ate grainstone cycles. The three reservoirs are offlapping and are separated from each other by clastic facies rich in terrigenous matter. The two oldest reservoirs were deposited as well-defined barrier-island complexes up to 4 mi (6.4 km) long and less than ½ mi (0.8 km) wide. The youngest reservoir is less well defined and was deposited primarily as coalescing bars which were only occasionally emergent. All carbonate facies were deposited as mud-free oolitic and rhodolitic grainstones. Most porosity occlusion was by early cementation in the meteoric phreatic and mixed phreatic zones, paralleling depositional strike.

Ten of the 13 producing wells and all four dry holes were conventionally cored. Thin sections were made at 1-ft (0.3 m) intervals from perm plugs, corresponding with measured values of porosity and permeability. Detailed petrographic correlation of wells allowed the individual reservoirs to be subdivided into distinct mappable units on the basis of a plot of the diameter of the largest coated grain ("clasticity index") in each thin section. Clasticity index provides a simple, rapid tool for precise well correlation within individual reservoirs; the correlation is not possible by conventional log methods.

Prior to the incorporation of petrographic analysis in the development drilling program, the field consisted of seven producing wells and three dry holes. Combining clasticity plots and other petrographic information with porosity isopach values enabled the field size to be almost doubled with the successful completion of the next six holes.

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Bayou Middle Fork Field, Claiborne Parish, Louisiana—Case History from Discovery to Waterflood

Bayou Middle Fork field, Claiborne Parish, Louisiana, is located in north-central Louisiana near the Arkansas-Louisiana border in an area known as the "State-Line trend" of the Upper Jurassic Smackover Formation. Smackover production in the area is associated with a complex fault system masked by approximately 10,000 ft (3,000 m) of younger sediments. A geophysical program combined with geologic studies indicated a faulted, deep-seated east-west-trending anticline. On the basis of this evidence, Cities Service Co. drilled a test well on the structure and discovered the Smackover reservoirs at Bayou Middle Fork field in March 1975.

Core and sample studies made as the field developed showed the Smackover at Bayou Middle Fork field to be a limestone composed mainly of oolites, hardened pellets, pisolites, oncolites, and micrite. This limestone has been divided into three units designated as the Smackover A, B, and C. The general environmental setting that produced these sediments varied from low- to high-energy conditions over a broad, shallow, gradually south-sloping marine shelf. This environmental setting underwent continual minor sea-level fluctuations and structural changes, producing an interfingering and mixing of the various carbonate sediments. One major change occurred as sea level completely receded. The shelf was exposed to supratidal conditions which resulted in the deposition of evaporitic and continental sediments. This regression ended Smackover "C" deposition and produced the Buckner "B" member of the stratigraphic section, which was followed by a partial transgression and subsequent regression resulting in the Smackover "B" and "A" being deposited in an offlap sequence. This second withdrawal of the sea ended Smackover deposition and again produced conditions for accumulation of supratidal and continental sediments.

Porosity preserved within the oolitic rocks is primary intergranular and has been enhanced by leaching of the oolites. Effective porosity varies from a low of 8% to a high of 23.7% and permeability ranges from less than 1 to 270 md. During early development of the field, the porosity and water values from log analysis indicated the possibility of substantial water production. However, as wells were completed, no water was produced; scanning electron microscope and petrographic work revealed the presence of microporosity containing irreducible water.

Smackover production at Bayou Middle Fork field is from three separate reservoirs, the Smackover "C," and upper and lower "A." The lower Smackover "A" reservoir, the largest of the three, contains volatile oil, that through primary production is produced by solution gas drive, with recovery of only 20% of the oil in place. To provide pressure maintenance, a water-drive system was chosen. It is estimated that an additional 20% of the oil in place will be produced by the waterflood program.

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Interpretive Well-Logging Concepts Solve South Texas Formation-Evaluation Problems

Proper selection and application of properly calibrated well logs provides valuable information for exploration, drilling, and reservoir engineering. Interpretive log-derived concepts allow determination of subsurface pressure, temperature, and salinity variations, define the type of depositional environment, and evaluate the production potential of clastic and carbonate reservoir rocks. Overpressure detection and pore-pressure evaluation are of further assistance. Gamma-ray spectral-logging techniques have located permeable and/or fractured reservoir intervals in the Cretaceous carbonate trend (Austin Chalk, Eagle Ford Shale, and Buda Limestone), to determine the source-rock potential of shales, and the type of clay minerals present. A new method allows a reliable log-derived estimate of the cation exchange capacity and hence improved water saturation estimates in shaly, hydrocarbon-bearing clastic reservoir rocks.

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Log Evaluation of "Tight Rocks" of South Texas

South Texas has several productive zones that can be described as "tight rocks"—the relatively low-porosity, low-permeability sandstones of lower Oligocene, Eocene, and Upper Cretaceous Gulfian Series. They include such important producing formation as "Deep

Frio," Vicksburg, Wilcox, Olmos, and San Miguel, and represent a vast amount of past and present production and future potential. Various petrophysical parameters such as matrix density and velocity, formation-water resistivity, porosity, and water-saturation ranges influence production. Identification of productive zones is assisted by use of the Dual Induction Laterolog, the Borehole Compensated Sonic Log, the Formation Density Log Compensated, and the Compensated Neutron Log, as well as hand- and computer-processed interpretations.

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Depositional Environment of Woodbine Sandstones, Polk, Tyler, and San Jacinto Counties, Texas

Woodbine sandstones produce mostly natural gas in stratigraphic traps at Seven Oaks, Hortense, Leggett, and R. B. fields in Polk County, Texas. The Woodbine section can be divided into lower, middle, and nonbioturbated and bioturbated upper units of interbedded sandstones and shales. Strike-trending, pod-shaped concentrations of bioturbated upper sandstones are the principal reservoirs in these fields.

The lower and middle Woodbine sandstones are thinly to thickly bedded and isolated in black, nonbioturbated shales. Thinner sandstones average 0.25 ft (7.5 cm) in thickness and typically consist of more complete turbidite sequences (ABCDE, ABCE, BCE, and CDE). Thicker sandstones that range from 0.5 ft (15 cm) to as much as 7.35 ft (22 m) contain less complete sequences (A, AB, and BC). Thicker sandstones with less complete bedsets represent channel deposits whereas the thinner sandstones with more complete bedsets represent overbank deposits. Thinly bedded, nonbioturbated upper Woodbine sandstones are gradational upward into the thickly bedded, bioturbated sandstones. The nonbioturbated sandstones contain only turbidite bedsets reflecting overbank deposition. Ordered sequences are absent in the bioturbated upper sandstones. A few relict, ripple-laminated intervals suggest that the bioturbated sands were deposited by more persistent, low-flow-regime, possibly geostrophic currents, rather than by turbidity currents.

Woodbine clastic deposition is associated with a prograding shelf margin. Electric-log correlation and seismic sections suggest that the lower sandstones were deposited as a group of channel and overbank turbidites on the lower slope. Middle sandstones were deposited in isolated feeder channels located farther up the slope and closer to the shelf break. The thick section of slope shale containing the lower and middle turbidite sandstones is overlain by thinly to thickly bedded upper sandstones interpreted to be shelf-margin sandstones that cap the prograding slope sequence. A turbidite origin for most Woodbine sandstones in the Seven Oaks producing area suggests that channel sandstones associated with submarine fans located farther downdip, possibly over the Sligo reef break, may form extensive dip-trending reservoir bodies.

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Middle Strawn (Desmoinesian) Cratonic Delta Systems, Concho Platform of North-Central Texas

Terrigenous clastic- and carbonate-rock units forming the middle third of the Strawn Group were deposited in the Fort Worth basin and on the adjacent Concho platform of north-central Texas. Four significant transgressive-regressive cycles comprising the interval between the top of the Brannon Bridge Limestone and the top of the Brazos River Formation have been evaluated employing data gathered from 4,000 well logs and 35 measured sections. Subsurface maps indicate that four discrete, vertically persistent, deltaic depocenters, two carbonate banks, and an embayment strand-plain complex are present within the area. The average thickness for the total vertical stratigraphic interval is 1,000 ft (300 m), or approximately 250 ft (75 m) per cycle of deltaic progradation and abandonment.

When active tectonic downwarping diminished in the central part of the Fort Worth basin, middle Strawn cratonic deltas prograded across the filled foreland basin and out onto the stable, gradually subsiding Concho platform. Deltaic facies present on the platform for all four cycles involve thin, usually less than 140 ft (42 m) thick, multilateral, high-constructive elongate and lobate systems. For the lower two cycles, the Buck Creek and Dobbs Valley sandstones of outcrop, deltaic progradation extended to the western margin of the platform more than 200 mi (320 km) downdip from the source area. Carbonate-bank deposition subsequently was established on the distal ends of these oldest delta sands and westward deltaic progradation was less extensive with the upper two cycles. A strand-plain—embayment system composed of mudflats, chenier sandstone bodies, and thin bay-head deltas developed between the two principal deltaic depocenters on the platform. The Midland basin on the west was a poorly defined, gradually deepening, depression; no true Desmoinesian shelf-edge or slope systems have been discovered.

High-constructive delta systems attributed to the Dobbs Valley (cycle II) and Brazos River (cycle IV) units have sandstone accumulations in excess of 200 ft (60 m) at one depocenter along the northwestern margin of the platform and at a second one on the northwestern rim of the Fort Worth basin. These thicker deltaic complexes contain linear, multistoried sandstone bodies whose geometries resemble bar-finger sands of the modern Mississippi delta. Valley-fill fluvial deposits incise the high-conservative deltaic facies. The Arbuckle and Wichita Mountains were the major sources for the more arkosic, northern delta systems. The Ouachita foldbelt furnished the chert-rich detritus for the fluvial-deltaic facies on the Concho platform.

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Upper Cretaceous–Lower Eocene Strata, Hainesville, Keechi, and Oakwood Salt Domes, East Texas

Salt domes in east Texas are possible sites for nuclear waste repositories. Tectonic stability is a critical factor in evaluating suitability as a repository. Subsurface studies were undertaken to determine stratigraphy and