panies, pumping test data, water-well data furnished by the Texas Department of Water Resources, and geological and soils maps. This information was incorporated into the U.S. Geological Survey three-dimensional finite-difference computer model to predict ground-water behavior in a heterogeneous and anisotropic aquifer. Results indicate leakage through confining beds and communication across growth faults, suggesting that the Oakville is a complex aquifer system rather than a simple confined aquifer.

Understanding the development of intricate flow paths and controlled movement of fluids through designed and controlled systems may improve methods of shallow waterflooding of petroleum reservoirs as well as management of water resources.

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Ocular Sinuses in Genera of Ostracod Family Trachyleberididae

The ocular sinuses of seven genera of ostracods (Trachyleberididae) were studied through the use of internal molds and thin and polished sections. The three-dimensional aspects of the ocular sinus in the genera *Actinocythereis, Henryhowella, Malzella, Orionina, Puriana,* and *Radimella* have not been studied before. *Echinocythereis,* previously studied, was included for comparison.

Morphology of the sinuses varies from the low moundlike form in some specimens of *Henryhowella,* to the long structure in *Actinocythereis.* With the exception of *Henryhowella,* all other genera have ocular sinuses with many features in common. These properties include a stalk-like appearance marked by a distinct constriction someplace along the length of the stalk. Most of the sinus is circular in cross section except the distal portion, which is expanded and irregular in shape, presumably to accommodate the portion of the eye with the lens cell, retinal cells, and rhabdomes. The surface of the distal portion is dominated by a concavity that is the complement of the convexity of the adjoining eyespot. Adjacent to the convexity is an anterior lobe or rim and usually a higher posterior rim. Channels with diameters of 2 to 6 μm probably are passageways for axons. Ontogenetic development includes an early, low, cone-shaped sinus with a central concavity. Later juveniles in most taxa have a stalk, as do adults.

Despite overall similarities of the ocular sinuses, detailed examination indicates that genera and species can each be distinguished using this feature. Variations in size, shape, proportions, and secondary topography are diagnostic; thus, another character is available for taxonomic purposes.

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Deeply Buried Tertiary Sand Bodies in Northern Gulf of Mexico: Examples from Lower Hackberry (Oligocene) and Houma Embayments (Miocene)

Ninety-three electric logs were used to analyze deep-seated sand bodies in two fields in the Hackberry embayment of southeastern Texas and the Houma embayment of southern Louisiana. The geometry and occurrence of these sand bodies can be related to the regional structural and sea level history of the study areas. The Hackberry embayment originated by shelf-edge retreat after a major drop in sea level. Large amounts of sediment were then supplied by the Frio delta systems that built out to the shelf margin. The Houma embayment originated during a slight increase in the rate of sea level rise, while the Miocene deltaic systems built out over the continental shelf, triggering mass movement on the continental slope.

Both areas are characterized by large-scale synsedimentary faulting and salt tectonics. Large arcuate growth faults form the updip boundary of each embayment. Displacement across faults is from 900 to 2,000 ft (300 to 650 m). In both embayments, the sand bodies are overlain by thick shale masses that contain similar "flysch-type" faunas. The sands have a blocky appearance on the SP curves of electric logs, are slightly more than 100 ft (35 m) thick, and can be correlated for only a few miles. The structures show typical rollover, or reverse drag, into the main growth faults. In the Hackberry embayment, it can be shown that some intervals on the expanded downthrown side of the fault contain additional section, whereas marker beds below and above continue across the fault. These expansions developed during a time interval represented by 400 ft (130 m) of section and are interpreted as erosional and depositional events across the growth fault.

Comparison with present-day large-scale rotational slumps on the continental slope off the Mississippi delta shows that the overall characteristics of the Tertiary sands are similar to such modern slump masses; therefore, these sands are interpreted as having originated in a similar fashion. Thus, it appears that these analogous sand bodies accumulated as a result of comparable processes, even though the associated changes in sea level in the two areas differed considerably.

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Transgressive-Regressive Cycles and Environments of Coal Deposition in Upper Cretaceous Strata of Trans-Pecos Texas

Paralic deposits of Late Cretaceous age are represented in Trans-Pecos Texas by the Aguja Formation in the Big Bend region and the correlative San Carlos Formation in the Sierra Vieja region. Although both units are broadly progradational, each records a single widespread transgressive pulse. This transgressive event began in the early Campanian and reached a peak during the middle Campanian. Regressive (progradational) deposits consist of prodeltaic shale and delta-front siltstone and claystone, overlain by coalesced lenticular fluvial-dominated deltaic sand bodies. Transgressive deposits consist of local storm-dominated shoal sandstone, thin laterally extensive oyster-rich sublittoral sand sheets, and shelf mud. Transgression occurred relatively rapidly and was expressed differently depending on the distance traversed landward of the previous shoreline. Coal and lignite deposition occurred in restricted interdistributary areas during progradation, and in more widespread areas during peak transgression when the strandline was neither advancing nor retreating. No evidence is found for barrier island development during transgressive events; hence, the coal and lignite accumulated along a muddy nonbarred coast in marshes directly adjacent to the sea. The coal-bearing strata consist of an alternating series of dark-gray root-mottled carbonaceous claystone with sideritic "ironstone" concretions, coal or lignite, and well-laminated light-gray pyritic shale with calcareous concretions bearing marine invertebrates. The cyclic alternation of these facies suggests the repeated inundation of coastal marshes by marine waters, followed by mud accumulation, subsequent regrowth of the marsh, and the deposition of lignite or coal.

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Interdomal Sediment Ponding: A New Lower Hackberry Play?

Lower Hackberry (mid-Frio) reservoirs are highly unpredictable in the subsurface due primarily to variations in sand thickness and sand distribution. Most exploration for lower Hackberry reservoirs has been limited to turbidite sand-filled channels cut between sea-floor paleotopographic highs, and lower Hackberry sands on the northern flanks of salt domes, where excellent stratigraphic traps exhibit north dip—in places with significant closure. Two other existing types of reservoirs have received little attention, both in the literature and in exploration. The suprafan lobe in the midfan position lying at the base of the slope is a prime exploration target, where massive lower Hackberry sands should be found. Several wells in northwestern Cameron Parish, Louisiana, penetrated thick lower Hackberry sands in a downdip position from the channel plays, suggesting that a mechanism for large-scale downslope movement was present during Hackberry deposition.

Another potential reservoir that deserves more exploration is the interdomal sediment "ponding" of lower Hackberry sands into topographic lows created by the scouring of the sub-lower Hackberry surface. These sands generally are concentrated in the center of the pond and may not be present in either the traditional lateral or updip pinch-out positions. Many of the ponds occur independently from ideal structural location, commonly with a pinch-out of the sands serving as the trap. Ideal prospect locations are where the sub-lower Hackberry unconformity and top of the lower Hackberry marker diverge, indicating the presence of a sand-filled scour feature. Southwestern Calcasieu Parish provides excellent examples of this ponding feature in the subsurface. Successful exploration efforts depend on careful attention to paleontological information, which is critical in identifying and establishing the placement of the sub-lower Hackberry unconformity that records erosion of the early Frio surface.

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Lyles Ranch Field, South Texas: Production from an Astrobleme?

The process of impact cratering results in the instantaneous formation of unique structures characterized by extensive fracturing and brecciation of the target rock. This process can be conducive to economic hydrocarbon accumulations (Red Wing Creek field with 130 million bbl of oil in place and Viewfield containing 100 million bbl in place—both in the Williston basin), provided these impact features can be recognized in the subsurface. Geologists generally are unfamiliar with cratering mechanics and the high-temperature, high-strain-rate, and high-pressure effects that cause quartzofeldspathic rocks to undergo the mineral transformations so often misinterpreted as being "volcanic" in origin.

Reservoirs associated with astroblemes generally are limited to a highly deformed central uplift in larger craters, or to the fractured and brecciated rim facies. The presence of reservoirs and trapping mechanisms largely depends on the preservation state of the crater in the subsurface.

A probable impact crater recently has been identified in south Texas. The poorly preserved, roughly circular crater outline has rim uplifts consisting of well-cemented ferruginous Carrizo sandstone that is overturned in places. Large allochthonous blocks of Carrizo sandstone litter the area outside the impact site, and thrust faults are present in the Indio shale outcrops along the Nueces River adjacent to the impact area. A test well was drilled in the center of the impact area to investigate a strong gravity maximum that had been observed previously. The well, drilled to 1,200 ft, was dry. However, subsequent wells drilled along the crater periphery have been completed as producers from depths as shallow as 200 ft. Lyles Ranch field, which lies in the immediate vicinity of the impact crater site, may represent another hydrocarbon accumulation associated with an astrobleme.

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Early Evolution of Salt Structures in North Louisiana Salt Basin

Several salt diapirs and pillows in southern and central areas of north Louisiana have been studied using approximately 355 mi (570 km) of seismic reflection data and information from 57 deep well holes. Seismic profiles, with deep well-hole data, are the most advantageous method to document regional salt tectonism through time.

Three stages—pillow, diapir, and postdiapir—are required to explain salt-stock growth through time in the North Louisiana salt basin. The pillow stage and its associated primary peripheral sinks exhibit 11-34% thinning over pillow crests and 12-50% overthickening in the primary peripheral sinks in the basin. Thinning values as great as 87% and overthickening values as high as 400% are inferred for prediapiric (juvenile) salt pillows. The diapir stage and its associated secondary peripheral sinks exhibit 50-250% overthickening. This stage is characterized by piercement diapirism and the withdrawal of large volumes of salt from the flanks of the pillow. The postdiapir stage and its associated peripheral sinks exhibit less than 45% overthickening. Moreover, in some instances dome growth is in a steady state with sedimentation. Growth stages are generally confined to the following stratigraphic units: Smackover to Terryville (pillow stage), Calvin (diapir stage), and Winn and younger sediments (postdiapir stage).

These considerations lead to the following observations and conclusions on diapirism in the North Louisiana salt basin: (1) timing of the diapiric event commenced early (Late Jurassic) in the southern and central portion of the basin, and later (Early Cretaceous) in the northern portion; (2) the initial diapiric event is much more rapid and intense in the southern and central diapirs compared to the later diapiric event in the northern diapirs; and (3) regional depocenter shifting, relative sea level fall, local erosion with salt extrusion, and rapid depositional loading of sediments are the major controls on diapirism in the basin.

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Tectonic Transpression in Northeastern Mexico: Its Relation to Sea-Floor Spreading in Gulf of Mexico

The visual analysis of the SIR-A images (Shuttle Imaging Radar) of the folded belt located between Saltillo, Coahuila, and Galeana, in northeastern Mexico, revealed the existence of several geologic features including: (1) a well-developed pattern of en echelon folds, (2) juxtaposition of tectono-stratigraphic domains, (3) fold structures ranging from fan-shaped asymmetric to recumbent doubly plunging anticlines, and (4) anticlinal-synclinal trends displaying marked morphologic variations, associated to regional plunging, twisting, and tilting of the structures. These structures are interpreted as the result of transpressive forces related to a complex, anastomosed wrench-faulting system in the basement, reactivated in the Late Jurassic during active sea-floor spreading in the Gulf of Mexico.

The Saltillo-Galeana orogenic belt is interpreted as the early Tertiary culmination of an ancient Mesozoic (Jurassic and Cretaceous) transpressive deformation generated from an oblique-slip mobile zone in the Gulf of Mexico. This transpressive tectonic model gives the adequate paleogeographic scenario to integrate all previously postulated, apparently incompatible, deformational models for northeastern Mexico, and conciliates the differences in fold vergences observed in the region.

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Bay-Margin Sand Distribution, North Texas Coast: Model for Sediment Distribution in Microtidal Bays and Lagoons

Analyses of sediment from four bays on the north Texas coast reveal that sand distributions in microtidal bays and lagoons can be related to wind regimes and bay geometries (i.e., fetch and water depth). In order to examine this relationship, bottom profiles were constructed and sediment samples were collected along the profiles in Christmas, West, Trinity, and Galveston Bays. Grain-size analyses of these samples showed a point of marked change in the sand-mud ratio along each profile. This marked change from muddy bay-center sediment to sandy bay-margin sediment occurs at increasingly greater depths in the larger, deeper bays and at greater depths along the southeast side of the bays than along the northwest side.

The difference in the depth of the sand-mud break point between the northwest (76 cm) and southeast (92 cm) sides of Christmas Bay, the northwest (132 cm) and southeast (147 cm) sides of West Bay, the northwest (160 cm) and southeast (174 cm) sides of Trinity Bay, and the south side of Galveston Bay (220 cm) can be related foremost to the wind regime of the Texas coast. During 9 to 10 months of the year, moderate southeasterly winds dominate, creating waves that mainly affect the northwest side of the bays. During the winter months, however, strong northerly winds create larger waves, effectively winnowing sediments to a greater depth along the southeast side of the bays.

In addition to the differences between break-point depths on the northwest and southeast bay sides, minor differences in break-point depths occur along the same side within a bay and are related to variations in bottom geometry.

On the basis of these preliminary analyses, it appears that sand distributions in analogous bays can be predicted using wind, fetch, and water-depth data.

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Application of Pleistocene Climate Models to Gulf Coast Hydrocarbon Reservoirs

The Quaternary is characterized by two climatic signatures: that of the last 800,000 years (the upper Pleistocene), and that of the period from 900,000 to 1,800,000 years ago (the middle Pleistocene). Glacial cycles within the upper Pleistocene climatic signature are 100,000 years long and contain interglacial periods of 10,000-12,000 years and a "full" glacial period of 20,000-30,000 years. Cycles of the middle Pleistocene climatic signature range from 20,000 to 40,000 years. Analysis of Miocene cores from the Deep Sea Drilling Project reveals eight widespread hiatuses. These hiatuses correspond to intervals of cooling, as indicated by fauna and flora, ^{18}O anomalies, and low sea levels. The Miocene hiatuses may result from decreased polar temperatures and concomitant increased bottom-water circulation and corrosiveness. Durations represented by