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A Study of Long-Term Satellite-Tracked Iceberg Drifts in Baffin Bay and Davis Strait

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ABSTRACT. Long-term, satellite-tracked iceberg trajectories were analyzed relative to the larger spatial and temporal scales of iceberg drift in Baffin Bay and Davis Strait. Berg movements were concentrated in the core of the Baffin Current which flows along the continental slope in a primarily southerly direction. The net rate of southward movements was found to be governed by a combination of grounding and landfast ice entrapment which tended to be of particular significance in areas of the coastal shelf adjacent to major submarine canyon systems.

Key words: Baffin Bay, Davis Strait, icebergs, satellite-tracking

RÉSUMÉ. Les trajectoires à long terme d'icebergs traqués par satellite ont été analysées en relation avec les mouvements à plus grande échelle dans l'espace et dans le temps, des icebergs de la baie de Baffin et du détroit de Davis. Les mouvements des icebergs étaient concentrés au coeur du courant de Baffin qui s'écoule généralement vers le sud le long du talus continental. Le taux net de déplacement dans cette direction dépend de la combinaison de facteurs tels que l'échouage et la prise au piège des icebergs dans la bordure de glace. Ces facteurs prennent beaucoup d'importance dans les secteurs du plateau continental adjacents à de grands systèmes de canyons sous-marins.

Traduit par Raymond Goulet, Arkéos Inc., Montréal.

INTRODUCTION

Little is understood of the processes which move icebergs from their principal West Greenland calving grounds and southward along the eastern shore of the North American continent. Some recent advances have been made as a result of extensive oceanographic studies in western Baffin Bay and eastern Lancaster Sound (Fissel *et al.*, 1982) and off the western Greenland coast (Dietrick *et al.*, 1979). These studies generally confirmed the overall counterclockwise (cyclonic) circulation in Baffin Bay. The data on the North American sector demonstrated that the southward-flowing Baffin Current is a relatively narrow, rapid flow which follows the sharply sloping portion of the continental slope and includes a shallow (horizontal) intrusion into Lancaster Sound. This current carries the icebergs south to temperate latitudes (Fig. 1).

Previous data on this aspect of berg movement are sketchy and have provided only rough estimates of the ranges of travel times required for the bergs to reach the North Atlantic shipping lanes. Recently developed satellite-based tracking systems have made possible long-term tracking of icebergs. Initial efforts were made by the U.S. Coast Guard in 1977 and 1978. They obtained between 138 and 202 days of positional data on five bergs in western Davis Strait and on two bergs initially located near Disko Island (Robe and Maier, 1979; Robe *et al.*, 1980).

The present study is primarily concerned with iceberg drift along the Baffin Island coast between 62°N and 73°N, particularly the characteristics of individual berg trajectories. Where possible, these characteristics are used to identify processes which control the net rates of southward berg movement.

METHODOLOGY

The present study was initiated during the summer of 1978 and utilized both the RAMS (Random Access Measurements System) and ARGOS tracking systems associated with the Nimbus-G and Tiros-N satellites, respectively. Positional data were obtained on 9-track magnetic tape from the Nimbus processing centre located in Greenbelt, Maryland, and from System ARGOS in Toulouse, France. These data were computed from satellite measurements of the Doppler shifts in the nominal 400 MHz frequency signals of the radio transmitters placed on the bergs. The root-mean-square accuracies of the calculated positions were approximately 2.0 and 0.5 km for the Nimbus and ARGOS data, respectively. These positions were obtained at an average rate of 10 times per day from System ARGOS/Tiros-N and less frequently, approximately twice per day from the Nimbus system.

Twenty-one trajectories were obtained, 11 of which began during July to September 1978. Tracking of these 11 bergs was continued until the summer of 1980 when either transmitter failure and/or berg breakup and rolling led to termination. The remaining 10 bergs were fitted with transmitters during the summer of 1979 and tracked until November of that year when data retrieval was interrupted and not resumed until 6 June 1980.

RESULTS AND DISCUSSION

Typical berg trajectories are represented in Figures 2, 3, 4 and 5 for bergs fitted with transmitters during the 1978 and 1979 seasons, respectively. Features on spatial scales of less than roughly 10 km were manually removed except

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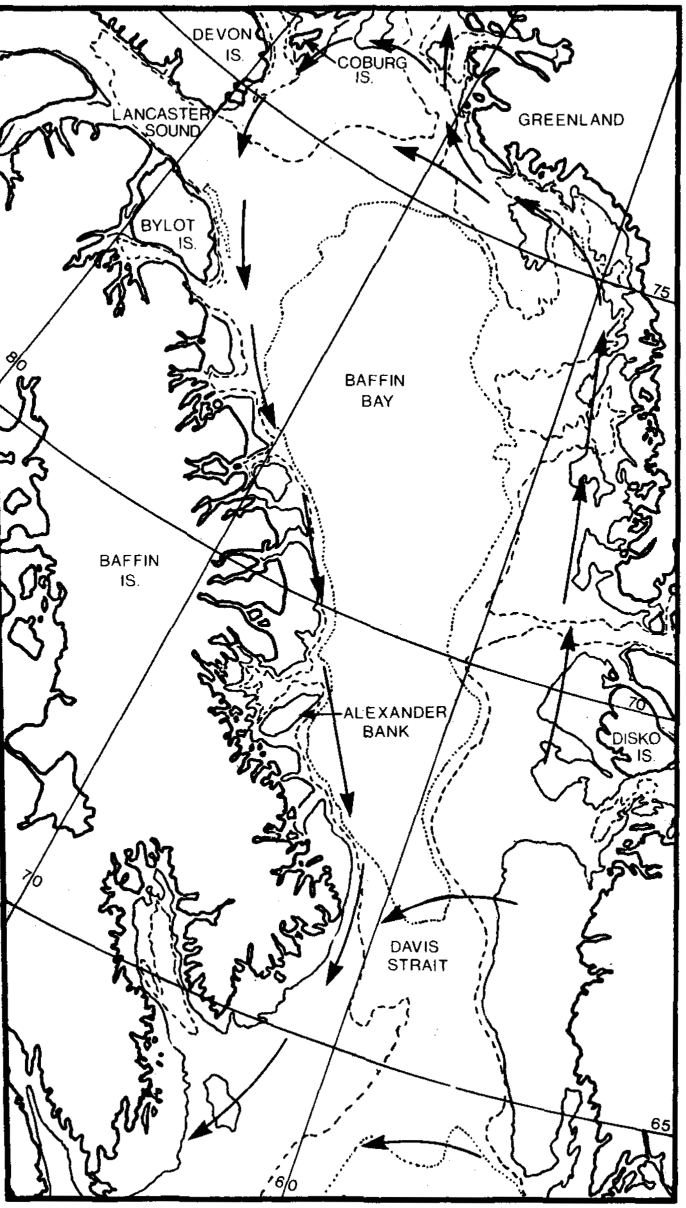

FIG. 1. The general circulation pattern and bathymetry of Baffin Bay and Davis Strait. The indicated contours correspond to 200, 500 and 1000 m depths.

in the immediate vicinity of coastlines and in connection with obvious looping or eddy-like structures. Annotations include the dates associated with initial and final positions, periods of immobility (negligible displacement), and a few intermediate reference points. Dotted-line segments indicate data gaps of periods greater than two days. The approximate physical dimensions and shape classification of the individual bergs are given in each figure.

Significant features of these trajectories include:

1) Cyclonic intrusions of the bergs into Lancaster Sound. This is due to the intrusive flow of the Baffin Current (Fissel *et al.*, 1982).
2) The intermittent presence (observed in roughly 50% of all trajectories) of a large-scale loop off the southeastern coast of Bylot Island. Both cyclonic and anticyclonic senses of rotation were observed, apparently associated with similar features observed by Fissel *et al.* (1982) in the surface layer circulation.
3) A well-defined concentration of berg flow along the continental slope. The core of the current appears to follow the continental slope along the coast of Baffin Island, marked by the dashed 500 m contour. The trajectory data show that the icebergs tended to follow the local bathymetry, often being deflected toward shore along one of the series of canyons which penetrate the continental shelf in the vicinity of Buchan Gulf, Scott and Clyde inlets and Home Bay.

The most rapid long-term net drifts observed in the study involved the three bergs (nos. 1987, 1988 and 1989) represented in Figures 3-5. Tracking of these three bergs began on 12-13 August 1979. Bergs 1988 and 1989 moved southward to approximately 69°N by late October 1979, corresponding to an average daily drift of about 12 km. If sustained, this rate of drift would have been sufficient to bring these bergs close to the entrance to Hudson Strait (61-62°N) by late February 1980. However, contact was lost with berg 1989 on 28 October 1979 and berg 1988 was immobilized prior to the late November interruption of tracking coverage. The trajectory data for June to October 1980 indicated that the latter berg moved southward sometime during the 1979 to 1980 winter-spring period, eventually reaching the coastal area south of Cape Dyer (66°N) from where it slowly drifted in an overall southwesterly direction. The remaining berg 1987 may have been immobilized as early as 16 September 1979 off the east coast of Bylot Island and may have remained in this area at least until the cessation of tracking in November. With the resumption of coverage in June 1980, this berg was located just to the northeast of Resolution Island at the eastern entrance to Hudson Strait, corresponding to a minimum 7 km d^{-1} net drift rate over the interval. The trajectories of these bergs indicate that the frequency and duration of the periods of berg immobility tend to be the controlling factors in the rate of southward berg movement. This is also apparent from the box-averaged velocities in Figure 6 that were derived from berg position versus time records after editing to remove periods of immobility. These data indicate that the highest "intrinsic" berg velocities generally lay near or on the deep water side of the 500 m isobath as compared to the slower and more directionally variable flows observed over the continental shelf.

The southerly components of the averaged drift velocities tended to range between 10 and 30 km d^{-1} which, if periods of immobility could be neglected, would correspond to a total travel time of 1.5 to 5 months between Bylot and Resolution islands. The discrepancy between these estimates and the observed travel times corresponds to the large fraction of time during which the bergs were

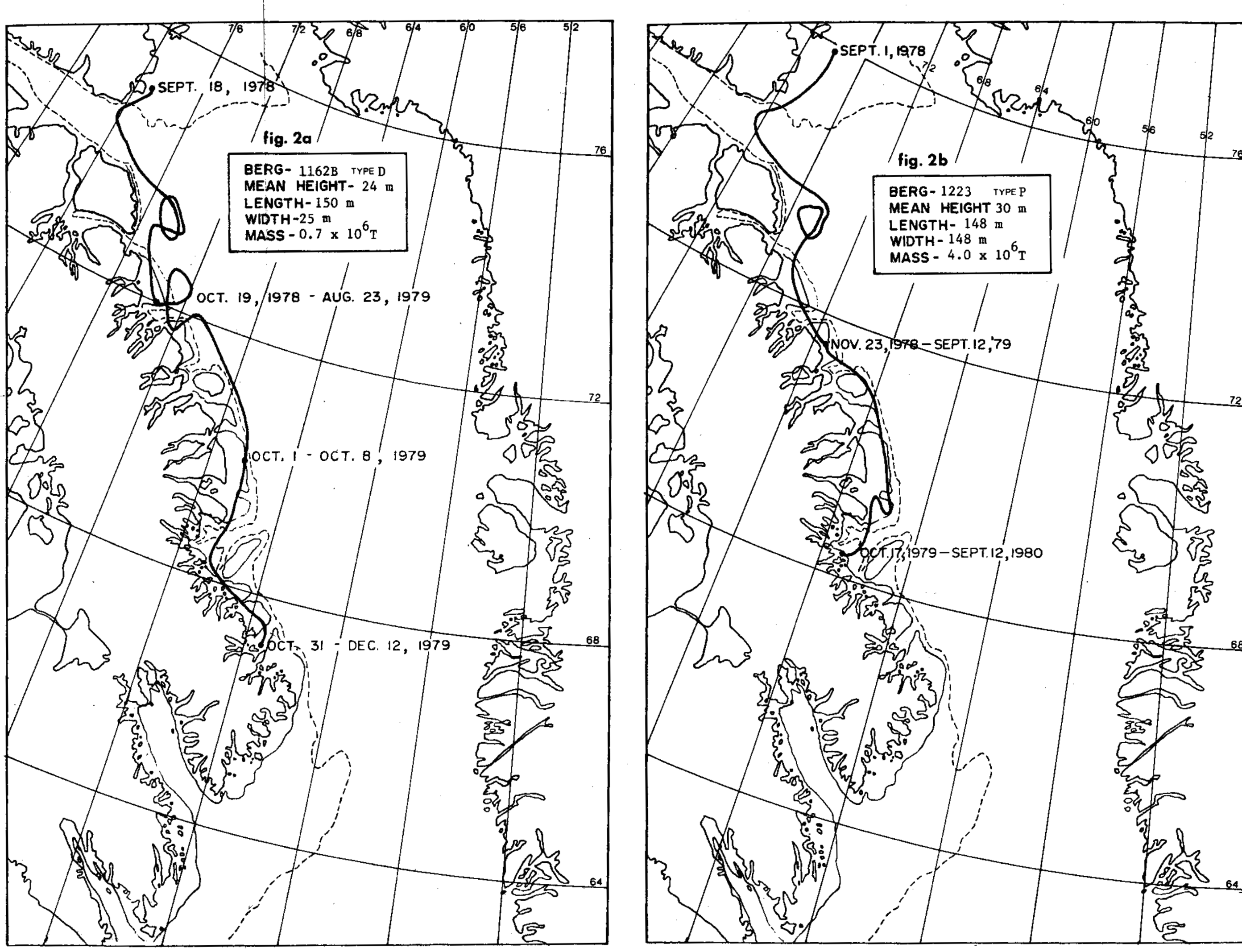

FIG. 2. Typical smoothed trajectories of bergs initially tracked in summer, 1978 (a) berg 1162B (b) berg 1223. Included are the 200 and 500 m bathymetric contours and berg dimensions. The latter data include type designation according to the categories: (T)-Tabular, (TT)-Tilted Tabular, (D)-Domed, (DD)-Drydocked, (B)-Broken, and (P)-Pinnacled (Robe, 1975).

either grounded or trapped in landfast or perhaps non-moving pack ice. Using Robe's (1975) 3.95:1 ratio of berg draft to peak height above the waterline and a simple 2:1 ratio between peak and mean heights, it was found that the drafts of the bergs studied would be expected to range from a minimum of 32 m to approximately 300 m. As a result, immobilization through grounding should largely have been confined to areas inside the 300 m isobath. This zone is not much wider than the zone of landfast ice which is generally in place from November to August in waters at least as deep as 170 m (Jacobs *et al.*, 1975). The 1978 and 1979 positions of the landfast ice zone are indicated in Figure 7 together with the locations of all significant berg immobilizations (those longer than a few days) recorded during the study. These sites are classified as short (○) or long (●) according to the duration of immobilization with an arbitrary division at one month. The long-term sites are labelled numerically with reference to Table 1 which gives details of each immobilization event. The same data are also plotted in Figure 8 relative to the regional bottom topography. This figure indicates that, excluding events north of 74°N, all long-term immobilizations occurred inside the 200 m isobath, with the majority occurring in the vicinity of major canyon systems. Evidently the bergs follow the shoreward currents paralleling the axes of these canyons. The subsequent entrapments in adjacent shallow water areas are due, at least in part, to the limited extent of water deep enough for refloatation.

These results also suggest that landfast ice is perhaps the principal factor in determining the duration of individual grounding/immobilization events. For example, the data in Figure 7 indicate that immobilizations which occur in areas of relatively shallow water outside of the landfast ice zone tend to be short-term. The one major exception to this observation is event number 6 (Fig. 7 and Table 1) which took place on the Alexander Bank in the mouth of Home Bay, outside the recorded position of the landfast ice boundary. A plot of the monthly frequencies of motion

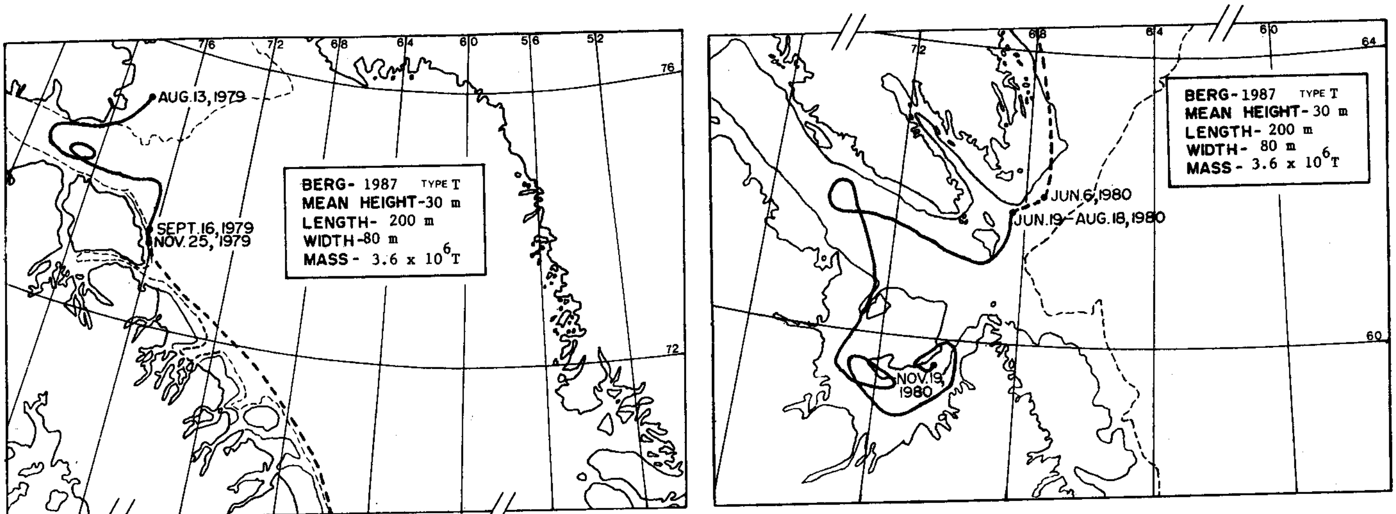

FIG. 3. Smoothed trajectory of berg 1987, initially tracked in summer 1979. Included are the 200 and 500 m bathymetric contours, berg dimensions, and type designation as in Figure 2.

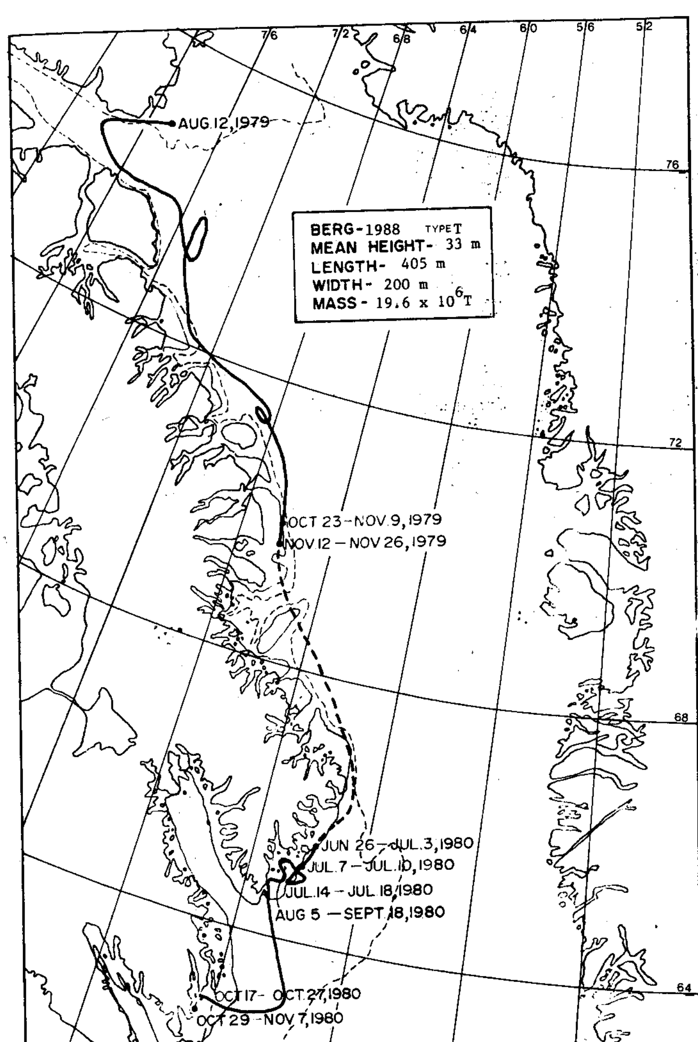

FIG. 4. Smoothed trajectory of berg 1988, initially tracked in summer 1979. Included are the 200 and 500 m bathymetric contours, berg dimensions, and type designation as in Figure 2.

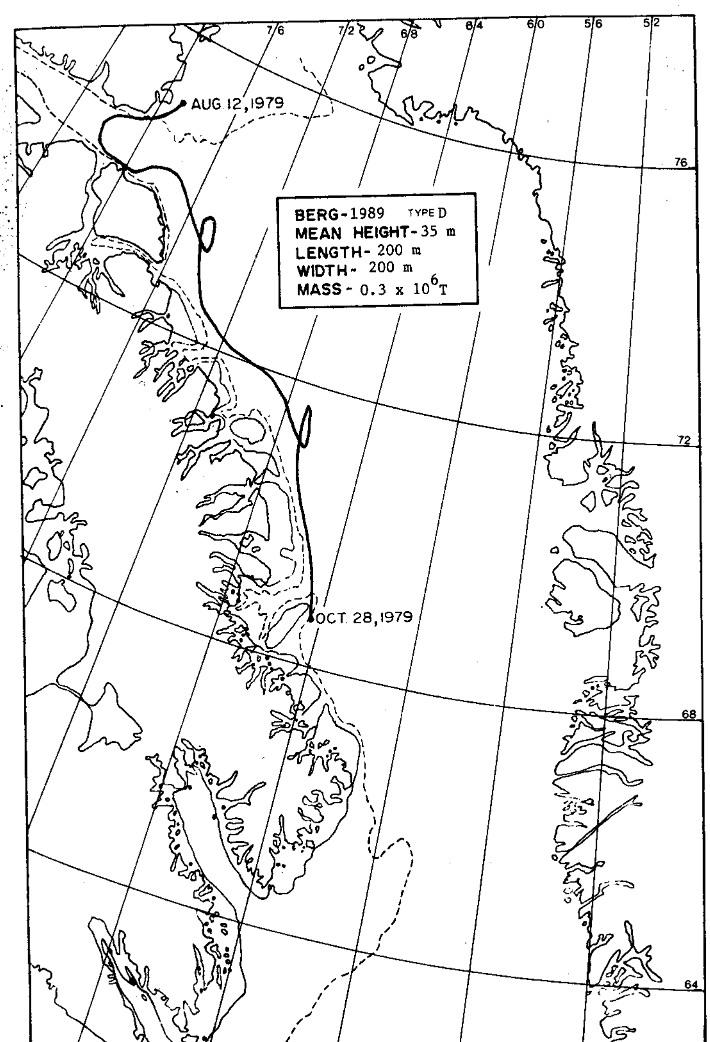

FIG. 5. Smoothed trajectory of berg 1989, initially tracked in summer 1979. Included are the 200 and 500 m bathymetric contours, berg dimensions, and type designation as in Figure 2.

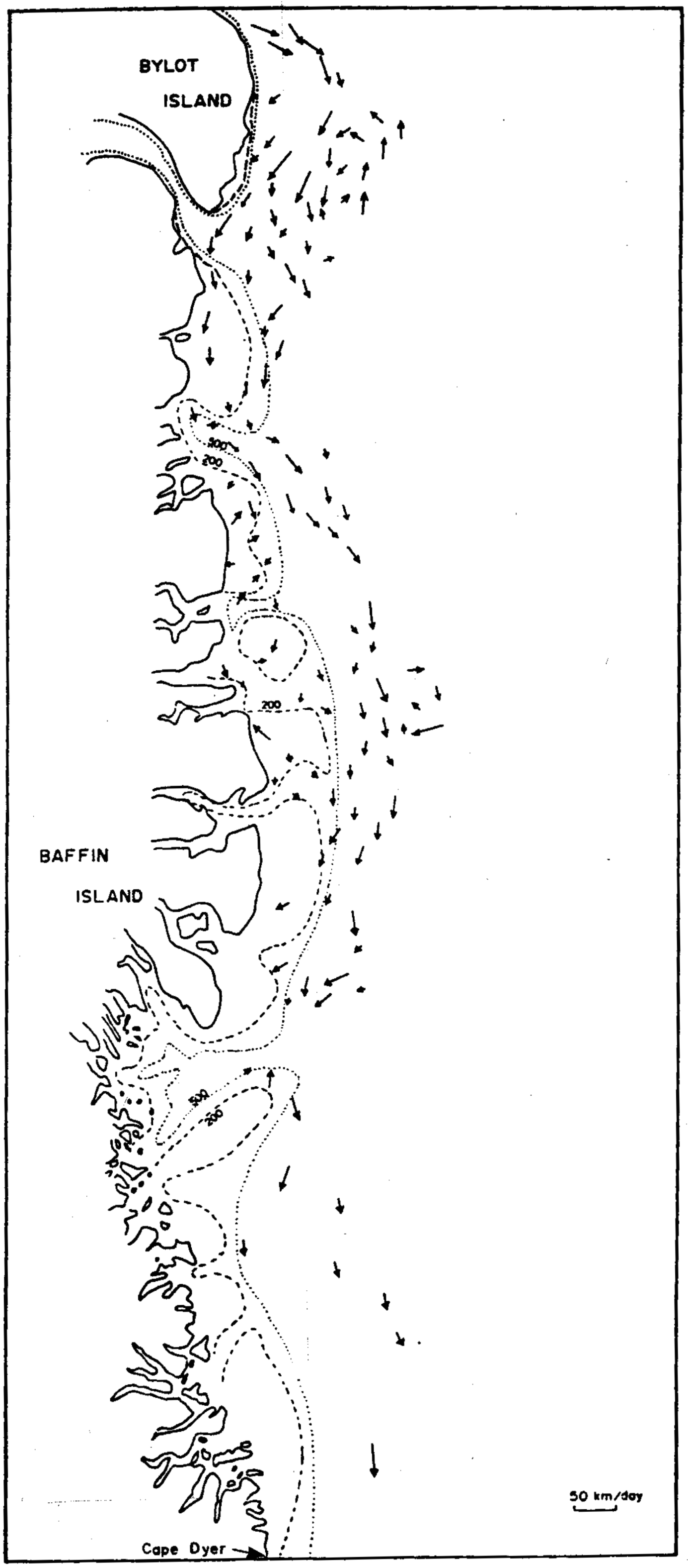

FIG. 6. The spatial distribution of mobile berg velocities as averaged on a 0.5° longitude by 0.167° latitude grid scale. The 200 and 500 m depth contours are indicated.

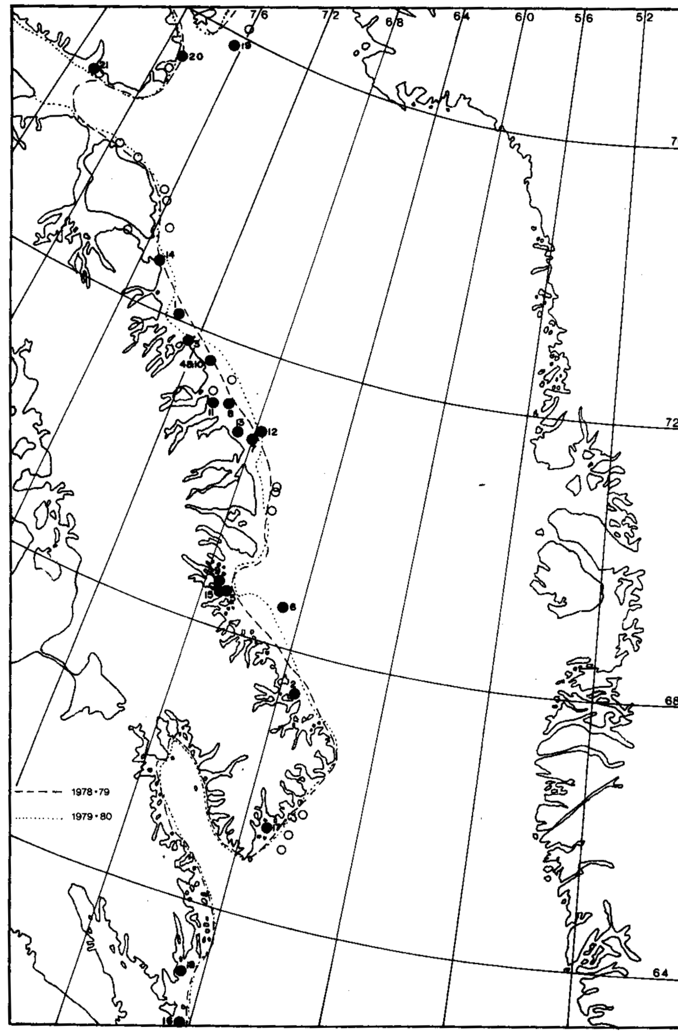

FIG. 7. Sites of long (●) and short-term (○) immobilization relative to the 1978 and 1979 seasonal landfast ice boundaries. Numbers identify each immobilization event according to the listing in Table 1.

resumption (Fig. 9) shows a strong peaking during August and September when the landfast ice is either non-existent or disintegrating. While ocean currents, wind and groundings no doubt influence the individual berg histories, it seems clear that the absence of landfast ice cover would appreciably shorten the duration of the immobilization events. Although no data are available to indicate whether berg 1987 (see Fig. 3) followed an offshore or coastal track, it may be significant that the extremly rapid drift of this berg occurred in the post-25 November 1979 period when entry and entrapment on the east Baffin Island coastal shelf was prevented by the presence of landfast ice cover.

Spatial variations in the frequency of berg entrapment and in the intrinsic drift speed apparently introduce a significant latitude dependence into the net rate of southward berg movement. Although the number of bergs studied was small and some bias may be present due to differing distributions of the dates of entry into each zone, the extent of this latitude dependence is illustrated in the distribution of the times taken for individual bergs to traverse the indicated 1.5° latitude zones (Fig. 10). These data suggest the particular importance of zones II (70.5° to

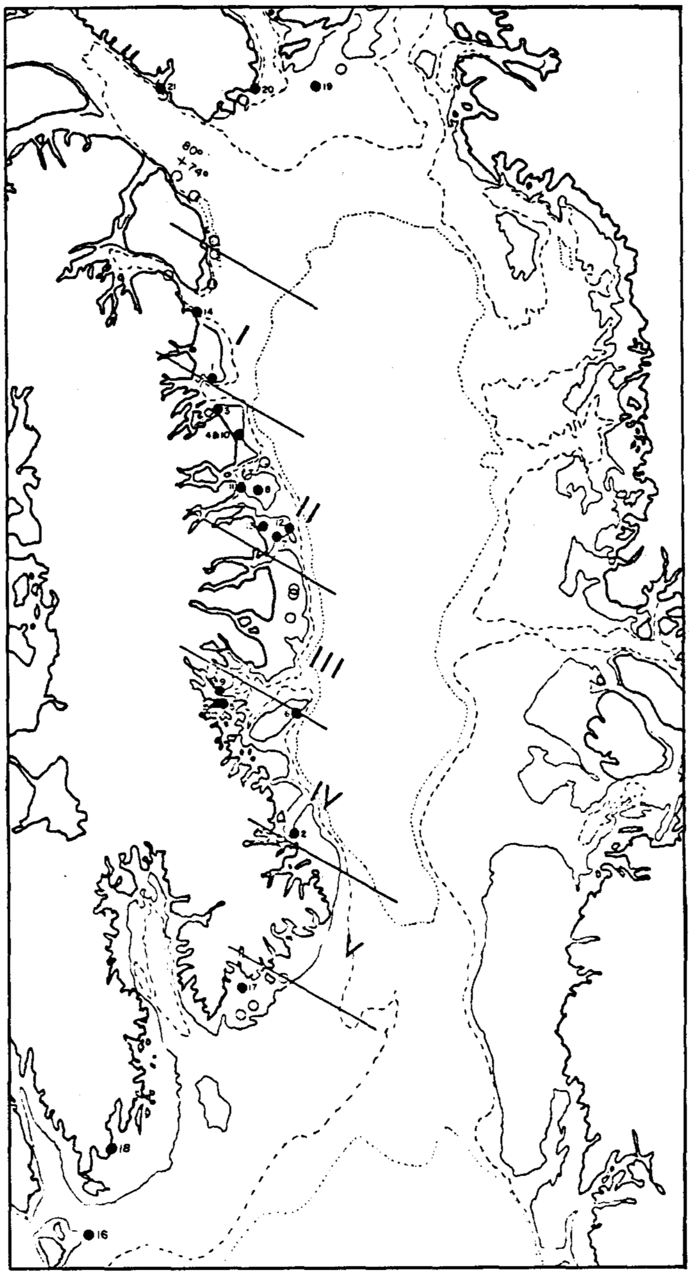

FIG. 8. Sites of long (●) and short-term (○) immobilizations and the 200, 500 and 1000 m bottom contours. For the purposes of later discussion, zones I to IV along the coast are defined at 1.5° latitude intervals.

TABLE 1. Immobilization event data for icebergs tracked during 1978-80 (numbers correspond to those in Figs. 7 and 8)

	Berg #	Duration of Immobilization (Months)	Dates
1.	1162B	10	Oct. 19/78-Aug. 23/79
2.	1162B	1.5 (at least)	Oct. 31/79-EOR* (Dec. 12/79)
3.	1163	21.5	Oct. 14/78-Aug. 1/80
4.	1223	9.5 (at least)	Before Nov. 23/78-Sept. 12/79
5.	1223	11 (before EOR)	Oct. 17/79
6.	1241	10	Jan. 5/79-Nov. 2/79
7.	1264	12 (at least)	Before Nov. 23/78-EOR (Nov. 21/79)
8.	1401	9 (at least)	Before Nov. 16/78
9.	1401	11.5 (at least)	Oct. 15/79-EOR (Nov. 26/80)
10.	1413	11.5	Sept. 22/78-Sept. 5/79
11.	1413	1 (at least)	Sept. 19/79-EOR (Oct. 27/79)
12.	1446	10.5	Oct. 5/78-Aug. 18/79
13.	1454	10.5	Oct. 6/78-Aug. 18/79
14.	1462	9	Oct. 6/78-July 9/79
15.	1986	1 (at least)	Before Oct. 20/80-EOR (Nov. 26/80)
16.	1987	2	June 19/80-Aug. 18/80
17.	1988	1.5	Aug. 5/80-Sept. 18/80
18.	1988	1 (at least)	Oct. 29/80-EOR (Nov. 7/80)
19.	1991	1	Sept. 27/79-Oct. 29/79
20.	1993	2 (at least)	Sept. 16/79-EOR (Nov. 12/79)
21.	1994	12.5 (at least)	Oct. 8/79-EOR (Oct. 21/80)

*EOR denotes end of record

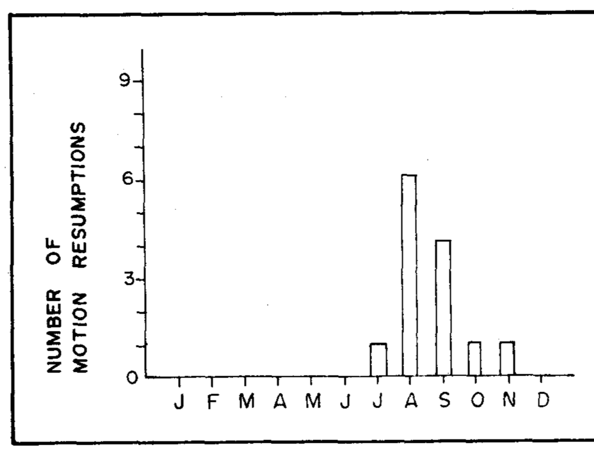

FIG. 9. Number of resumptions of iceberg motion as a function of calendar month.

72°N) and IV (67.5° to 69°N). The long residence times recorded in these areas would appear to be the result of the strong probabilities for diversion into shallow water.

Four of the bergs tracked in this study traversed Baffin Bay from Lancaster Sound to Davis Strait in 8-15 months. No other berg was observed to complete the same trip during the study, although four bergs were tracked for a full two-year period. A simple addition of the most frequently occurring travel times in each zone suggests that the most likely duration for the drift of an iceberg from Lancaster Sound (74°N) to 66°N would be in excess of three years.

In summary, the long-term berg trajectory results suggest the existence of a concentration of berg flow along the continental slope. The tendency of this flow to follow the major canyon systems of the adjoining continental shelf leads to groundings and berg immobilizations during the approximately nine to ten months of each year when landfast ice is present. The resulting berg movements consist of rapid 10 to 30 km d^{-1} drifts interrupted by long periods of entrapment in the shallow water-landfast ice zones. Bergs that remain in off-shelf areas during the critical August-November period of clearing and landfast ice regrowth may move southward with a sustained net speed of approximately 10 km d^{-1}.

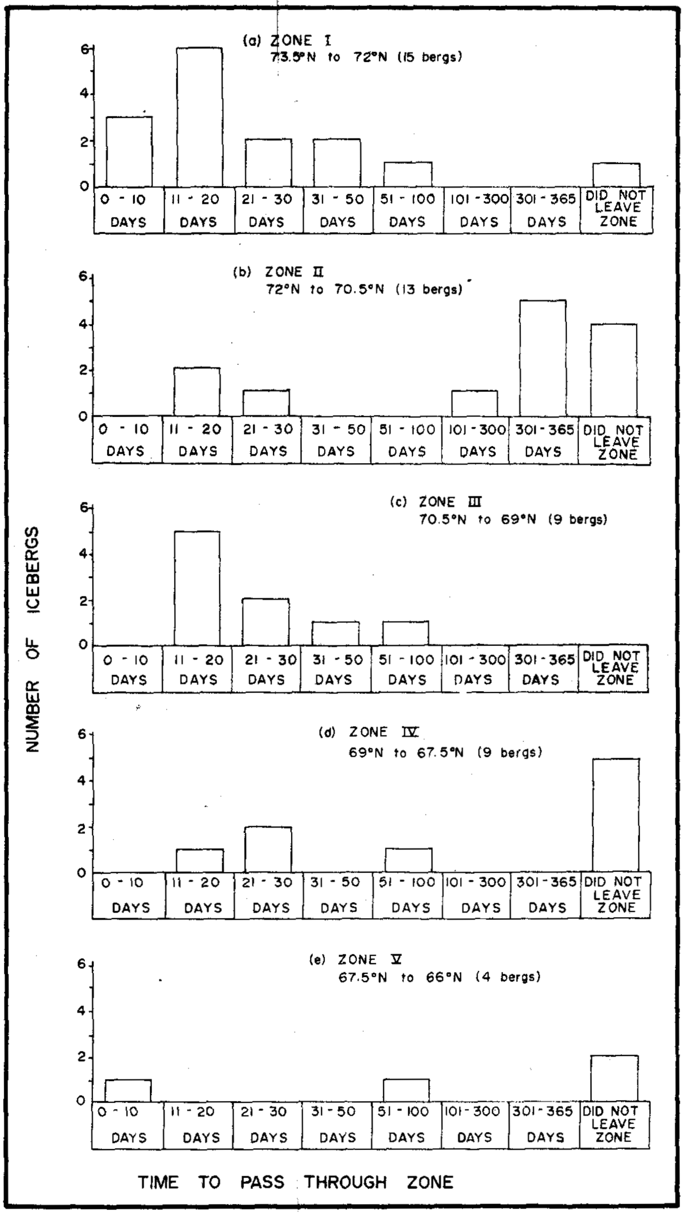

FIG. 10. The distribution of berg traversal times for zones I-V along the Baffin Island coast. Zone numbers coincide with those of Figure 8.

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