

in a shallow well drilled for water. The original development was on the structurally high main part of the dome and covered an area of about 200 sq mi (520 sq km). Most of the wells were completed naturally, through open holes at depths ranging from 800 to 1,000 ft (240 to 300 m). With the advent of higher gas prices and improved completion technology in the 1970s, the field was extended north to the Canadian border and now includes an area greater than 600 sq mi (1,560 sq km). The reservoirs in the expanded area are lower in permeability, occur at depths ranging from 1,200 to 1,800 ft (360 to 540 m), and require stimulation to provide economic flow rates.

Most of the recent wells have been drilled using conventional rotary rigs and mud systems designed to minimize formation damage. The wells are then cased, perforated, and hydraulically fractured using sand, carbon dioxide, and water. A combination of sonic, neutron, and density logs is an aid in reservoir evaluation, although better logging tools are needed. Reserve calculations in these unconventional reservoirs present problems. Production history, which is limited, will probably prove to be the best method of estimating recoverable reserves.

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#### Mount Taylor Uranium Deposit—Description and Comparison with Wyoming Roll Fronts

The Mount Taylor uranium deposit in the Grants mineral belt of New Mexico resembles the roll-front deposits of the Wyoming Tertiary basins in many respects. First, the deposit is spatially related to paleochannel systems in the arkosic sandstones of the Jurassic Morrison Formation. Second, the orebody has a cross-sectional form which is crudely C-shaped. It is also elongated along strike. Third, the trace elements arsenic, selenium, and molybdenum, which are known to occur in zones through the Wyoming rolls, do so in this deposit as well. Fourth, a calcite halo is present as cement in the sands near the outer down-dip limits of ore. Finally, the host sediments were derived by weathering granites and are overlain by a fairly thick sequence of continental tuffaceous mudstones.

The Mount Taylor deposit differs from the Wyoming deposits in one significant aspect—it does not reside at an iron redox interface. This deposit is not rich in pyrite, and hematite is not present immediately behind (up-dip from) the ore. Also, primary uranium-bearing minerals have not been identified in the Mount Taylor ore.

Organic carbon is associated with the Mount Taylor ore and probably served as a reducing precipitant for much of the uranium present in the deposit. Certain complexities in this relation imply, however, that organic molecules may have been an important factor in transporting uranium to points of precipitation.

Montmorillonite, chlorite, and kaolinite form a zonation pattern from unaltered down-dip rock through the ore and into altered up-dip rock. Limited data suggest

that this clay mineral zonation may not be associated with the Wyoming roll-front deposits.

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#### Vermillion Creek Coal Bed, High-Sulfur, Radioactive Coal of Paludal-Lacustrine Origin in Wasatch Formation of Vermillion Creek Basin, Wyoming and Colorado

The Vermillion Creek basin is an irregularly shaped topographic basin that occupies an area of approximately 500 sq mi (1,300 sq km) east of the common boundary of Wyoming, Colorado, and Utah. Nearly 4,000 ft (1,200 m) of exposed Eocene rocks in the basin compose parts of the intertongued Wasatch and Green River Formations. High-sulfur, radioactive coal beds of freshwater paludal-lacustrine origin have been identified in the upper part of the main body of the Wasatch Formation and in the upper and lower parts of the Niland Tongue of the Wasatch Formation. The Niland Tongue is about 300 ft (90 m) thick. It is composed of interbedded brown and gray shale, carbonaceous shale, sandstone, mudstone, oil shale, and coal. The Vermillion Creek coal bed is well exposed near the top of the Niland Tongue. Analyses of this coal bed indicate that it has unusual composition and an anomalously high bituminous B rank. It locally exceeds 6 ft (2 m) in thickness and is potentially minable.

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#### Minnelusa—Powder River Basin—Past, Present, and Future

The Permian-Pennsylvanian Minnelusa Formation of the eastern Powder River basin in northeastern Wyoming has yielded nearly 200 million bbl of oil since the initial discovery 20 years ago. This represents an average of approximately 350,000 bbl per well and it is anticipated that production will ultimately average 500,000 bbl per well. Many wells have already produced more than 1 million bbl. Production is derived predominantly from sandstones in the upper part of the Minnelusa from structural and/or stratigraphic traps. Exploratory activity has remained relatively steady until recently when competition for leases and drilling prospects accelerated significantly. Minnelusa oil has been discovered at depths ranging from 5,000 ft (1,500 m) on the east flank to 15,000 ft (4,500 m) near the basin axis in Reno field, Johnson County. Although the greatest exploratory effort has been directed toward the shallower east flank, with corresponding success, increasing attention is being given to Minnelusa prospects at depths below 10,000 ft (3,000 m) nearer the basin axis. Sophisticated geophysical techniques are being employed which should partly reduce risks inherent in stratigraphic exploration. This deeper part of the basin may yield an additional 500 million bbl from the Minnelusa, as well as additional production from Cretaceous sandstones which will be encountered at shallower depths.