of about 6.2 mi (10 km). Backsliding has occurred on some listric thrust faults, and middle Tertiary(?) extensional horst-and-graben faults offset or join most thrust faults. On the east, the lead thrust ramps up onto the broad open Purcell anticlinorium. On the west, the Libby thrust belt is overridden in the north by the lead thrust of the Yaak plate (whose central part is the broad, open Sylvanite anticline), and in the south, it is overridden by the Moyie thrust (which trends northwest and also overrides the west edge of the Yaak plate).

An essentially continuous section, 46,000 ft (14,021 m) thick, of Belt rocks is displayed on the south-plunging Sylvanite anticline. The base is not exposed, and the top is eroded. A section of similar thickness exists on the west flank of the Purcell anticlinorium, where the Belt Supergroup is overlain by about 3,000 ft (914 m) of Cambrian rock. The Cambrian occurs in the broad synclinal Libby trough that is paired with the Purcell anticlinorium, and these Cambrian strata are also caught up in the Libby thrust belt.

Geologic cross sections suggest that the Belt rocks have overridden the Cambrian at shallow depths only and that Cambrian and younger Phanerozoic strata probably do not occur at greater depths beneath and west of the Purcell anticlinorium. This interpretation differs significantly from interpretations that suggest intercalation of major wedges of Paleozoic and Belt rocks at depth in this same area.

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Carbon Isotope Variation in Mid-Continent "Ordovician-Type" Oils: Relationship to a Major Middle Ordovician Carbon Isotope Shift

"Ordovician-type" oils are found throughout the Mid-Continent and are characterized by strong odd-carbon predominance in the n-C_{11} to n-C_{19} alkanes, and relatively small amounts of branched and cyclic, and higher molecular weight normal (> n-C_{19}) alkanes. Detailed organic geochemical comparisons of these oils with extracts of potential source rocks show that in the Forest City basin of northeastern Kansas and southeastern Nebraska, oil source rocks are Middle Ordovician shales of the Simpson Group. For the Keota Dome field, Washington County, Iowa, the oil source rock is the Middle Ordovician Glenwood Shale Member of the Platteville Formation.

Analyses of saturated and aromatic hydrocarbon fractions of "Ordovician-type" oils from the Forest City basin, Keota Dome field, and the Michigan basin show that $\delta^{13}C$ of the two fractions are similar and that δ^{13} varies over a considerable range, from −32.5 per mil to −25.5 per mil (PDB). This large range in $\delta^{13}C$ reflects a major shift in the carbon isotope composition of organic matter during the Middle Ordovician. This shift is shown in a 62.5-ft (19 m) interval of core from the Decorah and Platteville Formations in the E. M. Greene 1 well in Washington County, Iowa, where organic carbon $\delta^{13}C$ changes regularly upward from −32.2 per mil to −22.7 per mil (PDB). The change in organic carbon $\delta^{13}C$ in this core is not related to variations in amount (0.13-41.4% TOC) or type (hydrogen index = 69 to 1,000 mg HC/g TOC) of the marginally mature (T_{max} = 440 ± 5°C) organic matter. "Ordovician-type" oils in both the Forest City and Michigan basins show variable $\delta^{13}C$, suggesting that the $\delta^{13}C$ shift displayed in the Middle Ordovician rocks of southeastern Iowa is a regional and possibly a global effect, related to changes in the $\delta^{13}C$ of the ocean-atmosphere carbon reservoir. Isotopic analyses of coexisting carbonate minerals support this interpretation.

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Source of Triassic Thaynes Hydrocarbons in Idaho-Wyoming-Utah Thrust Belt

Hydrocarbons have been tested or produced from the Triassic Thaynes Formation in at least four fields in the Overthrust belt. The source of these hydrocarbons has been a subject of speculation and research. Gas chromatographic analyses of Thaynes Formation hydrocarbons and pyrolitic analyses of rocks of the Thaynes Formation were done in an attempt to establish the source of hydrocarbon liquids produced from the formation in the Overthrust belt.

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Regional Trends in Porosity and Permeability of J Sandstone in Denver Basin—Controls of Burial History

The Lower Cretaceous J sandstone is the principal reservoir for oil and gas in the Denver basin of Colorado, Wyoming, and Nebraska. Net pay of the J sandstone depends strongly on sandstone depositional environments, but other important aspects of reservoir quality reflect the burial history. Most notable of these are porosity, permeability, depth, and degree of thermal maturation (as indicated by vitrinite reflectance). An understanding of the regional interrelationships between these variables is important in predicting reservoir quality and in estimating undiscovered petroleum resources in the Denver basin.

Statistical treatment of the core analysis and well-log data from 134 widespread boreholes across the basin, for which the U.S. Geological Survey has core, reveal the following. (1) Thermal maturity increases exponentially with depth, indicating increased temperature with burial. (2) Porosity decreases linearly with increasing R_0 and depth. The presence of authigenic clays and carbonate cements are important to porosity reduction. In many examples across the basin, however, quartz pressure solution and precipitation processes are the main causes of porosity reduction, and these phenomena may be temperature-limited. (3) Permeability decreases exponentially with increasing depth. The permeability data exhibit more scatter than porosity, indicating a less direct relationship to depth and reflecting the effects of both porosity loss and increased surface area of the pore network. Authigenic clays, especially ordered illite-smectite, control the specific surface area of the pore network in the J sandstone.

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Development of Structure and Porosity at Medicine Lake Field, Northeastern Montana, Williston Basin

Medicine Lake field produces oil from the Mississippian Charles, Devonian Winnipegosis, Silurian Interlake, and Ordovician Stony Mountain and Red River Formations. Drill-stem tests also show a potential for production from the Devonian Birdbear and Duperow Formations. Noncommercial quantities of oil were recovered from the Mississippian Mission Canyon Limestone and Ordovician Winnipeg Formation. Different combinations of bioclastic bank development, dolomitization, solution, and fracturing have contributed to the porosity of each of the producing formations. Porosity development in the Winnipegosis and Red River Formations may have been influenced by the Medicine Lake paleostructure.

The Medicine Lake structure is slightly elliptical, 1 mi (1.6 km) in diameter, and has 125 ft (38 m) of structural closure at the top of the Red River Formation. Growth of the structure was essentially complete by the end of Devonian time. On another structure at nearby Outlook field, structural movement can be shown to have continued into the Cenozoic.

The configuration of Cambrian and Precambrian rocks at Medicine Lake suggests that the structure there formed by the compaction of Cambrian sediments deposited around a hill on the Precambrian land surface. Regional-scale southeast-plunging anticlines in the eastern Montana Williston basin may also have formed by compaction of Cambrian sediments on a differentially eroded Precambrian land surface.

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Petroleum Potential of Western Washington and Oregon

An interpretive geologic history for western Washington and Oregon based on recent plate-tectonic theories suggests that there is a significant potential for large petroleum accumulations in an area that is very sparsely drilled.

If, as many workers think, the early Tertiary edge of the continent was marked by a subduction zone in the vicinity of the present-day Cascade Mountains, then the trench associated with that subduction zone could have been the site of deposition of reservoir-quality turbidites as well as petroleum source beds. The present-day Coast Range basalts, which were probably an oceanic (spreading?) ridge, apparently were in place to provide the western barrier for a sediment trap and may also have encouraged an anoxic environment. A suite of coarse-grained, nonmarine to deltaic arkoses (the Puget Group of Washington) was available to be dumped into the trench as fan-type reservoirs. Thermal maturity may have been achieved by heat flow from the ridge and/or the Cascades, and depth of burial. Numerous, apparently large, structures have been mapped and several unconformities have been defined on the surface and in the subsurface.

The area of greatest potential poses some problems, such as glacial and volcanic cover and very sparse subsurface control, but there are enough oil and gas shows to suggest that a focused program, emphasizing the search for reservoir facies, may well prove successful in this classic frontier province.

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Largest Exposed Anticline in Denver Basin Area: Model for Mountain-Front Subthrust Structures

More than 1,000 ft (305 m) of four-way closure exists on the doubly plunging Red anticline, which is exposed at the eastern front of the Wet Mountains, Colorado. This anticline is the only one with large closure exposed in the Denver basin area. The Precambrian basement, intermittently exposed through the overlying Pennsylvanian Fountain Formation, is folded concentrically with the overlying Paleozoic and Mesozoic section, as shown by structure contours and cross sections. The anticline is steeply asymmetric to the west, toward the mountains, and the east flank dips 10° eastward toward the Denver basin. The anticline is exposed in an 18-mi-long (29-km-long) window in the Wet Mountains thrust, and it plunges northwest and southeast under the window's edges.

Recent seismic work on the Rampart Range thrust along the southeastern flank of the Front Range, north of the Wet Mountain, permits about 6 mi (10 km) of overhang and allows an underlying structure similar to the 5 mi wide (8 km) Red anticline. The trace of the Rampart Range thrust plunges north and south from its midpoint at Monument, Colorado, and may reflect the double plunge of such a subthrust anticline.

In both the Wet Mountains and the southeastern Front Range, a system of normal faults is present about 6 mi (10 km) west of the mountain front. These faults probably are listric, and their downthrown west blocks probably collapsed down the west side of an anticline below the thrust.

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Depositional Environments and Diagenesis of Mississippian Midale Beds, Midale Field Area, Williston Basin, Southeastern Saskatchewan

The Midale oil field in southeastern Saskatchewan lies on the northeastern flank of the Williston basin. Oil occurs mainly in Mississippian strata that dip south-southwestward and are truncated progressively northward by a Late Mississippian–Early Jurassic erosion surface.

The reservoir is in the Midale beds, a suite of carbonates and evaporites that was deposited during several transgressive-regressive episodes in a shallow shelf environment.

The Midale beds produce predominately from the Midale carbonate, which is divided into three zones. The lower zone represents a restricted, possibly lagoonal environment in which moderate energy conditions occurred intermittently; the middle zone formed in a transgressive, moderate to high-energy shoal environment; and the upper zone carbonate originated in restricted subtidal conditions. Oil reservoirs are coarsely crystalline vuggy dolomite and fractured, bioturbated calcareous dolomite of the middle and upper zones, respectively.

Diagenesis resulted in the formation of various stratigraphic traps. Early syntaxially cemented crinoid banks form local reservoirs. Fieldwide leached intercrystalline porosity and microfractures are the economically most significant porosity types. Based on the knowledge of local depositional environments, diagenesis, structural contours, and isopach maps, it is possible to high grade reservoir predictability.

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Seismic Evaluation of Hanna Basin and Implications for Regional Structure

The Hanna basin is a deep, nearly circular, intermontane basin covering 2,600 km^2 (1,000 mi^2) in Carbon and Albany Counties in south-central Wyoming. The average elevation of the basin floor is 2,150 m (7,000 ft) above mean sea level. The Hanna basin is one of the deepest structural basins in the Rocky Mountains. It contains as much as 10,800 m (35,000 ft) of sediments beginning with the Cambrian Flathead Sandstone, but the majority of the rocks are Cretaceous and Tertiary in age. The Hanna basin is surrounded by Laramide mountain ranges or uplifts: the Sweetwater arch (Seminoe and Shirley Mountains and Bennet and Freezeout Hills) on the north, the Rawlins uplift on the west, and the Medicine Bow Mountains on the south. The eastern boundary is more poorly delineated—Simpson Ridge, a small northeast-southwest-trending anticline, separates the Hanna basin from the smaller Carbon basin, which in turn is separated from the Laramie basin by the Medicine Bow anticline. The Hanna basin provides an uplift-basin couplet in which both overthrusting, at the northwest end, and largely vertical uplift at the northeast end exist almost side by side. It is proposed that, with Hanna basin is a pivot point, the extent of overhang for Rocky Mountain foreland uplifts generally increases to the north and west whereas more vertical movement dominates to the south and east. The change in structural style may be due to the rotation of the Colorado Plateau block and a thickening of the crust toward the craton. Many different types of structures are to be encountered and expected around the Hanna basin owing to the anisotropy of the basement, the sedimentary cover, and the structural forces responsible for their deformation.

The Hanna basins full hydrocarbon potential has not been realized. Several small fields are present around the basin, but deep tests are rare, especially toward the center of the basin.

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Facies Control on Oil Production From Upper Member of Permo-Pennsylvanian Minnelusa Formation, Powder River Basin, Wyoming

Lateral and vertical facies variations within the predominantly eolian upper member of the Minnelusa Formation control both the regional reservoir distribution and the localization of oil-producing trends.

Sands sourced by northeasterly trade winds were deposited in a land area bounded on the west by the Lusk embayment, which was a shallow, restricted extension of the Permo-Pennsylvanian sea. This embayment was present throughout Minnelusa deposition, and was located in the western portion of the present-day Powder River basin. Another extension of the epeiric sea, located in western South Dakota, formed the eastern boundary of the land area. In the northern part of this area, an inland sand-sea developed; in the southern part, the sand supply was less and isolated barchan dunes migrated over a coastal sabkha. Dune sandstones are bounded laterally by predominantly sandy interdune deposits in the north and by coastal interdune deposits, including sandstone, dolomite, and anhydrite, in the south. Major marine transgressions deposited laterally extensive dolomites that separate the dune sandstones.

Interdune deposits constitute permeability barriers adjacent to dune sandstones. The dune sandstones, which can be of excellent reservoir quality, were subjected to early cementation by anhydrite. Later dissolution of the anhydrite cement, facilitated by good to excellent sorting and possibly enhanced by hydrocarbon migration, led to development of significant secondary porosity. Interdune sandstones are less well sorted and so did not develop good secondary porosity. Interdune carbonates and evaporites have virtually no permeability. The coastal interdune deposits in the southern part of the region, therefore, form more effective lateral permeability barriers than do the sand-dominated interdune deposits in the north.

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Structurally Controlled Sediment Distribution Patterns and Their Relationship to Uranium Deposits in Jurassic Morrison Formation, Northwestern New Mexico

Structures that were active in the Jurassic, inferred from isopleth and structure contour maps, significantly affected depositional patterns in the Westwater Canyon Member of the Morrison Formation in the south-