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.

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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.

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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.

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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.

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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

the southwestern San Joaquin Valley in sediments referable to the Pleito and Temblor Formations. Downdip from the basin margin, these subsurface sequences are commonly more continuous than in outcrop because they generally are free of structural complexities, unconformities, and the prevalence of inshore faunas.

Well cores from two such subsurface sequences permit a reconstruction of the foraminiferal succession from earliest Zemorrian to latest Saucesian time, as well as correlation with nearby outcrop sections. These two wells are the T. H. Purman (Hub) Cymric 1, in the Cymric oil field, northwest of McKittrick, Kern County, and the Texas P.U.P. 1, in the western San Emigdio foothills near Bitter Creek, Kern County.

In the Hub Cymric well section, the Temblor Formation lies, probably disconformably, on the Refugian "Oceanic Sand." On the basis of the foraminiferal content, the Salt Creek Shale and Phacoides Sandstone members are referred to the *Uvigerina gallowayi* Zone, lower Zemorrian Stage; the lower Santos Shale, including the basal subsurface, "Hub fauna," and the Agua Sandstone, to the *Uvigerinella sparsicostata* Zone, upper Zemorrian; the upper Santos Shale, the Carneros Sandstone, and part of the Media Shale, to the lower Saucesian Stage; and the upper Media, to the upper Saucesian *Uvigerinella obesa* Zone. This sequence is similar to and is correlated with the type Zemorrian and overlying Saucesian strata found in the Temblor Formation cropping out in Zemorra Creek on the northwest.

In the Texas P.U.P. well, claystones referable to the Pleito Formation provide an excellent continuum of benthonic foraminiferal assemblages across the Refugian-Zemorrian boundary. Overlying Temblor claystones interbedded with sandstones contain late Zemorrian and Saucesian assemblages. This subsurface sequence is correlated with foraminiferal Pleito and Temblor strata which crop out directly south along Bitter Creek.

Planktonic foraminifers are scarce in the Zemorrian assemblages, but are common and diverse in the Saucesian of the Hub Cymric section. Encountered in the *Plectofrondicularia miocenica* Zone (upper lower Saucesian) of that sequence was the tropical planktonic marker *Catapsydrax stainforthi* Bolli, Loeblich, and Tappan.

The benthonic foraminiferal assemblages are largely bathyal in character and indicate at least warm-temperate surface temperatures in the San Joaquin basin during Zemorrian and Saucesian times.

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REVIEW OF STRATIGRAPHIC NAMES AND MEGAFAUNAL CORRELATION OF PLIOCENE ROCKS ALONG SOUTHEAST MARGIN OF LOS ANGELES BASIN, CALIFORNIA

Three named stratigraphic units that are wholly or in part of Pliocene age form discontinuous outcrops around the southeast margin of the Los Angeles basin: the Fernando Formation (lower and upper Pliocene), the Capistrano Formation (upper Miocene and lower Pliocene), and the Niguel Formation (upper Pliocene).

The Fernando Formation is exposed in the Puente Hills, in the Northwestern Santa Ana Mountains, and at Upper Newport Bay; it consists of two stratigraphic units that typically are separated by an unconformity. The thickness of the formation ranges from nearly 6,000 ft in the western Puente Hills to about 1,300 ft at Newport. The common lithologic types in the upper unit are siltstone, sandstone, and conglomerate; the lower unit is predominantly siltstone. Gaps in the faunal record preclude accurate zonation, but much of the provincial Pliocene is represented by a composite section. Using a twofold chronology, the lower unit at most localities is early Pliocene in age, and the upper unit, late Pliocene, although a precise time boundary is difficult to define on the basis of mollusks. Megafaunas from the northeast part of the basin characteristically indicate inner sublittoral environments, whereas those nearer the present coast, which contain large displaced assemblages, suggest deposition in outer sublittoral to upper bathyal depths. Basinward, the Fernando Formation grades into subsurface strata that commonly are called Repetto and Pico Formations.

The Capistrano Formation is exposed at Newport Bay and in the Capistrano syncline. Most of the formation at Newport is composed of mudstone, but near Dana Point it consists of a radiolarian mudstone facies; a deep-sea, fan-valley, coarse-grained facies; and a foraminiferal mudstone facies. In the vicinity of San Juan Capistrano, the type area, the formation is about 2,100 ft thick and is composed chiefly of mudstone. Between El Toro and Arroyo Trabuco, the Oso Member, a large lenticular sandstone unit as much as 1,400 ft thick, constitutes most of the formation. The lower part of the Capistrano Formation and the Oso Member are assigned a late Miocene age; the upper part in the San Juan Capistrano-Dana Point area is early Pliocene and locally separated from the lower part by an unconformity. At Newport Bay the upper part is eroded, and the formation is entirely late Miocene in age. Small assemblages of mollusks from the upper part of the formation near Dana Point are displaced, and their species content suggests deposition in the upper bathyal zone. The lower part (Miocene) of the Capistrano Formation probably correlates with the Malaga Mudstone Member of the Monterey Shale and with the upper part of the Puente Formation; the upper part (Pliocene), with the lower unit of the Fernando Formation at Newport Bay and in the Puente Hills.

The Niguel Formation caps most of the low hills between El Toro and San Juan Capistrano. Much of the formation at the northernmost and westernmost outcrops may be nonmarine, and the uppermost beds in the type area 5 mi north of San Juan Capistrano may be nonmarine. The chief constituents of the formation are sandstone, conglomerate, and siltstone. Conglomeratic beds at the base are deeply channeled into older rocks. A thickness of 350 ft is estimated for the formation in the type area. Mollusk assemblages contain many species diagnostic of a Pliocene age, and the composite fauna is provisionally assigned to the latter half of the epoch. Mixed depth assemblages are common, but the localities in the inland area contain an abundance of shallow, warm-water species, whereas those nearer the coast contain some extant species that range into upper bathyal depths. The composite megafauna is strikingly similar to those from the San Diego Formation at Pacific Beach and from the upper member of the Fernando Formation in the eastern Puente Hills; it closely resembles those from the upper part of the Pico Formation in the eastern Ventura basin and from the Careaga Sandstone in the Santa Maria district.

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LUISIAN AND MOHNIAN BIOSTRATIGRAPHY OF MONTEREY SHALE AT NEWPORT LAGOON, ORANGE COUNTY, CALIFORNIA

Sediments of Luisian and Mohnian age are exposed almost continuously in a 1,400-ft section of Monterey Shale along the margin of Newport Lagoon. The lowermost 200 ft appears to be barren of fossils, consequently, no definite age assignment can be demonstrated for this part of the section. Overlying this barren interval is approximately 265 ft assigned to the Luisian Stage on the basis of occurrence of *Brizalina advena striatella, Brizalina imbricata, Pullenia miocenica, Siphogenerina* spp. and *Valvulineria californica californica.*

Approximately 40 ft of section directly above the Luisian sediments is assigned to the *Brizalina modeloensis* Zone of the lower Mohnian Stage as defined by the restricted occurrence of the nominate species (*sensu stricto*); also present, but not restricted to the zone, are *Bulimina unigerinaformis, Cassidulina monicana,* and *Concavella gyroidinaformis.*

Overlying the *Brizalina modeloensis* Zone is 325 ft of sedi-