Cutler Formation increases 1,050 ft (320 m) in thickness across the Orvis fault, which had down-to-the-south movement. During the Laramide orogeny, a significant reversal in movement occurred along the fault to cause the north-dipping monocline now present at the surface.

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Geomorphic Applications to Landscape Stability and Surface Coal Mining Reclamation, Northwestern New Mexico

The long-term success of surface coal mining reclamation in the strippable coal belts of northwestern New Mexico is dependent on the relative stability of undisturbed and restored landscapes. Landscape stability is measured by the rate of modification of a landscape component of a given age. Field instrumentation in selected watersheds measures modern rates of modification. Areas of rapid modification, or relative instability, include headwaters of high-relief watersheds and areas of active base-level lowering. Studies of the Quaternary geomorphic history in the coal belts indicate a variety of landscape ages. Relict landscapes of the Pleistocene indicate long-term stability, and many of these landscapes have been preserved by upper Quaternary eolian deposits. These stable landscapes are characterized by high infiltration rates, low sediment yields, low relief, and relatively dense root systems. Landscape classification schemes incorporating modern geomorphic processes and relative landscape ages serve as analogs for reclaimed landscapes.

Evaluating the success of postmining reclamation procedures requires that both internal (within reclaimed areas) and external (outside reclaimed areas) geomorphic variables be considered. Internal geomorphic variables include hillslope gradients and areal configurations, infiltration rates, degree of drainage integration, and surface roughness. External geomorphic variables include base-level changes, arroyo-headcutting rates, valley-fill geometry, and the ratio of bedrock to valley fill. Engineering designs are significant to internal variables, whereas the geomorphic history of a watershed influences the external variables. Research at the McKinley coal mine in northwestern New Mexico suggests that external variables pose the greatest threat to reclaimed landscapes.

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Constraints on Origin of Granitic Uranium-Source Rock, Granite Mountains, Wyoming

The origin of the granite of Lankin Dome from the Granite Mountains is of special interest to uranium geologists because of its spatial association with the large uranium deposits in central Wyoming and because the granite lost more than 5.5×10^{10} kg of uranium at approximately the same time as the surrounding deposits formed. Furthermore, the granite has been shown to be the source of the sediments that host the uranium ores. Thus, recognition of similar granites may lead to the discovery of hidden uranium deposits.

Chemical and radioisotope studies have suggested that the granite of Lankin Dome was derived from a sedimentary protolith. Stable isotope studies support this hypothesis and show that this granite is anomalously enriched in O^{18} relative to other Archean granites in Wyoming. δO^{18} values for the granite of Lankin Dome, the Louis Lake batholith, and the granite of the Owl Creek Mountains are 8.44 ± 0.34 (n = 36), 7.45 ± 0.40 (n = 15), and 7.43 ± 0.17 (n = 4), respectively. Investigations in progress indicate that the northern Laramide Range may be composed of more than one granite, and that at least part of the Archean granite has lower δO^{18} values than the mean observed in the Granite Mountains. Altered rocks within the granite of Lankin Dome are anomalously depleted in O^{18}, which suggests interaction with meteoric waters. The effects of this event on the uranium history are being investigated.

The combined oxygen and chemical data suggest at least a partly pelitic protolith, which was probably enriched in uranium, for the granite of Lankin Dome. By analogy, other crustally derived granites, within an area of general uranium enrichment, may prove to be favorable uranium source rocks.

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Potential for Ground-Water Pollution in New Mexico

Significant contamination of ground water requires, in combination, a source of pollutants, an aquifer which is susceptible to pollution, and geologic pathways capable of conveying contaminants to the aquifer. In New Mexico, major sources include pumping-induced saline intrusion, mill wastewater, septic-tank effluent, and (historically) brine disposal. Leaks, spills, municipal wastewater, animal confinement facilities, mine drainage, and industrial wastewater are locally important. Valley fill alluvium and fractured limestones represent the most vulnerable aquifers. Significant pathways reflect a highly permeable and/or thin vadose zone, or the presence of improperly constructed and abandoned wells which bypass vadose-zone protection. Northwestern and southeastern New Mexico contain most of the areas where sources, vulnerable aquifers, and pathways coexist. Because ground-water flow rates in vulnerable aquifers are generally 70 to 700 ft (21 to 213 m) per year, potential zones of pollution will be small and difficult to monitor. A surprising amount of ground-water monitoring occurs in the state, pursuant to regulatory programs, project evaluations, and scientific research. Monitoring can be improved through: (1) coordination of monitoring activity (especially among government agencies); (2) more focus on characterizing the pollutant sources; (3) measurements which define the hydrogeologic flow system in the immediate vicinity of the source; (4) reliance on indicator parameters rather than on comprehensive testing of water quality; and (5) much better quality control of the field sampling and laboratory analysis of ground water.

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Paleontology of "Fossil Forest," Interesting Late Cretaceous Fossil Assemblage, San Juan Basin, New Mexico

The Fruitland Formation in the region of the Bisti badlands contains a diverse and abundant fossil flora and fauna of Late Cretaceous age. Potential development of the substantial Fruitland Formation coal reserves has led to a cooperative investigation of a Fruitland "fossil forest" by the New Mexico Bureau of Mines and Mineral Resources and the U.S. Bureau of Land Management.

Within the fossil forest study area, at least 21 m of uppermost Fruitland strata are exposed. These contain at least two, and possibly three, levels of in-situ tree stumps, fallen logs up to 20 m long, and several leaf localities. Preliminary analysis indicates the presence of *Taxodium, Sequoia,* and palm. Pollen analysis will be conducted.

Fossil mammals, including multituberculates, marsupials, and insectivores, have been found at two sites in clay-pebble conglomerates, associated with freshwater fish, some sharks, amphibians, turtles, lizards, and dinosaurs. The mammals are represented by isolated teeth, jaw fragments, and the first reported postcranial elements from the San Juan basin.

Elsewhere in the area, channel sands and mudstones have produced a large assemblage of turtles, lizards, crocodiles, and dinosaurs. We have identified ankylosaurs, hadrosaurs, ceratopsians, and carnosaurs.

There are at least three stratigraphic levels of mollusk-rich beds containing bivalves, gastropods, and numerous gastropod opercula.

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Geology and Stratigraphy of Late Cretaceous "Fossil Forest" near Split Lip Flats, San Juan Basin, New Mexico

A paleontologic inventory contracted by the U.S. Bureau of Land Management (BLM) reported an interesting "fossil forest" in the region of Split Lip Flats, south of Farmington, New Mexico. The potential for coal development has led to a joint geologic investigation by the New Mexico Bureau of Mines and Mineral Resources and the BLM.

Numerous measured sections were made in the fossil forest study area. The exposed sequences consist of interbedded shales, siltstones, channel sandstones, carbonaceous shales, and coal; coal crops out only at the base of the sections. Virtually all the beds are laterally discontinuous except over short distances. The coal and carbonaceous shales have greater lateral extent; two continuous but slightly undulatory carbonaceous shales were identified and used as stratigraphic marker beds. Approximately 26 m of sediments is exposed, most of which are in the Fruitland Formation. In some sections, the uppermost 5 m is probably part of the lower shale member of the Kirtland Formation. Correlations of these sequences with those near Hunter Wash, 10 mi (16 km) west-northwest, is attempted.

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Overthrust and Disturbed Belt of West-Central Montana—Implications for Hydrocarbon Exploration

The Overthrust Belt of west-central Montana consists of a zone of Laramide (Late Cretaceous–early Tertiary) convex-eastward thrusts and folds that include the major Eldorado-Lombard overthrust that has brought Precambrian Belt rocks eastward over Paleozoic and Mesozoic strata. East of and structurally below the Eldorado-Lombard overthrust is the Disturbed Belt with deformed rocks ranging in age from middle Precambrian (Proterozoic or Y) to early Tertiary.

The Disturbed Belt here forms a salient that extends eastward into the foreland and is bounded on the north by thrusts having a left-lateral component of movement and on the south by folds characterized by right-lateral shift. Deformation is most intense in the western part of the Disturbed Belt and dies out eastward where gentle folds merge with structures of the Rocky Mountain foreland. This salient appears to be underlain by an eastward-yielding decollement fault that merges with tear thrusts on the north and dies out in the subsurface beneath the folds marking the eastern and southern margins of the Disturbed Belt. Deformation resulted from piling up of imbricate thrusts and folds where the major Eldorado-Lombard overthrust sheet of the Cordilleran orogen moved upward and onto the foreland margin. Thus, the strata of the Disturbed Belt have been crumpled and deformed independently of the basement rocks, with crustal shortening above the decollement.

Hydrocarbon exploration in this area should be guided by the tectonic features. Thrusts in the western part of the Disturbed Belt have displacements of several miles and may conceal structures beneath the thrusts, but in the eastern part of the area have smaller displacements and probably do not conceal major structures below. Some anticlines are broken by subsidiary thrusts, resulting in offset axial surfaces at depth. Also, many folds have inclined axial surfaces and the fold aces therefore will migrate with depth.

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Mobility of Uraniun and Other Elements During Alteration of Air-Fall Ash to Montmorillonite: Case Study

An unusual occurrence of juxtaposed glassy and clay-altered ash was sampled to determine the extent of element mobility during glass diagenesis. The results are particularly interesting in that major mobilization of uranium is indicated. Closely spaced samples of glassy and clay-altered ash were collected from the same 20 to 50-cm-thick stratum in the Troublesome Formation (Miocene) of northwestern Colorado. Sharp contacts present between glassy ash and underlying pink montmorillonite may indicate water-saturated conditions restricted to basal ash layers or deposition in a body of water that dried up during the course of the eruption. Formation of montmorillonite instead of zeolites indicates that the water was not highly alkaline or saline. Multielement analysis of glassy and clay-altered samples indicates three things. (1) Montmorillonite has 85 to 90% less uranium than the coexisting glass; similarly depleted elements include Cs, Rb, Na, and K; much smaller depletions of these elements in some glassy samples serve as particularly sensitive indicators of incipient alteration of this type. (2) The abundances of relatively insoluble elements such as Th or Ta are slightly higher (5 to 40%) in clay-altered ash and serve as indicators of the maximum levels of element enrichment in residual material; greater enrichment of elements such as Sc, Sr, and Co indicate adsorptive uptake by clay or by secondary oxides of iron and manganese. (3) The rare earth element (REE) patterns and abundances in glass are sufficiently mimicked by detritus-free montmorillonite to document the original compositional equivalency of the two.

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