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GEOGRAPHICAL PAPER No. 9

Miscellaneous Papers Series

A Report on Sea Ice Conditions in the Eastern Arctic, Summer 1956

W. A. Black

GEOGRAPHICAL BRANCH
Department of Mines and
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EDMOND CLOUTIER, C.M.G., O.A., D.S.P.
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PREFACE

For the past seven years the Geographical Branch has been collecting data on sea ice conditions, and investigating ice distribution in Canadian waters as part of the Canadian Ice Distribution Survey. During the summer of 1956 W.A. Black, a geographer on the permanent staff, carried out an ice reconnaissance survey in the Eastern Arctic from the northern supply ship C.G.S. d'Iberville.

The report of this survey is published to provide a picture of the nature, conditions and distribution of the ice encountered by Canadian Government ships on their annual supply missions, and its purpose is to record the special problems that ice presents to ships navigating in Canada's Arctic waters.

N. L. Nicholson,
Director,
Geographical Branch.

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A REPORT ON SEA ICE CONDITIONS IN THE EASTERN ARCTIC, SUMMER 1956

INTRODUCTION AND ACKNOWLEDGMENTS

This report describes the sea ice conditions encountered by the C.G.S. d'Iberville on her annual supply mission to Resolute and Eureka in August 1956.[1] Being on ship-board the writer was able to observe the condition and movement of sea ice encountered, and to note those ice conditions that seriously affect ship navigation.

Ship-board ice reconnaissance was supplemented by regular aerial ice reconnaissance reports issued by the U.S.H.O. ice observer at Resolute for August 9, 11, 14, 16 and 19, particularly for the Baffin Bay, Lancaster Sound and Jones Sound areas. The R.C.A.F. provided a Lancaster aircraft for a 3½-hour ice reconnaissance on August 17 from Resolute to Eureka Sound at the request of Capt. C.A. Caron, in command of the d'Iberville. This flight was made to ascertain the condition of the ice in the western part of Jones Sound, Hell Gate channel and Norwegian Bay prior to the sailing of the d'Iberville into these waters. On August 26 and 27, three flights of approximately 50 minutes each were made by the ship's helicopter over Slidre Fiord.

The writer wishes to acknowledge the cooperation given by R. James, U.S. Hydrographic Office, at Resolute; by the R.C.A.F., and particularly by Captain C.A. Caron and officers of the d'Iberville and by the crew of the ship's helicopters.

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[1] In the summer of 1955 the d'Iberville reached 77° 30' N. in Norwegian Bay before turning back because of heavy ice. For an account of the ice conditions existing during that summer see Dunbar, Moira, Notes on Sea Ice Observed from C.G.S. 'd'Iberville' and 'C.D. Howe'. Canada, Department of National Defence, Defence Research Board. Arctic Report No.4/55. Ottawa, Jan., 1956.

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GENERAL ICE CONDITIONS ENCOUNTERED

Throughout the reconnaissance area ice conditions were variable. In the Davis Strait-Baffin Bay area, on August 9, a wedge of ice with a concentration of 4/10 to 7/10 lay off the Baffin coast. On the return journey, September 2, only a small area remained as scattered ice near Padloping. The eastern part of Lancaster Sound was open; the western part from Cape Erebus to Griffith Island on August 15 was 4/10 ice covered. On the ship's departure from Resolute, August 21, a small band of scattered ice remained in the Lancaster Sound area. Jones Sound was open throughout except at the entrance to Cardigan Strait and Hell Gate. On August 22, and August 29 Hell Gate channel was 8/10 ice covered; areas of open water hugged the eastern side of the channel. Norwegian Bay on August 22 and 23, was covered with 10/10 (0010) concentration. In the southern part of the bay, except at the entrance to Hell Gate, there were few leads; in the northern part of the bay the leads were wider with a considerable amount of recently pressure-ridged ice. On August 28 and 29 leads were more extensive, frequently expanding into large open areas; recently formed pressure ridges, occupying from 1/10 to 3/10 of the ice surface extended irregularly throughout the area enclosing large ice pans. The ice in Norwegian Bay at this date was in the process of breaking up. Eureka Sound, on August 24, was 4/10 to 6/10 covered and on August 28 ice coverage was reduced to 2/10 or 3/10. Slidre Fiord, from August 24 to 28 was 6/10 to 8/10 covered, with the ice shifting back and forth between the north and south sides of the fiord.

In Baffin Bay and Lancaster Sound the ice consisted of small to medium floes with a considerable amount of brash and growlers. The winter-formed floe ice exceeded 8 to 10 feet in thickness. In the Hell Gate-Eureka Sound-Slidre Fiord area approximately 8/10 to 9/10 of the ice consisted of winter-formed ice 3 to 5 feet thick, approximately one-third of which consisted of grey-white rotten ice and

the remainder green-blue hard winter ice. The remaining 1/10 to 2/10 scattered throughout the area consisted of hard, hummocked polar-formed ice the thickness of which generally exceeded 6 feet. Icebergs and bergy bits were scattered throughout the reconnaissance area but were particularly concentrated between latitudes 72° and 74° N. and between longitudes 59° and 62° W.

Ice conditions observed during the survey are summarized graphically in Figures 1 to 8. A general report that follows gives a summary of ice conditions presented in each chart. The salient features of the conditions as they affect ship navigation are briefly summarized at the end of the report.

SELECTED ICE TERMINOLOGY

(a) The system and symbols of ice reporting used in this report are those of the U.S. Navy Hydrographic Office.

(b) Concentration by size: The first digit indicates tenths of brash and block, the second digit, tenths of small to medium floes and the third digit, tenths of giant floes and field. Example: 621 concentration indicates 6/10 brash and block, 2/10 small to medium floes and 1/10 giant floes and field. Total ice coverage 9/10.

(c) Young or very young ice: Newly formed level ice, usually transparent or may be opaque.

(d) Winter ice: Usually more or less unbroken, level sea ice of the current winter's growth.

(e) Polar ice: Usually ice of more than one winter's growth; the details of pressure ridges are subdued to form hummocks, the thickness of which is usually not less than 6 feet.

(f) Puddles: Depressions in floe ice filled with water melted from the surface of the ice. In this study puddling is expressed in 10ths coverage.

(g) Rotten ice: Ice that has become honeycombed in the course of melting.
Note:- Though the puddles may melt through the ice, the ice still may be very hard.

(h) Ram: An underwater projection of ice.

ICE CONDITIONS: BAFFIN BAY-DAVIS STRAIT
(Figures 1, 2: August 8-14; August 30-September 3.)

Ice Distribution

The aerial ice reconnaissance report of August 9 showed the ice pack in Baffin Bay and Davis Strait lying off the eastern and southeastern coast of Baffin Island. The ice in the area north of 68° had a concentration of 8/10 in the western part and 5/10 in the eastern part. South of 68° N. the remainder of the pack area had a concentration of 5/10 except in the southernmost part of the area where ice coverage was 2/10. The boundary of the pack extended eastward from Breevort Island to 63° N. and 60° W., thence northward in mid-channel through Davis Strait and northwestward to parallel Baffin Island as far as 72½° N. and 68° W. The remainder of Baffin Bay was open.

The ship's course along the edge of the pack from August 9 to 13 presented a pattern of alternating bights and ice tongues. Ice concentrations were generally about 4/10 to 5/10 with small to medium-sized floes predominating. From 62° N. to 67° N. much scattered ice of less than 1/10 coverage skirted the bights and ice tongues; north of 67° ice concentration along the ice edge reached 6/10 to 8/10 (240 to 350). The surface of the floe ice was rough and uneven with rams extending outward from individual floes; thickness exceeded 5 or more feet. Much of this ice may have come from Smith Sound. On September 1, during the return journey, the ship passed through ice with a concentration of 1/10 to 3/10 (100 to 210) between 67½° and 68-3/4° N. In the intervening period of approximately three weeks the extensive ice pack had been severely reduced in area.

Factors Affecting Distribution

A number of factors contributed to the rapid disintegration of the ice. The most important were air and water temperatures, wind direction and velocity, and wave erosion.

Winds tend to drive ice floes into strings and bands or to open up a pack of ice by driving the ice outward. Along the ship's track from Port Burwell to 68½° N. winds with a velocity of 11 to 16 m.p.h. blew chiefly from the southwest and northwest, driving the ice outward from its plotted position of August 9. An extensive area of brash (10) lay south of 63° N. Along the track, the ice edge was marked by long tongues of ice and deep bights containing scattered brash. Within the pack concentrations varied from 3/10 to 5/10. From 68½° to 73½° N., winds from 4 to 16 m.p.h. blew steadily from the east and northeast driving back the ice at the edge of the pack. The ice edge was smoother, the ice tongues were rounded, and the bights shallower with ice concentrations ranging from 5/10 to 8/10. In the interval between the northbound and southbound journeys, prevailing winds blew from a southerly quadrant. On the southbound journey prevailing winds blew from a southeast-southwest direction, with an average velocity of 17 to 21 m.p.h. and with maximum speeds up to 33 m.p.h. These winds contributed much to the disintegration of the ice field.

On the northbound journey air temperatures stood well above freezing (Table I). The average minimum temperature was 34.3° F., average maximum 43.4° F. and the daily average 37.7° F. Of some 42 readings taken during the 7-day period from August 8 to 14, three readings dropped to 32° F. and one to 28° F. Air temperatures were highest in the southern and the northern parts of Baffin Bay-Davis Strait area. A similar temperature pattern was noted on the return journey. These areas were free from ice. As the average daily temperature stood well above the daily minimums, air temperatures over the pack must have been well above these lowest recordings.

Air temperature effectiveness is given in Table I in the column 'daily heat accumulation'. Each day gave a positive temperature exceeding 32° F. The average accumulative daily temperature was 12° F. above freezing, and thus thawing

TABLE I

Daily Temperatures, Baffin Bay-Davis Strait, August 8-14

Day	Air (F.°) Min.	Max.	Av.	D.H. Accum.[1]	Surface Water (F.°) Min.	Max.	Av.	D.H. Accum.[2]
Aug. 8	34	51	40	21	32	40	35.6	14
Aug. 9	32	43	36.5	11	32	38	34	12
Aug. 10	33	44	36.5	12	33	37	34	12
Aug. 11	32	40	36.8	8	33	34	33.3	9
Aug. 12	28	40	35.6	4	34	34	34	10
Aug. 13	35	45	40	16	34	34	34	10
Aug. 14	36	41	39	13	34	36	35	12
Daily Av.	34.3	43.4	37.7	12	33.1	36.1	34.2	11

[1] Daily Heat Accumulation for air is the sum of the difference of minimum and maximum temperatures from 32° F.

[2] 29° F. as the freezing temperature of sea water is used, to make the calculation for sea water.

conditions were dominant. The daily temperature range for the 24-hour period is given in Table II. Of the nine minimum temperatures recorded one occurred at 2000, three at 2400, three at 0400 and two at 0800 hours. The lowest temperatures occurred during the period from 2400 to 0800 hours. Highest temperatures coincided with the period of highest rate of thaw, between 1000 and 1600 hours. The period of lowest temperatures occurred during and immediately after the lowest declination of the sun.

TABLE II

Cumulative Air Temperature (F.°), Baffin Bay-Davis Strait, August 8-14

Hours	0400	0800	1200	1600	2000	2400
Cum. temps.	245	250	300	291	258	245
Av. temps.	35	35.7	42.8	41.5	36.8	35

Surface water temperatures recorded followed a pattern that corresponded closely to air temperatures, (Table I). The ratio of water to air temperatures was

approximately 2:5. Open water appeared to warm up rapidly and remain above freezing within an open pack of approximately 4/10 coverage, consisting of brash and small to medium floes. The accumulative daily heat of sea water for each day was positive and above freezing. The average daily accumulative temperature for the water was 11° F. Surface water temperature range for the area is given in Table III. Maximum temperatures occurred from 2000 to 0400 hours. Both air and surface water temperatures approach coincidence in early morning.

TABLE III

Cumulative Surface Water Temperatures (F.°),
Baffin Bay-Davis Strait, August 8-14

Hours	0400	0800	1200	1600	2000	2400
Cum. temps.	240	235	237	234	245	240
Av. temps.	34.3	33.6	33.8	33.6	35	34.3

The effect of the relatively high water and air temperatures is to quicken the disintegration of the ice. This process proceeds at a rapid rate when temperatures remain above freezing throughout the 24-hour period. It is further aided by winds particularly when they blow outward to open up the pack, thereby subjecting the ice to the combined erosive action of the waves and relatively warm water.

ICE CONDITIONS: LANCASTER SOUND
(Figure 3: August 15-21.)

Ice Distribution

On August 9, Lancaster Sound was open from its eastern entrance to 92° W. From the ice edge to the harbour at Resolute ice coverage was 4/10, consisting chiefly of small floes south of 72½° N. and larger floes north of 74½° N. On August 11, the southern part of the edge had pushed outward in a southeasterly direction, with the ice having a concentration of 2/10. Between 92° W. and the harbour, and north of 74° 25' ice concentration was 3/10. South of this latitude concentration

was 1/10. Ice consisted of brash and block. Rapid disintegration of this ice followed and on August 14 the ice edge paralleled the 93rd meridian and extended eastward across the mouth of Wellington Channel. From 93° W. to the harbour the ice coverage was 4/10, consisting of brash concentrated in east to west belts by the force of strong 30 to 35 mile-an-hour easterly winds. On August 15, the ice edge had advanced eastward though remaining in the same relative position to that of August 14. On August 17, the ice edge extended southward from Griffith Island. On August 21, Lancaster Sound was entirely open in the vicinity of 94° W. except for occasional strings of brash which may have come down from Wellington Channel. The 7/10 ice coverage (250) lay to the west of 95° 15' until August 14. By August 21, it must have disintegrated, otherwise the strong prevailing westerly and northwesterly winds would have forced this ice into Lancaster Sound.

At the harbour, previous ice reconnaissance reported small to medium sized ice floes aground off the Eskimo village and extending along the line of shoals across the entrance to the harbour. Ice concentrations on August 9, were 5/10; on August 11, concentrations were 1/10 in the harbour and 5/10 across the harbour entrance; on August 14, concentrations were 2/10 in the harbour and 6/10 across the harbour entrance. Northerly winds cleared the harbour of ice by August 16. Ice concentration on the shoals increased to 6/10 or 7/10, but by August 20, it was reduced to 3/10.

The ice observed in Lancaster Sound on August 15 consisted of brash, small to medium floes, and large pans. The latter appeared to have a thickness of 3 to 5 feet and were in an advanced stage of disintegration. On the line of shoals across the harbour at Resolute, the ice consisted of massive floes, probably the result of shelving during the previous winter, and appeared to have a thickness of 8 or more feet.

Factors Affecting Distribution

There is a strong similarity between the factors affecting ice distribution in Lancaster Sound and those in Baffin Bay.

In the Resolute area from August 15 to 21, winds blew from a northerly or northwesterly direction for 4 days with an average velocity of 11 to 16 m.p.h.; for one day from a northeasterly direction at approximately 17 m.p.h.; and for two days from a west-southwesterly direction at 11 to 16 m.p.h. From August 14 to 16 westerly and northwesterly winds had cleared the ice from the south shore of Cornwallis Island except for beached ice on the shore. Lancaster Sound, east of Griffith Island was free of ice by August 17.

TABLE IV

Daily Temperatures, Lancaster Sound, August 15-21

	Air (F.°)			D.H.	Surface Water (F.°)			D.H.
Day	Min.	Max.	Av.	Accum.	Min.	Max.	Av.	Accum.
Aug. 15	36	43	39.5	15	34	36	34.8	12
Aug. 16	32	46	40.3	16	33	34	33.6	9
Aug. 17	33	52	41.1	21	33	34	33.6	9
Aug. 18	32	38	34.8	8	34	34	34	10
Aug. 19	30	37	33.5	3	32	34	32.3	8
Aug. 20	33	40	35.5	9	32	34	32.6	8
Aug. 21	33	38	35	7	33	36	34.6	11
Daily Av.	32.7	42	37.1	11	33	34.5	33.6	9.5

Air temperatures contributed to the disintegration of the ice, with temperatures standing well above freezing, Table IV. Average minimum temperature stood at 32.7° F., average maximum at 42° F. and the daily average at 37.1° F. Of the 42 temperature readings taken during this period three recorded a low of 32° F. and one of 30° F. Air temperature effectiveness, measured by daily heat temperatures gave a daily positive temperature exceeding 32° F. the average being 11° F. The

daily temperature range is given in Table V. The lowest air temperatures occurred from 2400 to 0800 hours. Of the eight minimum temperatures recorded five occurred at 0400, two at 2400 and one at 0800 hours. The period of highest temperature and of greatest insolation was from 1200 to 1600 hours. On the average, thawing temperatures continued throughout the 24-hour day.

TABLE V

Cumulative Air Temperatures (F.°), Lancaster Sound, August 15-21

Hours	0400	0800	1200	1600	2000	2400
Cum. temps.	237	250	280	277	269	246
Av. temps.	33.8	35.7	40	39.5	38.4	35.1

Surface water temperatures did not follow air temperatures so closely as in Baffin Bay. The water at the eastern entrance to Lancaster Sound afforded higher temperatures than those in the vicinity of Resolute, (Table I). Water temperatures were approximately similar to the Baffin Bay temperatures. Maximum temperatures were lower and the minimum temperatures similar. The daily accumulative effective temperatures of the water were positive, averaging 9.5° F. Surface water temperature range is given in Table VI.

TABLE VI

Cumulative Surface Water Temperatures (F.°),
Lancaster Sound, August 15-21

Hours	0400	0800	1200	1600	2000	2400
Cum. temps.	237	238	235	235	235	235
Av. temps.	33.8	34	33.5	33.5	33.5	33.5

The temperature range is relatively slight, however, with the advance of the ice-free season the range between high and low temperature would normally become more pronounced. Air and surface water temperatures approached coincidence at

0400 hours. The rapid disintegration of ice in Lancaster Sound following August 9 was due to relatively high water and air temperatures and to strong winds.

ICE CONDITIONS: RESOLUTE BAY-NORWEGIAN BAY
(Figure 3: August 17.)

In Wellington Channel previous air reconnaissance had indicated an ice coverage of 10/10 on August 9, 8/10 on August 11, and 6/10 on August 14. Norwegian Bay was 10/10 covered throughout previous flights and no evidence of disintegration was apparent. The northern part of Jones Sound was reported 4/10 covered on August 14.

Variation from Previous Aerial Reconnaissance

Major change in the distribution of the ice from previous flights consisted chiefly in its disappearance from the eastern half of Wellington Channel. In Jones Sound ice occurred at the entrance to Cardigan Strait and Hell Gate, and off Colin Archer Peninsula.

Ice Distribution

Ice coverage of 9/10 (009) paralleled the western side of Wellington Channel. The surface was from 7/10 to 9/10 puddled. Ice was rotten and disintegration seemed well advanced. At the entrance to Cardigan Strait and Hell Gate ice coverage was 3/10 consisting of brash and small to medium floes. Hell Gate was 8/10 (224) covered and approximately 6/10 puddled. The northern entrance was packed with ice of 9/10 concentration. Heavy undercast concealed the entrance and the greater part of Norwegian Bay. Visible ice concentration in the bay was 10/10 (0010) surface puddling varied from 4/10 to 6/10 and occasional holes were apparent. North of $77\frac{1}{2}^{o}$ a series of remarkably straight cracks 3 to 5 miles long cut across the ice in an east to west trending direction, indicative that the break-up of the winter ice field was imminent. Heavy undercast prevented further observation of the ice towards the entrance to Eureka Sound.

Open Water

Open water extended westward of Resolute to the limit of visibility in Barrow Strait, and the eastern half of Wellington Channel was open. Open water extended westward into Penny Strait to the limit of visibility, and Jones Sound was open eastward to the horizon. Two areas of open water lay along the east side of Hell Gate channel. No areas of open water were visible in Norwegian Bay.

ICE DISTRIBUTION: JONES SOUND-SLIDRE FIORD
(Figures 4, 5: August 22-24.)

Variation from Previous Reconnaissance

From observations on August 17, the major change consisted of an extension of the ice into Jones Sound from Hell Gate and Cardigan Strait. In Norwegian Bay numerous irregular-trending leads appeared in the ice north of 77° 10'. These, together with recent pressure ridges occurring north of 77° 45', indicated that the break-up of winter ice was under way.

On August 16, Eureka Sound was reported 4/10 covered with the ice concentrated chiefly in the southern part of the sound. The northern part was open. On August 19, arctic ice was reported moving southward across the northern entrance of the sound.

Ice Distribution

Ice concentration of 7/10 (241) covered the entrance to Hell Gate and Cardigan Strait. Both the south and north entrances to the 'Gate' were filled with pack ice of 7/10 to 9/10 concentration. In the central part ice concentration was 4/10. Throughout Norwegian Bay ice concentration varied from 10/10 (0010) in the southern and central parts to 8/10 or 9/10 (109) in the northern part of the bay. Except for the 'working ice' at the entrance to the bay, unbroken winter ice continued to 77° 10' N. North of this latitude frequent narrow irregular leads criss-

crossed the ice surface from 77° 45' to Eureka Sound. The leads were wider and new pressure ridges occupied 2/10 of the surface ice. Smooth, hummocked polar ice that appeared to have a thickness in excess of 6 feet was scattered throughout the Hell Gate-Norwegian Bay area. The most formidable areas of this ice occurred at the southern entrance to Norwegian Bay, in the central part of the bay, and off Goose Point near the southern entrance to Eureka Sound. This ice probably amounted to less than 1/10 of the total ice area and possibly entered the bay either from Eureka Sound or from the west through the channels leading into Norwegian Bay. The bay ice consisted of winter ice of which 5/10 was hard and 4 to 5 feet in thickness; approximately 3/10 was rotten and 3 to 4 feet in thickness. Surface puddling was well advanced and amounted to 6/10 to 8/10 in rotten winter ice, 4/10 to 6/10 in hard winter ice and about 1/10 to 2/10 in polar hummocked ice. Because of a recent snowfall combined with freezing temperatures a layer of opaque young ice of 1 to 2 inches in thickness covered the puddles. Undisturbed winter ice of 10/10 coverage occupied the entrance of Eureka Sound. From 78½° to 79° N. in Eureka Sound ice concentrations varied from 4/10 to 10/10, with medium to large floes and pans predominating. The most formidable mass of ice consisted of a single large field of hummocked polar ice off Depot Point with an estimated thickness of 10 or more feet.

Open Water

Open water occurred along the east side of Hell Gate, off the northern entrance to this channel, and off the southern entrance to Eureka Sound. In Eureka Sound open water continued from 78° 40' to Slidre Fiord, the west side of the channel being freer from ice.

ICE CONDITIONS: JONES SOUND-SLIDRE FIORD
(Figures 6, 7: August 28, 29.)

Variations from Previous Reconnaissance

The changes in the distribution of ice consisted of an extension of open water areas in Eureka Sound southward to Ulvingen Island, and at the southern entrance to the sound. In Norwegian Bay, irregular leads, wider than on the previous reconnaissance, criss-crossed the entire bay, and recent pressure ridges occurred throughout the area. Considerable open water lay off the northern entrance to Hell Gate. In the 'Gate' 2/10 to 5/10 ice covered the northern entrance, becoming 8/10 in the central and southern parts. Open water extended from Jones Sound into the entrance of Cardigan Strait.

Ice Distribution

Ice concentration of 3/10 to 4/10 covered Eureka Sound southward to Ulvingen Island. Much of this ice consisted of medium to large winter floes and a smaller part of hummocked polar floes. The latter occupied about 4/10 of the ice floes in the northern part of the fiord and less than 1/10 in the southern part. In Norwegian Bay ice varied from 8/10 to 10/10 coverage with large floes or pans predominating. Surface leads amounted to about 2/10 of the surface, and recent pressure ridges an additional 2/10. Polar hummocked floes were scattered in various parts of the bay particularly off Goose Point and at the eastern entrance to Hell Gate. The thickness of the young ice in the puddles had now reached 3 to 4 inches. Ice in Hell Gate channel varied from 2/10 to 5/10 at the northern entrance, and 7/10 to 10/10 in the central and southern part. Hummocked polar ice of 1/10 to 2/10 coverage was scattered in small to medium sized floes among the winter ice in the channel.

Open Water

Areas of open water are noted above. The break-up of winter ice in Norwegian Bay which had begun about August 17 continued after August 28. Eureka

Sound break-up began at an earlier date and was virtually completed by August 28.

ICE CONDITIONS: SLIDRE FIORD
(Figure 8: August 26, 27.)

Ice coverage in Slidre Fiord on August 10, was reported to be 4/10. On August 24 coverage in the fiord was still 4/10; however, two large belts of 10/10 concentration each lay within the fiord entrance. An area of open water extending across it from the station separated the two ice belts. On August 25, large ice pans entered the fiord completely suspending unloading operations. Ice breaking activities were resumed in the fiord to break up the pans and dislodge the ice mass from the beach facing the station.

Three helicopter flights were flown on August 26 and 27 of 50 minutes duration each to determine the nature, movement and distribution of the fiord ice, the main features of which are shown in Figure 8.

Ice Distribution

The upper part of the bay was covered by winter ice of which 8/10 was rotten, 1 to 2 feet thick, 7/10 to 9/10 puddled and occurring chiefly in large pans. Hard winter ice of 3 to 4 feet in thickness, about 5/10 to 6/10 puddled, lay in the vicinity of Eureka. This ice, together with scattered hummocked floes and pans, appeared to have drifted southward into the fiord from the sound. Currents appeared to be the principal factor in moving ice into and out of the fiord. The current set outward about 1300 hours and inward about 0100 hours with a rate of one-half to one knot per hour. The relationship between winds and currents in this movement was difficult to determine. For example, on August 25 a mass of ice entered the fiord against the prevailing 10 m.p.h. southeast wind. The affect of winds in transporting ice from one side of the fiord to the other is much more apparent. On August 26 a gentle 1 to 3 m.p.h. wind from the southeast held the ice against the

north shore piling up a 7/10 (250) concentration opposite the station. On August 27, a 7 to 10 m.p.h. wind from the northwest drove the ice off the north shore. As the prevailing winds are from a northerly quadrant the north shore is usually more free of ice obstructions than the south shore during the open period.

Factors Affecting Distribution

Lancaster and Jones sounds are extensions of Baffin Bay, and have relatively similar physical conditions. The physical conditions in the Norwegian Bay-Eureka Sound area are quite different. In the Hell Gate-Cardigan Strait area two different kinds of water, Arctic and Atlantic, meet. The Norwegian Bay-Eureka Sound areas are Arctic waters.

During the period, August 26 to 28, winds generally blew from a southern or northerly quadrant and averaged about 6 miles an hour. In Eureka Sound, the wind direction paralleled the orientation of the sound. In Norwegian Bay the effect of wind break-up is difficult to determine, except in conjunction with other factors.

Air temperatures were generally below freezing (Table VII) and account in part for the slow disintegration of the ice in Norwegian Bay. Average minimum

TABLE VII

Daily Temperatures, Jones Sound-Slidre Fiord, August 22-29

Day	Air (F.°) Min.	Max.	Av.	D.H. Accum.	Surface Water (F.°) Min.	Max.	Av.	D.H. Accum.
Aug. 22	25	38	32	-1	29	35	32	6
Aug. 23	24	32	28.6	-8	29	30	29.8	1
Aug. 24	28	34	31.8	-2	30	32	31	4
Aug. 25	29	40	34.1	5	32	32	32	6
Aug. 26	27	35	31.1	-2	32	32	32	6
Aug. 27	30	34	32	0	32	32	32	6
Aug. 28	16	30	25.8	-18	30	32	30.6	4
Aug. 29	20	34	28.5	-10	30	34	32.3	6
Daily Av.	26.1	34.7	30.5	-4.5	30.5	32.4	31.5	5

temperature was 26.1° F., average maximum 34.7° F. and the daily average 30.5° F. The narrow range in temperature indicates that freezing conditions are prevalent. Air temperature effectiveness shows an average negative temperature of 4.5° F. With the exception of August 25, air temperatures below 32° F. were predominant. It is considered that strong currents in Hell Gate and Eureka Sound rather than air temperatures contribute to the break-up of ice. Norwegian Bay does not appear to have strong currents as the winter ice remains undisturbed for a longer period of time. Of the 48 temperature readings taken during this period 35 registered temperatures of 32° F. or lower. The daily temperature range is given in Table VIII. The lowest temperatures occur from 1600 to 0800 hours. Of the

TABLE VIII

Cumulative Air Temperatures (F.°), Jones Sound-Slidre Fiord, August 22-29

Hours	0400	0800	1200	1600	2000	2400
Cum. temps.	227	248	265	260	239	226
Av. temps.	28.4	31	33.1	32.5	29.9	28.2

eight lowest temperatures three were recorded at 2400 and five at 0400 hours. The period of highest temperature takes place during and following the noon position of the sun. By interpolation the duration of the average thawing period begins about 1030 and continues to 1500 hours.

Although the surface water temperatures are low (Table IX) the daily effective heat accumulation is positive with an average temperature of 5° F. Undoubtedly,

TABLE IX

Cumulative Surface Water Temperatures (F.°), Jones Sound-Slidre Fiord, August 22-29

Hours	0400	0800	1200	1600	2000	2400
Cum. temps.	252	254	253	251	250	251
Av. temps.	31.5	31.7	31.6	31.4	31.3	31.4

this positive temperature explains the honeycomb structure that indicates the disintegration of winter ice as observed in Norwegian Bay. The water temperatures would also explain the formation of young ice in the surface puddles whose waters are relatively fresh with freezing temperatures close to 32° F. Temperatures in Jones Sound were approximately 2 to 3° F. warmer than those in the bay and sound.

It appears probable that unless wind and sea swell break up the winter ice, air and surface water temperatures can only be weak agents in the disintegration of the ice.

ICEBERGS

Throughout the entire voyage from the Strait of Belle Isle to Slidre Fiord icebergs were encountered and in general, numbered about twenty to thirty per day. The greatest concentration existed in Baffin Bay between 72° and 74° N. At 72° 20' N., sixty-five bergs were counted on the horizon; at 73° N. a count of one hundred and twenty-five bergs was made. At approximately 73° 03' N. and 60½° W. a giant iceberg with precipitous sides and a rolling upper surface, measured 2,210 feet long, 425 feet high, and had an estimated depth between 325 and 350 fathoms. This berg was visible for 7 hours. West and north of this concentration only an occasional berg was visible. A second concentration of bergs occurred off the east coast of Devon Island. Bergy bits, brash, growlers and small floes occupied considerably less than 1/10 of the water surface. Between Cape Sherard and Cape Cockburn a count of thirty-five bergs was made, and a similar count was made between Cape Horsburgh and Cape Parker. A third major concentration of icebergs lay between Coburg Island and Lee Point particularly against the south coast of Ellesmere Island. At 76° 08' N. and 82° W. a count of approximately fifty bergs was made. In this area there was a scattering of brash, bergy bits and growlers, the whole occupying considerably less than 1/10 coverage. The concentration appeared heavier north of Craig Harbour.

CONCLUSION

Navigation through sea ice presents special problems. In general, icebreaker escort appears necessary for ocean-going freighters when ice coverage reaches 4/10. However, ice coverage is rarely uniform over an extended area and strings of 5/10 to 9/10 concentration often occur. During the 1956 supply mission the cargo ship Federal Voyageur and the tanker GreenRanger hove-to at 65° N. 59° W. awaiting icebreaker escort in 5/10 ice coverage consisting of small to medium floes. Frequently as the ships moved through the ice the distance between the convoy following in the wake of the escort became too great permitting ice to flow back into the cleared channel. This condition reduced the speed of the convoy and resulted in frequent alterations in course. In field ice, an icebreaker may follow leads or utilize to advantage the zones of weakness formed by recent pressure ridges.

The accepted practice in taking a convoy northward through Baffin Bay from the Strait of Belle Isle is to follow the 55th west meridian northward to the vicinity of Disco Island, thence changing course toward Cape York. This course in midsummer is generally free from the ice that lies against the east coast of Baffin Island. The northern edge of this ice is passed by steering westward toward Lancaster Sound between 73° N. and 74° N. The ice breaker route from Resolute to Eureka follows the circuitous course by way of Lancaster and Jones sounds. This route is from 2 to 3 days longer than the more direct northerly route through Wellington Channel, Penny Strait and Belcher Channel. This latter route is considered sufficiently deep but it lacks a through track of soundings. Opening dates for navigation in the Norwegian Bay area are based on an ice coverage of 9/10 or less. Wellington Channel opens at approximately the same time as Jones Sound, i.e. from mid-July to mid-August. Penny Strait opens a week later than Wellington Channel. Eureka Sound generally opens during the first two weeks in August. Norwegian Bay opens between August 1 and September 1. Belcher Channel may open earlier or later than Norwegian

Bay, and depends chiefly upon the duration of the westerly wind holding the pack-ice against the channel's western entrance. For both routes, either through Wellington Channel or Jones Sound, the entire area was open sufficiently for icebreaker navigation on the following dates:

1949	-	August 20 to August 28
1950	-	No information available
1951	-	July 4 to August 4
1952	-	July 22 to July 28
1953	-	August 16 to August 20
1954	-	September 1 to September 7
1955	-	August 1 to September 6
1956	-	August 17 to August 22

Optimum conditions for navigating Norwegian Bay are reported to occur during the first two weeks of September when ice conditions in the area are considered to be the least hazardous. Prior to a ship sailing into Norwegian Bay an ice reconnaissance flight following a course from Resolute northward to Penny Strait, northeastward to Eureka Sound, and returning southward to Hell Gate and Resolute would readily establish the least difficult route to follow.

ILLUSTRATIONS

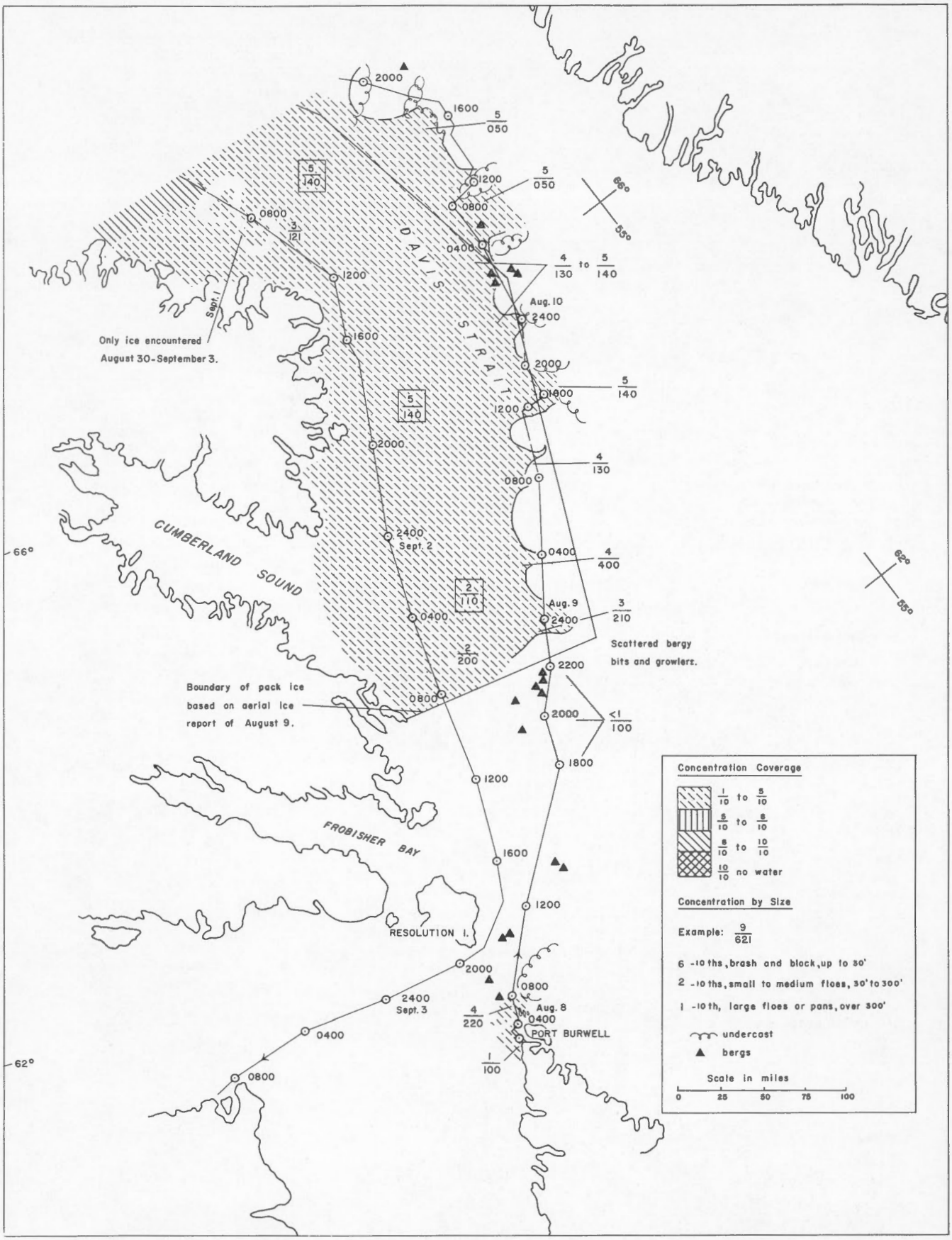

Figure 1. Ice distribution, Davis Strait, August 8-14, and August 30-September 3.

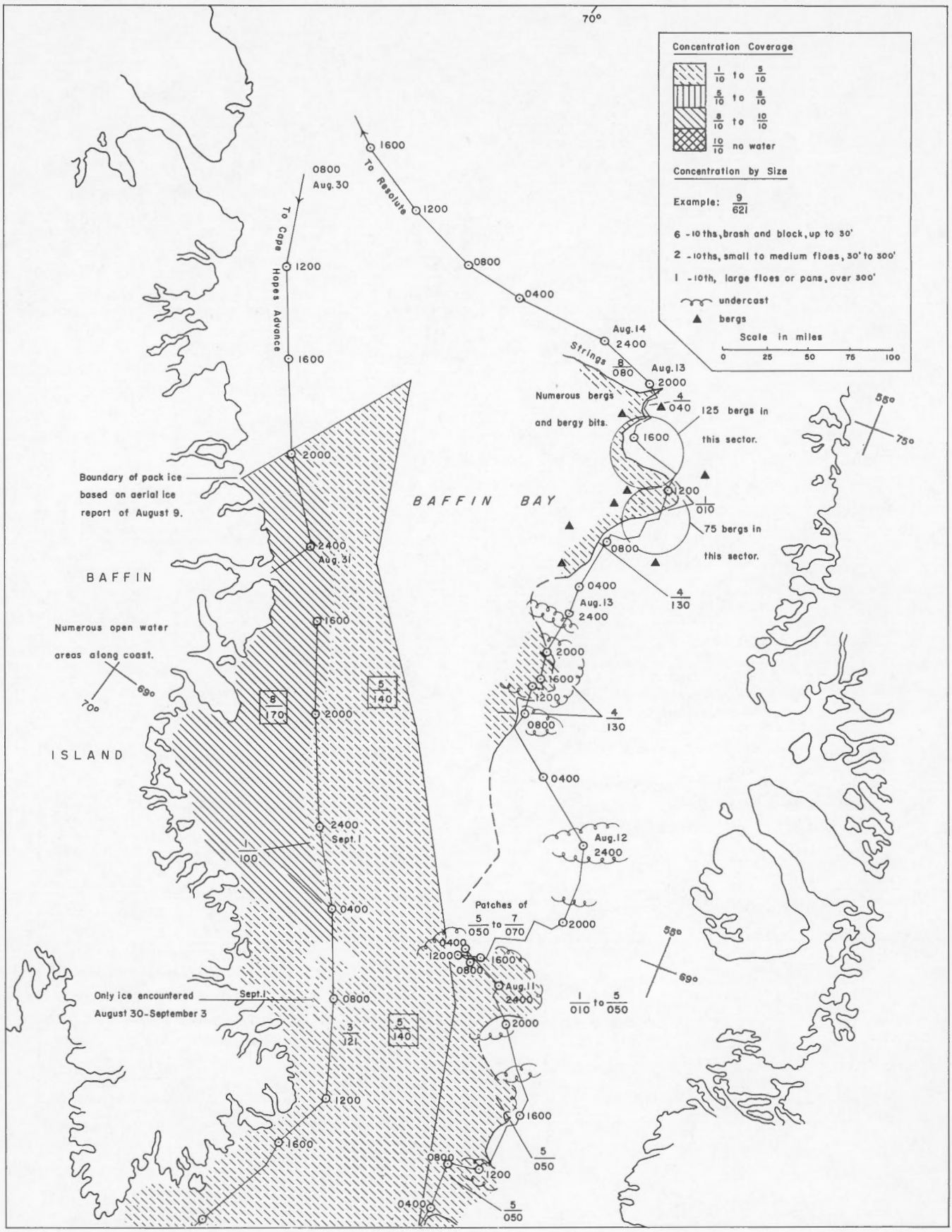

Figure 2. Ice distribution, Baffin Bay, August 8-14, and August 30-September 3.

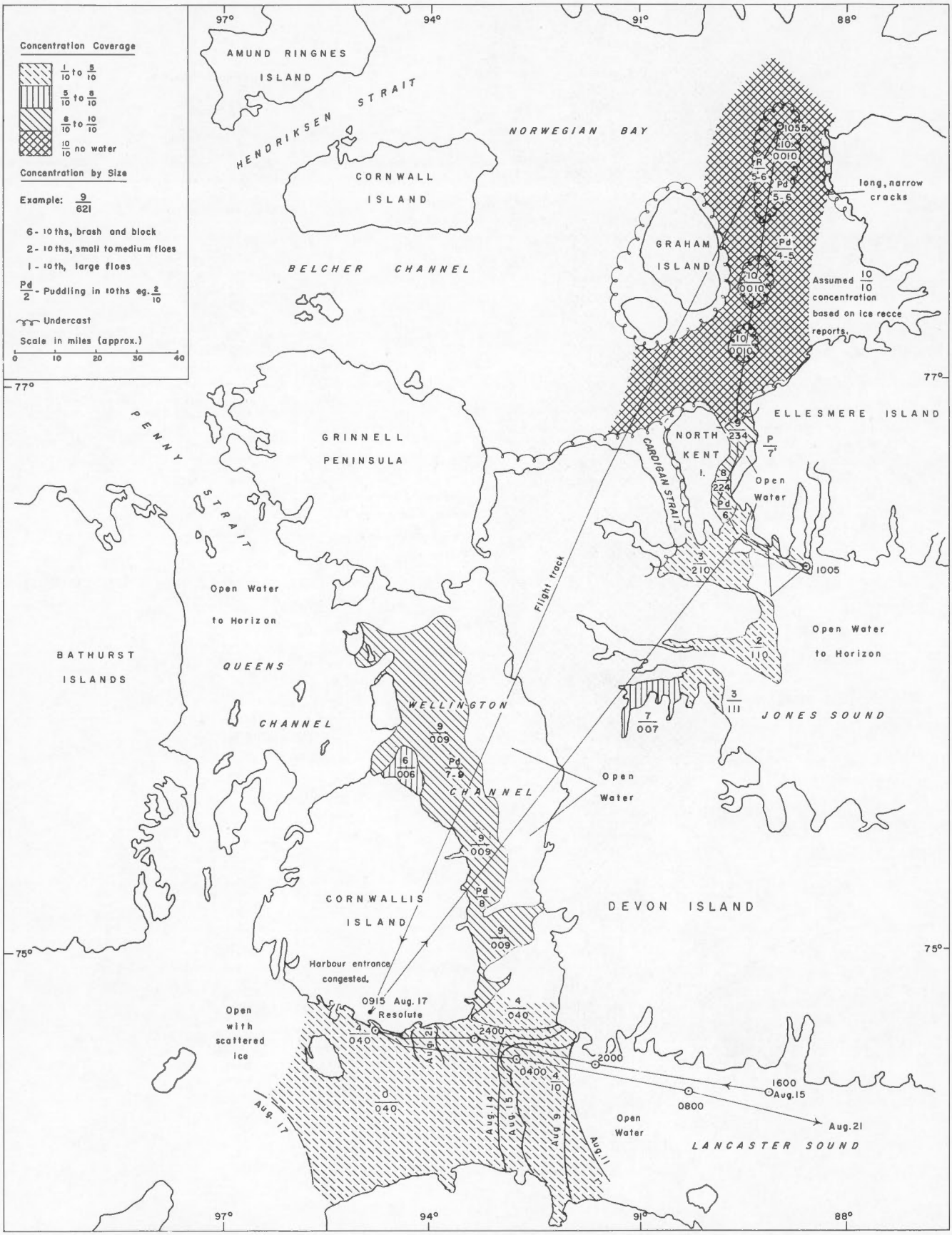

Figure 3. Ice distribution, Lancaster Sound, Wellington Channel, and Norwegian Bay, August 15-21.

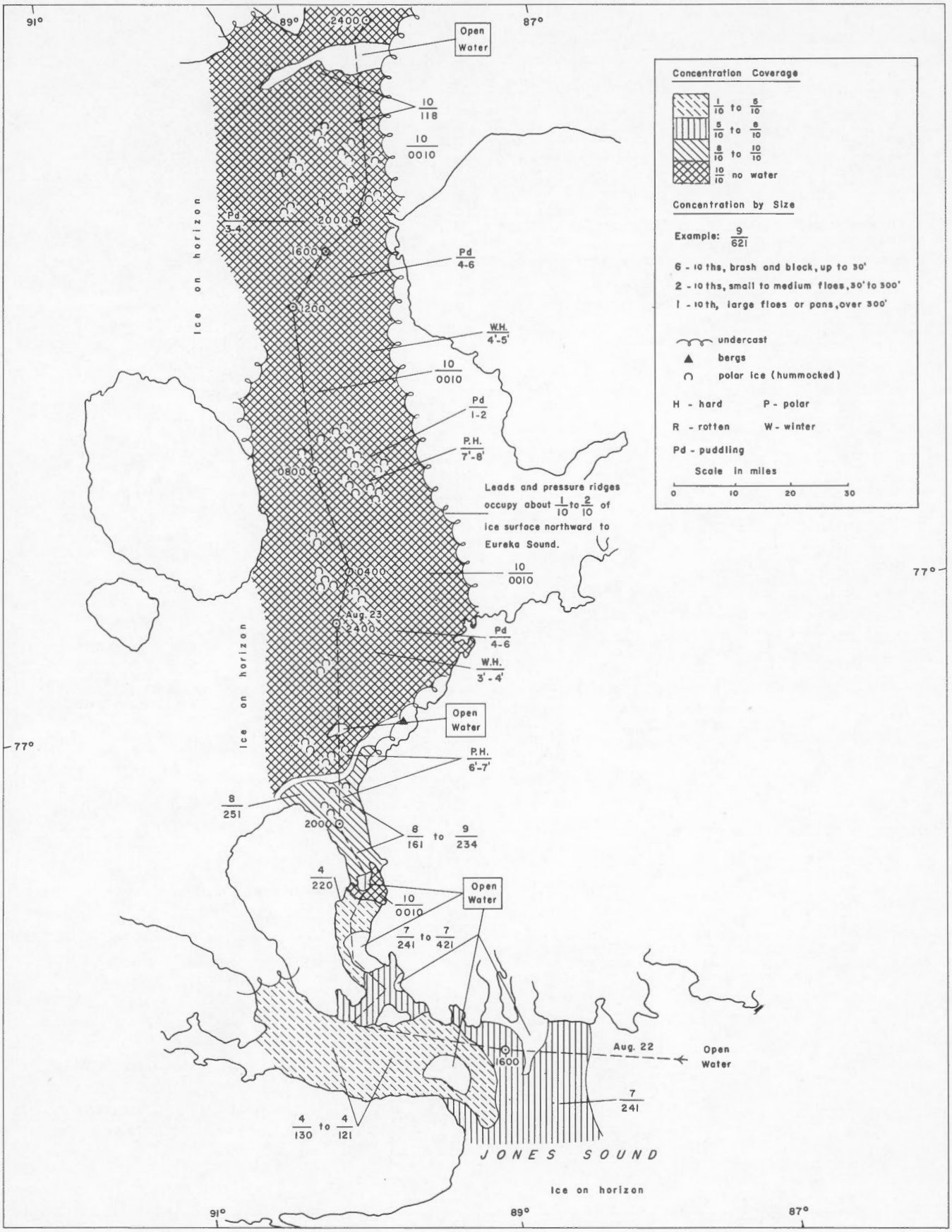

Figure 4. Ice distribution, Jones Sound, Hell Gate, and Norwegian Bay, August 22-24.

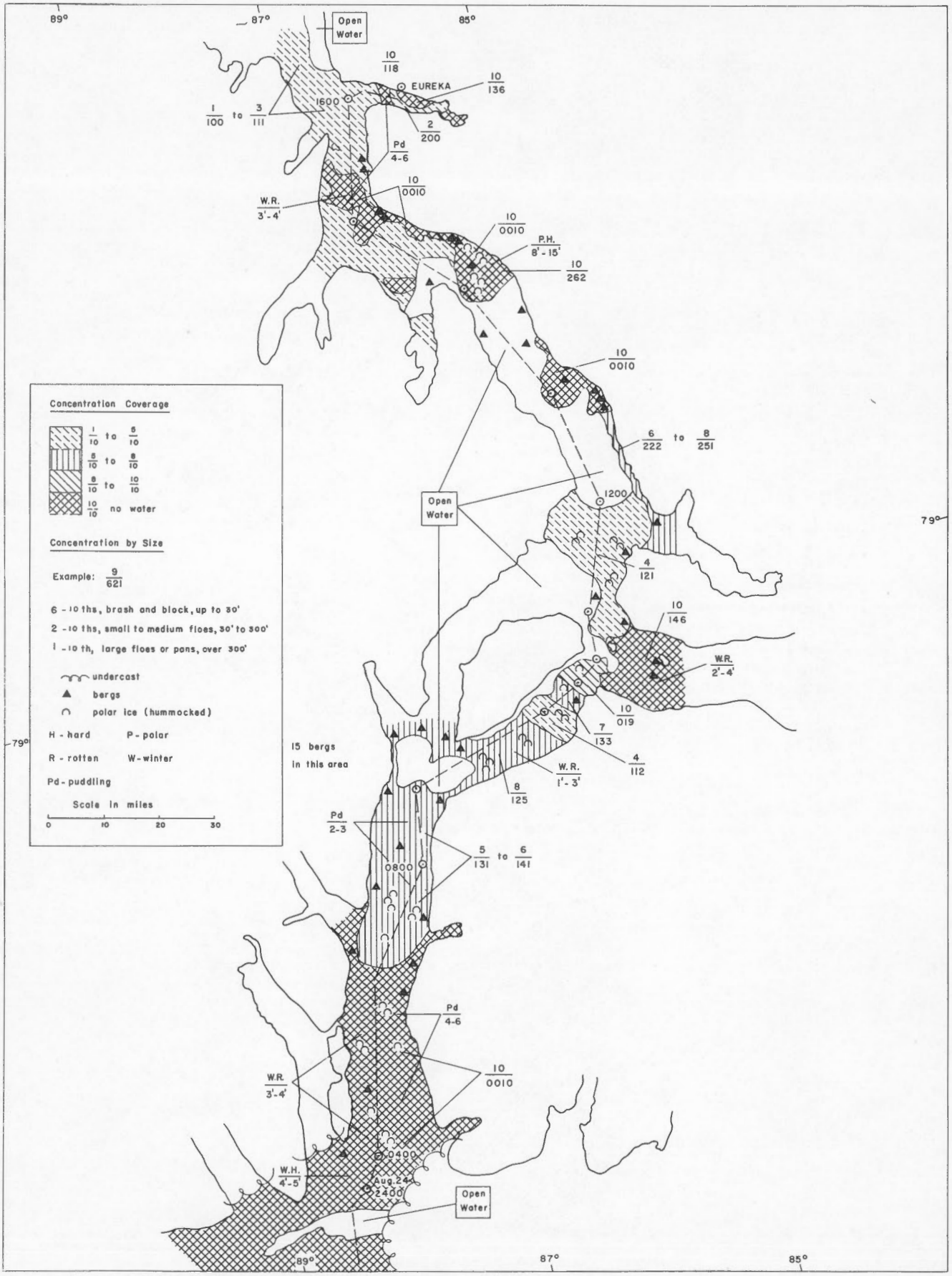

Figure 5. Ice distribution, Eureka Sound, August 22-24.

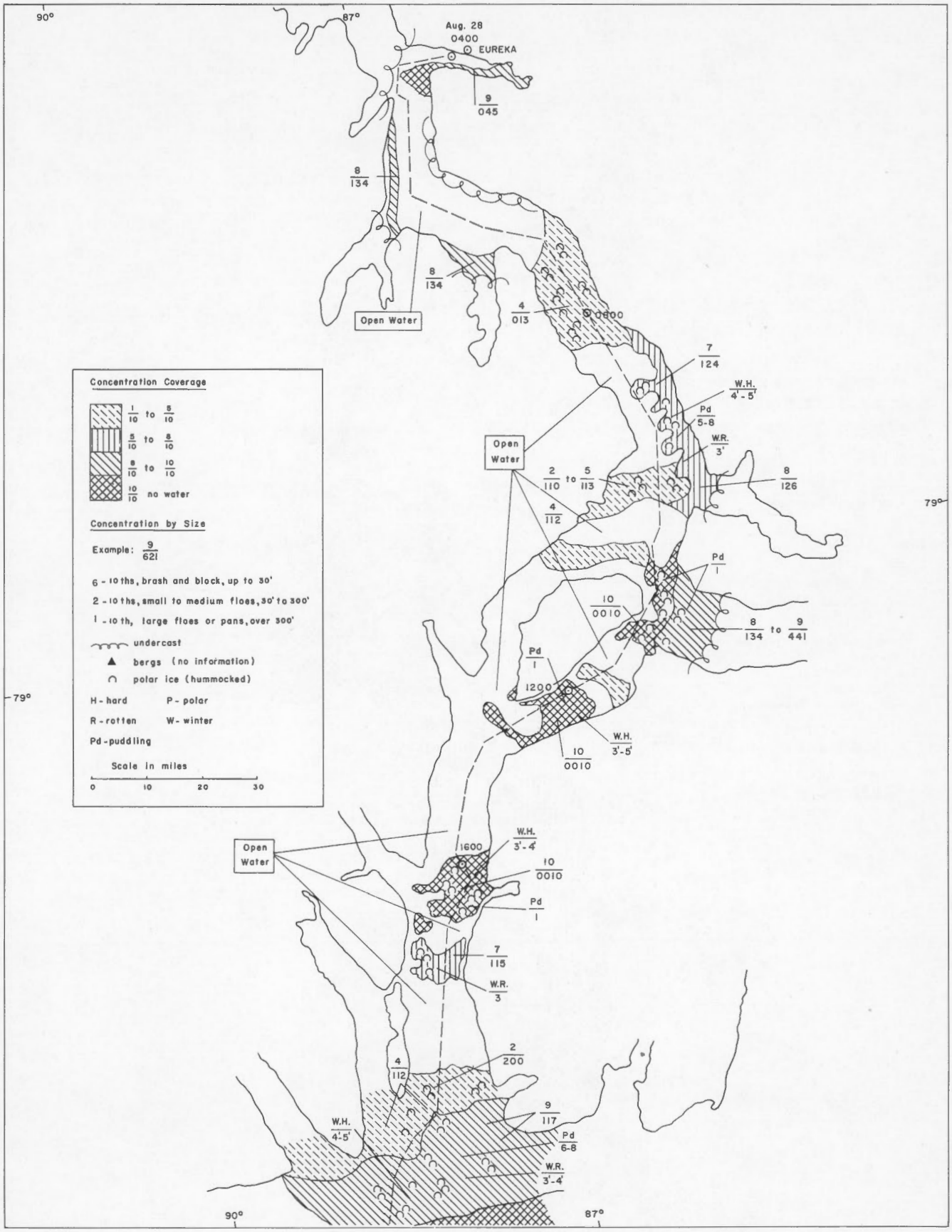

Figure 6. Ice distribution, Eureka Sound, August 28.

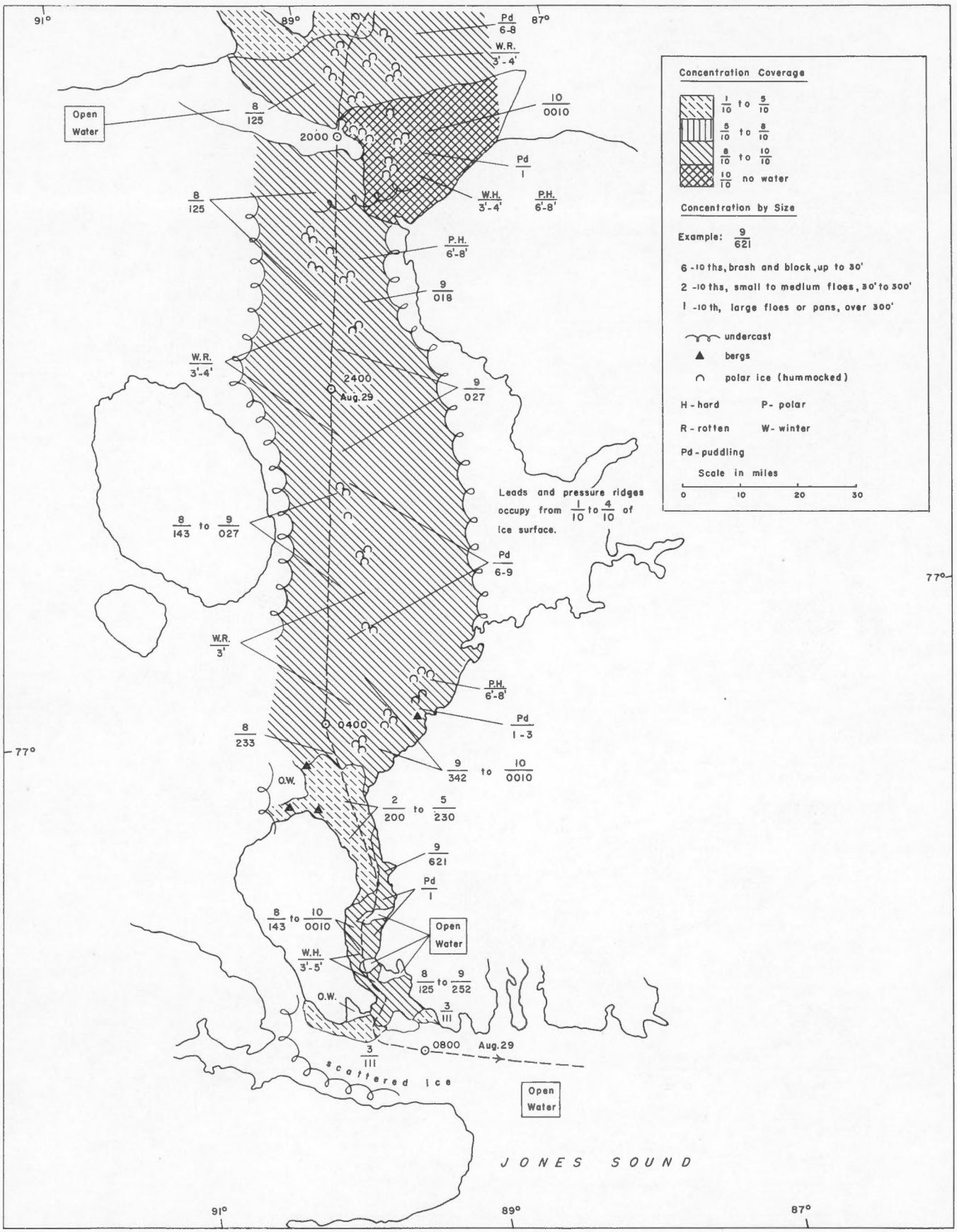

Figure 7 Ice distribution, Norwegian Bay, Hell Gate, and Jones Sound, August 28-29.

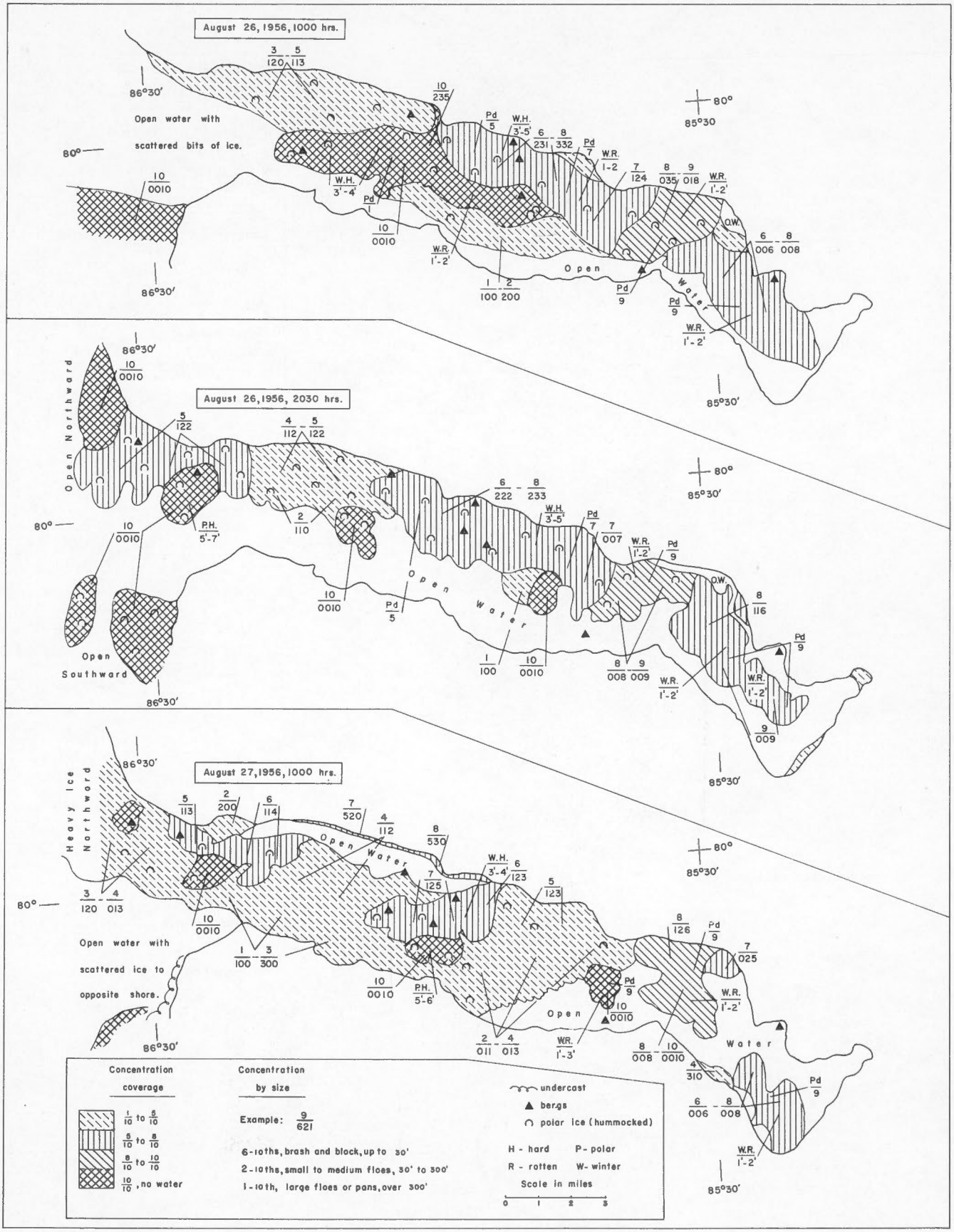

Figure 8. Ice distribution in Slidre Fiord, August 26-27.

Figure 9

Baffin Bay. Ice concentration 4/10 consists chiefly of small to medium floes; ram in foreground.

Figure 10

Southwest entrance to Hell Gate. Ice concentration consists of 3/10 brash and block, and 5/10 small to medium floes.

Figure 11

Norwegian Bay, 71°08′ N., 59°25′ W. Undisturbed winter ice consists of 10/10 concentration and thickness 3 to 5 feet. Surface puddling is 5/10; young ice covers the puddles.

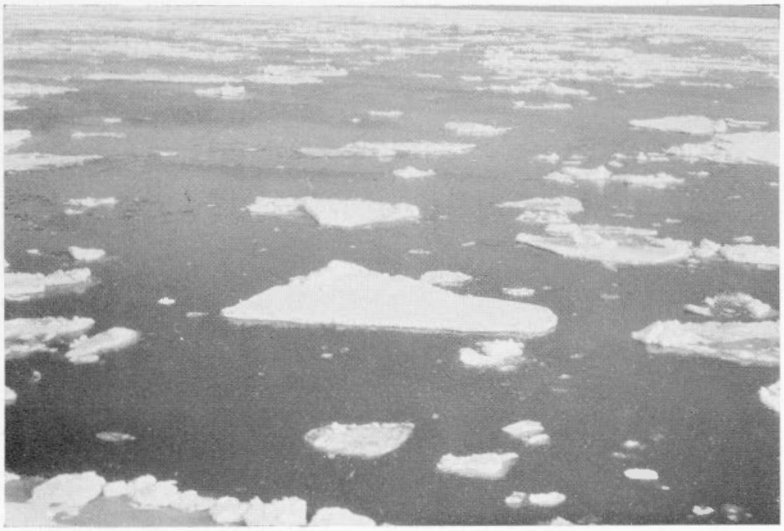

Figure 12

Southern entrance to Eureka Sound. The ice has a concentration of 2/10 brash and block, and 3/10 medium floes.

Figure 13

Eureka Sound with Cape Depot to the left. A massive floe of hummocked polar ice with a thickness of 8 to 15 feet is separated by a lead from Cape Depot.

Figure 14

Slidre Fiord. Hard winter pan ice of 4 to 5 feet in thickness, puddling 2/10 occupies the entrance of the fiord. Floe ice in background has 4/10 concentration.

GEOGRAPHICAL PAPERS

Miscellaneous Papers Series

No. 1. A List of the Place Names of the Island of Newfoundland with their Geographical Positions. Ottawa, 1950. 59 pp., mimeo.

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No. 8. Notes on Potential Building Sites in the Bathurst Inlet Area, N.W.T. By J.B. Bird and M.B. Bird. Ottawa, 1956. 15 pp., map, offset. *Price. 50 cents*

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