and litharenite (13%). Modal analyses of 41 thin sections show that framework grains consist of quartz (80%), rock fragments (15%), feldspar (5%), and trace amounts of micas and heavy minerals. Porosity of Chita Sandstone units ranges from 0 to 35%; mean percent of cement (mostly chalcedony, cristobalite, and opal) is 12.8%.

The Catahoula Formation is unique in that it records the last significant influx of volcanic detritus supplied to Gulf Coast sediments. Volcanic contributions include (1) abundant volcanic quartz (22% of total quartz); (2) rock fragments consisting mostly of silicic shards, felsite clasts, and tuffaceous clay clasts; (3) fresh sanidine (sanidine/orthoclase ratio = 1.2); and (4) a heavy mineral suite dominated by euhedral, elongated zircons. Onalaska Clay consists of mudstone and clay-ball lithoarenite beds composed mostly of montmorillonite, volcanic ash, and quartz silt. Volcanic ash in the Onalaska Clay is a likely source of most of the uranium mineralization in contiguous sandstone units. Silica leached from volcanic ash in the Onalaska Clay has been redeposited as pore-filling sequences of chalcedony (length slow and length fast), cristobalite, and opal cement in Chita Sandstone units.

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Creation and Application of Variable Density Grids to Oil Exploration Data

A significant problem in automatic interpolation procedures is that of honoring data points exactly. When maps of subsurface structures are made by computer, contours can pass on the wrong side of well data points or, where the well log depth is the same as the contour, not pass through them. They will be misplaced a varying amount depending on the grid size employed during interpolation. Honoring the data points can be guaranteed only if the rectangular or triangular grid base has as some proportion of its nodes the wells themselves. Therefore, the concept of a variable size grid is introduced using either rectangles or triangles, with the cell size decreasing in areas of closely clustered boreholes. By using locally defined functions it is possible to maintain a continuous surface over the whole map area and create a faithful representation of the structures in the map. FELIX, a minicomputer mapping and analysis system, is one system used to interpolate the subsurface structure of an oil field where the wells are distributed unevenly over the test area. In the triangular case in this system, it seems likely that little time need be spent searching for optimal triangular networks and a relatively simple algorithm is substituted.

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Paleoecologic Evaluation of Late Eocene Zonations of West Coast

Investigations of the late Eocene benthic forams along the West Coast indicate that the current zonal schemes can be modified to accommodate the constraints imposed on the organisms by ecologic conditions and thus become less provincial. The benthic foraminiferal assemblages of northwestern Oregon and southwestern Washington are used to develop a series of ecologic facies indicative of bathymetry and/or water mass. Upper depth limits, trends, clines, and morphologic variations of this group provide tools for determining ecology. The faunas of the type sections of the California and Washington stages, zones, and subzones, when analyzed in terms of this ecologic model illustrate some of the deficiencies inherent in these schemes. The late Eocene zones of California have a strong association with depth; that is, Narizian zones are lower or middle bathyal whereas Refugian zones are outer neritic or upper bathyal. The late Eocene zones of Washington are diagnostic of middle bathyal depths with considerable transport; as a result partial rather than total ranges are used in the development of these zones.

Although no new zones are proposed, it is possible to revise the existing zones to recognize the total ranges and bathymetric or other ecologic controls. The late Narizian Stage encompasses a bathyal and neritic facies. The bathyal facies is correlative with a modified *Bulimina corrugata* Zone of California and the *Uvigerina* cf. *U. yazooensis* Zone of Washington. The neritic late Narizian facies corresponds to a modified *Bulimina schencki–Plectofrondicularia* cf. *P. jenkinsi* Zone of Washington and a modified *Amphimorphina jenkinsi* Zone of California. The Refugian Stage can also be divided into a neritic and bathyal facies. However, the early and late subdivision of this stage is weak. The Refugian is equivalent to the modified versions of the *Cibicides haydoni* Subzone, *Uvigerina atwilli* Subzone, and the *Uvigerina vicksburgensis* Zone of California and a modified *Sigmomorphina schencki* Zone of Washington. The *Cibicides haydoni* Subzone is the neritic facies of the Refugian whereas the faunas of the *Uvigerina atwilli* Subzone, *Uvigerina vicksburgensis* Zone, and *Sigmomorphina schencki* Zone represent the bathyal Refugian facies.

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Computer Drafting—Its Application in Petroleum Exploration

Conventional or manual drafting of exploration data has been used since the early 1900s. Within the past 4 or 5 years, the use of small computer and digitizing equipment to supplement proved methods has saved time, improved accuracy, and simplified modifications.

Maps, charts, cross sections, etc, can be captured, edited, and drawn by plotters in half the time of conventional methods. Once in digital form, documents can be edited and easily combined with other graphics. Maps with different scales and projections can be transformed to common projections and scales.

Phillips Petroleum Co. uses a Bendix 100/101 digitizing-drafting system which consists of a Nova 100 computer with tape drive and disk pack, a Bendix cursor and table, and a Tektronix 4014-1 CRT. Output can be generated for both a Calcomp 748 plotter and/or a Versatec 42-in. electrostatic plotter. This type of system is not a replacement for manual drafting, but is a supplement. In many projects, the final product is a combination of manual drafting, computer drafting, and "standard" computer application techniques.

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Contourite Anticlines as Exploration Objectives

Regional seismic profiles off the east coast of the United States gathered by the University of Texas Marine Science Institute and Woods Hole Oceanographic Institute have crossed three types of contourite anticlines. They are symmetric, asymmetric, and half-anticlinal forms and have up to 3,000 ft (1,000 m) of relief. Off the east coast, contourite anticlines have been found in sections of Paleocene to recent age. They are the result of erosion, transport, and deposition by bottom currents that flow along the break between the continental slope and the continental rise. Because of the relation to deep-water currents flowing along this break in slope, the resulting deposits have been named "contourite anticlines." Explorationists should be alert to the presence of contourite anticlines and realize the limited exploration potential of this type of anticline. Recognition of their true nature early in exploration programs may save millions of dollars.

Seismic reflections from Wilcox (lower Eocene) deep-water sediments of south Texas show that large—more than 10 × 5 mi (16× 8 km), 2,000± ft (600± m) closure—anticlinal features were developed by deposition basinward from submarine fans. Texaco 1 Rodriguez was drilled in 1968 to 17,752 ft (5,326 m) on one of these contourite anticlines. The section within closure (below a drill depth of 8,700 ft; 2,610 m) penetrated by this test was entirely shale.

Available data on present-day contourite anticlines indicate that the currents that form them are capable of moving only clay-size material. Until stronger currents are documented, sandstones or any other type of reservoir, with the possible exception of fractured chalk, would not be expected in these features. Drape crestal grabens are present over some of the Wilcox contourite anticlines of south Texas. Production has been obtained from the median-depth (9,000±1,000 ft; 2,700±300 m) upthrown fault traps associated with these grabens.

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Depositional Environments and Their Relation to Porosity in Upper Smackover Formation (Jurassic), Paup Spur Field, Miller County, Arkansas

Cores from 13 upper Smackover wells in the Paup Spur field, Miller County, Arkansas, and adjacent areas have been studied to define depositional facies from sedimentary structures and carbonate textures. A depositional model is developed from these data. Petrographic studies of thin sections show the relation of diagenetic events to facies, and help unfold the history of porosity development.

The vertical succession of facies in the upper Smackover Formation may be interpreted as an upward-shoaling sequence. From the base, burrowed and oncolite-bearing pelmicrite is overlain by burrowed and bimodally cross-bedded oosparite and pelsparite. These in turn are overlain by algal biolithite and pelsparite. Shale and anhydrite of the Buckner Formation overlie the upper Smackover. Contacts between all facies are gradational.

A depositional model based on this vertical sequence consists of low-energy peloidal carbonate mud deposited seaward of a moderate to high-energy oolite and pelletal-shoal complex. Bimodal cross-bedding indicates tidal influence on the shoal. Landward of the shoal complex, algal mats and peloidal mud were deposited in a low-energy intertidal environment. Farther landward, sabkha evaporites of the Buckner Formation were deposited.

Porosity is highest in the cross-bedded oosparite and pelsparite facies (greater than 25%), where molds of oolites and pellets are the principal pore types. In the algal biolithite facies, porosity reaches 15% and is principally moldic, interparticle, and fenestral pore space. Some interparticle porosity in the algal facies may result from dissolution of anhydrite cement.

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Downcurrent Change in Miocene Canyon-Channel Systems in Indus Submarine Fan

Multichannel seismic profiles with excellent resolution reveal the internal morphology of Miocene canyon-channel-levee systems in a part of the Indus submarine fan. Individual canyon-channel-levee systems may be correlated from profile to profile in a down-canyon direction for at least 160 km. Each canyon or channel complex consists of numerous smaller canyons or channels which have migrated, avulsed, and aggraded during a long complex history to produce the morphology observed in the seismic profiles.

Detailed examination of seismic lines over two canyon-channel-levee systems has resulted in the recognition of degradational, transitional, and aggradational zones, respectively, in a distal direction. The distribution of these zones and their associated processes is controlled by canyon-channel gradient. The degradational zone is characterized by an erosional base and is dominated by bank migrational deposits. The processes responsible for these deposits are poorly known. The transitional zone also has an erosional base but is marked by the presence of small levees. Deposition in this zone results from bank migration followed by channel-current and overbank processes. The aggradational zone is characterized by a depositional base and large levees resulting from channel-current and overbank processes which may include both sediment and fluid density flows. In each of the two canyon-channel-levee systems studied, aggradation has resulted in the gradual proximal displacement of the degradational, transitional, and aggradational zones.

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