22. PHANEROZOIC STRATIGRAPHY AND SEDIMENTOLOGY OF SOMERSET ISLAND AND NORTHEASTERN BOOTHIA PENINSULA

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A.D. Miall and J.Wm. Kerr
Institute of Sedimentary and Petroleum Geology, Calgary

Introduction

Detailed studies of the stratigraphy and sedimentology of the Phanerozoic rocks were begun during the 1975 field season by Reinson *et al.* (1976) as part of Operation Boothia (Kerr, 1976) but were confined mainly to the Silurian to Devonian Cape Storm-Peel Sound sequence of northern Somerset Island. At the end of 1975, Miall replaced Reinson and assumed responsibility for the stratigraphic studies. The work was extended to the entire Phanerozoic succession of Somerset Island and northern Boothia Peninsula and was completed during a 7-week field season in 1976. Detailed ground studies were carried out by Miall, while mapping and correlation work were performed mainly by Kerr.

University of Ottawa graduate students or ex-students S.R. Williams, J. Savelle, M. Gibling and G. Narbonne have contributed unpublished information which the writers gratefully acknowledge.

A summary of the surface stratigraphy is given in Table 22.1.

Lang River Formation

The name Lang River Formation was given by Dixon (1973a, b) to a variegated succession of thin- to thick-bedded dolomite, stromatolitic dolomite, intraformational breccia and conglomerate, and (particularly at the base of the formation) cross-bedded sandstone that rests on the Precambrian basement on both the east and west flanks of the Boothia Uplift. The formation corresponds approximately to map-unit 8 of Blackadar and Christie (1963). Christie (1973) subdivided this map-unit into two new formations using type sections on southern Boothia Peninsula, but he did not attempt to map their distributions and the writers have not found it possible to do so on Somerset Island or on northern Boothia Peninsula.

The Lang River succession is varied, and characterized by marked and largely unpredictable lateral facies changes. However, it is a useful mapping unit which can be distinguished readily from the overlying Irene Bay and Allen Bay formations, and the formation will be retained for mapping purposes.

Partial or complete sections were measured through the Lang River Formation at nine localities along the east flank of Boothia Uplift (Fig. 22.1, Locs. 1, 2, 3, 7, 8, 9, 11, 13, 15). Those near Creswell Bay (Locs. 7, 8, 9) and Hunting River (Loc. 13) are structurally disturbed and a compilation of complete sections will follow the analysis of the regional mapping by Kerr. Some modifications of Dixon's (1973a) detailed work in these areas will be necessary in light of our more complete mapping coverage.

Table 22.1

Phanerozoic stratigraphy of Somerset Island and Northeastern Boothia Peninsula

Age	Formation	Lithology	Thickness (Metres)
Cretaceous-Tertiary	Eureka Sound	Sandstone, siltstone, shale	300
Lower Devonian	Peel Sound 4.	Polymict conglomerate	120
	3.	Pebbly sandstone, conglomerate	240
	2.	Dolomitic conglomerate	280
	1.	Sandstone, siltstone	60-400
Upper Silurian-Lower Devonian	Unnamed 2.	Siltstone, shale, dolomite	150-300
	1.	Dolomite, limestone	0-130
Upper Silurian	Read Bay	Limestone, rubbly, argillaceous	150-240
Lower-Upper Silurian	Cape Storm	Dolomite, thin bedded	120-260
Silurian	Cape Crauford	Dolomite, evaporite	50+
Upper Ordovician-Lower Silurian	Allen Bay	Dolomite, medium- to thick-bedded	340-540
Upper Ordovician	Irene Bay	Limestone	0-97
Upper Cambrian-Upper Ordovician	Lang River	Dolomite, sandstone, shale intraformational breccia	200-420

From: Report of Activities, Part A;
Geol. Surv. Can., Paper 77-1A (1977).

It has not been possible to detect any patterns in the thickness or facies variations except possibly a tendency for a westward thinning toward Boothia Uplift north of Creswell Bay. There are several possible reasons for this variability: (1) A variety of distinct but closely interrelated depositional environments ranging from supratidal to shallow subtidal are probably represented by the Lang River sediments. (2) The Precambrian unconformity surface may have been marked by erosional relief. (3) It is possible that gentle movement took place on the Boothia Uplift during earliest Paleozoic time, causing facies and thickness changes transverse to the Uplift. (4) It has yet to be demonstrated that the Lang River is completely conformable internally. Biostratigraphic evidence from the formation is very sparse and several periods of time are not represented by the available fossils. This may (as suggested by Christie, 1973) or may not indicate the presence of disconformities within the basal Phanerozoic succession.

Some lithologic similarities exist between the Lang River and the three Cambrian to Middle Ordovician units in northwestern Baffin Island described by Trettin (1969). Mayr (in press) correlated the subsurface section in the Garnier O-21 well (Fig. 22.1) with Trettin's units, and it is anticipated that further work on the surface outcrops of western Somerset Island will extend these correlations. By contrast, there is virtually no similarity between the Lang River and the vastly thicker lower Paleozoic succession on Cornwallis Island to the north, which serves to emphasize the very different tectonic settings of Somerset and Cornwallis islands at this time.

Irene Bay Formation

The Irene Bay Formation consists mainly of limestone, commonly bioclastic, and characterized by a suite of large invertebrate fossils known as the Arctic Ordovician fauna. The formation is distributed widely throughout the Franklinian Miogeosyncline (Kerr, 1967) but its recognition on Somerset Island marks the first record of this distinctive unit within the Arctic Platform.

The Irene Bay was studied at four localities, at Lang River (Fig. 22.1, Loc. 3) and three sections near Creswell Bay (Locs. 8, 9, 11). The formation has a maximum thickness of 97 m at Lang River, where it was described, but not identified, by Dixon (1973a, b), but elsewhere is considerably thinner and in many localities is absent altogether. North of Creswell Bay the formation thins westward, perhaps reflecting movement on Boothia Uplift. Other thickness variations may be, in part, the result of pre-Allen Bay erosion.

Allen Bay Formation

Blackadar and Christie (1963) mapped a succession of "light-weathering, relatively competent dolomite, dolomitic sandstone, and minor sandstone containing Ordovician and probably Silurian fossils" which they termed map-unit 9. Christie (1973) assigned these rocks to the new Franklin Strait Formation, designating a type section on western Boothia Peninsula. Dixon (1973a, b) studied the same rocks on Somerset and Prince of Wales islands and used the earlier name Allen Bay Formation (Thorsteinsson and Fortier, 1954). The latter is a well-established formation throughout the Arctic Islands and there is no reason not to use the same name on Somerset Island.

The Allen Bay Formation is recognizable readily by its pale weathering colours and its resistance to erosion. Complete sections are difficult to obtain owing to structural complications near Boothia Uplift, but three were studied during the 1976 field season (Fig. 22.1, Locs. 2, 3, 16). Partial sections were examined at several other localities, particularaly near Creswell Bay (Fig. 22.1, Locs. 8, 9, 10).

As summarized by Dixon (1973b, p. 139), the Allen Bay Formation probably represents a time of stability over Boothia Uplift, and of widespread establishment of tidal carbonate mud flats with the development of stromatolites. Occasional deepening to shallow subtidal conditions is suggested by horizons containing corals, nautiloids and brachiopods.

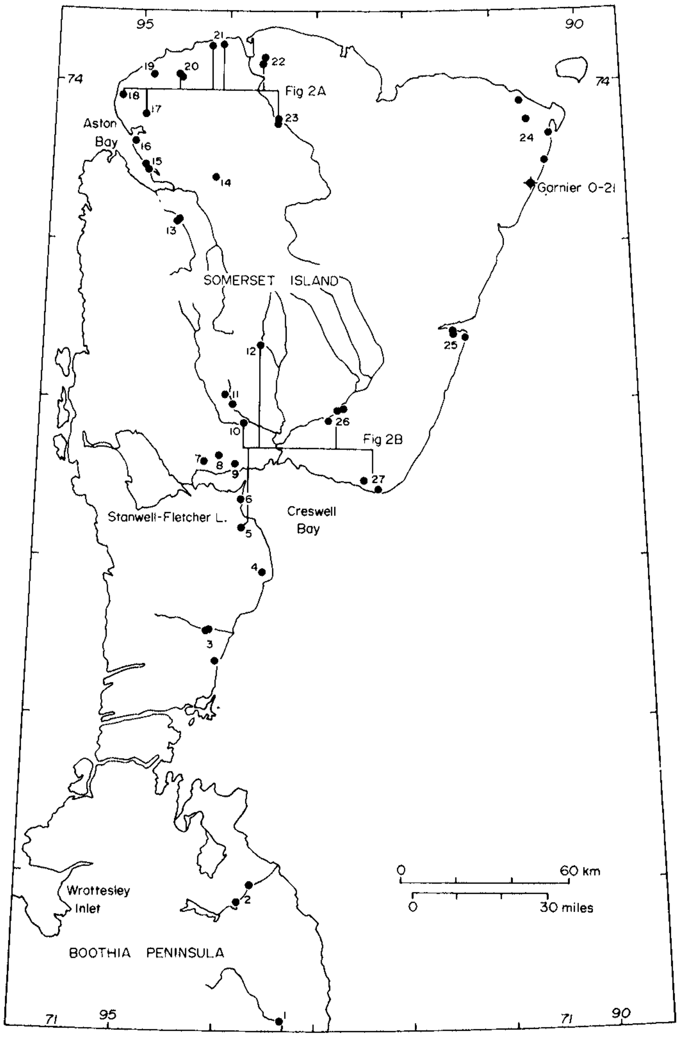

Figure 22.1. Location of the principal measured sections in the Phanerozoic rocks (including those studied by Reinson *et al.*, 1976).

Cape Crauford Formation

The Cape Crauford Formation was established in northwestern Baffin Island (Trettin, 1969) and is equivalent in age to the upper part of the Allen Bay Formation. It has been recognized in the Garnier O-21 well where it is 580 m in thickness (Mayr, in press), and the topmost beds are exposed along the east coast of Somerset Island between Port Leopold (Fig. 22.1, Loc. 24) and Batty Bay (Fig. 22.1, Loc. 25). The formation is distinguished from the Allen Bay by the presence of gypsum and a more varied succession of dolomitic rocks, including intraclast breccia, ripple-laminated stromatolitic and bioturbated units, and bioclastic dolarenite. The overlying Cape Storm Formation is very similar in lithology at Port Leopold except that it contains less gypsum, and the contact is drawn at the uppermost continuous evaporite bed as was done by Jones and Dixon (1975).

The Cape Crauford Formation probably represents a restricted, supratidal sabkha environment in part, and in part an intertidal environment with active tidal channels.

Cape Storm Formation

Blackadar and Christie (1963) recognized one map-unit (unit 11) between the pale weathering dolomites of the Allen Bay Formation and the red-weathering Peel Sound clastic rocks. The unit consists mainly of grey and greenish grey limestone and dolomite, and was correlated with the Read Bay Formation (Thorsteinsson and Fortier, 1954). Field work by S.R. Williams and J. Savelle of the University of Ottawa (unpublished data, 1968 to 1975) demonstrated that the lower part of map-unit 11 constitutes a separate, mappable formation, and Reinson *et al.* (1976) correlated it with the Cape Storm Formation (Kerr, 1975). Jones and Dixon (1975) carried out independent studies on the Silurian rocks of northern and northeastern Somerset Island and established a new unit, the Leopold Formation, which overlies the Cape Crauford Formation and which, on the basis of limited conodont and invertebrate evidence, was interpreted as a lateral equivalent of the Read Bay. Detailed mapping by Reinson *et al.* (1976) suggested that the Cape Storm and the Leopold are the same stratigraphic unit, and this was confirmed during the 1976 field season. Thickness and facies vary between eastern and western Somerset Island and possibly the unit is diachronous, but there is no need to treat these rocks as two formations. For the purposes of the present project the name Cape Storm will be used.

On eastern Somerset Island, the Cape Storm Formation consists mainly of laminated dolomite, sandy dolomite and minor limestone with intraclast breccia, ripple marks and stromatolites, and contains a limited fauna of gastropods, ostracodes and eurypterids. The formation differs from the Cape Crauford only in the absence of continuous evaporite beds. It grades up into the Read Bay Formation, such that the platy-weathering beds of the Cape Storm and the rubbly-weathering Read Bay limestones are interbedded over a vertical interval of up to 30 m. Several sections have been examined near Port Leopold (Loc. 24), the area studied in detail by Jones and Dixon (1975). Other sections were visited between Batty Bay (Loc. 25) and Fury Point (Loc. 27), and this area currently is being investigated in detail by G. Narbonne (University of Ottawa).

On western Somerset Island, partial or complete sections were examined by Kerr and Reinson in 1975 in the general area of Aston Bay (Locs. 14, 18) and by Miall in 1976 to the north and south of Creswell Bay (Locs. 2, 3, 10). Exposures in western Somerset Island contain shale and argillaceous dolomite, imparting a grey to greenish grey colour to the rocks, in contrast to the buff-brown colours of exposures in the eastern part of the island. The Cape Storm also is thinner near Boothia Uplift than farther east. The sedimentological and paleogeographical implications of these differences have yet to be analyzed.

Read Bay Formation

As discussed in the previous section, map-unit 11 of Blackadar and Christie (1963) has been redefined during the present project. The unit was correlated originally with the Read Bay Formation, but laminated dolomites forming the lower part of the unit now are assigned to the Cape Storm Formation, and similar rocks in the upper part of the map-unit are included now in a new, unnamed formation, described below. The Read Bay, as redefined for the purpose of this project, consists of a monotonous succession of rubbly-weathering argillaceous limestone, the weathering character reflecting the pervasive presence of oscillation ripple marks and bioturbation. Oolitic and bioclastic limestone are common. An abundant invertebrate fauna is present, as on Cornwallis Island (Thorsteinsson, 1958). Sections were measured at several localities along the east flank of Boothia Uplift by Reinson (Locs. 18, 23) and Miall (Locs. 2, 5, 6).

The Read Bay Formation represents open-marine, shallow subtidal conditions and is the only formation in the project area, other than the Allen Bay, that does not contain some clear evidence of the influence of Boothia Uplift on thickness or lithology. A general northward thickening is evident, from Aughterston River (Loc. 2) to Pressure Point (Loc. 18) but this probably reflects the northward tilt of the Arctic Platform toward the Franklinian Geosyncline.

Unnamed Formation

On Somerset Island there is a gradual upward transition from the Read Bay limestones into the Peel Sound sandstones and conglomerates. In earlier studies (Thorsteinsson and Tozer, 1963; Blackadar and Christie, 1963; Dineley, 1966; Brown *et al.*, 1969), the clastic units were included in the Peel Sound and the carbonates were assigned to either the Peel Sound or the Read Bay. The distinctiveness of the transition unit was recognized by all these workers, but none studied the island in sufficient detail to justify the introduction of a new formation. This has now been

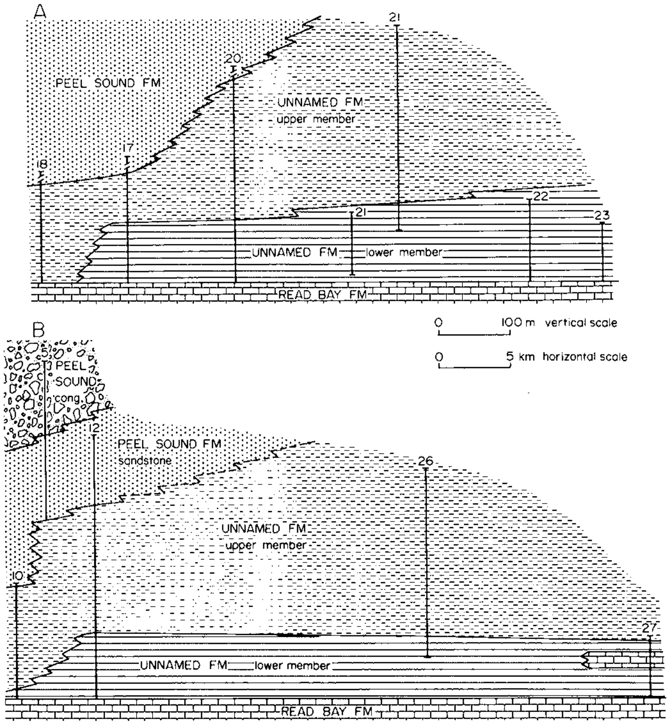

Figure 22.2. Stratigraphic relationships within the Peel Sound Formation and the unnamed formation. Lines of section are shown on Figure 22.1. The top of the Read Bay Formation is used as datum, although it cannot yet be demonstrated that the contact is a time plane.

done and a formal definition will shortly be proposed, in co-operation with M. Gibling (University of Ottawa), who has been working independently in the area since 1973.

The formation contains two members, which show a partial lateral facies transition into each other and into the overlying and underlying units. This relationship was documented by Gibling in 1973-1976 (unpublished data) and by Kerr and Reinson in 1975 (unpublished data) in northern Somerset Island (Locs. 17, 18, 20, 23). Additional information was obtained by Miall in this area (Locs. 21, 22) and the same relationships were established by Miall in southern Somerset Island in 1976 (Locs. 4, 10, 12, 26, 27). At the same time, the facies transitions were traced between the detailed sections by Kerr, using aerial photograph interpretation and helicopter traverses.

The stratigraphic relationships of the unnamed formation are shown in Figure 22.2. The facies changes demonstrate a gradual eastward encroachment of progressively more continental environments into the Read Bay sea. The lower member of the unnamed formation consists of platy weathering, laminated, grey or buff dolomite with a limited fauna of ostracodes, gastropods and rare brachiopods. Vertebrates are abundant in some outcrops. Bioclastic limestone, some beds containing oncolites or stromatoporoids, and stromatolitic dolomite, are present in sections on the east side of Creswell Syncline (Loc. 26). At Fury Point (Loc. 27), the lower member contains several beds of rubbly limestone indistinguishable from those of the Read Bay, suggesting a lateral as well as a vertical gradation into that formation. The same lateral transition into the Read Bay also has been mapped in much of northern Somerset Island and, east of Location 23, rubbly limestone predominates over laminated dolomite. The lower member is interpreted as being predominantly intertidal in origin. Bioclastic limestone units generally have scoured bases, and probably represent tidal channels or storm deposits. They normally grade up into laminated dolomites, suggesting an encroachment of tidal carbonate mud flat conditions.

The upper member of the unnamed formation is characterized by the presence of dolomitic siltstone and mudstone with a purple, red or green colour. The lithologies of the lower member also are present, with the exception of the Read Bay-type subtidal marine limestones. The clastic units contain abundant desiccation features, rare halite casts and gypsum nodules, and are interpreted as the product of fluvial, sheet-flood sedimentation on a supratidal flat, probably under arid or semi-arid conditions. Data from numerous sections have been subjected to Markov chain analysis (method described by Miall, 1973) to test for cyclicity; results are given in Figure 22.3. The succession is dominated by a carbonate-clastic cycle ranging from 2 to 10 m thickness. Laminated dolomite units with flat or scoured bases (Cl) grading up into mottled siltstone (Fl), constitute the commonest cyclic type. The cycles are interpreted as representing a regressive process, intertidal carbonate mud flat conditions being replaced upward by a supratidal alluvial flat environment as fluvial sheet floods caused an eastward progradation of the terrigenous sediments. The cycles commonly are capped by purple silty mudstone (Fm), which probably represents the deposits of ephemeral lagoons or playa lakes. Stromatolite beds (Cs) occur near the top of the dolomite units in some cycles and probably represent a high intertidal environment. Some cycles begin with a thin unit of bioclastic limestone (Cb), which invariably rests on a scoured base. In Figure 23.3, the upward transition from Cb to Cl is shown as occurring with greater than random frequency, but no transition into Cb is indicated. This implies that the occurrence of facies Cb is a random event, probably representing the erosion of the tidal flats or the cutting of a new tidal channel during a storm or exceptional high tide. Once the unusual event passed, however, the evolutionary, regressive sequence of events became re-established. Tidal range may be approximately equal to the thickness of the dolomite units, which averages 2.7 m. Individual cycles may have considerable lateral persistence; one dolomite unit has been traced for more than 20 km near East Creswell River.

As shown in Figure 22.2, the intertidal to supratidal conditions represented by the upper member appeared first in the west and gradually spread eastward over much of the area that is now Somerset Island. The sediment source presumably was Boothia Uplift, as indicated by the nature and direction of the facies changes. The relief of the uplift cannot have been great, however, for even in the westernmost exposures of the formation clastic material rarely is coarser than silt grade.

Peel Sound Formation

The unnamed formation passes laterally into, and is overlain by, red-weathering sandstone and conglomerate of the Peel Sound Formation (Fig. 22.2). In the original definition of the formation (Thorsteinsson and Tozer, 1963), the base was placed at the first red clastic unit, but the writers have redefined the Peel Sound so that the base lies at the first appearance of red sandstone. An underlying succession of interbedded dolomite and red siltstone is reassigned to the unnamed formation (described above). Dineley (1966) and Brown *et al.* (1969) recognized four members within the Peel Sound Formation. The lowermost unit has been redefined to coincide with the redefinition of the Peel Sound Formation, but the remaining members have not been modified by the writers. Their thicknesses and lithologies are given in Table 22.1 and are described below.

The Peel Sound Formation is well exposed in northwestern Somerset Island, and smaller areas of outcrop are present north and west of Creswell Bay. Detailed sections were measured at Localities 5, 12, 19 and 20, and the four members of the formation were mapped in the Cape Anne-Pressure Point area for the first time (Fig. 22.4).

The lowermost member of the Peel Sound (Dp1) is a succession of red sandstone and siltstone containing an abundance of trough and planar cross-bedding, parting lineation and ripple marks. Vertebrate remains are common. A study of the successions using Markov chain analysis reveals a variety of cyclic types, all of which are characterized by an upward decrease in grain size from sandstone to siltstone and an upward decrease in size of sedimentary structures. Virtually all cycles begin with a scoured base. Cycle thicknesses range up to approximately 8 m but 1 to 2 m is typical. The sediments are interpreted as the deposits of a braided river system, each cycle representing either lateral channel migration and bar accretion, or vertical channel aggradation. Most of the sedimentation took place by ripple and dune development in small, shallow channels; cycle thickness probably corresponds closely to channel depth. Paleocurrent determinations in these rocks (165 paleocurrent readings) indicate transport directions away from Boothia Uplift towards the southeast, east or northeast.

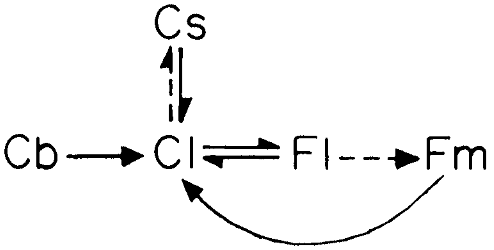

Figure 22.3. Transition path diagram, upper member of the unnamed formation, constructed from the Markov difference matrix (Miall, 1973). Principal transition paths are shown by solid arrows, less common paths by dashed arrows. Facies codes are explained in the text. Only those transitions which occur with a greater than random frequency are shown.

Member 2 of the Peel Sound is present only in northern Somerset Island. It is an oligomict conglomerate, consisting of dolmicrite clasts in a matrix of carbonate and quartz sand. Maximum clast size is 23 cm. Brown *et al.* (1969) recorded the presence of fossils derived from the Allen Bay Formation in some of the clasts and this formation, plus the Lang River, probably formed the main sediment source. The conglomerate is thought to represent the deposits of subaerial alluvial fans that prograded eastward from the rising Boothia Uplift. It disappears eastward in an abrupt lateral facies change into members 1 and 3 of the Peel Sound (Fig. 22.4).

Member 3 consists of medium- to very coarse-sandstone, pebbly sandstone and thin conglomerate beds. Clasts are more varied in type than in Member 2, and include Precambrian gneiss, quartzite from the Aston Formation (Proterozoic) and carbonate sediments from the Hunting Formation (Proterozoic) and the lower Paleozoic rocks. Planar and trough cross-beds are common, and occur in sets ranging up to 40 cm thick. In northern Somerset Island, where the member reaches its thickest development (it has not been separately mapped in the Creswell Bay region), paleocurrent determinations indicate northeast to northwest transport directions.

In the vicinity of Locality 19, Member 3 includes several units characterized by very large scale planar cross-beds, ranging up to 6 m in thickness (some of the outcrops of these units were very kindly shown to Miall by M. Gibling). These consist of well-sorted, finely laminated, pebble-free, sandstone, in which grain size ranges up to very coarse sand. Angular grains up to 2 mm in diameter were recorded in a few laminae. The orientation of these structures is different from that of the smaller scale cross-beds in the Peel Sound; transport directions range between north and west, with a mean of northwest. The structures are interpreted as the deposits of large dunes or sand waves that formed in deep fluvial channels, similar to those described in the Brahmaputra River by Coleman (1969). They probably represent the deposits of trunk streams flowing more or less parallel to the structural and depositional strike, as do many large modern rivers such as the Ganges, Indus, and Mackenzie. The interbedded, pebbly sands with smaller scale cross-beds presumably represent the deposits of tributary streams flowing perpendicular to depositional strike. The paleogeographic implications of this interpretation are that the eastern part of the Somerset Island area may have become land by the time Member 3 was deposited, and that somewhere north of Somerset

Island, where north-flowing trunk streams must have debouched into the sea, a large delta system may have developed. No traces of such a delta have yet been identified, although a unit such as the Bathurst Island Formation (Kerr and Christie, 1965; Kerr, 1974) is a possible candidate. Subsurface work by U. Mayr (pers. comm., 1976) shows that the formation is unusually thick (> 2000 m) in southeastern Bathurst Island, and that it could represent a distal delta facies.

Member 4 of the Peel Sound Formation is present in northern Somerset Island (Fig. 22.4) and to the west of Creswell Bay (Loc. 5). It consists of polymict conglomerate (clast types as in Member 3) and thin beds of red sandstone. Clasts reach 30 cm in diameter. The mode of origin of these rocks probably was very similar to that of Member 2, but continued erosion on the Boothia Uplift caused the stripping away of the Phanerozoic cover and the derivation of abundant detritus from the crystalline Precambrian basement. Several small outliers of the Peel Sound Formation, a few miles to the west of Stanwell Fletcher Lake, probably date from this period. The rocks of the outliers consist of immature, poorly sorted, purple and red, pebbly and silty sandstone and siltstone resting in hollows within the rugged metamorphic terrain. Sparse cross-bedding evidence indicates

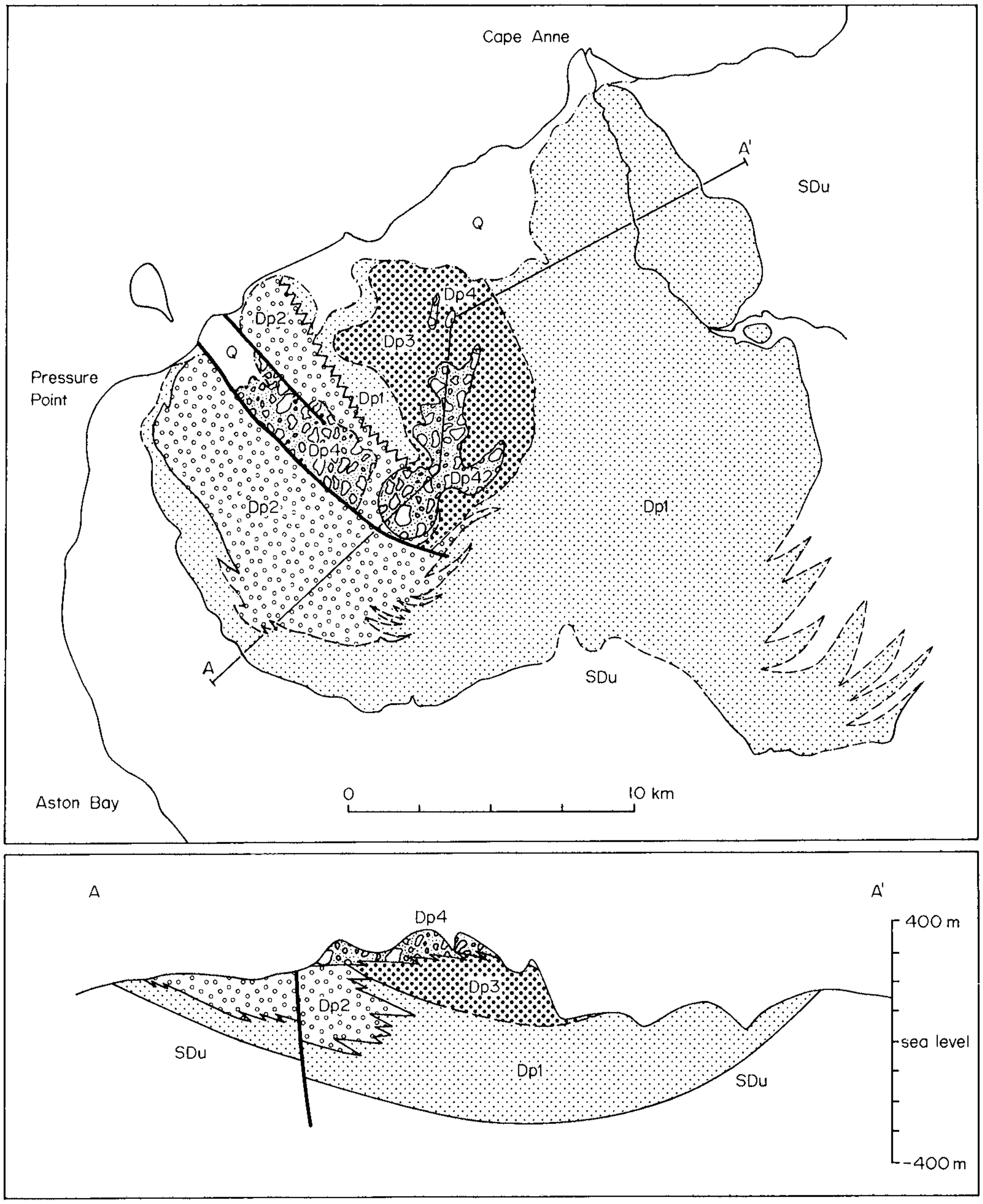

Figure 22.4.

Map and cross-section of the Cape Anne-Syncline area of northwest Somerset Island, showing facies relationships within the Peel Sound Formation. The members are numbered as in Table 22.1.

Dp: Peel Sound Formation
SDu: unnamed formation
Q: Quaternary

northward transport directions corresponding, no doubt, only to the local variation in direction of one of the eastward-flowing rivers that emptied onto the Somerset Island alluvial plain.

The base of Member 4 cuts down into younger rocks of the Peel Sound toward the west and, between Localities 17 and 19, rests directly on Member 2 (Fig. 22.4). The cause of this minor unconformity probably was uplift taking place to the west during deposition of Members 3 and 4 to the east. A similar type of syndepositional structure was described by Miall (1970) in the Peel Sound of Prince of Wales Island, and such structures appear to be common in areas of coarse clastic sedimentation adjacent to rapidly rising areas (Bryhni and Skjerlie, 1975; Riba, 1976).

Other aspects of Peel Sound sedimentation are currently under study by M. Gibling (University of Ottawa), including the depositional processes and clast fabric of the conglomerates and, in co-operation with D. Elliott (University of Bristol), the ecology of the vertebrates, which reach their greatest abundance in Member 1 of the formation.

Cretaceous-Tertiary Sediments

Numerous fault-bounded outliers of Cretaceous-Tertiary sediments are present in Somerset Island. Most are small in areal extent, such as those near Cunningham Inlet (Hopkins, 1971) and north of Creswell Bay (Dixon *et al.*, 1973). Larger outliers are present north of Stanwell Fletcher Lake (Dineley and Rust, 1968) and east of Wrottesley Inlet (discovered in 1976). The sediments near Creswell Bay correspond in age and lithology to the marine Kanguk Formation (Upper Cretaceous), but most are largely nonmarine and are assigned to the Eureka Sound Formation.

The rocks occupying the graben north of Stanwell Fletcher Lake consist of a succession of sandstone, siltstone, shale and conglomerate, named the Idlorak Formation by Dineley and Rust (1968). The formation contains marine fossils at the base, but passes up into a thick succession of cross-bedded sandstone and minor conglomerate containing only derived fossil material. Dineley and Rust (1968) interpreted the Idlorak as deltaic in origin. An examination of the sandstone by Miall suggested a close analogy with certain modern braided river environments dominated by dunes and linguoid or transverse bars. The complete succession, therefore, represents a regressive sequence.

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