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Petrology and Depositional Environment of Sunniland Producing Fields of South Florida

Oil exploration began in Florida in 1901, but no oil was found until 1943. In November of that year, Humble Oil and Refining Co. made a discovery near Sunniland in southern Florida. This field and the producing zone were called Sunniland. No further discoveries were made in southern Florida until 1954 when the Forty-Mile field was discovered by Gulf Oil Co. Ten years later, in 1964, the Sunoco Felda field was discovered by Sun Oil Co., followed by West Sunoco Felda field in 1968. Since that time, nine new fields have been discovered all from the same formation although none are as large as the Sunoco fields.

The examination of numerous cores and thin sections of this formation, both from producing fields and wildcat wells, reveals a sequence of deposition in the Sunniland formation. It has been reported that tintinnids or calpionellids have been observed in the lower mud section, but investigation of many thin sections from this section revealed only ostracod particles. Above the mudstone, the section becomes increasingly plentiful in fragmented microbored rudist particles and forams such as *Orbitolina texana, Dictyoconus floridanus,* and *Coskinolina sunnilandensis.* Above this section the sequence is considered regressive and consists of pellets and forams with a few mollusk fragments. This section is interpreted as the basal unit of a grainstone bar shoal. The grainstone bar shoal is made up of reworked particles of oysters (*Texigryphea*), coated caprinid fragments, forams, and echinoid fragments. This unit was deposited initially as a tidal bar shoal and then exposed to subaerial leaching.

For some years, the rocks of the Sunniland formation have been considered reefal, but based on the results of this study, these rocks are interpreted to be a barrier tidal-shoal bar deposited well behind the main reef crest, which lies farther offshore at the edge of the Florida escarpment.

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Submarine-Fan Sedimentation, Ouachita Mountains, Arkansas and Oklahoma

More than 10,000 m (32,808 ft) of interbedded sandstones and shales comprise the Upper Mississippian and Lower Pennsylvanian flysch succession (Stanley, Jackfork, Johns Valley, Atoka) in the Ouachita Mountains of Arkansas and Oklahoma. Deposited primarily by turbidity current and hemipelagic processes in bathyal and abyssal water depths, these strata formed major submarine-fan complexes that prograded in a westward direction along the axis of an elongate remnant ocean basin that was associated with the collision and suturing of the North American and African-South American plates.

A longitudinal fan system is visualized as the depositional framework for these strata, which were deposited in a setting analogous to the modern Bengal fan of the Indian Ocean. Facies analysis of the Jackfork formation indicates that inner fan deposits are present in the vicinity of Little Rock, Arkansas; middle fan channel and interchannel deposits occur at DeGray Dam and Friendship, Arkansas; and outer fan depositional-lobe deposits are present in southeastern Oklahoma.

Boulder-bearing units (olistostromes), many with exotic clasts, were shed laterally into the Ouachita basin. They occur throughout the flysch succession and in all fan environments (i.e., inner, middle, and outer). This relationship may serve as a useful criterion for recognizing analogous longitudinal fan systems in the rock record.

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Regional Patterns of Diagenesis, Porosity Evolution, and Hydrocarbon Production, Upper Smackover of Gulf Rim

The exploration fairway of the Upper Jurassic Smackover, from the Rio Grande to Florida Panhandle, consists of a rather simple carbonate-ramp depositional system characterized by thick, widespread blanket ooid sands. The ooid sand belt gives way landward to quartzose clastics and, locally, shales and evaporites. This high-energy ooid sand belt changes into dark, fine-grained limestones and shales in a short distance seaward. Early salt movement, buried basement structures, and growth faulting locally affected facies patterns within the upper Smackover. Salt anticlines, which were active during Smackover deposition and led to localization of favorable facies, are particularly important along the east Texas and south Arkansas parts of the trend. Buried basement structures, as well as salt structures, controlled detailed sedimentation patterns in the Alabama-Florida parts of the trend, whereas growth faults controlled sedimentation along a narrow belt straddling the Arkansas-Louisiana border. Initial porosities and permeabilities were generally quite high across the entire Smackover fairway prior to burial. Presently observed porosity-permeability trends were generally controlled by postdepositional processes including compaction, dissolution, cementation, and dolomitization. Regional differences in burial history across the Gulf rim, related in part to proximity to the isolated interior salt basins (Mississippi, North Louisiana, and East Texas salt basins), has resulted in striking differences in reservoir characteristics across the trend, reflecting significant regional differences in pathways of porosity evolution.

East Texas is a province dominated by dolomitized reservoirs, with production controlled by proximity to major fault trends, such as the Mexia-Talco, or to well-defined salt anticlines. Reservoir quality is tied inextricably to dolomitization. Dolomitization occurred early, associated with a regional fresh meteoric water system, hence reservoir characteristics were generally established prior to significant burial. Fracturing is a general feature of east Texas sequences, and there is evidence that fractures have acted as conduits for hydrocarbon migration. East Texas Jurassic rocks contain mainly gas. Oil migration occurred relatively early in the burial history of the sequence. Late burial diagenetic events in east Texas seem to have had little influence over ultimate porosity evolution.

Because of the depths involved, the south Texas Jurassic has not been explored to any extent and no production has been established. Recent work indicates a strong similarity to east Texas in terms of porosity evolution and general diagenetic framework, but with significant late subsurface secondary porosity development.

South Arkansas, Louisiana, and Mississippi stand out in stark contrast to the Texas parts of the trend. Reservoirs are generally limestones, with porosity either early fresh meteoric, secondary moldic, or preserved primary. The early meteoric moldic porosity occurs in a predictable trend across the updip portion of the fairway. Reservoirs with preserved primary porosity occur in a band seaward of the secondary trend, and show no evidence of freshwater influence or of early diagenetic processes other than minor marine cements. Porosity preservation in this zone was a function of grain type (ooids vs. pellets) and original sediment texture, and hence was ultimately controlled by depositional processes. In the primary porosity zone, production is, in almost all places, associated with salt-related structures, whereas in the early secondary zone, updip permeability barriers (diagenetic and stratigraphic?) as well as salt-related structures are important. Late diagenetic events that were associated with the migration of basinal derived fluids across the shelf during moderate burial, include cementation, dedolomitization, and calcite dissolution. All reservoirs in this part of the trend show ample evidence of significant porosity enhancement during this late solution phase. The limestone trend of Arkansas, Louisiana, and Mississippi is primarily an oil province with hydrocarbon migration that took place much later than migration on the west in Texas.

In Alabama and Florida, the trend is also toward dolomite reservoirs. Most dolomite, and hence porosity and permeability, formed early in association with meteoric water processes. Most large reservoirs, such as Jay, are associated with salt anticlines, with minor production from updip basement structures. This part of the trend produces mixed gas and oil. Hydrocarbon migration into reservoirs seems to have been a relatively late event.

The Jurassic upper Smackover of the Gulf rim is a simple sedimentologic system that has had a complex and variable burial history along the trend, which is distinctly reflected in major regional differences in diagenetic history, reservoir-porosity type, trap characteristics, and hydrocarbon-migration timing.

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Deep-Basin Lignite in Northwest Louisiana

Analysis of more than 2,000 electric logs has identified at least 63 sites in northwest Louisiana that have potential deep-basin (300-2,500 ft or 91-762 m) lignite deposits thicker than 5 ft (1.52 m). Locations are principally in Sabine, Webster, and Claiborne Parishes. The distribution of lignite in this depth range is governed primarily by the effects of the Sabine uplift on the Wilcox (Paleocene to Eocene) sediments in which the lignite is concentrated. Additional electric log analysis may reveal deep lignite deposits in other parishes affected by the uplift.

By using underground coal gasification (UCG) processes such as those developed at the Lawrence Livermore National Laboratory and in the Soviet Union, deep-basin lignite could produce low-btu methane suitable as a fuel, or carbon dioxide for enhanced oil recovery.

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Geology and Geophysics of South-Central Zavala and Adjoining Parts of Dimmit Counties, Texas

Gravity, magnetic, and seismic surveys combined with subsurface geologic investigations resulted in very intriguing interpretations of an area east of Crystal City, Texas. The study area includes the south-central part of Zavala County east of the Nueces River and the adjoining parts of Dimmit County to the south. The Elaine field is included in the study area.

Gravity and magnetic residuals were calculated using the least-squares method, and the magnetic surveys revealed several serpentine plugs, which are confirmed by seismic interpretations. Although no geophysics work was done, subsurface study shows that Elaine field is the largest of these plugs. Seismic studies also show that the Austin Chalk, on whose surface the lava was extruded, is highly fractured and faulted. The Austin under the Elaine field is the lowest structural feature in the area.

The Anacacho was deposited on the lava surface, and in the Elaine area it has a reeflike appearance. Isopachs of younger sediments show that they are draped and differentially compacted over the plugs, and that the Elaine plug affects sediments as young as Escondido.

Production in the area is mainly from the San Miguel, but significant amounts of hydrocarbons have also been produced from Eagle Ford, Austin, Anacacho, and Olmos reservoirs.

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Geology of De Queen Formation of Arkansas

Beds of the De Queen Formation are exposed in gypsum quarries within Pike and Howard Counties, Arkansas. The formation lies within the Lower Cretaceous Trinity Group that crops out in an east-west band across southwestern Arkansas. The De Queen Formation consists of a lower sulfate facies and an upper predominantly siliciclastic facies. The lower facies is approximately 40 ft (12 m) thick and is composed of interbedded gypsum, claystone, and limestone. This lower facies is equivalent to the subsurface Ferry Lake Anhydrite of the Gulf coastal plain. The upper facies is also approximately 40 ft (12 m) thick and contains interbedded clastics, limestones, and minor evaporites. Upper beds of the De Queen are equivalent to the lowermost beds of the subsurface Mooringsport Formation.

During Ferry Lake-De Queen deposition, a wide lagoon was located behind an extensive reef stretching around the Early Cretaceous shelf edge. This reef formed a barrier that restricted circulation and led to the deposition of the gypsum beds of the De Queen Formation and the Ferry Lake (later recrystallized to anhydrite during burial). Individual evaporite beds may be traced downdip from the outcrop across southern Arkansas into Louisiana and Texas. The regional extent of these evaporite beds reflects the variable geographic breadth of the lagoon during deposition of the Ferry Lake. Gypsum beds of the outcrop are the equivalent of the more widespread anhydrite beds of the Ferry Lake Anhydrite.

Faunal assemblages, sedimentary structures, and trace fossils (which include numerous dinosaur tracks) are important to the interpretation of depositional environments of rocks of the De Queen Formation. Much of the lower half of the formation was deposited in a shallow subaqueous setting, whereas depositional environments of beds within the upper half of the De Queen varied between subaqueous and exposed conditions.

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Jurassic Exploration Trends of East Texas

Gas and some oil are produced from both clastic and carbonate units in the Jurassic of the East Texas basin. In the Smackover Formation, the reservoir facies are generally shallow marine carbonates that formed in shoal-water environments in the western and northern parts of the basin during late Smackover deposition. Productive intervals contain interbedded dolomites and oolitic grainstones. The dolomite beds are laterally persistent and contain the necessary porosity. Traps are found (1) over low-relief salt structures, (2) against faults and in fault closures, (3) in relatively shallow updip areas over basement structures, and (4) in the northeastern part of the basin, in Cass and Marion Counties, where there are deep basement ridges. In theory, there is potential for Smackover stratigraphic traps in many parts of the basin. However, increased exploration for such traps in East Texas will probably be sparked only after the first significant stratigraphic-trap discovery.

The Haynesville (Cotton Valley) limestone was deposited in carbonate-shelf environments in the western part of the basin and in shallow water along the western part of the Sabine platform. On the western edge of the East Texas basin, a distinct narrow carbonate shelf can be documented. The shelf edge has been encountered in McSwane and Branton fields as a narrow basement-supported feature. Landward, to the west, shallow lagoonal facies grade into evaporites and terrestrial red beds. In this western area, both structural and stratigraphic traps are present. In the eastern part of the basin, Haynesville production is distributed around the western edge of the Sabine platform. Reservoirs overlie both the platform and salt-supported highs just basinward of the platform. Several elongate north-south-trending gas fields have been established in this area. For the Haynesville limestone, continued development of known trends is still possible. In addition, this unit has not been extensively tested along the Mt. Enterprise fault system or in the central part of the basin.

Sandstones of the Cotton Valley Group on the Sabine platform produce gas with fracture stimulation at depths from 8,000 ft (2,450 m) to more than 10,000 ft (3,050 m). These sandstones can occur over an interval of as much as 1,400 ft (425 m); they generally have low porosity and permeability and are interbedded with gray to black shales, which probably serve as local source rocks. The underlying Bossier shales may also be a source of the hydrocarbons. Traps are stratigraphic with permeability pinch-out in individual beds. Gas-bearing Cotton Valley sandstones can be found almost anywhere on the Sabine platform, as well as other parts of the basin, but commercial production is typically dependent on the presence of multiple beds with significant porosities. The Cotton Valley sandstone can be a favorable exploration target for the future with the development of appropriate pricing and a strong market for gas.

In places across the East Texas basin, thin sandstone or siltstone beds punctuate intervals of thick Bossier shale. These sandstone beds commonly release gas under relatively high initial pressures. Traps are stratigraphic with permeability pinch-out in individual beds, and confinement of the gas by thick shale above and below. The shales are also probably source beds. The sandstones are considered coarser grained facies of submarine fan systems that accumulated along the margins of the Bossier marine basin. Much of the Bossier production that has been developed to date is in structural lows in Haynesville reservoir trends. Presumably, the Bossier fans preferentially filled these lows, because structural position of the lows between Smackover-Haynesville structural highs had probably been established by the time of Bossier deposition, and paleobathymetry followed structure.

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Stratigraphy and Sedimentology of Kincaid Formation, Midway Group (Paleocene), Upper Rio Grande Embayment, Texas

Sedimentary rocks of the Kincaid Formation crop out along the northern and western edges of the Rio Grande Embayment. Siltstones are exposed at the type locality of the Kincaid Formation along the Frio River in Uvalde County, Texas. On the east and south, the Kincaid Formation changes facies to richly fossiliferous carbonate rocks; however, basinward, it grades into a shale facies that contains interbedded units of fine-grained sandstone.