

THE SEDIMENTARY HISTORY OF THE
PEEL SOUND FORMATION, PRINCE OF WALES ISLAND,
NORTHWEST TERRITORIES

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by
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ABSTRACT

The continental and marine sediments underlying most of Prince of Wales and adjacent islands were termed the Peel Sound Formation by Blackadar and Christie (1963). They are upturned against the Boothia Uplift in the Cornwallis Fold Belt, a north-south axis along the eastern margin of the island.

In this study the formation has been divided into Upper and Lower parts. The Lower Peel Sound (Lower Devonian, up to 600 feet thick) consists of limestones, sandstones and shales transitional from the underlying Read Bay Formation (Silurian), and is exposed along the Cornwallis Fold Belt. The transition is found at all localities except near the north end of the island where Peel Sound beds rest with angular unconformity on the Read Bay.

The Upper Peel Sound Formation comprises five distinct facies which are in part lateral equivalents and form a series of north-south belts across the island. They are, in westward order: the Conglomerate, Conglomerate-Sandstone, Sandstone, Sandstone-Carbonate and Carbonate Facies. The conglomerates (up to approximately 1000 feet thick) overlie the Lower Peel Sound in the Cornwallis Fold Belt, but the bases of the other facies successions are not exposed. Fossils from the Sandstone-Carbonate and the Carbonate Facies have been dated as mainly Lower-Middle Devonian.

The clastic rocks of the Peel Sound Formation were formed

as a result of uplift along the Boothia axis, which began to rise in earliest Devonian times causing deposition of littoral sands in the predominantly marine carbonate Lower Peel Sound succession. The base of the Peel Sound is drawn at the first conglomerate or redbed unit. Continuing uplift formed a major landmass, and clastic sediments derived therefrom were deposited as fluvial sands and alluvial fan wedges interbedded with marine and marginal marine sediments.

Orogenic uplift reached a peak at the beginning of Upper Peel Sound (mid-Lower Devonian) times. The volume and grain size of clastic detritus increased sharply; a wide alluvial plain developed alongside the Boothia Uplift, and the coastline receded 12-28 miles (19-45km) to the west. In the east, along the mountain front, coarse conglomerates were deposited. Outlines of some of the fans have been drawn from maps of clast distribution and size variations, and the conglomerates are interpreted as debris flood deposits. Clast types are all from Paleozoic and Proterozoic rocks of the Boothia Uplift area.

Fan deposits wedge out westwards into the Conglomerate-Sandstone Facies. Debris flood conglomerates were replaced by sands and silts deposited by braided streams. Fining upward cycles were formed by channel migration and infill. Sedimentary structures suggest a low stream sinuosity.

In the Sandstone Facies streams were probably of high sinuosity, but some horizontally bedded sandstones are

thought to have been formed by sheet-like floods that overrode stream channels and reached upper regime (planar bed) flow.

Red fluvial deposits are present up to approximately 28 miles (45km) from the Boothia Uplift. In the area of the Sandstone-Carbonate Facies rivers built short-lived deltas 5-10 miles (8-16km) into the sea. Their deposits are inter-bedded with carbonates and shales interpreted from lithologic and faunal evidence as marine and estuarine in origin. Sandstone-shale sequences were probably formed in coastal barrier complexes. These conclusions are based on comparisons with sediments of modern coastal regions, particularly the Mississippi Delta area.

The carbonate rocks are mainly dolomite, the origin of which is uncertain. The marine carbonates were probably laid down in a very quiet, shallow sea.

Uplift along the Boothia axis probably slowed down or ceased during the late Peel Sound times. The post-Middle Devonian history of the area is unknown.

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Geological map and cross section in envelope at end of thesis.

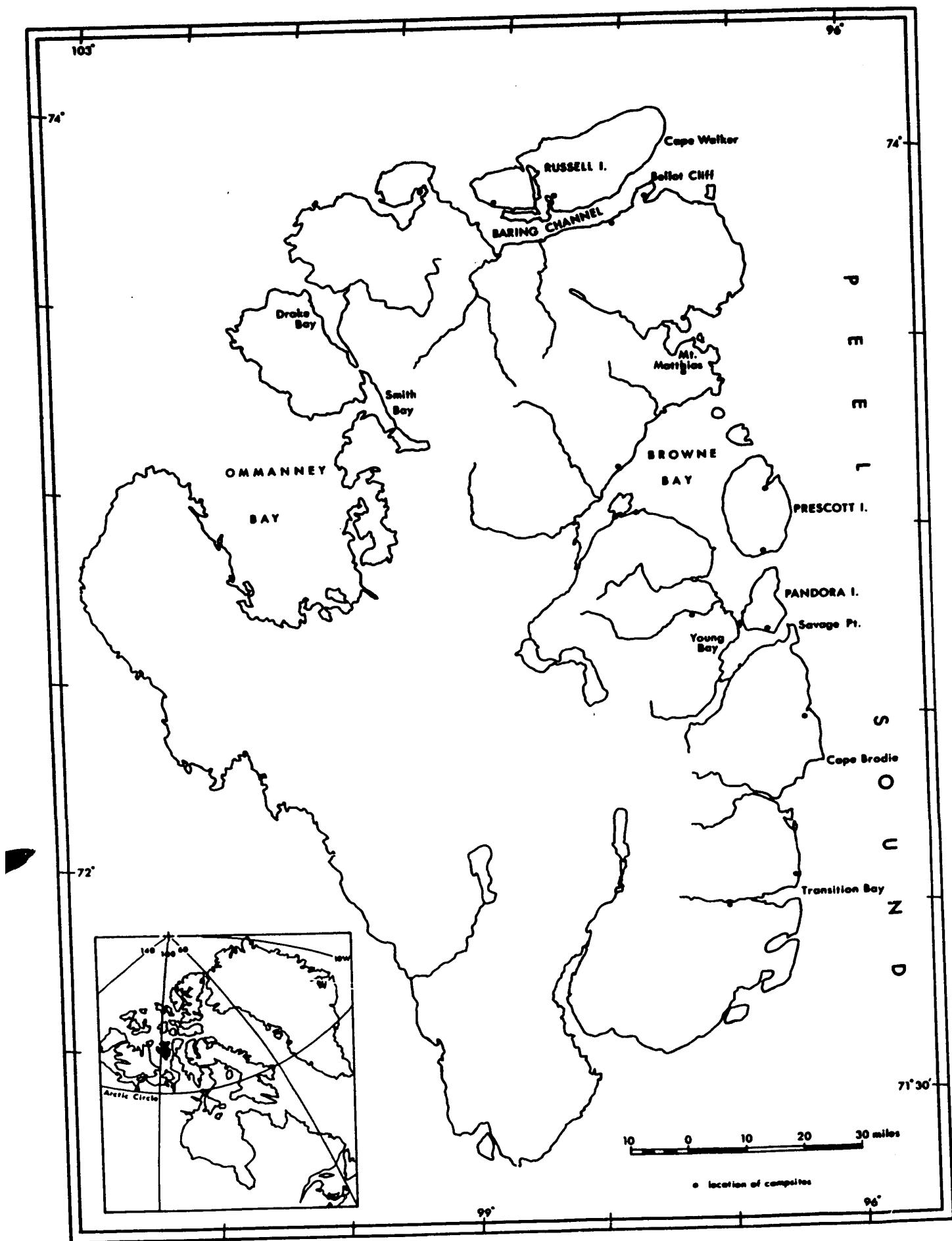


Fig. 1. Location map: Prince of Wales Island

I. INTRODUCTION

1) The University of Ottawa Group work.

In the summer of 1964 a small group from the Department of Geology, University of Ottawa began field work on Somerset Island, Northwest Territories (see fig. 2), under the leadership of Dr. D. L. Dineley. The general purpose was the study of the Boothia Uplift and its influence on the regional geology. Research continued in 1965, and in 1966 it was decided to extend the work west of the Uplift into Prince of Wales Island. This thesis presents the results of part of that work, carried out during the summer field seasons of 1966 and 1967.

2) Access

Prince of Wales Island forms part of the Canadian High Arctic, located between 71° and 74° N, and between 96° and 103° W (see fig. 1). The island is totally uninhabited, and lacks both permanently established means of access and land routes within it. However, the meteorological station and communications base at Resolute Bay, Cornwallis Island (maintained by the Department of Transport), lies 70 miles northeast of the northernmost tip of Prince of Wales Island. Resolute Bay is served during the summer by a twice-weekly flight from Montreal, operated by Nordair using Super-Constellation or DC4 aircraft. Movement beyond Resolute,

during both field seasons, was dependant upon aircraft chartered from Atlas Aviation Limited, normally a Beaver or single-engined Otter. These were equipped with ski landing gear during the early part of the season and with balloon tires from June onwards, thus permitting considerable freedom to land upon unprepared tundra. These aircraft, based at Resolute, were used for most camp moves, and were called up by radio when required.

Local travel was carried out using skis and a 1966 model 'Snow Cruiser' until the summer melt, after which time travelling by foot was necessary. The 'Snow Cruiser' proved particularly useful in visiting scattered out-crops early in the season and in establishing short-term camps; on one occasion forty miles were covered in a single day. A total of fourteen working campsites were established on the island during the two seasons, using mainly air transportation.

Standard vertical air-photos at a scale of approximately $1\frac{1}{4}$ inches to the mile were used at all times for location and geological mapping. They were obtained from the Department of Energy, Mines and Resources Air Photo Library, in Ottawa.

The author was always accompanied by a field assistant, both for physical and moral support, and for reasons of safety.

3) Topography and exposure

The Peel Sound Formation occupies the whole of Prince of Wales Island (and smaller adjacent islands) except for a narrow strip of land along the east coast. The area of outcrop extends nearly 200 miles from north to south, and at its widest point is 130 miles from east to west. More than half this area is of low relief, much of it covered in glacial drift, and exposure is poor or non-existent. Within a belt about fifteen miles from Peel Sound and extending the whole north-south length of the island, the relief is much greater; in several places the land rises to over 1000 feet above sea level. Exposure here is considerably better, but is still almost entirely limited, as elsewhere, to outcrops in river gorges.

Most of the land surface is covered with felsenmeer, there being no continuous vegetation cover. Ground colouration, therefore, closely reflects the underlying geology. Colour and surface texture can be assessed from the air and interpreted from air photos, and both methods are very useful during reconnaissance, and for extrapolating ground observations into unexposed or inaccessible areas. Stone polygons and stone stripes are very common, but observations suggest that mass movement by solifluction has rarely carried material far from its bedrock source.

The hydrographic chart of northeastern Prince of Wales

Island (Canadian Hydrographic Service, chart 7056) shows that Barrow Strait adjacent to the north end of the island is a gently sloping shelf, continuing offshore the gentle relief of the land to a depth of about 400 feet. Peel Sound is adjacent to the higher and more rugged eastern segment of the island, and plunges to a depth of over 1200 feet off Pandora Island. This is a reflection of the structural geology of the region, which will be discussed in a later section.

4) Previous work

No work published before the 1960's deals systematically with the geology of Prince of Wales Island. Prior to 1955, when the Geological Survey of Canada staged a major geological reconnaissance programme in the Arctic Archipelago, knowledge of the geology of the area consisted of little more than isolated observations made during some of the earlier voyages of geographical exploration, details of which are given in many Geological Survey of Canada publications (eg. Fortier *et al.* 1963; Blackadar and Christie 1963; Blackadar 1967.)

Gregory, Bower, and Morley (1961) published the findings of an airborne magnetic and radiometric survey over the Arctic Islands; three of their profiles crossed Prince of Wales Island. Redbeds were known to occur in the eastern part of the Island, and on the basis of their slightly higher than average content of radioactive elements the authors suggested that these beds extended some miles to the west, across the

unknown interior of the area. They also calculated that the depth to the Precambrian basement is between five and ten thousand feet in the southeast part of the island and probably more than ten thousand feet beneath the rest of the area.

As a result of the Operation Franklin fieldwork (see Thorsteinsson and Tozer, in Fortier, *et al.*, 1963, p.121-126) a type section was described in the Cape Anne area of northern Somerset Island (see fig. 2) and the name Peel Sound Formation was applied for the first time. Work in the Prince of Wales area extended no further south than Pandora Island. The possibility of facies changes was first tentatively suggested, and the beds were assigned an early Devonian age on the basis of meagre vertebrate and brachiopod collections.

In 1962 Prince of Wales, Somerset and King William Islands, plus the Boothia Peninsula, were studied by a second major reconnaissance expedition of the Geological Survey of Canada, which had the title 'Operation Prince of Wales'. This work has been largely responsible for the following series of publications:

Blackadar and Christie (1963): This paper was a preliminary report and included the first complete geological map of the area, on a scale of one inch to eight miles. Three facies of the Peel Sound Formation were clearly distinguished and were assumed to be time equivalents, though no supporting evidence was brought forward.

Kerr and Christie (1965) interpreted the structural history of the area in terms of a major tectonic feature which they called the Boothia Uplift. They suggested that the contact of the Paleozoic rocks with the Precambrian in Prince of Wales Island is one of steep reversed faulting, but only in one locality has such a fault been mapped. They also make the first mention in print of an unconformable contact between the Peel Sound and the underlying Read Bay Formation (McNair and Ormiston, personal communication to K. and C.) The Peel Sound clastic facies are described as comprising 'deltaic, alluvial fan and piedmont deposits', but no descriptive evidence is presented for this interpretation.

Blackadar (1967) described the Precambrian geology of the Boothia Uplift. Descriptive details are given for many rock types which are found as clasts in the Peel Sound conglomerates.

Ormiston (1967) assigned a Lower and/or Middle Devonian age to some trilobites collected from Drake Bay in northwestern Prince of Wales Island. (fig. 1).

Work on the Peel Sound Formation of Somerset Island has been carried out by other members of the University of Ottawa group. Preliminary reports have been published by Dineley (1965, 1966), and Broad, Dineley, and Miall (1968). At present Broad and Dineley are studying some very rich

vertebrate fossil collections taken from the Peel Sound Formation of Prince of Wales Island.

5) Purpose of present study

In general terms the aims of this study may be listed as follows:-

- a) To establish and describe the major facies belts suggested by reconnaissance work, and to determine their stratigraphic relations to each other.
- b) To investigate in detail the sedimentology of these facies types and their minor variations.
- c) To establish and describe the Lower Devonian history and paleogeography of the region.

6) Acknowledgements

Field work for this project was supported by grants from the National Research Council (Grant no. A-2672), the Geological Survey of Canada (Grant no. 34-66) and the Department of Indian Affairs and Northern Development. Thanks are due to J. C. Sproule and Associates Limited for considerable expediting assistance at Resolute Bay, and to Outboard Marine (Canada) Limited for the loan of a 'Snowcruiser' for the two field seasons.

Assistance from several members of the Geological Survey of Canada is warmly acknowledged: T. E. Bolton and M. J. Copeland identified the invertebrate faunas, and

R. L. Christie kindly donated lithologic specimens of carbonate rocks collected during Operation Prince of Wales.

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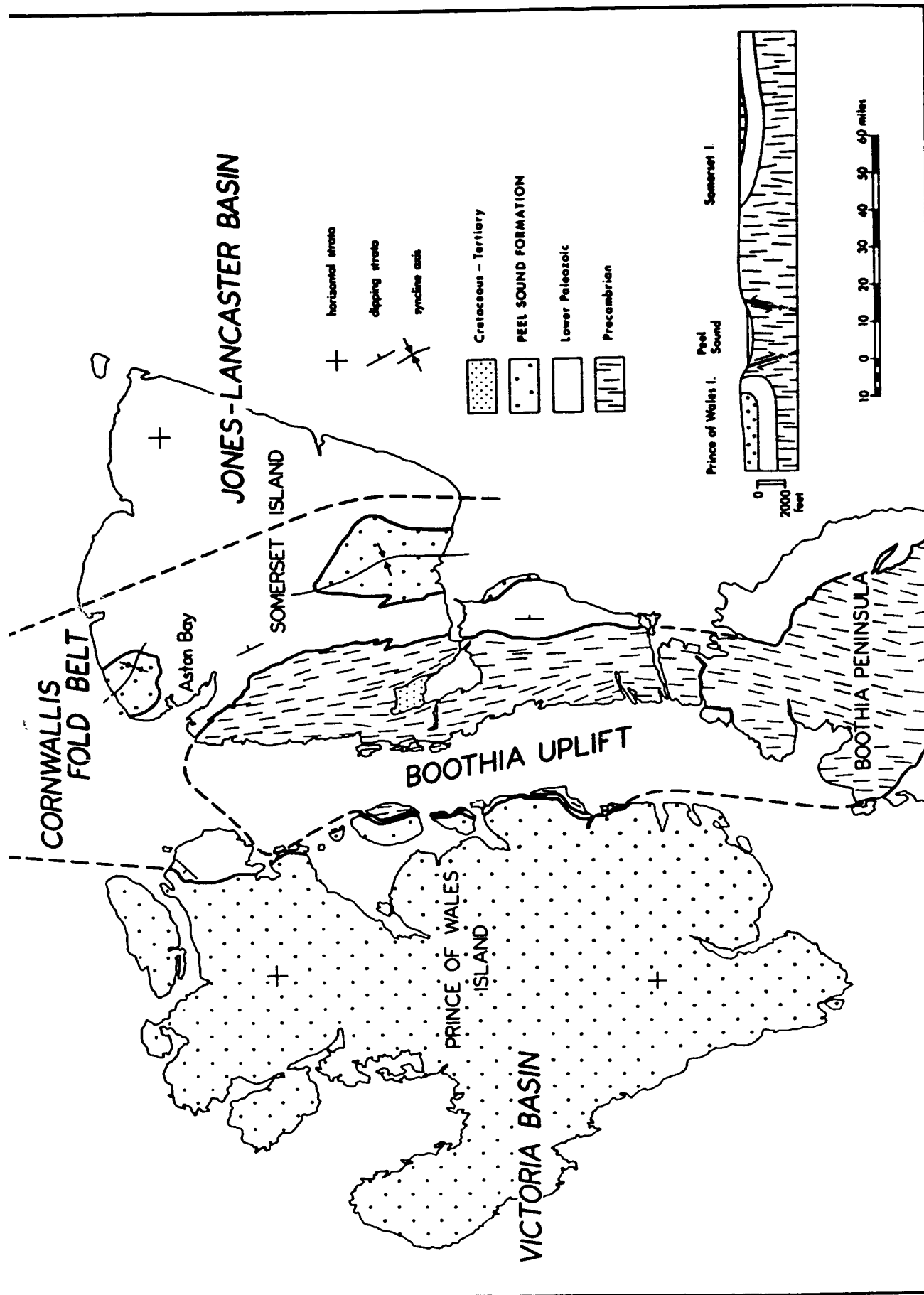


Fig. 2. Somerset - Prince of Wales Islands: regional geology

II. REGIONAL GEOLOGIC SETTING

1) Stratigraphy

Metamorphic rocks of Proterozoic age form the local basement. They are exposed in an elongated area, extending from northwest Somerset Island and Mount Matthias on Prince of Wales Island, southwards to the Boothia Peninsula (see fig. 2) and beyond to where the Precambrian rocks merge with those of the shield. The metamorphics occupy the whole of western Somerset Island and also a narrow strip of eastern Prince of Wales Island, parallel to Peel Sound and nowhere more than four miles wide. The rock types include very variable mafic and felsic gneisses and schists, plus small granite and ultrabasic bodies. Blackadar (1967) has shown that the geology of the basement is very complex.

Proterozoic and/or Cambrian sedimentary rocks outcrop on northwest Somerset Island, in the vicinity of Aston Bay (see fig. 2). The type areas of the Aston and Hunting Formations are located here (see Fortier *et al.*, 1963, p.146; more fully described by Tuke, Dineley, and Rust, 1966). The same rocks outcrop on Prescott Island, (see Blackadar and Christie, 1963) on Pandora Island and near Cape Brodie (the last two outcrops were discovered by the author, see Appendix IV.). Like the underlying metamorphics these rocks are important to the present study for they occur

abundantly as clasts in the Peel Sound Formation. The Aston Formation consists mainly of pink, green and white quartz sandstones (elsewhere referred to as quartzites, as they are highly indurated and contain more than 95% quartz and chert). There are also minor red shales and a basal conglomerate or breccia containing clasts of the underlying metamorphics. The Hunting Formation is predominantly dolomitic, and includes beds of a very distinctive intraformational breccia, stromatolites and nodular chert. The maximum thicknesses of the Aston and Hunting Formations are 800m and 2,250m respectively (Tuke, *et al.*, 1966, p.701, 702).

The Lower Paleozoic succession includes unnamed Cambrian sandstones and dolomites, Ordovician dolomites which have been correlated with the Cornwallis and Allen Bay Formations (Blackadar and Christie, 1963, p.10), and Silurian marine limestones of the Read Bay Formation. Cambrian beds have not yet been identified in Prince of Wales Island, whereas the Read Bay and Allen Bay Formations form a continuous outcrop along the east side of the island, everywhere underlying the Peel Sound Formation. At Young Bay the Allen Bay and Read Bay Formations have been measured at 2470 feet (741m) and 850 feet (255m), respectively (Christie, 1967).

The Peel Sound Formation is the youngest formation on

Prince of Wales Island. It overlies the Read Bay with, nearly everywhere, an apparently conformable, gradational contact. Nothing can be stated with any degree of certainty about the later geological history of the area until Pleistocene times, when glaciation left its mark.

2) Structure

The geology of the Boothia Peninsula - Somerset Island - Prince of Wales Island area is controlled by three tectonic elements which are described briefly below.

The Boothia Arch or Uplift: This is an axis along which predominantly positive movement has taken place; its outcrop corresponds to the outcrop of the Proterozoic metamorphic rocks (Blackadar and Christie, 1963, p.5. See fig. 2). There is a pronounced north-south trend to the rocks, parallel to the outline of the Uplift.

The Cornwallis Fold Belt: This tectonic zone everywhere flanks the Boothia Uplift. It resulted from upward movement of the latter during Paleozoic times, and the strata are steeply tilted, faulted, and in places overturned. In Prince of Wales Island the Cornwallis Fold Belt is everywhere less than a mile wide, but on Somerset Island it is several miles wide and the folds are much larger and more open in style (See photographs 1 and 2).

At the north end of Peel Sound the Proterozoic rocks

dip beneath the Paleozoics, but the Cornwallis Fold Belt continues approximately 200 miles (320km) to the north (into Cornwallis Island) and represents the influence of a buried extension of the Boothia Uplift.

The undeformed basins: The Paleozoic strata continue outwards from the Fold Belt into the 'Arctic Lowlands' portion of Somerset and Prince of Wales Islands. Here, where they are flat lying or only very gently deformed, they form part of two of the large intracratonic basins that border the Canadian shield. East of the Boothia Uplift lies the Jones-Lancaster Basin and to the west lies the Victoria Straits-Melville Basin (see fig. 2). Gregory, Bower, and Morley (1961) estimate that there may be more than 10,000 feet of sediment overlying the basement in these areas.

The lack of structural complication has considerably simplified the task of building up stratigraphic and paleogeographic reconstructions of the formation under study, in spite of the large area of outcrop and the comparative paucity of exposure.

III. STRATIGRAPHY

1) Introduction

The reconnaissance mapping by Blackadar and Christie (1963) suggested a threefold subdivision of the Peel Sound Formation:

- a) Conglomerates
- b) Sandstones
- c) Carbonates

The three subdivisions were interpreted as probably facies variations, at least in part time-equivalent, but, as in all the other papers, eg. Kerr and Christie (1965), very little evidence was presented for the stratigraphic and sedimentologic interpretations which the authors made. In this section evidence is given that permits a much more detailed and satisfactory description and interpretation of the stratigraphy to be made for the Prince of Wales area.

The term 'facies' will be used here in the broad, purely descriptive sense. Its use is intended to differentiate areally distinct parts of the Peel Sound Formation in which vertical sections contain very distinctive assemblages of rock types. This is the usage preferred by Moore (1949) and corresponds to the 'facies sequence' of Teichert (1958), the 'consanguinous association' of Pettijohn (1957) as modified by Fairbridge (1958), and the 'stratigraphic facies' of Weller (1960). The term 'facies' has been employed elsewhere

(Teichert, 1958; Williams, 1968) to describe individual lithologic types, but it is thought that such a narrow meaning should be avoided. For individual members of a vertical succession the term 'lithofacies' (Moore, 1949; Weller, 1960) may be used.

2) The Lower Peel Sound Formation

The lowest parts of the formation are only exposed in the Cornwallis Fold Belt, where they are tilted up against the older rocks. Seven sections have been visited on Prince of Wales and adjacent minor islands.

The thick limestones of the Read Bay Formation nearly everywhere pass up into a thick series of argillaceous limestones, shales, sandstones and pebble conglomerates. The base of the Peel Sound Formation is purely arbitrary, being drawn at the appearance of the first important clastic horizon. This may be a red sandstone unit, as in the original definition of the formation (Fortier, *et al.*, 1963, p. 121-126), or a thin pebble conglomerate. The succession of variegated lithologies comprising the Lower Peel Sound reaches a thickness of at least 600 feet (180m). Its upper limit is defined by the passage into the overlying thick and massive cobble and boulder conglomerates of the Upper Peel Sound Formation.

No accurate dates have yet been assigned to the Lower Peel Sound beds except for the section seven miles north of

Transition Bay, where the vertebrate fauna has been studied by Broad (1968). He states that the basal Peel Sound Formation is of Lower Devonian age and that the Read Bay-Peel Sound contact approximates to the Siluro-Devonian boundary. The remainder of the sections along this 120 miles (190km) of outcrop cannot yet be accurately correlated on a time basis. However, broad correlation seems reasonable, on a basis of general stratigraphic position and lithologic similarity. At the north end of the Island, seven miles (11.2km) due south of Bellot Cliff (grid reference NS403900), the Read Bay-Peel Sound contact is unconformable, with an angular discordance of over 20° . This is the only locality at which such a relationship has been proved (discovered by McNair and Ormiston, see Kerr and Christie, 1965, p.910). The local overstep at southern Prescott Island, suggested by Blackadar and Christie on their 1963 map, was not confirmed on examination in the field by the author.

Details of these sections are given in fig. 6 and their significance is discussed under 'Structure' and 'History and Paleogeography'. See also photographs 4, 5.

3) The Upper Peel Sound Formation

a) Conglomerate Facies

At the top of the Lower Peel Sound there is everywhere a rapid upward gradation into boulder and cobble conglomerates of the Conglomerate Facies. The increase in clast size is

abrupt, from a maximum diameter of $2\frac{1}{2}$ inches (6cm) to one of 10-40 inches (25-100 cm); there is a marked change in the pebble lithologies and the matrix of the conglomerates, and beds of shale and limestone disappear. These changes take place over a vertical thickness of 30-40 feet (10-13m).

The Conglomerate Facies is mapped as that area where the rocks are more than 90% conglomerate. The remaining ten percent (often much less) is red sandstone. The conglomerates commonly contain more than 30% cobbles and boulders and in some cases as much as 70%. A set of ten typical samples from the Bellot Cliff and Prescott Island areas gave an average mean grain size of -5.3ϕ , or $1\frac{1}{2}$ inches (4cm).

The red sandstones occur within the conglomerate as lenticles whose lateral extent varies from about 6 feet to several hundred feet. Vertically, they average $1\frac{1}{2}$ feet thick (50cm) and may be from 5 to 100 feet apart, though 30 feet (10m) is the mean.

Sedimentary structures are rare. The conglomerates are commonly devoid of bedding for several tens of feet vertically. In places pebble imbrication and crude cross bedding have been seen. In the sandstone lenticles small scale trough and planar crossbedding, ripple marks and primary current lineation were observed.

The Conglomerate Facies is estimated to reach a maximum

thickness of about 1000 feet (300m) in the east, though the amount removed by erosion is unknown. The outcrop forms a north-south belt up to seven miles (11km) wide which is continuous, except for an area near Savage Point where the amount of sandstone in the section rises above 10%. This area is thus mapped as Conglomerate-Sandstone Facies (see map accompanying this report). Typical exposures are illustrated in photographs 7-9.

b) Sandstone Facies

The typical exposure of this facies shows a series of monotonous red sandstones and siltstones with rare, thin reddish shales. Some of the sandstone beds are coarse, and may contain scattered pebbles. The beds are nowhere very massive, individual units being usually less than 5 feet ($1\frac{1}{2}$ m) thick.

Sedimentary structures are again rare, although the following have been observed:- small troughs 1-5 feet (30-150cm) in width, very rare large channels up to 30 feet (9m) wide, planar crossbedding, ripple marks (including ripple-drift crossbedding) primary current lineation and sole structures, such as groove casts and load casts.

The total thickness of beds in this facies is unknown as neither the base nor the top are exposed; but a minimum estimate is about 600 feet, and there may, in fact, be double

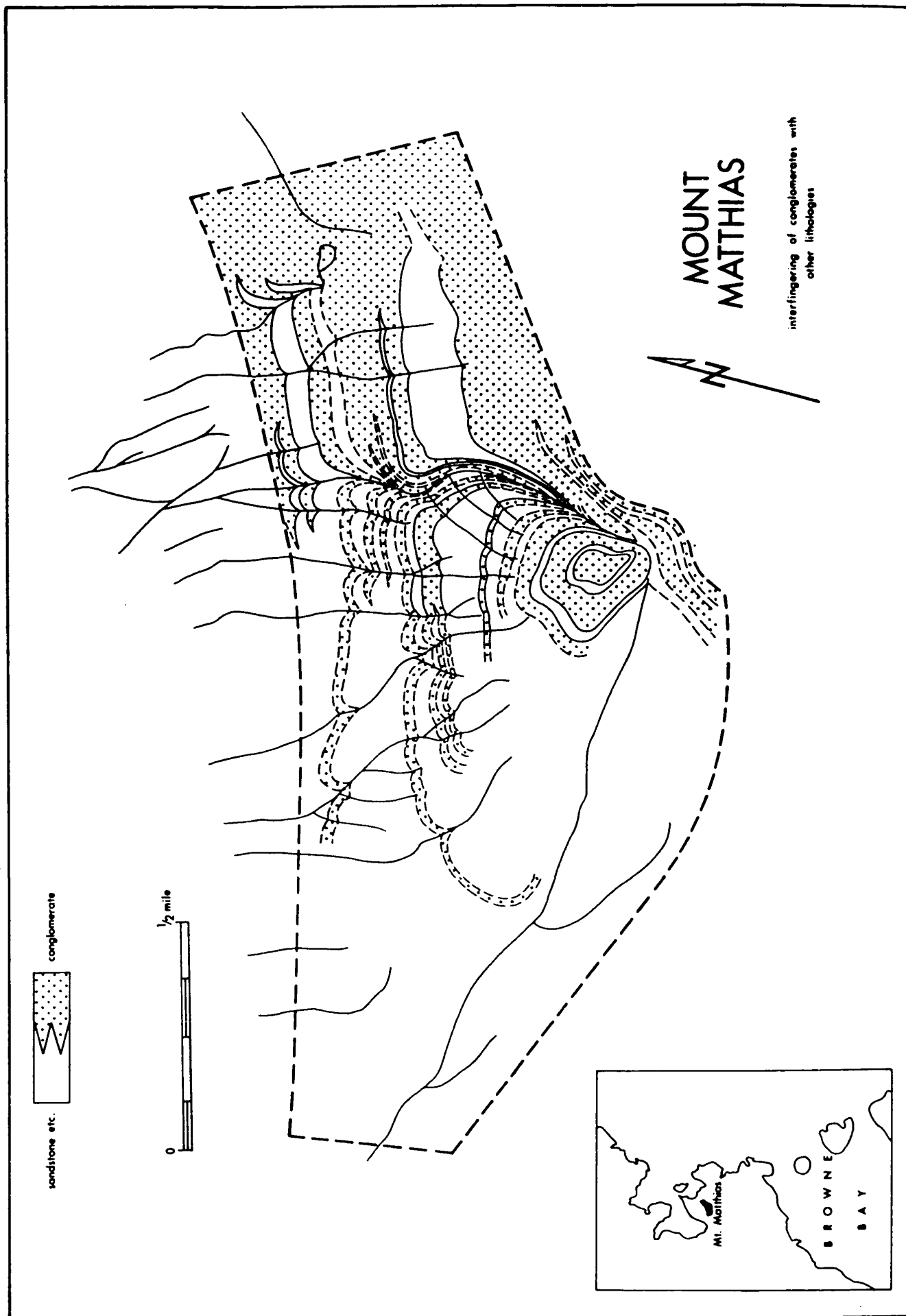


Fig. 3

this amount present. The Sandstone Facies belt is 4-18 miles (6-29km) wide and 160 miles (260km) in length (fig. 36).

c) Carbonate Facies

Occupying the western part of Prince of Wales Island and comprising about two thirds of its surface area, is a series of carbonate rocks with a marine invertebrate fauna (see fig. 43). Limestones and dolomitised limestones of various lithologic types make up the whole succession. Clastic content is generally less than 12%, and predominantly clastic beds are rare. Exposure is, except locally, very poor, and little is yet known about the detailed stratigraphy of this group of beds (see Appendix IO. Its thickness cannot be reliably estimated.

4) Facies Relationships

Evidence is here presented which supports the hypothesis of time equivalence of the three facies briefly described above.

a) The Conglomerate-Sandstone transition

The map, fig. 3, shows a small area one mile (1.6km) south of Mount Matthias. (The area is illustrated in photograph 10). From north to south there is a rise in elevation of about 700 feet (210m); the many large and small erosion gullies which descend this slope are shown on the map. The east end of the area lies in typical Conglomerate Facies, the west end in Sandstone Facies and bedding is horizontal throughout. The

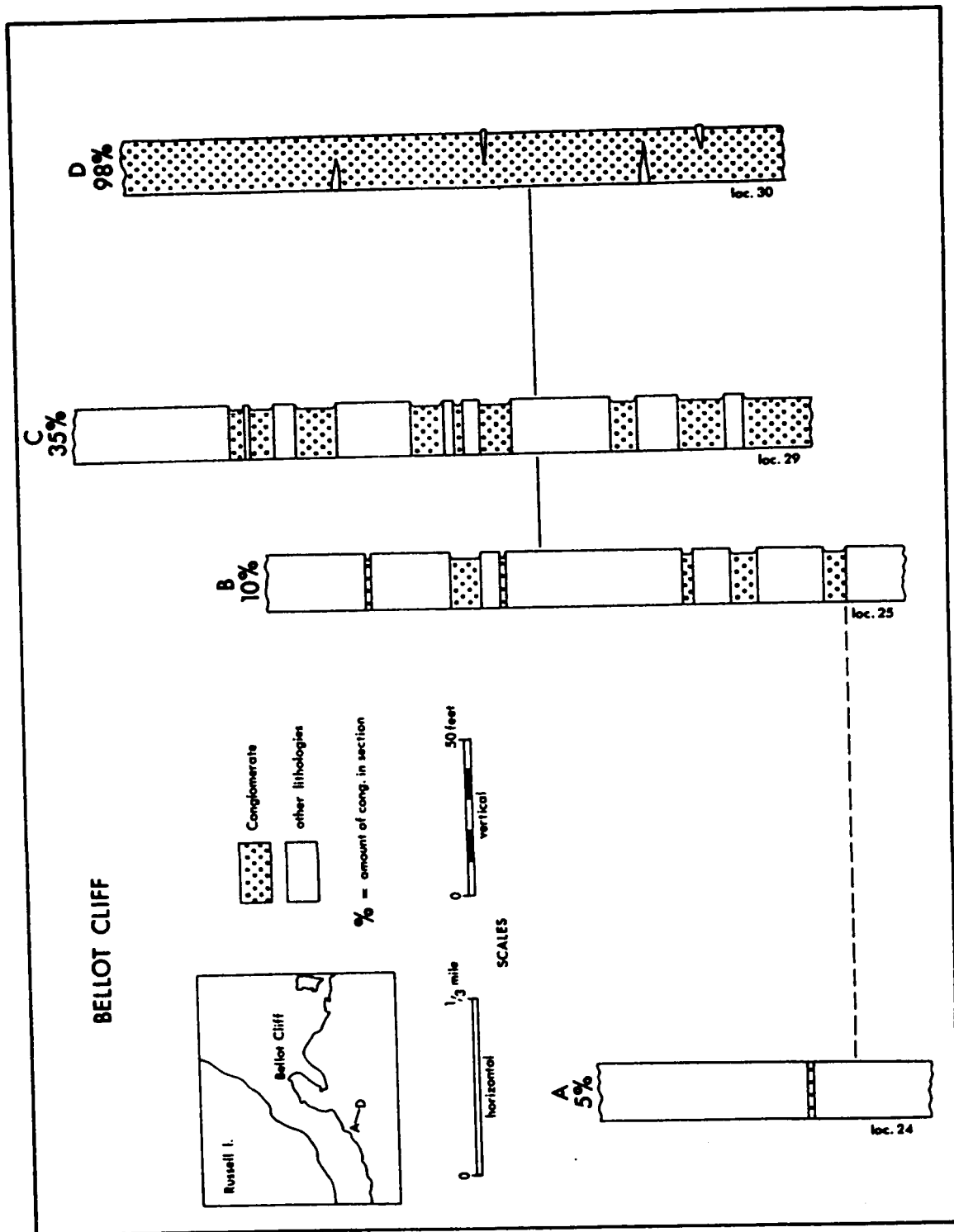
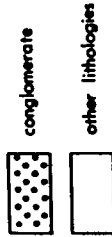
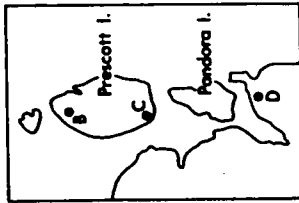
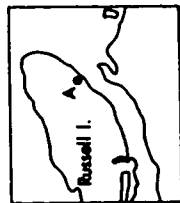


Fig. 4. Conglomerate - sandstone transition sections,
Bellot Cliff



% = amount of conglomerate in section

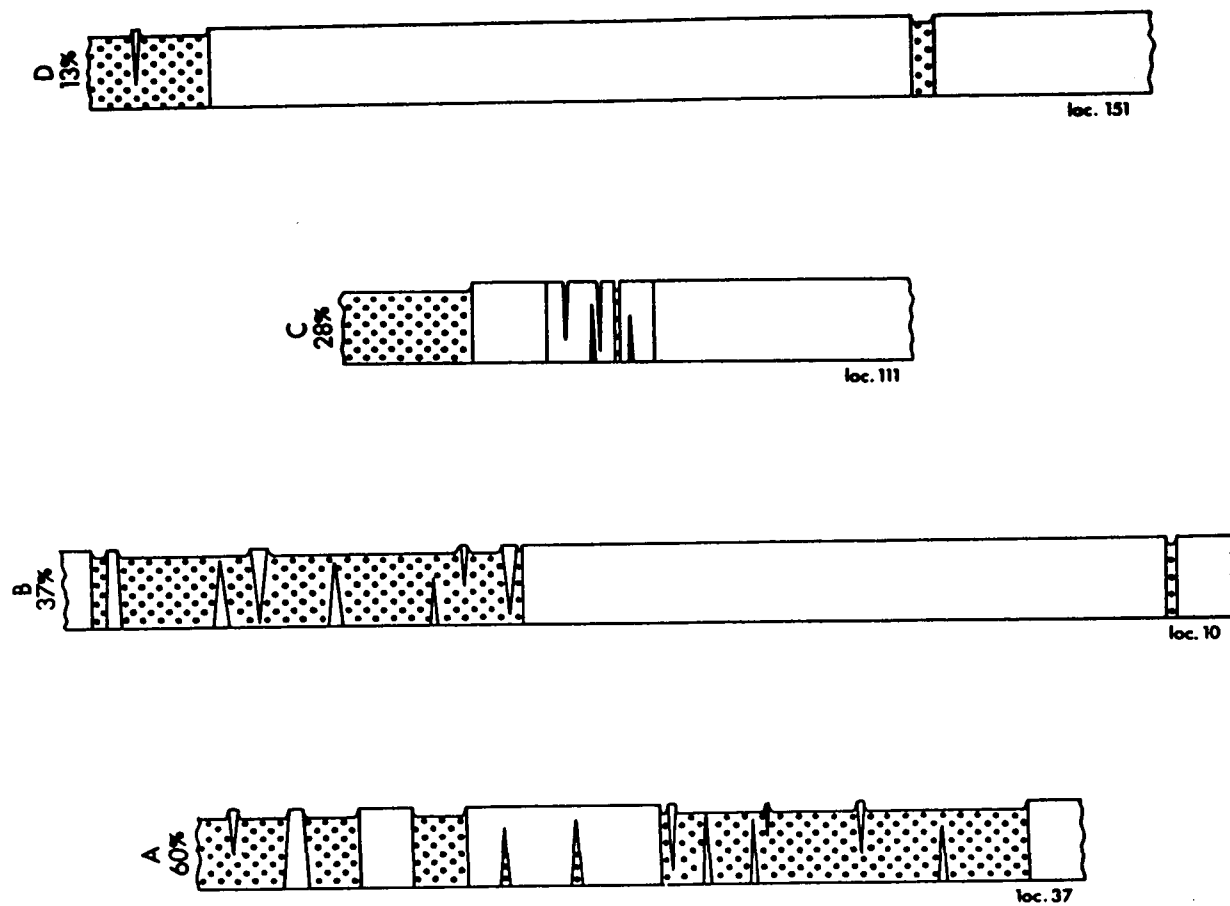


Fig. 5. Conglomerate - sandstone transition sections

purpose of the map is to show, in a simplified way, how the two facies interfinger over a distance of about two miles. Mapping is based on interpretation of land features, types of felsenmeer and air photo evidence, actual exposure being rather poor. It must be emphasized that because of the nature of the evidence the interpretation presented can only be a simplification.

At Bellot Cliff, (fig. 4, NS333923) a similar relationship is visible in a series of vertical sections, measured on prominent crags in a river gorge. The line joining horizontal sections B,C, and D can be walked out or traced by eye, but the relative position of section A is less certain. The rapid decrease westwards in the percentage of conglomerate in the section can be readily seen. Section B is illustrated in Photograph 11.

Sections very similar to B and C of fig. 4 have been measured in other areas (Russell Island, NT097340; Prescott Island, NS674175 and NR691954; and the Pandora area, NR754670; see fig. 5), but in these cases it has not been possible to conclusively prove the lateral gradation. The sections occupy the same position, between the Sandstone and Conglomerate Facies, but cannot be actually traced into one or the other because of lack of exposure.

Earlier workers eg. Thorsteinsson and Tozer (Fortier, *et al.*, 1963, p.124) suggested that the conglomerates are

younger than the sandstones because they occupy higher elevations and the sandstones were thought to dip eastwards beneath the conglomerates. It seems more likely that the higher altitude of much of the conglomerate outcrop is simply a reflection of its greater resistance to erosion. Sections through the lowest beds of the Conglomerate Facies (see fig. 6) show that the conglomerates are not underlain by sandstones but by the variegated lithologies of the Lower Peel Sound Formation.

A transition zone has been drawn on the map accompanying this report to indicate the westward decrease in the percentage of conglomerate. The limits of the zone are drawn at 90% and 10% conglomerate; this decrease normally takes place over a distance of one to three miles (1.6-5km) but on Russell Island there appears to be an increase in width to about seven miles (11km).

b) The Sandstone-Carbonate transition

The relationship between the Sandstone Facies and the Carbonate Facies is less easy to demonstrate, for exposure of the transition is limited to isolated gorge sections which cannot usually be inter-correlated. However, in the part of Prince of Wales Island where this transition has been studied dip is normally very low, and the total relief of the terrain is rarely greater than 400 feet. Thus it seems likely that the same few hundred feet of beds are present over

areas of many square miles. If this is the case, then a similar relationship prevails to the one described in section (a). Redbeds, mainly sandstones, decline in importance westward, whereas thin limestone beds appear and increase in proportion in the same direction.

This transition was studied in four areas - Baring Channel, Browne Bay, Musko Hill and Transition Bay and on the basis of the varying stratigraphy at these four localities a Sandstone-Carbonate transition zone has been drawn on the map accompanying this report (see also fig. 43). The boundaries are the approximate westerly limit of redbeds and the approximate easterly limit of carbonate rocks. Within the zone other lithologies such as shales, siltstones and nodular limestones are important. The definition of this zone is intended to replace the 'approximate boundary' of Blackadar and Christie (1963) redefined as a 'gradational contact' in the map accompanying Blackadar (1967). This line is thought to be of little real significance. A typical exposure is illustrated in photograph 12.

These lateral changes clearly demonstrate a great change in depositional environment, which will be discussed below.

5) Preliminary Stratigraphic synthesis

The broad paleogeographic picture of the area as established so far, may be summarised as follows: During Read

Bay (Silurian) times marine conditions prevailed throughout the area that is now Prince of Wales Island, and thick limestones were deposited. At about the beginning of Devonian times the pattern of conditions began to change. Clastic sediments appeared and gradually replaced marine limestones. These rocks, probably formed during the earliest Devonian, comprise the Lower Peel Sound Formation. They are transitional in nature, for the Lower Peel Sound grades up into cobble and boulder conglomerates with no marine horizons.

The Upper Peel Sound Formation is made up of three facies. In the east, where the upward passage from the Lower Peel Sound is exposed, there are thick and massive rudaceous rocks comprising the Conglomerate Facies. These wedge out westwards into the red arenaceous rocks of the Sandstone Facies, and these in turn are replaced still further to the west, by the marine rocks of the Carbonate Facies. The general decrease in grain size westwards suggests an easterly source area for the clastic rocks. The marine carbonates are lithologically similar to rocks of the Read Bay Formation, but meagre fossil evidence suggests that they are younger - probably Lower and Middle Devonian in age (see Appendix I). This supports the suggested correlation with the clastic beds.

IV. SEDIMENTOLOGY

1) INTRODUCTION

In this chapter are presented the detailed facies analyses with descriptions and interpretations of areal variations in lithologic characters. Included are the results of statistical studies on the conglomerates and analyses of the minor facies variations within the three major subdivisions established in the previous chapter.

2) THE LOWER PEEL SOUND FORMATION

a) General Statement

Between the thick marine limestones of the Read Bay Formation and the typically coarse, red, polymict conglomerates of the Peel Sound Formation there are up to 600 feet (180m) of transition beds. They consist of interbedded marine limestones and sandstones and continental sandstones and conglomerates, and the exact demarcation of the stratigraphic units within this succession is a matter of some dispute. Work to date (see Appendix I.) indicates that the Siluro-Devonian (Ludlovian-Downtonian) boundary probably occurs somewhere near the base of the transition beds and, ideally, this would be the best place to draw the Read Bay - Peel Sound boundary. However, until the work of age dating is more complete the position of the boundary

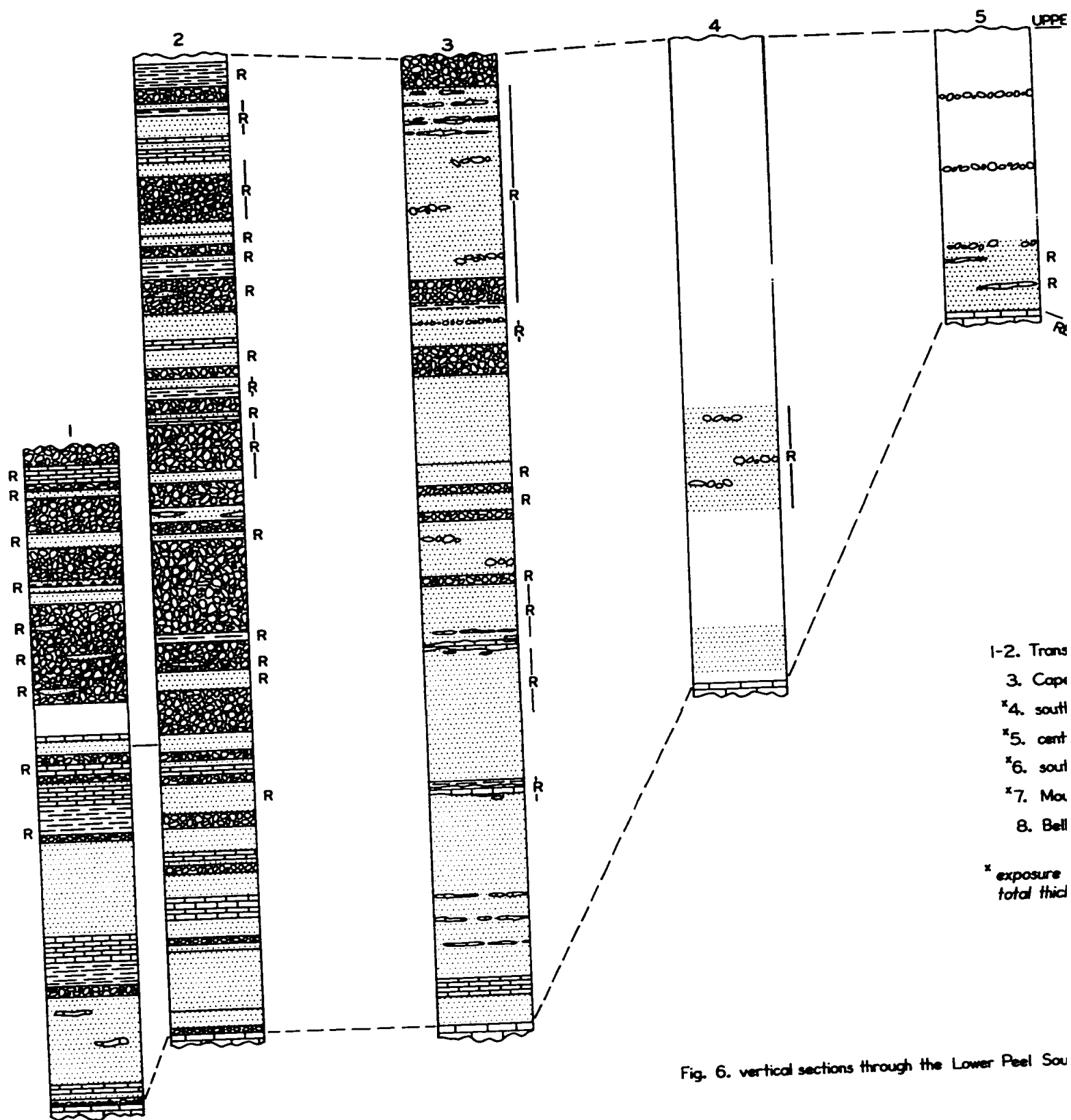
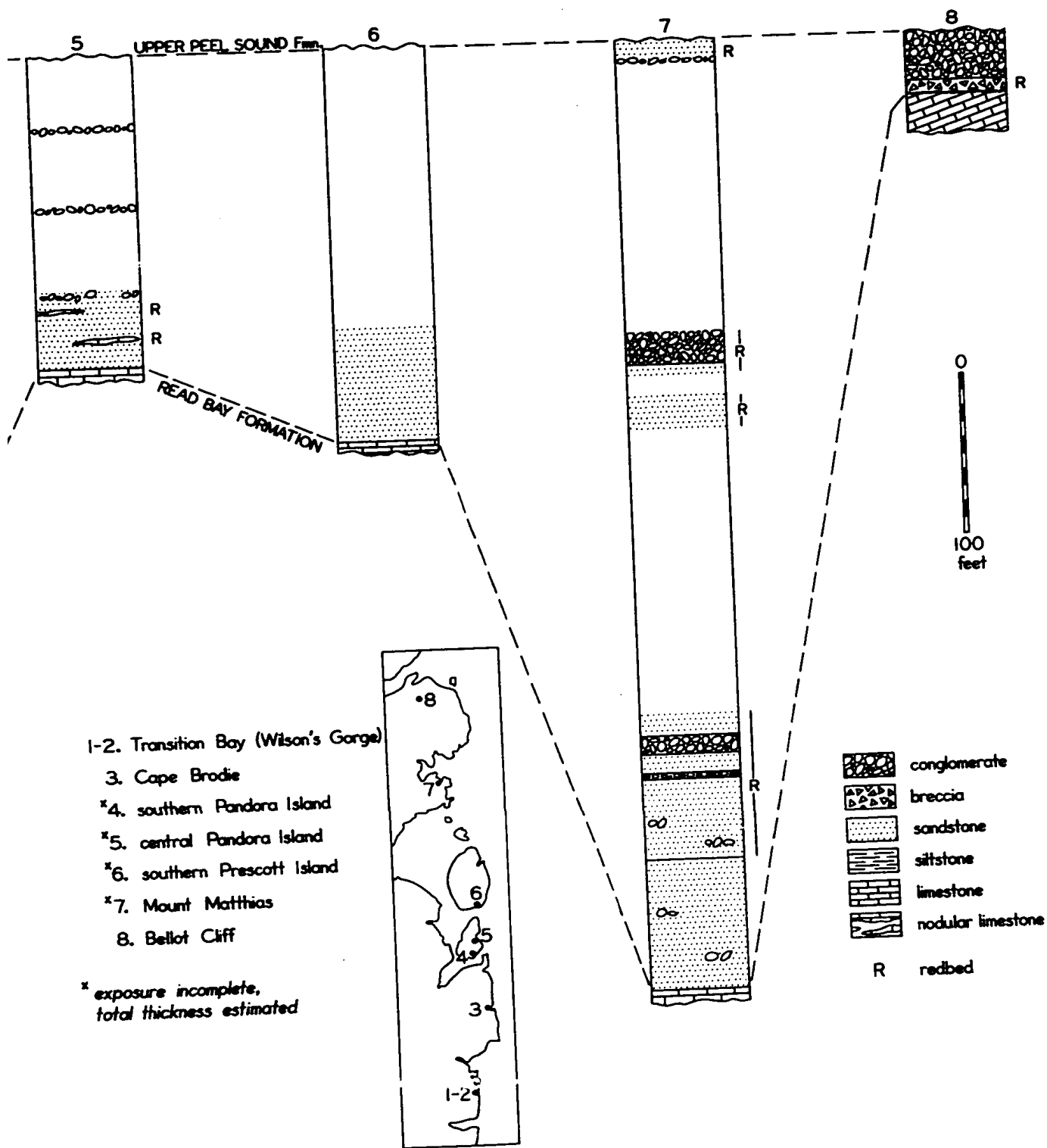


Fig. 6. vertical sections through the Lower Peel Sound



the Lower Peel Sound Formation

cannot be drawn everywhere with equal certainty. The name Peel Sound Formation is thus employed as a rock-stratigraphic term, and the base of the formation is defined, arbitrarily, as the horizon where the first important clastic bed appears - either a red sandstone or a pebble conglomerate. Seven sections of these transitional beds have been visited, and are illustrated in fig. 6.

In the discussion that follows certain points concerning the conglomerates are not fully discussed, for the reason that they are best considered under the section on the Conglomerate Facies. Thus clast types are identified without presenting the evidence, and a full discussion of the depositional environment is deferred to the later section. The Peel Sound conglomerates are thought to be nearly all genetically related, and the evidence is much more complete for these higher beds. Similarly, some of the marginal-marine horizons compare closely with those of the Sandstone-Carbonate facies, and will be discussed more fully in a later section.

b) The Lower Peel Sound sections

Transition Bay sections

These sections have been studied in detail by Broad (1968) with emphasis on the vertebrate fossils. The exposure was first visited and measured rapidly by the present author (loc. 182, NR859096, see Appendix II and

photograph 4), who discovered three fish horizons. The subsequent more intensive investigation by Broad uncovered a total of 28 fish bearing beds. The vertebrate evidence indicates a Downtonian age (see Appendix I. for details).

The Transition Bay ('Wilson's Gorge', Broad, 1968) sections demonstrate particularly well two important points:

a) The gradual nature of the Read Bay - Peel Sound transition, in which lithologies typical of both formations are interbedded over a vertical thickness of more than 600 feet (180m). Limestones containing brachiopods and cephalopods were found 589 feet (177m) above the first conglomerate horizon. Below this level there are several marine limestones, as well as many containing only ostracods and gastropods, which may not be of truly marine origin.

b) These sections also demonstrate the extreme vertical and lateral variability of all the lithologies and the lack of marker horizons. Thus compare the sections measured in vertical beds at Wilson's Gorge at stream level (A.D.M.) and along the top of the gorge (D.S.B.), a separation of about 200 feet (60m) (see fig. 6). Some of the fossil bearing horizons can be traced between both sections, but in detail the sections are very different. A gorge two miles (3.2km) along the strike to the northwest exposes a similar thickness of transition beds, but there are few sandstones and limestones here, and no abundantly fish-

bearing horizons. The section contains a high proportion of oligomict dolomitic pebble conglomerate. This grades up, as elsewhere, into the polymict cobble and boulder conglomerate that comprises the upper part of the Peel Sound Formation.

The clastic beds in the Read Bay limestones are commonly clean-washed grey or white quartz sandstones 2-3 feet (60-90cm) thick. The clastic beds in the lower half of the Read Bay - Peel Sound transition series are similarly lacking in iron-oxide staining. The first red-bed in the succession is a bright red, silty limestone (bed 12 in the section), 186 feet (56m) above the arbitrary base of the formation. Above this level, pink - or red-stained sandstones and siltstones are common until the red, polymict conglomerates are reached. But the grey, unstained limestones and the cream-coloured dolomitic conglomerates continue to be interbedded with red sandstones for a further 700 feet (210m) up the section.

Cape Brodie sections

The basal Peel Sound is well exposed in a number of gorge sections between 8 and 13 miles (13-21km) NNW of Cape Brodie. One of these sections was measured in detail (loc. 189, NR841517, see Appendix II and photograph 5, and has a lithologic assemblage very similar to that at Transition Bay. A marine limestone is present approxi-

mately 636 feet (191m) above the arbitrary base of the formation, and two beds containing fish remains have been noted (beds 25 and 35 in the measured section). More fish-bearing horizons would undoubtedly be discovered by an intensive search.

The first red bed appears 151 feet (45m) above the base of the transition series and is a coarse, even-grained, massive sandstone (bed 11 in the section). As at Transition Bay, above this horizon grey limestones, sandstones, siltstones and dolomitic conglomerates are interbedded with pink and red siltstones, sandstones and pebbly sandstones. Read Bay limestone pebbles are locally abundant high in the section (eg. bed 20) but dolomite and chert from the Hunting Formation form the bulk of the conglomerate clasts.

Pandora Island - Prescott Island area

The Read Bay - Peel Sound transition is not well exposed in this area. The steeply dipping or overturned Read Bay limestones form a prominent ridge, and the flat lying Peel Sound conglomerates give rise to a wide, elevated plateau, approximately a mile (1.6km) to the west. In between there is often a low-lying zone in which a small subsequent stream may be flowing. There are no deep gorge exposures, and the following descriptions are necessarily based on incomplete information.

The transition beds show a rather variable thickness in this area. At southern Pandora Island (loc.124, NR757748) they are estimated from structural reconstruction to reach 4-500 feet (120-150m) in thickness. Exposure is along the top of a strike ridge running northeast-southwest parallel to the more prominent Read Bay limestone feature. (Hilltop exposures are rare in the Peel Sound Formation). The beds consist mainly of coarse, reddish sandstone with abundant trough crossbeds. Near the contact with the Read Bay there are beds of white quartz sandstone and pebbly seams containing fragments of Read Bay-type limestone and sandy limestone, silicified fossil fragments and vein quartz.

Five miles (8km) to the north, near the centre of Pandora Island (loc. 149, NR755824) there is a gorge section exposing vertical Read Bay - Peel Sound beds. The contact with the Read Bay is not exposed. The lowest 40-50 feet (12-15m) of the Peel Sound Formation consists of white, quartzose sandstone containing red-streaked calcilutite seams up to one foot (30cm) thick. At the top of the sandstone there are pebbly layers containing fragments of Read Bay-type limestone and derived fossils. Above this an estimated 50 feet (15m) of the section is obscured, and then a 3 foot (90cm) limestone conglomerate bed is exposed, standing out as a prominent crag on the south face of the gorge. In this bed limestone pebbles up to 3cm in diameter comprise up to 100%

of the conglomerate clasts, but Aston quartzite pebbles occur locally as abundantly as 10%. Derived fossils from the Read Bay are present as well as fragmentary fish remains, thought to be indigenous. The conglomerate matrix consists of calcite and quartz grains. A few feet higher a slightly coarser conglomerate contains 95% Read Bay pebbles up to 6cm in diameter and 5% gneiss and Aston clasts (predominantly the latter) up to 12cm in diameter, set in a highly calcareous matrix. There is no exposure above this level but the nature of the scree slopes suggests a rapid upward transition into polymict cobble and boulder conglomerates. The transition beds are estimated to be no more than 200 feet (60m) thick at this locality.

On Prescott Island there is very little evidence for the presence of the transition beds. On the south coast (loc. 102, NR750953) there is one exposure of massive, fairly coarse, almost pure white quartz sandstone, with a non-calcareous matrix and a few planar crossbeds. The exposure occurs in the middle of the zone where transition beds would be expected. Reconstruction from dips suggests a thickness of from 2-300 feet (60-90m) for the interval between Read Bay Formation and Peel Sound polymict conglomerates.

Mount Matthias section

There is no single exposure covering the whole thickness of transition beds, but reconstruction from five small outcrops over a distance of three miles (5km) indicates that there may be about 600 feet (180m) of beds present. Read Bay limestones contain occasional sandy beds, and pass upwards without any apparent break into approximately 100 feet (30m) of white, cross-bedded quartz sandstones. There are a few interbedded sandy limestone beds and scattered pebbles of limestone and basic volcanics. The remaining thickness is formed of medium to coarse red, calcareous sandstone with pebbly seams and conglomerate layers up to at least 18 feet (5.5m) thick. Read Bay limestones and derived fossils (bryozoans, stromatoporoids, corals) are the dominant clasts, plus Hunting chert and dolomite, locally up to 5%, and Aston quartzites, locally reaching 25%. Clasts are rarely larger than 5 inches (13cm). At the top of the transition beds coarse, red, pebbly sandstones contain vertebrate remains (collected by D. S. Broad). Conglomerates rapidly become coarser higher in the section, and the maximum clast size reaches 12-18 inches (30-45cm).

Bellot Cliff section

An exposure seven miles (11.2km) south of Bellot Cliff (loc. 28, NS403900, see photograph 3) is the only locality where the Peel Sound has been seen to rest with an uncon-

formable relationship on the Read Bay (first reported by McNair and Ormiston, quoted in Kerr and Christie, 1965, p.910). The angular discordance between the two formations is more than 20° . Blackadar and Christie (1963) show the Peel Sound resting on the Allen Bay Formation at the Bellot Cliff unconformity, but this was not seen by the present author.

Resting on the plane of erosion there are 8 feet (2.4m) of limestone breccia, consisting of angular fragments of Read Bay limestone in a red matrix of limonite, calcite and angular to rounded quartz grains. Above the breccia the rest of the section consists of 30 feet (9m) of limestone conglomerate. Limestone clasts up to 12 inches (30cm) in diameter constitute 95% of the clast types, red Aston quartzites 3-4%, greenish quartzite and basic gneisses less than 1% each. The clasts are well rounded and are enclosed in a white calcarenite matrix. One boulder of Aston quartzite 4 feet (1.2m) in diameter was seen in the conglomerate. Above this bed there is a rapid transition into coarse, polymict conglomerate in which there are a few layers of oligomict limestone conglomerate, less than 1 foot (30cm) thick, containing pebbles rarely larger than 2 inches (5cm) in diameter.

c) Discussion

General Statement

The upward change from fine-grained marine limestone

to polymict boulder conglomerates indicates a very marked change in the depositional environments. The varied lithologies of the basal Peel Sound demonstrate the transitional nature of the change and show that it was not a smooth, one-way process. For example, the presence of brachiopod and cephalopod bearing limestones high in the succession indicates that marine conditions returned several time before continental deposition finally became firmly established. The general similarity of the sections from Mount Matthias to Transition Bay shows that a similar transition was taking place over a wide area - though the exact time-equivalence of these beds has not yet been proved. On the other hand, the great variability of the vertical sections when compared in detail, shows that depositional environments were very localised. At any given time the pattern of varying conditions must have been quite complex, so that markedly different lithologies were forming at the same time in close proximity to one another.

The exception to this pattern is the Bellot Cliff area, where transitional beds are absent. The unconformity represents the period of time when uplift and erosion took place while transition beds were being deposited elsewhere.

Environments of deposition

The limestones are the result of deposition in com-

paratively clear water, remote from sources of terrigenous clastic sediment. In many cases fossils prove a marine environment. In other limestone bands the presence of only gastropods and ostracods may indicate brackish water, perhaps lagoonal conditions.

At many levels in the Read Bay Formation sandy layers are present. Similar sandy limestones are found in these transition beds, and there are also thick, clean-washed quartz sandstones with or without a calcareous matrix. The well-rounded nature of the quartz grains and the lack of other mineral grains suggests a long sorting history. These are interpreted as littoral deposits, washed to and fro by the sea for an unknown period of time before being finally deposited (see photograph 29).

Red beds are normally considered to be continental deposits. The red colouration of the sandstones and siltstones was probably derived by residual weathering in a subaerial environment. Their presence in these transition beds suggests an influx of fluvial deposits.

The conglomerates present were probably derived in two different ways. The earlier, pale-coloured, oligomict conglomerates, eg. at Cape Brodie and Transition Bay, are often fairly well-sorted deposits with two modal sizes - a dolomite or limestone pebble fraction, and a matrix fraction of clean quartz sandstone. They are probably

beach deposits, the matrix originating as a littoral sand, and the contribution of pebble-sized material derived, perhaps, from a local cliff line. The other, polymict conglomerates have a reddish and immature sandy matrix, are less well sorted (eg. at Mount Matthias) and are probably fluvial deposits. They may represent an earlier appearance of alluvial fan conditions (discussed fully under 'Conglomerate Facies'), the streams debouching almost directly into the sea.

The absence of red colouration in some of these conglomerates should not, in itself, be taken to indicate non-continental deposition. The colour is caused by the presence of iron-oxides and is commonly derived by weathering and erosion of rocks rich in ferromagnesian minerals - the basement gneisses of the Boothia Uplift would be just such a source material. Deep weathering of iron-poor rocks such as limestones can also, if continued over a sufficient length of time, give rise to red residual deposits. Some of the red sandstones of the transition series may have been derived from this kind of source material. However, rapid erosion and transportation of iron-poor material is more likely to produce non-red continental sediments. During early Peel Sound times limestones and dolomites formed the stratigraphically highest formations in the source area - the Hunting, Allen Bay and Read Bay Formations. These would have been the first to have been eroded from a newly elevated Boothia Uplift. A

fluvial origin for some of the oligomict conglomerates cannot, therefore, be excluded. There is further supporting evidence in the form of a bed thickness: maximum clast size correlation, considered under 'Conglomerate Facies'.

Tectonic implications of the Lower Peel Sound Formation

In Prince of Wales Island the lowest members of the transition beds are grey clastics interbedded with grey limestones. The sandstones are very similar to those which appear occasionally in the Read Bay Formation, and suggest a shallowing of the sea to littoral conditions, accompanying a gentle elevation of the Boothia Uplift. In places beds regarded as true beach deposits were formed, eg. the lowest conglomerate unit in the Transition Bay sections.

The appearance of red beds several feet above the first major clastic horizon, and the increasing dominance of conglomerates indicates the appearance and growing influence of fluvial sedimentation. This must correspond to increasing uplift in the source area, while the area of deposition remained near sea-level, at least in the southern part of Prince of Wales Island, so that marine conditions returned at brief intervals to form thin limestone bands.

The marine influence finally disappeared after some 600 feet (180m) of beds had been deposited. Sandstones and limestones gave way to thick, almost unbedded, red

polymict conglomerates, with a greatly increased grain size.

The suggested time equivalence of the Lower Peel Sound sections is supported by one hypothesis that cannot yet be proved: that the change from nearly oligomict pebble conglomerate to polymict cobble and boulder conglomerate is an event of widespread tectonic significance. The same change takes place with almost equal abruptness everywhere the basal Peel Sound is exposed. (Clast type changes are considered in greater detail under 'Conglomerate Facies'.) It suggests a sudden uplift in the source area so that streams were rejuvenated and became capable of transporting much coarser material. Erosion was accelerated and rapidly cut through the higher-level source rocks - the Hunting, Allen Bay and Read Bay, down into the Aston quartzites and the basement complex. It is thought unlikely that an uplift of the magnitude necessary to produce these results was a local effect. It probably occurred at the same time over the whole length of the Boothia Uplift.

The coarse polymict conglomerates above the Bellot Cliff unconformity were probably formed during the same tectonic event, but the existence of an unconformity also points to a local, earlier uplift. Erosion of the upturned Read Bay was thus taking place here, while elsewhere the Read Bay - Peel Sound transition beds were being deposited.

The limestone breccia resting on the plane of the un-

conformity is interpreted as a deposit formed of very locally derived material. The angular nature of the limestone fragments indicates very little transport; the iron-rich matrix is probably a residual weathering product of the limestones and their included sandy beds.

LOCATION MAP

CONGLOMERATE OUTCROP

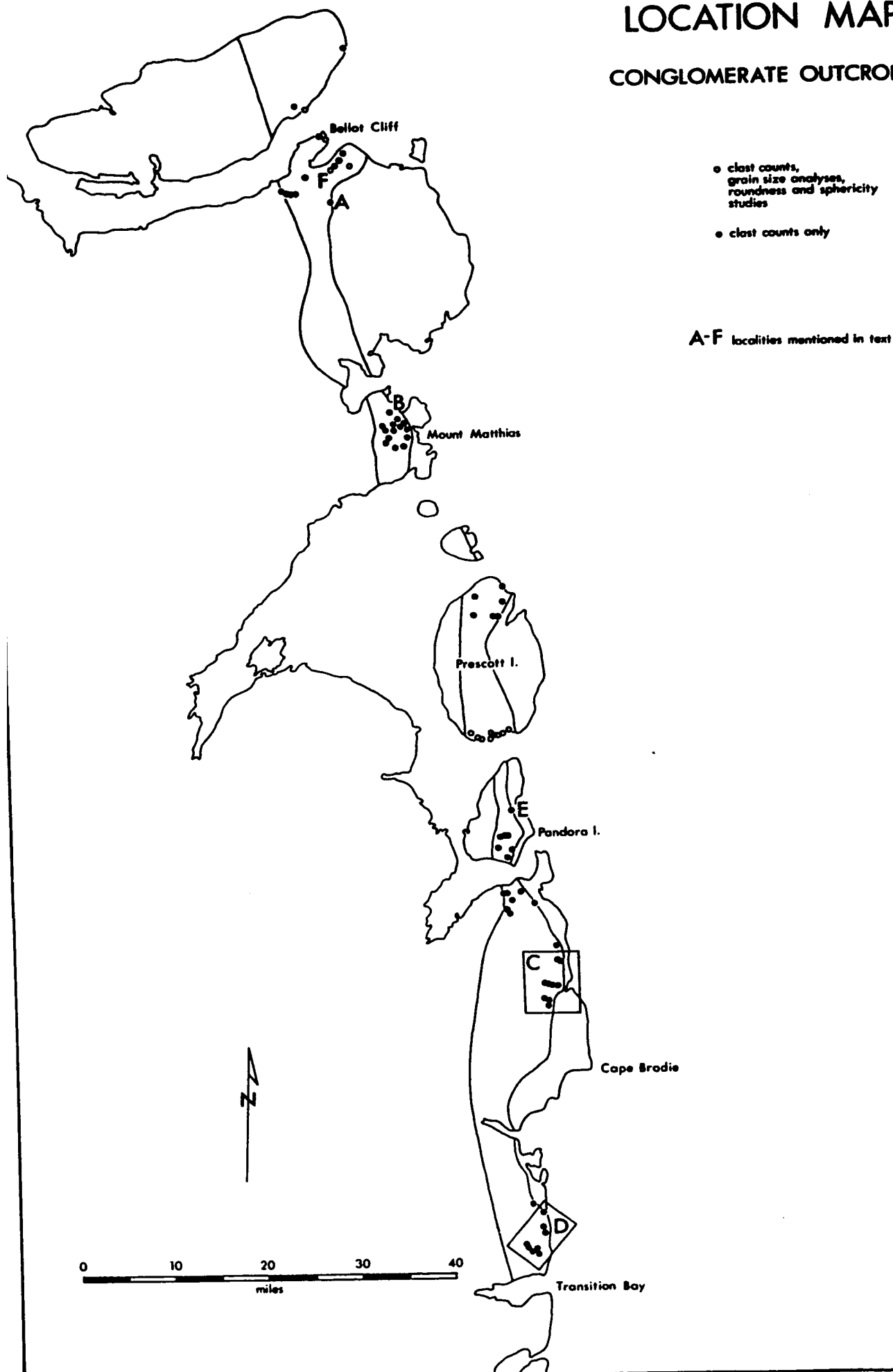


Fig. 7.

3) CONGLOMERATE FACIES

a) Methods of study

The conglomerates are the best exposed of the Peel Sound deposits and are thus the easiest to examine for textural and compositional properties. The following properties were investigated:

- i) Gross characteristics: thickness of individual conglomerate beds, distribution of other lithologies etc.
- ii) Clast lithotypes and their distribution.
- iii) Maximum clast size distribution
- iv) Whole rock grain size.
- v) Roundness and sphericity of certain clast types.
- vi) Orientation of directional sedimentary structures.

Field and laboratory procedures are described below:

Clast lithotype analysis

This was entirely a field study. Within the limits of the time available enough clast lithotype counts were made to ensure as wide and complete an areal coverage of the Conglomerate Facies as possible. Fortunately (as will be described below) nearly all the source rocks of the conglomerate are very distinctive and readily recognisable in hand specimen, so that the assessment of clast types at each exposure could be made very rapidly, and it was not

necessary to collect numerous samples for later laboratory identification. A site was chosen at each locality on the basis of clean exposure, lack of weathering and easy access. The procedure for making a count was to start from a given pebble and continue outwards in all directions until one hundred clasts had been identified and noted. This number was found to give reasonably consistent within-bed readings. The size limits chosen were from half an inch (1cm) upwards, including all but the largest boulders present. It was found that each clast type had a similar size distribution in the conglomerate. Thus, although counts were made in terms of number percent, the figures may also be regarded as an approximate measure of volume percent. After practice, each count rarely took longer than ten minutes to complete. A note was also made at each exposure of any rare types present - i.e. those comprising less than 1% of the conglomerate. A total of 120 counts were made during the two field seasons, covering most of the conglomerate facies outcrop (see Appendix III).

Maximum clast size analysis

The size of the largest clast present was measured for each lithotype at every exposure where clast lithologies were studied. In a large exposure measurement was confined to an area within a six foot radius of the location of the clast lithology count.

Whole-rock grain size analysis

The procedure for whole-rock size analysis is rather lengthy because of the extreme range in sizes present in the coarse conglomerates. From the finest sand size (the smallest conveniently measured in thin section) to the largest boulder a range of twelve phi size classes is commonly represented, and in some extremely coarse conglomerates the size range extends over fourteen phi classes. The comparatively simple methods of sieving and weighing fractions cannot be applied, because the conglomerates are normally fairly well consolidated. The technique evolved is given below and is based on summing grain diameters rather than measuring weights of fractions.

The coarse fraction of the rock, comprising particles larger than -3ϕ (8mm), was measured in the field. Clasts were grouped into size classes according to their intermediate diameter and counted, on a clean rock face, in much the same way that the clast lithologies were assessed (see above). In fact, wherever a grain size analysis was to be carried out the two procedures were combined, the whole process taking about half an hour, after practice. For statistical studies of this nature a minimum of one hundred clasts were found to be necessary for consistent results. In most cases during this study, 125 clasts were measured per outcrop. There was usually no difficulty

in determining the position of the intermediate axis of each clast for the matrix tended to weather out from between the pebbles, leaving their shapes well exposed.

The size distribution with the fine fraction of the rock, smaller than -3ϕ was determined from a matrix sample studied in thin section in the laboratory. (The term 'matrix' is used here for convenience, the limit of -3ϕ being chosen because of its position at the lower end of easy field measurement on partially weathered outcrops, and the upper limit of easy microscope measurement). The methods of Friedman (1958) were employed for measuring thin sections and converting the data to a sieve-size distribution.

Earlier workers (eg. Rosenfeld, Jacobsen, and Ferm, 1953) had concluded that thin-section and sieve size data could never be usefully compared. They found no consistency in the size of the discrepancy between the two methods of measurement, and could suggest no corrections that would have a general application. Friedman (1958) however, after an exhaustive laboratory study, showed that a correlation between the two methods did indeed exist, and was able to formulate the equation of the regression line expressing the correlation.

In the present study a Shadomaster was used for the thin section analysis, and considerably reduced the eye strain normally associated with microscope work. At $\times 10$ magnif-

ication the image of a section just filled the 38 x 30cm screen of this instrument. A squared grid was placed over the ground glass screen and traverses were made along the lines measuring grains at one centimetre intervals, a scale which represents one millimetre on the thin section. The apparent long diameter of each grain lying under the intersection of the grid lines was measured at each point. This measurement was converted to the correct ϕ size class, and a count was made of the number of grains falling into each class. Friedman's (1958) work suggested that for statistical validity a minimum of 200 points should be measured in each section; in this study 250 or 300 points were measured. It was then necessary to correct for the inherent error of thin-section grain-size analysis - the fact that most of the grains appearing in a section are not traversed at a point coincident with their intermediate diameter. The graph produced by Friedman (1958, fig. 4) was used when compiling cumulative percents on probability paper. Thus a ϕ size class of +1.0 ϕ as measured in thin section is, statistically, a true sieve size of +1.3 ϕ , and so on.

To combine the readings for the coarse and fine fractions for a complete whole-rock analysis, it is necessary to know the percentage of the rock occupied by the 'matrix'. This was estimated in the field and commonly lies between 15 and 30%. The figures for the fraction must

then be weighted by a factor F so that they make up this proportion relative to the coarse fraction figures. Factor F is calculated from the following equation:

$$F = \frac{\sum(\frac{1}{2}\phi \times n)_c}{\sum(\frac{1}{2}\phi \times n)_f} \times \frac{m}{100}$$

where $\frac{1}{2}\phi$ is the midpoint of each whole-phi class expressed in millimetres (eg. for the size -3 to -4 ϕ the midpoint is -3.5 ϕ , which is 11.3mm). This is assumed to be the average intermediate diameter of the total number of grains (n) falling in that size class. m = matrix percent; subscripts c and f represent coarse and fine fractions. Factor F is then used to multiply each class diameter total ($\frac{1}{2}\phi \times n$) for the fine fraction classes so that each appears as a proportion of the whole sample. The percentage of each coarse fraction class out of the whole rock is then given by:

$$\frac{\sum(\frac{1}{2}\phi \times n)_c}{\sum(\frac{1}{2}\phi \times n)_c + \sum((\frac{1}{2}\phi \times n)_f \times F)} \times 100$$

The percentage of each fine fraction class is given by:

$$\frac{\sum((\frac{1}{2}\phi \times n)_f \times F)}{\sum(\frac{1}{2}\phi \times n)_c + \sum((\frac{1}{2}\phi \times n)_f \times F)} \times 100$$

A sample worksheet is shown in table I.

TABLE I. Sample worksheet: conglomerate grain-size analysis.

Specimen 31A

$\frac{1}{2}\phi$	$\frac{1}{2}\phi$ mm	n	$\frac{1}{2}\phi \times n$ (mm)	$\frac{1}{2}\phi \times n \times F$	%	cum%
-8.5	360.0	2	720.0		11.08	11.08
-7.5	180.0	8	2440		37.57	48.65
-6.5	90.5	9	814.5		12.54	61.19
-5.5	45.3	17	770.1		11.86	73.05
-4.5	22.5	26	585.0		9.00	82.05
-3.5	11.3	28	316.4		4.87	86.92
-1.88*	3.70	9	33.30	172.49	2.66	89.57
-0.95	1.92	38	72.96	377.93	5.82	95.39
-0.10	1.08	21	22.68	117.48	1.80	97.19
+0.80	0.57	27	15.59	80.76	1.24	98.43
+1.72	0.31	35	10.68	55.27	0.85	99.28
+2.65	0.16	31	5.12	26.52	0.40	99.68
+3.60	0.084	21	1.76	9.12	0.14	99.82
rem.	0.047	31	1.46	7.56	0.11	99.93

* $\frac{1}{2}\phi$ sizes of fine fraction classes are corrected according to Friedman (1958)

matrix percent $m = 15$ (measured in field)

$\Sigma(\frac{1}{2}\phi \times n)$ coarse fraction = $T_1 = 5646$

$\Sigma(\frac{1}{2}\phi \times n)$ fine fraction = $T_2 = 163.54$

$$F = \frac{T_1}{T_2} \times \frac{m}{100}$$

$$= \frac{5646}{163.54} \times \frac{15}{100}$$

$$= 5.18$$

$$\begin{aligned} \text{whole rock} &= T_3 = T_1 + (T_2 \times F) \\ &= 5646 + (163.54 \times 5.18) \\ &= 6493 \end{aligned}$$

$$\text{therefore } \% -8 \text{ to } -9\phi \text{ class} = \frac{720.0}{6493} \times 100 = 11.08\%$$

$$\text{percentage } -2 \text{ to } -3\phi \text{ class} = \frac{172.49}{6493} \times 100 = 2.66\% \text{ etc.}$$

From the resultant figures phi mean grain size and standard deviation were calculated in terms of the graphical measures M_z and σ_I (Folk, 1968, p. 45-46). The percentiles were read from cumulative curves plotted on probability paper.

The modifications of Friedman's work introduced by Sahu (1964) were not employed in the present study because it was not considered that the degree of accuracy attained in the field and laboratory work, nor the variability of the sediments themselves warranted such refinement. Moreover, Sahu himself states that for calculations of mean and standard deviation Friedman's methods are sufficiently accurate to suit most purposes. . . . Errors become more marked for skewness and kurtosis, which have not been calculated for the Peel Sound conglomerates. Examination of the probability plots produced by this method (figs. 22,23) will show that most of the curves are bimodal and indicate a very low percentage for the size classes around -2ϕ . This is near the limits of the two methods of measurement which was set at -3ϕ , and the flat portions of the curves may indicate some inherent error in the procedure used. An alternative explanation for the bimodal distribution is the effect noted by Pettijohn (1957, p.50) and discussed at length by Spencer (1963). . . . These authors observe that taking clastic sediments as a whole, certain grain size

ranges are always present in only very small amounts. Most clastic sediments are thought to be mixtures of two or three 'fundamental populations' that reflect the nature of the normal subaerial weathering processes. Pettijohn (1957, p. 50) states "...there is an initial or primary deficiency of certain grain sizes. Some rocks characteristically yield blocks upon breakdown, whereas others undergo granular disintegration and yield grains of sand size.... Products of disintegration of intermediate sizes may be relatively rare." Spencer (1963) confirms this observation and presents the hypothesis that "All clastic sediments are essentially mixtures of three or less fundamental populations of log-normal grain sizes. The fundamental populations are:

- a) Gravel with a median of -3.5 to -2ϕ and a standard deviation of 1.0 to 2.0ϕ units.
- b) Sand with a median of 1.5 to 4ϕ and a standard deviation of 0.4 to 1.0ϕ units.
- c) Clay with a median of 7 to 9ϕ and a standard deviation of 2 to 3ϕ units."

The applications of this hypothesis will be discussed under the section 'Debris flood deposits in the Peel Sound Formation'.

Grain size analyses were made in two areas, at Bellot Cliff, and along the south coast of Prescott Island, with the intention of compiling a series of readings along traverses

parallel to the direction of sediment transport. Unfortunately, as in all studies on conglomerate clasts, stratigraphic control of the outcrops is poor or non-existent. The conglomerates are so lacking in distinctive marker horizons and fossils that the only means of placing an outcrop in the succession is by reference to its height above sea level - the beds being sensibly horizontal in most places. An exceptional case is a series of readings taken at locality 31, a large gorge section about four miles south of Bellot Cliff. Approximately 400 feet of beds can be measured and studied here and some of the vertical variations detected are described below.

Clast roundness

The roundness measurements were all made at the same localities as the grain-size analyses. Krumbein's (1941a) chart of roundness gradations from 0.1 to 0.9 was used, and was found to be easy to apply in the field. Measurements were all made on cobbles of the same size grade - from -6 ϕ to -7 ϕ , i.e. from 6.4 to 12.8cm, as this was a size class abundantly represented and easy to handle. Krumbein suggested a minimum of 25 readings for a statistical sample. In this study 30 cobbles were measured at each station. Clasts in each sample were restricted to a single lithology; in most cases this was a pink quartzite, identified (as described below) as belonging to the Aston Formation; some

readings were also made on the Precambrian gneisses. Both these clast types are abundant in the conglomerates.

Clast sphericity

Samples of cobbles taken for roundness measurements were also used for measuring sphericity. The distribution of samples, their size and lithologies are described under 'Clast roundness', above. The method of Krumbein (1941a) was used, in which the position of the longest, intermediate and shortest axes a , b and c are determined for each cobble. Using a pencil or ruler the ratios a/b and b/c are rapidly estimated by eye, and the sphericity can then be read from a series of curves published by Krumbein (1941a, fig. 5, p.68). Collection of cobbles and measurements of roundness and sphericity were carried out with the help of a field assistant, as the necessary instruction took but a few minutes. After practice it was found that two people could measure both parameters on a 30-cobble sample in about fifteen minutes.

Directional Sedimentary Structures

In general, sedimentary structures are rare. Those found were, wherever possible, examined for directional character. The determination of orientation presented some difficulty, for Prince of Wales Island lies very close

to the magnetic pole. The horizontal component of the magnetic field is thus very low and compasses are useless. The system adopted was to take sightings along the direction of the structure and compare sight lines with the position of prominent, preferably distant features. The orientation could then be plotted on an air photo and read off by protractor with reference to a photo north, given by its approximately north-south edge. The readings can be corrected later by checking the orientation of the flight lines on a topographic map. An accuracy of greater than 10^0 is not claimed for this method, but it is the best available.

b) Results

Clast lithotype analyses

As stated above, nearly all the clasts examined were readily identifiable with respect to a source rock known to outcrop elsewhere on Prince of Wales or Somerset Island. Thus numerous conclusions could be drawn concerning the sources of clastic material and the sedimentary history of the Peel Sound Formation. These identifications, described below, were made on the basis of published details of the regional geology (Blackadar and Christie, 1963; Tuke, Dineley, and Rust, 1966; Blackadar 1967.), by examination of materials collected by other members of the

University of Ottawa Group and by personal discussions with these members, particularly with B. R. Rust. Most of the source rocks have also been examined by the author in at least one outcrop on Prince of Wales Island.

Identification of clasts:

Precambrian metamorphics.

A varied suite of rock types is represented, whose only common feature is a fairly coarse gneissose banding. A variety of compositions is present, from acidic gneisses, rich in quartz and pink feldspar to basic, biotite-amphibole rich varieties. Augen texture is common. Purple and brown garnets are often very abundant - usually in bands parallel to the gneissic layering. Pebbles of poorly foliated granite were also noted, and rare clasts of amphibolite and coarse porphyry were seen in the Bellot Cliff area.

These clast types are, as a group, very abundant. In some localities, eg. parts of northern Prescott Island, they make up the entire conglomerate, and elsewhere they are commonly present in a proportion greater than 50%. In the clast lithotype studies they were considered as one group for counting purposes.

Vein Quartz. Scattered pebbles are present, consisting entirely of milky white quartz. They probably originated as late-stage veins in the Boothia metamorphics.

Aston Quartzites.

Another very common clast type (up to 70% of the clasts present) is a pink, well indurated quartz sandstone which has been identified with the Proterozoic or Cambrian Aston Formation. Grain size is normally of coarse sand grade, but pebbly layers are not uncommon. The quartzite is usually well enough indurated to break with a flinty fracture.

Occasional clasts of associated lithologies were found, that are known to outcrop in the type area of the formation at Aston Bay, on northwest Somerset Island. For example, near Bellot Cliff was found a pebble similar in lithology to the stromatolite bed that occurs near the base of the type succession (Tuke, Dineley, and Rust, 1966). Arkosic sandstone clasts were found in a few places. Near Mount Matthias is a large boulder of the granite-gneiss conglomerate which forms the base of the Aston on Somerset Island. In this clast angular to subangular fragments of quartz and acidic gneisses up to at least 4 inches (10cm) in length are embedded in a coarse sandstone matrix of quartz and pink feldspar. This lithology has also been seen, in outcrop, on Pandora Island.

One cobble of quartz-feldspar conglomerate was found near Bellot Cliff. The quartz is clear or milky, the feldspar a pink, simple twinned variety, and quite fresh. Fragments have a maximum size of half an inch (approximately

1cm) and are embedded in greenish, fine grained matrix. This lithology is not yet known from outcrop. Lastly, several pebbles of greyish shale and a bright reddish siltstone were noted throughout the conglomerate, never comprising more than about 2% of the total. These are believed to be associated with the Aston Formation though descriptions from known outcrop are meagre.

Grey-green quartzites.

In northern Prince of Wales there are abundant clasts (up to 66%) of a pure, fine grained quartzite with a distinctive greenish or greyish colouration. Some clasts show an interbedding of quartzite with grey siltstone and shale layers, and occasional shale fragments are included within the quartzite, though the latter is always the dominant lithology. The source of this group of clasts is uncertain, for there are no published descriptions of such rock types occurring in the region. However, G. E. Benson (University of Ottawa Group, unpublished report, 1964) mentions one occurrence of a 'greenish sandstone' from the Aston Formation of Aston Bay, Somerset Island, and a few clasts were found by the author on Russell Island that showed the grey-green quartzite interbedded with a pink quartzite similar to those described above. It is suggested, therefore, that the grey-green quartzites represent a variety of the Aston Formation that has now been largely removed by erosion.

The distribution patterns of the pink and the green quartzite clasts within the Peel Sound conglomerates are quite different. As discussed below the dispersal pattern of the latter suggests a source area somewhere within the north end of Peel Sound, northwest of Aston Bay and perhaps in line with the strike of the present Aston outcrop. Such a location for the source area, now covered by the sea but having formerly exposed a lateral variation of the type succession, would readily explain the existence of these clasts.

Gabbro.

Clasts of this lithology are very uniform in character throughout the conglomerate. They are very widespread and abundant comprising, for example, up to 52% of the clasts in parts of the Mount Matthias area. The rock is even-grained, consisting predominantly of plagioclase feldspar and pyroxene in about equal proportions. Crystals reach a maximum size of 3mm but 1-2mm is normal. No foliation is detectable. The rocks clearly belong to the 'younger' series of dykes and sills described by Blackadar (1967, p.27-31) which are abundant in the metamorphic rocks and the Aston Formation on Somerset Island; they intrude the Hunting Formation but do not reach the highest beds and do not appear in any later formations.

The gabbro clasts are more subject to present-day weathering processes than any others. They commonly appear as a completely rotten, greenish powder, half filling the rounded holes that represented the clast in the original rock.

Hunting Formation dolomites.

The last of the abundant clast types (locally up to 100%) is a creamy-yellow weathering dolomite, which has a number of the distinctive textures of the Hunting Formation. One of the most characteristic is an intraformational breccia, with dolomite fragments commonly about 1cm in length. Other clasts contain dolomitic oolite, in some cases silicified, and sandy dolomite with well rounded clastic quartz grains. However, the bulk of the clasts consists of structureless dololutite and dolosiltite, sometimes coarsely recrystallised - individual dolomite crystals reaching nearly a centimetre across.

The chert associated with the Hunting Formation is commonly found as smaller pebbles up to about $1\frac{1}{2}$ inches (4cm) in diameter and may comprise as much as 2 or 3% of the conglomerate.

It is not certain whether some of the dolomite clasts may have been derived from the overlying Allen Bay Formation, which is also largely composed of dolomite. However, as the Hunting and Allen Bay Formations are now believed to be conformable related to one another (Tuke, Dineley and Rust,

1966, p.709) it makes little difference to any interpretations of the paleogeography and paleogeology of Peel Sound times. The Allen Bay Formation is quite abundantly fossiliferous at Aston Bay, but very few of the dolomite clasts found in the Peel Sound Formation contained any fossils, which suggests that the Allen Bay Formation was probably not an important source rock. (The only fossils seen in dolomite clasts were some small, fragmentary crinoid ossicles in a few pebbles from the Transition Bay area). The scarcity of fossils also includes a complete absence of any of the Hunting stromatolites, though this may be merely an observational oversight, for stromatolites are very common in the Hunting Formation of Aston Bay.

Read Bay limestone.

Grey limestone containing corals, brachiopods, crinoids and ostracods is very common as clasts in some conglomerate beds near the base of the Peel Sound Formation. Some of the Read Bay limestones containing well-rounded, sand-size quartz grains are also represented as clasts, and highly weathered, derived Read Bay fossils are occasionally found in the red sandstones of the Conglomerate and the Sandstone Facies, eg. at Mount Matthias.

Basic volcanic rocks.

Fine grained basaltic rocks are among the more minor

constituents of the conglomerates. They are generally even grained, showing no texture visible to the naked eye. A cobble found near Bellot Cliff was the only exception; it contained an abundance of small, spherical masses, each approximately 5mm in diameter - either devitrification structures or spherulites. The source of these rocks is unknown, for none have been described from the country rocks of the region. They may represent the chilled margins of gabbro intrusions, although no such fine grained margins have been described by Blackadar (1967).

Intraclasts.

Angular to rounded fragments of red siltstone and shale are common in some of the finer grained conglomerates and in the interbedded sandstone lenticles. Their very localised abundance in channel fills and in arenaceous beds with cut-and-fill bases suggests an intraformational origin. They were probably derived from impersistent lenticles of these lithologies and transported only short distances.

Throughout the conglomerate there are a few clasts of lithologies believed to be derived from the Lower Peel Sound Formation or the upper parts of the Read Bay Formation, and now included in the coarse boulder conglomerates several hundred feet higher in the succession. Examples are a clean, white quartzose sandstone, pebbles and cobbles of which were found in northern Prescott Island, Mount Matthias and Russell

Island; an oligomict limestone conglomerate from Bellot Cliff and Cape Walker, and one similar clast from near Cape Brodie which was 12cm in diameter and contained pebbles of Hunting dolomite up to 3cm long, plus one recognisable fragment of grey Read Bay limestone, all set in a matrix of sand and crystalline dolomite. One boulder in the coarse conglomerates two miles southeast of Bellot Cliff consisted of white quartzose sandstone with wisps of grey shale and a number of rather fragmented, derived corals. It is thought that the corals were originally in the Read Bay Formation, and have been included in a sandstone of the basal Peel Sound Formation, only to be rederived as part of a clast of the sandstone.

It may well be that many of the clasts in the upper part of the Peel Sound Formation have been reworked in this manner, but show no evidence of the fact because the early Peel Sound beds had little time to consolidate before being re-eroded. Thus any reworked material present in higher levels of the formation would be found as discrete grains rather than conglomerate aggregates, and could not, therefore, be distinguished from first-cycle fragments.

The significance of these intrclasts will be discussed under 'History and Paleogeography'.

Vertical clast variation

In many places, where several hundred feet of conglom-

erate can be seen in one section, a study of the vertical variations in the clast lithologies reveals a 'reversed stratigraphy' effect. That is to say, at higher levels in the succession the conglomerate contains a progressively greater proportion of the older clast types described above. Read Bay limestones disappear in favour of Aston and Hunting rocks, and these in turn reduce in number upwards as the Precambrian metamorphics become dominant. The changing proportions clearly reflect a progressively deepening level of erosion in the source area.

The changes are most marked in the transition from the Lower to the Upper members of the Peel Sound Formation: Read Bay clasts are locally abundant in the lowest few hundred feet of the conglomerates and rapidly decrease in number upwards. Thus at the unconformity seven miles south of Bellot Cliff (NS403900; see fig. 7, loc. A) limestone boulder conglomerate consisting of 95% Read Bay limestone clasts rests on the eroded top of the Read Bay Formation. The remaining 5% consists of Aston quartzite and gneiss. However, only fifty feet higher in the succession the composition of the conglomerate is as follows: green basic gneiss 45%, Aston quartzite 30%, Hunting dolomite 25%; with a maximum clast size of 24 inches (60cm). Read Bay clasts appear only in occasional thin seams of limestone pebble conglomerate at this level.

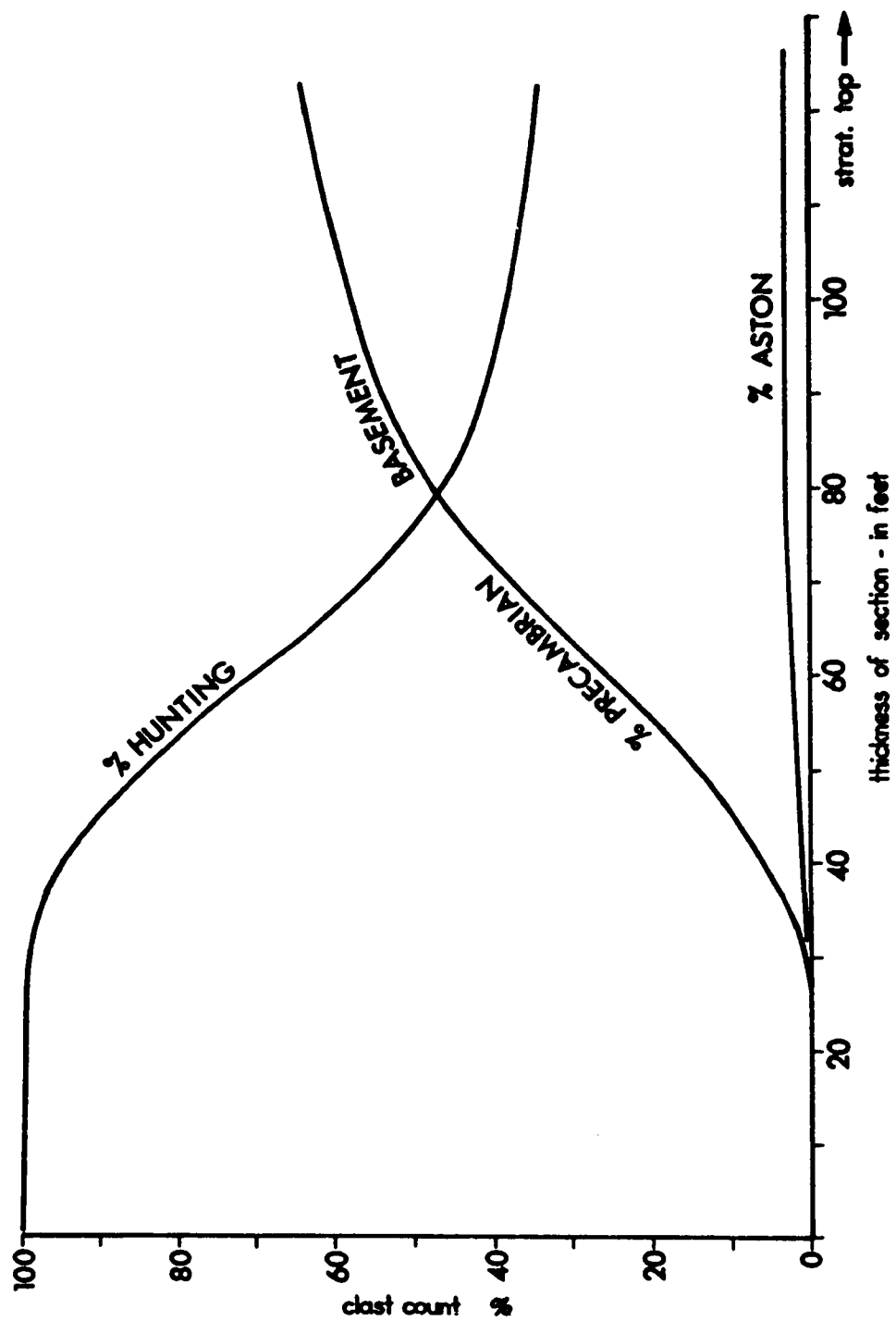


Fig. 8. Vertical clast changes at Cape Brodie

A similar upward disappearance of Read Bay material may be seen near Mount Matthias (NS526517, see fig. 7, loc B). Approximately 400 feet of basal Peel Sound beds with Read Bay pebble conglomerates and sandstones containing derived fragmentary Read Bay corals give way upward, in about twenty feet, to typical boulder conglomerates in which Read Bay clasts are absent. At a locality immediately above the change, the clast count is as follows: Aston 70%, Hunting 1%, gabbro 18%, gneiss 7%, basic volcanics 4%.

The vertical variations are particularly well seen at a number of localities some ten miles north of Cape Brodie, in three adjacent gorge sections (NR831486, NR840517, NR852558; see fig. 7, loc. C). The Read Bay limestones do not appear as clasts in these sections - the lowest Peel Sound conglomerates are entirely dolomitic. Most of the material is believed to be from the Hunting Formation, but may include a small amount of Allen Bay material. For several hundred feet of vertical succession the conglomerate composition and grain size does not vary, but at this level a sudden change takes place over a thickness of only 30 to 40 feet into the typical coarse, polymict boulder conglomerate as shown graphically in fig. 8. The conglomerate matrix shows a corresponding change, from clear washed quartz sandstone with a dolomite cement, to hematite stained lithic sandstone rich in felspar and rock fragments. Above this transition, as below, the

**GNEISSES
DOLOMITES**

BOULDERS → 50cm.
PEBBLES → 6cm.

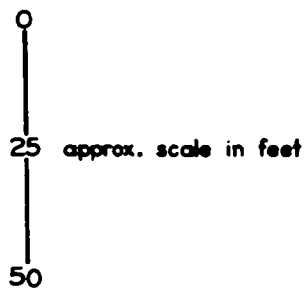


Fig. 9.

VERTICAL
CLAST VARIATION
at
TRANSITION BAY

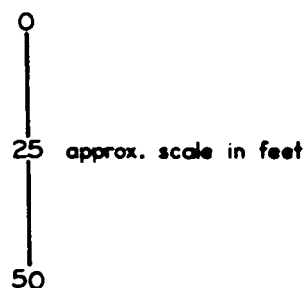
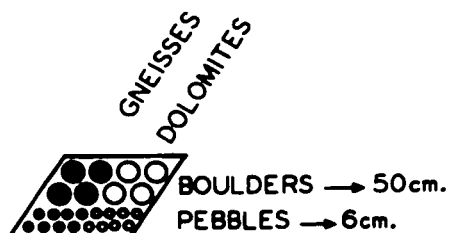
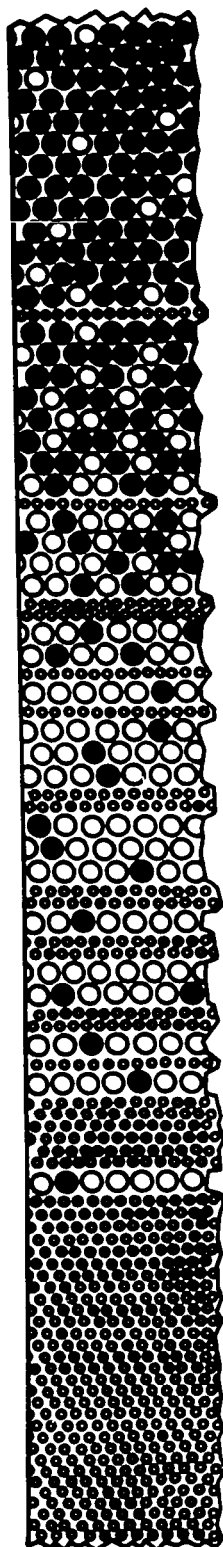


Fig. 9.

conglomerates are everywhere monotonously similar.

A slightly different pattern is seen in the Transition Bay area (fig. 7, loc. D, see fig. 9) although the evidence here was obtained from rather widely scattered outcrops, and the clast variations may not be of the strictly 'vertical' type discussed above. The lowest 700 feet of the Peel Sound Formation, well displayed in a gorge section seven miles north of the mouth of Transition Bay (NR855095; the section studied by Broad, 1968) contains pebble conglomerates entirely composed of dolomite clasts with a dolomite-rich matrix.

Exposures one to two miles south, estimated to be about 200 feet higher in the succession, show two types of conglomerate:

a) Coarse, polymictic, clast count: Hunting 83-85%, gneiss 15-17%, Aston - traces; maximum clast size 20 inches (50cm).

b) A finer grained, highly dolomitic conglomerate, clast count: Hunting 95-99%, gneiss 1-5%, Aston - traces; maximum clast size 2.5 inches (6cm).

The two rock types are quite distinct, occurring in separate, lenticular beds and readily distinguished from one another at a distance by the fact that conglomerate (b) is a much lighter colour and forms more compact layers, with a better resistance to erosion. It occurs in lenses 2-4 feet thick, separated on the average by about fifteen feet of conglomerate (a). The trend towards an increasing proportion of gneissic material is continued three miles to the southwest (NR835036), where

(b) type conglomerates die out upwards, and the coarser rocks have the proportions: gneiss 75-94%, Hunting 6-25%, Aston - traces.

It is thought that changes similar to these take place everywhere in the lower parts of the formation, but exposure outside the four areas described above is too poor to allow of a complete description. Thus in southern Pandora Island (fig. 7, loc. E) a Read Bay-rich conglomerate appears to pass upwards into a gneiss and dolomite rich variety, but exposure of the latter is very poor.

All the examples described above refer to the clast changes between the lower members of the Peel Sound Formation and the typical coarse boulder conglomerate that forms the remainder of the succession. Vertical variation within the latter is less obvious, and exposure is usually insufficient to allow vertical sampling of more than about a hundred feet of beds without extending the work some distance laterally, thus introducing the possibility of other complications. Near Bellot Cliff, however, a series of gorge sections each exposes at least 400 feet of boulder conglomerate. In one of these, four miles due south of the cliff (NS411977, see fig. 7, loc F) eight clast counts were made, with the object of revealing any stratigraphic variations in the clast composition. In this gorge, as in many others, small-scale variations can often be detected by eye - occasional imper-

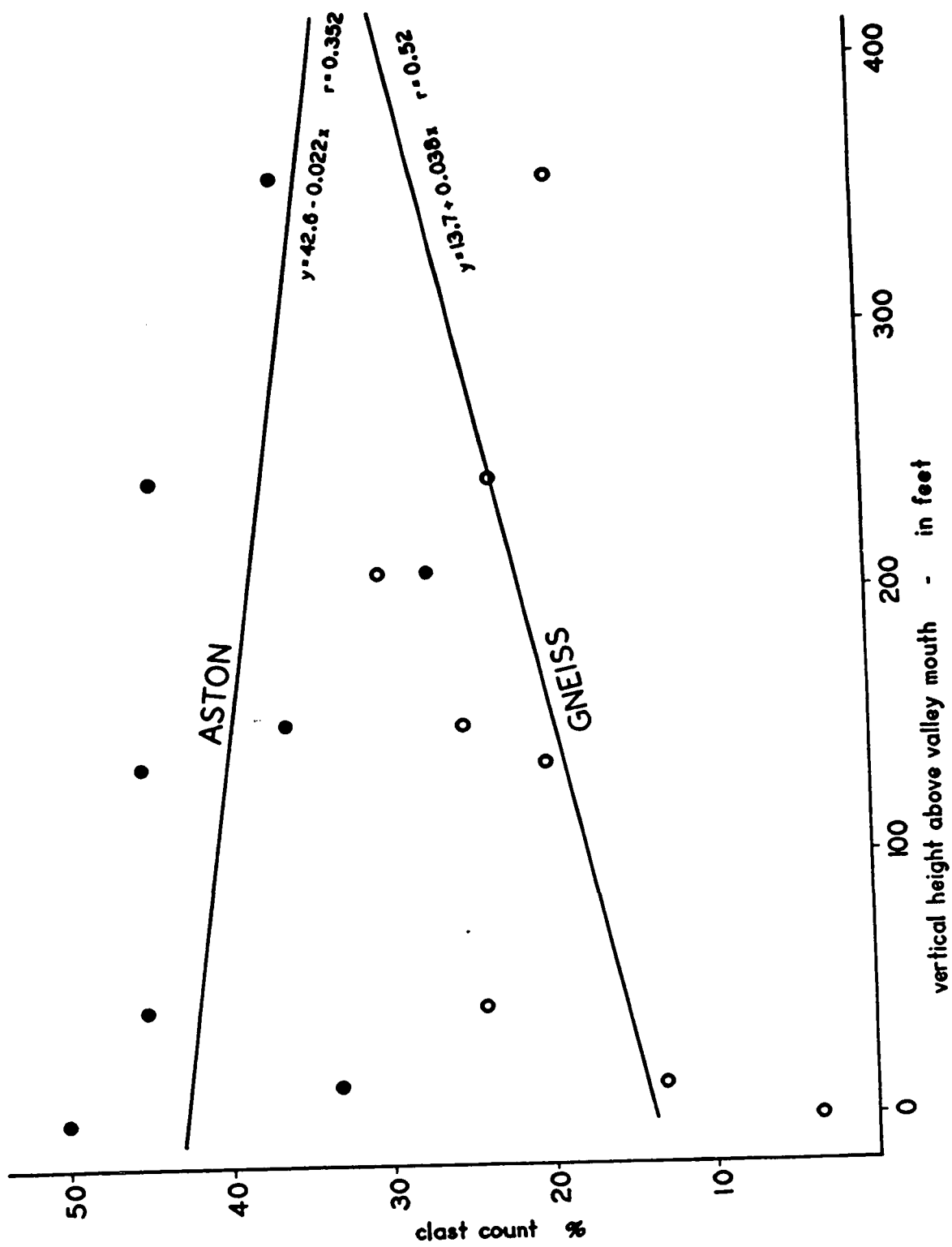


Fig. 10. Clast counts at loc. 31

sistent lenticles show, for example, slightly increased proportions of gabbro clasts or dolomite clasts; if the latter, there is usually a considerably increased amount of dolomite in the matrix. Such compositional variations are usually accompanied by small grain-size changes. Fig. 10 plots the percentage of the two most important clasts against vertical position in the section. Regression lines have been calculated by the standard 'least squares' method (Freund, 1960, p.316) and the correlation coefficient r (op. cit., p.413) has been computed for each line. There is considerable spread in the readings, and the correlation coefficients are correspondingly small. The coefficients of causation ($r^2 \times 100$) are low - for the gneiss percentage variations it is 27% and for the Aston quartzite variations 12%. These correlations are not statistically significant at the $P = 0.10$ level, i.e. there is a greater than 10% probability that the results could have arisen from random sampling of a homogeneous population (Davies, 1967, table E, p.372). However, as discussed below, the trends do make sense geologically. The results serve to emphasise how there may be many causes of variation in a given geological situation.

Areal elast variations

When investigated over wide areas the conglomerates show considerable variation in clast composition. In

three areas: 1) Bellot Cliff-Russell Island 2) Mount Matthias and 3) Pandora Island-adjacent mainland, a sufficient number of clast counts was made to show pebble dispersal patterns. In discussing these patterns the same qualifications already stated should be borne in mind - that there is no definite stratigraphic control of the outcrops. But the prevailing horizontal dip and the range of altitude of most of the exposures (from 100 to about 700 feet above sea level) together suggest that beds within the same stratigraphic interval of about 6-700 feet are being measured.

In the accompanying diagrams each clast type is treated separately. The relevant paleocurrent data from fig. 49 are included to clarify the dispersal patterns suggested by the clast counts.

In the Bellot Cliff area (figs. 11-16) the conglomerates appear to have two source areas. The green Aston quartzite is important only at Bellot Cliff itself and in Russell Island, whereas all the other major clast types (pink Aston quartzite, gneiss, gabbro, Hunting dolomite and basic volcanics) have their highest percentage south and southeast of the Cliff. This is emphasised by the contouring, the interpretation of which is discussed in the next section. The Hunting dolomite is the only clast type which does not show a well defined dispersal pattern

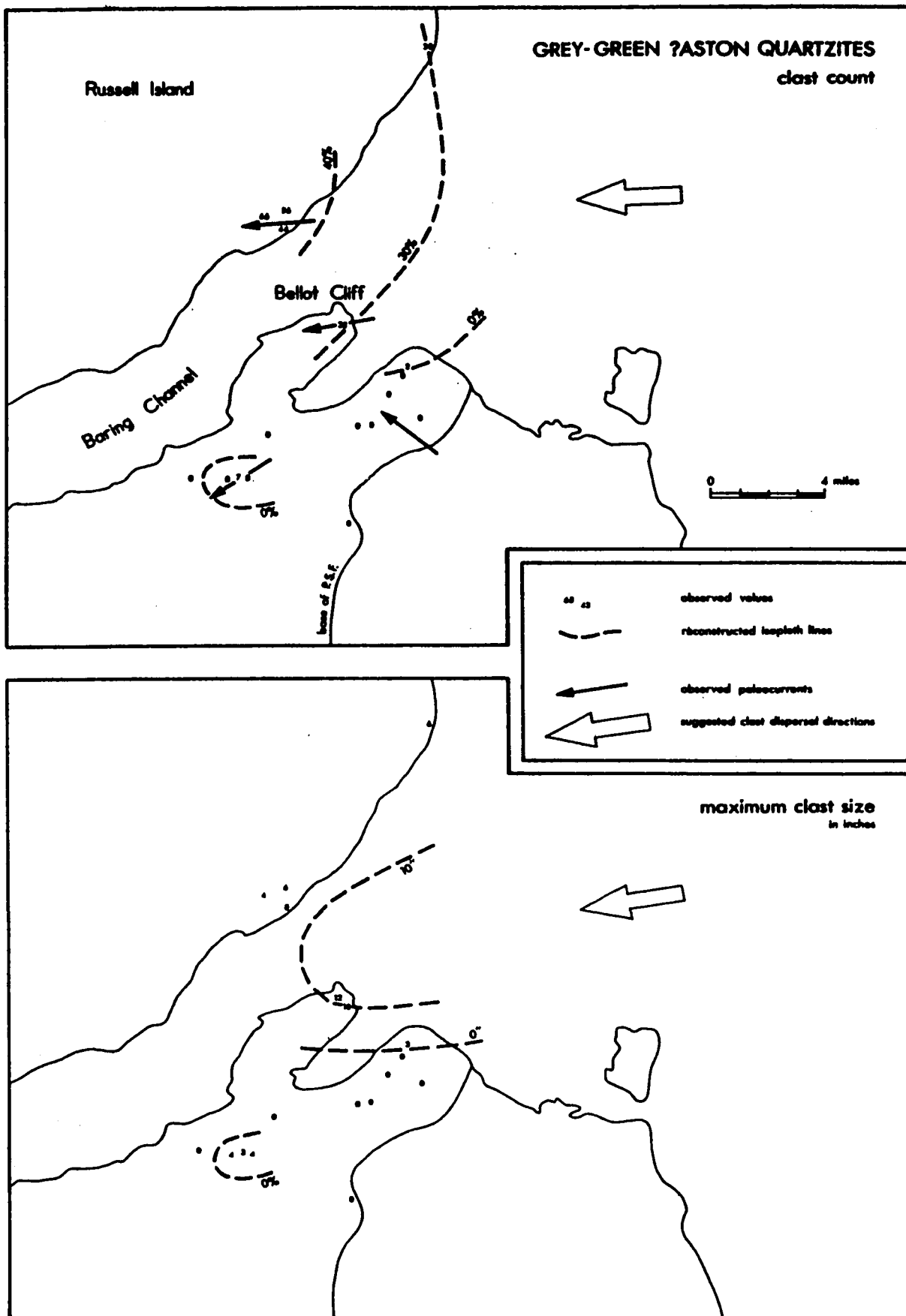


Fig. 11. Clast count (top), maximum clast size (bottom): Bellot Cliff area.
other lithologies illustrated in figs. 12-16, using the same layout

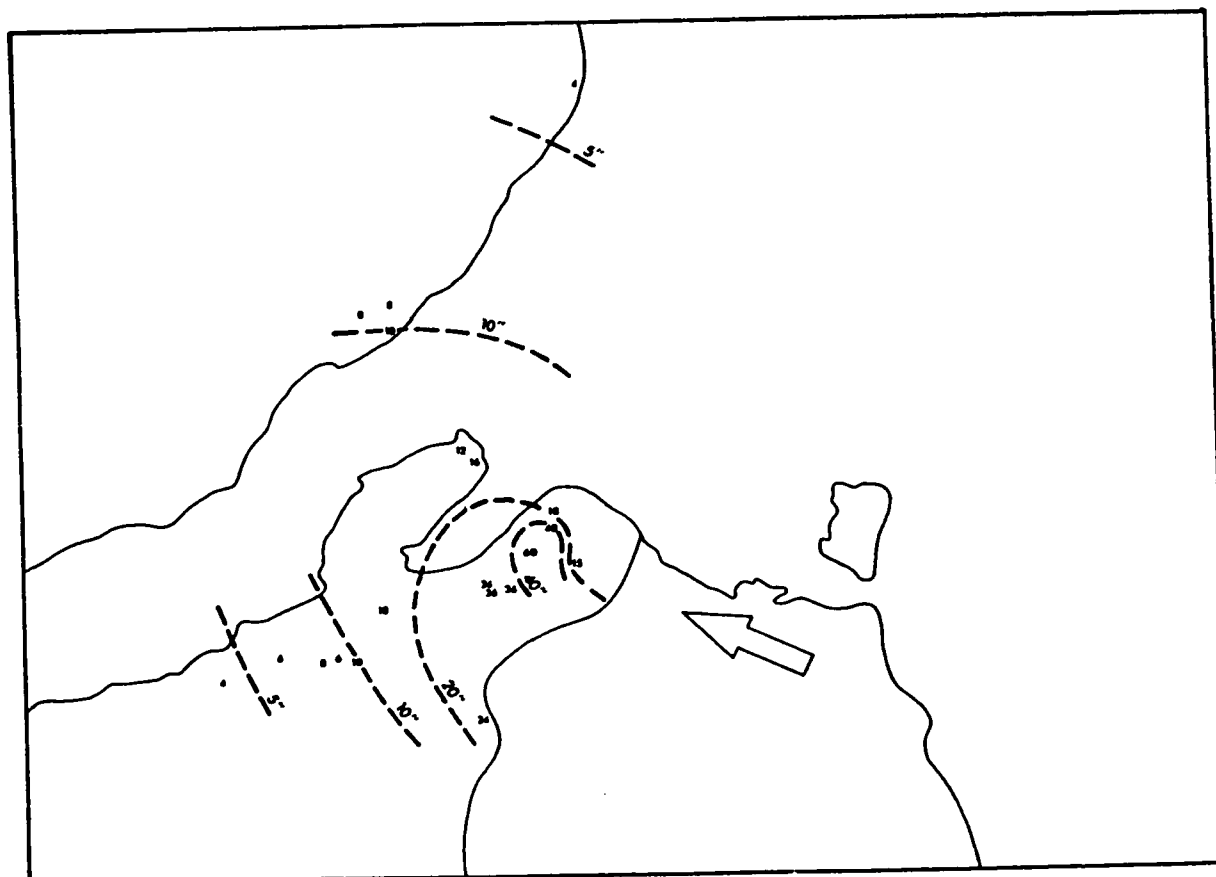
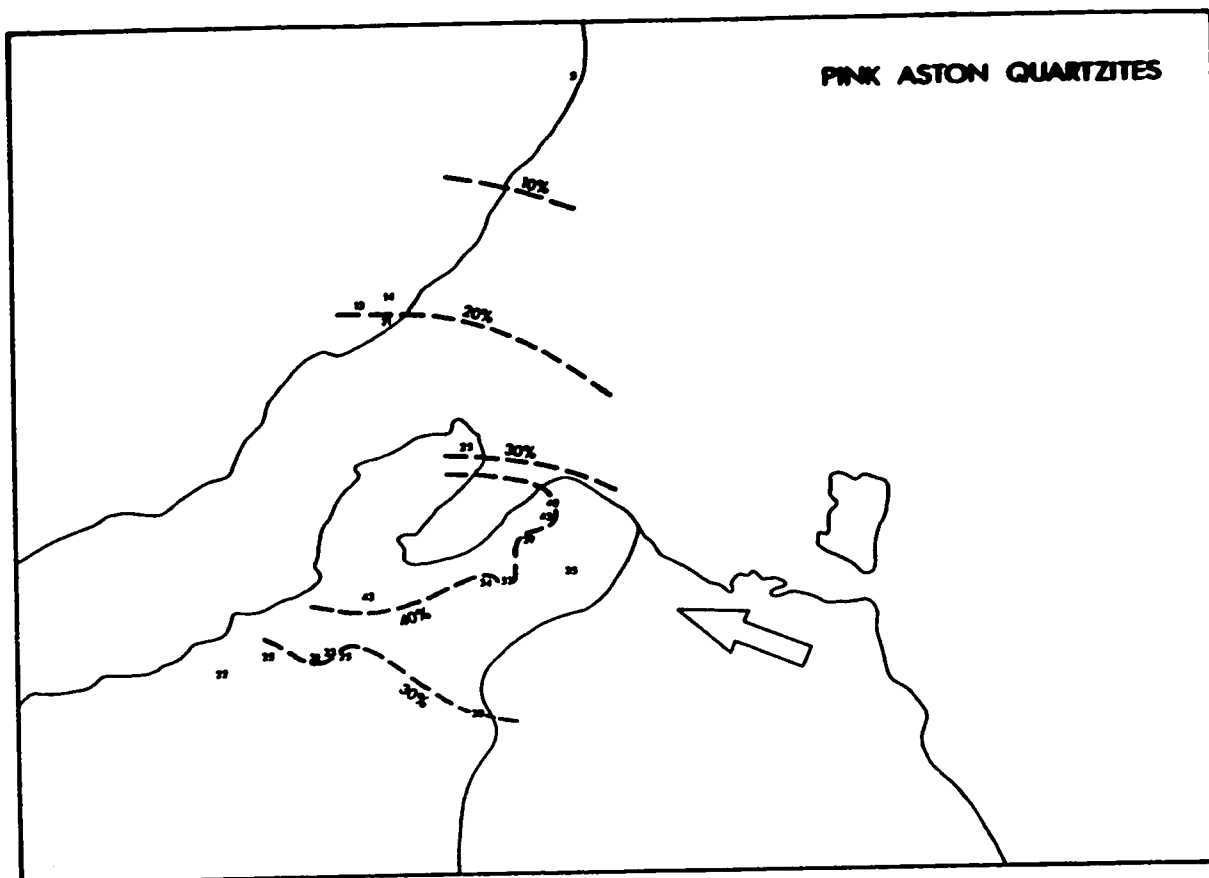


Fig. 12.

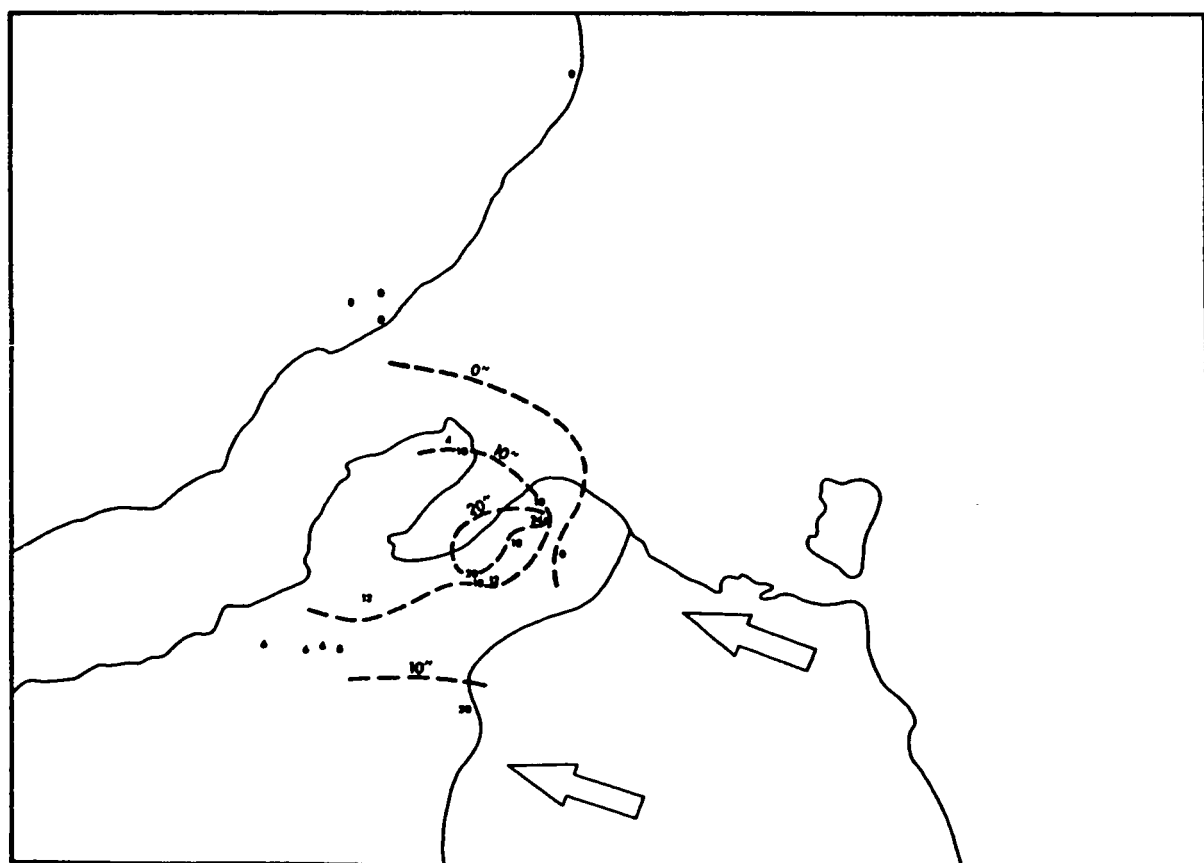
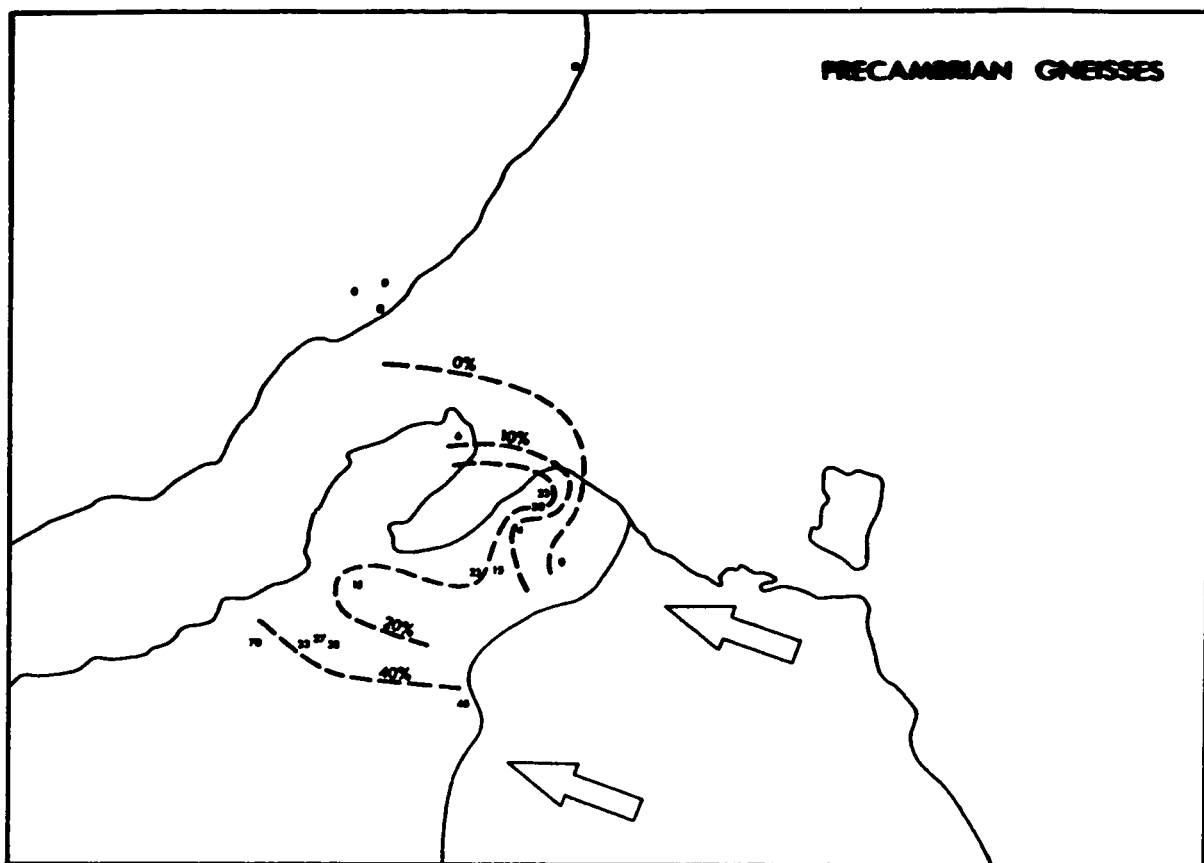


Fig. 13.

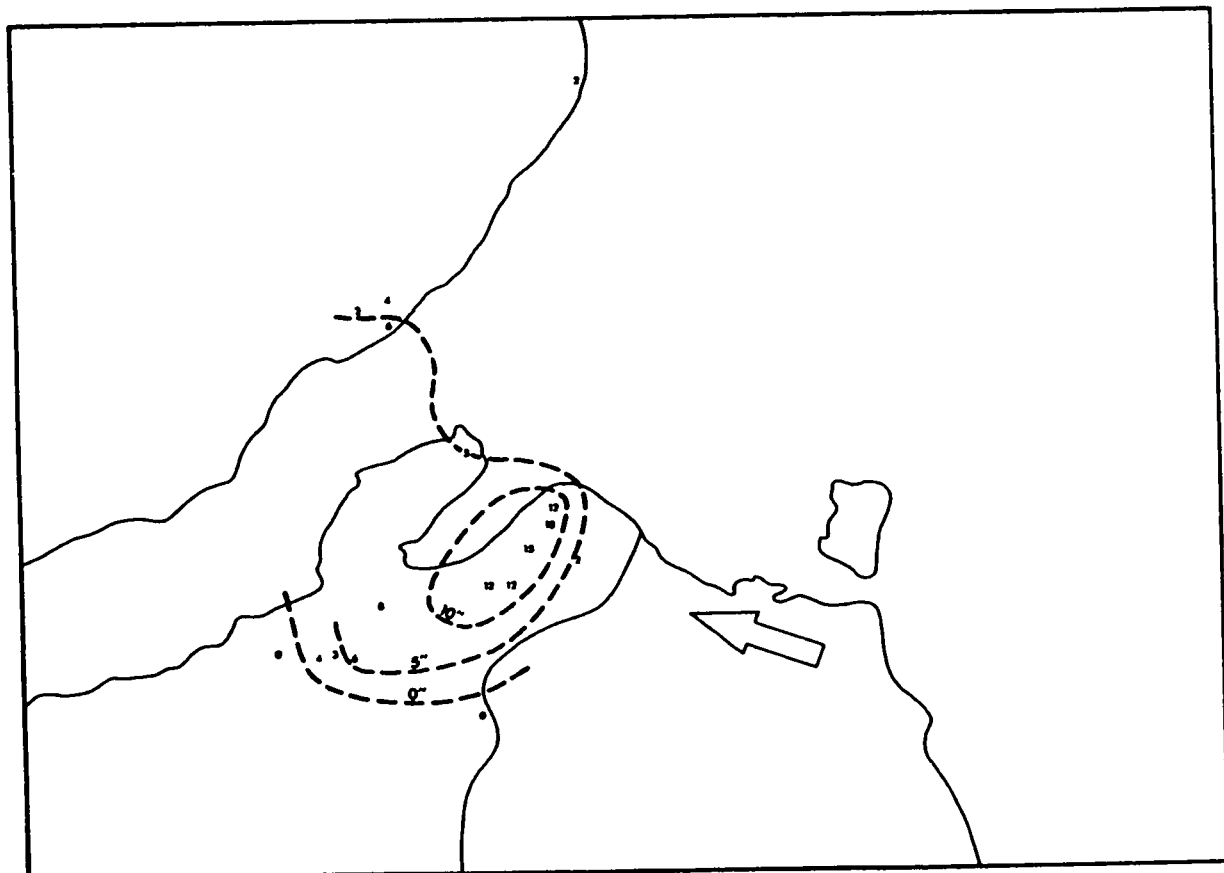
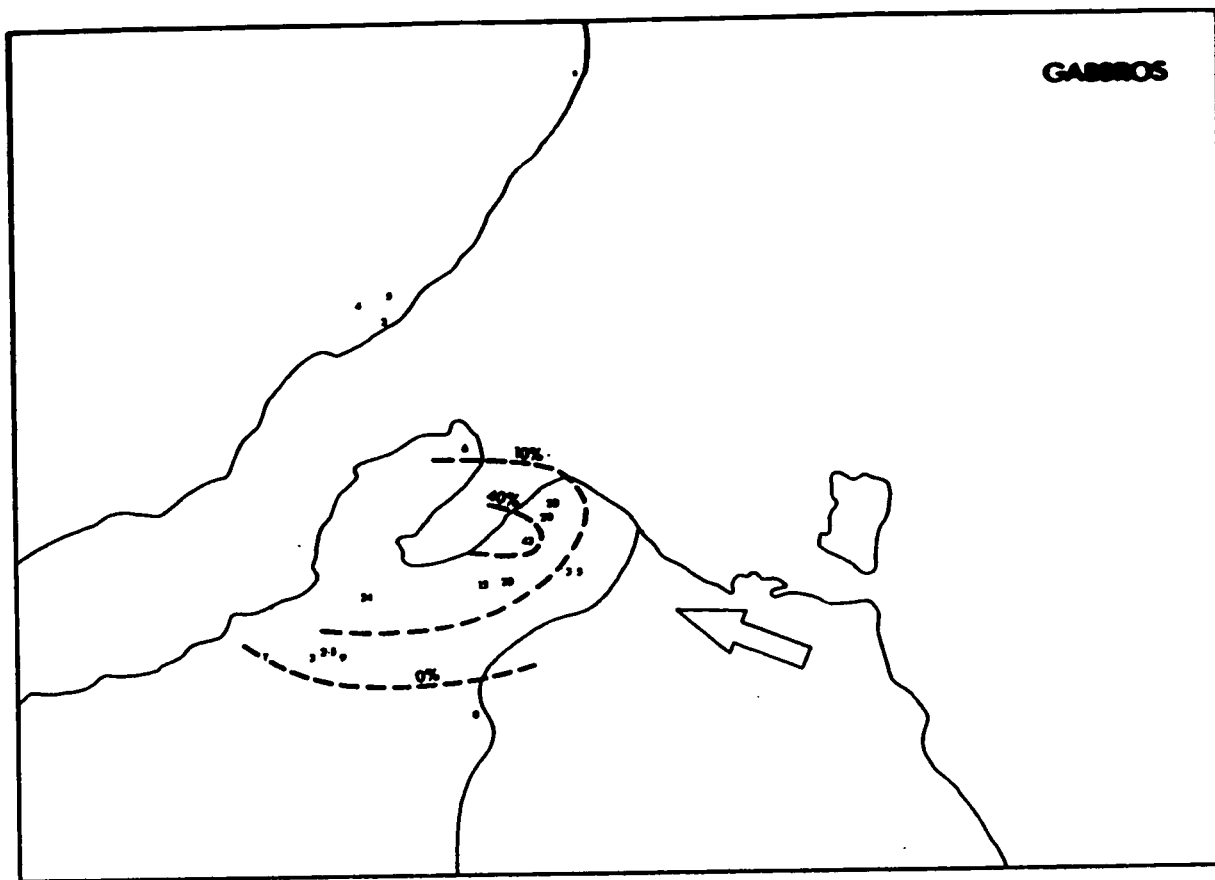


Fig. 14.

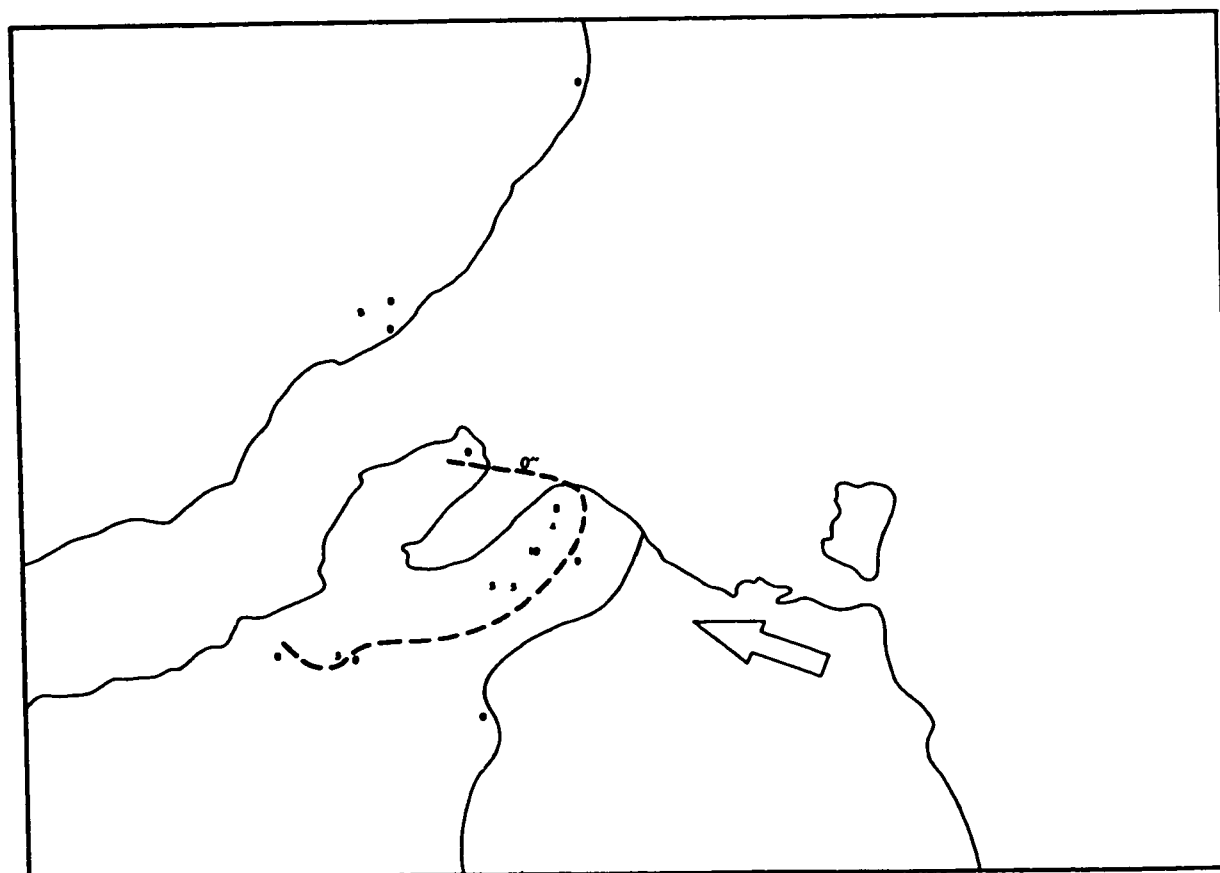
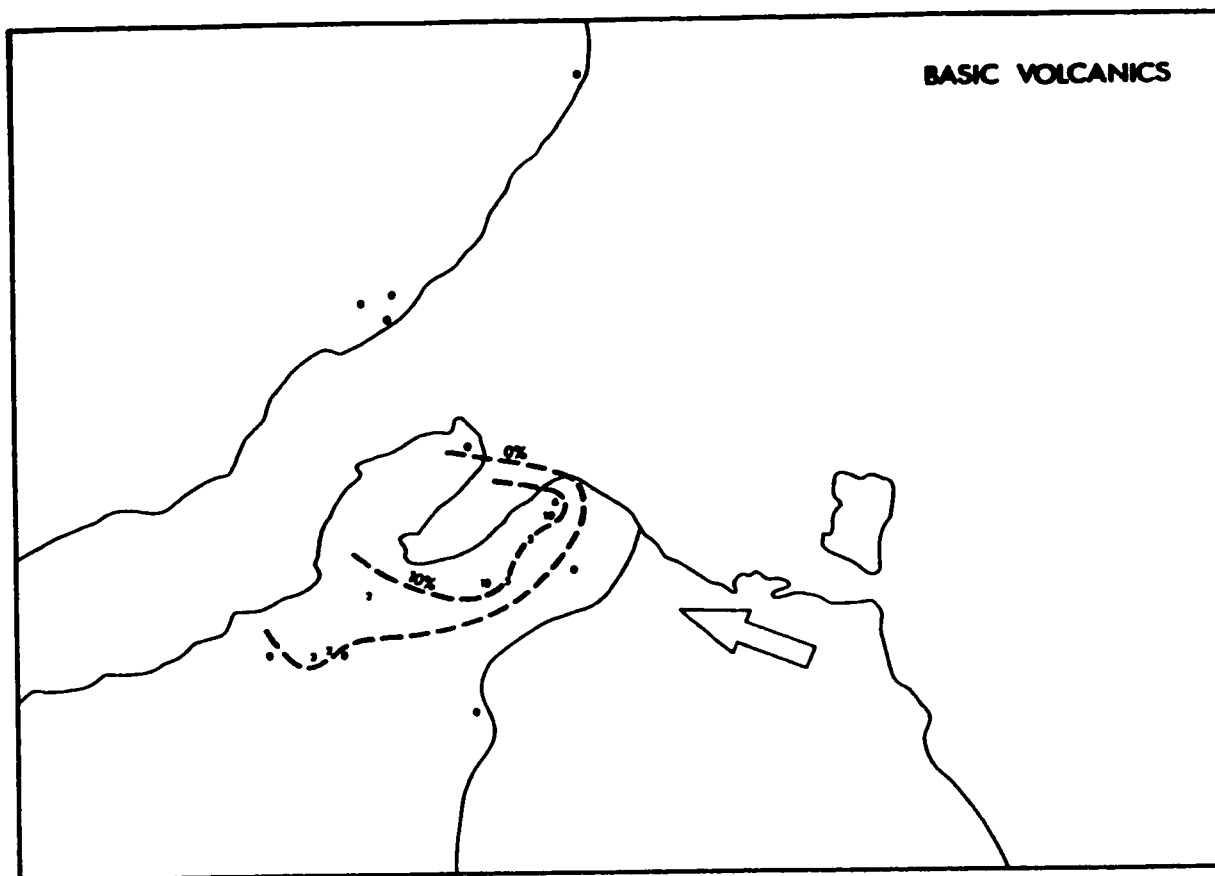


Fig. 15.

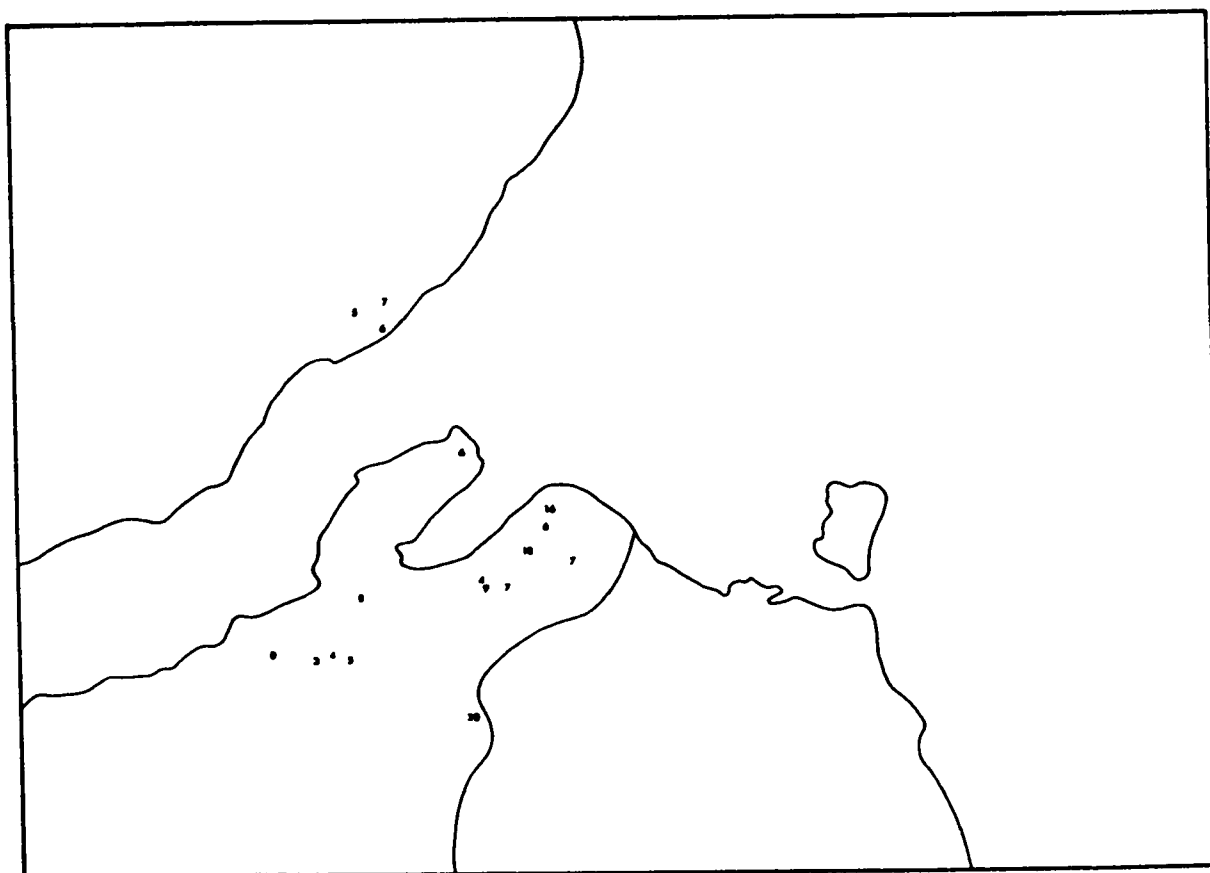
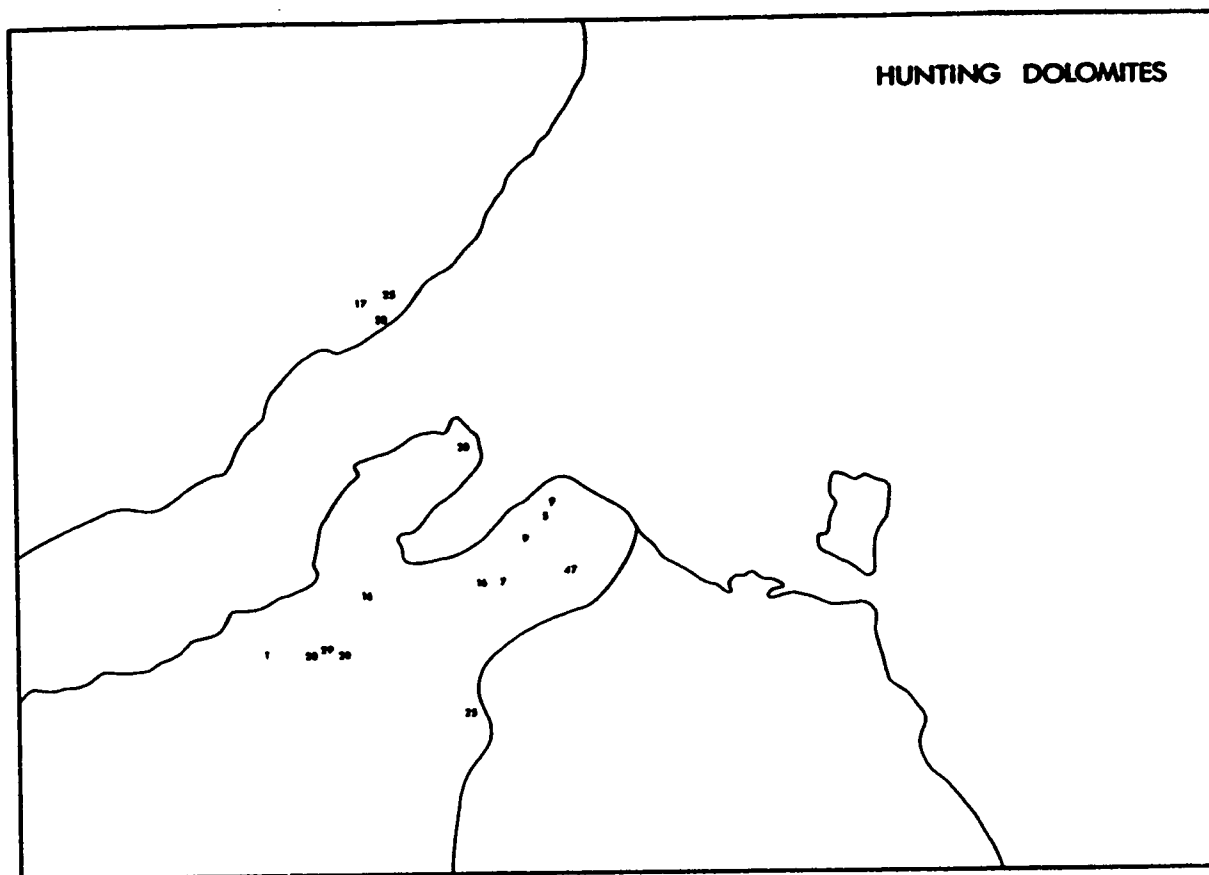


Fig. 16.

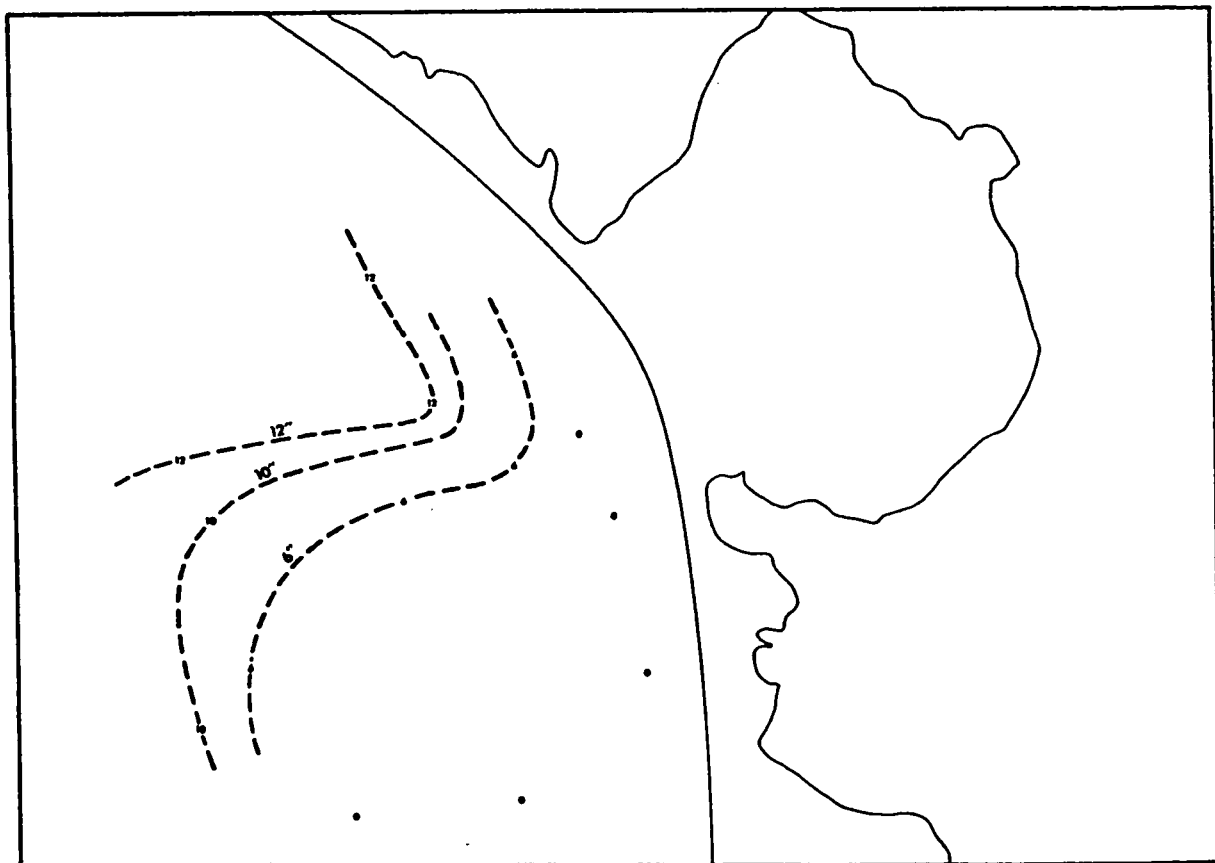
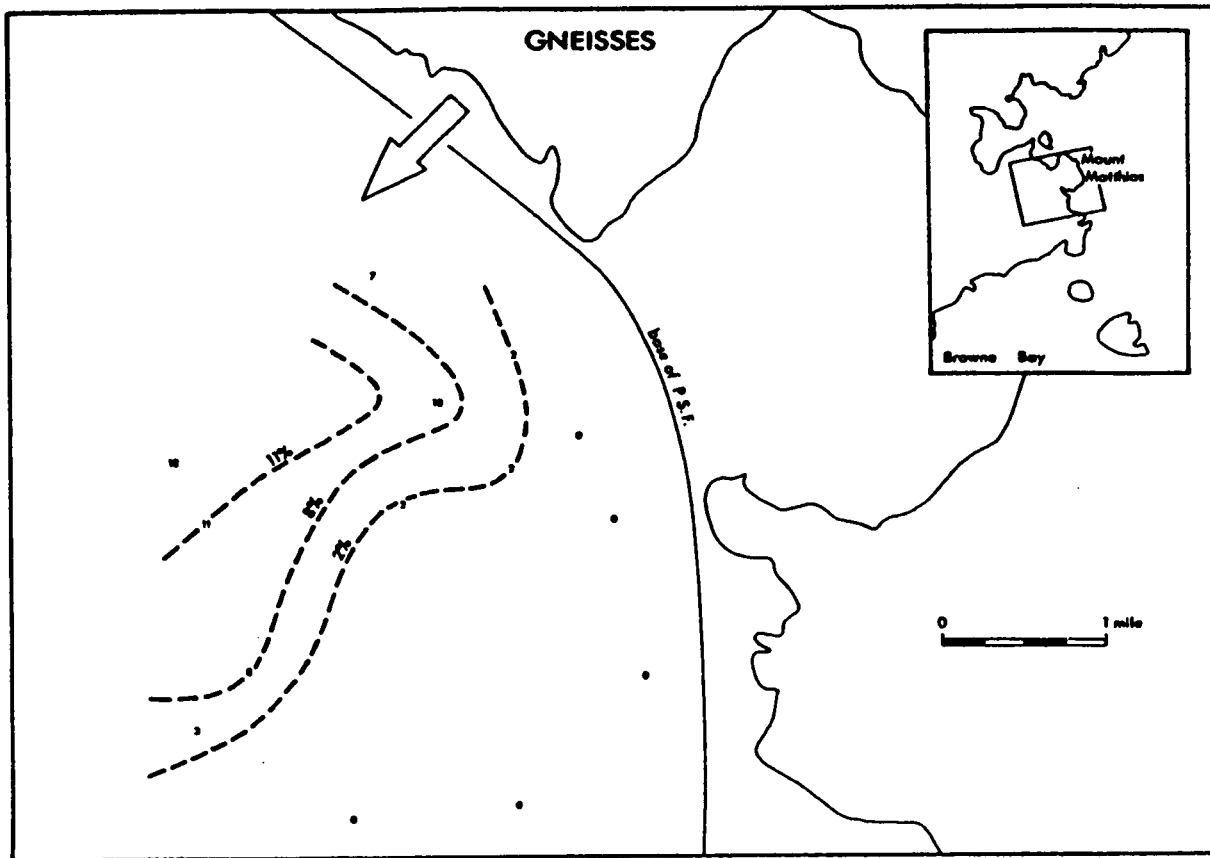


Fig. 17. Clast count (top), maximum clast (bottom): Mount Matthias.
other lithologies illustrated in figs. 18,19. symbols as in fig. 11.

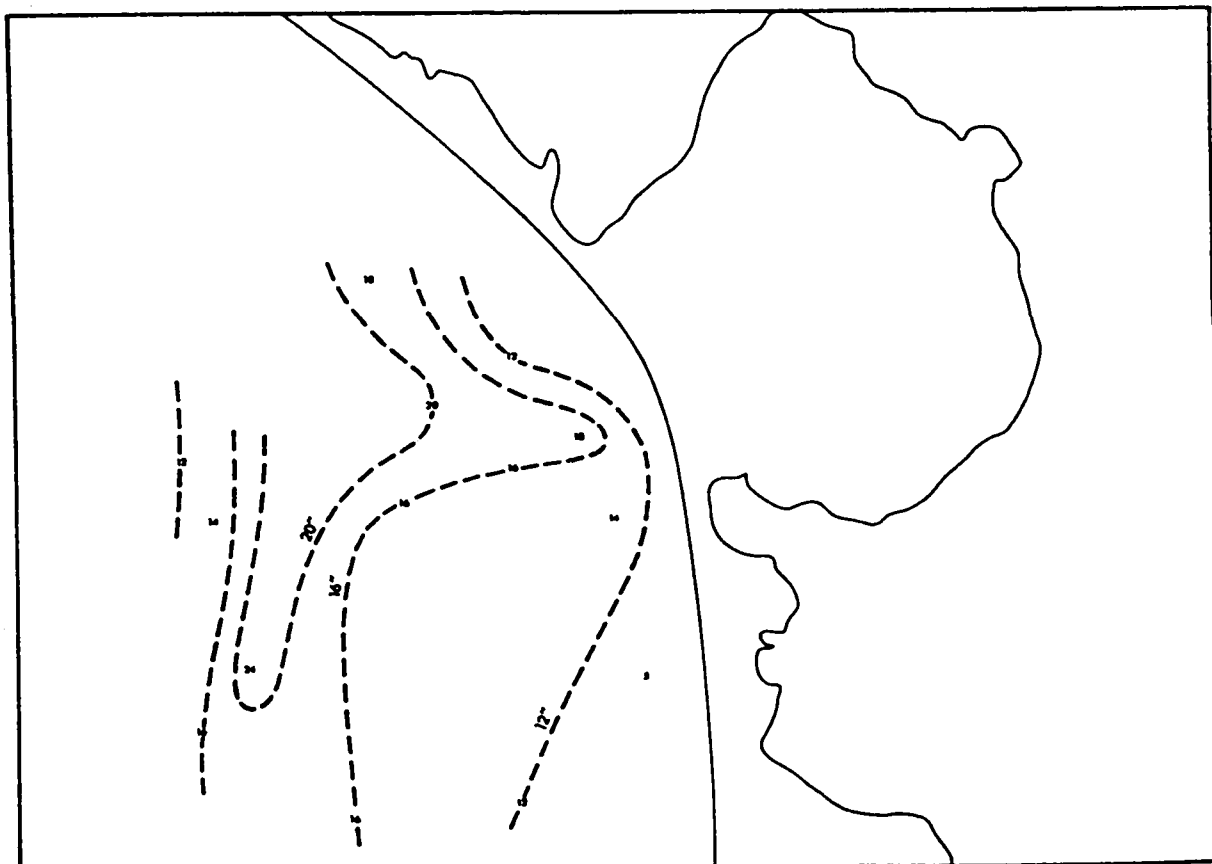
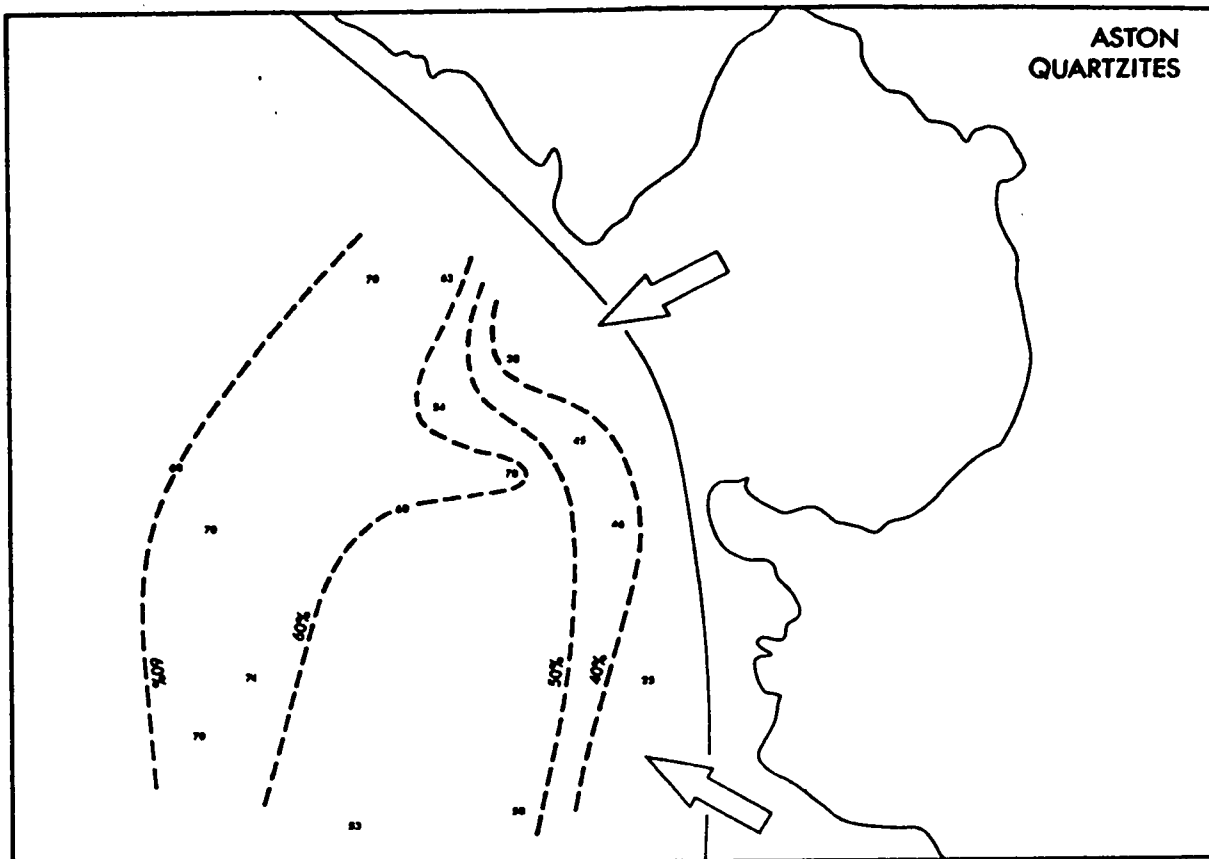


Fig. 18.

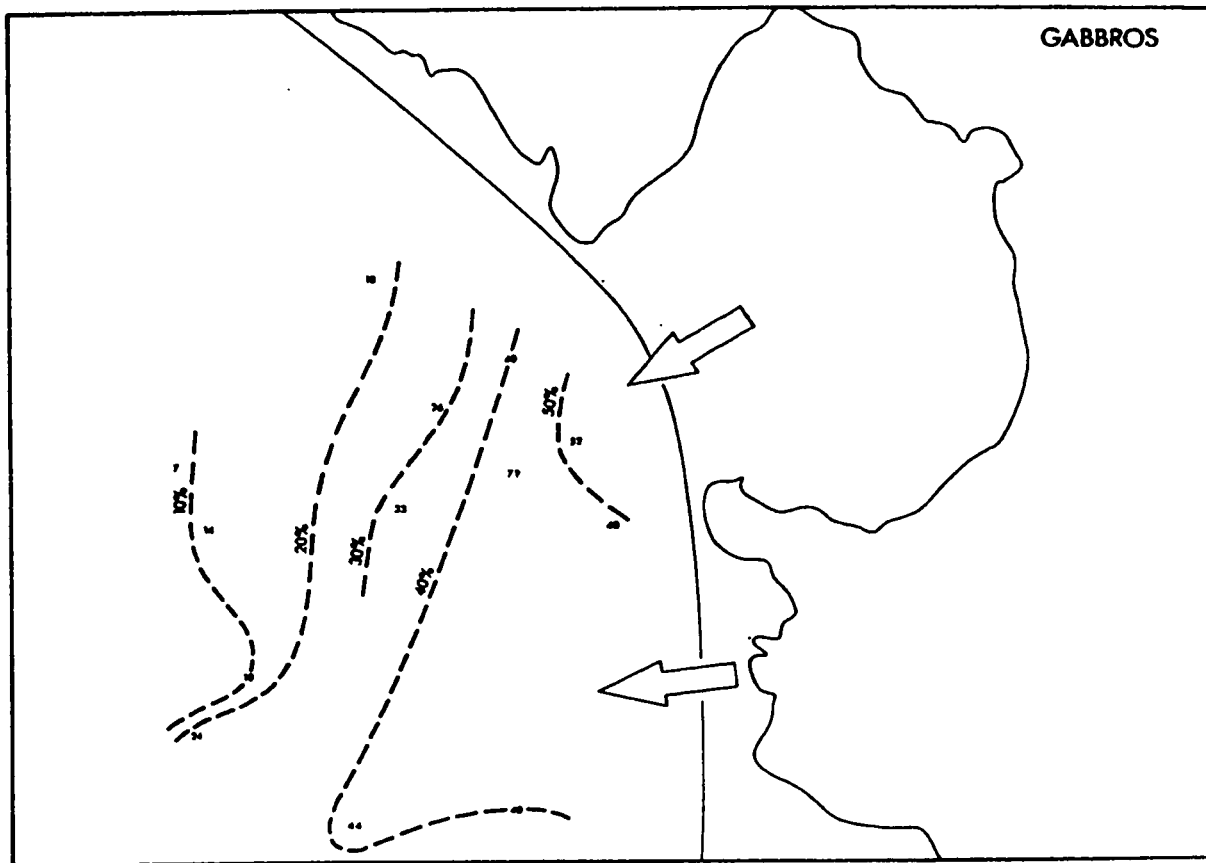


Fig. 19.

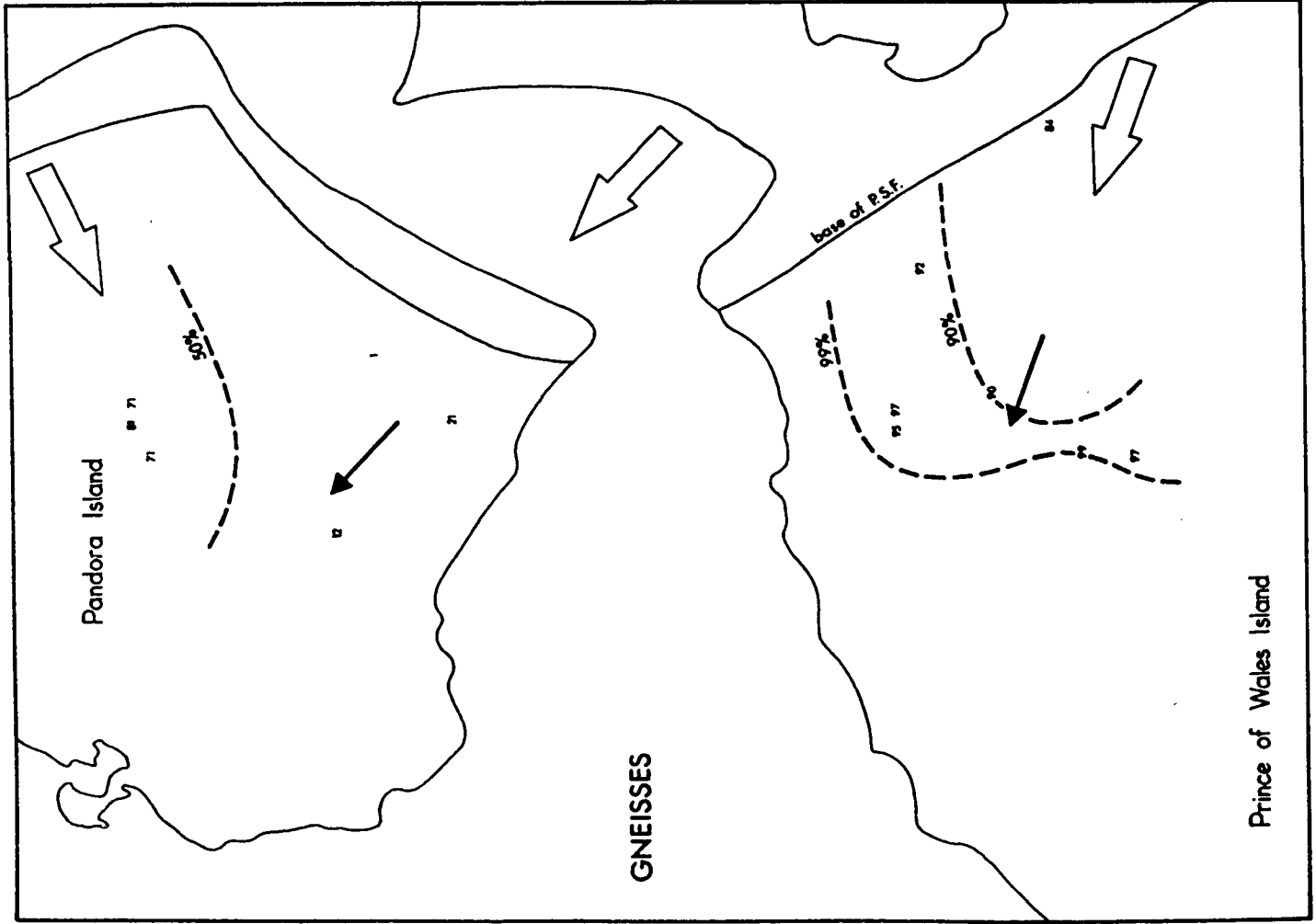
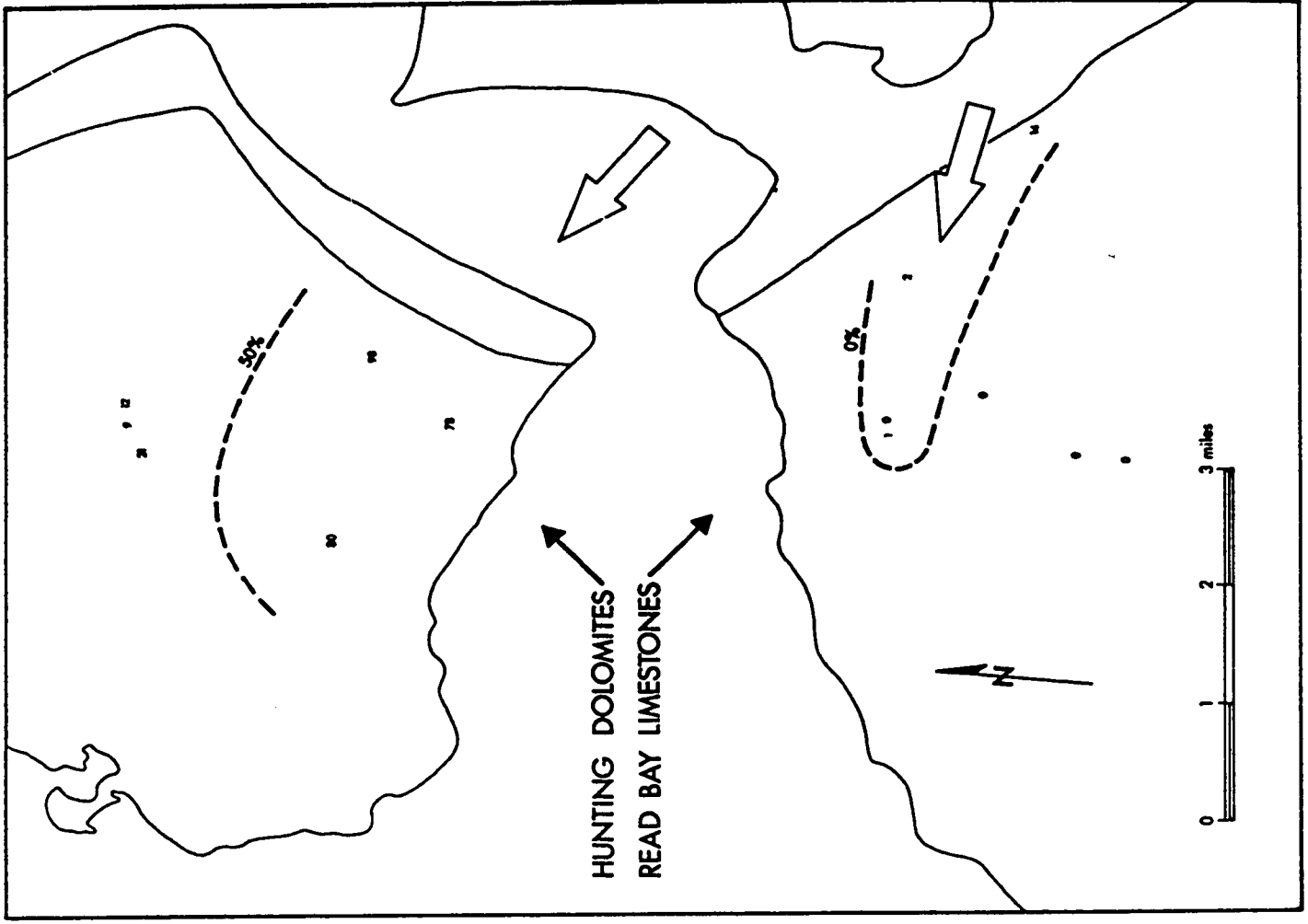


Fig. 20. Clast counts: Pandora Island area. Symbols as in fig. 11.

(fig. 16).

In the Mount Matthias area there are three important clast types - gneiss, Aston quartzite and gabbro. Clast counts for these are given in figs. 17-19. The one locality marked with a question mark seems to be anomalous in several respects. This is possibly due to some minor local fluctuation, for it is the only locality that cannot be fitted into the generalised schemes drawn for the area. Paleocurrent data is almost absent - sedimentary structures are very rare. The interpretations of dispersal directions are thus based almost entirely on the distribution patterns of the three clast types.

The third area again contains three widespread clast types: gneiss, Hunting dolomite and Read Bay limestone. Aston quartzite and gabbro are present in minor amounts and their distribution does not appear to be systematic. They are not, therefore, included in the accompanying diagrams (fig. 20). On Pandora Island there are two conglomerate types: (a) a Hunting-rich rock with minor quantities of gneiss and Aston quartzite in a dolomitic matrix - present in the southern part of the Island; (b) a gneiss-rich conglomerate in which dolomite and quartzite together comprise less than 30% - seen in the central part of the Island. In the second area, although the major part of the conglomerate is of the gneiss-rich variety,

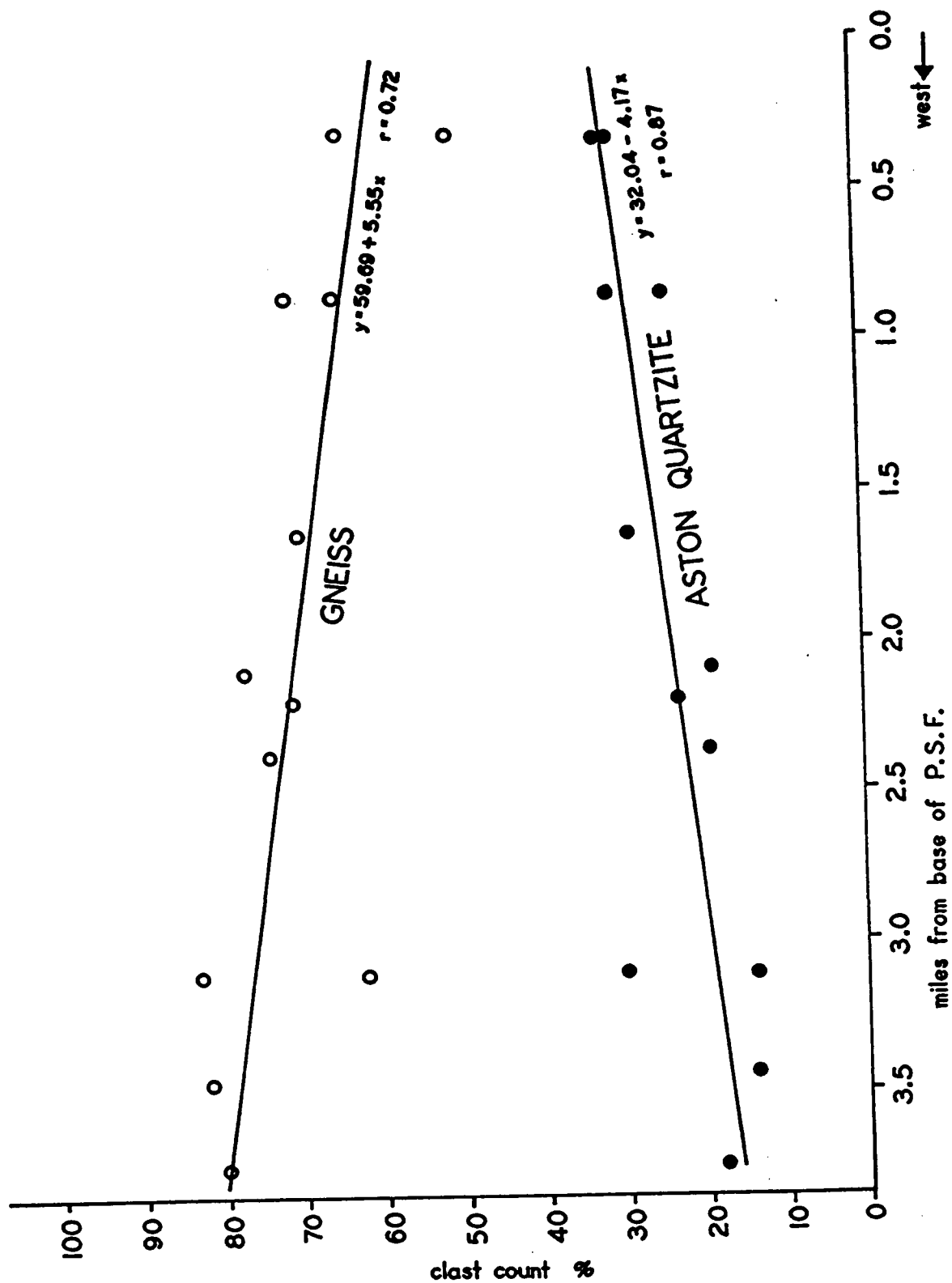


Fig. 21. Clast counts: southern Prescott Island

one laterally extensive three foot seam of highly dolomitic conglomerate caps the crest of a gorge section at NR732780. The smaller maximum pebble size (approximately 6cm as opposed to 50cm) and the virtual absence of all but dolomite in pebbles and matrix make this a very distinctive rock type. This mixing of conglomerate types is discussed below.

The mainland south of Pandora Island exposes a very gneiss-rich conglomerate. Read Bay material is present in small quantities and dies out westwards. Clasts from the Hunting Formation were not observed.

Finally, in fig. 21 are presented the clast counts for the two most important lithologies present in southern Prescott Island - gneiss and Aston quartzite. The results are given graphically for they were compiled on a traverse along a nearly linear series of outcrops. There is a clear trend westward from the Read Bay contact, towards diminishing content of Aston quartzite and an increase in gneiss percentage (Other clast types are present in minor variable amounts). The correlation coefficient for the gneiss variation (0.72) is significant at the $P = 0.01$ level; the correlation coefficient for the Aston variation (0.87) is significant at the $P = 0.001$ level.

Maximum clast size studies

Diagrams showing areal variations in maximum clast size

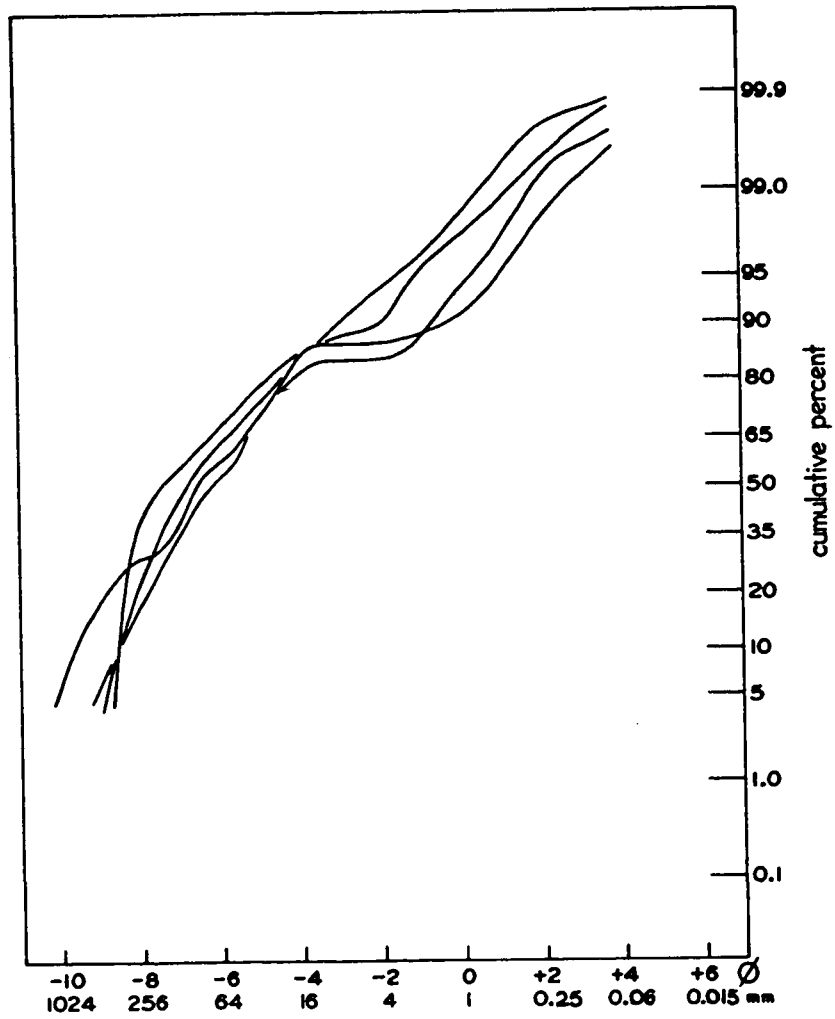


Fig. 22. Conglomerate size sorting: Bellot Cliff

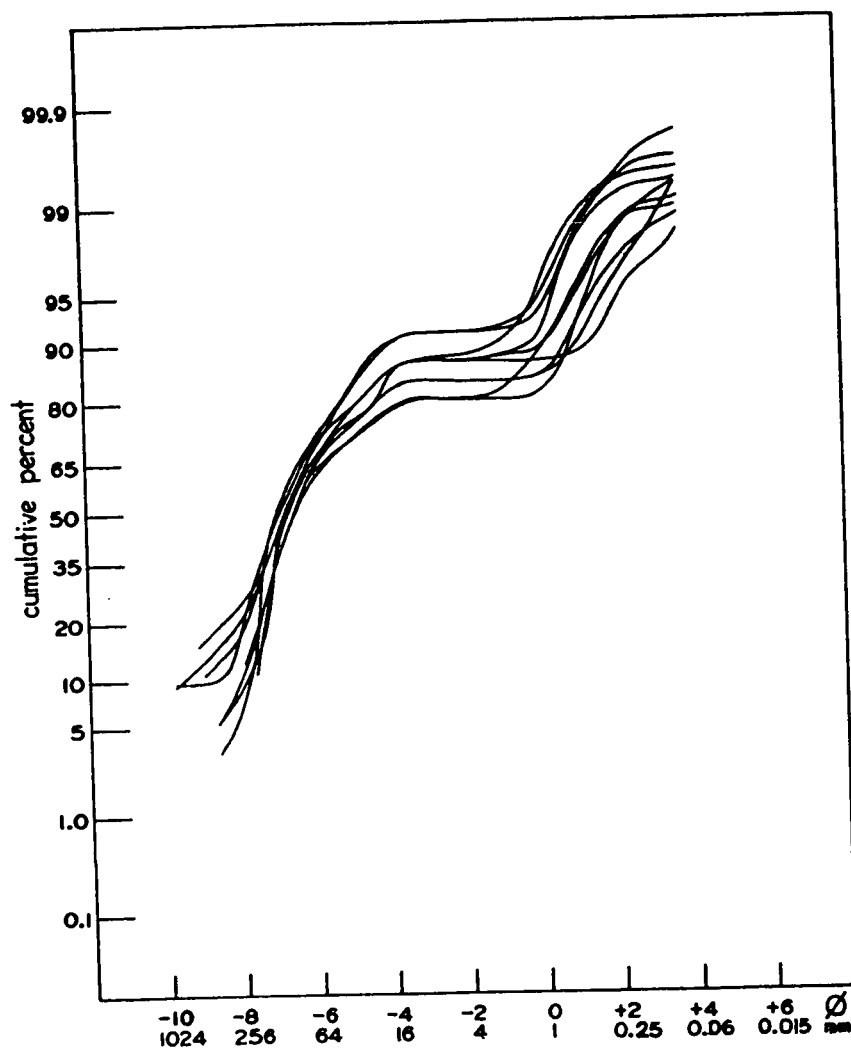


Fig. 23. Conglomerate size sorting: southern Prescott I.

are included with those drawn for the clast counts in figs. 11 to 19. The patterns they show can, in general, be correlated with those of the clast count variations, thus confirming the dispersal patterns suggested by the latter. The amount of variation caused by abrasion, and consequent reduction in size within each area, is questionable, as will be discussed below.

Three of the clast types at Bellot Cliff, gneiss, gabbro and basic volcanics (fig. 13-15) show an increase in maximum size away from the source area (i.e. to the northwest), which may indicate that sampling is from different levels of the conglomerate.

Grain size analysis

The distribution of samples is shown in fig. 7, results are given in table II and figs. 22 and 23. Mean grain size of the conglomerates varies from -4.4ϕ to -6.8ϕ and the average of seventeen samples is -5.7ϕ or 2.0 inches (5.0cm) which is in the coarse pebble range. The standard deviation figures range from 1.8 to 3.8 phi units, with an average of 2.64, which Folk (1968, p.46) would classify as 'very poorly sorted'.

Vertical variations in grain size characteristics were measured at Bellot Cliff (loc. 31, NS411977, fig. 7, loc F: see table IIB for results) but insufficient sampling was

Table II. A) Conglomerate statistics, Prescott Island

loc. no.	cong. M_z	cong. σ_I	Aston R	Aston S	Gneiss R	Gneiss S	Aston R: σ_I	Aston %	Gneiss %
101A	-6.1	2.4	0.70	0.69	0.67	0.70	0.098	31	64
101B	-6.3	2.5	0.74	0.68	-	-	0.085	32	51
100A	-6.6	2.4	0.72	0.64	0.69	0.70	0.101	24	71
100B	-6.8	2.6	0.72	0.68	0.69	0.70	0.069	31	65
105	-6.1	2.3	0.72	0.70	0.67	0.69	0.074	29	70
106	-5.9	2.2	0.72	0.69	0.67	0.69	0.089	26	96
107	-4.8	3.3	0.71	0.66	0.68	0.70	0.064	23	71
110	-	-	0.70	0.68	0.67	0.65	0.079	19	74
108A	-4.8	3.8	0.68	0.73	0.65	0.67	0.093	30	62
108B	-4.8	3.0	0.69	0.70	0.65	0.71	0.069	14	83
109	-4.8	3.4	0.67	0.70	0.66	0.66	0.085	14	82
111	-	-	0.68	0.67	0.67	0.69	0.079	18	80

Table II. B) Conglomerate statistics, Bellot Cliff

loc.	cong. M_z	cong. σ_I	Aston R	Aston S	Aston R: σ_I	Aston %	Gneiss %
31A	-6.7	2.2	0.62	0.69	0.100	33	13
31B	-6.3	2.2	0.67	0.68	0.113	36	22
31C	-5.3	3.0	0.69	0.69	0.096	27	30
31D	-	-	0.69	0.72	0.116	44	23
31E	-6.6	3.0	0.71	0.71	0.150	36	19
31F	-	-	-	-	-	45	24

Table II. C) Conglomerate statistics, Bellot Cliff

loc.	cong. M_z	cong. σ_I
15A	-4.4	2.5
15B	-5.1	1.8
15C	-5.0	2.5

M_z = graphic mean (Folk, 1968, p.45)

$$= (\phi 16 + \phi 50 + \phi 84) / 3$$

σ_I = inclusive graphic standard deviation (Folk, 1968, p.46)

$$= \frac{\phi 84 - \phi 16}{4} + \frac{\phi 95 - \phi 5}{6.6}$$

carried out to reveal statistically significant variations. Lateral variations were measured along the south coast of Prescott Island; the results are presented in table IIA. In this table the localities are arranged in descending order to correspond to increasing distance from the upturned base of the Peel Sound Formation, and it will be seen that mean grain size M_z shows a marked decrease with distance. For the linear relationship phi mean grain size: distance in miles the correlation coefficient r has a value of 0.88, which is statistically significant ($P = <0.001$). Standard deviation for the same samples shows an increase with distance ($r = 0.73$, $P = <0.02$). This is unexpected, and will be discussed in a later section.

The polymodal nature of the size distribution is apparent from the cumulative curves (figs. 22,23). Most of the curves have two distinct modes, a few have a subsidiary third mode. The sorting curves presented in figs. 22 and 23 were analysed by the method of Curray (1960): the percentage falling in each phi class was plotted against the mid point of that class, and a smooth frequency curve drawn. From the frequency curves thus produced the position of the modes was measured to the nearest 0.1 ϕ . Of the fourteen samples, one is unimodal (loc. 31B), nine are bimodal, and four are trimodal. The most prominent mode in all cases lies in the cobble

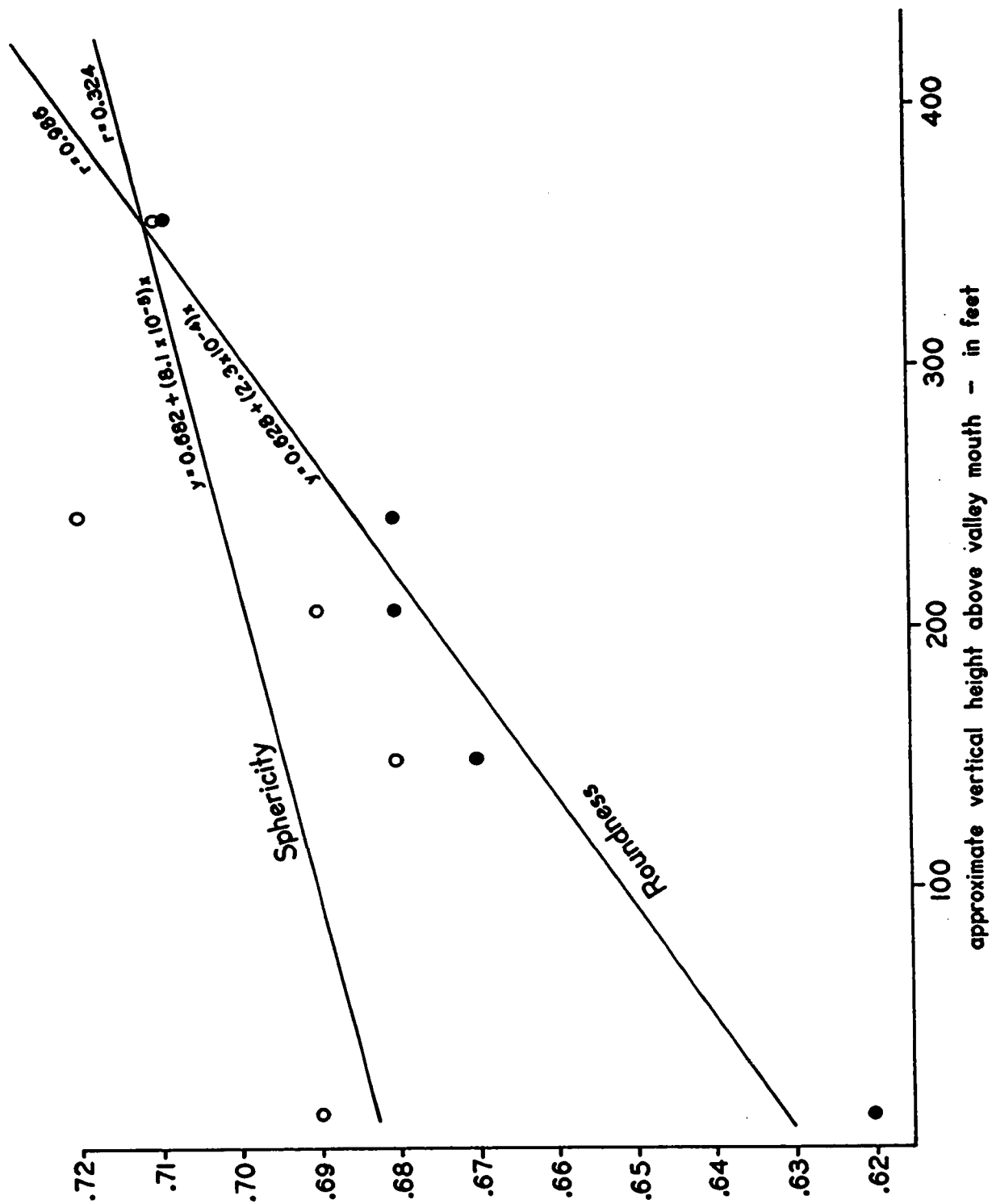


Fig. 24. Roundness and sphericity of Aston quartzite clasts, loc. 31, Bellot Cliff

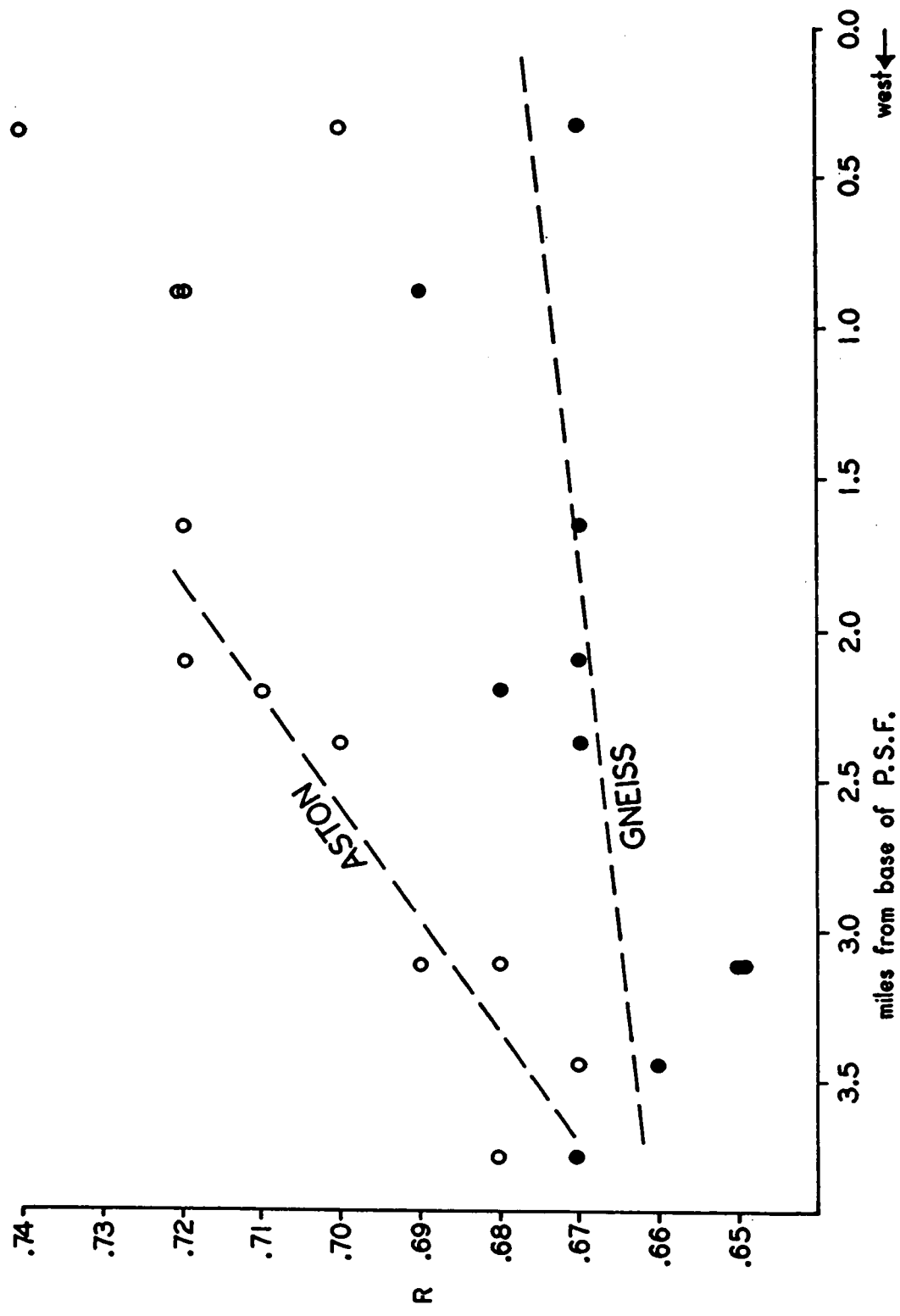


Fig. 25. Roundness of Aston quartzite and gneiss clasts, southern Prescott Island

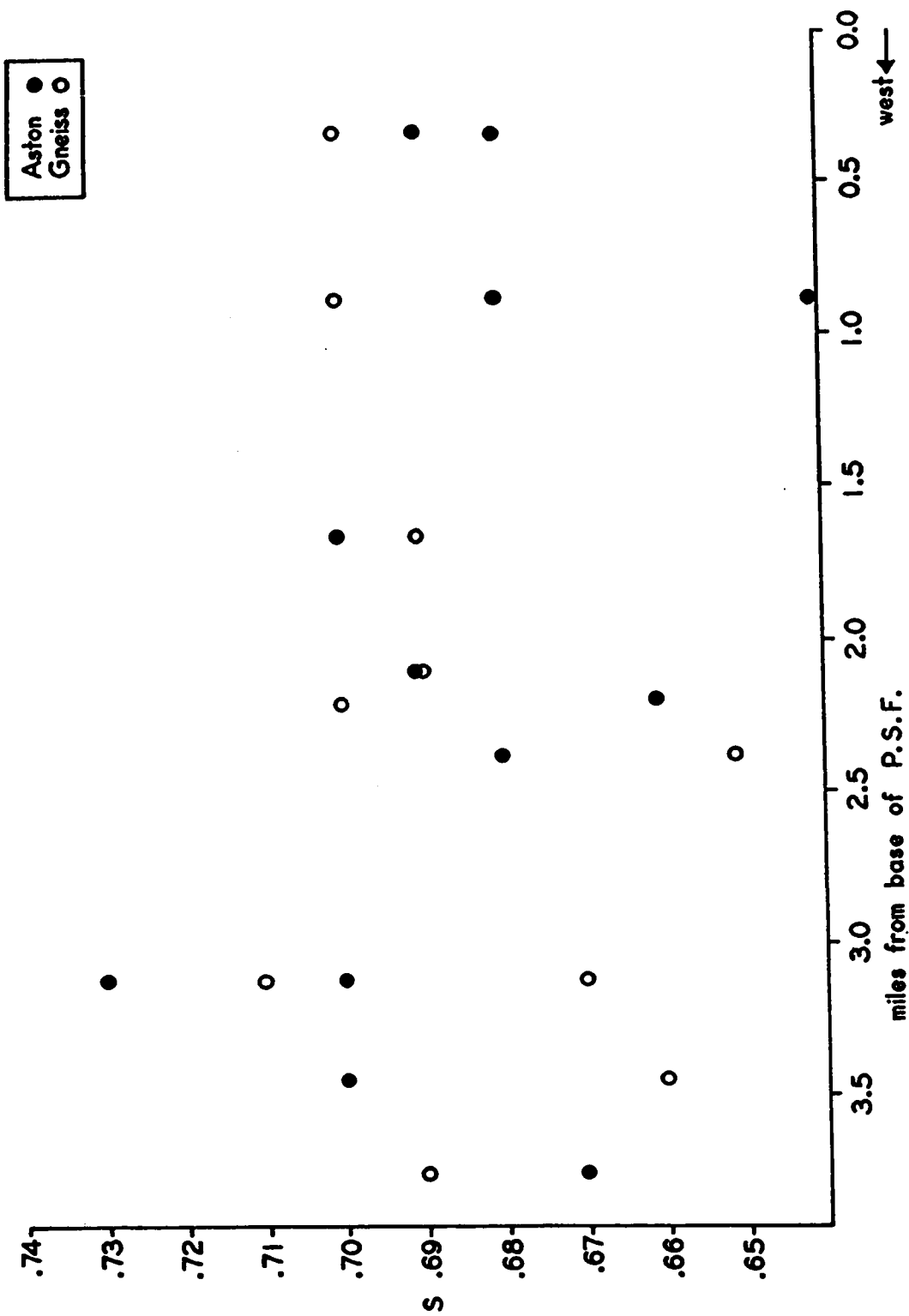


Fig. 26. Sphericity of Aston quartzite and gneiss clasts, southern Prescott Island

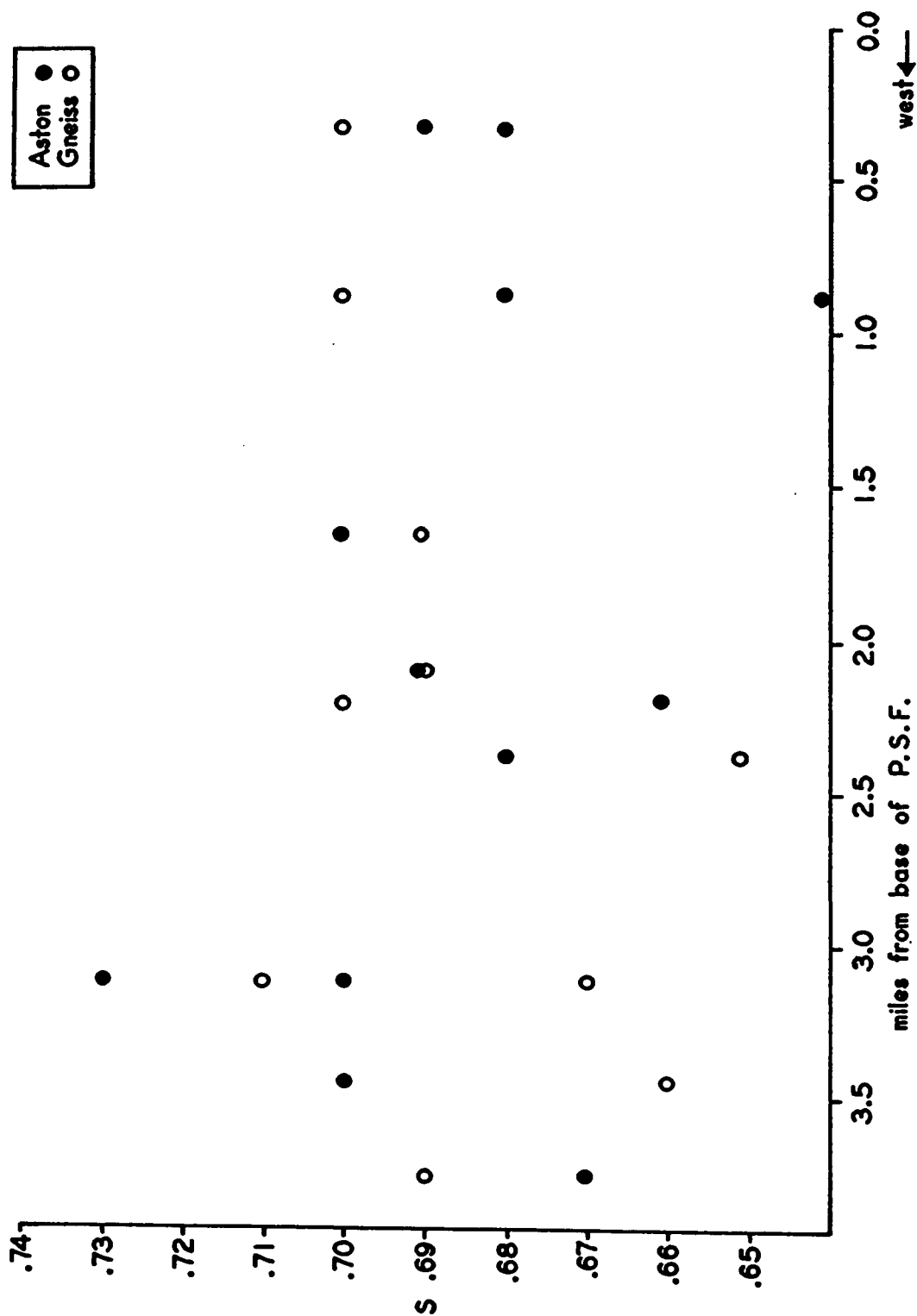


Fig. 26. Sphericity of Aston quartzite and gneiss clasts, southern Prescott Island

range, varying from -6.7ϕ to -7.7ϕ (10.2 to 20.5cm). All the samples except that from loc. 31B have a secondary mode in the medium to coarse sand range: $+2.0\phi$ to -0.8ϕ (0.25 to 1.75mm). A very weak third mode in the pebble range is present in the samples from locs. 31C, 31E, 101B and 106. The size range is from -4.0ϕ to -5.4ϕ (1.6 to 4.2cm). The presence of the two principle modes in all but one of the samples measured suggests selective transport or a deficiency in certain grain size ranges (Spencer, 1963). This will be discussed in the section 'Debris flood deposits in the Peel Sound Formation'.

Clast roundness

In most cases cobbles of Aston quartzite were measured, but in the Prescott Island traverse gneiss cobbles were also studied; readings are given in table II. At Bellot Cliff (loc. 31, fig. 7, loc. F) five measurements on Aston cobbles were made at the same places as the clast counts. (as in fig. 10). The roundness figures show a marked tendency to increase with height in the section (fig. 24), the correlation coefficient of the linear relationship being 0.986 (significant at the $P = 0.01$ level). Standard deviation of the roundness samples varies from 0.096 to 0.150.

The roundness figures for the Prescott area (see location map fig. 7) are given in fig. 25; they include

both Aston quartzite and gneiss measurements. The readings do show trends, but in a most unexpected direction, i.e. they decrease with increasing distance from the source area. This will be discussed in a later section. Aston quartzite roundness standard deviation varies from 0.064 to 0.101 for the Prescott Island samples. The linear relationship between Standard deviation and distance of transport has a correlation coefficient of -0.318, which is not significant at the $P = 0.10$ level.

Clast Sphericity

Cobbles measured for roundness were also investigated for sphericity. The results are shown on fig. 24: Bellot Cliff loc. 31, Aston cobbles; and fig. 26: Prescott Island, Aston and gneiss cobbles. A very weak trend is shown by the vertical series of readings in fig. 24 - with a correlation coefficient of only 0.324, but this is not statistically significant at the $P = 0.10$ level. At Prescott Island the results show an apparently random scatter.

Directional sedimentary structures

All measurements of orientation have been grouped within small areas, and a local mean calculated. It was not necessary to use a grid system for this, as most of the measurements were made in areally isolated groups, the number of readings included in each varying from three to nineteen.

Fig. 49 includes the readings from all three facies. The local vector means are plotted as arrows, with the number of readings shown. The grand vector mean of these readings is 260° , and the general westerly trend is readily apparent, in spite of the extreme paucity of readings.

c) Conglomerate Facies: discussion of results

The salient points emerging from this study are as follows: the conglomerates are monotonously similar in essential characters; they are generally very coarse, contain a high proportion of cobbles and boulders, and lithologies other than conglomerate form usually less than 10% of the succession. Clast lithologies do not show a random distribution, but vary in proportion according to recognisable trends, both laterally and vertically. In fact more or less distinct areal dispersal patterns can be recognised, which suggest particular directions of transport. In most cases paleocurrent evidence supports these dispersal directions, though the evidence is very meagre.

Roundness and sphericity are both high, and comparisons with other studies of these parameters, particularly those of Krumbein (1941b) - see table IV, suggest that the Peel Sound conglomerates are probably not proximal deposits. Roundness figures tend to show fairly distinct variation trends; sphericity values are more variable and trends are weak or absent.

Subaerial deposition on alluvial fans resulting from torrential rainfall is the only mechanism that could account for all these properties. Some very coarse conglomerates are known to have resulted from submarine faulting, but clasts do not attain the same degree of roundness or sphericity - the rocks are usually breccias. The Peel Sound conglomerates are, in any case, interbedded with red sandstones of typical fluvial aspect containing, for example, such sedimentary structures as primary current lineation, planar cross bedding and small trough cross beds.

The alluvial fan environment

The importance of alluvial fans in the desert erosion cycle has long been known to workers in the southwestern United States. Blissenbach (1954) was, however, the first to give a comprehensive description of their morphology and sedimentary development, following his studies of some of the fans actively accumulating in the deserts of California and Arizona. Interest, other than that of purely geological nature, has been focussed upon them mainly because of their frequent association with violent and damaging floods. The United States Geological Survey and other organisations have made detailed studies of modern fans in the hope of understanding the sedimentary processes involved, thus enabling some measure of flood control or avoidance to be devised. See, for example, Bull (1963,4)

and Lustig (1965), who deal with Californian fans; Beaty (1963) who worked in the White Mountains of the California-Nevada border area, and Bluck (1964) who investigated in detail a single alluvial fan in southern Nevada. Hooke (1967) studies some Californian examples and compared the processes of development with those of experimentally produced model fans; Denny (1967) discusses the equilibrium between sedimentation and erosion and provides further general descriptions.

Modern alluvial fans are thus fairly well known and understood, but their equivalents in ancient rocks have received far less detailed study. Many conglomerate bodies have been identified as alluvial fan deposits because of their general tectonic position and sedimentary associations, but detailed treatment is often lacking. There have been few intensive studies of grain size characteristics, clast roundness, sphericity, shape, orientation, lithologic content etc., to compare with those of the first two authors listed above. An exception to this is Bluck's (1965) reconstruction of small Triassic fans in South Wales, where preservation and exposure appear to be generally very good. His work demonstrates how isopleth lines drawn on equal values of many of the clast parameters such as maximum clast size and sphericity are arranged concentrically about the fan apex, i.e. perpendicular to the direction

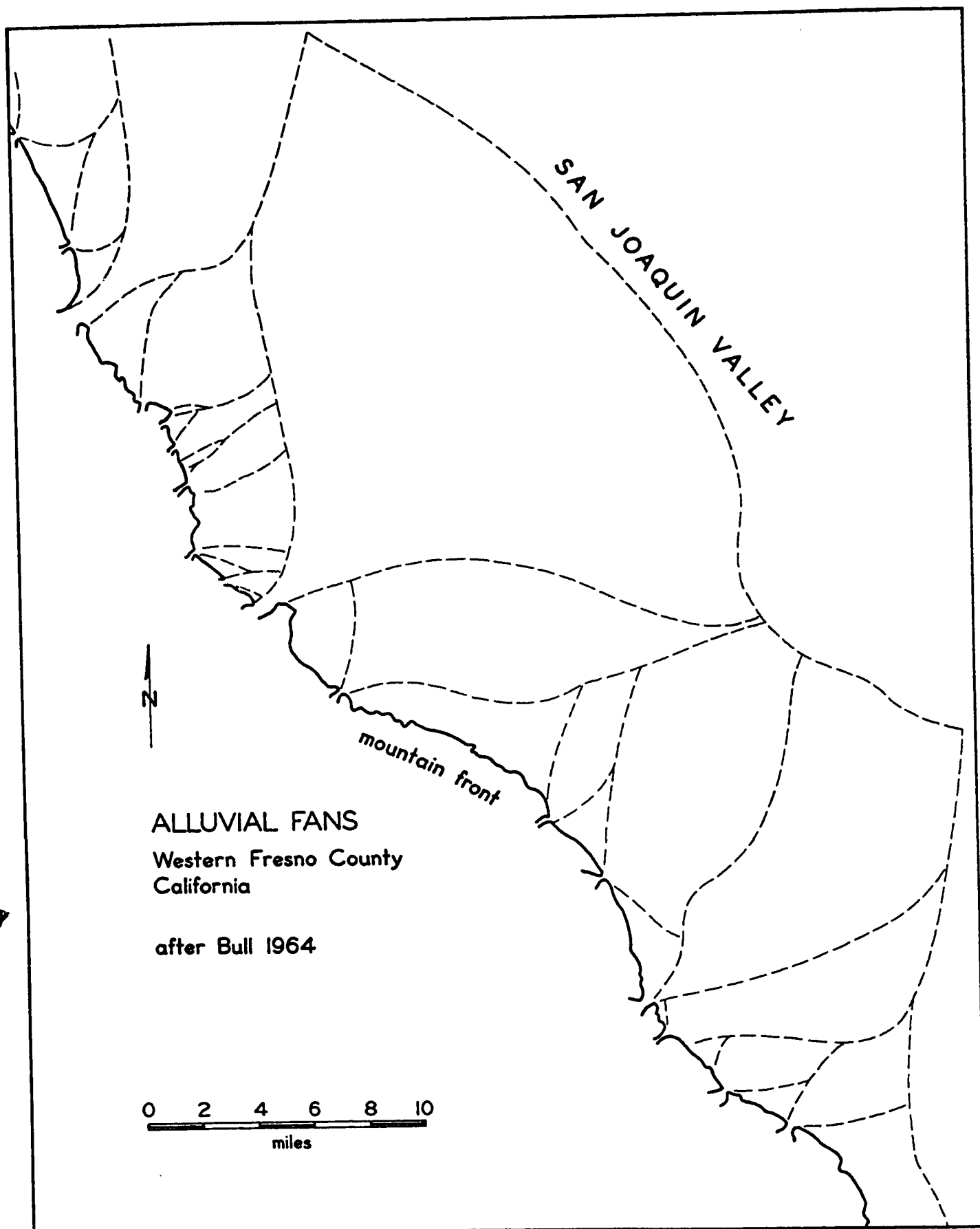


Fig. 27. A typical modern bajada

of transport. On single isolated fans this is to be expected, but there are many cases where alluvial fans coalesce by lateral merging along a mountain front (eg. Bull, 1964) - or by infilling a single, large broad valley (eg. Lustig, 1965). In these situations, as described by Lustig, the pattern of variation will be much more complex because of the mixing of materials eroded from several different sources. The area of active deposition below a mountain front is called the bajada.

The lateral persistence of the Peel Sound conglomerates for approximately 120 miles (190km) adjacent to a zone of strong upwarping, suggests that this is a typical mountain front bajada comparable to the example described by Bull (1964) at least in the way numerous fans of varying size overlap each other laterally. Fig. 27 is taken from Bull (1964) to illustrate the typical pattern of such a fan system. The detailed evidence for this depositional model will be discussed below, and the tectonic implications are considered in a later chapter on structure.

Causes of variability of clast parameters

On any fan or fan system none of the measureable clast characteristics have constant values. Therefore, in order to understand the results of the field studies described above it is necessary to consider the possible causes of the variations present.

Variability on single fans:

Several modes of transport are involved in the building of fans (discussed under mode of deposition). They have widely different energy levels and this will tend to produce very variable grain size characteristics (mean and maximum clast size, standard deviation etc.) in the resulting sediments. However, much reworking of material is to be expected on fan surfaces. The maximum clast size of the finally preserved deposit will reflect the highest energy level reached during its formation, for the coarser material is only moved by the stronger currents. Weak currents may re-sort and winnow out fine grained material although insufficient data has been collected on the grain size characteristics of the conglomerates for the importance of this factor to be assessed.

A second important factor is the distance the material of the fan has been transported. This distance will be an indication of the amount of size-sorting carried out by the transporting medium and the amount of abrasion of individual particles. The latter may, in turn, be measured by studies of clast roundness and sphericity. All these parameters may, therefore, be expected to show progressive changes on a fan surface from apex to toe.

Blissenbach (1954, p.183) believed that clast lithology counts showed little variation on a given fan surface

i.e. distance and mode of transport have little or no influence on the actual proportions of the various lithologies present. This will clearly be the case if all the clasts have the same density, similar resistance to erosion, and a tendency to produce similar shapes when fractured. Transport will not then be selective, and abrasion will reduce all clasts to sand size at a similar rate. In the case of the Peel Sound conglomerates the most important clast types are quartzites and Precambrian gneisses which are both extremely well indurated and have similar shapes - sphericity values of the two lithologies are comparable, but gneisses tend to have a lower average roundness (see figs. 25 and 26). Downfan changes in the Aston/gneiss ratio are thought, therefore, to be negligible compared with the vertical and lateral changes suggested below. However, this may not be the case for the Aston/gabbro ratio of Mount Matthias, also described below.

Variation in grain size characteristics, clast roundness and sphericity, as measured in a vertical section, can probably be attributed to the same factors of varying transport distance and power of the transporting medium. Given a stable mountain source area and bajada, erosion will tend to increase the lengths of streams by headward erosion, thus increasing the distance of transport of material to a given point on the fan. At the same time relief is being subdued and slope flattened out, thus slowing down the rate of trans-

port and reducing the power of streams to move material. Individual particles will tend to move less often and for shorter distances on each occasion, and will thus tend to be more exposed to the process of abrasion by finer materials when at rest. More time will also be allowed for chemical weathering before the material is buried at the point of final deposition. All these effects will tend to improve sorting, lower mean and maximum clast size, and raise roundness and sphericity figures.

A lack of clear trends in these parameters probably indicates that uplift of the source area relative to the area of accumulation is continuing to maintain the difference in relief, and is counteracting the effects of headward erosion.

Clast lithotypes will almost certainly show varying proportions in a vertical section, for unless the geology of the source area is very complex, or the strata are all vertical, the effect of downcutting will be to alter the pattern of outcrops, continually changing the relative areas of exposure of the rock groups present in favour of the lower members of the succession. Sediments derived from a given area will thus tend to contain clasts of progressively older rocks as one climbs the succession. This effect is known as reversed stratigraphy, and is well displayed near the base of the Peel Sound Formation.

Fan systems:

On single or separate fans, whether ancient or modern, it should be relatively easy to distinguish the various causes of clast variability. However, where fans merge laterally, as on a bajada, the differences between adjacent fans may be much greater than the vertical and down-fan variations on a single fan. Material may have originated in areas of different geology, and may have travelled varying distances at different rates. The set of fans in fig. 27 shows how a range of fan size makes this a very probable source of parameter variability. Denny, (1967) has shown how fan systems in equilibrium have a continually shifting pattern of distributaries, so that the points where deposition is actually taking place change with time. The area where two or more fans abut each other is thus likely to be affected by distributaries on both or all fans in turn. Considerable sorting and reworking takes place on fan surfaces, so that the deposits finally preserved show very mixed characteristics. The work of Lustig (1965), illustrates how complex the resultant patterns of variation can be.

Alluvial fans in the Peel Sound Formation

In this section it is hoped to show how the discussion presented above applies to the data collected. This fills in some of the detail of the bajada model for the Peel Sound

conglomerates.

Vertical variations in most places show the expected changes attributable to the evolution of a simple fan. Thus figs. 8 and 10 both illustrate the reversed stratigraphy effect in the clast lithotype counts at Cape Brodie and Bellot Cliff respectively. In fig. 9 the pattern is slightly different, because two distinctive conglomerate types are present, differing in grain size and clast lithotype count. This may represent material from two interfingering fans, one of which gradually gains dominance up the section. Alternatively the increasing importance of the coarser conglomerate at higher levels in the section may indicate a gradual increase in relief caused by uplift of the source area of a single fan. This would tend to increase the power of floods, and perhaps, by speeding up the process of headward erosion, allow transport of coarser material from deeper in the core of the source area - thus explaining the higher gneiss content of these younger conglomerates. The clast changes could have been caused by an alteration in the climate (increase in rainfall), but there is no other evidence for this.

The increase in grainsize and marked change in clast content seems to be a normal occurrence a few hundred feet above the base of the Formation. It suggests a single cause was responsible - such as a widespread positive movement of

the Boothia Uplift. There is further evidence of the syntectonic nature of the conglomerates: it will be discussed under 'Structure'.

Fig. 24 shows the upward increase in roundness and sphericity in conglomerates at Bellot Cliff. Together with the clast count changes (fig. 10) these changes as discussed above, are consistent with the idea of a gradual reduction of relief in the source area, which was probably coupled with a retreat of the mountain front. The only change not detected was an upward decrease in grain size within the section. The various parameters (mean, maximum clast size, standard deviation etc.) are presumably too variable to show any weak trends reflecting the lowering of relief.

Much information has been amassed on the areal variations in clast parameters - particularly clast lithotype analyses and maximum clast size values. This is presented in figs. 11 to 21. Although all the measurements were made on the same 6-700 feet of conglomerates, accurate vertical control within this range is almost absent. Attempts to interpret the data in terms of areal variations may thus be confused to an unknown extent by any of the types of vertical variation described above. However, as already explained in the previous section, inter-fan variations may be of much greater magnitude than those of intra-fan origin. This can be illustrated with reference to figs. 11 to 16,

which cover the Bellot Cliff area. The dispersal patterns of the six major clast types can be subdivided into three groups: (a) With high clast percentages and maximum clast size figures centred on Russell Island - represented by the grey-green quartzites; (b) With high readings immediately south and southeast of Bellot Cliff - represented by the Aston, gneiss, gabbro and basic volcanics patterns; (c) With apparently random distribution of readings - as shown by the Hunting domomites.

It is suggested that the grey-green quartzites were derived from the east, implying that an area northwest of Aston Bay, Somerset Island, now occupied by the sea, was the only important source of this lithology (discussed under 'identification of clasts' above). The paleocurrent evidence, such as it is, seems to support this interpretation. The four clast types showing pattern (b) were probably derived from the southeast, and again, the paleocurrent information is consistent with the suggestion. The isopleth patterns shown in figs. 11-16 can be attributed to deposition on two fans overlapping and mixing in the vicinity of Bellot Cliff. Given the size of the present outcrop, the fans must have extended at least twelve miles from apex to toe, although an unknown amount at the proximal end has been removed by erosion. The distinctive dispersal patterns thus appear to have been created by mixing of material from two

source areas of markedly different surface geology. The random nature of the Hunting dolomite distribution can be explained on the supposition that the lithology was derived in equal quantities from both areas. Much of the variation in clast distribution, including the variation within the contoured patterns of some of the other lithologies, reflects the scattered and largely uncontrolled vertical distribution of the sampling localities.

Maximum clast size figures are not necessarily an accurate indication of the distance of transport, where coalescing fans contain different proportions of the varying clast types. A fan containing a low percentage of a certain lithology is unlikely to contain large (cobble and boulder size) clasts of that particular lithotype. Patterns of clast percentage and maximum clast size are very similar for each lithology in the Bellot Cliff and the Mount Matthias areas (figs. 11-19) which suggests a similar origin, i.e. the mixing of material from adjacent fans. Variations in maximum clast size due to distance of transport are thought to be small by comparison.

In the Mount Matthias area the clearest trend is shown by the gneiss clast distribution (fig. 17). A fan containing approximately 20% gneiss material seems to have entered the area from the northeast. The southern half only is preserved, where it mixes with material containing no gneiss

at all. The Aston/gabbro ratio shows a fairly marked increase from east to west, which was probably the direction of transport of the Aston-gabbro rich material, though there is no paleocurrent evidence. If so, the decrease in gabbro material may be due to its much lower resistance to weathering and erosion on the fan surface. In present day outcrops of the conglomerates the gabbro clasts are often weathered to a friable powder, whereas the gneiss and quartzite show virtually no evidence of weathering changes, except for surface oxidation crusts. The Mount Matthias evidence thus seems to indicate derivation of sediment from at least two fans.

Southern Pandora Island and the Prince of Wales mainland immediately to the south is the area considered in fig. 20. The presence of three fans with a southeasterly source are suggested. Two conglomerate types occur on Pandora Island, as described above. Paleocurrent evidence supports the idea of a southeasterly source for the conglomerate rich in Hunting dolomite, but is lacking for the gneiss-rich rock. A single layer of highly dolomitic conglomerate within the latter probably represents a tongue from the southeasterly fan that retained its identity in the zone of fan merging, without being reworked. On the mainland south of Pandora Island the conglomerate is again very gneissose, with a small admixture of Read Bay lime-

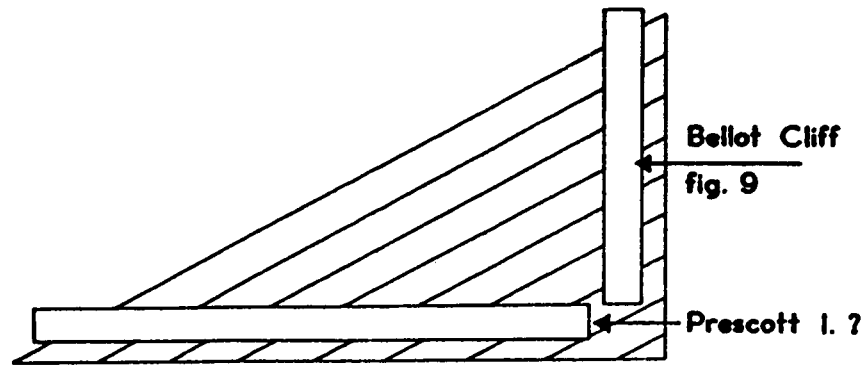


Fig. 28. Sampling of fan wedges

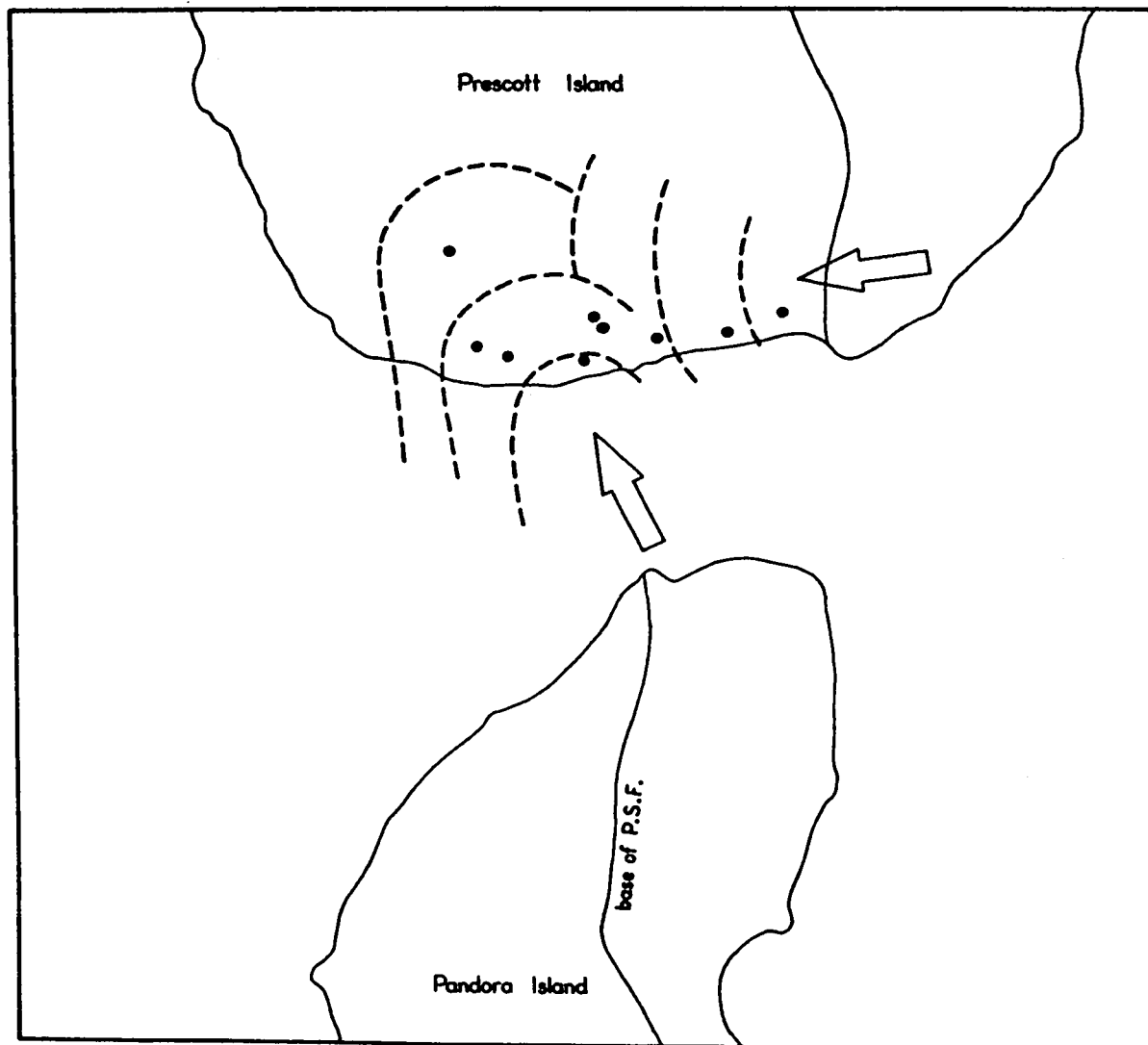


Fig. 29. Overlapping fans at Prescott Island. dots indicate clast count localities, other symbols as in fig. 11

stone. The mixture is distinctive, and suggests a third discrete fan source, for the presence of this limestone in the higher, coarser Peel Sound Conglomerates is unusual. The Read Bay Formation is the youngest in the succession of source rocks and might thus be expected to have been removed first when erosion commenced. It is, indeed, much commoner in the basal parts of the Peel Sound Formation. At the time of accumulation of the conglomerates the Read Bay was still a young formation, and was probably not very resistant to erosion. This might explain its rapid disappearance to the west on the fan under discussion.

In the southern Prescott Island area the distribution of localities for more detailed measurements on the conglomerates was chosen along a traverse at right angles to the base of the Peel Sound Formation. It was expected that this would parallel the direction of transport, but the picture that emerged calls for a more elaborate interpretation. The variation in clast count along the south coast of Prescott Island (fig. 21) shows close similarities to the vertical variations at Bellot Cliff, (fig. 10). It was at first thought that this similarity reflected a similar distribution of measurements i.e. sampling of successively higher layers in the fan wedge on a horizontal instead of a vertical plan, as shown in fig. 28. The cause of variation would, in this case, be the reversed stratigraphy effect. However, at all the Prescott localities the bedding

appears to be horizontal, so that the situation in fig. 28 seems unlikely, and the section is probably not of great thickness.

The trends of clast roundness (fig. 25) are even harder to explain. Roundness would normally be expected to increase with distance of transport, whereas the reverse is seen to be the case. A possible solution is illustrated in fig. 29. The area may contain the deposits of two fans; one, richer in Aston quartzite material entering from the east, and another, with a high proportion of gneiss clasts derived from the Pandora Island area to the southeast. If the latter was a more proximal deposit it would contain clasts of lower mean roundness, and the resultant mixing of material in the southwest corner of Prescott Island would result in a lowering of roundness values. In support of this idea - the more proximal nature of the Pandora fan - is the fact that on Pandora Island the base of the Peel Sound Formation is displaced at least a mile to the west relative to Prescott Island (fig. 29). This may reflect a bend in the original mountain front from which these sediments were derived, and it would also explain the decrease in conglomerate sorting discussed above in connection with table IIA. Unfortunately paleocurrent evidence is almost absent from the area; sandstone lenticles, normally showing current bedding structures are rare, and pebble orientation appears to be random. Maximum clast size measurements indicate very constant values

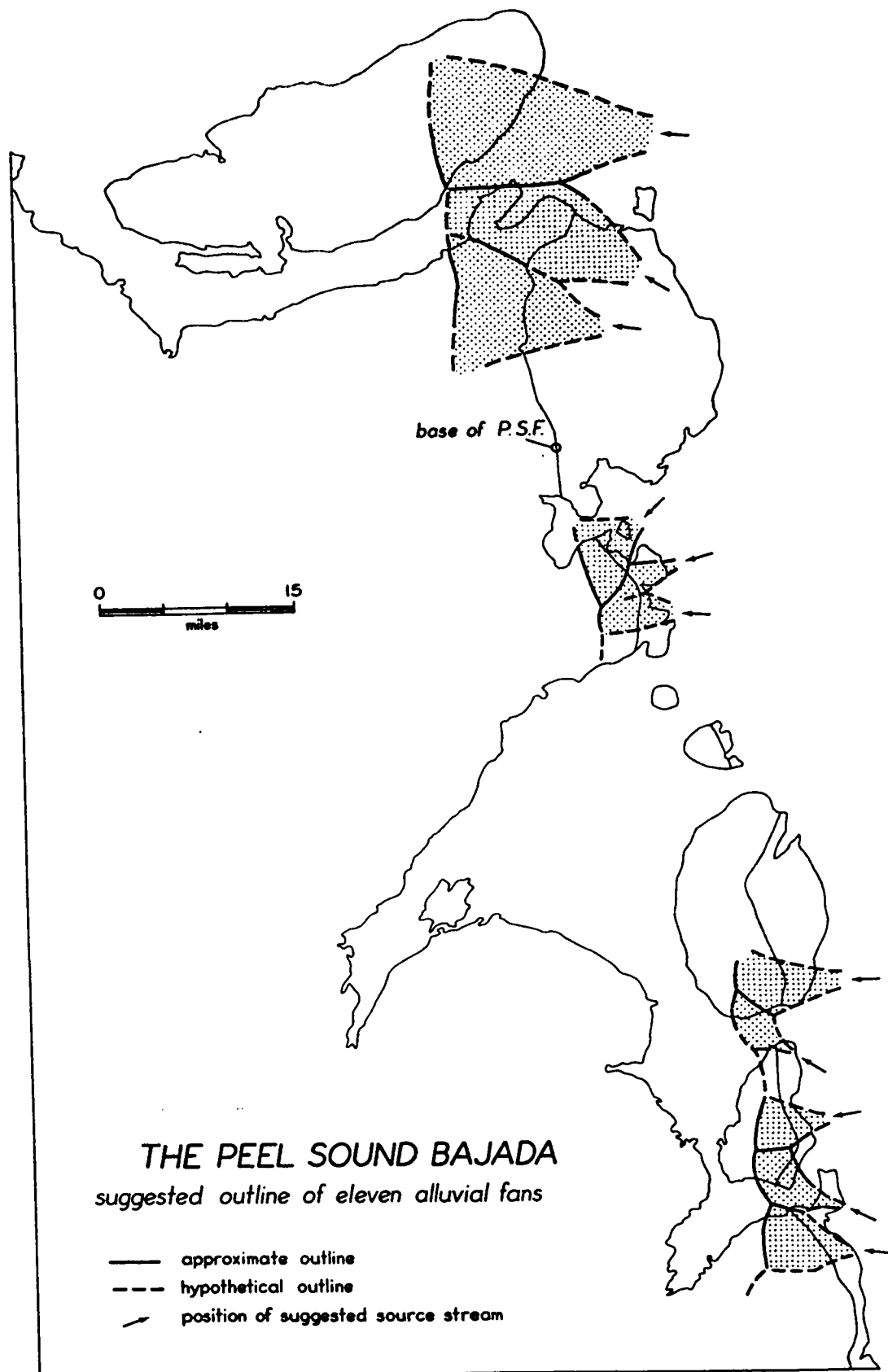


Fig. 30

for the full length of the traverse, except at the far western end, where a diminution in size is noticeable. Mean grain size diminishes to the west (see table IIA) but remains constant at -4.8ϕ at the four westernmost localities.

In summary, the evidence available suggests the existence of eleven ancient alluvial fans in the areas studied (see fig. 30). There is little doubt that others were also present but the complete pattern can never be completely reconstructed because of lack of exposure and the covering of much of the outcrop by the sea. It should be emphasized that the outlines drawn in fig. 30 can only be shown in approximate positions because boundaries are thought to shift from time to time due to fan mixing. The 'hypothetical' boundaries are included for the sake of clarity, but in many cases there is little or no evidence for their position. Source streams are placed so as to be consistent with paleocurrent data, wherever present.

Mode of deposition

The coarse nature of the Peel Sound conglomerates indicates torrential deposition, rather than normal stream flow. It is instructive, therefore, to compare the characters of modern floods and flood deposits with those of the rocks under study. The southwestern United States is again the main area of comparison.

Modern floods and flood deposits in semiarid regions

One of the earliest serious studies of flood deposits was made by Pack (1923) who found boulders 14 feet (4.2m) long and weighing 95 tons which had been carried for up to a mile from the point of origin. The importance of catastrophic events in building sediment piles was established by Blackwelder (1928) who described the most violent of them as mudflows. From eye-witness accounts of floods and his own observations of the deposits he listed these important features: Mudflows are occasional catastrophic events, but they are of great importance in the building of alluvial fans. They consist of a mobilised mass of material, moving something like a lava flow, often with very little free water but a very considerable boulder content. For their development they require abundant loose material in the source area, abundant water and a small vegetation cover, to allow rapid run-off. They are most common in semi-arid regions, where the rain comes in sudden storms. These points were emphasized by a flood in Montrose, California, described by Chawner (1935). Heavy rainfall over a forested area produced no serious effects, but in an area just previously deforested by fire, surface run-off assumed catastrophic proportions. This flood was of moderate stream flood type - there was no actual mobilisation of large masses of sediment, leaving little free water; the power to move material was

correspondingly lessened. Nevertheless Chawner found that boulders of more than 30 tons had been moved, and some of 1.2 tons had been transported for a distance of two miles (3.2km).

Sharpe (1938) emphasized the importance of mudflows as depositional agents and noted the lack of recognition of their deposits by earlier workers. He classified mudflows according to their origin into alpine (due to snow melting), volcanic and semiarid categories.

Mudflows, as described above, are capable of carrying very coarse material for comparatively short distances. More recently Sharp and Nobles (1953) have shown that they can flow for many miles, carrying surprisingly large boulders for almost the full length of the flow. Their observations were made on a flow which occurred in 1941 at Wrightwood, southern California as a result of a rapid spring thaw. Material was carried for fifteen miles (24km) from the point of origin. The flow originated in a mountainous area, on a slope of up to 32° , but after the first three miles the angle of slope was reduced to less than 3° , and became less than 1° near the end of the flow. Rare boulders of up to 6 feet (2m) in diameter were seen in the deposits, those of 2-3 feet (60-120cm) were common, and some of 18 inches (45cm) in diameter were carried as far as twelve miles (19km) from the source. Mudflows occurred several

times daily for more than a week. They eventually piled up conglomeratic deposits to a thickness of 3-6 feet (1-2m).

Blissenbach (1954, p.179) states that in his Arizona field studies mudflow deposits form 5-40% of the fan material, and moderate stream flood and stream flow deposits make up the remainder. He recognises (p.178) two types of mudflow, or debris flow - sheet floods and violent stream floods. The former tend to develop if there are no clearly defined channels on the fan surface. Blissenbach states: 'a striking peculiarity of sheetfloods is their shortness in distance as well as in time of their flows'. This contrasts with the second type, in which the flow is confined to stream channels, is more prolonged, and generally travels greater distances. The composite flow described by Sharp and Nobles seems to have been of this type, for though 15 miles (24km) long it was normally only 50 to 150 feet (15-45m) wide, in places up to 300 feet (90m). Similar lobate mudflows have been described by Beaty (1963).

Debris floods confined to streams show all gradations in violence down to moderate stream floods where the sediment to water ratio is lower and mobilisation of sediment into a viscous mass does not take place. Least violent is the normal stream flow. These types of flow may occur in sequence as the mudflow dwindles in power (Pack 1923, p.349) and they may result in a coarse, unsorted conglomerate

grading upwards into sand (Fahnestock, 1963, p.20; Sharp and Nobles, 1953, p.558).

The term 'mudflow' is often used as a descriptive name for the flood events, but strictly speaking it may be misleading. Bull (1964) found clay-grade particles formed over 30% of his debris flood deposits, and material of pebble size or coarser was comparatively rare, except near the apex of the fan. However, Lustig (1965) described mudflow deposits containing only 2.1 to 4.2% of clay grade material and a silt:clay ratio of approximately 4:1. The proportion of mud (silt plus clay) was therefore in places as little as 10%. The sorting measurements were made by Lustig on only the granule-clay fraction; the true percentage of clay-silt material must, therefore, be even less. The term mudflow should thus be used with caution; in many cases the more general term 'debris flood' is more appropriate.

Debris flood deposits in the Peel Sound Formation

Debris flood deposits are now known to be very important in modern alluvial fan successions, but their recognition in ancient rocks is as yet poorly documented. A close study of the textures and grain size of ancient conglomerates would probably show that many display features similar to those of the modern debris flood deposits described by Blissenbach (1954, p.185-7). Thus the Peel Sound conglomerates are coarse and poorly sorted and they lack a well developed

pebble framework. Clast orientation is generally random - crossbedding and imbrication are rarely seen. These are the chief characteristics of debris flood deposits as summarised by Blissenbach.

The Peel Sound conglomerates also compare closely with some Upper Devonian conglomerates in the Clyde area of western Scotland, described by Bluck (1967). This author recognises four conglomerate types; his type 'A' shows the textural features listed above, and it is interpreted by Bluck as a debris flood deposit.

Clast imbrication is present in a few outcrops of the Peel Sound rocks (photograph 14). Its presence probably indicates the action of less violent floods - Blissenbach's moderate stream floods. These beds compare with Bluck's type 'B' conglomerate, which is characterised by cross-bedding and imbrication.

The Devonian conglomerates described by Bluck can be separated into bedded units by the presence of internal erosion surfaces and the fact that each conglomerate grades up into a sandstone member (Bluck, 1967, fig. 13). Both these features are absent from the rocks of the Peel Sound Conglomerate Facies, though they are commonly present further to the west, as described in the section on the Conglomerate-Sandstone Faces (see also fig. 4.)

As discussed above, the term mudflow is not always

strictly accurate; the Peel Sound conglomerates certainly cannot be described using the term, for the clay-silt fraction of those rocks measured comprises less than 1% by volume of the total.

Modern debris floods, can carry coarse material for many miles. Therefore, the width of outcrop of the coarse Peel Sound conglomerates presents no problem. At its maximum this reaches 7 miles (11km) and individual conglomerate horizons are found across a further three mile (5km) zone - the Conglomerate-Sandstone Transition Facies. The proximal part of this bajada area has been eroded, and its original width cannot be determined exactly. If the watershed of the Boothia Uplift was somewhere near the centre of the mountain chain, up to 20 miles (32km) would have to be added to the distance of transport in the form of stream valleys and the upper end of the alluvial fans. The maximum figure for the transportation of pebbles and cobbles to their farthest west position is thus 30 miles (48km), but debris floods could have originated anywhere within the catchment area. The floods must have been of comparable size to the one described by Sharp and Nobles (1953).

The latter authors have shown that the depositional

slope need be no greater than 3^0 so long as the source area has sufficient relief to initiate mass movement. Depositional slope is unlikely to be preserved exactly as it was at the time of formation; a slope as low as 3^0 may even be reversed by only very gentle movement. In the Peel Sound conglomerates the bedding is nearly everywhere almost horizontal. In a few places, eg. at Cape Brodie, there is actually a low easterly dip, just to the west of the upturn of the Cornwallis Fold Belt. Such a synclinal structure could have been produced by subsidence in the area of maximum sediment accumulation, close to the mountain base.

On the fan surface debris floods have considerable erosive power, perhaps scouring earlier deposits to a depth measureable in feet. Sharp and Nobles (1953, p.553) record extensive channel widening and deepening in the upper part of the modern flow that they studied. Reworking will thus tend to take place, and some of the material may be moved several times before being finally buried. The process of fan-head trenching described by Bull (1968) causes a reworking of proximal fan sediments, and redeposits them lower on the fan surface. A deep fan head trench also acts as a confining channel for debris floods, so that they may tend to flow further down the fan surface before losing momentum. The reworking processes could account for the scarcity of sand deposits at the top of debris flood layers in the Peel Sound

rocks. They may be separated by tens of feet of very homogeneous conglomerate, probably representing the accumulation of several separate floods, all grading imperceptibly into one another. It would also account for the fact that only rarely can conglomerate layers of markedly different lithologic composition be identified in a single outcrop. Where fans of varying composition overlap, this might otherwise have been expected.

Sorting characteristics of the Peel Sound conglomerates compare quite closely with those of other debris flood deposits. Values for the Peel Sound are given in table II. Folk (1968, p.46) states that glacial tills and mudflows have σ_1 values in the neighborhood of 5 ϕ to 8 ϕ or even 10 ϕ . However, no deposits with figures as high as this have been reported, so far as the author is aware. All the figures from six authors are given below in Table III. Earlier workers used the Trask sorting coefficient S_o . However, this is an inaccurate measure, and the graphic standard deviation σ_ϕ has been adopted by many workers. This takes in the central two-thirds of a cumulative sorting curve. Better still is the inclusive graphic standard deviation σ_I which includes 90% of the distribution. σ_I and σ_ϕ are phi measures, and values calculated for the same sample will be similar, although σ_I is more accurate. S_o is calculated from millimetre size readings, and so the figures cannot be directly compared with

TABLE III.

Sorting characteristics: debris flood deposits.

Miall 1968 (Peel Sound Formn.)	σ_I σ_ϕ	1.82 - 3.36 av. 2.52 1.85 - 3.60	Devonian alluvial fans
Bluck 1967	σ_ϕ	0.72 - 1.15*	Devonian alluvial fans
Lustig 1965	σ_I	1.3 - 2.7+	modern fans
Krumbein 1942	σ_ϕ	2.37 - 2.86	canyon stream flood material
Bull 1964	σ_ϕ S_o	4.1 - 6.2 av. 4.7 5.0 - 25.0 av. 9.7	modern fans
Blissenbach 1954	S_o	av. 3.0	modern fans
Sharp and Nobles 1953	S_o	av. 3.94 ⁺	recent flood

* coarse fraction only

+ granule - clay fraction only

TABLE IV: Roundness and sphericity of debris flood deposits

Miall 1968	Devonian fans	Aston Quartzite Precamb. Gneiss	6.4 - 12.8 cm.class "
Bluck 1965	Triassic fans	Dinantian lsts	1.5 - 4.5 cm.class 6.5 - 9.5 cm.class 9.5 - 12.5 cm.class
Bluck 1964	modern fan	1st. clasts	3.0 - 4.5 cm.class
Blissenbach 1954	modern fans	mainly gneiss	'about equal size'
Krumbein 1942	modern canyon deposits	igneous & met. clasts	1.6 - 3.2 cm.class
Krumbein 1941b	experimental abrasion studies	1st clasts	4.5 - 5.3 cm.class

Abric flood deposits

Quartzite	6.4 - 12.8 cm.class	R S	0.62 - 0.74 0.64 - 0.73	-clear trends -no clear trends
amb. Gneiss	"	R S	0.65 - 0.69 0.65 - 0.71	-clear trends -readings scattered
ntian lsts	1.5 - 4.5 cm.class 6.5 - 9.5 cm.class 9.5 - 12.5 cm.class	S	0.69 - 0.78 0.77 - 0.78 0.77 - 0.81	3 mile traverse, trends claimed but very few readings. No roundness studies
clasts	3.0 - 4.5 cm.class	S	0.64 - 0.75	3 mile traverse No trend. No roundness studies
ly gneiss	'about eq- ual size'	R S	0.2 - 0.7----- constant at 0.65	good trend over 4 mile traverse
eous & . clasts	1.6 - 3.2 cm.class	R S	steady increase- to 0.4 almost constant- at 0.70	10 mile traverse good trend same traverse
clasts	4.5 - 5.3 cm.class	R S	0.13----- 0.50 0.59 0.61 0.64 0.65----- 0.68 0.72 0.75 0.77	initial reading after 1 mile " 5 miles " 12 miles " 20 miles initial reading. after 1 mile " 5 miles " 12 miles " 20 miles

those of the other measures. It is a very inaccurate measure, as it is based on only two percentiles of the sorting curve, and its use is not recommended except for unimodal sorting distributions. Bull (1964) calculated both σ_ϕ and S_0 for his samples, and so his figures serve as a comparison. (A full discussion of these sorting measures is given in Folk, 1968, p.45-46).

Bull's figures are high, and Bluck's surprisingly low for debris flood deposits. Bluck's figures are based on only the coarse fraction of the distribution curve and their value is open to question. Bull recommended a figure for σ_ϕ of 4.1 ϕ as the lowest that should be classified as a mudflow, but this is higher than any of the other sorting figures given in the table and so the figure of 4.1 ϕ cannot be accepted as having any useful general meaning.

It will be seen from the discussion above that information on the grain size of coarse flood deposits is very poor. Some studies, eg. those of Lustig (1965) and Bluck (1967) are based on only a partial sampling of the rock, and the figures that result are therefore of limited value. This is particularly the case when no indication is given as to the method used to measure the size-sorting - a criticism that applies to the papers of both Lustig and Bluck. The situation is further confused by the use of several different sorting parameters whose figures cannot

be directly compared except by recalculation from the original sorting curves. There is room for much further work on the problem. The method that is introduced in the present study of measuring the grain size of consolidated rocks, is only a first attempt to include the whole grain size range. It is in need of considerable refinement. Nevertheless, several meaningful results have emerged. The traverse west along the south coast of Prescott Island showed a significant decrease in mean grain size and an unexpected increase in standard deviation (decrease in sorting) over a distance of less than four miles. This is in contrast to the findings of Sharp and Nobles (1953) in their investigations of a recent debris flood deposit. Measurements over the 15 miles length of the deposit which they studied showed that although the coarsest fragments were gradually deposited along the flow, the median grain size of the fine fraction (smaller than approximately $\phi - 2\phi$) shows no regular decrease with distance. Similarly, they found that the deposits show no measureable change in sorting, except an increase near the outermost margin of the flow. The changes at Prescott Island can probably be attributed to the mixing of sediment from two fans, as suggested by clast lithotype analysis and roundness measurements (see fig. 29).

The bimodal nature of nearly all the samples measured may be interpreted in two ways, selective transportation of

certain grain size ranges or a primary deficiency in those grain sizes. The first explanation seems unlikely for debris flood deposits, for one of the most characteristic features of a debris flood is the fact that it is capable of mobilising a mass of sediment and transporting and depositing it with a minimum of sorting. Primary deficiencies in certain grain size ranges is an idea that has been discussed by Pettijohn (1950, p.50) and Spencer (1963) although these authors are primarily concerned with sediments falling in the granule to clay size range. According to these authors sediment of silt grade (+4 to +7 ϕ) and coarse sand grade (-2 to +1.5 ϕ) is scarce, because of the way in which most rocks break down under the influence of normal subaerial weathering processes.

In the case of the Peel Sound Conglomerate Facies silt and clay are scarce, but there is a prominent mode in the sand range which probably corresponds to the breakdown products of the abundant Aston quartzite clasts. However, this mode is somewhat coarser than the sand mode suggested by Spencer. It lies between -0.8 ϕ and +2.0 ϕ which falls in one of Spencer's scarce ranges. Cadigan (1961) analysed thirty six Triassic continental sandstones and the majority of the samples have mean grain sizes within Spencer's sand population range, i.e. +1.5 ϕ to +4 ϕ . However, one 'granite wash alluvium' has a mean grain size of +0.18 ϕ and a 'coarse arkose' has

a mean of $+0.85\phi$. These samples of Cadigan's are thus comparable with sand fraction of the Peel Sound conglomerates in that the mean grain size falls in the coarse sand range and the deposits were formed rapidly with little grain size or compositional sorting. Most of the sandstones that support Spencer's (1963) hypothesis of a fundamental sand population are sediments that were deposited in environments where a high degree of sorting and reworking is common, eg. the aeolian and marine environments. The phrase 'fundamental sand population' would thus seem to be misleading, for the grain size characteristics of this population can vary quite markedly between mature and immature sediments.

The coarsest of Spencer's (1963) three 'fundamental populations' is the gravel class with median size range between -2ϕ and -3.5ϕ . However, grains in the range -1ϕ to -3.5ϕ are very scarce in the Peel Sound Formation, (see fig. 23) whereas there is a subsidiary mode represented in four of the Peel Sound conglomerates in the range -4.0ϕ to -5.4ϕ . As in the case of the sand fraction, the size range of the Peel Sound pebble fraction modes is exactly two phi units coarser than the range of median size suggested by Spencer for his gravel population. (Spencer states that most clastic sediments are composed of two or three fractions each with log-normal distributions. If this is the case then the mode and the median of each fraction will be the same, and the

two measures can be directly compared). To explain the coarser nature of the Peel Sound modes it is suggested that being debris flood deposits the conglomerates will have been transported and deposited rapidly, and will therefore have undergone considerably less abrasion than the majority of the rocks studied by Spencer (1963) and Cadigan (1961).

The third and most prominent mode of the Peel Sound conglomerates is in the cobble size grade, ranging from -6.7 ϕ to -7.7 ϕ . This size range was not represented in the samples studied by Spencer or Cadigan. The cobble fraction probably represents the primary products of weathering in the Boothia Uplift area, and these clasts in turn disintegrated into sand grade material.

The persistence of certain grain size modes in the Peel Sound conglomerates thus lends weight to the hypothesis of Spencer (1963) that there is a primary deficiency in several grain size ranges in clastic sediments. However, the disparities discussed above between the modes of mature and immature sediments suggests that the term 'fundamental population' should be used with caution.

Maximum clast size:

In the Peel Sound Formation the largest clast commonly falls in the -8 ϕ to -9 ϕ size-grade, i.e. 25 to 51cm. The largest clast seen in the formation measured 150cm in maximum diameter (a boulder of gabbro at Mount Matthias),

whereas Bluck (1967) records no clast larger than 70cm across (from the Devonian conglomerates of western Scotland). These diameters are not as large as those of the proximal flood deposits described by Pack (1923), Chawner (1935), and Sharp (1948) which suggests that the Peel Sound conglomerates are probably mid-fan to distal in location. They are considerably coarser than the conglomerates of Bull (1964), in which clasts larger than gravel grade are rare - except, again, in the proximal portions of the fans.

Roundness and sphericity figures, although varying with distance of transport, will be completely different for different lithologies and for different size grades. The Peel Sound values cannot, therefore, be directly compared with any others yet published for in no previous work have all these criteria been the same. Some earlier measurements (all using the Krumbein 1941 method) are summarised in table IV., and it will be seen that the Peel Sound conglomerates (detailed results given in figs. 24-26) seem to be similar to other flood deposits in these parameters given the following qualifications:

- 1) Large clasts attain higher roundness and sphericity faster than small clasts.
- 2) Softer lithologies develop higher roundness and sphericity.

In general, roundness figures vary measureably with

distance of transport, as shown by all the roundness studies in table IV., but sphericity seems to be rather random in variation. Bluck (1967) claims that trends can be detected showing increases with distance, but his graphs are based on very few measurements. Blissenbach (1954) and Krumbein (1942) found no changes in sphericity with distance of transport. It is concluded from the present study that extensive measurements of sphericity are unlikely to serve any useful purpose. Jointing tendencies control the initial particle shape, and transport may be selective, moving certain shapes faster than others (Bluck, 1965). There are thus too many variables for sphericity figures to be very meaningful.

These results compare with those of Sneed and Folk (1958) who studied pebbles over a 200 mile stretch of the Colorado River. Roundness was shown to vary measureably with distance of transport, but sphericity values varied markedly with small changes in size and with lithology. Sneed and Folk obtained more meaningful sphericity values by dividing the pebbles of one phi size class (32 - 64mm) into three smaller size categories. This was not done in the present study. Measurements of 'form' as discussed by Sneed and Folk, would probably prove to be more useful than sphericity in relating particle abrasion to distance and method of transport.

Devonian climate:

At the present time, alluvial fan successions that have

an important debris flood element are present only in semiarid regions, with a rainfall of 10-20 inches per annum (Blissenbach, 1954, p.177). Fans are common in humid regions such as the Alps and the Himalayas but they are formed predominantly by stream flow and not by floods. The reason for this is that heavy vegetation cover normally prevents run-off from reaching catastrophic proportions. Where this cover is absent, as in areas of low rainfall, or has been removed (Chawner, 1935) rock material can be eroded very quickly, and surface run-off can build up rapidly. Sudden, heavy rainfall is not uncommon in humid regions, but its effects will usually be less drastic.

Information available at present (Seward, 1959) suggests that in Devonian times land vegetation had a very restricted distribution. At least during the first half of the period, most land plants were restricted to swampy or low lying country. It seems unlikely that evolution had proceeded so far as to produce a vegetation cover in high, mountainous areas. There is, therefore, no reason for supposing that the presence of debris flood deposits in the Peel Sound Formation indicates an arid or semiarid climate. Deposition in a humid climate with little or no vegetation, would simply have been more rapid than on modern fans in a semiarid environment such as the south-western United States.

d) Conclusions: Characteristics of ancient fan conglomerates

The results of the present study have indicated several methods of investigation that can profitably be used in studies of ancient continental conglomerate deposits. In general terms, vertical variations in conglomerate characteristics may be related to evolutionary processes on single alluvial fans and changes in their source areas, whereas lateral variations, if measured over a sufficiently large area, will reflect differences between adjacent fans. Down-fan and across-fan changes are likely to be small in comparison to the variability displayed between fans of markedly different size and source geology. Statistical studies include:

1) Clast lithotype analysis: counts of the proportions of the various clast types present enable dispersal patterns to be drawn. The presence of soft or easily weathered lithologies (eg. Read Bay limestone and gabbro, in the present study) enables direction of transport to be deduced, for these clasts decrease in numbers rapidly with distance of transport. Meaningful results can only be obtained from clast lithotype analyses if clast lithologies are readily recognisable in the field.

2) Maximum clast size: this parameter has been measured for every major clast lithology present. Variability may be

attributed to abrasion and to varying size of source material on different alluvial fans. The present study has shown that in general dispersal patterns indicated by measurements of maximum clast size are very similar to those produced by clast lithotype analyses.

3) Whole-rock grain size analyses: mean grain size and standard deviation have been shown to vary in statistically significant amounts from one alluvial fan to another. The standard deviation of debris flood deposits has been measured at approximately 2.0 to 4.0 ϕ . Analysis of cumulative curves has shown that debris flood deposits have polymodal size distributions, and that the most prominent grain size modes are approximately two phi size classes coarser than the common modes of well sorted clastic sediments such as aeolian and marine deposits. The principal modes are coarse sand (-0.8 to +2.0 ϕ), pebbles (-4.0 to -5.4 ϕ), and cobbles (-6.7 to -7.7 ϕ).

4) Clast roundness: measurements of this parameter on clasts of one phi class interval (-6 to -7 ϕ) have shown a high average roundness (up to 0.74 for quartzite clasts). Statistically significant variations have been measured in vertical and lateral directions and have been related to distance and rate of transport and to inter-fan changes.

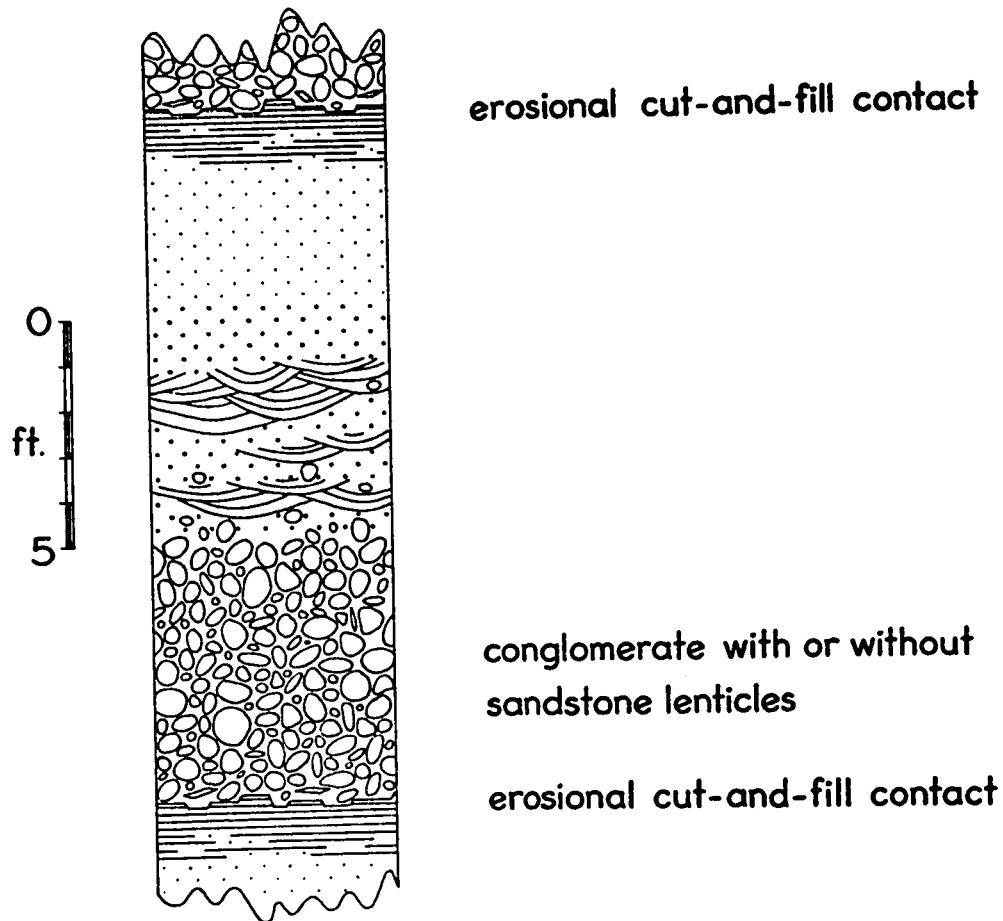
5) **Clast sphericity:** measurements of this parameter revealed a high average sphericity (up to 0.73 for quartzite clasts in the -6 to -7 ϕ size class). However, sampling in vertical and lateral directions revealed apparently random variations, probably at least in part because the size range measured was too large. Measurements of clast shape may prove more profitable.

6) **Directional sedimentary structures:** these are rare except in the interbedded fluvial sandstone lenticles. An upstream clast imbrication is occasionally detectable by eye in the conglomerates.

4) CONGLOMERATE-SANDSTONE TRANSITION FACIES

a) Introduction

The sections illustrated in a simplified version in figs. 4 and 5 are typical of the narrow zone occupied by the transition facies. There are no massive conglomerates present, only a series of thinner conglomerate units which thin out progressively to the west. They are interbedded with and gradually replaced westward by a variety of finer grained clastics including pebbly sandstones, pebble-free sandstones and siltstones. Detailed examination of some of these localities within this zone has shown the existence of a basic fining-upward sequence repeated with variations throughout the sections.



LEGEND

	laminated siltites
	fine to medium sandstones
	coarse sandstones
	festoon crossbeds
	coarse pebbly sandstones
	conglomerate
	erosional contact with intraclasts

Fig. 31. Type example of cyclic unit in the Conglomerate-Sandstone Facies

b) Cyclic sedimentation

A typical cycle is illustrated in fig. 31 and has the following succession: The lowermost unit is a coarse cobble conglomerate averaging about 5 feet (1.5m) in thickness, with a similar texture to rocks of the Conglomerate Facies. It is poorly sorted, with a reddish matrix of felspar, rock fragments and quartz. Clasts are of high roundness and sphericity, but are generally smaller than those of the Conglomerate Facies. Maximum clast size is nowhere greater than 10 inches (25cm); in most cases it varies from 4-8 inches (10-20cm). Rare upstream imbrication has been observed. Thin and impersistent sandstone lenticles are present in some cases and are generally no greater than 12 inches (30cm) in thickness. Lenticles that persist laterally for a few tens of feet, commonly contain trough crossbedding, and there are smaller sandstone lenses, approximately 6 feet (2m) in width, which in some cases form infills of a single trough cut in the underlying conglomerate.

The basal conglomerate commonly rests with erosional contact on the underlying bed, the lowest few inches frequently containing intraclasts eroded from this bed, such as angular and disoriented clasts of fine red siltstone or sandstone (see photograph 15). The erosional base has not been observed everywhere although in many cases this is due to inadequate exposure.

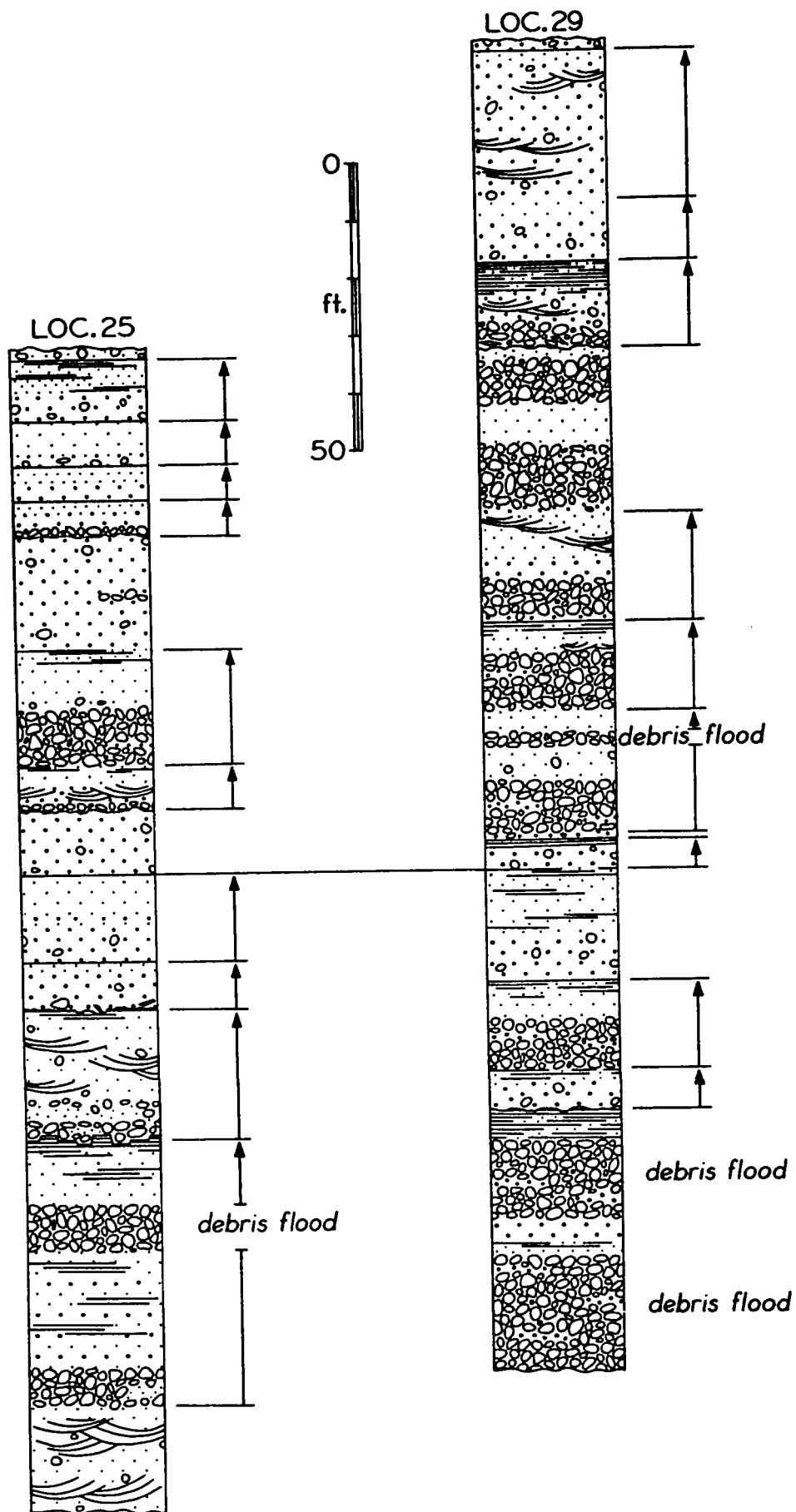


Fig. 32. Vertical sections in the Conglomerate-Sandstone Facies near Bellot Cliff, demonstrating cyclic sedimentation. symbols as in fig. 31

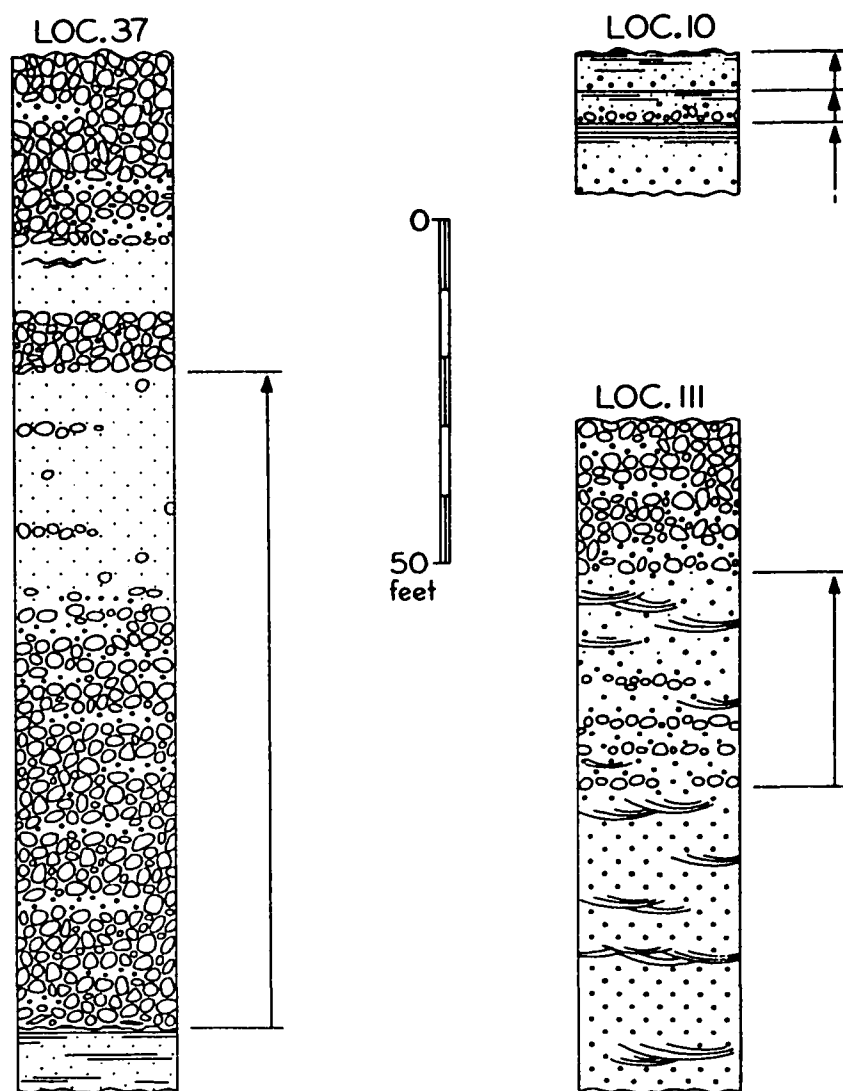


Fig. 33. Vertical sections in the Conglomerate-Sandstone Facies demonstrating cyclic sedimentation. loc. 37: Russell Island, locs. 10, III: Prescott Island. symbols as in fig. 31

Above the conglomerate is a coarse red sandstone, sometimes containing small, scattered pebbles of the commoner lithologies that are found in the conglomerate with which it generally has a gradational contact. The sandstone is commonly tabular bedded, with scattered shallow troughs up to 5 feet (1.5m) in width, similar to those illustrated in photograph 16.

The coarse sandstone grades up into fine, red sandstone, either by a smooth, progressive decrease in grain size, or by interbedding with finer sandstone lenticles which gradually gain dominance up the section. The top of the cyclic unit is formed of the finest red sandstone, commonly silty, micaceous and finely laminated, or showing very small scale planar cross beds. The thickness of the whole conglomerate-sandstone sequence averages about 15 feet (4.5m).

Some of the fining-upward successions do not show all the features described above. This may be seen from an examination of the sections illustrated in figs. 32 and 33. These are some of the sections of figs. 4 and 5 shown in greater detail, and the arrows indicate the limits of each fining-upward cycle. The differences may be listed as follows:

- 1) In many cases the basal conglomerate is thin or absent - the repeat unit starts with a pebbly or non-

pebbly sandstone - see particularly the top of the first Bellot Cliff section (loc. 25). The units here are thinner, ranging from 5 to 10 feet (1.5-3.0m) in thickness.

2) The coarse sandstone that normally forms the central part of each repeat unit may be disproportionately thick as, for example, at the top of the second Bellot Cliff section (loc. 29) where it reaches 23 feet (7m). In this particular example there is no basal conglomerate.

3) The Russell Island section shows a fining upward sequence 52 feet (16m) thick (loc. 37, fig. 33). Conglomerates and sandstone are interbedded, the latter becoming more and more important up the section as the conglomerate layers gradually diminish to thick pebbly seams. This is by far the thickest of the fining-upward sequences that have been observed.

Another feature readily apparent from the sections illustrated is the presence of conglomerate and sandstone layers that do not appear to belong in any gradational sequence, either fining-upward or coarsening-upward in character. If the conglomerate layers are omitted from the section, the beds above and below appear to form a fining-upward sequence. This suggests that such conglomerates were formed during an interruption in the normal sedimentation processes of the area. A consideration of the causes of the fining-upward sequences described here,

and of their repetitive nature (see next section) will show that this should be expected.

In the Mount Matthias area coarse sandstones of the transition facies often contain derived Read Bay fossils. They are normally broken fragments, showing considerable weathering. Many show the concentric ring texture of beekite replacement. Types found include heliolitid and favositid corals, broken and indeterminate solitary corals, bryozoa, a rhynchonellid brachiopod and gastropods. No such fossils have been found in the conglomerates, presumably because they were too fragile to be preserved in the extremely high energy conditions that accompanied the formation of these deposits. They can only have been transported across the Conglomerate Facies by the quieter stream flow between periods of flooding.

c) Environmental interpretation

The fining-upward sequences described above show close similarities to the fluvial cycles of Allen (1965a), Friend (1965), Visher (1965), and Williams (1968). The only significant difference is the much coarser grain size of the cycles when considered as a whole. The successions measured in this study commonly begin with a thick conglomerate member, which compares elsewhere with thin rubble lenses or lag conglomerates (Williams, 1968), intraformational conglomerates or simply pebbly sandstones (Allen,

1965a; Friend, 1965). Similarly, the tops of the Peel Sound cycles are never finer grained than sandy siltstone, whereas nearly all the other described examples contain an upper member with a greater or lesser amount of shale or mudstone (Allen, 1965a; Visser, 1965; Williams, 1968). This difference may be interpreted in any or all of three ways:

a) The sediment available for transport was much coarser than has been found to be the case elsewhere.

b) The energy level of the transporting medium was higher.

c) Finer grained tops may be lacking because they were removed by erosion before or during the formation of the succeeding cycle. This again implies a high energy level. In some cases erosion surfaces have been observed at the base of cyclic units, but in many cases exposure is too poor for the nature of the contact to be determined.

It is thought that these deposits occur at the very edge of the alluvial fan zone described in the first part of this chapter (see also fig. 48), a situation different to those described by earlier workers, who refer to wide flood plains or delta flats, sometimes close to sea level (Williams, 1968). Thus, although the general mode of deposition of the Peel Sound cycles is probably comparable to those described in previous studies (listed above), it

seems likely that rivers were operating at a higher energy level, only a little removed from the extreme conditions that give rise to debris flood deposits. The absence of very fine grained horizons may be due to either of factors (a) and (c), though the fact that clay grade materials are completely absent, not occurring even as intraformational clasts, suggests that such material must have been very scarce, or that conditions never became quiet enough for it to be deposited.

The cycles are thought to be the result of channel filling and migration in a braided stream environment. The sedimentary structures suggest a comparison with the low sinuosity stream model of Moody-Stuart (1966). A pattern intermediate between Allen's alluvial model B and model C (1965b, fig. 35) should be visualised. Model B is the braided stream environment consisting of many channels which migrate across the flood plain and which change their position suddenly during floods. Model C is the low sinuosity stream environment. Allen's diagram shows a single channel migrating slowly across the flood plain. (The separation of these two models is perhaps open to question for there are many streams which are both braided and of low sinuosity.) In the central coarse sandstone member of the cycles trough crossbeds are fairly abundant. They are often grouped and mutually interfering

and thus they fall into Allen's pi-cross-stratification class (Allen, 1963, p.110). The presence of these structures and the absence of laterally extensive planar crossbeds with planar bounding surfaces (alpha or epsilon cross-strata, Allen, 1963, p.101-4) is the main evidence for suggesting a low-sinuosity stream origin. Alpha and epsilon crossbeds may be expected to occur in high sinuosity streams in which laterally migrating point bars are very characteristic features. They are found in river systems near erosional base level, where wide meander belts are to be expected. As already discussed, this does not appear to be the model that should be considered for the Peel Sound Formation. Low sinuosity streams develop channel fills by vertical accretion rather than by lateral migration. They are characterised by festoon crossbeds (Moody-Stuart, 1966).

Doeglas (1962) described the conditions necessary for the development of braided streams. They correspond very closely with those conditions already suggested for the formation of the alluvial fan system immediately to the east:

- a) A climate characterised by sudden, very heavy cloudbursts, separated by long, dry intervals.
- b) Impermeable subsoil and lack of vegetation in the catchment area, causing strong surface run-off.
- c) Steep gradient.
- d) Heavy load.

If these conditions are satisfied, the result is that the bulk of the load is carried only during short periods of very high flow, in a complex system of anabranching channels which may shift and reform very suddenly by a process of avulsion. During periods of low water only a few major channels will continue to flow and evolve by the formation and migration of bars.

The basal conglomerates of the Peel Sound cycles are interpreted as the deposits of violent stream flow during a period of high discharge. At such times channel patterns would be drastically modified and new channels initiated. The term 'Stream flood' should not be used here in the sense described by Blissenbach (1954), for this implies a variety of debris flood. In many cases the conglomerates cannot have been deposited in a single flood, for they contain interbedded coarse sandstone lenses that imply quieter periods. They were probably formed by several more or less separate waves of flooding following closely behind each other (as described by Sharp and Nobles, 1953), the sandstone lenticles being deposited during the periods of diminishing water that followed each wave. These were probably the distal ends of the floods that deposited detritus on the alluvial fans, and they must have lost a considerable amount of their energy by the time they entered the braided stream zone. Many were probably debris floods

which had lost much of their sediment load and had become the 'violent stream flow' type, with a much lower sediment:water ratio.

The coarse, sometimes pebbly, festoon crossbedded sandstones that succeed the conglomerates represent channel fills. When quiet flow is resumed in a system of newly established channels, some are likely to be maintained and others silted up gradually. This probably explains the progressive fining-upwards of the coarse channel fills into laminated siltstones - a response to decreasing energy level in a secondary channel. Other more major channels may remain active for longer, thus accumulating thicker deposits of crossbedded sandstones, as seen in the sections illustrated. The pebbly sandstones are similar to Bluck's type 'C' conglomerate (1967, fig. 2). The latter contains a high proportion of sand and very abundant trough cross-bedding. It is interpreted by Bluck as a braided stream deposit.

In fining-upward sequences developed in high-sinuosity stream systems overbank deposits are believed to be of some importance. Wolman and Leopold (1957) suggest that 10-20% of all normal floodplain sediments are overbank deposits. This is not likely to be the case in a braided river where the floodplain consists almost entirely of active or abandoned channels. However, there may be

islands or bars, consisting of the eroded remnants of earlier stream courses, and at periods of high water there could be spillover into these areas. Laminated siltstones would probably be the result. In the sections under discussion those fine grained members which show no relationship to a fining-upward sequence were probably formed in this way. They rest on earlier beds with a sharp rather than a gradational contact.

It remains only to explain some of the conglomerate layers that appear to interrupt cyclic successions. Better exposure may show that in fact all could be accounted for in terms of fining-upward successions, but at present it is suggested that these deposits may represent the sediment load of floods - perhaps debris floods, that entered the area but did not radically alter the channel pattern so that after the flood subsided quieter water deposition continued more or less as it had been before.

Bluck (1967) showed that for conglomerate beds deposited by torrential floods, an arithmetic correlation exists between the thickness of each individual conglomerate unit and the size of the largest clast. This correlation is due to the fact that the magnitude of both these parameters is controlled by the size and intensity of the flood. The larger this is the more material it will be capable of transporting and hence the thicker the resulting deposit is

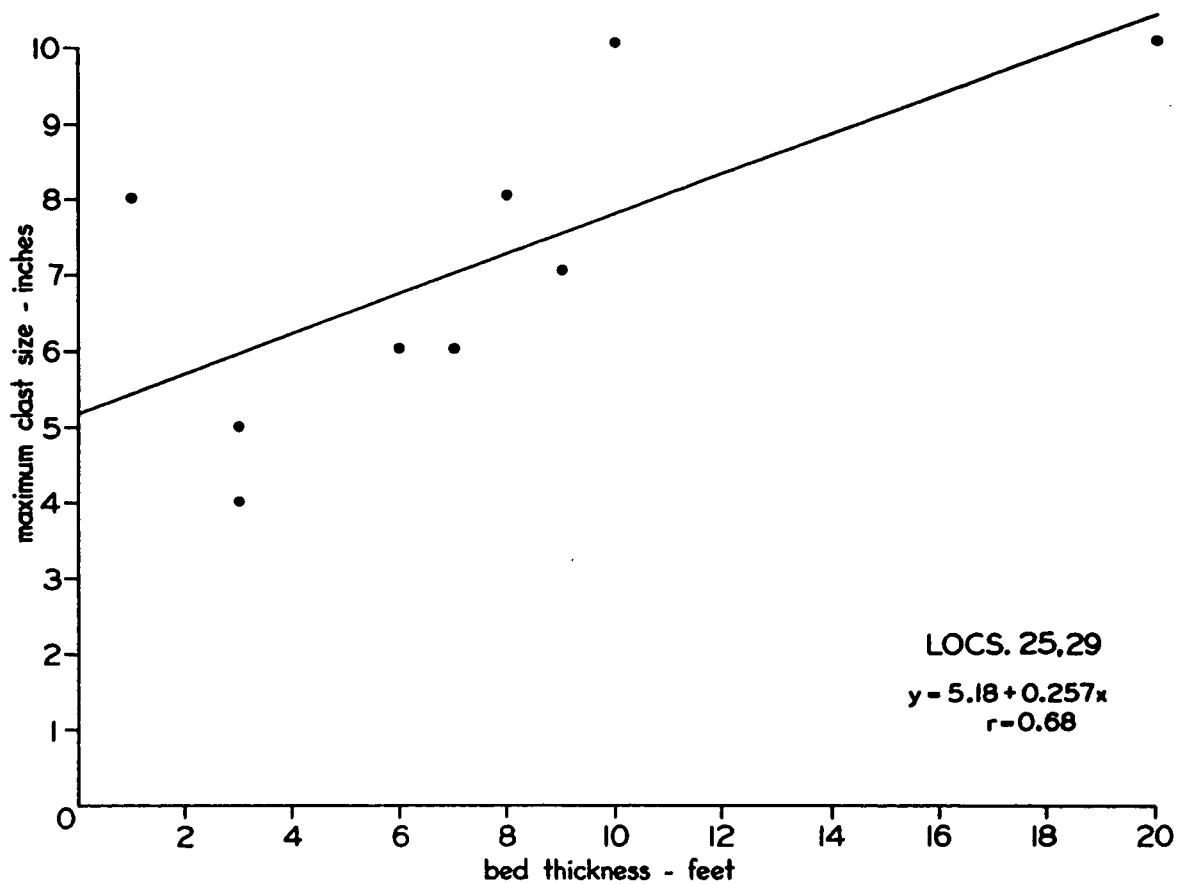


Fig. 34. Bed thickness: maximum clast size correlation: Bellot Cliff

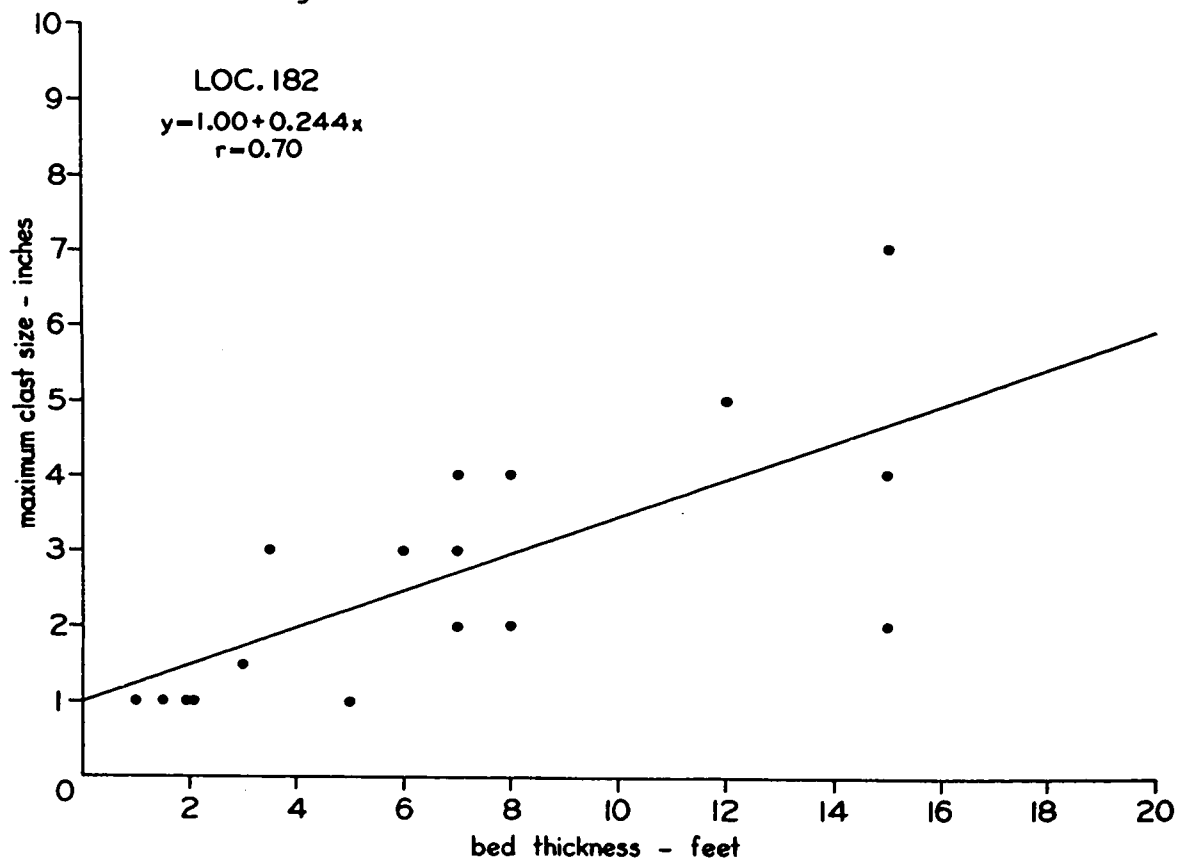


Fig. 35. Bed thickness : maximum clast size correlation: Transition Bay

likely to be. The larger, also, will be the size of the individual particles it can carry.

Figs. 34 and 35 present measurements from three sections. Fig. 34 shows the correlation between bed thickness and maximum clast size as it has been demonstrated for locs. 25 and 29 ($r = 0.68$, $P = <0.05$), and fig. 35 is included here for completeness. It shows details from Broad's (1968) section in the basal part of the Peel Sound Formation ($r = 0.70$, $P = <0.01$). It will be seen that the regression lines for the two graphs have an almost identical slope indicating, probably, a similar type of flood origin. However, the beds measured for fig. 34 are much more distal deposits, and the reasons for the very similar slope of the two graphs are not completely understood. Bluck was able to differentiate the deposits of debris floods and violent stream flow on the basis of detailed textural features (discussed under 'Conglomerate Facies'), and the graphs for the respective correlations show different slopes. The influence of debris flows is not thought to be important in this facies of the Peel Sound Formation and all the readings are plotted together. Figures from the Conglomerate (alluvial fan) Facies would probably show the more rapid increase of clast size with increasing bed thickness that Bluck demonstrated for debris flood deposits (compare figs. 3 and 4 of Bluck, 1967), but it is impossible to separate

the individual beds from one another, and thus impossible to take the required measurements.

Lateral variations: Sections 25 and 29 are less than one third of a mile (approx. 500m) apart and can be correlated by tracing out a prominent siltstone bed on the ground (see fig. 32). Yet it will be seen that apart from this one common bed there is practically no correspondence between the sections. Section 25 is further downstream than section 29, and hence has a smaller proportion of conglomerate, and it will be seen that both sections tend to decrease in grain size upwards when taken as a whole because conglomerates become thinner up the section. But no convincing correlations can be demonstrated between individual cycles. This would be expected from the discussion above, in which the stratigraphic variations are attributed to very localised causes such as wandering channels and the effects of adjacent bars or banks. An examination of other conglomerate-sandstone transition sections, such as the remainder of those illustrated in fig. 5, will show even greater differences. It does not seem likely, therefore, that cyclicity was caused by any of Beerbower's (1964) 'allocyclic' mechanisms - those created by external influences such as changes in discharge, load or slope, eustatic changes or periodic subsidence, all of which have widespread effects. Autocyclic mechanisms are defined as those developed entirely

within the alluvial plain. The fluctuations of a braided stream therefore seem to come under this heading.

It is not clear how much importance should be attached to the fining-upwards of sections 25 and 29 when considered as a whole. In the vicinity of Bellot Cliff hills consisting of nearly horizontal beds rise to 1360 feet (420m) above sea level. The two sections occur between the 400 and 600 foot (120 and 180m) contours as estimated from the 1:250,000 map, i.e. at about the middle of the formation. The upward decrease in grain size suggests filling of the sedimentary basin or reduction of relief in the source area, both possibilities implying an absence of tectonic activity. This may be a general tendency or merely a local pause; at present there is insufficient evidence to permit generalisations.

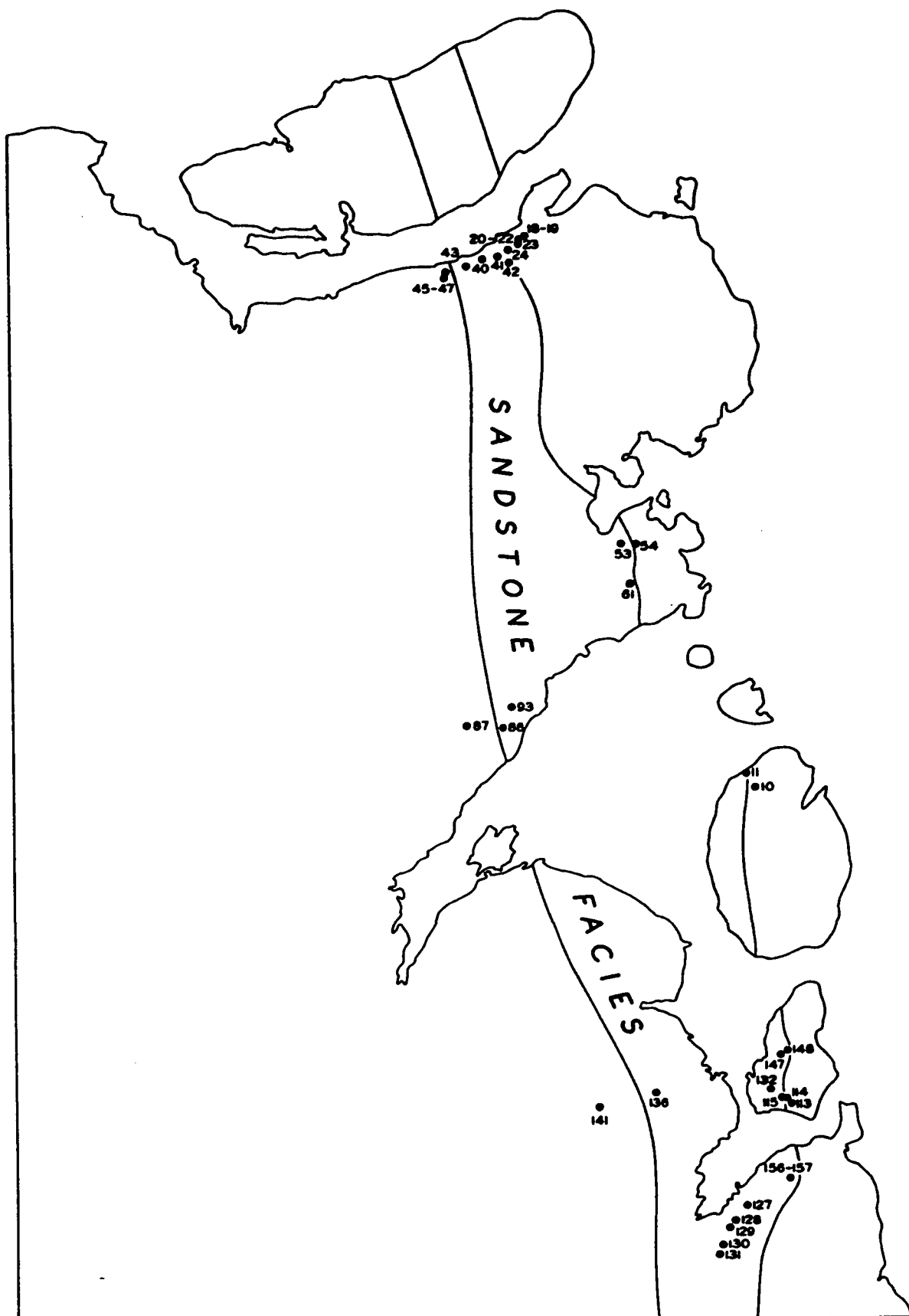


Fig. 36. Location of outcrops: Sandstone Facies

5) SANDSTONE FACIES

a) Introduction

Fig. 36 shows the distribution of the major exposures of this facies visited, and table V is a summary of the lithologic characters and sedimentary structures observed. There is a considerable uniformity in the characteristics of these beds, and recognition of the facies in the field is a simple matter. However, it should be emphasized that the lines drawn on the map represent arbitrary vertical boundaries. The Sandstone Facies grades into the Conglomerate Facies by the gradual increase in the number of clastic fragments larger than sand grade; it grades into the Carbonate Facies by the appearance of intertonguing carbonate beds. Many characteristics of the Sandstone Facies are thus displayed by parts of the typical transition-facies sections. Exposures 45-47, for example, are mapped as Sandstone-Carbonate Transition Facies because of the presence of a single 18 inch (45cm) layer of argillaceous limestone in a section showing at least 100 feet (30m) of red sandstone and related lithologies. The three exposures are included here for they demonstrate particularly well some of the variations to be found in the Sandstone Facies at its western edge.

Table V. Sandstone Facies: summary of field evidence

		LITHOLOGIES	SED. STRUCTS.	ORG. REMS.
LOC.	GRID REF.	mudflake cong. siltite fine ss. medium ss. coarse ss. pebbly ss.	fine lamination planar CB trough CB major channels primary current lin. ripples des. cracks sole strucls.	fish debris borings
10	NS675175	x x x x x x	x	x
11	NS672208	x x x x	x	x
18	NS331941	x x	x	
19	NS327940	x	x	
22	NS323932	x x		
23	NS322928	x x x x x	x x x	
24	NS315925	x x	x	
40	NS273904	x x x x	x x x x x	
41	NS288910	x x x	x x	x
42	NS291170	x x x x x x	x x	
43	NS249898	x		x
45	NS218883	x x	x x	
46	NS217891	x x	x	x
47	NS213878	x x		x
53	NS476498	x x	x	
87	NS266254	x x x	x	x
88	NS308246	x	x	
93	NS328278	x x x	x x	
113	NR734741	x x x x	x x x	x
114	NR728749	x x x x	x x	
115	NR724747	x	x	
127	NR675595	x x x x x	x x	
128	NR664573	x x x x x	x x	x
129	NR662563	x x x	x x	x
131	NR656530	x x x	x x	
132	NR701753	x		
136	NR543743	x x x x	x x	x
147	NR721812	x x x x		
156	NR742633	x x x x	x x	
157	NR741638	x x x x	x	

b) Lithologic characteristics

General description

Broadly speaking, the rocks of this facies are similar to those of the Conglomerate-Sandstone Transition Facies except for the absence of conglomerates. The coarsest lithology found is pebbly sandstone, which tends to occur more commonly in the eastern part of the facies. The pebbles are rarely larger than 2 inches (5cm) in diameter and consist mainly of Aston quartzite, gneiss and vein quartz. The matrix is coarse, immature sandstone.

Pebble-free sandstones of all grain sizes are present; they grade into silty sandstones and true siltstones, the latter often being very finely laminated. Thirty laminae were counted on one thin section an inch (2.5cm) in width. They are characterised by very small grain size variations, coupled with slight differences in intensity of the iron-oxide staining. Siltstones are commonest in the western part of the facies, particularly at locs. 45-47 where they comprise the larger part of the redbed succession. Elsewhere they are found as individual layers interbedded with coarser lithologies.

A very characteristic lithology of this facies is mudflake conglomerate. It is not found in the Conglomerate-Sandstone Facies or the finer-grained redbeds of the Sandstone-Carbonate Facies, but has been noted in nearly all

outcrops of the Sandstone Facies that contain beds of coarse sandstone. The conglomerate occurs as lenticles less than one inch (2.5cm) in thickness and contains abundant disc-shaped fragments of dark, red-brown, fine silty mudstone, sprinkled with very tiny mica flakes. The mudflakes may reach one inch in width but are rarely more than 0.2 inches (0.5cm) thick. They do not lie flat on a single bedding plane but are disoriented, often showing a crude imbrication. The space between them is filled with coarse, sometimes gritty sandstone. The lithology of the mudflakes is rarely seen as an undisturbed contemporaneous deposit, but it seems likely that the clasts are of intraformational origin (see photograph 15).

The typical outcrop in this facies shows an interbedding of several of these redbed deposits. Individual beds vary in thickness from approximately four feet to less than one foot (approx. 30-120cm). All the lithologies described above may be present, but their proportions vary considerably. Thus, silty beds are comparatively rare in sections of the eastern part of the facies and in the Conglomerate-Sandstone facies, but towards the west, as at Baring Channel, they tend to dominate the section. No true cyclicity was observed.

Petrography of the sandstones

Grain size and compositional analyses of six typical

sandstones are given in table VI. and fig. 37. Photograph 31 is a photomicrograph of the specimen from Mount Matthias. The grain size analyses were obtained by thin-section measurements using Friedman's (1958) corrections. The method employed is similar to that described in an earlier chapter for the fine fraction of the conglomerates. The compositional analyses were also carried out by thin-section traverses. 400 points were measured in each section, although it was found that fewer points were necessary for consistent results in the finer-grained rocks. Heavy minerals were extracted by crushing and grinding the sample and treating the fraction finer than 2.5 ϕ with bromoform. Quartz, feldspar, weathered grains and some of the dolomite matrix floated to the top and the heavy minerals sank. Calcite and dolomite were distinguished by staining, using the method of Warne (1962).

No attempt is made here to determine detailed north-south variations in grain size and compositional characteristics (that is to say, along the length of the facies outcrop). Initial investigations showed four reasons why this would be difficult or impossible:

- a) The lack of good stratigraphic control would prevent all but very gross characters from being delimited.
- b) Grain size is very variable within single outcrops on the bed to bed scale.

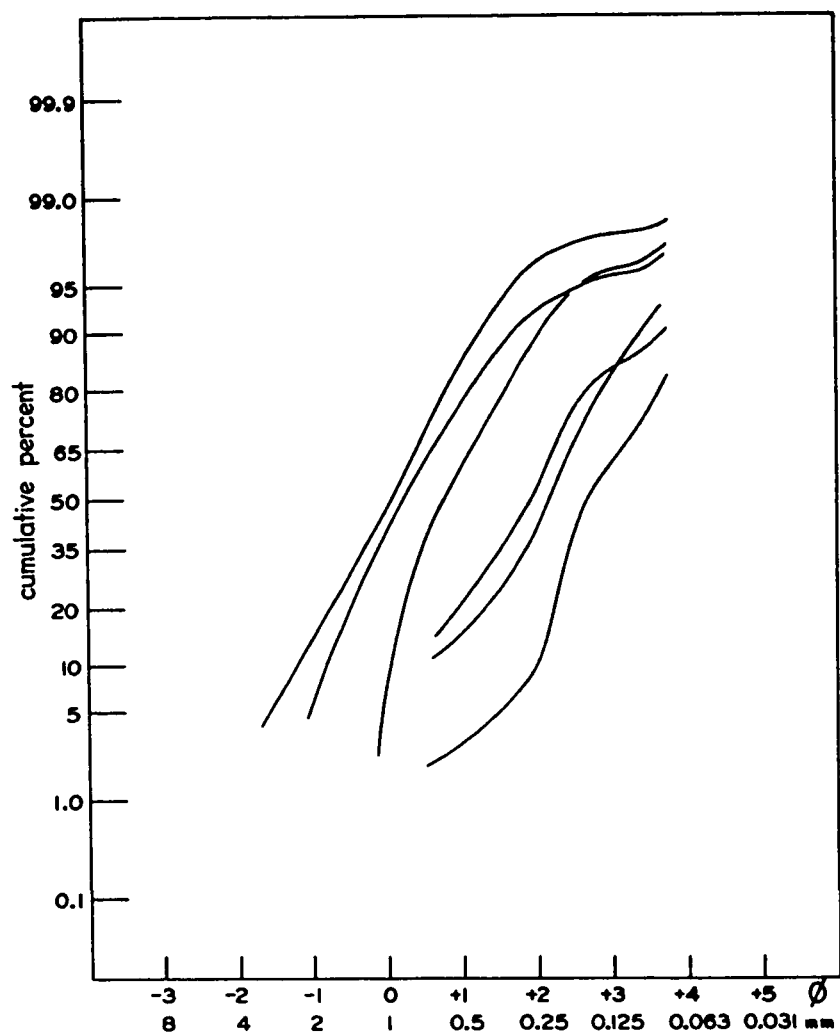


Fig. 37. Sandstone size sorting

Table VI. Petrography of six typical sandstones

LOC.	LOC. NO.	Mean grn. size M_z	Standard dev. σ_I	Qtz.	Chert	Qtzite.	Fsp.	weathd. grains	carbonate	intra-clasts	zircon rutile tourmaline garnet biotite apatite magnetite
B. Channel	20	+1.90	1.17	25%	3	3	2	21	44	2	c c r c a - -
B. Channel	41	+2.11	1.03	18	2	-	-	18	57	4	- - - r r - -
Prescott Is.	11	+0.31	1.03	31	-	-	5	31 ^x	32	-	t c - c c t t
Mt. Matthias	54	+0.05	0.95	22	1	-	1	21	54	-	c c r a - - -
Mt. Matthias	61	+0.91	0.78	37	-	-	-	17	39	7	r t t r t - -
Muskox Hill	141	+2.89	0.80	25	-	-	1	25	46	3	r r r r - - -

Heavy minerals:

t = traces

r = rare

c = fairly common

a = abundant

X This figure includes:

1% identifiable olivine,

1% identifiable garnet

c) Thin sections show the sandstones to consist of very weathered material, obscuring much important detail of their composition.

d) Heavy minerals can have been derived only from the metamorphic rocks or as second-cycle grains from the Aston or 'grey-green' quartzites. The conglomerates studies have shown how abundantly both the metamorphics and the Aston quartzites are represented as derived fragments almost everywhere, from north to south across the island. It is probable, therefore, that a very large sampling program would be necessary to uncover any heavy mineral variations that could be considered statistically valid, if, indeed, any such variations could be expected in the first place. Heavy minerals have thus been investigated, as discussed below, on little more than a qualitative basis.

Table VI shows that there are no major changes in composition throughout the facies. The same minerals occur in the same order of abundance in all six sections. The grain size data indicate that the individual sandstone beds are moderately to poorly sorted. Field work has indicated a progressive decrease in grain size from east to west across the facies, a decrease from coarse, often pebbly sandstones to fine-grained sandstones and sandy siltstones. This gradation is seen particularly well along Baring Channel where there is the best and most continuous exposure (see table V.)

A full discussion of the sandstone provenance cannot be entered into because of the very weathered nature of the material collected. Weathered grains amount to 17-31% of the total rock. The reasons for this will be discussed below. Most of the weathered grains have a discrete, rounded shape, indicating detrital origin; most are heavily limonite stained to a dark brown, nearly opaque colour, which obscures their original nature. A few less heavily stained grains have been identified as feldspar, colourless garnet and olivine altered to serpentine. Feldspar has been counted separately wherever it has been thus identified. Most of the weathered grains, however, probably represent the 'rock fragment' class, consisting of ferromagnesian minerals from igneous or metamorphic rocks.

Feldspar varies from 0-5% of the rock, though there may be a small percentage of feldspar grains altered and stained beyond recognition. Orthoclase, microcline, plagioclase and perthite have been noted. A few zoned crystals have been seen.

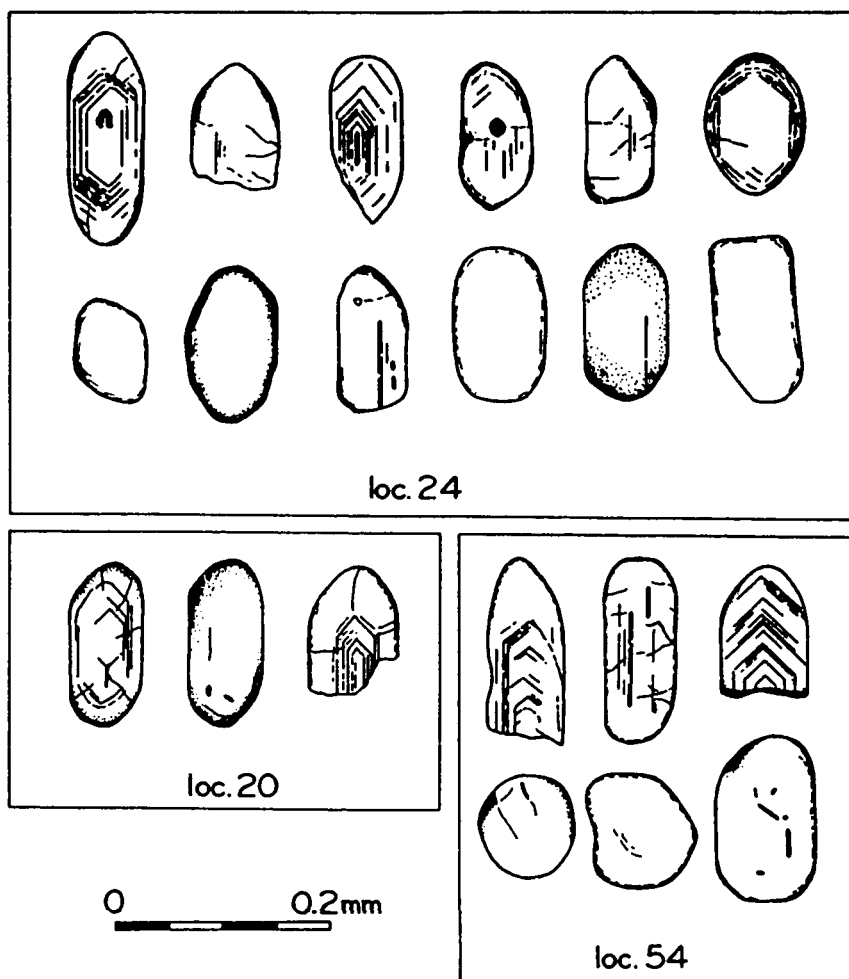
Quartz is abundantly represented as fresh, angular to rounded fragments. Grains showing undulous extinction are fairly common, and composite grains are rare. A few clasts showing graphic intergrowth of quartz and feldspar were noted. Secondary overgrowths of silica are quite common, preserving the original rounded grain outlines as

'ghosts'. Quartz grains are often in contact - their overgrowths are cemented together.

Chert is present in many of the sandstones and grains of quartzite were seen in one thin section. Some are of a clean washed rock, probably derived from the Aston Formation, others have a limonite-stained matrix. The specimen from loc. 54 contained a grain of limonite and hematite-stained ooliths set in a siliceous matrix.

Calcite and dolomite are present in approximately equal proportions. The crystal size varies from fine-grained aggregates to large, twinned crystals. Both minerals are present as detrital fragments, preserving the original rounded outline. Other areas of carbonate have vague, shapeless outlines and may merge into small, dark, sometimes iron-stained patches of material, probably of clay grade. Some of the shapeless grains may be secondary infills of interstices in the rock, but in other cases, the fine grain size and the fact that detrital grains are not in contact suggests that this carbonate is unaltered primary matrix.

Most of the sandstones contain detrital fragments of clay, sometimes colourless in thin section, sometimes limonite-stained. A few contain a sprinkling of fine quartz grains. These fragments are of similar size range to the quartz and other minerals and are usually well rounded.



**DETRITAL ZIRCON GRAINS FROM
THE P.S.F.**

Fig. 38.

They are thought to be intraclasts - smaller fragments of the same origin as those forming the typical mudflake conglomerate.

Accessory minerals visible in thin section include small fragments of green pleochroic chlorite and weathered muscovite.

The heavy minerals separated by the use of bromoform are listed with estimates of abundance in table VI. Zircon is present as very well rounded grains, generally of elongate, prismatic shape, though some almost ellipsoidal grains were noted. In fig. 38 some typical grains are illustrated as they were seen by transmitted light. Zoning is very prominent in some grains, in others it is entirely absent. Many grains show tiny, six-sided inclusions, arranged randomly or parallel to the long axis of the grain. They are probably negative crystals filled with fluid. Other inclusions form patches of minute, dark specks at the ends of the grains. Fractures are often present. Some grains are broken, and the breakage may be fresh, or worn as if by water transportation. All the grains seen in the Peel Sound Formation appear to be of polycyclic origin, because of their high degree of roundness, but the grains with water-worn fractures demonstrate this particularly well.

Rutile is present as small, shapeless or well rounded grains of a dark red-brown colour. Pleochroism is generally faint. One grain (loc. 11) was observed showing the

characteristic geniculate twin, with an inter-twin angle of 64° .

Small, rather shapeless grains of tourmaline are present in some of the samples. A deeply coloured variety is characteristic, with strong pleochroism from green to brown, but at loc. 141 grains of tourmaline with pleochroism from pale green to pale pink were noted.

Garnet is rather common in these sandstones; a dark red, opaque variety seems to be typical. The shape varies from irregular to a recognisable crystal form showing dodecahedral faces. Well rounded, water worn grains are also present.

Biotite is present as minute, nearly opaque flakes. They are usually slightly deformed and, by reflected light, often show reddish brown specks of incipient oxidation. Where present this reduces the otherwise bright surface lustre to a resinous or dull, earthy appearance.

Apatite was identified from one section. Magnetite is present in two of the samples studied, and shows octahedral form, irregular shape or a water worn outline.

Other rare heavy minerals tentatively identified from very few grains include hornblende, spinel and andalusite. The hornblende and the spinel were seen in the sample from loc. 24. Both species occurred as fresh, irregular shaped grains. One grain identified as andalusite was

noted in the sample from loc. 20. If the identification is correct, this is an unusual occurrence for the mineral.

c) Sedimentary Structures

One of the characteristics of the Peel Sound sandstones seems to be a paucity of sedimentary structures. Monotonous, tabular bedded successions are typical. The structures that are present are described here. The reasons for their lack of abundance are discussed at the end of this chapter.

Planar crossbeds have been seen in a number of outcrops, but their identification is difficult because close examination often shows that the observed structure is actually one side of a trough. However, in several places individual beds 10 inches to 1 foot (25-30cm) thick show tabular sets of planar crossbeds extending laterally for thirty feet (9m) or more (eg. locs. 93, 127). These are the typical 'alpha' crossbeds of Allen (1963, p.101). The largest examples extend for the full width of the outcrops, and their true lateral extent may be considerably greater. Measurements of foreset dip showed generally steep slopes, reaching a maximum of 30° (loc. 129).

Trough crossbeds are the commonest sedimentary structure in the Sandstones Facies (see photograph 16). They occur either as single sets or grouped cosets overlapping one another, i.e. of festoon type. They vary in size,

being typically from 1 to 5 feet (30-150cm) wide and 4-12 inches (10-39cm) deep. These structures correspond to Allen's pi-cross-stratification (1963, p.110). Occasionally, as at loc. 40, very small scale festoon cross-sets may be seen, one half to one inch thick (1.3-2.5cm), similar to nu-cross-stratification (Allen, 1963, p.107). All orientations of directional structures such as troughs had to be measured on vertical faces because horizontal bedding planes are rare - the softness of the sandstones makes hilltop exposures uncommon.

Major channels are rare - the sedimentary structures are mainly of medium or small scale. However, one side of a large channel was seen on Pandora Island (loc. 114, see photograph 17). Festoon crossbedded sandstones are eroded to a depth of at least three feet (90cm). The erosion surface is not smooth, but shows an irregular cut and fill relief on a small scale. The infill consists of coarse sandstone with intraclasts of red-brown silty mudstone at the base. This is followed by three feet of medium to coarse red sandstone showing internal erosion surfaces, indicating several separate periods of erosion and deposition along the stream course. The highest sandstone fill contains ripple-drift cross-stratification. The channel is at least 30 feet (9m) wide, but the other bank is not exposed.

Primary Current lineation: (This term, used by Allen, 1964; Stokes, 1947, 1968, is preferred to 'parting lineation' (Crowell, 1955) for it eliminates the possibility of confusion with certain tectonic lineations). An example from the Peel Sound is illustrated in photograph 18. This structure appears to be commonest towards the west, and is found in a number of localities of the Sandstone-Carbonate Transition Facies (to be described below). The presence of primary current lineation indicates current conditions transitional between the upper and lower flow regimes but as only a few examples of the structure were observed it seems probable that this flow condition was only established locally.

Ripple marks are not common in the coarse red sandstones of this facies. An exception is the ripple-drift cross-stratification in the large channel of loc. 114. Ripples seem to be more characteristic of the finer grained sandstones of the Sandstone-Carbonate Transition Facies. Asymmetric ripples 2-3 inches (5-7.5cm) in wavelength, primary current lineation and very small scale festoon crossbeds were all seen in fine grained beds at loc. 40. Asymmetric ripples and ripple-drift crossbedding were seen in the gorge section locs. 45-46, again in association with parting lineation.

Two examples of desiccation cracks were observed in

thin mud seams, a lithology which is not common in this facies.

The formation and preservation of sole structures appears to be dependent on the presence of mud seams. Load casts and groove casts from loc. 46 are illustrated in photograph 20. The load casts are less than a quarter of an inch (7mm) across.

d) Organic remains

The only identifiable fossils found in this facies are vertebrate remains. The material is usually very fragmentary, consisting of isolated plates and spines of ostracoderm fishes. Complete spines of acanthodians are rare (identification by D. S. Broad, personal communication); highly comminuted and indeterminate debris is more characteristic. The material is usually found in the coarse and medium grained sandstones, but its distribution within beds of this lithology seems to be erratic. Fish remains are more typical of the western part of the facies.

Indeterminate organic borings are common in silty beds. Occasional layers a few inches thick contain complex systems of ramifying and sinuous mud-filled tunnels averaging half an inch (1.3cm) in diameter. In most cases the borings are approximately vertical.

e) Discussion of Results

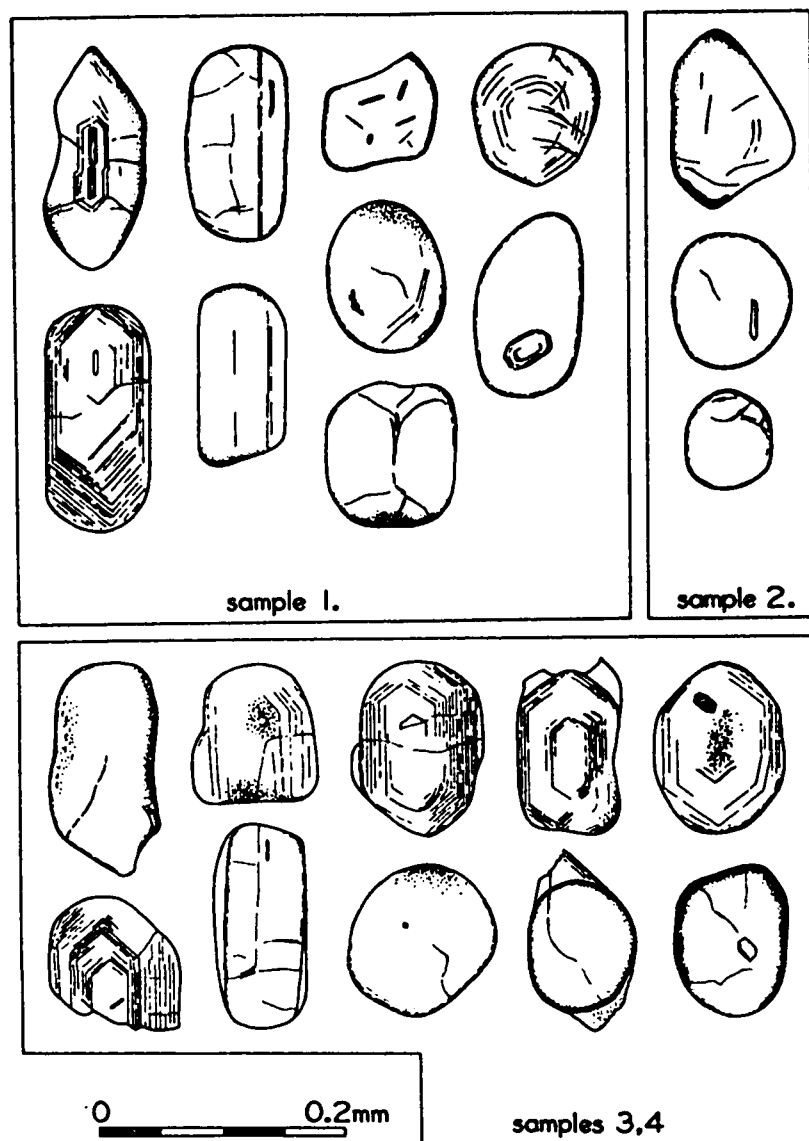
Provenance of the sandstone

In contrast to many other studies of arenaceous deposits

there is in this case very little doubt as to the source of the detritus forming the sandstone. The reason for this is the close genetic relationship between these beds and the conglomerates to the east (See section on Stratigraphy, and regional paleocurrent map fig. 49). As has already been discussed, the clasts in the conglomerates can be readily identified and assigned a source in the general region of the Boothia Uplift. The sandstones of the facies under discussion are thought to be the finer-grained downstream deposits of the same fluvial system that formed these conglomerates.

On the basis of this assumption first cycle material in the sandstones would have been derived from the granites, acidic gneisses and gabbros in the core of the Boothia Uplift. Much of the quartz and feldspar and many of the heavy minerals, particularly the rather unstable mineral biotite, probably originated here. The weathered grains, representing ferromagnesian minerals, were probably all derived directly from this source.

The Aston and Hunting Formations probably provided much second cycle or polycyclic material: quartz, quartzite and feldspar from the Aston, chert and dolomite from the Hunting. Tuke *et al.* (1966, p.701) record up to 10% feldspar (plagioclase and microcline) in the Aston Formation of Aston Bay. Chert is abundant in one of the four members of the Hunting Formation. Occasionally this



**DETRITAL ZIRCON GRAINS FROM
THE ASTON FORMATION**

location of samples given on Table VII.

Fig. 39.

replaces oolites, leaving a relict structure (*op. cit.*, p.703). A single grain of this has been observed in the Peel Sound sandstones.

The heavy mineral suite suggests a similar two-fold origin - first cycle grains from the igneous and metamorphic rocks of the Boothia Uplift, second cycle grains from the basal sedimentary rocks. Except for the absence of ilmenite this is a typical mid-Paleozoic suite as described by Pettijohn (1957, p.516) for it includes only the most stable and resistant of the common detrital species. Table VII lists the heavy minerals that have, to date, been identified from the various source rocks. For the purpose of the present study one sample of felsic gneiss and four samples of Aston quartzite were processed for heavy minerals, in order to supplement the work of the earlier authors. The location of these samples is given at the foot of Table VII.

Zircon is common in the basement rocks, and is also fairly common in the Aston quartzites which were derived from them. Some typical zircons from the Aston are illustrated in fig. 39. It will be seen that they differ very little in internal character (zoning, inclusions etc.) and external form (roundness, fracturing) from those of the Peel Sound Formation, illustrated in fig. 38. The only difference is the presence of secondary overgrowths on a few of the Aston zircons, a feature which has nowhere been

Table VII. Heavy mineral suites in Peel Sound source rocks

AUTHOR	ROCK TYPE	HEAVY MINS.	ABUN- DANCE
Blackadar 1967	Mafic gneisses	zircon apatite sphene garnet sillimanite cordierite	c c c c r r
	Felsic gneisses	garnet* cordierite sillimanite	c r r
	Granite	apatite biotite magnetite zircon	c c r r
	Quartz diorite	apatite magnetite biotite zircon	c c c r
	Quartz monzonite	zircon apatite magnetite	r r r
	ultrabasics	magnetite spinel	
Tuke et al 1966	Aston Qtzites	zircon	r
Miall: present study	Aston Qtzite 1.	zircon	r
	Aston Qtzite 2.	zircon	r
	Aston Qtzite 3,4	zircon tourmaline rutile	c c r

*Also rutile common (Miall: present study)

Location of Miall samples:

Felsic gneiss - cobble in P.S.F., northern Pres. I.
 Aston Qtzite 1. - cobble in P.S.F., northern Pres. I.
 Aston Qtzite 2. - Aston outcrop, Pandora I.
 Aston Qtzite 3. - Aston outcrop, Aston Bay.
 Aston Qtzite 4. - Aston outcrop, Aston Bay

r = rare or traces
 c = common

found in the Peel Sound.

Well rounded zircons are characteristic of very mature, polycyclic sediments. Tuke *et al.* (1966, p.707-708) believe that the Aston Formation was formed by 'prolonged sedimentary reworking' during a 'long transport history'. The observed secondary growths are probably of diagenetic origin. The zircons in the Peel Sound were probably derived largely from the Aston, for the Peel Sound sandstones are very immature whereas the zircon grains present point, as in the Aston, to a long transport history. Abrasion of these derived grains may have been sufficient to remove secondary overgrowths.

Blackadar (1967, p.38) states that most of the Boothia metamorphics are probably of sedimentary origin. The zircon recorded from them may thus be of secondary origin itself. No zircons from these rocks have been seen by the present author, and so the question of a deeper level source for this mineral cannot be entered into here. The evidence that would be most relevant is that of the external form, whether the grains are well rounded or rich in secondary overgrowths.

Rutile and tourmaline have not previously been recorded from the basement rocks or from the Aston quartzites. However, in the felsic gneiss sample and the two quartzite samples from Aston Bay, many small rutile grains were

found. Likewise, tourmaline was seen to be quite common in the Aston quartzites. The varieties of both minerals were found to be closely comparable to those in the Peel Sound sandstones. The rutiles are dark brown and faintly pleochroic, occurring in small, well rounded or shapeless grains. The tourmalines are generally poorly rounded, prismatic crystals, pleochroic from dark green to brown, or from very pale green to pale pink. These two minerals were probably derived from both the metamorphics and the Aston quartzites, but the fact that tourmaline has not yet been recorded from the basement complex may indicate a tourmaline-rich source that has, since the Devonian (or possibly since earliest Paleozoic times) been covered by sediments or destroyed by erosion.

No other heavy minerals have yet been identified from the Aston Formation. The garnet, biotite, magnetite and apatite found in the Peel Sound sandstones may thus have been derived entirely from the basement complex. As seen in table VII, all four have been recorded by Blackadar (1967) from these rocks. Garnet is the only member of the Peel Sound suites to have been found in all samples studied. It is, in fact, very common in the basement gneisses and is present in abundance in many of the derived metamorphic pebbles and cobbles of the Conglomerate Facies.

Depositional environment: General Statement

The rocks of the Sandstone Facies should be considered as part of the depositional continuum, which commences with coarse alluvial fan conglomerates and ends with marine silts and shales intertonguing with carbonate beds. By considering the position of this facies in the continuum, which demonstrates a gradually decreasing depositional energy level, much may be deduced concerning the conditions under which these rocks were formed. Immediately to the east alluvial fans graded into low-sinuosity braided streams; immediately to the west, as was described briefly in the section on stratigraphy, the influence of the sea was present.

Several general characteristics indicate the transitional nature of this facies:-

- 1) The predominance of arenaceous rocks over finer and coarser lithologies. Mudstones and siltstones are minor constituents; conglomerates, except for those described below, are confined to the eastern margin of the facies.
- 2) The wide distribution of the intraformational mudflake conglomerate, which is a highly distinctive lithology of the Sandstone Facies, and is not found in either of the bordering facies. The presence of this lithology suggests that conditions occasionally became quiet enough for thin mud seams to be deposited (in contrast to the Conglomerate-

Sandstone Facies), but that normally these were broken up and transported as intraclasts (in contrast to the Sandstone-Carbonate Facies), and that conditions were not usually turbulent enough to completely disaggregate the mud fragments and transport them out of the area.

3) The presence of planar crossbedding, particularly the 'alpha' type (Allen, 1963, p.101) which according to Allen (1963) and Moody Stuart (1966) results from lateral migration of bars and spits, and characteristically forms in a high sinuosity stream environment as river meanders migrate across their flood plains. The presence or absence of alpha crossbedding may therefore be used as one of several criteria for distinguishing the deposits of high and low sinuosity streams. It is absent in the Conglomerate-Sandstone Facies to the east, which was interpreted as a deposit of low sinuosity streams.

Fluvial model:

In general terms the depositional environment probably corresponded fairly closely to the high sinuosity stream model described by Moody Stuart (1966). The change from low to high sinuosity as the streams flowed westward from the Conglomerate-Sandstone Facies is similar to the change that may be observed in many modern rivers as they approach base level. The fluvial model described by Visher (1965, the fining-upward cycle, discussed under Conglomerate-

Sandstone Facies) is less appropriate here. A model is proposed which combines elements of Allen's braided stream and high sinuosity stream models (1965b, fig. 35, discussed in previous chapter). The Peel Sound sandstones show similarities to his type B sandstones (alternations of fine and coarse sandstones with large and small scale crossbeds) in the Upper Old Red Sandstone of Wales (Allen, 1965c), in contrast to the sediments of the Peel Sound Conglomerate-Sandstone Facies which compare well with his type A beds (sandstones and conglomerates with mainly large scale channel forms) in the same area. The predominance of trough and planar crossbedding over other structures compares closely with the descriptions of flood plain deposits by Lane (1963, modern point bar deposits) and Williams (1966, Precambrian fluvial sediments).

Davies (1966, Mississippi point bar deposits) showed that channel and bar deposits need not necessarily be characterised by large scale cross stratification. Small scale structures such as ripple drift crossbedding and load structures may be much more typical. However, Davies was working in fine grained deposits, chiefly fine sands and silts, reflecting a lower energy level of deposition. They compare more closely with the red sandstone members of the Peel Sound Sandstone-Carbonate Transition Facies, which are typically fine grained sandstones and siltstones showing small scale current structures.

Horizontally bedded sandstones:

Much of the sandstone in this facies is flat bedded. Many of the outcrops from which such structures as planar and trough crossbedding have been recorded show only a few such structures in tens of feet of sandstone. Occasionally a very close examination of an exposed rock face may reveal faint indications of crossbedding within an apparently tabular-bedded horizon, but this is not common. Weathering characteristics may be partly responsible for obscuring some of the sedimentary detail, as will be discussed below, but the apparent lack of directional structures may have a more fundamental cause.

McKee, Crosby, and Berryhill (1967) describe a flood deposit in Bijou Creek, Colorado which accumulated in a few hours following a catastrophic flood. It filled the flood plain to a width of up to half a mile (800m) and a thickness of from two to twelve feet (60-360cm). 90-95% of these deposits (coarse to fine sand) showed horizontal layering, whereas festoon crossbedding, ripple - drift cross-stratification and convolute bedding were formed during waning stages of the flood or in local, sheltered areas. The predominance of horizontal bedding was attributed to formation under conditions of upper regime, planar-bed flow.

The Bijou Creek deposit was formed during a catastrophic flood, but planar-bed flow conditions may be reached locally during the processes of quieter, more normal fluvial sedimentation. Rust (1968, personal communication) has noted channel bars in a braided stream (Donjek River, Yukon) which consist largely of horizontal finely laminated sands. Upper flow conditions are reached on shallow areas of these bars, and grade upstream and downstream into deeper areas where lower regime ripple bedforms predominate. Much of the Peel Sound sandstones may be accounted for in this way, but the widespread occurrence of planar beds and their comparatively large lateral extension - generally extending unchanged for 50 feet (15m) or more, across the visible width of an outcrop, suggests a more important cause than local rapid flow over channel bars, at least for some of these deposits.

Occasional catastrophic floods similar to the one that formed the Bijou Creek deposits may have occurred in the area of the Peel Sound Sandstone Facies. These may not be related to the debris floods that accumulated the rocks of the Conglomerate Facies. Debris floods tend to degenerate into stream floods or even into quiet stream flow as they deposit their load by filtering through the porous surface sediment (the 'sieving' action described by Hooke, 1967). The resulting slower, steadier flow may have

supplied part of the water that deposited the typical fluvial sediments of the Sandstone and Conglomerate-Sandstone Facies of the Peel Sound Formation.

Other floods, with low sediment:water ratio, may have originated in two ways:

- 1) Following times of considerable debris-flood activity, when the sediment supply in the source region (The Boothia Uplift landmass) was depleted. The formation of debris floods requires large masses of loose sediment that are accumulated slowly by long periods of mechanical weathering. As discussed in the section on conglomerates, the climate of the times may have been humid, and there was no vegetation to restrict the rate of run-off. There exists the possibility, therefore, that not infrequently large masses of water may have descended from the Boothia Uplift area bearing a small sediment load. Such floods would have had a powerful scouring and reworking action. They would have contributed to the mixing and dispersal of different clast types on the alluvial fan surface, and they may have been responsible for reworking and redepositing much of the fluvial sand material in the Conglomerate-Sandstone and the Sandstone Facies. Under these conditions, deposition from a planar-bed, upper flow regime, might well be expected.
- 2) Late in the history of Peel Sound times the source area may have been reduced to such a low level by erosion that

even though the rainfall continued unchanged the stream slopes became insufficient to initiate debris floods. Sudden floods forming at this time would have had a reduced rate of flow, but they would still tend more towards scouring and reworking than towards deposition, in their upper reaches.

There is some evidence for a reduction in source relief:

- a) The increased roundness and sphericity of conglomerate clasts at high levels of the Bellot Cliff section, loc. 31;
 - b) The upward decrease in the proportion of conglomerate in the Conglomerate-Sandstone Transition sections 25 and 29.
- If the planar bedded sandstones of the Sandstone Facies reflect more than just a local development of upper regime flow conditions in a normal, fluvial environment - as their abundance and lateral extent suggests - then it seems necessary to postulate a reworked origin for the sand grade material. The Bijou Creek flood (McKee *et al.*, 1967) deposited only sand sized sediment, but the flood-waters had sufficient power to destroy highways and to carry a 36 foot (11m) steel beam a distance of 1100 feet (330m). The deposits of this flood thus reflect the fine-grained nature of the sediment available at the time, rather than a low competency of the transporting medium. The floods of Peel Sound times may not have been as violent as this,

but there remains the fact that clasts from pebble to boulder in size were superabundant a few miles to the east, at this time, and yet conglomerate horizons wedge out westwards, and are completely absent from the larger part of the Sandstone Facies. There are only a few pebbly sandstones, in which the pebbles comprise less than 10% of the total rock.

It is suggested that the ephemeral nature of the floods may account for the fact that although much material may have been re-eroded and re-transported, none of it was carried any great distance. This would apply particularly to the larger clasts, whereas sand sized material could have been maintained in a state of near-suspension over much longer distances. Conglomerate layers as far west as the Conglomerate-Sandstone Transition Facies were covered by fluvial sandstones accumulated largely by lateral accretion, and were therefore removed from the zone of active reworking.

Origin of red colouration

The sandstones studied in detail contain between 17 and 31% weathered grains, thought to consist mainly of the limonite-rich weathering products of ferromagnesian minerals (grains of the rock-fragment class). In addition, some of the matrix, and some coatings on quartz grains show the same reddish-brown iron-oxide colouration. Van Houten (1961, p.89-139) states that "the ferric oxide in

most redbeds probably originated in red upland soils developed in a tropical or sub-tropical climate", though he also adds that in the absence of well developed land floras somewhat different conditions may have been obtained during weathering and erosion and at the place of deposition.

Van Houten (1961) emphasises the necessity for oxidizing conditions during deposition for preservation of iron in the ferric state. Walker (1967) investigated some recent alluvium in the hot, semiarid regions of Baja, California. He arrives at the same conclusion but adds that red colouration may develop by post-depositional weathering of fresh alluvial material, because of an in-place breakdown of iron-rich minerals such as biotite and hornblende. In the case of the Californian alluvium a non-red surface colouration was shown to change to a typically red, iron-stained appearance a short distance below the surface. These deposits were thus neither residual nor derived laterites.

In the case of the Peel Sound sandstones the important points seem to be that:

- a) Freshly deposited fluvial sands would have a high permeability, thus allowing rapid drainage and a maintenance of oxidizing conditions.
- b) The lack of abundant decaying organic matter would have the same effect.
- c) The climate of the times may have been both hot and

humid, so that chemical weathering would have been particularly rapid, at the point of origin of the sediment and during its subsequent deposition.

Further to the west, in the Sandstone-Carbonate Transition Facies, many of the clastic beds, particularly those of finer grain size, show red and green mottling, or even a complete predominance of a green or grey colour. This may be explained by the presence of organic material (sparse fossil remains found) and by an approach to base level, which would bring the water table much nearer the surface. Both these features would have tended to tip the balance in favour of reducing conditions.

Scarcity of sedimentary structures

Much of the sandstone, as described above, is made up of tabular bedding, in which lamination is poorly defined or absent. It is suggested that various weathering effects may have been partly responsible for obscuring some of the detail of sedimentary structures.

Arctic weathering processes are characterised by deep freeze-thaw shattering and by a very low rainfall (as distinct from snow fall). In humid regions the washing and etching effect of rain is of some importance in emphasising the minute compositional or grain size differences of laminated sediments; but this effect is almost completely

lacking in the Arctic. This lack may be of only minor importance, for other clastic sediments in the area, eg. the basal quartzose sandstones of the Peel Sound Formation, and Tertiary-Cretaceous sandstones comprising the Idlorak Formation on Somerset Island (Dineley and Rust, 1968), show clearly visible current structures. In both cases there are well defined laminae, formed by compositional variations. In the Idlorak Formation there are scattered biotite flakes and carbonized plant fragments (op. cit., p.794).

The Peel Sound sandstones often appear to lack such compositional variations. Thin section examination shows there is sometimes a crude grain-size layering, but colour banding is uncommon. Percolation of iron oxides during diagenesis or weathering could partly account for obscuring the colour layering, particularly as the climate of the times may have been humid and groundwater abundant. However, colour variations normally represent compositional variations, such as concentrations of heavy minerals, and thin section analysis has shown that this is not common in the coarse Peel Sound sandstones.

It must be concluded, therefore, that diagenetic or recent weathering changes can have had only a limited effect in obscuring sedimentary structures. Primary causes were largely responsible for their observed scarcity, notably the widespread occurrence of floods, depositing

sediment rapidly on planar beds with little time for size or density sorting.

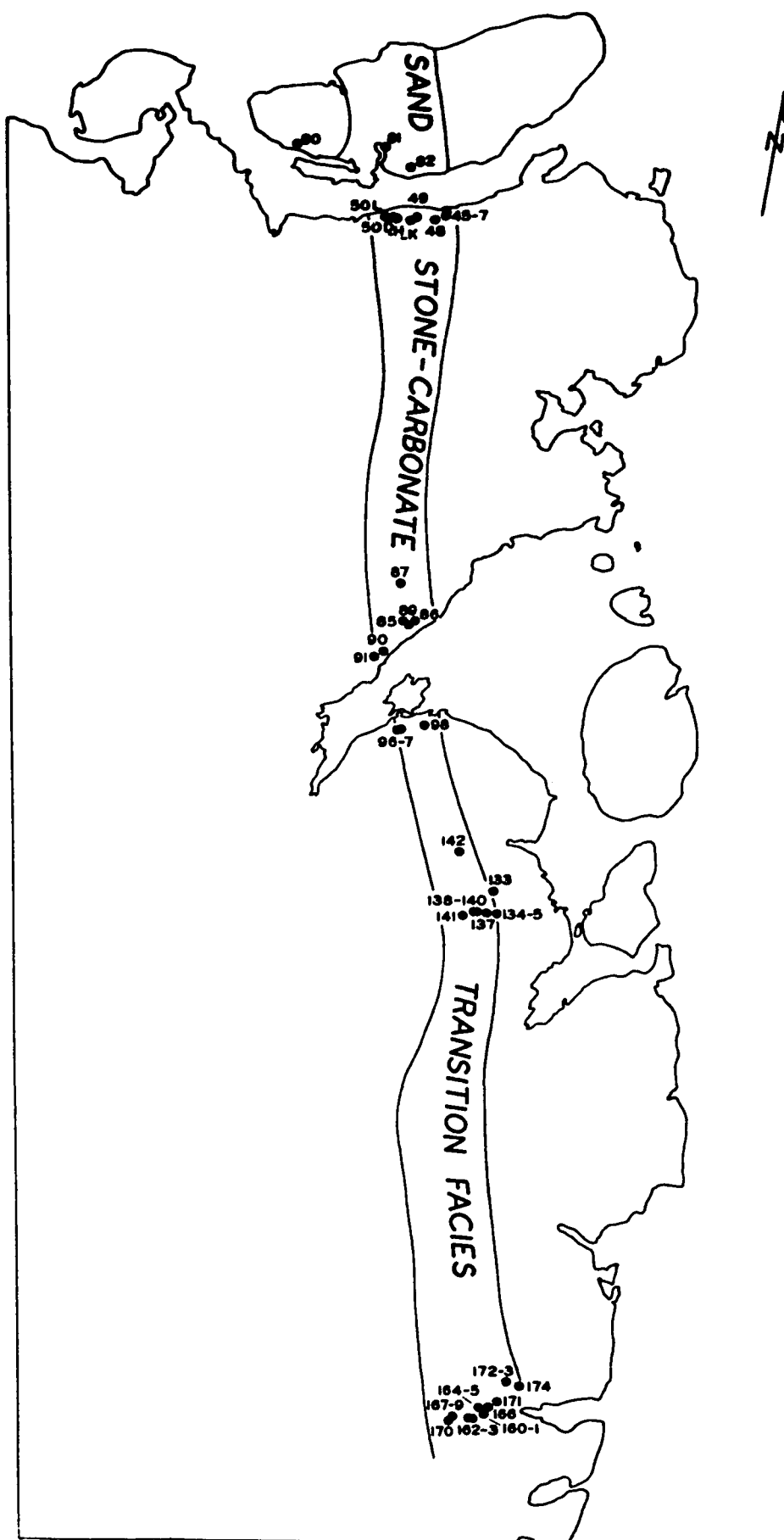


Fig. 40. Location map: Sandstone-Carbonate Facies outcrops

6. SANDSTONE-CARBONATE FACIES

a) Introduction

The Sandstone-Carbonate Transition Facies is defined on the map as the area between the western limit of redbeds and the eastern limit of carbonates. These boundaries enclose a belt of country between 5 and 10 miles (8-16km) wide, extending from central Russell Island to the head of Transition Bay.

The facies was studied in four areas: Baring Channel, Browne Bay, Muskox Hill and Transition Bay. Fig. 40 shows the facies limits and the distribution of outcrops visited. In the country between these four areas exposure is rather poor, because of the lack of large stream gorges. Information gathered from the four groups of exposures is summarised in table VIII, measured sections are described in Appendix II and typical vertical sections are illustrated in fig. 41.

Very little order was discovered in the areal distribution of redbeds. Paleogeographic considerations would suggest that the redbeds should show a decrease in importance to the west, but this has only been seen at Baring Channel and Browne Bay (see table VIII). At Muskox Hill (see loc. 141, table VIII) and at Transition Bay (see loc. 170) red clastics form a large proportion

Table VIII. Summary of lithologies, sedimentary structures

and for

Loc. no.	grid ref.	redbeds (fluvial)		'grey beds' (marginal marine)				'grey marine margin marine eviden	
		siltst. & fine ss	sh	grey, grn.ss siltst.	gry grn sh.	carb /sh.	carb	ss	sl
80	NS952965	FE							
81	NS090986	x							
50(L)	NS120870			FO			0	x	x
50(D)	NS128871			FO					
50(H)	NS131872			FO s		0			
82	NS155870	F m	s	rl	c		PGV		
50(K)	NS166872	FE ls	x	FVBL l	c			x	x
49	NS172878	x						x	
48	NS204874	x							
47	NS213878	s							
46	NS217891	trs		GPL					
45	NS218883	F lr		l			GPL		
91	NS238128								
96	NS308000								
97	NS314003							x	
90	NS250143	x	x	F ptm		0		x	
98	NS344015	pm		F t					
85	NS279196	F m				GO		x	x
89	NS291192	x		l		FPL			x
86	NS298200								
87	NS266254	m							
142	NR443832			t	VFP	F			
141	NR469722	F m	x	m					x
140	NR487736	m		L		0			
139	NR495737	F m	x	F		P		x	
138	NR497738	F m		F m					
137	NR512738	x	x	F		OGP		x	
134-5	NR530739	F mp trls	x	FPL mt				x	x
133	NR515784	F ts		F m					x
170	NQ622904	x						x	
169	NQ622913	mp							
168	NQ630915			t					
167	NQ634917	mp							
163	NQ657916			VF r			FO	x	x
162	NQ663918	t		F		0 i		x	x
164-5	NQ669937	p				OG		x	
161	NQ675922	p		FBOL					
160	NQ682931								
166	NQ684943							x	
171	NQ697950			GV r			GBV	x	
172	NQ706986	x		r					
173	NQ712990			P					
174	NQ723986	x		F pd				x	

fossil content of Ss/Carb. transition beds

ey beds' ine or ginal ine (no dence)			marine			
sh	c/ sh	c	grey ss.	sh	carb/sh	carb
x		x	FBA			OA
		x				CAF
x		x				C
	i					VON
	i				OGN	
x	x				ON	
					OGC	
x	x	x				
x						
x						
	x				FOGNA rd	
x				C		
x					AO	
		x				GNA
		x				
	i					
	x					

LEGEND

Lithology present,
no fossils or sed structs.
= x

Fossils (Capital letters)

plants - - - - - V
fish - - - - - F
eurypterids - - - - - E
borings - - - - - B
ostracods - - - - - O
gastropods - - - - - G
pelecypods - - - - - P
nautiloids - - - - - N
colonial corals - - - - - C
art. brachiopods - - - - - A
Inart. b. (*Lingula*) - - - - - L
Indet. debris - - - - - i

Sed. structures
(small letters)

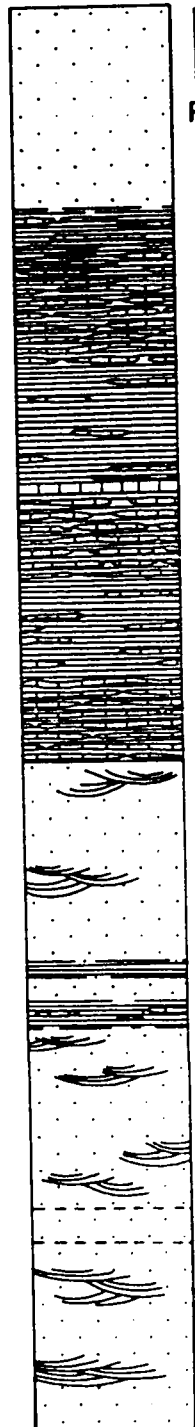
Mudflake cong. - - - m
planar C.B. - - - p
trough C.B. - - - t
ripples - - - - - r
primary current
 lineation - - - - - l
sole structures - - - s
salt casts - - - - - c
desiccation cracks - d

Distribution of localities

Group 1. - Baring Channel
Group 2. - Browne Bay
Group 3. - Muskox Hill
Group 4. - Transition Bay

Within each of the four
groups, localities are
arranged in descending
order from west to east.

Loc. 90
Browne Bay



Loc. 134-5
Muskox Hill

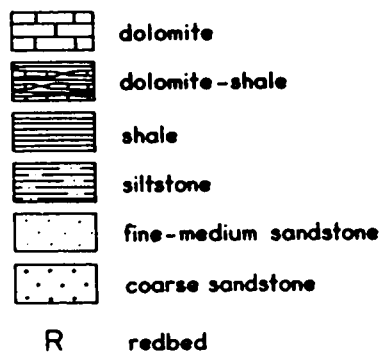
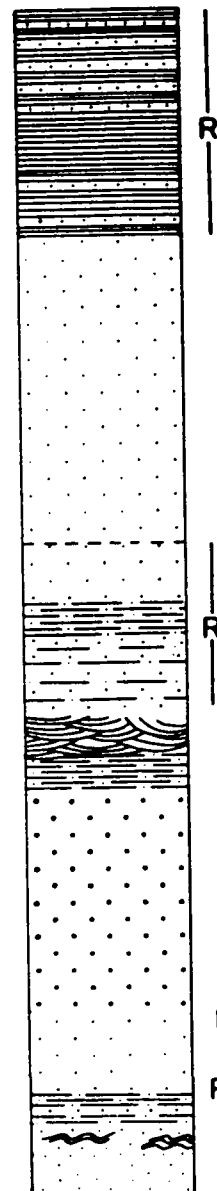


Fig. 41. Typical vertical sections in the Sandstone-Carbonate Facies

of the exposed rocks as far to the west as traverses have yet been carried. It is, of course, not valid to assess at any given point the total proportions of a given lithology in a formation from only a few tens of feet of vertical section. The western limit of the Sandstone-Carbonate Facies south of Browne Bay may, therefore, be much further to the west than has been shown on the map, fig. 40. For this part of the outcrop the map should be regarded as showing a minimum width of the facies belt.

b) Lithologic characteristics (Lithofacies)

Red sandstones, siltstones and shales form a conspicuous part of many sections throughout this facies. Red members are generally between 6 and 20 feet (1.8-6.0m) in thickness; the thicker members may include several horizons of different grain size. Coarse sandstones are uncommon in the redbeds of the Sandstone-Carbonate Facies.

The detailed petrography of the red sandstones will not be discussed here, for these rocks are identical to the red sandstones of the Sandstone Facies, which are described in a previous section.

In the Sandstone-Carbonate Facies every gradation in colour has been observed, from bright red to grey or white. Pink or buff coloured sandstones are common.

Siltstones show the same range of colours; shales may be red, green, mottled red and green, or grey. Colour is generally fairly constant in each bed within the limits of the outcrop. Mudflake conglomerates in the redbeds show the same colour variations. In some cases the flakes of mud or shale are green in colour, suggested that the iron staining has been reduced to the green, ferrous state.

The colour variations depend on the presence or absence of iron oxides, and the oxidation state of the iron, if present. In contrast to the red sandstones, pink and buff coloured sandstones show a lower proportion of iron-stained quartz grains and of weathered grains. There are other petrographic variations between the grey and coloured sandstones which indicate differences in the mode of deposition (discussed below), though the source of the clastic material of all these sandstones is thought to be the Boothia Uplift.

Grey sandstones are generally clean-washed, consisting of quartz and dolomite grains with an absence of any iron colouration from iron containing minerals or grain coatings. Thin sections of the grey sandstones show that the majority of the quartz grains are very well rounded. Few show any authigenic growth. There is generally no true grain framework, for sand-grade dolomite

grains (identified by staining, Warne 1962 method) form at least 50% of the total volume. Many are original detrital grains or intraclasts - they preserve the rounded detrital outline and are 'dirty', containing scattered dark inclusions, probably of clay. There are occasional isolated grains or patches of grains showing clean dolomite, often in an interlocking crystal texture, indicating diagenetic recrystallisation. Fossil debris, chiefly ostracods and gastropods, is common but is usually recrystallised to dolomite, with a consequent loss of structural detail. Plagioclase feldspar grains comprise less than 1% of the grey sandstones. Rare pebbles of quartz and chert up to 0.5 inches (1.2cm) are present, as are intraclasts of silty material, sand-sized grains of chert, rutile, and clay (see photograph 30 which is a photomicrograph of a typical grey sandstone).

Green and mottled shales are not common. Grey shale with or without interbedded carbonates is an important lithology. Most of the grey shales are medium to dark in colour; a few black shales and a few grey-green shales have been noted. Carbonate interbeds are mainly dolomite. A wide range of dolomite shale ratios is present, from rare, scattered argillaceous nodules in shale beds to a repetitive dolomite-shale rhythm, to massive dolomite beds with shaly wisps and streaks. The lateral extent

of the carbonate beds is correspondingly variable. Small nodules are typically disc shaped and approximately 3 inches (8cm) in diameter. The dolomite shale rhythm consists of units 0.25 to 1.50 inches (0.5-4.0cm) thick which extend laterally for a few inches to tens of feet. Bedding is often nodular or undulatory; this is thought to be a compaction effect. In a single vertical section dolomites vary markedly in importance. A grey shale may grade into a dolomite-shale rhythm - a very common occurrence, and the latter may itself pass vertically into massive carbonates with little argillaceous material. The rhythmic members are rarely more than 10 feet (3m) thick; massive carbonates may reach twice this thickness.

Carbonate beds are mainly fossiliferous dolsparrites and dolmicrites (classification of Folk, 1959, 1968). Some dolmicrites contain shell debris composed of calcite, eg. at loc. 94, see photograph 33. In this example the fibrous shell structure is visible, demonstrating a lack of recrystallisation. Some of the bivalve shells, such as ostracods, contain coarse, sparry calcite formed during diagenesis.

The dolsparrites consist of dolomite mosaic with an average grain size rarely smaller than 0.05mm. This texture, according to Folk, (1968, p.170) indicates a replacement origin for the dolomite. Shelly fossil debris

is abundant and is commonly dolomitised and recrystallised so that the outlines have become blurred.

Some of the carbonate rocks show a very variable grain size, demonstrating a partial recrystallisation. When stained they show a speckled colouration, indicating the presence of both calcite (red patches) and dolomite (unstained). Selective dolomitisation may have taken place in some cases. Fine grained material will be replaced before sparry grains - thus shell debris may remain as calcite whereas the fine grained matrix in which they are enclosed may have been completely dolomitised. In other cases pseudobreccia texture may have developed (Bathurst, 1959) resulting from patchy replacement of calcite by dolomite or patchy recrystallisation.

Other textural elements include pellets and intra-clasts. Oolites have nowhere been observed. Some beds contain extensive Chondrites - like borings. Quartz grains of silt or very fine sand grade are almost invariably present in these rocks. Where abundant, they are usually concentrated into clastic streaks and wisps containing small quantities of argillaceous or bituminous material. Most of the dolomites have a bituminous smell when freshly fractured.

c) Sedimentary structures

Structures in the redbeds are similar to those observed in the Sandstone Facies. Little overall difference was observed between the structures of the red sandstones and those of the grey sandstones, except that mudflake conglomerates and planar crossbeds seem to be slightly more common in the former. Trough and planar crossbeds are less abundant in the redbeds of the Sandstone-Carbonate Facies than in those of the Sandstone Facies. Those observed are of a comparatively small size, eg. at loc. 133 (illustrated in photograph 22) there is a trough 0.5 inches deep and 5 inches wide (1.3 by 13.0cm). The largest size recorded is 6 inches by 2 feet (15 by 60cm) at locs. 90 and 162. No major channels have been observed, nor any laterally extensive planar cross-sets. Planar cross-sets one inch thick at loc. 161, and 5 inches thick at loc. 174 (both at Transition Bay) are typical.

Ripples have been observed at seven localities in the red and grey sandstones. Symmetric and asymmetric ripples and ripple-drift crossbedding have been noted. In addition, many of the carbonate rocks show small-scale ripple structures one inch or less in wavelength. They are emphasised by the presence of thin and impersistent fine clastic layers.

Primary current lineation has also been observed at seven localities, usually in association with ripple marks and sole structures.

Sole structures are most abundant in redbeds, where sandstone layers are underlain by thin mud seams. They include groove casts and small load casts (see photographs 20 and 21). The trends of the groove casts are generally within a 20° arc on any given bed. A small trough was observed which contained a number of unusual tool marks arranged approximately parallel to the trough axis (see photograph 22). The casts of the structures consist of groups of 5 to 9 short ridges, 0.5 inches (1.3cm) long, arranged side by side and parallel to one another. It is thought that they may represent the marks left by transverse movements of the fins or tails of fish swimming or drifting with the current. Only one example of these structures has been observed.

Salt casts have been observed only at two Baring Channel localities (see photograph 23). They are the cubic, hopper shaped variety, developed from halite crystals, and are nowhere more than 0.5 inches across.

Desiccation cracks are rare.

d) Organic remains

In this chapter organic remains are discussed only for

the evidence they contribute towards an understanding of environmental conditions at the time of deposition. Many of the fossil groups present tolerated a wide variety of conditions and it is often only by consideration of whole assemblages and their lithologic associations that conclusions may be drawn concerning detailed paleoecology. The faunal and lithologic associations are summarised in table VIII and are described below; interpretation is deferred to a later section. The age of the fossils is discussed in Appendix I.

Plant remains have not been found in the redbeds, but they are present in all the grey lithologies. They are usually very poorly preserved, consisting of dark grey or greenish-grey streaks on bedding planes; they probably represent roots or stems of swamp plants.

Vertebrate remains are widespread, having been found at 22 of the 43 localities visited during the present study, and in all lithologies except red shales. With two exceptions they are the only organic remains to be found in the redbeds. In other lithologies they are associated with fossils of marine and ?estuarine origin. Vertebrates are most abundant and best preserved in pink, buff and grey coloured fine sandstones and siltstones. The remains vary widely in their state of preservation, from comminuted, unrecognisable debris (usually in the

coarse sandstones) to complete carapaces. Where fish remains are well preserved they are in places so abundant that the carapaces overlap each other in an imbricate structure. The direction of stacking is thought to be related to local current directions.

It is not intended to discuss vertebrate remains in any detail as the material is being intensively studied by other members of the University of Ottawa Group (see Broad *et al.*, 1968, and Broad 1968). Broad (1968, p.22-24) has identified the following groups from large collections made on the south side of Baring Channel: ctenaspids, pteraspids, cephalaspids, arthrodires, placoderms and crossopterygians. Ostracoderms were collected from the Browne Bay localities. Cyathaspids and traquairaspids were identified from the Muskox Hill area and the same two groups plus the genus *Corvaspis* have been identified in material from Transition Bay.

The only other fossil remains found in the redbeds are eurypterids (identified by D. L. Dineley, personal communication, 1967). Fragmentary material was collected from two Baring Channel localities. In both cases the enclosing lithology is a pink, silty sandstone.

Chondrites type borings have been found at four localities, three of these in grey sandstone. They are generally restricted to well defined beds within each outcrop.

Ostracods are extremely abundant. They are found in all the grey lithologies, and are most common in the rhythmic shale-carbonate beds. Bedding planes packed with ostracods have been found in the dolomites and dolomitic siltstones and shales. Small ostracods 1mm or less in diameter are scattered throughout the finer grained rocks and may only become obvious in hand specimen by staining, which renders their calcite infill a bright red. Generic or specific identification of ostracods is rarely possible, because of the state of preservation. Bolton and Copeland (Unpublished Geol. Surv. Canada reports S&D-1-1968-TEB and MP-2-68-MC) have identified the majority of the better preserved ostracods as leperditids. *Herrmannina* sp. is tentatively identified in Baring Channel material (G.S.C. locs. 82754, 82755) and *Leperditia gibbera* Jones is found in material from west of Transition Bay (G.S.C. loc. 82758).

Pelecypods and gastropods are most common in the fine grained clastics and the carbonates. A few shell beds have been noted, consisting of many closely packed pelecypod shells, probably all of the same species. Generic identification within the two groups is possible in a few cases: a high spired gastropod identified as *Hormotoma* sp. has been found at Browne Bay (G.S.C. loc 82462), Muskox Hill (82464) and Transition Bay (82466).

Redbeds at Baring Channel contain the pelecypods *Megambonia* sp. and *Modiomorpha* or *Modiolopsis* (82480).

Isolated specimens of *Lingula* sp. are found in the carbonates, shales and grey and cream coloured sandstones.

Fossils of known marine origin include orthoconic nautiloids, compound corals and articulate brachiopods. No trilobites have been found within this facies zone, though they are quite abundant immediately to the west. Marine fossils have been found mainly in the dolomites and the grey shales. One articulate brachiopod locality has been noted in the grey sandstones at Baring Channel.

Bolton (*op. cit.*) has made the following identifications of marine forms: Baring Channel collections (G.S.C. locs. 82475-82484): *Halysites* sp., *Favosites* sp., *Prismatophyllum* sp., *Thecostegites* sp., *Alveolites* sp., and *Stegerhynchus* sp. From Muskox Hill (G.S.C. loc 82485): an atrypid brachiopod. From Transition Bay (G.S.C. locs. 82457-82460, 82466, 82478): *Prismatophyllum* sp., *Thecostegites* sp. ("Somewhat like *T.compactus* Dubatolov"), "*Cyathophyllum*" and an *Atrypella* type brachiopod.

In many sections marine fossils are associated with ostracods. Less frequently fish remains and small gastropods are found in marine rocks.

e) Analysis of vertical sections

A large number of lithologic types is found in the Sandstone-Carbonate Facies, and a considerable variation in the vertical sequence of lithologies may be seen in exposed sections (see measured sections, Appendix II). Analysis of vertical sections is here attempted in order to determine if there is a rhythmic or cyclic element present in the succession of rock types.

The presence of rhythmic sequences would be of considerable use in determining the geological history of the facies, for it would indicate that some overriding process or processes were responsible for controlling the geological evolution - in the Peel Sound Conglomerate-Sandstone Facies, for example, cyclic deposits can be related to the process of fluvial channel migration. The absence of rhythmic successions indicates a much more complex geological history, and one that is correspondingly more difficult to interpret.

On a small scale the dolomite-shale alternations are an obvious example of rhythmic deposits. However, these are thought to be of post-depositional origin, as will be discussed in the next section.

Analysis of vertical sections in search of rhythmic sedimentation tends to be a rather subjective process. Unless there are particularly well defined units such as

the fining-upward cycles of Conglomerate-Sandstone Facies (described in a previous chapter) there is a tendency to describe a supposed ideal cycle and then allow many variations and omissions from the ideal in an attempt to find cyclicity everywhere. This psychological process has been well described by Zeller (1964). In the present study insufficient data were collected for a rigorous investigation of the problem. However, it is thought that the analysis presented in table IX allows several useful conclusions to be drawn.

Table IX shows how many times any one lithology of the Sandstone-Carbonate Facies is overlain directly by any one of the other lithologies. This is a simple Markov chain analysis, see Amorocho and Hart (1964). Information is taken from sections measured by Miall at Browne Bay, Muskox Hill and Transition Bay. (Many of the upward passages are completely gradational. In others there is a small erosional break, and in some cases exposure is not good enough for the contact to be described.) Thus, as an example, it will be seen that fine red sandstone is overlain by medium to coarse red sandstone in two instances, whereas it is never overlain by red shale. Rigid sub-division of lithologies into ten types results, sometimes, in rather arbitrary classifications. Thus grey shale, dolomite-shale and dolomite are all distinctive

Table IX: Frequency of all possible lithologic pairs in vertical sections of the Sandstone-Carbonate Facies

			upper bed	
			RED	GREY
			Coarse-m ss fine ss siltstone shale	coarse-m ss fine ss siltstone shale dol/shale dolomite
lower bed	RED	coarse-med.ss	/ 1	2 1
		fine ss	2 / 1	1
		siltstone	5 1 /	2
		shale	1 /	2 1
	GREY	coarse-med.ss	1 2	/ 1 6 4 5
		fine ss	1	/ 1
		siltstone		2 / 1
		shale	1 2	4 1 1 / 5 1
		dol/shale	2 1 1	3 2 / 1
		dolomite		2 1 3 /

lithologies, but in places they grade imperceptibly into each other. A shale with scattered dolomite nodules is classified as a shale for the purpose of the table, but if the nodules extend laterally into lenticular bodies, the unit is classified as rhythmic dolomite-shale. Lithologies are arranged in table IX in a supposedly logical order of decreasing clastic grain size, down to zero, where clastics are replaced by chemical precipitates. Redbeds are separated and placed first.

Bearing the limitations in mind, table IX nevertheless brings out some valuable points. Firstly, the distribution of figures is rather symmetrical about the diagonal line from top left to bottom right, particularly in the square representing grey beds resting on grey beds. In most cases where a high figure shows a frequent passage up from lithology A to lithology B, there is a corresponding figure on the other side of the diagonal showing a frequent upward passage from B to A. This suggests that a 121212 type of rhythm is of some significance. The frequent interbedding of shale, dolomite-shale and dolomite reflects the gradational nature of these lithologies. Another important relationship is demonstrated between beds of this group on the one hand, and the medium to coarse pale coloured sandstones on the other hand.

More complex rhythms would contain more than two

lithologies. Examples are the fining upward or coarsening upward cycles. Repeated fining upward sequences would show, ideally, a row of high figures next to the diagonal and just above it, plus one high figure in the bottom left corner representing the contact of one cyclic unit with the next above. In fact, in table IX the opposite seems to be the case. In the square representing redbed on redbed relationships there is a higher frequency of readings in the bottom left half, indicating a tendency for coarsening upwards.

On the whole, however, it will be seen that there is a rather wide scatter of readings. There are many bed on bed relationships represented by only one reading, while the high figures are nowhere very high. It is concluded that rhythmic sedimentation is not of great importance in the Sandstone-Carbonate Facies, suggesting a complex geological history. The few relationships that do appear to be significant will be discussed below.

f) Discussion

General statement

In broad terms the complex of marine, marginal-marine and fluvial sediments with their associated fossils and sedimentary structures, described above, is similar to that of some modern deltaic assemblages. The latter have been described by many authors, eg. Shepard, Phleger

and van Andel (1960): the Mississippi complex; Allen (1964b): Niger; Oomkens (1967): Rhone. The redbeds are comparable with those of the Peel Sound Sandstone Facies (described in the previous chapter), carbonate beds show similarities with those of the Carbonate Facies (described in the next chapter). The distinctive feature of the Sandstone-Carbonate Facies is the presence of rocks formed in the marginal marine environment. These are estuarine rocks, in the broad sense described by Klein (1967, p.213), who uses the term 'estuarine environment' to mean any area where fresh and salt water mix. Klein points out that this may include lagoons, tidal channels, salt marshes and certain parts of deltas, as well as river mouths.

Depositional environments: Fluvial deposits

The generalised depositional model proposed for the Sandstone-Carbonate Facies is presented in fig. 42. This should be referred to throughout the ensuing discussion.

The redbed members are of fluvial origin. They represent the most distal deposits of the streams flowing west from the Boothia Uplift, and differ from the rocks of the Sandstone Facies only in a slightly smaller average grain size and current structures of smaller scale, including ripple marks and planar crossbeds. They are interpreted as the topset deposits of deltas entering the sea, compar-

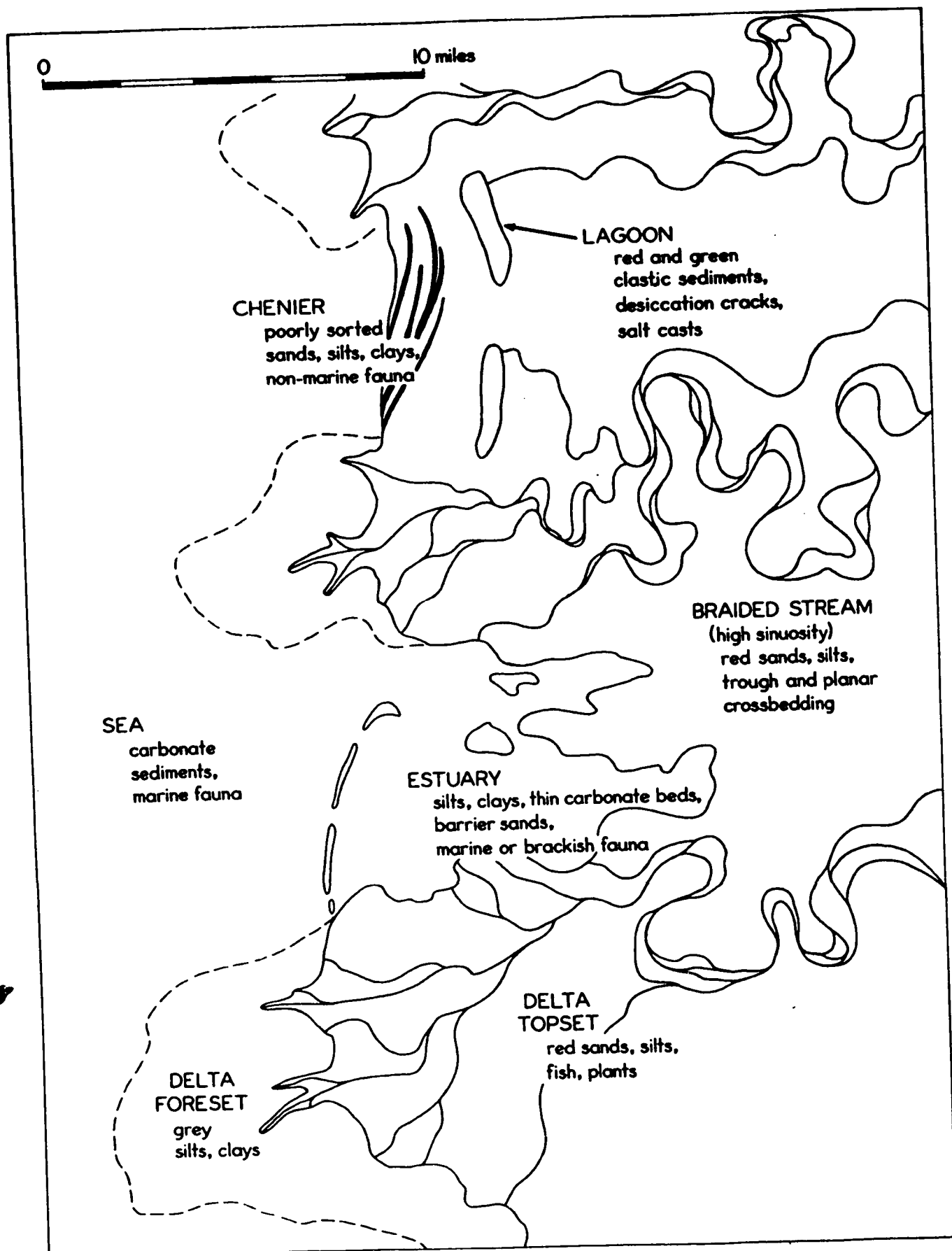


Fig. 42. Sandstone-Carbonate Facies: suggested depositional model

able with the deltaic floodplain deposits of Allen (1964b) and, to a lesser degree, with those of Oomkens (1967). They were probably deposited entirely in fresh water and were frequently exposed to the air so that oxidising conditions were maintained. The small scale of the current structures suggests shallow water and comparatively low energy. Streams were probably diverging into small distributaries and major channels were rare. The sandstones and siltstones probably represent channel deposits, shales may be overbank deposits. However, the fining-upward cycles that are characteristic of alluvial channel-fill deposits (Oomkens, 1967; Allen, 1965a) have not been found in the Sandstone-Carbonate Facies. In fact, as shown in table IX, there is a tendency towards upward coarsening. This may be due to rapid shifting of distributary channels, so that coarse channel deposits rest directly on overbank siltstones and shales and rarely pass up into the fine grained sediments representing later stage channel infills. Such rapid shifting of distributaries may be related to the scouring action of stream floods, discussed above in connection with the Sandstone Facies rocks. Alternatively, the tendency towards upward coarsening may reflect the effects of a gentle uplift. The result is a 'regressive' sequence. The process has been described by Oomkens (1967) from work in the Rhone delta area.

As described in the first part of this chapter, there is a gradation from the typical redbed lithologies through pink, buff and greenish coloured sandstones into those of grey and white colour (which have a somewhat different petrography). The rocks of intermediate colour are similar in other characters to the redbeds. They are interpreted as fluvial deposits layed down in lower wetter areas, perhaps in brackish water, where aereation was not sufficient to maintain oxidising conditions. The presence of plant debris in these rocks is significant, for decaying organic matter is an important reducing agent, and the Middle Devonian flora was probably restricted to swampy areas.

It is in the pink, buff, and greenish coloured fine sandstones and siltstones that vertebrate remains are the most abundant and the best preserved. The large collections of fossil material made at Baring Channel (Broad, Dineley, and Miall, 1968, p.89; Broad, 1968, p.22) were from these lithologies. Broad *et al* (1968, p.90) state that "the mode of preservation of the fossils suggest in almost every instance a thanatocoenose assemblage which has been transported some distance". In the Sandstone Facies and the Carbonate Facies vertebrate material is usually fragmentary, which may reflect a high energy level. Thus fish were probably able to live far upstream

in the vigorous streams of the Sandstone Facies, but on death their remains were rapidly broken up. As will be discussed below, it seems unlikely that the sea was also in a high energy state. The fish fragments in the marine carbonate rocks were probably carried into the sea by rivers. All this implies that the fresh or brackish water deltaic environment was the preferred habitat. The same conclusion was reached by Denison (1956) from a review of world wide early Devonian vertebrate occurrences. Lower Devonian Heterostraci and Osteostraci (the main groups represented) were found to occur most abundantly in rocks interpreted as fresh or brackish water in origin. The balance of evidence suggests that the Peel Sound vertebrates favoured a fresh or brackish water deltaic environment.

The presence of eurypterids (in pale pink coloured siltstones) also indicates a fresh or brackish water environment according to Størmer *et al* (1955, p.P23).

Red, green, and mottled shales occasionally contain cubic halite casts. These structures are generally taken to indicate desiccation (Shrock, 1948, p.146), but as Krynine (1950, p.165-68) has pointed out, the occurrence of scattered crystal casts cannot be taken to indicate aridity, only the existence of long, dry periods. The specimen illustrated in photograph 23 was the only example found at the locality (loc. 82, Russell I.). The shales

with halite casts are interpreted as the deposits of on-delta lakes such as abandoned distributary channels or cut-off interdistributary areas (Morgan, 1967, p.117), or of coastal lagoons, perhaps similar to, though smaller than the Laguna Madre, described by Rusnak (1960). High salinities were developed locally and the lakes were subjected to periods of desiccation.

The fluvial deposits of the deltaic environment are interbedded with deposits of marine and marginal marine origin over a zone between 5 and 10 miles (8-16km) wide. The individual deltas that formed part of the coastal complex (see fig. 42) must have been of the same order of size. The deposits they accumulated during single, uninterrupted phases of deposition reached thicknesses of up to 20 feet (6m) - the maximum observed figure. The deltas were, therefore, small compared with the best known of modern deltas. In terms of size (though in few other characteristics) they were probably comparable to the modern St. Clair delta, near Detroit.

Depositional environments: Estuarine and marine deposits

A close relationship was demonstrated above (table IX) between medium to coarse grey and white sandstones and shales and dolomites. Shales, with or without dolomite

layers, frequently pass up into sandstones, and vice versa.

In only one case has a definitely marine fauna been found in grey sandstone (see table VIII), but many of the shales contain marine fossils, such as nautiloids, compound corals and articulate brachiopods. These are often associated with fossils of uncertain habitat such as fish, ostracods, gastropods, pelecypods and *Lingula*. The fish are probably fresh or brackish water organisms (see discussion in previous section). Ostracods and *Lingula* are tolerant of a wide range of environments. In the absence of definite marine forms, therefore, rocks containing the fish-ostracod-gastropod-pelecypod-*Lingula* assemblage are interpreted as estuarine in origin.

It is thought that the grey sandstone + shale + dolomite successions represent the deposits of coastal barrier complexes, showing similar features to the modern examples described by Shepard (1960a), van Andel and Curray (1960), and Curray and Moore (1964).

In contrast to the red and pink sandstones, the grey and white Peel Sound sandstones are quite mature, texturally and mineralogically (see photograph 30). They are thought to be beach sands, and were probably derived from deltaic deposits; the iron containing minerals were removed and the quartz grains further abraded in the reworking process. Shepard (1960b, p.72) has described how Mississippi

delta deposits are reworked by the sea as soon as active deposition ceases on a section of the delta. The fine fractions are winnowed out, the immature components are broken down, and the remaining material is often redeposited as a beach or dune sand. In the case of the Peel Sound, the sands were intermixed with much primary carbonate before final deposition. The complete lack of oolitic texture in these rocks suggests that the sediments were laid down under rather low energy conditions - the process of accumulation may have been slow.

Interbedded with the supposed beach sands are shales and dolomites (see photograph 13). The shales probably represent fluvial clays, flocculated by the presence of cations in the brackish or marine waters (Postma, 1967, p.160). The carbonate lenticles and nodules are now mainly dolomite. As discussed above, in the section on lithofacies, the texture suggests a replacement origin. The original carbonate material was probably precipitated micrite. It is thought to have assumed nodular or lenticular form through post depositional compaction and chemical segregation effects. Degens (1965, p.125) states that most carbonate concretions are formed during the early stages of diagenesis. Weeks (1957) describes fish bearing concretions in a Cretaceous shale and argues that in newly formed sediments decomposing organic material releases

ammonia, which raises the pH of pore waters sufficiently for calcium carbonate precipitation to take place. In the Peel Sound shale-dolomite rhythmic sediments, shell debris is often more abundant in the dolomitic beds. The local concentrations of organic remains may have been sufficient to create small zones of preferential carbonate precipitation, shortly after deposition. The dolomite probably replaced the original calcite precipitate during diagenesis.

The shales and dolomites could represent bottom-set deltaic deposits, lagoonal deposits or sediments accumulated in interdeltic estuary areas (Morgan, 1967, p.117-118). The presence or absence of a marine fauna may be significant in this respect (though negative evidence may not be reliable). Shales and dolomites with marine fossils are possibly bottom set delta or coastal marsh deposits. Those containing only the tolerant fossil groups (Ostracods, *Lingula* etc.) may be barrier lagoon or interdeltic estuary deposits.

In detail, the mode of deposition of the shale + dolomite + sandstone assemblage is not clear. As stated above, these rocks are interpreted in a general way as the deposits of coastal barrier complexes, and most of the clastic material is probably reworked deltaic sediment. However, the method of accumulation depends on such factors as the width and depth of coastal shelves, the strength of winds

and tidal and river currents, and so on, all of which control the type of barrier complex developed and hence the shape of the resultant deposit. Knowledge of the three-dimensional geometry of the Peel Sound rocks is scanty.

The simplest situation is that described by Curray and Moore (1964) from an area on the Gulf of Mexico coast. Sand deposits develop offshore as bars and are eventually raised above sea level by a combination of low wave action and high tide. Behind the new beach an elongate lagoon is formed and this gradually fills with mud or sandy mud. If the sand bar forms at the outer edge of a wide, shallow shelf a number of sub-environments may develop, as described by Shepard (1960a). These include the beach itself, a belt of dunes, a barrier-flat marsh and the lagoon. The beach and dune deposits are sand, the marsh and lagoon deposits silt and clay. Barataria Bay, between the Mississippi and the Mississippi-Lafourche deltas, is a lagoon of this type. It is an interdeltaic estuary, protected by a chain of barrier islands (see Shepard, 1960, fig. 1, and Morgan, 1967, fig. 7). Some of the Peel Sound sediments may have been deposited in a comparable environment - see fig. 42.

However, it is thought that the energy level of the sea was probably low. A type of coastal complex that develops in areas of comparatively low energy is called

the 'chenier facies' (van Andel and Curray, 1960, p.353-354). The chenier sediments consist of 'extensive fine grained marsh and mudflat deposits alternating laterally with rather wide-spaced groups of sand bodies, many miles long but narrow and thin.' The environment develops in areas of 'moderate marine winnowing and dispersion' and results from 'periodic alternation of coastal erosion, producing winnowed sand and shell beaches, and mud flat accretion.' The sand beaches of the Gulf Coast cheniers are formed during the infrequent hurricanes that pass over the area. Many of the Peel Sound grey sediments may have accumulated in a type of chenier environment.

g) Comparisons with the Lower Peel Sound Formation

Many of the conglomerate beds in the Lower Peel Sound Formation are thought to have had a similar origin to those of the Conglomerate Facies. They are interpreted as the earliest Peel Sound alluvial fan deposits, formed soon after the initial elevation of the Boothia Uplift in late Silurian or earliest Devonian times. The fans bordered directly on the sea, as the presence of interbedded marine limestones testifies.

Among the other lithologies present in the Lower Peel Sound successions (see chapter on Lower Peel Sound Formation and Appendix II) there are several that compare

closely with marine and marginal marine sediments of the Sandstone-Carbonate Facies, indicating that similar environments were developed in a zone between the alluvial fans and the sea. Redbeds (sandstones, siltstones, and shales) are present but are not important in the Lower Peel Sound, indicating that fluvial conditions were developed on only a very localised scale.

In the Lower Peel Sound Formation there are siltstones, quartz sandstones and sandy dolomites that are identical in every way with sediments of the Sandstone-Carbonate Facies. Compare, for example, photographs 29 and 30, which are photomicrographs of two sandy dolomites. By analogy with the grey sandstones of the Sandstone-Carbonate Facies, discussed above, the Lower Peel Sound example is interpreted as a littoral deposit.

Grey shales are scarce in the Lower Peel Sound. Therefore, there were probably no extensive estuarine areas, as has been suggested for the Sandstone-Carbonate Facies. Grey shaly wisps appear in some of the carbonate horizons, their wavy cross section suggesting ripple form.

Carbonate beds are similar to some of those of the Sandstone-Carbonate Facies. Many are nodular, but the carbonate-shale rhythm has not been found. Photograph 24 shows an etched and stained specimen of one of the nodular limestones, and the staining reveals very clearly the

origin of the nodular texture. Dark areas are deep red in the original specimen. They are the stained calcium carbonate. Light areas are unstained and represent dolomite in the process of replacing the calcite. The grainy appearance of the dark areas is not a photographic effect. It is due to incipient dolomitisation, the small clusters of dolomite crystals appearing as light, unstained areas in the red calcite groundmass.

In summary, many of the environments that developed in Lower Peel Sound times along the western edge of the Boothia Uplift were present again in Upper Peel Sound times at the edge of a wide alluvial plain, 10-20 miles (16-32km) further west. There is no reason to doubt that the marginal marine environment migrated continuously westward from its position in Lower Peel Sound times, as the alluvial plain bordering the Boothia Uplift gradually widened in response to the influx of continental sediments. Thus the Sandstone-Carbonate Facies of the Upper Peel Sound Formation probably represents this same coastal zone at a later stage in time (see fig. 48).

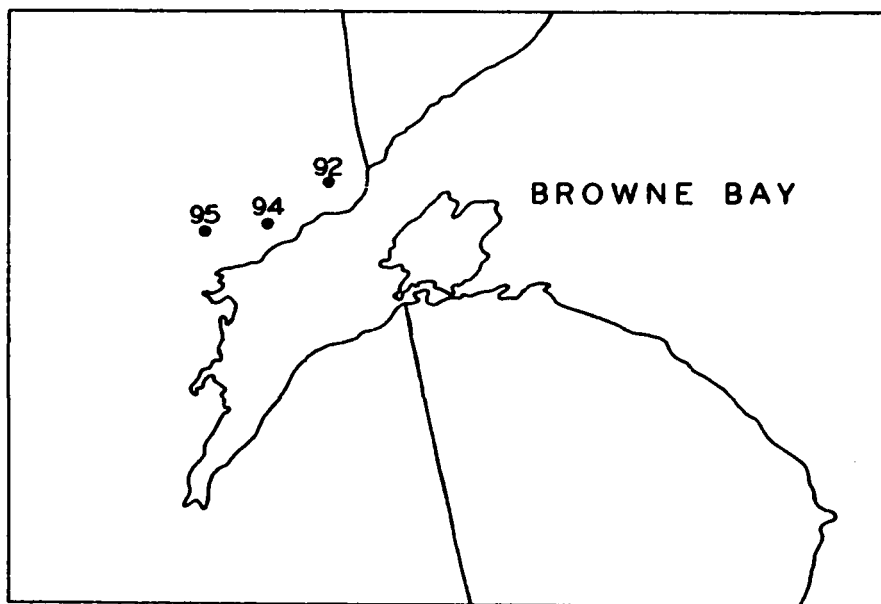
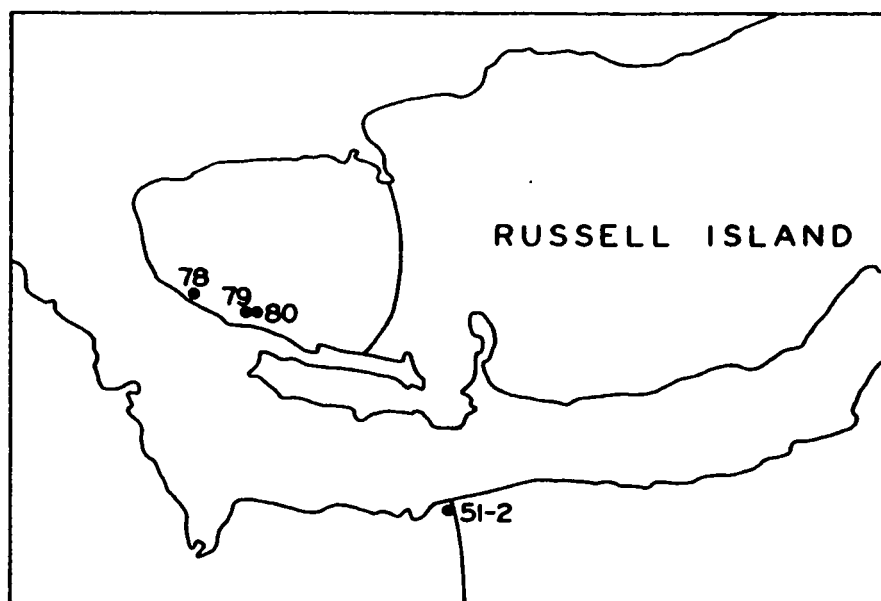


Fig. 43. Locality map: Carbonate Facies outcrops

7. CARBONATE FACIES

a) Introduction

Although more than half of the land area of Prince of Wales Island has been mapped as carbonate rocks (Blackadar and Christie, 1963), this part of the island remains the least well known, for exposure is in general very poor. The strata are flat-lying, giving rise to low, rolling hills with few stream exposures. Recent work on marine invertebrate collections by Ormiston (1967), and Bolton and Copeland (1968, unpublished Geol. Surv. Canada reports on Univ. of Ottawa collections) indicate a Lower and/or Middle Devonian age for those exposures that have so far been studied in detail - mainly in the northwest part of the island (see Appendix I). Discussions elsewhere in the present study (see Stratigraphy) suggest that the rocks of the Carbonate Facies are at least in part contemporaneous with the sandstones and conglomerates of the Upper Peel Sound Formation.

During the present study field work was carried out in only two areas of the Carbonate Facies, at Russell Island and the western end of Browne Bay - see fig. 43. The data presented below are thus not necessarily representative of the facies as a whole. A measured section from Russell Island is included at the end of Appendix II.

b) Lithologic Characteristics

The majority of rocks seen at Browne Bay and Russell Island are yellowish dololutites. Dolosiltites and dolomitic siltstones are present in a few sections. In the dololutites sedimentary structures and fossils are preserved in fine detail. Many of the rocks are finely laminated with light brown, probably bituminous material, a few specimens contain thin layers of intraclasts and there are occasional pelmicrite seams, but no oolitic texture has been observed. Shell fragments commonly show the original fibrous texture and both shell and crystalline infill are normally of calcite (see photograph 34). Coarsely crystalline layers have been found in which fossil structures are partially destroyed and the rock may be very porous, with a patchy appearance resulting from variable grain size. In some cases this is due to partial dolomitisation (see photograph 32), in other cases a pseudobreccia texture is present (discussed below).

Fossil debris has a very variable distribution in the dolomites; in places it is abundant and the rock is a biolomicrite (classification of Folk, 1959, 1968). Nodular dolomites show localised enrichment of fossil material, and compare with the nodular beds of the Sandstone-Carbonate Facies except for the absence of shaly layers.

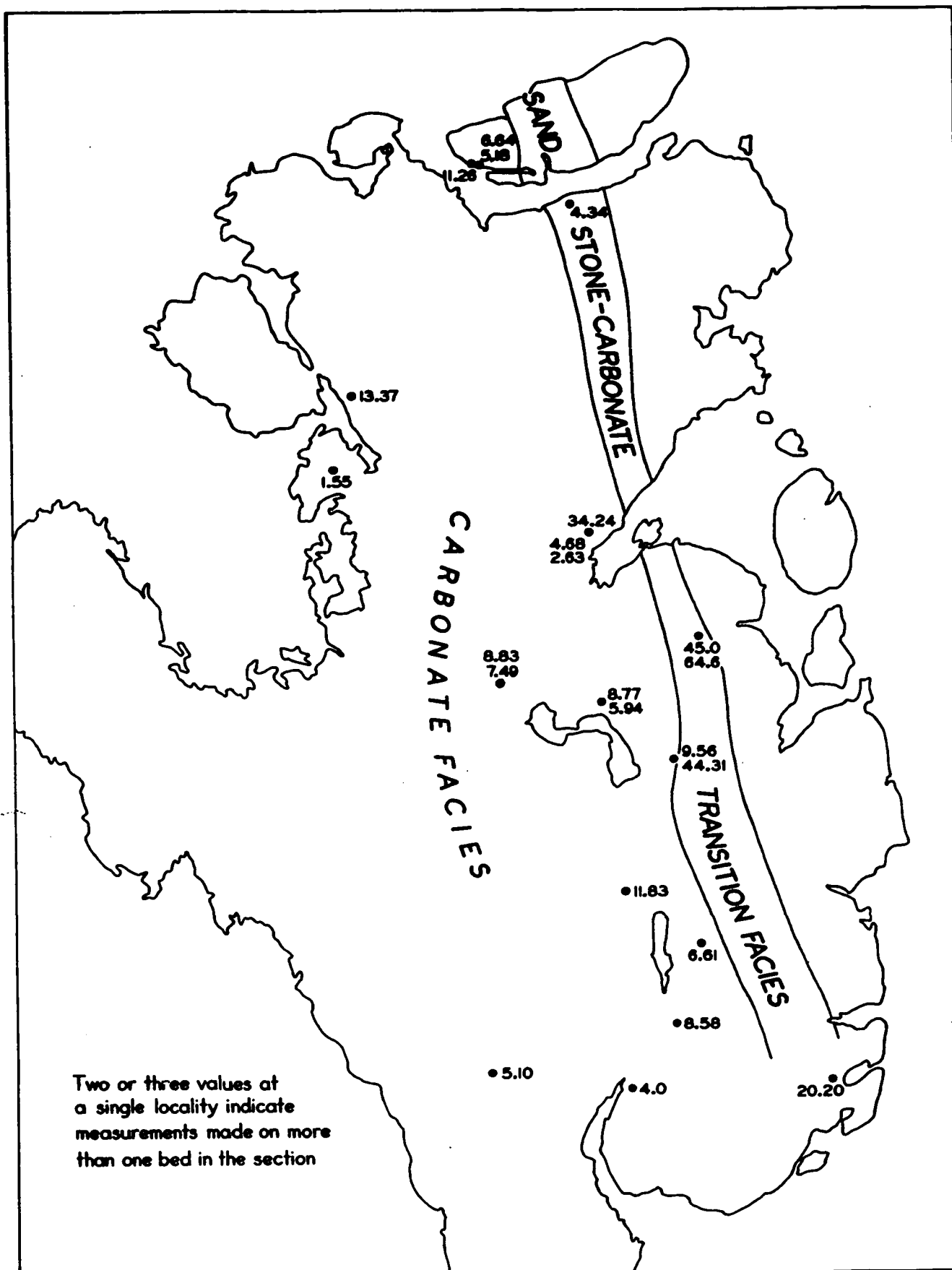


Fig. 44. Carbonate rocks: insoluble residues, percentage by weight

The clastic content of the carbonate rocks is variable. Most contain scattered silt-sized quartz grains, and they grade into buff coloured dolomitic siltstones. A series of carbonate specimens were analysed for insoluble residue (clastic content) by digestion in acid. (Most of the specimens were kindly donated by R. L. Christie). Fig. 44 presents the results and shows the variability of the proportion of insoluble residue in these specimens. Highest figures are found in the Sandstone-Carbonate Facies, as would be expected from paleogeographic considerations, for the insoluble fraction probably represents suspended clastic material of continental origin that was carried into the sea by the streams flowing westward from the Boothia Uplift.

c) Sedimentary structures

Most of the dolomites are either structureless or very finely and evenly laminated. No crossbedding has been observed, although some horizons show small scale ripple marks (see photograph 25). Several specimens collected at the Russell Island localities contain thin lenses full of small platy crystal casts 1-4mm in length (see photograph 27). They show random orientation and are not confined to single bedding planes. Under thin section they are seen to be filled with finely crystalline dolomite. The

original mineral was probably gypsum or anhydrite as suggested by the platy habit of the crystal casts, but the casts are not sufficiently well preserved to indicate whether they are orthorhombic or monoclinic.

At loc. 79 (Russell Island, see Appendix II) a bed of pseudobreccia is present in the section. As shown by Bathurst (1959) this texture results from patchy recrystallisation of a micrite deposit, in this case dolmicrite. The 'matrix' of the pseudobreccia is full of crystal casts similar to those described above. In recrystallised areas these casts are absent, but careful thin section examination reveals occasional ghost outlines.

Photograph 26 is of a true intraformational breccia in finely laminated dololutite (from loc. 95 Browne Bay). Many fragments are disoriented and distorted. They diminish in size upwards and are replaced by a dolarenite zone with comminuted shell debris.

d) Organic remains

Fossils are abundant in many of the carbonate rocks. They are mainly shelly, benthonic forms including trilobites, articulate brachiopods, compound corals, gastropods, pelecypods and ostracods. Comminuted fish debris is occasionally found; eurypterid fragments are present in one buff-pink siltstone on Russell Island.

Bolton (unpublished Geol. Surv. Canada report S&D-1-1968-TEB) has identified the following material: from Russell Island, loc. 78 (G.S.C. Loc. 82456): auloporid and disphyllid corals, *Favosites* sp.; atrypid and chonetid brachiopods, *Lingula* sp.; *Nucula* (*Nuculoides*) sp.; *Euomphalus*(?) sp.; an orthonic cephalopod; *Deschenella* (*Basideschenella*) sp.; *Schizoproetus-Schizoproetoides*; kloedenid ostracod; from Browne Bay, loc. 92 (G.S.C.loc 82467): *Favosites* sp.; loc. 94 (G.S.C.loc 82468): *Macropleura* sp.

A single layer of stromatolitic dolomite was seen at loc. 80 (Russell Island) interbedded with laminated and structureless dolosiltites. The morphology is of *Collenia* type, i.e. laterally-linked domes, and it is illustrated in photograph 25. The specimen shown contains a number of sedimentary structures, such as a ripple mark and desiccation cracks.

e) Discussion: Depositional environment

Most of the fossils present are shelly, benthonic forms, indicating a shallow, marine environment. Desiccation cracks and crystal casts indicate occasional exposure to the air. The crystal casts suggest high salinities, perhaps due to local temporary isolation and evaporation of bodies of sea water behind coastal barriers. Logan *et al.* (1964) state that modern stromatolites of the *Collenia* type

(as found in the Peel Sound at Russell Island) grow in intertidal mudflat areas where wave action is weak. Quiet water deposition is also suggested by the very fine, even lamination of some of the dolomites and by the absence of oolitic texture. Occasional thin shell beds and layers of intraclasts were formed under the influence of local currents, perhaps related to infrequent storms. The intraformational breccia illustrated in photograph 26 was formed shortly after deposition, for the sediment shows both brittle and plastic deformation. The bed has been fractured and fragments disoriented, and many of the fragments show folded lamination. The two effects indicate partial lithification at the time of formation, and suggest a local current scour action.

The origin of the dolomite is a question that cannot be entered into fully in the present study. The bulk of the carbonate material is probably chemically precipitated, but it is not known in all cases whether this precipitate was originally calcite, aragonite or dolomite, i.e. whether the dolomite is primary or secondary. The finely preserved detail of some of the sedimentary structures eg. in the stromatolite bed, would suggest a primary shallow water origin for the dolomite. Similarly, the presence of unaltered calcite shells with sparry calcite infills in a dolmicrite matrix, suggests that the sediment has not

been chemically altered since deposition, although this could result from preferential dolomitisation of the finer grained material. The pseudobreccia structure, and the coarsely crystalline, porous nature of some of the carbonate rocks is probably due to comparatively late stage, diagenetic recrystallisation of the primary or secondary dolomite.

Primary dolomite is not known to be forming in abundance anywhere at the present day. Shinn *et al.* (1965) and Illing *et al.* (1965) note that dolomite is forming by penecontemporaneous alteration of aragonite in present-day carbonate tidal flats of the Persian Gulf and the Bahamas. These areas are hot and dry, the sea water is of high salinity and the mudflats are only covered by the highest tides. As discussed at the beginning of this section, there is evidence to suggest that the Peel Sound carbonates were formed under similar conditions, although there is no evidence of extreme desiccation. Halla *et al.* (1962) consider the thermodynamic conditions necessary for the formation of dolomite and state that high temperatures and high sodium chloride concentrations aid the process of penecontemporaneous dolomitisation. But in sea water the reaction is slow, and the authors conclude that at the present day primary dolomite can only be forming in negligible quantities.

Calcium carbonate is abundant as a chemical precipitate in modern seas, eg. Wells and Illing (1964) describe the process of rapid accumulation of aragonite needles in vast quantities on the floor of the Persian Gulf. The precipitation process is triggered by sudden diatom growth in calcium-carbonate saturated waters. The Peel Sound carbonate rocks may have been formed by penecontemporaneous dolomitisation of precipitates such as this. However, as Fairbridge (1957) has pointed out, conditions of salinity and carbon dioxide partial pressure could have been very different in the distant past, and thus may have been more favourable for the formation of dolomite as a primary precipitate.

V. STRUCTURE

1) Unconformities

In only one place is the Peel Sound Formation known to rest unconformably on older strata. Seven miles south of Bellot Cliff (NS403900) coarse boulder conglomerates, probably of Upper Peel Sound age, rest on upturned Read Bay limestones with a marked angular discordance. The unconformity was first described by McNair and Ormiston (quoted in Kerr and Christie, 1965) who report an angular difference of 40^0 between the two formations. They estimate that a minimum of 2500 feet of erosion took place before the deposition of the Peel Sound conglomerates. However, field work by the present author indicates a lower figure for the angular discordance - approximately 20^0 , and the estimate of the amount of erosion is considered to be excessive.

Stratigraphic sections published by Christie (1967) give a thickness of 850 feet for the Read Bay Formation at Young Bay, Prince of Wales Island, and air photo interpretation suggests a similar thickness for the formation over the remainder of the island. Blackadar (1967, Geol. Surv. Canada map 3-1967) shows the Peel Sound Formation resting on the top of the Allen Bay Formation at the Bellot Cliff unconformity. The amount removed by erosion is

therefore unlikely to be more than about 1000 feet - that is, slightly more than the estimated thickness of the Read Bay Formation. The Lower Peel Sound is missing in the Bellot Cliff section (see fig. 6) but was probably never deposited, as the erosion was taking place during Lower Peel Sound times.

The unconformity shown by Blackadar (*op. cit.*) at the south end of Prescott Island has not been confirmed by field work during the present study. Air photo interpretation suggests a local thinning of the Read Bay Formation in this area, which Blackadar attributed to an overstep by the Peel Sound Formation. However, field evidence shows that the thinning of the Read Bay outcrop is due to a steepening of the dip and not to erosion.

No other unconformities or marked disconformities were discovered within or at the base of the Peel Sound Formation.

2) Folds

Over most of Prince of Wales Island the strata are horizontal or very gently dipping. Only along the extreme eastern edge of the Peel Sound outcrop has the formation been markedly affected by tectonic activity. Here there is a zone, generally less than one mile in width, along which the strata are steeply upturned (see photographs 1, 2,

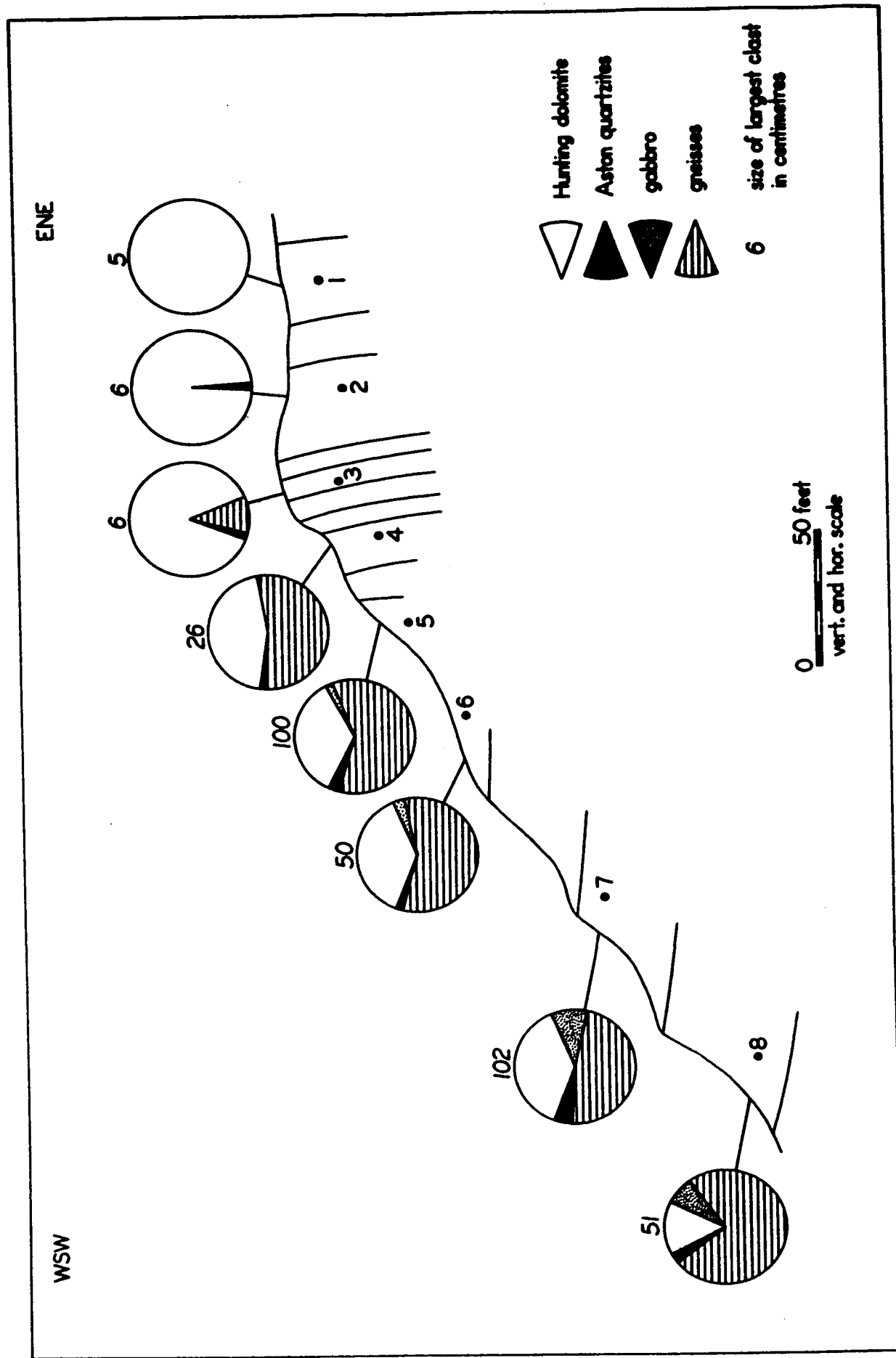


Fig. 45. Horizontal section through Lower-Upper Peel Sound conglomerates 10 miles north of Cape Brodie, showing clast counts and maximum clast size

4-6). The folding has resulted in the formation of an asymmetric syncline, with the Upper Peel Sound conglomerates forming the western limb, while the Lower Peel Sound and older Paleozoic rocks are brought up to the surface on the eastern limb. The fold can be traced along a sinuous axis from north to south along the eastern margin of the island. Dips on the west limb are everywhere very low, but on the eastern limb they vary from 45° (at Cape Brodie) to an overturned dip of 36° (at Mount Matthias). Vertical strata are common.

This structure represents the extension of the Cornwallis Fold Belt southwards along the west side of the Boothia Uplift (see fig. 2). A typical horizontal cross section is included with the map that accompanies this report. North of Mount Matthias the Cornwallis Fold Belt broadens, and at the Bellot Cliff unconformity the Peel Sound has a maximum dip of only 10° .

At one locality, ten miles north-northwest of Cape Brodie (NR850558) field work has shown that on the two limbs of the syncline the conglomerates have markedly different characteristics. Fig. 45 gives the results of eight clast counts. The fold is illustrated in photographs 5 and 6. A careful examination of the outcrop was carried out in an attempt to find a fault, shear planes or a brecciated zone to explain these anomalous results. The actual closure

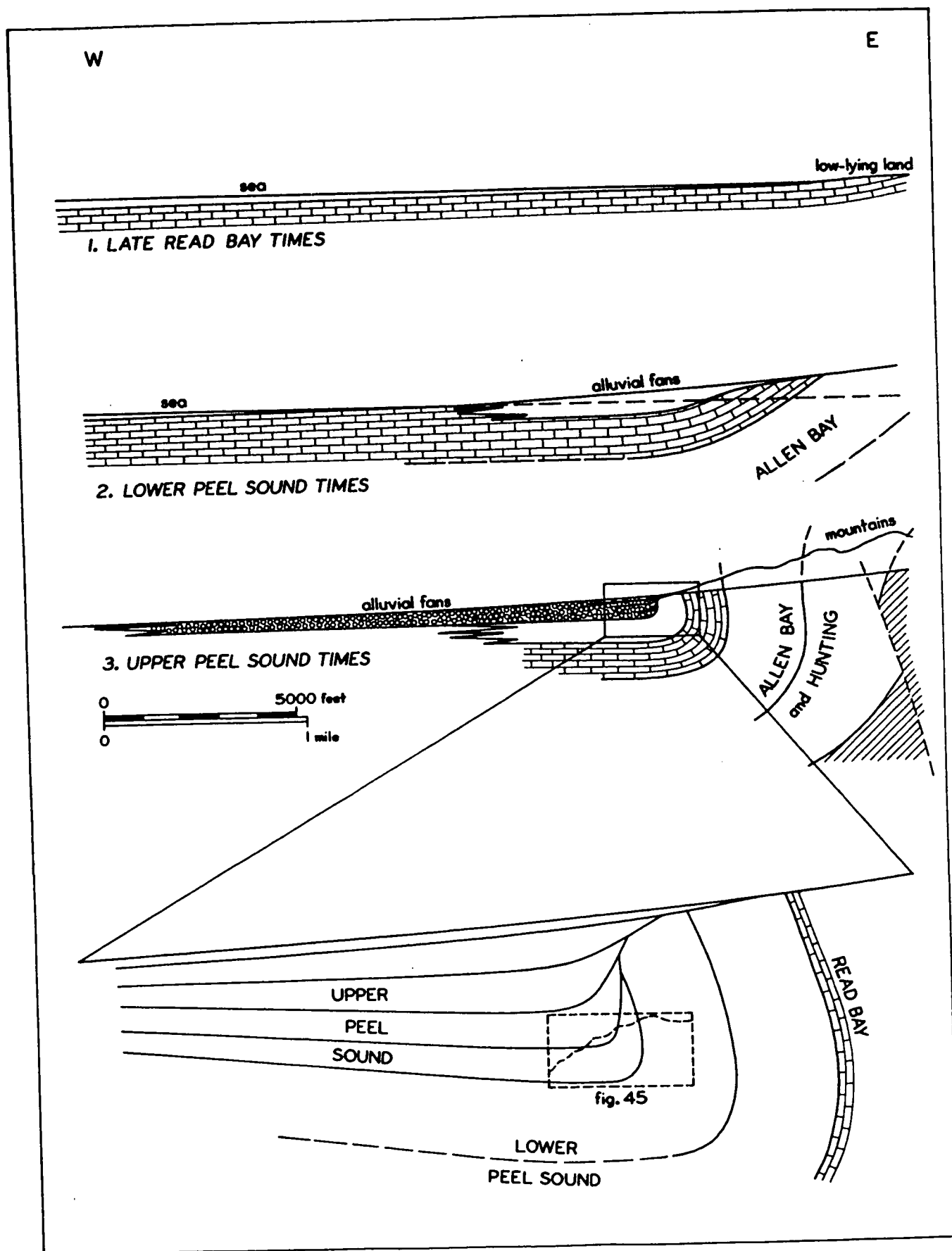


Fig. 46. Suggested history of development of the Cape Brodie fold. No vertical exaggeration, scale is approximate.

of the fold is covered by talus, but outcrop within 10 feet (3m) of the axis shows well lithified conglomerate with very few fractured clasts. Within the more massive conglomerates on the east limb of the fold (from which clast counts 1-4, fig. 45 are taken) a few dislocation planes show displacements up to 4 feet (1.2m). Thus there is no major faulting involved.

The Cape Brodie structure is interpreted as a syn-depositional fold, and a mechanism for its development is illustrated in fig. 46. The nearly oligomict conglomerates comprising the base of the Lower Peel Sound represent the deposits formed during or following an early, gentle elevation of the Boothia Uplift. Later movement was more marked. Uplift may have taken place along steep reversed faults as suggested by Kerr and Christie (1965, fig. 3), but, if so, faulting is confined to the basement rocks. In the cover rocks movement is expressed by folding. The renewed movement caused much coarser debris than before to be transported out of the uplifted area. Erosion cut down into the basement rocks, and the debris rapidly became enriched in metamorphic rock material. Coarse, polymict conglomerates accumulated in a wedge along the edge of the uplift while the latter was still active. They are, therefore, syntectonic conglomerates. Continued movement must have allowed the removal of much of the newly formed con-

glomerate wedge, but the earlier parts of it are themselves folded, as demonstrated by the beds from which clast counts 5 and 6, fig. 45, were taken. The conglomerates at these two points are of almost identical composition, showing that they probably represent one horizon.

It is not known whether similar structures are developed elsewhere along the western margin of the Boothia Uplift. A deeper erosion level than at Cape Brodie, or lack of exposure at the fold axis could prevent their recognition. It is a fact that the polymict cobble and boulder conglomerates rarely have dips of more than 10^0 , while the oligomict limestone or dolomite conglomerates are everywhere steeply dipping and often overturned. This may be an accident of exposure, for an asymmetric syncline with one horizontal limb could show just this contrast (see horizontal section accompanying the map, in folder at end of this report).

At Transition Bay (including 'Wilson's Gorge' of Broad, 1968), Mount Matthias and other sections in the Cape Brodie area, exposures show a gradual decrease in dip westwards (downdip) away from the Boothia Uplift. At the level of the Lower-Upper Peel Sound transition the dip may be nearly horizontal, so that a continued traverse westwards will encounter only the same beds. This suggests a normal relationship of folding having succeeded deposition. However, an examination of fig. 46 will show that lower

levels of erosion of a depositional fold could show exactly this arrangement. The importance of the Cape Brodie fold is, therefore, a question that cannot be resolved at present. Rare clasts of the Lower Peel Sound are found in the conglomerates of the Upper Peel Sound Formation - this is the only other evidence yet discovered for contemporaneous uplift and erosion of the newly formed deposits.

3) Faults

Kerr and Christie (1965) interpret the western margin of the Boothia Uplift as a zone of major reversed faulting. They suggest that this zone may continue without break from north to south along the eastern edge of Prince of Wales Island. But on the published geological map (G.S.C. map 3-1967) bounding faults are shown in only three places.

Present work indicates that at least two of the three faults do indeed exist, but nearly everywhere else the contact between the Paleozoic sediments and the underlying metamorphics is simply a folded unconformity. The folding may, however, represent the deformation of comparatively plastic cover rocks overlying faults in the more brittle basement.

At Mount Matthias the contact does not appear to be faulted, but a few miles to the south, near the northeast corner of Browne Bay, air photo evidence suggests that the

Read Bay Formation is at least partly faulted out. Work on the ground indicates the presence of parallel subsidiary faulting, that has formed steeply dipping fault slices of the Lower Peel Sound three to four miles north of Browne Bay. (see geological map accompanying this report for details described here and in succeeding paragraphs).

At the northern and southern ends of Prescott Island exposure is poor, but there is no evidence of major faults along the Paleozoic-Precambrian boundary. The faulted area mapped by Blackadar (1967, map 3-1967) in the central part of the island was not visited during the present study.

The bounding fault shown on Pandora Island in map 3-1967 has been confirmed by field work during the present study. All but 50 feet of the Read Bay Formation and all of the Allen Bay Formation has been removed by faulting.

From the south end of Pandora Island southwards to the small unnamed bay ten miles (16km) north of Cape Brodie, field work suggests an unfaulted Paleozoic-Precambrian contact. From the unnamed bay southwards towards Cape Brodie the Allen Bay and Read Bay Formations are again largely faulted out. This fault is shown on map 3-1967 but the outcrop patterns have been incorrectly drawn. Field work has shown that two miles southwest of the unnamed bay (at ref. NR836485) approximately the upper fifty feet (15m) of the Read Bay limestones are faulted directly

against Precambrian ultrabasic rocks. The sediments show an overturned dip of 50° to the east, suggesting that this is a steep reversed fault.

The country between Cape Brodie and a point 8 miles (13km) north of Transition Bay has not been visited in the field. Air photo interpretation suggests an unfaulted Paleozoic-Precambrian contact. In the Transition Bay area the contact is sharply folded but there is no major faulting.

Throughout the remainder of Prince of Wales Island tectonic deformation is of very minor importance. Gently tilted strata and normal faults have been observed on the south coast of Baring Channel and at the head of Transition Bay - both areas are in the Sandstone-Carbonate Facies. Dips reach a maximum of 15° locally, and faults have a throw of a few inches to approximately 30 feet (9m). Elsewhere the beds are virtually undisturbed.

VI. SUMMARY AND CONCLUSIONS

1) History and Paleogeography

In Read Bay (late Silurian) times, a shallow sea covered the area that is now Somerset and Prince of Wales Islands. The Boothia Uplift was not active, and marine carbonates with a rich benthonic fauna were accumulating over wide areas. The fauna included corals, brachiopods, trilobites and nautiloids; the corals often formed small reef structures, and a warm climate is indicated. The clastic influence was small; thin grey shales and occasional sandy horizons are interbedded with the thick and commonly massive limestones.

At a stage in time corresponding closely to the beginning of the Devonian period (the Ludlovian-Downtonian boundary) uplift commenced along the Boothia axis. Small land areas appeared in the vicinity of the present-day Peel Sound and western Somerset Island, and from this time on clastic material eroded from the rising land areas formed an increasingly large proportion of the accumulating sedimentary pile.

The first important clastic sediments were littoral sands, and slightly later in time beach conglomerates appeared, indicating active coastal erosion. The base of the Peel Sound Formation is defined as the lowest conglomerate or redbed horizon, but these lithologies may not have begun forming everywhere at the same time.

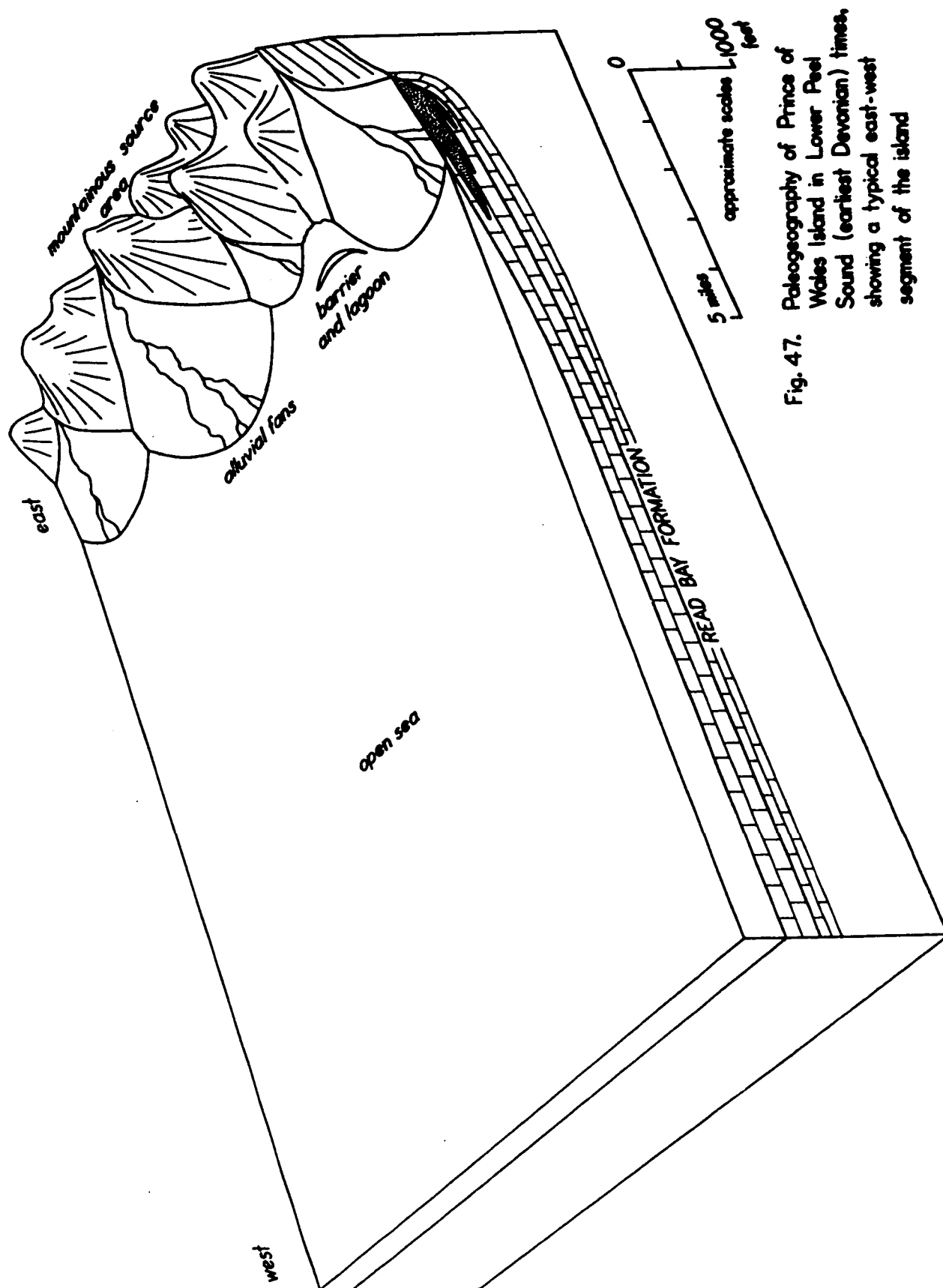


Fig. 47. Paleogeography of Prince of Wales Island in Lower Peel Sound (earliest Devonian) times, showing a typical east-west segment of the island

Along the western margin of the Boothia Uplift a complex system of different environments developed in early Devonian times (see fig. 47). The land area was by this time sufficiently extensive that large quantities of coarse clastic debris (up to pebble size) were being carried into the sea by torrential streams and building up a series of alluvial fan wedges. Reworking of this material by streams during periods of low flow gave rise to red fluvial deposits, and in these streams lived many species of fish. The continental sediments were accumulated close to sea level, and local shifts in the pattern of streams and fan distributaries allowed the sea to return. Some of the sediment was then reworked, forming littoral deposits of sand and pebble conglomerate; but in other areas, perhaps in sheltered bays, the energy level of the sea was low and carbonate precipitates accumulated and a benthonic invertebrate fauna thrived. Occasionally small areas of the sea may have become partially isolated by the development of coastal barriers, and then some of the typical marine forms such as corals, brachiopods and nautiloids were unable to enter the area. The fauna was restricted to the more tolerant types such as *Lingula*, ostracods etc.

The shifting and reforming of these environments continued for an extended period of time, perhaps several million years, so that the resulting sedimentary pile shows

extreme lateral variability all along the margin of the Boothia Uplift. During this time the Uplift must have been slowly rising, for pebble sized debris was being poured off the land area in gradually increasing abundance. At this stage clasts still consisted mainly of carbonate rocks from the older Paleozoic formations (the Read Bay, Allen Bay and Hunting), showing that erosion had not penetrated very deep into the rocks forming the Boothia landmass. Near Bellot Cliff is the only locality where the early Peel Sound erosion surface has been preserved. (The Bellot Cliff unconformity) The Read Bay Formation is here tilted and truncated. A breccia, possibly representing a mudflow or talus deposit rests on the upturned limestones.

The subdivision of the Peel Sound Formation into Lower and Upper parts is based on widespread lithologic changes in the rocks, which are thought to have been brought about by a relatively sudden increase in the rate of uplift along the Boothia axis. All along the western margin of the Boothia axis pebble conglomerates with interbedded shallow marine and littoral deposits, grade upwards into massive cobble and boulder conglomerates with interbedded fluvial sandstones. The change is a rapid one, taking place everywhere over a vertical thickness of about 40 feet (12m). It suggests a comparatively sudden rejuvenation of the source area, although this may not have been everywhere

exactly contemporaneous. Erosion cut deeply into the newly elevated landmass and broke through the cover of Paleozoic sediments into the basement complex. The coarse debris was carried westwards by debris floods and torrential stream floods to accumulate in a much enlarged alluvial fan zone beyond the mountain front. Local folding accompanied the uplift. Bounding faults developed in places, affecting the earlier Paleozoics along the margin of the Boothia axis, and everywhere the rocks (including the Lower Peel Sound) were tilted, giving them a steep westerly dip. In at least one place a probable syn-depositional fold structure developed, with an increased thickness on the western limb.

The marine and marginal marine environment shifted westwards in response to the uplift and the great influx of continental sediments. A wide alluvial plain developed between the mountains of the Boothia Uplift and the sea to the west. During the remainder of Lower Devonian times and probably for at least part of the Middle Devonian, continental sediments accumulated continuously on this coastal plain zone, which was 12 to 28 miles (19-45km) wide and at least 170 miles (270km) long. The pattern of environments that was established at this time is shown in fig. 48. The evidence for deducing paleocurrents is summarised in fig. 49.

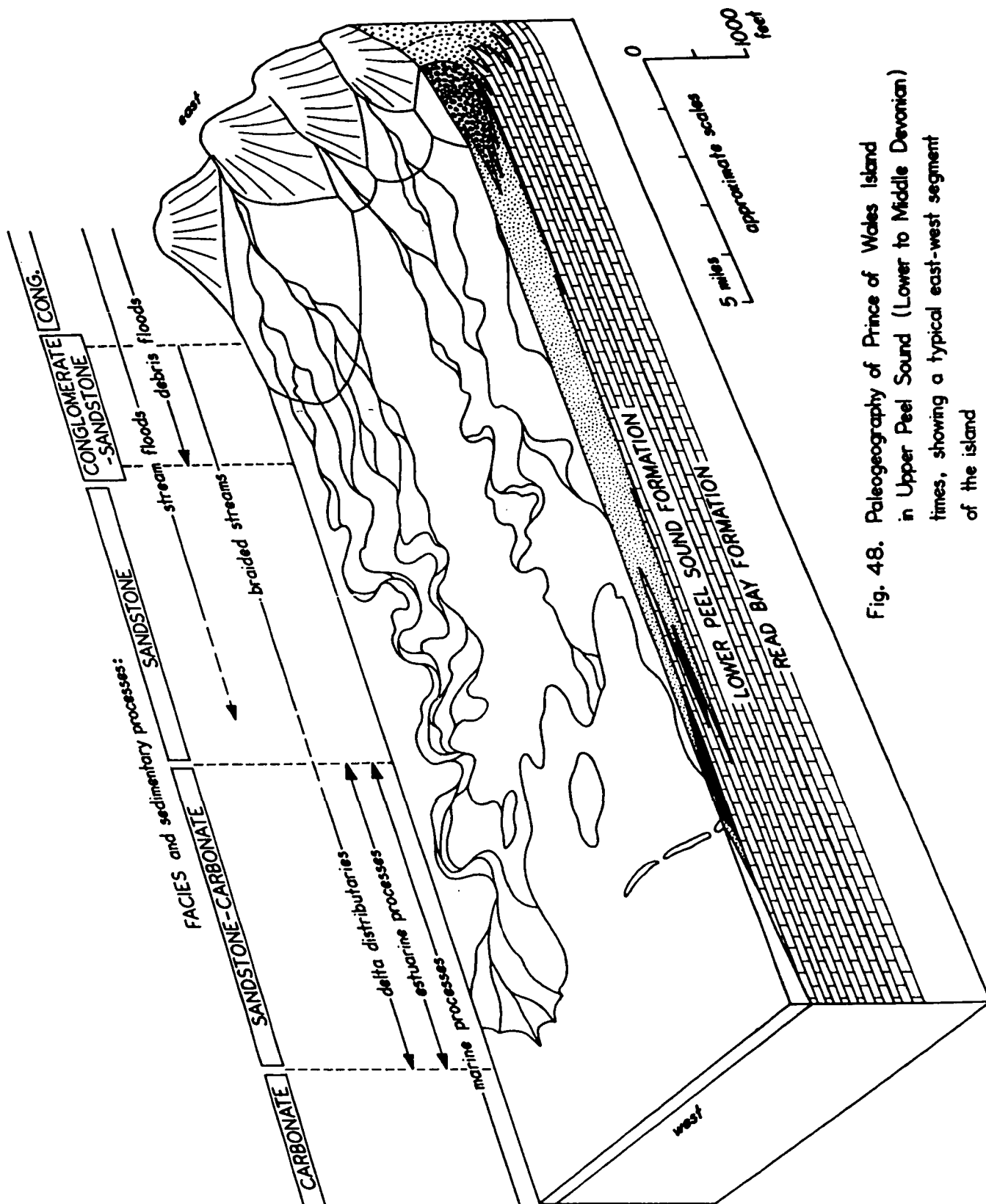


Fig. 48. Paleogeography of Prince of Wales Island in Upper Peel Sound (Lower to Middle Devonian times, showing a typical east-west segment of the island)

In the east, bordering the mountains of the Boothia Uplift, a bajada up to 7 miles (11km) wide developed, consisting of a series of large and small alluvial fans overlapping each other laterally along the mountain front. Coarse debris, including a large proportion of cobbles and boulders, was carried on to the fans by debris floods and stream floods, and deposited with very little sorting action. The mid-Lower Devonian uplift had, in places, caused Lower Peel Sound sediments to be tilted up and eroded, so that rare clasts from these rocks are included in the Upper Peel Sound conglomerates. However, the bulk of the clastic material consisted of older Paleozoic sediments and Precambrian rocks - chiefly metamorphics, derived from the core of the Boothia Uplift. Variations in local geology caused variations in the composition of the debris, and mapping of these variations has revealed the probable original outlines of some of the fans (see fig. 30). Shifting of distributaries on the fan surfaces and the process of fanhead trenching were responsible for reworking and redistributing some of the clastic material, and adjacent fan wedges are now often seen to grade almost imperceptibly into one another. In between periods of flood quieter streams flowed, forming crossbedded fluvial sands. The massive conglomerates reach an estimated thickness of 1000 feet (300m), though an unknown amount may

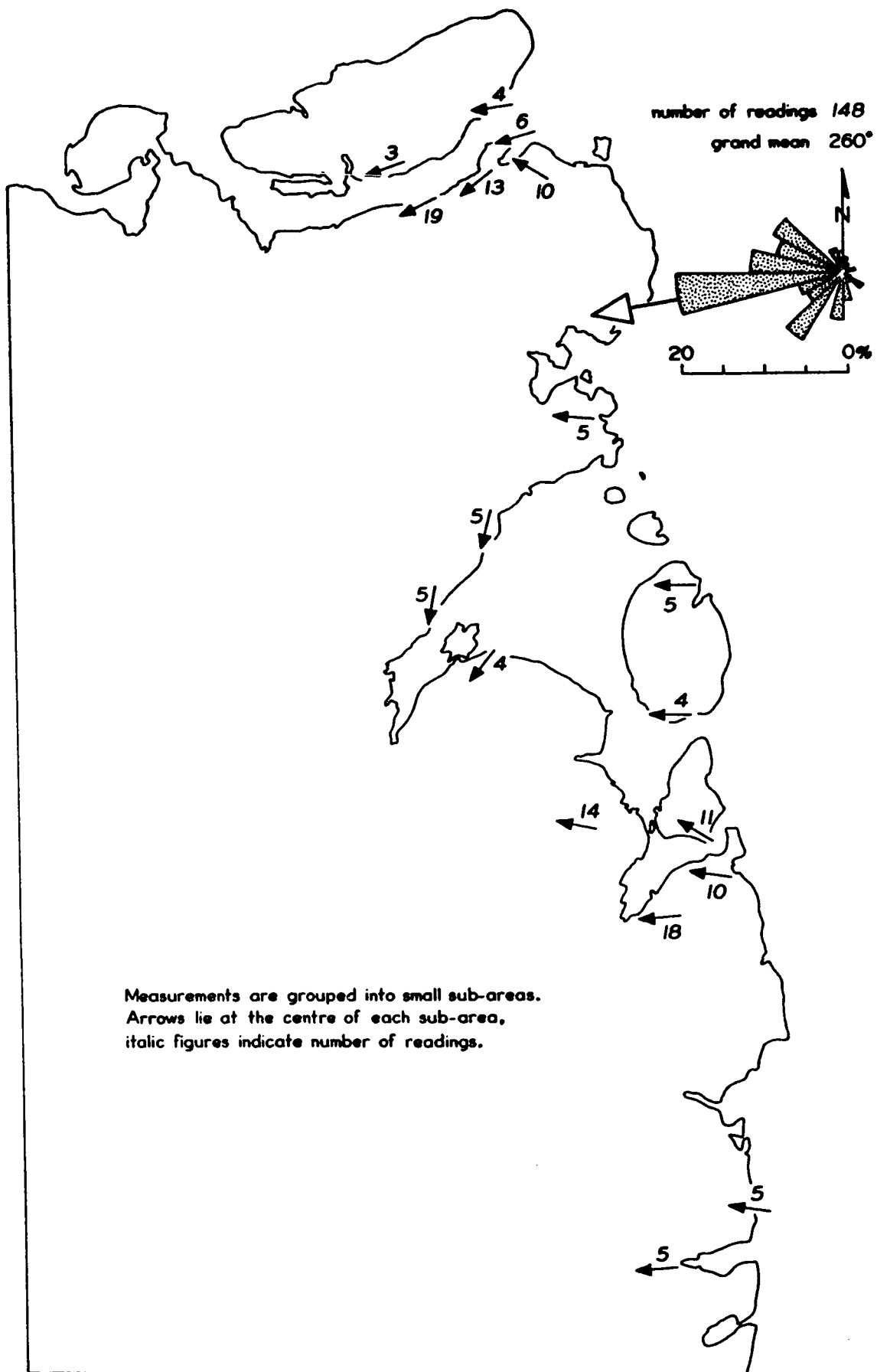


Fig. 49. Paleocurrent data

have been removed by post-Middle Devonian erosion. The belt of alluvial fans reached a maximum width of 7 miles (11km) at Bellot Cliff. It is at its narrowest near the south end of Pandora Island, where uplift may have been less than elsewhere along the Boothia axis.

At the foot of each alluvial fan debris flood deposits died out, and the surface run-off developed a complex series of braided streams. Occasional debris floods extended up to 3 miles (4.8km) out onto this fluvial plain, so that there is a narrow zone of interbedded stream and fan-type deposits. This is now mapped as the Conglomerate-Sandstone Transition Facies, in which a series of fining-upwards sequences records the process of channel migration. New channels were initiated in times of flood and conglomerates were deposited. During the quieter periods of flow between floods, channels migrated and were infilled gradually with sandy deposits that decrease in grain size upwards. In some cases these pass up into silty overbank deposits.

Conglomerate beds extend a maximum of ten miles (16km) from the present edge of the Boothia Uplift. Further west coarse debris is limited to a few scattered pebbles, and the bulk of the sediment is sandstone, deposited by a complex of braided streams. This is the area of the Sandstone Facies.

In the Conglomerate-Sandstone Facies the braided streams were probably of low sinuosity, but further to the west the appearance of laterally extensive planar crossbeds provides evidence to suggest that channel sinuosity increased. This increased sinuosity would correspond to a decreased slope as the streams approached base level (the sea). Occasional stream floods entered the area of the Sandstone Facies and deposited sediment under conditions of upper regime flow, resulting in extensive bodies of horizontally bedded sandstone. These stream floods were probably of low sediment:water ratio and were not related to the debris floods of the alluvial fan facies. They may have originated in the Boothia upland area following periods of active debris flood flow, when the supply of detritus had been considerably depleted. In their passage across the alluvial fan zone the stream floods would have been responsible for much scouring and reworking of the surface deposits.

In Upper Peel Sound times the coastline lay 12 to 28 miles (19-45km) to the west of the Boothia Uplift mountain front, having regressed westwards by approximately this amount from its position near the mountain front in earliest Devonian times. Streams built small deltas out into the sea, and wherever the fluvial influence was small the sea transgressed in the reverse direction - eastwards - to form beds of precipitated carbonates. Deposits formed

in these two environments are interbedded over a zone 5-10 miles (8-16km) wide. This is now mapped as the Sandstone-Carbonate Facies. In detail the interbedding of many different sediment types demonstrates a considerable fluctuation in the position of the shoreline.

The high sinuosity streams of the Sandstone Facies probably diverged into smaller distributaries in the coastal zone, and deposited the remainder of their transported sand and silt in small deltas (see fig. 42). On the outer fringes of the deltas fluvial deposition may have been taking place in low, waterlogged conditions, and here the sparse Lower Devonian flora would have flourished. Unlike the other Peel Sound fluvial sediments those formed here are pink, buff or green instead of bright red, reflecting local reducing conditions. Deltaic sediments nowhere form continuous thicknesses of more than 20 feet (6m) in the sections so far studied. This suggests that the centres of fluvial accumulation may have shifted rapidly at fairly short intervals, the cause possibly lying in the power of the stream floods flowing westwards from the Sandstone Facies.

Coastal barrier complexes developed between the deltas. Beach sands and estuarine clays were among the sediments deposited. The sand was probably derived from reworked deltaic material; the clay was probably fluvial in origin,

flocculated and deposited by the influence of cations in the sea water. The geometry of the barrier deposits depended on local variations in water depth, current strength etc. Beach bars and lagoons may have developed in some areas, whereas in others sheltered conditions may have resulted in the formation of cheniers, similar to those forming at the present day on the coast of the Gulf of Mexico.

Carbonate precipitates formed in estuarine and marine areas. Carbonate/shale rhythmic beds may have developed by post-depositional carbonate precipitation around pockets of shell debris. Thick clastic-free carbonate beds are probably primary precipitates, but whether they were originally calcite or dolomite is at present an open question. Most carbonate beds in the Upper Peel Sound are now dolomite, but this may have been formed by penecontemporaneous alteration of calcite or aragonite.

The fauna in the coastal area was varied, reflecting the diversity of environments present. Many species of fish inhabited the rivers and estuarine areas; ostracods, gastropods, pelecypods and *Lingula* flourished in brackish waters, and in the sea these forms were joined by corals, brachiopods, trilobites and nautiloids.

The sea was shallow, and probably at a very low energy level. The presence of desiccation cracks, crystal casts and *Collenia*-type stromatolites suggest occasional

exposure to the air. Quiet water is indicated by the fine lamination in some of the sediments, by the low percentage of clastic material and by the absence of oolitic texture.

There is evidence to suggest that once the pattern of continental, estuarine and marine environments had become established in Upper Peel Sound times, uplift along the Boothia axis slowed down or ceased altogether. A vertical section in conglomerates at Bellot Cliff shows that clast roundness and sphericity increase in the direction of the youngest rocks. In the Conglomerate-Sandstone Transition Facies vertical sections show a decrease in proportion of conglomerate in the same direction. Both these facts may be related to a gradually diminishing relief in the source area. Streams were lengthening by headwards erosion, and gradually reducing their slope. Rate of flow would decrease with such changes, and transport would be slower. Thus individual clasts would be more abraded and stream competency would be reduced, so that less coarse debris would be carried out into the alluvial plain.

Climate: the presence of alluvial fans containing an important debris flood element cannot be taken to indicate a semiarid or arid environment. One of the chief requirements for the development of debris floods is an absence of vegetation in the source area. At the present day, vegetation is only scarce in arid and semiarid climates,

but in early Devonian times it was scarce because of the early stage of evolution - the land flora was probably confined to the lowest, wettest areas. There was, therefore, nothing to modify the intensity of the rainfall or its rate of surface runoff in the upland regions. Debris flood deposits are thus of little value as indicators of climate in Peel Sound times.

In rocks formed near the coast occasional desiccation cracks and crystal casts have been found, suggesting dry periods that resulted in the evaporation of restricted bodies of saline water. However, they are not present in sufficient abundance to indicate true aridity.

On the balance of evidence it may be concluded that the climate in Peel Sound times was probably warm or hot, and may well have been humid.

Post-Middle Devonian history: Virtually nothing is known concerning the later history of the Peel Sound Formation, for the Upper Peel Sound is the youngest formation present on Prince of Wales Island. Thus there is no evidence to indicate how long continental sedimentation continued in the area. Diagenetic changes can be seen, such as lithification, recrystallisation of some of the dolomite, and the development of joint systems. But the next event to leave a sedimentary record in the area was the Quaternary glaciation.

2) Comparison with other areas

The area covered by the present study includes all that part of the Peel Sound Formation which was formed west of the Boothia Uplift. Very similar continental sediments were accumulating east of the Uplift in the area that is now Somerset Island. The rocks here are now at a slightly higher structural level, and the Peel Sound is only preserved in three outliers straddling the axes of two shallow synclines. (see fig. 2) Several authors have studied the formation in Somerset Island. See Fortier *et al.* (1963, original description of formation); Blackadar and Christie (1963); Dineley (1965, 1966). The fullest description is given by Dineley (1966, p.273-275), and from the limited evidence available strong similarities emerge with the Peel Sound of Prince of Wales Island. Near Aston Bay the Read Bay grades up into a series of transition beds containing 500 feet (150m) of sandstone, siltstone, limestone and dolostone. The beds become coarser and more consistently red up the section and pass up into 1850 feet (555m) of oligomict dolostome conglomerate. The gradual change to clastic sedimentation that terminates Read Bay times is interpreted as a change from marine through transitional (possibly lagoonal) to fluviatile conditions of deposition. Higher in the succession the oligomict conglomerate is succeeded by 850 feet

(255m) of red sandstone and 300 feet (90m) of polymict conglomerate. The latter contains at least ten distinct clast types, including quartzite, calcilutite and gneiss; individual clasts reach a maximum diameter of 12 inches (30cm). Similar sequences are found in the two southern outliers on Somerset Island. Evidence is not available to show a lateral transition into a marine environment eastwards from the Boothia Uplift, but limestones containing evaporite beds and salt casts are found overlying the Read Bay near the southeast corner of Somerset Island. Paleocurrent measurements indicate that the Boothia Uplift was the source of the material, and by analogy with the coarse conglomerates of Prince of Wales Island the polymict conglomerate that forms the top of the Somerset Peel Sound section may be interpreted as alluvial fan deposits. In many ways the Peel Sound Formation of Somerset Island is a mirror image of the Peel Sound of Prince of Wales Island. Detailed work on associated fish remains may indicate whether the two areas of sedimentary accumulation were geographically connected as well as being tectonically related.

The Boothia Uplift is not exposed anywhere to the north of Aston Bay, Somerset Island, but the genetically related Cornwallis Fold Belt extends northwards for more than 200 miles (320km), and on Cornwallis Island there is a small

thickness of continental sediments of similar age to the Peel Sound Formation. This is the Snowblind Bay Formation, described by Thorsteinsson (1958, p.75-78) and Kerr (1967, p.687-688). At the type locality the Read Bay limestones pass up into limestone breccias with subordinate sandstone and siltstone. Fish remains obtained from these beds indicate an early Devonian age; Kerr (1967) places them in the Emsian stage. In central Cornwallis Island the Snowblind Bay rests with a strong angular unconformity on the lower part of the Read Bay Formation. On Bathurst Island it passes laterally into a marine formation called the Stuart Bay. The general pattern of sedimentation thus shows some similarities to that developed in the Prince of Wales - Somerset Island area.

Red continental sediments of similar age were deposited in a few other localities in the Canadian Arctic Islands, indicating local tectonic activity, eg. the Vendom Fiord Formation of eastern Ellesmere Island, dated as Middle Devonian (Eifelian) by Kerr (1967, p.684). There are large areas in which non-red continental sediments accumulated, but these cannot be correlated with the Peel Sound Formation.

The continental sediments of the Boothia Uplift area were formed in one of a large number of 'Old Red Sandstone' provinces that developed at this time in various parts of

North America and northwest Europe (Allen, Dineley, and Friend, 1967). The name Old Red Sandstone is applied to all non-marine sediments of Devonian age. The continental environment was of great importance during Devonian times, because of a series of major orogenic movements in Arctic Canada, the Appalachians, the 'Caledonian' belt of Great Britain-Scandinavia, and elsewhere. Two types of Old Red Sandstone province were formed (Allen and Friend, 1967):

- a) The 'external' facies type, in which continental sediments formed at the edge of an orogenic belt and passed laterally into marine deposits.
- b) The 'internal' facies; deposition took place in intermontane basins, and there are no associated marine sediments. The external facies has been found to be by far the most important in volume and areal extent (Allen, Dineley, and Friend, 1967, p.92). The Boothia Uplift province is clearly of this first type.

3) Suggestions for further work

During this project the approach used has been that of a broad-scale field study with limited follow-up work in the laboratory. The latter has consisted mainly of thin section analyses. Any further work on the Peel Sound Formation should concentrate on accumulating and correlating more field data, and using different field and labora-

tory techniques.

Except for the country around Transition Bay, that part of Prince of Wales Island which lies south of Cape Brodie has not been well covered by field work. Air photo interpretation suggests that there are a number of exposures in the various clastic facies present here, but many had to be omitted from the field programme through lack of time. Similarly, in the Carbonate Facies, there are scattered exposures, particularly in the Smith Bay area, where no detailed sedimentological study has yet been carried out.

North of Cape Brodie there are several sections exposing the Read Bay-Peel Sound transition beds. Field work has shown the existence of several fish horizons in these beds and the area is worthy of a detailed study similar to that carried out by Broad (1968) on a section near Transition Bay. Further light may be thrown on the nature of the Siluro-Devonian boundary.

Little is known concerning the three-dimensional geometry of many of the lithologic units. Further information of this nature would be very useful, particularly in the Sandstone-Carbonate Facies where it would enable much more reliable environmental interpretations to be made of the deltaic and estuarine deposits. In the absence of useable marker horizons the only ways in which such informa-

tion could be collected are by detailed surveying or geophysical techniques. Exposure is probably sufficient for such a study in the Transition Bay area.

Directional structures are not abundant in the Peel Sound Formation. The study of oriented sandstone specimens by X-ray techniques might provide additional information on paleocurrents, of considerable use in making more detailed environmental interpretations of fluvial and estuarine rocks.

In general terms, detailed quantitative information concerning continental conglomerates is very incomplete. Thus many published studies of grain size have only considered a fraction of the whole rock, and many authors have employed inaccurate sorting measures such as the Trask sorting coefficient. Studies of whole-rock grain size as attempted in the present study, would be fruitful and should employ the accurate sorting measures recommended by Folk (1968). Sampling of a boulder conglomerate for sieve analysis is impractical as the size of a single sample would be enough to fill a small truck. For consolidated rocks such sampling is, of course, impossible in any case. The approach employed here seems to be the solution, but the technique is thought to be in need of considerable refinement.

Further studies of roundness and clast shape would also be of interest in determining the relationships between distance of transport, mode of transport and amount of clast abrasion. The roundness chart of Krumbein (1941a) was found to be quick and easy to apply in the field. Sphericity is also easy to measure, but the present study, coupled with a review of the literature, has persuaded the author that this parameter is probably subject to too many variables and thus sphericity values are not likely to be amenable to easy interpretation. Studies of shape (rod, disc, blade etc.) were not attempted in the present study. It is important that in any statistical study of conglomerate clasts such as roundness and shape, the size limits and the lithology of the clasts under study should be clearly stated, for clast parameters vary widely with different sizes and different lithologies. A size range of one phi class is probably satisfactory for roundness measurements, but smaller size limits are probably necessary for sphericity measurements (Sneed and Folk, 1968) . Particle shape is probably a more useful measure than sphericity for relating distance and method of transport to particle abrasion.

APPENDIX I. FAUNAL EVIDENCE FOR THE AGE OF THE PEEL SOUND
FORMATION ON PRINCE OF WALES ISLAND

1) Lower Peel Sound Formation

The most detailed work on the Lower Peel Sound Formation is that carried out by Broad (1968), who used invertebrate faunas to date a section in the Read Bay-Peel Sound transition beds at 'Wilson's Gorge' (informal name) six miles north of Transition Bay. Large collections of heterostracan fishes indicate a Downtonian and Dittonian (Lower Devonian) age for the first 400 feet (120m) above the arbitrary lithologic base of the Peel Sound Formation (see fig. 6).

Broad states (p.119-120):

"The oldest age, Ludlovian or Downtonian is indicated by ?*Ariaspis*. This is an unusual and specialised cyathaspid from the bone bed (fish horizon three) near the base of the Peel Sound Formation. The youngest age, Dittonian, is indicated by *Pteraspis* (*Simopteraspis*) *arctica* n.sp. from one of the highest fish horizons. The most important index fossils are the genera *Traquairaspis* and *Pteraspis*. Their stratigraphic ranges are well established in Britain, where the base of the Dittonian is marked by a distinctive faunal change, the replacement of *Traquairaspis* by *Pteraspis*. This faunal change occurs in

Wilson's Gorge and the incoming of *Pteraspis* 370 feet above the base of the formation is therefore considered indicative of the beginning of Dittonian time."

Invertebrate material from Wilson's Gorge has been studied by Bolton (1968, unpublished Geol. Surv. Can. report S&D-1-1968-TEB) who has made the following determinations on collections from the Read Bay Formation, just below the base of the Peel Sound: G.S.C.loc. 82470: smooth brachiopod, *Atrypella* or *Clorinda*; a cephalopod, possibly *Amphicyrtoceras*; *Leperditia gibbera* Jones. G.S.C. loc. 82471: a brachiopod, *Pentamerifera?* or *Harpidium?* G.S.C. loc. 82472: *Harpidium?* sp. Bolton assigns these collections to the Silurian.

Copeland (1968, unpublished G.S.C. report MP-2-68-MC) has identified ostracods from a bed 406 feet (122m) above the base of the Peel Sound Formation at Wilson's Gorge, G.S.C. locs. 82762-82766:

Leperditia gibbera Jones

"*Beyrichia*" *plagosa* Jones

cf. *Welleriopsis* sp.

Bairdiocypris sp.

"*Bythocypris* sp.

Primitia? sp.

Copeland states that this fauna is "similar to that found in the Read Bay Formation and to which an Upper Silurian age has been assigned." (Fortier *et al.*, 1963, p.207).

Bolton (*op. cit.*) identifies the following invertebrates from a bed 589 feet (177m) above the base of the Peel Sound Formation at Wilson's Gorge, G.S.C. loc. 82473:

Clorinda sp.

Conocardium sp.

amphicyrtocerid cephalopod

This collection is also assigned to the Silurian.

The evidence of the vertebrates and the invertebrates thus appears to be conflicting. The marine invertebrates suggest a Silurian age for the whole thickness of the Wilson's Gorge section, whereas the vertebrate evidence indicates a Downtonian to Dittonian age for the first 400 feet (120m) of the Peel Sound clastic beds. Bolton (1968, personal communication) states that similar conflicting ages are found elsewhere in the Arctic, and that dates can only be assigned on the basis of the balance of evidence available for a given formation. In the Siluro-Devonian type sections in Britain the Downtonian overlies the Ludlovian, but elsewhere, faunas characteristic of both often appear to be contemporaneous. Some authors include the Downtonian in the Silurian for this reason. In the case of Wilson's Gorge invertebrate collections from the Peel Sound Formation are rather scanty, whereas vertebrate material is abundant and allows a very detailed comparison to be made with the British Downtonian-Ditt-

onian, although it should be born in mind that in general dates based on vertebrate fossils have been found to be less reliable than those assigned on the basis of invertebrate fossils. Thus the Lower Peel Sound in southern Prince of Wales Island is assigned to the Lower Devonian. A similar age has been suggested for the Peel Sound of Somerset Island (Fortier *et al.*, 1963, p.125.)

An example of the confusion arising from the use of incomplete data is presented by the trilobite *Hemiarges bigener* Bolton (1965). This species was first described from a locality near Bellot Cliff. Material was collected from a thin argillaceous limestone band in the midst of massive conglomerate beds near the base of the Peel Sound Formation. Other specimens were obtained from Cornwallis and Ellesmere Islands. The stratigraphic evidence for the age of *H.bigener* is not conclusive and Bolton dates the species as "most probably of very late Silurian and only possibly early Devonian age." However Kerr (1967, p.682) states that *H.bigener* Bolton is probably early Devonian in age "because it occurs in the Peel Sound Formation which Thorsteinsson and Tozer (in Fortier *et al.*, 1963, p.125) regarded from vertebrate remains, as most probably of Early Devonian age, but possibly Late Silurian." This evidence is considered by Bolton (1965) in his discussion of the age range of the species, but Kerr omits to mention

that Bolton also describes specimens of *H. bigener* in association with Lower and Middle Ludlovian fossils in Ellesmere Island, as well as Middle Devonian corals in Cornwallis Island (Bolton, 1965, p.12). The age of the species is thus far from being accurately known. Kerr's quotation of Thorsteinsson and Tozer is itself misleading. The latter authors note the presence of vertebrates in the Peel Sound Formation of Somerset Island (on the other side of the Boothia Uplift, and 60 miles away from the occurrence of *H. bigener* at Bellot Cliff). They state (p.125):

"....fish remains. . . include representatives of the Cyathaspididae. As presently known this family ranges from Wenlockian (Middle Silurian) to the Lower Devonian. *Corvaspis* and *Anglaspis*, which the forms from Somerset Island resemble most closely, are not known in rocks older than Downtonian (Upper Silurian) so that the general morphological aspect of the cyathaspidids from the Peel Sound Formation suggests a Lower Devonian rather than an Upper Silurian age."

Clearly, as stated here, the evidence suggests nothing conclusive. It could equally well indicate an Upper Silurian age.

Further evidence for the Lower Devonian age of the Peel Sound on Somerset Island is stated by Thorsteinsson and Tozer to be "...the stratigraphic position of the Peel Sound

beds, for the upper age limit of the Read Bay Formation, on which the Peel Sound Formations rest, has been established as middle, and probably upper Ludlovian (Upper Silurian) on Cornwallis Island (Thorsteinsson, 1958)."

This again, does not preclude the possibility of a Silurian age for the lowest Peel Sound beds, especially in view of the fact that the type sections of the Read Bay Formation on Cornwallis Island are 60 miles (96km) to the north of northern Somerset Island, and detailed correlation over such a distance on the basis of a general faunal content is unreliable.

On the basis of the evidence quoted by Kerr (1967, p. 682) and Thorsteinsson and Tozer (in Fortier *et al.*, 1963, p.125) it must be concluded that the rather precise assignation of *H. bigener* Bolton to the Early Devonian (Kerr, 1967) is quite without foundation.

The importance of this discussion lies not so much in the doubt it casts on the age of the Peel Sound Formation, but rather in illustrating how fossil evidence is not being used in rigorous manner in an area of complex faunal and stratigraphic interrelationships. There has been a tendency to identify certain redbed successions as 'Old Red Sandstone' and then to proceed to equate these successions with the Devonian Old Red Sandstone of Britain and elsewhere because of their lithologic similarity. The

name Peel Sound Formation is a useful lithologic term for it can be applied to a body of sediments which were all laid down in a certain limited number of environments. However, it has been emphasised elsewhere in this report that the Peel Sound is not a time-stratigraphic unit. The base of the formation and the subdivision into an upper and lower part are both defined on the basis of important lithologic changes, but these changes are probably more or less diachronous. It is argued elsewhere that the lithologic changes indicate major tectonic movements along the Boothia Uplift, but it is far from proven that movement was simultaneous everywhere along the nearly 200 miles (320km) of the Uplift exposed in Somerset and Prince of Wales Islands.

Wilson's Gorge is the only section from which a reasonable body of evidence has been collected with which to date the Read Bay-Peel Sound transition on Prince of Wales Island. Even here, as discussed above, there is some confusion over the varying interpretations that can be placed on the different faunal elements preserved in the section. As far as the rest of Prince of Wales Island is concerned it can only be stated that the Read Bay-Peel-Sound boundary is probably late Silurian or early Devonian.

2) Upper Peel Sound Formation

It has been argued elsewhere in this report that the Conglomerate, Sandstone and Carbonate Facies of the Upper

Peel Sound Formation are at least in part time equivalent. The three facies are grouped together as the Upper Peel Sound, but it is only the Conglomerate Facies which can actually be seen in the field to overlies the beds of the Lower Peel Sound. Fossil remains in the Conglomerate and Sandstone Facies are too scanty to permit any age determinations to be made. In the Carbonate and Sandstone-Carbonate Facies, however, there are comparatively rich and well preserved faunas.

Listed below is all the available published and unpublished information concerning fossil collections from these two facies to which dates have been assigned.

a) Two collections which were made between Drake Bay and Baring Channel, and are described in Fortier *et al.*, (1963, p.126). G.S.C. loc. 25914:

Leptaena sp.

Camarotoechia cf. *nucula* (Sowerby)

Atrypa sp.

stated by D. J. MacLaren to be latest Silurian or early Devonian. G.S.C. loc. 17195:

Leptaena sp.

Atrypa sp.

Howellella sp.

also considered to be latest Silurian or early Devonian.

b) Collections made by R. L. Christie at Smith Bay, identified by Bolton (1964, unpublished G.S.C. report S-1-1964-TEB) G.S.C. loc. 50758:

Howellella sp.

Delthyris sp.

proetid trilobite, *Warburgella*-type

Beyrichia cf. *arctigena* Martinsson

G.S.C. loc. 50755:

Trepostome bryzoan

Salopina cf. *lunata* (Sowerby)

"*Schuchertella*" sp.

Howellella sp.

Orbiculoides sp.

a pelecypod, *Leioptera*-type

G.S.C. locs. 50743, 50737:

Isorthis? sp.

Bolton states that these collections may be youngest Silurian.

c) Trilobites collected from the vicinity of Drake Bay, and studied by Ormiston (1967, see p.6, 17) indicate a Lower to Middle Devonian (Emsian to Givetian) age. The key types include

Dechenella (*Basidechenella*) *laticaudata*

Ormiston

Schizoproetoides ellesmerensis Ormiston

Cyrtodechenella macnairi Ormiston

Other fossils collected at these localities have not yet been studied in detail.

d) Collections made by A. D. Miall near the west end of Russell Island, identified by Bolton, 1968, (unpublished G.S.C. report S&D-1-1968-TEB) G.S.C. loc. 82456 (Miall loc. 78):

auloporid and disphyllid type corals

Favosites sp.

chonetid brachiopod

Lingula sp.

atrypid brachiopod "of Middle Devonian type according to A. W. Norris."

Nucula (*Nuculoides*) sp.

Euomphalus? sp.

orthoconic cephalopod

Dechenella (*Basidechenella*) sp.

Schizoproetus-Schizoproetoides sp.

kloedenid ostracod

This collection is compared by Bolton to that of Ormiston (1967) above, and is regarded as probably Middle Devonian in age.

e) Collections made by D. S. Broad in the Sandstone-Carbonate Facies on the south side of Baring Channel. Invertebrates studied by Bolton (*op cit.*). G.S.C. locs. 82475-82477

(Miall loc. 50):

Halysites sp.

Favosites sp.

Alveolites sp.

These fossils are assigned to the Silurian.

Preliminary work on vertebrate remains (Broad, 1968, p.22) has shown that the fauna includes *Ctenaspis*, pteraspids, cephalaspids, arthrodires, acanthodians, placoderms and crossopterygians. This assemblage suggests a Downtonian-Dittonian age, but crossopterygians from the Carbonate Facies approximately four miles to the west may be Middle Devonian.

f) Collections made by Miall and Broad in the Sandstone-Carbonate Facies, 4 miles west of the head of Transition Bay. Invertebrates were identified by Bolton (*op. cit.*) G.S.C. locs. 82457-82461, 82478 (Miall loc. 163):

Prismatophyllum sp.

Thecostegites sp.

"*Cyathophyllum*" sp.

These fossils are assigned to the Devonian. Preliminary work on associated vertebrates (Broad, 1968, p.24) indicates the presence of cyathaspids, traquairaspids and *Corvaspis*, suggesting a Downtonian-Dittonian age.

In summary: fossils from the Carbonate and Sandstone-Carbonate Facies indicate ages ranging from highest Silurian

to Middle Devonian. This evidence this confirms the hypothesis that the two facies are at least in part time equivalent to the Conglomerate Facies, and therefore younger than the Lower Peel Sound Formation.

APPENDIX II. MEASURED SECTIONS

All sections are numbered from base and are measured in feet.

1) Read Bay - Peel Sound transition (Lower Peel Sound Formation)

a) Loc. 182, NR859096, seven miles north of Transition Bay:

Section covered by scree, partial exposure
for 200 feet.

32)	Dolomitic conglomerate, pebbles up to 12cm, rests with cut and fill base on (31)	10
31)	Very flaggy, pink stained limestone with shaly streaks, becoming silty in top 4 feet.	12
30)	Dolomitic conglomerate, pebbles up to 6cm.	5
29)	Laminated silty sandstone, red coloured with greenish patches.	5
28)	Dolomitic conglomerate, pebbles up to 13cm, gneiss pebbles up to 3 cm very rare.	25
27)	Reddish, fine grained silty sandstone, laminated in places.	10
26)	Dolomitic conglomerate, pebbles up to 13cm, commonly 2-3cm in diameter.	23
25)	Red, silty, medium grained sandstone, laminated in places, scattered dolomite pebbles.	1½
24)	Dolomitic conglomerate, pebbles up to 3cm, top ten inches pink stained. Abrupt contact with (23), grades up into (25).	3
23)	Pinkish, sometimes laminated silty sandstone	4
22)	Grey calcareous sandstone, grading up into (23).	8

- 21) Dolomitic conglomerate, pebbles up to 13 cm, no limestone pebbles seen. Aston quartzite pebbles up to 6cm, very rare. Some thin, impersistent lenticles of bright red, fine grained silty sandstone, often eroded by troughs in the overlying conglomerate 69
- next 22 feet of section obscured by scree
- 20) Flaggy limestone, some shaly wisps. 3
- 19) Slightly calcareous medium grained sandstone with scattered dolomite pebbles up to 3cm, fish remains. 9
- 18) Dolomitic conglomerate with some calcite in matrix, pebbles up to 6cm, comminuted fish debris. 7
- 17) Laminated slabby limestone with shaly streaks and ripple marks. Pink stained near top. 7
- 16) Dolomitic conglomerate with rare scattered limestone pebbles up to 6cm, dolomite and calcite crystals in matrix 5
- 15) Coarse grained grey sandstone with dolomite pebbles up to 3mm. 3
- 14) Flaggy grey limestone, fairly abundant ostracods. 13
- 13) Slightly calcareous grey siltstone with rare scattered dolomite pebbles, pink in places, sometimes finely laminated. 19
- 12) Bright red, silty, nodular limestone, grades up into (13). 1
- 11) Conglomerate, 100% dolomite pebbles up to 12cm in diameter. Some crystalline calcite in matrix. 5
- 10) Fine grained calcareous, silty, flaggy sandstone, grey, some dolomite pebbles. Section partly obscured. 64
- 9) Grey silty limestone with abundant and persistent shaly laminations every 0.25 to 2.0 inches. Flat bedded and flaggy, sharp contact with (8). 20

8)	Slightly calcareous grey siltstone with scattered dolomite pebbles at base.	16½
7)	Dolomitic and chert conglomerate, pebbles up to 12cm, rests on (6) with sharp contact, grades into (8).	7
6)	Grey silty sandstone with slightly calcareous matrix and scattered limestone nodules.	60
5)	Laminated grey limestone with silty base resting on (4) with sharp contact. Grades up into (6).	5½
4)	Non-calcareous, silty grey sandstone.	4½
3)	Laminated, slightly nodular limestone, grades into (4).	2
2)	Medium grained, grey dolomitic sandstone, scattered dolomite pebbles up to 3cm.	1
1)	Conglomerate, dolomite pebbles up to 3cm in calcite matrix. Cut and fill contact with Read Bay limestones, grades up into (2), contains fish fragments.	1

Bed (1) underlain by highly fossiliferous limestones of the Read Bay Formation.

TOTAL----- 429 feet.

b) Loc. 189, NR841517, 10 miles NNW of Cape Brodie:

Approximately 200 feet of conglomerates overlies bed (37).

37)	Nodular limestone with fragments of orthoconic cephalopods.	3
36)	Mainly red stained, medium to coarse grained sandstone with abundant pebbly and conglomeratic layers. Chert and dolomite pebbles abundant.	130

35)	Conglomerate : limestone pebbles 95% (probably Read Bay Formation), 5% Hunting dolomite and chert, pebbles up to 6cm, matrix clean washed quartz sandstone. Some red stained sandy layers with fish fragments.	15
34)	Pink, medium grained sandstone.	3
33)	Grey siltstone, grades up into (34).	2
32)	Medium grained grey sandstone, grades up into (33).	9
31)	Conglomerate, clean white quartz sandstone matrix.	1
30)	Pink and grey medium grained sandstone, grading up into (31).	17
29)	Conglomerate, limestone, chert and dolomite clasts up to 13cm.	20
28)	Medium grained grey sandstone.	60
27)	Medium grained red sandstone, scattered chert fragments.	15
26)	Conglomerate with limestone and dolomite clasts, scattered chert pebbles.	6
25)	Pink silty sandstone, abundant fish remains.	12
24)	Conglomerate as (35).	6
23)	Medium to coarse, even bedded, even grained sandstone; grey with some pink staining. Scattered pebbles and pebbly seams of chert, dolomite and limestone.	34
22)	Grey pebbly sandstone, becoming conglomeratic at top. Clasts as in (35).	3
21)	Similar to (35) with red stained matrix, becoming very sandy at top.	3
20)	Conglomerate, 95% limestone clasts (probably Read Bay Formation), 5% Hunting chert and dolomite, both lithologies up to 6cm, matrix clean washed quartz sandstone.	3

19)	Medium grained sandstone with scattered white chert fragments, rapid gradation into (20).	36
18)	Nodular grey limestone containing gastropods.	0½
17)	Pink, medium grained sandstone, gradational contact with (16).	4
16)	Grey limestone with shaly wisps.	4
15)	Red stained, well bedded medium grained sandstone with some silty and flaggy layers	45
14)	Medium grained grey sandstone, some laminated layers, symmetrical ripples.	45
13)	Flaggy pink and green siltstones, borings and desiccation cracks.	4
12)	Limestone/shale alternations. Limestone is nodular, shale shows desiccation cracks. Grey at base, becoming pink near top, also very bored and silty near top.	4
11)	Coarse, even-grained massive sandstone, pink in colour.	4
10)	Fine grained silty grey sandstone, scattered coarse quartz grains after first few feet.	64
9)	Nodular limestone with shaly wisps, rapid transition into (10).	1½
8)	Same as bed (3).	15
7)	Nodular, sandy limestone.	0½
6)	Grey silty sandstone with mud streaks fine laminae and coarse grains, similar to bed (3).	16
5)	Nodular limestone with shaly wisps showing desiccation cracks. Brachiopods present.	1½
4)	Transition from (3) to (5), silty sandstone with limestone nodules.	

- 3) Mainly fine grained grey, silty sandstone, with patches and streaks of medium grained quartz grains, also very finely laminated beds with greenish shale streaks, sometimes ripple marked, ripped up or showing desiccation cracks. 20½
- 2) Nodular limestone with shaly wisps and coral fragments. 12
- 1) Fine grained grey silty sandstone, much bored and churned. 20

Bed (1) underlain by Read Bay limestones, which contain occasional beds of white quartz sandstone 2-3 feet thick.

TOTAL (beds 1-37) ----- 639 feet

Other Lower Peel Sound Formation sections not completely exposed. See text and fig. 6 for reconstructions of sections at Pandora Island, Prescott Island and Mount Matthias.

2) Conglomerate-Sandstone Transition Facies

a) Loc. 25, NS334923, 7½ miles southwest of Bellot Cliff.

Sandstone scree, 10-15 feet.

25)	Pebbly sandstone.		2
24)	Variegated sandstone unit: dark brown silty sandstone grades up into laminated medium grained sandstone, grades up into finely laminated orange silty sandstone.		5½
23)	Coarse grained pebbly sandstone		5
22)	Repeat of (21), pebbly layer at base.		7
21)	Coarse grained sandstone grading up into fine grained sandstone. The latter is orange coloured and finely laminated		6
20)	Coarse grained sandstone grading up into fine grained sandstone.		4½
19)	Conglomerate, pebble count: maximum clast size:		
	Aston quartzite	40%	8 inches
	green quartzite	13	4
	calcisiltite	2	2
	acid gneiss	33	6
	gabbro	6	4
	Hunting oolite,		
	dolomite	5	3
	vein quartz	1	1
	chert	rare	3
			1½
18)	Coarse grained pebbly sandstone		19
17)	Medium grained sandstone grading up into fine grained orange, finely laminated sandstone at top.		10
16)	Conglomerate with thick coarse grained sand lenticles up to 2 feet thick. Grades up to (17).		10
15)	Sandstone unit: very coarse grained at base,		

	grading up from (14), becoming gradually finer grained to orange fine grained silty sandstone at top. Trough crossbedding.	6
14)	Conglomerate with sandy patches and lenticles. Erosional base, max clast size 5 inches.	1
13)	Same as bed (9), pebbles scattered and in lenticles.	11
12)	Fine grained, orange, finely laminated sandstone, showing very small scale planar crossbeds, one inch thick or less.	9
11)	Same as bed (9), grades by intertonguing into (12).	6
10)	Fine grained sandstone with lenticles of medium grained sandstone.	2
9)	Medium to coarse grained sandstone with scattered clasts of fine grained silty sandstone.	6
8)	Fine grained, micaceous silty sandstone.	2
7)	Variegated sandstone unit: alternating medium and fine grained lenticles 0.25 to 4.0 inches thick. Rare, scattered pebbles, some trough crossbedding.	17
6)	Conglomerate with three thick sandstone lenticles, resting on (5) with cut and fill contact, grading up into (7).	3
5)	Sandstone: medium grained at base, becoming fine grained and in places silty and micaceous after one foot.	11
4)	Conglomerate, maximum clast size 8 inches, clast count:	
	Aston quartzite	26%
	green quartzite	8
	Hunting dolomite	26
	foliated gneiss	37
	gabbro	3
		8
3)	Medium to coarse grained sandstone with occasional silty layers.	20

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2)	Conglomerate with abundant sandstone lenticles, maximum clast size 6 inches.	6½
1)	Medium grained sandstone with occasional pebbles, trough and planar crossbeds.	18
TOTAL -----		197 feet

b) Loc. 29, NS337922, 7½ miles southwest of Bellot Cliff.

	Above (35) section scree covered.	15
35)	Fairly coarse grained, pebbly sandstone.	2
34)	Fine grained orange sandstone, sharp contact with (35)	1½
33)	Coarse grained pebbly sandstone, trough crossbeds.	23
32)	Fine grained sandstone, grading up into (33)	3
31)	Coarse grained pebbly sandstone; sharp, flat contact with (30).	7
30)	Same as bed (5). Gradational contact with (29), rather dark brown colour at base.	5
29)	Coarse grained pebbly sandstone with channels up to five feet across.	4½
28)	Conglomerate, resting on (27) with cut and fill base.	4
27)	Medium grading up to fine grained orange sandstone.	2
26)	Conglomerate with sandstone lenticles, maximum clast size 8 inches.	8
25)	Alternating lenticles of medium and fine grained sandstone.	6
24)	Conglomerate with sandstone lenticles at top	

and bottom. Clast count:

	Aston quartzite	36%	
	green quartzite	8	
	Hunting dolomite	32	
	gneiss	19	
	weathered gabbro	3	
	basic volcanics	2	12
23)	fine grained orange silty sandstone with medium grained sandstone lenticles; fairly well laminated, abundant trough cross- beds.		8
22)	Coarse grained sandstone.		3
21)	Pebbly sandstone, grading up into conglom- erate with sandstone pockets and lenticles. Maximum clast size 7 inches.		7
20)	Medium grained sandstone grading up into bed (5) lithology.		5½
19)	Conglomerate with sandstone lenticles, maximum clast size 10 inches.		10
18)	Medium to fine grained sandstone.		3
17)	Conglomerate, maximum clast size 5 inches.		3
16)	Medium grained sandstone, some fine lenticles and scattered pebbles.		5½
15)	Conglomerate with occasional sandstone lenticles, maximum clast size 7 inches.		9
14)	Coarse grained pebbly sandstone.		1
13)	Dark brown siltstone.		1
12)	Coarse grained pebbly sandstone.		4
11)	Bed (5) lithology, with some medium grained sandstone lenticles at top.		11
10)	Coarse to medium grained sandstone with rare pebbles.		8
9)	Medium grained sandstone, grading up to		

	bed (5) lithology.			6
8)	Conglomerate with coarse grained sandstone lenticles, clast count, maximum clast size:			
	Aston quartzite	29%	6 inches	
	green quartzite	6	3	
	Hunting dolomite	26	4	
	gneiss	35	6	
	basic volcanics	2	5	
	gabbro	2	3	7
7)	Pebbly sandstone			1½
6)	Coarse coarse pebbly sandstone, cut and fill contact with (5), grades up to bed (5) lithology.			7
5)	Fine grained orange, silty, micaceous sand- stone.			5
4)	Conglomerate with sandstone lenticles, clast imbrication.			14
3)	Medium to coarse grained sandstone.			4
2)	Coarse grained sandstone, grading up into bed (5) lithology.			2
1)	Conglomerate with sandstone lenticles, maximum clast size 10 inches.			20
	TOTAL-----			238 feet

c) Loc. 37, NT097340, eastern end of Russell Island:

6)	Conglomerate.	15
5)	Medium grained sandstone, asymmetric ripples near top.	5
4)	Conglomerate.	5
3)	Coarse grained sandstone with abundant pebbles and thin conglomerate seams. Gradational contact with (2).	18

- 2) Conglomerate resting with cut and fill base on (1). Sandstone lenticles, becoming more frequent near top. Clast count and maximum clast size:

Aston quartzite	13%	8 inches
Hunting dolomite	17	5
laminated green sediment	66	4
weathered gabbro	4	2

clasts show imbrication. 34

- 1) Fine grained, commonly laminated, orange sandstone, asymmetric ripples. 5

TOTAL----- 82
feet

d) Loc. 10, NS674175, northwest coast of Prescott I.

- 8) Boulder conglomerate with sandstone lenticles every 3-10 feet. Maximum clast size 10 inches. 40
- scree covered interval. 12
- 7) Thin bedded, medium grained sandstone. 3
- scree covered interval, probably mainly sandstone and pebbly sandstone. 40
- 6) Repeat of bed (5), resting on (5) with sharp contact. 3
- 5) Coarse grained, red, finely laminated sandstone, grading up to siltite. Gradational contact with (4). 1½
- 4) Coarse grained pebbly sandstone with clasts of gneiss and intraformational conglomerate seams. Maximum clast size 4 inches. 1
- 3) Greenish grey siltstone. 1½
- 2) Fine grained micaceous, reddish sandstone, gradational contact with (1). 1

- 1) Coarse grained, red, finely laminated sandstone.

3

TOTAL----- 106
feet

e) Loc. 111, NR691954, southwest Prescott Island:

- 4) Boulder conglomerate with abundant sandstone lenticles extending laterally for 6-30 feet, maximum clast size 10 inches.

12

- 3) Medium to coarse grained sandstone, rare pebbles, some trough crossbedding.

7

- 2) Coarse grained red sandstone beds 1 foot thick, alternating with conglomerate beds 1 foot thick. Clasts mainly gneiss and Aston quartzite, trough crossbeds.

10

- 1) Coarse grained red pebbly sandstone, trough crossbeds up to 3 feet wide.

24

TOTAL----- 53
feet

3) Sandstone-Carbonate Transition Facies

a) Loc. 50(L), NS120870, south side of Baring Channel,
measured by D. S. Broad.

19)	Grey blue, nodular limestone.	3
18)	Grey limestone.	1
17)	Grey, flaggy limestone, abundant fish fragments.	2
16)	Grey limestone with abundant ostracods.	1
15)	Grey siltstone with well preserved fish, including <i>Pteraspis</i> and arthrodires.	8
14)	Hard blue, nodular limestone with colonial corals.	5½
13)	Grey, flaggy siltstone.	6
12)	Grey limestone with articulate brachiopods.	3
11)	Grey limestone with abundant ostracods.	5
10)	Finely laminated greenish siltstone.	1
9)	Flaggy grey limestone with occasional articulate brachiopods.	5
8)	Medium grained grey flaggy sandstone, with abundant articulate brachiopods, trace fossils and occasional fish fragments.	5
7)	Greenish siltstone with occasional fragments of porolepid bone.	2
6)	Grey blue siltstone with occasional ostracods.	8
5)	Rubbly limestone with arenaceous laminae, brachiopods.	2
4)	Grey blue limestone.	2
3)	Light blue, rubbly limestone, sandy near base.	10

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2)	Grey siltstone with fine arenaceous lenses, passing up into (3).	1
1)	Greenish siltstone with occasional fish fragments, passing up into (2).	2

TOTAL----- 73
feet

b) Loc. 50(D), NS128871, south side of Baring Channel,
measured by D. S. Broad:

3)	Flaggy yellow sandstone with abundant fish remains, often resting on each other with imbricate structure. Occasional ostracods.	10
2)	Limestone with <i>Favosites</i> .	0½
1)	Hard, dark blue limestone	8

TOTAL----- 18½
feet

c) Loc. 50(H), NS131872, south side of Baring Channel,
measured by D. S. Broad:

9)	Dark blue limestone with colonial corals	4
8)	Blue grey, calcareous siltite.	4
7)	Light blue, yellow weathering limestone with corals.	4
6)	Light blue, calcareous siltite with trace fossils, <i>Pteraspis</i> .	3
5)	Light blue limestone with colonial corals.	5
4)	Light blue, shaly limestone with abundant ostracods.	2
3)	Calcareous siltite with fish fragments,	

ostracods abundant in upper part.	6
2) Hard, dark blue, irregular bedded limestone, <i>Favosites</i> .	8
1) Yellow weathering, calcareous, flaggy siltstone, abundant ostracods.	2
TOTAL-----	38 feet

d) Loc. 50(K), NS166872, south side of Baring Channel,
measured by D. S. Broad:

15) Fine grained, cream coloured, laminated sandstone, alternating with calcareous shale. Some reddish patches, <i>Pteraspis</i> .	30
FAULT ?	
14) Red and grey, finely laminated sandstone.	3
13) Bluish, calcareous shale.	2
12) Calcareous siltstone with calcareous shale beds, plant fragments, trace fossils, <i>Pteraspis</i> .	3
11) Buff weathering sandstone with fragments of arthrodires, <i>Pteraspis</i> , load casts.	2
10) Red, well bedded, calcareous shale with pteraspids.	1½
FAULT ?	
9) Massive, light blue, calcareous siltstone with abundant pteraspids, ctenaspids, arthrodires, in one horizon 1 foot thick.	15
8) Massive, calcareous siltstone.	1
7) Massive, bluish, calcareous siltstone with <i>Lingula</i> , pteraspids.	3

6)	Laminated, yellow-grey, calcareous sandstone	3
5)	Grey, micaceous sandstone with occasional intercalations of green and reddish shale, trace fossils.	2
4)	Bluish, calcareous siltstone.	2
3)	Fine to medium grained calcareous, yellow sandstone, with pteraspids, ctenaspids, arthrodiures.	4
2)	Yellow, calcareous sandstone.	2
1)	Calcareous siltstone.	2
TOTAL-----		75½ feet

N.B. A single coral-bearing limestone is used as a marker horizon to correlate the following beds: Bed 14, Loc. 50(L); Bed 2, Loc 50(D); Bed 2, Loc. 50(H). Fish bearing beds above these coral limestones are correlated with bed 11, Loc. 50(K). (D. S. Broad, personal communication, 1968.)

e) Loc. 85, NS279196, Browne Bay

7)	Medium grained red sandstone with mud-flake conglomerate layers, scattered comminuted fish debris. Rests with sharp contact on (6).	10
6)	Medium grained red silty sandstone.	5
5)	Dolomite/shale alternations; dolomite beds 0.25-1.0 inches thick, shales 1-2 inches thick. Dolomites contain gastropods, ostracods.	9
4)	Grey shale, passing up into (5).	12
3)	Medium grained white sandstone.	12
2)	Dolomite/shale alternations; dolomite seams nodular in places, elsewhere up to 5 inches thick. Fairly abundant indeterminate shell debris.	6
1)	Grey shale.	6
TOTAL-----		60 feet

f) Loc. 90, NS250143, Browne Bay:

12)	Fine grained, reddish and greenish mottled sandstone, mudflake conglomerate, abundant fish debris.	20
11)	Dolomite/shale alternations, more than 25% dolomite beds, grades up into (12)	15
10)	Shale with occasional dolomite lenticles.	12
9)	Massive dolomite, fossils as in (6).	1
8)	Dolomite/shale alternations, dolomites become thicker near top, passing into (9).	8
7)	Shale with occasional dolomite beds.	10
6)	Grey dolomite/shale alternations, shales	

very thin near centre of unit. Ostracods abundant, orthocone cephalopods and high-spire gastropods are also common.		8
5)	Massive grey sandstone.	20
4)	Very friable, reddish silty shale, passing up into (5).	1½
3)	Grey sandstone passing up into (4).	2½
2)	Grey silty shale with 1 inch thick dolomite beds extending laterally for 3 inches to several feet. Abundant ostracods in the dolomites.	2½
1)	Creamy-greenish weathering medium grained sandstone, scattered fish remains, abundant trough crossbeds, one 4 foot reddish layer. Grades up into (2).	40
TOTAL-----		140½ feet

g) Loc. 98, NS344015, Browne Bay:

4)	Red and green mottled siltstone	2
3)	Grey shale with scattered nodules and lenticles of dolomite, ostracods and orthoconic cephalopods.	10
2)	Cream, coarse to medium grained sandstone, trough crossbeds, fish debris.	20
1)	Medium grained red sandstone with mudflake conglomerate layers, small scale planar crossbeds.	20
TOTAL-----		52 feet

h) Loc. 134, NR529747, Muskox Hill:

5) Greenish grey and reddish, fine grained sandstone, coarse layers contain mudflake conglomerate and fish debris, and occasional pelecypods.	3
scree of red sandstone and coarse grained white sandstone.	25
4) Medium grained red sandstone with occasional mud seams and mudflake conglomerate showing red or green colour.	8
3) Greenish and reddish siltstone with lenticles of white sandstone, one lenticle occurs as a trough infill.	3
2) Fine grained pinkish sandstone with abundant ripple drift crossbedding, planar crossbedding and primary current lineation.	3
1) Dark red, fine grained, silty sandstone.	4
TOTAL-----	46 feet

i) Loc. 135, NR530739, Muskox Hill:

11) Alternations of red siltstone and medium grained red sandstone in beds 10-12 inches thick. Gradational contact with (10).	10
10) Fine grained red siltstone, gradational contact with (9).	6
9) Green silty shales containing lenticles of medium grained white sandstone with greenish mudflakes. Sandstone lenticles are 3 inches thick and at least 30 feet in lateral extent, and they contain <i>Lingula</i> , and abundant casts of small pelecypods.	6
8) Fine grained greenish grey sandstone, mainly scree.	30

7)	Fine to medium grained red sandstone with mudflake fragments.	6
6)	Greenish siltstone with streaks and lenticles of fine grained sandstone.	3
5)	Medium grained red sandstone.	1
4)	Fine grained red sandstone and siltstone.	6
3)	Green siltstone and coarse grained white sandstone in festoon crossbedded relationship, erosional base.	1
2)	Green siltstone with lenticles and patches of medium grained red sandstone, some mudflakes. (This bed equivalent to bed 5, loc. 134)	4
1)	Coarse grained white sandstone, grading up into (2).	3
TOTAL-----		76 feet

j) Loc. 137, NR512738, Muskox Hill:

8)	Fine grained greenish sandstone with scattered but well preserved fish remains.	2
7)	Red and green siltstone.	3
6)	Fine grained greenish sandstone.	2
5)	Red silty shale, gradational contact with bed (4).	1½
4)	Greyish silty shale with nodular dolomite layers. Dolomites contain ostracods, pelecypods and high spire gastropods.	8
3)	Coarse grained white sandstone, grading up through medium grained sandstone to (4)	1
2)	Greenish grey shaly siltstone, with occasional thin but persistent coarse grained white sandstones.	6

250.

1) Fine grained reddish sandstone. 6

TOTAL----- 29½
feet

k) Loc. 139, NR495737, Muskox Hill:

11) Fine grained, greyish-white sandstone. 0½

10) Greenish grey shale. 1½

9) Red shale. 1

8) Grey dolomite/shale alternations, as (6). 10

7) Medium grained white sandstone. 1

6) Grey shale with scattered nodules and
lenticles of dolomite, small pelecypods. 6

5) Medium grained white sandstone. 1

4) Medium grained red sandstone with scattered
fish remains. 5

3) Red and green siltstones. 1

Scree. 10

2) Fine grained greenish white sandstone 10

Scree. 5

1) Fine to medium grained red sandstone with
mudflake conglomerate and comminuted fish
debris. 1

TOTAL----- 53
feet

1) Loc. 141, NR469722, Muskox Hill:

5)	Medium grained red sandstone with mudflakes and comminuted fish debris, interbedded with fine grained, well laminated sandstone and red siltstone.	6
4)	Green shale with occasional dolomite nodules. Grades up to (5).	5
3)	Coarse to medium grained white sandstone with fine grained sandstone and shale intercalations.	6
2)	Green and red shale.	2
1)	Coarse to medium grained white sandstone, with scattered mud intraclasts.	6
TOTAL-----		25 feet

m) Loc. 142, NR443832, Muskox Hill:

6)	Grey sandy shale, with sandstone layers up to 3 inches thick.	10
5)	Grey shale with small dolomite nodules containing indeterminate shell debris. Shales contain small fish and plant fragments, and <i>Lingula</i> .	4
4)	Shale with lenticles of fine to coarse grained white sandstone.	5
3)	Massive shaly dolomite with well preserved fish remains, including whole pteraspid carapaces.	5
2)	Grey shale with scattered dolomite nodules, grading up into (3).	4
1)	Greyish sandy dolomite.	1
TOTAL-----		29 feet

n) Loc. 162, NQ663918, Transition Bay:

7) Reddish silty sandstone.	1
6) Grey shale.	1
5) Silty dolomite/shale alternations, units each 0.5-1.0 inches thick. Very even bedding, grades up into (6).	10
4) Grey silty shale. Near top dolomite nodules appear, nodules are 1-4 inches long, 0.5-1.0 inches thick, they contain abundant indeterminate shell debris. Abundant ostracods in the shales.	5
3) Medium to coarse grained sandstone with fish fragments, occasional quartz pebbles up to 0.5cm present. Grades up to (4).	1½
2) Grey silty shale, grades up to (3).	3
1) Fine to medium grained grey sandstone, grades up to (2).	1
TOTAL-----	22½ feet

o) Loc. 163, NQ657196, Transition Bay:

11) Medium grained sandstone resting on (10) with erosional base, erosional relief of about one inch. Well preserved fish remains.	6
10) Grey silty shale.	1
9) Medium grained grey sandstone, grading up to (10).	1
8) Silty shale, grading up into (9).	4
7) Medium to coarse grained grey sandstone, scattered pebbles of quartz and chert up to 0.5cm in diameter, fish fragments, grades up into (8).	2

6)	Grey sandstone and shale, poorly exposed. Sandstone contains plant fragments, shales contain well preserved fish remains.	1
	Scree	8
5)	Silty dolomite with ostracods and fish fragments, some wisps and streaks of argillaceous material, some showing ripple form.	6
4)	Medium grained grey sandstone, occasional coarser grains up to 2mm in diameter.	2
3)	Grey shale with dolomitised compound corals at base, grading up into (4).	4
2)	Sandy siltstone, gradational contact with (1), becoming laminated at top, finer grained and with ripples. Grades up into bed (3).	4
1)	Grey calcareous shale with compound corals near base.	5
TOTAL-----		44 feet

p) Loc. 171, NQ697950, Transition Bay:

9)	Massive grey dolomite.	4
8)	Medium grained grey quartzose sandstone, grading up into (9).	1
7)	Finely laminated grey siltstone, grades up into (8).	1½
6)	Medium to coarse grained grey quartzose sandstone, with ripples.	1
5)	Silty dolomites, mainly nodular or in beds with minor shale intercalations, some faint ripples. Borings, carbonaceous streaks (plants?), high spire gastropods, articulate brachiopods and orthocone cephalopods. Grades up into (6).	16

4)	Fine grained greenish siltstones with occasional sand grains and carbonaceous streaks.	3
3)	Silty, laminated dolomites.	4
2)	Medium grained grey sandstone, generally massive, but with some laminated or ripple marked layers. Top shows pebbles up to 1cm and some siltstone intraclasts. Rapid transition into (3).	4
1)	Silty dolomite, occasionally nodular, some shaly streaks. Shell debris includes gastropods, brachiopods. Grades up into bed (2).	5
TOTAL-----		39½ feet

q) Loc. 174, NQ723986, Transition Bay:

3)	Variegated fine to medium grained grey sandstones with very thin shale intercalations, desiccation cracks, planar crossbeds, fish fragments. Upper half mainly silty with some dolomitic streaks and nodules.	18
2)	Grey, fine to medium grained sandstone.	5
1)	Reddish and greenish-grey, mottled silty sandstone, becoming coarse at top. Colour gradation into (2).	4
TOTAL-----		27 feet

4) Carbonate Facies

a) Loc. 79, MS942966, west end of Russell Island.

8) Massive dololutites, small shell fragments.	6
Section obscured.	15
7) Laminated dololutites.	2
Section obscured.	10
6) Massive dololutites.	2
5) Dolomitic pseudobreccia.	2½
4) Laminated dololutites.	1½
Section obscured.	9
3) Laminated dololutites, intraformational breccia, some trace fossils.	4
2) Laminated dololutites.	6
1) Dark grey crystalline dolomite.	0½
TOTAL-----	58½
	feet

APPENDIX III. CONGLOMERATE FIELD DATA

Grid references of localities,
 clast counts, (number of clasts percent),
 maximum clast sizes for each lithology (in inches).

TABLE X: Clast counts, grid references, Bellot Cliff area:

Loc.	grid ref.	GN	A	GQ	GAB	H	RB	BV	o
15	NT388019	4	35	35	3	20	-	2	-
15A	"	11	27	18	8	36	-	-	-
15B	"	11	18	31	10	30	-	-	-
15C	"	2	29	38	6	24	-	-	-
16	NT382022	2	15	40	2	40	-	-	-
24	NS313926	70	25	-	t	t	-	-	2
25a	NS333921	37	26	8	3	26	-	-	-
25b	"	29	26	4	-	30	-	9	-
25c	"	33	40	13	6	5	-	-	2
26	NS401903	45	30	-	-	25	-	-	-
29a	NS375920	35	29	6	2	26	-	2	-
29b	"	19	36	8	3	32	-	2	-
30	NS345921	38	25	8	9	20	-	-	-
31a	NS397963	4	50	-	31	4	1	10	-
31b	"	20	45	-	17	10	-	6	-
31A	"	13	33	-	28	18	-	6	-
31B	"	22	36	-	25	11	-	6	-
31C	"	30	27	-	24	14	-	-	1
31D	"	23	44	-	19	10	-	2	-
31E	"	19	36	-	31	8	-	4	-
31F	"	24	45	-	16	14	-	-	-
32	NS402967	15	53	-	20	7	-	5	-
33	NS409979	4	39	-	43	9	-	5	-
34	NS418990	20	45	-	20	5	-	10	-
35	NS422997	23	40	2	20	9	-	6	-
36	NT353093	-	21	48	3	28	-	-	-
36A	"	-	34	38	12	15	-	-	-
36B	"	-	38	48	4	10	-	-	-
37	NT341097	-	13	66	4	17	-	-	-
38	NT350103	-	14	56	5	25	-	-	-
39	NT350103	-	5	30	1	-62-	-	-	-
83	NS342943	15	43	-	24	16	-	2	-
84A	NS425962	-	42	-	2	47	5	-	3
84B	"	-	29	-	5	49	15	-	1

GN=gneiss
 A=Aston quartzite
 GQ=green quartzose seds.
 GAB=gabbro

H=Hunting dolomite and chert
 RB=Read Bay limestone
 BV=basic volcanics
 o=others.

TABLE XI: Maximum clast size, Bellot Cliff area:

loc.	GN	A	GQ	GAB	H	RB	BV	o
15	10	16	10	4	6	-	3	-
16	4	12	12	6	6	-	-	8
24	6	6	-	-	-	-	-	1.5
25	6	8	4	4	3	-	-	2
26	20	24	-	20	-	-	-	-
29	6	6	3	3	4	-	5	-
30	8	10	4	6	5	-	-	-
31a	20	24	-	12	4	4	6	-
31b	10	20	-	12	9	-	4	-
32	12	36	-	12	7	-	5	-
33	18	24	-	15	6	-	10	-
34	24	48	-	18	6	-	4	-
35	10	18	-	12	16	-	8	-
36	-	10	8	6	6	-	-	-
37	-	8	4	2	5	-	-	-
38	-	8	6	4	7	-	-	-
39	-	4	6	2	10	10	-	-
83	12	18	-	8	8	-	-	-

TABLE XII: Grid references, clast counts, Mount Matthias area:

loc.	grid ref	GN	A	GQ	GAB	H	RB	BV	o
55	NS501494	16	60	10	7	2	3	1	1
56	NS504488	11	70	5	14	-	-	-	-
57	NS512476	8	74	8	10	-	-	-	-
58	NS506467	3	70	-	24	-	1	2	-
62	NS517516	7	70	-	18	1	-	4	-
65	NS531510	2	38	-	40	2	2	16	-
66	NS523504	10	54	9	26	-	-	-	1
68	NS539504	-	45	-	52	2	-	1	-
69	NS534500	2	79	-	7	2	-	10	-
70	NS522492	2	60	-	33	1	-	4	-
71	NS543493	-	46	-	48	-	1	6	-
73	NS550479	-	25	-	-	15	59	1	-
76	NS539464	-	52	-	40	-	8	-	-
77	NS524461	-	53	-	44	-	-	3	-

TABLE XIII: Maximum clast size, Mount Matthias area:

loc	GN	A	GQ	GAB	H	RB	BV	o
55	12	12	4	6	5	6	2	2
56	10	14	6	8	-	-	-	-
57	6	24	4	14	-	-	-	-
58	10	16	-	10	-	6	4	-
62	12	18	-	10	4	-	5	-
65	6	12	-	10	2	1	4	-
66	12	20	4	12	-	-	-	2
68	-	18	-	12	2	-	1	-
69	6	16	-	4	3	-	3	-
70	6	16	-	10	2	-	1	-
71	-	14	-	10	-	-	5	-
73	-	5	-	-	1	4	4	-
76	-	12	-	10	-	3	-	-
77	-	16	-	12	-	-	2	-

TABLE XIV: Grid references, clast counts, Prescott I. area.

loc	grid ref.	GN	A	GAB	RB	BV	o
100A	NR738951	71	24	2	-	1	2
100B	"	65	31	3	-	-	1
101A	NR744957	64	31	5	-	-	-
101B	"	51	32	16	-	-	1
105	NR727947	70	29	1	-	-	-
106	NR718944	77	19	2	1	-	-
107	NR716946	71	23	6	-	-	-
108A	NR704962	62	30	8	-	-	-
108B	"	83	14	3	-	-	-
109	NR698937	82	14	4	-	-	-
110	NR715940	74	19	6	-	-	2
111	NR689955	80	18	2	-	-	-

TABLE XV: Grid references, clast counts, Pandora I. area:

loc	grid ref.	GN	A	GAB	H	RB
166	NR718746	12	8	-	80	-
118a	NR727776	21	2	-	77	-
118b	"	71	8	-	21	-
119	NR731778	81	10	-	9	-
120	NR734779	71	15	2	12	-
122	NR742734	21	2	-	78	-
123	NR749746	1	1	-	98	-
144	NR803654	84	2	-	-	14
145	NR775668	92	2	4	-	2
151	NR751670	95	4	-	-	1
152	NR754670	97	2	1	-	-
153	NR759657	90	9	1	-	-
154	NR753640	99	1	-	-	-
155	NR753634	97	3	-	-	-

APPENDIX IV. NEWLY DISCOVERED EXPOSURES OF THE ASTON
AND HUNTING FORMATIONS ON PRINCE OF WALES I.

The Aston Formation has previously been recorded at one locality west of the Boothia Uplift, on central Prescott Island (G.S.C. map 3-1967). Field work in 1967 showed the existence of two more small outcrops of the Aston Formation and one outcrop of the Hunting Formation (See geological map accompanying this report).

Pandora Island (loc. 126, NR790782: cliffs at the coast of east central Pandora Island expose the Aston Formation. Several hundred feet of red clastics are exposed, including well lithified quartz sandstones and interbeds of coarse breccia. The latter is poorly sorted, arkosic and very well indurated. It contains clasts up to 50cm of metamorphic rocks, chiefly acid gneisses. The sandstone is, in places, well laminated. One sample was processed for heavy minerals and was found to contain well rounded zircon grains (see fig. 39 and table VII). The beds dip at 70° to the northwest and are faulted against steeply dipping beds of the Allen Bay and Read Bay Formations; the lower contact was not seen.

Eight miles northwest of Cape Brodie (loc. 193, NR838475) the Aston and Hunting Formations are exposed in the fault zone bordering the Boothia Uplift. The outcrops of the two formations are separated by a stream valley

along the fault line. The Aston (east of the fault) consists of reddish quartzites. The Hunting outcrop (west of the fault) shows 20 feet of yellow-weathering dolomites, mainly intraformational dolomitic conglomerates with minor shale, overlain by approximately 10 feet of grey sandy dolomite. Dip is 80° to the west. Approximately 200 feet to the west up a stream gorge, overturned Read Bay limestones are exposed, passing up into the Peel Sound Formation. Between the Read Bay and the Hunting the section is obscure.

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Photograph 1.

Pandora Island: general view from the south. Steeply dipping Allen Bay and Read Bay Formations of the Cornwallis Fold Belt strike northeast and form a prominent ridge extending to the horizon at right. Dip decreases to the west, and hills at left are underlain by horizontal Upper Peel Sound Formation. Steeply dipping Read Bay Formation is overlain by Peel Sound beds at right.

Photograph 2.

Read Bay Formation near Cape Brodie, looking north. The beds are tilted and overturned, forming part of the Cornwallis Fold Belt.

PS

RB / AS

PS

RB





Photograph 3.

The unconformity near Bellot Cliff. Upper Peel Sound conglomerates dipping 10° at E 45° S rest on tilted and eroded Read Bay limestones. The angular discordance between the two formations is approximately 20° .

Photograph 4.

Transition Bay, 'Wilson's Gorge' section looking northwest. Steeply dipping Lower Peel Sound beds (conglomerates, sandstones and limestones) pass up into coarse conglomerates of the Upper Peel Sound. The Upper Peel Sound beds (exposed in crags at left) are horizontal. The strata are upturned sharply about a northwest-southeast axis in the position of the stream just left of centre.





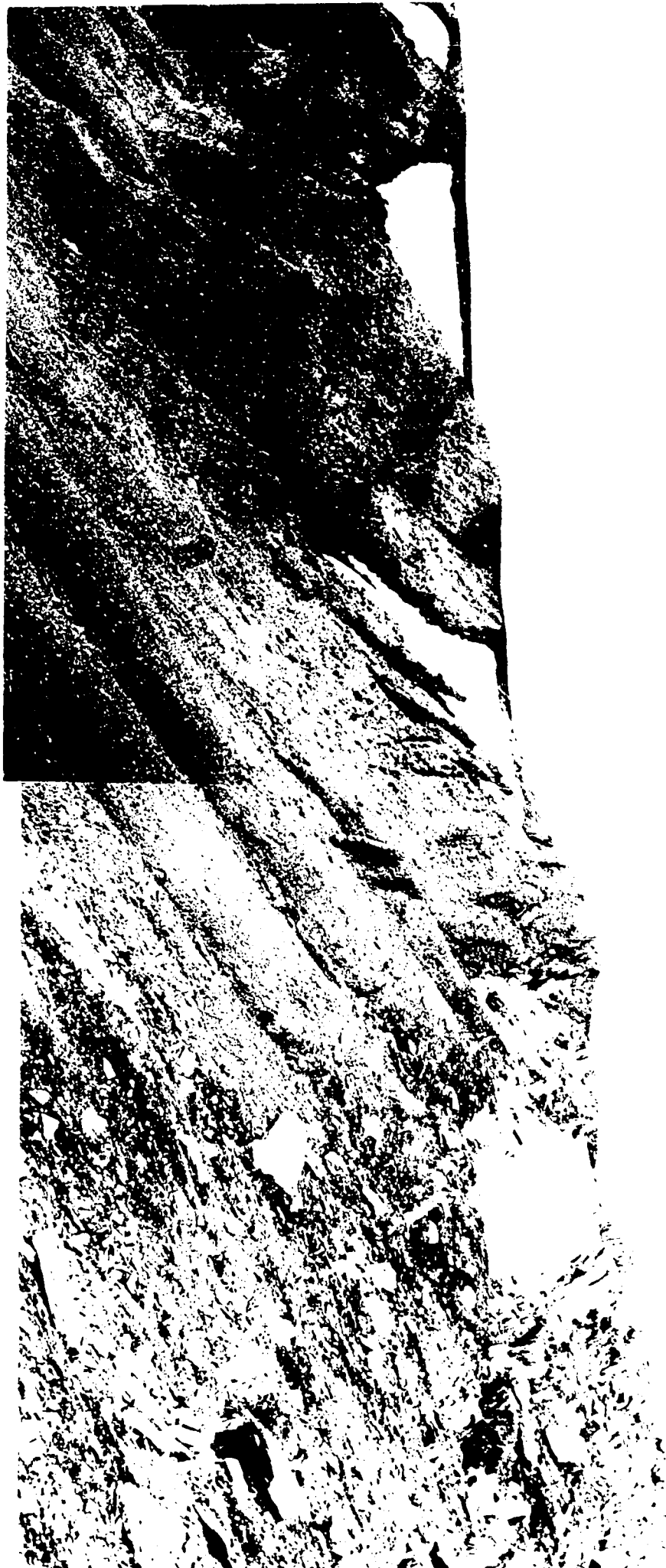
Photograph 5.

Overtuned Lower Peel Sound beds near Cape Brodie, viewed from the air looking northeast. The beds are folded into an asymmetric syncline just above the bend in the stream, near left centre. This syncline is probably a syn-depositional fold (see text.)



Photograph 6.

The Cape Brodle syn-depositional fold, looking north. Steeply dipping dolomitic conglomerates, at right, are overlain by coarse polymict conglomerates forming cliffs at left. The two limbs of the fold are thus composed of different lithologies.

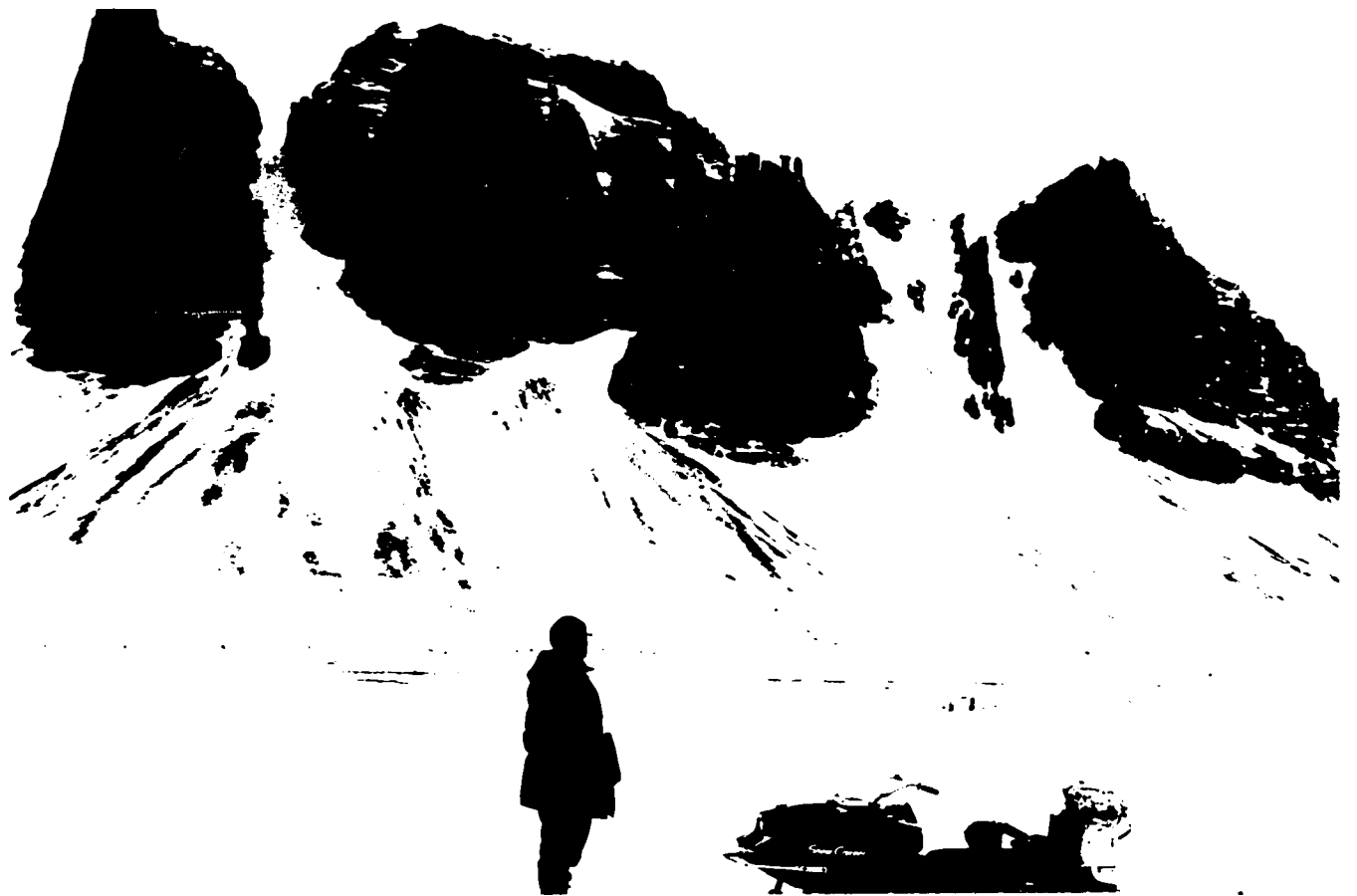


Photograph 7.

Bellet Cliff. Cliffs of massive conglomerate of the Upper Peel Sound Formation rise 400 feet from the sea.

Photograph 8.

Typical inland exposure of the Upper Peel Sound conglomerate, three miles north of the mouth of Transition Bay.



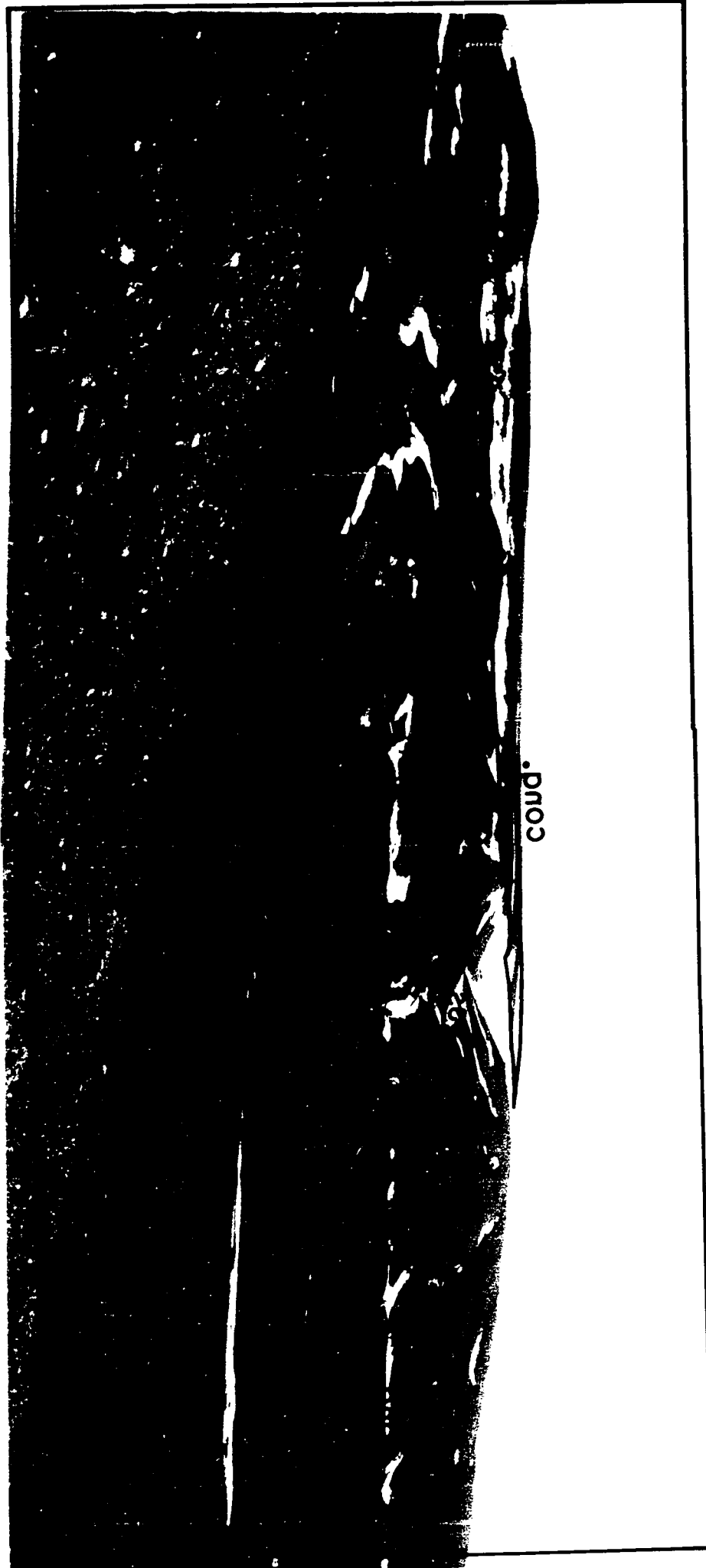
Photograph 9.

Boulder conglomerate of the Upper Peel Sound Formation, near Bellet Cliff, loc. 31. The two boulders against which the hammer is resting are pink quartzites derived from the Aston Formation.



Photograph 10.

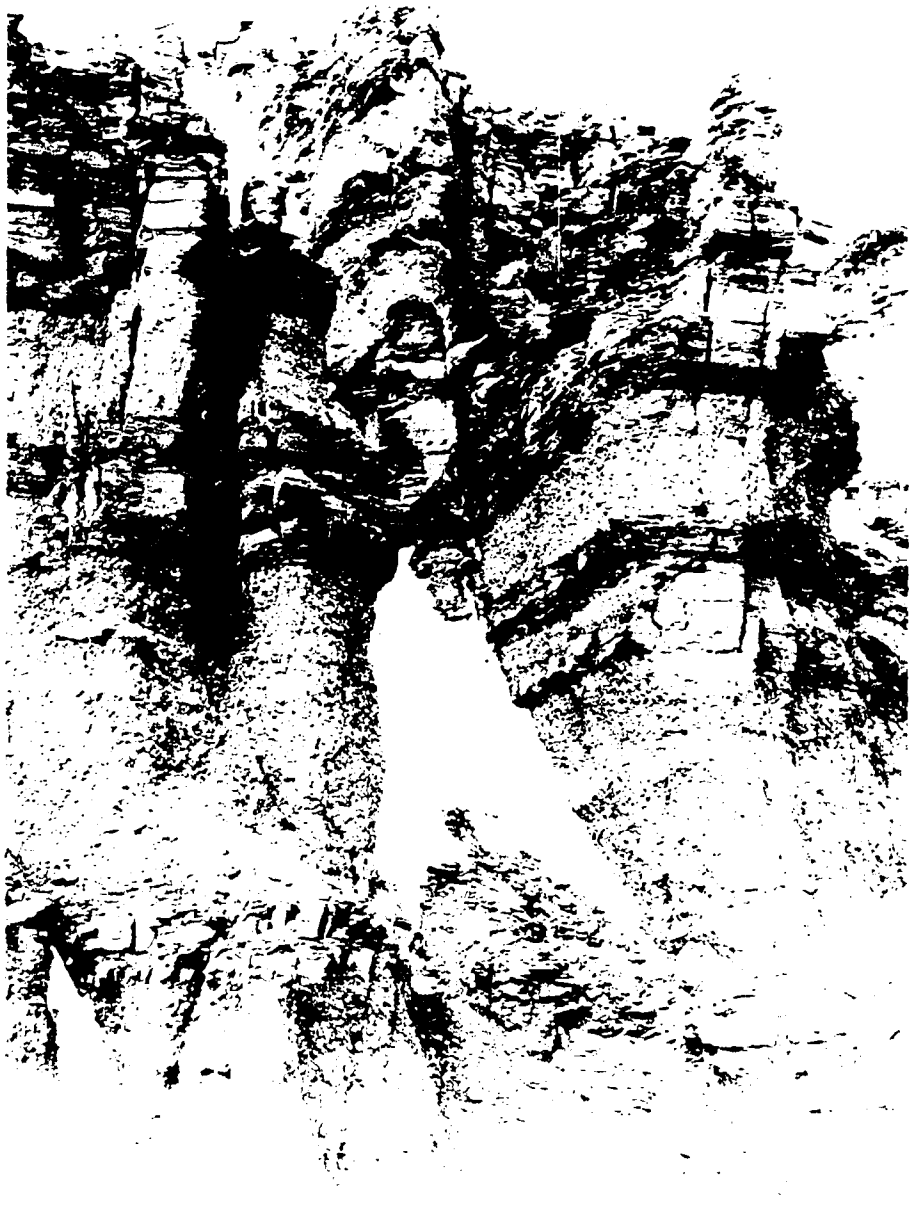
The conglomerate-sandstone transition at Mount Matthias, looking southeast. Horizontal conglomerate beds wedge out westwards (to the right) and are replaced by sandstones.





Photograph 11.

Beds of the Conglomerate-Sandstone Transition
Facies; loc. 25, near Bellot Cliff.



Photograph 12.

The Sandstone-Carbonate Transition Facies, loc. 163, 6 miles west of Transition Bay. This section consists of grey limestones, sandstones and shales. The sandstones contain vertebrate remains, and a shale bed near stream level contains compound corals.

Photograph 13.

Nodular and lenticular dolomites in beds of dolomitic shale. Sandstone-Carbonate Transition Facies, Browne Bay.

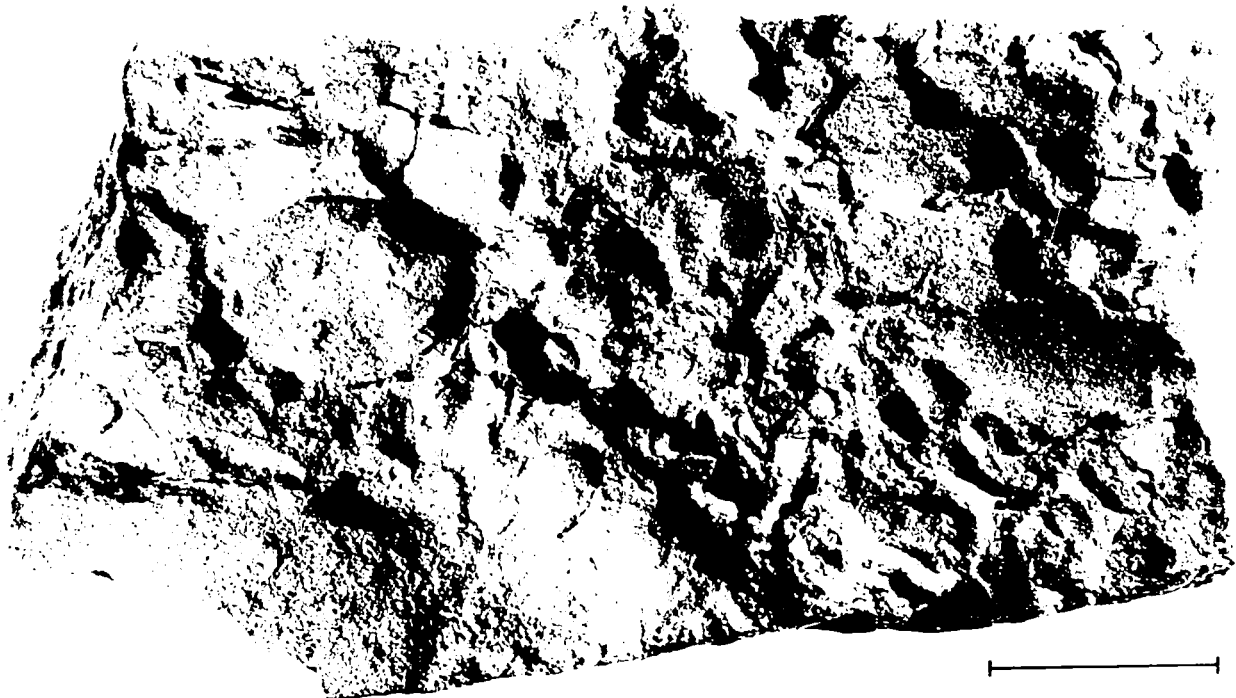


Photograph 14.

Imbrication in conglomerate, near Transition Bay.
The hammer handle is perpendicular to bedding; the
inferred current direction is from right to left.

Photograph 15.

Mudflake conglomerate. Disc-shaped fragments of
mud and silt are enclosed in a red, immature sandstone
matrix. Bar scale is one inch in length.

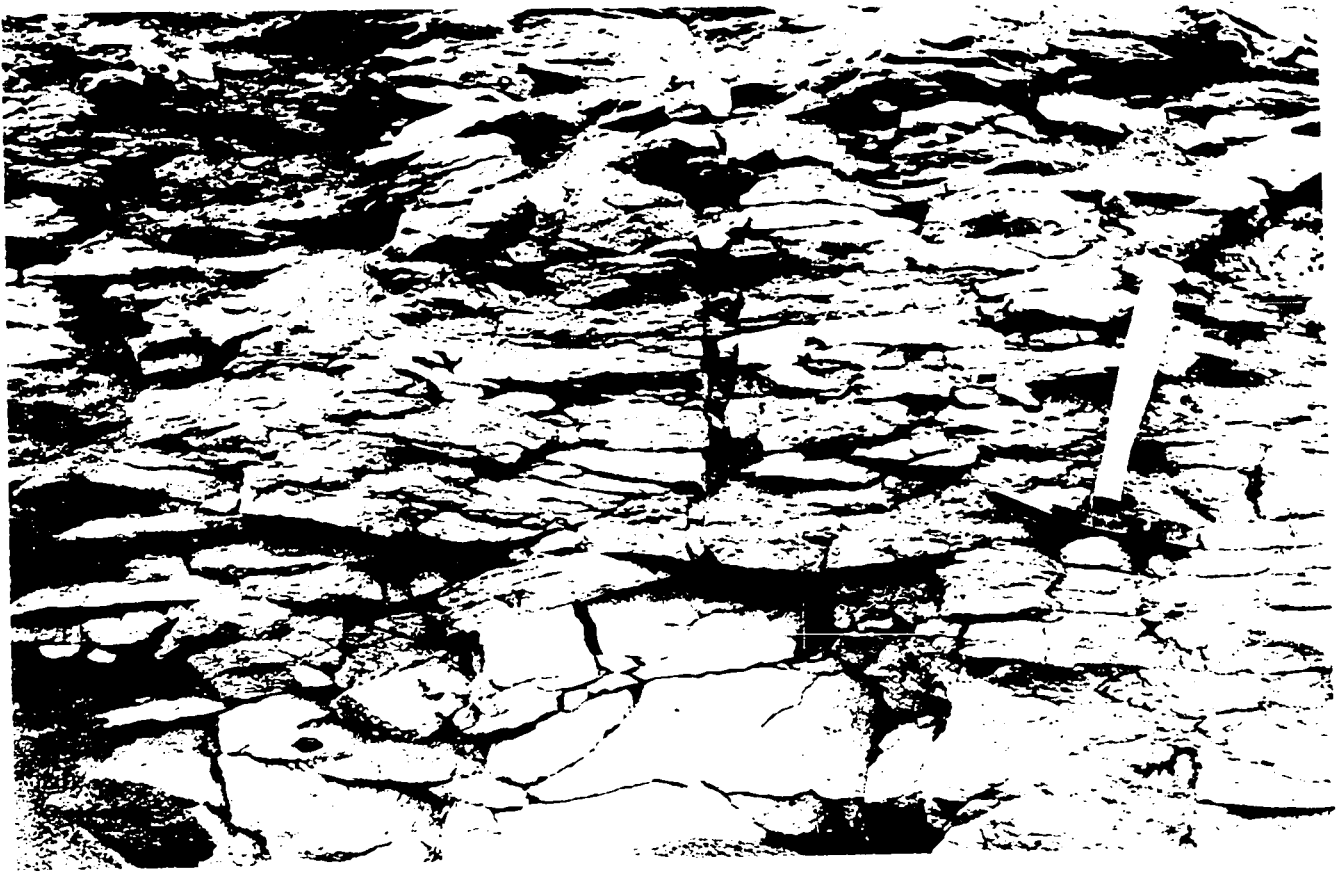


Photograph 16.

Grouped trough crossbeds; pi-cross-stratification of Allen (1963). Conglomerate-Sandstone Facies, southwest corner of Prescott Island.

Photograph 17.

One side of a large channel. The channel is cut in coarse red sandstones showing pi-cross-stratification (Allen, 1963). Sandstone Facies, southern Pandora Island.



Photograph 18.

Primary current linea-
tion in a sandstone lenticle,
Conglomerate Facies, five
miles north of the mouth of
Transition Bay.

Photograph 19.

Symmetrical ripple marks
in steeply dipping sandstones of
the Lower Peel Sound Formation,
loc. 189, near Cape Brodie.

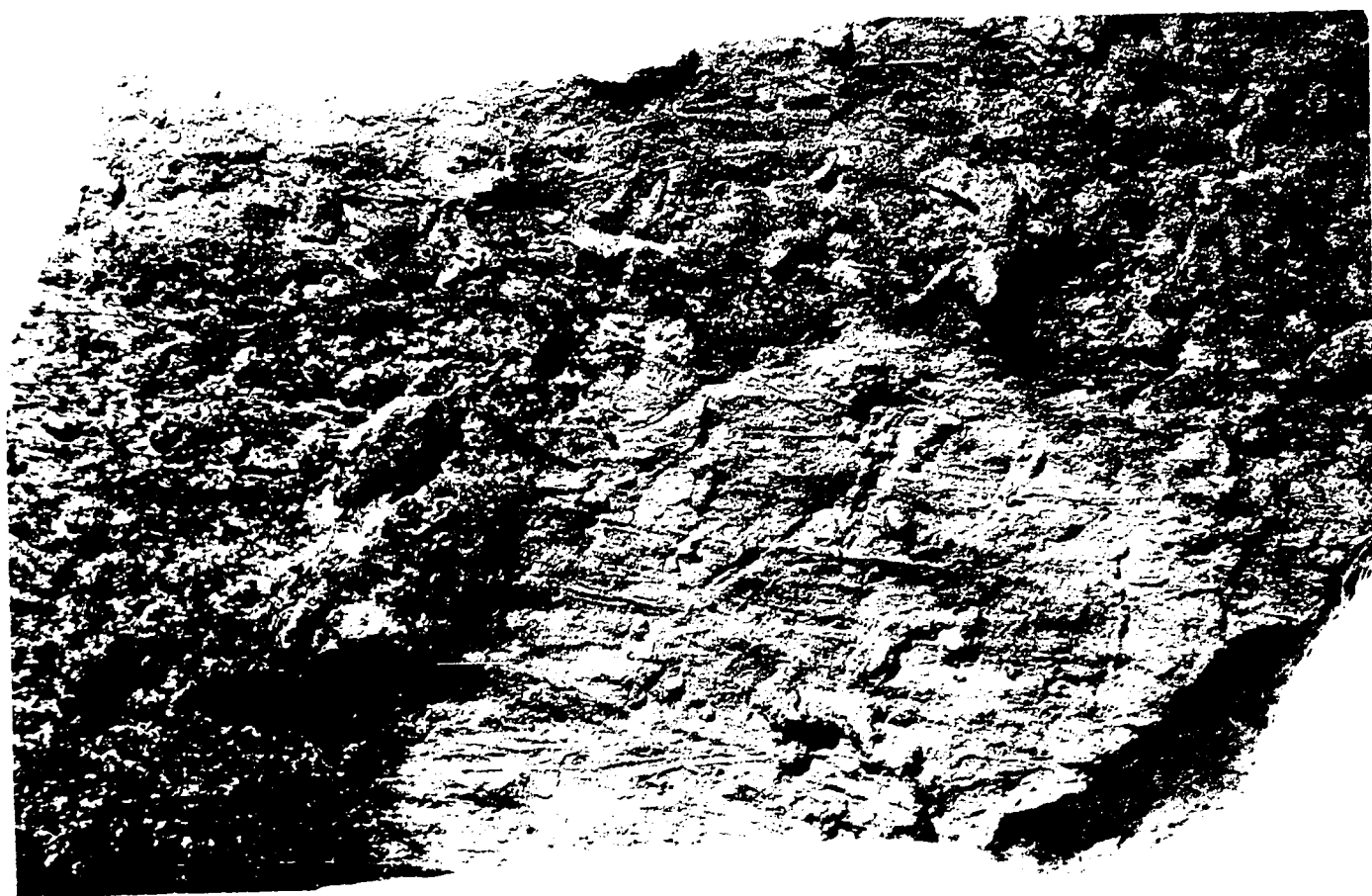


Photograph 20.

Grove casts and load casts in a thin mud seam at the base of a sandstone bed, Sandstone Facies, loc. 46, Baring Channel. Scale is one inch in length.

Photograph 21.

Groove casts and load casts in red sandstone, Sandstone-Carbonate Facies, loc. 134, Muskox Hill. Scale is one inch in length.

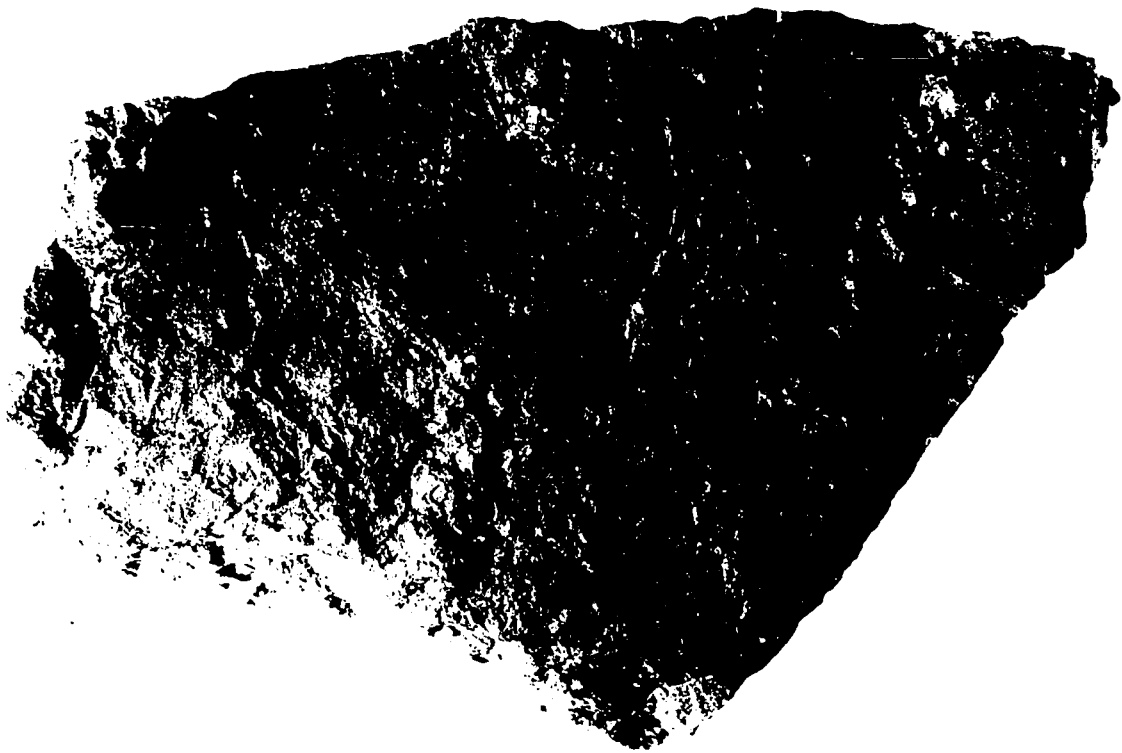


Photograph 22.

Underside of small channel (top) and cross section (centre) at same scale. Arrow shows direction of current movement; it is 1.1 inches long. Note the groups of small groove casts, possibly caused by fish fins. Sandstone-Carbonate Facies, loc. 133, Muskox Hill.

Photograph 23.

Casts of halite crystals in mottled red and green shale, Sandstone-Carbonate Facies, loc. 82, Russell Island. Scale is one inch in length.

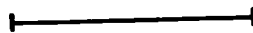
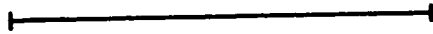


Photograph 24.

Stained limestone showing partial dolomitisation. Dark, stained areas are calcite; light areas, including veins and white specks in the calcite areas are dolomite. Note the presence of two ostracods infilled with calcite. Lower Peel Sound Formation, loc. 189, near Cape Brodie. Scale is one inch in length.

Photograph 25.

Dolomite with "Collenia"-type Stromatolite. The downward bend in lamination at right is a small erosion channel between colonies. The core of the colony is light coloured dolomite in which there are faint horizontal laminae which do not show on the photograph; these are truncated at right by the erosion channel. Note desiccation cracks and small scale imbricate structure in one layer near the centre of the laminated beds. Asymmetric ripple at base of specimen. Carbonate Facies, loc. 80, Russell Island. Scale is 2 inches in length.

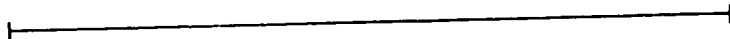
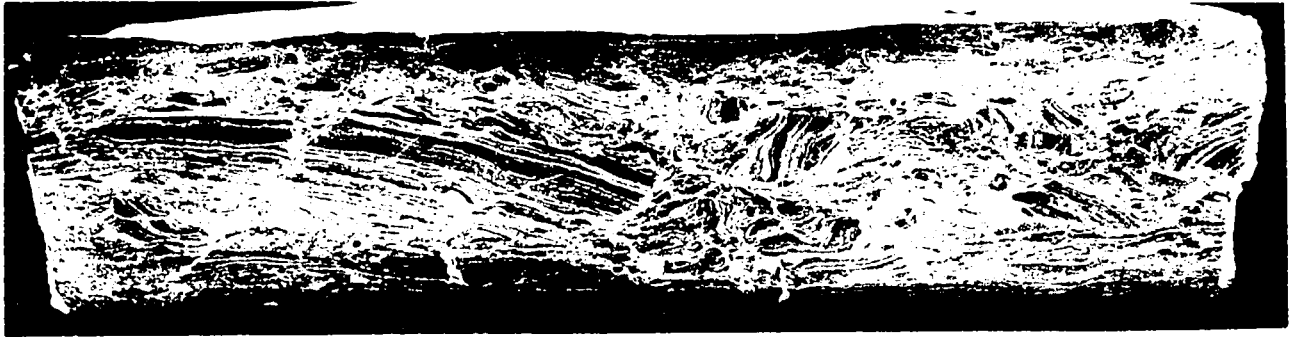


Photograph 26.

Penecontemporaneous breccia in dolomite, showing disturbed bedding, and disorientation and distortion of detached fragments. Carbonate Facies, loc. 94, Browne Bay. Scale is one inch in length.

Photograph 27.

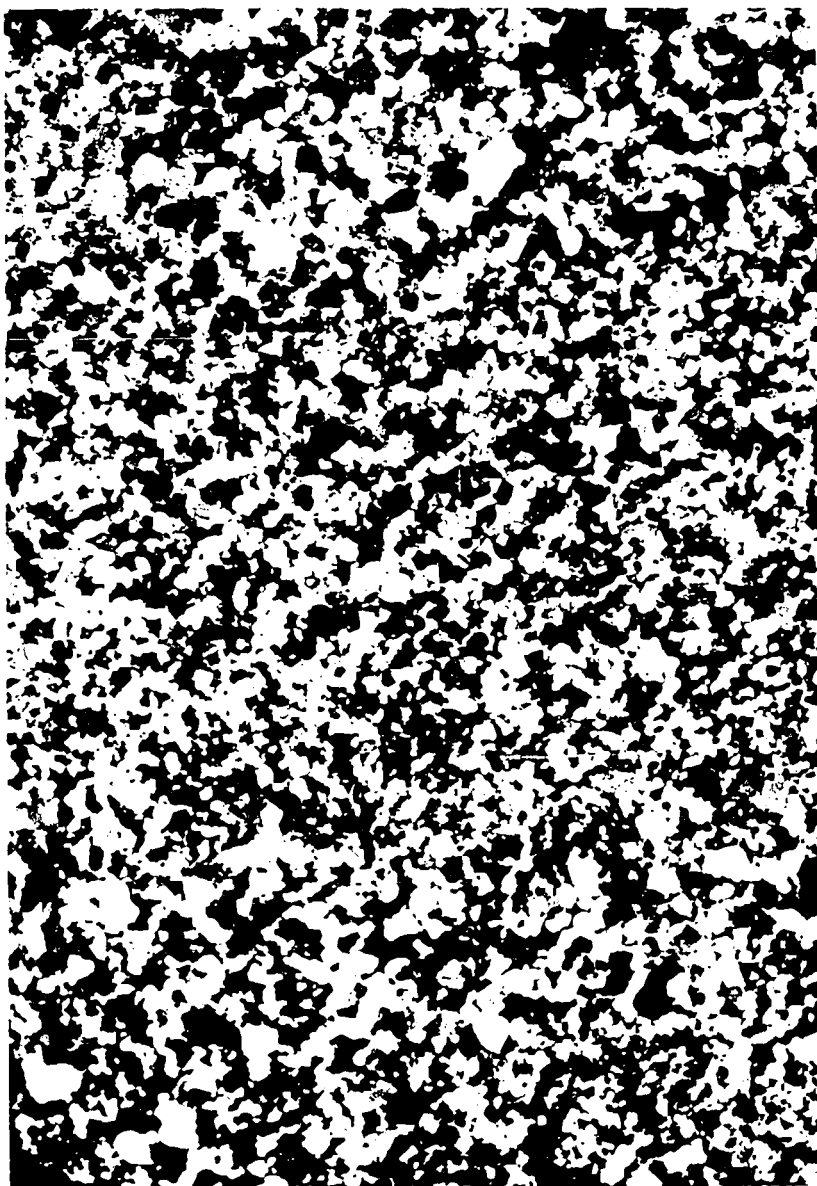
Crystal casts of gypsum or anhydrite in dolomite. Casts are infilled with sparry dolomite. Carbonate Facies, loc. 78, Russell Island. Scale is one inch in length.



PHOTOMICROGRAPHS

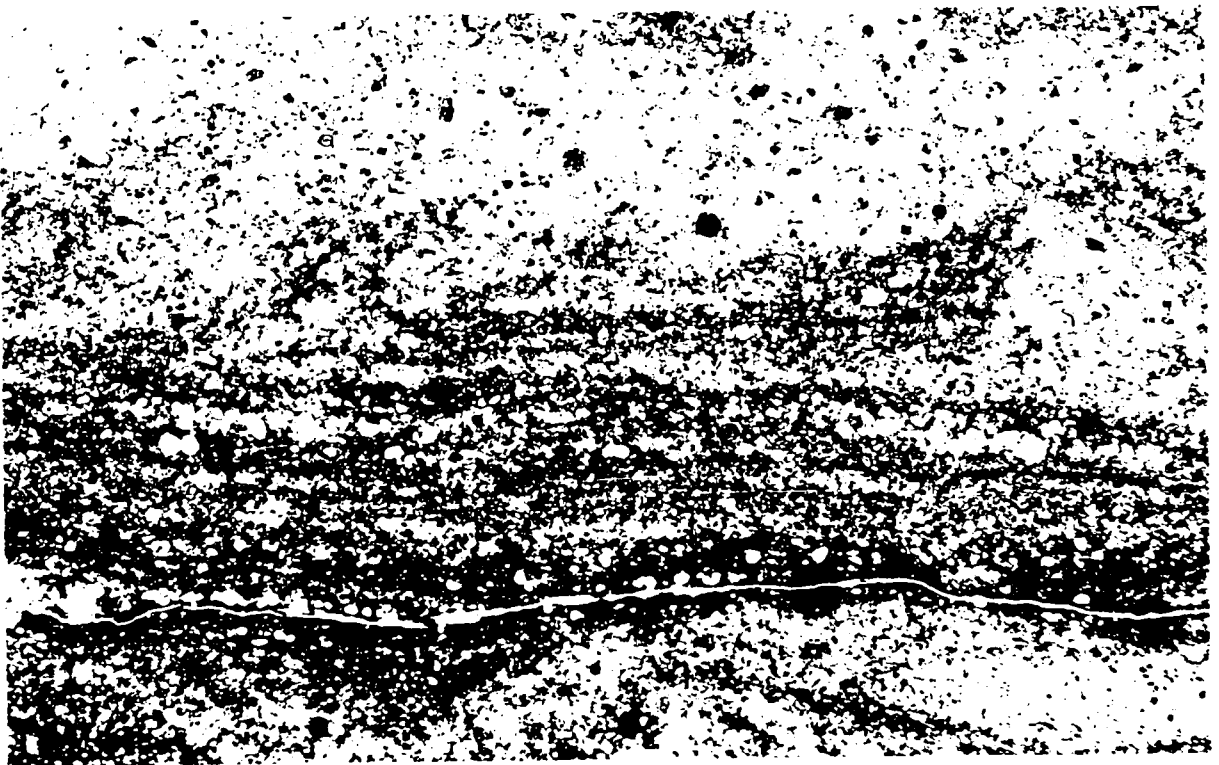
Photograph 28.

Clean washed quartz sandstone under crossed nicols. 10% dolomite - mainly detrital grains, plus minor quantities of dolomite matrix. Less than 1% feldspar and chert. Grains are well rounded, showing little secondary overgrowth. Interpreted as a littoral deposit. Lower Peel Sound Formation, loc. 64, Mount Matthias. Scale is 0.1 inches in length.



Photographs 29 and 30.

Sandy dolsparrites, under non-polarised light. Photographs are at same scale (bar is 0.1 inches in length); they show well rounded quartz grains set in laminated dolsparrites. Rare, rounded detrital dolomite grains and rare felspar grains are present. The two sandstones are interpreted as littoral deposits. Photograph 29 (top) is from the Lower Peel Sound Formation, loc. 134, near Cape Brodie. Photograph 30 (bottom) is from the Sandstone-Carbonate Facies in the Upper Peel Sound, loc. 171, near Transition Bay.

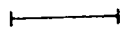
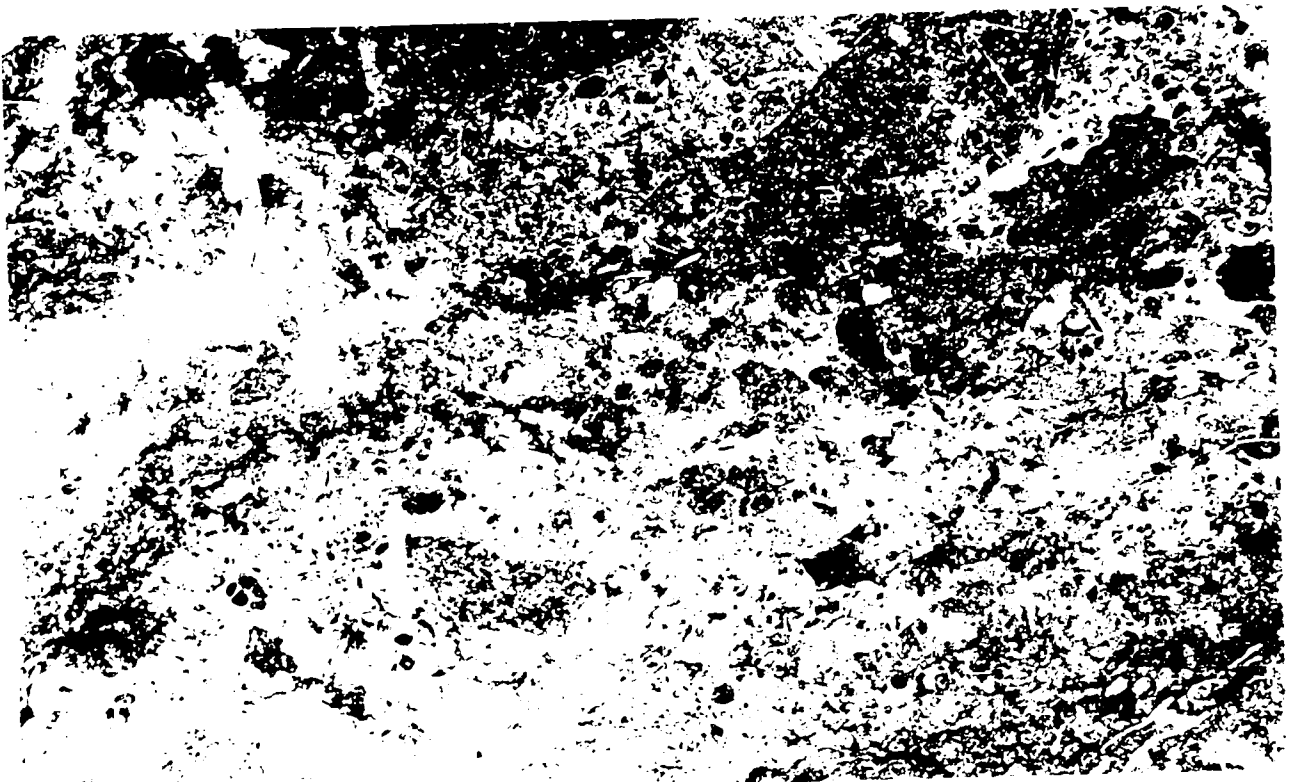
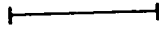
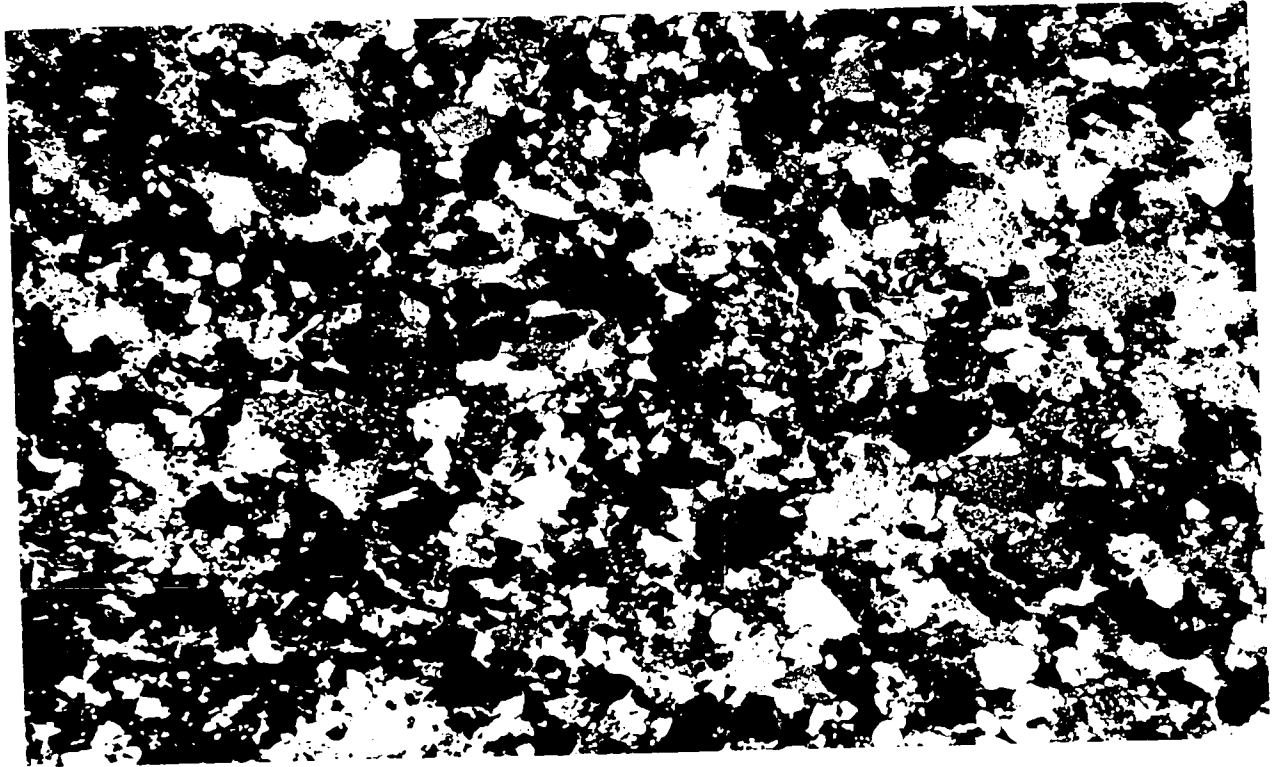


Photograph 31.

Immature sandstone, under crossed nicols. Contains sub-round grains of quartz, quartzite, chert, iron-stained weathered grains, detrital dolomite, and rare felspar. Cement is carbonate. Sandstone Facies, loc. 54, Mount Matthias. Scale is 0.1 inches in length.

Photograph 32.

Partially dolomitised limestone, under non-polarised light. Fine grained calcite (dark areas) is partially altered to dolomite which forms crystalline aggregates (light areas). Fossil material includes gastropods and ostracods. Sandstone-Carbonate Facies, loc. 163, near Transition Bay. Scale is 0.1 inches in length.



Photograph 33.

Shelly dolomite, under
non-polarised light. Calcite
shell debris includes gastro-
pods, ?pelecypods and ostracods
(ostracods near top of section).
Matrix is dolmicrite. Sand-
stone-Carbonate Facies, loc 94,
Browne Bay. Scale is 0.1 inches
in length.

Photograph 34.

Shelly dolomite, under non-
polarised light. Abundant broken
and comminuted calcite shell debris
is set in a dolmicrite matrix. Car-
bonate Facies, loc. 78, Russell
Island. Scale is 0.1 inches in
length.



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