petroliferous areas. Of these, the Cement oil field has produced the only commercial uranium deposit in Oklahoma. Less well known is a small occurrence in Kiowa County (in the Hennessey group) where uranium is associated with pyrobitumen nodules. The nodules contain between 2,225 and 10,110 ppm U. Available field, microscopic, and geochemical evidence suggest that the pyrobitumens are secondary, i.e., alteration products of crude oil. Uranium was provided by ground water.

Petroliferous areas in Oklahoma hold the greatest potential for discovery of significant uranium mineralization. Oil-field brines can, in some places, be a useful tool in exploration for such minerlization. While high radium-226 concentrations in natural waters are not a specific indicator of subsurface uranium mineralization, relatively high ratios of Ra-226/Ra-228, Ra-226/Ba, Ra-223/Ra-228, and Ra-223/Ba in such waters from sedimentary terranes may better reflect the presence of uranium accumulations in the subsurface. Available analyses of several radioactive oil-field brines and springs from various parts of Oklahoma indicate that these waters do not meet the above criteria and are not, therefore, surface expressions of buried uranium mineralization.

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COCORP Deep Seismic Reflection Traverse Across Southern Oklahoma Aulacogen

COCORP deep seismic reflection profiles across the width of the southern Oklahoma aulacogen, from the Hardeman basin on the south, through the Wichita Mountains and Anadarko basin on the north, reveal basement deformation that necessitates major revision of ideas about the geologic history.

The profiles south of the Wichita Mountains show that the Precambrian crust is highly layered to depths of 10 to 13 km over an area at least 2,500 km^2, and probably much more. Judging by COCORP surveys elsewhere in the United States, such extensive Precambrian layering is very unusual. The layered crust can be interpreted as a large Proterozoic basin, probably filled mainly with clastic sediments and felsic volcanics since these lithologies are widespread in the Precambrian of the southern Mid-Continent region.

The layering is truncated on the south side of the Wichita Mountains, and under the mountains is either absent or only present in a highly altered form. The truncation is probably caused by Precambrian faults in conjunction with granitic intrusions. Pennsylvanian compression reactivated these faults.

The COCORP profiles across the northern flank of the Wichita Mountains and into Anadarko basin are in an early stage of processing, but preliminary results suggest that the Precambrian layering that is so distinctive south of the mountain does not extend beneath the Anadarko basin. Crystalline rocks of the Wichita Mountains appear to have thrust north along a moderately dipping fault, overlapping the basin by 8 to 9 km. The attitude of the fault at depth beneath the mountains is unclear at present.

Simple models for the southern Oklahoma area as an aulacogen must be revised to consider the complex Precambrian history revealed by the COCORP data.

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Horizontal Seismic Sections and Their Utility in Petroleum Exploration

Horizontal seismic sections are one type of product from a three-dimensional seismic survey. Three-dimensional surveys have been performed in every type of environment worldwide and have contributed to many exploration, appraisal and development successes.

Horizontal, or Seiscrop, sections display the spatial extent of subsurface features and are particularly valuable for direct mapping. Three dimensional data from several areas, including the Mid-Continent, will be used to demonstrate the utility of Seiscrop sections for structural mapping, and for the delineation of hydrocarbon flat spots, carbonate features, stream channels, and sand bars.

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Washita Valley Fault System—A New Look at an Old Fault

With the application of plate tectonic concepts to southern Oklahoma, the structural style has more recently been characterized as a wrench fault system. In particular, the Washita Valley fault (WVF) is generally considered by many geologists to be a major left-lateral strike-slip fault with an offset of approximately 40 mi (64 km).

The map most commonly used to demonstrate this magnitude of lateral offset is the basal Oil Creek sand distribution map. The zero edge of the basal Oil Creek sand provides the necessary piercing point to judge lateral offset along the WVF. However, the published basal Oil Creek map depicts the present-day distribution of the sand which is the result of cumulative movements since the deposition of the basal Oil Creek sand. Individual orogenic episodes must be sorted to determine what contribution possible strike-slip movements have made toward the present-day basal Oil Creek sand distribution.

To unravel these various orogenic episodes a palinspastic restoration must be made. In such a sequential restoration, the last movement should be restored first or the known movements restored first to determine the unknown movements. In this presentation, the observable folds along the WVF have been "unfolded" and the known reverse faults have been restored to a pre-fault position. When this has been accomplished the partly restored basal Oil Creek sand map may be used to determine the amount of lateral offset on the WVF.

The resulting restoration indicates that the commonly quoted figure of 40 mi (64 km) of lateral offset is too large. Surface and subsurface data demonstrate that the crustal shortening represented by folds and reverse faults alone can account for the present-day basal Oil Creek sand distribution and thus very little strike-slip movement is needed along the Washita Valley fault system.

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Petrologic Factors Controlling Internal Migration and Expulsion of Petroleum from Source Rocks: Woodford-Chattanooga of Oklahoma and Arkansas

Upper Devonian-Lower Mississippian black shales are excellent oil source rocks throughout Oklahoma and much of western Arkansas. Black shales were deposited in shallow-water shelf or epeiric sea environments in the north and deep basins in the south (i.e., Arbuckle province). Silty black shale is more common in the north whereas silicified black shale increases to the south. Overall low rates of clastic sedimentation and high planktonic organic productivity prevailed over the entire region. The small amounts of clastic silt and clay came from the north and northeast with local derivation from the Nemaha ridge and Ozark dome. Some silt was probably contributed from the northwest along the axis of the southern Oklahoma aulacogen (Anadarko basin). Primary carbonate deposition occurred locally on or near a distal southern platform between the Arbuckle and Ouachita provinces (Pauls Valley uplift).

Diagenesis in the Woodford-Chattanooga source rock section proceeded through the following relative time sequence: (a) silicification, chiefly by recrystallization of radiolarians, which probably followed the reaction conversion of amorphous opal-A to opal-CT to chert; (b) dolomitization of deep basin opal or chert and shallow-platform carbonate laminae; (c) tectonic faulting, folding, and associated fracturing and stylolitization predominantly associated with the late Paleozoic Arbuckle and Ouachita orogenies; (d) late silicification and mineralization along fractures contemporaneous with (e) generation and expulsion of petroleum.

The principal expulsion mechanism for these Upper Devonian-Lower Mississippian oil source rocks is "whole oil" migration through coarser grained matrix pores, stylolites, and fractures, rather than diffusion on a molecular scale. Diffusion migration does occur but appears only to affect internal migration over a few millimeters within the source rock, and thus cannot account for expulsion of large volumes of oil.

Preliminary calculations based on source rock extract data indicate that approximately 147 billion bbl of oil have been generated within Woodford shales in the 23,000 sq mi (598,000 sq km) geographic area of southern and western Oklahoma underlain by the Woodford formation.

Minimum relative oil expulsion efficiency appears to have been approximately 18 to 19% of the oil generated within the Woodford. Thus, at least 27 billion bbl of oil have been expelled into adjacent formations in southern and western Oklahoma while 120 billion bbl of oil remain in the source rock.

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Hydrocarbon Occurrences in Frontal and Central Ouachita Mountains, Oklahoma

Hydrocarbons in the frontal and central Ouachitas are in three distinct forms: crude oil, asphaltite, and as organic matter disseminated in potential source rocks. Each of these types has been examined geochemically, in an attempt to correlate oil to asphaltite and oil to source rock. In addition, the general source rock potential of the central Ouachitas has been evaluated. Results show that the crude oil produced to date is chemically mature and largely undergraded, although production is as shallow as 148 ft (45 m) in one field. The asphaltite is predominantly grahamite throughout the Ouachitas, and correlates geochemically to the crude oil, as indicated by similar stable carbon isotope ratios. An examination of the Ouachita section for source potential indicates that several formations are high enough in organic carbon to have produced oil, although some may be ruled out on the basis of the type of organic matter present.

Association of oil and asphaltite along the strike of the Windingstair fault indicates that this listric reverse fault may have served as a migration conduit. Geochemical similarities between analyses of asphaltite from the Upper Ordovician Bigfork and that from the Mississippian Stanley group further indicate the possibility of vertical migration. Finally, migration along a listric fault, with subsequent near-surface degradation of the oil, would provide a concise explanation for the close association of near-surface solid asphaltite with sightly deeper liquid oil.

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Enhanced Oil Recovery Using High-Pressure Inert-Gas Injection, East Binger (Marchand) Unit, Caddo County, Oklahoma

September 1981 will complete four years of high-pressure inert-gas injection in the East Binger Unit area. The process was designed to attain miscible conditions in the low permeability Marchand sand, and although complete miscibility is yet to be obtained because of lower than desired injectivity, stimulation has occurred.

Recent development of the East Binger Marchand field began in 1972. The productive Marchand sand, i.e., Hogshooter sand, is found at an average depth of 10,000 ft (3,048 m) and is of the Pennsylvanian Hoxbar series. The sand generally lies on top of the Hogshooter regional marker, a black low-density shale. The sand is a turbidite depositional feature with some postdepositional bedding deformation, the latter supported by evidence of minor east-west fracturing between some injectors and producing wells.

The major part of the East Binger field was unitized August 1, 1977, and through careful planning, inert flue-gas injection began September 10, 1977. The urgency with which the operators completed the unitization task was predicated by the rapid decline in bottom-hole pressure and predicted primary on only 10.7% of OOIP. Computer simulator studies predicted an additional recovery of 24.7 MMSTB if miscible fluid displacement could be attained in the reservoir.

Flue gas is purchased from Production Operators, Inc., plant facility centrally located in the unit area. The dehydrated gas is delivered to the unit at 4,800 psi and distributed to 17 injection wells. Injectivity has been lower than desired, due partly to lube oil carry-over plugging the low permeable Marchand sand. Other operational problems, and subsequent revision to net hydrocarbon sand thickness, have resulted in a reduction in predicted ultimate recovery from 33.4 to 21.0 MMSTB. Operational problems are being corrected, and infill drilling to develop part of the unit on 80-acre (32 ha.) spacing is in progress. These actions should assure the current predicted ultimate of 21.0 MMSTB will be realized.

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Future Hydrocarbon Potential of Viola Limestone in Oklahoma

The Viola Limestone as a potential hydrocarbon source has been recognized for years in the literature, but only in the last couple of years has the industry actively pursued this target as a primary reservoir. The Viola is stratigraphically similar to the Hunton formation and produces from both fracture porosity and primary porosity zones. The Viola can be subdivided into three units with characteristics similar to the Bois d'Arc, Henryhouse-Haragan, and Chimneyhill members of the Hunton. Little formation water has been encountered and the higher prices for crude oil have made economic entire trends heretofore left undeveloped. Some of these trends are untested at any horizon, and others are thoroughly tested for the shallower zones, but virtually untested for Viola. The most ac-