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Contrasting Depositional Processes of Sub-Clarksville and Woodbine Reservoir Sandstones

The sub-Clarksville and Woodbine sandstones are newly discovered gas reservoirs in Grimes County, Texas. Although the sandstone accumulated in a dominantly shallow marine environment, depositional processes and transport mechanisms were different for each sand body. The sub-Clarksville represents rapid deposition by storm-generated bottom currents. Sand accumulations are lens shaped and were restricted to lows by shelf topography. Sedimentary structures grade from laminated to massive sandstone above a sharp basal contact, to churned shaly sandstone at the top, overlain by Austin micrite. Mean grain size decreases upward with an average composition of 83% quartz, 6% rock fragments, 9% matrix, and abundant carbonate cement. Quartz content decreases and matrix increases upward. Bedding sequence and textural gradation suggest that sand was eroded from preexisting Woodbine sediments to the east and transported to the shelf during passage of a major storm.

In contrast, Woodbine sandstones represent a prograding deltaic environment. The sandstones are highly quartzose (80 to 94%) and show an increasing grain size upward. The "C" sandstone at Hill field is directly overlain by the Austin, and grades from bioturbated mudstone at the base to massive or faintly laminated sandstone near the top. Woodbine sandstones "C" and "D" thicken significantly eastward as an extension of a giant prograding deltaic system to the northeast. Conversely, Woodbine "A" and "B" sandstones were deposited as offshore bars farther west at Kurten field. Distribution of both the sub-Clarksville and Woodbine sandstones was affected by deep-seated salt movement at Hill field and the unconformity associated with this local high. Future exploration will depend on a detailed knowledge of the depositional framework in these downdip areas.

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Evolution and Porosity of Carbonate Shoaling Cycles, Lower Glen Rose (Lower Cretaceous), South Texas

The lower Glen Rose Formation in the subsurface of south Texas exhibits three cycles of shoal-water complexes, consisting of high-energy bank, bar, and biogenic reef deposits that developed on the Pearsall arch. Facies distribution shows that these elongate complexes trend northeast-southwest for at least 78 mi (125 km) and are located 44 mi (70 km) seaward of the Lower Cretaceous shoreline. Although barren of oil and gas, these vertically stacked cycles contain facies development and porosity preservation essential for attractive exploration targets.

Each cycle represents three major depositional facies: open-marine shelf, shoal-water complex, and protected lagoon. The open-shelf facies is characterized by terrigenous mudstone to wackestone. The shoal-water complex consists of skeletal and oolitic grainstone surrounded by lower energy packstone deposits. High-energy patch reefs of coral, stromatoporoid, and caprinid boundstone cap the grainstones. Lagoonal deposits of low-energy wackestone and laminated mudstone overlie each of the shoal-water sequences and indicate seaward progradations, which were interrupted by transgressions of open-marine shelf deposits of the succeeding cycle. The high-energy patch reefs may have prograded seaward across the shelf as the initial build-up of the Stuart City shelf margin.

Diagenesis during burial has resulted in loss of porosity in the rocks. The greatest remaining porosity occurs in the grainstone facies. There are two major porosity types: primary interparticle and secondary moldic. The primary porosity resulted from early meteoric cementation and preservation of high initial interparticle pore space prior to extensive grain compaction. The secondary porosity is the result of aragonite allochem dissolution.

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Potassium-Argon Age Dating of Interlayered Glauconites from Eocene Queen City Formation, East Texas

X-ray characterization of green pellets from the Eocene Queen City Formation near Jacksonville, Texas, reveals that these pellets are interlayered glauconite and chlorite. Because chlorite contains no potassium, it would dilute the potassium and argon concentrations in the whole rock with respect to the glauconite. These pellets were dated using the K-Ar age method. The results give an average age of approximately 50 ± 3 m.y. for the Queen City Formation. This age may reflect the time-transgressive nature of the beds as the ages slightly south of this location are younger—45 m.y. for the overlying Weches Formation.

BENSON, D. JOE, Univ. Alabama, University, AL, and ERNEST A. MANCINI, Alabama Geol. Survey and Univ. Alabama, University, AL

Petrology and Reservoir Characteristics of Smackover Formation, Hatter's Pond Field—Implications for Smackover Exploration in Southwestern Alabama

Hatter's Pond field in northern Mobile County, Alabama, has produced 11 million barrels of condensate and 43 bcf of gas since its discovery in 1974. Production is from multiple-pay zones in the Upper Jurassic Norphlet and Smackover Formations. The trapping mechanism in the field is a highly complex, combination structural and stratigraphic trap involving salt movement in association with normal faulting.

The Smackover in the Hatter's Pond field area is enigmatic for the Smackover in Alabama for two principal reasons. First, the Smackover is very thin, less than 200 ft (60 m), in comparison to thicknesses on the northwest and southeast. Second, the Smackover does not show the characteristic lower Smackover-upper Smackover lithologic subdivision so apparent throughout southern Alabama and the Gulf Coast.

These unique features are a product of the field's position on the northwest flank of the Wiggins uplift. Smackover deposition was significantly affected by the uplift which maintained the Hatter's Pond area as a subaerial high while lower Smackover carbonates were being deposited in the deeper areas of the Mississippi Interior Salt basin and Conecuh embayment. It was not until near maximum transgression that the seas covered the Hatter's Pond area and deposited shallow-water upper Smackover lithologies. These lithologies were later massively dolomitized by mixing-zone dolomitization during the subsequent Buckner regression. This dolomitization almost completely masked depositional textures, but was largely responsible for the development of reservoir-grade porosity in the Hatter's Pond area.

Six major lithofacies can be identified in the Smackover in

Hatter's Pond field: anhydritic mudstone, skeletal-peloidal packstone or grainstone, oolitic grainstone, microcrystalline dolomite, finely crystalline dolomite, and coarsely crystalline dolomite. The microcrystalline dolomite is commonly associated with bedded and nodular anhydrites and is interpreted to represent early replacement in a sabkha environment. Both the finely and coarsely crystalline dolomites are secondary in nature and represent replacement of low-energy skeletal-peloidal packstones and high-energy oolitic grainstones, respectively.

The majority of the reservoir porosity in the Smackover is late stage vuggy and/or moldic and is facies-selective and preferential to the coarsely crystalline dolomite. This porosity, which commonly ranges from 4 to 22% with permeabilities of 2 to over 100 md, is a product of mesogenetic leaching related to migration of carbon dioxide-charged fluids during the early stages of hydrocarbon maturation. The porosity is facies-selective to the coarsely crystalline dolomite, as this lithology possessed the greatest porosity and permeability at the time of migration of the carbon dioxide-charged solutions.

Evidence suggests the oolitic grainstones, which were the precursors of the coarsely crystalline dolomites, were deposited as a series of linear bars along the flanks of the Wiggins uplift. If this is the case, and more study is needed to document this definitively, the coarsely crystalline dolomite should occur in elongate mappable trends. Hydrocarbon exploration in this area and all along the flanks of the Wiggins uplift should involve location and mapping of these trends, with the greatest success occurring in areas where the trends are superimposed over structural highs produced by faulting and/or salt diapirism.

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Abnormal Pressures in Lower Vicksburg, McAllen Ranch Field, South Texas

The Vicksburg Formation consists of an upper shale member about 2,000 ft (610 m) thick and a lower member of interbedded sandstones and shales about 4,000 ft (1,220 m) thick. The entire section is abnormally pressured, and gradients reach 0.94 psi/ft (21.2 kPa/m). Pressures within the section were established by extrapolation of shut-in buildup pressures and by estimation of pressures from conductivity logs. Hydrostatic heads were then calculated and displayed in a vertical potentiometric profile. Head distributions suggest that hydrodynamic flow is taking place from areas of high pressure to an underlying major, listric normal fault and then updip along the fault plane. There is also upward flow from Jackson Shale below the fault. The top of abnormal pressures occurs at a depth of 7,500 ft (2,286 m) and at a temperature of about 210°F (99°C) where there is an abrupt decrease in smectite within the mixed-layer illite-smectite clays. Pressure increase with temperature does not follow isodensity lines for water as in the case of aquathermal pressuring. Therefore, it is concluded that abnormal pressures are largely the result of clay transformation, perhaps accompanied by pressuring caused by hydrocarbon generation.

A second zone of abnormal pressures with gradients to 0.74 psi/ft (16.7 kPa/m) occurs at about 6,000 ft (1,829 m) in the lower Frio Formation. In this zone, pressure increase with temperature follows isodensity lines for water, and it is concluded that aquathermal pressuring is the major cause of abnormal pressures. Shale densities suggest that nonequilibrium compaction may have played a minor role in creating abnormal pressures in the Frio.

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Geometry and Mechanisms of Folding Related to Growth Faulting in Nordheim Field Area (Wilcox), De Witt County, Texas

The Nordheim area in western De Witt County, Texas, has produced over 121 bcf of gas, of which over 53 bcf has come from the deep lower Wilcox. Consequently, a better understanding of folding in the Nordheim area should aid future exploration efforts, especially in the deeper (greater than 10,000 ft, 3,000 m) Wilcox. The folding mechanisms recognized are: mechanical folding, or folding due to faulting; drape compaction; and differential compaction. As a consequence of separating the various folding mechanisms, important geometric aspects of folding were recognized at Nordheim. They include: (a) the upward movement of folds relative to regional dip, (b) the shift of fold crests along dip and strike at various depths, and (c) the role of compaction in the final fold geometry. Upfolding is the term used to define the upward movement of folds relative to regional dip. Upfolding is recognized where intervals thicken off a fold crest in all directions, not just in the direction of the growth fault. For example, the deepest interval in the lower Wilcox, the Migura, has over 200 ft (60 m) of isopach relief and about 250 ft (76 m) of closure. Shallower intervals and zones show similar relationships between structure and isopach, but with less relief. Upfolding is the dominant mechanism of folding in the Nordheim area. Most of the folding not explained by upfolding is explained by either drape or differential compaction.

Previously proposed mechanisms of folding related to growth faulting have only incorporated two dimensions. Upfolding is a three-dimensional concept, and it is believed to be caused by material moving down a concave listric normal fault. The concave shape may cause a volume problem, which is overcome by the upward movement of material.

Three specific exploration concepts have been developed as a result of this study.

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Relation of Smectite-Illite Transformation and Development of Abnormal Fluid Pressure and Structure in Northern Gulf of Mexico Basin

Water expelled from smectite into the pore system of the host shale during the process of diagenesis may migrate out of the shale early, or may be totally or partially trapped and released slowly through time. In areas such as the northern Gulf of Mexico basin, where much of the water is partially trapped, clay diagenesis data indicate a close relation between high fluid pressure build-up and the smectite-illite transformation process.

Abnormal pressures affect, in part, the type and quantity of hydrocarbons accumulated, as pressure controls the direction of fluid flow and partially controls the geometry of structures formed in basins where shale tectonism is the primary mechanism for structural development. In basins of these types, contemporaneous faults and related anticlines are the most common types of productive structures found. The depth to which faults can penetrate and the angle of dip that faults assume at depth is dependent largely on fluid pressure in the sedimentary section at the time of faulting. Some faults, formed in the overpressured Tertiary section of Texas, have been observed to flatten and become bedding plane types at