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Woodbine Palynofacies—Their Relationship to Tuscaloosa of Gulf Coast

A recent palynologic study of the Texas Woodbine and comparison with the Gulf Coast Tuscaloosa have produced some interesting depositional models and increased our basic understanding of the relationship between these 2 petroliferous formations. Although age considerations and environments of deposition for the Woodbine were already determined from previous work, the distribution of palynomorphs is documented in this study. Inasmuch as the Woodbine is exposed in outcrop, several localities were available for detailed collecting. The Woodbine delta is interpreted to be a complex depositional system, and the palynomorph occurrences were sensitive to the ever-changing environments (interpreted from the many facies). Although widely separated geographically, the presence of such diagnostic palynomorphs as the dinoflagellate species *Kiokansium unituberculatum* and the spore *Klukisporites crassiterminatus* in both the Woodbine and the Tuscaloosa established at least a partial Cenomanian stratigraphic equivalence for these formations. While the Woodbine and the Tuscaloosa deposition began in the earliest middle Cenomanian, the Woodbine culminated in the early late Cenomanian, and Tuscaloosa sedimentation continued through late Cenomanian. Strata older than middle Cenomanian are recognized by the occurrence of the dinoflagellate species *Ovoidinium verrucosum* in both formations, suggesting the stratigraphic equivalence of the Texas Grayson Formation and the Louisiana Washita facies. The species associations (palynofacies) seen in the Woodbine and in some places in the Tuscaloosa could aid in the reconstruction of the environments of deposition for the Tuscaloosa Formation.

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Diagenesis, Fracturing, and Production from Monterey Formation, Offshore California

Diagenesis of the Monterey Formation includes the opal-A→opal-CT→ microcrystalline-quartz transformation, dolomitization, and in some places the formation of brittle, vitreous cherts. These diagenetic transformations produce a more brittle rock. Diagenesis is thus considered a major control on the fracture potential of Monterey rocks. Once formed, fractures become excellent fluid migration paths. Fluid migration along fractures creates vuggy porosity adjacent to the fractures and may promote the generation of secondary matrix porosity, primarily in carbonate-rich lithologies.

The Monterey is characterized by high matrix porosity but very low matrix permeability. The vast quantities of hydrocarbons produced from this formation require production from matrix porosity in addition to production from fracture porosity.

A model is suggested in which matrix-bound hydrocarbons migrate into fractures that intersect high porosity-low permeability beds. These fractures either intersect other fractures, the borehole, or stratigraphic breccias; any or all of these conditions should enhance productivity. This model diminishes the problems associated with fluids migrating long distances through a low-permeability matrix. Implications of the model include the following: (1) fractured carbonate-rich rocks with matrix porosity should yield the best production; (2) chert-rich lithologies with no matrix porosity will produce primarily from fractures; (3) high-porosity shales with few fractures are candidates for hydrofracture treatments to enhance productivity.

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Effects of Area-Wide Leasing in Gulf of Mexico

Area-wide lease sales in the Gulf of Mexico over the past 2 yr have received an enthusiastic response from the oil industry. More tracts have been bid upon and acquired per sale, total larger lease bonuses have been paid, and exploratory drilling has rebounded. Several new geologic plays are now under way in Texas, deep-water Louisiana, and the eastern Gulf. Many companies are now involved in offshore leasing and exploration. This activity has returned people to the work force and boosted the economies of effected coastal states. Industry should be able to reduce the reserve and production decline and decrease forthcoming supply shortfalls as a result of area-wide leasing.

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Smackover Reservoirs in Southwestern Alabama

One of the major problems encountered during exploration for hydrocarbons in the Smackover in southwestern Alabama is delineation of porosity trends within the unit. Unlike Smackover reservoirs in Arkansas, Louisiana, and Mississippi, which are dominated by primary interparticulate porosity, much of the porosity in the Smackover in southwestern Alabama is secondary in nature and does not correlate with primary depositional features. Smackover reservoirs in southwestern Alabama can be divided into 3 general classes: interparticulate-moldic reservoirs, dolomitic intercrystalline reservoirs, and vuggy reservoirs. Interparticulate-moldic reservoirs occur in a narrow band that parallels and lies 10-20 mi downdip of the updip limit of the Smackover. Porosity consists of small amounts of interparticulate and moderate amounts of oomoldic or pelmoldic porosity. Interparticulate-moldic reservoirs are characterized by moderate to high porosities (10-20%) but relatively low permeabilities (5-10 md) unless the lithology is dolomitized. Moldic porosity is also associated with large amounts of microporosity, which can significantly affect water saturation. Intercrystalline dolomite reservoirs are common along the updip limit of the Smackover and across several prominent paleohighs such as the Conecuh Ridge and the Wiggins arch. Reservoirs possessing only intercrystalline porosity have highly variable permeability but low porosity (6-8%) and are rarely productive unless fractured or leached to produce vuggy porosity. Vuggy reservoirs are common across paleohighs or along the updip margin. They are characterized by good porosity (10-20%) and permeability (10-100 md), but also possess large amounts of microporosity.

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Naturally Fractured Jambalaya—Analyzing a New Reservoir Type

The difficulty in analyzing naturally fractured reservoirs has in the past been severely hampered by the application of old technology to this jambalaya of geologic, structural, and petrophysical features. Making sense of fractured reservoirs now requires the application of new analytical techniques in combination with computer analysis of the data.

There are two keys to understanding fractured formations like the Monterey Shale, Austin Chalk, or Nugget Sandstone. These keys are the use of full diameter whole-core samples in the analysis process and computerized data acquisition and reduction programs to prepare the results for evaluation and interpretation. Only recently has the capability to analyze 5-in. diameter cores been developed. Determination of all petrophysical properties is no longer limited to plug samples 1 in. in diameter.

The result has been a dramatic increase in the amount of information obtainable on reservoir properties. Permeability can now be measured in up to six horizontal directions versus one from plug samples. The flow capacity of specific fracture morphologies, such as partially mineralized, incipient, and natural open fractures, has been measured at simulated in-situ reservoir conditions. Experimental evidence indicates fracture permeability reductions of greater than three orders of magnitude occur in some lithologies.

By allowing the computer to prepare the time-consuming pole plots, rose diagrams, K vs. ϕ crossplots, and geologic descriptions, the geologist is free to concentrate on analysis and interpretation of the prospect. This significantly improves their productivity and understanding of the reservoir and assists in identification of optimal locations for further drilling.

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Lagoa Feia Formation (Lower Cretaceous), Campos Basin, Offshore Brazil—Rift-Valley-Stage Lacustrine Carbonate Reservoirs

The Lagoa Feia Formation, buried in excess of 3,000 m, is the exploration frontier of the prolific Campos basin. It contains the source beds of all the basin's oil in addition to having its own potential carbonate reservoirs. The faulted margins of the basin fed a system of alluvial fans, sand flats, and mud flats. Alternating dry and rainy periods regulated the size and nature of contemporaneous basinal alkaline lakes. Dry periods corresponded to contracted playa lakes with ostracod carbonates and euxinic shales; rainy periods corresponded to expanded pluvial lakes with pelecypod banks. Subaqueous intrusions of basaltic magma generated hyaloclastites with kerolitic ooids and hyalotuffs.

Petrographic analysis reveals 5 diagenetic stages: (1) syndepositional alteration of lithoclasts to trioctahedral smectites; (2) early dolomitization, early silicification, and cementation by bladed-rim calcite and zeolites; (3) freshwater-vadose dissolution of bioclasts and lithoclasts, freshwater-phreatic sparite cementation, and neomorphism; (4) mixed saline-freshwater silicification; and (5) burial with compaction, late dolomitization, and partial conversion of smectites to illite.

Pelecypod limestones with primary interparticle, secondary intraparticle, moldic, and moldic-enlarged porosities are the potential reservoirs. Ideal conditions for porosity generation and preservation were subaerial exposure followed by rapid lake expansion and burial.

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Exploration Model for Unconformity-Related Hydrocarbon Accumulations in Cherokee Group of Western Kansas

The sandstones of the Desmoinesian Cherokee Group in western Kansas are important hydrocarbon producers. The Start oil field in Rush and Ness Counties is an example of an unconformity-related Cherokee accumulation from which an exploration model can be made. In this field, the upper Cherokee member is economically important and is interpreted to be a marine unit deposited on the distal portion of an alluvial plain. Traps and reservoirs in this unit were formed by winnowing of clay and silt-sized material from sediments deposited on the crests of paleohighs.

Four maps are useful in exploring for upper Cherokee hydrocarbon accumulations such as Start. An isopach map of the Cherokee Group is useful for locating thins that coincide with paleohighs on the basal Pennsylvanian unconformity. An isopach map from the Cherokee top down to the first sandstone porosity is useful. "Thins" of this interval define areas where wave and current action have winnowed finer material from sands. Closed anticlines on a Cherokee structure map are areas where Cherokee reservoirs are likely to be oil bearing rather than water bearing. An isopach map from the Cimarronian Stone Corral anhydrite top down to the Missourian Lansing Group top is also useful. "Thins" of this interval correspond to paleohighs on the basal Pennsylvanian unconformity. This interval can be picked from seismic records. Prospective areas occur where isopach thins of Stone Corral to Lansing, of Cherokee Group, and of Cherokee top to first sandstone porosity coincide with Cherokee anticlinal structure.

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Lunar Resources—Enabling Factor in Industrialization of Near-Earth Space

The industrialization of near-earth space has already begun during the last few space shuttle flights and will continue at an ever-accelerating pace as the first United States space station is built in the next 8 yr. However, the economic return from near-earth space industry is limited by the high cost per kilogram of launching into orbit the structural elements needed to build the space stations and the raw materials that are to be made into products in them. This limiting factor can be overcome if the moon is used as a source of the material needed to build the space structures and as the source of the raw materials needed in the processing. First, O, Si, Mg, Fe, Ca, Al, and Ti are the major constituents (> 1% by weight) in lunar rocks, and can be obtained directly from them by one of several proposed processes. Of these, O is needed as a rocket fuel, Si for making solar cells to generate space-station electricity, and light weight Mg, Al, and Ti to make structural elements for the space stations. Second, the rocket fuel per kilogram of payload needed to reach low earth orbit from the moon is 68% of that needed from the earth's surface, assuming that decelerating into earth orbit is achieved by a rocket maneuver. The amount of fuel is reduced to 15% if orbit is achieved by aero-braking. If the payload is launched from the moon by a "mass driver" and aero-braking is used, the cost in the rocket fuel needed to reach low earth orbit is reduced to nearly zero.

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Depositional Environment of Lower Cambrian Limestones, Nahant, Massachusetts

About 130 m (427 ft) of Lower Cambrian Weymouth Formation is exposed at Nahant, Massachusetts, 11 km (7 mi) northeast of Boston. Several beds of white to light-gray, fossiliferous limestone, up to 3 m (9.8 ft) thick, occur in a sequence of dark, very thinly bedded argillite. Portions of the argillite contain altered and chertified carbonate nodules. Limestone beds contain irregular, very thinly laminated chert layers with structures characteristic of silicified laminate stromatolites.

The limestone is comprised of 4 microfacies: (1) thinly bedded unfossiliferous micrite, (2) irregular intraclasts surrounded by sparry cement or biomicrite, (3) biomicrite (wackestone to packstone) containing small shelly fossils, primarily hyolithids, and (4) biosparite (hyolithid grainstone).

Conoidal hyoliths do not show a strong preferred current orientation on slabs and peels, but are often irregularly disposed with long axes at high angles to bedding. Biomicrites (packstones) and biosparites occasionally overlay irregular scour surfaces. Irregular bioclastic-rich pockets are surrounded by and grade into micrite or biomicrite.

A shallow subtidal, partially protected shelf of platformal environment best explains the textural and bedding characteristics of limestones. Storm events are recorded as bioclastic-rich and intraclastic sediments over scour surfaces. Irregular cyclic repetition of microfacies and lack of progressive shoaling or deepening during carbonate deposition suggest that limestones represent periods of stillstand at relatively low sea level positions. Carbonate deposition ceased when extrabasinal mud input increased, possibly during episodes of rapid sea level rise.

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Eocene and Upper Cretaceous Carbonate Reservoirs in East-Central Tunisia

Regionally, well-defined belts of lowest Eocene (Ypresian) Metlaoui carbonates trend northwest-southeast. On the northeast is an open-marine, basinal facies of planktonic foraminiferal micrite and marl. Thick bars of shallow marine nummulitic wackestone, packstone, and grainstone trend northeastward at an angle to the paleoshelf. Lagoonal or supratidal carbonates are widespread between the shelf deposits and thick evaporites that crop out in intermontane basins.

The reservoir is confined largely to nummulitic packstone, and visible effective porosity is best developed between forams in zones filled with sand-size debris where secondary solution-enlargement has occurred. Porosity within nummulite chambers, while abundant, is ineffective, although a few open fractures were observed in cores. This lithology tested oil in 2 recent wildcats and is a commercial reservoir at Sidi El Itayem and Ashtart fields.

Distribution of Zebbag carbonates of Late Cretaceous (Turonian) age is more complex. A northwest-southeast–trending platform is bounded on 3 sides by basinal shale and micrite with planktonic forams which grade into a transitional facies of micrite and wackestone that shows some evidence of shallow-water deposition, such as dolomitization, bioclasts, rare ooliths, etc. Predominately back-reef and lagoonal bioclastic wackestones and packstones occur in narrow belts, apparently controlled at least locally by block faulting. The rest of the platform lithology comprises mostly dolomite and dolomitic limestone.

The most significant porosity is interparticle (generally solution-enlarged) in foram packstones, but intraparticle porosity in forams and rudists commonly enhances the reservoir. Intercrystalline porosity in dolomitized zones is common, and fenestral porosity occurs in a few places. All are modified by nonfabric-selective channel and vuggy porosity and in some instances by fractures.

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Measurement of Contemporary Thermal Properties in Sedimentary Basins