significant place in both the exploration and production aspects o the petroleum industry.

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A Shorthand Notation for Carbonate Facies—Dunham Revisited

Carbonate facies can be described in a concise format that reads like an algebraic equation:

CARBONATE FACIES = (LITHIC DESCRIPTOR) (COMPOSITION) (TEXTURE) ± REMARK.

Lithic descriptors are portrayed by symbols for sedimentary structures, admixtures of argillaceous or arenaceous material, diagenetic features, and/or porosity. The second term, composition, generally used for describing the sand-size fraction of the rock, is represented by symbols designed to look like the grains themselves. Compositional symbols that appear in the equation should include only common rock-forming particle types, listed in order of decreasing abundance. The third term of the equation, texture, consists of a one-letter or two-letter abbreviation for the textural terms of Dunham or of Embray and Klovan. The fourth term of the descriptive equation is optional and allows a qualifying remark, using a minimum of appropriate symbols. Thus, a limestone that is cross-stratified and consists of 75% ooids and 25% carbonate cement is written as XOG.

Advantages of this shorthand system are (1) it is graphic and can be used to expedite routine sample logging and digital data recording; (2) it is useful in maps and cross sections to illustrate facies patterns in carbonate rocks, (3) it provides an international shorthand that transcends language barriers, and (4) it is both descriptive and genetic and has important implications for porosity prediction, and is thus an aid in the search for stratigraphic traps.

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Depth-Gradient Analysis and Biotic Succession in Colony Creek Cycle (Late Pennsylvanian) of North Texas

The Colony Creek Shale (Canyon Group) in north Texas contains a vertical succession of lithologies and biotas deposited during regression from deep water to shallow water and strandline deposition. Stratigraphic successions in the Colorado River valley and the Brazos River valley of the outcrop belt are similar, showing that regression was of regional extent. A thin layer of platy, phosphatic black shale containing an ammonoid fauna occurs at the base of the Colony Creek and is diagnostic of deep-water deposition. This unit is similar to deposits of maximum transgression (stillstand) of many Pennsylvanian cycles. The overlying shoaling-upward portions of the Colony Creek are characterized by upward increase in sand content, increasing numbers and thicknesses of sand beds, and culmination in a horizon of subaerial exposure.

Statistical analysis reveals a continuum of communities in the shales of the Colony Creek. These communities represent the continuing response of organisms to shoaling but are partly the result of an increase in sand content within the shales. The basal phosphatic black shale contains a community distinguished by its ammonoids. The overlying gray shales contain a diverse pleurotomariid community, which grades upward into a *Neospirifer*-productid community. In shoal-water deposits a distinct *Neospirifer*-myalinid community appears. The top of the sequence contains a molluscan community in sand substrates, which is characterized by *Permophorus.* The brachiopod *Crurithyris* is dominant in most shales in the succession and is not depth controlled. This succession of lithologies and biotas is typical of cyclothem deposits in other regions of North America and in Europe.

KNIGHTS, WILLIAM J., Circle Seven Oil & Gas, Inc., Fort Worth, TX

Subsurface Strawn and Atokan Series, Southwest Jack County, Texas

Lower Pennsylvanian sediments in the Fort Worth basin are prolific hydrocarbon producers. These sediments are deltaic in nature and are characterized by complex stratigraphy. The problem of locating new reserves and exploiting producing zones depends largely on subsurface mapping and a detailed knowledge of the stratigraphy.

The Atokan and Strawn progradational sediments in the study area consist of 13 separate depositional cycles, each of which isolated several reservoirs. Each of these groups of reservoirs has potential for structural and/or stratigraphic hydrocarbon traps. Mapping located prospects in the Strawn on noses in the Dog Bend Limestone, in Atokan conglomerates in structural lows associated with faulting in the Marble Falls, and in deeper horizons, such as Mississippian reefs and Ellenburger highs, and on structural highs in the Marble Falls.

MCKEE, BRYCE J., Baylor Univ., Waco, TX

Oolite Shoal Reservoirs in Pettet Formation (Lower Cretaceous), Southeast Shelby County, Texas

The Pettet Formation is a southward-thickening carbonate wedge, deposited during Aptian (Early Cretaceous) time in the region that is now the Gulf coastal plain of east Texas, Arkansas, and Louisiana. Within the Pettet are characteristic oolite sequences which formed in a northwest-southeast-striking belt paralleling the shelf edge.

In southeast Shelby County, Texas, the Pettet oolite shoals were studied, using available well cores and induction-electric logs. The oolite shoals appear to have formed on top of remnant topographic highs in the underlying Travis Peak Formation, in series of vertically stacked cycles of grainstone development.

The oolite shoals display five constituent lithofacies: (1) mudstone, (2) oolitic packstone, (3) skeletal-oolitic packstone, (4) skeletal-oolitic grainstone, and (5) oolitic grainstone. The oolitic grainstone lithofacies is the most volumetrically significant constituent of the Pettet oolite shoal reservoirs, comprising approximately 95% of each sequence.

Three diagenetic environments are seen in the oolite shoals: marine phreatic zone, vadose zone, and freshwater phreatic zone. Porosity is mainly primary interparticle, with some secondary intraparticle and vuggy porosity also being important. The freshwater phreatic diagenesis appears to have had the most effect on the Pettet reservoirs, creating minor recrystallization-induced porosity occlusion and excellent porosity-enhanced dissolution zones.

Hydrocarbon reserves in the Pettet Formation are related to certain structurally modified oolite shoals. Salt swelling and diapirism in the underlying Jurassic Louann Salt appear to be the mechanism responsible for the formation of locally developed anticlinal noses and domes. These small anticlinal features, when occurring beneath or adjacent to an oolite shoal, result in the upward tilting of the strata with subsequent migration and stratigraphic trapping of oil and gas.

SHANMUGAM, G., Mobil Research & Development Corp., Dallas, TX

Significance of Framework Dissolution in Interpreting Sandstone Provenance

Dissolution of unstable framework grains such as feldspar and rock fragments (including chert) is common in sandstones worldwide. Such framework dissolution usually results in a depletion of unstable framework grains and a corresponding enrichment of quartz. Failure to recognize this diagenetic modification of composition of a sandstone will result in misinterpretation of its provenance. A proper evaluation of sandstone composition may be achieved by including the dissolved portion of a framework grain as a grain, rather than as porosity, while point counting. This should be useful in interpreting original composition of sandstones and their provenance.

STAPLES, MARCUS E., Bass Enterprises Production Co., Fort Worth, TX

Exploration of Basal Bend Bar System, Southeast Foard County, Texas

The Bend conglomerates of north Texas are lithologically diverse Lower Pennsylvanian sandstones and conglomerates deposited by a variety of depositional systems. In southeast Foard County, the basal Bend conglomerates form oil-productive sandstone bodies morphologically identical to both ancient and modern coastal marine bars.

A basal Bend shale isopach map of southeast Foard County delineates the paleotopography of the eroded Mississippian surface over which the

Early Pennsylvanian sea transgressed. Its contours parallel paleostrike and ancient shoreline positions. Wells within a narrow 20-ft interval of this map penetrated a thin sand at the base of the basal Bend shale. These sandstones form elongate, lenticular bodies that parallel isopach contours and an ancient shoreline.

This critical isopach interval is interpreted as representing the depositional strike of a coastal marine bar system developed during a stillstand of the encroaching Early Pennsylvanian sea. These small, narrow bars are beyond the resolution of the sparse well control in the study area. Superimposition of known basal Bend bars on the basal Bend shale isopach, however, allows the projection of these narrow stratigraphic traps along an ancient shoreline into undrilled prospective areas.

SURLES, MILTON A., JR., Baylor Univ., Waco, TX

Stratigraphy of Eagle Ford Group (Upper Cretaceous) in East Texas Basin

The Eagle Ford Group of the Upper Cretaceous Gulfian Series is one of the most stratigraphically complex terrigenous units in the East Texas basin. At the type locality in Dallas County, Texas, the Eagle Ford consists of bluish-black, carbonaceous sediments exceeding 400 ft in thickness. In this area, the Eagle Ford includes the Tarrant, 15-20 ft of brownish-gray calcareous sandstone, the Britton, 250-300 ft of interbedded brown calcareous mudstone, and the Arcadia Park, 100-200 ft of dark gray calcareous mudstone.

Eastward into the basin, the Eagle Ford thickens to 500 ft as the upper Eagle Ford acquires 100 ft of Lake Crockett terrigenous clastics on top of the Arcadia Park. Westward out of the basin, the Eagle Ford thins by truncation and changes lithologic character; consequently the previously named subdivisions are no longer recognizable. Near Waco, the lower Eagle Ford consists of mostly montmorillonitic clays with disseminated calcium carbonate, called the Lake Waco Formation, and the upper Eagle Ford consists of dark gray, blocky shales, named the South Bosque Formation. The upper 30-50 ft of the South Bosque is completely noncalcareous. In the deepest portions of the basin near the Cretaceous continental margin, 150-200 ft of Eagle Ford and Woodbine are underlain by the Buda Limestone and overlain by the Austin Chalk.

TIPNIS, RAVINDRA S., Texas Southern Univ., Houston, TX

A Geochemical Strategy for Identifying Lower Paleozoic "Source" Units, Using Ellenburger Group of West Texas as a Case Study

Lower Paleozoic reservoir rocks generally have a predominantly carbonate lithology and are singularly lacking in organically rich dark shales. Attempts to trace the source for many such deposits have proven to be difficult because of the absence of routine techniques normally used in source rock evaluation. A good example is the occurrence of hydrocarbons in the Lower Ordovician carbonate strata of the Ellenburger Group. Very little information is available on the nature of the source rocks involved in generating the hydrocarbons found in the Ellenburger. One viewpoint remains untested, namely, that these hydrocarbons have been generated within the fine-grained carbonates of the lower Ellenburger rocks themselves and trapped in the upper porous portions of the formation. Several factors may be responsible for not accepting this hypothesis. Three of these are the following. (1) Do carbonates make good source rocks? Carbonates with algal or sapropelic matter make excellent source rocks; it also appears that the total organic carbon values of carbonates in ancient rocks could be as low as 0.2% for adequate generation. (2) With vitrinite absent, how can organic maturation in lower Paleozoic rocks be determined? Conodonts and acritarchs, as well as sapropelic organic matter, can be used to determine maturation with considerable accuracy. (3) Could hydrocarbons generate in rocks as old as the early Paleozoic and situated at great depths? Drilled data from several regions of the world support this viewpoint.

Recent field and theoretical considerations suggest that the source units for the majority of the lower Paleozoic hydrocarbon occurrences in carbonates, including those of the Ellenburger, are fine-grained carbonates, which are frequently in contact with the productive zones.

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Depositional Systems and Stratigraphic Relationships of Strawn Group (Pennsylvanian), Colorado River Valley, Central Texas

The Strawn Group (late Atokan-early Missourian) comprises a thick sequence of terrigenous clastic and carbonate facies that crop out in central Texas in two roughly triangular areas separated by Cretaceous overlap. The exposures in the Brazos River valley have been studied in detail and interpreted as fluvial, deltaic, and shallow marine deposits. The Strawn Group of the Colorado River valley has been cited in the literature, but little detailed work regarding subdivision or interpretation has been done.

The Strawn Group exposed in the Colorado River valley can be informally subdivided into two general stratigraphic units. The lower Strawn represents submarine fan and basin depositional systems that prograded southwestward. At least two but possibly several cycles of fan progradation are recognizable based on vertical succession of distal to more proximal middle-fan facies associations. In marked contrast, the upper Strawn represents three regressive and transgressive cycles of typical Pennsylvanian deltaic, perideltaic, and shallow submarine depositional systems.

Stratigraphic relationships of the Strawn Group are complex and reflect changes in the evolving Ouachita foldbelt and its associated tectonic features. The lower Strawn occurs only in the Fort Worth basin and apparently was deposited with a clinoformal relationship to the underlying basinal Smithwick Shale. It records foreland basin subsidence and regional block faulting synchronous with orogenesis. As active tectonic subsidence shifted westward, upper Strawn deltaic systems prograded to the west, onlapped the Concho platform, and truncated older units particularly on horst blocks. In the southeastern portion of the Concho platform, the overlying Canyon Group completely onlaps the Strawn Group and rests unconformably on the Marble Falls Limestone.

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Depositional Trends in Carbonate-Dominated and Clastic-Dominated Late Pennsylvanian Cycles in North Texas

Late Pennsylvanian cycles with thin, carbonate-dominated transgressive sequences and thick clastic-dominated regressive sequences have been considered the norm for cyclic sequences in north Texas, but they represent only a special case associated with higher rates of clastic sedimentation prevailing during falling sea levels. There are many cycles with carbonates in regressive as well as transgressive portions of cycles. Completely exposed cycles usually begin on an exposure surface and, between the exposure surface and the transgressive carbonate, have a thin clastic sequence showing upward change to normal marine conditions. Transgressive carbonates generally contain large amounts of clay muds and quartzose silts. The transgressive sequence culminates in a deeper water, dark-colored phosphatic shale. The regressive sequence is thicker, begins with a richly fossiliferous offshore marine shale, and continues upward into either limestone or sand-dominated sediments. Regressive limestones tend to be thicker and composed of more pure carbonate than transgressive ones, and to be capped with shoal calcarenites. These usually are overlain by nonmarine clastics, which may contain redbed layers, and a paleosol horizon at the top. In clastic-dominated regressive sequences, the offshore marine shales are overlain by an interval with upward-increasing sand content, and are capped by nonmarine deposits. Carbonate deposition in these cycles occurred only within a limited range of water depths. These cycles are similar to mid-continent cyclothems, and support the case for allogenic control and major fluctuations in sea level during cycle deposition.

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Depositional Environments and Facies Distribution of Millican Carbonate Buildup, Coke County, Texas

Millican field, located in northwest Coke County, Texas, is part of an extensive trend of Pennsylvanian carbonate buildups that exists on the flanks of the Midland basin, just seaward of the shelf edge. The Millican