NOAA Technical Memorandum NESS 119

SATELLITE OBSERVATION OF GREAT LAKES ICE: 1980-81

Washington, D.C.
December 1982

U.S. DEPARTMENT OF COMMERCE / National Oceanic and Atmospheric Administration / National Earth Satellite Service

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NESS 77 Algorithm for Correcting the VHRR Imagery for Geometric Distortions Due to the Earth Curvature, Earth Rotation, and Spacecraft Roll Attitude Errors. Richard Legeckis and John Pritchard, April 1976, 31 pp. (PB-258-027/AS)

NESS 78 Satellite Derived Sea-Surface Temperatures From NOAA Spacecraft. Robert L. Brower, Hilda S. Gohrband, William G. Pichel, T. L. Signore, and Charles C. Walton, June 1976, 74 pp. (PB-258-026/AS)

NESS 79 Publications and Final Reports on Contracts and Grants, NESS-1975. National Environmental Satellite Service, June 1976, 10 pp. (PB-258-450/AS)

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NESS 82 The GOES Data Collection System Platform Address Code. Wilfred E. Mazur, Jr., October 1976 26 pp. (PB-261-968/AS)

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SATELLITE OBSERVATION OF GREAT LAKES ICE: 1980-81

Annie Lou L. Bell

Washington, D.C.
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UNITED STATES
DEPARTMENT OF COMMERCE
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National Oceanic and
Atmospheric Administration
John V. Byrne, Administrator

National Earth Satellite Service
John H. McElroy,
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SATELLITE OBSERVATION OF GREAT LAKES ICE: 1980-81

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ABSTRACT: Ice conditions on the five Great Lakes and Lake St. Clair were studied from satellite imagery. The study involved the formation, movement, and dissipation of lake ice from December 1980-May 1981. Wind speed and directions were studied as components of ice formation and dissipation.

INTRODUCTION

This report concerns the formation and dissipation of ice on the Great Lakes region during the December 1980-May 1981 time period. Maximum extent of ice was observed in the Great Lakes region, except Lake St. Clair, between February 5 and 27. Because Lake St. Clair is the most shallow lake, it freezes quickly and thaws early. Maximum ice extent on Lake St. Clair was observed on January 7 and all its ice was gone by March 31. Ice was seen on Lake Superior as late as May 6 due to continued low air temperatures. Ice was last seen on the other four lakes the following days: Lake Erie, May 2; Lake Huron and Lake Michigan, April 16; Lake Ontario, April 2.

DATA SOURCES

Satellite

Data were gathered by Geostationary Operational Satellite (GOES). The primary sensor onboard was the Visible and Spin Scan Radiometer (VISSR) which is sensitive to visible radiation between 0.55 and 0.75mu. Resolution for VISSR is 1 km in the visible and 8 km in the infrared. All GOES data are from the VISSR visible channel.

Climatological Data

The Environmental Data and Information Service (EDIS) in Asheville, North Carolina provided climatological data from the following stations: Chicago, Illinois; Alpena, Detroit, Flint, Grand Rapids, Marquette, and Sault Ste. Marie, Michigan; Duluth, Minnesota; Buffalo, Rochester, and Syracuse, New York; Cleveland and Toledo, Ohio; Erie, Pennsylvania; Green Bay and Milwaukee, Wisconsin. The daily average air temperatures and daily resultant wind speed and direction were essential for this report.

SUMMARY OF THE ICE GENERATION, MOVEMENT AND DECAY

LAKE ERIE ICE COVER: 1980-81

First evidence of ice formation on Lake Erie could be seen on the December 20, 1980 image (fig. 2). Leads showed up south of Point Pelee and southeast of Long Point. The formation of the ice is related to the fact that air temperatures had been below freezing from December 14-January 24. Prior to December 20, the temperature had varied from -8 to 8°C but after December 20, the temperature range dropped to -17 to 0°C. From December 25-January 11, increasing concentrations of ice were seen in the leads at Point Pelee and Long Point. The areas farther south, east and west of Point Pelee and Long Point were not discernible because of excessive cloud cover.

From January 19 (fig. 6) - February 27 (fig. 10), 50-70 percent of the lake, from Port Stanley down to Fairport northeastward, was covered with thin ice. Ice was 100 percent concentrated adjacent to Buffalo, New York and a lead formed between Toledo and Cleveland. Temperatures were generally below freezing during the period; winds were from the west and south-southwest at 11 knots. The lake was covered with thin ice from Long Point to Buffalo (fig. 10) from February 27-March 14 (fig. 14), greater concentration remaining at Buffalo.

Eight days later on March 22 (fig. 15), ice was 100 percent concentrated from Long Point to Buffalo. By this time temperatures were well above freezing and winds out of the west and northwest gusted between 10-18 knots. Clouds persisted during the next six days but warmer temperatures (-1 to 4°C) aided the continuation of ice thaw.

From March 28 (fig. 16) - April 2 (fig. 17), ice began breaking up south of Long Point. During April 6-18, temperatures ranged from 4 to 15°C. An ice plug at Buffalo persisted from April 18-May 1. By May 2 all ice on Lake Erie had melted (fig. 21).

In summation, ice was present on Lake Erie from December 20 to about May 2, a total of 132 days, with maximum extent of ice occurring February 27 accompanied by 70 percent concentration.

<u>LAKE ST. CLAIR ICE COVER:</u> 1980-81

Temperatures in the area were mostly below freezing after December 10. As a result, thin ice (fig. 5) was later observed in the northeast section of Lake St. Clair on December 14. During the next two weeks, ice began to build-up on the lake as a response to northwest and north winds accompanied by temperatures from -4 to -2°C. On January 7 (fig. 4), the lake was totally ice covered. Generally cloudy conditions prevailed over Lake St. Clair until March 11. On March 12 (fig. 13), the lake was observed to be about 25 percent ice covered and westerly winds had pushed the ice to the eastern shore. Later, ice was seen in the southeast section of the lake on March 23. The lake was observed to be ice free on March 31 following eight days of cloud cover.

In summation, the ice season on Lake St. Clair began December 14 and ended near March 31 with 100 percent coverage observed as early as January 7.

LAKE HURON ICE COVER: 1980-81

Air temperatures at Sault Ste. Marie dropped to below freezing after November 5. Thin ice then appeared along the northern boundary of the North Channel on December 13. On December 20 (fig. 2), 50 percent of St. Joseph Island was surrounded by thin ice. In addition, thin ice was observed north of Drummond Island to 81°N. Ice began to accumulate around the Strait of MacKinac on December 27. From January 3-30, ice was concentrated along St. Joseph Island to the northern part of the Georgian Bay. By this time, temperatures had dropped to well below freezing (-29 to -1°C). The images were 60 percent cloud covered, making it difficult to see the entire lake until Janaury 3. On this day, areas west of the Strait of MacKinac were 100 percent ice covered with a lead extending to the northeast. Ice was also observed offshore near Saginaw Bay and in the vicinity of Harbor Beach, pushed there by winds from the west, northwest, and south. From January 31-February 14, ice was observed from Saugeen Peninsula southward to Goderich. The February 14 image showed the maximum concentration of ice cover for the time period. On this date the Georgian Bay area (fig. 9) was 90 percent ice covered.

By February 27, ice near Harbor Beach had dissipated due to the presence of higher temperatures and a southerly flow of air. Seven days later on March 6, however, ice could still be seen in Georgian Bay and along Saugeen Peninsula southward to Port Huron. Temperatures ranged from -1 to 13°C during this period with winds from the south-southwest pushing the ice north and northeast. Fast ice was also seen north of Harbor Beach. After March 22, temperatures rose to above freezing thus causing some of the ice to melt. On April 2, ice was still concentrated near Goderich, Saugeen Peninsula, Collingwood, and North Channel. During the April 6-18 period, ice melted rapidly while temperatures ranged from 7 to 9°C. On April 16 (fig. 19), Lake Huron was observed to be ice free.

In summation, the ice season on Lake Huron began on December 13 and lasted until April 16, a total of 124 days with maximum ice extent (65 percent concentration) occurring February 14.

LAKE MICHIGAN ICE COVER: 1980-81

Ice was discerned on Lake Michigan on December 14 to the east of Gladstone. Eleven days later, the northern part of Green Bay was also observed to be ice covered. On January 4 (fig. 3), fast ice covered the entire Green Bay area as well as part of Lake Michigan to the north of the Strait of MacKinac. Temperatures had been well below freezing with winds from the west and northwest. The lake was cloud covered for the next two weeks. By January 19 (fig. 6), the cloud had dissipated, exposing fast ice to the west of Grand Rapids, Big Sable Point, and Frankfort. During the next five days, ice moved to the east and increased in area in response to a westerly flow of air. Rising temperatures after January 16 (1 to 9°C) accompanied by southwest and west winds at 10 knots signaled the onset of melt. Maximum ice extent was observed on the lake on February 14 (fig. 9). The greatest concentrations were in Green Bay, north of Beaver Island, and from St. Joseph to Frankfort.

During the next twenty-five days, cloudy conditions prevailed. Temperatures were above freezing from February 15-28. On March 12, fast ice still persisted along Green Bay, Big Sable and Frankfort. Leads developed south of Gladstone and at Grand Traverse Bay (fig. 9). The southern part of the lake was ice free. Additionally, the next three weeks were also mostly cloudy and the few cloud free images showed sections of thin and fast ice dissipating. By April 6, high air temperatures and southwest winds had combined to melt ice at all locations; only thin ice remained from Petroskey to the Straits of MacKinac and at the tip of Gladstone. On April 16, the entire lake was observed to be ice free.

In conclusion, the ice season on Lake Michigan began on December 14 and ended near April 16, a total of 123 days. The maximum ice extent occurred on February 14.

LAKE ONTARIO ICE COVER: 1980-81

Temperatures were mostly below freezing from December 3-February 15. Due to excessive cloudiness, ice was not detected until January 10. On that date, thin ice was located east of Prince Edward Peninsula. Nineteen days later ice was detected at the tip of Hamilton and, on February 5, ice was seen southwest of Oswego. Winds had been predominantly from the south and southwest at 10 knots during this period.

By February 27, the temperatures had risen above freezing and winds were from the southwest to northwest at 6 knots. Also on that day, the ice near Hamilton had melted. By March 14, the entire lake was predominantly ice free except an area north of Oswego. Seventeen days later remnants of this ice were still visible north of Oswego. Lake Ontario was finally observed to be ice free on April 2.

The ice season on Lake Ontario lasted from December 3 until April 2, a total of 80 days, with maximum ice extent occurring about February 5.

LAKE SUPERIOR ICE COVER: 1980-81

Due to excessive cloudiness, ice was not detected on Lake Superior until December 13. The first formation occurred in the southeast part of Thunder Bay, Black Bay, the western half of Nipigon Bay, and the eastern portion of Isle Royale. Temperatures remained mostly below freezing from November 8-March 22. On January 4, thin ice was seen at the tip of Duluth to Ashland and by January 9 (fig. 5), ice covered 90 percent of the area from Whitefish

Bay to Coppermine Point. Ten days later on January 19, thin ice (fig. 6) was seen along Keweenaw Peninsula, fast ice was at the tip of Keweenaw Bay and the ice was expanding at Sault Ste. Marie. By January 30 (fig. 7), Whitefish Bay was 100 percent ice covered. Ice also continued to thicken from Ashland to Keweenaw Peninsula. The February 9 image showed fast ice extending from southwest of Keweenaw Bay to Whitefish Point. Temperatures of -15 to -12^{O}C in combination with winds from the west, northwest, and north at 6-8 knots had caused the ice to thicken and concentrate at these locations.

About two weeks later on February 12, the ice on Lake Superior (fig. 8) reached its 1980-81 season maximum concentrations. Temperatures during this period had varied from -24 to -14^{O}C. The lake was mostly cloud covered on the images during February 13-March 2. By March 3, most of the lake ice (fig. 11) was concentrated on an axis from Duluth, southwesterly through the middle of the lake. Thunder Bay, Black Bay, Nipigon Bay, and Slate Island were still 100 percent ice covered. Ice had expanded in area from Pic Island along the coast to Coppermine Point. On the March 11 image, leads (fig. 12) were observed near Nipigon and Black Bays as well as in the vicinity of Slate and Pic Islands. Floes were discernible at Ashland and Munising (fig. 12). Fast ice also persisted at these various locations: 1) from Michipicoten to Coppermine Point, 2) extending north and south of Keweenaw Bay, and 3) from Marquette to Munising. February temperatures ranged from lows of -19 to -16^{O}C early in the month to highs of -6 to 9^{O}C later in the month. On March 11, thin ice was seen to extend from Duluth to Keweenaw Peninsula and thick ice southward from Duluth to Keweenaw Peninsula. By March 14, the thin ice north of Duluth dissipated leaving only the thicker ice, pushed there by northerly winds, to the south. Whitefish Bay was still 100 percent covered. Leads and broken floes were prevalent throughout the middle and western part of the lake.

On March 21, ice was observed to have melted from Otter Head to Michipicoten, with this melt having been aided by winds out of the south and southwest. By April 5 (fig. 18), most of the floes and fast ice had dissipated (from Slate Island southwest of Keweenaw Bay, Duluth northwest to Ashland, and Marquette to Munising) in response to above freezing temperatures. The eastern half of the lake was mostly ice free. However, ice persisted in Nipigon Bay, Black Bay, and in the northeast and southwest parts of Thunder Bay. Winds during this period were generally from the west, north and northeast. Thin ice was seen on the lake as late as April 17. The lake was cloud covered on satellite images from April 18-30 but on May 1, thin ice was visible in the northeastern part of Black Bay and Nipigon Bay (fig. 20). A May 6 image (fig. 22) finally showed the lake to be free of ice.

The ice season on Lake Superior began December 13 and lasted until May 6, a total of 133 days with maximum ice extent occurring February 12.

CONCLUSION

In general, ice formed on the lakes in response to northwesterly and northerly winds accompanied by below freezing air temperatures. It appeared that the lower the temperatures, the thicker the ice concentration in the Great Lakes region. Winds from a southerly and southwesterly direction, usually caused dissipation of lake ice. Mostly cloudy conditions prevailed over the lakes throughout this study period. Temperatures and wind direction were the controlling factor in determining ice movement, formation, and dissipation.

ACKNOWLEDGMENTS

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NOAA, Environmental Data and Information Service, National Climatic Center, Climatological Data for the following 16 selected station from November 1980 through May 1981: Chicago, Illinois; Alpena, Detroit, Flint, Grand Rapids, Marquette, and Sault Ste. Marie, Michigan; Duluth, Minnesota; Buffalo, Rochester, and Syracuse, New York; Cleveland and Toledo, Ohio; Erie, Pennsylvania; and Green Bay and Milwaukee, Wisconsin.

Figure 1.--GOES VISSR (visible) image for 14 December 1980.

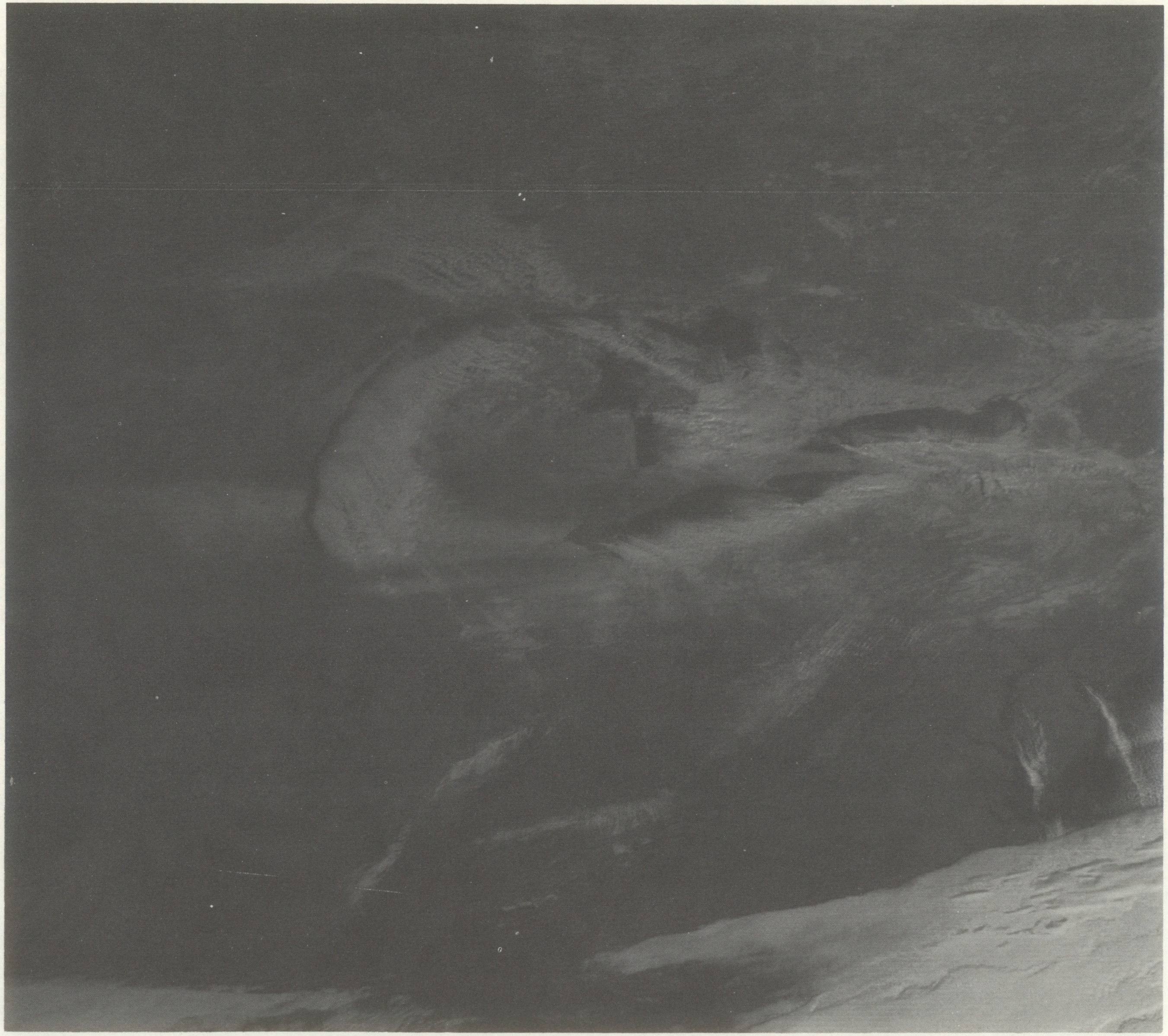

Figure 2.--GOES VISSR (visible) image for 20 December 1980.

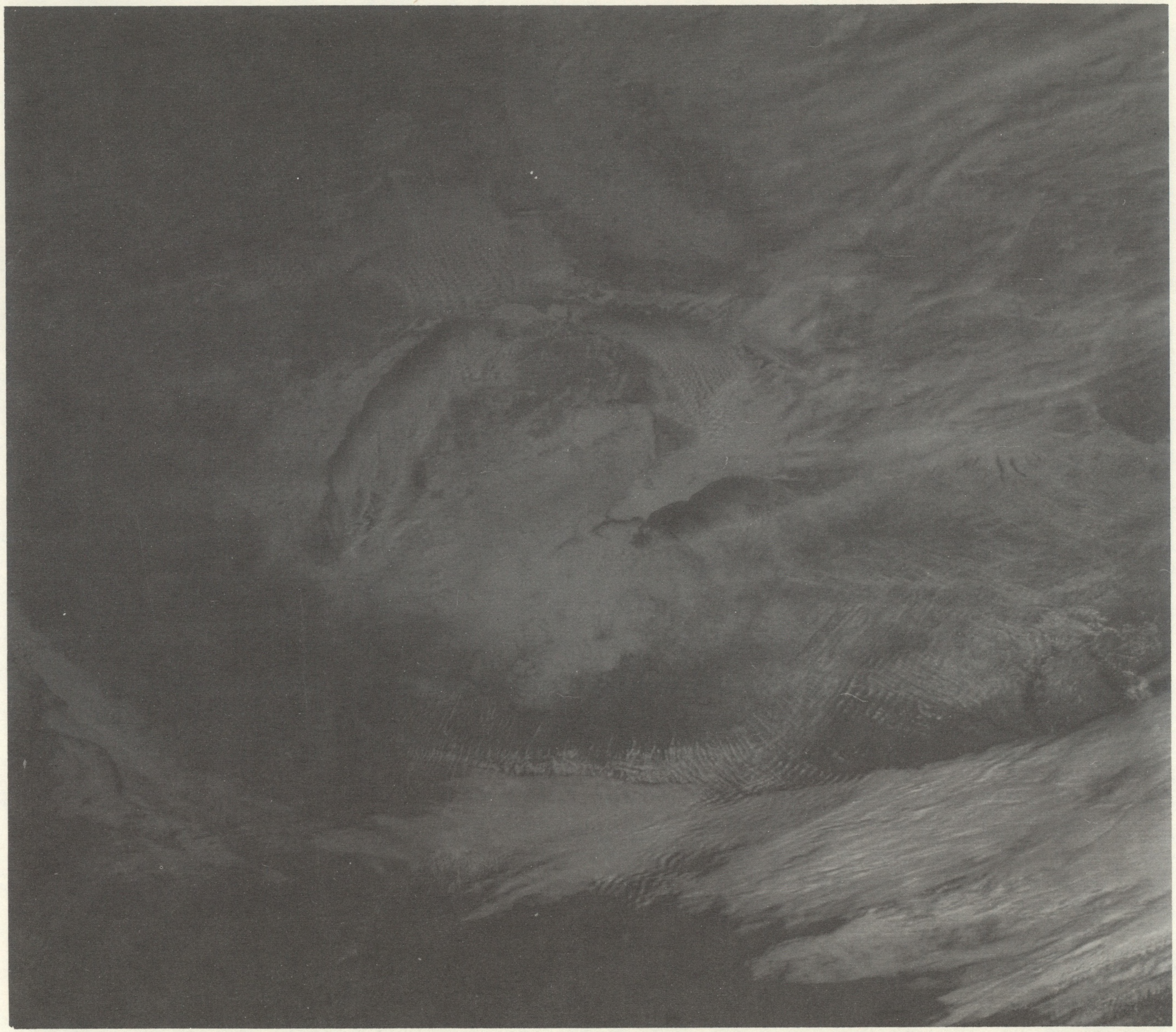

Figure 3.--GOES VISSR (visible) image for 4 January 1981.

Figure 4.--GOES VISSR (visible) image for 7 January 1981.

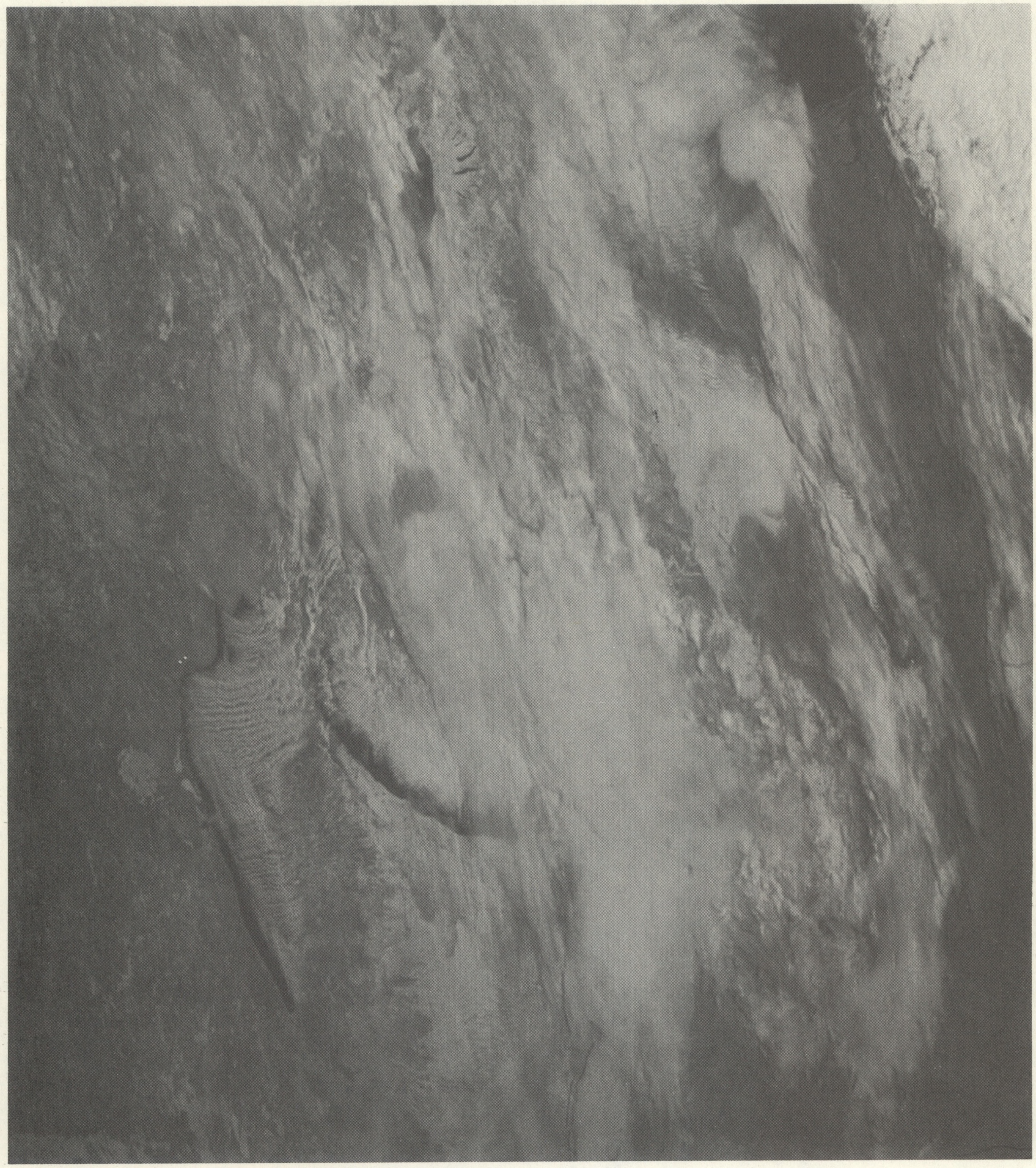

Figure 5.--GOES VISSR (visible) image for 9 January 1981.

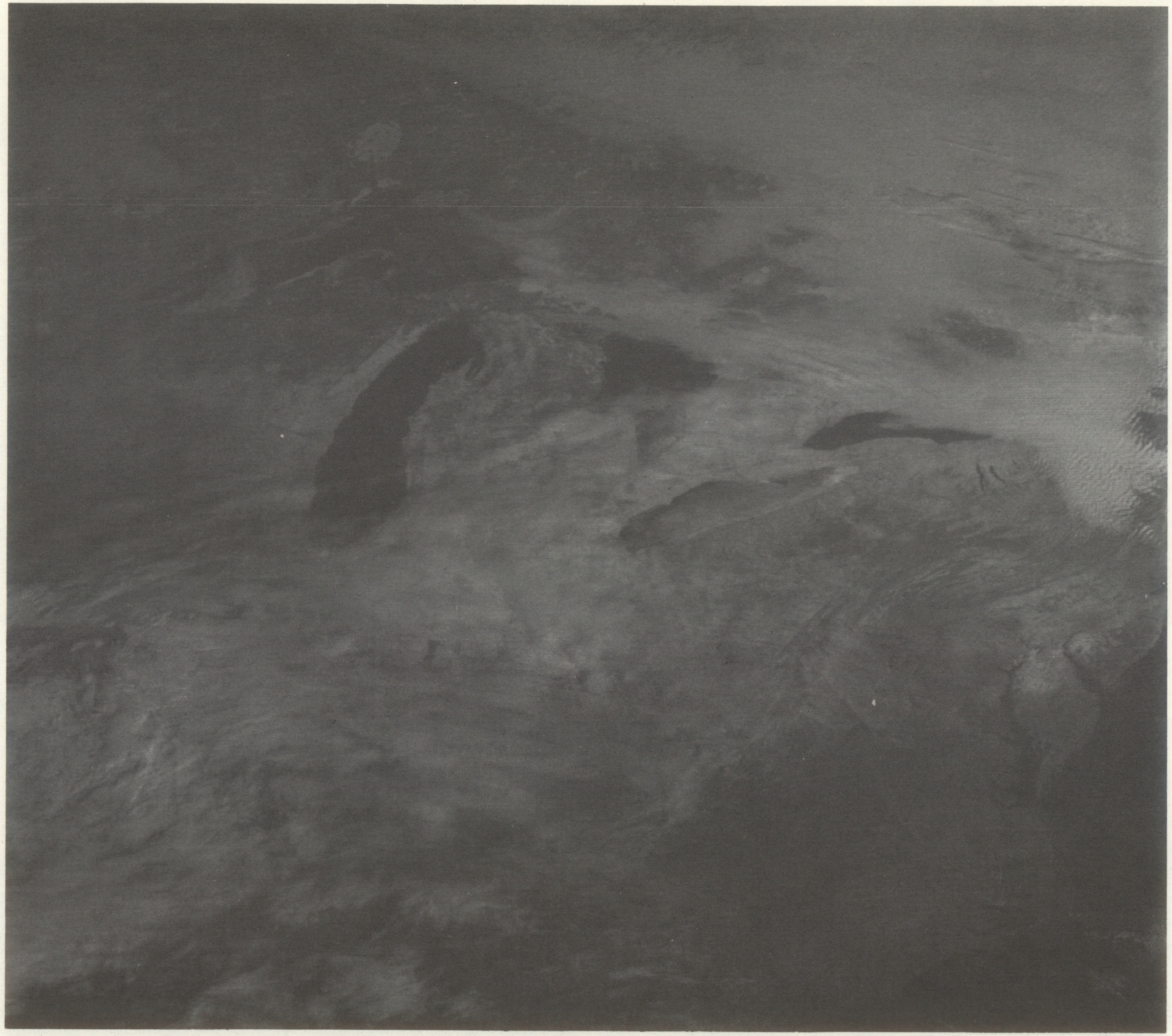

Figure 6.--GOES VISSR (visible) image for 19 January 1981.

Figure 7.--GOES VISSR (visible) image for 30 January 1981.

Figure 8.--GOES VISSR (visible) image for 12 February 1981.

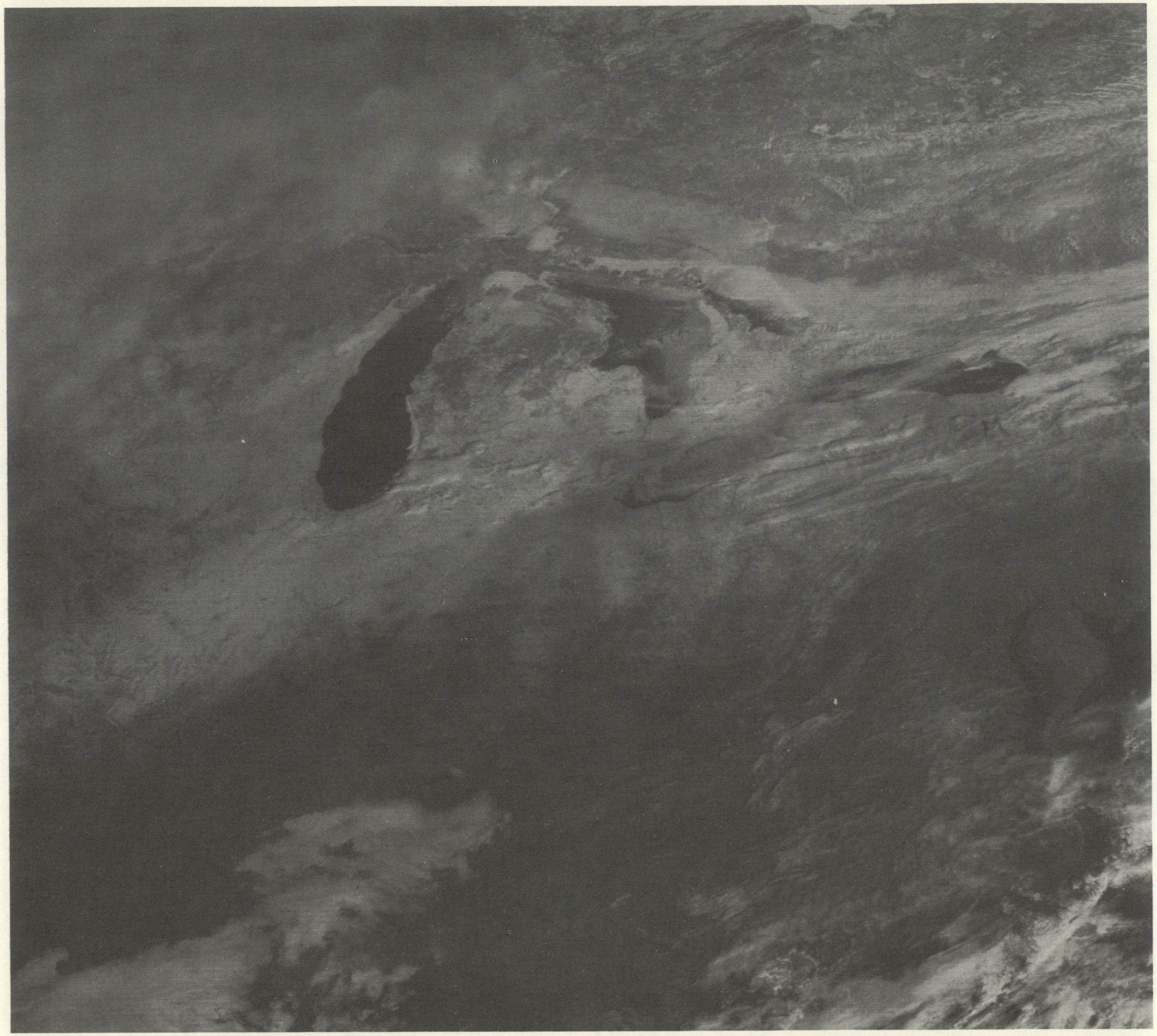

Figure 9.--GOES VISSR (visible) image for 14 February 1981.

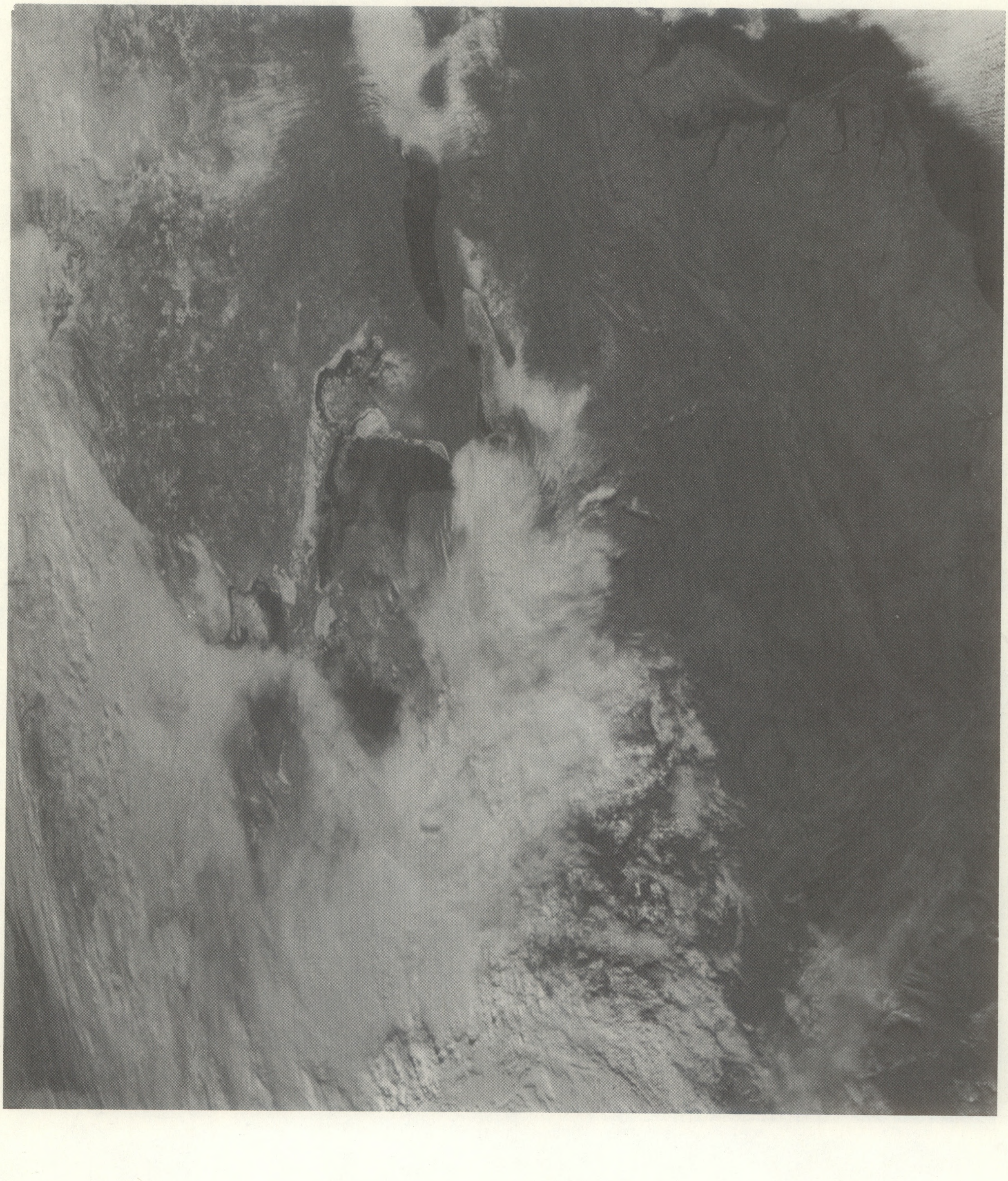

Figure 10.--GOES VISSR (visible) image for 27 February 1981.

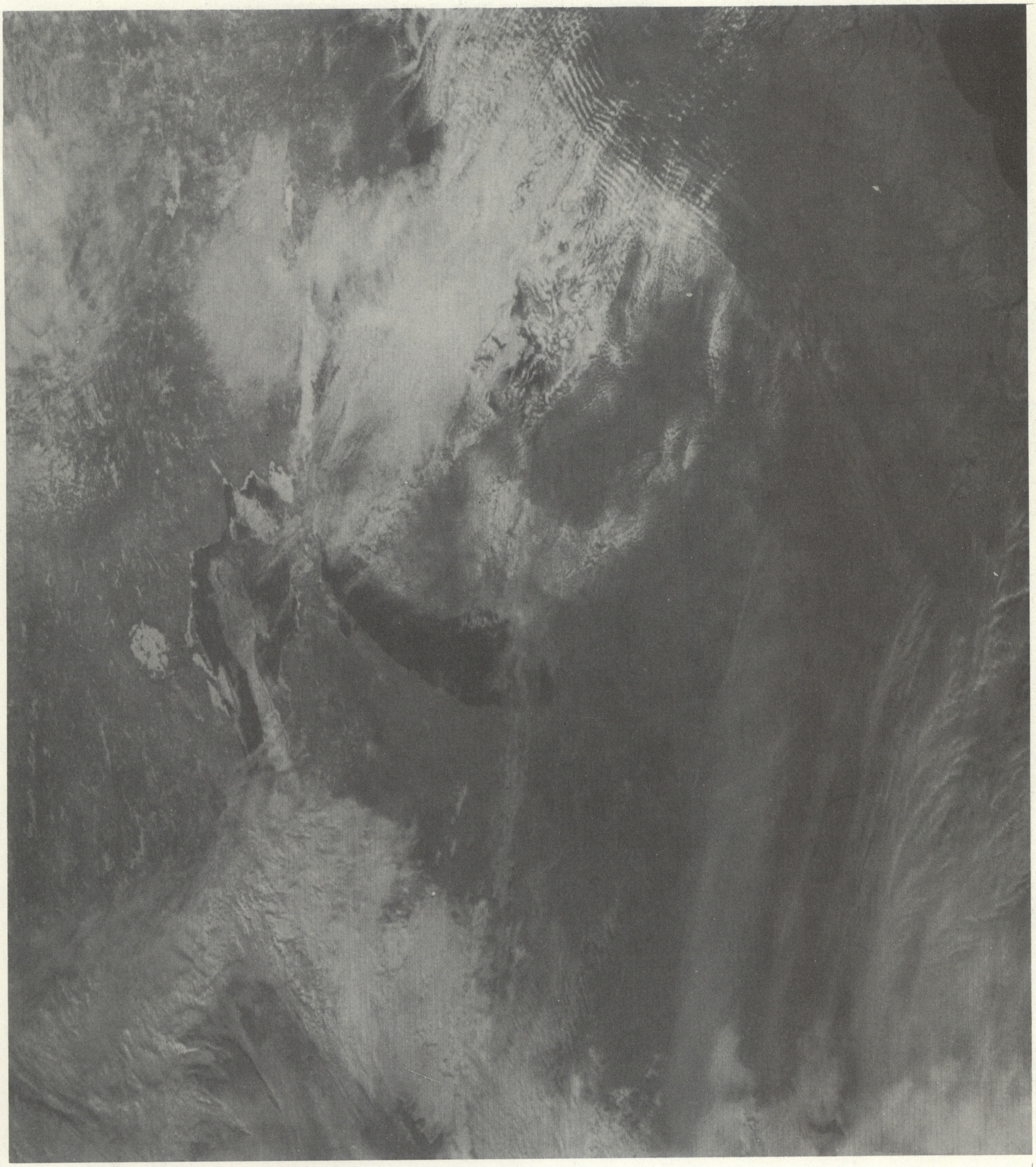

Figure 11.--GOES VISSR (visible) image for 3 March 1981.

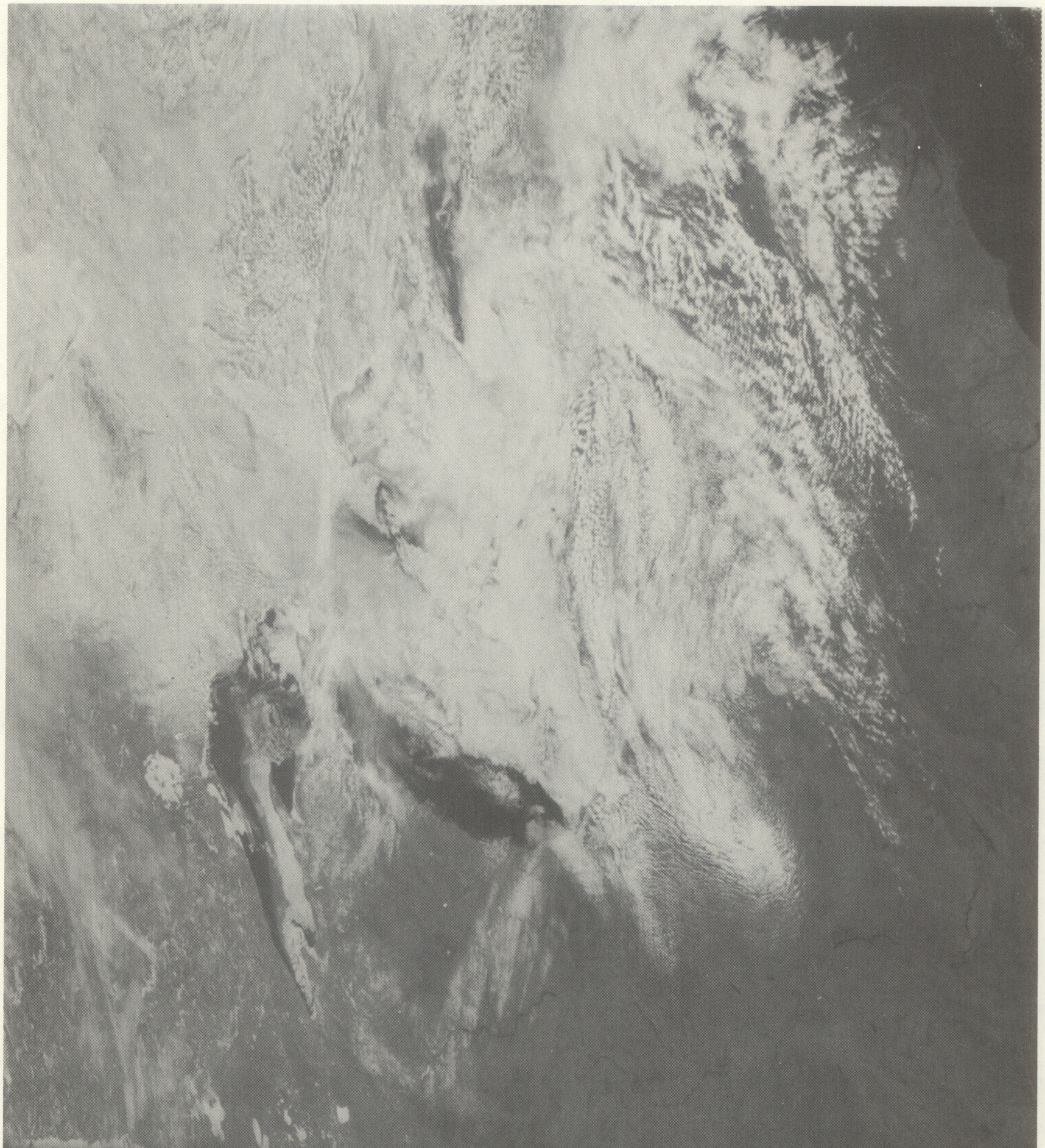

Figure 12.--GOES VISSR (visible) image for 11 March 1981.

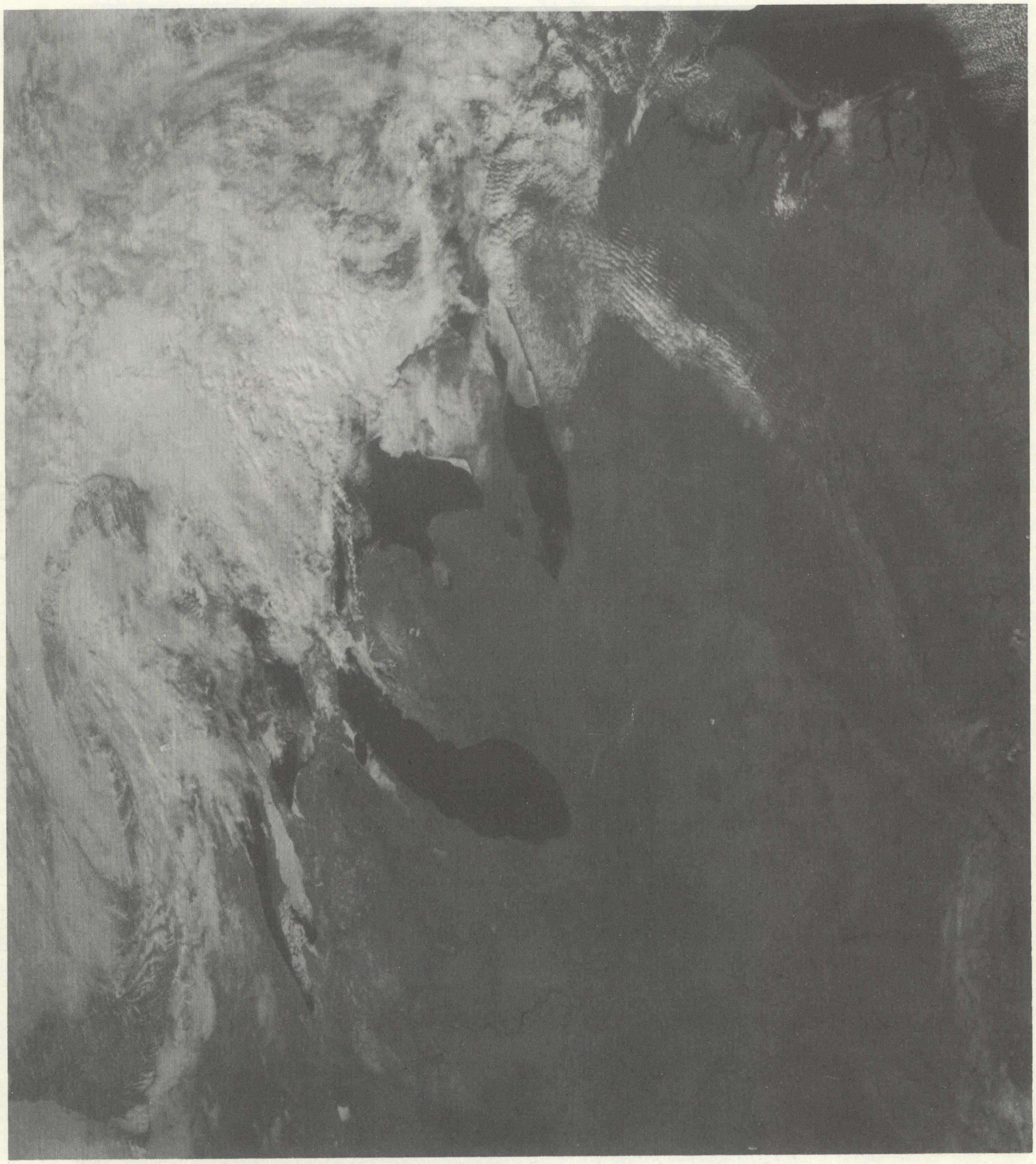

Figure 13.--GOES VISSR (visible) image for 12 March 1981.

Figure 14.--GOES VISSR (visible) image for 14 March 1981.

Figure 15.--GOES VISSR (visible) image for 22 March 1981.

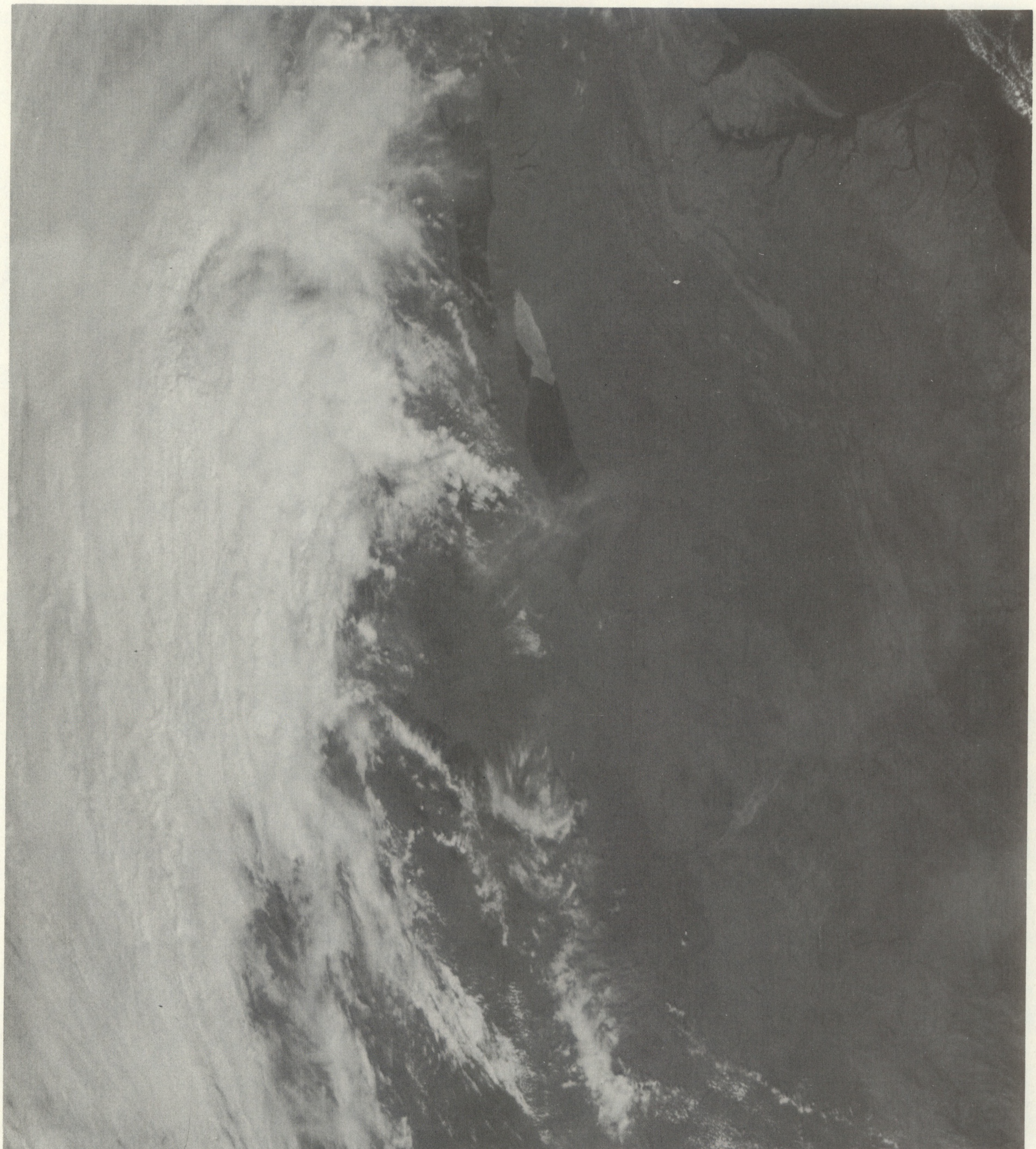

Figure 16.--GOES VISSR (visible) image for 28 March 1981.

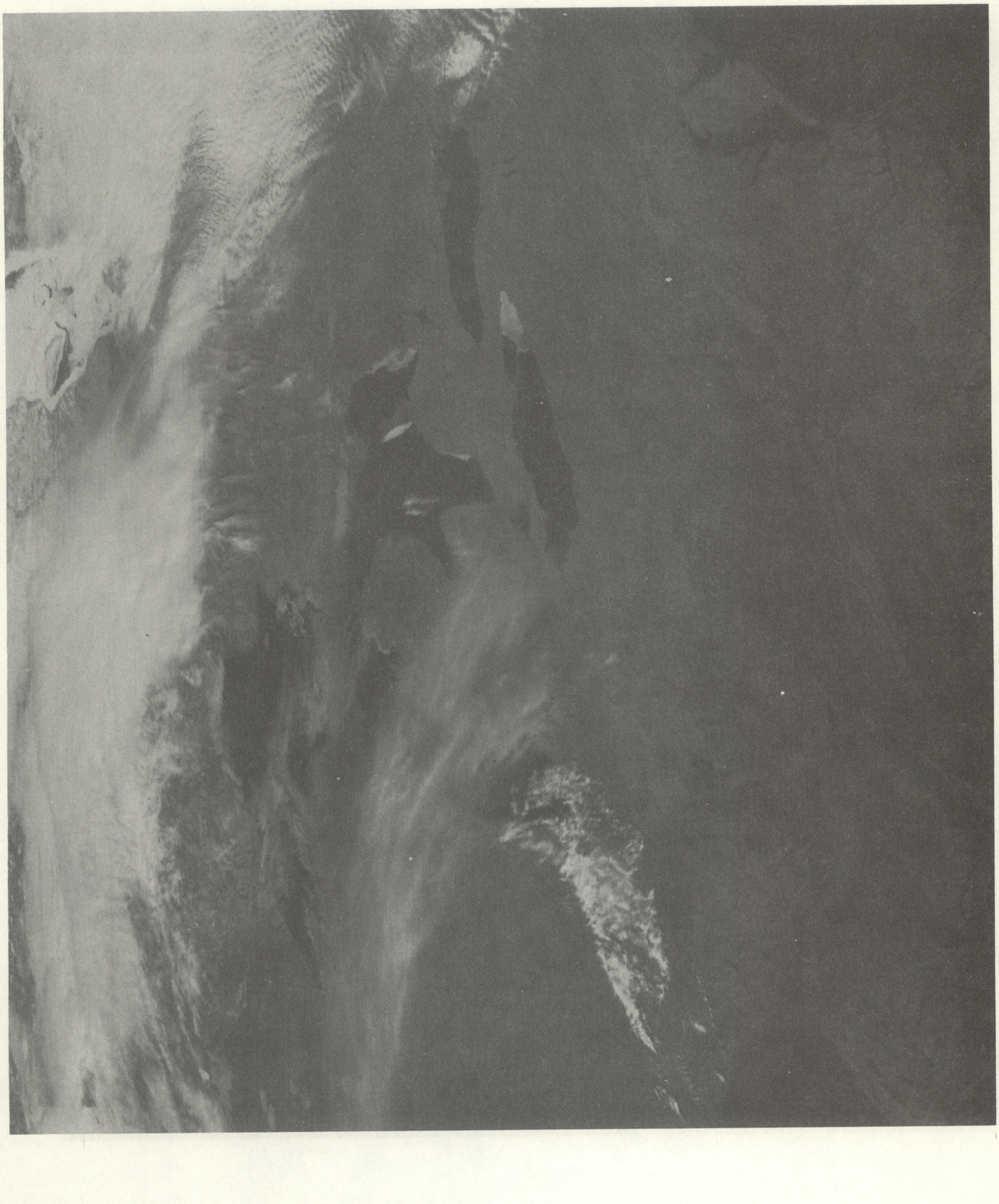

Figure 17.--GOES VISSR (visible) image for 2 April 1981.

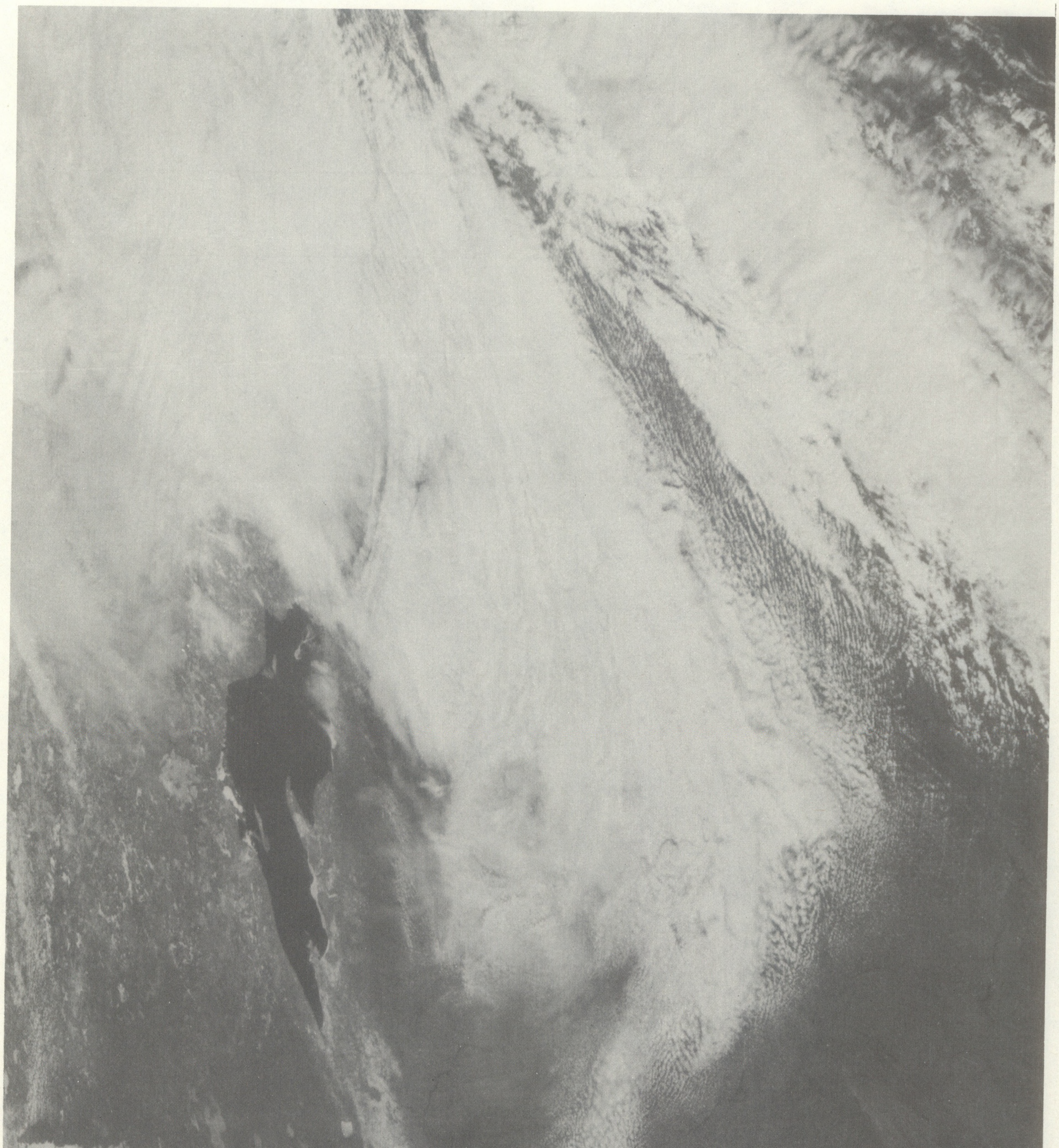

Figure 18.--GOES VISSR (visible) image for 5 April 1981.

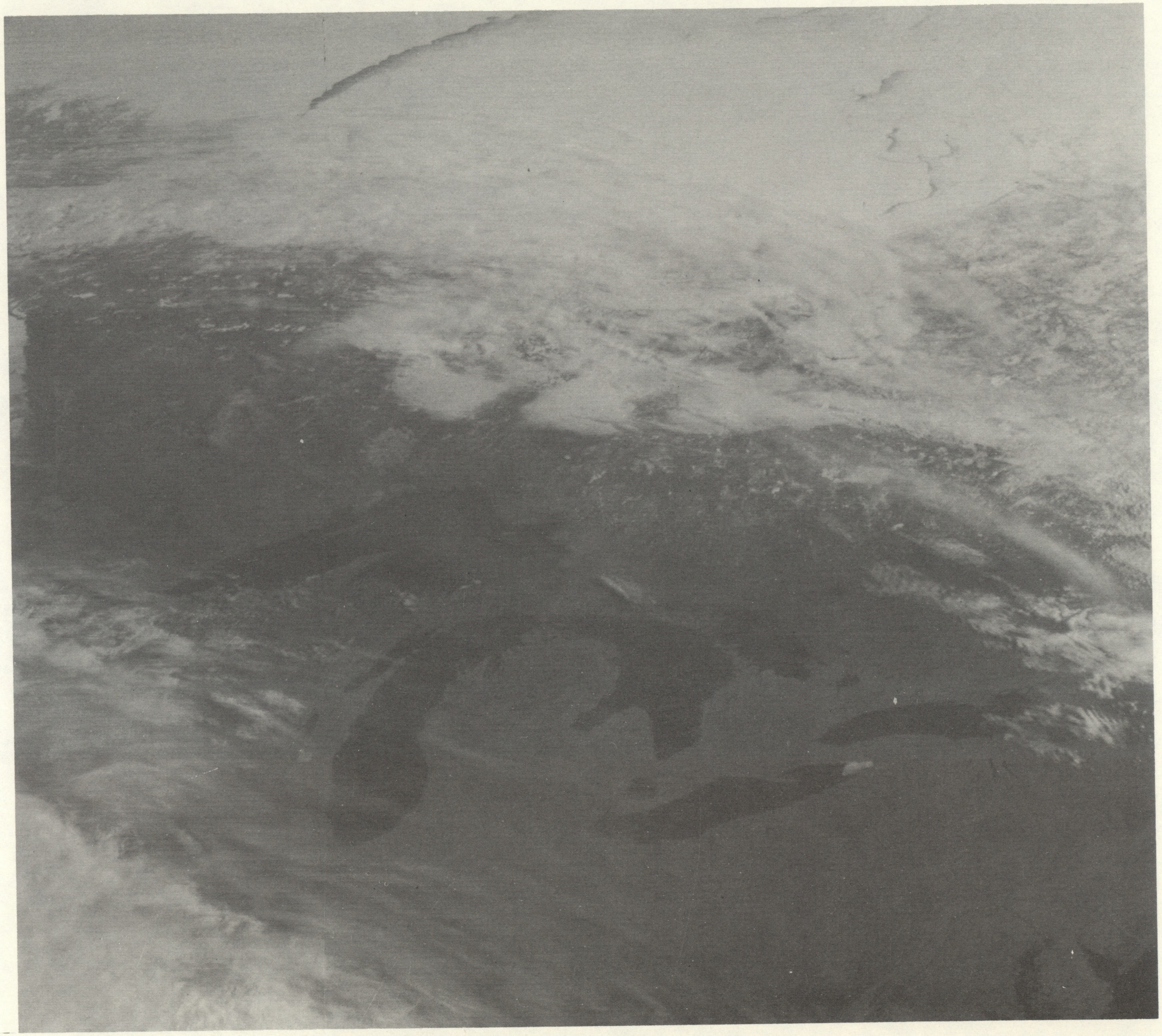

Figure 19.--GOES VISSR (visible) image for 16 April 1981.

Figure 20.--GOES VISSR (visible) image for 1 May 1981.

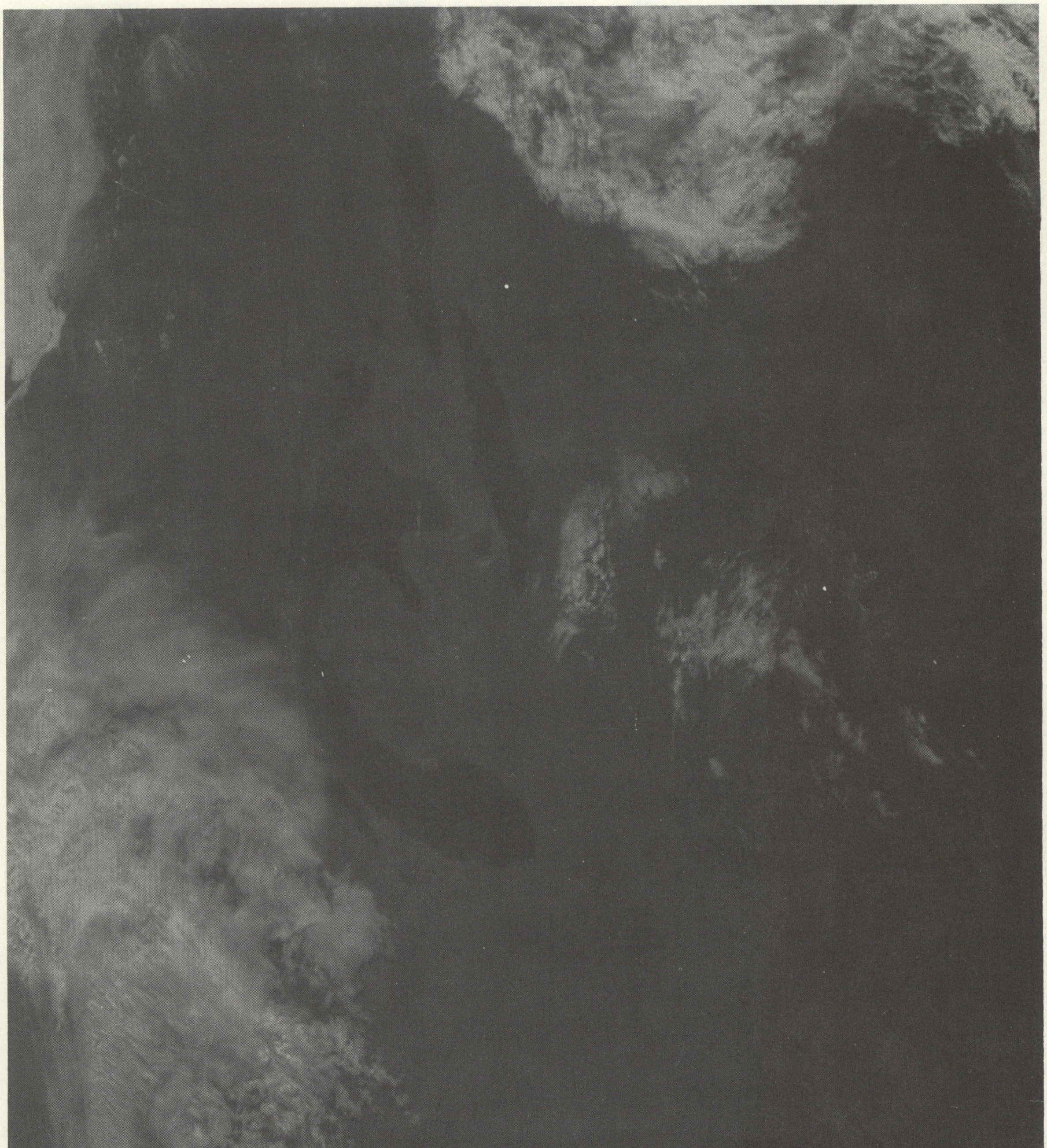

Figure 21.--GOES VISSR (visible) image for 2 May 1981.

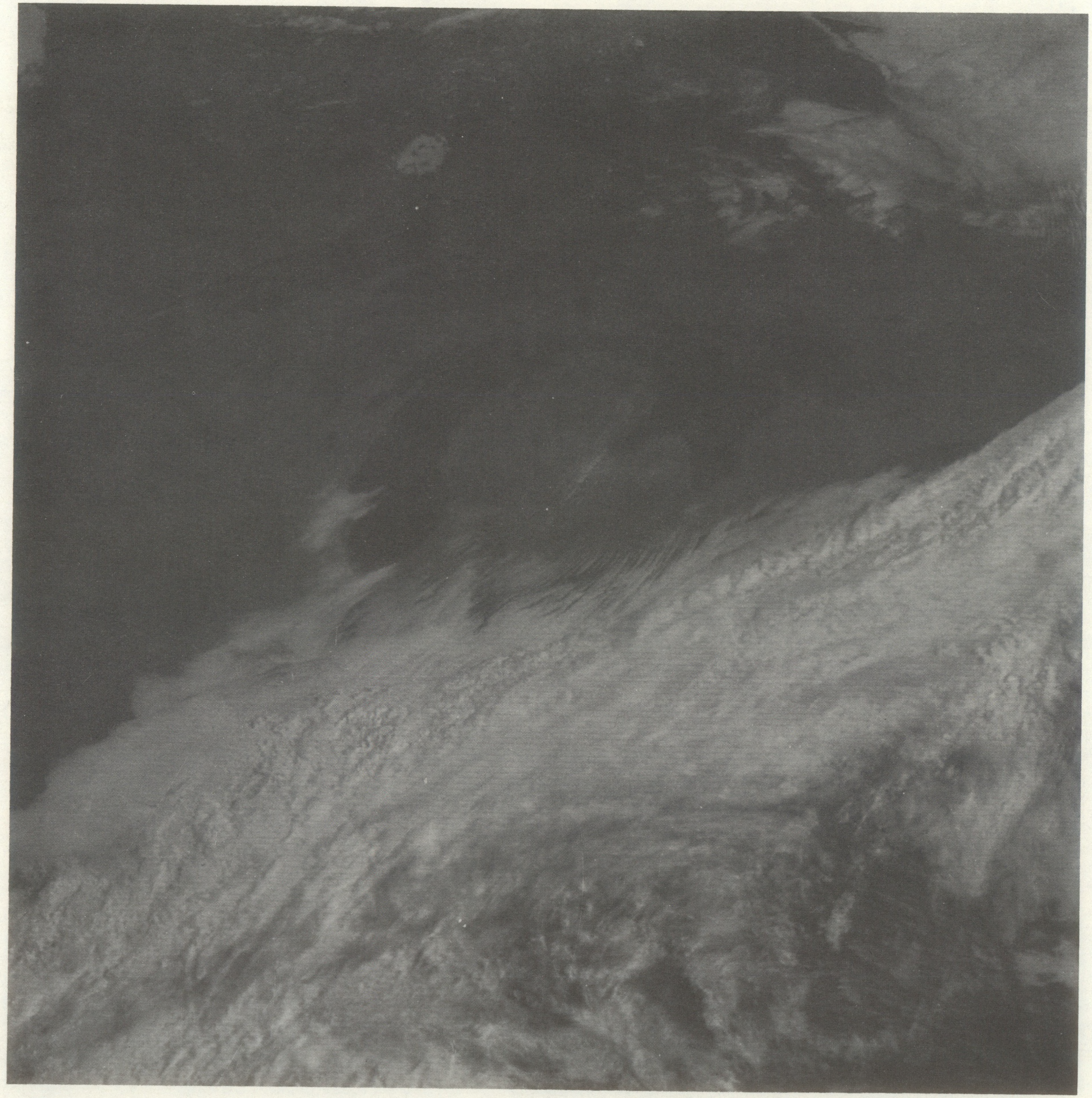

Figure 22.--GOES VISSR (visible) image for 6 May 1981.

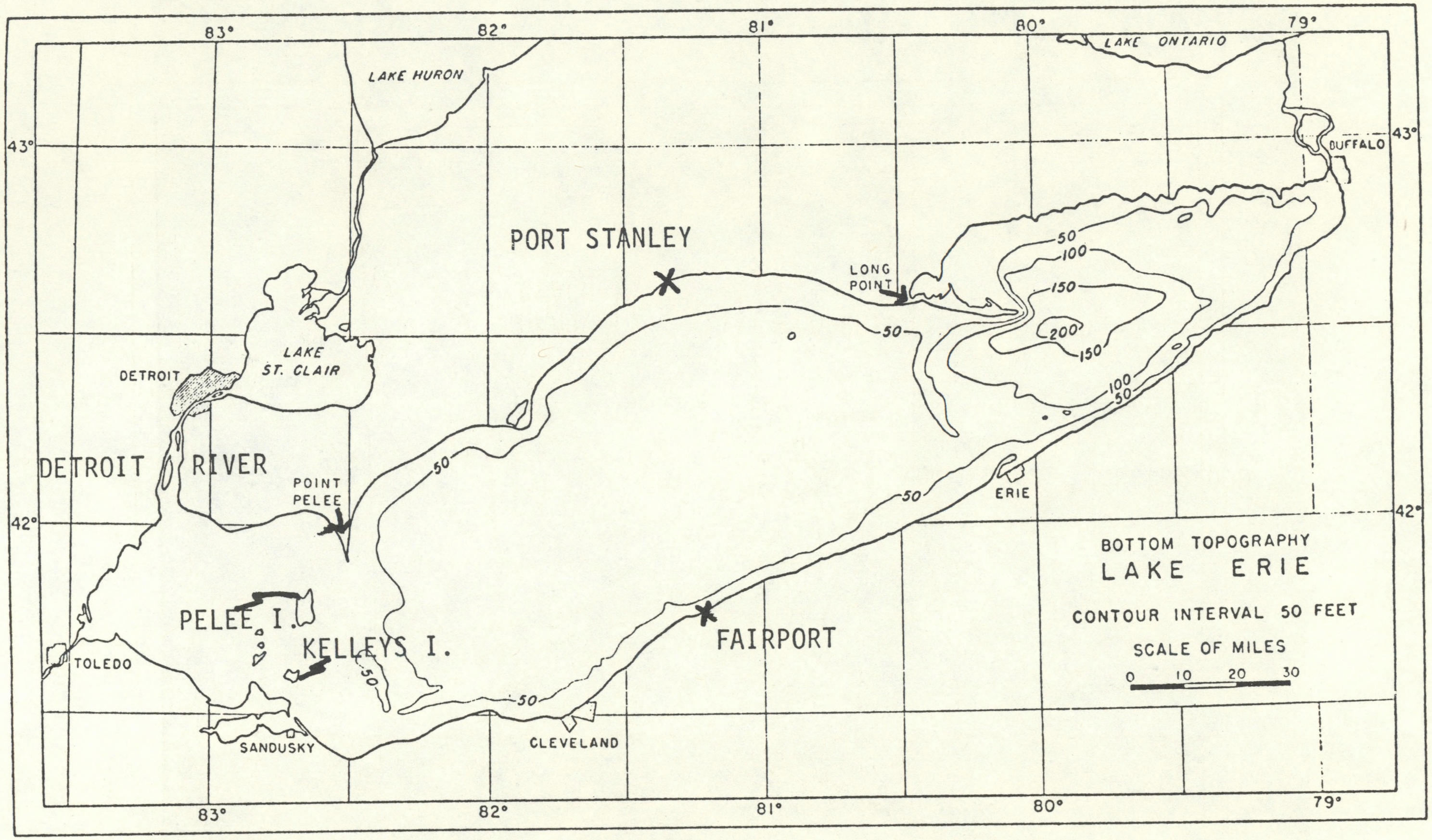

Figure 23.--Bathymetric and geographic location chart for Lake Erie and Lake St. Clair.

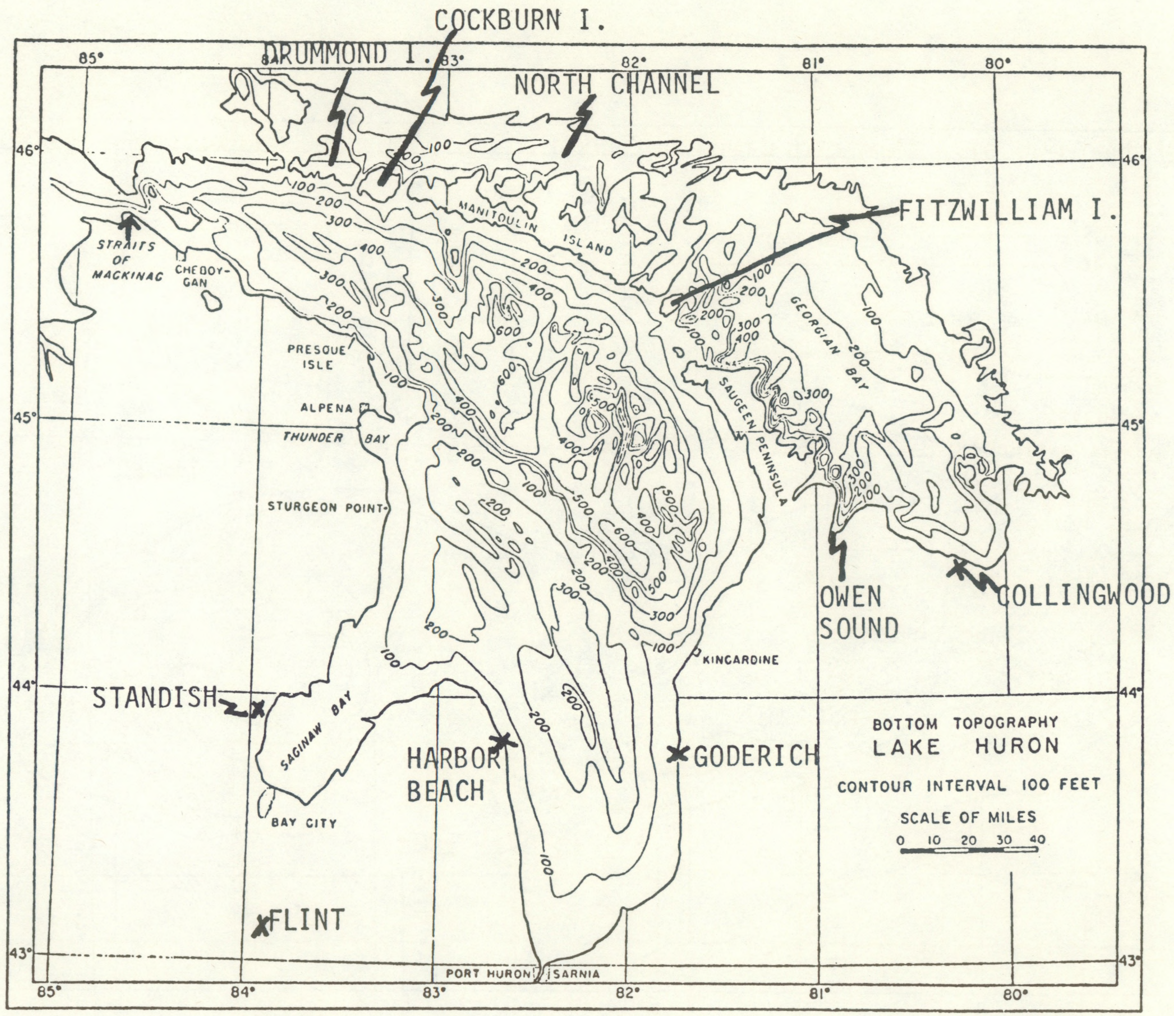

Figure 24.--Bathymetric and geographic location chart for Lake Huron.

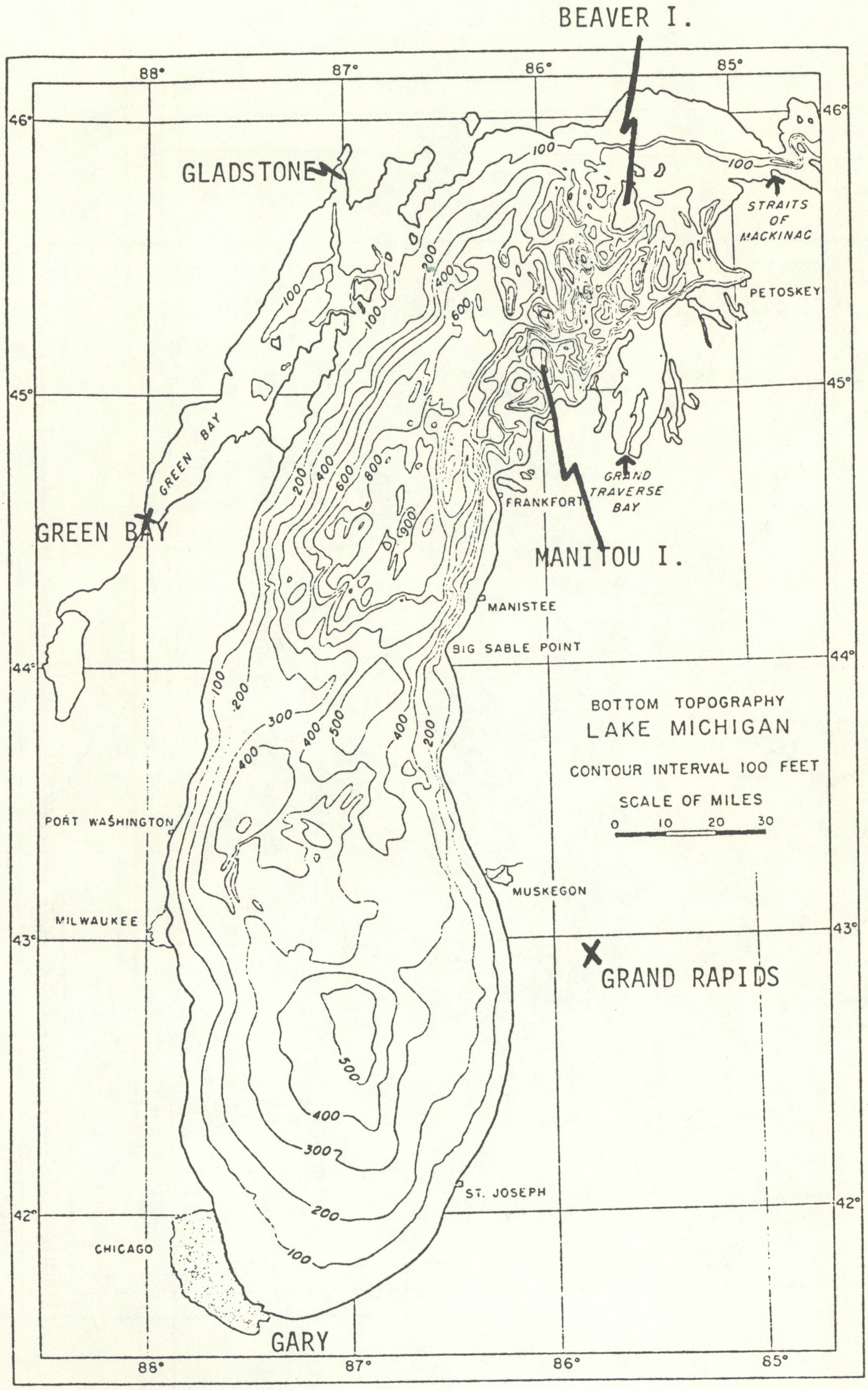

Figure 25.--Bathymetric and geographic location chart for Lake Michigan.

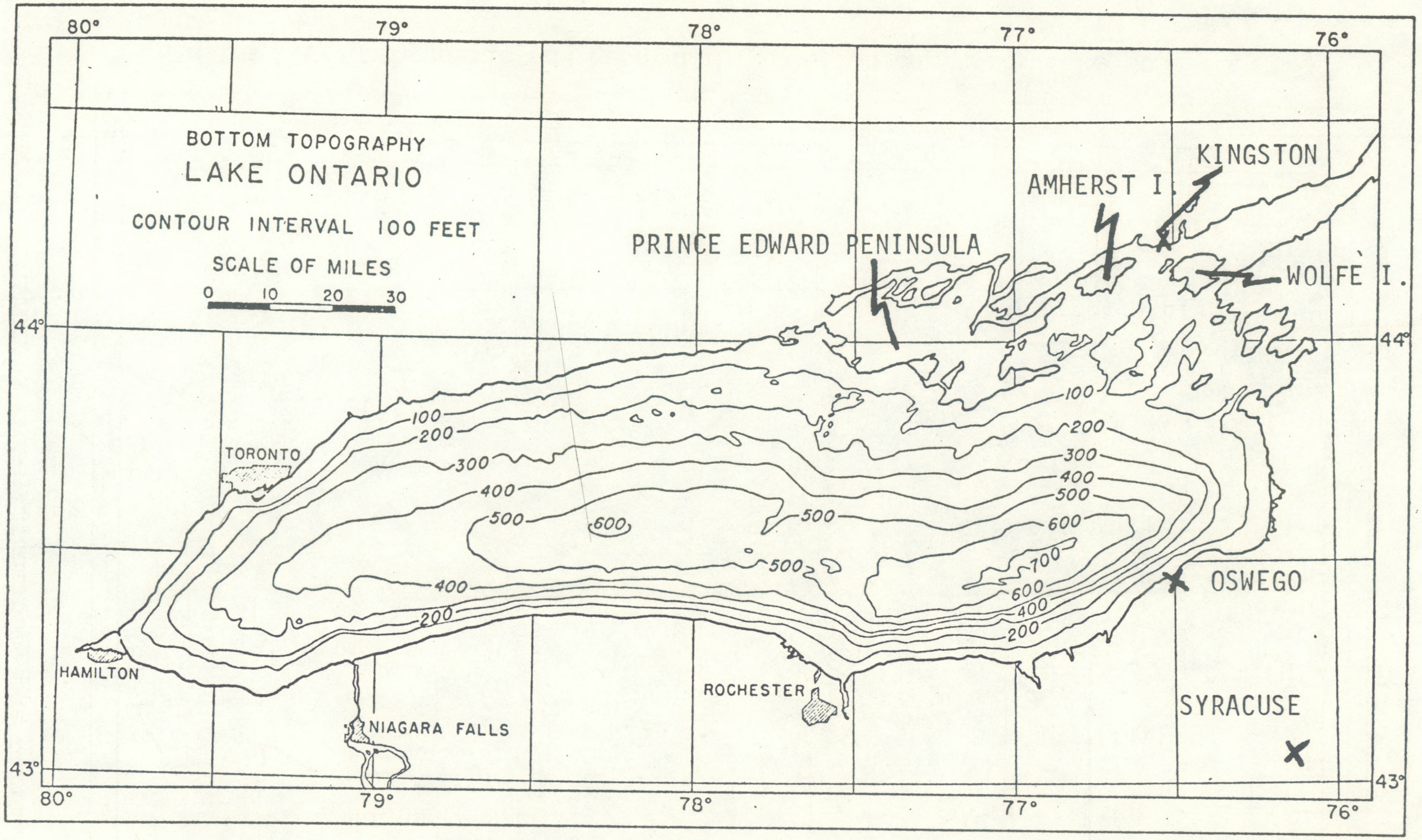

Figure 26.--Bathymetric and geographic location chart for Lake Ontario.

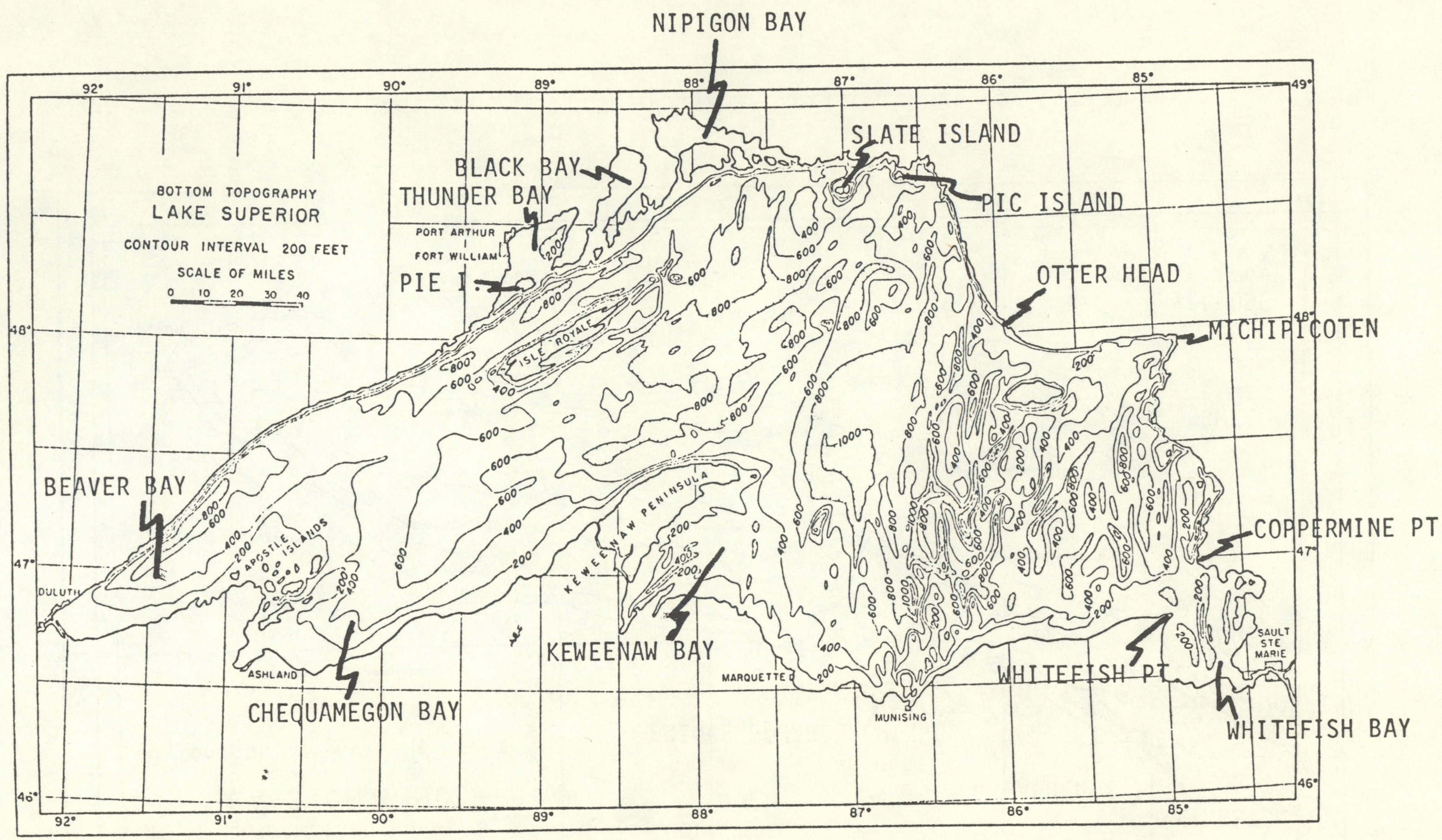

Figure 27.--Bathymetric and geographic location chart for Lake Superior.

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