rived from the lake itself. The total amount of organic carbon in the surface sediments increases with distance from the river mouth and is accompanied by a decrease in mineral grain size as expected. However, within a single sediment sample, organic carbon content is not a strong function of grain size over the range from 5 to 11ϕ. Visual examination of the separated insoluble organic matter showed that structured, wood-derived organic matter predominates in the coarser fractions ($>62\mu$) but the finer fractions ($<62\mu$) contain mainly microorganisms and amorphous material. Pyrolysis experiments gave a ratio of (total response/organic carbon content) that increased from low values in the coarse fractions to higher values in the fine ones—a trend consistent with the visual kerogen observations because high ratios are usually produced by amorphous organic matter. However, infrared spectra of the organic matter from coarse and fine sediments closely resemble that generally observed for the humic substances associated with soils, suggesting that even the finer grained, amorphous organic matter is derived largely from the terrestrial organic matter. X-ray diffraction indicated the presence of quartz, feldspars, calcite, dolomite, mica, kaolinite, illite, and montmorillonite in the sediments. The composition was rather uniform with no major variations due to clay size or areal distribution.

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Controls on Pennsylvanian Hydrocarbon Accumulations in Mid-Continent

Approximately 8.8 billion bbl of oil and about 31.5 Tcf of gas have been found in Pennsylvanian reservoirs in the Mid-Continent as of January 1, 1978. Although these volumes of hydrocarbons were trapped in thousands of fields throughout the region, most of these resources were emplaced in a relatively few fields: about 6.4 billion bbl of oil has been found in 90 significant and giant oil fields, and 18.5 Tcf of gas has been discovered in 50 significant and giant gas fields. Our calculations of the total oil and gas accumulations in Pennsylvanian reservoirs were extrapolated from these data.

Most oil and gas accumulations of Pennsylvanian age in the Mid-Continent were stratigraphically trapped in lenticular sandstone bodies; the environments in which most of the clastics were deposited range from fluvial to deltaic to shallow marine. Even though this region is now in a late mature stage of exploration and development, important stratigraphic accumulations of oil and gas remain to be found. These fields will be discovered through detailed subsurface analysis, the reconstruction of depositional environments, and the application of high-resolution seismic data to stratigraphic problems.

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Upper Morrow Fan-Delta Deposits of Anadarko Basin

The Pennsylvanian upper Morrow fan delta chert conglomerates are located in the Texas Panhandle and Oklahoma parts of the Anadarko basin. The source area for these chert conglomerates was the Amarillo–Wichita Mountain complex where erosion of cherty limestones and dolomites of Mississippian age occurred. The presence of these chert conglomerates in the upper Morrow sequence precisely defines a time of uplift and erosion of the highlands not previously recorded and therefore provides a new time-stratigraphic marker for the Morrow. Unusually high porosity and permeability in the chert conglomerates at depths greater than 15,000 ft (4,572 m) in a reservoir which may contain a billion cubic feet of gas per net foot of porosity are adequate incentives and justification for deeper drilling in the basins. Successful efforts in the search for these stratigraphic traps have resulted at Shreikey, Buffalo Wallow, Viking, Cheyenne, Elk City, and other fields.

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Stimulation Design for Upper Morrow Reservoirs in Reydon-Cheyenne Area, Western Oklahoma

Recent deep, high-pressure upper Morrow reservoir completions in the western Oklahoma part of the Anadarko basin indicate the area to be a major natural gas producing area. These Morrow sandstone reservoirs consist of poorly sorted medium to coarse-grained feldspar-rich sandstones to chert-pebble conglomerates. Diagenetic minerals present include calcite, siderite, and quartz overgrowths. Clay minerals present include small to moderate amounts of iron-rich chlorite, mixed-layer clays, and illite. Generally, the diagenetic minerals and the clays tend to fill the intergrain pore space. Reservoir porosity ranges from 6 to 12%, and effective reservoir permeabilities range from 0.1 to 10 md.

Wells are generally drilled to total depth, logged, and a 5-in. (12.7 cm) OD liner is cemented back to the intermediate casing. Once perforated and cleaned up, the well is allowed to flow and a pressure buildup test is performed. Buildup-test analysis commonly indicates that a fracture-stimulation treatment may be needed to obtain satisfactory production rates. With bottom-hole temperatures in excess of 260°F (127°C), potassium chloride treated water in a cross-linked gel system is being used as the treatment fluid. Use of high-strength proppant instead of sand appears to help provide sustained production increases after fracturing.

Treatment designs must consider the following parameters: depth, bottom-hole temperature, reservoir pressure, and bottom-hole treating pressure, as well as surface-pressure limitations, tubing size, job volume, and type of proppant system used with respect to closure stresses expected.

Following the stimulation treatment and fluid cleanup, another pressure-buildup test is performed to evaluate the treatment. Field results indicate that stimulation treatments have been successful.

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Deltaic Deposits in Upper Morrow Formation of Anadarko Basin

Environmental facies analysis of Pennsylvanian upper Morrow deposits of the Anadarko basin show a variety of deltaic facies. The important reservoir deposits

are both point-bar and stream-mouth-bar sandstones and conglomerates. The point-bar deposits are the most important reservoirs and many well-documented examples show their sizes, shapes, trends, and reservoir characteristics.

Detailed data from dry holes in the Morrow Formation show relations which give reliable clues to the existence of nearby reservoir deposits. Study of the stratigraphic and facies framework of the Morrow gives insight into processes of deltaic sedimentation which should be useful in local and regional exploration as well as in production operation.

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Channel Sandstone Oil Reservoirs of Pennsylvanian Age, Northwestern Ness County, Kansas

Channel sandstones of Pennsylvanian (Desmoinesian, Cherokee) age are unusual oil reservoirs in T17S, R24W, Ness County, Kansas. A thickness map of the interval from an overlying marine marker, the Fort Scott Limestone, to the underlying Mississippian carbonate rocks depicts the topography of a former land surface now buried 4,400 ft (1,340 m) deep. Where the mapped interval exceeds 125 ft (38 m) sandstone deposits fill incised paleovalleys.

The sandstones are interpreted as channel-fill sandstones because of: (1) their position filling sinuous valleys; (2) their cross-section shape, convex base, and flat upper surface; (3) their dimensions—to 60 ft (18 m) thick, one-fourth mi (0.4 km) wide, and over 6 mi (9.6 km) long; (4) the coarsening downward from very fine quartz grains to coarse sand and pea gravel at the base; (5) the enhanced permeability (over one darcy) near points of change of valley direction (point-bar deposits?); (6) the common presence of 10 to 20° dips and cross-bedding in cores; (7) the lateral gradational mixing of quartz sand with residual cherts. Greenish clay is present in the upper fine-grained sandstones and glauconite in the lower coarse sandstones.

Six wells encountered isolated sandstone lenses (pressure decline on drill-stem tests) and produced only 7,131 bbl of oil per well before abandonment. The other 28 wells produce oil from channel sandstone reservoirs with water drive. Over 100,000 bbl of oil per well (40 acre or 16 ha. spacing) will be recovered from them. It is estimated that the 17 best wells (50% of the wells) will have gross ultimate production of 164,000 bbl of oil per well.

Prospecting for channel-sandstone oil reservoirs is hazardous with 43 dry holes surrounding the 34 channel-sandstone oil wells.

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Palynologic and Plant Compression Evidence for Desmoinesian-Missourian (Pennsylvanian) Series Boundary in Northeastern Oklahoma

Palynologic and plant-compression-bearing coal and shale deposits in Tulsa County (northeast Oklahoma) contain floristic evidence for separating the Desmoinesian and Missourian Series at the base of the Checkerboard sandstone (upper Seminole Sandstone). Three coal seams, Dawson (below), Seminole, and Checkerboard, were formerly placed in the Missourian Series. The two lower seams and their associated shales and sandstones are here removed to the Desmoinesian Series. Dawson coals contain approximately 42% *Thymospora pseudothiessenii* spores and 17% those of *Lycospora* sp., whereas the Seminole coals contain none of the former and only 1% of the latter. Sphenopsid spores increase from 4% in the Dawson to 25% in the Seminole. Filicineae and Pteridospermae palynomorphs are 65% in the Dawson and 37% in the Seminole. More abundant in the Seminole are the genera *Endosporites, Calamospora, Triquitrites,* and *Laevigatosporites.* Checkerboard coals and shales contain the Missourian genera *Centonites, Trivolites, Plicatisporites,* and *Tuberculatosporites.* Compression floras associated with the Dawson and Seminole coals contain only 9 known species of which *Calamites suckowii, Annularia stellata, Pecopteris pseudovestita(?), Alethopteris serlii,* and *Neuropteris scheuchzerii* are common. The Checkerboard shales contain possibly 29 species. The brachiopod, *Mesolobus mesolobus,* a Desmoinesian Series invertebrate, is present in shale above the Dawson coal, giving further support to the removal of that unit from the Missourian to the Desmoinesian Series.

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Early Pennsylvanian Braided Stream Sedimentation, Northwest Arkansas

The Bloyd Formation (Morrowan) of northwest Arkansas is a heterogeneous succession of sandstone, limestone, shale, and siltstone units that accumulated in shallow-marine and nonmarine environments during Early Pennsylvanian time. Sedimentation occurred on a gentle paleoslope inclined to the south. The basal Brentwood Limestone Member is overlain in extreme western Arkansas by coal-bearing shale and siltstone strata of the nonmarine Woolsey Member. Eastward, Woolsey strata pass into a thick and laterally extensive sandstone body characterized by abundant sets of tabular cross-strata, medium to coarse-grain size, and beds of quartz-pebble conglomerate. The unit is bounded below by a marked unconformity that displays up to 6 ft (1.8 m) of erosional relief on the underlying Brentwood Member.

Erosion surfaces occur throughout the unit and bound genetically significant intervals characterized by a consistent succession of sedimentary structures. Quartz-pebble conglomerates resting directly on erosion surfaces are overlain by sets of large-scale tabular cross-strata. Thin intervals of ripple-laminated sandstone containing well-developed ripple bed forms with occasional clay drapes overlie the tabular sets and are bounded above by erosion surfaces. These genetic intervals are repetitive throughout the unit and reflect sedimentation by initially competent but rapidly waning current systems. Paleocurrent measurements derived from tabular cross-strata indicate that the sediment was emplaced by south-flowing unidirectional currents characterized by low dispersion.

The succession of sedimentary structures contained within genetic sequences and paleocurrent data indicates that the middle Bloyd sandstone body accumulated in several south-flowing braided stream systems in northwest Arkansas.