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.

VEDDER, J. G., U. S. Geol. Survey, Menlo Park, Calif.

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.

WARREN, A. D., Mobil Oil Corp., Dallas, Tex.

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-

ments which is assigned to the *Bulimina uvigerinaformis* Zone of the lower Mohnian Stage. The *Bulimina uvigerinaformis* Zone can be readily divided into an older subzone designated the *Concavella gyroidinaformis* Subzone and a younger subzone here designated the *Brizalina woodringi* Subzone. The top of the older subzone is marked by the last occurence of *Concavella gyroidinaformis*; the *Concavella gyroidinaformis* Subzone is approximately 210 ft thick at this locality. The overlying *Brizalina woodringi* Subzone is based on the continued occurrence of *Bulmina uvigerinaformis* after the extinction of *Concavella gyroidinaformis*. This subzone is approximately 115 ft thick with its top, and the top of the lower Mohnian Stage, marked by the last occurrence of *Bulimina uvigerinaformis*.

Above the lower Mohnian Stage at Newport Lagoon is approximately 470 ft of foraminiferal Monterey Shale assigned to the upper Mohnian Stage. Among the many species present are *Bolivina hughesi, Brizalina benedictensis, Brizalina decurtata, Brizalina giradensis, Brizalina granti, Cassidulinella renulinaformis* and *Discorbinella valmonteensis*. No foraminifers were found in the uppermost 100 ft of Monterey Shale which overlies the sediments of demonstrable Mohnian age.

Cyclococcolithina neogammation, a fossil coccolith, was found to have its last occurrence coincident with the top of the lower Mohnian *Concavella gyroidinaformis* Subzone at Newport Lagoon. Another coccolith, *Reticulofenestra pseudoumbilica*, was observed to have its first occurrence at the base of the lower Mohnian *Brizalina modeloensis* Zone. The last occurrence of *Sphenolithus heteromorphus* was confirmed to be in the uppermost Luisian Stage.

WEAGANT, FRANK E., and RODNEY NAHAMA, Consulting geologists, Bakersfield, Calif.

EXPLORATORY TECHNIQUES ALONG MARKLEY GORGE, SACRAMENTO VALLEY, CALIFORNIA

The Markley gorge channel, an ancestral Sacramento river channel, is in the central part of the Sacramento Valley of California. This fossil channel was cut subaerially during late Eocene time and filled in a marine to marginal marine environment during late Eocene and Oligocene times. Before the late Eocene transgression, an early mature stage of stream erosion was reached. Terraces, islands, meanders, and tributaries can be delineated by subsurface methods. The slope along the channel banks ranges from 6 to 36°. Variations of the slope along the channel banks depend on the existing faults, structures, and drainage configuration. Because the gorge fill is unconformably overlain by Miocene continental sediments, the original relief is not known, but it at least exceeds 3,000 ft. This channel has been traced in the subsurface more than 80 mi and has a maximum width of 10 mi. The north end of the gorge is the Wheatland Formation cropping out at the foot of the Sierra Nevada Mountains near the town of Marysville. The south end of the gorge is in the Montezuma basin where gorge sediments merge with deeper water sediments of the Sidney Shale and shallower water sediments of the Kirker Formation.

The gorge fill consists predominately of shale with minor amounts of sandstone and conglomerate which have considerable lateral and vertical lithologic variation.

Truncation of the underlying Eocene, Paleocene, and Upper Cretaceous formations by the Markley gorge combine with local structure to form commercial gas accumulations. Examples are: Maine Prairie (75 Tcf, 1,020 BTU); Liberty Island (24 Tcf, 988-996 BTU); Millar (18 Tcf, 980 BTU); Todhunters Lake (57 Tcf, 890-897 BTU); and Greens Lake (8 Tcf, 830-850 BTU). Along the north part of the Markley gorge, in the proximity of the city of Sacramento, gas traps exist in westerly dipping Upper Cretaceous sandstone reservoirs. These reservoirs occur in reentrants and islands within the predominantly shale-filled gorge. These spurlike reentrants were created by easterly trending tributaries which intersected the main southerly trending Markley channel.

Techniques in locating Upper Cretaceous reentrants and islands are well control, drainage pattern analysis, gravity profiling and mapping, seismic profiling and mapping, and differential compaction features.

An understanding of the geologic history of the gorge and of the truncated sediments is also necessary to locating potential future gas fields along the gorge.

WEAVER, D. W., and A. TIPTON, Univ. of California, Santa Barbara, Calif.

FORMATIONS AND AGE—SUBDIVISIONS OF WEST COAST MIDDLE TERTIARY

Equivalents of Lyell's Tertiary subdivisions were recognized early within the upper part of the West Coast marine sedimentary sequence. Boundaries between these series, however, have long remained controversial. The presence of the Eocene here was established clearly once the disputed presence of ammonites in the Pacific Coast Eocene had been resolved in the negative. The scene was thus set for the eventual recognition of Schimper's Paleocene in what had originally been termed lower Eocene Martinez, as distinguished from the first recognized, and higher, Eocene near Tejon Pass, California. The Pliocene-Pleistocene boundary soon was clarified, at least to the extent that this boundary had ever been clear in the typical terrain of Italy. On the West Coast, the tendency has been to place it between the two faunal zones in the Santa Barbara Formation (*i.e.*, at the base of the original lower San Pedro), or more recently, following Woodring's recommendation, at the base of the Santa Barbara and its age-equivalents.

In the middle Tertiary, however, the lower and upper boundaries of the Miocene, and subsequently of the Oligocene, were not as readily drawn. Some workers have placed the base of the Miocene as low as the lowest beds of the Vaqueros Formation, a Blakeley Oligocene age-equivalent and placed the top to include even the Pliocene Etchegoin Formation.

The persistence on the West Coast of these middle Tertiary boundary problems has been due in part to the common presence in that stratigraphic interval of the organic Monterey Shale, with its sparse and commonly undiagnostic marine megafaunal assemblages. Another source of confusion, as pointed out by Schenck, has been the failure of many workers to note the qualification placed by Conrad on his age-evaluation of those megafossils found in the strata defined subsequently as the Vaqueros Formation; in effect, Conrad had simply said that those fossils indicated an age closer to Miocene than to the Eocene age of Blake's fossiliferous boulder from Tejon Pass. Finally, clarification of these middle Tertiary boundary problems was hampered further by the prevalent use of formational names for time-rock subdivisions of Lyellian series-epochs. These subdivisions were defined on the basis of nothing more than the presence of a fauna or a species thought, on the basis of reconnaissance work, to be an "index species," at some zone within such a formation.

Facies problems, too, were part of the trouble. The term "Temblor-Monterey" came into use when fossiliferous strata of these two formations were seen to interdigitate superpositionally. The major early work on the relations among the Monterey, Vaqueros, and Temblor Formations, attempted to resolve the problem by turning the Monterey into a middle Tertiary time-rock term of series magnitude. This legalism, both confusing and unnecessary, persisted for more than 20 years before the Monterey formally was restored to its original formational status by the U.S. Geological Survey. Meanwhile, terms such as Salinas and Maricopa had been coined for local developments of the Monterey Shale.

Because microfossils are commonly abundant in the offshore, generally finer grained age-equivalents of the mollusk-bearing strata, micropaleontology has played a leading role in the clari-