a water block similar to that described by J. A. Masters in the Deep Basin of Canada and the San Juan basin of New Mexico and Colorado. Recent work suggests that the formation of the water block in the Greater Green River basin is related to a dewatering process associated with the thermal generation of gas.

Data from reference wells indicate that in the deeper parts of the basin, the relatively closed nature of this system imposes severe restrictions on the ability of gas to migrate appreciable distances from the interbedded source rocks. Consequently, the temporal relationships of hydrocarbon generation and migration with respect to the development of structural and stratigraphic traps are not as important in these unconventional reservoirs as in more conventional ones. The more important factors related to gas generation and occurrence are source-rock quantity and quality, organic maturation, thermal history, formation pressure, porosity and permeability variations, and the nature of formation-water occurrence.

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Evolution of Fluvial Style—Lower Devonian Battery Point Formation, Gaspé Peninsula, Quebec, Canada

The Battery Point Formation (Emsian) forms part of a broadly upward-coarsening alluvial suite. The formation is 2,300 m (7,550 ft) thick, rests unconformably on shallow marine sandstones of the York River Formation, and is transitional upwards into a proximal braid-plain sequence of the Malbaie Formation.

A lower, 110 m (360 ft) thick, sequence from the Battery Point was previously interpreted as braided-fluvial based mainly on the recognition of laterally migrating, shallow transverse bar deposits and on a paucity of vertically accreted fine-grained sediment.

Between Cap-aux-Os and Penouille, Gaspé Peninsula, these braided-fluvial facies are succeeded by quite different fluvial deposits mainly comprising 30–40 m (100–130 ft) multistory channel sandstone complexes, often thinning laterally to 15–18 m (50–60 ft), and separated by 6–10 m (20–33 ft) of laterally persistent mudrock sequences. The latter can be traced laterally up to 6.5 km (4 mi), allowing the geometry of the sandstones to be evaluated in great detail.

Within the sandstones, medium-scale trough cross-bedding is dominant, with subordinate, isolated (0.8–3 m or 32 in.–10 ft thick) planar-tabular sets and parallel laminated units. Mudclast-lined erosion surfaces commonly define individual channel-fill events.

The scarcity of cut-bank phenomena, and lack of lateral accretion surfaces suggest laterally unstable channels of fairly low sinuosity within large (possibly up to 15 km or 9 mi wide) stable channel belts. These were rapidly abandoned, accumulating the mud-rock sequences, which are exceptionally up to 50 m (165 ft) thick. The paucity of desiccation features and lack of mature calcretes, together with abundant plant activity and much wave rippling, suggest that large areas of standing water existed on the flood plain.

Extrinsic controls, such as climatic change, are proposed for this evolution in fluvial style.

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Uranium Occurrence in Major Rock Types by Fission-Track Mapping

Microscopic occurrence of uranium has been determined in about 50 igneous rocks from various locations, and in a genetically unrelated sandstone from south Texas.

Precambrian granites from the Llano uplift of central Texas contain from a few ppm uranium (considered normal) to over 100 ppm on a whole-rock basis. In granite, uranium is concentrated in: (1) accessory minerals including zircon, biotite, allanite, Fe-Ti oxides, and altered sphene, (2) along grain boundaries and in microfractures by precipitation from deuteric fluids, and (3) as point sources (small inclusions) in quartz and feldspars.

Tertiary volcanic rocks from the Davis Mountains of west Texas include diverse rock types from basalt to rhyolite. Average uranium contents increase from 1 ppm in basalts to 7 ppm in rhyolites. Concentration occurs: (1) in iron-titanium-oxides, zircon, and rutile, (2) in the fine-grained groundmass as uniform and point-source concentrations, and (3) as late uranium in cavities associated with banded, silica-rich material.

Uranium in ore-grade sandstone is concentrated to more than 3%. Specific occurrences include (1) leucoxene and/or anatase, (2) opaline and calcite cements, (3) mud clasts and altered volcanic rock fragments, and (4) in a few samples, as silt-size uranium- and molybdenum-rich spheres. Uranium content is quite low in pyrite, marcasite, and zeolites.

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Mid-Continent Rift System—A Frontier Hydrocarbon Province

The Mid-Continent rift system can be traced by the Mid-Continent geophysical anomaly (MGA) from the surface exposure of the Keweenawan Supergroup in the Lake Superior basin southwest in the subsurface through Wisconsin, Minnesota, Iowa, Nebraska, and Kansas. Outcrop and well penetrations of the late rift Keweenawan sedimentary rocks reveal sediments reflecting a characteristic early continental rift clastic sequence, including alluvial fans, deep organic-rich basins, and prograding fluvial plains.

Sedimentary basins where these early rift sediments are preserved can be located by upward continuation of the aeromagnetic profiles across the rift trend and by gravity models. Studies of analog continental rifts and aulacogens show that these gravity models should incorporate (1) a deep mafic "rift pillow" body to create the narrow gravity high of the MGA, and (2) anomalously thick crust to account for the more regional gravity low. Preserved accumulations of rift clastics in central rift positions can then be modeled to explain the small scale "notches" which are found within the narrow gravity high.

Indigenous oil in Keweenawan sediments in the outcrop area and coaly partings in the subsurface penetrations of the Keweenawan clastics support the analogy between these rift sediments and the exceptionally organic-rich sediments of the East African rift. COCORP data across the rift trend in Kansas show layered deep reflectors and large structures. There is demonstrable source, reservoir, and trap potential within the Keweenawan trend, making the Mid-Continent rift system a frontier hydrocarbon province.

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Estimation of Oil Potential of Beaverhill Lake Group, Alberta

The Devonian Beaverhill Lake reefs in the subsurface of central Alberta are among the most prolific oil-producing reservoirs in Canada. More than 1,600 exploratory wells have penetrated into the Beaverhill Lake beds in the area. Nineteen oil pools have been discovered, and make up a reserve of 848×10^6 m^3 (5.3×10^9 bbl) of oil in place. Subsurface studies reveal that episodic growth of reef occurred on the Swan Hills platform. The questions for petroleum resource evaluation are: (1) how many undiscovered pools may exist, and (2) what are their possible sizes?

This talk will use the Beaverhill Lake data to discuss the following questions. (1) What is the role of play definition in resource evaluation? (2) What types of geological data or information are required to construct a pool-size distribution scheme? (3) What geological information can and cannot be inferred from pool-size distribution data? (4) What types of procedures are available for determining the number of pools? (5) How can pool sizes by rank be estimated? (6) What types of uncertainty can be handled and reduced by the present method? Finally, the number of possible undiscovered pools and their sizes in the Beaverhill Lake Group also will be addressed.

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Deep Wilcox Structure and Stratigraphy in Fandango Field Area, Zapata County, Texas

The Fandango field in Zapata County, Texas, is a new deep Wilcox trend extension. The deep Wilcox sands are commonly found at depths of 15,000–20,000 ft (4,500–6,100 m). Enough well log and seismic control exists to make an accurate integrated interpretation of regional deep Wilcox structure and stratigraphy.

Deep Wilcox structure and stratigraphy are controlled by regionally extensive shale anticlines. These shale uplifts control deep Wilcox sand distribution, create large anticlines, and cause regional growth faults which frequently influence local structure. Each regional uplift presents a new exploration frontier holding the promise of vast reserves in the deep Wilcox.

The history of Frio-Vicksburg exploration is analogous to the deep Wilcox trend of today. It took 40 years to expand Frio exploration from shallow stratigraphic traps down into the enormous reserves in the Gulf of Mexico, because each new fault block extension was considered to mark the downdip limit of Frio production. This assumption was not true, and is not true in the deep Wilcox today. The deep Wilcox trend remains virtually unexplored, and it is my belief that continued work will prove the existence of much more deep Wilcox potential than is currently thought to exist.

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Are Our Oil and Gas Resource Assessments Realistic?

This paper reviews the results of assessments made in the past of United States oil and gas resources, including bidding in OCS lease sales (which are considered to reflect industry estimates of resources). It concludes that most estimates tend to be overly optimistic and suggests that the problem may be partially in the assessment of risk and partially in errors in the assumed resource distribution. It recommends that more use be made of the historical record in making these assessments.

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Electron Microscopy and Microanalysis of Uranium Phases in Primary Ores, Eocene and Miocene of South Texas

Two contrasting types of roll-front uranium deposits occur in south Texas. In the barrier-bar sands of the Eocene Jackson Group, organic matter was essential to uranium reduction, whereas in the fluvial sands of the Miocene Oakville Formation, epigenetic pyrite was the reductant.

In a sample of reduced Oakville ore, a uranium phase with grains ranging in diameter from < 1 to $20 \mu m$ was recognized by SEM backscattered-electron imaging and wavelength-dispersive spectrometer (WDS) elemental-dot mapping. Quantitative microprobe analyses indicated that the phase is a uranium-calcium silicate-phosphate with molar Ca/P approximately equal to 1.0, U/P equal to 2.8 ± 0.4 ($n = 27$), and U/Si approaching 1.0 in samples uncontaminated with quartz, feldspar, or clay minerals. Highest uranium content is 59%. Oakville ore is typically easy to leach by in-situ methods.

Jackson ore contains 2 uranium phases. Sulfur-rich organic matter contains $4.1 \pm 1.6\%$ uranium ($n = 27$). Although individual grains of a possible uranium mineral within the organic matter are too small to be resolved by electron imaging, a consistent molar U/Fe (0.5 ± 0.1) suggests a uranium-iron oxide phase. Alternatively, uranium is adsorbed by or otherwise bound to the organic matter. The second phase is a uranium-calcium silicate-phosphate that differs from the Oakville ore. Molar Ca/P equals 0.8 ± 0.2 ($n = 13$), and U/P equals 4.7 ± 0.4. Small grain size (generally less than $1 \mu m$) prevented analysis of samples uncontaminated with quartz and pyrite. The grain with highest uranium content (43%) has U/Si equal to 0.34. Jackson ore is less favorable for in-situ leaching than Oakville ore in part because the organic-associated uranium is difficult to extract.

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Sedimentary Sequence of Offshore Southeastern United States: Preliminary Study Based on Exploration Wells

In 1982, geologic data from the exploratory wells in the offshore southeastern United States were released to the public. Prior to this time, well data were limited to the COST (Continental Offshore Stratigraphic Test) GE-1 well, the first deep-penetration well, which was completed in 1977. Six additional exploration wells were completed thereafter. Although these wells were dry holes, information provided by them has contributed to the geologic interpretation of the Atlantic margin.

The oldest rocks penetrated by these wells are Paleozoic indurated shale and argillite, sandstone and weakly metamorphosed quartzite, and igneous rocks. The post-Paleozoic section ranges from 2,220 to 3,660 m (7,280 to 12,000 ft) thick at the well sites, but seismic data indicate that the equivalent section thickens to 10–12 km (6–7 mi) beneath the Blake plateau. The Lower Cretaceous through Cenozoic section represents a progression from nonmarine and marginal marine to marine sedimentation. Three main units are recognized: lower siliciclastic, middle calcareous mudstone, and upper limestone. The siliciclastic unit consists of interbedded gray to red-brown sandstone, siltstone, and shale with some conglomerate, coal, evaporites, and carbonate rocks. Based on petrographic examination, the sandstone compositions vary between arkose, litharenite, and quartz arenite.

Calcareous clay and shale (grading to shaly limestone) overlie the siliciclastic rocks. The upper limestone contains chert, oolites, and shell fragments and ranges in composition from micrite to sparite. By comparing these units to the onshore Georgia sedimentary section, regional lithofacies trends that can be useful for future exploration are recognized.

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Diagenetic Capping of Carbonate Reservoir Facies

Submarine cementation commonly forms a narrow zone of low permeability within a carbonate unit that may act as a diagenetic seal over potential reservoir facies. Although the process of submarine cementation still is not clearly understood, it does appear to be a near-surface, rock or sediment/water interface phenomenon. The diagenetic model proposed here involves the effect of submarine cementation on previously lithified carbonates, such as submerged relict shelf-margin buildups (e.g., drowned reefs, ooid shoals) or previously subaerially exposed formations (e.g., dune ridges) that were submerged by later sea level rise. These deposits generally have pronounced topographic relief (visible on seismic), good reservoir geometries, and high internal porosity of either primary or secondary origin.

Petrologic studies on examples of both of these situations—a submerged early Holocene barrier reef off Florida and a 175-km (110-m) long submerged Pleistocene eolian ridge in the Bahamas—show that their exposed surface and uppermost facies (0-1 m, or 0.3 ft, below top) are further infilled and cemented, creating an extensively lithified, low porosity/low permeability zone or "diagenetic cap rock." Quantitative mineralogic studies of occluding cements reveal an exponential reduction in porosity while moving upward into the seal zone. Submarine cements effectively infill and form a surficial permeability barrier that acts to impede further diagenesis and porosity reduction within underlying potential reservoir facies.

To form this diagenetic seal only requires that the original carbonate buildup be resubmerged for some brief period of time prior to subsequent burial by sediments. If buildup accumulation later resumes without intermediate sediment burial—a common stratigraphic situation—the diagenetic seal would represent a disconformity separating two similar facies.

The early formation of a diagenetic cap rock lends support to models of early hydrocarbon migration and emplacement. Prediction and recognition of submarine diagenetic seals will aid in exploration and development of obvious buildup reservoirs as well as subtle intraformational traps.

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Contrasts Between Ordovician and Mississippian Carbonate Depositional Styles in Williston Basin

Upon superficial comparison, the Madison Group (Mississippian) and the Bighorn Group (Ordovician) in the Williston basin appear to be similar sequences of carbonate mudstones and wackestones capped by evaporite-carbonate alternations. Detailed studies demonstrate significantly different depositional styles.

The Madison Group is an example of a deep-water sediment-starved basin that was filled in by turbidites derived from a ringing carbonate shelf. As the basin filled, the Madison was capped by a basinward pro-