The Winnipeg Sandstone is present throughout most of the Williston basin and extends into the Kennedy basin. At its featheredge (zero isopach), it is overlapped by the Winnipeg shale. The sand appears to have originally extended farther because isolated remnants occur in a few wells on the Pierre arch. An erosional episode is believed to have removed the sand from areas east of its present regional limit except in a few downwarped or downfaulted areas. This episode was followed by a rapid advance of the Middle Ordovician sea, during which no sand was deposited. The Winnipeg shale was deposited immediately after this transgression. The overlap creates a regional seal over the Winnipeg Sandstone reservoir.

The Winnipeg shale is a mature petroleum source bed in the northern part of the Williston basin. Maturation and migration probably occurred by Permian time when the Winnipeg was buried beneath about 6,000 ft (1,800 m) of younger beds. Although some of the petroleum migrated upward into the Red River Formation, the underlying Winnipeg Sandstone was an ideal conduit for lateral migration. Documented Winnipeg shows indicate that oil migrated at least as far as Mellette County, South Dakota. One of the shows appears to be a "fossil oil field," indicating that entrapment and accumulation did occur. Isopachs of the Minnelusa to Winnipeg interval indicate preferential directions of lateral migration. Live oil shows suggest the possibility of commercial accumulations.

The Winnipeg Sandstone is thick, porous, and permeable. Depending on local conditions, a Winnipeg oil well might yield up to 500,000 bbl or more. Anticlines located basinward from the regional pinch-out of the Winnipeg Sandstone are the most logical exploration targets. Subsurface mapping and interpretation of aerial photographs and Landsat images suggest several large structures capable of containing major oil fields.

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Mid-Tertiary Conglomerate Deposition and Structural Implications, Southwestern Wind River Range, Wyoming

Study of a granule-to-boulder conglomerate of probable middle to late Eocene age provides evidence that the last pulse of uplift of the Wind River Range occurred along a fault or fault zone within the crystalline core of the range. The conglomerate is preserved on the northeast side of the Continental fault between Tabernacle Butte on the west and Horsetrack anticline on the east. It overlies rocks of the Bridger Formation (Eocene), locally overlies Precambrian crystalline rocks, and appears to be overlain by lower Miocene strata.

The conglomerate consists of numerous coarse pebbles, cobbles, and boulders floating in a matrix ranging from coarse sand to granules. Many of the nonequidimensional pebbles and cobbles are imbricated and isolated, suggesting current scour on the upstream side of the pebbles, and are oriented with their long axes between transverse and longitudinal positions, indicating later reworking of orientations developed during initial high velocity flows. Thus, fabric indicates deposition in a fluvial system having highly variable current velocities.

Distributary paleocurrent patterns, proximity to a major uplift, and the presence of large boulders suggest deposition on alluvial fans. These alluvial fans were characterized by deposition of moderately to poorly sorted coarse sand to boulder-size material in a braided stream environment. Although the conglomerate is matrix supported, deposition by fluvial processes is indicated by well-defined stratification, lenticularity of bedding, common scour surfaces, local cross-stratification, channel fills ranging up to 31 m (102 ft) wide, and fabric as noted above. Evidence of mass flows is very rare in this unit.

Composition of pebbles and cobbles in the conglomerate is quite variable, indicating both the complex Precambrian geology and the erosion of Precambrian units within the core of the range as well as those exposed locally. The large amount of finer sediments (sand and granules) in the conglomerate at exposures near the Precambrian paleohighs suggests, at least in part, a distal source. Mapping of other Eocene sedimentary deposits in the Big Sandy Opening area suggests the presence of fluvial tributaries well within the crystalline core of the range. These characteristics suggest a middle or late Eocene pulse of uplift within the core of the range resulting in incision of tributary systems into the Precambrian rocks of the southwestern margin of the Wind River Range. A decrease in stream gradient at the southwestern limit of the uplifted crystalline rocks resulted in deposition of much of this core-derived sediment on basin-margin alluvial fans. This system was probably morphologically similar to but smaller in scale than, the modern Kosi fan system of northeastern India.

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Facies, Fabrics, and Porosity of Selected Pre-Permian Rocks in Williston Basin, North Dakota

Cores of pre-Permian rocks presented include most major carbonate depositional facies, fabrics, and porosity types, as well as a terrigenous-clastic delta and barrier island complex. Stratigraphic units discussed span the Tippecanoe to Absaroka sequences. Formations and intervals included are the Tyler, Mission Canyon, Ratcliffe, Frobisher-Alida, Bakken, "Sanish," Birdbear, Duperow, Winnipegosis, Ashern, and Interlake. All of these units, except the Ashern Formation, have produced substantial amounts of hydrocarbons, and cores show different facies, fabrics, and porosity types associated with them.

Facies and fabrics vary considerably both interformationally and intraformationally throughout the presented pre-Permian sequences. Depositional facies represented in the rocks include subtidal, intertidal and supratidal deposits from both the marine and transitional marine (deltaic and barrier island) depositional environments. The most common carbonate lithofacies are mudstones, wackestones, and packstones, although boundstones and grainstones are also present. The most common terrigenous clastic lithofacies are shales, silty mudstones, and both mature and immature sandstones. Notable facies include evaporites (both shallow and deep water), stromatoporoids, ostracodal limestones, and thin coal beds. Significant sedimentary structures include burrows, flat pebble intraclasts, desiccation cracks, birdseye structures, cone-in-cone structures, compaction slickensides, and collapse breccias.

Porosity types common to all, except the Ashern, Bakken, and Tyler, are intercrystal, interparticle, moldic, vuggy, and breccia. Significant porosity in the Sanish, Ashern, and Bakken formations is from fractures, whereas in the Tyler, interparticle porosity dominates.

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Geothermal Development and Problems in South Dakota

Geothermal applications in South Dakota have been ongoing on a small scale since the early 1950s with a few additions in the 1960s. The real surge developed as a result of the oil embargo in 1973 and the efforts of ERDA and DOE. South Dakota started its first study in 1975.

Application of hot water has focused primarily on the Madison Limestone as the main source of water due to wells already in the aquifer and some history from oil tests. Three feasibility studies and four demonstration projects have been funded by the federal government and one by the state government. In addition, three privately funded projects have begun. All but one project are for space heating of buildings, primarily state and municipal. The other project is for grain drying.

To date, corrosion is the largest single problem, followed closely by scaling, and disposal of the spent fluid. Because of the quality of most of the waters tested to date, the disposal has been limited primarily to dumping into reservoirs from which it is used for irrigation or other conventional uses.

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