Reports

Lower Cretaceous Sediments from the Northwest Pacific

Abstract. *The first occurrence of deep-sea Lower Cretaceous (Albian) sediments in the Pacific Ocean is reported from the Shatsky Rise at 31°51′N, 157°20′E. Seismic-profile records indicate that the core was taken between the extensive seismic reflectors A′ and B′. Two hundred meters of unconsolidated sediment lies between the core site and basement (B′) and suggests that the sediment just above basement may be at least as old as Middle Jurassic.*

During her 21st cruise, R.V. *Vema* raised a Lower Cretaceous (Albian) core, V 21-143, from Shatsky Rise (*1*) between the Emperor Seamount chain and the Japan Trench, at 31°51′N, 157°20′E (Fig. 1). Figure 1 shows three units on the rise that stand more than 3000 m above the adjacent basins and trend generally from northeast to southwest. The core was taken at a depth of 3500 m from the southwestern flank of the largest and most southerly of these three units. A continuous seismic-profile record made across the rise indicates stratified sediments as thick as 1 km on the crest; the core source was an outcrop exposing part of the sedimentary section.

The oldest sediments previously recovered from the Pacific Ocean were shallow-water reefal deposits from the tops of the Hess and Cape Johnson Guyots of the Mid-Pacific Mountains (*3*); their ages are considered Aptian-Cenomanian, although Hamilton regarded the total aspect of the faunas as most likely Urgonian (Upper Barremian and Aptian), during which time massive zoogenic limestones, bearing a characteristic rudistid fauna, accumulated in the neritic zone of the world-encircling Tethys Sea. An Upper Cretaceous (Campanian-Maestrichtian) foraminiferal fauna, mixed with Tertiary and Recent species, was reported by Hamilton (*4*) from two cores raised at 19°34′N, 171°54′W, near Guyot 20171. Riedel and Funnell (*5*) described reworked Cretaceous and Miocene Radiolaria from cores CAP 5 BG (09°03′S, 174°52′E) and CAP 5 BP (09°03′S, 174°52′E). Further coring in the area suggested that the source of the Cretaceous sediment lies in the shallower regions to the south, in the vicinity of Alexa Bank. Kagami *et al.* (*6*) reported Cretaceous (Aptian?) shallow-water gastropods (*Nerinea*) from the Shisoef Seamount, a solitary seamount located near the junction of the Japan and Kuril-Kamchatka Trenches. Reworked Cretaceous Radiolaria were found by Hays (*7*) in core V 18-267 from the Manihiki Plateau in the southeast Pacific.

The continuous seismic-profile records of two crossings of Shatsky Rise appear in Fig. 2; the uppermost is the more northerly of the two. The device used (*8*) is essentially an echo sounder that records the topographic profiles of both the sea floor and buried surfaces.

The records in Fig. 2 show that sediments buried several hundred meters deep on the rise and in adjacent basins are exposed at the coring site on the flank of the rise, apparently by erosion. Hence, determination of the age of the sediments (Albian) at the outcrop enables us, by correlation of reflectors, to establish the stratigraphic position of the Albian on the rise and, even more important, in the undisturbed sections of sediments in the Pacific Basin.

Although the record is interrupted at short intervals and the sedimentary layers themselves are interrupted by erosion, faulting, and sharp peaks, correlation of the reflectors marked α, A′, β, and B′ with reflectors in the adjacent basins is supported by several lines of evidence. For instance, reflectors A′ and B′ are moderately smooth, and each forms the sharp upper sur-

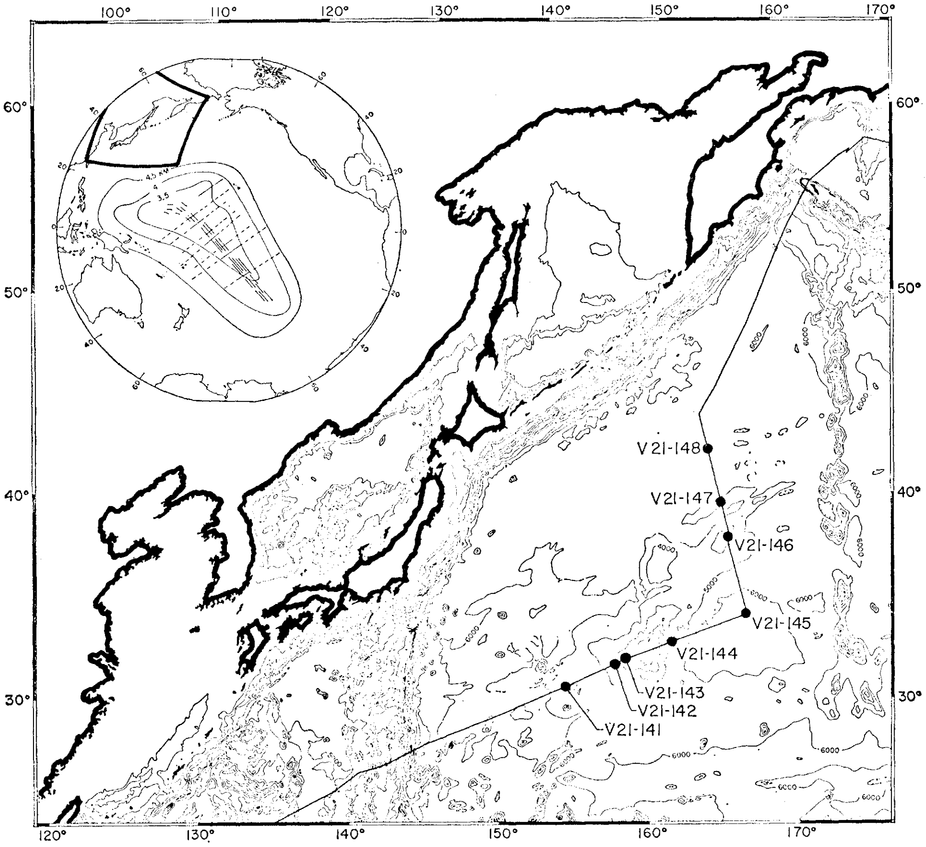

Fig. 1. *Vema's* track and the sources of cores. The inset (*37*) shows approximately the probable position of the former Darwin Rise.

face of an acoustically opaque layer (9). Such layers could represent highly stratified sediments in which the stratification is too fine for resolution by the profiler. These opaque layers are separated by a lower, acoustically transparent layer over most the traverse. The interval between reflector A′ and the sea floor ("the upper acoustically transparent layer") can be unmistakably identified except on the crest of the rise, where the presence of additional reflectors complicates the positive identification of A′. According to our correlation, this layer is thicker and more stratified on the crest of the rise than elsewhere. Reflectors α and β are identified only on the crest of the rise in this traverse, β being near the bottom of the upper opaque layer. Reflectors A′ and B′, on the other hand, extend over major parts of the Pacific Ocean (*10*).

Core V 21-143 (Fig. 2) sampled sediments at about the level of reflector β, whose stratigraphic position in the crestal area is about 200 m above reflector B′ and an equal distance below A′. Correlation of the strata at the source of the core with those in the basin to the southwest is established on the basis of continuity of the lower transparent layer and of the two opaque layers; thus the core is placed stratigraphically near the bottom of the upper opaque layer (reflector β).

Cores 141, 144, 145, and 147 (Fig. 2) definitely sampled the upper transparent layer, all apparently in undisturbed areas. The upper transparent layer is thickest over the crest of the rise, but is only slightly thinner to the northwest, in which area the thick sediment may result from high production of plankton in the Kuroshio Current. Core 142 is from a saddle between two peaks; core 146, from a steep slope near the crest. Core 146 was located to sample reflector B′, but apparently penetrated only a thin covering of younger sediments. We should emphasize that the resolution of the profile record is not fine enough to show a thickness equal to the core depth. The accessibility (for coring) of outcrops indicated by the profiler should be further judged by the appearance of local roughness on the record of the precision depth recorder; Fig. 3, for example, indicates local roughness at the source of V 21-143.

Core V 21-143 is 73 cm in length (Fig. 4). The top 24 cm is composed of a pale yellowish-brown foraminiferal ooze, with manganese nodules and at least one piece of angular chert. The Foraminifera, *Globorotalia inflata* (d'Orbigny), *G. truncatulinoides* (d'Orbigny), *G. tumida* (Brady), *Globoquadrina dutertrei* (d'Orbigny), *Globigerina pachyderma* (Ehrenberg) (right coiling), and *Pulleniatina obliquiloculata* (Parker and Jones), indicate a Pleistocene or Recent age for this layer; mixed foraminiferal assemblages of Recent Pleistocene and Cretaceous age suggest submarine erosion of Cretaceous sediments.

At 24 cm there is an abrupt change to a white foraminiferal chalk containing Cretaceous fossils; at the top of this layer is a large fragment of a manganese nodule, which may also be interpreted as a manganese crust. The

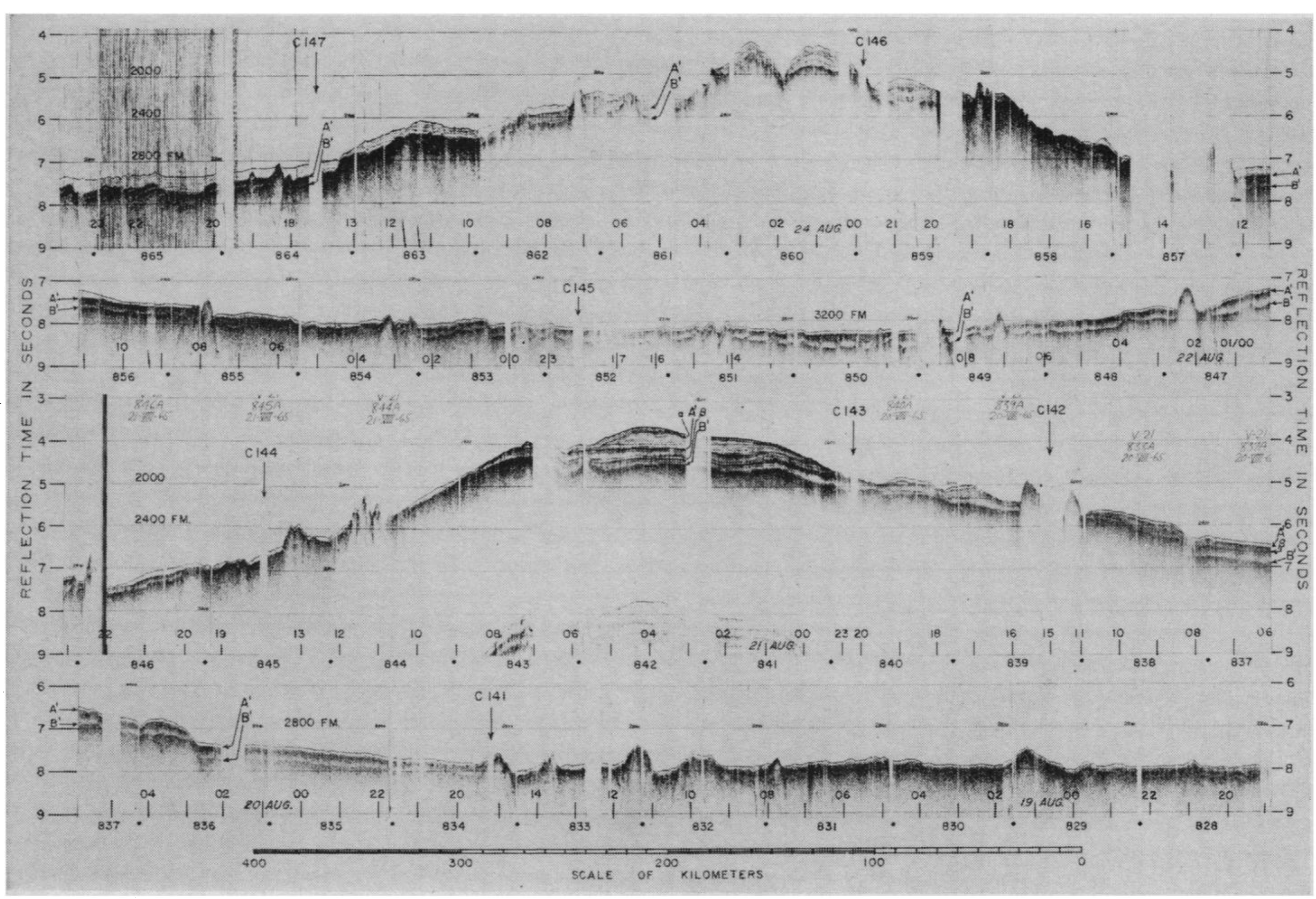

Fig. 2. Seismic-profile records across Shatsky Rise and adjacent basins. The numbers above the arrows identify sources of cores.

clay-size particles are generally made up of coccolith plates; calcite rhombs occur, and some of the foraminiferal tests and the plates are recrystallized. Below 45 cm is a mixed layer of white foraminiferal chalk, manganese nodules, and angular chert fragments; the chalk is soft but contains occasional "slugs" of hard, semi-indurated chalk. Beside Foraminifera, *Inoceramus* prisms and juvenile pelecypod shells (< 2 cm) also were noted in the bottom two layers; their poor preservation prevented specific identification of the shells.

When the corer was raised, mud on the core head (portion of the device) indicated that it had toppled after the coring. As a result, the bottom layer of the core was mixed with sediment from the top layer; thus the true, undisturbed bottom of the core is at 45 cm (Fig. 4); there is evidence in the presence of a mixed assemblage of Cretaceous and Recent Foraminifera and Radiolaria in the 45- to 73-cm layer.

Examination of planktonic foraminifers in the Cretaceous portion of this core reveals a rather monotonous assemblage consisting of five species: *Ticinella primula* Luterbacher, *T. roberti* Gandolfi, *Hedbergella planispira* (Tappan), *Biglobigerinella cushmani* (Tappan), and *Biticinella* sp. (Fig. 5). The Albian age of the white chalk is based upon the presence of *T. primula, T. roberti, H. planispira*, and *B. cushmani*.

Ticinella primula, the planktonic species most abundant in the white chalk, was identified in the upper and middle portion of the Albian in a core from Le Maley, Canton de Neuchatel; it is also reported from the pyritic Albian of Vraconne, Canton de Waadt, and from the lowest (Albian) part of the Scaglia section from near Balerna (all locations are in Switzerland) (*11*).

Ticinella roberti, originally regarded as a species of the benthonic foraminiferal genus *Anomalina*, was identified by Gandolfi (*12*) in the Lower Cenomanian at Breggia, Switzerland; according to Sigal (*13*) it is characteristic of the middle Albian of Algeria. In Tanganyika, Banner and Blow (*14*) found a specimen referable to this species in Upper Albian or Lower Cenomanian strata. Klauss (*15*) studied the succession of planktonic foraminiferal assemblages in the Complex Schisteaux Intermediaire, Switzerland; he established six zones between the Albian and Middle Turonian, the lower two serving to divide the Albian into lower and upper parts; he regarded *T. roberti* as ranging stratigraphically from the upper part of zone 1 to the top of zone 2.

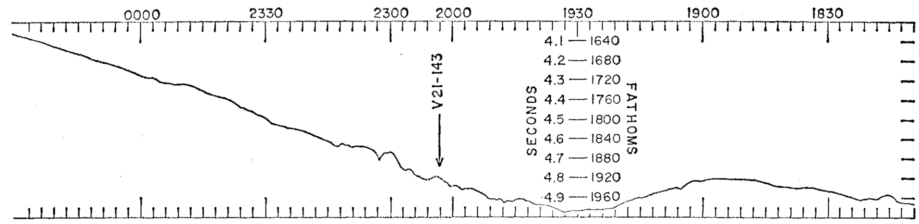

Fig. 3. Tracing from precision depth recorder near source of V 21-143.

Originally described from the Grayson Formation of Texas, *Hedbergella planispira* has a wide geographic distribution; it is reported from the Washita and Eagle Ford groups of Texas, the Greenhorn limestone of South Dakota, Wyoming, and Kansas, a submarine core from the edge of Blake Plateau, the Cenomanian of Germany, and in the Albian and Cenomanian of the U.S.S.R. and Trinidad (*16*).

Biglobigerinella cushmani is described from the Duck Creek Formation of Oklahoma as a species of the genus *Globigerinella* (*17*); the formation is the second-lowest unit of the Washita group in the Gulf Coast region and is widely recognized as the equivalent in the United States of the Albian (*18*).

Strata equivalent to Albian are well developed in Hokkaido, the northernmost island of Japan; although five species and subspecies of planktonic foraminifers are reported (*19*), there is little similarity in fauna to Shatsky Rise. Monoclinal Neocomian-Albian formations also outcrop in a few scattered areas along the northeastern coast of Honshu, Japan (*20*); they generally dip toward the Pacific, and were mostly deposited in shallow seas in which ammonities, rudistids, trigonians, corals, and *Orbitolina* (large benthonic foraminifera) thrived. The Lower Cretaceous fauna of Shatsky Rise seems to have greater affinity with that of the Albian strata of Switzerland and the Gulf Coast than of Japan.

The proportion of planktonic to benthonic foraminiferal specimens in samples of sediment is known to provide an approximate method for estimating the depth of deposition (*21*): in general, planktonic foraminifers increase in number with increasing water depth. The predominance of planktonic foraminifers is the most characteristic feature of the Albian fauna of the rise; they constitute 96 percent of the foraminiferal assemblage. Additional evidence of deep-water deposition of this fauna is the occurrence of benthonic foraminiferal species of genera such as *Robulus, Astacolus, Dentalina*, and *Nodosarella*, which indicates that the depth over the rise during Cretaceous time was about 1800 m or greater (*22*). A few poorly preserved Radiolaria also were recovered from the white chalk.

Core V 21-141 consists of moderate-yellowish-brown manganese lutite containing a 7-cm layer of whitish-gray altered tuff. Core 142 comprises alternating zones of moderate-yellowish-brown manganese lutite and very-pale-orange lutite; the manganese content increases with depth. Core 144 consists entirely of a grayish-orange manganese lutite. Core 145 is largely a moderate-yellowish-brown manganese lutite containing a few interbedded layers of altered tuff. Core 146 differs from cores taken on the southern crossing of the rise in that it contains, besides the brown manganese lutite, numerous layers of olive-brown, olive-gray, and yellowish-green lutite, as well as two layers of white carbonate-rich lutite. Core 147 resembles 146 except that it lacks the white lutite layers.

Hess (*23*) suggested that the drowned atolls and guyots in the Mid-Pacific Ocean represent the site of a former trans-Pacific rise that preceded Middle Cretaceous time; he postulated a width of 3000 km and a length of about 14,000 km. Since Cretaceous time the rise, named the Darwin Rise (*24*), was considered to have subsided about 1 to 2 km. Raitt (*25*) pointed to a high-velocity layer in the upper mantle of this feature, which Menard suggested may be characteristic of ancient, subsided rises.

Raitt also observed in the Pacific

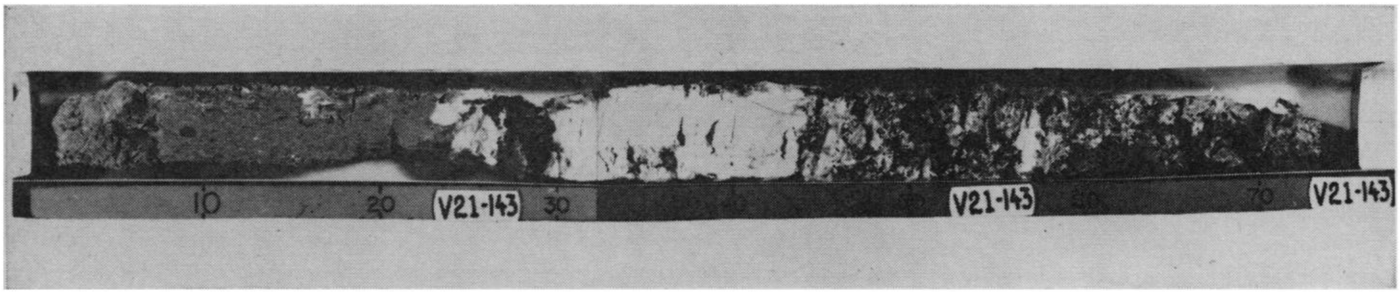

Fig. 4. Core V 21-143; Cretaceous portion is the white layer from 24 to 45 cm.

Ocean basin that 200 to 500 m of unconsolidated sediment overlays material thought to be basalt. Revelle *et al.* (*26*) have remarked that this thickness accounts for sediment accumulation only since the Cretaceous, if one assumes that rates of sedimentation during Cretaceous and Tertiary times resembled that determined for the last 14,000 years (*27*). Proponents of continental drift suggest that major reorganization of the Atlantic Ocean basin took place during Mesozoic time, and Ericson *et al.* (*28*) reported in 1959 that no sediment older than Cretaceous had yet been found.

Hamilton (*29*), using soil-mechanics techniques, concluded that the ocean basins were Paleozoic to pre-Paleozoic in age, while Beloussov (*30*) believes the oceans to be no older than Mesozoic. Menard and Hamilton (*31*) stated unequivocally that the Mid-Pacific Mountain area in mid-Cretaceous time had a depth of at least 3200 m; the sediments of V 21-143 support this view.

As we have mentioned, the seismic-profiler records (Fig. 2) indicate at least 200 m of sediment above "basement" at this coring site. Accumulation of Upper Eocene pelagic sediments at 0.3 cm/1000 years (*32*) required 66 million years for the deposition of 200 m. Using the age for Albian of 106 million years (*33*), we calculate, at the bottom of this sedimentary column, a value of 172 million years, which is equivalent to the Bajocian epoch (Middle Jurassic). We do not mean to imply, however, that we believe the Pacific Ocean basin to be no older than Middle Jurassic; there is a good possibility that the deepest layer measured, which we are calling "basement" may in fact be consolidated sediment, as Hamilton suggests (*29*); the smoothness of this basement reflector in the Shatsky Rise vicinity supports the opinion that it consists of sedimentary rock.

If one applies the rate of 0.3 cm/1000 years to the zone A′–β, the age of A′ is about 46 million years. However, this rate, which was determined for a very different environment, or any single rate is so questionable that the result of the calculation is only approximate. The thickness of the upper acoustically transparent layer varies by at least a factor of 10, (Fig. 2), even if one excludes the crest of the rise, and the same may be said of the upper acoustically opaque layer in other areas (*10*). It seems preferable to consider that A′ and B′ represent major changes in sedimentation, oceanwide in extent, whose age must bracket that of the Albian sediments cored. This line of thought suggests that reflectors A′ and B′ of the Pacific correlate with Atlantic reflectors A and B (*34*), and with A″ and B″ in the Caribbean (*35*).

In the absence of direct evidence of the age of reflector B′, speculation should recognize two facts: (i) If the proposed correlations are correct, these two very extensive reflectors record major changes in the sedimentary regime in the Atlantic, Pacific, and Caribbean, changes that very likely correlate with events that have long been recognized as marking major divisions of geologic history. (ii) The smoothness of reflector B′ in many places strongly suggests that it is the top of a layer of sedimentary rock; it marks the earliest event recorded in our reflection surveys; for instance, one is tempted to correlate it with an event of the magnitude of a boundary between eras.

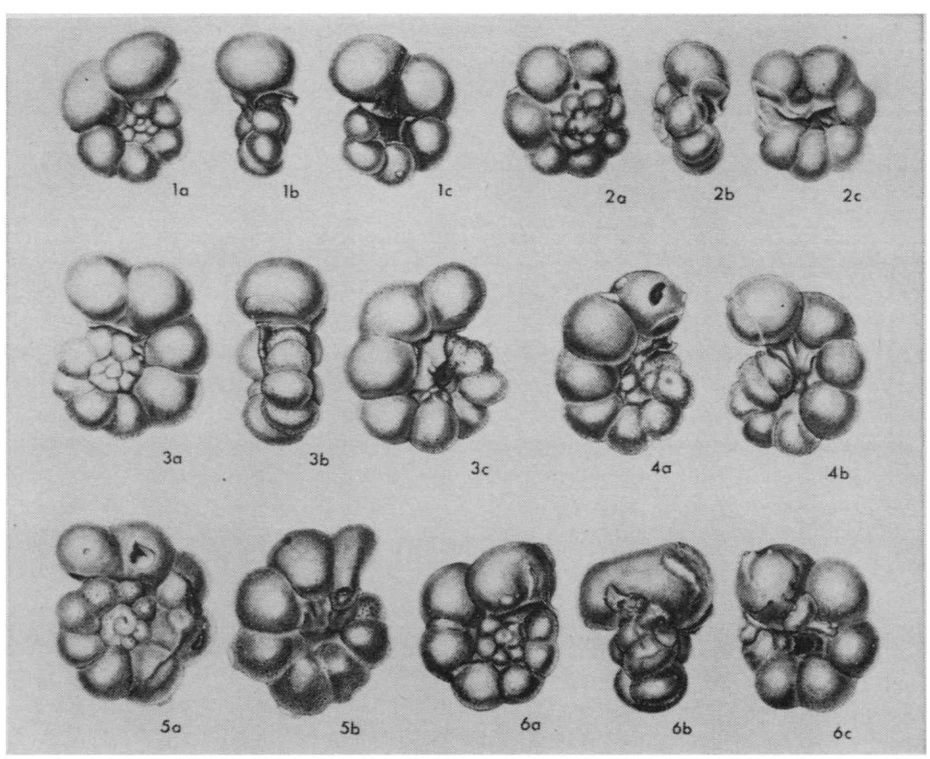

Fig. 5. Diagnostic species of Albian planktonic foraminifers from core V 21-143: *1*, *Hedbergella planispira* (Tappan); *2*, *Ticinella roberti* (Gandolfi); *3–5*, *Ticinella primula* Luterbacher; *6*, *Biticinella* sp. (× 125).

The Albian core is located a little to the north of the former Darwin Rise (Fig. 1). The lithology, fauna, and seismic results suggest that Shatsky Rise may have been a sedimentary basin during Mesozoic time, receiving fragments of shallow marine organisms that inhabited the fringes of nearby atolls or islands on the Darwin Rise; this idea could explain the presence of shallow-water mollusc shells and *Inoceramus* prisms in pelagic sediments. Sometime after early Cretaceous, this basin was uplifted. It appears that the greater thickness of the layers on Shatsky Rise, than of those of the adjacent Pacific floor, results from subsidence and subsequent deposition; and that the subsidence and deposition continued, perhaps in a narrowing belt, considerably beyond Albian time, until uplift to the present position occurred. Determination of the exact age of this uplift must await more cores from Shatsky Rise. We cannot preclude the possibility, however, that the basement arch forming Shatsky Rise is older than the sediments, and that the thickness of the sedimentary layer results from a type of deposition in which the rate is greater in lesser depths. This hypothesis, however, does not explain the presence of *Inoceramus* prisms and molluscs in pelagic sediments of V 21-143.

Zverev, Kobylin, and Udintsev (*36*) reported seismic-reflection traverses over Shatsky Rise very near the traverse in Fig. 1; they assigned sound velocities to the various layers on the basis of the observed amplitude of reflected signals and of Rayleigh's formula relating reflection coefficient to sound velocity and density. Despite the well-known limitations of this method of estimating velocity, they have produced cross sections showing basaltic rocks, probably of Hawaiian type, outcropping near the crest of the rise. If such outcrops are present in the section of Fig. 2, they are the small peaks in sheets 839, 844, and 845.

On the more-northerly crossing of the rise (Figs. 1 and 2) the maximum elevation is about the same as that on the southern crossing; the sediment cover is far less regular, and cores V 21-147 and 148 (Fig. 2) consist of radiolarian clay and red clay respectively. These results suggest that during future work, when the profiler is used to guide selection of coring sites, a substantially larger number of older Tertiary and Mesozoic cores will be obtained from the rise. For example, a steep slope, shown in sheet 839 (Fig. 2), appears to be an even-better site than the source of core 143.

MAURICE EWING
TSUNEMASA SAITO
JOHN I. EWING
LLOYD H. BURCKLE

Lamont Geological Observatory, Columbia University, Palisades, New York

References and Notes

1. The name "Northwestern Pacific Plateau" has been proposed by Tayama, *Japan. Hydrog. Bull.* **3**, 160 (1952).
2. G. V. Udintsev, Ed., *General Bathymetric Map of the Ocean: Pacific Ocean* (Dept. Geod. Cartog., Geol. Comm., Moscow, 1964).
3. E. L. Hamilton, *Geol. Soc. Amer. Mem.* **64**, 22 (1956).
4. ———, *J. Paleontol.* **27**, 204 (1953).
5. W. R. Riedel and B. M. Funnell, *J. Geol. London* **120**, 14 (1964).
6. H. Kagami *et al.*, *J. Geol. Soc. Japan* **70**, 414 (1964).
7. Radiolarian species identified by J. D. Hays, Lamont Geological Observatory.
8. J. Ewing and G. B. Tirey, *J. Geophys. Res.* **66**, 2917 (1961).
9. Acoustically transparent and acoustically opaque refer to characteristics exhibited by the sediments in the frequency range used (60 to 150 cy/sec).
10. M. Ewing, J. Ewing, T. Aitken, in preparation.
11. O. Renz, H. Luterbacher, A. Schneider, *Eclogae Geol. Helv.* **56**(2), 1085 (1963); I. P. Silva and H. Luterbacher, *Bull. Ver. Schweiz. Petrol. Geol. Ing.* **31**(81), 160 (1965).
12. R. Gandolfi, *Riv. Ital. Paleontol. Mem.* **4**, 1 (1942).
13. J. Sigal, *Congr. Geol. Intern. 19th Algeria Monogr. Ser.* **1**, 1, 26 (1952).
14. F. T. Banner and W. H. Blow, *Palaeontology* **2**, 24, pl. 3, fig. 3 (1959).
15. H. Klauss, *Eclogae Geol. Helv.* **52**(2), 753 (1959).
16. A. Loeblich and H. Tappan, *Micropaleontology* **7**(3), 257 (1963).
17. H. Tappan, *J. Paleontol.* **17**(5), 476 (1943).
18. R. Perkins, *Geol. Soc. Amer. Mem.* **83**, 24 (1960).
19. Y. Takayanagi and J. Iwamoto, *Trans. Proc. Palaeontol. Soc. Japan New Ser.* **45**, 183 (1962).
20. T. Matsumoto, in *Geology of Japan*, F. Takai, T. Matsumoto, R. Toriyama, Eds. (Tokyo Univ. Press, Tokyo, 1963), p. 99.
21. T. F. Grimsdale and F. P. C. M. von Morkhoven, *World Petrol. Congr. Rome Proc.* **4**, 473 (1955); F. B. Phleger, *Ecology and Distribution of Recent Foraminifera* (Johns Hopkins Press, Baltimore, 1960).
22. R. Todd and D. Low, *Deep-Sea Res.* **11**, 395 (1964).
23. H. H. Hess, in *Intern. Oceanog. Congr. Preprints* (AAAS, 1959), p. 33; in *Petrologic Studies: A Volume in Honor of A. F. Buddington* (Geol. Soc. Amer., New York, 1962), p. 260.
24. H. W. Menard, *Marine Geology of the Pacific* (McGraw-Hill, New York, 1964), p. 260.
25. R. W. Raitt, *Bull. Geol. Soc. Amer.* **67**, 1623 (1956).
26. R. Revelle, M. N. Bramlett, G. Arrhenius, E. D. Goldberg, *Geol. Soc. Amer. Spec. Paper*, **62**, 221 (1955).
27. G. Arrhenius, G. Kojelloberg, W. F. Libby, *Tellus* **3**, 222 (1951).
28. D. B. Ericson, M. Ewing, G. Wollin, B. C. Heezen, *Geol. Soc. Amer. Bull.* **72**, 241 (1961).
29. E. L. Hamilton, *J. Sediment. Petrol.* **30**, 370 (1960).
30. V. V. Beloussov, *J. Geog. Res.* **65**, 4127 (1960).
31. H. W. Menard and E. L. Hamilton, in *Proc. Pacific Sci. Congr. 10th Hawaii* (1963), p. 193.
32. "Ocean drilling on the continental margin," report prepared for participants in JOIDES program, *Science* **150**, 709 (1965).
33. "Geological Society Phanerozoic time scale 1964," *Quart. J. Geol. Soc. London* **120S**, 260 (1964).
34. M. Ewing and J. Ewing, *J. Geophys. Res.* **68**, 251 (1963); in *Studies on Oceanography: A Volume Dedicated to K. Hidaka*, K. Yoshida, Ed. (Tokyo Univ. Press, Tokyo, 1964), pp. 525–37; M. Ewing, W. J. Ludwig, J. I. Ewing, *J. Geophys. Res.* **69**, 2003 (1964).
35. M. Ewing, M. Talwani, J. I. Ewing, in *Proc. Caribbean Geol. Conf. 4th 1965*, in press.
36. S. M. Zverev, V. M. Kobylin, G. V. Udintsev, *Doklad. Akad. Nauk SSSR* **135**, 1461 (1960).
37. From H. W. Menard, *Marine Geology of the Pacific* (McGraw-Hill, New York, 1964).
38. Supported by the Office of Naval Research [contract Nonr 266 (48)], NSF, United States Steel Foundation, and the Institutional Scientific Research Pool of Columbia University. We thank the officers, crew, and scientific staff on *Vema's* cruise 21; especially Paul Chelminski who as Chief Scientist chose the coring locations, W. J. Ludwig and J. D. Hays for reviewing the manuscript, and L. A. Smith who examined the molluscan fossils. Lamont Geological Observatory Contribution No. 903.

4 March 1966

Superconductivity of Alpha-Uranium and the Role of 5f Electrons

Abstract. *A much sharper and lower superconducting transition has been found for α-uranium than any reported previously. A model that explains the unusual volume dependence of α-uranium below 43°K and the unusual pressure dependence of its superconducting transition temperature is presented.*

We report the superconducting transition of a single crystal of α-uranium. This transition (T_c), between 0.21° and 0.25°K, is sharper by about an order of magnitude and occurs at a much lower temperature than that previously reported for α-uranium (*1–3*). Such behavior was anticipated in the recent work on superconductivity in β-uranium (*4*), although at that time a consideration of published heat-capacity data led to an estimate that T_c would be < 0.15°K. A qualitative model involving the gradual transfer of electrons from the *6d–7sp* band (*5*) to an almost pure *5f* band below 43°K is offered to account for the unusual behavior of α-uranium at low temperatures (see *6*, *7*).

The superconducting transition of a small single crystal of α-uranium (approximately 1 by 3 by 5 mm, heavily etched and without any sharp edges) grown by the grain-coarsening technique (*8*) is shown in Fig. 1. The transition is representative of pure α-uranium in a relatively unstrained condition and is not complicated by the presence of filaments of other phases. The small tail