siderably more abundant in the displaced shallow-water sands. The probability of finding other fields which are somewhat analogous to the West Mahala pool are good. Geologic models used in exploration should include deep-water turbidite fan-channel complexes which may be distributed along the northeast side of the Chino, Puente, and San Jose Hills.

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GEOLOGY AND FUTURE PETROLEUM POTENTIAL, VENTURA BASIN, CALIFORNIA

The Ventura basin is the western part of Transverse Ranges geomorphic province. It is a complex, highly folded and faulted synclinorium. Maximum thickness of sediments is 67,000 ft. The ages of formations range from Cretaceous through Holocene. In areal extent—including the onshore, the Santa Barbara Channel and the continental shelf—it is approximately 215 mi long, and averages 30 mi wide. Total volume of sediments is estimated at 40,000 cu mi.

Despite its long history as an oil-producing basin, exploration of its ultimate potential is far from complete. Much of the thick sedimentary section has not been penetrated except in limited areas on the basin margins. Large volumes of marine lower Tertiary and Upper Cretaceous rocks are completely unexplored. Evaluation of the known profilic structures has rarely been carried below depths of 15,000 ft.

In areas where the upper Tertiary beds are best developed, the obvious surface features have been drilled, and most are productive. Stratigraphic elements of entrapment occur in virtually all accumulations in the Ventura basin. Several primary stratigraphic accumulations are productive. It is believed that the greatest future potential of the basin lies in stratigraphic accumulations, and in the same general areas and measures which have been most productive to date. Estimates of 20-30 billion bbl of remaining oil in place do not appear unreasonable. Exploration for this potential awaits favorable future breakthroughs in economic, technologic, and political developments.

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GEOLOGY OF SACRAMENTO BASIN AND ITS FUTURE GAS POSSIBILITIES

The Sacramento basin occupies the northern half of the Great Valley of California. It is a long, narrow asymmetric basin, with a steep west flank and a broad, shallow east flank. Sediments range in age from Jurassic to Holocene, with essentially dry gas production coming from sediments of Late Cretaceous, Paleocene, and Eocene age. The basin can be divided into four areas: the northern San Joaquin, Delta, Suisun, and northern Sacramento areas.

In the northern San Joaquin area, production has come from anticlinal closures, mostly along the upthrown sides of two major faults. Future production probably also will be located on anticlinal highs.

In the Delta area, production has come from anticlines, fault traps, some stratigraphic traps, and traps against two major gorges. Future production will probably be found in fault and gorge traps. Production in the Suisun area has been located on anticlines. Future production may come from presently unknown anticlines and from new pools found on known anticlinal trends.

In the northern Sacramento area, production has come mostly from stratigraphic traps in sandstone of the Forbes Formation, with additional production from anticlinal trends and from domes overlying buried volcanic plugs. Future production will probably be from Forbes stratigraphic traps.

Over half the gas in the Sacramento basin probably has been discovered. Future exploration will be concentrated in the Delta and northern Sacramento areas. It is possible, but doubtful, that future major production may come from formations deeper than those presently productive, and from parts of the basin presently considered nonprospective.

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BIOSTRATIGRAPHY AND PALEOECOLOGY OF EARLY MIOCENE THROUGH EARLY PLEISTOCENE BENTHONIC AND PLANKTONIC FORAMINIFERA, SAN JOAQUIN HILLS-NEWPORT BAY, ORANGE COUNTY, CALIFORNIA

A uniquely complete and continuous sequence of early Miocene through early Pleistocene marine sediments is exposed in Bonita Canyon on the western flank of the San Joaquin Hills and at adjacent Newport Bay, California. These sediments are assigned to the early to middle Miocene Topanga Formation, middle to late Miocene Monterey Shale, late Miocene to early Pliocene Capistrano Formation, and early Pliocene to early Pleistocene Fernando Formation. The total thickness of the sequence studied is more than 2,400 m.

Quantitative analysis of benthonic foraminiferal biofacies indicates that: (1) the lower parts of the Topanga Formation were deposited at inner to outer shelf depths, (2) upper Topanga and Monterey Shale diatomaceous sediments were deposited at upper to middle bathyal depths within a closed basin where ambient water contained less than 1 ml/l of dissolved oxygen, (3) lower bathyal depths marked by abundant radiolarian tests occurred during deposition of the Capistrano Formation, and (4) the Fernando Formation was deposited at lower bathyal through outer shelf depths. Stratigraphic variations of gross faunal parameters including foraminiferal number, radiolarian number, planktonic-benthonic ratio, and percent of displaced benthonic species provide additional quantitative evidence of the shelf-to-basin-to-shelf paleobathymetric history of this sequence. Ranges of individual species of benthonic Foraminifera allow the Saucesian, Relizian, Luisian, Mohnian, Repettian, Venturian, Wheelerian, and Hallian Stages to be recognized. Cool to warm temperate planktonic foraminiferal biofacies dominated by *Globigerina concinna* sl. and *G. angustiumbilicata* occur in the Topanga Formation and lower Monterey Shale. Temperate planktonic assemblages dominated by *G. bulloides* sl. dominate in the upper Monterey Shale and parts of the Fernando Formation. A subarctic biofacies containing sinistral populations of *G. pachyderma* is present at discrete intervals within late Miocene, middle and late Pliocene, and early Pleistocene sediments, whereas a subtropical-warm temperate biofacies dominated by *Globoquadrina dutertrei* is restricted to the early Pliocene. Ranges of critical planktonic Foraminifera including *Globorotaloides trema, Globorotalia mayeri, G. menardi, G. crassaformis, G. inflata, G. truncatulinoides, "Orbulina universa," "Sphaeroidinella dehiscens,"* and the radiolarian *Prunopyle titan* provide additional criteria for age assignment and correlation with the paleomagnetic-radiometric time scale.

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ENERGY AND OUR FOSSIL FUELS

America has a high energy society, and as our demand for energy increases, our reserves of fossil fuels steadily decline. Oil provides 43% of our energy needs, natural gas 33%, electric power 20%, and coal 4%. Although electric power provides only one fifth of our energy needs, 83% of all electricity is created by burning the fossil fuels. Hydro (16%), nuclear (1%), and geothermal (0.1%) power account for a relatively small share of the electric budget.

During 1920, America consumed slightly more than a half billion bbl of oil. By 1935 our needs had grown to over 1 billion bbl and in 1950 we exceeded 2 billion bbl annual consumption. A 3 billion bbl yearly need was approached in 1960 and today 5 billion bbl will not meet the needs of 1972's demand for oil.

In the past 10 years, our consumption of natural gas has risen from 13 Tcf to a present rate of 23 Tcf. Should this rate of increase continue at its present trend, we could deplete our known reserves in 10 years. Possible future sources of gas are coal degasification, western oil shale, and imports (Alaska pipeline and LNG). Drawing on any of these alternate sources for oil or gas will have a profound impact on our environment.

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HISTORICAL REVIEW OF EARLY PACIFIC COAST MICROPALEONTOLOGY

From its beginnings in the wake of World War I, Pacific Coast industrial micropaleontology had at its disposal the superjacent stratigraphic column blocked out by predecessors chiefly on the basis of marine megafossils. Only a few stratigraphically isolated foraminiferal faunules had been recorded in print, as by Chapman and by Bagg. With the growing interest in micropaleontology, several such local microfaunules soon were being analyzed and taxonomically described, notably by the Hanna brothers, Wissler, Church, Hughes, Hobson, Barbat and von Estorff, Galliher, Goudkoff, the Stewarts, Parker, and Siegfus. Age equivalents of the classic Tertiary time-rock subdivisions of Series-Epoch magnitude had been recognized here by Conrad, Arnold, and others. Finer time-rock subdivisions, however, still were spoken of in terms of faunas, usually as found in mapped and formally named formations.

Soon, in spite of earlier traditions to the contrary, in the minds of geologists and palentologists alike, formational terminology was being transferred into time terminology, and unhappily so, as subsequently clarified by Schenck and Muller. Other finer subdivisons, based more intrinsically upon fossils, had previously been given zonal terms. Some were simply fossil beds. J. C. Merriam's two valuable middle Tertiary *Turritella* zones proved, however, to be teilzones; eventually they were shown by Loel and Corey to overlap in time-stratigraphic range. Helpful echinoid bioseries proved limited in their correlative usefulness because of the lateral as well as vertical evolutionary sensitivity to selective environmental change. In turn, a fauna or an "index fossil" found at one or a few stratigraphic zones within a formation, were apt automatically to be taken as indicative of the age of the entire formation. In short, correlations more refined in magnitude than an epoch were in essence local and particular synchroneities defying general classification, rather than biochronological deductions derived through references to some typifying standard stemming from multiple induced generalizations. Resultant confusion in semantics was reflected in the use of formational names for "stages," as reflected in the West Coast Paleogene, and the analogous use of terms such as San Lorenzo, Vaqueros, Temblor, Santa Margarita, Pancho Rico, Repetto, and Pico. For refined correlations of the sort required for the recognition of structural and stratigraphic traps in oil exploration, such symbols were woefully inadequate.

With Elliot's perfection of the core-barrel for use in rotary drilling, the significance of micropaleontology for refined correlations in oil geology was immensely enhanced. The chief vehicle involved was detailed biostratigraphy, carried on in private industrial micropaleontology after the manner of 19th century paleontologist August Quenstedt. The first published record of such a local detailed biostratigraphic continuum was that of Herschel Driver in 1928, using informal taxonomy for natural phyletic realities. In the same year, consistency along strike, of Pliocene biostratigraphic units such as Driver's, was emphasized by the late O. C. ("Jimmy") Wheeler, and soon also Neogene by Rankin, Lohman, and others.

Yet biostratigraphy, left in a purely empirical state, has its chronologic hazards even over and above the factor of error that is inherent in any scientific deduction at its syllogistic best. Criticisms based on demonstrable lateral change in fauna were particularly telling; yet many geologists, by then wary, were nevertheless still thinking biochronologically in terms of William Smith's principle, which is not relevant below System-Period levels in paleontologic time-refinement. In 1933 Natland published his demonstrated parallels between five living, bathymetrically controlled, foraminiferal community-types ("ecological formations") and comparable groupings in a nearby Pliocene sequence; and though his work did not extend to either whole true communities or faunules, and biostratigraphic chronology was not attempted until later, the significance of foraminiferal chorology and facies in biostratigraphic chronology was clearly documented.

Meanwhile the late Ralph Reed—active field geologist, oil company executive, and voracious reader in the field of earth history generally—had suggested that seemingly Albert Oppel, Quenstedt's student, had managed to circumvent the stumbling blocks of both ecologic and lithologic facies by culling them out of biostratigraphic data for purposes of refined biostratigraphic chronology. The suggestion was appreciated by his associates, and the germ of the consequences already appears formally in a 1931 paper by Cushman and Laiming. Subsequently 15 benthonic foraminiferal stages and more than twice as many zones, in the sense of Oppelian zonation, have been recognized within the Pacific Coast provinces of the Tertiary.

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LATE EOCENE TO EARLY MIOCENE PASSAGE ALONG SOUTHERN PERIMETER OF SAN JOAQUIN VALLEY, CALIFORNIA

The stratal succession along the southern perimeter of the San Joaquin Valley affords a unique opportunity to observe the late Eocene to early Miocene passage within sequential marine episodes where faunal relations of the upper Narizian (Late Eocene), Refugian and Zemorrian (Oligocene), and Saucesian (early Miocene) Stages can be studied.

A monophyletic group of species of *Uvigerina* and *Siphogenerina* aids in defining successive faunal zones or biozones that correlate in part with the type sections of the Refugian, Zemorrian, and Saucesian Stages. For example, *Uvigerina jacksonensis (= U. cocoaensis)* characterizes the Refugian, *U. tumeyensis* characterizes a provisionally defined lower Zemorrian, *Siphogenerina nodifera* characterizes a provisionally defined upper Zemorrian and *S. transversa* characterizes a provisionally defined Saucesian. The application of these biozones offers a feasible method to account for all of past geologic time within this depositional continuum, something which is not possible using existing time-rock units or stages.

Vaqueros mollusks occur consistently in lowermost Saucesian strata. This suggests that the *Uvigerinella sparsicostata* Zone (Zemorrian of current usage) of the Santa Barbara embayment, which overlies the Vaqueros Formation, is mostly coeval with early Saucesian as applied in the San Joaquin Valley. This requires an expanded concept of the Saucesian Stage as the type section for the Saucesian overlies the *U. sparsicostata* Zone in the Santa Barbara embayment.

Faunal bases for comparing the Eocene—Oligocene and Oligocene-Miocene boundaries in California with those of the Middle Americas are discussed. In both regions the boundaries seemingly coincide with eustatic lowering of sea level, as observed in other parts of the world.