subsidence in the foreland basin, (5) the disjunct history of subsidence and subsequent uplift of the Colorado-Wyoming-Utah (CWU) region beyond the foreland basin, and (6) the initial stability and subsequent subsidence of the High Plains region.

During normal subduction, thin-skinned crustal deformation was continuous opposite the convergent margin. During the ensuing period of low-angle subduction, the Colorado Plateau region was underpinned by subducted lithosphere, anomalous subsidence occurred in the CWU locus, and deformation was transferred to the position of greatest contrast in mechanical properties of the crust (the eastern and northern boundaries of the plateau). Decoupling of subducted lithosphere from overlying lithosphere caused uplift and erosional stripping of the CWU region, crustal flexure to the east, and sediment accumulation on the High Plains.

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Appropriate Stratigraphic Nomenclature for Coal Reservoirs in Piceance Basin, Colorado

Coal-bearing intervals occurring within the Upper Cretaceous Mesaverde Group in the Piceance basin have been described by various authors. The most current and widely accepted work has the Sego, Corcoran, Cozzette, and Rollins Sandstone Members comprising the Iles Formation. The overlying Williams Fork Formation is divided into the basal Bowie Shale Member and Paonia Shale Member, with the upper remaining section undifferentiated.

Coal seams associated with the Iles Formation belong to the Black Diamond coal group. The Fairfield coal group and the South Canon coal group are part of the Bowie Shale Member. These two coal groups, continuous throughout the basin, are also called the Sommerset coals in the Sommerset coal field and the Cameo coal measures in the Grand Mesa coal field. Although priority of nomenclature dictates otherwise, established usage of the "Cameo coals" for coal seams in the Bowie Shale Member should be continued as the most appropriate nomenclature.

The basal coal seam of the proposed Cameo coal group is laterally continuous throughout the Piceance basin. A second coal seam 40-120 ft (12-37 m) above the basal coal also has large areal extent. Both coal seams, as existing and potential future pay zones, are of significant economic importance and should, in ascending order, be classified as the Cameo coal A and D seams.

The coal seams in the Paonia Shale Member, extremely variable in thickness, continuity, and quality, have been established as the Coal Ridge coal group.

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Paleogeographic and Sedimentologic Significance of Mississippian Sequence at Mt. Darby, Wyoming

Mississippian strata at Mt. Darby comprise the Madison Group and the overlying Humbug Formation. This sequence, although initially transgressive, exhibits an overall regressive character produced by progradation of platform carbonates in response to sea level fluctuations related to Antler orogenic events.

The Paine Member of the Lodgepole Limestone, the basal formation of the Madison Group, consists of relatively deep-water carbonates including a possible Waulsortian-type carbonate bank that accumulated on a Kinderhookian foreslope. At least five shoaling-upward grainstone cycles are recognizable in the Woodhurst Member of the Lodgepole Limestone. These cycles record Osagean deposition in shallow agitated environments that developed high on a clinoform ramp. Shelf-margin and platform carbonates dominate the Mission Canyon Limestone, the upper formation of the Madison Group. This unit consists of two asymmetric depositional cycles, each with a thick regressive phase, capped by an evaporite solution breccia and an overlying thin transgressive phase.

The Humbug Formation, a sequence of fine-grained carbonates and sandstones, represents part of a deltaic complex that developed offshore from the Meramecian karst plain. Humbug sediments were transported northward to the Mt. Darby area from the area of the present Uinta Mountains, or another deltaic system formed there. Deposition in the study area was apparently continuous upward from the Madison carbonates into the Humbug. The middle Meramecian shoreline trended northwest between the present locations of Mt. Darby and Haystack Peak.

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Stratigraphy and Depositional Environments of Middle Member of Minnelusa Formation, Central Powder River Basin, Wyoming

Regional correlations, from the southern to northern Black Hills and across the central Powder River basin to the Bighorn Mountains, serve as the frame work for a depositional model of middle Minnelusa sediments. In the eastern part of the study area, deposition took place in a carbonate sabkha environment. During transgressive periods, most of this region was covered by a restricted shallow sea. In the northern Black Hills, close to the limit of the transgression, deposition occurred in a coastal dune setting. During regressions, the sabkha prograded westward toward the Lusk embayment. Coastal dune fields to the north and isolated dune complexes to the south migrated southwestward across this prograding sabkha. West of the Lusk embayment, deposition occurred in a sand-dominated tidal-flat environment during transgressions and along the coastal edge of an eolian sand sea during regression.

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Burial History of Upper Cretaceous and Tertiary Rocks Interpreted from Vitrinite Reflectance, Northern Green River Basin, Wyoming

The burial history of Upper Cretaceous and Tertiary rocks in the northern Green River basin is difficult to reconstruct for three reasons: (1) most of these rocks do not crop out, (2) there are few stratigraphic markers in the subsurface, and (3) regional uplift beginning during the Pliocene caused erosion that removed most upper Tertiary rocks. To understand better the burial and thermal history of the basin, published vitrinite reflectance (R_o) data from three wells were compared to TTI (time-temperature index) maturation units calculated from Lopatin reconstructions. For each well, burial reconstructions were made as follows. Maximum depth of burial was first estimated by stratigraphic and structural evidence and by extrapolation to a paleosurface intercept of R_o = 0.2%. This burial was completed by early Oligocene (35 Ma), after which there was no net deposition. The present geothermal gradient in each well was used because there is no geologic evidence for elevated paleotemperature gradients.

Using these reconstructions, calculated TTI units agreed with measured R_o values when minor adjustments were made to the estimated burial depths. Reconstructed maximum burials were deeper than present by 2,500-3,000 ft (762-914 m) in the Pacific Creek area, by 4,000-4,500 ft (1,219-1,372 m) in the Pinedale area, and by 0-1,000 ft (0-305 m) in the Merna area. However, at Pinedale, geologic evidence can only account for about 3,000 ft (914 m) of additional burial. This discrepancy is explained by isoreflectance lines, which parallel the Pinedale anticline and indicate that approximately 2,000 ft (610 m) of structural relief occurred after maximum burial. In other parts of the basin, isoreflectance lines also reveal significant structural deformation after maximum burial during early Oligocene to early Pliocene time.

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Conditional Simulation: Geostatistical Tool Applied to Athabasca Oil-Sands Deposit

Geostatistical modeling of reservoir variability in the Athabasca oil-sands deposit prior to either surface or in-situ mining can provide valuable information to guide the extraction process. Geologic and engineering characteristics (variables), such as elevations of bitumen-saturated and waste (barren) zones, and percentage bitumen saturation, porosity, and permeability, have a controlling effect on recovery methods.

Each geologic variable is considered to be a particular realization of a random function defined within a geologic domain. This function can be inferred from available data (boreholes) under the hypothesis of stationarity. Other realizations (models) of the same random function can then be generated using the technique of conditional simulation, which is

a combination of kriging and simulated correlated variables. The statistical models of geologic variables so produced are in conformity with the histogram, variogram, and actual data values, and most important, they mimic spatial variability between sampled locations.

The key factor in geologic applications of geostatistics is the translation of geologic reality into mathematical abstraction. Each random statistical function is a function of the physical processes that produced the deposit, which processes in turn varied in both space and time. The deposit under study has been divided into seven domains based on the best available geologic model, and different random functions established for each variable in each domain.

Three-dimensional models describing the spatial fluctuation of elevations and bitumen saturations were produced and stored as grids having 25 m (82 ft) vertical and 1 m (3 ft) horizontal resolution. These models will be used to develop strategies for mine planning.

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C^{13}-Rich Diagenetic Carbonates Associated with Heavy-Oil Deposits

The isotopic composition of secondary calcites in 120 samples from biodegraded heavy-oil deposits of the Lower Cretaceous Mannville Group of Alberta ranged in $\delta^{13}C$ from -1.3 to $+14.1$ ‰ PDB. The calcites postdate oil emplacement and are anomalously enriched in C^{13} in comparison with common sedimentary and diagenetic carbonates associated with conventional oil pools and authigenic carbonates of other shallow Cretaceous sediments of Alberta. In contrast to previously reported occurrences of heavy carbonates (Moneray Formation, Kimeridge Clay of Dorset, Caspian syncline), the heavy-oil calcites are not related to organic-rich clayey sediments and no coexisting low ^{13}C-carbonates were found. The API gravities of the biodegraded oil correlate with the $\delta^{13}C$ values of the carbonate, suggesting a relationship between the biodegradation process and C^{13}- enriched cements. Different isotopic systematics were observed in 25 samples from other heavy-oil deposits (Indonesia, Malagasy, Brazil, Sicily, Zaire, California, Kentucky, Utah) whose $\delta^{13}C$ ratios ranged from -21.6 ‰ to $+1.1$ ‰ PDB.

An explanation may involve oxidation of the paraffinic oil components by microorganisms producing alcohols, organic acids, and ketones. A change to anoxic conditions causes fermentation of these biodegradation products, leading to the formation of ^{13}C-rich CO_2, which precipitates as heavy carbonate. If anoxic conditions are not achieved, oxidation will persist and lead to the formation of light carbonate cements.

The detection and understanding of the formation mechanism of anomalously heavy carbonates can be useful in both future exploration strategy and exploitation of heavy oil deposits, particularly to enhanced recovery schemes based on CO_2 flooding.

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Regional Aquifers and Petroleum in Williston Basin Region of United States

At least five major aquifers underlie the northern Great Plains of the United States, which includes parts of the Williston basin in Montana and North Dakota. These aquifers form a hydrologic system that extends more than 960 km from recharge areas in the Rocky Mountains to discharge areas in eastern North Dakota and the Canadian Provinces of Manitoba and Saskatchewan. The regional flow system in the aquifers has had a major effect on the chemical composition of ground water within the Williston basin. Hydrodynamic forces may contribute to the accumulation of petroleum within the basin.

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Application of Principal Axis Ordination (Q-Mode Analysis) in Classification of Depositional Environments of Morrow (Upper Carboniferous) Strata in Southeastern Colorado

A variation of Q-mode analysis, termed "principal axis ordination," is evaluated as a tool for classifying depositional environments from well log data. The stratigraphic interval investigated is in the upper Morrow (Upper Carboniferous) of the Las Animas arch region in southeastern Colorado. Variables derived from digital induction and gamma-ray log data are used for classification based on principal axis ordination (PAO). The resulting classes closely match a set of inferred sedimentary environments in wells from a densely drilled area. These results allow the PAO classification technique to be extended to wells in sparsely drilled areas as a reliable aid in predicting reservior trends.

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Geologic Analysis System—Oil and Gas Exploration and Research Applications

The Geologic Analysis System is an applications software package designed to integrate and display geologic data used in petroleum exploration and research. The Geologic Analysis System contains two components: (1) a file management system (TECH/SYS) that builds, edits, merges, and extracts data for geologic applications, and (2) applications programs including a geologic mapping and contouring system (PICS), cross section and fence diagram programs, a time-temperature index (TTI) model, a stratigraphic report graphic (SRG), paleontological and geochemical displays, a sample data-display module (SDS), and a variety of multivariate statistical routines.

The Geologic Analysis System has been under development since 1977 when the U.S. Geological Survey assumed responsibility for the National Petroleum Reserve (NPR) exploration program in Alaska. The Geologic Analysis System represents the application of techniques developed during the NPR program for use with data collected by geologists throughout the United States. In cooperation with Petroleum Information Corporation, files of well data, base maps, lithology, petroleum geochemistry, and paleontology have been constructed and analyzed using applications software.

Geologic Analysis System utility is demonstrated using the following examples: (1) a contoured well-data map, cross section, and fence diagram from the Paradox basin, (2) SRG summaries from the San Juan basin, (3) SDS-generated ternary diagrams and downhole plots of petrographic data, (4) C_1-C_7 hydrocarbon and headspace-gas displays from Alaska, and (5) species abundance versus depth plots.

System benefits to the geologist include (1) publication- or report-ready graphic displays, (2) file manipulation to optimize data analysis, and (3) graphically and statistically displayed data from cores, measured sections, and well cuttings that objectively characterize the exploration potential of a stratigraphic sequence.

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Mechanism for Enhanced Reservoir Porosity Generation in Tripolitic Chert

Tripolitic chert is present in many Rocky Mountain basins. In the Green River basin, enhanced porosity in tripolitic chert comprises a significant portion of the porosity in the Ericson Sandstone. Prediction of enhanced reservoir porosity within tripolitic chert is dependent on understanding the mechanism for creation of this porosity. Dissolution experiments were performed on selected chert samples to determine the causal mechanism.

Chert samples used in the dissolution experiments were from the Phosphoria Formation in the Overthrust belt. Paleocurrent directions and the presence of sponge spicules and apatite in the Ericson cherts all indicate a Phosphoria source within the thrust belt for much of the Ericson chert. Both acid-treated and untreated chert fragments were placed in organic acid solutions. Results of the experiments show it is the 25-30% carbonate fraction within the chert that dissolves to create tripolitic chert. Silica solubility was not affected by the organic acids.

The opportunity to dissolve calcite and dolomite within detrital chert fragments exists at several times during progressive burial. Depending on the fluid chemistry, carbonate could be dissolved by an early pulse of organic acids generated prior to hydrocarbon migration. This would be