type sandstone deposits. The Wyoming type of roll deposit though in similar environments is unique, having mineralogic and compositional zoning, a feature of epigenetic deposits of other minerals and one which may be indicative of truly epigenetic origin.

The hypothesis of near-surface, quasisyngenetic origin presumes that formations are unique at their time of formation, which explains the ubiquitous stratigraphic control. Objections to this hypothesis are based largely on the high temperatures and salinities indicated by fluid inclusions and the late dates given by Pb-U dating methods. However, these are the results of diagenesis which recrystallized the quasisyngenetic deposits at high temperature and produced discordant dates. In contrast, hypotheses that postulate ore formation long after deposition and burial of the sediments fail to account for the stratigraphic control. Unique features such as the presence of volcanic debris acting as an intrasediment source of uranium are commonly cited as ore controls, but only a very small proportion of sediments with such features has uranium deposits in spite of an apparent consistency of diagenetic processes.

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Organic Geochemistry and Uranium in Grants Mineral Belt

Organic material is closely associated with the primary uranium deposits of the Grants mineral belt. This organic material is now insoluble and nonvolatile, and most of it is lacking in physical structure. The mixture of organic matter and uranium coats sand grains and fills interstices, which seems to indicate that both the organic matter and uranium were introduced as soluble materials after sedimentation. The relation of organic matter and uranium can be shown physically, chemically, and statistically.

Pyrolysis–gas chromatography, mass spectrometry, and elemental analysis have been used to examine the organic matter from several ore deposits. The results show carbon-rich materials which have been severely degraded by radiation from uranium and daughter products. The organic material now resembles amorphous carbon, having lost most of its hydrogen and oxygen. From the uranium content and approximate age, the radiation dose is calculated to be 10^{11} rads. The radiation damage has also produced an interesting new carbon-isotope fractionation effect, by which the carbon associated with ore is enriched in carbon-13 relative to the non-ore carbon.

Laboratory model experiments using freshly extracted soluble organic material from recent sediments and uranium—as $UO_2(CO_3)_2{}^{-2}$—show large enrichment of uranium by chelation and ion exchange, which are pH dependent. The greatest concentration factor for uranium is at slightly acid pH values.

From model experiments and laboratory work on samples from the Grants district, the following hypotheses are made: first, the soluble organic matter (of unknown origin) coated or precipitated on the mineral grains; subsequently, the uranium—probably as $UO_2{}^{+2}$ or $UO_2(CO_3)_2{}^{-2}$—concentrated in and on this organic matter by ion exchange and chelation with functional groups. This cycle of organic coating and uranium concentration could have been episodic or continuous, but must have lasted at least 10^6 years based on calculations using assumed porosity, permeability, hydraulic gradient, uranium content of water, and organic concentration factors. Finally, after 10^8 years, the radiation damage has created an amorphous carbon material which is deficient in hydrogen and oxygen but which helps protect the ore from mobilization owing to its chemical inertness.

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Geology and Development of Marquez, New Mexico, Uranium Deposit

Uranium deposition in the Marquez, New Mexico, area occurs almost exclusively in the lower Westwater Canyon Member of the Morrison Formation of Jurassic age. The average aggregate thickness of the Westwater is 90 m but ranges from a minimum of 73 m to a maximum of 100 m. A "K" shale separates the upper and lower Westwater sandstone boundaries. The lower Westwater sandstone development is more pronounced in an east-southeast direction parallel with strike of the orebody(ies). Three distinct ore zones were deposited in peneconcordant elongate patterns. The upper zone occupies a stratigraphic interval just below the "K" shale and two lower zones lie above and below the "K_1" shale. Coffinite and uraninite predominate as the stable uranium species; other extrinsic elements were added during the mineralization process. Humates undoubtedly exerted major control on formation of the uranium. Ferrous iron pervades both within and outside the deposit whereas ferric iron, though limited in quantity, is confined principally to the orebody(ies). The lower "K_1" shale, parameters of permeability, and recurrence of meanders along the paleochannels also seem to influence enrichment.

Surface drilling is continuing, a vertical mine shaft to approximately 2,100 ft (630 m) is nearing completion, and a mill is being constructed on the property.

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Magnitude and Variability of Disequilibrium in San Antonio Valley Uranium Deposit, Valencia County, New Mexico

The San Antonio Valley deposit is a flat-lying tabular body of uranium mineralization in the Westwater Canyon Member of the Morrison Formation. The deposit is elongate northwest-southeast, is approximately 1.6 km long and 0.3 km wide, and averages from 2 to 4 m in thickness. The "trend-type" deposit has a chemically reduced mineralogy and occurs below the water table.

The average disequilibrium factor for the deposit shows a 4% enrichment in chemical uranium. Variations occur throughout the deposit, however, with the northeastern edge being chemically excessive by 11% and the southwestern edge being chemically deficient. Three ore-reserve correction factors have been assigned, one to each of three longitudinal zones. This use of multiple correction factors will optimize mine planning and uranium recovery.

Vertical profiles of radiometric and assay data through ore zones show dispersion of daughter isotopes away from uranium concentrations. Horizontal data plots show removal of daughter isotopes from the northeastern edge of the deposit and fixation of daughter isotopes in the central and southwestern parts of the deposit. Local loss of uranium is also suggested in the central and southwestern parts of the deposit. It is hypothesized that recent groundwater flow from east to west has redistributed the isotopic species. This flow system caused both the local vertical migration of daughter isotopes and also the transport of daughter isotopes and uranium in the direction of the hydrologic gradient. These conclusions are based wholly on chemical and gamma-equivalent uranium assays.

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Mineralogy and Geochemistry of Mariano Lake Uranium Deposit, Smith Lake District, New Mexico

The Mariano Lake uranium deposit is located on the west side of the Smith Lake district of the Grants mineral belt. Mineralization is restricted to a basal arkosic sandstone of the Brushy Basin Member of the (Jurassic) Morrison Formation. This sandstone, called the Poison Canyon sandstone (economic usage), consists of a sequence of paleochannels in which mineralization has been deposited in a roll-type tabular deposit. This roll front is directly related to an oxidation-reduction interface.

Chemically, the deposit is somewhat different from other Grants mineral belt deposits. Calcium and CO_3 content are low, but V, Ba, and S are relatively abundant. Sulfur found in pyrite is also possibly associated with uranium sulfates. Titanium is found as a secondary oxide, derived from titanomagnetites of the originally deposited mineral assemblage. Molybdenum, arsenic, and other trace elements show a regular zoning across the deposit, but cerium is slightly depleted.

The mineralogy of the Mariano Lake deposit includes abundant disseminated pyrite in mineralized reduced areas and hematite in the oxidized barren areas. Calcite, barite, gypsum, and jordisite are rare. Clay mineralogy includes kaolinite, chlorite, illite, and mixed layer illite-montmorillonite. Contrary to what has been found in other deposits of the Grants mineral belt, zonation of the clays is reversed, with kaolinite being more abundant in the downdip reduced sediments. The phenomenon is thought to be the result of backwash off the south-dipping flank of the Mariano anticline.

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Uranium in Todilto Limestone—Sabkha-Like Deposit

The Todilto Limestone was deposited in or near a large lake that at times became restricted and evaporated to dryness. The formation has two members: a lower limestone and an upper gypsum member. The limestone member has been divided informally into three zones: the lower "platy" zone, a middle "crinkly" zone, and an upper "recrystallized" zone. The platy zone is interpreted to have been deposited below wave base under anoxic conditions. The crinkly zone has thin stromatolitic laminations and may form algal domes. The upper recrystallized zone appears in part to be a collapsed breccia caused by the removal of interbedded gypsum. Uranium ore is restricted primarily to the "crinkly" and recrystallized zones. These two zones may have been formed in a sabkha-like environment.

A. R. Renfro has proposed a sabkha origin for some stratiform copper deposits. The same conditions that cause copper to precipitate would also cause uranium to precipitate. Groundwater bearing U^{+6} could be drawn upward by evaporative pumping through the decaying algal-mat zone where the uranium would be reduced to U^{+4} and precipitated. Carbonate materials lithify early destroying permeability so that uranium emplacement must occur before lithification. Radioisotope dates on uraninite in the Todilto Limestone indicate ore emplacement shortly after deposition. Uranium-bearing groundwater moved basinward in the underlying Entrada Sandstone and was drawn upward through the stromatolitic zones along the southwest margins of Lake Todilto and uranium was precipitated.

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Roll-Type Uranium Occurrence at Dennison-Bunn Claim and Possibility of Uranium Deposits in Eastern Part of San Juan Basin, New Mexico

Uranium at the Dennison-Bunn claim, south of Cuba, New Mexico, along the east margin of the San Juan basin, occurs in stacked fluvial-channel sandstones interbedded with gray-green mudstones of the Westwater Canyon Sandstone Member of the Morrison Formation of Jurassic age. Although all the sandstone units are mineralized, the greatest concentration of uranium occurs in the uppermost sandstone unit. The uranium deposits are low to medium grade, range from 0.001 to 0.07% U_3O_8, and are irregularly distributed along the margins of intertonguing oxidized and unoxidized sandstone. The configuration indicates that these are roll-type uranium deposits and that they formed at the interface between oxidizing and reducing solutions.

The host rocks dip 45° west into the basin. Reconstruction of the tectonic and sedimentologic history along the eastern margin of the basin suggests that conditions favorable for the solution, transportation, and deposition of uranium probably occurred from Late Cretaceous into Eocene time. Uranium in the mineralizing solutions may have originated from within the Morrison Formation or may have been leached from the Paleocene Ojo Alamo Sandstone or Nacimiento Formation, or from the Eocene San Jose Formation which once covered the area.

Similar uranium deposits occur in the Morrison Formation at the Goodner lease, north of Cachana Spring. The presence of oxidized sandstone in the Morrison