Canada

GEOGRAPHICAL PAPER No. 25

Gulf of St. Lawrence Ice Survey, Winter 1960

W. A. Black

GEOGRAPHICAL BRANCH
Department of Mines and
Technical Surveys, Ottawa

Price: $1.50

CANADA

GEOGRAPHICAL PAPER No. 25

Gulf of St. Lawrence Ice Survey, Winter 1960

W. A. Black

GEOGRAPHICAL BRANCH
Department of Mines and
Technical Surveys, Ottawa

Price: $1.50

90422-7—1

A deep-sea freighter following the icebreaker's track on course to Dalhousie, is passing Point Bonaventure on the north coast of Chaleur Bay. The ice-field consists of young ice. (Altitude 1,500 feet, February 17, 1960)

PREFACE

The Gulf of St. Lawrence ice survey, winter 1960, is a study resulting from the fifth winter aerial ice survey conducted over the Gulf of St. Lawrence region. In addition, a survey of the St. Lawrence River between Montreal and Quebec is included.

It is hoped that this report may bring about a clearer understanding of the nature, extent and distribution of the ice and thus contribute to the solution of problems associated with winter navigation of the St. Lawrence River and the Gulf of St. Lawrence.

N. L. Nicholson
Director
Geographical Branch

TABLE OF CONTENTS

GULF OF ST. LAWRENCE ICE SURVEY, WINTER 1960

INTRODUCTION AND ACKNOWLEDGEMENTS

The aerial survey of sea ice conditions in the Gulf of St. Lawrence from January to May, 1960 is a continuation of the ice distribution surveys commenced by the Branch in the winter of 1956,* and extended in 1959 to include the St. Lawrence River upstream to Montreal. The primary purpose of the survey was to observe and map the coverage and distribution of the various types of ice and to relate ice conditions to climatic factors. The long-term objective is to provide annual information on ice and climatic relationships that are of practical value to shipping interests, and of use in ice forecasts for winter navigation.

The ice survey was conducted by the Geographical Branch with the cooperation of Air Transport Command, RCAF, and was coordinated by the Geophysical Research Section of the Defence Research Board. Specific acknowledgements are made to T. A. Harwood, Geophysical Research Section, DRB, W/C W. H. MacDonell of 408 (R) Squadron RCAF, and P. D. McTaggart-Cowan, Meteorological Branch, Department of Transport. The writer wishes to acknowledge the excellent cooperation received from the RCAF officers and crews responsible for the flights.

The operation in 1960 was planned to begin early in January and to continue until the early part of May; the first flight was made on January 4, and the last on May 4. Lancaster aircraft and crews were provided by RCAF station, Rockcliffe, the base of operations. RCAF Station Summerside on Prince Edward Island was the forward base of operations; Stephenville and Bagotville air bases were also used in the course of the survey. Air Transport Command organized eleven flights at approximately 10-day intervals. These were made from Rockcliffe on the following dates: January, 14 and 25; February 3 and 16; March 1, 16 and 29; April 11 and 21; and May 3. The average duration of each operation was about 2 days with a total flying time of 15 hours. Aircraft were flown from several hundred feet to 7,000 feet altitude, depending on local visibility.

The aerial reconnaissance was conducted so that the St. Lawrence River from Montreal to the Saguenay River was surveyed during the outward and return flights. Cornwall, Ontario formed the western limit of the survey and the Strait of Belle Isle formed the eastern limit. Flight patterns were arranged to

*For an account of previous ice surveys, see Bibliography.

90422-7—2½

permit the greatest possible observation of ice conditions and to avoid unfavorable local weather conditions. Flight tracks along the coastline permitted observation of ice in the harbors and bays.

In conjunction with the ice survey, RCAF photographers made a systematic photographic record of ice conditions.* The photographs included in this report are by courtesy of the Royal Canadian Air Force.

Part I of the report includes weather conditions, gulf ice distribution and ice distribution maps of the gulf. Part II includes weather conditions, river ice distribution, and ice distribution maps of the St. Lawrence River.

Although the symbols and main outline of ice classification used are based on those followed by the U.S. Hydrographic Office in reporting ice, the plan used is that developed by the writer in Geographical Paper No. 19. The graphic and quantitative classification method developed to include new, young and winter ice forms, is followed in this report. The amount of winter ice in the distribution is considered to be the critical element in the ice cover. Whenever winter ice occurs in amounts of 3/10 or more in association with new or young ice forms, a close graphic pattern to represent winter ice is used. An open, graphic pattern to represent young ice is used to show an ice distribution that consists of 3/10 or more young ice in association with new ice forms. An open pattern shows new ice types that include such ice as grease, slush, frazil, very young ice and the early stages of sludge or slob ice. The quantities of each of the various types of ice are expressed in tenths; a similar procedure is followed with such topographical ice forms as shelving and pressure ridging.

For this survey new river and gulf map bases have been prepared, and ice data on the gulf is shown by colored overlay, and with a more selective use of the fractional information.

PART I

THE GULF OF ST. LAWRENCE

WEATHER CONDITIONS

The winter of 1959-60 was relatively mild for the Gulf of St. Lawrence region, and as a result the extent of the ice cover was considerably reduced from that observed in the previous year.

Mean monthly temperature for November varied from -2 to 2 degrees from the normal. For the winter months December recorded 2, January 5, February 12 and March 1 degrees above the

The photos were taken with an F 224 camera (6-inch focal length) normal seasonal temperatures (Table I). The outstanding characteristic of the mean values is the relative similarity of mean temperatures for December, February and March with a range of 2 degrees. January was the coldest month with 20 degrees.

Regional variations in mean temperatures are evident from Table I. The northern half of the gulf region experienced much lower temperatures in December and January than the southern half. The range in temperature of various parts of the gulf for February and March were 8 and 6 degrees respectively. The St. Lawrence River and the North Shore areas were the coldest, and therefore, most conducive to ice formation, whereas, the central and eastern areas experienced the highest temperatures and generally were unfavorable for ice formation. Only the Strait of Belle Isle favored ice forming conditions in April; otherwise, April was a month of rapid deterioration of the ice fields with an average mean temperature of 33 degrees.

TABLE I*

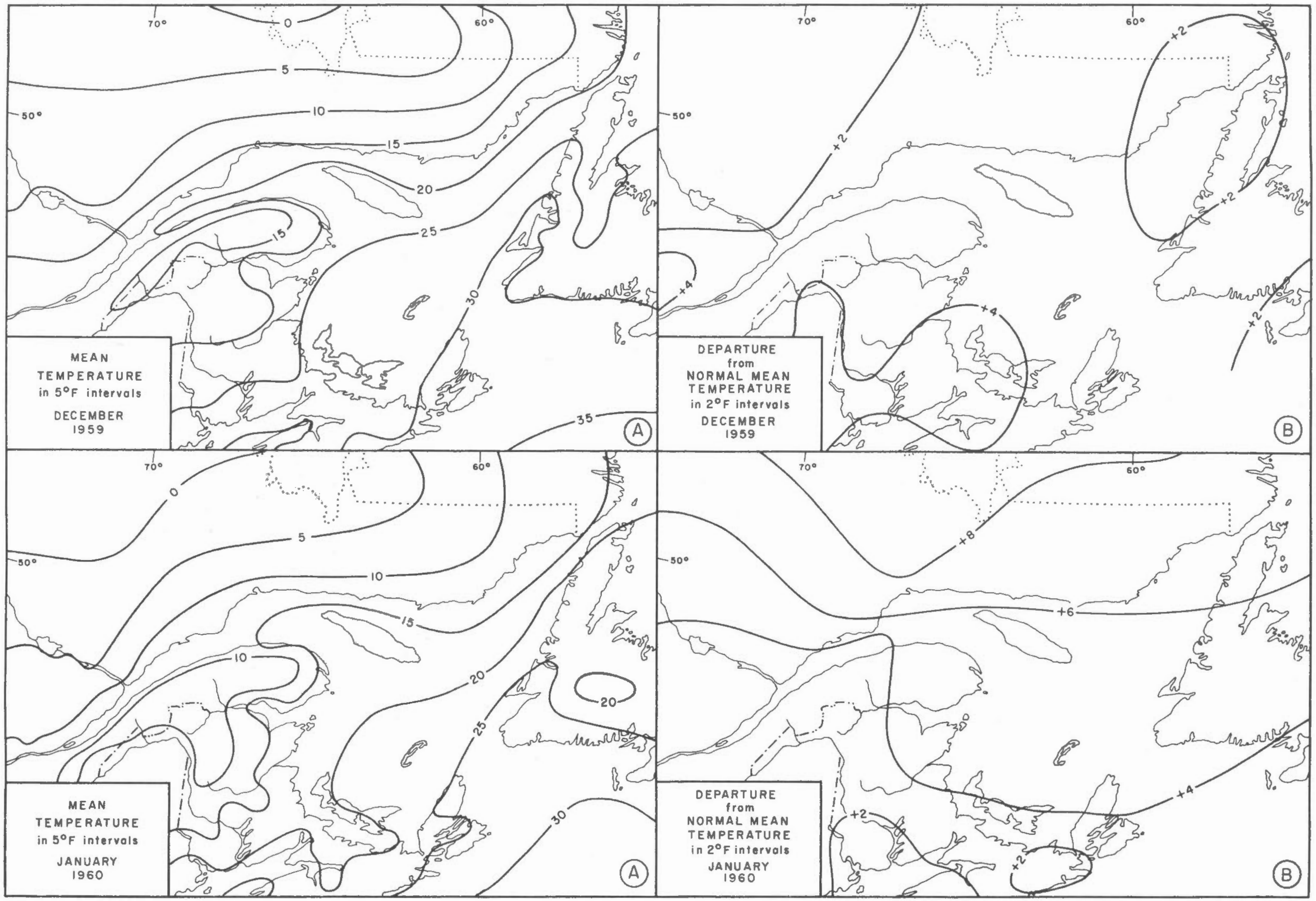
Average mean and normal monthly temperatures (F°) for the gulf region from December 1959 to April 1960.

Area	DECEMBER Mean : Normal	JANUARY Mean : Normal	FEBRUARY Mean : Normal	MARCH Mean : Normal	APRIL Mean : Normal
St. Lawrence R.	19 : 17	13 : 10	22 : 12	22 : 23	34 : 35
North Shore	17 : 14	15 : 7	25 : 9	20 : 19	30 : 30
St. of Belle Isle	21 : 19	18 : 11	26 : 10	20 : 19	27 : 27
Gaspé-Chaleur	21 : 19	15 : 12	24 : 13	23 : 23	34 : 34
Eastern gulf	29 : 27	25 : 20	30 : 18	26 : 25	34 : 34
Central gulf	29 : 26	23 : 19	27 : 16	27 : 24	33 : 32
Southern gulf	27 : 26	20 : 17	27 : 16	26 : 26	37 : 37
Cabot Strait	31 : 29	27 : 23	30 : 20	28 : 27	36 : 36
Av. gulf temp.	24 : 22	20 : 15	26 : 14	24 : 23	33 : 33

*The normal temperature values in this table should be used when comparing the mean temperatures recorded in Table I, Geographical Papers, Nos. 19 and 23 (See Table V).

January mean temperatures (20°) tended to coincide with normal December temperatures (22°) while those for February (26°) and March (24°) were well above the normal December values and emphasize the abnormally mild winter conditions that existed. Generally, temperatures in the northern half of the gulf were more conducive to ice formation than elsewhere, with maximum ice forming conditions being experienced in January and to a lesser extent in December. The main effect of these well-above normal

*All degrees are in Fahrenheit.


MEAN
TEMPERATURE
in 5°F intervals
DECEMBER
1959
(A)
DEPARTURE
from
NORMAL MEAN
TEMPERATURE
in 2°F intervals
DECEMBER
1959
(B)
MEAN
TEMPERATURE
in 5°F intervals
JANUARY
1960
(A)
DEPARTURE
from
NORMAL MEAN
TEMPERATURE
in 2°F intervals
JANUARY
1960
(B)
70°
60°
50°
0
5
10
15
20
25
30
35
+2
+4
+6
+8

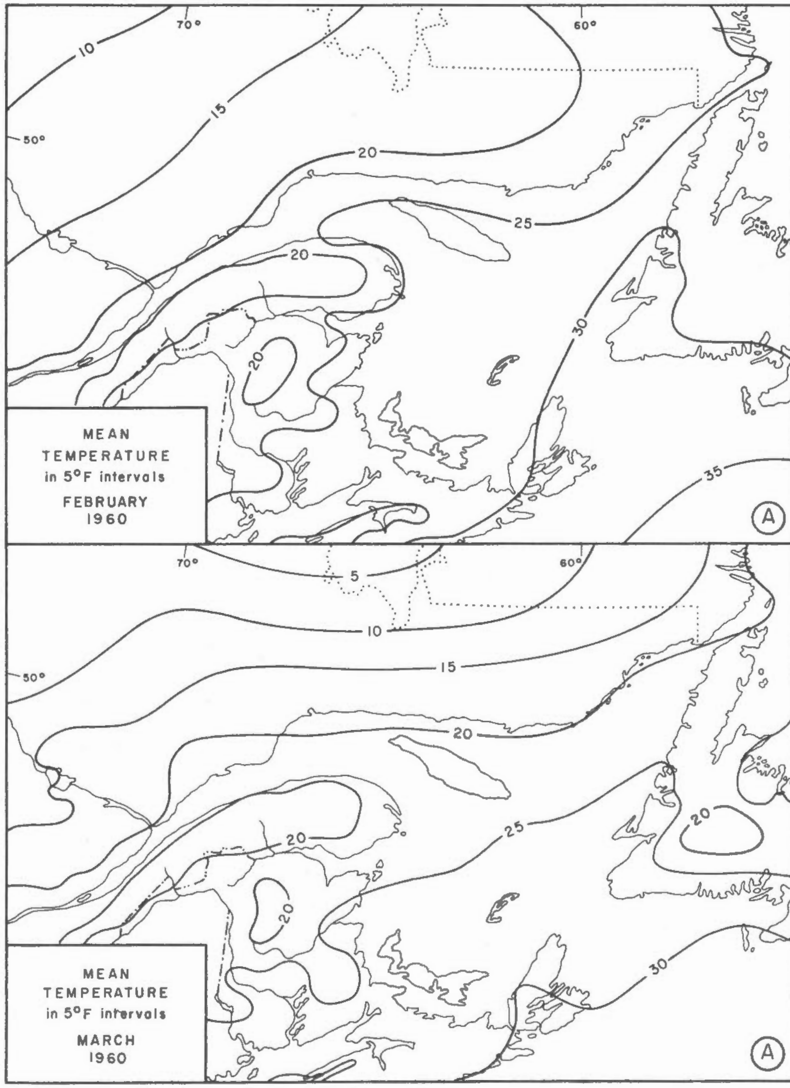


Figure 1(A). Mean temperatures, December 1959 to March 1960.

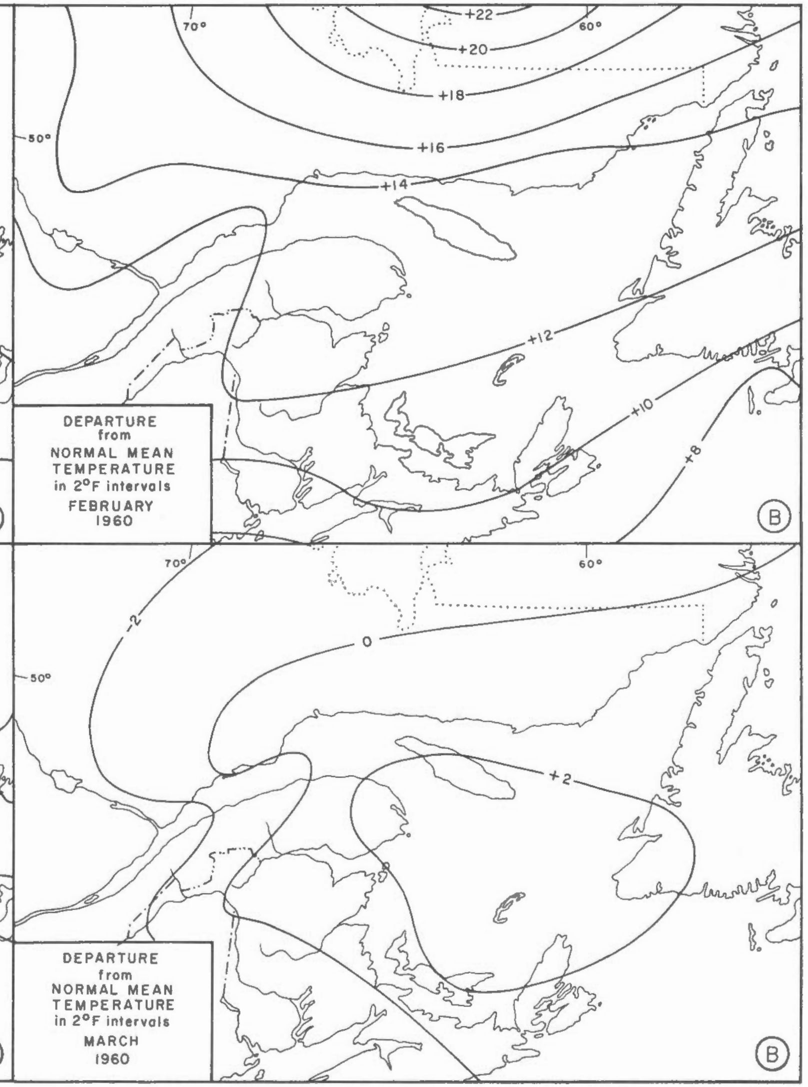


Figure 1(B). Departure from normal mean temperature, December 1959 to March 1960.

temperatures resulted in the area of ice coverage being substantially reduced and limited generally to the areas where ice forming conditions existed.

In the gulf region, the mean isotherms for the winter months of 1959-60 (Figure 1A) trended in a general northeast-southwest direction from December to February, and an east-west direction for March. They show the North Shore for December and January to be 15^{o} colder than Cabot Strait and, 10 degrees colder for February and March. Although the pattern of the isotherms is normal, the isothermal values that usually reflect more southern maritime coastal winter conditions, dominated the gulf region. They demonstrate where the main ice-forming conditions existed in the gulf region.

The departure from the normal isotherms (Figure 1B) shows the extent to which various parts of the gulf differed from normal winter conditions. In December, the region lay in the path of southern flows of mild Atlantic air, but towards the end of the month an outbreak of cold air over the gulf reduced temperatures. On the whole, temperatures 2 to 4 degrees above normal prevailed during the month. A succession of storms in January passed through the gulf region and brought strong flows of northerly and southerly air; the departure of temperatures from the normal increased from 2 to 4 degrees in the southern parts of the gulf to 4 to 6 degrees in the northern parts. In February it lay in the paths of easterly flows of mild Atlantic air with the result that temperatures varied from 10 degrees above normal in the Cabot Strait area to 15 degrees above normal in the northern parts of the gulf. Essentially the prevailing weather of March was a continuation of that prevailing in February with the result that temperatures were more equable, varying from -2 to 2 degrees throughout the gulf region. The trend towards lower winter temperatures was arrested in December and for the remainder of the winter air temperature favorable for the formation of ice at 29* degrees was limited largely to the lee-shore regions of the gulf. On the whole, prevailing temperatures favored the development of new and young ice forms rather than winter ice.

Winter Winds

Prevailing winds in winter blow, on the average, from the west and northwest. They are generally northerly to northwesterly along the north shore and southwesterly - westerly - northwesterly over the southern gulf region. The drift of the ice across the gulf is closely related to prevailing winds. The direction frequency of the winds for the 1959-60 winter season is shown in Figure 2A.

---

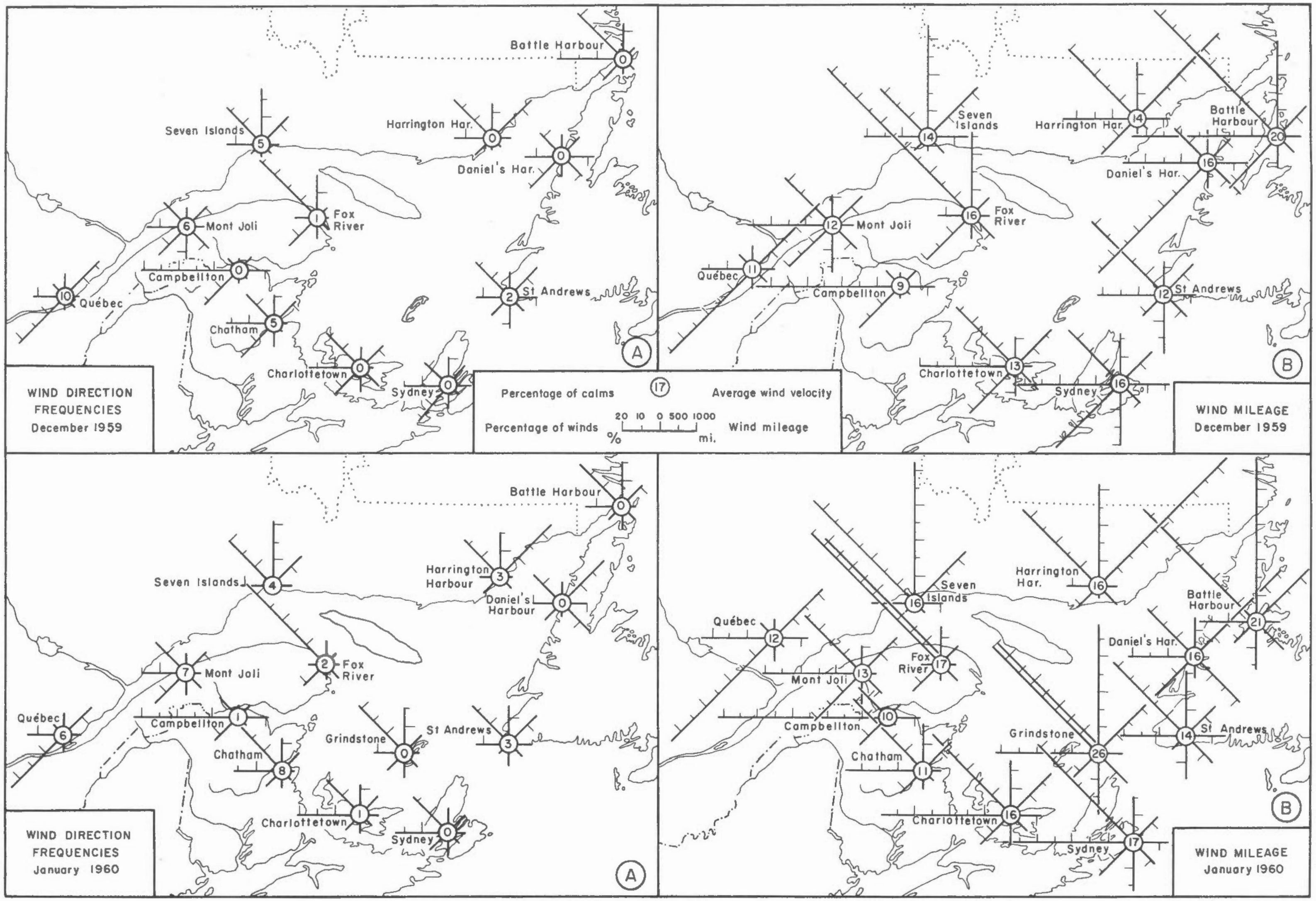
*The temperature is based on the general distribution of surface salinity of 30.00 to 32.00 ($S^{o}/00$). See Lazier, L.M. A Preliminary Report of .... 1956 (Figure 4).

The variable nature of the winds for December 1959 is associated with the series of storms that crossed the region during the month. Westerly and northerly sector winds were strong; southerly and easterly winds were weak. Generally, local areas were marked by strongly developed winds from a specific sector; thus, northerly sector winds were pronounced on the North Shore, and westerly winds in the Strait of Belle Isle areas. January winds were essentially a continuation of December conditions; the western and central gulf regions were marked by strong northwesterly winds which resulted in a strong eastward advance of the ice. February, however, with its flows of maritime air, was marked by strong easterly sector winds. Only in the extreme western part of the gulf region was the normal type of wind pronounced. The main effect of these winds was to arrest the southeasterly advance of the ice across the gulf. During March, low pressure air masses generally passed northeastward, south of the gulf region, so that winds were generally variable with northerly sector winds prevailing. With an increasing number of lows passing through the gulf during April, winds continued to be variable, but southerly and easterly components were stronger.

Winds that were associated with the December storms were generally strong, averaging from 9 to 20 m.p.h. Fresh breeze-type winds (17 to 21 m.p.h.) were prevalent in the Strait of Belle Isle area. Elsewhere throughout the gulf moderate breeze-type winds (11 to 16 m.p.h.) prevailed. Calm periods were most pronounced in the ice forming areas of the St. Lawrence estuary. Breeze-type winds of 10 to 16 m.p.h., prevailed throughout January although strong winds occurred with passing storms. The central gulf region was marked by strong winds and together with the Strait of Belle Isle area continued to have stronger winds than elsewhere in the gulf. Only the eastern parts of the gulf were free from calm intervals. Winds for February and March were on the average a continuation of the breeze-type wind with strong to gale-like winds occuring with the passing of storms. The St. Lawrence estuary continued to report a higher percentage of calms than elsewhere in the gulf.

Gulf Ice Drift

The direction, velocity and sustained mileage traversed by the wind are important additional factors affecting the surface distribution of the ice. Wind mileage and wind frequency tend to coincide. In the 1960 winter survey, winds from the westerly and northerly sectors were the strongest, and together with mileage distance caused a steady southeastward drift during December and January (Figure 2B). This southeastward drift was not sustained for the balance of the season as February winds were mainly northeasterly, and March northerly.


WIND DIRECTION FREQUENCIES December 1959
WIND MILEAGE December 1959
WIND DIRECTION FREQUENCIES January 1960
WIND MILEAGE January 1960
A
B
Percentage of calms
17
Average wind velocity
Percentage of winds
20 10 0 500 1000
%
mi.
Wind mileage
Battle Harbour
Seven Islands
Harrington Har.
Harrington Harbour
Daniel's Har.
Daniel's Harbour
Mont Joli
Fox River
Québec
Campbellton
Chatham
St Andrews
Grindstone
Charlottetown
Sydney

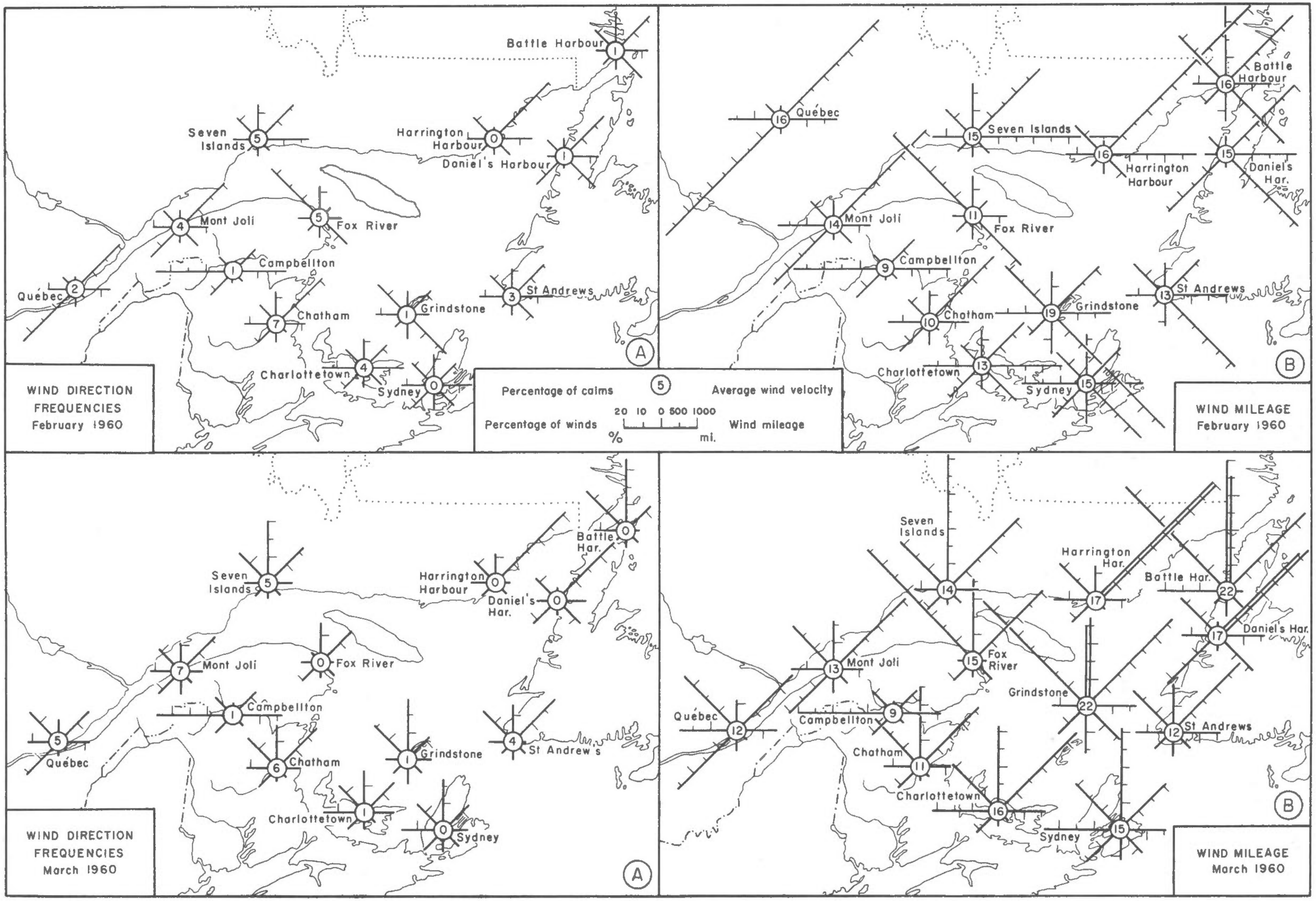


Figure 2(A). Wind direction frequencies, December 1959 to March 1960.

Figure 2(B). Wind mileage, December 1959 to March 1960.

Shuleykin's (Armstrong, 1955) ratio of ice drift to wind speed (1:25) provides a practical estimate of the rate that ice is driven by wind. In January, westerly and northerly winds were particularly strong and provided a free daily average ice drift of 9 and 9.8 miles respectively. In February, easterly winds provided the highest rate of drift of 7.3 miles per day. Northerly winds provided a strong rate of drift of 5.7 miles per day. southerly winds at 4.3 produced the least drift. The free ice drift provided by northerly winds was particularly strong from the North Shore and Strait of Belle Isle areas during January and March. In general, each of the wind sectors developed strong rates of free ice drift so that the opposing sectors (south and east) reduced considerably the southeastward drift of the ice. The free ice drift force of winds from the northerly sector was the greatest (about 8.3 miles per day), westerly free ice drift was 6.4 miles, easterly was 5.3 miles, and free ice drift of southerly winds was the least, at 3.0 miles per day (Table II).

The actual mileage of effective ice drift is found by deducting the ice-drift miles from the opposing wind sector. Winds from an adjacent sector tend to hinder or assist in the movement of drifting ice. Westerly winds thus tend to deflect southerly drifting ice towards the southeast; easterly winds tend to drive it to the southwestern parts of the gulf. In the St. Lawrence estuary the general drift of the ice is from west to east diagonally across the river to the south shore. This fact also provides an explanation for ice congestion on the south shore of the river as the effectiveness of assisting winds is considerably reduced by opposing winds and the trend of the coast. After rounding the Gaspé coast where both westerly and northerly sector winds are more effective, the consolidated ice is shattered and reduced to open fields of ice. The ice-drift values for February illustrate this principle: westerly winds drive the ice east 7 miles per day; easterly winds, however, oppose this drift at the same rate; northerly winds drive the ice to the south shore at 6 miles per day and are opposed by southerly winds at 5 miles. The main result is the development of consolidated ice field on the south shore and the dependence upon the river current to move the ice into the gulf.

January drift values from the northerly and westerly parts of the gulf indicate that westerly and northerly winds provided a strong, daily rate of ice drift towards the southeast; by comparison, the east and south drift values were relatively weak. The free southeastward drift of the ice from the North Shore was 19 miles per day; but the deductive of the free ice drift values from opposing sectors results in an effective drift rate of about 13 miles per day. Similarily, effective southeastward ice drift from the western gulf region was 14 miles per day, and from the central gulf region was 24 miles. The main effect was the extension of the icefields to the Cape Breton coast and the expansion of the icefields in the northeast arm of the gulf (see ice chart for Feb. 3 and 4).

TABLE II

Free ice drift per day in miles by sector, January, February and March, 1960

Area	WEST (SW - W - NW) Jan: Feb: Mar.	NORTH (NW - N - NE) Jan: Feb: Mar.	EAST (NE - E - SE) Jan: Feb: Mar.	SOUTH (SE - S - SW) Jan: Feb: Mar.
St. Lawrence River	8 : 7 : 6	4 : 6 : 6	3 : 7 : 4	5 : 5 : 3
North Shore	6 : 3 : 4	13 : 8 : 13	5 : 10 : 9	.8 : 2 : 1
Strait of Belle Isle	9 : 4 : 8	14 : 8 : 18	4 : 8 : 5	3 : 5 : 1
Western Gulf	10 : 5 : 5	7 : 4 : 7	1 : 4 : 5	2 : 2 : 1
Northumberland Str.	8 : 4 : 5	7 : 4 : 9	2 : 5 : 5	2 : 3 : 2
Central Gulf	15 : 5 : 7	17 : 6 : 6	4 : 10 : 7	4 : 8 : 4
Cabot Strait	7 : 4 : 5	7 : 4 : 7	3 : 7 : 5	3 · 5 : 3
Average free ice drift	9 : 4.6 : 5.7	9.8 : 5.7 : 9.4	3.1 : 7.3 : 5.7	2.8 : 4.3 : 2.1

During February, the expansion of the icefields was checked. The effect of the strong northerly and easterly winds was the retreat of the icefields from the central gulf region and of ice congestion in the southern parts of the gulf. The southwest drift of the arctic, or Labrador, ice to Anticosti Island was pronounced; effective sustained ice drift was 7 miles per day for February and 5 miles per day for March.

In March the effective ice drift of the west and north wind sectors for the northern parts of the gulf was substantially less than the north and east wind sectors for the same area. The latter provided an effective ice drift to the southwest of 5 miles per day.

A number of factors caused the ice to be slow in leaving the southern parts of the gulf when the St. Lawrence estuary, northern and western parts of the gulf were ice-free. Because of the northeast trend of the Cape Breton coast, and a northwest-southeast tidal action that rocks the ice back and forth in Northumberland Strait, the southern gulf area forms a cachment basin for ice. Westerly, northerly and easterly component winds drive the ice into this area; whereas, southerly component winds being relatively weak are quite ineffective in freeing the area of ice.

GULF ICE DISTRIBUTION

The extent of ice coverage varies with the severity of the winter. The winter of 1959-60, compared with normal winter conditions, was mild. From the outset of the winter season temperature conditions were not favorable for the development and preservation of the icefields. The earlier stage of winter however, was more favorable than the mid-winter period, and as a result ice formation and growth was arrested (Table III).

TABLE III

Mean Monthly Degree-days of Frost, 1959-1960

Area	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.
St. Lawrence River	0	10	17	8	8	-6
North Shore	1	12	14	5	9	-1
Strait of Belle Isle	2	9	11	4	9	1
Gaspé-Chaleur	-3	8	12	5	6	-5
Eastern gulf	-7	1	4	-1	3	-5
Central gulf	-6	0	6	2	2	-4
Southern gulf	-9	2	9	2	2	-8
Cabot Strait	-11	-2	2	-1	1	-6
Average for gulf area	-4.1	5.0	9.4	3.0	5.0	-4.2

Air temperatures on the whole were favorable as an ice-forming factor. The month of November was unfavorable for the production of an ice cover. In the period from December to March, ice-forming conditions were most effective in January, with 9.4 degree-days of frost, and least in February with 3.0 degree-days.* The most favorable ice-forming conditions in December prevailed over the northwestern parts of the gulf, with conditions becoming still more favorable during January. The rapid change in temperature conditions in February reduced the effectiveness of these areas as ice-producing grounds, although, during February and March the northern gulf areas continued to be effective. Oceanographic conditions prevented any sustained advance of the ice beyond these areas.

The southern half of the gulf was considerably less effective as an ice-forming area than the northern parts. Once the ice had reached its thicker and more durable winter form, temperatures were sufficient to maintain these icefields for a considerable period. Perhaps more notable was the duration of the massive arctic or Labrador ice in the Strait of Belle Isle in the spring months. This area experienced -9 degree-days of frost in May and -21 in June; extensive icefields dominated the area in May, and invasions of Labrador ice were poured into the Strait of Belle Isle by the Labrador current in June.

Gulf Ice Cover

The expansion of the Gulf of St. Lawrence icefields in the winter of 1960 is shown by the advance of the ice fronts (Figure 3). By January 4, the icefields in the St. Lawrence estuary below Quebec had

*A degree-day of frost is defined as a day with a mean temperature one Fahrenheit degree below the freezing point of sea water (29°).

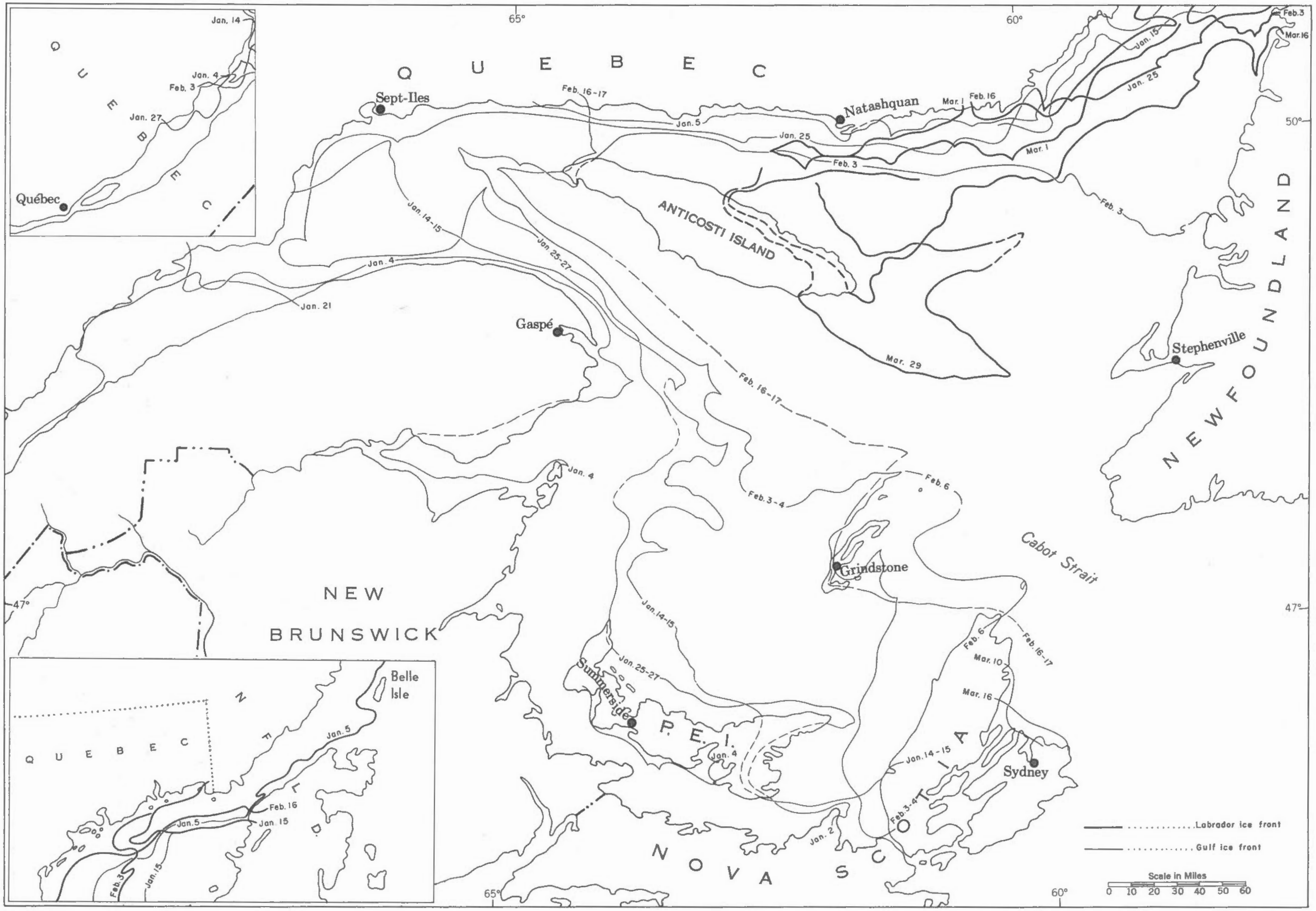


Figure 3. Advance of the ice fronts in the Gulf of St. Lawrence, Winter 1960.

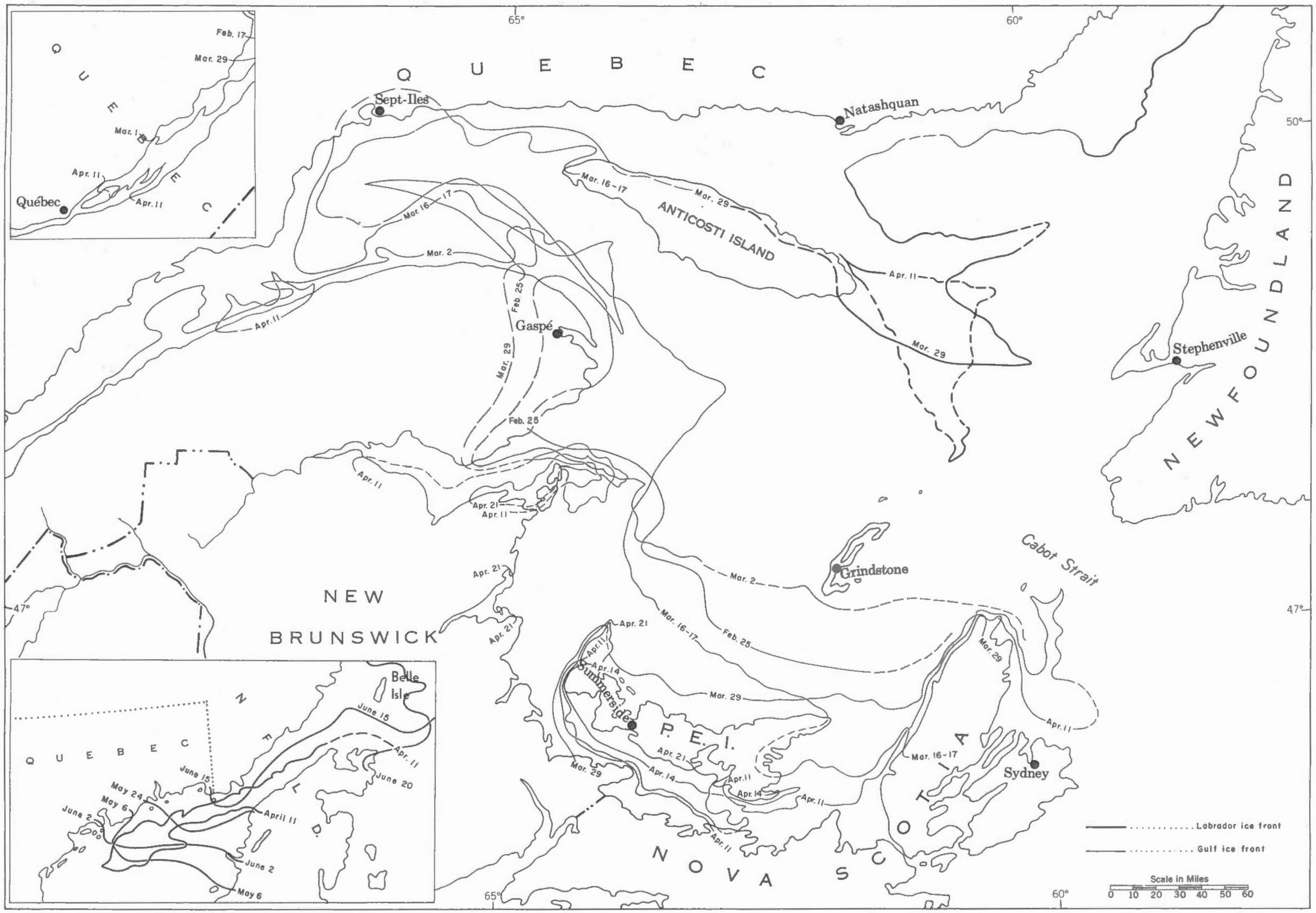


Figure 4. Retreat of the ice fronts in the Gulf of St. Lawrence, Spring 1960.

reached the mouth of the Saguenay River. Icefields were expanding in the ice-forming area of the lower estuary, and ice bordered the Gaspé coast and the south coast of Chaleur Bay. In the northeast arm of the gulf ice extended northwards from Harrington Harbour to cover the Strait of Belle Isle. By February 3 and 4, about two-thirds of the gulf was ice covered; icefields extended across the St. Lawrence estuary, and in the gulf, had reached the Magdalen Islands; in the northeast arm the ice edge extended west from the Bay of Islands. By mid-February gulf ice was entering Cabot Strait by passing around Cape Breton Island; a detached part reached Scatari Island on March 26. By mid-February, however, the areal extent of the ice was reduced substantially.

One of the most interesting features of the gulf region was the advance of the Labrador icefields through the Strait of Belle Isle. On January 4, a tongue of Labrador ice extended into the strait; by mid-February this ice lay off Cape Whittle, and on March 1 it had reached Natashquan on the North Shore. The advance of the Labrador icefields continued; in mid-March, the ice bordered the northern coast of Anticosti Island and by the end of March - it is maximum advance - it extended southeast of Anticosti Island. During its advance the main body of this ice became detached from its source by a withdrawal of the Labrador ice in the upper part of the northeast arm northwards through the Strait of Belle Isle.

The retreat of the gulf ice, shown on Figure 4, was well advanced in the northern gulf region by mid-February. In the central gulf area, the ice front had maintained a relatively stable position for about two weeks. After mid-February the gulf ice retreated rapidly, and open water was more extensive in the St. Lawrence estuary and in the northwest arm of the gulf than ice cover. The retreat of the ice was interrupted in March by an expansion of the icefields in the northwestern parts of the gulf, the area of ice in the southern parts of the gulf, however, continued to diminish. By the end of March the deterioration of the gulf icefields was well advanced; parts of the gulf with ice cover were separated by extensive areas of open water. Prior to mid-February the gulf ice had begun to feed into Cabot Strait, but this movement ceased during the early part of March. In mid-April scattered fields of ice were restricted mainly to the ice-forming or protected areas. By the end of the month the gulf ice had virtually disappeared.

The retreat of the Labrador icefields was stalled at various times during the winter by the renewal of ice through the Strait of Belle Isle. Their retreat was therefore marked first by a reduction of the area of Labrador ice in the northeast arm and the Strait of Belle Isle, and secondly by extensive areas becoming detached from the main influx of ice. Deterioration of the fields were well advanced by mid-April, and by April 23 the Strait of Belle Isle was almost ice-free. The advance and retreat of the Labrador ice in this area for May and June is shown in Figure 16.

Ice Types and Concentration

In the winter of 1960 new and young ice types dominated the gulf ice cover. New ice types were generally extensive on the leeward sides of the gulf coasts or in seaward areas. As, in general, mild weather conditions prevailed over the gulf region, the development of very young ice was associated with invasions of cold air from the land, and at such times shelving advanced rapidly. Mild weather and wave action turned this ice into slush and slob. In advanced stages of ice growth new ice was usually replaced by young ice. Young ice, an important constituent in icefields of new and winter ice types, disappeared as an important element about mid-February. New ice types disappeared from the southern gulf ice cover toward the end of March. It was the last ice type to disappear from the St. Lawrence estuary, and it disappeared from the icefields of the northeast arm at the end of April.

Winter ice was usually the most important constituent of the ice cover where the ice became congested in bays or on the windward side of coasts such as Gaspé or those of the southern parts of the gulf. In such areas winter ice varied from 7/10 to 10/10 in coverage and consisted of concentrations of giant floes and fields (009 - 00 10) with surface pressure ridges varying from 4/10 to 8/10. In seaward areas winter ice occasionally exceeded 3/10 of the ice surface. Winter ice reached its greatest extent during February.

The Labrador ice that entered the gulf region through the Strait of Belle Isle is described in this report as polar ice that originated in arctic or sub-arctic areas outside of the confines of the Gulf of St. Lawrence region. This ice was intensely worked over and pressure ridging was severe, reaching as much as 9/10 of the ice surface in the Strait of Belle Isle. This ice disappeared from the Strait of Belle Isle after mid-June, when, except for belts and patches, the ice front of the Labrador pack lay off the coast of Labrador well to the north of Battle Harbour.

The invasion of Labrador ice was marked by an influx of small bergs and growlers. A number of small bergs reached the southeast coast of Anticosti Island about April 21, and a number drifted south off the west coast of Newfoundland to enter Cabot Strait in late April. In the Strait of Belle Isle small bergs and growlers were numerous throughout the winter and spring season.

On the first flight of January 4, landfast ice was observed to cover the sheltered bays and harbors on the western side of the gulf and a number of protected harbors on the North Shore. Although the area of landfast ice continued to expand during the winter, the breaking up of landfast ice was frequent, especially on the North Shore. Harbors in the eastern parts of the gulf, and those exposed to the open sea, were generally ice-free. The break-up of landfast ice occurred mainly after mid-April. The harbors of the North Shore were mainly ice-free by April 21 and those of the New Brunswick coast were ice-free by the end of the month.

ICE DISTRIBUTION MAPS

The various features of the distribution of gulf ice that were observed in the course of the 1960 ice reconnaissance survey are shown graphically in Figures 5 to 15. These maps cover the period from January 4 to May 3. For the months of May and June when the icefields were restricted to the northeast arm and the Strait of Belle Isle areas of the gulf 6 insets from the Meteorological Branch ice surveys are included. These insets were selected to show the deterioration of the ice in this area (Figure 16).

Explanation of Terms

Block: A fragment of sea ice ranging in size from 6 to 30 feet across.

Brash: Fragments of floating ice, less than 6 feet across, resulting from the wreckage of other forms of ice.

Consolidated ice: Ice of different sizes that is compacted into larger ice forms.

Floe: A piece of sea ice. A small floe is from 30 to 600 feet across; a medium floe is 600 to 3,000 feet; a large, or giant floe is 3,000 feet to 5 miles.

Ice concentration: The ratio of the areal extent of ice present to the total combined extent of the ice and water surface. Concentration is usually measured in tenths: for example 9_{621} concentration indicates 6/10 brash and block, 2/10 small to medium floes and 1/10 giant floes and field; total surface of ice coverage 9/10.

Icefield: An area of sea ice greater than 5 miles across.

Landfast ice: Any type of ice attached to the shore, beached, stranded in shoal water, or attached to the bottom of shoal areas. It is also known as shorefast ice.

New ice: New ice includes such forms as grease, slush, frazil, very young ice and the early stage of sludge.

Polar ice: In this report, polar ice is defined as ice originating in arctic or sub-arctic areas outside of the confines of the Gulf of St. Lawrence region.

Pressure ridge: A ridge of ice. Wherever a substantial area of the ice is in the form of pressure ridges, coverage may be expressed in tenths; for example $\frac{PR}{3}$ denotes 3/10 of the area of the ice surface is in the form of pressure ridges. This is also a measure of surface roughness.

Rafting: In this study, rafting denotes the overriding of one floe by another floe of winter ice.

Shelving: Shelving refers to the interlocking rectangular pattern of new and young ice types.

Sludge: An accumulation of small pieces of soft ice mixed with slush. The surface of the sludge is usually hardened into an ice crust. Slob ice is a dense form of sludge. Sludge coverage may be expressed in tenths: thus $\frac{Sg - 4}{4}$/10 of sludge.

Slush: An accumulation of ice crystals such as would result from snow that has fallen into water at approximately freezing temperature. Slush forms a thick white soupy mass in the water. The coverage of slush may be expressed in tenths: thus $\frac{S1}{5}$ - 5/10 of slush.

Very young ice: Ice that is recently formed in calm water and is dark in appearance. Coverage is expressed in tenths; thus $\frac{VY}{6}$ - 6/10 of very young ice.

Winter ice: Ice produced during the current winter, usually ridged and capable of maintaining a snow cover without the snow becoming grey from water seepage through the ice. Coverage is expressed in tenths; thus $\frac{W}{5}$ - 5/10 of winter ice.

Young ice: Newly formed ice that is generally grey in appearance and varying from 2 to 6 inches thick. It is older than new ice types. Coverage is expressed in tenths; thus $\frac{Y}{7}$ - 7/10 of young ice.

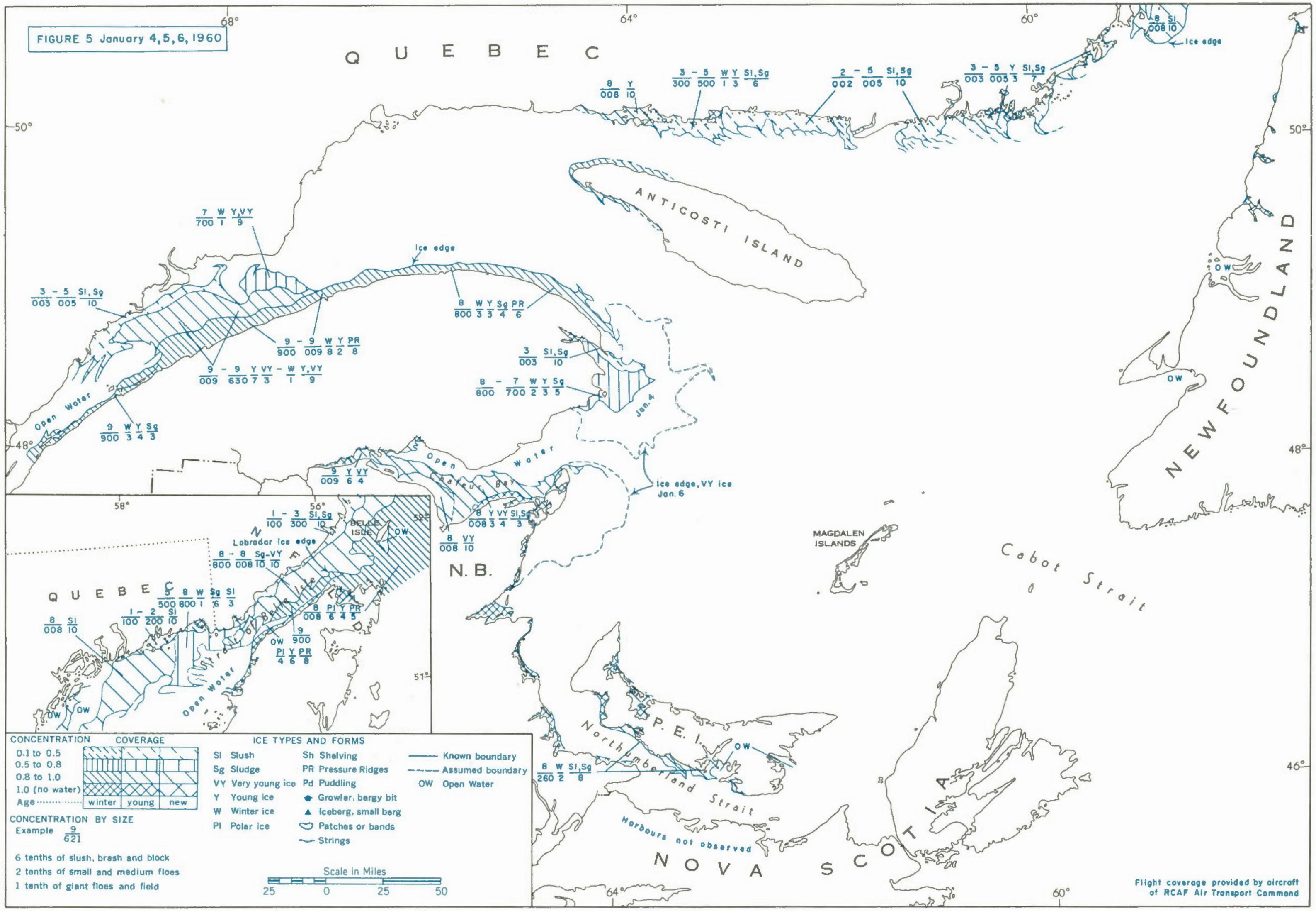


Figure 5. Ice distribution, Gulf of St. Lawrence, January 4, 5, 6, 1960.

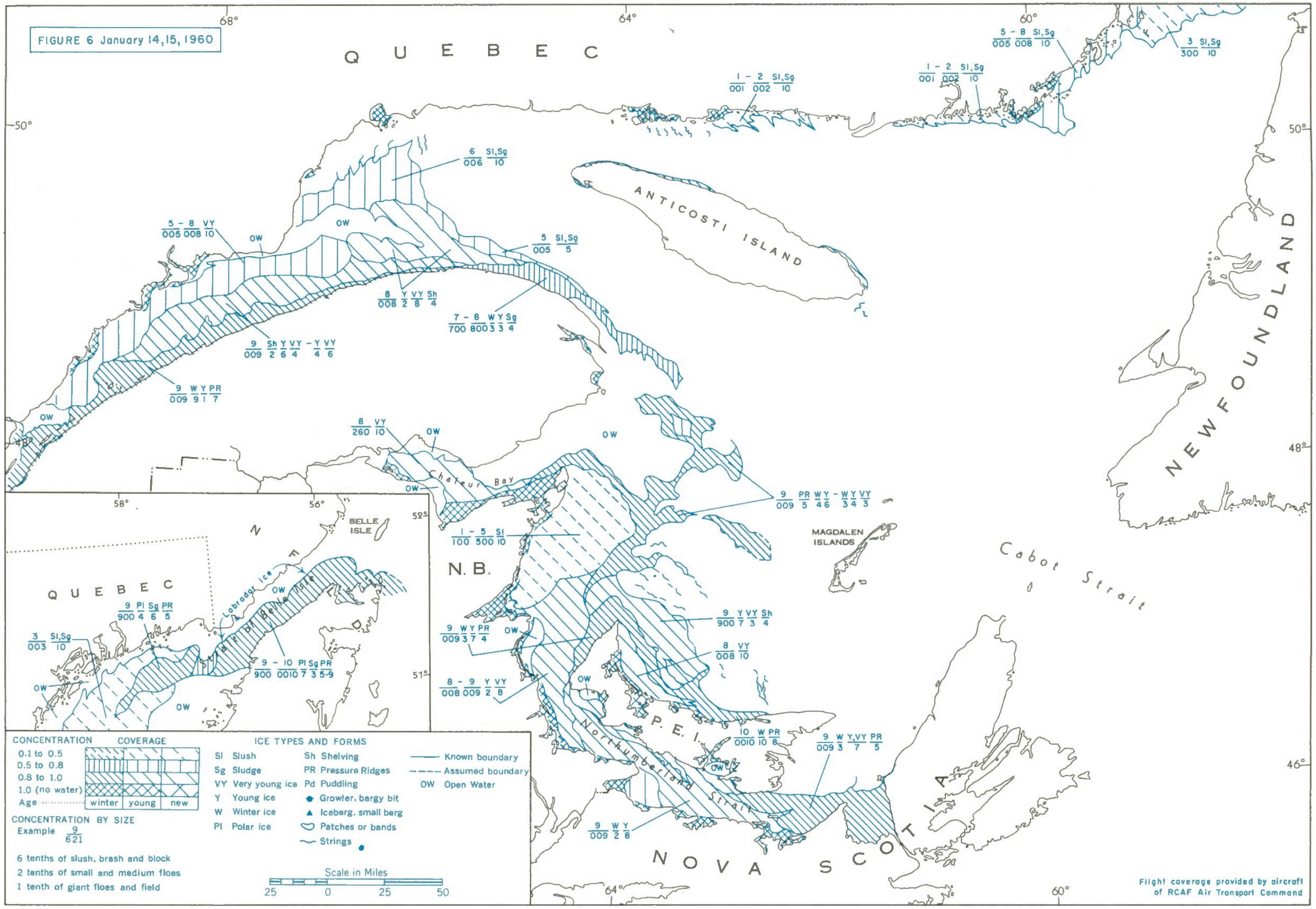


Figure 6. Ice distribution, Gulf of St. Lawrence, January 14, 15, 1960.

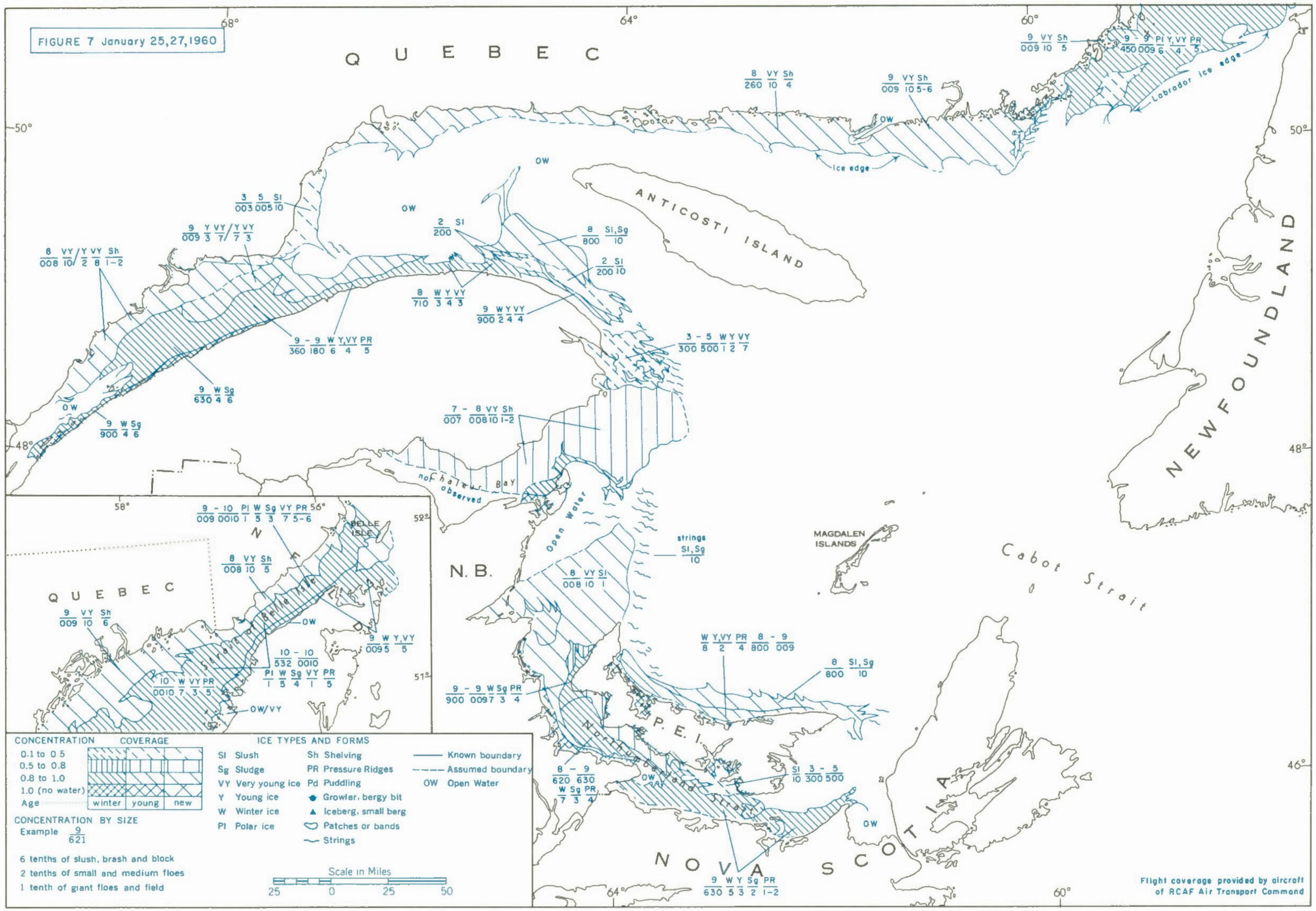


Figure 7. Ice distribution, Gulf of St. Lawrence, January 25, 27, 1960.

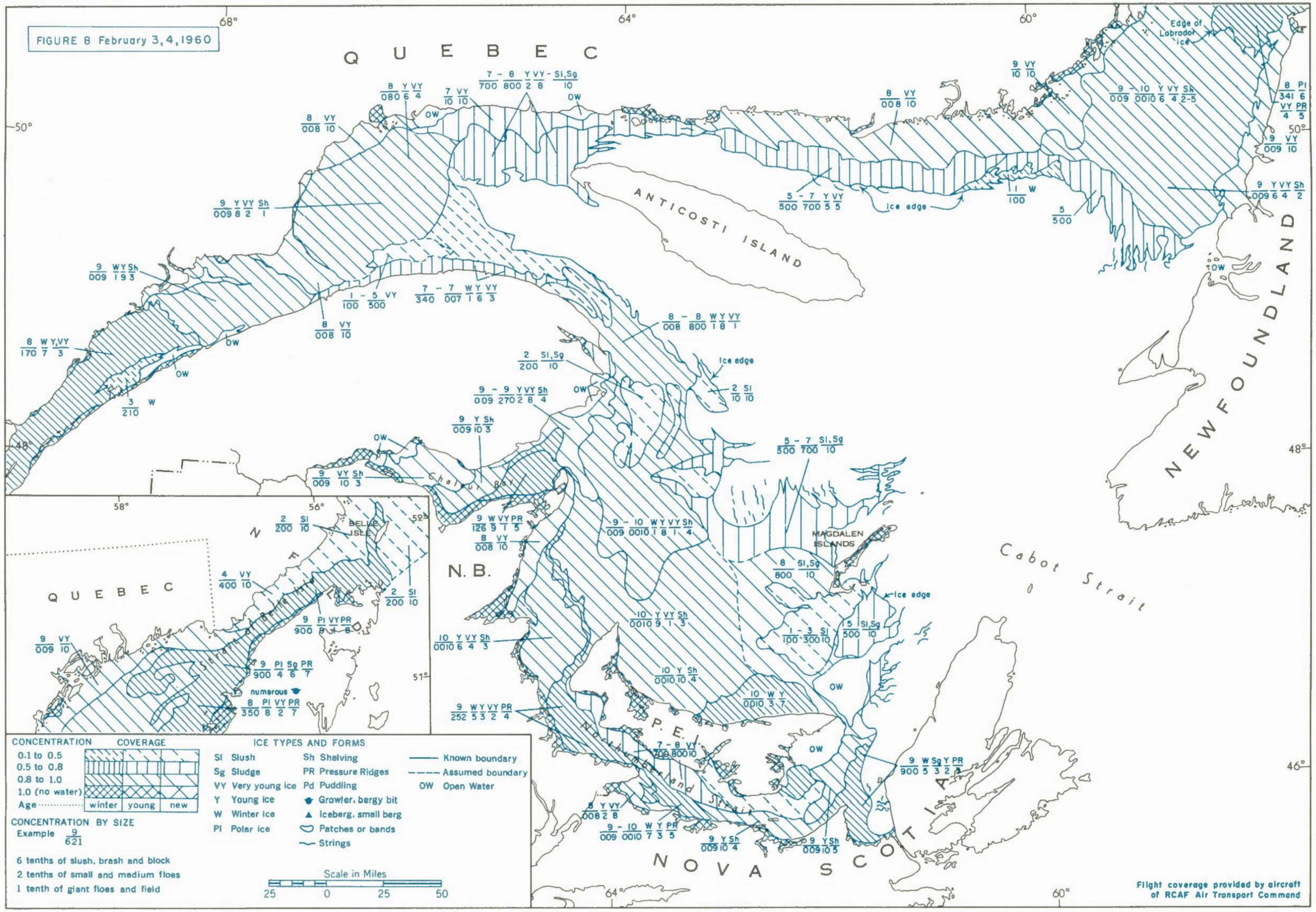


Figure 8. Ice distribution, Gulf of St. Lawrence, February 3, 4, 1960.

90422-7—5

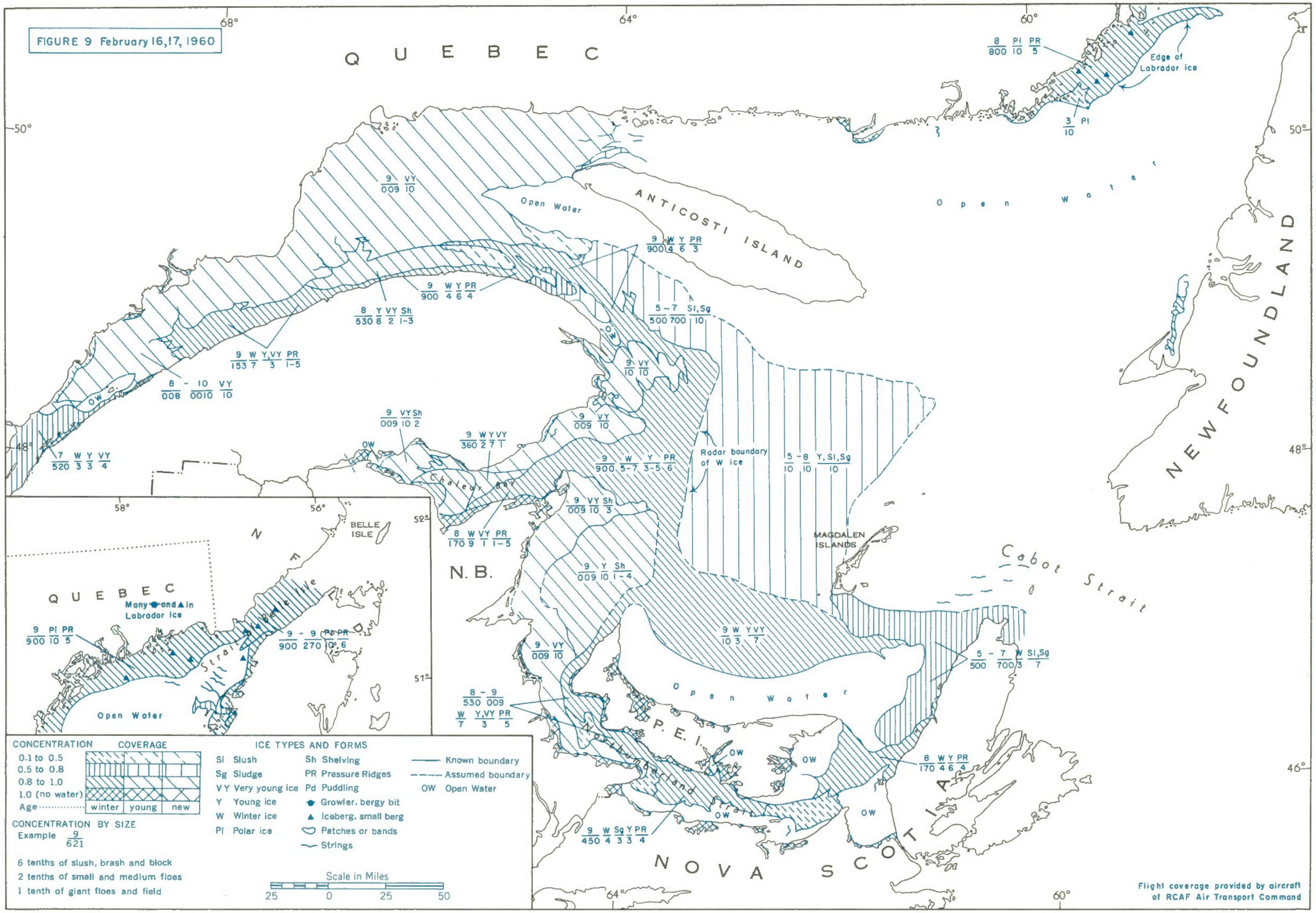


Figure 9. Ice distribution, Gulf of St. Lawrence, February 16, 17, 1960.

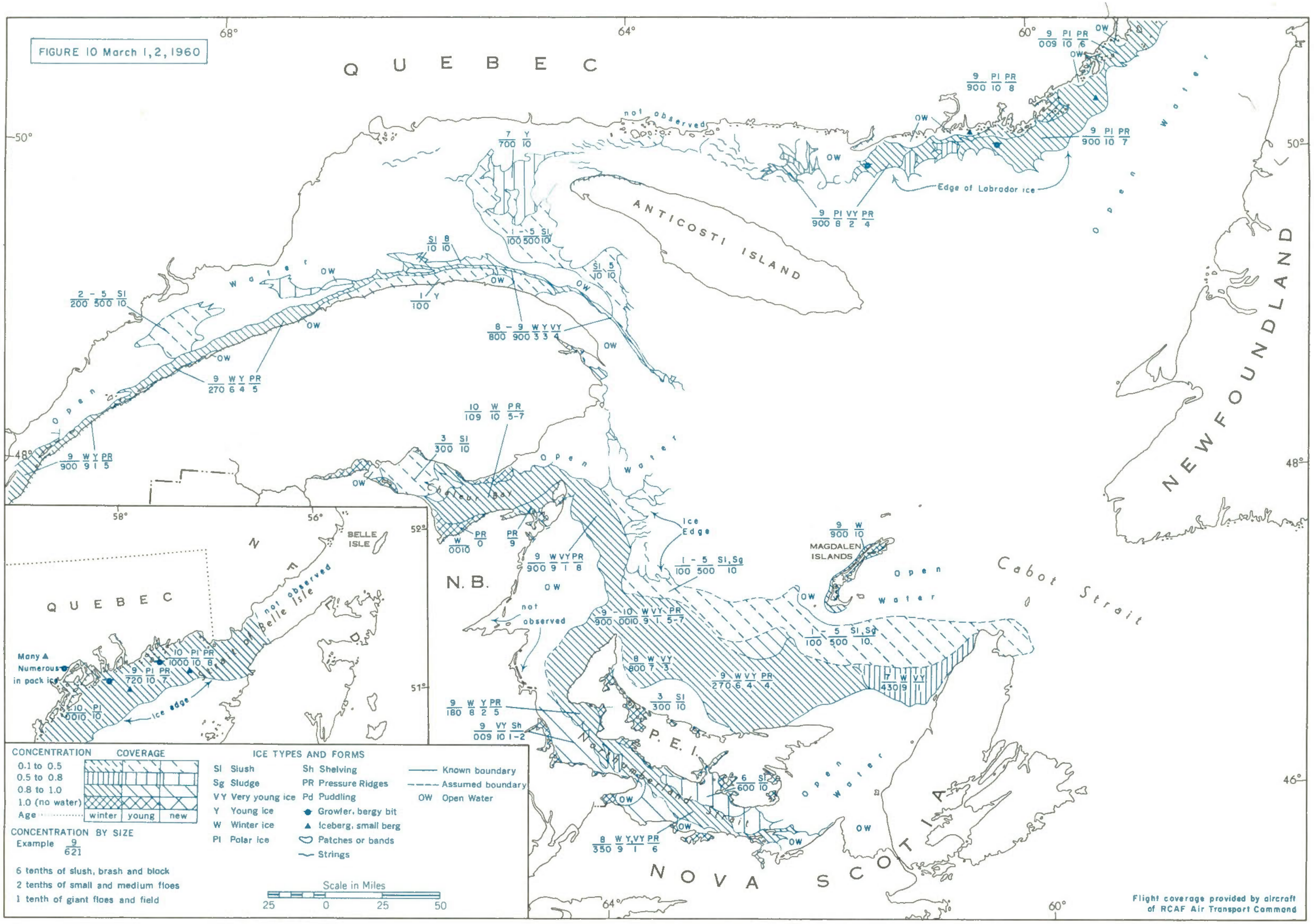


Figure 10. Ice distribution, Gulf of St. Lawrence, March 1, 2, 1960.

90422-7—5½

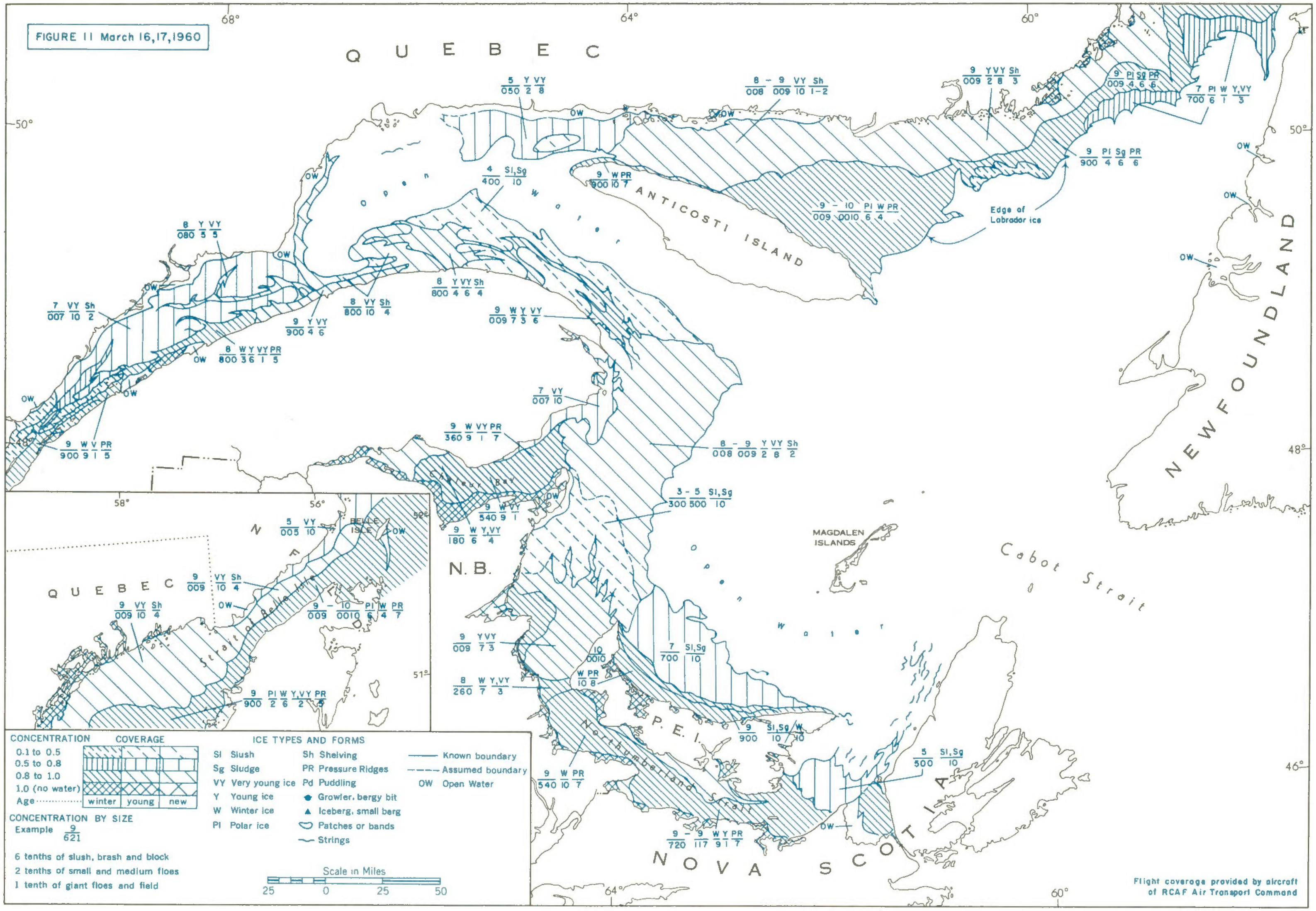


Figure 11. Ice distribution, Gulf of St. Lawrence, March 16, 17, 1960.

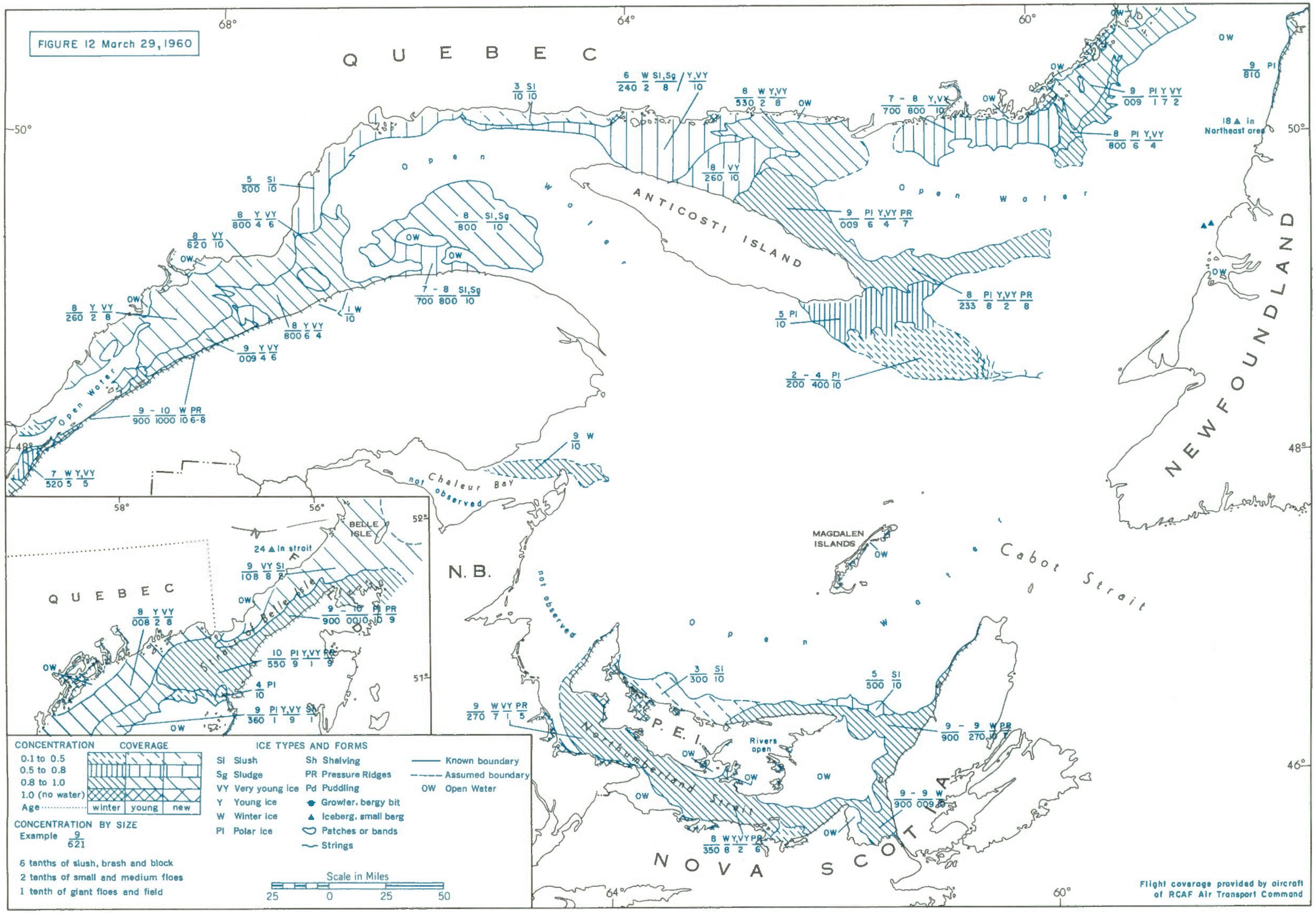


Figure 12. Ice distribution, Gulf of St. Lawrence, March 29, 1960.

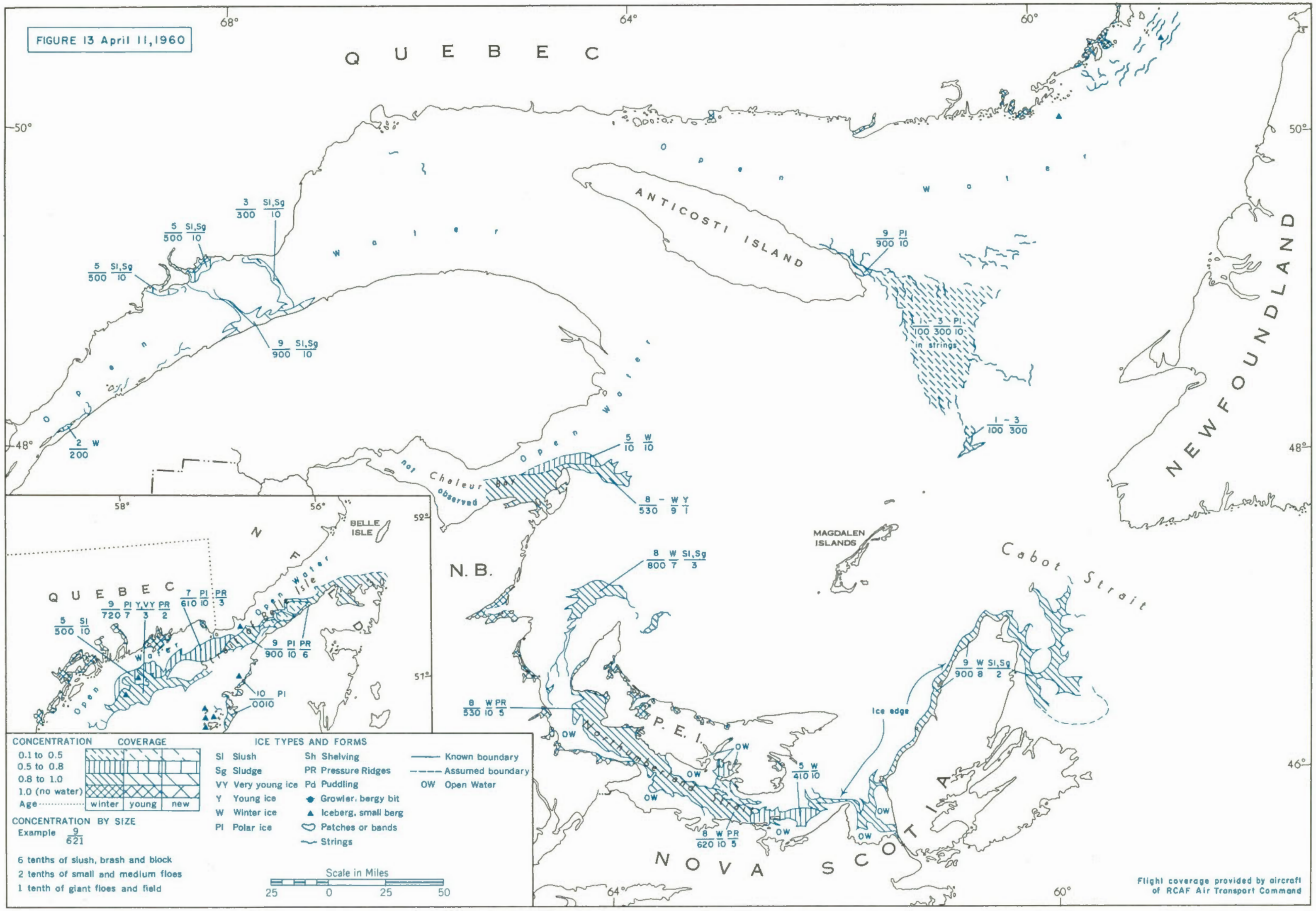


Figure 13. Ice distribution, Gulf of St. Lawrence, April 11, 1960.

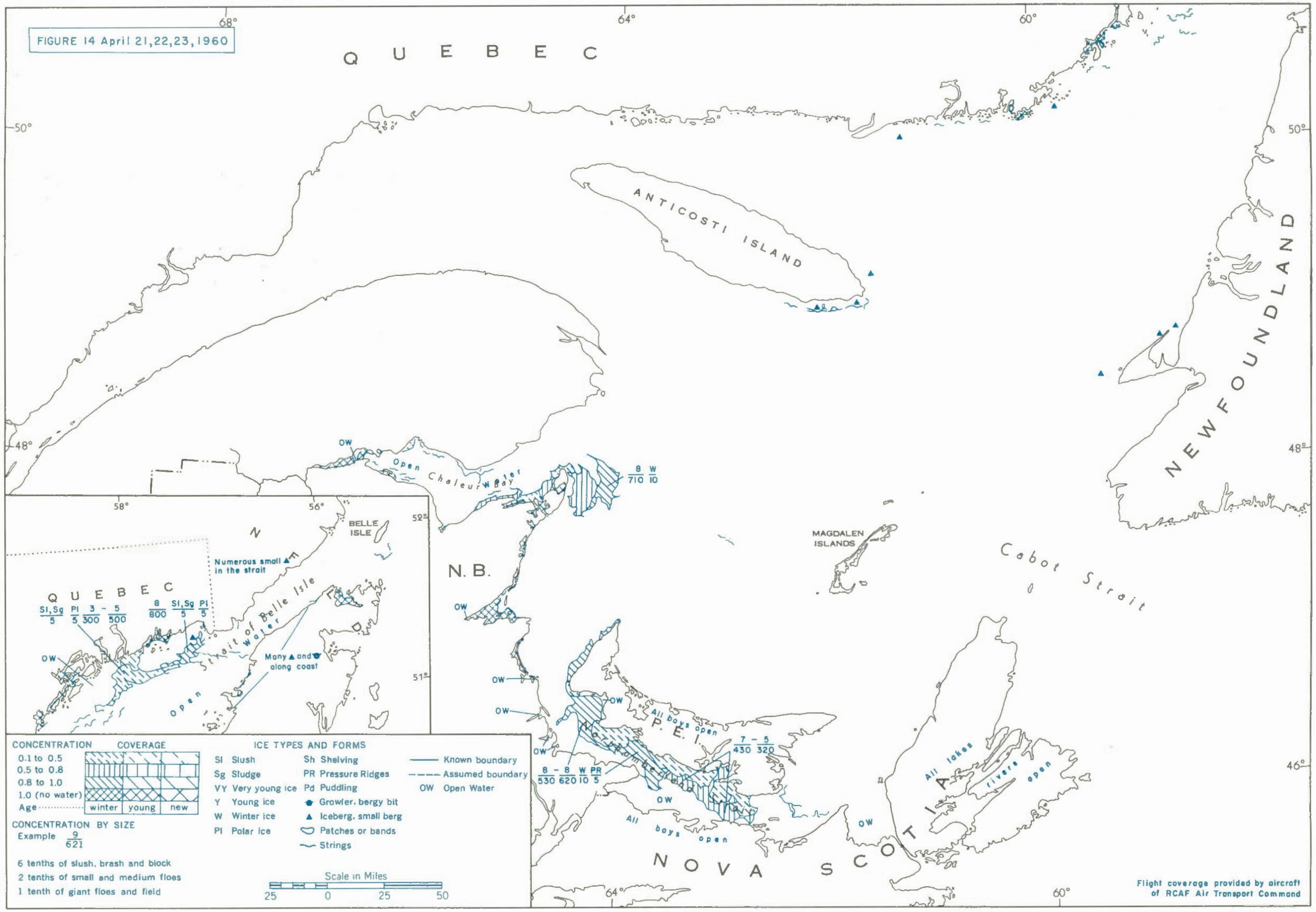


Figure 14. Ice distribution, Gulf of St. Lawrence, April 21, 22, 23, 1960.

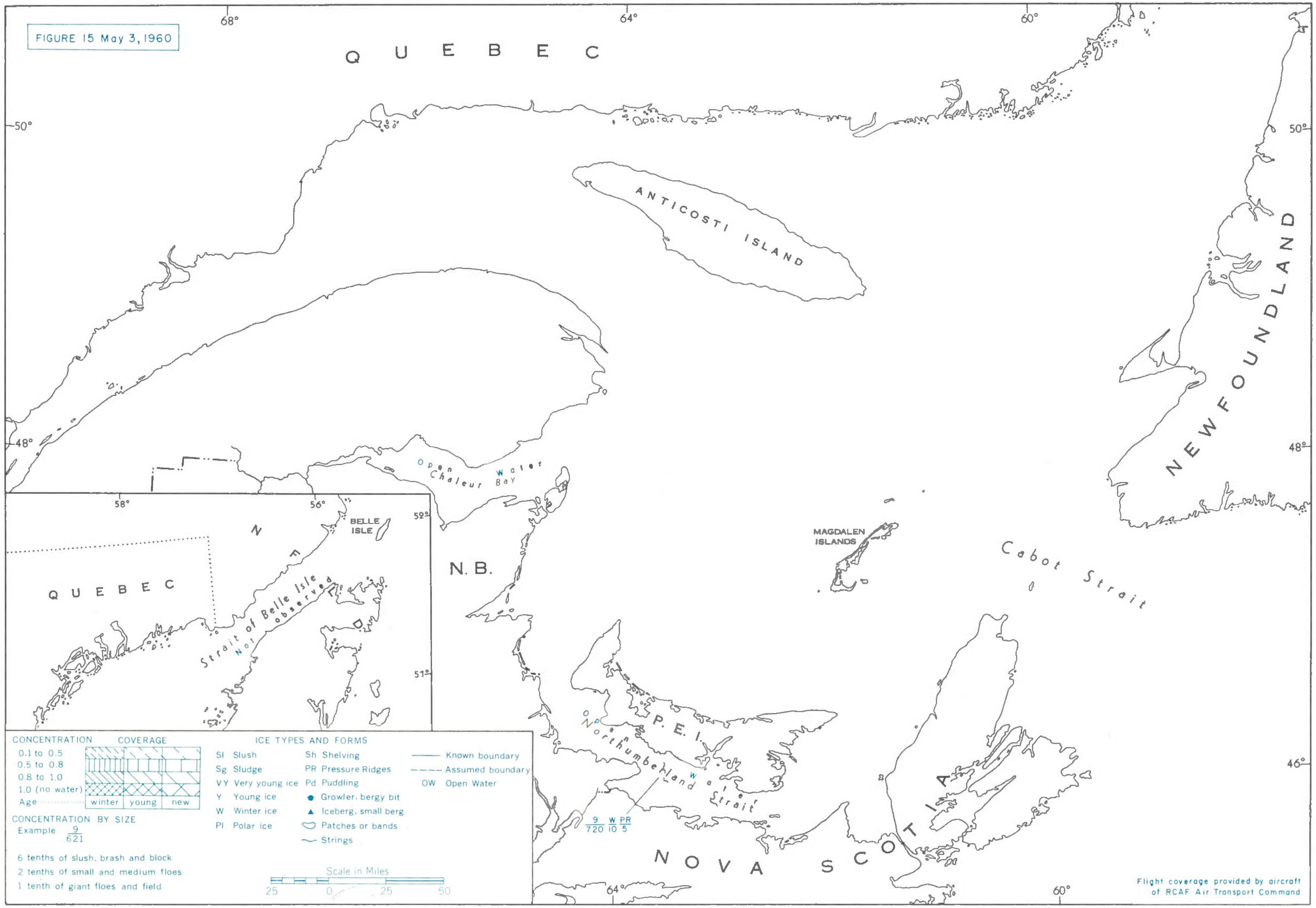


Figure 15. Ice distribution, Gulf of St. Lawrence, May 3, 1960.

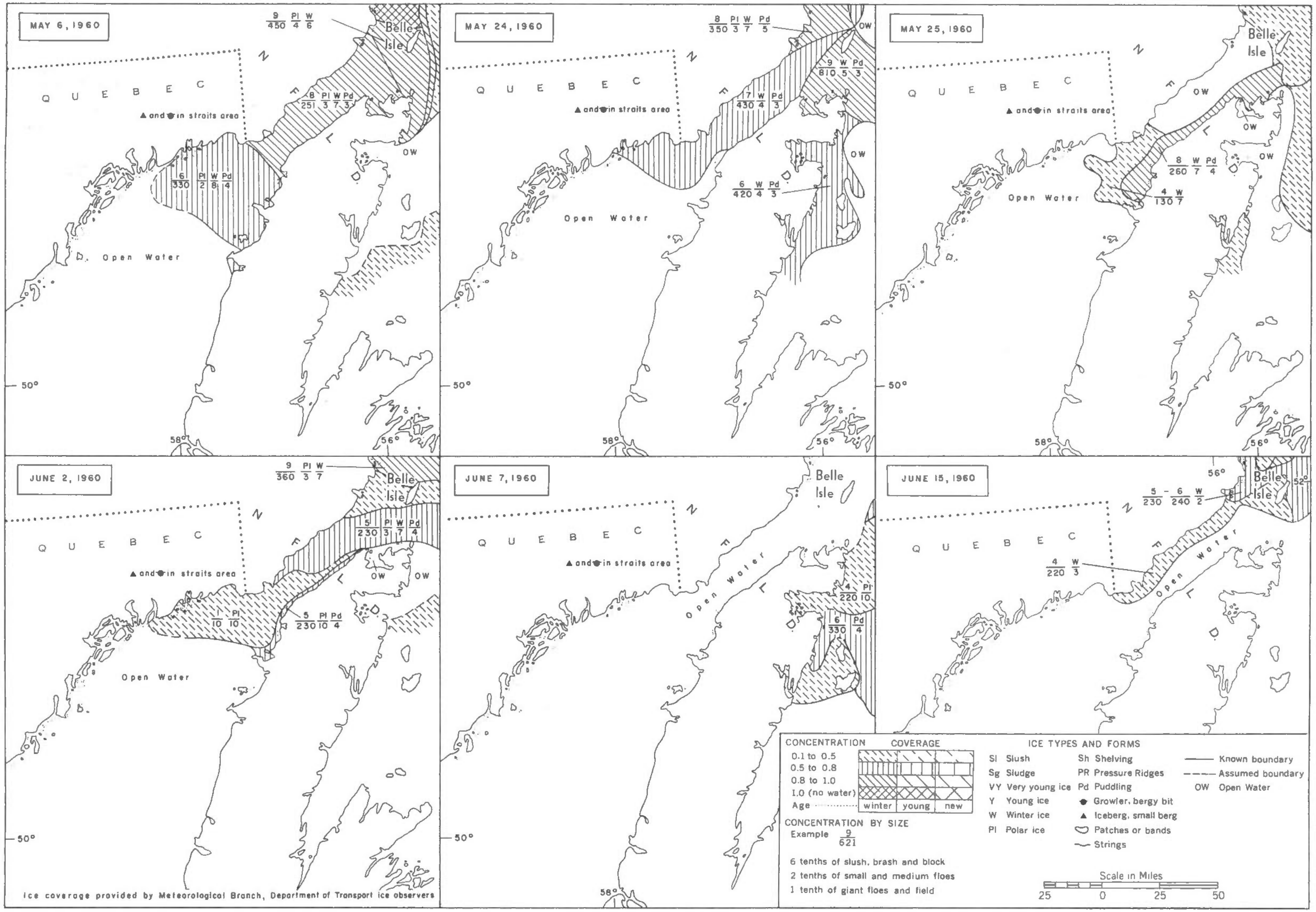


Figure 16. Ice distribution, Northeast Arm of the Gulf of St. Lawrence, and Strait of Belle Isle, May 6 to June 15, 1960.

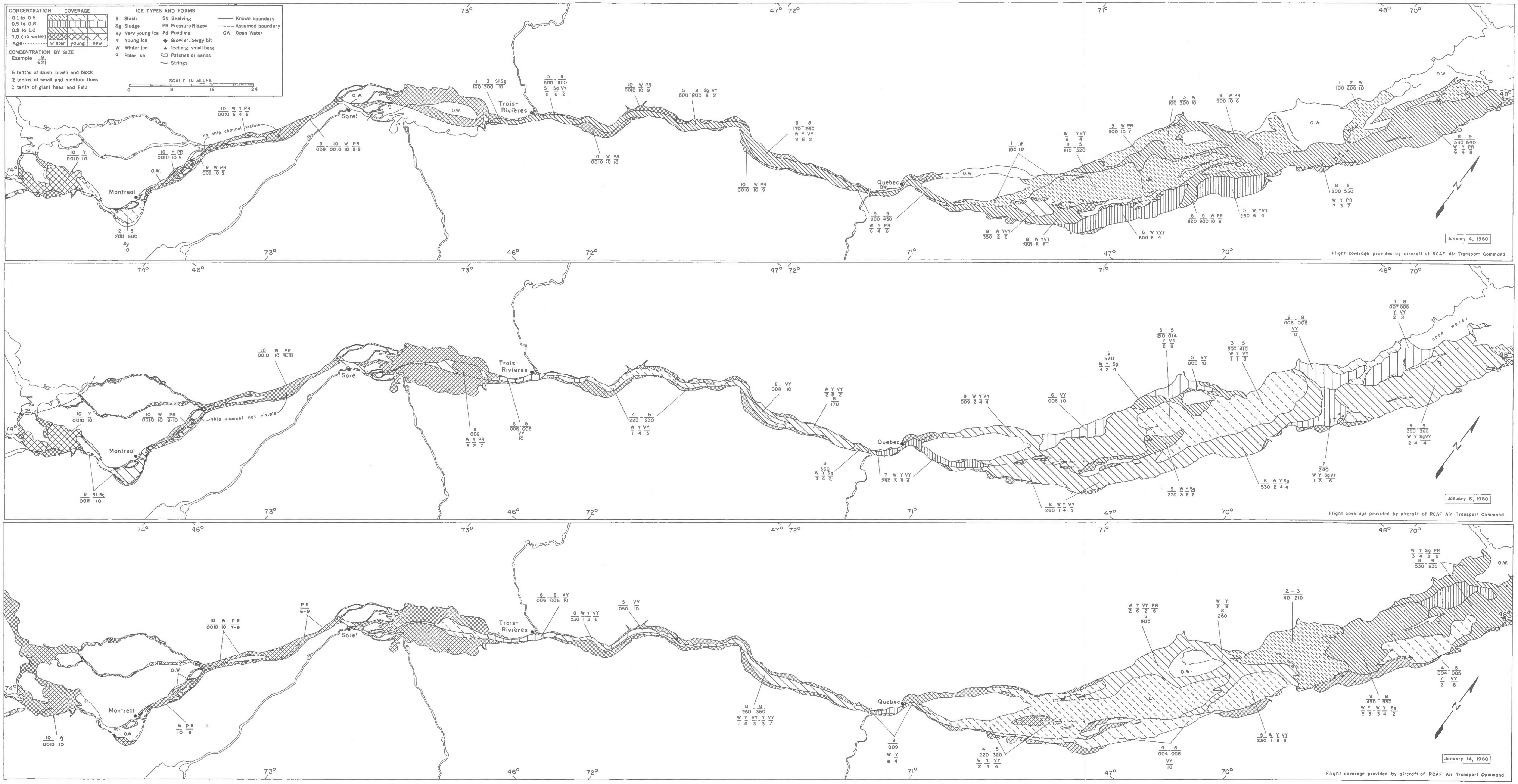


Figure 17. Ice distribution, St. Lawrence River, January 4, 6, 14, 1960.

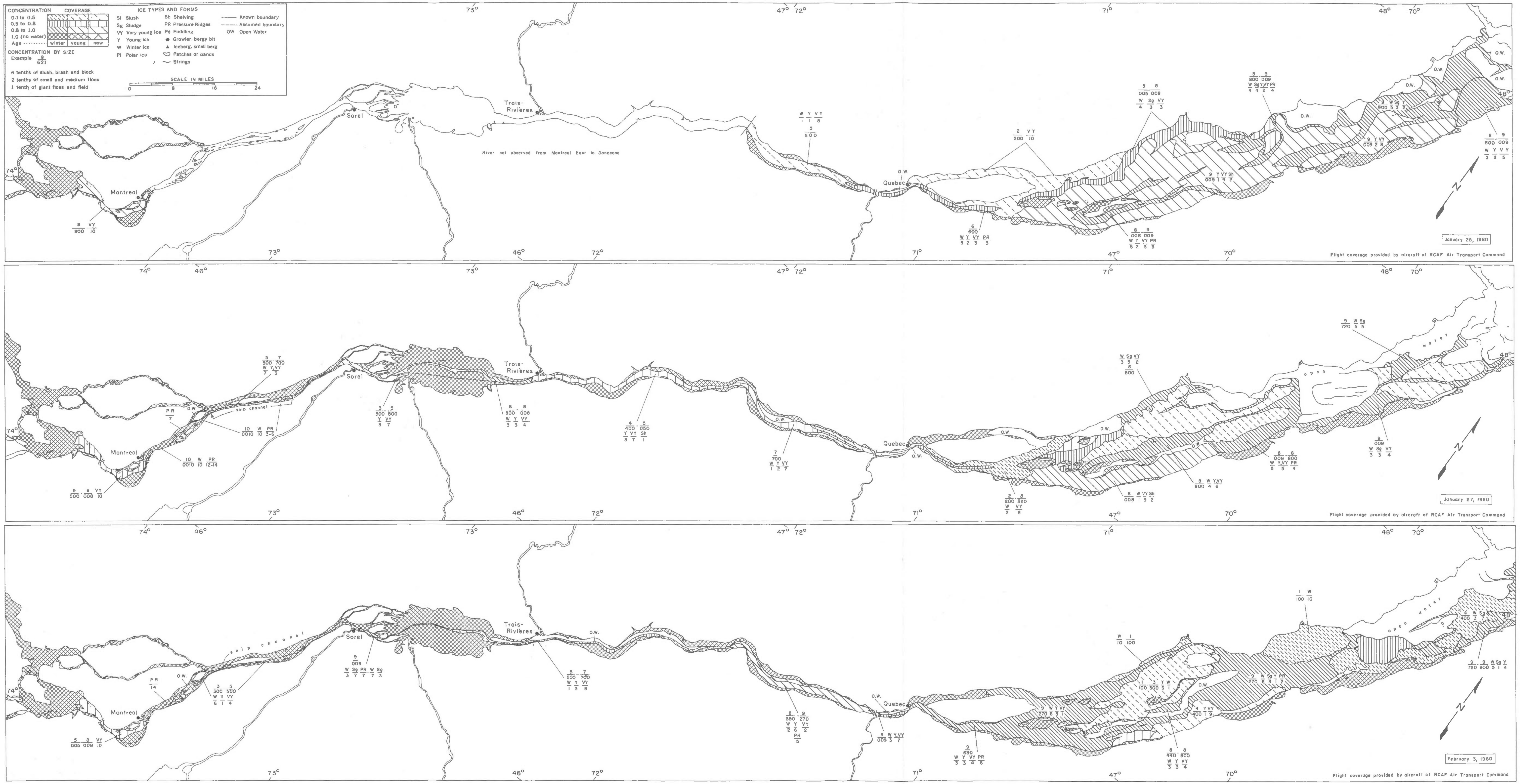


Figure 18. Ice distribution, St. Lawrence River, January 25, 27; February 3, 1960.

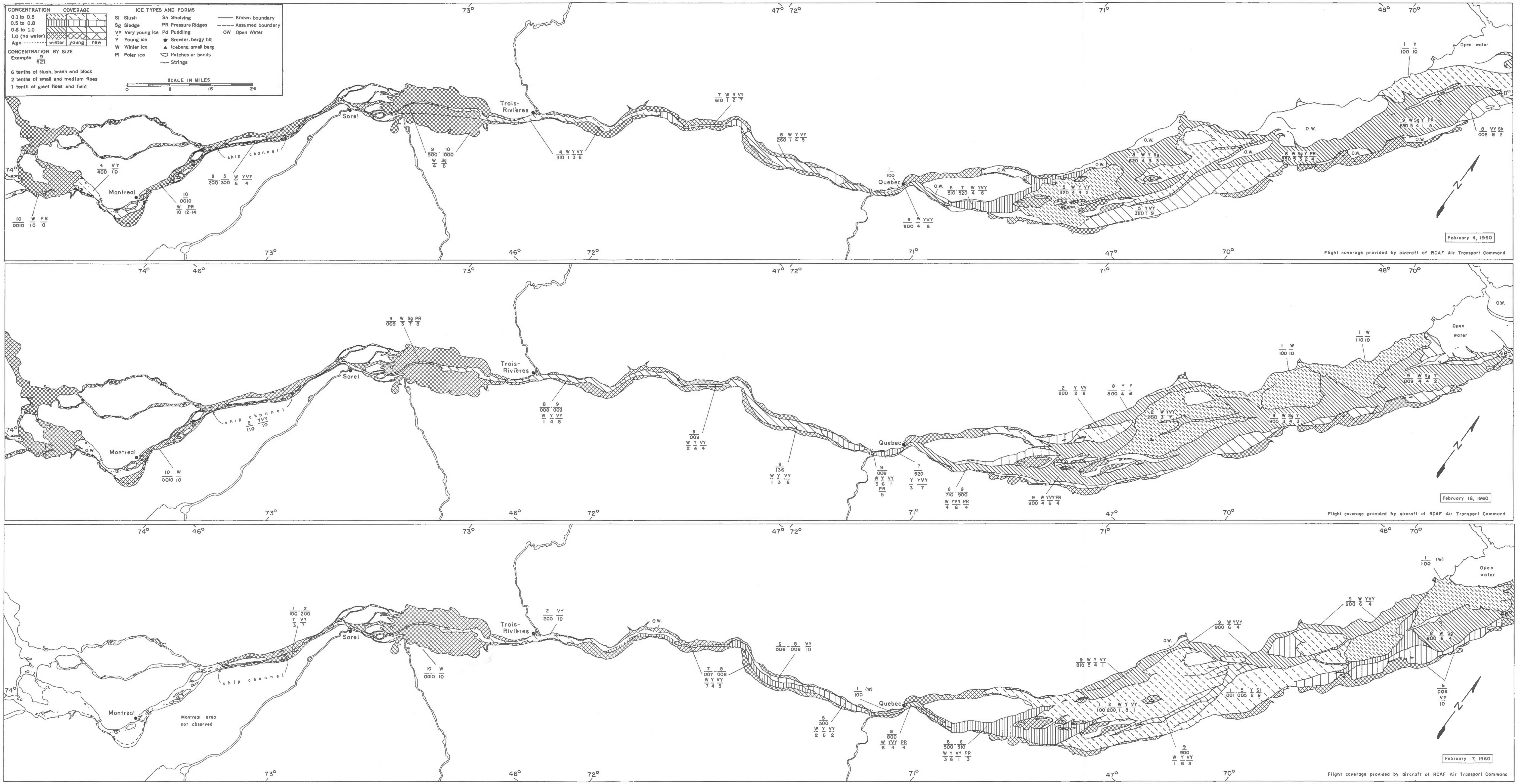


Figure 19. Ice distribution, St. Lawrence River, February 4, 16, 17, 1960.

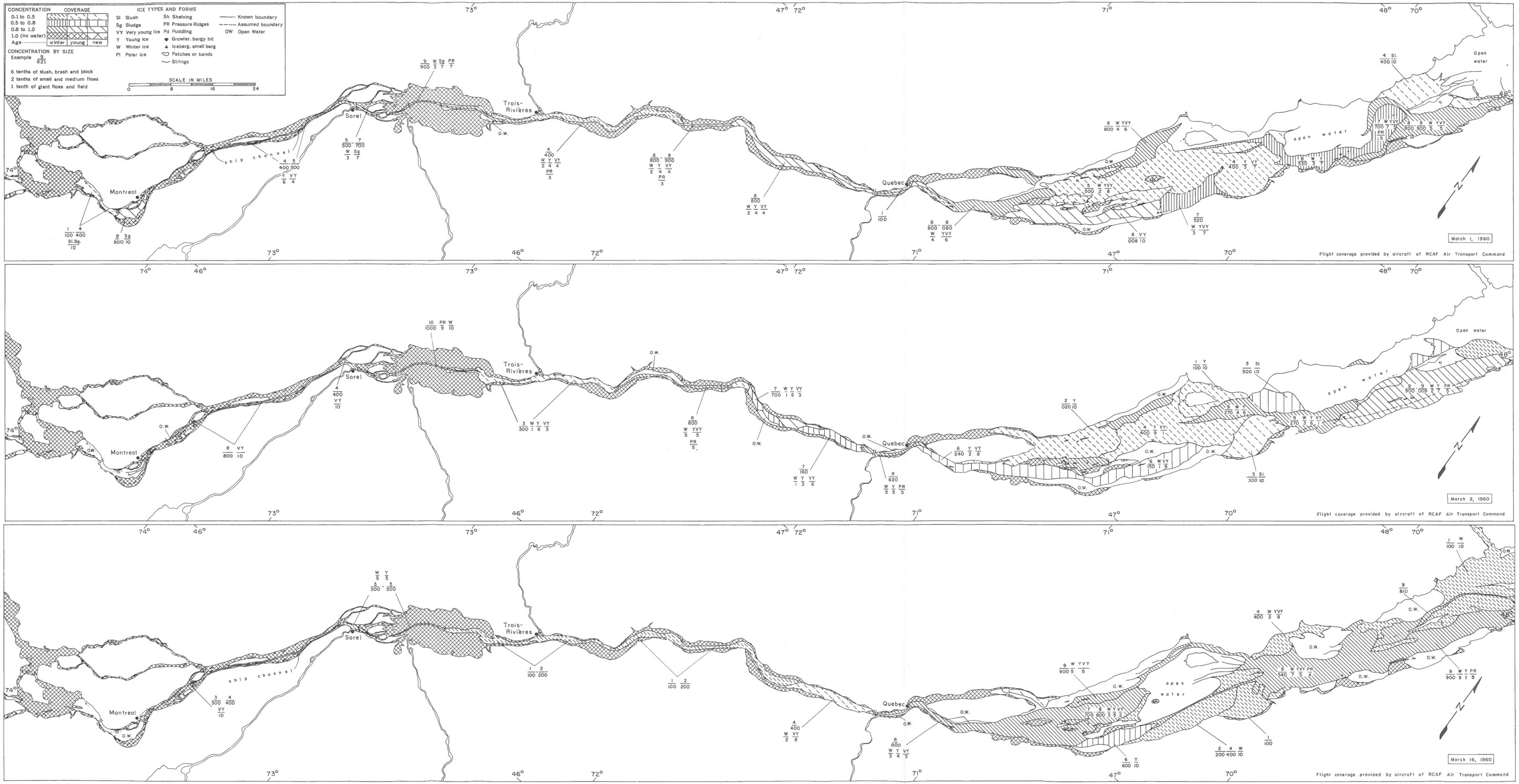


Figure 20. Ice distribution, St. Lawrence River, March 1, 2, 16, 1960.

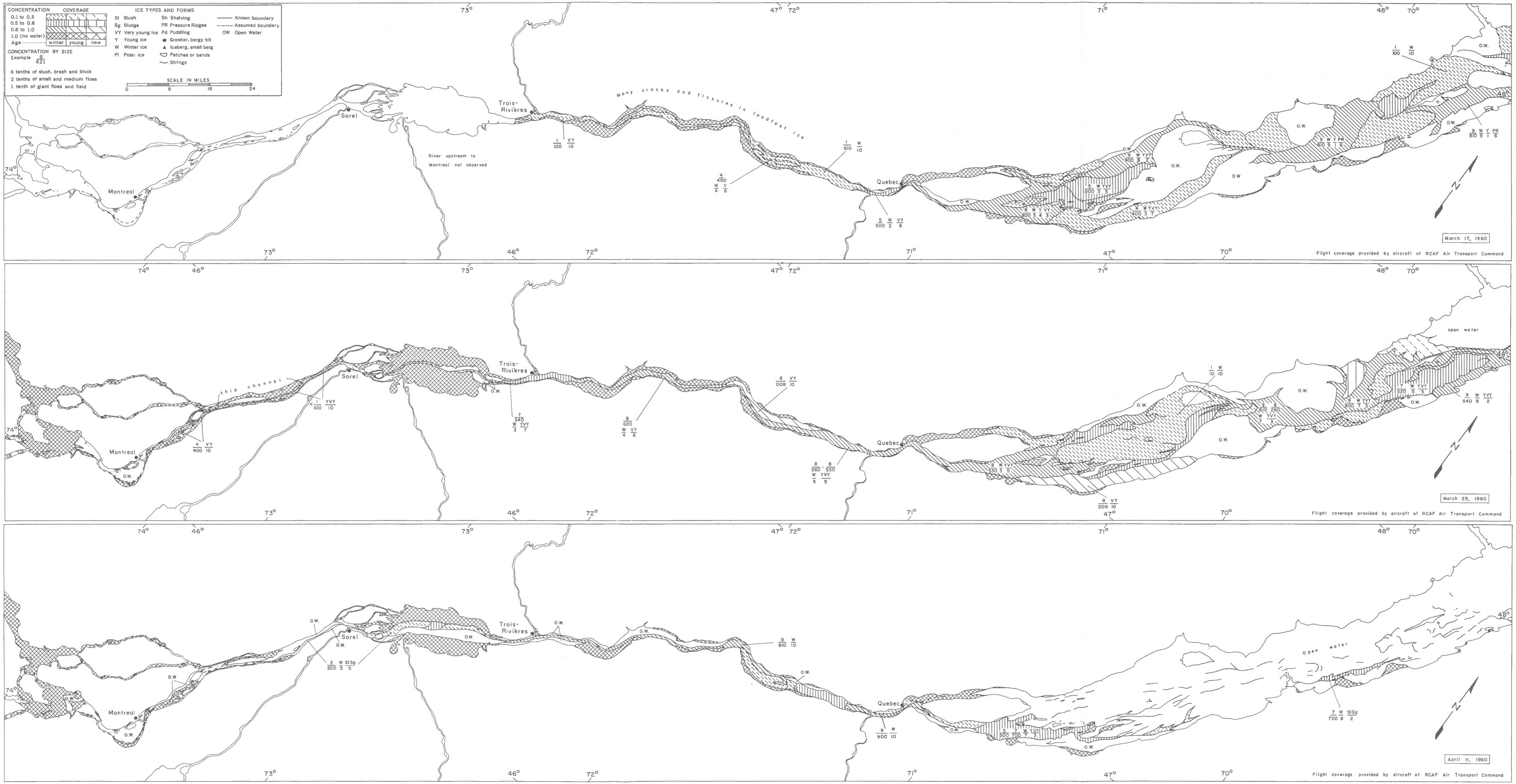


Figure 21. Ice distribution, St. Lawrence River, March 17, 29; April 11, 1960.

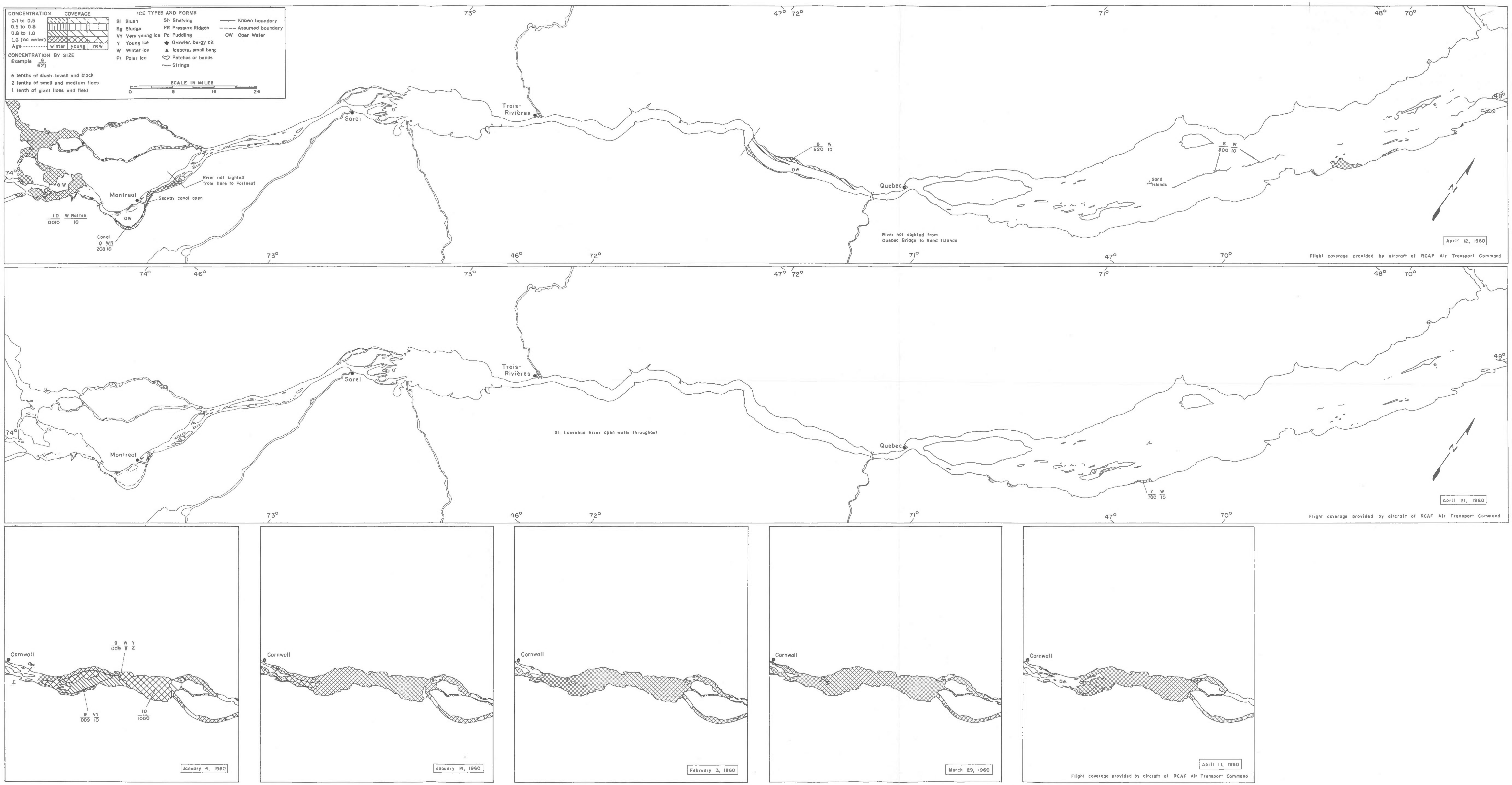


Figure 22. Ice distribution, St. Lawrence River, April 12, 21, 1960. Insets show the distribution below Cornwall on selected dates.

PART II

THE ST. LAWRENCE RIVER

The middle St. Lawrence River extends from Lake St. Louis to the Island of Orleans. The lower St. Lawrence River is the broad part of the river that extends from the Island of Orleans eastward to the mouth of the Saguenay River.

WEATHER CONDITIONS

November was a cool month in the St. Lawrence River valley; mean temperatures, ranging from 31 to 38 degrees, were 2 degrees above normal and were unfavorable for ice growth (Table IV). The months of December and January were slightly above normal; February was 6 to 10 degrees above normal; whereas March was 3 to 4 degrees below normal. The difference in temperatures between the southwestern and northwestern parts of the river was greatest at the beginning and the end of winter. The lowest temperatures were experienced in January, the regional difference being 2 degrees. An examination of the mean temperatures and the range of mean temperatures within the area for each month show that the period was very favorable for the formation of ice in the St. Lawrence River. Temperatures in Lake St. Peter area were from 1 to 2 degrees lower than either the upper or lower parts of the middle St. Lawrence River. April, with high mean temperatures of 38 to 43 degrees, was a month of rapid removal of the shorefast river ice.

TABLE IV

Mean Temperature values (F°)
(Middle St. Lawrence River area)

	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.
Mean temperature	33	21	13	21	23	39
Range in temperatures	30 to 35	18 to 24	11 to 14	20 to 22	22 to 24	38 to 43
Difference from normal	-1	4	1	6 to 10	-3 to -4	0 to 2
Degree-days of frost	-1	11	19	11	9	-7
Excess of temperatures at Montreal over Quebec	4	3	1	0	0	4

Ice formation and growth was a rapid process during the winter of 1959-60 as indicated by the degree-days of frost.* By the end of February the number of degree-days of frost had reached 41, a figure higher than that attained by any of the northern parts of the gulf for the same period.

*For the formation of fresh water ice the degree-day is based on 32° F.

RIVER ICE DISTRIBUTION

By the end of December the main outlines of the shorefast ice were well established; winter ice predominated except on the upper river above Varennes where young ice was an important constituent of the ice cover (see Figure 17, January 4). Landfast ice bordered both shores of the river downstream to the east end of the Island of Orleans. In the lower St. Lawrence River the north shore was relatively free of shorefast ice except for that formed at the heads of coves or beached by the tide. On the south side of the river the main outline of the shorefast ice was not established until mid-January; with a few gaps it then extended from Lévis to Father Point or Matane. Drifting ice on the lower river had advanced to the mouth of the Saguenay by January 4.

On the middle part of the St. Lawrence River from the Island of Orleans to the eastern entrance to Lake St. Peter, the ship channel was clearly defined. Shorefast ice extended across the tidal zone and anchored upon the lines of shoals that border various parts of the navigable channel. In this area the current flows at a variable rate of about 2 to 5 knots and tidal action, with a maximum rise of 1 foot at Three Rivers to 17 feet at Quebec, maintains an open channel carrying a load of drifting ice. Ice congestion occurs periodically, particularly at bends and in narrow constrictions of the river. In such places drifting ice accumulates and consolidates with the shorefast ice; the most notable of such features is the funnel-shaped constriction of the St. Lawrence River at the Quebec bridge.

From Lake St. Peter to Montreal harbor the river is much narrower, and is bordered by lines of islands and shoals that form anchors for the rapid expansion of shorefast ice. Thus with normal or lower seasonal temperatures, shorefast ice could be expected to bridge parts of the navigable channel. In the first half of January, it extended across the river from Montreal East to Sorel. That the channel was not difficult to open is indicated by the passage of a small icebreaker to Montreal prior to January 27 (see ice chart, January 27). In this reach of the St. Lawrence, the current flows at a variable rate of about 2 to 4 knots in a much narrower channel. The current provides a number of unusual effects: first, the current tends to move ice rapidly downstream and also to widen the channel; second, when an ice bridge or blockade forms, the ice piles up in a mass of pressure ridges that fuse with the shorefast ice.

The ice observed in the upper part of the middle St. Lawrence River consisted generally of new and young ice types; young and winter ice types were more important in the downstream parts of the river. A large part of the upper river ice originates in the open water area of the Lachine rapids. In normal winter weather new ice is constantly forming and drifting downstream; thus, the 15-mile long stretch of open water provides a breeding ground for ice that is constantly being fed into Montreal harbor and downstream channel areas. Here the effect is similar to that noted above; namely, that once an ice bridge has been established, massive pressure ridges varying from 5 to 15 feet high pile up in the lower Montreal harbor area.

Because of the shallow nature of Lake St. Peter, and the reduced flow of the current, winter ice develops rapidly on the lake. Two characteristics in relation to the ice are noted: with increasing flow of the current open water extends into the lake from its eastern entrance; because of reduced rate of flow the navigable channel is a congested ice area at the western end of the lake. The passage of small icebreakers through this channel during the winter months assisted the movement of ice downstream.

Ice continued throughout the winter to break off and to accumulate along the leading edge of the shorefast ice. Numerous cracks and fissures appeared in this ice above Quebec by mid-March. The first observation of a general retreat of the ice was on the lower St. Lawrence in mid-March. By the end of March the ice coverage of the lower St. Lawrence consisted of broad belts of ice separated by large areas of open water or by areas of low ice concentration. By April 11 these ice-fields were mainly reduced to strings.

Up to the end of March, changes in the outline of the shorefast ice in the middle St. Lawrence River were of a minor nature. After this date rapid changes occurred. On April 11, the upper St. Lawrence River was ice-free above Cornwall; from Cornwall to Three Rivers the break-up of the shorefast ice was well advanced, but below Three Rivers it was less well advanced. The river became ice-free between April 12 and 21.

ICE DISTRIBUTION MAPS

The various features of the distribution of the St. Lawrence River ice that were observed in the course of the 1960 ice reconnaissance survey are shown graphically in Figures 17 to 26. These maps cover the period from January 4 to April 21. As the survey covered the area between Cornwall and Montreal five insets were selected that are representative of ice conditions in this area at the time of freeze-up and the spring break-up. These insets are shown on Figure 26. The graphic and fractional method of showing ice types and ice concentrations is similar to that used in the ice distribution maps for the gulf.

SUMMARY

The aerial ice survey of the winter of 1960 showed the Gulf of St. Lawrence to be generally unsuited for an extension of the gulf icefields similar to that of the 1959 winter season. A comparison of average mean monthly temperatures for the gulf region for the 1958, 1959 and 1960 seasons is shown in Table V. Mean temperatures were higher than the 1959 winter season, but were in general lower than in the 1958 season. The ice distribution in the gulf during these seasons represented extreme conditions, whereas that of 1960 represented an ice cover that was intermediate to the two extremes in a relationship similar to that of mean temperature.

TABLE V

A comparison of mean, monthly winter temperatures ($F.^{o}$) for the years 1958, 1959 and 1960

	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.
1957 - 1958	35	27	24	23	30	38
1958 - 1959	33	14	18	19	19	36
1959 - 1960	34	24	20	26	24	33
Normal temperatures	32	22	15	14	23	33

The mean winter temperature from December 1959 to March 1960 ranged from 13 to 26 degrees in the northern gulf, from 23 to 29 degrees in the central gulf, from 20 to 31 degrees in the southern gulf, and from 13 to 23 degrees in the middle St. Lawrence River region. Of these regions the St. Lawrence River and the northern parts of the gulf were most conducive to the formation and maintenance of icefields.

By the end of December ice formations were well developed on the middle and lower St. Lawrence River. With January temperatures conducive to ice growth, the gulf icefields expanded rapidly so that two-thirds of the gulf was ice covered by February 4. In February the advance of the icefields was arrested, and retreat of the ice fronts followed; the deterioration of the icefields took the form of a fan-like retreat, progressing from the ice-free area of the southeastern gulf region. The middle St. Lawrence River became ice-free after mid-April, and the northern and western parts of the gulf after April 21. The most interesting feature of the season was the invasion of the gulf by the Labrador icefields. This ice entered the gulf about the first of January, reached its maximum penetration about the end of March, and disappeared from the gulf toward the end of April. Incursions of Labrador ice into the Strait of Belle Isle and the northeast arm continued until after mid-June.

Gulf ice consisted mainly of new and young ice types. For the most part winter ice rarely occupied more than 3/10 of the ice surface except on windward coasts or protected bays where the ice accumulated and consolidated into winter ice.

Winter Navigation

Winter navigation to the principal ports of the gulf region was not seriously threatened by the ice-fields as the greater part of the gulf remained open. The southern half of the west coast of Newfoundland was ice-free. Sydney, Nova Scotia was blocked for several weeks prior to mid-March, and shipping was aided with icebreaker assistance. Although Chaleur Bay was ice congested for 4 months of the winter, a continuous shipping service was maintained to Dalhousie, New Brunswick with the assistance of 3 and sometimes 4 icebreakers. Continuous service was maintained by the M.V. Abegweit across the ice-congested Northumberland Strait between Borden and Cape Tormentine. In the first half of March about 11 sealing vessels became trapped in the heavy ice that lay off the north coast of Prince Edward Island. An icebreaker based at Rimouski on the lower St. Lawrence esturary provided assistance to shipping in that area.

The first deep-sea vessel, the S.S. Baskerville, reached Quebec on January 3. Between January 1 and February 29, 1960 eleven deep-sea vessels reached Quebec with one proceeding to Three Rivers. The shipping season was opened to Montreal on March 21, with the arrival of the M.V. Eskimo which broke the previous record by 8 days. On April 11, the St. Lawrence Seaway canal was opened by the icebreaker C.G.S. Ernest Lapointe; shipping, however, did not pass through until April 19. The port of Bathurst on the south side of Chaleur Bay was opened by the M.V. Irvinglake on April 20, with icebreaker support. The Saguenay River was opened by the C.G.S. d'Iberville during the period March 28 to April 6.

In the period between December 1, 1959 and February 29, 1960, the principal gulf and river ports handled 397,554 tons from 121 vessels, with the port of Quebec accounting for 49,600 tons.

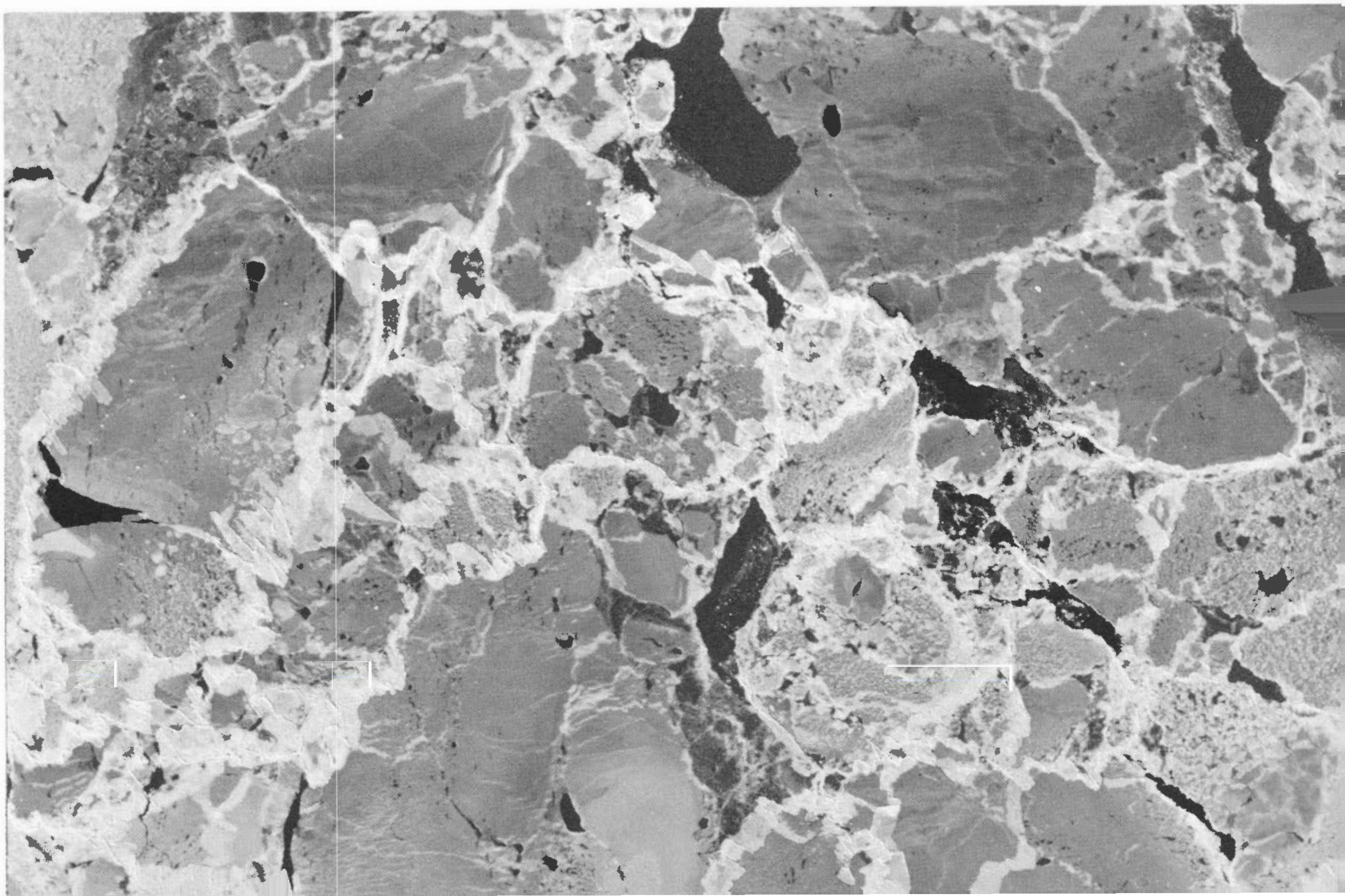
PHOTOGRAPHIC RECORD OF ICE COVERAGE

Because of the increasing importance of winter navigation and of the St. Lawrence Seaway, photographs were selected to illustrate ice conditions that existed at various times during the winter months. The photos provide a picture of the nature and distribution of the ice that may be encountered by ships using the St. Lawrence maritime winter route. The purpose of this visual presentation is to provide a clearer understanding of the special problems that ice presents to navigation at this time of the year. The photos are arranged according to ice types and in chronological order.

Figure 23. Landfast ice, bordering the south shore of the St. Lawrence estuary near Rimouski, shows the contact zone with new sea ice in the upper part of the photo. (Alt. 700 feet, Jan. 6, 1960)

Figure 24. A new icefield is being shattered by strong winds. The ice at this stage is often called slob ice. (Northumberland Strait, alt. 2,700 feet, Jan. 27, 1960)

Figure 25. Very young ice is dark in appearance. This icefield consolidating areas of slush and sludge is under pressure; the interlocking of the ice edges shows that shelving is in progress. (Gaspé coast, alt. 3,000 feet, Jan. 14, 1960)



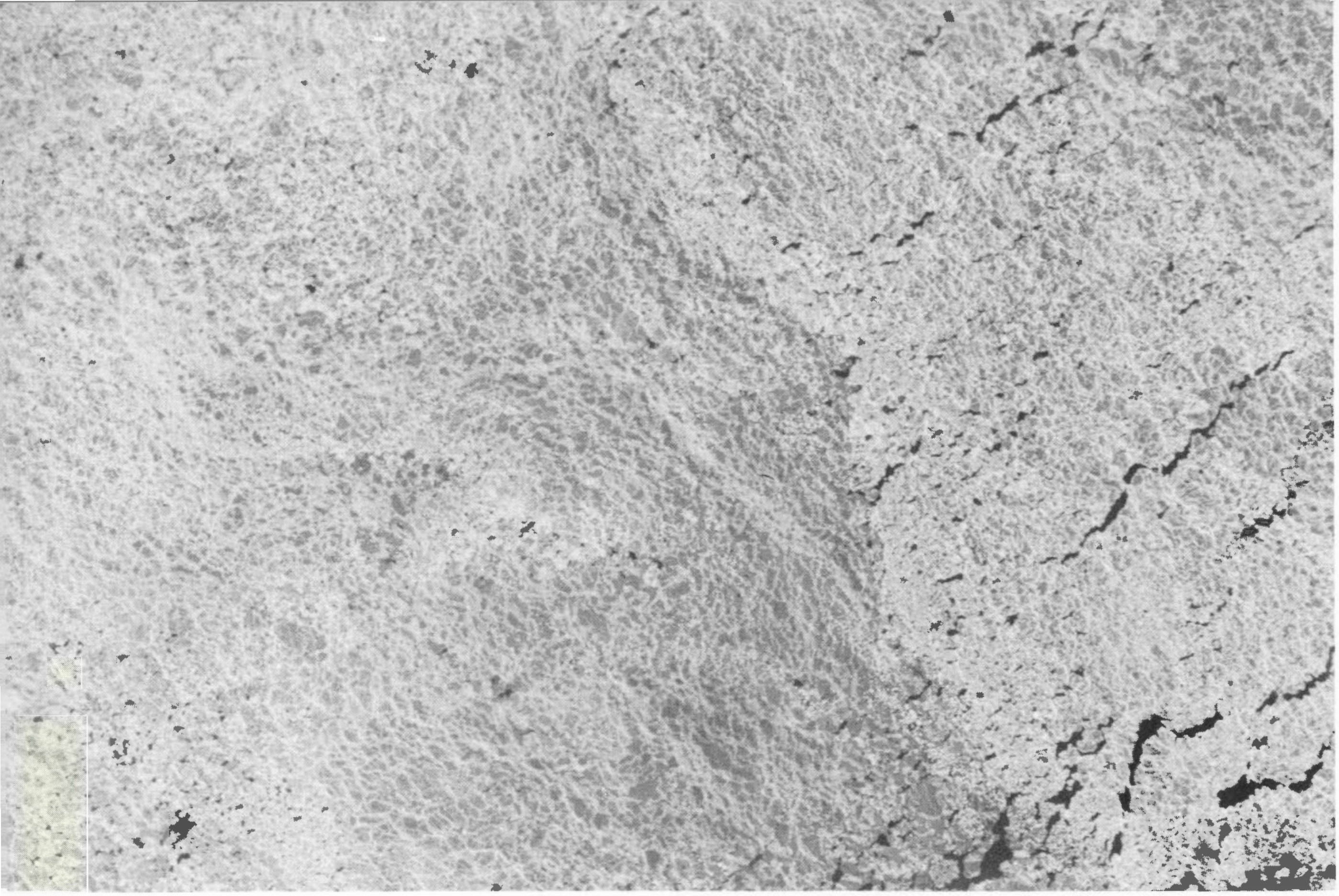


Figure 26. Frequently because of the intricate nature of the shelving process, very young ice may take on a grey appearance similar to young ice. (Strait of Belle Isle, alt. 1,800 feet, Jan. 5, 1960)

Figure 27. Very young ice advances to form young ice by means of shelving. (St. Lawrence estuary, alt. 1,000 feet, Jan. 15, 1960)

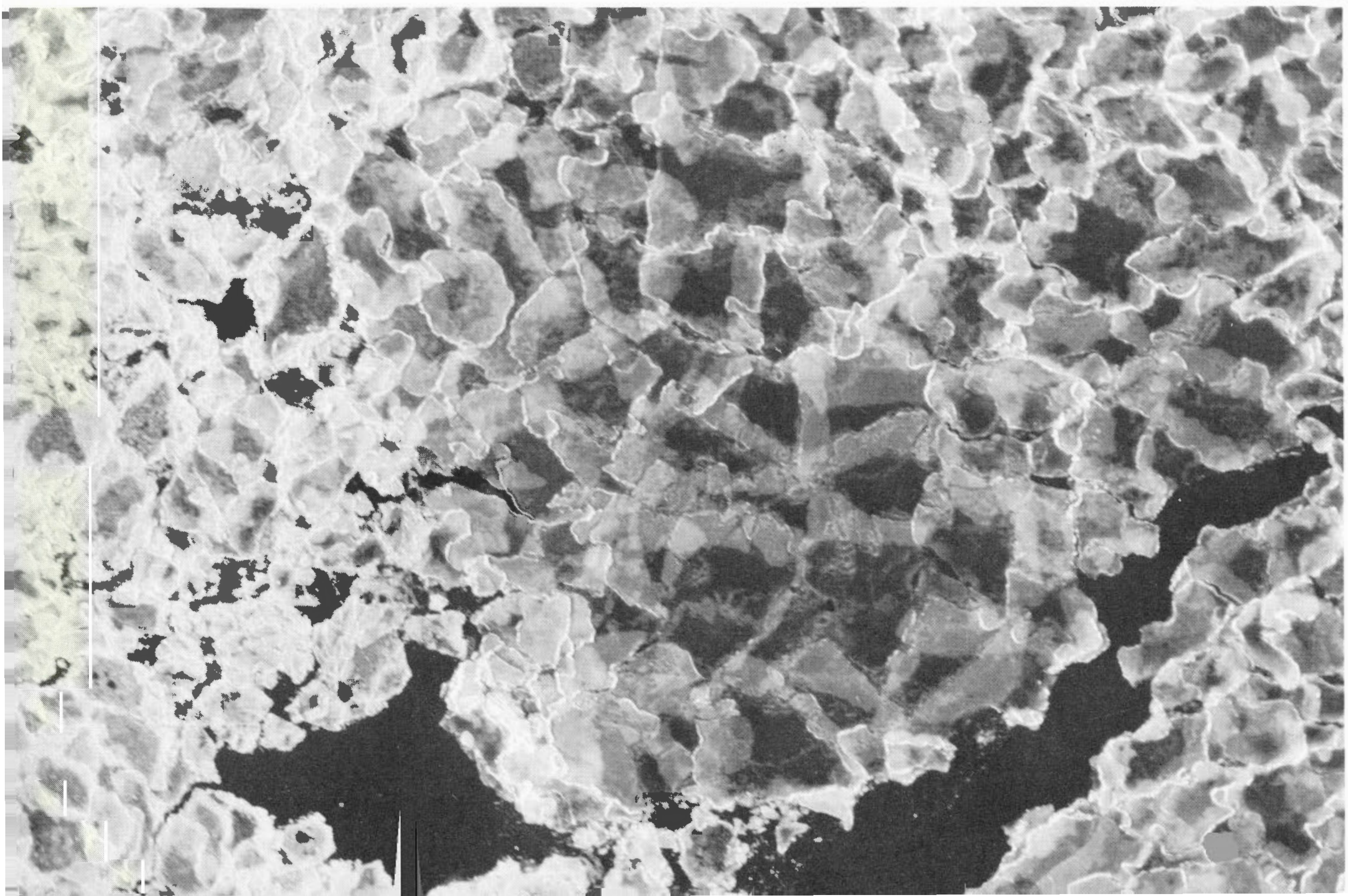


Figure 28. A field of winter ice showing heavy ridging. A consolidated field of winter ice seems to provide the most suitable conditions for seals at whelping time. (North coast of Prince Edward Island, alt. 1,000 feet, March 7, 1960). Courtesy Hunting Survey Corporation Ltd.

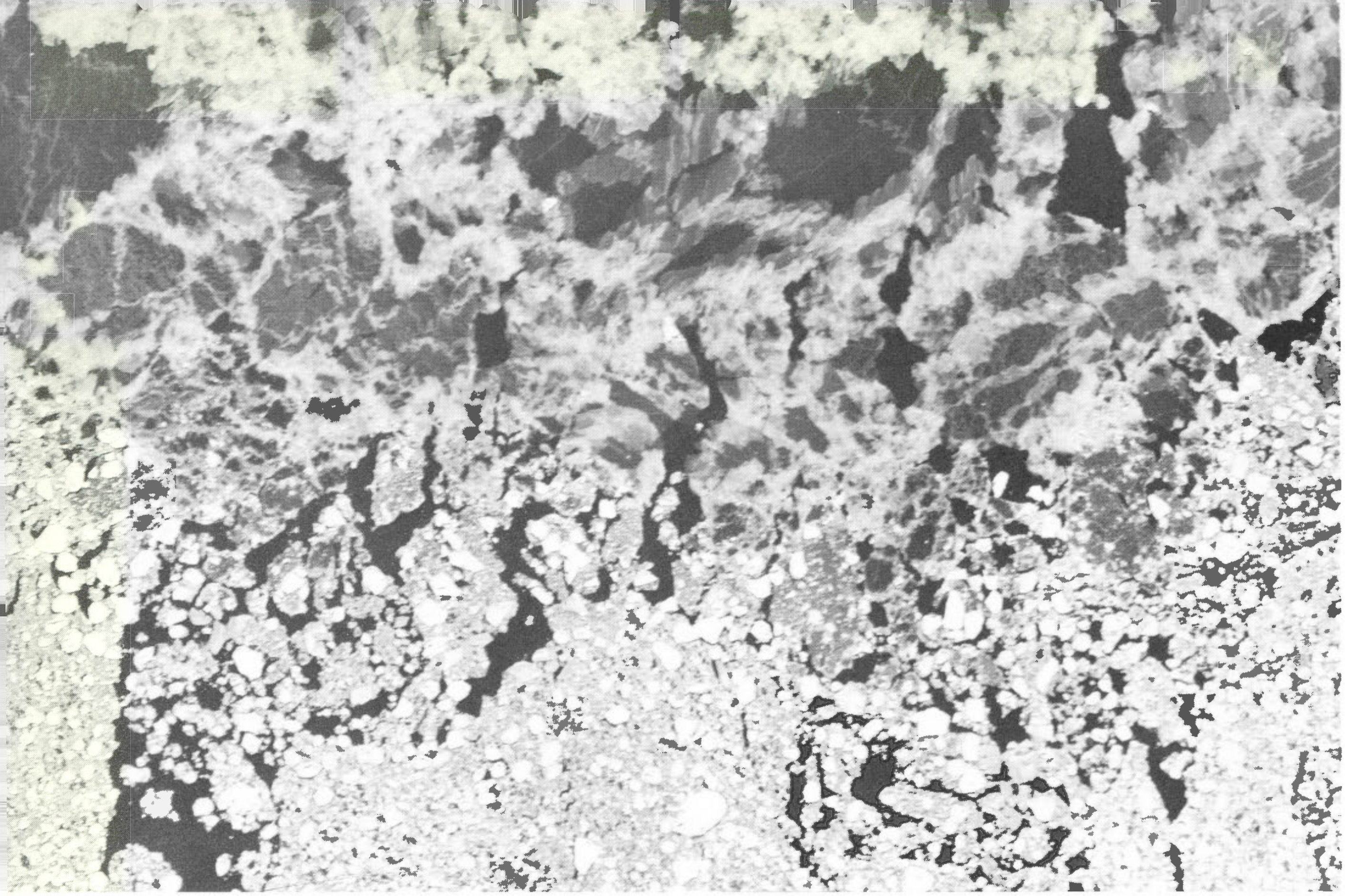
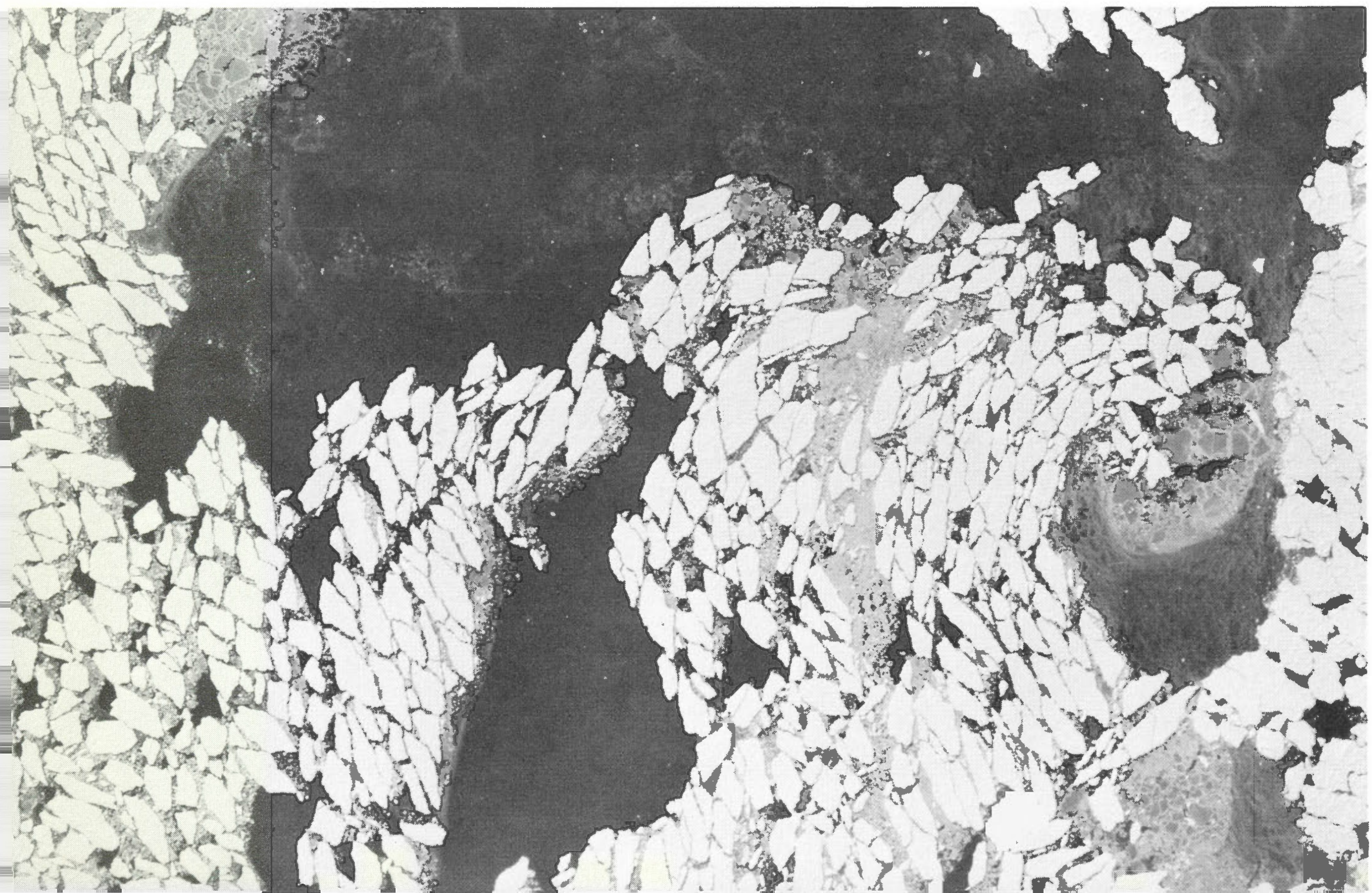


Figure 29. Small winter floes are contained in slob ice in the lower part of the photo. In the upper part, intensive shelving is taking place in new ice. (Chaleur Bay, alt. 1,800 feet, Feb. 17, 1960)

Figure 30. A field of winter ice and new ice types. The winter ice, fractured into even-sized floes, is in turn being consolidated by the formation of new ice. (North coast of Prince Edward Island, alt. 2,700 feet, Jan. 27, 1960)



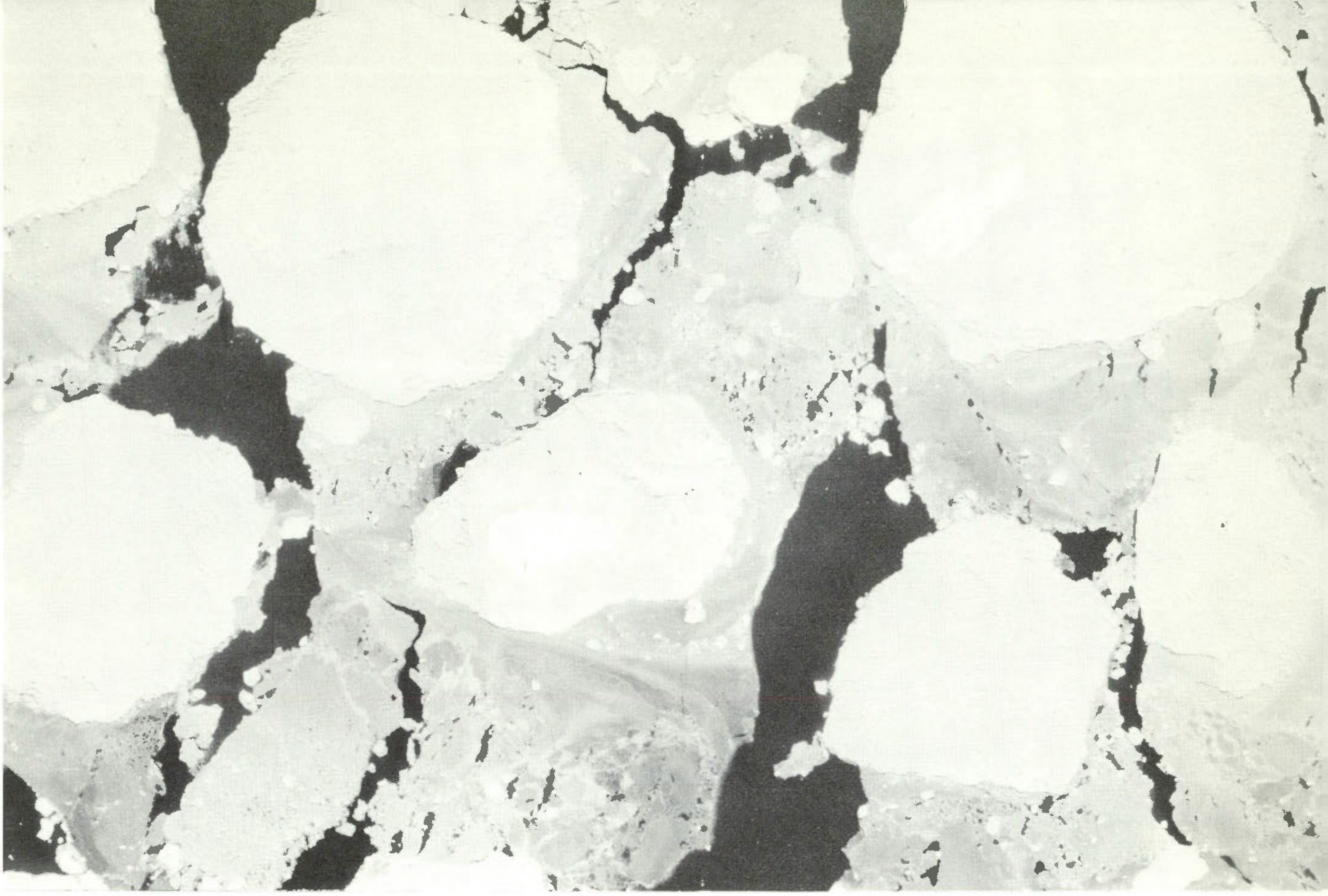
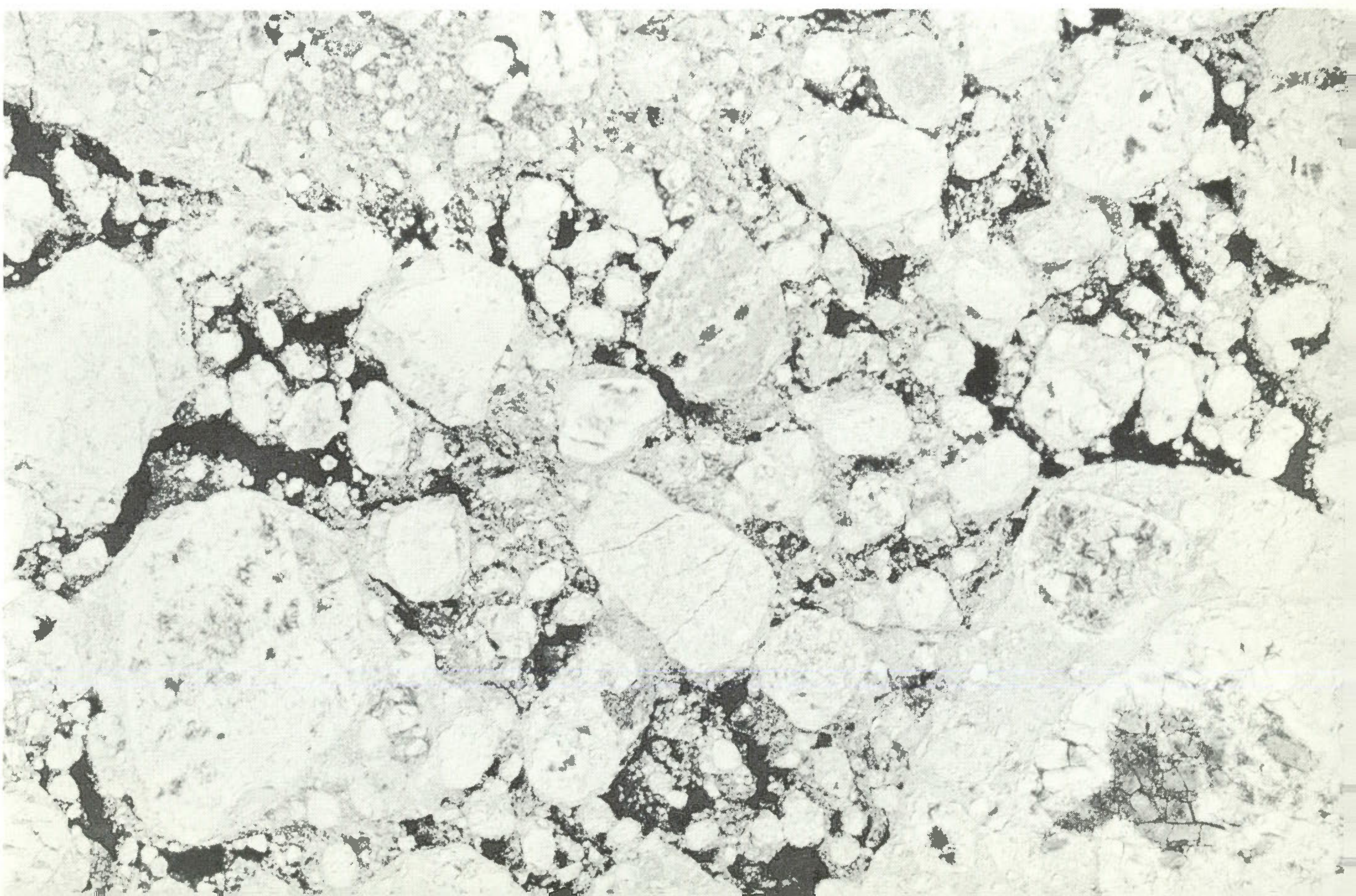


Figure 31. A field of new, young, and winter ice types. Floes of winter ice are being consolidated by the formation of new and young ice; the latter is breaking apart. (St. Lawrence estuary, alt. 3,000 feet, Feb. 16, 1960)

Figure 32. Winter ice that has been severely worked over is in a state of decay. (Northumberland Strait, alt. 3,000 feet, April 21, 1960)



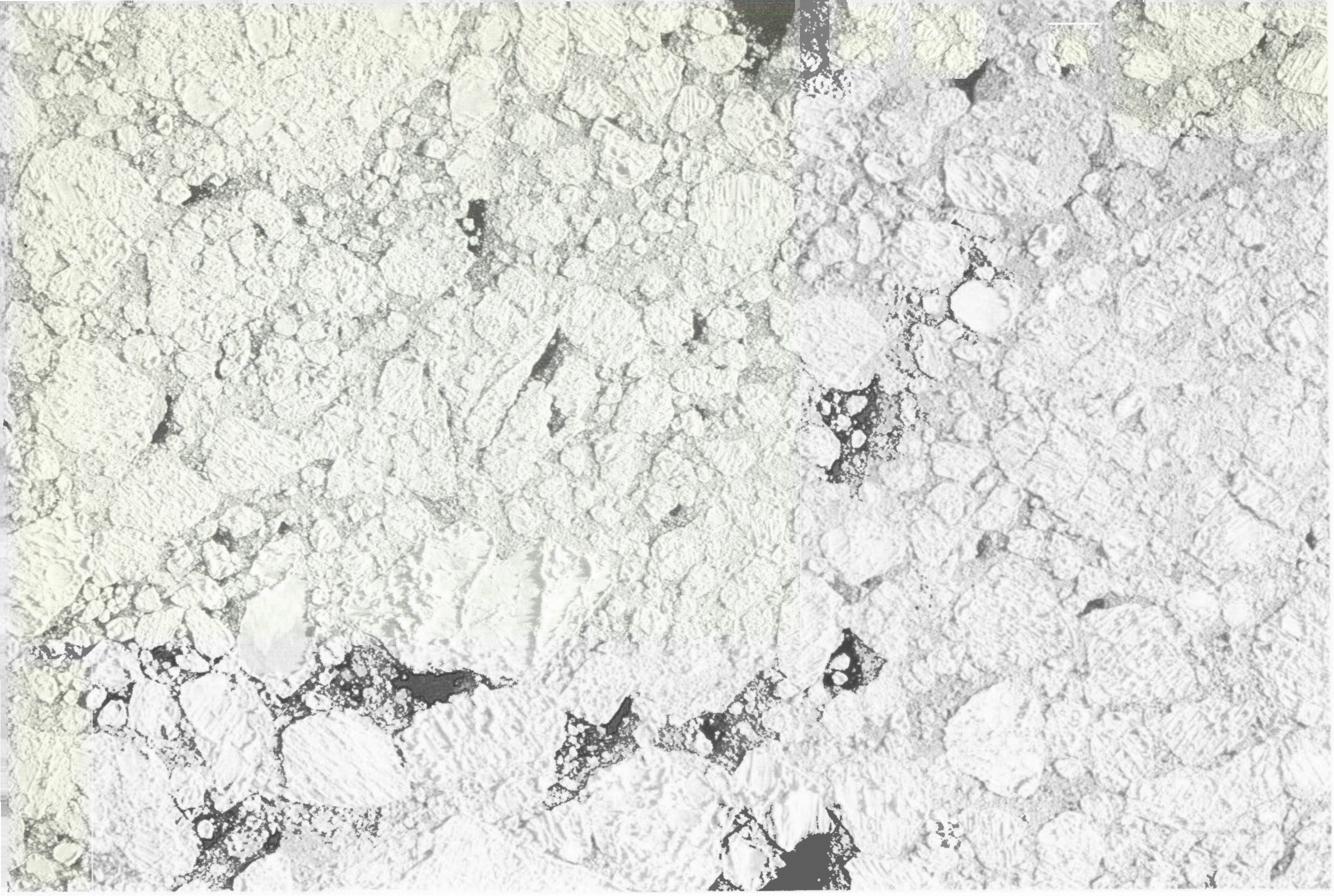


Figure 33. A field of polar ice that has been severely worked over. The floes contain a jumbled mass of pressure ridges. (Strait of Belle Isle, alt. 2,000 feet, Jan. 29, 1960)

Figure 34. The ice edge formed by new and young landfast ice is bordered above by a field of slob ice formed from the wreckage of new, young, and winter ice types. (Miscou Island, alt. 2,700 feet, Jan. 27, 1960)

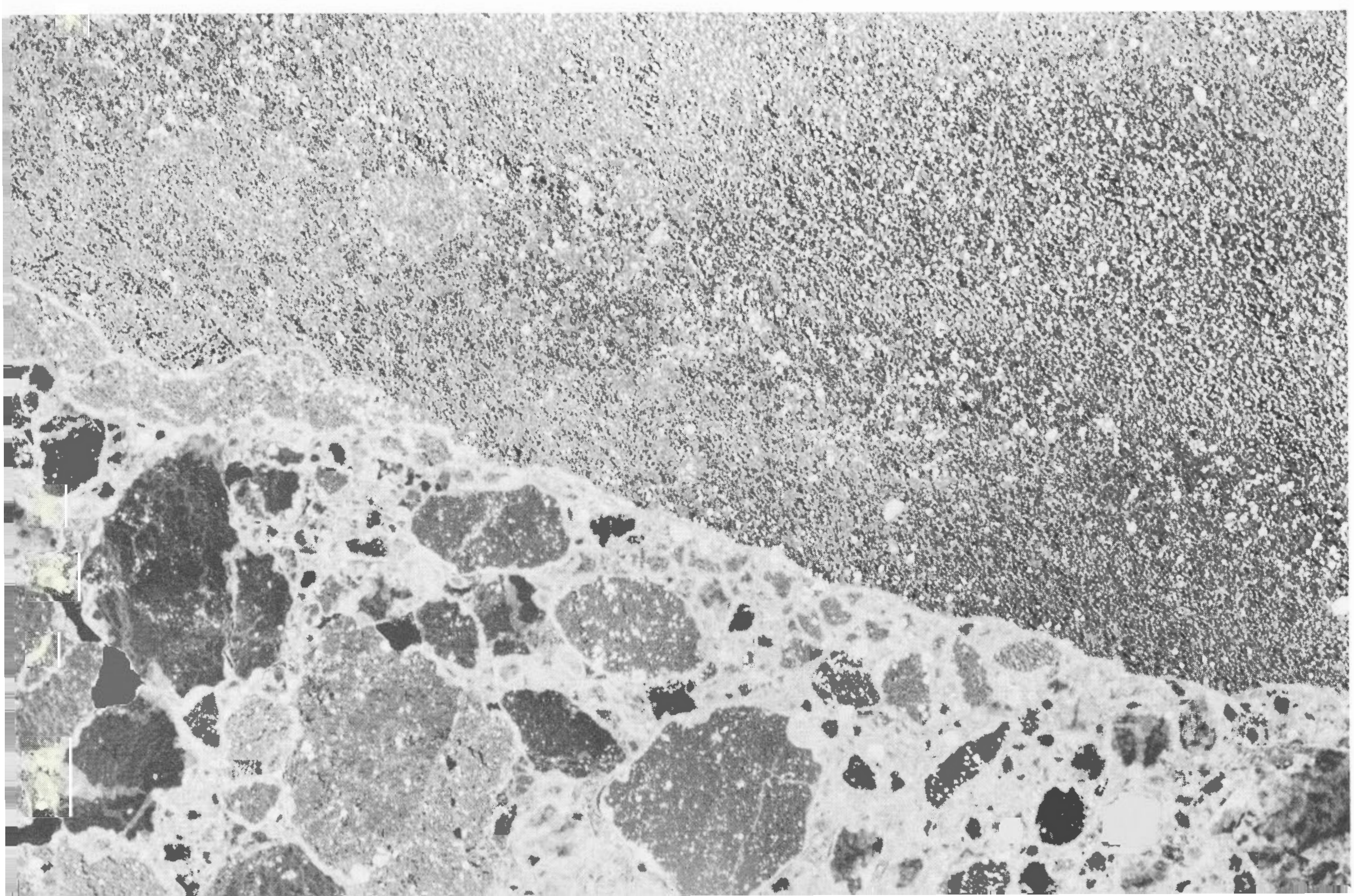


Figure 35. A landfast field of new and young ice, with winter ice in the lower right. The disturbance in the ice is caused by the passage of an icebreaker. (St. Lawrence River near Sorel, alt. 1,100 feet, Jan. 6, 1960)

Figure 36. Winter ice, bordering the south coast of the Strait of Belle Isle at Wreck Cove, is prevented from becoming landfast ice because of the tide and the current. (Alt. 1,800 feet, Jan. 5, 1960)

Figure 37. A well-developed field of winter landfast ice showing fractures caused by tidal movements. (St. Lawrence River near Donnacona, alt. 1,680 feet, Jan. 4, 1960)

Figure 38. The St. Lawrence River estuary looking northeast over the winter icefields from Rimouski showing the edge of the winter ice on the north shore bordered by open water or by new ice. The trace of an icebreaker appears in the foreground. (Alt. 2,900 feet, Jan. 27, 1960)

Figure 39. This photo of the St. Lawrence estuary near Rimouski shows the edge of the winter icefields and the northern part of the river which is mainly ice free. (Alt. 1,600 feet, Mar. 2, 1960)

Figure 40. A view of the icefields looking towards Father Point on the south side of the St. Lawrence estuary, and showing the winter ice bordering the coast with new ice adjacent to the winter ice. Two deep sea freighters are hove-to outside the winter ice pack. (Alt. 1,800 feet, March 29, 1960)

Figure 41. A view of the Strait of Belle Isle looking north from its southern shore over polar icefields. (Alt. 2,000 feet, Jan. 25, 1960)

Figure 42. View looking southeast down Northumberland Strait, showing a broad band of new ice that parallels the south coast of Prince Edward Island, and winter ice that borders the southern side of the strait. (Alt. 7,000 feet, Feb. 4, 1960)

Figure 43. A view north across Northumberland Strait to the Prince Edward Island shore showing the C.G.S. *Abegweit* passing through fields of young and winter ice. (Alt. 1,500 feet, Feb. 16, 1960)

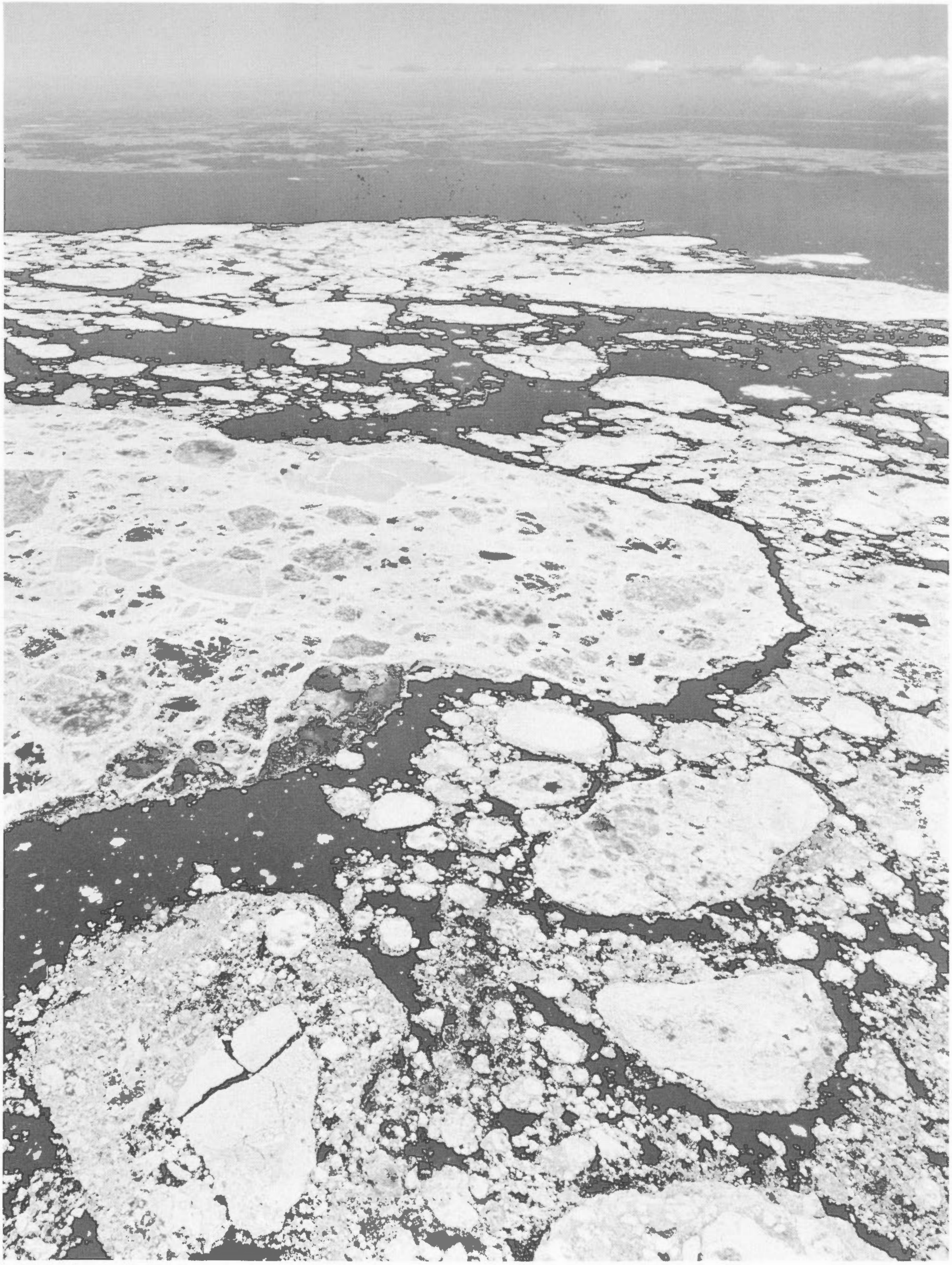


Figure 44. A view looking north across Northumberland Strait to Prince Edward Island showing that landfast ice has disappeared from the bays. A belt of winter ice is being rocked back and forth with the tide in the strait. (Alt. 6,000 feet, Apr. 23, 1960)

Figure 45. The icebreaker C.G.S. *Labrador* escorts a freighter through young ice to Dalhousie off the north shore of Chaleur Bay. (Alt. 1,500 feet, Feb. 17, 1960)

Figure 46. South across the Chaleur Bay icefields to Bathurst, N.B. (Alt. 1,500 feet, Feb. 17, 1960)

Figure 47. A deep sea freighter, hove-to in young ice, in the vicinity of Rimouski. (Alt. 1,200 feet, Jan. 14, 1960)

Figure 48. An icebreaker, driving astern to free a low-powered freighter, is pushing through young ice near Matane. (Alt. 1,200 feet, Jan. 14, 1960)

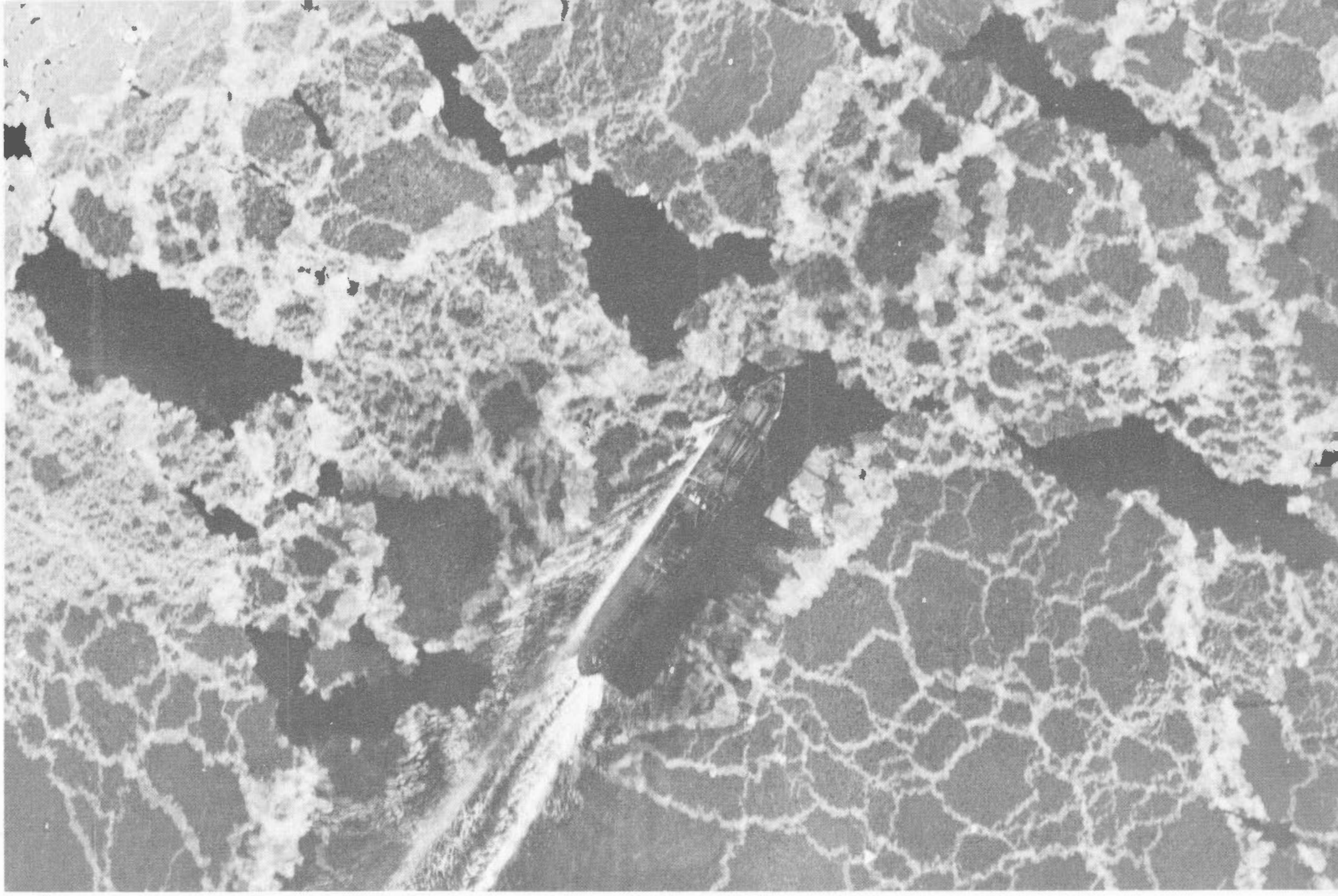


Figure 49. A deep sea freighter, outbound, is passing through new ice in the lower St. Lawrence estuary east of Baie Comeau. (Alt. 1,700 feet, Jan. 14, 1960)

Figure 50. A deep sea freighter is passing through a field of slush and sludge in the northwest arm of the Gulf of St. Lawrence. (Alt. 3,000 feet, Feb. 16, 1960)

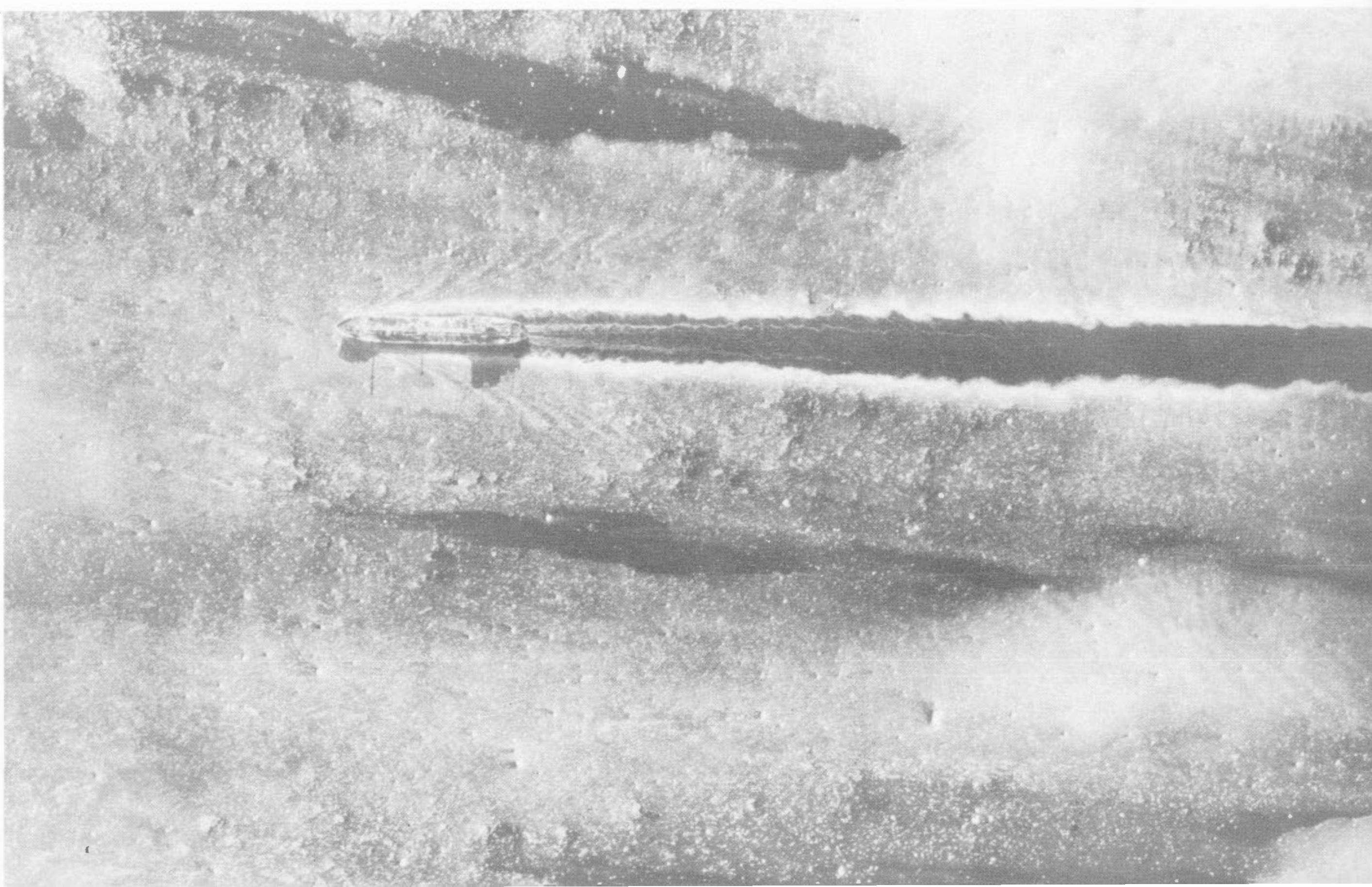


Figure 51. This view shows the congested nature of the winter ice in the Montreal harbor area. (Alt. 900 feet, Feb. 3, 1960)

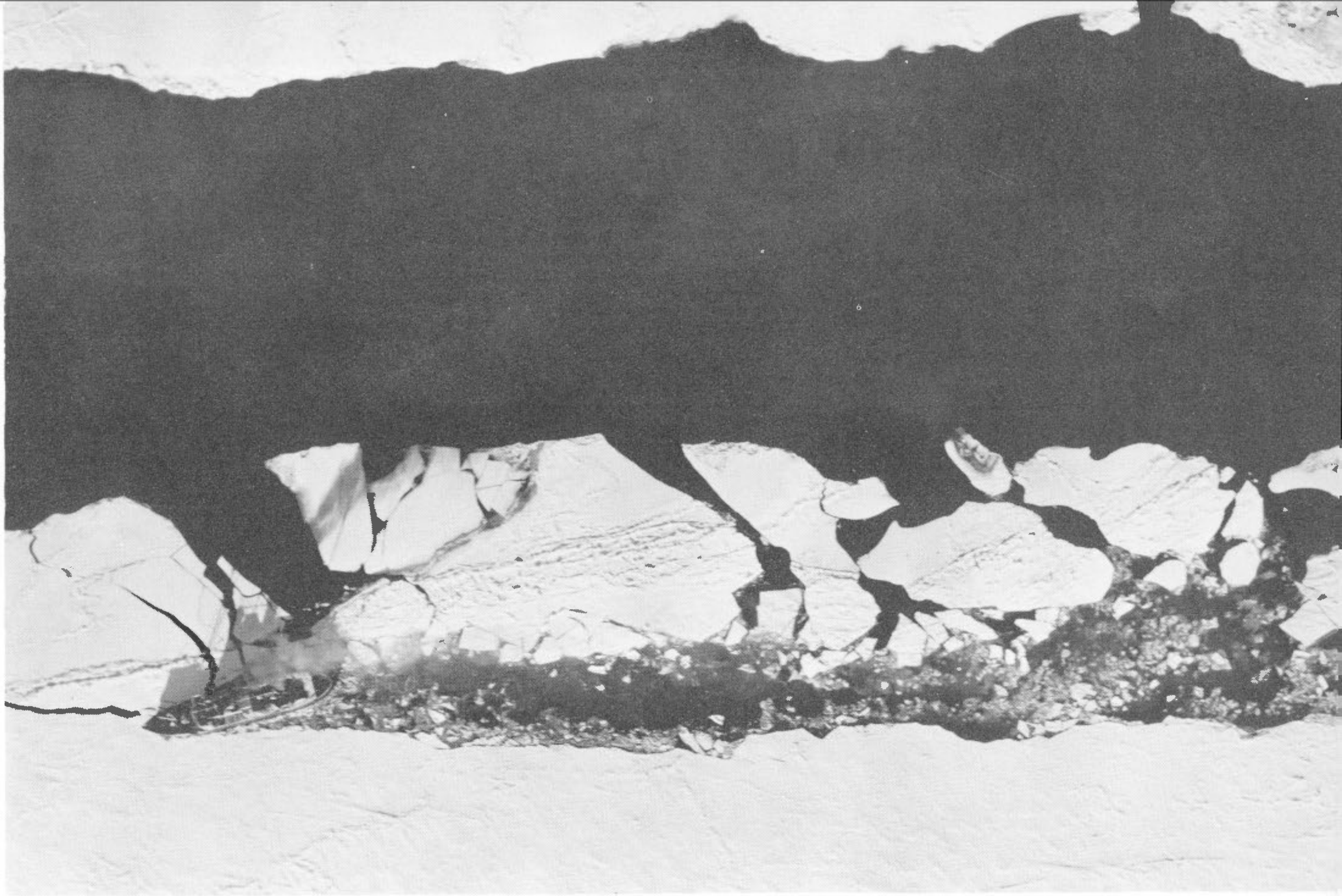


Figure 52. The winter ice, pushed by the icebreaker from the encroaching edges of the shorefast ice of the middle St. Lawrence River, is carried downstream by the current. (Varennes, Alt. 1,200 feet, Jan. 14, 1960)

Figure 53. This view, looking north across the St. Lawrence River near Batiscan, shows the navigable channel well-defined between the leading edges of the shorefast ice. (Alt. 1,640 feet, Jan. 27, 1960)

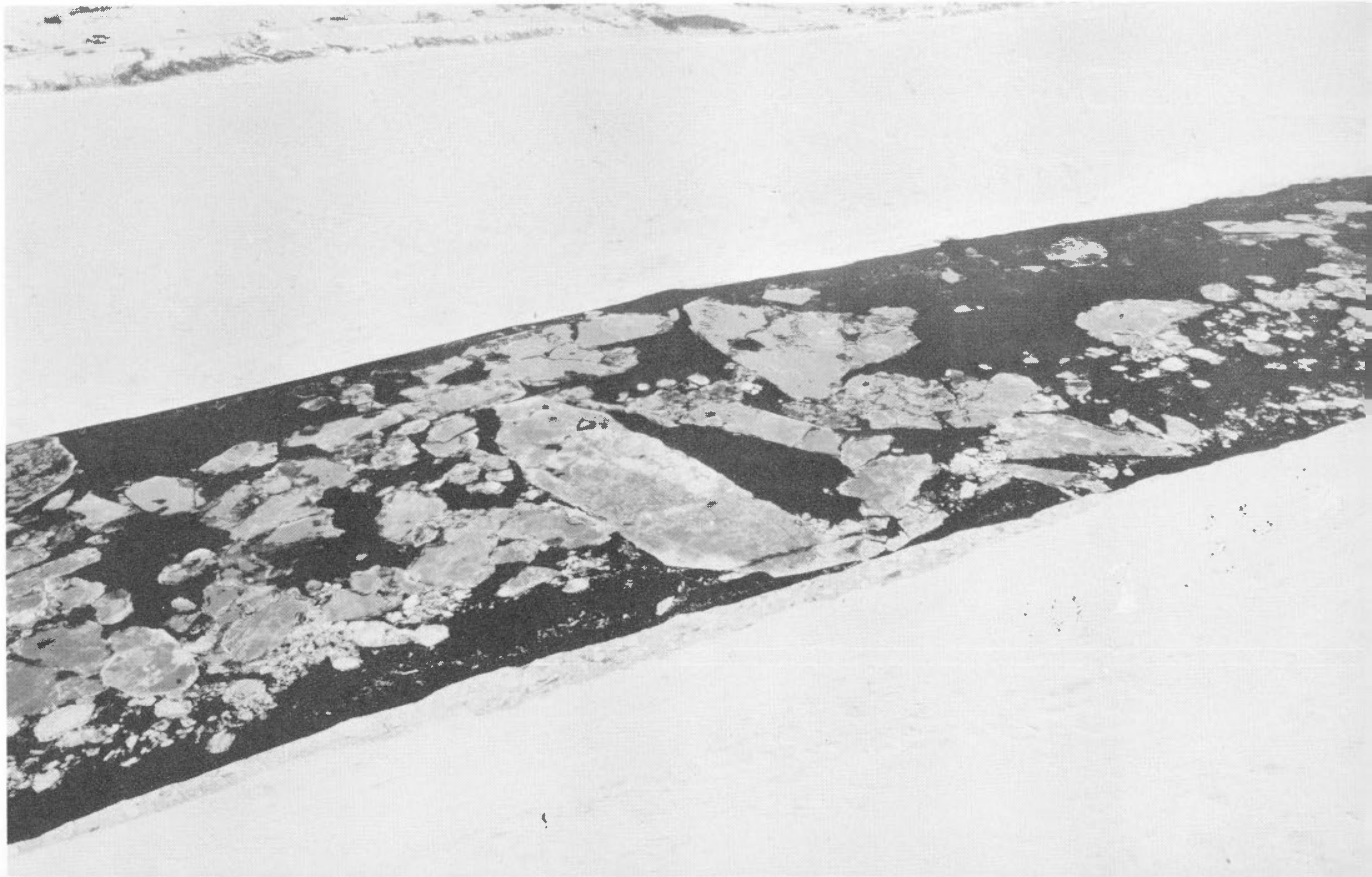


Figure 54. View of the St. Lawrence River looking downstream from Verchères showing a well-defined channel bordered with shorefast ice. During the first part of January shorefast ice extended across this channel but was readily freed by the passage of an icebreaker. (Alt. 900 feet, Feb. 3, 1960)

Figure 55. This view, looking northeast downstream across Lake St. Peter, shows the eastern part of the navigable channel open, and the western part ice congested. (Alt. 7,000 feet, Feb. 4, 1960)

Figure 56. The navigable channel through the western part of Lake St. Peter is generally filled with congested ice. The C.G.S. *d'Iberville* is pushing through this ice toward Sorel. (Alt. 900 feet, Feb. 3, 1960)

Figure 57. The congested nature of the ice in the navigable ship channel at the western end of Lake St. Peter is clearly defined. The icebreaker tracks through this ice are clearly shown. (Alt. 3,000 feet, Feb. 16, 1960)

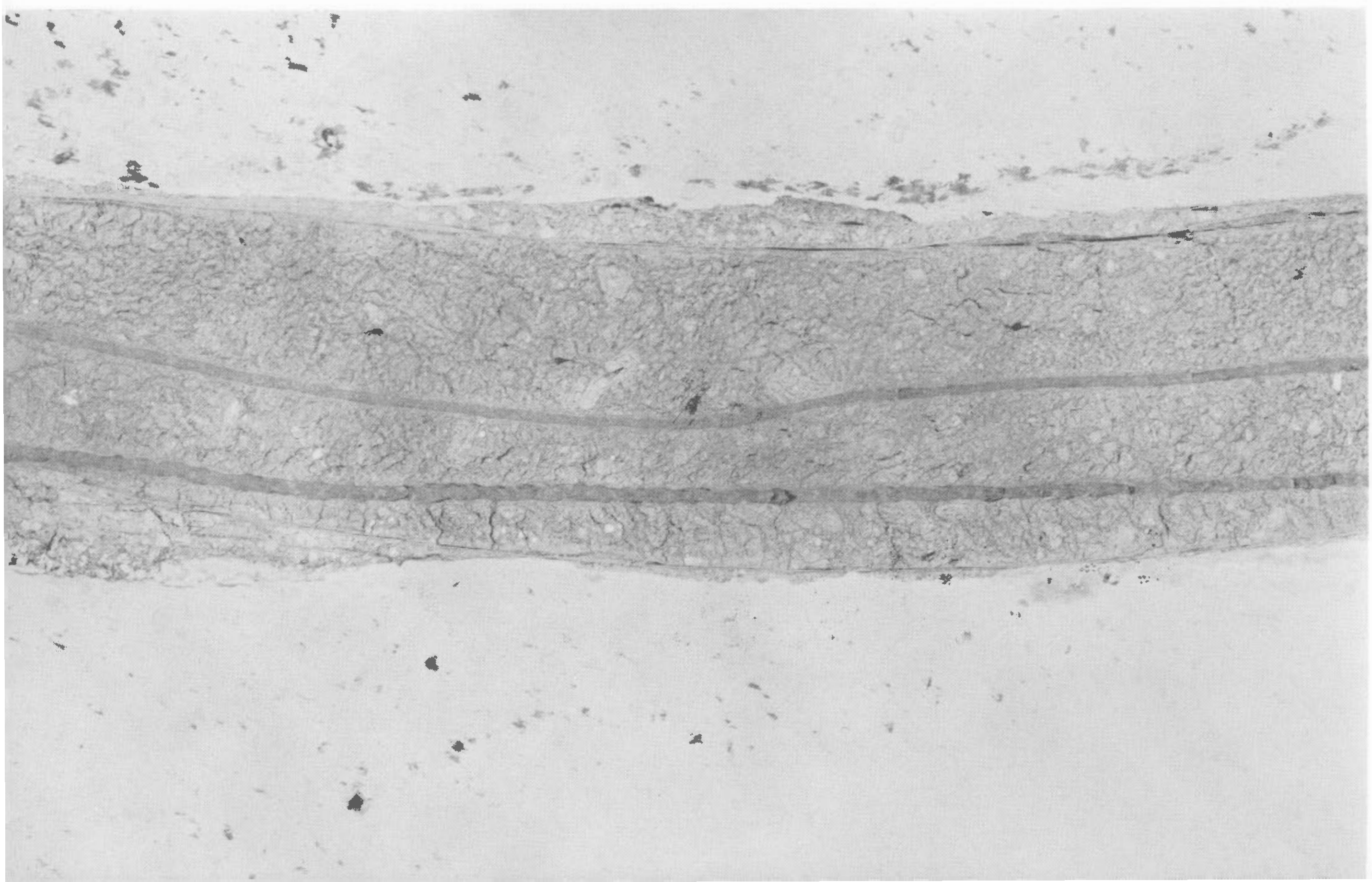


Figure 58. Congestion and consolidation of the ice in the Lake St. Peter reach of the river begins early and ends late. The main problem for the icebreaker in this area is to keep the ice moving downstream. (Alt. 1,600 feet, Mar. 1, 1960)

Figure 59. This ice congestion at the Quebec bridge is composed mainly of new and young ice types. (Alt. 2,100 feet, Feb. 3, 1960)

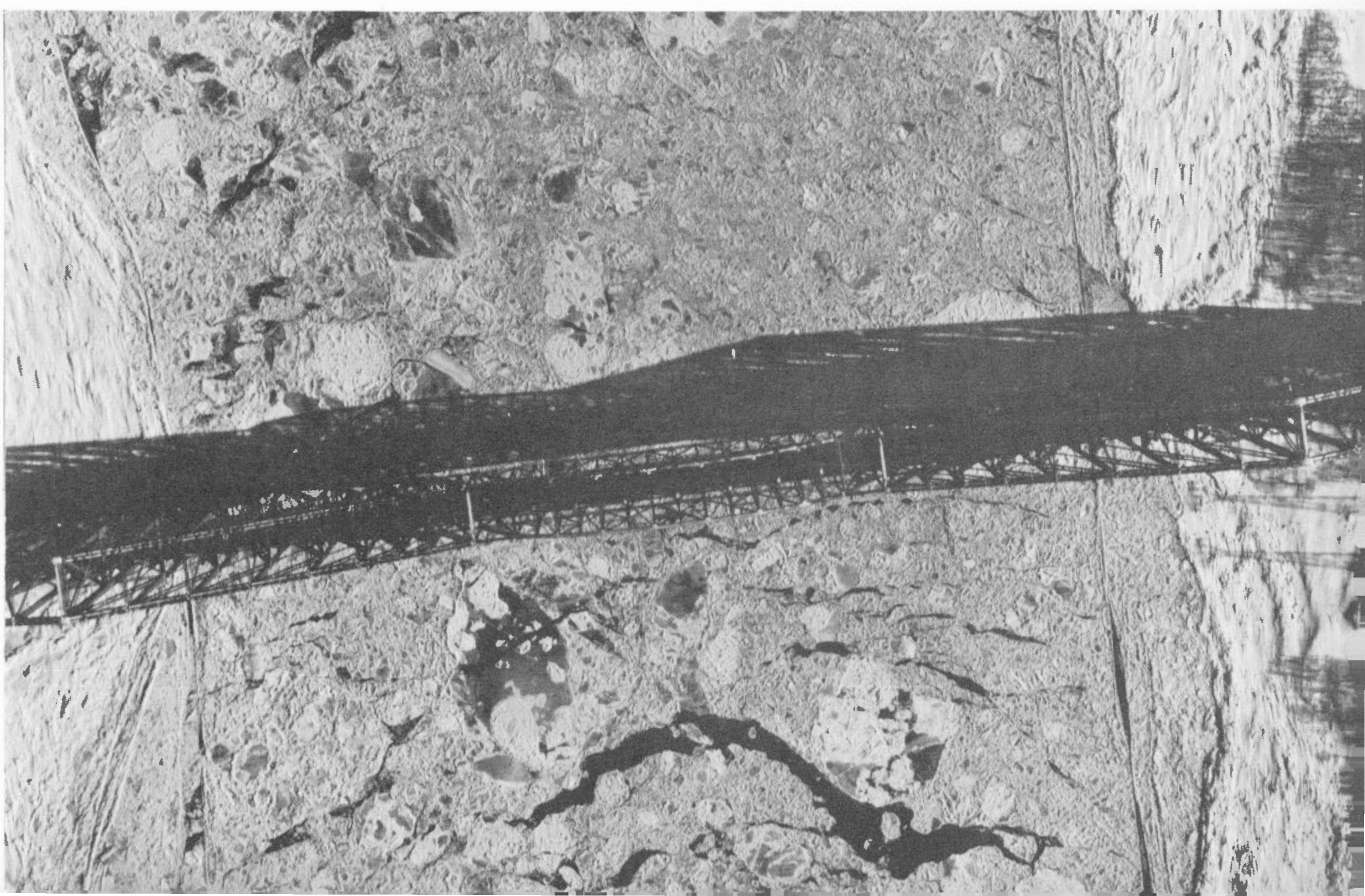


Figure 60. A sealing vessel caught in the rapidly consolidating pack ice northeast of North Point, Prince Edward Island. (Alt. 1,000 feet, March 2, 1960)

Figure 61. By April 11, shorefast ice had retreated from Lévis to a position opposite Donnacona on the south side of the river. Ships bound to upstream points on the river above Quebec are passing through the wreckage of shorefast ice. (Alt. 2,000 feet)

Figure 62. The ice on the St. Lawrence River at Quebec on January 27 consisted mainly of new and young ice types intermixed with small floes of winter ice that had broken from the edge of the shorefast ice. (Alt. 2,900 feet)

BIBLIOGRAPHY

Armstrong, Terence,
1955 : Soviet Work in Ice Forecasting. The Polar Record, Vol. 7, No. 49, p. 302-311.

Black, W.A.
1957 : Ice Conditions: Gulf of St. Lawrence, 1956. Geog. Bull. No. 10, p. 77-83.

1957 : An Illustrated Glossary of Ice Types in the Gulf of St. Lawrence. Geog. Paper No. 11, 50 p.

1957 : Gulf of St. Lawrence Ice Survey, Winter 1957. Geog. Paper No. 14, 29 p.

1958 : Gulf of St. Lawrence Ice Survey, Winter 1958. Geog. Paper No. 19, 56 p.

1959 : Gulf of St. Lawrence Ice Survey, Winter 1959. Geog. Paper No. 23, 56 p.

Black, W.A. and Forward, C.N.
1957 : Gulf of St. Lawrence Ice Survey, Winter 1956. Geog. Paper No. 12, 23 p.

Brochu, Michel
1960 : Dynamique et caractéristiques des glaces de dérive de l'estuaire et de la partie nord-est du golfe Saint-Laurent, hiver 1957 - 1958. Geog. Paper No. 24, 93 p.

Forward, C.N.
1954 : Ice Distribution in the Gulf of St. Lawrence during the Break-up Season. Geog. Bull. No. 6, 45-84.

1958 : Ice Conditions in the Gulf of St. Lawrence during the Spring Seasons 1953-1957. Geog. Paper No. 16, 13 p.

1959 : Sea Ice Conditions in the Northumberland Strait Area. Geog. Paper No. 21, 15 p.

Lauzier, L.M.
1957 : A Preliminary Report of the Winter Oceanographic Survey in the Gulf of St. Lawrence, 1956. Fisheries Res. Bd., Canada, Atlantic Oceanographic Group, St. Andrew's, N.B.

1958 : Some Aspects of Oceanographic Conditions in the Gulf of St. Lawrence from Autumn 1956 to Spring 1957. Manuscript Report Series No. 9. Fisheries Res. Bd., Canada, Atlantic Oceanographic Group, St. Andrew's, N.B.

Lauzier, L.M. and Graham, R.D.
1958 : Computation of Ice Potentials and Heat Budget in the Gulf of St. Lawrence. Manuscript Report Series No. 11. Fisheries Res. Bd., Canada, Atlantic Oceanographic Group, St. Andrew's, N.B.

Meteorological Branch. Department of Transport. Canada. Monthly Weather Map. November, 1959 to 1960. (Toronto), 1960.

Meteorological Branch. Department of Transport. Canada. Temperature and Precipitation Normals for Canadian Weather Stations Based on the Period 1921 - 1950. (Toronto), 1959.

United States Navy Hydrographic Office.
1952 : A Functional Glossary of Ice Terminology. Hydrographic Office Pubn. 609. Government Printing Office, Washington, D.C.

Papers Nos. 1 to 6 are out of print.

No. 7. Extracts relating to the Navigability of Canadian Inland Waterways. By W. A. Black, Ottawa, 1956. 55 p., offset. *Price 50 cents.*

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 p., map, offset. *Price 25 cents.*

No. 9. A Report on Sea Ice Conditions in the Eastern Arctic, Summer 1956. By W. A. Black, Ottawa, 1956. 32 p., maps, illus., offset. *Price 50 cents.*

No. 10. A Preliminary Report on Ice Conditions at Cacouna Island, Quebec. (Bilingual). By B. Robitaille, Ottawa, 1957. 24 p., maps, illus., offset. *Price 50 cents.*

No. 11. An Illustrated Glossary of Ice Types in the Gulf of St. Lawrence. By W. A. Black, Ottawa, 1957. 50 p., map, illus., offset. *Price 75 cents.*

No. 12. Gulf of St. Lawrence Ice Survey, Winter 1956. By W. A. Black and C. N. Forward, Ottawa, 1957. 23 p, maps, offset. *Price 25 cents.*

No. 13. Notes on Small Boat Harbours, N.W.T. By J. Ross Mackay, Ottawa, 1957. 12 p., illus., offset. *Price 25 cents.*

No. 14. Gulf of St. Lawrence Ice Survey, Winter 1957. By W. A. Black, Ottawa, 1957. 29 p., maps, illus., offset. *Price 75 cents.*

No. 15. A Report on Sea Ice Conditions in the Eastern Arctic, Summer 1957. By W. A. Black, Ottawa, 1958. 32 p., maps, illus., offset. *Price 50 cents.*

No. 16. Ice Conditions in the Gulf of St. Lawrence during the Spring Seasons 1953-1957. By C. N. Forward, Ottawa, 1958. 13 p., maps, offset. *Price 25 cents.*

No. 17. Étude du Port de Québec. Par P. Camu, Ottawa, 1958. 79 p., cartes, ill., offset. *Prix 75 cents.*

No. 18. A Subsurface Organic Layer Associated with Permafrost in the Western Arctic. By J. Ross Mackay, Ottawa, 1958. 22 p., maps, illus., offset. *Price 50 cents.*

No. 19. Gulf of St. Lawrence Ice Survey, Winter 1958. By W. A. Black, Ottawa, 1959. 56 p., maps, illus., offset. *Price 75 cents.*

No. 20. A Report on Sea Ice Conditions in the Eastern Arctic, Summer 1958. By W. A. Black, Ottawa, 1959. 36 p., maps, illus., offset. *Price 75 cents.*

No. 21. Sea Ice Conditions in the Northumberland Strait Area. By C. N. Forward, Ottawa, 1959. 14 p., illus., offset. *Price 50 cents.*

No. 22. Notes on the Glaciation of King William Island and Adelaide Peninsula, N.W.T. By J. Keith Fraser and W. E. S. Henoch, Ottawa, 1959. 39 p., maps, illus., offset. *Price 75 cents.*

No. 23. Gulf of St. Lawrence Ice Survey, Winter 1959. By W. A. Black, Ottawa, 1959. 56 p., maps, illus., offset. *Price 75 cents.*

No. 24. Dynamique et caractéristiques des glaces de dérive de l'estuaire et de la partie nord-est du golfe Saint-Laurent, hiver 1957-1958. Par Michel Brochu, Ottawa, 1960, 93 p., cartes, offset. *Prix $1.00.*

Price $1.50 Cat. No. M67-22
Available from the Queen's Printer, Ottawa, Canada

Roger Duhamel, F.R.S.C., Queen's Printer and Controller of Stationery, Ottawa, 1960