

tems (Wolfcampian), Southeastern Palo Duro Basin, Texas

In Late Pennsylvanian and Early Permian time the Palo Duro basin was part of a relatively deep seaway that extended northward from the Midland basin into the Mid-Continent. Deep, central-basin areas were surrounded by massive, carbonate-shelf margins and shallow-shelf terrane.

In the southeastern Palo Duro basin, high-constructive, elongate delta systems deposited quartzose sand derived from eastern sources (Wichita Mountains). Late Pennsylvanian and early Wolfcampian delta-front sandstones (>200 ft or 60 m thick) are present on the basinward side of the shelf margin, suggesting that deltas prograded beyond the shelf margin and into deep water. Later, as terrigenous sediment supply was sharply reduced, the shelf margin prograded basinward over deep-water delta facies. During middle Wolfcampian time, clastic input was increased and high-constructive deltas once again prograded into the southeastern Palo Duro basin. However, progradation was not so extensive as earlier episodes and most delta-front sands were deposited in shallow-shelf environments. Consequently shallow-water conditions precluded formation of thick delta-front sequences in shelf environments.

Upper Pennsylvanian-Lower Permian deltaic sandstones in the southeastern Palo Duro basin are subarkoses. Porosity ranges from 0 to 13% and averages 4.8%. Both primary and secondary (leached feldspars) porosity are present. Cementation began with clay coats, followed by quartz overgrowths. Iron-rich dolomite replaced margins of framework grains and filled most remaining pores. Timing of feldspar leaching and kaolinite cement is unknown.

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Geochemical Prospecting for Stratigraphic Traps

Petroleum geochemistry has received considerable attention in recent years and has emerged as a useful tool in exploration efforts. Most of the methods currently being used find maximum benefit and application in frontier exploration areas. Such studies generally provide information on source-rock quality, maturity level, and migration history. Some techniques, however, are applicable to more mature petroleum provinces and are especially suited for stratigraphic-trap exploration efforts. One such method involves pyrolysis of samples (well cuttings) and measurement of the quantity of hydrocarbons that are volatilized. Detecting, quantifying, and mapping hydrocarbon content of samples from specific stratigraphic units help to assess proximity to oil accumulations.

As oil moves to a trap, small quantities of hydrocarbons are invariably left in the rocks which served as avenues of migration. Concentrations of these hydrocarbons are highest near an oil accumulation and become progressively lower at greater distances from an accumulation. Concentration gradients can be mapped and interpreted in much the same way as conventional subsurface data and thus can provide the exploration geologist with a quantitative tool. Data are rapidly ob-

tained, and information derived from initial boreholes can be used to help position subsequent tests. Preliminary results from several Mid-Continent study areas have been encouraging.

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Investigation of Desmoinesian Rocks in Northeastern Oklahoma for Heavy-Oil Potential

Various estimates of the heavy-oil resources of the Tri-State area of Kansas, Oklahoma, and Missouri have ranged from 30 million to several billion bbl of oil in place. During 1977-78 the Oklahoma Geological Survey, in conjunction with the state geological surveys of Missouri and Kansas and the U.S. Department of Energy, conducted an 18-hole drilling and coring program to assess the heavy-oil potential of northeastern Oklahoma. Reported bituminous material in shallow wells and the presence of asphalt-bearing sandstone in mine shafts suggested that Craig and Ottawa Counties might hold the best potential for shallow heavy-oil accumulations.

The results of our 18-hole program show that the Lower Pennsylvanian sandstones in this area are somewhat discontinuous and vary considerably in reservoir quality. Seven of the boreholes indicated the presence of oil; however, 1-mi (1.6 km) offsets from these sites commonly demonstrated lack of continuity of specific sandstones and an absence of heavy oil where adequate-quality reservoirs exist. We feel that the Oklahoma part of the Tri-State area does not contain as much heavy oil as had been estimated.

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How Many Wildcats Must We Drill?

Decline of United States oil and gas reserves could be moderated by increased exploratory drilling. In 1978 U. S. production was 3.0×10^9 bbl crude oil, 0.7×10^9 bbl natural-gas liquids (NGL), and 19.3×10^{12} cu ft natural gas ($= 3.3 \times 10^9$ bbl oil equivalent-BOE), for a total of 7.0×10^9 BOE. To continue production at this rate until 1990 (12 years) would require discovery of 84×10^9 BOE.

Annual estimates of ultimate recovery (past production + reserves) are made for each year since 1920 by API and AGA. To each of these estimates must be added an estimate of reserve growth from revisions, extensions, new-pool discoveries, in-field drilling, and enhanced recovery. From the derived annual totals and AAPG estimates of footage drilled annually in new-field wildcat wells, the oil and natural gas discovered/foot were estimated. In the late 1940s the average discovery/foot was more than 350 BOE. By the late 1970s the average discovery/foot had dropped to 52 BOE. Projections of these decline curves determined the number of feet of new-field wildcats needed to find 2×10^9 BOE/yr, approximately the present rate of discovery in the U.S. Projected average drilling depth permits calculation of the number of needed wildcats/yr (12-yr total = 388,514 wells). Estimated discoveries are 7% oil and 8% gas.