THE DRIFT OF ICE ISLAND WH-5

David C. Nutt*

ABSTRACT. From 1962 to 1964 Ice Island WH-5 drifted south from the Arctic Ocean through Nares Strait and Baffin Bay. The movements of WH-5 indicate that the southward water transport through Nares Strait is not continuous, and during the summer of 1963 was interrupted by pulses of surface water to the north and the development of a sluggish counter-clockwise gyre in Kane Basin. By the time they reached the waters of Labrador and Newfoundland in 1964 the WH-5 pieces were extensively scattered due to their irregular escape from Smith Sound and the vagaries of the Baffin and Labrador Current systems.

RÉSUMÉ. *La Dérive de l'île de glace WH-5.* De 1962 à 1964, l'île de glace WH-5 a dérivé vers le sud, de l'océan Arctique à travers le détroit de Nares et la baie de Baffin. Les mouvements de WH-5 indiquent que le transport d'eau vers le sud à travers le détroit de Nares n'est pas continu et que durant l'été de 1963, il fut interrompu par des poussées d'eau de surface vers le nord et le développement d'un lent mouvement lévogyre dans le bassin de Kane. Lorsqu'ils atteignirent les eaux du Labrador et de Terre-Neuve en 1964, les débris de WH-5 avaient été considérablement dispersés par leur sortie irrégulière du détroit de Smith et les caprices des systèmes de courants de Baffin et du Labrador.

АБСТРАКТ. ДРЕЙФ ЛЕДЯНОГО ОСТРОВА WH-5. С 1962 по 1964 год, ледяной остров WH-5 (Ward Hunt — 5) дрейфовал на юг от Арктического океана через пролив Нерса * и Баффинов залив. Движение WH-5 свидетельствует, что вынос воды к югу через пролив Нерса не постоянен, и в течение лета 1963 г. он прерывался пульсированием поверхностной воды к северу и образованием медленного круговорота против часовой стрелки в Бассейне Кейна. Когда в 1964 году части WH-5 достигли вод Лабрадора и Ньюфаундленда, они были значительно рассеяны во время их нерегулярного выхода из пролива Смита и капризами течений Баффинова залива и вод Лабрадора.

*) Географическое название «Пролив Нерса» (Nares Strait) употребляется как сборное имя системы проливов, соединяющих Баффинов залив с морем Линкольна, начиная с пролива Смита на юге и кончая проливом Робсона на севере.

Introduction

GATHERING data on quantitative measurements of the drift of sea ice and ocean currents has long been an objective of oceanographic observation and study. Although ice movements in the Baffin Bay — Eastern Arctic system, as a reflection of winds and surface currents, are generally known, they are little understood. Knowledge of the seasonal pattern of the occurrence of sea ice has been built up over a long period and added to in recent years through the Canadian, United States, and Danish ice observing programs. Quantitative aspects of drift however are obscured by the growth of new ice and the disintegration of old ice.

For quantitative data on ice drift, an identifiable object is required. Such objects may be a ship beset by ice, a camp on the ice, or a marker of some sort. Individual pieces of sea ice, however distinctive, cannot safely be used except over the shortest periods and under continuous surveillance. Distinctive icebergs are possible markers and have recently been used by the International Ice Patrol (Lenczyk 1965). Specific marking of floes or icebergs has not been extensively used because of the lack of development of practical methods and the large commitment for surveillance.

The recorded ship drifts of the last century (Fig. 1) provide some quantitative idea of the Baffin Current within Baffin Bay (Ross 1850; Kane 1857; M'Dougall 1857; M'Clintock 1859). The spectacular drift of the *Polaris* party in 1872-73 on

*Research Associate in Geography, Dartmouth College, Hanover, U.S.A.

an ice floe from Smith Sound to the coast of Labrador, a total distance of some 1,600 miles, was previously the longest documented drift (Davis 1876; Tyson 1874). These drifts, summarized and discussed by Dunbar (1962), suggested that winter movements from the Northern Baffin Bay area to the waters south of Davis Strait and even to Labrador was possible (Fig. 1). More recently the Russian Ice Station NP-7, abandoned north of Greenland in latitude 85°N. on 11 April 1959, was two years later found off the coast of Baffin Island in latitude 70°28'N. on 9 April 1961. That it reached this point via Nares Strait has been concluded independently by Gudkovich and Balakshin (1962) and by Dunbar (1962).

Winter drift of icebergs from northern Baffin Bay to the waters of Labrador and Newfoundland has been established by the International Ice Patrol, upon whose background and experience we must draw in the interpretation of the drift of Ice Island WH-5. This Patrol is conducted by the U.S. Coast Guard and hereafter is referred to in the text as the Ice Patrol. Its mission is to protect North Atlantic shipping from the hazards of icebergs which in varying numbers drift into the shipping lanes off Newfoundland each spring, and in carrying out this mission it has an obvious interest in the supply of icebergs to the north and the factors influencing their drift. Since its foundation, the Ice Patrol has accumulated extensive practical experience in interpreting iceberg drift, and the present assessment of the iceberg problem is summarized by Lenczyk (1965).

The points which have specific bearing on the interpretation of the drift of WH-5 are:

1. The icebergs lying in the Baffin Current between Cape Chidley, Labrador, and Bylot Island during late November are the potential supply for the Grand Banks in the following spring. Those between Cape Chidley, Labrador, and Cape Dyer, Baffin Island, are the primary source, while those north of Cape Dyer are a secondary threat which may, under favourable conditions, reach the Grand Banks.

2. Winds would seem to exercise the primary control in determining to what extent the iceberg supply will reach the Grand Banks. Records have demonstrated a close correlation between the winter wind patterns and the severity of the iceberg season. Under normal winter conditions, when there is a favourable air flow as shown by mean monthly maps of surface pressure, the average rate of drift from Baffin Bay to the Grand Banks appears to be approximately 8 to 9 miles per day. With the coming of late spring and early summer this pattern breaks down with the advent of neutral or unfavourable winds which may slow or halt the drift. Onshore winds will drive many bergs into the coastal waters where they may become trapped in the bays or go aground. A period of offshore winds may drive bergs to seaward out of the Currents.

3. Pack ice plays an important role in the protection and preservation of icebergs. Bergs that are located between Cape Chidley and Cape Dyer during the preceding autumn are most likely to reach the farthest south while still remaining within the pack ice and associated cold water. Once bergs escape from the pack ice into open water, disintegration takes place quite rapidly. Thus bergs arriving off Labrador in June and July when the pack ice has retreated have little chance of reaching the Grand Banks, and are no more than a threat to local shipping in the waters of northern Newfoundland and Labrador.

In the immediate postwar years 'ice islands' that apparently calved from the

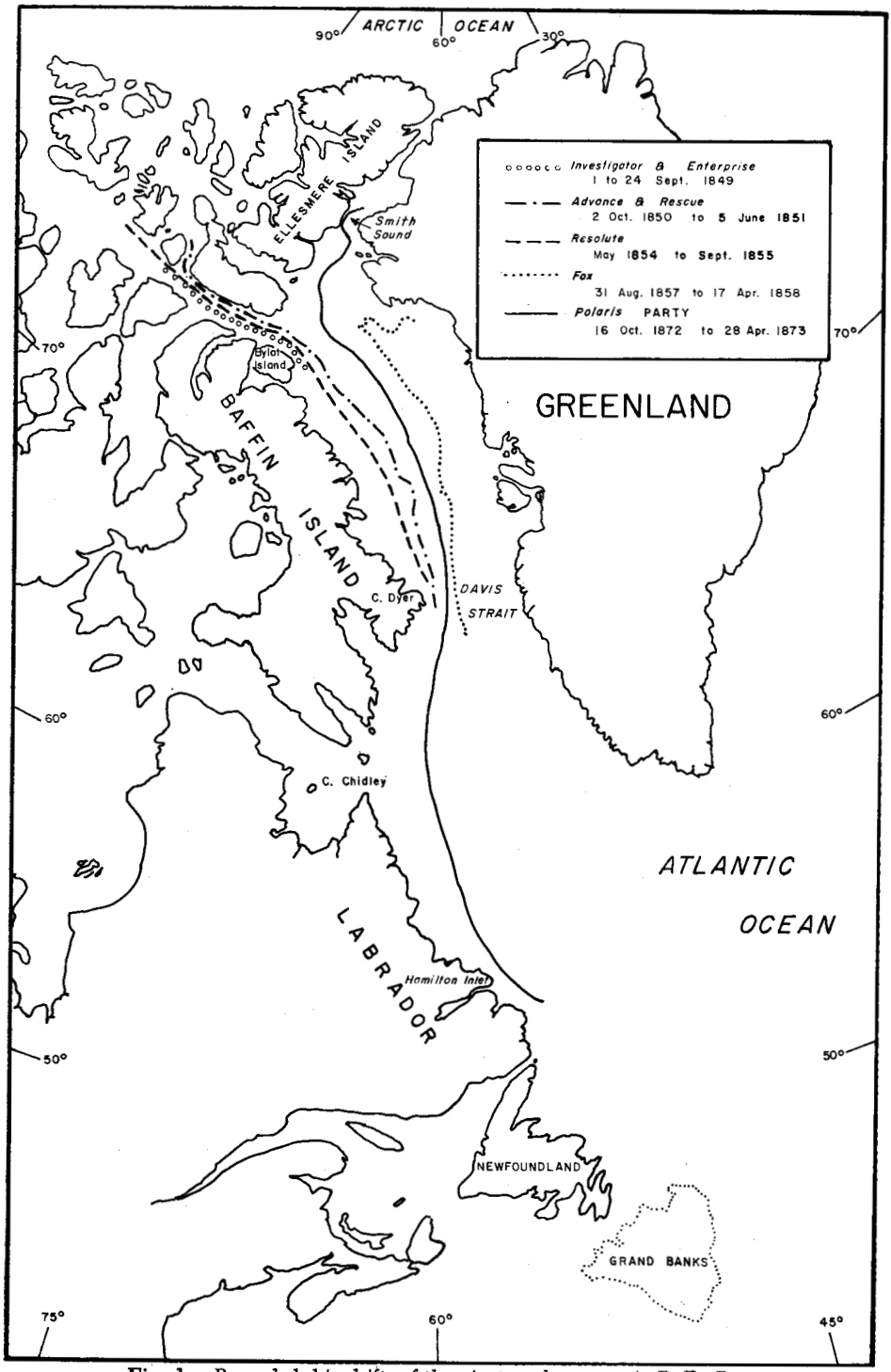


Fig. 1. Recorded ship drifts of the nineteenth century in Baffin Bay.

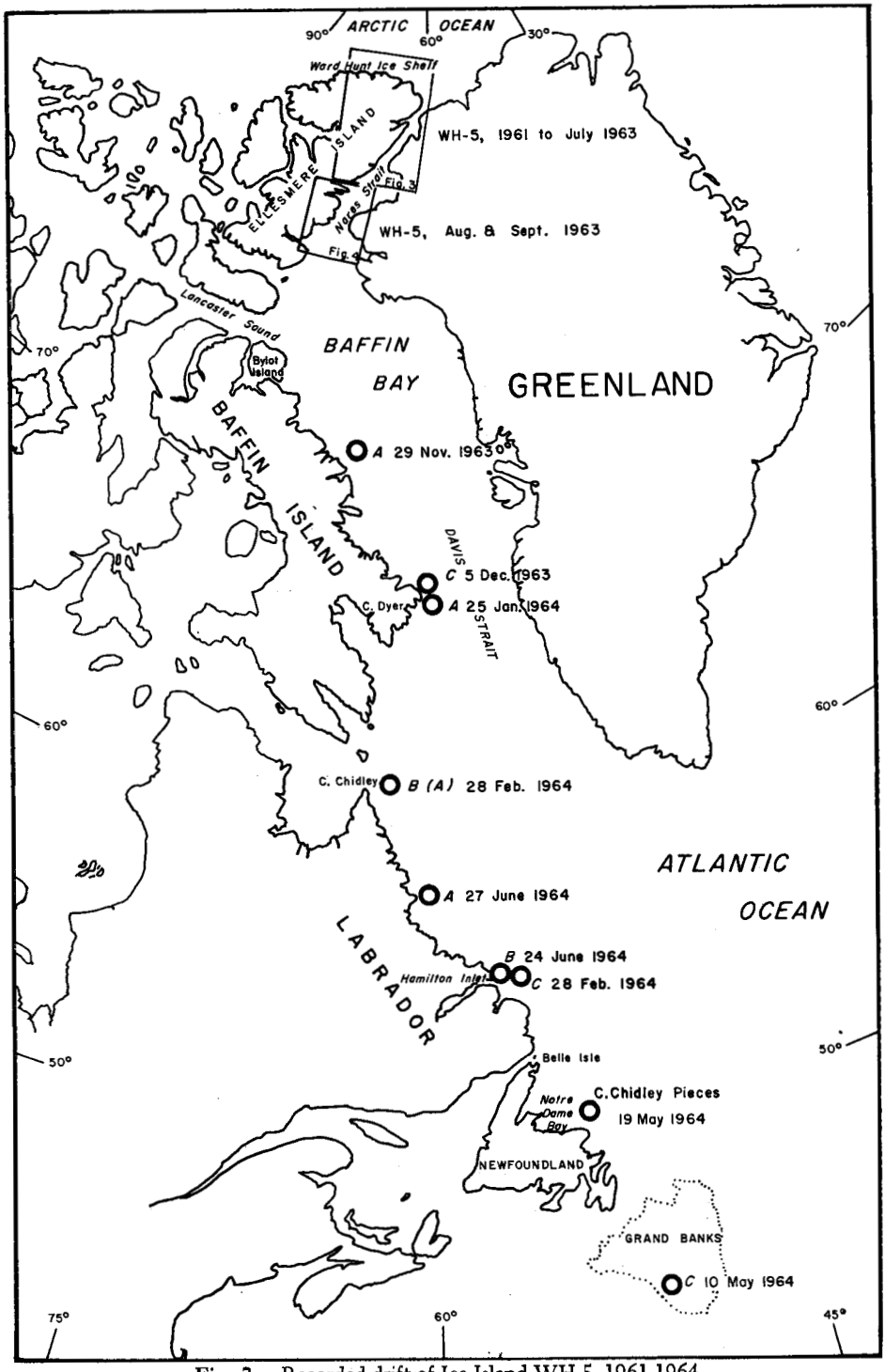


Fig. 2. Recorded drift of Ice Island WH-5, 1961-1964.

shelf ice areas along the northern coast of Ellesmere Island, were found to be drifting in the Arctic Ocean. Two of these have served as secure floating platforms for scientific stations. Ice islands of uniform tabular shape and 30 m. or more in thickness, make excellent drift markers because from the air their characteristic ridge and trough surface pattern renders them readily identifiable visually, and their uniform shape and thickness make then identifiable by radar imagery. The rate of drift represents essentially the integrated movement of the surface water layer.

In the past three years two ice islands have drifted out of the Arctic Ocean into southward flowing current systems. The massive calving of the Ward Hunt Ice Shelf north of Ellesmere Island during the winter of 1961-62 (Hattersley-Smith 1963) produced five large ice islands, of which one, WH-5, entered Nares Strait the following winter and drifted south in the Baffin and Labrador Current systems to the coasts of Labrador and Newfoundland by the summer of 1964 (see Figs. 2 to 5). Ice Island ARLIS II, on which the Office of Naval Research had supported a scientific station, escaped from the Arctic Ocean system during the winter of 1964-65 and drifted south in the East Greenland Current.

In a preliminary report by Nutt and Coachman (1963) the movements of WH-5 up to the summer of 1963 were summarized, and information on the radio beacons installed on two of the pieces was presented. The purpose of this paper is to present in summary the final documentation of the drift of Ice Island WH-5 from the time of its calving from the Ward Hunt Ice Shelf during the winter of 1961-62 until the final sightings of the remaining fragments in the waters of Labrador and Newfoundland during the summer of 1964, and to discuss the oceanographic implications. The documentation of the drift is based on visual sightings from ships and aircraft and from aerial radar photography. Unless otherwise indicated, all dimensions and distances are given in nautical miles. The drift will be considered and discussed in three phases:

1. Calving from Ward Hunt Ice Shelf during winter of 1961-62 to the blocking of Kennedy Channel from February until July 1963.
2. Breakout from Kennedy Channel in July 1963 to escape from Smith Sound in August and September 1963.
3. Winter, spring, and summer records 1963-64, Baffin Bay to waters of Labrador and Newfoundland.

1. Ward Hunt Ice Shelf to Kennedy Channel

The actual time or cause of the massive calving is not precisely known. It occurred during the winter of 1961-62 when the entire northern part of the Ward Hunt Ice Shelf, some 200 square miles in area, broke off as five major pieces. Four of these drifted to the westward in the Arctic Ocean whereas one, the largest, with dimensions of about 11 x 5 miles and identified as WH-5, drifted to the eastward (Hattersley-Smith, 1962). During the summer and autumn of 1962 WH-5 was observed on five occasions, two visually during June and July by Canadian investigators and three during the autumn by radar photography of the U.S. Navy *Birdseye* flights, a periodic ice reconnaissance mission conducted by the U.S. Naval Oceanographic Office. The best estimate of these positions is given in Fig. 3. Around 1946 there was a calving of a 1.5 x 4 mile segment of

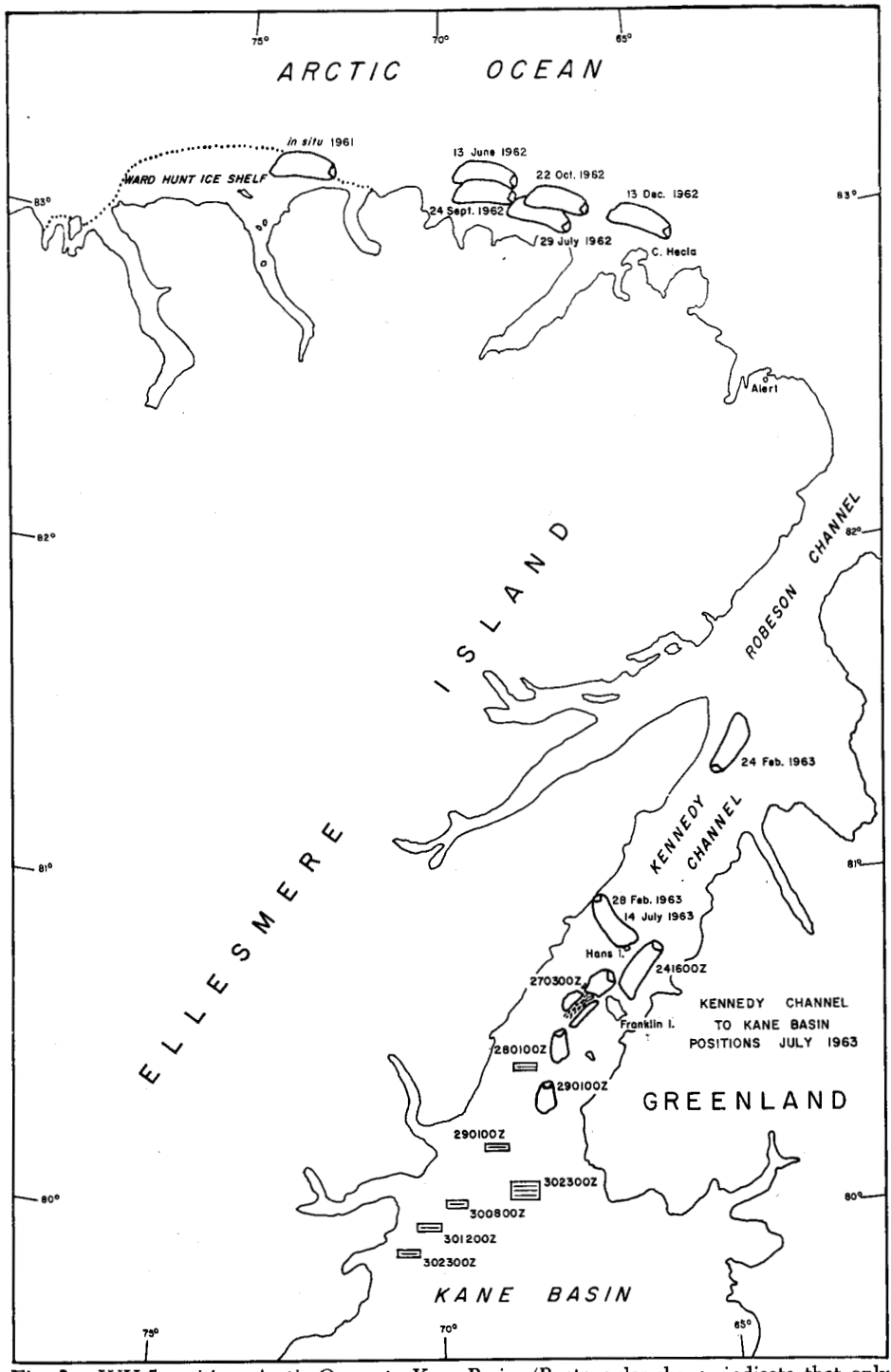


Fig. 3. WH-5 positions Arctic Ocean to Kane Basin. (Rectangular shapes indicate that only longitudinal orientation is known).

the eastern part of the Ward Hunt Ice Shelf. New shelf ice, which apparently regenerated in this area, showed the same characteristic ridge and trough pattern, but on a very much smaller scale. This regenerated segment of the Ice Shelf, termed 'reentrant' by earlier glaciological investigators, made it possible to determine the original eastern end of WH-5. Where it was later identified in the course of the drift, is shown in Figs. 2 to 4.

By 13 December WH-5 had made a total net eastward movement of approximately 62 miles from its original position as a part of the Ward Hunt Ice Shelf, to a position off Cape Hecla with, however, evidence of a net westerly component of motion between the 29 July and 24 September sightings.

Between 13 December 1962 and 24 February 1963 WH-5 continued an eastward and southward drift, which undoubtedly accelerated upon entering Robeson Channel. During this period a net distance of 120 miles was covered at an average daily rate of 1.6 miles per day. On 24 February 1963 a *Birdseye* flight covering Nares Strait observed WH-5 lying in the north end of Kennedy Channel with its axis parallel to that of the Channel. Four days later the Ice Island had drifted further south slightly less than 40 miles and had rotated counterclockwise 90° to become lodged across the Channel. The reentrant end lay against the Ellesmere Coast while the other end impinged upon Hans Island. The *Birdseye* radar imagery and identifications by the U.S. Naval Oceanographic Office are given in Fig. 6.

From 28 February until after 14 July WH-5 remained lodged across Kennedy Channel. During this period it was observed on 13 occasions by U.S. and Canadian flights. Careful interpretation of the photography, radar imagery, and visual sightings, established positional stability during this period.

Shortly after WH-5 became lodged, open water began to appear to the south while solid pack ice was dammed up to the north and formed a bridge to Franklin Island and the Greenland Coast. The open water area to the south continued to expand and by June extended throughout the west central area of Kane Basin connecting with open water areas in Smith Sound and northern Baffin Bay. Ice remained in the Canadian fjords and in the apparently stagnant area in the eastern side of Kane Basin. It is interesting to note that with the ice cover removed, the surface temperatures in the open water area were as high as 5° to 6°C., while temperatures as high as 4°C. were occasionally found at a depth of 10 m. With the onset of winter normal conditions were restored.

Discussion

The scarcity of reports and the difficulties of accurate position determinations north of Ellesmere Island, as well as the comparatively slow movement, make detailed quantitative analysis inconclusive. But Hattersley-Smith (1962) has suggested that slow and irregular initial movements of the Ward Hunt Ice Islands were influenced by the winds. These could have in part been the explanation for the westward component of motion during the summer of 1962 and particularly the ensuing drift eastward toward Nares Strait with the onset of westerly winds in the fall as recorded at the Alert weather station.

The positional stability and the development of the open water area across Kane Basin would seem to argue for an almost continuous southward transport of surface water from the Arctic Ocean through Nares Strait during this period. The

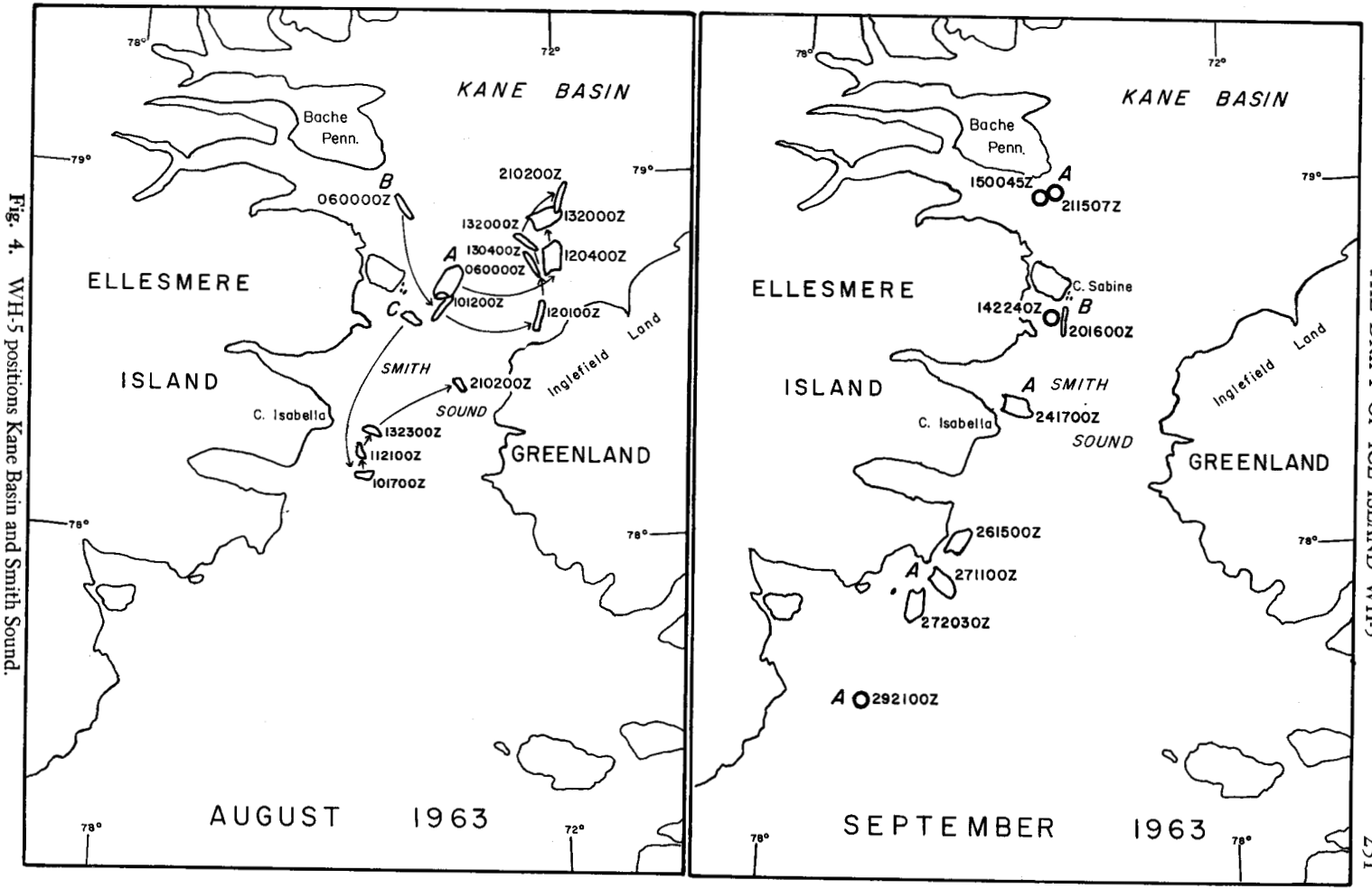


Fig. 4. WH-5 positions Kane Basin and Smith Sound.

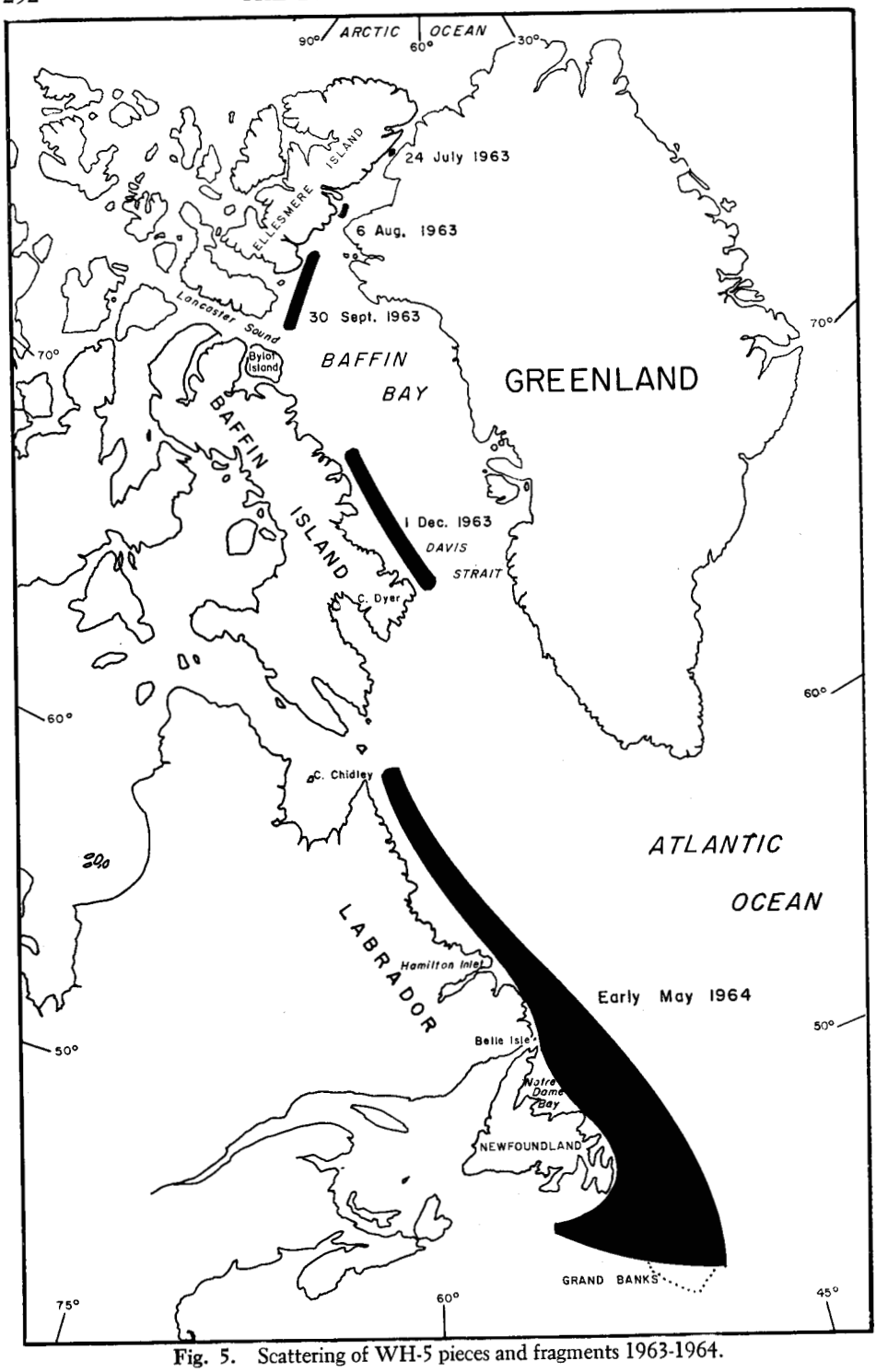
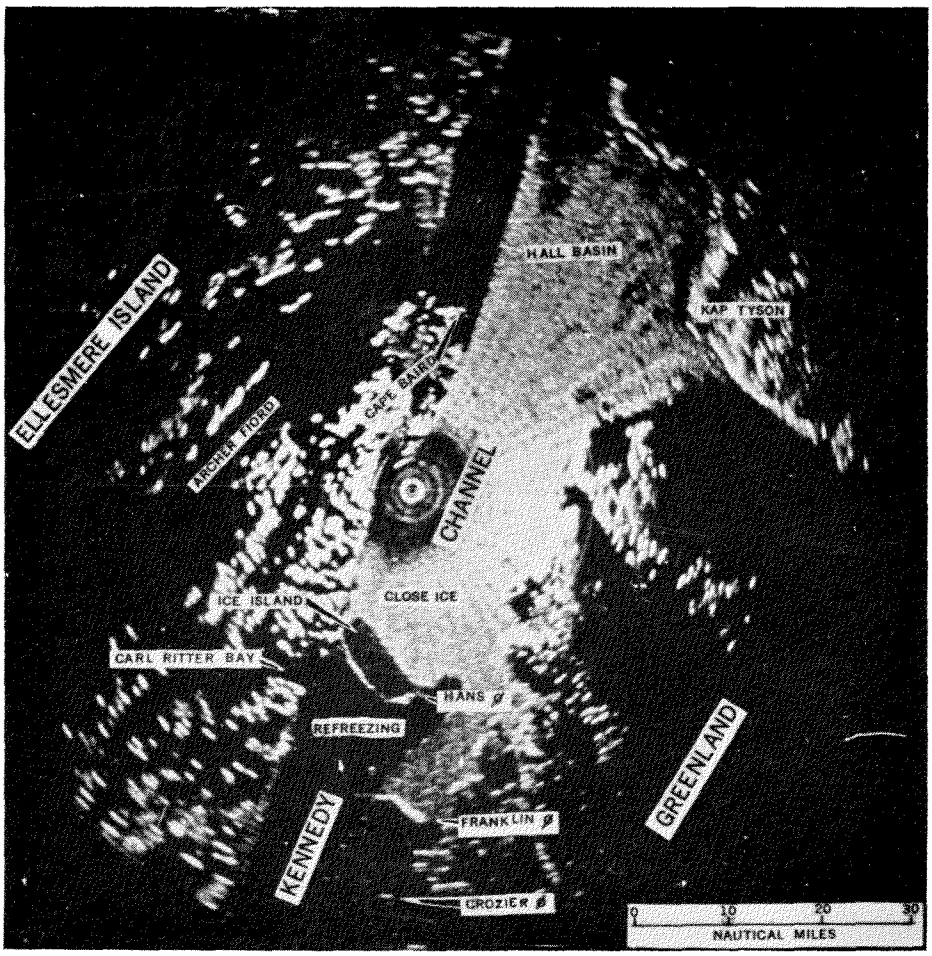


Fig. 5. Scattering of WH-5 pieces and fragments 1963-1964.



(*Photo: Courtesy of U.S. Navy*)

Fig. 6. *Birdseye* radar photograph of WH-5 in Kennedy Channel, 28 February 1963.

pattern of development of open water indicates that this transport took place through the west central part of Kane Basin while the eastern part was little affected. And this development of open water in Kennedy Channel and Kane Basin gives support to the suggestions of Smith (1931), Schule and Wittmann (1958), Simpson (1958), and Kupetskiy (1962), that the regular open North Water in northern Baffin Bay is caused by the removal of any ice which forms south of the usual sea-ice bridge across Smith Sound, through action of the southward flowing current and prevailing north and northeast winds.

2. Kennedy Channel to Escape from Smith Sound

On 14 July WH-5 was observed from a *Birdseye* flight and photographs were obtained. These revealed a loosing of the ice to the north with fine leads of open water. This may have been the beginning of the dramatic breakout during the

following 10 days. The next reconnaissance, in which the author participated, was made on 24 July by the U.S. Air Force. WH-5, still one piece, had moved away from the western side of the channel and was located east of Hans Island and north of Franklin Island, with its axis parallel to that of the channel and the reentrant end to the north (see Fig. 3 for this and subsequent positions in this area). Fig. 7 shows the last photograph of WH-5 as a single piece. Neither the end that had lain against Hans Island, nor the reentrant end had changed substantially. It therefore would seem reasonably conclusive that the breakout must have taken place first with a dramatic movement northward to free the Ice Island, followed by movement to the eastward with clockwise rotation, and then movement to the south, eastward of Hans Island. Furthermore, by 24 July there was again a rapid new southerly movement of water in Kennedy Channel particularly on the western side where forerunners of the pack ice which had been released were observed more than 30 miles south of the former ice dam.

Observations from a special U.S. Navy reconnaissance flight on 26 and 27 July showed that WH-5 had moved southwestward between Hans and Franklin islands and had broken into 3 major pieces and many small fragments. Fig. 8 shows the almost explosive breakup. (The pieces later designated may be identified as follows: A in the foreground, B to the left and C to the right). By 30 July these pieces were located in northern Kane Basin. The best estimates of the positions of two major pieces based on reports from the U.S.C.G.C. *Westwind* have been shown in Fig. 3 (times given in the figures are Greenwich Mean Time indicated by Z). The actual shapes and orientation of the pieces are given where known. In other cases rectangular shapes indicate that the longitudinal orientation as determined by the ridge and trough pattern is known, but that the end to end relationship is not. The differential movements of the two major segments whose positions were observed indicate a more rapid southward transport close

Fig. 7. WH-5 in Kennedy Channel to east of Hans Island, 24 July 1963.

Fig. 8. Breakup of WH-5 in Kennedy Channel, 27 July 1963.

to the Ellesmere Island shore than in the centre of the Channel. Also, a random scattering of the many other smaller fragments was beginning to take place.

Between 30 July and 6 August the pieces of WH-5 continued rapidly to drift southward across Kane Basin at 12 to 16 miles per day. A special U.S. Navy ice reconnaissance flight on 5 and 6 August showed the three major pieces to be located in southern Kane Basin. For identification purposes these pieces were then labelled A, B, and C, and their positions are shown in Fig. 4 together with subsequent positions in this area during August and September.

The major pieces and fragments of WH-5 were then in open water. The pack ice ahead of and around them in northern Kane Basin appeared to have disintegrated in the warmed surface waters while the heavier ice island pieces survived. There was also severe attrition from early August until mid-September in the open waters of Kane Basin and Smith Sound, as well as undercutting of the edges by the warm water and frequent cracking off of fragments along the lines of weakness in the troughs. The reentrant on A was completely broken off or melted by 12 August leaving only the roughly concave shape of the main part of the piece to indicate where it had been.

From 10 to 13 August the WH-5 pieces were under the surveillance of the U.S.C.G.C. *Westwind*. Pieces A and B were instrumented with radio beacons and distinctive patterns of oil drums and trail flags to aid in later identification. The positions during this period are also shown in Fig. 4. All pieces, both off the Ellesmere Island coast and off the Greenland coast, moved to the northward during this period. The positions determined from a *Birdseye* flight, a U.S. Air Force flight from Thule, and by Hattersley-Smith (personal communication)

from 20 to 23 August, indicate a continued net northeastward drift of pieces *C* and *B*, while piece *A* seems to have remained stationary or drifted only slightly eastward (Fig. 4).

During the remainder of the summer and early fall piece *C* was not reported again, having evidently escaped to the southward. Pieces *A* and *B* must have drifted slowly and aimlessly north and west and separated, with piece *B* taking a more southerly route. On 14 and 15 September the C.C.G.S. *Labrador* reported that piece *B* lay to the south of Cape Sabine, whereas piece *A* was located south of Bache Peninsula. A further report from the U.S. Air Force and from the C.C.G.S. *Labrador* on 20 and 21 September indicated that each piece had moved only a few miles to the eastward (Fig. 4). Where orientation of the pieces was not determined, the positions are indicated by a circle only.

Then a dramatic southward movement started. Piece *B* must have escaped southward first. It was never sighted again although its radio beacon was picked up on several subsequent occasions. A helicopter flight from the U.S.S. *Edisto* on 24 September located piece *A* close off and just north of Cape Isabella, Ellesmere Island, and the final landing for the season was made at the radio beacon site (Fig. 4). From off Bache Peninsula it had drifted southward a distance of 40 miles at an average rate of 10 miles per day. The U.S.C.G.C. *Westwind* stood by piece *A* until 27 September in an attempt to refit the radio beacons for over winter operation, but a strong northerly wind, at times reaching gale force, forestalled this attempt and with little doubt was the cause of the rapid escape of the WH-5 pieces from Kane Basin and Smith Sound. The U.S.C.G.C. *Westwind* 1963 positions on 26 and 27 September, and the final C.C.G.S. *Labrador* 1963 position of 29 September are given in Fig. 4. During this period of strong northerly winds piece *A* drifted south a total of 96 miles at an average rate of 10.7 miles per day. Radio signals were heard by the C.C.G.S. *Labrador* from both pieces on 3 and 4 October and from Piece *B* on 7 October, but a helicopter search failed to locate them.

Discussion

The behaviour of the Ice Island WH-5 from the time of its breakout and breakup in Kennedy Channel until its escape southward from Smith Sound casts some light on the nature of the water exchange between the Arctic Ocean and Baffin Bay through Nares Strait. Discussion is limited to the specific implications of the drift of WH-5, and not an overall consideration of the oceanography of the area. All recent analyses of the water balance of the Arctic Ocean (for example, Treshnikov 1959, Timofeyev 1960, Vowinkel and Orvig 1961, and Mosby 1962) require a net transport of water from the Arctic Ocean southward through the Canadian Channels to Baffin Bay. This would seem to be supported in Nares Strait by the well-established drift and escape southward of sea ice. Actual dynamic calculations of transport have been made from seven sections in Smith Sound. A section from the *Godthaab* cruise of 1928 (Killerich 1939) and 5 sections from the *Labrador* cruises of 1962, 1963, and 1964 (Collin 1965) all showed that a flow to the south was taking place; while a single section from the Labrador cruise of 1954 (Bailey 1957) indicated that a flow to the north was in progress at that time.

The behaviour of WH-5, with its pieces and fragments providing conclusively identifiable drift markers that had originated from a single source, extends our knowledge of this exchange. As suggested by Bailey's single section in 1954, southward transport does not appear to be a continuous process. In 1963 the movements of WH-5 clearly demonstrated intervals of distinct northward transport or of virtually no transport. Its positional stability, while blocking Kennedy Channel from February to July, would suggest a continuous southerly flow over this period. But the breakout as described required a northerly surge after 14 July to loosen the Ice Island and the ice packed to the north of it. By 24 July a rapid southerly transport had been re-established. Then this southerly movement ceased between 5 and 10 August, and a rather general northerly movement was established in Smith Sound and southern Kane Basin. There appears to be no clear explanation for the separation of piece C from piece A, or for the virtual joining of pieces A and *B* between 5 and 13 August. This must have resulted from uncertain local eddies and local winds.

The slow northward and westward movement of pieces A and *B* suggested development of a sluggish counterclockwise gyre in Kane Basin from 10 August to 20 September. Southerly transport seemed to have taken place intermittently on the western side, while on the eastern side, especially in Peabody Bay, movements were sluggish as the ice, although broken up, remained there while central and west Kane Basin emptied. After 20 September rapid southerly movement was again restored under the influence of strong northerly winds. It is possible that these periods of northerly transport are seasonal and limited to the summer.

The general counterclockwise circulation in the very northern part of Baffin Bay (Killerich 1939; Dunbar 1951) together with the indicated counterclockwise gyre and intermittent periods of northward transport in Kane Basin appear to make Smith Sound an area of very irregular currents and eddies. Such vagaries undoubtedly contributed to the separation of the three major pieces and fragments and had a far-reaching effect on their winter drift south in the Baffin and Labrador Current systems.

3. Northern Baffin Bay to Labrador and Newfoundland

At the end of September the best estimate of the positions of the principal pieces of WH-5 was as follows: Piece C was possibly as far south as Lancaster Sound; piece A was off southern Ellesmere Island in Latitude 77°30′N., with *B* presumably somewhere in between, but probably nearer to A. It must be added that owing to the initial breakup and the attrition in the open water of Kane Basin and Smith Sound there were many smaller fragments scattered throughout this area, ahead of the three major pieces, in between, and behind them.

It is unfortunate that more intermediate positions were not positively determined, although two negative reports and one probable radar contact are of some help. The *Birdseye* flight of 29 November 1963 failed to identify piece A in a 30-mile wide radar search from central Baffin Bay to Baffin Island in latitude 72°N., thence along the Baffin coast to Bylot Island, and on to Thule.

On 4 and 5 December 1963 the Ice Patrol made a reconnaissance in the Labrador and Baffin Currents as far north as Cape Dyer, Baffin Island, in latitude 67°37′N. The visibility was good, but since no Ice Island pieces were seen, they were presumed to have been to the north. Thus at the beginning of December

it is quite likely that many of the pieces and fragments were within the area of some 340 miles of Baffin Current which had escaped surveillance.

On 25 January 1964 the *Birdseye* flight reported that "a possible radar contact was made with WH-5 at 67°30'N." off Cape Dyer, Baffin Island. This most likely was a reference to piece *A* which, because of its size, would offer the best target for a single identification within the pack ice.

From 26 to 28 February 1964 the Ice Patrol definitely located two groups of Ice Island pieces. One group of approximately 16 pieces averaging 800 x 400 feet was located off Hamilton Inlet in Latitude 54°30'N., and was at the time presumed to be fragments of piece *C* (supported by later observations). Four or 5 fragments were scattered 150 miles to the northwest. The second group, composed of 8 larger fragments averaging about 1,500 x 700 feet and rather close together, was located off Cape Chidley, Labrador, in latitude 61°15'N. These must have been fragments of either piece *A* or piece *B*.

The *Birdseye* flight on 2 April 1964 reported, "Numerous fragments of Ward Hunt 5 were sighted along the Labrador Coast. None of these fragments was of significant size." On 19 May the Ice Patrol observed near Notre Dame Bay, Newfoundland in latitude 50°N., several fragments, considered by Lenczyk (1965) to have been from among those sighted earlier on 26 and 28 February off Cape Chidley.

In the spring and summer, positive identifications were made of remnants of the three original major pieces. Beginning in the south we have:

Piece *C*: As reported by Lenczyk (1965) ice-island fragments were sighted by the Ice Patrol in early April lying just to the north of the Grand Banks, and these were considered to be the remnants of the 16 ice-island fragments sighted off Hamilton Inlet on 26 and 28 February. By late April an estimated 50 fragments were in the vicinity of the Grand Banks in latitude 46°N., longitude 51°W., and in early May a few leaders had reached latitude 44°N. That these must have been portions of major piece *C* is confirmed by subsequent identification in late June of the remnants of pieces *A* and *B* farther north along the Labrador Coast.

Piece *B*: An isolated fragment was located by the U.S.S. *Edisto* lying close off the north shore of Hamilton Inlet on 24 June 1964. It was positively identified by means of an oil drum and flag placed on it by the U.S.C.G.C. *Westwind* during the summer of 1963 in Kane Basin.

Piece *A*: A segment of WH-5 whose horizontal dimensions were 1.5 x 3.5 miles was observed by a U.S. Navy ice reconnaissance flight on 27 June some 25 miles off the Labrador Coast, in latitude 57°10'N. From its size we may safely conclude that it is the remaining major segment of piece *A*.

The Ice Patrol reported that once the fragments of piece *C* escaped the pack ice off Newfoundland to open water, they rapidly disintegrated, surviving only 10 to 20 days. Therefore, after the above sightings and identifications of the remnants of the major pieces, all in open water, their life was limited. Piece *C* had disintegrated on the Grand Banks by the end of May. Ice Island fragments were seen by the Ice Patrol off Hamilton Inlet in July, with a final sighting of a fragment from the disintegration area on 11 August off Belle Isle. Therefore, pieces *A* and *B* must have disappeared on the coasts of southern Labrador and northern Newfoundland. However, two final fragments were

observed by the Ice Patrol in Baffin Bay during October 1964. These were either stragglers which escaped the Baffin Current and remained far north, or fragments from another ice island altogether. And so the documented drift of Ice Island WH-5 is concluded.

From these reports it is possible to obtain certain quantitative data on the drift of the major pieces and fragments of WH-5. To arrive at the drift calculations presented in Table 1 certain reasonable assumptions have been made that are believed to represent the most probable interpretation of the data. They are:

1. Piece C escaped southward by, on, or just after its last sighting on 21 August and lay somewhere north of Cape Dyer (assumed latitude 68°N.) at the time of the Ice Patrol reconnaissance of 4 to 5 December 1963. It is pertinent to note here that WH-5 has been considered to be the only source of the reported ice-island pieces and fragments. It is, however, a possibility that random pieces of other ice islands such as T-1, then breaking up in Parry Channel, might have found their way through the Canadian islands into Baffin Bay concurrently with the WH-5 pieces; and in particular the report of 2 ice-island pieces from Baffin Bay in October 1964 could possibly have been from a source other than WH-5. However, it is overwhelmingly clear that most of the WH-5 pieces did enter the Baffin Current during the summer and autumn of 1963; and it is doubtful that any other major contribution from another ice-island in the Canadian Channels could have been made without being detected. All reports that have been recognized: 8 large pieces off Cape Chidley, 16 off Hamilton Inlet, and 50 or more fragments on the Grand Banks, must have come from

Table 1. Summary of drift of WH-5 pieces

PIECE OR FRAGMENT	FROM DATE	FROM POSITION LAT. °N.	TO DATE	TO POSITION LAT. °N.	DISTANCE NAUTICAL MILES	RATE OF DRIFT NAUTICAL MILES/ DAY
C	21 Aug. 63	Smith Sound 78° 25′	5 Dec. 63	N. of C. Dyer 68°	785	7.3
C	5 Dec. 63	N. of C. Dyer 68°	28 Feb. 64	Off Hamilton Inlet 54° 30′	820	9.6
C	28 Feb. 64	Off Hamilton Inlet 54° 30′	10 May 64	Grand Banks 44°	700	9.7
C Overall	21 Aug. 63	Smith Sound 78°	10 May 64	Grand Banks 44°	2305	8.7
A	29 Sept. 63	Smith Sound 77° 30′	29 Nov. 63	S. of Birdseye Track 71°	440	7.2
A	29 Nov. 63	S. of Birdseye Track 71°	25 Jan. 64	Off Cape Dyer 67° 30′	310	5.4
A	25 Jan. 64	Off C. Dyer 67° 30′	27 June 64	Off Labrador 57° 10′	575	3.7
A Overall	29 Sept. 63	Smith Sound 77° 30′	27 June 64	Off Labrador 57° 10′	1325	4.9
B (*A* ?)	29 Sept. 63	Smith Sound 77° 30′*	28 Feb. 64	Off Cape Chidley 61° 15′	1130	7.4
Cape Chidley Fragments	28 Feb. 64	Off Cape Chidley 61° 15′	19 May 64	Off Notre Dame Bay 50°	750	9.3
Overall *B* Fragment	20 Sept. 63	Smith Sound 78° 37′	24 June 64	Off Hamilton Inlet 54° 30′	1600	5.8

*Approximate position *A* or *B*

more than a random source. I believe there is little doubt that we have been dealing almost exclusively with WH-5, and that 'intruders', if any, have played only a minor role and have in no way affected the principal conclusions.

2. Piece A lay to the south of the *Birdseye* flight track in latitude 72°N. on 29 November 1963 (assumed latitude 71°N.).

3. The possible radar contact of WH-5 on 25 January off Cape Dyer in latitude 67°30′ was piece A.

4. The group of pieces located off Cape Chidley on 28 February 1964 were sufficiently close together and of such size that they must have come from a recent breakup of one of the major pieces, in this case either A or B, but more likely the latter in view of later identification of a large segment of piece A.

5. The report of the Ice Patrol that the pieces observed on 19 May 1964 off Notre Dame Bay, Newfoundland, were from those sighted off Cape Chidley on 28 February appears reasonable.

These reported and assumed positions of the WH-5 pieces are shown in Fig. 2 and the distribution and scattering of WH-5 remnants from Smith Sound in 1963 to waters of Labrador and Newfoundland in 1964 are shown in Fig. 5.

Discussion

The drift of Ice Island WH-5 from northern Baffin Bay to the coast of Labrador and Newfoundland is a demonstration of the net surface movements of the Baffin and Labrador Current systems, and reveals something of their nature. The major pieces and the many fragments represent essentially a single source of identifiable drift markers released in Kennedy Channel. Eventually all or in any case the majority of these drift markers escaped south into the Baffin and Labrador Currents. Most remarkable is the very wide variation in times of arrival in the southern waters and the very great scattering of the pieces in the course of their drift. The first forerunners from piece C were observed off Hamilton Inlet in late February, while the last stragglers from A or B were appearing there well into July, nearly 5 months later. Maximum scattering occurred during early May when Ice Islands remnants were stretched out from Latitude 44° on the Grand Banks to the vicinity of Cape Chidley, Labrador (or even further north), a distance of some 1,100 miles (Fig. 5).

Although concentrated within a comparatively small area in Smith Sound and southern Kane Basin in early August, the pieces and fragments later escaped southward irregularly over a period of approximately one month from late August to late September, which must reflect the local vagaries in this area during the period of weak northerly transport and the development of the counterclockwise gyre in Kane Basin. It is particularly remarkable how piece C, less than 5 miles from piece A on 6 August, escaped approximately a month earlier. This, and the irregular movements of pieces A and B, serve to emphasize the uncertain surface water movements which existed in Smith Sound and southern Kane Basin at that time (Fig. 4).

After its escape from Smith Sound the rapid and great southward movement of piece C is significant in demonstrating the importance of timing and location of entry to the Baffin Current as proposed by Lenczyk (1965). Piece C or its fragments must have been close to the north of Cape Dyer at the time of the reconnaissance on 4 and 5 December, and have joined with the bergs in the

primary threat area between Cape Dyer and Cape Chidley. From here piece C was transported far south to the Grand Banks under the favourable wind circulation prevailing during the winter and early spring of 1964, while still remaining protected within the pack ice limits.

The somewhat later escape of pieces A and B from Smith Sound resulted in quite a different pattern of drift. They were late enough to lie only in the area of secondary threat north of Cape Dyer, thus drifting south initially at slower rates than piece C, and subsequently slowing even more off the Labrador coast with the diminishing favourable winds in early spring. Escape from the pack ice off Labrador in June led to their final disintegration there and in the waters or northern Newfoundland.

The drift of the Cape Chidley pieces to off Notre Dame Bay from February to May at a rate of 9.3 miles per day is near the normal established by the Ice Patrol, and reflects the generally favourable wind conditions during that period.

That the fragment of piece B, positively identified by the drum and flag, was found well inshore and isolated, may have provided us with an anomalous record. This individual piece may have wandered inshore out of the main stream and become slowed or stopped in the coastal waters, while other fragments of piece B continued to drift south. It would seem in fact that the Cape Chidley and Notre Dame Bay pieces were more likely to have been the main body of piece B.

It thus appears that the initial scattering took place because of the irregular escape of the ice island pieces from Smith Sound and entry into the Baffin Current. The local vagaries of the Baffin and Labrador Current systems then resulted in further extensive scattering during the transit from northern Baffin Bay to the disintegration areas off Labrador and Newfoundland.

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