BATHYMETRIC DATA FROM THE SEARCH FOR USS " THRESHER " (*)

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The United States nuclear submarine *Thresher*, SSN 593, was last heard from in the course of test dive at about 0915 in the morning on 10 April 1963. During the two weeks following the loss of *Thresher*, more than 23 ships made various, and often somewhat unrelatable, observations in the area. By 24 April, the U. S. Navy Oceanographic Office Thresher Analyses Group was established at Woods Hole, Massachusetts, and careful analyses of all information relating to the last known position of *Thresher* was made. It was decided that the search should be centered at a position 41°45′ N and 65°00′ W. Four ships were assigned to make a high precision systematic echo sounding survey of a ten mile square area centered on this position. The vessels employed were USNS *Mission Capistrano*, an ex-T-2 tanker, USS *Allegheny*, a small seagoing tug, USS *Rockville*, a converted patrol craft, and USS *Prevail*, a converted minesweeper. All ships were equipped with Edo AN/UQN1 or T.H. Gift & Associates, Inc., echo sounders, and at least two PDR's (Precision Depth Recorders) or PGR's (Precision Graphic Recorders). Electronic navigation equipment for the survey was provided each ship for reception of the best available navigation systems, Loran C and Decca. Figure 1 shows the approximate relationship of the

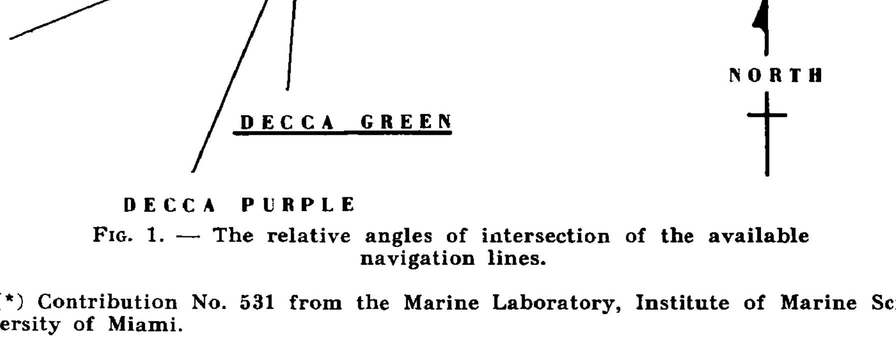

Fig. 1. — The relative angles of intersection of the available navigation lines.

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four available navigation lines in the area. SO-Y and Decca Green were preferred for quality of reception and angle of intersection. Plotting was done simultaneously with ship operations on a scale of 3″ to the mile. The survey was conducted principally between 5 and 16 May, 1963. Figure 2 shows the locations of the survey lines that were obtained. The majority of the line spacing is about 250 yards. This is doubtless one of the most precise and detailed bottom surveys of the sea floor beyond the continental shelf that has become available. In that the immediate objective of the

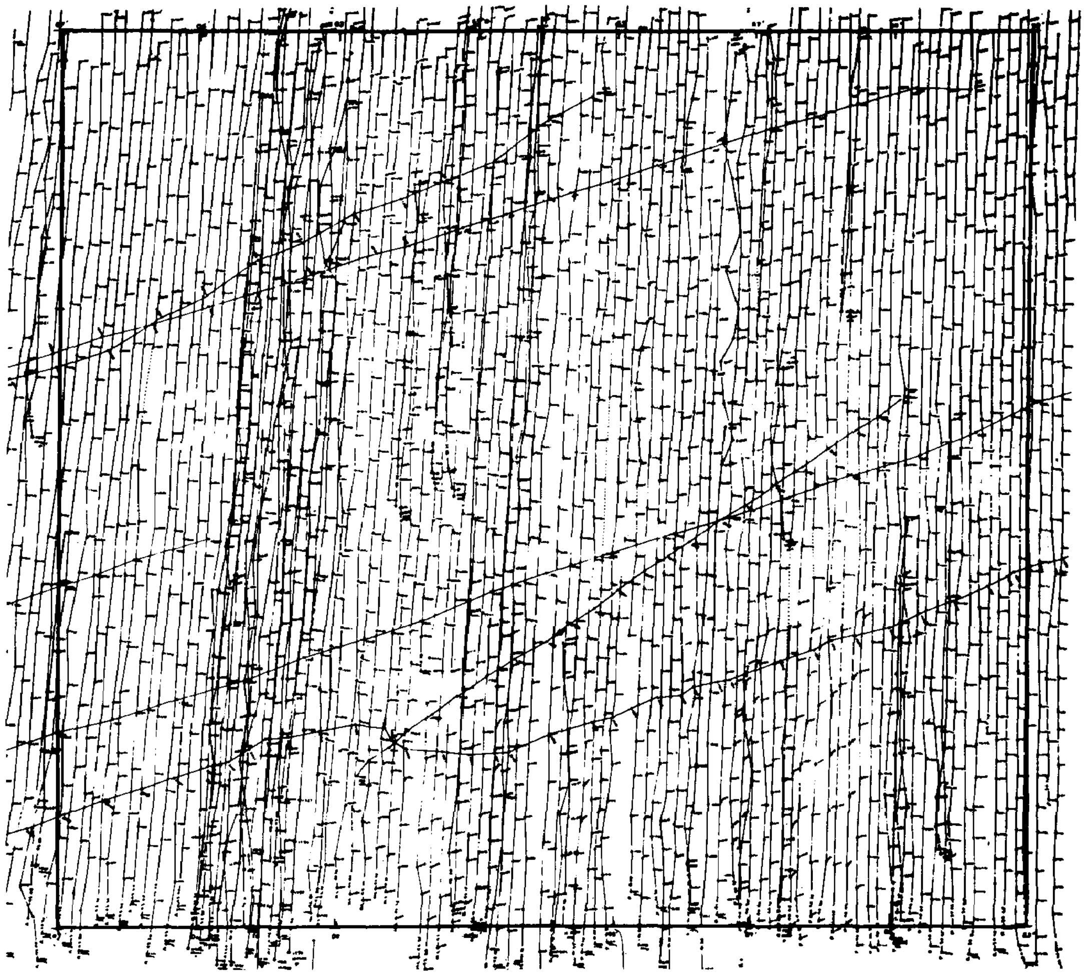

FIG. 2. — Tracks of the survey lines.
The heavy boundary lines are 10 miles long.

effort was to find the hull of *Thresher*, the records obtained were first examined primarily for small features of roughly appropriate size. Depending upon the examiner, a wide variety of possible points could be selected. In fact, at one time, several hundreds of points were regarded as possible. In order to establish one form of priority, early efforts were directed towards understanding the general geography, to establish, if possible, many of the points under consideration as being more likely topographic features than *Thresher*.

While the principles of interpreting such sounding profiles of the sea floor have long been established and discussed (HOFFMAN, 1957, KRAUSE, 1962) dealing with such an abundance of rather precisely controlled data has rarely been the problem. In addition, despite the efforts for precision, a variety of errors remained. Table 1 is an abbreviated list of some of the errors. The first two are comparatively obvious, only the latter two will be discussed briefly.

The AN/UQN echo sounder is a wide beam device. It has a total beam width of some 40° (Anonymous, 1951). As a consequence, the echoes recorded may be coming from a large area of sea floor. In fact, the circular area illuminated with sound is of the order of 3/4 the depth of water, in diameter. Considering now only irregularities in the vertical plane of the ship's track for simplicity, the echo from a feature ahead of the ship arrives relatively late because of the increased slant range (Figure 3). As

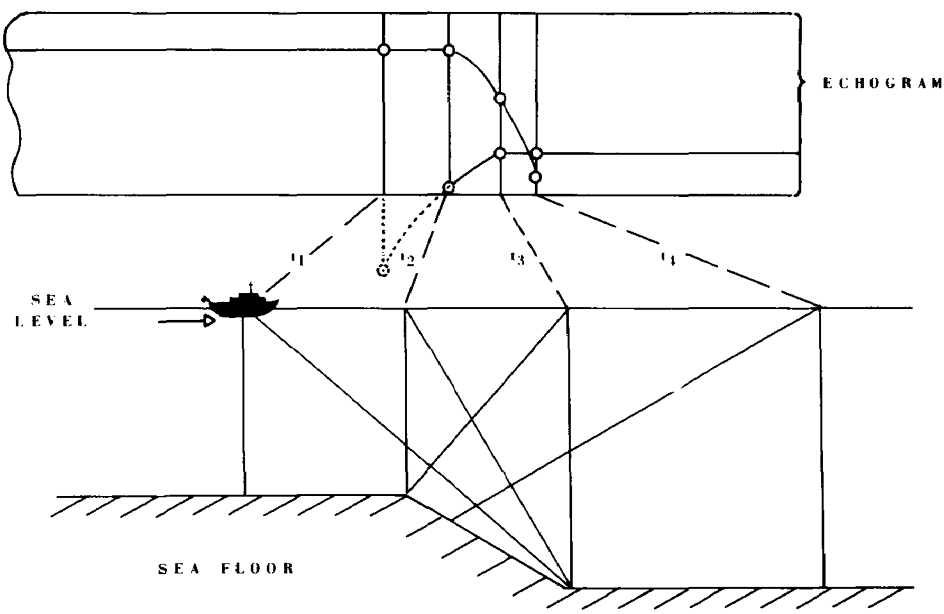

FIG. 3. — Schematic diagram showing the relationship of the seafloor profile and the resulting echogram.
The vertical scale of the profile is greatly compressed.

the ship crosses over the feature a minimum depth is recorded, followed by an apparent increase in depth. This apparent decrease then increase of depth describes a hyperbola, or a so-called side echo. Figure 4 shows qualitative comparisons of sea floor profile, and the resulting echogram. Note particularly the sketch labeled " 3 " in Figure 4, as this is a feature of some importance in the *Thresher* area. In Figure 5, are diagrammatic representations of three adjacent echograms very similar to several from the *Thresher* area. The tick marks on the upper profile might represent the places where depth readings are made at say, 6-minute intervals.

A reading would also be made at the deepest place in the valley at the left as shown by the arrow. Ordinarily, the second or deeper echo would be ignored, attributing it to a reflector off to one or the other side of the ship's track as are frequently seen. However, here, having well located and closely spaced profiles, minimum depths were read on these later arrivals and it was found that they indicated an evenly descending valley floor. Remembering that the maximum depth read on the first arrival, as indicated

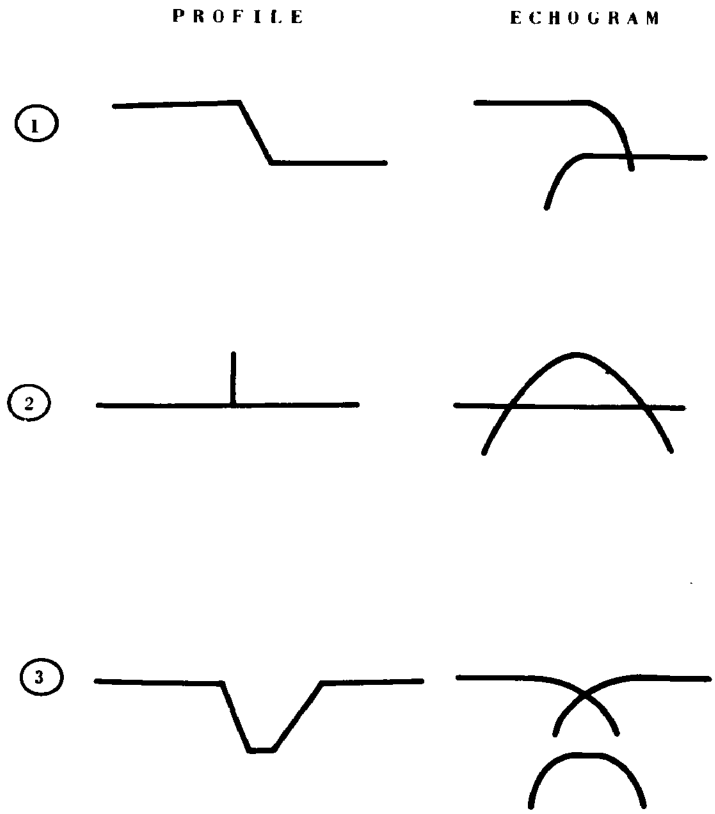

FIG. 4. — Qualitative comparison of profiles of seafloor profile and the echograms.

in the upper profile in Figure 5 by the arrow, is greatly dependent, among other things, on the width of the top of the valley; it is easy to see how a valley might easily be contoured as an irregular area of basin depressions looking perhaps almost like Karst topography. Figures 6 and 7 are examples of this problem. In Figure 6 is shown a small region in the south-western part of the search area. These are very carefully drawn contours based on depths read at the first arrival. It is a peculiar topography and difficult to relate to any sedimentological or geological process that might be expected here. Also notice the corrugations indicated near the western edge of the area. In Figure 7 is shown contours of the same area using valley bottom depths read as indicated above, and ignoring the hyperbolic side echoes from the valley edges. This chart indicates a somewhat sinuous, steep-sided channel, with pronounced levees, that becomes deeper to the south and east.

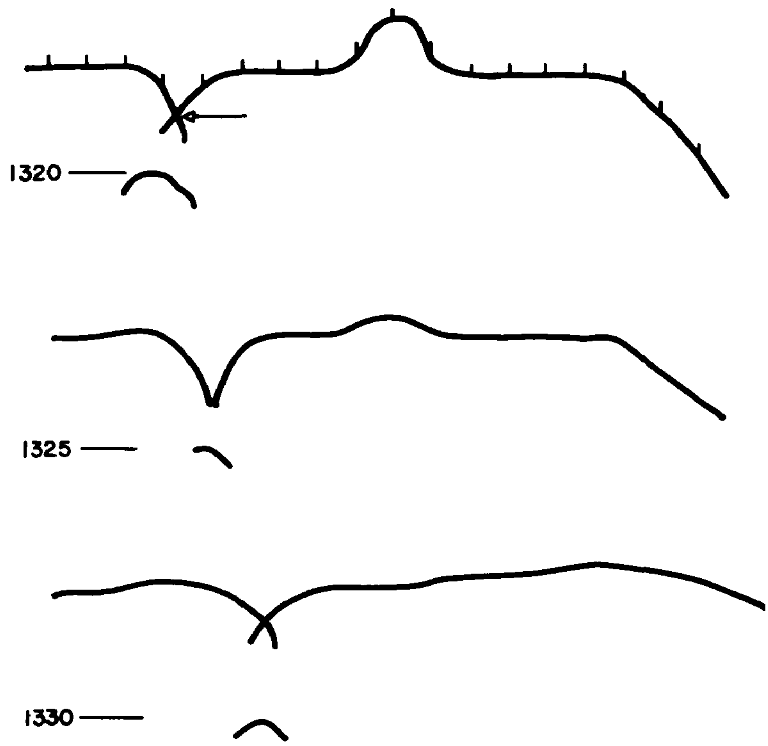

Fig. 5. — Diagrammatic representations of three adjacent echograms.

The washboard corrugations on the left side of the Figure 6 are absent in Figure 7. These corrugations are the consequence of another error, a navigation error. At first glance, these ripples are suspicious in that they are parallel to the sounding lines, and further in that they have a wave length about equal to the line spacing. In that most lines were run in alternate directions, a simple time delay in reading depth or position would produce such corrugations. However, in carefully examining the directions of the lines, it seems that the depths are recorded 0.1 to 0.3 miles too early rather than too late. The cause of these errors is unknown but may be related to difficulties in certain of the navigation equipment, particularly the *Loran C* in that it was used to obtain cross fixes as the ships steamed along Decca lines. Confirmation that the sea floor has no such corrugations is obtained from examining the cross lines. It was concluded that the best results can be obtained from smooth contours drawn through the averaged locations of the depth of adjacent lines. A variety of other navigation errors, many more subtle and more difficult to understand and resolve, occurred and were treated similarly to those discussed, by comparison of side echoes or adjacent lines and checking the apparent topography with the cross lines. After all of this, the resulting chart is probably precise to no better than 1/4 mile and certain local areas are doubtless considerably worse. This is not really very precise, being at least 2 or 3 orders of magnitude worse than a routine air photo survey on land.

The region of *Thresher's* loss is on the continental slope and continental rise at depths between 1 100 and 1 400 fathoms. In fact, the area

Fathoms

FIG. 6. — Contours based on first arrival sounding echoes and without any navigation corrections.

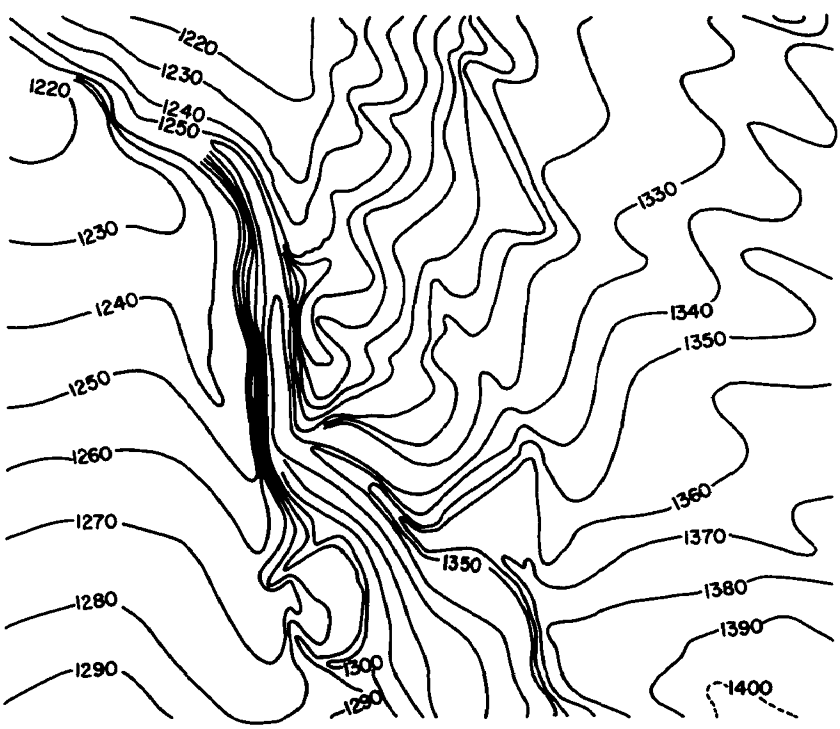

FIG. 7. — Same area as Fig. 6, contoured using corrected navigation and interpreted depths.

straddles the boundary between continental slope and continental rise, defined by HEEZEN et al. (1959, p. 19 et seq.) as a slope of 1 in 40 (25 parts per thousand or about 25 fms. per nautical mile). Average slopes are mostly greater than this in the west and less in the eastern part of the *Thresher* area.

If we now consider the current hypothesis on the nature of the continental slope and rise in the light of this recently obtained detailed topographic information, it is possible to make a test of this hypothesis.

The continental slope is the structural boundary of the continents. It is a comparatively steep slope and it is very frequently cut by submarine canyons. These canyons have been shown, particularly on the Pacific Coast

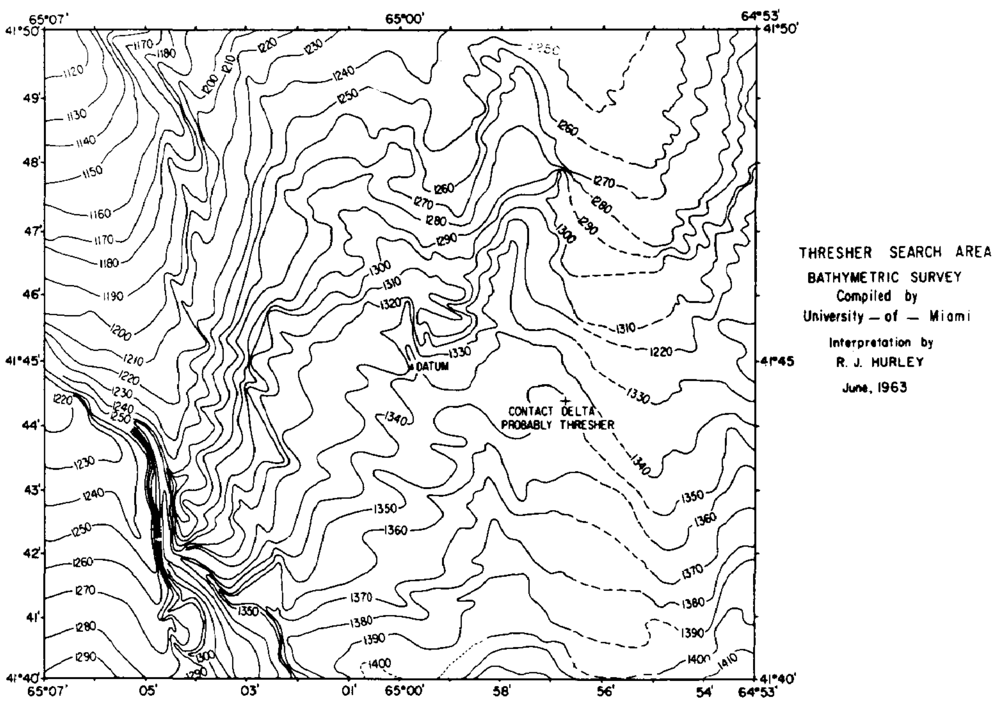

FIG. 8. — Final contours of *Thresher* search area based on precision survey.

often to be associated with deep-sea fans (MENARD, 1955, HURLEY, 1959). There is abundant evidence that many continental slopes, particularly in their upper parts, are of rock covered by very little or no sediment (SHEPARD, 1948).

The more gently sloping continental rise, has, off our east coast, been described by HEEZEN et al. (*ibid.*, p. 53) as being underlain by " truly geosynclinal thickness of sediment ". We may then visualize the continental rise as a wedge or apron of largely, continent-derived sediment accumulated at the foot of a steeper, and largely rock supported continental slope. It is probable that the succession of adjacent and locally coalescing fans that have been described in the Northeast Pacific (HURLEY, 1959), are a younger stage of the development of a continental rise. With further growth, the pronounced effect of individual canyons as sediment sources will be largely masked by the lateral migration of the lower canyons or channels and by the accumulation of sediment not transported in these large canyons. The result will be an even apron of sediment as found here in the Northwest Atlantic. The topography in the region of the upper rise will probably resemble somewhat that found on subaerial fans, perhaps having valleys or gullies and lacking undrained depressions. Figure 8 shows the resulting chart of the *Thresher* area. In general, it is of better quality in the western two-thirds than near the eastern edge. This area is ten nautical miles on a side and is centered at the estimated loss position of *Thresher.* Point Delta, a contact picked early in the search by Woods Hole Oceanographic Institution scientist in *Atlantis II,* and still at this time a very possible location of *Thresher,* is also shown. Incidently, if *Thresher* is in the vicinity

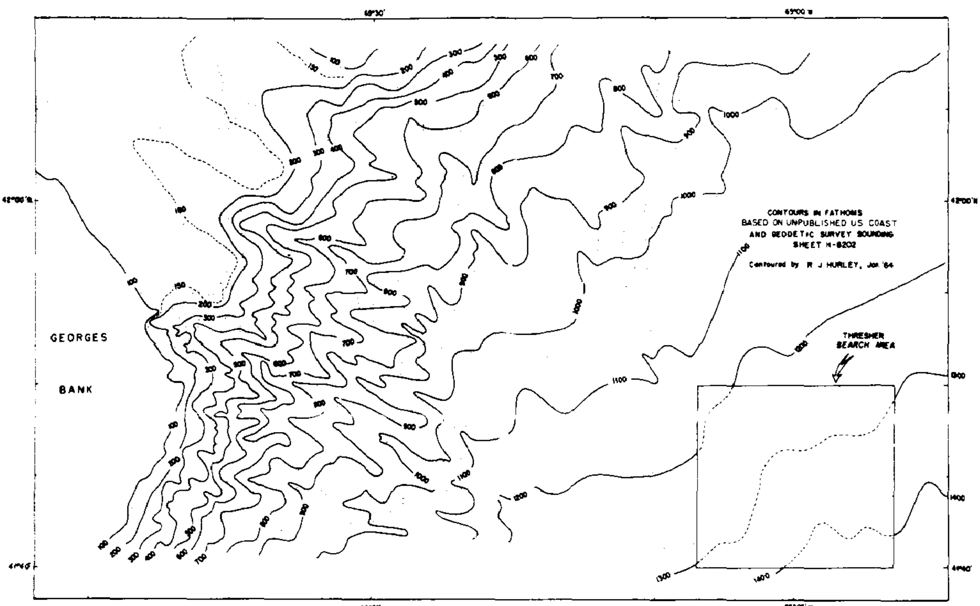

FIG. 9. — Chart showing topography in the vicinity of the *Thresher* search area and the adjacent continental shelf edge.

of point Delta, the submarine certainly landed in a fortunate location. There are many places, particularly in the channel a few miles to the west, where several hundred ships could be put, with little likelihood of their ever being found by echo sounding techniques.

An examination of available information, primarily collections of unpublished soundings by the U.S. Coast & Geodetic Survey, indicates that many small canyons cut into the upper part of the nearby continental slope (Figure 9). In the western part of the *Thresher* area there is a narrow, steep-sided channel. It has, at least where surveyed, a graded axial slope. Doubtless this leveed channel is the seaward continuation of one or more of these canyons, however, there is far too little information to demonstrate the connection. There are a large number of small gullies in the *Thresher* search area that can only be suggested in the chart. This is because they have apparent relief of only a few fathoms and the position errors are frequently as large or larger than the gullies themselves. Also, of course, the side echo effects conceal the true shape of the features. As a consequence, all efforts to analyze these gullies in more detail are quite fruitless. The impression gained is, however, that the small scale drainage continues in smaller sizes to and probably beyond the limitations of the equipment.

Earlier versions of this chart have indicated a number of closed basin depressions. All were found to be explainable by applying the analysis techniques described earlier. While the actual occurrence of small basins is still possible, closures of more than 10 fathoms are extremely unlikely.

In summary, a survey of a ten mile square area of continental rise and slope was made using the best available techniques. These techniques of mapping in great detail even a small area of deep-sea floor are found to have considerable imperfections. The echograms have been analyzed to correct, insofar as possible, for these limitations, or at least to remove topographic artifacts produced by them. The resulting chart shows one large leveed channel and many smaller gullies. Basin depressions are, at most, only small and are probably absent. In general, the appearance of the sea floor in this area suggests a confirmation of the hypotheses that the continental rise is a wedge-shaped apron of continentally derived sediment at the foot of the continental slope.

Acknowledgement

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Table 1

Sounding errors

1) Recording timing errors :
   — at different occasions with same machine — minor
   — between different machines in the same or different ships — may be larger, but uncommon.
2) Errors in estimate of sound velocity :
   — all assumed to be 4 800 ft./sec.
   — areal and temporal variations in a small area, probably are quite small
   — not significant here in comparing topography
   — corrected depths were not generally required.
3) Geometric errors (as, side echo effects) :
   — cause considerable distortion of topographic features
   — quantitative correction not worthwhile with wide beam sounding equipment.
4) Navigation errors :
   — comparatively quite large and by far, the major problem.

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