

have a greater influence on sedimentation than these individual components. Studies using fluorescent-tagged grains aided in determining the sedimentary responses of sand to the complicated interactions of wave surge and tidal flow.

In shallow, subtidal areas, bedform orientations and the greatest distances of sediment transport generally are determined by the directions of tidal flow. In shallower areas around the margins of offshore sand banks, bedform configurations and orientations are predominantly affected by wave surges, whereas the greatest distances of sediment transport are determined by tidal currents.

At intertidal parts of offshore sand banks, the characteristics of sedimentation during the flooding tide are predominantly controlled by surging waves. During the ebbing tide, the periodic wave surges and tidal currents are in opposite directions and sediment transport is in gyral paths.

At the shoreline, tidal and longshore currents are in separate zones and sediment transport is controlled by the directions of the water flow in the respective zones. When tidal and longshore currents flow in opposite directions, sediment transport is in bipolar flow directions corresponding to the flow in the respective current zones.

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#### PLEISTOCENE HISTORY OF *GLOBIGERINA PACHYDERMA* (EHRENBERG) IN SITE 36, DEEP-SEA DRILLING PROJECT, NORTHEASTERN PACIFIC

Sinistral *Globigerina pachyderma* (Ehrenberg) appears for the first time in the Deep-Sea Drilling Project site-36 section in the lower Pleistocene. The location of this site, 40°59.08'N lat., is within the Holocene transitional faunal zone for planktonic Foraminifera. From scattered occurrences in the lower Pleistocene sediments, this species gradually increases in abundance until, midway in the Pleistocene, it becomes a predominant element. This indicates that the boundary between the subpolar and the transitional water masses did not shift over the site-36 location until mid-Pleistocene time, thus bringing in subpolar faunas for the first time. The proportion of left-coiling forms to right-coiling forms is not always diagnostic in identifying cold cycles, nor does it apparently give very good diagnostic data on the intensity of cold cycles.

Ontogenetic growth analyses on Pliocene dextral and sinistral forms often referred to as *G. pachyderma* by workers indicates that there is a fundamental difference between these forms and the sinistral *G. pachyderma* of the Pleistocene and Holocene. They are placed in *Globorotalia pseudopachyderma* Cita, Permolli Silva, and Rossi. Whether the sinistral form of this species was adapted to subpolar conditions is uncertain, and, in fact, some populations of this form seem to have lived in warmer waters than the dextral populations.

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#### CHANGES IN ISOTOPIC ABUNDANCES OF CARBON ( $C^{13}/C^{12}$ ) AND SULFUR ( $S^{34}/S^{32}$ ) DURING PETROLEUM MATURATION—BIG HORN BASIN PALEOZOIC OILS

Big Horn basin (Wyoming) Paleozoic oils are believed to have been similar in composition initially, but they now differ greatly as the result of maturation caused by variations in thermal history. With increasing maturity, API°, GOR, S/N,  $\delta C^{13}$  and  $\delta S^{34}$  all increase whereas the percentage of sulfur, nitrogen, and asphaltenes decreases. Except for increases in  $\delta S^{34}$  and S/N ratio, these changes are generally recognized as typical of the thermal-maturation process.

$\delta C^{13}$  increases are reasonably explained by  $C^{12}$  enrichment in evolved gas. Profiles of  $\delta C^{13}$  versus B.P. show systematic changes with maturation. In particular, a  $\delta C^{13}$  maximum in the 50–125°C B.P. range increases with maturity, suggesting

that molecules in this size range have undergone more cleavages, on the average, than higher MW-components.

Isotopic evidence indicates that  $H_2S$  produced by microbial reduction of sulfate in shallow reservoirs (low temperature) generally does not react sufficiently with associated oil to alter  $\delta S^{34}$  of organic sulfur.  $\delta S^{34}$  of oils and  $H_2S$  are essentially unrelated in these cases.

Thermal desulfurization of organic sulfur compounds occurs with negligible isotopic fractionation. However, isotopic evidence indicates that, in the temperature range of 170–300°F, sulfate reduction (probably nonmicrobial) occurs slowly without isotopic fractionation, and the produced sulfide is incorporated into both oil and  $H_2S$ . Organic sulfur thus becomes a dynamic system with competing sulfuration and desulfurization leading to changes in  $\delta S^{34}$  toward that of the reservoir sulfate (about 15‰ heavier isotopically than S in initial oils). The percentage of sulfur in oil, thus may attain a steady-state concentration although the percentage of nitrogen continues to decrease, resulting in increasing S/N ratios with increasing maturity. These changes in  $\delta S^{34}$  and S/N ratio would not be expected in reservoirs devoid of sulfate.

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#### GEOTHERMAL ENERGY

Geothermal energy is used mostly for electric power generation with a current worldwide installed capacity of about 1,000 Mw. This is equivalent to one nuclear power plant. The only geothermal area in the world completely developed by private enterprise is at The Geysers in northern California, where it has proved to be a viable, mechanically sound, and economic resource, competing with alternative forms of power generation, such as oil, gas, nuclear, and hydro in the Pacific Gas and Electric system. The Geysers field produced 300 Mw and is estimated to have a potential production in excess of 1,000 Mw.

The National Petroleum Council estimates that by 1985 about 15,000 Mw of geothermal power can be developed in the western United States. With improved exploration, drilling, and utilization technology, and modification of certain institutional barriers, it has been estimated that geothermal power may be of the order of 75,000 Mw by the year 2000.

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#### JAY FIELD, FLORIDA—JURASSIC STRATIGRAPHIC TRAP

The first Jurassic oil discovery in Florida was made in June 1970, near Jay, 35 mi north of Pensacola. Current estimates indicate recoverable reserves in the Smackover Formation should exceed 300 million stock-tank bbl of oil and 300 Bcf of gas. Production occurs on the south plunge of a large subsurface anticline, with the updip trap formed by a facies change from porous dolomite to dense micritic limestone.

The Smackover consists of a lower transgressive interval of laminated algal-mat and mud-flat deposits, and an upper regressive section of hardened pellet grainstones. Early dolomitization and freshwater leaching have provided a complex, extensive, high-quality reservoir. Irregular distribution of facies types presents difficult problems in development drilling, unitization, and planned pressure-maintenance programs.

Hydrogen sulfide content of the hydrocarbons requires expensive processing facilities. A typical completed well costs \$650,000, with an additional \$200,000 for flowline and inlet-separation facilities. Add to this \$550,000 for plant facilities to sweeten the oil for market, and each well investment approaches \$1,400,000. Daily production from Jay field will approach 85,000 bbl/day from approximately 85 wells, less than 3

years after discovery. This rapid development results from a coordinated development program with modular plant design.

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#### QUANTITATIVE ENVIRONMENTAL GRADIENT MODEL FOR INTERPRETING HABITATS OF MICROFOSSIL ASSEMBLAGES

A robust Q-mode ordination model has been derived from samples of diverse microfossils from Atlantic, Gulf, and Pacific coastal localities representing many different Cenozoic marine environments. Major environmental-gradient complexes are defined on the basis of their relations to major microfossil ecoclines; gradient complexes include depth of water, distance offshore, and rate of sedimentation/nutrient enrichment. By using principal taxonomic and bionomic groups that differ widely in ecologic requirements and tolerances, it is possible to obtain maximum information in spite of "noise" occasioned by heterogeneous groups. Because the groups are not restricted in time or geographic area, it is also possible to compare assemblages from different eras and provinces. Easily recognized groups that are used include several types of foraminifers, ostracodes, and ectoprocts, radiolarians, diatoms, sponge spicules, echinoid spines, holothurian sclerites, fish scales, and alcyonarian spicules.

Q-mode-cluster analysis defines discrete microfossil biotopes that can be arrayed in the model, and these can be related to well-known depositional environments such as lagoons, beaches, deltas, carbonate banks, outer continental shelves, and deep-water borderland basins. However, unknown samples are interpreted best in light of the multidimensional model, recognizing the influences of independent gradients; in this way anomalous assemblages usually can be resolved readily. Present microorganism death assemblages are used to validate the model and confirm interpretations based on indicator microfossil groups and independent sedimentological and stratigraphic evidence.

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#### HIGH-RESOLUTION MARINE SEISMIC PROFILING

A small seismic system (Mini-Sparker) has been developed to use frequencies in the 200-2,000 Hz band for highly detailed marine profiling. Reflections down to 500- to 800-ft depths are recorded in clastic sediments, with resolution of 6-8 ft.

The Mini-Sparker profile is recorded as a single channel on facsimile paper. The equipment is man-portable, and the acoustic source is equally effective in freshwater or saltwater areas.

A procedure has been developed for high resolution recording at variable offsets between source and receiver, thus providing the information for a  $T^2 - X^2$  computation of average velocities to various reflection levels.

Examples illustrated include profiles from (1) a freshwater lake in a glaciated area, (2) the Gulf Coast continental shelf, and (3) the North Sea. The first and last examples include velocity-determination sections as well as structure sections.

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#### ORIGIN OF PETROLEUM—STERANES AS PRODUCTS OF EARLY DIAGENESIS IN RECENT MARINE AND FRESHWATER SEDIMENTS

Steranes are minor hydrocarbon components of crude oil which are derived from the sterols of living systems and provide a vehicle for the study of the origin and chemical development of petroleum. Sterols, the precursors of steranes, were found in a number of freshwater and marine sedimentary environments exhibiting a range of redox conditions. Up to 10 ppm of the plant sterols beta-sitosterol, stigmasterol, cholesterol, and cam-

pesterol were found in the sediments by using gas chromatography and mass spectrometry. Steranols, which are intermediate between the oxygenated unsaturated plant sterols and the reduced crude-oil steranes, were found in modern Arctic marine sediments, as were hydrocarbon steranes similar in structure to those of petroleum. Steranols were about half as abundant as the corresponding sterols. The steranes totaled about 0.1 ppm. The presence of steranols and steranes in such recent sediments indicates that some processes which are necessary for the formation of petroleum constituents—in this case reduction—occur very early in the diagenetic conversion of organic debris to crude oil.

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#### DOLOMITIZATION OF CARBONATE MEMBERS IN LOWER GOOSE EGG FORMATION (PERMIAN) OF SOUTHEASTERN WYOMING

The lower part of the Goose Egg Formation (Permian) of southeastern Wyoming consists of carbonate members interstratified with thicker, red clastic members. The carbonates are interpreted as having been deposited in subtidal, intertidal, and supratidal environments during transgressions of the Phosphoria sea.

Evidence of at least 2 periods of dolomitization is present in the carbonates. The first stage is represented by fine-grained dolomite, 5-20 microns in diameter. Abundant in strata interpreted as peritidal, this fine-grained dolomite is uncommon in strata interpreted as subtidal. This stratigraphic distribution suggests that the fine-grained dolomite formed in the depositional environment rather than later, in a postdepositional site. This conclusion is further supported by comparisons of features common to recent, as well as to other ancient, fine-grained dolomite which has been interpreted as penecontemporaneous in origin. Dolomitized Foraminifera tests and peloids indicate that at least some of the penecontemporaneous dolomite is a replacement phenomenon; however, the possibility that some is "primary" cannot be eliminated. The penecontemporaneous dolomite in the Goose Egg carbonates may have been formed by capillary concentration of hypersaline brines.

A later, postdepositional period of dolomitization is represented by euhedral and subhedral dolomite rhombs, 50-200 microns in diameter. Unlike the fine-grained, penecontemporaneous dolomite, the coarse dolomite is more evenly distributed throughout the carbonate members, contains numerous inclusions, and cross cuts other grains and crystals. This second period of dolomitization occurred during a late stage of diagenesis and was probably caused by circulation of ground waters rich in magnesium.

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#### MINERALS AND ENERGY—THEIR ECONOMIC IMPACT ON A REGION

A knowledge of the interrelations of the mineral and energy industry with the total national or regional economy is critical for formulation of fuels and minerals policies. The scope of the Colorado mineral industry starts with raw natural resources, their discovery by exploratory effort, and their production by extraction industries. These materials enter the mineral processing industries to yield energy and processed materials of mineral origin.

Traditional measurements of the mineral industry's contribution to the economy are based on the U.S. Bureau of Mines' tabulation of production at the mineral raw-material stage. However, the commonly accepted view of the mineral industry's contribution is much broader in scope.

The particular industry parameters assessed in this study are the amount of investment, level of employment, quantity and