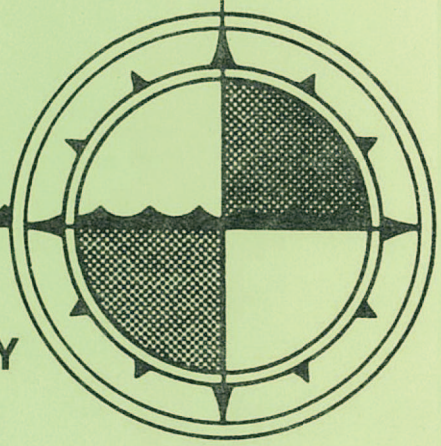
Contractor report series 77-4

A SATELLITE-BASED STUDY OF SEA ICE DYNAMICS IN THE CENTRAL CANADIAN ARCTIC ARCHIPELAGO

J.R. Marko



For
INSTITUTE OF OCEAN SCIENCES, PATRICIA BAY
Victoria, B.C.

Contractor Report Series 77-4

A SATELLITE-BASED STUDY OF SEA ICE DYNAMICS IN THE CENTRAL CANADIAN ARCTIC ARCHIPELAGO

by

J.R. Marko

For

Institute of Ocean Sciences, Patricia Bay

Victoria, B.C.

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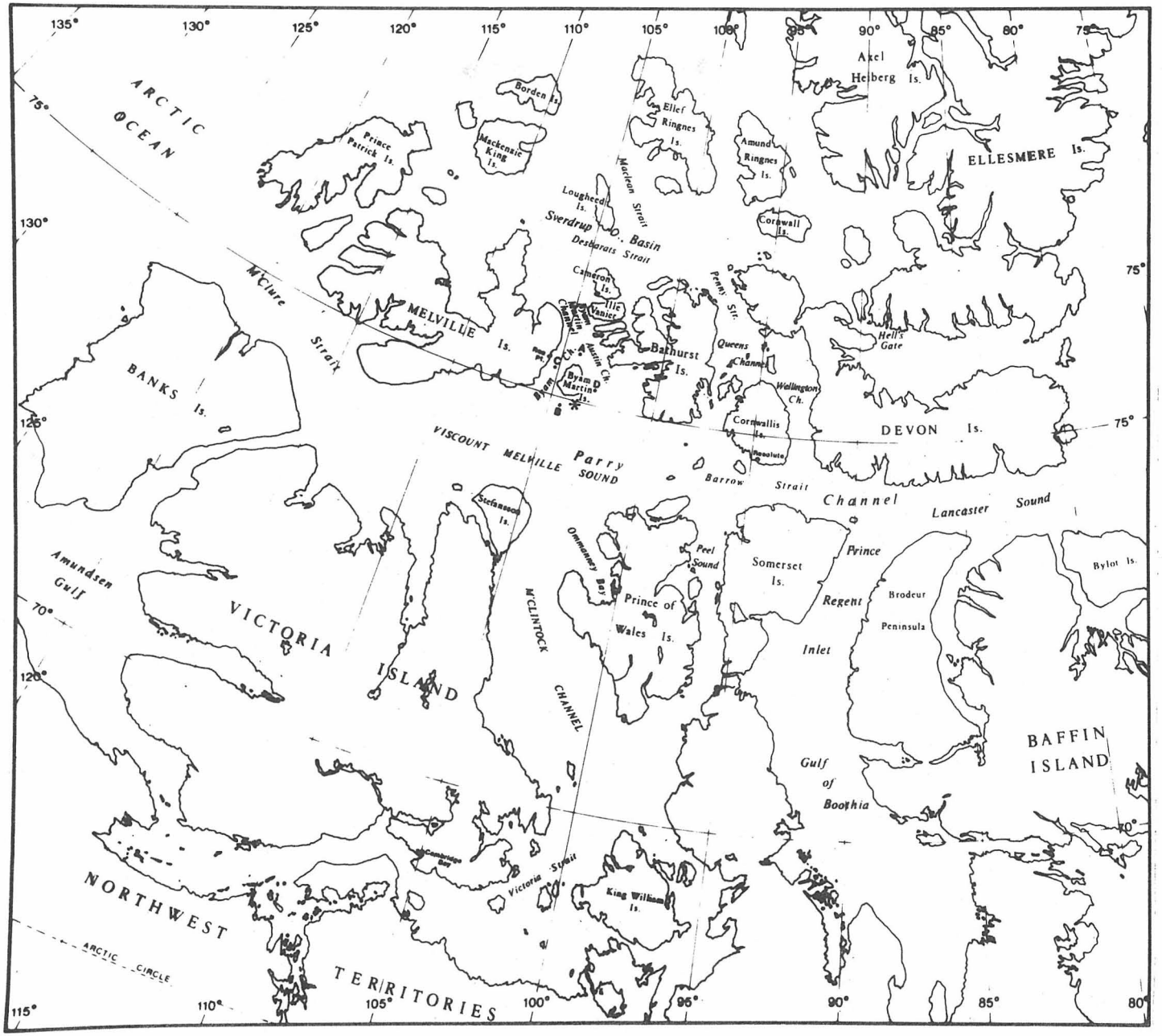
ABSTRACT

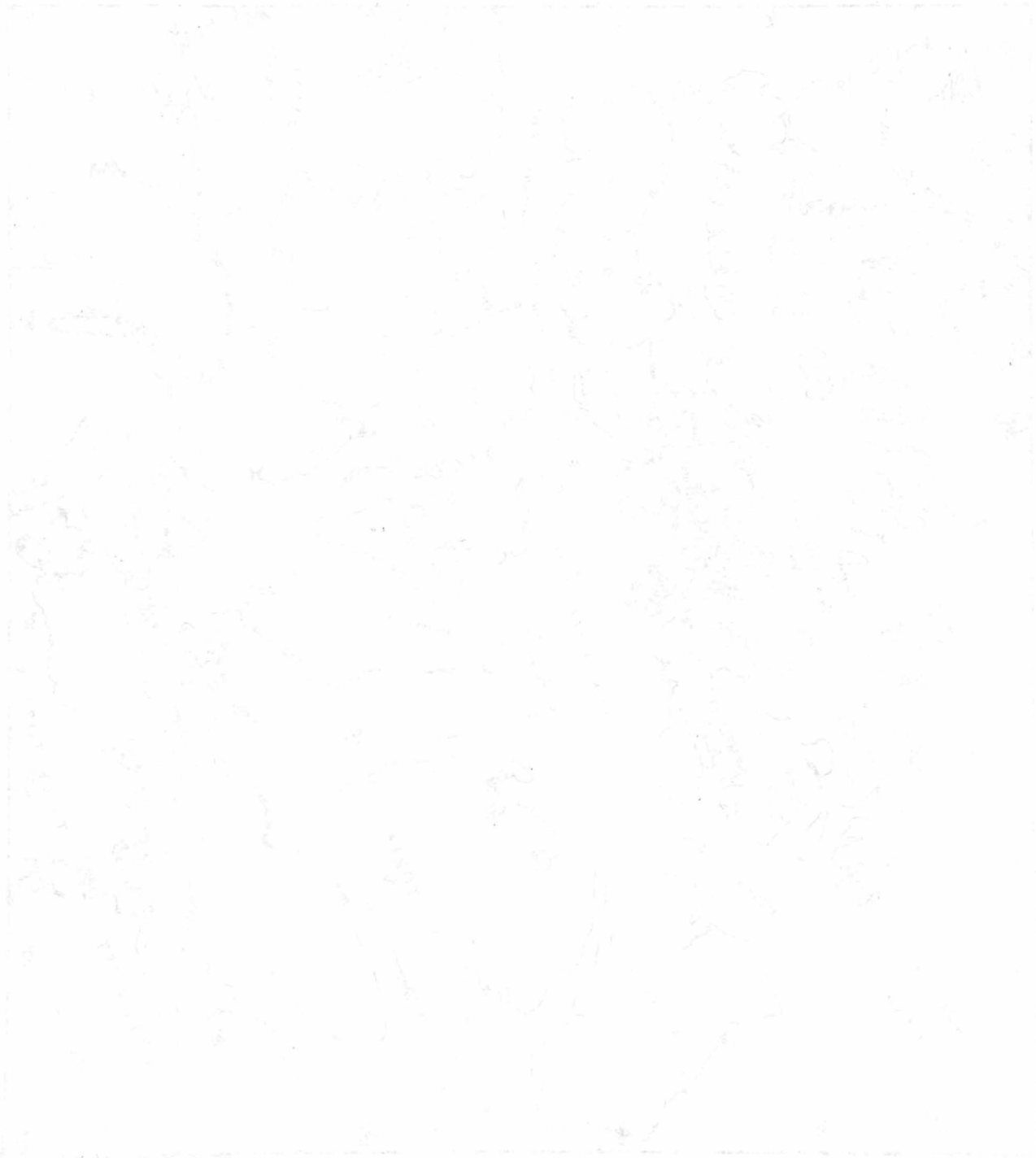
NOAA and LANDSAT satellite imagery, as well as historical ice chart data, have been used to establish the characteristic distributions and movements of sea ice in the central Arctic Archipelago. The dominant features of the ice circulation were the strong easterly and southerly movements, after break-up, of the Parry and McClintock Channels, respectively. In the eastern Parry Channel (Lancaster Sound), the easterly trend of motion continued throughout the year. The cited movement tendencies combined with the observed, extremely sluggish behaviour of the western Sverdrup Basin to produce characteristic late summer open water areas extending along the northern edge of Viscount Melville Sound and reaching as far north as the multiyear ice edge in Byam Martin Channel.

Ice floe displacement data indicate that large-scale ice motion first ceased in the north-south oriented side channels of Parry Channel. The directions of ice-drift in these side channels, e.g. Byam and Austin Channels, were largely determined by surface winds. Ice speeds were significantly larger when the wind and prevailing water-current velocities were, more or less, parallel. In Parry Channel, on the other hand, evidence indicated that macroscopic ice motion was dominated by surface current, and possible internal icepack forces.

Qualitative and quantitative ice data were used to construct scenarios whereby oil spilled in the Sverdrup Basin may work its way downstream into the biologically-critical areas of Barrow Strait and Lancaster Sound.



1. A map of the Canadian Arctic Archipelago. Offshore points near



I. INTRODUCTION

The accelerating pace of oil and gas exploration in the southern Sverdrup Basin of the Canadian Arctic Archipelago (Figure 1) has created a need for detailed data on sea ice and surface water movements downstream from those regions where oil spills could occur. This report contains a collection of relevant data on ice movements and the distribution of ice and open water obtained from satellite imagery and aircraft flights for pollutants which could originate in the southern Sverdrup Basin and flow through Byam Martin Channel. Due to the prevailing southerly direction of flow, the ice and surface water of this Channel move past Byam Martin Island through the Byam and Austin Channels before eventually entering Viscount Melville Sound which is the central portion of the famed Parry Channel or "Northwest Passage". Viscount Melville Sound is also a major link in the north-to-south waterway from the Arctic Ocean through the Prince Gustaf Adolf Sea, Byam Martin Channel, Byam and Austin Channels across to McClintock (M'Clintock) Channel and terminating in Queen Maud Gulf. The ice cover of Viscount Melville Sound is dynamic, having a nearly continuous motion greater than 1 km per day from July through November and having significant year-to-year variations in its ice-type composition. It contrasts with the more sluggish Sverdrup Basin where macroscopic movements of the ubiquitous 10/10 multiyear ice cover are confined to, at most, an 8-week period from August to October. As a result, the eventual fate of an oil spill in the Byam Martin and adjacent channels must depend on the behaviour of Viscount Melville Sound and its major outlets - McClure (M'Clure) Strait, Barrow Strait and McClintock Channel. Ice movements in the Sverdrup Basin are of interest primarily in determining the arrival times and the spreading of pollutants which might enter Byam Martin Channel. This study has accordingly been extended to include not only these areas but Lancaster Sound as well, covering in the process the circulation of ice in a major portion of the Archipelago.

Most of the analysis offered in this report was based on images obtained for the years 1973-76 from the Landsat and NOAA satellite systems. The Landsat system produces high resolution (100 m) imagery, but with a low repeat frequency (5 consecutive days every 18 days), whereas the NOAA system offers low resolution (1 km), daily coverage. The NOAA system has an additional infrared (10.5 - 12 micron) VHRR or "thermal" band facility which allows observation through the winter's darkness. Additional ice data, extending as far back as 1962, were available from Ice Forecasting Central overflights in the form of weekly maps and approximately bi-monthly summaries. These data for the years 1961/68 were extracted and compiled in atlas form by Lindsay (1976). Earlier, pre-1960 data were consulted as summarized by Swithinbank (1960) in terms of schematic representations of the probability of specific ice concentrations at weekly intervals during the summer season.

Section II of this report is a description of ice concentrations and movement in the vicinity of Byam Martin Island. Also considered are nearly simultaneous observations of changes in the ice cover of Viscount Melville Sound and in the critical McClintock Channel waterway. The analysis is carried one step further in Section III where the behaviour of the ice in Viscount Melville Sound is, in turn, related to ice behaviour in its major outlet passages and in the Sverdrup Basin. Finally, in Section IV, a summary of the principal features of the ice circulation is given, together

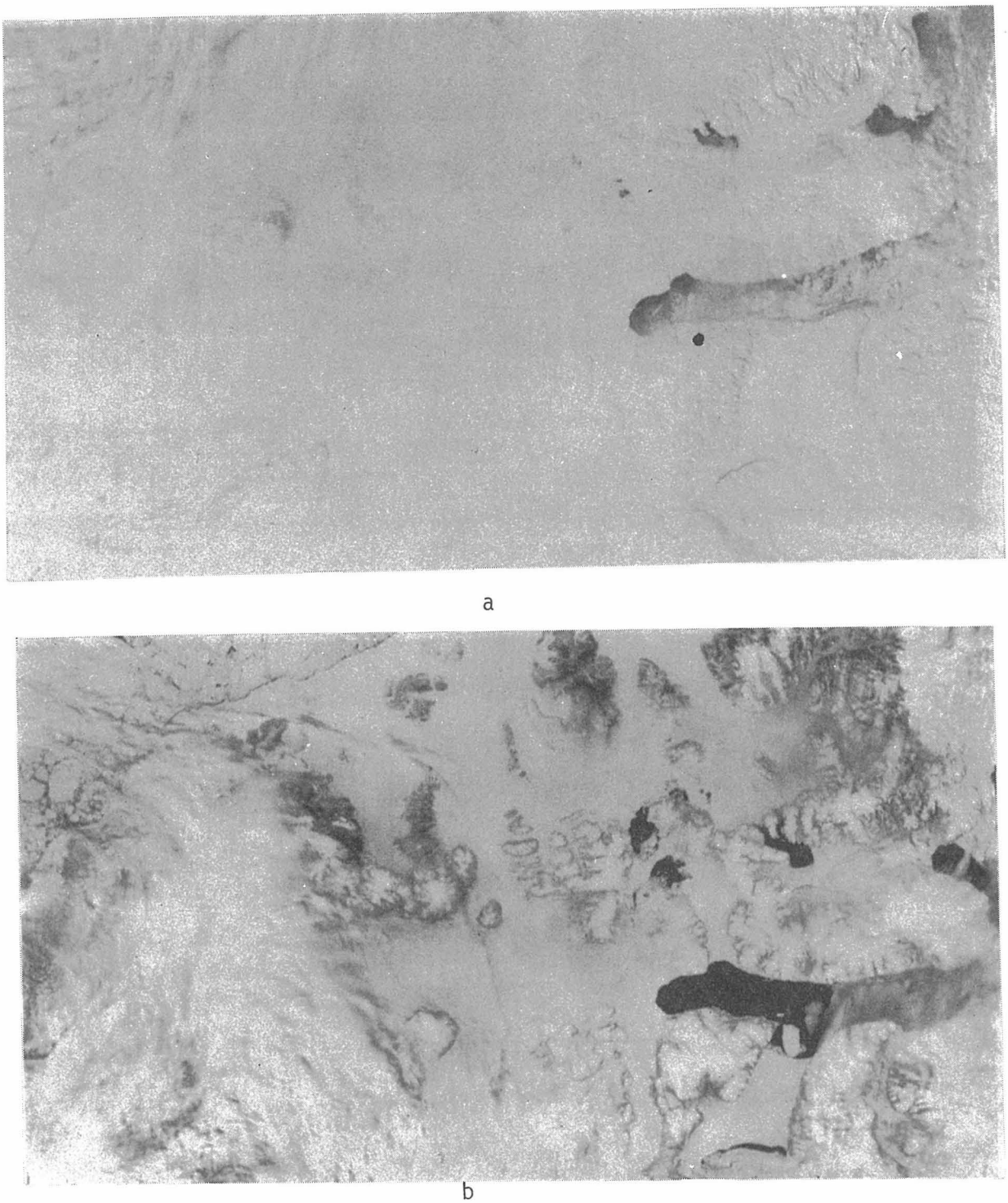
with simple scenarios describing the likely fate of oil spilled in the southern Sverdrup Basin. Suggestions are included for future Archipelago research programs.

II. ICE OBSERVATIONS IN THE VICINITY OF BYAM MARTIN ISLAND AND VISCOUNT MELVILLE SOUND

Changes in the central Arctic icepack near Byam Martin Island are rarely discernible in the NOAA and Landsat imagery prior to the month of June. With the exception of a few open water areas such as persist in Penny Strait and Hell's Gate, there is little to distinguish one marine area from another since all are covered with a visually similar snow layer (Figure 2a). The melting of this snow layer and the subsequent moistening of the underlying ice surface is the prelude to the summer break-up process which can then be followed through June (Figure 2b), and early July (Figure 3a) aided by the gradual, non-uniform darkening of the ice cover. This darkening, in addition to indicating surface wetness, may also reflect localized snow removal in areas of unusually high winds such as the north-south passes near Byam Martin and Eglinton Islands.

The first appearance of open water along the shores of Byam Martin Island or in the adjacent channels, usually occurs in late July or early August (Figure 3b). The timing of this step is illustrated by the surface density circles compiled by Swithinbank for the asterisked area Figure 1. The appearances of open water in this area followed closely the onset of large-scale motions in Viscount Melville Sound. These motions, in turn, should depend upon events in the outlets of Barrow Strait, McClure Strait and McClintock Channel because of the limited ice cover compressibility. The first of these outlets usually clears almost completely well before the start of ice motion in Viscount Melville Sound, which usually follows the break-up of McClure Strait in July (Figure 5). The initiation of the Viscount Melville Sound ice movement and the establishment of open water in the channels around Byam Martin Island may be understood in terms of the close correspondence between the patterns of ice movement and the surface currents inferred by Swithinbank (Figure 6). In view of the vast reservoir of ice in the Beaufort Sea available to sustain the easterly Parry Channel flow, a blockage of the Byam and Austin Channel southerly flows would occur by the convergence of ice in central Viscount Melville Sound unless a slackening occurs as a result of southerly ice movement in McClintock Channel. Evidence is presented below in Table I which suggests that the appearnace of open water in the Byam Martin Island area follows shortly the clearing of ice in Queen Maud Gulf through Victoria Strait. The data cited were obtained from the weekly Ice Forecasting Central charts for the years 1971-3 and supplemented by data from NOAA satellite imagery for 1974-6. Only in 1972 was the apparent relationship in serious error. One can speculate that the very limited extent of break-up that year in Viscount Melville Sound was related to the unusually late and limited break-up of the Queen Maud Gulf ice pack.

A typical ice configuration near Byam Martin Island, shortly after the onset of open water, is shown in the August 11, 1976 Landsat image of Figure 7. A very definite transition zone of relatively finely broken ice appears, separating the still landfast ice of the north from the eastward moving pack in Viscount Melville Sound, the movements of which are plotted in



a

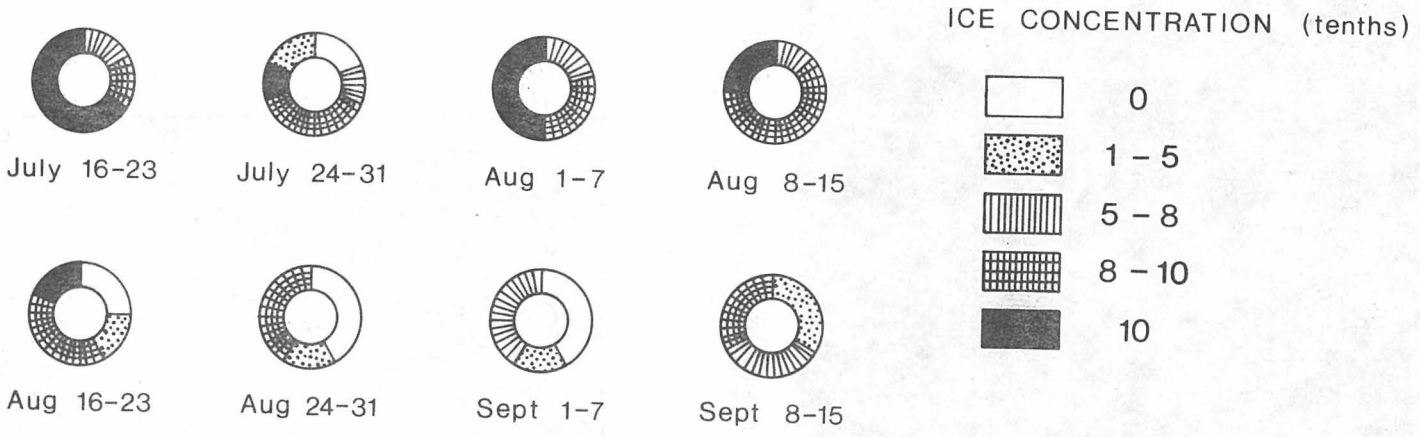
b

2. NOAA Satellite Images of the Canadian Arctic Archipelago on (a) May 14, 1976 and (b) June 23, 1976. Byam Martin Island is at the approx. centre of each image, and the large extended body of low or zero ice density, right of centre, encompasses Barrow Strait and Lancaster Sound.

a

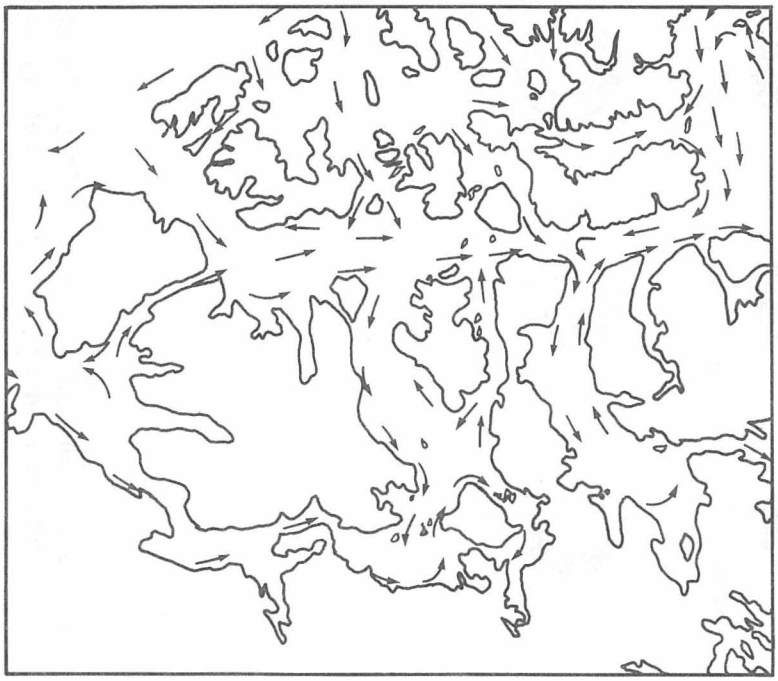
b

3. NOAA Satellite Images of the Canadian Arctic Archipelago on (a) July 3, 1976, and (b) August 8, 1976.

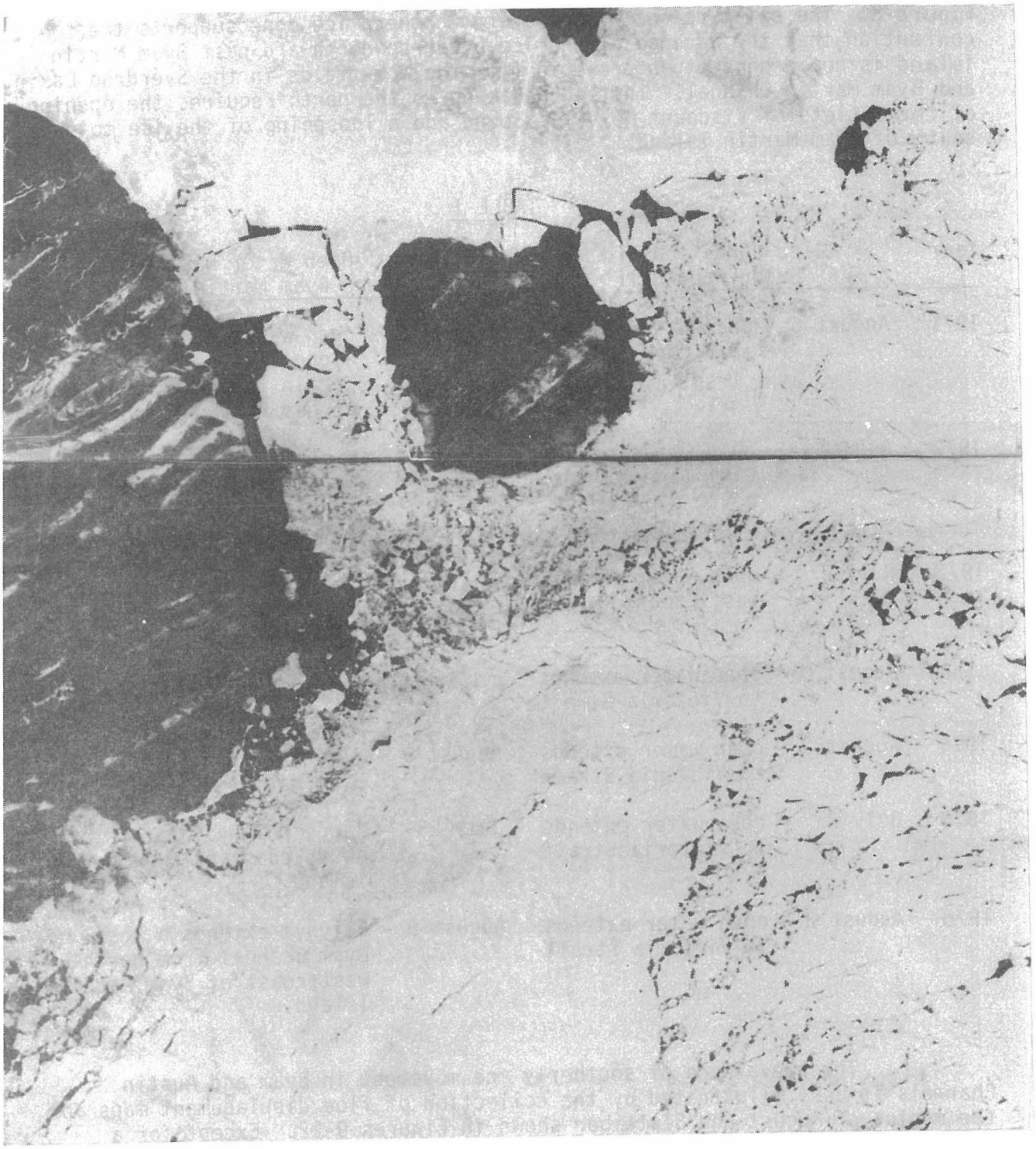


4. Distribution of ice densities in tenths near Byam Martin Island (asterisked location in Figure 1), at weekly intervals (Swithinbank).

5. A July 28, 1976 NOAA Satellite image of the Canadian Arctic Archipelago.



6. Prevailing surface current directions in the Canadian Arctic Archipelago, (Swithinbank, 1960).



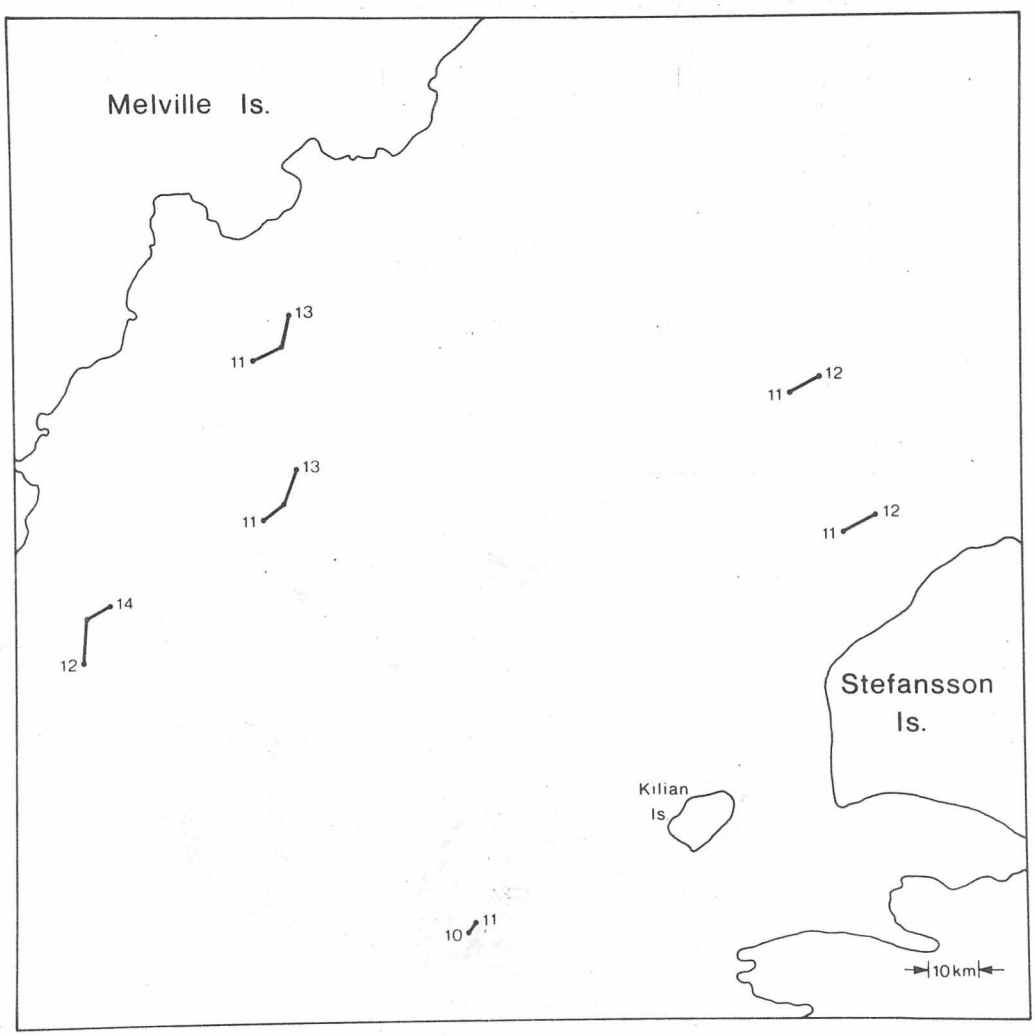
7. An August 11, 1976 Lansat image of Byam Martin Island, and surrounding ice-fields.

Figure 8. The existence of a stationary northern ice zone supports the contention that the advance of the ice break-up northward past Byam Martin Island is not dependent on pressure from the ice-fields in the Sverdrup Basin and Byam Martin Channel. Instead break-up to the north requires the opening of the outlets of Viscount Melville Sound and a loosening of the ice to the south of Byam Martin Island.

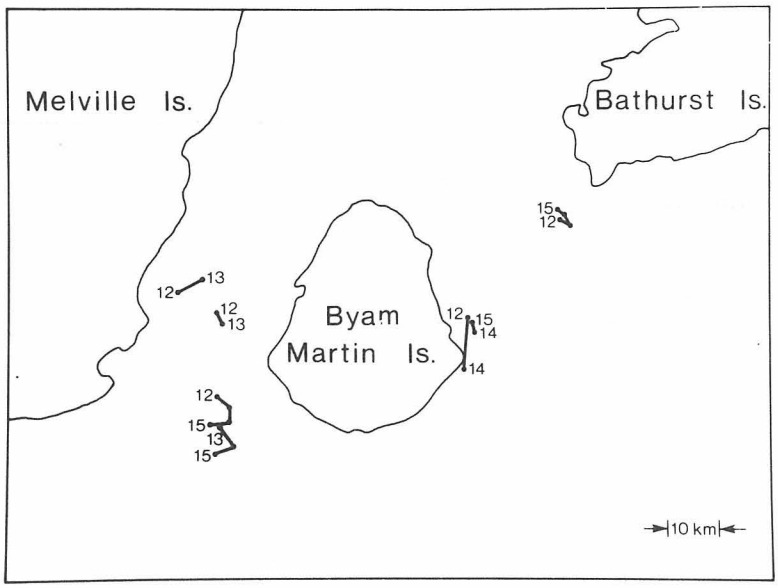
TABLE 1

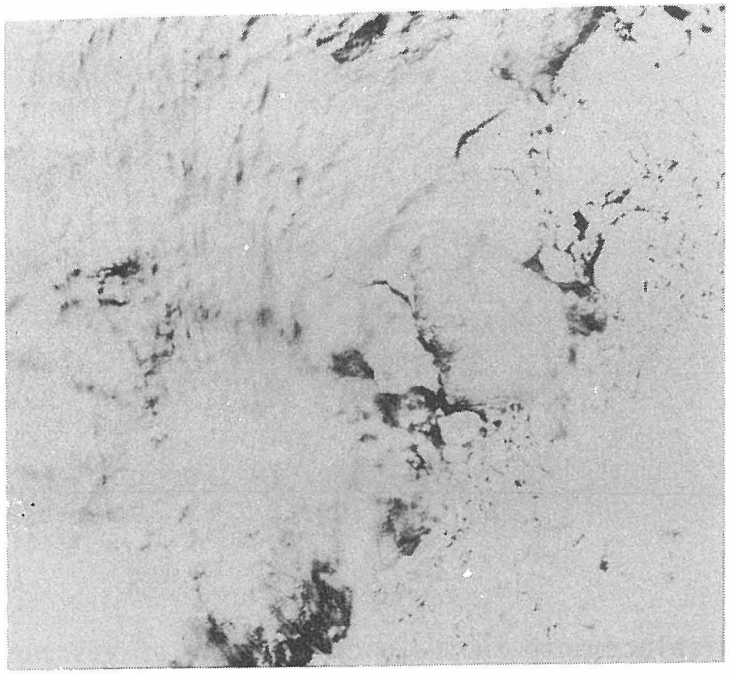
Year	Ice Conditions In Queen Maud Gulf	Initial Open Water Distribution Near Byam Martin Island
1971	August 6 - open water extends to Victoria Strait	August 6 - open water first appears along east coast of Byam Martin Island extending across Austin Channel.
1972	August 14- open water reached Cambridge Bay but never did extend to Victoria Strait	August 7 - first open water observed in 9/10 ice zone off north west coast of Byam Martin Island.
1973	July 27 - open water extends past Cambridge Bay	July 27 - 6/10 ice zone appears off south coast of Byam Martin Island.
	August 10 - open water extends to Victoria Strait	
1974	August 2 - open water extends to Victoria Strait	August 9 - 9/10 ice zone appears in Byam Martin Channel.
1975	July 25 - open water extends to Victoria Strait	July 25 - large polynya appears off south coast of Byam Martin Island.
1976	August 3 - open water extends to Victoria Strait	August 8 - Polynya extends across Byam Channel from north-west coast of Byam Martin Island.

The prevalence of southerly ice movement in Byam and Austin Channels is best illustrated by the collection of floe displacement maps for the months of August and September shown in Figures 9-22. Except for a single anomalously northward moving floe in Byam Channel in Figure 9, all northward floe displacements were significantly smaller in magnitude than the mean of the southward displacements. As might be expected, the northward displacements seem to result from strong southerly winds. This point is illustrated with the aid of Table II where wind speed and directions from Rea Pt. are listed for August 25-26, 1975 and September 4 to 6, 1975 (note that satellite observations were made daily at ≃1800Z).

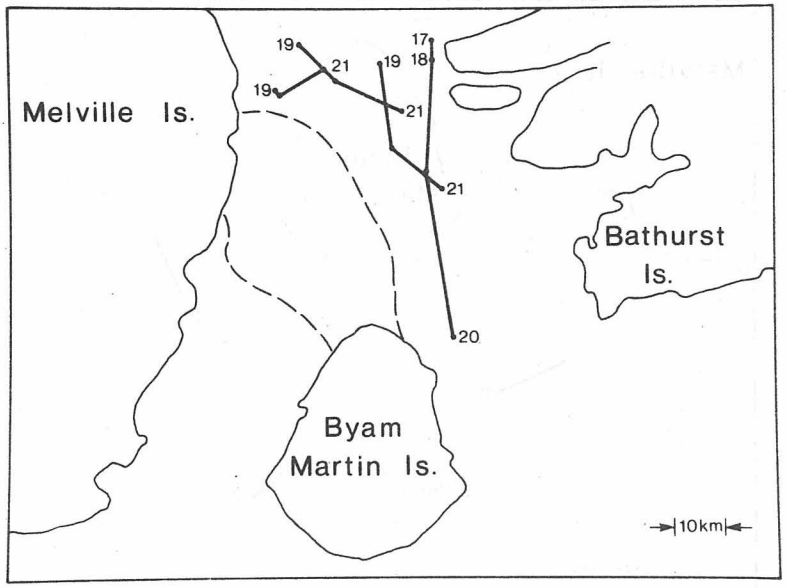


8. Ice-floe displacements in the pack-ice zone of Viscount Melville Sound, August 11 - 14, 1976. The areas covered lie just outside the lower left-hand corner in Figure 7. Numbers labelling the points on floe trajectories refer to the corresponding August dates of these positions.

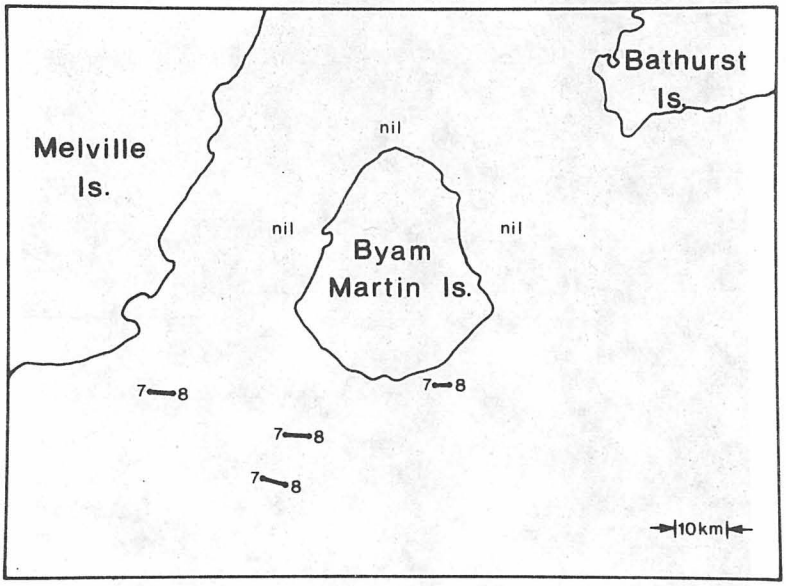




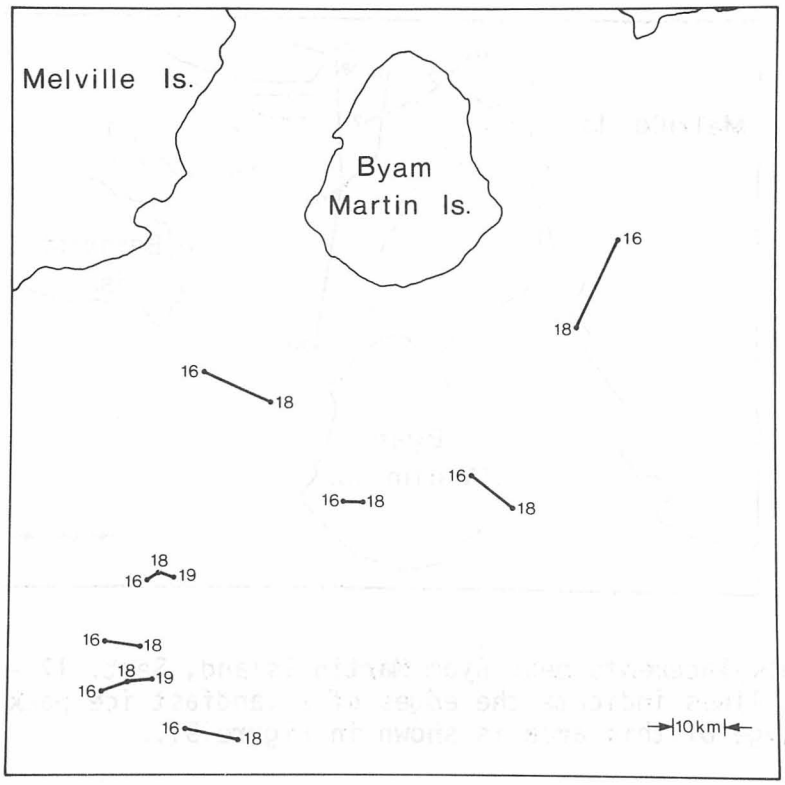
9. Ice-floe displacements near Byam Martin Island, August 12 - 15, 1974. An August 14 Landsat image of the area is also shown.

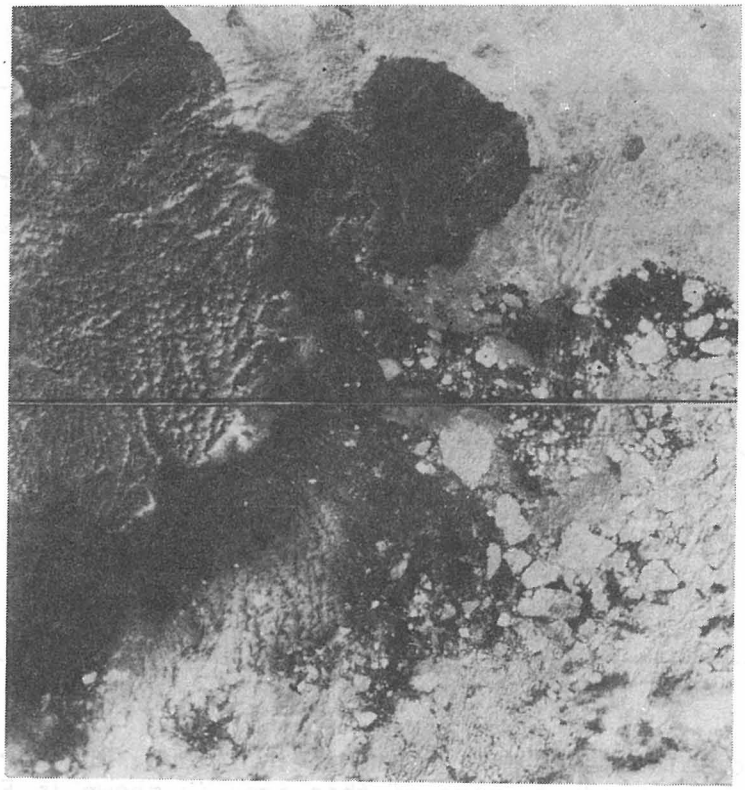


10. Ice-floe displacements near Byam Martin Island, Sept. 17 - 21, 1974. The broken lines indicate the edges of a landfast ice pack. A contemporary Landsat image of this area is shown in Figure 91.

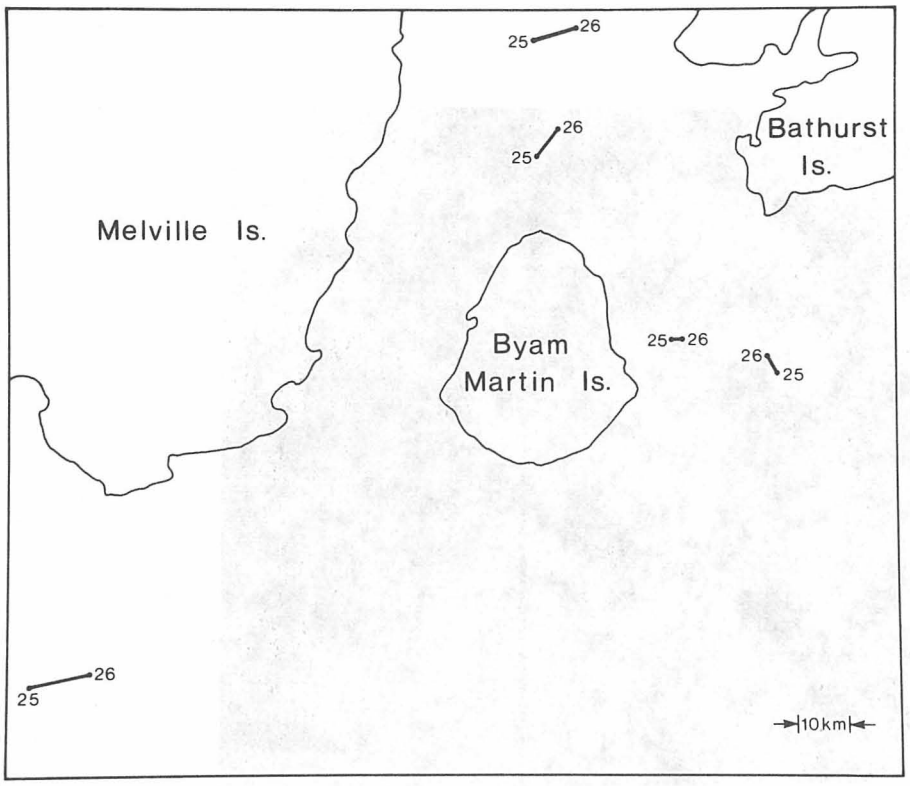


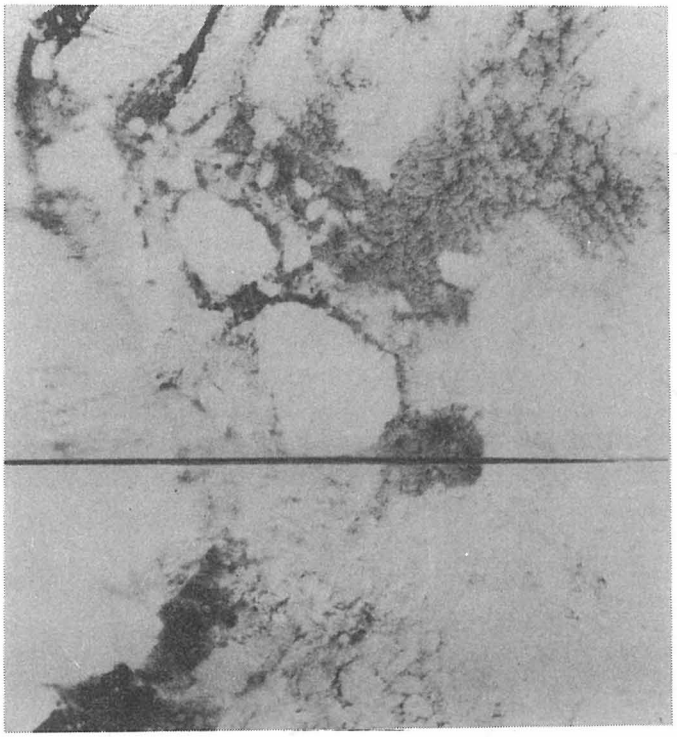
11. Ice floe displacements near Byam Martin Island, October 7 - 8, 1974. A contemporary Landsat image of this area is shown in Fig. 34.



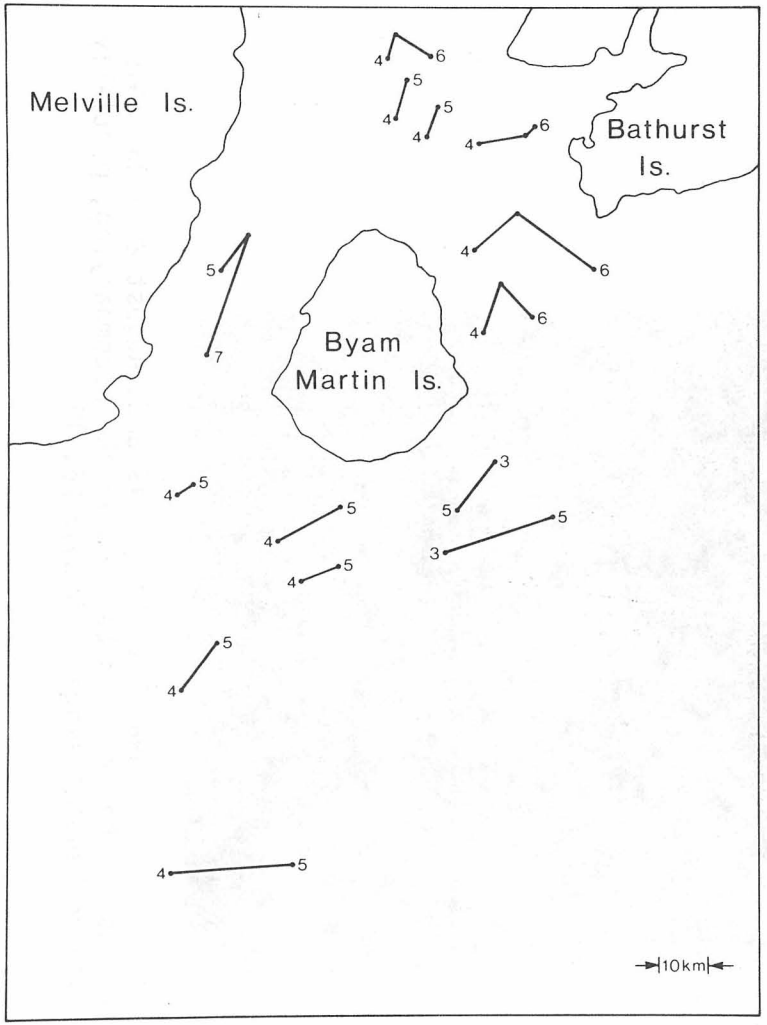


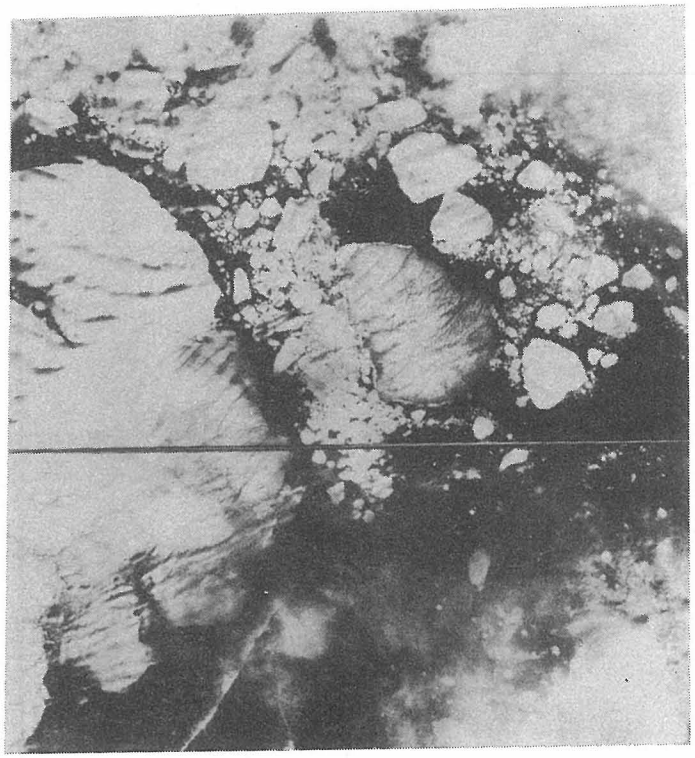
12. Ice floe displacements near Byam Martin Island, August 16 - 19, 1975. Ice conditions in the area can be seen in the accompanying Landsat image, August 18, 1975.



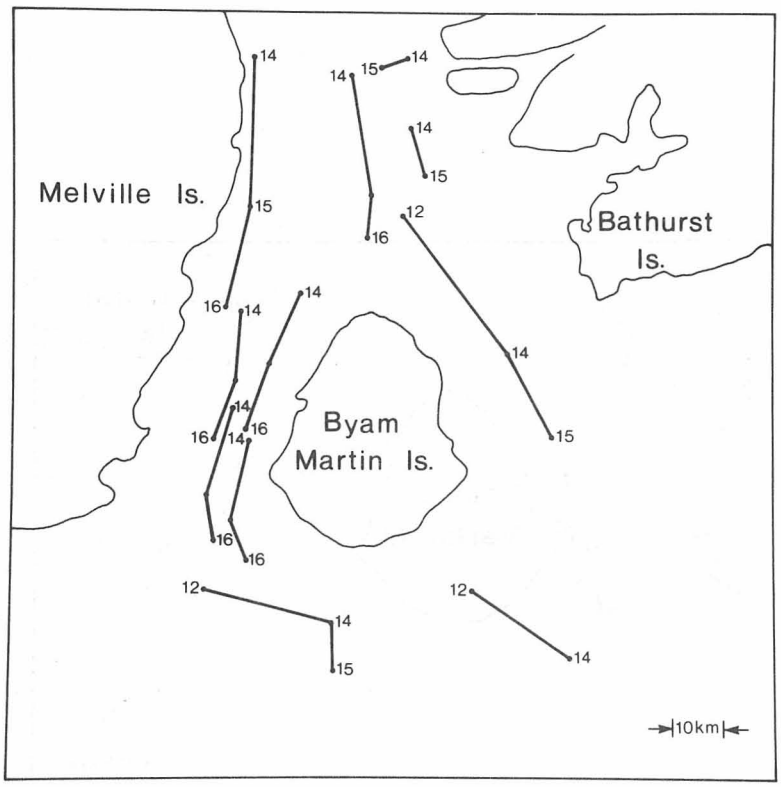


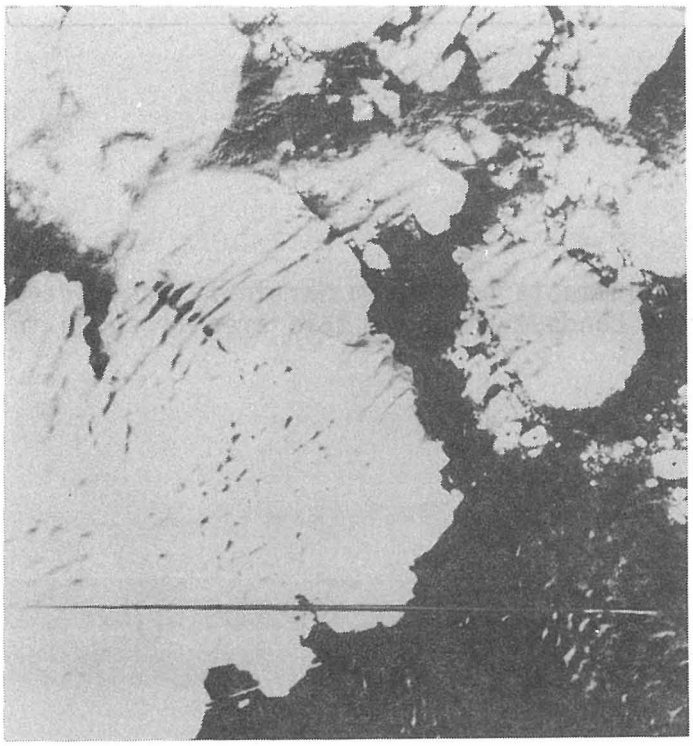
13. Ice floe displacements near Byam Martin Island, August 25 - 26, 1975. Ice conditions in the area can be seen in the accompanying, partially cloud -obscured Landsat image of August 26, 1975.



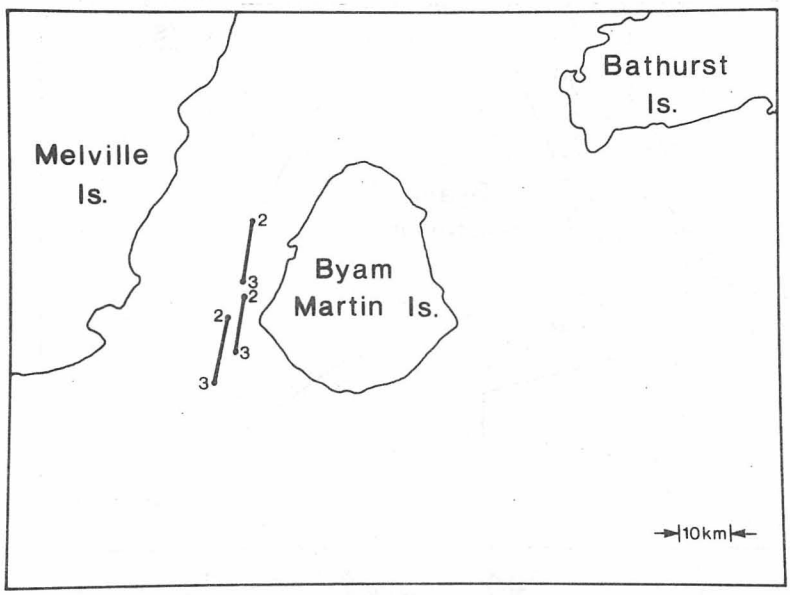


14. Ice floe displacements near Byam Martin Island, September 3 - 7, 1975. Ice conditions in the area can be seen in the accompanying Landsat image of September 5, 1975.

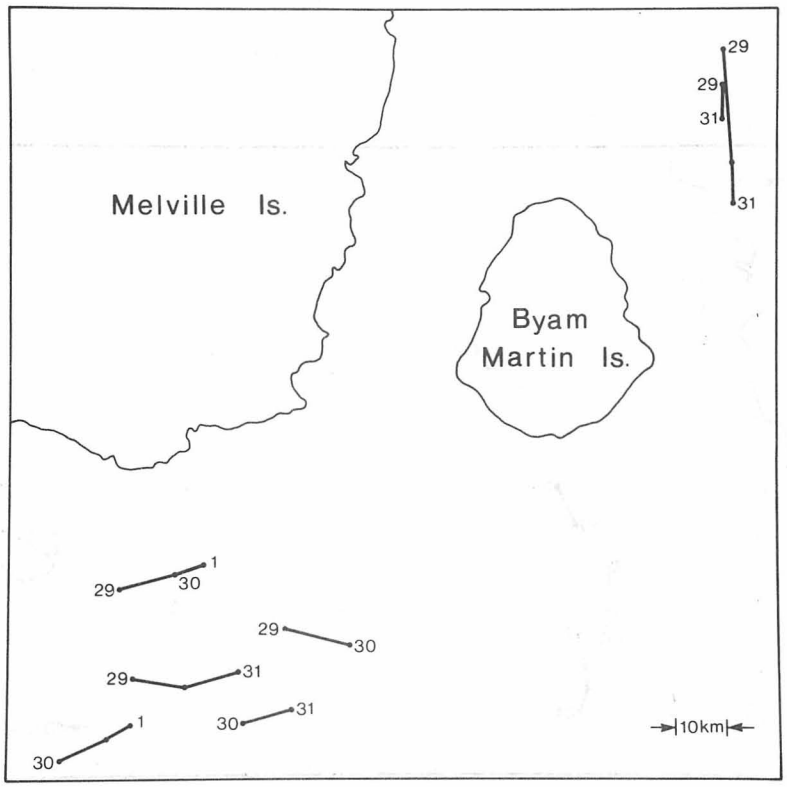




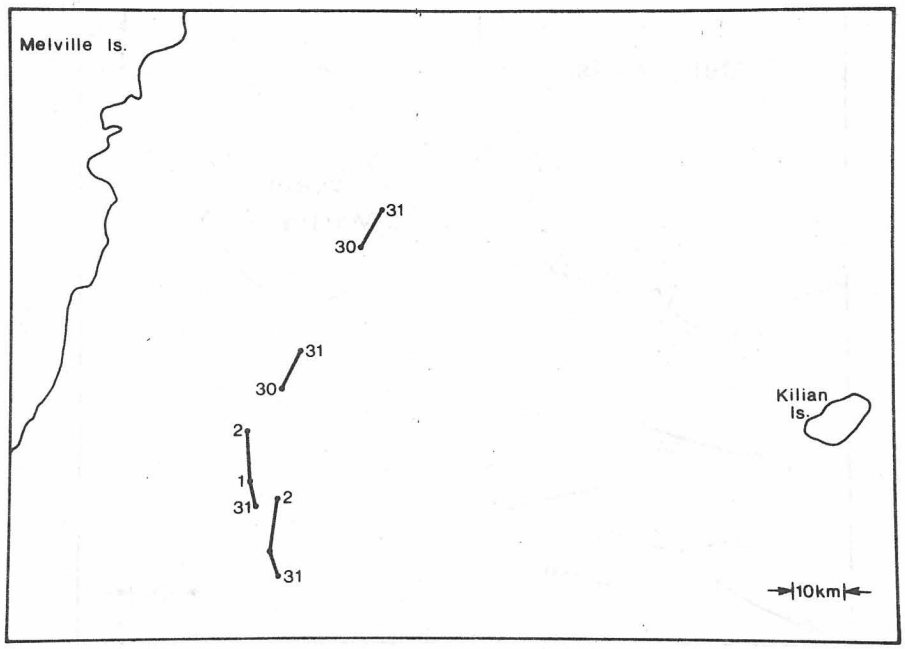
15. Ice floe displacements near Byam Martin Island, September 12 - 16, 1975. Ice conditions in the area can be seen in the accompanying Landsat image of September 15, 1975.



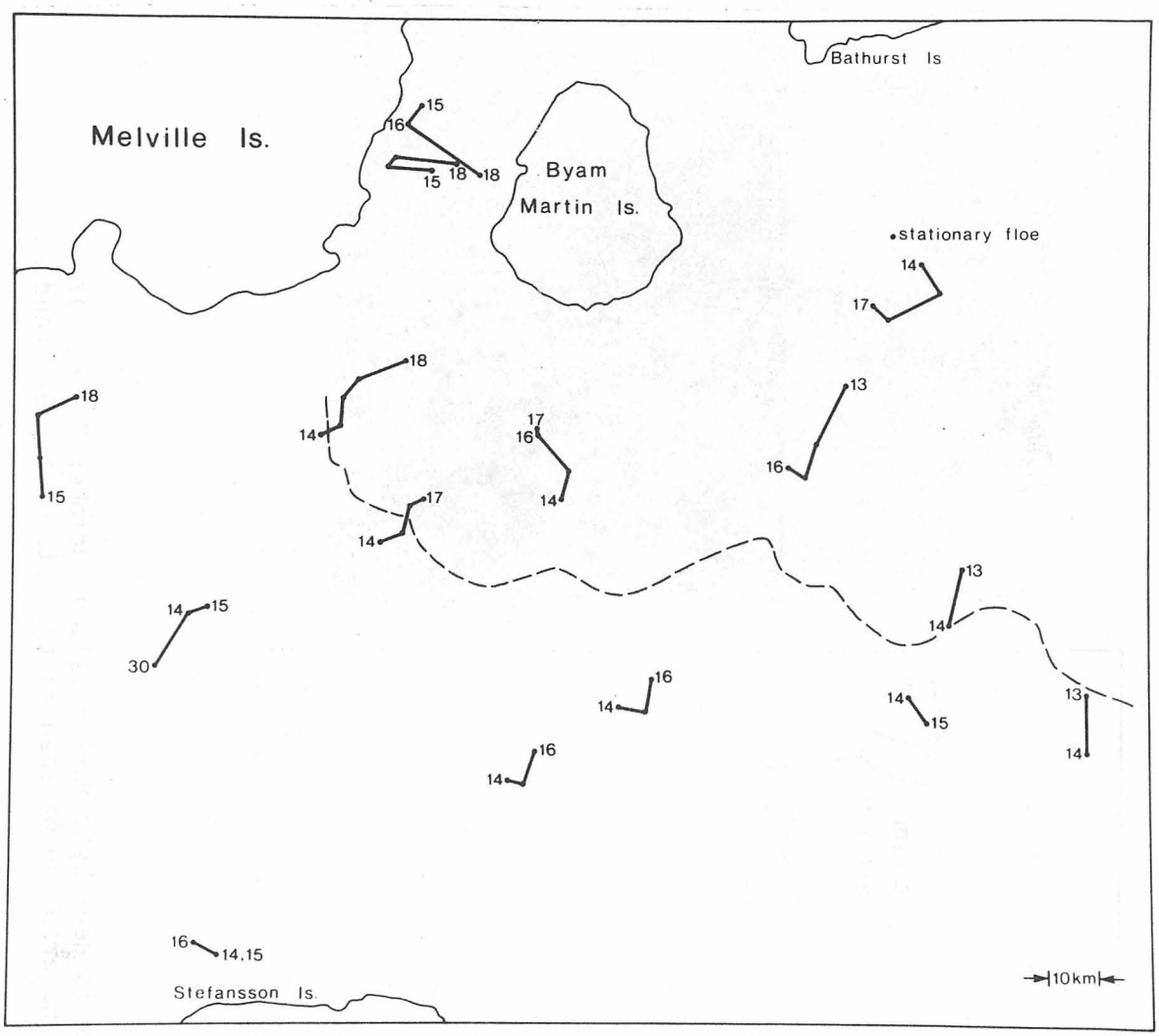
16. Ice floe displacements near Byam Martin Island, October 2 - 4, 1975. A contemporary Landsat image of this area is shown in Figure 35.



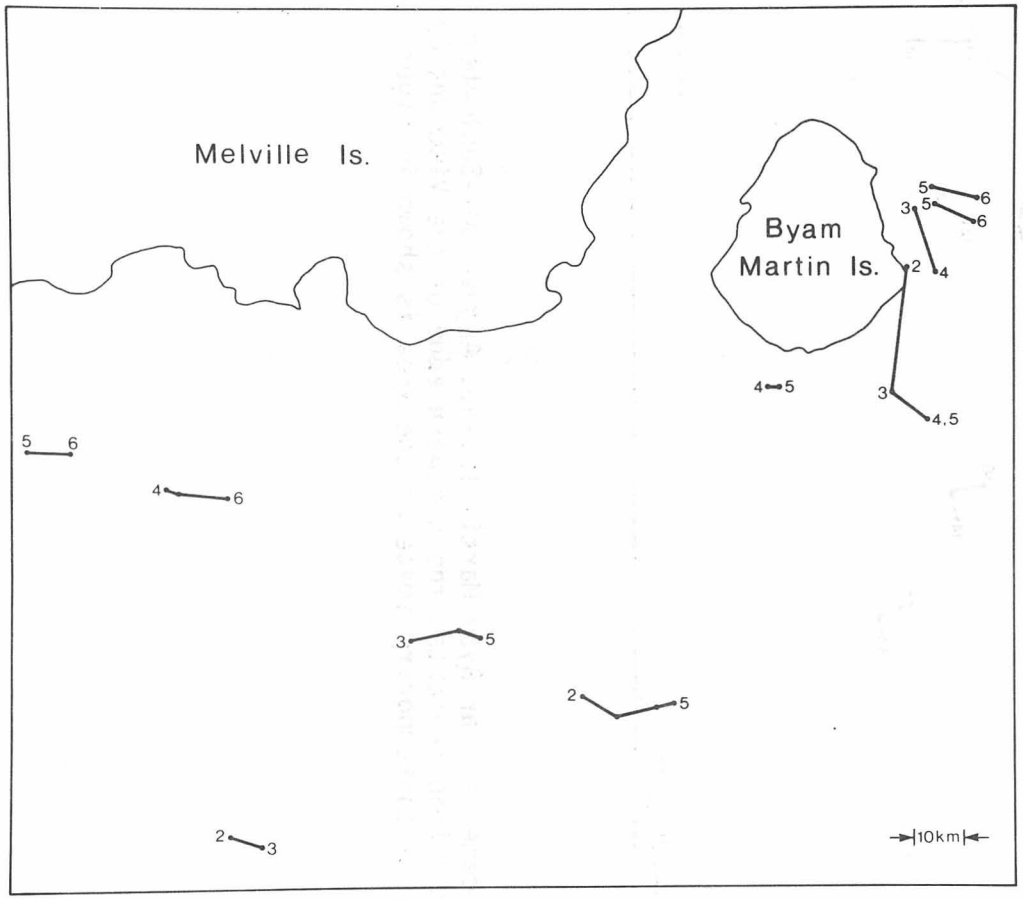
17. Ice floe displacements near Byam Martin Island, August 29 - 31, 1976. Ice conditions in the area can be seen in the accompanying Landsat image of August 30, 1976.

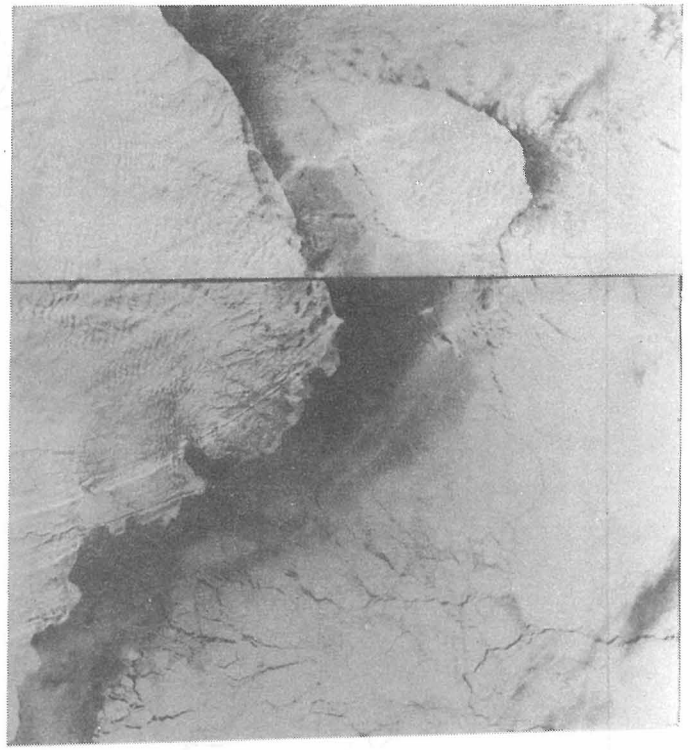


18. Ice floe displacements in Viscount Melville Sound, southwest of Byam Martin Island, August 30 - Sept. 2, 1976.

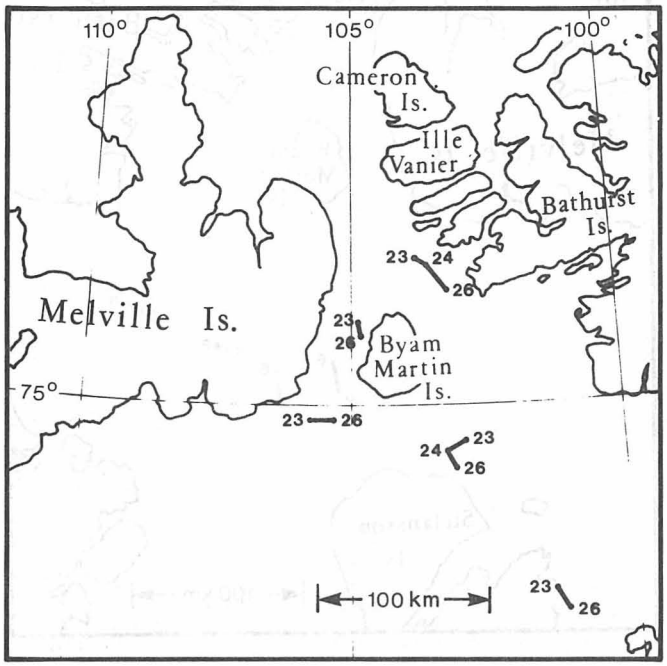


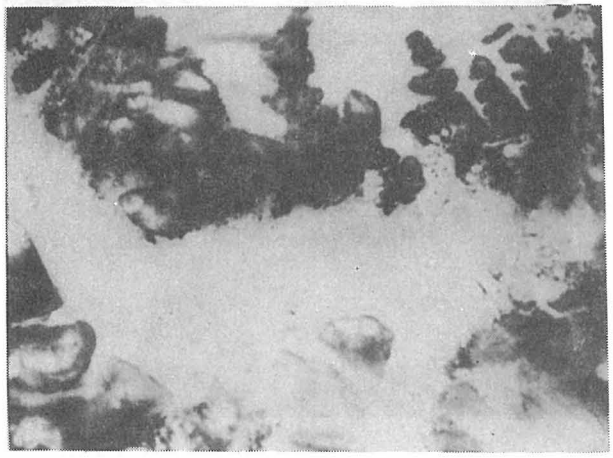
19. Ice floe displacements near Byam Martin Island, August 30--September 18, 1976. The broken line indicates the northern edge of the Viscount Melville Sound ice pack. A contemporary image of the area is shown in Figure 44.



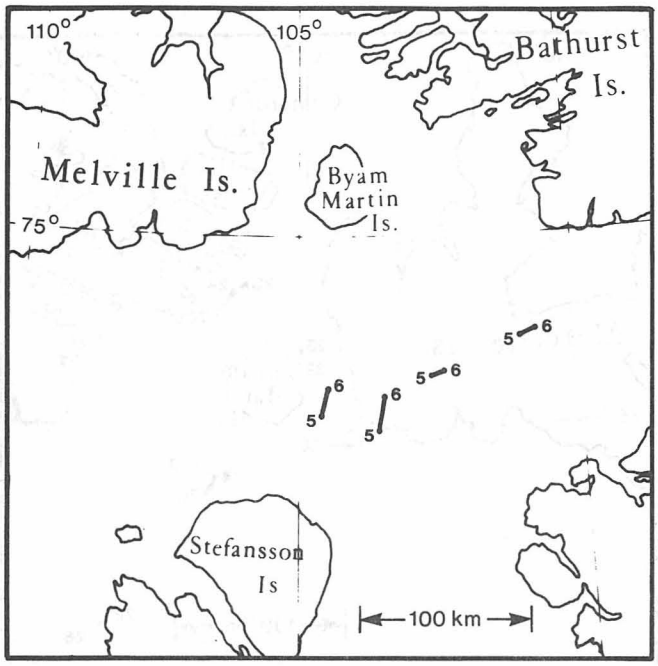


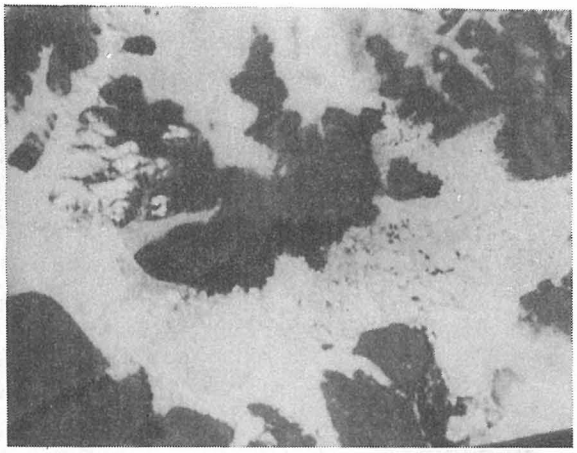
20. Ice floe displacements near Byam Martin Island, October 2 - 6, 1976. Ice conditions in the area can be seen in the October 5, 1976 Landsat image.



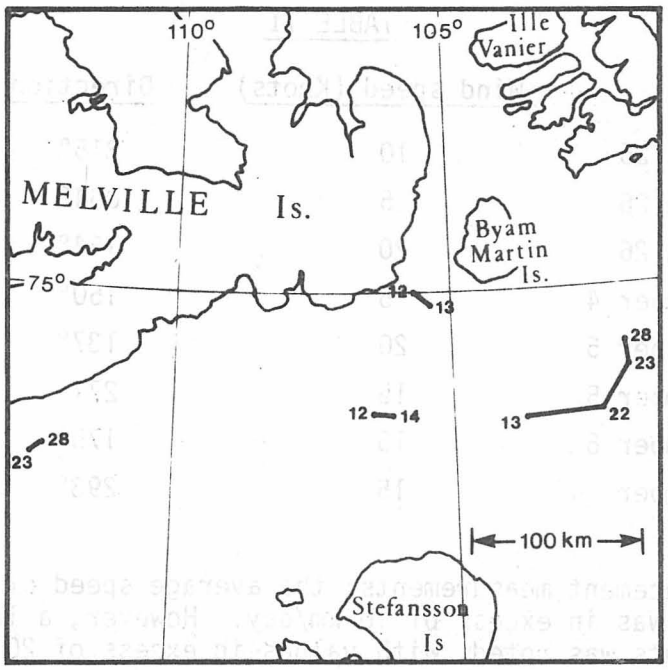


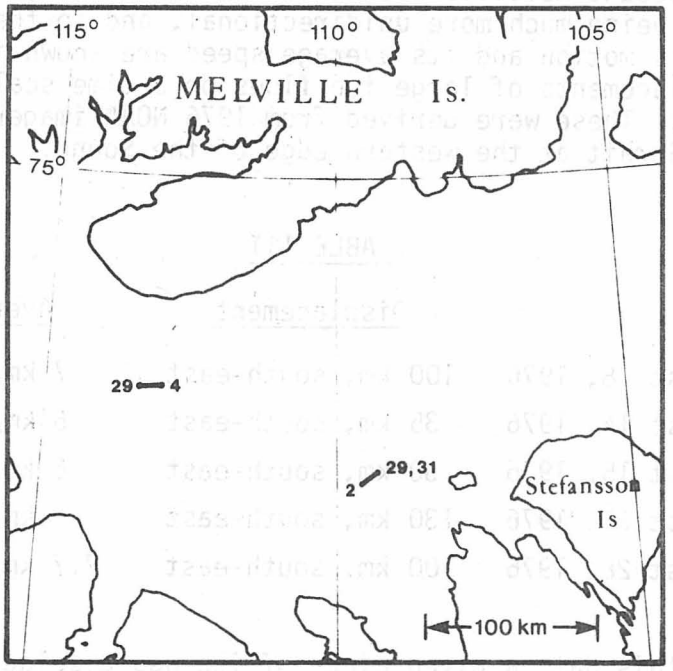
21a. Ice floe displacements near Byam Martin Island, August 23 - 26, 1974; as determined from NOAA satellite imagery. A contemporary (August 24, 1974) NOAA image of the area is also shown.





21b. Ice floe displacements near Byam Martin Island, August 5 - 6, 1975; as determined from NOAA satellite imagery. A contemporary (September 6, 1975) NOAA image of the area is also shown.





22. Ice floe displacements near Byam Martin Island and in western Viscount Melville Sound during (a) the October 12 - 28, 1976 and (b) the October 29 - November 4, 1976 intervals as determined from NOAA satellite imagery. Contemporary NOAA images of these areas are shown in Figure 39.

TABLE II

	Wind speed (Knots)	Direction
August 25	10	315°
August 26	5	004°
August 26	20	184°
September 4	5	150°
September 5	20	137°
September 5	15	271°
September 6	15	175°
September	15	293°

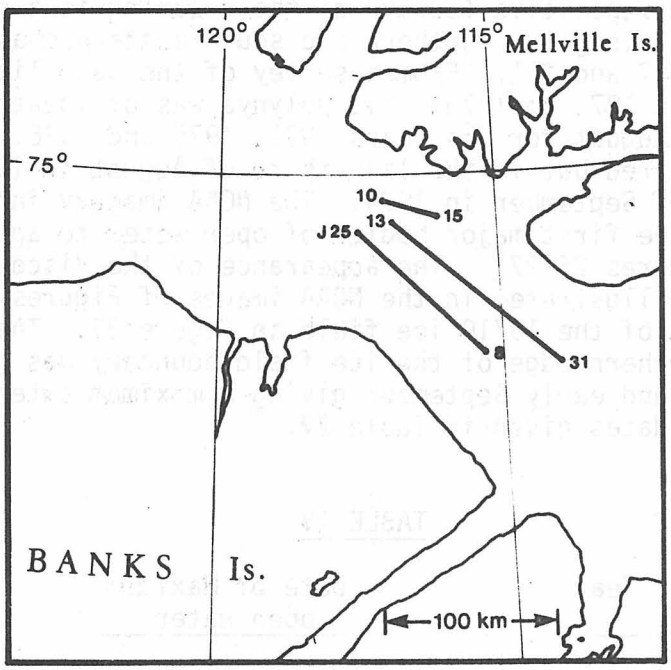
From these displacement measurements, the average speed of the southerly moving ice floes was in excess of 10 km/day. However, a large spread in daily displacements was noted, with values in excess of 20 km being commonly recorded.

In Viscount Melville Sound, on the other hand, the ice motion was slightly slower, being much more unidirectional, and to the east. The steadiness of this motion and its average speed are shown in Table III. In this table, displacements of large ice floes on a time scale of one to two weeks are listed. These were derived from 1976 NOAA imagery (Figure 23) of eastern McClure Strait at the western edge of the Sound.

TABLE III

	Displacement	Average Velocity
July 25 - August 8, 1976	100 km, south-east	7 km/day, south-east
August 8 - August 14, 1976	35 km, south-east	6 km/day, south-east
August 10 - August 15, 1976	30 km, south-east	6 km/day, south-east
August 13 - August 31, 1976	130 km, south-east	7 km/day, south-east
August 15 - August 28, 1976	100 km, south-east	7.7 km/day, south-east

On the basis of this data a given piece of ice was displaced roughly 250 km eastward along the Parry Channel axis in a single 5 week period. The resultant flow pattern in Viscount Melville Sound is similar to that deduced in Figure 21a from the NOAA imagery of August 23-26, 1974, with a pronounced southward component in the portion of the Sound north of McClintock Channel. The high impedance of Byam Martin Channel to ice movement evidently slows down the ice flow out of the Sverdrup Basin sufficiently to allow the formation of a characteristic open water area in the lower Byam and Austin Channels and northern Viscount Melville Sound. This open water persists from late August to October. To illustrate the timing of this feature the ice



23. Ice floe displacements in eastern McClure Strait, July 25 - August 31, 1976; as determined from the NOAA satellite imagery. Floe locations on July dates are labelled with the prefix "J".

surface density readings, obtained from Ice Forecasting Central charts, were calculated at points near Byam Martin Island, (indicated on Figure 1) at roughly the 10th and 25th days of August and September, as averaged over the years 1971 to 76. These results, plotted in Figure 24, show the early September maximizing of open water in almost all areas near Byam Martin Island with perhaps the exception of point C in the middle of Byam Channel. The most consistent repetitive feature of the clearing is a characteristic polynya which forms along the southern and south-eastern coast of Melville Island (see Figures 7 and 25). From a survey of the satellite imagery and ice charts for the years 1971 to 1976, this polynya was of identifiable size by the first third of August for the years 1971, 1975 and 1976. Similar states of development occurred but in the last third of August in 1972 and 1973 and in the first week of September in 1974. The NOAA imagery indicate that this polynya is one of the first major bodies of open water to appear in the central Arctic (Figures 25-27). The appearance of the Viscount Melville Sound open water area is illustrated in the NOAA images of Figures 28-31 and in the sketched boundaries of the 10/10 ice field in Figure 32. The southward movement of the northern edge of the ice field boundary was generally observed during late August and early September giving a maximum extent of open water on the approximate dates given in Table IV.

TABLE IV

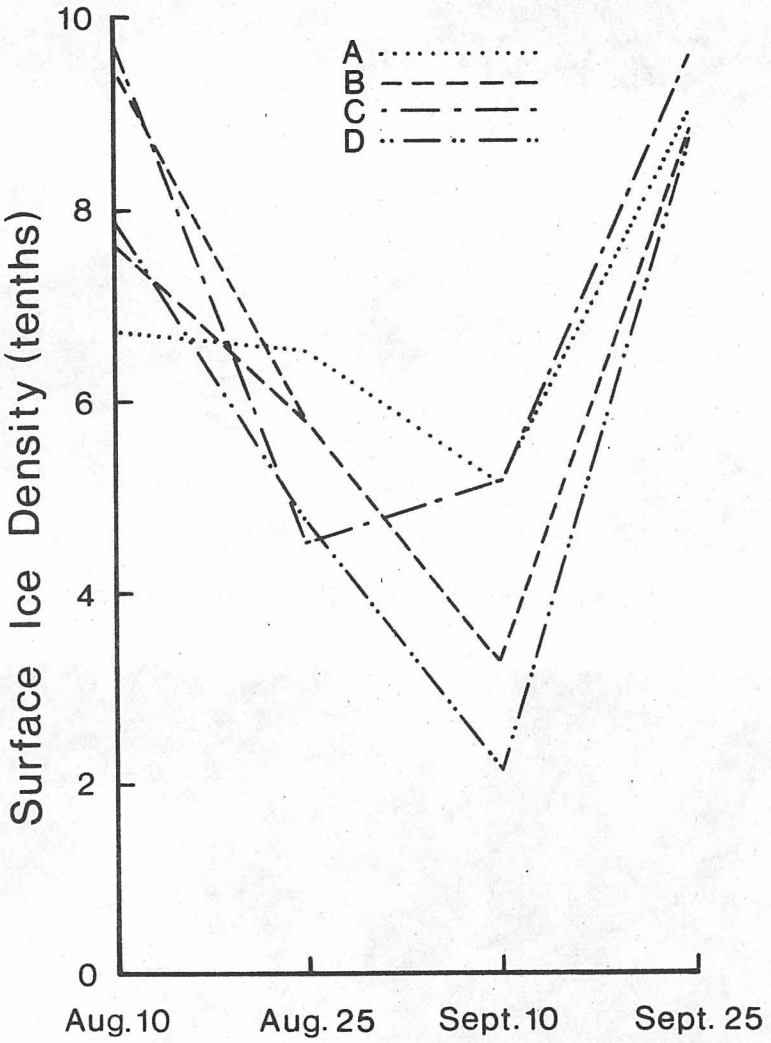
Year	Date of Maximum open water
1971	September 3
1972	September 11
1973	September 14
1974	September 13
1975	September 5
1976	September 22

These dates coincide reasonably well with the early September minimum in ice density south of Byam Martin Island indicated in Figure 24.

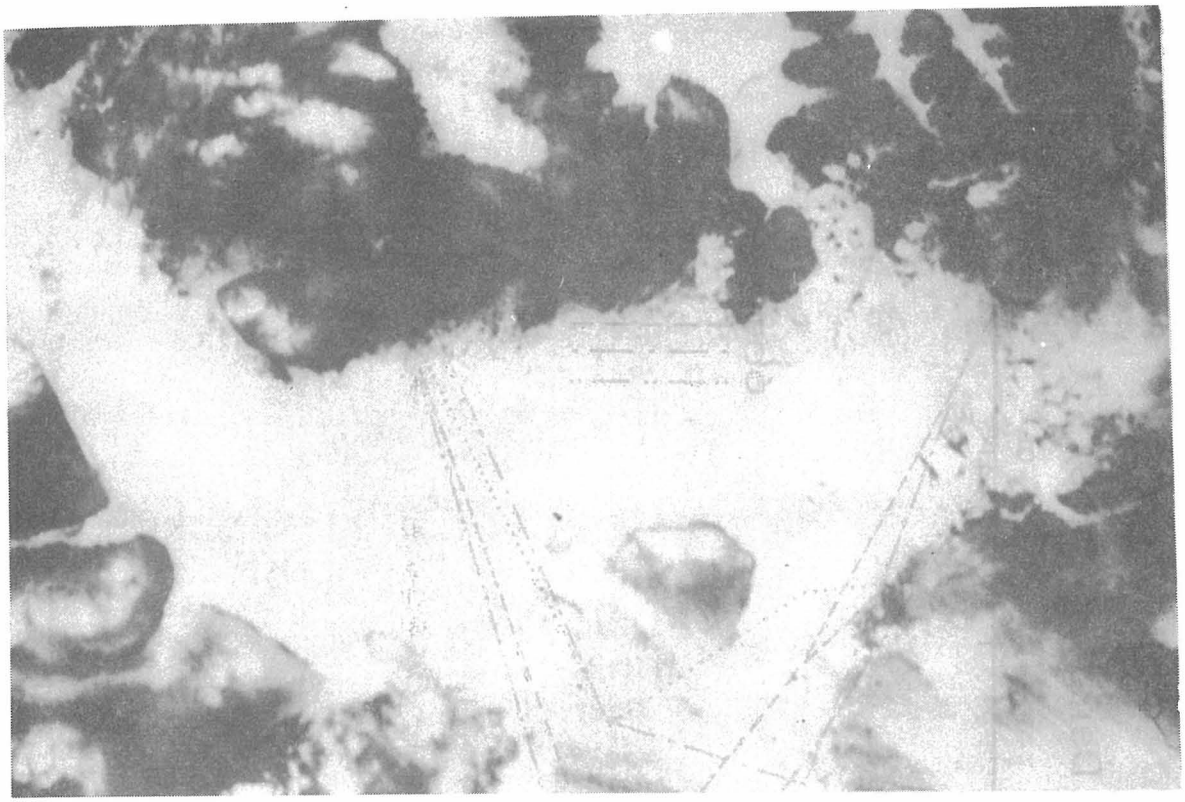
The mappings of Figure 32 and the corresponding late season satellite imagery clearly indicate that an annual southward concavity in the ice edge occurs in the portion of Viscount Melville Sound directly north of McClintock Channel. This is believed to be yet another manifestation of a southward flow of ice in this area.

It is worth calling attention at this point to the unusually limited extent and northerly location of the late season open water area which existed in 1972 (Figure 33). As indicated earlier, this situation may have been the result of incomplete clearing of the Queen Maud Gulf ice pack and the consequent decreased southward mobility of ice in McClintock Channel.

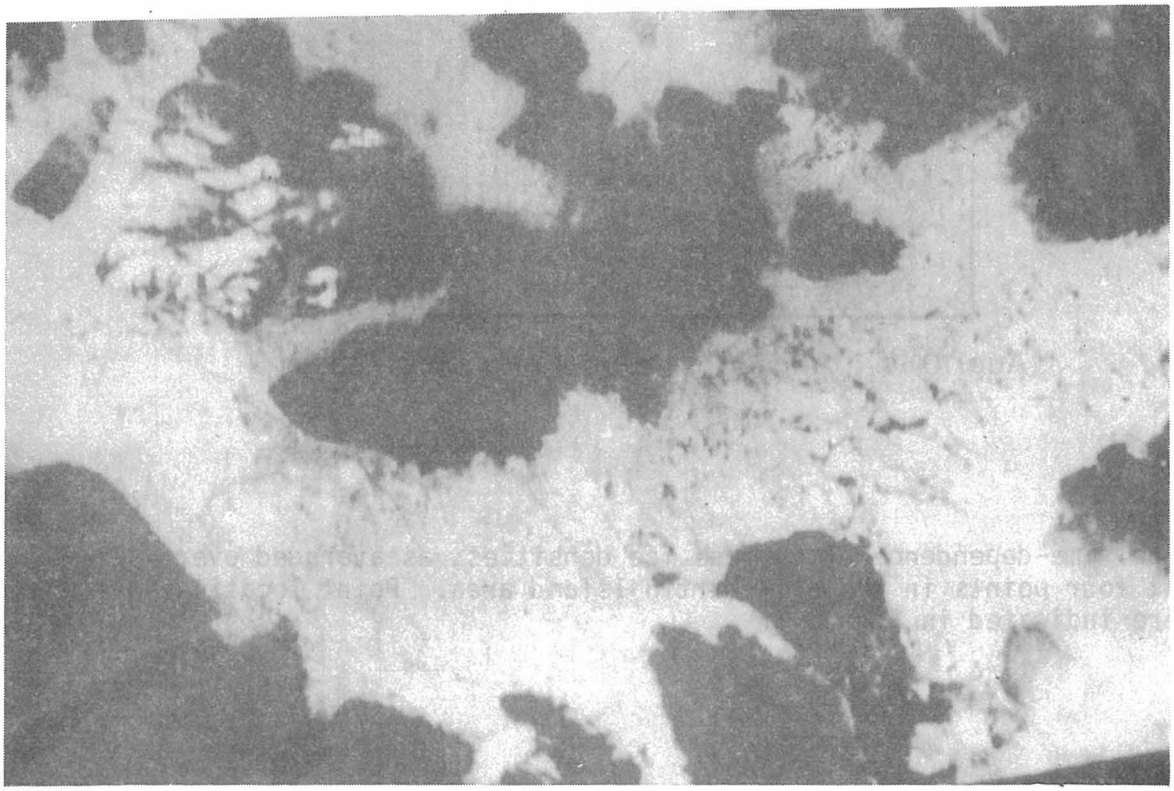
As may be inferred from the plots of Figure 24, the refreezing of



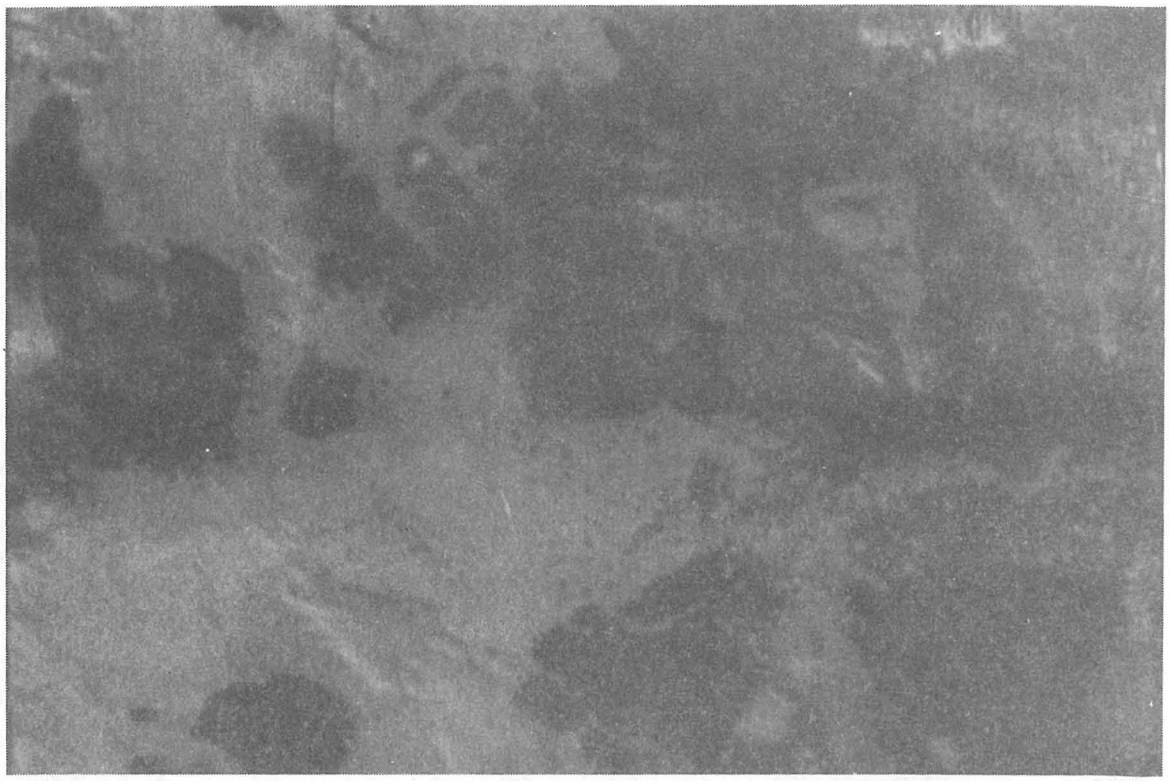
24. The time-dependence of surface ice densities, as averaged over 1971-76, at four points in the Byam Martin Island area. Point locations A - D are indicated in Figure 1.



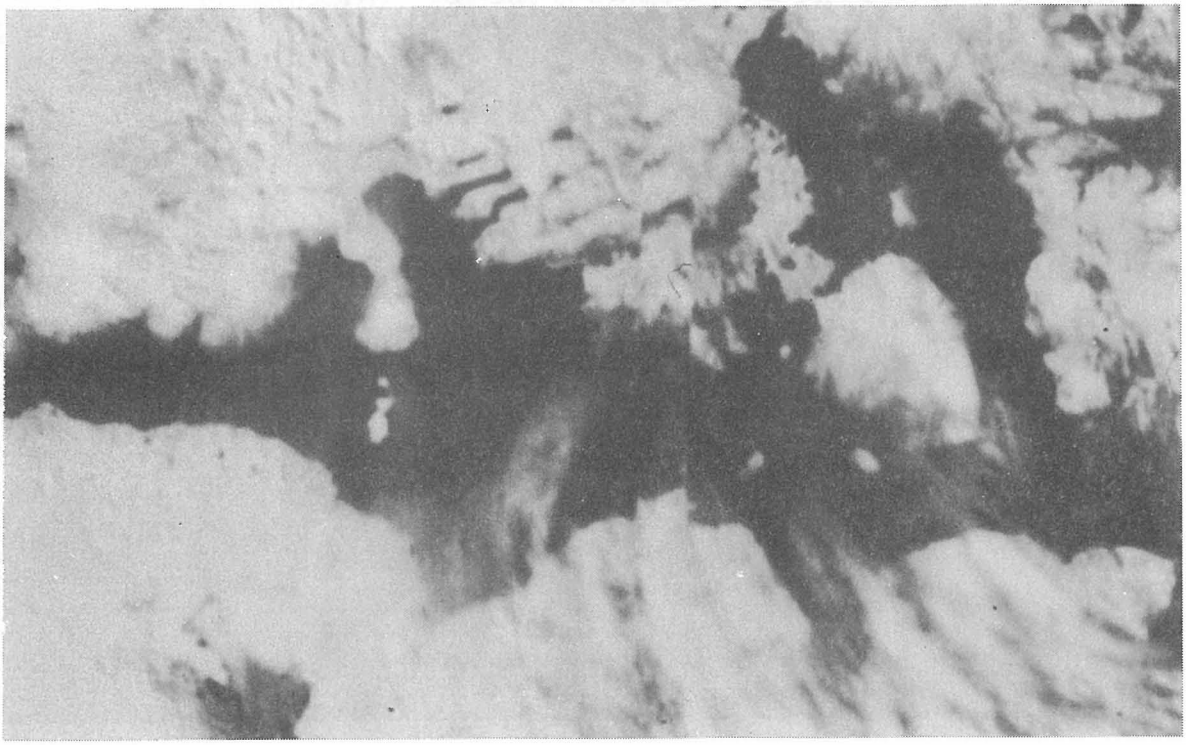
25. An August 24, 1974 NOAA image showing the Melville Island coastal polynya.



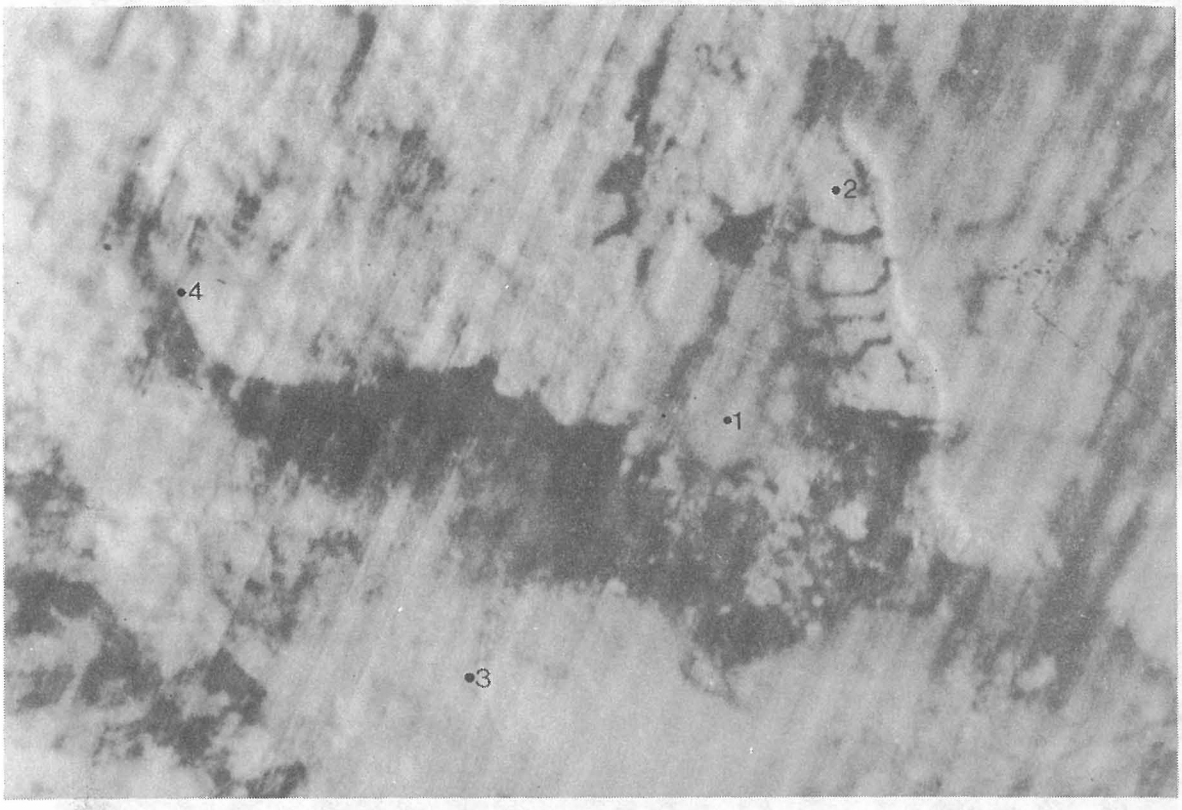
26. An August 5, 1975 NOAA image, showing the Melville Island coastal polynya.



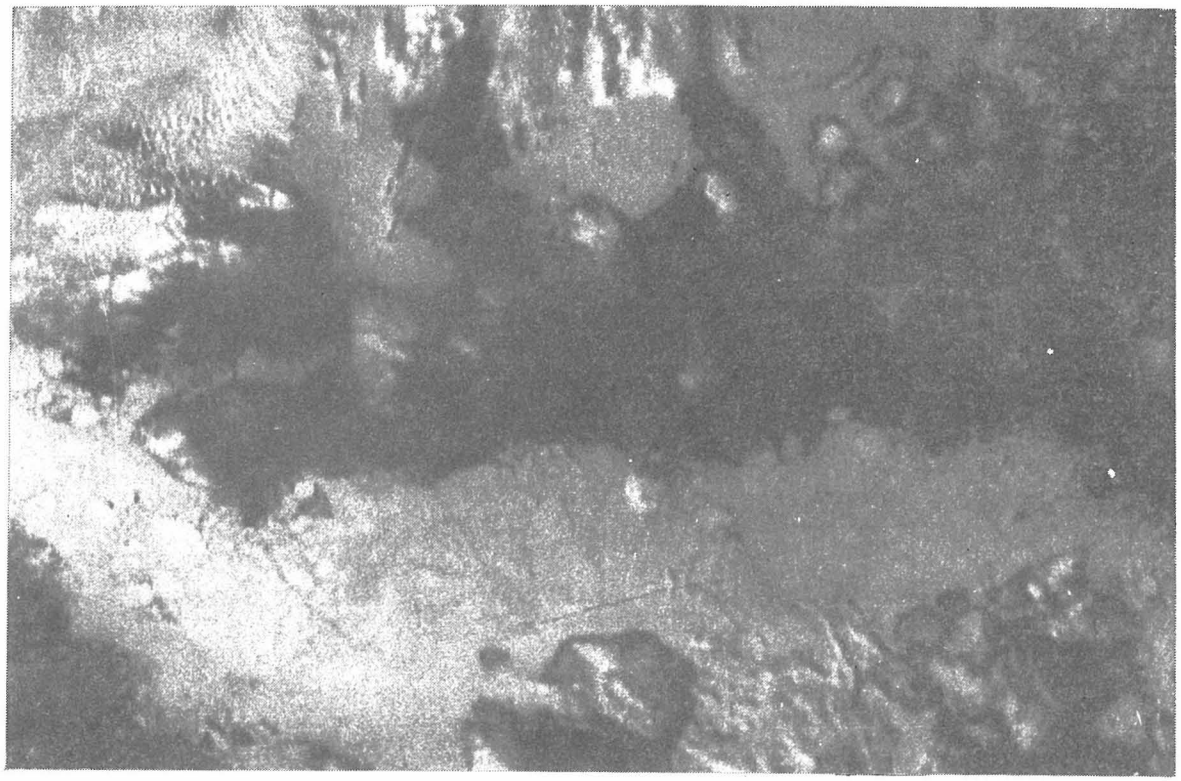
27. An August 11, 1976 NOAA image, showing the Melville Island coastal polynya.



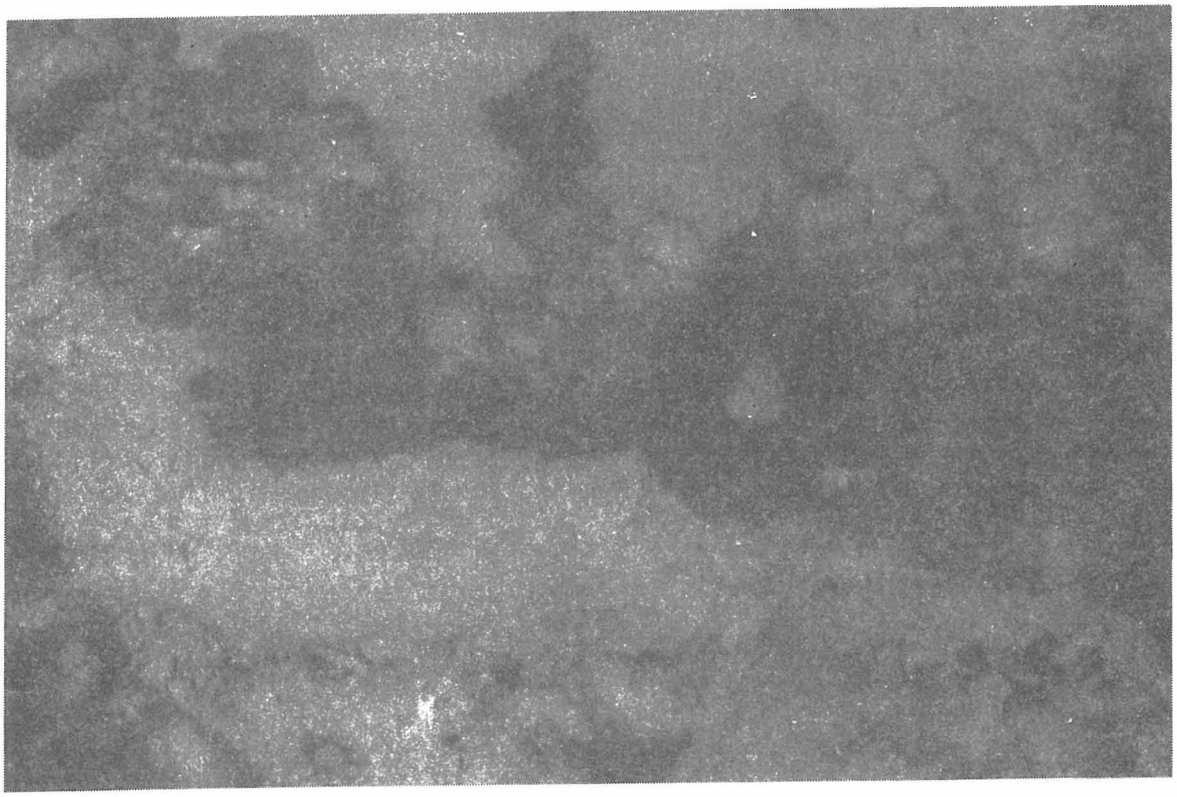
28. A September 11, 1974 NOAA image of Viscount Melville Sound. Byam Martin Island, connected by an ice-bridge to Melville Island, is to the left of centre, while Cornwallis Island is approximately one-quarter of the way in from the middle of the right-hand edge.



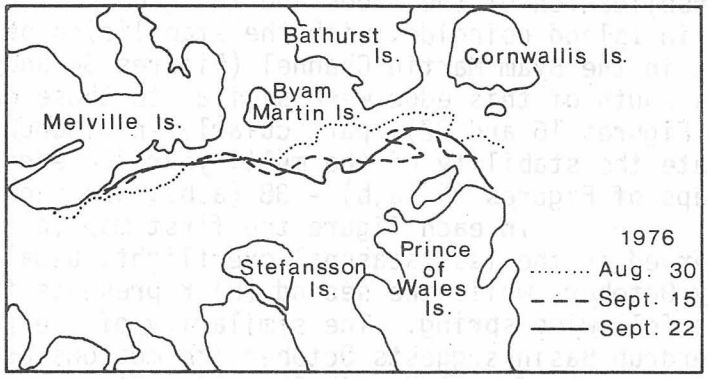
29. A September 5, 1975 NOAA image of Viscount Melville Sound. To assist with identification of features in the cloud-obscured image, the following points have been labelled : (1) the centre of Byam Martin Island; (2) the centre of Cameron Island; (3) the western tip of Stefansson Island and (4) the western tip of the Sabine Peninsula of southern Melville Island.



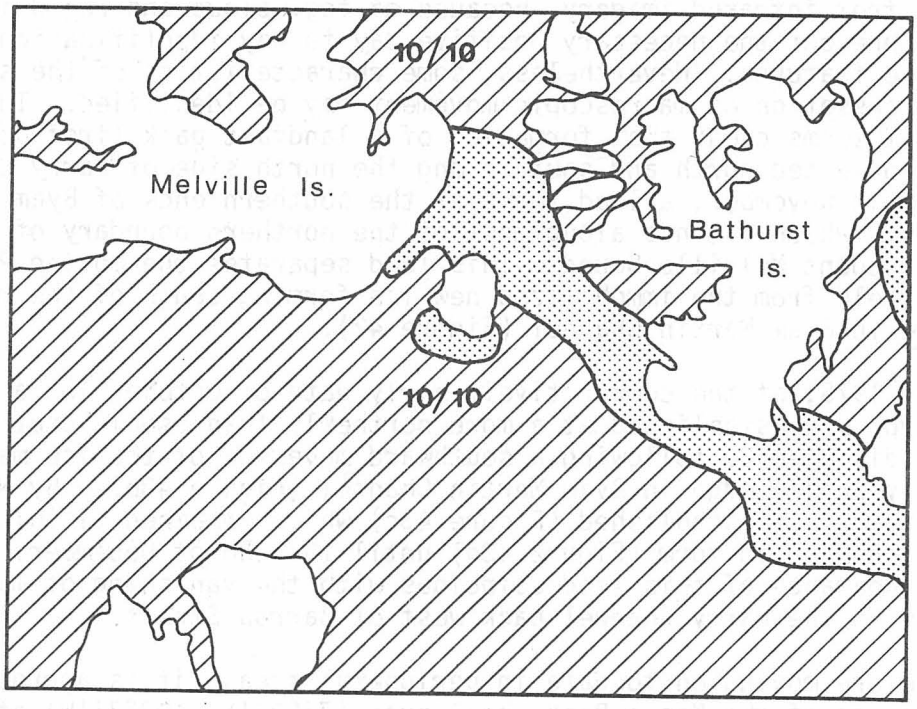
30. An August 31, 1976 NOAA image of Viscount Melville Sound.



31. A September 14, 1976 NOAA image of Viscount Melville Sound.



32. A mapping of the northern edge of the 10/10 ice pack in Viscount Melville Sound, late summer, 1976.

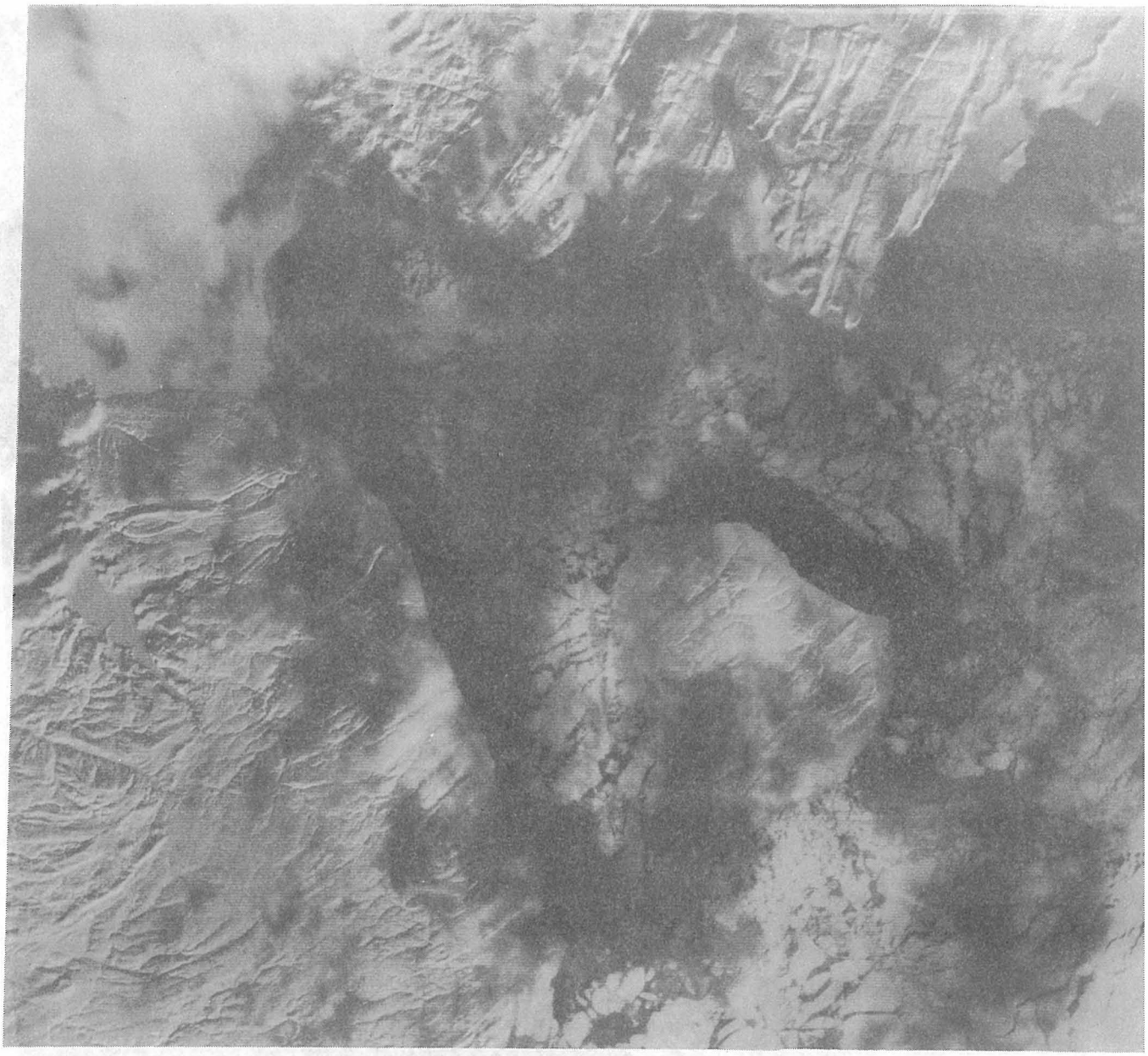


33. The distribution of ice densities near Byam Martin Island on September 4, 1972. Open water areas are denoted by the closely-spaced dots.

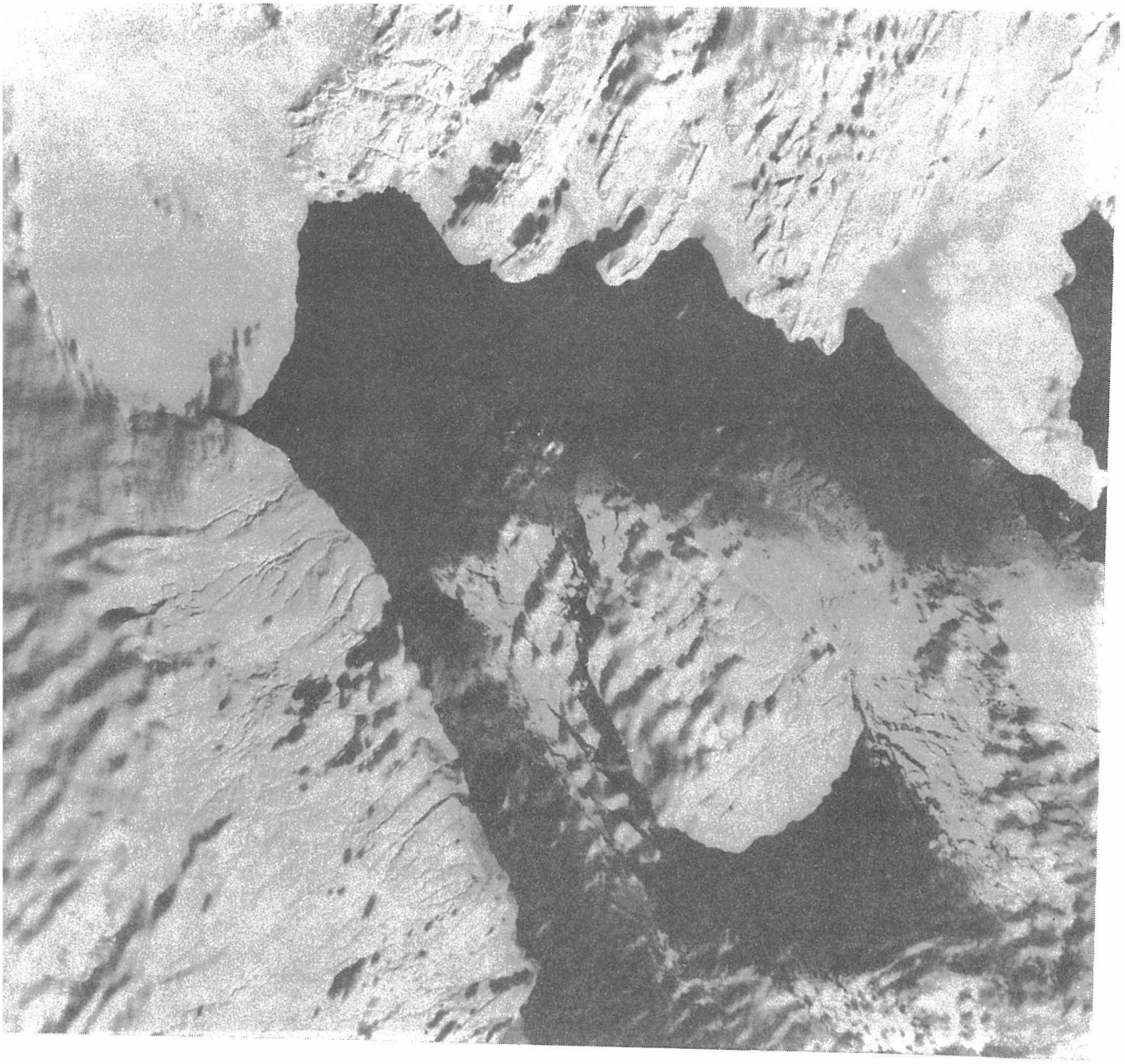
the great open water area characteristically begins in mid- to late-September. The consolidation of the floes and the growth of new ice in the region of Byam Martin Island coincides with the stabilizing of a definite multi-year ice edge in the Byam Martin Channel (Figures 34 and 35). Early October ice motions south of this edge were similar to those observed earlier in the season (see Figures 16 and 22), particularly in Viscount Melville Sound. To illustrate the stability of the multi-year ice edge in Byam Martin Channel, the ice maps of Figures 36 (a,b) - 38 (a,b), are shown as extracted from Lindsay (1976). In each figure the first map (a) represents the configurations observed in the last seasonal overflight, usually in late September and early October, while the second (b) represents the first observations of the following spring. The similarity of the paired mappings in the southern Sverdrup Basin suggests October ice motions are restricted to areas more or less south of Byam Martin Channel. Strong motions in these regions often open up new areas south of the boundary of the multi-year ice which are either ice-free or covered with a thin ice layer (See the sequence of NOAA images in Figure 39). An exception to this behaviour was noted during the winters of 1962-63, and 1963-64, which followed summer seasons during which almost all first-year ice was removed from the McClure Strait-Viscount Melville Sound portion of Parry Channel. In these instances (Figures 40 and 41) the newly formed ice was apparently unable to block the northern ice of the Sverdrup Basin and a large penetration of multi-year ice into Viscount Melville Sound occurred during the October to June interval. In any case, with the absence of such unusual summer conditions, late October and November are usually characterized by a general slow-down of ice motion in the central Arctic. Precise motion data are difficult to obtain for this period, even from infrared imagery, because of fog, cloud and rapid ice growth which prevent the necessary positive day to day identifications of repetitive ice features. Nevertheless, some characteristics of the slow-down and eventual cessation of macroscopic movement may be identified. Thus, for example it seems clear that formation of a landfast pack first occurs in the channels oriented north and south along the north side of Parry Channel. Thus, usually in November, a lead forms at the southern ends of Byam and Austin Channels which extends along most of the northern boundary of McClure Strait and Viscount Melville Sound. This lead separates the moving Parry Channel ice field from the immobilized new ice forming south of the multi-year ice edge in Byam Martin Channel (Figure 42).

In 1975, at the comparatively early date of October 15, a lead of the latter type was established at a more northerly than usual location. It subsequently disappeared following a southward movement of the ice mass south of the multi-year ice edge in Byam Martin Channel (Figure 43b). By November 2, a new boundary was established (Figure 43c) which remained visible and relatively unchanged in form (Figure 43d) until the end of December. The gradual disappearance of this lead coincides with the vanishing of macroscopic motion in the Parry Channel pack west of Barrow Strait.

Before moving on to data in peripheral areas, it is appropriate to note the presence of the Keene Bank shoal area (75°21'N, 102°71'W) at the southern end of the Austin Channel. Largely unexplored hydrographically, this feature not only constitutes a navigational hazard but also is capable of grounding floe ice. One such floe is indicated by the dot in Figure 44. No other abnormalities were observed in the ice cover of this area.

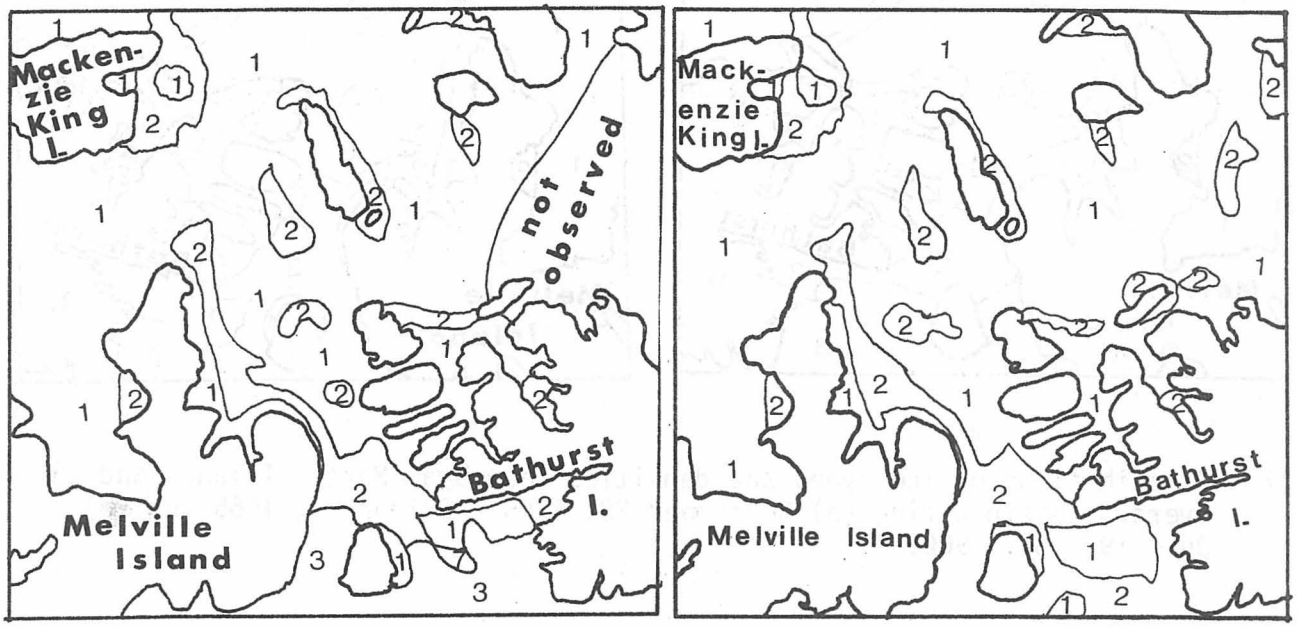


34. An October 7, 1974 Landsat image of the Byam Martin Island area.



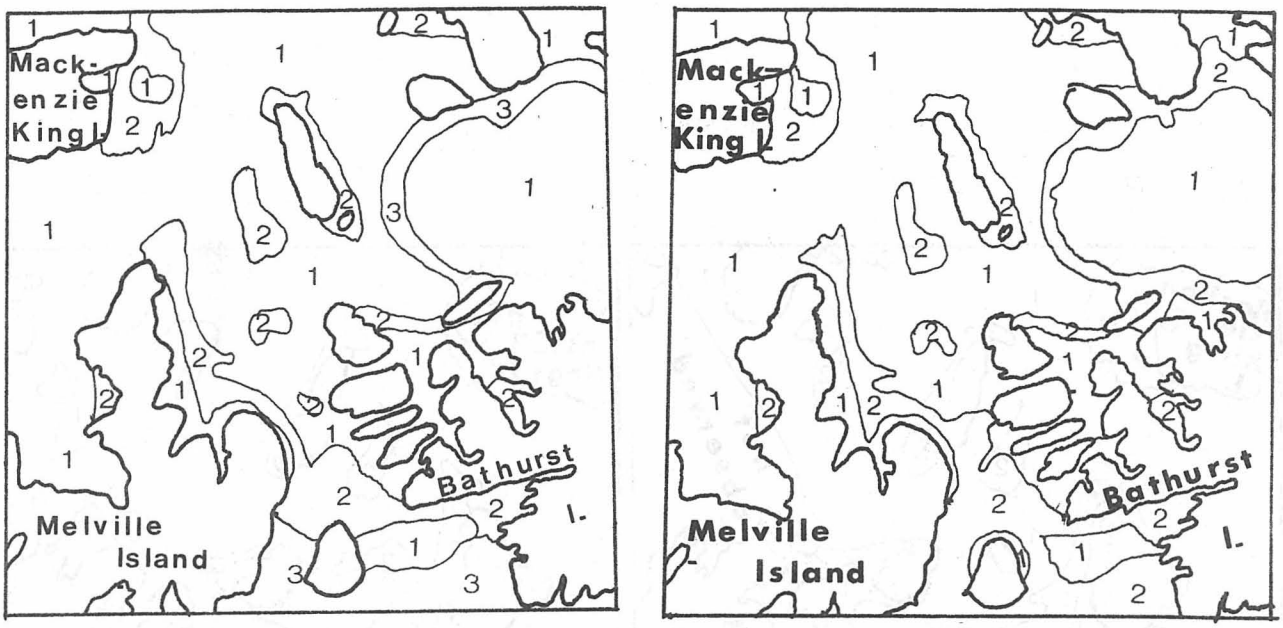
35. An October 2, 1975 Landsat image of the Byam Martin Island area.

a b



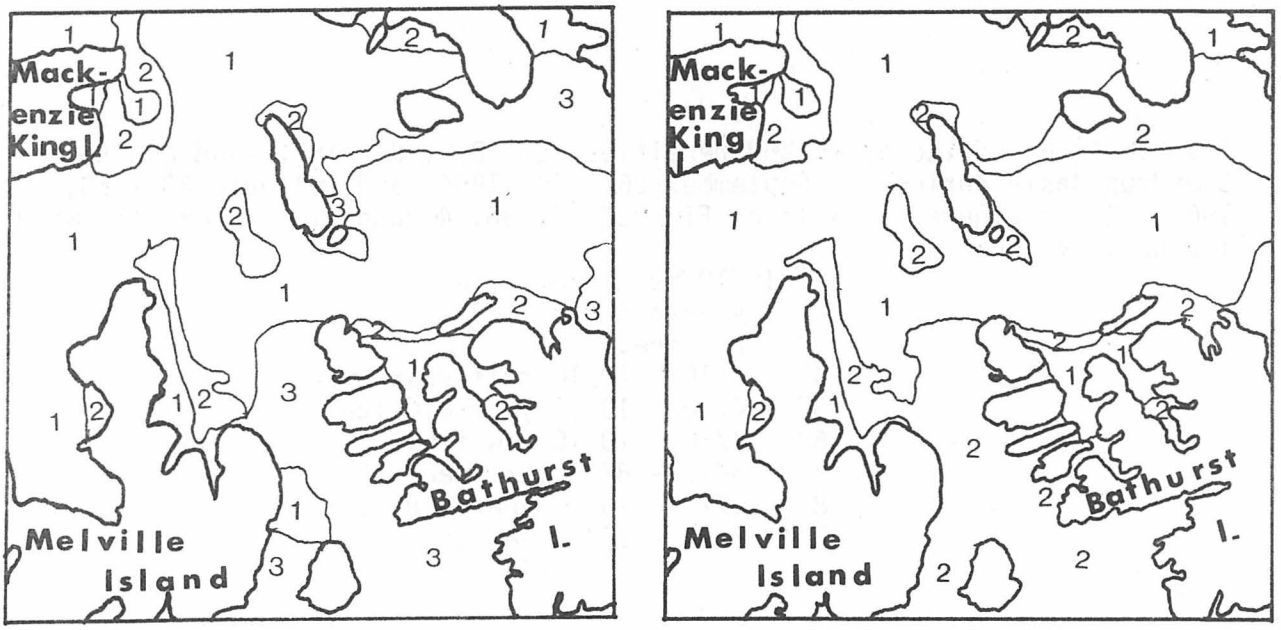
36. Distributions of ice types and densities near Byam Martin Island and the Sverdrup Basin during (a) September 26 - 29, 1964, and (b) June 23 - 28, 1965. These Figures as well as Figures 37, 38, 40 and 41 use the following ice density code :

"1" 10/10 multi-year ice;
"2" year-old ice;
"3" new ice;
"4" 4/10 - 10/10 multiyear ice;
"5" 4/10 - 10/10 year-old ice;
"6" 4/10 - 10/10 new ice;
"7" 5/10 - 8/10 multiyear ice;
"8" 5/10 - 10/10 year-old ice;
"9" 5/10 - 10/10 new ice.



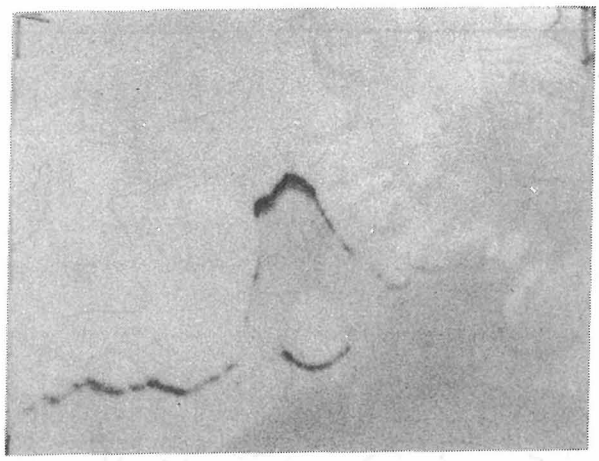
a b

37. Distributions of ice types and densities near Byam Martin Island and the Sverdrup Basin during (a) September 28, 1965 - October 4, 1965 and (b) June 19 - 30, 1966.

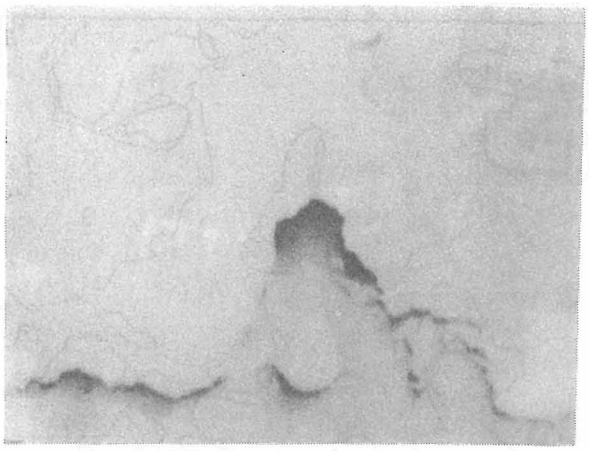


a b

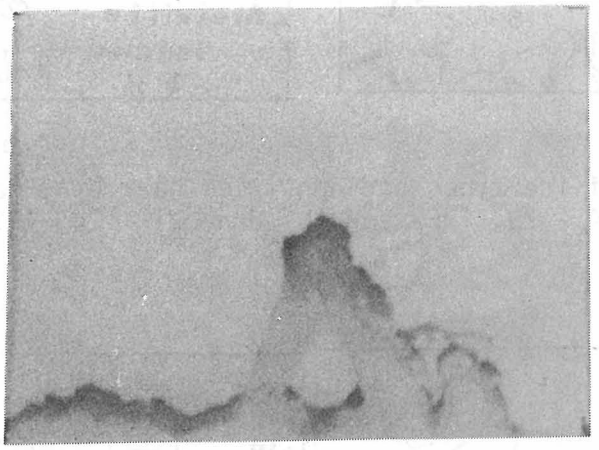
38. Distribution of ice types and densities near Byam Martin Island and the Sverdrup Basin during (a) October 6 - 10, 1966 and (b) March 16, 1967.



a

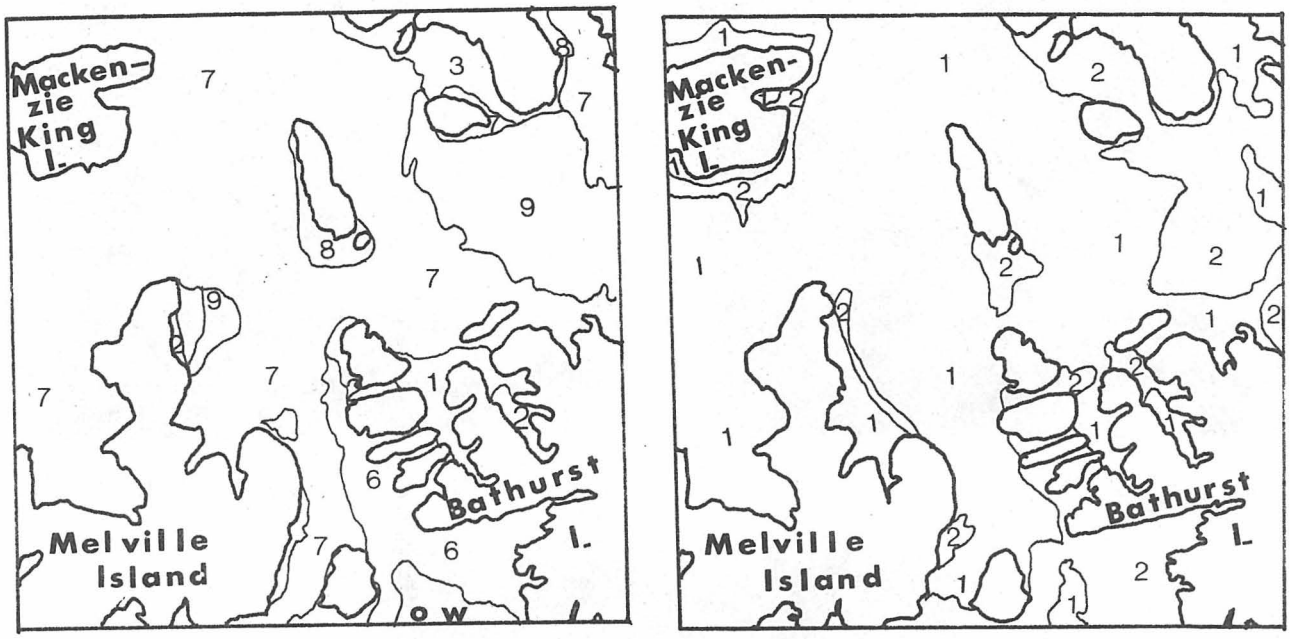


b



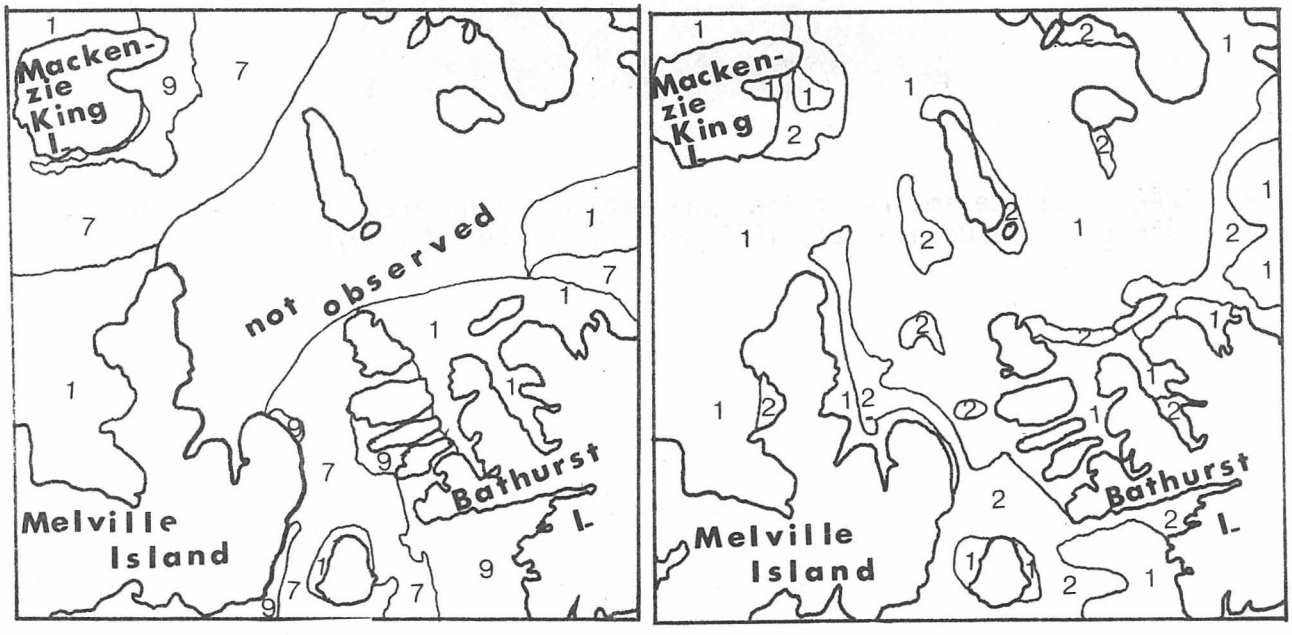
c

39. NOAA satellite images of the Byam Martin Island area on (a) October 20, 1976 ; (b) October 21, 1976 and (c) October 22, 1976.



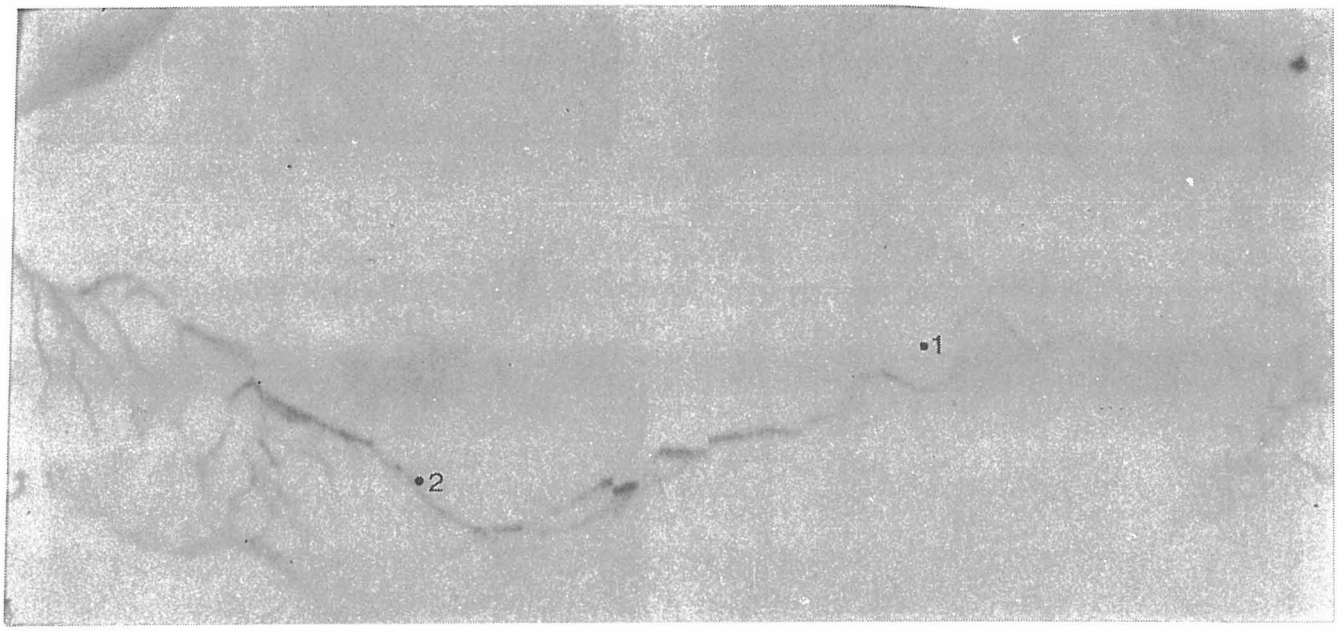
a b

40. Distributions of ice types and densities near Byam Martin Island during (a) September 24 - 29, 1962 and (b) June 21 - 24, 1963.

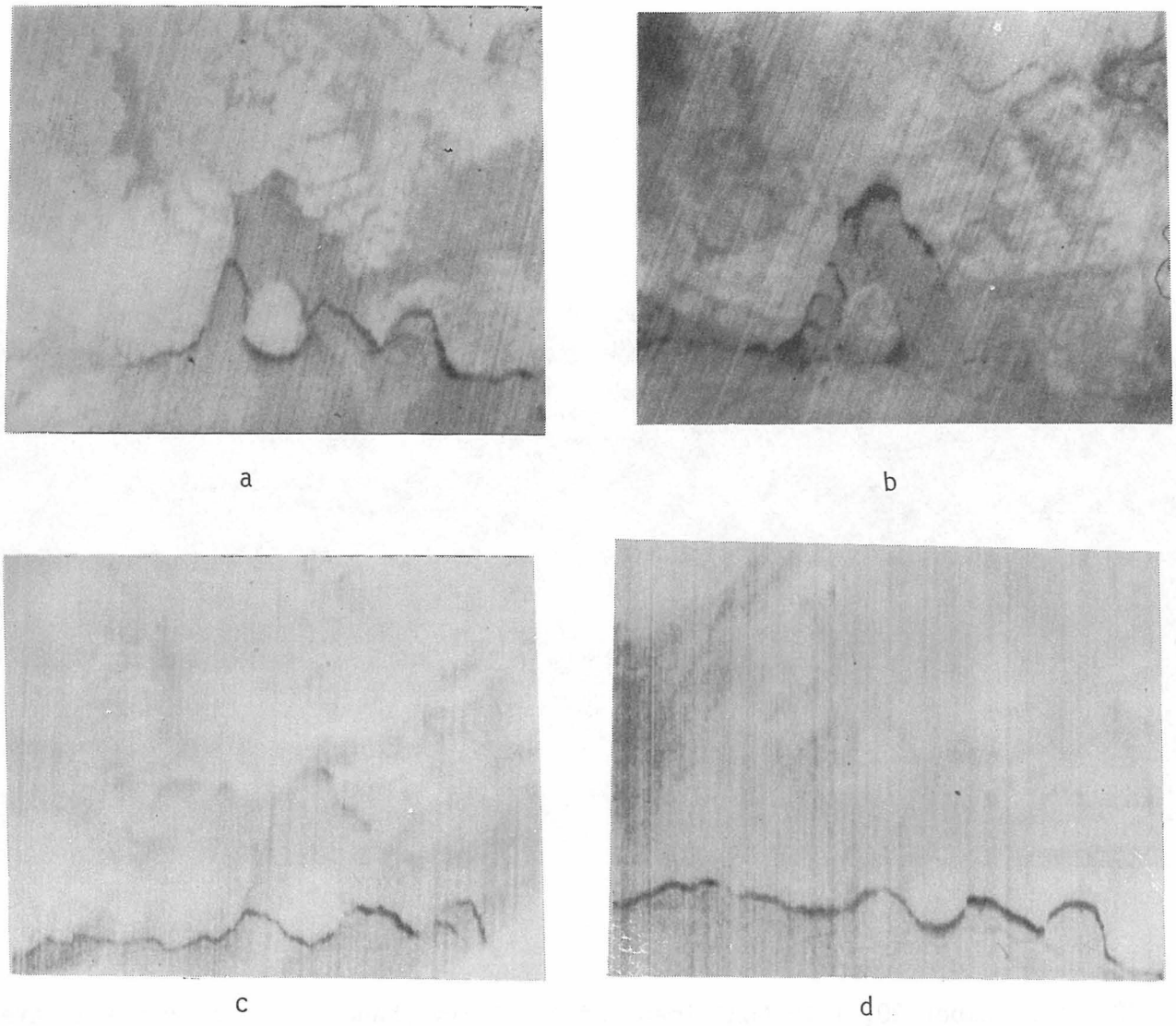


a b

41. Distributions of ice types and densities near Byam Martin Island during (a) September 28 - 30, 1963 and (b) June 21 - 25, 1964.

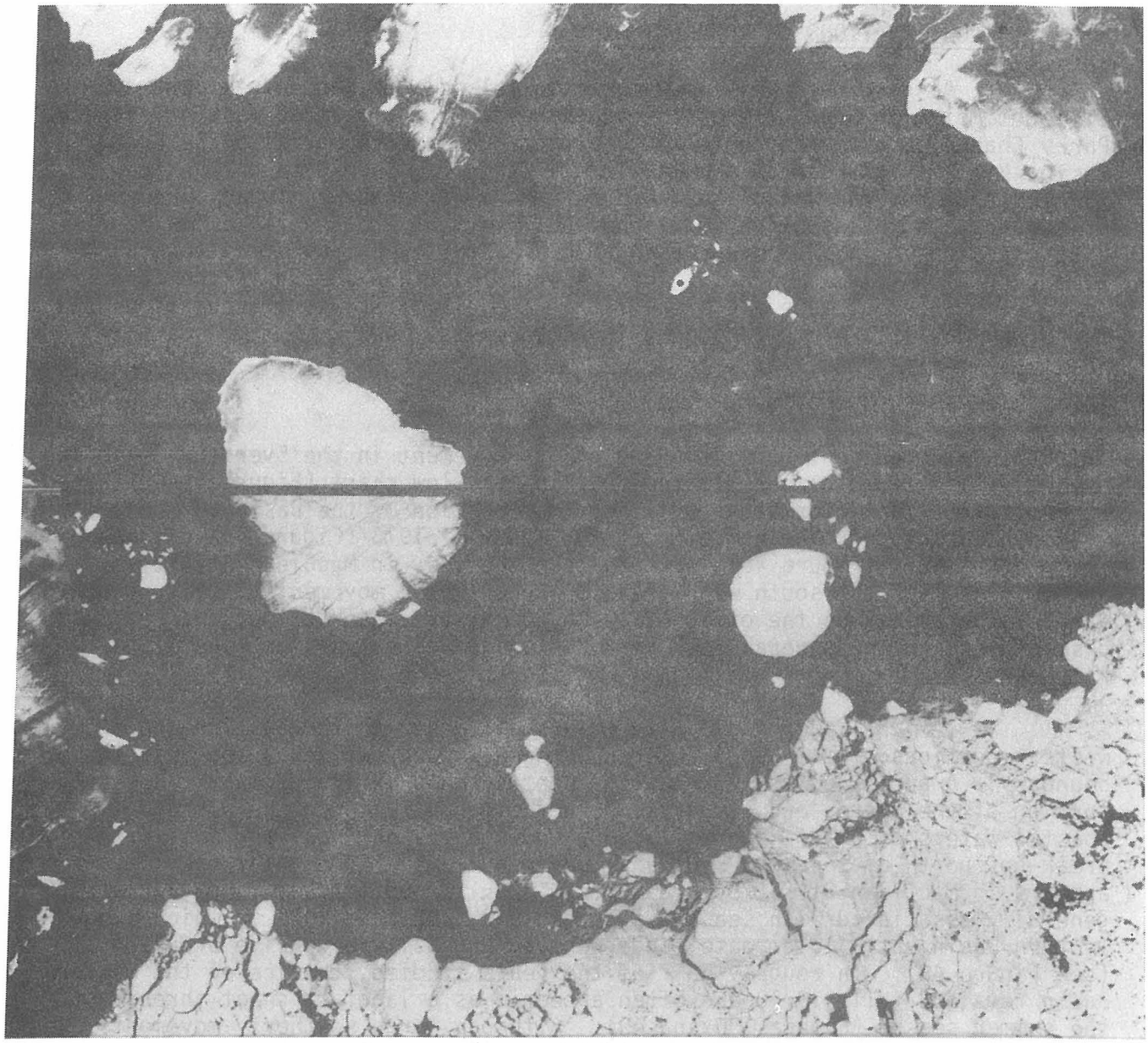


42. A November 20, 1976 NOAA image of the Parry Channel. Denoted points are (1) the centre of Byam Martin Island; (2) the western tip of the Sabine Peninsula, Melville Island and (3) Resolute Bay.



a b c d

3. NOAA satellite images (thermal infrared band) of the Byam Martin Island area on (a) October 15, 1975 ; (b) November 1, 1975, (c) November 2, 1975 and (d) November 20, 1975.



44. A September 15, 1976 Landsat image of the Byam Martin Island area. The marked floe east of the Island is grounded and breaking up in the Keene Bank shallows.

III. ICE OBSERVATIONS IN ADJACENT AREAS

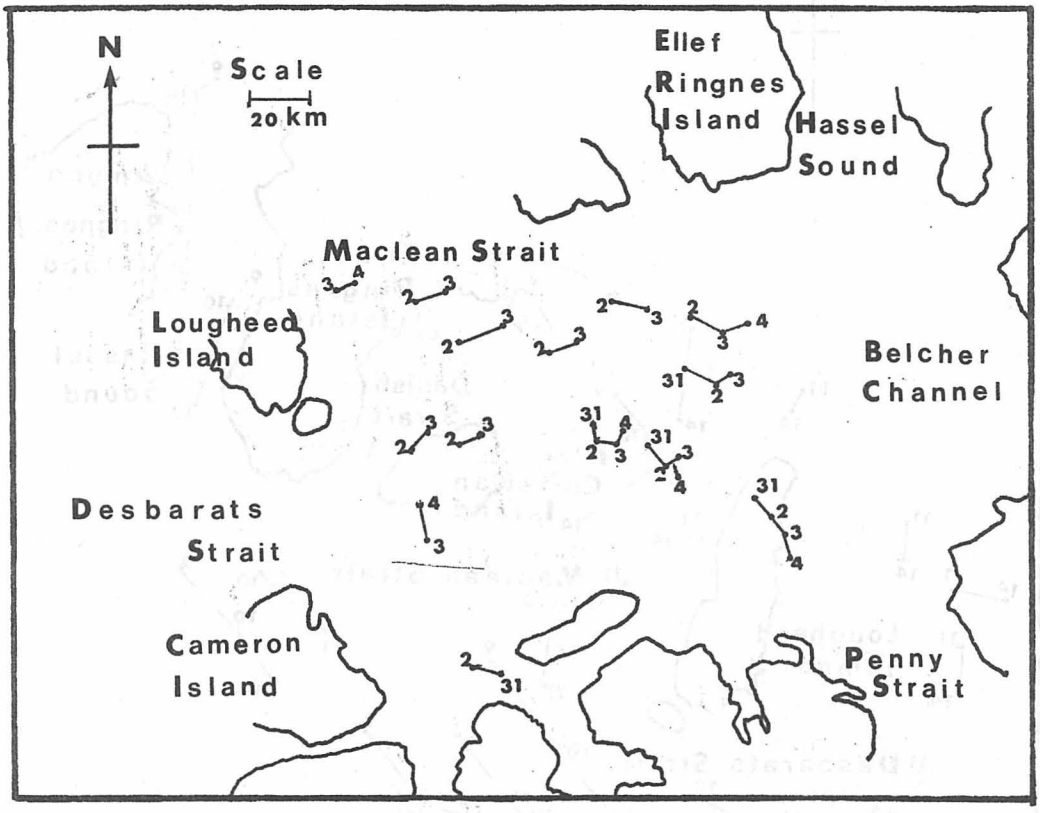
As described above, Byam Martin Island and the central part of Viscount Melville Sound lie at the cross-roads of the east to west-oriented Parry Channel and the north to south-oriented channel comprising the Sverdrup Basin, Byam Martin Channel and McClintock Channel. Some data on the ice movement and concentrations in these peripheral areas have already been presented. In this section additional observations are described for four of these areas: the Sverdrup Basin, McClure Strait, Barrow Strait-Lancaster Sound, and McClintock Channel. The presented data are mostly in the form of ice displacement maps and are included to justify previous assumptions and to form a basis for future studies in these areas.

III.I The Sverdrup Basin

The present understanding of ice movement in the Sverdrup Basin is unusually limited; for example the Swithinbank flow chart (Figure 6) contained current direction information only for that portion of the Basin to the west of Lougheed Island. The Ramseier et al. study of 1976 (Figure 45a-c), and the present work (Figure 46) indicate that the flow in MacClean Strait is predominantly to the south with occasional northerly movements. Daily southward displacements on the order of 10 to 20 km were observed but the net displacement in the several week period of 1976 was only a few tens of kilometres.

Ice and water flow patterns are different in the eastern and western portions of the Basin, where Lougheed Island defines a convenient boundary. A survey of Ice Forecasting Central maps indicates that the eastern portion of the Basin, and in particular MacClean Strait and the western coastal waters of Ellef Ringnes Island, undergo the earliest and most extensive break-ups north of the most southerly Basin outlets. Open water usually appears in MacClean Strait by mid-August. Earlier openings (Figure 47) were generally associated with seasons such as 1972, 1963 and 1975 in which the western Basin, at a later date, underwent an unusually extensive break-up (see Figure 48). In roughly half of the years studied, the ice of the western Basin remained fully 10/10 and often appeared as a landfast sheet throughout the summer season (Figures 30 and 49). Although large southerly movements have been tracked in Prince Gustav Adolph Sea (Arsenault et al, 1976), the western Basin cover sometimes remains almost stationary for years at a time. This may be seen from the unchanging ice configurations observed in this area during the years 1964-67 (Figures 36-38).

In Desbarats Strait, Arsenault's data (1976) and the 1961-64 trajectory of the ice island T1 (Figure 50) suggest the predominance of a westward flow with speeds varying up to 40 km/day. Because of the sluggish movements of the western Basin pack, these data suggest that a significant fraction of the ice traversing Byam Martin Channel passes through or develops in MacClean Strait and in the eastern Basin. This data would appear to confirm that Byam Martin Channel would be the Sverdrup Basin exit for pollutants spilled near the Ellef Ringnes, King Christian and Cameron Islands. However, the much more extensive data presented in Figure 51-55 suggest instead the existence of a prevailing easterly flow through Desbarats Strait which is usually small ($\simeq$2 km/day). This flow would force ice in the



45a. Ice floe displacements in the Sverdrup Basin, July 31 - August 5, 1973 [extracted from Arsenault et al (1976)].