

7. MARIANA TROUGH—BACKGROUND AND OBJECTIVES¹

S. Uyeda, Earthquake Research Institute, University of Tokyo, Tokyo, Japan
and
D. M. Hussong, Hawaii Institute of Geophysics, Honolulu, Hawaii

The Philippine Sea is divided into three major basins (Figure 1), each with different times of formation and being elongated in shape in a north-south direction. From west to east, they are the West Philippine Basin, the Shikoku and Parece-Vela Basins, and the Mariana Trough. The West Philippine Basin is believed to be the oldest and the Mariana Trough the youngest (and still actively forming) basin.

Various hypotheses have been advanced for the origin of the West Philippine Basin (i.e., Karig, 1971; Uyeda and Ben-Avraham, 1972; Louden, 1976; Erlandson et al., 1976; Watts et al., 1977). In most of these, crustal formation by sea-floor spreading in the Eocene or earlier time is postulated. Although the results of DSDP Legs 31 (Karig, Ingle, et al., 1975) and 59 (Kroenke, Scott et al., 1980) indicate younger basement ages (early Oligocene or older, Leg 31; middle Oligocene, Leg 59), the scientific party of Leg 59 still appear to favor the Eocene spreading on the basis of evidence for the existence of a later hiatus. From the direction of the magnetic lineations, the spreading in this basin is believed to be in the west-northwest-east-southeast direction.

In contrast, the younger basins to the east are believed to have spread in an approximately east-west direction, parallel with the ridges that separate them. The Shikoku and Parece-Vela Basins opened in the late Oligocene to middle Miocene time (Watts and Weissel, 1975; Kobayashi and Isezaki, 1976; Mrozowski and Hayes, 1979; Klein, Kobayashi, et al., 1980; Kroenke, Scott, et al., 1980), and then spreading opened the Mariana Trough at a later time and has continued to the present.

Karig (1971) hypothesized that these basins were formed during two episodes of spreading, a process associated with the subduction of the Pacific plate. He further suggested that the onset of the spreading of the Mariana Trough took place during the late Pliocene (~3 m.y. ago), and therefore, the average extensional rate has been about 8 cm/y. An analysis of magnetic lineations in the central portion of the Mariana Trough (Bibee et al., 1980) reveals some correlation of spreading-type anomalies, and suggests an extensional rate of 3 cm/y. (equivalent to a symmetric half-rate of 1.5 cm/y.). If this rate is extrapolated for the entire width of the Mariana Trough, it would suggest that opening began in the latest Miocene or very early Pliocene (~5

m.y. ago). These earlier data for the onset of the opening provide an age/depth relationship that is closer to the model advanced by Sclater et al. (1976).

The mechanism of back-arc spreading is one of the most challenging problems in plate tectonics, because it requires an explanation of tensional forces behind a plate boundary where two plates are converging. Many different hypotheses have been presented for back-arc spreading; they may be grouped roughly into two categories. In one group back-arc spreading is caused by an *active* tensional force inherent to subduction (Karig, 1971; McKenzie, 1969; Matsuda and Uyeda, 1971; Sleep and Toksöz, 1971). In the other group of hypotheses, the back-arc extension is regarded as a *passive* process caused by either seaward retreat of trenches (Moberly, 1972; Kanamori, 1971) or relative motion between landward and seaward plates (Scholz et al., 1971; Hyndman, 1972; Wilson and Burke, 1972; Uyeda and Kanamori, 1979). Here, the style of back-arc spreading may be more similar to normal ocean-floor spreading than in the other group. In order to test these hypotheses, the spreading history, in particular the rate and degree of symmetry, is of key importance.

There are, however, definite differences between mid-ocean spreading and back-arc spreading, apparently controlled by the proximity of the subduction zone in the back-arc situation. The most prominent ones are contrasts in the clearness of magnetic lineations, heat-flow-age relationship, depth-age relationship, possibly in the gravity anomalies, and in the structure of the crust and upper mantle. To define the extent of similarities and dissimilarities between mid-ocean spreading and the two back-arc spreading models would be the most important step at this stage of our investigation.

There are several other problems concerned with marginal basin evolution that are ideally suited to DSDP drill hole studies. Of very high priority is the petrologic comparison of deep basement rocks of oceans and back-arc basins. Hawkins (1976, 1977) emphasized the similarity of the basement rocks of the Lau Basins with mid-ocean ridge basalts, whereas Fryer (1978) maintained that there is a definite difference between mid-oceanic basalts and back-arc basin basalts, the latter having undergone a change in composition with the evolution of the arc and back-arc system. Similarities in the degree and type of hydrothermal and other modes of alteration may suggest similarities in the crustal evolution in these two tectonic provinces.

Also, the history of tectonic movements, such as subsidence, faulting, and volcanic activity, which are re-

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

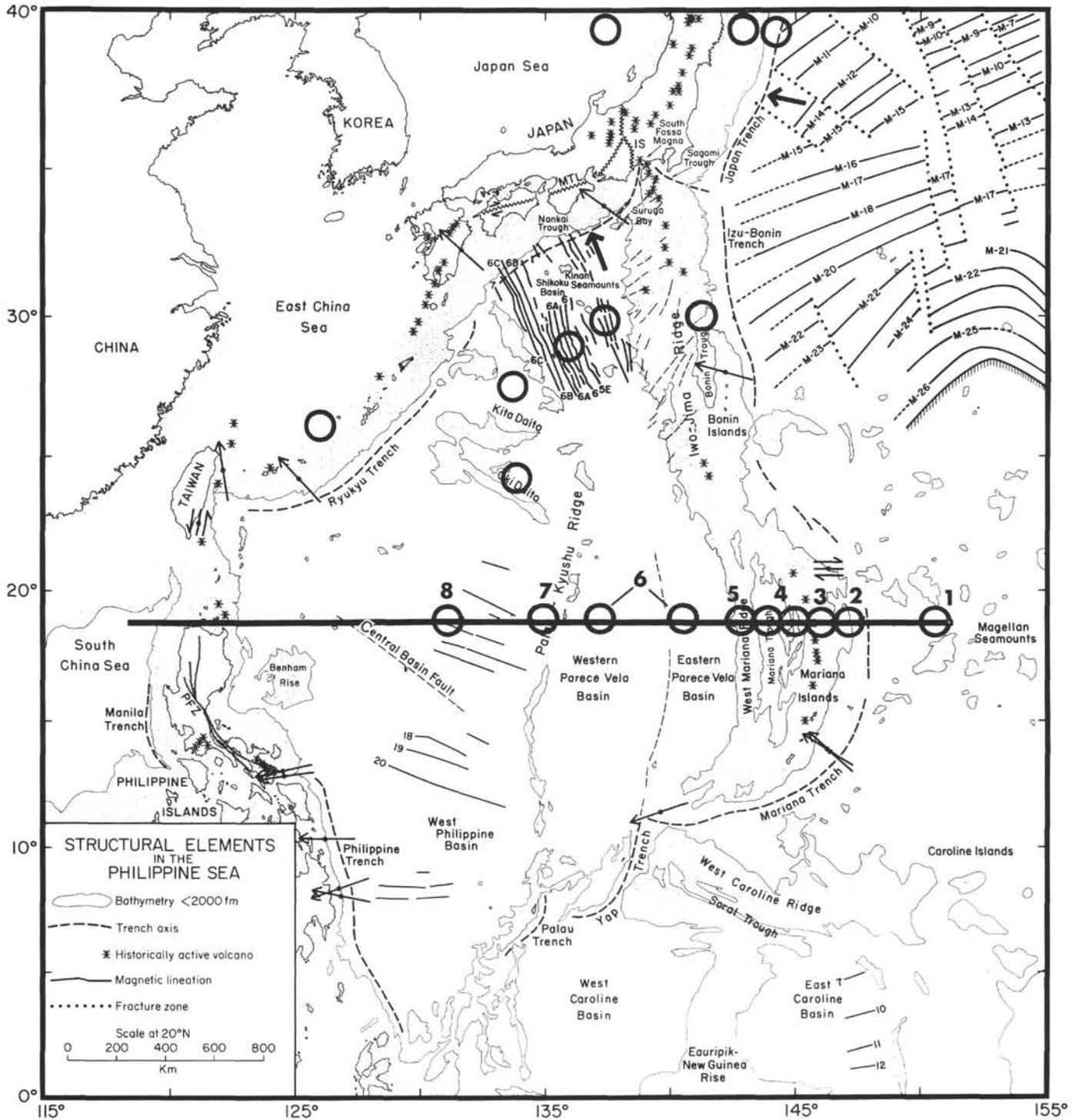


Figure 1. Basic tectonic features in the Philippine Sea (from Watts and Weissel, 1975). The IPOD South Philippine Sea transect, drilling targets SP-1 through SP-8, is shown as open circles.

corded in the sedimentary sequence in back-arc basins, will provide most valuable information to the problems addressed above.

The three SP-4 sites (Figure 2) were designed as an integral part of the Mariana-Philippine transect, and as a minimum data set to meet the forementioned objectives in the presently active Mariana Trough. SP4-F was the

westernmost target, designed to drill crust that formed during the initial stages of basin opening. SP4-E is on a very small sediment pond that is the closest drillable location to the sediment-free axis of the trough where extension is probably presently occurring. It is therefore very nearly the most recently formed Mariana Trough crust. SP4-D is on the eastern side of the apparent axis

of extension, is covered by an apron of pyroclastic sediments from the presently active volcanic arc, and if reasonably symmetric spreading has occurred should be of intermediate age between SP4-F and SP4-E. Sites SP4-E and SP4-D will be discussed in more detail in the Site Reports for Sites 454 and 456, respectively.

REFERENCES

- Bibee, L. D., Shor, G. G., and Lu, R. S., 1980. Inter-arc spreading in the Mariana Trough. *Mar. Geol.*, 35:183-197.
- Erlandson, D. L., Orwig, T. L., Kulagaard, Mussells, G., and Kroenke, L. W., 1976. Tectonic implications of the East Caroline and Lyra Basins from reflection profiling investigations. *Geol. Soc. Am. Bull.*, 87:453-462.
- Fryer, P., 1978. Chemical variation in basalts from marginal basins. Abstracts of Papers, International Geodynamics Conference Tokyo, p. 232.
- Hawkins, J. W., 1976. Petrology and geochemistry of basaltic rocks of the Lau Basins. *Earth Planet. Sci. Lett.*, 28:283-297.
- _____, 1977. Petrologic and geochemical characteristics of marginal basin basalts. In Talwani, M., and Pitman, W. C., (Eds.), *Island Arcs, Deep Sea Trenches and Back-Arc Basins*: Maurice Ewing Series 1, Washington (Am. Geophys. Union), 335-366.
- Hyndman, R., 1972. Plate motion relative to the deep mantle and the development of subduction zones. *Nature*, 238:263-265.
- Kanamori, H., 1971. Great earthquakes at island arcs and the lithosphere. *Tectonophysics*, 12:187-198.
- Karig, D. E., 1971. Structural history of the Mariana Island Arc system. *Geol. Soc. Am. Bull.*, 82:323-344.
- Karig, D. E., Ingle, J. C. et al., 1975. *Init. Repts. DSDP*, 31: Washington (U.S. Govt. Printing Office).
- Klein, G. deV., Kobayashi, K., et al., 1980. *Init. Repts. DSDP*, 58: Washington (U.S. Govt. Printing Office).
- Kobayashi, K., and Isezaki, N., 1976. In Sutton, G., Manghanani, M. H., and Moberly, R. (Eds.), *Magnetic Anomalies in Japan Sea and Shikoku Basin and their Possible Tectonic Implications in the Geophysics of the Pacific Basin and its Margins*, Geophys. Monogr. 19: Washington (Am. Geophys. Union).
- Kroenke, L., Scott, R., et al., 1980. *Init. Repts. DSDP*, 59: Washington (U.S. Govt. Printing Office).
- Louden, K., 1976. In Sutton, G., Manghnani, M. H., and Moberly, R. (Eds.), *Magnetic Anomalies in the Western Philippine Basin, in the Geophysics of the Pacific Basin and its Margins*, Geophys. Monogr. 19: Washington (Am. Geophys. Union), 253-267.
- Matsuda, T., and Uyeda, S., 1971. On the Pacific-type orogeny and its model—extension of the paired belts concept and possible origin of marginal seas. *Tectonophysics*, 11:5-27.
- McKenzie, D. P., 1969. Speculations on the consequences and causes of plate motions. *Geophys. J. Roy. Astron. Soc.*, 18:1-32.
- Moberly, R., 1972. Origin of lithosphere behind island arcs, with reference to the Western Pacific. *Geol. Soc. Am. Memoir*, 132:35-55.
- Mrozowski, C. L. and Hayes, D. E., 1979. The evolution of the Parece-Vela Basin, eastern Philippine Sea. *Earth Planet. Sci. Lett.*, 46:49-67.
- Scholz, C. H., Barazangi, M., and Sbar, M., 1971. Late Cenozoic evolution of the Great Basin, Western United States, as an ensialic inter-arc basin. *Geol. Soc. Am. Bull.*, 82:2979-2990.
- Sclater, J. G., Karig, D. E., Lawver, L. A., and Loudon, K., 1976. Heat flow depth and crustal thickness of the marginal basins of the South Philippine Sea. *J. Geophys. Res.*, 81:308-336.
- Sleep, N., and Toksöz, M. N., 1971. Evolution of marginal basins. *Nature*, 233:548-550.
- Uyeda, S., and Ben-Avraham, Z., 1972. Origin and development of the Philippine Sea. *Nature*, 240:176-178.
- Uyeda, S., and Kanamori, H., 1979. Back-arc opening and the mode of subduction. *J. Geophys. Res.*, 84:1049-1061.
- Watts, A. B., and Weisell, J. K., 1975. Tectonic history of the Shio-koku marginal basin. *Earth Planet. Sci. Lett.*, 25:239-250.
- Watts, A. B., Weisell, J. K., and Larson, R. L., 1977. Seafloor spreading in marginal basins of the Western Pacific. *Tectonophysics*, 37:167-181.
- Wilson, J. T., and Burke, K., 1972. Two types of mountain building. *Nature*, 239:448-449.

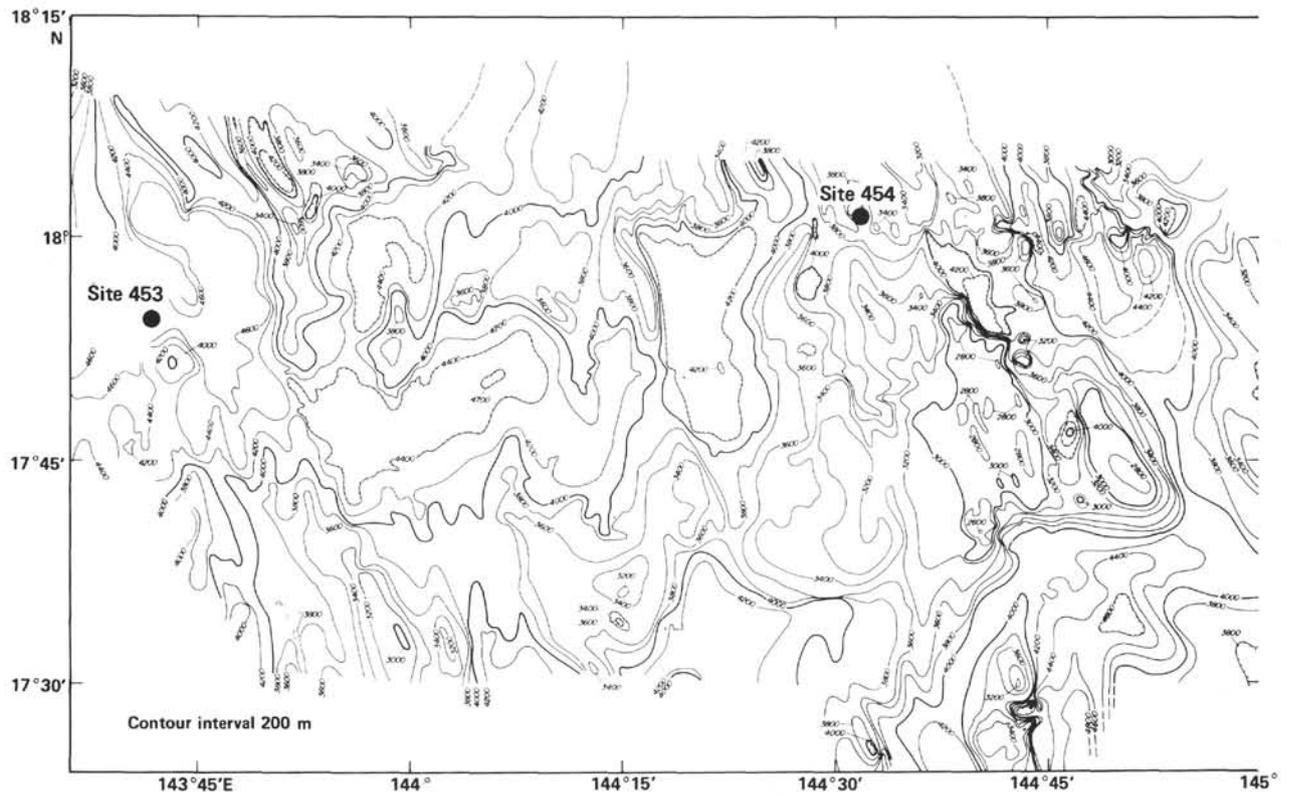


Figure 2. Bathymetry around drilling targets SP-4F, SP-4E, and SP-4D, and Sites 453–456 in the Mariana Trough (from Hussong, this volume).

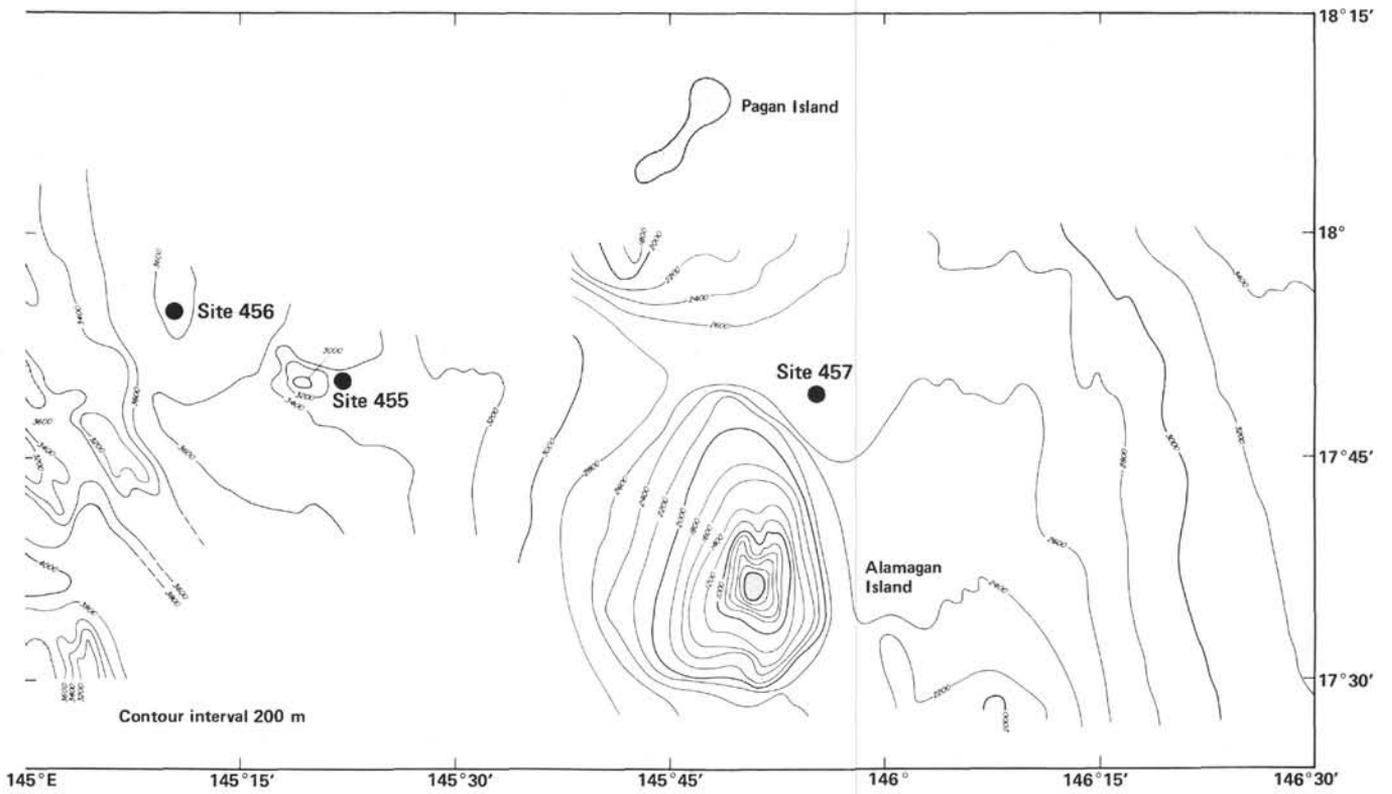


Figure 2. (Continued).