creases 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 active trend to develop has been along the north flank of the Marietta basin in southern Oklahoma. There has been great interest in the Viola on both sides of the Arbuckle Mountains, and in a new discovery along the complex mountain front province of the Anadarko basin. In addition, there are numerous OWWO attempts along the southern end of the Central Oklahoma platform

Few wells in the Viola have the capability to produce without large frac treatments, and some require some special treatments for paraffin and other impurities. To date, no H_2S has been encountered. The future of Viola development across large parts of Oklahoma is excellent with some very promising trends still untested.

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Comments on Structure Within Wichita Mountains Crustal Block

Work in preparation for a new map of the Wichita Mountains has led to revisions of the surface structure within the exposed igneous rocks. As the presumed faulting pattern will have bearing on the development of regional tectonic models, it is important to document clearly whether major structural discontinuities exist inside this crustal block. Fault distributions within the main igneous outcrops in the eastern Wichitas have been shown on the Oklahoma state geologic map and carried forward in *Oklahoma Geol. Survey Hydrologic Atlas* 6. These faults can be grouped into two categories based on stratigraphy: those separating rocks of the *same* stratigraphic unit, and those separating rocks of *different* stratigraphic units. Field work over the period of 1977 to the present now shows that all those previously accepted faults which allow contact of different igneous lithologies are actually *intrusive* contacts. Accordingly, such faults do not exist. No unequivocal major faults (i.e., separations of tens to hundreds of meters) have been identified in the igneous rocks although prominent lineaments do exist.

The work described above plus new published stratigraphic information on the igneous sequence leads to several speculative ideas on regional deformation associated with the Wichita arch. These ideas follow somewhat the reasoning advanced by Ham, Denison, and Merritt, but with modifications as required by new data.

(a) The integrity of the main Wichita Mountains horst block results from its underlying gabbroic substrate (Raggedy Mountain gabbro group) rather than the covering, thin Wichita granites, or Carlton rhyolite.

(b) Intrusion of the Roosevelt gabbros as small plutons into the Glen Mountains layered complex marks the beginning of the Wichita Mountains block as a structural unit. This timing is not yet well-dated but is clearly pre-rhyolite and pre-granite in age.

(c) Few faults will be found in areas underlain by much gabbro. For example, faults bounding the south side of the Anadarko basin may indicate the most northerly extent of gabbro. Basement beneath the Anadarko basin should have little gabbro.

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Lignite Development and Utilization in Mid-Continent Region

Until recently, the Mid-Continent region, with large supplies of oil and gas, had little incentive to exploit lignite, a low-grade coal of Tertiary age. Increasing prices for natural gas and the Powerplant and Industrial Fuel Use Act changed this situation in the 1970s and today we find major utility use of lignite as a boiler fuel in Texas, development beginning in Louisiana, and considerable interest by utilities in Arkansas. The greatest lignite reserve base in the Mid-Continent area is in Texas with 8.6 to 11.1 billion short tons of near-surface lignite reserves, followed by Arkansas with 2.5 billion and Louisiana with 1.1 billion tons.

The first use of lignite in the modern era of lignite development occurred in Texas in 1954 near Rockdale where it was developed as a boiler fuel for electricity generation in connection with aluminum refining operations. In 1971, Texas Utilities opened a major lignite-fired generating station near Fairfield, Texas, followed by two other large mines and generating stations in east Texas by the same company and announcements of additional mines by Texas Utilities and others. Development of lignite will begin in Louisiana in 1981. Five mines are planned in northwest Louisiana for the mid-1980s with Phillips Coal Co. the largest lignite reserve holder in the Gulf Coast area, responsible for the two largest mines. Three of the mines will be developed for electricity generation, two will be for industrial use of lignite. Firm commitments to lignite use in Arkansas are pending with Arkansas Power and Light Co. the closest to opting for lignite use. All current operations and announced developments rely on surface mining techniques; most are classic drag-line area-stripping operations.

Many large blocks of near-surface lignite reserves in Texas and Louisiana have been committed to use for power generation. Use for gasification is under consideration by Exxon at a large deposit near Troup, Texas. Pilot in-situ gasification projects have been conducted in Texas to develop methods for extracting lignite too deep to mine.

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Middle Atokan Delta Systems in Arkoma Basin of Arkansas

The Arkoma basin, located in southeast Oklahoma and west-central Arkansas, is a Pennsylvanian basin which produces gas exclusively, primarily from stratigraphic traps in Atokan and Morrowan sandstones. Many analogies can be made with the Gulf Coast basin; low-angle normal faults, growth faults (both large and small), and abundant sand deposition in a shallow-marine environment.

A series of large growth faults separates the shelf from the deep basin. These faults were active during middle Atokan, adding thick additional section to the deep basin. No correlation exists at this time between the shelf and deep basin sandstones in the middle Atokan.

Throughout the Morrowan and Atokan, a series of delta systems developed across the northern shelf of the basin, mainly from the middle Atokan; the Alma, Carpenter 'B,' Morris, Tackett, and Areci sandstones. Although variable in lateral extent, thickness, and location all have a northeast source and a broad lateral distribution along the shelf. Post-Pennsylvanian erosion has removed the upper distributary part of the above delta systems.

All middle Atokan sandstones produce gas from stratigraphic traps within distributary mouth bars, barrier bars, and delta front sands. All are complicated by normal faults.

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