

SEA FLOOR BATHYMETRY NEAR THE CLARION AND CLIPPERTON FRACTURE ZONES

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Abstract

Three areas of approximately 3 600 square miles each were selected for bathymetric exploration. Surveys were conducted in 1961 aboard USNS *Richfield* and USNS *Huntsville*. Two of the areas investigated were south of the Clarion Fracture Zone at 13°30' N, and 116°30' W, the third was south of the Clipperton Fracture Zone at 6°00' N and 119°00' W. A detailed survey of a small seamount was also made. Many small-scale features possibly related to the fracture zones were observed. A correlation may exist between topography and observed heat-flow values in these areas.

Introduction

During the summer of 1961 three areas were surveyed in the East-Central Pacific by personnel of the U.S. Naval Oceanographic Office and the Pacific Missile Range. The ships assigned for the surveys were the USNS *Richfield* and the USNS *Huntsville*. The survey of Area 1 was conducted by *Richfield* and the surveys of Areas 2 and 3 by *Huntsville* (fig. 1). Both ships were equipped with AN/UQN-1 echo-sounding sets and Mark V Times Facsimile Precision Depth Recorders (PDR) (LUSKIN *et al.*, 1951, and LUSKIN and ISRAEL, 1956). In addition to standard navigational instruments, each ship was equipped with an electronic underwater log for speed determination which was carefully calibrated prior to departure for the survey areas.

Navigation was accomplished by conventional celestial methods and dead-reckoning techniques. All positions and sounding lines were corrected to the best navigational fixes obtained. Estimated fix accuracy is considered to be not greater than ± 3 nautical miles. Sounding lines which did not meet accepted standards of navigational accuracy were rejected (Hydrographic Office, 1961).

Selected bottom profiles from the three survey areas have been prepared and represent the dominant features of the ocean-floor relief. Area 3 has been contoured and a bathymetric chart of a small seamount investigated separately is also presented.

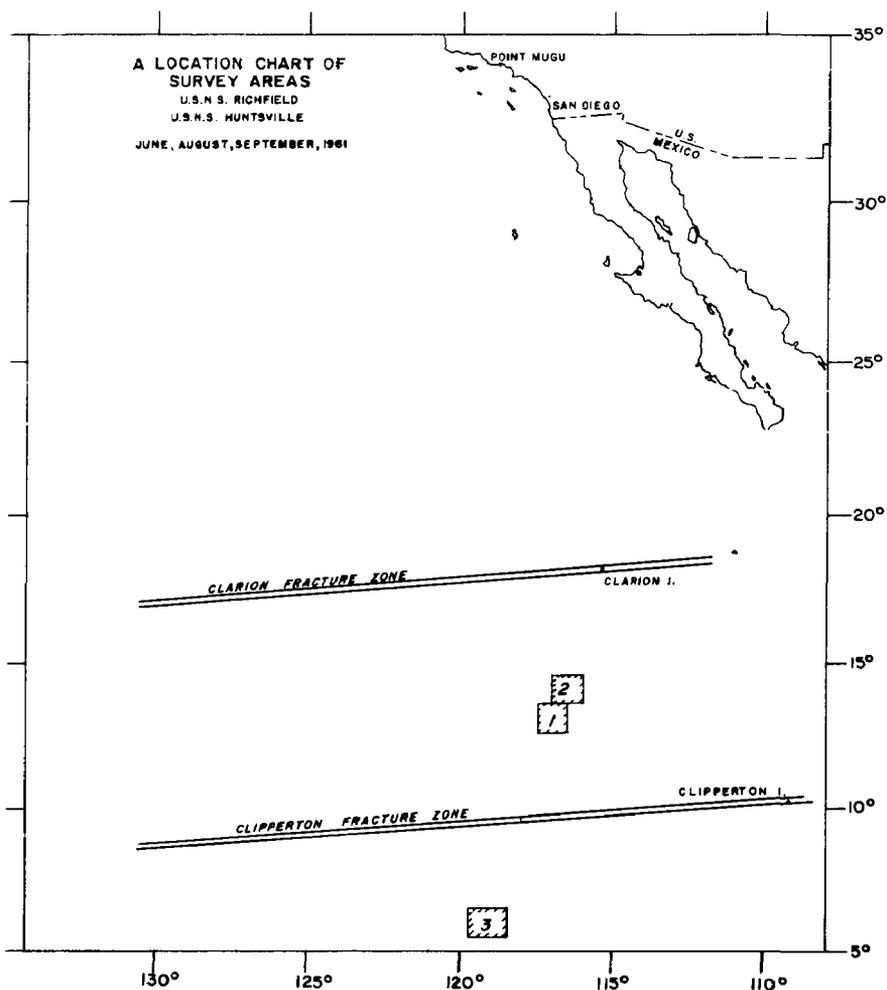


FIG. 1. — Location chart of survey areas.

Area 1

Area 1 was surveyed by USNS *Richfield* during 4-12 June 1961. It was traversed by 14 North-South lines and 13 East-West lines (figure 2). Weather conditions were such that celestial observations were not deemed accurate enough for contouring (BUELL, 1961).

Five East-West profiles were constructed from PDR records and are considered representative of the ocean-floor terrain in this area (figure 3). The dominant features are small seamounts and/or abyssal hills. Since the dividing line between seamounts and abyssal hills is arbitrary, two kinds of features may exist, features of different size but of the same origin (MENARD, 1959a).

The seamount on profile D-D' rises 500 fathoms (914 m) above the

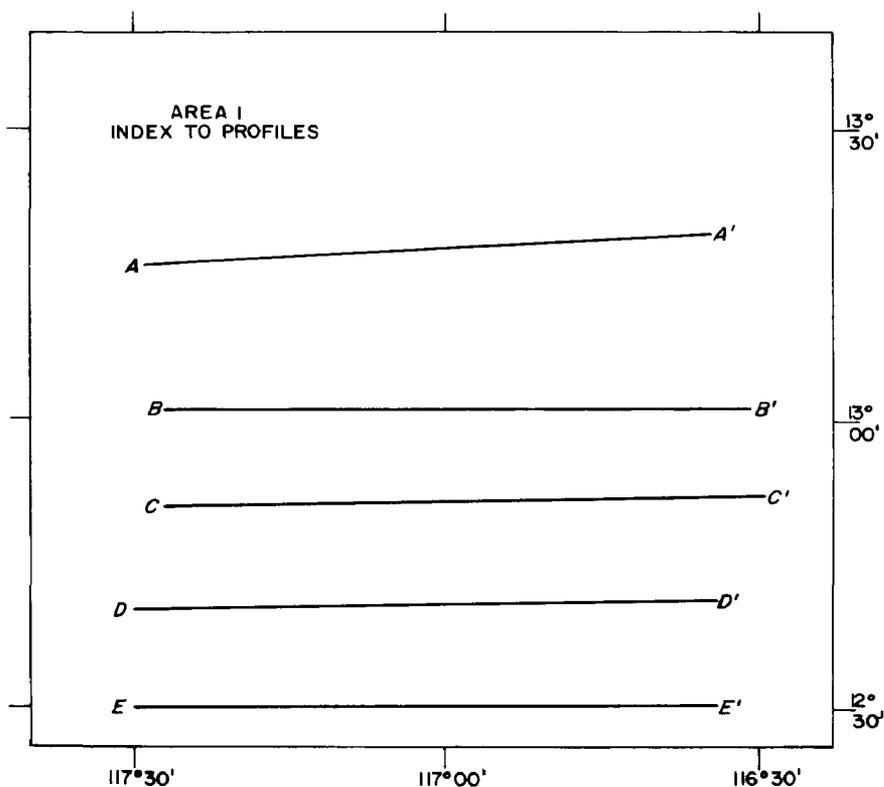


FIG. 2. — Index to profiles of survey area 1. (See figure 3).

surrounding terrain. Examination of the PDR record at this point indicates that reflections from this seamount are made up of numerous small hyperbolae and the maximum elevation above the seafloor may be greater than the 500 fathoms (914 m) indicated. In general the relief is typical of abyssal hill regions, the individual hills having steep side slopes and gently sloping tops (MENARD, 1964).

Area 2

Area 2 was surveyed by USNS *Huntsville* during 1-5 September, 1961. A total of 10 survey lines spaced about 10 nautical miles apart were made over this area (figure 4).

The bottom topography of Area 2 differs markedly from that found in Area 1 as can be seen from the selected profiles (figure 5). The most significant feature in Area 2 is the 150 fathom (274 m) escarpment on profile F-F'. Since this feature does not appear on profile C-C' it must be of small dimensions. A wide, shallow trench or trough with a maximum depth of about 100 fathoms (182 m) can be seen on profiles D-D' and E-E'. The wide depression on profile G-G' may also be a crossing of this trough, but at a shallow angle.

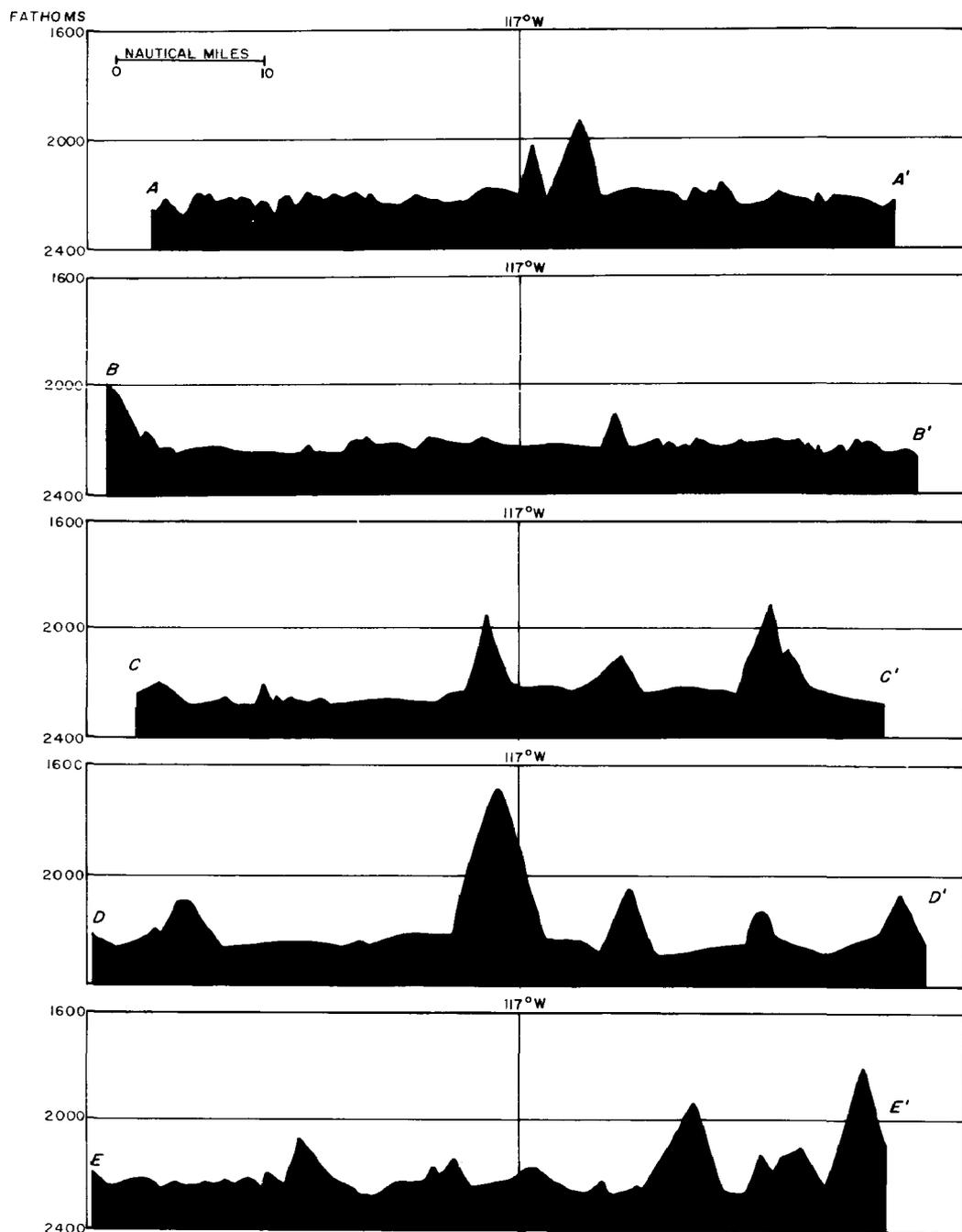


FIG. 3. — Area 1 profiles centred on 117° W longitude.
Vertical exaggeration 20 ×. (See figure 2 for index to profiles).

Both Areas 1 and 2 lie approximately midway between the Clarion and Clipperton Fracture Zones. Comparison of East-West profiles in both areas indicates a regional depth of about 2 200 fathoms (4 024 m), although Area 1

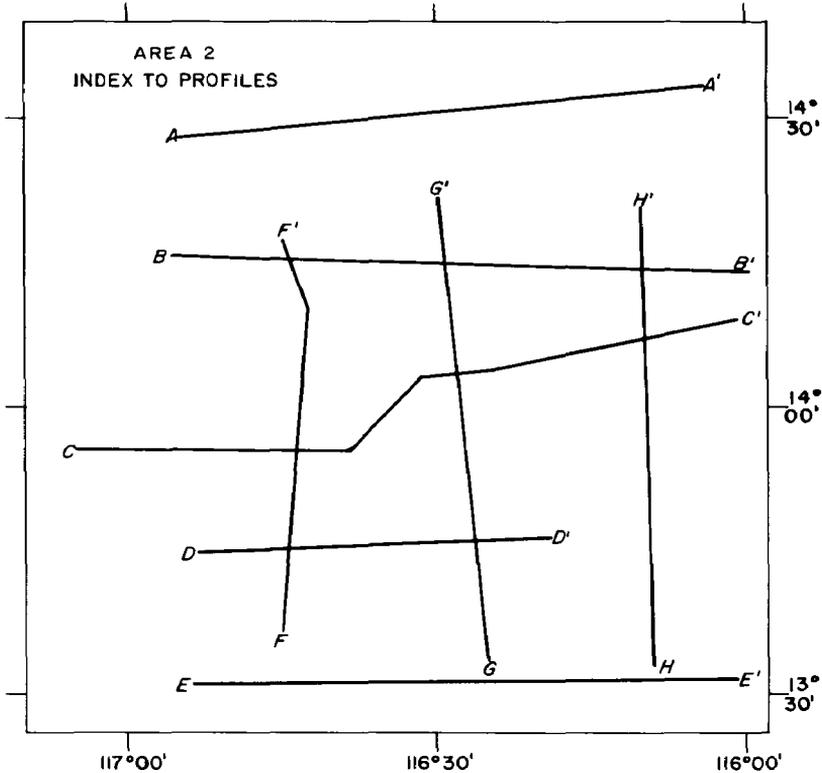


FIG. 4. — Index to profiles of survey area 2. (See figure 5).

is slightly deeper regionally. The apparent trend of the abyssal hills in Area 1 is northwesterly, as are the trough patterns of Area 2. This pinnate pattern of these minor lineations, if they in fact extend further to the northwest, would indicate a relation to the Clarion Fracture Zone rather than the Clipperton Fracture Zone (MENARD, 1959b). The topography of both areas confirms the similarity of the crustal block between the two fracture zones as being part of the same geologic province (MENARD, 1955).

Area 3

Area 3 was surveyed by USNS *Huntsville* during 23-30 August, 1961. The area was traversed by 11 North-South lines and 2 East-West lines (figure 6). Weather conditions were fair during the survey period. An adequate number of celestial observations were obtained to position the survey lines within ± 1 to 3 nautical miles. To develop contours for the chart (figure 9), depths were read to the nearest fathom directly from the PDR record every 20 fathoms, at all intermediate high and low points, and at each major change in slope. Sounding plots and contour overlays were constructed on a stable, non-dimensional translucent plastic with no adjustments made for either slope or sound velocity.

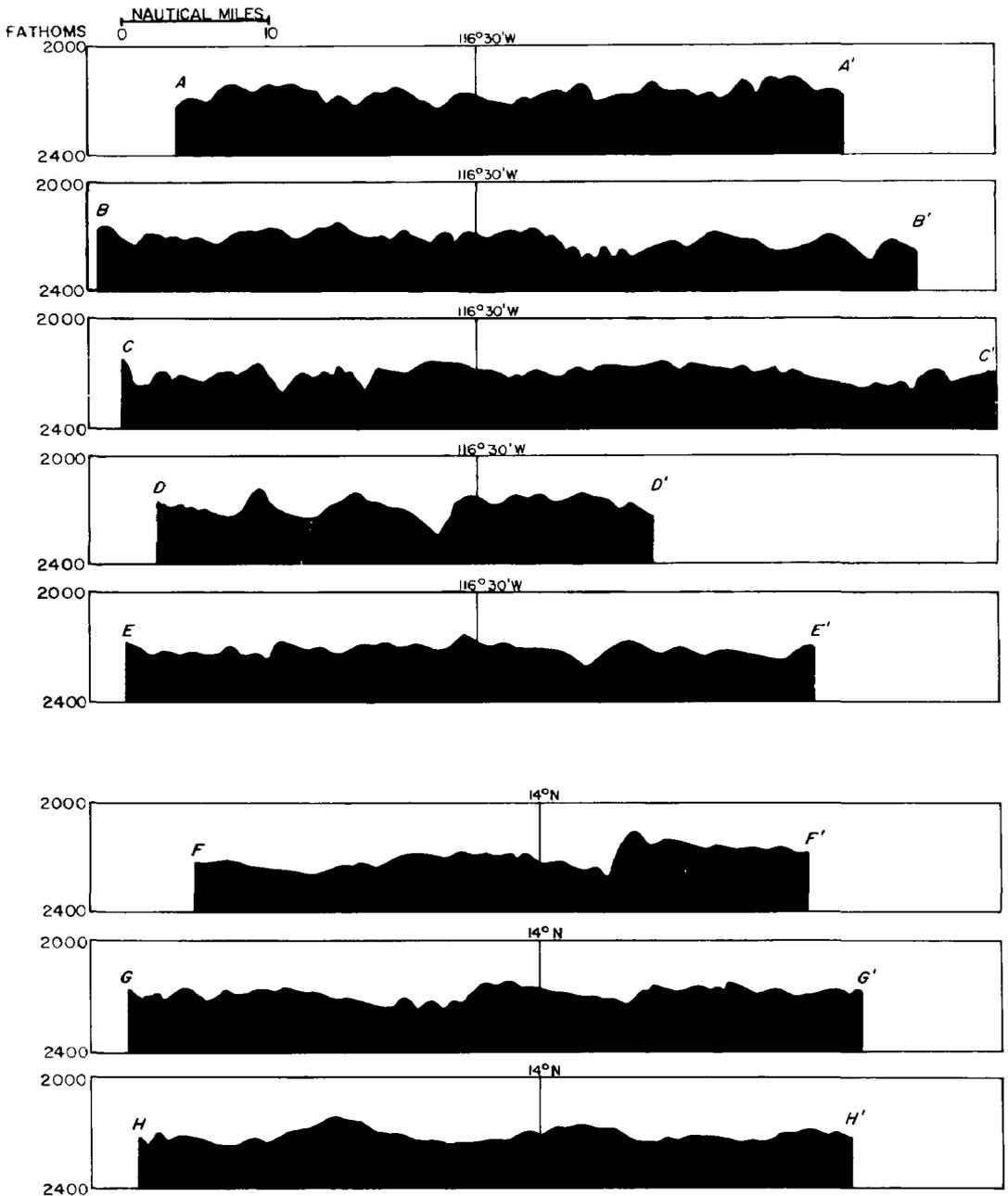


FIG. 5. — Area 2 profiles centred on 116°30' W longitude, and profiles centred on 14° N latitude. Vertical exaggeration 20 ×. (See figure 4 for index of profiles).

The profiles, figures 7 and 8, show a much greater range of relief than the two survey areas to the north. Two small seamounts, profiles A-A' and H-H', were observed. The seamount on profile A-A' was later subjected to a detailed survey (figure 10). Small abyssal hills, and what appear to be enclosed depressions are features common to all profiles and are so shown on the contour chart.

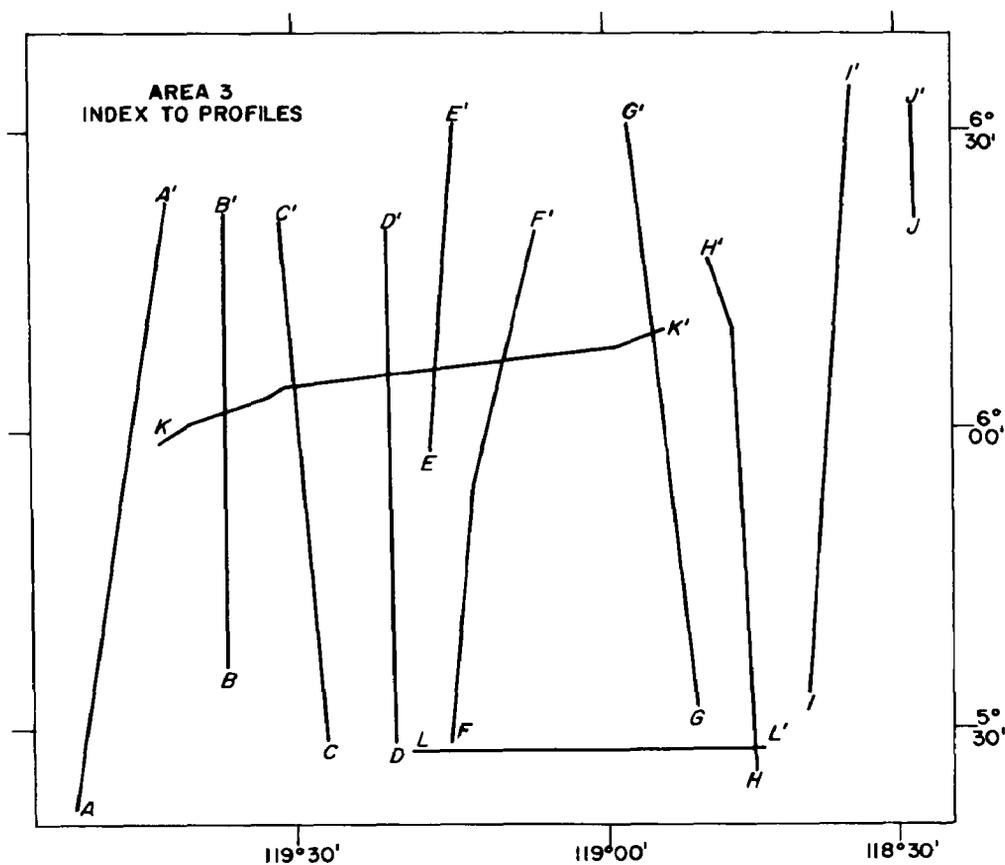


FIG. 6. — Index to profiles of survey area 3.
(See figures 7 and 8).

Regional charts of this area indicate the median depth to be between 2 200 and 2 450 fathoms (4 024 m and 4 481 m) (MENARD, 1960). This would appear reasonable considering that these depths were derived from rather widely spaced random sounding lines and spot soundings. In detail however, Area 3 has some individual features of considerable size that are less than the previously referred to median depth. The maximum relief between the deepest and shallowest points in this area is about 600 fathoms (1 097 m), these points being about 35 nautical miles apart.

The trough on profile F-F', and on profiles K-K' and L-L' tends toward the northwest and also shows a steep northeast side slope. The linear extent of this trough is not known, but it can be inferred that it extends some distance to the southeast. The trough is flanked by a ridge on either side, and although this area exhibits rather complex topography, the ridges and trough appear to terminate near the center of the survey area.

A second trough to the east, somewhat shallower and less well defined, is inferred by the contours, it too being flanked by ridge-like structures. This trough also tends toward the northwest, but turns sharply to the northeast, and terminates in the northern part of the survey area. Profiles

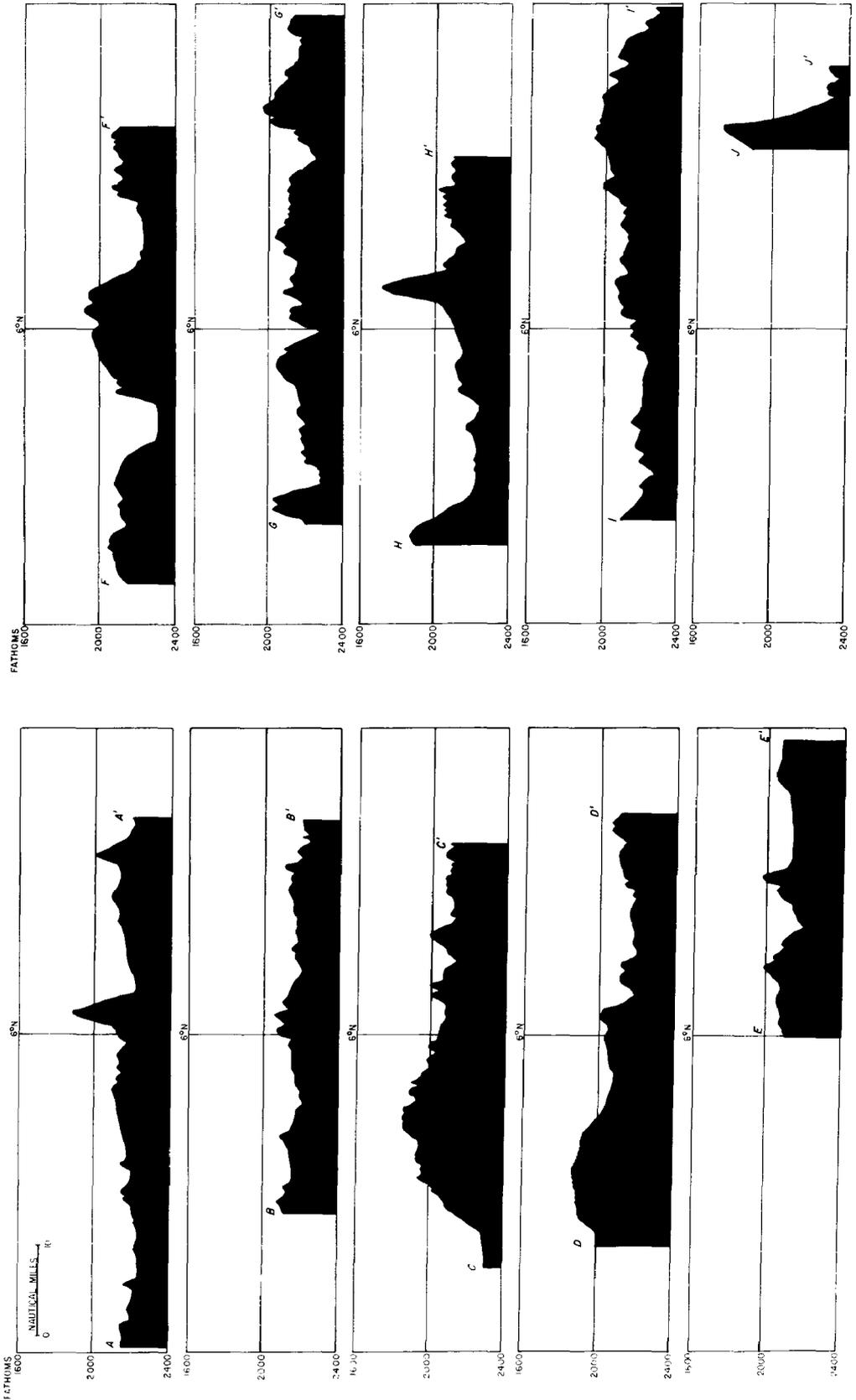


Fig. 7. — Area 3 profiles centred on 6° N latitude. Vertical exaggeration 20 X. (See figure 6 for index of profiles).

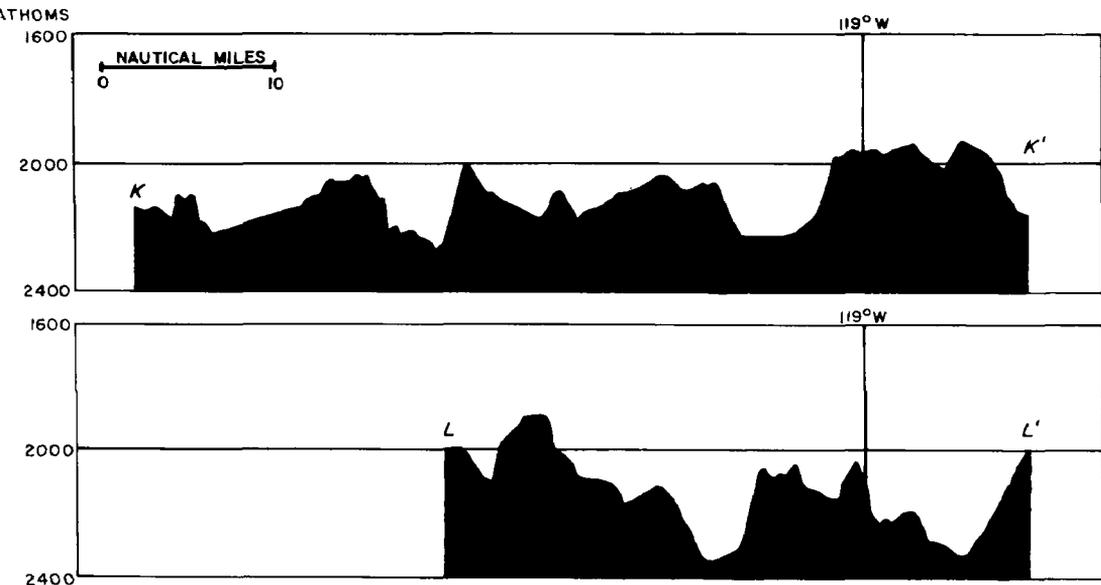


FIG. 8. — Area 3 profiles centred on 119° W longitude.
Vertical exaggeration 20 ×. (See figure 6 for index of profiles).

G-G' and K-K' indicate this trough. Isolated troughs of similar characteristics have been previously reported in this region (MENARD and FISHER, 1958).

Seamount Investigation

A detailed investigation of a small seamount was undertaken as part of the survey of Area 3 (figure 10). This seamount is located on the western edge of the area at 5°59' N, and 119°46' W. The seamount has a rounded, almost flat surface above the 1 800 fathom contour, with a small sharp peak rather ill-defined on the echogram, rising to a depth of 1 759 fathoms (3 217 m). The southwest side is the steepest, dropping more than 400 fathoms (732 m) with a slope of over 23°. A low, narrow ridge extends south and east of the peak for a distance of about 4 nautical miles. The abrupt change in slope on the south and east sides of the peak occurs at about the 2 000 fathom contour, while on the north and west sides the slope change occurs at the 2 200 fathom contour. There is a class of abyssal hills with shapes similar to the tops of higher volcanoes, and side slopes not exceeding 25° (MENARD, 1964). It is assumed that this seamount is volcanic in origin as it meets the criteria of such peaks. On the basis of one or two sounding lines this seamount would be judged to be circular but the detailed survey has revealed a more complex structure. The ridges to the northwest and southeast may be a significant feature of small shield volcanoes, and used to distinguish them from the more common dome-shaped abyssal hills. Detailed surveys of abyssal hills have shown them to be linear off California, but in the equatorial Pacific are low, irregular

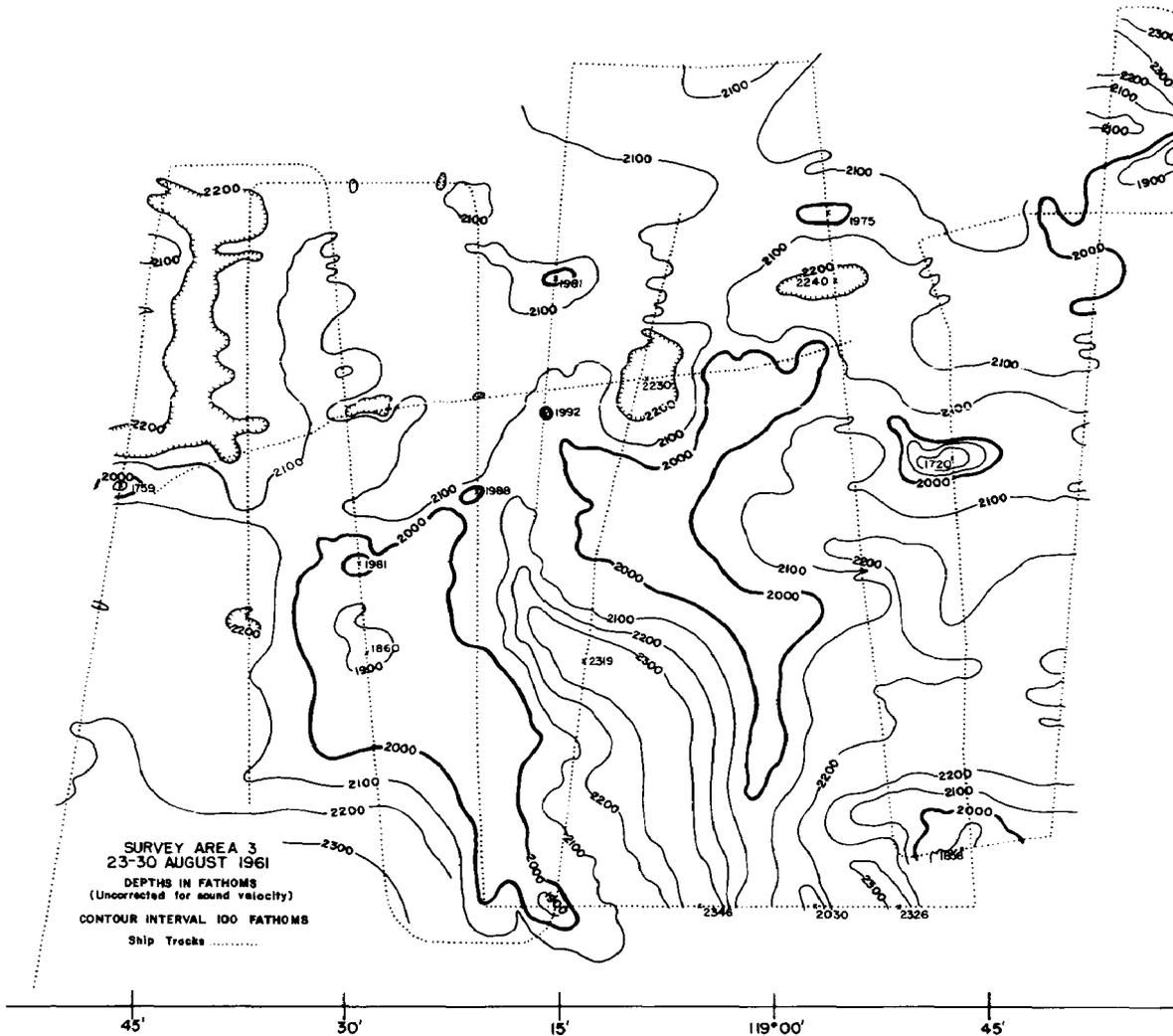


FIG. 9. — Contour chart of survey area 3.

domes probably formed by laccolithic intrusions (HEEZEN and MENARD, 1963). The position of individual volcanoes is probably determined by cross faulting (MENARD, 1964). In the case of the seamount investigated, and the others observed in Area 3, there would be a relationship between the local cross-faulting and the Clipperton Fracture Zone.

Discussion

The three survey areas, although lying between well-defined fracture zones, are quite dissimilar in topographic detail (Plate 1). Not only do these areas lie about mid-way between fracture zones, they are also at

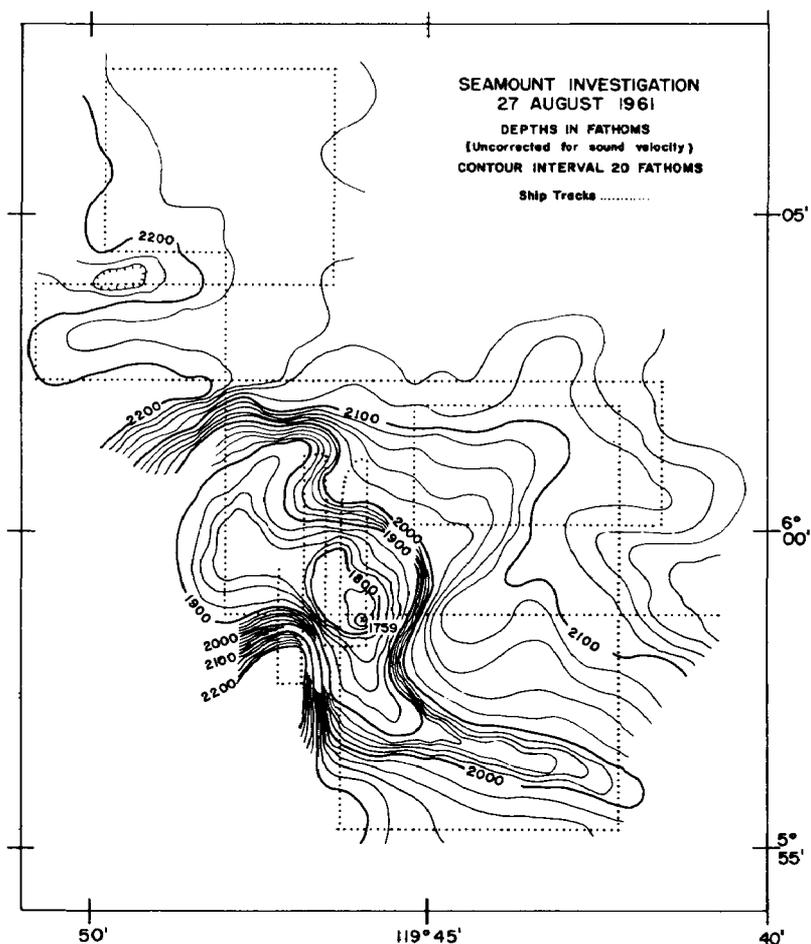


FIG. 10. — Contour chart of seamount investigated in area 3.

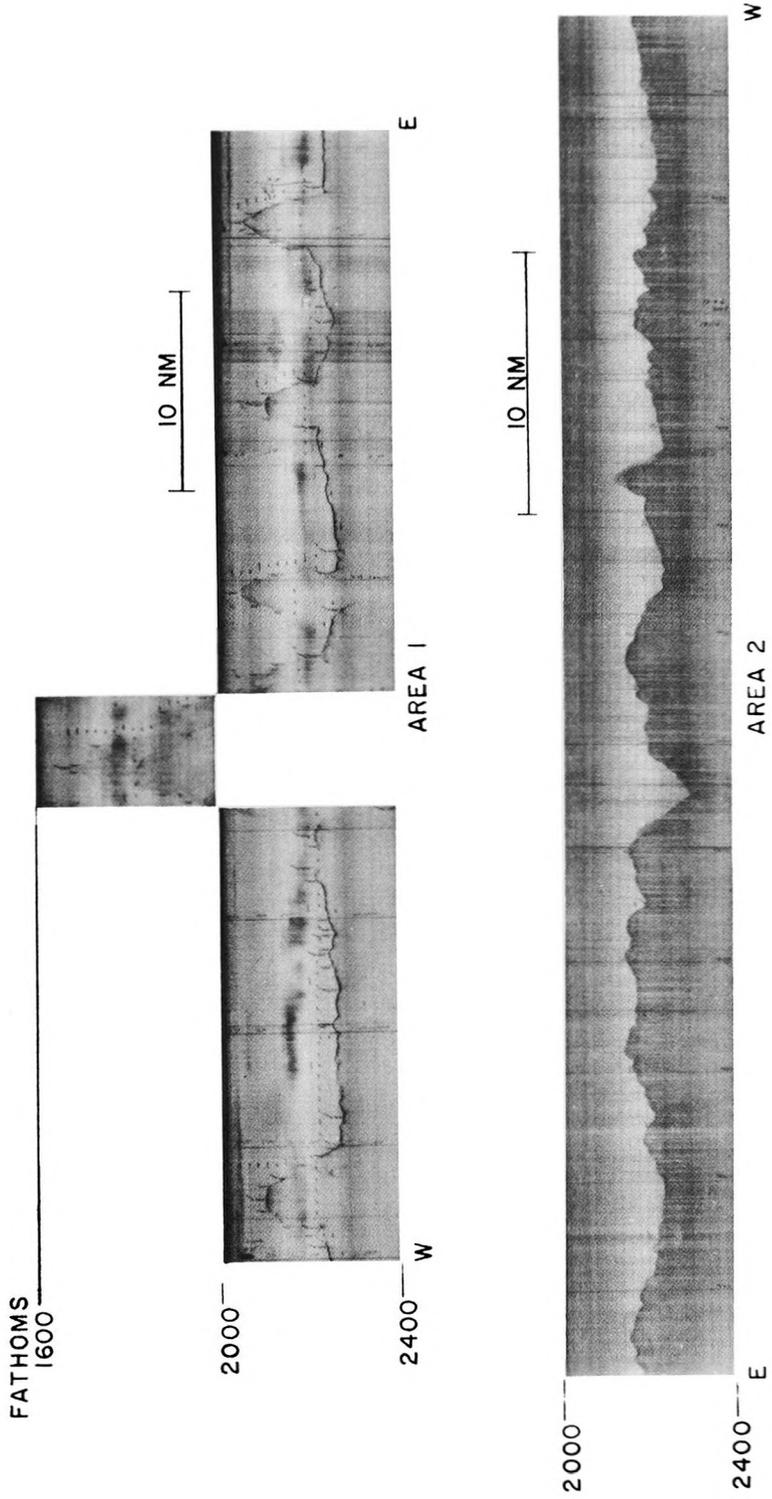
about the mid-line of the western flank of the East Pacific Rise. The detailed topography of this region is not well known, but it consists of volcanoes, low domes, and troughs (MENARD, 1960). These survey areas are not inconsistent with this description.

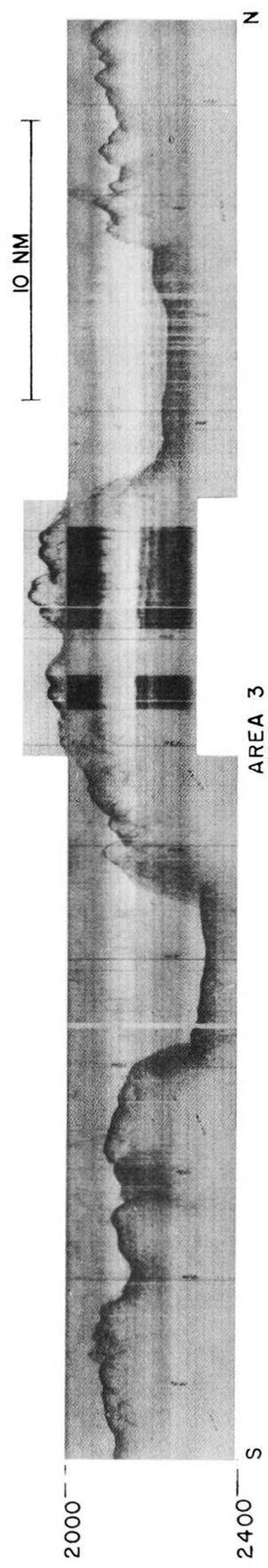
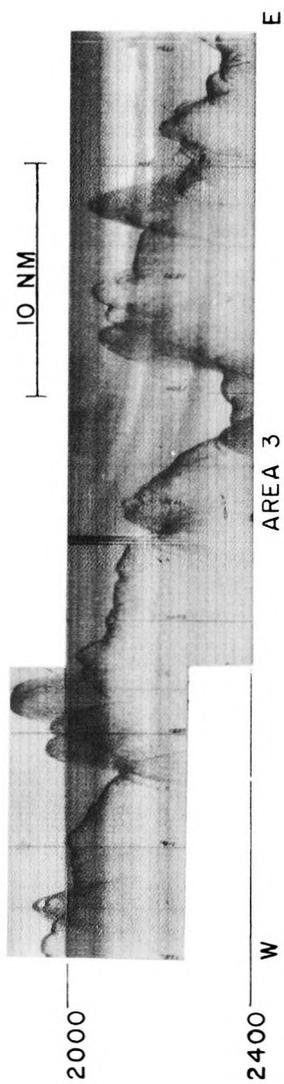
Convection cells in the upper mantle have been proposed as an attempt to explain the formation of the East Pacific Rise (MENARD, 1960). By this mechanism the oceanic crustal layer under the East Pacific Rise is thinned and the undistorted crust on the flanks moves away from the center. Differential spreading moves some crustal blocks more than others, and wrench faults or fracture zones form at the boundaries between blocks.

The evidence of higher than average heat-flow values on the crest of the East Pacific Rise supports the hypothesis that it lies over the ascending limbs of a pair of convection cells (BULLARD *et al.*, 1956; VON HERZEN and UYEDA, 1963). The descending limb on the west flank of the rise should therefore be marked by a zone of compression and corresponding low heat-flow values (MENARD, 1960, 1964).

PLATE 1

Selected echograms (PDR) from survey areas 1, 2 and 3.





VON HERZEN and UYEDA (1963) have shown that heat-flow values both above and below the average were observed in the region of the survey areas. This study also points out that oceanic heat-flow values show a wide variability that is frequently correlated with large-scale topographic features. Survey areas 1 and 3 are within the low heat-flow region to the west of the rise, and area 2 is immediately adjacent. These authors point out that there is a significant correlation between low heat-flow values and areas of abyssal hills separated by very flat areas. LANGSETH *et al.* (1965) have pointed out that future work in heat-flow measurement should be precisely located with respect to the bottom topography, and that they have observed extremely low values of heat-flow next to average or high values.

The optimum physiographic or structural evidence for this zone of compression would be a parallel ridge with an accompanying line of seismic activity, but to date this has not been found (HEEZEN, 1962). MENARD (1959*b*) has shown that various topographic features have been observed within the crustal blocks between fracture zones. These minor lineations are related to stresses within the blocks and because of the observed pinnate pattern suggest a relationship to the fracture zone. These features or "pinnate lineations" may be the physiographic expression of the descending limb of the convection cell and the westward zone of compression. The discontinuity of these features may be explained by differential movement of the crustal blocks between fracture zones and the lack of complete bathymetric surveys.

Conclusions

1. Minor lineations such as small seamounts, abyssal hills, and u-shaped troughs are manifestations of topography associated with the westward descending limb of the convection cell beneath the East Pacific Rise.
2. The lineations exhibit a discontinuity across crustal blocks because of differential movements of the blocks between the fracture zones.
3. Small shield volcanoes may be distinguished from abyssal hills by shape if subjected to detailed surveys.

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Note. — The opinions and assertions contained herein are the private ones of the writer, and are not to be construed as official, or as reflecting the views of the Navy Department or the naval service at large.

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