gymnospermic pollen grains, a few Hystrichospheres and Dinoflagellates) is presented.

Evolutionary trends of the associations and lateral variations and environmental influences are discussed. Choice of stratigraphical characteristics and zonation of the series, which have an aggregate thickness of several thousand meters, are indicated. Correlation is made between wells at distances extending to as much as 600 kilometers and across various deposits of continental, brackish, and marine facies.

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Sedimentary Basins and Exploration for Oil and Gas in California

California is one of the prolific oil and gas producing provinces of the United States. To date 12,350,000,000 barrels of oil and 17,122,000,000 MCF of gas have been produced. Estimated oil reserves are 3,550,000,000 barrels and estimated gas reserves 8,822,000,000 MCF.

The six important oil-producing sedimentary basins with estimated ultimate proved production are: (1) San Joaquin, 7,270,000,000 barrels; (2) Los Angeles, 6,070,000,000 barrels; (3) Ventura, 1,919,000,000 barrels; (4) Santa Maria, 684,000,000 barrels; (5) Cuyama, 375,000,000 barrels; (6) Salinas, 225,000,000 barrels. The most important dry gas producing basin, the Sacramento, has an estimated ultimate recovery of 4,800,000,000 MCF.

These basins are aligned in a general northwest-southeast trend paralleling the mountain systems of California. The San Joaquin basin with 10,000 square miles is the largest and the Los Angeles basin with 700 square miles is the smallest. The east-west-trending Ventura basin lays claim to being the narrowest and yet the deepest with approximately 60,000 feet of sediments in the synclinal trough. The sedimentary section in these basins ranges from Upper Cretaceous through Quaternary. Intensive folding, thrust faulting, and abrupt facies changes are common. Most of the oil fields are anticlinal and are characterized by high productivity per acre. Sandstones are the predominant reservoirs with Miocene (48%) and Pliocene (41.6%) accounting for most of California's oil.

California's first commercial oil field was discovered in 1898. The peak discovery years were the twenties when a plethora of new fields flooded the market and resulted in the first curtailment program. The advent of the seismograph in the thirties was followed by major discoveries. During the last 20 years, with the exception of 1948 and 1949, it has been a struggle to maintain reserves. Economic factors, including the increased cost of drilling to deeper objectives, higher royalties and land costs, expanding suburban development and the flood of foreign imports have become deterrents to many operators.

Despite this somewhat darkening picture there remain substantial parts of California's sedimentary basins that have not been adequately prospected and which should contain profitable oil and (or) gas accumulations. Provided with the opportunity, imaginative and aggressive geologists can keep California in the "prolific producing" category.

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Applied Paleozoic Palynology

Delineation of specific segments of the Paleozoic geological column by palynological methods is based on the concept that plant composition throughout geological time underwent changes that are recorded in the recoverable spores and pollen grains. These changes are largely the result of plant evolution and paleoecology.

The application of Paleozoic palynology originated 32 years ago with attempts to correlate economically important coals. In subsequent years, palynological data have been used in correlation studies of other strata, both non-marine and marine.

Separate thresholds of guide fossils are required when plant microfossils from different environments are compared in attempting to establish correlation lines. The coal-swamp environment, at a given point in time, has a particular set of fossils not necessarily duplicated in other non-marine environments elsewhere.

In recent years, palynological data have become available from many localities throughout the world. From these data it is possible to evaluate selected taxa potentially useful for correlation studies.

Palynology has certain limitations inherent to the science and others common to biological methods of correlation. Although palynology can not be used in every correlation problem, it has been useful and practical for parts of the geological column, in some cases after other biological methods have failed to be definitive.

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Computer Analysis of Stratigraphic Maps

Stratigraphic maps, such as structure, isopach, and facies maps, are commonly prepared as contour-type maps from measurement data obtained in wells and outcrops. In recent years geologists have experimented with methods for extracting additional information from these maps by application of various mathematical and statistical procedures. Most of the methods are very time-consuming and do not justify their cost as routine procedures without high-speed computers. The advent of computers has made possible a change in the entire framework of map preparation, analysis, and interpretation by furnishing quicker ways of assembling, storing, and processing the basic data. In this respect the computer and associated equipment act as a superspeed desk calculator and filing system that frees the geologist from much busy-work and gives him more time to interpret and use his final maps.

Among problems that can be examined conveniently with the aid of computers are similarities or differences among maps; the use of maps as predicting devices; and the more general question of setting up criteria for the selection of mappable variables that will give the most information per dollar in terms of the objectives of the map study.

Map comparison and the use of maps as predicting devices can be achieved at reasonable cost by trend surface analysis, by which the "observed" map data can be separated into two main parts—the trend surface that represents the broad areal changes in the mapped variable, and the deviations from the trend that represent small-scale local or anomalous variations. Sometimes the trend surface is of major importance in a study, but in some applications the deviations may rise to major importance. Selection of particular aspects for stratigraphic mapping can be approached in several ways—by regression procedures that "sort out" the important mappable variables; by multiple correlation procedures; or by use of factor analysis that identifies certain groups of variables as being of first-rank importance in the context of a map study.

Emphasis in this paper is on some principles that underlie map analysis, illustrated by sequential trend analysis of map data. The influence of open and closed number systems—rock thicknesses in contrast to percentages—is developed by examples to show how map patterns are in part controlled by the ways in which the mapped data are expressed.

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Normal Paraffin Hydrocarbons in Recent Sediments from San Francisco Bay, California

Post-Pleistocene sediments of San Francisco Bay, California, have been analyzed for the presence of normal paraffin hydrocarbons. Gas-liquid chromatography was used to examine sediment extracts for normal paraffins containing 8 through 13 carbon atoms per molecule (intermediate molecular weights). Liquid-solid chromatography, infrared and mass spectrometry were used to determine in sediment extracts normal paraffins containing more than 18 carbon atoms per molecule (high molecular weights). Knowledge of normal paraffins in recently deposited sediments may be useful in explaining the origin of crude oils.

The results of analyses of sediments of San Francisco Bay show that normal paraffins containing 8 through 13 carbon atoms are probably absent, or each is present in a concentration less than one part per million dried sediment. Concentrations from 3 to 6 parts per million dried sediment were determined for the normal paraffins containing more than 18 carbon atoms per molecule. Among the normal paraffins containing 23–35 carbon atoms per molecule, the relative number of molecules having an odd number of carbon atoms is greater than the relative number of molecules having an even number of carbon atoms.

Normal paraffins of intermediate and high molecular weights are present in most crude oils, but only normal paraffins of high molecular weights were detected in the sediments of San Francisco Bay. In the sediments the normal paraffins containing 23–35 carbon atoms per molecule show a predominance of odd-carbon-number molecules. In crude oils the normal paraffins in the same weight range are distributed so that odd-carbon-number molecules and even-carbon-number molecules are present in about equal amounts.

If the sediments of San Francisco Bay are to yield crude oil, changes probably should take place in the molecular distribution of the normal paraffins already present. The ratio of odd- to even-numbered normal paraffins should be reduced so that the odd- and even-numbered molecules are about equally abundant. Also, normal paraffins of intermediate molecular weights probably should be added to these sediments. The additional normal paraffins may be derived from other organic materials dispersed in the sediments.

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Cook Inlet Basin—Structure, Stratigraphy, Exploration Techniques, Logistics, Discoveries

Exploratory objectives in the Cook Inlet Basin are confined largely to the Kenai Formation, a 15,000–20,000-foot series of non-marine, coal-bearing sediments of Eocene or younger Tertiary age, underlain by marine Mesozoic sediments. The Kenai Formation on the Kenai Peninsula is divisible into an upper sand member, a middle siltstone and coal member, and a lower sand member. The gas fields on the Kenai Peninsula occur in the upper member; Swanson River oil production is from the lower member. The Kenai beds have been gently to moderately folded and locally faulted.

Exploration techniques consist of surface mapping, gravity and airborne magnetometer surveying, and reflection seismic shooting. Marine reflection shooting and gas exploder-sparker surveys have been used to explore Cook Inlet. Some structural leads can be obtained by field mapping but seismic work is needed to confirm closure. To date only structures defined by seismic methods have been drilled.

The Swanson River oil field is producing in excess of 28,000 barrels per day from the Hemlock zone, a series of sands and conglomerates near the base of the Kenai Formation. The structure is a large, faulted anticline.

Five gas fields have been discovered—the Kenai, Swanson River, West Fork, Falls Creek, and Sterling fields. Gas from the Kenai field is being delivered to Soldotna and Anchorage; the other fields are shut in although some gas from the Swanson River gas field is used in oil-field operations.

The gas consists of 99% methane and is believed to have originated within the Kenai Formation. There is insufficient evidence to determine whether the oil originated in the Kenai Formation or in underlying Mesozoic shales.

Seismic crews cost between $60,000 and $85,000 per month. Costs of deep exploratory wells on the Kenai Peninsula vary between $20 and $50 a foot, exclusive of road costs. Completed oil wells in Swanson River cost nearly $400,000. Road costs range from $10,000 to $50,000 per mile.

An increase in the tempo of exploratory drilling in 1962 is indicated.

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Stratigraphic and Paleoecologic Significance of Tertiary Diatoms of California and Nevada

Many areas of both California and the Great Basin contain diatom-bearing sediments which range in age from Late Cretaceous to Recent. The diatom assemblages in these rocks contain both short-ranging species that are useful for stratigraphic correlation and others, still represented in living assemblages elsewhere, that are useful for paleoecologic interpretations. Although thousands of square miles of diatom-bearing sediments have been mapped by petroleum geologists and have been penetrated and cored during drilling operations, the diatoms have been neglected as a stratigraphic and paleoecological tool. Some of the reasons most often presented for this lack of attention are claims that Foraminifera are easier to work with, are better known, and that laboratory manipulation of them is easier and more suited to assembly-line methods. This is true in part only, as assembly-line methods have been developed for handling large numbers of samples of diatomaceous sediments. Furthermore, diatoms are commonly found in sediments that are completely barren of Foraminifera or other fossils.

The present interest in palynology by the oil companies indicates that new techniques are no longer viewed with disfavor. As far as the necessary laboratory preparation and study are concerned, diatom samples can be prepared and significant species identified at least as expeditiously as samples containing pollen and spores.

Distinctive diatom assemblages are known from the Moreno Shale of Late Cretaceous and Paleocene (?) age and from many sedimentary formations in Eocene, Oligocene, Miocene, Pliocene, and Pleistocene rocks in California from the San Francisco Bay area southward. These assemblages from rocks of Cretaceous through Miocene age are virtually all marine. Pliocene rocks in different localities contain either marine or non-marine