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Bathymetry and Magnetics of a Region (POL-421-3) 29° to 35°N, 155° to 165°W

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TABLE OF CONTENTS

	Page
ABSTRACT	1
1. INTRODUCTION	1
1.1 Field Methods and Data Processing	3
1.2 Location	4
2. PHYSIOGRAPHY	4
2.1 Murray Fracture Zone	4
2.2 Hawaiian Arch	6
2.3 Musicians Seamounts	6
2.4 Central Block (Musicians Horst)	10
2.5 Abyssal Hills	12
3. MAGNETIC ANOMALIES	13
3.1 Anomalies Associated With Topography	13
3.2 Anomalies Not Associated With Topography	16
4. ACKNOWLEDGEMENTS	18
5. APPENDIX A: List of Seamounts	19
6. REFERENCES	20

PLATES (in pocket)

Plate 1 - Bathymetric Map

Plate 2 - Magnetic Anomaly Map

BATHYMETRY AND MAGNETICS OF A REGION (POL-421-3)

29° TO 35°N, 155° TO 165°W

David K. Rea

Bathymetric and magnetic anomaly maps of an area in the central north Pacific Ocean have been prepared from data collected for ESSA's SEAMAP project to delineate and interpret the topographic and magnetic features present. The bathymetric map includes the northern portion of the Musicians Seamounts, a part of the Murray fracture zone, a large elevated fault block, a small part of the Hawaiian Arch, and abyssal hills. The magnetic anomaly map shows normally polarized local dipole anomalies associated with the seamounts and linear dipole anomalies associated with fault scarps. Two linear dipole anoamlies not associated with topography may reflect shear zone that resulted from a change in direction of sea-floor spreading and that was offset by a minor transform fault.

I. INTRODUCTION

Data used in this report were collected by the U. S. Coast and Geodetic Survey during project SEAMAP, the Scientific Exploration and Mapping Program. Bathymetric, magnetic, and gravity observations on a 10 n mi (18.5 km) trackline spacing were made by the USC&GS Ships PIONEER and SURVEYOR. Approximately 36 ship months have been spent in the SEAMAP area as of 1 January 1970, resulting in the areal coverage shown in figure 1. This report supplements POL Technical Report ERL 82-POL 1 (Naugler, 1968) which similarly treats a comparable area immediately to the south.

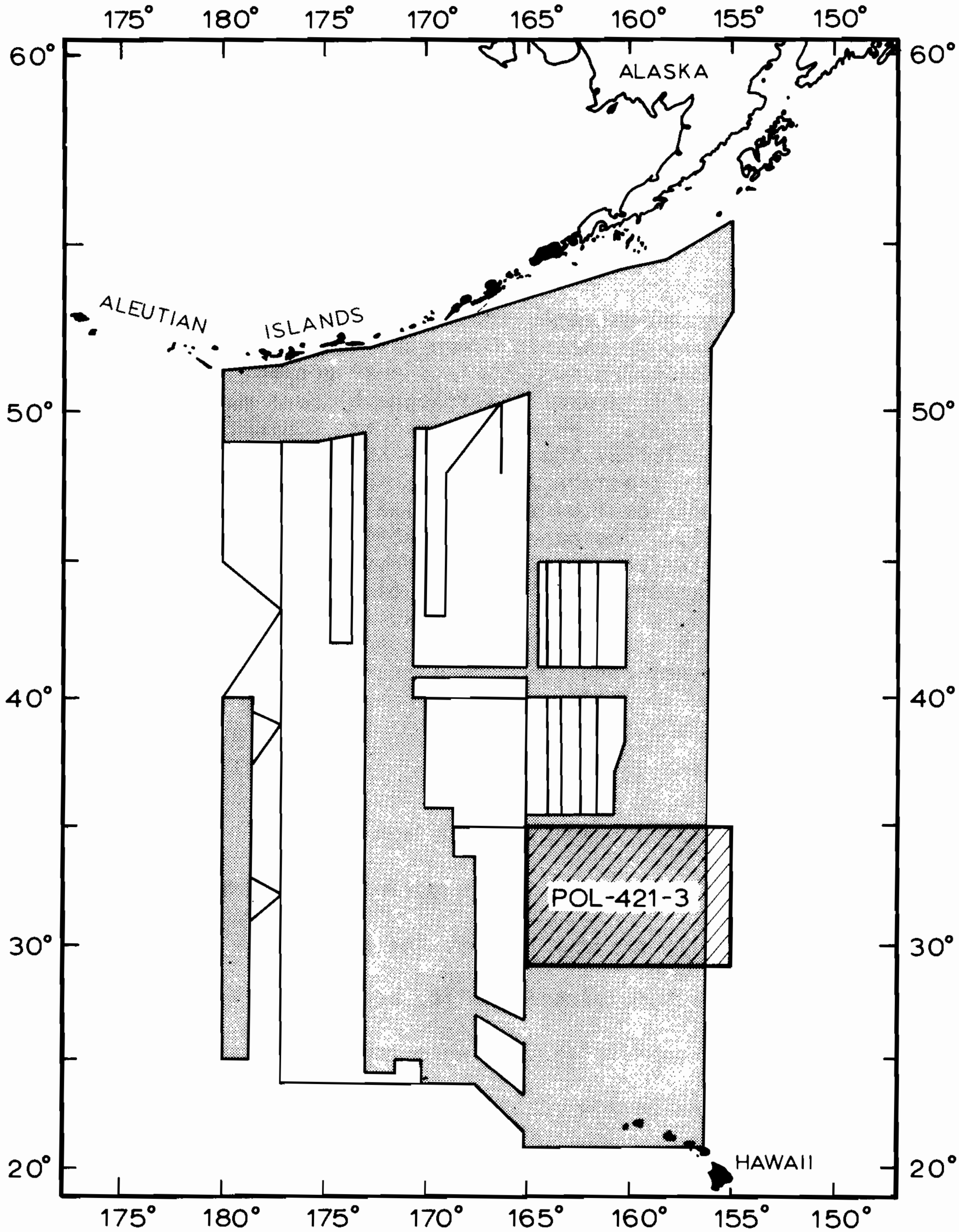

Figure 1. Location may and SEAMAP tracklines. Shaded areas indicate 18.5 km (10 n mi) trackline spacing.

1.1 Field Methods and Data Processing

Precision Depth Recorders (PDR) were used for all soundings. Depths were scaled from the PDR traces every 5 min and at intermediate times when peaks and deeps were encountered. Prior to 1964, each sounding and its time of observation, position number, and navigation data were manually logged in a "sounding volume". Ship position data were plotted on ocean survey sheets. Data logging methods, begun in 1964, now record depth, time, and position data directly on punched paper tape (Naugler, 1968). Data were processed at ESSA's Pacific Marine Center according to procedures reported by Ryan and Grim (1968), Naugler (1968), and Mobley (1965). The result was a plot of corrected depths in meters on a Mercator projection at a scale of 1° longitude equal to 5.45 in.

Total intensity magnetic data were obtained with a Varian proton precession magnetometer towed behind the ship. The data were recorded on an analog strip chart and since 1963 on punched paper tape. At the Pacific Marine Center, magnetic data were transferred to punch cards and processed to remove the regional field, calculated with the GSFC 9/65 set of spherical harmonic coefficients (Hendricks and Cain, 1966). Residual values were then plotted at the same scale as the bathymetric data.

Navigation in the project area was largely by Loran-C, having an optimum accuracy of 0.75 to 1.0 km. Loran-A and celestial navigation were used when necessary. A few lines were controlled by a satellite navigation system.

1.2 Location

The area covered by this report lies between 29°N and 35°N and 155°W and 165°W and is centered approximately 1,100 km north of Kauai Island, Hawaii (fig. 1).

2. PHYSIOGRAPHY

Several physiographic areas appear on the bathymetric map (Plate 1). These include: the Murray fracture zone, a minor part of the Hawaiian Arch, the northern portion of the Musicians Seamounts, a large ridge trending east-west through the center of the area (fig. 2), and abyssal hills.

2.1 Murray Fracture Zone

The Murray fracture zone has been traced as a major geologic feature from the coast of California to the Hawaiian Ridge near Laysan Island (Naugler and Erickson, 1968). The northern part of the 100-km wide fracture zone appears as a series of asymmetrical ridges and troughs in the south-east portion of plate 1 (see also fig. 3d,e,f,g); the southern portion has been described by Naugler (1968). At approximately 162°W, 29°N, the northern edge of the Murray fracture zone is masked by the Musicians Seamounts. Here the fracture zone trends 265°, although the individual ridges and troughs within it trend approximately 250° to 255°. Relief averages about 1100 m; the greatest depth found in troughs is 6735 m (fig. 3f). These ridges and troughs trending at an angle to the major trend of the Murray fracture zone probably were

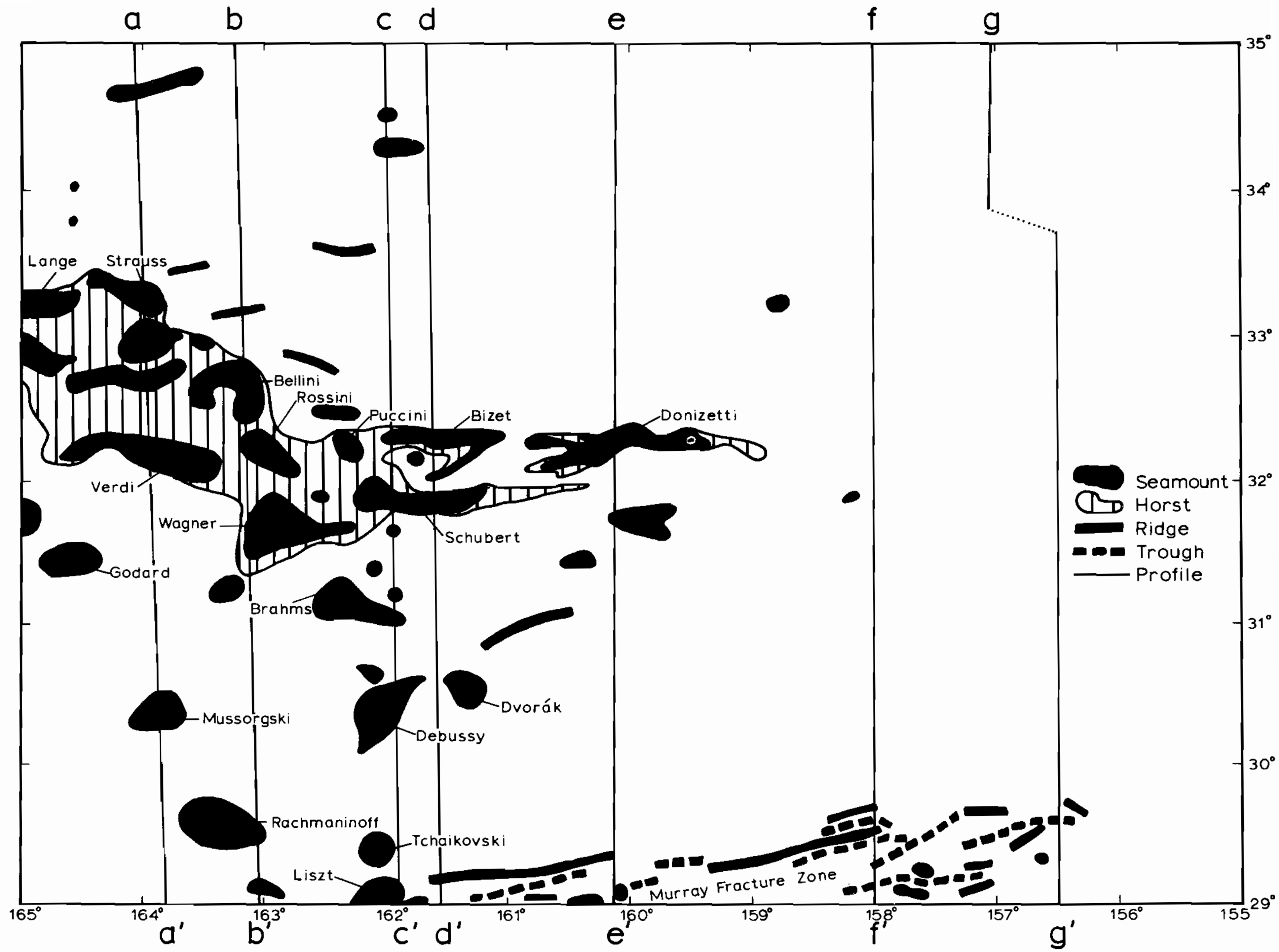

Figure 2. General bathymetry and index to profiles.

caused by en echelon faulting within the fracture zone following a change in direction in sea-floor spreading (Menard and Atwater, 1968). Several small seamounts, or large hills, occur within the Murray fracture zone. Largest of these, located at 29.1°N, 160.1°W, has a relief of 1800 m and a shoalest depth of 3931 m.

2.2 Hawaiian Arch

The gently north-northeast sloping sea floor shown in the extreme southwest corner of plate I may represent the outer flank of the Hawaiian Arch (fig. 3a). A regional slope extends northward from the Arch to about 32°N along 165°W. Harian (in his fig. 1, 1967) indicates that the outer margin of the Hawaiian Arch between 155° and 160°W is about 700 km north of the Hawaiian Ridge. The outer margin of the Arch, shown in the southwest corner of plate I, may be as much as 880 km north of the ridge.

2.3 Musicians Seamounts

The Musicians Seamounts comprise a major volcanic province that trends northwesterly for about 1000 km from a point 200 km north of Nihoa Island, Hawaii, to at least 34°N where data coverage becomes sparse. Names have been assigned to the more prominent seamounts using a system whereby classical and modern composers names are given to seamounts in the southern half of the area, names of operatic composers are assigned to seamounts on the uplifted central portion of the map,

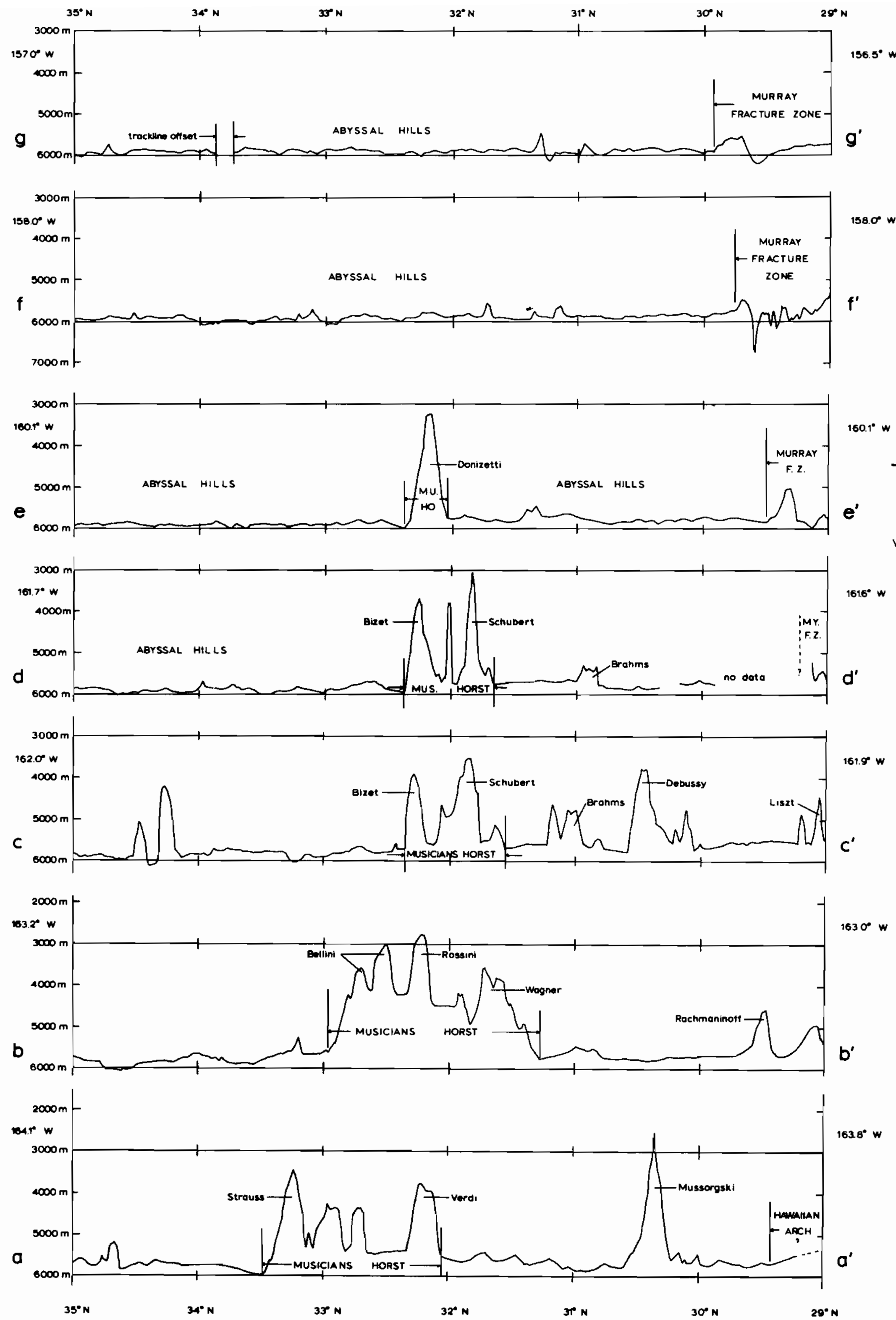

FIGURE 3
BATHYMETRIC PROFILES
Vertical Exaggeration x37

and names of light classical composers given to the seamounts north of the central block (fig. 2).

In the map area, the Musicians Seamounts have a relief of up to 4000 m, the average being approximately 3000 m. Slopes average 10° and may be as much as 25°. Basal outlines are circular to elliptical, with short axes measuring 25 to 45 km and long axes measuring up to 80 km. The largest seamount, Debussy, measures 45 by 80 km at the base and rises 4000 m above the regional depth to a shoalest sounding of 1796 m. In the northern Musicians Seamounts most of the seamounts are elongated and trend northwesterly in contrast to the southern Musicians Seamounts that appear randomly oriented (Naugler, 1968). Debussy Seamount, the one notable exception to the general northwest trend, extends northeast. A nose extending east from the north slope of Liszt Seamount is associated with Murray fracture zone.

None of the seamounts have flat tops. Apparent gentler slopes near the top of several seamounts, resulting in rounded summits (fig. 3), are possibly the result of trackline location on the flank of a generally conical seamount. Such a trackline would result in a hyperbolic profile - thus the rounded tops.

Double peaks appear on the summits and shoulders of several seamounts (plate I, fig. 3). Rachmaninoff has double peaks on its summit 1.7 km apart and separated by a depression 200 m deep below the southern, higher peak. The trackline crossing the western shoulder of Rachmaninoff shows a more pronounced double peak, 3.5 km apart with a

500 m depression. If these features were connected, a crestal graben extending west of the summit would be indicated. Wagner Seamount exhibits a double peak about 8.35 km apart with an intervening depression of 585 m. Three crossings of the crest of Verdi Seamount show two ridges along its crest separated by 3.00 km on the eastern end and widening to the west to 10.0 km (fig. 3a). Relief of the central valley ranges from 50 to 325 m. Both the ridges and the valley slope downward and broaden to the west. A similar feature is shown on two tracklines crossing the east shoulder of Brahms Seamount (fig. 3c,d).

It is not possible to determine from one crossing whether a double peak represents two individual peaks on the summit of a seamount or opposing rims of a volcanic crater. If the features are separate peaks, they probably represent individual vents with local accumulations of volcanic material. Should the double peaks represent craters, they are much larger than those deemed "typical" by Menard (1964, p. 62), which measure 0.3 to 1.0 km in diameter and 100 to 200 m deep. Valley type features such as the one along the axis of Verdi Seamount might represent crestal grabens.

Several of the Musicians Seamounts are surrounded by moats. Depressions occur around Rachmaninoff, Debussy (fig. 3c), Dvorák, and Godard Seamounts. Less obvious depressions associated with Mussorgski and Tchaikovski Seamounts are not well illustrated by the 100 m contour interval. Depressions surrounding the central block are probably caused by marginal downwarping resulting from subsidence of the block.

2.4 Central Block (Musicians Horst)

The most prominent bathymetric feature on plate I is an elevated block, termed the Musicians Horst, lying between 159° and 165°W and 31.5° and 33°N. Boundaries of the horst are illustrated in figure 2. The northern boundary of the horst between Puccini and Donizetti Seamounts is formed by a pronounced scarp, often over 2000 m in relief and averaging 1700 m in relief (fig. 3c,d,e). A similar scarp, averaging 1500 m in relief and extending from Donizetti west-southwest to Wagner Seamount, forms the southeastern boundary of the horst. The area of the Musicians Horst on plate I is about 41,000 square km.

The scarps bounding the Musicians Horst are probably the result of normal faulting. Four grabens, two large and two small, exist within the Musicians Horst. The largest, located north of Verdi Seamount (fig. 3a) evidently has dropped 1200 to 1500 m below the level of the surrounding topography. The most unusually shaped graben is the trough located between Bizet and Schubert Seamounts (fig. 2; 3c,d) which extends from 32.3°N, 160.9°W, southwest around the fishhook extension of Bizet and then turns north and spreads out. This trough is 800 to 1500 m below the surrounding topography and at one point reaches a depth of 6035 m. Two smaller grabens found near the center of the Musicians Horst along 162.4°W have relief of up to 1000 m. All of the grabens have extremely flat floors; the deeper ones have relatively steep sides.

Several seamounts and ridges appear on top of the Musicians Horst. Largest of these is Wagner Seamount with a shoalest sounding of

2243 m. North of Wagner lie Rossini and Bellini Seamounts, which rise to within 2674 m and 2984 m of the surface, respectively (fig. 3b). The ridge extending west-southwest from the northern part of Bellini Seamount culminates in a small seamount with a shoalest sounding of 3788 m. Strauss and Lange Seamounts form the northern border of the western end of Musicians Horst in the map area. Due west of Rossini Seamount lies Verdi Seamount. Verdi has a least depth of 2871 m and is bounded on the north by an east-west scarp that is on trend with the scarp that forms the northern boundary of the eastern part of the Musicians Horst.

Bizet Seamount to the north and Schubert Seamount to the south are parallel east-west trending features that comprise the boundaries of that portion of the Musicians Horst which lies between 161°W and 162.5°W. Bizet is bordered on the north by the northern boundary scarp that attains its greatest relief, 2350 m in this area (fig. 3d). A smaller ridge, 1000 to 1500 m high, extends southwest from the eastern end of Bizet Seamount.

Easternmost major feature on the Musicians Horst is Donizetti Seamount extending from about 159°W, 32.3°N west to almost 161°W. A peak with a shoalest sounding of 2888 m forms the highest portion of this feature. East of 159°W the Musicians Horst becomes unrecognizable; the boundary faults appear to die out between 158°W and 159°W.

Depressions border the Musicians Horst. These depressions are more pronounced where the boundary scarps are better developed. Along the northern side of Bizet and Donizetti Seamounts these depressions exceed 6000 m in depth, over 200 m below the regional level. Depths greater than 5900 m found south of the southern boundary scarp are also 200 m below the regional level. Depressions of somewhat lesser magnitude border the western portion of the Musicians Horst (fig. 3).

2.5 Abyssal Hills

Abyssal hills are found throughout the area of plate I, occurring unmasked by other topography in the eastern and northern portions (fig. 3f,g). Hills range in size from several tens of meters relief to 1000 m, the average relief being a few hundred meters. Exact size of the base of the abyssal hills is difficult to assess because the 18.5 km trackline spacing is greater than the basal dimensions of the hills. Hills on the sea floor in the map area seem to be similar in form to those described by Moore and Heath (1967) but slightly larger. Hills occasionally are elongated and form low ridges. Minor depressions, on the order of 10 to 30 m and too small to be defined by the 100 m contour interval of plate I, often are associated with the abyssal hills.

Gentle topography and the relatively large contour interval render contouring of the abyssal hills somewhat subjective. General depth of the sea floor is about 5900+ m in the northeastern portion of the area, with floors of the depressions as deep as 6168 m. South of 32°N the general depth of the sea floor is about 100 m less.

Comparison of fathograms from the few east-west tracklines in the northeast portion of plate I with those from north-south lines reveals a much greater frequency of slope reversals along the east-west lines, indicating that the east-west lines are more nearly perpendicular to the grain of the abyssal topography. The dominant grain of the topography, therefore, probably is oriented nearly north-south. Since the width of the abyssal features varies from 2 to 7 km, they do not show up well on north-south tracklines spaced 18.5 km apart. Conversely, any east-west trends are very obvious with north-south tracklines. These two factors combine to impart an apparent east-west grain to the abyssal topography on plate 1.

3. MAGNETIC ANOMALIES

Residual magnetic anomalies were plotted on a Mercator projection at the same scale as the bathymetry and were contoured at an interval of 100 gammas. This interval is sufficient both to delineate the major anomalies and to mask any minor discrepancies among data gathered at different times and with different techniques. Plate 2 is the resultant magnetic anomaly map.

3.1 Anomalies Associated With Topography

All of the named seamounts, almost all of the unnamed ones, and many of the hills in the area under consideration have normally polarized, local dipole anomalies. Anomalies are always parallel to the trend of an elongated seamount. Intensities of the anomalies vary; greatest are related to Tchaikovski Seamount (1252 gammas peak to peak) and Rachmaninoff Seamount (1186 gammas peak to peak). The largest positive anomaly is +709 gammas on Debussy Seamount and the largest negative is -712 gammas on Rachmaninoff Seamount. Origin of these local dipole anomalies is attributed entirely to vulcanism (Malahoff and Woollard, 1966).

The Musicians Horst has linear, negative anomalies along all northern scarps and linear, positive anomalies along the south-facing scarps. Theoretical magnetic anomalies were calculated over six crossings of the Musicians Horst using the method of Heirtzler et al. (1962), which assumes a 2-dimensional structure. Results indicate that, assuming a magnetic susceptability of 0.01 EMU, the shape and amplitude of the observed anomalies can be accounted for largely by induced magnetism in the present-day earth's magnetic field. Computed and observed anomalies for two of these crossings are shown in figure 4. Observed anomaly amplitudes over some of the seamounts on the horst are greater than the computed amplitudes, suggesting that these seamounts may have some thermoremanent magnetism.

Large positive anomalies along the southeastern edge of plate 2 are associated with the Murray fracture zone. These anomalies are the result of intrusion at depth along the Murray. Topographic and magnetic features of the Murray fracture zone in this area are discussed in detail by Naugler and Erickson (1968).

Some smaller seamounts, ridges, and hills have no noticeable anomalies associated with them. Most prominent of these are the 1000 m high ridge extending northeast from the saddle between Debussy and Dvorák Seamounts and a 1400 m high seamount located at 160.0°W, 31.7°N.

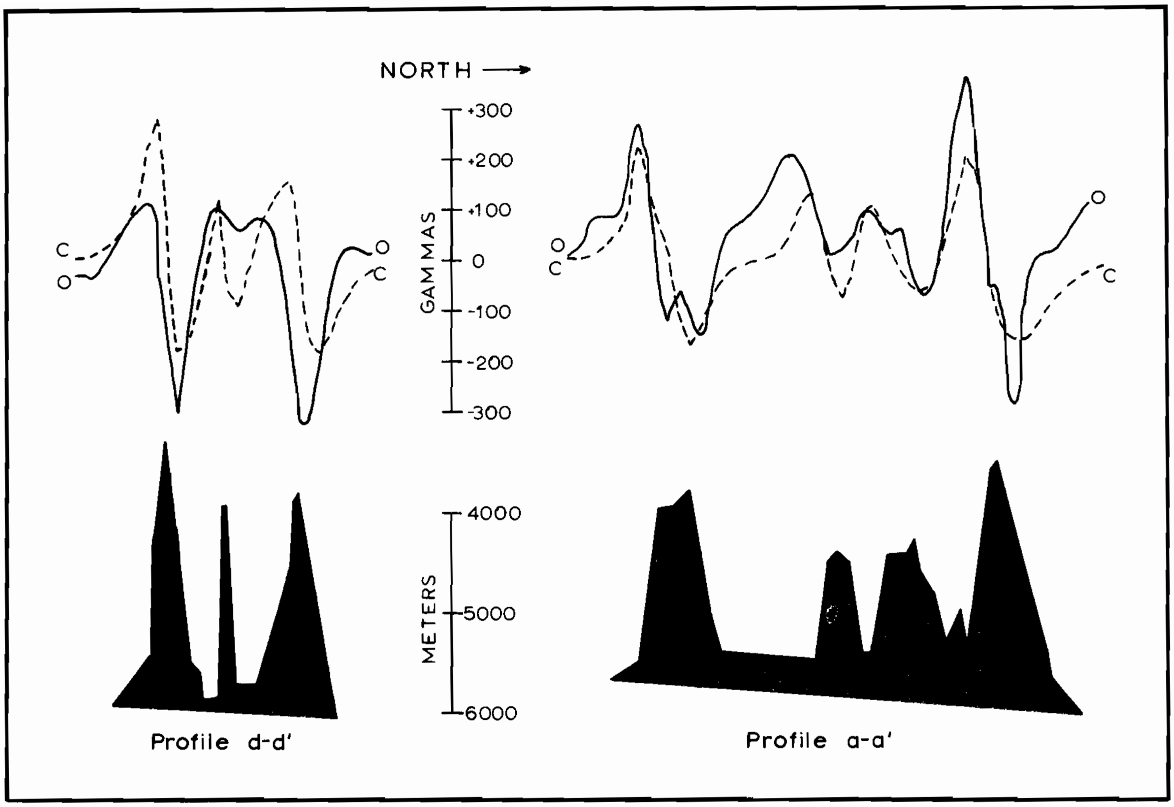

Figure 4. Computed (C-C) and observed (O-O) magnetic anomaly profiles across the Musicians Horst. Bathymetric profiles are approximations of bathymetry (fig. 3) made for the computation of theoretical anomalies.

The seamount has small anomalies not noticeable at the 100 gamma contour interval; the ridge has none. Many abyssal hills, especially larger ones, have small local dipole anomalies.

Dvořák Seamount has a reversed local dipole anomaly located over its southern flank, measuring 580 gammas, peak to peak. This may be the result of a later intrusion at a time of reversed polarity. The main portion of Dvorák Seamount possesses a normal local dipole anomaly, although it is much less than that of the other large seamounts.

Magnetic anomalies in the southern portion of the report area also have been described by Vajk (1968) and Halpin and Vajk (1967). This report agrees with their work, indicating the area characterized by abyssal hills as one of low magnetic relief (0 - 50 gammas), the Murray fracture zone as an area of moderate magnetic relief (100 - 300 gammas), and seamounts with high magnetic relief (over 300 gammas).

3.2 Anomalies not Associated with Topography

Two long linear dipole anomalies appearing on plate 2 are not associated with topography. Both anomalies trend generally northwest, have wave heights of 300 to 500 gammas, wavelengths of 50 to 90 km, and are normally polarized with the positive anomaly to the southwest. The northern dipole anomaly appears at the northwest corner of the map, extends southeast, and meets the anomaly associated with the northern boundary scarp of the Musicians Horst. West of the map area is a holiday area (fig. 1) so the anomaly cannot be traced to the northwest. Intensities of the northern dipole anomaly range from +302 to - 530 gammas.

The southern anomaly appears just south of the southern boundary scarp of the Musicians Horst at about 164°W and extends southeast to join the Murray fracture zone at 161°W. It is offset left laterally along the northeastern trend defined by Debussy Seamount and the non-magnetic ridge extending northeast from Debussy. Another small left lateral offset occurs just north of the Murray. Intensities of the southern anomaly, where not influenced by other structures, range from +336 to -253 gammas. The large magnetic positive noted by Vajk (1968, p. 14) at 29°22'N, 160°58'W, occurs at the junction of the positive portion of this linear anomaly with the positive anomaly along the northern margin of the Murray fracture zone. SEAMAP data shows that this magnetic anomaly high reaches +630 gammas.

Because these two anomalies are not associated with topography, they are probably associated with intrusive rocks found below the ocean floor. Such anomalies could be associated with the intrusion of the Musicians Seamounts, perhaps reflecting large feeder dikes.

Results of an investigation of the major east-west fracture zones north of the Hawaiian Ridge (Rea, 1969) indicate an alternative explanation of these anomalies. This study demonstrated a change in the direction of sea floor spreading along a zone termed the bending line, approximated in part by the Musicians Seamounts. Spreading direction changed 12° to 15° along this line in the area between the Murray and Pioneer fracture zones. The southern of the two dipole anomalies joins the Murray fracture zone at its bending point and the northern one trends northwest toward the bend in the Pioneer. These anomalies may represent intruded shear zones resulting from differential movement at the axis of bending. It is possible that these two anomalies were originally the same, perhaps a sea-floor spreading type anomaly, and was offset 350 km right laterally by an intermittent transform fault. Development of such an intermittent fault in areas of change in direction of sea-floor spreading was suggested by Menard and Atwater (1968). The Musicians Horst marks the location of this possible intermittent fault.

4. ACKNOWLEDGEMENTS

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5. APPENDIX A

List of Seamounts

NAME	LOCATION OF PEAK (nearest 0.05°)	LEAST DEPTH (meters)	RELIEF (nearest 100 m)
Lange	33.25°N, 164.75°W	3072	2600
Strauss	33.30°N, 164.15°W	3244	2700
Verdi	32.15°N, 163.50°W	2871	2800
Bellini	32.50°N, 163.15°W	2984	2500
Rossini	32.10°N, 162.80°W	2665	3000
Wagner	31.80°N, 162.95°W	2243	3400
Puccini	32.25°N, 162.35°W	3598	2100
Bizet	32.35°N, 161.20°W	3532	2500
Schubert	31.95°N, 162.15°W	2571	3200
Donizetti	32.20°N, 160.30°W	2888	3200
Godard	31.45°N, 164.60°W	2599	3200
Brahms	31.15°N, 162.35°W	2815	3100
Mussorgski	30.35°N, 163.85°W	2527	3200
Debussy	30.30°N, 162.10°W	1796	4000
Dvorák	30.55°N, 161.35°W	2909	2900
Rachmaninoff	29.60°N, 163.40°W	1846	3900
Tchaikovski	29.40°N, 162.10°W	2290	3300
Liszt	28.95°N, 162.20°W	1582	4000

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GPO 859 292