as a result of strip mining or by erosion and deposition.

The Dilco, Gibson, and Cleary coal deposits are part of an intertonguing sequence of Upper Cretaceous marine and nonmarine deposits consisting principally of fine-grained clastics. Aquifer tests have established a range for the hydrologic parameters of strata in the coal sequence. Chemical quality of the ground water also has been determined.

Natural erosion of the coal deposits generally occurs in the form of mass wasting, sheet wash, and eolian deposition. This material is periodically reworked by ephemeral streams to produce thin valley-fill deposits. Infiltration of runoff into the underlying sediment creates a perched ground-water aquifer that is likely to go dry during periods of limited runoff. These ephemeral aquifers have hydrologic characteristics and water quality similar to the undisturbed coal sequences.

Through conventional reclamation processes, spoil material replaces the original coal sequence. The spoil material has been found to have hydrologic characteristics and water quality similar to the natural coal-bearing deposits and the valley-fill material.

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Geologic Controls of Uranium Mineralization in Tallahassee Creek Uranium District, Fremont County, Colorado

Two important orebodies have been defined by drilling in the Tallahassee Creek uranium district, Fremont County, Colorado. They are the Hansen orebody, which contains about 12 million kg of U_3O_8, and the Picnic Tree orebody, which contains about 1 million kg of U_3O_8. Host rock for the Hansen is the upper Eocene Echo Park Alluvium, and host rock for the Picnic Tree is the lower Oligocene Tallahassee Creek Conglomerate. Average ore grade for both deposits is about 0.08% U_3O_8.

The principal source rock for the uranium in the deposits is the lower Oligocene Wall Mountain Tuff, although a younger volcanic rock, the Oligocene Thirtynine Mile Andesite, and Precambrian granitic rocks probably also contributed some uranium. Leaching and transportation of the uranium occurred in alkaline oxidizing ground water that developed during alteration of the ash in a semiarid Oligocene or early Miocene environment. The uranium was transported to sites where it was deposited in a reducing environment controlled by carbonaceous material and biogenic products such as hydrogen sulfide.

Localization of the ore was controlled by ground-water-flow conditions and by the distribution of organic matter in the host rock. Ground-water flow, which was apparently to the southeast in Echo Park Alluvium that is confined in the Echo Park graben, was impeded by a fault that offsets the southern end of the graben. This fault and attendant displacement prevented efficient discharge into the ancestral Arkansas River drainage, and protected chemically reducing areas from destruction by the influx of excessive amounts of oxidizing ground water. Localization of orebodies in the Echo Park Alluvium may have occurred in areas where overlying rocks of low permeability were breached by erosion during deposition of the fluvial Tallahassee Creek Conglomerate (which overlies the Wall Mountain Tuff), allowing localized entry of uranium-bearing water. Paleohydrologic control in Tallahassee Creek Conglomerate may have been affected by the alteration of pervious ash beds to impervious clay beds.

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Palynological Evidence for Miocene Age of Abiquiu Tuff, North-Central New Mexico

The Abiquiu Tuff crops out at the north end of the Nacimiento uplift and in the western part of the Espanola basin in north-central New Mexico. No paleontologic or radiometric age dates have been published for this unit, but regional correlations based on lithology and stratigraphic position suggest a Miocene age. At the south end of the Nacimiento uplift are extensive outcrops of the Zia sand of early to middle Miocene age based on vertebrate fossils. Between the outcrops of these two units are scattered exposures tentatively identified as Abiquiu(?) formation.

To determine if the Abiquiu Tuff, Zia sand, and Abiquiu(?) formation are stratigraphically equivalent, sections of each were analyzed for pollen content. The Abiquiu Tuff near the village of Abiquiu, the Zia sand at its type locality near Zia Pueblo, and an outcrop in the Nacimiento uplift near Gilman were sampled at 30-ft (9.3 m) intervals. Most samples were barren, but sufficient pollen was recovered to indicate a Miocene age for all of the outcrops. Pollen from the Abiquiu Tuff and Zia sand are similar to pollen from the Miocene Split Rock Formation of Wyoming and Brown's Canyon Formation of Chaffee County, Colorado.

The Zia sand and Abiquiu Tuff are exposed along the west margin of the Rio Grande rift. Extensional faulting that cuts these formations cannot have occurred earlier than late Miocene. The Abiquiu(?) formation at Gilman rests against Precambrian rocks along the Sierrita fault, the major bounding fault between the south part of the Nacimiento uplift and the Rio Grande rift. The juxtaposition of Miocene and Precambrian rocks along this fault indicates that 530 to 685 m of movement associated with rifting and uplift occurred in post-middle Miocene time.

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Preliminary Pore Structure Analysis of Tight Sandstones Using Computer-Processed Photomicrographs

The complexity of pore networks in fine-grained low-permeability sandstones makes accurate modeling of fluid-flow properties difficult owing to the lack of quantitative information concerning the pore structure. Many such sandstones in the Uinta basin, Utah, are reservoirs for large amounts of natural gas. These sandstones, most of which are Tertiary and Cretaceous in age, commonly contain pores that vary greatly in size. Variation in pore size is partly due to the dissolution of mineral grains and pore-filling cement; however, many of the secondary pore spaces contain authigenic clay, principally illite and kaolinite, which has served to create micropore space.

We have developed a method to digitize and quantify pore networks of fine-grained rocks using the apparent pore space observed in photomicrographs of thin sections. By digitizing numerous photographs, statistical data were generated, thereby making it possible to address the problem of pore structure. Pore structure data include such parameters as the pore size and shape, anisotropy of the pore arrangement within the rock matrix, and pore connectivity.

Specimens obtained from CIG Exploration, Inc., Natural Buttes 21 cores (Sec. 15, T10S, R22E) were used to determine pore anisotropies of tight sandstones. Several analysis methods were used; each indicated that little anisotropy was present in the pore structure.

Statistical-shape parameters, derived from the measured perimeters and areas of the pores, suggest that most of the pores within each sample are tabular rather than tubular in shape. Knowledge of the pore structure suggests that the pores should be treated as oblate rather than prolate spheroids in modeling the electromagnetic or fluid-flow properties of these rocks.

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Cretaceous-Tertiary Boundary, San Juan Basin, New Mexico and Colorado

The Cretaceous-Tertiary boundary in the San Juan basin, New Mexico and Colorado, has been variously placed at the base, at the top, and somewhere within the Ojo Alamo Sandstone. New evidence bearing on the location of this boundary includes palynologic analyses, vertebrate paleontology, paleomagnetism, and trace-element analyses.

The Ojo Alamo Sandstone is a series of fluvial, high-energy, braided stream deposits consisting of from one to several conglomeratic sandstone sheets separated by overbank or floodplain shales. The conglomerates contain pebbles and cobbles of quartzite, jasper, and andesite on the west side of the San Juan basin. The pebbles and cobbles diminish in size eastward and are rare to nonexistent on the east side of the basin. There is a major unconformity at the base of the Ojo Alamo.

The Cretaceous-Tertiary boundary, as determined earlier from palynologic criteria, is below the base of the Ojo Alamo Sandstone in the uppermost part of the underlying Kirtland Shale on Mesa Portales. New evidence from the Star Lake area, New Mexico, tends to confirm that boundary location. Other new data based on vertebrate remains, also from the Star Lake area, indicate that the boundary is within the Ojo Alamo Sandstone. Recently published paleomagnetic data and trace element studies now underway may also help in solving the Cretaceous-Tertiary boundary problem.

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Upper Cretaceous Tocito Sandstone Lentil of Mancos Shale, San Juan Basin, New Mexico—Is There Any Oil Left?

The Upper Cretaceous Tocito Sandstone Lentil of the Mancos Shale consists of a series of northwest-trending linear sandstone bodies in the San Juan basin of New Mexico. This sandstone unit, which has produced most of the basin's crude oil (more than 125 million bbl to date), was referred to as the "Gallup" Sandstone for many years. Recent stratigraphic studies of the Tocito by several authors clearly demonstrated that the Tocito Sandstone Lentil is a totally different stratigraphic unit from the Gallup; thus, the Tocito name was reinstated as a lentil of the Mancos Shale. (Actually, the "Tocito" was thought to be part of the Gallup years ago and the Tocito name was dropped in favor of the "Gallup" name.) Even though hundreds of holes drilled to produce natural gas from the deeper Dakota Sandstone have penetrated the Tocito, these holes cannot be thought of as Tocito dry holes because, for many of them, no attempt was made to test the Tocito for its possible oil potential. There is still a good chance that significant amounts of oil remain to be found in the Tocito.

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Facies Distribution and Reservoir Quality of Biogenic Gas Reservoirs of Northern Great Plains—Example From Eagle-Telegraph Creek (Upper Cretaceous) Interval

The quality of reservoirs containing biogenic gas in the northern Great Plains is predictable on the basis of facies distribution. Rocks of the Upper Cretaceous Eagle Sandstone-Telegraph Creek Formation stratigraphic interval include excellent examples of several reservoir types.

Conventional reservoirs of the Eagle Sandstone are restricted to a north-south trending band of coastal sandstones in central Montana. These reservoirs are highly porous and permeable and display evidence of extensive diagenetic alteration. Conventional Eagle reservoirs are exemplified by gas fields in the vicinity of the Bearpaw Mountains, where gas is found in structural traps.

Coarsening-upward sequences of the Shannon Sandstone Member of the Gammon Shale were deposited on a shallow shelf seaward (eastward) of the coastal sandstones. Reservoir quality improves upward through each sequence, and depends upon the distribution and amount of sand accumulation. The Shannon reservoirs are transitional between conventional reservoirs of the Eagle Sandstone and low-permeability (tight) reservoirs in the Gammon Shale. The Liscomb Creek field, in southeastern Montana, produces gas from the Shannon in a structural-stratigraphic trap.

Gas reservoirs in offshore marine mudstones of the Gammon Shale consist of thin, discontinuous lenses and laminae of siltstone enclosed in silty shale. The reservoirs are tight with permeabilities of 0.1 md or less. They have high irreducible water saturations ($>80\%$; however, they produce little free water). The reservoirs are extremely susceptible to formation damage when exposed to water-based fluids used during drilling and hydraulitc fracturing. The Gammon reservoirs have low productivity but volumetrically make up the greatest part of rocks equivalent to the Eagle-Telegraph Creek sediments, and they probably have the greatest potential for reserves of shallow gas in the northern Great Plains. Examples of low-permeability reservoirs include pay zones in the Little Missouri field in southwestern North Dakota and in Gammon-equivalent rocks of the Milk River pool in southeastern Alberta.

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Progress in Modeling Natural Fracture Distributions

Recent interest in the influence of rock fractures on fluid movement through rock has created a need for modeling techniques which can predict fracture geometry, spacing, and opening in large, heterogeneous rock bodies. A suggested approach involves the simultaneous development of (1) a rock body model which represents the distribution of rock physical properties and the boundaries between property domains; (2) an empirical model representing fracture geometry, distribution, and opening for as much of the rock body as is feasible; and (3) a theoretical strain model which allows the strains indicated by the empirical model to be generalized over the body model. The theoretical model is based on the analysis of strain mechanisms during field work for the empirical model. This methodology has been applied to a complex nearshore sedimentary rock sequence in an area having widely spaced basement-rooted faults of the Laramide type. The resulting model was sufficiently powerful to predict acceptably fracture aperture size and spacing in the strata of interest. These predic-