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Replacement Costs of Domestic Crude Oil

In the long run, selling prices will equate with replacement costs if companies are to remain in business. Thus, the study of replacement costs provides a powerful analytic tool for further understanding of the uncertainties in future oil prices and domestic crude oil productive capability.

The analysis provides insights about the time at which supplemental sources of fuel from synthetic or alternative sources may become economic, and provides one means for quantifying the costs and benefits of these alternative decisions.

Most important, the engineering and geologic methodology used in the replacement cost analysis provides the essential and long sought-for "bridge" between the domestic resource base and economically producible supplies.

Much of the uncertainty in future prices and productive capacity for conventional oil stems from international decisions. Use of the replacement cost methodology will help to more clearly understand the effect of other uncertainties, such as: (1) the size of the conventional oil resource base; (2) the level of domestic oil production capacity the industry and nation may wish to maintain; (3) the timing and technical success in enhanced oil recovery; and (4) the constraints that may impede the development of energy in frontier areas.

This analysis discusses these uncertainties and quantifies their impact on domestic energy replacement costs and sustainable levels of oil supply. The major findings of the analysis are:

A. The source of future domestic crude oil supplies will increasingly shift toward frontier, hostile geographic areas and toward enhanced oil recovery.

B. If crude oil exploration and development remain orderly and relatively free of constraints, considerable quantities of lower cost crude oil will be available for the remainder of this decade. However, as these supplies are consumed, the replacement costs will begin to rise rapidly.

C. Many events could dramatically accelerate the time when domestic replacement costs begin their steep climb. Three such occurrences are: (1) a low crude-oil resource base (U.S. Geological Survey, 95%) case; (2) low success with, or constraints on, enhanced oil recovery technology; and (3) lack of access to Arctic or deep-water resources.

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Petrography, Diagenesis, and Depositional Setting of Glenn (Bartlesville) Sandstone, Berryhill Unit, Glenn Pool, Oklahoma

Petrography and physical stratigraphy of the "Glenn" (Bartlesville) sandstone in the 160-acre Berryhill unit, Glenn Pool, were established from 10 cores and more than 60 modern well logs. The reservoir mostly is sublitharenite to litharenite; lithic constituents chiefly are metamorphic rocks and rip-up clasts. Principal diagenetic minerals are kaolinite, chlorite, and illite. This evidence and data from the regional and local stratigraphic framework indicate that sands were upper delta-plain deposits. Logs of the closely spaced wells show moderately complex short-distance change in geometry of the sandstone and attendant reservoir heterogeneity. All this information is integral in ongoing plans for enhanced recovery and in current research on enhancement of well logs by signal processing.

LAFEHR, T. R., Colorado School Mines, Golden, CO

Integrated Geology and Geophysics

We have an increasing need for geologists and geophysicists to work together on exploration projects. Pitfalls or weakness in a subdiscipline may be minimized or even avoided by an integration of all available data (e.g., geologic constraints, well logs, core analyses, seismic and nonseismic geophysical information).

Two case histories are provided to demonstrate the importance of integration. The first is lithologic identification by combining seismic reflection, refraction, and gravity data in a situation where any one tool, if used alone, could not solve the problem. The second geologic example is a structural problem taken from the overthrust of Wyoming. The examples include drilling results after the interpretations were performed.

LAND, LYNTON S., Univ. Texas, Austin, TX

Evidence for Vertical Movement of Diagenetic Fluids, Texas Gulf Coast

Both the study of burial diagenesis and the study of present-day formation waters of Jurassic through Pleistocene formations from the Texas Gulf Coast document local vertical fluid transport of at least several kilometers. Evidence includes the following. (1) Discharge at the land surface of Mesozoic-derived brines as "bad water." (2) Emplacement of Mississippi Valley-type lead-zinc mineralization by fluids derived from Mesozoic formations in salt dome cap rocks at or near the land surface. (3) Emplacement of uranium in Tertiary aquifers as a result of reduction by ascending reduced sulfur, presumably of Mesozoic origin. (4) Emplacement of calcite cement derived from Mesozoic strata in Tertiary sandstones. (5) Presence of fluids in Plio-Pleistocene rocks with chemical signatures that could only have been derived from Mesozoic strata.

Material-transport calculations indicate that the volumes of fluid involved far exceed the volume of connate water deposited in the basin, strongly suggesting some mechanism of thermally driven convective flow.

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Effects of Diagenesis on Porosity Development, Tuscaloosa Sandstone, Louisiana

The Lower Cretaceous Tuscaloosa sandstone is of interest because of high porosity (up to 29%) at depths as great as 21,000 ft (6,400 m). We believe that the porosity is 70% primary and 30% secondary. Diagenetic events are major controls for the high porosity but overpressure also contributes.

Primary porosity exists because quartz diagenesis was retarded by chlorite grain coats. Where grains coats are absent or thin, prismatic quartz overgrowths occur. Chlorite coats constitute up to 29% of the rock. Chlorite originates from alteration of lithic material (i.e., volcanic and basic igneous intrusives) in the sandstone. An excellent direct correlation exists between the amounts of lithic fragments and chlorite coats. Sandstones with extensive chlorite and lithic fragments are not good reservoirs because of reduced permeability resulting from rearrangement and mechanical breakage of weak grains during compaction. Commonly, authigenic titanium minerals (e.g., anatase) are associated with the altered lithic material.

Secondary porosity has formed from the dissolution of lithic fragments and feldspars, and to a lesser degree carbonates. Secondary porosity related to highly chemically susceptible lithic fragments developed early (prechlorite) and was subject to later collapse; whereas pores related to later dissolution of less soluble lithic material and feldspar were less affected by compaction because of a more stable framework. Diagenetic evidence indicates that the dissolution occurred prior to, during, and after the formation of chlorite coats.

Calcite cement occludes porosity in some intervals. However, textural evidence from leaching experiments suggests that dissolution of this calcite is not a major source of secondary porosity.

LAW, BEN E., U.S. Geol. Survey, Denver, CO

Geologic Characteristics of Low-Permeability Gas Reservoirs in Greater Green River Basin of Wyoming, Colorado, and Utah

Large gas resources occur in low-permeability Upper Cretaceous and Lower Tertiary reservoirs in the Greater Green River basin of Wyoming, Colorado, and Utah. Most of the gas-bearing reservoirs are overpressured, beginning at depths of 8,000–11,500 ft (2,440–3,500 m). The reservoirs are typically lenticular nonmarine and marginal marine sandstones. In situ permeabilities to gas are generally less than 0.1 md, and porosities range from 3–12%. Secondary porosity, after dissolution of framework grains and cements, is the dominant type of porosity. Gas accumulations are characterized by the presence of water updip and little or no recoverable water downdip. The seal of these overpressured gas-bearing reservoirs cuts across structural and stratigraphic boundaries and is not associated with any particular lithologic unit. The trapping mechanism is

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.

LAWRENCE, DAVID A., and BRIAN P. J. WILLIAMS*, Univ. Bristol, Bristol, England, U.K.

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.

LEE, CAROL KINDLE, Kerr & Associates, Denver, CO, and S. DUFF KERR, JR., KEWA Exploration Inc, Denver CO

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.

LEVIN, DAVID M., Levin Consulting, San Antonio, TX

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.