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Types of Tight Gas Reservoirs, San Juan Basin, New Mexico and Colorado

The San Juan basin of New Mexico and Colorado is an asymmetrical basin formed during the Late Cretaceous and early Tertiary. The structurally deepest part of the basin is near the Colorado-New Mexico border. Presently, the only applications for the incentive price for gas produced from tight sandstones involve reservoirs of Cretaceous age. These reservoir rocks were deposited in open shelf to lower delta-plain environments associated with the Western Interior Cretaceous sea which transgressed and regressed the area in a general southwest-northeast direction. Coastal-barrier sandstones are significant gas producers and typically exhibit a strong marine influence. These sandstones are represented by long, linear northwest-southeast reservoir trends.

The tight gas applications for the San Juan basin, to date, concern reservoirs which can be placed into a spectrum with two end-member types. One type is characterized by continuation of mappable sand trends which extend from economic producing areas. Even though reservoirs of this type generally look similar to those in economic wells, they require production testing to determine their economic potential. This unpredictability is caused by the presence or absence of natural fractures. The other type of tight gas reservoir is related to the thinning of the good reservoir section or the increase in content of silt and clay-size material within the productive interval. This type of reservoir looks poor on well logs because of interbedding of siltstones and shales with thin, good reservoir sandstones and/or the presence of considerable silt and clay in the sandstones themselves.

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Cenozoic Diapiric Traps in Eastern China

Genetically, there are 2 types of Cenozoic diapiric traps in the oil fields in eastern China. One type is produced by "cold diapirism" owing to the rise of evaporites and soft mudstone. This type can be divided into 3 patterns. The first pattern is the faulted ridge with 1,000 m (3,300 ft) closure and flanks dipping up to 30°. A complex graben system is developed on the top. The amplitude of the core of the anticline is about 3,000 m (9,800 ft). The Xiangzheng structure in the Shengli oil field and the Wang-cung structure in the Qian-jiang depression are examples. The second pattern is the gentle anticline or dome with 50-300 m (160-985 ft) closure and 3°-10° dip on the flanks. The incompetent strata beneath it are about 1,000 m (3,300 ft) thick. The Tuocung-Shengli structure in the Shengli oil field is an example. The third pattern is a nose-like structure with less than 50 m (160 ft) closure. This pattern is usually located near the zero edge of incompetent strata. The Serniusi structure in the Dagang oil field is an example.

Another type of Cenozoic diapiric trap results from "hot diapirism" associated with the intrusion of gabbro or diabase. Such traps are typically small, round domes. The dip of the flanking strata generally increases with depth as the diapir is approached. A graben system is developed on top of the diapir. The distribution of these traps is related usually to regional fault zones and coincides with the distribution of the magmatism. The Matouzung structure in the Jinhu depression is one of the examples.

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Probability Distribution of United States Oil and Gas Discoveries for Various Levels of Exploratory Drilling Density

Comprehensive computer-supported analyses of the exploration histories of the main sedimentary provinces of the conterminous United States have led to the development of a large number of discovery functions by basins and depth zones. This paper extends the previously reported results by presenting frequency distributions of the amounts of hydrocarbon discoveries for successive increments of exploratory drilling density (ft/mi^3). The manner in which these distributions vary with depth is illustrated by considering successive depth zones across all the United States sedimentary provinces. The analysis further distinguishes between frequency distributions of the discovery of oil and of nonassociated gas. These frequency distributions can be interpreted as representing the probabilities of discovering different amounts of oil and/or gas at different future stages of exploration, i.e., at different exploratory drilling densities.

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Oil and Gas Production from Submarine Fans of Los Angeles Basin

The Los Angeles basin is a small but relatively deep Neogene basin located in the most northeast portion of the southern California continental borderland. It was formed along a transform margin during the early to middle Miocene, as were numerous basins within the continental borderland south of the Transverse Ranges.

A series of prograding submarine fans filled most of the basin during the middle to upper Miocene, Pliocene, and Pleistocene. The morphology of these fans appears to fit most basin-floor fan models but these models were greatly modified by paleobathymetry. The sediment transport mechanism was primarily turbidity flows from submarine canyons but other mass sediment transport such as debris flows, fluidized sediment flow, grain flow, etc was also significant.

Three primary, often coalescing, submarine fans have been recognized: the Tarzana fan in the northwestern Los Angeles basin, the San Gabriel fan in the central and southern parts, and the Santa Ana fan in the eastern part of the basin. Most of the oil produced in the Los Angeles basin comes from submarine fan sandstones. Much of the future oil to be found will be from the same fans or heretofore unrecognized submarine fans. Structural geologic concepts will be of equal importance when exploring for these subtle traps.

Total cumulative production to 1982 has been 7.3 billion bbl of oil and 5.8 tcf of gas. Per unit volume of sediment, the Los Angeles basin is one of the richest in the world. It was a silled basin within the oxygen-minimum oceanographic zone during the upper Miocene and Pliocene. A combination of rich biogenic sedimentation along with rapid burial by coarse to fine clastics and relatively high paleoheat flow provided almost perfect conditions for the generation and migration of oil and gas. Structural deformation was intermittent throughout the Neogene but was most intense and culminated in the late Pleistocene to Recent. The multistoried oil sands with different crude oil types suggest most of the oil is indigenous to the formation in which it is found.

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Controls of Shallow Gas Accumulations in Low-Permeability Reservoirs of Northern Great Plains

Significant resources (about 100 tcf in place) of natural gas are entrapped in low-permeability, low-pressure reservoirs at depths less than 3,000 ft (900 m) in Montana and the Dakotas. The gas occurs in fine-grained sequences of Late Cretaceous age deposited on a shallow, open-marine shelf. The low-permeability reservoirs were deposited during progradations and consist of discontinuous lenses and laminae of siltstone and sandstone enclosed by silty clay shale. The siltstone and sandstone layers are porous and permeable, whereas the enclosing shale is impermeable. The large proportion of allogenic clay, including highly expansive mixed-layer illite-smectite, causes extreme water sensitivity as well as high measured and calculated water saturation values in the reservoir sequence.

Gas production has been established in "sweet spots" on structural highs where the reservoirs are best developed. Recurrent tectonic movement resulted in winnowing of coarser grain sizes on the highs by southward-flowing, geostrophic currents. In the future, exploration will occur off structure for lower quality reservoirs.

The gas was generated in the marine environment by decomposition of organic matter by anaerobic microorganisms and is referred to as biogenic gas. The most important mechanism of methane generation in marine sediments is reduction of CO_2. Organic carbon values, rates of sedimentation, and products of early diagenesis indicate that biogenic gas production was widespread during deposition. Most of the gas was initially retained in solution in the pore waters because of higher methane solubility at higher hydrostatic pressures owing to the weight of the overlying water column; the gas subsequently exsolved because of uplift and erosion during the Tertiary.

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Ferruginization and Phosphatization of Foraminifera in Pleistocene/Holocene Sands on Mid-Atlantic Continental Shelf

Pleistocene/Holocene sands up to several meters thick, which contain 5% to 40% phosphate grains, occur on the continental shelf of Onslow Bay, North Carolina. Altered foraminiferal specimens, 98% of which belong to the genus *Quinqueloculina,* exhibit gradational surface discoloration (white to dark yellow-brown) that progresses from late to early-formed chambers. The percentage of extensively altered specimens varies directly with phosphate concentration in the sand fraction. Microprobe analyses of polished sections from completely discolored specimens indicate that alteration involves a decrease in %CaO and concomitant enrichment in %FeO and %P_2O_5. Degree of alteration diminishes from the outside to the inside of exterior-facing chamber walls (mean values are: 70 to 78 to 82% CaO; 18 to 11 to 7% FeO; 0.8 to 0.5 to 0.4% P_2O_5). Interior chamber walls are less altered (mean values are: 84% CaO, 6% FeO, 0.3% P_2O_5). On a CaO-FeO-P_2O_5 diagram the compositional changes through successive chambers of a single specimen parallel those from unaltered through altered specimens. The chemical compositions of completely discolored specimens fall on a proposed alteration trend between unaltered calcareous specimens and chamber fillings. Chamber fillings contain 0.9% CaO, 49% FeO, 12% MgO, and 1.6% P_2O_5; they are generally black. Relative concentrations of CaO-FeO-MgO plot within the compositional range of siderite and magnesite. Constant MgO values (7.5%) in altered foraminiferal tests demonstrate that initial diagenesis involves conversion to high-magnesium calcite. Subsequent alteration is largely ferruginization and minor phophatization of the test and the diagenetic materials forming within the chambers.

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Coal Beds—Source Rock and Reservoir

Coal beds are known to exist in parts of almost all major sedimentary basins in the conterminous United States from outcrop to depths in excess of 15,000 ft (4,570 m). Coal-bearing strata often exist interbedded with tight gas reservoirs, making it very difficult to differentiate the tight gas resource from the methane-from-coal beds resource. Studies of the methane-from-coal beds resource have determined that it may exceed 400 tcf. Measurements of methane in coal beds have shown that much gas generated during coalification is not currently present in the coal beds and may have escaped into stratigraphically contiguous formation which are now tight gas reservoirs.

Bituminous coals have been analyzed that contain more than 600 ft^3 of methane per ton of coal, or approximately 1 mmcf of gas per acre-foot of coal. More than 5,000 ft^3 is generated during the thermochemical alteration of peat to the low volatile bituminous-semi-anthracite boundary. Only a fifth to a third of that gas appears to be retained in the coal. The excess gas may be a source for other reservoirs.

Analysis of coal samples collected throughout the United States shows gas contents ranging from less than 25 ft^3/ton for subbituminous coals in the Powder River and San Juan basins to more than 500 ft^3/ton for coals in parts of the Green River, Raton, San Juan, and Appalachian basins. In the Powder River basin, where the coal resource is very large, even the low gas content coals have potential as producing gas reservoirs.

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Provenance and Depositional Environments of Middle Eocene Canoe Formation, Big Bend National Park, Brewster County, Texas

The middle Eocene Canoe Formation contains the first sedimentologic evidence of local volcanism in the Big Bend region. Sediments comprising the formation's lower member, the Big Yellow Sandstone, were deposited by sandy braided streams which were scoured by ancient carbonate highlands and volcanic terranes to the west. The unit represents a continuation of the depositional styles and compositional trends recorded in the Paleocene and early Eocene strata of the region. In contrast, sediments comprising the upper, unnamed member of the Canoe Formation were deposited as a volcanic sediment apron on the fringes of the newly forming Chisos Mountains volcanic center. The sandstones (feldspathic litharenites and lithic arkoses) are dominated by volcanic rock fragments and, as such, document an abrupt change in depositional style and sediment composition brought about by the onset of local volcanism.

A comparison of Canoe Formation and earlier Tertiary sediment compositions results in the delineation of distinct petrologic trends which record the tectonic evolution of the early Tertiary sediment source area. The Paleocene sediments of the area were derived primarily from ancient magmatic arcs in northeastern Mexico. With the onset of the Laramide orogeny in late Paleocene-early Eocene, a new source of sediment—newly uplifted carbonate highlands—was added. Local volcanism in the middle Eocene produced yet another source of sediment, lava flows, ash flow tuffs, and sand-size pyroclastic materials from the Chisos Mountain volcanic center. Rapid erosion of these materials produced volcanic sediment aprons such as the one described here. As regional volcanic activity increased, typical Paleocene and early Eocene depositional styles may have been completely abandoned, especially in areas proximal to the volcanic centers.

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Size Distributions of World's Largest Known Oil and Tar Accumulations

Gross volumes of oil, which must be kept in mind by resource estimators to address the volume/size framework, may be thought of in order from largest to probably smallest volumes as follows: (1) generated; (2) dissipated; (3) degraded, partially preserved; and (4) trapped and conventionally producible. Basic knowledge of these volumes may be from greatest to least in essentially reverse order.

The 332 largest known accumulations (less than 1% of the total number) account for more than three quarters of the known 8.2 trillion bbl of oil and heavy oil or tar in more than 35,000 accumulations in the world. About 2.6 trillion bbl of estimated undiscovered conventional oil added to the known volume of 8.2 trillion bbl yields a total of 10.8 trillion bbl known or reasonably estimated. Worldwide cumulative production of about 461 billion bbl of oil accounts for only 4% of the gross.

Oil in place must be estimated for conventional oil fields before comparison with heavy oil and tar accumulations. The size range of accumulations considered in the size distribution of the 332 largest known accumulations is from 0.8 to 1,850 billion bbl of oil. The smallest conventional fields in the distribution are about 1 billion bbl because the size cut-off is 0.5 billion bbl of oil recoverable. The size distribution of the 332 largest known accumulations approaches log normal and is overwhelmed by the largest 3 supergiant tar deposits which hold nearly half of the total 6,267 billion bbl.

Globally, the largest 3 accumulations, all heavy oil or tar, are in South and North America; the 2 largest conventional oil fields are in the Middle East. Prudhoe Bay and east Texas fields rank 25th and 35th respectively in descending size order.

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Sedimentology of Mudflow Deposits in Mississippi River Delta-Front Environment

Shelf deposits of the active Balize Lobe of the Mississippi River delta, are constantly displaced from their original depositional environments by a variety of deformational and mass-movement processes. Consequently, hydraulically controlled sedimentation patterns are altered in favor of sediment displacement to deeper water settings. High-resolution seismic and side-scan sonar surveys have shown that complex mudflow systems are the most important means of sediment transport from the upper and intermediate delta front to deeper shelf and upper-slope environments. With expanding exploration and production of hydrocarbons from shelf depths and deeper, it has become important to identify and understand both the surficial and subsurface characteristics of sediments associated with sea floor instabilities.

The sedimentology of mudflow deposits has been determined from