pre-200-m.y.B.P. formation of the evaporite minerals and stability of the rocks since that time.

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Tertiary Mineralization in Part of Grants Mineral Belt, New Mexico

Mineralization in the Grants mineral belt, except for minor occurrences of secondary minerals, is commonly attributed to several distinct periods: (a) early epigenetic (Late Jurassic), (b) early redistributed (middle Cretaceous), or (c) late redistributed (Laramide). Previous geochronologic studies have supported the geologic data favoring these periods of mineralization. More recent geologic studies indicate post-Laramide mineralization, although the source for the uranium may well have been from an older, destroyed deposit as opposed to an entirely new supply of uraniferous solutions. Work on clay minerals formed penecontemporaneously with uranium mineralization at the Silver Spur Mine (host rocks, Dakota) and the Doris Mine (host rocks, Morrison) yield Rb-Sr isochron ages of 41 ± 9 m.y.B.P. with initial Sr(87/86) = 0.715 ± 0.001 and 44 ± 7 m.y.B.P. with initial Sr(87/86) = 0.724 ± 0.001. These clay minerals formed in the presence of fairly radiogenic $^{87}Sr$ as Sr(87/86) from pre-ore, host-rock calcites yields 0.709 ± 0.001; thus simple, in-situ rehomogenization of Sr isotopes did not occur. Further, at least two other suspected occurrences of Tertiary mineralization in the Churchrock district do not yield isochrons at all, but the preceding Rb-Sr data plot references 135, 120, and 90 m.y.B.P. isochrons with initial Sr(87/86) = 0.710. These data suggest incomplete rehomogenization of Sr isotopes during the Tertiary. At present the data suggest, but do not prove, a period of Tertiary mineralization in the Grants mineral belt at about 35 to 50 m.y.B.P.

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Uranium in Permian Cutler Formation, Lisbon Valley, San Juan County, Utah

The Cutler Formation is composed predominantly of fluvial arkosic sandstones, siltstones, shales, and mudstones deposited by meandering streams that flowed across a flood plain and tidal flat. Sedimentary structures indicate two types of channel deposits: meandering and distributary. The area was occasionally transgressed by a shallow sea from the west, resulting in the deposition of several thin limestones and marine sandstones. The marine sandstones were deposited as longshore bars. Wind transported sand along the shoreline of the shallow sea, forming a coastal dune field. Marine and eolian sandstones are more common in the upper part of the Cutler Formation in the southern part of the area, whereas in the central and northern part the formation is predominantly fluvial. Cross-bed orientation indicates that streams flowed S67°W on the average, whereas longshore marine currents moved sediment S36°E and N24°W, and onshore wind transported sand S80°E.

The uranium in the Cutler Formation is found in the central and northern part of the area, in the upper part of the formation, in fluvial sandstone bodies that were deposited in a distributary environment. No uranium is known in the marine or eolian sandstones. Petrographically, the uranium-bearing sandstones are identical to other Cutler fluvial sandstones except that they contain less calcite cement and more clay and are slightly coarser grained. The diagenetic sequence indicates that uranium and vanadium were introduced late in the sequence, after oxidation had formed hematite and before the formation of calcite cement. Ore formation has modified the host sandstones very little.

The uranium and vanadium minerals are finely disseminated and thus difficult to identify but seem to include some uraninite, coffinite, uranophane, and carnotite. Much of the uranium is associated with iron oxide grain coatings and matrix. The uranium and vanadium are present together and independently. Both calcium and iron are depleted, and barium is concentrated in the ore zone. No significant organic carbon was found in the ore zones, and small amounts of selenium are concentrated at the base of the ore zones.

Formation of these orebodies has occurred without any obvious reductant. Perhaps sorption of uranyl by hematite was the concentration mechanism. The time of formation is not known; evidence is present for both a Permian age and a Triassic or younger age.

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Stratigraphy and Depositional History of Thousand Pockets Tongue of Page Sandstone and Crystal Creek Member of Carmel Formation (Middle Jurassic), Southwestern Utah

Between the East Kaibab monocline and Zion National Park in southwestern Utah, gray, cliff-forming, cross-bedded quartz sandstone of the Thousand Pockets Tongue of the Page Sandstone grades northwestward into red, slope-forming, flat-bedded quartz sandstone of the Crystal Creek Member of the Carmel Formation. On the basis of stratigraphic position, both members are considered Bathonian in age. Coastal deposits of the Thousand Pockets Tongue prograded northwestward and interfingered with contemporaneous submarine deposits of the Crystal Creek Member along a northeast-southwest trending shoreline of the Middle Jurassic seaway.

The Thousand Pockets Tongue is divided into three parts characterized by distinct sedimentary features and paleoenvironments. The gray lower part contains cross-bedded eolian sandstones (cross-bedded sandstone facies) which grade into evenly laminated and cross-bedded beach sandstones (Round Valley Draw facies). The red middle part is characterized by flat laminations, echinodern fragments, and a distribution which suggest a lagoon/tidal-flat environment. In the gray upper part, cross-bedded sandstones of eolian origin (Paria Canyon facies) grade into evenly laminated and cross-bedded beach sandstones (yellow sandstone ledge facies) and locally enclose red, flat-bedded units deposited in a washover channel-wind-tidal flat complex (red lenticular sandstone facies). The Crystal Creek Member is typified by evenly laminated, massive, and cross-bedded units and a lateral facies relation which suggest a lower beach and subtidal environment where storm and tidal currents dominated.

Cross-stratification measurements from eolian facies in lower and upper Thousand Pockets Tongue indicate north-northeasterly winds during Bathonian time. The marginal-marine and submarine interpretation of the red beds in the Thousand Pockets Tongue and Crystal Creek Member, respectively, lends support to a diagenetic origin for the red color of these beds.

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Facies Control of Upper Cretaceous Cleary and Gibson Coal Members near Gallup, New Mexico

The Upper Cretaceous Point Lookout Sandstone separates the Cleary Coal Member of the Menefee Formation from the Gibson Coal Member of the Crevasse Canyon Formation in much of the Chaco slope and southwest San Juan basin. These coal-bearing members merge as the intervening Point Lookout Sandstone pinches out to the southwest in the direction of the Nutria monocline and Gallup coal field. The deposits of the merged coal interval supported widespread mining activity northwest and north of Gallup, New Mexico, near the turn of the century; however, renewed mining of these coals for the past few years has concentrated northwest of the town. Closely spaced outcrop sections provided data from which to infer the depositional settings of the merged coals.

Northwest of Gallup (Enterprise mine area), an alluvial facies of channel sandstones, deposited by northward-flowing streams is complexly interspersed with interfluvial siltstones and with laterally discontinuous coal deposits. North of Gallup (Gibson and Heaton mine areas), better integrated sandstones deposited in north-to-northeast flowing distributary channels, subordinate crevasse-splay sandstones, more widespread coal zones, and common bioturbations in laminated carbonaceous siltstones suggest coal accumulation in a deltaic to lagoonal transition environment. Further northeast of Gallup, where the Nutria monocline changes to an easterly strike toward the Chaco slope, well-developed coals remain associated with the deltaic and lagoonal environments. However, these coal-forming environments grade northeastward into the Point Lookout back-barrier to lagoonal transition environments, where coal deposits are poorly developed.

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Unconformity-Related Uranium Deposits in Upper Cretaceous Sandstones, Datil Mountains Area, West-Central New Mexico

The north flank of the Datil Mountains is underlain by gently south-southwest dipping strata of the Late Cretaceous Crevasse Canyon Formation, which is unconformably overlain by the Eocene Baca Formation. This erosional unconformity is well exposed where the upper 30 to 60 m of the Crevasse Canyon forms a 15-km-long belt of mesas, which probably represents an east-trending, fine-grained, meander-belt complex.

Numerous uranium anomalies and several small orebodies (Red Basin area) generally form a coaxial uranium belt within (and below) a 20 to 30-m-thick, intensely bleached zone at the top of the Crevasse Canyon. In drill cuttings and canyon walls, the light-gray sandstones and light-purplish-gray shales of the bleached zone grade downward into the dark-gray sandstones and carbonaceous shales typical of the Crevasse Canyon Formation. Tabular uranium deposits commonly occur in bleached channel sands where they are in contact with carbonaceous shales. Thin laminae of black hematite are common along the mineralized contacts. Carbonized wood and pyrite concretions, common in the lower Crevasse Canyon, occur as silicified logs and limonite concretions in the bleached zone.

The basal 0 to 10 m of the Baca Formation is usually a light-brownish-gray conglomeratic sandstone containing abundant hematite flakes, broken limonite concretions, and bits of silicified wood, suggesting that bleaching (and mineralization?) may have predated Baca deposition.

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Disequilibrium and Possible Origin of Uranium Deposit in Cretaceous Lower Dakota Scour Channel, Church Rock District, McKinley County, New Mexico

Uranium mineralization has been intersected in a Cretaceous Dakota fluvial channel in the Church Rock district of the Grants mineral belt, New Mexico. This channel scours into the Brushy Basin Member of the Jurassic Morrison Formation and contains the only mineralization discovered in the Dakota Sandstone on the property. Two hypotheses may explain the source of the uranium: (1) a reworking of the Westwater Canyon sediments south of the orebody where the Brushy Basin is absent, and (2) the expulsion of uranium-bearing waters from the underlying Brushy Basin mudstone.

A Laramide uplift created a hydrologic gradient which resulted in the encroachment of oxidizing ground waters upon the orebody. The southern half of the orebody exhibits a limonitic(?) staining and paucity of actual uranium compared to radiometrics whereas the northern half lacks obvious iron staining and possesses an abundance of uranium over the associate radiometrics.

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Tartaric Acid Leaching of Selected Ore Samples, Grants Mineral Belt, New Mexico

Composite samples of high-grade ore samples from the Doris and Johnny M mines were leached under controlled laboratory conditions to determine which elements are more mobile in the presence of organic acids. The samples selected consisted of $-2$-$\mu$ composites of kaolinite + mixed layer smectite/illite + U-mineral + accessory organic matter and sulfides; and chlorite + mixed layer smectite/illite + U-minerals + accessory organic matter and sulfides. These samples were leached with 0.01 molar tartaric acids in tightly sealed Erlenmeyer flasks, with constant agitation, for 100 hours and the leachates and insoluble residues were analyzed by neutron activation analysis. Uranium, Th, and the REE (rare earth element) were strongly leached and presumbably form chelates with the tartaric acid; Na, K, and Ba were also leached but Rb and Cs were either not leached or else fixed on the outer armor of the insoluble residue. Fe and Hf were also leached but Cr, Co, Sb, and Ta concentrated in the insoluble residues. The distribution patterns for the REE for leached and untreated samples are parallel, but the amount of REE leached is proportional to U leached, thus suggesting that organic transport of the REE with U (and Th?) may account for the high REE contents common in many uraniun deposits of the Grants mineral belt. The source for the REE and for at least some of the U may have been the Brushy Basin Member (Morrison Formation) for deposits in the underlying Westwater Canyon Member.

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Effects of Mining and Reclamation on Hydrologic Parameters

Studies in west-central New Mexico show that the hydrologic parameters of a coal sequence do not change appreciably