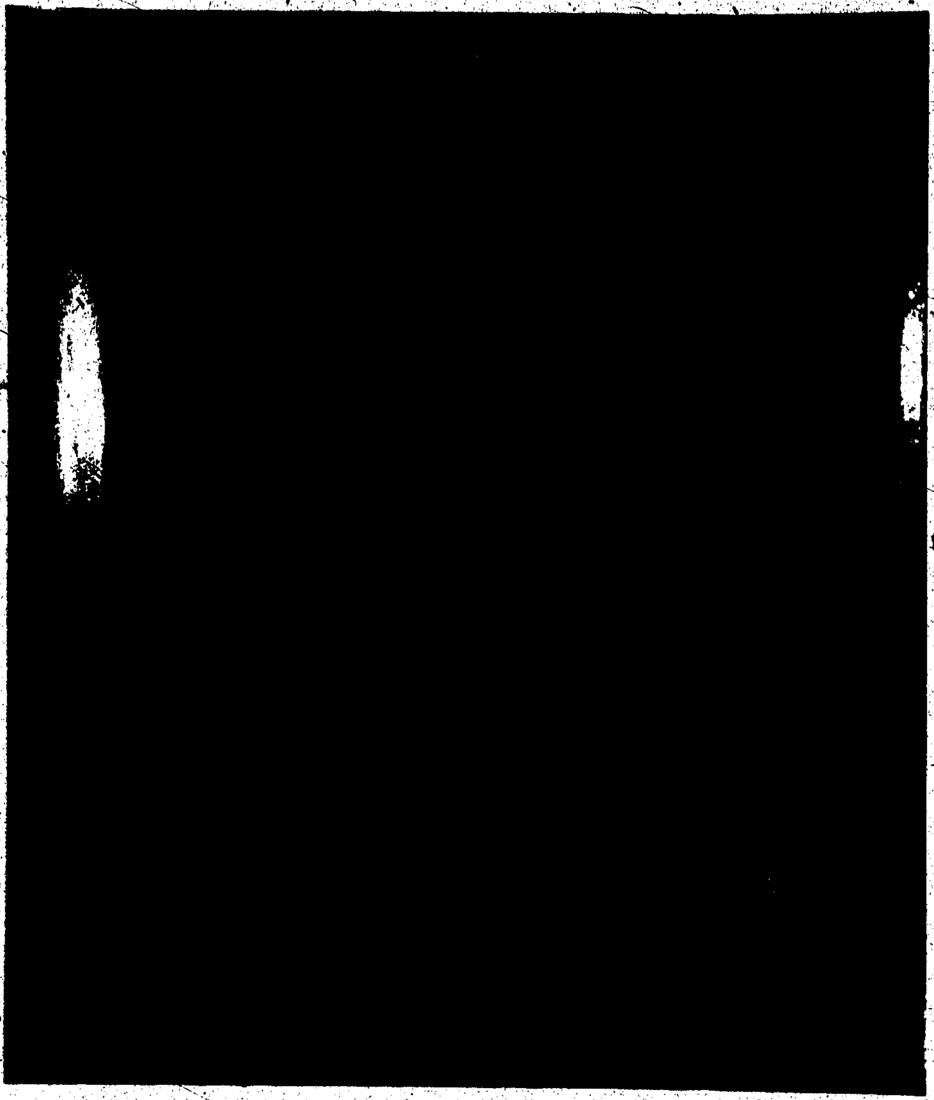


FIG. 41: Vegetation distribution (%) observed on till. Carbonate restricts vegetation growth. Therefore, distribution of carbonate from carbonate bedrock (1) east over clastic bedrock (2) is illustrated by low vegetation cover at Transition Bay (A), Le Feuvre Inlet (B), Young Bay (C) and Muskox Valley (D).

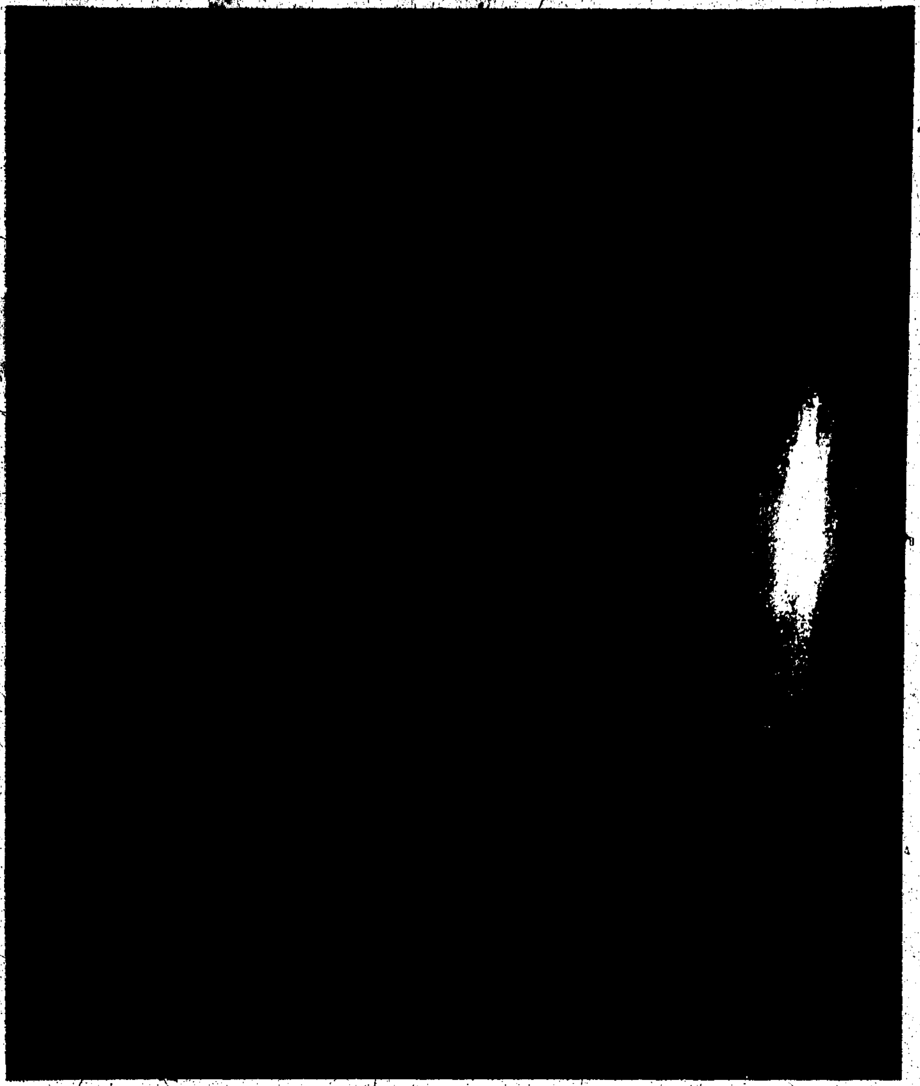


FIG. 42: Depth to frost table (cm). Dispersal of fine grained carbonate from carbonate bedrock (1) east over coarse grained clastic bedrock (2) should restrict depth to frost table within carbonate dispersal plumes. This occurred at Transition Bay (A), Le Feuvre Inlet (B) and Muskox Valley (C).

3.3 ICE SHEET SURFACE CONFIGURATION

Ice sheet surface topography is controlled by snow drift pattern, basal shear stress, basal topography and most importantly, ice streams (Hughes et al., 1977, p. 19; Hughes, 1987). Ice streams, the most dynamic part of an ice sheet, are zones of rapidly flowing ice flanked by ice moving more slowly (Robin et al., 1970, p. 229; Dyke and Morris; 1988, Hughes, 1987; Sugden and John, 1978). Ice streams lower ice sheet surfaces where they evacuate ice faster than the surrounding areas (Hughes, 1987). Ice streams presently drain most of the ice from the Antarctic and Greenland ice sheets (Hughes, 1987).

Ice streams develop by drawdown of ice to the periphery of an ice sheet. Drawdown occurs where bedrock declines to sea level and ice is removed freely. An ice shelf pinned to a sill, for example, can inhibit ice stream development (Hughes et al., 1985). An ice stream will not develop if the ice shelf grounding line is not adjusted to a position at or above the sill. Once the ice shelf "unpins" drawdown can occur. Similarly, removal of sea ice can destabilize the periphery of an ice sheet initiating an ice stream.

Convergence of flow occurs at the upstream end of ice streams. Convergence is caused by perpendicular flow from two different ice divides to a low area caused by drawdown or by flow between mountains and islands as outlet glaciers (Hughes, 1977). A record of flow convergence is sometimes preserved by streamlined landforms and/ or dispersal trains. Dyke and Prest (1987) postulated that two secondary ice divides extended from the M'Clintock Ice Divide to account for convergent flow at ice stream heads.

Ice streams have a distinct surface expression on the ice sheet. For example, a line of maximum surface slope circumscribes Antarctic ice streams. Ice streams traversing ice shelves cause a boundary between the convex surface of the floating ice stream from the generally flat ice shelf (Hughes et al., 1977, p. 19). Extending flow produces a concave surface on the grounded part of an ice stream. Such extending flow can be caused by flow convergence or by increases in basal sliding. Compressive flow produces a convex surface when an ice stream contacts the ocean. Such compressive flow can be caused by flow divergence or lateral shear between the ice stream and the ice shelf (Hughes et al., 1977, p.19).

Ice moulded features form under ice sheets and indicate former flow lines in them (Shilts, 1980). Ice moulded features that dovetail to distinct narrow bands probably formed under ice streams (Sugden, 1977). Ice flow lines drawn parallel and back to the farthest upstream end of ice moulded landforms may define the length of basal flow. Ice flow lines plotted for southern

Prince of Wales Island reveal ice moulded landforms converging into three narrow bands at Transition Bay, Le Feuvre Inlet and Young Bay (Figs. 43, 44). These landforms probably indicate basal flow under ice streams. Because they do not cross-cut but rather are aligned with each other it is possible that these ice streams flowed simultaneously (Fig. 43). If these ice streams did not flow simultaneously, up to six different flow events are possible.

Ice flow lines that are broadly spaced and non-converging occur at Inner Browne, Coningham and Guillemard bays and north of the megafluted till. These ice moulded features are all aligned differently (Fig. 45).

3.4 DISCUSSION

3.4.1 TIMING OF GLACIATION

Amino acid ratios measured from marine shells collected from inter-till sands at sections 1 and 2 (Fig. 46) can be divided into two groups. These two groups represent different periods despite the fact that shell fragments were collected from similar enclosing materials and stratigraphic positions. The same observations were made elsewhere in the central Arctic. For example, shells collected from fluvial sands and gravels below till on

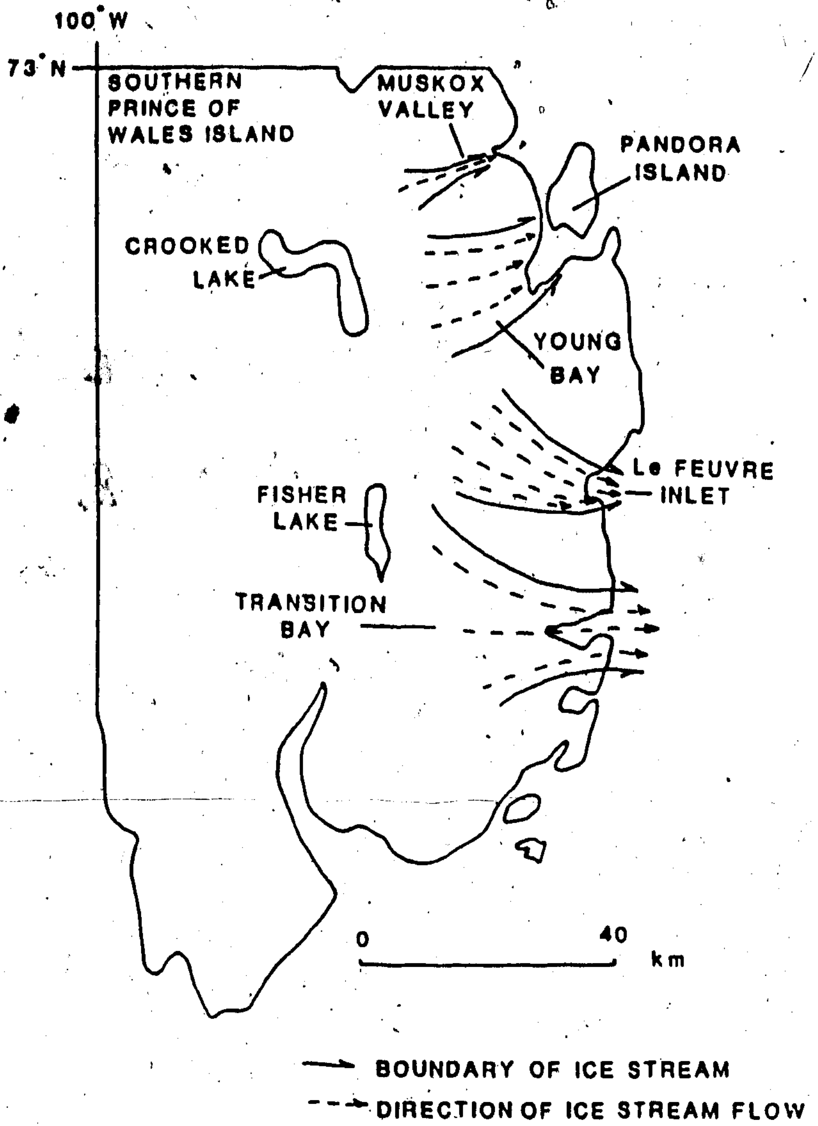


FIG. 43: Location of Transition Bay, Le Feuvre Inlet, Young Bay and Muskox Valley ice streams.

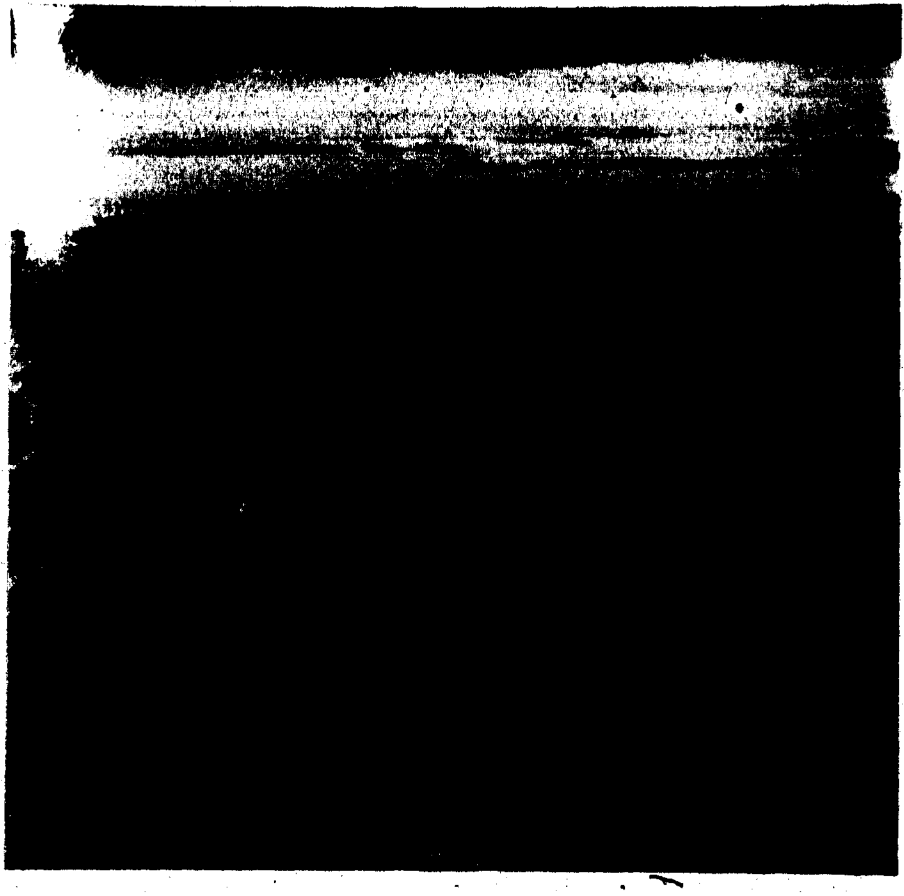


FIG. 44: Transition Bay dispersal plume (E). Note boundary between carbonate charged till (B) and till not so highly charged (A). Drumlinoid forms also delineate boundary. Note convergence of carbonate and drumlinoid forms (C & D) into main plume (E).

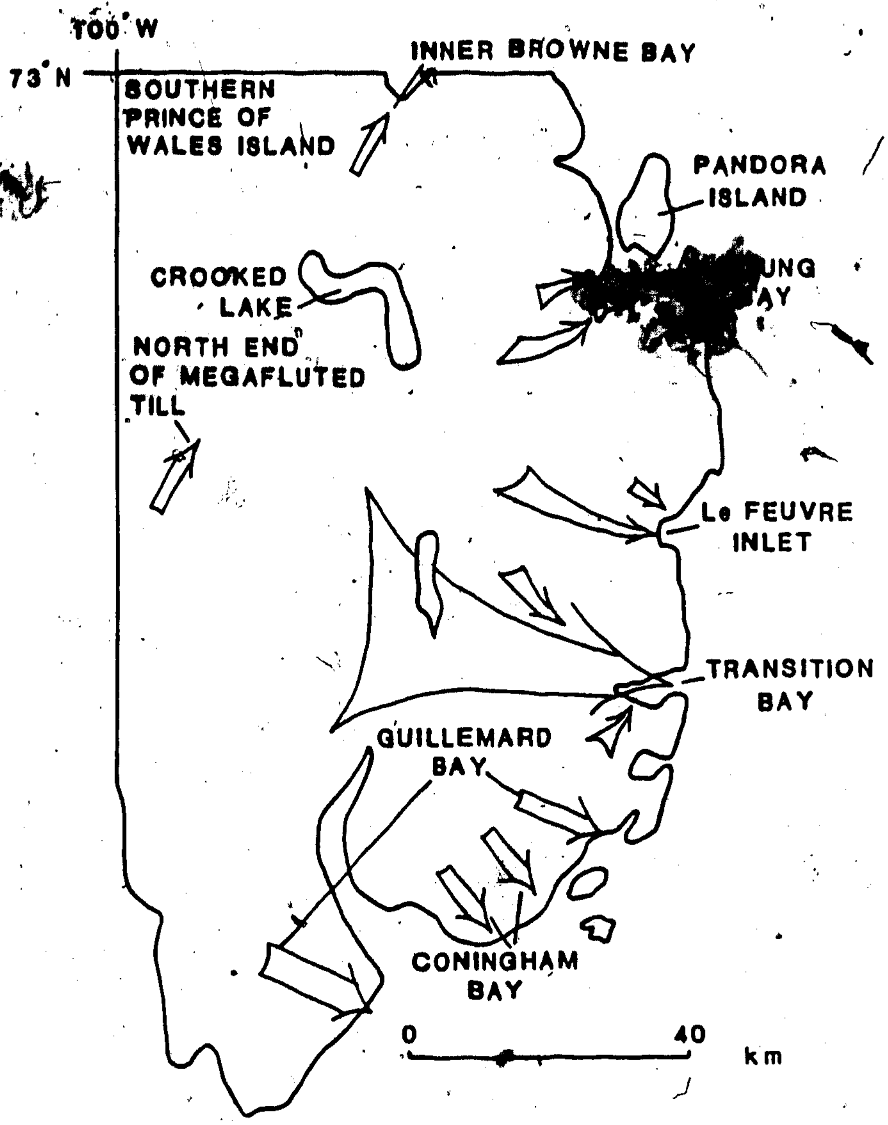
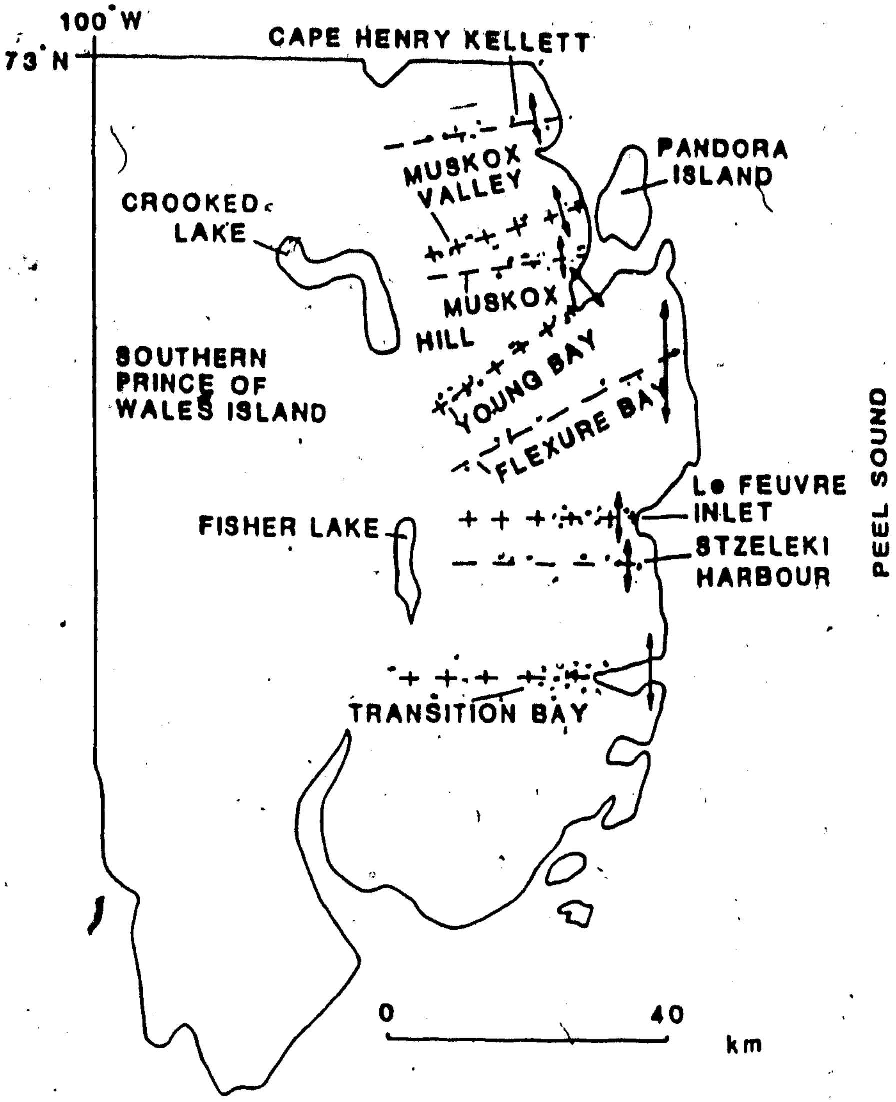


FIG. 45: Distribution of low relief streamlined till related to last glaciation.



+++ :Line drawn through dispersal plumes. Cross-section drawn parallel to this line.

--- :Line drawn between dispersal plumes. Cross-section drawn parallel to this line.

↕ :Topographic cross-sections drawn perpendicular to plumes.

• :Control point

FIG. 46: Locations of lines drawn through each carbonate dispersal plume and intervening area from which values for simple regression analysis were derived. Topographic cross-sections were made parallel and perpendicular to these lines.

northern Prince of Wales Island (section 4; Fig. 19), yielded two ratios similar to those on shells collected from the Fisher River sections. Furthermore, fragments of Mya Truncata collected from fluvial sand and gravel underlying till at Back Bay, northern Prince of Wales Island (section 5; Fig. 19), also contained shells that plotted in both ratio groups (Dyke and Matthews, 1987). Although sands and gravels at sections 1 and 2 contain shells with two different ratios this does not necessarily mean that there were two different periods of deposition. A river could erode shell from an older deposit and subsequently mix with younger shell.

To date, the amino acid racemization dates on shells collected from the central Arctic may be placed in three groups. Radiocarbon dating of group 1 shells indicate that they are Holocene. Uranium-series dating of group 2 shells collected from section 1 (Fig. 19) initially indicated that they are Late Wisconsinan (39000 BP, Dyke, pers. comm.) whereas group 2 shells collected from section 4 (Fig. 19) are Sangamonian (80000 BP, Dyke, pers. comm.). This discrepancy is caused by shells in section 1 having experienced considerable uptake of uranium sometime after original deposition (suggesting the till became unfrozen to allow movement of uranium) while group 2 shells collected from section 4 had not (Dyke, pers comm., 1987). A high pressure radiocarbon date (GSC-4470 HP) on group 2 shells from section 1 confirm they are >49000 BP clearly separating them from the Late Wisconsinan.

Group 3 shells are found in a section beside the Pasley River on Boothia Peninsula (section 3, Fig. 19). In this section a glacigenic assemblage (unit 2, consisting of till and water-laid sediment) underlies Sangamonian fluvial gravels (unit three). Shells collected from the glacigenic assemblage, based on its stratigraphic position, are probably pre-Sangamonian. These amino acid ratios are similar to the second group of amino acid ratios on shells collected from section 2 (Fig. 19).

Fluvial sands and gravels in sections 1 and 2 were both probably deposited during the Sangamonian. Additional amino acid dates from erratic marine shells collected from section 2 would likely reveal the presence of group 2 shells.

Fluvial sands and gravels in sections 1 and 3 (Fig. 19) underlie till associated with eastward ice flow and overlie a glacial deposit. In addition, the fluvial sand and gravel beds at both sections are composed of local materials and are of low elevation suggesting that relative sea level had fallen to present interglacial levels or lower. Fall in relative sea level to present interglacial levels suggests that the fluvial gravels represent flow during an interglacial, the Sangamonian. It is therefore likely that sands and gravels at sections

1 and 3 are Sangamonian.

Eastward oriented till overlying fluvial sands and gravels at sections 1 and 2 is considered to represent a continuous ice cover over Prince of Wales Island during the Wisconsinan. Underlying till at section 1 is therefore pre-Sangamonian and if it is associated with the high relief streamlined till then it would be pre-Sangamonian. However, it is unlikely that ice which deposited the high relief streamlined till withdrew and then readvanced to generate the eastward flow without altering or destroying the high relief streamlined till. Therefore it is concluded that the till beneath the fluvial sands and gravels represents an earlier glaciation. The high relief streamlined till represents an early ice cover during the Wisconsinan that eventually led to the formation of the M'Clintock Ice Divide and the subsequent eastward flow.

Consequently megafluted till, high relief streamlined till, lateral shear and ribbed moraine probably represents glaciation during the Early Wisconsinan when ice advanced to the central Arctic. An ice stream subsequently developed forming high relief streamlined till, lateral shear and ribbed moraine. Change in location of drawdown or ice sheet surface topography caused an eastward ice flow recorded by till with a strong eastward fabric and related eastward oriented drumlins and flutings. These regional changes in ice flow direction do not require retreat and re-establishment of ice sheets to account for all surficial features on Prince of Wales island.

3.4.2 MATERIALS DISTRIBUTION

Narrow bands of carbonate rich till are located at Transition Bay; Le Feuvre Inlet; Young Bay; and a valley south of Muskox Hill (referred to as Muskox Valley; Fig. 43). A sharp lateral boundary exists between these carbonate bands and local surface materials. These carbonate bands or plumes, have at their upstream ends, an apparent convergence of material reflecting the former convergence of ice flow (Fig. 44).

Low relief streamlined till is confined within three of the four carbonate dispersal plumes (Transition Bay, Le Feuvre Inlet, Young Bay). Low relief streamlined till also converges, at the upstream end, to the centre of each carbonate dispersal plume suggesting a funnelling of ice flow (Fig. 44).

Ice stream characteristics were discussed earlier (Chapter 3. 3). Ice streamlined landforms and debris plumes are concentrated under ice streams (Boulton et al., 1985, Shilts et al., 1979; Dyke and Morris, 1988; Tippet, 1985). Furthermore, ice streams in the Antarctic and Greenland display abrupt boundaries separating the fast moving ice stream from the slower moving ice sheet.

Strongly convergent flow also occurs in the upper reaches of these ice streams. Boothia type dispersals at Transition Bay, Le Feuvre Inlet and Young Bay have straight, clearly defined lateral boundaries and display a strong convergence of streamlined forms and carbonate concentration in their up-ice source areas. Therefore, it is concluded that these carbonate plumes were probably dispersed by ice streams at Transition Bay, Le Feauvre Inlet and Young Bay (Fig. 43). Carbonate was also dispersed by an ice stream through Muskox Valley but this was not as vigorous as those areas to the south and there are no associated streamlined forms. Therefore, ice stream flow was likely less vigorous or of shorter duration (Fig. 43). Finally, four other low relief streamlined tills have no associated carbonate dispersal plumes, no evidence of convergent flow and lack a clear lateral boundary (Fig. 45). These drumlin fields were probably formed by regional flow during deglaciation.

Carbonate dispersal begins to the west of the carbonate-carbonate sandstone boundary (Fig. 37; Table 4). This dispersal of carbonate within the presumed zone of carbonate bedrock may indicate that the geologic boundary is mapped incorrectly and is located where the carbonate dispersal starts. This is possible because the bedrock west of Transition Bay and Le Feuvre Inlet is obscured by drift. Alternatively the transport of clastic material west during a previous glaciation could also

TABLE 4: Maximum Concentration Of Carbonate West Or East Of Geologic Boundary.

Dispersal Plume	West/ East	Distance (km)
Transition Bay	W	34
Le Feuvre Inlet	W	11
Young Bay	-	-
Muskox Valley	E	3

account for the dispersal of carbonate west of the presumed carbonate-carbonate sandstone boundary. Clastic material transport to the west could have occurred during the advance which deposited the high relief streamlined till.

3.4.3 ICE STREAM DYNAMICS

The distribution maps of the surficial materials illustrate several trends that allow for the calculation of erosion and transportion by each ice stream. Colour distribution maps are excluded because colour isopleth lines are not based on numbers. The following discussion attempts to use ~~the surficial~~ materials to further refine our understanding of ice stream dynamics.

The largest carbonate dispersal plume measured from all distribution maps occurs at Transition Bay followed by Le Feuvre Inlet (Table 5). However, carbonate dispersal based solely on the map of carbonate granules distribution indicates that Muskox Valley displaces Le Feuvre Inlet as the second largest plume. The third and fourth largest plumes measured on the basis of clastic granules, carbonate and vegetation are not consistent.

Measurements of the carbonate dispersal plumes (from the two granule distribution maps) indicate that they are larger at Muskox Valley than at Young Bay. However,

TABLE 5: Measured Carbonate Dispersal Plume Area

Distribution Map	Transition Bay (km)	Le Feuvre Inlet (km)	Young Bay (km)	Muskox Valley (km)
Carbonate Granules	490	264	162	450
Clastic Granules	465	350	112	203
Carbonate	820	378	240	45
Texture, Sand	303	206	-	39
Texture, Silt and Clay	-	240	152	-
Vegetation	243	124	70	41
Depth To Frost Table	394	302	-	-

measurements based on the carbonate and vegetation maps show that carbonate dispersal is larger at Young Bay than at Muskox Valley. Carbonate rock transport indicates that there was less comminution in the plume at Muskox Valley, implying slower flow rates, than occurred at Young Bay where faster flow rates would have brought particles into contact more often.

The relative rates of sediment transport and deposition within each plume can be estimated from the distribution maps (Figs. 34- 42). Values used to calculate relative rates of transport (such as; % carbonate; % carbonate granules; % sandstone and gneiss; % sand; % silt and clay; % vegetation; and depth to frost table (cm)) were derived from drawing a line through the middle of each dispersal plume from its start to the east coast (Fig. 46). Four simple regression analyses (linear $Y= a+bx$; exponential $Y= \{a+bx\}$; reciprocal $1/Y= a+bx$; multiplicable $Y= ax$) were run using these values. The test having the most significant R value, determined by Spearman's Rank Correlation Test (Ebdon, 1985), and the most accurate plotted line was chosen to represent the rate of carbonate dispersal or clastic incorporation. The same tests were run using values derived from lines drawn between and parallel to the dispersal trains. These lines are oriented toward Strzelecki Harbour, Flexure Bay, Muskox Hill and south of Cape Henry Kellett (Fig. 46).

Several regression analyses on values from the carbonate dispersal plumes and areas between them were rejected because of insignificant R values or Y intercept (Tables 6; 7). Except for one, tests accepted from values of the carbonate dispersal plumes are linear. Values derived from the Young Bay dispersal plume on the carbonate granules distribution map tested exponential. A low number of sample points may account for an exponential test.

Between carbonate dispersal plumes simple regression analysis varied. The granules and depth to frost table distribution maps tested linear while carbonate and vegetation distribution maps tested exponential (Tables 8; 9). Exponential (rapid) rate of debris dispersal indicates low sliding velocities,relatively high frictional resistances, high basal debris concentrations or some combination of these. Linear or more gradual change of debris dispersal indicates high sliding velocities and transport of material higher in the ice allowing farther transport of material (Clark, 1987).

3.4.4 DISCUSSION

Regression analysis on values derived from till in dispersal trains of Europe and elsewhere in North America test exponential (Clark, 1987). The magnitude of dispersal depends on distance of transport with local dispersal having the most rapid lithological changes.

TABLE 6: SIMPLE REGRESSION ANALYSIS FOR CARBONATE DISPERSAL PLUMES.

Distribution Map/ Values	Transition Bay	Le Feuvre Inlet	Young Bay	Muskox Valley
-Carbonate granules				
* Regression Test	Linear^	Linear^	Expon.	Linear^
* # Control Points	6	14	8	8
* R Value	79.6%	77.5%	92.7%	87.6%
* Y Intercept	106.5	104.6	5.1	152.4
-Clastic granules				
* Regression Test	Linear^	Linear^	Linear	Multi.^
* # Control Points	6	13	8	8
* R Value	79.6%	76.5%	81.5%	89.2%
* Y Intercept	-6.5	-4.4	0.2	-4.5
-Texture, Sand				
* Regression Test	Linear^	Recip.^	-	Linear^
* # Control Points	7	5	-	2
* R Value	57.8%	82.9%	-	98.9%
* Y Intercept	26	-	-	42.2
-Texture, Silt and Clay				
* Regression Test	Linear^	Linear^	-	Linear^
* # Control Points	7	5	-	2
* R Value	57.8%	81.4%	-	87%
* Y Intercept	74	66.5	-	62.2
-Carbonate				
* Regression Test	Linear	Multi.^	Linear^	Linear
* # Control Points	17	4	4	8
* R Value	78.4%	77.9%	96.8%	95%
* Y Intercept	97.8	4.4	94.9	68.8
-Vegetation				
* Regression Test	Linear^	Linear^	Expon.^	Linear
* # Control Points	6	5	5	6
* R Value	34.3%	92.7%	80.1%	92.8%
* Y Intercept	4.9	-0.1	2.6	12.8
-Depth To Frost Table				
* Regression Test	Linear^	Linear	-	-
* # Control Points	4	8	-	-
* R Value	91.5%	74.9%	-	-
* Y Intercept	-3.2	20.6	-	-

^ Best possible test rejected.

TABLE 7: SIMPLE REGRESSION ANALYSIS FOR AREAS BETWEEN CARBONATE DISPERSAL PLUMES.

Distribution Map/ Variables	Strzelecki Harbour	Flexure Bay	Muskox Hill	Cape Henry Kellett
-Carbonate granules				
* Regression Test	Linear	Linear	Linear^	Linear
* # Control Points	8	8	8	8
* R Value	97.1%	95.9%	91.7%	90.7%
* Y Intercept	98.3	80.9	119.6	97.9
-Clastic granules				
* Regression Test	Linear	Linear	Linear^	Linear
* # Control Points	8	8	8	8
* R Value	97.1%	95.9%	90.7%	91%
* Y Intercept	1.7	19.1	-30.2	10.5
-Texture, Sand				
* Regression Test	Recip.^	-	Recip.^	Linear^
* # Control Points	4	-	2	4
* R Value	11.4%	-	81.2%	85.9%
* Y Intercept	-	-	-	47.4
-Texture, Silt and clay				
* Regression Test	Linear^	-	Linear^	Recip.^
* # Control Points	4	-	2	4
* R Value	6.7%	-	79.6%	92%
* Y Intercept	57.2	-	46	-
-Carbonate				
* Regression Test	Expon.	Expon.	-	Expon.
* # Control Points	9	7	-	6
* R Value	85.5%	86.8%	-	94.5%
* Y Intercept	4.3	5	-	4.3
-Vegetation				
* Regression Test	-	Expon.	-	Expon.^
* # Control Points	-	7	-	5
* R Value	-	85.4%	-	80.1%
* Y Intercept	-	2.6	-	2.7
-Depth To Frost Table				
* Regression Test	Linear	Recip.^	-	-
* # Control Points	7	6	-	-
* R Value	85.1%	70.9%	-	-
* Y Intercept	25.6	-	-	-

^ Best test rejected

TABLE 8: RATE OF CARBONATE DISPERSAL-CLASTIC INCORPORATION FOR CARBONATE DISPERSAL PLUMES.

Distribution Map	Transition Bay	Le Feuvre Inlet	Young Bay	Muskox Valley
-Carbonate granules				
* Regression Test	-	-	Expon.	-
* Rate, carbonate granule dropoff	-	-	41%^	-
-Clastic granules				
* Regression Test	-	-	Linear	-
* Rate, clastic granule pickup	-	-	3%/km	-
-Texture, Sand				
* Regression Test	-	-	-	-
* Rate, pickup	-	-	-	-
-Texture, Silt and Clay				
* Regression Test	-	-	-	-
* Rate, dropoff	-	-	-	-
-Carbonate				
* Regression Test	Linear	-	-	Linear
* Rate, dropoff	1.13%/ km	-	-	1.62%/km
-Vegetation				
* Regression Test	-	-	-	Linear
* Rate, increase	-	-	-	3.6%/km
-Depth To Frost Table				
* Regression Test	-	Linear	-	-
* Rate, depth increase	-	1.07cm/km	-	-

^ Measured over the first 10km.

TABLE 9: RATE OF CARBONATE DISPERSAL-CLASTIC INCORPORATION FOR AREAS BETWEEN CARBONATE DISPERSAL PLUMES.

Distribution Map	Strzelecki Harbour	Flexure Bay	Muskox Hill	Cape H[illegible]y
-Carbonate Granules				
* Regression Test	Linear	Linear	-	L[illegible]
* Rate, carbonate granule dropoff	4.46%/km	4.98%/km	-	5%/[illegible]
-Clastic Granules				
* Regression Test	Linear	Linear	-	Linear
* Rate, clastic granule pickup	4.46%/km	4.98%/km	-	3.7%/km
-Texture, Sand				
* Regression Test	-	-	-	-
* Rate, pickup	-	-	-	-
-Texture, Silt and clay				
* Regression Test	-	-	-	-
* Rate, dropoff	-	-	-	-
-Carbonate				
* Regression Test	Expon.	Expon.	-	Expon.
* Rate, dropoff	22%^	29%^	-	68%^
-Vegetation				
* Regression Test	-	Expon.	-	-
* Rate, increase	-	40%^^	-	-
-Depth To Frost Table				
* Regression Test	Linear	-	-	-
* Rate, increase in depth	1.07cm/ km	-	-	-

^ Measured over first 10km.
^^ Measured over last 10km.

Primary controls on scales of transport are topography and basal ice velocity (Clark, 1987). Ice flow accelerates from an ice divide to equilibrium line, where it then decelerates as it enters the ablation zone.

Till collected from eastern Prince of Wales Island is near the zone of acceleration from the M'Clintock Ice Divide which may account for linear rates of debris dispersal. Values from till down-ice on Somerset Island and Boothia Peninsula may prove that the whole debris dispersal is exponential. Regression analysis on % granule values derived from till within other dispersal plumes in North America indicate dispersal of debris is initially very rapid from the source area and then decreases over distance at an exponential rate.

Pre-existing topography may enhance the development of ice streams (Denton and Hughes, 1981; Hughes et al., 1985). Carbonate dispersal plumes are found on eastern Prince of Wales Island where a west-east aligned trough exists through the Barrow Surface (Figs. 47, 48). Ice flow could be rapid through these troughs keeping particles in transit. Where no trough occurs, ice is forced over the west side of the Barrow Surface decreasing basal ice velocity and increasing friction between bed and particle, causing the release of particles in transit (Fig. 49). Appendix 1 provides the other cross-sections drawn for the other plumes and intervening areas shown in Fig. 46. These show similar

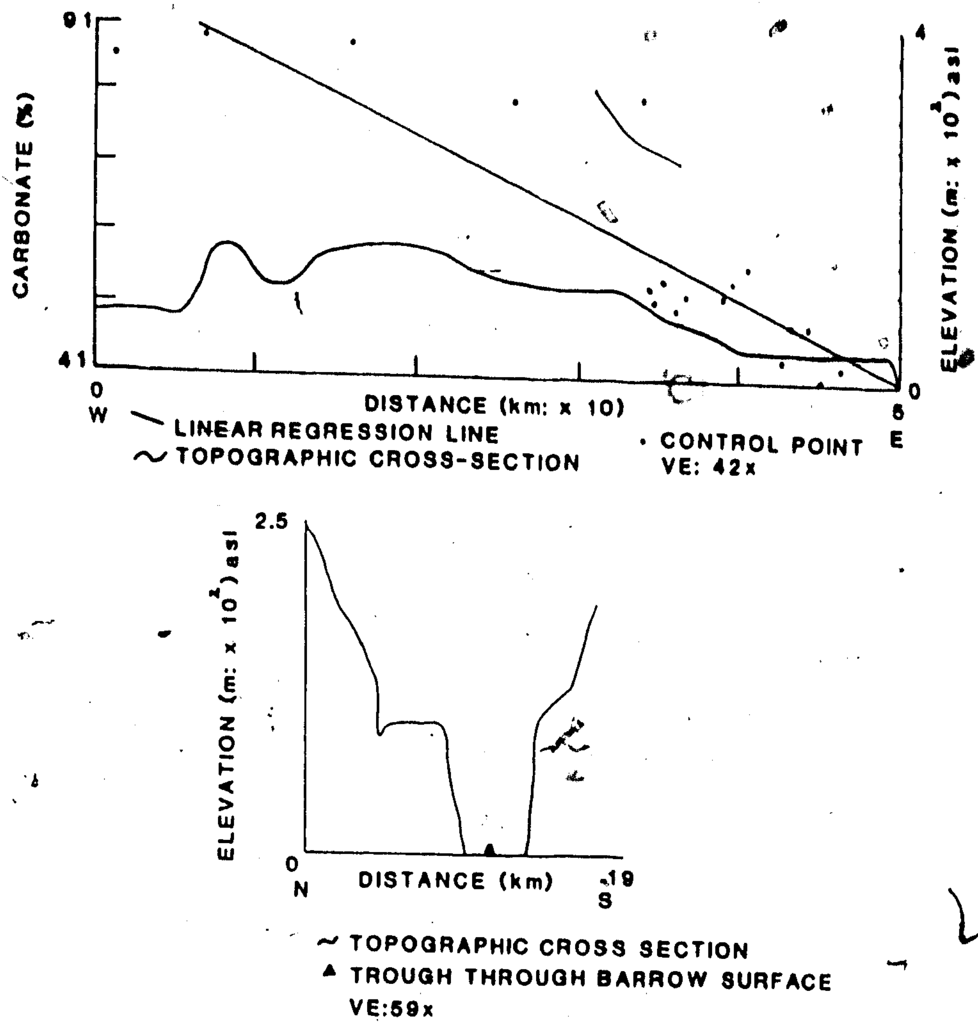


FIG. 47: Simple regression analysis from the carbonate distribution map, Transition Bay line. Carbonate is dispersed through a trough in the Barrow Surface (cross- section across the axis of the trough north- south; A). N= north, S= south, W= west, E= east and VE= vertical exaggeration.

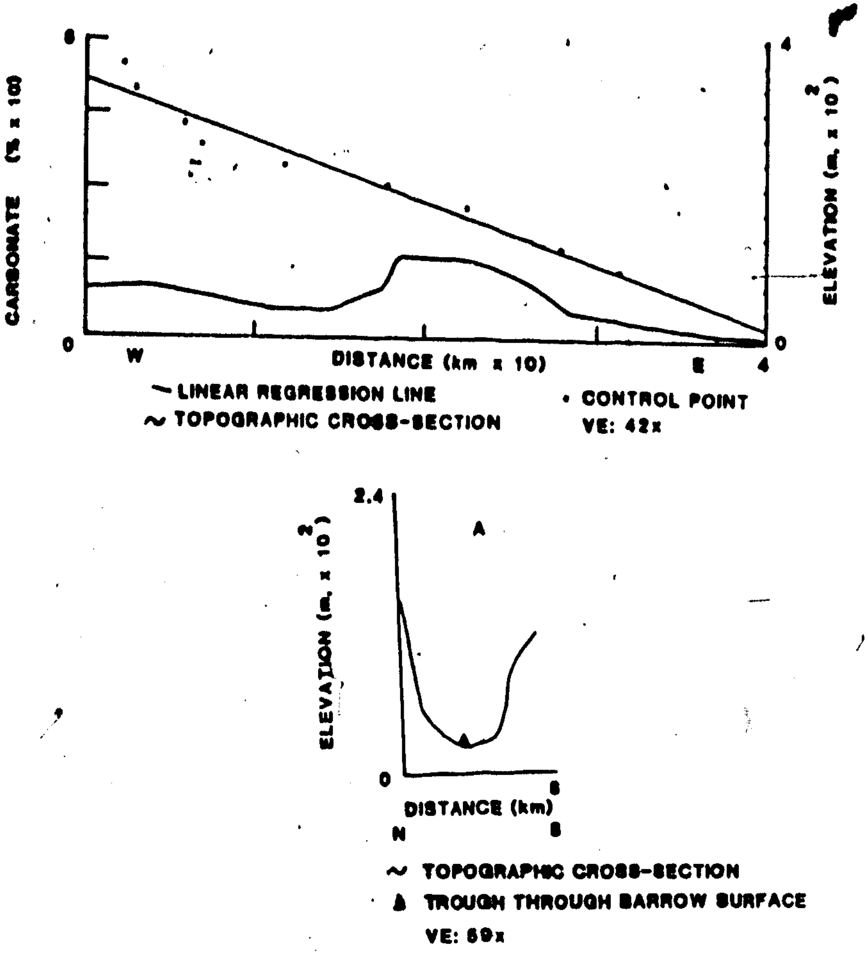


FIG. 48: Simple regression analysis from the carbonate distribution map, Muskox Valley line. Carbonate is dispersed through a trough in the Barrow Surface (cross- section across the axis of the trough north- south; A). N= north, S= south, W= west and VE= vertical exaggeration.

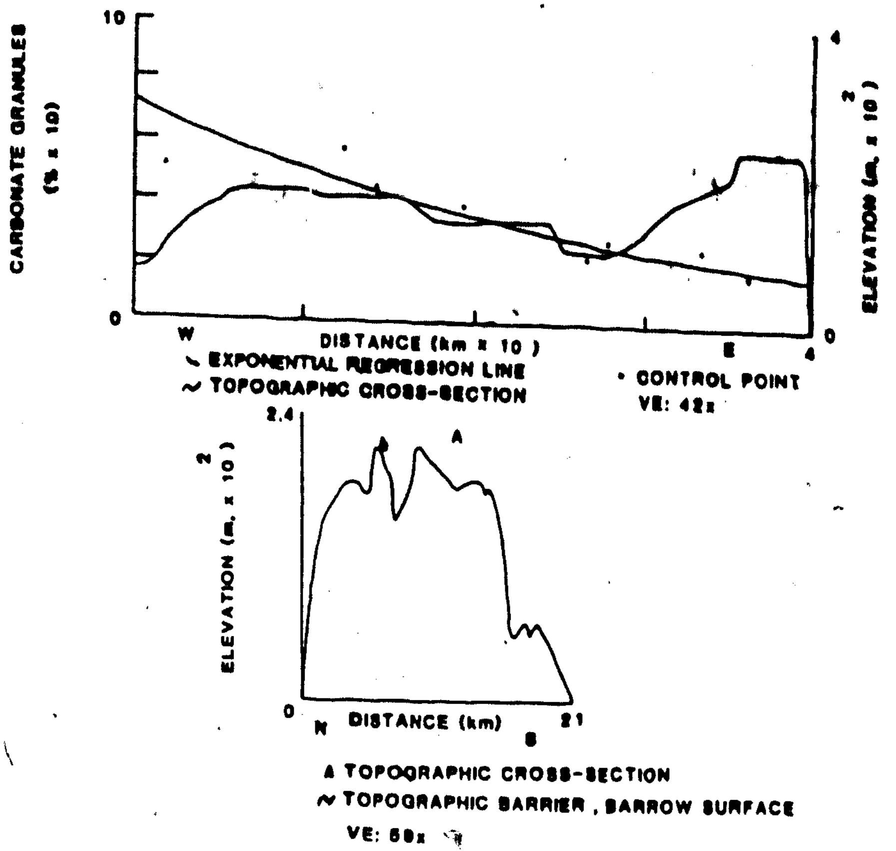


FIG. 49: Simple regression analysis from the carbonate distribution map, Strzelecki Harbour line (line between the Transition Bay and Le Feuvre Inlet dispersal trains). Carbonate is dispersed over the Barrow Surface (A). N= north, S= south, W= west and VE= vertical exaggeration

relationships to those in Figs. 47- 49.

It is concluded from these analyses that carbonate is not carried as far over topographic barriers than in troughs. Granule distribution maps have linear dispersal of carbonate granules and incorporation of clastic granules over topographic barriers whereas carbonate and vegetation distribution maps show exponential carbonate dispersal over the topographic barriers. This pattern of dispersal and incorporation may indicate that granules are transported farther and higher in the ice whereas carbonate rich matrix is transported basally. Rate of carbonate dispersal through the Wisconsinan (120000-10000 BP) and Late Wisconsinan (25000--10000 BP) can be calculated (Tables 10, 11) if rate of carbonate dispersal is considered constant. Although rate of carbonate dispersal is less rapid when time is included in the rate of dispersal, the same conclusions can be drawn regarding topography and its affect on material transport when time is not included.

3.4.5 Ice Sheet Surface Configuration

Reconstruction of the surface configuration of the M'Clintock Ice Divide is possible for part of the Wisconsinan. This reconstruction is made possible by the west-east streamlined landforms which record regional and ice stream flow during parts of the Wisconsinan. Regional

Table 10: **RATES OF CARBONATE DISPERSAL-CLASTIC INCORPORATION THROUGH THE WISCONSINAN (120000-10000 BP) AND LATE WISCONSINAN (25000-10000 BP) FOR CARBONATE DISPERSAL PLUMES.**

Distribution Map		Transition Bay	Le Feuvre Inlet	Young Bay	Muskox Valley
-Carbonate granules					
* Wiscon.	(%/km)	-	-	3.7 10 ^	-
* L. Wiscon.	(%/km)	-	-	2.7 10 ^	-
-Clastic granules					
* Wiscon.	(%/km)	-	-	2.7 10	-
* L. Wiscon.	(%/km)	-	-	2 10	-
-Texture, Sand					
* Wiscon.	(%/km)	-	-		-
* L. Wiscon.	(%/km)	-	-		-
-Texture, Silt and clay					
* Wiscon.	(%/km)	-	-	-	-
* L. Wiscon.	(%/km)	-	-	-	-
-Carbonate					
* Wiscon.	(%/km)	1 10	-	-	1.5 10
* L. Wiscon.	(%/km)	7.5 10	-	-	1.1 10
-Vegetation					
* Wiscon.	(%/km)	-	-	-	3.3 10
* L. Wiscon.	(%/km)	-	-	-	2.4 10
-Depth To Frost Table					
* Wiscon.	(%/km)	-	9.7 10	-	-
* L. Wiscon.	(%/km)	-	7.1 10	-	-

^ Measured over first 10 km.

TABLE 11: RATES OF CARBONATE DISPERSAL-CLASTIC INCORPORATION THROUGH THE WISCONSINAN (120000-10000 BP) AND LATE WISCONSINAN (25000-10000 BP) FOR AREAS BETWEEN CARBONATE DISPERSAL PLUMES.

Distribution Map		Strzelecki Harbour	Flexure Bay	Muskox Hill	Cape Henry Kellett
-Carbonate granules					
* Wiscon.	(%/km)	4 10	4.5 10	-	4.5 10
* L. Wiscon.	(%/km)	3 10	3.3 10	-	3.3 10
-Clastic granules					
* Wiscon.	(%/km)	4.5 10	4.5 10	-	3.4 10
* L. Wiscon.	(%/km)	3 10	3.3 10	-	2.5 10
-Texture, Sand					
* Wiscon.	(%/km)	-	-	-	-
* L. Wiscon.	(%/km)	-	-	-	-
-Texture, Silt and Clay					
* Wiscon	(%/km)	-	-	-	-
* L. Wiscon.	(%/km)	-	-	-	-
-Carbonate					
* Wiscon.	(%/km)	2 10 ^	2.6 10 ^	-	6.2 10 ^
* L. Wiscon.	(%/km)	1.5 10 ^	1.9 10 ^	-	4.5 10 ^
-Vegetation					
* Wiscon.	(%/km)	-	3.6 10 ^^	-	-
* L. Wiscon.	(%/km)	-	2.7 10 ^^	-	-
-Depth To Frost Table					
* Wiscon.	(%/km)	9.7 10	-	-	-
* L. Wiscon.	(%/km)	7.1 10	-	-	-

^ Measured over the first 10 km.
^^ Measured over the last 10 km.

flow is also defined on Somerset Island and Boothia Peninsula across Peel Sound to the east (Fig. 50). Carbonate transported east from Prince of Wales Island was spread onto metasedimentary rock of Somerset Island and Boothia Peninsula as a dispersal train 150km wide (Dyke, 1984). Streamlined forms south of Creswell Bay, Somerset Island, are aligned west-east and indicate no convergence. These regional flow lines and those from southern Prince of Wales Island probably represent regional ice flow during full glacial conditions because regional flow lines defy even large relief elements (eg. Peel Sound; Fig. 50).

Whether all the ice streams on Prince of Wales and Somerset islands (Figs. 43, 50) are coeval is unknown. However, if all ice streams were not coeval the catchment areas of each individual ice stream would likely cross-cut one another. Streamlined forms associated with each catchment area would illustrate the cross-cutting of the catchment areas. Streamlined landforms associated with each catchment area do not cross-cut each other on southern Prince of Wales Island. Therefore the Muskox Valley, Young Bay, Le Feuvre Inlet and Transition Bay ice streams probably occurred simultaneously. Tertiary and secondary ice divides, extending from the M'Clintock Ice Divide would be required to allow simultaneous flow of these four ice streams. It is unknown when ice stream flow to the east commenced. However, the position of the

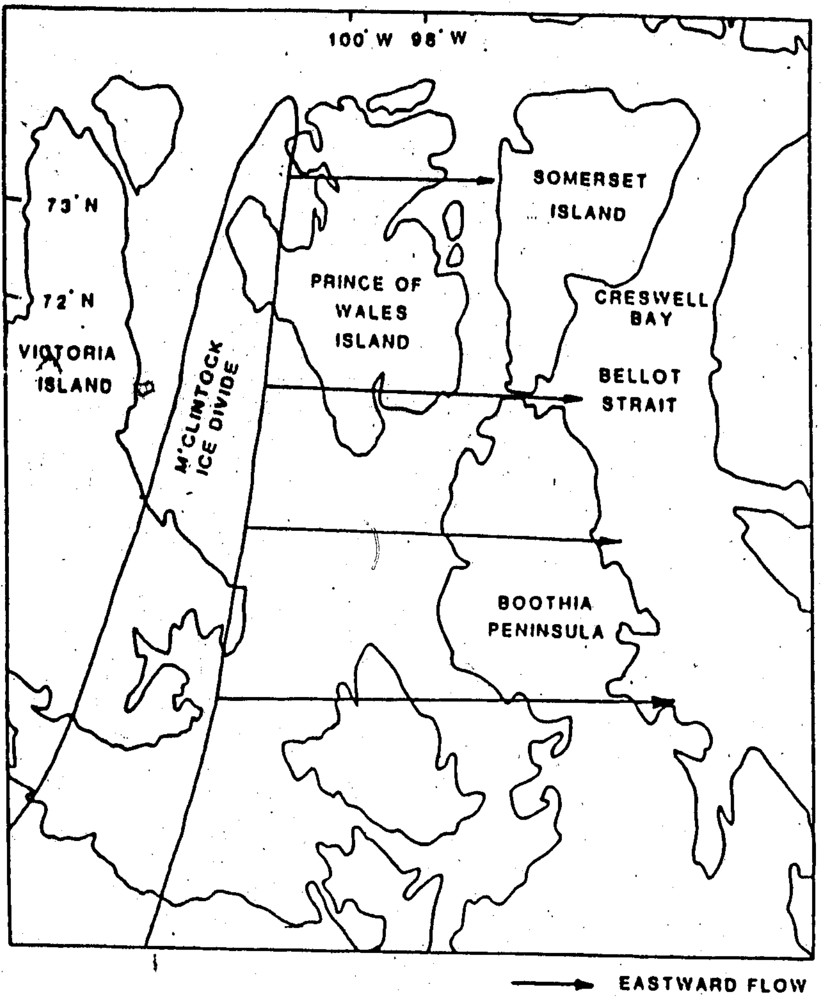


FIG. 50: Initial west-east flow from the M'Clintock Ice Divide over Prince of Wales Island, Somerset Island and Boothia Peninsula.

M'Clintock Ice Divide (Dyke and Prest, 1987) would have allowed coeval flow of all four ice streams until 12000 BP (Fig. 51).

Streamlined landforms converge through Bellot Strait indicating the coalescence of ice streams flowing through Le Feauvre Inlet and Transition Bay. At present there is no evidence that ice streams were deflected north and south by Peel Sound and this is considered unlikely because ice from the initial advance probably filled Peel Sound prior to ice stream flow. Also, water depth in Peel Sound may have been much shallower during the advance (see Chapter 4). Ice streams flowing through Young Bay and Muskox Valley could not have coalesced with ice streams flowing through Le Feuvre Inlet or Transition Bay. Young Bay and Muskox Valley ice streams either terminated in Peel Sound or abutted against western Somerset Island.

3.5 SUMMARY

Age of erratic marine shells collected from the subsurface within two sections on the Fisher River were calculated by amino acid racemization and uranium-series dating. These ages and the stratigraphy of the two Fisher River sections were compared to others on northern Prince of Wales Island and at Pasley River on Boothia Peninsula and all were ascribed to the Sangamonian. Comparison of

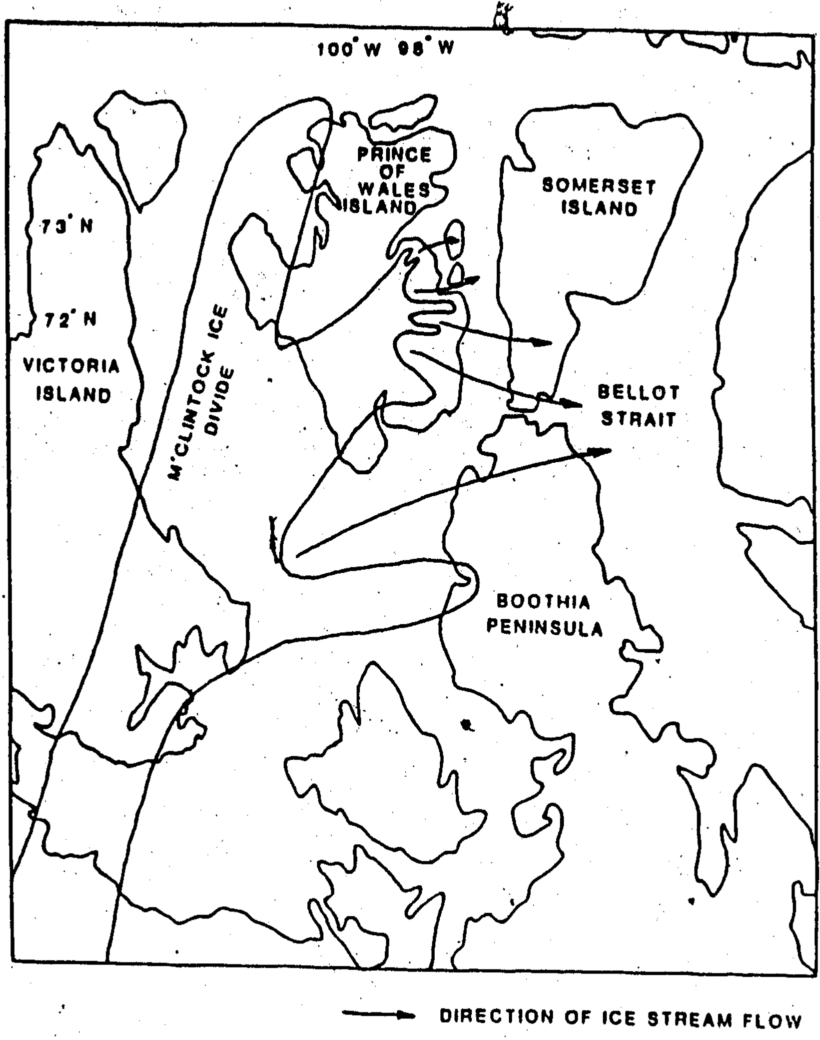


FIG. 51: Subsequent development of ice streams from second and tertiary ice divides on southern Prince of Wales Island.

the Fisher River sections to others led to the conclusion that the subtill fluvial gravels at sections 1 and 2 record southward drainage during the Sangamonian. Lower till at section 1 is therefore pre-Sangamonian. The lower till at section 1 is probably not associated with the high relief streamlined till as discussed below.

Low relief streamlined till is associated with upper till at sections 1 and 2; and is therefore post-Sangamonian because low relief streamlined till caps the Sangamonian fluvial gravels. An ice divide would be necessary to account for eastward flow responsible for the upper till and associated streamlined forms. It is unlikely that the establishment of the M'Clintock Ice Divide occurred by renewed flow of ice to the central Arctic after deposition of all the older landforms which have not been subsequently altered. Ice divide formation in the M'Clintock Channel is also unlikely due to its low topography. Therefore the surficial landforms of Prince of Wales Island are best explained by disassociating the lower till at section 1 from the high relief streamlined till and associated landforms. Rather, it is concluded that Early Wisconsinan ice flow from the south deposited the high relief streamlined till followed by the re-orientation of flow to the east depositing the low relief streamlined till during the Late Wisconsinan. This persistance of the Wisconsinan ice cover on Prince of Wales Island best explains the distribution and presence of all surficial features associated with glaciation.

Eastward ice flow during the Wisconsinan was regional as indicated by the broad dispersal of carbonate over eastern Prince of Wales Island and widely distributed, high elevation, west-east oriented, streamlined landforms. Carbonate was then transported east in four well defined dispersal plumes (Fig. 43). Properties of till samples collected from the study area and observations made at each till sampling site were mapped. Lines were drawn through the carbonate dispersal plumes from their up-ice position to the east coast using several distribution maps (Fig. 46). Lines were also drawn parallel to but between dispersal plumes. Regression analyses on specific till values derived from these lines indicate that rates of carbonate dispersal was greatest between dispersal plumes recording the least amount of comminution. Topographic cross-sections were constructed from lines drawn parallel and through each carbonate dispersal plume and perpendicular to each carbonate dispersal plume where it crossed the Barrow Surface into Peel Sound. These cross-sections indicated that low carbonate dispersal rates or clastic incorporation occurred where a trough exists in the Barrow Surface.

Simple regression analysis on the carbonate and vegetation distribution maps generally tested linear from within the dispersal plumes and exponential between dispersal plumes. Linear dispersal of carbonate means high sliding velocities and extended transit of particles facilitated by low topography. Exponential dispersal of carbonate means low sliding velocities probably caused by a topographic barrier.

Measurements made on the area of each dispersal plume indicated that the greatest transport of carbonate was toward Transition Bay followed by Le Feuvre Inlet. Ice streams at Le Feuvre Inlet and Transition Bay probably coalesced to form a larger ice stream flowing across Peel Sound to Bellot Strait. Ice streams at Young Bay and Muskox Valley, which were smaller than those at Le Feuvre Inlet and Transition Bay, probably terminated in Peel Sound or flowed against the west coast of Somerset Island.

CHAPTER 4

CHRONOLOGY AND PATTERN OF DEGLACIATION AND EMERGENCE

This chapter presents the pattern and timing of ice retreat from southern Prince of Wales Island. This ice retreat is based upon the distribution of end and lateral moraines, kames, lateral and proglacial meltwater channels and eskers. Timing and character of ice retreat is based on radiocarbon dating and measurement of marine limit elevation. Six emergence curves have also been constructed.

4.1 Southern Prince of Wales Island Ice Retreat

4.1.1 Distribution Of Ice Marginal Features

The pattern of ice retreat is best defined in the east part of the study area. End moraines are located east of Crooked Lake and west of the Barrow Surface (Fig. 52). The largest concentration of end moraines is south of Young Bay. Lateral moraines are located on the north and south flanks of the abandoned Tertiary river channel west of Young Bay and north and south of Le Feuvre Inlet (Fig. 52).

Kames and associated deposits are also distributed

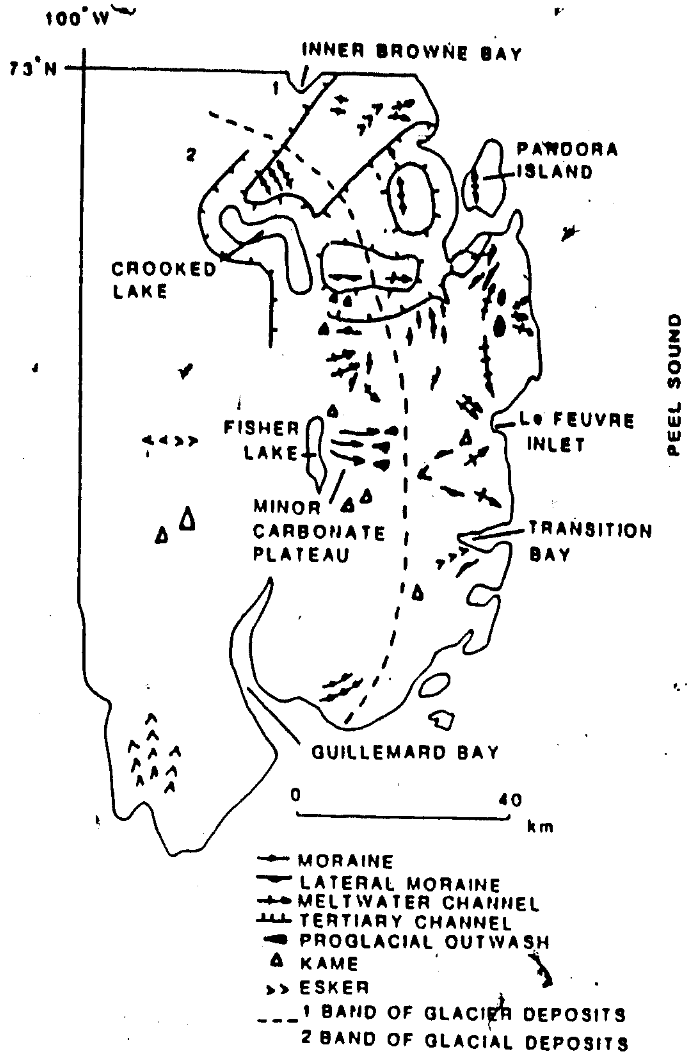


FIG. 52: General distribution of selected glacial deposits. Note: due to the scale of this map not all selected glacial deposits are included or are in their exact geographic location. Please refer to Fig. 13 for detail.

around the eastern parameter of the study area. Kames are concentrated in a north-south belt east of Fisher Lake on the eastern flank of a minor carbonate plateau. Kames are also concentrated west of Fisher Lake (Fig. 52).

Proglacial and lateral meltwater channels are the most abundant ice marginal features. There are two parallel, distinct belts of proglacial and lateral meltwater channels. The first belt is located on the west slope of the eastern plateau (Barrow Surface) and consists of large canyons and smaller channels. These were cut by meltwater as ice retreated downslope to the west. The second belt, consisting of channels similar in size to the smaller channels on the Barrow Surface, are located north of Crooked Lake and east of Fisher Lake (Fig. 52). Proglacial outwash is associated with both belts. An esker system, aligned southwest-northeast, is located east of Inner Browne Bay (Fig. 52). A second esker system, aligned west-east, is located west of Transition Bay (Fig. 52). Eskers are most abundant in the southwest where three south-north aligned eskers and two smaller west-east aligned eskers are located (Fig. 52).

4.1.2 DISTRIBUTION AND AGE OF MARINE LIMIT

Inside the last ice limit, marine limit is formed at the instant of deglaciation marking the highest level reached by the postglacial sea. Because the whole study area was overrun with ice during the last glaciation marine limits date from the time of deglaciation and provide important chronological control when dateable material is contained in these raised shorelines. Furthermore, relative rate of ice retreat is recorded by the slope of marine limit at a local scale. For example, marine limit increases in elevation towards a former ice centre when ice retreat is rapid whereas it decreases towards a former ice centre when ice retreat is slow (Andrews, 1968).

Marine limit is recorded on southern Prince of Wales Island by three features; 1) uppermost beach ridges which may coincide with the highest occurrence of marine fossils and/ or lowest occurrence of meltwater channels; 2) wave-washed till benches associated with the highest occurrence of marine fossils; and 3) a glaciomarine delta. Marine limit was measured on: the east coast of Inner Browne Bay; three locations on the east coast of southern Prince of Wales Island; three locations on Pandora Island; and one location east of Fisher Lake (Fig. 53). Land west of these sites lies below marine limit.

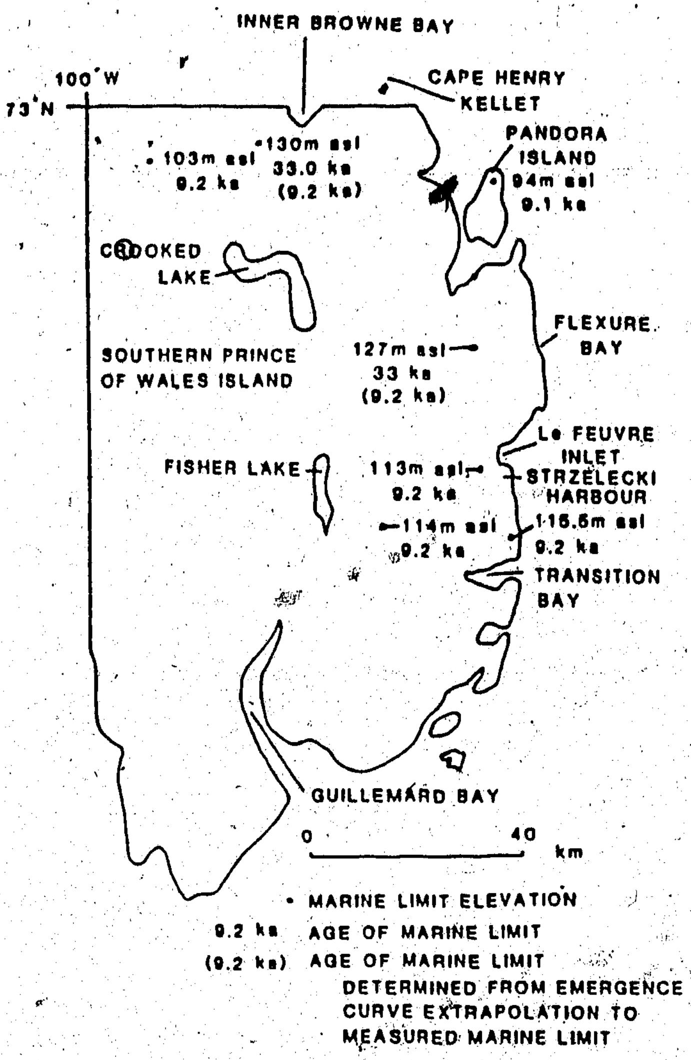


FIG. 53: Location of measured marine limits on southern Prince of Wales and Pandora islands.

Marine limit is marked on the east coast of Inner Browne Bay by the highest beach (103m asl) contacted by a meltwater channel on its landward side. Marine limit is recorded south of Cape Henry Kellett by the highest beach at 130m asl (Fig. 53) where meltwater channels also terminate. A radiocarbon date on marine shells collected from this highest beach dated >33000 BP (S-2712). Marine limit is similarly recorded west of Flexure Bay, on the west slope of the eastern plateau, at 127m asl. A radiocarbon date on shell fragments and valves collected from this highest beach indicates marine limit is also >33000 BP (S-2713). A third marine limit probably exists west of Strzelecki Harbour where Bird (1961) measured a terrace at 113m asl. Marine shells collected from this terrace were radiocarbon dated at 9200+/- 160 BP (L- 571B). A wave-washed till bench (115.5m asl) marks marine limit north of Transition Bay. Whole valves of Mya truncata were collected and radiocarbon dated at 8940+/- 130 BP (GSC- 3996). Marine limit is recorded at three different locations by highest beaches on Pandora Island. On the northwest coast a meltwater channel contacts the highest beach at 94m asl. Whole valves of Mya truncata collected from this beach were radiocarbon dated at 9140+/- 130 BP (S- 2828). Finally, a glaciomarine delta was deposited east of Fisher Lake at 114m asl. Marine shells collected from bottomset silts were radiocarbon dated at 9190+/- 170 BP (GSC- 4049). Collectively, the elevation of marine limit on southeast Prince of Wales Island neither rises or falls towards a former ice-load centre. Similar dates of marine limits suggests that ice retreated from the area rapidly.

4.1.3 EMERGENCE

Seventeen whalebone and twenty-one driftwood samples were submitted for radiocarbon dating (Table 12). Sample elevations were determined with a Wallace and Tiernan altimeter which when corrected for temperature and pressure changes has an accuracy of +/-2m at 100 to 200m asl and +/-1m asl for lower elevations (Bednarski, 1984). Marine limit elevations were checked against sea level where possible. When samples were collected closer to base camp than sea level, these elevations were checked against the surveyed elevation of base camp. Altimeter readings were taken before and after sample excavation. Six emergence curves were constructed from 45 radiocarbon dates obtained from samples collected at and below marine limit. These emergence curves were constructed within as small an area as possible in order to limit the effects of differential emergence. Each emergence curve is discussed in turn from south to north (Fig. 54).

TABLE 12: Radiocarbon Dates From Southern Prince of Wales Island

Location On Fig. 54	Date (BP)	Lab. No.	Location	Collected Elevation (asl, m)	Related Relative Elevation To Sea Level (m)	Material
1	3170+/-075	S-2860	71^52'N99^52'W	9	9	Driftwood
2	7620+/-345	S-2719	71^57'N98^56'W	46	46	Driftwood
3	1900+/-325	S-2717	71^29'N99^24'W	4	4	Driftwood
4	6630+/-100	S-2830	71^51'N99^38'W	26	26	Driftwood
5	1620+/-220	S-2718	71^22'N98^54'W	6	6	Driftwood
6	4505+/-085	S-2861	71^40'N98^24'W	18	18	Whalebone
7	6275+/-175	S-2595	71^50'N98^05'W	103	103	Whalebone
8	6660+/-160	S-2594	71^50'N98^05'W	81	81	Whalebone
9	0660+/-095	S-2596	71^50'N98^10'W	4	4	Whalebone
10	4400+/-070	GSC-3989	71^41'N98^08'W	16	16	Driftwood
11	7650+/-120	S-2602	71^35'N97^20'W	98	98	Whalebone
12	8520+/-190	S-2604	71^35'N97^20'W	84	84	Whalebone
13	8675+/-135	S-2603	71^35'N97^20'W	75.5	75.5	Whalebone
14	4870+/-095	S-2600	71^40'N97^15'W	1	17	Whalebone
15	6100+/-080	GSC-3985	71^39'N97^21'W	31.5	31	Driftwood
16	6910+/-080	GSC-3967	71^39'N97^22'W	39	39	Driftwood
17	6940+/-155	S-2601	71^41'N97^15'W	48	48	Whalebone
18	8645+/-205	S-2599	72^00'N96^30'W	87	87	Whalebone
19	8940+/-130	GSC-3996	72^05'N96^33'W	115.5	115.5	Shell
20	9225+/-215	S-2597	72^10'N97^50'W	99	99	Whalebone
21	8630+/-195	S-2598	72^10'N97^50'W	81.5	81	Whalebone
22	9190+/-170	GSC-4049	72^13'N97^31'W	97	114	Shell
23	9200+/-160	L-571B+	72^13'N96^38'W	113	113	Shell
24	4370+/-085	S-2863	72^19'N96^51'W	4	-	Driftwood
25	0360+/-065	S-2862	72^33'N96^26'W	2.5	[illegible]5	Driftwood
26	>33, 000	S-2713	72^29'N96^51'W	127.5	[illegible]7.5	Shell
27	8660+/-395	S-2720	72^36'N97^00'W	84	[illegible]	Driftwood
28	5795+/-090	S-2829	72^46'N96^53'W	23	23	Driftwood
29	0845+/-060	S-2834	72^51'N96^54'W	7	7	Driftwood
30	0315+/-060	S-2833	72^53'N96^49'W	2	2	Driftwood
31	8265+/-120	S-2832	72^51'N96^52'W	10.5	-	Driftwood
32	8565+/-125	S-2835	72^53'N96^47'W	66	66	Whalebone
33	9140+/-130	S-2828	72^53'N96^53'W	94	94	Shell
34	8905+/-405	S-2716	72^49'N97^18'W	100	100	Whalebone
35	2270+/-230	S-2715	72^52'N97^17'W	10	10	Whalebone
36	8655+/-130	S-2864	72^53'N97^30'W	68	68	Whalebone
37	0275+/-105	S-2714	72^52'N97^23'W	4	4	Driftwood
38	>33, 000	S-2712	72^55'N97^34'W	130	130	Shell
39	0605+/-065	S-2859	72^55'N98^22'W	6	6	Driftwood
40	4890+/-090	S-2839	72^50'N98^27'W	19	19	Driftwood
41	3765+/-080	S-2837	72^49'N98^29'W	12	12	Driftwood
42	7100+/-110	S-2838	72^46'N98^34'W	30	30	Driftwood
43	5965+/-095	S-2831	72^46'N98^35'W	25	25	Driftwood
44	9040+/-130	S-2836	72^40'N98^17'W	79.5	79.5	Whalebone
45	6740+/-150	GSC-235*	72^37'N98^27'W	18.5	-	Shell

+Olson and Brocker (1961)
*Craig (1962)

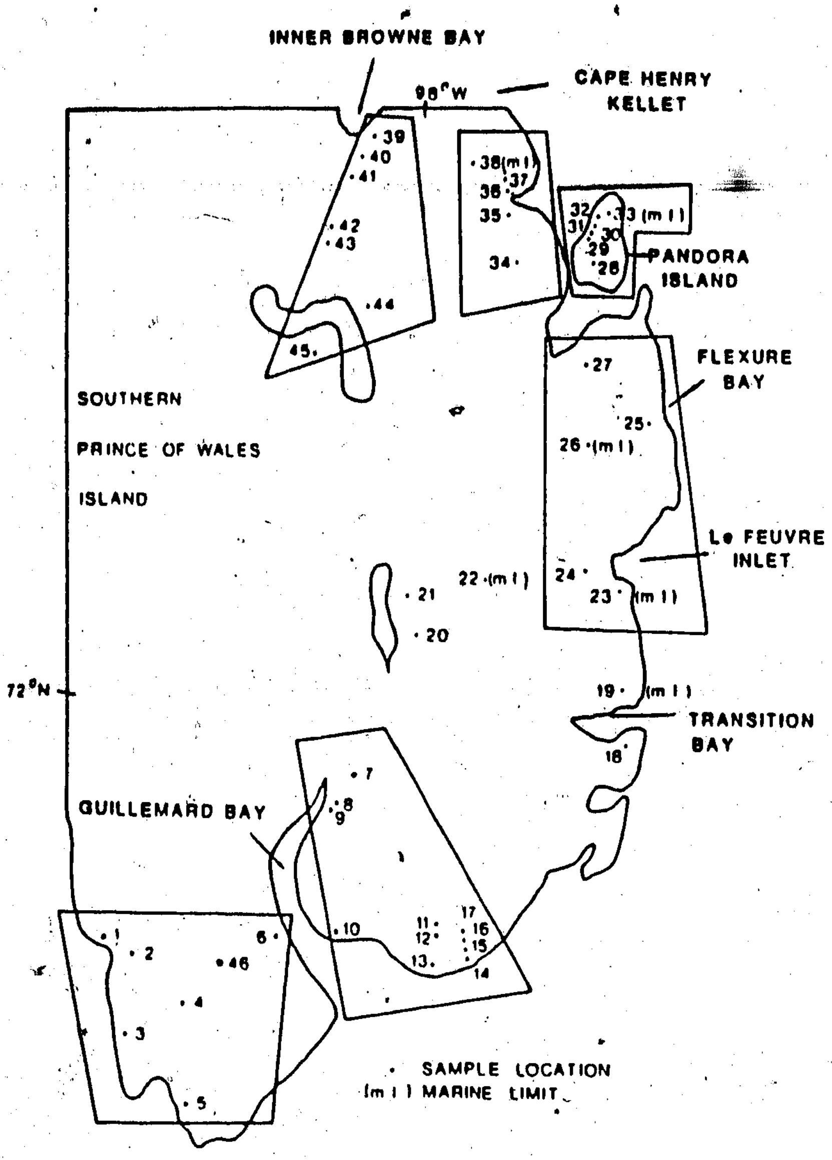


FIG. 54: Location and distribution of organic samples collected from marine limit and below. Corresponding number is in Table 11. Boxes indicate samples used in construction of emergence curves.

4.1.3.1 Thackeray Point

Radiocarbon dates from five driftwood samples and one whalebone sample were used to construct an emergence curve for Thackeray Point (sites 1- 6, Table 12 and Fig. 54). This emergence curve represents postglacial emergence since 7600 BP (Fig. 55) but does not date marine limit for Thackeray Point as the area is below marine limit.

4.1.3.2 Coningham Bay

Radiocarbon dates from three driftwood samples and four whalebone samples were used to construct an emergence curve for the area west of Coningham Bay (sites 10, 12, 14-17, Table 12 and Fig. 54). An eighth radiocarbon date from whalebone (site 11, Table 12, Fig. 54) is considered spurious because the date is anomalously young for the elevation from which it was collected. The emergence curve represents postglacial emergence since 8500 BP (Fig. 56) but does not date marine limit for Coningham Bay as the area is below marine limit.

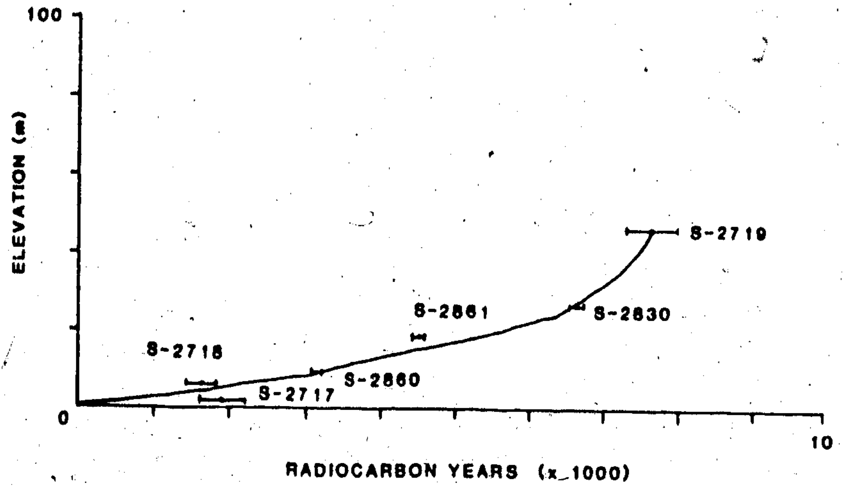


FIG. 5.5: Thackeray Point emergence curve. Marine limit occurs at an unknown elevation above local topography.

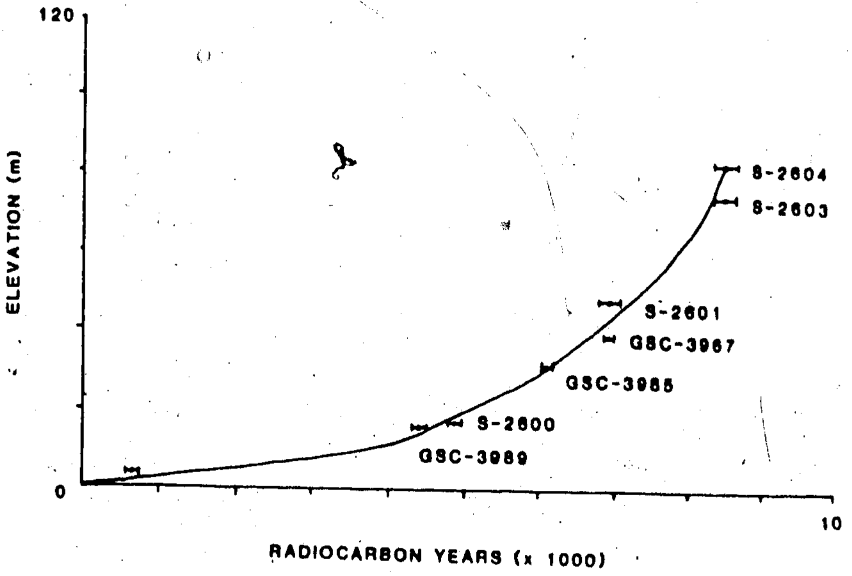


FIG. 56: Coningham Bay emergence curve. Sample S-2602 is considered spurious. Marine limit occurs at an unknown elevation above local topography.

4.1.3.3 Flexure Bay

Radiocarbon dates from three driftwood samples and one shell sample were used to construct an emergence curve for a broad area west of Flexure Bay (sites 23- 27, Table 12, Fig. 54). Shell fragments (site 26, Table 12, Fig. 54) collected from the marine limit beach surface dates >33000 BP. These marine shells may be erratics reworked from till by wave action. A more likely age for the marine limit can, however, be estimated (9300 BP) by extrapolating the emergence curve to the measured marine limit of 127.5m asl (Fig. 5).

4.1.3.4 Pandora Island

Radiocarbon dates from four driftwood samples, one whalebone sample, and one marine shell sample were used to construct an emergence curve for Pandora Island (sites 28- 33, Table 12, Fig. 54). One data point (site 31, Table 12, Fig. 54) is considered spurious because it is too old for the elevation from which it was collected and does not come close to fitting the "normal" emergence curve established by the other data points. The driftwood log probably was redeposited downslope from an unknown elevation (Fig. 58). This is a common problem in Arctic Canada (Stewart and England, 1983).

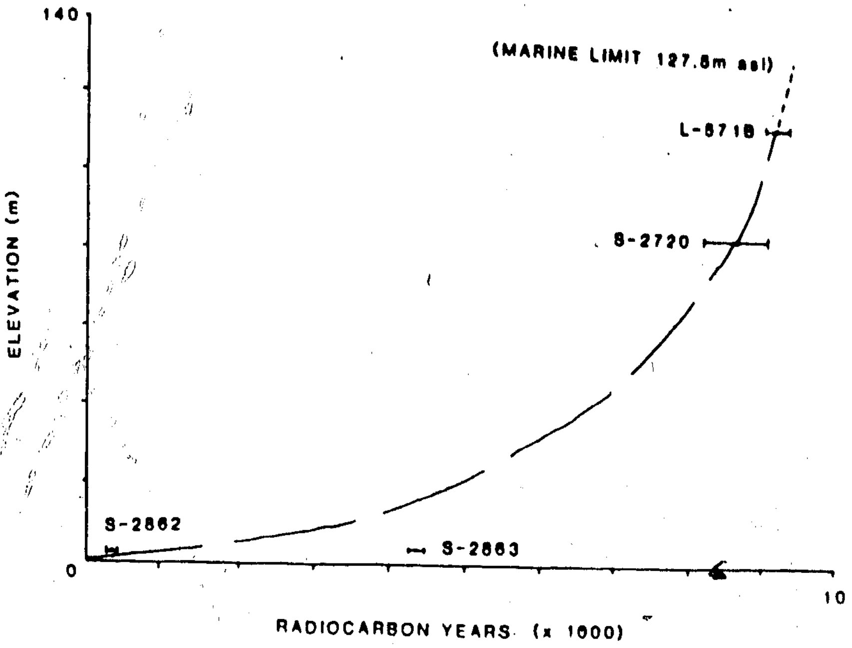


FIG. 57: Flexure Bay emergence curve. Upper dashed line is an extrapolation of the curve to the measured but undated marine limit (127m asl).

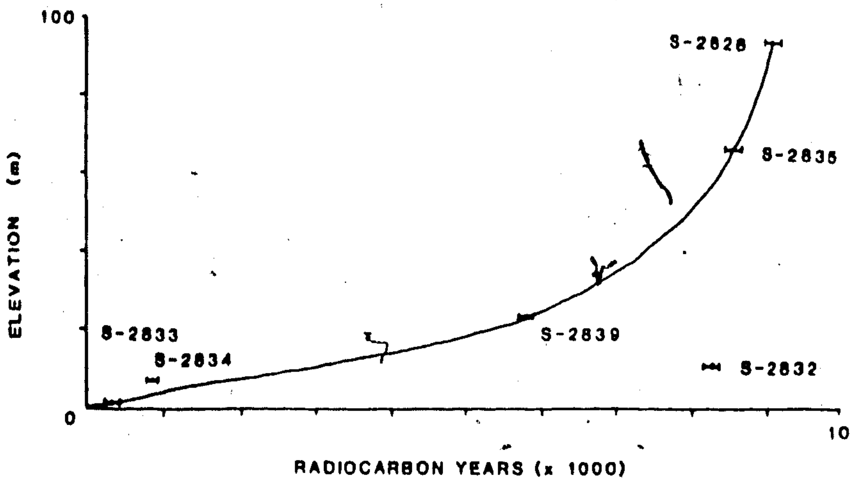


FIG. 58: Pandora Island emergence curve. Sample S-2832 is considered to have been redeposited downslope.

4.1.3.5 Cape Henry Kellett

Radiocarbon dates on one driftwood sample and three whalebone samples were used to construct an emergence curve south of Cape Henry Kellett (sites 34- 38, Table 12, Fig. 54). Shell fragments (site 38, Table 12 and Fig. 54) collected from this marine limit beach dated >33000 BP. However, this is regarded as too old for this shoreline. Shell fragments were also collected from the surface of marine limit and these are probably erratics derived from the adjacent or underlying till. An estimated age for marine limit is 9200 BP based on the extrapolation of the emergence curve to the marine limit at 130m asl (Fig. 59).

4.1.3.6 Inner Browne Bay

Radiocarbon dates from five driftwood samples, one whalebone sample, and one shell sample were used to construct an emergence curve for an area east of Inner Browne Bay (sites 39- 45, Table 12, Fig. 54 and Fig. 60). This emergence curve was extrapolated to the marine limit of 103m asl suggesting its establishment at 9200 BP. Collectively, the emergence curves have a similar form to others constructed in the central Arctic (Dyke 1983, 1984; Green 1984; Hodgson et al., 1984 and Washburn and Stuiver 1985). Few marine limits were dated because

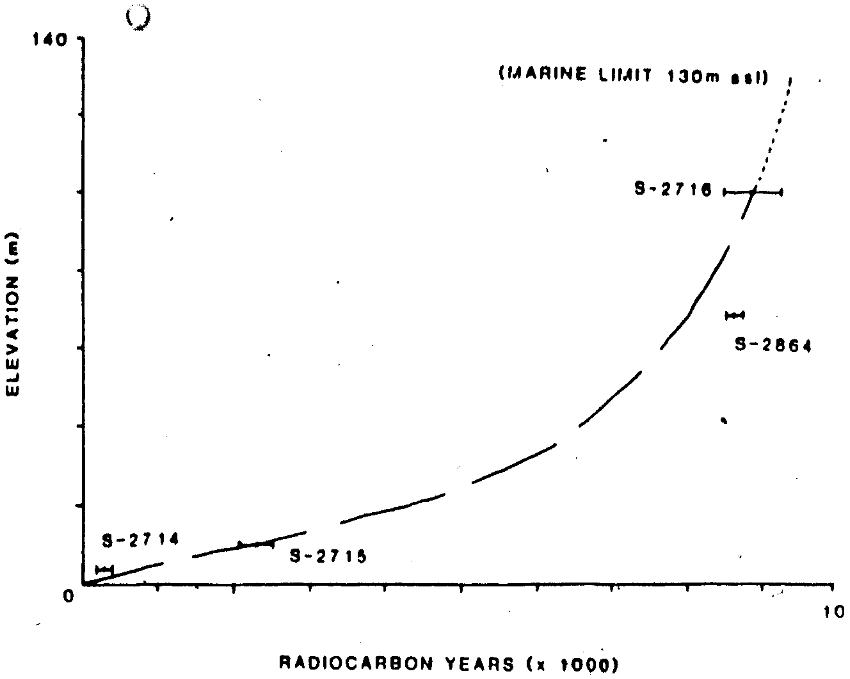


FIG. 59: Cape Henry Kellett emergence curve. Upper dashed line is an extrapolation of the curve to the measured but undated marine limit (130m asl).

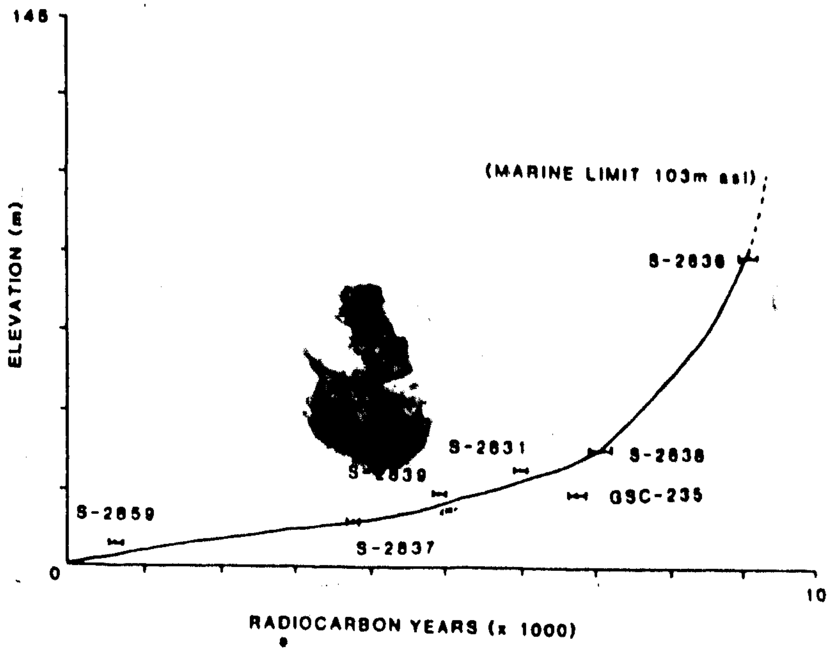


FIG. 60: Inner Browne Bay emergence curve. Upper dashed line is an extrapolation of the curve to the measured but undated marine limit (103m asl).

of scarcity of dateable material.

4.1.4 ANOMALOUSLY OLD WHALEBONE DATE

Whalebone was found partly embedded in the highest beach east of Thackeray Point (Fig. 55, site 46). An accelerator radiocarbon assay on the collagen fraction of the bone yielded an age of 12830+/-90 BP (TO-316). This age implies that ice withdrew to a point south of Prince of Wales Island about 13000 BP. All other dates associated with marine limit and deglaciation of southern Prince of Wales Island indicate final deglaciation about 9000 BP and the age of Winter Harbour till requires complete ice cover on Prince of Wales Island between 11300 and 11000 BP. Hence either the age determination of TO-316 is seriously in error or that bone, correctly dated, constitutes the only known evidence of an interval of complete deglaciation of Prince of Wales Island prior to deposition of Winter Harbour Till on islands lying down-ice of Prince of Wales Island. At present the date is clearly a regional anomaly and the conservative interpretation is to regard it as being erroneous. The problem, however, is that there is no known way of contaminating collagen in such a way as to make it too old (Blake, 1975a).

4.2 DISCUSSION

4.2.1 ICE MARGINAL FEATURES

Ice retreat on southern Prince of Wales Island is determined principally from the distribution of ice marginal features (Figs. 13, 52, 61). Ice margins were drawn by linking moraines and kames located within similar areas at similar elevations. Ice margins were also re-constructed by linking meltwater channels. This was done by extrapolating their upslope gradients until they roughly intersected interfluves (Dyke,1983 Fig. 61).

Ice retreated west from Flexure Bay and Strzelecki Harbour. A large number of meltwater channels are located in these areas aligned north-south across the west slope of the eastern plateau. Similar canyons are aligned north-south across the west slope of the plateau on Pandora Island (Figs. 13, 52). Meltwater, blocked to the west by retreating ice was forced to flow north-south against the west slope of the eastern plateaus, cutting these canyons into bedrock.

Lateral meltwater channels illustrate that the ice margin was lobate where it retreated west: from an unnamed bay south of Cape Henry Kellett, Young Bay, Flexure Bay and Le Feuvre Inlet (Fig 61). These areas represent troughs extending through the east coast plateau. These troughs controlled ice flow during

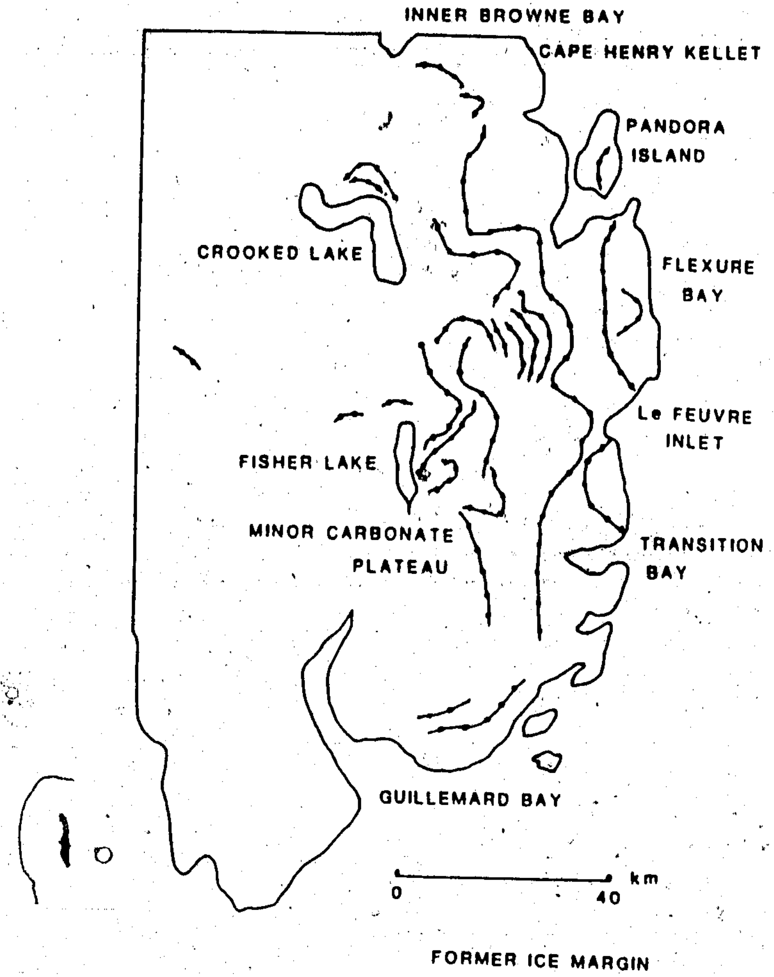


FIG. 61: Ice marginal positions derived from the elevation and orientation of ice marginal features. Note lobate form of ice margin in the north and east- central area whereas straight ice margins occur to the southeast. A cross-cutting ice margin exists southeast of Crooked Lake, suggesting ice advance.

westward retreat. The ice margin west of Transition Bay was generally straight (Fig. 61).

Ice retreat in the north part of the study area was initially west, after which it shifted southwest. This shift in the deglacial flow is determined by changes in the orientation of deglacial landforms. Ice occupying the Tertiary channel west of Young Bay retreated southwest (Figs. 13, 52, 61) leaving two distinct areas of lateral meltwater channels. A later reorientation of deglacial flow to the south occurred, indicated by the ice marginal features (Figs. 13, 52, 61).

Deglacial flow continued west from Flexure Bay and Le Feuvre Inlet (Fig. 61). A series of end moraines indicate that ice stabilized as lobes at least five times west of Le Feuvre Inlet (Fig. 52). Kames west and southwest of Transition Bay indicate a straight north-south alignment of the ice margin (Figs. 13, 52, 61). Two distinct sets of these deglacial landforms suggest that the ice margin stabilized at least twice. On the minor carbonate plateau west of Fisher Lake lateral meltwater channels indicate that the ice margin was lobate (Figs. 13, 52, 61). Two end moraines, one nested inside the other on the southeast coast, also suggest that the ice margin stabilized at least twice (Figs. 13, 52, 61). The orientation of these indicates that ice flow was southwest and the two ice margins were generally straight.

Two observations are derived from the orientation of these various ice margins. First, ice retreat south and west was directed toward the minor carbonate plateau east of Fisher Lake as illustrated by the distribution of lobate ice margins. Second, there are two ice marginal configurations in the area, lobate and straight. Ice flow which formed lobate margins was controlled by troughs. Lobate ice margins in troughs may suggest that ice in these was grounded. West of Transition Bay and northwest of Coningham Bay few landforms record ice retreat but define straight ice margins which may indicate instability and rapid retreat caused by calving in the sea.

An ice margin cannot be defined west or southwest of the minor carbonate plateau. "Unpinning" of ice from this plateau probably caused the ice margin to become unstable. Rate of retreat would have increased then as the ice margin calved into the sea that transgressed most of western Prince of Wales Island which is everywhere below marine limit. Regional evidence (discussed later) indicates ice retreat continued rapidly southward.

4.2.2 DISTRIBUTION OF ICE MARGIN FEATURES, CENTRAL ARCTIC

On Boothia Peninsula ice marginal features, such as DeGeer moraines on Abernethy Lowland and end moraines on Simpson Peninsula, indicate a westward receding straight to broadly arcuate ice margin (Dyke, 1984; Fig. 62). Westward ice retreat also occurred across higher parts of Boothia Peninsula whereas it was southward along western Boothia Peninsula Fig. 62). Dyke (1984) proposed that the west to south shift in deglacial flow resulted because a calving bay penetrated southward along the west coast of Boothia Peninsula.

On Somerset Island meltwater channels are abundant indicating Laurentide ice retreat westward accompanied by a roughly concentric retreat of a local ice cap on the north-central plateau (Fig. 62). The record of westward ice retreat from southern Somerset Island was complicated by transgressions of the sea (Dyke, 1984). A southward calving bay developed in Peel Sound because of "flooding" of the sea into the area (Dyke, 1983).

North and west of Prince of Wales Island ice retreat is recorded by end moraine and ice streamlined landforms. On Russell Island, ice retreat was initially southeastward as indicated by cross-cutting striae. A northwest deglacial flow followed originating from Peel Sound as recorded by roches moutonnees, till flutings on the

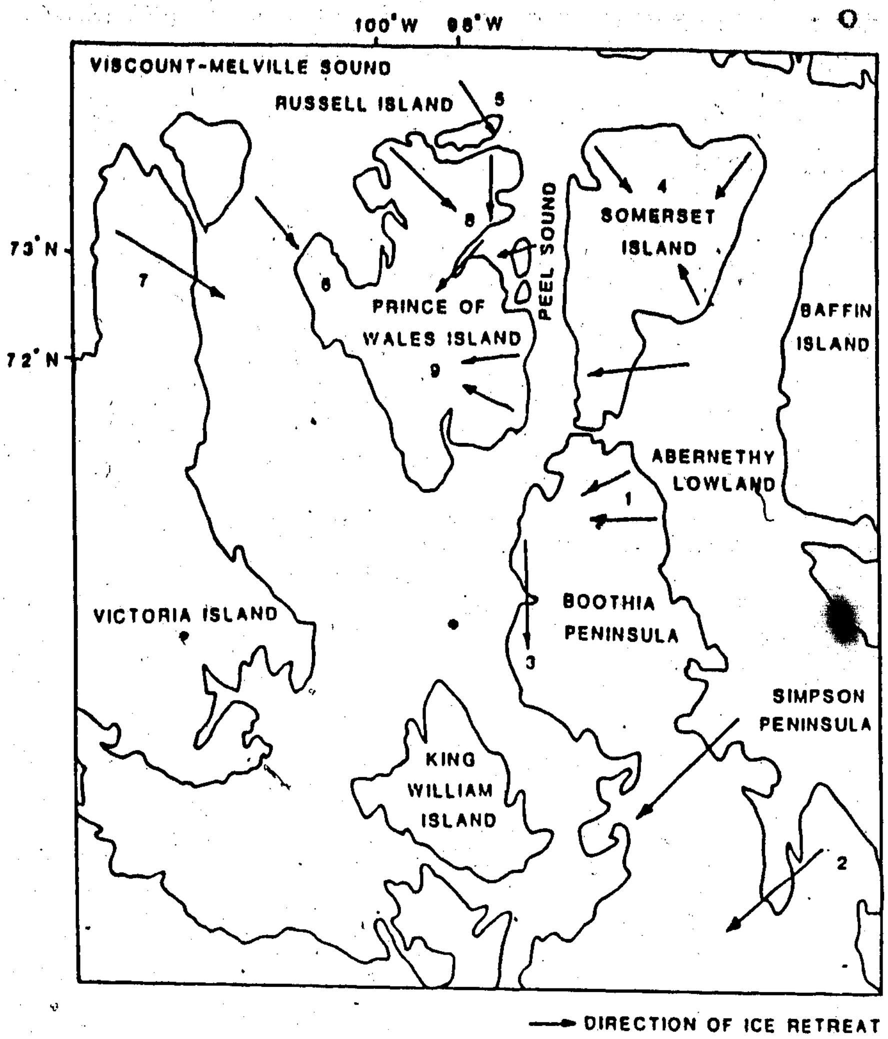


FIG. 62: Ice retreat was east-west across Abernethy Lowlands (1) and Simpson Peninsula (2), south along the west coast of Boothia Peninsula (3), towards the interior of Somerset Island (4), southeast across Russell (5), northern Prince of Wales (6, 8) and northeast Victoria (7) islands. Initially, ice retreated to a minor carbonate plateau on southern Prince of Wales Island (9).

eastern uplands of Russell Island and an end moraine (Green, 1986; Fig. 63).

Large moraines are located on northwest Prince of Wales and eastern Victoria islands (Dyke, 1987). These moraines indicate the demise of the Viscount Melville Sound Ice Shelf as originally proposed by Hodgson et al. (1984) and they define ice retreat to the southeast (Dyke, 1987; Fig. 62). The overall implication of these patterns is that the latest ice in the area was located on southwest Prince of Wales Island.

4.2.3 MARINE LIMIT

Collectively, marine limit dates suggest that deglaciation of southern Prince of Wales island occurred rapidly; between 9500- 9200 BP. Nonetheless, deglacial landforms which may be grouped into two distinct bands (see Chapter 4.2.1), indicating at least two periods of stabilization, were deposited despite such rapid ice retreat. Marine limit shorelines should rise towards the former centre of an ice load providing that the ice retreated rapidly (Andrews, 1968). Marine limits on southern Prince of Wales Island, however, do not illustrate a discernible gradient vis a vis any former centre of ice loading (Fig. 53). For example, marine limit elevations are 130m asl south of Cape Henry Kellett and 127m asl west of Flexure Bay, whereas marine limit on

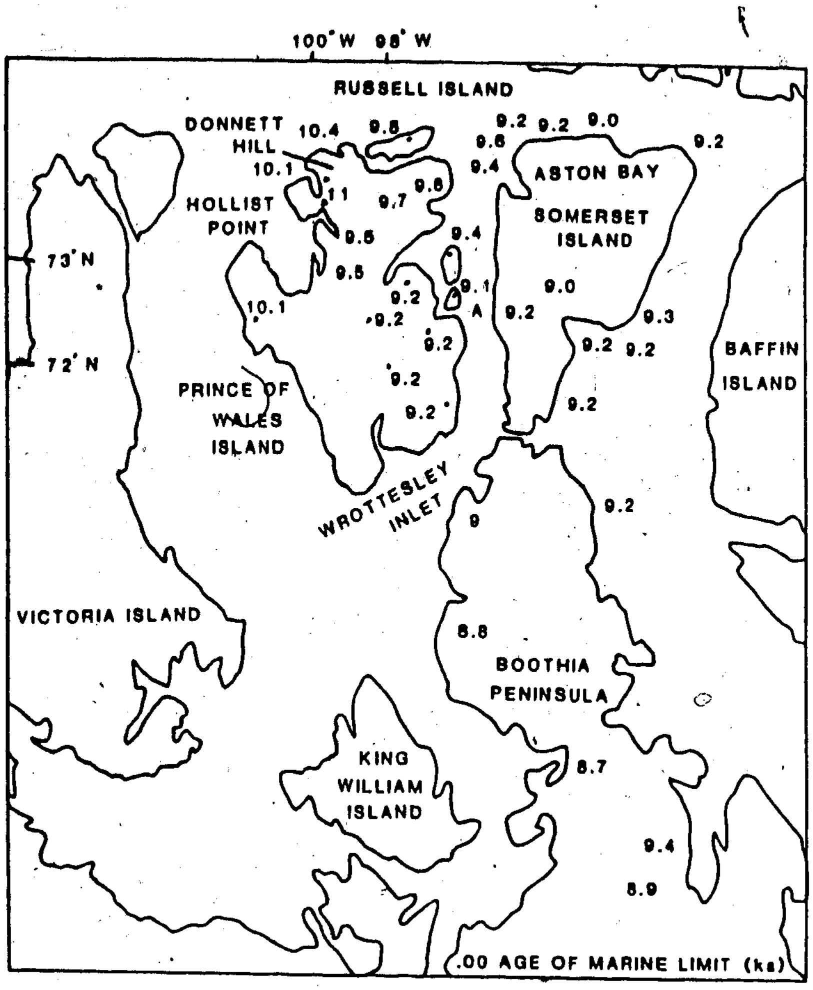


FIG. 63: Distribution of marine limit dates, Prince of Wales Island, Somerset Island and Boothia Peninsula. A) Pandora Island.

Pandora Island, which lies between them, is only 94m asl. Marine limit on Prescott Island, north of Pandora Island, is 107m asl. Restrained rebound occurring under a local ice cap on Pandora and/ or Prescott islands could account for these lower marine limit elevations. Such a local ice cap could have kept the sea from establishing marine limit on Pandora Island until 9140 BP while a local ice cap on Prescott Island could have persisted until ca. 9400 BP. However, evidence for local ice caps, as was observed on Somerset Island (Dyke, 1983), is missing. This implies that lower marine limits cannot be explained by the persistence of local ice. Marine limit elevations are also lower west of Cape Henry Kellett and west of Flexure Bay. Marine limit at Inner Browne Bay is 103m asl and 114m asl east of Fisher Lake. Evidence was not found of local ice caps having once been in these areas. An alternative explanation, such as faulting, may account for these and other marine limit elevations in the central Arctic.

4.2.4 ELEVATION OF MARINE LIMITS, CENTRAL ARCTIC

Dyke (1984) demonstrated that marine limits decline towards the west across northern and southern Boothia Peninsula (Fig. 63). Variations of marine limit elevation is a function of proximity to the former ice centre and the amount of recovery beneath the ice cover prior to deglaciation (restrained rebound, Andrews 1968). On Boothia Peninsula the largest emergence should occur to the west and south because the greatest former load of ice was there (Dyke, 1984, p. 17). Consequently, shorelines of any given age to the west and south on Boothia Peninsula dip to the east. The dip of synchronous shorelines (across Boothia Peninsula) and dip of marine limit are opposite here because marine limits are progressively younger to the west.

Marine limit elevations rise from the northeast corner of Somerset Island (76m asl) to the head of Creswell Bay (157m asl; Fig. 63). This west-southwest rise in marine limit suggests rapid ice retreat during deglaciation. However, marine limit drops from 157m asl at Creswell Bay to 90m asl along much of the west coast. This drop of marine limit towards the former ice centre indicates slow retreat and therefore an increasing amount of restrained rebound.

Marine limits dip northwest-southeast across northern Prince of Wales Island (Fig. 63). Again, marine limits decline in the direction of ice retreat because deglaciation was slow. Dates on marine limit between Donnett Hill and a site on the west side of Inner Browne Bay indicate that the deglaciation of this area took >1500 years. Marine limits also decline towards Cape Hardy (95m asl) and Inner Browne Bay (95m asl) from Donnett Hill (188m asl). However, marine limit elevations rise from north-central Prince of Wales Island (95m asl) to Back Bay (108m asl). Marine limit on the east coast of Inner Browne Bay (95m asl) rises to Prescott Island (107m asl). The inconsistency of marine limit elevations suggests that they neither rise nor fall towards the former ice centre.

The marine limit profile varies considerably across Prince of Wales Island. On southern Prince of Wales Island ice retreat was rapid and consequently shorelines of any given age should dip eastward toward Peel Sound because a greater ice load existed over the island's interior. However, the 8000 BP shoreline from Inner Browne Bay (50m asl) rises toward the east coast south of Cape Henry Kellett (68m asl). Therefore, a factor other than former ice thickness may be controlling the shoreline profile.

Elevations of marine limit at Pandora (94m asl) and Prescott (107m asl) islands are lower than those located south of Cape Henry Kellett (130m asl) and west of Flexure Bay (127.5m asl; Fig. 63). Marine limit west of Inner Browne Bay across from marine limit south of Cape Henry Kellett (130m asl) is 95m asl (Fig. 63). A substantial difference in elevation exists between marine limit west of Flexure Bay (127.5m asl) and marine limit just west of Strzelecki Harbour (113m asl; Fig. 63). Again, former ice thickness does not seem to dominate control.

4.2.5 AGE DISTRIBUTION OF MARINE LIMITS, CENTRAL ARCTIC

Two marine limits have been dated along the east coast and three along the west coast of Boothia Peninsula (Fig. 64). The two oldest dates are associated with marine limit along the east coast suggesting ice retreated from the east coast at 9200 BP (Dyke, 1984). The oldest of the western marine limit dates occurs on north-western Boothia Peninsula indicating that ice had retreated by 9040+/- 100 BP (GSC- 2722). The two younger west coast marine limits are located farther south and they indicate that ice had retreated from Boothia Peninsula by 8700 BP (Dyke, 1984). Age distribution of marine limits from Boothia Peninsula indicates ice retreated westward from the east coast before retreating south.

There are nine radiocarbon dates on marine limit from the southeast and north coasts of Somerset Island (Dyke, 1983). These marine limit ages range between [illegible]200 and 9300 BP indicating rapid ice retreat. Marine limit at Aston Bay has not been radiocarbon dated but the age must be between 9000 and 9200 BP (Fig. 64; Dyke, 1983). This age range for marine limit at Aston Bay is based on the penetration of the sea across the east coast of Prince of Wales Island at 9200 BP (L- 571B) and on the arrival of the sea at Wrottesley Inlet on western Boothia Peninsula

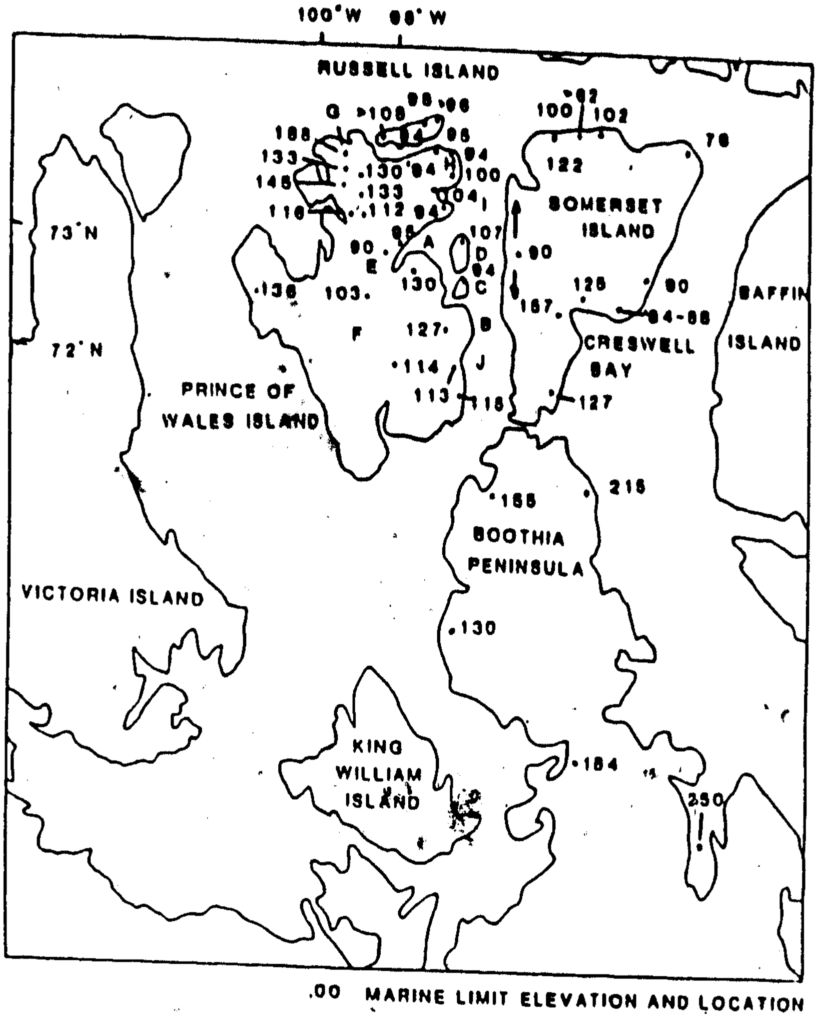


FIG. 64: Marine limit elevations, central Arctic, decline east-west across Boothia Peninsula, southwest across Somerset Island, southeast across northern Prince of Wales Island. Marine limit elevations on southern Prince of Wales Island do not rise or fall towards or away from any former centre of ice load. A) Cape Henry Kellett, B) Flexure Bay, C) Pandora Island, D) Prescott Island, E) Inner Browne Bay, F) Fisher Lake, G) Donnett Hill, H) Cape Hardy, I) Back Bay, J) Transition Bay.

at 9040+/- 100 BP (GSC- 2722). These ages of marine limit suggest that ice which had occupied western and southern Somerset Island disappeared completely during one or two centuries (Dyke, 1983, p. 27).

Distribution of marine limit ages indicates that the Laurentide Ice Sheet retreated southeast across northern Prince of Wales and Russell islands (Fig. 64). Oldest marine limit dates are at Donnett Hill, and southwest of Hollist Point (Dyke, 1987; Fig. 64). These dates suggest ice retreated from Donnett Hill by 11000 BP and from Hollist Point by 10000 BP. The ice margin had retreated into Inner Browne Bay by 9500 BP (Fig. 64).

Ice retreated across northern Prince of Wales Island in 1500 years; a rate of 5.3km/ century. Only 300 years elapsed for ice retreat from the west coast of Inner Browne Bay to the minor carbonate plateau east of Fisher Lake; a rate of 36.6km/ century. This retreat rate is compatible with observations made west of Somerset Island where ice retreated south to Wrottesley Inlet on Boothia Peninsula between 9200 and 9000 BP (Dyke, 1984). Therefore, there appears to have been a major change in regional ice retreat rate at 9300 BP.

Steepness of the emergence envelope for any area should increase progressively as one approaches the ice load. The emergence envelope from southern Prince of Wales Island falls between the emergence envelopes from northern Prince of Wales Island and the District of

Keewatin, indicating ice retreat south from the central Arctic (Fig. 65). The emergence curves which make-up the emergence envelope for southern Prince [illegible]ales Island are randomly distributed.

4.3 CONCLUSIONS

The M'Clintock Ice Divide, which had maintained its position west of Prince of Wales Island since at least 18000 BP, began shifting east at 12000 BP (Dyke and Prest, 1987). Melville Island was ice free by 11000 BP, western Victoria Island by 12000 BP. Timing of deglaciation from the western Arctic indicates that the west side of the M'Clintock Ice Divide retreated faster than the east side causing a shift of the ice divide towards the east. Consequently, ice streams on Prince of Wales Island defined in Chapter 3 could have maintained flow until 12000 BP (Fig. 66).

By 11000 BP, the continued eastward migration of the M'Clintock Ice Divide could no longer supply ice streams to Peel Sound through Young Bay and Muskox Valley. The Le Feuvre Inlet and Transition Bay ice streams could have maintained flow until 10000 BP (Fig. 67). By 9500 BP the ice margin was located somewhere north of the study area near Inner Browne Bay (Fig. 68). Between 9500 and 9200 BP the ice margin retreated southwest from Inner Browne Bay and westward from the east coast towards a

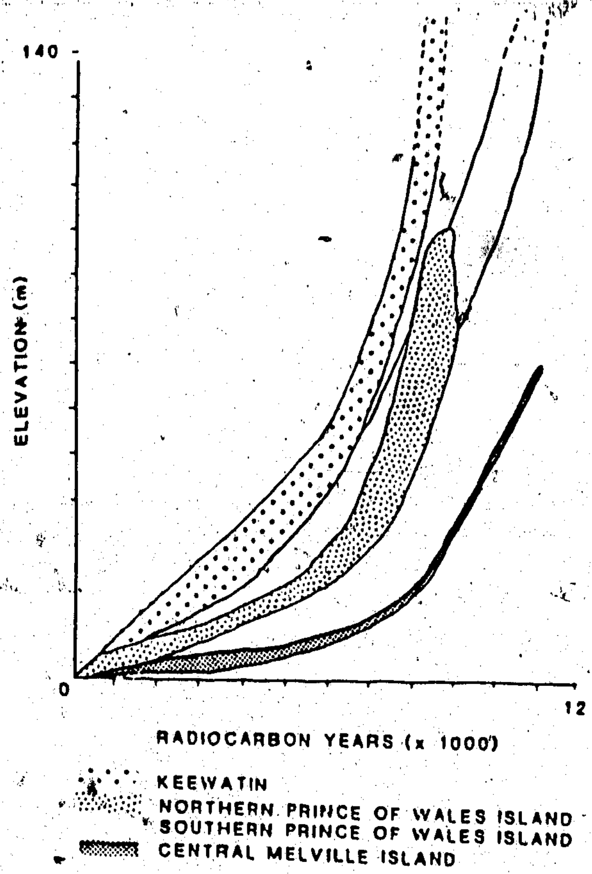


FIG. 65: Emergence envelopes for the central Arctic. The envelopes increase in gradient from north (Melville Island) to south (Keewatin), suggesting ice retreat south.

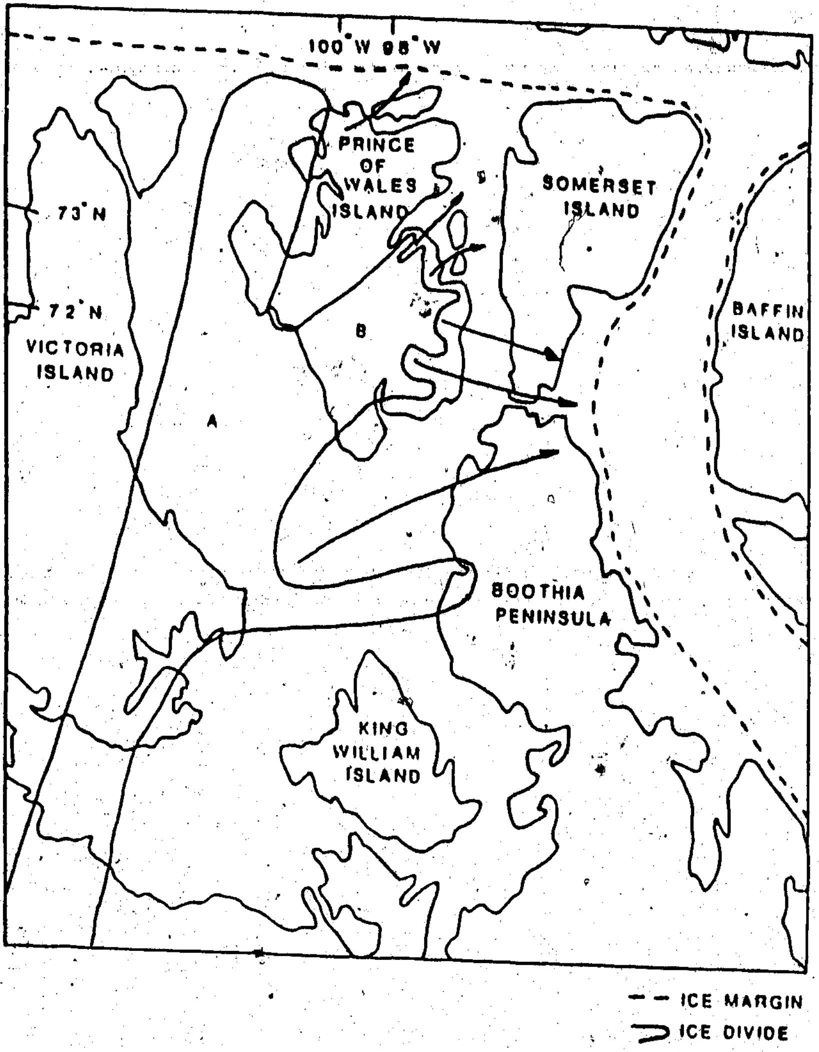


FIG. 66: At 12000 BP ice streams over eastern Prince of Wales Island (B) maintained flow east from the M'Clintock Ice Divide (A).

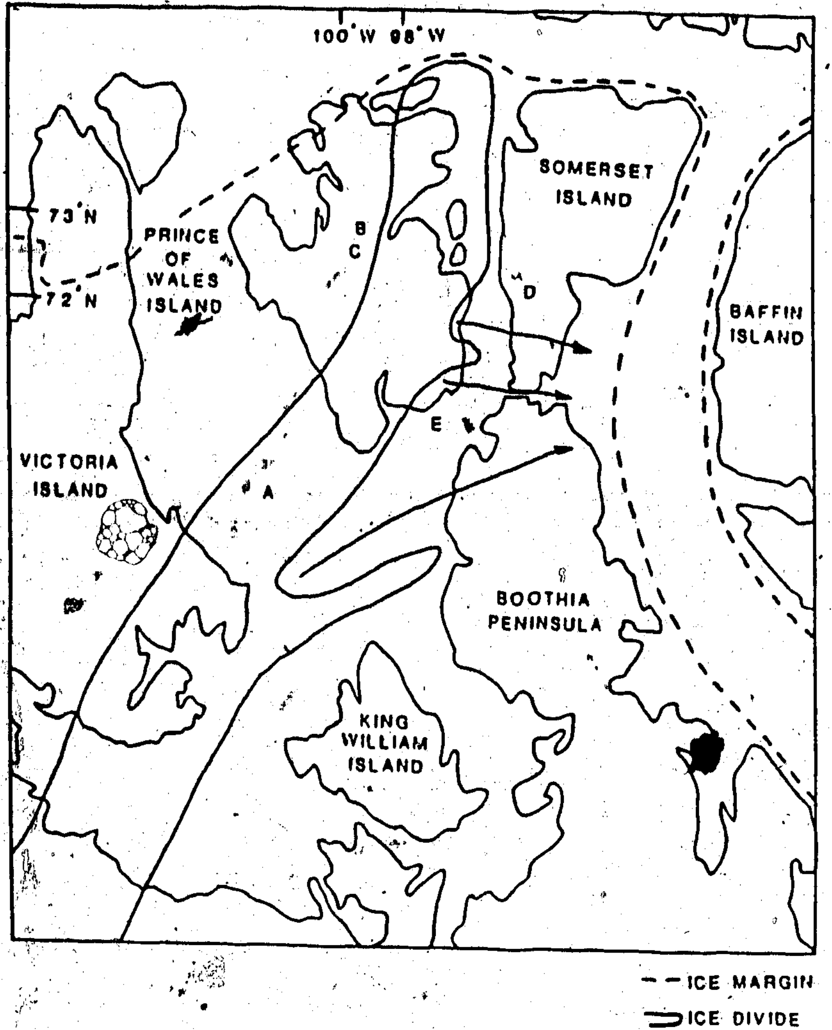


FIG. 67: At 11000 BP, the M'Clintock Ice Divide (A) shifted east, terminating northward flow through Muskox Valley (B) and Young Bay (C). Ice stream flow probably continued through Le Feuvre Inlet (D) and Transition Bay (E).

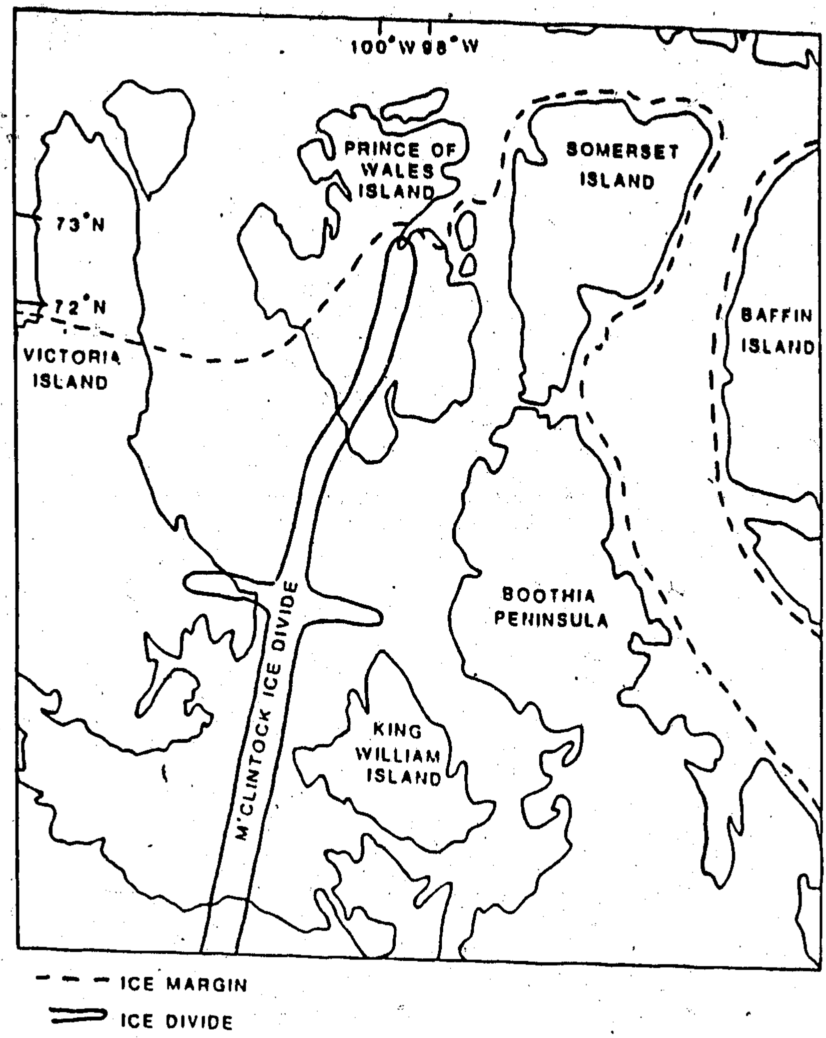


FIG. 68: Possible location of the ice margin and M'Clintock Ice Divide at 9500 BP.

minor carbonate plateau east of Fisher Lake (Fig. 69). The minor carbonate plateau was probably an anchoring point for the northern margin of the ice sheet.

Ice continued retreat south from the minor carbonate plateau. This is illustrated by superimposition of the southern Prince of Wales Island emergence envelop onto others from the central Arctic. The ice margin probably left Prince of Wales Island prior to 9040 BP as indicated by a marine limit date at Wrottesley Inlet, Boothia Peninsula; located south of Prince Of Wales Island (Fig. 70).

The profile of marine limits does not follow any discernable pattern vis a vis the former centre of the M'Clintock Ice Divide. No conventional explanation for this distribution exists. Residual ice caps may explain some of the anomalies, but, no evidence exists to support their former presence.

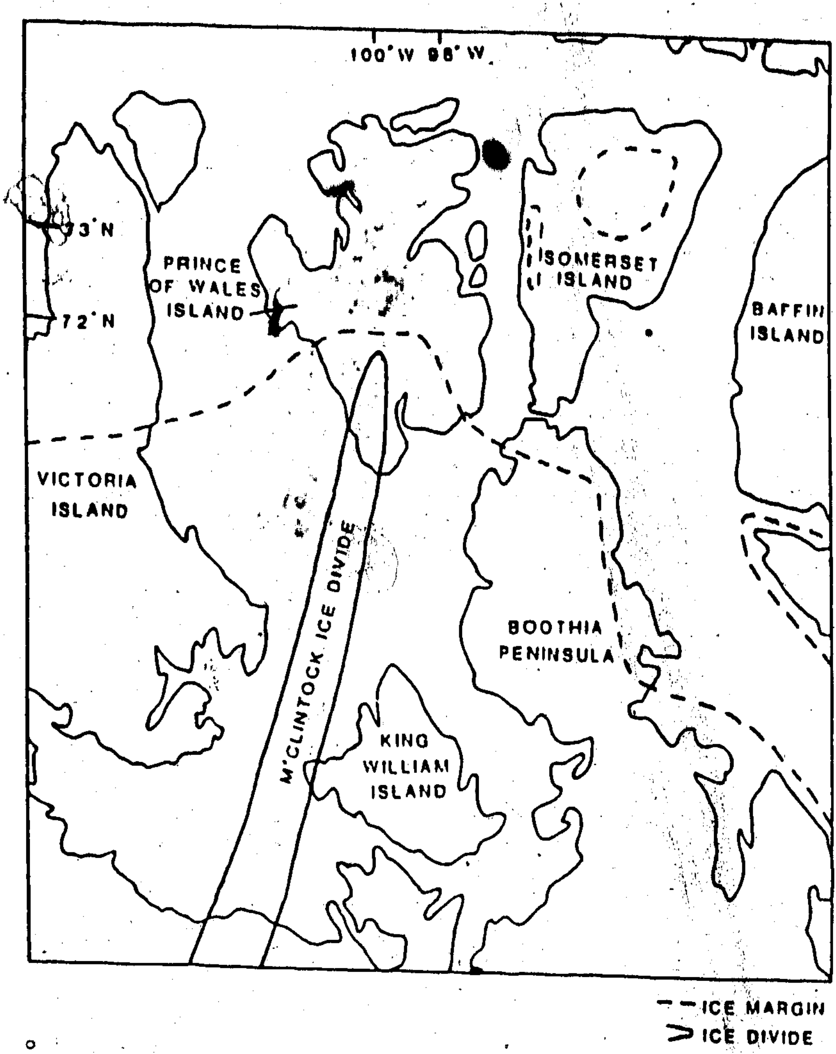


FIG. 69: Possible location of the ice margin and M'Clintock Ice Divide at 9200 BP.

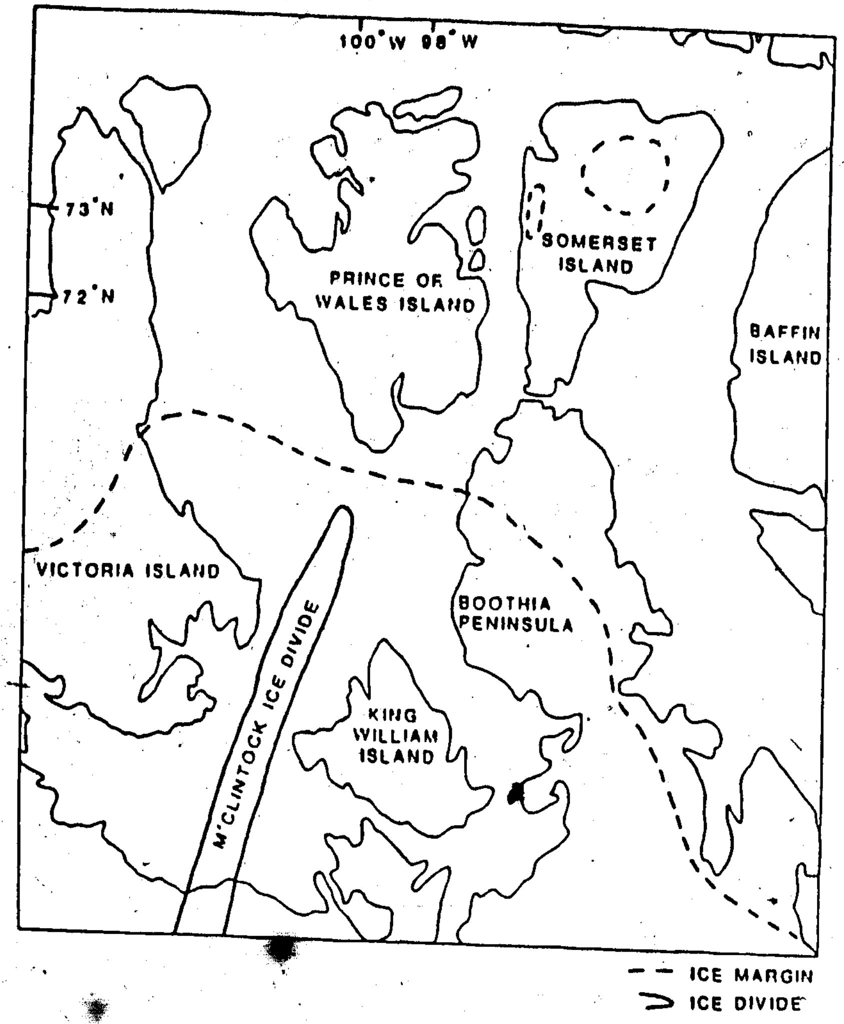


FIG. 70: Possible location of the ice margin and M'Clintock Ice Divide at 9000 BP (Dyke and Prest, 1987).

CHAPTER 5

CONCLUSIONS

5.1 Introduction

Landscape evolution of southern Prince of Wales Island is summarized in this chapter. Maps are presented illustrating landscape evolution from the Sangamonian to the Holocene. Speculation on some of the more important questions raised in this thesis are presented at the end of this chapter.

5.2 Pre- Quaternary History

The geology of Prince of Wales Island is tied directly to the Boothia Uplift. During the Silurian and Devonian faults associated with the Late Silurian carbonate sub-basins, which abut the western edge of the Precambrian gneiss and granites, were active and affected the deposition from floods off the Boothia Uplift. As these floods flowed west material was sorted resulting in five bedrock units west of the Precambrian gneiss and granites and Silurian carbonate outcrop; conglomerate being the coarsest (deposited closest to the Uplift) and the finest being carbonate (deposited in a sea distal to the Uplift). The east coast of Prince of Wales Island was part of a broad central Arctic continent during the Mesozoic. Subaerial planation during this time formed the Barrow Surface. The Eurekian Rifting episode, which occurred towards the end of the Mesozoic and into the Late Tertiary, broke up the Barrow Surface into islands and channels. These events formed the general physiography of southern Prince of Wales Island today; a narrow 300m high eastern plateau which drops dramatically on its western flank to a relatively broad horizontal plain.

5.3 Quaternary History

5.3.1 Pre-Sangamonian

The oldest evidence of glaciation in the study area is the lower till from section 1 located beside the Fisher River. This till is thought to represent a pre-Sangamonian glaciation due to its stratigraphic similarity to better-dated sections elsewhere in the central Arctic. Lower till fabric at section 1 implies an association of the lower till to the high relief stream-lined till. Fluvial gravels, which are at least Sangamonian in age, cap the lower till. An upper till representing eastward flow, perhaps during the whole of the Wisconsinan, caps the fluvial gravels. Upper till deposition requires ice flow from a divide situated over or west of the megafluted till. Establishment of such a divide would require flow of ice to the central Arctic eroding all older landforms ie; the megafluted till. Alternatively, an ice divide forming by instantaneous glacierization would preserve older landforms. However, it is unlikely such a divide could form in place given the present topography. Therefore, it is unlikely that the lower and high relief streamlined tills are coeval and that the high relief streamlined till represents a later glaciation.

5.3.2 Sangamonian

Deposition of fluvial sands and gravels at sections 1 and 2 beside the Fisher River occurred after ice, which deposited the lower till at section 1, had left the area. These sands and gravels contain erratic marine shells derived from emerged marine sediments and till deposited prior to or during the Sangamonian. Valleys, partially filled with drift and aligned north-south, may indicate the presence of other pre-Sangamonian river channels.

Evidence for other Sangamonian deposits in the central Arctic include mid-section fluvial sands and gravels at Pasley River, Boothia Peninsula and fluvial sands and gravels in sections on northern Prince of Wales Island (Dyke and Matthews, 1987).

5.3.3 Wisconsinan

The surficial geology map (Fig. 13) compiled for this study helps illustrate the Wisconsinan glacial chronology for southern Prince of Wales Island. Southeast-northwest oriented megafluted till probably formed by ice flowing northwest to the central Arctic, possibly from Keewatin (Fig. 71). An ice stream developed within the ice sheet following its initial advance. This is recorded by high relief streamlined till which cross-cuts the north end of the megafluted till. Megafluted till could only have been preserved beneath later ice that experienced little basal flow whereas, to the east, rapidly flowing ice formed high relief streamlined till. A ridge marking the boundary between the megafluted and high relief streamlined tills is interpreted to be a lateral shear moraine (Fig. 72). Ribbed moraine, located north-west of the high relief streamlined till, probably developed at the base of the ice stream which formed the high relief streamlined till as ice flowed into a lowland.

Reorientation of flow occurred within the ice sheet following the formation of the high relief streamlined till. This change in flow direction is recorded by the eastward dispersal of carbonate and the eastward orientated low relief streamlined till. Characteristics

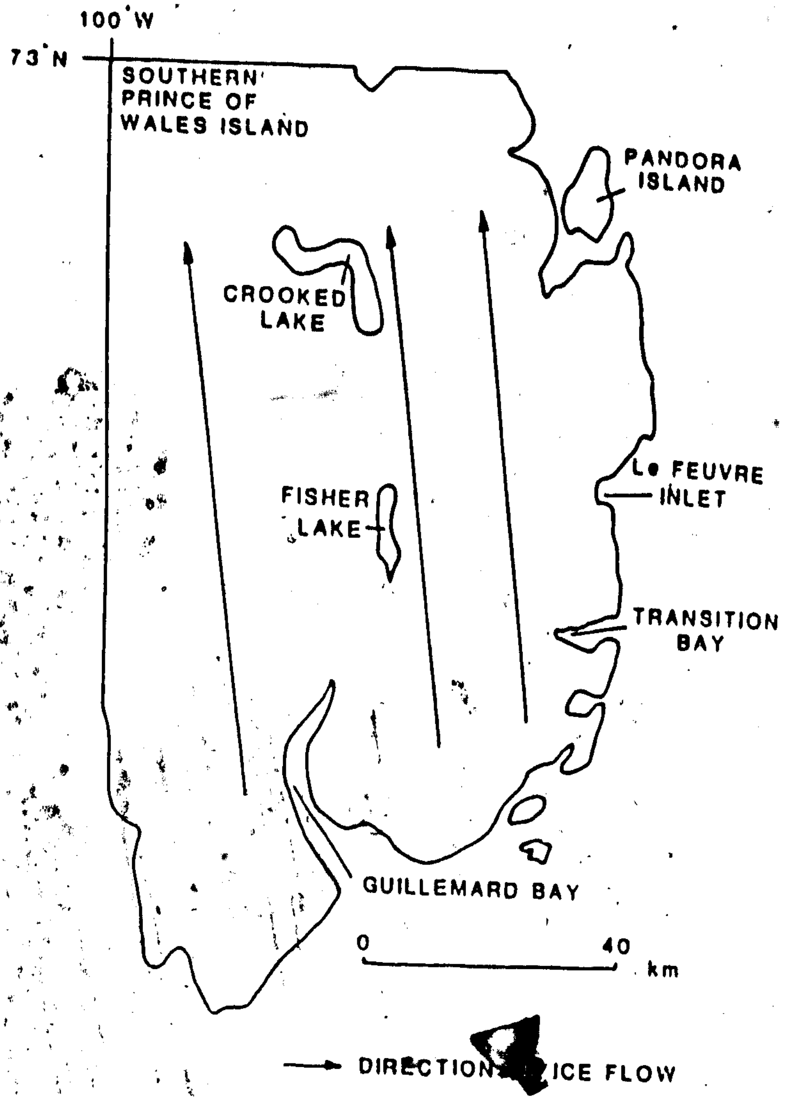


FIG. 71: Megafluted till is the earliest surface record of ice advance onto Prince of Wales Island. Orientation of megafluted till suggests that ice flow to the central Arctic was from the Keewatin.

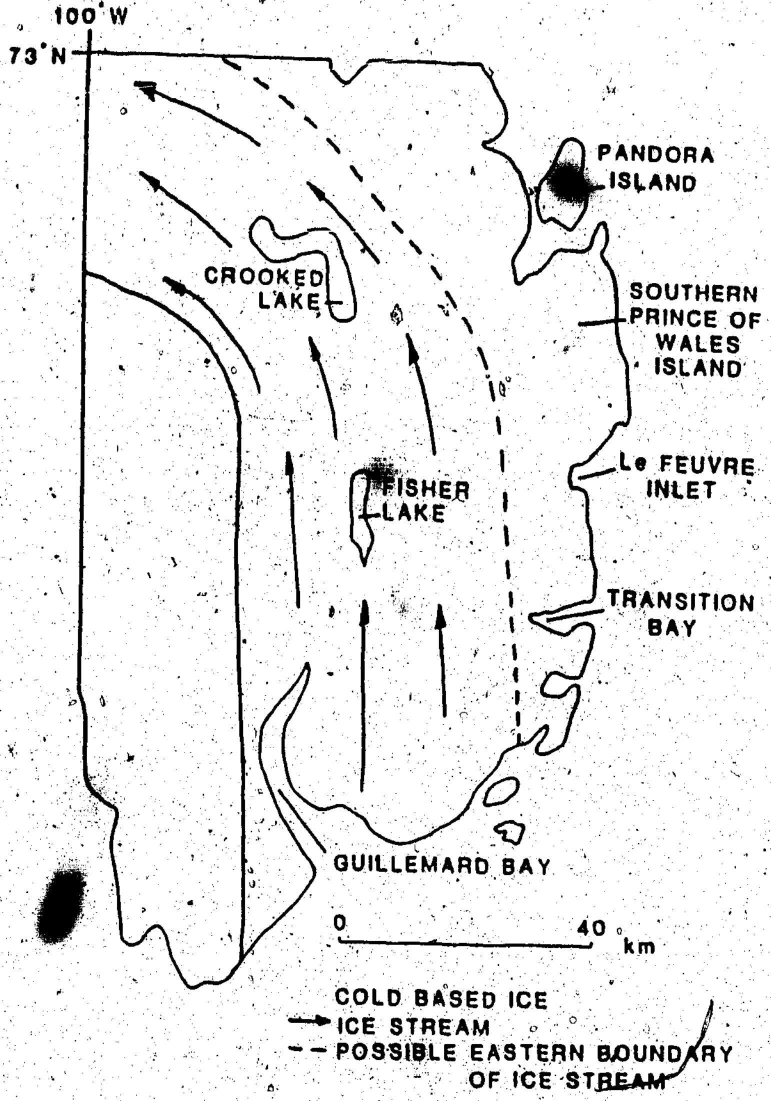


FIG. 72: High relief streamlined till and lateral shear moraine formed when an ice stream developed in the ice sheet.

of the carbonate dispersal was determined by mapping the properties of the till. These maps include; distribution of carbonate granules, sandstone and gneiss granules, texture (% sand, silt and clay), carbonate, geochemistry, colour (d, m), vegetation and depth to frost table. These maps illustrate three types of ice sheet flow. First, regional eastward flow is indicated by broad dispersal of carbonate and drumlin distribution (Fig. 73). Second, four ice streams developed, flow being partially controlled by troughs through the Barrow Surface at Transition Bay, Le Feuvre Inlet Young Bay and Muskox Valley (Fig. 74). Third, clastic granules distributed west of the carbonate-carbonate sandstone bedrock boundary suggests clastic granules were transported from the Barrow Surface by an earlier flow. Northwest flow which formed either the megafluted or high relief streamlined till could have been responsible for this transport and deposition.

Relative rates of eastward carbonate dispersal were determined from these distribution maps. A line was drawn west-east through, and on either side of, the carbonate dispersal plumes from which values (such as % carbonate) were derived. Simple regression analysis was run using these values to determine the relative rate of carbonate dispersal. The relative rate at wh[illegible] carbonate was dispersed east was lower in the dispersal plumes and higher in the intervening areas. Relative rates of

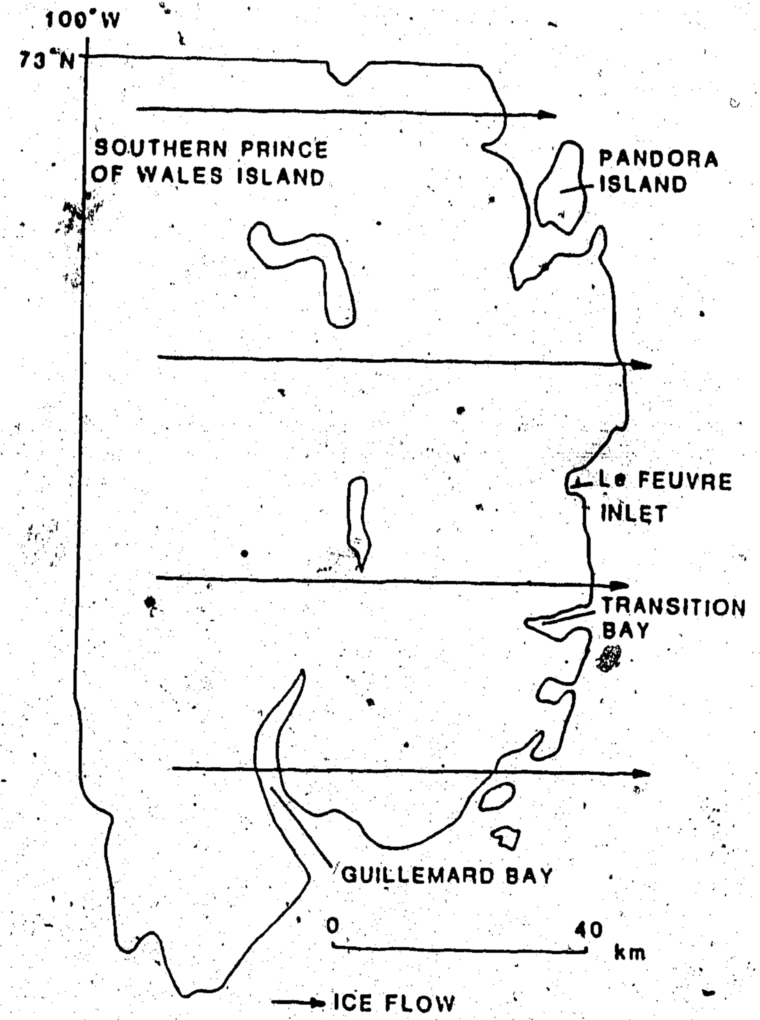


FIG. 73: Broad dispersal of carbonate and widely spaced high elevation drumlins indicate initial eastward flow was as an ice sheet. Reorientation of flow is most easily explained by a shift in flow in the ice sheet which formed the megafluted and high relief streamlined till.

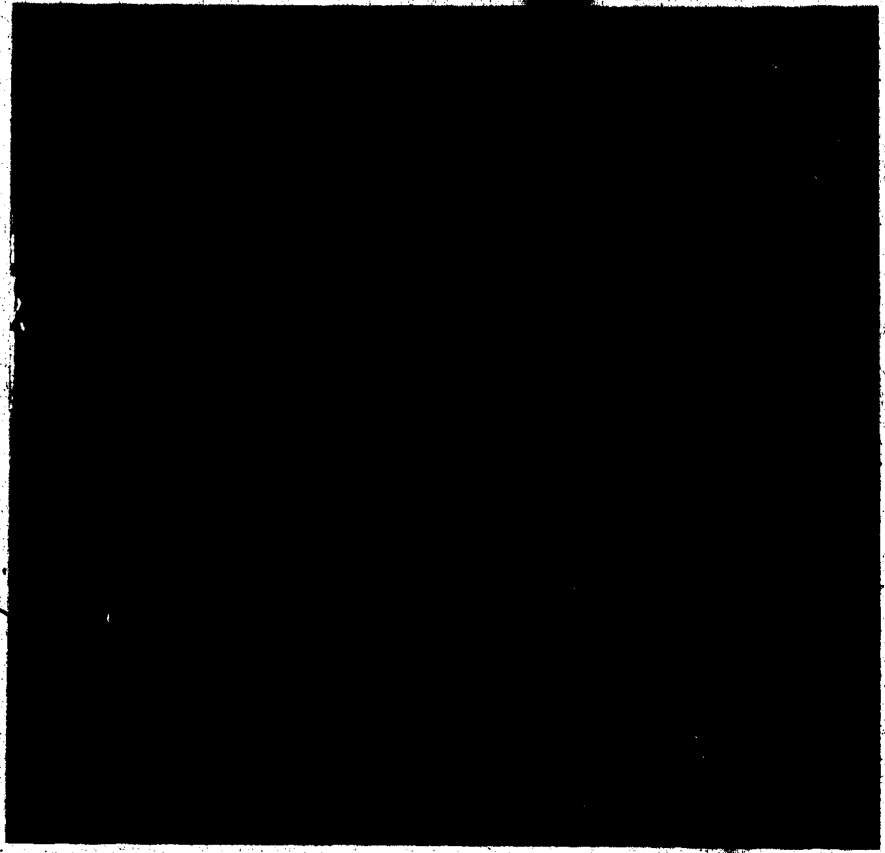


FIG. 74: Ice streams defined by dispersed carbonate and in most cases, low relief streamlined till at; A) Muskox Valley, B) Young Bay, C) Le Feuvre Inlet and D) Transition Bay. Note broad dispersal of carbonate over southern Somerset Island and northern Boothia Peninsula (E, arrows enclose width of carbonate dispersal plume). Transition Bay and Le Feuvre Inlet ice streams probably converged down-ice into a larger ice stream over southern Somerset Island and northern Boothia Peninsula. Smaller ice streams flowing through Muskox Valley and Young Bay may have flowed against western Somerset Island.

carbonate dispersal may have been controlled by topography as high rates occurred where ice flowed against a topographic barrier. Where troughs existed through the Barrow Surface relative rate of carbonate dispersal was low. Low relative rates of carbonate dispersal indicates ice flow was fast, there was relatively low frictional resistances, low basal concentrations of debris or some combination of these. These debris-carrying characteristics of ice may suggest the presence of ice streams flowing in these troughs.

Ice streams were also defined by: 1) light coloured, carbonate-rich till which contrasts sharply with till not so charged with carbonate on the other side; 2) the lateral extent of low relief streamlined till which lies within the carbonate charged till; and 3) by the convergence of drumlins at the up-ice end of the low relief streamlined till indicating former flow convergence. Drumlins are not associated with a carbonate plume at Muskox Valley. However, an ice stream may have existed there as carbonate dispersal is similar to the characteristics of dispersed carbonate in the other dispersal plumes (Fig. 74).

Ice streams flowing through Le Feuvre Inlet and Transition Bay probably converged down-ice into a larger ice stream flowing over southern Somerset Island and northern Boothia Peninsula (Fig. 74). Ice streams flowing through Muskox Valley and Young Bay, which were much, smaller than ice streams flowing through Le Feuvre Inlet and Transition Bay, probably terminated in Peel Sound or flowed against western Somerset Island.

At the height of the eastward flow megafluted and high relief streamlined tills to the west were protected under an ice mass experiencing little or no basal flow. Transition from little basal flow (colder ice) to [illegible] flow (warmer ice, associated with eastward [illegible] ice streams) is defined by ribbed moraine around [illegible] up-ice end of some low relief streamlined tills.

The four ice streams [illegible] Prince of Wales Island probably flowed simultaneously until 12000 BP (Fig. 75). By 11000 BP, however, the M'Clintock Ice Divide had shifted east terminating flow through Muskox Valley and Young Bay. Eastward flow through Le Feuvre Inlet and Transition Bay could have continued (Fig. 76).

Between 11000- 9500 BP the ice margin retreated slowly southeast across northern Prince of Wales Island. From 9500- 9200 BP the ice sheet retreated rapidly southwest from Inner Browne Bay and the east coast of southern Prince of Wales Island to a minor carbonate plateau west of Fisher Lake (Fig. 77). During rapid retreat low relief steamlined till at Inner Browne, Coningham and Guillemard bays formed. Further retreat from this area formed the low relief streamlined till on the northeast edge of the megafluted till.

Deglacial flow is well illustrated by the

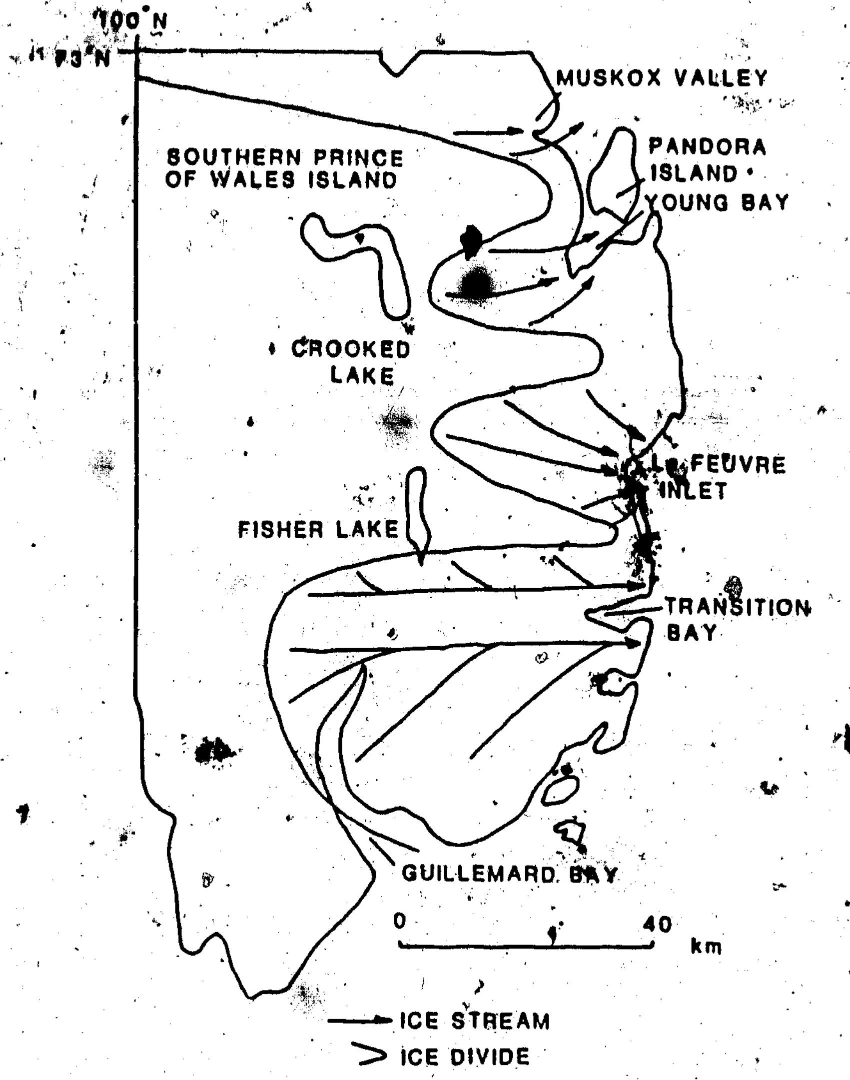
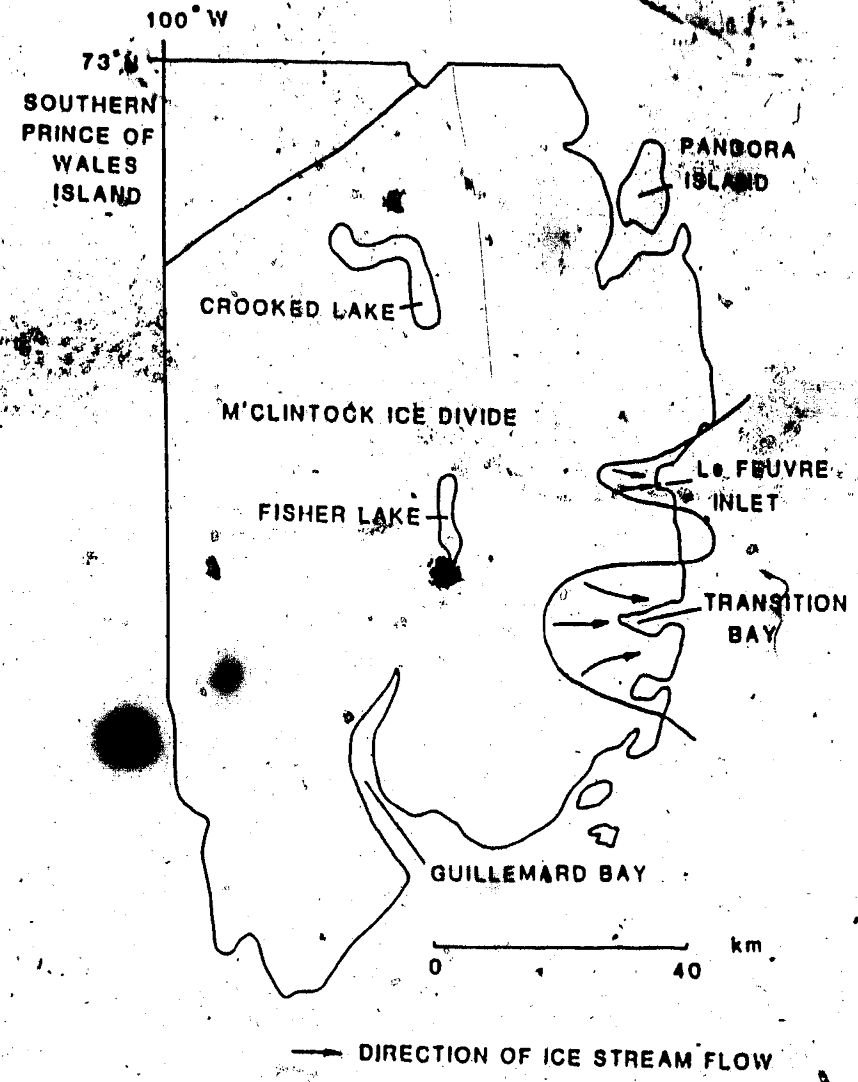


FIG. 75: Ice stream flow at 12000 BP. Flow was from tertiary ice divides through troughs in the Barrow Surface at Muskox Valley, Young Bay, Le Feuvre Inlet and Transition Bay.



G. 76. Ice stream flow at 11000 BP. The primary ice divide has shifted east, negating flow of ice through Muskox Valley and Young Bay. Flow still could have continued through Le Feuvre Inlet and Transition Bay, amalgamating down-ice into a larger ice stream flowing over southern Somerset Island and Boothia Peninsula.

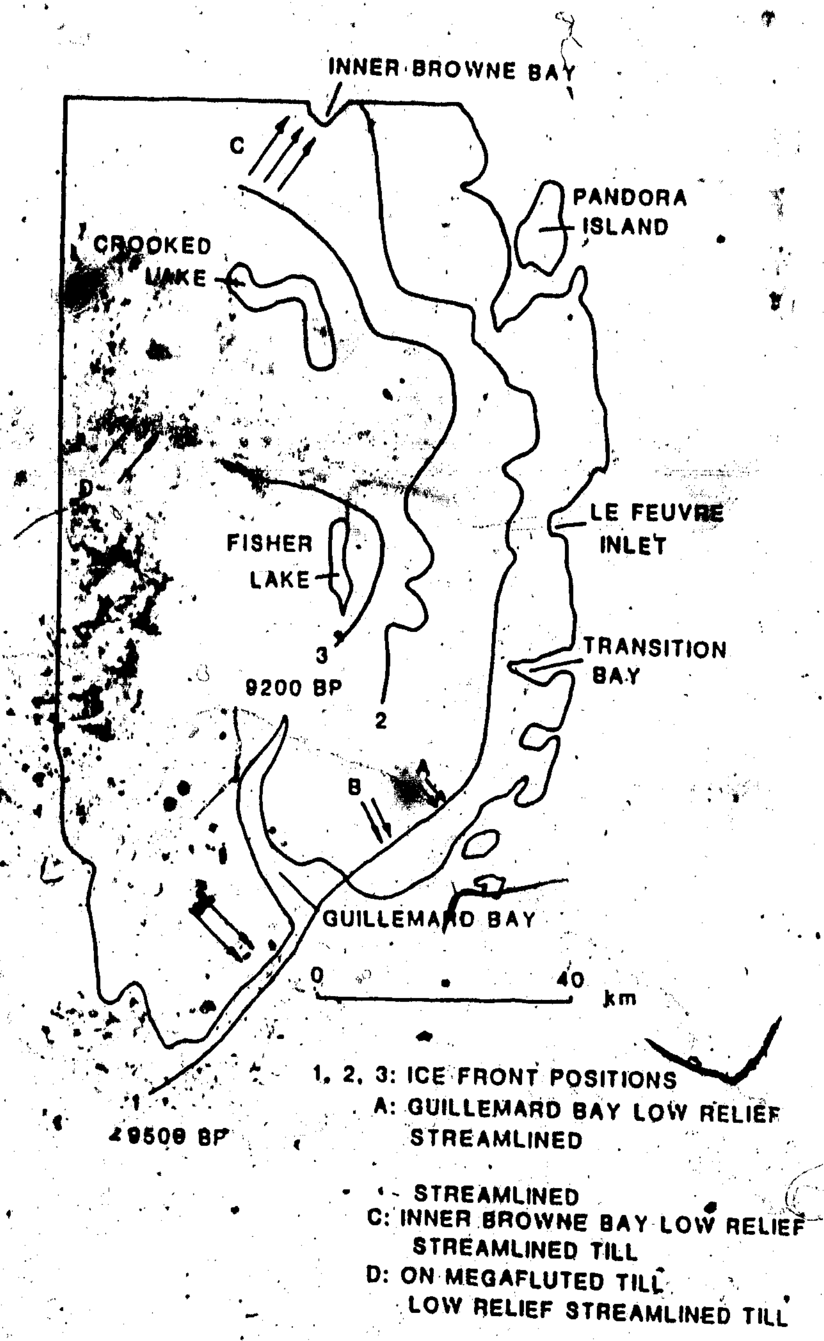


FIG. 77: Possible ice margin positions between 9500-9200 BP, southern Prince Of Wales Island. Ice margin had retreated from the study area by 9000 BP.

distribution of ice marginal features and ages of marine limit. However, the pattern of retreat is not defined by the profile of marine limit. Low marine limits in some areas might be interpreted to indicate more restrained rebound induced by local ice caps. However, ice marginal features associated with such local ice caps were not observed. Alternatively, Holocene block tectonics may better explain the irregular profile of marine limits.

At 9200 BP the ice sheet had continued its retreat south as indicated by superimposition of the southern Prince of Wales emergence envelope onto others from the central Arctic. By 9040 BP, the ice margin had retreated south to Wrottesley Inlet on Boothia Peninsula.

Deposition of sand from sandy Quaternary deposits and local bedrock occurred in Browne Bay during the Holocene. Uplift has since exposed these deposits as emerged shallow marine sands between Prince of Wales and Pandora islands. Emergence elsewhere in the study area during the Holocene has produced a large amount of raised marine sediment at elevations up to 130m asl.

Permafrost and associated landforms have become well established throughout the Holocene. Most active periglacial processes include; 1) frost shattering of exposed carbonate bedrock; 2) gelifluction of weathered bedrock, beach sediment and till; and 3) cryoturbation of fine grained till. Alluvium (as fans and plains) have been an important deposits during the Holocene.

Little geomorphic evidence of Holocene climatic fluctuations exist on southern Prince of Wales Island. However, there is an abundance of driftwood on southern Prince of Wales Island below 15m asl. Abundance of driftwood below 15m asl has also been observed on Russell Island (Green, 1986), northern Prince of Wales Island (Dyke, 1987, pers. comm.) and southern Ellesmere Island (Blake Jr., 1972). The abundance of driftwood probably reflects the establishment of the boreal forests at 4000 BP coupled with less severe summer sea ice which would have allowed wood to be transported by ocean [illegible]s. A tremendous abundance of whalebone occurs around 90m asl suggesting a large population of whales around 8000 BP. The Laurentide Ice Sheet's northern margin had left the area by 9000 BP and sea ice conditions must not have been severe at this time.

5.4 GEOLOGICAL IMPLICATIONS

Glacial features on southern Prince of Wales Island are some of the most remarkable observed anywhere in the world. Megafluted till, for example, is almost unrecognizable on the ground or on black and white (1: 63000 scale) aerial photographs but it stands out well on coloured Landsat imagery. Megafluted till has not been described elsewhere to the author's knowledge. However, with the use of Landsat imagery similar landscapes may be recognized elsewhere.

The lateral shear moraine on Prince of Wales Island was identified and described for the first time and is now recognized as an important landform in identifying former ice streams. Eastward aligned low relief streamlined tills and related carbonate dispersal plumes define the most dramatic evidence of former ice streams in North America. The potential to link this geomorphic and sedimentologic evidence of ice streams to glaciological modelling is exceptional but will require some means of translating dispersal data into paleo-ice flow rates.

The distribution, characteristics and associations of glacial landforms raise important glaciological questions. For example, the position of ribbed moraine around the up-ice end of low relief streamlined till at Transition Bay and Le Feuvre Inlet at the transition between cold and warm-based ice zones has never been described before. Elsewhere, ribbed moraine and drumlins occur in alternating bands perpendicular to ice flow or in alternating bands parallel to flow. The origin of ribs around the heads of the low relief streamlined till on Prince of Wales Island is unknown but they may relate to a zone of sporadic subglacial permafrost transitional between continuous subglacial permafrost (cold-based ice) to the west and no subglacial permafrost (warm-based to the east.

High relief streamlined till, west of Transition Bay, is badly water eroded. The water erosion of these streamlined landforms may be due to their non-resistant composition. Alternatively, this high relief streamlined till may have been affected by moister conditions at the base of the head of the ice stream that formed the ribbed moraine and low relief streamlined till west of Transition Bay.

The abrupt switch northwestward to eastward ice flow is indicated by the absence of streamlined features with intermediate orientations. The cause for such a dramatic shift in flow remains obscure but the morphostratigraphic relationships on Prince of Wales Island illustrate clearly that rather sudden rotation of ice sheet flow lines occurs well behind the margins of ice sheets. By inference, ice divide locations and orientations can shift suddenly as well.

A unique permafrost history may be preserved on southern Prince of Wales Island. As ice probably became cold-based after each major flow event (north, northwest, east) it is possible that are at least three different ages of permafrost developed.

Further research could answer some of the questions raised, as well as test and refine many of the observations and conclusions presented in this thesis. Comparison of this research to the ongoing project on northern Prince of Wales Island may provide new insights or alternative interpretations to those made in this study.

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QUATERNARY GEOLOGY AND GEOMORPHOLOGY OF SOUTHERN PRINCE of WALES ISLAND, N.W.T., CANADA.

by

THOMAS F. MORRIS

A THESIS

SUBMITTED TO THE FACULTY OF GRADUATE STUDIES AND RESEARCH
IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE
OF DOCTOR OF PHILOSOPHY

DEPARTMENT OF GEOGRAPHY

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FACULTY OF GRADUATE STUDIES AND RESEARCH

The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research for acceptance, a thesis entitled Quaternary Geology and Geomorphology of Southern Prince of Wales Island, N.W.T., Canada submitted by Thomas F. Morris in partial fulfilment of the requirements for the degree of Doctor of Philosophy in Geography.

(Supervisor)

Arthur S. Dyke

R B Rains

Date: Sept. 19th /88

ABSTRACT

The Upper Peel Sound Formation of southern Prince of Wales Island formed during the Late Silurian and Devonian. Ice flow west-east over the Upper Peel Sound Formation dispersed carbonate which allowed the defining of ice flow characteristics. The east coast plateau (Barrow Surface) represents the highest area and formed by subaerial planation of a broad central Arctic continent during the Mesozoic and Tertiary. Glacial landforms occur on a lowland extending west from the Barrow Surface.

Megafluted till formed during the Early Wisconsinan by ice flowing north to the central Arctic. An ice stream then developed forming northwest orientated high relief streamlined till and a lateral shear moraine. Low relief streamlined till formed by eastward flow after ice stream flow which formed high relief streamlined till ceased.

Two sections beside the Fisher River have an upper till capping low elevation fluvial gravels containing erratic marine shells. Amino acid ratios and a uranium series date of these shells, and comparison of the sections' stratigraphy to others in the central Arctic with better dating control, suggest that the fluvial gravels in the Fisher River sections are at least

Sangamonian in age. The upper till resulted from ice flow east during at least the Late Wisconsinan.

Initially, ice dispersed carbonate by flowing west-east over a broad area. Subsequently, four ice streams concentrated carbonate through troughs in the Barrow Surface. Low relief streamlined till is closely associated with three of these carbonate dispersal plumes. A larger ice stream, formed by convergence of two of these ice streams, extended over Peel Sound to Somerset Island. The other two were smaller and terminated in Peel Sound or abutted against the west coast of Somerset Island.

The distribution of ice marginal landforms indicates that deglacial flow was generally west to a minor carbonate plateau which acted as an anchoring point for the northern margin of the ice sheet. Ice took only 300 years to retreat from southern Prince of Wales Island south, indicating rapid deglaciation. Irregular marine limit profiles may be related to Holocene block tectonics.

Megafluted till and a lateral shear moraine are described for the first time. In addition, the geomorphology of southern Prince of Wales Island defines the most dramatic evidence of former ice streams in North America.

ACKNOWLEDGEMENTS

I would like to thank my two principal supervisors, John England and Art Dyke, for their support and the long hours they spent editing earlier drafts of this thesis. Thanks also to Bruce Rains, Ian Campbell, Steve Hickock and Brian Jones for th[illegible]ts which improved the content of the thesis. I would also like to [illegible] three very capable field assistants, James Hooper, Dave Ness and Christie Taylor. Thankyou also to the cartography division, Geography Department, University Of Alberta, who helped greatly in the production of this thesis.

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CHAPTER 1

INTRODUCTION

1.1 NATURE OF THE STUDY

The Laurentide Ice Sheet covered northern North America several times during the Quaternary and various authors have reconstructed its development and demise. Two schools of thought have evolved. One school suggests a single dome of ice centred over Hudson Bay (Dawson 1886, 1890; Chamberlain 1894; Flint 1943). The second suggests several domes or divides which coalesced to form a single ice sheet (Tyrrell 1898; Shilts et al. 1979; Denton and Hughes 1979; Andrews and Miller 1979; Dyke et al. 1982; Dyke and Prest 1987).

Prince of Wales Island is ideally located to test the local validity of these two contrasting models. For example, in the single ice dome model of Denton and Hughes (1979) Prince of Wales Island lies behind the north-central margin at the Late Wisconsinan maximum and is covered and flanked by northward flow lines. In the multidome model of Dyke and Prest (1987) Prince of Wales Island lies behind the northeastern margin of Keewatin Ice and is crossed by eastward flow lines.

Several techniques were used to test the two contrasting models. First, pattern of glacial flow was determined by mapping surficial materials and landforms. Second, ages of marine shells collected from sediments separating an upper till from a lower till were used to establish a chronology for past glacial activity. Third, information on ice flow dynamics was determined through mapping dispersal of materials and defining extent of ice flow and ice sheet surface configuration. Fourth, postglacial emergence was determined through construction of five postglacial emergence curves that record the history of deglaciation and the nature of glacio-isostatic unloading. Fifth, relevent data from elsewhere in the central Arctic were added.

1.2 PHYSIOGRAPHY

Prince of Wales Island is the eighth largest in the Arctic archipelago, with an area of 33,338 km^2 (Zoltai, 1985, p. 1481). However, only southern Prince of Wales Island constitutes the study area (Figs. 1, 2) involving 18000km^2 and two N.T.S. map sheets (Franklin Straight, Fisher River, both at the scale of 1: 250000). Pandora Island, also in the study area, is a much smaller island with an area of about 200km^2.

The topography consists of plateaus and lowlands thought to be pre-Quaternary landscape elements (Bird, 1967). A narrow plateau, 15km wide, 300m high and aligned

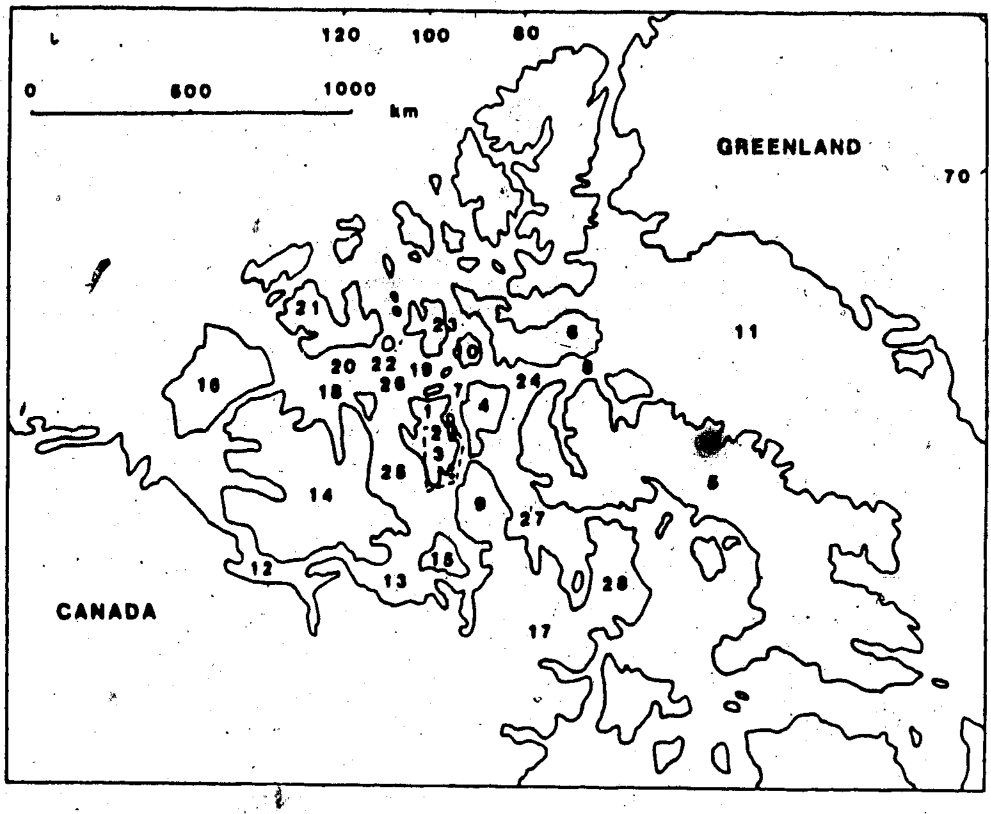


FIG. 1: Location of study area and other areas cited in the thesis; 1) Prince of Wales Island, 2) Pandora Island, 3) study area, 4) Somerset Island, 5) Baffin Island, 6) Devon Island, 7) Peel Sound, 8) Lancaster Sound, 9) Boothia Peninsula, 10) Cornwallis Island, 11) Baffin Bay, 12) Coronation Gulf, 13) Queen Maud Gulf, 14) Victoria Island, 15) King William Island, 16) Banks Island, 17) Keewatin, 18) Stefansson Island, 19) Lowther Island, 20) Viscount Melville Sound, 21) Melville Island, 22) Byam Martin Island, 23) Bathurst Island, 24) Prince Regent Inlet, 25) M'Clintock Channel, 26) Russell Island, 27) Gulf of Boothia, 28) Wales Island.

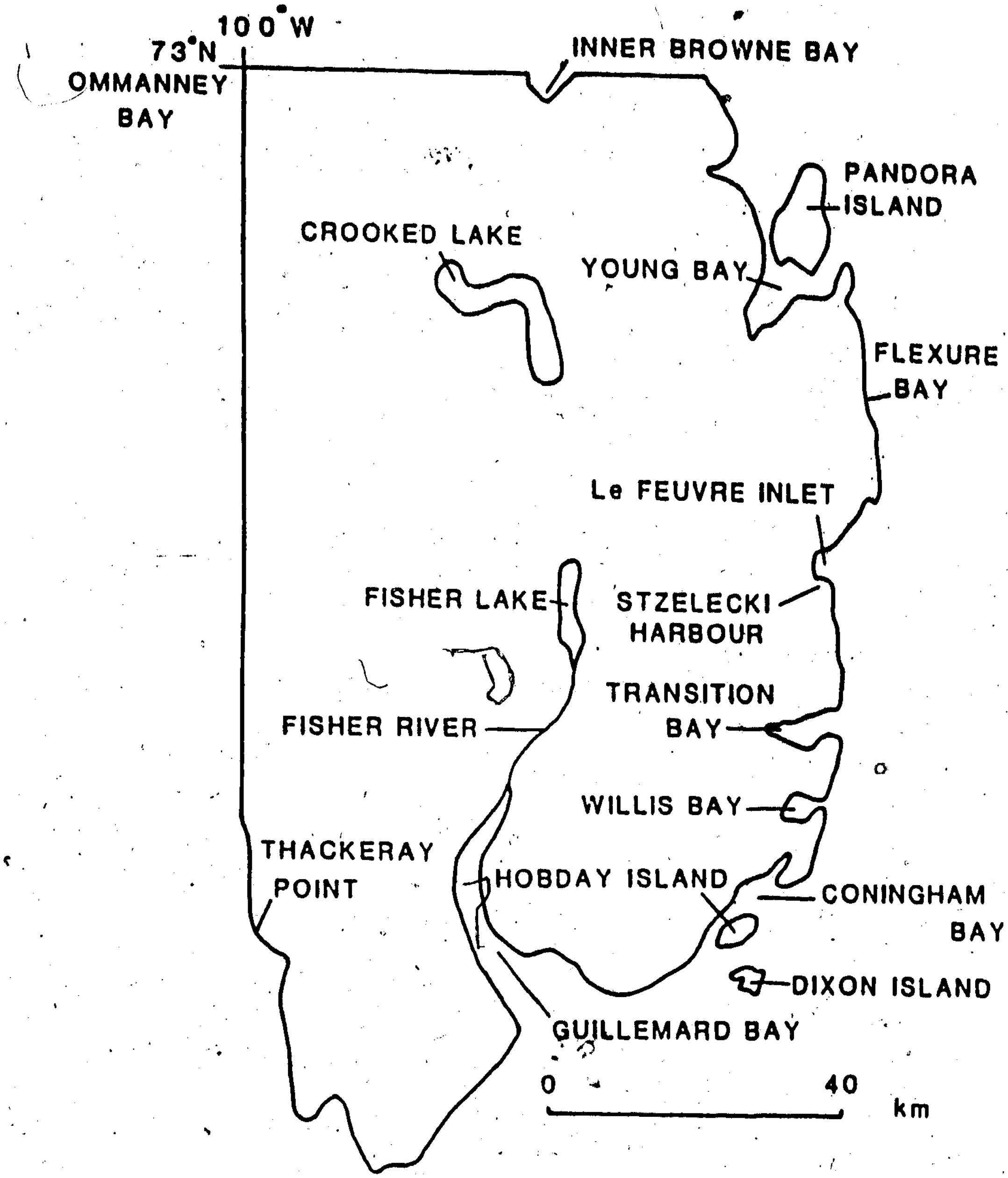


FIG. 2: Southern Prince of Wales Island, N.W.T., Canada. Relevant place names in the study area.

north-south, comprises the east coast. This plateau was once part of a much larger plateau, remnants of which can be found on Pandora, Somerset, Baffin and Devon islands (Bird, 1967, p. 68). Inland from the plateau the elevation drops sharply (150m) to an extensive lowland covering two-thirds of the study area (Miall, 1970a).

Netterville et al., (1976) mapped topographic elements as 31 terrain regions on Prince of Wales, Somerset and surrounding islands. Of the 31 different terrain regions, 8 occur in the study area ranging from almost bare bedrock to large till sheets.

1.3 BEDROCK GEOLOGY

The geology of Prince of Wales and Pandora islands is tied to the development of the Boothia Uplift. The Boothia Uplift is an elongated mass of Precambrian gneiss and granite extending north from the Canadian Shield to the Arctic lowlands (Brown et al., 1969,p. 525). This Uplift (referred to as a Horst by Dixon et al., 1971) has positive relief except in Peel Sound (Fig. 3).

Rocks were deposited east-west due to vertical movement of the Boothia Horst through the Late Proterozoic to Devonian. However, only the surface rocks are discussed because these represent the only lithologies that were accessible to the Late Quaternary glaciations.

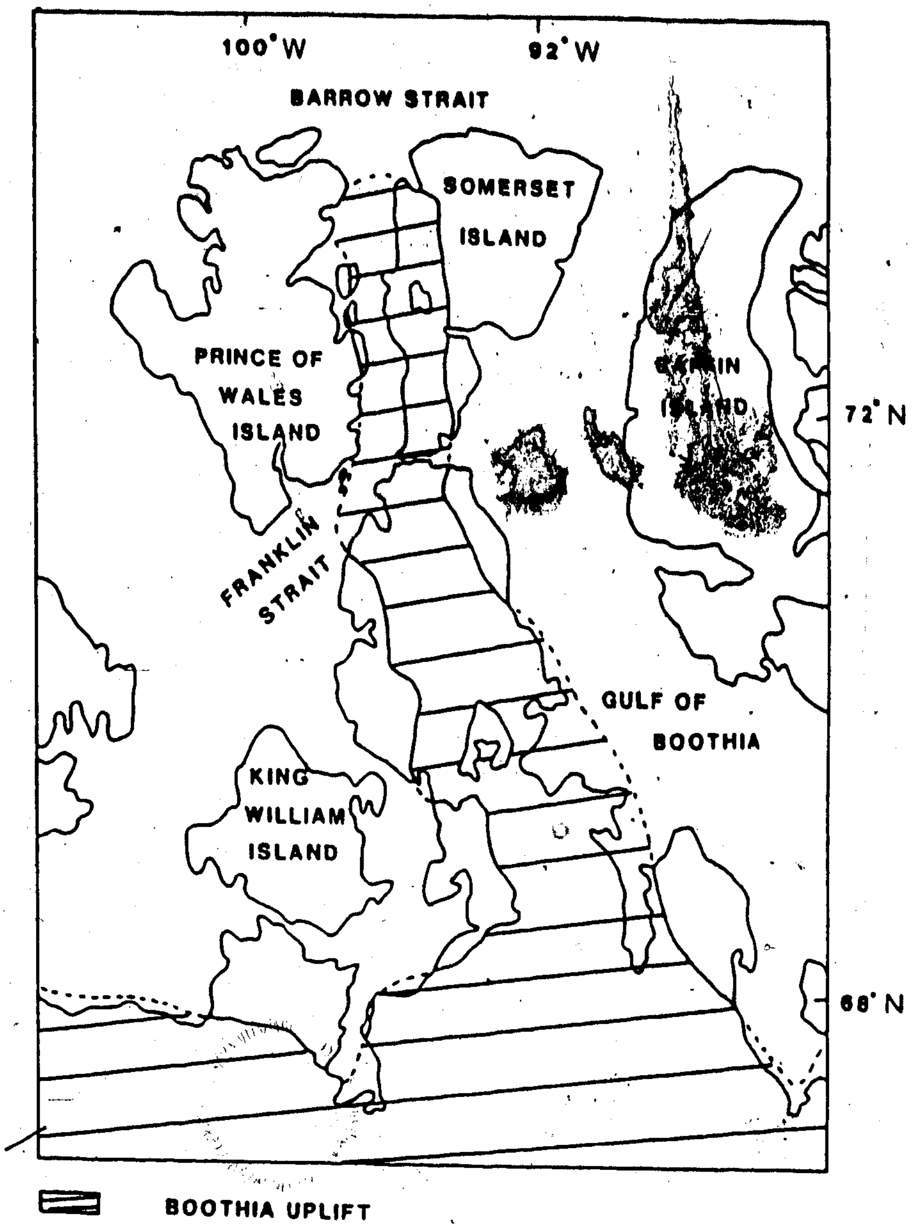


FIG. 3: Location of Boothia Uplift. Bedrock geology, physiography and to some extent the Quaternary geology of the study area are tied directly into the tectonic history of this feature.

The Boothia Horst was a Highland during the Devonian (Miall, 1970a). Walcott (1970) proposed that the Boothia Horst is a simple basement horst affected by isostatic movement. Faults and drape folds in the covering strata support this concept (Kerr and Christie, 1965; Kerr, 1977). Okulitch et al., (1986) propose that movement of the Boothia Horst was caused by a west-directed stress during the late stages of the Caledonian Orogeny. This hypothesis is based on Miall's (1983, p. 495) proposal that the Boothia Horst is a "deep seated, east-dipping thrust block."

Whatever caused the uplift, Miall (1970a) proposed that uplift produced the Peel Sound Formation, divided into lower and upper members (Fig. 4). The lower member is comprised of red and grey sandstone and conglomerate, interbedded with marine carbonates. A rapid change in characteristics of clasts (fine to coarse) from lower to upper Peel Sound Formation suggests rejuvenation of the source area. Rejuvenation resulted in debris floods producing a series of bajadas now consisting of conglomerate.

As the debris floods graded into braided streams, the gravels thinned westward to a gravel-sand unit. Contact of braided streams with estuaries produced sand deltas. Carbonate deposited in a marine environment, in which the deltas were also being constructed, produced sand-carbonate and carbonate units. These five units

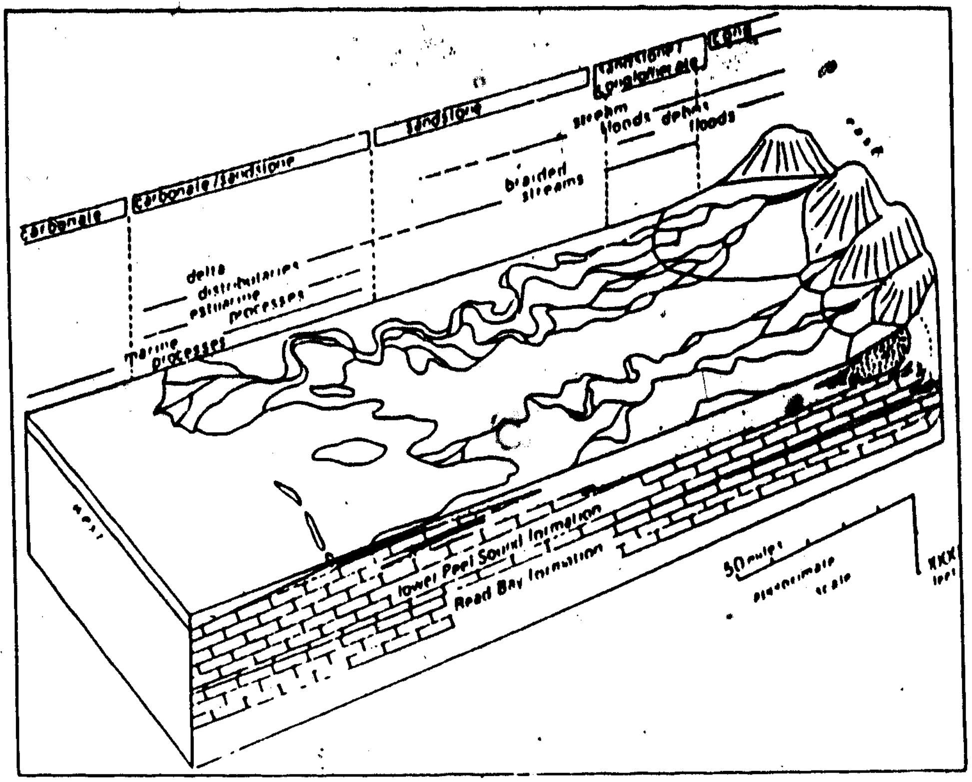


FIG. 4: Development of the Peel Sound Formation (after Miall, 1970).

(conglomerate, conglomerate-sandstone, sandstone, sandstone-carbonate, carbonate) which cap the Paleozoic succession, constitute the upper Peel Sound Formation (Fig. 4). This unit is important in debris dispersal studies which will be discussed later.

Miall (1970a) did not discuss the thin band of Silurian carbonate rock abuts the Precambrian gneiss and granite. Mortenson (1985) and Mortenson and Jones (1986) proposed that the boundaries of alluvial fans (as defined by Miall, 1970a) are associated to margins of Late Silurian sub-basins. Tectonic activity during the Late Silurian through to the Cretaceous-Tertiary, along basement faults associated with the Late Silurian sub-basins, caused the coarsening-upward sequences observed in the fans. The alluvial fans and margins of the sub-basins were uplifted then eroded resulting in the (east-west) distribution of gneiss-granite, carbonate, conglomerate, conglomerate-sandstone, sandstone, sandstone-carbonate and carbonate rock.

The central Arctic was probably part of a broad continental area throughout the Mesozoic because marine sedimentation, which was ongoing in the Sverdrup Basin to the north, apparently did not extend to Lancaster Sound (Kerr, 1980, p. 11). Subaerial planation probably occurred during this time and formed the Barrow Surface. The Barrow Surface was broken up during the Eurekian Rifting episode, towards the end of the Mesozoic and into the Late Tertiary, and resulted in establishment of islands and channels (Kerr, 1980, p. 19). Before this rifting episode sands were deposited on Somerset Island and northern Boothia Peninsula where they are preserved in small grabens.

1.4 CLIMATE

No weather station exists on Prince of Wales or Pandora islands. The closest weather stations are at Spence Bay, to the southeast on Boothia Peninsula, and Resolute Bay to the north on Cornwallis Island. Climatic information was collected at Fort Ross until 1950. All three stations have closely similar weather patterns (Table 1). Winters are long and cold (commonly <30 C) with more than half of the annual precipitation (10cm) falling as snow. Summers are brief, cool and damp with mean temperatures (June, July, August) between 2 and 4 C. Rainfall intensity is usually low and rain falls only between May and September. Prevailing winter winds are northerly to northwesterly.

The most important aspect of the area's climate to Quaternary studies are its aridity and cool summers which limit glaciation levels to somewhere between 400-600m asl, well above the highest elevation on southern Prince of Wales Island (Miller et al., 1975). A drop in the present average temperature and increase in the present

TABLE 1: Climatic data, Resolute, Fort Ross and Spence Bay.

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year	Range
Average monthly and annual daily mean temperatures (°C).														
Resolute	-32	-34	-31	-23	-11	00	04	03	-05	-15	-24	-29	-16	38
Fort Ross	-29	-32	-26	-22	-09	00	04	02	-04	-12	-22	-26	-15	36
Spence Bay	-34	-35	-32	-22	-10	01	07	06	-01	-12	-24	-30	-15	42
Average monthly and annual precipitation.														
Resolute														
rainfall (mm)	0.00	0.00	0.00	0.00	T	5.80	23.8	25.7	3.80	T	0.00	0.00	58.70	-
snowfall (mm)	2.00	3.30	3.30	5.80	8.90	6.60	3.30	4.80	14.2	15.5	5.60	4.80	78.60	-
Fort Ross*														
rainfall (mm)	0.00	0.00	0.00	0.00	2.60	12.5	21.8	35.0	0.00	0.00	0.00	0.00	69.00	-
snowfall (mm)	17.0	7.60	20.0	8.40	11.2	23.5	1.00	1.50	29.2	31.2	23.0	8.20	160.0	-
Spence Bay														
rainfall (mm)	0.00	0.00	0.00	T	T	6.90	24.9	29.0	11.9	0.30	0.00	0.00	73.00	-
snowfall (mm)	4.60	5.60	6.10	5.60	8.10	8.40	0.30	T	10.2	19.3	7.60	5.10	80.90	-

*Rae (1951)
Source; Atmospheric Environment Service, 1975.
T= trace

average precipitation (Loewe, 1971; Williams, 1978) would presumably lower glaciation levels to the Barrow Surface (300m asl).

1.5 PERMAFROST, SOILS AND VEGETATION

The study area lies in the mid-Arctic ecoregion (Woo and Zoltai, 1977) and hence has sparse vegetation cover, active cryoturbation, weak soil development and considerable wind erosion. Generally, vegetation consists of dwarf shrubs, sedge meadows, mosses and grasses. Vegetation cover is discontinuous except in wetlands. Permafrost occurs within a metre of the surface and attains a thickness of ca 400-600m (Judge, 1973).

1.6 PREVIOUS STUDIES

This section discusses the basis for the single ice dome model, subsequent research within the central Arctic and the development of research which lead to the model of several coalecsing sectors.

1.6.1 SINGLE ICE DOME MODEL

Dawson (1886, 1890) and Chamberlain (1894) recognized that most glacial deposits and landforms east of the Cordillera had been produced by a single ice sheet centred on the Laurentian Shield (now called the Canadian Shield). This ice sheet was named the Laurentide Ice Sheet. Flint (1943, p. 337) elaborated on this concept through "...the hypothesis of highland origin and windward growth." He envisaged a single dome of ice centred over Hudson Bay and formed by coalescence of valley glaciers originating in the "mountains" of Labrador and Baffin Island. Flint (1943) proposed that snowfall, originating from warm air masses moving into the mountains of Labrador and Baffin Island from the south and west, allowed ice to form and advance towards Hudson Bay (Fig. 5). As ice advanced, areas of greatest precipitation maintained their position on the periphery of the ice sheet and migrated with it.

Flint's (1943) model is based on: 1) gradation of valley glaciers through piedmont glaciers into ice sheets, 2) comparison with the history of the Scandinavian Ice Sheet, 3) climatological speculation, and 4) tilt of shorelines around Hudson Bay. His model did not involve field observations.

1.6.2 LATER QUATERNARY STUDIES WITHIN THE CENTRAL ARCTIC.

Flint's (1943) hypothesis gained support until the mid-1970s. For example, Washburn (1947) stated that dominant movement of ice through Coronation and Queen

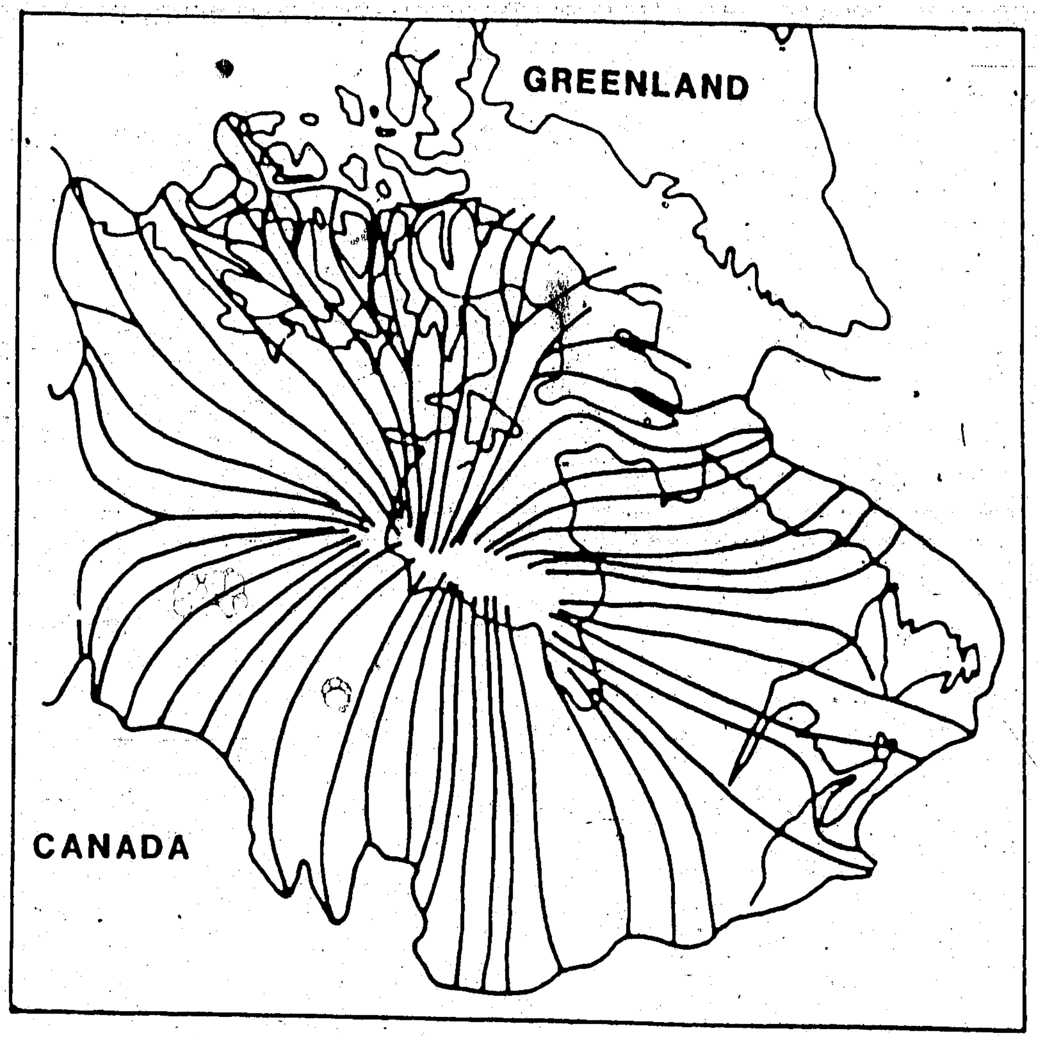


FIG. 5: Single ice dome model. Ice radiating out from a single dome of ice located over Hudson Bay during the last glaciation (after Flint, 1943).

Maude gulfs, as well as Victoria Island (Fig. 1), was from the south and southeast. Jenness (1952) also recognized flow of ice to the central Arctic from a source south of King William Island. Jenness (1952, p. 950) defined the limit of Laurentide Ice during the last glaciation on Banks, Prince of Wales and Somerset islands (Fig. 1).

Craig and Fyles (1960) placed the northern margin of the Laurentide Ice Sheet on Prince of Wales Island between "...southern lowlands with fresh glacial landforms and northern highlands..." that "...bear indefinite evidence of regional glaciation." Later, Craig (1964, p. 4) concluded that the northern plateau of Prince of Wales Island had been covered by Laurentide Ice. This was based on recognition of a thin layer of silty, rubbly till. On southern Prince of Wales Island drumlins indicating northward advance of ice were thought to have formed when continental ice covered all of Prince of Wales Island.

Craig and Fyles (1960) and Craig (1964) also proposed a deglacial pattern where southward retreat of ice was toward an ice centre situated over Keewatin. Nevertheless, this general retreat was complicated by flows controlled by deep channels between the islands. For example, ice flowing east on Prince of Wales Island formed drumlins that cross older features. Southward retreat continued to Keewatin where "...radial ice flow patterns record successive positions of the ice margin during deglaciation" (Craig and Fyles, 1960, p. 5).

Fyles (1963) concluded that Victoria and Stefansson islands (Fig. 1) lay within the northwest part of the Laurentide Ice Sheet during the last glaciation and retreat of ice was generally southeast. As the ice sheet thinned, topography increasingly controlled ice-flow. This, coupled with the re-activation of ice, lead to the complex distribution of drumlin fields on Victoria and Stefansson islands.

Bird (1967) proposed that the northern limit of Laurentide ice on Prince of Wales Island was located between Browne and Ommanney bays (Fig. 2) which left the northern plateau unglaciated. However, he also presented evidence of a local ice cap on Somerset Island (Bird, 1967, p. 95). Like Craig and Fyles (1960) and Craig (1964), Bird (1967, p. 96) used the distribution of landforms to define a southward retreat of ice from the central Arctic back to an ice divide over Keewatin.

Boydell et al., (1975) concluded from orientation of ice moulded landforms that Late Wisconsinan ice flowed north over Boothia Peninsula from Keewatin. Based on freshness of glacial landforms on southern Prince of Wales Island Netterville et al. (1976, p. 153) agreed with Craig and Fyles (1960) and Bird (1967) that Late Wisconsinan, Laurentide ice had extended northward to Browne and Ommanney bays. However, Netterville et al., (1976, p. 153) did not recognize an independent centre of ice on Somerset Island. Barnett et al., (1976, p. 204) placed the margin of the Late Wisconsinan, Laurentide ice between Lowther and Griffith islands; till and fresh straie occur on Lowther Island but not Griffith.

Vincent (1982, 1983, 1985) proposed two stages of Wisconsinan Laurentide ice advance on Banks Island. The first advance involved three lobes and deposited the Jesse, Sachs and Mercy tills. The second advance was less extensive than the first and only a single lobe advanced from Viscount Melville Sound to the northeast tip of Banks Island. The second advance is recorded by a ridge of glacially deformed, fine marine sediments that overlie Jesse Till. Vincent (1982, 1983, 1985) concluded that this ridge formed after 10600+/- 270 BP (GSC-1437, Lowdon and Blake, 1973) and likely after 10300 BP (Hodgson and Vincent, 1984).

Hodgson et al., (1984) identified four tills on Melville Island. Liddon and, possibly, Bolduc tills correlate with Early Wisconsinan Jesse, Sachs and Mercy tills on Banks Island suggesting that all these tills were deposited by the same glacial event. The youngest till (Winter Harbour Till) identified by Hodgson et al., (1984) on Melville Island was correlated with Vincent's (1982) Russell Stade, a Late Wisconsinan advance. Hodgson et al., (1984) and Hodgson and Vincent (1984) propose that Winter Harbour Till was deposited by an ice shelf grounded on the south shore of Melville and Byam Martin islands between 10340+/- 150 and 9700+/- 150 BP.

These studies all conclude that Prince of Wales and surrounding islands were last overrun by ice from a source centred southeast of the central Arctic. These studies, however, begin to re-evaluate the location of a single dome of ice centred over Hudson Bay as proposed by Flint (1943).

1.6.3 MULTIPLE COALESCING ICE SECTORS MODEL.

Tyrrell's (1898, 1913) model of three coalescing ice domes gained more acceptance in the late 1970's as additional data and observations were compiled. Flint (1971) doubted but did not abandon his single ice dome model. A significant departure from Flint's model came with the recognition of the M'Clintock Ice Divide that occupied the central Arctic during the Late Wisconsinan and possibly earlier (Dyke, 1984; Dyke and Matthews, 1987).

The interpretation of the M'Clintock Ice Divide (Dyke and Prest, 1987) was based on the fact that ice flowed east-northeast across Boothia Peninsula and southern Somerset Island depositing two, fine grained carbonate-rich tills. This ice coalesced with the southern margin of the ice cap centred on northern Somerset Island (Bird, 1967; Dyke, 1983, p. 30). Eastward flowing M'Clintock ice also coalesced in Committee Bay with westward flowing ice from the Foxe Dome. It is speculated that this coalescence may have formed an ice shelf in Prince Regent Inlet (Dyke, 1984, p. 15).

Dyke (1984, 1987) defined the westward flow from the M'Clintock Ice Divide from Fyles' (1963) observations of westward orientated ice flow features on Victoria and Stefansson islands. Dyke (1987) suggested that Jesse Till on Banks Island was deposited during the Late Wisconsinan rather than Early Wisconsinan (and therefore Liddon and possibly Bolduc tills on Melville Island, Hodgson et al., 1984).

Dyke and Prest (1987) developed a model of the Laurentide Ice Sheet that consists of four coalescing Late Wisconsinan Ice Domes. According to these authors the Laurentide Ice Sheet at its maximum consisted of three sectors with a system of ice divides joined at intersector saddles. The main ice divide, which runs through the heart of their reconstruction of the Laurentide Ice Sheet was named the Trans-Laurentide Ice Divide (Fig. 6). The northern arm of the Trans-Laurentide Ice Divide is Dyke's (1984) M'Clintock Ice Divide.

The Laurentide Ice Sheet's northern margin (or Keewatin Ice) is based on the distribution of ice marginal features and radiocarbon dated marine limits. Inside the last ice limit all marine limits form at the time of local deglaciation which corresponds with the initial penetration of the sea. The chronology of retreat

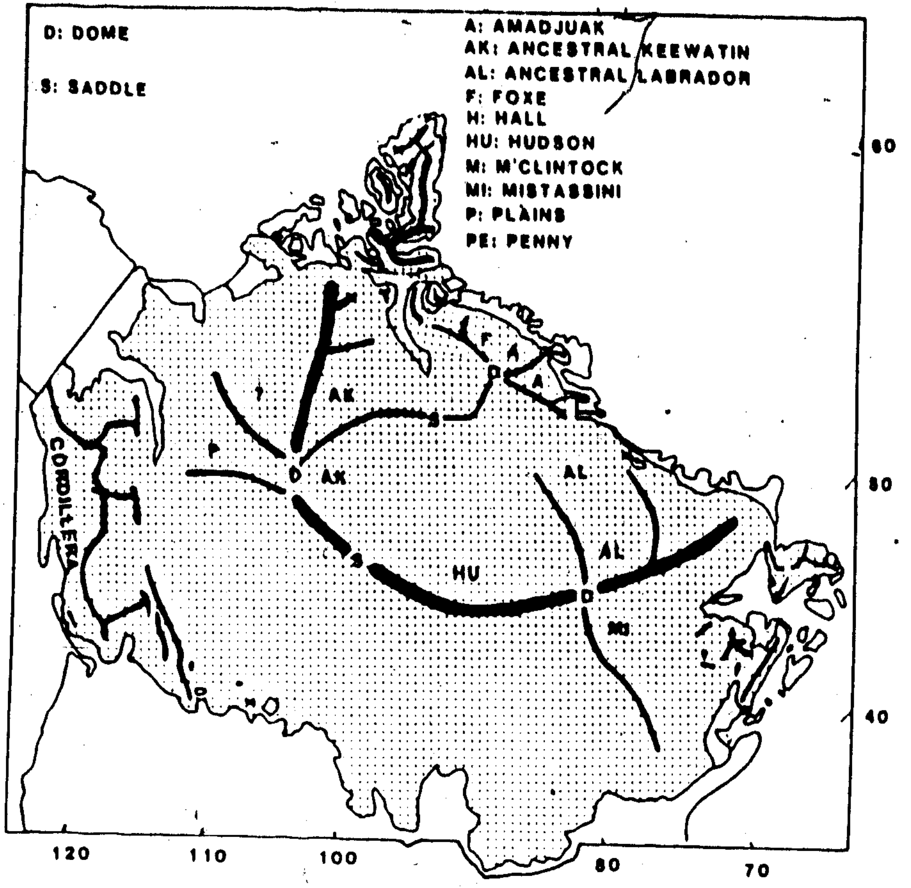


FIG. 6: Multi-ice dome model (modified after Dyke and Prest, 1987). Ice sheet made up of several ice domes and divides during the last glaciation.

summarized by Dyke and Prest (1987) draws largely on work by Dyke (1983, 1984, 1987) on Boothia Peninsula, Somerset and Prince of Wales islands and by Green (1986) on Russell Island.

The north-central Laurentide Ice Sheet retained its full glacial configuration and extent until 12000 BP. The Laurentide Ice Sheet began retreat from its position in Viscount Melville Sound (Dyke and Prest, 1987) just after 12000 BP as Melville and western Victoria islands began to rebound at about this time. On Somerset Island and Boothia Peninsula at this time the Laurentide Ice Sheet's margin remained stable (Fig. 7).

At 11000 BP the Laurentide Ice Sheet margin, situated in the middle of Viscount Melville Sound, surged across Viscount Melville Sound to Melville Island (Fig. 8). Dyke (1987) based this interpretation on 7 new radiocarbon dates on shell and whalebone collected on northern Prince of Wales Island. Shortly after 11000 BP, the ice shelf had disintegrated and the northern margin of the Laurentide Ice Sheet stabilized on Prince of Wales Island at a large morainal belt.

The northern margin of the Laurentide Ice Sheet retreated east across northwestern Prince of Wales and Russell islands between 11000 and 10000 BP (Fig. 9). The margin then retreated southeast at an average rate of 4km/ century (Green, 1986, p. 122). Ice had withdrawn from Russell and northern Prince of Wales islands by 9800

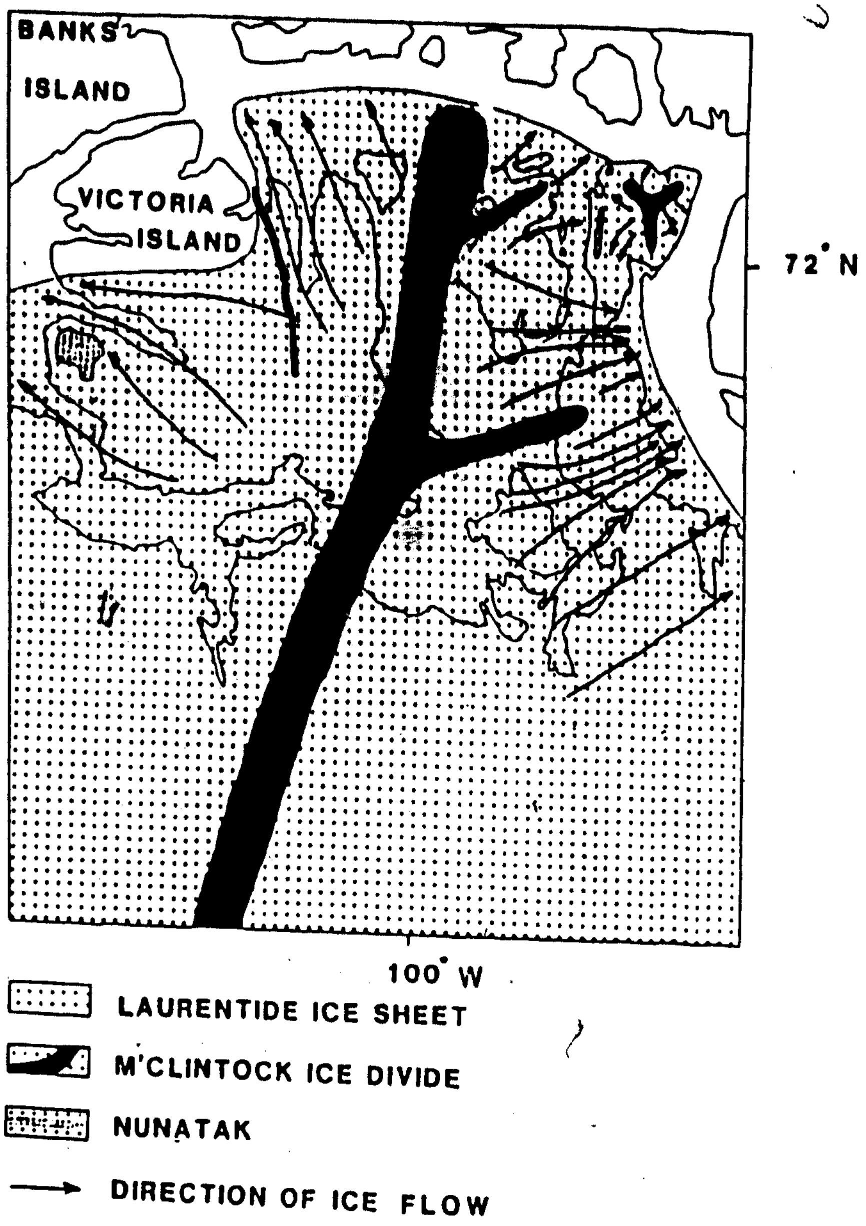


FIG. 7: The north-central Laurentide Ice Sheet at 12000 BP (after Dyke and Prest, 1987).

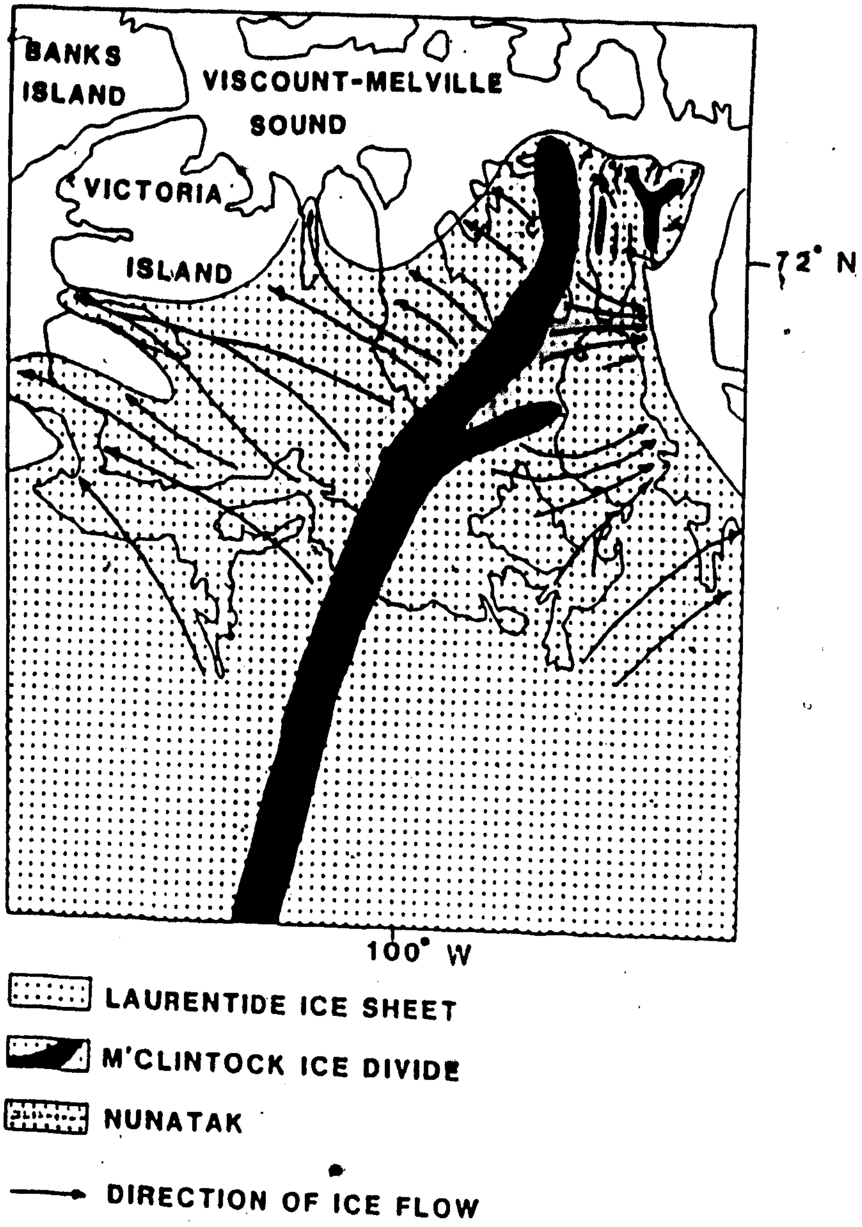


FIG. 8: The north-central Laurentide Ice Sheet at 11000 BP (after Dyke and Prest, 1987).

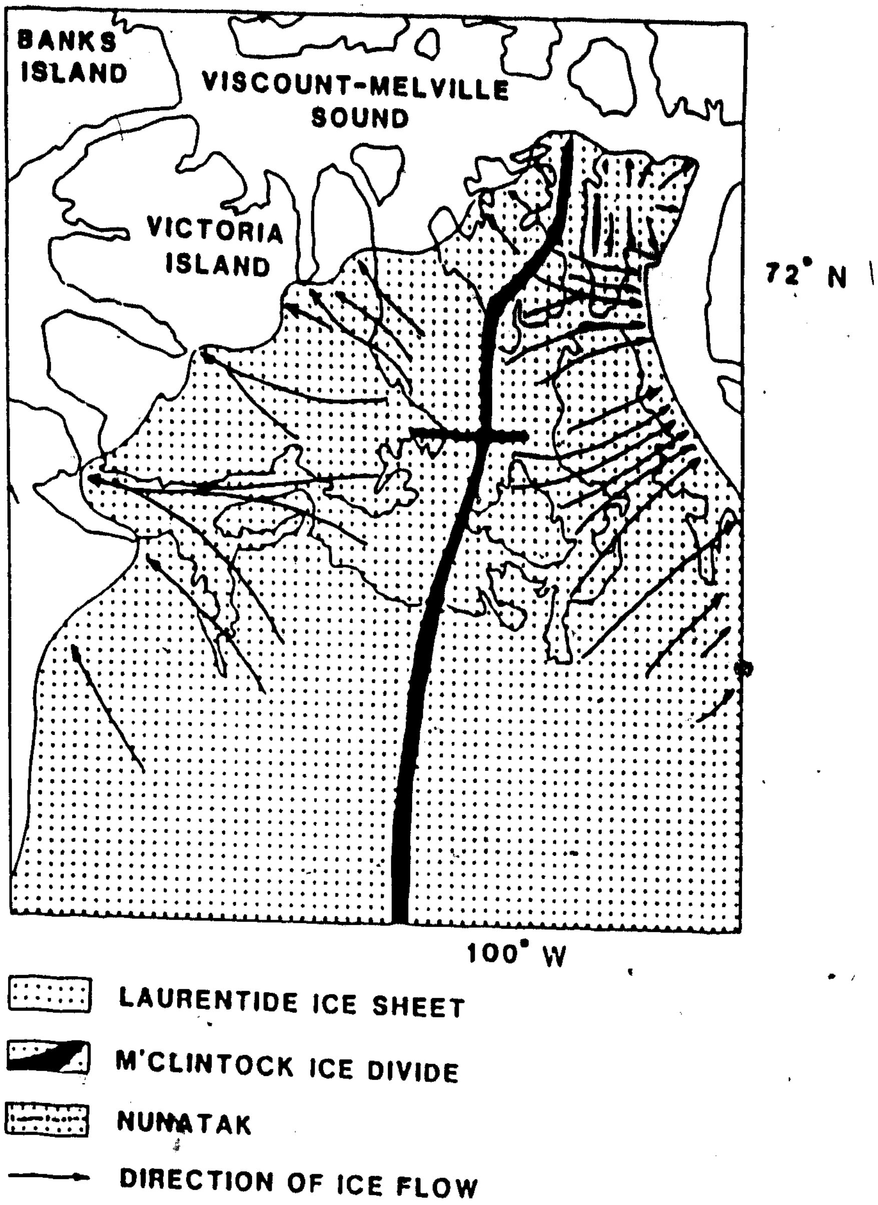


FIG 9: The north-central Laurentide Ice Sheet at 10000 BP (after Dyke and Prest, 1987).

BP and was forming the Nygaard moraine on eastern Victoria Island. The margin had changed little in the Gulf of Boothia.

The northern margin of the Laurentide Ice Sheet had retreated from Prince of Wales Island by 9000 BP. This northwest margin had been much reduced across southern Somerset Island while a local ice cap occupied most of the north. The north-west margin covered southeastern Victoria Island (Fig. 10).

Between 9000 and 8400 BP, ice retreated from interior Boothia Peninsula at a rate of 200m/ yr, while to the west, retreat was 670m/ yr (Dyke, 1984, p. 21). During this interval emergence of northern Boothia Peninsula exceeded 30m/ century. Nowhere has this rate of emergence been recorded in the Arctic, which would indicate very rapid glacial unloading. Such fast retreat rates were probably accommodated by ice calving into the sea. Rapid re-advances, probably caused by surging as the ice front was destabilized by rapid retreat, produced large cross-cutting drumlin and fluting fields on south-eastern Victoria and King William islands (Fig. 11). By 8000 BP, Boothia Peninsula, Prince of Wales and Somerset islands were ice free. The north end of the Ancestral Keewatin Ice Divide had shifted southeast and occupied its near final-position.

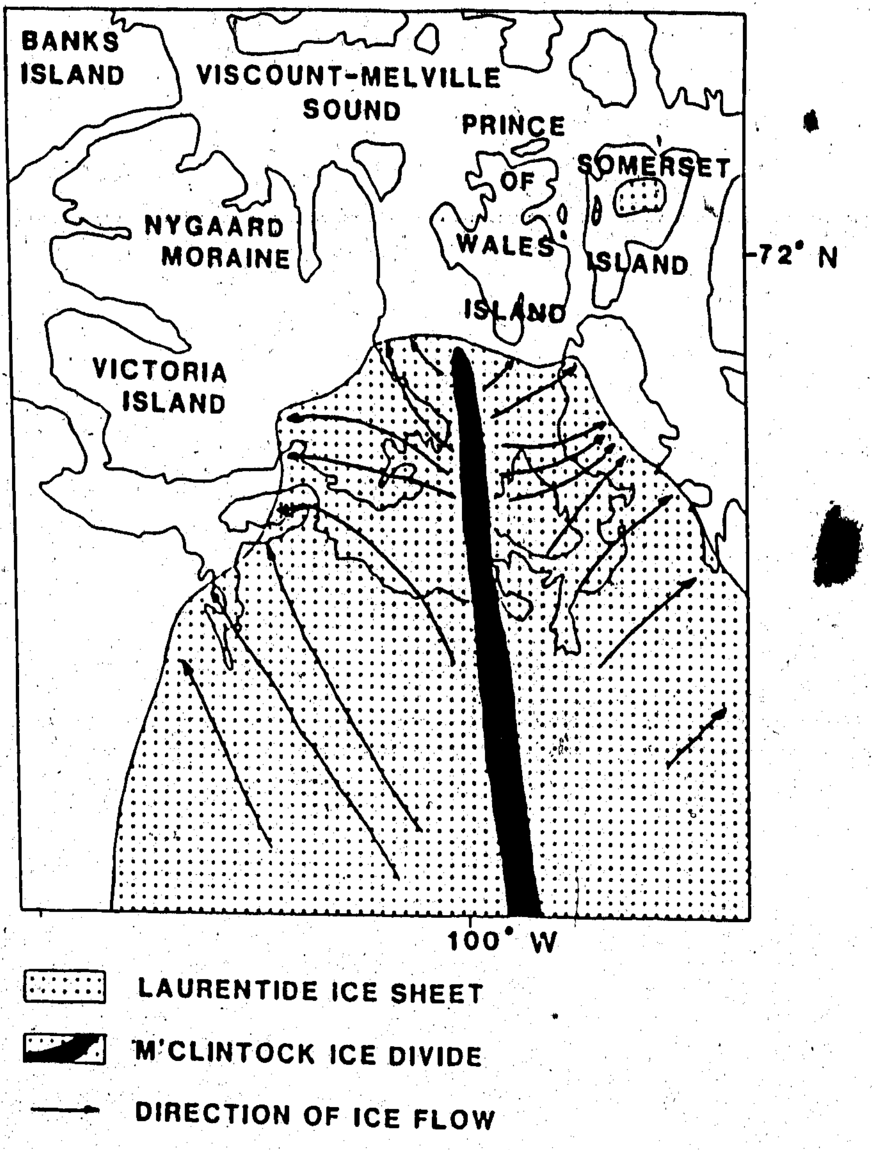


FIG. 10: The north-central Laurentide Ice Sheet at 9000 BP (after Dyke and Prest, 1987).

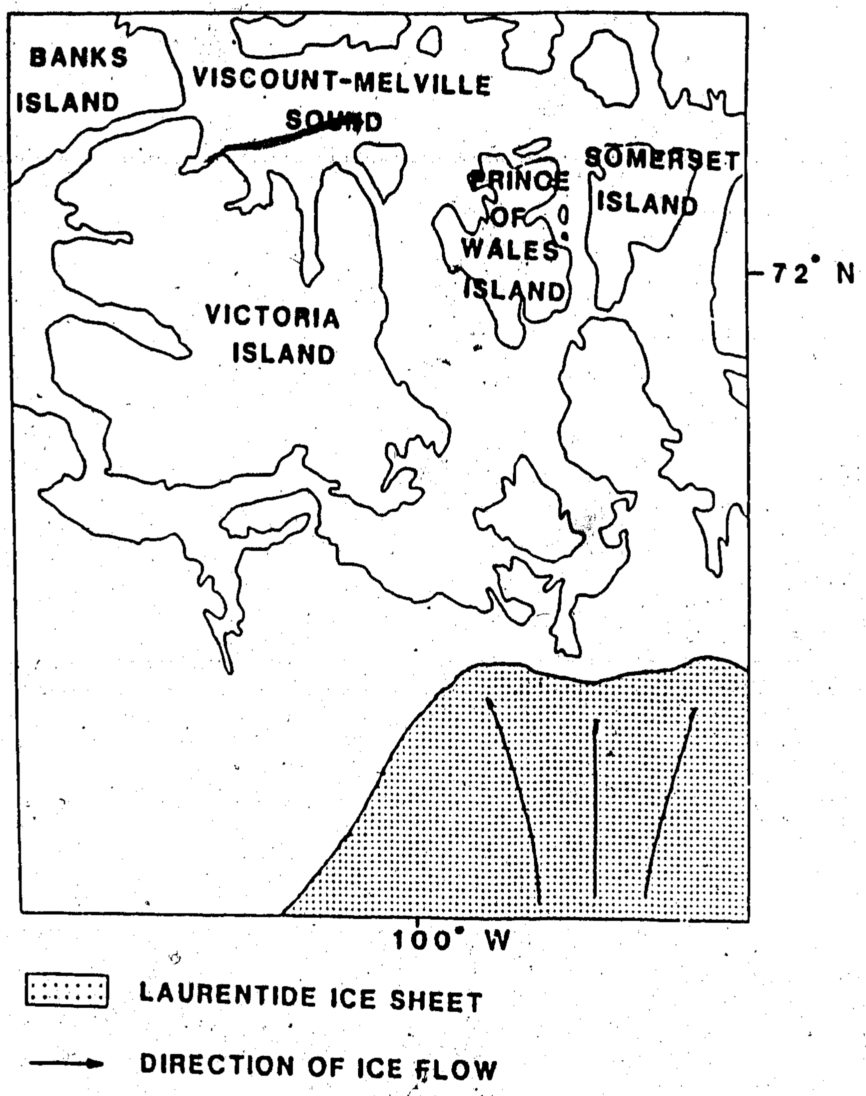


FIG. 11: The north-central Laurentide Ice Sheet at 8400 BP (after Dyke and Prest, 1987).

1.7 SEA LEVEL STUDIES

Early marine limit studies were used by Flint (1943) to support his single ice dome model. Such studies included those by De Geer (1892) and Upham (1896) who summarized measurements on highest beaches (which they called marine limit) in the form of an isobase map of northeastern America. An isobase map consists of lines which indicate the present altitude of former shorelines which rise toward former centres of glacial loading. These maps indicated that marine limit rose northwest from the St.Lawrence Valley to James Bay.

These maps prompted studies on raised marine sediments and related features around Hudson Bay. Low (1896), Bell (1896) and Tyrrell (1898) indicated that Hudson Bay was still emerging because of glacial unloading. Such studies continued elsewhere into the twentieth century by researchers such as Goldthwait (1908), Fairchild (1918), Daly (1934), Stanley (1939) and Gutenburg (1941). Their isobase maps showed that shorelines tilted towards Hudson Bay, indicating that a dome of ice had existed there. Flint (1943) used these maps to support his single ice dome model.

With the advent of radiocarbon dating (Libby, 1946) a new source of data was available. Farrand (1962) compiled radiocarbon dates on materials collected from raised shorelines and developed uplift curves including one for Prince of Wales and Somerset islands. All of these early uplift curves were corrected for eustatic sea level rise derived from unglaciated parts of the world during the 1950s and 1960s (Bloom, 1963; Frye and Willman, 1961; Godwin et al., 1958; Shepard, 1963, 1964). These eustatic curves were based on the assumption that changes of sea level could be measured at tectonically stable sites (Walcott, 1972) and changes in sea level were globally uniform.

Walcott (1972) proposed the concept of non-uniform hydro-isostatic deformation of ocean basins which would produce a unique sea level history for each area on a transect away from the ice margin. Walcott (1972) further developed Nanson's (1921), Daly's (1934) and Brotchie and Silvester's (1969) concept of a migrating forebulge. He postulated that an ice load displaces viscous upper mantle material outward, creating a peripheral depression around the margin of the load with a forebulge beyond that. Removal of the load causes movement of displaced viscous material back into the unloaded area. This causes uplift in areas that were formerly depressed, and subsidence in those areas across which the forebulge migrates. Farrell and Clark (1976) and Clark et al. (1978) later derived the same conclusions as Walcott (1972).

Several emergence curves have been constructed for the central Arctic. These include curves for Melville

Island (Hodgson, 1982), Cornwallis Island (Washburn and Stuiver, 1985), Somerset Island (Dyke, 1979, 1980, 1983), Russell Island (Green, 1986) and northern Prince of Wales Island (Dyke, pers. comm., 1987).

Dyke (1984) constructed an isobase map for the central Arctic (Fig. 12). The 9300 BP shoreline rises to a ridge over M'Clintock Channel. More recently, Dyke and Dredge (in press) and Dyke (1987) published a 9470+/- 90 date on marine limit (95m) at Browne Bay. This was the first reliable date on a specific relative sea level from Prince of Wales Island and does not fit the isobase pattern proposed by Dyke (1984). The radiocarbon date from Browne Bay may indicate faulting since 9300 BP (Dyke and Dredge, in press). Hence a major objective of field work was to date Holocene shorelines to determine the degree of departure from the 9300 BP isobase pattern derived by Dyke (1984) and to provide further details on postglacial emergence in the area.

1.8 SUMMARY AND STATEMENT OF OBJECTIVES

Research in the central Arctic (Craig and Fyles, 1960 and Craig, 1964) seemed to support Flint's (1943) single ice dome model. Northward orientated drumlins were thought to have formed when continental ice covered the whole northern part of Prince of Wales Island. The formation of eastward orientated drumlins and flutings

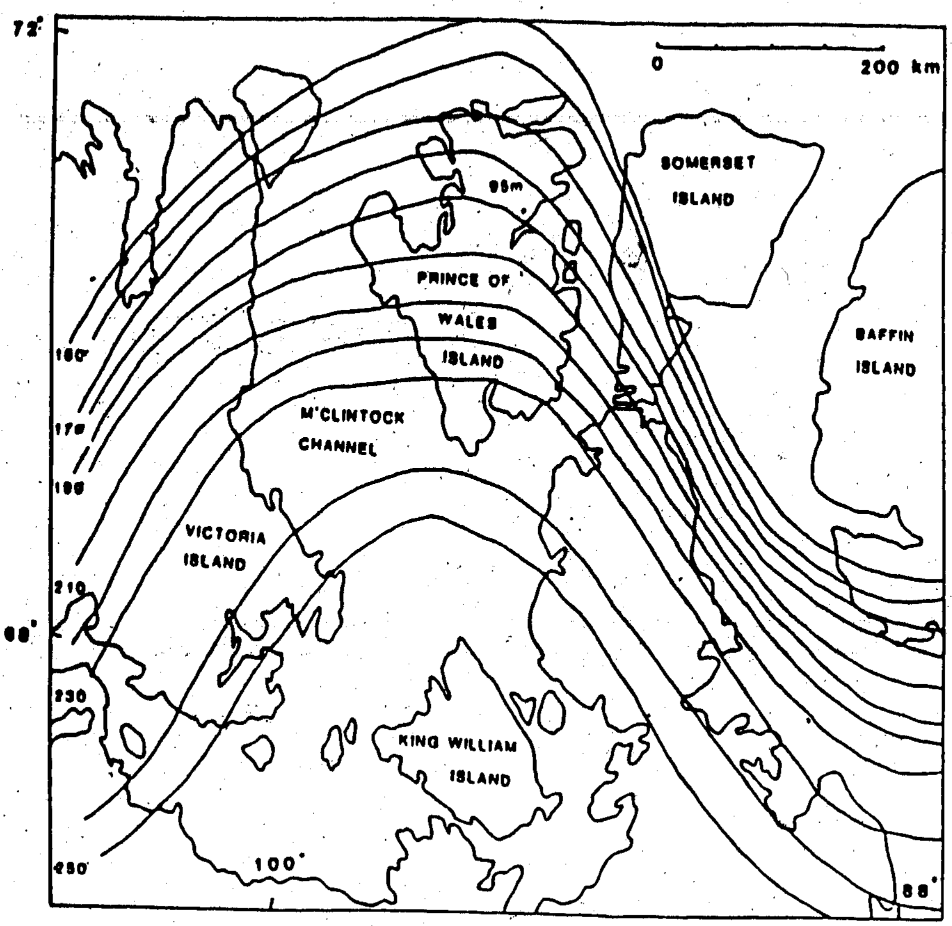


FIG. 12: 9300 BP isobase pattern for the central Arctic (modified after Dyke, 1984). Note 95m marine limit (9470+/- 90 BP) on northern Prince of Wales Island. Isobases indicate that marine limit should be between 180- 190m asl.

were attributed to late-glacial flow into Peel Sound during ice retreat.

An alternative model was introduced in the late 1980s. This model involves several ice divides with interlocking saddles forming a complex Laurentide Ice Sheet during the Late Wisconsinan. The northern part of this ice sheet is the M'Clintock Ice Divide. The concept of this ice divide as proposed by Dyke (1984) was developed from observations made on Somerset Island and Boothia Peninsula. Ice flowed east over these areas from the M'Clintock Ice Divide during the last glacial maximum. This hypothesis implies that northwest oriented features observed earlier on Prince of Wales Island predate the last glacial maximum.

A means by which Craig and Fyles (1960) and Craig's (1964) hypothesis can be further evaluated against that of Dyke's (1984), is through a study of the geomorphology and glacial history of southern Prince of Wales Island. Therefore objectives of this study are,

1) To map the surficial geology of southern Prince of Wales Island,
2) To determine the chronology and pattern of glaciation,
3) To determine the chronology and pattern of deglaciation,
4) To determine the emergence history.

CHAPTER 2

SURFICIAL MATERIALS AND LANDFORMS

2.1 INTRODUCTION

The characteristics and distribution of landforms, surface and subsurface materials are described in this chapter (Fig. 13; back pocket). Surface materials are divided into seven genetic categories and mapped according to Geological Survey of Canada standards.

2.1.1 BEDROCK

Bedrock consists of: 1) Proterozoic gneiss and marble, 2) Late Silurian carbonate rock, 3) Devonian clastic sedimentary rocks and 4) Devonian carbonate rock. Proterozoic gneiss and marble are aligned north-south along the east coasts of southern Prince of Wales and Pandora islands. Late Silurian carbonates abut this Proterozoic rock. Devonian clastic rocks are exposed at the surface up to 38km west of Late Silurian carbonate rocks on southern Prince of Wales Island. Coarse conglomerate found close to Late Silurian carbonate rock grades to sandstone farther west. On Pandora Island a similar association occurs except clastic rock does not extend as far west. Devonian carbonate rock outcrops intermittently west of the sandstone on southern Prince of Wales Island.

Postglacial weathering has removed glacial abrasion marks from most outcrops. Striae are best preserved on recently exposed carbonate rock and some occur on conglomerate and gneiss but not on sandstone. Most striae indicate eastward flow which occasionally cross-cut striae oriented northwest. On Dixon Island, off southeast Prince of Wales Island, striae orientated northeast cross-cut striae oriented east-northeast. Grooves occur on conglomerate and gneiss, are aligned east-west, and are located on Pandora Island and at Le Feuvre Inlet on Prince of Wales Island. Large ice streamlined forms, aligned west-east on northern Pandora Island, southwest-northeast, north of Crooked Lake and southeast-northwest, east of Guillemard Bay, occur on carbonate rock.

2.1.2 SURFACE TILL

The definition of till as defined by the INQUA Till Working Group (2A, 1987), which is accepted as the definition of till for this thesis, is "...a sediment that has been transported and subsequently deposited by or from glacier ice, with little or no sorting by water." Surface till is subdivided into two thickness categories, veneer and blanket. Till veneer is 0.5- 3m thick and does not mask minor relief of underlying bedrock. Till blanket is >3m thick and masks minor relief of underlying bedrock. Till veneer is widespread over elevated areas in the east but is rare in the west.

Till blanket is subdivided into six morphological categories. These include: 1) megaflutes, 2) high relief streamlined till, 3) lateral shear moraine, 4) low relief streamlined till, 5) ribbed moraine and 6) end and lateral moraine.

Till with megaflutes orientated southeast-northwest, is located on the west coast of southern Prince of Wales Island. This till extends 125km from the southwest coast north to the edge of the study area, with a maximum width of 38km. It is difficult to map from the ground or airphotos, but is conspicuous on satellite images which clearly display streamlined features of low relief (<10m), but great length (up to 26km) and width (0.5 km; Fig. 14).

Megafluted till is superimposed and cross-cut by high relief streamlined till farther to the east (Fig. 14). This till is aligned with the megafluted till to the south. However, high relief streamlined till arcs across the north end of the megafluted till. High relief streamlined till extends 113km from Guillemard Bay northwest to Crooked Lake, covering a width of 46km. Streamlined appearance is imparted by drumlins 100m high, 5km long and 1km wide.

FIG. 14: Satellite photo of southern Prince of Wales Island. Megafluted till (A), lateral shear moraine (B), high relief streamlined till (C), low relief streamlined till (D). The lateral shear moraine is interpreted as produced in a dynamic boundary separating warm-based ice over (C) from cold-based ice over A (moulded earlier).

A single narrow ridge of till delineates the western side of the high relief streamlined till (Fig. 2[illegible] This ridge is 74km long and is much lower and narrower than related drumlins. The attenuated shape of the ridge suggests it is similar to a drumlin yet its location at the western edge of the high relief streamlined till suggests a different origin. The ridge could have formed in two ways. First, it could mark the side of a large re-advance lobe if ice was absent to the west. In the lobe no splaying occurred as indicated by perfect parallelism between the ridge and the high relief drumlin field.

Secondly, the ridge could mark a former shear zone at the side of an ice stream. In this case ice west of the ridge would be experiencing little or no basal flow while to the east flow would be rapid. Thus, the ridge could be referred to as a lateral shear moraine (Dyke and Morris, 1988).

Low relief streamlined till is located east of high relief streamlined till and has a strong east-west orientation. Streamlined appearance is imparted by drumlinoid ridges <5km long, 10m high and 0.5km wide. Seven distinct low relief drumlin fields occur in the area. Three low relief drumlin fields cross-cut the eastern boundary of high relief streamlined till. These drumlins are aligned towards Le Feuvre Inlet, Transition and Young bays (Fig. 15). Orientations of drumlins at the heads of each low relief drumlin field indicate strong

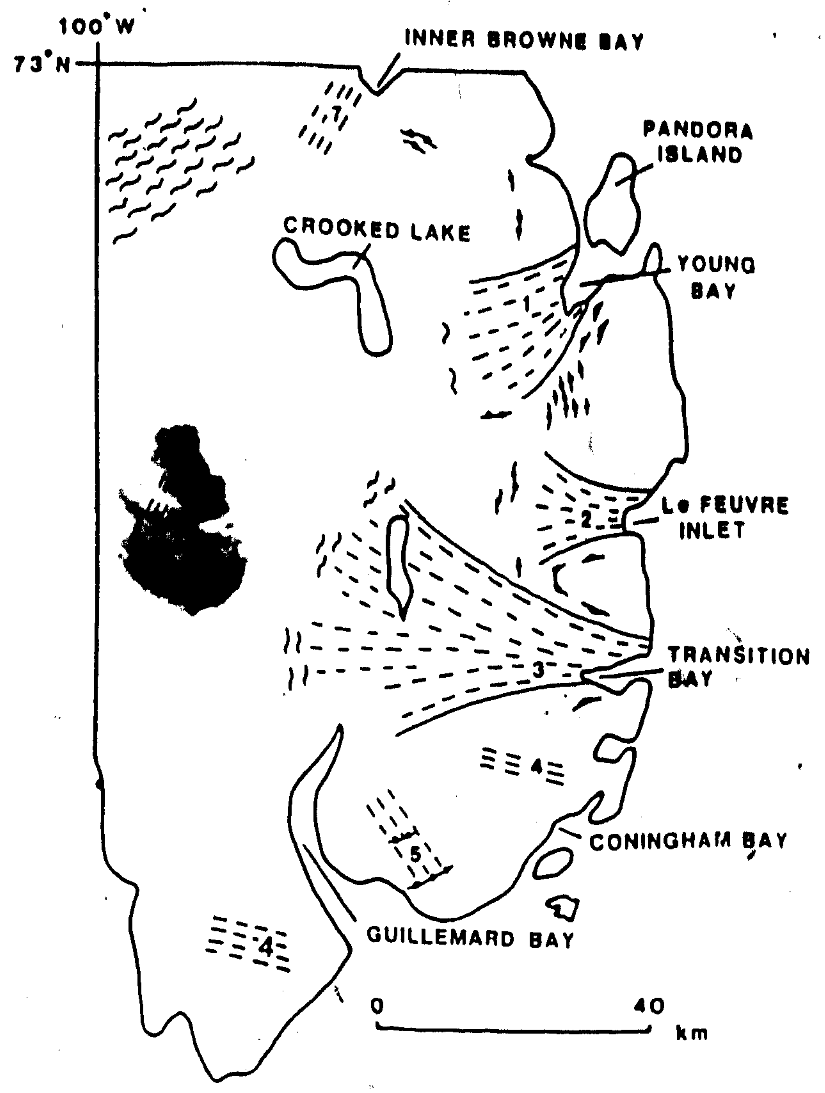


FIG. 15: Distribution of low relief streamlined till, ribbed moraine, end moraine and lateral moraine.

END MORAINE
LATERAL MORAINE
RIBBED MORAINE
LOW RELIEF STREAMLINED TILL INDICATING FLOW CONVERGENCE AT;
1) YOUNG BAY
2) LE FEUVRE INLET
3) TRANSITION BAY
LOW RELIEF STREAMLINED TILL AT;
4) GUILLEMARD BAY
5) CONINGHAM BAY
6) NORTH END, MEGAFLUTED TILL
7) INNER BROWNE BAY

flow convergence.

Other low relief drumlin fields are aligned toward Coningham, Guillemard and Inner Browns bays. Streamlined forms cross-cut the northeast margin of megafluted till (Fig. 15). Streamlined forms within each of these indicate parallel flow.

Ribbed moraine is associated with two different streamlined landforms. A large ribbed moraine field is located at the distal end of the high relief drumlin field (Fig. 15). Fluted ribbed moraine marks the transition from high relief drumlin field to the large area of ribbed moraine. Individual ridges are concave down ice, <20m high and <2.5 km long.

Fields of minor ribbed moraine are located around the heads of low relief drumlin fields at Transition and Young bays (Fig. 15). This ribbed moraine is similar to the larger ribbed moraine field, except individual ridges are only 1km long and marks the boundary between high relief streamlined till and low relief streamlined till.

End and lateral moraines are located in the east part of the study area (Fig. 15) and are <10km long and <40m high. Four end moraines are recognized between Inner Browne and Young bays, twenty-three south of Young Bay and two along the southeast coast of Prince of Wales Island. Lateral moraine is located where the Barrow Surface is dissected at Strzelecki Harbour, Transition and Young bays. Three small lateral moraines are located south of Young Bay on the Barrow Surface north face, south of Strzelecki Harbour, and north and south of Transition Bay.

2.1.3 GLACIOFLUVIAL SEDIMENT AND LANDFORMS

Glaciofluvial deposits are subdivided into ice contact and proglacial sediments. Ice contact stratified drift include eskers and kames consisting of locally derived cobbles and sand with some Precambrian erratics. Kames occur as ridges and conical hills and occur throughout southern Prince of Wales Island. The largest esker is aligned east-northeast towards Transition Bay (Fig. 16). Smaller eskers, aligned south-north, are located throughout southern Prince of Wales Island.

Proglacial outwash occurs only above marine limit east of Fisher Lake and on elevated plateaus along the east coast (Fig. 16). Proglacial outwash consists of gravel and sand, 1- 10m thick, deposited by glacial melt-water streams.

Pre-Wisconsinan fluvial channels carved in carbonate rock and gneiss are located on the east coast of Prince of Wales Island (Fig. 16). These fluvial channels must be pre-Wisconsinan because they are partially drift filled and unassociated with landforms of the last glaciation. The largest fluvial channel is 10km wide,

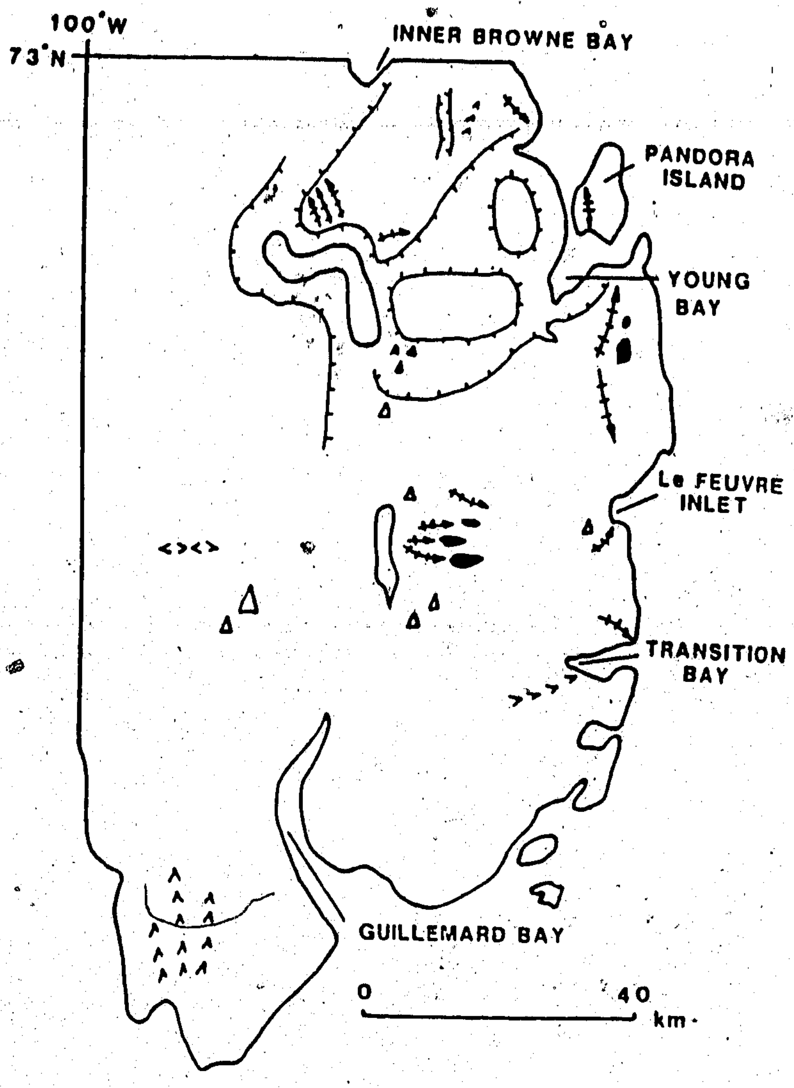


FIG. 16: General location of major eskers, kames, proglacial outwash and glaciofluvial channels. This figure also presents location of probable Tertiary and post-Tertiary fluvial channels.

- PRE-WISCONSINAN FLUVIAL CHANNELS (PROBABLY FROM TERTIARY)
- SMALLER, DRIFT FILLED VALLEYS (PROBABLY POST- TERTIARY).
- >>> ESKER
- ▲ KAME
- PROGLACIAL OUTWASH
- GLACIOFLUVIAL CHANNELS

100m deep and probably formed during the Tertiary (Bird, 1967, p. 81). This fluvial channel cuts through the Barrow Surface at Young Bay, looping west through Crooked Lake, then north to Inner Browne Bay (Fig. 16). Dyke (1983) mapped similar channels on Somerset Island which he interpreted as remnants of a Tertiary drainage system severed by the block faulting that formed the present islands and channels. Smaller channels west of the Barrow Surface (<100 m deep, 0.5 km wide) are aligned north-south and probably formed after the Tertiary (Fig. 16).

Other channels carved in carbonate rock and gneiss are glaciofluvial. These channels are aligned south-north and east-west (300m deep, 0.5km wide) carved in the Barrow Surface on Pandora and Prince of Wales islands. These channels are drift free and are associated with Late Wisconsinan, deglacial landforms (Fig. 16).

2.1.4 MARINE AND GLACIOMARINE DEPOSITS

Most raised marine sediments were deposited when ice retreated in contact with the sea. These include fine grained glaciomarine sediments as well as nearshore and beach deposits all of which are widely distributed (Fig. 13). Nearshore deposits are stony to stone free silts, further divided into blanket and veneer. Marine silt veneers are <3m thick and do not mask relief of underlying materials. Much of this sediment represents fine particles agitated from till by wave action and re-deposited in the littoral zone.

Beaches consist of either gravel or sand and have a stepped swale and ridge topography. Throughout the western and central parts of the study area beaches consist of angular to sub-angular carbonate gravels. East coast beaches consist of material derived from Precambrian rock, Devonian sandstone and conglomerate. Beach material does not exceed 1m in thickness in most places because armouring of underlying till by gravel restricts availability of material. Beaches in the north-east part of the study area consist of sand because local till is sandy and bedrock is sandstone.

2.1.5 ALLUVIUM

Alluvium occurs throughout the map area along rivers and streams (Fig. 13). Alluvium is not extensive due to the area's aridity, short period of runoff, and the presence of permafrost under stream beds and banks. Materials are derived principally from till and are commonly rounded to subangular. Alluvium is divided into active sediments located in the present flood zone and inactive sediments forming terraces.

Alluvial fans and plains (Fig. 13) generally lie in the present flood zone. Fans form where fluvial deposits spread laterally as rivers escape steep, confining valleys. The largest fan is located north of Fisher Lake. Alluvial plains are broad deposits of fluvial sediments spread over a braidplain. The largest is located in the extreme northeast of the study area.

Alluvial terraces (Fig. 13) are perched above the present flood zone. The largest area of inactive alluvium is located at the mouth of Fisher River (Fig. 13).

2.1.6 EMERGED SHALLOW MARINE SANDS

Broad, flat areas of sand are located on the north-east coast of Prince of Wales Island and the adjacent coasts of Pandora and Prescott islands (Fig. 17). Abandoned river channels, incised no deeper than 0.5m, are located on the surface of these broad, flat areas of sand. The surface of these have pockets of Mya truncata and are littered with Precambrian clasts ranging in size from several centimetres to one metre in diameter. Precambrian outcrop does not occur locally and must have been transported by sea ice to these sites.

Unconsolidated sand was probably derived from rivers cutting through sandy surface deposits, and to a lesser extent, exposed sandstone on northeast Prince of Wales Island and Pandora and Prescott islands. Sand was transported by rivers to Browne Bay where it was then deposited on horizontal sandstone bedrock possibly by

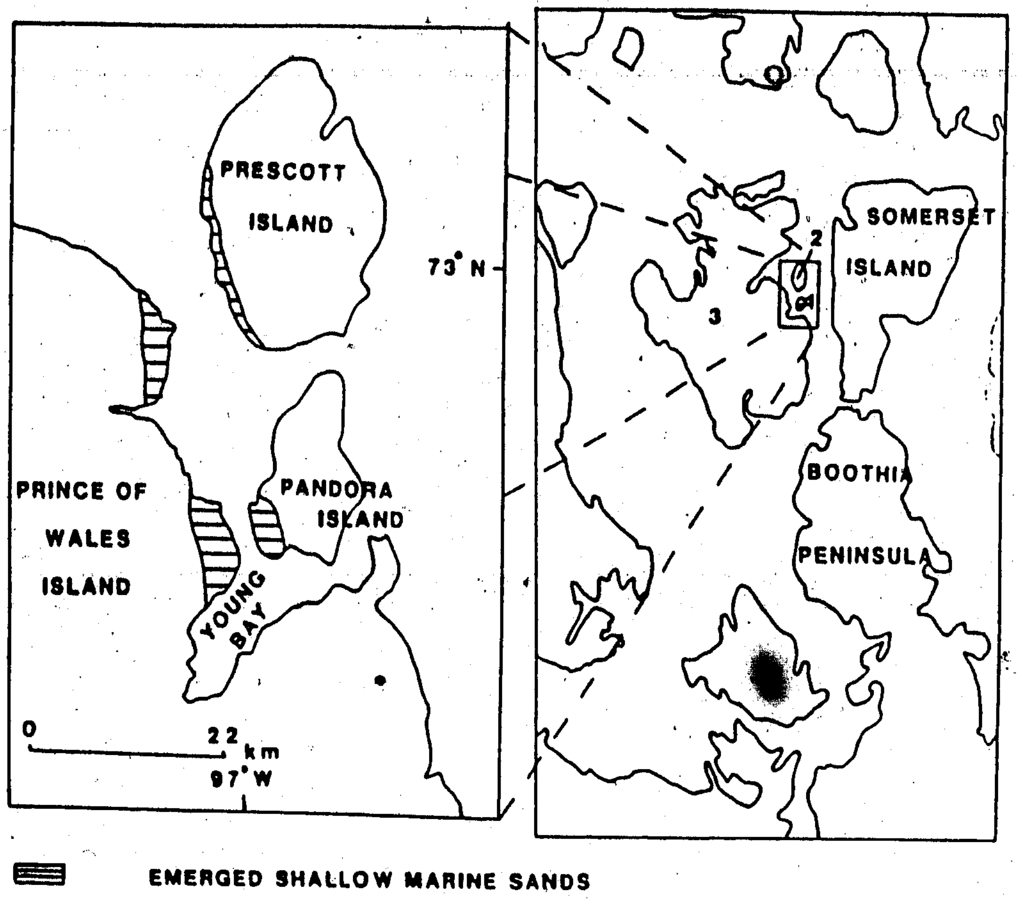


FIG. 17: Location of emerged shallow marine sands. 1) Pandora Island; 2) Prescott Island; 3) Prince of Wales Island.

littoral drift. Emergence has since exposed part of the Browne Bay floor, but, swales and ridges associated with sand beaches elsewhere are not present. The absence of swales and ridges, the sand matrix, presence of dropstones and Mya truncata all characterize these features as emerged shallow marine sands.

2.1.7 AEOLIAN

Emerged shallow marine sands have undergone erosion by strong northwest winds as indicated by sand shadows on lee sides of dropstones; surface morphology of quartz grains and lack of vegetation. Sand transport south is illustrated by streaks of sand oriented north-south on sea ice in Young Bay (Fig. 18).

Sand deposition occurred on the south shore of Young Bay. Perhaps the wind's transport capability dropped as it rose 300m from sea level to the Barrow Plateau. Whatever the cause, sand is draped over till and beach ridges indicating deposition. Airphotos illustrate an aeolian sheet with two distinct down-wind lobes (Fig. 18).

2.2 SUBTILL SEDIMENTS

Two sections along Fisher River expose sediments beneath the surface (sections 1 and 2; Fig. 19). The oldest unit is a diamicton exhibiting a northwest fabric,

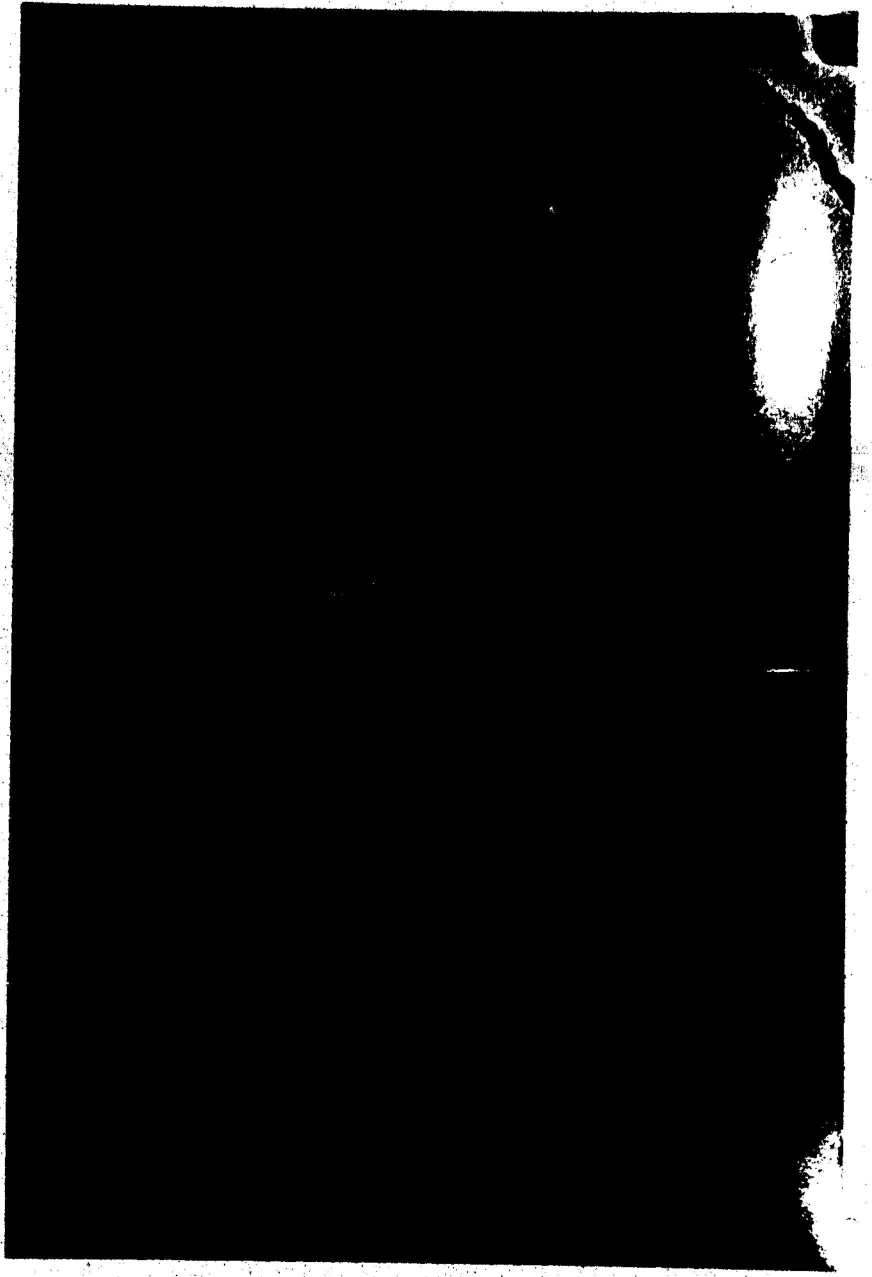


FIG. 18: Streaks of wind-transported sand aligned north-south (arrow) across sea ice in Young Bay. Sand is transported south from emerged shallow marine sand (A) and deposited on the south coast of Young Bay (B) as an aeolian sheet.

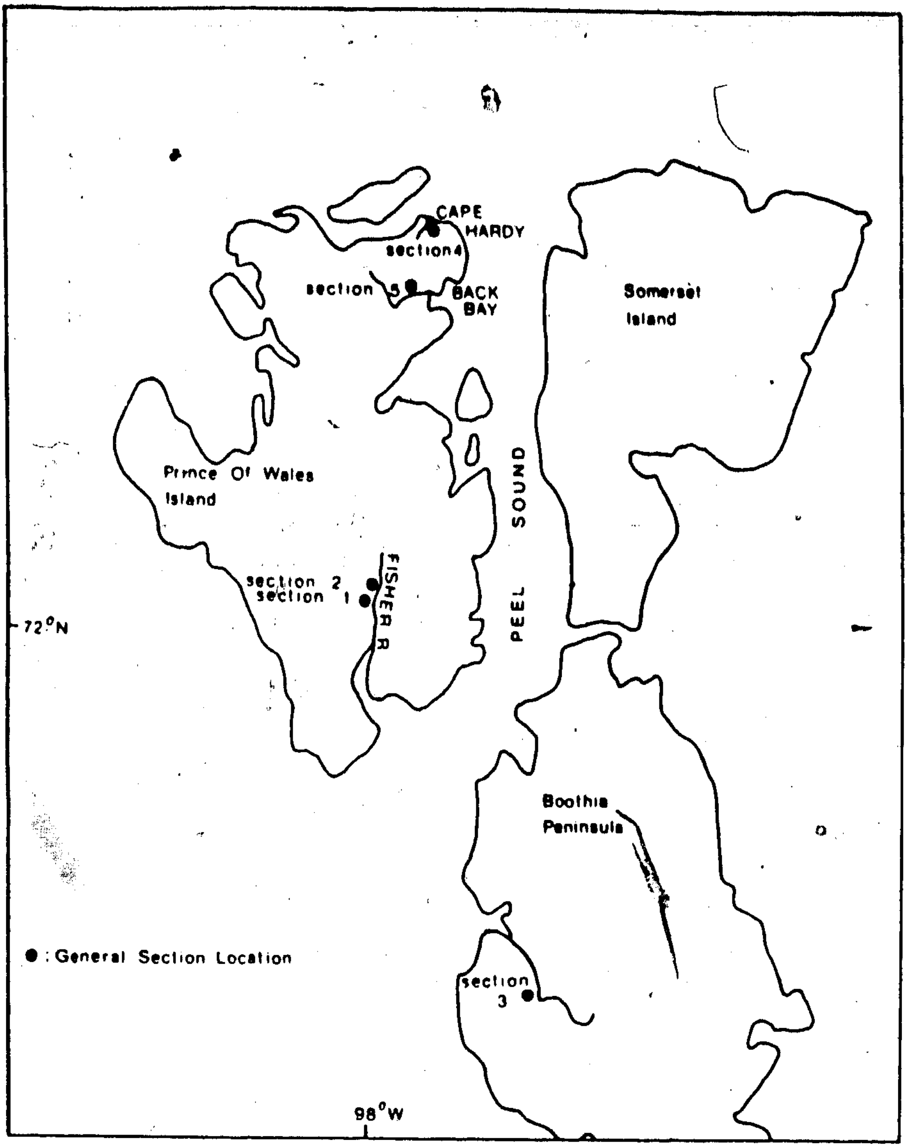


FIG. 19: Locations of important central Arctic stratigraphic sections.

an abundance of angular clasts, striated parallel to the clast's long axis and supported by a compact matrix of sand, silt and clay. This unit is interpreted as a till and differs from upper surface till both in colour and fabric (Fig. 20). Where the surface till is exposed there is a strong east fabric (Fig. 21).

The younger of the two subtill units at section 1 (Figs. 22, 23) consists of rounded to sub-rounded boulders which fine upward to sand. The boulders are bedded and dip north at an angle of ≅2 . Boulder imbrication indicates paleocurrent to the south. The planar sand beds contain fragments of marine shells. A 10cm thick lens of clay separates the boulders from the underlying till. This clay lens probably formed by translocation of clay from overlying materials. The clay may have accumulated over the lower till because of change in grain size from the coarse fluvial gravels through which clay was being transported to the finer grained lower till. The clay lens is homogeneous, lacks organic material or shell and coats all clasts.

The sand and boulder gravels are either fluvial or glaciofluvial. A glaciofluvial interpretation is suggested because the sands and gravels dip to the north whereas the present drainage is to the south. However, the imbrication of clasts suggests a paleocurrent to the south. Sand beds dipping north could represent the upstream end of a point bar (Allen, 1986; Catto, 1986).

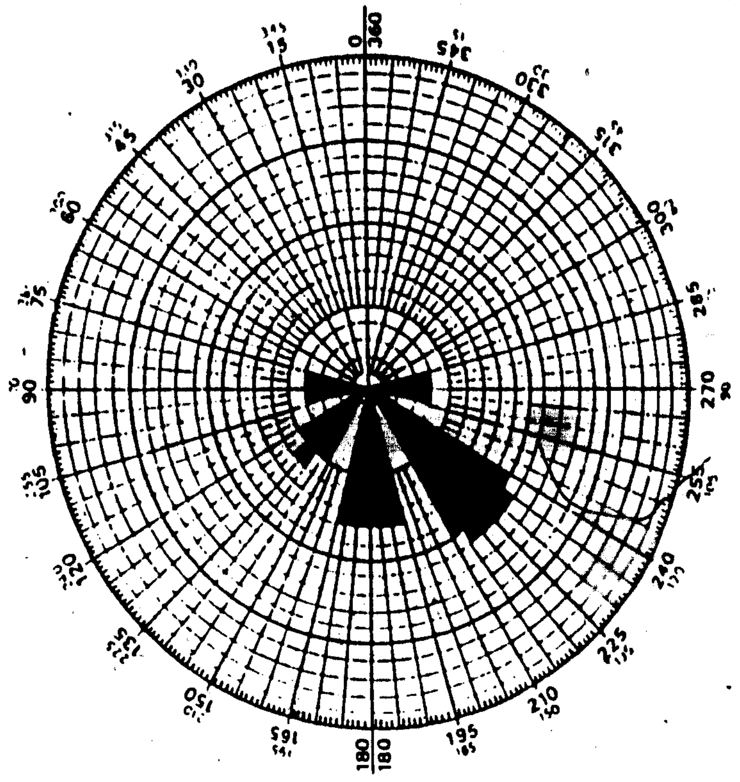
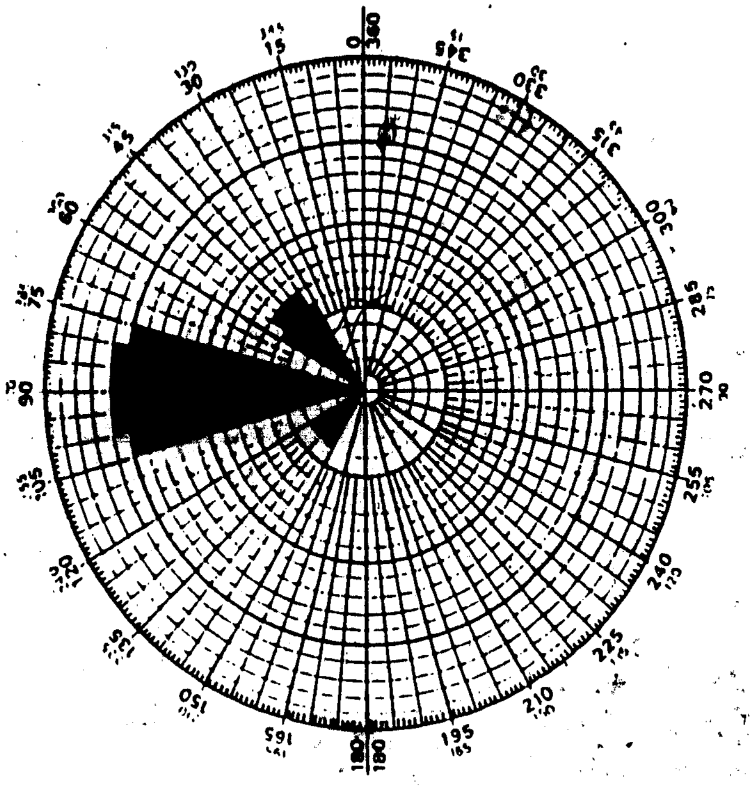


FIG. 20: Fabric of lower till from section 1 located beside the Fisher River.



n= 50

FIG. 21: Fabric of upper till from section 1 located beside the Fisher River.

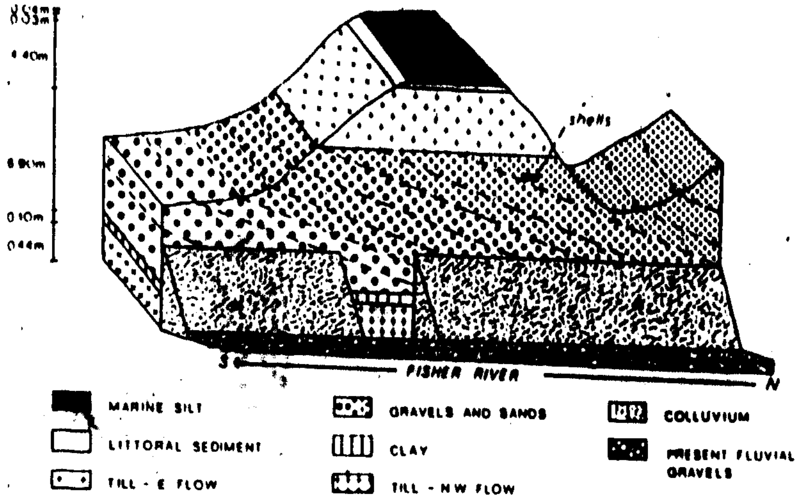


FIG. 22: Section 1, Fisher River. Fluvial gravels and sands dip ≅2° north. Imbrication, however, suggests a paleocurrent south.

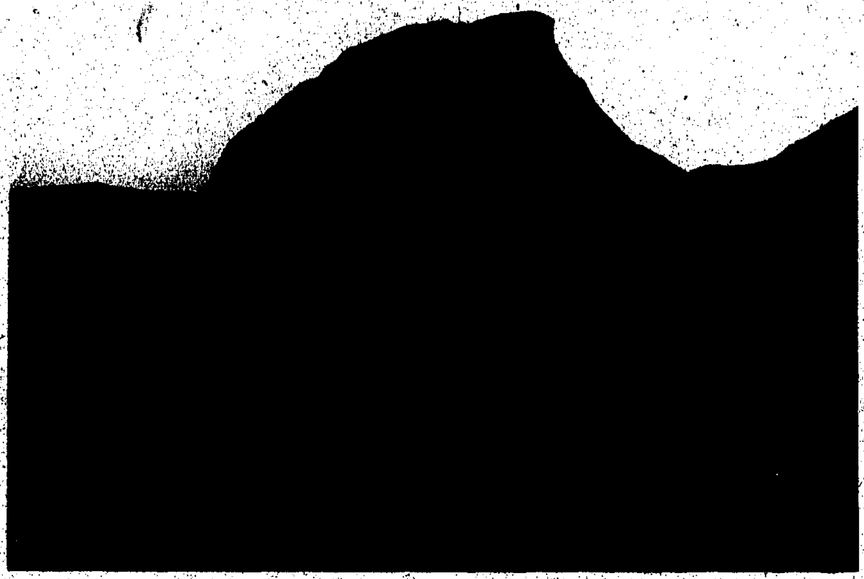


FIG. 23: Section 1, Fisher River.

A: Till related to eastward flow (Flow towards reader).

B: Fluvial gravels and sands (arrow indicates possible direction of flow).

C: Till related to northwest flow (arrow indicates direction of flow).

Therefore these sands and gravels are interpreted as fluvial.

The upper half of section 1 appears to correlate with section 2 (Figs. 24, 25). Sands in section 2 are planar bedded and underlie till with an eastward fabric. Section 2 also has a sharp erosional contact between the upper till and sands. Abundant erratic marine shells occur in the sand which may correspond to the sands and gravels of section 1. A (basal) till was not observed at section 2.

2.3 PATTERNS OF ICE FLOW

Morphological subdivision of till reveals a clear relative chronology of glacial events. This chronology is evident from the positions of end moraines and the cross-cutting relationships of ice moulded and inscribed features. The oldest surficial glacial deposit is megafluted till on the west coast. Megafluted till probably represents advance of ice from the south, possibly Keewatin. Northward advance is inferred from the shape of streamlined forms. Furthermore, ice apparently never crossed the island or adjacent islands from the north.

Formation of the high relief streamlined till and lateral shear moraine followed initial advance of ice. Ribbed moraine located in the northwest of the study area probably developed simultaneously with the high relief

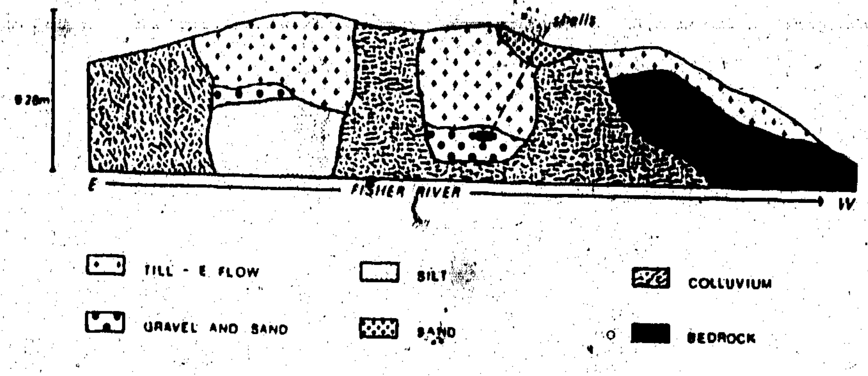


FIG. 24: Section 2, Fisher River.

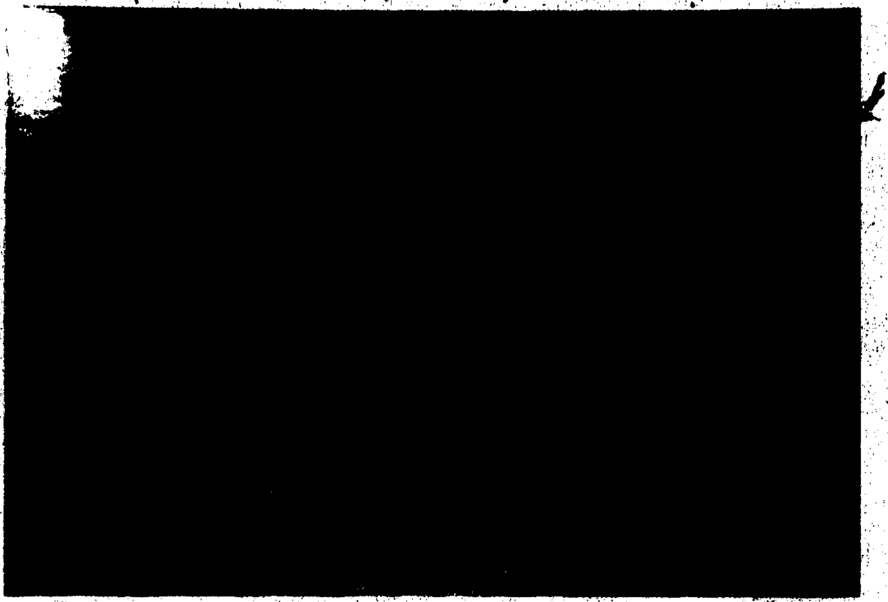


FIG. 25: Section 2, Fisher River.

A: Till related to eastward flow (arrow indicates direction of flow).

B: Fluvial sands (arrow indicates possible direction of flow).

streamlined till

The low relief streamlined till, which contains the seven west-east oriented drumlin fields, developed when an ice divide formed west of Prince of Wales Island. The ice divide may have formed by: 1) ice flow to the area from elsewhere; 2) development in M'Clintock Channel or 3) from a pre-existing ice mass whose configuration and flow subsequently changed. Ice flow from elsewhere is unlikely because the megaflutes, high relief streamlined till, lateral shear moraine and ribbed moraine were left unaltered which would not be expected from actively advancing ice. Development of an ice divide in M'Clintock Channel by instantaneous glacierization (Ives, 1978) is unlikely as the M'Clintock Channel is occupied by the sea. The most likely explanation for development of low relief streamlined till is through formation of a new ice divide from a pre-existing one whose flow originally formed the high relief streamlined till and associated ribbed moraine. This hypothesis does not require removal and re-establishment of ice.

Shift in ice flow does not explain lower till and fluvial gravels in section 1 if lower till is associated with the high relief streamlined till. Fluvial gravels suggest that ice, which deposited the high relief streamlined till, left the area for deposition of these fluvial gravels to occur. However, lower till in section 1 may not have been deposited simultaneously with the high relief streamlined till, but by an earlier flow. Landforms associated with the lower till may have been destroyed by a later event. Fluvial gravels overlying till at section 1 may have been deposited prior to a later flow. Till associated to the high relief streamlined till may have been removed from section 1 by eastward flow.

Ice flow forming the low relief streamlined till was less erosive up ice toward the divide. Distinct tails of till on the eastern sides of the high relief streamlined till were deposited when general eastward flow was superimposed on the northward oriented landforms. However, the low relief streamlined till completely disappears still farther up ice, where the older bedforms are left entirely unmodified by the younger flow. This implies that the older bedforms were under a protective covering of cold-based ice whereas warm-based ice occurred farther from the divide eroding the older bedforms while forming the low relief streamlined till.

Change in temperature regime from cold-based (up-ice) to warm-based (down-ice) ice is indicated in two ways. First, in three low relief drumlin fields (Young Bay, Le Feuvre Inlet and Transition Bay) length to width ratios were determined on drumlin forms both at the down-ice and up-ice locations of low relief streamlined tills (Transition Bay, Le Feuvre Inlet, Young Bay).

Ratios (Table 2) show an increase in size of

TABLE 2: Drumlin Measurements

Location	Up-Ice Stream	Down-Ice Stream
Transition Bay		
Drumlins Counted;	209	112
Width (m);	160	210
Length (m);	560	930
Ratio;	3.5	4.3
Le Feuvre Inlet		
Drumlins Counted;	110	64
Width (m);	232	230
Length (m);	689	930
Ratio;	3.0	4.0
Young Bay		
Drumlins Counted;	55	18
Width (m);	220	242
Length (m);	620	1000
Ratio;	2.8	4.2

drumlinoid forms from west (up-ice) to east (down-ice). Larger drumlinoid forms down-ice show that erosiveness increased away from the cold-based ice. Second, ribbed moraine located at the head of low relief drumlin fields at Transition and Young bays may have formed in an area of stick and slip between cold and warm-based ice. Formation of ribbed moraine occurs when ice flows into a depression which results in compressive flow (Shaw, 1979). Cross-sections through these ribbed moraine fields (Fig. 26) indicate that ribbed moraine formed on both ascending and declining slopes and topographically high areas (Figs. 27, 28, 29, 30). Therefore, formation of ribbed moraine as described by Shaw (1979) or Lundqvist (1969b) does not apply for these two ribbed moraine fields. Sticking and slipping of ice in a zone between cold and warmed-based ice may have wrinkled or deformed debris rich basal ice into ribbed moraine features.

In the Antarctic and Greenland, flow lines converge at the up-ice end of ice streams (Hughes et al., 1985). A clearly defined boundary exists between the ice sheet and ice stream. Streamlined forms converge at the up-ice position of the low relief streamlined tills at Young Bay, Le Feuvre Inlet and Transition Bay and are concentrated in well defined bands. Such drumlin concentrations have been interpreted as evidence of former ice streams (Sugden, 1977; Shilts, 1980).

Drumlins in low relief drumlin fields at Inner

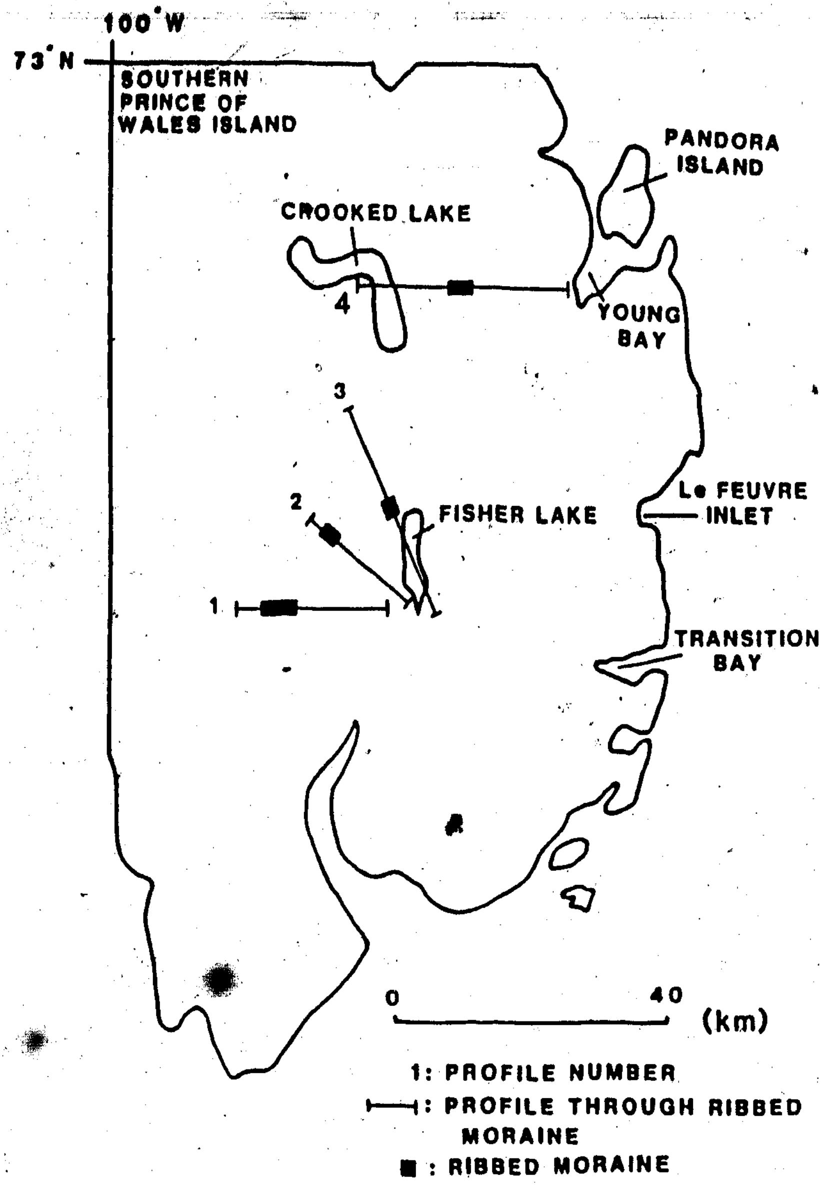


FIG. 26: Locations of transects through ribbed moraine west of Transition and Young bays.

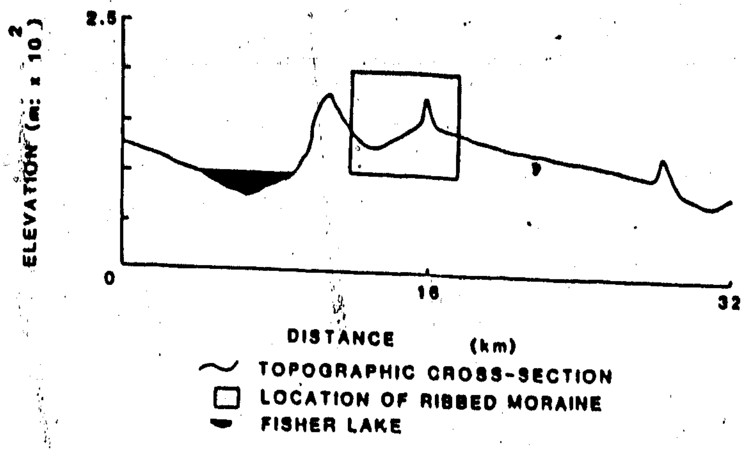


FIG. 27: Transect 1, through ribbed moraine west of Transition Bay. Ribbed moraine is located on ascending and declining slopes (see text for detail).

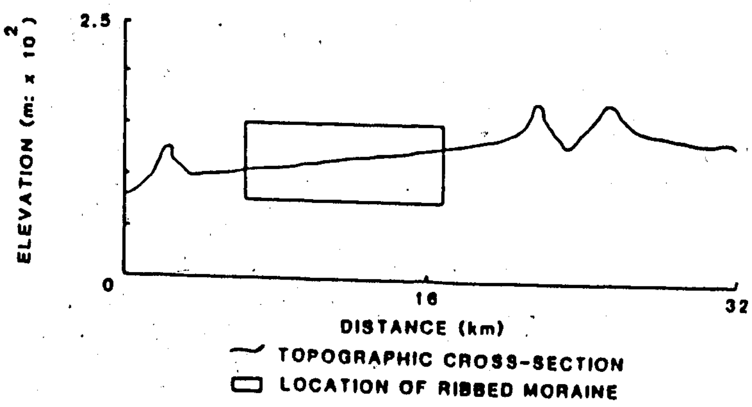


FIG. 28: Transect 2, through ribbed moraine west of Transition Bay. Ribbed moraine is located on inclining slope (see text for detail).

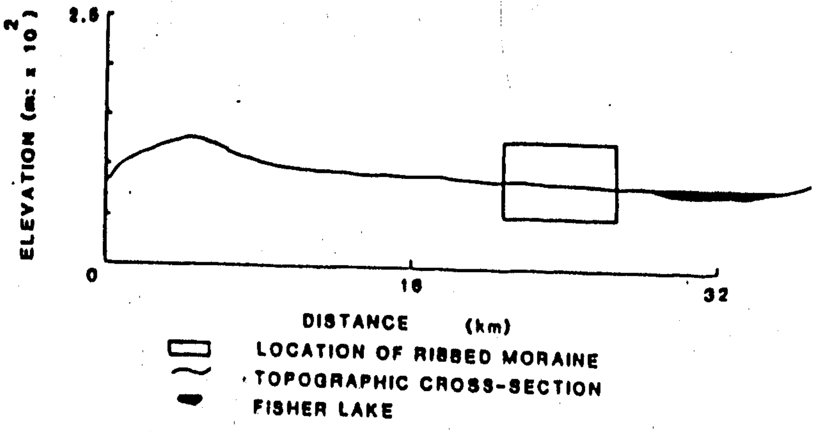


FIG. 29: Transect 3, through ribbed moraine west of Transition Bay. Ribbed moraine is located on a generally flat surface (see text for detail).

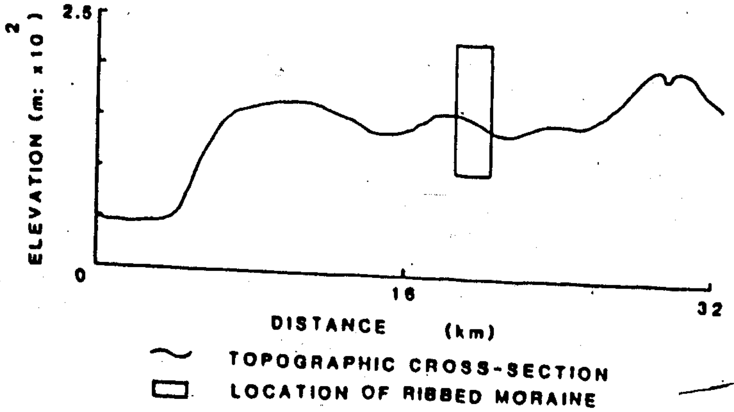


FIG. 30: Transect 4, through ribbed moraine west of Young Bay. Ribbed moraine is located on a declining slope (see text for detail).

Browne, Coningham and Guillemard bays, and one north of the megafluted till, do not show convergence or concentration in well defined bands. Similar ice moulded features described elsewhere have benn interpreted to indicate regional flow lines within an ice sheet (Shilts, 1980, p. 216).

Ice retreat is recorded on southern Prince of Wales Island through the presence and distribution of striae, subglacial and ice marginal meltwater channels, low relief streamlined till, end and lateral moraines, eskers and kames. These features indicate that direction of ice retreat was toward an ice centre located over south-western Prince of Wales Island.

This chapter has introduced seven genetic categories for surface materials. Subsurface stratigraphy was described for two sections located beside the Fisher River. Former pattern of ice dispersal and relative chronology were described from the distribution of surficial till and stratigraphy of sediments found in two sections beside the Fisher River. The next chapter proposes an absolute chronology for pattern of ice dispersal and describes characteristics of material distribution and ice flow patterns.

CHAPTER 3

CHRONOLOGY AND PATTERN OF GLACIATION

The interpreted absolute chronology of ice advance and retreat is outlined in this chapter. Ice flow patterns from the last glaciation are defined from material distribution maps which indicate the location of former ice divides.

3.1 DETERMINING CHRONOLOGY OF GLACIATION

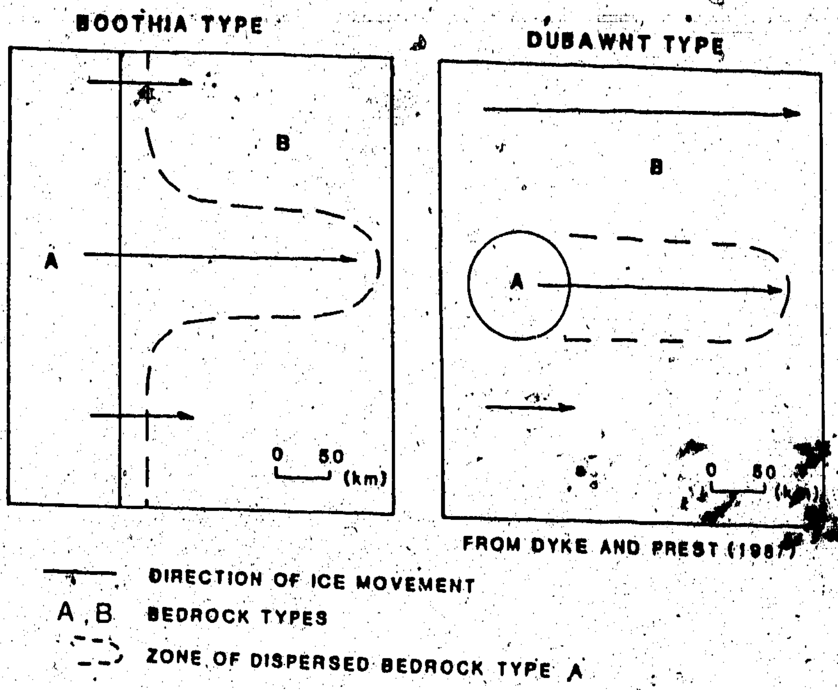
Absolute age determination of the glacial event which formed megafluted till is presently impossible because datable material which would have provided such a determination was not found. However, a maximum age of the lower till and a minimum age of the upper till are provided by a variety of dates on marine shells collected from inter-till sands and gravels at section 1 and from subtill fluvial sands at section 2. Amino acid determinations were made on both shell samples (AAGL) whereas uranium series (UQAM) and radiocarbon dating (GSC) were done on shell fragments collected from section 1 (Table 3).

TABLE 3: Amino Acid Ratios, Uranium Series Date And Radiocarbon Date For Southern Prince of Wales Island.

Dating Technique	Fisher River (section 1)	Fisher River (section 2)
	84-DCA-26 S	84-DCA-8 S
Amino Acid Racimization		
- Free	0.160 0.200 0.200	0.400 0.390 0.410
- Total	0.044 0.048 0.042 (AAL- 4306)	0.106 0.126 0.117 (AAL- 4305)
Uranium Series Date	34000 BP (Dyke, pers. comm., 1988)	-
Radiocarbon Date	>49000 BP (GSC- 4470HP)	-

3.2 MATERIALS DISTRIBUTION

Surficial material on Prince of Wales Island is characterized by either Dubawnt or Boothia dispersal patterns (Fig. 31). The Dubawnt dispersal train of Keewatin (Shilts et al., 1979), records the distribution of debris down-ice from a discrete source area. Material dispersed from such small areas provides information on flow direction, transport distance and rate of mixing of source area material with local debris. On the other hand, the Boothia dispersal trains (Fig. 31) have an extensive source area. Ice flow in the same direction and duration over a distinct bedrock type provides the same information as the Dubawnt dispersal train but also provides differential rates of ice movement because faster moving ice transports far more material than the slower ice on either side. Such rapid flow transports well defined plumes of debris which mark the location of former ice streams (Dyke and Prest, 1987, p. 244). For example, Dyke's (1984) work on Somerset Island and Boothia Peninsula illustrates the purpose of analyzing till samples for such properties. Ice flowed east over Somerset Island and Boothia Peninsula as ice streams depositing calcareous material over gneiss. This resulted in abundant carbonate clasts, low percentage of sand, high carbonate content and relatively low amounts of trace elements.



FROM DYKE AND PREST (1987)

FIG. 31: Boothia and Dubawnt dispersal trains formed by Wisconsinan Laurentide Ice Sheet.

Ice flowing west-east across southern Prince of Wales Island incorporated and deposited carbonate over east coast clastic rock and gneiss. A Boothia Type dispersal of carbonate east across southern Prince of Wales Island occurred because of the large area of carbonate rock. Therefore, till samples collected from throughout the study area should define carbonate dispersal patterns portraying direction of ice flow. The thin band of Late Silurian carbonate bedrock would not affect dispersal as it is down-ice from the initial point of dispersal.

Till samples (380) were collected from about 75% of the study area (Fig. 32). These samples are from well drained sites, 5- 10cm above frost table, and each sample was analyzed for lithology, grain size, carbonate content, geochemistry and colour (dry). Lithology is determined by identifying clasts >2mm from a random selection of 100. This method differs from the percentage by weight method used by the Geological Survey of Canada. Three lithological types are mapped, carbonate rock (Fig. 33), sandstone and gneiss (Fig. 34).

Percentages of sand, silt and clay are determined through particle size analysis as developed by Bouyoucos (1962) and outlined in the Canadian Soil Science Manual (McKeague, 1978). A standard 50g of the <2mm fraction of each sample is soaked for 16 hours in a 6N solution of sodium hexametaphosphate to ensure deflocculation of clay

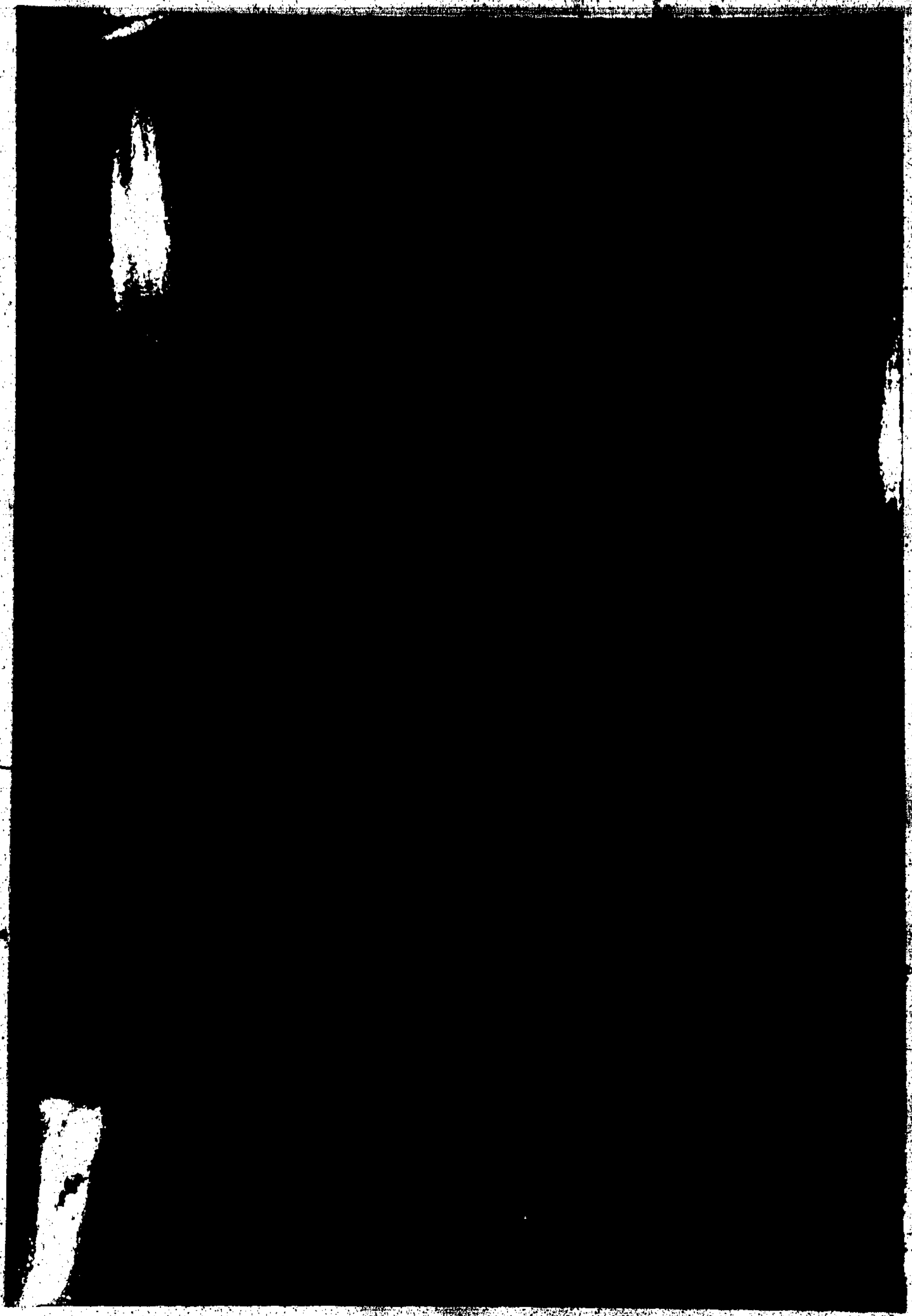


FIG. 32: Distribution of transects on southern Prince of Wales Island.

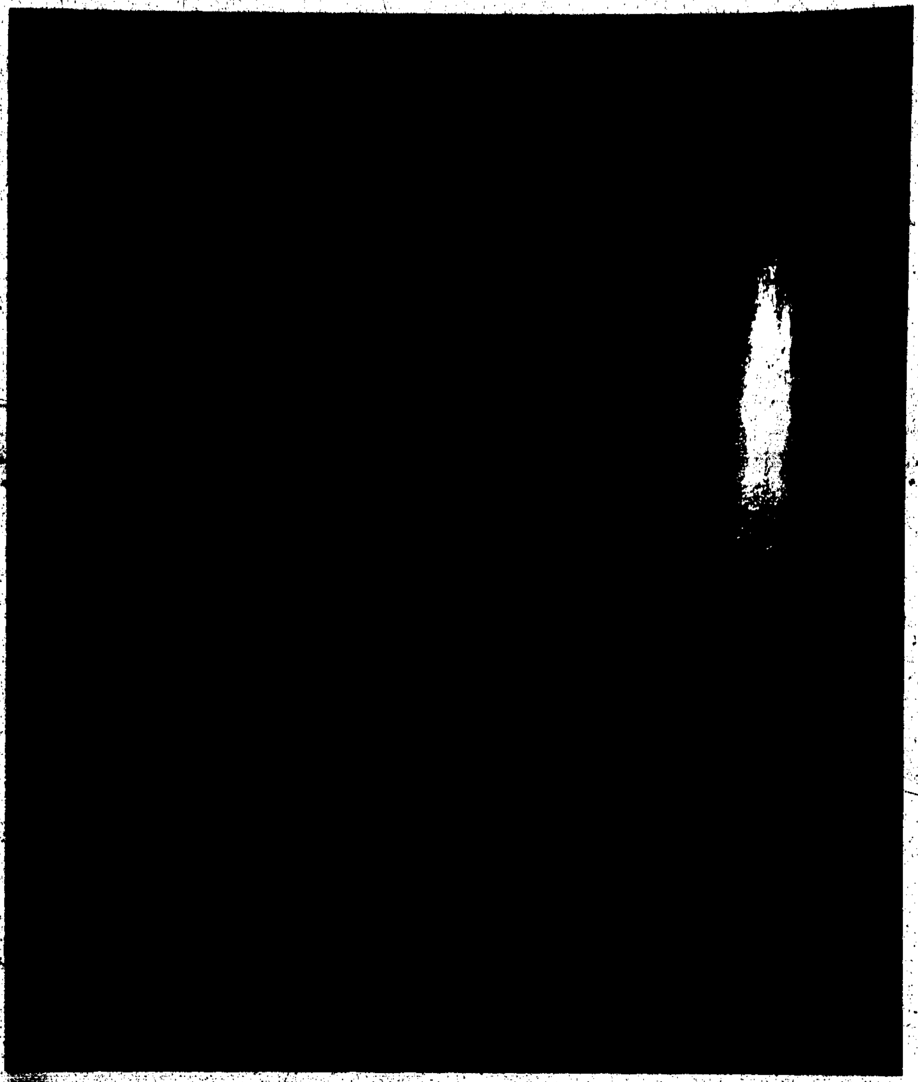


FIG. 33: Carbonate clast content (%) of the granule fraction of till on southern Prince of Wales Island. Carbonate granules are distributed from their source (1) east onto clastic and metamorphic rock (2). Four granule dispersal trains are illustrated at Transition Bay (A), Le Feuvre Inlet (B), Young Bay (C) and Muskox Valley (D).

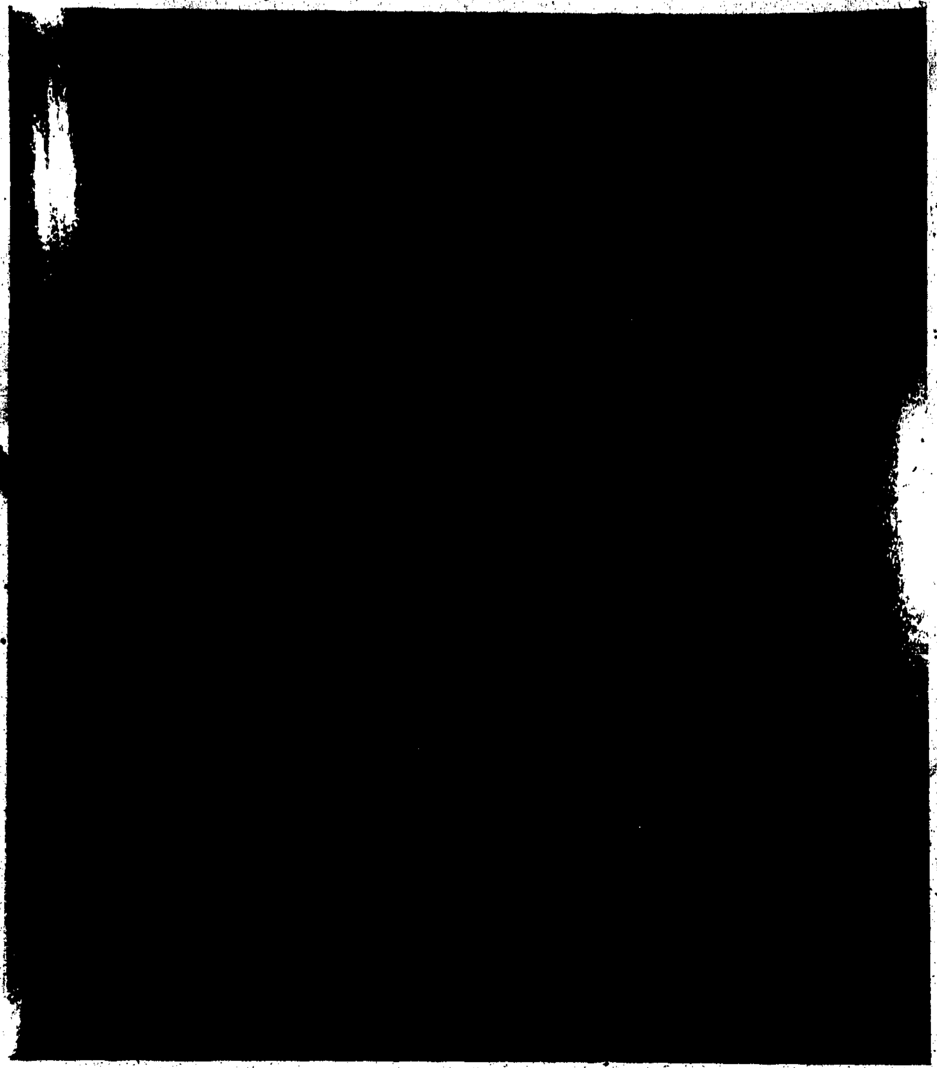


FIG. 34: Sandstone and gneiss clast (%) of the granule fraction of till on southern Prince of Wales Island. Deposition of carbonate granules (1) onto clastic granules (2). Four carbonate dispersal trains and illustrated at Transition Bay (A), Le Feuvre Inlet (B), Young Bay (C) and Muskox Valley (D).

minerals and material dispersion. This slurry undergoes a one-minute mechanical stirring and then is suspended in a sedimentation column. Eleven hydrometer readings are taken over 18 hours for the construction of grain size curves from which percentages of sand, silt and clay are determined. Distribution of % sand (Fig. 35) is determined by plotting derived values. Silt and clay percentages are combined (Fig. 36) to enhance their distribution patterns.

Carbonate content is determined from the method developed by Dreimanis (1962). A dried sample (1. 7 g; <64um) is placed in a flask with a 20% solution of hydrochloric acid. The CO_2 produced displaces a solution in a sealed Chittick apparatus. Displacement of solution is measured once all carbonates react with the acid (up to 1 hour). Carbonate distribution is determined by plotting the total carbonate content of each sample (Fig. 37).

Base metal concentration (cobalt, copper, nickle, zinc) are determined by atomic absorption spectrometry on the clay fraction of a random 200g sub-sample split from the original. Because the distribution of zinc is similar to the distribution of cobalt, copper and nickle only it is presented (Fig. 3.8). Colour (dry) is determined by a Munsell colour chart after a sub-sample is oven-dried at 110 C for 24 hours. Colour distribution is determined simply by plotting each sample colour (Fig. 39). Gneiss of the east coast of Prince of Wales Island contains dark

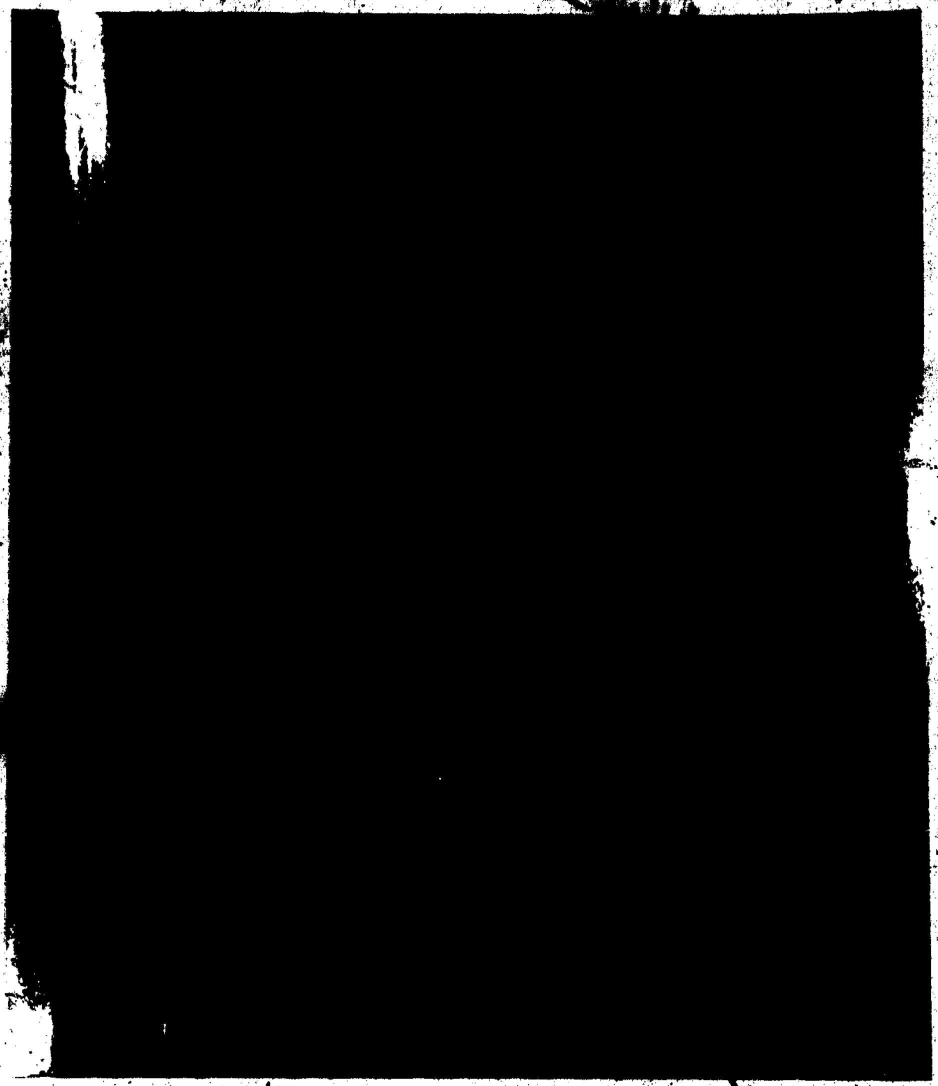


FIG. 35: Sand content of the till matrix (>2mm fraction). Dispersal of finer material from carbonate bedrock (1) east over coarser clastic bedrock (2) through Transition Bay (A), Le Feuvre Inlet (B), and Muskox Valley (C). Regional dispersal of fine grained material is illustrated by the lower values of sand on Somerset Island and Boothia Peninsula.

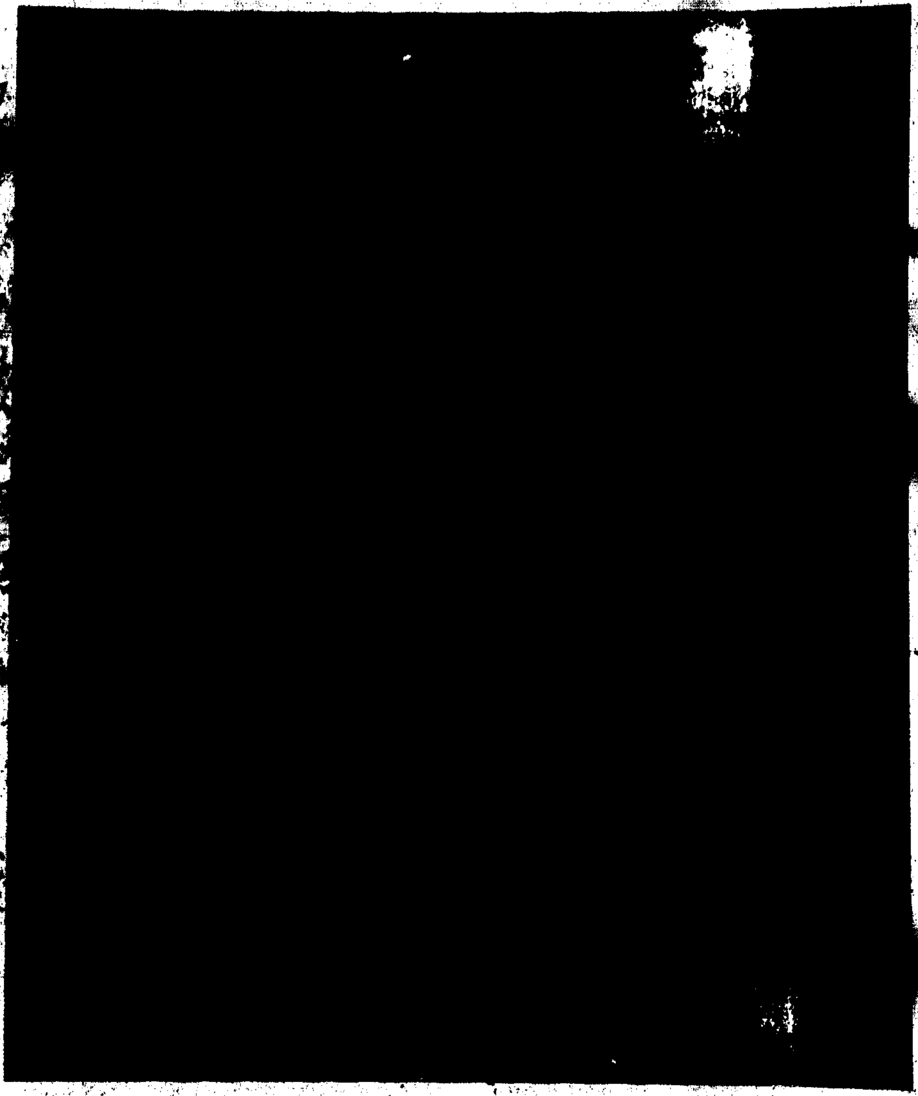


FIG. 36: Silt and clay content of the till matrix (<2mm fraction). Dispersal of finer material from carbonate bedrock (1) east over coarser clastic bedrock (2) through Transition Bay (A), Le Feuvre Inlet (B) and Young Bay (C).

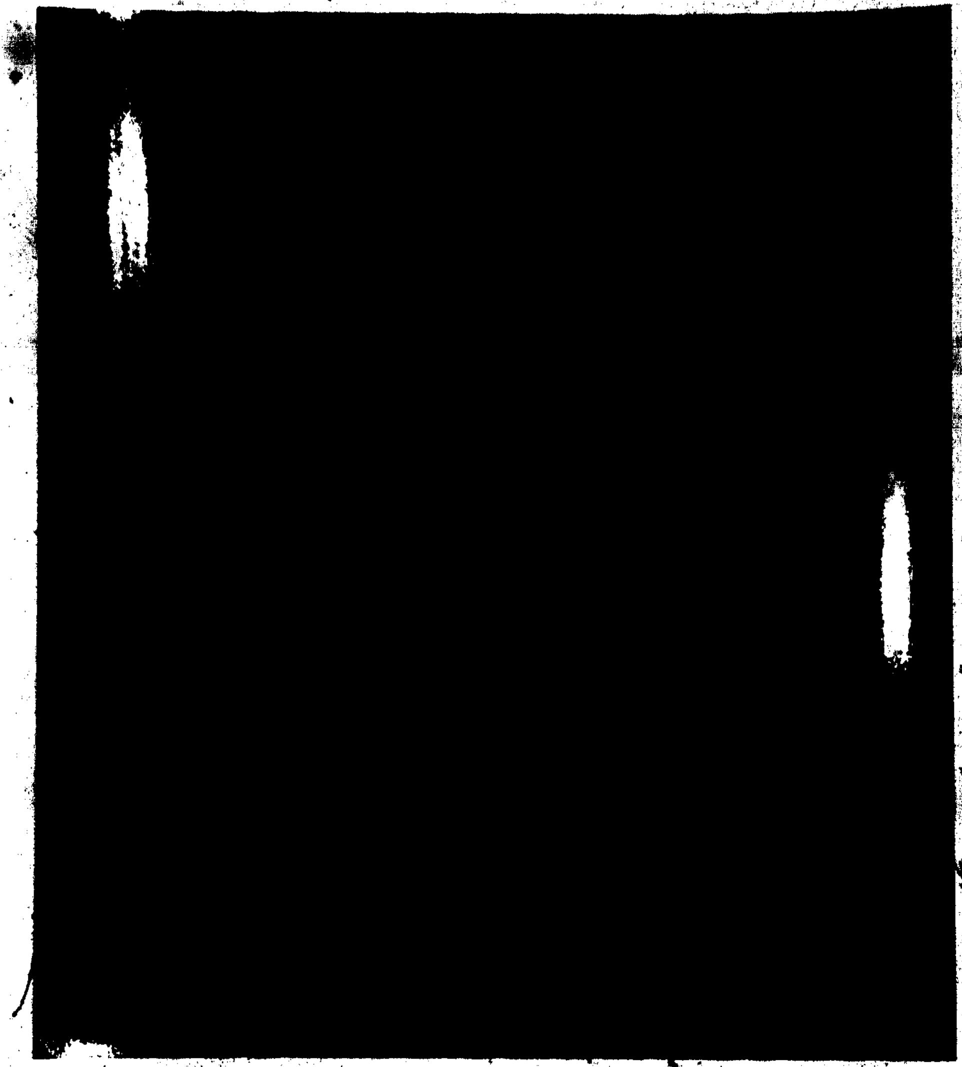


FIG. 37: Carbonate content of the <63um fraction of the till matrix. Distribution of carbonate from carbonate bedrock (1) east over clastic bedrock (2) illustrates four carbonate dispersal trains at Transition Bay (A), Le Feuvre Inlet (B), Young Bay (C) and Muskox Valley (D). The Transition Bay carbonate dispersal train extends across Peel Sound onto Somerset Island and Boothia Peninsula (E).

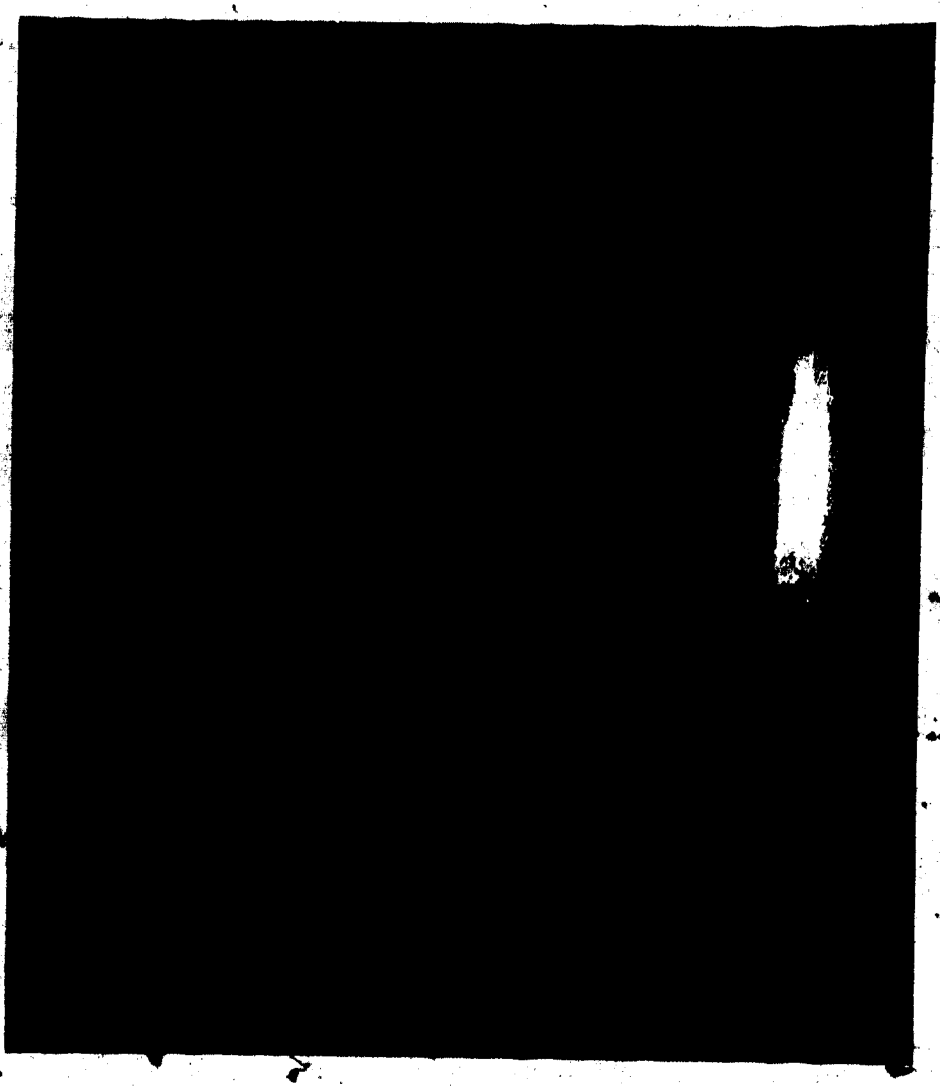


FIG. 38: Zinc content of the clay (<2um) fraction of till, southern Prince of Wales Island. Dispersal of carbonate is not reflected by the zinc distribution on southern Prince of Wales Island but is on Somerset Island and Boothia Peninsula (A).

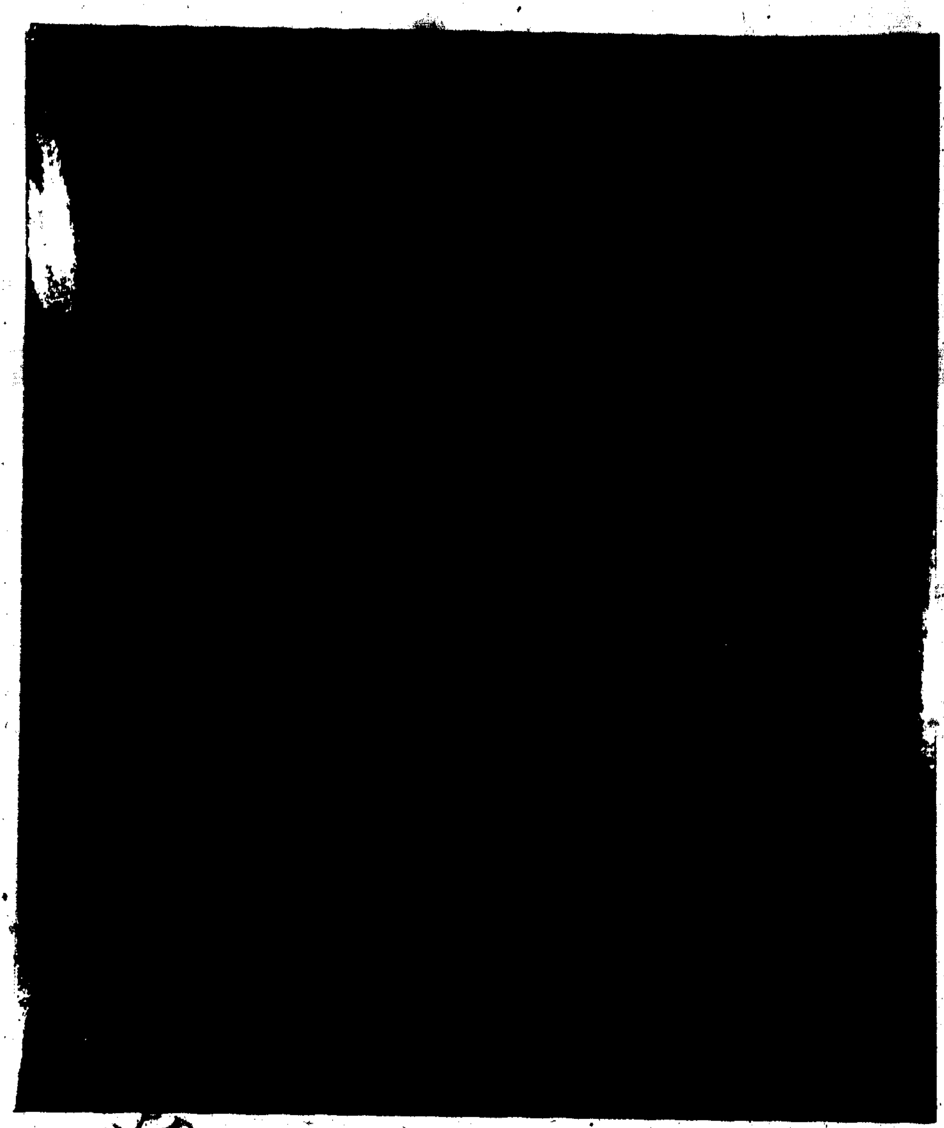


FIG. 39: Till matrix colour (d) of southern Prince of Wales Island illustrates dispersal of light coloured carbonate from carbonate bedrock (1) east over dark coloured clastic bedrock (2) at Transition Bay (A), Le Feuvre Inlet (B), Young Bay (C) and Muskox Valley ([illegible]). This is also well portrayed on Landsat imagery for the same area.

minerals (biotite, olivine, pyroxene, amphiboles and/ or tourmaline; Blackadar, 1967). Carbonate rock consists primarily of calcite and dolomite. Where carbonate-rich materials dominate light hues and chromas are expected (Fig. 40).

Percent vegetation cover, depth to frost table (cm) and colour (moist) were determined at each sample site. Vegetation cover is restricted on materials rich in carbonate because carbonate is nutrient-poor (Dixon and Weed, 1982). Therefore, vegetation cover should define the extent and distribution of eastward carbonate dispersal (Fig. 41).

Depth to frost table is controlled partially by grain size. Material rich in carbonate generally has a small grain size whereas till rich in gneiss generally has a larger grain size. Permeability is potentially higher in coarser grained material due to the packing arrangement of coarser particles. If permeability is higher in coarser grained material, transfer of heat through the soil (by air and moisture during the summer) should lower the depth to frost table. Depth to frost table, therefore, may reflect the distribution of carbonate (Fig. 42).

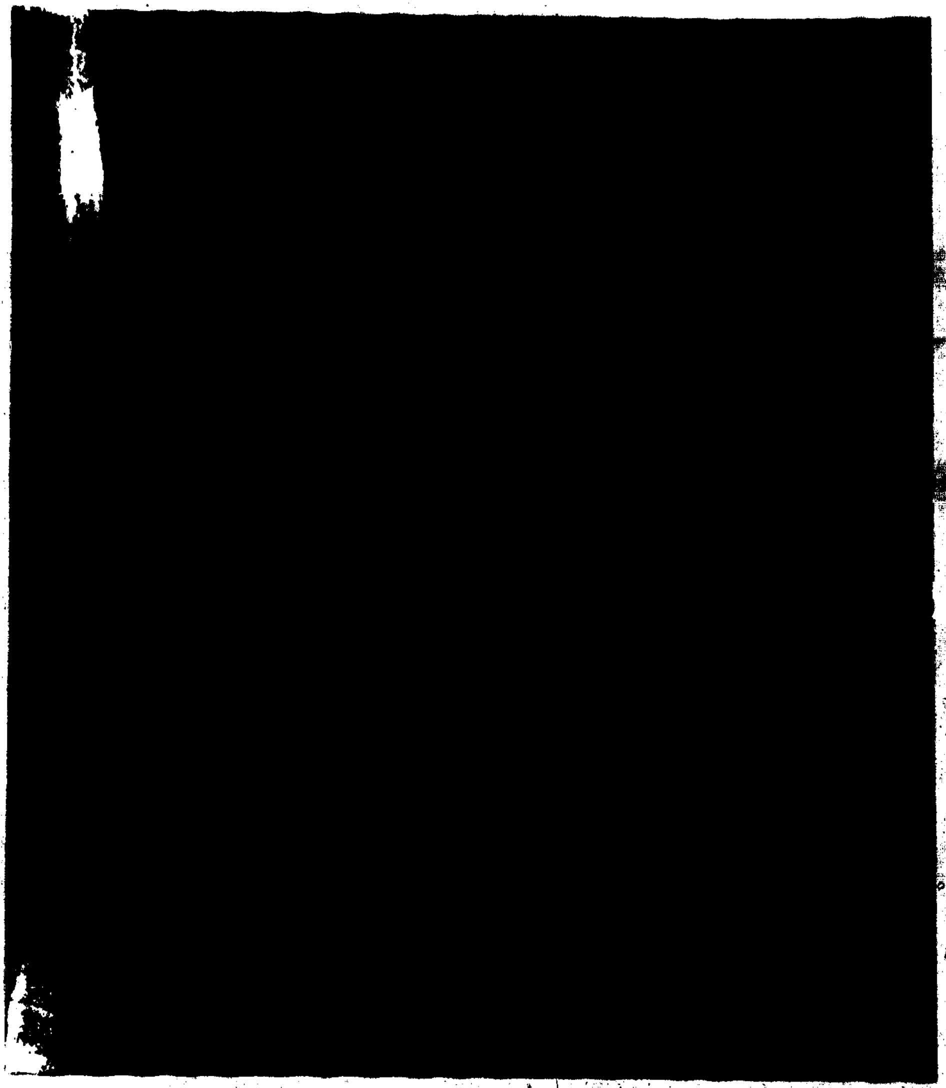


FIG. 40: Till matrix colour (m) of southern Prince of Wales Island illustrates dispersal of light coloured carbonate from carbonate bedrock (1) east over dark coloured clastic bedrock (2) at Transition Bay (A), Le Feuvre Inlet (B) Young Bay (C) and Muskox Valley (D).

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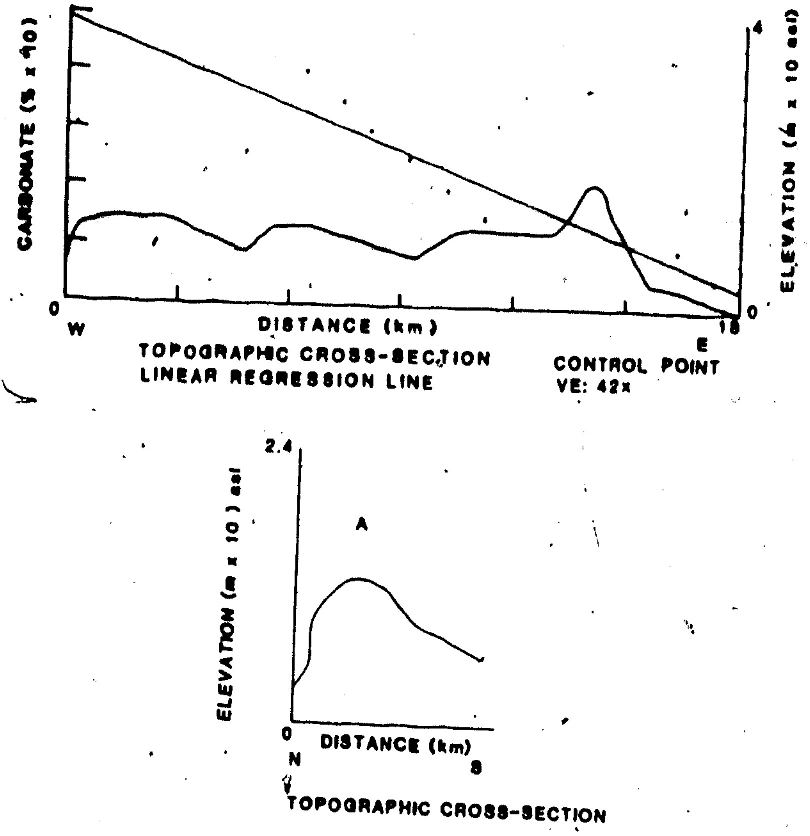
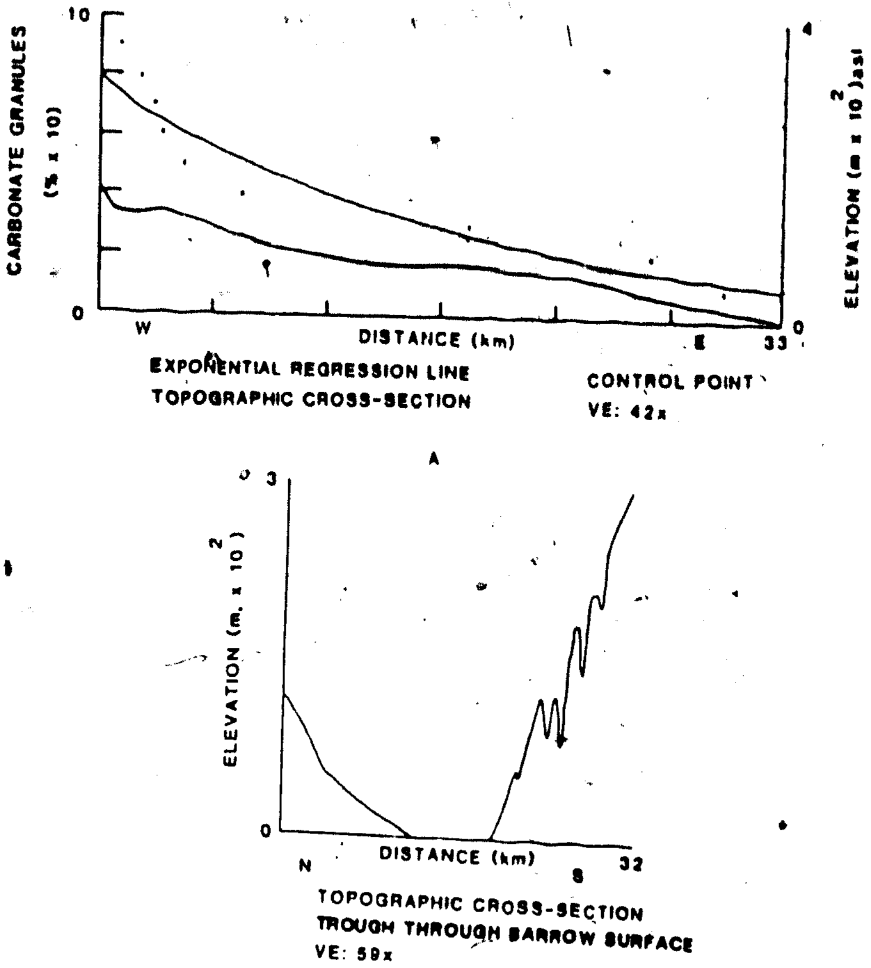
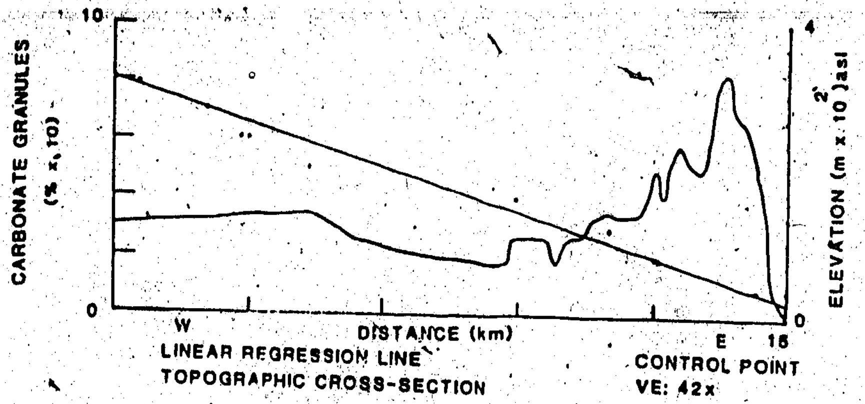
APPENDIX

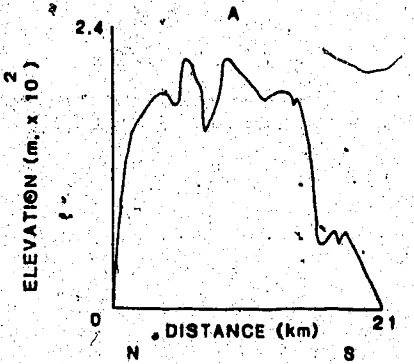


Simple regression analysis from the carbonate granule distribution map, south of Cape Henry Kellett line. Carbonate granules are dispersed over the Barrow Surface (A). N= north, S= south, W= west, E= east and VE= vertical exaggeration.



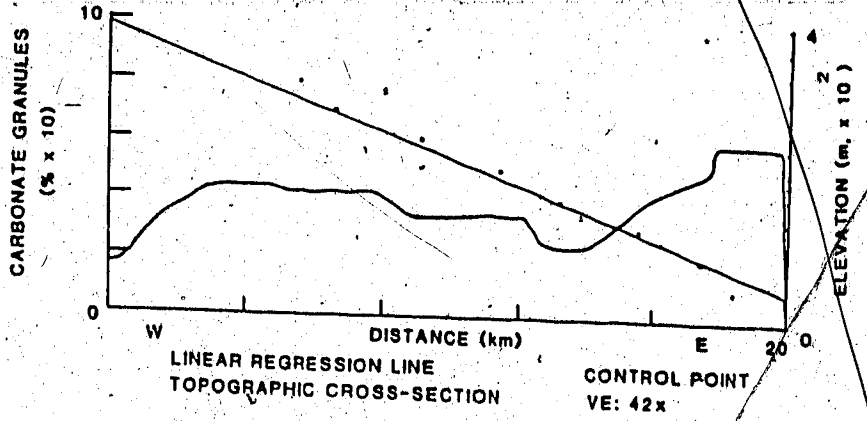
Simple regression analysis from the carbonate granule distribution map, Young Bay line. Carbonate granules are dispersed through a trough in the Barrow Surface (cross-section across the axis of the trough north-south; A). N= north, S= south, W= west, E= east and VE= vertical exaggeration.

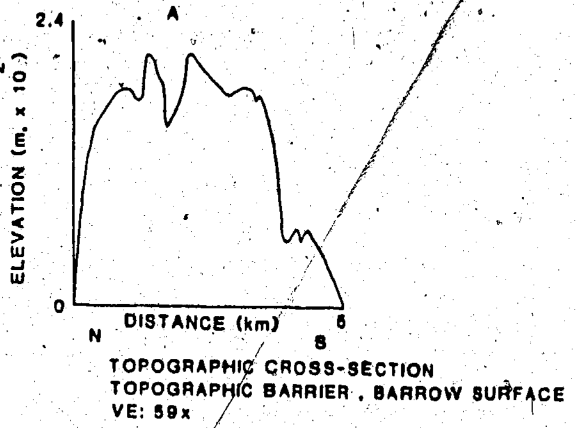




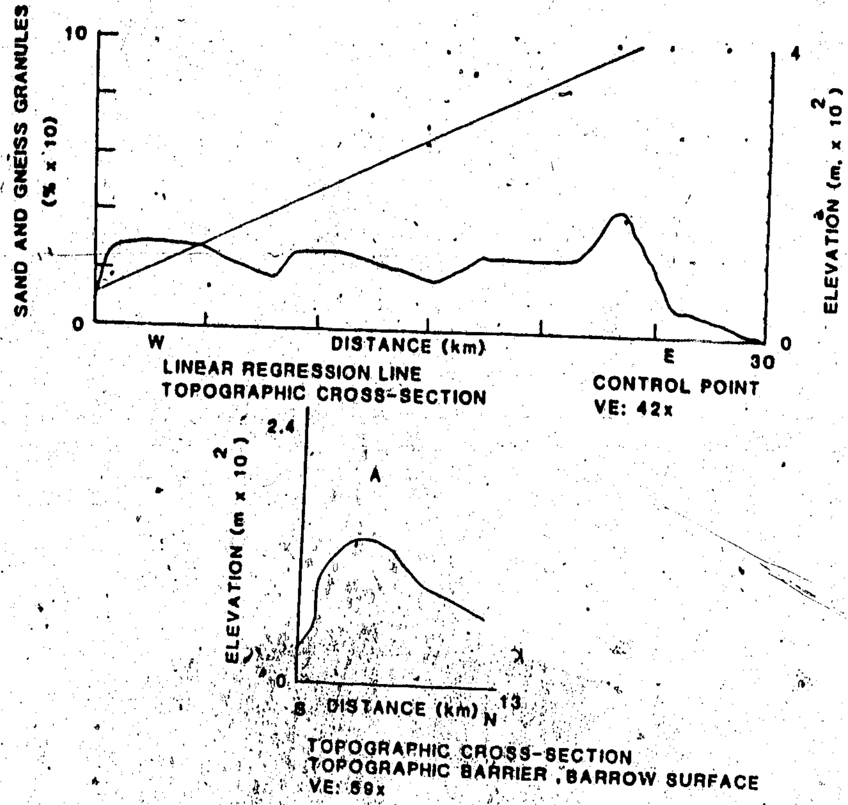
TOPOGRAPHIC CROSS-SECTION
TOPOGRAPHIC BARRIER, BARROW SURFACE
VE: 59x

Simple regression analysis from the carbonate granule distribution map, Flexure Bay line. Carbonate granules are dispersed over the Barrow Surface (A). N= north, S= south, W= west, E=east and VE= vertical exaggeration.

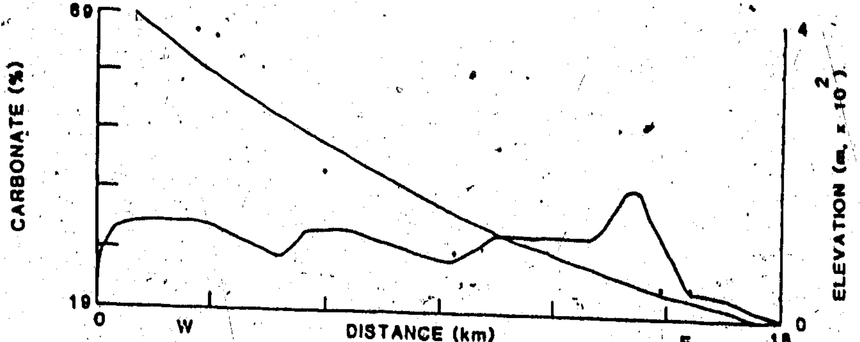




Simple regression analysis from the carbonate granule distribution map, Strzelecki Harbour line. Carbonate granules are dispersed over the Barrow Surface (B). N= north, S= south, W= west, E= east and VE= vertical exaggeration.

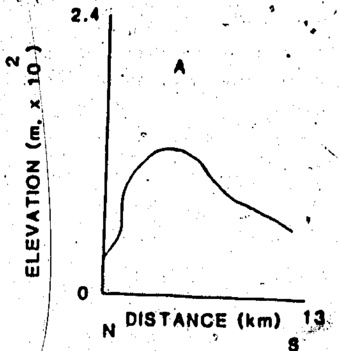


Simple regression analysis from the clastic granules map, south of Cape Henry Kellett line. Clastic granules are being incorporated over the Barrow Surface (A). N= north, S= south, W= west, E=east and VE= vertical exaggeration.



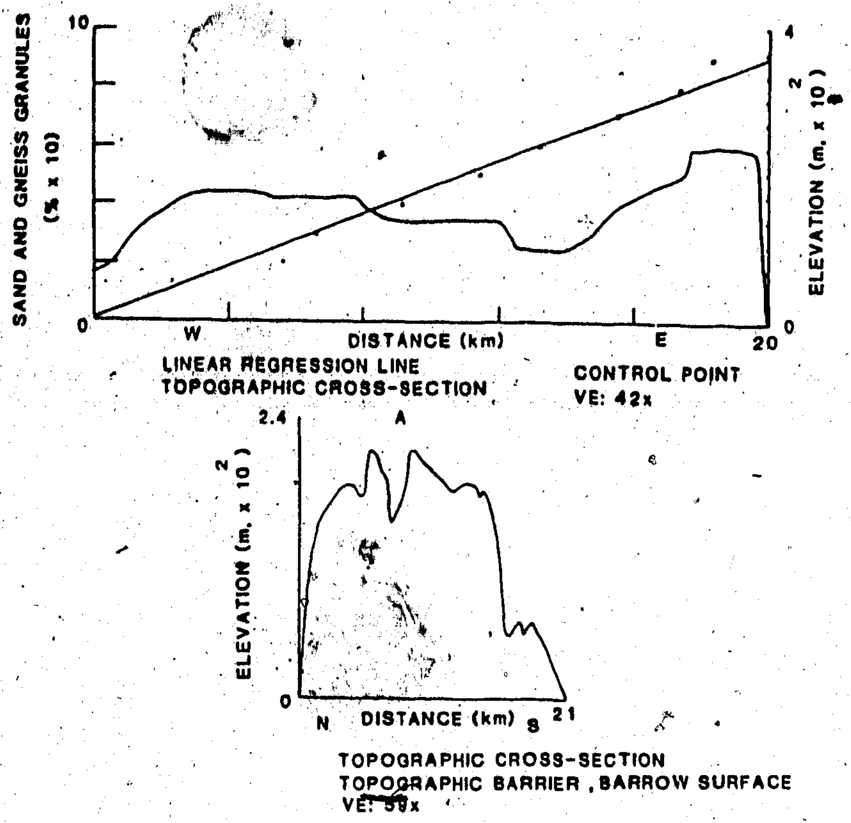
TOPOGRAPHIC CROSS-SECTION

CONTROL POINT
VE: 42x

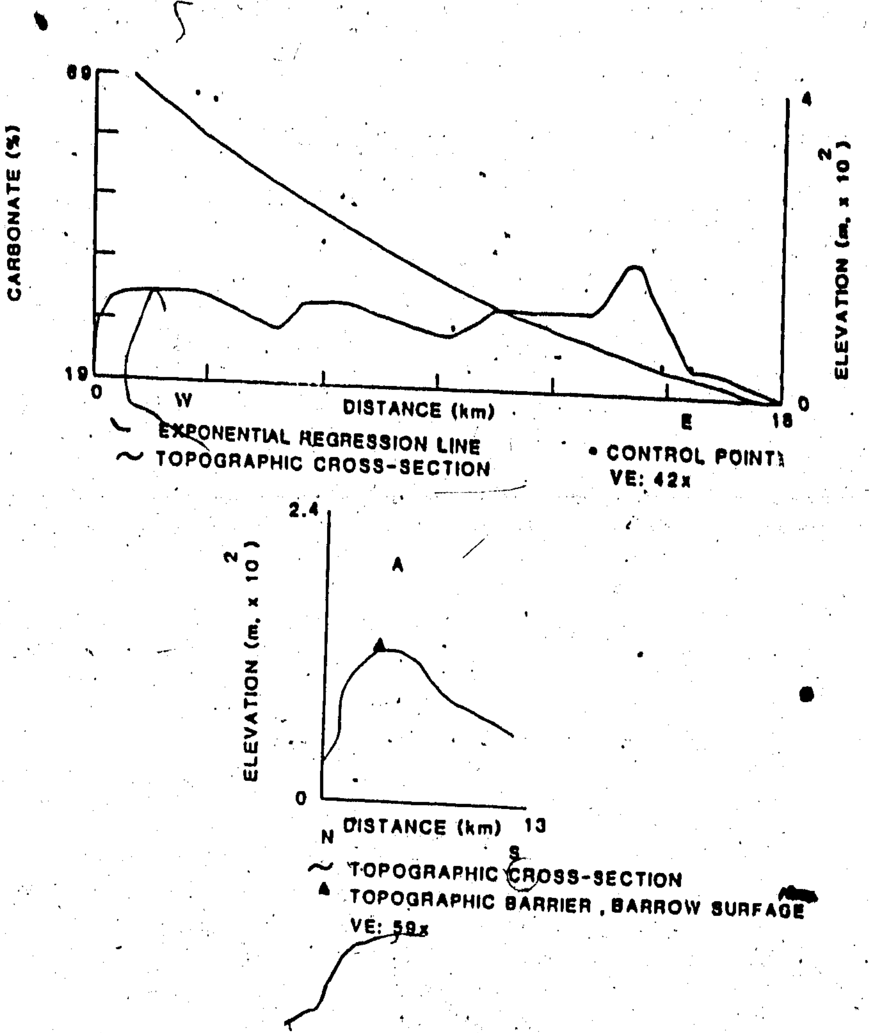


TOPOGRAPHIC CROSS-SECTION
TOPOGRAPHIC BARRIER , BARROW SURFACE
VE: 59x

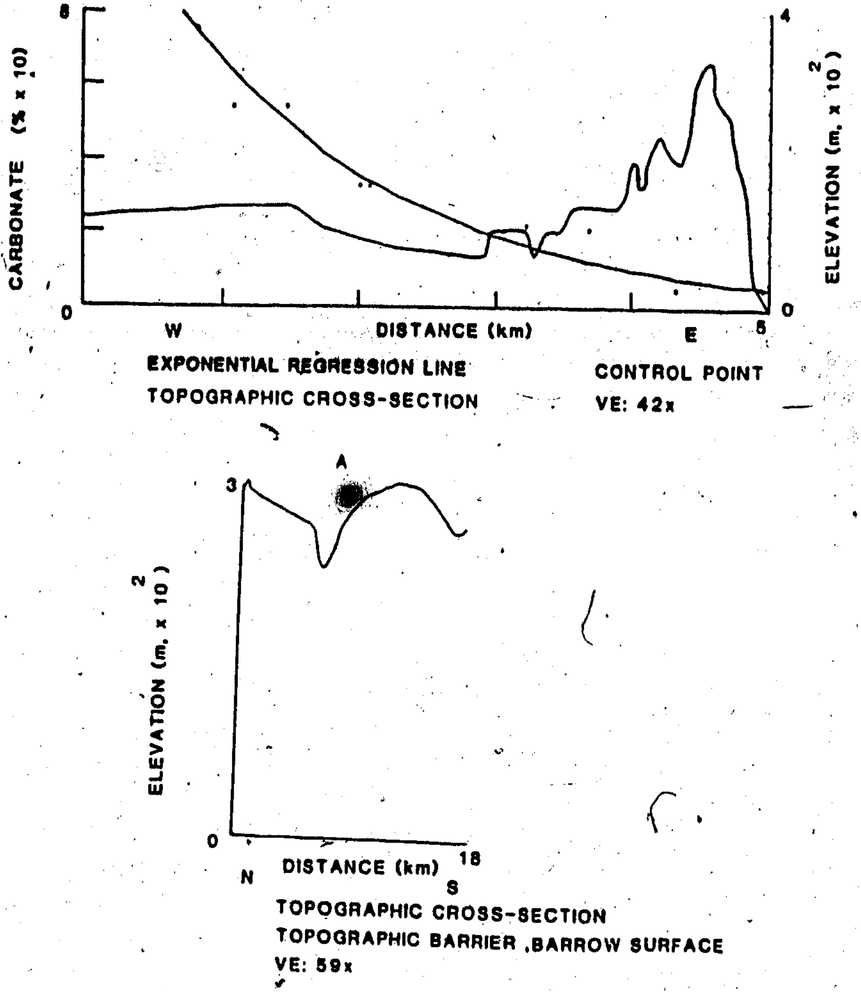
Simple regression analysis from the clastic granules map, Flexure Bay line. Clastic granules are being incorporated over the Barrow Surface (A). N= north, S= south, W= west, E= east and VE= vertical exaggeration.



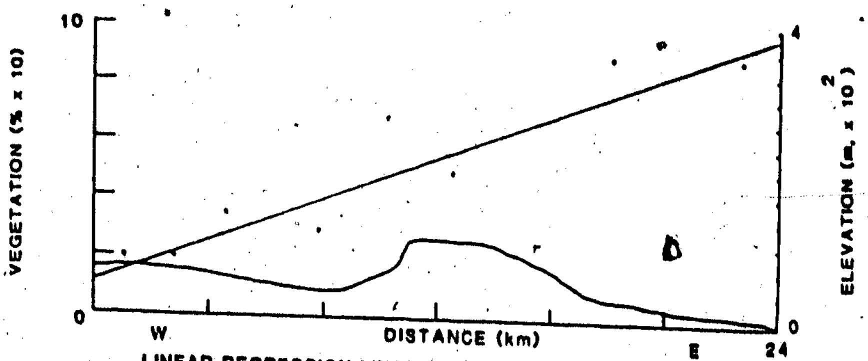
Simple regression analysis from the clastic granules map, Strelecki Harbour line. Clastic granules are being incorporated over the Barrow Surface (A). N= north, S= south, W= west, E= east and VE= vertical exaggeration.



Simple regression analysis from the carbonate distribution map, south of Cape Henry Kellett line. Carbonate is dispersed over the Barrow Surface (A). N= north, S= south, W= west, E= east and VE= vertical exaggeration.

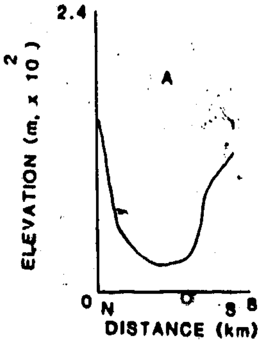


Simple regression analysis from the carbonate distribution map, Flexure Bay line. Carbonate is dispersed over the Barrow Surface (A). N= north, S= south, W= west, E=east and VE= vertical exaggeration.



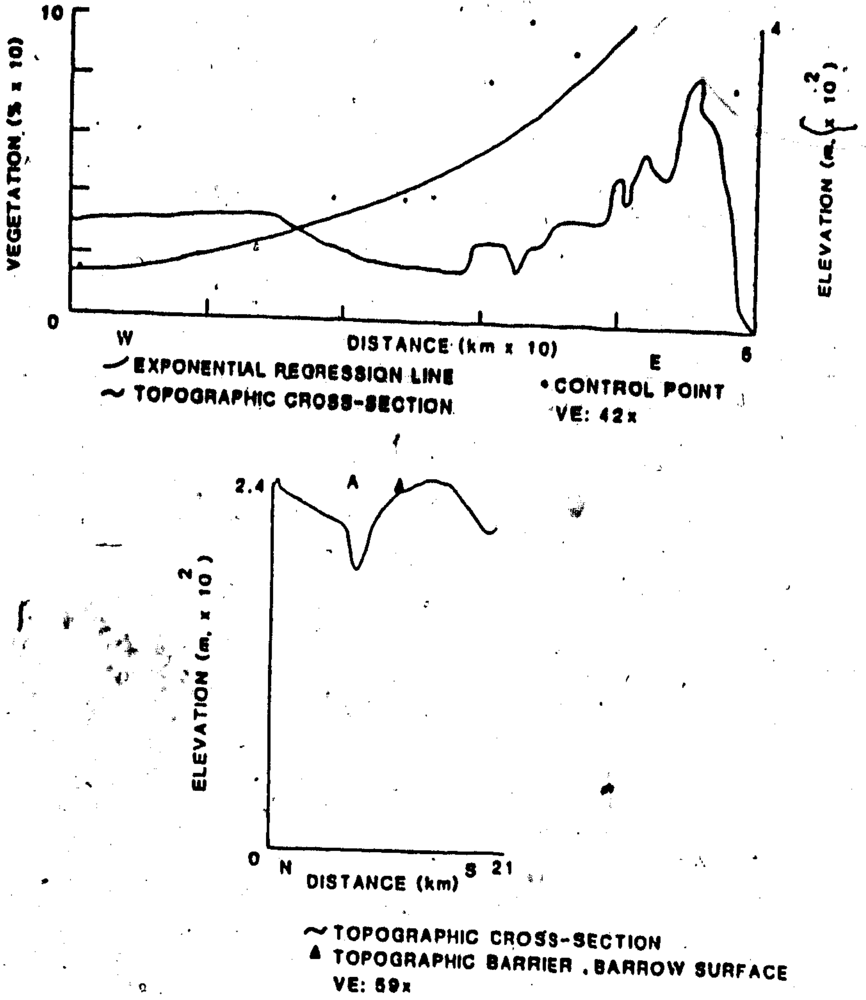
LINEAR REGRESSION LINE
TOPOGRAPHIC CROSS-SECTION

CONTROL POINT
VE: 42x

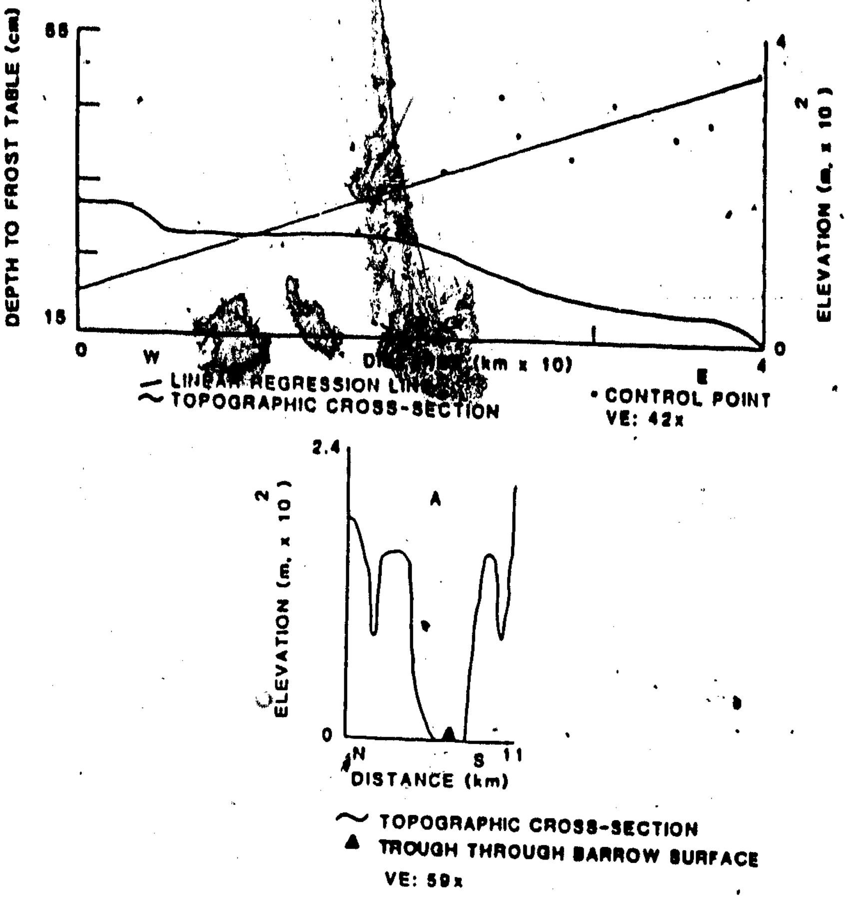


TOPOGRAPHIC CROSS-SECTION
TROUGH THROUGH BARROW SURFACE
VE: 59x

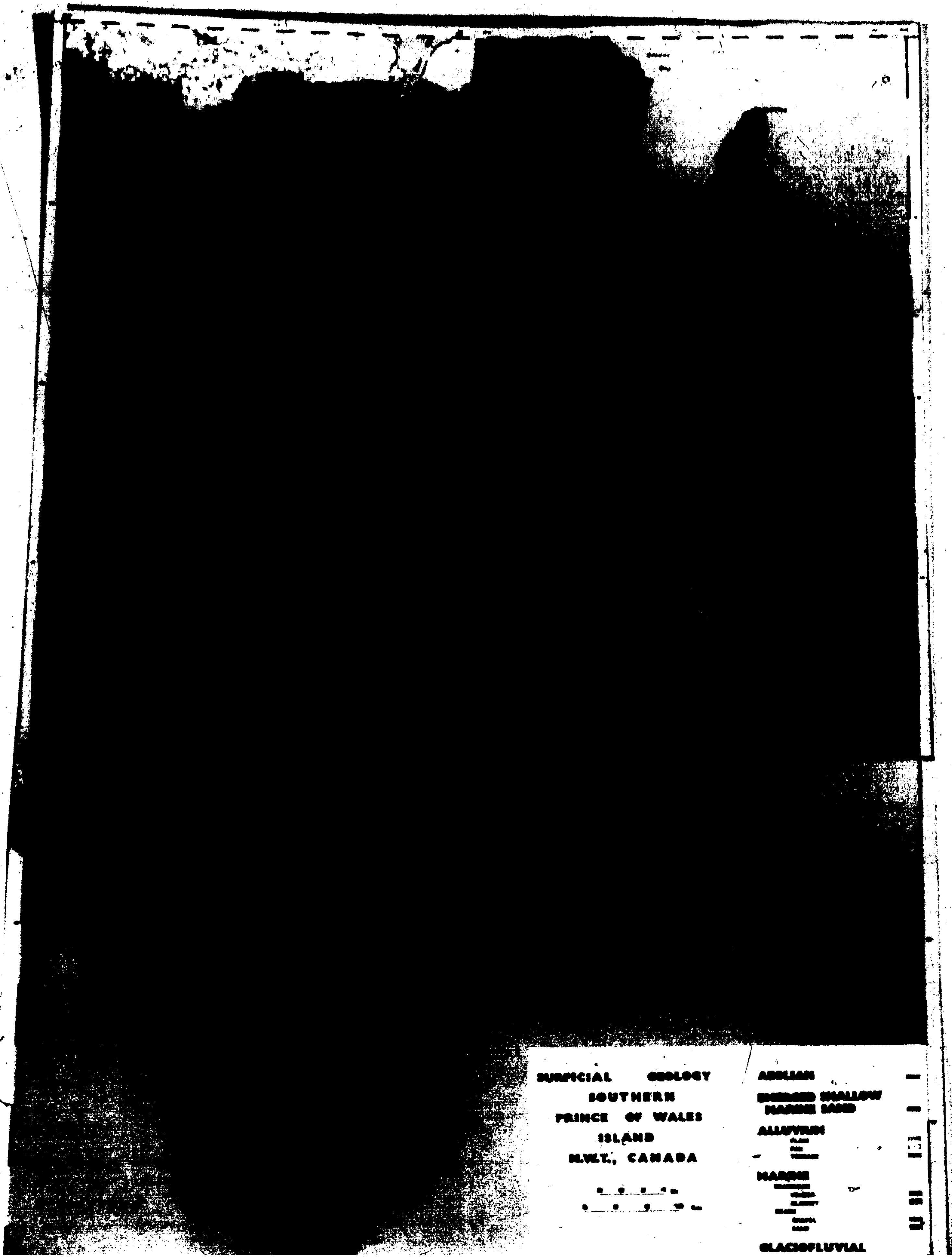
Simple regression analysis from the vegetation distribution map, Muskox Valley line. Carbonate, which controls vegetation, has been dispersed through the Barrow Surface (cross-section across the axis of the trough north- south; A). N= north, S= south, W= west, E= east and VE= vertical exaggeration.



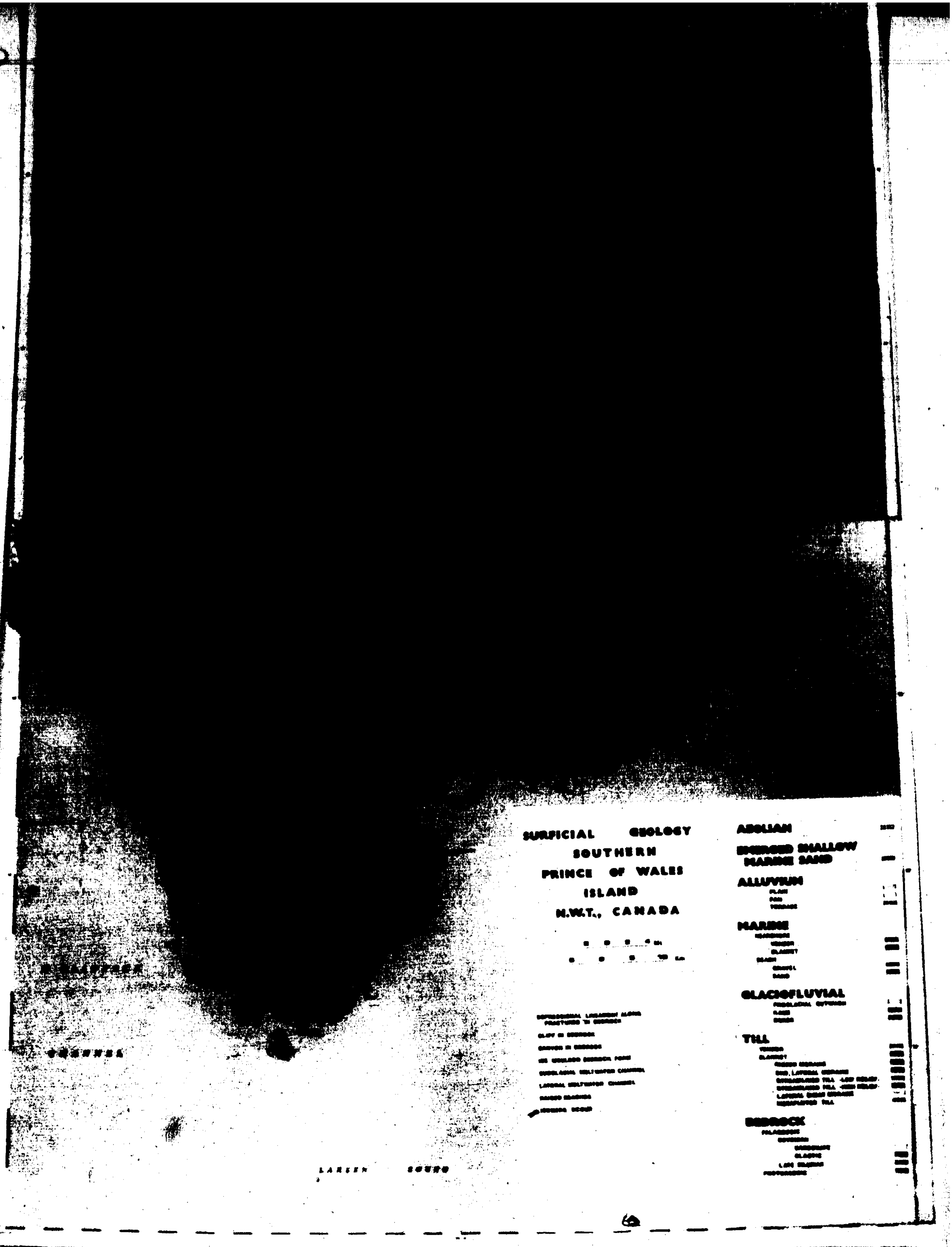
Simple regression analysis from the vegetation distribution map, Flexure Bay line. Carbonate, which controls vegetation, has been dispersed over the Barrow Surface (A). N= north, S= south, W= west, E= east and VE= vertical exaggeration.



Simple regression analysis from the depth to frost table map, Le Feuvre Inlet line. Carbonate, which controls depth to frost table, has been dispersed through a trough in the Barrow Surface (cross-section across the axis of the trough north-south; A). N= north, S= south, W= west, E= east and VE= vertical exaggeration.



SURFICIAL GEOLOGY
SOUTHERN
PRINCE OF WALES
ISLAND
N.W.T., CANADA


SURFICIAL GEOLOGY
SOUTHERN
PRINCE OF WALES
ISLAND
N.W.T., CANADA
AEOLIAN
EMERGED SHALLOW MARINE SAND
ALLUVIUM
MARINE
GLACIOFLUVIAL
TILL
BEDROCK
CHANNEL
LARSEN SOUND