27. Remarks on Tertiary Sequences of Two Cores from the Pacific

By

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During the Swedish Deep-Sea Expedition 1947–1948 some cores were raised in regions where Tertiary deposits outcrop or where only thin layers of Pleistocene age rest upon much older sediments. Two of these cores are dealt with in the following in order to discuss a facies shift in one of them. The cores have earlier been described by OLAUSSON (1960).

Core 90 (lat. 3°21′ S., long. 174°12′ E.; depth 4830 m) and Core 91 (lat. 2°50′ S., long. 171°18′ E.; depth 4096 m) are both Lower Miocene in age. Core 91 has earlier been studied by RIEDEL (1959). He has also kindly analyzed for my paper the radiolaria in Core 90: "Radiolaria in the sample from 2–3 cm indicate a Quaternary age, with considerable admixture of Eocene and Miocene. At 56–57 cm and all samples below that level, the Radiolaria indicate a lower Miocene age—approximately *Catapsydrax dissimilis*—*C. stainforthi* zones established for the Trinidad Cipero formation by BOLLI (1957)" (RIEDEL, personal communication). Dr. M. N. BRAMLETTE has also kindly analyzed the coccolithophorids and has informed me that "sample 2–3 cm contained Quaternary coccolithophorids; samples 56–57, 104–105, and 154–155 contained Radiolaria but no coccolithophorids; samples 204.5–205.5 and others down through 404.4–405.5 contain coccolithophorids indicating an Oligo-Miocene (approximately Aquitanian) age".

Core 90 consists at 258–515 cm of pure coccolith chalk ooze which between 258 and 194 cm grades into radiolarian ooze with no coccolithophorids. This radiolarian ooze extends up to the top of the core. The content of radiolaria in the pure coccolith ooze is rather low especially at the base of the core. No forams were seen. There is thus a shift in the facies.

Core 91 consists predominantly of calcareous oozes with an appreciable amount of radiolaria between 8.2 and 11 m. In this core, raised from an adjacent station (ca 300 km westwards), the coccolithophorids are responsible for the predominating part of the core division up to about 11 m. Above 8.2 m and especially at the topmost 3 m of the core, forams play a large role as regards the content of carbonate, even if the coccolithophorids are still present. The lower content of radiolaria above approximately 8 m and especially above 3 m is more likely due to the dilution effect of forams than a lower supply of such

Table 1. Approximate correlations of Cores 90 and 91 based on radiolarian analyses made by RIEDEL (cf. text below).

	Zones of BOLLI (1957)	Approximate correlations based on Radiolaria
Lower Miocene	*Globorotalia fohsi barisanensis* zone, Cipero formation	
		— Core 91, 409–410 cm
	Globigerinatella insueta zone, Cipero formation	
		— Core 91, 1409–1410 cm
	Catapsydrax stainforthi zone, Cipero formation *Catapsydrax dissimilis* zone, Cipero formation	} ? Core 90, 56–405 cm

tests to the bottom (see further diagram in OLAUSSON, 1960). The deposits at the base of Cores 90 and 91 are thus similar with a predominance of coccolithophorids and with smaller amounts of radiolaria. The content of forams, however, is still lower in Core 90 than in Core 91. The relative ages of both cores are given in Table 1, which is based on RIEDEL's paper of 1959 and his personal communication. Judging from this table, the deposits in Core 90 are slightly older than or possibly of the same age as those at the base of Core 91. It may therefore be assumed that the organic production in this region has been approximately the same both from the qualitative and the quantitative point of view up to the deposition of the base of Core 91. Judging from the foram curve of Core 91 it would seem that the increase in the rate of organic production starts higher up in the Lower Miocene. The radical change of facies in Core 90 must consequently be due to a dissolution of carbonates, e.g. factors which have decreased and finally stopped the deposition of coccolithophorids.

The solubility of calcium carbonate in the ocean has been discussed by, *inter alia*, REVELLE and FAIRBRIDGE (1957). At a depth of approximately more than 4000 m, the water is undersaturated for $CaCO_3$ and the pelagic skeletons are dissolved. The amount of dissolution increases with increased depth, so that, at an average depth of more than 4200 m in the Pacific, the bottom sediments consist of non-calcareous matter (op. cit., p. 283). The temperature of the bottom water during Middle Oligocene was 10.4° and during Lower-Middle Miocene 7.0° (both with $\pm$ 0.5°C) according to EMILIANI (1954). The present bottom water temperature is of the order of + 1°C. REVELLE (in BRAMLETTE, 1958, p. 124) has calculated that the present critical depth of about 4500 m would correspond to about 6700 m for comparable solubility conditions, with a Tertiary bottom water temperature of 12°.

From this statement it seems probable that the critical depth of Lower Miocene was larger than the coring depth of Core 90 (4830 m). In the area where Core 76 was raised, carbonate was deposited up into the Pliocene at a depth of 5155 m (OLAUSSON, 1961, p. 28).

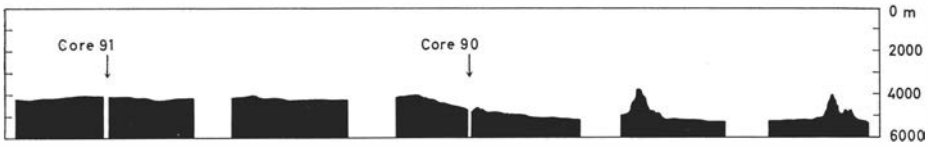

Fig. 1. Bottom topography in the vicinity of the stations of cores 90 and 91 (after KOCZY, 1956).

The transition zone in Core 90 has a thickness of some 64 cm. If we assume a rate of deposition of, e.g., 1 mm/1000 years, the transition division would represent a time of the order of 640,000 years. From a geological point of view the facies shift must have occurred rapidly. Consequently, for this reason it is also less probable that the decreased size of the critical depth due to a general temperature decrease would be responsible for the dissolution of the carbonates. Hence, the main cause of the dissolution of the coccolithophorids must be some other factor which, however, for want of a better explanation, must be taken hypothetically.

There are several indications of submergences in the Pacific. Thus the goyots of Alaska show evidence of having been downwarped (MENARD and DIETZ, 1951). DIETZ and MENARD (1953), and HAMILTON (1956) have found indications of downwarping of the ocean floor in the depression that surrounds the Hawaiian Islands, showing that this mass has constituted a burden on the earth's crust causing a depression. MENARD (1956) has found many smoothly sloping areas in the Pacific. The development of an even area into archipelagic aprons is shown in his Fig. 7, partly redrawn in this paper. Comparison between the profile of the bottom (Fig. 1) and the schematic drawings of MENARD (Fig. 2) inclines one to assume a downwarping of the ocean floor around the area where Core 90 was collected. The two sea mounts on Fig. 1 are situated among the Gilbert Islands.

The dissolution of deep-sea carbonates by magmatic volatiles, together with the intense local bottom currents which may have been produced by the volcanic activity, is dealt with by PETTERSSON (1954, p. 92). An assumption that the facies change is due to supply of magmatic volatiles set free by submarine volcanic activity seems to the author the most probable explanation for the time being. In that way we may expect a local and rapid decrease of the critical depth. Let us thus assume that the sea-floor around the coring place of Core 90 has been depressed and that the cause of the submergence is the growth of submarine volcanic cones or shields. This submergence may have occurred during the time of the formation of the transition zone from an original depth equal to that of Core 91 (cf. Fig. 1). We must not exclude the possibility that the submergence may have occurred earlier but in this case we must assume that the volcanic activity has been awakened again and that during this time, magmatic volatiles have been brought into the waters from below.

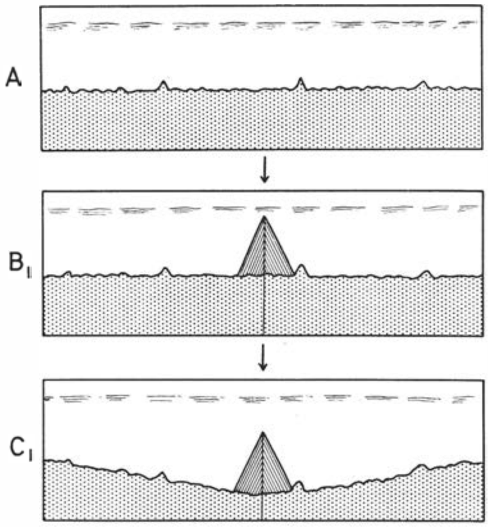

Fig. 2. Possible sequence of development of archipelagic aprons (after MENARD, 1956). All stages in this sequence have been found on sea floor.

An influx of volcanic phosphate into the euphotic zone may have increased the rate of organic production (cf. BULJAN 1955). It is also possible that siliceous emanations from volcanoes may have constituted a favourable condition for the growth of radiolaria (cf. TALIAFERRO, 1933; BRAMLETTE, 1946; RIEDEL, 1959 *b*). Judging by the increased content of radiolaria and forams in the middle and top parts of Core 91, the organic production was intensified in that area higher up in the Lower Miocene. Whether this increase is isochronous or influenced by the events assumed to have happened further east is open to conjecture.

A few shards of volcanic glass are found in the lower and middle part of the transition zone in Core 90; at other levels no glass is observed. In Core 91 no glass > 150 μ is recorded. The top of the sea mounts discussed occur at a depth of more than 2000 m, a depth where pumiceous lava cannot form because of a high hydrostatic pressure (RITTMANN, 1936, p. 52).

A development of an apron (*sensu* MENARD) has not been possible around these sea mounts as shown in Fig. 1 because this region has been essentially an area of non-accumulation from approximately Lower Miocene up into the Quaternary.

The age of the volcanic activity in the area of Gilbert Islands is not known to the author. The Lau effusives from the Fiji Islands are known to be Aquitanian-Burdigalian in age (GLAESSNER, 1959). From Saipan, tuff of Upper Oligocene age is recorded, and from Guam, basalt of Miocene age is known (*op. cit.*). The oldest rock of the reef, to the depth penetrated by the drill on Bikini, appears to be of Miocene age (LADD *et al.*, 1953, p. 2271). The coralline material at the bottom of the drill holes on Eniwetok above the subjacent basalt was Eocene in age (*op. cit.*).

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