Along the southern shores of the Persian Gulf, Holocene carbonate sediment infilling of coastal lagoons has generated extensive salt-encrusted, supratidal surfaces or coastal sabkhas, which are the site of penecontemporaneous dolomitization. Recent diagenetic dolomite is present mainly in the unlithified, upper-intertidal facies sediments, although minor quantities are at greater depths in other sediment facies. The aragonite fraction of the sediment is replaced, and the process may be complete (100% dolomitization) within 1,500 years after primary sediment deposition. Dolomitization is local in effect, depending on a combination of fluids high with $^{m}Mg^{++}/^{m}Ca^{++}$ ratios, a rapid interstitial flow rate (2-3 cm/yr), and a high surface-flooding frequency; the flanks of flood channels and peninsulas best achieve these requirements, and their primary sediments may be completely dolomitized. The local distribution of intensively dolomitized sediments is related to rapid sedimentation and associated shoreline progradation (approximately 2 m/yr); at slower progradation rates, more extensive dolomitization would ensue. The diagenetic dolomite occurs as 1-4 micron rhombs, is nonstoichiometric ($Ca_{51-54}$), is partly ordered, has $\delta O^{18} = +2.5$ to $+3.7$ °/₀₀, and $\delta C^{13} = +4.0$ to $+4.4$ °/₀₀. Radiocarbon ages increase progressively inland from the present shoreline (1,500-3,500 years ago); these dates, however, reflect more the age of the original sediment than the age of the dolomitization event, most of the carbon in the reaction being derived from the original aragonite. The dolomitizing fluids are of marine origin and have the following characteristics: 3.25-3.75 $^{m}Cl^{-}$/Kg: $^{m}Mg^{++}/^{m}Ca^{++}$ ratios between 7 and 22, pH between 6.3 and 6.9, a minimum $^{P}CO_2$ of $10^{-3}$ to $10^{-2}$ atmospheres, temperatures between 25° and 40°C and at saturation with respect to gypsum and celestite. Associated early diagenetic minerals within the coastal sabkha sediments include huntite, magnesite, gypsum, bassanite, anhydrite (nodular), celestite, and halite. Many ancient dolomites of probably analogous, penecontemporaneous, sabkha origin can be shown to have undergone later diagenetic recrystallization with a concomitant coarsening of grain size, approach to a stoichiometric composition, an increase in ordering, and a loss of trace cations.

KOLPACK, RONALD L., Environmental Geology, Univ. Southern California, Los Angeles, Calif.

## COASTAL ZONE—SEARCH FOR OPTIONS

Man's involvement with the water environment is most intense in the shallow-water zone bordering landmasses. This area provides food, pleasure, mineral commodities, a means of transportation, an avenue for military exploitation, and a convenient place to dump waste. Historically, rewards for utilization were accrued by the aggressive, imaginative, respectful, and the lucky; losses were sustained by those who tempted or disregarded nature. This relation was direct and accountability was short-term.

Studies have been presented in which evidence was cited for environmental degradation or an apparent increase in the level of contaminants in the water realm as a result of man's activities. Journalists have publicized these studies, but often have neglected or ignored the less sensational reports which are not amenable to instant analysis. Consequently, the public reacts in alarm by advocating stricter governmental control or abolition of activities which may be detrimental to the environment. Conflicts among users arise and a recipe for a confrontation battleground evolves.

This enigmatic situation poses an interesting question: is anyone interested in comprehensive evaluations which require great effort and understanding; or has our capacity for reasoning been limited by impatience, cynicism, and emotionalism?

The present dilemma to choose between two alternatives can be illustrated by several incidents involving environmental concern in coastal waters. These case histories lead to the question: are we really limited to only 2 options?

KRINSLEY, DAVID, Dept. Earth and Environmental Sci., Queens College, City Univ. New York, Flushing, N.Y., and N. KEITH TOVEY, Dept. Engineering, Univ. Cambridge, Cambridge, England

## STUDIES OF QUARTZ SAND GRAINS BY CATHODOLUMINESCENCE

Surfaces and cross sections of individual quartz sand grains have been examined and compared in the cathodoluminescence (CL) mode with the scanning electron microscope. Six kinds of nontopographic CL have been found; the presence of non-CL areas commonly is due to the occurrence of a disrupted lattice layer wherever grinding has taken place. This layer is shown to be irregularly distributed, both in cross sections and on grain surfaces; its distribution, depth, and intensity can be examined in detail for the first time. Reversal of CL contrast has been accomplished experimentally by raising the temperature of grains above the alpha-beta transition in quartz (573°C); a similar reversal, found in certain natural sedimentary grains, suggests that they likewise have been heated above the transition temperature. Fractures present on natural grain surfaces in the CL mode can be observed in omissive-mode photographs and probably could be used for environmenta. interpretation. Detail of the same kind, observed in the CL mode but not in the emissive mode on other grains, could further extend the use of sand-grain surface textures for environmental interpretation.

KVENVOLDEN, KEITH A., Planetary Biology Div., NASA-Ames Research Center, Moffett Field, Calif.

## DIAGENESIS OF AMINO ACIDS AND THEIR ENANTIOMERS

Diagenesis of amino acids in sediments and shells involves many processes including (1) conversion of one amino acid to another, (2) interconversion of amino acid enantiomers from dominantly L- to D, L- configurations, and (3) ultimate destruction. Amino acids, generally in the form of biopolymers such as proteins, enter the lithosphere from the biosphere. Hydrolytic processes begin immediately to release monomeric amino acids, and in some shells amino acid polymers no longer exist after about 12 m.y. As with any other organic compounds, destruction of amino acids occurs with time, but for many amino acids, such as glycine, alanine, valine, leucine, and isoleucine, the rate is very slow. Evidence for conversion of one amino acid into another is provided by observations wherein certain amino acids tend to disappear with time, while new amino acids are created. For example, pipecolic acid recently found in Pleistocene and Miocene *Mercenaria* is thought to have been derived from lysine through deamination and internal cyclization. The mechanism for the conversion is not yet known.

Interconversion of amino acid enantiomers also takes place with time, L-amino acids racemize to D, L-amino acids at different rates. In deep-sea sediments from the Atlantic Ocean and Caribbean Sea, valine, glutamic acid, and leucine racemize at slower rates than do phenylalanine, aspartic acid, alanine, and proline. Rates of racemization are temperature dependent; in the lithosphere, racemization of amino acids should be complete in about 15 m.y. at the maximum. Measurement of the extent of racemization of amino acids provides a potentially useful geochronologic tool for the very late Cenozoic Era.

LAMAR, DONALD L., Earth Sci. Research Corp., Santa Monica, Calif.

## MICROSEISMICITY AND RECENT TECTONIC ACTIVITY, WHITTIER FAULT AREA, CALIFORNIA

The Whittier fault is a principal strand of the San Andreas fault system near the southwest edge of the Puente Hills in the northeastern Los Angeles basin. Physiographic evidence indicates recent movement along the Whittier fault and its southeast extension, the Elsinore fault. Exposures in test trenches

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.

LAND, LYNTON S., Dept. Geol. Sci., Univ. Texas, Austin, Tex.

## 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.

LAPLANTE, ROGER E., Research Dept., Amoco Production Co., Tulsa, Okla.

## 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.

LATTMAN, LAURENCE H., Dept. Geology, Univ. Cincinnati, Cincinnati, Ohio

## 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.

LIPPS, JERE H., Dept. Geology and Bodega Marine Lab., Univ. California, Davis, Calif.