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Uranium Exploration in 1970s and 1980s, Lessons for the Future

During the period 1974-83, the uranium industry spent $1.8 billion on domestic exploration, including 264 million ft of surface drilling. Exploration activities reached a high level in 1978-79, and have declined each year since. This effort was largely concentrated in the Colorado Plateau, Wyoming basins, and the south Texas coastal plain where ore deposits were located in the vicinity of producing mines. Significant new deposits also were found adjacent to producing areas, in inactive districts, and in frontier areas. Discoveries in nonsandstone environments in Canada, Australia, and Mexico gave impetus to exploration for similar deposits in the United States. The rapid decline in the uranium market caused many well-planned exploration programs to be cancelled just as they were getting under way. However, this past cycle of exploration has shown that (1) world class deposits exist in the Appalachians and in the Great Plains, (2) concepts of "mineral belts" are often oversimplified, (3) deposits in collapsed pipe structures are more widespread than originally thought, (4) large deposits can be found in old, inactive districts, and (5) nonsandstone environments throughout the United States appear to be attractive exploration targets. The large amount of geologic information now available from the Department of Energy's National Uranium Resource Evaluation Program, and from the other sources should aid in the development of geologic models before the next increased demand for uranium.

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Three Oil Types in Paleozoic Rocks of Northern Denver Basin—Implications for Exploration

Analysis of 22 oil samples produced from Pennsylvanian and Permian rocks across the northern Denver basin revealed three genetically distinct oil types. One type is produced from the Permian Lyons Sandstone from fields located near the structural axis and along the west flank of the basin. This oil type is characterized by pristane-phytane ratios of less than 1.0 (average 0.8), $\delta^{13}C$ values of -28.5 to -29.1 ppt for saturated hydrocarbons, low relative amounts of n-alkanes, and absence of hopanoid biomarker compounds. The second oil type is produced from rocks of Virgilian and Wolfcampian ages in northeastern Colorado and southwestern Nebraska. This oil has a pristane-phytane ratio of about 1.5, n-alkanes dominant in the saturated hydrocarbon fraction, abundant hopanoid biomarker compounds, and $C_{15}+$ saturated hydrocarbon fractions depleted in carbon-13 compared to the Lyons oil type ($\delta^{13}C$ values -28.8 to -30.4 ppt). Oil produced east of the Denver basin from rocks of the Lansing Group ("F" zone) and Ordovician rocks at Boveau Canyon and Sleepy Hollow fields, respectively, is geochemically similar to this second oil type. The third oil type is produced from rocks of Desmoinesian age. This oil has a pristane-phytane ratio near 1.0, contains intermediate amounts of n-alkanes relative to isoprenoids compared to the other oil types, and contains the isotopically heaviest saturated hydrocarbons of the three oil types ($\delta^{13}C$ values -27.7 to -27.8 ppt). These three oil types have probably been generated from three different source rocks. The geographic distribution of the Virgilian-Wolfcampian and the Desmoinesian oil types suggest at least two broad areas for possible future exploration: for the Desmoinesian type, along a trend subparallel to the eastern limit of Desmoinesian rocks in the subsurface from the Nebraska panhandle to east-central Colorado; and for the Virgilian-Wolfcampian type, along a generally east-west trend in northern Colorado, southwestern Nebraska, and northwestern Kansas.

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Cedar Creek—Significant Paleotectonic Feature of Williston Basin

More than 327 million bbl of oil have been produced from Paleozoic carbonate reservoirs in 15 fields along the Cedar Creek anticline. This pronounced fold developed through a geologic history of recurrent tectonic movements along a northwest-southeast-striking fault zone. Four major periods of tectonism from early Paleozoic through mid-Tertiary are documentable in the Cedar Creek area.

Post-Silurian to pre-Middle Devonian.—Uplift and fault movement accompanied north and east tilting of the main Cedar Creek block. Several hundreds of feet of Silurian strata were eroded and a karst plain developed on the Silurian surface. Middle and Upper Devonian sediments onlapped and infilled the uplifted, northwest-plunging element.

Late Devonian to pre-Mississippian.—During latest Late Devonian and possibly earliest Mississippian, the Cedar Creek block was uplifted and tilted north and east. Extensive erosion resulted in the near peneplanation of the structure and significant truncation of Upper Devonian strata.

Late Mississippian (Chester) through Triassic.—During the Late Mississippian (Chester) and Early Pennsylvanian, the central and northern portion of the Cedar Creek area underwent gentle downwarping and periods of subsidence occurred with relative down-to-the-east fault movement along most of the ancestral master and subsidiary faults. Similar fault movement(s) and subsidence continued during the Permian and Triassic Periods. Relative tectonic stability was attained by the Middle Jurassic and essentially maintained until post-Paleocene time.

Post-Paleocene.—The Cedar Creek block underwent its greatest magnitude of uplift during post-Paleocene tectonism resulting in an extensive, linear belt of symmetric drape-folding generally aligned with the ancestral fault zones, and deep fault adjustment. During epeirogenic phases of the mid-Tertiary in the northern Rocky Mountain region, 1,500 ft (457 m) of Paleocene and Upper Cretaceous strata were eroded along the axis of the present structure.

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Rock Types, Pore Types, and Hydrocarbon Exploration

A proposed exploration-oriented method of classifying porosity in sedimentary rocks is based on microscopic examination of cores or cuttings. Factors include geometry, size, abundance, and connectivity of the pores. The porosity classification is predictive of key petrophysical characteristics: porosity-permeability relationships, capillary pressures, and (less certainly) relative permeabilities. For instance, intercrystalline macroporosity typically is associated with high permeability for a given porosity, low capillarity, and favorable relative permeabilities. This is found to be true whether this porosity type occurs in a sucrosic dolomite or in a sandstone with pervasive quartz overgrowths.

This predictive method was applied in three Rocky Mountain oil plays. Subtle "pore throat" traps could be recognized in the "J" sandstone (Cretaceous) in the Denver basin of Colorado by means of porosity-permeability plotting. Variations in hydrocarbon productivity from a Teapot Formation (Cretaceous) field in the Powder River basin of Wyoming were related to porosity types and microfacies; the relationships were applied to exploration. Rock and porosity typing in the Red River Formation (Ordovician) reconciled apparent inconsistencies between drill-stem test, log, and mud-log data from a Williston basin wildcat. The well was reevaluated and completed successfully, resulting in a new field discovery. In each of these three examples, petrophysics was fundamental for proper evaluation of wildcat wells and exploration plays.

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Variations in Plate Kinematics and Subduction Geometries: Unifying Explanation of Mesozoic and Cenozoic Deformation in Rocky Mountains Region

The variety of late Mesozoic through early Cenozoic tectonic elements and events in the Rocky Mountains region shows temporal and spatial correspondence with inferred variations in kinematics of plate interactions and geometries of subducted oceanic lithosphere. From this space and time correspondence and current understanding of subduction processes and responses, we suggest a unified explanation for the occurrence and genesis of these features. The following tectonic elements and events are regarded as genetic expressions of variations in subduction modes and geometries: (1) the history of igneous activity in the western United States, (2) the contrasting styles and loci of deformation along the foreland fold and thrust belt (Sevier style) and the basement-cored uplifts (Laramide style) bordering the northern and eastern margins of the Colorado Plateau, (3) the development and maintenance of the Colorado Plateau as a relatively rigid tectonic block, (4) the timing and geometry of