were previously estimated at 113 billion short tons. This deposit is in the Paleocene Tongue River Member of the Fort Union Formation; overburden ranges from 700 to 2,400 ft (213 to 732 m).

The "Big George" bed was initially outlined using geophysical logs from nearly 300 oil and gas drill holes. More logs were studied in the northern portion of "Big George" and as far north as the Montana state line to examine the entire system of coal beds that includes this thick bed. We interpreted geophysical logs primarily for coal and sandstone, digitized lithologic intervals, and generated strip logs of lithologic sequences using a microcomputer. These computer-generated logs were generated in lines of sections, on matching elevations, to reconstruct the stratigraphic framework of subsurface coal in this part of the Powder River basin.

The framework was used to trace the interval containing the Anderson deposit into the Decker, Montana, and Recluse, Wyoming, areas. This interval appears to be confined by the Smith coal bed above; the bottom of the interval is less well defined. Lithologic patterns of the framework suggest that a major fluvial channel system defined part of the northwestern boundary of the "Big George" coal bed. The locations of these channels may have been controlled primarily by Laramide deformation in the Powder River basin.

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Stratigraphic Controls on Duperow Production in Williston Basin, Montana and North Dakota

There are presently over 200 wells in Montana and North Dakota that produce from, or have indicated pay, behind pipe in the Duperow Formation. Production is primarily confined to the basin center, decreasing greatly as the shallower rim of the basin is approached. There is no production from the Duperow Formation in the Canadian portion of the Williston basin.

Production in the Duperow Formation is primarily from dolomitized stromatoporoid-assemblage patch reefs that occur in the lower unit of the formation. Published work by others concisely defines the stratigraphy, paleontology, and facies subdivisions within the Duperow Formation. The formation consists of series of distinctive shoaling-upward carbonate sequences, and contains cyclic or repetitious bedding characteristic of the formation.

There appear to be three types of traps in the Duperow Formation reservoirs in the Williston basin. The structural type is most common on the Nesson anticline. The structural-stratigraphic type is the most common trap found in the Billings nose area. The unconformity-stratigraphic type is uncommon and found only at Seven Mile and Ollie fields in Montana.

The growth of stromatoporoid bioherms appears to have been influenced by tectonic activity. Many structurally positive areas, such as the Billings nose and the Nesson anticline in North Dakota and the Poplar dome and Sweetgrass arch in Montana, have stromatoporoid biohermal accumulations. These areas, probably slight topographic expressions during Duperow deposition, apparently offered optimum growth position for framework builders.

A stromatoporoid bioherm is interpreted to be the reservoir at Ridgelawn field, Montana. Eight wells appear to be capable of production from the basal portion of cycle 3. The wells appear to define a patch reef that is oriented northwest-southeast and is perhaps 1-1.5 mi (1.6-2.4 km) in its longest dimension.

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Source-Potential Rating Index—Evaluation of Bakken Formation

The Bakken Formation, an organic-rich, oil-prone unit, is the source of the crude oils found in the middle Bakken and overlying Madison Group. Thickness, organic carbon, and vitrinite reflectance data for the Bakken were gathered from 101 wells within the Williston basin and evaluated in terms of source potential.

An index exists that combines sediment thickness, organic carbon content, and thermal maturity data into a single mappable parameter that indicates areas of potential hydrocarbon generation. Multiplying the average percent organic carbon by the effective source rock thickness of a formation yields a richness factor that is then multiplied by maturity scaling factors to give source potential ratings for oil and/or gas generation. By using burial-history curves and thermal-maturation modeling, the rating index can be used to look at source potential through geologic time. The Bakken Formation has been evaluated with the aid of the rating index.

The source-potential rating index provides objective semiquantitative measures by which the source potential of a single formation can be compared within an area or the source potential of two or more formations can be compared within the same or different basins. The Bakken did not begin to reach high source potential until toward the end of the Late Cretaceous. This contrasts with previous authorities who believed the Bakken was at peak generation and expelling hydrocarbons throughout the Cretaceous.

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Depositional Environments, Diagenesis, and Hydrocarbon Potential of Nonmarine Upper Cretaceous and Lower Tertiary rocks, Eastern Uinta Basin, Utah

Core studies of nonmarine rocks from the Natural Buttes field, Utah, indicate that depositional environment and diagenetic alteration control the geometry and quality of low-permeability gas reservoirs in the eastern part of the Uinta basin. The Tuscher Formation (Upper Cretaceous) is composed of fine to medium-grained, moderately to well-sorted sandstones and less abundant carbonaceous and coaly shale that formed on the lower part of an alluvial braidplain. The Wasatch Formation (Paleocene and Eocene) unconformably overlies Cretaceous rocks and consists of fine-grained lenticular cross-bedded sandstones, argillaceous siltstones, and variegated mudstones, which were deposited in lower delta-plain settings along the margin of Lake Uinta. Cretaceous and Tertiary sandstones have been modified by minor quartz overgrowths, by the precipitation and subsequent dissolution of ferroan and nonferroan calcite, by poikilotopic anhydrite, and by the formation of authigenic illite, mixed-layer illite-smectite, kaolinite, chlorite, and corrensite. Most authigenic carbonate and anhydrite formed during early burial, before significant compaction. During later stages of diagenesis, precipitation of authigenic clay in secondary pores created by carbonate dissolution reduced porosity and permeability. Large amounts of natural gas generated in situ are stratigraphically trapped in these lenticular, diagenetically modified sandstones. Source rocks in the Tuscher Formation have reached the advanced stages of thermogenic gas generation (0.7% R_o) but are only moderately mature with respect to liquid hydrocarbon generation. Interbeds of lacustrine Green River shale are in the early stages of gas generation (0.5% R_o) and are source rocks for gas produced from the Wasatch Formation.

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Origin and Distribution of Fractures in Tertiary and Cretaceous Rocks, Piceance Basin, Colorado, and Their Relation to Hydrocarbon Occurrence

Gas production in the lower Tertiary Wasatch Formation and Upper Cretaceous Mesaverde Group, Piceance basin, Colorado, is controlled by a network of open and partly mineralized natural fractures. These fractures formed in response to high pore-fluid pressures that developed during hydrocarbon generation, and to widespread tectonic stress associated with periods of uplift and erosion that occurred during the late Tertiary. Sandstone beds commonly contain vertical extension fractures that are cemented with fine to coarsely crystalline calcite and locally with quartz, barite, and dickite. These minerals cut detrital grains, authigenic cements, and secondary pores, indicating that fracture mineralization occurred during later stages of diagenesis. Isotopic compositions for fracture-fill calcite in the Wasatch vary from -5.0 ‰ to -11.6 ‰ for $\delta^{13}C$ and from -9.5 ‰ to -14.9 ‰ for $\delta^{18}O$. In the Mesaverde, calcite ranges from -0.7 ‰ to -10.4 ‰ for $\delta^{13}C$ and from -13.3 ‰ to -17.7 ‰ for $\delta^{18}O$. These isotopic data indicate that fractures were mineralized during burial by fluids of meteoric origin, with temperatures that remained fairly constant, or by fluids that circulated at a rate that prohibited significant cooling. The wide range in $\delta^{13}C$ compositions reflects mixtures of organically derived carbon and dissolved marine carbonate. In reservoir rocks that are extensively fractured, gas generated in situ from carbonaceous and coaly shales and tongues of lacustrine rock may have migrated locally along open faults and fractures.

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Electric Utilities' Stake in Applied Coal Geoscience

Representing 85% of domestic coal consumption, electric utilities are burning more coal under stricter environmental regulations than ever before. Their stake in the application of coal geoscience and related disciplines is urgent and ranges from national issues to local fuel management practices. At a national level, the availability and price of Appalachian low-sulfur coal are critical unresolved questions. Uncertainties in resources in-place are compounded by uncertainties in recoverability, marketability, and transportation. In the face of acid deposition legislation, utility fuel and compliance strategies are influenced by these considerations and a host of other utility-specific factors, none of which are well understood. Day-to-day fuel management practices call for increased attention to coal quality, reliability, variability, and performance in efforts to reduce electricity-generation costs, but the necessary information is rarely available. The role of applied coal geoscience, properly integrated with other disciplines, is enormous and will yield benefits to both coal producers and utilities.

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Seismic-Stratigraphic Analysis of Lanyard–Lost Creek Field Area, Denver Basin, Colorado: Application to Exploration and Field Delineation

The Lanyard and Lost Creek fields are located on the eastern flank of the Denver basin in Weld County, Colorado. Production is from the "D" sandstone interval of the Dakota Group (lower Upper Cretaceous). Combined cumulative production from both fields is in excess of 3.5 million bbl of oil and 6.7 bcf gas. Both fields are currently under secondary recovery operations.

The "D" sandstone in this area is believed to have been deposited within a channel system as part of a westward-prograding coastal plain. In places, the productive channel is no more than 1,000 ft (305 m) wide. The "D" sandstone ranges in thickness from less than 10 ft (3 m) outside of the channel to as much as 40 ft (12 m) within the channel.

An analysis of a detailed seismic grid across these fields reveals a consistent relationship between a seismic-stratigraphic anomaly and the occurrence of thick "D" sandstone. This analysis is supported by a series of seismic models based on known geologic conditions.

Depending upon localized geologic conditions, the seismic signature of a thick "D" sandstone varies across the Denver basin. However, an integrated geologic-geophysical approach can be used for the delineation of field limits as well as support for explanatory prospects or prospect leads.

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Petroleum Source Rock Potential and Crude Oil Correlation in Great Basin

Petroleum source beds in the Great Basin region include marine Paleozoic rocks and nonmarine upper Mesozoic and lower Cenozoic rocks. Potential source beds have been identified in continental-rise deposits of the Ordovician Vinini and Devonian Woodruff formations in the eastern part of the Roberts Mountains allochthon (Antler orogene), in central and north-central Nevada; in flysch-trough and prodelta-basin deposits of the Mississippian Chainman Shale and equivalent rocks of the Antler foreland basin, in Nevada and western Utah; and in lake-basin deposits of the Cretaceous Neward Canyon Formation and the Paleogene Sheep Pass and Elko formations and equivalent rocks, in central and eastern Nevada. Oil fields in the Great Basin are located within Neogene-Quaternary basins that formed during Neogene basin-range block faulting. Most of the oil shows and crude oils analyzed can be correlated with Mississippian or Paleogene source rocks. The Mississippian Chainman Shale is confirmed as the major petroleum source rock, having generated the oil in the Trap Spring, Bacon Flat, and Grant Canyon fields in Railroad Valley and the Blackburn field in Pine Valley. The Paleogene Sheep Pass Formation is the source of the oil in the Eagle Springs field and probably the Current field in Railroad Valley. Oil occurrences in the northern Great Basin are believed to be derived from two or more other Tertiary lacustrine sequences.

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Exploration Applications of a Transgressive Tidal Flats Model to Mississippian Midale Carbonates, Eastern Williston Basin

Midale (Mississippian) production was first established in 1953 in Saskatchewan, Canada. The unit was initially defined in the subsurface as the carbonate interval between the top of the Frobisher Anhydrite and the base of the Midale Anhydrite. That nomenclature is used in this report. During 1953, Midale production was found in the United States portion of the Williston basin in Bottineau County, North Dakota. Later exploration extended Midale production westward into Burke County, North Dakota. Cumulative production from the Midale is approximately 660 million bbl, of which 640 million bbl are from Canadian fields.

Initially, hydrocarbon entrapment in the Midale was believed to be controlled by the Mississippian subcrop, with the Burke County production controlled by low-relief structural closure. Petrographic examination of cores and cuttings from the Midale in both Saskatchewan, Canada, and Burke and Bottineau Counties, North Dakota, indicates that production is controlled by facies changes within the unit. Stratigraphic traps are formed by the lateral and vertical changes from grain-supported facies deposited in tidal channel, subtidal bar, or beach settings; seals are formed by mud-rich sediments. Use of a transgressive carbonate tidal flats model best explains current production patterns and indicates substantial potential for additional production in eastern North Dakota and South Dakota.

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Absaroka Thrust Exploration Plays in Wyoming-Utah-Idaho Thrust Belt

The magnitude of undiscovered onshore oil and gas resources on Federal lands in the United States is an important resource appraisal question that remains unanswered. A new U.S. Geological Survey project to assess the resource potential of these lands relies on play analysis as its method of assessment.

The first result of this project is the delineation of two plays in the Wyoming-Utah-Idaho thrust belt province: the Absaroka Paleozoic (western line of folding) and Mesozoic (eastern line of folding) plays. The two plays are aligned northeast-southwest along two subparallel anticlinal trends formed during emplacement of the Absaroka thrust. Nine fields discovered in the Absaroka Paleozoic play produce sour gas and condensate from Paleozoic carbonate reservoirs in thrust folds in the hanging wall of the Absaroka thrust. Hydrocarbons in this play are believed to be derived from Cretaceous source rocks in the footwall of the thrust. In contrast, 14 fields discovered in the Absaroka Mesozoic play produce mainly oil and sweet gas from Mesozoic clastic reservoirs in thrust folds in the hanging wall of the same thrust. Hydrocarbons in the Mesozoic play are also believed to have been generated from the same Cretaceous source rocks in the Absaroka footwall. The boundary separating the two plays is drawn on the basis of distinct differences of types of hydrocarbons produced, and lithology and age of the producing reservoir.

Preliminary geologic estimates were made of potentially recoverable hydrocarbons from fields in both plays and were based on available field and well data. The estimates were fitted to graphs that show field sizes in millions of barrels of oil equivalent (BOE) by month and year of discovery. The resulting field-size distributions indicate that the largest fields were discovered early in the 10-year exploration period (1975-84) of both plays: Whitney–Carter Creek in the Paleozoic play (1,300 million BOE), and Anschutz Ranch East in the Mesozoic play (1,200 million BOE). It seems likely that future exploratory drilling may discover additional