Géographie physique et Quaternaire

Late Pleistocene and Holocene glaciation and deglaciation of Melville Peninsula, Northern Laurentide Ice Sheet

La glaciation et la déglaciation de la péninsule de Melville au Pléistocène supérieur et à l'Holocène

GLaciación y desglaciación del inlandsis lorensiano en la península de melville durante el pleistoceno tardío al holoceno

Lynda A. Dredge

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Article abstract

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LATE PLEISTOCENE AND HOLOCENE GLACIATION AND DEGLACIATION OF MELVILLE PENINSULA, NORTHERN LAURENTIDE ICE SHEET*

Lynda A. DREDGE** Terrain Sciences Division, Geological Survey of Canada, 601 Booth St., Ottawa, Ontario K1A 0E8.

ABSTRACT Melville Peninsula lies within the Foxe/Baffin Sector of the Laurentide Ice Sheet. Pre-Foxe/Pre-Wisconsin ice may have covered the entire peninsula. Preserved regolith in uplands indicates a subsequent weathering interval. Striations and till types indicate that, during the last (Foxe) glaciation, a local ice sheet (Melville Ice) initially developed on plateaus, but was later subsumed by the regional Foxe ice sheet. Ice from the central Foxe dome flowed across northern areas and Rae Isthmus, while ice from a subsidiary divide controlled flow on southern uplands. Ice remained cold-based and non-erosive on some plateaus, but changed from cold- to warm-based under other parts of the subsidiary ice divide, and was warm-based elsewhere. Ice streaming, generating carbonate till plumes, was prevalent during deglaciation. A late, quartzite-bearing southwestward ice flow from Baffin Island crossed onto the north coast. A marine incursion began in Committee Bay about 14 ka and advanced southwards to Wales Island by 8.6 ka. The marine-based ice centre in Foxe Basin broke up about 6.9 ka. Northern Melville Peninsula and Rae Isthmus were deglaciated rapidly, but remnant ice caps remained active and advanced into some areas. The ice caps began to retreat from coastal areas ~6.4 to 6.1 ka, by which time sea level had fallen from 150-180 m to 100 m.

RÉSUMÉ *La glaciation et la déglaciation de la péninsule de Melville au Pléistocène supérieur et à l'Holocène*. La péninsule de Melville fait partie du secteur de Foxe/Baffin de l'Inlandsis laurentidien. Une glace pré-wisconsienne a pu avoir couvert la péninsule entière. La présence d'un régolithe préservé dans les hautes-terres signale un intervalle d'altération subséquent. Les stries et la composition des tills indiquent que, pendant la dernière glaciation (de Foxe), une calotte de glace locale (glace de Melville) s'est d'abord étalée sur les plateaux, mais a par la suite été englobée par la calotte glaciaire de Foxe. La glace du dôme de Foxe a envahi la partie nordique de la péninsule de Melville ainsi que l'isthme de Rae, alors que l'écoulement glaciaire sur les hautes-terres du sud a été contraint par une ligne de partage secondaire. Sur certains plateaux, la glace à base froide s'est maintenue ainsi et n'a pas eu d'action érosive, mais, en certains secteurs de la ligne de partage secondaire, la base est passée de froide à tempérée ; ailleurs, la glace était à base tempérée. Les courants glaciaires ayant produit des traînées de till carbonaté ont dominé durant la déglaciation. Pendant le Tardiglaciaire, un écoulement glaciaire vers le sud-ouest, en provenance de d'île de Baffin, a transporté de la quartzite sur la côte nord. Une invasion marine ayant pris naissance dans la baie du Comité aux environs de 14 ka a progressé vers le sud-ouest jusqu'à l'île de Wales vers 8,6 ka. La calotte glaciaire du bassin de Foxe s'est fragmentée vers 6,9 ka. Le nord de la péninsule de Melville et l'isthme de Rae ont rapidement été déglacés, mais quelques calottes glaciaires résiduelles sont demeurées actives et se sont avancées par endroits. Les calottes se sont retirées des zones côtières de ~6,4 à 6,1 ka, alors que le niveau de la mer s'était abaissé de 150-180 m à 100 m.

RESUMEN *GLaciación y desglaciación del inlandsis lorensiano en la península de melville durante el pleistoceno tardío al holoceno.* La península Melville se sitúa en el sector Foxe/Baffin del Inlandis lorensiano. Es probable que hielos del periodo pre-Foxe/prewisconiano hayan cubierto la península por completo. La presencia de regolitos en las tierras superiores indica un intervalo de alteración subsecuente. El tipo de estriaciones y tillitas indican que durante la ultima glaciación (Foxe), la capa de hielo local (Hielo de Melville) se formo primero en la meseta pero fue recubierto posteriormente por la capa regional de Foxe. El hielo proveniente del domo central de Foxe se extendió hacia la parte norte y el istmo de Rae, mientras que el avance del hielo sobre las tierras altas del sur fue retenido por una vertiente secundaria. En algunas de las mesetas, el hielo de base fría se mantuvo sin cambios y no muestra evidencias de erosión, pero en ciertos sectores de la línea divisoria secundaria, la capa basal paso de fría a templada. En otros sitios el hielo presentaba ya una región basal templada. Las corrientes glaciares que originaron las corrientes de tillitas carbonatadas predominaron durante la desglaciación. Durante el periodo glaciar tardío, un escurrimiento glaciar hacia el sudoeste, proveniente de la isla de Baffin provoco el transporte de cuarcita desde la costa norte. Hace unos 14 ka, una invasión marítima generada a partir de la bahía del *Comité* hizo su progresión hacia el sudoeste llegando hasta la isla de Wales hacia 8,6 ka. La capa glaciar de la cuenca de Foxe se fragmento hacia 6,9 ka. El norte de la península de Melville y el istmo de Rae sufrieron una desglaciación rápida, pero algunas reminiscencias de la capa de hielo permanecieron activas y avanzaron hacia algunas áreas. Las capas de hielo empezaron a retirarse del área costera alrededor de 6,4 a 6,1 ka, al mismo tiempo que el nivel del mar disminuyo de 150-180 m hasta 100 m.

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* Geological Survey of Canada, contribution nº 1998204
**email: ldredge@gsc.nrcan.gc.ca

INTRODUCTION

Melville Peninsula (Fig. 1) lies on the northeastern side of the Laurentide Ice Sheet (Dyke and Prest, 1987). Although there has been much recent work on eastern and offshore Baffin Island, and around Hudson Strait, research pertaining directly to Melville Peninsula has been relatively limited. The first early descriptions of landforms on Melville Peninsula were explorers' observations of features along the eastern coast. Later, Sim (1960a) proposed a glacial history for the area, based on air photo interpretation, detailed ground traverses near the coast, and more limited information from inland sites. He also reported on sea level change (Sim, 1960b, 1960c), drift dispersal, and ice flow around Foxe Basin (Andrews and Sim, 1964). Craig (1965b) later provided a brief summary of the surficial geology as part of Operation Wager, and with Falconer *et al.* (1965) and Blake (1966), discussed the moraine that runs down the west coast of the peninsula. Craig (1965a) also provided the first radiocarbon dates for the area, and determined that deglaciation occurred about 6900 years ago. In this paper, new data resulting from regional mapping and interpretation of surface materials (Dredge 1994, 1995) have been combined with Sim's work to provide new insights on the nature and sequence of glacial and deglacial events on Melville Peninsula. The last part of the paper puts the data from Melville Peninsula into the broader regional context of the Foxe Ice Sheet.

In the past, the terms Baffin Ice, Foxe Ice, and Foxe/Baffin Ice (or Sector) have been used interchangeably by various authors. For clarification in this paper, the term "Melville Ice" refers to ice which accumulated on Melville Peninsula, and "Foxe Ice" refers to ice from the centre of outflow in Foxe Basin. Foxe Ice, Melville Ice, and other separate ice masses on Baffin Island (Baffin Ice) comprise the Foxe/Baffin Sector of the Laurentides Ice Sheet.

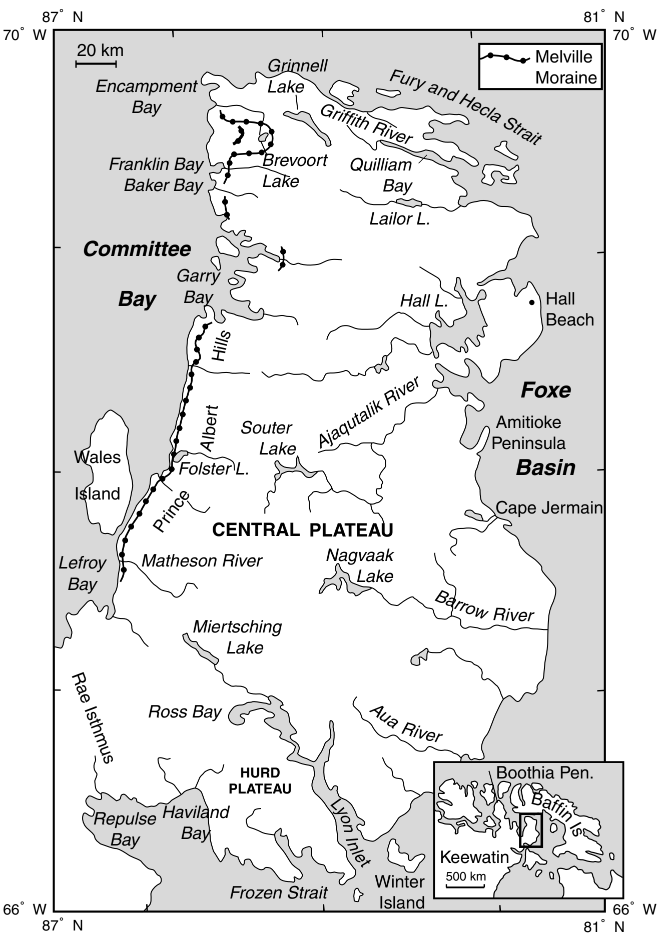

FIGURE 1. Melville Peninsula, location and place names.
La Péninsule de Melville : localisation et toponymie.

GEOLOGY AND PHYSIOGRAPHY

Melville Peninsula lies on the eastern Arctic mainland west of Foxe Basin (Fig. 1). It consists of a southeast-tilted central horst flanked by lowlands (Heywood, 1966; Schau, 1993). The upland areas range from moderately rugged in the west, to gently rolling in the east. Remnants of old erosion surfaces of subdued relief form the Central Plateau and the Hurd Plateau. The uplands are underlain by Precambrian rocks, chiefly granite, gneiss, and schist, impure marble, and quartzite. Lowland areas, particularly around Hall Beach and Wales Island, are underlain by Paleozoic limestone and dolostone.

SURFACE DEPOSITS AND LANDFORMS

Glacially polished and striated rock is widespread in the Prince Albert Hills on the western peninsula (Fig. 1). Glacial troughs trend east-west through the Hills, mostly along faults. Other smaller glacial troughs also follow bedrock structure. In the north near Grinnell Lake, they have a northwesterly orientation, whereas in the southeast, they follow weaker marble belts.

Till plains occupy much of the peninsula, either as cover deposits (Fig. 2), or as thin veneers interspersed with bedrock. The till is stony, with a silty sand matrix where it is derived from granitic bedrock; it has a finer clayey silt matrix where it is derived from carbonates. Hummocky till patches are present on southern parts of the peninsula in the Aua River area, west of Hall Lake, and on western parts of the Central Plateau. The Melville Moraine, a ridge of till and glaciomarine sediment (Dredge, 1990), is traceable for a distance of 250 km along the west side of the peninsula from Encampment Bay to a point south of Matheson River, where it intersects the coast.

Eskers are rare on Melville Peninsula, and tend to be small features trending towards the south and east coasts. Nested sets of lateral meltwater channels occupy one part of the Ajaqutalik River valley on the eastern side of the Central Plateau, and the north side of the Hurd Plateau. Proglacial outwash deposits are limited in extent, although major valley trains occupy the glacial troughs that transect the Prince Albert Hills. Outwash trains and deltas, and swaths of washed rock up to 20 km long, are also present west of Cape Jermain.

Small areas of glaciolacustrine deposits or washed till lie near Brevoort Lake, Souter Lake, and Miertsching Lake.

FIGURE 2. Till plains and glaciated outcrop in gneissic terrain, northern Melville Peninsula.

Les plaines de till et les affleurements d'érosion glaciaire en terrain gneissique, dans la partie nord de la péninsule de Melville.

Felsenmeer or block fields (Fig. 3) dominate the Central Plateau and the Hurd Plateau, and occupy other smaller areas on southern Melville Peninsula. These are characterized by angular blocks and a matrix consisting primarily of intensely-hued sandy gruss, with clay minerals in finer material (Dredge, 2000b). There are no striae or streamlined rock forms, and erratics are rare. The surface material commonly forms large sorted circles that are an order of magnitude larger than those formed in similar-textured materials in postglacial times (Fig. 3).

Marine deposits are common below 220 m in the northwest and below 100-150 m elsewhere (Fig. 4). They consist of deltaic sediments, some fossiliferous, where meltwater streams entered deglacial seas, cover sands underlain by silt, or flights of raised cobble beaches. Areas of washed rock separating unmodified till from marine sediment mark the upper limit of postglacial marine submergence. Key radiocarbon dates on marine shells from deltas that relate to specific sea levels at the time of deglaciation are summarized in Table I.

ICE FLOW INDICATORS

The principal indicators of ice flow direction are striated bedrock surfaces, streamlined rock and till forms (Fig. 5), distinctive erratics in the boulder and pebble fraction of the till, and dispersal trains discerned from mapping the composition of the till matrix (Fig. 6; Dredge and Nixon, 1993; Dredge, 1994). These types of indicators are all conspicuously absent from the Central and Hurd plateaus.

STRIATIONS AND STREAMLINED TILL FORMS

Ice flow directions determined by striae and glacial landforms are shown in Figure 5. Relative ice flow sequences were determined where there were crossing striae. There are no striae preserved in the blockfields of the Central Plateau or the Hurd Plateau. Roches moutonnées, crag and tail forms, and

FIGURE 3. Peneplain and block field on the central plateau. Note large stone circle at field book.

Pénéplaine et champs de blocs sur le plateau central. Noter le grand cercle de pierre près du carnet de terrain.

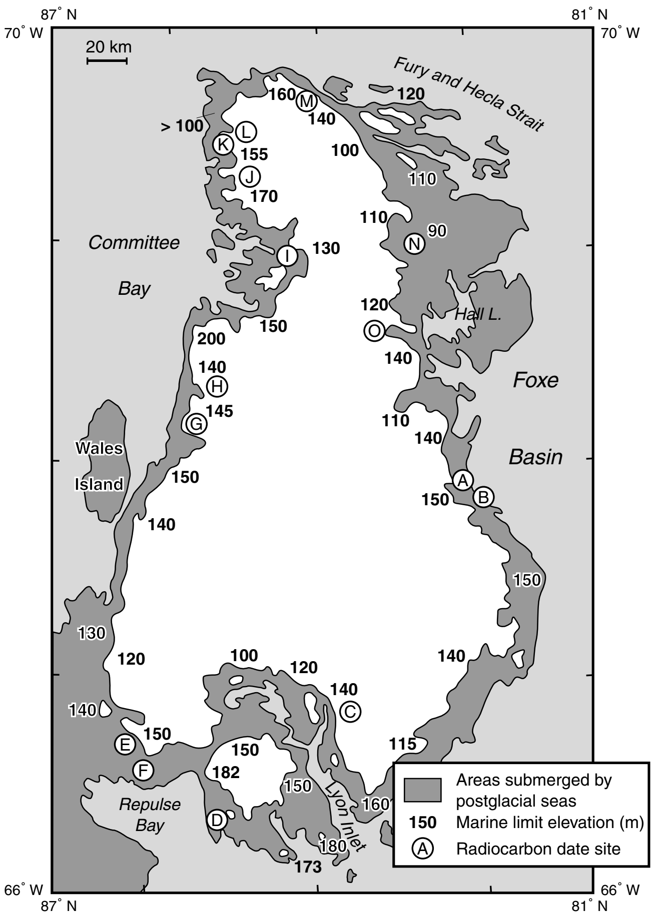

FIGURE 4. Postglacial limits of marine submergence. Lettered sites refer to dates in Table I.

Limites postglaciaires de la submersion marine. Les lettres se rapportent à des dates au tableau I.

TABLE I

Summary of radiocarbon dates on marine shells that pertain to deglaciation on Melville Peninsula

Site (Fig. 4)	Lab number	Raw ^{14}C Date	δ13 (ppt PDB)	Corrected date (to δ13 = 0 ppt)	Elevation (m)	Reference
A	GSC-4812	6150 ± 80	+1.5	6170 ± 80	104	McNeely and Jorgensen, 1992
B	GSC-291	6880 ± 180			134	Dyck *et al.*, 1966
C	GSC-5112	6470 ± 140	+1.5	6490 ± 140	125	McNeely and Atkinson, 1996
D	GSC-5132	6890 ± 100	+1.5	6920 ± 100	100	McNeely and Atkinson, 1996
E	GSC-286	6850 ± 140			121	Dyck *et al.*, 1966
E	GSC-5110	6480 ± 120	+1.5	6500 ± 120	105	McNeely and Atkinson, 1996
F	GSC-5146	6740 ± 100	+1.2	6760 ± 100	80	McNeely and Atkinson, 1996
G	GSC-4786	6430 ± 70	+1.5	6450 ± 70	92	McNeely and Jorgensen, 1993
H	GSC-4857	6130 ± 90	+1.3	6150 ± 90	45	McNeely and Jorgensen, 1993
I	GSC-4831	6920 ± 90	+0.2	6920 ± 90	100	McNeely and Jorgensen, 1993
J	GSC-4225	6780 ± 80	+2.3	6810 ± 80	100	McNeely and Jorgensen, 1993
K	GSC-4324	9070 ± 100	+2.3	9110 ± 100	220	McNeely and Jorgensen, 1993
L	GSC-4465	8550 ± 100	+1.4	8570 ± 100	190	McNeely and Jorgensen, 1993
M	GSC-4378	6490 ± 70	+1.5	6520 ± 70	121	McNeely and Jorgensen, 1993
N	GSC-4453	5490 ± 70	+1.3	5510 ± 70	75	McNeely and Jorgensen, 1993
O	GSC-4693	6500 ± 110	+1.4	6530 ± 110	113	McNeely and Jorgensen, 1992

drumlins of low to moderate relief occur on the till plains, but are concentrated in several swaths, the main ones being a west-trending belt of streamlined rock forms across the northern part of the peninsula and between Hall Lake and Garry Bay; a north-northwest trending field of low-relief drumlins on Rae Isthmus and associated streamlined rock forms at Repulse Bay; and two northwest trending fields of drumlins and crag and tail forms near Miertsching Lake and Matheson River. There are also isolated northeasterly-trending drumlins on till plains west of Cape Jermain, and streamlined marble landforms oriented towards the southeast coast, or into Lyon Inlet.

ERRATICS

Distinctive erratics record former ice flow directions and transport distances. Two distinctive rock types on the peninsula are 1) Proterozoic quartzite/sandstone (Fury and Hecla Group) on the northernmost part of the peninsula (Fig. 6), and 2) Proterozoic marble, (within the Penrhyn Group of the Foxe Fold Belt) in the southeast part of the peninsula. The distribution of pebble-sized sandstone/quartzite clasts extends 30-40 km southwest beyond source rocks near Fury and Hecla Strait. Marble pebbles are principally confined to areas of marble outcrop on the southern part of the peninsula, and indicate only minimal local dispersal northwestward in the area north of Ross Bay.

Limestone/dolomite erratics in till derive from Paleozoic carbonate formations which outcrop on the northeastern lowlands, and underlie much of Foxe Basin (Fig. 6): glacial landforms and striae indicate that the erratics were not carried eastward from Committee Bay. Limestone pebbles/boulders in till cover the northern third of the peninsula, and continue from Hall Lake across to the west coast. They are also abundant across Rae Isthmus, but are exceedingly rare on the Central plateau, Hurd plateau, the till plains west of Cape Jermain, and on the Aua River lowland above marine limit. On the southeast part of the peninsula, they are limited to a coastal fringe, even in areas directly west of limestone bedrock.

CARBONATE DISPERSAL TRAINS

Carbonate contents in the silt/clay matrix fraction of the till (shaded areas in Fig. 6) show distribution patterns similar to those of limestone pebbles, and indicate regional-scale carbonate dispersal from Foxe Basin across northern Melville Peninsula and through Rae Isthmus, with more limited dispersal onto southern coastal parts of the peninsula. On northern Melville Peninsula, carbonate concentrations within the main dispersal train range from > 90 % (of the matrix weight) at the source rocks along the east coast, down to about 30 % at the west coast (Fig. 7). The distribution of carbonate within the main dispersal train shows pronounced lateral and longitudinal variation. Along trajectories where carbonate-charged glaciers fed into calving bays along the west coast, carbonate plumes, 200-1 000 m across, lie within the regional dispersal train. In these plumes, carbonate contents do not decrease with increasing distance from source areas (Dredge, 2000a). The second major dispersal train, through Rae Isthmus, typically has matrix carbonate contents that vary from 25 to 50 %. Carbonate concentrations tend to remain constant along specific ice-flow trajectories, despite increasing distances from source rocks in, or southeast of, Repulse Bay.

Carbonate in till north of Ross Bay is derived from local sources of impure marble, but carbonate in a patch of till near Nagvaak Lake contains some limestone pebbles as well, and cannot be explained solely as a marble derivative. The Nagvaak carbonate more likely relates to transport from Foxe Basin, although its isolated occurrence, together with striations in the vicinity that indicate that most ice flow was eastward, towards the coast, suggest that they may belong to early glacial events.

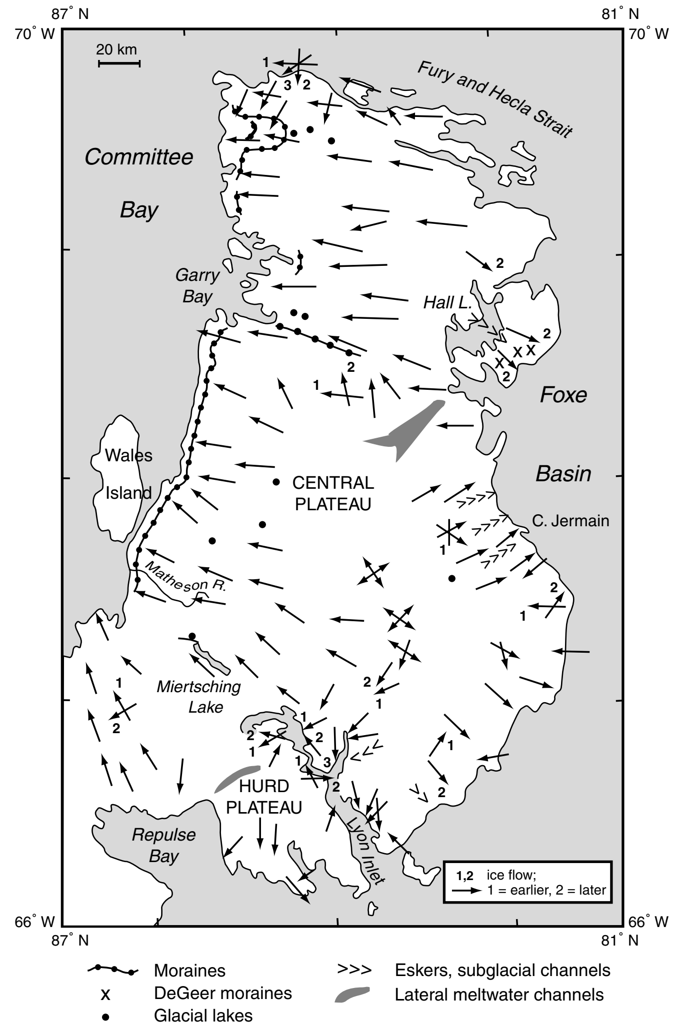

FIGURE 5. Ice flow indicators used to reconstruct glacial events.

Les indicateurs de l'écoulement glaciaire utilisés pour reconstituer les événements glaciaires.

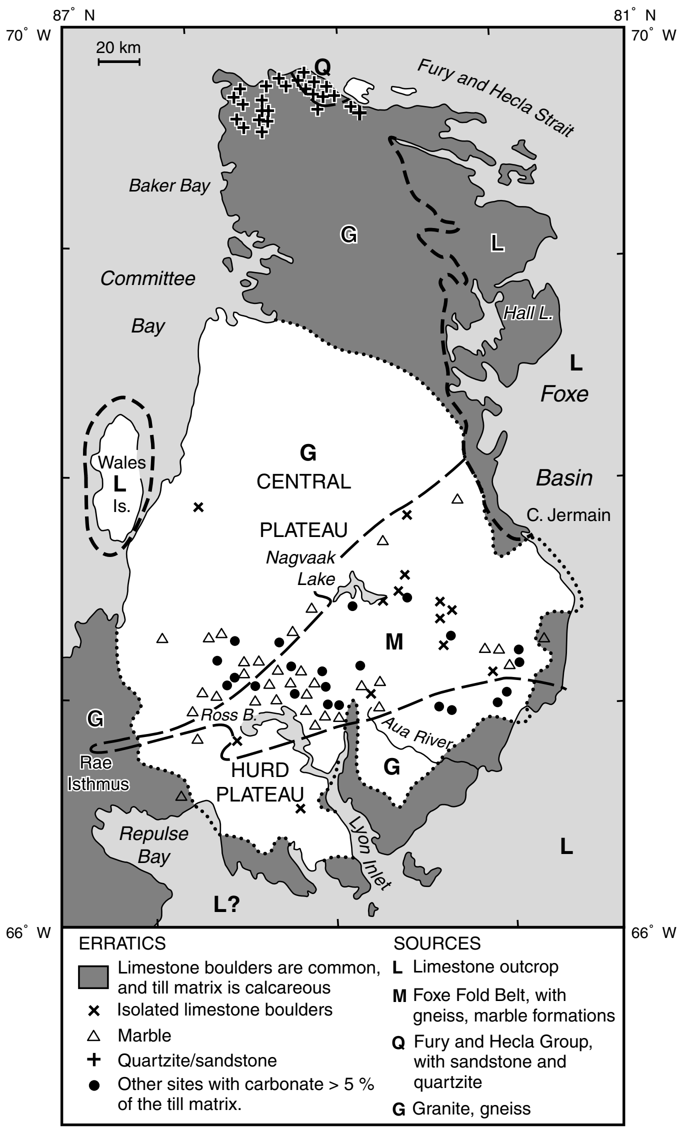

FIGURE 6. Glacially transported erratics, with bedrock source areas. Regional-scale dispersal trains of calcareous till on northern Melville Peninsula and Rae Isthmus are shaded. The dashed lines are geologic contacts.

Les erratiques glaciaires et leur provenance. Les traînées de till calcareux à échelle régionale sur la partie nordique de la péninsule de Melville et l'isthme Rae sont tramées. Les lignes pointillées identifient les contacts géologiques.

OTHER FEATURES

Features such as moraines and ice marginal lakes, shown in detail on surficial geology maps (Dredge and Nixon, 1993; Dredge, 1994), and summarized on Figure 5, are also indicators of ice flow directions, particularly the position or orientation of recessional ice margins. Nested ice marginal channels, cut into both bedrock and blockfields along one part of the Ajaqutalik valley and on the northern edge of the Hurd Plateau, indicate recessional positions and elevations of late ice tongues.

RECONSTRUCTION OF GLACIAL EVENTS

From the distribution of surface materials and landforms, shown in detail in GSC maps, and summarized above, a sequence of glacial and deglacial events can be reconstructed. Due to an absence of chronologic controls, some degree of conjecture is involved. However, the arguments are based on field observations at 1 200 sites throughout the whole peninsula, and consideration of all lines of evidence, taken together. The reconstruction differs from previous interpretations and compilations (*e.g.* Sim, 1960a; Dyke and Prest, 1987) because of new information on the distribution of surface landforms and carbonate across the peninsula, striation patterns, and additional radiocarbon dates.

EARLY ICE FROM FOXE BASIN

A few, widely scattered, weathered limestone cobbles in till in the interior of southern Melville Peninsula (Fig. 6) indicate that an ice sheet, transporting carbonate from Foxe Basin,

FIGURE 7. A plume of carbonate till overlying gneissic bedrock west of Hall Lake. Most boulders, and about 70 % of the matrix, are derived from limestone sources beneath the lowlands and Foxe Basin to the east.

Une traînée de till carbonaté sur la roche gneissique à l'ouest du Hall Lake. La plupart des blocs et environ 70 % de la matrice proviennent de sources de calcaire situées sous les basses-terres et du bassin de Foxe, à l'est.

once covered the central plateau. However, despite the sporadic occurrence of limestone clasts inland, there are negligible amounts of carbonate in the till matrix at corresponding sites, even though the limestone source rocks are easily eroded. It is possible that carbonate from the till matrix associated with the glaciation that left the scattered inland erratics has been leached out and removed from the till, and that the scattered cobbles are the remains of an early glaciation. In contrast, in parts of northern Melville known to have been covered with Foxe Ice during the "last" glaciation, carbonate erratics are abundant, and matrix concentrations are high.

The timing of the limestone-emplacing glacial event is unknown, but due to the absence of matrix carbonate, this event is thought to predate the "Sangamon" interglaciation. This time assignment is supported by the presence of extensive areas of incoherent rock and weathered regolith that would have been eroded away if active, till-depositing ice from Foxe Basin had covered the area during the last glaciation. An alternative interpretation, that the ice depositing the erratic limestone cobbles dates to the later Foxe Glaciation, but that the ice was cold-based, would only be reasonable if there had been some matrix carbonate in the till.

Early flows of ice from Foxe Basin probably covered northern Melville Peninsula as well, but due to the abundance of carbonate emplaced during the last glaciation, there is no definitive evidence relating to the early ice flow.

INTERGLACIATION AND WEATHERING

Although field evidence indicates that the entire area was ice-covered during the last glaciation (Wisconsin/Foxe Glaciation), remnants of weathered regolith are present in the block fields of the Central and Hurd plateaus (Dredge, 2000b). It is thought that the weathered material was preserved beneath areas covered by ice that was non-erosive; patches of fresh till and abundant glacial meltwater features incised into the regolith indicate that the area had been glacier-covered after the weathering interval. The clay minerals, spalled boulders, and deep hues of the regolith suggest that a relatively prolonged period of subaerial weathering occurred prior to the last glaciation. The simplest age assignment for this non-glacial event is the Sangamon Interglaciation (isotope stage 5), but the weathering interval that is represented could have occurred even earlier. Most limestone clasts and carbonate matrix materials from the early glaciation from Foxe Basin could have been weathered-out during this interval, leaving only the clasts found at two sites.

INITIAL GROWTH CENTRES DURING THE LAST (FOXE) GLACIATION (FIG. 8A)

Melville Peninsula lies within the Foxe/Baffin Sector (or Foxe Dome) of the Laurentide Ice Sheet (Ives and Andrews, 1963; Andrews and Miller, 1979; Dyke and Prest, 1987; Andrews, 1989), an area governed by flow from an ice dome centred in Foxe Basin during the Last Glacial Maximum (LGM). Ives (1962), Ives and Andrews (1963), and Andrews (1989) proposed that there was a rapid initial build-up of ice on the upland plateaus of Baffin Island before it was inundated and controlled by ice from the dome in Foxe Basin. Numerical modelling (Andrews and Mahaffy, 1976) showed that regional ice caps could have developed on the uplands in a 5 to 10 thousand year period after the onset of glaciation. Field evidence presented here suggests that an analogous situation probably occurred on Melville Peninsula, with local glacier growth and ice dispersal on plateau areas of central and southern Melville Peninsula.

Furthermore, Ives (1962) and Williams (1978) suggested that, with a 1.5 °C decline in temperatures during the Little Ice Age, the glacial equilibrium line on Baffin Island was lowered to 400 m, and to about 500 m on Melville Peninsula. With a slightly greater temperature decline associated with the onset of glaciation, the central Melville plateau, most of which is above an elevation of 450 m, would also have been covered with perennial ice and snow, leading to "instantaneous glacierization" (Ives, 1962) and an early ice cap on the Melville Peninsula uplands. These same areas have snowfields persisting throughout some summers at present.

Preserved regolith suggests that there was little transport of debris, and a prevalence of cold-based conditions beneath the growing ice centres. Warm based ice farther from the ice centres produced those striations that cannot be attributed to later flow phases, particularly some of the striae in the southeast. Possible cold ice zones are depicted on Fig. 8A.

FOXE ICE (FIG. 8B)

Striation patterns, till types and distribution, and glacial landform assemblages, together with reconstructions of the size and vigour of the Foxe Ice Dome on Baffin Island (Ives and Andrews, 1963; Andrews and Sim, 1964; Andrews, 1989), suggest that Foxe Ice later covered all of Melville Peninsula,

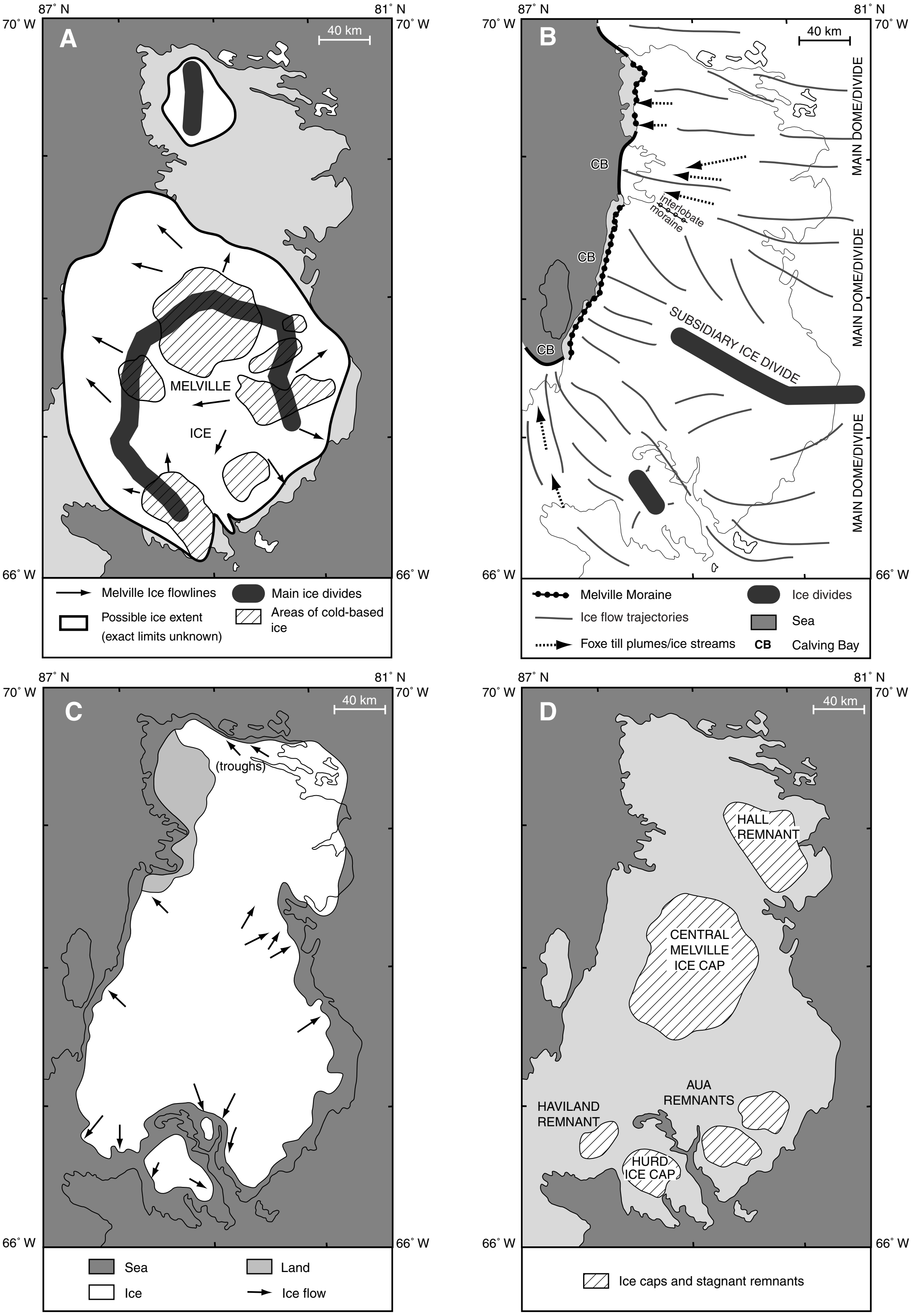

FIGURE 8. Glacial history. A) Early growth centres. B) Ice flow during the last glacial maximum: Foxe ice with a subsidiary ice divide on Melville Peninsula. C) Ice/sea relations, about 7000-6500 BP, with radial flow of ice from Melville Peninsula. D) Remnant ice masses and ice caps.

L'évolution glaciaire. A) Premiers centres d'accumulation de glace. B) L'écoulement glaciaire au dernier maximum glaciaire : le dôme de Foxe avec une ligne de partage glaciaire secondaire sur la péninsule de Melville. C) Rapports entre la glace et la mer vers 7000-6500 BP, avec un écoulement radial à partir de la péninsule de Melville. D) Masses de glace résiduelles et petites calottes glaciaires.

subsuming earlier Melville Ice. The absence of carbonates on southern Melville and curving ice flow-pattern indicators suggest, however, that a subsidiary ice divide may have persisted on the central and southern uplands as part of the main Foxe Ice mass, producing a complex pattern of ice flow across and around the southern uplands (Fig. 8B). An alternative and simpler idea, that ice from a gently westward sloping Foxe Basin ice mass crossed all of the peninsula but was thinner and cold-based on the plateau, would not by itself explain the absence of carbonate, because englacial ice from the Foxe flow centre would then still have transported limestone clasts and measurable matrix carbonate across the plateau area to the opposite coast, as it did on Baffin Island (Andrews and Sim, 1964; Andrews and Miller, 1979). In addition, the stark contrast between carbonate contents on uplands on northern vs southern parts of the peninsula, argues for a more complex ice sheet configuration. Lastly, if a subsidiary ice divide was not present during the LGM, then lower areas with drumlins and mature till on southern Melville directly west of Foxe Basin would be expected to have some carbonate in the till: they do not.

The interlobate moraine south of Garry Bay may be a result of converging ice-flow lines. Cold-based ice persisted on the high Central and Hurd plateaus, preserving old regolith, but other areas in the southeast that were cold-based during early flow phases became warm-based, and were mantled with an immature bouldery till. Ice surface topography governed flow directions, producing striations crossing early ice flows in the southeast, and westward flow aligned with earlier movements near Committee Bay.

Drumlin swarms trending westward across northern Melville Peninsula, north-trending drumlins through Rae Isthmus, and a northwest drumlin field at Miertsching Lake developed during this phase. Carbonate dispersal trains of regional scale were produced by flow from trajectories originating in Foxe Basin. Crossing striae and quartzite erratics suggest that, towards the end of the main glacial phase, there was a southwest flow from Baffin Island (Dredge, 1995; Hooper, 1995) that crossed Fury and Hecla Strait.

Between 18 and 14 ka a marine incursion began in the north part of Committee Bay (Dyke and Prest, 1987; Hooper, 1995). This calving bay had expanded into the northern coast of Melville Peninsula by 9.1 ka BP (Fig. 4 and Table I) when sea level was about 220 m above present. The marine reentrant, which formed the western margin of the receding ice sheet, had penetrated as far south as Wales Island by 8.6 ka BP (Craig, 1965b: GSC-288).

Ice streams, which can be delineated as till plumes within the broader carbonate dispersal trains in the north and through Rae Isthmus, probably developed during this late phase as a response to drawdown and calving along the west coast, augmented by fast flow due to poor basal drainage in the fine-textured carbonate till (Dredge, 2000a).

Radiocarbon dates on shells within glaciomarine deltas associated with the Melville Moraine indicate that the western ice margin remained near the west coast from 8.6 ka to 6.5 (or 6.1) ka, during which time sea level dropped to about 130 m asl.

OPENING OF FOXE BASIN (FIG. 8C)

Deglaciation, crustal rebound, and sea level change are concurrent interrelated events. Marine limit elevations reflect the total ice load in an area (*i.e.* the size of an ice sheet), the position of a site relative to the loading centre, and the time elapsed since unloading (deglaciation) began. Retreat patterns based on ice-contact marine deposits, washing limits, and a limited number of radiocarbon dates indicate that break up of Foxe ice was rapid and that it proceeded generally from south to north, beginning on the south coast and Rae Isthmus about 6.9 ka BP (Fig. 4 and Table I). Deglaciation did not occur on portions of the northern coast (near site M, Fig. 4) until 6.5 ka. Along the Foxe Basin coast, the marine limit elevations decline from 180 m in the south, to 150 m on the central east coast, to 120-140 m in the northern part of Melville Peninsula. They are highest where deglaciation was earliest, and lowest where deglaciation occurred latest.

Recession of ice governed by the central Foxe divide

The opening of Foxe Basin cut off source areas of ice flow over northern Melville Peninsula, but had little affect over most of southern Melville Peninsula, where ice flow was governed by subsidiary divides (Fig. 8C). Removal of ice from Foxe Basin caused rapid deglaciation in the north, in coastal lowland areas in the southeast, and over Rae Isthmus where flow was governed by the main Foxe dome; *i.e.*, those areas which display limestone-charged drift, on-shore striae, and north-trending drumlins (Rae Isthmus).

After removal of the main Foxe dome, ice recession from parts of the Melville Moraine north of Garry Bay was rapid. A string of small glacial lakes developed in valleys draining to Committee Bay, where meltwater flow was impounded by the Melville Moraine. Once the ice margin retreated to a position east of the drainage divide, ice-dammed lakes developed (locations on Fig. 5).

During wasting of the remnant ice sheet, valley glaciers occupied two U-shaped troughs flowing into Fury and Hecla Strait. The recession of these outlet glaciers is marked by small moraines in the valleys of Quilliam Bay and Griffiths River (Fig. 1).

Recession of plateau ice (Melville subsidiary divide)

Ice flowing from divides in the south remained active after the disappearance of Foxe Basin ice. Cross-cutting striae show that the northern edge of the remnant Melville Ice mass advanced northwards across areas formerly occupied by Foxe Basin ice. Streamlined forms, and the trend of one esker terminating at a glaciomarine delta at its eastern extremity, indicate that there were flow reversals along the southeast coast (Figs. 5 and 8C).

FINAL GLACIAL STAGES (FIG. 8D)

In the area between Hall Lake and Lailor Lake (site N, Fig. 4), marine limits are at elevations of 75-90 m, much lower than along the rest of the east coast, indicating persistence of late ice. Radiocarbon dates on shells at 75 m indicate that ice persisted until just before 5.5 ka BP (Dredge, 1991; GSC-4453). Small eskers containing shield clasts derived from the central uplands show that the ice gradient was eastward, the reverse of that of the Foxe dome, and De Geer moraines (Dredge and Nixon, 1993) also record recessional positions where the ice front abutted the sea. Above the marine limit, hummocky, ablation till marks the last position of the stagnant northern ice remnant.

Within the area of remnant ice on the plateau west of Cape Jermain, parallel swaths of washed rock up to 20 km long, containing small esker segments, indicate removal of till/regolith by subglacial meltwater beneath the receding ice sheet. The location of these features relative to block fields suggests that they formed where, and when, there was rapid melting of cold-based ice that had carried little glacial debris. The parallel arrangement of channels (vs networks) suggests that they formed near the receding ice margin, where the ice surface slope was steep. Channels west of site B (Fig. 4) end in marine-limit deltas which formed about 6.4 to 6.9 years ago, but others grade into proglacial outwash and deltas that formed later, when sea level had dropped to about 100 m, approximately 6.2 ka BP (GSC-4812).

Near the southeast coast, small eskers radiating from the Aua River area and low marine limit elevations, suggest that a remnant ice mass existed after the sea had inundated other parts of the coast. The marine limit of about 130 m there, compared with limits and deglaciation dates in nearby areas (Table I), suggests that ice persisted about 300 years after it had withdrawn from adjacent areas. Hummocky till in the vicinity suggests that remnants of this late ice mass stagnated.

Remnant ice caps on Hurd Peninsula and the central Plateau persisted at least until the mid-Holocene (later than 6.2 ka BP). Subglacial and supraglacial meltwater were the most important agents modifying the landscape as these ice caps thinned. The sudden abundance of subglacial meltwater implies a rapid change from cold-based to warm-based conditions. Extensive boulder lags amidst islands of unmodified regolith suggest widespread subglacial drainage through permeable sandy regolith in the blockfields. In the Ajaqutalik River valley on the east side of the central plateau, nested lateral meltwater channels record the recessional pattern of outlet ice tongues onto the central plateau. These channels are subparallel, short, shallow, and interconnected, cutting into both rock and block fields. Less extensive flights of lateral meltwater channels on the north side of the Hurd plateau attest to late ice tongues in that area as well. The nested stacking of these channels suggests that downwasting exceeded backwasting during their formation. The last small remnants of the ice caps probably stagnated, but the time of final disappearance of the ice caps is unknown. However, these upland areas are snowfree for very brief periods at present: cap ice could have persisted until Late Holocene.

REGIONAL CONTEXTS

ICE SHEET MODELS

Until 1960, diagrams and regional maps showing the extent of glaciation were either blank in the area of Melville Peninsula, or showed ice flowing eastwards across the peninsula from an ice centre in the District of Keewatin (Prest, 1957; Craig and Fyles, 1960 summarized in Prest, 1990). This ice configuration was maintained into the 1980s by some modellers (*e.g.* Mayewski *et al.*, 1981), although as early as 1962, field work by Sim (1962) had shown that many ice flow features in fact trended westward. In Sim's interpretation, westward flowing ice from an unspecified ice centre in Foxe Basin crossed all of Melville Peninsula during the last glaciation (Fig. 9A), but local ice caps on the central plateau developed during late stages of deglaciation after Foxe Basin became ice-free. His basic model has been upheld by more recent field work reported in this paper, although some details differ. He believed that the westward-flowing ice encountered eastward-flowing Keewatin Ice on the west side of the peninsula (Sim 1960a; Fig. 9A), forming an interlobate moraine (the Melville Moraine). In contrast, Ives and Andrews (1963; Fig. 9B) explained all ice flow on Melville Peninsula and Baffin Island during the last glacial maximum as radiating from a central dome in Foxe Basin, as did Andrews and Sim (1964). Craig (1965a), and later Dyke and Prest (1987; Fig. 9C), upheld these ideas, and Andrews (1989) continued to show carbonate dispersal across southern parts of the peninsula.

Dredge (1995) indicated that there were major ice flows from Foxe Basin and later from Baffin Island across the northern part of Melville Peninsula, but that there may have been a non-erosive ice cap on central Melville Peninsula. Dredge (1990) also reinterpreted the Melville Moraine as a part of the recessional Cockburn Moraine System, related to deglacial calving bays rather than as the full-glacial interlobate feature of Sim (1960a). The model presented in this paper argues for ice that initially accumulated on upland areas and formed an ice dome on Melville Peninsula. This dome was subsumed into the larger ice sheet during the last glacial maximum, but remained as a subsidiary ice divide (Fig. 9D). During the last glacial maximum, warm-based ice controlled by the central Foxe divide crossed northern Melville Peninsula and followed through Rae Isthmus, whereas trajectories of ice on southern Melville Peninsula, which was cold-based in some areas, emanated outwards from the subsidiary ice divide. Boothia Peninsula (Dyke, 1984), and the area west of Rae Isthmus were covered by Keewatin/M'Clintock ice. The zone of convergence of ice from the Keewatin and Baffin Sectors lies along Rae Isthmus and extends northward into Committee Bay.

MULTIPLE GLACIATIONS IN THE NORTHEASTERN ARCTIC

Most of the glacial events discussed in this report probably correlate with events of the Foxe Glaciation on Baffin Island and the Eclipse Glaciation on Bylot Island (summarized in Andrews, 1989). The Foxe Glaciation had been divided into three stades, roughly corresponding to the Early, Middle and Late Wisconsin glacial stades in southern Canada. Dated coastal exposures on Baffin Island reveal that, unlike southern Canada, glacial ice was present throughout much of the Middle Foxe stade, although there is some evidence of deglaciation around the coasts. The nature of the regolith in the blockfields suggests that the last non-glacial interval on

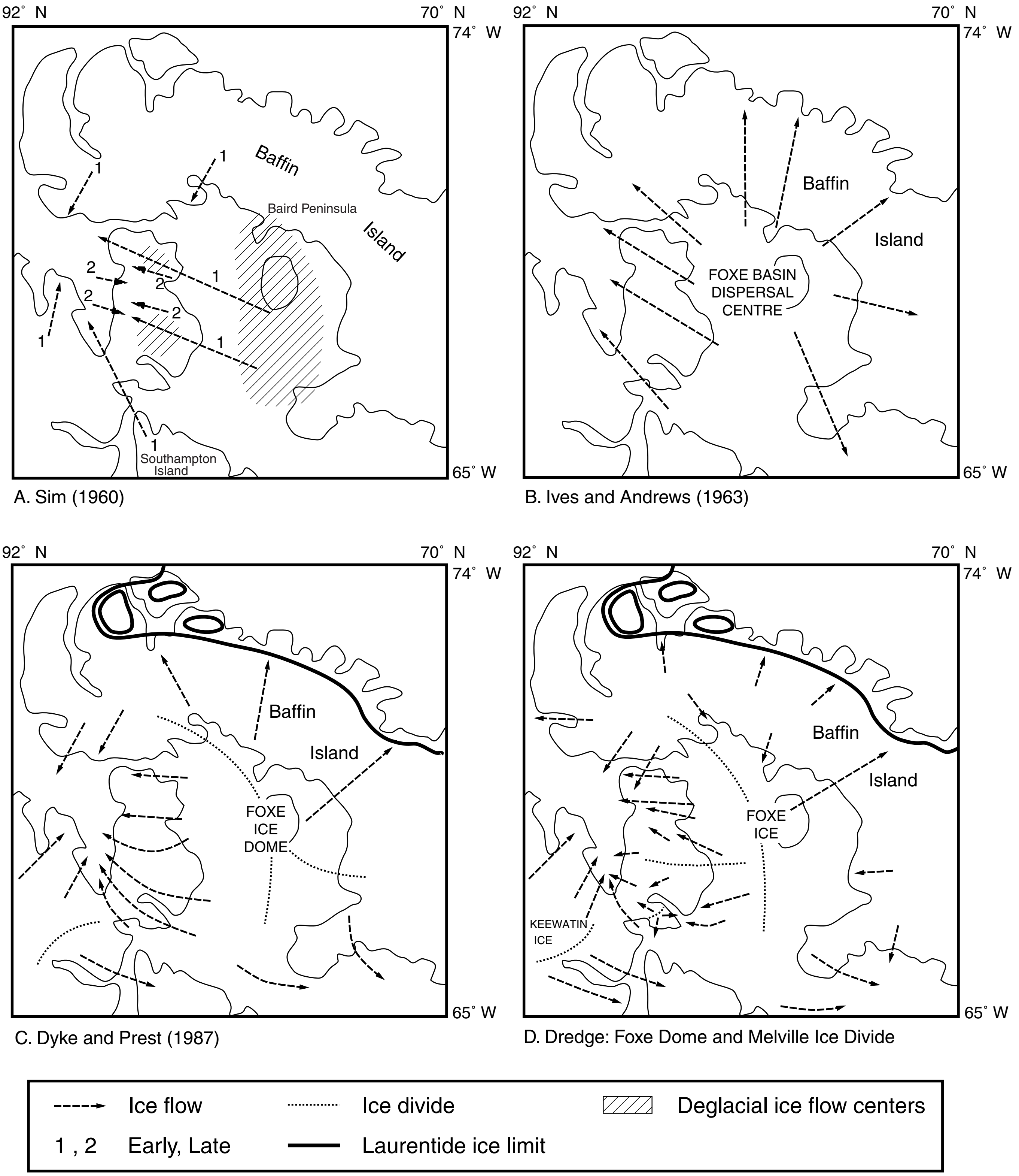

FIGURE 9. Ice sheet models.

Différents modèles de l'inlandsis.

Melville Peninsula was a full interglaciation, suggesting that Melville Peninsula was also ice-covered throughout the Foxe Glaciation.

DEGLACIATION AND ISOSTASY IN WESTERN FOXE BASIN

The marine-based ice sheet in Foxe Basin broke up about 1 000 years later than its counterpart in Hudson Bay (Dyke and Prest, 1987), in part due to paleoclimatic factors, and in part because the Foxe dome was stabilized by high ground around much of its perimeter. Dates from near the marine limit along the east coast of Melville Peninsula suggest that the marine-based ice sheet destabilized about 6.8-6.9 ka (6880 ± 180; GSC-291; Craig, 1965b). The oldest eastern Melville dates, compared with other dates from around Foxe Basin, such as 6930 ± 150 (GSC-782) and 6890 ± 210 (GSC-838; Lowdon *et al*., 1971) from northern Southampton Island, and 6725 ± 250 (I-406, Ives, 1964) from Baird Peninsula (Fig. 9) and southern Baffin Island (Andrews, 1966; Blake, 1966), indicate that all areas peripheral to Foxe Basin were deglaciated at roughly the same time. However, a date of 7.0 ka BP (GBL-311-66; Bird, 1970) from southern Southampton Island, while similar to others, is from a site at 127 m, roughly 50 m below marine limit; Bird estimates that the time of deglaciation was actually about 7500 BP on Southampton Island. The date of 6.9 ka BP (GSC-5132), from north of Frozen Strait on Melville Peninsula and also well below marine limit, supports the idea that the southern part of Foxe Basin opened up earlier than the north, so that there may have been a rapid south-to-north removal of the marine-based ice sheet throughout Foxe Basin. Areas away from the Foxe Ice Centre, such as Fury and Hecla Strait, were deglaciated later.

In western Foxe Basin, there is a steady lowering in the elevation of the marine limit northward from 180-190 m on Southampton Island (Bird, 1954, 1970) to 170-180 m along Frozen Strait on southern Melville Peninsula and Vansittart Island (Mattiassen, 1933); to 150 m at Cape Jermain; to 110-120 m on northern Melville Peninsula; and to 110 m on Baird Peninsula and 95 m at Steensby Inlet (Ives, 1964) on Baffin Island. If all of Foxe Basin was deglaciated at approximately the same time, as shown by radiocarbon dates, then the regional marine limit pattern suggests that the centre of loading about 6900 BP was in south-central Foxe Basin. Glacioisostatic unloading probably began while ice still covered Foxe Basin (Farrand and Gajda, 1962) and definitely predated deglaciation of most of southern Melville Peninsula, which was covered by Melville Ice.

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