21. LITHOFACIES OF THE SHIKOKU AND PARACE VELA BASINS

Doris M. Curtis, Consultant, Robertson Research (U.S.) Inc., Houston, Texas
and
Dorothy J. Echols, Department of Earth and Planetary Sciences, Washington University, St. Louis, Missouri; Consultant, Robertson Research (U.S.) Inc., Houston, Texas

ABSTRACT

The lithofacies of the Shikoku and Parece Vela Basins are typical of marginal or back-arc basins of this type, consisting predominantly of hemipelagic and pyroclastic sediments with minor pelagic components. Thickness relationships and distribution of principal facies in each of five time-equivalent intervals (early Miocene through Pleistocene) at eight DSDP sites suggest the time-variable source areas for coalescing clastic wedges within the basins and indicate the timing of volcanism in neighboring volcanic arcs.

Clastic sediments came principally from a northern and eastern source during the middle Miocene; from a northern and northeastern source during the late Miocene; and from northern, northeastern, and northwestern sources during the Pliocene and early Pleistocene. The appearance of pelagic clay and calcareous biogenic sediments in the upper Pleistocene at Site 297 probably marks the inception of the Nankai Trough in mid-Pleistocene time, restricting the previously rapid accumulation of hemipelagic muds in the northern Shikoku Basin. Neogene sedimentation rates were generally lower in the Parece Vela Basin than in the Shikoku Basin.

Major volcanic activity during the middle Miocene was east of these basins, and volcanism was also prominent to the west and north. During the late Miocene, minor volcanism was restricted to the eastern arc. Pliocene volcanism was active only to the northeast. During the late Pleistocene, there was active volcanism to the north.

INTRODUCTION

The object of this paper is to describe and interpret the vertical and lateral distribution of lithofacies in two adjoining back-arc or marginal basins, for the purpose of interpreting the sedimentary and tectonic history of these basins. To do this, we divided the sections penetrated on four Deep Sea Drilling Project legs (Legs 6, 31, 58, and 59) at eight sites (Sites 53, 54, 297, 442, 443, 444, 449, and 450) into five readily identifiable time-equivalent intervals defined by paleontologic datum levels, according to chronostratigraphic criteria used in the reports on Sites 442, 443, and 444 (this volume). The sequence penetrated in these two basins falls naturally into five time-stratigraphic subdivisions: early Miocene (22.5–16 m.y.), middle Miocene (16–10.5 m.y.), late Miocene (10.5–5 m.y.), Pliocene (5–1.6 m.y.), and Pleistocene (1.6–0 m.y.). Figure 1 shows the location of the Shikoku and Parece Vela Basins behind the Marianas arc, and the sites used in this study. Figure 2 shows the position of each interval boundary by core number at each site.

For each site, the lithologic details of each interval are generalized into lithofacies (see White et al., this volume), then plotted on ternary diagrams (Figure 3) to show the relative dominance of each significant lithofacies component for each interval at each site.

The lithofacies distribution has been plotted in three ways: (1) in a series of cumulative paleostratigraphic cross-sections, showing thickness and lithofacies at close of each time interval (Figure 4); (2) in a series of isopach maps with lithofacies symbols, showing lateral facies distribution relative to source areas (Figure 5); and (3) in two composite time-stratigraphic sections which show lithofacies distribution by time, without reference to relative thicknesses (Figure 6). The lithofacies are:

- I Hemipelagic (clays and mudstones)
- II Resedimented (mudstones, sandstones, conglomerates)
- III Resedimented (carbonates)
- IV Pelagic (non-biogenic clays)
- V Pelagic biogenic
  - Va - calcareous
  - Vb - siliceous
- VI Pyroclastic (volcanic ash, tuff, vitric volcaniclastics).

For this study, we have combined the facies units into three principal groups, each of which contains one or more genetically related facies, as follows:

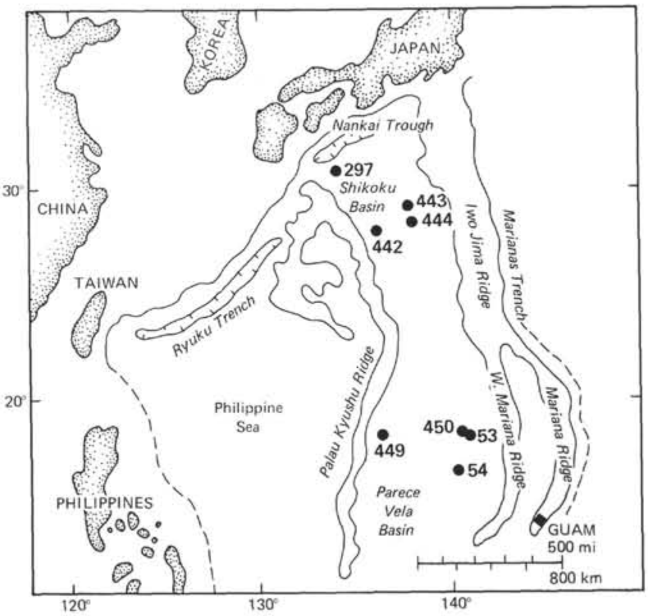

Figure 1. *Location of Shikoku Basin, Parece Vela Basin, and DSDP sites.*

Terrigenous (I, II, III)
Pelagic (IV, Va, and Vb)
Pyroclastic (VI)

These make up the three major components in the ternary diagrams (Figure 3). The diagrams are subdivided to show relative proportions of each major component, and the symbols used in Figure 3 are repeated to show the facies distributions plotted in Figures 4, 5, and 6.

EARLY MIOCENE (22.5–16 m.y.)

Sedimentary facies deposited during this time interval are difficult to define because of poor core recovery, poor age determinations, and very short sections. In general, sediments of this age tend to occur as thin interbeds between basalt layers. Thus, they may be baked, brecciated, or otherwise altered. They appear to be absent at Site 450, and may also be absent at Sites 297, 443, and 444, where age determinations are uncertain. Where they can be identified, however, the dominant lithofacies are pelagic. In the Shikoku Basin, this is the only time interval in which true pelagic sediments were deposited. In the Parece Vela Basin, where sedimentation rates are generally lower, pelagic sediments are more common. The facies include pelagic non-biogenic clays, pelagic biogenic calcareous oozes, and pyroclastics. The non-biogenic pelagic facies is dominant at Sites 442, 444, and 449. The pelagic calcareous facies is present as calcareous ooze at Site 449, and as limestone at Sites 442, 443, 54, and 53. The limestone is brecciated. Pyroclastic deposits are conspicuous only at Site 53, but are also present at Sites 297, 442, and 449.

No attempt was made to map the thickness distribution of this unit, because of the fragmentary recovery and dubious age identifications. Sediments assigned to this interval, however, appear to be thickest (51 m or more) at Site 449, and possibly at Site 53.

Age m.y.		Site 297			Site 442			Site 443			Site 444			Site 449			Site 54			Site 53			Site 450		
		Nanno-fossils	Fora-minifers	Radio-larians	Nanno-fossils	Fora-minifers	Radio-larians	Nanno-fossils	Fora-minifers	Radio-larians	Nanno-fossils	Fora-minifers	Radio-larians	Nanno-fossils	Fora-minifers	Radio-larians	Nanno-fossils	Fora-minifers	Radio-larians	Nanno-fossils	Fora-minifers	Radio-larians	Nanno-fossils	Fora-minifers	Radio-larians
0	Pleistocene	1–5 6–10	1 5	1 5	2–5 7–13	1 2–4 12–13	1–4	1–7 8–13	1–4 5(?) 12–13	1–3	1–2 3–4 5–6	1–2 3–4	1–4			2									
1.6	Pliocene	11	11 16 17 18					17–18			7 10,B1	7 8													
5	Late Miocene						24	22 23 24 25 26		27 28(?) 29(?)	B2 B3 B4 B5 B9		B2 B6 B6–B7 B8 B9							(2)1 (1)2 (1)3		(1)2 (1)3	4 5		4 5
10.5	Middle Miocene	24 26 27		26	26 27 30,B2	30	25 26 27	30 46(?) 47	48?		B10 B14 B22 B23	B22–B23	B11 B12 B22	5 6 7 8		5,6 7	1 4 5–7	1 5	1 1 4 5–7	1			6 7 8 9–12 13–17 18–35	17 17	
16	Early Miocene			27(?)	B9	B9		46(?) 47–49(?)						10 11 12 13	13		8?	8?		4? 7?					
22.5																									

Figure 2. *Time-equivalent intervals at eight DSDP sites in the Shikoku and Parece Vela Basins, with core numbers and fossil groups by which cores have been dated.*

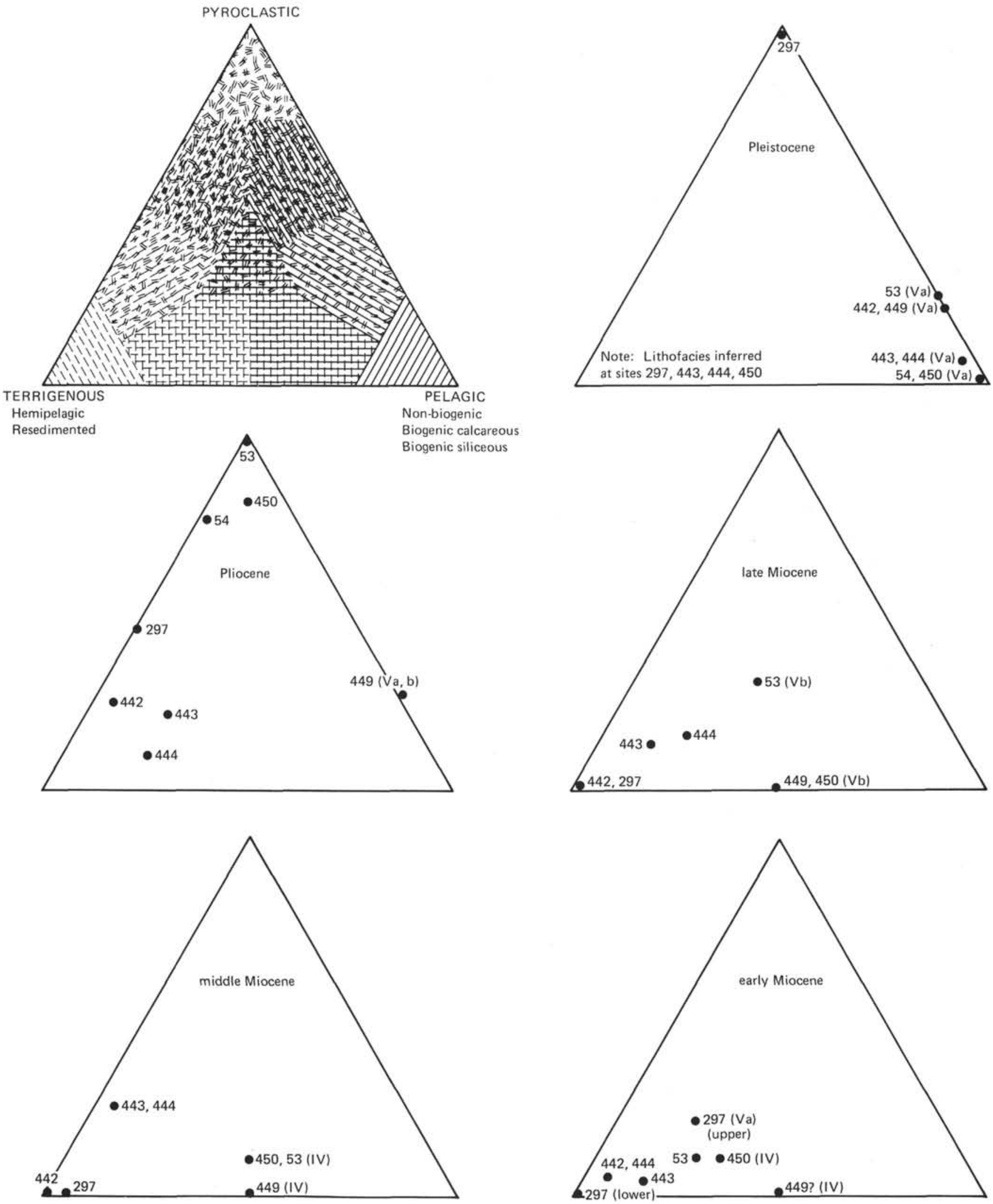

Figure 3. *Ternary diagrams of major lithofacies components (three major components and seven combinations of these) for five intervals.*

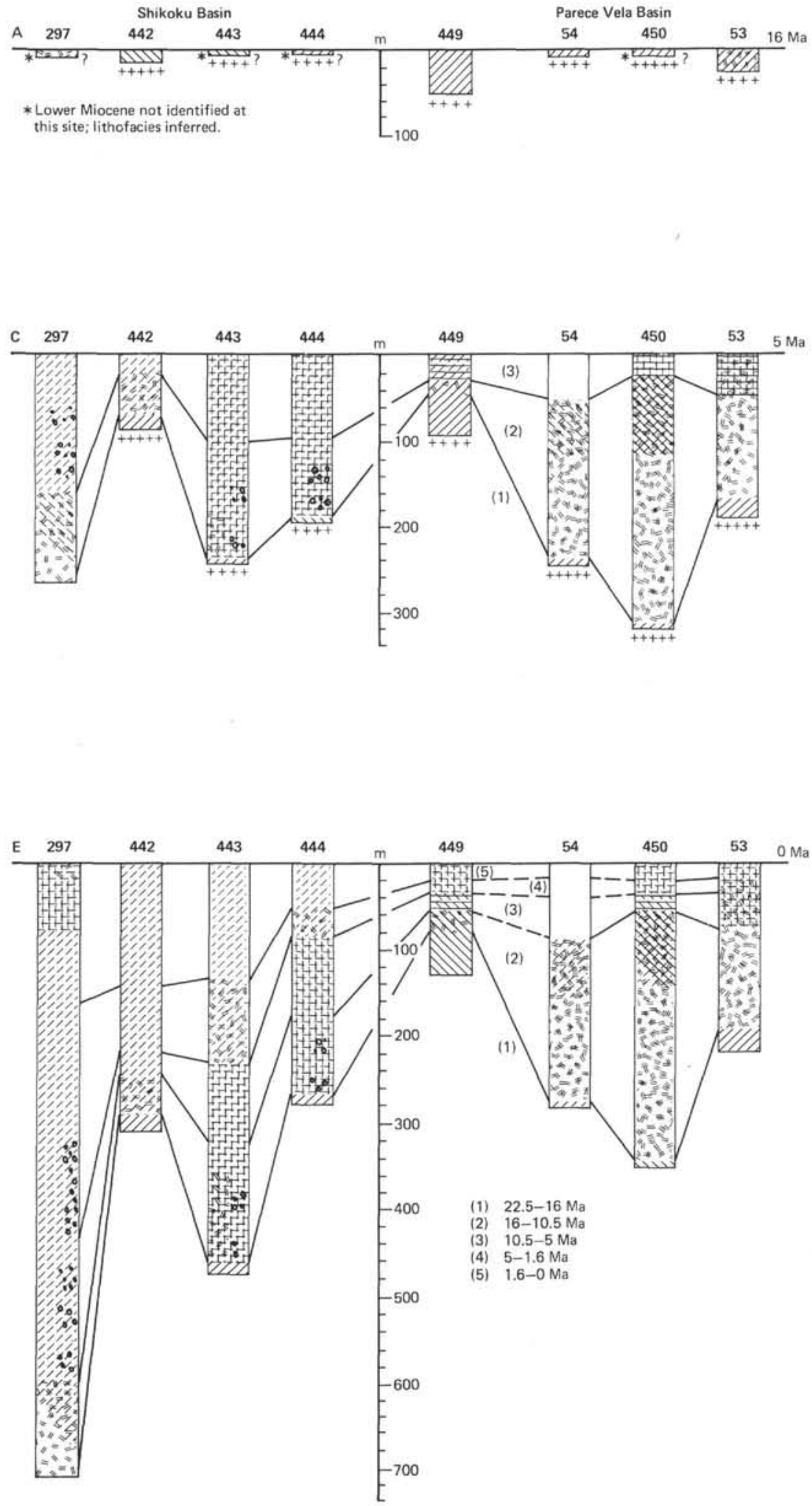

Figure 4. *Cumulative paleostratigraphic cross-sections showing thickness and lithofacies at the eight sites for:* (A) *early Miocene;* (B) *early and middle Miocene;* (C) *early, middle, and late Miocene;* (D) *early, middle, and late Miocene, and Pliocene;* (E) *early, middle, and late Miocene, Pliocene, and Pleistocene; and* (F) *thickness of total sequence at each site referred to present sea-floor topography. Lithofacies symbols explained in Figure 3.*

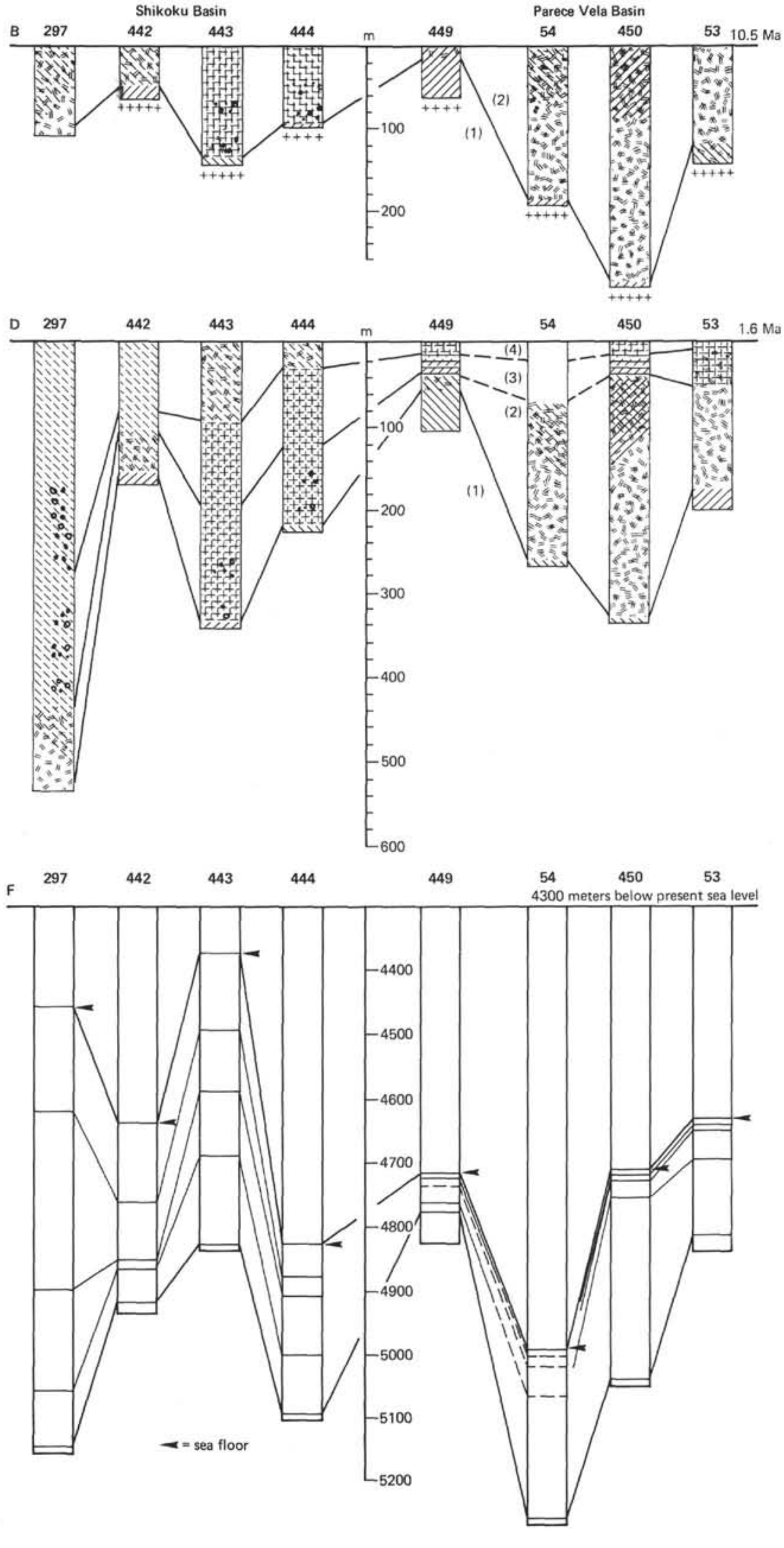

Figure 4. *(Continued).*

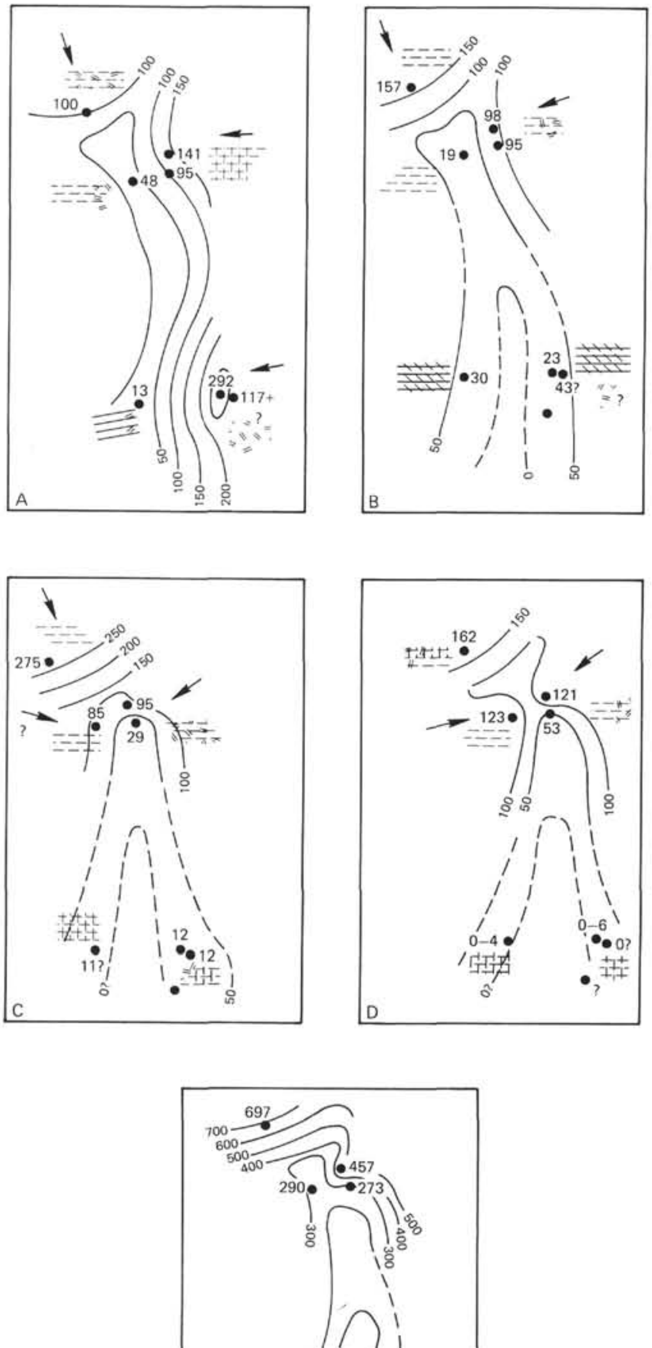

Figure 5. *Lateral facies distribution and thickness relative to source area for each interval:* (A) *16–10.5 Ma;* (B) *10.5–5 Ma;* (C) *5–1.6 Ma;* (D) *1.6–0 Ma;* (E) *total sediment thickness. Data points correspond to sites shown in Figure 1. Arrows indicate sediment influx. Thickness in meters. Lithofacies symbols explained in Figure 3.*

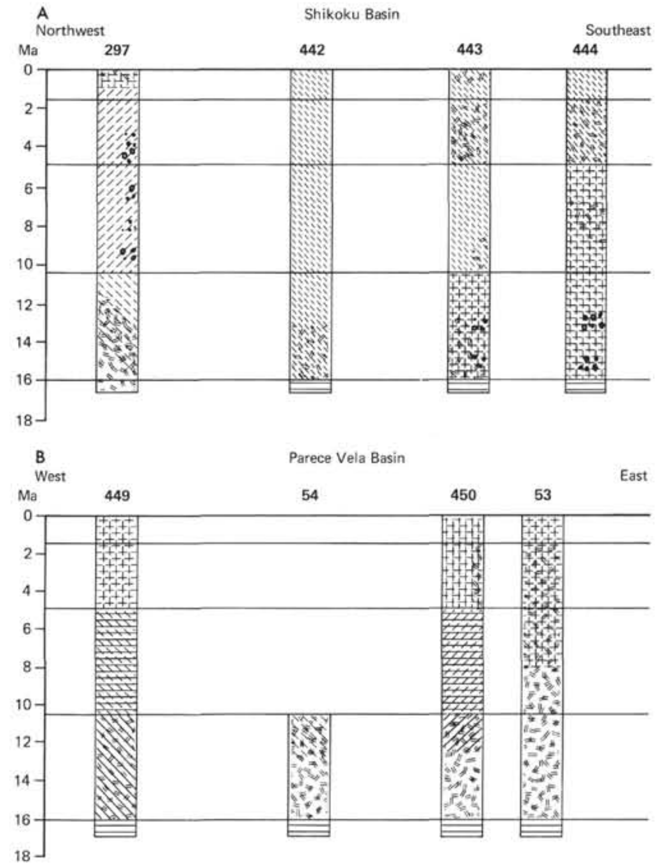

Figure 6. *Lithofacies distribution by time:* (A) *Shikoku Basin;* (B) *Parece Vela Basin. Lithofacies symbols explained in Figure 3.*

Since very little volcanic material was deposited at Site 449, and the 51 meters of section is largely pelagic, it is obvious that the Palau-Kyushu Ridge was submerged (not supplying sediments) at this time, and had little or no active volcanism. If the time designation is correct for Site 53, the West Mariana Ridge could have been an early-Miocene source for volcaniclastics in the eastern Parece Vela Basin. However, Site 450 (which offsets Site 53) has no sediments definitely identified as early Miocene. The Japanese Islands, to the north, may have already begun to supply volcaniclastics at Site 297. The age of the ash at Site 297 is in doubt, however. A small quantity of volcaniclastic material identified at Site 442 could have come either from the north or from the Palau-Kyushu Ridge on the west.

MIDDLE MIOCENE (16–10.5 m.y.)

The dominant lithofacies during this time interval is pyroclastic in the eastern Parece Vela Basin (Sites 53, 54, 450), pelagic (both siliceous and calcareous biogenic) at Site 449 in the western Parece Vela Basin, and hemipelagic (mudstones) plus resedimented sandstones and pyroclastics in the Shikoku Basin.

A calcareous biogenic facies is present at Sites 449 and 444, and in the upper and lower parts of the interval at Site 443. There also are minor amounts of calcareous biogenic facies at Site 450, and at the base of the interval at Site 54. The siliceous biogenic facies is present at Sites 449 and 444, and (a very minor occurrence) in the lower part of the interval at Site 442. Pelagic non-biogenic clays are present in the upper part of the sequence at Site 450, and are a very minor component at the bottom of the interval at Site 444.

Resedimented mudstone occurs, along with hemipelagic mudstone, in the lower half of the interval at Sites 443 and 444. Pyroclastics constitute almost all the interval at Sites 450, 53, and 54, and they are very prominent but decrease upward at Site 297. The pyroclastics are also significant at Site 443, especially in the lower half. They are present at Site 444, and prominent in the lower half of the interval at Site 442.

The thickest sediments (up to 292 m) deposited during this time interval are at Sites 450, 54, and 53, in the eastern Parece Vela Basin, where they virtually form a pyroclastic wedge of sediments. In the Shikoku Basin, the section at Site 443 is thickest (141 m ?), followed by that at 297, then 444. The thinnest section is at Site 442 (48 m).

The facies and thickness distributions for this time interval suggest the following interpretation: The Japanese Islands to the north supplied hemipelagic and pyroclastic sediments at Site 297, where a clastic wedge began to develop at this time. The volcanic materials and mudstones at Site 442 could have come from the north as well, but it is also possible that their source was a slightly elevated and volcanically active Palau-Kyushu Ridge during the early middle Miocene. The Iwo Jima Ridge was volcanically active, especially during the first half of the middle Miocene, and was also an emergent source area for the resedimented and hemipelagic mudstones. A clastic wedge began to develop in the eastern Shikoku Basin during this time.

In the eastern Parece Vela Basin, the West Mariana Ridge was a very active volcanic source, becoming slightly less active toward the latest middle Miocene. The slight amount of volcanics at Site 449, along with the pelagic sediments, indicates that the southern part of the Palau-Kyushu Ridge probably was still submerged and was not supplying sediments to the western Parece Vela Basin.

LATE MIOCENE (10.5-5 m.y.)

The dominant lithofacies in the Shikoku Basin for this time interval is hemipelagic. In the Parece Vela Basin, the dominant facies is a combination of hemipelagic clay and pelagic non-biogenic clay.

The calcareous biogenic facies is present in the upper part of the interval at Sites 443 and 444. The siliceous biogenic facies is present at Site 444 in the lower part of the interval, and in very minor amounts along with the calcareous facies in the lower part at 443. A siliceous biogenic facies is present also at Site 53, and, with the calcareous facies, at 450.

Site 297 has prominent resedimented sandstones. Pyroclastics are prominent at Sites 443 and 444, and in the lower half of the interval at Sites 450 and 53.

The sediments are thickest at Site 297 (157 m), and thinnest at Site 442. The sequence at Sites 443 and 444 is thick (98 and 95 m) compared with the thin sequences at 442 and in the Parece Vela Basin.

Thickness distribution and facies distribution lead to the interpretation that the principal sources of sediment during the interval were to the north and east of the Shikoku Basin. Clastic wedges continued to accumulate at Site 297, 443, and 444. The Japanese Islands were emergent, but there is no indication of active volcanism in that area. The Iwo Jima Ridge was emergent and probably had minor volcanism, especially during the early part of the late Miocene. The northern part of the Palau-Kyushu Ridge could have been supplying sediments at a very low rate at Site 442, or these thin sediments could have come from the Japanese Islands to the north.

In the Parece Vela Basin, almost no sediments were being supplied on the west at Site 449 from the probably submerged Palau-Kyushu Ridge. On the east, minor volcanism in the West Mariana Ridge was supplying pyroclastics at a relatively low rate, decreasing from earlier to later late Miocene.

PLIOCENE (5-1.6 m.y.)

The lithofacies of this interval is almost entirely hemipelagic, with prominent resedimented sandstones in the northern Shikoku Basin at Site 297 in the lower half of the interval. Minor pyroclastics are present in the eastern part of both basins (Sites 443, 444, 450, and 53). Although no ash is present at Site 442, Chamley (this volume) has observed abundant clays of volcanic origin at this site for this time interval.

Pelagic non-biogenic sediments are present at Parece Vela Basin sites. Biogenic facies are conspicuously absent. Sites 443 and 444 have very minor occurrences of calcareous biogenic components.

The thickest sedimentary sequence in this interval is at Site 297 (275 m). A thickness of 95 meters at Site 443, eastern Shikoku Basin, and 75 meters at 442, western Shikoku Basin, indicate relatively rapid sedimentation at these sites. Very thin sequences were deposited in the Parece Vela Basin, and at Site 444.

Facies and thickness suggest an emergent source to the north in the Japanese Islands, from which a clastic wedge continued to be deposited in the northern Shikoku Basin. The sequence at Site 442, including hemipelagic mudstones and volcanic clays, could have come from the Palau-Kyushu Ridge, or from the north and from a more distant source for the volcanic clays. A western Shikoku Basin clastic wedge began no earlier than Pliocene time. An emergent Iwo Jima Ridge on the east, with minor volcanism, supplied sediments in the eastern Shikoku Basin. The southern part of the Palau--Kyushu Ridge and the West Mariana Ridge were probably submerged, because very little clastic sediment was being supplied to the Parece Vela Basin.

PLEISTOCENE (1.6-0 m.y.)

The dominant Pleistocene facies in the Shikoku Basin is hemipelagic mudstone. In the Parece Vela Basin, almost no sediments were deposited (recovered?), except for very thin deposits of pelagic non-biogenic clays.

Calcareous biogenic sediments are prominent in the middle Pleistocene at Site 297 and in the early Pleistocene at Sites 443 and 444. The siliceous biogenic facies is common in late-Pleistocene sediments at Sites 297 and 442. Minor volcanism produced ash deposits at Sites 443 and 444, lesser deposits at 442, and only in the late Pleistocene at 297.

The thickest Pleistocene sequences are at Sites 297 (162.5 m), 442 (123.5 m), and 443 (121 m). The thickness and facies distribution indicate that a northern source continued to supply clastic sediments at Site 297 until mid-Pleistocene time. The appearance of the planktonic calcareous biogenic facies and clay at this site probably marks the inception of the Nankai Trough in mid-Pleistocene time, restricting the previously rapid accumulation of hemipelagic muds in the northern Shikoku Basin. Development of the northern clastic wedge ceased at this time. The Iwo Jima Ridge on the east and the northern Palau–Kyushu Ridge on the west were emergent during this time and continued to supply hemipelagic mudstones to the western and eastern clastic wedges, but volcanism was not prominent on either ridge. The West Mariana Ridge and the southern Palau–Kyushu Ridge were low or submerged.

SUMMARY AND CONCLUSIONS

Generalized dominant facies sequences in each basin are as follows:

Northern Shikoku Basin

Late Pleistocene	Pelagic biogenic (calcareous and siliceous); hemipelagic; pyroclastic
Early Pleistocene and Pliocene	Hemipelagic mudstone
Pliocene and late Miocene	Hemipelagic mudstone and resedimented sandstone
Late Miocene and middle Miocene	Hemipelagic mudstones
Middle Miocene and early Miocene	Pyroclastics

Eastern Shikoku Basin

Pleistocene and Pliocene	Hemipelagic mudstones with minor pyroclastics
Late Miocene	Hemipelagic mudstones and pyroclastics
Middle Miocene	Resedimented sandstones, pelagic biogenic sediments, and pyroclastics
Early Miocene	Pelagic clays

Western Shikoku Basin

Pleistocene, Pliocene, and late Miocene	Hemipelagic mudstones; possibly volcaniclastic clays in the Pliocene
Middle Miocene	Hemipelagic mudstones and pyroclastics
Early Miocene	Pelagic clays and pyroclastics

Western Parece Vela Basin

Pleistocene, Pliocene, and late Miocene	Pelagic clay and hemipelagic clay
Middle Miocene	Pelagic biogenic sediments and pyroclastics
Early Miocene	Pelagic clays with minor pyroclastics

Eastern Parece Vela Basin

Pleistocene	Pelagic clays
Pliocene	Pelagic clays
Late Miocene	Pelagic clays and pyroclastics
Middle Miocene and early Miocene	Pyroclastics

A summary of the geologic history of sediment source areas, and the accompanying sedimentation rates in the basins, follows:

Japanese Islands (northern source) and northern Shikoku Basin

Pleistocene	Source emergent; inception of Nankai Trough in mid-Pleistocene; development of northern clastic wedge ceased in mid-Pleistocene time; volcanism in the late Pleistocene; sedimentation rate 101.6 m/m.y.
Pliocene	Source emergent; no volcanism; northern clastic wedge; sedimentation rate 81 m/m.y.
Late Miocene	Source emergent; no volcanism; northern clastic wedge; sedimentation rate 28.5 m/m.y.
Middle Miocene	Source emergent; active volcanism; northern clastic wedge began; sedimentation rate 18.2 m/m.y.
Early Miocene	Active volcanism; insufficient evidence for other conclusions

Northern Palau–Kyushu Ridge (western source) and western Shikoku Basin

Pleistocene	Source emergent; little volcanism; western clastic wedge; sedimentation rate 77.2 m/m.y.
Pliocene	Source emergent; no volcanism evident, except clays of volcanic origin; western clastic wedge began; sedimentation rate 25.2 m/m.y.
Late Miocene	Source very low, emergent; no volcanism; sedimentation rate 3.5 m/-m.y.
Middle Miocene and early Miocene	Source emergent, low; active volcanism; sedimentation rate 8.7 m/m.y.

Iwo Jima Ridge (eastern source) and eastern Shikoku Basin

Pleistocene	Source emergent; very minor volcanism; eastern clastic wedge; sedimentation rate 33 to 75.6 m/m.y.

Pliocene	Source emergent; minor volcanism; eastern clastic wedge; sedimentation rate 8.5 to 27.9 m/m.y.
Late Miocene	Source emergent; minor volcanism; eastern clastic wedge; sedimentation rate 17.8 m/m.y.
Middle Miocene	Source emergent; active volcanism; eastern clastic wedge began; sedimentation rate 17.3 to 25.6 m/m.y.
Early Miocene	No ridge

West Mariana Ridge (eastern source) and eastern Parece Vela Basin

Pleistocene	Source submergent; no volcanism; sedimentation rate <3.5 m/m.y.
Pliocene	Source submergent; minor active volcanism; sedimentation rate 3.5(?) m/m.y.
Late Miocene	Source submergent; active volcanism; sedimentation rate 4.2 to 7.8 m/m.y.
Middle Miocene	Source submergent; active volcanism; sedimentation rate 21.4 to 53.1 m/m.y.
Early Miocene	Source submergent; active volcanism; no thickness data

Southern Palau-Kyushu Ridge (western source) and western Parece Vela Basin

Pleistocene	Source submergent; no volcanism; sedimentation rate 0 to 2.5 m/m.y.
Pliocene	Source submergent; no volcanism; sedimentation rate 3.2 m/m.y.
Late Miocene	Source submergent; no volcanism; sedimentation rate 5.5 m/m.y.
Middle Miocene	Source submergent; minor volcanism; sedimentation rate 2.5 m/m.y.
Early Miocene	Source submergent; minor volcanism; no thickness data

Early-Miocene active volcanism took place in the area of the Japanese Islands, northern Palau-Kyushu Ridge, and West Mariana Ridge. Middle-Miocene active volcanism continued in the area of the Japanese Islands, northern Palau-Kyushu Ridge, and West Mariana Ridge, and began on the Iwo Jima Ridge. Late-Miocene minor volcanism took place only on the West Mariana Ridge. Pliocene volcanism was minor. Pleistocene volcanism was generally minor on Iwo Jima Ridge and in the Japanese Islands during the late Pleistocene. We assume that the relative geographic positions of these features remained the same, whichever spreading model is used.

During the early Miocene, prominent sources of sediments did not exist. Middle-Miocene sources producing high sedimentation rates were the Japanese Islands and the Iwo Jima Ridge. During the late Miocene, the Japanese Islands and Iwo Jima Ridge were the ony prominent sources of sediments. Pliocene sediment sources were the Japanese Islands, Iwo Jima Ridge, and the northern part of Palau-Kyushu Ridge. During the Pleistocene, prominent sources were the Japanese Islands (early Pleistocene only), northern Palau-Kyushu Ridge, and Iwo Jima Ridge.

Sedimentation rates (m/m.y.) are tabulated below:

	N. Shikoku	W. Shikoku	E. Shikoku	E. Parece	W. Parece
Pleistocene	101.6	77.2	33–75.6	<3.5	0–2.5
Pliocene	81	25.2	8.5–27.9	3.5	3.2
Late Miocene	28.5	3.5	17.8	4.2–7.8	5.5
Middle Miocene	18.2	8.7	17.2–25.6	21.4–53.1	2.5
Early Miocene	(insufficient data to permit calculation of rates)				

The facies are typical for marginal or back-arc basins of this type, consisting predominantly of hemipelagic and volcaniclastic sediments with very minor pelagic components. Thickness relationships and depositional sequences for each time interval suggest the time-variable development of coalescing clastic wedges at several loci within the basins, and indicate the timing of volcanism in neighboring volcanic arcs.

ACKNOWLEDGMENTS

This manuscript was reviewed by John Warme, Colorado School of Mines, and Lee Russell, Shell Development Company.