also indicate recent movement along a fault parallel with the principal trace of the Whittier fault in the Puente Hills. However, no major earthquakes or rupturing of the ground surface have occurred along the Whittier-Elsinore fault in historic time. A destructive earthquake occurred in 1929 along the Norwalk fault 6 mi south of the Whittier fault.

Analysis of precise level lines run by the Los Angeles County Engineers since 1951 indicates that the Puente and Montebello Hills area and the Santa Fe Springs-Coyote Hills trend are rising at a rate of 0.01 to 0.04 ft/year relative to the synclinal area between the Puente and Montebello Hills on the north and the Santa Fe Springs-Coyote Hills trend on the south. This relative motion may be caused by tectonic motion, or by withdrawal of ground water and compaction of sediments within the synclinal area. Because of oil production and waterflood activities, motion of the ground over oil fields also was detected.

Several oil fields are located along the Whittier fault and on anticlinal structures along the Santa Fe Springs—Coyote Hills trend southwest of the Whittier fault. The Whittier and Coyote (west) oil fields are undergoing extensive waterfloods. The Whittier fault provides the updip closure for oil sands in the Whittier oil field. Thus, the Whittier fault area was considered an ideal test site to search for a relation between subsurface pressure and the distribution and frequency of microearthquakes.

A network of portable seismometers was operated in the Whittier fault area between July, 1971 and April, 1972. Because of the background noise, the smallest event that could be reliably located had a magnitude of 1.0. Epicenters of 31 microearthquakes with a maximum magnitude of 3.0 were determined, but no direct evidence could be established for a relation between oil production and waterflood activities and the distribution of microearthquakes. Sufficient data were available to determine hypocentral depths for 17 events. Assuming a range of 60-70° north dip on the Whittier fault, 8 of the 17 hypocenters are on the subsurface projection of the Whittier fault; one hypocenter is on the Norwalk fault. Eight of the hypocenters cannot be related to any known structure. On the basis of the microearthquakes detected during this study, the Whittier fault must be considered active.

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HOLOCENE METEORIC DOLOMITIZATION OF PLEISTOCENE LIMESTONES, NORTH JAMAICA

Wholesale stabilization of the unstable carbonate phases aragonite and magnesium calcite, and reprecipitation of calcite and dolomite are currently taking place where the phreatic zone (modern water table) invades 120,000-year-old Pleistocene biolithites (Falmouth Formation), north Jamaica.

Pleistocene rocks in the vadose zone are relatively unaltered, and consist of *in situ*, mineralogically unstable scleractinian biolithites. At the water table, a narrow zone of solution, a "water-table cave," commonly is present. Below the water table, the rocks are invariably more highly altered than those above. Magnesium-calcites are very scarce, and considerable dissolution of aragonite commonly has occurred.

Dolomite occurs as 8-25-micron, subhedral crystals precipitated as void linings. The isotopic composition of the dolomite ($O^{18} = -1.0$ °/₀₀, $\delta C^{13} = 8.4$ °/₀₀) and its high-strongtium content (3,000 ppm) suggest precipitation as CO_2-oversaturated meteoric groundwaters invade the mineralogically unstable biolithites, dissolve magnesium-calcites and strontium-rich aragonites, and remove the gas. Because some dolomitized rocks are enriched in magnesium relative to primary biolithites, magnesium addition to the system is necessitated and probably is derived from seawater in the mixing zone.

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HYDROCARBON GENERATION RELATED TO CARBONIZATION AND FACIES TYPES IN DENVER BASIN UPPER CRETACEOUS

The mechanisms of kerogen carbonization in Gulf Coast Tertiary sediments have been studied. The principal phase of hydrocarbon generation was found to occur at carbonization levels of 75% carbon and greater, and the quantities generated were indicated to depend largely on the hydrogen content of the kerogen. Low-hydrogen kerogen, similar to coal, was suggested as a better source for gas than oil. High-hydrogen kerogen, similar to that of oil shales, was suggested as a better source for oil. The study has been extended to Upper Cretaceous sedimentary rocks of the Denver basin, where additional support for these conclusions was obtained.

In the Denver basin Upper Cretaceous, differences in the depositional environment affect the composition of the kerogen, its carbonization track, and the type of the hydrocarbons generated. The Pierre Shale generally contains low-hydrogen kerogen that is cellular or highly structured in appearance. These characteristics indicate a major contribution from terrestrial organic detritus. This type of kerogen has been correlated with gas generation, suggesting that the Pierre Shale is principally a gas generating facies.

The Niobrara-Graneros interval contains high-hydrogen kerogen that is amorphous in appearance. These characteristics indicate a major contribution from lipid-rich detritus of aquatic organisms. This type of kerogen has been correlated with oil generation, suggesting that the Niobrara-Graneros interval is principally an oil generating facies. Rock-extract to oil-correlation measurements indicate the Niobrara-Graneros interval may be a source of Cretaceous oil in the Denver basin.

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EVALUATION OF REMOTE SENSORS FOR EXPLORATION GEOMORPHOLOGY

Remote-sensor imagery embraces black and white aerial photography—including black and white infrared photography and various film-filter combinations—color aerial photography, color infrared aerial photography, thermal infrared, and radar. For the 3 general types of geomorphic exploration techniques—drainage analysis, tonal analysis, and fracture analysis—no single remote sensor is best. Terrain, vegetative cover, and extent of human activity influence the selection of imagery for analysis.

Black and white and color photography seem best for routine surface—drainage analysis, especially of low-order streams. Thermal infrared and color infrared give considerable information on groundwater-discharge locations and soil-drainage characteristics. Radar imagery allows excellent mapping of higher order drainage patterns of large areas, and is least affected by vegetative cover.

Tonal anomalies are best seen on black and white infrared and black and white panchromatic photography. Color photography is less useful for this technique, and color infrared is poor to unusable, especially in grass-covered regions. Thermal infrared is very poor, and radar cannot be used for tonal studies in exploration geomorphology.

Fracture-trace analysis is done best on stereo-aerial photography of all types, and least well on thermal-infrared and radar imagery. Lineament analysis is done best on aerial photographic mosaics, and particularly well on radar.

Radar and aerial photographic mosaics are well-suited for regional studies, as are images from satellites; aerial photographs and thermal infrared imagery are best for local, detailed studies.

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COMPARATIVE BIOLOGY AND ECOLOGY OF TROPICAL AND ANTARCTIC FORAMINIFERA

Studies of shallow-water benthonic Foraminifera are under way currently at Eniwetok Atoll in the equatorial Pacific and on the Antarctic Peninsula utilizing scuba gear for direct observation of natural situations and laboratory experimentation. On the atoll, species are distributed by microhabitat without regard for depth (to at least 150 ft), whereas in Antarctica, the benthic Foraminifera do not select specific microhabitats. Instead they are zoned according to depth, mostly in association with changing macrofaunal and floral changes. Because of ice abrasion in the Antarctic, few or no Foraminifera live between the intertidal zone and 18 ft in depth. Below that, a zone characterized by large kelps, sponges, tunicates, and brachiopods contains many Foraminifera, and at 120 ft the association is dominated by large glass sponges with about 25 species of Foraminifera.

Heavy predation on Foraminifera takes place on the atoll by fish and grazing invertebrates; in Antarctica, Foraminifera are fed on mostly by invertebrates. There are at least 3 nutritive strategies in reef Foraminifera, although they seem to feed largely on bacteria in Antarctica. Like some tropical species, some Antarctic ones seem to live a long time (years) before reproducing.

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URANIUM AND ITS FUTURE ROLE IN NATIONAL ENERGY REQUIREMENTS

This paper is addressed generally to the use of uranium as an energy source for our future national energy requirements. It deals in part with the problem areas of; recent and pending legislation in the fields of health and safety, environment, public land laws, exploration, production, lead time between start of exploration and production of yellow cake, industry slippage, intervenors, and the effect of all of these on planning for the future. Uranium will play an important role not only in our future national energy requirements, but also in our balance of payments and national security.

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STRATIGRAPHY AND SEDIMENTATION OF DEEP-SEA OCEANIC FORMATION ON BARBADOS, WEST INDIES

Detailed study of the Oceanic Formation on Barbados has revealed a record of pelagic sedimentation from earliest middle Eocene through latest Oligocene (20–50 m.y. ago). A succession of diverse lithologies and lateral facies changes within contemporaneous sediments is recognized. The succession consists of foraminiferal, radiolarian, and nannoplanktonic clays and marls, radiolarites, spiculites, diatomites, cherts, brown clays, and volcanic ash beds. All are eupelagic, deep-sea sediments. Of particular interest are (1) radiolarites and cherts which correlate with middle Eocene cherts shown by Deep Sea Drilling Projects to be widespread in both the Atlantic and Pacific; and (2) regular, periodic fluctuations of carbonate sedimentation rates and Foraminifera-nannoplankton ratios, in the upper Oligocene foraminiferal marls, which are similar to those frequently observed in Pleistocene foraminiferal oozes and attributed to climatic periodicities.

No evidence for progressive shallowing of the Barbados Ridge is apparent until after deposition of both the Oceanic Formation and the overlying Conset Marl. No *in situ* shallow-water sediments on Barbados are older than 10–15 m.y. This is consistent with the predicted arrival of the Caribbean plate into the present eastern Caribbean.

Middle and late Eocene sediments exhibit lateral facies changes. These are characterized by both a decrease and an increase in absolute sedimentation rates of carbonate and terrigeneous clay, respectively, from north to south. The paleoslope determined from sedimentary structures deepens from north to south and suggests that the observed facies change may be attributed to increasing carbonate dissolution with depth. However, the accompanying increase in absolute sedimentation rate of terrigenous clays indicates that dissolution alone is an inadequate explanation. Either dilution by terrigenous clays from the south, or local sediment redistribution by currents and slumping, must have occurred.

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ALTAMONT—A MAJOR FRACTURED AND OVERPRESSURED STRATIGRAPHIC TRAP

Altamont field in the Uinta basin of Utah is a much-overpressured accumulation of high pour-point crude, producing from multiple, thin, Tertiary reservoirs in a 40-mi long stratigraphic trap. Postdepositional shift of the structural axis of the basin created an updip pinchout of low-porosity sandstones into a lacustrine "oil shale" sequence. Reservoir performance is enhanced significantly by vertical fractures and initial pressure gradients which sometimes exceed 0.8 psi/ft.

Field limits in large part are undetermined, and few dry holes have been drilled. Average well drilling and completion costs approach $1 million. The initial potential of field wells ranges from 500 to 2,500 BOPD with an average GOR of about 1,000 cu ft/bbl. Matrix permeability generally is less than 0.2 md; therefore, high well performance is a function of fracture permeability. Inability to define reservoir parameters and oil in place causes individual well reserve estimates to depend mainly on pressure decline-cumulative relations.

Significant engineering problems are related to evaluation and completion of these thin, low-porosity, fractured and overpressured pay intervals, which span up to 2,000 ft of stratigraphic section in some wells. These problems are compounded by the problem of handling 110°F pour-point waxy crude. Inability to pipeline the crude conventionally from the relatively remote area has delayed full production of the field. About 40 drilling rigs are active in development of the trend, and a field potential is suggested of in excess of 250 million bbl with significant delineation of field limits yet to be accomplished.

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DOLOMITE, LIMESTONE FACIES, AND INSOLUBLE RESIDUE—A RELATIONSHIP?

Almost 600 insoluble-residue and quantitative X-ray analyses have been performed on samples collected from the Callville and Pakoon Formations (Pennsylvanian and Lower Permian) of southern Nevada. The gross lithologies present are limestone, dolostone, and carbonate-cemented sandstone. The insoluble residues range from 0.7 to 77.0% and consist of fine-sand size quartz with varying amounts of illite (clay).

Plots of the total insoluble residue against percent dolomite show that more than 500 of the samples fall into either limestone (greater than 90% calcite) or dolostone (greater than 90% dolomite) end members. Plots of the dolomite percentage in the 100 remaining, mixed-calcite-dolomite mineralogy specimens versus total insoluble residue showed no obvious trends. Plots of the mixed-mineralogy specimens versus the illitic clay content likewise showed no obvious trends.

Five limestone facies (micrite, sparse micrite, packed micrite, biopelsparite and oosparite) were recognized. No relation was found between limestone facies and percent total insoluble residue or between percent dolomite and limestone facies.

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