Cyclammina cancellata Brady shows marked variations of diameter and thickness in Holocene sediments from depths of 500 m to more than 3,500 m in the Peru-Chile Trench area. The mean diameter increases consistently to a maximum of 5 mm at 2,000 m. Fluctuations between 4 and 5 mm follow from 2,000 to 3,500 m, and a decreasing trend characterizes deeper samples. The mean thickness increases steadily downward to about 3,500 m where a slight decrease sets in.

Using mean diameter, thickness, and a ratio between both, populations of this study can be characterized as to depth zones. Thus, small and relatively thick forms appear at about 500 m; larger and proportionally thinner forms live deeper than 1,000 m; large but relatively thick specimens characterize depths of about 2,000 to 3,500 m; and somewhat smaller and thicker ones are typical for depths below 3,500 m.

Temperature may be the principal factor affecting size, because it increases markedly to about 2,000 m—which coincides with the greatest size change in the populations. In deeper water other factors may play a role. Oxygen, salinity, and nitrate values do not show significant trends. Pressure alone is not directly involved, because off southern California similar size variations occur in different depth zones.

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GEOLOGIC SIGNIFICANCE OF *Prunopyle Titan* CAMPBELL AND CLARK

The radiolarian *Prunopyle titan* Campbell and Clark has been shown by Ingle to be an index of the upper Miocene in California. Its greatest abundance is within the upper Mohnian of southern California where it occurs with sinistrally coiled populations of *Globigerina pachyderma* (Ehrenberg), a cold-water index. In deep-sea cores from high latitudes, *Prunopyle titan* has an upper stratigraphic limit within what is termed by some authors the "Gauss Normal Magnetic Epoch" and a bottom limit below what has been termed the "Gilbert Reversed Magnetic Epoch." The range of *Prunopyle titan* is below the zone of *Pterocanium prismatium* Riedel; the latter is considered to be an index of the Pliocene.

In land sections, K-Ar dates indicate that the upper limit of *Prunopyle titan* is about 9–10 m.y. before the present; in deep-sea cores the upper stratigraphic level of *P. titan* is equated with an age of about 3 m.y. or less. At least three upper Miocene radiolarians are associated with *P. titan* in both its occurrences in deep-sea cores and in the upper Miocene of southern California. No Pliocene radiolarian indices occur in the *P. titan* zone of deep-sea cores. If the paleomagnetic record of deep-sea cores is correctly related to that of volcanic rocks, and the radiometric dates of the latter are valid, the radiometric dates for the later Tertiary marine section of California are about three times too old.

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ULTRASTRUCTURE STUDIES OF SELECTED BENTHIC FORAMINIFERA

Electron microscopy of benthic calcareous Foraminifera reveals the presence of a calcite layer on both external and internal test surfaces. This layer is analogous to the calcite crust which has been reported on external surfaces of planktonic Foraminifera. The crust was observed on two granular-walled species, *Nonionella scapha* and *Nonionella miocenica,* and on two radial-walled species, *Cancris indicus* and *Bolivina spissa.* On these four species, the crust is a very thin layer which occurs only on specimens from the greater depth ranges. Where no crust is present, test surfaces of granular- and radial-walled species have different appearances at high magnifications. However, crusts may cause surfaces on both groups to appear similar. On the radial-walled species *Bolivina argentea,* crust is noticeable on specimens from shallow water and becomes progressively thicker, reaching a maximum thickness of more than 4 μ at the lower end of the depth range. Specimens of *B. argentea* from a low oxygen environment have thinner crusts than specimens from a normal environment of the same depth. The crust is not a postmortem feature because it is found on specimens which have absorbed a rose bengal stain. The crust is generally thicker on early than on late chambers, indicating its probable secondary origin.

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TERTIARY FORAMINIFERAL PALEOECOLOGY AND BIOSTRATIGRAPHY OF PART OF OREGON CONTINENTAL MARGIN

Several thousand feet of late Tertiary marine sediments crop out across Heceta Bank on the central Oregon shelf. Rock samples from two east-west profiles (44°05′ and 44°10′ N) have yielded large, well-preserved foraminiferal faunas. The stratigraphic sequence of the samples has been determined using sparker subbottom profiles.

Two possible stratigraphic units are delineated on the basis of their foraminiferal content, seismic-reflection characteristics, and lithology. The older is characterized by *Bolivina seminuda foraminata, B. semiperforata, B. spissa, Bulimina subacuminata, B. subcalva, Buliminella* cf. *B. exilis, Epistominella pontoni californica,* and *Uvigerina peregrina;* less than 10 percent planktonic foraminifers; and right-coiling *Globigerina pachyderma.* This fauna represents paleodepths of 500–1,000 m and is dated as Pliocene. The younger unit is characterized by *Cassidulina minuta, Eilohedra levicula, Epistominella exigua, Nonionella* spp., *Trifarina angulosa,* and *Uvigerina juncea;* more than 50 percent planktonic foraminifers; and left-coiling *G. pachyderma.* This unit was deposited at depths of 100–200 m. This fauna could be Pliocene or Pleistocene. Paleoenvironmental data require minimal uplifts ranging from approximately 1,000 m for the oldest sampled strata to 100 m for the youngest. There was a general shoaling throughout the deposition of the units.

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CORRELATION OF MARINE MIDDLE TERTIARY STAGES OF CALIFORNIA WITH TROPICAL PLANKTONIC ZONES

The Oligocene-Miocene boundary is equated with the *Globigerinoides trilobus* datum of the tropics; this is approximately equivalent to the base of the Saucesian Stage of California. In ascending order, the lower Miocene *Catapsydrax dissimilis, C. stainforthi,* and *Globigerinatella insueta* zones correlate with the Saucesian and basal Relizian Stages. Assemblages characterizing the *Catapsydrax stainforthi* zone have been identified in the upper part of the lower Saucesian Stage of Reliz Canyon, California. Further, *Sphenolithus belemnos* is a good index of the lower Miocene of tropical areas and of the Saucesian Stage of California.

The orbuline datum of the tropics, which is in the uppermost part of the *Globigerinatella insueta* zone, is the base of the middle Miocene. This level appears to correspond to the base or the lower part of the Relizian Stage of California. In ascending order, the middle Miocene *Turborotalia peripheroronda* and *Globorotalia peripheroacuta* zones correlate with the Relizian Stage, and the *Globorotalia praefohsi* and *Globorotalia fohsi* zones correlate with the Luisian Stage. *Sphenolithus heteromorphus* occurs in the Relizian Stage and also in the *Globigerinatella insueta* and *Turborotalia peripheroronda* zones of the tropics. *Discoaster kugleri* is an index of the uppermost zone of the *G. fohsi* sequence and it is identified in the upper Luisian Stage of Newport Bay, California. Orbulines first appear in the Luisian Stage in California.

The *Globorotalia menardii* datum is the base of the upper Miocene in tropical areas, and it corresponds approximately to the *Globigerina pachyderma* datum of California or the base of the lower Mohnian. The dextral *Globigerina pachyderma* zone of the lower Mohnian contains *Catinaster coalitus* and *Discoaster bollii,* which are indices of the *Turborotalia mayeri* and *Globorotalia menardii* zones of the tropics. The sinistral *Globigerina pachyderma* zone of the upper Mohnian and basal Delmontian Stages represents the first major cool event in the middle Neogene; it correlates with the *Turborotalia acostaensis* (*Globigerina bulloides*) zone of tropical areas and with the sinistral *G. pachyderma* zone of the Messinian of Italy.

The base of the Pliocene is marked by the appearance of "*Sphaeroidinella dehiscens*" and by the change from sinistral to dextral populations of *Neogloboquadrina dutertrei.*

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Sedimentation in Santa Barbara Basin, California

The Santa Barbara basin off California (depth, 575 m) obtains its surface water from the California Current, which brings cold, nutrient-rich waters from the north and from the subsurface through upwelling. This combination of events causes a high level of plankton productivity. The deep basin water is derived from the oxygen-minimum zone below the California Current, which is centered between 500 and 1,000 m depth and which is a consequence of *in situ* oxygen depletion by decay and respiration processes and of advection of oxygen-poor water. The bottom water of the basin is trapped below sill depth (480 m) and is nearly depleted of oxygen, because the only exchange is with low oxygen water and because the sediments have high organic content.

Burrowing animals therefore are absent in the center of the basin and sediment deposition is undisturbed. Sediments come from two sources, plankton and land detritus. The winter rains increase the supply of terrigenous detritus, whereas summer production supplies organic material. This biannual variation is recorded in the sediment as annual layers or varves.

Varves develop only below sill depth, and sediments away from the central region show progressively less stratification. Freeze coring and other new sampling techniques, as well as X-radiography, show that the varving extends from the surface to at least a 2-m depth in the central basin sediments, except where turbidite layers disturb the sequence. The characteristics of varved sediments may be useful in reconstructing the history of ancient anaerobic basins.

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Anaerobic Basin Sedimentation and Differential Preservation of Planktonic Foraminifera

In paleoclimatic reconstruction, fossil planktonic Foraminifera usually are related to ancient surface-water conditions. Processes on the ocean floor, however, are able to alter faunal composition drastically.

Ten core samples from various depths were taken in the Santa Barbara basin which is anaerobic below a sill depth of about 480 m. Sixteen samples were analyzed for their microfossil content, in four size fractions. In each size fraction there is a pronounced difference in composition between samples above and below sill depth. The anaerobic, black, laminated sediments obtained below sill depth contain numerous species and specimens, including very fragile forms such a *Hastigerina digitata.* Fragments are almost absent; pelagic gastropods and pelecypods (aragonite) are plentiful, as are thin-walled calcareous benthonic Foraminifera.

Just above sill depth, sediments are dark green and homogeneous, suggesting moderate aeration. The percentages of *Globoquadrina dutertrei* and of *Globigerina pachyderma* s.s. are much greater there than in the anaerobic samples. Fragments of both planktonic and benthonic Foraminifera are abundant. Thin-walled benthonic Foraminifera are much scarcer than in the deeper samples; aragonitic shells are virtually absent. Well above sill depth sediments are light green and homogeneous and appear well aerated. Both planktonic and benthonic foraminiferal numbers are greatly reduced and *G. dutertrei* strongly dominates all but the finest fraction. Fecal pellets are abundant.

There are several possible causes for the pronounced change in fossil fauna across the anaerobic-aerated boundary: (1) changes in supply, (2) mechanical destruction by benthonic organisms, and (3) chemical dissolution.

A change in supply from the overlying water is unlikely, because the effects of the aeration boundary do not extend into the productive zone. Mechanical destruction by benthonic animals is possible in the aerated zone. The siliceous skeletons of diatoms and Radiolaria, however, are much less affected by the aeration boundary than are calcareous fossils, which suggests that chemical dissolution is the most important factor. Two mechanisms may be responsible: (1) production of CO_2 by the oxygenation of organic matter in the aerated zone, and (2) a more vigorous exchange of interstitial solutions with bottom water by burrowing activity. These two effects of bottom aeration should enhance calcite solution.

The study of the distribution of the resistant Foraminifera, such as *G. dutertrei, G. pachyderma* s.s., *G.*