SOME GEOGRAPHICAL RESULTS OF THE SECOND BYRD ANTARCTIC EXPEDITION, 1933-1935

I

The Submarine Topography of the Ross Sea and adjacent waters. (*)

by

S. EDWARD ROOS.

(Extract from *Geographical Review*, New York, October 1937, p. 574).

The oceanographic program of the Second BYRD Antarctic Expedition, which left Boston in the latter part of September, 1933, included a systematic bathymetric survey in the form of echo soundings begun as soon as the Pacific Ocean was entered.

Soundings were taken hourly, *i. e.* about seven miles apart. However, when any outstanding change in the bottom configuration was encountered, or when a continental or insular shelf was approached and left, the soundings were increased to any number required to obtain the detailed profile of the bottom. In all, ten series, totaling 2723 soundings, were carried out by the *Bear of Oakland* during her various cruises (1). They are: Panama to Tahiti; Tahiti to New Zealand (North Island); Dunedin, N. Z. to Bay of Whales, Ross Sea; an exploratory cruise to the waters northeast of King Edward VII Land; a cruise across the Ross Sea to latitude 72° S. for a rendezvous with the R. R. S. *Discovery II*; Bay of Whales to Dunedin, N. Z.; Dunedin, N. Z., to the Bay of Whales (including the Scott Island Rise, western sector of the Ross Sea, and front of the Ross Shelf Ice); Discovery Inlet, Ross Sea, to Dunedin, N. Z.; Dunedin, N. Z. to Easter Island; Easter Island to the Gulf of Panama.

The soundings fall into two main divisions: the trans-Pacific series and the series related directly to the Antarctic. The present paper deals chiefly with the latter (2); for the former see Appendix II.

THE SECTIONS: SOUTH OF NEW ZEALAND.

In general, the bottom contours crossed by the *Bear* on her four passages between New Zealand and the Ross Sea have an east-west trend. The most conspicuous feature of the sections is the pronounced ridge with its crest in 64° S. It is, in fact, a westward extension of the Easter Rise and separates the South Pacific Basin from the Pacific Antarctic Basin. The soundings from two of the sections are plotted in Figure 3.

The profiles (Fig. 3) show the New Zealand insular shelf receding in a very steep slope to 5000 meters about 500 miles (3) south of the starting point, Dunedin. The trend of this contour on the chart (Fig. 1) indicates that the South Pacific Basin extends far to the southwest possibly terminating at Macquarie Island. The maximum depth of water found by the *Bear* when crossing this deep tongue was 5500 meters; the bottom remained deeper than 5000 meters for a distance of 300 miles, until, at first gradually and then with greater incline, it shoaled to form the extensive rise mentioned above, the crest of which shows an elongated depression. The soundings indicate that the ridge deepens rapidly eastward. For the next 300 miles southward the depths again increase, except in the vicinity of Scott Island.

SCOTT ISLAND AND VICINITY.

Scott Island, 67°24' S., 179°55' W., was discovered on Christmas Day, 1902, by the relief ship *Morning*, Captain COLBECK, of Scott's National Antarctic Expedition (4). As figure I suggests, this island might well be called the boundary stone between the South Pacific and the Ross Sea.

(*) Constituting *Contribution* N° 91 of the Woods Hole Oceanographic Institution.

(1) Photostats of the tabulated soundings have been distributed to the various hydrographic agencies. Additional copies can be obtained by request from the Woods Hole Oceanographic Institution, Woods Hole, Mass.

(2) A line of echo soundings between Dunedin, N. Z., and the Bay of Whales was obtained on the First Byrd Antarctic Expedition. These soundings are plotted, uncorrected, on the map of the routes of the *City of New York*, Plate II in W. L. G. JOERG'S: "The Work of the Byrd Antarctic Expedition 1928-1930", Amer. Geogr. Soc. 1930.

(3) All miles are nautical.

(4) G. S. DOORLY: "The Voyages of the *Morning*", New York, 1916, pp. 58-62.

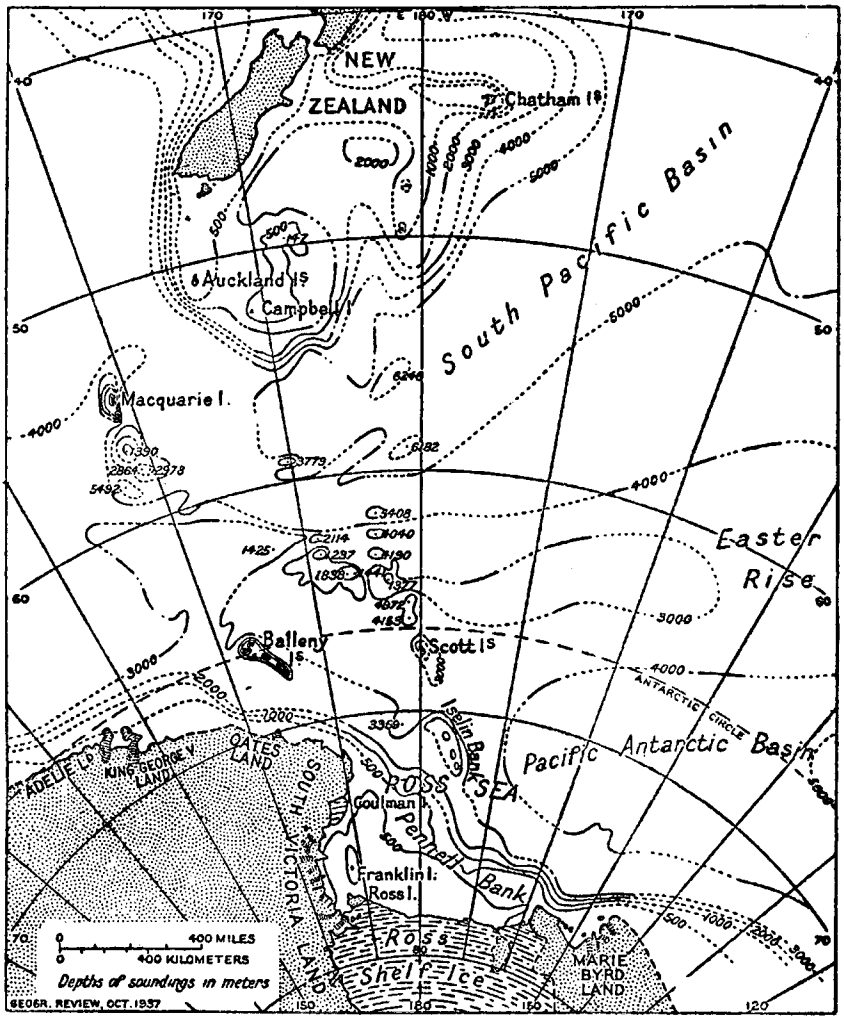

FIG. 1

Bathymetric Map of the Ross Sea and adjacent waters ; scale approximately 1:35,000,000. *The map revises that part of the American Geographical Society's Bathymetric Map of the Antarctic* (1:20,000,000), 1929. *In addition to the soundings obtained by the* Bear *use has been made of the echo soundings by the S. Y.* Discovery, *B. A. N. Z. Antarctic Expedition* (MAWSON) 1929, 1930, 1931, *in* "List of Oceanic Depths Received at the Admiralty during the Year 1932", *Publication H. D.* 308, *London,* 1933 ; *soundings by R. R. S.* William Scoresby, 1928, *in* Discovery *Reports, Vol.* 3, *pp.* 1-134 (*Ross Sea Soundings, pp.* 124-131), 1930 ; *soundings by R. R. S.* Discovery II, 1932, *in* "List of Oceanic Depths... 1932" ; *soundings by* Thorshavn, 1933-1934, *list sent by H. E.* HANSEN, *Norges Geografiske Opmaling.*

Figure 4 shows the profile obtained on the second cruise of the *Bear* season 1934-1935. The bottom rises steeply from a depth of 3800 meters for a distance of 12 miles to emerge as a rocky island about 175 feet in height, with precipitous sides, crowned with the characteristic Antarctic icecap, which extends seaward in a southeasterly direction. This shelf-ice formation was not apparent when the island was sighted — the second time since its discovery — by the First BYRD Antarctic Expedition in December, 1928. The near-by jagged peak of Haggitt's Pillar is really a part of Scott Island. Just south of Scott Island the bottom recedes steeply to 2900 meters, then rises again to 300 meters within 25 miles of the island. One may believe that this peak culminates in rocks awash. However, no breakers were observed from the deck of the *Bear*.

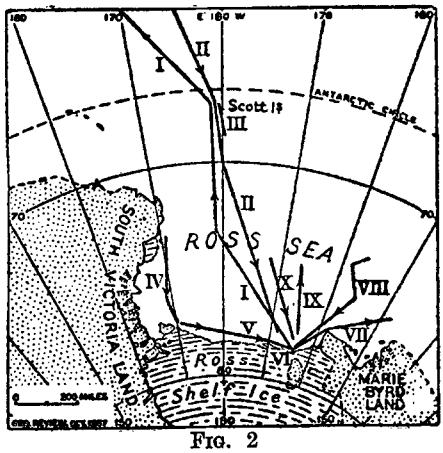

FIG. 2

Index map to the profiles in the Ross Sea and neighboring waters. Scale 1:40,000,000

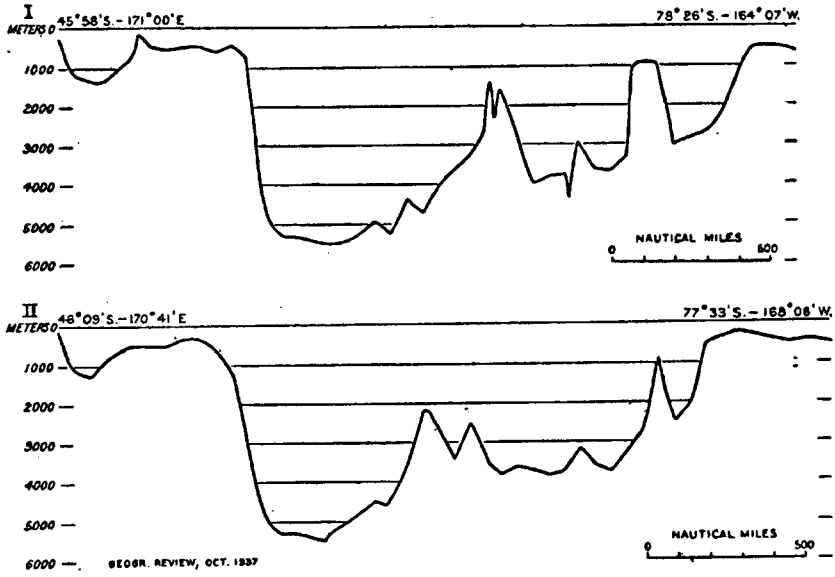

FIG. 3

Profiles I and II, New Zealand-Bay of Whales.

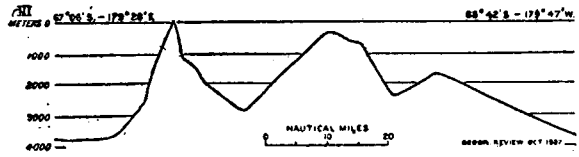

FIG. 4

Profile III, Scott Island, based on 35 *soundings.*

THE ISELIN AND PENNELL BANKS.

About 200 miles south of Scott Island the *Bear's* soundings disclosed a heretofore unknown ridge, at a minimum depth of 700 meters, separated by a deep gully from the Antarctic continental shelf (see Fig. 3), which here rises with a steep gradient from a depth of 2800 meters. The discovery of this ridge, which has been named the Iselin Bank after Mr. C. O'D. Iselin, 2nd of the Woods Hole Oceanographic Institution, is of interest in relation to the hypothesis of a structural connection between New Zealand

and West Antarctica, comparable to the Scotia Arc postulated as a link of the Antarctandes (1). The axis might run from the Alexandra Mountains by way of the Pennell Bank (2), the Iselin Bank, Scott Island, and Macquarie Island to the New Zealand shelf. There are deep water gaps between these links, as there are between links of the Scotia Arc, but this objection is not insuperable. However, many more soundings are needed before any definite conclusions can be drawn.

The Pennell Bank extends southeast and northwest across the Ross Sea. The suggestion of Griffith TAYLOR that the bank represents a vast terminal moraine (3), a remnant from the maximum glaciation, has been further strengthened by the results of the dredging carried out from the *Bear*. After all the hauls the dredges were recovered filled with rocky bits of glacial debris. They were chiefly acid igneous rocks, though there were occasional fragments of the more basic varieties; sedimentary rocks were represented by small quantities of green shale and friable sandstone. When the *Bear*

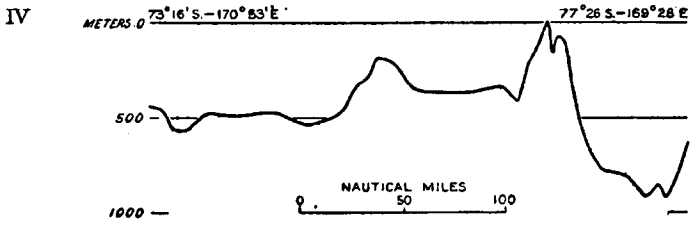

FIG. 5

Profile IV, Coulman Island to Ross Island, based on 57 soundings.

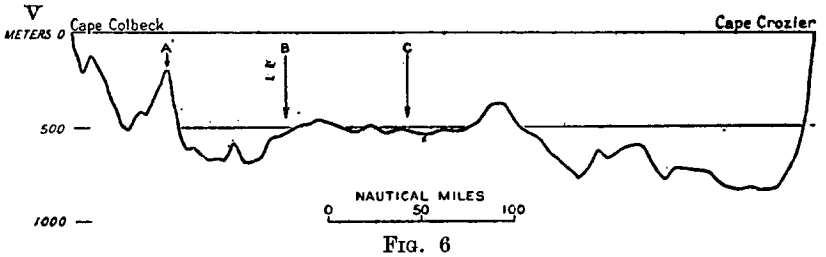

FIG. 6

Profile V, along the front of the Ross Shelf Ice, based on 151 *soundings.* A) *Eastern junction of the Shelf Ice*; B) *Bay of Whales*; C) *Discovery Inlet.*

was leaving the Ross Sea in 1935, a shallow with a minimum depth of 134 meters was observed on the Pennell Bank in 74° 11' S., 179°43' E. A bottom sampler was lowered at this point, where the bank tends to turn northward; however, the corer was recovered dented, an indication that it had struck a hard or rocky surface.

WESTERN SECTOR OF THE ROSS SEA AND THE SHELF ICE.

The profile reveals an irregular submarine topography in the western sector of the Ross Sea (Fig. 5). In the southwest is a depression bordered on the north by the Pennell Bank and interrupted by Franklin Island, a small volcanic island. Although separated from them by a gully with a depth of 900 meters, this island is structurally related to Ross Island, to the south, and Coulman Island, to the north.

Figure 6 is a profile parallel to the face of the Ross Shelf Ice from Cape Crozier, on Ross Island, to Cape Colbeck, King Edward VII Land. The slopes of Ross Island recede steeply to 850 meters; and for a distance of 150 miles eastward the bottom remains at a depth of about 600 to 750 meters — an indication that the depression continues under the shelf ice. Farther to the east the bottom rises markedly to the

(1) For a discussion of the problem of the Scotia Arc see H. F. P. HERDMAN: "Report on Soundings Taken during the Discovery Investigations, 1926-1932, *Discovery Reports*, issued by the Discovery Committee, Colonial Office, London, Vol. 6, pp. 205-236, Cambridge, 1932.

(2) An alternative course would be from the Pennell Bank via the Balleny Islands.

(3) Griffith TAYLOR: "Antarctic Adventure and Research", New York and London, 1930, p. 160.

lowest recorded depth of 352 meters. The profile shows another drop, to about 700 meters, at the Bay of Whales (Fig. 6), where an arm of deeper water penetrates into the Pennell Bank.

The probability that the Ross Shelf Ice is resting on the bottom at any point along its front seems remote, though evidence seems to indicate that it does so farther south (1).

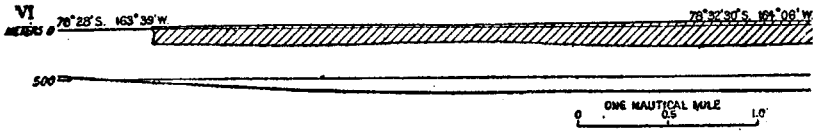

FIG. 7

Profile VI, the floor of the Bay of Whales showing the extension of the shelf ice in relation to the bottom as observed January, 1935. Vertical and horizontal scales equal.

The minimum depth of 352 meters, shown in Figure 6, was obtained at a point (78°19' S., 172°56' W.) where the altitude of the barrier above the sea level was about 80 feet, and this would seem, by reason of the buoyancy of the ice alone, to indicate that the edge is afloat. The floor of the Bay of Whales and its relation to the ice as observed January, 1935, are shown in Figure 7. A wire sounding taken while the ship was moored to the barrier on the east side of Eleanor Bolling Bight gave a depth of 642 meters, and one taken three miles farther south while the ship was moored to the bay ice gave a depth of 644 meters. In neither case was there any wire angle noted. A depth of 480 meters was recorded half a mile off West Cape and also at the eastern extremity of the bay, and a depth of 492 meters half a mile off the eastern extremity. Should any point of the shelf ice be grounded in this region, it must be on a pinnacle, or pinnacles, rising steeply from the gentle southward slope. In the region just north of the Bay of Whales the bottom rises to a minimum depth of 179 meters.

NORTHEASTERN SECTOR OF THE ROSS SEA.

In 1934 the northeastern sector of the Ross Sea remained a virgin field as regards submarine topography. Soundings on a line from the Bay of Whales to Cape Colbeck and beyond (Fig. 8) were begun as soon as the eastern extremity of the bay was cleared. There is no distinguishing mark or point that can properly be called the east cape. The barrier here curves eastward in a wide sweep, and the extremity of the bay was judged by the visibility of the bay ice and the bearing of the west cape. After the ship had crossed the deep tongue penetrating into the Pennell Bank toward Cape Colbeck, the bottom began to rise gently. It culminated in a ridge at a minimum depth of 89 meters (76°51' S., 157°15' W.), on which were a great number of stranded icebergs. Through their general direction the ridge could be traced, trending in a northwesterly direction, seemingly as if the Alexandra Mountains were continued beneath the surface of the sea. From this narrow beginning the bank broadens as it continues across the Ross Sea.

The isobaths east of Cape Colbeck have heretofore been drawn on the assumption that here is a broad continental shelf. However, when the spur off Cape Colbeck had been passed, it was found that the bottom at once receded to 3500 meters, then remained level at 3800 meters for the distance traversed by the *Bear*. While on this section, the ship was forced to alter her course to the north after reaching the farthest east in 75°6' S., 148°8' W. However, the soundings were continued while the ship was navigating in or skirting the pack ice. The whaling factory ship *Thorshavn* reached a position of 71°44' S., 134°11' W. on February 10, 1934, and reported a depth of 3722 meters (2). From this position a flight was made to 72°8' S; from which was obtained "a clear sight of the ice barrier about 35 miles south". This would support the belief that the lands in the wide unknown expanse to the south consist of islands locked in an ice-shelf formation similar to the Ross Shelf Ice. In conjunction with the westerly current this also explains the presence off Cape Colbeck of the great number of huge tabular and peculiarly dome-shaped icebergs grounded there.

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(1) L. M. GOULD: "The Ross Shelf Ice", Bull. Geol. Soc. of America, Vol. 46 (Part 2) 1935, pp. 1367-1393.

(2) This is the corrected depth (2204 fathoms) in "List of Oceanic Depths", 1936, Publ. H. D. 327, Hydrographic Department, Admiralty, London, 1937; see p. 18.

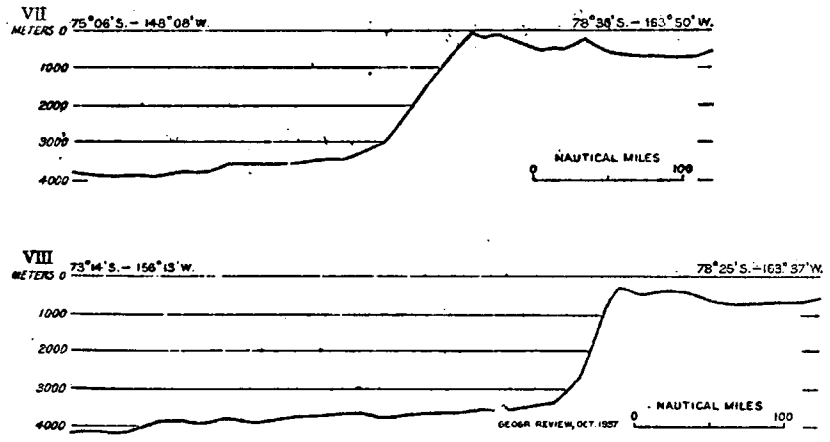

FIG. 8—Profiles VII and VIII, northeastern sector of the Ross Sea.

These observations remove any doubt that the continental land east of the Ross Sea extends conspicuously northward. The southern limit of the Pacific Antarctic Basin is brought farther to the south and can be separated from the coast by only a narrow strip of continental, or perhaps insular, shelf.

The *Bear* reached her farthest north in 73°14' S., 156°13' W, and the course was altered to return to the Bay of Whales. Profile VIII (Fig. 8) shows the gentle southward rise of the Pacific Antarctic Basin and the steep, almost precipitous slope to the Pennell

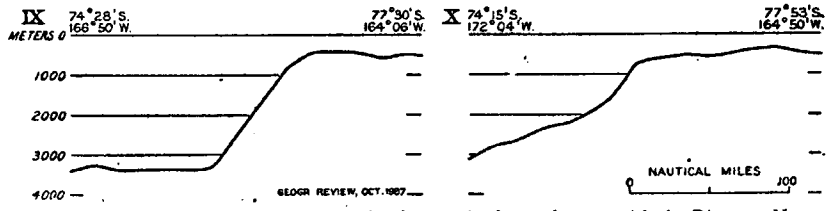

FIG. 9—Profiles IX and X, in the Ross Sea from cruise for rendezvous with the *Discovery II*.

Bank and the Antarctic shelf. Because of the uniformity of the deeps in the eastern sector of the Ross Sea — which contrasts with the irregularities of the western sector — curiosity was aroused concerning a shallow of 117 meters in 74°45' S., 164°18' W. shown on the international bathymetric charts. A line of soundings run parallel to the 165th meridian west (Fig. 9) while the *Bear* was en route to a rendezvous with the R.R.S. *Discovery II* revealed depths between 3382 and 3660 meters in these waters (1).

The floor of this section, bordered on the south by the narrow continental shelf and the Pennell Bank and on the north by a continuation of the great Easter Rise, is a depression. Yet it is not impossible that rocky islands exist therein. Submarine and subaerial volcanic activity is known, and precipitously rising cliffs are not uncommon. One need mention only Scott Island, to the west, and Peter I Island, to the east, as examples.

APPENDIX I — EQUIPMENT AND METHODS.

The *Bear* was equipped with a fathometer, of unlimited depth range, manufactured by the Submarine Signal Company of Boston, Mass., before our departure. On a ship of such unusually heavy construction as the *Bear*, an old icebreaker, the installation of the hydrophone and oscillator must differ considerably from the installation on the usual steel ship. The hydrophone tank, containing a deep hydrophone, Type 341 *A*, was

(1) Subsequent communication with the International Hydrographic Bureau, Monaco, in regard to this revealed that the shoal shown on the chart and also a number of other soundings south of this were plotted on the second edition (1912-1925) of the "Carte Générale Bathymétrique des Océans", Sheet C'II, in West longitudes, whereas the longitudes should have been east. These soundings should, therefore, appear on Sheet C'III. They will thus be found located close to the coast of South Victoria Land. The longitudes are correctly given in Part 3 (1914) of the publication "Carte Générale Bathymétrique des Océans", p. 218, and in the "List of Oceanic Depths", 1911, published by the Hydrographic Department of the Admiralty, London, 1912, p. 23.

placed in the starboard garboards 3 feet from the keel, where a hole with a diameter of 8 inches had been cut through the planking. The tank was fitted and bolted to the hull so that a part of it protruded 8 inches outside. Around this protruding part was constructed a wooden fore-and-aft fairwater so as to eliminate as much as possible the noises created by the ship's headway. The oscillator, deep Type 324 ("pancake" type), located 12 meters aft of the hydrophone, was set in a heavy steel casting bolted through the hull. Here also wooden fairwaters were constructed. Both instruments were so placed that they would be clear of any ice that might wash downward. To prevent freezing, the hydrophone tank was filled with a solution of equal parts of sea water and an antifreeze mixture.

The sounding unit, operating on a frequency of 525 cycles, was controlled in the laboratory, located below deck off the wardroom aft. The equipment installed did not include an indicator, or automatic timing device, which is usually a part of the fathometer. The outgoing signal was controlled by a key, and the returning echo was received in earphones, the volume being adjusted by an amplifier. The timing was done with delicate, 1/100-second Longines stop watches.

A table converting the time elapsed into depths in meters was constructed based on a sounding velocity of 1500 meters a second (820 fathoms). The stop watches were checked from time to time against the ship's chronometers, but no errors were detected. Steps were taken to guard against error. An average of three series of three soundings each was usually accepted as the depth to be recorded. Allowance was made for personal error, ascertained by a constant checking against known depths. On the voyage from Norfolk, Va., to Panama ample opportunity was offered to compare the recorded depths with known depths in well surveyed waters.

A puzzling feature was an inexplicable sudden weakening of the echoes. SOULE and ENNIS wrote concerning their observations on board the *Carnegie* (1):- "The weakness of the returning echo was a puzzling element which sometimes made sounding difficult — puzzling in its seeming independence of slope, type of bottom, or depth".

The phenomenon was particularly noted in the little-surveyed area of the sub-Antarctic waters between the New Zealand insular slope and Scott Island (67°24' S., 179°55' W.). The condition of the bottom may have had something to do with this: it is generally believed that a soft bottom has a tendency to return a weak echo. Another explanation may be that, when the rolling of the ship produces an excessive angle between the ocean floor and the face of the hydrophone tank, the incoming echo perhaps is less audible.

For correcting the soundings the British Admiralty tables (2) were used. The tables had to be extended by extrapolation for the deeper waters in their regions 13, 16 and 20. The boundary between regions 20 and 23 along the lines southward from New Zealand could be determined on the basis of surface temperature readings made from the *Bear*. As an average value for draft, 5 meters has been added to each sounding.

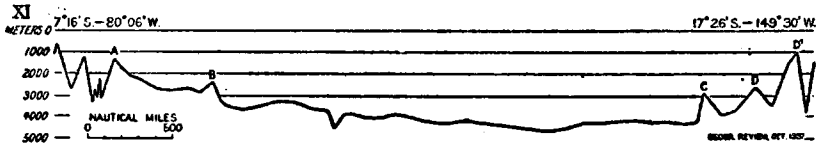

FIG. 10

Profile XI, Punta Mala, Panama, to Tahiti, Society Islands. A) *Cocos Island shelf*; B) *Galapagos Island shelf*; C) *Indications of Marquesas shelf*; D-D') *Tuamotu shelf.*

APPENDIX II — THE TRANS-PACIFIC PROFILES.

For completion of the record the trans-Pacific profiles obtained by the *Bear* are given here without discussion.

Profile XI (Fig. 10) was begun off Punta Mala, Panama, and concluded off Tahiti, Society Islands. This fairly well known sector had previously been surveyed by echo-sounding lines from several vessels, notably the *Ara* and the *Carnegie*, Cruise VII.

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(1) F. M. SOULE and C. C. ENNIS: "Sonic Depth-Finding on the Carnegie, Cruise VII", Trans. Amer. Geophys. Union, Tenth, Ann. Meeting, April 25 and 26, 1929, Eleventh Ann. Meeting May 1 and 2, 1930, Washington, 1930, pp. 264-274; reference on p. 269.

(2) Tables of the Velocity of Sound in Pure Water and Sea Water for use in Echo-Sounding and Sound-Ranging, H. D. 282, Hydrographic Dept., Admiralty, London, 1927.

Profile XII (Fig. 11) was run over a part of the deepest region of the South Pacific. The soundings that have been taken in this region, chiefly those of the *Challenger*, are few and far between. Of outstanding interest is the discovery of the two pinnacles or ridges (*B* and *B'*), in the so-called Aldrich Deep. The deepest readings shown in the profile are identified as the south end of the Kermadec Deep, which, apparently, curves toward the southeast in this sector.

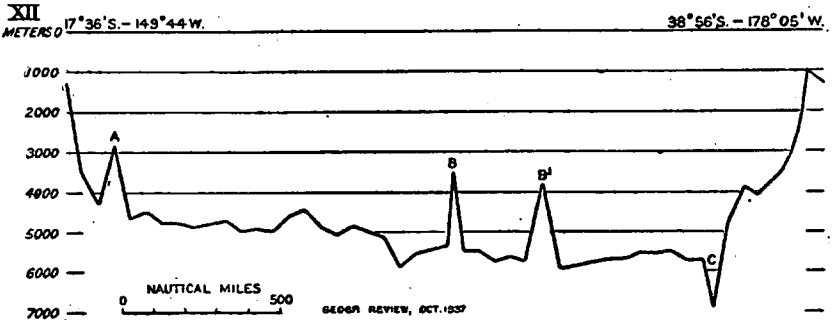

FIG. 11

Profile XII, Tahiti, Society Islands, to New Zealand. A) *Cook-Austral ridge*; B-B') *Pinnacles or ridges in the so-called Aldrich Deep*; C) *Kermadec Deep.*

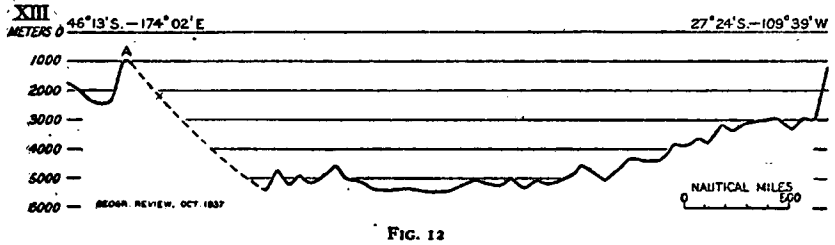

FIG. 12

Profile XIII, New Zealand to Easter Island. A) *Bounty-Antipodes ridge. Dotted line indicates lack of soundings.*

Profile XIII (Fig. 12), New Zealand to Easter Island, crosses a region that has hitherto been a part of the greatest unknown area of the Pacific Ocean. Our previous knowledge of the submarine topography of this region was based chiefly on the line of soundings along the 50th parallel carried out by the U.S.S. *Enterprise* during a trans-Pacific crossing in 1884. As will be noted by comparing this profile with that of Figure 11, the South Pacific Basin deepens considerably to the south before reaching its southern border, the Easter Rise.