The South Texas Plays

Operators are pursuing unconventional plays in addition to the Eagle Ford, including the Olmos heavy oil and tight rock plays, the Escondido Shale play, the Austin Chalk and Buda fractured carbonate plays, and the Pearsall Shale play.

Editor's Note: Isopach maps of the plays mentioned herein can be found on the wall map included in this playbook. Complete details on the references noted within this article are included in the last chapter of this playbook, "Additional Information on the South Texas Plays."

A discussion of the unconventional plays in South Texas must begin with deposition and diagenesis of the Eagle Ford Formation. The petroleum industry has been aware of this formation for decades; after all, it is a known source rock for Austin and Buda carbonate formations as well the famous East Texas (Woodbine) Field. However, it was not until 2008 when Petrohawk drilled its STS-2411 #1H gas well in LaSalle County and discovered Hawkville Field that the industry became aware of the Eagle Ford's potential as a primary hydrocarbon source. When Petrohawk's gas discovery was followed by an updip Eagle Ford oil discovery drilled by EOG in 2009, industry interest skyrocketed. However, from a geologist's viewpoint, no Eagle Ford dialogue would be complete without a discussion of exactly how the Eagle Ford became the hydrocarbon-rich formation that is causing so much industry excitement. In Texas it is typical to drill through thousands of feet of hydrocarbon-barren shale to reach an oil or gas deposit. Why then is the Eagle Ford, a hydrocarbon source rock, capable of producing oil and gas, while all these other thousands of feet of shale are not? Numerous factors, all working together millions of years ago, made the Eagle Ford Formation the hydrocarbon-producing juggernaut known today.

The Eagle Ford story begins approximately 91 million years ago during the Late Cretaceous Period. Earth was a much different place then. Much of Texas was covered by the marine waters of the Rio Grande Embayment and the Western Interior Seaway, a narrow waterway running in a south/southeast direction from what today would be the Arctic Ocean to the...
Gulf of Mexico. During this time, earth was going through an intense global warming period. Warming had reached a point where the polar ice caps had melted, causing a much higher sea level than is found today. Based on multiple data sources, scientists are convinced that the Late Cretaceous global warming was brought on by an overabundance of atmospheric CO₂ gas. The abundant CO₂ was thought to be the result of vigorous volcanic and magmatic activity going on at the time. Volcanic activity is particularly evidenced by numerous bentonite layers in the Late Cretaceous strata, the result of wind-blown volcanic ash layering large areas after volcanic eruptions. The resulting greenhouse effect, coupled with an upwelling of basic nutrients, particularly iron and magnesium, caused vigorous organic growth in the warm shallow marine waters. The vigorous organic growth eventually overwhelmed the shallow waters oxygen capacity causing hypoxic (low oxygen) and anoxic (no oxygen) water conditions with a resulting die-off of the marine organisms.

The deeper marine waters were another matter entirely. When the polar caps warmed, the world’s oceans lost much of their deep seafloor, cold-water, oxygen-rich currents. Normally, these cold oxygen-rich currents originate at the polar ice caps and spread toward the equator. The ocean bottom currents are the direct result of the cold polar seawater being heavier and denser than the warmer surface water, causing it to sink to the ocean floor, and spread horizontally outwards toward the equator. Cold water is able to hold much more oxygen than warm water. Without the ongoing oxygen-rich water supply, many areas of the world’s oceans became oxygen depleted, resulting in either hypoxic or anoxic water conditions. Because there was little or no oxygen, organic material falling to the seafloor was not consumed by the normal bottom dwelling scavengers and bacteria.

In addition, without oxygen, the organic matter was not broken down by oxidation, and because of the associated sea level rise, more of the ocean was too deep to allow organic breakdown by UV radiation from the sun. Instead, ongoing sedimentary deposition buried the preserved organic material, where it was slowly broken down by anaerobic bacteria as well as the heat and pressure of burial. Over time, the anaerobic bacteria died also, leaving the hydrocarbon-rich shale layer that we know today as the Eagle Ford Formation. Explorationists should take note: During the Late Cretaceous this process was going on globally. Additionally, the Late Cretaceous was not the only time in the earth’s history when these hydrocarbon-accumulating conditions occurred. Earth scientists have found evidence of several other global anoxic periods in the Cretaceous oceans alone.

**The South Texas Eagle Ford Formation**

Examples of the Eagle Ford Formation, or its stratigraphic equivalents, can be found not only in South Texas, but in East Texas as well. Along the eastern margins of the West Texas Permian Basin, the Eagle Ford outcrops and is known by its local name, the Boquillas Formation. As mentioned previously, during the Late Cretaceous much of Texas was part of a shallow marine embayment and seaway, but with the sea level raised several hundred feet making it deeper than it had been earlier. This shallow embayment and seaway was bound by mountainous areas to the west and a broadly uplifted area dominated by the Ouachita Uplift close by to the north, as well as the Appalachian Uplift farther to the northeast. A broad carbonate area, known as the Comanche Shelf, formed over South Texas during the Early Cretaceous period. The Comanche Shelf was bound by the subsiding Maverick Basin to the south and the San Marcos Arch, an eastward extension of the Llano Uplift, to the north. Geological research into South Texas Eagle Ford sedimentary sources points to deltaic sedimentation, mainly from sediments being shed from mountainous areas to the west, while the East Texas Eagle Ford received deltaic sediments mainly from the adjoining Ouachita Uplift to the north.

The South Texas Eagle Ford extends in a crescent-shaped swath from the Texas/Mexico border in the south, to approximately Fayette County, Texas, to the north. Across the Rio Grande in Mexico, the Eagle Ford is part of the Agua Nueva Formation. The Eagle Ford outcrops updip in a band running generally west to east from Val Verde County along the Rio Grande River east to San Antonio where it swings north to Austin. Down dip, the formation deepens to more than 17,000 ft and then plunges much deeper as it goes off the edge of the buried Cretaceous shelf margin, extending in a general line through the Middle of
Overview reveals the known Texas extent of the Eagle Ford Formation with the major tectonic features affecting Eagle Ford deposition. (Unless otherwise noted, illustrations from “Regional Stratigraphic and Rock Characteristics of Eagle Ford Shale in Its Play Area: Maverick Basin to East Texas Basin,” by T.F. Hentz and S.C. Ruppel, reprinted with permission of the Bureau of Economic Geology)

Stratigraphic column describes the Eagle Ford in South and East Texas.

Webb County at the Rio Grande River northeast through Colorado County. What is causing additional excitement, in these days of severely depressed natural gas prices, is that as the formation goes from deep to shallow, it goes from producing dry gas in the deeper eastern Eagle Ford, to wet gas as it gets progressively shallower toward the west, until finally a shallow band is reached in the west that predominately produces oil. Again, explorationists should take note, as it is not uncommon for these hydrocarbon-rich source rocks to go from gas to oil as the depth of burial decreases.

The South Texas Eagle Ford Formation, overlain by the Austin Formation and underlain by the Buda Formation, averages 250 ft thick, with maximum thickness recorded in excess of 600 ft. The formation is composed primarily of carbonate-rich mudstones, wackestones, and packstones, containing varying amounts of total organic carbon (TOC) and Type I & II kerogen. A recent researcher using core data identified nine separate and distinct Eagle Ford facies. In addition, the Eagle Ford Group encompasses numerous local outcrop names, remaining from earlier local studies. However, this report will simply focus on the main two South Texas Eagle Ford zones, rather than individual facies. Researchers have generally broken up the South Texas Eagle Ford into two distinct zones, the lower Eagle Ford zone and the upper Eagle Ford zone. There is also what is considered to be a transitional zone, between the predominately clastic Eagle Ford Formation and the carbonate Austin Formation, sometimes making exact correlation difficult. Each zone has the following gross characteristics and areal extent.

The lower Eagle Ford zone covers an area from the Texas/Mexico border (and into Mexico) to the San Marcos Arch and beyond into the Dallas area and East Texas. In South Texas the lower zone reaches its greatest thickness, in excess of 200 ft, near the Texas/Mexico border in the Maverick Basin area, while thinning to less than 50 ft as it approaches the San Marcos Arch area. The lower Eagle Ford, with an average carbonate content of 51% and an average TOC of 5.1%, is the most hydrocarbon-rich zone of the Eagle Ford zones. Its high carbonate content...
makes the Eagle Ford especially susceptible to hydraulic fracturing.

The upper Eagle Ford zone, like the lower Eagle Ford zone, covers an area from the Texas/Mexico border (and into Mexico) but pinches out before it reaches the San Marcos Arch. The upper zone reaches its greatest thickness, in excess of 400 ft, near the Texas/Mexico border in the Maverick Basin area, while pinching out completely as it approaches the San Marcos Arch area. The upper Eagle Ford with an average carbonate content of 67% is also susceptible to hydraulic fracturing, and an average TOC of 3.2% is the second-highest hydrocarbon-rich zone of the two primary Eagle Ford zones.

The transitional zone, between the Austin and Eagle Ford formations, covers an area from the Texas/Mexico border (and into Mexico), but pinches out before reaching the San Marcos Arch. The transitional Eagle Ford, with an average TOC of 1.3%, is the least hydrocarbon-rich zone of the three Eagle Ford zones. However, the transitional zone has its richest hydrocarbon layers near the laminated wackestone Eagle Ford top zone, becoming leaner toward the more bioturbated carbonate Austin Formation.

Operators are advised to core while drilling through the Eagle Ford. When planning a fracturing program in a new area, rock knowledge is critical and that goes multifold for the Eagle Ford Formation. Because of formation heterogeneity, an operator should not simply assume that one zone is better than another based only on TOC. Other issues such as thickness, friability, and clay content/type are just a few of the obvious formation factors engineers need to take into account when designing a fracture program.
Sediment deposition throughout the South Texas Eagle Ford is horizontally and vertically affected by:

- Tectonic activity, such as the Maverick Basin. The result of the Maverick Basins active tectonic subsidence during the Late Cretaceous is that the Maverick Basin became an important sedimentary depo-center.
- Salt movement and withdrawal affected sediment deposition. Even though tectonic subsidence may have terminated in the Maverick Basin, the overburden accumulation was sufficient to cause large-scale salt movement and withdrawal toward the Gulf of Mexico, causing subsidence and increased localized deposition.
- The salt withdrawal also caused several strike trending large scale normal and reverse fault zones, the Charlotte Fault Zone and Fashing Fault Zone in South Texas. Farther north of the San Marcos Arch are the Luling Fault Zone and the Balcones Fault Zone. The result of the faulting is that numerous downthrown blocks or grabens formed between the normal and reverse faults causing additional sediment to accumulation in these areas.
- Active sedimentary source areas affected sediment deposition. In the South Texas Eagle Ford’s case, sediment poured into the area mainly from the mountainous areas in the west. The mountainous areas are likely the result of early Laramide Uplift activity.

The East Texas Eagle Ford Formation

The East Texas Eagle Ford Formation outcrops in a band extending from Austin through Waco and Dallas north to the Texas/Oklahoma border. The formation makes a formal outcrop appearance in its namesake Dallas suburb Eagle Ford, located eight miles west of downtown Dallas. From Dallas and Waco the Eagle Ford trends eastward across the East Texas Basin until it pinches out against the overlying Austin Chalk Formation in a north-south trending line along the western flank of the Sabine Uplift.

Researchers have correlated several locally named area formations with the Eagle Ford Formation. As in South Texas, the Eagle Ford is represented by several locally named outcrops, all named and mapped during earlier studies. To avoid confusion, this report will only deal with the various current Eagle Ford-related formation names used in the subsurface. In addition, and not covered in this report, is the fact that the Eagle Ford reappears in the subsurface off the eastern flank of the Sabine Uplift, where savvy Louisiana operators are making successful Eagle Ford completions.

The Eagle Ford Formation in the Austin-Waco-Dallas area has been described as consisting of two depositional units. The first is a lower transgressive unit consisting of dark laminated shales showing almost no bioturbation, an indicator of an anoxic depositional environment. The second is an upper regressive unit shows interstratified shales, limestones, and carbonaceous quartzose siltstones. In the Western Dallas/Waco area of East Texas, the Eagle Ford is overlain by the Austin Formation and underlain by the Buda Formation, thickening as it moves northward away from the San Marcos Arch. As the Eagle Ford moves eastward across the East Texas Basin it thickens to as much as 700 ft in Hopkins County before thinning as it approaches the Sabine Uplift. In general the Eagle Ford is between 100 ft and 300 ft thick throughout East Texas. While the Eagle Ford becomes thinner it is gradually underlain, first by the Pepper Shale, which then grades further eastward into the siliciclastic-rich Woodbine For-
mation. Underlying the Woodbine Formation the Pepper Shale also grades into a darker hydrocarbon-rich minor source rock zone named the Maness Shale. The Buda Formation underlies the Maness Shale. To further complicate the regional picture, in the Dallas area the Eagle Ford becomes sand-rich, locally changing into an oil-producing reservoir rock called the Sub-Clarksville Sandstone. Though the East Texas Eagle Ford is time equivalent to the Lower Eagle Ford in South Texas and represents a transgressive unit, it does not have as high an average TOC content as found in South Texas. East Texas Eagle Ford TOC’s typically range from 2.1% to 5.2%, with individual units having a TOC as high as 9.1%. Core porosities range from 1.5% to 8% while log porosities range from 10% to 15%; permeabilities are poor. The East Texas Eagle Ford remains carbonate-rich and fracture prone, but has different interstitial clays than South Texas Eagle Ford, the result of having a different sedimentary source. However, the clays are not generally affected by water.

Sediment deposition throughout the East Texas Eagle Ford is horizontally and vertically affected by:

- Tectonic activity, such as the San Marcos Arch to the south, subsidence in the East Texas Basin in the middle of East Texas, and the Sabine Uplift terminating the East Texas Eagle Ford, Woodbine, and Maness Shale to the east. The result of this tectonic activity during the Late Cretaceous is that the East Texas Basin area became an important sedimentary depo-center.
- Salt movement and withdrawal affected sediment deposition. In the East Texas Basin, the overburden accumulation was sufficient to cause large-scale salt movement, causing increased deposition in localized areas.
- The Mexia – Talco fault zone, running in a north/south direction between Dallas and Tyler, Texas, provided opportunity for additional sedimentary deposition along this growth fault zone as did the short east/west trending Mt. Enterprise fault zone located south of Tyler.
- Active sedimentary source areas affected sediment deposition. In East Texas, sediment was deposited into the area from the nearby Ouachita Uplift to the north, as well as the larger Appalachian Uplift farther to the northeast.

**Testing the East Texas Eagle Ford**

While the South Texas Eagle Ford is getting nearly all the attention, clever operators have been quietly testing the East Texas Eagle Ford as well.

The “Lower Woodbine” or “Eaglebine” play in Madison, Leon, Grimes, and Robertson counties uses horizontal drilling combined with hydraulic fracturing in a heretofore overly tight Woodbine sand, located just underneath the Eagle Ford, to make some extremely prolific oil wells. From the description of the Lower Woodbine, one has to wonder if this zone isn’t an extension of the locally hydrocarbon-rich source rock, the Maness Shale. The Maness Shale is a carbonate cemented mudrock, trending from a thickness of 130-plus ft south/southwest of Tyler while pinching out toward Waco to the west. To the north of Tyler, the Maness thins to 35-plus ft. Even if it turns out that the Lower Woodbine is not the Maness Shale, with its fracture-susceptible carbonate cementation and high hydrocarbon content, the Maness Shale may still prove to be a locally productive future oil target.

**Other South Texas plays**

South Texas operators are pursuing several other unconventional plays in addition to the Eagle Ford. These include the Olmos heavy oil and tight rock plays, the Escondido shale play, the Austin Chalk and Buda fractured carbonate plays, and the Pearsall Shale play.

**The Olmos and Escondido plays**

Deposition of the overlying Escondido seal/source rock shale and underlying Olmos sandstone took place during Upper Cretaceous times in the South Texas Maverick Basin. Operators have been producing oil and gas conventionally from the Olmos since the 1920s. Early production was from structural traps as well as updip stratigraphic traps. Since historically the percentage of oil produced from most Olmos fields is low, these legacy fields are worth a thorough review using modern technology. Lately, operators have been taking a look fur-
ther updip at tar and heavy oil accumulations, as well as far downdip shelf edge oil accumulations. The shelf edge potential was known but previously bypassed because of inadequate fracture technology. Geologists have been aware of the updip Olmos tar sands for more than a century. In the late 1800s settlers mined the tar sands for asphalt. It was only logical that with downdip burial and less oxidation the tar would grade into heavy oil. It has been estimated that there is 7 Bbbl to 10 Bbbl of tar and heavy oil in place in South Texas.

Based on the deposition of Olmos sands and the lack of technology available to early wildcaters, many researchers feel that much recoverable oil remains in existing Olmos oil fields, waiting only for further exploration and infiel drilling.

The downdip Olmos shelf edge tight-rock oil accumulations were known but were considered uneconomic to produce until recent advances in hydraulic fracturing.

At the end of the Olmos was an erosional period. The Olmos Formation is overlain unconformably by the Escondido Formation. The Escondido is 875 ft thick in outcrop and consists of alternating layers of sandstones, siltstones, mudrocks, and thin limestones. The Escondido unconformably overlies the Olmos causing hydrocarbon accumulations along the resulting stratigraphic pinchout. Being a thick hydrocarbon seal/source rock, the Escondido has hydrocarbon potential, as was found in the Eagle Ford.
The Austin Chalk and Buda plays
The twin carbonate Austin Chalk and Buda plays, trending in an arc from the Texas/Mexico border to the Sabine Uplift, just east of the Texas/Louisiana border for the Buda and across the Uplift for the Austin Formation, were both Gulf Coast oil darlings in the late 1970s and early 1980s. The Giddings area had so much Austin Chalk drilling activity, a local entrepreneur purchased large sections of concrete drain pipe, installed floors, added walls with doors and windows on either end, equipped them with bunk beds, and rented them out to desperate oil workers for lodging. Then oil dropped to $8/bbl and it seemed like the end of the road for the two unconventional reservoirs that relied on natural fracture systems (sweet spots) to produce oil from the otherwise impermeable carbonate rocks. As the price of oil has returned to adequate levels, and operators have improved horizontal drilling and hydraulic fracturing techniques, there has been a resurgence of interest in these two formations. It certainly doesn’t hurt having the incredible source rock potential of the Eagle Ford sandwiched in between these two formations.

The Pearsall play
The South Texas Maverick Basin Pearsall Formation, a 600-ft- to 900-ft-thick Lower Cretaceous, mixed carbonate/siliclastic, hydrocarbon-rich shale, is made up of three members: the youngest, the Bexar Member; the Cow Creek Member; and the oldest, the Pine Island Member. Gas production currently comes from the lower Bexar Member.

The Pearsall Formation is a familiar South Texas source rock.

In a 2009 article, US Geological Survey researchers performed geotechnical analysis of the Pearsall in 12 Maverick County wells and two McMullen County wells. The analysis revealed an average TOC of 0.8% with a TOC range of 0.17% to 2.97%, with some Type II kerogen, but mainly Type III kerogen (gas prone) dominating. Pearsall Ro values are in the gas window, ranging from 1.5% to 2.3%. Operators were beginning to drill and produce the gas-rich Pearsall Formation when it became overshadowed by the shallower Eagle Ford, which can produce either oil or liquids-rich gas in the same area. With natural gas prices currently at extremely low levels, while oil is between $80/bbl to $110/bbl, many Pearsall players abandoned the deeper play for the more economically attractive Eagle Ford. However, several operators are currently pursuing Pearsall hydrocarbon production, apparently relying on the initial potentials of four Pearsall wells that made 451 b/d to 740 b/d condensate and 4.4 MMcf/d to 6.2 MMcf/d of gas as indicators of the expected mixed liquids/gas production.