Sedimentologic and Paleoclimatic Controls on the Distribution of Uranium Deposits in the Upper Triassic Chinle Formation, Colorado Plateau, USA

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Continental strata of the Upper Triassic Chinle Formation contain uranium deposits over much of the Colorado Plateau. Three units are the primary hosts for uranium. In ascending order, these are the Shinarump, Monitor Butte, and Moss Back Members. The Shinarump is coarse-grained to conglomeratic gray sandstone; the Monitor Butte is green sandstone to black mudstone; and the Moss Back is medium-grained brown sandstone. Whichever of these members is in contact with the underlying Lower Triassic Moenkopi Formation is the ore host. A combination of factors, including depositional environment, paleoclimate with seasonal rainfall, and burial history, all controlled the distribution of uranium deposits. The lower Chinle was deposited within extensive paleovalleys eroded into the top of the fine-grained Moenkopi, which later acted as an aquitard below Chinle strata. The upper Chinle was deposited in meandering stream, lacustrine, and eolian systems. Paleosols are abundant throughout the section.

Shinarump sandstones were deposited within trunk rivers and tributary streams that flowed northwest from the continental interior and local highlands. Meanderings and avulsions of the trunk rivers blocked drainage of tributary streams and formed dendritic lakes with extensive marginal marshes. Lacustrine deltas and levees gradually prograded and filled the lakes with siliciclastic sediment and ash from volcanic eruptions. The lacustrine deltas contained abundant plant material both as whole fossil specimens and abundant comminuted fragments. Marshes developed at the margins of the deltaic systems and locally deposited black organic-rich mudstones. Rapid deposition and detrital organic matter in the marshes produced reducing conditions responsible for the characteristically green and gray beds of Monitor Butte strata.

The formation of uranium ore bodies in the basal sandstones of the Chinle required a specific set of sedimentologic and post-depositional geochemical conditions to mobilize, localize, and precipitate uranium and related elements. Uranium-bearing fluvial sandstones at the base of the Chinle thus occur only within paleovalley systems that subsequently contained lacustrine deltas and adjacent organic-rich

marshes. These deposits established reducing geochemical conditions that resulted from the degradation of organic plant material below the water table or the sediment-water interface. Fluvial channel systems that lack associated overlying lacustrine deltaic and marsh systems contain no uranium ore bodies. Uranium was most likely released from the volcanic ash-rich sediment under oxidizing conditions that existed in subaerial floodplain paleosols and in deltaic strata deposited in oxygenated lake water. As soluble uranium entered the ground-water system, it flowed through the paleoaquifers formed by the underlying Shinarump channels. Further downward flow was retarded by the fine-grained clay-rich character of the underlying Moenkopi. Uranium precipitated to form ore bodies in pore spaces within these coarse-grained sandstones, a process initiated by the mixing of oxygenated uranium-bearing ground waters with reducing, downward-migrating organic acid-rich fluids generated within and expelled from the lacustrine marshes. These interpretations of the paleogeography, paleoclimate, and geochemical conditions allow for the reconstruction of depositional systems that contain lakes and marshes and thus belts of channel sandstones likely to contain ore bodies, as well as unfavorable fluvial channel systems that contain no ore bodies.