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 southern San Juan basin, northwestern New Mexico. Isopleth maps illustrate geometry of the major depositional units, distribution of sandstone depocenters, and large-scale lithofacies variations within the units. A reconstruction of topography at the base of the Westwater Canyon Member shows a series of subparallel paleotopographic lows and highs that trend east-southeast. The Westwater Canyon is thick and sandy along paleotopographic lows, but is thin and less sandy over the paleotopographic highs. These relationships suggest active structural control of sedimentary facies along east-southeast-oriented folds or faults by differential subsidence during deposition of the unit. Locally, east-southeast-oriented basement faults that were episodically reactivated since the Precambrian may be detected by detailed seismic reflection studies.

Depositional patterns and lithofacies distribution, in turn, appear to have controlled the location of uranium deposits. Primary and remnant uranium ore in the Westwater Canyon is restricted to east-southeast-trending depocenters defined by anomalously thick and sandy facies with relatively high sandstone:mudstone ratios. Redistributed ore is also localized in anomalously thick zones of the Westwater Canyon with relatively low sandstone:mudstone ratios.

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Plate Tectonics of Ancestral Rocky Mountains

The Ancestral Rocky Mountains were intracratonic block uplifts that formed in Colorado and the surrounding region during Pennsylvanian time. Their development related to the collision-suturing of North America with South America–Africa, which also resulted in the Ouachita-Marathon orogeny. During Early Pennsylvanian time, suturing was taking place only in the Ouachita region, and foreland deformation took place largely in the Mid-Continent. By Middle Pennsylvanian time, the length of the suture zone had increased, and it was active from the Ouachita to the Marathon region. At this same time, deformation of the craton also increased in intensity and in areal extent, culminating in the Ancestral Rocky Mountains. By Late Pennsylvanian time, suturing was taking place only in the Marathon region, and cratonic deformation decreased areally, spreading southward into New Mexico and west Texas and west into the Cordillera miogeocline. The Ancestral Rocky Mountains, and related features over a broad area of the western United States were formed while an irregularly bounded peninsula of the craton (including the transcontinental arch) was pushed northward and northwestward by the progressive collision-suturing of North America and South America–Africa. This intraplate deformation is, in some respects, similar to the deformation of Asia in response to the Cenozoic collision with India.

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Paleotectonic, Stratigraphic, and Diagenetic History of Weber Sandstone, Rangely Area, Colorado

Rangely field is in Rio Blanco County, Colorado, on a doubly plunging anticline of Laramide age. The Rangely structure is asymmetrical with the steepest flank to the southwest. The Permo-Pennsylvanian Weber Sandstone is the primary producing formation with cumulative production exceeding 670 million bbl of oil. The Weber is a subarkosic arenite deposited in an eolian regime. It interfingers with the alluvial Maroon Formation in the southern and southeastern portions of Rangely field. Isopach maps of the Pennsylvanian formations suggest a paleotectonic platform in the Rangely area and a Permo-Pennsylvanian north-south-trending arch west of the Laramide-age Douglas Creek arch. Hydrocarbons migrated into the Rangely area prior to the Laramide orogeny and were stratigraphically trapped at the Weber-Maroon transition zone. Subsequent Laramide structure localized and hydrocarbon accumulation.

Diagenetic history of the Weber Sandstone differs between the Uinta and Piceance basins. Weber diagenesis in the Uinta basin is dominated by silica precipitation and porosity appears to be residual primary. Weber diagenesis in the Piceance basin includes dissolution of detrital material and precipitation of a complex sequence of carbonate cements. Weber porosity in the Piceance basin appears to be both residual primary and secondary. The boundary between these two diagenetic regimes appears to coincide with the Pennsylvanian paleoarch.

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Potential Exploration Targets for Roxby Downs–Olympic Dam Type Mineral Deposits

The Olympic Dam deposit near Roxby Downs, central South Australia, appears to be another type of sediment-hosted stratabound ore deposit. It contains copper, gold, silver, uranium, and rare earths, and in terms of present market prices, is valued at over $100 billion, making it one of the world's most valuable deposits. When brought on line in 1988, the projected production of 4,000 tons/year of U_3O_8 as a by-product will have a significant impact on the world uranium market.

The deposit is hosted in middle Proterozoic rocks in a deep, small basin within the Gawler craton, and is overlain by 350 m (1,148 ft) of unmineralized late Proterozoic miogeoclinical Adelaidean sediments on the Stuart shelf. The nearest host rocks are no closer than 150 km (93 mi). According to Western Mining Corporation, the discovery resulted from regional considerations, with target selection being decided by nearly superimposed gravity and magnetic highs identified from detailed geophysical studies.

The present study is a synthesis and integration of large amounts of geological, geophysical, and geochemical data available from the South Australian Department of Mines and Energy, mining companies, and universities. The presence of a probable analog deposit at Mt. Painter, approximately 270 km (168 mi) east-northeast of Olympic Dam, available for field study and sampling, makes possible the testing of ideas and hypotheses. The exposed Gawler craton and surface and drill core samples from Mt. Painter have supplied materials for further study.

Plate tectonic reconstructions of the Gawler craton make it possible to apply Olympic Dam genetic models to other continents. The present study undertakes this application to the United States resulting in several areas being interesting targets.

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Fossil Basin and its Relationship to Absaroka Thrust System, Wyoming and Utah

The Fossil basin of southwestern Wyoming and adjacent north-central Utah is a Late Cretaceous–early Tertiary depositional basin formed largely on the hanging wall of the Absaroka thrust system. The basin is divided into the northern Fossil basin and the southern Fossil basin by the cross-basinal, northwest-southeast-trending Little Muddy Creek transverse ramp, which appears to be related to a lateral change in the stratigraphic position of the Absaroka thrust fault in both hanging wall and footwall rocks. The Absaroka thrust sheet is characterized by distinctly different structural styles north and south of this transverse ramp.

North of the ramp the Late Cretaceous–early Tertiary northern Fossil basin lies between the toe of the Absaroka thrust on the east and the Rock Creek anticline on the west. The basin was created by movement on, and erosion, of the Absaroka thrust sheet in pre-late Campanian-Maestrichtian time. Exploratory drilling has not as yet found significant oil and gas reserves in the northern Fossil basin even though Ordovician Bighorn Dolomite on the hanging wall of the Absaroka thrust has been juxtaposed with Cretaceous source beds in the footwall.

South of the transverse ramp the Late Cretaceous–early Tertiary southern Fossil basin lies between the toe of the Absaroka thrust system on the east and structure created on the hanging wall of the Medicine Butte thrust on the west. Within the southern Fossil basin, Cambrian through lower Upper Cretaceous rocks within the Absaroka thrust sheet are in fault contact with organic-rich Lower Cretaceous (on the west) and lower Upper Cretaceous (on the east) source rocks in the footwall. Essentially all oil and gas production established to date has been found in the southern Fossil basin in three lines of folding in the Absaroka thrust hanging wall. The westerly two lines of folding produce from Paleozoic and, locally, Mesozoic objectives, and the easterly folding produces from Mesozoic objectives. Exploratory and development drilling permits better interpretation of timing of thrust motion and subsurface structural geometry in the Fossil basin area.

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Parautochthonous Core-Thrusted Kink Folds and Chronologic Sequence of Thrusting, La Barge Platform, Sublette County, Wyoming