THE SEDIMENTOLOGY OF THE LATE PRECAMBRIAN RENCONTRE FORMATION, FORTUNE BAY, NEWFOUNDLAND

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by

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ABSTRACT

The Rencontre Formation is a sequence of Late Precambrian sediments outcropping around Fortune Bay in southeastern Newfoundland. The formation is variable, consisting of red conglomerates, coarse sandstones, red siltstones, with subordinate pale sandstones, and gray-green siltstones with fine sandstones. The exact thickness of the formation is uncertain as a complete section is not seen at any one locality, but the maximum possible thickness is in the order of 1500m.

The Rencontre Formation is divided into facies associations on the basis of lithology and sedimentary structures. Five of these have been recognised in northern Fortune Bay, and four others on Brunette Island in the south. These associations reflect the vertical and lateral variability of the Rencontre Formation.

The formation consists of fan delta, braided river, low energy marine, marginal marine, and tidal-marine deposits. In certain cases, there are no closely analogous modern environments with which to compare these sediments, in particular the basal 300m in the north of Fortune Bay. These are the deposits of fan deltas, but show a poor distinction between delta plain and delta front environments.

A palaeogeographic model is developed in which

deposition occurred in a northeast to southwest trending basin. Initially this was small, probably fault-bounded, with a marine connection to the northeast. Basin growth to the west and southwest is implied by the progressive overstepping of older deposits by younger strata, and led to a elongate basin with marine connections to the northeast and southwest. The basin history was complicated with alternating tectonic activity, quiescence, and sea-level changes. The upper part of the sequence signals a change from deposition in a narrow, elongate, basin, a motif characteristic of late Precambrian sedimentation in the Avalon terrane, to one of stable cratonic-type sedimentation, with broad depocentres, a motif characteristic of Early Palaeozoic sedimentation in the Avalon terrane.

ACKNOWLEDGEMENTS

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Brian Boyd gave valuable and cheerful assistance in the field. Wilf Marsh prepared photographs and diagrams for this work. Greg Bennett, of M.U.N. computer services, printed the final version of the manuscript, despite numerous vicissitudes.

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CHAPTER ONE

INTRODUCTION

1.1 Location

This thesis studies a Late Precambrian sequence of sediments, the Rencontre Formation. This formation is exposed in a number of outcrops in Fortune Bay on the southeast coast of Newfoundland (fig.1.1), where it overlies volcanics of the Long Harbour Group, and is overlain by sediments of the Chapel Island Formation.

In the northern part of the Bay outcrops are found at several localities. The major ones are in the cores of northeast to southwest trending synclines at Hare Harbour, Femme Bay, and Rencontre East. Farther west a thick sequence is exposed on Chapel Island and on the mainland at Bob Head. In the south of Fortune Bay the sequence makes up most of Brunette Island (fig.1.2).

Several smaller outcrops, generally inaccessible and poorly exposed, exist at Terrenceville, Gaultois, and on islands in Belle Bay (northwest Fortune Bay).

1.2 Previous work

The geology and stratigraphy of Fortune Bay has been studied by several workers in the past. As a result, the stratigraphic relations of the Rencontre Formation are now reasonably well understood, but little is known of its

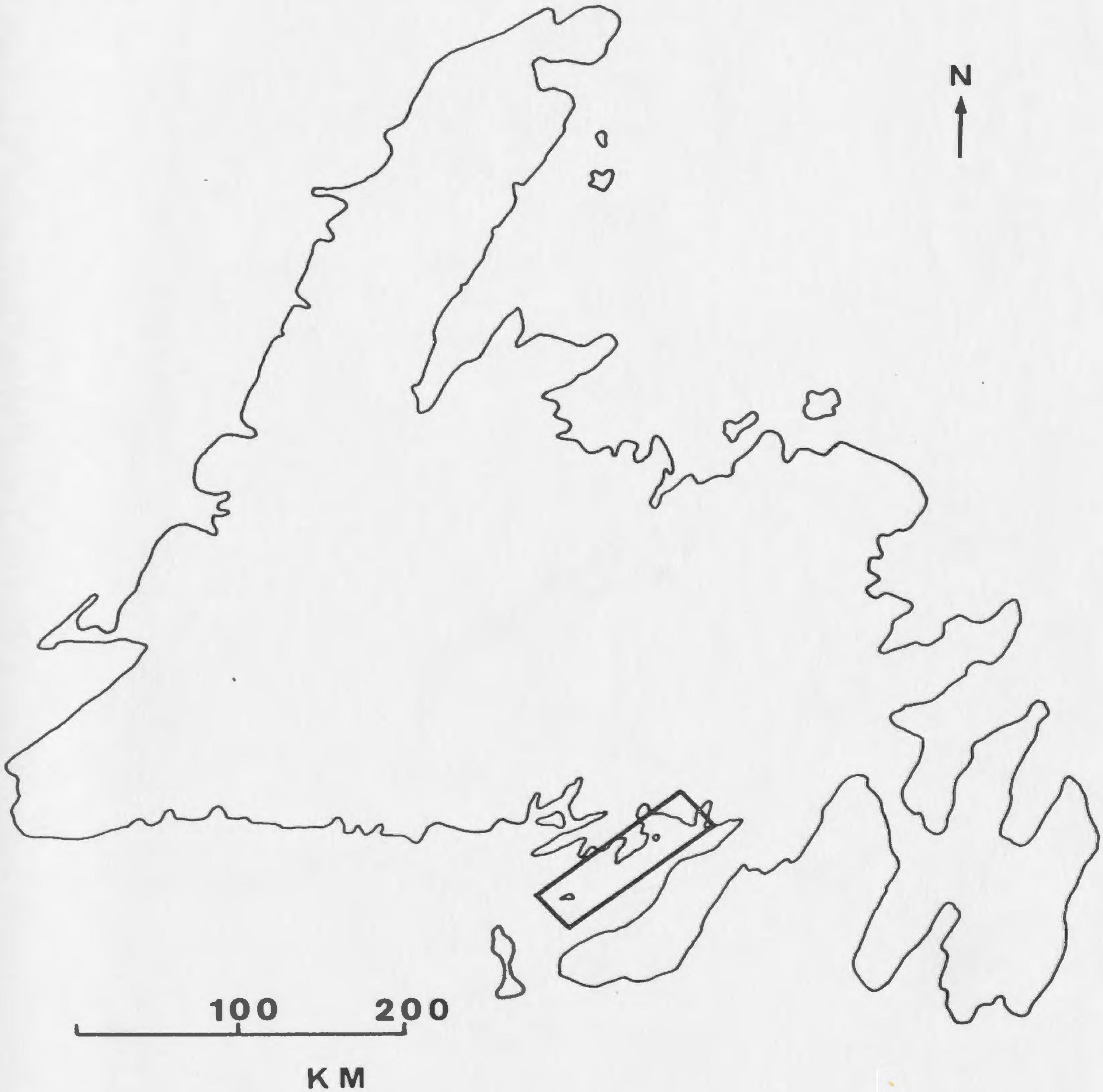


FIG. 1.1 Location of the study area.

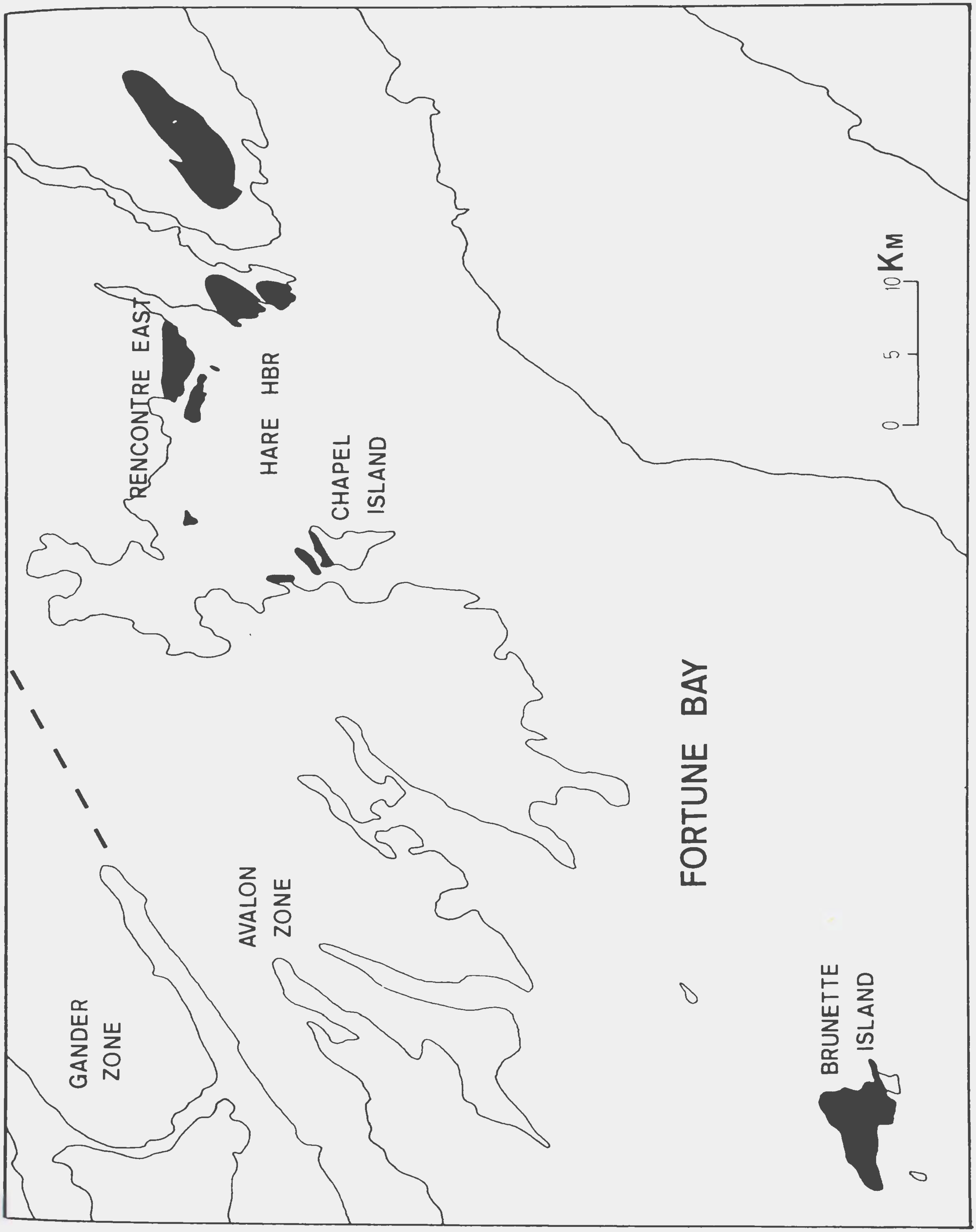


FIG. 1.1 Major outcrops of the Rencontre Formation.

sedimentology.

White (1939), in an early study of Fortune Bay stratigraphy, mapped and described several outcrops belonging to the Rencontre Formation. He recognised a group of volcanics with minor sediments, the Long Harbour Group, which he subdivided into the Belle Bay, Anderson's Cove, and Mooring Cove Formations. This group is overlain by a thick red bed sequence, which he defined as the Rencontre Formation. This he divided into two units, a lower member consisting of red and purple shales, greywackes, and minor interbedded volcanics, and an upper member of coarse sandstone, greywackes, and local "impure quartzites".

White (1939) suggested a Silurian age for the Rencontre Formation, as he believed the Long Harbour Group lay disconformably on the Chapel Island Formation at Corbin Bay (northwest Fortune Bay). At this locality, fossil fragments were thought to indicate a Cambrian age for the Chapel Island Formation. The red beds underlying the Chapel Island Formation at Bob Head and Chapel Island, actually part of the Rencontre Formation, were therefore thought to be Cambrian, and were assigned to the Doten Cove Formation.

Twenhofel (1947) studied the Rencontre as part of a regional study of the Silurian of Newfoundland. Although more of a sedimentological study than White's, its ambitious scope unfortunately meant that the resulting descriptions and interpretations were generalised and inaccurate. Twenhofel suggested that a Late Devonian, or Early Carboniferous age, was more suitable for the Rencontre Formation. He argued that the Rencontre was preceded by an orogeny as it overlays the Long Harbour Group disconformably. He assumed that this was the Acadian orogeny, believing that the Long Harbour Group was Lower Palaeozoic in age, and that the Rencontre was therefore post-Silurian.

Theses by Potter (1949) and Widmer (1950) involved regional studies of southern Fortune Bay, and supported the stratigraphy developed by White (1939). The same stratigraphy was used on the first 1:250, 000 geological map of the whole of Fortune Bay (Anderson, 1965).

Mapping of northern Fortune Bay by Williams (1971) led to a major revision of the stratigraphy. Williams found that the contact between the Long Harbour volcanics and Cambrian sediments, described by White, was actually a thrust fault, and concluded the following: (1)the correct stratigraphic sequence is, in ascending order, Long Harbour volcanics, Rencontre Formation, and Chapel Island Formation, (2)the Doten Cove Formation is part of the upper Rencontre Formation, and (3) the Rencontre is of Late Precambrian age.

Subsequent work has supported this stratigraphy.

Detailed mapping of the Gaultois map area by Greene and O'Driscoll (1976) showed that the sediments on Brunette Island belonged to the Rencontre Formation. They overlie Long Harbour like volcanics, and are conformably overlain by the distinctive Chapel Island Formation. Mapping on the southern tip of the Burin Peninsula (O'Brien et al., 1977) demonstrated the presence of thin sequences of Rencontre sediments, probably the uppermost part of the formation.

1.3 Present study

1.3.1 Philosophy and approach

The aims of this study are to describe the sedimentology of the Rencontre Formation and to suggest interpretations for its depositional environments. Succinct descriptions and objective interpretations of the Rencontre Formation are difficult because of the variability of rock types, the absence of fossils and distinctive marker beds, and the scattered nature of outcrops. As a result the formation cannot be classified into true chronostratigraphic units, nor can it be classified and described as a few simple facies types. In this report a facies association approach is used in an attempt to take into account these difficulties. A facies association is here defined as a part of the formation that consists of interbedded facies of distinctive lithologies and sedimentary structures. The thicknesses of the various associations are variable as are the number of facies which they contain. As it happens each association occurs only once in the vertical sequence, although this is not a precondition of the definition of a facies association.

The outcrops in the north and south of Fortune Bay have been divided into facies associations I to V in the north of the bay and VI to IX on Brunette Island.

This thesis is divided into three parts, firstly the outcrops in northern Fortune Bay are described and interpreted, secondly those on Brunette Island and in the final part of the thesis, the Rencontre is placed in a regional context and palaeogeographic models are suggested.

1.3.2 Methods

The study is based on detailed logging of the major sections in the north and south of the bay. Most of these are coastal, with excellent exposure, although many are rather inaccessible, and can only be studied from a boat on calm days. Certain outcrops were studied only briefly because of extremely poor exposure. Further data were obtained by field measurements of palaeocurrents, followed by correction for tectonic tilt and statistical analysis, and by petrographic analysis of thin sections.

The data collected is presented in the text as descriptions of the lithogies and as generalised stratigraphic columns with relevant palaeocurrent diagrams. The sections are composite, produced from detailed logs of the coastal outcrops, of which the crucial ones are included in the text.

1.4 The stratigraphy of the Rencontre Formation

Before providing detailed descriptions and interpretations a stratigraphic summary of the facies associations is presented. In the north of Fortune Bay the formation is about 1,300m thick and is subdivided into five facies associations whose distribution is shown in figure 1.3. Association I consists of conglomerates and sandstones interbedded with siltstones and sandstones. The thickness of association I is about 300m and the association is only found in the eastern part of Fortune Bay where it is overlain by a sandstone-rich association II, which is about 150m thick and overlaps association I to the west. Association III consists of gray-green silts and sandstones and is up to 180m thick. It overlaps and thins to the west, and forms the base of the Rencontre Formation at Bob Head. Association IV is a 200m thick sequence of coarse sandstones, granule conglomerates, and silt which thins towards the west. Association V, quartz-rich sandstones and red siltstones, caps the Rencontre Formation. The contact with the overlying Chapel Island Formation is gradational over 50m and is marked by

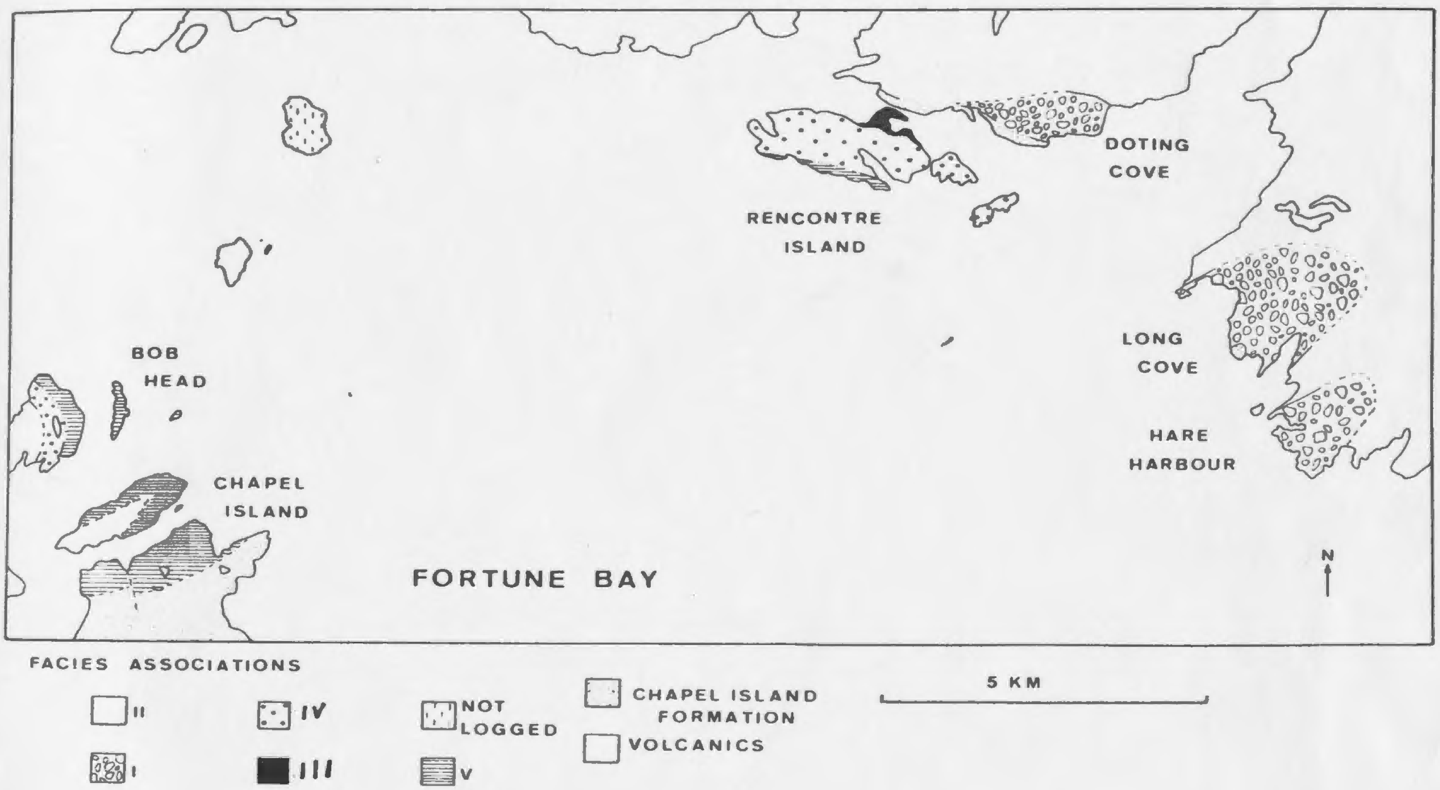


FIG. 1.3 Outcrops of the facies associations of northern Fortune Bay.

interbedding of red and green siltstones. All contacts between facies associations appear to be conformable.

The Rencontre Formation is about 1000m thick on Brunette Island (fig. 1.4). Association VI consists of 450m of red, black, and green siltstones with subordinate sandstones. Association VII, about 260m thick, consist of coarse sandstones. The remaining associations are dominated by red siltstone and variations in sandstone abundance and sedimentary structures are used to subdivide them.

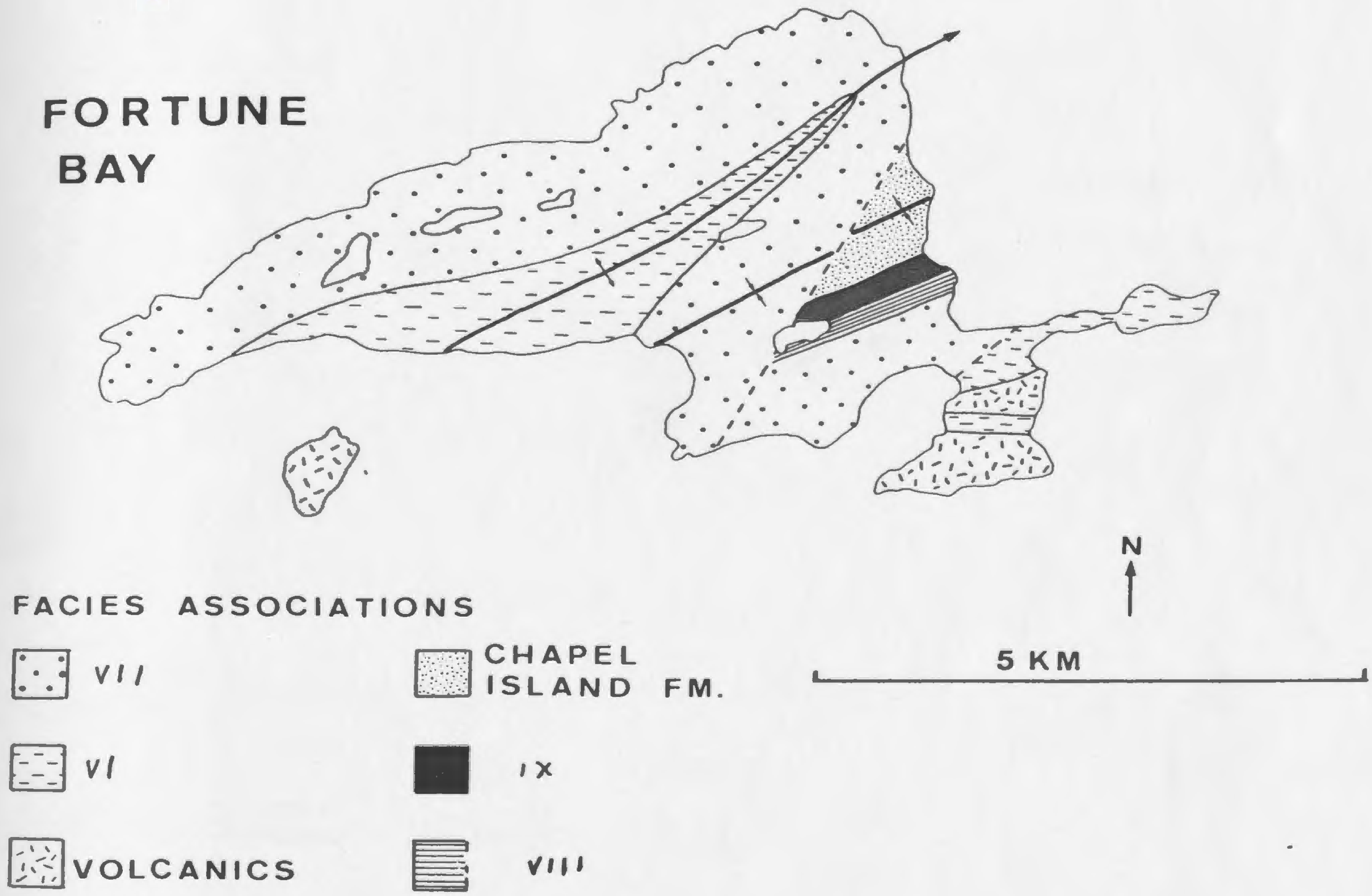


FIG. 1.4 Outcrops of the facies associations of southern Fortune Bay.

CHAPTER TWO

FACIES ASSOCIATION I, NORTHERN FORTUNE BAY

2.1 Introduction

Facies association I forms the basal 300 m of the Rencontre Formation in the north of Fortune Bay at Hare Harbour, Femme Bay, Long Cove, and Doting Cove (fig. 1.3). The association forms a distinctive assemblage of conglomerates interbedded with sandstones and siltstones and is subdivided into the following facies based on lithological characteristics and sedimentary structures: facies 1, conglomerate; facies 2, pebbly sandstone; facies 3, sandstone dominated; and facies 4, siltstone dominated.

2.2 Description of association I

2.2.1 Conglomerate facies

This facies consists of red, clast supported conglomerate with minor coarse- to medium-grained sandstones. The conglomerates are poorly sorted, with clasts varying in diameter from 0.5-5cm, set in a arenaceous matrix which makes up 10-20% of the rock. The clasts are subangular with a low sphericity. The typical crudely stratified nature of the conglomerate is shown in figures 2.1 and 2.2.

FIG. 2.1 Conglomerate with crude parallel stratification, Hare Harbour.

FIG. 2.2 Conglomerate with low-angle cross bedding, Hare Harbour.

Mineralogically the rocks are strikingly immature. They are volcaniclastic, with a mean quartz-feldspar-lithic ratio of about 7-5-88. There are no significant lateral or vertical variations in the composition of the sediments. The lithic clasts are mainly felsite, with minor basalt, agglomerate and siltstone. Feldspar is present as poorly rounded grains, in places subhedral. Quartz grains are poorly rounded, and some grains show embayed margins.

The conglomerate facies shows crude parallel stratification, which is defined by alternating conglomerate rich and poor layers, on a scale of 5-15cm. In places, units show a lenticularity, with erosive, concave up bases and internal scours. Locally, sets of planar cross-bedded conglomerate are seen. These have a mean set thickness of 0.5m and tend to occur in the coarser units.

The conglomerate shows very poorly developed clast imbrication; an unusual feature in this sort of lithology (Rust, 1972, 1978). At the Long Cove and Hare Harbour outcrops, the orientations of pebble long axes were measured on bedding plane exposures. The results show a crude preferred orientation of the long axes (fig.2.3). A comparison with the palaeocurrent data (see section 2.4) shows the "a" axes are broadly parallel to the flow direction (to the east and northeast).

Thin interbeds of sandstone occur, both as thin

(A)

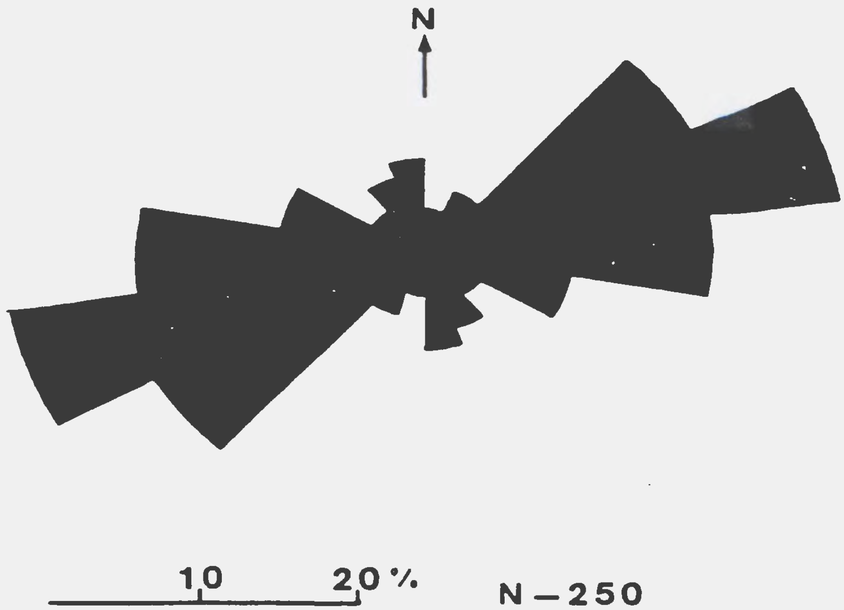
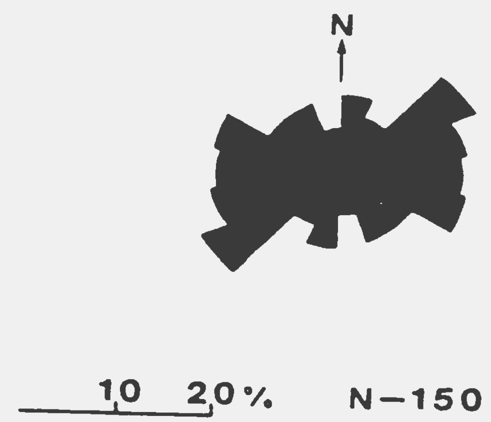


FIG. 2.3 Clast "a" axes orientation, (A) Long Cove,
(B) Hare Harbour.

(B)



sheets, and as lenticular, cross-bedded units, which wedge out rapidly. The most common set thickness is in the range 0.15-0.3m (fig.2.4).

2.2.2 Pebbly sandstone facies

This is the second facies making up association I. It consists of coarse pebbly sandstone with minor conglomerate and discrete silt beds. Sedimentary structures include crude parallel bedding, and stacked or solitary cross beds. Commonly the sandstone beds show normal grading in basal parts with inverse grading towards the top. Inverse grading is also seen in thin (less than 10cm), sheet like units, which coarsen up from silt to coarse sandstone which shows ripple cross laminae.

2.2.3 Sandstone-dominated facies

This facies consists of sandstone, granule conglomerate, and silt. The proportion of silt to coarser clastics varies considerably, but silt usually makes up 40-50% of this facies.

Coarse sandstone occurs as both sheet-like and lenticular units, 0.2-0.6m thick. Bases are commonly erosive and are charged with silt intraclasts and grains of granule conglomerate. The units frequently show normal grading into a cap of medium-grained sandstone. Internally the most common structure is small scale planar

FIG. 2.4 Cross-bedded sandstone wedge, Hare Harbour.

cross-bedding (fig.2.5) which mainly occurs as solitary sets, although some stacked cosets are seen. Locally the units show parallel laminae overlain by cross-beds.

Coarse sandstone may occur as sheet-sandstones without planar cross-bedding. In such units bases are erosive, normal grading is present, and the beds are massive, or have a cap of irregular silt layers, small scale trough cross-bedding, or ripple cross-lamination (fig.2.6) with local bipolar foreset azimuths.

The coarse sandstones exhibit several unusual features. Up to 40% of the sandstones have irregular bed tops of low relief domes and depressions, lined with a granule lag one to three grains thick. The beds showing these features tend to be the most lenticular. Any internal structures are discordant with the bed tops, implying an erosional origin for these surfaces (figs.2.7, 2.8).

Granule conglomerate, as well as occurring as lags, also forms thin (less than 40cm), discrete units which commonly show normal grading. Lenticular beds are most common, although sheet-like units are seen locally (fig.2.9). Bed tops commonly show an irregular waviness with a wavelength on the order of 20cm and amplitude on the order of 3cm. Granule conglomerate also occurs as layers, one to three grains thick, enclosed in silt. Interbedded silt units tend to show irregular and wavy laminae of fine

FIG. 2.5 Thin sandstone bed with a solitary set of planar cross-bedding, Long Cove.

FIG. 2.6 Sandstone bed which shows a transition from a basal massive zone to a cap of small scale trough cross-beds, Long Cove.

FIG. 2.7 Lenticular sandstone unit with a scoured bed top overlain by siltstone, Long Cove.

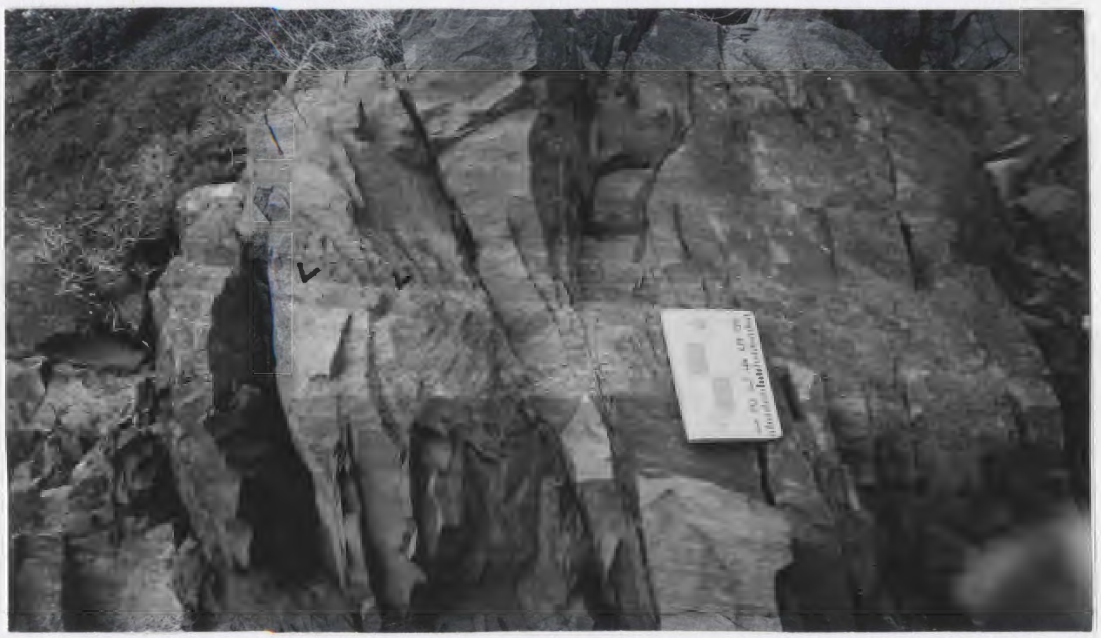


FIG. 2.8 Granule lag lining the top of a sandstone bed, Long Cove.

sandstone.

2.2.4 Siltstone-dominated facies

Sandstone is subordinate to red silt in this facies, but more diagnostically, stratification and bed geometry are distinct from the previous facies.

Coarse- to medium-grained sandstone occurs as thin- to medium-bedded (0.12-0.6m), sheet-like units, or as thin laminae. The former often have erosive bases and basal silt intraclasts (fig.2.10). These beds often fine up and are usually internally structureless.

Sandstone laminae are thin and rather irregular, showing pinching, swelling and lenticularity. Internally these units show micro-cross laminae (fig.2.11). These two features may well be diagnostic of "flat stratification" as defined by Lindholm (1982). This is a type of planar stratification produced by the migration of very small ripples in shallow water (less than 5cm).

Commonly the sandstones and silts of this facies show a fining up motif, 1-4m thick. The sandstone beds become thinner and more widely spaced upwards. Other features of this facies are type "B" climbing ripples of Jopling, (1968), rare desiccation cracks and various marks on siltstone bedding planes (fig.2.12). Some consist of elongate ridges and runnels, possibly surge marks (Bull, 1978). The granule lags and irregular bed tops of the

FIG. 2.9 Lenticular sandstone and granule conglomerate of the sandstone dominated facies, Long Cove.

FIG. 2.10 Sheet like sandstone of the siltstone dominated facies.

sandstone-dominated facies are absent.

2.2.5 Red and grey-green silt facies

This facies consists of red and grey-green silts with small amounts of sandstone. Fine laminae are common and are regular to wavy. Discrete thick sandstone beds are absent, as is any correlation between laminae type and sandstone content.

2.3 Sequences in facies association I

Sequences in association I are variable although some generalisations can be made. These will be described and followed by accounts of the sequences at the different localities. In facies association I the contacts between the conglomerate and pebbly sandstone facies are always sharp, whether the transition is from conglomerate to pebbly sandstone, or vice-versa. The conglomerate facies is often interbedded with the sandstone-dominated facies where conglomerate interbeds are 0.5-3m thick. The pebbly sandstone facies, however, does not show this relationship. The lower contacts of the sandstone-dominated facies are often sharp and coarsening-up sequences are poorly developed. Only at two localities in Doting Cove are 3m thick coarsening-up transitions with the red and green silt facies seen. Transitions between the latter and the siltstone-dominated facies are more gradational. Detailed logs of representative outcrops are presented in fig. 2.13.

At Hare Harbour the conglomerate facies of association I makes up the entire sequence of about 100m. Parallel-bedded conglomerate makes up 87% of the succession, cross bedded conglomerate 6%, and sandstone 6%. The sequence is rather uniform, except for a 10m interval at about 45m from the base. Here, the conglomerate is slightly finer grained, rather better stratified and is associated with buff coloured sandstone and thin, dark silts.

Femme Pond is a inland outcrop, poorly exposed and inaccessible, and was subject to only reconnaissance studies. These show that the lithologies are similar to those at Hare Harbour.

At Long Cove, the section consists of about 320m of Rencontre sediments overlying basalt of the Mooring Cove Formation (fig.2.14). The basal 100m consists of the sandstone-dominated facies within which two units of the red-green silt facies occur, 4m and 10m thick. The thicker one of these is grey-green, and sandstones at its base show "herring-bone" cross-beds. This is followed by about 140m of conglomerate and pebbly sandstone. The contact is gradational, conglomerates interbedding with the silts. Overall, this sequence shows an asymmetric coarsening upwards, followed by a thinner, fining-up cap.

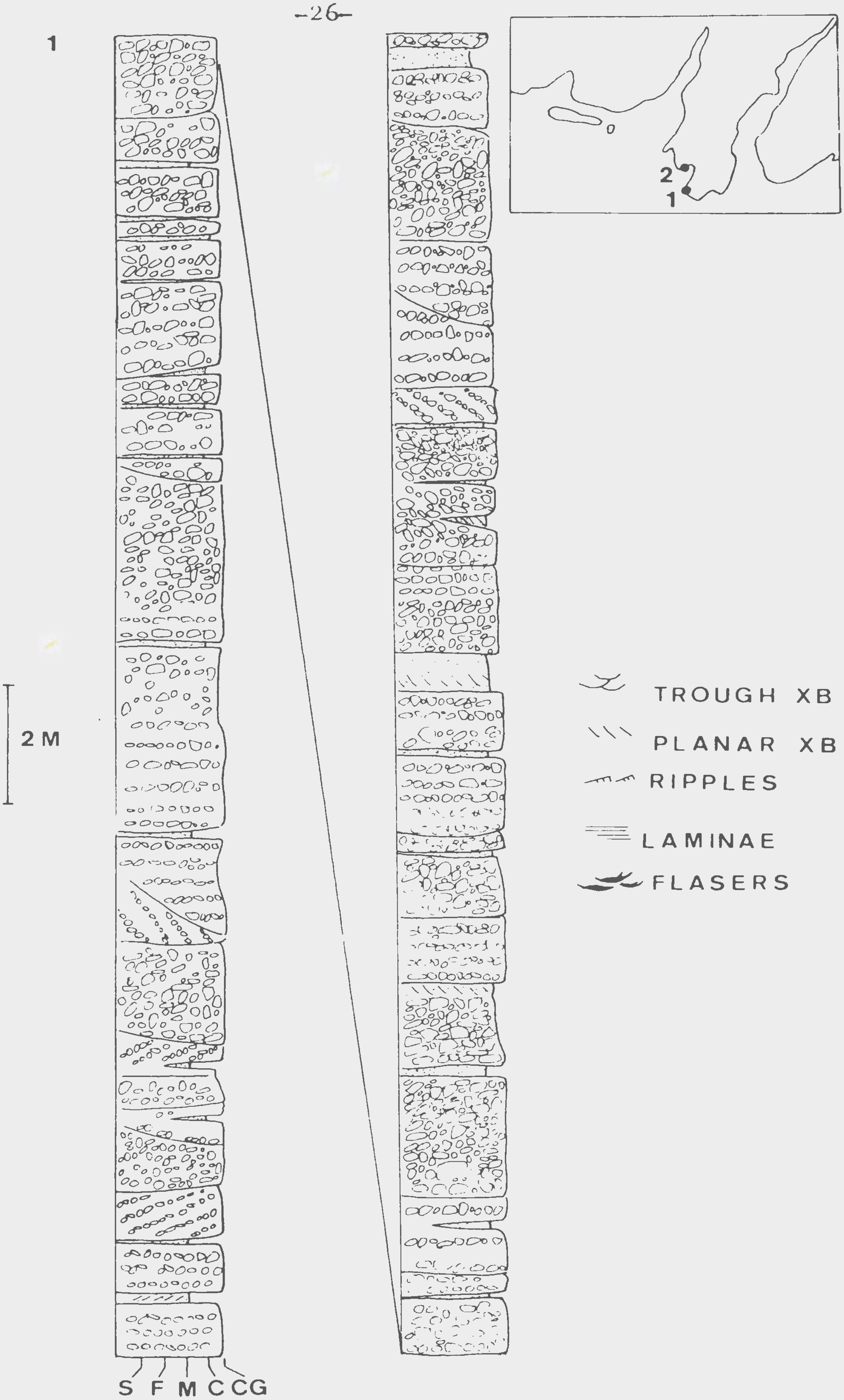


FIG. 2.13 A representative section of facies association I.

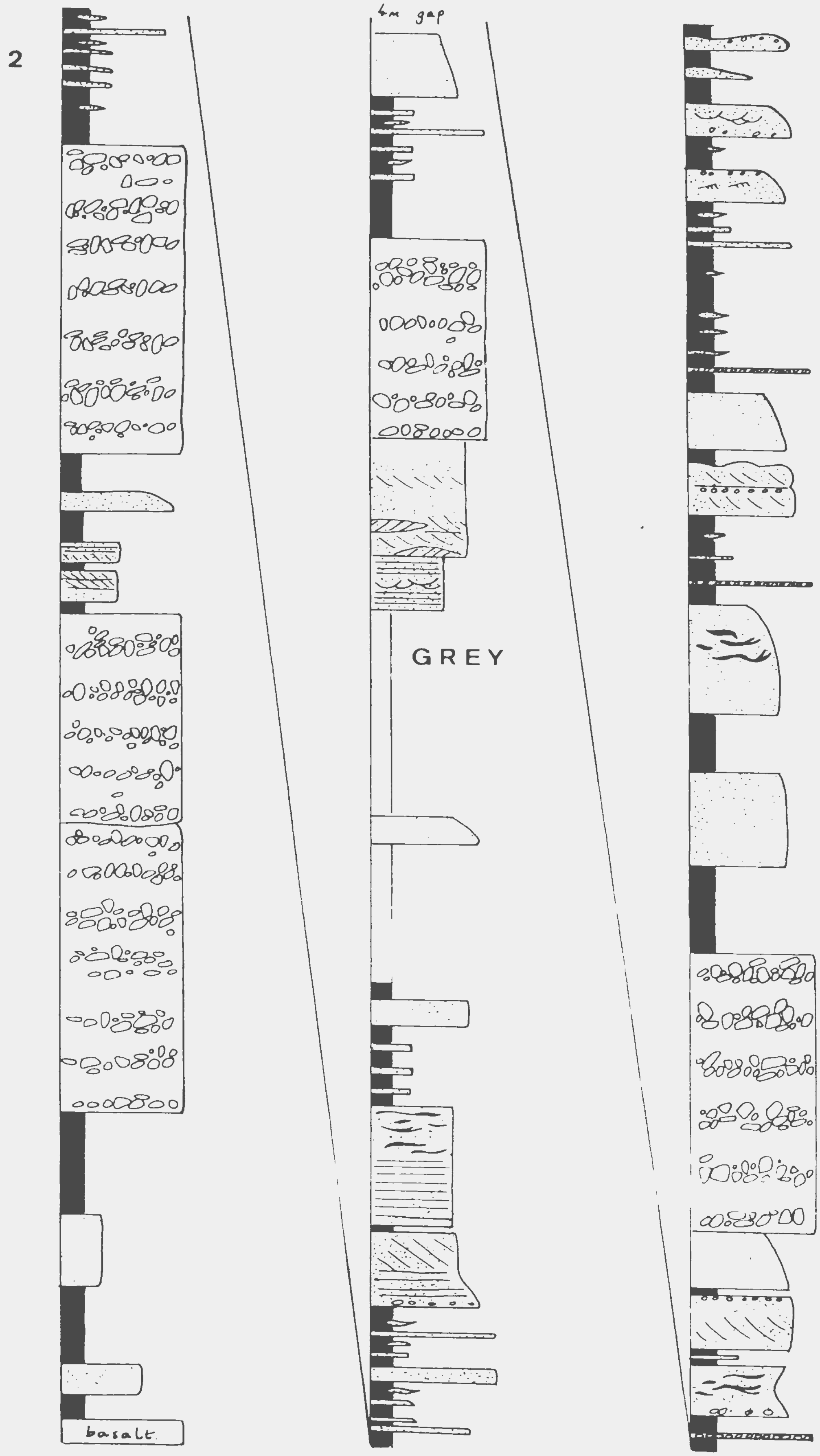


FIG. 2.13 con'd. A representative section of facies association I.

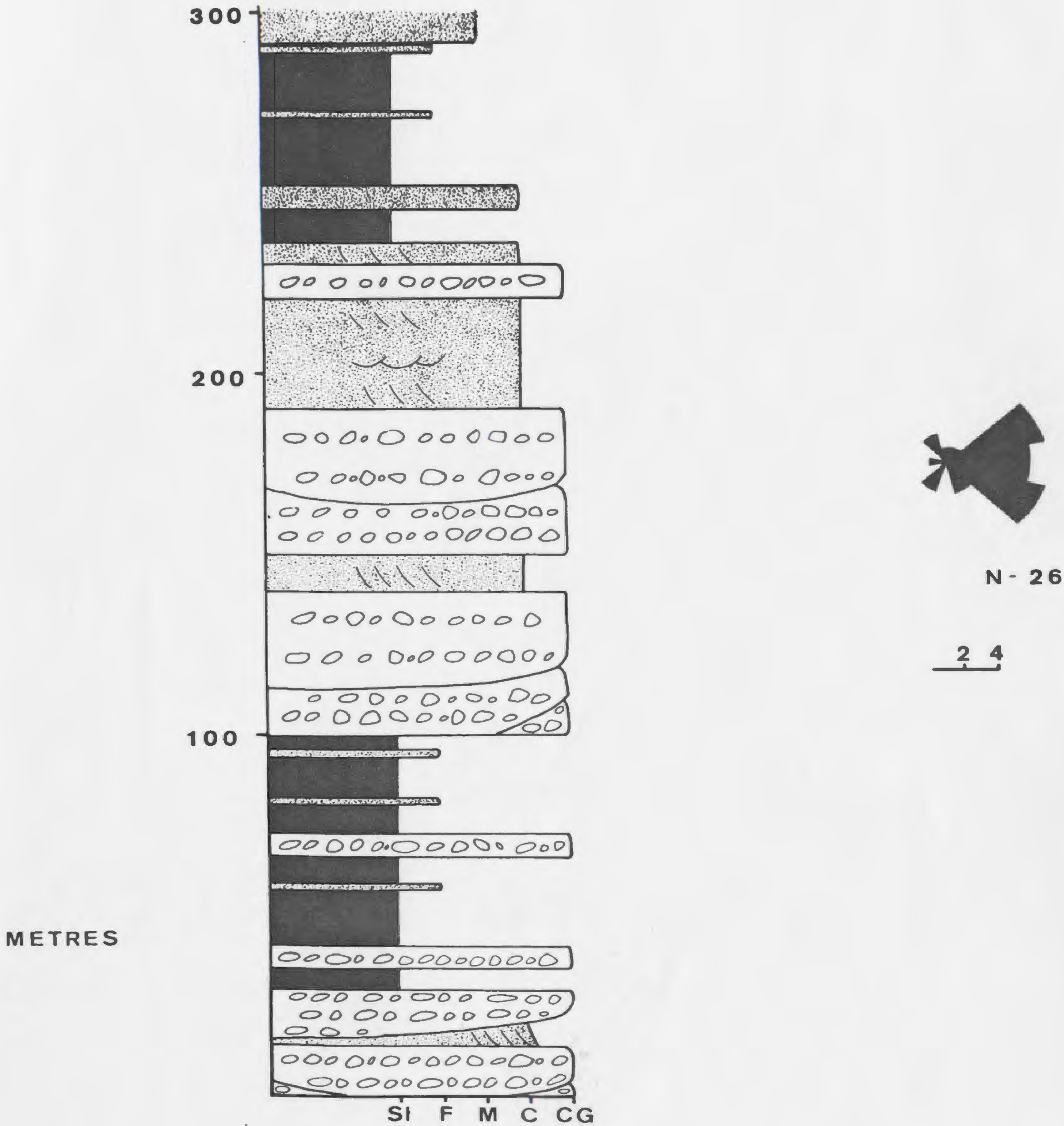


FIG. 2.14 Long Cove section.

Superimposed on this are grain size changes related to interbedded pebbly sandstone units.

The sequence at Doting Cove (fig. 2.15), some 300m thick, is included in the Rencontre Formation, although Williams (1971) included it in the Mooring Cove Formation, defining the base of the Rencontre at the top of the last volcanic unit. In most places this is a useful working definition, as the Mooring Cove is predominantly volcanic. An exception should be made here however, as the volcanic unit involved is a mere 5m thick, and overlies sediments indistinguishable from Rencontre sediments elsewhere (Mooring Cove sediments are purple-grey clastics and siliceous silts).

The Doting Cove sequence shows an interbedding of facies similar to that at Long Cove (fig.2.14). A 12m sequence of conglomerate occurs at the base, overlying Mooring Cove volcanics. The following 180m contains only one other conglomerate unit, 10m thick, with sharp contacts while the rest of the sequence consists mainly of the siltstone-dominated facies. The succession is capped by a 70m interval of conglomerate and pebbly sandstone. A fine-grained conglomerate (mean grain size is 0.6cm), 10m thick, is overlain by 5m of basalt, which is followed by another 10m of conglomerate. The succeeding 40m consists of interbedded conglomerate and pebbly sandstone. The latter shows some differences with other pebbly sandstone

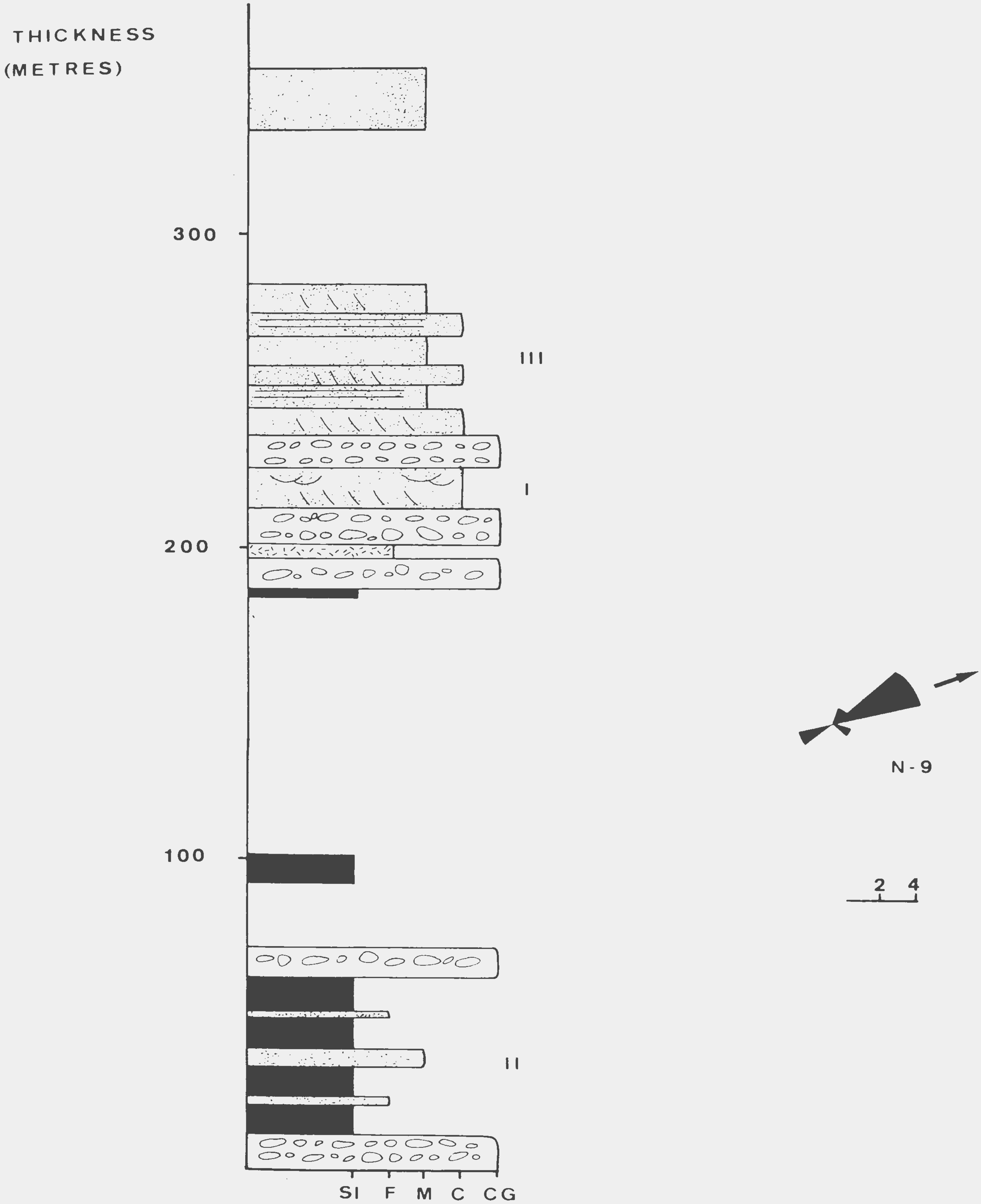


FIG. 2.15 Generalised stratigraphic section, Dating Cove.

units. Compound cross-bedded units occasionally occur. These range from 0.15-0.2m thick, the first-order surfaces are marked by granules and silt intraclasts. Their internal structures are similar to Allen's (1981) type IV sandwave. Other units include conglomerate lenses with vertically imbricated clasts, solitary planar cross-beds and ripple cross-laminated sandstone. The top 10m consists of beds which show a fining-up sequence: erosive base; thin, coarse sandstone with imbricated silt clasts; massive sandstone (0.5m thick); sandstone with sets of silt draped cross-bedding (0.2-0.3m thick); flaser-bedded fine sandstone; and silt. Four of these sequences are present, ranging in thickness from 1-3.3m. Cross-bed azimuths are variable and sometimes opposed (fig.2.15).

2.4 The interpretation of association I

The conglomerate and pebbly sandstone show evidence for dominantly braided fan processes, while sandstone- and siltstone-dominated units show evidence for both fluvial and marine processes. This leads to a fan delta interpretation. Fan deltas are alluvial fans that prograde into a body of water from an adjacent highland (Holmes, 1965; McGowen, 1971). Interest in fan deltas has only developed quite recently; for example, see the discussion in Wescott and Ethridge (1980). As a result, fan delta models are not as well developed as those for other environments.

The evidence for fan and marine processes will be outlined, and this will be followed by a detailed interpretation and discussion of the various facies.

2.4.1 Evidence for braided fans

A combination of criteria are used; no one feature is sufficently diagnostic (Ori, 1982; Collinson, 1978) :

1)Stratification types, consisting of crude parallel-bedded conglomerate, with subordinate cross-bedded conglomerate, are characteristic of coarse, braided alluvium (Rust, 1978; Hein and Walker, 1977; Harms et al., 1975; Ori, 1982). Stratified conglomerate of submarine fans can be distinguished by its common inverse to normal grading, scarcity of cross-bedding, and associated turbidite sands and marine shales (Rupke, 1978; Lowe, 1982; Pickering, 1981).

2)The conglomerate shows lenticularity and poor pebble segregation. This is characteristic of fluvial rather than marginal marine depositon; swash and wave processes lead to well sorted, laterally persistant units (Clifton, 1973).

3)Beds commonly show concave up, scoured bases and flat tops. This is indicative of fluvial processes (Ori, 1982; Reading, 1981).

4)The conglomerate shows rapid thickness and lithological changes. Both are characteristic of alluvial fans (Collinson, 1978; Boothroyd and Nummedal, 1978; Bull, 1977).

5)A broadly radial spread of palaeocurrents is seen.

6)The red colour is most easily explained by deposition and early diagenesis in subaerial, oxidizing conditions (Chandler, 1980).

2.4.2 Evidence for marine processes

1)Ripples in the red and green silt facies commonly have undulatory bases and opposed cross-laminae. These are features of wave ripples and imply deposition by oscillatory wave motions (De Raaf et al., 1977; Collinson and Thompson, 1982). Additional support for a subaqueous origin is the green colour of some units. This indicates deposition, or early diagenesis, in somewhat reducing conditions and is a common feature of subaqueous deposits.

2)The sandstone-dominated facies shows features which are difficult to explain without invoking wave reworking. Many sandstone units show irregular tops which are clearly erosional as they truncate internal sedimentary structures. Granule layers on these bed tops likewise imply erosion via winnowing to give a granule lag. Two possible mechanisms are erosion by fluvial sheetfloods, or marine, storm-related reworking. The former is unlikely. The eroding current was sediment-starved, as the units are draped by silt, yet fluvial floodwaters are usually charged with sediment (Milliman and Meade, 1983; Claude and Loyer, 1977; Drake et al., 1972). In shallow marine settings however, the volume of water moved by storms is conducive to sediment-starved , high-velocity currents (Levell, 1980a; Belderson and Stride, 1966; Kenyon and Stride, 1970).

The geometry of the bed tops likewise points to marine processes. One would expect fluvial reworking to produce flat or concave-up tops. Wavy tops, however, are commonly produced by marine reworking. For example, Dott and Bourgeois (1982), Homewood and Allen (1981), and Johnson (1977) all noted that the oscillatory motion of strong waves produced wavy bed tops.

3)Some conglomerate and sandstone units show southwest-directed palaeocurrents, opposed to the general northeasterly-directed pattern.

4)Some units in facies association I show features which are difficult to account for without times of marine influence (fig.2.16). For example, units near the top of the Doting Cove sequence show flaser bedding, wavy lamination, opposed palaeocurrents, and fining-up beds. These are similar to some descriptions of estuarine distributary deposits (Reineck and Singh, 1980; Nio et al., 1980; MacCarthy, 1979). Eriksson (1979) described similar features from inferred tidal channels in Archean deltaic sediments.

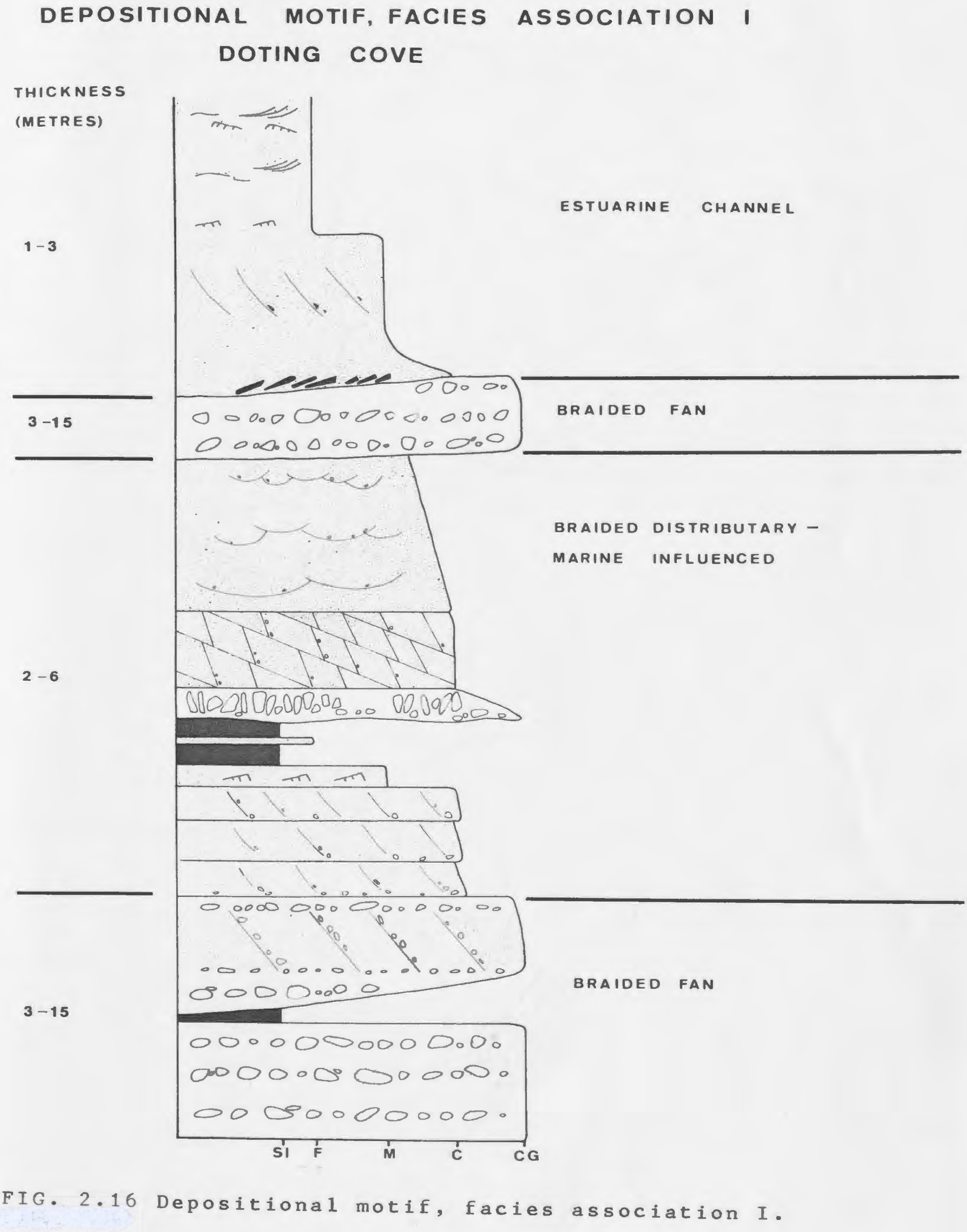


FIG. 2.16 Depositional motif, facies association I.

5)Desiccation cracks are conspicuously absent despite abundant bedding plane exposures of siltstone. Their rarity might be partly explained by the removal of desiccated bed tops by erosion, although it would be ensured by subaqueous deposition.

Considered in total, these points are persuasive. A marine rather than lacrustrine presence is the preferred interpretation because of evidence for tides, storm activity, and the nature of overlying facies associations (see chapters 5, 6, and 7).

2.5 Facies interpretations

2.5.1 Conglomerate and pebbly sandstone

The thick sequence of conglomerates and pebbly sandstones of association I are interpreted as the deposits of proximal braided fans. These deposits thicken towards the southwest and show palaeocurrents directed to the northeast, indicating a southerly source for the fans.

The characteristic structure of the conglomerate, crude parallel bedding, is the result of the aggradation of low relief, longitudinal, braid bars (Rust, 1978; Hein and Walker, 1977). These form when the ratio of water depth to grain size is too small for the bar to build up high enough to develop a slip face (Ashmore, 1982; Boothroyd, 1981). These bars are characteristic of braided fans with poorly defined, low relief channels (Collinson, 1978; Hardie et al., 1978).

The subordinate cross-bedded conglomerates represent transverse to linguoid bars, probably migrating in the deeper parts of channels. Some are probably lateral bars, accreted onto the channel margins (Bluck, 1979, 1980). These are the cross-beds with palaeocurrent azimuths at high angles to the mean channel trend.

The minor interbedded sandstones are low flow stage deposits, either accreted onto the bar edge ("bar edge sand wedge") or draped over the bar tops.

The fabric of the conglomerate gives some indications of the conditions under which the sediments were deposited. The rocks show no imbrication, poor sorting and clast "a" axes are, on average, flow parallel (see chapter two). These features imply high applied shear stress and some grain interaction to create dispersive pressure (Hein, 1982), with clasts moving by intermittent saltation, rather than by purely tractional processes. Rust (1972) and Johansson (1962) showed that high flow velocities and sediment concentrations suppress traction and imbrication and encourage saltation and the development of an "a" axis fabric parallel to flow. Velocities and grain concentrations were not high enough, however, to make grain to grain interactions dominant, as basal inverse grading is absent (Walker, 1978, 1975; Allen, 1981). The "flashiness" of the flows is shown by the poor sorting and occasional silt layers.

The condition of intermittent saltation, implied by the orientation of clast axes, can be used to estimate flow velocities. For this condition, u*=w, where u* is the shear velocity and w is the settling velocity of the grain involved (Middleton and Southard, 1977; Middleton, 1979). Substitution of the appropriate values gives maximum shear velocities of 0.85 metres per second. This value can then be substituted into the empirical equation:

$$u/u^* = (8/f)$$

where f is the appropriate friction coefficent, which in the case of low relief braid bars is about 0.025, and u is the mean velocity of the flow. Substitution of these values gives a mean velocity of 1.5 metres per second, which is within the range of values reported from similar modern environments.

Some proximal-distal changes can be seen. Hare Harbour sediments are coarser, with more lenticular bedding than those of Long Cove and Doting Cove. The former characteristic is a result of down fan grading, the latter possibly a result of more entrenched channels near the fan apex (Bull, 1977; Boothroyd and Nummedal, 1978).

The pebbly sandstone facies represents braided fluvial deposition, but flow was of lower velocity and rather better established. This is shown by the stacked sets of cross-bedded, finer sediment. Sequences within this facies compare well with those ascribed to the migration of braid bars within channels and to the migration of the channel itself. Sandstone and conglomerate beds showing basal normal grading, cross-bedding, and an inversely graded top, may represent a bar-tail to bar-head sequence (Bluck, 1979, 1980). Silts and thin sandstone units may represent overbank deposition.

The relationship between the conglomerate and pebbly sandstone is enigmatic. The sharp contacts, and the fact that only the conglomerate interbeds with the finer grained facies, show that the pebbly sandstone was a sharply defined facies, localised near the fan apex. Caution is needed when explaining these sequences, as the identification of the various autocyclic and allocyclic controls is an ambiguous matter (Miall, 1978).

The sharp contacts make allocyclic climatic change an unlikely explanation of the conglomerate-sandstone alternations. Climatically induced changes are usually more gradational, for example, the sequences described by Graham (1981) and Steel (1974). Pulses of high sediment supply, due to tectonic uplift or episodic volcanism (Kuenzi et al., 1979) might explain the sharp changes from pebbly sandstone to conglomerate, but cannot explain the sharp changes of conglomerate back to pebbly sandstone (these mechanisms would give a gradational change).

The alternative is some autocyclic mechanism, such as fan avulsion. This can occur because of changing patterns of fan head entrenchment (Heward, 1978; Denny, 1967; Bull, 1977). For example, the pebbly sandstones can be seen as the deposits of secondary fans, either parasitic on the larger conglomerate fans and reworking their deposits, or as neighbouring small fans.

Entrenchment, due to climatic, tectonic, or complex feed-back responses (Schumm, 1981) of these fans may have led to the capture of the feeder channels of the primary fans. This would give a sharp change from pebbly sandstone to conglomerate. Subsequent avulsion of this channel feeding lobe could have led to the re-establishment of the secondary fans and a quick change back to pebbly sandstone.

Sequences occur on several scales, and one mechanism cannot explain them all. At Long Cove an overall asymmetric coarsening up, followed by fining up, is seen. This reflects fan progradation and retreat associated with major tectonic pulses. Alternations of conglomerate and pebbly sandstone may reflect channel avulsion and entrenchment. Sequences within these units reflect individual flood and channel migration events. The interpretation is summarised in figure 2.17.

2.5.2 Sandstone-dominated facies

The nature of many coarse sandstone bed tops in this

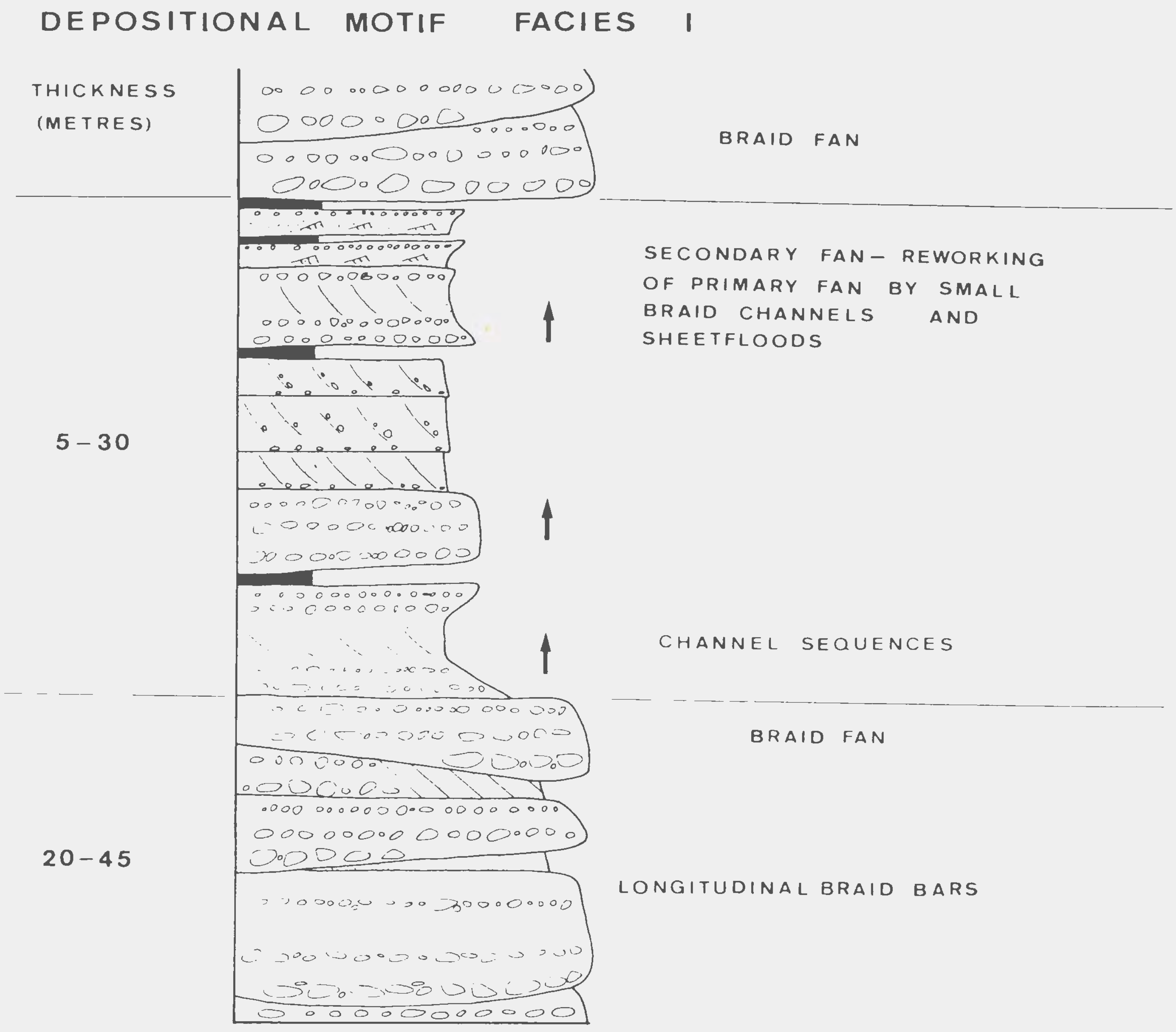


FIG. 2.17 Interpretation of conglomerate and pebbly sandstone facies, association I. Alternations reflect deposition by primary and secondary fans.

facies provides evidence for marine reworking. This process, however, is an erosional one and not ipso facto evidence for storm deposition of the sandstone beds. In this setting a fluvial, as well as a storm, mechanism is possible. The units were compared with floodplain and storm sediments described in the literature. Overbank sands associated with braided channels are deposited as sand sheets with lobate sand fingers, are thin to medium bedded, show erosive bases, normal grading, and small scale solitary cross-beds or parallel laminae (McKee et al., 1967; Bluck, 1978, 1980; Allen, 1982). Storm deposited sandstones show sharp erosive bases, normal grading, laminae with gentle undulations and discordances (which may include "hummocky cross-bedding") with a possible cap of wave ripples (Kelling and Mullin, 1975; Harms et al., 1975; Kreisa, 1981; Mount, 1982; Dott and Bourgeois, 1982). The crucial differences between the two is the absence of structures formed by tractional deposition under unidirectional currents, and presence of wave ripples in storm deposits.

Most of the sandstone units display clear evidence of fluvial deposition because of the abundant solitary cross-beds and and absence of wave ripples. No convincing storm sands are seen, but some units, especially those with irregular silt layers, may have been storm deposited.

The granule conglomerates, however are probably storm deposited. They compare well with descriptions of storm-emplaced gravels from the modern (Yorath et al., 1979) and ancient environments (Wright and Walker, 1981; Leckie and Walker, 1982). The grain-thick layers of granule conglomerate are probably "lag-suspension couplets". These are produced by winnowing where sand grade material is scarce (Bourgeois, 1980; Kreisa, 1981).

Apparently the sandstone-dominated facies was largely fluvially deposited, but was reworked by storms. This paradox can be resolved by a fan-delta distributary origin for this facies. This environment often shows the interaction of both fluvial and marine agents (Elliot, 1978) as distributaries formed during fluvial flood become subject to marine reworking.

The sandstone-dominated facies may have been formed when periodic floods shed detritus from the fan. This was deposited as sheet splays (Galloway, 1981; Coleman, 1969), sheet floods and by ephemeral braided channels. These rapidly prograded across mudflats into a shallow sea, building thin, extensive, stringers of sand and conglomerate. These newly formed lobes seem to have been extremely vulnerable to marine reworking following flood. Vos and Eriksson (1977) described similar reworking of sediments following a fluvial flood. The shallow depths involved are certainly no obstacle to reworking. For example, Dott and Bourgeois (1982) and Johnson (1977) described storm deposits in intertidal settings while Hunter and Clifton (1981) described Eocene examples deposited in a suggested depth of 2m. The interpretation of the sandstone-dominated facies is summarised in figures 2.18 and 2.19.

At times, some of the braided distributaries were longer lived. For example, conglomerates and sandstones at the top of the Doting Cove succession show stacked, tidally-influenced, channel deposits .

As distributary deposits, one might expect coarsening-up sequences, several metres thick, to be present. However, the absence of such features is not a serious objection to the model. Pollard et al. (1982) described a fan delta sequence, and explained the absence of well developed coarsening-up sequences as the result of one of the following: (1)the basal fines accumulated only in local ponded areas within the floodplain, or (2) the basal fines were eroded.

An alternative explanation is that shallow water depths inhibited coarsening-up sequences. This has been noted in several fan delta sequences; for example, the studies of Vos (1977), Flores (1975), and Dutton (1982). This is believed to be the main control here, as several lines of evidence point to deposition in shallow water.

FIG. 2.18

A summary of delta-fringe processes. A: fluvial sandstones are deposited by sheet-floods or shallow ephemeral streams, B: marine reworking of some fluvial sandstones produces scoured and silt-draped bed tops, C: small lenticules of sandstone and granule conglomerate are deposited during storms. Alternating fluvial flood and marine inundation result in a complex fan-fringe sequence.

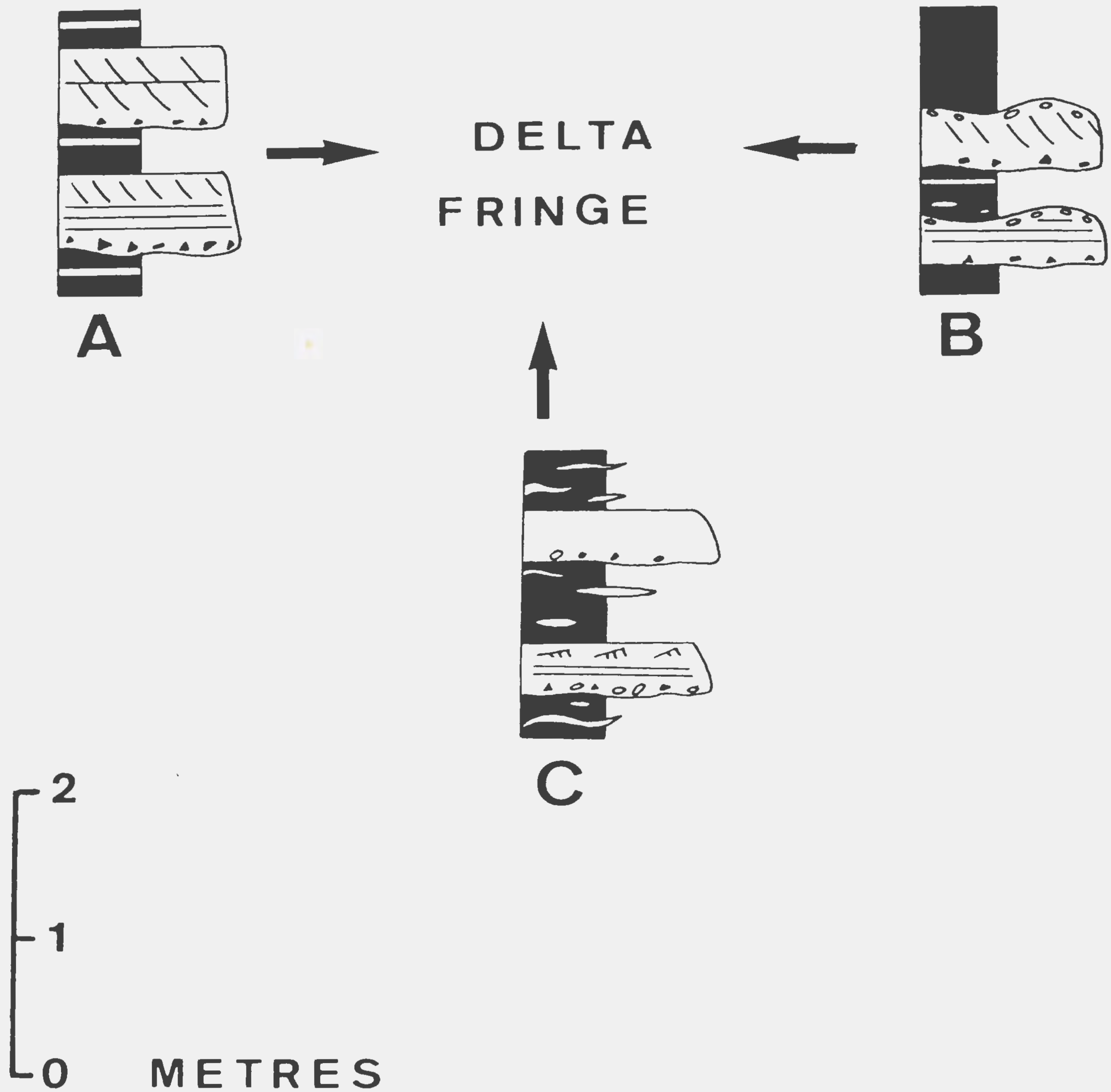
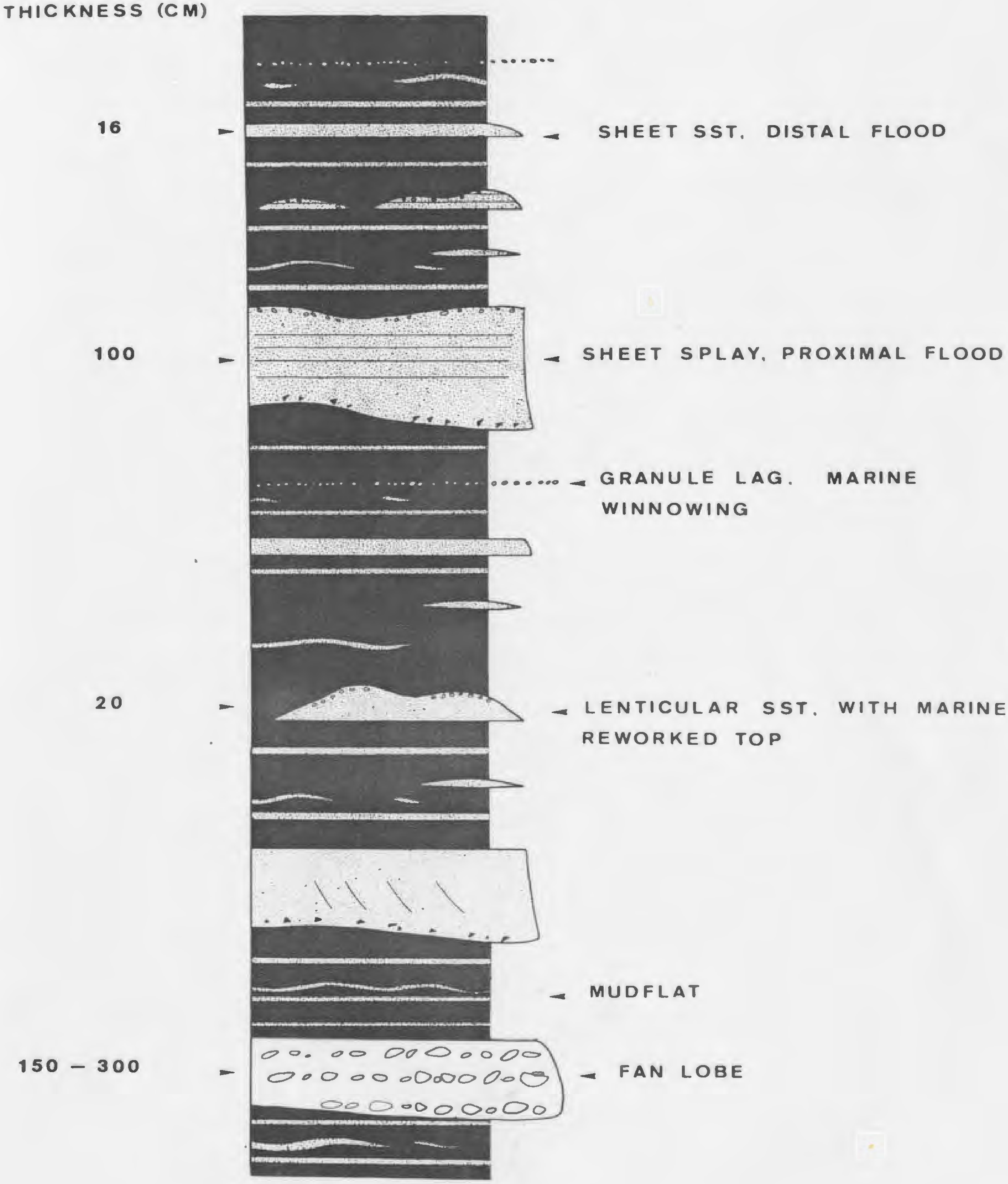

DELTA
FRINGE
A
B
C
2
1
0
METRES

FIG. 2.19

An idealised section of the sandstone-dominated facies with suggested interpretations of the individual units, average thicknesses are indicated, different units are not represented at the same scale.


THICKNESS (CM)
16
SHEET SST. DISTAL FLOOD
100
SHEET SPLAY, PROXIMAL FLOOD
GRANULE LAG. MARINE WINNOWING
20
LENTICULAR SST. WITH MARINE REWORKED TOP
MUDFLAT
150 – 300
FAN LOBE

2.5.3 Siltstone-dominated facies

Similar sequences have been described by several workers. Such thin sheet sandstones and sandstone laminae are often found as distal fan facies, representing deposition by sheet flood from the fan (Hubert and Hyde, 1982; Parkash et al., 1981; Hardie et al., 1978).

The similarity of this facies to such descriptions prompts a distal fan, playa-mudflat interpretation. The facies was probably deposited adjacent to the sandstone-dominated facies and the differences in sandstone abundance and processes are explained by the absence of fan distributaries. Evidence on marine reworking is absent, and this probably reflects the relatively sheltered position of deposits compared with the prominent stringers of distributary sand.

This facies shows more evidence for exposure than the sandstone dominated-facies. For example, desiccation cracks, surge marks (Bull, 1978) and small siltstone clasts were all locally noted. This is probably because exposure was more common (sediments were not covered by the sea following floods) and because of a higher preservation potential (no storm reworking).

The variations in sandstone thickness and stratification type of this facies are probably explained by the progradation and retreat of the fan fringe and the varying size of floods. For example, Parkash et al.

(1981) showed that on a modern fan, proximal sheet floods gave sandy deposits with small scale cross-bedding. In more distal settings, deposits were finer and thinner, with parallel laminations and climbing ripples.

2.5.4 Red and green siltstone facies

This facies is interpreted as delta front deposits. This is suggested because of the presence of wave ripples and absence of coarse sandstones.

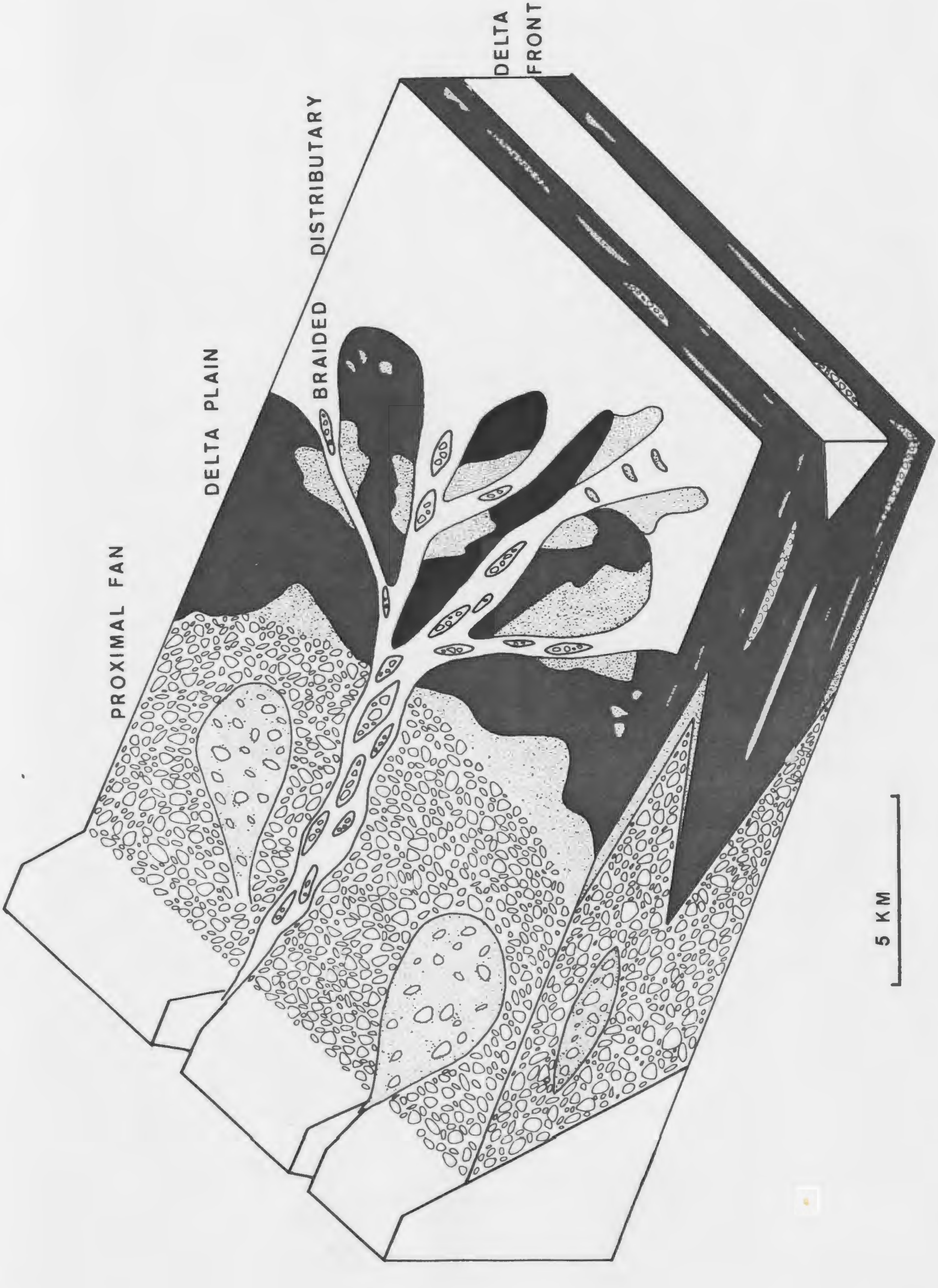
The technique of Klein (1974) was applied to estimate the water depth. The model assumes that the thickness of the delta front deposit approximates the water depth. This can be used as an estimate, provided that progradation was faster than subsidence and that compaction was syn-sedimentary. Using the mean thickness of this facies, the estimated water depth is 6.5m. Other features pointing to shallow depths include the red colour of much of this facies and the alternations of fluvial and marine processes in the sandstone-dominated facies.

2.6 Discussion

The Rencontre fan deltas consisted of a coarse apex, distributary lobes, and distal-fan, delta-plain embayments (fig.2.20). During times of flood shallow braided channels built out across fan toe mudflats into a shallow sea. They probably built lobes of sediment that penetrated far into

FIG. 2.20

A cartoon illustrating process and product in the Rencontre fan deltas , note the down-fan decrease of grain size and finer braided pattern of the channels, the ephemeral delta-fringe oscillates in response to fluvial flood and marine inundation.


PROXIMAL FAN
DELTA PLAIN
BRAIDED
DISTRIBUTARY
DELTA
FRONT
5 KM

the basin. Following flood these were subject to marine reworking, until a more stable, less exposed, geometry was formed. At times, larger, more stable distributaries existed. These show signs only of tidal activity and not of catastrophic reworking. Embayments were probably dominated by sheetfloods from the fan , and did not suffer marine reworking in their more protected positions.

The main effects of marine processes were reworking of fluvial sandstones and the deposition of granule conglomerate during storms. The absence of sandstone storm deposits indicates a scarcity of sand grade detritus as the storm waned, a paradoxical conclusion in a fan delta setting. A possible explanation lies in the nature of storm processes, which are often most effective during the storm ebb-surge. This may result in intertidal and shallow subtidal areas being zones of net erosion, while slightly deeper regions are zones of net deposition (Winkelmolen and Veenestrsa, 1979; Allen, 1982b). In the case of the Rencontre fan delta, this may mean that sand was transported offshore during storms, while much of the less mobile granule grade sediment remained at the delta fringe.

These deposits were compared with modern and ancient fan deltas described in the literature, some of which seem to share some characteristics with the Rencontre sediments. These include the following:

(1)Intimate interbedding of coarse and fine deposits.

(2)Poorly developed coarsening-up sequences.

(3)The division into delta front and delta plain is blurred, and the strandline is an ephemeral and unstable feature.

For example, Winston (1978, p.352), studying the Belt Supergroup, found that "during times of fluvial progradation into the Belt sea, the demarcation between fluvial and marine margin environments was indeed vague. The beach may have been nothing more than discontinuous shoals..."

Moore (1979, p.1240) argued that for a Cambrian fan delta sequence in Australia, a standard delta interpretation could not apply as it implies "...markedly different subaerial and submarine parts: a situation which is not observed..."

Similar examples include the South African Proterozoic Witwatersrand deposits (Vos, 1975), the Proterozoic sequence described by Vos and Eriksson (1977), and the Cambrian sediments of Kangaroo Island, Australia (Daily et al., 1980).

These sorts of fan deltas, with a transient fan-fringe of fine-grained sediment, might be termed mudflat-fronted fan deltas. Interestingly, these examples are all Proterozoic or Early Palaeozoic in age. One might speculate that the absence of vegetation would favour this sort of fan delta by encouraging extreme channel instability and a poorly developed strand line. Today, vegetation stabilizes tidal creeks and high intertidal berms and limits the movements of the sea to more or less defined paths (Fry and Bason, 1978). These buffers against the sea would not exist in pre-vegetation times. Fluvial systems would have a "flashy" regime and show extreme channel instability. This would be conducive to the development of shallow, ephemeral distributary channels.

Another condition that might favour this sort of fan delta is a shallow sea with a very gently sloping floor. This would (1) hinder the development of coarsening-up sequences, (2) encourage distributary avulsion by providing gradient advantages (Elliot, 1978), leading to intimate interbedding of fluvial and marine deposits, and (3) enable the inundation of large portions of the delta plain during storms.

The palaeocurrents of association I show that the sediments were deposited in a basin opening to the east-northeast. The margins of the basin may have had considerable relief, and were possibly fault controlled. Certainly, this is a common setting for modern fans (Collinson, 1978; Bull, 1977). The western margin was at Doting Cove, where it is marked by a rapid pinching-out of association I against basalt of the Mooring Cove Formation. The eastern margin may have been close to Femme Bay, the present eastern limit to the outcrop of the Rencontre.

CHAPTER THREE

FACIES ASSOCIATION II, NORTHERN FORTUNE BAY

3.1 Introduction

Association II is a sequence of coarse- to medium-grained sands, up to 150m thick, with subordinate silts and fine sandstone. It outcrops on the mainland at Rencontre East, forming a strip parallel to the coast, and on the northern tip of Rencontre Island (see fig.1.3). Its base is seen 1km west of Rencontre East, where it overlies amygdaloidal basalt of the Mooring Cove Formation. Its eastern base is exposed in the southern tip of Doting Cove where it overlies some 300m of sediment belonging to association I. This represents a depositional overlap to the west. On Rencontre Island its top is in sharp contact with green silts and sandstones of association III. A schematic section of the Rencontre East outcrop is shown in figure 3.1. A small outcrop, 20m thick, is also seen at the top of the Long Cove sequence.

The association is distinguished from others by its sandy nature, small scale cross-bedding and parallel lamination. Two facies are recognised, a sandstone rich facies, and a silt and fine sandstone facies.

3.2 Facies descriptions

RENCONTRE EAST

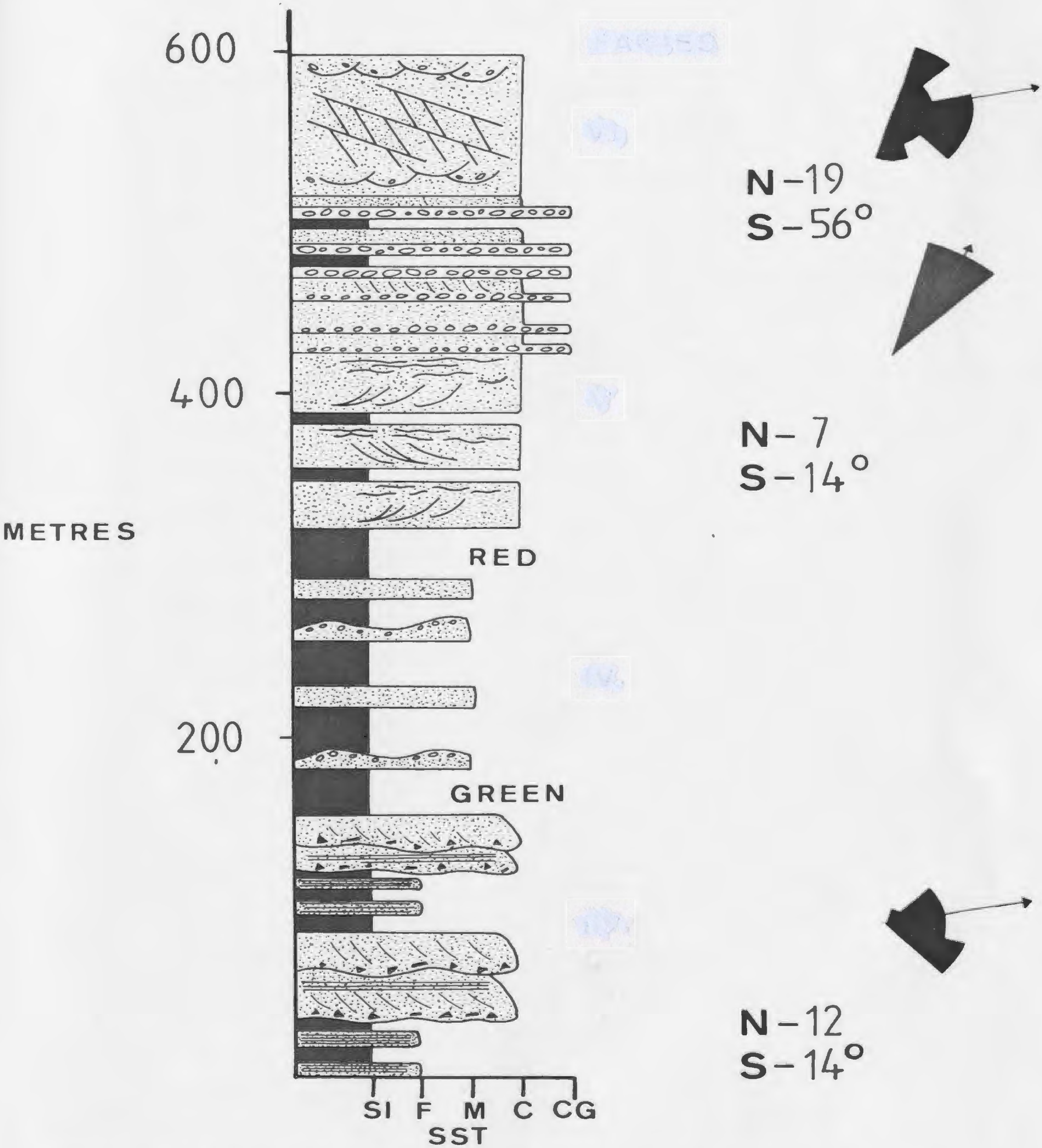


FIG. 3.1 Section through the Rencontre Formation at Rencontre East. Facies Association II forms the lowest 150 m.

3.2.1 Sandstone facies

This facies includes medium to coarse sandstones, which either show planar cross-bedding and parallel lamination, or are massive.

The facies makes up 80% of the succession, occurring as medium- to thin-bedded units, with a mean bed thickness of 0.5-0.6m. The beds are sometimes separated by silt, but are usually stacked, layers of silt clasts, erosive surfaces and sharp grain size changes, show that amalgamation has occurred.

The beds have erosive bases, are normally graded and are sheet like. Elongate silt intraclasts occur at the bases of beds, overlain by parallel lamination or planar cross-bedding. The latter generally occurs as solitary, small- to medium-scale sets (0.2-0.6m).

Silt locally occurs within the beds as layers or wedges (see fig.3.2). In places, soft sediment deformation is seen such as convolute bedding and deformed cross beds.

3.2.2 Siltstone facies

This facies consists of discrete beds of silt and fine sandstone. The facies is most abundant near the base of the section. The siltstone locally shows large sand-filled desiccation cracks (see fig.3.3). The silt can occur in units several metres thick, either as massive units or with faint laminae of fine sandstone.

FIG. 3.2 Siltstone wedge erosively truncated by sandstone Rencontre East.

FIG. 3.2 Large sand filled desiccation cracks, Rencontre East.

Fine sandstone occurs as massive or laminated beds, with a mean thickness of 0.5m. Some units show ripple cross-lamination or dish structures.

3.3 Interpretation of facies association II

Several lines of evidence suggest a fluvial origin for association II. These are as follows: (1)unidirectional palaeoflows to the east, (2)desiccated silts, (3)the sheet-like nature of the beds, with erosive bases and flat tops (Reading, 1981), and (4)the red colour of the sediments.

The conditions of deposition can be inferred from the sorts of sedimentary structures. The abundance of parallel laminae indicates deposition in the upper flow regime. Subsequent waning flow is shown by normal grading and transition to ripple cross-laminae in many beds.

The sediments are similar to those of modern, ephemeral, braided streams as described by McKee et al. (1967) and Chilingarian (1972) and incorporated into facies models by Miall (1977, 1978) and Rust (1978). During floods, parallel-laminated sand is deposited as sheets as the channel is breached. With waning flow, ripples and small scale cross-beds might form along the outer margin of depositional sheets. In the channels trough cross-bedding develops. These conditions could well account for the sandstone facies of association II.

The interbedded silts and sands of the Rencontre section probably represent the most marginal part of the flood sediments. Tunbridge (1981) interpreted some Devonian sediments in the same way.

The sequence shows that major changes in palaeogeography had occurred after deposition of facies association I. The sharp transition from coarse fan delta sediments shows an abrupt decrease in the calibre of the sediment being supplied. This is associated with a major depositional overlap. Apparently, the narrow, and probably fault bounded, basins that nourished fan deltas disappeared. They were replaced by a broad, low relief basin, that still however, opened to the northeast. Association II probably represents a time of tectonic quiescence.

Changes also occur within association II. Towards the top, silt becomes rarer and cross-bedding more abundant. The implication is that flows were becoming deeper and less ephemeral.

CHAPTER FOUR

FACIES ASSOCIATION III, NORTHERN FORTUNE BAY

4.1 Introduction

This association of green-gray silts and sandstones is a striking one, compared with other predominately coarse and red Rencontre sediments. The association outcrops on Rencontre Island, where it is about 180m thick, and at Bob Head, in western Fortune Bay, where it is a mere 5m thick.

Two facies occur, a green-gray silt and fine sandstone facies and a minor medium grained to coarse grained, gray sandstone facies. The former makes up 80% of the section.

4.2 Facies descriptions

4.2.1 Green-gray silt facies

This facies is made up of green-gray silt with varying amounts of fine sandstone. Lithologies range from massive silt to very sandy silt. The only sedimentary structures are sandstone laminae, most commonly these are rather irregular, wispy and wavy, but sometimes they are regular and uniform (fig.4.1). There is no obvious correlation between sandstone content and laminae type.

In thin section, the silts are composed of cryptocrystalline green phyllosilicate minerals and silt-sized quartz grains. Some larger detrital mica flakes

FIG. 4.1 Laminated siltstones of the green-grey silt facies Rencontre Island, object is 5 cm long.

FIG. 4.2 Conglomerate and coarse sandstone with low-angle discordances and vertically imbricated silt clasts, Rencontre Island.

are seen, and these can be identified as iron rich chlorite because of the anomalous blue interference colours that are seen under crossed polars.

4.2.2 Gray sandstone facies

These sandstones are commonly nondescript as their colour is uniform and they appear massive. The most common type is moderately to poorly sorted and contains scattered green silt clasts. Beds occur in packages about 2m thick, scattered throughout the section.

There are two much rarer types. Near the base, thin (less than 40cm), coarse sandstones and granule beds occur. These have erosive bases, irregular tops with granule lags, and show marked lateral pinching and lenticularity. Near the top of the section on Rencontre Island, a six metre coarsening up sequence is seen. This is capped by a granule conglomerate with low angle discordances, laminae and vertically imbricated silt clasts (fig.4.2).

Compositionally, the sandstones are quite mature for Rencontre sediments. Quartz-feldspar-lithic ratios can reach 60-20-20; occasional detrital chlorite flakes and rare glauconite grains are seen.

4.3 Sequences in facies association III

No regular motif can be seen in the sequence. The basal contacts at both localities are not well exposed. At

Rencontre Island, the upper contact with association IV consists of an interbedding of red and green silts. At Bob Head, this contact is sharp.

4.4 The interpretation of association III

4.4.1 Introduction

A marine setting is likely for these sediments. This is supported by the following: (1)the irregular and wavy lamination of the silt implies that oscillatory wave motions were active (De Raaf et al., 1977; Collinson and Thompson, 1982), (2)the green colour indicates deposition in somewhat reducing conditions (Chandler, 1980), (3)the compositional maturity and presence of glauconite in the sediments are characteristic of marine settings (Odin and Matter, 1981), and (4)rare sets of "herringbone" cross-stratification suggest tidal or storm-generated currents.

4.4.2 Green-gray silt facies

A subtidal, generally low energy setting is suggested by the fine grain size and rarity of storm or tidal features. A more detailed interpretation is difficult because of the dearth of diagnostic features. Generally, facies models for muddy, shallow water sediments are poorly developed (Johnson, 1978) as sedimentological information is sparce. In Phanerozoic sediments, much of the interpretation is based on palaeoecology, a technique which cannot be used in this case.

The variations in laminae type do suggest some fluctuations in wave energy. The regular, parallel laminae and irregular, wavy laminae are responses to variations in wave base between storms and periods of fair weather (De Raaf et al., 1977).

4.4.3 Gray sandstone facies

It is difficult to give unique interpretations for many of the sandstones in this facies because of their nondescript nature. The scattered units in the middle parts of the section may be either sand shoals on a sediment starved substrate, storm deposits, or the remains of transgressed and reworked beaches. All these mechanisms can give the normal grading which is sometimes seen in these sandstones (Figuerdo et al., 1982).

The sandstones in the basal 10m of the Rencontre Island section are less cryptic. They may well be the remains of a transgressed beach deposit. These are formed during relative sea level rise, when sediment supply is too low to support beach progradation. Similar sequences described from the rock record (Bridges, 1976; Graham, 1975) show thin swash and wave reworked beach deposits, and a possible fining up, as lower shoreface deposits replace upper shoreface and foreshore deposits. Often such a transition is truncated because of the efficency of erosion during transgression (Rampino and Saunders, 1981; Swift, 1968).

The Rencontre shows many of the same features. Some beds show regular lamination defined by heavy minerals which is a feature of swash zone laminae (Clifton, 1969). The sequence fines up into marine green silts but overlies fluvial sands. The lowermost silts are interbedded with coarse, wavy-topped beds. These are good candidates for shoreface deposits, as they are similar to storm produced sublittoral sheet sandstone deposits (Goldring and Bridges, 1973; Kreisa, 1981). These decrease in abundance up section as the deposits progressively represent more offshore environments (Reineck and Singh, 1980, p.395).

Sandstones near the top of the section on Rencontre Island may also be beach deposits. A six metre coarsening up sequence begins with fine sandstone and silt with wave ripples and lenticular bedding, passes into medium and coarse sands and then into granule conglomerate with vertically imbricated silt clasts. The coarsening up and evidence for swash activity (vertically imbricated clasts), points to a beach origin (Sanderson and Donovan, 1974). The sharp change back to silts implies that deposition was followed by rapid submergence.

4.5 Discussion

Although some details of the interpretation are difficult, this association does give some clues about the palaeogeography at this time.

The association is the result of the transgression of a low energy sea. Sediment supply was low and probably the tectonic quiescence characteristic of association II, continued. The sea flooded areas that were not previously sites of deposition. Sedimentation was extended to the west of Fortune Bay (Bob Head) and probably as far south as Brunette Island (see chapters 8 and 13). It is difficult to be definitive about the most likely direction from which the sea advanced. At least by the end of association III times, a northeast to southwest marine basin had been established, so the sea could have advanced from either direction. Later infra Cambrian transgressions advanced primarily from the west or southwest (Anderson, 1981; Hiscott, 1982). Association I, however, requires an earlier marine connection to the north as well.

The detrital chlorite in some silts was probably derived from older volcanics of the Marystown and Burin groups, which had undergone metamorphism by this time (Strong et al., 1978). Its preservation shows that chemical weathering was ineffective, possibly a result of an arid climate, as the ferrous iron of the brucite layer is usually oxidized in more temperate conditions (McManus, 1970; Leeder, 1982).

CHAPTER FIVE

FACIES ASSOCIATION IV, NORTHERN FORTUNE BAY

5.1 Introducton

Facies association IV is a distinctive assemblage of heterolithic sandstones, granule conglomerates, and siltstones, with a maximum thickness of 200m. The association outcrops on Rencontre Island, Mal Bay Island, and on the west coast of Fortune Bay at Bob Head. The sequence overlies the green silts and fine sandstones of association III and, in turn, is capped by the coarse, cross-bedded, association V.

5.2 Description of association IV

5.2.1 General

Four facies are recognized: (1) a heterolithic facies (Johnson, 1978) of coarse- to medium-grained sandstone with silt; (2) coarse- to medium-grained sandstone with planar and trough cross-bedding, erosive, concave-up bases, or low-angle, regular, silt laminae; (3) granule conglomerate and coarse sandstone with subordinate medium to fine sandstone, planar cross-bedding and parallel laminae; and (4) silt with interbedded sandstone.

5.2.2 Heterolithic facies

This facies makes up about 70% of the facies association. The sandstone is coarse- to-medium grained and poorly to moderately sorted. The red silt gives the facies its special character and commonly occurs as drapes outlining tangential foresets in sets up to 0.3m thick. It also occurs as wavy and irregular layers and as flaser bedding (see figures 5.1 and 5.2). The draped bedforms show a wide range in orientation, indicating flow to the northeast and southwest (although accurate measurement of azimuths is difficult in this facies).

The beds generally show little internal ordering, although they sometimes show an upward increase in silt with the laminae becoming progressively more regular. The beds often show evidence of internal scouring as silt laminae are sharply truncated by drapes outlining low relief scours.

Granule conglomerate occurs as lags on the top of some beds and as small lenticles, or wavy-topped sheets.

Red silt, as well as occurring as drapes and laminae, forms thin, below 30cm thick, discrete beds, and locally abundant silt intraclasts.

5.2.3 Coarse- to-medium grained sandstone

This consists of coarse grained to medium grained sandstone with some granule conglomerate. The

FIG. 5.1 Heterolithic sandstone with siltstone flasers, drapes, and layers, Rencontre Island.

FIG. 5.2 Heterolithic sandstone, note the siltstone rip-up clasts indicative of penecontemperaneous erosion, Rencontre Island.

characteristic feature of this facies is the concave-up, channelised bases of the beds. These often show marked erosive relief, up to 0.5m in a lateral distance of 0.6m (see fig.5.3).

The beds show planar and trough cross-bedding, with variable set thickness (0.1-1m). The smaller sets often show scour and fill features. The cross-bed foresets are usually oriented towards the northeast, although some units are reversed, or at a high angle to this.

Included in this facies, are beds of coarse sandstone with regular silt laminae. There is often a low angle discordance between sets of silt laminae (fig.5.4) the angle of discordance sometimes decreases upwards.

5.2.4 Granule conglomerate facies

Poorly sorted coarse sandstone and granule conglomerate makes up this thick-bedded facies. Parallel laminae, defined by granule layers 2-4cm apart, make up 50% of the facies. Solitary sets of planar cross bedding, about 0.5m thick, make up 20% of the facies. Both these structures often show syn-sedimentary deformation, such as convolute bedding and overturned foresets.

5.2.5 Silt and sandstone facies

This is a minor façies making up only 5-10% of the facies association. It consists of discrete, thin beds of

FIG. 5.3 Channelised sandstone, note the different orientation of cross-beds above and below the scour, Rencontre Island.

FIG. 5.4 Angular discordance between sets of laminated sandstone Rencontre Island.

silt, fine sandstone and coarse sandstone. The silt is massive or has fine sandstone laminae. Desiccation cracks are sometimes found. Coarse sandstones occur as markedly lenticular units less than 0.5m thick which have erosive bases, fine up and show small scale cross bedding. Thin sheets of conglomerate (under 0.3m) are found locally.

5.3 Rencontre Island and Mal Bay sequences

About 160m of association IV are seen at these localities, where the representative sections of figure 5.5 were measured. The base of the facies association is seen on the north coast of Rencontre Island, where it involves a gradational change from green to red silt over 10m. This is followed by a 10m coarsening up-sequence of silt and sandstone, which is capped by the first heterolithic unit of the section. This is in turn followed by about 70m of the heterolithic sandstone and coarse grained to medium grained sandstone facies, containing at least two small coarsening up sequences (5m thick). The next unit consists of about 40m of granule conglomerate. The section is capped by 40m of interbedded granule conglomerate and silt and sandstone. The scale of interbedding varies from 2-20m.

The sequence shows cyclicity on several scales. There is a overall change from heterolithic beds to conglomerate and then silt. But within this, there are smaller cycles of heterolithic beds, medium to coarse sandstone and conglomerate.

5.4 Bob Head

A relatively thin sequence (40m) of facies association IV forms the base of the Rencontre Formation at Bob Head, where it overlies volcanics of the Long Harbour Group. The sequence is mainly one of heterolithic sandstone, although it shows some interbeds of green silt, red silt and conglomerate. The conglomerate at the base of the section has a mean grain size of 3.5cm, while interbeds of conglomerate have a mean grain size of 0.8cm. Locally, pale, quartz-rich beds occur.

5.5 Interpretation

5.5.1 Introduction

The gross vertical sequence seen in association IV, a change from marine green silts to coarse red sands with interbedded desiccated silts, is a regressive one. Such sequences are commonly formed by beach progradation (Tavener-Smith, 1982), delta progradation (Elliot, 1978; Coleman and Wright, 1975; Wescott and Ethridge, 1980) or regressive estuaries (Geer, 1975).

A fan delta interpretation seems most plausible here. The rocks show none of the swash laminae or ridge and

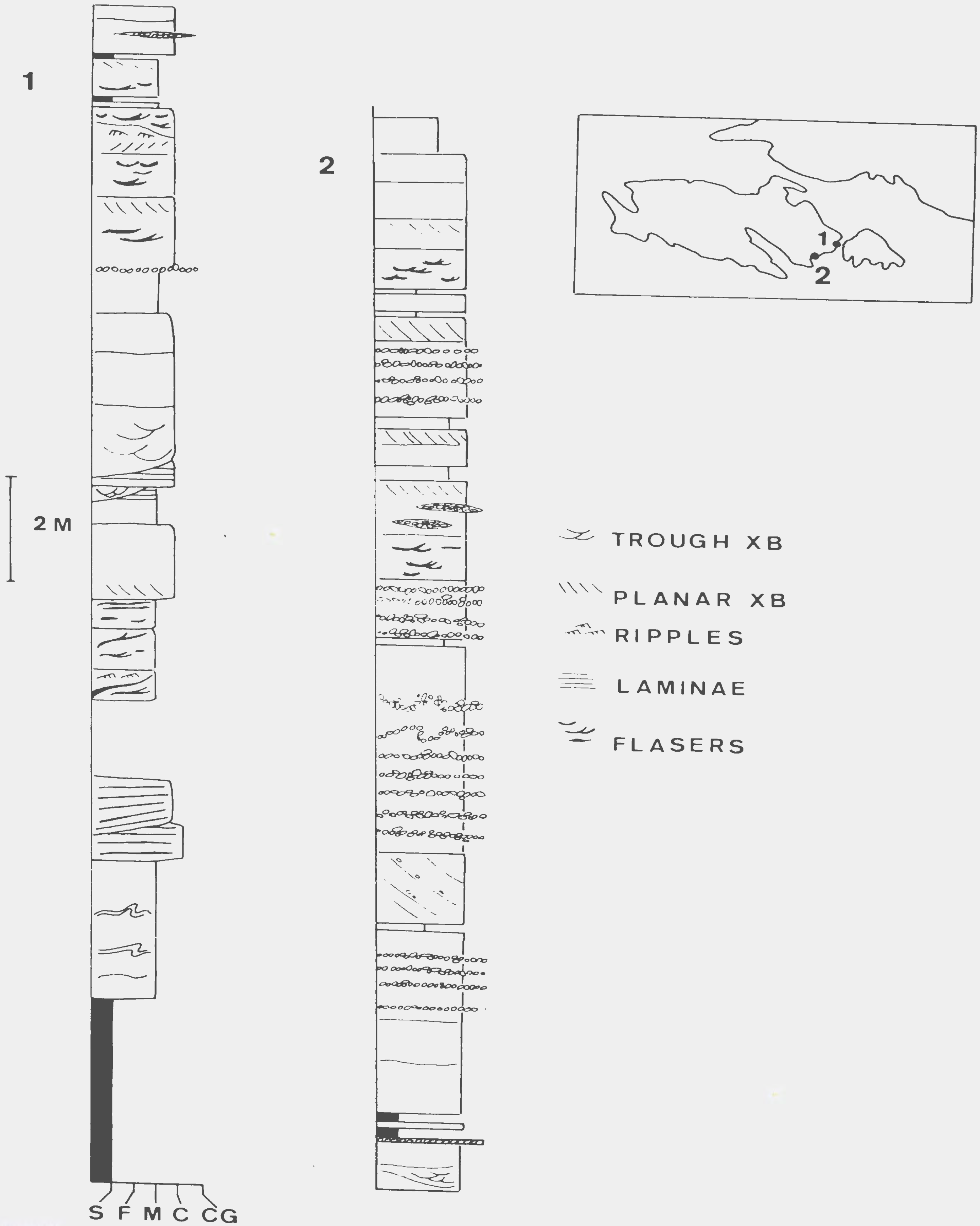


FIG. 5.5 Representative section of facies association

runnel structures that characterise beaches. An estuarine interpretation cannot explain the number of coarsening upwards sequences seen. Estuaries are inherently ephemeral in a regressive situation (Pritchard, 1967). The sequence compares well however, with published accounts of fan deltas with their coarse grain size, coarsening up motif, and cap of braided fluvial sediments (Wescott and Ethridge, 1980; Galloway, 1976; McGowen, 1971).

The various facies will be interpreted in detail, and the processes, controls, and problems of a fan delta model will be discussed.

5.5.2 Heterolithic facies

This facies is interpreted as delta front sandstones, deposited as subtidal sand sheets and shoals prograding into shallow water in front of braided distributaries. This is suggested by stratigraphic position and evidence for marine activity. The facies overlies marine silts (association III) and is overlain by fluvial sandstones (granule conglomerate facies). Marine indicators include silt drapes, flaser bedding and opposed palaeocurrent azimuths.

There is some uncertainty about the exact origin of flasers and heterolithic laminae. Some workers claim that variations in tidal currents are sufficient to give alternating bedload and suspension deposits (Terwindt and

Breusers, 1972, 1982; Terwindt, 1981; Allen, 1982). Others claim that a purely tidal origin necessitates unrealistically high suspended mud concentrations (McCave, 1970; Hawley, 1981); instead, storms and fluctuations of sediment play a part.

In the Rencontre Formation, it is unlikely that the structures are purely tidal as the deltaic setting allows variations in both fluvial discharge, and sediment supply. Tankard and Barwis (1982) describe similar heterolithic sandstones in a delta front setting. They interpret flasers in terms of tidal action superimposed on fluctuating river discharge. Dorjes and Howard (1975) describe similar features and deposits in a modern estuary. The common upward increase in silt may be related to emergence of a shoal. Dorjes et al. (1970) described sand shoals that have smaller scale bedforms and mud on parts of the shoal that are above the low water mark.

This facies shows signs of wave reworking, probably related to storms. For example, the bed top lags are characteristic of wave winnowing (Levell, 1980a; Reading, 1981) and the internal scours may also be the result of storm-generated rip currents (Vos and Hobday, 1977).

Water depths were probably quite shallow. This is indicated by the poorly developed nature of the coarsening-upward sequences. Several workers have shown that bottom friction, related to fan delta progradation into shallow water, results in a "dumping" effect which inhibits coarsening up (Wright, 1977; McGowen, 1971; Dutton, 1982). Further evidence for shallow depths comes from the small size of the cross beds; in the subtidal zone bedforms tend to increase in size with water depth (Rubin and McCulloch, 1980). Depths were estimated to be in the range of 2-20m, by using the equations of Rubin and McCulloch (1980) and Saunderson and Jopling (1980).

5.5.3 Medium and coarse sand facies

This facies overlies heterolithic beds with erosive, channelised contacts. Its stratigraphic position suggests an interpretation as distal distributary deposits.

The distributaries were tidally influenced, as is indicated by reversed palaeoflow directions and occasional interbeds of heterolithic units. Beds showing laminae of silt with low angle discordances may well be larger scale scour and fill features. This is supported by the upward decrease in the angle of discordance.

Rare units of pale, parallel-laminated sand are sometimes found, for example at Bob Head. A barrier-beach origin is plausible. The beaches would be formed on segments of the delta experiencing low sediment supply and marine reworking (Wescott and Ethridge, 1982).

Hine and Boothroyd (1978) described a possible modern analogue in Iceland, where accreting barrier spits locally front fan deltas and are backed by a wide zone of braided streams. This model may also offer an explanation for some other enigmatic features of this facies. The lenticular nature and low width-depth ratios of the channels are puzzling for a braided delta plain of this scale. One might expect rather broad distributaries. In their studies, Hine and Boothroyd (1978) noted that the barrier spits were breached in only a few places, and that the distributaries narrowed considerably at these localities.

Galloway (1976), studying the Copper River fan delta of Alaska, described two types of distributary. Braided distributaries were broad and shallow, while in other parts of the delta distributaries were narrow and sinuous. This offers another possible explanation if the distributaries described here are analogous to the ones described by Galloway. The reason for the existence of the two types is, however, unknown.

5.5.4 Granule conglomerate facies

This facies also represents deposition by braided distributaries. They were more proximal than those of the above facies as they are coarser and often stratigraphically higher. But, in cases where the conglomerate overlies the heterolithic facies directly, a more complicated explanation is required.

One possibility is that the more proximal braided distributaries sometimes reworked the more seaward ones during progradation. Indirect support for this comes from a comparison of the probable channel depths of the two facies. The larger bedforms in the conglomerate facies imply greater depths in the proximal distributaries compared with the distal ones. This would certainly be conducive to reworking during progradation, paricularly if the braided delta plain had low relief.

5.5.5 Silt facies

This facies is placed in a delta plain setting due to its occurrence at the top of the sequence, the presence of desiccation cracks, and association with fluvial conglomerates. The limited occurrence of this facies may be explained by preservational factors. In the upstream parts of the delta, channels were fewer and migrated less actively than in the lower regions (Wright, 1978). Thus, overbank deposits might have a higher preservation potential in this part of the delta.

5.6 Discussion

Facies association IV is interpreted as a fan delta deposit. Delta front sediments were deposited in quite shallow water and show tidal and wave reworking. The delta plain was possibly locally fringed by barrier spits. Increasing bifurcation of distributaries seaward may have formed a fringe of numerous, narrow, tidally-influenced, distributaries (fig.5.6).

The main controls were sediment supply and basin energy. Hayes and Michel (1982) demonstrated their importance for Alaskan fan deltas. Sediment was generally abundant, leading to the progradation of bedload- dominated distributaries. Basin energy was high enough to cause some reworking of delta sediments.

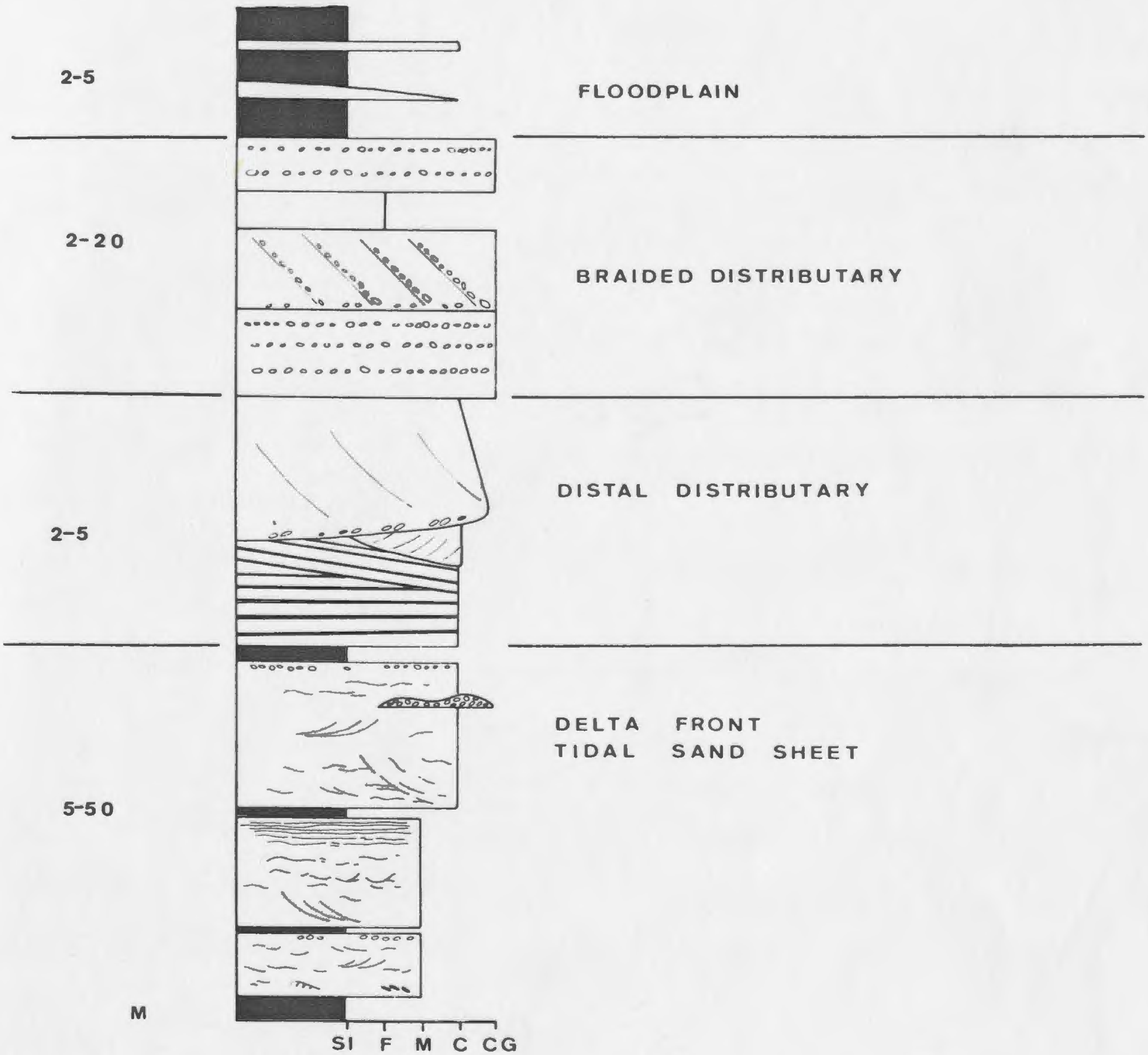
Water depths and seafloor slopes were also important, they were certainly greater than those that controlled the deposition of associations I and II. However, they were not great enough for more than crude coarsening up sequences to develop, or for delta front turbidites to appear (Jones, 1980; Ricketts, 1981; McCabe, 1978).

Preservational factors must be also be considered, as truncation of the sequence can occur, not only during transgression of delta lobes (Chafetz, 1982; Heward, 1981), but also during progradation, when large and deep distributaries come to overlie the former delta fringe.

In palaeogeographic terms, this association is important. Sediment supply increased, and the basin was once more tectonically active. The conglomerates at Bob Head show that the basin margin was nearby. Palaeocurrents suggest a north-easterly orientation for the basin.

FIG. 5.6

The interpretation of facies association IV, northern Fortune Bay. Crude coarsening upwards sequences represent progradation by the fan delta. The range of thickness of the various units is indicated. Si: siltstone, F: fine grained sandstone, M: medium grained sandstone, C: coarse grained sandstone, CG: conglomerate.


2-5
FLOODPLAIN
2-20
BRAIDED DISTRIBUTARY
DISTAL DISTRIBUTARY
2-5
DELTA FRONT
TIDAL SAND SHEET
5-50
M
SI F M C CG

CHAPTER SIX

FACIES ASSOCIATION V, NORTHERN FORTUNE BAY

6.1 Introduction

This is an association of relatively compositionally mature rocks (quartz-feldspar-lithic ratios can reach 49-15-36) with distinctive sedimentary structures. It forms the top of the succession in Northern Fortune Bay, outcropping on Rencontre Island and in the west at Bob Head and Chapel Island. Its basal contact with association IV is sharp; the contact with the overlying Chapel Island Formation is gradational over 40m.

The thickness of this association is not known as no complete section is seen. The measured total is 200m but gaps make the maximum possible thickness 1000m. See figure 6.1 for a summary of the sections.

The association is subdivided into three facies on the basis of grain size and sedimentary structures. These are: (1) compound and trough cross-bedded sandstones, (2) red sandstone and silt, and (3) red silt and fine sandstone.

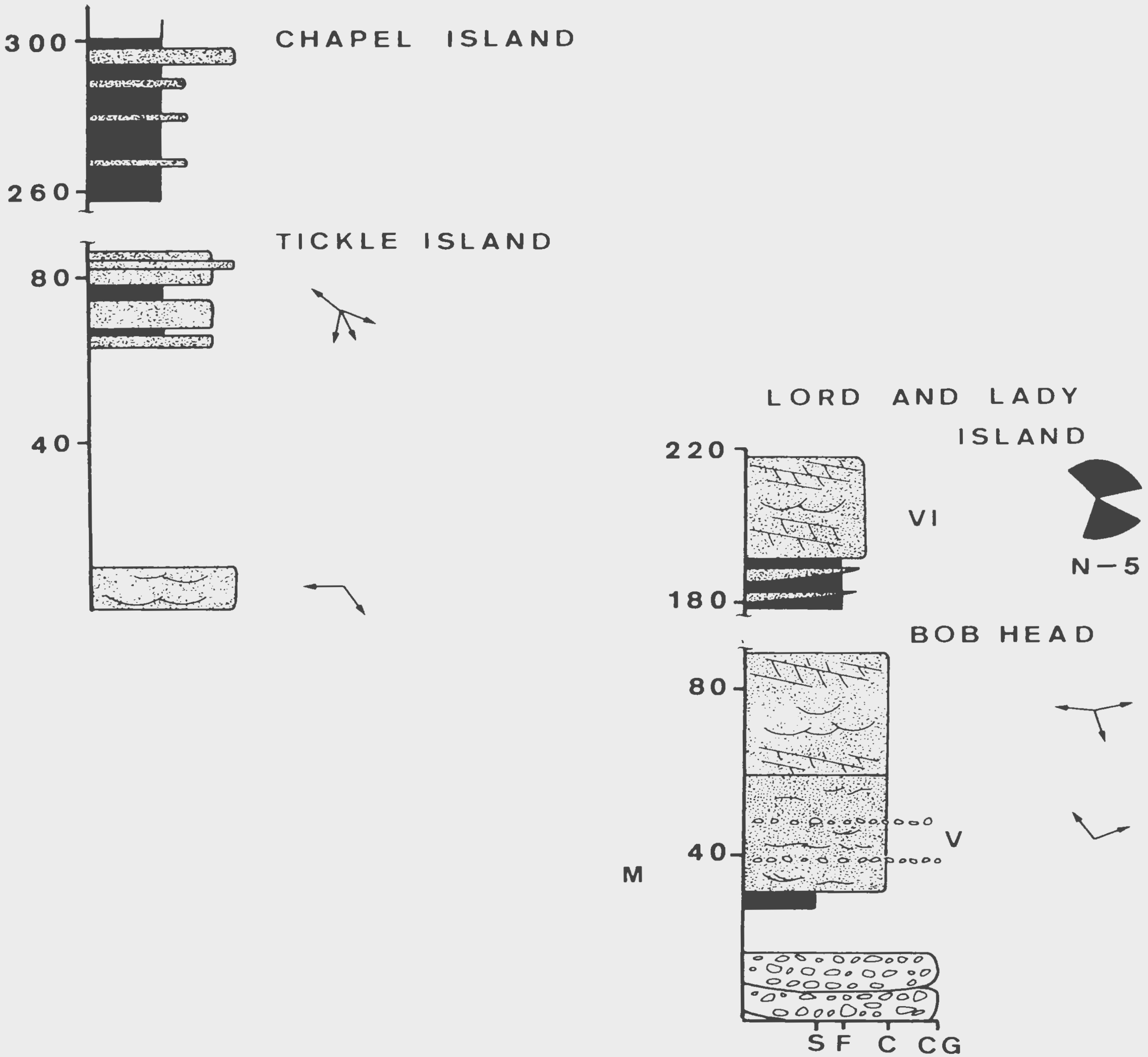
6.2 Facies descriptions

6.2.1 Compound and trough cross-bedded sandstone

This facies consists of coarse grained to medium grained litharenites and arkosic arenites. Compound

FIG. 6.1

Generalised stratigraphic sections of facies associations IV and V , western Fortune Bay. The top of the Lord and Lady - Bob Head section is correlated with the base of the Chapel Island - Tickle Island section. The considerable gaps in the sections reflect the insular nature of the outcrop. Arrows and rose diagram represent cross-bed azimuths, the number of readings are indicated.


300
260
CHAPEL ISLAND
80
40
TICKLE ISLAND
LORD AND LADY
ISLAND
220
180
VI
N-5
BOB HEAD
80
40
V
M
S F C CG

cross-bedded units make about 30% of this facies. The compound sets are usually of small, planar, cross-beds (8-15cm) superimposed on first order surfaces with an original dip of 10-20 degrees (see figs.6.2 and 6.3). Occasionally, the secondary sets are of tangential or trough-cross beds. The mean thickness of compound beds is about 0.9m.

Bed bottoms are usually flat, but can be erosive or pass gradationally into trough cross-beds. Bed tops are commonly truncated by trough cross beds and are locally cut by well defined scours (figs.6.4 and 6.5).

Trough cross-beds make up 30-40% of this facies. Sets are 7-14cm thick, have low foreset dips, and are stacked to form cosets. Bed thickness ranges from 0.4-2.5m (see fig.6.6).

On Rencontre Island, relatively large-scale planar cross-beds make up 10% of the facies. The mean set thickness of these is 1.3m and foreset spacing is bimodal (fig.6.7). Palaeocurrents for the compound cross bedded facies show a bimodal to trimodal pattern (see fig.6.1 and 3.1).

6.2.2 Red sandstone and silt facies

This occurs in the middle part of the succession, outcropping on Lord and Lady Island and Tickle Island (to the north of Chapel Island). Sandstones are medium grained

FIG. 6.2 Compound cross-bedded sandstone with a wavy bed top Rencontre Island.

FIG. 6.3 Compound cross-bedded sandstone, the upper set shows reactivation surfaces, while the top of the lower set is scoured and filled with small trough cross-beds, Rencontre Island.

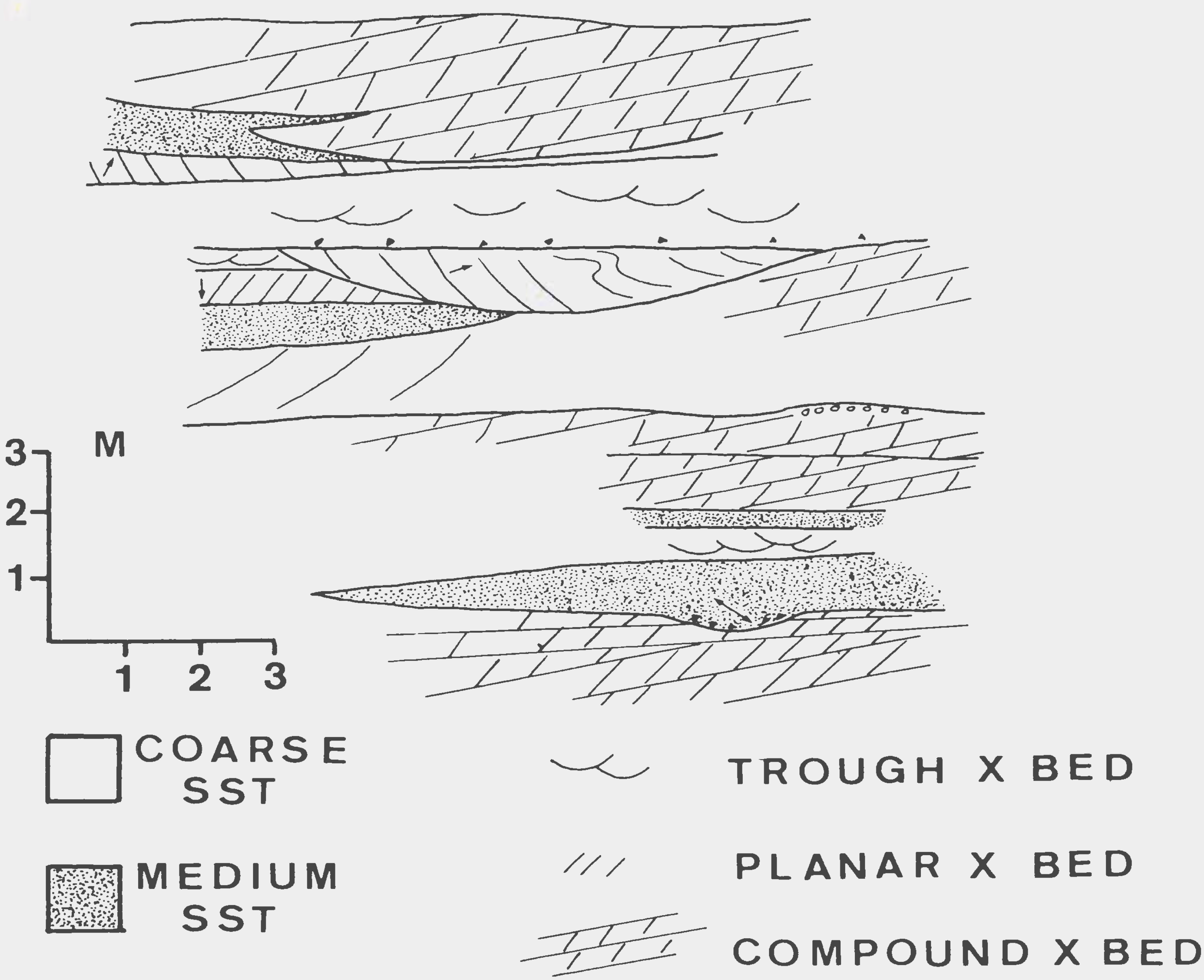


FIG. 6.5 Bed top geometry

FIG. 6.5 Characteristic geometry of bed tops in the compound cross-bedded facies, the field of view is represented by the lower portion of fig. 6.4, Rencontre Island.

FIG. 7.6 Trough crosss-bedded sandstone erosively overlying a compound cross-bedded unit, Bob Head.

FIG. 6.7 A large scale planar cross-bed, bottom sets interfinger with lenses of granule conglomerate, Rencontre Island.

to fine grained, well sorted and rounded, the colour is a deeper red than other Rencontre sediments. Thick, discrete silt beds occur.

On Lord and Lady Island a 12m sequence of red silt and lenticular sandstone occurs. The sandstone occurs as lenses up to 0.2m thick and 5m wide, with concave up, asymmetric bottoms. These are channelised units which show a fining of grain size away from the thalweg (fig.6.8). They are overlain by laminae of sandstone, which become less abundant upwards, defining a fining-up sequence about 6m thick. In the field, these appear to be very lenticular and irregular, but this is a result of patchy, differential cementation along layers of sand grains. At the top of the sequence, desiccation cracks and runzel marks (Reinick and Singh, 1980 p.69) occur (fig.6.9).

The red sandstone making up the rest of this sequence on Lord and Lady Island shows only obscure sedimentary structures. This a function of the small range of grain sizes present. However, some compound and trough cross-bedding can be seen.

On Tickle Island, a 12m sandstone sequence contains discrete beds of silt and shows some wave ripples. Some of the sandstones show a bed top waviness with an amplitude of 0.4m and wavelength of 18m. Sedimentary structures are obscure.

FIG. 6.8 A small, asymmetrical, channel sandst ne, Lord and Lady Island.

FIG. 6.9 Desiccation cracks and irregular sandstone laminae. Pencil is 10 cm long, Lord and Lady Isalnd.

6.2.3 Red silt and fine sandstone facies

This caps the facies association and passes gradationally into the Chapel Island Formation. The facies is about 50m thick and consists of thin beds of micaceous red silt and thin beds of well sorted fine sandstone. There are some thicker beds of medium grained sandstone, with irregular silt layers and small scale cross-bedding. No obvious sequential pattern is seen. Desiccation cracks are abundant throughout the section (fig.6.10).

The facies passes into the Chapel Island Formation, which here consists of green silt and fine sandstone with wave ripples and some synaeresis cracks (fig.6.11).

6.3 Interpretation

6.3.1 Introduction

This is a variable sequence, and probably represents several sub-environments. Several lines of evidence point to a general marine, subtidal to intertidal, setting. These are as follows: (1) flat bed bottoms but irregular bed tops with granule lags (Levell, 1980a, b; Reading, 1981; Cotter, 1982), (2) bimodal to trimodal palaeocurrents are characteristic of tidal settings (Klein, 1977), (3) compound cross-bedding like the characteristic internal structure of marine sandwaves (Allen, 1980; Stride et al, 1982), (4) bimodal foreset spacing can be

FIG. 6.10 Red siltstone with smakk polygonal desiccation cracks, Chapel Island.

FIG. 6.11 Wave-rippled sandstones and siltstones of the Chapel Island Formation, internally the ripples show form discordance and bundle-wise upbuilding.

explained by variations in tidal currents, such as spring-neap cycles (Visser, 1980), and (5) compositional maturity compared with their fluvio-deltaic counterparts. Sutter et al. (1981) and Mack (1978) showed the efficiency with which marine processes remove immature components.

Individually these points do not prove a marine origin, but in concert they suggest that such an interpretation is plausible. Although a general fluvial interpretation is unlikely, it is possible, because of insufficient paleocurrent data and gaps in the sections, that some fluvial incursions exist. There is no evidence for beach sedimentation. The characteristic low-angle swash laminae and coarsening upwards sequences (McLane, 1982; Tavener-Smith, 1982) are absent.

6.3.2 Compound cross-bedded facies

This facies is believed to represent tidal marine sands, but its exact setting is more ambiguous. There is no evidence for exposure, such as desiccation cracks, runoff marks or interference ripples, so that a subtidal setting is suggested. However, the small size of the bedforms suggests shallow water as sandwaves commonly show a crude a correlation with water depth (Rubin and McCulloch, 1980). Using this relationship, and that of Saunderson and Jopling (1980), water depths are estimated at 2-7m. The compound cross-bedded units probably represent shallow subtidal sandwaves with small straight-crested megaripples superimposed on larger megaripples. A comparison of these sandwaves with the stability fields outlined by Dalrymple et al. (1978), indicates formative velocities in the range of 0.7-1.2 metres per second. Their internal structures compare well with Allen's (1980) type IV sandwave which implies only minor reversal of sediment transport with the reversing tide.

The trough cross-bedded units were probably not genetically related to the sandwaves as they commonly erosively cap the sandwaves. Their different geometry indicates that they were not merely megaripples migrating on top of the sandwaves. Instead, they may well have been generated during storms. Their low angle foresets certainly imply high velocities (Jopling, 1965) and similar forms have been related to storm rip currents (Anderton, 1976; Vos and Hobday, 1977).

Channels that cut into the top of some sandwaves may also be related to storms. Homewood and Allen (1981) described similar features in Miocene sandwaves which were interpreted as showing storm or tidal current scour of existing bedforms.

The large scale planar cross-beds probably represent deposition in deeper water (Rubin and McCulloch, 1980), either in depressions between sandwave shoals, or in more offshore regions. Those associated with channels cut into bed tops may might be tidal deltas (Deery and Howard, 1977; Homewood and Allen, 1981). The interpretation is summarised in figure 6.12.

6.3.3 Red sandstone and silt facies

The lower silt unit shows many features of the classic tidal flat model (Klein, 1977). The sequences fine up, contain channel sandstones that suggest meandering, and their upper parts show evidence for exposure.

On modern tidal flats, tidal channels become larger and migrate more freely on the lower parts of the flats (Van Straaten, 1961). The small size and limited extent of the Rencontre channels suggest an upper- to mid-tidal flat origin.

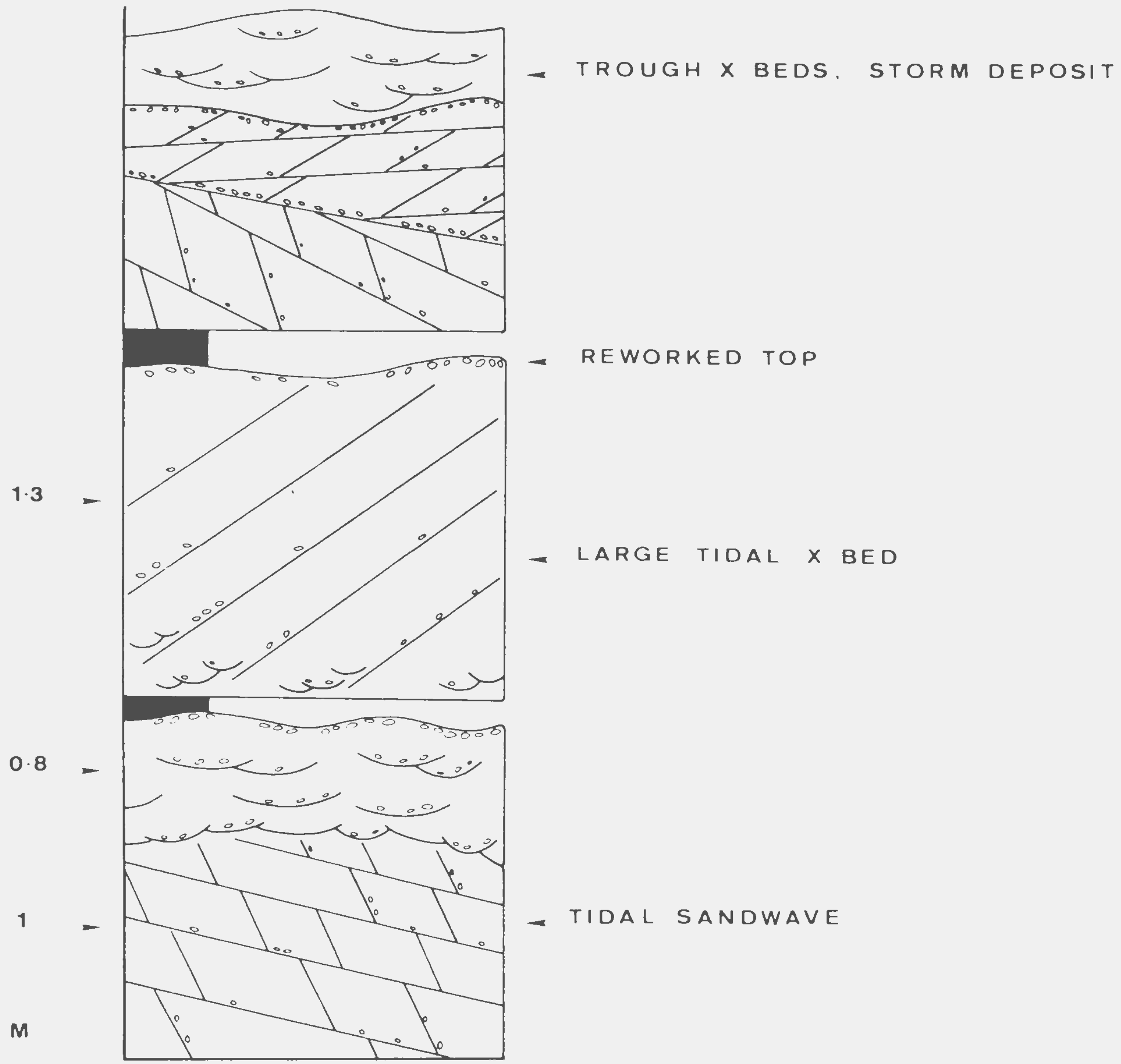
The sandstone units show similar structures to the compound cross-bedded facies, and were probably deposited in similar environments. The obscurity of the sedimentary structures prohibits a more detailed interpretation.

6.3.4 Red silt and fine sandstone facies

These deposits probably represent an intertidal to supratidal setting with some marine incursions. There is abundant evidence for exposure in the form of desiccation cracks, rills, interference ripples and micro-silt clasts. It is difficult to distinguish supratidal from upper intertidal flats (Arkhtar and Srivastava, 1976) but the

FIG. 6.12

The interpretation of the compound cross-bedded facies of facies association V', northern Fortune Bay. Sequences reflect the alternation of fair-weather tidal currents, which produce large scale cross-beds and compound cross-beds, and foul-weather processes which scour bed tops and deposit trough cross-beds. The average thickness of the units is shown.


TROUGH X BEDS, STORM DEPOSIT
REWORKED TOP
1·3
LARGE TIDAL X BED
0·8
1
TIDAL SANDWAVE
M

thickness of these deposits makes a supratidal origin for some units likely. The green interbeds, with their wave ripples, herald the base of the transgressive Chapel Island Formation.

6.4 Discussion

Facies association V represents deposition in shallow subtidal sand shoals and intertidal and supratidal flats. A macrotidal regime probably prevailed; according to Hayes and Kana (1976), extensive tidal flats, without beach deposits, form where tidal range exceeds 4m. The thickness of the fining up sequence on Lord and Lady Island, 6m, also points to a macrotidal regime (Klein, 1972). Storms probably played some part, catastrophically reworking sandwaves into low angle trough cross-beds.

This association overlies a predominately fluvial to deltaic sequence indicating transgression. This was accompanied by a change in depositional style resulting in the formation of a broad region of similar sedimentation from Chapel Island to Brunette Island, and Fortune to Gaultois (see chapter 11 for evidence of coeval sedimentation). Facies association V records this change in depositional style.

CHAPTER SEVEN

FACIES ASSOCIATION VI, BRUNETTE ISLAND

7.1 Introduction

Rocks of the first facies association of Brunette Island outcrop on the south coast (see fig.7.1 and 7.2). The association is 450m thick and consists of black, green, and red silts with subordinate sandstone. These are classed together as an association because of the striking contrasts with overlying thick sandstones. The association is subdivided into five facies : (1) black silt with grey sandstone, (2) green silts with fine sandstone, (3) red silts with sandstone, (4) heterolithic sandstone, and (5) coarse, lenticular sandstone.

7.2 Facies descriptions

7.2.1 Black silt facies

This only occurs at the base of the sequence; 90m are seen in the core of the south coast anticline. The silt is dark grey to black with very fine sandstone laminae (see fig.7.3). The facies coarsens up, initially discrete sandstone beds are 2-5cm thick, but reach thicknesses of 30cm towards the top. They show sharp bases, some laminae, and rare wavy tops. The contact with the overlying green silt facies is gradational over 5m.

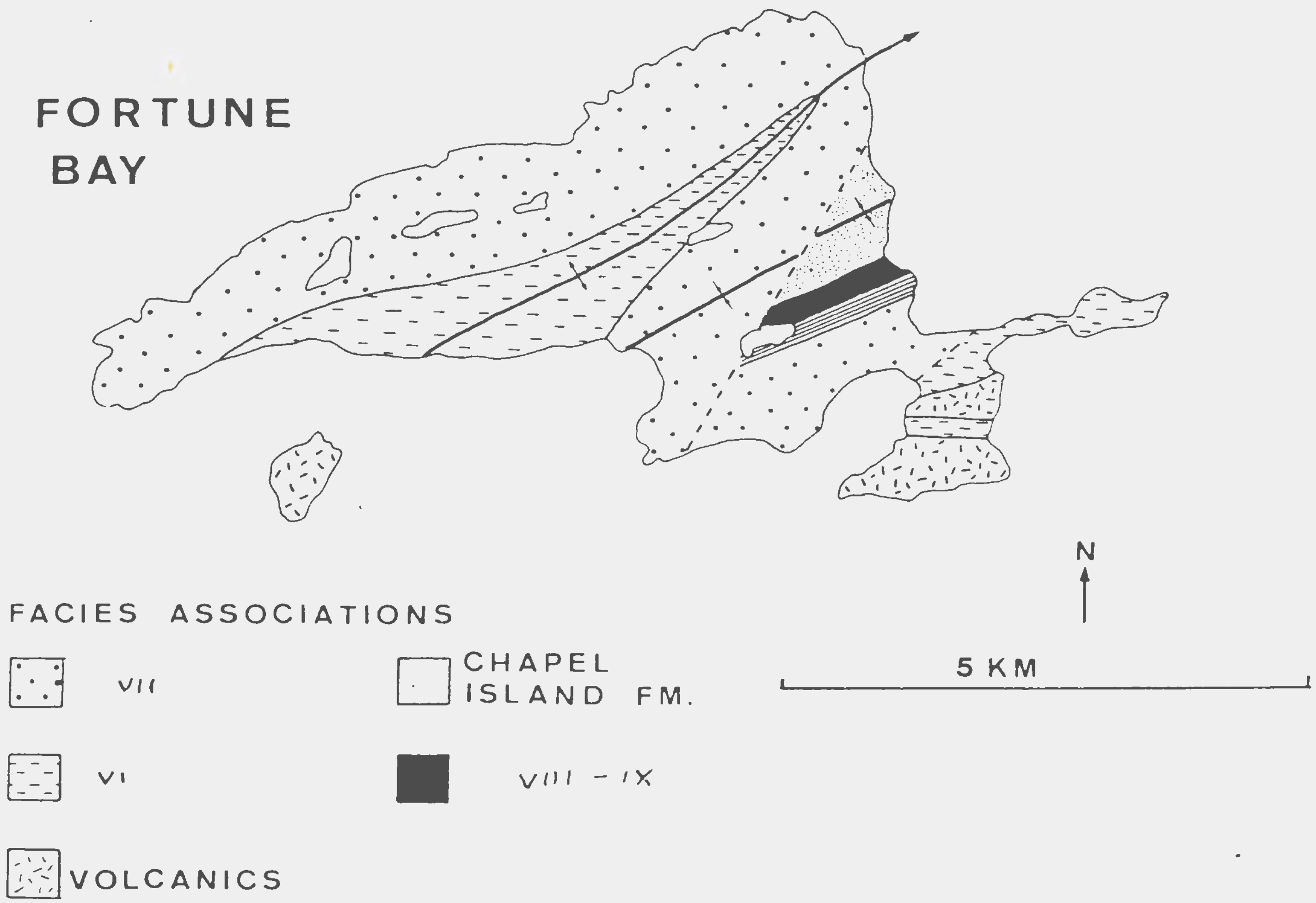


FIG. 7.1 Outcrop of the facies associations of Brunette Island.

FIG. 7.2

Generalised stratigraphic section, Brunette Island, southern Fortune Bay. Rose diagrams represent cross bed azimuths for the units as marked. N: number of observations, S: standard deviation. S: siltstone, F: fine grained sandstone, M: medium grained sandstone, C: coarse grained sandstone, CG: conglomerate.

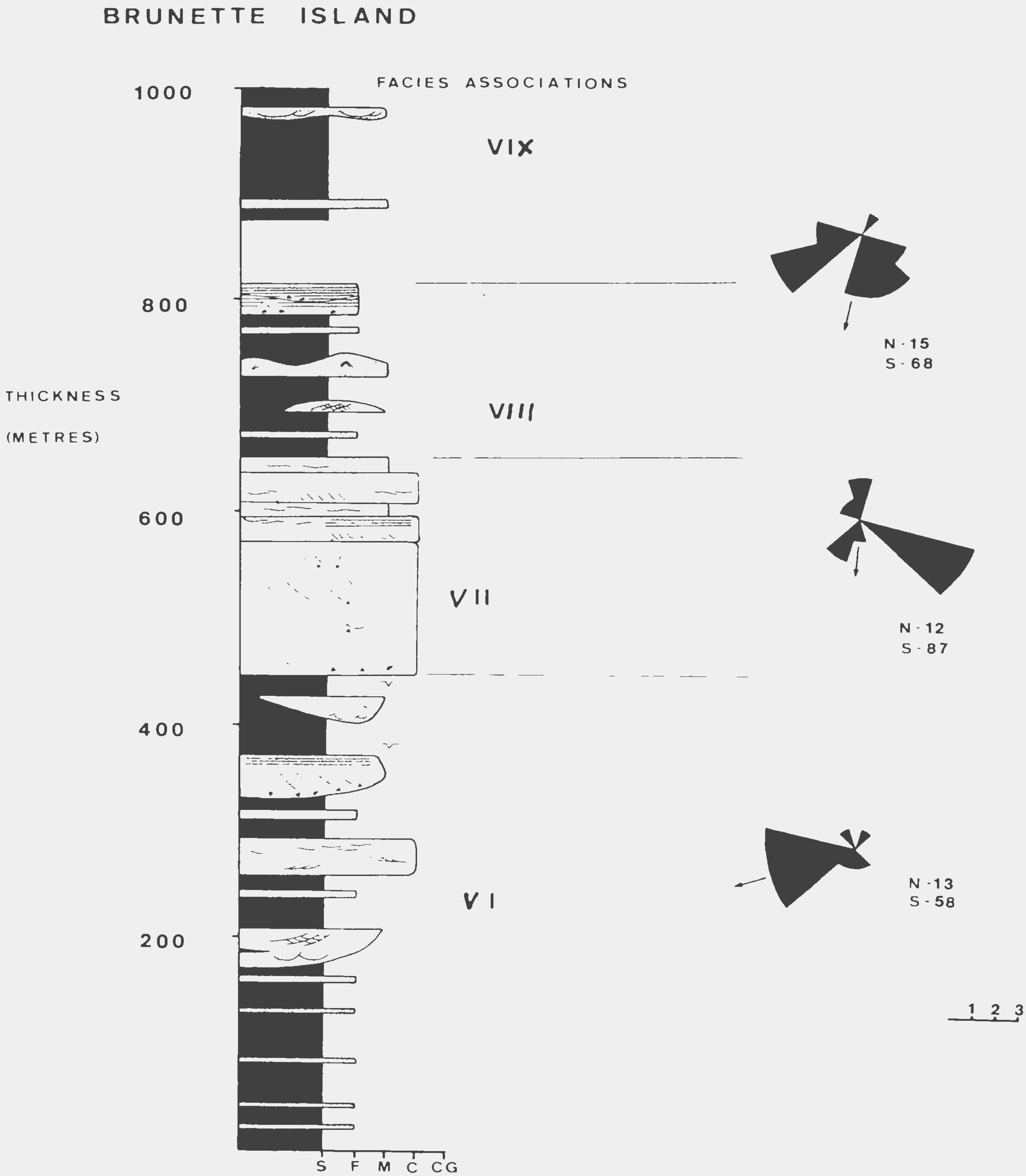

BRUNETTE ISLAND
FACIES ASSOCIATIONS
1000
800
600
400
200
THICKNESS
(METRES)
VIX
VIII
VII
VI
N - 15
S - 68
N - 12
S - 87
N - 13
S - 58
1 2 3
S F M C CG

FIG. 7.3 Black siltstone with intercalated fine grained sandstone south coast, Brunette Island.

7.2.2 Green silt facies

This consists of green-gray silts with fine sandstone laminae, which are commonly irregular and wavy, and discrete beds of fine grained to medium grained sandstone. The latter are 0.2-4m thick, with some parallel lamination, normal grading, and basal silt clasts. Convolute bedding and small scale planar cross-beds with azimuths to the southwest, are locally found.

The main outcrop of this facies is a 90m sequence overlying the black silt. However thin units (less than 2m) occur sporadically throughout the section intercalated with other facies.

7.2.3 Red silt facies

This forms the bulk of association VI, about 40% of the section. It consists mainly of silt with fine sandstone laminae, although there is a continuum from massive silt to units where fine grained sandstone makes up 30% of the rock.

There is a correlation betweeen sandstone content and sedimentary structures. Sandstone-poor units show quite regular laminae. With increasing sand content, laminae become more irregular, wavy, and lenticular (fig.7.4). Sandstone-rich units also show ripple cross-laminae, desiccation cracks, and micro-silt clasts.

Some units of coarser sandstone are included in this facies. These are beds of medium- to coarse-grained sandstone with flat, non-erosive bases. They are commonly massive, although some small scale cross-beds and parallel laminations are seen. Bed thicknesses are bimodal, clustering about 0.3m and 1m. The beds are characteristically sheet-like and can be traced up to 20m across the shore without any thickness change.

7.2.4 Heterolithic facies

This makes up 15% of the succession. The facies includes coarse to medium sandstone which is poorly to moderately sorted. The red silt layers, which give the rock its heterolithic character, occurs as flaser and wavy laminae and as drapes of low angle, tangential foresets (fig.7.5). The draped bedforms give palaeocurrent azimuths directed towards the northeast and southwest. Silt also forms discrete interbeds which overlie sandstones that show irregular, scoured tops. The silt itself often shows erosively-truncated margins. Silt intraclasts are locally abundant.

7.2.5 Lenticular sandstone facies

Although making up only a small part of the association (about 8%), this facies is distinctive and unusual. The units have erosive bases, which are concave up, and are markedly lenticular. Two types can be

FIG. 7.4 Typical outcrop of the red silt facies with intercalated beds and laminae of sandstone, about 3.5m of section can be seen, Brunette Island.

FIG. 7.5 Heterolithic sandstones with silt drapes outlining low-range trough foresets, south coast Brunette Island.

distinguished in the field.

The first type shows an erosive base with marked asymmetry; a thalweg cross section is formed by one steep, and one gently, inclined slope. The scour is infilled with fine- to medium-grained sandstone with small scale planar and trough cross-beds, which are often stacked. These cross beds give southwestly and northeasterly-directed palaeocurrents. Some units show a lateral sorting, the grain size fining toward the gentle slope of the scour. The mean thickness of the units is 0.5m, they pass up into silt which in turn shows an upward decrease in sandstone content (fig.7.6).

The most common type shows a symmetrical, concave up base. The beds often consist of amalgamated units, the basal scour is followed by a fining up-sequence with silt clasts, cross-bedding, and a silt cap. This is cut by another scour, and a similar sequence is repeated (fig.7.6). Up to four of these stacked sequences can occur in one bed (the mean bed thickness is 2m). Rarer structures include ripple cross-lamination, climbing ripples, and deformed cross-bedding (fig.7.7). Cross-bed azimuths show flow towards the southwest

7.3 Sequences in association VI

Several scales of sequence can be seen. On a large scale, the lower 220m are mainly silty with common

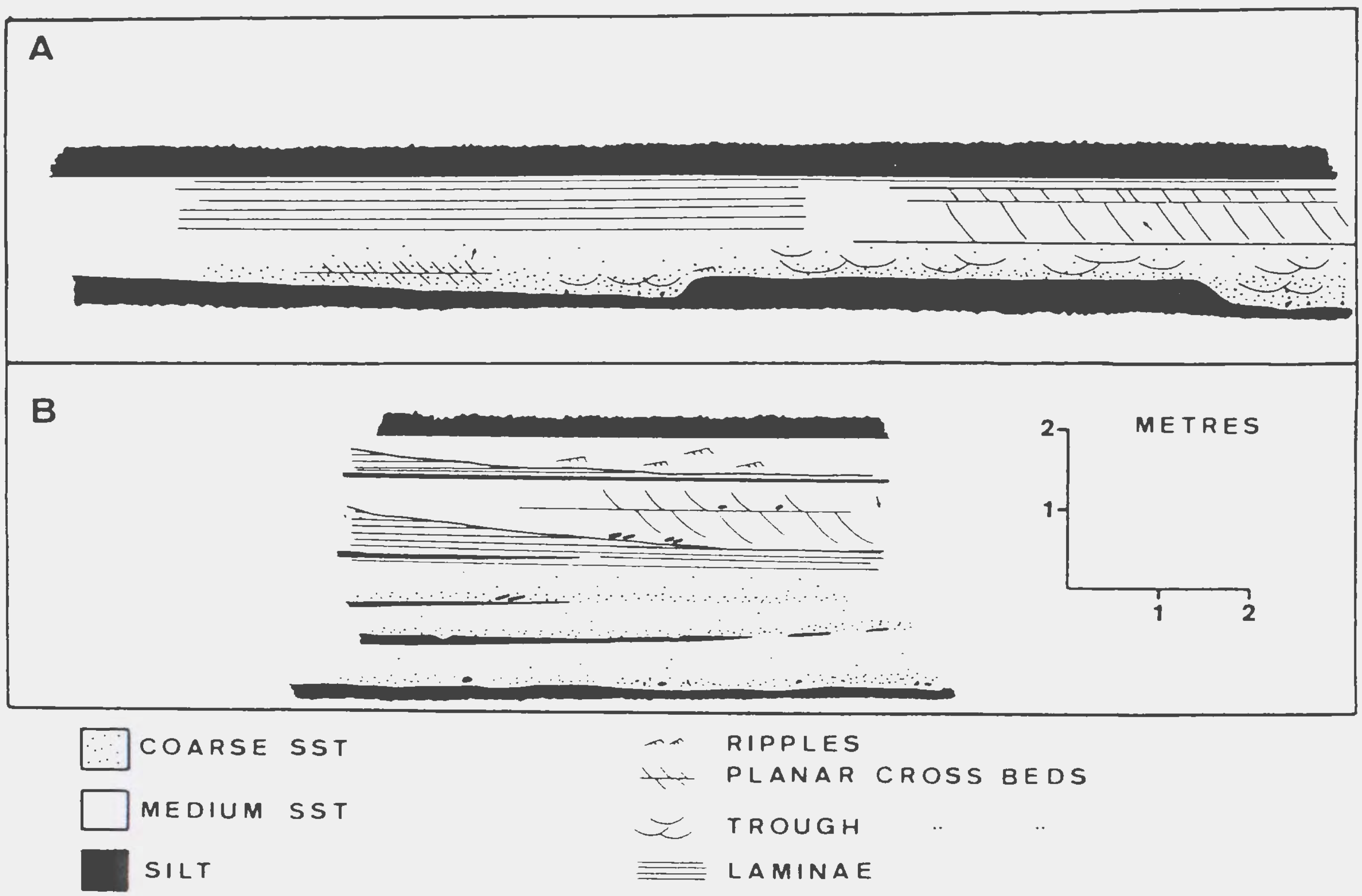


FIG. 7.6 Field sketch of the lenticular sandstone facies, (A) asymmetrical channel sandstone, (B) symmetrical channel sandstone.

FIG. 7.7 Stacked channel-fill sandstone, features include sharp, erosive base with marked relief, deformed cross-beds, and pseudo-nodules, south coast, Brunette Island.

interbeds of green silt and lenticular sandstone but few heterolithic units. The remaining 230m contains more sandstone units, has no green interbeds, and has a 40m sequence of heterolithic sandstones at its base.

Within the lower sequence, minor cycles can be recognised. These start with green silt and fine sandstone, pass into red silt which is poor in sandstone, but becomes sandier upwards, and are capped by thick-bedded lenticular sandstones. Three of these sequences follow the basal black silt (fig.7.8).

Internally, the upper part of the succession merely shows a upward change from heterolithic, to silt and lenticular sandstone units. The contact with the overlying association VII is sharp. 7.4 Interpretation

Evidence suggests that the depositional milieu of association VI was a muddy coastal plain environment. The association consists of progradational sequences with subtidal to intertidal muds, extensive supratidal plains, fluvial, and chenier plain environments. Analogous modern coastal plain environments have been described by Rhodes (1982), Nair (1976), and Wells and Coleman (1981).

This interpretation is supported by: (1)upward change from green to red silts, representing a change from relatively reducing (subtidal) to oxidising (intertidal to supratidal) environments (2) desiccated silts at the top of sequences (3) channelised sandstones, with fining up

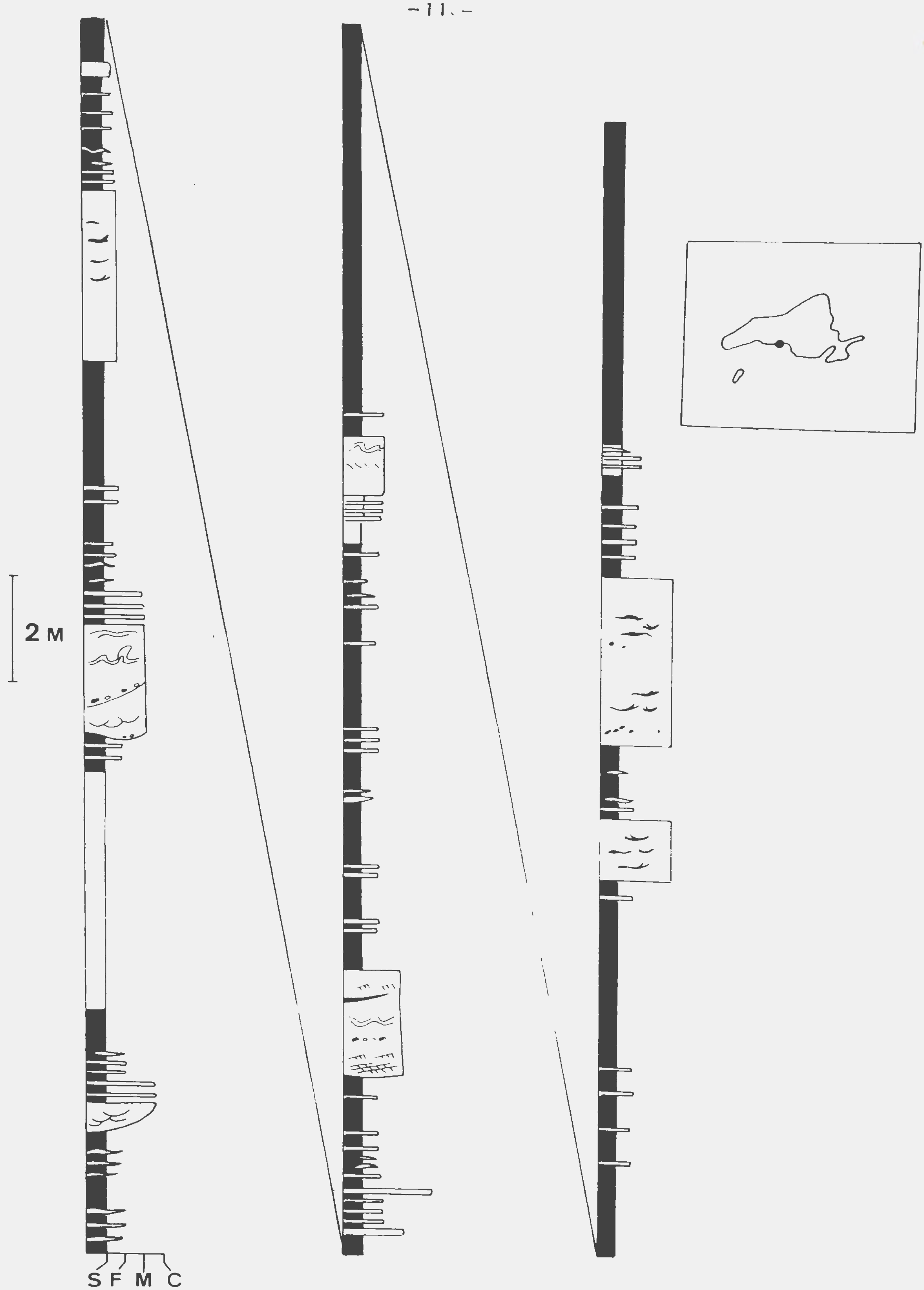


FIG. 7.8 Representative section, facies association V. Brunette Island.

sequences, that are characteristically fluviatile.

Other models that might explain these features are stacked tidal flat sequences or lower delta plain deposits.

A tidal flat model cannot adequately explain all the pecularities of association VI. Tidal flat deposits commonly show a fining up motif as they prograde (Reineck and Singh, 1980), but coarsening up is seen here. Also, individual sequences are too thick to be simple tidal flat deposits. Tidal flats prograde to give deposits whose thickness is the same order of magnitude as the tidal range (Klein, 1972), yet individual sequences are up to 30m thick here. The position of the channel sandstones prohibits a tidal flat model; they occur near the base of a tidal flat sequence (Driese et al., 1982; Tankard and Barwis, 1982), not at the top, as they do on Brunette Island.

A more plausible alternative is a muddy, lower delta plain environment. This may give the coarsening up motif seen, with a change from subtidal to supratidal deposition, and channel sandstones capping the sequence. Modern examples of muddy delta plains have been described by Van Andel (1967), Meckel (1975), and Johnson (1982). However, a non-deltaic model is preferred because of the absence of major distributary channel sandstones. The channel sandstones seen are less than 3m thick, and would be unable to provide the volume of sediment that association VI represents.

More likely, is deposition in a coastal mud plain with fluvial sediment supply important, but not great enough to build deltas. Progradation of such an environment would still produce a coarsening up sequence. The suggested model is summarised in figures 7.9 and 7.10.

7.5 Facies interpretation

7.5.1 Black silt facies

The dark colour and fine laminations of this facies indicate deposition below normal wave base; the facies represents hemi-pelagic deposition (Jenkyns, 1978). The fine sandstones show structures typical of distal turbidites, possibly generated by storms (Nelson, 1982). Occasional wave ripples show that wave base periodically extended to greater depths.

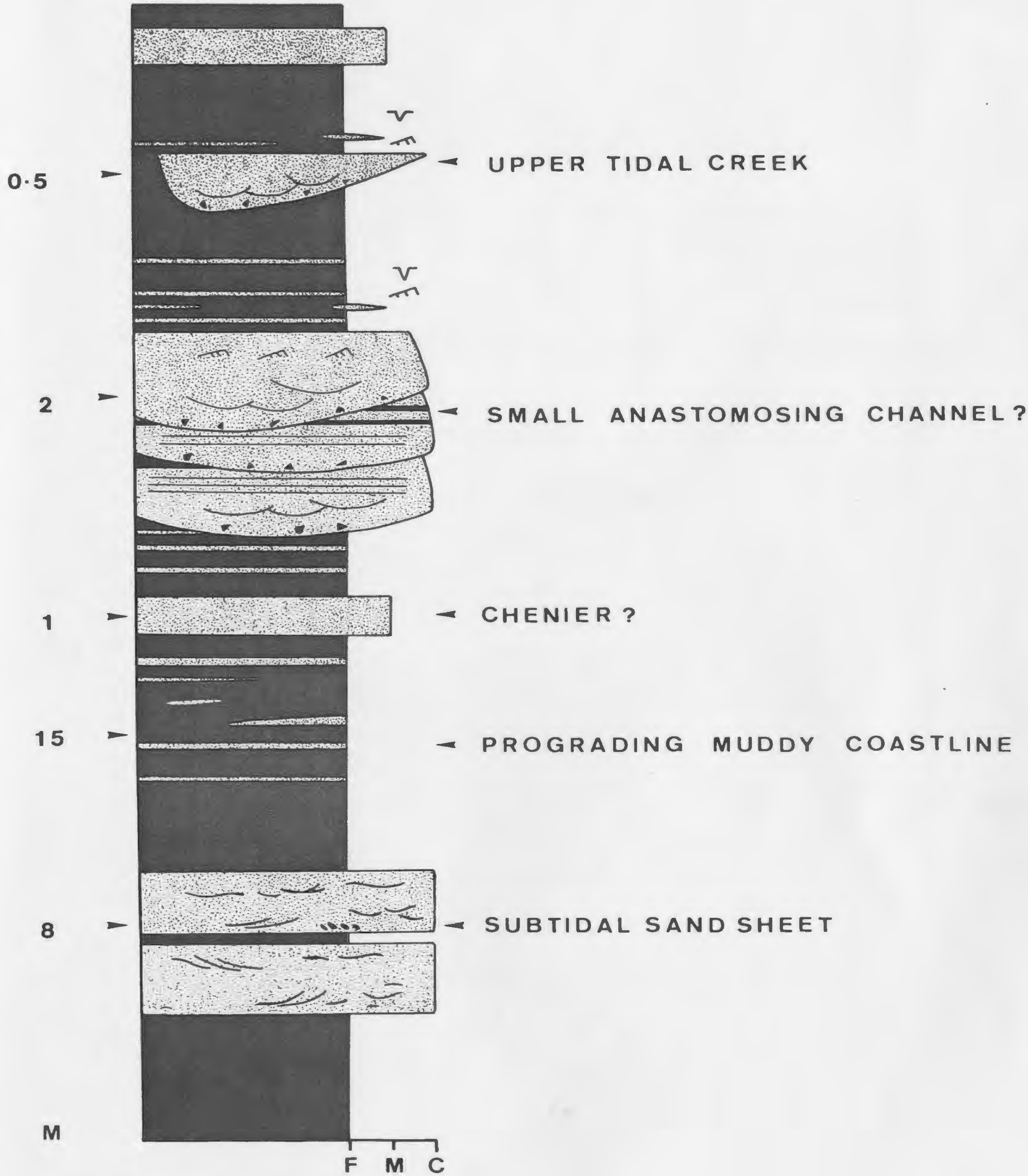
This facies only occurs at the base of the association, and it represents initial deposition in deep water, followed by shoaling of the basin. The transition to shallow water occurs without intervening turbidite fan deposits, reflecting the localised nature of these features (Graham, 1982).

7.5.2 Green silt facies

This is thought to represent subtidal deposition, often above wave base, but generally in low energy. Its

FIG. 7.9

Schematic section illustrating rock types and their interpretations. The section shows an upward progradation from subtidal sandstones and siltstones to supratidal coastal plain environments. Symbols represent ripples and desiccation cracks. The average thickness of the units is indicated in metres.


UPPER TIDAL CREEK
0·5
2
SMALL ANASTOMOSING CHANNEL?
1
CHENIER?
15
PROGRADING MUDDY COASTLINE
8
SUBTIDAL SAND SHEET
M
F M C

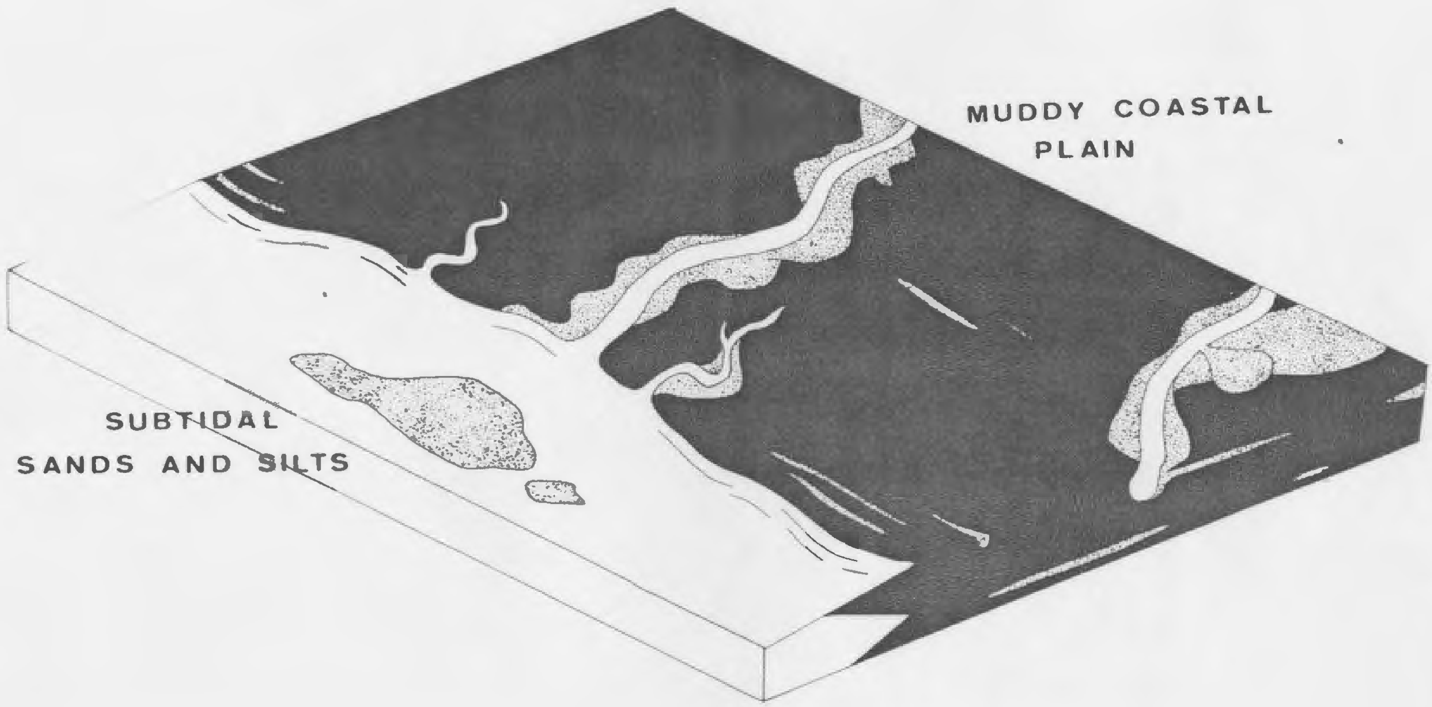


FIG. 7.10 The depositional environment of association VI, Brunette Island.

colour, wavy laminae, fine grain size, and position relative to other facies, supports this interpretation. Overlying the black silt facies, it shows shoaling and a greater sediment supply.

7.5.3 Heterolithic facies

This facies shows abundant evidence for fluctuating current velocities and alternating deposition by traction and suspension (silt drapes, flaser bedding, and diverse palaeocurrents). These are common features of subtidal sand sheets, subject to tidal currents (Terwindt, 1981; Klein, 1977; Reineck and Singh, 1980).

In obvious contradiction to this model, is the compositional immaturity of the sediments of this facies. This may reflect the low energy nature of the coast, or that storm activity was not intense and tidal range was low. Under such conditions the sands would undergo only limited reworking before being buried by the prograding coastal deposits.

This facies occurs sporadically in the section; it is entirely absent from the lower part, it forms thin units in the upper part and its main occurrence, 40m, is in the middle of the section. Such an irregular pattern may be a result of a spasmodic supply of coarse sediment to the coastline.

7.5.4 Red silt facies

This facies makes up the bulk of the muddy coastal plain sequence. Its position above subtidal deposits, evidence for exposure, and intercalation with channelised sandstones, suggest a dominantly supratidal origin. This facies tends to occur in coarsening up packages which may have been produced by progradation of the coastal plain.

The facies shows a considerable variation in sandstone content. In sandstone-rich units, the irregular laminae were probably formed in several ways. Possible mechanisms include fluvial flooding, tidal deposition, and deposition related to storm surge. Sandstone-poor units show a lower supply of sediment, a result of greater distances from rivers or deposition on sand-starved parts of tidal flats.

Thicker beds of coarse sandstone (1m) have more enigmatic origins. One possibility are chenier ridges. Cheniers are sand ridges created at times of low sediment supply and might be expected in this sort of environment (Rhodes, 1982; Augustinus, 1980). This interpretation is supported by the non-erosive bases of the beds, although without three dimensional data their presence cannot be confirmed.

7.5.5 Lenticular sandstone facies

The two types of sandstone have different origins. The small asymmetric units represent the upper parts of meandering tidal channels; their cross sectional shape and lateral and vertical grading are typical of meandering creeks (Schumm, 1977). The deposits also show the tidal creek characteristics described by Barwis (1978): high proportion of muddy overbank deposits, poorly developed levees, and bipolar palaeocurrents. Their small size and limited lateral extent show that they represent the uppermost parts of the tidal creek.

The other type of sandstone might be interpreted in several ways. The possibilities are tidal creeks, intertidal channels, and small, anastomosed channels.

The multilobate, tidal-creek point bars described by Barwis (1978) have some similarities with these units. They show high proportions of overbank silts, poorly developed levees, and massive lower parts. Multilobate point bars also have segregated ebb and flood channels which might explain the stacked appearance of the sands. However, this interpretation is not the preferred one as the expected bipolar flow directions and flaser bedding are absent.

Hereford (1977) interprets similar sandstones in the Tapeats sandstone of Arizona as intertidal, meandering channel deposits. He claims that the stacked arrangement of scours, lags and lenticular silt partings show that deposition was frequently interrupted by tidal reversals. Their fining up nature is taken to show that the channels were meandering. Such an interpretation is not valid for association I; tidal channels rarely show stacking because of tidal interruption of migration and deposition (Reineck and Singh, 1980) but instead, tend to migrate to produce longitudinal cross bedding (Bridges and Leeder, 1976).

Another possibility is deposition by small anastomosing rivers. These are low energy, low sinuosity channels with large scale bifurcations and a dominantly vertical pattern of aggradation (Smith and Smith, 1980). The Rencontre sandstones satisfy many of the criteria outlined by Smith and Putnam (1980); they consist of stacked multistory sandstones, show fining up, are enclosed in abundant overbank silts, and show no lateral accretion structures. It is likely that the environment proposed for association VI would be favourable for the development of anastomosing channels. The main requirements are bank stability and vertical aggradation (Smith and Putnam, 1980). Bank stability can be induced by vegetation and cohesive, fine-grained, bank sediment. Rust (1981)described a modern anastomosing river in semi-arid conditions, showing that a cohesive substrate can give the required stability in itself. The fine-grained, but vegetationless substrate of association I would give similar channel stability.

The second condition, aggradation, can be stimulated by rapid subsidence, high sea levels, or local downstream controls on base level, such as fan aggradation. The controls in this case may be high sea level, and high subsidence rates.

Possible problems with this model are the small thickness of the deposits and the absence of identifiable crevasse splay deposits which are common features of anastomosed channels. Descriptions of modern and ancient anastomosed rivers show that a range of sizes exist. For example, Legun and Rust (1982) described a sequence just an order of magnitude bigger than the present deposits. A size continuum is likely (Putnam 1982,pers.comm.) and so it is unreasonable to dismiss the interpretation merely because of the thinness of the deposits.

The absence of identifiable crevasse splay deposits may be related to the size of the channels. On such a small scale, sheet floods rather than discrete splays would be expected during times of flood, and so their absence here is not damning.

7.6 Discussion

Facies association VI represents the progadation of a muddy coastline. Intertidal to supratidal mudshoals and plains, tidal creeks, anastomosed fluvial channels, and chenier environments are feasible.

A regime of low wave energy and tidal range was likely because of the fine grain size of the deposits, the immaturity of the sandstones, and absence of structures indicating high flow velocities. Further evidence for a low tidal range is the absence of well developed tidal flat sequences, which develop best in macrotidal conditions.

Explanations for the stacking of the progradational sequences are obscure. On coastal plains an autocyclic mechanism, such as river migration, is common, yet the small size of the rivers makes it unlikely that they are the control in this case. Possible allocyclic causes of the Rencontre sequences are changes in sediment supply, sea level changes and subsidence.

These conditions are totally different from those which accompanied the deposition of the basal Rencontre in the north. This may well be because they are not time equivalents (see chapter eleven). Instead, the Brunette association represents a time of tectonic quiescence and passive subsidence, when marine and marginal marine environments encroached southwards to initiate deposition there.

CHAPTER EIGHT

FACIES ASSOCIATION VII, BRUNETTE ISLAND

8.1 Introduction

This is a thick, about 260m, succession of coarse, red to buff sandstones and conglomerates with subordinate pale to gray sandstones. The association outcrops on the southern, eastern, and northern coasts of the island (fig.7.1) as a result of the complicated folding that effects this association.

The folding disrupts the middle part of the succession most, and ensures that exposures are very poor for this part of the section. However, the upper and lower contacts of the association are well exposed, both the basal contact with association VI and the upper contact with association VIII, are sharp.

The association shows some variation in grain size and in the abundance of various sedimentary structures. These are used to divide the association into a coarse grained sandstone and granule facies which makes up the basal 180m of the association, and a pale sandstone facies and gray sandstone facies that are interbedded to form the remaining 80m.

8.2 Facies descriptions

8.2.1 Coarse sandstone and granule facies

This facies consists of coarse grained sandstone, granule conglomerate, minor dark silt and medium grained sandstone. The sandstones are poorly sorted, thick bedded (about 0.8m), and sheet-like. Beds often have silt-charged erosive bases. The basal 60m measured coarsens upwards and at the bottom of this sequence, coarse sandstones with interbedded lenses of silt occur. Small scale trough cross-bedding (set thickness 8-15cm) is the main sedimentary structure. This passes up into granule and coarse sandstone beds, also with small scale, low angle, trough cross-beds (fig.8.1).

8.2.2 Description of pale sandstone facies

Sharply overlying the basal red and buff sandstones are 80m of pale to gray sandstones. These are strikingly compositionally mature compared with other Rencontre sediments. For example, quartz-feldspar-lithic ratios may reach 88-8-4, while values in the rest of association VII are about 20-20-60.

The pale sandstone facies consists of poorly to moderately sorted, poorly rounded, coarse sandstone. Units are commonly medium bedded and sheet like (about 0.6m thick).

Sedimentary structures are sometimes obscured by tectonism, but parallel lamination and small scale planar

FIG. 8.1 Medium bedded sandstone of the coarse sandstone facies, association VII, unit shows small scale planar cross beds, erosive base, and bounding by thin siltstone beds, east coast Brunette Island.

cross-beds are seen. The set thickness averages only about 0.1m and palaeocurrents are directed to the south-east.

Some units show thin, irregular streaks of dark gray silt. These are essentially parallel to the bedding and do not seem to be bedform drapes (fig.8.2). Dark silts also occur as discrete, poorly sorted beds, and intraclasts.

8.2.3 Gray sandstone facies

This consists of gray, poorly-sorted, medium-grained sandstones and dull red silts. In common with the pale facies, units show small planar cross-beds, parallel laminae and silt streaks.

The facies differs from the pale sandstone facies in showing erosional features, including scour and fill cross bedding, sharp internal discordances, and bed lenticularity. Small scale compound cross bedding is locally developed.

Limited cross bed measurements indicate flow to the southeast and southwest.

Pale and gray units are interbedded with each other, usually on a scale of several metres. There are no obvious changes within the sequence except at the top where there is a rapid coarsening up, over 10m, to conglomerate, with a mean grain size of 2cm.

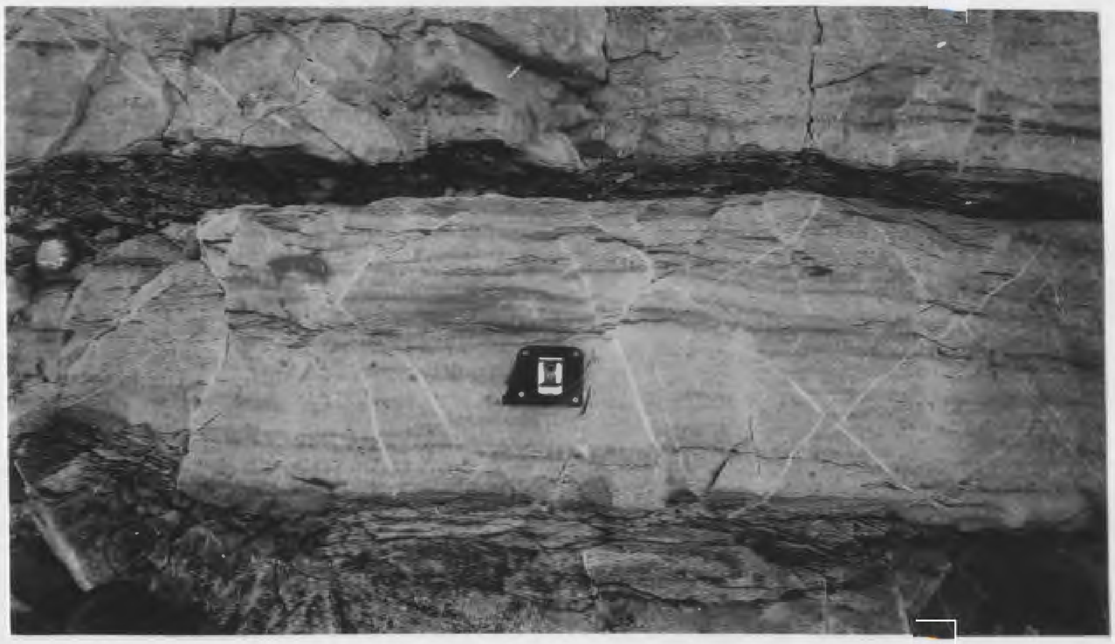


FIG. 8.2 Pale, quartz-rich sandstone with dark siltstone streaks and pervasive tectonic fracturing, east coast Brunette Island.

8.3 Interpretation

8.3.1 Coarse sandstone and granule facies

A fluvial interpretation is suggested by several features of this facies. The beds show erosive bases, but flat, uniform bed tops (Levell, 1980,a,b; Reading, 1981), and palaeocurrents are unidirectional (although there is a spread). The red colour corroborates this model.

The sediments are similar to the Donjek-type braided stream model, as developed by Miall (1977, 1978) and Rust (1978). That is, some conglomerate and minor silt are present and cycles are only crudely developed. Certainly, some sort of braided stream model is supported by the sheet-like nature of the beds and lack of extensive overbank deposits. The wedge-like nature of the silts might also be diagnostic of braided fluvial deposits. The well defined channels of meandering systems ensure that the channel sands are lenticular and enclosed in laterally extensive silts, while the shifting of braided channels reworks silt into laterally impersistent units.

Sedimentary structures, such as small scale, low-angle cross-bedding, and poor sorting, show that flows were of high velocity and rather shallow (Jopling, 1965). The isolated granule conglomerate grains may also indicate high velocities and sediment discharge. Schumm et al. (1982) argued that this feature is related to pulsating flow and bedform break-up.

The striking contrasts in lithology, and sharp contacts with association VI, represent a significant change in palaeogeography. Coarse detritus buried the former coastal plain, impling source region uplift and rejuvenation. Palaeocurrents suggest an easterly and northeasterly derivation. Vertical grain size variations within the facies reflect the progradation and retreat of the braided system.

8.3.2 Pale and gray sandstone facies

Any model for this sequence must explain the interbedding of units of different composition and sedimentary structures and the palaeocurrent pattern. The palaeocurrents of the gray facies are towards the southeast and southwest, yet those of the pale facies are only directed towards the southeast.

The compositional maturity and palaeocurrent patterns make a marine influence likely. There are several possibilities. The deposits may be those of tidal deltas, washover fans and lagoons, beaches and shorefaces, or a spit-fronted, fan delta plain.

Barwis and Makurath (1978) noted that tidal inlet sequences fine up, contain little mud, and show bi-polar palaeocurrents. Reineck and Singh (1980) and Hayes (1980) described large scale cross bedding and bi-polar palaeocurrents in tidal deltas. Both these descriptions compare poorly with the sequences here, which contain silt, small scale cross-beds, and no bi-polar currents.

A beach-shoreface interpretation is also unlikely. The sequence shows no coarsening up and has abundant silt interbeds; features atypical of beaches (Elliot, 1978; Dabrio and Polo, 1981). Also, such an interpretation inadequately accounts for the scoured bases of the gray sandstones.

More likely is a washover fan-lagoon origin. There are similarities between washover fans and the pale sandstone facies. The former are often quite thick bedded, show parallel laminations, small scale crossbedding and may contain silt streaks which can be deposited in depressions on the fan top (Reineck and Singh, 1980,p.360; Leatherman and Williams, 1977). Using this model, the gray sandstone facies must represent either a lagoonal setting or runoff channels related to drainage of the washover (Schwartz, 1982). The latter is more likely as the scoured bases of the gray sandstones indicate shallow erosive flows, which would not be generated within a lagoon, but is characteristic of runoff channels. Inhibiting acceptance of this model are the differences in composition between the two facies. The model cannot adequately explain this as sediment for both the washover and runoff channels is from the same source; that is, the beach (Schartz, 1982).

The most convincing interpretation is a braid plain fronted by a barrier spit; i.e., narrow sand and gravel spits fringing a broad, shallow system of braided channels. These flow into the sea through small, narrow channels cut into the spits (Hine and Boothroyd, 1978; Kirk, 1980).

The sequence shows several similarities with descriptions of modern examples. The pale sandstone facies shows parallel lamination, small scale cross-bedding, and compositional maturity, comparable to those of the modern berms. The gray sandstone shows small scale cross bedding and scour and fill features comparable to those of the shallow braid plain. The model can conveniently explain the palaeocurrent pattern, as, in modern examples, the braided channels may flow parallel to the spit for some distance before they breach it. The interbedding of these deposits for 80m can be explained by the oscillation of spit and fluvial environments, reflecting storm beach construction and changes in sediment supply (Hine and Boothroyd, 1978).

A spit-fronted braid plain interpretation is practicable, although there are some problems. Silt streaks were not decribed in the rare accounts of modern equivalents, and the palaeocurrent data are too scanty to be sure of the relative orientation of the two facies.

This facies overlies a thick fluvial sequence, showing that transgression has occurred. Kirk (1980) and Orford and Carter (1982) suggested that this sort of gravelly coast is able to retreat for considerable distances during transgressions, reworking and truncating underlying fluvial deposits. A transgression is also supported by abundant evidence for wave and tidal activity in immediately overlying deposits. Like association IV in northern Fortune Bay, this facies marks a final pulse of fluvio-deltaic sedimentation, which is followed by the start of more pacific, shallow water to intertidal sedimentation in the Rencontre basin.

CHAPTER NINE

FACIES ASSOCIATION VIII, BRUNETTE ISLAND

9.1 Introduction

This is a silty red sequence, about 150m thick, that outcrops on the eastern coast of Brunette Island. The lower contact with association VII is sharp and striking, as it is a change from quartzo-feldspathic conglomerate to red silt.

The subdivisions recognised are red silt, thin-bedded sandstone, medium-bedded sandstone, and a fine-grained sandstone facies. There seems to be no regular arrangement in the succession of these facies.

9.2 Facies descriptions

9.2.1 Silt facies

The silt is predominately red with minor beds of dull gray-red silt. The facies, making up about 63% of the section, ranges from massive silt to silts with up to 30% fine sandstone. The sand rich units show regular, fine laminae. Other structures include regular sand filled cracks, interpreted as desiccation cracks, and irregular, spindle-shaped cracks, interpreted as synaeresis cracks (Plummer and Gostin, 1981).

9.2.2 Thin-bedded sandstone facies

Thin (0.1m) discrete beds of fine- to medium-grained sandstone make up about 10% of the association. The beds can be sheet like or lenticular with convex up tops. Ripple cross-lamination, small scale cross-beds, and climbing ripples are common. Small silt intraclasts, often imbricated are seen locally.

9.2.3 Medium-bedded sandstone facies

Two types of quartz-arkose unit make up this facies. The first type , making up 10% of the association, consists of sandstones with erosive bases, basal silt intraclasts, and stacked cosets of small-scale, low-angle, trough cross-beds. Beds, on average about 1m thick, often fine up. They are sheet like or lenticular, for example, beds 1m thick wedge out in 4m. The few palaeocurrent measurements obtained show flow to the south.

This type of sandstone is often associated with the thin-bedded sandstone facies, while associated silts can be massive or rich in fine sandstone

The second type of medium bedded sandstone, making up 7% of association VIII, consists of thick (0.8-2m), sheet-like units with non-erosive bases. They can show bi-polar cross bedding (to the east and west) and megarippled bed tops. Silt drapes and irregular laminae occur. Fining up sequences and silt intraclasts are usually absent. This type is found interbedded with massive red silts or dull gray-red silts.

9.2.4 Fine sandstone facies

This unusual facies, making up 10% Of the association, occurs at only one place in the section. It consists of dull gray-red, fine grained, well sorted sandstone, with subordinate medium grained sandstone and red silt with some desiccation cracks. The fine grained sandstone occurs in two ways. It can form thin, sheet-like units (mean thickness 0.17m), showing low angle climbing ripples (fig.9.1). The bases of these units show loading and pseudo-nodules, but some are clearly erosive and show small silt intraclasts. Fine sandstone can also occcur as medium bedded units (about 0.4m) with small scale, low angle, trough cross bedding. These units can show lenticularity.

The medium grained sandstone also occurs in two modes. The most common is as thin (0.1m), erosive-based sheets with basal silt intraclasts. These beds can be parallel laminated, ripple cross laminated, or massive.

Less commonly, medium sandstones form thick (about 0.8m) lenticular units (see fig.9.2). Internally, they show low angle, small scale cosets of trough cross bedding, with azimuths to the southwest.

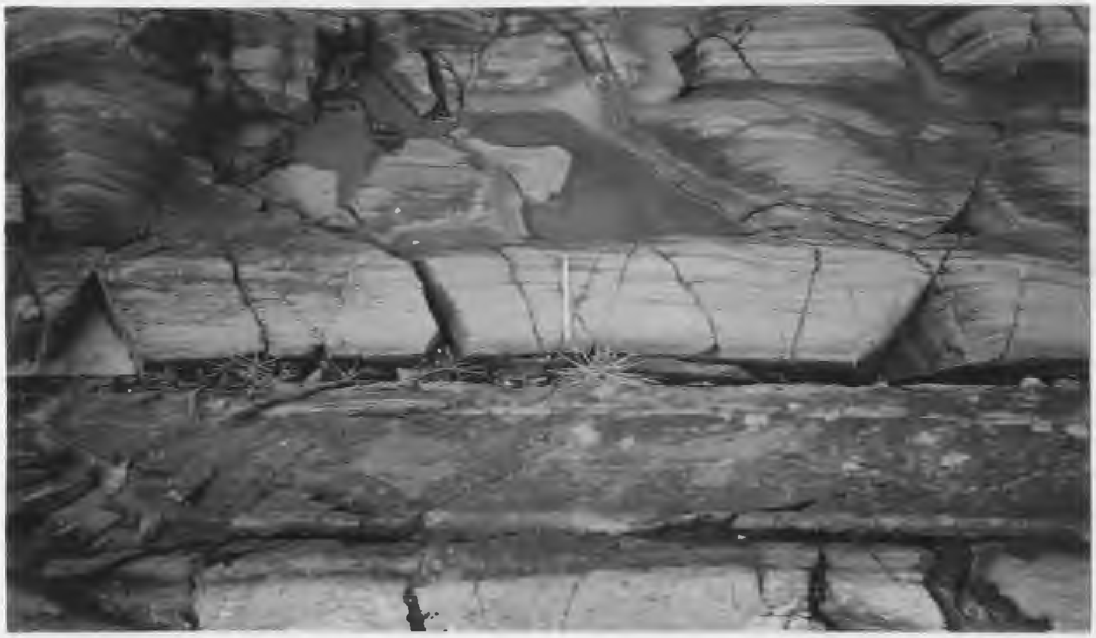


FIG. 9.1 Thin-bedded sandstone with low-angle climbing ripples, pseudo-nodules are present in the top right, east coast Brunette Island.

FIG. 9.2 Lenticular unit of medium grained sandstone (just above hammer), east coast Brunette Island.

9.3 The interpretation of association VIII

9.3.1 Introduction

There are several indicators that readily place these sediments in a marginal marine setting. Wave rippled thin sandstones, wavy-topped thick sandstones, flaser bedding, and the variable orientation of palaeocurrents testify that marine processes were, at times, important. Periods of fluvial and/or tidal flat sedimentation are indicated by the occurrence of desiccation cracks and channelised, fining up, sandstones.

A marginal marine setting can encompass the range of subenvironments that deposited these variable sediments. A plausible scenario includes subtidal silts and sand shoals, lower to upper tidal flats with tidal channels, mud and sand flats, and occasional fluvial incursions. While the sequence demands that a range of subenvironments be present, it is not possible to interpret every unit unequivocally. Some beds are rather nondescript, while in any case, this sort of environment can produce variable and complicated sequences (Reineck and Singh, 1980 p.455; DeRaaf and Boersma, 1971; Reineck, 1979).

9.3.2 Silt facies

This is a facies with variable colours, sedimentary structures, and sandstone contents. It is reasonable to suppose that this facies represents several environments.

Silt with abundant regular sandstone lamination ("pinstripe lamination") is found with lenticular, fining up, sandstones. This sort of stratification can be found on the lower and middle parts of modern tidal flats (Reif and Slatt, 1979; Reineck, 1967).

Red silt with rare sandstone laminae also occurs with fining up sandstones with erosive bases. This sort of silt often shows desiccation cracks. The rare laminae and desiccation cracks indicate that a mid- to supra-tidal flat origin is likely. Driese et al. (1981) showed that these features have both a higher preservation potential, and are formed more often in these settings.

The final variant, gray-red silt with occasional synaeresis cracks, is found with flat based, wavy topped, sandstone units. It is difficult to place these unambiguosly, as synaeresis cracks can form subaerially or subaqueously, due to salinity changes (Plummer and Gostin, 1981). The colour of the silts might indicate less oxidising conditions, and so, subtidal deposition, but it is the nature of the interbedded sandstone facies that is more suggestive of a depositional environment.

9.3.3 Medium and thin bedded sandstone facies

The first type of medium bedded sandstone described is intimately interbedded with the thin bedded sandstone facies. The former, with its erosive bases, occasional lenticularity, and cosets of fining up cross beds, represents channelised sandstones. The relatively small size of the cross beds and thinness of the sandstones shows that flows were quite shallow. Their similarity to the tidal channels described by Mazzullo (1978) and Kellerhals and Murray (1969), and association with "pinstriped silts", may place them in a lower- to mid-tidal flat setting. The associated thin bedded sandstones may represent sand shoals on the lower intertidal flats (Evans, 1965).

These sandstones show some variability in geometry and associated sediments. The former may be explained by variations in the amount of lateral migration of the channels, those in the lower portions of the flats migrating more freely to give more sheet like bodies (Van Straaten, 1961). Variations in the sequence that contains this sort of sandstone may reflect the fact that not all these units are tidal channels; some may be small, supratidal, fluvial sandstones.

The second type of medium bedded sandstone shows evidence for tidal activity. Beds show bi-polar palaeocurrents, silt drapes, and irregular silt laminae. Other indicators of marine processes are the sheet-like nature of the beds, and their wavy tops. Possibily the sands are subtidal, or lower intertidal flat deposits (Johnson, 1975). The associated sediments, dull red silts with synaeresis cracks, are not very helpful in placing the rocks in a more specific context; this facies itself could be lower intertidal (a zone where exposure is not excessive).

9.3.4 Fine sandstone facies

There are indications that this facies is a fluvial one of some kind. The beds show erosive, concave up bases, lenticularity, desiccation cracks, and unidirectional palaeocurrents to the southwest.

But if this facies is fluvial, it shows a singular combination of features. The parallel laminae and climbing ripples are common in sheet flood or levee deposits, yet this is not compatible with the channelised base of the units.

A modern sequence that does show this combination was deposited by the Gomti river in India (Kumar and Singh, 1978). This is a small meandering river with a flashy discharge and fine sediment load. Deposits are rather thinly bedded, and because of the restricted grain size, there is little textural difference between the levee and point bar deposits. Parallel laminae and climbing ripples dominate. There are similarities with the fine sandstone facies, and the Gomti river may be a modern analogue for the sequence.

9.3.5 Discussion

This facies association is complicated and probably represents deposition in several environments. Any simple, single interpretation is precluded by the variability of the sediments and the variability of the sequences.

Some generalisations can be made. Sediment supply was limited, deposition was in a marginal marine setting, and tidal processes were sometimes important. A similar synopsis was made for the upper part of the Rencontre in northern Fortune Bay, which shows that towards the end of Rencontre time the style of sedimentation was becoming uniform throughout the Fortune Bay basin.

CHAPTER TEN

FACIES ASSOCIATION IX, BRUNETTE ISLAND

10.1 Introduction

This facies association caps the Rencontre Formation on Brunette Island. The association, about 100m thick, is found on the eastern shore of the island. The lower contact with association VIII is not exposed; the upper contact with the Chapel Island Formation is sharp, although a 70m interval of Chapel Island-like rocks is found in the middle of the association (the top of the Rencontre is drawn at the top of the last red bed).

The association consists of red silts, quartzo-feldspathic sandstones, and green silts and fine sandstones. Based on bed geometry and composition, three facies are recognised (fig.10.1).

10.2 Facies descriptions

10.2.1 Sheet sandstone and red silt facies

This 20m sequence occurs at the base of the section. Its lower contact is not exposed; its upper contact with green silts and sands is gradational.

This facies consists of dull-red quartzo-feldspathic sandstones, relatively compositionally mature, and red silts. The sandstones occur as thin to medium bedded

FIG. 10.1 Representative section of facies association

(0.1-0.4m), sheet-like units, making up about 70% of the facies. They are flat based, but bed tops are wavy and irregular. The sandstones are usually massive, although some small scale planar cross beds, with their azimuths to the northeast, are seen.

Silt beds have fine sandstone laminae, while thicker silt units also show thin lenticules of medium grained sandstone. Irregular, sand-filled synaeresis cracks are common. The sequence fines upwards as the proportion of silt increases.

10.2.2 Green silt and fine sandstone facies

This 70m interval is typical of the lower Chapel Island Formation; it has been incorporated into the Rencontre because of a thick overlying interval of red beds. This facies is made up of green-gray fine sandstone and silt. The sandstone (60% of the succession) occurs as discrete sheet-like beds, 1-5cm thick, interbedded with silts that are 0.5-8cm thick. The sandstones often show irregular ripple cross laminations that may be wave ripples. Synaeresis cracks are plentiful.

10.2.3 Lenticular sandstone and silt facies

This 40m thick sequence shows sharp contacts. The lower one is particularly striking where granule conglomerates erosively overlie green silts (see fig.10.2).

The facies consists of pale-weathering granule conglomerate and coarse to medium sandstone (60% of the section) and red silt (40%).

The coarse units commonly have erosive bases with marked relief, which are sometimes lined with silt intraclasts. Often this is overlain by a small scale set of planar cross bedding (set size 0.1-0.2m) and then stacked cosets of small scale trough cross bedding. Cross bed azimuths are towards the southwest although there is considerable spread.

Towards the top of the sequence, thin-bedded sandstones (0.2-0.3m) with impressive scour and fill cross bedding are seen (fig.10.3). Silt occurs as discrete beds with rare sandstone laminae (in contrast with previous units). Units of massive silt are common.

The section shows three fining up sequences, 5-25m thick. Thick bedded granule conglomerate and coarse sandstone pass up into coarse and medium grained sandstone. These beds become thinner, and silt interbeds thicker. The sequences are capped by massive silt. At the very top of the 40m section, massive silt with metre-scale polygonal desiccation cracks is seen.

10.3 Interpretation

This association reflects alternating deposition in subtidal and nonmarine environments. While evidence is

FIG. 10.2 Pale granule conglomerate erosively overlying green siltstones and fine grained sandstones, east coast Brunette Island.

FIG. 10.3 Scour and fill trough cross-beds with basal silt intraclasts, east coast Brunette Island.

strong for this broad setting, it is difficiult to arrive at any satisfying detailed interpretation because of the nondescript nature of some sections.

The first part of the sequence, the sheet sandstone facies, represents shallow, subtidal marine deposits. This is supported by the sheet-like and wavy topped nature of the beds, the palaeocurrents to the northeast (the onshore direction), and gradational contact with the green silt. There is no evidence for temporary emergence, for example desiccation cracks or modified ripples, although a fairly shallow, near-shore location is implied by the the red colour of the silts.

The green silt facies is also a subtidal deposit. This is indicated by the irregular ripples, possibly wave ripples, and colour of the sediments. The contrasts with the first facies might be taken to imply greater water depths, as the finer grain size and absence of red silt show a diminished supply of terrestrial sediment. This may be due to greater water depths and distance from the shore, or alternatively, a reduced sediment supply because of reduced relief in the hinterland.

The lenticular sandstone facies indicates a temporary regression. The palaeocurrents to the southwest, erosive channelised bases, and desiccation cracks show subaerial deposition. Attempts at more specific models are not convincing. The sequence compares poorly with tidal creeks

(Barwis, 1978) and tidal flats (Muzzarulo, 1978).

Palaeogeographically, the association continues the theme typical of the upper parts of the Rencontre Formation. That is, deposition in low energy, marginal marine environments during a period of tectonic stability. Sea level fluctuations were important, but because of the probable shallow water depths and slopes involved, they were probably small.

The sequence is similar to that on Chapel Island, but one difference is interesting. The interbed of Chapel Island-like facies on Brunette is twice as thick as the one on Chapel Island. This may indicate that the transgression came from the southwest.

CHAPTER ELEVEN

PALAEOGEOGRAPHIC MODELS AND REGIONAL CONTEXT

11.1 Introduction

The main purpose of this chapter is to combine facies interpretations into a palaeogeographic model for the Rencontre Formation. A palaeogeographic model is "a reconstruction of the presumed geography, especially the relative positions of land and water, at some particular period in the past" (Whitten and Brooks, 1972).

Previous palaeogeographic models will be reviewed and a new one suggested, and the possibility of fitting the Rencontre into a tectonic model will be discussed. To do this, Avalonian stratigraphy, possible correlations of the Rencontre with other units on the Avalon Peninsula, and proposed tectonic models will be reviewed briefly.

11.2 Previous palaeogeographic models

Although previous studies have been rather cursory, two models have been proposed. White (1939) developed a model based on his studies of Fortune Bay, while the model of Twenhofel (1947) was developed in a study of the Silurian rocks of Newfoundland (when the Rencontre was thought to be Silurian).

White interpreted the lower parts of the formation as the deposits of a fluvial floodplain or topset of a delta, on the basis of mudcracks, colour, and the immature composition of the sediments. A marine origin was suggested for some parts, because they were "impure quartzites". He suggested deposition in a northeasterly-trending basin, probably near sea level. This was based on the thickness variations of the Rencontre and Long Harbour volcanics.

Twenhofel's (1947) interpretation has become the standard in works which mention the Rencontre _en passant_. The Rencontre was envisaged as alluvial fan deposits on the basis of colour, absence of fossils, the coarse, poorly sorted nature of the sediments, and the palaeocurrents. Apparently, Twenhofel found the latter to be unidirectional towards the west. This led to the idea that "the site of deposition lay on the western margin of a large upland area with a moderate slope" (Twenhofel, 1947 p.101). Williams (1971), having included the outcrops near Chapel Island in the Rencontre Formation, found further evidence for the model in the apparent decrease of grain size from east to west.

In his paper, Twenhofel does not explain how he obtained his palaeocurrent information, and certainly does not present any data to support his statement. Considering that this work was carried out during the field seasons of 1945 and 1946, during which time Twenhofel also studied sediments at Baie d'Espoir, Gander Lake, Gander Bay, and

Exploits Bay, it is unlikely that much time was spent on palaeocurrent measurement.

Another objection is that the model is not based on all the outcrops; crucial ones at Bob Head and Brunette were not included. This limitation also applies to White's study. The apparent westward decrease in grain size, described by Williams (1971), is only apparent. It is based on the assumption that the eastern and western outcrops are time equivalent, but since there is depositional overlap to the west, this assumption is erroneous. Clearly, neither model is very satisfying.

11.3 A palaeogeographic model for the Rencontre Formation

11.3.1 Introduction

The model was developed with several constraints in view; that is, the nature of the sedimentary environments, palaeocurrents, thickness patterns, correlations of units, and the condition that the model must be internally consistent.

The major problems in developing a model are those of correlation, for, without an idea of which units are laterally equivalent, and what the stratigraphic succession is, it is impossible to get beyond broad generalisations. A system of correlations has been developed, and because this is the basis of the model, they will be discussed in detail.

11.3.2 Correlation of units within the Rencontre

There are several methods which can be used to correlate packages of sediments. The most common are fossils (Raup and Stanley, 1978), stratigraphic and lithological similarity (Donovan, 1966); radiometric methods (dating intercalated volcanics or authigenic minerals) and marker beds can also be used. Unfortunately, these methods cannot be applied here; the Rencontre is barren of fossils, shows rapid lateral and vertical facies changes, and contains no datable intercalated volcanics.

One possible way out of this conundrum is to use the idea of event stratigraphy. That is, to try and correlate the results of geologically "instantaneous" events. For example, tectonic pulses, rapid sea-level change, or climatic change might occur almost synchronously over a small basin, and these events will be reflected in the rock record. If one can recognise these in different parts of the basin, it might be possible to draw approximate time lines between the sections.

This method most commonly uses sea level changes as the "events". These need not necessarily be eustatic if only a small basin is involved. Ramsbottom (1973), working in the Lower Carboniferous of Great Britain, recognised sea level changes from changes in lithology and was able to use these to produce a workable correlation scheme. Brenchley and Newall (1980) used a similar technique in the Upper Ordovician of Sweden.

Several sea level changes probably occurred during deposition of the Rencontre Formation. These have been recognised by studying the sedimentary facies, composition, and palaeocurrents of the sediments. The sea level changes deduced for the sediments in the north and south of the bay seem to match up (fig.11.1) and this has been used to link the sections with tie-lines representing sea level fluctuations.

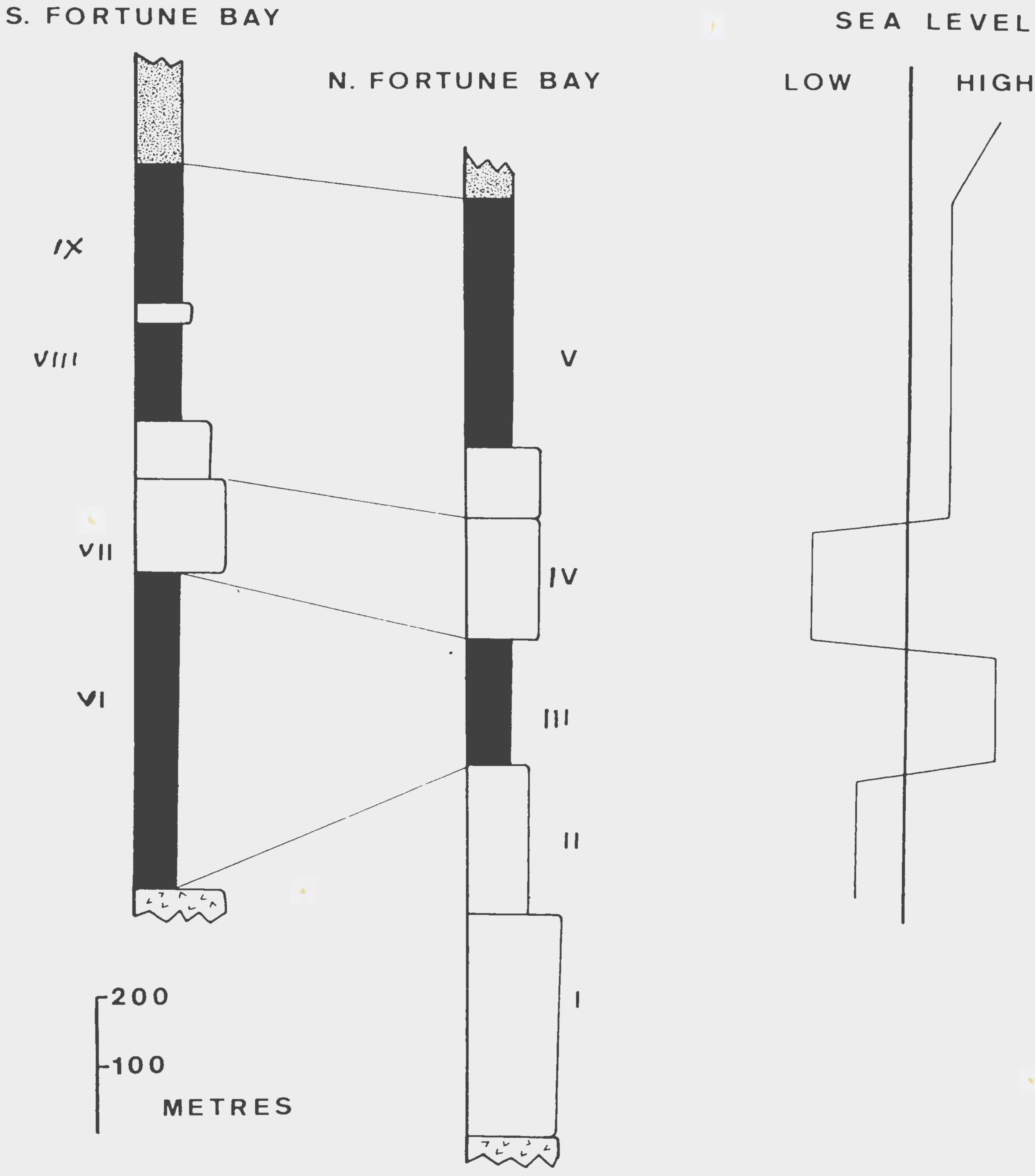
Obviously, the technique has to be treated with caution. There are several ways in which it might break down. The recognition of events is based on interpretations of changes in the sequence, and these may be subjective, especially when dealing with relatively deep water deposits where the changes may be subtle and amenable of other interpretations. However, this is not a major difficulty here; water depths were shallow so that changes are from subaqueous to subaerial environments, and are marked by unambiguous changes in the sections.

The technique assumes that eustatic sea level changes were effectively instantaneous, which need not necessarily be true. But it is probably fair to make the assumption here because of the small size of the basin.

Other possible objections include the assumption that

FIG. 11.1

A correlation scheme for the Rencontre Formation. The schematic sea-level curve is based on facies analysis of sections in the north and south of the Bay, equivalent sea-level changes have been used to draw tie-lines between the two sections. Nummerals refer to facies associations, stippled section represents the Chapel Island Formation.


S. FORTUNE BAY
N. FORTUNE BAY
SEA LEVEL
LOW
HIGH
IX
VIII
VII
VI
V
IV
III
II
I
200
100
METRES

the sections are complete and that differential vertical movements, or warping within the basin, did not occur. If it did, different parts of the basin would experience different sea level histories. The first is not too serious, provided that breaks in the sections are due to sea level changes and can be recognised as such. The second forces one to assume that the basin behaved as a tectonically coherent unit. Because of the small size of the unit, this is a workable assumption here.

The technique of event stratigraphy has been used here as most of the potential difficulties are not too great. The fact that the sea level curves match up and that they give a fairly sensible geological model may be more than circumstantial.

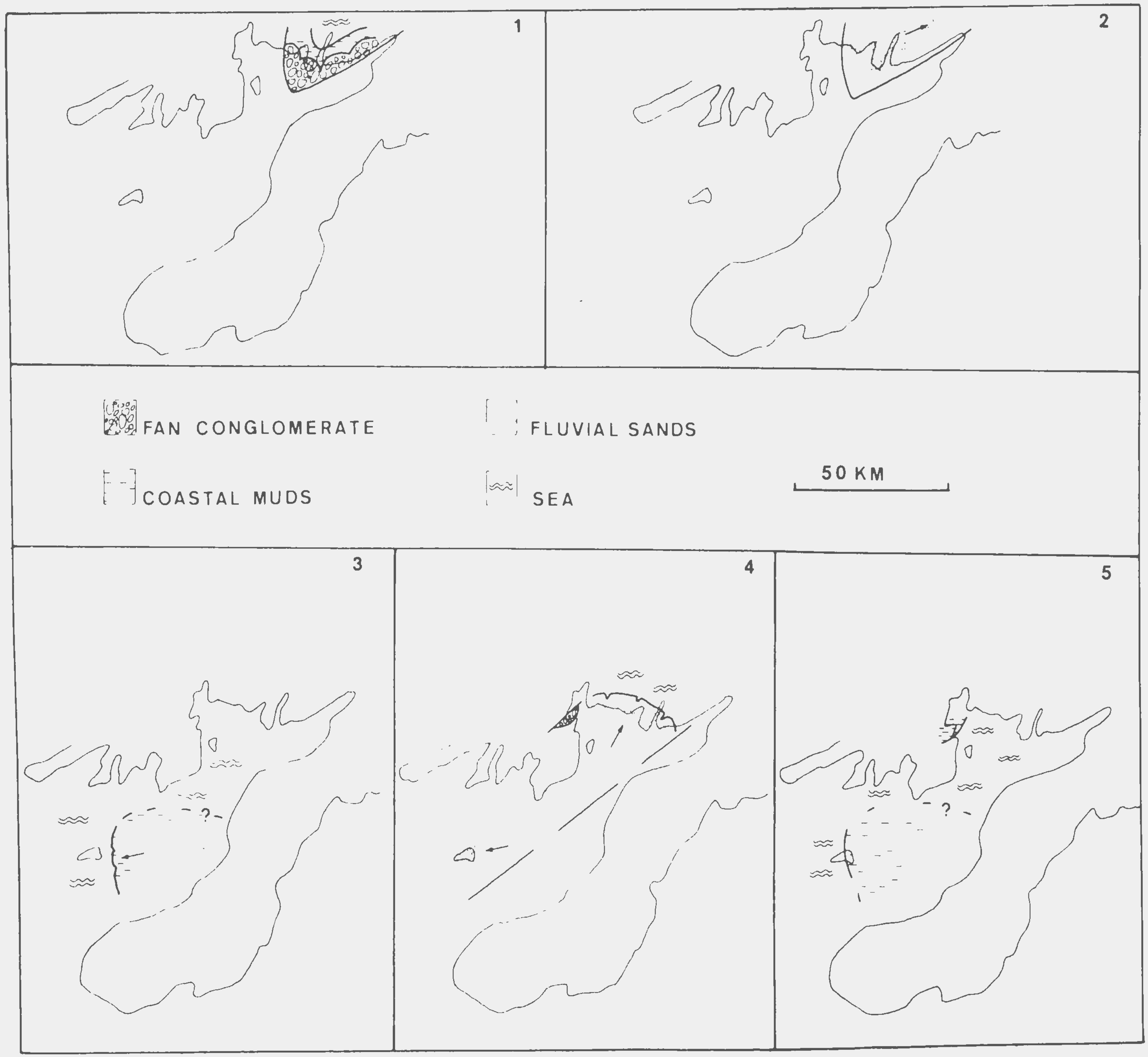
11.3.3 A palaeogeographic history

Using these correlations and the other constraints already mentioned, a palaeogeographic history is suggested. This is summarised in figure 11.2.

Five stages can be recognised. Following Mooring Cove volcanism, a small northeast trending basin, opening to the north, was formed. Basin formation was accompanied by some folding, faulting, and erosion of older Long Harbour Group rocks (White, 1939; Williams, 1971). The basin was probably fault controlled, with a high sediment supply feeding fan deltas which prograded to the northeast.

FIG. 11.2

A palaeogeographic model for the Rencontre Formation. (1) Basin initiation, fan delta sequences are deposited in a small tectonically active basin (facies association I northern Fortune Bay). (2) Basin growth to the west by passive subsidence results in a lower sediment supply and ephemeral braided stream deposition (association II, northern Fortune Bay). (3) Continued passive basin growth and transgression initiates deposition on Brunette Island, marginal marine and marine sedimentation (association VI, northern Fortune Bay, association I, Brunette). (4) Tectonic rejuvination of the basin, note the radial pattern of sediment dispersal (association V northern Fortune Bay, association VII, Brunette). (5) The demise of the Rencontre basin, extensive marginal marine and marine deposits represent sedimentation on a broad depocentre.


1
2
FAN CONGLOMERATE
FLUVIAL SANDS
COASTAL MUDS
SEA
50 KM
3
4
5

This was followed by a phase of tectonic quiet, as the sediments of association II of northern Fortune Bay are relatively fine grained. This was accompanied by basin growth and depositional overlap, at least to the west (sharp depositional overlap at Doting Cove) and possibly to the south as well. Sedimentation was dominated by passive subsidence rather than active basin and block tectonics (fig.11.2).

In the third stage this theme continued, but was accompanied by a marine transgression that deposited association III in northern Fortune Bay, and initiated deposition on Brunette Island (association VI). Further depositional overlap occurred to the west, where, at Bob Head, facies association III rocks occur at the base of the sequence. At this locality, interstratified conglomerates imply that the western margin of the basin was nearby.

This transgression may have been the result of passive subsidence or eustatic changes. The latter is certainly a possibility as the basal Cambrian transgression was preceded by several eustatic fluctuations (Matthews and Cowie, 1979; Anderson, 1981). The transgressive seas may have advanced from the northeast or southwest.

The fourth stage was marked by tectonic rejuvenation of the basin. Coarse sand was supplied to form fan deltas in the north and braided stream deposits in the south. Interbedded conglomerates at Bob Head imply that the western margin had become fixed there. When palaeocurrents from the delta deposits (association IV, northern Fortune Bay) and braidplain (association VII, Brunette) are extrapolated, they meet at a point on the west coast of the Burin peninsula (some point north of Garnish). It is likely that a northeast- to southwest-trending basin had become established, the western margin passing near Bob Head, the eastern one along the Burin. Most of the sediment was supplied from a cone radiating from the Burin.

The final stage is one of tectonic quiet and is initiated by a transgression. In the south, this reworked the fluvial deposits into a spit-fronted braid plain, while the deltas of the north were reworked by a shallow tidal sea. These initially coarse deposits were replaced by fine grained silty sequences deposited in a marginal marine environment. Conditions of sedimentation became uniform over large areas. For example, the sequences on Chapel Island and Brunette Island are similar and compare well with isolated Rencontre outcrops outside Fortune Bay (Potter, 1949; Greene and O'Driscoll, 1976; O'Brien et al., 1977; Strong et al., 1978).

The sequence monitors a change from deposition in narrow, elongate basins, a motif characteristic of the upper Precambrian Avalonian sediments (McCartney, 1967), to stable, cratonic-type sedimentation that characterises the Palaeozoic sediments of the Avalon (Greene and Williams, 1974; O'Brien et al., 1977; King, 1982).

11.4 The regional context of the Rencontre Formation

A brief summary of Avalonian stratigraphy and models will be given in an attempt to place the Rencontre Formation in a regional context.

The Avalon zone of Newfoundland consists of a thick sequence of Hadrynian to infra-Cambrian volcanics and sediments with local plutonism. In a broad sense, the sequence is as follows: (1) oceanic volcanics, (2) subaerial volcanics with plutonics, (3) marine flysch-like sediments, and (4) terrestrial molasse-like sediments with local bi-modal volcanics (King, 1982).

The oldest volcanics outcrop on the Burin Peninsula. This Burin Group consists of mafic volcanics, with geochemical similarities to ocean floor tholeiites (Strong et al., 1978; O'Brien, 1979). The overlying subaerial volcanics occur in belts running northeast to southwest. These include the Long Harbour and Connaigre Groups in the west, and Harbour Main and Love Cove Groups in the east of the Avalon. In the east and northwest, these are overlain by hemi-pelagic shales and turbidite sandstones of the Conception and Connecting Point Groups (Williams and King, 1980).

The stratigraphy is capped by thick sections of coarse, red clastics of latest Precambrian age. In the east, these are the Signal Hill and St. Johns Group; in the central Avalon, the Hodgewater Group, and in the west, the Musgravetown group. The Rencontre has been placed in this assemblage by several workers and tentatively correlated with the Crown Hill Formation of the Musgravetown Group on the basis of similarity of lithology and place in the stratigraphic sequence (McCartney, 1967; Strong et al., 1978; King, 1982).

Several tectonic models have been proposed for the Avalon Zone (see the review in O'Brien et al., 1983). Models attempting to explain the entire evolution of the Avalon in terms of one simple tectonic setting have had little success. The model recently proposed by O'Brien et al. recognises the complexity likely in such an extensive terrain with such a long history. This model compares the Avalon with the possibly analogous evolution of the late Proterozoic Pan-African belts of north Africa. The history of the Avalon as seen by these workers is one of prolonged and extensive crustal extension. But this was variable, so that different parts of the belt have different histories; only locally was rifting successful, and small marginal basins formed. These were subject to closure with limited subduction and crustal thickening.

The latter phases are most relevant to the Rencontre Formation. O'Driscoll and Strong (1979) claimed that the Connaigre and Long Harbour Groups (respectively to the west of, and underlying, the Rencontre) represent such a period of localised subduction. This is based on the calc-alkaline nature of the suite and its increase in alkalinity eastwards (a common trend in modern subduction zones).

What is the significance of this for the Rencontre Formation? The themes that the Rencontre shows; such as alternating tectonic activity and quiet, the formation of a elongate, probably fault-bounded basin, and basin growth and elongation, might occur in several tectonic environments. For example, fore-arc or intra-arc basins (Dickinson, 1974), back-arc basins (Karig and Moore, 1975), pull apart basins, or even a rift-related basin (Manspeizer, 1981).

Some of the alternatives can probably be eliminated. A rift setting can be ruled out by the geochemical evidence of the volcanics, while a back-arc basin, at least one of any size, is unlikely because of the absence of ocean floor volcanics and pelagics (Aiello et al., 1977). Some sort of fore-arc or intra-arc setting is most likely. Of these two, a intra-arc basin is most attractive, as there is no associated deformed turbidite terrain (Reading, 1978).

One might speculate that the basin was influenced by strike-slip movements (perhaps related to oblique subduction?). Certainly, the growth of the basin (Rodgerson, 1980; Bluck, 1980), basin parallel palaeocurrents, and rapid facies variations are characteristic of such basins (Reading, 1980; McLaughlin and Nilsen, 1982; Howell et al., 1980).

CHAPTER TWELVE

SUMMARY AND GENERAL CONCLUSIONS

12.1 Sedimentary environments and facies

This study has attempted to describe the lithologies and sequences present in the Rencontre Formation. These have proved to be variable, both vertically and laterally. The Rencontre has been classified into facies associations using lithology, sedimentary structures, and palaeocurrents as criteria . To encompass the variability of the formation, five associations have been recognised in the north of Fortune Bay, and four different ones in the south on Brunette Island.

The Rencontre represents several depositional environments and cannot be interpreted using a simple fluvial model as previous studies have attempted. In the north of Fortune Bay, the deposits of fan deltas, braided streams, tidal marine, and marginal marine environments are represented. In the south, on Brunette Island, the deposits of muddy coastal plains, braided streams, spit fronted fan deltas, and marginal marine environments are represented.

In certain cases there are no adequate modern analogues to help interpret the sequences. For example, the basal 300m in northern Fortune Bay (association I) was deposited by fan deltas, but unlike modern examples, they were fronted by mud-silt flats over which the sea was able to migrate with ease. Strandlines were ephemeral, moving in response to fluvial floods and marine, possibly storm-related, surges. A search of the literature indicates that similar examples exist, especially in Late Precambrian to Early Palaeozoic sediments. The Rencontre sediments may be an example of a distinctive type of fan delta, that has not previously been recognised, and that could be termed a mud-flat fronted fan delta.

12.2 A palaeogeographic model

A palaeogeographic model is suggested for the Rencontre Formation. This is based on the sedimentary environments, patterns of sedimentary overlap, and correlations of sections in the north and south of the Bay. The usual methods of correlation are difficult to apply to the Rencontre Formation and the scheme used is based on an event stratigraphy reflecting sea-level changes. While there are clear limitations, the method does give reasonable results in this case.

The Rencontre Formation was deposited in a northeast to southwest trending basin, which experienced a complicated history of growth, tectonic activity, tectonic quiet, and sea-level changes. A setting in a intra-arc basin, possibly with some strike-slip processes, is feasible.

12.3 Implications for Avalonian tectonic development

There are some contrasts between the evolution of the Rencontre basin and Late Precambrian basins on the eastern Avalon. Although the specialised nature of this study precludes any regional models, these differences might have some implications for Avalonian tectonic development.

The molasse-like, Late Precambrian sediments of the eastern Avalon were deposited in northeast to southwest trending basins, with a palaeoslope and marine connection to the southwest (King, 1979, 1982). While the Rencontre basin had the same trend, it eventually developed marine connections to the northeast and southwest. Marine processes played an important part in the deposition of the Rencontre, as much of the sediments are either deltaic, subtidal, or intertidal. Marine processes were not so important further east, although deltaic deposits occur. These two contrasts may reflect the closer position of the Rencontre basin to the seaboard of the Avalonian micro-continent during Late Precambrian times. If so, this may indicate that the present margin of the Avalon zone (Williams, 1979) is near to the late Precambrian one, and that there was no westward extension of the Avalon that has since been tectonically removed to become a distant suspect terrain (Williams and Hatcher, 1982).

Basin growth and elongation can be demonstrated for the Rencontre basin, but so far, not for the basins of the eastern Avalon. This may simply be a function of poor exposure, problems of correlation, and lack of detailed studies in many parts of the Avalon. Nevertheless, if it is a real difference, it may be explained by contrasts in tectonic processes, reflecting position relative to the active margin of the Avalon.

A further contrast between the Rencontre and sequences to the east is the transition from active basin and block tectonics to stable, cratonic-type tectonics that is seen in the Rencontre Formation. This is a change from a style typical of the Late Precambrian, to one typical of the Lower Palaeozoic of the Avalon. The transition is commonly not preserved in the east as the upper parts of the sections are commonly truncated and overlain disconformably by the Random Formation or by Cambrian sediments.

The Rencontre Formation records the initiation, filling, and demise of a small, but tectonically active basin. The basin contrasts with those of the eastern Avalon Zone of Newfoundland, suggesting that the zone is a heterogeneous patchwork of basins and blocks of varying scale and not a simple uniform one. This is a significant characteristic and should be incorporated into any tectonic models.

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