shales of the Morrison Formation may have served as "source rocks" for the humate in uranium-bearing sandstones of the Westwater Canyon Member and Poison Canyon sandstone (of economic usage). This hypothesis provides a convenient, local source for the humic substances associated with tabular ore, as the K shales are interspersed with, and the Brushy Basin Member immediately overlies, the ore-bearing sandstones. The reduced nature of these claystones and mudstones suggests that organic matter incorporated during sedimentation would have been initially preserved in the pore waters of lake-bottom sediments. The diagenetic alteration of volcanic ash contained in these sediments would have raised the pH of the pore water, causing solution of humic substances. Subsequent compaction would have forced the alkaline, humic-rich pore fluids out of the claystones and mudstones, into the nearby sandstones.

The two stages of ore in the Grants mineral belt—the primary tabular or trend ore and the secondary redistributed or stacked ore—can be related to the hydrology of a compacting basin. During early burial, formation water moves generally upward and laterally toward basin margins. Meanwhile, fresh meteoric water flows downdip from recharge areas that flank the basin. A similar early-burial hydrology is envisioned for the formation of tabular ore in the San Juan basin. In this case, humic substances, derived from pore waters expelled from the greenish-gray mudstones and claystones, moved into sandstone beds that served as escape conduits for formation water. When these alkaline formation waters encountered fresh meteoric water, the pH was lowered, facilitating organo-clay reactions that resulted in precipitation of humate. The meteoric water also delivered uranium to the humate masses; the uranium probably had been leached by ground water moving through the sandstone beds.

Sometime after compaction ceased, the basin achieved hydrologic unity, and water flowed from areas of recharge to areas of discharge deeper in the basin. Redistribution of ore into stacked or roll-type orebodies probably occurred during this time, destroying some preexisting tabular humate ores. Redox mechanisms were involved in this redistribution of uranium into rolls but not in the formation of the earlier tabular ores. Location of tabular ores within reduced ground and the association with humate indicates that uranium in these orebodies was fixed by organic materials, which does not necessarily involve redox processes.

WEBB, JOHN CHARLES, AGAT Consultants, Inc., Denver, CO

Petrology and Potential Sources of Uranium in Tertiary Rocks, Logan County, Northeastern Colorado

Chemical analyses of < 0.15-mm (< 100 mesh) fractions from Holocene stream sediment in Chimney and Spring Canyons in Logan County, northeastern Colorado, reveal values of uranium in excess of the regional background (3.8 ppm). These values reach a maxima of 60.2 ppm U. Chimney Canyon sediment ranges from 4.4 to 5.5 ppm U, and is composed of volcanic glass, quartz, and minor amounts of plagioclase, calcite, mica, and mixed-layer illite-smectite. Heavy minerals are rare and consist mainly of biotite and hornblende. Spring Canyon sediment ranges from 3.7 to 60.2 ppm U and is composed of quartz, potassium, and plagioclase feldspar, calcite, mica, and mixed-layer illite-smectite. Heavy minerals are common and include ilmenite, magnetite, hornblende, epidote, and zircon.

Content of uranium in samples of bedrock from the Brule, Arikaree, and Ogallala Formations ranges from 1.8 to 16.3 ppm U, and varies according to the composition of the detrital fraction and the amount and type of cement. Poorly cemented arkose and vitric siltstone contain between 1.8 to 2.9 ppm and 4.0 to 5.7 ppm U respectively. Bedrock cemented by micrite contains from 6.3 to 9.1 ppm U and silicified bedrock contains between 12.1 and 16.3 U.

Petrographic studies reveal that initial deposition of the bedrock was followed by: (1) mechanical infiltration of clay, bioturbation, and precipitation of mixed-layer illite-smectite; (2) precipitation of sparry calcite or micrite; (3) dissolution of framework grains, including volcanic glass; (4) destruction of mixed-layer illite-smectite and the development of caliche structures; and (5) precipitation of opal-CT and chalcedony.

Mica fission-track maps show that uranium is homogeneously distributed within micrite, opal-CT, and chalcedony cements. Fission-track density indicates that opal and chalcedony contain more uranium than micrite. Sparry calcite cement contains no uranium.

Four major conclusions result. (1) The content of uranium in Holocene stream sediment is related to the detrital composition of the parent bedrock. Uranium in the Chimney Canyon sediment occurs in volcanic glass, which is derived from tuffaceous siltstone of the Brule Formation, whereas the uranium in Spring Canyon sediment is contained in heavy minerals, which are derived from the Ogallala Formation. (2) Uranium in the bedrock is contained in volcanic glass, heavy minerals (mainly zircon, iron-titanium oxides, and monazite), and in cements of micrite, opal, and chalcedony. (3) Uranium in micrite, opal, and chalcedony is derived from intrastratal dissolution of volcanic glass. Volcanic glass is also the source for silica precipitated as opal or chalcedony. (4) The postdepositional alterations observed in this study represent the earliest stages of mobilization of uranium required for the development of an epigenetic deposit.

WEIMER, PAUL C., Sohio Petroleum Co., San Francisco, CA

Upper Cretaceous Stratigraphy and Tectonic History of Ridgway Area, Northern San Juan Mountains, Colorado

Detailed mapping and stratigraphic studies in the Ridgway area, along the northern flank of the San Juan Mountains in Colorado, indicate that the lower Mancos Group (Upper Cretaceous) can be subdivided into four formations. From oldest to youngest, they are the Benton Formation, Juana Lopez, Sage Breaks Shale, and Niobrara Formation. These formations have lithologic and paleontologic content similar to their equivalents in the Denver and San Juan basins and Black Hills.

The underlying Benton Formation consists of 470 ft (143 m) of black shale that includes the Greenhorn Limestone Member (12 ft or 3.5 m thick) lying 300 ft (91 m) above the base. The overlying Juana Lopez is 40 ft (12 m) thick and consists of alternating layers of calcareous siltstone and black shale. The succeeding Sage Breaks is a 155-ft (47 m) calcareous shale unit. The overlying Niobrara Formation is an 85-ft (26 m) resistant, cliff-forming, calcareous shale.

Subsurface and outcrop data in the south indicate that the study area straddles the margin of the Pennsylvanian Uncompahgre uplift. Structural evolution has been controlled largely by three east-west trending Precambrian fault blocks—the Ouray graben, the Orvis block, and the Uncompahgre block. Recurrent movement of these fault blocks from the Paleozoic through the Cenozoic affected both sediment thickness and facies distribution. A cross section restored to the base of the Dolores Formation (Upper Triassic) indicates that the Permian

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.

WELLS, STEPHEN G., and ROSE DEVON, Univ. New Mexico, Albuquerque, NM

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.

WENNER, D. B., Univ. Georgia, Athens, GA, J. S. STUCKLESS, U.S. Geol. Survey, Denver, CO, and K. K. CHANG, Univ. Georgia, Athens, GA

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.

WILSON, LEE, Santa Fe, NM

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.

WOLBERG, DONALD L., New Mexico Bur. Mines and Mineral Resources, Socorro, NM, and J. KEITH RIGBY, JR., U.S. Bur. Land Management, Albuquerque, NM

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 upper-