mation. The Uncompahgre uplift established an initial ancestral pattern of northwest-trending anticlinal structures. These propagated northeastward throughout the Uinta and Piceance basins as a result of compression during the Pennsylvanian Period. Planes of weakness were imprinted vertically along the axes of these folds and subsequently affected the overlying Mesozoic sediments. Next, the Uinta uplift reenforced these northwest-trending folds and planes of weakness during the early Laramide orogeny. The third stage of formation involves contemporaneous deposition of Eocene sediments, including the kerogen of the Green River Formation. Differential compaction during diagenesis, over the northwest-trending residual highs formulated subperpendicular, localized tensile stresses. Vertical fractures propagated rapidly in an en echelon fashion along the imprinted axial planes of weakness. In the fourth stage of formation, fractures penetrated overlying reservoir intervals, which contained various combinations of liquid hydrocarbons and connate water. Released fluids entered the low-pressure voids and spread laterally and vertically throughout the Eocene sediments. A final period of inspissation and/or metamorphosis quickly altered the various liquid hydrocarbon deposits to form gilsonite and other bitumens.

The variation of these bitumens is dependent on the original chemical composition of the individual reservoir zones during deposition.

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Regional Lithostratigraphy of Permian Phosphoria Formation, Western Overthrust Belt

A regional synthesis of the lithostratigraphic relationships for the Permian Phosphoria Formation illustrates the cyclic lithofacies types, carbonate reservoir, and potential organic facies for the western Overthrust belt of Wyoming, Idaho, and Utah. Palinspastically restored subsurface control sections (70) and measured outcrop sections (35) indicate a complex, intertonguing, transgressive-regressive sequence of shallow-water carbonates, clastics, and highly organic phosphatic mudstone deposited in a shallow marine shelf-margin environment. Distribution of facies types was affected by paleostructural growth of late Paleozoic structural elements including the Sublette basin of Utah and Bannock highs of western Wyoming-southeastern Idaho. These highs helped define the Wyoming shelf-margin slope. Identification of paleostructural growth is based on interpretation of depositional environments and thickness patterns of the Permian deposits.

The Phosphoria Formation and the equivalent beds of the Park City Formation are divisible into two main depositional cycles—the Meade Peak-Franson Members and the Retort-Ervay Members—based on the regional correlation network generated for the Overthrust belt. Carbonate deposition and reservoir development occurred during maximum transgressive stages, whereas deposition of phosphorite and organic shales occurred during maximum regressive stages. The reservoir facies is closely associated with early diagenetic dolomitization of carbonate shelf deposits concentrated along paleostructural high areas of the shelf-margin environment.

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Influence of Tectonic Terranes Adjacent to Precambrian Wyoming Province of Petroleum Source and Reservoir Rock Stratigraphy in Northern Rocky Mountain Region

The perimeter of the Archean Precambrian Wyoming province can be generally defined. A Proterozoic suture belt separates the province from the Archean Superior province to the east. The western margin of the Precambrian rocks lies under the western Overthrust belt, but the Precambrian province extends at least as far west as southwest Montana and southeast Idaho. The province is bounded on the north and south by more regionally extensive Proterozoic mobile belts. In the northern belt, Archean rocks have been remobilized by Proterozoic tectonic events, but the southern belt does not appear to contain rocks as old as Archean. The tectonic response of these Precambrian terranes to cratonic and continental margin vertical and horizontal forces has exerted a profound influence on Phanerozoic sedimentation and stratigraphic facies distributions. Petroleum source rock and reservoir rock stratigraphy of the Northern Rocky Mountain region has been correlated with this structural history. In particular, the Devonian, Permian, and Jurassic sedimentation patterns can be shown to have been influenced by articulation among the different terranes comprising the ancient substructure. Depositional patterns in the Chester-Morrow carbonate and clastic sequence in the Central Montana trough are also related to this substructure. Further, a correlation between these tectonic terranes and the localization of regional hydrocarbon accumulations has been observed and has been useful in basin analyses for exploration planning.

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Implications to Exploration of Porosity Relationships and Paragenetic Sequences, Jurassic Navajo (Nugget) Sandstone, Utah and Southwestern Wyoming

We have studied in outcrop and in the subsurface the reservoir characteristics and diagenesis of the Early Jurassic, eolian, Navajo (Nugget) Sandstone in Utah and southwestern Wyoming. Principal topics include: texture, framework constituents, intergranular and intragranular cements, matrix, directional porosity, porosity types, and hydraulic conductivity.

Present characteristics of the sandstone are related to variations in dune and interdune environments, fluctuating ground-water chemistry, and postdepositional environments. Diagenesis, in which an open-system diagenetic model is considered, superimposes and is influenced by these variations and events.

The sandstone was deposited principally in dune and interdune settings. Surface and/or near-surface cementation, mostly by grain overgrowth and calcite from ground-water solutions, consolidated the sediment. Thereafter, the succession was uplifted, eroded, and buried by Middle Jurassic formations. During the Late Jurassic through Eocene, the sandstone was affected by compressional folding and thrust faulting in central and northern Utah and southwestern Wyoming. During the Tertiary, extensional deformation occurred.

Petrographic criteria in thin sections indicate that secondary leached porosity generally is common to dominant in surface, near-surface, and possibly in deep subsurface sequences. Variations in porosity and volume of cements with depth exist and are correlative in all areas studied. Porosity changes with depth, as well as the volume of cements, are the result of downward-decreasing surface leaching of intergranular and intragranular cements, creation of secondary porosity, effects of initial stratification types, and facies changes.

Compaction of the sandstone due to mechanical rearrangement of detrital grains and intergranular pressure solution played little or no role in modification of porosity or hydraulic conductivity. Likely, they account for not more than 5% of the porosity reduction. Greatest porosity reduction (16%) was by cementation. Present mean total porosity is 19%, ranging from 3 to 35%.

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Geothermal Exploration Using Surface Mercury Geochemistry

Shallow soil mercury surveys are an inexpensive and effective exploration tool for geothermal resources. In a geothermal system at depth, mercury is leached from the country rock and transported to the surface by the geothermal fluids. The mercury is fixed by clays and organic material in the soil above the geothermal system and can be detected by analyzing the near-surface soil. Surface mercury surveys can be used in regional reconnaissance to discriminate prospective from nonprospective areas. Closely spaced mercury surveys over individual prospects typically enhance the structural understanding of the prospect and show which structures are important as migration pathways.

The use of probability graphs greatly enhances the interpretation of mercury geochemical data. Probability graphs have a logarithmic ordinate scale versus a cumulative percentage abscissa scale. This graph is arranged such that a typical lognormal population plots as a straight line on the graph. Deviations from a straight line show deviations in the data from a standard lognormal population distribution. The mercury data are easily plotted on the graph and can be evaluated visually. Anomalous and background populations can be separated consistently even when considerable overlap occurs between populations. In Nevada and California, soil mercury surveys have detected up to four distinct mercury populations in one area. These populations are related to background