DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY

PREPARED IN COOPERATION WITH
THE BUREAU OF LAND MANAGEMENT

MISCELLANEOUS FIELD STUDIES
MAP MF-1193
AARON AND OTHERS—ENVIRONMENTAL CONDITIONS RELATING TO POTENTIAL GEOLOGIC HAZARDS.
U. S. NORTHEASTERN ATLANTIC CONTINENTAL MARGIN
SHEET 1 OF 3

INTRODUCTION

The Continental Shelf off the New England States is underlain by up to 10 kilometers (km) of Jurassic, Cretaceous, and Tertiary sedimentary rocks that have filled a complex structural trough floored by block-faulted metamorphic, igneous, and older sedimentary rocks (Schlee and others, 1979). During the Pleistocene Epoch the shelf was partially to completely covered by continental glaciers which deposited up to 80 meters (m) of coarse detritus. Outwash from the melting glaciers carried sediment to the shelf edge (Knott and Hoskins, 1968; Schlee, 1973; Lewis and Sylwester, 1976).

The area under discussion is shown in figure 1 and outlined in the inset map, figure 2. This area, particularly Georges Bank, is a prominent target for oil and gas exploration, one of three designated lease areas on the Atlantic coast of the United States. Georges Bank also is one of the world's most productive fishing grounds, and the coastal states nearby not only have high population densities and important fishing industries, but also have coastlines with extraordinary recreational and scenic value.

Since 1975, the U.S. Geological Survey (USGS), in cooperation with the Bureau of Land Management, has conducted scientific studies aimed at assessing environmental impacts and potential geologic hazards related to the exploration, development, production, and transportation of hydrocarbon resources on or around Georges Bank. Of particular interest are those hazards that might cause or distribute spilled oil or other pollutants that may be introduced during exploration and development activities. These studies fall into five major categories: (1) systematic high-resolution seismic-reflection profiling to determine the shallow stratigraphy and structure of the Continental Shelf and Slope; (2) direct study of the sea floor using manned submersibles; (3) long-term *in situ* observations of the bottom and parts of the overlying water column using moored instrument packages that measure and record hydrographic data (current speed and direction, pressure, temperature, and light transmission) and that periodically photograph the sea bottom; (4) observations of the nature and abundance of suspended matter in the water column; and (5) bottom sampling and coring for studies of the composition, texture, structure, age, trace metal content, and geotechnical properties of sediments and rocks that make up the sea floor.

In the sheets of this map we present a summary of data from these and other studies that relate to potential geologic hazards on the Continental Shelf and Slope in the North Atlantic lease area. The map shown in figure 1 is simplified from Uchupi (1965).

REFERENCES CITED

Knott, S. T., and Hoskins, H., 1968, Evidence of Pleistocene events in the structure of the Continental Shelf off the northeastern United States: Marine Geology, v. 6, p. 5-43.
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Schlee, John, 1973, Atlantic Continental Shelf and Slope of the United States—sediment texture of the northeastern part: U.S. Geological Survey Professional Paper 529-L, 64 p.
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Uchupi, Elazar, 1965, Map showing relation of land and submarine topography, Nova Scotia to Florida: U.S. Geological Survey Miscellaneous Geologic Investigations Map I-451.

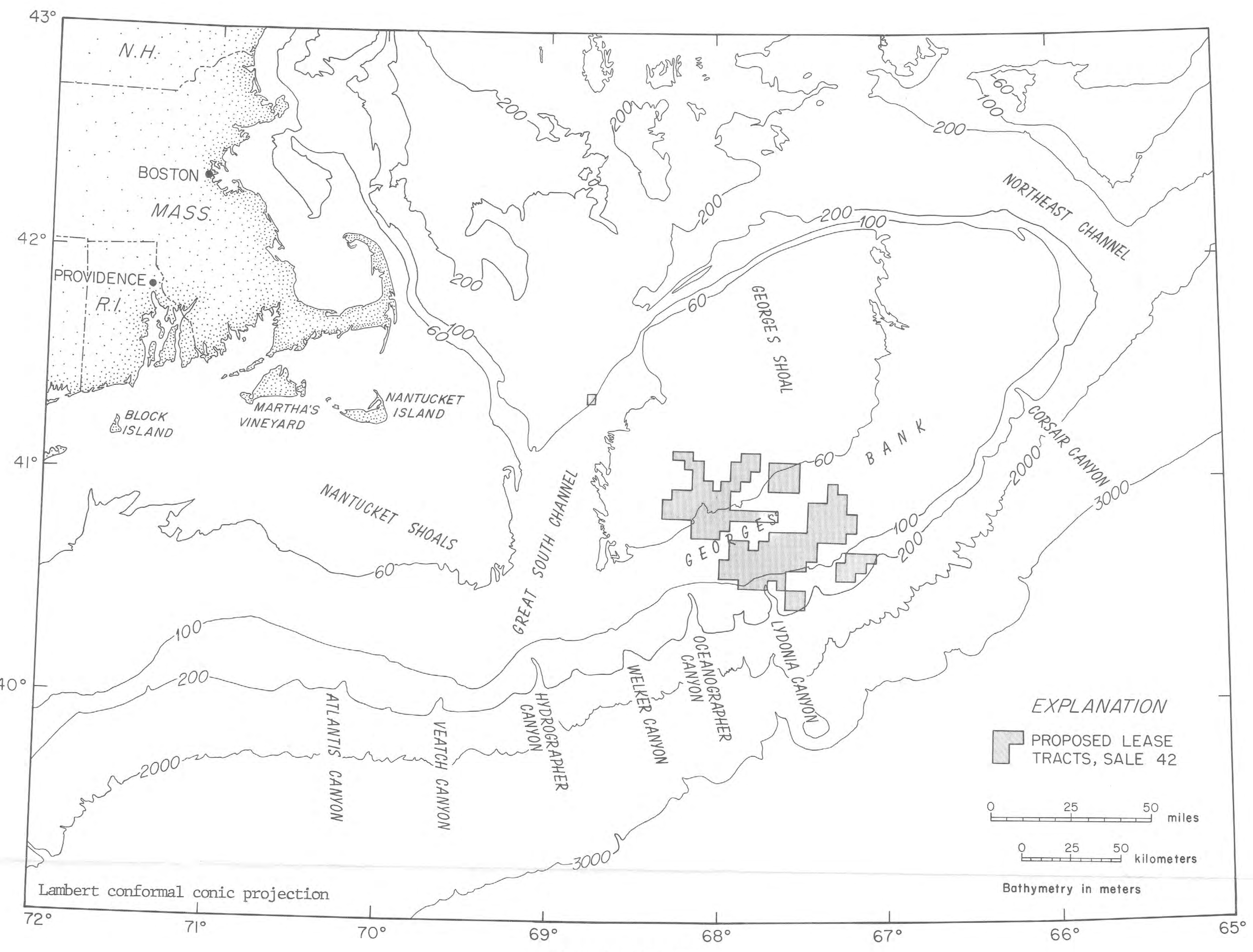

Figure 1.—Study area.

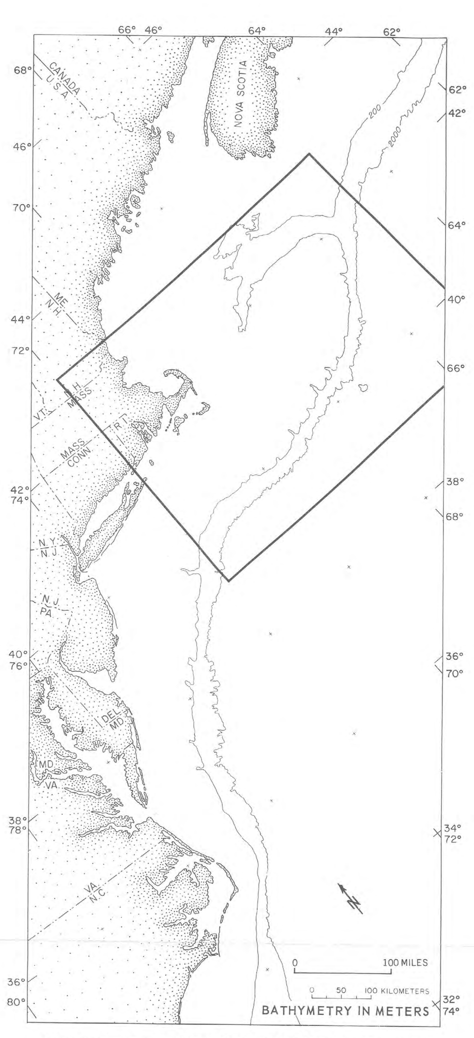

Figure 2.—Part of the U.S. Atlantic Continental Shelf and Slope, showing the study area outlined.

Units of Measurement

International System (SI or metric) units of measurement herein are used in preference to Customary (English) units.
Some conversion factors are given below.

Multiply	By	To obtain
centimeters (cm)	0.3937	inches
meters (m)	3.281	feet
kilometers (km)	0.6214	miles (mi)
kilometers	0.540	nautical miles (nmi)

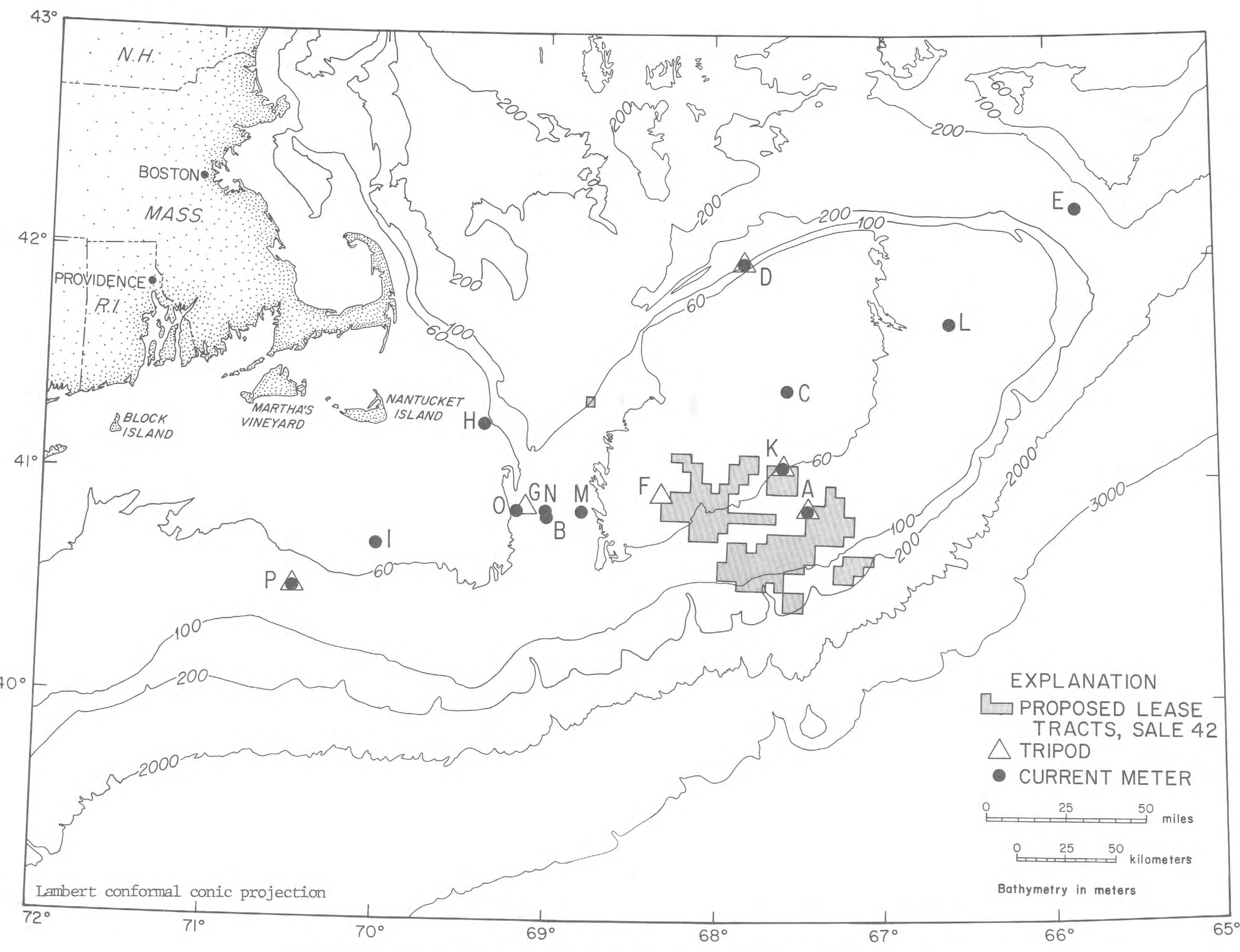

Figure 3.—Locations of instrument deployment, stations A-P, in the Georges Bank area.

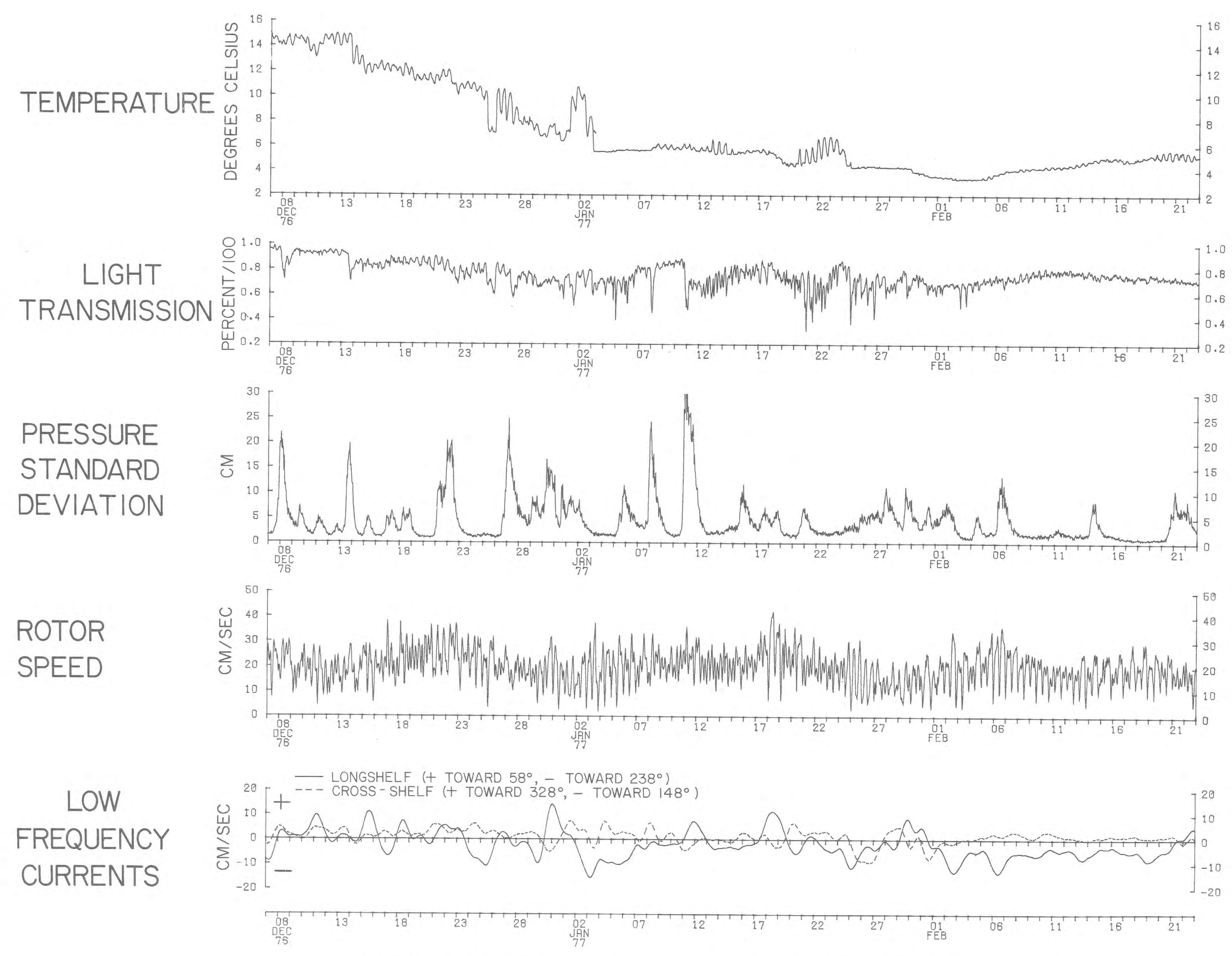

Figure 4.—Graphs showing sea-bottom conditions recorded by tripod-mounted instruments at station A.

SEDIMENT TRANSPORT

Currents and sediment transport in the Georges Bank area have been studied by the USGS since May 1975. Collected data include: (1) current observations recorded by vector-averaging current meters deployed at several depths, chiefly 15 m, 45 m, and 75 m; (2) water column observations using profiling instruments (conductivity-temperature-depth sensors, transmissometers, and expendable bathythermographs); (3) *in situ* observations of bottom conditions recorded by tripod-mounted instruments that measure current speed and direction, pressure, temperature, and light transmission (turbidity), and that take time-lapse photographs of the bottom (Butman and Folger, 1979); and (4) direct observation of the sea floor using manned submersibles. Figure 3 shows locations of instrument deployment in the Georges Bank area.

Data obtained from a tripod system located at station A are illustrated in figure 4. The records, from December 7, 1976 to February 23, 1977, show the variability in speed and direction of bottom currents and clearly indicate resuspension and transport of bottom sediments. The temperature record shows seasonal cooling and displacement of warmer slope water by cooler shelf water. Resuspension events are marked by a sharp reduction in light transmission, which is a function of the quantity and type of sediment in suspension. These events correlate inversely with peaks in pressure standard deviation that indicate the passage of storms generating large surface waves. The tanker *Argo Merchant*, carrying 7.7 million gallons of oil, broke apart near Nantucket in the storm of December 20-22, 1976.

The record of current speed shows the effect of the semidiurnal tides. Typically, bottom current speed ranged from 10 to 30 centimeters per second (cm/s). The threshold near-bottom current speed required to transport fine sand is about 25 cm/s. Obviously, bottom sediments at this location and depth (85 m) are frequently in motion.

The speed and direction of low-frequency currents are illustrated in the bottom graph of figure 4. This plot results from filtering the high-frequency periods (shorter than 30 hours) from the current data, thus removing fluctuations due to tidal currents. Both along-shelf (solid line) and cross-shelf (dashed line) current components are shown. Directional reference of the along-shelf component is northeast (+) and southwest (-); the cross-shelf reference is northwest (+) and southeast (-). A near-bottom current flowing up to 15 cm/s dominantly southwestward along the shelf was observed at this location (station A); cross-shelf currents were much weaker. Near bottom, both along-shelf and cross-shelf components reversed.

The upper sequence of time-lapse bottom photographs in figure 5 illustrates the effect of winter storms at station A at 85 m water depth. The camera was located 1 m above the sea floor. Photograph A is in very clear water and shows much biological activity. On the bottom surface are patches and small mounds of fecal material, probably from ocean quahogs. Photograph B, taken a month later, after at least six storms had passed (peaks in pressure standard deviation graph, fig. 4), shows the bottom swept clean of fecal material and littered with shell hash. Note the numerous tracks and trails left by benthic organisms in the soft bottom sediment. Photograph C, taken approximately 12 hours later, shows the bottom obscured by turbid water; even the current meter (right side), much closer to the camera, is barely visible. Twelve hours later (photograph D), the water has cleared and the bottom is strongly rippled and littered with new shell hash. The formation of the asymmetrical ripples is by itself direct evidence of erosion.

The lower sequence of bottom photographs in figure 5, obtained at station K at a water depth of 62 m, illustrates the effects of tidal currents on bottom sediments during a single tidal cycle. The camera was located 1 m above the sea floor. The current direction is indicated by the vane of the compass in the right side of each photograph. The vane rotated through 360° during the sequence. Note also that the orientation and symmetry of the ripples changed as the current direction rotated through the tidal cycle.

Studies during the past years show that tidal currents are sufficient to rework surficial bottom sediments over much of Georges Bank. Near-surface tidal currents (15 m depth) near the crest of the bank typically were 75 cm/s (1.5 knots (kn)), and on the north and south flanks of the bank were about 35 cm/s (0.7 kn). Maximum currents measured were 100 cm/s (2 kn) (Folger and others, 1978). During storms tidal currents are augmented by wave-driven flow that increases bottom stress and causes increased sediment resuspension. In one summer season some scour and resuspension by internal waves were observed on the south side of the bank at 85 m water depth. Clearly, the surficial sediments on Georges Bank are frequently reworked, and in the shallow water near the top of the bank, surficial sediments are in constant motion even in normal tidal currents.

Figures 6 and 7 summarize the available USGS data on the magnitude and orientation of mean currents and tidal currents on Georges Bank and adjacent parts of the New England Shelf. Part of the data were collected in a cooperative program with R. C. Beardsley and J. Vermersch at the Woods Hole Oceanographic Institution. The pattern of mean flow (fig. 7) shows a residual clockwise circulation pattern, as was suggested by Bumpus (1973); on the south side of the bank the flow was southwestward, parallel to the isobaths; mean flow was northeastward on the north side of the bank. Tidal currents (fig. 6) were strongest on top of the bank and diminished in strength in the deeper water on the flanks; they also diminished southwestward along the bank and to the west. These current patterns could have significant implications in terms of the trajectory and fate of pollutants introduced on Georges Bank, and also regarding the time during which such pollutants might remain entrained in the area.

REFERENCES CITED

Bumpus, D. F., 1973, A description of the circulation on the Continental Shelf of the East Coast of the United States, *in* Warren, B. A., ed., Progress in Oceanography, v. 6, p. 111-157.
Butman, Bradford, and Folger, D. W., 1979, An instrument system for long-term sediment transport studies on the Continental Shelf: Journal of Geophysical Research, v. 84, no. C3, p. 1215-1220.
Folger, D. W., Butman, Bradford, Knebel, H. J., and Sylwester, R. E., 1978, Environmental hazards on the Atlantic Outer Continental Shelf of the United States: Proceedings, Offshore Technology Conference, v. 4, paper 3313, p. 2293-2306.

STATION A

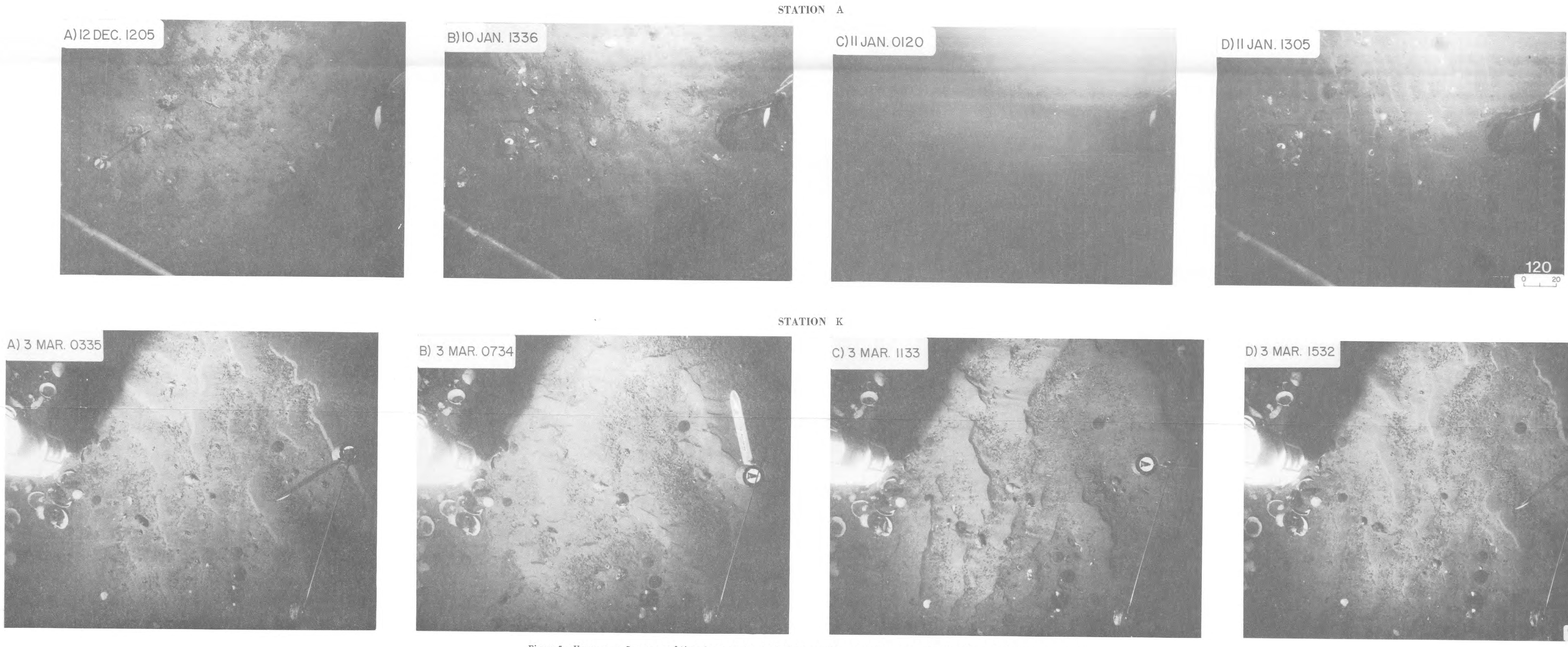

Figure 5.—Upper row: Sequence of time-lapse photographs of the sea floor at station A, showing the effect of winter storms at 85 m water depth. The camera was 1 m above the bottom. Current meter appears in the right side of each photograph; compass is on the left. Scale (in centimeters) for all four photographs is shown in the lower right corner of photograph D.
Lower row: Sequence of time-lapse photographs of the sea floor at station K, showing the effects of tidal currents on bottom sediments at 62 m water depth, during a single tidal cycle. The camera was 1 m above the bottom. Current direction is indicated by the vane of the compass in the right side of each photograph. Instrument on the left is a current meter. Scale (in centimeters) for all four photographs is shown in lower right corner of photograph D.

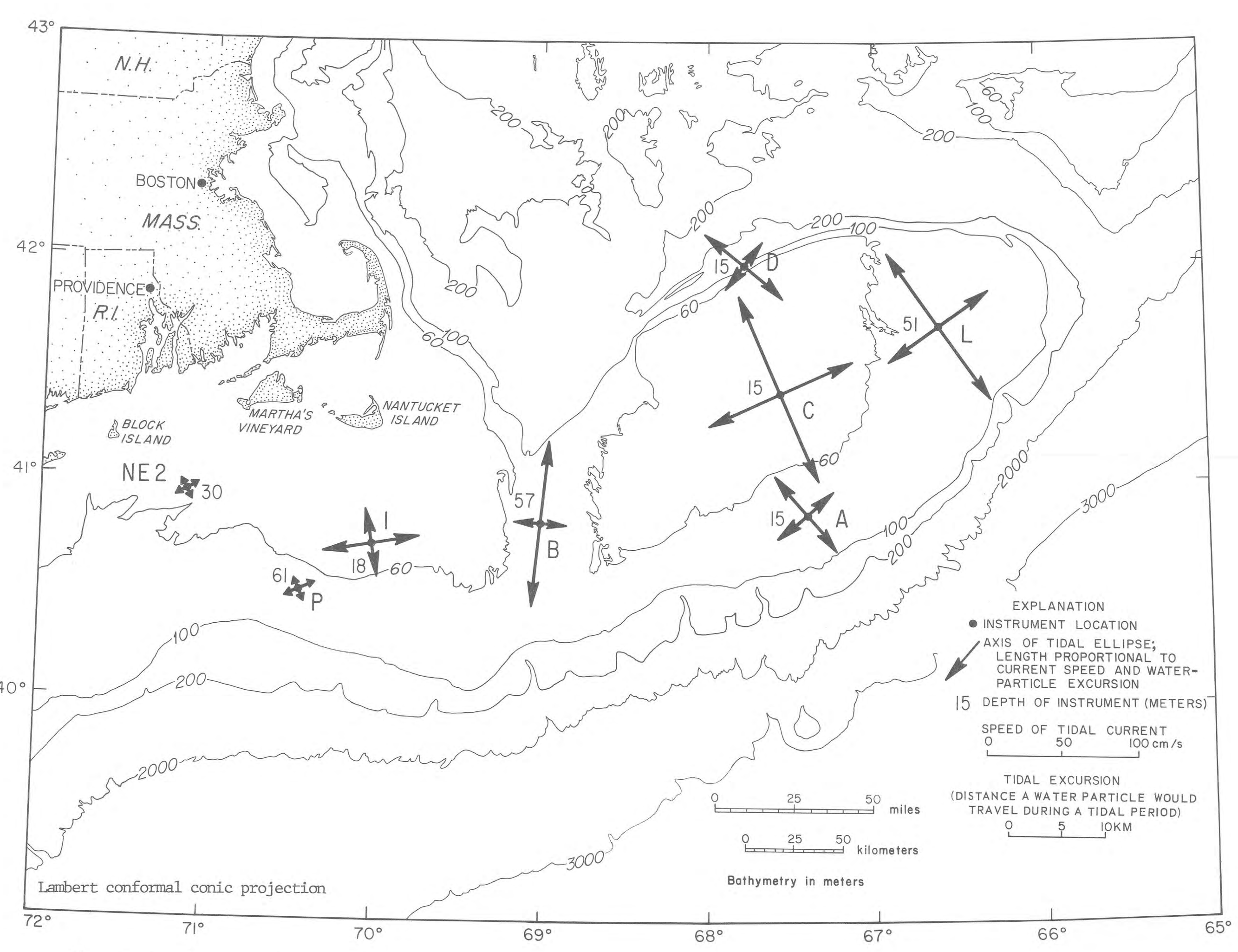

Figure 6.—Magnitude and orientation of semidiurnal tidal currents on Georges Bank and the adjacent shelf area. The data shown were collected at stations A, B, C, D, I, L, P, and NE 2. The measurements were not made simultaneously.

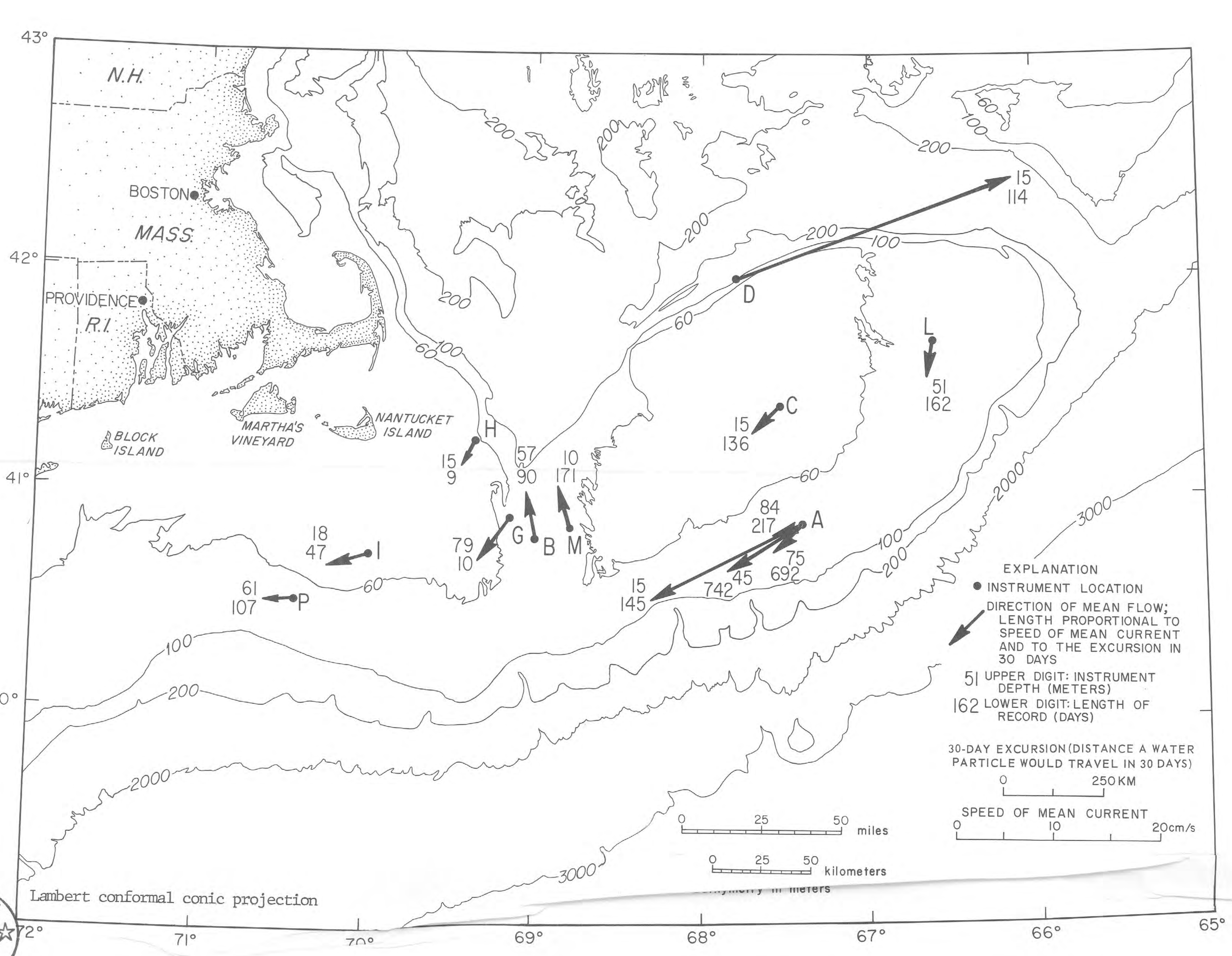

Figure 7.—Magnitude and orientation of mean currents on Georges Bank and the adjacent shelf area. The data shown were collected at stations A, B, C, D, G, H, I, L, and P, but not simultaneously.

MAPS SHOWING ENVIRONMENTAL CONDITIONS RELATING TO POTENTIAL GEOLOGIC HAZARDS ON THE UNITED STATES NORTHEASTERN ATLANTIC CONTINENTAL MARGIN

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1980

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