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.

LOVE, KAREN M., HENRY S. CHAFETZ, LAWRENCE BRUNO, and CHRIS BUCZYNSKI, Univ. Houston, Houston, TX

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 both hiatuses and preserved sediments are approximately 1-2 m.y. The inferred Miocene glacial epochs are of the same duration as the glacial epochs of the Pliocene-Pleistocene. Oligocene hiatuses are found in all of the world's oceans, indicating cold bottom-following waters. Evidence (e.g., hiatuses or ice-rafted material) demonstrates the occurrence of Eocene continental glaciers in Antarctica. Interaction between the three planetary orbital parameters of eccentricity, tilt, and precession apparently control much of long-term climate change, with the dominance of eccentricity dictating glacial cycles. Continuity of climate pattern for the Tertiary is indicated, given constancy of planetary motion. Miocene, Frio, and Wilcox hydrocarbon reservoirs in the Gulf Coast should be reviewed in terms of a more subtle climatic model to refine interpretation of known depositional sequences.

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Ostracoda of Cretaceous-Tertiary Contact Sections in Central Texas

At the Littig Quarry in Travis County, the Navarro claystones yield sparse ostracod assemblages with low species diversity and equitability, dominated by *Haplocytheridea,* which suggest stressful coastal environments with rapid sedimentation. The ostracod assemblages in the overlying Midway glauconitic claystones are fully marine, moderately diverse, and characteristically Paleocene but sparse, except in the three condensed zones, the lowest of which marks the disconformable contact.

At Walkers Creek in Milam County, the Navarro assemblages are richer and of normal marine, nearshore aspect, with moderate diversity but low equitability, dominated by *Cytherella.* They belong to the "*Cythereis*" *lixula* interval zone, but perhaps not to the youngest part. The condensed zone at the disconformable base of the Midway yields a fully Paleocene fauna with moderately high diversity, either younger or farther offshore than at Littig, with a few reworked specimens of Cretaceous species.

On the Brazos River in Falls County, the Navarro claystones yield assemblages of offshore aspect with moderate species diversity and equitability; they belong to the upper part of the "*Cythereis*" *lixula* zone. A barren sandstone ledge marks a turbidite deposit at which a few Cretaceous species disappear. The claystones above this ledge have sparse, fragmentary assemblages, which gradually become more abundant, more diverse, and better preserved but less equitable upward, reflecting offshore but somewhat stressful conditions with intense naticid predation. *Brachycythere plena, Bairdoppilata suborbiculata,* and other characteristic Paleocene species appear one by one through this 3-m transitional interval, as holdover Cretaceous species gradually disappear, until a fully Paleocene fauna is established.

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Plate Tectonic Controls of Hydrocarbon Traps in Carbonate Rocks

Recent advances in understanding depositional environments and diagenesis of carbonate rocks provide a wealth of information regarding the nature of carbonate hydrocarbon traps. Projections of such data from control wells to unexplored areas are somewhat limited in scope because of paucity of data. This problem is particularly acute in frontier regions, where observations from only a few wells must be projected into a vast unexplored area.

The effects of eustatic sea level fluctuations on the carbonate facies are another focus of recent research. Undoubtedly, sea level fluctuations greatly influence the environmental and diagenetic stratigraphy of carbonate rocks. Additionally, the subsidence mechanisms in various types of basins profoundly control the morphology and distribution of carbonate facies.

This paper documents the various influences of synsedimentary tectonics on development of carbonate traps in various plate tectonic settings. Understanding such models allows projection of environmental and diagenetic data from a limited number of control wells into the sparsely explored areas.

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Upper Jurassic Norphlet Hydrocarbon Potential Along Regional Peripheral Fault Trend in Mississippi, Alabama, and the Florida Panhandle

Recent Upper Jurassic Norphlet oil discoveries associated with the West Bend fault system in Clarke County, Alabama, and Foshee fault system in Escambia County, Alabama, have renewed interest in exploring for hydrocarbons along the regional peripheral fault trend in Mississippi, Alabama, and the Florida Panhandle. The recently discovered Chavers Creek and Sizemore Creek oil fields and the Strickland 10-4 2 oil discovery in Escambia County, Alabama, are upthrown to the Foshee fault system. The trapping mechanism at Chavers Creek field is a faulted salt anticline, and the petroleum trap at Sizemore Creek field is an elongate salt anticline. The 1985 Womack Hill Field Unit 14-5 oil discovery in Clarke County, Alabama, is upthrown to the West Bend fault system. The petroleum reservoirs at Chavers Creek and Sizemore Creek oil fields include eolian and wadi sandstones of the Norphlet Formation. Porosity is estimated to be 11-22%, and permeability is estimated to be 14-47 md. Oil gravity in Chavers Creek field is 42.7° API, and that in Sizemore Creek field is 59.9° API.

The Norphlet oil discoveries in Clarke and Escambia Counties, Alabama, and the existence of established productive Norphlet hydrocarbon fields in Mississippi, Alabama, and the Florida Panhandle demonstrate the petroleum potential along the regional peripheral fault trend in central and eastern Mississippi, southwestern Alabama, and the Florida Panhandle. The key to successful prospecting for hydrocarbons along this fault trend is to delineate faulted salt anticlines or other salt anticlines and identify reservoir-grade eolian, wadi, and marine sandstones of the Norphlet Formation.

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Sources of Pleistocene and Holocene Sand for Northeast Gulf of Mexico Shelf and Mississippi Fan

Grain shape, surface texture, and mineralogic analyses were conducted on the Pleistocene and Holocene sands of the northeast Gulf of Mexico shelf and the Mississippi fan to determine their sources. Two distinct petrologic provinces of sand are present in this area: the Mississippi province, characterized by spherical quartz grains derived from older strata in the drainage basin of the Mississippi River, and the eastern Gulf province, characterized by a mixture of spherical and elongate quartz grains. The former is derived from Cretaceous and Tertiary coastal plain strata; the latter is derived from sedimentary and crystalline rocks of the southern Appalachian Mountains.

Sand distribution patterns of these two provinces on the northeast shelf are distinct; Mississippi province sands are found in the western part of the shelf near the Mississippi delta, while Eastern Gulf province sands are found throughout the remaining parts of the shelf. However, sands of the Mississippi fan are a mixture of Mississippi and Eastern Gulf province sand. Glacial sand is uncommon in both the Holocene and Pleistocene deposits of the Mississippi province.

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Fluid-Flow Patterns in Central Tuscaloosa Trend, Louisiana

Contoured hydraulic-head cross sections constructed from well logs in the central Tuscaloosa gas trend of Louisiana provide information about fluid flow near the hydropressure-geopressure interface. Extensive head inversions correspond to long, dip-oriented convolutions of the interface. The inversions occur where permeable, hydropressured, massive sandstone facies in the lower Tuscaloosa underlie geopressured Eagle Ford Shale updip of fault zones that preserve geopressures downdip. Thus, regional fluid pressure regimes in the Tuscaloosa and Eagle Ford are predominantly structurally controlled, with some lithofacies control updip.

Hydraulic-head trends indicate an overall pattern of regional upward flow from depth, with highest hydraulic gradients corresponding to the top of the Austin Chalk in most places. This pattern is complicated by inversions—which are nearly horizontal and tend to show high hydraulic gradients—and by a sharp, upward-protruding head peak that becomes nearly vertical along a trend above the Lower Cretaceous limestone shelf edge. This peak represents the escape of highly pressurized fluids from depth along a preferred path, which may be fault controlled.

Highest hydraulic gradients occur locally and regionally where fluids flow from geopressured shale toward permeable, hydropressured sandstone. Salinities are also reported to show a regional increase toward