the Ocean City and Quillayute Formations. A late Miocene age for these rocks is supported by the presence of *Rotalia garveyensis*, *Uvigerina hootsi*, and *Pulvinulinella gyroidinaformis*.

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STRATIGRAPHY, STRUCTURE, AND OIL POSSIBILITIES IN MONTEREY AND SALINAS QUADRANGLES, CALIFORNIA

The 7,900-foot-thick Cenozoic section in Monterey and Salinas Quadrangles, northern Santa Lucia Mountains, lies on Mesozoic granite and Paleozoic (?) Sur Series schist. Age of the 1,100-foot-thick Carmelo Formation is confirmed by new micro- and megafossil material. Eocene and Oligocene rocks are missing from the section. An 850-foot-thick middle Miocene sandstone-conglomerate formation of two members, containing a typical Temblor fauna, is assigned new member and formation names. Conformably above it is the Monterey Formation consisting of three mappable members: a lowermost Luisian sandstone, up to 200 feet thick; a Luisian through Mohnian siliceous shale, 2,000 feet thick; and an uppermost Delmontian diatomite, up to 800 feet thick. A 60-foot-thick olivine basalt lies between the Monterey and underlying Temblor-age formations, dating this volcanism as middle Miocene. Conformably overlying the Monterey Formation is the Santa Margarita Formation, up to 1,600 feet thick.

Choice of the Monterey vicinity as the type locality of the Monterey Formation was unfortunate because the section there is not typical of the Monterey Formation in well-known localities elsewhere in California, either in age, thickness, or completeness. A few miles east of the type section, the shale and diatomite members of the Monterey Formation begin to interfinger with the Santa Margarita Formation and the entire Miocene section grades into sandstone against the Sierra de Salinas.

Overlapping the Miocene and basement units is the Plio-Pleistocene Paso Robles Formation, up to 500 feet thick, and several thin younger Quaternary units.

The structural pattern is essentially a series of northwest-trending open folds punctuated by the development of three horsts. Several Miocene units are warped over the noses of these horsts. The sense of movement on the northwest-trending faults is normal and strike-slip; thrusting was not identified.

The best possibilities for oil are possible fault-stratigraphic traps along the western side of the Salinas Valley, northeast of the projection of the King City fault.

BROOKS, RICHARD L., Richfield Oil Corp.

REVIEW OF BIOSTRATIGRAPHY OF LOS ANGELES BASIN

The Los Angeles basin contains a thick sedimentary sequence, mainly of late Miocene and Pliocene age. Sedimentary rocks from Cretaceous through Oligocene age crop out in places along the fringe of the basin, but these strata have not been encountered in the central portion of the basin.

A rich foraminiferal assemblage makes it possible to subdivide the Miocene and Pliocene into a number of stages and zones.

Luisian fauna, generally the oldest encountered within the basin, is indicated by *Valvulineria californica* and *Anomalina salinasensis*.

Strata of the overlying late Miocene, lower Mohnian stage, contain the marker fossils *Bulimina uvigerinaformis*, *Bolivina modeloensis*, and *Epistominella gyroidinaformis*.

The upper Mohnian fauna is recognized by the presence of *Cassidulinella renulinaformis* and *Bolivina hughesi*.

The upper Miocene Delmontian stage has fauna similar to the early Pliocene Repettian stage, but contains the marker *Rotalia garveyensis* and abundant Radiolaria.

The Pliocene is divided into three stages, these being —from oldest to youngest—Repettian, Venturian, and Wheelerian.

The Repettian stage is divided into 18 zones. Typical Repettian forms are: *Ellipsonodosaria verneuili*, *Karreriella milleri*, *Bulimina rostrata*, and *Nonion pompilioides*.

The Venturian stage has the markers *Bulimina subacuminata* and *Bolivina sinuata*.

Fauna of the Wheelerian stage includes *Uvigerina peregrina*, *Epistominella pacifica* and *Bolivina interjuncta*.

The early Pleistocene guide fossils include *Cassidulina limbata* and *C. tortuosa*.

The late Pleistocene fauna has the forms *Elphidium poeyanum* and *Elphidiella hannai*.

Water depth during Luisian time was about ±1,500 feet. Water depth increased at a fairly steady rate, through the Miocene and early Pliocene, until a maximum depth of about ±5,000 feet was reached during mid-Repettian time. The water depth then slowly decreased through late Repettian and sharply decreased during the Venturian. Wheelerian water depths commenced at ±2,000 feet and ended at ±1,000 feet. The basin was filled by the close of Pleistocene time.

The main production in the basin is from strata of Repettian age. This is followed by production from the late Miocene. Rocks of other ages produce relatively minor amounts of oil.

BURG, KENNETH E., Geophysical Service, Inc.

GEOLOGICAL VALUE OF DIGITAL PROCESSING IN HIGHLY EXPLORED AREAS

Effective and economic use of seismic methods in highly explored areas requires a different approach to the exploration problem than that used in less developed areas. In highly explored areas the subsurface structure and stratigraphy generally are well known and the exploration objective is the extension of known areas, search for new productive zones, or establishment of deeper production. Thus the seismic method must be capable of much greater resolution and accuracy, and ambiguities caused by multiple reflections and other signal-like events must be eliminated.

The Digital Seismic Exploration System, consisting of digitally recording and processing of seismic data to achieve specific objectives, is uniquely applicable in highly explored areas. Effective utilization of the system requires a step-by-step approach to the exploration problem: (1) the exploration objective must be defined in seismic terms; (2) the ability of digital technology to solve the problem must be evaluated; (3) the exploration system, consisting of special digital data collection techniques and sophisticated data-reduction processes by digital computers, must be designed; and (4) close coordination of geologist and geophysicist is required to evaluate continuously the achievement of the exploration objective and to make necessary modifications in the system to achieve the objective in a better way.

The application of these principles to the solution of a stratigraphic trap problem by digital seismic technology is described in detail.

CASEY, RICHARD, University of Southern California

RADIOLARIAN ECOLOGY IN WATERS OFF CALIFORNIA COAST

Living radiolarians have been collected from the waters of the Catalina basin. Plankton tows have been taken during all seasons, sampling the entire water column to 1,000 meters with closing nets. The most significant findings which may be useful in paleoecology are: the enumeration of shallow-water (0 to about 200 meters) and deep-water (about 100 to 1,000 meters) species, and the finding of subspecific variations in differing water masses which shift with a mixing or shifting of the water masses in the study area. A good correlation between water-mass-indicator radiolarians, foraminiferans, and diatoms also was found.

CHURCH, CLIFFORD C., consultant

FORAMINIFERA FROM LOWER CRETACEOUS OF DEVILS DEN AREA, KERN COUNTY, CALIFORNIA

This paper describes a large and well-preserved fauna of Foraminifera from the area of the Hex Formation which was described by Owen T. Marsh in 1960 in his paper, "Geology of the Orchard Peak area," Special Report 62, California Division of Mines, and provisionally classed as Upper Jurassic.

The present paper expresses the opinion, based upon the identification of megafossils not known to Marsh, that the Hex Formation is of Early Cretaceous age. These fossils are belemnites (known to Marsh), aucellas, and ammonites, in addition to the 104 species of Foraminifera. Of these Foraminifera, 82 are calcareous and 22 arenaceous. Of the calcareous species, only 3 are pelagic. Of all calcareous species, a large percentage is of the family Nodosariidae (formerly Lagenidae). Many of the species have not been described heretofore from California and a few are believed to be new. The collecting locality is the Devils Den area in the eastern half of Sec. 20 and western half of Sec 21, T. 25 S., R. 18 E., and the northern half of Secs. 31 and 32, T. 25 S., R. 18 E., M.D.B.M., southeastern flank of Orchard Peak, in the northwestern corner of Kern County, California, the type area of the Hex Formation.

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PLIOCENE GAS AND OIL IN SEMITROPIC-TRICO AREA, SAN JOAQUIN VALLEY, CALIFORNIA

Gas and oil occur in the Pliocene in a number of fields located along three major northwesterly-trending anticlinal structures of low relief in the east-central portion of the San Joaquin Valley. The upper member of the Pliocene, the San Joaquin Formation, is 1,200–1,800 feet of alternating brackish and marine clays and thin sands; the lower member, the Etchegoin, is 3,000–5,000 feet of largely marine shales and tight sandstones. The majority of the production comes from the First Mya-B Zone of the upper portion of the San Joaquin, at depths ranging from 2,200 feet at Semitropic to 2,800 feet at Harvester. Thickness ranges from 5 to over 50 feet, averaging about 10 to 15 feet. The more important fields (Trico, Buttonwillow, Semitropic) are primarily structurally closed elongate domes, but lensing and stratigraphic trapping are important contributory factors to the accumulation in each field, and are the primary causes at Harvester. The Atwell Island sandstones, one or more of which are productive at Trico, Harvester, and Garrison City (?), are next in productive importance. They occur in the lower portion of the San Joaquin and are of cyclical or repetitive depositional character in the Trico-Harvester area. Additional productive zones in the San Joaquin are present at Northwest Trico, Semitropic, Buttonwillow, and Bowerbank.

The Etchegoin is of considerably lesser productive importance than the San Joaquin, primarily because of lack of permeability. Productive gas zones include the Mulinia (Semitropic, Garrison City, and Bowerbank), Mitchel (Garrison City), and the "E-7" (Shafter).

Indications of oil in the Pliocene so far have been observed only in the Etchegoin in this area, and only one zone, the Randolph (at Semitropic), is productive. The Randolph is a series of fine-grained, silty sandstones in the lower portion of the Etchegoin. Five wells are currently producing a total of about 110 B/D of 30° oil from depths of 7,000–7,650 feet. At least 700 acres so far have been proved productive. A combination of faulting and permeability changes probably controls the accumulation here. Non-commercial oil showings in the Etchegoin have been encountered at Buttonwillow, Wasco, and in additional zones at Semitropic, but none have been reported in the several deep tests at Trico. Recent drilling at Semitropic suggests that the Pliocene structure may be the result of deep-seated faulting and, consequently, prospects for deeper production from Miocene and Eocene sandstones may be considerably greater than previously suspected.

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MIDDLE AND LATE MIOCENE PALEOSLOPE IN SOUTHEASTERN CALIENTE RANGE, CALIFORNIA

Independent lines of evidence indicate a generally westward regional slope in the vicinity of the southeastern Caliente Range during the middle and late Miocene epoch. Regional lithofacies variation of middle Miocene strata suggests a north-trending shoreline. Lateral variation and internal structures of middle Miocene basalt flows (the lower and middle flows of the "Triple" basalts of Eaton, 1939) indicate that the lava flowed westward. Pebble imbrication within non-marine pebbly sandstones of probable late Miocene age (Caliente Formation of Hill, Carlson, and Dibblee, 1958) likewise denotes westward-flowing paleocurrents. Extrapolation according to Sternberg's Law of the systematic lateral increase in size of the larger clasts suggests a granitic source for these sediments in what is now the southern end of the San Joaquin Valley.

Knowledge of paleoslope direction can facilitate the environmental interpretation of lithofacies variation and sedimentary structure in other units of the same sequence. In the Caliente Range, the middle Miocene Branch Canyon Formation of Hill, Carlson, and Dibblee (1958) is a sandstone facies transitional between marine and non-marine sedimentary deposits. Among the many types of cross-stratification present in this sandstone, one distinctive type consists of irregularly spaced, laterally graded foresets in tabular units up to 5 feet thick. This type of cross-bedding is consistently inclined toward the west. Because this direction is normal to the strand line, this particular facies may be interpreted as foreshore terrace deposits of an ancient beach.