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Bathymetry of a Region (PORL-421-2) North of the Hawaiian Ridge

FREDERIC P. NAUGLER

PACIFIC OCEANOGRAPHIC RESEARCH LABORATORIES
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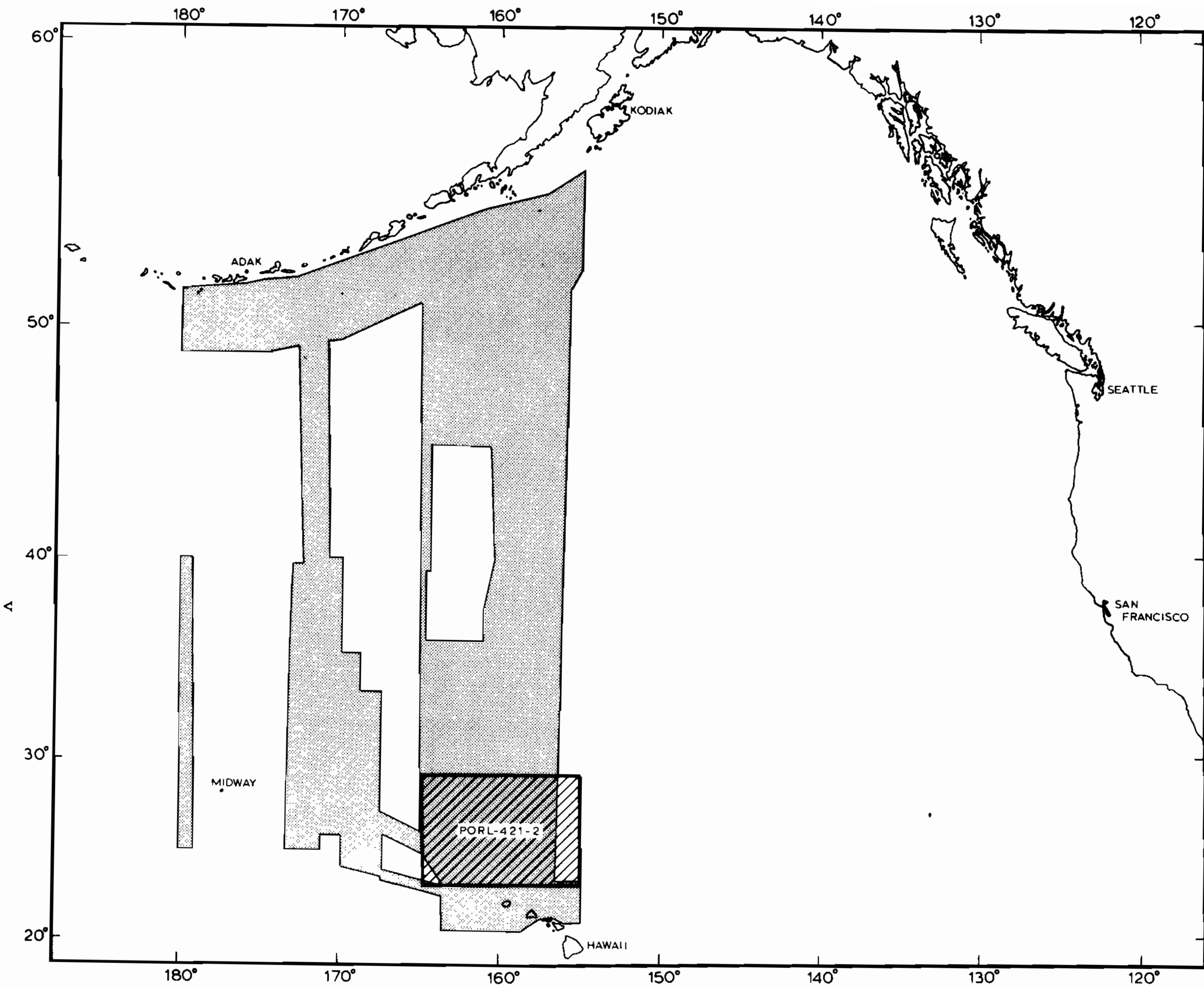

Figure 1. Location diagram for bathymetric map PORL-421-2. The extent of the SEAMAP survey completed with line spacing of 10 n mi as of January 1967 is indicated by shading.

BATHYMETRY OF A REGION (PORL-421-2)
NORTH OF THE HAWAIIAN RIDGE

Frederic P. Naugler

A bathymetric map of a 665,000 km^2 area centered about 450 km north of Kauai Island, Hawaii, has been prepared from echo soundings obtained on ESSA's SEAMAP survey. It is the first of a proposed series of maps based on the SEAMAP data and was prepared to support a geophysical study of the north central Pacific Ocean Basin underway at the Pacific Oceanographic Research Laboratory. The map includes the southern portion of the Musicians Seamount Province and sections of the Hawaiian Ridge and the Murray Fracture Zone. Several pronounced east-west ridges and a band of northeast-southwest trending lineations add to the complex structure of this region.

1. INTRODUCTION

Following a broad study of the status and prospects of oceanography in the United States, the National Academy of Sciences Committee on Oceanography (NASCO, 1960) advanced the argument that reasonably complete maps of the oceans were a necessary prerequisite to an efficient program of oceanographic research and resource exploitation. Specific recommendations were made for a comprehensive survey that would permit the preparation of maps portraying geological, geophysical, hydrological, and biological elements. The U. S. Coast and

Geodetic Survey, acting with the support and guidance of the Survey Panel of the Interagency Committee on Oceanography, accepted the NASCO recommendation and started the North Pacific SEAMAP (Scientific Exploration And Mapping Program) surveys in 1961. The basic plan provided for continuous echo sounding and magnetic and gravity observations on a line spacing of 10 n mi (18.5 km), with Loran-C control, for oceanographic station observations (temperature, salinity, oxygen) and for the collection of geological samples. In addition to the basic plan, concurrent observations and special investigations have been carried out by ESSA scientists and by personnel from other research laboratories. These supplementary programs include studies of deep currents, light transmissivity, biological populations and primary productivity, time changes in physical properties, bottom photography, natural and man-induced radioactivity, etc. Thirty-three ship-months, as of January 1967, produced the areal coverage illustrated in figure 1.

2. FIELD METHODS AND TREATMENT OF DATA

The bathymetric map (in pocket) is based on data collected from 1961 to 1966 by the Coast and Geodetic Survey ships PIONEER and SURVEYOR. Tracklines, spaced at about 18.5 km, were run in a north-south direction to minimize errors in gravity data. In September 1967, a survey was made by the author aboard the SURVEYOR in order to define more clearly several prominent ridges located near the center of the map area. Navigation was controlled by Loran-C which, under optimum conditions, assures a positioning accuracy of about 0.5 km.

Soundings were scaled from precision depth recorder traces every 5 min and at intermediate times when peaks and depressions were encountered. Before 1964, each sounding and its time of observation, position serial number, and certain position control data were manually recorded in a "sounding volume". Ship position data were recorded on plotting sheets. Since 1964, sounding, time, and position data have been encoded at sea on punched paper tapes.

The bathymetric data were further processed and edited jointly by the Coast and Geodetic Survey and the Pacific Oceanographic Research Laboratory (PORL), both located at ESSA's Pacific Marine Center in Seattle, Washington. Following several edit procedures, the soundings and navigation data were encoded on punch cards. From these cards, as a further edit procedure, the computed ship's velocity between successive position fixes has been evaluated. The Coast and Geodetic Survey's IBM 1620 computer was programmed to calculate positions for the soundings by time interpolation between the navigation fixes and to apply sound velocity corrections to the soundings (Ryan and Grim,1968). The corrected depths were plotted by a Gerber plotter (Mobley, 1965) on a Mercator projection at a scale of 5.5 in. equal to 1° of longitude. Based on a preliminary contour map of the bathymetric data, further adjustments to position data were made where systematic discrepancies between adjacent tracklines were noted.

3. DISCUSSION

Bathymetric map PORL-421-2 (in pocket) covers an area of 665,000 km^2 centered about 450 km north of Kauai Island, Hawaii. A variety of topographic features, including sections of the Hawaiian Ridge and the Murray Fracture Zone and the southern portion of the Musicians Seamount Province, are shown in detail.

Hawaiian Ridge, Deep, and Arch

The Hawaiian Archipelago is the subaerial expression of large seamounts located along the crest of the 2600-km long Hawaiian Ridge. The volcanism responsible for these seamounts is believed to have migrated southeasterly along a zone of weakness in the earth's crust (Menard, 1964). The tremendous mass of volcanic material accumulated along this lineation has apparently downwarped the surrounding sea floor and caused a peripheral depression or moat, the Hawaiian Deep, and a compensating rise farther seaward, the Hawaiian Arch (fig. 2). The deep and arch show their greatest expression as they sweep around the southeastern (younger) end of the ridge (Hamilton, 1957, fig. 4).

A part of the Hawaiian Ridge trends northwesterly across the bottom of the map (in pocket), with the wave-planed platforms of several

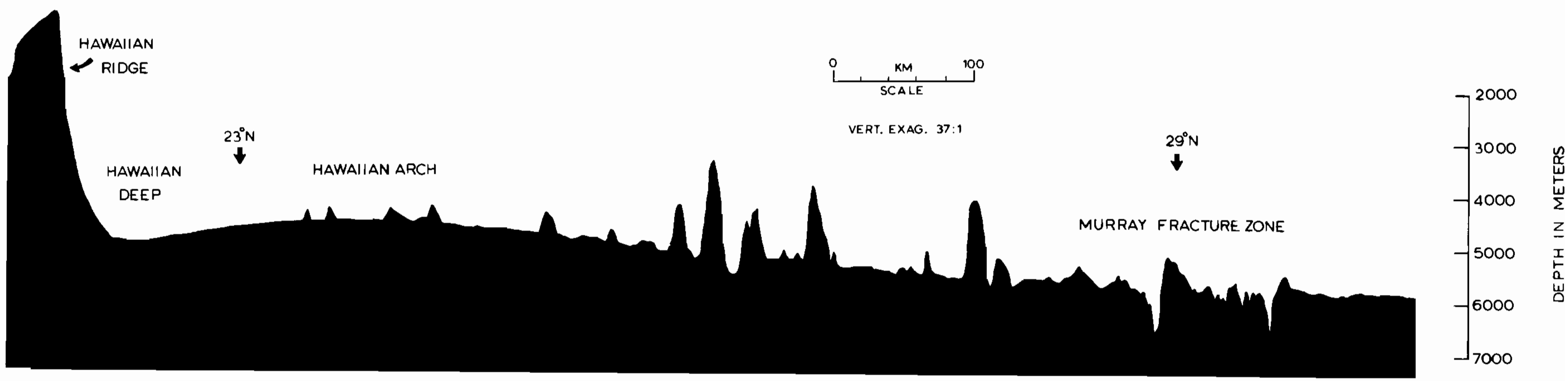

Figure 2. Bathymetric profile from the Hawaiian Ridge to the Murray Fracture Zone along 158°W longitude.

large seamounts defining the crest. These features have subsided relative to sea level, leaving two small islands, Necker and Nihoa, as subaerial remnants. The deep is expressed by several depressions, at 4800 and 5000 m, adjacent to the northern flank of the ridge.

A fan-like feature, radiating from Nihoa Island, partly fills the deep between about 161°W and 162°W. This feature apparently was produced by lava flows that spread northward from a center of eruption near Nihoa Island. Several east-west ridges have impeded the flows and provide excellent examples of topographic damming. The possibility that this fan-like feature is composed of sedimentary debris eroded from the crest of the ridge is unlikely because of the limited source area provided by the Nihoa region. A slump origin can also be eliminated for lack of sufficient source material and because the fan slopes away from the Nihoa platform in a uniform and radial manner, unlike the irregular topography generally associated with slumping.

The broad asymmetrical arch (fig. 2) is somewhat obscured by irregular topography but retains much of its identity across the area shown in the map contained in the pocket of this report. In the southeast part, the crest of the Hawaiian Arch is revealed by a series of arcuate regional contours between 4300 and 4700 m that show a deepening toward the northwest. A bathymetric profile along 158° W (fig. 2) shows a well-developed arch in this region. The crest of the arch can be recognized north of Necker Island between about 25°N and 27°30'N, but the configuration of the contours (notably those at 4800 and 4900 m) shows a deepening toward the southeast. Thus there is a saddle in the Hawaiian Arch between about 161°W and 162°W where the depth of the crest exceeds 4900m.

The arch has a width of approximately 500 km when measured from the axis of the deep east of Nihoa Island to the apparent limit of its northern flank at about 27°30'N and 158°W. This northern limit is defined roughly by the 5500-m isobath, which enters the eastern part of the map area just north of 27°N and trends in a general westerly direction to 158°W where the arch becomes obscured by complex topography.

Necker Lineations

The saddle in the arch between 161°W and 163°W may be related to a band of subtle northeast-southwest bathymetric lineations that trend toward Necker Island. These lineations are most prominent around 158°W, between 26°N and 27°N, where they intersect two east-west trending ridges. They are not seen between 163°W and Necker Island, but re-appear southwest of the Hawaiian Ridge (outside the map area) as the well-defined Necker Ridge. It has been suggested (e.g., Woollard, 1965, fig. 1) that these northeast-southwest bathymetric trends are related to the Murray Fracture Zone. However, a recent study of the bathymetric and magnetic trends within the map area (Naugler and Erickson, 1968) shows that these northeast-southwest trending features have no high-amplitude, elongate magnetic anomalies associated with them as is characteristic of the Murray Fracture Zone elsewhere. In this paper the latter interpretation is accepted, and these northeast trending features will be referred to as the "Necker lineations".

Murray Fracture Zone

The Murray Fracture Zone has been traced as a major geologic feature from a point off the coast of southern California to west of the map area where it meets the Hawaiian Ridge near Laysan Island (172°W). It is seen trending slightly south of west across the northern part of the map as a band of parallel asymmetrical ridges and deep troughs. In the vicinity of 157°W the fracture-zone topography is chaotic, with no continuous ridge defining the southern limit. Farther west, at about 157°30'W, a prominent ridge appears, marking the southern limit of a well-developed fracture zone (see fig. 2). This zone is almost identical in profile to a crossing of the Murray Fracture Zone at 152°30'W, which Menard (1964, fig. 3.3) gives as a typical example of a double-asymmetrical-ridge type of fracture zone. It has a width of about 130 km and a ridge-to-trough relief in the order of 1000 m, with a depth of 6520 m in one of the troughs at about 158°W.

The Murray Fracture Zone is masked for about 130 km by the

Musicians Seamounts but reappears to the west as a well-defined zone. Here it has encountered the northern flank of the Hawaiian Arch and, while retaining its general morphologic character, loses about half of its vertical relief. High-amplitude linear magnetic anomalies are closely associated with the fracture-zone topography (Naugler and Erickson, 1968). These apparently reflect deep-seated intrusives along zones of primary rifting (Malahoff et al., 1966) and give no indication that the Murray Fracture Zone branches or widens within the area covered by the map contained in this report.

Musicians Seamount Province

The Musicians Seamounts comprise a major volcanic province that trends northwesterly for more than 1000 km from a region north of the Hawaiian Ridge to about 35°N. The southern portion of the province lies within the map area.

Seamounts. In general the seamounts of the Musicians Province have elevations between about 2000 and 4000 m, are nearly circular to elongate in plan, and have basal dimensions ranging between 10 and 25 km. The larger seamounts tend to be elongated in random directions. One relatively isolated seamount, located at 26°N and 162°W, is elongated in a west-northwest direction and has a distinct ridge-like crest 100 km long. Its shallowest recorded depth is 1827 m, giving it an elevation of at least 3300 m above the surrounding sea floor.

The shallowest depth recorded in the entire province is 1582 m. This occurs on the summit of a more or less circular seamount lying on the northern margin of the Murray Fracture Zone at 162°W (partly outside the map area). This prominent feature rises more than 4000 m above a flat basin, delineated by a depression contour at 5600 m, located to the south.

The bathymetric relations between the Musicians Seamounts and the Murray Fracture Zone suggest that the seamounts are superposed across the older fracture zone. The prominent southern ridge of the Murray Fracture Zone (northwest portion of the map) terminates abruptly on encountering a northwest trending trough that parallels several seamounts closely, suggesting a portion of the fracture-zone relief has been obliterated by formation of the seamounts.

From an examination of echograms, none of the Musicians Seamounts appear to have flat tops. Thus, in contrast with the Mid-Pacific Mountain Range located southwest of the Hawaiian Ridge and characterized by numerous flat-topped seamounts (or guyots), the Musicians Seamount Province apparently was never exposed to wave erosion at the sea surface.

Ridges. Three prominent east-west trending ridges located between about 26°N and 27°N form the southeastern portion of the Musicians Seamount Province. The northernmost of these is the best developed, averaging about 12 km in width and maintaining an elevation of over 2000 m along most of its 280-km length. Two other, less well-defined, east-west trends occur at about 27°15'N and 28°N. Here, elongate seamounts are seen coalescing along a general east-west trend. Similar trending structures occur within the Musicians Seamounts north of the area covered by the map. Thus it appears that a system of en echelon faults is associated closely with the general northwest trend of the seamounts.

Small-scale east-west lineations characterize the southeastern part of the area, where the crest of the Hawaiian Arch is well developed. Menard (1959) shows the east-west trends, which characterize the region north of the Hawaiian Ridge, as part of a pinnate system of lineations branching from, and possibly structurally related to, the ridge. Thus, the prominent east-west trends within the Musicians Province may indicate local enhancement of structures associated with the Hawaiian Ridge, including possible gravity faulting associated with uplift of the arch. Alternately, they may indicate regions intersected by secondary faults associated with the Murray Fracture Zone.

4. ACKNOWLEDGEMENTS

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