THE U. S. NAVY INTERNATIONAL GEOPHYSICAL YEAR ANTARCTIC PROGRAM IN OCEANOGRAPHY

by John LYMAN (*)

The logistic support provided by the United States Navy for the Antarctic IGY program has created an opportunity for carrying out a limited program of oceanographic investigation in the area. Icebreaker escorts have been furnished for the cargo vessels engaged in establishing and resupplying the U.S. Antarctic IGY bases, and since the icebreakers of the U.S. Navy and Coast Guard are equipped with winches and other gear for collecting oceanographic information, the Hydrographic Office has embarked oceanographers on most of the icebreakers to take charge of such work.

NARRATIVE OF THE CRUISES

The 1955 *Atka* Cruise

As a preliminary to establishment of the U.S. IGY bases, the U.S.S. *Atka* (AGB-3) in January and February 1955 reconnoitered the western Antarctic from the Ross Sea eastward to the Princess Martha Coast. She was the first U.S. Navy icebreaker to enter the Antarctic since 1948. Under the supervision of Dr. Willis L. Tressler, 13 oceanographic stations were obtained, 7 in the Ross Sea, 3 in Bransfield Strait, and 3 close to the shelf ice off the Princess Martha Coast. Bathythermograms were obtained frequently when underway. An 80-lb Phleger corer was used to raise cores, 12 of which came from the Ross Sea, 5 from off the Princess Martha Coast, and 4 along the route between these two areas. Observations of the deep scattering layer were also made from fathograms, and ice conditions were recorded.

A full report of the oceanographic results of this cruise is contained in Hydrographic Office Technical Report 48, *Field Report, Oceanographic Observations, U.S. Navy Antarctic Expedition 1954-55* (1956; reprinted 1957).

Deep Freeze I

Task Force 43 has conducted the IGY logistic expeditions to Antarctica, the first of which bore the operational name of Deep Freeze I. In 1955-56 the task force included three icebreakers, the U.S.S. *Edisto* (AGB-2) and *Glacier* (AGB-4) and the U.S.C.G.C. *Eastwind* (WAGB-279). All three ships

(*) Director, Division of Oceanography, U.S. Navy Hydrographic Office. Opinions or assertions herein are the author's and are not to be taken as official.

collected bathythermograms, some 1 300 of which were taken by the *Edisto*, 700 by the *Glacier*, and 300 by the *Eastwind*. Dr. Tressler in the *Glacier* occupied 12 oceanographic stations, and Mr. W. H. Littlewood in the *Edisto*, assisted after 30 December 1955 by Mr. Lloyd Wilson, occupied 21 stations. Mr. Wilson was previously in the *Eastwind*, and Mr. J. Q. Tierney transferred to that vessel from the cargo ship *Arneb* on 18 February 1956, but owing to operational priorities and mechanical difficulties no oceanographic stations were obtained by the *Eastwind*. All three icebreakers operated primarily between New Zealand and the Ross Sea, and the *Glacier* subsequently circumnavigated Antarctica to the westward as far as the Weddell Sea. Observations of the deep scattering layer and of ice were made as in the previous year. Some 30 bottom cores were obtained by the ships in the Ross Sea and four more by the *Glacier* on her circumnavigation track. Full sediment analyses, as well as details of the other oceanographic observations, are given in H. O. 16331-1, *U.S. Navy Hydrographic Office Report on Operation Deep Freeze I* (1956).

Deep Freeze II

For the second season of its operation in the Antarctic, Task Force 43 had four icebreakers available. Dr. Tressler was again in the *Glacier*, and he obtained 11 oceanographic stations; Mr. Littlewood, in the U.S.S. *Staten Island* (AGB-5) occupied 26 stations; Mr. Tierney in the U.S.C.G.C. *Northwind* (WAGB-282) occupied 5 stations; and Mr. R.B. Starr in the *Atka* occupied two stations. Bathythermograms were also obtained as follows : *Glacier*, 1 595; *Staten Island*, 721; *Atka*, 1 057; and *Northwind*, 984. Other ships of the Task Force also contributed bathythermograms : U.S.S. *Arneb* (AKA-56), 290w U.S.S. *Wyandot* (AKA-92), 155; and U.S.S. *Brough* (DD-148), 154. The *Staten Island* escorted the *Wyandot* to the far southwest corner of the Weddell Sea.

Except for an excursion by the *Glacier to* Wilkes Station in 110° E in January 1957, where four stations were occupied, the three other icebreakers confined their operations to the Ross Sea sector. Several detailed bathythermograph profiles across the Antarctic Convergence were obtained.

Hydrographic Office Technical Report TR-29, *Operation Deep Freeze II, 1956-1957, Oceanographic Survey Results* (1957) contains a complete report of the oceanographic results of this cruise, including ice observations, deep scattering layer, and descriptions of the bottom samples.

Deep Freeze III

For the 1957-58 operations, Task Force 43 employed the icebreakers *Glacier, Atka,* U.S.S. *Burton Island* (AGB-1), and U.S.C.G.C. *Westwind* (WAGB-281). Dr. Tressler this year was appointed Scientific Leader at Wilkes Station, and Mr. Littlewood in the *Glacier* was senior Hydrographic Office representative with the Task Force. The *Glacier* occupied 30 stations in the Ross Sea area. Mr. Wilson in the *Atka* occupied 23 stations in the Ross Sea, 6 off Wilkes Station in 110° E, and several more in the vicinity of Macquarie Island. Mr. Tierney in the *Westwind* obtained 8 stations in the Weddell Sea, 2 in Bransfied Strait, 14 in the Bellingshausen Sea, and 4 in Drake Passage. Mr. Starr in the *Burton Island* occupied 5 stations in the Ross Sea, and then circumnavigated Antarctica to the westward, obtain-

ing one station near 93° E, 4 off Lützow-Holm Bay in 40° E, and one in 23° E.

Bathythermograms collected numbered 950 from the *Burton Island,* 1 141 from the *Atka,* 2 110 from the *Westwind,* and 1 800 from the *Glacier.*

A total of 45 cores and 15 additional bottom samples was also obtained. These are now being analyzed, and it is anticipated that the results, together with data on the oceanographic stations and crossings of the Antarctic Convergence, will be published in a format similar to the reports of the previous three seasons.

Collateral observations

In addition to observations which have been reported by the Hydrographic Office, its oceanographers have carried out several programs of sample collection for other scientific agencies. Some of these are rather remote from oceanography — for example, specimens of maize that had been taken as pony fodder to the Antarctic by Shackleton in 1907-08 were brought back for the United States Department of Agriculture. In plantings at Beltsville, Maryland, in 1957, some of the kernels proved viable, and ears were harvested.

Antarctic sea water samples have been turned over to Dr. Irving Friedman of the United States Geological Survey for his work on the world-wide distribution of deuterium, the heavy isotope of hydrogen. On Deep Freeze I, two 70-liter samples were collected for Dr. Frederick Begemann of the University of Chicago, for analysis for tritium, the triple-weight isotope of hydrogen.

Marine biological specimens were collected on each cruise, using plankton nets, trawls, and handlines. The specimens from the first three cruises were deposited in the U.S. National Museum; those taken in 1957-58 were sent to the George Vanderbilt Foundation at the Stanford University Natural History Museum. Bottom samples from the Weddell Sea were frozen in 1957 and sent to the Scripps Institution of Oceanography for bacteriological analysis.

Future plans

Four icebreakers are scheduled to operate on Deep Freeze IV in 1958-59, and it is anticipated that oceanographic observations will be continued at the same level as in past years. A program of collecting large-volume water samples for carbon-14 analysis is an addition to the program for the forthcoming season.

OCEANOGRAPHIC RESULTS

Crossings of the Antarctic Convergence

Since detailed sections of the temperature structure of the Antarctic Convergence have been largely lacking in the past, and since the use of the bathythermograph permits obtaining such information in the top 100 meters of the ocean without delaying the icebreakers on their primary logistic missions, special emphasis has been placed on such work throughout the cruises.

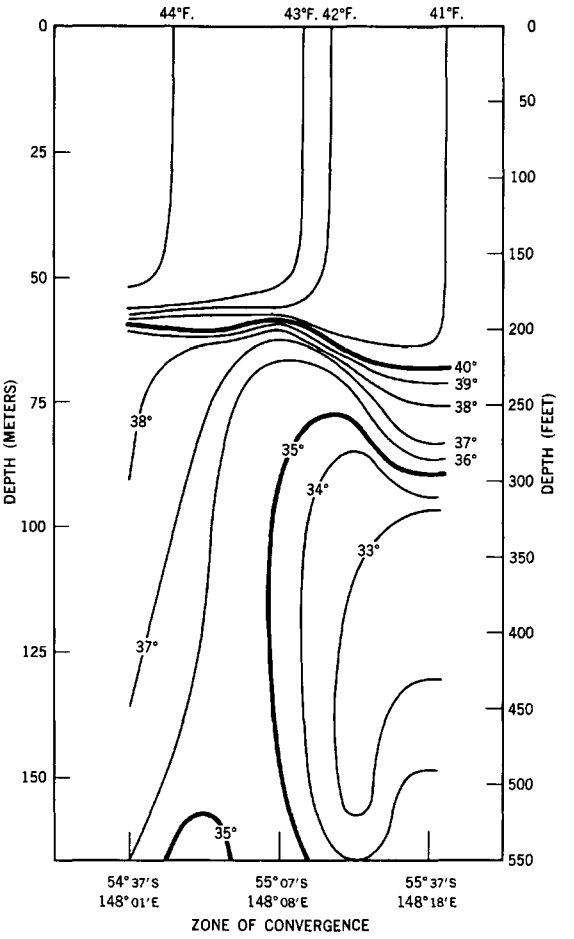

Fig. 1. — Vertical Temperature Section, February 1957.

Figure 1 shows the single crossing in the Indian Ocean Sector that has been analyzed. Here the Convergence was identified in the vicinity of 55° S.

Three crossings in the Atlantic Sector are shown in figures 2 and 3. The Convergence was identified near 56° S in 55° W and near 52° S in 38° W.

The other crossings for which data are available are all near the Date Line (Pacific Sector), where the Convergence is found near 62° S (figures 4-7). Figure 8 gives the results of 5 *Edisto* stations, showing salinity and density relationships across the Convergence. The temperatures, since they were taken with reversing thermometers, are given to a greater depth but in less detail than in the preceding figures.

Water masses

Besides their ability to obtain detailed bathythermograph sections, the icebreakers have the capability to penetrate Antarctic areas « out of season », and thus some of their oceanographic samplings have been in zones or at seasons never before available.

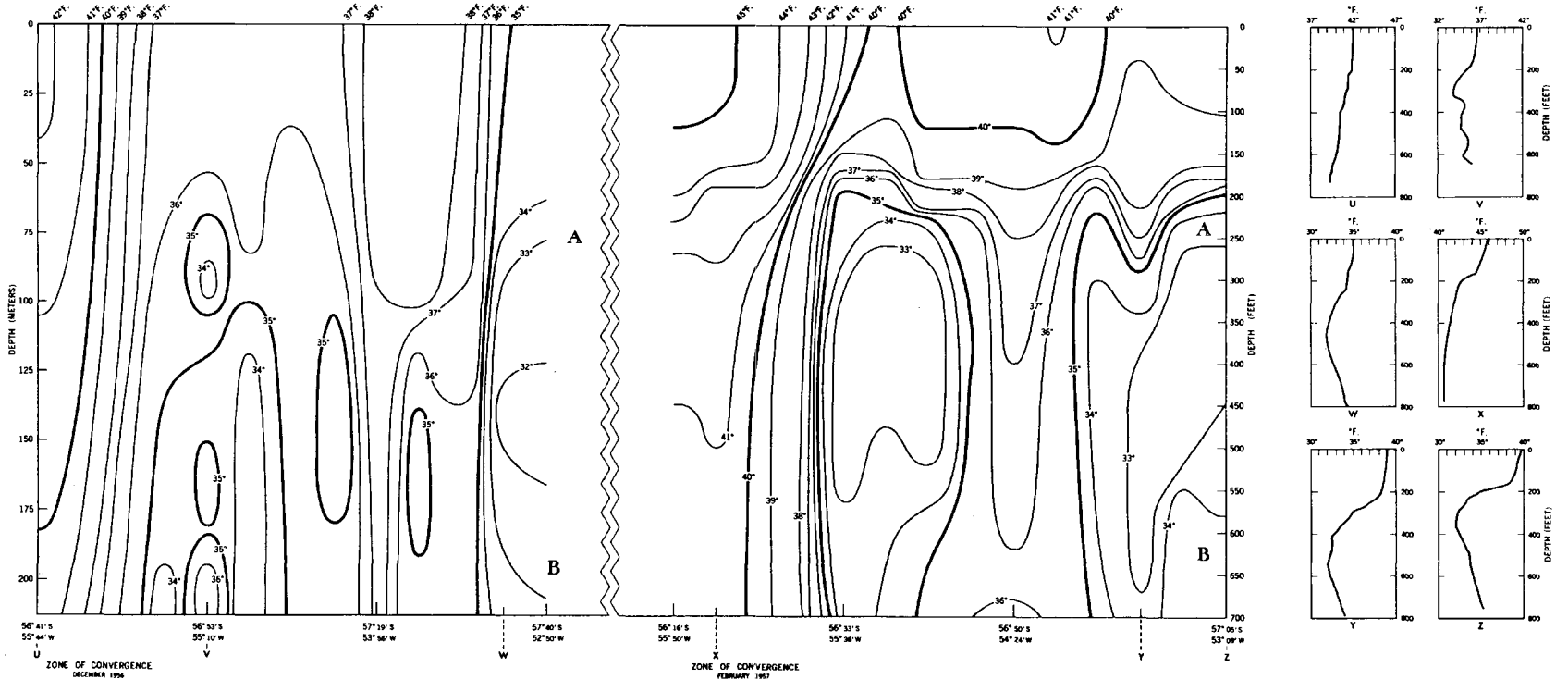

Fig. 2. — Vertical Temperature Sections, December 1956 and February 1957

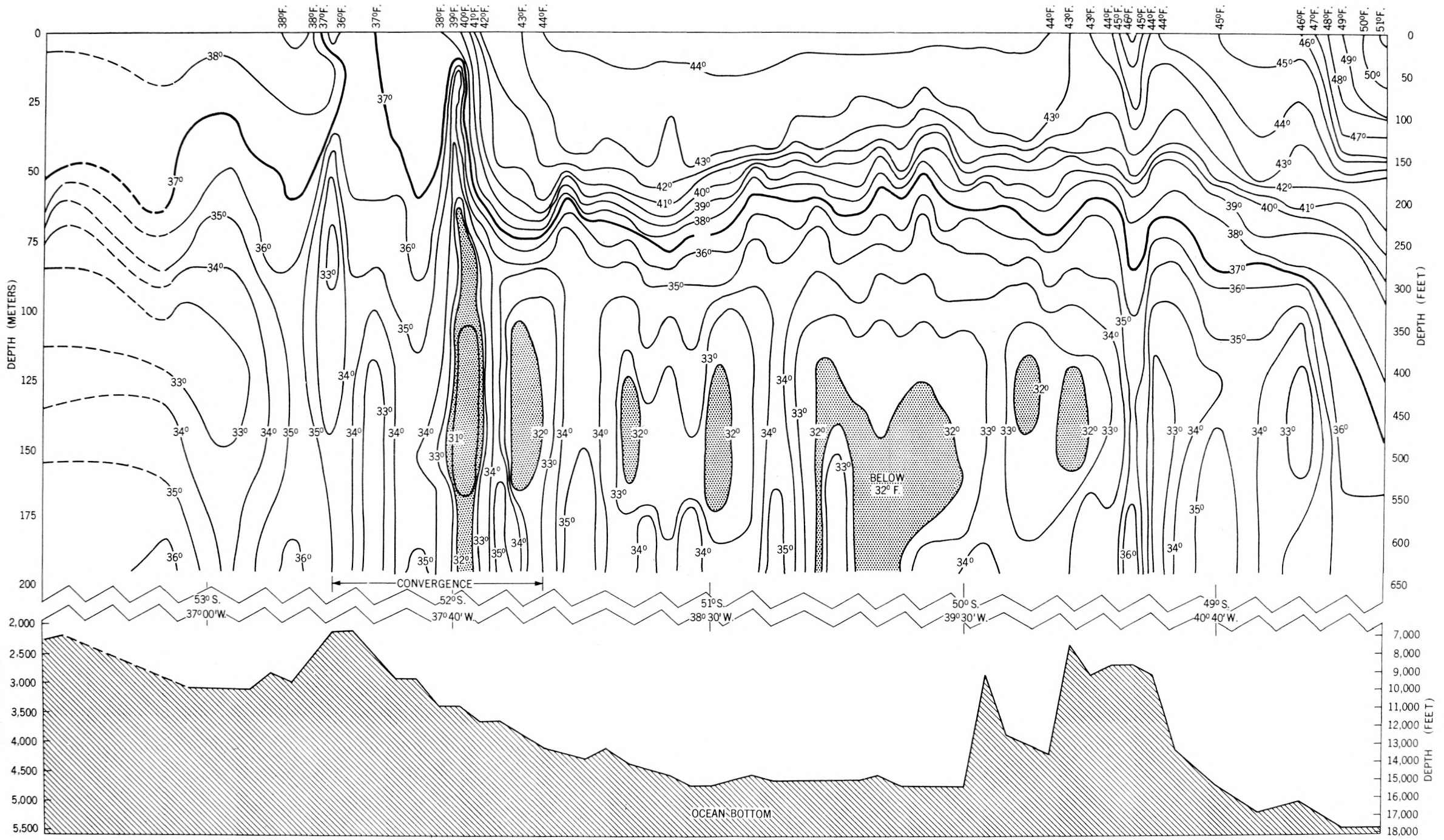

Fig. 3. — Vertical Temperature Section, February 1955.

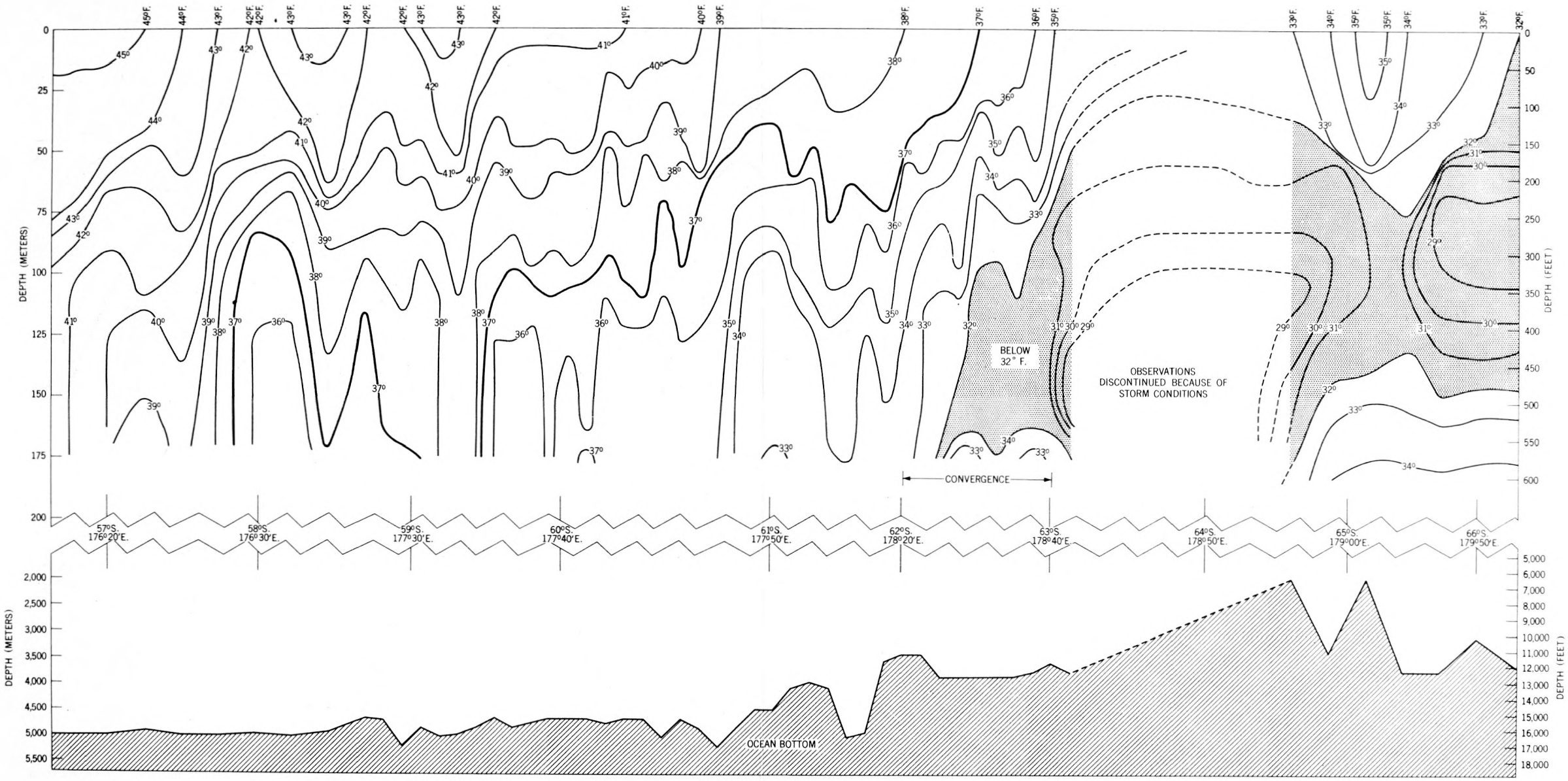

Fig. 4. — Vertical Temperature Section, January 1955

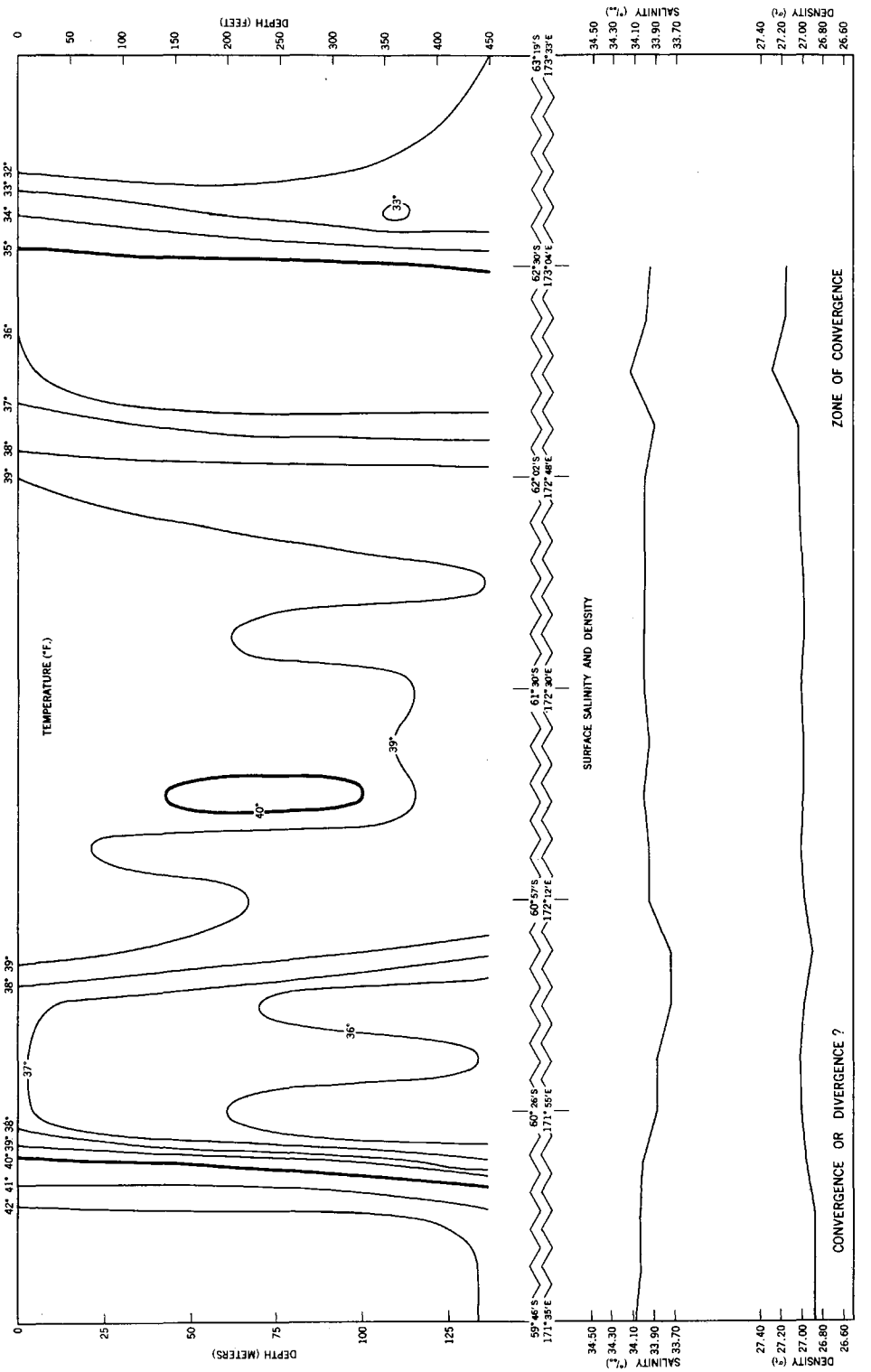

Fig. 5. — Vertical Temperature Section, November 1956.

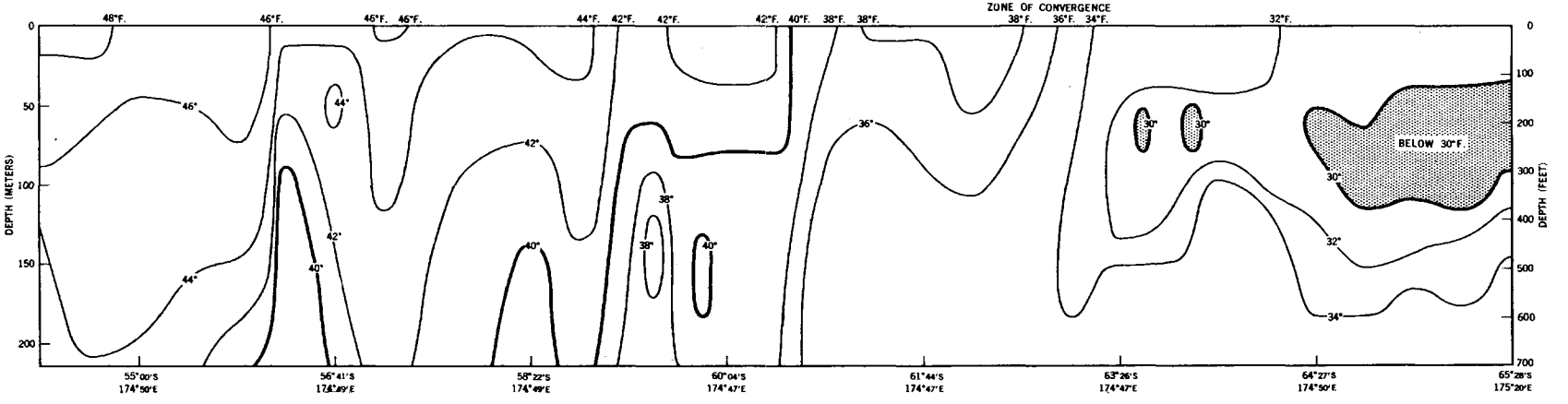

Fig. 6. — Vertical Temperature Section, December 1956.

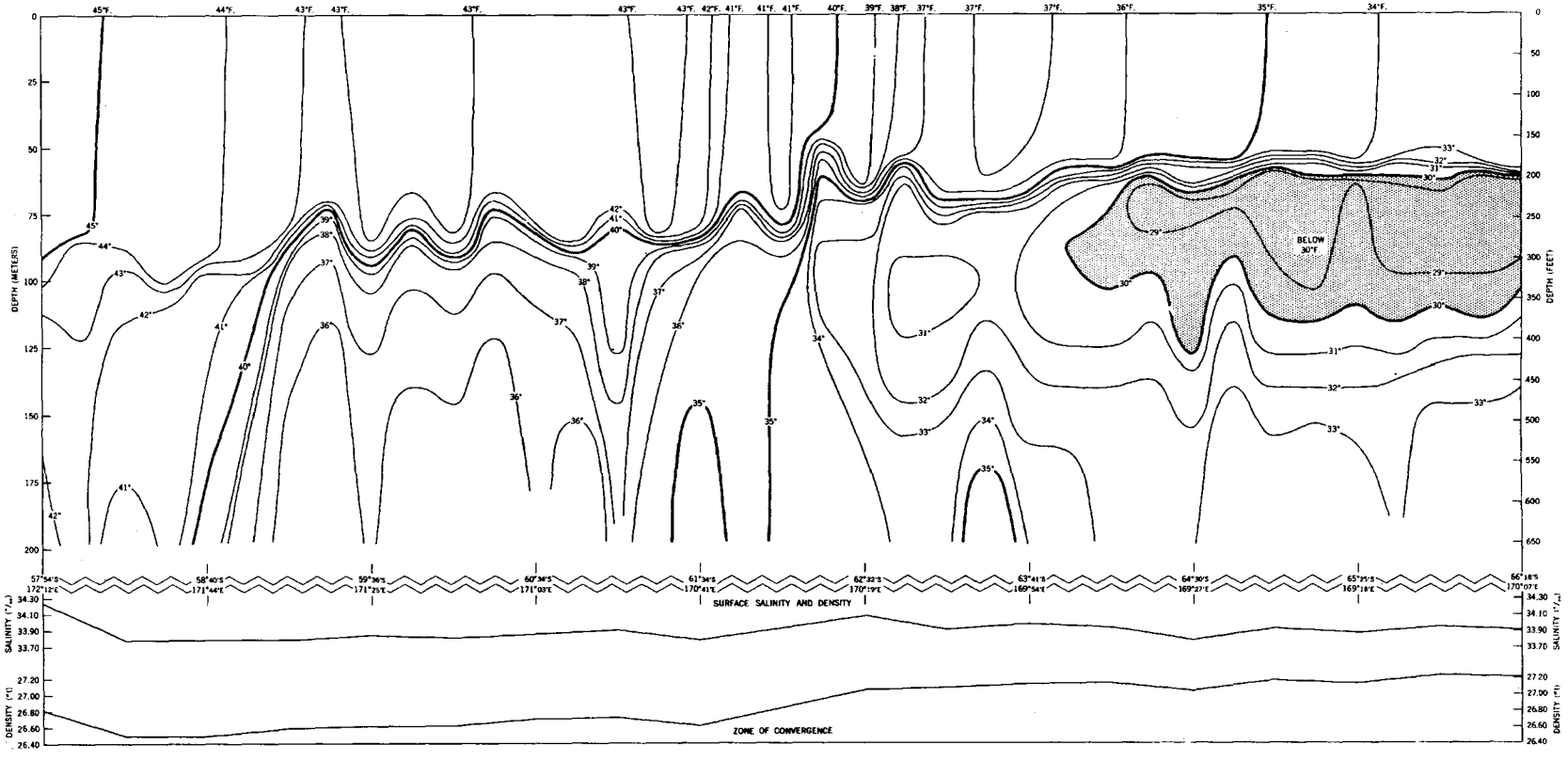

Fig. 7. — Vertical Temperature Section, February 1957

Figures 75 and 76 of Hydrographic Office Publication 705, *Oceanographic Atlas of the Polar Seas, Part I* (1957), show the locations of all available oceanographic stations south of 60° S. The Deep Freeze stations make a significant addition to the previous coverage of the Antarctic.

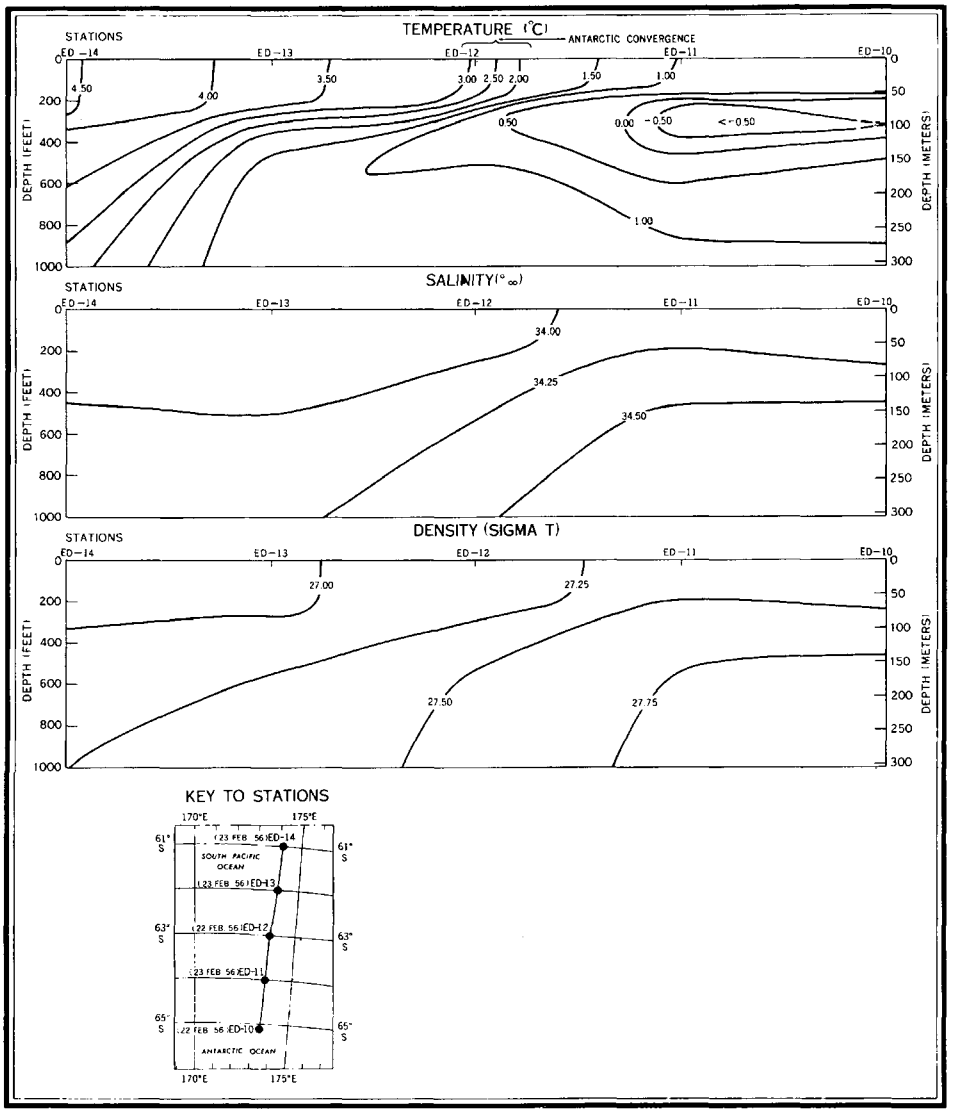

Fig. 8. — Vertical Temperature, Salinity, and Density Section, February 1956

For the Weddell Sea, the *Staten Island* stations of 1956-57 represent a major advance in the oceanography of the area. The locations of these stations are shown in figure 9. Figure 10 is a meridional section near 15° W based on 5 of these stations, showing temperature and salinity maxima near 400 meters. The density gradient in the deeper water is almost nonexistent, Station 13 having a σ_t value of 27.85 at 2 495 meters, and Station 15 27.86 at 3 464 meters.

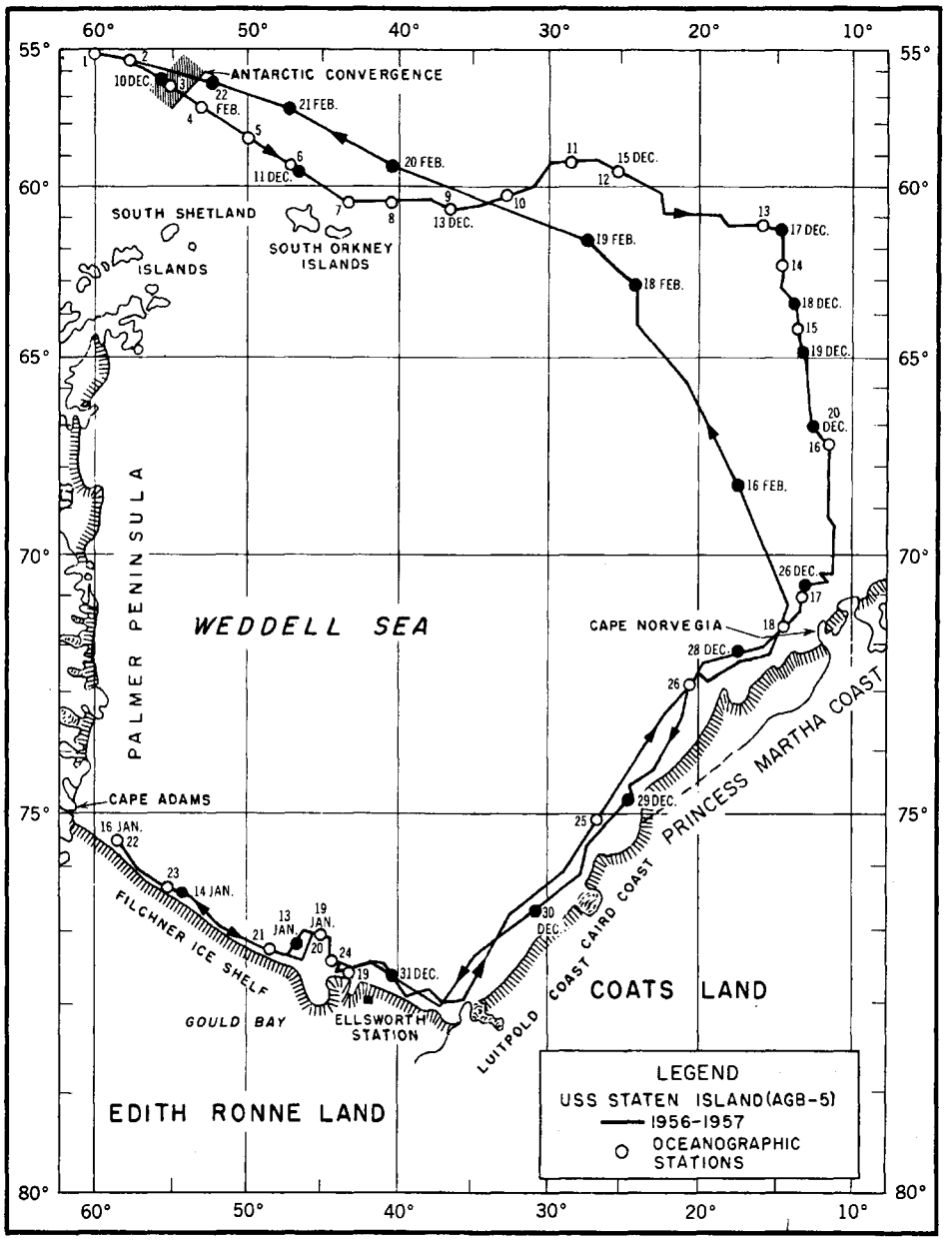

Fig. 9. — Stations in Weddell Sea, 1955-56.

The stations across the head of the sea, 19 to 24, were all on the continental shelf. From 100 meters down to 600 meters (the deepest available sample), the water was uniformly of a temperature slightly above — 2.0° C, with salinity increasing from about 34.60 ‰ to 34.75 ‰, and σ_t from 27.80 to 28.00. Although it was less than a month past mid-summer (11 to 20 January), air temperatures ranged from — 2.8° to — 6.2° C, so that the sea was losing heat to the atmosphere, and apparently winter cooling had already commenced.

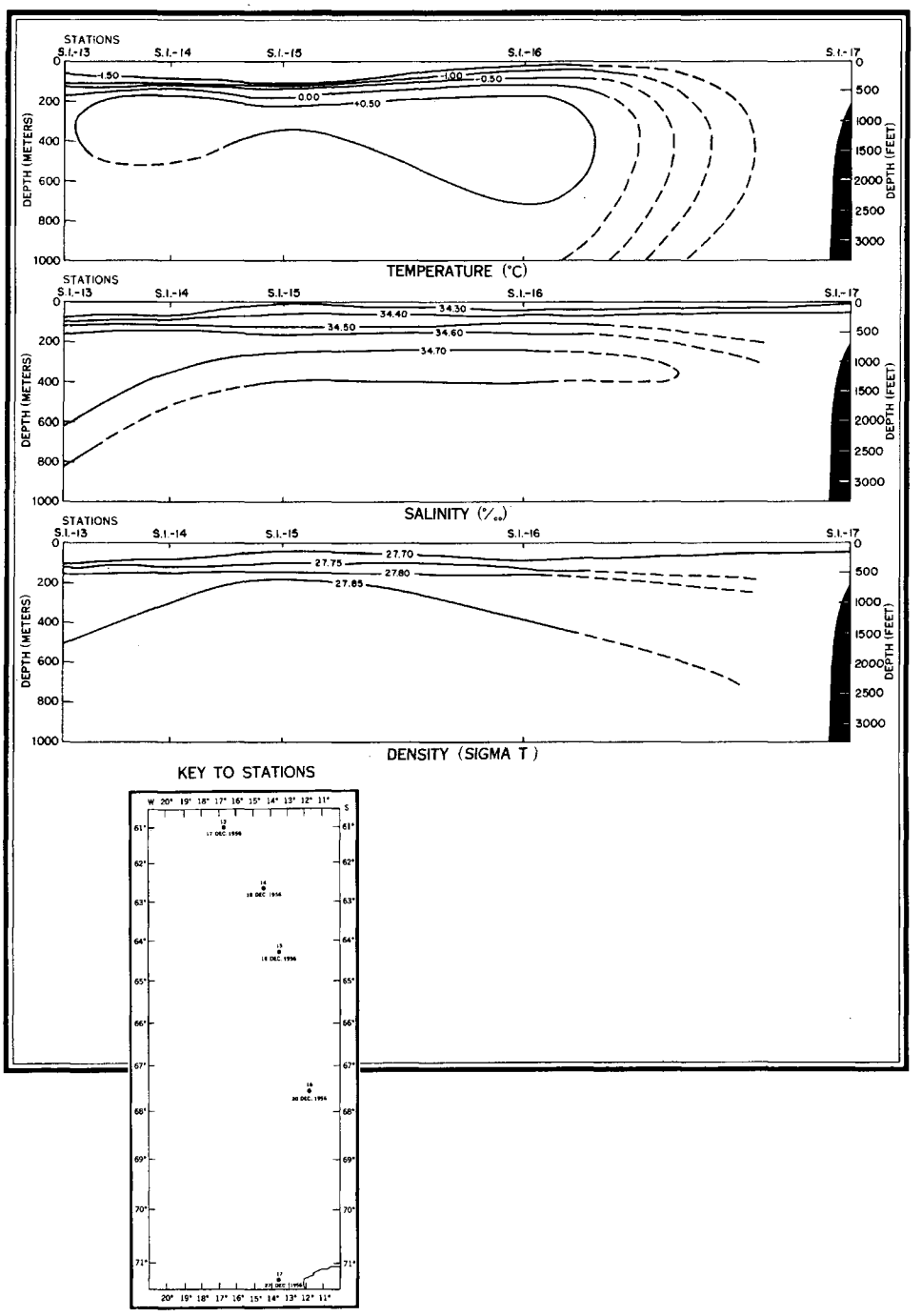

Fig. 10. — Vertical Temperature, Salinity, and Density Section, December 1956

These results verify the conclusion of Mosby (1934) that the bottom water of the Antarctic is formed from a mixture of heavy, cold surface water, formed on the continental shelf by winter cooling and freezing, with the warmer Antarctic Circumpolar Water. We now know that the shelf area of the Weddell Sea is much greater than it was thought to be 24 years

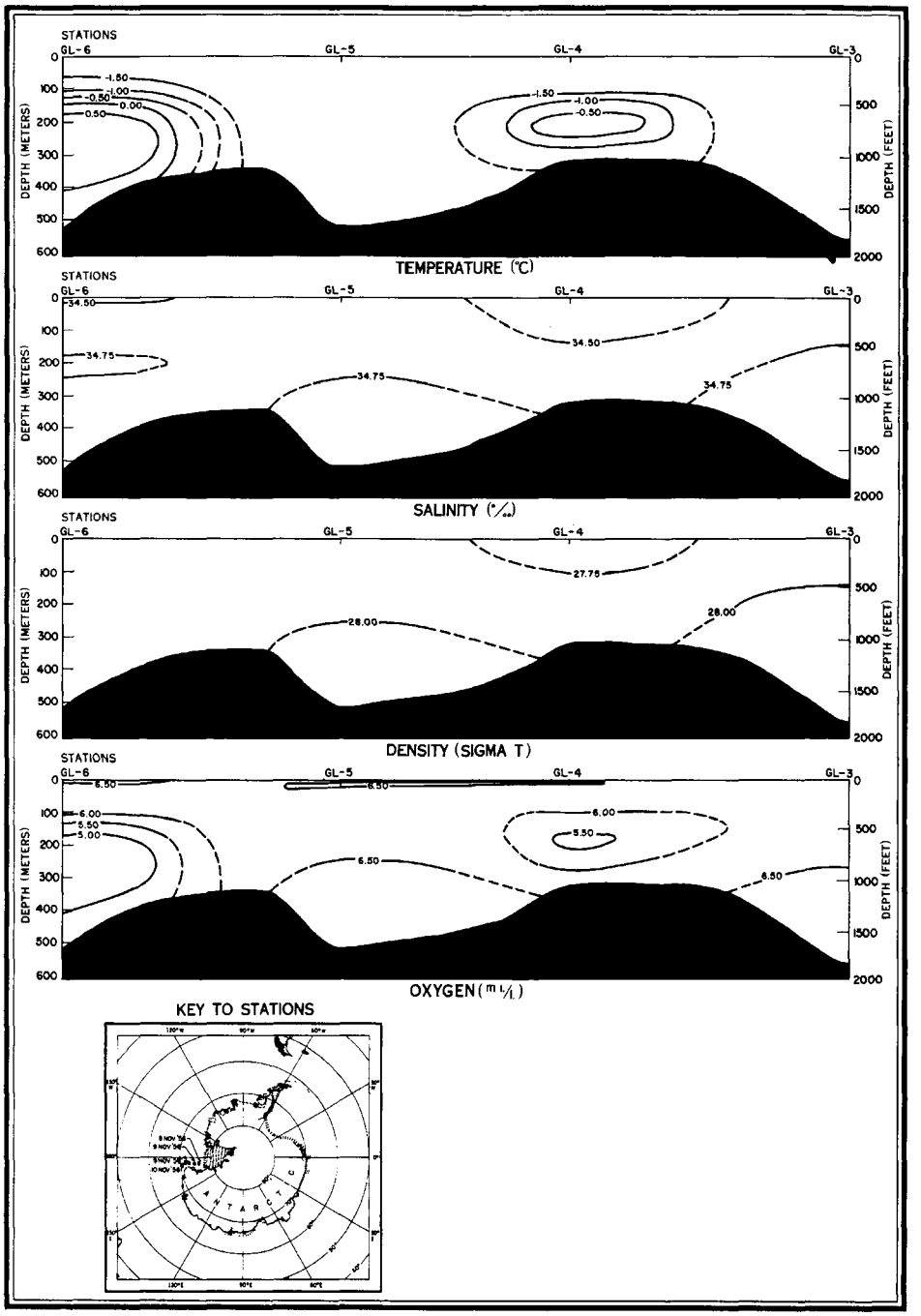

Fig. 11. — Vertical Temperature, Salinity, Density, and Oxygen Sections, November 1956.

ago. Hence the rôle of the head of the Weddell Sea in the formation of Antarctic Bottom Water needs to be reevaluated in the light of the IGY data.

In the Ross Sea, the penetration in the second week of November 1956 by the *Glacier* is the earliest on record for a vessel equipped for oceano-

graphic observations. She arrived a week earlier in 1957. Figure 11 shows vertical sections of temperature, salinity, density, and oxygen based on four stations. At Station 5 the water was nearly isothermal, the temperature ranging from — 1.80° C at the surface (air temperature — 9.7°) to — 1.90° at 515 meters, 5 meters above the bottom; but the salinity, which was uniformly 34.70 °/₀₀ from 0 to 200 m, increased to 34.92 °/₀₀ at 515 m. The value of σ_t at 515 m, 28.14, must be one of the highest ever encountered in the ocean, and indicates that Station 5 was probably located over a basin in which very dense water was trapped.

Seasonal cycles

At two locations near United States Antarctic IGY bases, stations have been reoccupied over a period of months. Figure 12 shows the seasonal march of temperature and salinity off Little America V at a position roughly 78° 08′ S, 162° 10′ W, while figure 13 shows the same for a position in McMurdo Sound off Hut Point in about 77°50′ S, 166°30′ E.

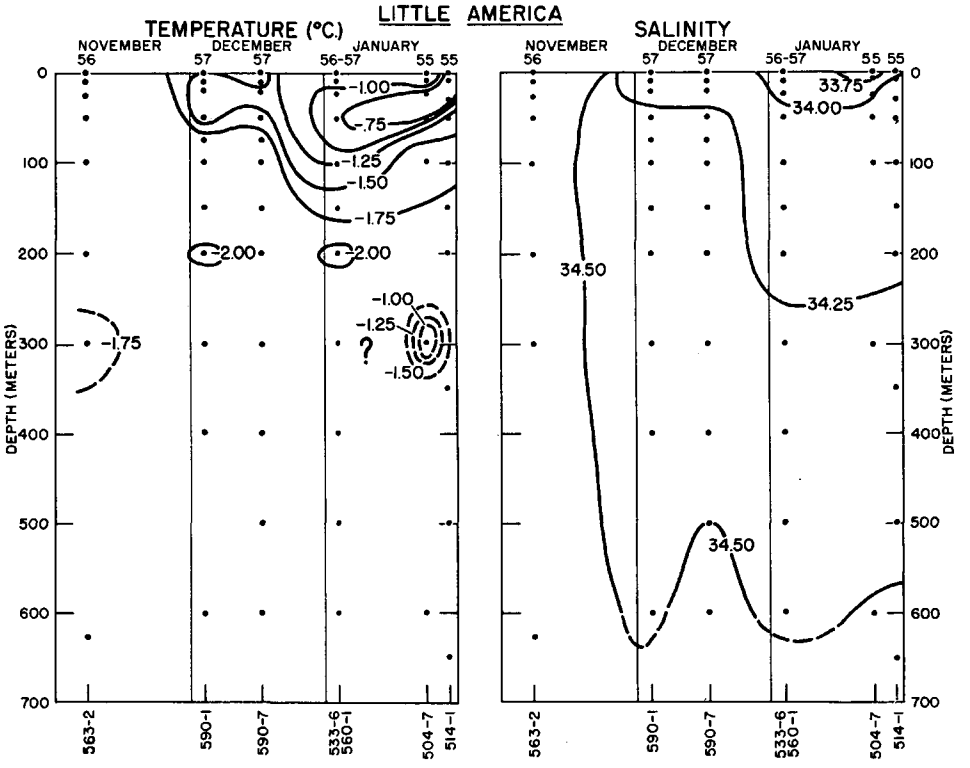

Fig. 12. — Seasonal Variation of Salinity and Temperature, Little America V.

Both sites show a rapid summer decrease in salinity, undoubtedly reflecting melting of pack and shelf ice, with warming confined to the upper layers. At the onset of autumn, temperatures rapidly revert to spring values (near freezing), but salinity is much slower to respond. At the low temperatures, density depends more on salinity than on temperature. In the course of the winter, cold brines sink from beneath the thickening pack ice and raise the salinity of the waters over the continental shelf.

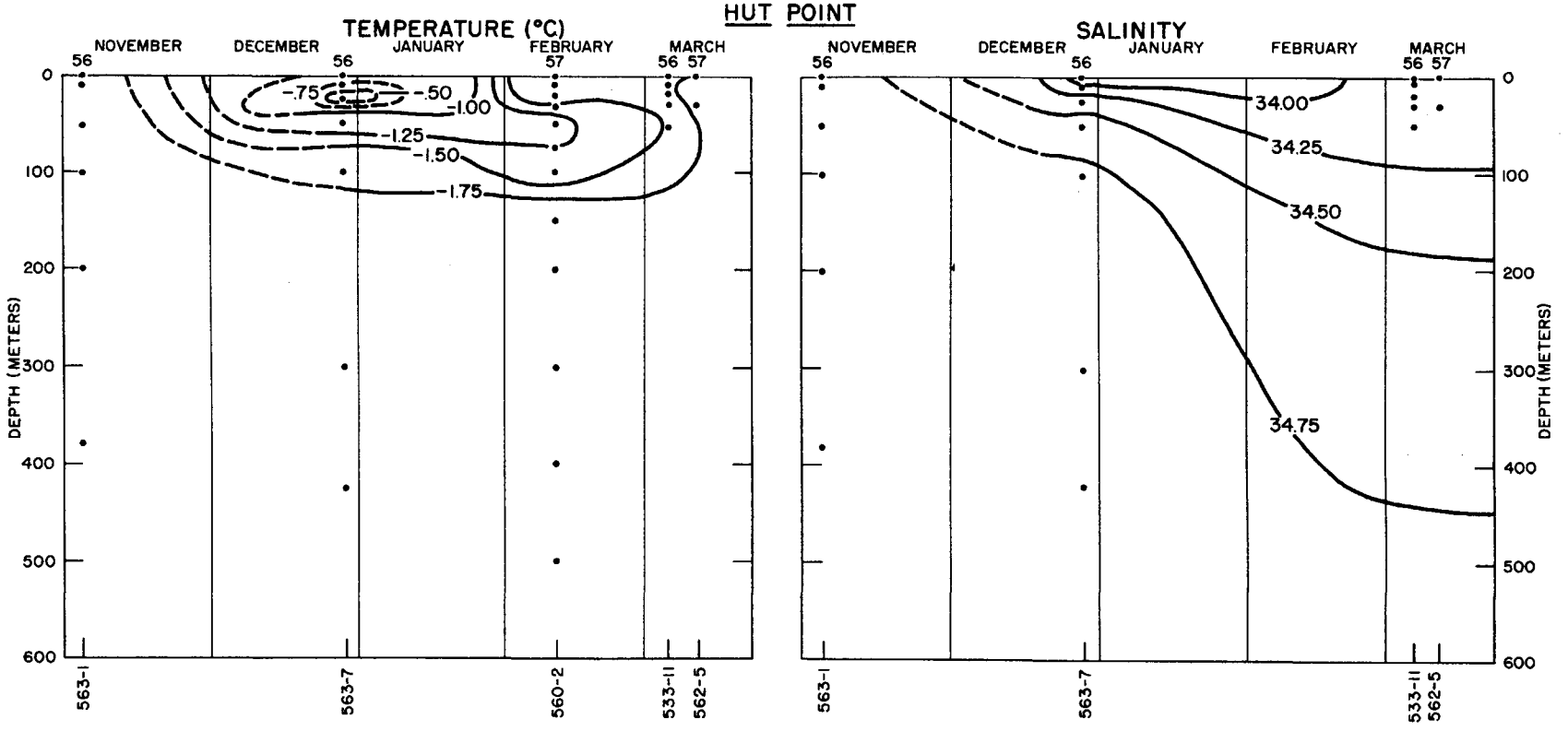

Fig. 13. — Seasonal Variation of Salinity and Temperature, Hut Point.

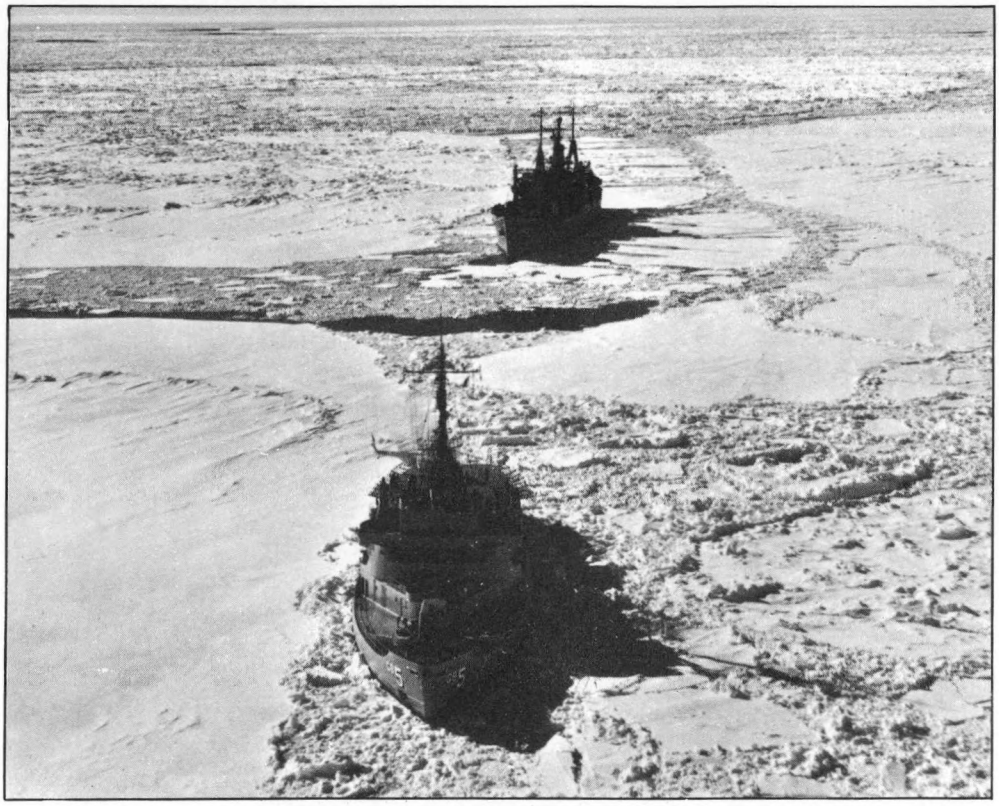

Fig. 14. — The *Staten Island* escorting the *Wyandot* in the Weddell Sea

Fig. 15. — The *Atka* in the Ross Sea pack ice.

The marked difference in the regimes at Hut Point and off Little America is explainable partly by the more exposed location of the latter, which facilitates mixing below the surface, but is probably mainly due to the proximity of an ice shelf some 250 meters thick (Poulter, 1947) whereas at Hut Point the ice barrier is for the most part produced by Koettlitz Glacier and is much thinner.

REFERENCES

MOSBY, H., The waters of the Atlantic Antarctic Ocean, *Sci. Results Norweg. Antarctic Exped. 1927-1928,* No. 11, 131 pp., 1934.

POULTER, T. H., Seismic measurements in the Ross Shelf Ice, *Trans. Am. Geophy. Union,* 28 : 162-170, 367-384, 1947.