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.*

truncatulinoides, and *G. inflata,* in ancient Californian sediments should lead to a better understanding of paleobasin oceanography by making it possible to determine sill depths and oxygen minimum distributions. Such studies have obvious applications in the determination of petroleum source rocks, because organic material is preserved in anaerobic conditions but destroyed in aerated sediments.

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MIDDLE TERTIARY STRATIGRAPHY OF SANTA ROSA ISLAND, CALIFORNIA

(No abstract submitted)

DAVID DOERNER, Dept. of Geology, Univ. of California, Santa Barbara, Calif.

PALEOGENE SEQUENCE IN NORTHERN CHANNEL ISLANDS, CALIFORNIA

Cretaceous and/or lower Tertiary marine sedimentary rocks crop out on the three major northern Channel Islands. Study of the rocks and their contained foraminiferal assemblages reveals many faunal and lithologic similarities between these three islands.

On Santa Cruz Island foraminiferal assemblages indicate that deposition of Cretaceous and Paleocene strata took place in a shallow-water marine basin which became continuously deeper during Eocene time until lower bathyal depths were present by the end of late Eocene time. Sedimentary structures and textures, as well as lateral thickening of strata, suggest source areas on the north or northeast.

On Santa Rosa Island, where the oldest rocks exposed are of middle and late Eocene ages, foraminiferal assemblages indicate a similar deepening.

On the west, however, foraminifers from Cretaceous and early Tertiary strata of San Miguel Island indicate continuous deep-water conditions and open-ocean circulation during Cretaceous, Paleocene, and Eocene times.

The writer suggests that all three depositional sites were part of a single basin or two closely contiguous basins with a northwest-southeast axial trend.

S. ROBERT BERESKIN, Dept. of Geology, Univ. of California, Santa Barbara, Calif.

MIOCENE BIOSTRATIGRAPHY OF SOUTHWESTERN SANTA CRUZ ISLAND, CALIFORNIA

A 2,265-ft conformable sequence of marine conglomerate, sandstone, and mudstone crops out along continuous sea-cliff exposures on southwestern Santa Cruz Island. Disconformably overlying rocks of late Eocene age, the Vaqueros Sandstone, the Rincon Formation, the San Onofre Breccia, and the Monterey Formation contain mollusks and foraminifers, which indicate the presence of a Miocene sequence of Zemorrian through Mohnian(?) ages.

The southwestern corner of the island is structurally represented by a doubly plunging anticline trending approximately N40°W. Outcrops of the Vaqueros, Rincon, and San Onofre formations are on both the southwestern and northeastern limbs of the fold enveloping a Paleocene-Eocene core. The Monterey Formation is exposed only on the southwestern limb and, although this unit is not lithologically identical to the typically siliceous Monterey Formation on the mainland, it can be correlated with these mainland exposures on the basis of fossil Foraminifera. Paleoecologic and paleotopographic studies based on field relations and foraminiferal paleoecology indicate that the shallow part of the basin was on the east or northeast, and that the deeper areas extended westward and perhaps southward.

SEG TECHNICAL PROGRAM SUMMARY

THURSDAY AFTERNOON, MARCH 27

1. R. L. MAXWELL, P. A. GAECHTER: Geophysical survey application of Doppler sonar navigation
2. G. B. MORRIS, R. W. RAITT, G. G. SHOR, JR.: Velocity anisotropy of upper mantle
3. THANE H. MCCULLOH: Oil fields, gravity anomalies, and surface chemical manifestations—correlations, causes, and exploration significance
4. JOHN K. ALDRICH: Gravity of northern Channel Islands
5. E. BERKMAN, J. R. LAFFHR: Bouguer reduction technique for surface ship gravity meter data

FRIDAY MORNING, MARCH 28

1. M. D. CARTER AND OTHERS: Applications of continuous reflection parameter selection
2. J. M. HORNSBY: Seismic record section at depth
3. C. H. DIX: Searching for stratigraphic traps
4. MILTON DOBRIN: (Title to be announced)

FRIDAY AFTERNOON, MARCH 28

5. H. GARY GREENE: A portable refraction-seismography survey of gold placer areas near Nome, Alaska
6. RICHARD TAGG: (Title to be announced)
7. W. E. BALES, L. D. KULM: Structure of continental shelf off southern Oregon
8. L. D. KULM, W. E. BALES: Shallow structure and sedimentation on upper continental slope off southern and central Oregon
9. LEE C. BENNETT, JR.: Continuous seismic profiling on continental shelf off Washington

ABSTRACTS OF PAPERS

(in order of presentation)

ROBERT L. MAXWELL and P. A. GAECHTER, Marquardt Corp., Los Angeles, Calif.

GEOPHYSICAL SURVEY APPLICATION OF DOPPLER SONAR NAVIGATION SYSTEMS

Recent developments in Doppler sonar-velocity-measurement techniques have made available a new navigational aid for marine survey operations. This paper describes the capabilities of the Marquardt Doppler sonar system. A description of currently available equipment, a summary of its performance in the operational marine environment, and applications of this equipment to geophysical survey navigation also are presented.

G. B. MORRIS, R. W. RAITT, and G. G. SHOR, JR., Univ. of California, San Diego, and Marine Physical Laboratory of Scripps Institution of Oceanography, La Jolla, Calif.