22. SEDIMENTOLOGIC SUMMARY: CLUES TO ARC VOLCANISM, ARC SUNDERING, AND BACK-ARC SPREADING IN THE SEDIMENTARY SEQUENCES OF DEEP SEA DRILLING PROJECT LEG 59

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In partial agreement with the results of DSDP Leg 31 and other published works, the Leg 59 staff concedes that arc volcanism and sundering along with back-arc spreading have occurred in distinct pulses in the Philippine Sea region, migrating eastward relative to the Eurasian plate. Igneous basement becomes younger eastward ranging from pre-middle Oligocene at Site 447 in the West Philippine Basin, lower to middle Oligocene at Site 448 on the Palau-Kyushu Ridge, upper Oligocene at Site 449 in the western Parece Vela Basin, early to middle Miocene at Site 450 in the eastern Parece Vela Basin, to middle Miocene at Site 451 on the West Mariana Ridge. Details of the sequence of volcanic and tectonic events are preserved in the Leg 59 sedimentary columns. Fossil and paleomagnetic data cited in this volume (see Martini et al., Keating) indicate that since the Oligocene the entire region has remained at low latitudes, presumably within the equatorial belts of easterly trades and ocean currents. Thus older (western) sites have received the debris of more recent frontal-arc volcanism farther to the east.

The shallow sites on the Palau-Kyushu and West Mariana ridges accumulated their thick volcaniclastic sediments in fairly shallow water above the carbonate compensation depth (CCD), as evidenced by their biogenic carbonate contents. In both cases, cessation of arc volcanism and arc sundering was followed by slow ridge subsidence. The deeper sites in the West Philippine and Parece Vela basins, although initially shallower than they are at present, accumulated their basal sediments below or slightly above the CCD. Pelagic clays of the region are relatively uniform and owe much of their bulk to volcanism. Smectite, much of it diagenetically associated with volcanic glass, is the dominant clay mineral (Balshaw, this volume).

Perhaps the most dramatic sedimentary units cored are the great thicknesses of volcaniclastic sediments on the Palau-Kyushu and West Mariana ridges, together with the lesser polymictic and volcaniclastic sedimentary aprons west of each ridge. Only Site 449 received no predominantly volcaniclastic units; however abundant ashes accumulated in the lower Miocene units of this site. Hydrothermal alteration of basal volcaniclastic sediments is significant only at Site 450 (Sartori and Tomadin, this volume).

The regional geologic history recorded in the sediments, summarized in Figures 1 and 2, can be reconstructed as follows:

1) *Active-arc volcanism in the middle Oligocene.* Volcanism of the Palau-Kyushu arc provided the basal volcaniclastics of the sedimentary apron at Site 447 west of the Palau-Kyushu Ridge. The inception of this volcanism is uncertain, but it probably ceased about 31 m.y. ago.

2) *Sundering of the Palau-Kyushu Ridge in the late Oligocene.* It is assumed that the sundering of the ridge was initially penecontemporaneous with the cessation of volcanism and that continuing movements caused the downslope movement of the polymictic materials of Site 447 and the accumulation of epiclastic volcaniclastics at Site 448. The contemporaneity of sundering and deposition is documented by the many small normal faults that deformed the volcaniclastics during sedimentation and after compaction (Chotin, this volume). Arc sundering was complete at about 28 m.y. ago, the age of the youngest polymictic breccias of Site 447 and youngest volcaniclastics of Site 448.

3) *Back-arc spreading of the Parece Vela Basin in the late Oligocene and early Miocene.* Arc sundering and back-arc spreading are really a continuum of processes. It is clear from the sedimentary column at Site 449 that by 25 m.y. ago the Palau-Kyushu Ridge was tectonically inactive. It was slowly subsiding but was not shedding epiclastics on the newly formed basaltic basement. It is noteworthy that until about 20 m.y. ago back-arc spreading was not accompanied by frontal-arc volcanism.This is documented clearly at Site 449 by the basal sedimentary unit, a nannofossil ooze lacking a volcaniclastic component. At the time this unit was accumulating (24 to 20 m.y. ago), Site 449 must have been closer to the West Mariana Ridge than it is at present and thus would have received volcaniclastics had the ridge been active volcanically. During this period of volcanic quiescence, Site 449 was above the CCD but must have been subsiding, as indicated by the lithologic change to pelagic clay in the overlying unit.

4) *Renewal of frontal-arc volcanism in the early Miocene.* Approximately 20 m.y. ago, Site 449, now below the CCD and still subsiding, began to accumulate significant quantities of volcanic ash in addition to pelagic clay. Presumably this influx was caused by renewal of frontal-arc volcanism; in turn, this influx of ash caused accumulation rates to become *greater* than they had been during deposition of the basal nannofossil ooze at this site. Normally, the transition from carbonate to pelagic-clay sedimentation would have resulted in a decrease in sedimentation rates.

5) *Cessation of Parece Vela Basin spreading in the early to middle Miocene.* From 20 to about 15 m.y. ago, the Parece Vela Basin continued to spread, receive

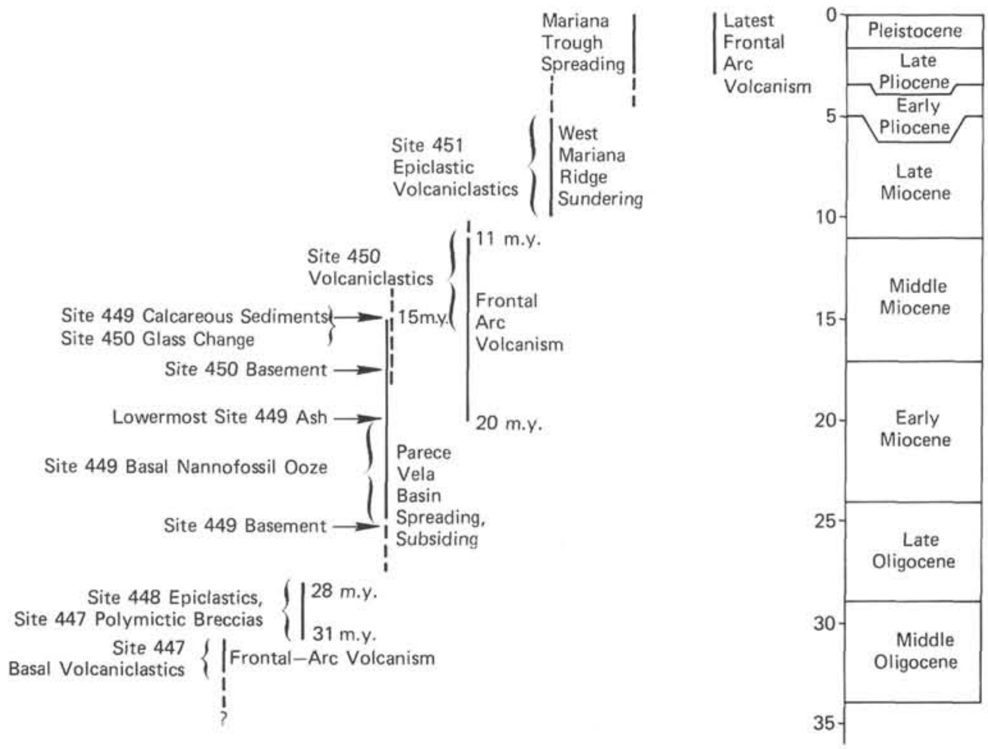

Figure 1. Summary of sedimentology and tectonic interpretations.

volcaniclastics from the frontal arc to the east, and slowly subside. During this interval, at about 17 m.y. ago, the bottom-hole basalts at Site 450 were intruded. The volcaniclastics that subsequently accumulated at this site were mainly arc derived but also included a minor fraction of fine basaltic glass shards tentatively interpreted as hyaloclastites produced during extrusion of the Parece Vela Basin basalts (Rodolfo and Warner, this volume).

The Parece Vela Basin ceased to spread approximately 15 m.y. ago. This event is marked by changes in sediment character at both Sites 449 and 450. Prior to 15 m.y. ago, the sites lay close to but below the CCD and accumulated barren, carbonate-free deposits. The cessation of spreading resulted in an abrupt change in accumulating lithotype at Site 449 (Sartori, this volume) to nannofossil and radiolarian oozes. At the same time Site 450 stopped receiving its minor basaltic glass component. The change in carbonate contents here is less dramatic than at Site 449, but foraminifers began to be preserved in the sediments.

There is some difference of opinion concerning the interpretation of these changes, as discussed at length elsewhere in this volume by Sartori and by Scott et al. The simplest explanation for the synchronicity of the lithotype changes and the time of basin completion estimated from magnetic data is a tectonic one. If subduction at the trench continued after spreading stopped, a brief period of compression causing minor uplift (estimated at 200 m by Sartori, this volume) could have occurred. In any case, the event causing the sedimentologic changes was very short, inasmuch as Site 449 was again below the CCD and continuing to subside 14 m.y. ago.

6) *Cessation of frontal-arc volcanism in the latest middle to earliest Miocene.* By about 11 m.y. ago both Sites 449 and 450 stopped receiving significant quantities of volcaniclastics.

7) *Sundering of the West Mariana Ridge in the latest Miocene.* Great thicknesses of coarse, arc-derived epiclastics were deposited at Site 451 on the West Mariana Ridge throughout the late Miocene, indicating that tectonism in this area did not stop with frontal-arc volcanism. This tectonism, most reasonably ascribed to the sundering of the West Mariana Ridge, occurred penecontemporaneously with epiclastic sedimentation, as seen in the abundant synsedimentary and postdepositional normal faulting of the sediment pile (Chotin, this volume). Subsequently, the sundered and inactive West Mariana Ridge began subsiding and accumulating its uppermost units of calcareous pelagic oozes.

Completion of this history requires examination of evidence not gathered in the drilled transect of Leg 59. As at the Palau-Kyushu Ridge, the sundering of the West Mariana Ridge passed transitionally into the spreading of the Mariana Trough, an event that Karig (1971) estimated to have commenced in the late Pliocene, or about 3 m.y. ago. Finally, the latest and continuing episode of frontal-arc volcanism also commenced in the late Pliocene. Details of Pliocene and Pleistocene events, however, are more properly the subject of the DSDP Leg 60 report.

REFERENCES

Karig, D. E., 1971. Structural history of the Mariana island arc system. *Bull. Geol. Soc. Am.*, 82:323–344.

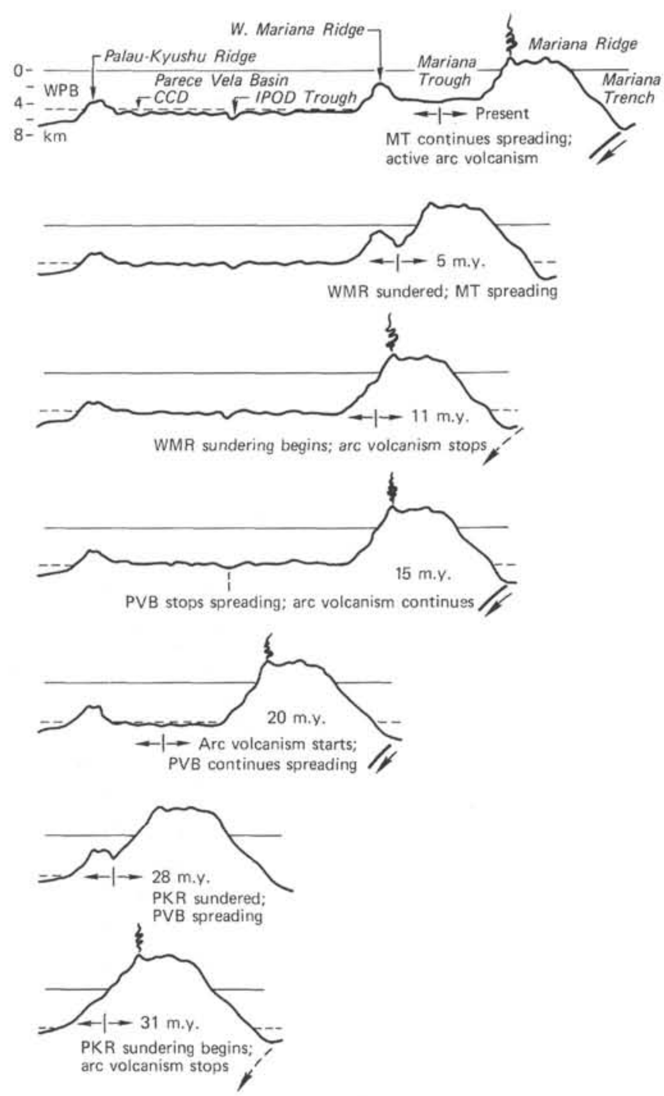

Figure 2. Diagrammatic reconstruction of tectonic and volcanic events in the Philippine Sea. (WPB = West Philippine Basin, MT = Mariana Trough, WMR = West Mariana Ridge, PVB = Parece Vela Basin, PKR = Palau-Kyushu Ridge.)