5. UNDERWAY GEOPHYSICS—LEG 60 AND RELATED SURVEYS[1]

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ABSTRACT

Two plates in the back pocket to this volume are described in this chapter. The first plate summarizes the underway bathymetry, gravity, and magnetics data collected during preparation for DSDP Leg 60 and describes the reduction procedures used to prepare these data as contour maps. The second plate summarizes and interprets the structure of the Mariana arc system based on the geophysical data and the drilling results.

INTRODUCTION

The success of Leg 60 can be attributed largely to the background knowledge of the Mariana arc region acquired during extensive site selection surveys conducted prior to drilling. Seventeen holes were drilled at 10 sites in a wide variety of geologic environments, and nearly 2100 meters of sediment and 609 meters of igneous basement were cored. We encountered numerous problems, generally because of adverse drilling conditions, that necessitated constant changes in plans and the drilling of four unplanned alternate sites. Nevertheless, scientists on the *Glomar Challenger* were always able to utilize the site survey data and interpretations to alter their cruise plan in an effective and logical manner.

This chapter describes the geophysical maps (Plate 1, back pocket) that are synthesized from all the site survey efforts. In Plate 2 (back pocket) the site survey data, a seismic reflection profile acquired by the *Challenger* during Leg 60, and the drilling results are synthesized into an interpretive block diagram of the crustal structure of the entire active portion of the Mariana arc.

REGIONAL GEOPHYSICS (Plate 1)

The general results of individual site selection surveys—specifically in the Mariana Trough (Fryer and Hussong) and in the Mariana Trench and fore-arc region (Hussong and Fryer)—and for multichannel seismic reflection profiles around the entire island arc system (Mrozowski et al.) are described elsewhere in this volume.

The bathymetry, gravity, and magnetics data from all the site survey cruises, together with data collected earlier by the Scripps Institution of Oceanography, have been compiled and made into contour maps presented as Plate 1. This chapter will describe the general data reduction procedures used to prepare Plate 1. Interpretations of these data are made throughout this volume, particularly in the site survey and site report chapters, and in Plate 2 of this chapter.

Bathymetry

The bathymetry map utilized all ship tracks on Plate 1. Most of the data were collected by Hawaii Institute of Geophysics (HIG) during drill site selection cruises in 1976 and 1977 and were located by satellite positioning, with constant interpolation and recomputation based on digitally recorded ship's speed and direction sensors. Because crossing errors during these survey were small, discrepancies with other data sets were usually resolved by repositioning the latter tracks to fit the HIG survey. Water depth was picked from 3.5-kHz reflection records every 5 min. (1 mile of track or less) at all bathymetry peaks and troughs and at inflection points where relief exceeds 0.01 s. Depths are in meters corrected for sound velocity in water using Matthew's Tables.

Gravity

The free air gravity anomaly map (Plate 1) utilized only the 1976 HIG survey data. These data were obtained with a LaCoste and Romberg S-33 gravimeter and picked at 5-min. intervals.

Most sea gravity meters can measure gravity to ± 1 mgal, and Eotvos correction must be applied to this measurement to compensate for the velocity of the ship on the Earth. The correction used for these surveys is Eotvos correction = $7.487(S)(\sin C \cos\varphi) + (S^2/240.8)$, where S = ship's speed, C = ship's true course, and φ = latitude. Because the Mariana surveys are laid out across the strike of the trench and island arc, gravity measurements and navigation are most accurately determined along the long east-west tracks. Water currents in the Mariana arc region—also generally east-west—are variable and are as great as 1.5 kts. Thus even under good conditions the survey ship's true velocity can be ascertained only to about ± 0.3 kts. On an east-west track this produces an Eotvos correction that is good only to ± 2.5 mgals. These inaccuracies, combined with rapid variation of gravity in the area, produced high crossing errors in the gravity data.

The 1976 HIG survey had several long profiles that are constrained by multiple satellite navigation fixes. The gravity data along these lines are therefore more accurate because the navigation is better. Later HIG data (1977) were collected in short profiles as part of grid surveys. The resultant gravity data and data from other institutions are less accurate and were therefore of little use for improving the contour map prepared from the 1976 survey, although the 1976 track was adjusted with a few cross lines from the 1977 HIG survey. Although

[1] *Initial Reports of the Deep Sea Drilling Project*, Volume 60.

the shape of the free air gravity anomaly field is probably representative, there were often crossing errors as great as 20 mgals; this level of inaccuracy should therefore be assumed for any specific point on the map.

As expected, the shape of the gravity field mimics the bathymetry. A notable exception is the +40-mgal anomaly on the fore-arc described by Hussong and Fryer (this volume) and drilled at Site 458.

Magnetics

The total intensity magnetic field was also picked on 5-min. intervals. The IGRF (1965 parameters) was calculated at every data point and removed from the observed total field observation to obtain the magnetic anomaly.

Again, the available data density compared to the accuracy of the data made it ineffective to use more than the 1976 HIG data alone to prepare the map on Plate 1. In this case the major problem is the proximity of the survey area to the magnetic equator (~8°N at this longtiude) and the large diurnal variations in the Earth's magnetic field (up to ±150 gammas) encountered near the Mariana arc. Using magnetic observatory records from Guam (almost 500 km south of the survey area) and estimated diurnal variations in our survey area calculated by comparing crossing errors at various times during each survey day, we were able to prepare estimated correction curves for diurnal variation during the survey. These were applied to the 1976 data to prepare the map on Plate 1, but the inaccuracies were still too great to warrant adding data to the map.

On the Pacific plate east of the Mariana Trench the magnetic anomalies are smooth and of sufficient amplitude to be readily correlated and contoured; they show an apparent seafloor spreading stripe striking about 35°–45°. These anomalies are probably of Mesozoic age and are described by Hussong and Fryer (this volume).

In the Mariana Trough, poorly defined magnetic anomalies have been correlated in patterns suggestive of back-arc seafloor spreading by Bibee et al. (1980) and Hussong and Fryer (1980) but are not sufficiently well defined to show up on this contour map.

MARIANA ARC STRUCTURE (Plate 2)

Plate 2 (back pocket) is a structural interpretation of the Mariana arc prepared from Leg 60 drilling results, geophysical profiles, and earlier data. The reflection seismic profile was collected by the *Challenger*, using a 120 in.^{3} airgun sound source and a single-channel hydrophase array as a receiver. The seismic data were acquired at a 10-s repetition rate and were band-pass-filtered from 20 to 80 Hz. At the very beginning of the profile the *Challenger* deployed a smaller (20 in.^{3}) airgun, recorded the signal filtered from 40 to 60 Hz near Site 452, and successfully revealed the thin sediment layer above the cherts that was drilled at this old Pacific plate site.

Most of the large-scale structural trends in the Mariana arc system are visible on this profile. From east to west, we first encounter high-angle faulting in the Pacific Ocean basin which increases toward the trench as the top of the plate is stretched during bending prior to subduction. The trench axis and the inner (island arc) wall of the trench are apparently devoid of ponded sediments. West of the trench slope break (at about 5.2-s depth), there are thick sediments on the Mariana fore-arc that are disrupted by normal faults across the entire arc. The structure of the fore-arc and arc is discussed in more detail in Hussong and Fryer (this volume).

The axis of present arc volcanism is over 5 km west of the location of Site 457 on the reflection seismic profile. Note that the acoustic basement is shallowest considerably east of the axis of volcanism. The thick, and relatively shallow, sediments at Site 457 are actually the northeastern flank and Alamagan Island. Thus if the individual active volcanic cones were removed from the broad arc, the shallowest portion of the arc would be over 20 km east of the present axis of volcanism. It may be that this regional bathymetric trend is indicative of the location of older arc rifting when the Mariana Trough began opening. Thus the broad arc bathymetric high is the western side of the portion of old island arc that moved with the Mariana Trench to the east relative to the West Mariana Ridge. If this speculation is correct, the present volcanic arc is located over crust that is structurally the easternmost part of the Mariana Trough, a position that is the mirror image of Site 453 in the westernmost part of the back-arc basin.

The magnetic field contour map on Plate 1 also shows a change in anomaly character 15–20 km east of the volcanic arc that could also represent the transition from underlying island arc to back-arc basin crust.

West of the axis of the Mariana volcanic arc a thick apron of volcaniclastic sediment covers the eastern side of the Mariana Trough. When the back-arc basin crust is not covered by sediments it clearly displays rotated fault blocks whose steep sides form an axial graben that is the center of back-arc spreading at this latitude (see Fryer and Hussong, this volume). The western end of the reflection profile on Plate 2 is about 10 km from the edge of the West Mariana Ridge.

The crustal block diagram in Plate 2 is generalization and interpretation of the drilling results, HIG and LDGO site survey data, and crustal structure models of Ambos (1980), Bibee et al. (1980), LaTraille and Hussong (1980), and Sager (1980). The bathymetry is modified from a physiographic diagram first prepared by William Coulbourn. The velocity structure is smoothed and constrained to reflect the evolution of the arc system described by Hussong and Uyeda (this volume), including the symmetry of back-arc spreading and the occurrence of relatively thin back-arc basin crust beneath portions of the active Mariana volcanic arc.

In the arc the crustal structure is drawn to reflect the interpretation that the boundary between old island arc and young back-arc basin crust is east of the present axis of volcanism, so that the active Mariana island arc volcanoes are located over the eastern edge of the back-arc basin.

With the exception of the actual contact zone between the converging Pacific plate and the Mariana Island arc, tensional tectonic features occur everywhere in the region. The leading edge of the Mariana arc is apparently subject to net subsidence caused by tectonic erosion of the island arc by the subducting Pacific plate.

ACKNOWLEDGMENTS

The acquisition and reduction of the data in this report required considerable effort from many individuals. First, the crews and scientific staff of research vessels from Hawaii Institute of Geophysics, Lamont-Doherty Geological Observatory, Scripps Institution of Oceanography, and the Deep Sea Drilling Project acquired the data. Patricia Fryer, Larry Wipperman, and Jon Tuthill helped reduce, compile, and contour the data in Plate 1. Steve Dang drafted the contour maps. William Coulbourn provided essential artistic talent and geologic insight for the block diagram on Plate 2. Virginia Roman and Tommy Hilliard prepared the final plates. The chapter was reviewed by David Epp, L. W. Kroenke, and J. H. Natland. The preparation of these data was funded through the NSF/DSDP site survey program; 1976 and 1977 subcontracts CU-Hawaii-25903 (prime contract NSF-C482). This text and accompanying plates were prepared while the author was on sabbatical leave at the Lamont-Doherty Geological Observatory, with support from National Science Foundation grant OCE79-19636. This paper is Hawaii Institute of Geophysics Contribution No. 1145.

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