tion in the saline environment, through K^+ adsorption and/or cation exchange, of either degraded illites or mixed-layered illite-smectite derived from nonsaline fluvial channels. This conclusion is supported by results of laboratory studies conducted on fresh and brackish water clays with seawater. The observed environmental variations in clay mineral assemblages may have important implications on paleogeographic interpretations.

There are two clay-mineral zones in the shallow-marine facies of the deltaic complex. Clays west of Oliktok Point have markedly lower illite/smectite and illite/kaolinite ratios than clays east of the Point. These lateral variations probably are related to differences in clay-mineral sources rather than depositional environments.

NILSEN, TOR H., U.S. Geol. Survey, Menlo Park, Calif.

CONTINENTAL-MARGIN SEDIMENTATION OF EOCENE TEJON FORMATION, WESTERN TEHACHAPI AND SAN EMIGDIO MOUNTAINS, CALIFORNIA

The Tejon Formation was deposited from early to late Eocene time in a variety of shallow-to-deep marine environments along the western margin of the North American continent. It crops out in east-west-trending mountain ranges along the southern margin of the Great Valley of California. These ranges offer the only exposures of Eocene rocks underlying the Valley on the north. On the basis of new megafaunal data, deposition of the Tejon commenced in the early Eocene with the Uvas Conglomerate Member, a shallow-marine basal conglomerate and sandstone that rests unconformably on pre-Tertiary crystalline basement rocks. The Uvas records a slow transgression of the sea from west to east. It grades upward into the Liveoak Shale Member, consisting of shales, siltstones, and thinly bedded, fine-grained sandstones. The Liveoak was deposited seaward of the Uvas in middle and late Eocene time; it grades laterally eastward into shallow-marine sandstones and conglomerates and laterally westward into hemipelagic foraminiferal shales. The Metralla Sandstone Member was deposited by the westward-retreating, late Eocene sea. It is a locally conglomeratic, shallow-marine sandstone that overlies the Uvas in the easternmost part of the area, and the Liveoak in all other areas. It grades laterally westward into thinly interbedded, fine-grained sandstones and shales deposited in deeper water, and farther west into the hemipelagic shale facies of the Liveoak. The Reed Canyon Siltstone Member, the uppermost member of the Tejon Formation, discontinuously overlies the Metralla and was deposited during the late Eocene in shallow-marine environments, including probably lagoonal areas behind barrier islands. Thus, the Tejon Formation records an advancing and retreating shoreline across a narrow continental shelf, bordered on the east by alluvial plains and on the west by an irregular continental borderland containing deep-sea basins in which submarine fans were being deposited.

NILSEN, TOR H., U.S. Geol. Survey, Menlo Park, Calif., and SAMUEL H. CLARKE, Dept. Geology & Geophysics, Univ. California, Berkeley, Calif.

SEDIMENTATION AND TECTONICS IN EARLY TERTIARY CONTINENTAL BORDERLAND OF CENTRAL CALIFORNIA

The most prominent Eocene paleogeographic elements of central California were the Sierran continental landmass on the east and the Salinian continental borderland on the west, both underlain by granitic crust and separated by a trough-shaped, deep-marine area underlain by oceanic crust. These linear elements trended approximately north-south, parallel with the edge of the continent. Erosion of the Sierran area yielded clastic detritus that was transported westward and deposited in successive fluvial, near-shore, shallow-marine, and deep-marine environments. The Salinian borderland, which probably had been detached from the Sierran landmass by pre-Eocene right-lateral faulting along its eastern edge, consisted of irregular island uplands interspersed with deep marine basins. Detritus eroded from these islands was deposited as submarine fans within the borderland basins and on the sea floor on the east and west. Microfossils indicate deposition in basins of bathyal to abyssal depths and unrestricted access to the ocean. The early Tertiary submarine-fan deposits are similar throughout the central Coast Ranges, and contain assemblages of proximal and distal turbidites, deep-sea conglomerates, grain-flow deposits, and hemipelagic shales. They differ from most modern deep-sea fan deposits and typical flysch sequences in that they are very thick, limited in areal extent, and consist mostly of coarse clastic detritus. The conglomerates contain coarse clasts, including boulders, and have very thick, irregular bedding. Proximal sandstones consist of Bouma *ae* to *abcde* sequences that are very thickly bedded and amalgamated, poorly graded to ungraded, commonly structureless, and contain large mudstone rip-up clasts and dish structures. Distal sandstones contain more complete Bouma sequences, a greater variety of sedimentary structures, and are graded. The borderland region was tectonically active during sedimentation, so that island source areas and depositional basins formed and changed abruptly. Submarine fan sedimentation was rapid, but the supply of sediment was probably not continuous for long periods of time. Paleocurrent directions are varied, reflecting the irregular distribution of source areas and depositional basins.

NUMMEDAL, DAG, Dept. Geography, Univ. Illinois, Urbana, Ill.

DETERMINATION OF SOME PALEOHYDRAULIC PARAMETERS

New river measurements combined with existing laboratory evidence show that, in a river reach where traction motion as well as net sediment deposition take place, the mean applied bed shear stress is equal to the critical shear stress required to move particles of median bed material size. Consequently, application of Shields' relation between shear stress and material size permits the determination of mean applied shear stress at an ancient depositional site from the grain-size distribution of the sediment. Furthermore, by applying laboratory values for the friction factor, determined for the appropriate bed configuration, we can calculate the paleoflow velocity by the Darcy-Weisbach relation. This method for the determination of paleoflow velocity is generally applicable to any sedimentary deposit if a reasonable estimate of the friction factor can be made.

For rock units containing climbing ripple cross-lamination, we can go one step farther and determine the rate at which the sediments were accumulated. The rate of bedload transport has a known functional relation to the mean velocity of the overlying column of water as determined in the first part of this study.

Very high rates of sedimentation are found to exist in nature. Late Pleistocene deltaic sediments in the Truckee Canyon of Nevada, locally contain climbing ripple cross-laminated units indicating a local rate of aggradation of 0.1 mm/sec or 36 cm/hr.

OERTEL, GEORGE F., Dept. Geology, Skidaway Inst. Oceanography, Savannah, Ga.

SAND-DISPERSION PATTERNS PRODUCED BY WAVE-CURRENT AND TIDAL-CURRENT INTERACTIONS IN NEARSHORE ZONE

In mesotidal nearshore zones, patterns of sedimentation commonly are dependent on the characteristics of the interactions between wave surge and tidal flow. Sedimentary processes associated with waves alone or with tidal currents alone are generally insufficient for explaining the distributions, orientations, textures, and structures of bedforms in zones exhibiting wave-surge/tidal-current interactions. The resultant forces produced by the interaction of wave surge and tidal currents generally

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.

OLSSON, RICHARD K., Dept. Geology, Rutgers Univ., New Brunswick, N.J.

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, Permoli 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.

ORR, WILSON L., Mobil Research & Development Corp., Dallas, Tex.

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, δC^{13} and δS^{34} all increase whereas the percentage of sulfur, nitrogen, and asphaltenes decreases. Except for increases in δS^{34} and S/N ratio, these changes are generally recognized as typical of the thermal-maturation process.

δC^{13} increases are reasonably explained by C^{12} enrichment in evolved gas. Profiles of δC^{13} versus B.P. show systematic changes with maturation. In particular, a δC^{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 δS^{34} of organic sulfur. δS^{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 sulfurization and desulfurization leading to changes in δS^{34} toward that of the reservoir sulfate (about 15°/oo 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 δS^{34} and S/N ratio would not be expected in reservoirs devoid of sulfate.

OTTE, CAREL, Union Oil Co. of California, Los Angeles, Calif.

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.

OTTMANN, ROBERT D., Exxon Co., U.S.A., Harvey, La., PAUL L. KEYES, Exxon Co., U.S.A., New Orleans, La., and MARTIN A. ZIEGLER, Esso Production Research Co., Houston, Tex.

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