evidence from fossil fishes indicates that Lake Idaho extended into northern Utah, where it is recorded in an uninterrupted sequence 60 m thick of diverse carbonate facies in the fluviolacustrine Salt Lake Formation.

In Utah, the lake carbonates are best exposed in a landslide scarp in the Junction Hills, near the northern end of the Wasatch Range. Distinctive carbonate facies in the scarp and nearby exposures include: (1) cross-stratified oolitic calcarenite, in which ooids range from 0.1 to 4.0 mm in diameter, in foreset units from a few cm to 17 m thick; (2) algal stromatolites in cabbage-shaped heads and laterally linked hemispheres as high as 50 cm; (3) skeletal carbonate beds composed predominantly of tests of ostracods and mollusks; (4) convoluted bodies of contemporaneously slumped carbonate sand up to 3 m thick; and (5) a 55-m thick unit of lithographic limestone overlying the scarp sequence. These lake beds appear to represent the thickest and most diverse succession of nonmarine Neogene carbonates known in North America.

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New Surface-Sediment Distribution Maps for Pacific Ocean

New surface-sediment distribution maps at 1:10,000,000 have been compiled as part of the Circum-Pacific Map Project. These maps represent the first depiction of such sediments on a systematic and uniform scheme for the entire ocean basin. The primary data used were the qualitative analysis of all Pacific cores in the Lamont-Doherty Geological Observatory collection (3,710 at last count) using smear-slide analyses by petrographic microscope combined with laboratory determinations of $CaCO_3$ content for quantitative control; additional data were taken from published smear-slide descriptions by others, and secondarily from the World Data Bank and the published literature. Ten dominant sediment types are depicted, with three minor types, in a classification based upon calcareous-biosiliceous biogenic components and conventional textural attribution. Base maps for the new maps, including bathymetry, are the five, 1:10,000,000 sheets produced by the Circum-Pacific Map Project on an equal-area projection. The maps depict unconsolidated sedimentary deposits exposed on the Pacific Ocean floor, at least those presumably at the sediment-water interface recovered by coring and dredging, and do not necessarily represent Holocene or recent material. The Circum-Pacific Map Project is a cooperative international endeavor intended to summarize the relation of known hydrocarbon and mineral resources to the major geologic features of the Pacific basin and surrounding continental areas.

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Burial Diagenesis of Illite/Smectite, a Kinetic Model

X-ray diffraction analysis of clay-rich sediments of Miocene and younger age from 14 wells in offshore Louisiana supports the published conclusion that diagenetic changes in the mixed-layer illite/smectite (I/S) clays involve a progressive downward increase in the proportion of illite layers, followed by a change from random to regular interstratification and a further increase to about 80% illite layers. We also found that the depth at which these diagenetic changes begin and the degree of alteration at any given depth vary substantially from well to well and are related to the age and burial rate of the sediments as well as to present-day subsurface temperatures.

This burial alteration was modeled using a first-order reaction equation with a term to describe a non-linear increase in temperature with time. For each of several wells where we had complete data, we solved this equation for values of activation energy (E) and frequency factor (a). The resulting values of (E) are fairly consistent among wells and are close to those determined experimentally by others. The calculated values of (a) are lower by two orders of magnitude than the reported experimental values, but range considerably. The same equations can be used to calculate the degree of reaction for different times and temperatures, assuming these or other values of (E) and (a). This kinetic model should be helpful in deciphering the influences of I/S reactions on interstitial fluid pressures, fluid and rock chemistry, and shale physical properties.

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Middle Tertiary Laumontite Isograd Offset 37 Km by Left-Lateral Strike-Slip on Santa Ynez Fault, California

The Santa Ynez fault is mappable for 133 km westward from its apparent truncation by the Agua Blanca thrust on the east, nearly to Point Conception on the west. Neogene dip separation is locally large, and substantial left-lateral strike-slip is suspected. Total slip, however, is undefined, and the movement history has been obscure, partly owing to the lack of recognition of any trustworthy piercing point or steep plane.

Some Paleogene and older strata along the fault contain laumontite. This mineral is a distinctive indicator of burial changes in mineralogically immature rocks that have been heated with dilute pore waters at above-average geothermal gradients. Laumontite crystallizes from the surface to more than 7,000 m (controlled by temperature, fluid pressure, and fluid composition); alteration fronts at intermediate depths are clearly defined and locally steep.

Preliminary results of a reconnaissance study suggest that a steeply inclined northeast edge (isograd) of laumontite alteration is offset by the fault 37 km left-laterally. Pervasive alteration south of the fault is conspicuous everywhere in susceptible lithologies of the lower Matilija Sandstone (Eocene) and all older strata west of lat. 118°57′W. Alteration north of the fault is conspicuously absent wherever the same units are visible (subsurface and surface) east of the alteration edge near lat. 119°20′W. Stratigraphic and structural reasoning suggests that the laumontite crystallized about 22 to 25 m.y.B.P. Santa Ynez fault left-lateral slip necessarily predates the inception of San Gabriel fault right-lateral strike-slip (10 to 13 m.y.?B.P.).

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Sandstone Tongue of Cherry Canyon Formation and Upper San Andres Formation (Permian), Last Chance Canyon Area, Southeast New Mexico

The sandstone tongue of the Cherry Canyon Formation and the overlying upper San Andres Formation, exposed in the Last Chance Canyon area, represent a progradational sequence of slope, shelf, and nearshore systems. Based on lateral and vertical lithofacies relations, a paleoenvironmental model in a landward to basinward transect consists of the following: a supratidal through subtidal mixed carbonate-siliciclastic tidal flat; a mixed carbonate-siliciclastic lagoon; a fusulinid shelf shoal or bank complex; a predominantly carbonate open-

marine shelf containing sporadic patch reefs; a predominantly siliciclastic slope.

Numerous basinward-trending channels, commonly about 35 m deep and 400 m wide, are incised into the shelf and slope systems. The channels were cut and filled by shelf-derived, saline density currents. Breaches created by storms in the shoal complex allowed dense saline water, which had accumulated in the lagoon, to spill basinward as gravity-driven underflows beneath the less dense normal-marine waters. The bottom-hugging currents dissected the shelf and slope systems eroding deep basinward-trending channels. Large volumes of lagoonal sediments were moved through the channels in traction transport, ultimately filling the channels. Eventually the flows that maintained the channels ceased, resulting in channel abandonment and annealing of the shelf shoals and a return to normal shelf and slope processes.

The sandstone-filled channels extend as subparallel nonbifurcating features far into the basin environment and thus differ markedly from radially branching submarine fan channels. In contrast to offlapping lobes observed in submarine fan deposits, the Delaware Mountain Group channels are probably backfilled, resulting in onlapping siliciclastic packages.

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Microfossils from Type Relizian and Luisian Stages of California

Kleinpell designated the strata of the Monterey Formation in Sec. 28, T28S, R14E, as the type locality of the Luisian Stage. Microfossils from this section, however, were never described; instead, the Luisian Stage was characterized by foraminiferal faunas in strata from Reliz Canyon that overlie strata of the type Relizian Stage. The two Relizian and three Luisian Zones described by Kleinpell can be recognized in the benthic foraminiferal faunas from recently collected samples from Reliz Canyon. This sequence of zones cannot be recognized in benthic foraminiferal faunas of the type Luisian section or in the nearby Wilson's corner section, partly because the Reliz Canyon faunas represent deeper and more diverse faunas than those from the type Luisian area.

In the Reliz Canyon section, benthic foraminiferal faunas diagnostic of the Saucesian-Relizian boundary coincide with the base of the *Helicosphaera ampliaperta* Zone. The Relizian-Luisian boundary as indicated by the benthic foraminifers occurs near the *H. ampliaperta-Sphenolithus heteromorphus* boundary. Poor preservation and limited exposures prevent a more definitive calibration. Occurrence of late Luisian benthic foraminifers with meager floras containing *Cyclogargolithus floridanus* suggests an age no younger than the lower part of the *Discoaster exilis* Zone. In the type Luisian section, benthic foraminifers diagnostic of the Luisian Stage occur both above and below strata designated by Kleinpell as type Luisian. Nannofossil floras in the lower part of the type section are indicative of the *S. heteromorphus* Zone and diatoms diagnostic of the *Denticulopsis lauta* Zone and the lowermost part of the *D. hustedtii-D. lauta* Zone also are present. Sparse radiolarian faunas are dominated by long-ranging species, typical of present-day California-current faunas.

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Resedimented Deposits and Evolution of Thornton Reef (Niagaran) Northeastern Illinois

The significance of the Thornton reef, long established as a major reef model by paleoecologic studies, is enhanced by the recent recognition that significant volumes of the reef were deposited by submarine sediment-gravity flows and that these resedimented deposits document a distinct stage of reef growth. The Thornton reef (2 km diameter) is an erosionally truncated carbonate buildup that consists mostly of flank beds that dip steeply (30 to 40°) and radially away from the reef's center. The flank beds are thin, even, continuous, and consist of syndepositionally cemented crinoid wackestone and packstone. They were deposited by in-place sediment accumulation. In contrast, the resedimented conglomerates, which comprise 10 to 20% of the reef, occur as wedges, tongues, and sheets 0.1 to 25 m thick of lithoclast/skeletal wackestone/packstone. Lithoclasts range from 1 mm to 20 m across, and are made up of wackestones and boundstones. Debris flows were probably responsible for the thick boulder-bearing tongues and sheets in the interreef facies. A more prevalent and enigmatic resedimented deposit consists of steeply dipping (to 15°) wackestone/packstone conglomerate wedges that mantle the reef's outer margin. These are interpreted as the product of grain cascades down the reef flank.

Clasts in the resedimented deposits, derived from the now-eroded part of the reef are more stromatoporoid-rich and faunally diverse than the contemporaneous flank. This difference is attributed to a more energetic environment in the eroded part of the reef. There is no evidence in these clasts for lagoonal restriction, emergence, or shallow-water surf action.

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Applications of Fluid Inclusion Studies to Reservoir Diagenesis and Petroleum Migration: Smackover Formation, U.S. Gulf Coast, and Fateh Field, Dubai

The Smackover trend of the United States Gulf Coast is a prolific producer of oil and gas. The distribution of porosity is partly controlled by precipitation of late, void-filling calcite. The timing of the formation of these cements is interpreted from fluid inclusion geothermometry. In general, the fluid inclusion filling temperatures closely approximate those of the formation of the calcite and indicate that cementation occurred near the maximum depth of burial. The trapped fluid is a dense calcium-rich brine, consistent with modern formation fluids. The geochemistry of the fluid inclusions reflects the environment of diagenesis; for example, H_2S-rich inclusions occur in cements from deep, dolomitic, reservoirs.

The Fateh field, offshore Dubai, has estimated petroleum reserves of 2.3 billion bbl of oil. Production is principally from the Mishrif Formation, an Upper Cretaceous rudist reef complex. Late, coarse-grained, calcite cements partly occlude porosity. These cements contain both aqueous and oil-bearing fluid inclusions. Fluid inclusion geothermometry indicates temperatures consistent with the geothermal gradient indicating a Miocene age for cement deposition. Since oil was trapped during growth of the calcite cement, petroleum generation and migration are also Miocene in age. Preliminary analyses of the oil trapped in inclusions show it to be different than the oil in the reservoir. The oil trapped in the inclusions may be an early generated, less mature, oil.

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Distribution of Foraminifera on North Florida Atlantic Inner Continental Shelf