Submarine Topography South of Hawaii[1]

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GEOMORPHIC AND STRUCTURAL evidence strongly suggests that the center of volcanism in the Hawaiian Islands has migrated slowly from northwest to southeast. This movement is reflected in a progression from the eroded and reef-covered volcanic platform of Midway Island to the periodically active volcanoes of Kilauea and Mauna Loa on the island of Hawaii. From the general age relationships of the islands it might be supposed that a still younger center of volcanism may now be building one or more new cones on the sea floor southeast of Hawaii, eventually to form new islands at that end of the chain.

Soundings shown on charts of the area south and southeast of Hawaii prior to 1954 were taken mostly by various ships that happened to be passing through the area. They are too sparse and poorly positioned to reveal many details of the topography; however, several single isolated soundings on U. S. Coast and Geodetic Survey Chart No. 4179 suggested the presence of as many separate submarine mountains. At the request of the Office of Naval Research the Commander Service Forces Pacific made available a ship for a brief bathymetric survey of these areas. This ship was U.S.S. Patapsco, AOG 1, a 16,000 barrel 10-knot oil tanker that carried a NMC-2 echo-sounder. The great stability of the ship permitted routine sounding operations to be carried on in spite of the fact that most of the sounding traverses paralleled the trough of waves produced by winds of up to Force 6.

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METHOD

Between 0100 June 29 and 1000 July 2, 1954 about 800 miles of sounding traverses were run in the area of Figure 1. Soundings were read visually at one-minute intervals by crew-members but only alternate soundings were plotted on the base chart for Figure 1. Index error and motor speed error were constant within the accuracy of their measurement. Accurate positions were obtained within 4 miles of shore by visual pelorus bearings. Radar fixes to 15 miles from shore proved less reliable. Only star fixes could be used farther off-shore because the area is one of base line extension for Loran. Accordingly, the survey was set up in such a way that sounding in the nearshore areas was done during the daytime, and the long radial traverses were started from a land fix at dusk and ended with a landfall after dawn. Errors in the dead-reckoning positions at the ends of traverses were pro-rated over the entire traverses, taking into account ship speed and offsetting of the course by the wind and sea.

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About 2,430 two-minute interval soundings resulted from the survey. These soundings were plotted on U. S. Coast and Geodetic Survey Chart No. 4115 (1951 edition) which also contains 380 soundings in the area of interest. An additional 220 useful soundings were transferred to the plotting chart from a compilation made by Dietz and Menard (1953) for their general map of the Hawaiian region. A few additional old soundings were omitted because they differed markedly from others in the vicinity and were considered erroneous in position. The total of 3,030 soundings served as the basis for the sea floor contour lines of Figure 1.

Corrections for true sound velocity in the water were made using data from the Marshall Islands (Emery, Tracey, and Ladd, 1954) so that the contour lines would indicate actual depths. Contour lines of land topography at the same interval of 1,500 feet (250 fathoms) were added to the chart from the geological map of Hawaii (Stearns and Macdonald, 1946).

RESULTS

The survey shows the presence of three main physiographic units: lower slopes of Hawaii, Hawaiian Deep, and Hawaiian Arch (Figures 1 and 2). Superimposed on these units are five seamounts.

Lower Slope of Hawaii

The lower slope of the island of Hawaii extends a distance of between 10 and 20 miles from shore to a depth of more than 15,000 feet. Instead of being a simple smooth surface the slope has been made somewhat irregular by four kinds of secondary features. One such feature is volcanic cones, two of which are located directly south of Kilauea. These cones will be discussed in the section on seamounts. A second irregularity is that of elongate ridges that extend seaward off both South Cape and Cape Kumukahi. Both ridges are probably the result of vulcanism along rifts or zones of weakness, extensions of which have been recognized on land (Stearns and Macdonald, 1946, p. 25) and are exemplified by a row of many small craters between Cape Kumukahi and Kilauea Crater. As would be expected of volcanic activity, at least one hill rises above the general level of the outer end of the ridge off Cape Kumukahi. A second hill is shown on U. S. Coast and Geodetic Survey Chart No. 4115 to rise from depths of more than 1,800 feet to within 210 feet of the sea surface (35 fathoms—Existence Doubtful) at a point 5 miles off Cape Kumukahi, but detailed sounding traverses made in this area failed to reveal depths shallower than 1,800 feet. The ridges bear a striking resemblance to similar features of guyots in the Marshall Islands, particularly Sylvania Guyot near Bikini Atoll (Emery, Tracy, and Ladd, 1954).

The third kind of irregularity of the slope is a greater than usual steepness near the shore from south of Kilauea Crater northeastward to near Cape Kumukahi; this steepness is believed to result from the presence of a normal fault that is parallel to shore and is *en echelon* with faults of the Hilina zone on land. The latter is marked by two scarps 1,000 to 1,500 feet high and the scarp on the sea floor is nearly as high. The fourth and last kind of irregularity on the slope is a long broad low ridge that extends eastward from the northernmost parasitic cone. This area is one in which 4,553 earthquakes were detected in a six-week period of 1952 (Macdonald, 1952). Whether this low ridge is of volcanic or structural origin is unknown. The submarine slope appears to be free of a fifth kind of secondary land form, submerged wave-formed terraces, unlike the northeastern coast where Dietz and Menard (1953) reported an extensive terrace at a depth of 1,080 feet.

The steepness of the lower slopes was measured along 11 of the sounding traverses, using for each measurement the gradient of the steepest 6,000-foot depth zone and avoiding as much as possible the influence of secondary features. The mean of these values is 11°. In comparison, the maximum, mean, and minimum slopes of 6,000-foot height zones of the subaerial part of Mauna Loa were found to be 11°, 7°, and 3°, respectively. It is evident from these measurements as well as from inspection of the contour lines of Figure 1 and of the profiles of Figure 3 that the submarine slopes of this part of Hawaii are steeper than the subaerial slopes.

Hawaiian Deep and Arch

Beyond the foot of the lower slope of Hawaii is a broad depression that extends along most of the northeastern side of the entire chain and along part of the southwestern side, as mentioned by Stocks (1950) and described more fully by Dietz and Menard (1953). The 18,000-foot contour of Figure 1 shows the deepest part of the Hawaiian Deep; farther southwest the axis of the Deep shallows to 17,200 feet and its course is uncertain west of 155° 10′ W. owing to its low relief and the low density of soundings.

South and east of the axis of the Deep the bottom gradually becomes shallower until at the end of each long radial sounding traverse the depths are about 1,000 feet shallower than where the traverse crosses the Hawaiian Deep. This gentle northwestward-facing slope marks the inner side of the Hawaiian Arch, a 200-mile wide bulge that borders the Hawaiian Deep. The scarp that Dietz, Menard, and Hamilton (1954) found to border the outer edge of the Hawaiian Arch was not reached in this survey. In only a few places do the sounding traverses in the Hawaiian Deep and Arch have local depth variations that exceed 100 feet, the probable limit of accuracy of reading the echo-sounder; accordingly, it is supposed that the bottom is mantled by a thick layer of sediment.

The Hawaiian Deep is attributed by Dietz and Menard (1953) to crustal depression caused by the great load of the volcanic pile that comprises the Hawaiian Islands. The adjacent Hawaiian Arch they believed to be a related elastic bulge.

Seamounts

Five separate topographic highs were investigated during the survey. For convenience all will be called seamounts though three of them approach the lower limit of size and isolation required for application of the term, seamount, by the International Committee on Nomenclature of Ocean Bottom Features (1953).

Four of the seamounts were indicated by single soundings on previous charts (Table 1); however, the survey located new shallowest soundings as much as 4,100 feet shallower than the original ones (Table 1). One small deep seamount (*Hohonu*—"deep as a pit or

TABLE 1
CHARACTERISTICS OF THE FIVE SEAMOUNTS

	Present Survey—Corrected Feet	Previous Chart—Uncorrected Fathoms	Previous Chart—Corrected Feet	Height above Surroundings—Feet	Diameter of Base—Statute Miles	Mean Steepness of Slopes—Degrees
Papa'u	2490	450	2910	3000	6	9?
Loihi	3222	783	4932	9000	14	17
Wini	5346	990	6198	12000	20	16
'Apu'upu'u	5832	1600	9924	10500	21	18
Hohonu	11478	....	....	5500	6	20

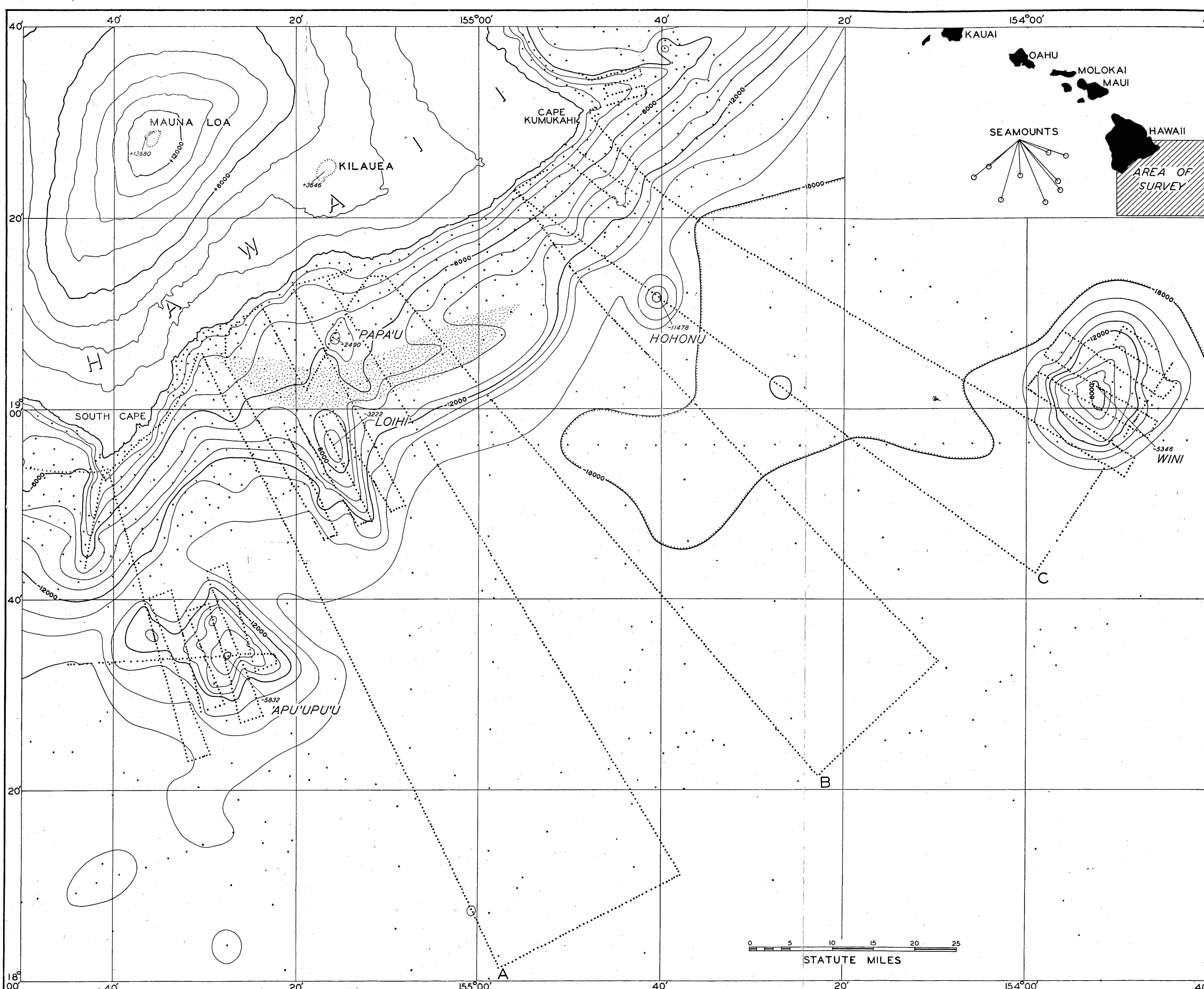

FIG. 1. Map showing topography of southern portion of Hawaii and vicinity. Submarine topography based principally on the survey of June 29 to July 2, 1954, made by the U.S.S. "Patapsco." Contour interval—1,500 feet (250 fathoms); large dots indicate soundings (those closely spaced were taken by the "Patapsco," the widely scattered ones from other sources); finely dotted portion is the area of seismic activity in 1952.

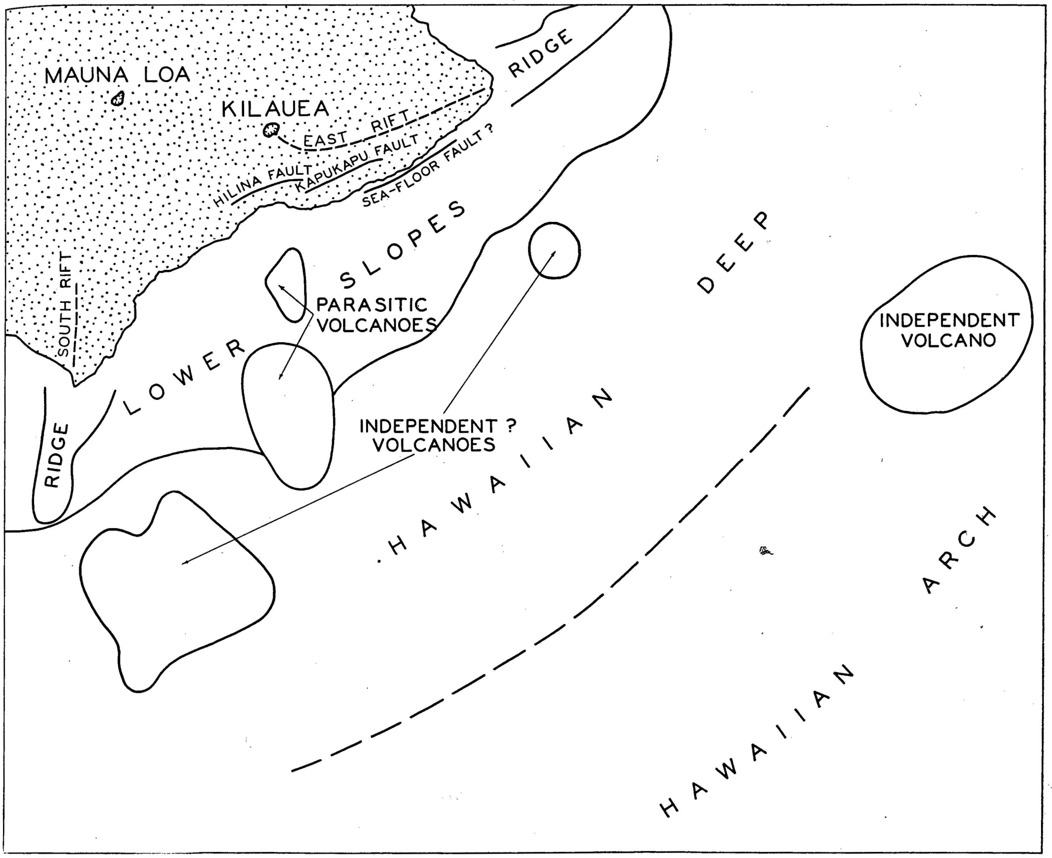

FIG. 2. Physiographic interpretation of Figure 1.

well, the deep sea") was not previously known.

The mean basal diameters of the seamounts range from 6 to 21 miles, so that two of them are intermediate in diameter between the subaerial part of Lanai Island (13 miles) and Kauai Island (27 miles). The seamounts rise 3,000 to 12,000 feet above their surroundings, a relief that is about three times that of the subaerial portions of the various islands in the Hawaiian Chain when expressed as ratio of relief to diameter. The greater relief is, of course, also indicated by steeper slope: a mean of 17° for the seamounts as compared to 11° for the submarine slope of Hawaii and 7° for the subaerial slope of Mauna Loa (Table 1 and Fig. 3). If slope corrections had been applied to the soundings, the submarine slopes would have been slightly steeper.

One of the seamounts (*Wini*—"coming to a point, sharp pointed") is conical in shape, one (*Loihi*—"to extend, to be long") is elongate, one (*'Apu'upu'u*—"a rough, uneven surface, such as a hillock") is irregular with several peaks, and the other two smaller ones (Hohonu and *Papa'u*—"to be shallow, as water") are of uncertain shape, possibly conical. Small irregularities suggestive of craters are present at the tops of three (Wini, 'Apu-'upu'u, and Hohonu), though it is obvious that the existence of small craters cannot be proven without much more detailed surveys than this one. None of the seamounts has a flat top like guyots but then most of the seamounts are deeper than most guyots and they probably also are younger.

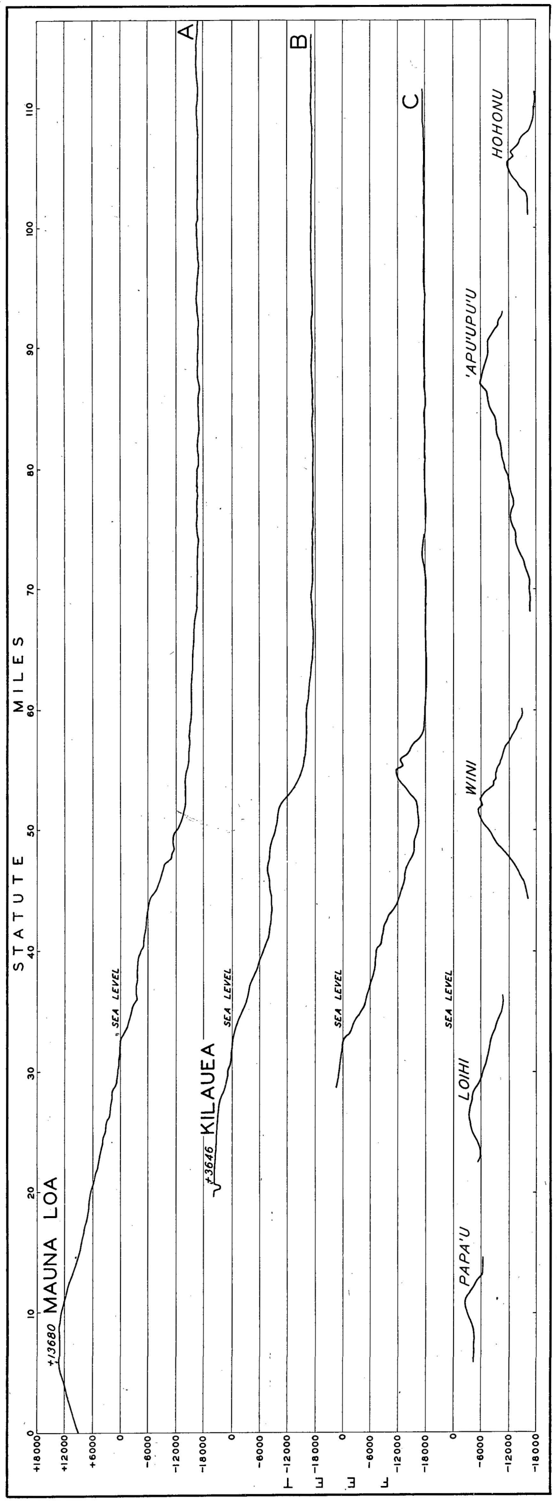

FIG. 3. Profiles of three sounding traverses (A, B, and C) of Figure 1 and of the five seamounts. Vertical exaggeration = 2.0. The slope from the top of Mauna Loa to the bottom of the Hawaiian Deep is the highest continuous slope in the world, approximately 32,000 feet.

None of the seamounts is seismically active within the limitations of the seismograph net on Hawaii. The 1952 belt of active seismicity south of Hawaii appears to pass between the two shallowest seamounts (Papa'u and Loihi) (Fig. 1), but conceivably some of the recorded seismic activity may still be related to them.

In summary the seamounts differ from the known Hawaiian volcanoes in some respects: higher relief (relative to diameter), steeper slopes, and lack of seismic activity. In spite of these differences the general shapes of the features and the geological and geographical environment is such that there is a high degree of probability that the seamounts are of volcanic origin, and correspondingly that the differences which exist may be indications of the nature of the early stages of a volcano forming well below sea level. If this conclusion is correct then the two shallowest seamounts (Papa'u and Loihi) must be considered parasitic (in the sense of topography—not activity) volcanoes on the flank of Kilauea-Mauna Loa, two ('Apu'upu'u and Hohonu) are probably independent volcanoes located at the foot of the slope, and one (Wini) is certainly an independent volcano, being located on the opposite side of the Hawaiian Arch from Hawaii (Fig. 2). If they are volcanoes, their age may be Late Tertiary to Pleistocene in accordance with the youth of the rest of the Hawaiian Chain. Quite probably they are even younger than the rest of the islands as suggested by the general movement of the center of volcanic activity from northwest to southeast (Stearns, 1946). It is impossible to state definitely, however, that the seamounts do constitute such an extension, but such is more likely than that they are unrelated and isolated volcanoes like the ones scattered about the area west of Hawaii (insert map of Fig. 1).

CONCLUSIONS

The relationship of Mauna Loa and Kilauea to the lower slope of Hawaii and its parasitic cones, ridges, fault scarp, and belt of seismic activity, to the Hawaiian Deep and Arch and to superimposed seamounts is such that it is exceedingly desirable to obtain more information on the submarine topography and bottom materials of the region. This is even more important in a geophysical sense when one considers that the submarine area of the chain far exceeds the subaerial area and that the effort expended on the land area to date is almost infinitely greater than that devoted to study of the submarine area.

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