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Hackberry Oil and Gas Fields in Southeast Texas: Channel/Fan Depositional Systems and Structural Controls

Deep-water sandstones of the Hackberry Formation (Oligocene) host significant quantities of oil and gas. They remain one of the most important deep exploration targets in southeasternmost Texas; new fields producing from the Hackberry have been discovered at a steady rate from 1946 to the present.

The Hackberry contains two hydrocarbon plays. The updip play is relatively shallow, oil-rich, and lies near the updip limit of deep-water deposition. Some of the fields in this play actually produce from shallow-water Frio sandstones of Hackberry age rather than from Hackberry sandstones. The downdip play is gas rich and generally geopressured. The reservoirs lie either within or on the flanks of major channel systems and are often bounded updip by small growth faults. The discontinuous distribution and complex lithofacies of these channel and fan sands demand a careful understanding of the component depositional environments in order to discover and efficiently produce hydrocarbons.

The Hackberry Formation is a wedge of sand and shale with bathyal fauna that separates upper Frio sandstone and shale from middle and lower Frio shale and sand. The main sandstone lies atop a channeled unconformity at the base of the formation; some sandstones are also found locally within the shale wedge. Sandstones in a typical sand-rich channel evolve upward from a basal channel-fill sand to more widespread valley-fill deposits of interbedded sand and shale. Topmost are proximal to medial fan deposits with slightly meandering channels and overbank turbidites. This sequence suggests that the Hackberry sands were laid down by an aggrading, onlapping submarine canyon-fan complex that eroded headward into the contemporaneous Frio barrier bar-strand plain. Regional mapping and seismic interpretation outlines a network of partly sand-filled channels extending from the strand plain toward the southeast. The downdip limits of lower Hackberry sand are not defined by available well data.

The early structural history of the area is obscure, but Vicksburg-age faulting associated with continental slope sedimentation is possible. Small growth faults displace the Hackberry section less than 500 ft (150 m) and extend upward into the Miocene strata. Isopach and isolith maps indicate that the Orange, Port Neches, and Fannett salt domes were active uplifts during Frio and Anahuac deposition. Near Spindletop dome, however, only a north-south trending salt-cored ridge was present. The Hackberry channels are somewhat influenced by salt activity, but major channel axes extend across the uplifts.

The genesis of the deep-water Hackberry embayment is obscure. Middle Frio strata underlying the Hackberry are neritic shelf deposits to the west but may include deeper water shales in the central and eastern parts of the area. The embayment may have formed by subsidence of a large part of the Frio-Vicksburg continental shelf with consequent canyon erosion. Alternatively, the Hackberry canyons may be analogous to canyons currently forming on the flanks of the Niger delta in an entirely deep-water regime.

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Tectonic Map of Texas—A Progress Report

The Bureau of Economic Geology is compiling a new Tectonic Map of Texas—a detailed, up-to-date display at 1:500,000 of surface and subsurface structural history for the entire state and adjoining areas of Mexico and the continental shelf and slope. This is the first comprehensive structural mapping of Texas since E. H. Sellards' "Structural Map of Texas" some 40 years ago. A companion illustrated text is also being compiled to systematically describe and summarize the tectonic evolution of the state from Proterozoic to Holocene.

Deformed Precambrian crust is exposed in the Llano uplift and in western Trans-Pecos Texas. It is subdivided by the tectonic setting of the sedimentary rocks and the timing of intrusion and deformation. The late Paleozoic basins and the intervening fault-bounded basement uplifts of west Texas are shown by 200-m and 100-m contours on the top of Precambrian or the top of Ellenburger, depending on the nature of well control. The principal features of the buried Ouachita Overthrust belt are displayed, along with a more detailed rendition of the exposed Ouachita rocks in the Marathon region. The East Texas, Maverick, and Sabinas basins and the inner Gulf coastal plain are shown by contours on the Edwards Limestone and the Austin Chalk; features due to salt tectonism, growth faulting, and Cordilleran deformation are prominent. Seaward of the Cretaceous shelf margin, the growth-fault trends of the Gulf Coast are shown with contours on the Tertiary formations most affected. Available offshore data have been integrated to provide a picture of the shelf, slope, and a corner of the Sigsbee abyssal plain. In the multiply deformed Trans-Pecos region, the surface expressions of structures related to Laramide folding and thrusting, middle Tertiary volcanism, and Miocene to Holocene basin and range faulting are shown, in addition to the Precambrian and Ouachita-Marathon structures, where exposed.

The final edition will be multicolor, with colors emphasizing subsurface contour horizons and depths, tectonic units in deformed or volcanic areas, salt domes, igneous bodies, faults, and axial traces of folds. Faults will be identified, where possible, by their age. Inset maps will include basement age and lithology, gravity, magnetics, and topography. The map and text will provide a valuable summary of Texas structural geology and suggest new approaches to the search for energy resources.

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Tectonic Analysis of a Viking Graben Border Fault

The Viking graben is interpreted as an aulacogen on a passive continental margin. Rifting started in the Late Permian and continued periodically throughout the Mesozoic. The main tectonic events occurred in the Late Jurassic and Early Cretaceous, namely the late Kimmerian phases. Toward the end of the Cretaceous, the taphrogeny ceased and the graben became part of a rigid continental margin.

The Tertiary basins had their depocenters close to the Viking and the Central graben axes, but the outlines of these smooth and rounded basins were independent of the graben border faults. However, in the central part of the North Sea, a Viking graben border fault was reactivated in the Paleocene/Eocene. This rejuvenation resulted in such features as flower structures and normal faults along the old Cimmerian Viking graben border fault.

Tensional features are found along one border fault "dog-leg" trend, and the compressive features are found along another. This may be explained as a response to strike-slip reactivation of the old fault.

These transient movements coincide with the incipient seafloor spreading in the Norwegian-Greenland Sea and may be related to consequent rotation and/or tilting of the Shetland platform.

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Stratigraphy, Sedimentology, and Petrology of Upper Cretaceous Horsethief and St. Mary River Formations, Western Montana

The Horsethief and St. Mary River formations were deposited along the Late Cretaceous epicontinental seaway, which then covered much of the western interior. Where these formations presently crop out along the disturbed belt in western Montana, the sedimentary units form a volcaniclastic sequence deposited during the final regression of the Montana Group and contemporaneously with early stage development of the Laramide orogeny. The facies preserved within these volcaniclastic sequences represent barrier island, high-destructive wave-dominated delta, and fluvial plain environments of deposition.

The Horsethief, lower of the two formations, is divided into two facies sequences. Facies sequence A consists of coarsening-upward sequences of sandstones and interbedded shales. The predominant sedimentary structures include multidirectional planar and trough cross-bed sets, micro-cross-beds, and ripples. *Ostrea sp.* and *Ophiomorphia* are present and most abundant near the top of this sequence. These facies comprise a barrier island system consisting of shoreface, dune, tidal channel, and lagoonal environments. Facies sequence B, deposited along the depositional strike, consists of a coarsening-upward sequence of vertically stacked distributary channels that thicken and become more abundant upsection. Delta fringe and prodelta facies are absent; marine processes reworked the detritus into barrier island systems.

The St. Mary River Formation is divided into a lower and upper member. The lower member consists of shales, sandstones, limestones, and coals deposited in a lagoon landward of the barrier island system. The upper member contains trough cross-bedded, channel sandstones, overbank sandstones, shales, and carbonate-nodule horizons indicative of fluvial plain sedimentation. These genetically related sequences were deposited along a basin margin characterized by temperate-continental climates, moderate to high rainfalls, rugged relief, and marine processes characterized by microtidal to mesotidal ranges and dominated by longshore currents.

Petrographic analysis indicates the detritus of these formations was derived from a magmatic arc provenance. The texture and composition of these sediments are dependent on the relative distance of sediment transport. Statistically significant correlations document a decrease in grain size as the distance of sediment transport increases within the entire section and within distinct environments, including middle shoreface, upper shoreface, and dune facies. The high percentage of volcanic constituents decreases as the distance of sediment transport increases and the grain size decreases. Additionally, higher energy environments result in deposition of coarser grained detritus and higher percentages of volcanic components.

The interpretation of the depositional environments and petrographic characteristics as observed within these formations can be useful in analyzing facies sequences that have similar source lithologies and were deposited in basins with a similar evolution. The recognition of these facies is significant because of the potentially important application associated with hydrocarbon source and reservoir conditions, as well as heavy mineral assemblages.

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Prevention of Carbonate Cementation in Petroleum Reservoirs

By the time a carbonate unit has been buried to the depths of most petroleum reservoirs, the significant question is often not "how did the pores originate?" but rather, "why are they still there?" Preservation of porosity, regardless of its origin, is a consequence of one or more of the following mechanisms: (1) minimal burial; (2) reduced burial stress, generally due to overpressured pore fluids; (3) increased framework rigidity, which prevents compaction; (4) exclusion of pore waters by petroleum entry; (5) stable mineralogy; (6) permeability barriers, isolating porous intervals from diagenetic fluids; and (7) pore resurrection, a consequence of the temporary filling of pores with cement that is subsequently removed. Examples from the stratigraphic record demonstrate that each of these pore-preserving mechanisms may control reservoir quality.

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Significant Role of Structural Fractures in Ren-Qiu Buried-Block Oil Field, Eastern China

Ren-qiu oil field is in a buried block of Sinian (upper Proterozoic) rocks located in the Ji-zhong depression of the western Bohai Bay basin in eastern China. The main reservoir consists of Sinian dolomite rocks. It is a fault block with a large growth fault on the west side which trends north-northeast with throws of up to 1 km (0.6 mi) or more. The source rocks for the oil are Paleogene age and overlie the Sinian dolomite rocks.

The structural fractures are the main factor forming the reservoir of the buried-block oil field. Three structural lines, trending northeast, north-northeast, and northwest, form the regional netted fracture system. The structural fractures are best developed along the north-northeast fault zones and at the intersections of other structural lines. Since the regional stress field was changed during the late Mesozoic Era, the mechanical properties of the north-northeast fault zones were changed from compressive shear to extensive shear. Therefore, the expansion of the structural fractures provided a good pathway for the activity of karst water.

The north-northeast growth fault controlled the structural development of the buried block. The block was raised and eroded before the Tertiary sediments were deposited, so that the Sinian dolomite rocks were exposed to the surface and underwent weathering and leaching for a long period. In the Eocene Epoch, the Ji-zhong depression subsided, but the deposition, faulting, and related uplift of the block happened synchronously as the block was gradually submerged. At the same time, several horizontal and vertical karst zones were formed by the karst water along the netted structural fractures. The Eocene oil source rocks lapped onto the block and so the buried block, with many developed karst fractures, was surrounded by a great thickness of source rocks.

As the growth fault developed, the height of the block was increased from 400 m (1,300 ft) before the Oligocene to 1,300 m (4,250 ft) after. As the petroleum was generated, it migrated immediately into the karst fractures of the buried block along the growth fault. The karst-fractured block reservoir has an 800-m (2,600-ft) high oil-bearing closure and good connections developed between the karst fractures. This is the high-yield Ren-qiu buried block oil field.