Arctic and Alpine Research, Vol. 10, No. 3, 1978, pp. 617-633
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"COCKBURN" NOMENCLATURE AND THE LATE QUATERNARY HISTORY OF THE EASTERN CANADIAN ARCTIC*

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ABSTRACT

A system of end and lateral moraines, extending from near Frobisher, Baffin Island, to the west of the Penny Ice Cap, and roughly parallel to the fiord heads of the northeast coast to Bernier Bay, was identified in the 1960s and given the name "Cockburn end-moraine system." Since then the name "Cockburn" has been used in conjunction with several distinct types of stratigraphic units and landform assemblages. The three main uses are (1) Cockburn end-moraine system, Cockburn moraines, Cockburn Moraine, which are all morphostratigraphic units; (2) Cockburn Stade, which is a geologic-climatic unit; and (3) Cockburn Glacial Phase, which was originally defined as occurring between 8000 and 9000 radiocarbon years ago, and which is, therefore, a chronostratigraphic unit. Thus there is an ambiguity in present usage that has developed over the last 15 yr as knowledge of the glacial morphology and stratigraphy of the eastern Canadian Arctic has expanded. In this paper an attempt is made to reduce this ambiguity by preparing new definitions.

Cockburn Substage. A chronostratigraphic division of the Holocene Series based upon radiocarbon-dated sediments between 8000 and 9000 BP. Analysis of available radiocarbon dates, all on marine shells, indicates that the original definition of the "Cockburn Glacial Phase" is sufficiently within the possible margin of dating errors and stratigraphic content to warrant retention of the time span prior to the disintegration of the Laurentide ice sheet and entry of the sea into Hudson Bay. Many major moraines were deposited during that period and in places the Laurentide ice sheet may have readvanced to reach its maximum late-glacial extent. Moraines deposited between 8000 and 9000 BP can properly be referred to as "moraines of Cockburn age."

Baffinland Drift. This litho-/morphostratigraphic unit replaces "Cockburn end-moraine system," as originally described, and synonymous terms. The Baffinland Drift includes the complex of moraines, till, outwash deposits, and glaciomarine deposits that together form the recognizable and mappable unit paralleling the fiord heads of northeastern Baffin Island. It can be differentiated from older Quaternary units on air photographs by freshness of topographic expression and a general absence of solifluction features and large-scale patterned ground. The type region for the Baffinland Drift is defined as the fiord heads between Iterbilung and Cambridge fiords; the type area is the inner reaches of Sam Ford Fiord. The youngest glaciomarine units within the Baffinland Drift are radiocarbon dated at between 5000 and 6000 BP. The moraines of Cockburn age (8000 to 9000 BP) are found within the Baffinland Drift on Baffin Island. Correlative

*This paper is a contribution to the IUGS-UNESCO International Geological Correlation Program (IGCP), Project 73/1/24: Quaternary Glaciations of the Northern Hemisphere.

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units, such as the MacAlpine Moraine of north central Keewatin, and the moraines fringing the west coast of Melville Peninsula, were formed during a period of Laurentide ice sheet stillstand and/or readvance that had been preceded by and was followed by, periods of rapid retreat, thus contrasting with events along the northeastern perimeter of the ice sheet on Baffin Island.

The use of terms such as "Cockburn Moraines" or "Cockburn end-moraines" should be discontinued. Individual morainic ridges need to be mapped, named, and correlated, either by direct field mapping or by reference to radiocarbon dated glaciomarine facies.

Kangilo Substage (5000 to 8000 BP) and *Remote Lake Substage* (9000 to 10,000 BP) are defined as subdivisions, along with Cockburn Substage, of the Holocene.

INTRODUCTION

The purpose of this paper is to review the evolution of the term "Cockburn[1] Moraine System" (Ives and Andrews, 1963) and to propose restrictions on future usage through presentation of a more rigorous set of definitions. The need for such a stand arises from the use of the term in 1961 to provide a general name for a massive system of moraines that were seen to extend for more than 1000 km inland from and parallel to the northeast coast of Baffin Island, but which had not been investigated in the field. Because the name was proferred before the full extent of the moraine system had been determined, or its significance fully understood, it was inevitable that conflicting usages would arise as the intensity of research increased. We will concern ourselves primarily with the deposits comprising the "Cockburn Moraines" that extend from northern Baffin Island approximately parallel to the fiord heads, passing to the west of the Penny Ice Cap in the south, and reaching tidewater in Frobisher Bay (Figure 1). We will only briefly refer to correlatives elsewhere in arctic and subarctic Canada.

The discussion is divided into three parts: the first consists of a review of the development of the stratigraphic nomenclature related to "Cockburn"; the second is a series of definitions which are intended to lay the foundation for less ambiguous usage in the future; and the third considers the spatial and temporal position of the "Cockburn Moraine System" within the Late Quaternary history of Baffin Island.

Terms such as "Cockburn Moraines" and "Cockburn end-moraine system" have been used to designate morphostratigraphic units. Such units are not recognized by the American stratigraphic code (American Commission on Stratigraphic Nomenclature, 1961), the *International Stratigraphic Guide* (Helberg, 1976), nor were they favored by Flint (1971: 200). However, Frye and Willman (1962) and Willman and Frye (1970) argued for the use of morphostratigraphic units, and in Fennoscandia, Quaternary geologists favored the retention and use of such units (Mangerud *et al.*, 1974). In Canada, morphostratigraphy forms the key element in the Quaternary mapping program of the Geological Survey of Canada (cf. Hodgson and Haselton, 1974; Fulton *et al.*, 1975). In other parts of North America the word "drift" is frequently used to designate the complex of landforms and sediments associated with a major glacial cycle of advance, stillstand, and retreat (Flint, 1971, Figure 8-1). The recognition of different drift sheets is based on moraine morphology, morphostratigraphic relations of moraines (cross-cutting relationships), volume of associated meltwater, and the extent of former glaciers and regional reconstructions of former glacier equilibrium-line altitudes (Denton, 1974; Hamilton and

[1]Sir George Cockburn (pronounced "Coburn") was First Chairman of the Arctic Committee, Lord of the Admiralty 1834-35 and 1841-46. W. E. Parry says he named the northern portion of Baffin Island after Cockburn "whose warm personal interest in everything relating to northern discovery can only be surpassed by the public zeal with which he always promoted it." (p. 330) (Parry, W. E., 1824: *Journal of a Second Voyage for the Discovery of a Northwest Passage.* John Murray, London. 571 pp.) At the time Parry named "Cockburn Island," Cockburn was a Vice-Admiral and Lord Commissioner of the Admiralty.

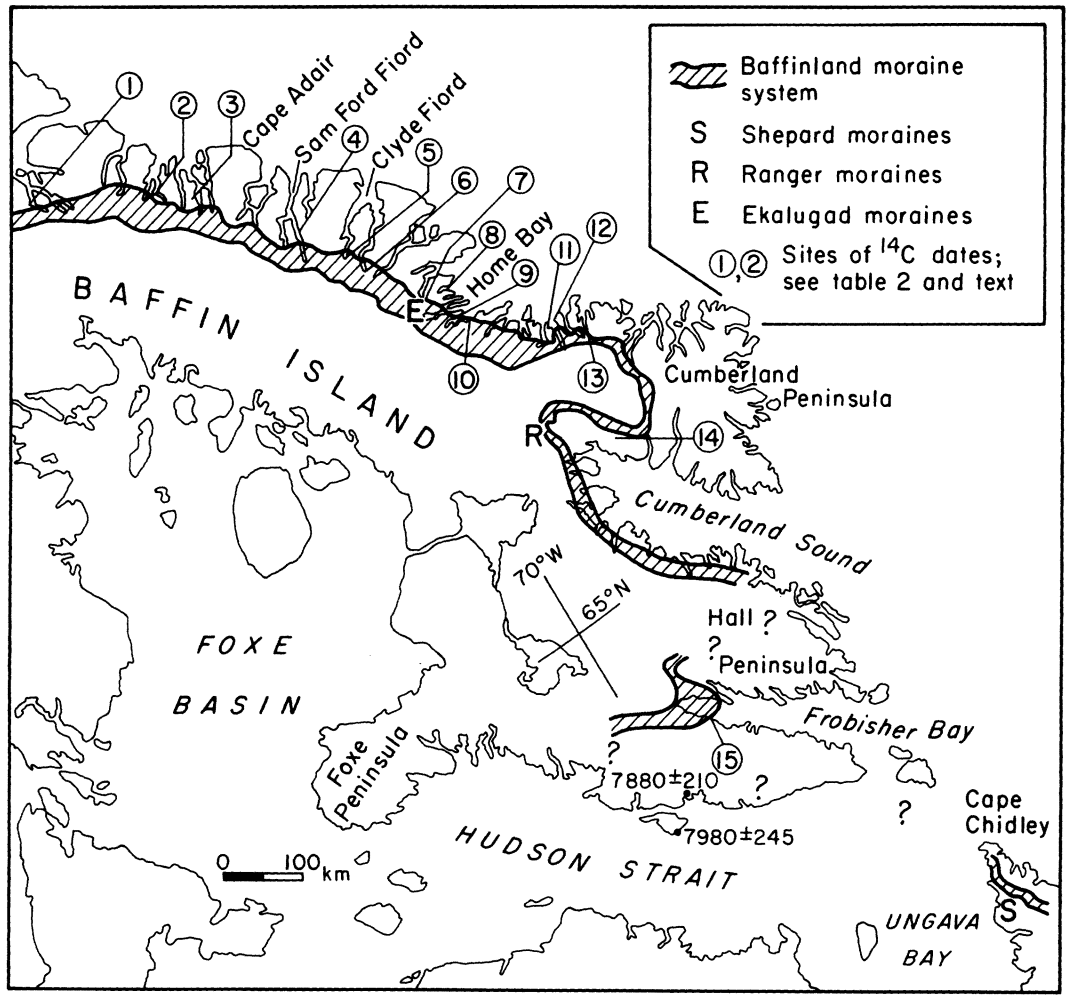

FIGURE 1. Location map of the "Cockburn end-moraine system" (after Falconer *et al.*, 1965b) showing location of radiocarbon dates associated with the moraines (see Table 2).

Porter, 1975). Correlation is aided by radiocarbon dates. Willman and Frye (1970: 44) recommended that "drift" be the formal morphostratigraphic glacial unit. Morphostratigraphic units, such as moraines, may or may not transgress time, and they may or may not be lithologically distinct (Frye and Willman, 1962: 112).

"COCKBURN" NOMENCLATURE (1960 TO 1978)

The history of "Cockburn Moraine System" nomenclature can be traced to the preliminary air-photograph interpretation by Ives during the 1960/61 winter. This was in preparation for what was to become the major research program of the former Geographical Branch, Canada Department of Energy, Mines and Resources, during the period 1961 to 1967. Rapid examination of hundreds of photographs revealed an extensive system of end and lateral moraines which formed a broad belt stretching almost the entire length of Baffin Island inland from the high mountains and fiords of the northeast coast. Following consultation with R. P. Goldthwait (pers. comm., March 1961), it was realized

that members of the 1950 Arctic Institute of North America expedition to Baffin Island, and especially Goldthwait himself, had observed large morainic loops that extended between Clyde and Sam Ford fiords; these were judged to be potentially important for any attempt to decipher the Quaternary history of the region. "Regular stages of thinning of the ice tongues are marked by many lateral moraine benches on fiord walls, and a few of these connect from the head of one fiord to another suggesting simultaneous stages" (Goldthwait, 1950: 139-141).

Following fieldwork in 1961 by Ives and Andrews (during which it proved impossible to visit the "Cockburn Moraines" on the ground because of logistical difficulties), a preliminary overview paper was prepared, which included the Cockburn Land map sheet of glacial features of the north-central tract of Baffin Island (1:500,000, N.T.S.). This involved more detailed air-photograph reinterpretation and the first formal use of the name "Cockburn end-moraine system" to be applied to the moraines occurring "just inland of the heads of the Baffin Bay fiords—as a broad belt of closely spaced, individual morainic arcs—[which] in places send offshoots as lateral and end-morainic lobes into the heads of the fiords" (Ives and Andrews, 1963: 17).

Individual morainic crests were noted to be between 4 and 40 m high, while the system varied in width between 10 and 26 km. Between 8 and 25 discrete ridge crests in any one area were identified. The system is distinct from, and much younger than, an equally massive moraine system that loops around the headlands between the fiord mouths on the outer coast of Baffin Bay and which were given the preliminary name of "Clyde Moraines" (Ives and Andrews, 1963: 36).

The names Cockburn Lake and Cockburn River were proposed for a major unnamed lake and a major unnamed river of the area. These names were accepted by the Canadian Permanent Committee on Geographical Names. This move was made to ensure preservation of the toponym "Cockburn" on Baffin Island since at that time no official place name remained following discontinuance of the old name "Cockburn Land."

The "Cockburn Moraines" were used as a basis for delimiting two geologic-climatic units: Cockburn I Phase (or glaciation) and Cockburn II Phase. This rather crude separation was made to distinguish an earlier period, when outlet glaciers penetrated to tidewater in most of the major fiords, from a later period when most of the Laurentide ice sheet perimeter on Baffin Island had withdrawn southwest of the local watershed and ice-dammed lakes had begun to form along its margin. No radiometric dates were available in 1963. Despite this, it was speculated that Cockburn II dated at about 7000 BP; Cockburn I may either correlate with the Saglek Moraines of northern Labrador (Ives and Andrews, 1963: 36) or date from about 10,000 BP. These intuitive propositions have been at least partially substantiated by subsequent radiocarbon dates. The 1963 paper formed the basis for a concerted drive to study further this important moraine system. This task has received additional attention as part of the University of Colorado INSTAAR Eastern Arctic Program (Andrews *et al.*, 1972; Miller and Dyke, 1974; and others).

The first detailed fieldwork on the moraines was undertaken in 1964 by Smith (1966) following brief aircraft visits in selected fiords by J. T. Andrews, G. Falconer, J. D. Ives, and O. H. Løken. This work led to a fuller understanding of the importance of the "Cockburn Moraines" in two ways: (1) Smith's study provided the beginnings of an absolute chronology and pointed to the complexity of the system in one particular area (Sam Ford Fiord) (Figures 1, 2, and 3); and (2) it was suggested that the perimeter of the system could be extended from Baffin Island onto Melville Peninsula and across central Keewatin to appear as one of the most widespread and continuous moraine systems recognized anywhere in the Arctic (Falconer *et al.*, 1965a, 1965b). This set the stage for a considerable growth in interest in the "Cockburn moraine system." Table 1 synthesizes the major papers of the last 14 yr that have discussed "Cockburn" terminology and associated concepts. Only a few of these will be examined here to illustrate the profusion of usage, with its ensuing confusion, so that a foundation can be laid for a reiteration of essential definitions.

With the recognition that the "Cockburn Moraines," or their correlatives, could be traced across central Keewatin and possibly even into northeastern Manitoba and northwestern Ontario, Falconer *et al.* (1965a,

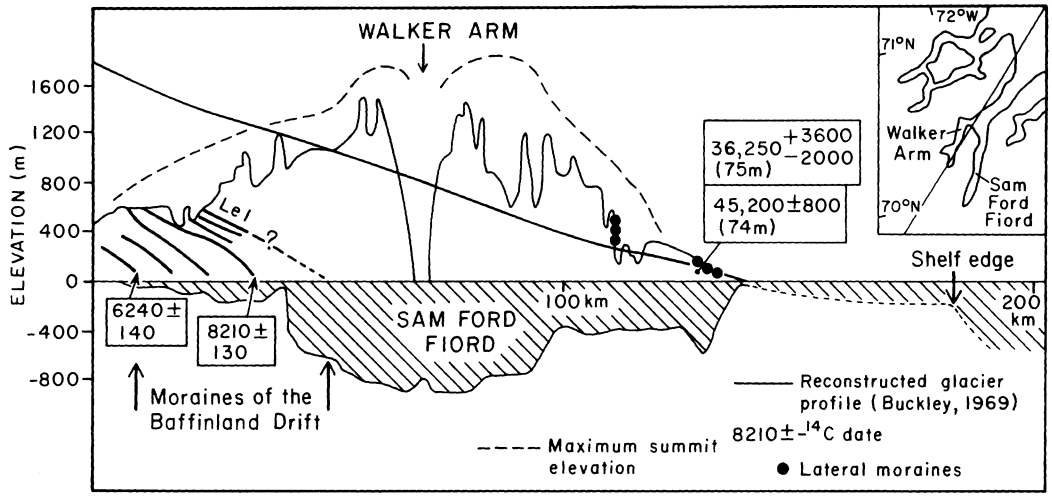

FIGURE 2. Cross section along Sam Ford Fiord (from Buckley, 1969) from the inner reaches of the fiord, studied by Smith (1966), to the outer part of the fiord (Ives and Buckley, 1969). The profile of the ice sheet during the time when moraines were deposited above Remote Lake is taken from Buckley's study of the gradient of present outlet glaciers (Buckley, 1969). Radiocarbon dates from Smith (1966), Ives and Buckley (1969), and Miller *et al.* (1977).

1965b) concluded that they had identified the northern perimeter of a major ice sheet that centered over Hudson Bay and Foxe Basin between 8000 and 9000 yr ago. In addition, they also stated that the "Cockburn Moraines" are "complex and span a time range from 5,000 to 9,000 years." Thus two concepts were emerging; one of which refers to a specific and rather short interval of time, and the other concerns the greater age range of the entire *width* of the moraine system. The shift toward a specific and restricted time definition was accentuated by Falconer *et al.* (1965b: 148) where they stated: "Under these circumstances it is proposed that the term 'Cockburn' be restricted to the moraines constructed between 8,000 and 9,000 years ago so that the single 'Cockburn Phase' will represent the Late Wisconsin residual ice sheet . . . ." The term "Cockburn Phase" was intended to represent that relatively short period of time when the residual Laurentide ice sheet retained its integrity immediately prior to its rapid, and presumably catastrophic collapse and disintegration with the entry of salt water into Hudson Bay. It was at this stage in the evolution of "Cockburn" usage that the attraction of the concept of the "Cockburn Phase" began to complicate stratigraphic terminology and chronology of the actual multiple moraine ridges and associated deposits on Baffin Island.

During the same period, the first opposing interpretations appeared. Craig (1965), dealing with northern Baffin Island and the Arctic mainland, argued that the various and somewhat distinct lengths of moraine, which Falconer *et al.* (1965b) proposed to mark the northern perimeter of a single ice sheet, were in fact delimitations of the outer margins of a series of separate remnant ice caps, the inner margins of which lay beneath tidewater in Hudson Bay and Foxe Basin. Blake (1966: 2) concluded that the Falconer *et al.* (1965b) correlation of the "Cockburn Moraines" of southern Baffin Island with the Sheppard Moraines of northern Labrador (Løken, 1964) was incorrect. Falconer *et al.* (1965b) had assumed an ice margin across eastern Hudson Strait, whereas Blake (1966) argued for correlation with a series of prominent end moraines on Foxe Peninsula (Figure 1), thus concluding, in agreement with Craig (1965), that Hudson Strait and Hudson Bay were already partly open water by approximately 8200 BP. On current evidence it seems that the Falconer *et al.* (1965b) hypothesis is the most realistic, although a firm conclusion will await adequate radiometric dating control from the east coasts of Ungava Bay and Hudson Bay, and Foxe Peninsula.

Andrews and Ives (1972) and Andrews *et*

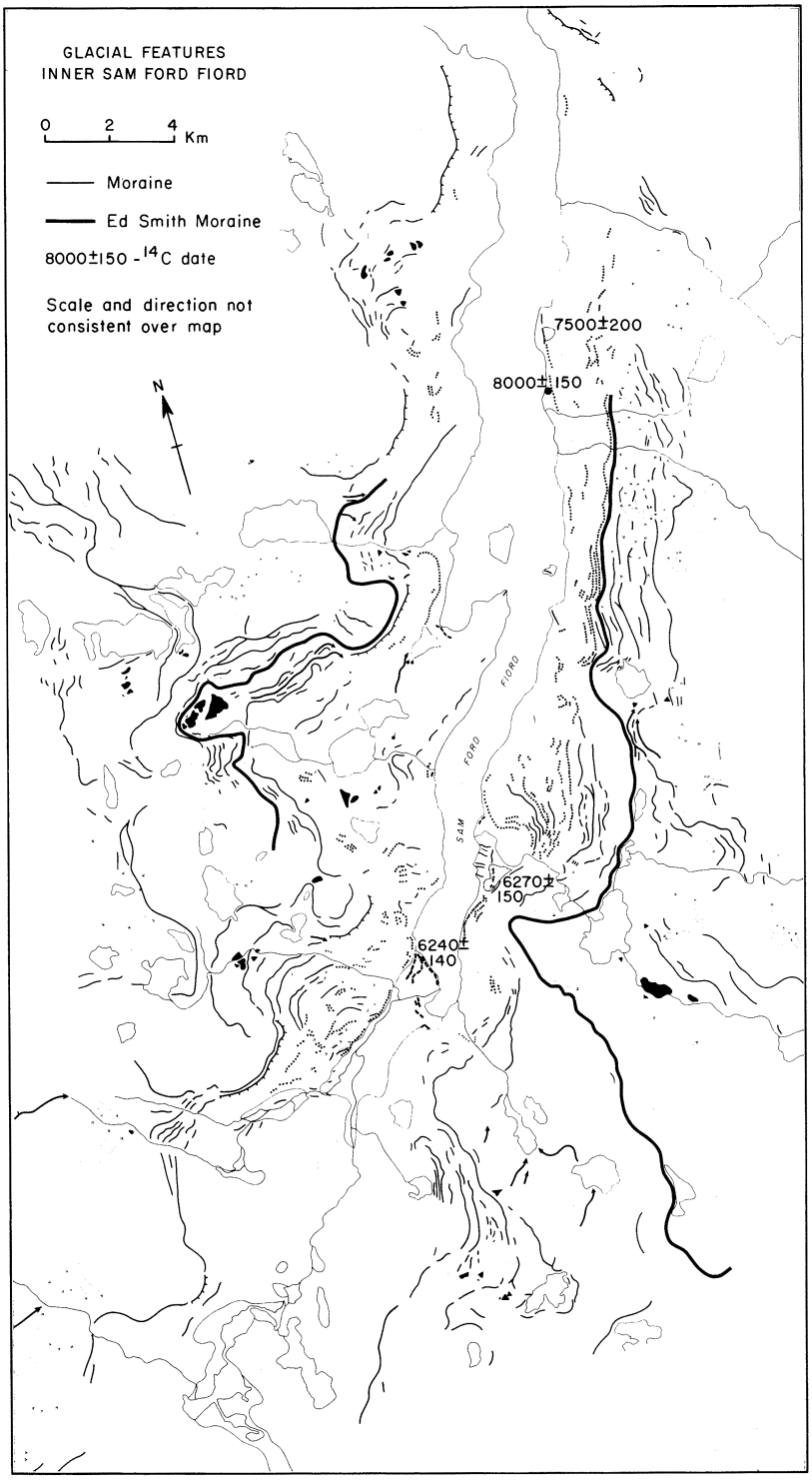

FIGURE 3. Map of the moraines in inner Sam Ford Fiord (from Smith, 1966) showing available radiocarbon dates and the Ed Smith Moraine (Le4 moraine, Smith, 1966).

TABLE 1

References, terminology, and definitions in papers dealing with the Cockburn end-moraine system

Reference	Terms used (when new)	Comments
Ives and Andrews (1963)	Cockburn end-moraine system Cockburn I phase (or glaciation) Cockburn II phase	The original recognition and definition of the moraine belt near the fiord heads. Age was unknown, but Cockburn II was suggested to be 7000 BP or Cochrane (~ 8000 ± BP).
Falconer *et al.* (1965a)	Cockburn moraine system Cockburn moraines	Extended concept to include suggestion that the Baffin Island Cockburn moraines were part of a larger system.
Falconer *et al.* (1965b)	Cockburn Moraines sensu lato Cockburn Phase Cockburn Glacial Phase Cockburn system Cockburn Moraine System	An elaboration of 1965a. The Cockburn phase on Baffin Island suggested to represent a stillstand or readvance dated between 8000 and 9000 BP. Correlative moraines used to suggest outline of continental-size ice sheet.
Craig (1965)	Cockburn end-moraine system	Adds new dates and points out area of north Baffin Island is complex. ". . . radiocarbon dates do not contradict such a reconstruction" (i.e., Falconer *et al.*, 1965a).
Smith (1966)	Cockburn phase	Detailed field mapping and dating of shells.
Blake (1966)	Usage as in Falconer *et al.* (1965b, 1965a)	"Necessitates a considerable change in the outline of a diminished Laurentide Ice Sheet during the so-called 'Cockburn Glacial Phase.'"
Bryson *et al.* (1969)	Usage as in Falconer *et al.* (1965b)	
Andrews and Ives (1972)	Cockburn Moraines	Point out absence of dates older than 10,000 BP; evidence for marine transgression; suggest Cockburn Moraines = Late Wisconsin maximum.
Andrews *et al.* (1972)	Cockburn Stade	Late glacial advance dated ca. 8000 BP; Cockburn associated with marine transgression; Cockburn = Late Wisconsin maximum.
Miller and Dyke (1974)	Cockburn Moraine System Cockburn Moraine	Consideration of variety of evidence for restricted Late Wisconsin-ice. Ice *remained* at moraine until 8000 BP. Data indicated similar late glacial history applied to local cirque glaciers.
Miller (1973)	Cockburn advance	Two closely spaced moraines.
Hodgson and Haselton (1974)	Cockburn end-moraines	Readvance stage in general retreat of Laurentide ice sheet.

al. (1972) examined radiocarbon dates from glaciomarine facies deposited at the margin of the ice during the "Cockburn Phase" and shoreline deposits from the outer coast. Andrews and Ives (1972) concluded that evidence from Clyde and Inugsuin fiords (5 and 6) (numbers refer to sites in Figure 1 and Table 2) suggested that the "Cockburn Moraines" were the same age as a major marine strandline that tilted up toward the southwest. Andrews *et al.* (1972) reached a similar conclusion from radiocarbon dates on marine shells from sites on northern Cumberland Peninsula (11, 12, 13). In each area, the "Cockburn Moraines" were apparently associated with an early Holocene marine transgression along the outermost coast of Baffin Island. Both papers argued that the "Cockburn Moraines" represented the maximum stand of the Late Wisconsin Laurentide ice sheet along much of its northeastern perimeter (Figure 4, curve A).

In northeastern Baffin Island, morphostratigraphic mapping by Hodgson and Haselton (1974) led them to state that "the pattern of 'Cockburn' end moraines shows two closely spaced ice marginal positions and a number of minor readvances" (p. 5). Radiocarbon dates of 8090 ± 140 BP and 7890 ± 160 BP were obtained from associated glaciomarine sediments (2 and 3). Their morphostratigraphic map (CGS Map 1395 A) appears to indicate a difference in till morphology between the "Cockburn" drift sheet, and deposits distal to it, which are frequently labelled as a soliflucted till. Hodgson and Haselton (1974) used "Cockburn end moraines" to designate the entire moraine belt, thus reverting to the original usage of Ives and Andrews (1963). They dated the inner limit of the moraines at 6330 ± 140 BP, a date similar to radiometric determinations from the head of Sam Ford Fiord (Løken *in* Smith, 1966), and from Frobisher Bay (Blake, 1966). Løken (1965) also shows that members of the moraine system at the head of Inugsuin Fiord occur on both sides of marine deposits dated at 7900 ± 210 BP. Hodgson and Haselton (1974) questioned the argument presented by Andrews and Ives (1972) and Andrews *et al.* (1972) that the moraines represented the maximum extent of Late Wisconsin Laurentide ice, and instead interpreted them as a readvance stage during the Late Wisconsin deglaciation (e.g., Figure 4, curve B).

TABLE 2
Radiocarbon dates

No.[a]	Date (BP)	Lab. No.	Assessment[b]
1	8350 ± 300	(I-724)	B
2	7890 ± 160	(GSC-1064)	D
3	8090 ± 160	(GSC-1060)	B
4	8210 ± 130	(I-1933)	A
5	7940 ± 130	(I-1932)	C
6	7970 ± 340	(I-1673)	C
7	8430 ± 140	(Y-1830)	A
8	8630 ± 190	(GSC-813)	A
9	8435 ± 105	(GX-0930)	D/A
10	7820 ± 140	(Y-1834)	B
11	8410 ± 340	(GSC-1638)	B
12	8760 ± 350	(St-3816)	B
	8290 ± 170	(GaK-3092)	B
13	8930 ± 180	(GaK-5479)	D
14	8660 ± 110	(GSC-2183)	B/C
15	8230 ± 290	(GSC-462)	B/C

[a]Refers to Figure 1.
[b]Assessment of dates and associated moraines
A = dates readvance, or prior to readvance
B = dates ice-contact glaciomarine unit
C = dates retreat from moraine
D = exact relationship not known or specified

Miller and Dyke (1974) remapped the "Cockburn Moraine System" along its entire length in Baffin Island. They noted that "well-developed patterned ground"[2] occurs on drift on its distal side and concluded that "the Cockburn end-moraine system is coincident with the Late Wisconsin glacial maximum." The difference in interpretation between Hodgson and Haselton (1974) and Miller and Dyke (1974) is fundamental and is illustrated in Figure 4 (curves A and B). Studies of surface weathering on boulders, and the development of soil profiles from Cumberland Peninsula (Isherwood, 1975; Locke, 1976; Dyke, 1977; Birkeland, in press) demonstrate that a distinct break in degree of weathering coincides with the "Cockburn Moraine System."

[2]However, it must be noted that massive ice-wedge polygons also occur within the borders of the "Cockburn end-moraine system," according to extensive aerial reconnaissance by Ives (unpublished) and specific field study by Falconer (1966).

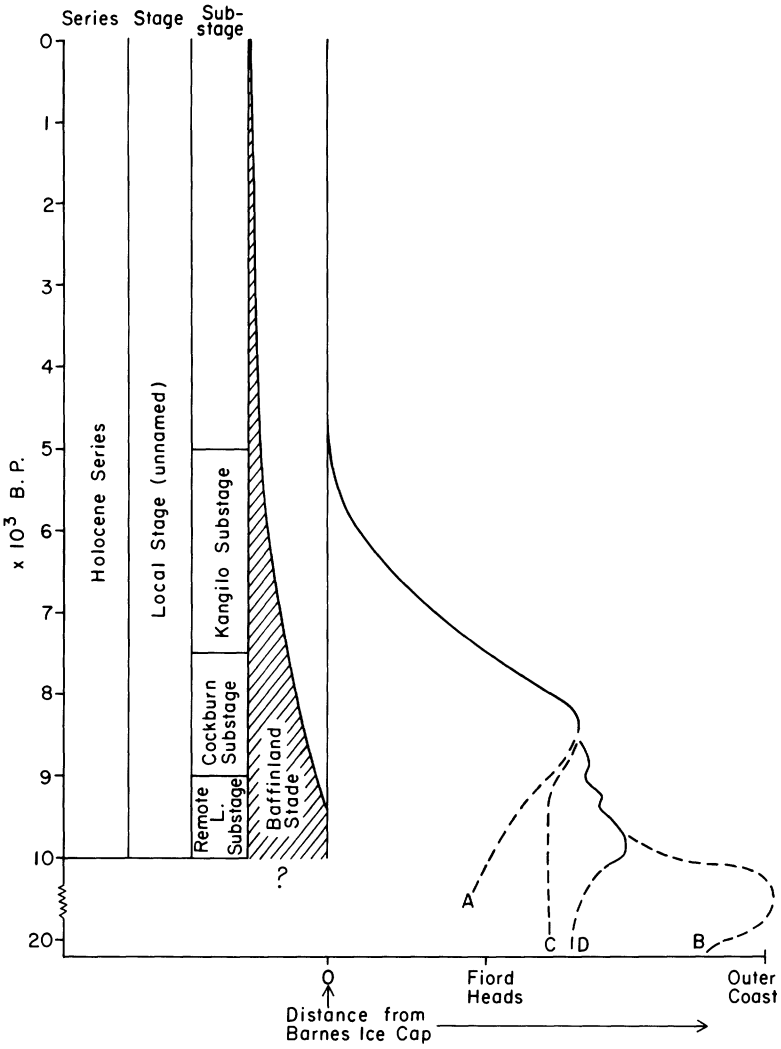

FIGURE 4. Time-distance diagram of possible models for the northeastern margin of the Laurentide ice sheet during the Baffinland Stade. *Left:* chronostratigraphy.

Miller (1973) and Dyke (1977) studied the chronology of glaciation on Cumberland Peninsula. Miller (1973) showed that outlet glaciers from an expanded Penny Ice Cap and from local cirque basins were associated with glaciomarine sediments dated at 8290 ± 170 BP, 8410 ± 350 BP, and 8760 ± 350 BP (12 and 11). These dates are related to the outer limit of the "Cockburn Moraine System." The variability of local glacier response is seen by the fact that Miller (1973) recorded no major glacial oscillations between 8000 and 6000 BP, a time when several minor oscillations of the ice margin affected areas both to the north and south (Løken, 1965; Blake, 1966; Smith, 1966; Andrews *et al.*, 1970; Hodgson and Haselton, 1974). Dyke (1977) mapped moraines on southern Cumberland Peninsula which trace the connection between the Laurentide ice sheet and the local Penny Ice Cap (Figure 1). These were named the Ranger moraines which Dyke, from their association with glaciomarine deposits, dated at 8660 ± 110 BP (14). Eleven closely spaced end moraines were mapped by Dyke at the head of Cumberland Sound and record slow retreat of the Laurentide ice sheet between 8600 and 5600 BP.

A solution to the problem of explaining the pattern of radiocarbon dates from raised

marine sediments (few between 10,000 and 40,000 BP and a clustering of dates between 8000 and 9000 BP) was attempted by Andrews (1975) who used three distinct ice-load histories (cf. Figure 4) in a dynamic, but simple, glacial isostatic model. The results of the experiments indicated that the observed postglacial emergence (elevations and ages) could not be explained by ice extending to the outer coast during the late glacial maximum; the emergence could, however, be accounted for if the "Cockburn moraine system" represented the Late Wisconsin terminal position of the Laurentide ice sheet (Figure 4, curve A). Similar data are presented by Dyke (1977) from Cumberland Sound and his emergence curves have been successfully modeled using a viscoelastic, self-consistent earth model which includes the gravitational effect of the ice mass (Clark, 1976 and in press).

While our review has focussed primarily on those papers that deal with the "Cockburn" problem on Baffin Island, it cannot be entirely divorced from the expanded usage of Falconer *et al.* (1965b) and Bryson *et al.* (1969). Nevertheless, it is evident from the discussion (and Table 1) that the adjective "Cockburn" has been used to describe two different morphostratigraphic units (a series of moraines formed between 5000 and about 10,000 BP and a part of this series formed between 8000 and 9000 BP); a geologic-climatic stratigraphic unit (Cockburn Stade); and what was intended to be a chronostratigraphic unit (Cockburn Glacial Phase). In addition, sections of moraine in central Keewatin, dated 8000 to 9000 BP, have been correlated with the 8000 to 9000 BP "Cockburn Moraines" of Baffin Island. Finally, cirque moraines and moraines formed by outlet glaciers from local ice caps on Cumberland Peninsula have also been termed "Cockburn Moraines." The original definition (Ives and Andrews, 1963) clearly includes the entire belt of closely spaced moraines. These moraines are conveniently distant from the lateral- and end-moraine systems (Clyde Moraines) of the outer Baffin Bay headlands (Figure 2) and from the more recent moraines adjacent to the Barnes Ice Cap. The subsequent usage, with the exception of that by Hodgson and Haselton (1974), has favored the more restrictive definition (8000 to 9000 BP). This narrower usage is clearly apparent in the linkage of Cochrane readvance of southern James Bay with the "Cockburn" readvance (Falconer *et al.*, 1965b: 150), and Denton (1974: 890) may therefore refer to the Cochrane-Cockburn readvance of the Laurentide ice sheet.

DEFINITIONS

Multiple use of the term "Cockburn" for different stratigraphic units is not conducive to clarity of description or interpretation. The solution to the "Cockburn" nomenclature problem is possible via two different routes. The first would restore the original definition of the "Cockburn end-moraine system" (Ives and Andrews, 1963) and then go on to define the materials that make up these landforms as the "Cockburn Drift," and thus use the drift to define the "Cockburn Stade." This, strictly, would require the identification of an appropriate type section for the proposed "Cockburn Drift." The second route is to endorse the change in definition proposed by Falconer *et al.* (1965b) and used by Bryson *et al.* (1969). Thus a chronostratigraphic unit, the Cockburn Substage, would be defined using laboratory dates on marine molluscs as the basis for choosing appropriate boundaries (cf. Mangerud *et al.*, 1974). The term "Cockburn Moraines" would, therefore, be abandoned although the glacial and glaciofluvial material deposited between 8000 and 9000 BP would be of Cockburn age. Thus a new name would be required for the entire moraine system as defined by Ives and Andrews (1963), and the way would be open for identifying, dating, and naming individual units.

The choice between these two alternatives must be influenced by considerations of the most frequent present-day usage of "Cockburn" and by the requirement that it be widely adopted by the scientific community. In our estimation, the most frequent recent literature use of "Cockburn" is clearly in the context of events dated between 8000 and 9000 BP, since this refers to a distinct glaciodynamic response of the Laurentide ice sheet

prior to its ultimate disintegration at about 8000 BP. This usage favors the definition of a chronostratigraphic "Cockburn" unit. The following terms are therefore proposed and defined:

BAFFINLAND DRIFT

Porter (1975, 1976) used the term "Drift" to designate surface lithostratigraphic units. Surface weathering of boulders, rind thickness of basalt clasts, and soil development can be used to differentiate one drift unit from another, as can position and gross morphology (e.g., Denton, 1974). We view the concept of "drift units" as a more meaningful approach to Quaternary stratigraphy than morphostratigraphy alone. We thus propose to develop a working definition of the deposits that constitute the "Cockburn end-moraine system." These deposits can be recognized and mapped over extensive areas by different individuals with only minor variations in their boundaries (Ives and Andrews, 1963; Hodgson and Haselton, 1974; Miller and Dyke, 1974). There is still ambiguity in the literature for the area from Hall Peninsula southward to Hudson Strait.

We propose that the term "Baffinland" be used for the drift unit and the associated moraine system. Use of the archaic name for Baffin Island seems appropriate in this case because we are referring to a drift unit that extends almost the entire length of the island. The most conspicuous feature of the Baffinland Drift is the moraine ridges. However, the landform assemblages that we refer to the Baffinland Drift also include ground moraine, outwash plains, and glaciomarine and marine surfaces and deposits. We suggest that the type area for the Baffinland Drift be the inner reaches of Sam Ford Fiord (Figures 1, 2, and 3) to commemorate the work and life of Smith (1966) who undertook the first systematic mapping and dating of deposits along this fiord. Figure 3 is from Smith's unpublished dissertation. He recognized 10 major lateral moraine systems and delimited 5 terminal positions. Moraine Le4 terminates 37 km from the fiord head and is associated with ice-pushed marine clays which are dated at 8210 ± 140 BP (I-1933). Terminal position 6 is 0.4 km from the fiord head and is dated by associated marine sediments at 6240 ± 140 BP (I-1556). Additional radiocarbon dates are located on Figure 3. We propose to name the prominent and massive Le4 moraine (Figure 3) the "Ed Smith Moraine." The oldest members of the Baffinland moraine system, and the outermost limit of the Baffinland Drift remain to be dated in the type area.

Baffinland Drift can be distinguished from both older and younger drift units on the basis of morphology, position, weathering of exposed bedrock (e.g., Mears, 1972; Dyke, 1977), difference in soil development, the weathering of surface boulders, and in the etching of heavy minerals in the soil profile (cf. Mears, 1972; Isherwood, 1975; Locke, 1976; Dyke, 1977; Birkeland, in press) (Table 3). All these data, however, are from the region of Cumberland Peninsula (Figure 1) and this area should be considered a paratype for the Baffinland Drift. No relative-age dating methods have been attempted in the northern fiords close to the suggested type area. However, radiocarbon dates are available (e.g., Falconer *et al.*, 1965b; Løken, 1965) and can be directly compared to the sequence on Cumberland Peninsula (Miller, 1973; Dyke, 1977).

BAFFINLAND STADE

The Baffinland Stade is a division of the Foxe Glaciation (cf. Miller *et al.*, 1977) and is used to designate the glacial-climatic events manifest in the Baffinland Drift. We recognize that we can only document the retreat part of the Baffinland Stade because we lack stratigraphic evidence to date its glacial advance phase. In Figure 4, we illustrate possible alternative models for the time/distance history of the ice margin.

COCKBURN SUBSTAGE

Mangerud *et al.* (1974) proposed that regional chronostratigraphic subdivisions of the Holocene Series be based on radiocarbon dates. They thus subdivided the Holocene Series of Norden into chronozones. We also concur with the argument of Vita-Finzi (1973) that, when radiocarbon dates are available, chronostratigraphic units should be defined on the basis of radiocarbon years. We thus define the Cockburn Substage as a regional, eastern Canadian Arctic, subdivision of the Holocene Series (Figure 4) and adopt the proposal of Falconer *et al.* (1965b) that the time range of this substage be 8000 to 9000 radiocarbon years BP. The Cockburn

Substage includes the deposits that delimit a coherent ice sheet centered over Hudson Bay and Foxe Basin. The upper boundary of the Cockburn Substage marks the date of the change from a single ice sheet to a series of individual ice masses as the sea penetrated rapidly into Hudson Bay and James Bay (Falconer *et al.*, 1965b; Blake, 1966; Bryson *et al.*, 1969; Skinner, 1973; Hardy, 1977). Hillaire-Marcel (1976: 192-193) has obtained a suite of dates from the east coast of Hudson Bay near Great Whale River. Material collected from 2 m and 3 m a.s.l. from the lower part of the section provided ^{14}C dates of 8230 ± 135 BP (I-8363) and 7940 ± 140 BP (Qu-281). The materials dated were carbonate concretions which, because of isotopic fractionation (Hillaire-Marcel, 1976: 193 and table 1) should be corrected to about 8000 BP and 7700 BP, respectively. An additional date of 7625 ± 120 BP (I-9005) was obtained on shells 1 m higher in the section. Finally, Hardy (1977) has obtained a date of 7880 ± 160 BP (Qu-122) from mollusc shells in glaciomarine drift at 162 m a.s.l. on the distal side of the Sakami moraine.

We bring these new dates to the reader's attention because they relate to our general concept of the Cockburn Substage and the final breakup of the Laurentide ice sheet (Falconer *et al.*, 1965b). This is because of our insistence that one method of testing our hypothesis is to look for mollusc shells within the Hudson Bay drainage basin that are significantly older than 8000 BP. We urge that the search continue. The new dates of Hillaire-Marcel (1976) and Hardy (1977), however, while approaching the 8000 BP threshold, and, perhaps, even crossing it, do not yet offer a strong enough challenge.

The 8000 and 9000 BP boundaries for the Cockburn Substage refer specifically to dates based on marine shells. Such dates can be calculated in different ways (Mangerud, 1972; Krog and Tauber, 1973; Mangerud and Gulliksen, 1975; Blake, 1975; Stuiver and Pollach, 1977) and there are disagreements about the exact interpretation of dates from different laboratories. Modern shells from Baffin Island give an apparent age of about 300 yr (Blake, 1975) corrected to $\delta^{13}C = 0\%$ but there is no guarantee that this "apparent age" has been constant throughout the Holocene. Accordingly, we do *not* correct any of the dates we list on Figures 1 and 5 or

TABLE 3

Weathering and soil characteristics and other age-dependent criteria of the Baffinland Drift

Reference	Criteria	"Younger" (Neoglacial Deposits)	Baffinland Drift	"Older" Deposits
Miller (1973)	Ice-cored moraines	Yes	No	No
Carrara and Andrews (1972)	Lichen cover (%)	0-63	>80	>80
Isherwood (1975), Birkeland (in press)	Soil depth (cm)	0-2	~10-15	>30
Isherwood (1975)	Clay minerals	Illite	Illite	Vermiculite
Pheasant (1971)	Fresh surface boulders[a] (%)	96	40	<10
	Large-scale patterned ground	No	No	Yes
Locke (1976; in press)	Etching of hornblende (at surface) (μ)	1.5	2.5	2.5-3.2
Mears (1972)	Weathered bedrock[b] (%)	0	4	40
Dyke (1977)	Striations	Present	Present	Absent

[a]Weathering classes 1, 2, and 3.
[b]Weathering classes 6 and 7 (Dyke, 1977).

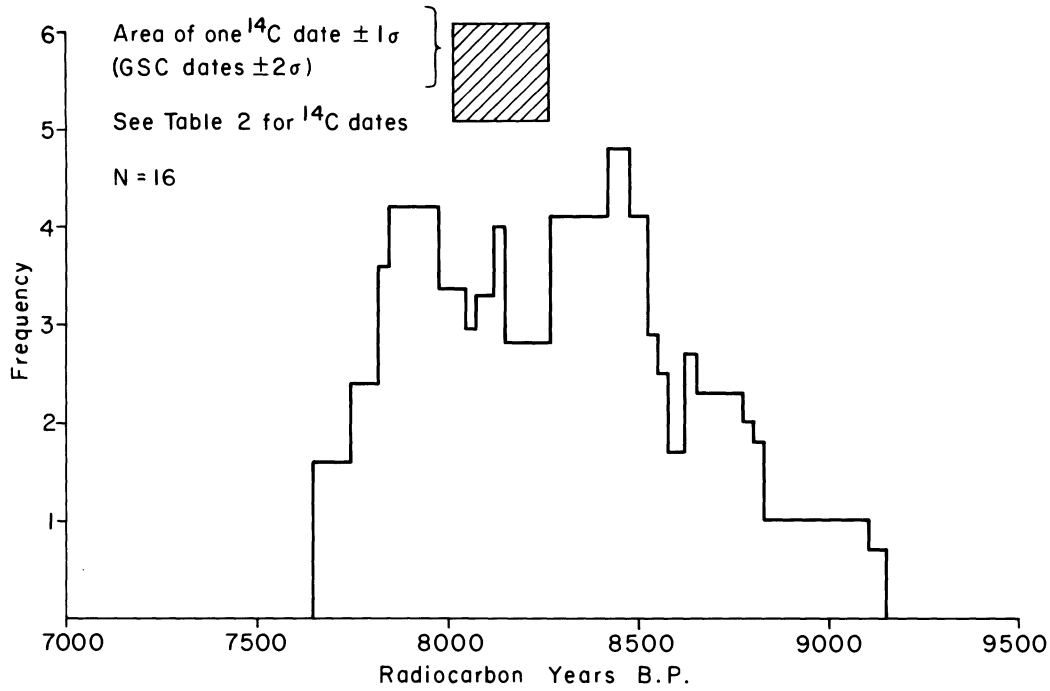

FIGURE 5. Histogram of radiocarbon dates that have been associated with moraines of Cockburn age.

Table 2; they are reported as received from the respective laboratories. The importance of this discussion is that the end of the Cockburn Substage at 8000 BP is based upon marine shells and may be equivalent to a date on terrestrial organics of between 7300 to 8000 BP. However, we note that Krog and Tauber (1973) have argued that the corrections are virtually self-cancelling.

Figure 5 is a histogram of radiocarbon dates from deposits associated in the literature with moraines of Cockburn age. There are many more dates between 8000 and 9000 BP which are associated with marine sediments well beyond the limits of the Baffinland Drift. These marine sediments and the morphological shoreline forms are associated with an early Holocene marine transgression and frequently are deposited on, or cut into, marine sediments dated at ≥40,000 BP (Ives and Buckley, 1969; Andrews, 1975; Miller *et al.*, 1977). The dates in Table 2 and Figure 5 have been associated (where possible) with specific glacial responses: dates on readvances, or from the distal side of major moraines, fall between 8100 and 8800 BP; dates on ice-contact glaciomarine deltas range from 7650 to 9100 BP; and dates on retreat fall between 7650 and 8800 BP. It is clear from this analysis that the Cockburn Substage boundary of 8000 BP forms no clear time of separation between a period of glacial readvance or stillstand and one of retreat, at least so far as eastern Baffin Island is concerned. Work by Blake (1966), Smith (1966), Andrews *et al.* (1970), and Dyke (1977) indicates that the northeastern margin of the Laurentide ice sheet retreated slowly and with several episodes of moraine building after 8000 BP, and fiord heads were not deglaciated until between 6300 and 5000 BP. It is thus obvious that the upper boundary of 8000 BP for the Cockburn Substage has no intrinsic importance in terms of a major event during the Baffinland Stade, whereas the date of 8000 BP is immensely important in terms of the disintegration of the Laurentide ice sheet. Moraines and sediments deposited between 8000 and 9000 BP on Baffin Island can be referred to as moraines of Cockburn age[3] and

[3]We do not imply that these moraines were under construction during the entire 1000-yr period (cf. Blake, 1966).

Baffinland Drift of Cockburn age. This would include the Ed Smith Moraine (Figures 2 and 3), the Ekalugad Moraine, and the Ranger moraines. Correlation with other areas of arctic Canada (Falconer *et al.*, 1965b) will depend on the presence of associated fossiliferous sediments that date between 8000 and 9000 BP.

Although it is not the purpose of this paper to present a complete chronostratigraphic scheme for the eastern Canadian Arctic, nevertheless, it is appropriate to consider the nomenclature of pre- and post-Cockburn substages. The history of the slow recession of the Laurentide ice sheet between 8000 and the sixth millenium has been discussed by Dyke (1977) for the area at the head of Cumberland Sound. We propose the term Kangilo Substage (after one of the fiords at the head of this sound) to include the period between 8000 and 5000 BP. Sediments dated between 9000 and 10,000 BP are associated with an early Holocene marine transgression against the outer coast of Baffin Island. Evidence for a distinct lower marine level of probable Holocene age was reported from the Remote Lake area (Figure 3) by Ives and Buckley (1969). That area lies close to Scott Inlet where Miller (*in* Andrews, 1976) reports radiocarbon dates on marine shells of 10,095 ± 95 BP (SI-2612) and 9550 ± 90 BP (SI-2610). It would be appropriate to name the period between 9000 and 10,000 BP the Remote Lake Substage (Figure 4). Our scheme has the additional advantage of proposing a chronostratigraphy parallel to that for Fennoscandia (Mangerud *et al.*, 1974). Thus

Kangilo Substage	= Atlantic chronozone
Cockburn Substage	= Boreal chronozone
Remote Lake Substage	= Preboreal chronozone

GLACIAL RESPONSE DURING THE BAFFINLAND STADE

Figure 4 illustrates different time/distance histories for the Laurentide ice sheet margin along the northeast coast of Baffin Island. The contention that the Baffinland Drift represents the maximum Late Wisconsin advance and subsequent deglaciation throughout much of the region is based upon (1) the marked increase in surface weathering from the proximal to the distal side of the Baffinland Drift (Table 3); (2) the history of relative sea-level movements; and (3) the distribution of radiocarbon dates (Figure 2). However, the possibility that the maximum Late Wisconsin occurred prior to 10,000 BP in some areas (Hodgson and Haselton, 1974) in no way alters the definition of the Baffinland Drift.

The time/distance diagrams (Figure 4) are models of glacier response during the Baffinland Stade. In the first case (A), the ice-margin advanced to a maximum during the Cockburn Substage and subsequently underwent rapid retreat. This situation prevailed over northern Cumberland Peninsula (Miller, 1973). In another model (C), the ice-margin advanced early in the Baffinland Stade, experienced a slightly more advanced position during the Cockburn Substage, and then retreated rapidly. This model is supported by the requirements of the glacioisostatic analysis (Andrews, 1975), but it has not been stratigraphically documented. In a third case (D) the outermost moraines of the Baffinland Drift are considered to date from 10,000 BP. This model is also supported by the relative sea-level history and applies to the Sam Ford Fiord area. The observations of Miller (1973) and Hodgson and Haselton (1974) indicate that there are two major moraines within the Baffinland Moraine System in areas that they have studied. The inner moraine was probably formed during the Cockburn Substage (8000 to 9000 BP) whereas the outer one may be significantly older (10,000 BP, or possibly 20,000 BP, cf. Dugdale, 1972). Model (B) (Hodgson and Haselton, 1974) must also be carefully considered in each field area. The four models (Figure 4) may well represent actual histories for different sectors of this northeastern margin of the Laurentide ice sheet, but one or more of the "histories" may be the result of misinterpretation due to difficulties in determining the precise relationships between the marine deposits and the moraines.

Insofar as the interregional variations in Holocene glacial events have been worked out on Baffin Island, it would appear that the timing of the termination[4] of major moraine formation varied by a few hundred years. On

Cumberland Peninsula, Cockburn Substage moraines appear to have formed between 8200 and 8900 BP; in Home Bay, the massive Ekalugad Moraine dates from 7800 to 8200 BP (Andrews *et al.*, 1970); and north of Home Bay, dates on the glaciomarine ice-contact deltas group around 8200 BP. In Quajon Fiord, northern Cumberland Peninsula, the oldest date from deposits immediately distal to a large moraine is 8980 ± 180 BP (GaK-5479), although dates of 9180 ± 1140 BP (GSC-707) and 10,000 ± 1000 BP (GaK-2574), both from small samples, have been obtained from marine deposits proximal to moraines of Cockburn age. Evidence for a glacial readvance close to 8000 BP is available from Sam Ford Fiord and Home Bay with dates of 8210 ± 130 BP (I-1933) and 8430 ± 140 BP (Y-1830), respectively. Finally, Blake (1966), Smith (1966), Andrews *et al.* (1970), and Dyke (1977) all report that moraine formation, punctuated by retreat, continued until at least 6700 to 6000 BP. Ice was in contact with the sea both north and south of Cumberland Peninsula until 5700 to 5000 BP (Andrews *et al.*, 1970; Dyke, 1977).

CONCLUSIONS

The Baffinland Drift includes a major moraine belt and represents a major glacial event in the late Quaternary history of Arctic Canada. Within this drift system, many of the more prominent ridges, often the outermost, are radiocarbon dated at between 9000 and 8000 BP and are of Cockburn age. These moraines can be correlated by their associated radiocarbon dates with other moraines in Keewatin and southern Canada (Falconer *et al.*, 1965a, 1965b), northeast Ellesmere Island (England, 1976), probably northern Labrador (Løken, 1964; Falconer *et al.*, 1965b), and West Greenland (Ten Brink, 1975: 34). Although it is apparent that together some of these correlatives of moraines of Cockburn age represent a last dynamic response of the margins of the Laurentide ice sheet, prior to its disintegration about 8000 BP, the broader pattern of marginal response over the longer period ($\leq$10,000 to $\geq$6000 BP) differed markedly between Baffin Island and the mainland areas (cf. Bryson *et al.*, 1969; Prest, 1969).

Full understanding of the pattern of glacial events which occurred during the Cockburn Substage, however, will require much more fieldwork. In particular, the process of deglaciation in Hudson Strait and Ungava Bay must be depicted more precisely. This should test the tentative correlation of the moraines of Cockburn age on Baffin Island with the Sheppard Moraine of northern Labrador and lead to evaluations of (1) the time of ice disintegration in Ungava Bay and the draining of the Naskaupi Glacial Lakes (Ives *et al.*, 1976) and (2) the age of the moraines on Foxe Peninsula (Blake, 1966).

Perhaps it is appropriate to conclude with a quotation from the late Professor R. F. Flint: "The development of a stratigraphic scheme can have no final conclusion because the work is never finished" (Flint, 1976: 407).

ACKNOWLEDGMENTS

Early versions of this paper were read by Drs. L. Clayton, A. Dreimanis, G. H. Miller, and S. C. Porter. Two reviewers provided suggestions and comments which proved useful in compiling this final manuscript. Support from the National Science Foundation (EAR-74-01857) is acknowledged.

[4]Because the moraines are dated by their association with glaciomarine sediments, usually from delta foresets, the shell dates reflect the date of retreat rather than advance.

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