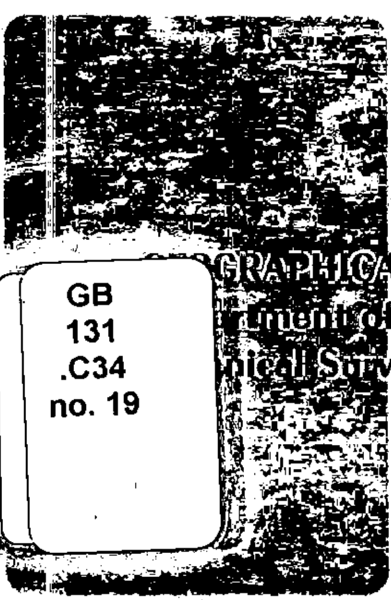
Canada

GEOGRAPHICAL PAPER No. 19

Gulf of St. Lawrence
Ice Survey, Winter 1958

W. A. Black



GEOGRAPHICAL BRANCH
Department of Mines and
Technical Surveys, Ottawa

Price: 75 cents

CANADA

GEOGRAPHICAL PAPER No. 19

Gulf of St. Lawrence Ice Survey, Winter 1958

W. A. Black

GEOGRAPHICAL BRANCH
Department of Mines and
Technical Surveys, Ottawa

Price: 75 cents

62850—1

The ice breaker, C.G.S. N. B. *McLean*, with the freighter *Liverpool Rover* following in her wake, steaming through Chaleur Bay to Dalhousie. In ice congested areas icebreaker escort is necessary (March 25, 1958).

PREFACE

The Gulf of St. Lawrence ice survey, winter 1958, is a study resulting from the third winter aerial ice survey conducted over the Gulf of St. Lawrence region. During the winter of 1958, the writer carried out part of the observations for this report. In addition, the report included ice observations made by the Department of Transport ice observers.

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 the problems faced in the winter navigation of the lower St. Lawrence River and the Gulf of St. Lawrence.

N. L. Nicholson,
Director,
Geographical Branch.

62850—2

EDMOND CLOUTIER, C.M.G., O.A., D.S.P.
QUEEN'S PRINTER AND CONTROLLER OF STATIONERY
OTTAWA, 1958

GULF OF ST. LAWRENCE ICE SURVEY, WINTER 1958

INTRODUCTION AND ACKNOWLEDGMENTS

The aerial survey of sea ice conditions in the Gulf of St. Lawrence during February, March and April, 1958 is a continuation of the survey first undertaken by the Branch in the winter of 1956*. The primary purpose of the survey is to observe and map the coverage and distribution of the various types of ice and to note the possible effects of the ice distribution upon ship movements in various parts of the gulf region.

The ice survey was conducted by the Geographical Branch and the Royal Canadian Air Force, and was coordinated by the Geophysical Research Section of the Defence Research Board. The Department of Transport provided active co-operation, but, the Royal Canadian Navy and the Atlantic Oceanographic Group were unable to collaborate in this year's project. Specific acknowledgments are made to T. A. Harwood, Geophysical Research Section; G/C W. H. Swetman, R.C.A.F. Maritime Air Command; D.C. Archibald, Basic Weather Division; C. C. Boughner, Climatological Division; and P. Sheridan, Marine Services.

The operation was planned to begin at the same time as the 1956 and 1957 surveys, about February 1st, but this year the duration of the survey was extended a month, to mid-April. Aircraft and crews were provided by the Royal Canadian Air Force station at Summerside, the base of operations. The flying program necessitated, weather permitting, two flights a week during February, and one flight a week through March to mid-April. A total of twelve flights was made, on

---

*See bibliography.

the following dates: February 4, 7, 13, 19, 21, 24, 27; March 4, 18, 25; and April 2 and 9. The Department of Transport operated ice survey flights from Quebec City and from Moncton, N.B. Nine flights were flown from Quebec City on February 21, 23, 27; March 6, 13, 18-19, 28; and April 3 and 10; eleven flights were flown from Moncton on March 14, 19, 28; and April 1, 9, 10, 14, 17, 21, 26 and 28. The flights operated independently of each other, but tended to concentrate on special areas within the range of the aircraft, although the flying schedules were varied sufficiently to avoid serious duplication of coverage. Aircraft used in the survey were generally flown from 1,000 to 3,000 feet altitude depending on local visibility conditions.

Aerial reconnaissance was concentrated chiefly over the St. Lawrence River, the western part of the gulf, and the Strait of Belle Isle. Flight patterns were varied to permit the greatest possible observation of ice conditions, particularly along the coastline, and to avoid unfavourable local weather conditions. The flight track generally followed the coastline and the return flight followed the ice edge. This flight plan permitted observation of the ice in the harbours and along the shore, and of the ice conditions existing near the ice edge.

The report falls into three main parts: Weather Conditions; Ice conditions; and Ice Distribution. The first two parts are mainly concerned with the relationship of ice cover to the prevailing climatic conditions; the last part provides a graphic presentation of the ice forms, concentration and coverage. The symbols and system of ice classification used are based on those followed by the United States Hydrographic Office in reporting ice. Following the plan adopted in the preparation of Gulf of St. Lawrence Ice Survey, Winter 1957, Geographical Paper No. 14, the U.S.H.O. procedure was modified to meet the local conditions existing in the Gulf of St. Lawrence. This modification was carried further in the 1958 survey in order to report both graphically and quantitatively, the new, young, and winter ice forms. The value of such a distinction was recognized during the course of the 1957 winter ice survey, particularly in its application to sea navigation. An additional change has been made in the graphic presentation of ice distribution; for example, winter ice showing a distribution of 3/10 or more in association with new or young forms of ice, is given in the closed pattern of winter ice; young ice showing a distribution of 3/10 or more in association with new ice is shown in the open pattern of young ice. Where new ice, which includes such forms as grease, slush, frazil, very young ice, and the early stages of sludge, is the predominant form on the sea surface, a more open pattern is used. These alterations in ice reporting should provide a fuller understanding of the sea ice conditions that exist in the Gulf of St. Lawrence during the winter months.

In conjunction with the ice survey a photographic record of ice conditions was made, using an F.24 aerial camera with a 5-inch focal lens. As the photos were taken between 800 and 1,000 feet elevation they have a scale of 180 to 200 feet to one inch, and are published by courtesy of the Royal Canadian Air Force.

WEATHER CONDITIONS

The winter of 1958 was unusually mild and was unfavourable for the formation of sea ice (Table 1). Mean temperatures for December were 3 to 7 degrees* above normal in the gulf region, and by January mean temperatures ranged from 7 to 13 degrees above normal. In February, the mean monthly temperatures were much above normal, particularly in the southeastern, eastern and northern parts of the gulf where mean temperatures reached 10 to 13 degrees above normal. These abnormal conditions arose from Atlantic storms that carried mild maritime air over the region and generally moved NNE from the Nantucket area to pass over the St.

---

*All degrees are in fahrenheit.

Lawrence valley towards Labrador, Newfoundland. Normally, storms follow the Gulf Stream to pass in an ENE direction across Nova Scotia thereby bringing in cold continental air over the gulf region. During the first half of February, flows of cold air reduced the above-normal temperatures in the western part of the gulf and St. Lawrence River to 2 to 4 degrees above normal. The dominance of mild maritime air over the gulf region continued for the remainder of the winter with the mean monthly temperatures ranging from 5 to 11 degrees above normal for March. The peak of abnormal climatic conditions had already passed, so that, for April mean temperatures were 3 to 5 degrees over normal temperatures and were above normal for May. These mild conditions had a bearing on the small quantity of ice that was observed in the gulf during the winter of 1958.

Normal, mean monthly temperatures are generally similar for the St. Lawrence River and the North Shore of the Gulf of St. Lawrence with average temperatures for January and February of 7° to 9°. The mean monthly temperatures for these areas during January and February of 1958 were 14° to 22°. Normal, mean monthly temperatures for the Strait of Belle Isle and the Gaspé-Chaleur coast tend to be similar with temperatures for the same period being from 10° to 13° but during the previous winter the mean temperatures were 19 to 24 degrees above normal. During March, the average mean temperatures for the gulf were from 30° to 32°, whereas the Strait of Belle Isle was experiencing temperature conditions that were prevalent in other parts of the gulf a month earlier. The St. Lawrence River and the North Shore generally have the lowest temperatures in the gulf region. The Gaspé-Chaleur area tends to have lower temperatures than the Strait of Belle Isle during December and January, but higher during February and March (Table I).

TABLE I

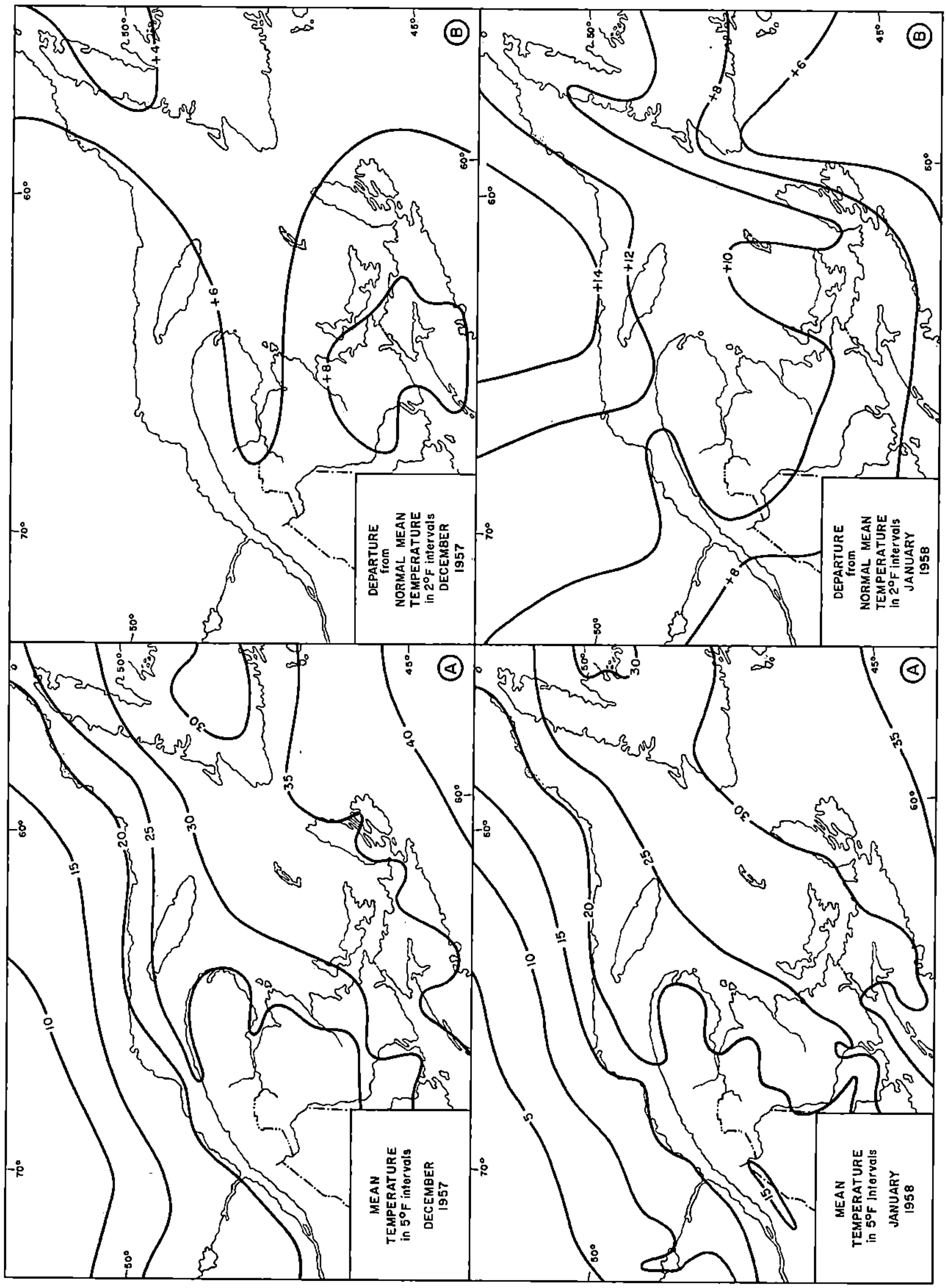
Average mean and normal monthly temperatures (fahrenheit) for the gulf region from December, 1957 to March, 1958

	DECEMBER		JANUARY		FEBRUARY		MARCH	
	Mean	Normal	Mean	Normal	Mean	Normal	Mean	Normal
St. Lawrence R.	23	16	18	9	14	7	30	21
North Shore	21	14	20	7	22	9	30	19
St. of Belle Isle	25	20	23	12	24	11	23	18
Gaspé-Chaleur	24	18	21	10	19	13	32	25
Central gulf	31	26	28	19	26	16	31	23
Eastern gulf	32	27	29	20	28	18	32	25
Southern gulf	32	24	28	18	23	18	32	26
Av. Temp.	27	21	24	14	22	13	30	22

The central, eastern and southern gulf region has normal monthly temperatures of 16° to 20° in January and February, but during the winter of 1957-58 the mean monthly temperatures for these areas from December to March were between 28° and 32°. February temperatures of 23° to 26° over the gulf were the lowest.

Mean temperatures during April were from 30° to 35° over the St. Lawrence River and North Shore, and from 35° to 40° over the central and southern parts of the gulf.

The mean isotherms (Figure IA), and the departure from the normal isotherms (Figure IB), show that winter temperatures were above normal for the gulf region during the winter months of 1957-58. Normal winter isotherms which trend in a northeast-southwest direction usually show the southern gulf area to have temperatures about 10 degrees higher than the North Shore; however, during the winter of 1957-58 the southern gulf region was 7 degrees higher than the North Shore. Normal March isotherms indicate the southern gulf area to be 6 degrees higher than the North Shore, but during this winter the southern gulf area was about 3 degrees higher than the former


DEPARTURE from NORMAL MEAN TEMPERATURE in 2°F intervals DECEMBER 1957
DEPARTURE from NORMAL MEAN TEMPERATURE in 2°F intervals JANUARY 1958
MEAN TEMPERATURE in 5°F intervals DECEMBER 1957
MEAN TEMPERATURE in 5°F intervals JANUARY 1958
A
B
A
B

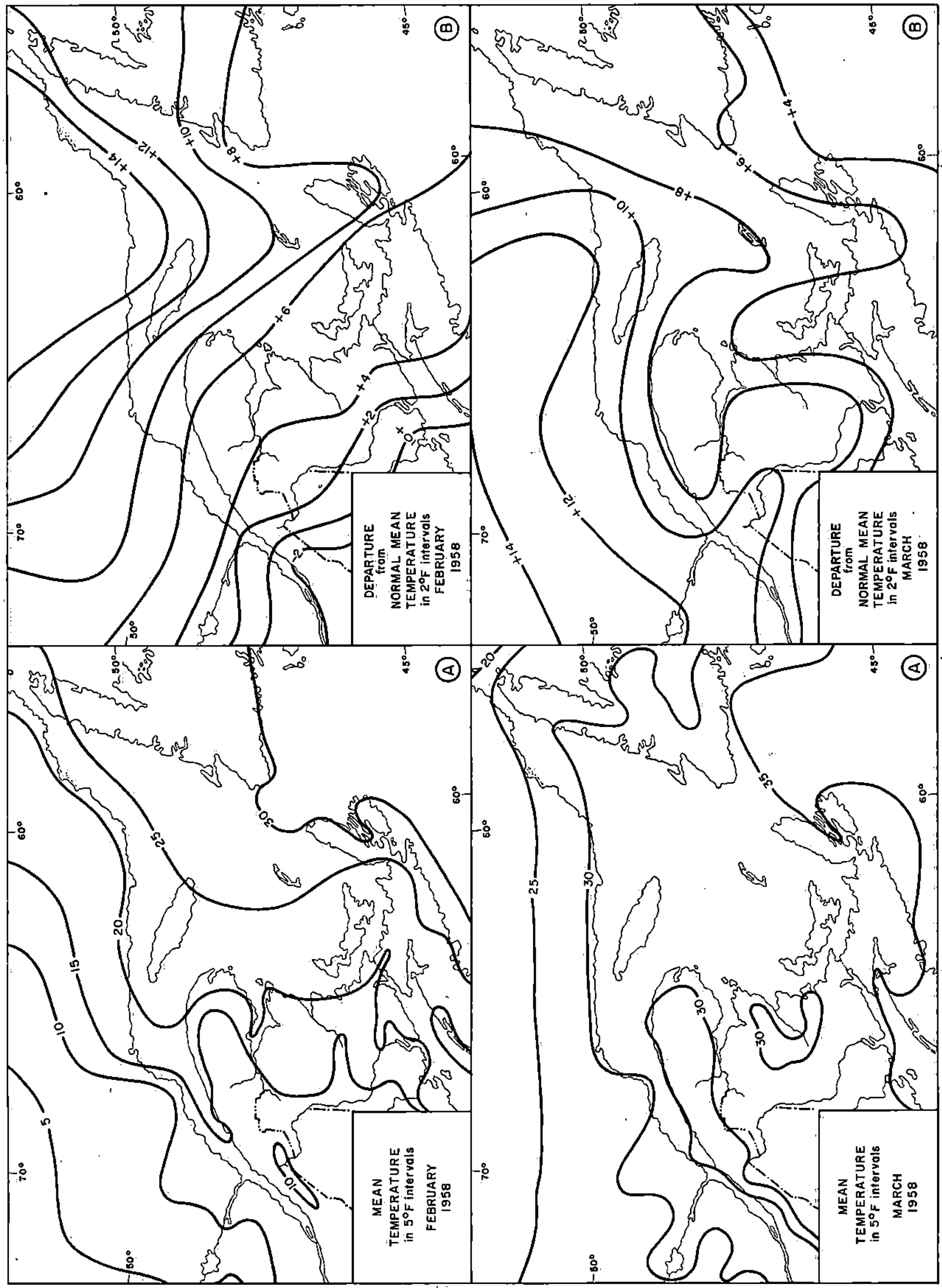


Figure 1. **(A) Mean temperatures, December 1957 to March 1958** **(B) Departure from normal mean temperature, December 1957 to March 1958**

area. This narrow range of temperatures between the northern and southern parts of the gulf during March emphasizes the uniformity of climatic conditions that prevailed over the gulf region at this time; the only exception to this was the Strait of Belle Isle. The mean isotherm for April showed the North Shore area to be 10 degrees lower than the southern gulf and the St. Lawrence River in the vicinity of Quebec City, indicating that climatic conditions in various parts of the gulf were returning to normal.

Temperatures varied sufficiently over different parts of the gulf to affect the local formation of ice. Air temperatures favourable for the formation of ice at 29 degrees* on gulf waters prevailed on the Strait of Belle Isle from December to March; the North Shore, St. Lawrence River and Gaspé-Chaleur area from December to February; and the southern, eastern and central gulf areas for January and February.

Winds

Prevailing winds in winter blow on the average from the west and northwest. They are predominantly northwesterly along the North Shore of the gulf and westerly over the southern gulf region. These winds tend to blow the ice from the north to the south shore of the St. Lawrence River, from the North Shore to Anticosti Island and from the western and southern gulf toward Cabot Strait.

During the winter of 1957-58 the normal wind frequencies associated with the movement of continental air masses were replaced by winds associated with the movement of maritime air. In December northerly winds prevailed over the North Shore and southwesterly winds over the southern gulf. By January northeasterly and easterly winds had become important components of the air circulation. In February,

*The temperature is based on the general distribution of surface salinity of 30.00 to 32.00 (S°/oo). (See footnote reference to Lauzier, Figure 4).

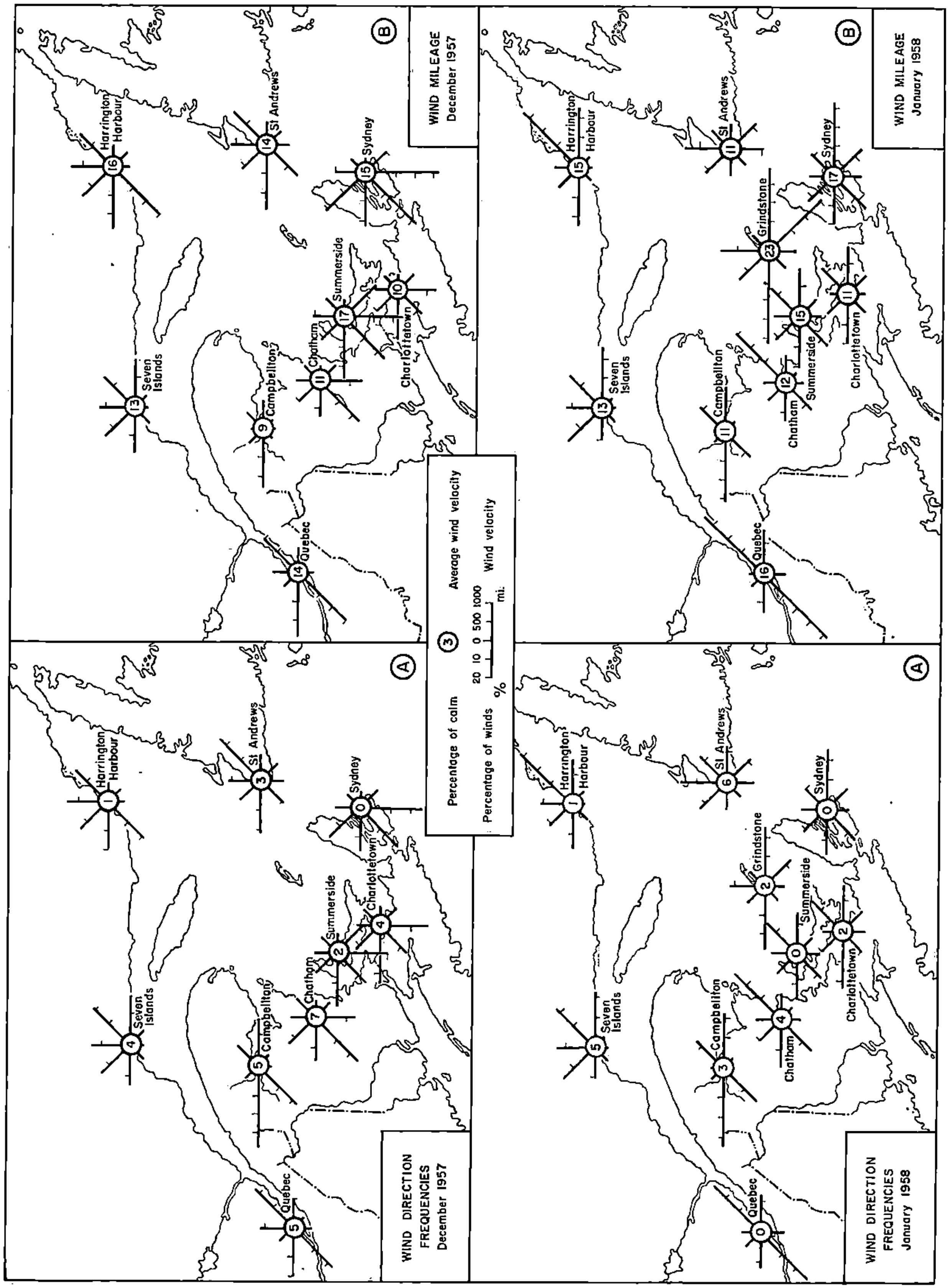
westerly winds associated with the movement of continental air prevailed over the western gulf, while easterly winds associated with maritime air masses prevailed over the remainder of the region. In March, strong flows of mild maritime air swept over the area so that easterly winds prevailed, except over the central gulf region where northerly winds were prevalent. The frequency of changes in wind direction is shown in Figure 2A.

Wind velocities varied considerably; from 7 to 12 m.p.h. in the western gulf; 11 to 17 m.p.h. over the St. Lawrence and North Shore; 10 to 17 m.p.h. in the southern gulf; 9 to 14 m.p.h. in the eastern gulf and from 13 to 25 m.p.h. in the central gulf region.

Ice Drift

In the Gulf of St. Lawrence the distribution of the ice is closely related to wind velocity as well as to wind direction and sustained wind mileage (Figure 2B). Considering wind velocity and wind mileage as a factor in ice distribution, Shuleykin's (Armstrong, 1955) ratio of speed of drift to wind speed (1:25) indicates that during February westerly winds provided a free daily drift of 6.5 miles. Drift from southerly winds was the least, at 5 miles per day. The distance the ice could drift varied with different wind sectors in various parts of the gulf; thus, on the St. Lawrence River with westerly winds, the daily ice drift was 10 miles; whereas, on the central gulf with northerly winds and on the North Shore with easterly winds, daily ice drift was 9 miles.

The actual number of miles the ice drifts is found by deducting the ice-drift miles from the opposing wind sector (Table II). In the western gulf the daily eastward drift was 3 miles and the downstream drift on the St. Lawrence River was 7 miles. Opposing winds from the northeast and southwest parallel to the St. Lawrence


B
WIND MILEAGE
December 1957
Harrington Harbour
St Andrews
Sydney
Summerside
Charlottetown
Chatham
Campbellton
Seven Islands
Quebec
B
WIND MILEAGE
January 1958
Grindstone
Percentage of calm
Average wind velocity
Percentage of winds
Wind velocity
20 10 0 500 1000
%
mi.
A
WIND DIRECTION
FREQUENCIES
December 1957
A
WIND DIRECTION
FREQUENCIES
January 1958

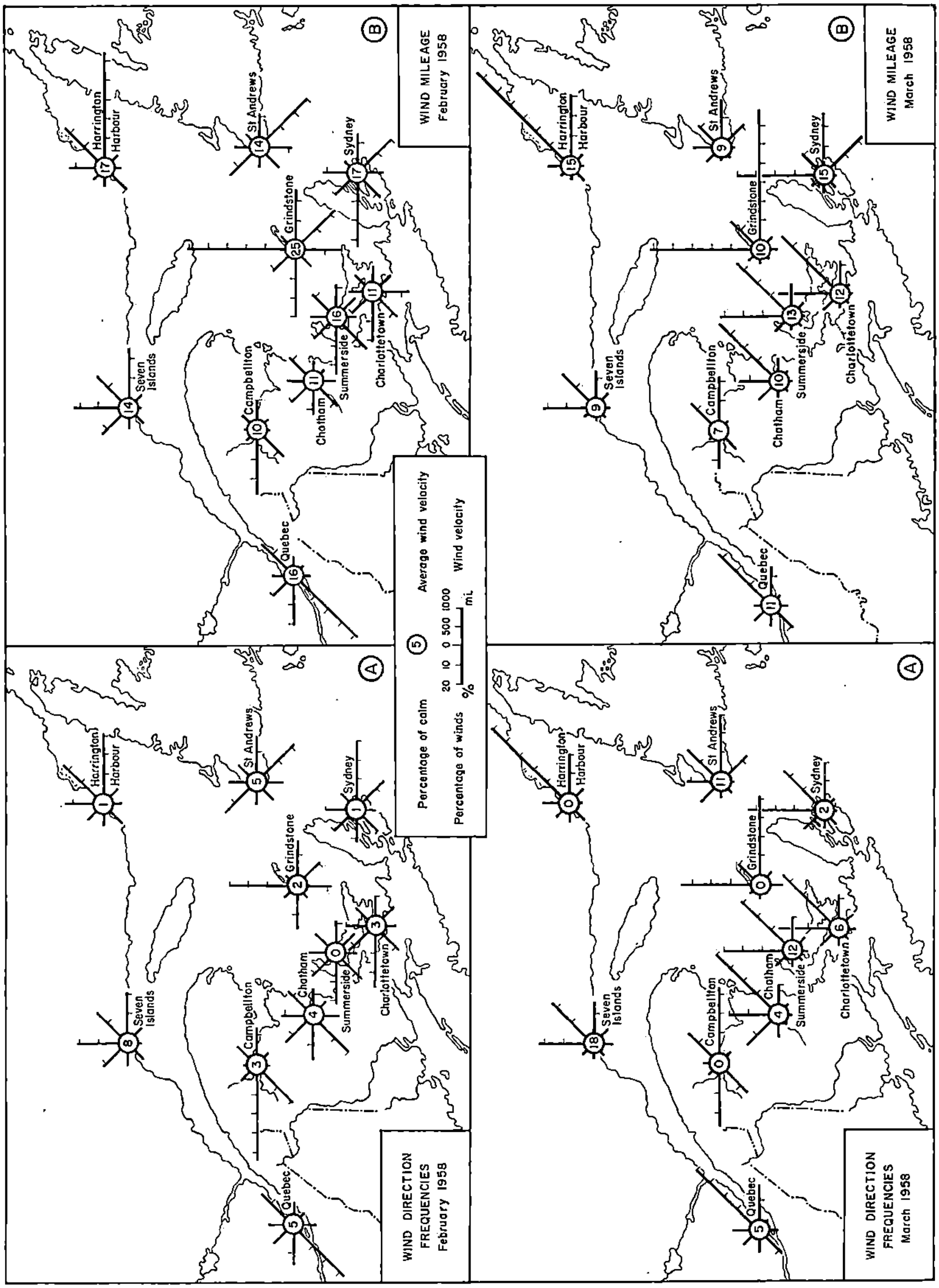


Figure 2. (A) Wind direction frequencies, December 1957 to March 1958 (B) Wind mileage, December 1957 to March 1958

River tend to provide an ice cover that extends from shore to shore. In the northwest arm of the gulf easterly winds retard the westward drift of the ice considerably; for example, a daily eastward drift of 7 miles was offset by a westward drift of 7 miles, but drift from northerly winds was also 7 miles. This resulted in an effective

TABLE II

Free ice drift per day in miles by sector, February and March 1958

	WEST (SW-W-NW) Feb. : Mar.	NORTH (NW-N-NE) Feb. : Mar.	EAST (NE-E-SE) Feb. : Mar.	SOUTH (SE-S-SW) Feb. : Mar.
St. Lawrence R.	10 : 3	5 : 6	3 : 6	7 : 2
North Shore	3 : 1	7 : 8	9 : 9	2 : 1
Western Gulf	6 : 2	3 : 7	3 : 6	3 : $\frac{1}{4}$
Northumberland St.	7 : 1	4 : 10	4 : 7	5 : $\frac{1}{2}$
Central gulf	7 : $\frac{1}{2}$	9 : 9	8 : 11	7 : $\frac{1}{4}$
Av. drift	6.5 : 1.5	5.6 : 8	5.4 : 7.8	5 : 1

southward drift. These drift values explain in part the large changes in ice coverage that are observed between one flight and the next in this area and, together with the Gaspé current, explain the orientation of ice drift toward the Gaspé coast. On the North Shore a southward ice drift of 5 miles near the western end gradually became a southwesterly drift of 10 miles at the eastern end of the shore. Although temperatures led to ice formation on the North Shore the drift distances were sufficient to keep the shore ice-free; in the northeast arm the drift speed of the northeasterly winds held the Labrador ice against the western side of the arm. In the central gulf, the daily ice-drift distance of northerly winds offset the drift produced by southerly winds by an excess of 2.5 miles. Ice drift distance produced by easterly winds offset that of westerly winds by one mile per day. This affords an explanation for the eastward-drifting ice at its maximum extent not reaching the Magdalen Islands, and also for the ice being held against the north coast of Prince Edward Island.

During March, southward and westward free ice drift associated with strong northerly winds and strong easterly winds was 10 miles a day respectively. These winds were of sufficient strength to hold the winter ice against the north coast of Prince Edward Island and to retain the ice-field at the western end of Northumberland Strait. On the North Shore the south and west drift speeds were particularly high, whereas the northward-eastward speeds were low, and thus account for the ice being carried westward into the Jacques Cartier Passage.

High temperatures associated with strong flows of mild maritime air reduced the ice-fields in the western gulf, St. Lawrence River and the northeast arm during April. A change in wind direction after April 17 drove the ice off the north coast of Prince Edward Island and later caused dispersion of the ice in Northumberland Strait.

ICE CONDITIONS

Temperatures were unfavourable for the formation of ice in the Gulf of St. Lawrence during November, but were favourable during December and January, particularly in the northern and northwestern gulf areas. In addition, unfavourable oceanographic conditions (Lauzier, 1957), aided by the prevailing winds, helped to weaken the low temperatures as an ice-forming factor. At the end of January the gulf region was largely free of ice except on the southern side of Chaleur, Miramichi and on some of the smaller bays fed by fresh river water on the east coast of New Brunswick. Ice was also prevalent on the south shore of the St. Lawrence River above the mouth of the Saguenay River. At this time ice drifting southward along the Labrador coast began to enter the Strait of Belle Isle.

At its maximum extent, ice covered about one-half of the surface of the gulf. In the ice-covered areas ice conditions were variable; large changes in ice coverage often occurred between surveys. After the passing of a continental high pressure air mass, there was normally an extension of the new and young ice areas and a consolidation of the ice into giant floes and fields. With the passing of a low pressure air mass, the ice surface relaxed, followed by disintegration of the ice into brash, block and small to medium floes (Karelin in Armstrong, 1955). Generally, heavy ice concentrations from 7/10 to 10/10 coverage tended to occupy the bays and windward coast, whereas light ice concentrations from 1/10 to 4/10 coverage occupied the leeward and exposed areas of the gulf. The concentration of ice in the Strait of Belle Isle varied from 8/10 to 10/10, consisting mainly of 5/10 to 8/10 tightly packed sludge and brash, and with pressure ridges amounting from 5/10 to 7/10. These surface details indicated the Labrador ice to be under severe pressure before entering the strait. Because of prevailing climatic conditions and currents, the ice fronts during the winter were continuously changing position, and, except for the Labrador ice, did not present a steady, consistent advance (Figure 3). The retreat of the ice fronts followed a pattern similar to the advance of the ice fronts (Figure 4).

The sea ice reached its greatest extent at different times in various parts of the gulf. The western gulf ice reached its maximum extent during February 21 and 24, and that of the northwest arm reached the Mingan Islands about February 27. In the southern gulf, the sea ice pushed eastward along the north coast of Prince Edward Island and reached Cape Breton Island about February 19. This ice extending southward between Prince Edward Island and Cape Breton reached its greatest extent about February 24. Ice in Northumberland Strait tapering eastward extended past Cape George about February 19; thereafter it began to degenerate. The Labrador ice gradually penetrated southward filling the strait and expanding outward in the northeast arm of the gulf; this ice-field reached its maximum extent about March 19.

From February 1 to 24 the sea ice had drifted about half-way across the central gulf; from February 1 to 28, it had pushed eastwards along the North Shore as far as the Mingan Islands. The Labrador ice moving southwestward took much longer to cover the same distance. After the ice had reached its maximum extent it began to degenerate rapidly, particularly in Northumberland Strait and in the southern gulf.

From February 26 to March 14, the weather was dominated by a succession of low pressure air masses with maximum temperatures well above freezing. A rapid disappearance of the new and young ice forms followed, so that the ice in the western gulf was reduced to four main areas; namely, St. Lawrence River, Chaleur Bay, Northumberland Strait, and the north coast off Prince Edward Island. At no time did ice in the central gulf reach the Magdalen Islands, nor did the Northumberland Strait ice form a continuous belt with that off the north coast of Prince Edward Island; nor did ice in the northwest arm meet the Labrador ice drifting westward along the North Shore.

After March 14 the western ice steadily degenerated. The Lower St. Lawrence River was almost ice-free by March 24 and the upper St. Lawrence sufficiently free to permit the first ship, the German vessel "Valaria", to dock at Montreal on March 28 at 1600 hours, four hours short of an all-time record. The Saguenay was ice-free on April 10. In the gulf, the ice-field that had bordered the north coast of Prince Edward Island since February 13 drifted northward after April 17 and disappeared about April 21. Rapid deterioration of the ice-field in Northumberland Strait occurred after mid-March; about mid-April this ice became localized in the western part of the strait where it was driven back and forth by the wind. This ice and also the Chaleur Bay ice probably did not disappear before May 5. The Labrador ice degenerated rapidly after mid-April and by April 28, except for scattered bergy bits and growlers, had disappeared from the northeast arm and the Strait of Belle Isle.

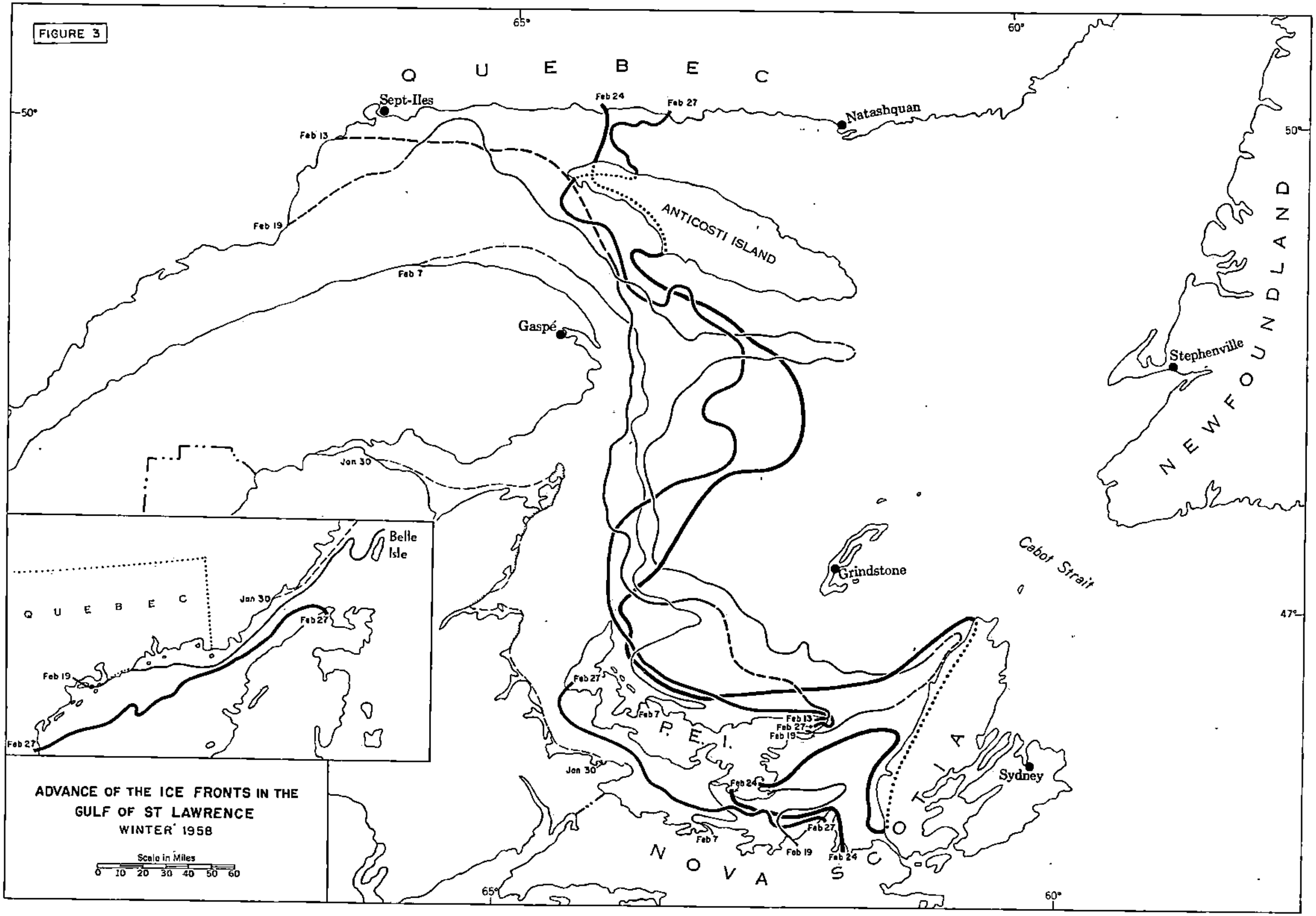


Figure 3. Advance of the ice fronts in the Gulf of St. Lawrence, Winter 1958

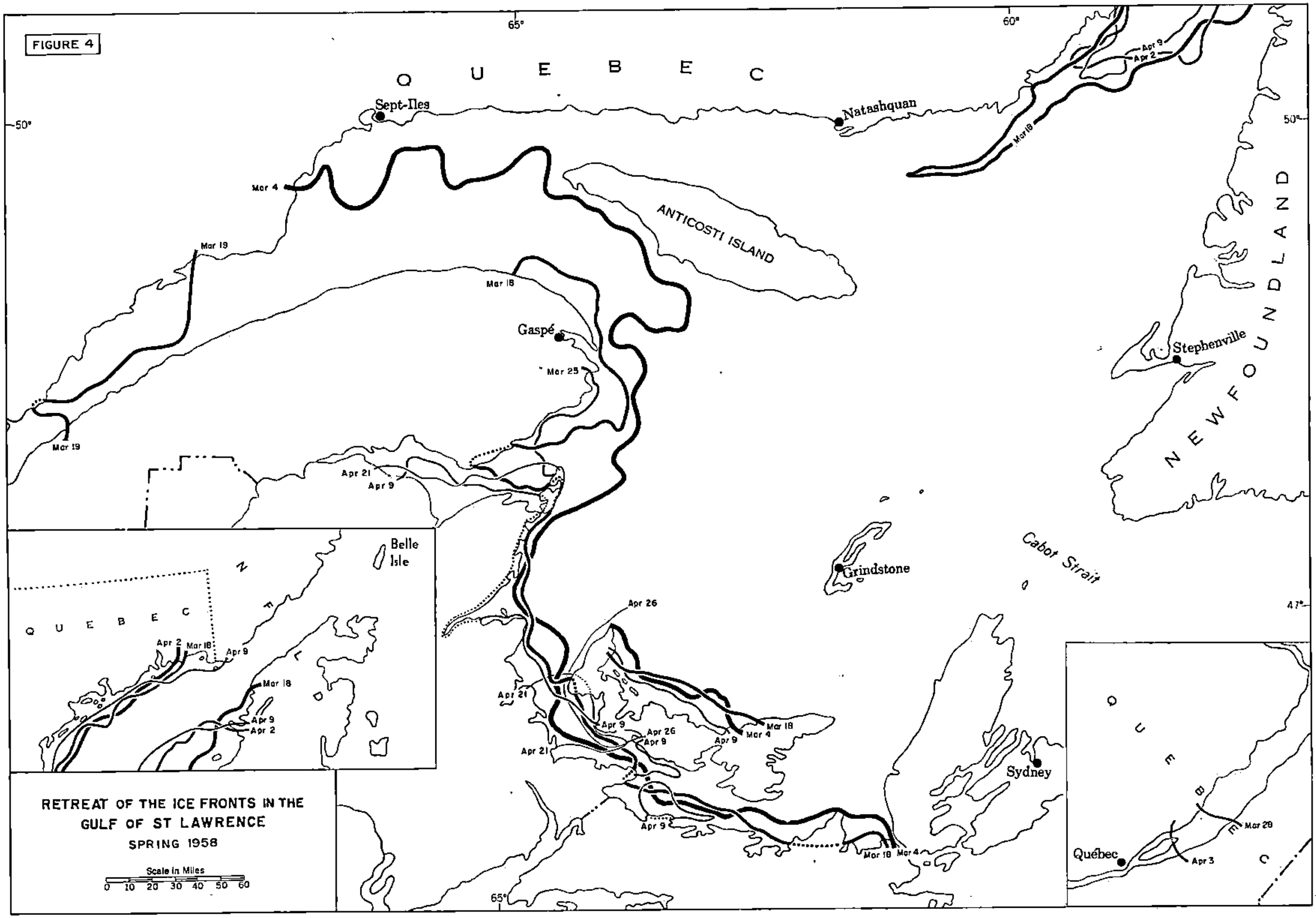


Figure 4. Retreat of the ice fronts in the Gulf of St. Lawrence, Spring 1958

At the beginning of the season new ice forms, particularly slush and very young ice, dominated the ice cover to February 13; by February 19 young ice had become the main cover, and by February 24 winter ice had expanded to occupy about one-third of the ice surface. By February 28, young and winter ice were the predominant forms of cover. Although after this date new and young ice forms were important elements, winter ice tended to be the prevailing type. Temperatures during February were sufficiently low and sufficiently sustained to produce winter ice. However, during March, with the mean monthly temperatures above the freezing point of gulf waters, new ice melted and disappeared rapidly. Thus after mid-March new ice forms were unimportant elements in the cover; young ice remained important until the end of March; thereafter, winter ice was the principal cover.

Scattered bergy bits and growlers that entered the gulf with the Labrador ice were observed on each flight to the Belle Isle area. The greatest number of these (eighteen) were sighted near Belle Isle on March 25. Two icebergs, or bergy bits, reported on April 14 in the vicinity of Heath Point, Anticosti Island, represented the most southerly advance of this form of ice. Except for the scattered bergy bits and growlers at the eastern entrance of the strait, the Strait of Belle Isle was entirely free of them by May 28 west of a line from Cape Norman to Red Bay. However, this type of ice continues to drift into the strait during the summer season.

By the end of February landfast ice occupied the harbours of the south shore of the St. Lawrence River, the Gaspé coast, the southern side of Chaleur Bay, the west coast of New Brunswick, the northern coast of Nova Scotia westward of Merigomish Harbour, the southern and northern coasts of Prince Edward Island and the southern shore of the Strait of Belle Isle. The freeze-over of the harbours in the southern and western part of the gulf was completed by January 30, the north and south coasts of Prince Edward Island, the south shore of the St. Lawrence River and the Gaspé coast by February 24, and the south shore of the Strait of Belle Isle about March 1.

Harbours that were bordered by open water were entirely ice-free during the winter months; these included the North Shore from the Mingan Islands to Harrington Harbour, both shores of Anticosti Island, the west coast of Newfoundland, the coasts of the Magdalen Islands, Cape Breton Island and the east coast of Prince Edward Island.

Occasionally, loose ice entered the harbours of the north shore of Chaleur Bay, the North Shore from Pointe-des-Monts to Sept Iles, and the northeast arm from Harrington Harbour to Blanc Sablon. Ice frequently congested the harbours on the north shore of the St. Lawrence River and those on the north side of the Strait of Belle Isle. In the northeast arm the extension of the Labrador ice-field southward tended to close on the coastal islands rather than to push into the harbours.

Harbours on the Gaspé coast became ice-free about March 18 and on southeast Prince Edward Island about March 15. Harbours on the southwestern gulf coast between Miscou Island and Cape George and on the north coast of Prince Edward Island began to open about April 2. These harbours were not free of landfast ice for another two weeks. However, drift ice continued to obstruct the harbours at the western end of Northumberland Strait, particularly on the Prince Edward Island side, until the first of May.

During the winter months the shipping lanes from Cabot Strait through the gulf were free of any major ice hazard that would affect ships proceeding to the St. Lawrence River. Fishing vessels were observed at different times between Cape Breton Island and the east coast of Prince Edward Island, and between the Magdalen Islands and Newfoundland. During the winter, ships crossed the gulf to enter and depart from Dalhousie at the western end of Chaleur Bay. An attempt to maintain winter navigation between Sept Iles and the ports on the lower St. Lawrence estuary was not completely successful as the vessels were too under-powered to move readily through young ice forms. Ice congestion in the western part of Northumberland Strait and along the north shore of Prince Edward Island was sufficient to entrap a number of under-powered sealing vessels for 4 to 6 weeks.

Compared with average conditions, the ice was unusually light during 1958. The largest part of the ice cover consisted of new and young ice as air temperatures were generally unfavourable for the development of winter ice or the expansion of the ice cover over the gulf waters. Temperatures for the North Shore at the end of February were higher than normal in December. In the central gulf, at the end of February temperatures were equivalent to normal December values. The southern gulf experienced temperatures in February that are normally reached in December. For these areas the season was 2 months late, the St. Lawrence River area about 6 weeks late, and Chaleur Bay 4 weeks. In the Strait of Belle Isle winter conditions were generally equivalent to those experienced in November.

The extent of ice coverage depends on the severity of the winter. Considering air temperatures over the gulf from November to March as an ice forming factor, the months of November and March were unfavourable for ice consolidation (Table III). Ice forming conditions were most effective during January and February.

Temperatures over the central, eastern and southern parts of the gulf were unfavourable for the formation and growth of ice. Thawing conditions exceeded the number of degree days* of frost by 10 per cent. The St. Lawrence River and North

*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^{o}).

Shore areas were generally the most favoured for the formation of ice with 46 per cent of degree-days favourable for ice formation.

TABLE III

Mean Monthly Degree-days of Frost, 1957-1958

AREA	NOV.	DEC.	JAN.	FEB.	MARCH	Cum. D-d
St. Lawrence R.	-4	6	11	15	0	28
North Shore	-1	8	9	7	-1	22
St. of Belle Isle	-1	4	6	5	6	20
Gaspé-Chaleur	-6	6	8	10	-3	14
Central gulf	-9	-3	1	3	-2	-10
Eastern gulf	-6	-3	-1	0	-2	-12
Southern gulf	-11	-3	2	7	-3	-8
Av. for total gulf area	-5.4	2.0	5.1	6.7	-.7	

The mild temperatures in the southern gulf during April do not explain the cause for the ice-field remaining at the western end of Northumberland Strait until the first of May. The reason for this may be largely due to oceanographic conditions; namely, the reduced heat budget in spring resulting from winter cooling of the gulf waters in a relatively shallow part of the gulf.

SUMMARY

The aerial ice survey of the winter of 1958 revealed an unusually small quantity of ice in the Gulf of St. Lawrence. This was in part related to the unusually high temperatures that existed over the gulf region. The mean winter temperatures, from December 1957 to February 1958 were from 18° to 24° in the northern gulf region and from 26° to 31° in the southern gulf region; whereas normal temperatures for these areas for the same period are 9° to 16° and 17° to 25° respectively. Except

62850—5½

for a brief period, from mid-February to the end of February, ice did not extend over the shipping track through the gulf nor did it reach the Magdalen Islands. Although the Labrador ice reached the vicinity of Natashquan on the North Shore, it did not extend from shore to shore across the northeast arm of the gulf.

Except for the ice that had formed in the lagoons and bays of the western part of the gulf and the upper St. Lawrence River, there was almost no ice in the gulf at the end of January 1958. At the end of February the ice observed was mostly new and young ice; and, winter ice tended to be the prevailing cover during March and, as it is more resistant to melting, continued as the main cover during April. The Labrador ice that entered the Strait of Belle Isle had been severely 'worked over' as it contained an unusually large proportion of sludge and brash. This ice melted rapidly when its concentration was reduced by fanning out in the northeast arm. As Zubov (<u>in</u> Armstrong, 1955) states "....the amount of heat required to reduce nine-tenths ice cover to eight-tenths is the same as that required to reduce five-tenths to open water". This ice disappeared from the straits area before the end of April.

Winter navigation across the Gulf of St. Lawrence was possible throughout the winter of 1957-58. However, in the St. Lawrence River, young ice, particularly where extensive shelving had occurred, was observed to be a major obstacle to navigation, especially with under-powered ships. In close pack ice on the north side of Prince Edward Island and at the western end of Northumberland Strait, small sealing ships were easily beset. Sealing ships sailing northward off the east coast of Newfoundland reached the Strait of Belle Isle about April 9 and encountered no major hazard in navigating through the Labrador ice. Ice in Northumberland Strait at no time proved to be a hindrance to the C.G.S. ferry "Abegweit".

Successful winter navigation of the congested ice area of Chaleur Bay indicates the practical value of an icebreaker escort. During the closed season from December 16 to April 20, 26 ships moved 81,769 tons of newsprint from Dalhousie to United Kingdom markets, thereby establishing a new shipping record for this port. By February 24, 14 ships had crossed Chaleur Bay, by March 6, two more ships had entered Dalhousie, and by the end of March, 21 ships had crossed the bay.

BIBLIOGRAPHY

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

Black, W.A.
1957 : Ice Conditions: Gulf of St. Lawrence, 1956. Geog. Bull. 10, pp. 77-83.

1957 : An Illustrated Glossary of Ice Types in the Gulf of St. Lawrence. Geog. Paper 11, 50 p.

1957 : Gulf of St. Lawrence Ice Survey, Winter 1957. Geog. Paper 14, 29 p.

Black, W.A. and Forward, C.N.
1957 : Gulf of St. Lawrence Ice Survey, Winter 1956. Geog. Paper 12, 23 p.

Forward, C.N.
1954 : Ice Distribution in the Gulf of St. Lawrence during the Break-up Season. Geog. Bull. 6, pp. 45-84.

1958 : Ice Conditions in the Gulf of St. Lawrence during the Spring Seasons 1953-1957. Geog. Paper 16, 13 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.

Robitaille, B.
1957 : A Preliminary Report on Ice Conditions at Cacouna Island, Quebec. Geog. Paper 10, 24 p.

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

ICE DISTRIBUTION

The various important features of the ice coverage are shown graphically in Figures 5 to 30. These maps cover a period from the first part of February to the end of April. Each chart covers the duration of a single period of observation. On some of the charts, two flights have been included where they do not overlap and when the times of the flights are relatively close together.

In conjunction with the aerial survey a photographic record of ice types was made. Twelve photographs have been selected to illustrate ice types particularly where ships are involved.

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, and an ice-field is an area of sea ice greater than 5 miles across.

Ice concentration: The ratio of the areal extent of ice present to the total extent of the ice and water surface. Concentration is usually measured in tenths; for example $\frac{9}{621}$ 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.

Landfast ice: Any type of ice attached to the shore, beached, stranded in shoal water, or attached to the bottom of shoal areas.

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

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 young ice.

Sludge: An accumulation of small pieces of soft ice mixed with slush. The surface of the sludge is usually hardened into an ice crust. 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 soupy mass in the water. The coverage of slush may be expressed in tenths; thus $\frac{Sl}{5}$ - 5/10 of slush.

Very young ice: Ice that is recently formed in calm water. 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 two to eight inches thick. Coverage is expressed in tenths; thus $\frac{Y}{7}$ - 7/10 of young ice.

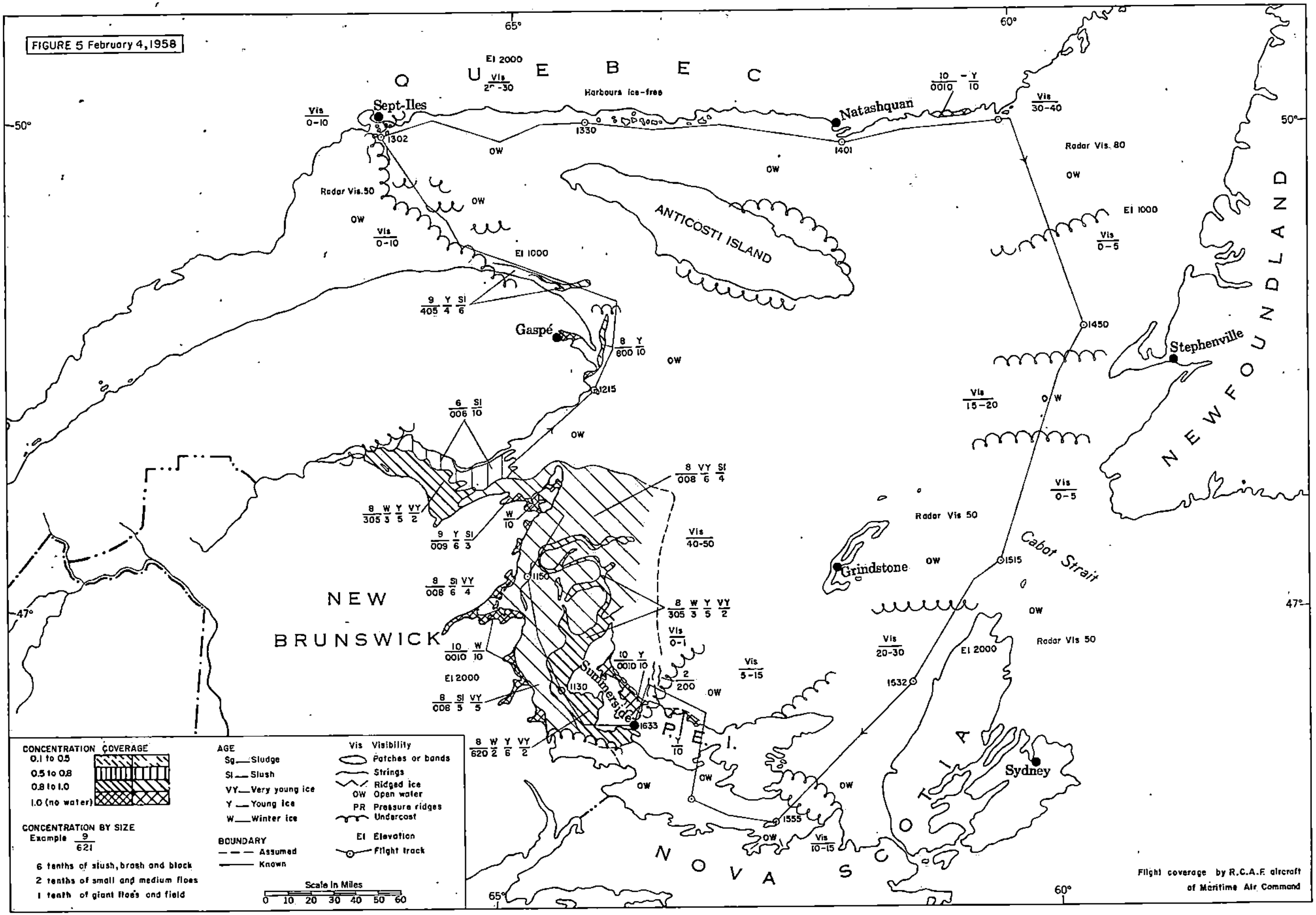


FIGURE 5 February 4, 1958

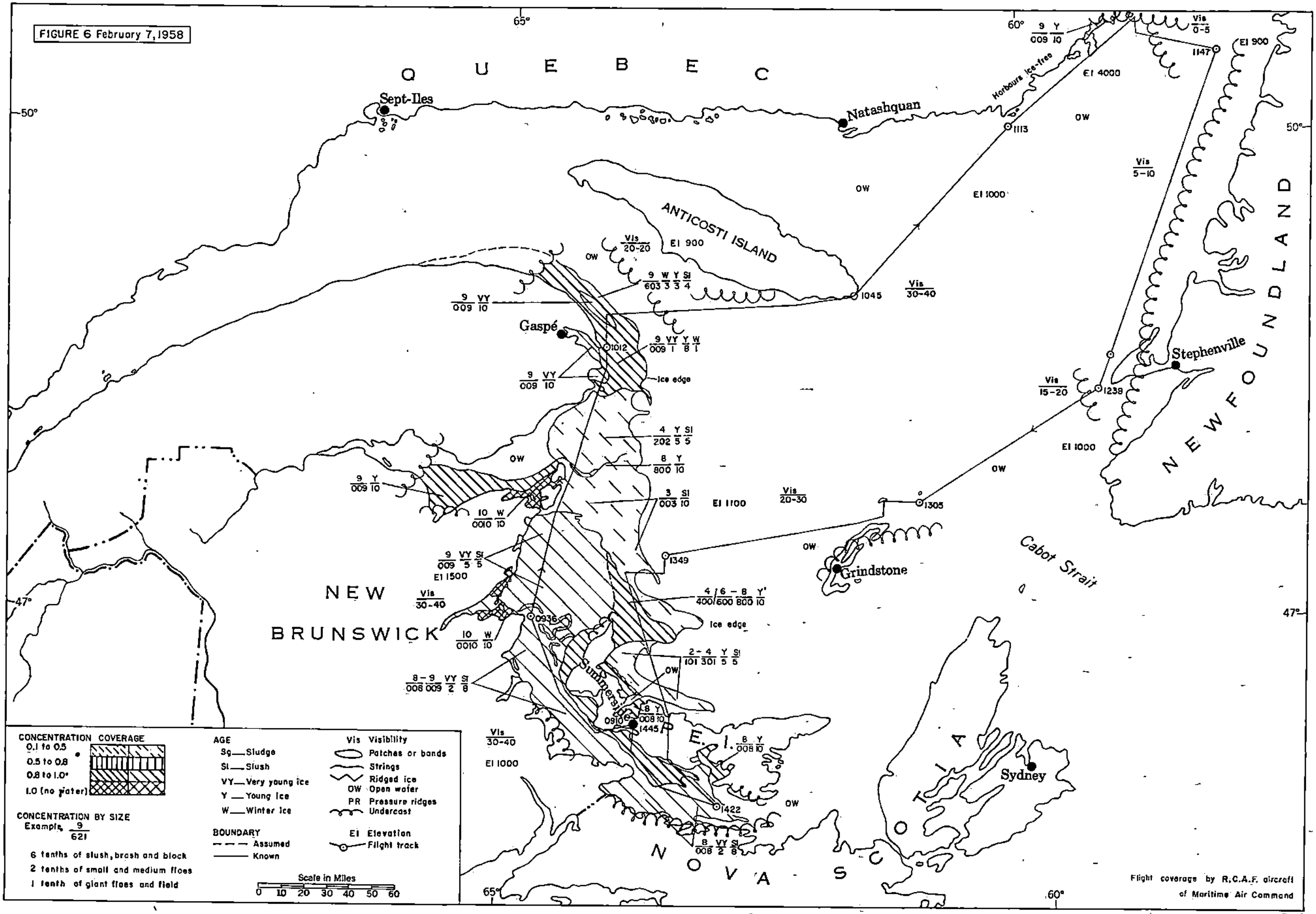
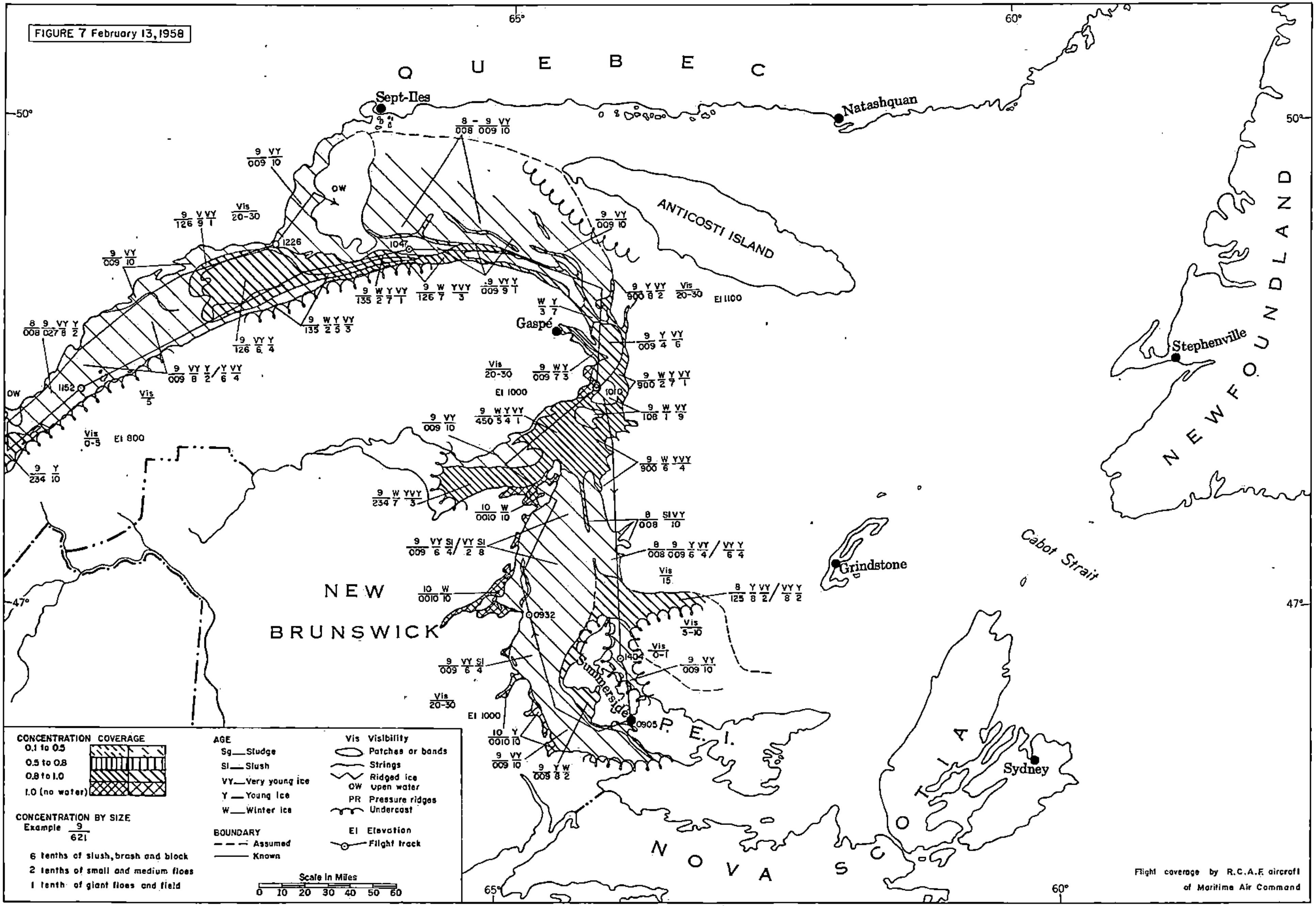


FIGURE 6 February 7, 1958
QUEBEC
Sept-Iles
Natashquan
Harbours ice-free
ANTICOSTI ISLAND
Gaspé
NEW BRUNSWICK
Summerside
P.E.I.
Grindstone
Cabot Strait
NEWFOUNDLAND
Stephenville
NOVA SCOTIA
Sydney
Ice edge
OW
El 900
El 4000
El 1000
El 1100
El 1500
Vis 0-5
Vis 5-10
Vis 20-20
Vis 30-40
Vis 15-20
Vis 20-30
1113
1147
1045
1012
1238
1305
1349
0936
0910
1445
1422
CONCENTRATION COVERAGE
0.1 to 0.5
0.5 to 0.8
0.8 to 1.0
1.0 (no water)
CONCENTRATION BY SIZE
Example 9/621
6 tenths of slush, brash and block
2 tenths of small and medium floes
1 tenth of giant floes and field
AGE
Sg — Sludge
Sl — Slush
VY — Very young ice
Y — Young ice
W — Winter ice
BOUNDARY
Assumed
Known
Vis Visibility
Patches or bands
Strings
Ridged ice
OW Open water
PR Pressure ridges
Undercast
El Elevation
Flight track
Scale in Miles
0 10 20 30 40 50 60
Flight coverage by R.C.A.F. aircraft of Maritime Air Command

FIGURE 7 February 13, 1958



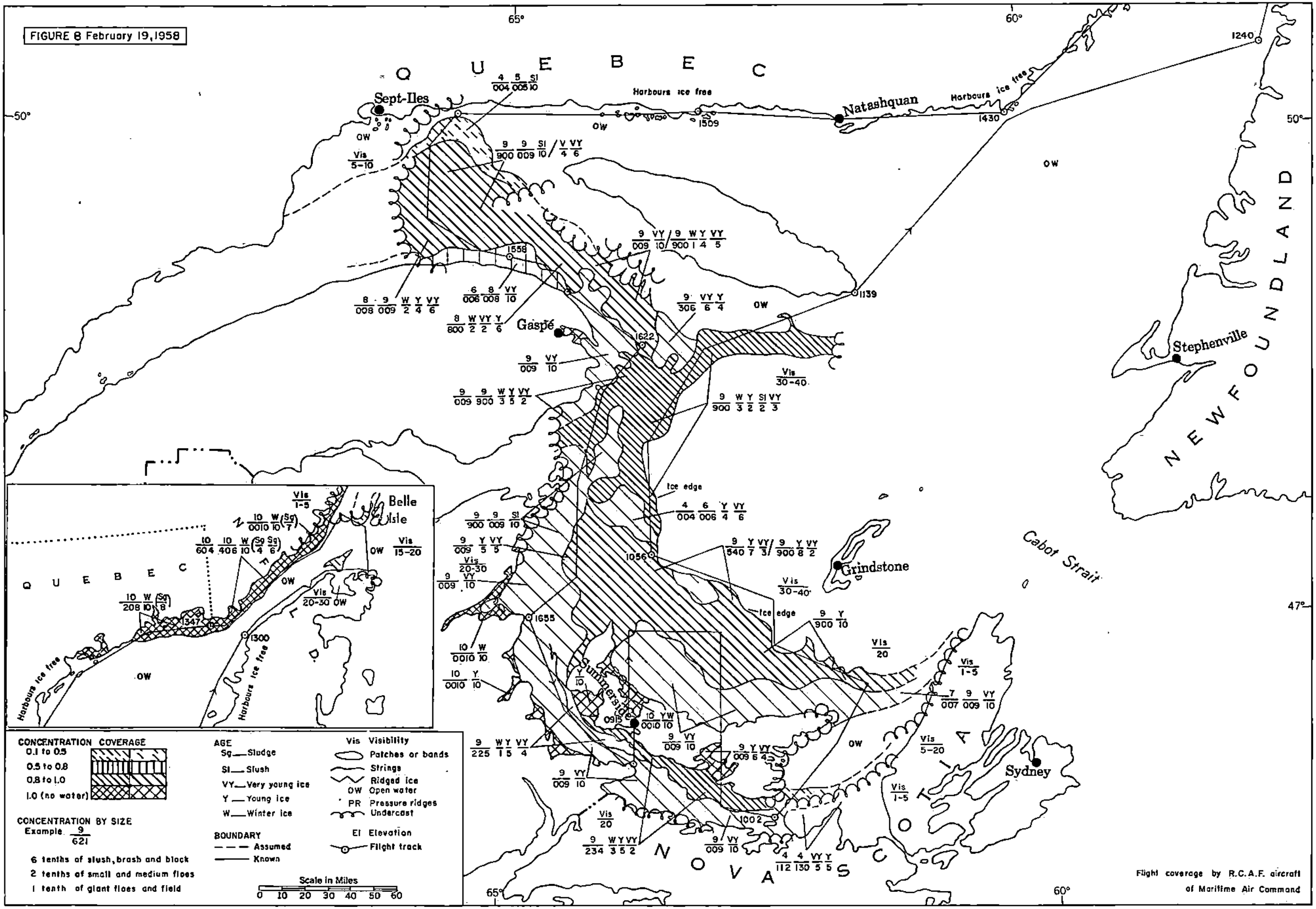


FIGURE 8 February 19, 1958

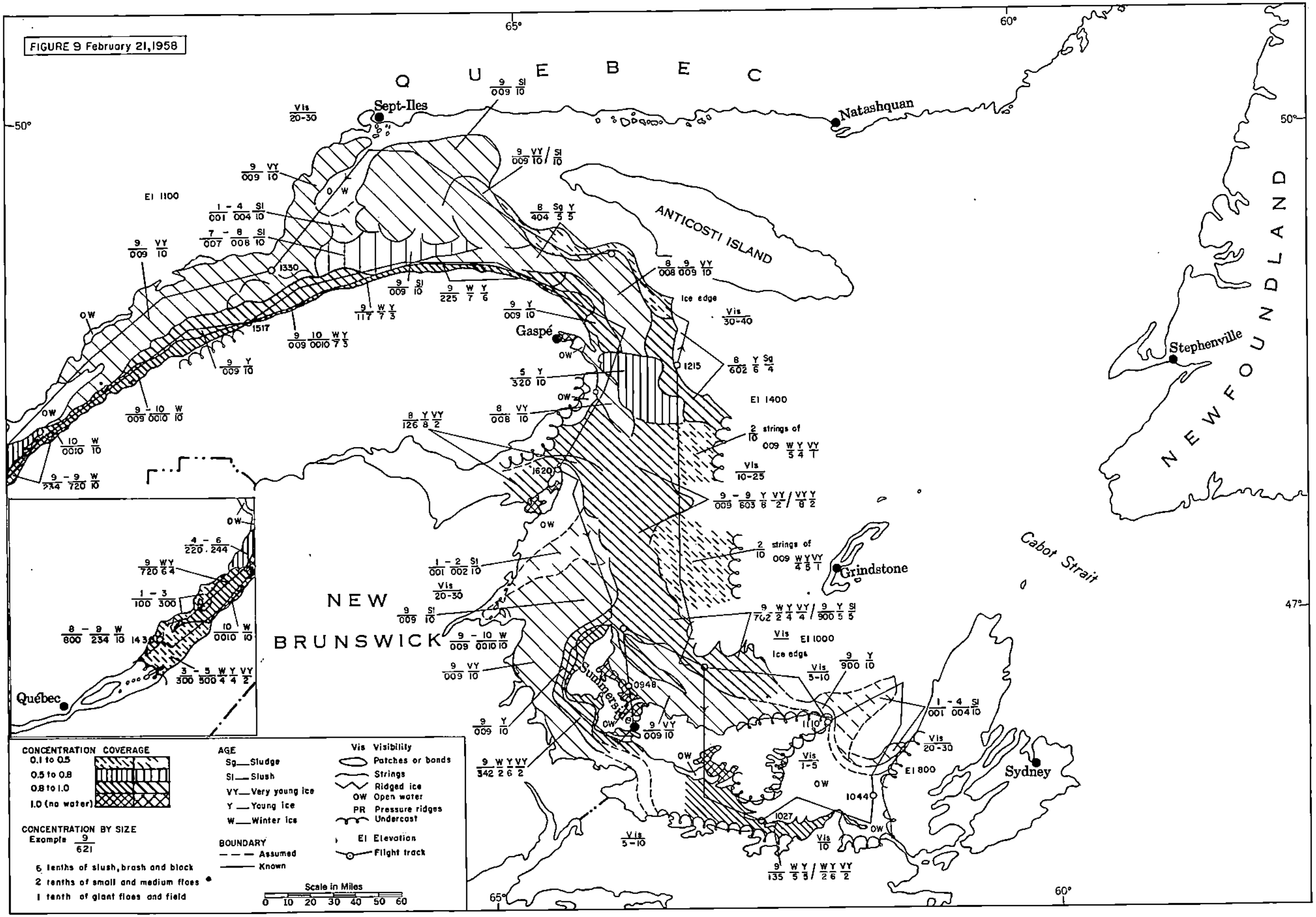


FIGURE 9 February 21, 1958

FIGURE 10 February 21, 1958

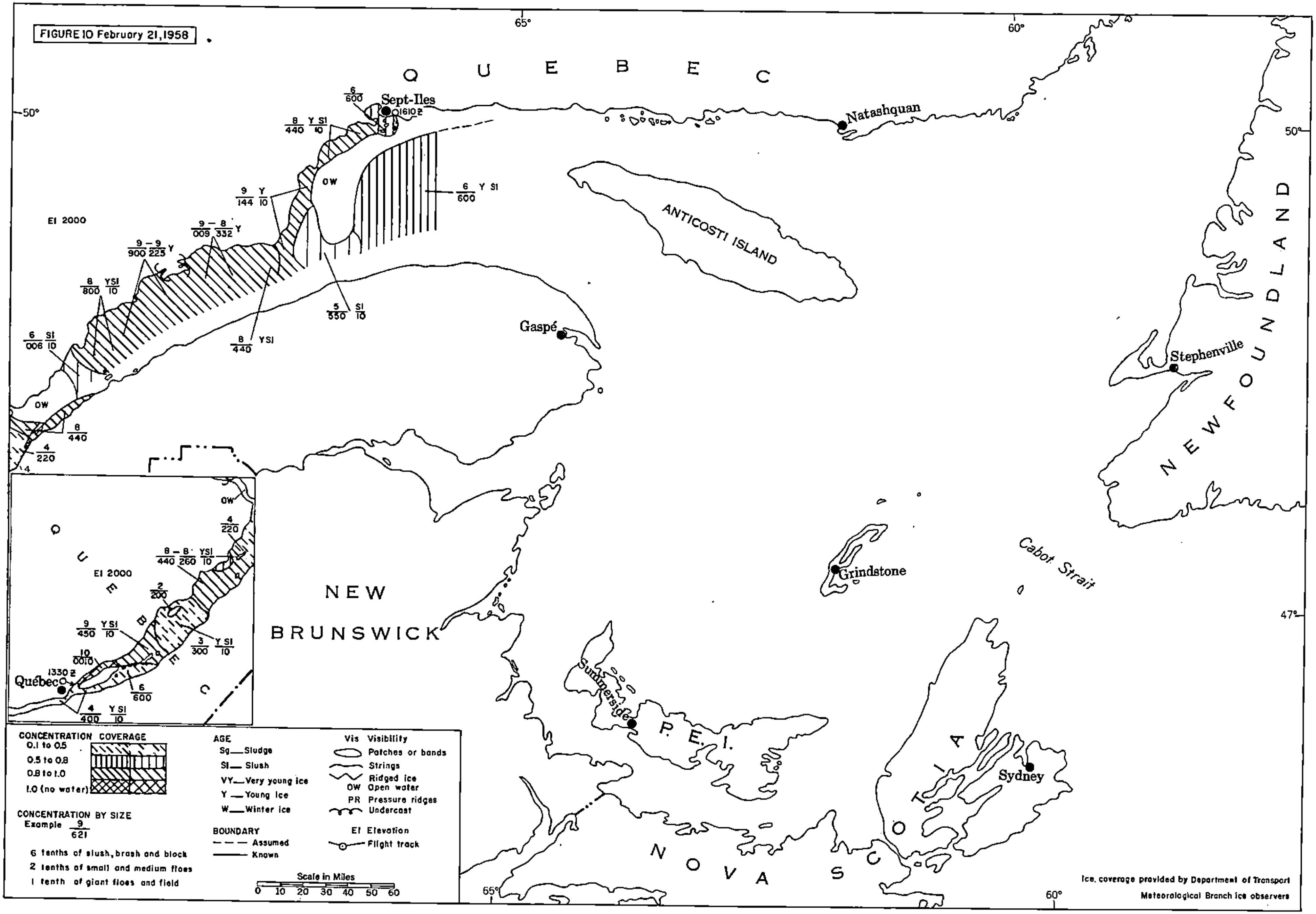
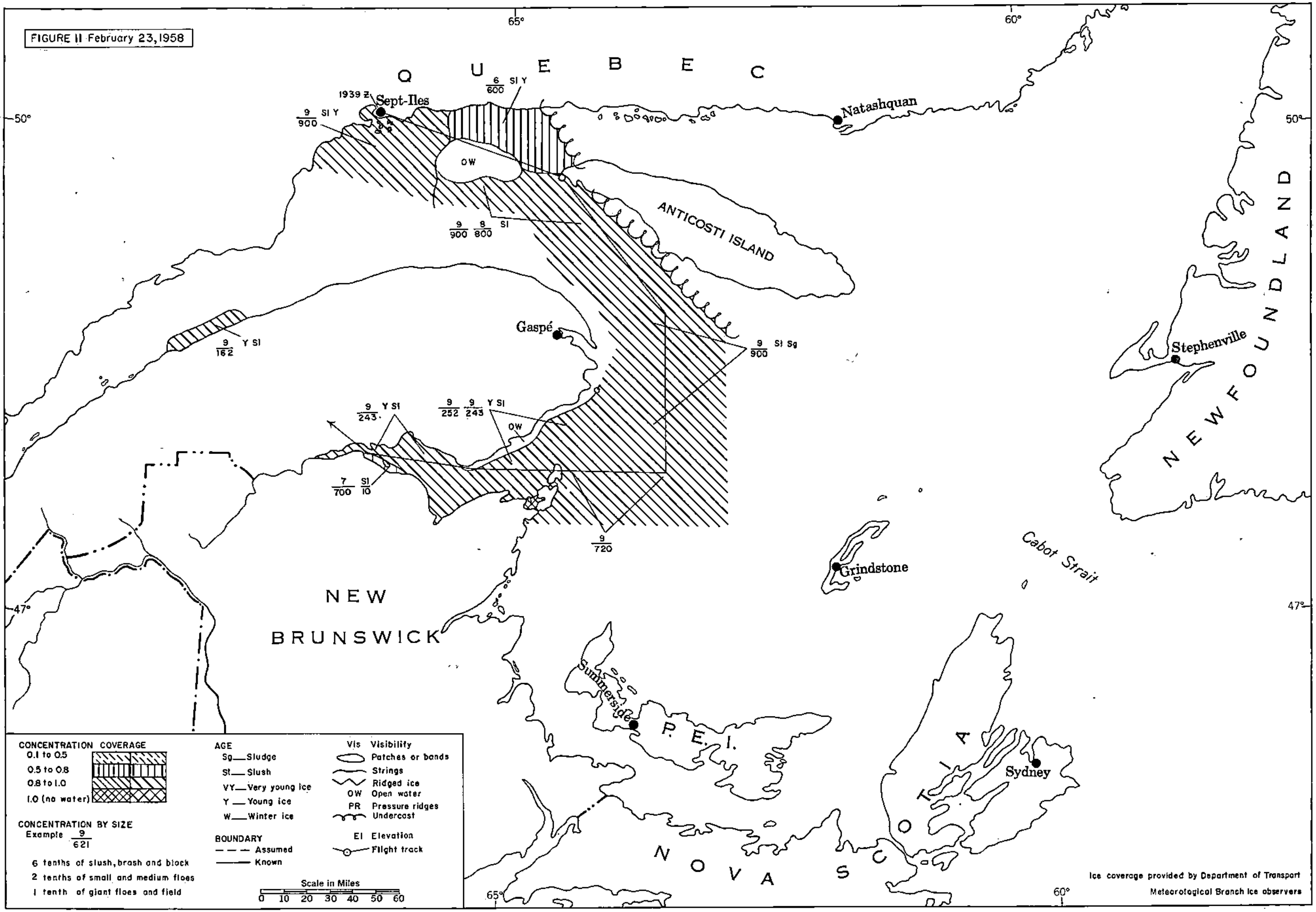


FIGURE 11 February 23, 1958



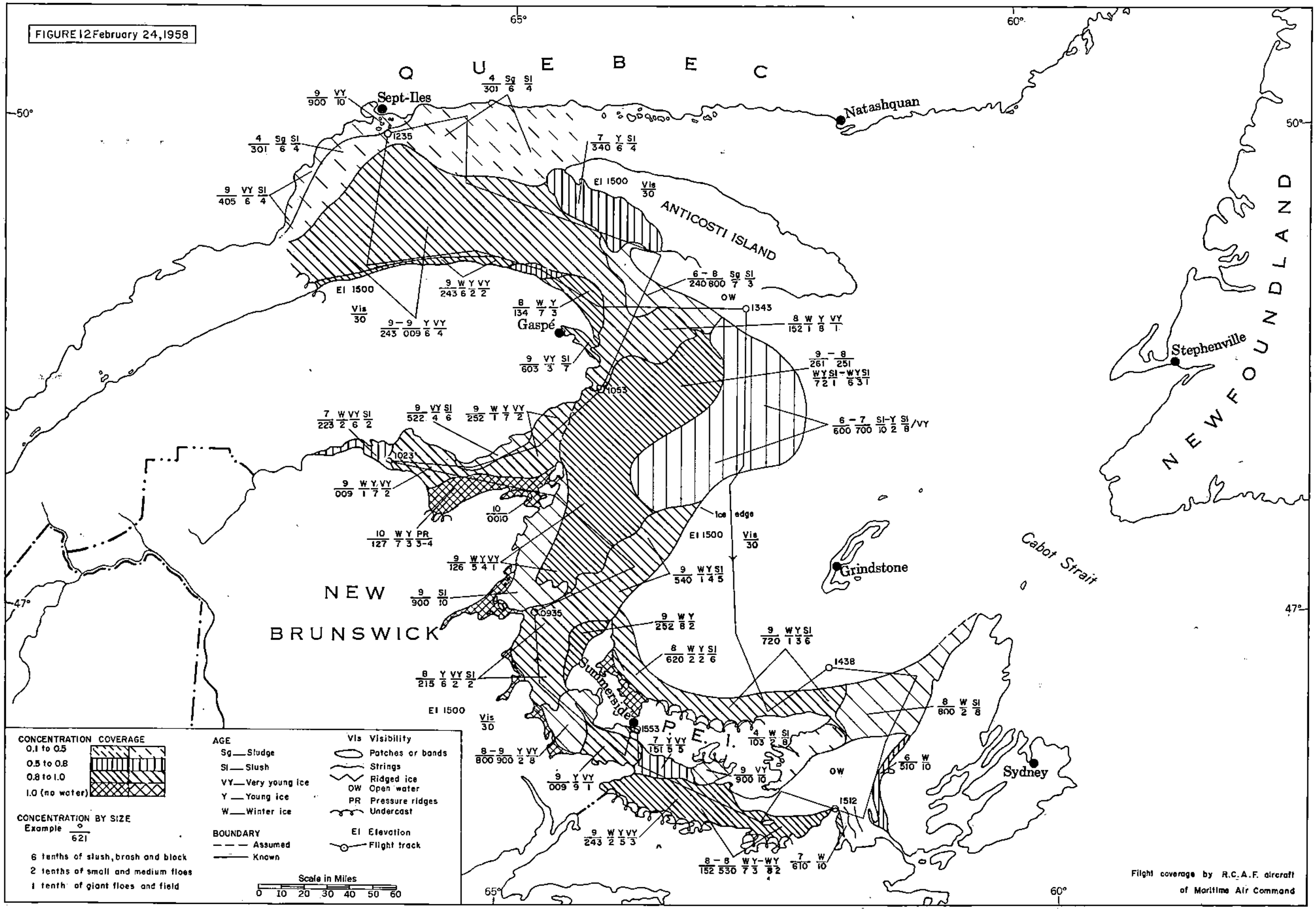


FIGURE 12 February 24, 1958

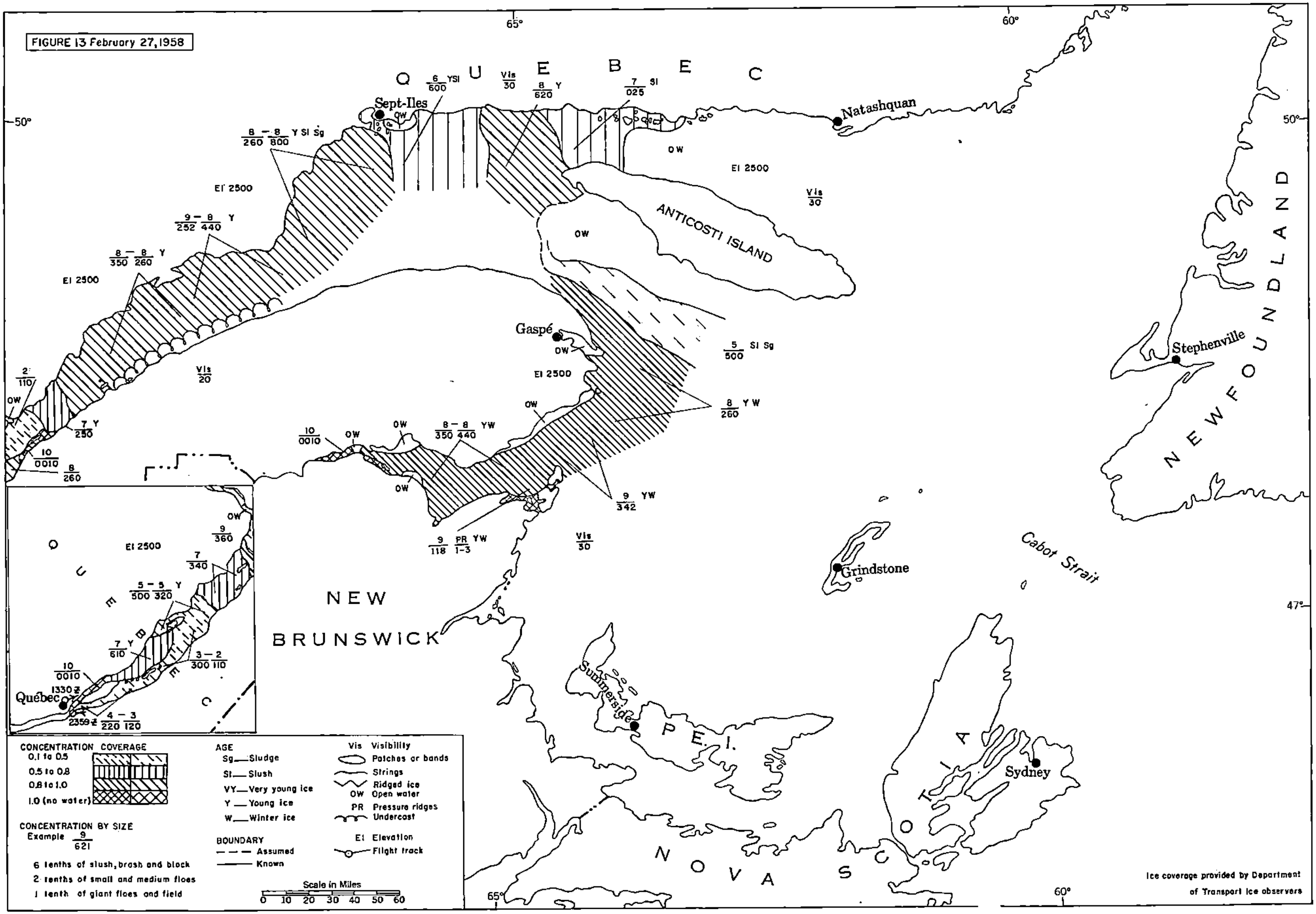


FIGURE 13 February 27, 1958

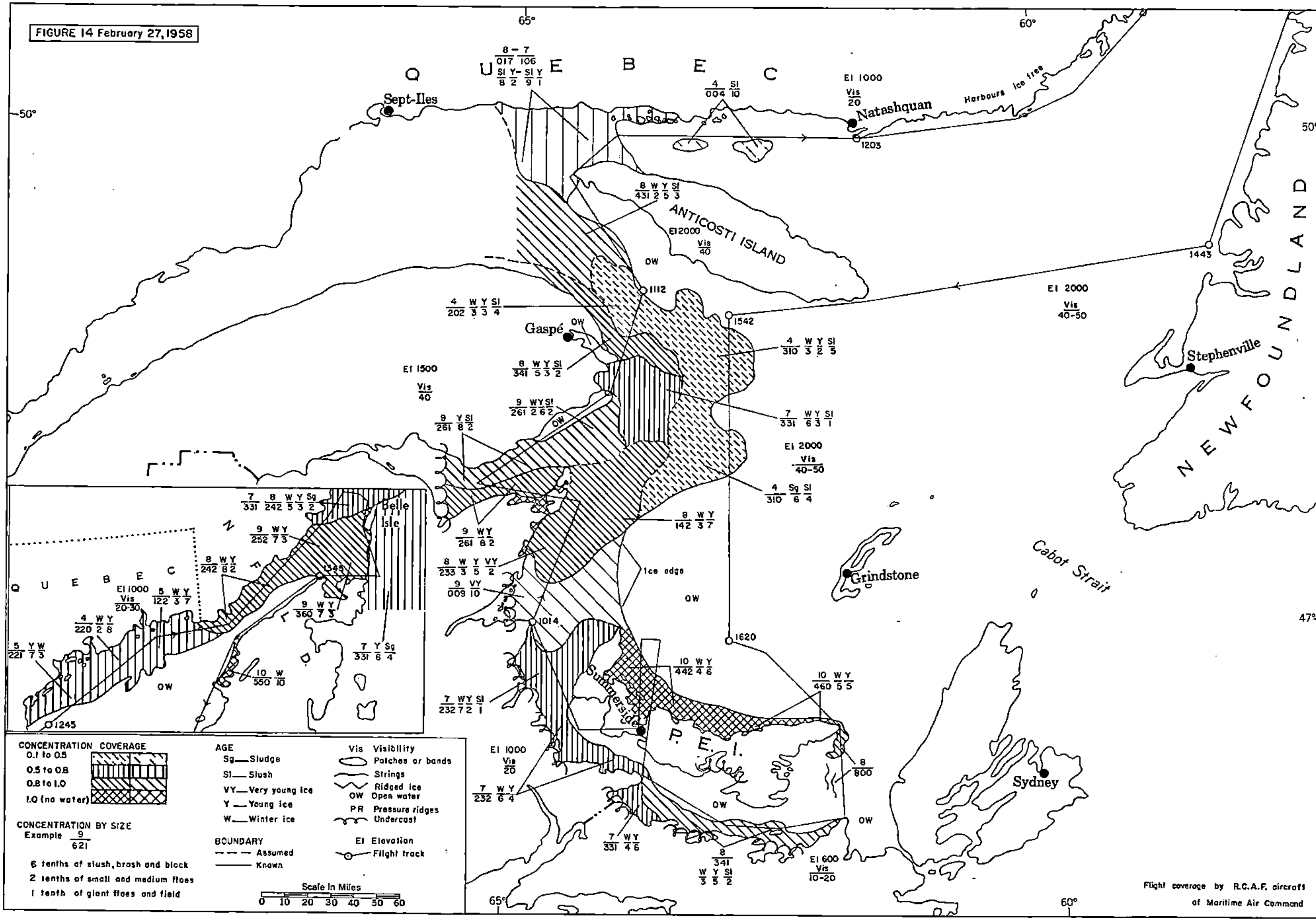


FIGURE 14 February 27, 1958

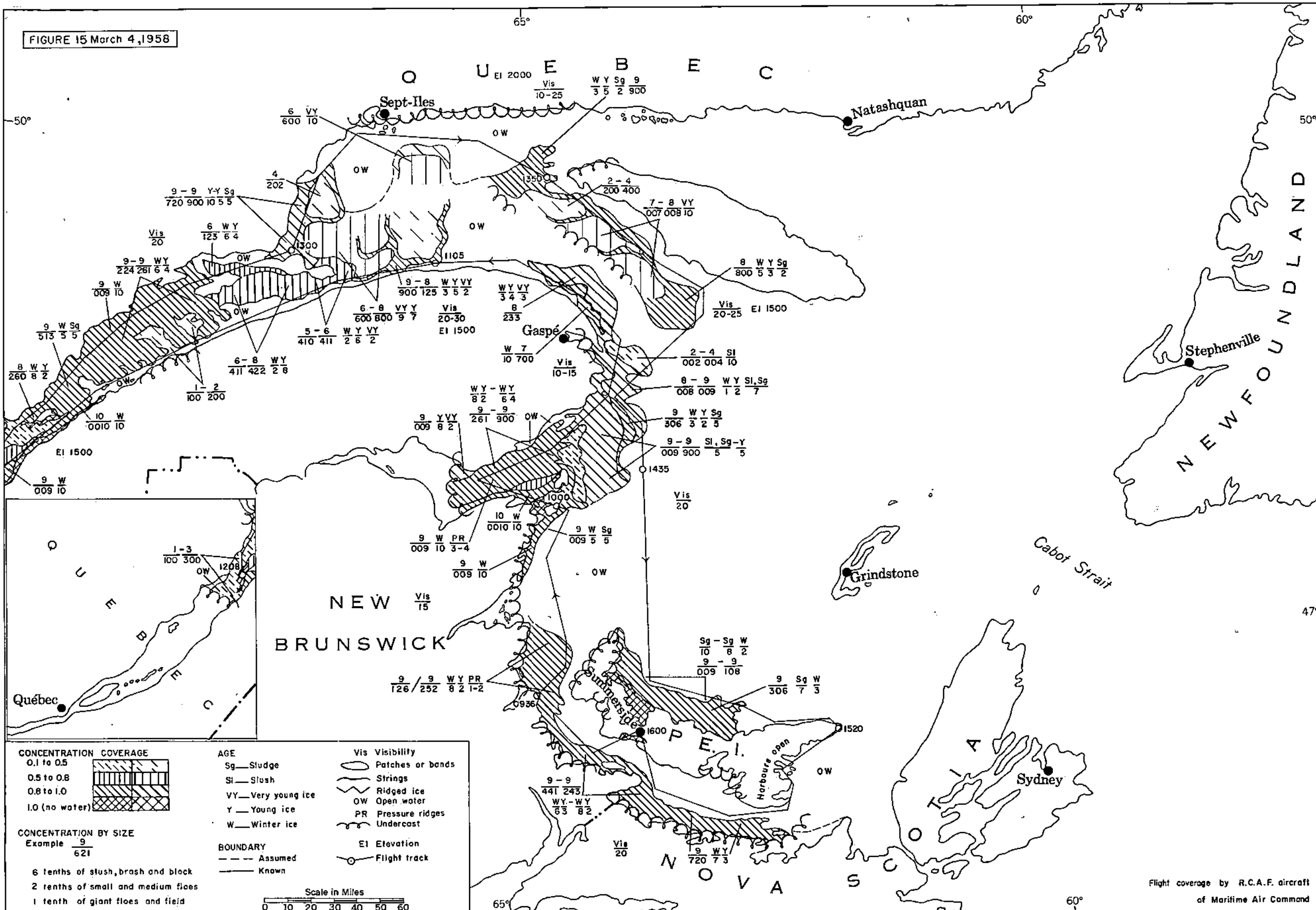


FIGURE 15 March 4, 1958

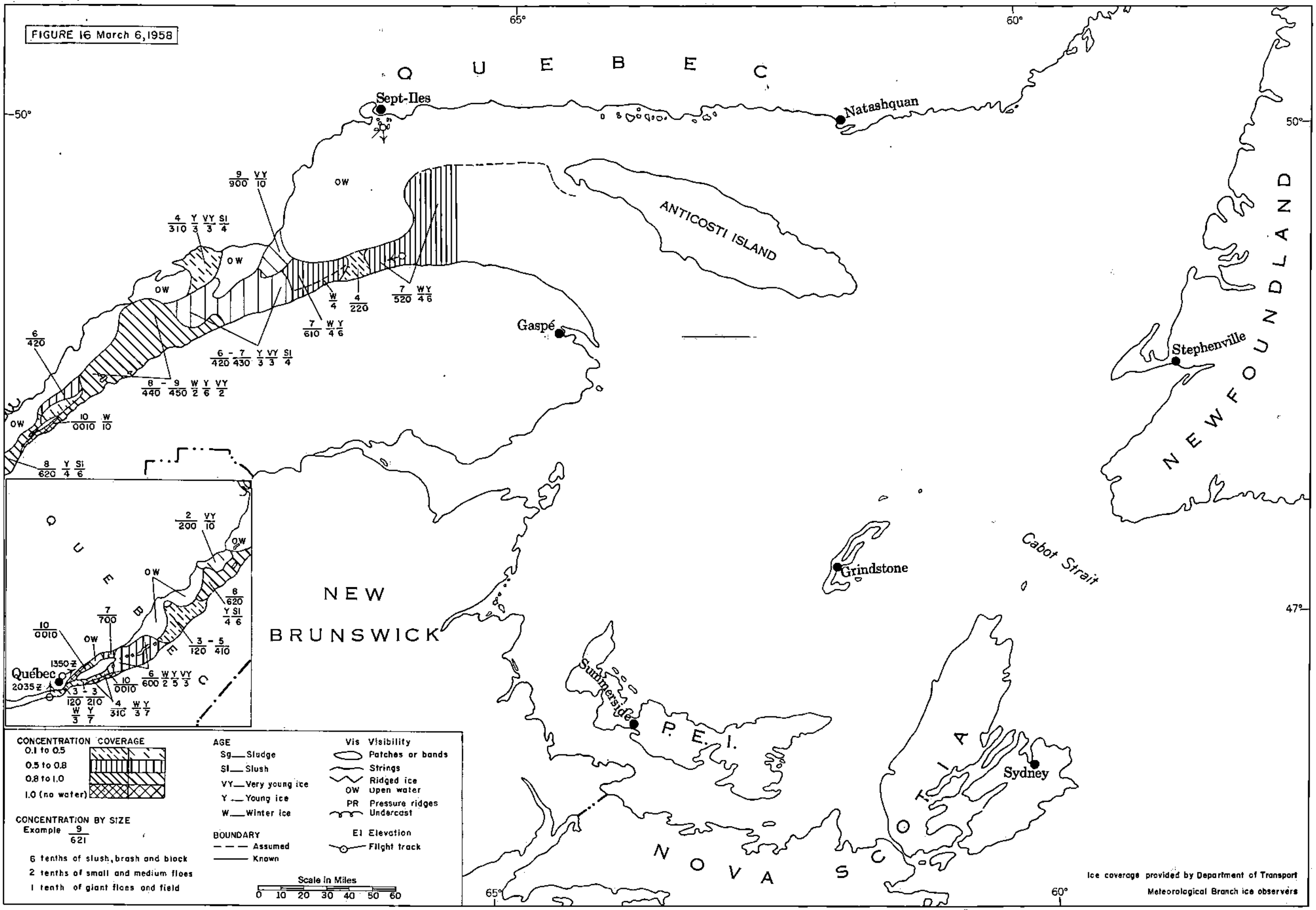


FIGURE 16 March 6, 1958

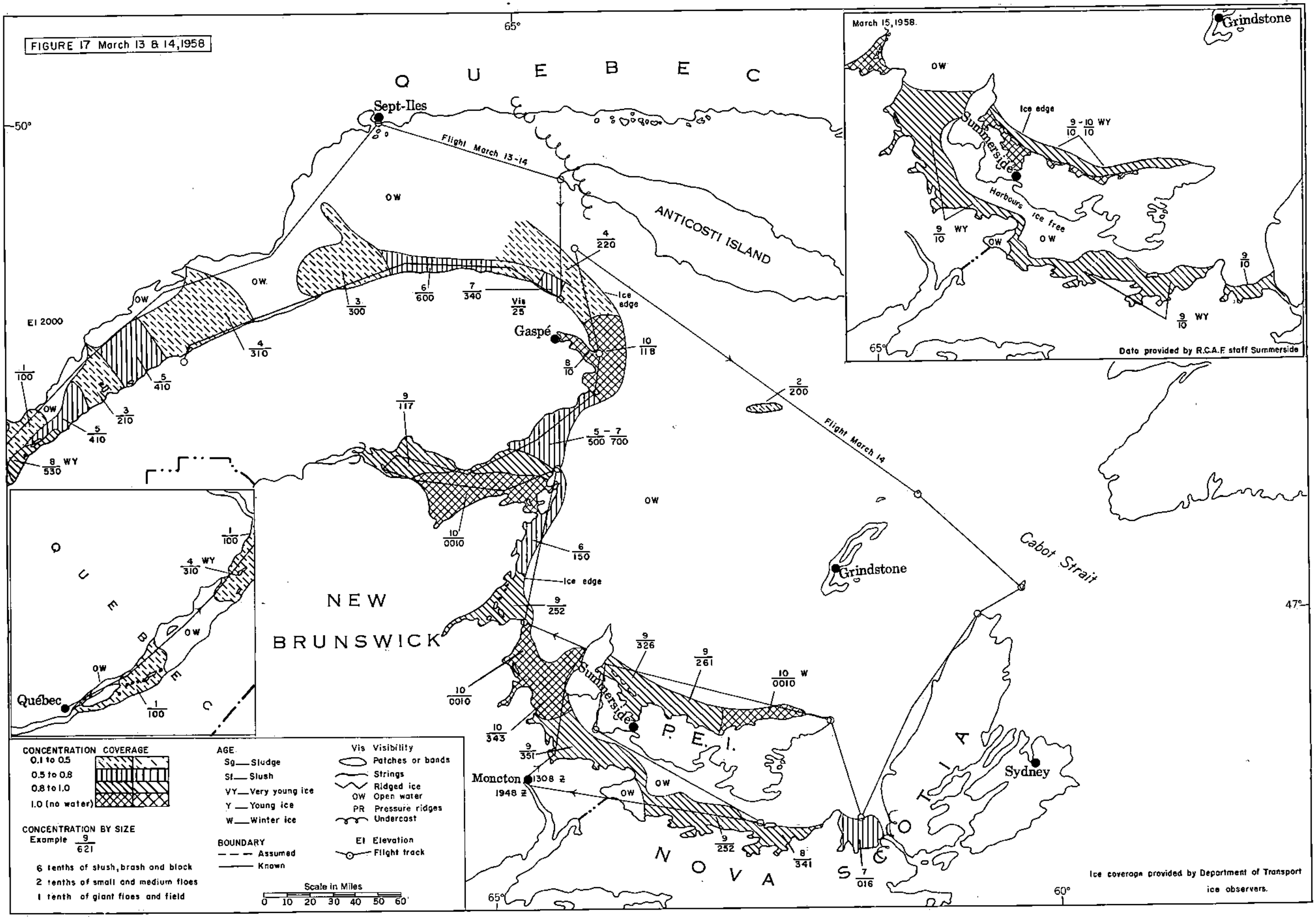


FIGURE 17 March 13 & 14, 1958

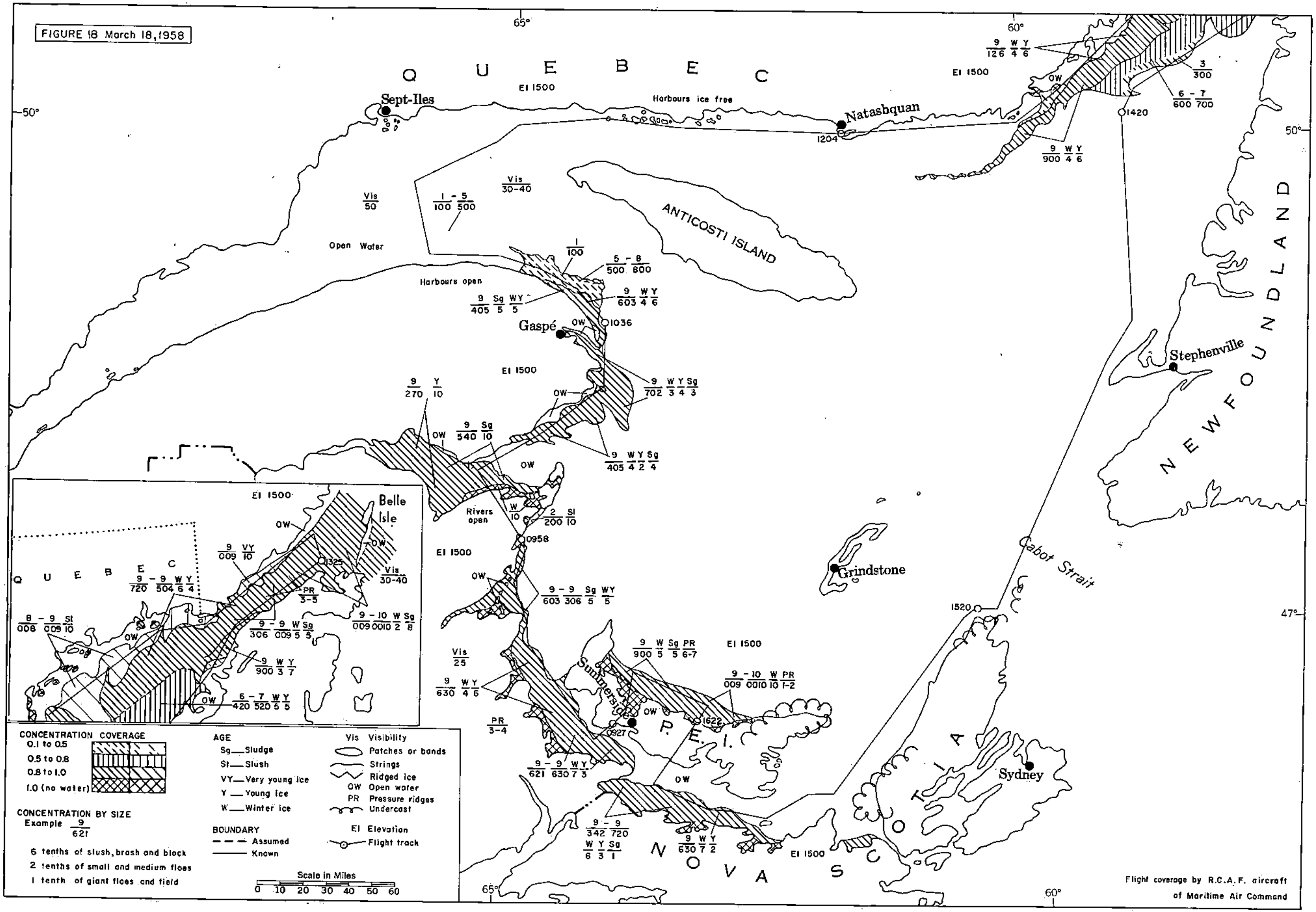


FIGURE 18 March 18, 1958

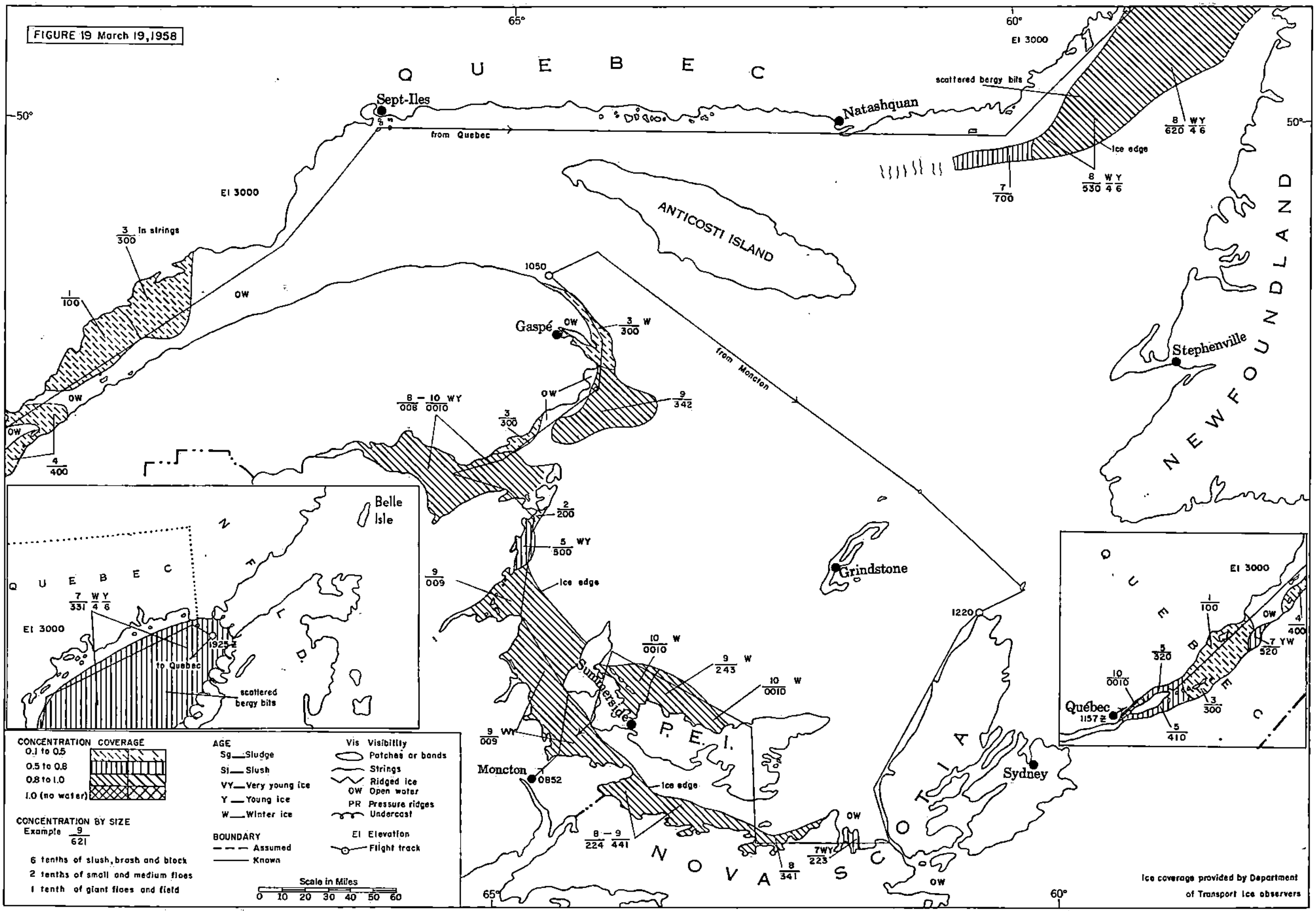


FIGURE 19 March 19, 1958

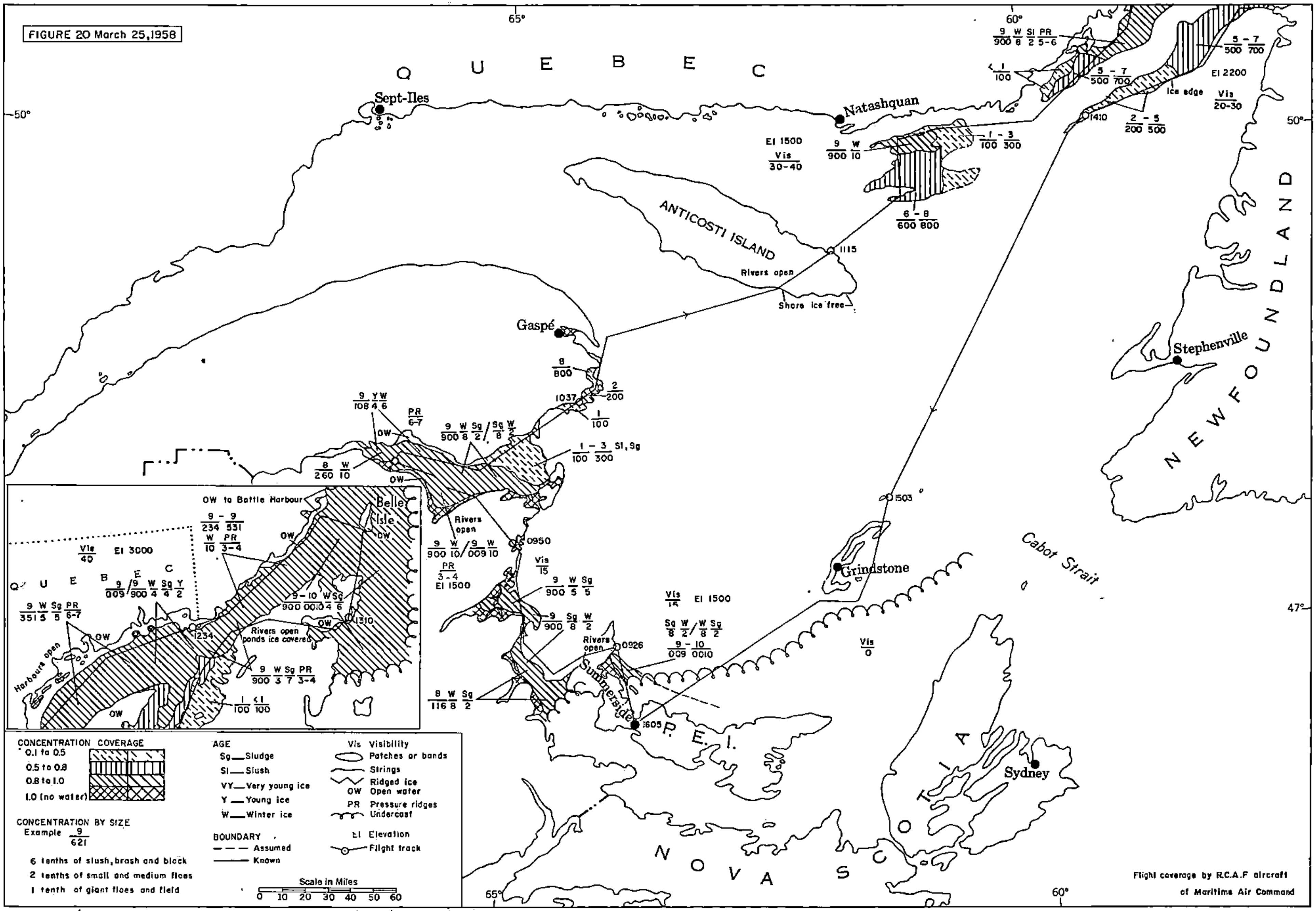


FIGURE 20 March 25,1958

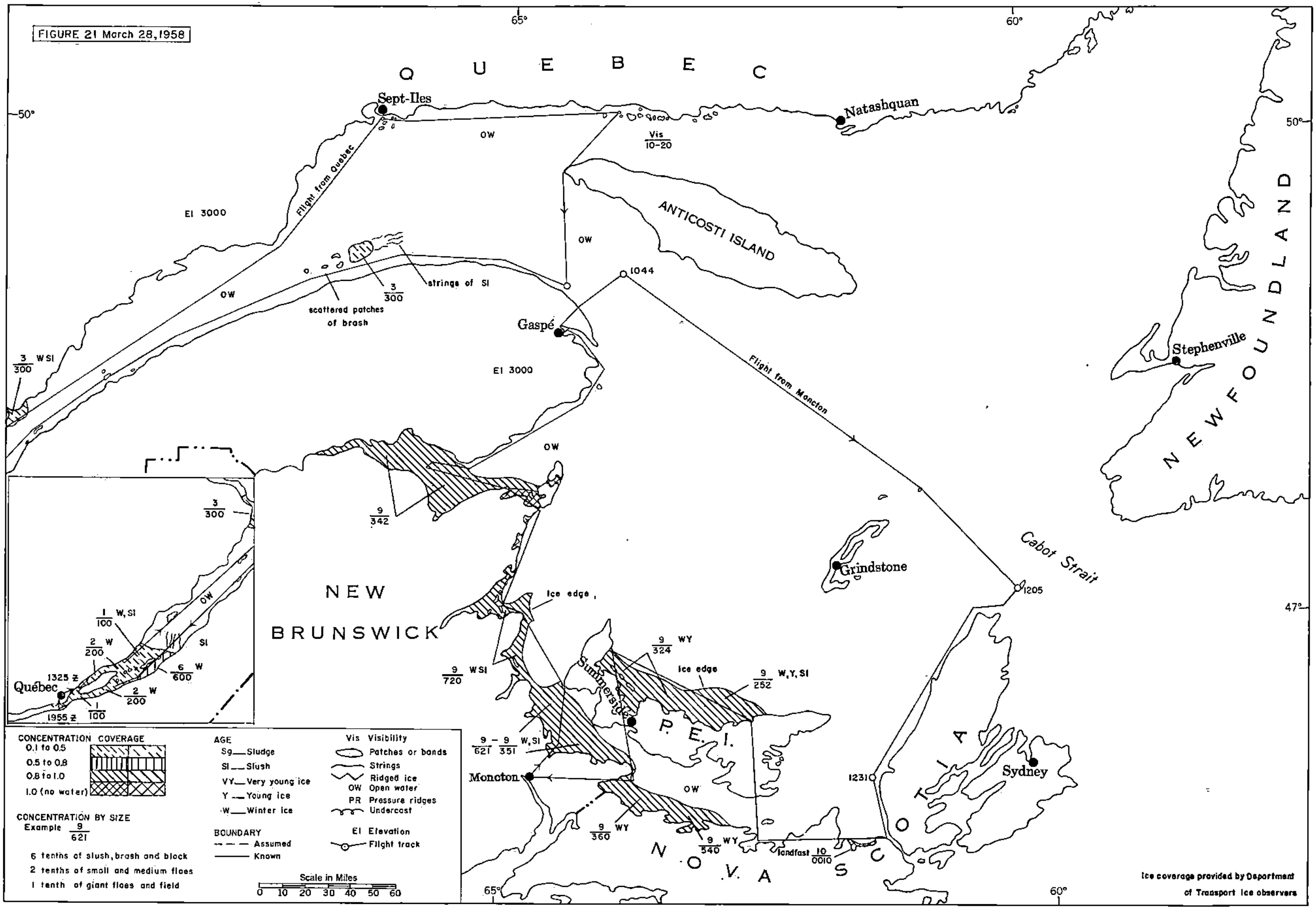


FIGURE 21 March 28, 1958
QUEBEC
Sept-Iles
Natashquan
ANTICOSTI ISLAND
NEWFOUNDLAND
Stephenville
Gaspé
NEW BRUNSWICK
Grindstone
Cabot Strait
Summerside
P.E.I.
Moncton
Sydney
NOVA SCOTIA
Québec
Flight from Quebec
Flight from Moncton
OW
Vis 10-20
El 3000
1044
1205
1231
strings of SI
scattered patches of brash
Ice edge
landfast 10/0010
CONCENTRATION COVERAGE
0.1 to 0.5
0.5 to 0.8
0.8 to 1.0
1.0 (no water)
CONCENTRATION BY SIZE
Example 9/621
6 tenths of slush, brash and block
2 tenths of small and medium floes
1 tenth of giant floes and field
AGE
Sg — Sludge
Sl — Slush
VY — Very young ice
Y — Young ice
W — Winter ice
BOUNDARY
Assumed
Known
Vis Visibility
Patches or bands
Strings
Ridged ice
OW Open water
PR Pressure ridges
Undercast
El Elevation
Flight track
Scale in Miles
0 10 20 30 40 50 60
Ice coverage provided by Department of Transport Ice observers

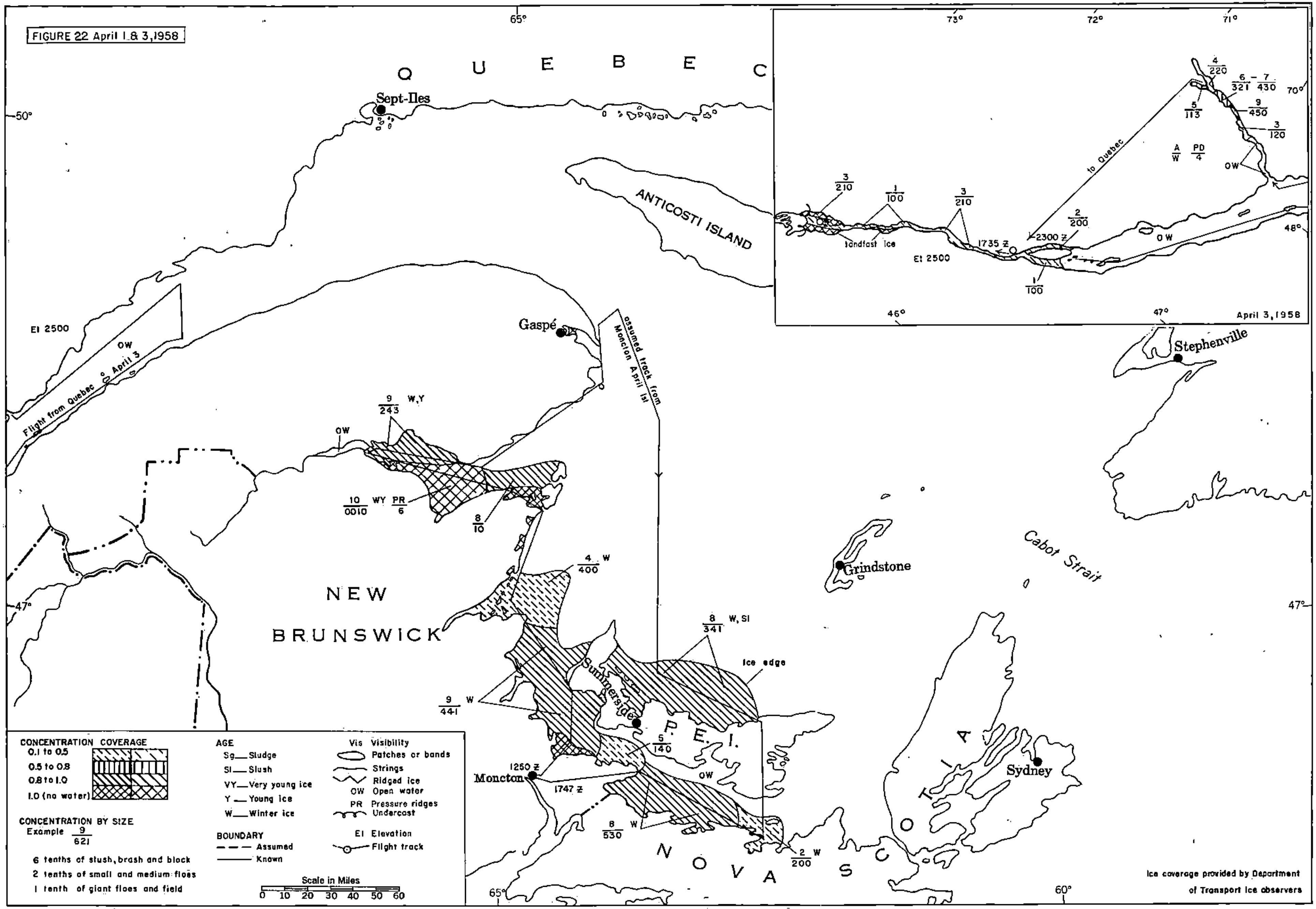


FIGURE 22 April 1 & 3, 1958
QUEBEC
Sept-Iles
ANTICOSTI ISLAND
Gaspé
El 2500
OW
Flight from Quebec April 3
assumed track from Moncton April 1st
NEW BRUNSWICK
P.E.I.
Summerside
Moncton
Grindstone
Cabot Strait
Stephenville
Sydney
NOVA SCOTIA
Ice edge
1250 Z
1747 Z
April 3, 1958
to Quebec
landfast ice
1735 Z
2300 Z
CONCENTRATION COVERAGE
0.1 to 0.5
0.5 to 0.8
0.8 to 1.0
1.0 (no water)
CONCENTRATION BY SIZE
Example 9/621
6 tenths of slush, brash and block
2 tenths of small and medium floes
1 tenth of giant floes and field
AGE
Sg — Sludge
Sl — Slush
VY — Very young ice
Y — Young ice
W — Winter ice
BOUNDARY
Assumed
Known
Vis Visibility
Patches or bands
Strings
Ridged ice
OW Open water
PR Pressure ridges
Undercast
El Elevation
Flight track
Scale in Miles
0 10 20 30 40 50 60
Ice coverage provided by Department of Transport Ice observers

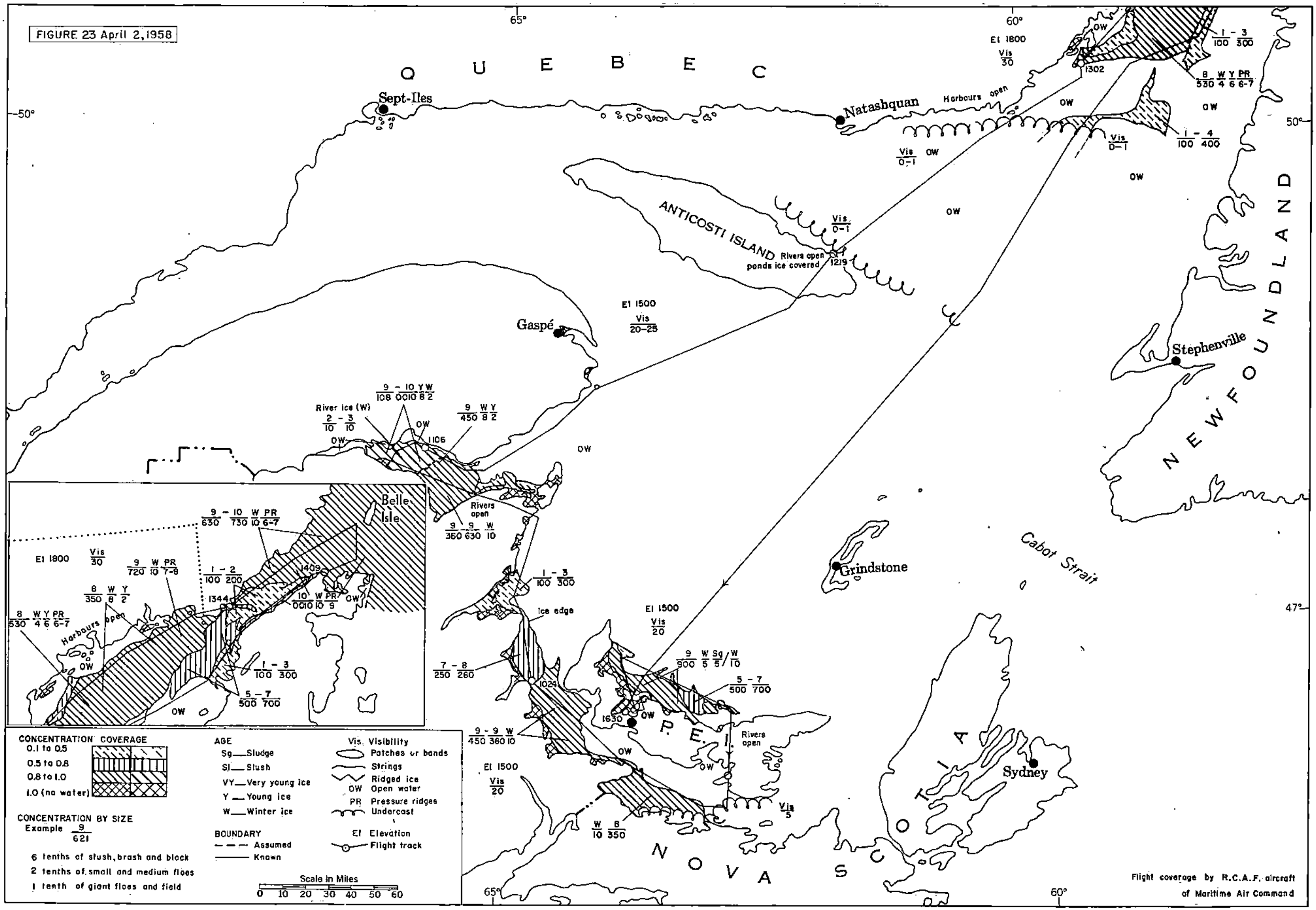


FIGURE 23 April 2, 1958

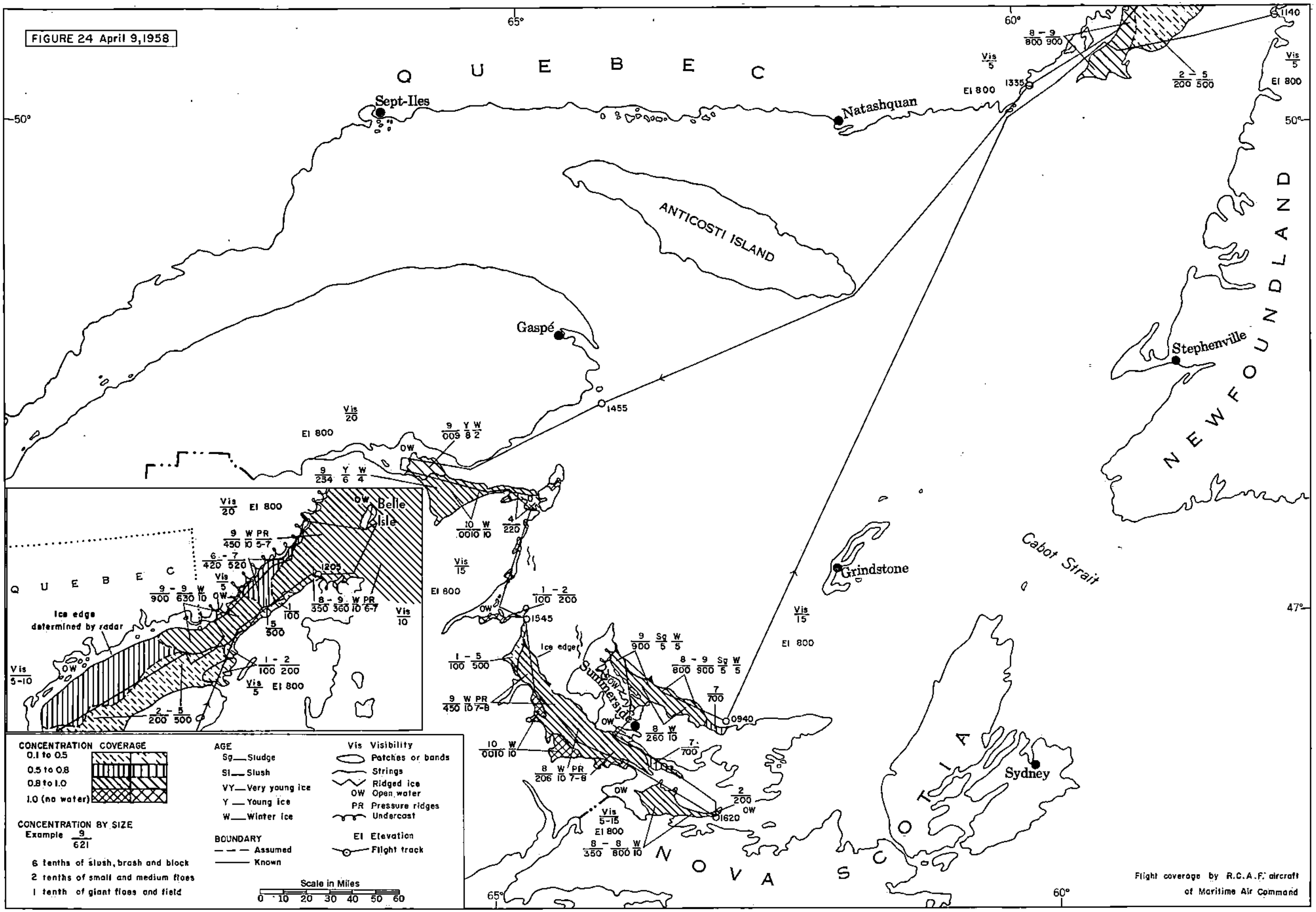


FIGURE 24 April 9, 1958

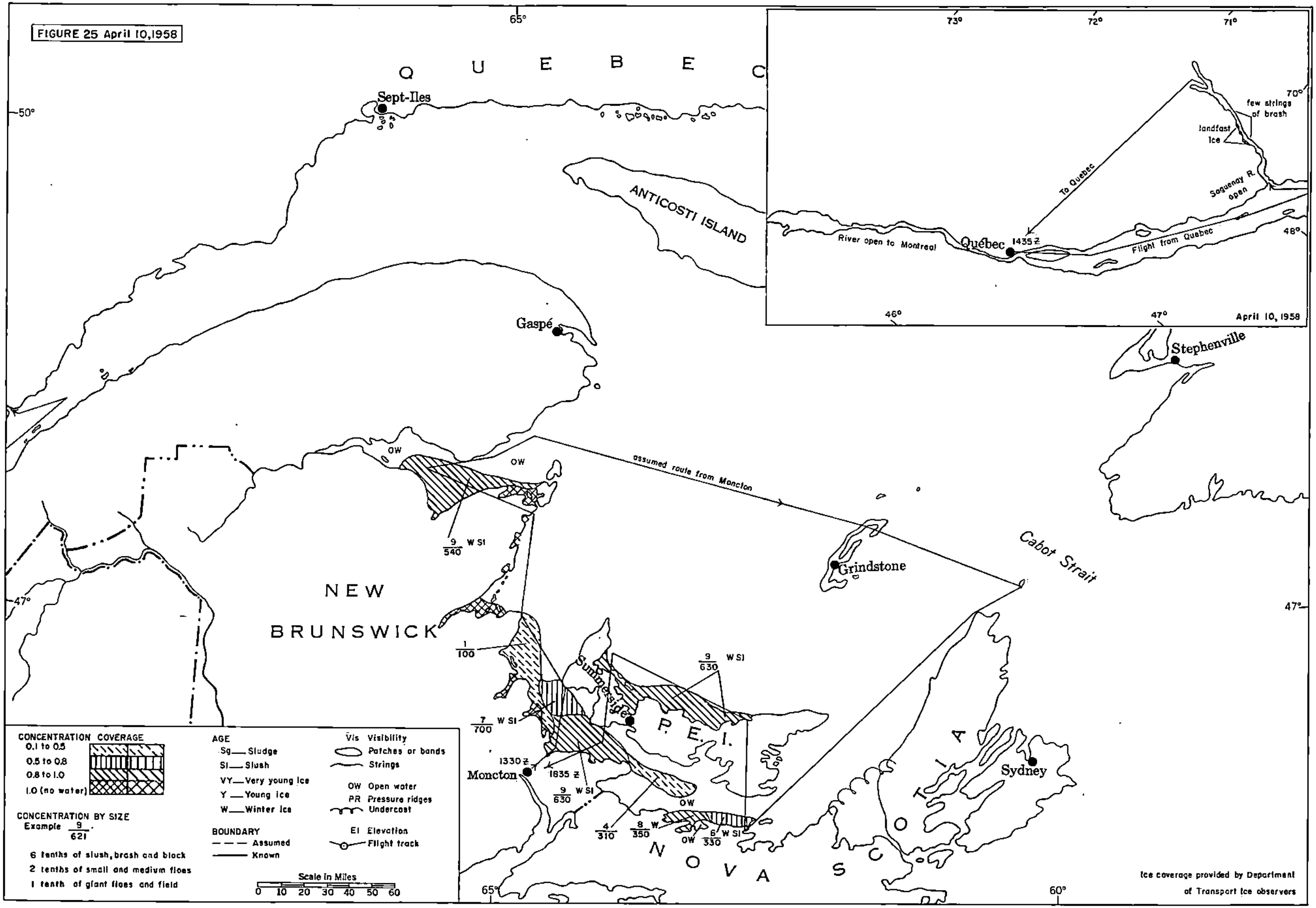


FIGURE 25 April 10,1958

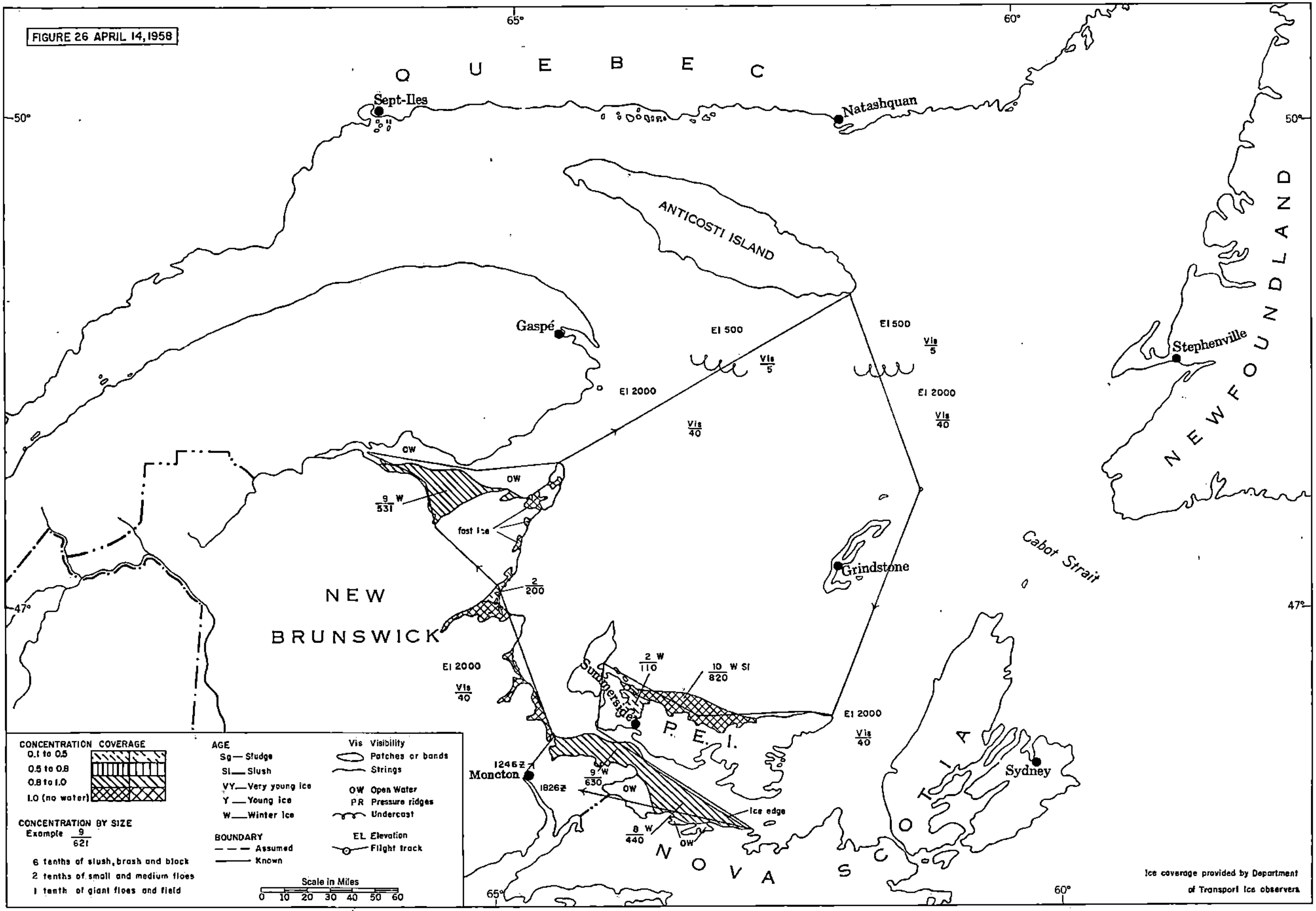


FIGURE 26 APRIL 14, 1958

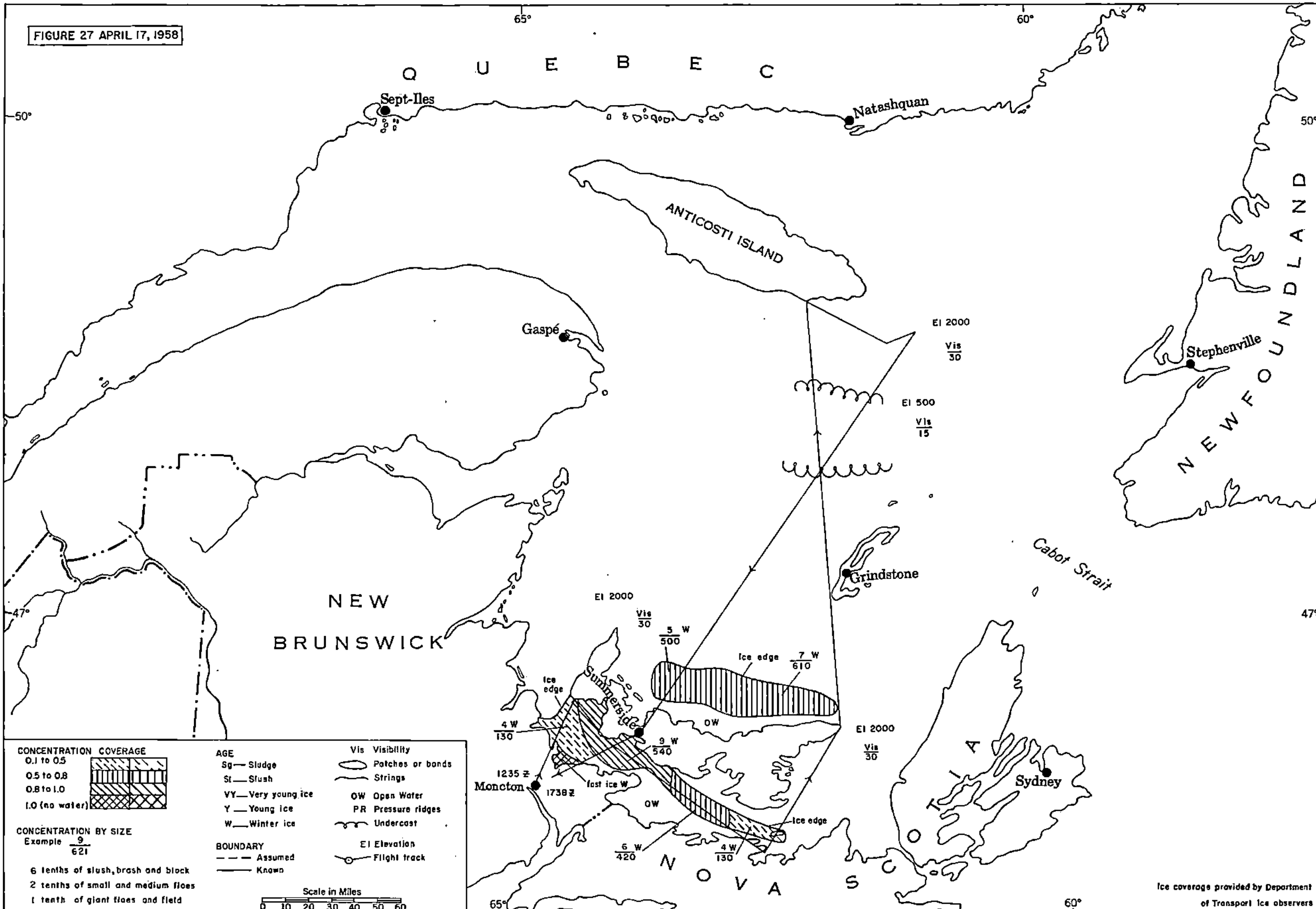


FIGURE 27 APRIL 17, 1958

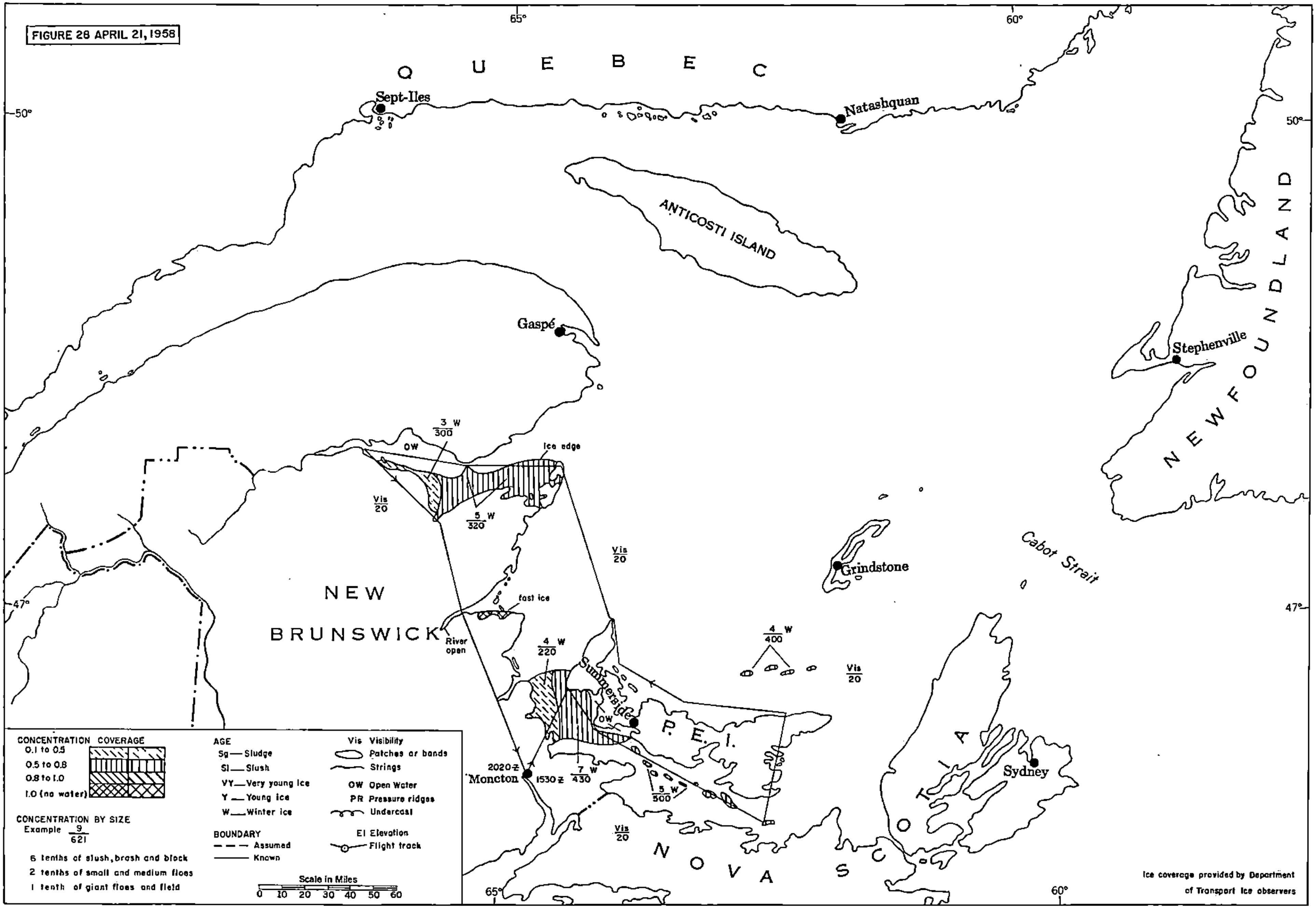
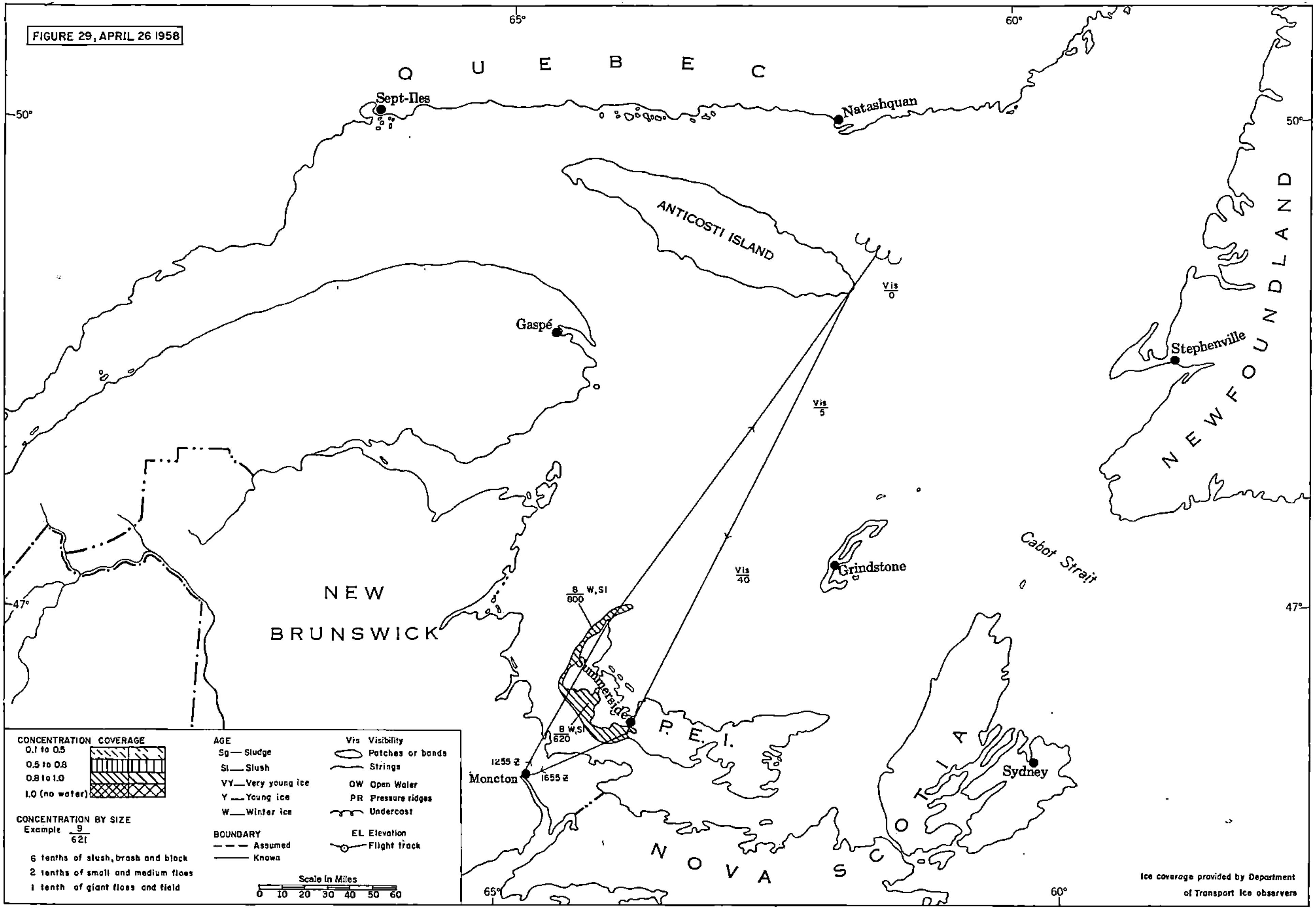


FIGURE 28 APRIL 21, 1958

FIGURE 29, APRIL 26 1958



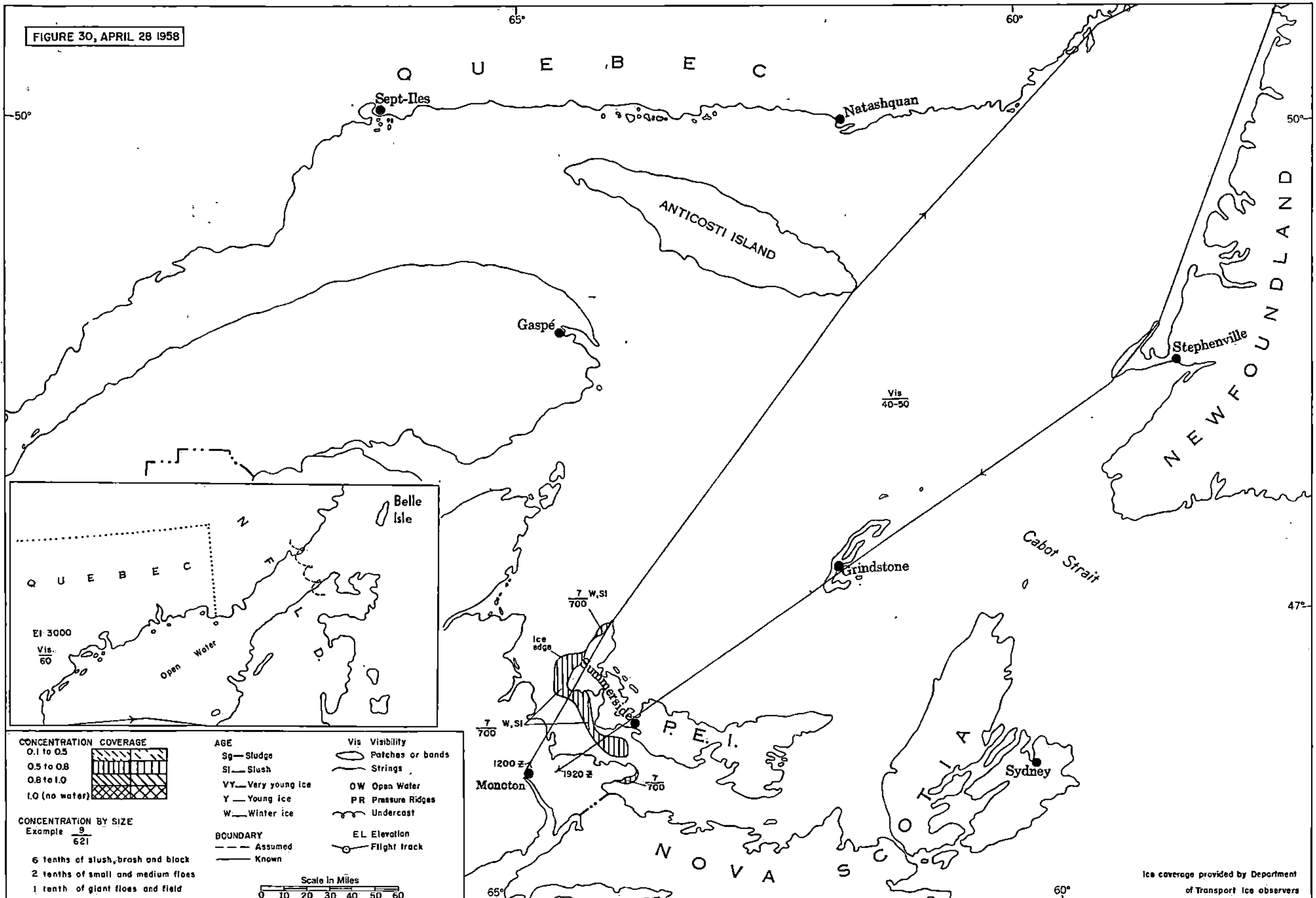


FIGURE 30, APRIL 28 1958
QUEBEC
Sept-Iles
Natashquan
ANTICOSTI ISLAND
Gaspé
NEWFOUNDLAND
Stephenville
Vis
40-50
Grindstone
Cabot Strait
Belle
Isle
QUEBEC
NFLD.
El 3000
Vis.
60
Open Water
7
700
W, SI
Ice
edge
Summerside
P. E. I.
1200 Z
Moncton
1920 Z
Sydney
NOVA SCOTIA
65°
60°
50°
47°
CONCENTRATION COVERAGE
0.1 to 0.5
0.5 to 0.8
0.8 to 1.0
1.0 (no water)
CONCENTRATION BY SIZE
Example 9/621
6 tenths of slush, brash and block
2 tenths of small and medium floes
1 tenth of giant floes and field
AGE
Sg — Sludge
Sl — Slush
VY — Very young ice
Y — Young ice
W — Winter ice
BOUNDARY
Assumed
Known
Vis Visibility
Patches or bands
Strings
OW Open Water
PR Pressure Ridges
Undercast
EL Elevation
Flight track
Scale in Miles
0 10 20 30 40 50 60
Ice coverage provided by Department
of Transport ice observers

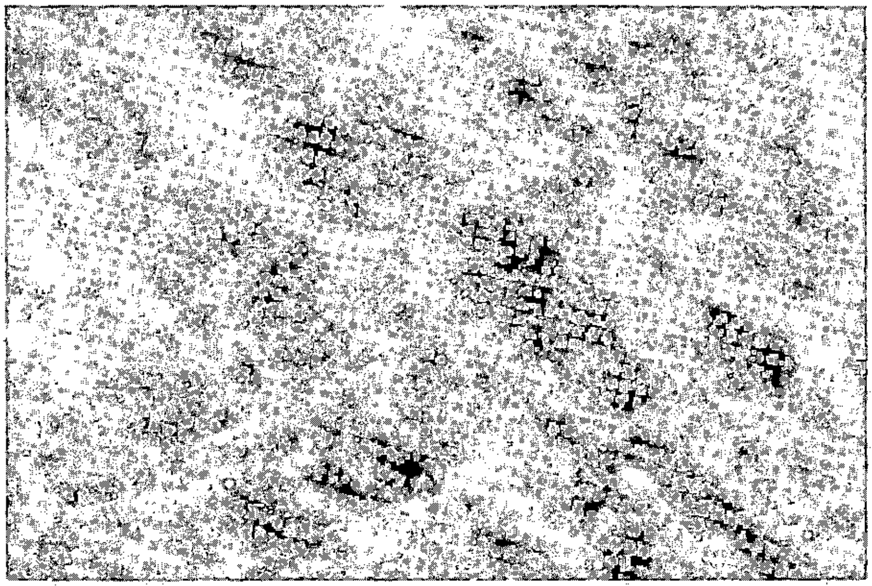


Plate 1.

Slush forms a soupy mass in the water. This pattern is produced by wind and wave action (February 21).

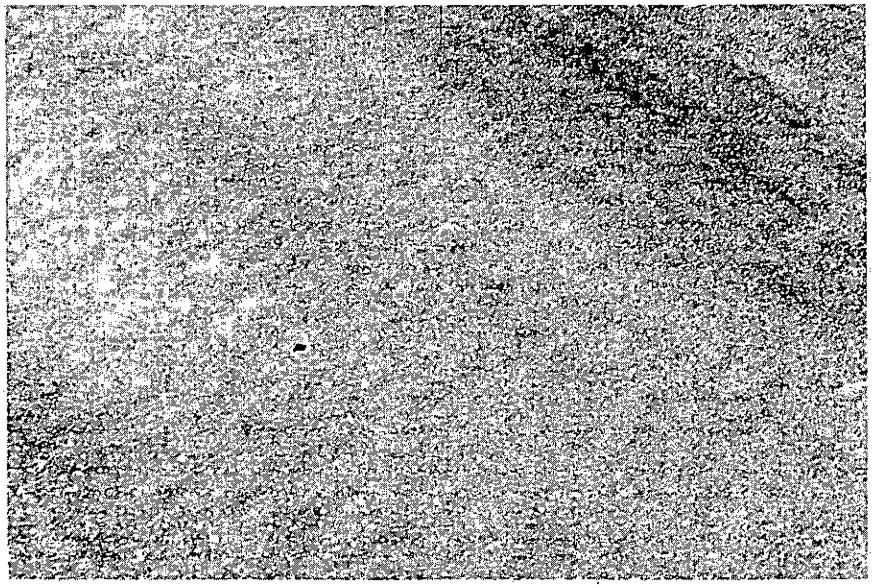


Plate 2.

An accumulation of slush and brash (February 19).

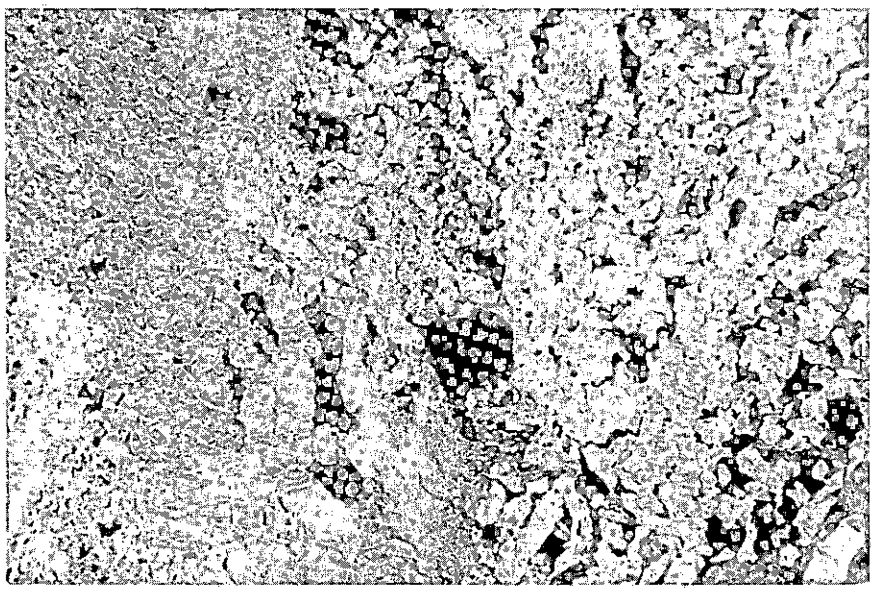


Plate 3.

This field of new ice consists of very young ice that has incorporated slush and sludge. Sludge has hardened sufficiently to shatter under pressure (February 21).

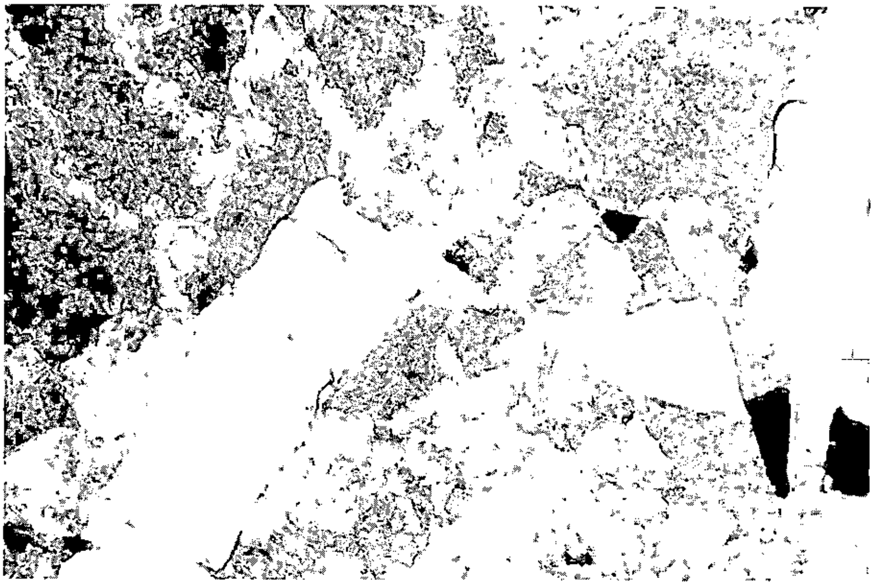


Plate 4.

This new ice field consists of very young ice. Shelving is in progress and indicates the way in which young ice develops (February 27).

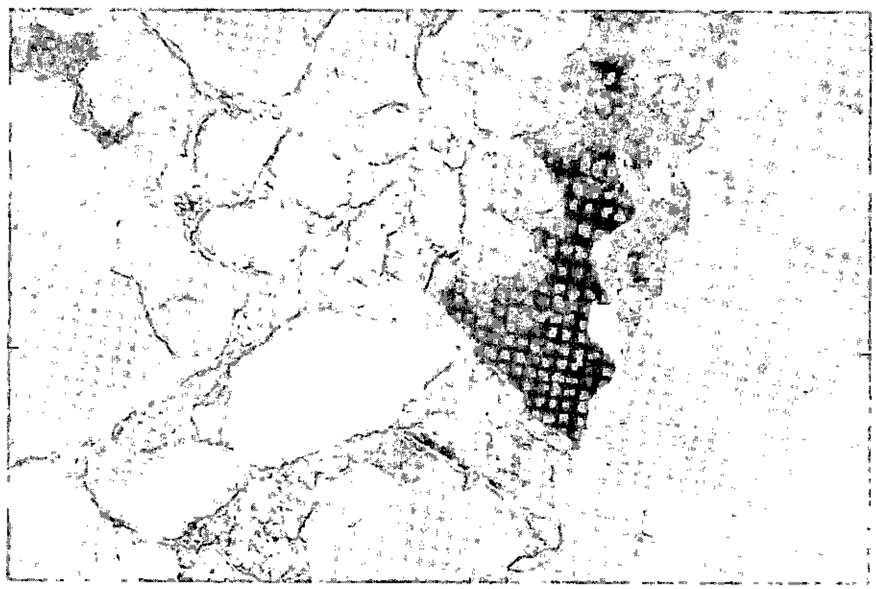


Plate 5.

Through a process of shelving, new ice becomes young ice, the latter being grey in appearance (February 27).

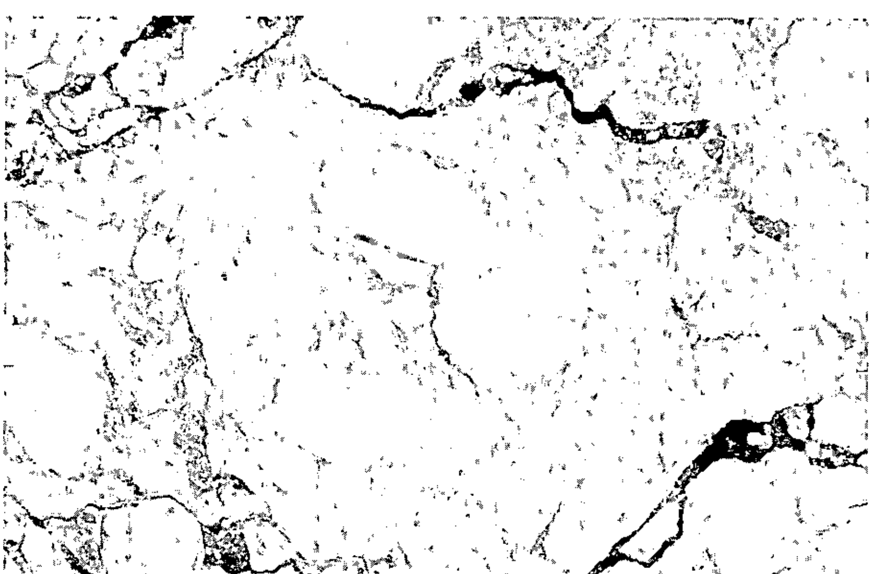


Plate 6.

This ice before consolidation consisted of brash, block and small floes. It is now breaking up (February 21).

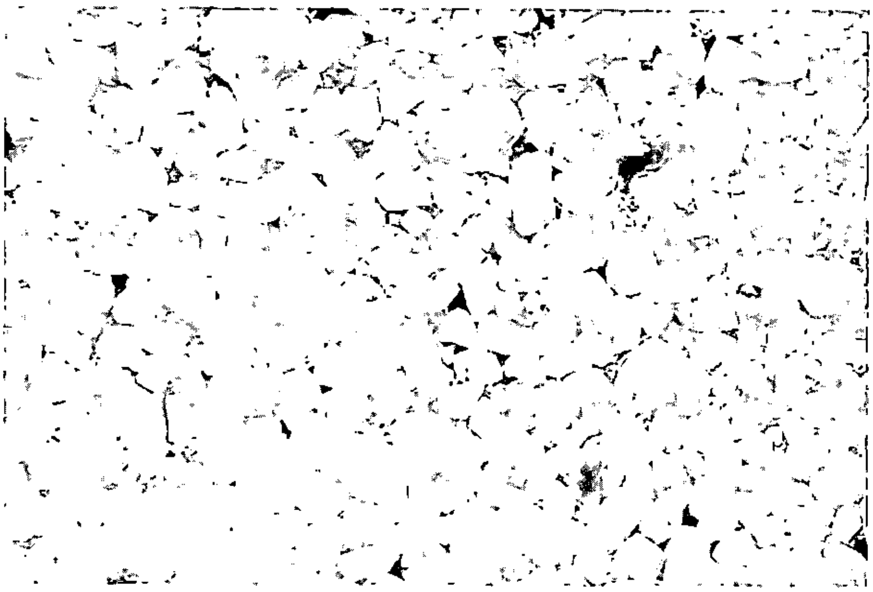
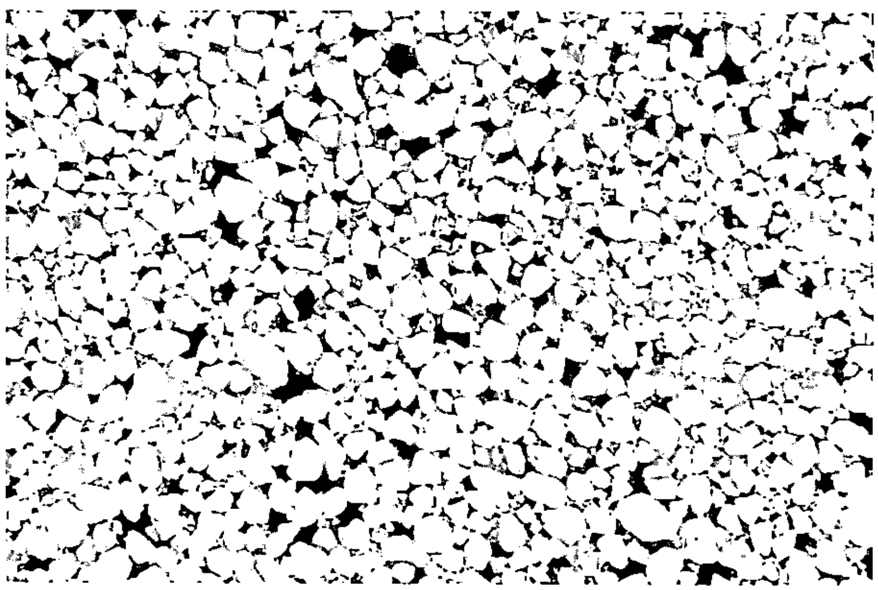


Plate 7.

Young ice, consisting of small floes, occupies 9/10 of the surface. Rafting is in progress (March 4).

Plate 8.

A field of winter ice consisting of 9/10 block (February 21).



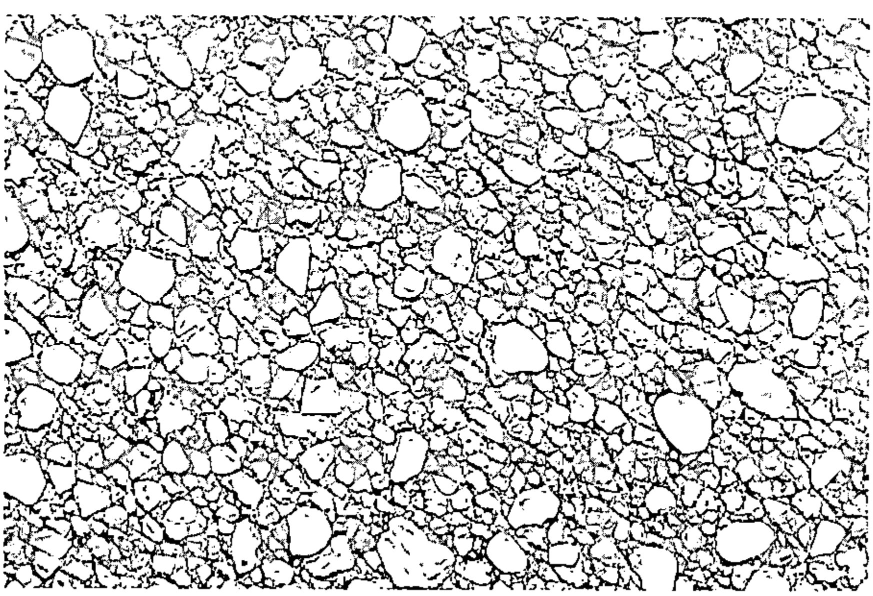


Plate 9.

This icefield in the Strait of Belle Isle, consisting of 4/10 brash and block and 6/10 sludge, has been subjected to intense pressures (February 19).

Plate 10.

This pressure-ridged winter ice field has broken up under pressure and now covers 8/10 of the sea surface. The surface of the ice is marked with snow drifts (February 27).

Plate 11.

A consolidated field of young ice in the Northumberland Strait area is in the process of breaking up. The straightness of the snow drifts indicates the high velocity of the winds that sweep over the ice (April 2).

Plate 12.

A field of 'Labrador' ice in the Strait of Belle Isle consisting of 8/10 sludge and 2/10 brash and block. The compression lines indicate that this ice field is under strong pressure (March 4).