LIPPS, JERE H., and MAURICE KALISKY, Dept. of Geology, Univ. of California, Davis, Calif.

CALCAREOUS NANNOPLANKTON BIOSTRATIGRAPHY AND PALEOECOLOGY IN OLIGO-MIOCENE OF CALIFORNIA

Calcareous nannoplankton are abundant in some rocks assigned to the California microfaunal stages. Most species are stratigraphically long ranging, although some have restricted stratigraphic ranges in low-latitude tropical regions. These species permit partial correlation of the California stages with the widely recognized plankton biostratigraphic zones of the tropics.

The upper Zemorrian is correlative with the *Sphenolithus distentus* through the lower *Triquetrorhabdulus carinatus* (NP 24-NN1) zones (upper Oligocene) the Saucesian with the upper *T. carinatus* through the lower *Helicopontosphaera ampliaperta* (NN1-4) zones (lower Miocene), the Relizian with the upper *H. ampliaperta* through the lower *S. heteromorphus* (NN4-5) zones (lower-middle Miocene), the Luisian with the upper *S. heteromorphus* through *Discoaster kugleri* (NN5-7) zones (middle Miocene), and the Mohnian with the *Catinaster coalitus* through *D. calcaris* (NN8-10) zones (middle-upper Miocene).

The species diversity of nannofossils in the California Oligocene-Miocene rocks is low. Like the planktonic Foraminifera from the same rocks, the nannofossils are analogous to species now living in the modern transitional water mass off California. There are no elaborate species as in the tropics and the floras tend to be dominated by single species (*i.e., Coccolithus*). These observations indicate that California was under the influence of a current flowing southward, with velocities nearly that of the modern California Current. The dominance of the assemblages by a single species, as well as other evidence from the rocks, indicates that upwelling was likely as important during the Miocene as it is today.

NILSEN, TOR H., U.S. Geol. Survey, Menlo Park, Calif.

SEDIMENTOLOGY OF TYPE TEJON FORMATION OF SAN EMIGDIO MOUNTAINS, CALIFORNIA

The type Tejon Formation of the San Emigdio Mountains is a marine clastic sedimentary sequence of middle and late Eocene age that was deposited primarily in a variety of shallow-marine environments during an eastward transgression followed by a westward regression. It lies unconformably on a pre-Tertiary crystalline basement complex and is overlain by the marine San Emigdio Formation and the nonmarine Tecuya Formation. It is more than 4,000 ft thick in the center of the range, but thins and grades laterally eastward into nonmarine conglomerates and sandstones. Paleocurrent data indicate dominant transport of sediments toward the west.

Marks defined four members of the Tejon Formation (in ascending order): Uvas Conglomerate, Liveoak Shale, Metralla Sandstone, and Reed Canyon Siltstone. The Uvas contains medium- to large-scale cross-stratification, ripple markings, well-sorted planar-stratified beach-type sandstones, large burrows, boulder beds, locally abundant megafauna, and was deposited adjacent to the transgressive shoreline. The Liveoak shale is primarily an extensively bioturbated silty shale with locally abundant microfauna and abundant sandstone interbeds in its lower and upper parts; it grades laterally eastward from a deep-water shale into shallow-marine sandstones. The Metralla Sandstone Member is typically a bioturbated silty fine-grained sandstone which contains interbedded conglomerates, medium- and large-scale cross-stratification, ripple markings, beach-type sandstones, and abundant megafauna in its eastern exposures where it was deposited adjacent to the regressive shoreline; however, on the west it grades laterally into thinly bedded flyschlike sandstones and shales deposited in deeper water. The Reed Canyon Siltstone Member is in an extensively bioturbated thin unit that locally contains some megafauna, microfauna, and thin coal interbeds.

PATET, ALIX, Dept. of Paleontology, Univ. of California, Berkeley, Calif.

SUBSURFACE STUDY OF FORAMINIFERAL FAUNA OF VAQUEROS SANDSTONE, RINCON SHALE, AND LOWER MONTEREY FORMATION, FROM ELWOOD OIL FIELD, SANTA BARBARA COUNTY, CALIFORNIA

Core samples taken from Texaco's Bishop A-1 well in the Elwood oil field in Santa Barbara County, California, penetrated 4,350 ft of section consisting of sediments of the lower Monterey Formation, the Rincon Shale, and the Vaqueros Sandstone. The two uppermost samples recorded at 558 and 561 ft contained Foraminifera indicating a Luisian age. The Relizian was represented by a thickness of about 700 ft. Approximately 1,500 ft of Saucesian age sediments were present. The upper Zemorrian was represented by 190 ft of section. The bottom 900 ft of preponderantly sandstones proved to be barren of Foraminifera. A foraminiferal faunule of late Zemorrian age, 138 ft below the Vaqueros/Rincon contact indicated an upper bathyal depth in this particular area, as opposed to much shallower conditions, indicated elsewhere at the time of deposition of the Vaqueros Sandstone. Bathyal conditions persisted throughout the subsequent deposition of the Rincon Shale and lower Monterey Formation.

SAVAGE, DONALD E., Univ. of California, Berkeley, and San Diego State College, and LAWRENCE G. BARNES, University of California, Berkeley, Calif.

MIOCENE VERTEBRATE GEOCHRONOLOGY OF WEST COAST OF NORTH AMERICA

Part 1—*Nonmarine vertebrates and marine-nonmarine tie-ins* by Donald E. Savage.

With the conviction that an agreement regarding precise Miocene-Pliocene and Oligocene-Miocene boundaries within the stratal succession of the West Coast region of North America is less important than the establishment of refined age and subage correlations within this region, we assign the following to the Miocene Epoch:

Latest Miocene (10-12 m.y. ago) Clarendonian mammal "age," Cerrotejonian and Montediablan mammal ages, San Pablo (Cierbo-Neroly) of Santa Margarita mega-invertebrate "ages," Mohnian and? Delmontian (in part?) foraminiferal ages.

Late to middle Miocene (12-17 m.y. ago) Barstovian mammal "age," Briones and upper part of Temblor mega-invertebrate "age," later part of Saucesian plus Relizian and Luisian foraminiferal ages.

Middle to early Miocene (17-21 m.y. ago) Hemingfordian mammal "age," earlier part of Temblor mega-invertebrate "age," middle part of Saucesian foraminiferal age.

Earliest Miocene (21-26 m.y. ago) Arikareean mammal "age" (early part may be Oligocene), Vaqueros-Temblor transition plus Vaqueros or Vaquerosian mega-invertebrate "ages," earliest part of Saucesian plus later part of Zemorrian foraminiferal ages.

The Arikareean, Hemingfordian, Barstovian, and Clarendonian "ages" are easily recognized from joint occurrence of fossils representing certain genera of insectivores, rodents, carnivores, mastodonts, horses, rhinos, oreodonts, camels, and other groups of mammals. We are now concerned chiefly with deciphering a more precise time-stratigraphic range for each of the species. We intend to establish a well-disciplined (vertebrate) paleontologic stratigraphy, which can lead to zonation within the basins of nonmarine deposition.

Unfortunately, fossils of land vertebrates are scarce in districts of littoral deposition, but the "classic" sections in the Tejon Hills, San Francisco East Bay, North Coalinga, Sharktooth Hill-Pyramid Hill, Caliente Range-Cuyama Valley, Tecuya-San Emigdio Range, South Mountain, and Santa Ana Mountains districts provide tie-ins between the generalized ma-

rine and nonmarine paleontologic stratigraphies and geochronologies of the Miocene.

Part 2—*Marine vertebrates* by Lawrence G. Barnes.

Emphasis on faunal studies and intensified fossil collecting have shown that marine vertebrates in Miocene strata of the West Coast of North America are useful in paleontologic correlation and in geochronology. Mammals, sharks, and bony fishes, in that order, are probably the most useful groups for correlation and chronology; birds and turtles are less useful at present because they are less well studied. Associations of marine vertebrate fossils with terrestrial mammals and marine invertebrates at several localities have permitted correlations between land-mammal "ages" and marine ages. There are three major chapters in the evolutionary history of marine vertebrates in the West Coast Miocene. These are termed *early, middle,* and *late* and are roughly equivalent to "Vaqueros," "Temblor," and "Santa Margarita" ages respectively. Early Miocene faunas are characterized by archaic mammals (eurhinodelphid dolphins, squalodonts, early sea lions) and birds, and mixed types of sharks. Middle Miocene faunas are characterized by relict archaic mammals (eurhinodelphids, squalodonts, primitive sea lions), some highly specialized mammals (desmatophocine sea lions, desmostylians), and the earliest ancestors of living groups (modernized dolphins, cetotheres). Middle Miocene fishes are tropical, the birds are related to modern taxa, and the sharks are noticeably different from early Miocene species. Late Miocene faunas closely resemble middle Miocene faunas, with similar sharks and birds, but usually lack most of the archaic mammals and turtles and show increased numbers of modernized mammals (dolphins, baleen whales, modern sea lions). Transitions between these three major marine faunas of the Miocene are rarely found.

SCHULTZ, F. E., Humble Oil & Refining Co., Los Angeles, Calif.

HISTORY OF SEISMIC EXPLORATION-SANTA BARBARA CHANNEL

The Santa Barbara Channel is 50 mi northwest of Los Angeles, and represents the offshore part of the Ventura basin, which covers an area of approximately 70 mi in length and 25 mi in width. Structurally, the basin is characterized by sharply folded, highly faulted anticlines, some of which are offshore extensions of onshore producing trends. The basin contains up to 40,000 ft of Tertiary sediments, with production from Pliocene through Eocene reservoirs.

The history of Humble's geophysical activity in the Santa Barbara Channel spans the period from early 1948, when the first reconnaissance lines were shot, through the 1969 digital CDP program. During this period, Humble compiled approximately 10,000 mi of seismic data. All of the data accumulated through 1967 was incorporated into a regional interpretation of the Santa Barbara Channel in preparation for the Federal lease sale in February 1968. Later surveys continued to improve data quality and velocity control for prospect evaluation on Humble leases.

Early seismic surveys, 1948-1953, used dynamite or black powder as an energy source and were recorded on paper records. An "L" spread cable configuration was commonly used, which enabled the geophysicist to resolve a true strike and dip at each shot point. These seismic events were laboriously hand picked, plotted, and migrated. Interpretation of the deep structure was greatly limited on these data by lack of penetration and a severe multiple problem. The near surface structures could be defined and resulted in the discovery of several fields on State offshore leases.

The development of CDP shooting techniques, first used by Humble in 1964 in the Santa Barbara Channel, gave the first insight into the deep structural complexity. Attenuation of multiple energy was possible and greatly needed velocity information could be obtained. Regulations limiting the amount of dynamite which could be used, were the greatest incentive for industry to change to non-dynamite sources. Air gun, gas exploder, and Aquapulse became the principal sources used. Data quality continues to be enhanced by improvements in the energy source, shooting technique, and data processing.

SPARKS, D. M., W. WALOWEEK, and R. A. BALLOG, Shell Oil Co., Los Angeles, Calif.

PALYNOLOGY OF MONTESANO FORMATION (UPPER MIOCENE) OF WESTERN WASHINGTON

Plant microfossils from the Montesano Formation have been studied qualitatively and quantitatively in the type section along the Middle Fork of the Wishkah River. The age of the Montesano Formation has been established independently by Foraminifera as Late Miocene (Mohnian-Delmontian).

Over 100 species of palynomorphs have been recognized from the Montesano Formation with the following taxa most common: *Pinus, Picea, Pseudotsuga, Tsuga,* Taxodiaceae, Cupressaceae, Taxaceae, *Alnus, Betula, Carya, Castanea, Pterocarya, Quercus, Salix,* Compositae, and *Ulmus-Zelkova, Fagus, Juglans.* This assemblage indicates that in late Miocene time elements of the Eastern deciduous forest and coastal plain provinces co-existed with elements of the Cordilleran forest province.

The major floristic difference between the Montesano Formation and the overlying Pliocene-Pleistocene sequence is the disappearance of elements of the Eastern deciduous forest and coastal plain provinces in the younger rocks. Also *Artemisia,* which is absent in the Montesano Formation, becomes an important element in the younger flora. The underlying Astoria Formation, of early to middle Miocene age, is similar floristically to the Montesano Formation with the major differences being an almost complete lack of Compositae as well as the absence of *Polygonum californicum* in the Astoria Formation.

STARK, HOWARD E., Consulting geologist, Ventura, Calif.

FUTURE PETROLEUM POSSIBILITIES OF LOS ANGELES BASIN

The Los Angeles basin is an old and prolific petroleum-producing area, which should produce another 2 billion bbl of oil in the next 20 years. Estimates of ultimate recoverable oil range from 8 to 10 billion bbl, and 1-2 billion bbl of this oil is still undiscovered.

Exploration and production operations are difficult to initiate because of continually increasing governmental restrictions. Oil and gas potential is still geologically good. Three areas are unexplored: the center of the basin, the southeastern end, and the San Gabriel Valley.

Upper Miocene and lower Pliocene rocks are the most prospective for future discoveries and particularly the Soquel sandstones of the Miocene. New accumulations should be expected from both structural and stratigraphic traps.

The most important tool for finding new reserves is good data. We could improve the data situation by a general release of well information and the publication of more measured stratigraphic sections. Because geophysical work is severely restricted, we must use all available tools and investigate all new tools.

TIPTON, ANN, Dept. of Geology, Univ. of California, Santa Barbara, Calif.

ZEMORRIAN AND SAUCESIAN (OLIGO-MIOCENE) FORAMINIFERAL SEQUENCES IN SUBSURFACE, SOUTHWESTERN SAN JOAQUIN VALLEY, CALIFORNIA

Exceptional foraminiferal sequences of Zemorrian and Saucesian (Oligocene-Miocene) age occur in the subsurface of