parts of the tidal flats probably provided most of the detrital dolomite. Gibling (1978) made similar observations for the Peel Sound Fm. and Somerset Island Fm. on Somerset Island. A local source is consistent with the limited input of the uplift area at that time (5% gravels).

2. Enlargement of rhombic crystals in the matrix with the formation of iron-free, clearer outer rims on the dolomite crystals. The syntaxial rims may reflect gradually changing diagenetic solutions (Lumsden and Chimahusky, 1980). Folk (1974) suggested that increased influence of meteoric water with lower ionic strength would result in fewer lattice impurities in

the crystal. The clear euhedral rims may be growing in diagenetic fluids that are undersaturated with respect to calcite, hence calcite inclusions that may be present in the dolomite cores are excluded from continued growth (Sibley, 1980).

3. Iron-rich dolomite rims superimposed on iron-free rims and coarse-grained iron-rich dolomite infilling voids. Meteoric waters may have significant Fe and Mn, if there is a ready source of iron. Examination of the thin sections revealed traces to 2% iron oxides. Fe is incorporated into the dolomite crystal under reducing conditions (Folk, 1974).

4. Late-stage infilling of intercrystalline porosity by sparry calcite. Euhedral dolomite rhombs appear to 'float' in coarse iron-free calcite patches; however, no enlargements in the rhombs were observed. Folk and Land (1975) observed that once Mg/Ca ratios drop below 1:1 to 1:10, sparry calcite is the typical cement formed by meteoric waters. Sibley (1980) suggested that in a marginal-marine regressive sequence, once there is sufficient P_{CO2} in meteoric ground water, dolomitization will cease and residual calcium carbonate will be involved in solution-precipitation phenomena to form low magnesium calcite.

The petrography records progressive changes in carbonate mineralogy in response to the chemical evolution of the diagenetic fluids. This occurred as the influence in the mixing zone became subordinate to the influence of meteoric water, which is consistent with the progradational nature of the clastic sequence.

4.5.3 Geochemistry of the dolostone units

Introduction

Tidal flat environments are transitional between marine and meteoric conditions. Folk and Land (1975) described a schizohaline dolomitization model involving rapid changes in salinity.

The low ionic strength of meteoric waters and a readily available source of Mg^{2+} (sea water) favour dolomitization of carbonate muds. The mixing zone may be related to successive shoaling cycles controlled by episodic tectonic processes. Thus dolomite formation should display a close spatial relationship to local paleogeography (Davies, 1978). The driving force for the mixing zone may also be influenced by local evaporation of the upper part of the fresh water lens, eustatic changes in sea level and variations of the inflow and recharge of the fresh water aquifer (Folk and Land, 1975; Davies, 1978).

Dolomitization processes in the schizohaline environment require the following conditions:

1. a sufficient source of Mg^{2+} to enable dolomitization to proceed.
2. a driving mechanism to move large volumes of water through the rock. (Davies, 1978).

These processes include capillary concentration, the flood recharge and evaporative "reflux" model (Gibling, 1978). In these cases, dolomite formation occurs in response to the reaction of $CaCo_3$ with hypersaline brines. Dolomitization is rapid and near the water - sediment interface. "Early diagenetic" dolostone is formed from an aragonite precursor prior to inversion to calcite (Veizer et.al., 1978). "Late diagenetic" dolostone is formed from calcite (Veizer et.al., 1978), and is characteristic of the mixed-water or schizohaline dolomitization model. The mixing water zones may be close both laterally and vertically to hypersaline environments (Dunham and Olson, 1980).

Veizer and Demovic (1974) provided evidence to conclude that the bimodal distribution of Sr observed in ancient limestones is facies dependent (i.e. controlled by the mineralogy and trace element content of the original sediment). Chemical studies of the dolostone units together with sedimentological and petrographic studies (Appendix 1) may provide valuable information for understanding carbonate diagenesis. The chemical results are tabulated in Appendix 2.

Insoluble Residue

The variations of the non-carbonate fraction are presented in Fig. 20. The overall mean I.R. content is 54.3%. There is no significant difference in the means between the mixed mud flat facies and the sand flat - tidal flat facies (students' t-test; 95% level of significance). The percentage of detrital silicate constituents cannot be utilized to distinguish dolostones from either group.

Linear regression analysis yielded a high positive correlation coefficient value ($r = 0.777$) for I.R. amd Mg^{+2} data.

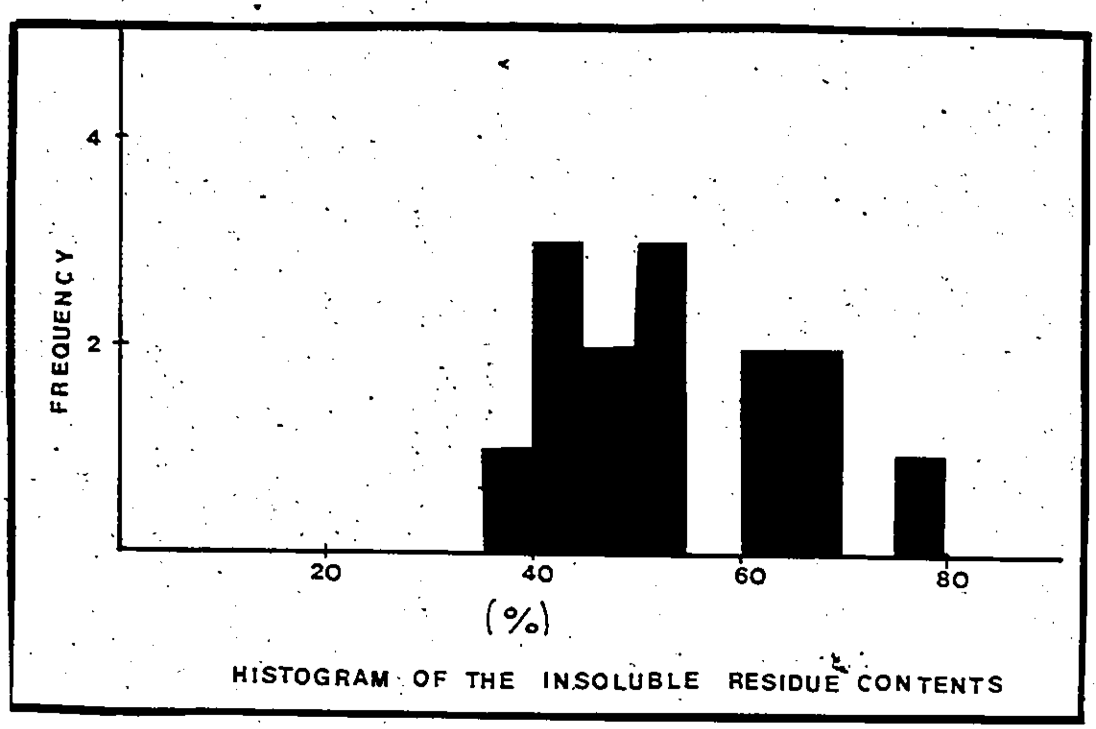


Fig. 20: Dolostone samples obtained from the Cf lithofacies in the fine-grained facies association.

The positive correlation between insoluble residue and magnesium may indicate that some magnesium was derived from the acid leaching of clay mineral silicates such as chlorite.

Strontium

Bathurst (1975), Kinsman (1969) and other authors have noted that trace concentrations of strontium offer clues to the diagenetic history of carbonate minerals. Most work has utilized Sr as a trace because of its importance as a constituent in the precursor carbonate sediment (Land, 1980). Because of relative ionic sizes, strontium substitutes for Ca and Mg positions in dolomite and calcite. This is reflected by weak negative correlation between Ca and Sr, and between Mg and Sr.

$$(Mg,Sr) \; ; \; r = -0.394$$
$$(Ca,Sr) \; ; \; r = -0.226$$

Veizer et al. (1978) noted that because Sr content in a polycomponent carbonate rock depends on its relative proportion of calcite and dolomite, it is convenient to discuss data in terms of Sr/Ca. This data will correct for possible mineralogical inhomogeneities. The bimodal distribution of Sr/Ca in limestones is facies-dependent (Veizer and Demovic, 1974). Low Sr/Ca values in littoral zones may in part reflect loss of strontium after transformations from aragonite to low magnesium calcite, and also more effective diffusion in zones with substantial grain surfaces (Pingitore, 1978).

High Sr/Ca values characterize hypersaline muds, which have lower effective diffusion rates and high aragonite content.

Veizer and Demovic (1974) concluded that "early" diagenetic dolomites frequently had 1000 Sr/Ca ratios greater than 0.4. Dolomite probably formed by the dolomitization of aragonite under conditions of high salinity (Veizer et.al., 1978; Gibling, 1978).

Insoluble residue content and 1000 Sr/Ca values possess a strong negative correlation ($r = -0.795$). If insoluble residue contents are indicative of proximity to source, i.e. zones influenced by meteoric water, then the lower 1000 Sr/Ca values may reflect the dominance of the schizohaline dolomitization model. High 1000 Sr/Ca values and low insoluble residue contents favour an early diagenetic dolomitization model. Fig. 21 displays data which permit the interpretation that both models were operative. Fig. 22 shows an upward trend in decreased 1000 Sr/Ca values, probably indicative of increased fresh water influence.

1000 Sr/Ca values cannot be utilized to distinguish mixed mud flat facies from sand flat - tidal flat facies. The values likely correspond to the "transitional" diagenetic dolostones of Veizer and Demovic (1974).

Therefore, dolomite probably formed in an "early" diagenetic, hypersaline or hyposaline environment, but the chemical character has been modified by later post-depositional stages of diagenesis. This is especially evident in light of the sedimentological and petrographic data provided in the previous sections in this chapter.

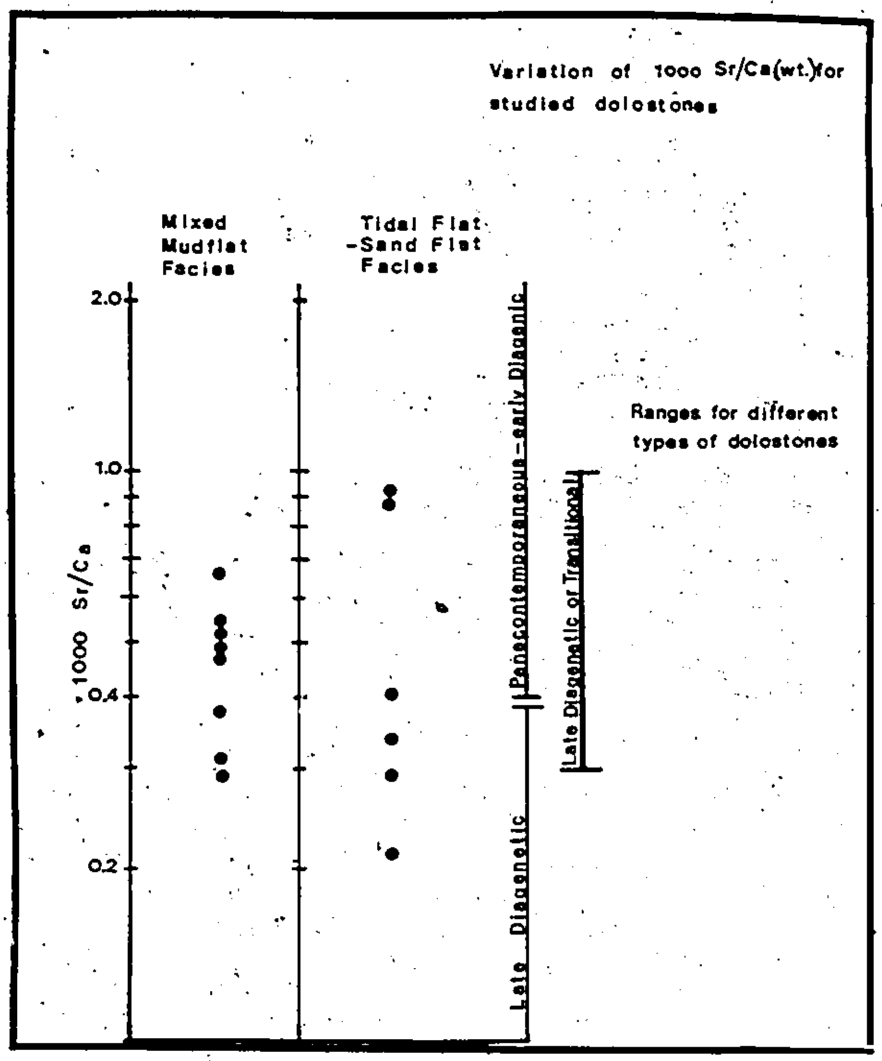


Fig. 21: After Veizer and Demovic (1974).

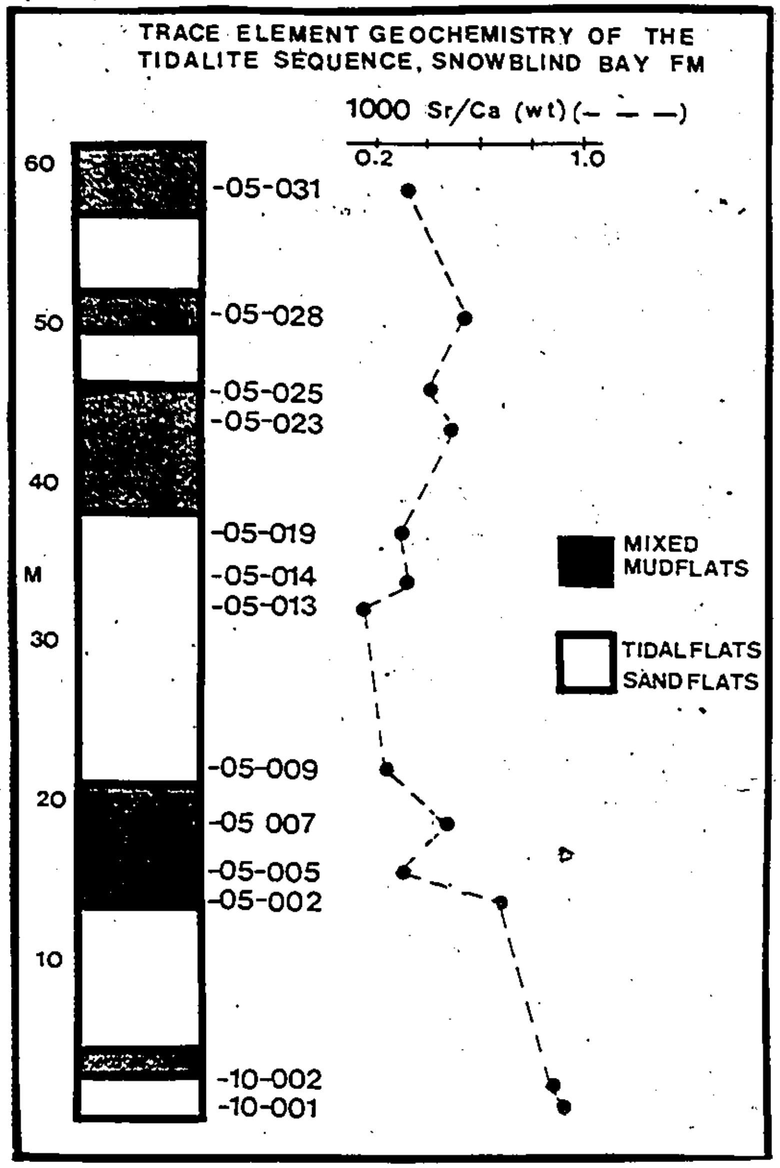


Fig. 22: 1000 Sr/Ca (wt.) values in the fine-grained facies association. See Fig. 19 for corresponding lithological log.

4.6 Depositional Environment

The fine-grained facies association is interpreted as an intertidalite succession. Lithofacies include: 1. sediments deposited as wave - and current - generated traction load; 2. sediments deposited as slack water suspension sediments.

Deposition of fines in shallow water may be related to the frictional loss of wave and current energy during passage into sheltered parts of the tidal flat (Daily et.al., 1980). Therefore sand carried off by storms, terrestrial floods and strong current re-working is unable to return to the landward portions of the tidal flats (mixed mud flats). This hypothesis predicts a fining shoreward and upwards in the regressive tidalite sequence. Unfortunately only the basal 60 m of the Snowblind Bay Fm. could be observed and this trend could not be ascertained.

Horizontally laminated sandstones and dolostones display scattered unimodal paleocurrent directions (fig. 17) with only rare bimodality reflected in small-scale structures (reactivation surfaces; micro-cross lamination). The defective bimodality observed in the sedimentary structures may reflect one or a combination of several processes that are operative in this environment.

1. The dominant constructional phase is the ebb-tidal current. Asymmetry of the tidal ellipse would indicate that subordinate currents were not strong enough to reverse the bedforms (De Raaf and Boersma, 1971).

2. Bedforms may display partial reversal at the highest point of the structure which has the lowest preservation potential. Reactivation surfaces may also form by wave reworking or represent convex-upwards set boundaries formed by eroding leeside eddies of advancing superimposed megaripples (Levell, 1980).
3. Tidal currents may be reinforced by another current system (eg. terrestrial floods; tidal range is insufficient to reverse flow directions during periods of high terrestrial discharge).

If large volumes of sediment were derived from an active prograding fan complex and wave-, or tidally-reworked inactive fans, an accreting barrier spit shore line may have existed during deposition of the Snowblind Bay Fm. The development of barrier islands is enhanced by the following conditions (Reinson, 1979):

1. low gradient continental shelf adjacent to a low-relief coastal plain
2. abundant sediment supply
3. moderate to low tidal range

The absence of deep tidal channels in the intertidal flats suggests a small tidal range (Tankard and Hobday, 1977), since the quantity of water removed from the tidal flats would have been small. The scattered, weakly unimodal paleocurrent directions points out that the tidal range was not sufficient to reverse bedforms during periods of high terrestrial floods.

Furthermore, the close vertical association of marine and nonmarine elements on a high-gradient depositional surface (proximal to fan complex) indicates a low tidal range. Nonmarine or supratidal elements (Gm, desiccated Fl, Fm) commonly overlie (<2 m) lithofacies containing trace fossils of marine affinity (e.g. Diplocraterion).

Microtidal barrier islands (tidal range <2 m) tend to be long and linear with extensive storm washover features because tidal inlets are not large enough for storm surge flow (Reinson, 1979). During Snowblind Bay time, barriers were frequently overwashed and storm surge deposition took place on the intertidal flats and subaerial fan complex (e.g. Cf unit in the conglomerate-sandstone facies association). Because of the high gradient depositional slope, there was no wide surface for enhanced tidal inlet development.

The barrier island complex was presumably extensively eroded by strongly varying terrestrial discharge and by wave processes inundating inactive tracts as the locus of sediment supply shifted (Hine and Boothroyd, 1978).

In summary, the fine-grained facies association exhibits features indicative of intertidal deposition. However other geologic processes including terrestrial floods and storm wave activity occurred at various times during the deposition of the sequence. This is signified by the presence of sheet-like conglomerate and sandstone units, wave ripple cross -

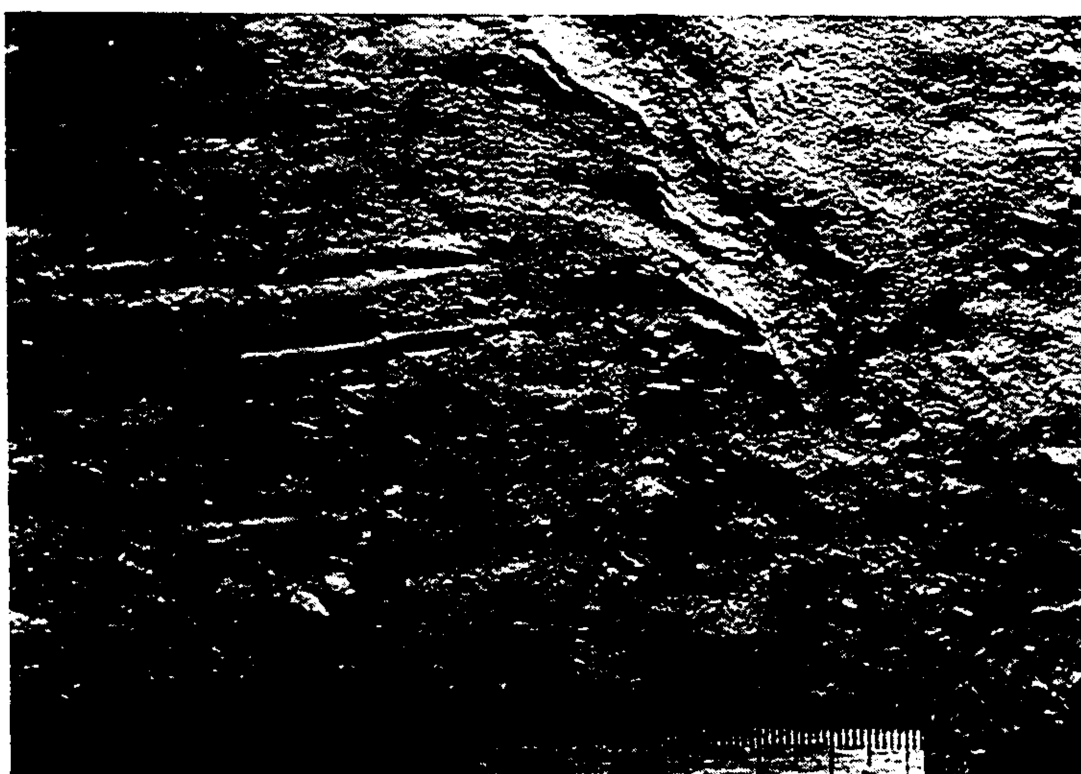
stratification, and abundance of upper flow regime sedimentary strucures in the dominant Sh, Sl, and Cf lithofacies of the fine-grained facies association.

Plate 17

Fig. 1. Oblique aerial view of the fine-grained facies association at Read Bay. Note sheet-like geometry of constituent lithofacies. Cliff exposure is approximately 30 m high.

Fig. 2. Chevron structure, groove and prod marks. The large prod mark and chevron structure show a paleocurrent direction towards the bottom of the photograph. Scale is in mm. Location at section 10.

1



2

Plate 18

Fig. 1. Soft sediment deformation structures in Cf unit. Note box-shaped flame structures and load casts above scale (1·5 cm). Possible water escape structures in strata adjacent to the scale. Location at section 05.

Fig. 2. Ostracoderm head shield recovered from scree 100 m east of section 10. Scale is in mm. View is on bed top.

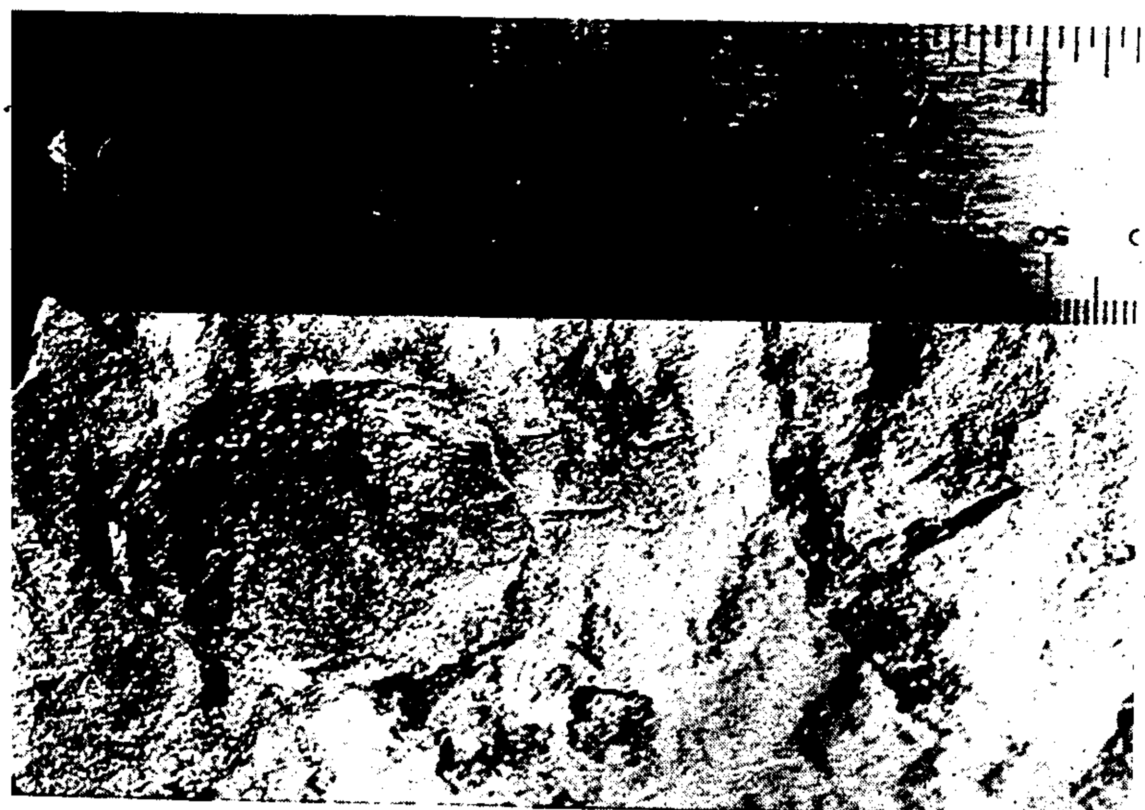

1

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Plate 19

Fig. 1. Deep U-shaped burrows (Diplocraterion) with retrusive spreite. Scale adjacent to large burrow is 14 cm long. Location at section 05; unit 028.

Fig. 2. Polarichnus, an intertidalite trace fossil, in basal scree at section 10. Pen is 15 cm long. Other traces may be Lingulichnus (bottom of photograph).


1

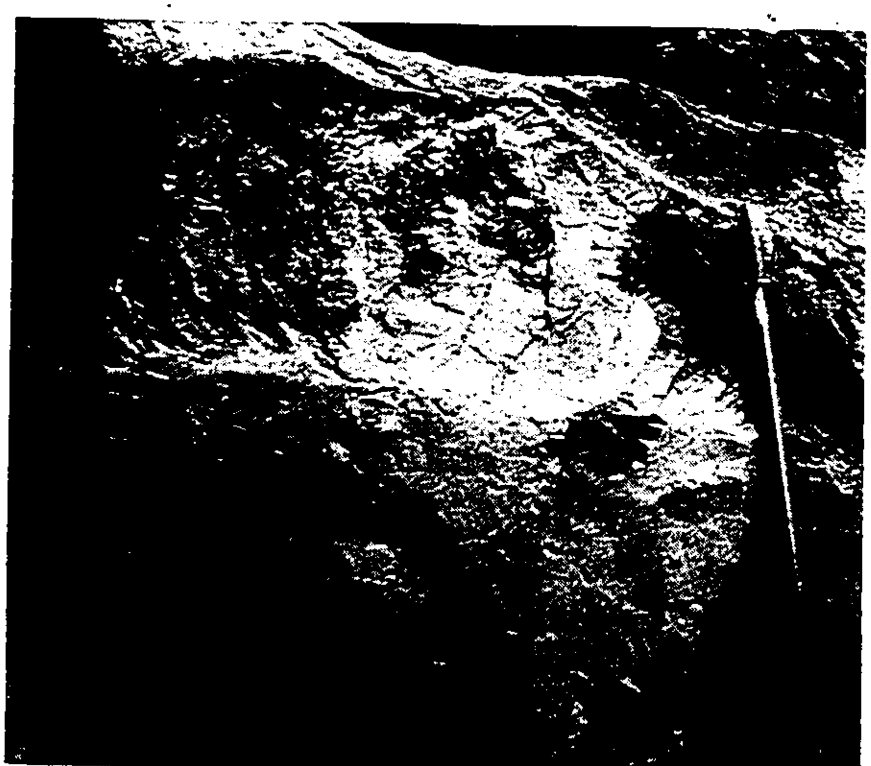
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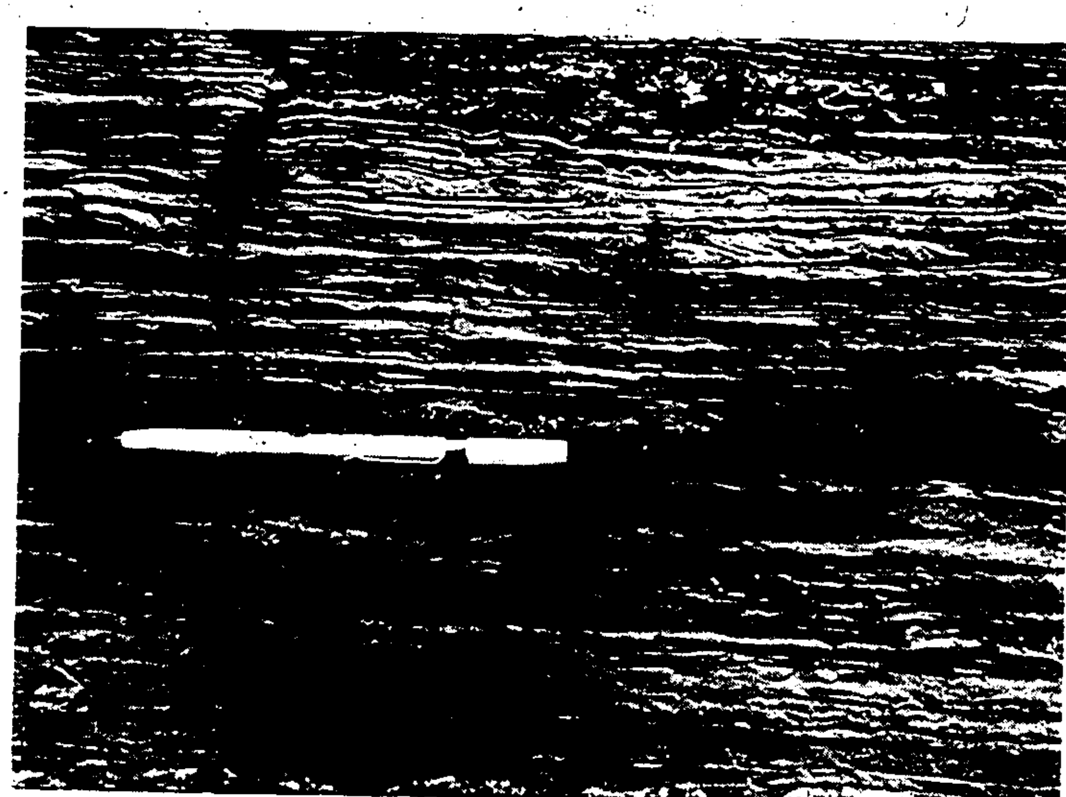
Plate 20

Fig. 1. Pinstripe bedding in Fl lithofacies at section 05, including lenticular and wavy varieties. Note rippled sandstone lenses above the pen (14 cm).

Fig. 2. Rounded, bifurcating ripple crests display syneresis cracks. Silt-infilled trough areas. Lens cap is 6 cm diameter. Location at section 10; unit 005.

2

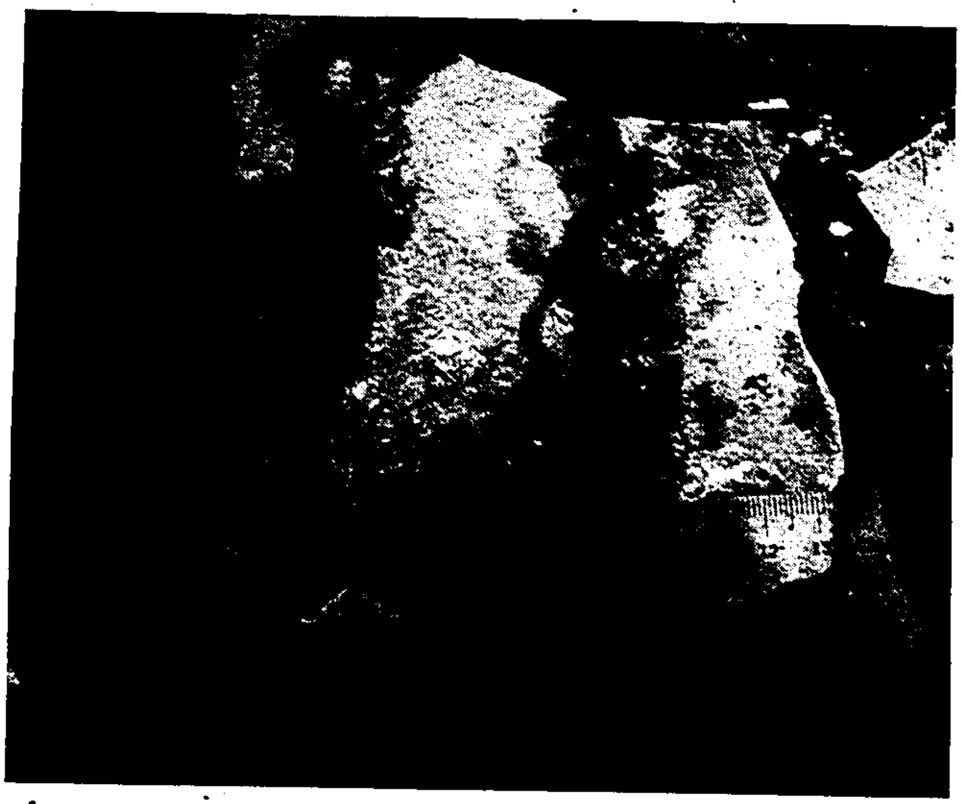


1

Plate 21

Fig. 1. Symmetrical ripple marks in Fl lithofacies. Crests were preferentially hematitized (dark). Note abundant salt casts. Scale is in mm. Location at section 05.

Fig. 2. Interference ripple marks. The two sets are at approximately 90° to each other. Note double-crested nature of the smaller ripple marks. Scale is in mm. Location at section 05.

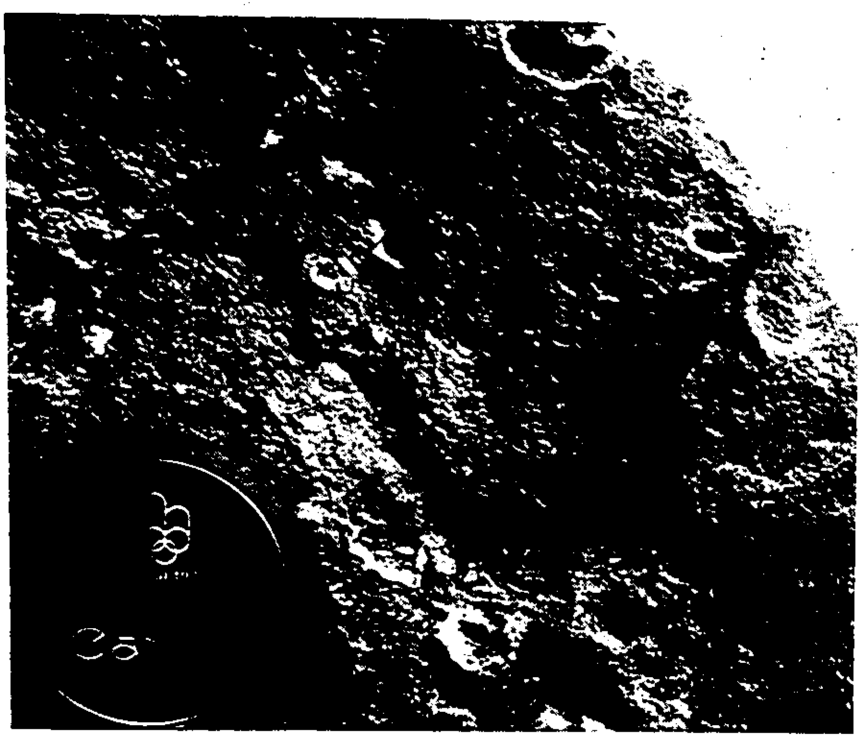


1

2

Plate 22

Vugs are partially infilled with sparite cement in a Sh unit. Lens cap is 6 cm diameter. Location at site 10.



Chapter V

PALEOENVIRONMENTAL RECONSTRUCTION OF SILURO-DEVONIAN CLASTIC WEDGES IN THE BOOTHIA UPLIFT REGION

5.1 INTRODUCTION

In this chapter the paleocurrent data, lithofacies distributions and paleodispersal trends are integrated to reconstruct the paleogeography of the Snowblind Bay Formation in the study area. Sediment dispersal patterns are based on:

1. lateral changes in mean clast size
2. changes in scale and type of sedimentary structures
3. changes in bedding styles and bed thicknesses

Primary sedimentary structures are indicators of depositional processes and signify changes in flow regime during the development of the clastic wedge.

The second part of this chapter is a review of other Siluro-Devonian clastic wedges bordering the Boothia Uplift. Sedimentological comparisons of the Snowblind Bay, Peel Sound and Prince Alfred Formations are discussed. Regional evolution of the clastic wedges is examined in the light of recent work published by Gibling, 1978; Miall, 1969; Kerr, 1977; Miall and Gibling, 1978; Morrow and Kerr, 1977; and Thorsteinsson, 1980.

5.2 PALEOGEOGRAPHIC EVOLUTION OF THE SNOWBLIND BAY FORMATION

The coarsening-upward Snowblind Bay Formation is interpreted as a subaerial alluvial fan complex that prograded over a tidalite sequence (Fig. 23) on the basis of data in previous chapters.

Alluvial fans which build into a standing body of water have been termed fan deltas (Brown et al., 1973). Rust (1979) suggested that these bodies should be called coastal fan complexes where they form principally in response to tectonism in the adjacent highlands.

Directional features in the conglomerate facies association were measured mainly from clast imbrication studies on Gm unit bedding surfaces (Appendix 3). Dispersal of the sediment in a radiating pattern is evident in Fig. 5. A source area to the north or northwest is indicated. This hypothesis is substantiated by the discovery of three graptolite-bearing clasts in sections 02, 03. Thorsteinsson (1980) suggested that the most probable source of the chert and graptolite-bearing clasts is the Cape Phillips Formation which is exposed north and west of the Snowblind Bay Formation. The radiating dispersal pattern is consistent with the distribution of facies associations, reflecting a south - southeastward shift of the source area (Figs, 5, 17). Sandstone clasts were probably derived from the erosion of the alluvial fan distal equivalent lithofacies (i.e. fine-grained facies association; conglomerate-sandstone facies association) as the fan complex prograded southward. Downslope trends display a distinct decrease in clast size, ratio of conglomerate to other lithology types, and

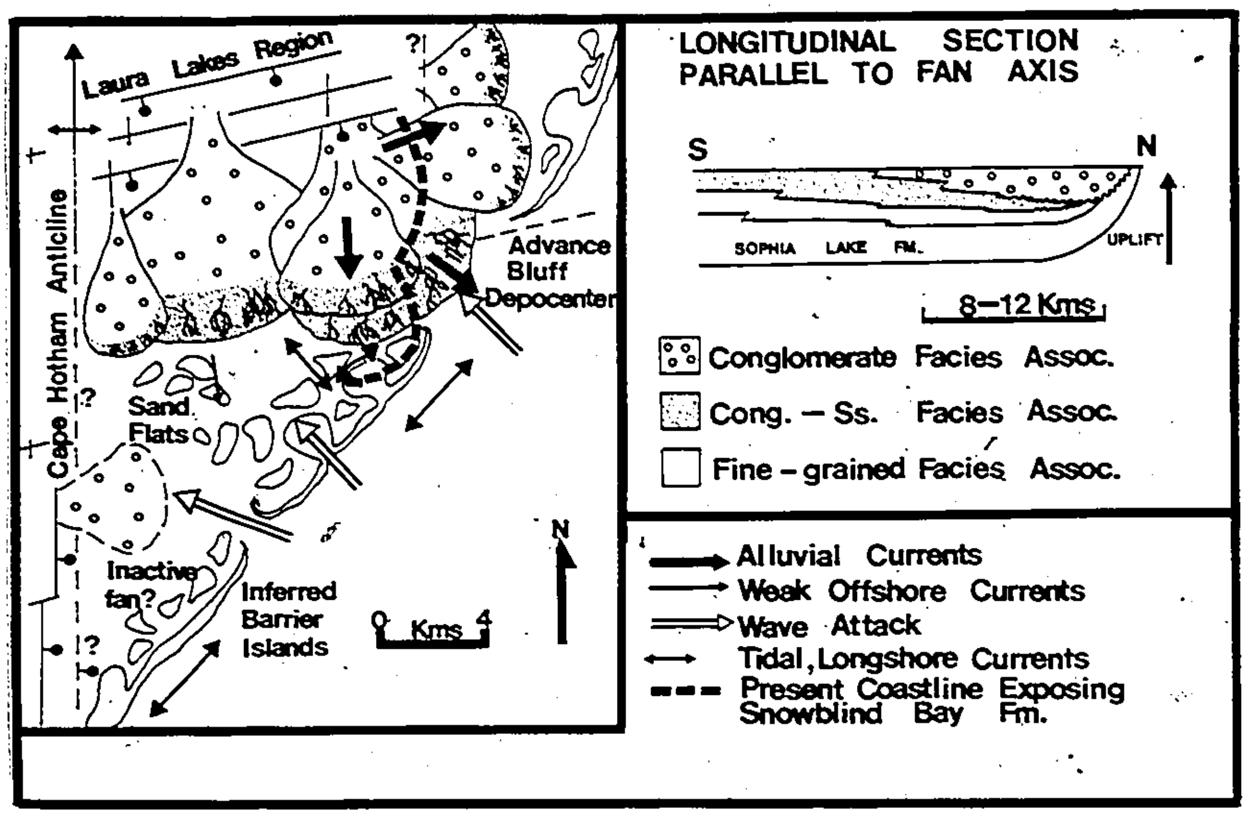


Fig. 23. Paleogeographic reconstruction of the Snowblind Bay Formation (L.Devonian). The coastal fan complex may have been fed by an entrenched feeder system following structural lineaments in a side-stepping fault system. Wave attack directions and marine current directions are postulated.

sedimentary unit thickness (Fig. 24).

The fan complex was likely fed by an entrenched feeder river system which prograded southwards with progressive episodic uplift. The radiating dispersal pattern in the conglomerate facies association was controlled by sheetflood deposition downslope of the fan intersection points. Section 08, 09 are proximal to a fanhead entrenched system for reasons outlined in Chapt. 2. Paleocurrent directions obtained from these sections indicate a southerly flow. Stream power was high enough to spread gravel sheets through wide, shallow channels on the proximal fan surface. The crude horizontal stratification and scarcity of avalanche faces in the Gm units suggest that shallow sheetfloods deposited debris on a low paleoslope (Allen, 1981).

Bed contacts are predominantly sharp and flat in the proximal fan environment (Fig. 25). An increased percentage of erosional, irregular contacts is observed for the <u>conglomerate-sandstone facies association</u> (distal fan). Flow probably became more channelized because of a decrease in sediment concentration with progressively decreasing competency (Bull, 1977). Paleocurrent data indicates southeasterly transport directions away from the source areas (Fig. 17). The data are unweighted to permit the inclusion of azimuths obtained from parting lineations. Nonetheless, the dispersion pattern is consistent with the proximal fan dispersal pattern (Fig. 5). Unfortunately measurements were restricted to coastal sections 06, 07, 07A

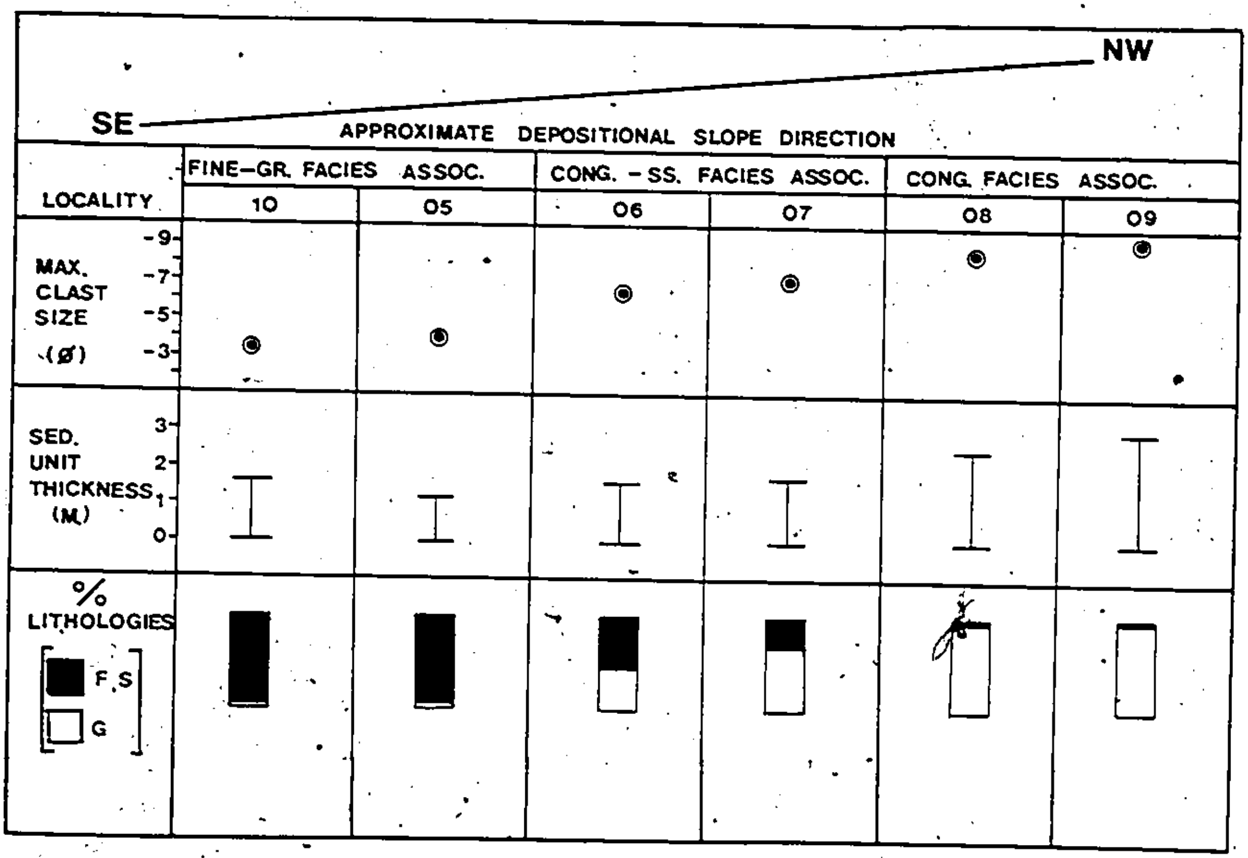


Fig. 24. Downslope trends for maximum particle size, sedimentary unit thickness, and relative abundance of lithologies in the Snowblind Bay Formation. F = mudstone, siltstone; S = sandstone; G = conglomerate. Note that section 10 includes an anomalously thick (7 m) Sh, Sl unit (overwash surge deposit).

FACIES ASSOCIATION	BED CONTACTS (%)			
	SHARP, FLAT	EROSIONAL, IRREGULAR	LOADED	GRADATIONAL
CONGLOMERATE	60.6	18.1	—	21.3
CONGLOMERATE -SANDSTONE	49.0	33.0	2.8	15.1
FINE-GRAINED	46.0	7.0	10.0	37.0

Fig. 25. General abundance of bed contact types in the Snowblind Bay Formation.

because of lack of outcrop further inland.

Proximity to marine influence is indicated by the presence of trace fossils Polarichnus sp. and Planolites sp., salt casts and a 2 - 3 m dolarenite unit interpreted to be a storm surge deposit. The reader is referred to Chapt. 3 where these features are described in detail. Thorsteinsson (1980) reported the occurrence of marine acanthodian scales and spines in some of the conglomerate units. He suggested that their abundance and lack of wear indicate that they could not have been derived from abraded clasts.

Other downfan trends include an increase in preserved structures formed during low discharge flood conditions, in particular low angle and trough cross-stratification as well as ripple and climbing ripple stratification (Figs. 26, 27). Coarse, graded conglomerate units are abundant in the conglomerate facies association. Finer-grained, crudely to horizontally bedded conglomerate units are abundant in the conglomerate-sandstone facies association, probably representing broad longitudinal bar deposits. There is an increase in the percentage of loaded and gradational bed contacts in the fine-grained facies association. This was a response to tidal sedimentation and the influx of terrestrial sheetfloods into a low gradient, low energy tidal zone. Spasmodic terrigenous input, storm activity, and the migration of fan lobes complicated the distribution of facies belts such that the tidalite sequence was characterized primarily by noncyclic sedimentation

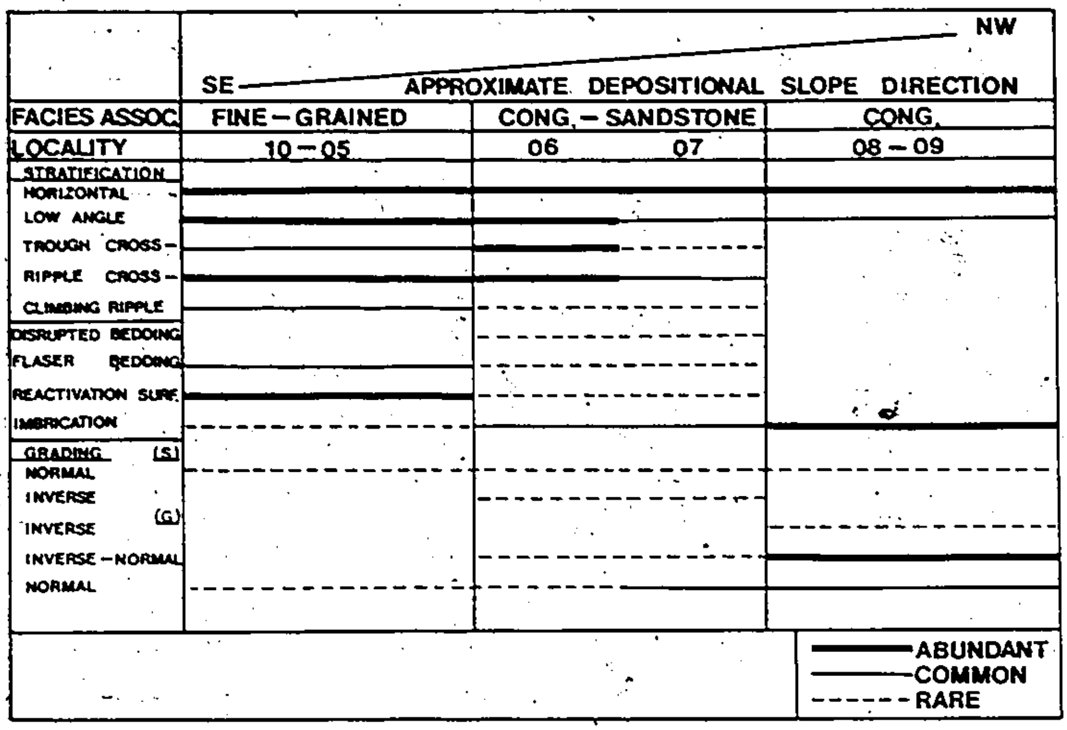


Fig. 26. Downslope trends for stratification in the Snowblind Bay Formation. (S) represents grading in sandstones. (G) represents grading of clast size in conglomerate units.

processes.

The Snowblind Bay fan complex displays:

1. rapidly decreasing grain size downslope
2. evidence for syntectonic activity
3. restricted areal distribution; radiating dispersal pattern parallel to the paleoslope
4. thick, local accumulation
5. rapid facies changes downslope
6. presence of ephemeral lacustrine deposits in the conglomerate facies association

The apparent lack of entrenched fanhead channel deposits and debris flow units may be explained by the intraformational erosion of the proximal fan deposits, as the regressive clastic wedge built out southward and southeastward.

Table 2 summarizes the sedimentological and stratigraphic characteristics for the Snowblind Bay Formation.

Although the clastic wedge flanks an uplifted source area, the succession does not appear to be directly related to a fault scarp. The fan complex may have been fed by entrenched trunk stream systems to the north or northwest.

The Cape Hotham Anticline is a north-trending, 50 km long structural complex of connected anticlines which can be traced into the study area by a series of steeply dipping faults and offsetting cross-faults (Figs, 28, 29). Coarse detritus may have been channeled into feeder canyons following parallel structural lineaments into a block faulted structural re-entrant. An episodic but increasing rate of uplift in the source area to the north and northwest provided a greater abundance of eroded debris through time. The encroachment of progressively coarser-grained sediment over the tidalite sequence implies increased slopes and subsequent fan

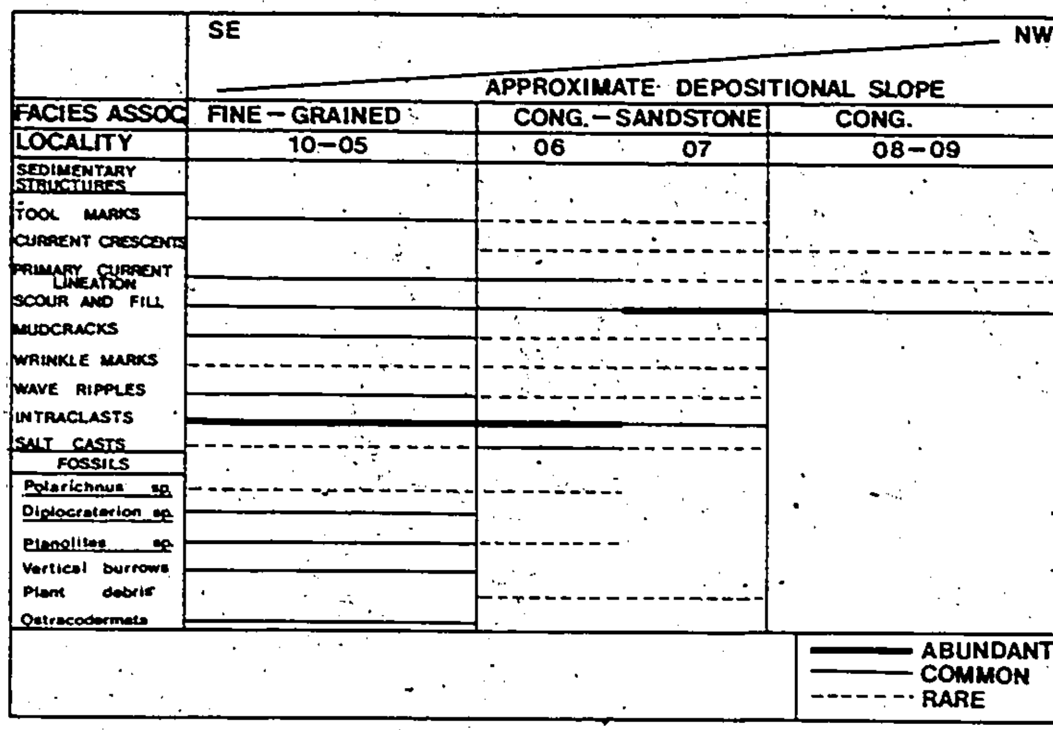


Fig. 27. Downslope trends for sedimentary structures in the Snowblind Bay Formation.

Table 2 Stratigraphic and sedimentological characteristics of the Snowblind Bay Formation

1. The asymmetric distribution of the facies associations indicates that the proximal subaerial fan unconformably overlies older strata.

2. Subaerial fan oversteps marine deposits.

3. Depositional sequence coarsens upwards.

4. Subaerial fan is essentially composed of stream deposits. No caliche development. Debris flow deposits are absent.

5. Drab coloured, horizontally-stratified Gm units pass downfan into distal cross-stratified pebbly sandstone and finer-grained Gm units organized in distinct fluvial cycles.

6. Presence of wave-reworked, matrix-supported conglomerate units in the fine-grained facies association (tidalite sequence).

7. Directional features on subaerial fan complex indicate source to the north, northwest.

8. "Sheet-style" sedimentation; CU, CUFU, FU sequences display evidence for tectonic control of sedimentation processes.

progradation (Fig. 23). A feeder trunk system would be particularly effective in transmitting the influence of tectonic and climatic processes, as torrential rainstorms in the highlands triggered floodwaters which spread out onto the fan surface beyond the intersection point.

Evidence for an east-west trending fault that provided the source of terrigenous detritus is conjectural. An extension of the Snowblind Anticline as a lineament in the Laura Lakes region (Figs. 28, 29) approximately 4 km north of the Snowblind Bay Formation may represent a possible fault zone. This lineament roughly coincides with the major east-west Silurian facies boundary which separates the basinal sediments of the Cape Phillips Fm. to the north from the platform carbonates of the Read Bay Group (Fig. 2). This may indicate that the break in the depositional slope was related to older lines of weakness in the basement structure. Vertical reactivation of this structural weakness(es) may have provided an uplifted northerly source area for sediments of the Snowblind Bay Formation.

Bedrock is not well exposed in the Laura Lakes region and an east-west fault zone with significant structural relief has not been mapped by previous workers (Thorsteinsson, 1958; Thorsteinsson and Kerr, 1968; Thorsteinsson, 1980). Minor WSW-ENE faults which parallel the trend of the Advance Bluff Syncline have been documented in the Laura Lakes area (Thorsteinsson and Kerr, 1968). Whether these faults mark reactivation sites of an older fault system is speculation at this time.

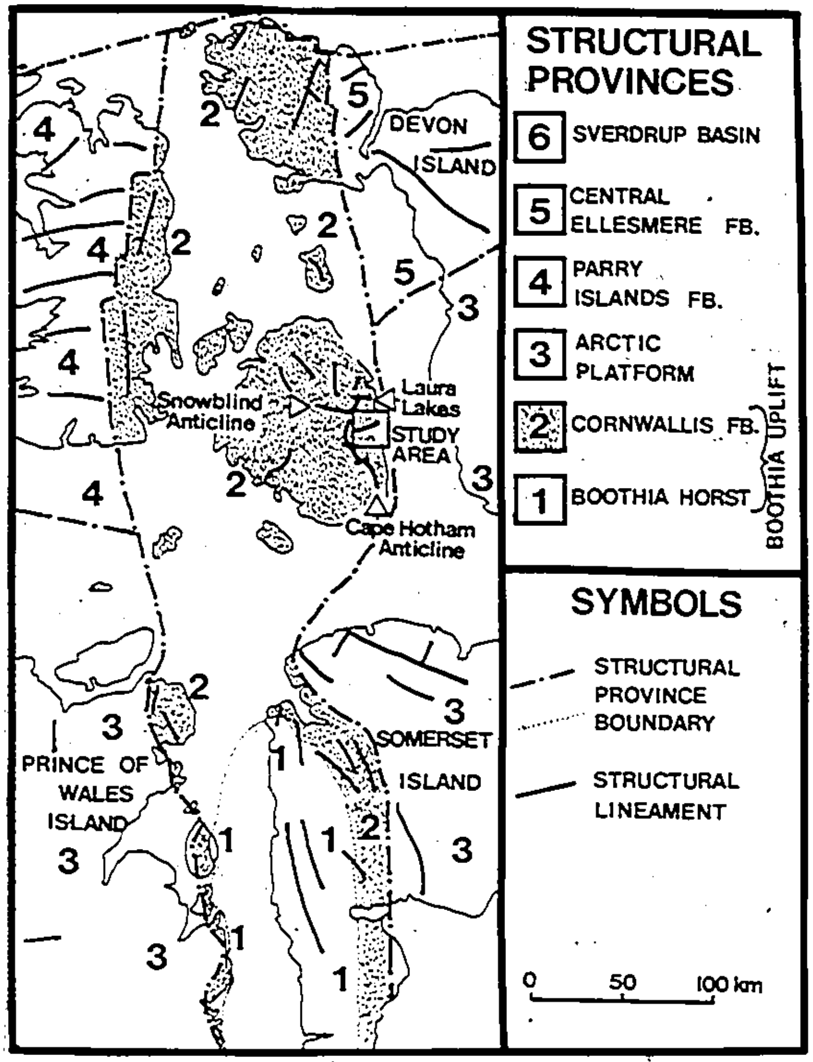


Fig. 28. Cornwallis Fold Belt and surrounding structural provinces (modified after Kerr, 1977; Thorsteinsson and Kerr, 1968). Note en echelon north-south trending structural lineaments. Structures prominent in the study area are shown in Fig. 29.

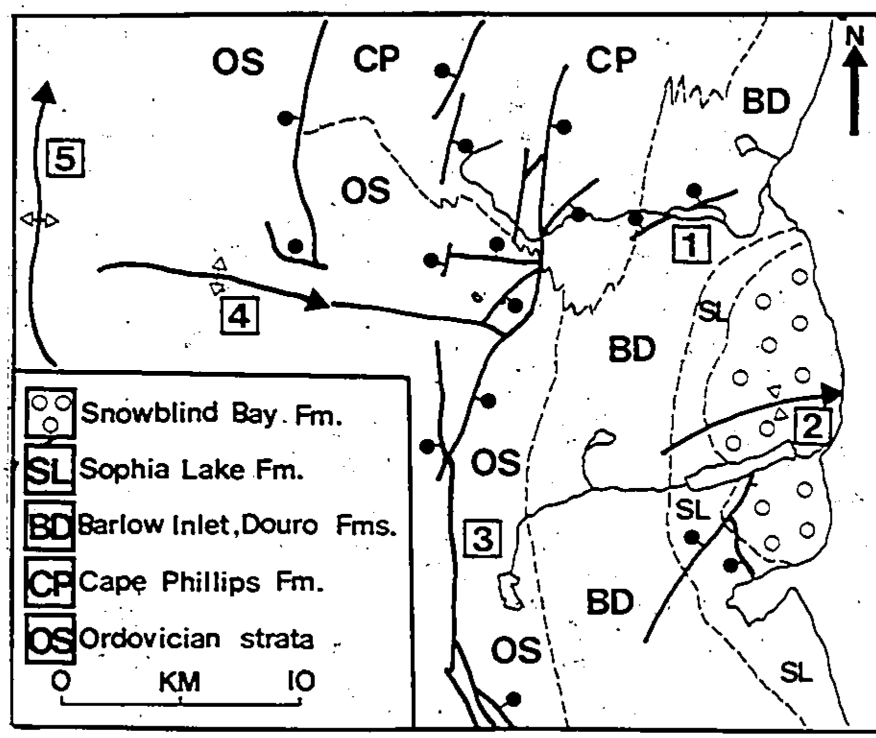


Fig. 29. Structural lineaments in the study area. Solid dots on the downthrown sides of faults where direction of movement is known. Anticlines (diverging arrows) and synclines (converging arrows) plunge in the direction designated by arrows.

1. Laura Lakes region, in the vicinity of the Silurian shelf-basin facies change
2. Advance Bluff Syncline
3. Cape Hotham Anticline
4. Snowblind Anticline
5. Centre Anticline

(Modified after Thorsteinsson and Kerr, 1968; Thorsteinsson, 1980).

5.3 CORRELATION WITH OTHER SILURO-DEVONIAN CLASTIC WEDGES BORDERING THE BOOTHIA UPLIFT

5.3.1 Stratigraphy

The Cornwallis Fold Belt structure was primarily formed by distinct periods of uplift during the Upper Silurian to Middle Devonian interval (Kerr, 1977). The strongest tectonic episode occurred in earliest Devonian time as clastic wedges of synorogenic and post-orogenic origin including sediments composing the Peel Sound Fm., Snowblind Bay Fm., and Prince Alfred Fm. were derived from the Boothia Uplift region. Deposition occurred in marginal basinal depocenters (extramontane basins) developed within the flanking sags of the uplift.

The locations of the clastic wedges are shown in Fig. 30.

1. Peel Sound Fm.
   (Prince of Wales Island)

The Peel Sound Fm. is divided into two members (Miall, 1970a). The lower member on Prince of Wales Island is mainly composed of thick grey-yellow conglomerate units interbedded with red sandstone, siltstone and argillaceous and fossiliferous limestone (Miall, 1969). The base of the Peel Sound Fm. is defined at the appearance of the first extensive clastic horizon, which is either red sandstone or thin, small-pebble conglomerate (Miall, 1969). Several marine limestone beds occur above the first conglomerate horizon. The lower member on the east coast is approximately 450 m thick (Thorsteinsson, 1981). It is unconformably overlain by the upper member. The base of

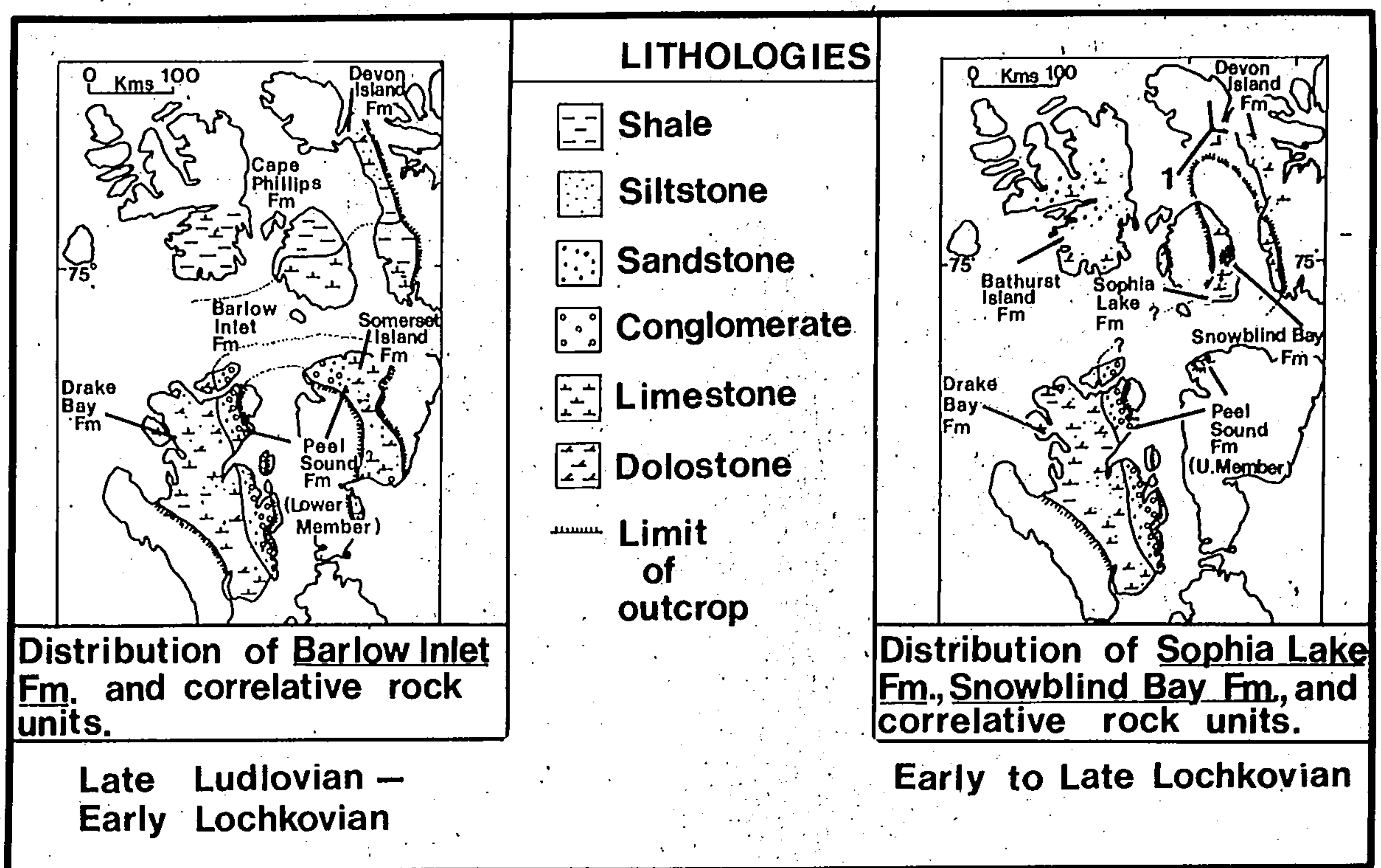


Fig. 30: Paleogeography of correlative rock units in the study area. Late Ludlovian to Late Lochkovian (modified after Thorsteinsson, 1980). Distribution of Prince Alfred Fm. (1) on northwestern Devon Island has only been mapped in the Prince Alfred Bay - Sutherland River map areas. Ages of the Prince Alfred Fm. and upper member of the Peel Sound Fm. are tentative.

the Upper Peel Sound Fm. was defined by Miall (1970[b]) on the following criteria:

a) An abrupt increase in clast size from 6-25 cm to 100 cm.

b) Marked change in pebble lithologies (oligomictic conglomerates to polymictic conglomerates).

c) Disappearance of shale and limestone beds.

Miall (1969) divided the upper member (approximately 300 m thick) into five facies associations:

a) Conglomerate facies association (>90% conglomerate)
b) Conglomerate-sandstone facies association (10 - 90% conglomerate)
c) Sandstone facies association
d) Sandstone-carbonate facies association
e) Carbonate facies association

The latter association is now included in the Drake Bay Fm., the western facies equivalent of both members of the Peel Sound Fm. (Miall and Gibling, 1978).

The clastic wedge was deposited as an alluvial fan complex passing westwards to the predominantly carbonate sequence of the Drake Bay Fm. (Miall, 1970[b]).

2. <u>Peel Sound Fm.</u>
<u>Somerset Island Fm.</u>
<u>(Somerset Island)</u>

The <u>Somerset Island Fm.</u> is probably time-correlative with the Lower Peel Sound Fm. on Prince of Wales Island, but lacks the abundant pebble conglomerate and sandstone which characterizes the latter sequence (Miall and Gibling, 1978). The basal contact of the Somerset Island Fm. is marked by a sharp change from argillaceous and bioclastic limestones (Douro Fm.) to planar-bedded, sandy dolomitic rocks (Thorsteinsson, 1980). The Somerset Island Fm. contains subsidiary amounts of dolomitic siltstone, sandstone, limestone and shale, with abundant tidal flat characteristics such as salt casts, wave-generated ripple marks, desiccation cracks, restricted fauna and various forms of tidalite bedding (Gibling, 1978). The sequence ranges in thickness from 150 to 300 m (Miall and Kerr, 1977).

The base of the Peel Sound Fm. on the east flank of the Boothia Uplift is marked by the incoming of the first prominent, cross-stratified sandstone unit (Miall and Kerr, 1977). Four informal members, some of which are, in part, lateral equivalents (Fig. 31) are based on the work of Brown et al., (1969) and Miall and Gibling (1978).

a) Sandstone, siltstone (60 - 400 m) with minor conglomerate units, probably deposited in a braided stream environment.

b) Oligomictic conglomerate (280 m), which may represent alluvial fan or proximal braided stream deposits.

c) Pebbly sandstone, conglomerate, sandstone (240 m), which may have been formed by large sand waves in a trunk river environment or a mixed fluvial and eolian environment.

d) Polymictic conglomerate (120 m), probably representing alluvial fan deposits.

Lateral transitions of the members may take place in distances of less than 10 km, but generally indicate that gradual encroachment of progressively coarser clastic sediments occurred from west to east (Miall and Kerr, 1977). Thorsteinsson (1980) suggested that the polymictic conglomerate member everywhere unconformably overlies the three lower

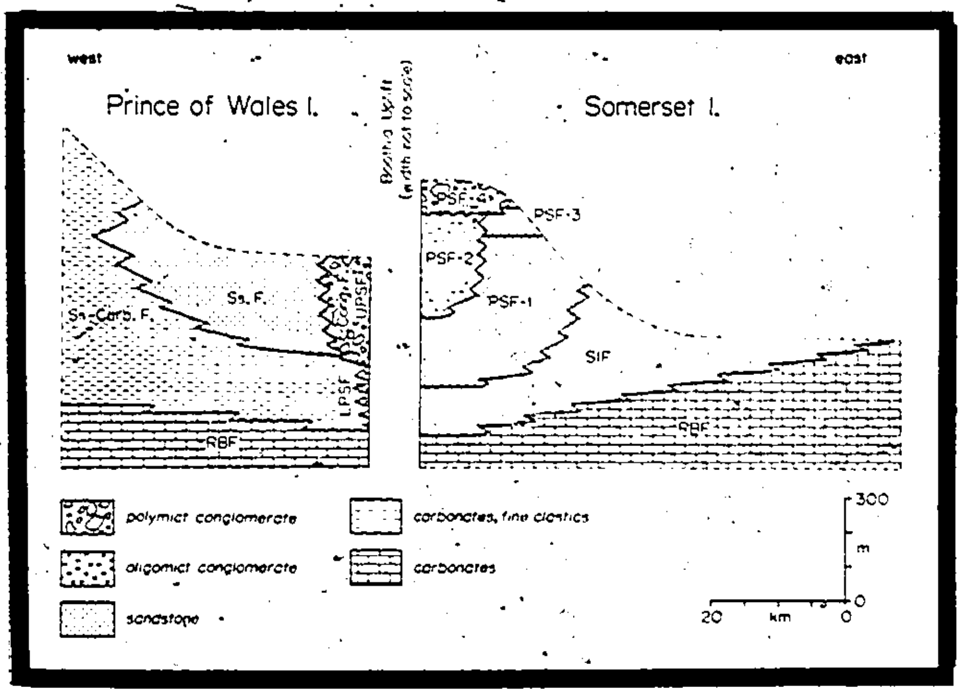


Fig. 31: Comparison of the Peel Sound Fm. on either side of the Boothia Uplift. RBF = Read Bay Fm. (Douro Fm.; Thorsteinsson, 1980) SIF = Somerset Island Fm. F = Facies as in Sandstone - Carbonate, Sandstone and Conglomerate Facies on Prince of Wales Island. (After Miall and Gibling, 1978).

informal members defined by Miall and Gibling, (1978). He argued that the polymictic conglomerate unit can be correlated with the upper member of the Peel Sound Fm. on Prince of Wales Island, on the basis of lithology and stratigraphic position. Furthermore he equated the lower three informal members to the lower member based on gross lithological similarity, stratigraphic position, and Pridolian faunal elements. The time interval represented by the lower member - upper member unconformity is unknown due to lack of biostratigraphic control. The regional extent of the unconformity may, in fact, be restricted to the proximal areas of the Boothia Uplift depocenters and could simply reflect localized syntectonic influences on sedimentation, similar to the CUFU sequences observed in the Snowblind Bay Fm.

3. Prince Alfred Fm.
Sutherland River Fm.
(NW Devon Island)

The Sutherland River Fm. is an approximately 135 m thick sequence of alternating siltstones and dolostones (Thorsteinsson, 1980). The basal contact is conformable on the darker coloured, recessive dolostones of the Devon Island Fm. Beds in the Sutherland River Fm. are easily distinguished from the underlying Devon Island Fm. by their resistant, lighter coloured nature (Thorsteinsson, 1980). The sequence was likely deposited in an intertidal environment and is notably barren of faunal elements (Morrow and Kerr, 1977). The Prince Alfred Fm. is a markedly resistant unit that disconformably overlies the Sutherland River Fm. It consists primarily of sandstone, minor conglomerate and dolomite, with thin mudstone beds. The outcrop distribution pattern has only been examined at Prince Alfred Bay and further studies are required.

The clastic sequence displays a decrease in thickness towards the east flank of the Boothia Uplift from the Sutherland River area, probably as a result of the northwestward decrease in original depositional thickness and to pre-Disappointment Bay Fm. erosion (Morrow and Kerr, 1977). Consequently, the thickness estimates for the sequence range from 0 - 610 m. (Thorsteinsson, 1980).

Fig. 32 represents the proposed depositional model for the Prince Alfred Fm. The silty dolomite lithofacies is a tidal flat tongue representing a marine transgression episode in an otherwise coarsening-upward, regressive clastic wedge.

Horizontally laminated, laterally extensive siltstone and sandstone lithofacies (sandstone facies) were presumably deposited by shallow sheet floods downslope of the fan intersection point(s) (Morrow and Kerr, 1977). On this premise, entrenched fan distributaries are postulated to exist in the proximal fan equivalent. Conglomerate units were interpreted as debris flood and braided channel deposits (Morrow and Kerr, 1977).

Because of the possible diachroneity of these sequences, and lack of evidence to suggest that the clastic wedges bordered the entire length of the exposed Boothia Uplift, the remainder of this chapter will discuss the Peel Sound, Prince Alfred and

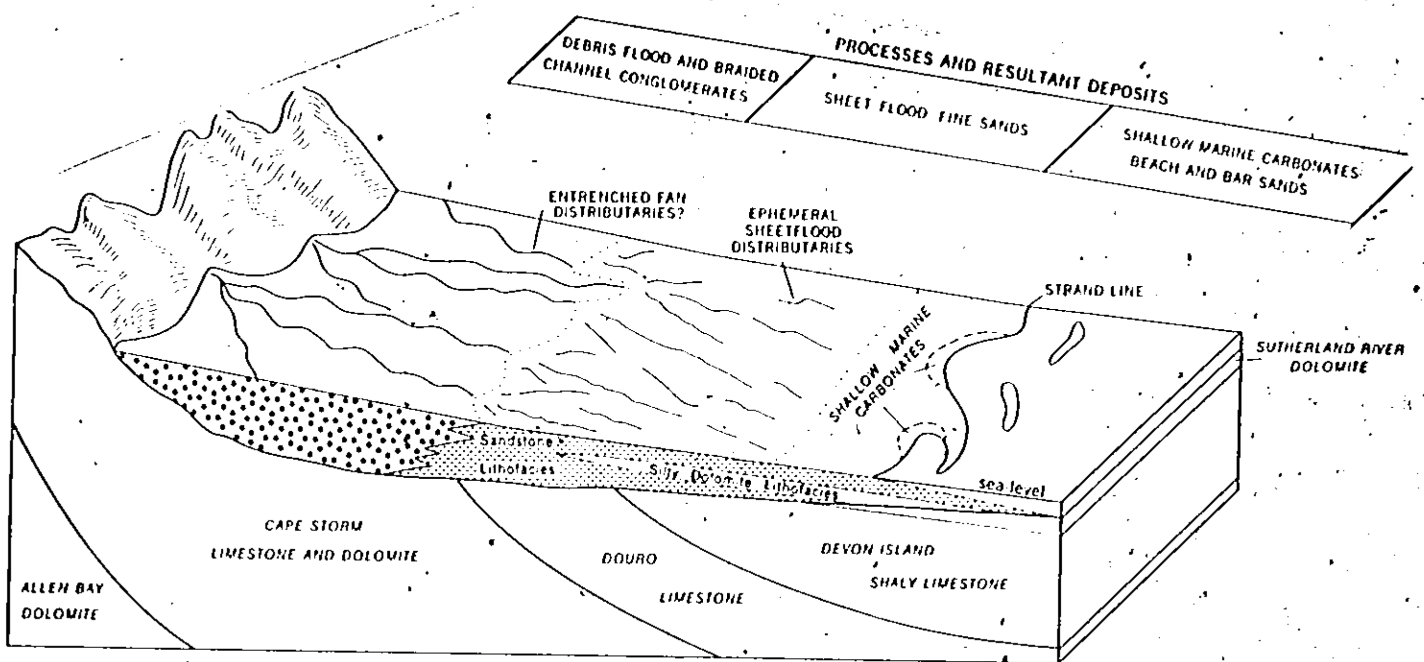


Fig. 32: Proposed depositional model of the Prince Alfred Formation. The Boothia Uplift has exposed lower Paleozoic carbonates in mountainous terrain to the west. This resulted in construction eastward of an alluvial fan complex, which encroached on areas of marine deposition (after Morrow and Kerr, 1977).

Snowblind Bay Fms. as distinct stratigraphic packages. A comparison of these clastic wedges will be made under the subheadings: age, tectonic setting, climate and sedimentological observations.

5.3.2 Age

The age of initiation of clastic sedimentation on the flanks of the Boothia Uplift during Late Silurian - Early Devonian time is based primarily on ostracoderm, conodont and spore elements listed in Tables 3, 4, 5. Although more data are required to ascertain if uplift and subsequent development of (local?) clastic wedges proceeded northwards with time, it appears that coarse clastic sedimentation began earlier on Somerset Island and Prince of Wales Island (Peel Sound Fm.) than on Cornwallis Island (Snowblind Bay Fm.) and Devon Island (Prince Alfred Fm.).

The onset of upper Ludlovian clastic sedimentation on Prince of Wales Island and Somerset Island is recorded by the Lower Member of the Peel Sound Fm. as deltaic and barrier beach deposits west of the Boothia Uplift and by the Somerset Island Fm. as tidal flat deposits east of the tectonic element (Miall and Gibling, 1978; Gibling, 1978).

Thorsteinsson (1980) argued that the deposition of the Lower Member beds in the Peel Sound Fm. may have extended past the late Pridolian, but they were removed by erosion during a second rise of the uplift. He also postulated that tidal flat sediments constituting the lower Lochlovian Sophia Lake Fm. are related to the second rise of the uplift, based on two lines of evidence:

1) quartz content in the Sophia Lake Fm. increases southwards towards the source Boothia Uplift .

2) Sophia Lake Fm, thins southward (980 m on Baillie Hamilton Island; 560 m on Cornwallis Island)

On these criteria, Thorsteinsson suggested that the Sophia Lake Fm. thins into the unconformity between the Lower Peel Sound and Upper Peel Sound members. He postulated that the deposition of the Upper Member of the Peel Sound Fm., Snowblind Bay Fm., and possibly the Prince Alfred Fm. were coeval. However there is no biostratigraphic evidence to suggest that the Upper Member of the Peel Sound Formation is younger than the Sophia Lake Fm. Fig. 33 summarizes the tentative Silurian-Devonian stratigraphy in the Boothia Uplift region according to Thorsteinsson (1980).

Another hypothesis for the timing of the clastic wedges has been summarized by Kerr (1977), Gibling and Narbonne (1977), Gibling (1978), and Miall and Gibling (1978). These authors suggested that the episodic, diachronous nature of the tectonic disturbance resulted in the erosion of local uplifts and deposition of clastic wedges as the Boothia Uplift emerged northwards with time.

Further biostratigraphic data are required to determine whether the major diastrophic event(s) resulting in clastic wedge development during Late Silurian - Early Devonian time were diachronous or contemporaneously affected localized

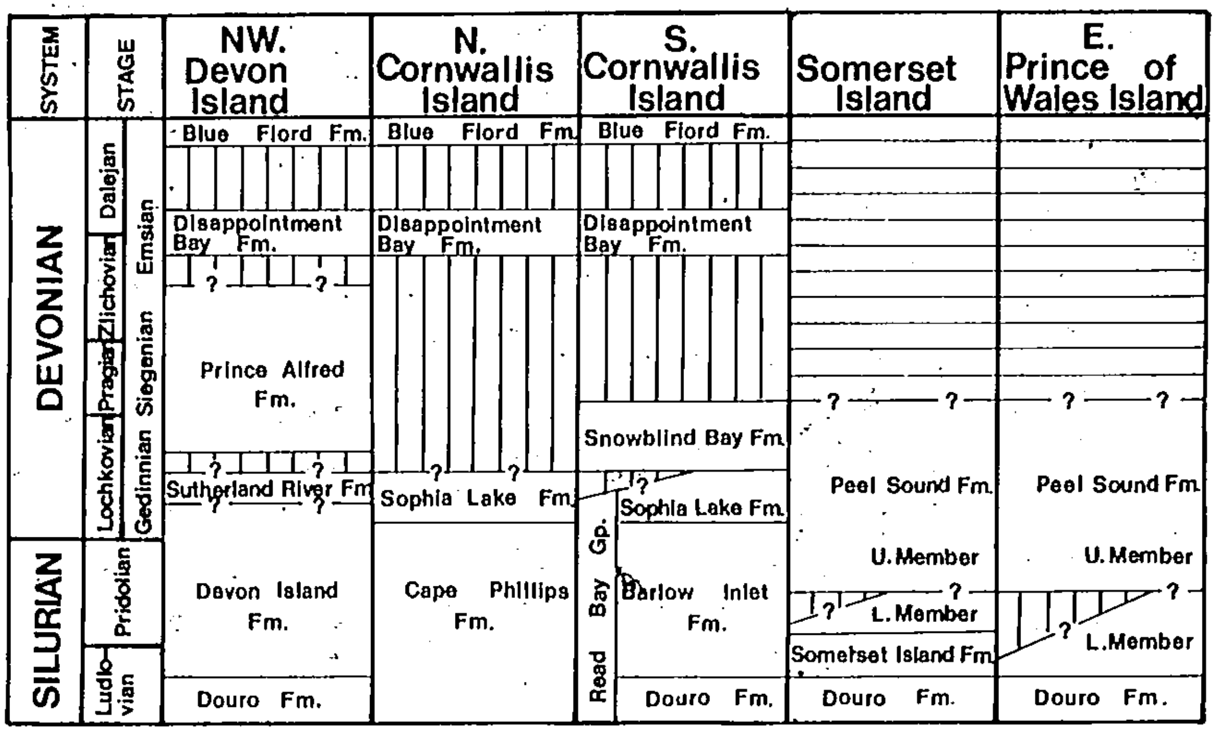


Fig. 33: Silurian-Devonian stratigraphy in the Boothia Uplift region. Horizontally ruled areas represent present day erosional surface. Vertically ruled areas represent absence of strata owing to unconformity. The time intervals represented by the unconformities are tentative (modified after Thorsteinsson, 1980).

Table 3 Age data for the Peel Sound and Somerset Island Formations

PEEL SOUND FM. (U.MEMBER)	Location: E. Prince of Wales Is. Biotic Elements: pteraspids, cephalaspids, cyathaspids, *Ctenaspis obruchevi*, *Baringaspis dineleyi*, *Ctenaspis russelli* (Thorsteinsson, 1980) Age: Gedinnian?
(L.MEMBER)	Biotic Elements: Corvaspididae, gen. et sp. nova; *Pedavis* sp., *P. thorsteinssoni*, *Torpedaspis elongata*, *Hemiarges bigener* (Thorsteinsson, 1980) Age: Late Ludlovian - Pridolian
PEEL SOUND FM. (U.MEMBER)	Location: Somerset Island Biotic Elements: --- Age: ?
(L.MEMBER)	Biotic Elements: *Hemicyclaspis murchisoni* (Dineley, 1968) Age: Pridolian?
SOMERSET ISLAND FM.	Biotic Elements: ostracoderm fauna including: *Hemicyclaspis murchisoni*, *Pedavis* sp., *Pedavis thorsteinssoni*, *Torpedaspis elongata* (Dineley, 1968; Gibling, 1978; Thorsteinsson, 1980) Age: Pridolian

Table 4 Age data for the Snowblind Bay and Sophia Lake Formations

SNOWBLIND BAY FM.	Location: Cornwallis Is. Biotic Elements: ostracoderm fauna including: porolepids, psammosteids, cephalaspids, *Ctenaspis* sp., *Anglaspis* sp., *Pteraspis* sp. (Gibling and Narbonne, 1977; Thorsteinsson, 1980) Spore elements including: *Apiculatisporis* sp., *Apiculiretusispora? plicata*, *A. spicula*,? *Cymbosporites senex*, *Dibolisporites* n.sp., *D.* cf. *D. echinaceus*, *Emphanisporites micrornatus*, *E.* sp., *Retusotriletes* sp., *Streelisporites newportensis*, *Tholisporites chulus* McGregor var. *nanus* (McGregor, pers.comm., 1981) Age: Gedinnian - Siegenian
SOPHIA LAKE FM.	Biotic Elements: conodont faund including: *Ozarkodina* n. sp. G of Uyeno (1980), *Pelekysgnathus* n. sp. B of Uyeno (1980), *Ozarkodina remscheidensis remscheidensis*, *O.* n. sp. F of Klapper and Murphy (1975), *Oulodus* sp. (Uyeno, 1980) Age: Gedinnian

Table 5 Age data for the Prince Alfred and Sutherland River Formations

PRINCE ALFRED FM.	Location: NW Devon Island Biotic Elements: age based on faunal elements from the overlying Disappointment Bay Fm. Recovered in beds 1 - 5 m above the disconformity. Faunal elements include: *Cortezorthis* sp., *Meristella* sp., *M. robertsensis*, *Pandorinellina exigua*?, *Polygnathus inversus*, *Sannemannia glenisteri*, *Panderodus* sp., *Belodella* sp. (Morrow and Kerr, 1977; Uyeno 1980) Age: Siegenian - M.Emsian?
SUTHERLAND RIVER FM.	Biotic Elements: No diagnostic fossils Age: Gedinnian?

tectonic activity along the entire length of the Boothia Uplift (i.e. coeval sedimentation of the Snowblind Bay Fm., Prince Alfred Fm., and Upper Member Peel Sound Fm.).

5.3.3 Tectonic Setting

Three main interacting variables influence type and magnitude of sedimentary processes:

1) position of sea level
2) climatic variables
3) tectonic movements

Tectonic movement is a particularly important control for sedimentation because it directly affects the rate of uplift of the source area, the gradient upon which sediment is transported, the rate of basin subsidence and the type, shape and position of the depositional basin (Mitchell and Reading 1979).

The Boothia Uplift is an elongate structural high extending northwards some 1000 km from the Arctic Platform region to the overlying sediments of the Sverdrup Basin. Tectonic movements during late Ludovian to Siegenian are recorded by the development of clastic wedges. Critera indicating that the Boothia Uplift was the source of terrigenous detritus include:

1. Deposition of progressively finer detritus away from the Uplift (Miall and Gibling, 1978).

2. Clast types in the conglomerates reflect the rock types exposed in the Boothia Uplift (Miall and Gibling, 1978).

3. Decrease in clastic wedge thickness toward the Boothia Uplift (Morrow and Kerr, 1977).

4. Paleocurrent data and downfan decrease in maximum clast size.

5. Facies association distributions reflecting a downslope decrease in energy for operating depositional processes.

The Boothia Uplift wedges occupy nonmarine-paralic sedimentary depocentres. The marginal basin geometry was likely controlled by both sediment dispersal and downwarp, possibly along older lines of weakness (Miall, 1978). Tectonic movement occurred in rapid, episodic pulses, in part contemporaneous with sedimentation. This is recorded by CUFU sequences; basal discontinuous unconformities; evidence of marine trangressions and regressions; rapid aggradation rates as indicated by predominant sheet flood sedimentation, reflecting rapid uplift relative to local base level; and syndepositional folding (Peel Sound Fm.).

The Boothia Uplift wedges are coarsening-upward megasequences. Miall (1978) attributes this to accelerated uplift and erosion in advance of deformation. Therefore sediments possessed greater preservation potential on the margin depocentres than within intramontane basins.

The driving mechanism for tectonism in the Boothia Uplift cannot be explained by known features of plate tectonics. However the clastic wedges were probably formed on flanks resembling basin margins (Kerr, 1977; Miall 1978), where the rate of uplift was greater than the rate of downward erosion in the source area, and basin subsidence was less than the rate of vertical accretion. Under these conditions, coarse sheet-like alluvial deposits built outwards over finer-grained shallow marine deposits.

Miall (1978) suggested that structural salients and re-entrants may be important in controlling sediment dispersal patterns. The Upper Member of the Peel Sound Fm. on the west side of the Boothia Uplift was deposited as an alluvial fan complex (bajada) that extended north-south at least 150 kms on the east coast of Prince of Wales Island (Fig. 30). Miall (1970a) postulated that structural salients acted as source areas for short, high gradient streams. The Lower Peel Sound - Upper Peel Sound Fm. succession (40 kms wide) displays different facies variations from the Somerset Island (greater than 70 kms wide). Coarser conglomerate units and a higher sandstone/carbonate ratio indicate that deposition was under higher energy levels on Prince of Wales Island compared with Somerset Island (Miall and Gibling, 1978).

The asymmetry of the Boothia Uplift is further emphasized by differences in structural style in the east and west flanks (ibid, 1978):

1. narrow folded and faulted zone west of the uplift
2. broad area of block faulting and relatively gentle folding to the east of the uplift

The two styles of deformation probably reflect the asymmetric nature of upward movement of the Boothia Uplift flanks (Kerr, 1977). Because tectonic movement influenced the depositional slope, hence sedimentation processes reflect "steep slopes to the west, resulting in transportation of coarser debris and the building of deltas into the sea; and gentle to the east, resulting in the development of a broad, low-energy alluvial plain and tidal-flat complex" (Miall and Gibling; 1978, p.115).

Thorsteinsson and Kerr (1968) noted that most of the faults in the Cornwallis Fold Belt appear to be steeply-dipping normal faults. Kerr (1977) suggested that the Boothia Horst was uplifted along major, near-vertical faults which gradually changed northwards and upwards (in section) through reverse faults, overturned folds, to asymmetric folds (Fig. 34). En echelon structural lineaments of the Cape Hotham Anticline and Snowblind Anticline (Figs. 28, 29) are probably drape folds marking the position of en echelon faults in the underlying uplifted basement blocks. These subparallel blocks moved upwards during tectonic pulses, and as the fold belt was partly unroofed by erosion, the confining pressure decreased and lateral expansion occurred (Kerr, 1977).

This could explain the coarsening-upwards nature of the Boothia Uplift wedges. As discussed in Chapter 2, the Snowblind Bay Fm. was probably preserved in a structural re-entrant, possibly controlled by en echelon block faulting. The Advance Bluff Syncline (Figs. 2, 23) may coincide with an older, parallel structural low upon which a major fan complex from a northerly source area was deposited.

The coastal fan complex composing the Prince Alfred Fm. has been examined only on a reconnaissance basis (Morrow and Kerr, 1977; Thorsteinsson, 1980). The narrow, elongate outcrop pattern (greater than 50km, generally less that 3 km wide) and presence of thrust and normal fault zones suggest that tectonic controls on Prince Alfred sedimentation were similar to those on

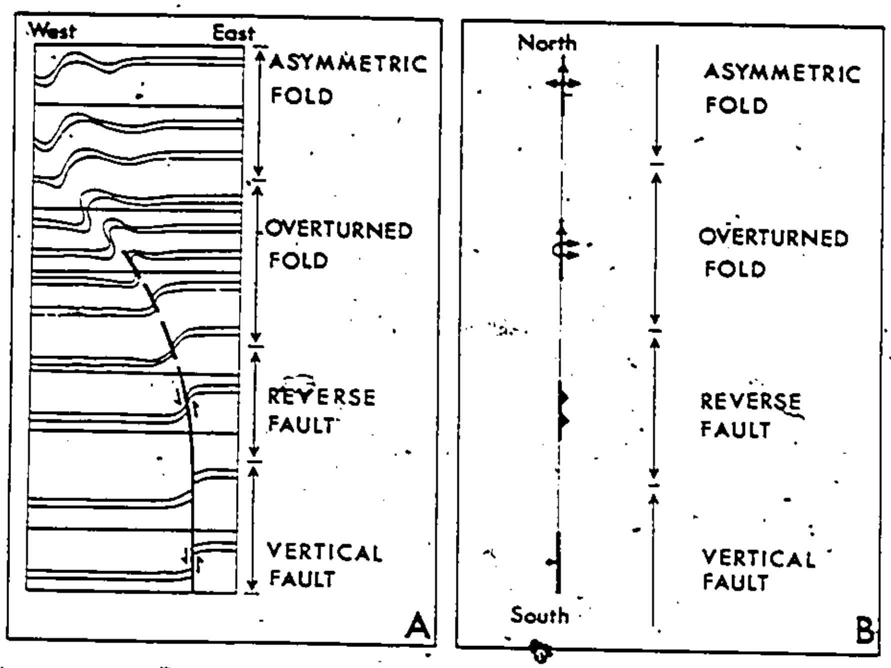


Fig. 34: Changes in types of structures with different levels of erosion on the western margin of the Boothia Uplift (after Kerr, 1977).

the western flank of the Boothia Uplift on Prince of Wales Island. A detailed sedimentological study is required to test this hypothesis.

The Boothia Uplift region lacks well developed strike-slip structural systems. Progressive onlap of sediments northwards parallel to the fault zone bordering the western flank of the Boothia Uplift could have produced a coarsening-upward sequence; however, there is no evidence for a longitudinal mode of sediment dispersal. A trunk river system flowing northwestwards has been postulated as a possible mode of origin for giant cross-bedded units in member 3 of the Peel Sound Fm. on Somerset Island (Miall and Gibling, 1978). However Gibling (1978) argued for an eolian origin because:

1. Large scale cross-stratification displays variability in foreset orientations.

2. Bright red, relatively uncemented, giant cross-bedded units (low water table?) are almost devoid of pebbles and alternate sharply with grey-dull red, thin, pebbly trough cross-stratified units (wadi?).

If there was a significant erosional hiatus between the Lower and Upper Members of the Peel Sound Fm., it may further support an eolian interpretation for the giant, planar-wedge, cross-bedded units in member 3.

Thus there appears to be no evidence of a longitudinal mode of fluvial sediment dispersal for the Boothia Uplift. Furthermore, mismatch of clast lithotypes and clast size with respect to adjacent source areas has not been observed in the Peel Sound Fm., Snowblind Bay Fm., and Prince Alfred Fm.

It is therefore concluded that the Boothia Uplift clastic wedges were derived from a source area undergoing predominantly vertical uplift. Although the Boothia Uplift tectonism and resultant sedimentation has been discussed in terms of compressional basin margins, it is reiterated that the ultimate genesis of these episodes is not known.

5.3.4 Climate

Flash flood deposits are frequently associated with semi-arid alluvial fans (Bull, 1964). In the Snowblind Bay Fm., the presence of halite and gypsum casts, runzel marks, desiccation cracks in the Fl lithofacies; intraclasts in the St lithofacies, penecontemporaneous dolomite in the Cf lithofacies, and rarity of plant material in the distal portion of the fan complex records evidence of periodic aridity. The lacustrine deposits in the conglomerate facies association show alternating green and red Fl lithofacies reflecting a fluctuating water table. The chaotic mudstone horizons may represent evidence for disrupted bedding associated with the growth of saline minerals.

The abundant Sh,Sl lithofacies (25%) as extensive, "sheet-like" beds in the conglomerate-sandstone facies association were probably deposited by ephemeral floods. Horizontal, discontinuous lamination of Picard and High (1973) is reported to be the most abundant bedding type observed in channel deposits of flash flood streams. The Bijou Creek deposits described by McKee et al. (1967) contain primarily Sh and Sp lithofacies. However, Williams (1971) observed that St lithofacies represented 60% of a 1967 flood deposit in central Australia. Approximately 18% of the lithofacies in the conglomerate-sandstone facies association is represented by St. Floodplain sediments (Fl,Fm) are extremely variable in thickness, from a thin veneer to thicknesses of 1.3 m, presumably representing the waning phase deposits of flash floods. These deposits frequently display evidence for subaerial exposure (see Fl,Fm lithofacies, Chapt. 3).

Gm-Sh couplets in the conglomerate facies association represent distinct flood events in the proximal portion of the fan complex. The rarity of Gp lithofacies indicates shallow channel depth and bar relief, possibly reflecting low or seasonal rainfall conditions in the source area (Rust, 1979). The predominance of sharp, flat bed contacts instead of deep (15 cm), erosive contacts suggests an ephemeral flood situation rather than prolonged channel occupation (Heward, 1978b). Channel-fill deposits are rare in the Snowblind Bay Fm. although common in modern ephemeral deposits (Picard and High, 1973). The presence of fresh feldspar grains in the sandstones and absence of debris flows containing a muddy matrix indicates that intense weathering products may have been absent in the Snowblind Bay Fm. source area. An arid or alpine climate would favour mechanical weathering and the production of gravel (Abbott and Peterson, 1978).

Although the Snowblind Bay clastic wedge was probably constructed in a semi-arid climate, there is some evidence to suggest that the flood events were longer in duration and more frequent than flash flood deposits studied by McKee et al. (1967) and Williams (1971):

1. In flash flood settings, the size of the clasts transported is frequently not in equilibrium with flow conditions (Allen, 1981). However, units deposited in the conglomerate and conglomerate-sandstone facies association display positive maximum particle size to bed thickness correlation, demonstrating that there was sufficient time to establish a positive discharge - competency correlation. The Gm-Sh couplets commonly show FU, CUFU trends and tend to be thick (1 - 6 m), suggesting substantial depositon during flood episodes.
2. Exposure of fan sediments was not long enough between flood events to allow development of eolian deposits or calichification of soil profiles, even with an abundant source of carbonates and evidence of dry, intervening conditions.
3. Flash flood deposits generally display poor hierarchical ordering of sedimentary structures as a result of frequent fluctuations in flow regime (Gibling, 1978). The development of distinct cyclicity in the conglomerate-sandstone facies association argues against flash flood deposition.
4. Debris flow deposits, which are commonly present in

semi-arid alluvial fans, were not observed in the Snowblind Bay Fm. However these units may have been removed by intraformational erosion of the proximal fan deposits.

The proximity of an uplifted source area and seasonally variable discharge could effectively introduce coarse sediment-charged flood waters into distal portions of the fan complex (Galloway, 1976). This may have been the setting for deposition of the Snowblind Bay clastic wedge.

Paleomagnetic restorations (Lapointe pers. comm., 1981) indicate that during Early Devonian time the Snowblind Bay region lay at a latitude of about 10° north from a paleoequator trending northeast-southwest relative to present coordinates. In this position the prevailing trade wind directions would have been north to south. Tropical storms may have triggered catastrophic floods in the Snowblind Bay area. Gibling (1978) suggested that the mountainous Boothia Uplift could have influenced local weather patterns, hence variations in climatic controls of deposition for the clast wedges should be expected. Tables 6-9 summarize evidence provided by various authors which may reflect a generally semi-arid to seasonally wet climate during deposition of the Boothia Uplift wedges.

5.3.5 Sedimentary Observations

A detailed sedimentological study has not been conducted on the Prince Alfred Fm., and therefore sedimentological

Table 6 Source-area climate for the Peel Sound Formation, Upper Member; Prince of Wales Island

CHARACTERISTICS	-	debris flow deposits in conglomerate facies association (low mud content)
	-	episodic flood events in conglomerate-sandstone facies association; reflected by interrupted FU cycles
	-	Sh dominant lithofacies in sandstone facies association. Sheet-like geometry and rare sedimentary structures due to rapid deposition
SOURCE-AREA CLIMATE		semi-arid
REFERENCES		Miall (1969, 1970a, 1970b), Thorsteinsson (1980)

Table 7 Source-area climate for the Peel Sound Formation, Somerset Island

CHARACTERISTICS	- penecontemporaneous dolomite and presence of gypsum beds and halite casts in the underlying Somerset Island Formation
	- probable eolian deposits in Member 3 (giant cross-stratified sandstone units) and absence of cyclic sedimentation for fluvial deposits (wadi sediments?)
	- absence of plant material
	- cyclic sedimentation in Member 1. Evidence for desiccation and brecciation in Fl, Fm lithofacies
	- ephemeral nature of streams reflected by the fact fluvial channel sandstone bodies are virtually absent from the coastal plain and tidal flat deposits
	- absence of caliche development, debris flow units and abundance of fluvial sediments may indicate that torrential rainfall occurred periodically
SOURCE-AREA CLIMATE	semi-arid to seasonally wet
REFERENCES	Gibling (1978), Miall and Gibling (1978), Miall and Kerr (1977) Thorsteinsson (1980)

Table 8 Source-area climate for the Prince Alfred Formation, Devon Island

CHARACTERISTICS	- desiccation cracks in sandstone lithofacies
	- no apparent caliche development
	- predominance of Sh, and massive tabular deposits, reflecting rapid deposition, possibly by sheet floods
	- debris flood deposits in proximal fan environment
	- fenestrate fabric, restricted fauna in silty dolomite lithofacies
	- fresh feldspar grains
	- intraclasts outlining shallow scours. Beds continue without interruption beyond trough confines in minor sheet flood St units
SOURCE-AREA CLIMATE	semi-arid
REFERENCES	Morrow and Kerr (1977), Thorsteinsson (1980)

Table 9 -- Source-area climate for the Snowblind Bay Formation, Cornwallis Island

CHARACTERISTICS	- desiccation cracks, salt casts in tidal flat and fluvial accretion deposits (Fl, Fm)
	- penecontemporaneous dolomite; restricted fauna; scarcity of flora elements in distal fan and tidal flat environments
	- ephemeral lake deposits
	- distinct, extensive Gm-Sh flood cycles display FU, CUFU trends and positive maximum particle size to bed thickness correlation
	- sheet-like geometry of lithofacies
	- abundant Sh, Sl lithofacies in conglomerate-sandstone facies association
	- lack of calcrete, debris flow, and eolian deposits
	- presence of fresh feldspar
	- well-developed cyclicity in conglomerate-sandstone facies association
SOURCE-AREA CLIMATE	semi-arid to seasonally wet
REFERENCES	this study

comparisons will be restricted to the Peel Sound Fm. (Somerset Island) and the Snowblind Bay Fm.

A high-gradient depositional slope is proposed for the proximal fan deposits in the Snowblind Bay Fm., and Peel Sound Fm. based on criteria outlined by Gibling (1978) and Rust (1978):

1. Horizontally stratified Gm units and Gp units. Shallow, multi-channeled, low sinuosity streams were prevalent under sediment-charged, high discharge flow conditions. Significant slope is implied.

2. Well-developed imbrication (25°- 30°) of clasts with high vector magnitudes and low directional variance in framework-supported conglomerates. Laterally continuous Gm units.

Distal fan equivalent sediments display good cyclicity in the conglomerate-sandstone facies association (Snowblind Bay Fm.) and Member 1 (Peel Sound Fm.). Gibling (1978) suggested that the presence of minor mudstone, moderately well-developed cycles and the dominance of trough cross-stratified over planar cross-stratified units is consistent with a low slope setting. Braided fluvial cycles are grossly similar in the Snowblind Bay and Peel Sound Fms. and show good lateral continuity:

1. Peel Sound Fm. (Gibling, 1978)
   (Member 1) ES → Sh → Fl, Fm
   ES → St → Fl
   ES → St → Sr → Fl, Fm

- cycles average 3.4 m thick and the lower "coarse member" representing channel and bar deposits average 2.1 m thick
- FU sequence; flood accretion deposits display evidence for subaerial exposure

2. Snowblind Bay Fm. (this study)
(Cong. - ss facies assoc.) ES → St → Sh → Sr → Fl,Fm

- cycles average 3.0 m thick and the lower "coarse member" average 1.6 m thick.
- FU sequence; flood accretion deposits display evidence for subaerial exposure

Although both fan sequences were characterized by a decreasing slope gradient towards the intertidal flats, there is evidence to suggest an overall low gradient depositional slope. Gm-Sh couplets and Gm units with Sh lenses typically document flood cycles in low slope proximal braided and alluvial fan deposits. There is also a general absence of proximal high slope criteria, including debris flows and greater heterogeneity of lithofacies (Rust, 1978).

Chapter VI

CONCLUSIONS

1. The Lower Devonian (Gedinnian - Siegenian) Snowblind Bay Formation (578 m) preserved in the Advance Bluff Syncline, Eastern Cornwallis Island, Arctic Canada, is interpreted as the deposit of a regressive coastal fan complex. It is divided into three facies associations on the basis of constituent lithologies, sedimentary structures and biota.

2. The conglomerate facies association (210 - 240 m thick) contains more that 90% horizontally bedded, framework-supported conglomerate lithofacies. The units display sheet-like geometry with only minor evidence of reworking or scouring; are freqently graded (CUFU, FU trends) and capped by thin horizontally laminated sandstone; and display significant positive correlation between maximum particle size and bed thickness. Deposition occurred in response to episodic flood events in sheet flow conditions. The presence of a surge deposit unit in a probable fanhead entrenched channel; thin ephemeral lacustrine units; and predominant sheet-flood deposits indicate that deposition of the facies association took place on the mid-reaches of an alluvial fan complex.

3. The cyclic nature of the sheet-flood units (CU, CUFU trends) are superimposed on a larger scale (7 - 30 m thick) and

reflect sedimentological responses to increased slope initiated primarily by fault movement.

4. The conglomerate-sandstone facies association (120 - 300 m thick) is subjacent to the conglomerate facies association and contains 10 - 90% horizontally bedded conglomerate. Sedimentation occurred in two major types of fining-upward fluvial cycle. The sand-dominated, sheet-braided cycle (3.0 m thick) displays abundant evidence for scouring and reworking in the channel/bar sequence. The thicker, gravel-dominated sheet-flood cycle (3.7 m thick) shows sharp, flat bed contacts; common FU, CUFU trends in the basal conglomerate units; significant maximum particle size to bed thickness correlation; and overall sheet-form geometry which indicates depositon by high discharge flood episodes, similar to flood events and resultant sheet flood deposits in the conglomerate facies association.

The sheet flood cycle gains dominance towards the top of the conglomerate-sandstone association, reflecting the episodic progradational nature of the alluvial fan complex. The depositional setting for the conglomerate-sandstone facies association was a proximal braided stream/distal fan environment, where relatively unconfined sheet flow from the fan midreaches was collected into shallow rills and channels at the toe of the fan complex.

5. The fine-grained facies association (70 - 220 m thick) conformably overlies the Sophia Lake Formation at Read Bay and contains less than 10% conglomerate lithofacies. The assemblage

arose from noncyclic processes including fluvial episodes, storm and fairweather wave activity and tidal influences, operating in a supratidal-intertidal depositional environment. Nearshore mud flat facies are distinguished from sand flat - tidal flat facies by the presence of terrestrial conglomerate units, scarcity of faunal elements, higher mud content, and higher abundance of preserved low-energy sedimentary structures and stratification. The boundaries are gradationally interbedded, reflecting the patchy, interdigitating areal distribution of the mud flats and sand-tidal flats.

6. There are no distinct petrographic or chemical differences (Sr,Ca,Mg,IR) between the dolostone samples taken from the mud flat and sand flat - tidal flat facies. However diminishing Sr/Ca values and increasing I.R. content upwards in the section records increasing freshwater influence in the lee of the advancing clastic wedge.

7. The Snowblind Bay Formation was derived from an uplifted source to the north or northwest. This is evident from consistent paleocurrent data, clast lithotypes, areal distribution of the three facies associations and sedimentological indicators of decreased energy in their respective depositional regimes (southward direction). A postulated source area is the Laura Lakes region which lies 4 km to the north of the Snowblind Bay Formation.

8. The Upper Silurian - Lower Devonian clastic wedges that formed the Peel Sound, Snowblind Bay, and Prince Alfred

Formations are coarsening-upwards, coastal fan complexes which formed in response to tectonism in the Boothia Uplift region. Tectonic movement occurred in rapid pulses which, in part, were contemporaneous with sedimentation. This is recorded by the presence of CUFU sequences, evidence of marine transgressions - regressions, local unconformities, syndepositional folding, and sedimentological evidence which reflect rapid uplift relative to the local base level. Development of the clastic wedges appears to have resulted from vertical movements attributable primarily to compression.

9. Evidence for periodic aridity during sedimentation of the clastic wedges is present in the Peel Sound, Snowblind Bay and Prince Alfred Formations. Flood events were probably less sporadic and of longer duration in the Peel Sound Formation (Somerset Island) and the Snowblind Bay Formation, based on the lack of calcrete development and debris flow units; good development of fluvial cyclicity in dustal portions of the fan complexes and positive correlation of bed thickness to maximum particle size (Snowblind Bay Formation).

10. The Snowblind Bay Formation and Peel Sound Formation (Somerset Island) display sedimentological evidence for overall, low-gradient depositional slope settings for the coastal fan complexes, including well-developed cyclicity in the distal fan facies; the dominance of sheet-form Gm-Sh couplets ofer cross-stratified units in the proximal fan facies; and the general absence of proximal high slope criteria such as debris flows and

extreme heterogeneity of lithofacies.

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APPENDIX 1		TIDALFLATS--SANDFLATS						MIXED MUDFLAT FACIES						
		10 -001	10 -002	05 -009	05 -013	05 -014	05 -019	05 -002	05 -005	05 -007	05 -023	05 -025	05 -028	05 -035
Bedding	-thin	*	-	*	*	*	-	*	*	*	-	-	-	*
	-massive	-	*	-	-	-	*	-	-	-	*	*	*	-
Solution cavities,		*	-	*	-	-	*	-	-	-	-	*	-	*
Salt casts (halite, minor gypsum)		-	-	-	-	-		-	-	-	-	-	-	*
Mudcracks		*	-	*	-	*		-	-	-	*	-	*	*
Biogenic Features	-ostracoderm fragments	-	-	-	-	-	*	-	-	-	*	*	-	-
	-ostracoda	-	*	-	-	-	-	*	-	-	*	*	*	-
	-*Diplocraterion*	-	*	-	-	-	-	*	*	-	-	*	*	-
	-*Skolithos*	*	-	-	-	-	-	*	-	-	-	*	*	-
	-*Planolites*?	-	-	*	-	-	-	-	*	-	-	*	*	-
	-pelloids	*	*	-	-	-	-	-	-	-	-	-	-	-
Approx. %	-calcite	25	10	1	-	-	15	30	tr	5	tr	15	5	tr
	-dolomite	30	50	45	50	50	45	40	60	55	40	30	40	55
	-siliciclastics	40	40	55	50	50	40	30	40	40	60	55	55	45
Fe-dol./total dol. (%)		0	10	5	10	5	15	0	5	20	5	7	25	15
avg. dolomite grain size (mm)		.07	.05	.10	.12	.15	.12	.13	.07	.15	.04	.08	.08	.07

Petrography of tidalflat--sandflat facies; mixed mudflat facies. The thirteen dolostone samples are listed under their locality numbers. *Denotes presence.

APPENDIX 2: Chemical data (I.R. in %, elements in ppm). Trace elements recalculated on 100% carbonate basis.

Sample No.	I.R.	Sr	Mg	100 Mg/Ca	1000 Sr/Ca
10-001	35.8	363	60466	15.2	0.91
10-002	43.2	370	89480	20.7	0.86
05-009	79.9	378	372019	20.4	0.21
05-013	68.2	148	197924	20.8	0.16
05-014	63.3	297	123467	14.2	0.33
05-019	53.2	212	70399	9.7	0.29
05-019(Dupl.)	48.8	209	79979	15.2	0.40
05-002	44.7	293	52179	11.7	0.66
05-005	62.3	165	125866	17.6	0.29
05-007	43.4	201	77582	18.1	0.47
05-023	51.9	281	90372	15.7	0.49
05-025	69.6	270	183865	25.8	0.38
05-028	47.3	233	68273	15.8	0.54
05-028(Dupl.)	50.5	265	74041	14.0	0.51
05-035	52.8	133	80435	18.8	0.31

APPENDIX 3: Paleocurrent Data

1. Fine-grained Facies Association

Location	Lithofacies	n	$\overline{\theta}$	L%	P	Remarks
Section 05 Unit 009	Sh,Sl	26	47.5	97.4	2.0×10^{-11}	Prod marks, chevron structures
Section 05 Unit 012	Sh,Sr	7	120.3	78.6	1.3×10^{-2}	Perpendicular to asymmetrical ripple axes
Section 05 Unit 014	Sh	11	63.2	97.5	2.9×10^{-5}	Prod marks, chevron structures
Section 05 Unit 016	Sh(set 1)	20	356.4 / 176.4	95.8	1.1×10^{-8}	Primary current lineations
Section 05 Unit 016	Sh(set 2)	18	259.9 / 79.9	92.0	2.4×10^{-7}	Primary current lineations
Section 05 Units 023, 024	St	24	131.1	90.2	3.4×10^{-9}	Trough axes Avg.set = 7.8 cm

n = number of readings
$\overline{\theta}$ = vector mean
L% = vector magnitude
P = significance

APPENDIX 3: Paleocurrent Data

2. Conglomerate-sandstone Facies Association

Location	Lithofacies	n	$\bar{\theta}$	L%	P	Remarks
Section 06 Unit 005	Sh	23	287.3/107.3	94.8	$1.0X10^{-9}$	Primary current lineations
Section 06 Unit 007	St	26	116.1	84.9	$7.4X10^{-9}$	Trough axes Avg.set = 8 cm
Section 06 Unit 024	Gm	40	87.6	85.0	$2.8X10^{-13}$	Imbricated clasts $\bar{A}$ = 5.3 $\bar{B}$ = 3.6
Section 06 Unit 048	St	26	102.2	85.8	$4.8X10^{-9}$	Trough axes Avg.set = 11.3 cm
Section 400m north of 07	Gm	36	113.6	71.3	$1.1X10^{-8}$	$\bar{A}$ = 7.7, $\bar{B}$ = 4.4 AB = 28°
Section 07 Unit 005	Sh	37	146.6	88.0	$3.7X10^{-13}$	Ribs and furrows, grooves, primary current lineations

$\bar{A}$ = Avg. long dimension of clasts measured (cm)
$\bar{B}$ = Avg. intermediate dimension of clasts meausred (cm)
$\bar{C}$ = Avg. small dimension of clasts measured (cm)
AB = Avg. imbrication angle of AB plane

APPENDIX 3: Paleocurrent Data

3. <u>Conglomerate-sandstone Facies Association</u>

Location	Lithofacies	n	$\bar{\theta}$	L%	P	Remarks
Section 02 Unit 004	Sr	9	55.0	97.6	$1.9X10^{-4}$	Ribs and furrows
Section 02 Unit 018	Sl, Sr	5	78.4	93.8	$1.2X10^{-2}$	Ribs and furrows grooves
Section 03 Unit 011	Sl	23	228.2 / 48.2	97.0	$4.0X10^{-10}$	Primary current lineations
Section 04 Unit 018	Sh, Sl	18	196.1 / 16.1	97.4	$3.8X10^{-8}$	Primary current lineations
Section 08 Unit 001	Gm	32	93.6	69.3	$2.1X10^{-7}$	$\overline{AB}$ = 31.4 $\overline{A}$ = 16.1, $\overline{B}$ = 10.0
Section 08 Unit 009	Gm	40	127.9	75.3	$1.4X10^{-10}$	$\overline{AB}$ = 25.0 $\overline{A}$ = 10.7, $\overline{B}$ = 6.9, $\overline{C}$ = 2.6
Section 1000m south of 09	Gm	43	191.1	69.5	$9.6X10^{-10}$	$\overline{AB}$ = 30.4 $\overline{A}$ = 13.2, $\overline{B}$ = 8.4, $\overline{C}$ = 3.1

Con't.

APPENDIX 3: Paleocurrent Data

3. <u>Conglomerate-sandstone Facies Association</u>

Location	Lithofacies	n	$\overline{\theta}$	L%	P	Remarks
Section 700m south of 09	Gm	42	172.1	67.6	4.7×10^{-9}	$\overline{AB}$ = 28.9 $\bar{A}$ = 6.1, $\bar{B}$ = 3.6, $\bar{C}$ = 1.6
Section 09 Unit 005	Gm	40	173.5	57.3	2.0×10^{-6}	$\overline{AB}$ = 29.4 $\bar{A}$ = 18.2, $\bar{B}$ = 10.6, $\bar{C}$ = 4.1
Section 09 Unit 010	Gm	36	177.7	62.9	6.6×10^{-7}	$\overline{AB}$ = 28.8 $\bar{A}$ = 10.6, $\bar{B}$ = 6.7 $\bar{C}$ = 3.1
Section 2000m south of 03	Gm	31	157.5	75.3	2.3×10^{-8}	$\overline{AB}$ = 25.2 $\bar{A}$ = 10.2, $\bar{B}$ = 6.1, $\bar{C}$ = 25
Section 500m north of 01	Gm	33	100.7	82.8	1.5×10^{-10}	$\overline{AB}$ = 29.5 $\bar{A}$ = 10.6, $\bar{B}$ = 5.5, $\bar{C}$ = 2.2

Con't.

APPENDIX 3: Paleocurrent Data

3. Conglomerate-sandstone Facies Association

Location	Lithofacies	n	$\overline{\theta}$	L%	P	Remarks
Section 1000m south of 04	Gm	44	48.1	72.9	6.8×10^{-11}	$\overline{A} = 7.7$, $\overline{B} = 4.0$
Section 50m east of 01	Sh, Sr	4	141.2	95.5	2.6×10^{-2}	Ribs and furrows

APPENDIX 4: Data on Bed Thickness and Maximum Particle Size

Two independent variables, thickness (t) and size (s), are fixed quantities preselected by the investigator and have no distributional properties.

Therefore, two regression lines are plotted for each group of data in the following manner:

1) using (s) as the independent variable and (t) as the dependent variable, i.e.

$$t = a_0 + a_1 s$$

2) using (t) as the independent variable and (s) as the dependent variable, i.e.

$$s = b_0 + b_1 t$$

3) the linear correlation coefficient (r) may be determined from either regression line or calculated from the equation,

$$r = \sqrt{a_1 b_1}$$

Con't

APPENDIX 4: Data on Bed Thickness and Maximum Particle Size

1. Sections 08, 09

Clast size (MM)	Bed thickness (cm)
145	80
115	330
300*	130*
120*	240*
370	210
110	260
320	420
80	120
400	320
220	280
200	250
155*	250*
140*	200*
225	310
170	260
85	140
240	430
200	180
290*	470*
190*	230*
520	570
240	330

n = 22

* - denotes no apparent clast size grading in bed

Con't

APPENDIX 4: Data on Bed Thickness and Maximum Particle Size

2. Sections 03, 04

Clast size (MM)	Bed thickness (cm)
95*	90*
280*	290*
120	320
150*	220*
95*	300*
105*	280*
80	180
130*	260*
100	300
80	240
90	320
165*	450*
300*	200*
90	350
100*	150*
85	240
75*	110*
80	230
120	120
120*	430*
130	230
275	520
80	310
160*	220*
140	220
120	320
95*	480*
55	250
115	210
70*	240*

n = 30

* – denotes no apparent clast size grading in bed

Con't

APPENDIX 4: Data on Bed Thickness and Maximum Particle Size

3. Sections 06, 07

Clast size (MM)	Bed thickness (cm)
24*	35*
85	320
40	60
19	50
32	100
34	140
24*	30*
33*	35*
35*	200*
40*	430*
23*	25*
90	460
42*	130*
80	180
45	65
45	140
26*	70*
32*	160*
42	260
27*	50*
19*	40*
65	500
95	230
35*	50*
60	160
115*	230*
42	100
24*	25*
85	210
135	350
95	160

n = 31

* = denotes no apparent clast size grading in bed