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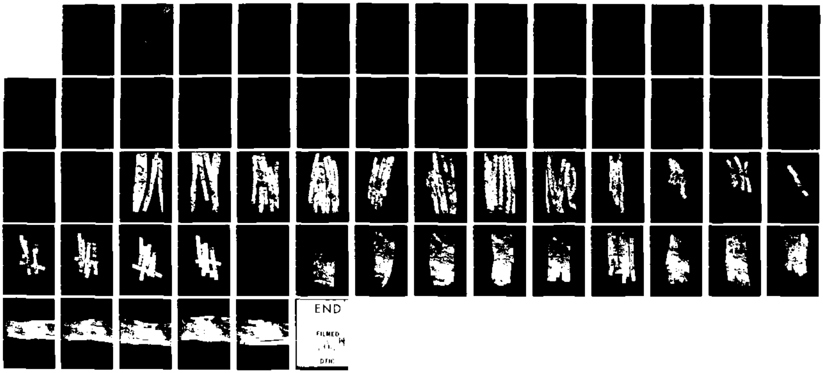

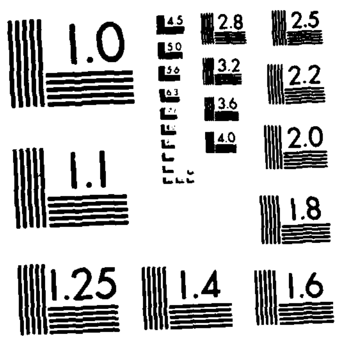

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REPORT NO: CG-D-51-82

AERIAL PHOTOGRAPHIC SURVEYS ANALYZED TO DEDUCE OIL SPILL MOVEMENT DURING THE DECAY AND BREAKUP OF FAST ICE, PRUDHOE BAY, ALASKA

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SEPTEMBER 1982

FINAL REPORT

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U. S. DEPARTMENT OF TRANSPORTATION
UNITED STATES COAST GUARD

OFFICE OF RESEARCH AND DEVELOPMENT
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NOTICE

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16. Abstract

During the summers of 1979 and 1980 aerial photographs of the land fast ice north of Prudhoe Bay, Alaska, were taken. These photographs, covering two-week periods, highlight the decay and break-up of the land fast ice sheet. During the period of photography, wind speed, wind direction, barometric pressure, and tidal height measurements were recorded continuously. Several larger ice floes were "tagged" with colored plywood markers during 1979. Both these marked flows and other distinctively shaped floes were tracked on the photographic surveys to determine the effect the wind had on their movement. Within the barrier islands, average ice floe velocities as a percentage of wind speed exceeded the 3.5% figure "normally" found in the literature. North of these islands average ice floe velocities as a percentage of wind speed were less than the 3.5% value.

In addition to the flow drift calculations the photographs provide information on melt pool formation and a comparison of the decay and breakup processes between the 1979 and 1980 seasons. The decay and breakup process appears to be triggered by strong wind events in early July.

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METRIC CONVERSION FACTORS

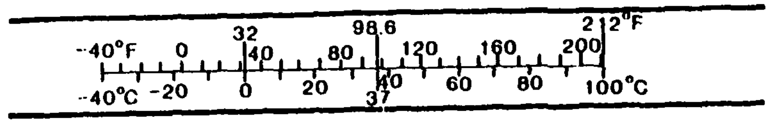
Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (WEIGHT)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (EXACT)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures. Price $2.25. SD Catalog No. C13 10 286

Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (WEIGHT)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	0.125	cups	c
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (EXACT)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



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1.0 INTRODUCTION

Oil drilling activity along the Northern Alaskan Coast has increased substantially since the discovery of oil at Prudhoe Bay, Alaska. Offshore drilling within the barrier islands is common, and this drilling will surely extend outward onto the continental shelf in the future. Response to oil spills that may occur offshore will be a formidable challenge. A review of available techniques for combating these spills is given in Morson and Sobey (1979). A valuable part of any response plan will be oil spill drift forecasting models for Alaskan shelf waters. This in turn indicates the need for ice movement forecasting models. For this reason, an ice dynamics experiment was conducted at Prudhoe Bay, Alaska, to further our understanding of the fast ice zone regarding breakup and subsequent movement of the ice.

2.0 EXPERIMENT

The experiment conducted during the summers of 1979 and 1980 focused on the forces which affect ice motion and drift, and their time dependence. It was assumed that the driving forces causing ice motion are: winds, currents, and tides. During the experiment, wind speed and direction and barometric pressure were recorded continuously. Wind data were obtained from a recording anemometer located on a tower on Reindeer Island as well as from land stations. While these measurements were made, aerial photographs of the land-fast ice were taken. The main area chosen to study the ice movement was site A (figure 1) during 1979 and site B (figure 2) during 1980. Both these areas were expanded during the course of the experiments as ice conditions changed. This is apparent from the photographic mosaics presented in Appendices A and B. Photographic surveys of the area were conducted as often as possible depending on ice and weather conditions.

During the period 29 June 1979 to 12 July 1979, fourteen photographic surveys were made of the ice field inside the barrier islands north of Prudhoe Bay. Cameras were mounted on a helicopter and aerial positioning was accomplished using a Microwave Ranging System (MRS) mounted aboard, *with control unit mounted aboard the helicopter and transponders positioned on the ground. Four MRS transponders were located at Cross Island, Reindeer Island, East Dock, and West Dock (see figure 1). Available helicopter time was budgeted to allow us to fly, weather permitting, once each day until the ice was well broken. Then, for two days, flights were made as often as possible. Photographic surveys (Appendix A) of the ice were made on 30 June and 1, 2, 3, 5, 7, and 9 July. In addition two photographic surveys were made on 10 July and four on 11 July. During 1980 a fixed-wing aircraft was used to complete the photographic surveys. An OMEGA navigational system was used for positioning. Photographic surveys (Appendix B) were made on 24, 26 and 28 June, 1, 2, 3, 7, 9 July, and two surveys were made on 14, 15 and 16 July.

Movement of the floes was determined by comparing the location of identifiable floes from one survey to the subsequent survey. The distance the floe moved was calculated and then divided by the time interval between surveys to obtain the speed of floe movement.

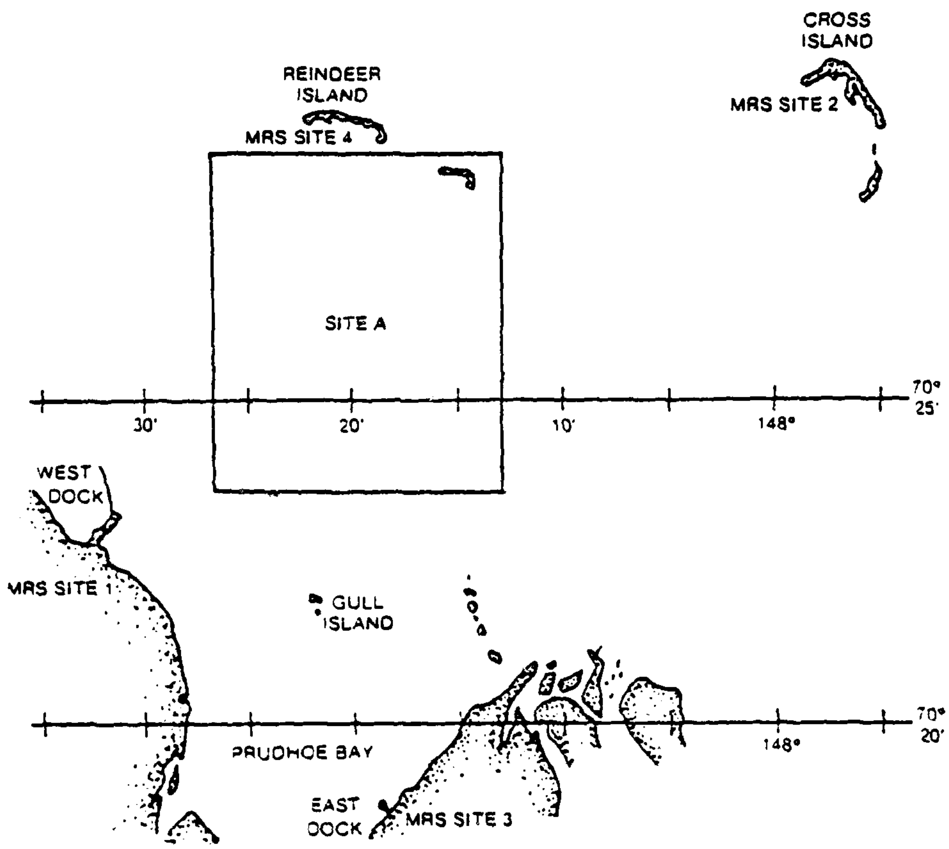


Figure 1: AERIAL PHOTOGRAPH SITE AND MRS TRANSPONDER POSITIONS, (1979).

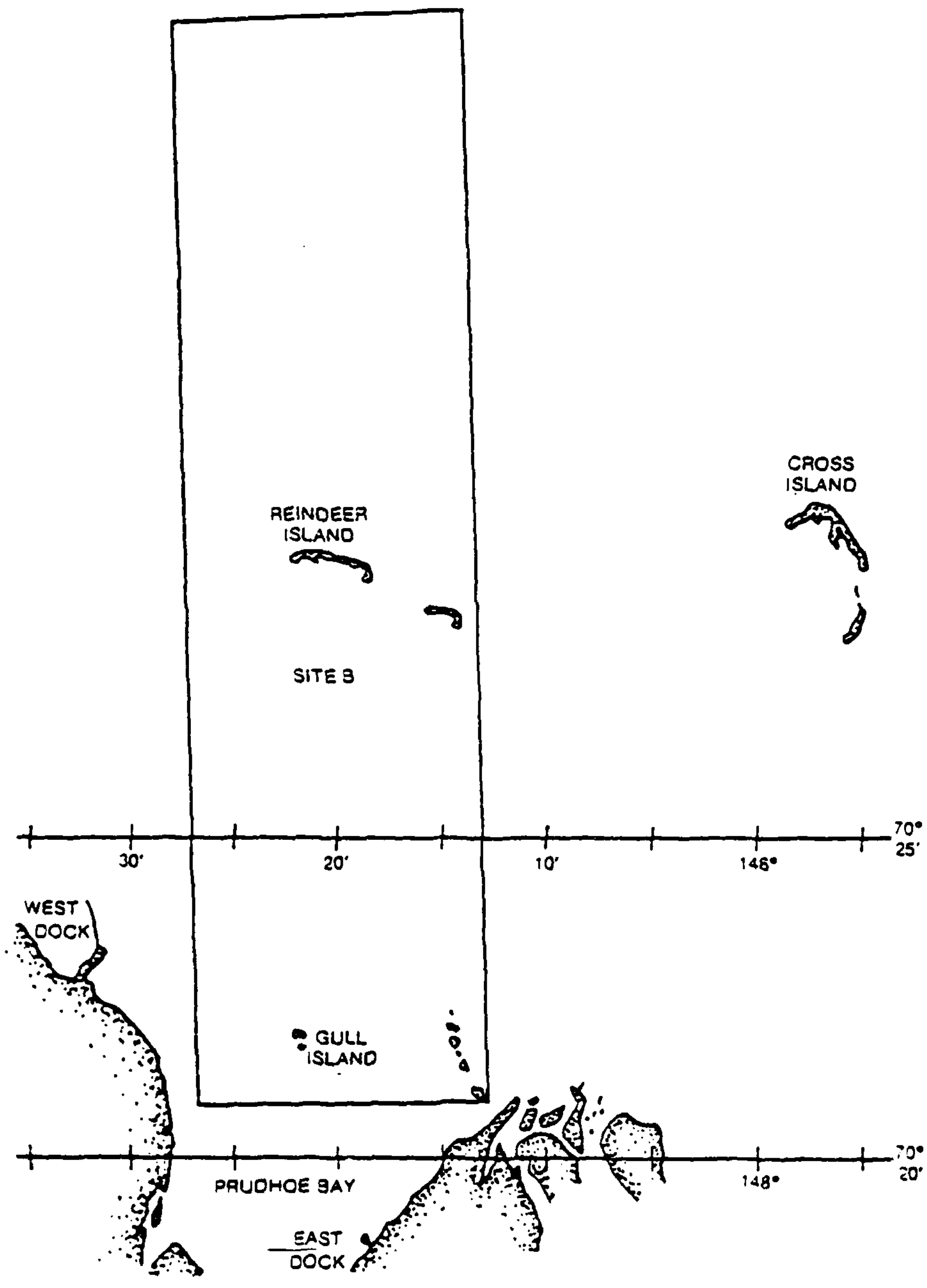


Figure 2: AERIAL PHOTOGRAPH SITE (1980).

3.0 COMPARISON OF ICE CONDITIONS 1979/1980

A comparison of ice conditions between 1979 and 1980 can be made from the surveys. The initial photographs for 1979 were taken at an altitude of 2000 feet and those for 1980 at 5000 feet. Although survey areas differed for 1979 and 1980, the surveys can be examined for the area south of Reindeer Island (figure 1) and general details of the ice conditions compared. In June, the ice cover for both years was solid south of the islands with the exception of small open water areas around the islands. Generally these areas around the islands are ice free from a few meters to several hundred meters offshore on the southern sides of the islands. These open water areas are caused by the persistent northeast winds in this area pushing the ice away from the island. Another interesting feature of this wind is the ice pile-ups it can cause on the windward side of the islands. For 1980, particularly on Reindeer Island, there is a line of rubble ice on the north shore caused by the northeast winds (Appendix B). By 3 July 1980 the ice south of Reindeer Island has broken into large floes and there is significant open water south of the islands. By 7 July 1980 virtually all the ice south of Reindeer Island is gone. In 1979 breakup occurred only one day later on 4 July. By 5 July there is still 80% ice coverage made up of large identifiable ice floes. For 1979 there is still a significant amount of ice south of the islands until 12 July, the end of our survey period for that year.

It is interesting to note that breakup for both years occurred within a 2-day period, 3 and 4 July. It appears that the winds play a significant role in the breakup of the ice. During the summer the ice slowly melts. As it becomes thinner and weaker a strong wind event can then fracture and break the ice inside the barrier islands. In 1979 winds exceeded 20 knots on 4 July and the ice broke, and similarly on 3 July 1980 20-knot winds from the northeast fractured and broke the fast ice.

4.0 ICE MOVEMENT - 1979

In conjunction with the aerial photography phase of the summer work in 1979, another companion experiment was undertaken. Plywood markers, 1.2 meters square, were used in this experiment. Each of the eight markers was assigned a recognition code. This code was painted on the marker using fluorescent ink on a black background. This color scheme was chosen to facilitate aerial location of the markers. The markers were placed on large ice floes south of Reindeer Island on 30 June. During breakup, it was hoped that the markers would remain on the floes and move in the mixed ice and open water environment. This experiment was intended to simulate the movement of oil which was trapped in the ice.

Two methods were to be used to plot the position of the markers. The first method was to determine the location of the markers using the aerial photographs. The second method was to determine the locations of the markers during the experiment through aerial positioning. This was accomplished using the rented Bell 206 Jet-Ranger helicopter with the R&DC Mini-Ranging System (MRS) mounted aboard. Positions for each marker were determined by locating them visually, hovering over the markers, and taking an MRS position. Figure 3 shows the location of the markers when they were set out on the ice and their subsequent drift through 12 July 1979. The underlined letters indicate the initial positions where the markers were set. We were not able to find

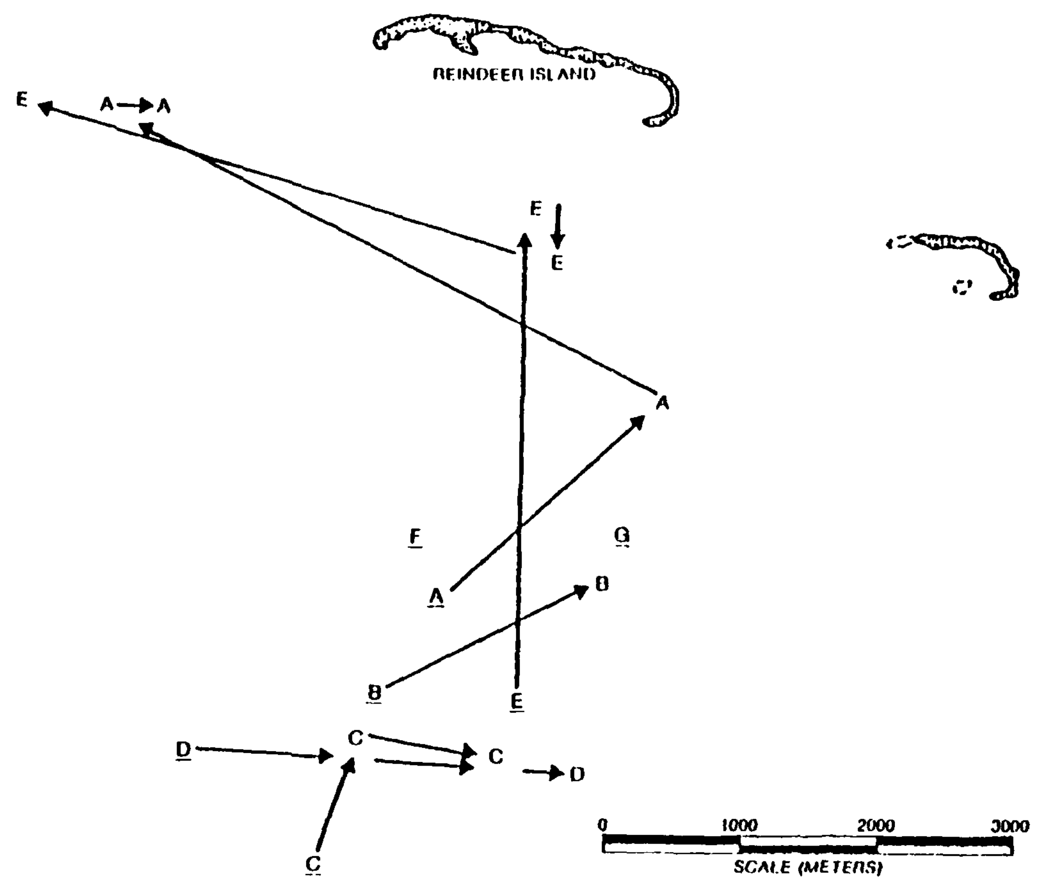


Figure 3: DRIFT TRACK OF MARKERS SET ON ICE FLOES IN PRUDHOE BAY, ALASKA. THE MARKERS WERE SET ON ICE FLOES ON JUNE 30, 1979 AND POSITIONS WERE DETERMINED TILL JULY 12, 1979. THE LOCATION OF THE MARKERS IS AT THE CENTER OF EACH LETTER. THE DIFFERENT LETTERS REPRESENT DIFFERENT MARKERS. EACH UNDERLINED LETTER IS THE INITIAL LOCATION AND OTHERS ARE INTERIM POSITIONS.

two of the markers (F, G) visually. The other markers were all sighted visually or located on a photograph at least once during the period 30 June through 12 July. At first, the markers tended to move towards the east and northeast. During the latter part of the period, two of the markers moved towards the west. It is interesting to note that during this period, the maximum movement of any of the markers over the 9-day period after breakup was approximately 7000 meters. This indicates that oiled floes and oil trapped within the ice would not have traveled far during this period in 1979.

During the period 30 June to 3 July, the ice inside the barrier islands off Prudhoe Bay remained intact. The first analysis of the data compared the movement of the ice floes with the wind field for two periods, one of 53 hours between 3 July and 5 July and the other of 55 hours between 5 July and 7 July. The wind vector for the first period was from 049^{o}T at an average speed of 2.4 knots (1 knot = 51.48 cm/s). The wind vector for the second period was from 098^{o}T at an average speed of 3.7 knots. Although these winds would be expected to cause the ice floes to move primarily to the west, the observed movement of the floes during these two time periods was towards the east, and southeast, opposite to the wind. Some explanation of this behavior can be found by observing the ice conditions during this time period and the topography of the area. The ice south of the barrier islands was in the form of floes with 50% to 80% ice coverage. However, the ice just north of these islands was still a solid sheet, the edge of which formed a barrier running east to west. The shoreline to the west of Prudhoe Bay is oriented in a northwest-southeast direction. Thus, as you move west of Prudhoe Bay, the shoreline tends to converge toward the pack ice edge. This funneling effect of shoreline and pack ice prevented the ice floes from moving west. Therefore, during these two time periods, the average movement of thirty ice floes was calculated. The maximum movement of any of the floes was 7275 meters. Thus over two extended periods of time, ice floe displacement between surveys was minimal even though the easterly winds were strong. These results indicate that simple wind-driven drift models are not entirely applicable to oil and ice movement in Prudhoe Bay during periods of heavy ice concentrations.

During surveys conducted on 10 and 11 July, ice concentration was less than 50%. Table 1 shows floe speed and direction, measured from surveys 1 and 2 on 10 July. The time interval between the surveys was two hours. Winds were blowing from 100^{o}T to 130^{o}T during the survey period and for the 24-hour period prior to the surveys. Floe direction was consistently downwind. Wind speed averaged six knots (with gusts to 10 knots) prior to and during the surveys. Using six knots as an average, floe speed varied between 6.0 and 11.7% of the wind speed.

Table 2 shows floe speed and direction between surveys 1-2, 2-3 and 3-4 on 11 July. Wind during the 12-hour period prior to the first survey was consistently west/northwesterly, i.e., from 280^{o}T to 320^{o}T. The flow trajectories for the time period between surveys 1-2 were essentially downwind to the east-southeast. During the 1-hour period in which the four surveys were conducted, the winds became southeasterly, i.e., from 130^{o}T to 150^{o}T. Thus, the data for surveys 2-3 and 3-4 show that the floe direction gradually changes to the east-northeast possibly under the influence of the southeasterly winds. Wind speed varied between 5 and 10 knots prior to and during the surveys. Thus the average ice velocities are between 5.5% and 12.4% of the wind speed for this wind range.

TABLE 1

Movement (speed and direction) of ice floes for
a two-hour period on 10 July (1979)

Floe #	Drift speed (knots)	Drift Direction (^{o}T)
1	0.70	270
2	0.36	290
3	0.43	296
4	0.50	288
5	0.43	303
6	0.52	307
7	0.61	306
8	0.69	313
AVG.	0.53	

TABLE 2

Movement (speed and direction) of ice floes
for three periods on 11 July (1979)

Floe #	Drift Speed (knots)	Drift Direction (^{o}T)
	Survey 1-2 (time interval - 4 hours)	
1	0.69	127
2	0.67	146
3	0.45	132
4	0.65	149
AVG.	0.62	
	Survey 2-3 (time interval - 2.5 hours)	
1	0.59	158
2	0.60	137
3	0.63	103
4	0.36	137
5	0.53	120
6	0.60	98
7	0.71	90
8	0.46	103
9	1.01	101
10	0.41	96
11	0.97	112
12	0.65	116
13	0.35	136
14	0.50	120
15	0.82	114
AVG.	0.61	

Survey 3-4 (time interval - 2.5 hours)

1	0.50	117
2	0.39	88
3	0.50	98
4	0.63	72
5	0.56	84
6	0.68	93
7	1.02	87
8	0.45	100
9	0.28	103
10	0.29	86
11	1.05	72
12	1.13	100
13	0.15	104
14	0.30	95
15	0.37	72
AVG.	0.55	

5.0 ICE MOVEMENT - 1980

During 1980 the movement of the ice was analyzed for ten different periods which are illustrated in figures 4 through 13. The first figure (4) shows the movement of the ice just after breakup of the solid ice sheets. This movement of ice was caused by the northeast to east winds which prevailed throughout the experiment. These winds caused the solid ice south of Reindeer to fracture and move. This movement is readily apparent on the photo mosaics for 2 and 3 July of 1980. Examining figures 5 through 13 indicates that the wind plays a primary role in moving the ice after breakup. In all these figures the ice floes that were tracked generally moved towards the west. The movement shown in figures 5 through 10 occurs over periods of several days as indicated on the illustrations. The spatial movements shown are not very large considering the winds were 10-20 knots from a constant direction. Impedance to the movement of the ice are the concentration of the ice and shallow areas north and south of Reindeer Island which cause grounding of the larger ice floes. This grounding is evident on the 1980 photos. North of Reindeer and Cross Islands the larger ice floes remain fixed throughout the period. Significant ice movement is seen only for ice floes which are several kilometers or more north of the islands and very small floes. This is particularly evident on the photos for 14, 15 and 16 July.

On 14, 15 and 16 July two overflights of the ice were made. The movement of the ice between the two daily surveys for each of these days is shown on figures 11, 12 and 13.

Table 3 shows floe speed and direction for the surveys on 14, 15 and 16 July. Winds during the entire period varied between 040°T and 080°T with speeds between 10 and 15 knots. The floe trajectories were essentially downwind. The variations in direction noted were caused by the floes entering the shallower areas north of Reindeer Island. The interaction of the grounded ice with the moving floes caused the variance in the movement of some of the floes. In addition some of these floes may have been partially grounded when they entered the shallower waters.

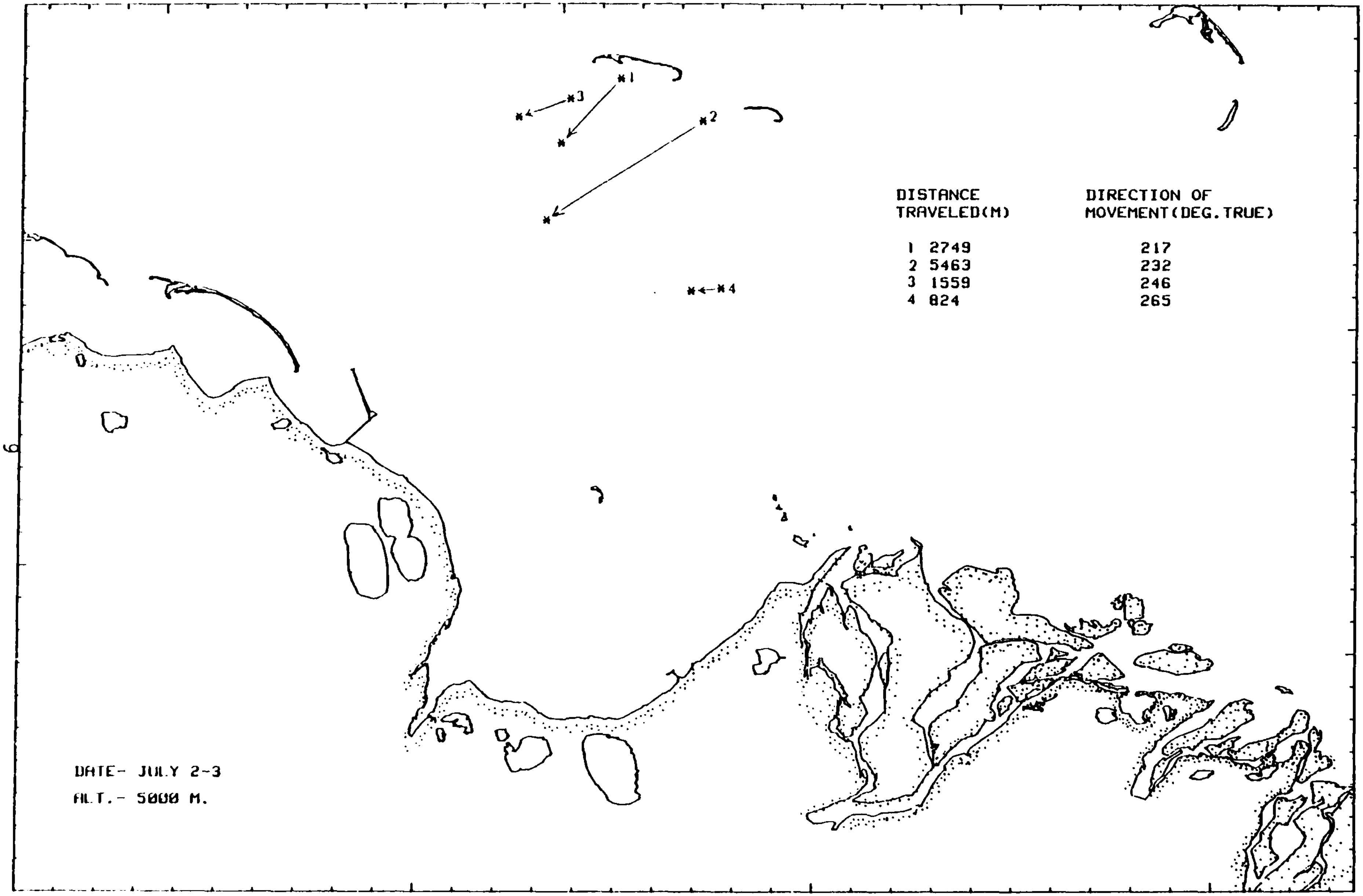


FIGURE 4. Movement of ice between July 2 and July 3. The numbers represent identifiable ice floes. The distance traveled and directional movement of each floe is listed.

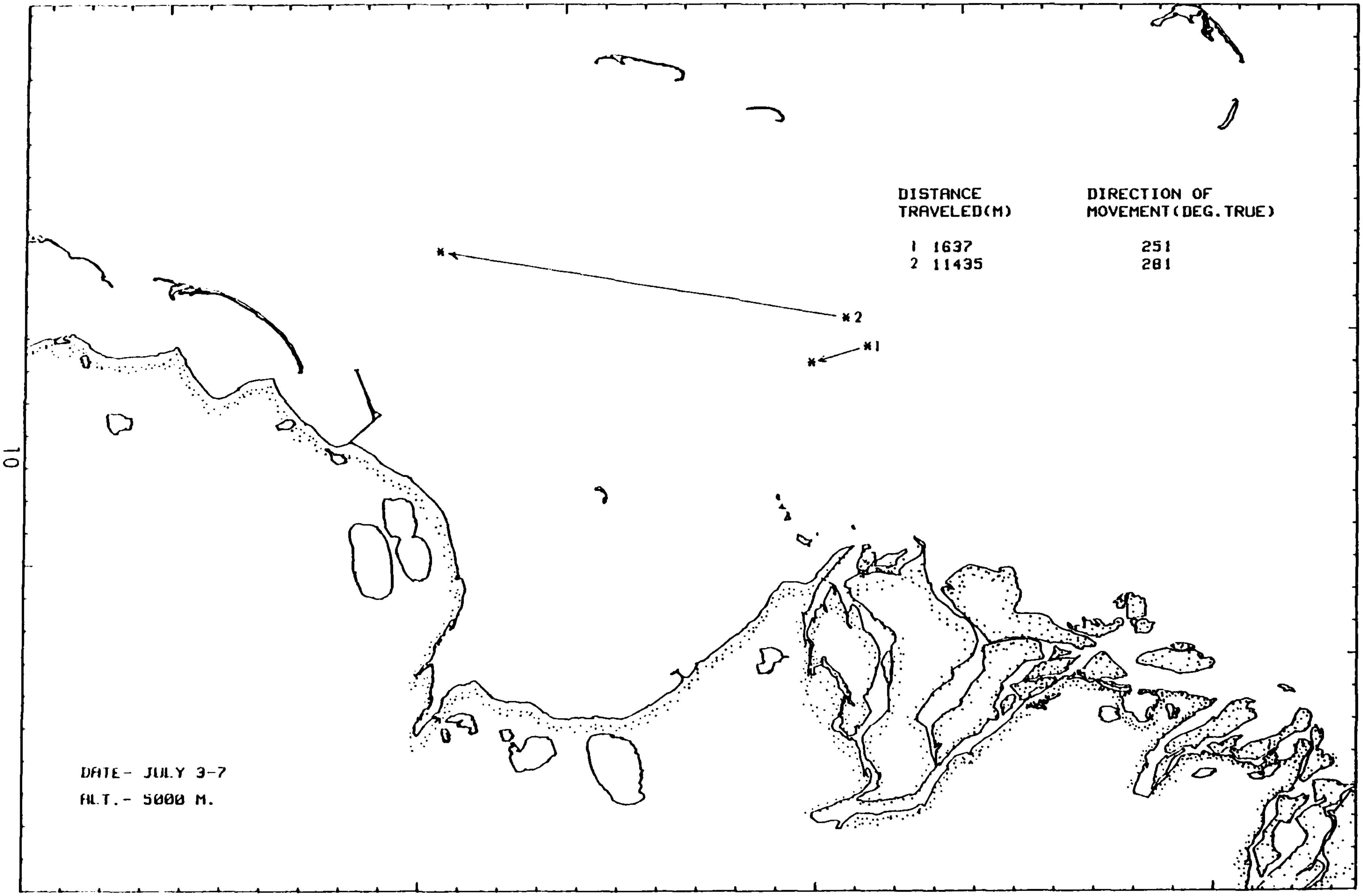


FIGURE 5. Movement of ice between July 3 and July 7. The numbers represent identifiable ice floes. The distance traveled and directional movement of each floe is listed.

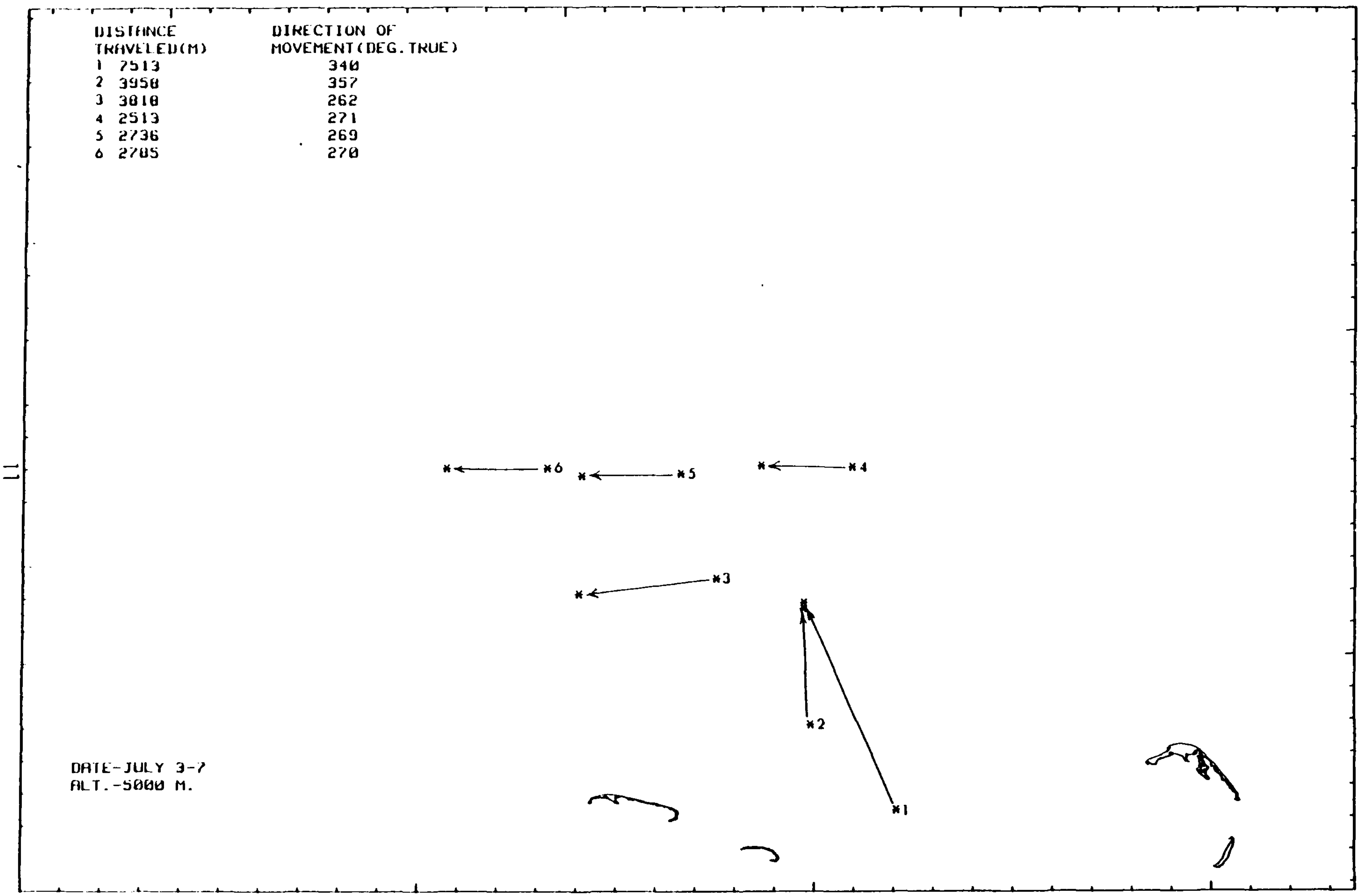


FIGURE 6. Movement of ice between July 3 and July 7. The numbers represent identifiable ice floes. The distance traveled and directional movement of each floe is listed.

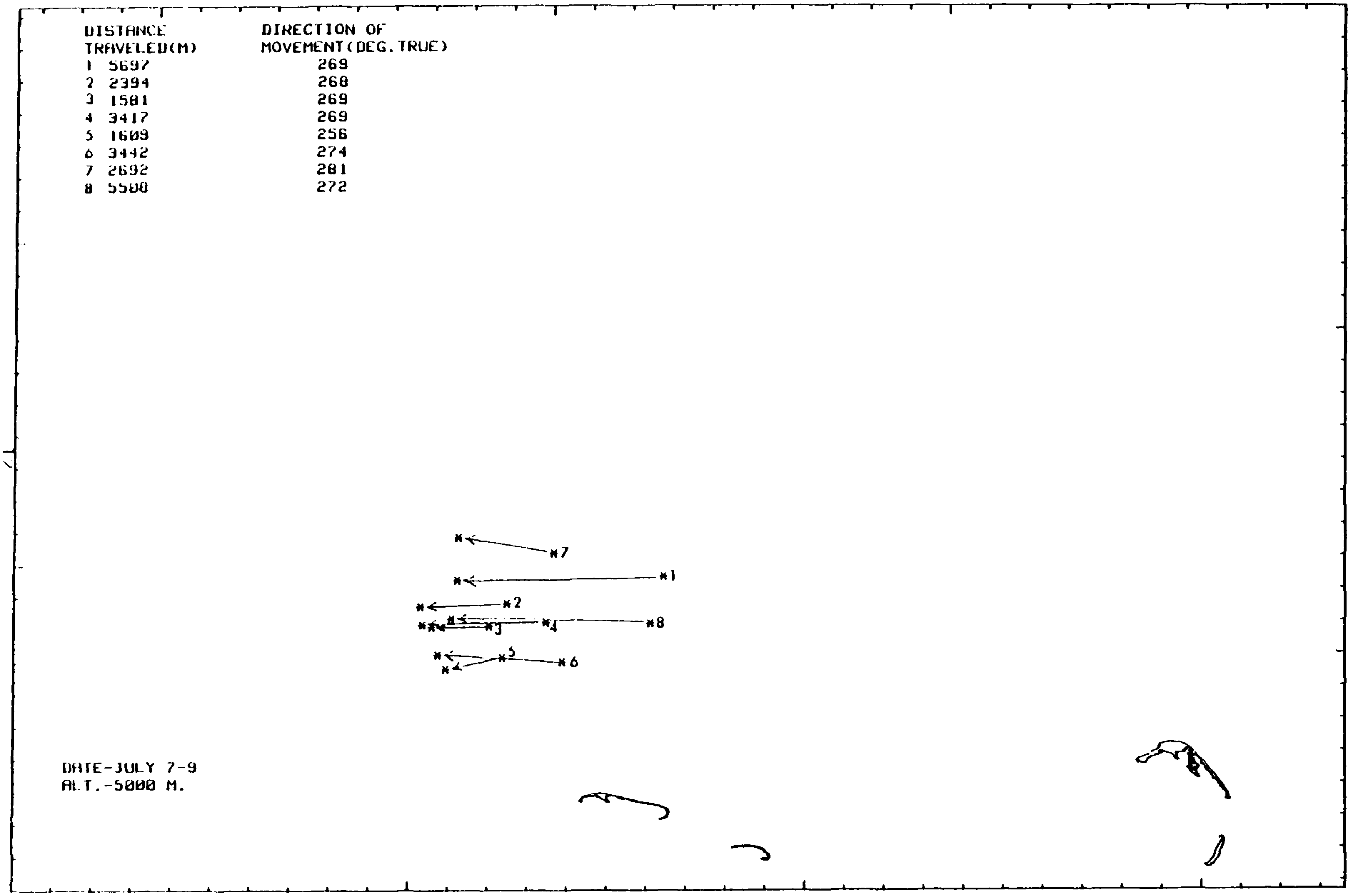


FIGURE 7. Movement of ice between July 7 and July 9. The numbers represent identifiable ice floes. The distance traveled and directional movement of each floe is listed.

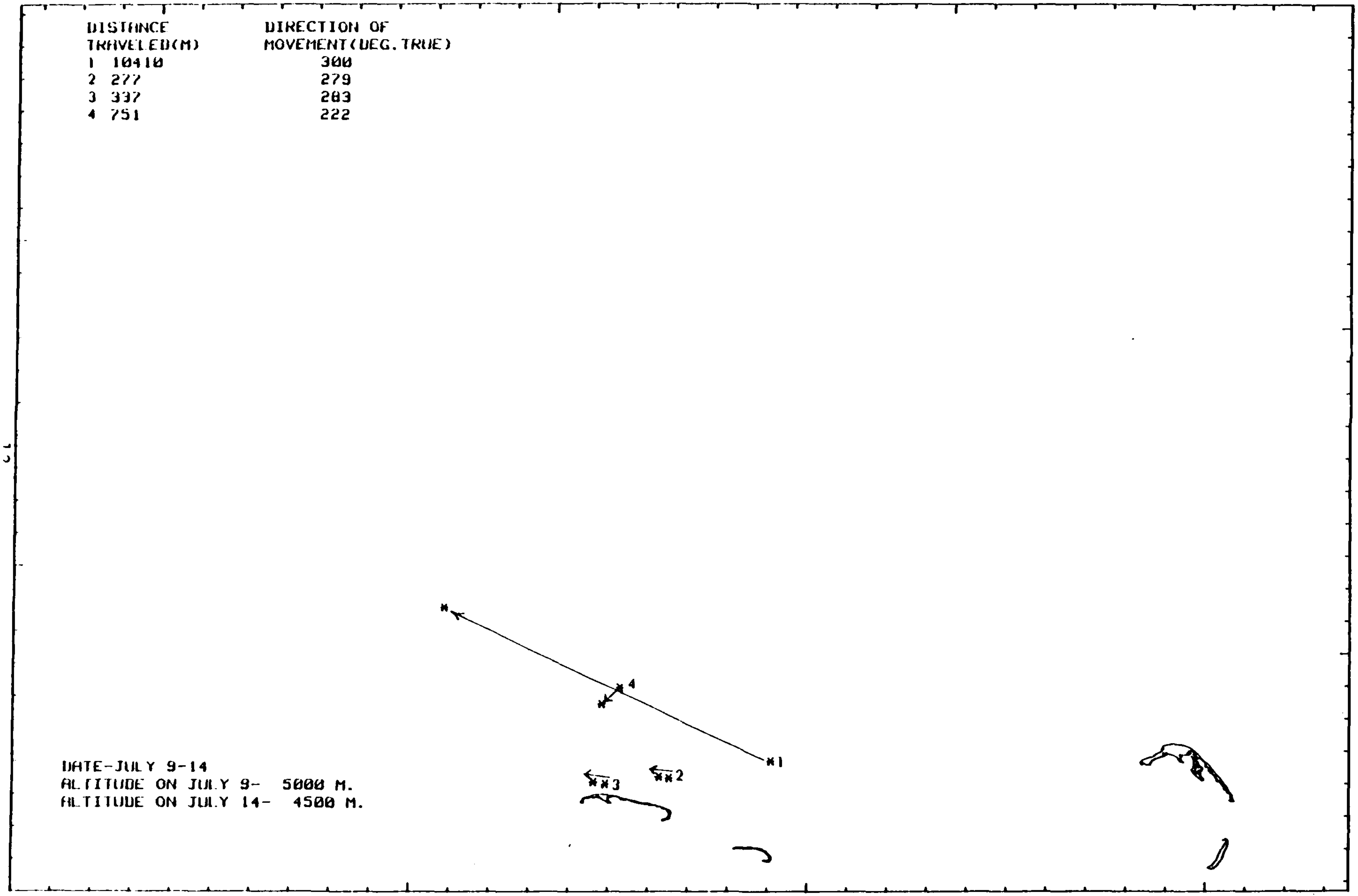
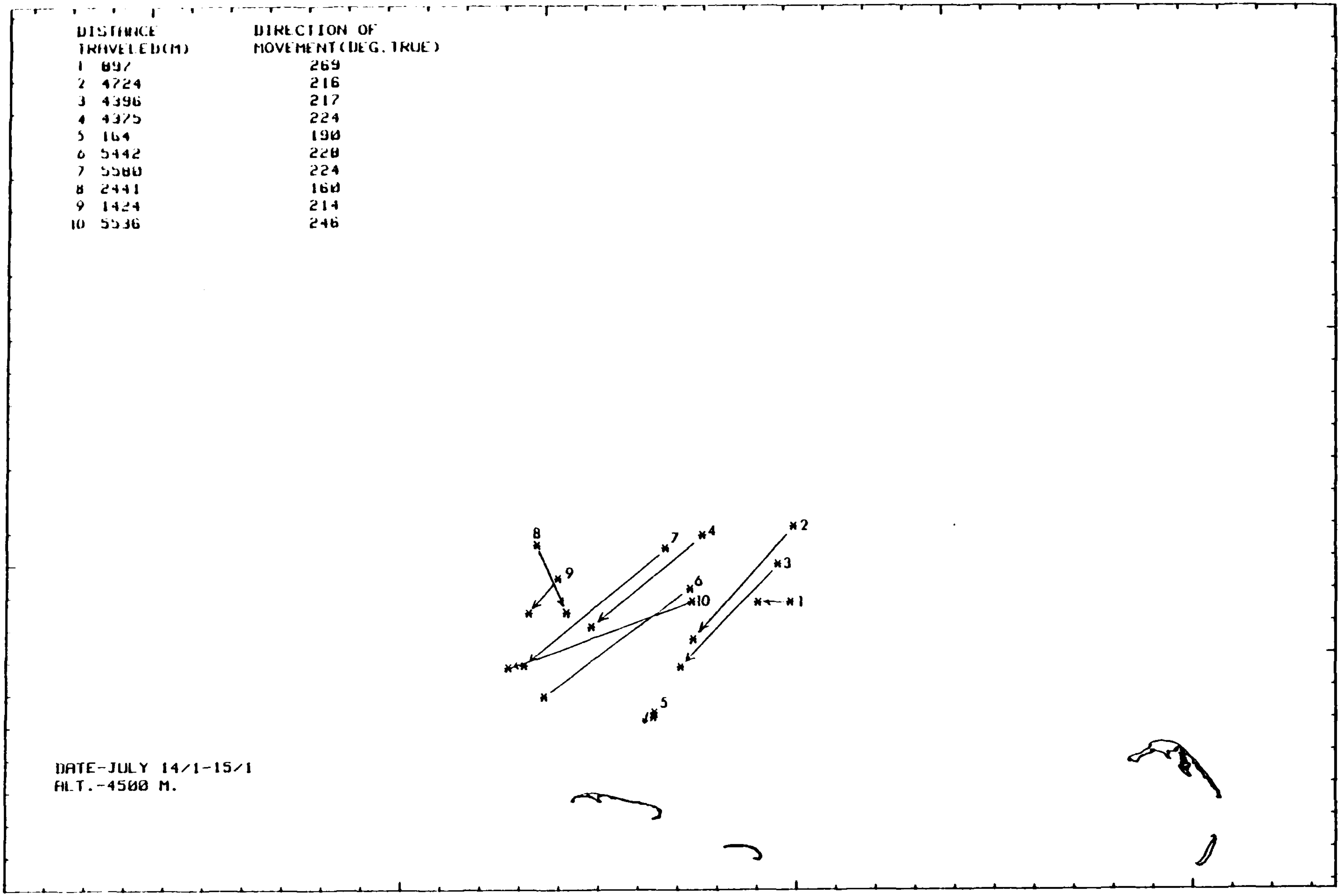


FIGURE 8. Movement of ice between July 9 and July 14. The numbers represent identifiable ice floes. The distance traveled and directional movement of each floe is listed.



DISTANCE TRAVELED(M)		DIRECTION OF MOVEMENT(DEG. TRUE)
1	897	269
2	4724	216
3	4396	217
4	4375	224
5	164	190
6	5442	228
7	5580	224
8	2441	160
9	1424	214
10	5536	246

FIGURE 9. Movement of ice between Flight 1 on July 14 and Flight 1 on July 15. The numbers represent identifiable ice floes. The distance traveled and directional movement of each floe is listed.

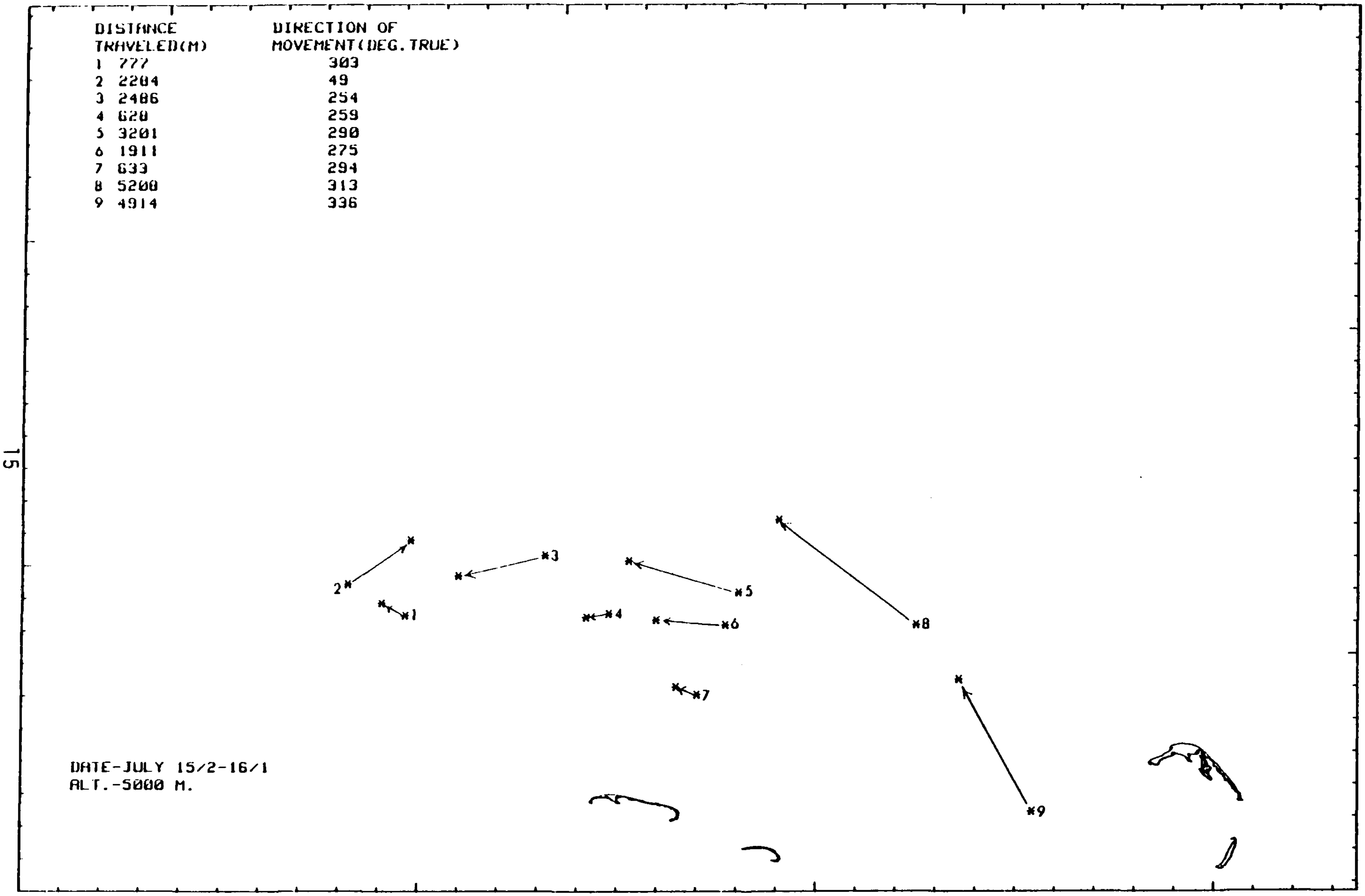


FIGURE 10. Movement of ice between Flight 2 on July 15 and Flight 1 on July 16. The numbers represent identifiable ice floes. The distance traveled and directional movement of each floe is listed.

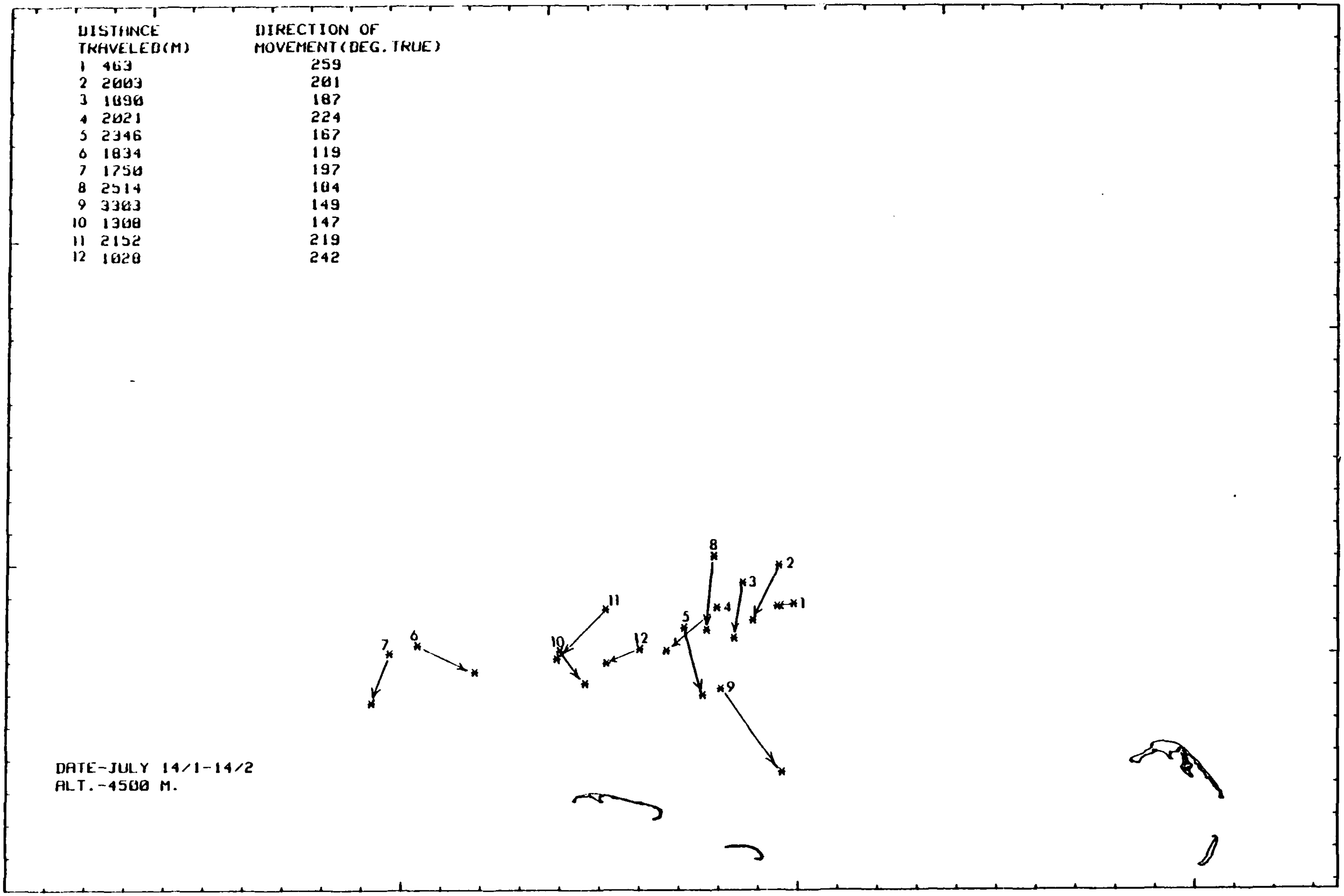


FIGURE 11. Movement of ice between Flight 1 on July 14 and Flight 2 on July 14. The numbers represent identifiable ice floes. The distance traveled and directional movement of each floe is listed.

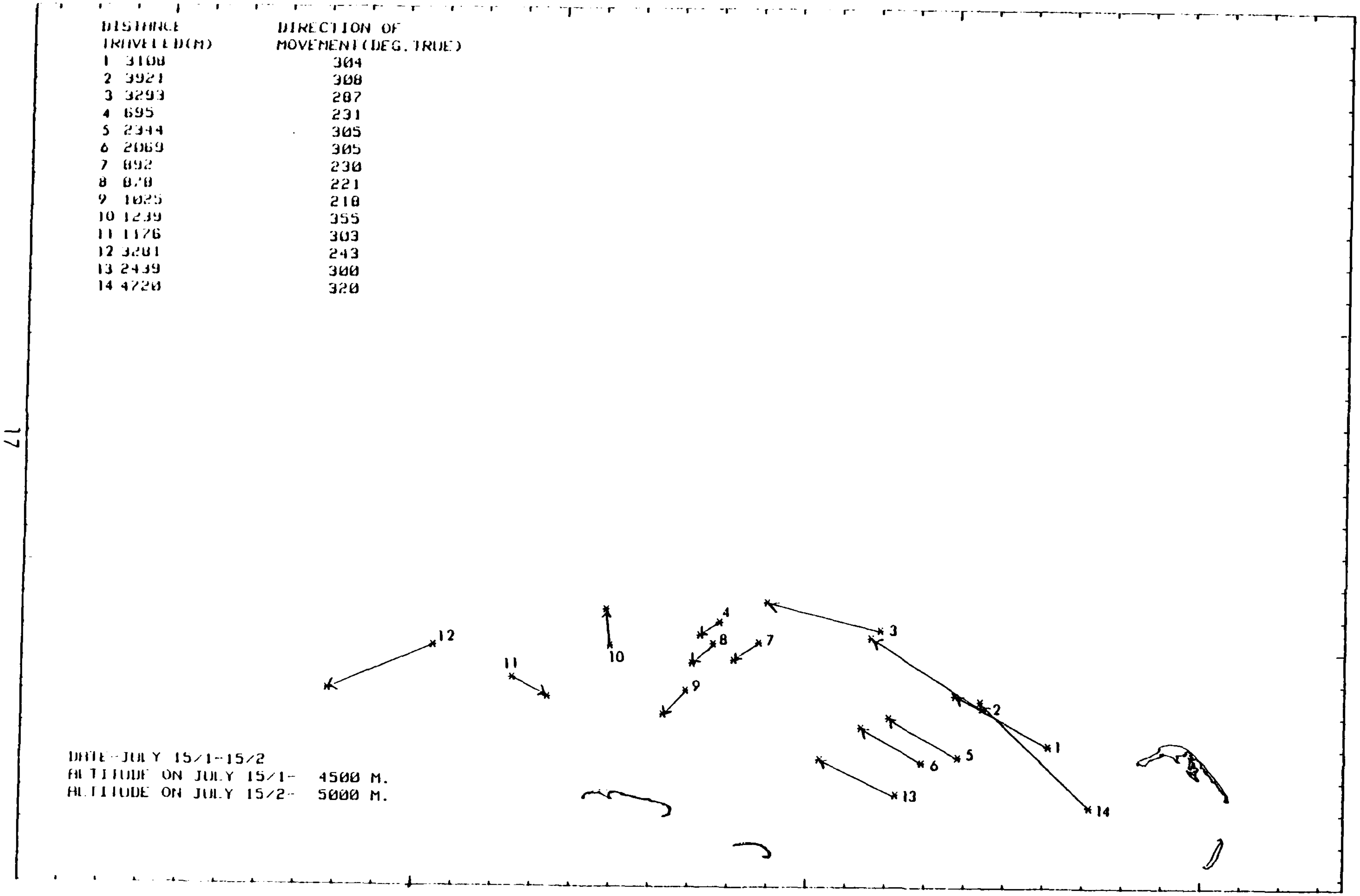


FIGURE 12. Movement of ice between Flight 1 on July 15 and Flight 2 on July 15. The numbers represent identifiable ice floes. The distance traveled and directional movement of each floe is listed.

DISTANCE TRAVELED(M)		DIRECTION OF MOVEMENT(DEG.TRUE)
1	713	336
2	617	335
3	681	338
4	536	339
5	838	308
6	753	306
7	521	300
8	543	309
9	626	299
10	668	318
11	578	339
12	296	255
13	621	335
14	407	3
15	646	341
16	1510	299
17	1000	286
18	1172	296
19	280	226
20	541	231
21	1299	343

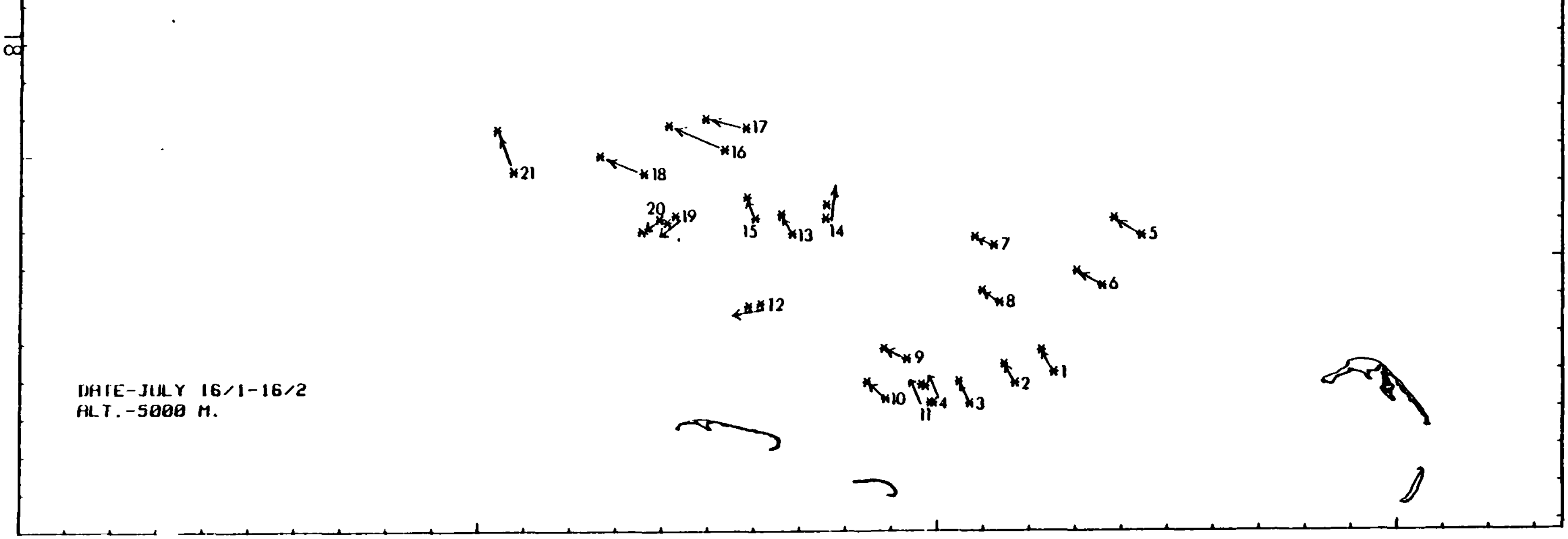


FIGURE 13. Movement of ice between Flight 1 on July 16 and Flight 2 on July 16. The numbers represent identifiable ice floes. The distance traveled and directional movement of each floe is listed.

Wind speed varied between 10 and 15 knots for the surveys on 14, 15 and 16 July. Using an average of 12.5 knots, floe speed varied between 0.5% and 3.8% on 14 July, 0.3 and 2.3% on 15 July, and 0.2 and 1.1% on 16 July. These values are lower than those for 1979. The 1979 data is for floes south of Reindeer Island and the 1980 data was for floes north of the island. The disparity in floe velocity as a percentage of wind for the two years cannot be simply explained. The current dynamics along the coast appear to be more than simply wind-driven. The next step in the process of defining movement in this area is the use of current meter moorings both north and south of the islands. This type data will complement the ice movement analysis accomplished to date.

TABLE 3

Movement (speed and direction) of ice floes
for 14, 15 and 16 July (1980)

14 July
Time Interval = 3.75 Hours

Floe #	Drift Speed (Knots)	Drift Direction (^{O}T)
1	0.07	259
2	0.29	201
3	0.27	187
4	0.29	224
5	0.34	167
6	0.26	119
7	0.25	197
8	0.36	184
9	0.48	149
10	0.19	147
11	0.31	219
12	0.15	242
AVG.	0.27	

15 July
Time Interval = 8.83 Hours

Floe #	Drift Speed (Knots)	Drift Direction (^{O}T)
1	0.19	304
2	0.24	308
3	0.20	287
4	0.04	231
5	0.14	305
6	0.13	305
7	0.05	230
8	0.05	221
9	0.06	218
10	0.08	355
11	0.07	303
12	0.20	243
13	0.15	300
14	0.29	320
AVG.	0.13	

16 July
Time Interval = 6.0 Hours

1	0.06	336
2	0.06	335
3	0.06	338
4	0.05	339
5	0.08	308
6	0.07	306
7	0.05	300
8	0.05	309
9	0.06	399
10	0.06	318
11	0.05	339
12	0.03	255
13	0.06	335
14	0.04	003
15	0.06	341
16	0.14	299
17	0.09	286
18	0.11	296
19	0.03	226
20	0.05	231
21	0.12	343
AVG.	0.07	

6.0 CONCLUSIONS

1. Breakup appears to be triggered by strong wind events in early July.

2. Ice floes in Prudhoe Bay do not respond solely to the wind field. Circulation patterns appear to have some effect on the movement of the ice floes. These circulation patterns have not been determined but could be with additional field studies.

3. At ice concentrations of 50^{o}% - 80^{o}%, ice floe movement (and presumably oil spill movement) will be negligible. At ice concentrations less than 50^{o}%, movement is primarily affected by the winds with circulation patterns being a secondary but important cause of movement.

4. Circulation patterns both in Prudhoe Bay and north of the barrier islands must be defined before any reliable predictions of oil/ice movement can be made. Current meter studies with concurrent drifter surveys would be necessary to define the circulation patterns.

REFERENCES

Morson, B. and E. Sobey, 1979. Response to oil spills in the Arctic environment: A review. In: Proceedings of Oceans 79. San Diego, California, pp 407-414.

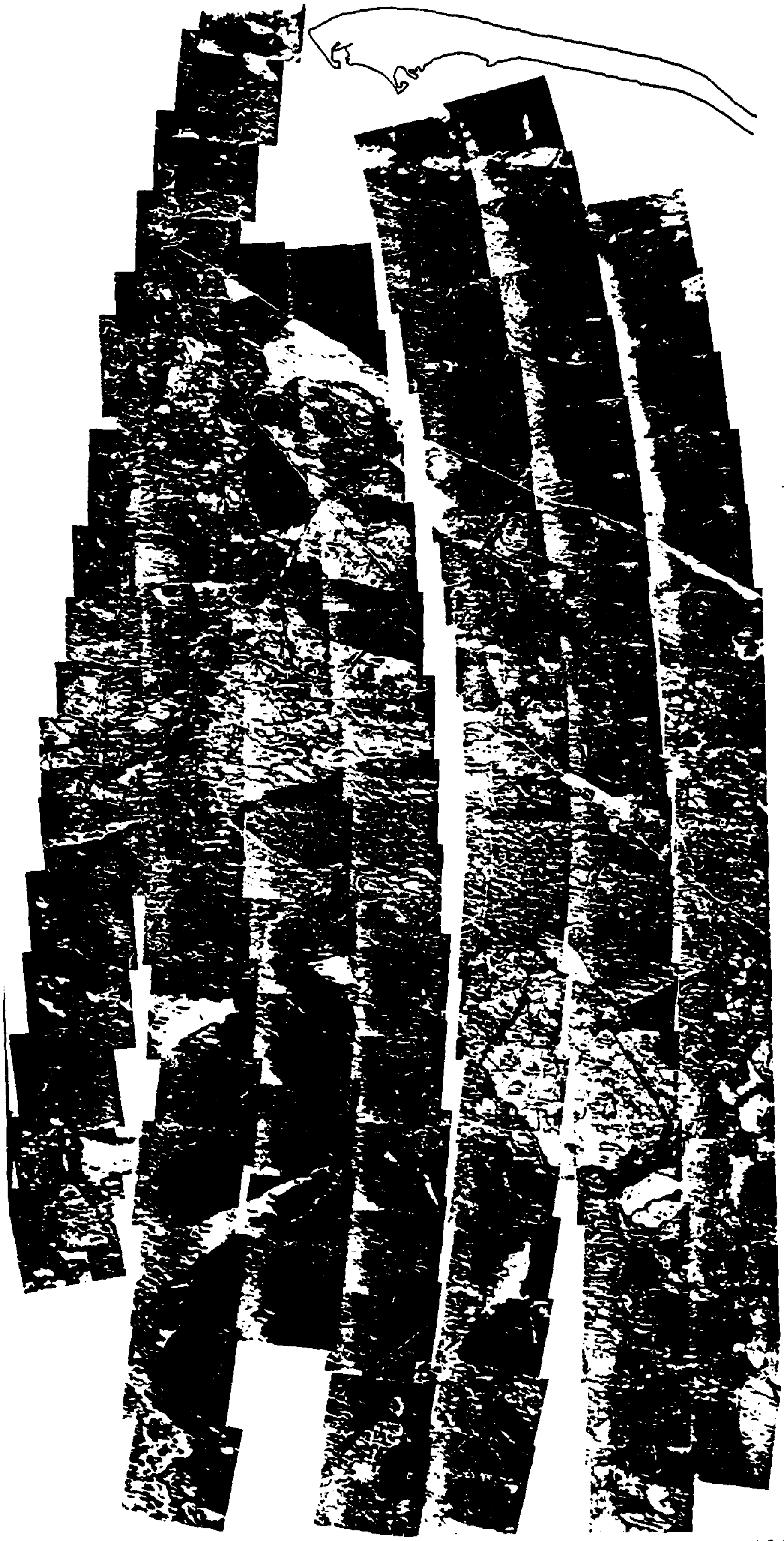
APPENDIX A

AERIAL PHOTOGRAPHIC SURVEYS FOR 1979

Aerial photographic mosaic taken on June 30, 1979. Altitude - 2000 ft. The Barrier Islands are located at the top of the mosaic. The outline of the islands is lightly sketched in where photos were not taken. Orientation of the mosaics for 1979 is shown in Figure 1.

Aerial photographic mosaic taken on July 1, 1979. Altitude - 2000 ft. The Barrier Islands are located at the top of the mosaic. The outline of the islands is lightly sketched in where photos were not taken. Orientation of the mosaics for 1979 is shown in Figure 1.

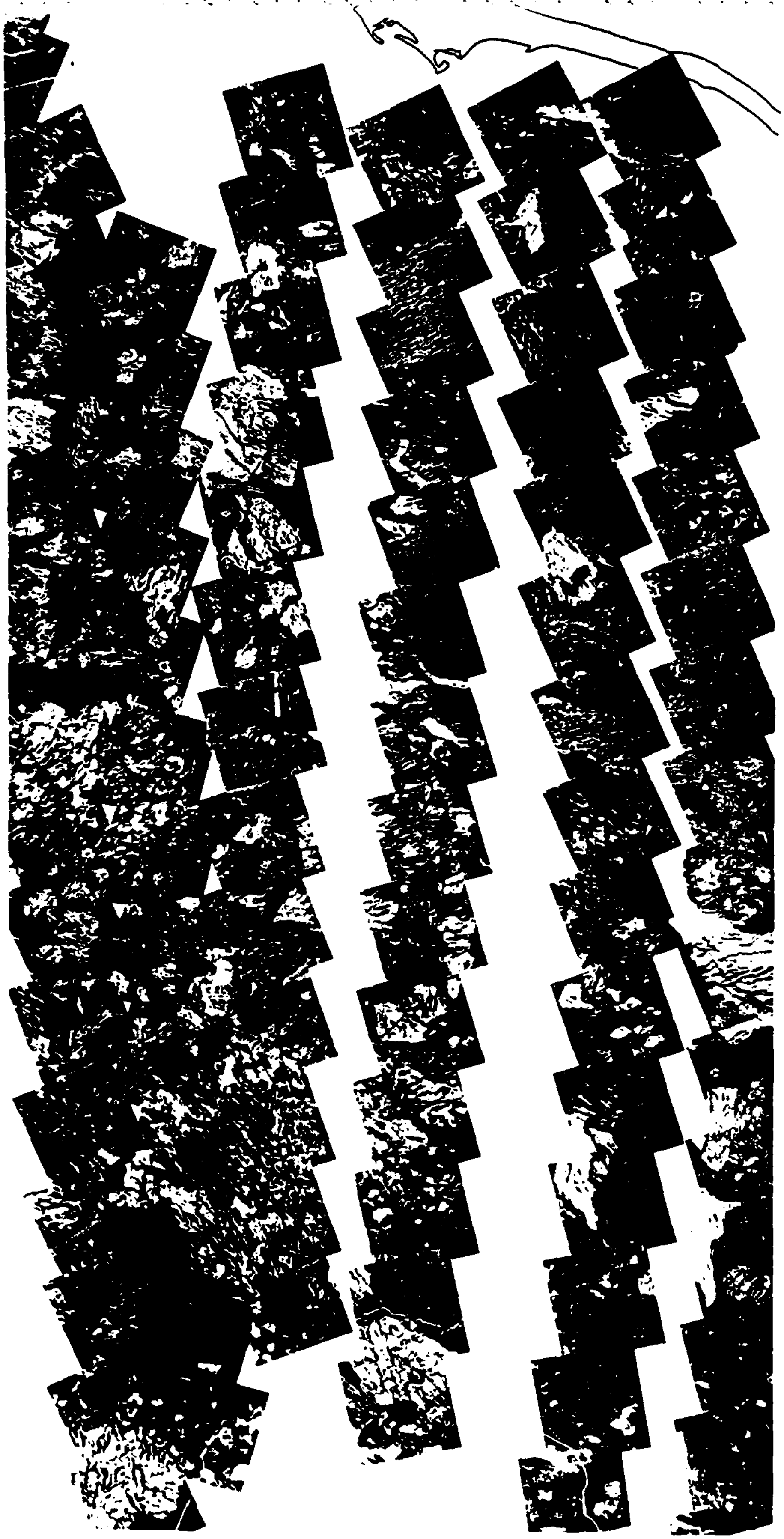
Aerial photographic mosaic taken on July 2, 1979. Altitude - 2000 ft. The Barrier Islands are located at the top of the mosaic. The outline of the islands is lightly sketched in where photos were not taken. Orientation of the mosaics for 1979 is shown in Figure 1.



Aerial photographic mosaic taken on July 3, 1979. Altitude - 2000 ft. The Barrier Islands are located at the top of the mosaic. The outline of the islands is lightly sketched in where photos were not taken. Orientation of the mosaics for 1979 is shown in Figure 1.

Aerial photographic mosaic taken on July 3, 1979. Altitude - 2000 ft. Orientation of the mosaics for 1979 is shown in Figure 1. This set of photographs was taken just to the west of the previous set. This allowed identification of more ice floes.

Aerial photographic mosaic taken on July 5, 1979. Altitude - 2000 ft. The Barrier Islands are located at the top of the mosaic. The outline of the islands is lightly sketched in where photos were not taken. Orientation of the mosaics for 1979 is shown in Figure 1.



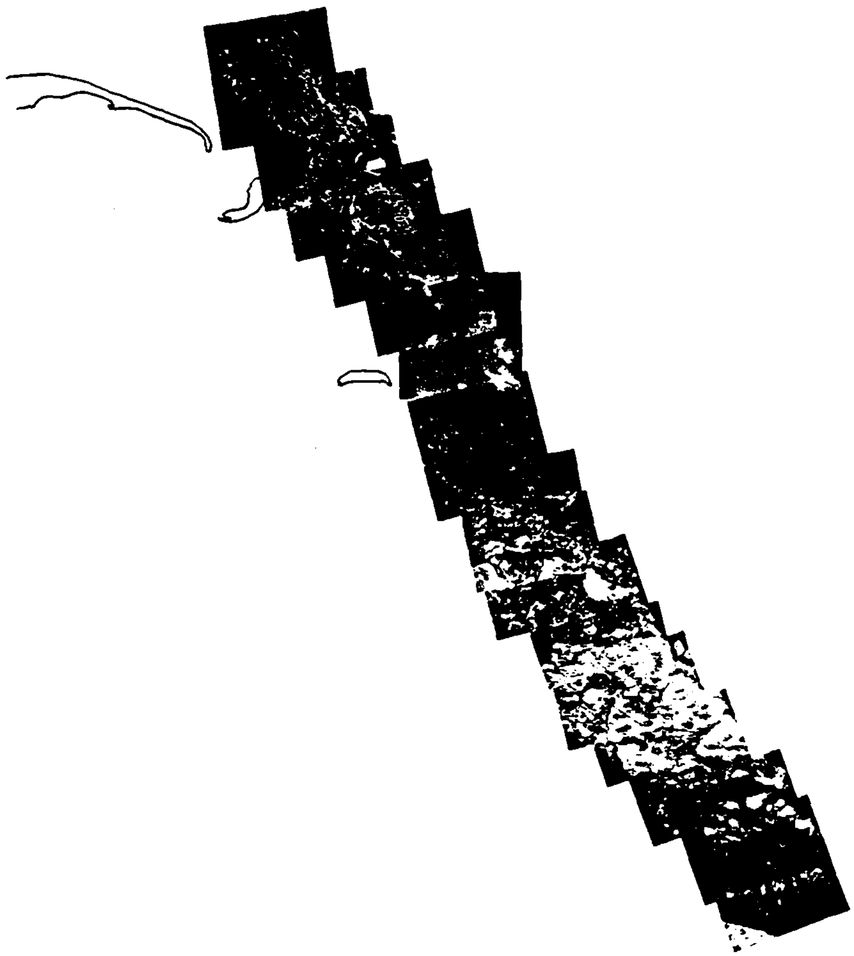
Aerial photographic mosaic taken on July 7, 1979. Altitude - 2000 ft. The Barrier Islands are located at the top of the mosaic. The outline of the islands is lightly sketched in where photos were not taken. Orientation of the mosaics for 1979 is shown in Figure 1.

Aerial photographic mosaic taken on July 9, 1979. Altitude - 2000 ft. The Barrier Islands are located at the top of the mosaic. The outline of the islands is lightly sketched in where photos were not taken. Orientation of the mosaics for 1979 is shown in Figure 1.

Aerial photographic mosaic taken on July 7, 1979. Altitude - 2000 ft. The Barrier Islands are located at the top of the mosaic. Orientation of the mosaics for 1979 is shown in Figure 1. This set of photographs was taken just to the east of the previous set. This allowed identification of more ice floes.

Aerial photographic mosaic taken on July 10, 1979. Altitude - 5000 ft. The Barrier Islands are located at the top of the mosaic. The outline of the islands is lightly sketched in where photos were not taken. Orientation of the mosaics for 1979 is shown in Figure 1. This is the first of three mosaics on this date.

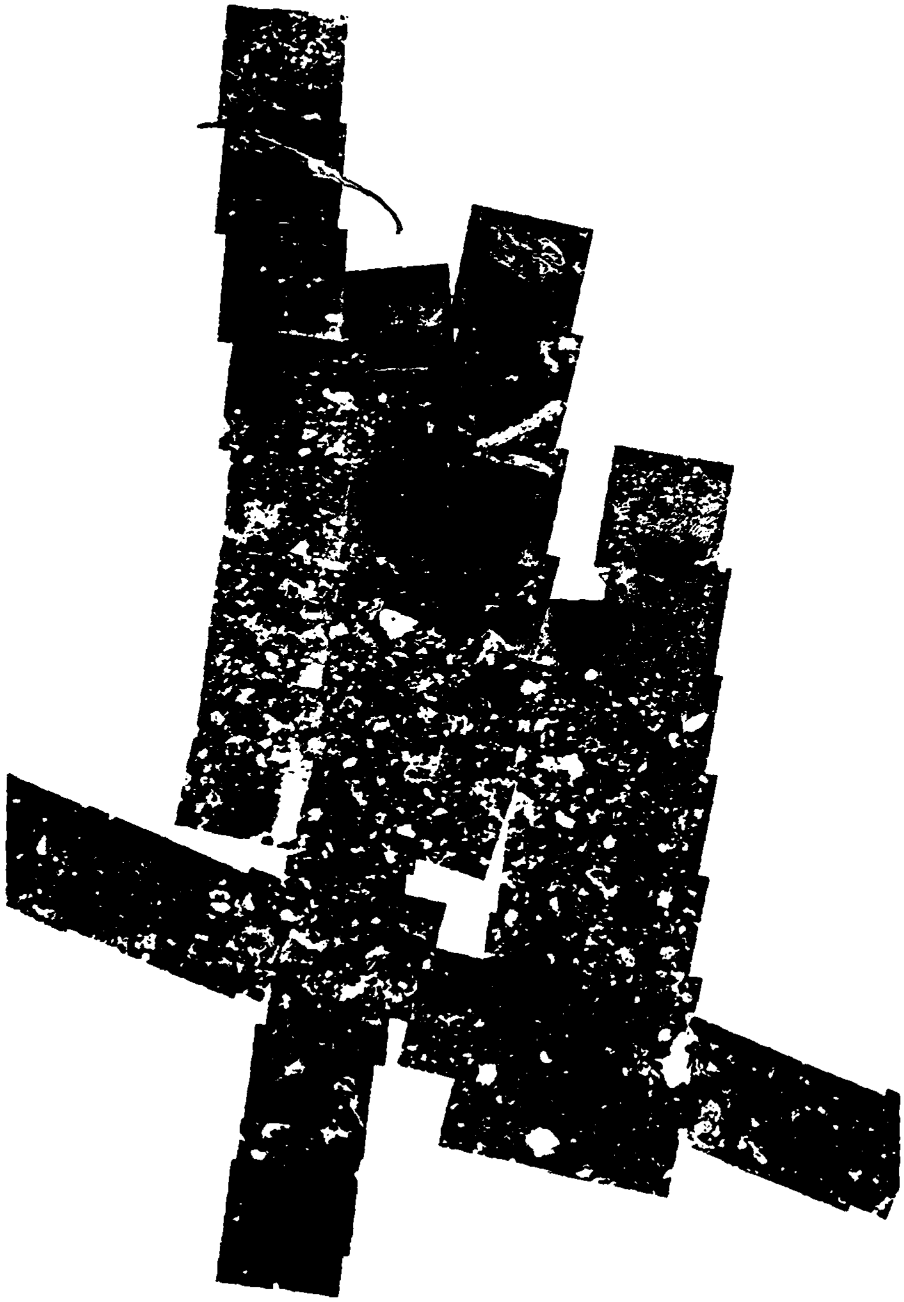
Aerial photographic mosaic taken on July 10, 1979. Altitude - The mosaic on the left side was taken at 4500 ft. The two runs on the right side were at 4100 ft. This is the second of three mosaics on this date.. The Barrier Islands are located at the top of the mosaic. The outline of the islands is lightly sketched in where photos were not taken. Orientation of the mosaics for 1979 is shown in Figure 1.



Aerial photographic mosaic taken on July 10, 1979. Altitude - 5000 ft. This is the third of three mosaics on this date.. The Barrier Islands are located at the top of the mosaic. The outline of the islands is lightly sketched in where photos were not taken. Orientation of the mosaics for 1979 is shown in Figure 1.

Aerial photographic mosaic taken on July 11, 1979. Altitude - 5000 ft. This is the first of four mosaics on this date.. The Barrier Islands are located at the top of the mosaic. The outline of the islands is lightly sketched in where photos were not taken. Orientation of the mosaics for 1979 is shown in Figure 1.

Aerial photographic mosaic taken on July 11, 1979. Altitude - 5000 ft. This is the second of four mosaics on this date.. The Barrier Islands are located at the top of the mosaic. The outline of the islands is lightly sketched in where photos were not taken. Orientation of the mosaics for 1979 is shown in Figure 1.



Aerial photographic mosaic taken on July 11, 1979. Altitude - 5000 ft. This is the third of four mosaics on this date.. The Barrier Islands are located at the top of the mosaic. The outline of the islands is lightly sketched in where photos were not taken. Orientation of the mosaics for 1979 is shown in Figure 1.

Aerial photographic mosaic taken on July 11, 1979. Altitude - 5000 ft. This is the fourth of four mosaics on this date.. The Barrier Islands are located at the top of the mosaic. The outline of the islands is lightly sketched in where photos were not taken. Orientation of the mosaics for 1979 is shown in Figure 1.

APPENDIX B

AERIAL PHOTOGRAPHIC SURVEYS FOR 1980

Aerial photographic mosaic taken on June 24, 1980. Altitude - 5000 ft. The barrier islands are located in the center of the mosaic. Orientation of the mosaic is shown in Figure 2.

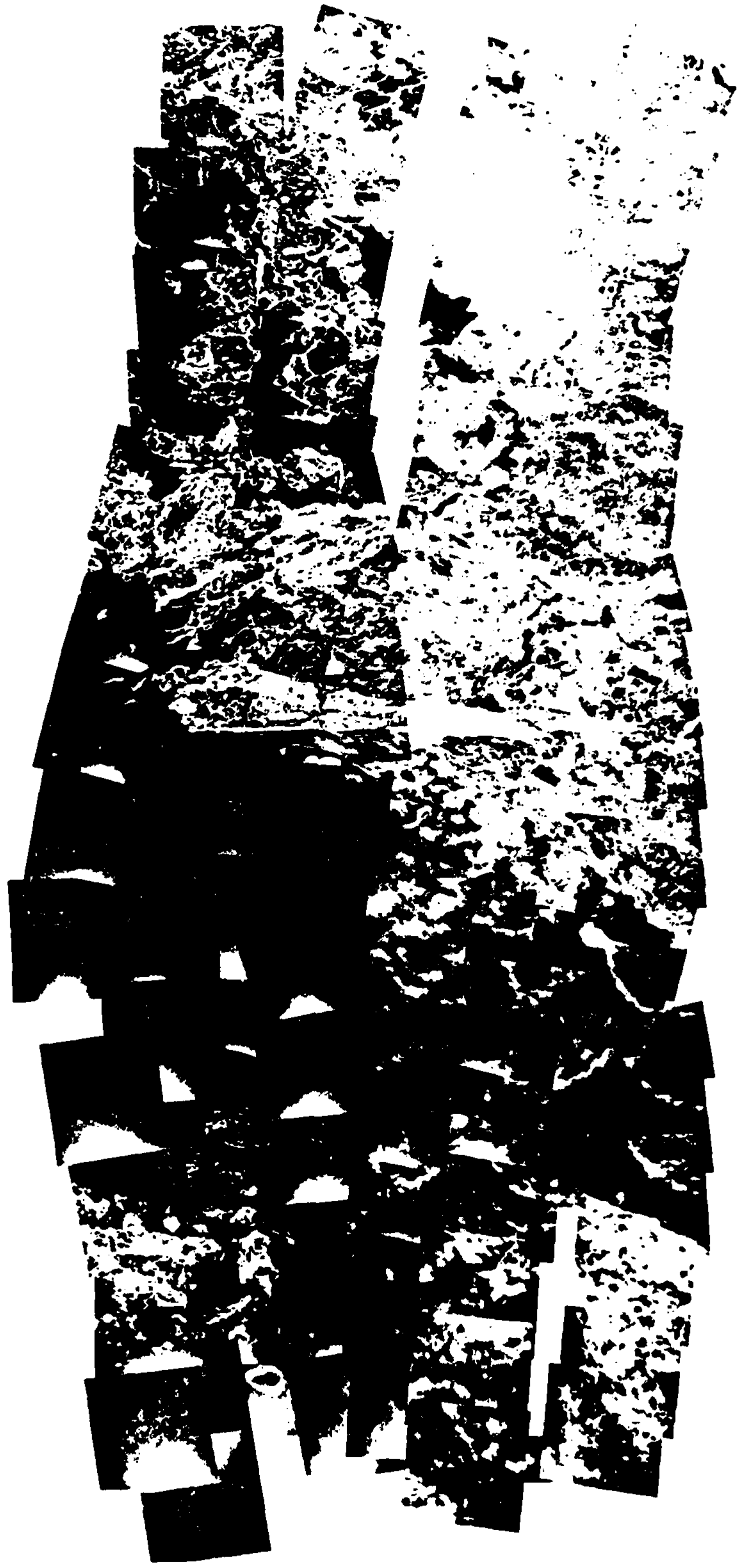
Aerial photographic mosaic taken on June 26, 1980. Altitude - 5000 ft. The barrier islands are located in the center of the mosaic. Orientation of the mosaic is shown in Figure 2.

Aerial photographic mosaic taken on June 28, 1980. Altitude - 5000 ft. The barrier islands are located in the center of the mosaic. Orientation of the mosaic is shown in Figure 2.

Aerial photographic mosaic taken on July 1, 1980. Altitude - 5000 ft. The barrier islands are located in the center of the mosaic. Orientation of the mosaic is shown in Figure 2.

Aerial photographic mosaic taken on July 2, 1980. Altitude - 5000 ft. The barrier islands are located in the center of the mosaic. Orientation of the mosaic is shown in Figure 2.

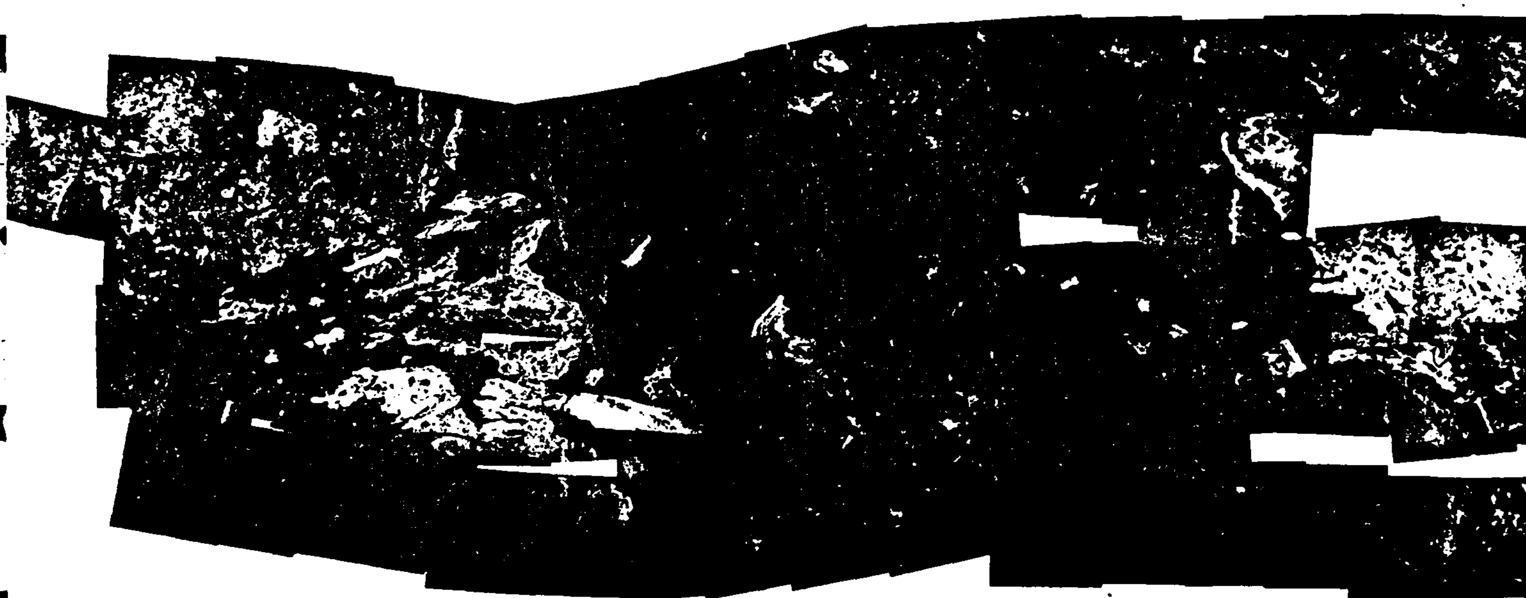
Aerial photographic mosaic taken on July 3, 1980. Altitude - 5000 ft. The barrier islands are located in the center of the mosaic. Orientation of the mosaic is shown in Figure 2.



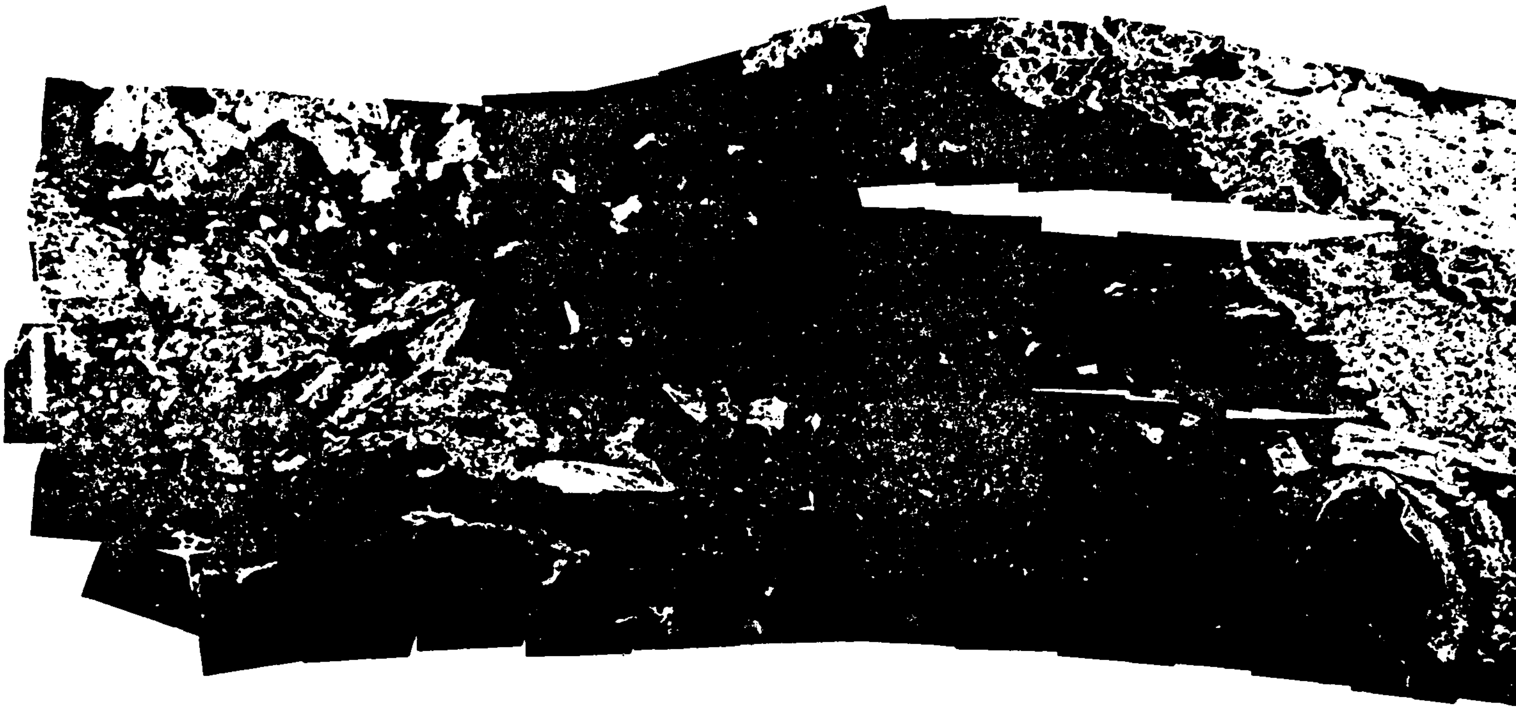
Aerial photographic mosaic taken on July 7, 1980. Altitude - 5000 ft. The barrier islands are located in the center of the mosaic. Orientation of the mosaic is shown in Figure 2.

Aerial photographic mosaic taken on July 9, 1980. Altitude - 5000 ft. Only the area north of the barrier islands was photographed because ice-free conditions prevailed south of the islands.

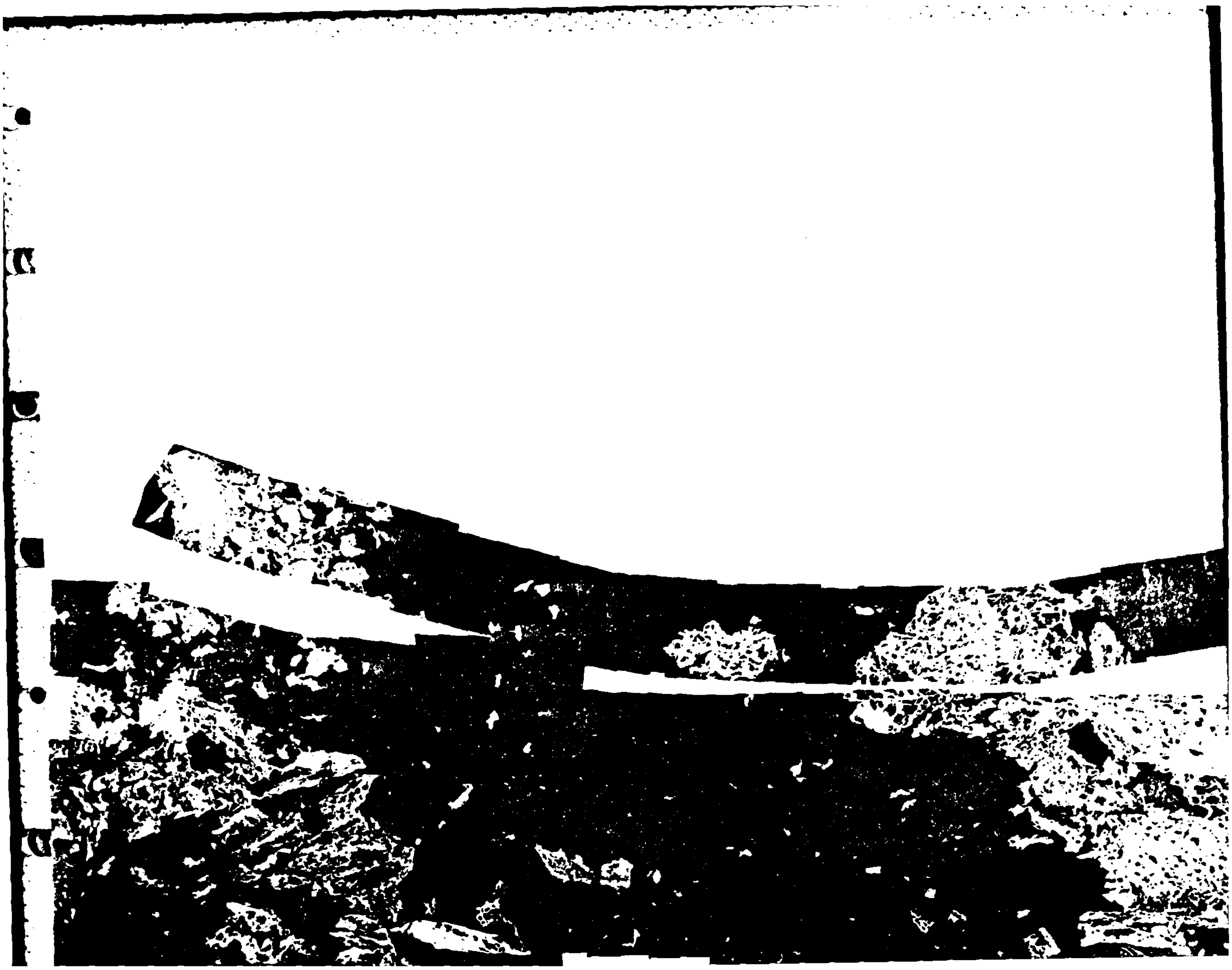
Aerial photographic mosaic taken on July 14, 1980. Altitude - 5000 ft. The survey area was increased to the east to include Cross Island (Figure 2) because of the ice-free conditions south of the islands. This is the first of two mosaics on this day.



Aerial photographic mosaic taken on July 14, 1980. Altitude - 5000 ft. The survey area was increased to the east to include Cross Island (Figure 2) because of the ice-free conditions south of the islands. This is the second of two mosaics on this day.



Aerial photographic mosaic taken on July 15, 1980. Altitude - 5000 ft. The survey area was increased to the east to include Cross Island (Figure 2) because of the ice-free conditions south of the islands. This is the first of two mosaics on this day.



Aerial photographic mosaic taken on July 16, 1980. Altitude - 5000 ft. The survey area was increased to the east to include Cross Island (Figure 2) because of the ice-free conditions south of the islands. This is the first of two mosaics on this day.

Aerial photographic mosaic taken on July 16, 1980. Altitude - 5000 ft. The survey area was increased to the east to include Cross Island (Figure 2) because of the ice-free conditions south of the islands. This is the second of two mosaics on this day.

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