Association Round Table

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Abstracts

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Plate Tectonics, Organic Matter, and Basin Evaluation for Petroleum Potential

Application of plate-tectonic concepts to sedimentary basin development has been important in petroleum geology. Physical aspects have been stressed, but a complete classification must include the amount, type, and distribution of organic matter because this is the material that generates petroleum. Organic matter can be classified into two broad categories: (1) land-derived ("terrestrial") organic matter that may include major amounts of lignin and surface coatings which give gas or waxy crudes respectively, and (2) aquatic organic matter which commonly is dominantly of algal origin and generates normal crudes. The relative amounts of these two types of organic matter, and hence the relative amounts of oil and gas, depend on the depositional environment and this can be related to plate-tectonic setting.

Rifts that form in the early stages of continental breakup receive high percentages of terrestrially derived organic matter initially, but aquatic organic matter becomes quantitatively more significant as the rift widens and marine conditions develop. Thus pull-apart continental margins develop a vertical profile from terrestrial organic matter deep to aquatic organic matter shallow. The deeper continentally derived sedimentary sections of these margins produce waxy crudes, gas, and some condensate reflecting the character of the organic matter. Pull-apart margins and rifts with waxy crudes were within 20° of the equator at the time of rifting. They include the Sirte, Cambay, Reconcavo, Gabon, and Cuanza basins. When rifting occurred farther from the equator, gas-dominated provinces were developed, such as northwest Australia, offshore Newfoundland, Baltimore Canyon, and the central Viking graben.

Rivers transport continental sediments and organic matter to continental margins, and the association of transported terrestrial organic matter with clastic sediments makes deltas one of the most gas-prone depositional environments. Organic materials are not distributed uniformly in deltas because terrestrial organic matter has its highest concentration nearshore whereas aquatic material is also produced in large amounts offshore. This separation and distribution lead to gas fields near paleoshorelines and oil farther out. As the delta progrades, terrestrial organic matter is deposited over the previously deposited aquatic organic matter. This profile of organic matter type is exactly the opposite of that developed on passive continental margins and leads to the opposite trend for the distribution of oil and gas with depth.

Although organic-matter type exercises initial control over the nature of the hydrocarbons generated, the composition may be changed later by maturation and migration. Maturation is the thermally induced trend from oil to gas and the depth for this conversion will depend on geothermal gradient. Migration distance is also controlled by plate-tectonic setting with distances in excess of 100 km being well documented for structurally simple interior basins. In contrast, migration distances are much shorter when migration pathways are interrupted, for example, by block faulting in rifts and growth faults in deltas.

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Applying Modern Geologic Methods to Petroleum Exploration and Development—Case Study of Jurassic Reservoirs in East Texas, North Louisiana, and South Arkansas

The stratigraphic and structural framework of the Cotton Valley and Smackover can be divided into distinct producing trends. Each trend has predictable producing characteristics and geographic limits.

The Cotton Valley producing trends lie in four different areas: (1) a semicircular belt of lower Cotton Valley limestone reservoirs along the west flank of the Sabine uplift covering parts of Rusk, Shelby, Smith, Upshur, and Cass Counties, Texas; (2) a northeast-trending belt of lower Cotton Valley limestone reservoirs on the west flank of the East Texas basin covering parts of Henderson, Navarro, Freestone, Limestone, and Robertson Counties, Texas; (3) an arcuate belt of "blanket" strandline sandstones in north Louisiana centering in Lincoln Parish; and (4) a broad circular area covering most of the Sabine uplift where very fine-grained upper Cotton Valley sandstones produce from a 1,400-ft (427 m) stratigraphic interval. Minor Cotton Valley sandstone production is developing on the west flank of the East Texas basin from low-permeability Bossier sandstones. Cotton Valley reservoirs are generally low-permeability (less than 1 md) and require fracing for commercial flow rates. Higher gas prices and improved fracing techniques have caused a high level of exploration for Cotton Valley reservoirs.

Smackover producing areas are in six different trends: (1) updip fault traps along the Mexia-Talco fault system; (2) salt anticlines along the flank of the salt basins; (3) basement structures updip from the salt anticline and fault system; (4) stratigraphic traps near the Arkansas-Louisiana state line downdip from the salt anticlines; (5) complex graben-fault traps associated with more intense salt features deeper within the basin; and (6) updip from the Mexia-Talco fault trend, a possible new trend opened in western Henderson County, Texas, by a recent highly significant discovery of McFarlane Oil Co.

The five producers (and no dry holes) drilled to date in the new trend show only very slight structural turnover at the Smackover level in an area of regional east dip into the basin with the possibility of minor (under 100 ft or 30 m) fault interruptions. Current interpretation is that the trap is due to a combination of slight structural closure and updip porosity pinch-out. Updip oil migration may have occurred through "breaks" in the Mexia-Talco fault system with oil entrapment in numerous updip small fault closures and possible porosity pinch-outs. Well control is inadequate for further definition of this trend. Flow rates over 1,000 BOPD have been reported in several of McFarlane's wells. Producing characteristics appear to be excellent with 48° gravity oil and under 1,100:1 GOR. Hydrogen sulfide is reported at 2% or under. In view of its possibly large area and shallow depth (9,000 ft or 2,743 m)—and a price of $40/bbl—this field could prove to be the most significant oil field discovered in east Texas in 20 years.

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Potential of Evaporitic Environment as Source of Petroleum

Examination of modern saline lakes, solar evaporation ponds, and lagoons shows that the evaporitic environment can be very productive of organic matter. Few species survive in the brines, but those that do commonly are in great profusion. In a marine evaporitic embayment, the flow of surface currents is persistently toward regions of highest salinity, so that there is a continual supply and concentration of nutrients. Prolific growth of phytoplankton may be similar to that in areas of upwelling in modern oceans. Only carbonates precipitate in the "mesosaline" part (4 to 12% salinity) of such an evaporitic environment and no great dilution of organic matter by clastic or biogenic sediments occurs. Because stratification of brine may occur and reducing conditions may be associated with the bottom waters, much of the organic matter produced can be preserved. Upon maturation, the result may be a rich carbonate source rock, frequently unrecognized in the geologic column. In the Middle East, mesosaline conditions have occurred many times from the Triassic to the Cretaceous and may be responsible for the vast reserves of petroleum in the area. Evaporitic conditions may also have played a part in the petroleum productivity of many other areas, including the Michigan and Paradox basins.

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Clastic Depositional Models

Depositional models of clastic rock sequences provide a valuable insight into many exploration and production problems in the energy business. The size, shape, lateral relations, and physical properties of sedimentary bodies have obvious and well-recognized relevance to searching for and developing petroleum, coal, and some ores. Acknowledgement of the value of depositional models by industry stimulated incisive research beginning more than 30 years ago and has sustained a very active and growing interest throughout the scientific community. As a result, today we face the blessing and the perlexity of a large and rapidly expanding fund of data.

No person can now really cope with assimilating the literature, past and present, on clastic depositional models, especially a person busy searching for mineral resources. My goal is to review some of the important advances that have happened, may be happening now, or should be promoted. These views are certainly personal and biased. As examples of my opinion, marine shelf and slope models are very poorly understood; knowledge of modern processes, Holocene deposits, and ancient examples has not led to unifying principles that can bolster exploration predictions in these general depositional environments. At the other end of the information spectrum, stream deposits are well known from many studies of modern and ancient examples and considerable experimental data. Yet embarrassing gaps in understanding remain because of accidents of geography, climate, or scale. Clastic depositional models from outcrop and subsurface provide case histories of fluvial, marine-shelf, and basin-slope environments that illustrate the state of the art and applications to practical oil exploration problems.

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Sedimentology and Petrology of Tar Sands

The two largest tar sand provinces of the world are those of the Orinoco petroleum belt in Venezuela (estimated in-place reserves of 1,000 to 2,000 × 10^9 bbl) and the Mannville Group oil sand deposits of Alberta (1,350 × 10^9 bbl estimated in-place reserves). Possible additions to these ranks are the Russian deposits of the Melekess depression and the Olenek area (reserve figures very erratic), and the bitumen-bearing Paleozoic rocks of the Carbonate Triangle in Alberta (reserves tentatively estimated to be more than 1,000 × 10^9 bbl). Other significant accumulations including those in the United States (principally Utah and California), Madagascar, Albania, Romania, the Caribbean, and the Canadian Arctic are all markedly smaller (reserves two or more orders of magnitude less).

Elements common to most of the major accumulations include: stable tectonic settings, usually in large foreland basins; thermally immature and only moderately compacted reservoir sediments, commonly uncemented, with very high porosities and permeabilities; far-reaching hydrocarbon migration networks with access to organic-rich source beds; near-surface settings, within the realm of pervasive oil degradation by water washing and bacterial action; and complicated, often enigmatic trapping configurations, involving both stratigraphic and structural factors, with bitumen plugs perhaps serving locally as updip seals. The deposits in which the reservoirs are dominantly hydrophyllic (water wet), including those of both Venezuela and Alberta, are the most amenable to exploitation in that they can be processed by the inexpensive and relatively efficient hot-water extraction method.

Athabasca is the largest of Alberta's oil sand deposits. It encompasses a total area of 32,000 sq km and is estimated to contain 870 billion bbl of oil in place. The Lower Cretaceous McMurray Formation reservoir is 35 to 70 m thick of uncemented, very fine to fine-grained, moderately sorted quartz sand and associated shale. The most important control on the grade of the oil sands is the distribution of primary porosity and permeability in the McMurray Formation sediments. Achieving a cogent understanding of the facies patterns thus leads directly to a predictive capability regarding the geometry and character of the oil-bearing zones.

Initial infilling of the McMurray depression appears to have developed in a wide variety of fluvial-deltaic environments, many of which are not yet fully understood. Subsequently, there developed a regime marked by the presence of deep channels, trending north and northwest, which locally incised the preexisting sedimentary sequences and deposited a characteristic, fining-upward cycle in many areas, particularly in the northern half of the deposit: trough cross-bedded channel-bottom sands at the base; giving way upward to solitary sets of epsilon cross-strata deposited on the sloping