ROBERT G. DOUGLAS *Department of Geology, Case Western Reserve University, Cleveland, Ohio 44106*
MICHEL MOULLADE *Laboratory of Structural Geology, University of Nice, Nice, France*

Age of the Basal Sediments on the Shatsky Rise, Western North Pacific Ocean

ABSTRACT

The basal beds on the Shatsky Rise cored during Leg 6 of the Deep Sea Drilling Project are the oldest sediments recovered to date in the Pacific Ocean. Based on benthonic Foraminifera, the sediments correlate with the lower Barremian to upper Hauterivian (Lower Cretaceous) rather than the Upper Jurassic or Lower Cretaceous as previously reported. Thus the oldest sediments presently known from the Pacific Ocean are considerably younger than those in the western North Atlantic Ocean (Oxfordian; Upper Jurassic).

INTRODUCTION

The Shatsky Rise is a large submarine plateau located in the western North Pacific Ocean. During Leg 6 of the Deep Sea Drilling Project, four sites were drilled on the rise, two located near the crest and two located on the western flank near the base of the rise (Fig. 1). Coring at Sites DSDP 47 and DSDP 48 near the crest recovered Maestrichtian (Upper Cretaceous) sediments but failed to penetrate more than about one-tenth of the total sediment cover interpreted from the acoustic profile record (Fischer and others, 1971, p. 70). Therefore, DSDP 49 and DSDP 50 were selected far down the western flank of the rise, where acoustical profiles indicated a thin sedimentary thickness, in an attempt to core the basal part of the sequence and to sample the acoustic basement, Horizon B′.

The age of the basal sediments cored at Sites DSDP 49 and DSDP 50 indicates a maximum age for the oceanic crust beneath the Shatsky Rise, and by implication, the age of the acoustic reflector Horizon B′. Because the basal sediment is the oldest recovered so far in the Pacific Ocean it is useful in understanding the geological history of the western North Pacific basin.

STRATIGRAPHIC SEQUENCE AND PREVIOUS AGE DETERMINATION

The sedimentary sequence cored at Sites DSDP 49 and DSDP 50 is similar. At DSDP 49 a thin mantle of brown zeolitic clay overlies white nannoplankton marl ooze and chert. Two holes were attempted and both were abandoned because of hard chert layers and insufficient overburden for drilling. At DSDP 50, which was drilled farther down slope at a spot where Horizon B′ appeared to be near the surface, brown zeolitic clay with volcanic ash overlies nannoplankton chalk ooze with chert.

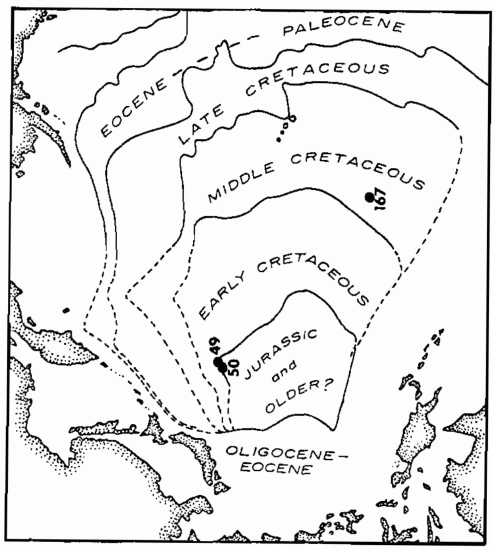

Figure 1. Sites DSDP 49 and DSDP 50, located on the west flank of the Shatsky Rise, are shown on a base map of extrapolated basement ages in the North Pacific Ocean (modified *from* Fischer and others, 1970). At Site DSDP 167, also shown, Late Jurassic basal sediments were recently recovered (Winterer and others, 1971).

Geological Society of America Bulletin, v. 83, p. 1163–1168, 5 figs., April 1972

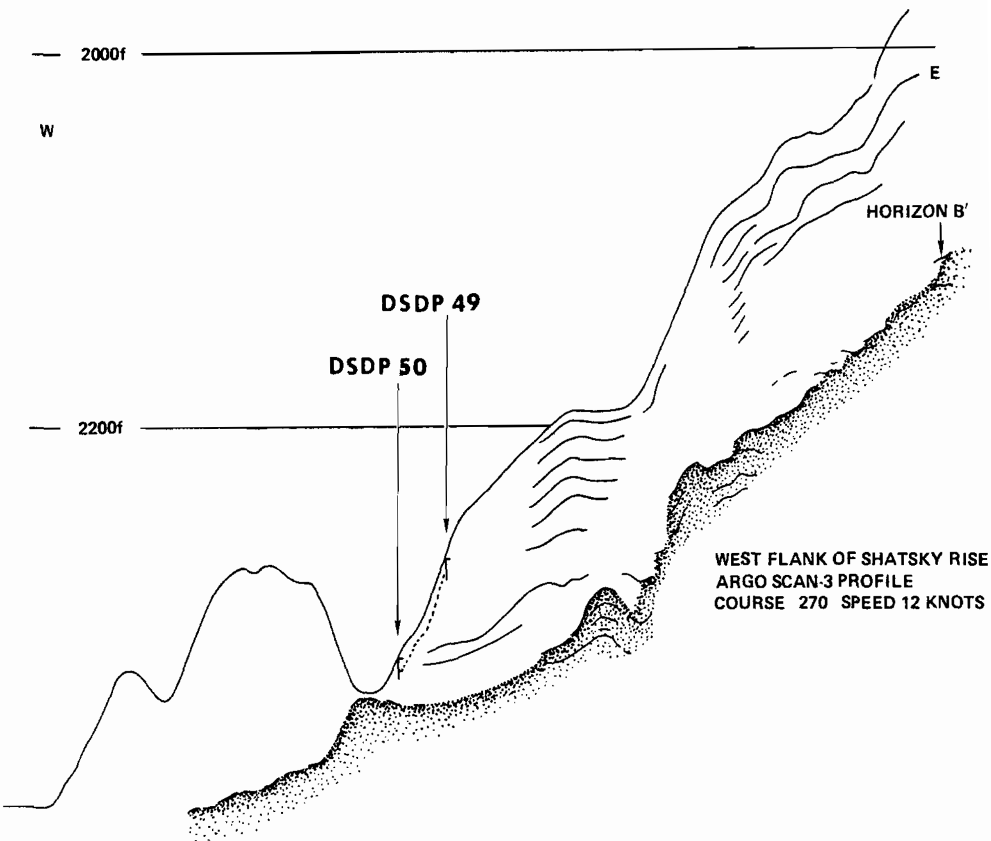

Figure 2. Drawing of the R/V *Argo* acoustic profile at Sites DSDP 49 and DSDP 50 on the west flank of the Shatsky Rise. Holes cored at the sites have been projected into the profile section. Note that DSDP 50 occupies an apparent lower stratigraphic as well as bathymetric position with respect to DSDP 49. Depth lines in fathoms (f; *after* Fischer and others, 1970).

Jasper and basalt pebbles found in the core-catcher sample at DSDP 50.0 suggest that Horizon B′ was encountered but not penetrated (Fischer and others, 1971, p. 199). When the location and total depth of the two holes are projected onto the acoustic profile record, it can be seen that DSDP 50 occupies a lower bathymetric and stratigraphic position relative to DSDP 49 (Fig. 2).

The nannoplankton marl and chalk ooze at the two sites contain a moderately well preserved microfossil assemblage of abundant coccoliths, and sparse benthonic Foraminifera and ostracods. No nannoconid nannofossils or planktonic Foraminifera were found in the sediments so that precise correlation was difficult. In the nannofossil summaries in the initial report volume for Leg 6, the age of the nannofossil assemblages is given as "uncertain, possibly early Albian, but no younger than late Albian" (Hay, 1971, p. 1008) and Upper Jurassic or Lower Cretaceous, and Tithonian or Valanginian (Bukry, 1971, p. 978, 979, and Fig. 4, p. 978). The benthonic Foraminifera and ostracods from the same cores are correlated as Neocomian at DSDP 49 and slightly lower, and Upper Jurassic–lowermost Cretaceous at DSDP 50 (Douglas, 1971, p. 1035). The site summaries in the same volume state the age of the sediments at DSDP 49 as Late Jurassic or Early Cretaceous (p. 175), as Tithonian at various places (p. 174, 175), and at DSDP 50 as Late Jurassic (Kimmeridgian and early Tithonian; p. 199). A *Science* article on the geological history of the western North Pacific restates the correlations given in the site summaries (Fischer and others, 1970, p. 1211).

SAMPLES / SPECIES	49.0–2,cc	49.1: 1–4,130–135	49.1: 2–2,0–5	49.1: 2–2,145–150	49.1: 2–3,0–5	49.1: 2,cc	50.0: 2–1,145–150	50.0: 2–3,0–5	50.0: 2–4,145–150	50.0: 2–6,0–5	50.0: 2–6,145–150	50.0: 2,cc
Dorothia zedlerae		X										
D. hauteriviana		cf	cf	cf	cf	cf				cf		cf
D. ouachensis	X	X	X	X	X	X		X	X	X	X	X
D. praeoxycona	X	X	cf	X	cf	cf		X	X		X	X
Spirillina neocomiana		X	X	X	X		X					
Lenticulina ouachensis		X						X				
L. heiermanni		X	X	X	X	X	X				X	X
L. muensteri	X	X	X			X	X		X	X	X	X
L. kugleri	X		X		X	X						
L. cuvillieri			cf	X						X	X	
L. eichenbergi		X				X						
Pseudonodosaria humilis		X			X		X			X	X	X
Tristix acutangula	X				X							

Figure 3. Occurrence of some well known benthonic foraminiferal species in samples from DSDP 49 and DSDP 50 and their stratigraphic range in western Europe. cf = closely related to but not conspecific with listed taxon.

REVISED BIOSTRATIGRAPHY

Subsequent to the completion of the Leg 6 report, R. G. Douglas has been preparing a more comprehensive report on the Cretaceous microfossils in the North Pacific Ocean which involved further study of the benthonic Foraminifera on the Shatsky Rise. We have undertaken jointly a comparison of benthonic Foraminifera with correlative faunas from the western North Atlantic Ocean and Europe. Some of the results of these studies indicate that: (1) the benthonic foraminiferal assemblages from DSDP 49 and DSDP 50 are more similar to each other than originally realized; (2) nearly all the species found in the Pacific core samples also occur in northwestern and southern Europe; (3) the age of the Foraminifera from the two sites is essentially the same; (4) based upon well known stratigraphically diagnostic species in Europe, the Foraminifera are lowermost Barremian or uppermost Hauterivian.

These conclusions differ from the earlier reports on the microfauna (Douglas, 1971) and slightly alter conclusions regarding the geology of the western North Pacific basin. The basis for our determination is briefly discussed below.

AGE AND CORRELATION

The benthonic foraminiferal assemblages from the cores at DSDP 49 and DSDP 50 are dominated by species of the single family Nodosariidae and a few simple agglutinated species of the genus *Dorothia*. About 70 species have been identified or referred to open nomenclature and most of them are either known from England, Germany, and France (where the majority were originally described) or are closely related morphologically to species which occur in western Europe. This cosmopolitan aspect of Early Cretaceous Foraminifera is well known and permits precise correlation between continents and ocean basins (Bartenstein and others, 1957, 1966).

Based on the joint occurrence of species with restricted ranges, the basal sediments can be easily restricted to lower Barremian and upper Hauterivian. *Dorothia praeoxycona* Moullade, *Lenticulina heiermanni* Bettenstaedt, *L. kugleri* Bartenstein, Bettenstaedt and Bolli, and *L. cuvillieri* Moullade range from the Barremian to lower Aptian (Bartenstein and others, 1957, 1966; Bartenstein and Bettenstaedt, 1962; Moullade, 1961, 1966). These species occur most frequently in cores from DSDP 49 (Fig.

3). In most of the same samples are found *Dorothia ouachensis* (Sigal), a late evolutionary stage of *D. hauteriviana* Moullade, *D. zedlerae* Moullade, *Spirillina neocomiana* Moullade (Fig. 4), *Lenticulina ouachensis* (Sigal), *L. eichenbergi* Bartenstein and Brand, *L. muensteri* (Roemer), *L. bronni* Bartenstein, Bettenstaedt and Bolli, *L. crassa* (Roemer) and rare occurrences of *Tristix acutangula* (Reuss), which extend from the lower Neocomian into the Barremian or lower Aptian (Bartenstein and Brand, 1951; Bartenstein and Bettenstaedt, 1962; Moullade, 1961, 1966). The joint occurrence of these species indicates that the cored beds at DSDP 49 cannot be higher than early Barremian nor the cored beds at DSDP 50 lower than late Hauterivian (Fig. 3). The cores from DSDP 49.1 can be further defined stratigraphically as occurring within a narrow interval represented by the evolutionary transition of *D. hauteriviana* to *D. praeoxycona*. The ancestral form, *D. hauteriviana*, is typically narrow and elongate with an oval cross section. Near the Hauterivian-Barremian boundary *D. hauteriviana* gives rise, via a series of transitional forms, to *D. praeoxycona* which is shorter with a more distinctive V-shaped profile and rounded shoulder on the last-formed pair of chambers. Specimens from the Shatsky Rise include both the late evolutionary stage of *D. hauteriviana* (herein referred to as *D.* cf. *hauteriviana;* Fig. 5G, 5H) and the early stage of *D. praeoxycona* (Fig. 5E, 5F). The latter species differs slightly from the typical *D. praeoxycona* found in southern Europe in having slightly sharper shoulders on the last-formed pair of chambers. In core samples from DSDP 50 there is a higher frequency of species common to the Hauterivian and early Neocomian. We interpret this as evidence that the cored beds at DSDP 50 are slightly older, latest Hauterivian, which agrees with the apparent lower stratigraphic position of this site relative to DSDP 49 (Fig. 2). There is no evidence, however, to suggest that the age of the benthonic Foraminifera from the two boreholes is significantly different.

The Foraminifera from Shatsky Rise can be correlated with the Lower Cretaceous benthonic Foraminifera which occur at Sites DSDP 4 and DSDP 5 in the western North Atlantic Ocean (Douglas, 1972). The Atlantic and Pacific assemblages are very similar and many of the stratigraphically diagnostic nodosariid species are the same. In making a comparison between the Atlantic and Pacific we noted that the coccolith assemblage from DSDP 4, Core 4, was dated as Hauterivian (Bukry and Bramlette, 1969, p. 373) and Kimmeridgian or Portlandian (Hay, 1969, p. 390). More recently the coccoliths from the same core have been reaffirmed as Kimmeridgian (Worsley, 1971). The benthonic Foraminifera from this core are correlated with the lower Barremian and upper Hauterivian (Douglas, 1972). It is perhaps coincidental, but in both this example and in the cores from the Pacific, Foraminifera and nannofossils suggest different correlations and in each case the nannofossils indicate an older age. We point out this situation because nannofossils are frequently the only means for biostratigraphic control in the Upper Jurassic–Lower Cretaceous in the deep sea and because the age of the basal sediments, particularly the oldest sediments, plays a significant role in geological interpretations (for example, sea-floor spreading rates). Foraminifera and nannofossil correlation in the Upper Cretaceous and Tertiary is nearly always in close agreement. The apparent disagreement for the Early Cretaceous–Jurassic is indicative of the preliminary stage of development of microfossil biostratigraphy for the Early Cretaceous and Jurassic in the deep sea, and until more comprehensive comparisons have been made between classical outcrop sections on the continents and fossil sequence in deep-sea cores, we believe a note of caution is justified concerning pre–Late Cretaceous age determinations.

In comparing the benthonic microfossils from the Shatsky Rise to those in Europe we noted

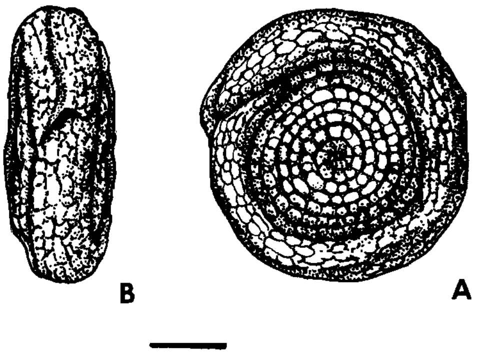

Figure 4. *Spirillina neocomiana* **Moullade DSDP no. 60307. Length of bar equals 0.1 mm.**

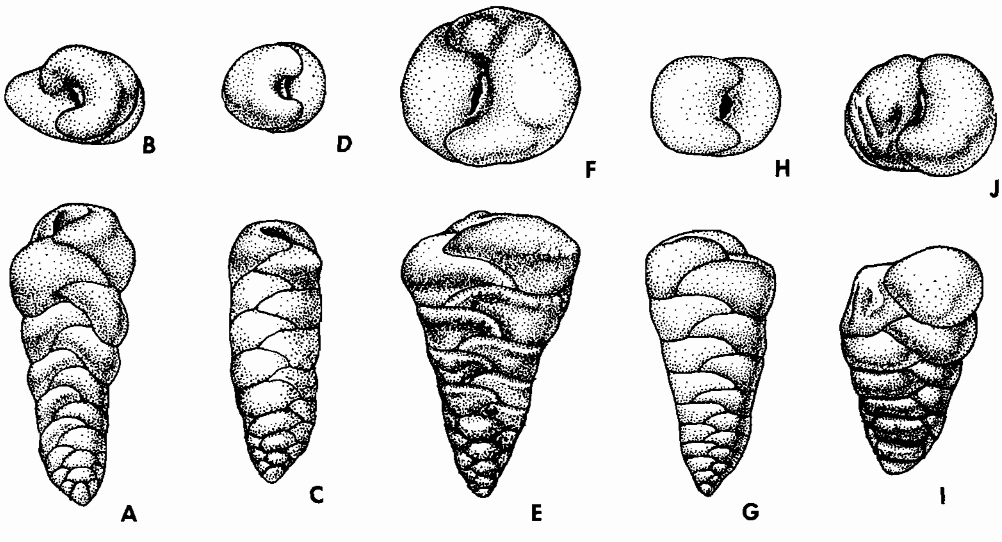

Figure 5. A, B = *Dorothia ouachensis* (Sigal) DSDP no. 60303. A typical specimen with irregular biserial arrangement in last few pairs of chambers. Such specimens are a rare but consistent part of deep-sea populations.

C, D = *D. ouachensis* (Sigal) DSDP no. 60304. Typical form. E, F = *D. praeoxycona* Moullade DSDP no. 60302. G, H = *D.* sp. cf. *D. hauteriviana* (Moullade) DSDP no. 60300. An early evolutionary stage in the development of the species which occurs near the Hauterivian-Barremian boundary in Europe. I, J = *D. zedlerae* Moullade, DSDP no. 60301. Length of bar equals 0.1 mm.

that the strongest over-all resemblance was with shallow-water platform assemblages rather than deep-water assemblages. At the present time, both DSDP sites are situated at depths of > 4,000 m deep, below the carbonate compensation depth, and brown clay overlies the Cretaceous nannoplankton ooze. The paleobathymetry of the Foraminifera and ostracods suggests depths of several hundred meters rather than several thousand meters and supports the conclusion of Fischer and others (1970) that the seafloor has subsided relative to sea level. The amount of subsidence appears to have been on the order of at least one kilometer.

CONCLUSION

The age of the extreme western North Pacific basin has been extrapolated as Jurassic and older (Fischer and others, 1970) and the recent discovery of Late Jurassic sediments in the mid-Pacific (DSDP 167; Winterer and others, 1971) suggests the extrapolated age is a minimum age (Fig. 1). A basement age of Barremian or Hauterivian for the Shatsky Rise would require that the plateau be a younger feature than the surrounding sea floor provided that a stratigraphic gap does not exist between the basal sediments and the basement encountered at DSDP 50. At any rate, the oldest sediments recovered to date in the Pacific Ocean are significantly younger than the Oxfordian (Late Jurassic) sediments recently found in the western North Atlantic (Ewing and others, 1970).

ACKNOWLEDGMENTS

The authors gratefully acknowledge the National Geographic Society, and The North Atlantic Treaty Organization for their financial assistance; the Deep Sea Drilling Project which made samples available for study; and David Bukry of the U.S. Geological Survey, and Anthony Pimm of the Deep Sea Drilling Project, for discussion and criticism of the original manuscript.

REFERENCES CITED

Bartenstein, H., and Brand, E., 1951, Mikropalaeontologische Untersuchungen zur Stratigraphie der nordwestdeutschen Valendis:

Abhandl. Senckenb. Naturf. Ges., no. 485, p. 239–336.

Bartenstein, H., and Bettenstaedt, F., 1962, Marine Unterkreide (Boreal und Tethys), *in* Leibfossilien der Mikropalaeontologie: Berlin, Geb. Borntraeger, p. 225–297.

Bartenstein, H., Bettenstaedt, F., and Bolli, H. M., 1957, Die Foraminiferen der Unterkreide von Trinidad, B.W.I. Erster Teil: Cuche-und Toco-Formation: Ecologae Geol. Helvetiae, v. 50, no. 1, p. 5–67.

——— 1966, Die Foraminiferen der Unterkreide von Trinidad, W.I. Zweiter Teil: Maridale-Formation (Typlokalitaet): Ecologae Geol. Helvetiae, v. 59, no. 1, p. 129–177.

Bukry, D., 1971, Coccolith Stratigraphy Leg 6, Deep Sea Drilling Project, *in* Fischer, A. G., and others, Initial Reports of the Deep Sea Drilling Project, Vol. VI: Washington, U.S. Government Printing Office, p. 965–1006.

Bukry, D., and Bramlette, M. N., 1969, Coccolith age determinations, Leg 1, Deep Sea Drilling Project, *in* Ewing, M., and others, Initial Reports of the Deep Dea Drilling Project, Vol. I: Washington, U.S. Government Printing Office, p. 369–387.

Douglas, R. G., 1971, Cretaceous Foraminifera from the northeastern Pacific Ocean: Leg 6, Deep Sea Drilling Project, *in* Fischer, A. G., and others, Initial Reports of the Deep Sea Drilling Project, Vol. VI: Washington, U.S. Government Printing Office, p. 1027–1053.

——— 1972, Lower Cretaceous benthonic Foraminifera from the northwest Atlantic Ocean: Jour. Paleontology (in press).

Ewing, J., and others, 1970, Deep Sea Drilling Project; Leg 11: Geotimes, v. 15, no. 7, p. 14–16.

Fischer, A. G., Heezen, B. C., Boyce, R. E., Bukry, D, Douglas, R. G., Garrison, R. E., Kling, S. A., Krasheninnikov, V., Lisitzin, A. P., and Primm, A. C., 1970, Geological history of the western North Pacific: Science, v. 168, p. 1210–1214.

Fischer, A. G., and others, 1971, Initial Reports of the Deep Sea Drilling Project, Vol. VI: Washington, U.S. Government Printing Office, 1329 p.

Hay, W. W., 1969, Preliminary dating by fossil calcareous nannoplankton, Deep Sea Drilling Project, Leg 1, *in* Ewing, M., and others, Initial Reports of the Deep Sea Drilling Project, Vol. I: Washington, U.S. Government Printing Office, p. 388–391.

——— 1971, Preliminary dating by fossil calcareous nannoplankton, Deep Sea Drilling Project, Leg 6, *in* Fischer, A. G., and others, Initial Reports of the Deep Sea Drilling Project, Vol. VI: Washington, U.S. Government Printing Office, p. 1005–1012.

Moullade, M., 1961, Quelques Foraminiferes et Ostracodes nouveaux du Cretace inferieur vocontien: Rev. Micropaleont., v. 3, no. 4, p. 213–216.

——— 1966, Etude stratigraphique et micropaleontologique du Cretace inferieur de la "fosse vocontienne": Doc. Lab. Geol. Fac. Sci. Lyon, no. 15, p. 369.

Winterer, E. L., and others, 1971, Deep Sea Drilling Project: Leg 17: Geotimes, v. 16, p. 12–14.

Worsley, T. R., 1971, Calcareous nannofossil zonation of Upper Jurassic and Lower Cretaceous sediments from the Western Atlantic: 2d Planktonic Conf. Proc., Rome, p. 1334–1344.

MANUSCRIPT RECEIVED BY THE SOCIETY OCTOBER 18, 1971

DEPARTMENT OF GEOLOGY, CASE WESTERN RESERVE UNIVERSITY, CONTRIBUTION NO. 75

PRINTED IN U.S.A.