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A possible relationship between subsidence and uranium mineralization in the Petrified Forest Member of the Chinle Formation in the Cameron and Holbrook-St. Johns areas of Arizona

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Abstract

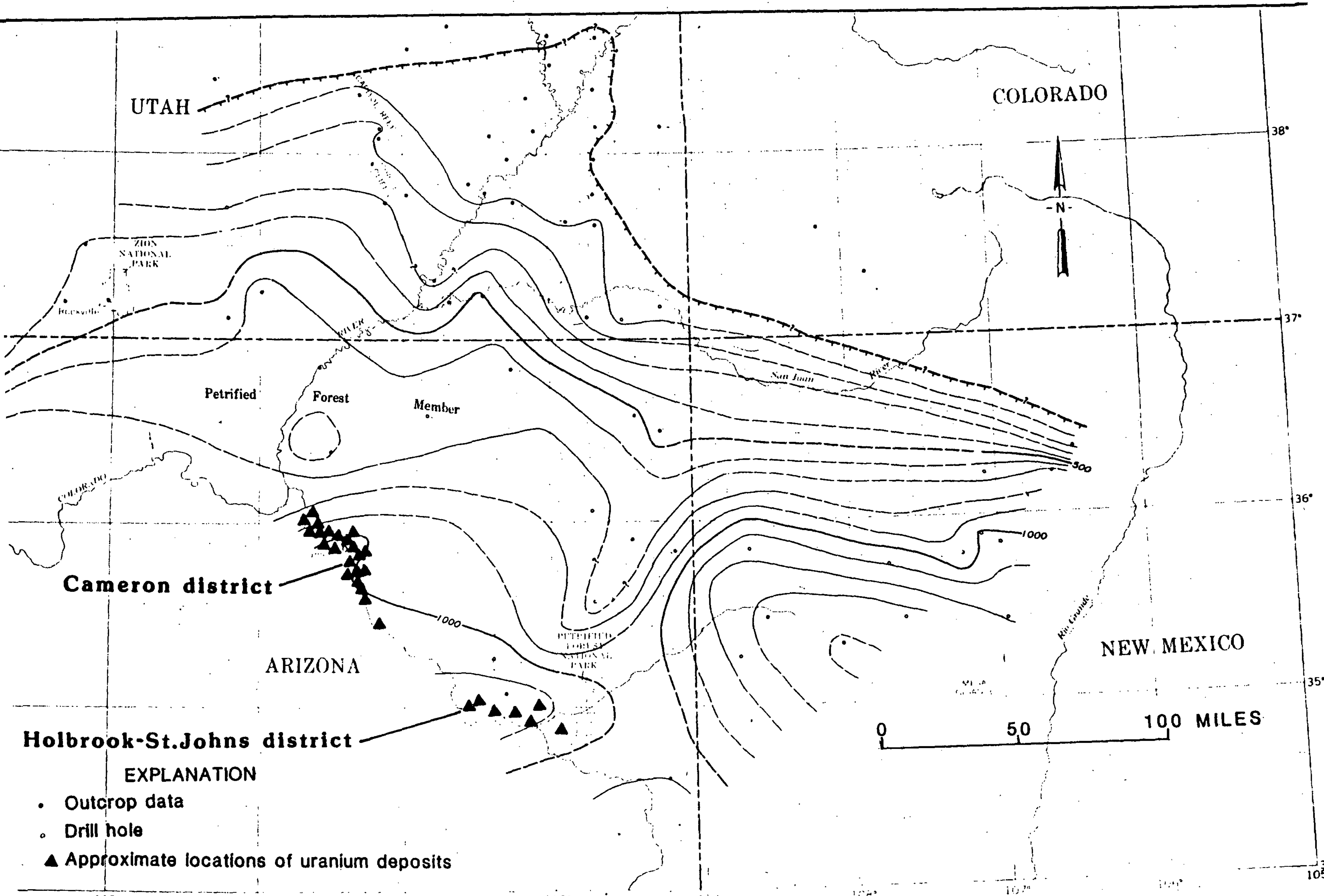
Concentrations of uranium within the Petrified Forest Member of the Chinle Formation are believed to be in areas that were subsiding concomitant with sedimentation. Local subsidence kept detrital organic material below the water table much of the time. Thus subsidence shielded the organic material from the effects of atmospheric oxidation. This preservation of the organic material was a prerequisite for the formation of the uranium ore deposits.

Discussion

Uranium ore in the Petrified Forest Member of the Chinle Formation was deposited in the Cameron uranium district and to a lesser extent in the Holbrook-St. Johns area. Elsewhere in this member, concentrations of uranium have been found in isolated mineralized logs, but economic deposits of uranium are unknown. The depositional environment of the host unit, a broad flood plain according to Wilson (1956) and Repenning and others (1969), does not appear to be the sole factor controlling the localization of the ore inasmuch as this environment characterizes much of the Petrified Forest Member. However, known concentrations of uranium are confined to the Cameron and Holbrook-St. Johns areas and almost exclusively to the lower twenty meters of the member. The source of uranium is another factor that might dictate the distribution of the ore. The likely source of the uranium in these deposits is the bentonitic units (derived from volcanic ash) in the member; these bentonitic units extend far beyond the bounds of the known mineralized areas. Thus, some factor (or factors) in addition to the source of uranium and the depositional environment of the host rock must be critical to the formation of these deposits. The nature of the deposits and of the tectonics in the area suggest that subsidence concomitant with sedimentation was the additional factor.

The deposits are described by Gregg and Moore (1955), Hinckley (1955), Birdseye (1958), and Chenoweth and Malan (1973). All of these studies and my observations agree that the deposits formed in sandy fluvial channels in association with coalified detrital organic material and sulfide minerals. Silicified wood is common away from the ores, but silicified wood typically is not mineralized. The association of uranium with coalified organic material suggests that reduction by either organic material itself or by sulfide minerals produced by microorganisms which metabolized the organic material was the precipitation mechanism for uranium--an old and widely accepted concept. Obviously, preservation of the reducing capacity of the organic material and the anoxic conditions necessary for sulfate-reducing bacteria require a shielding from atmospheric oxidation. One means of accomplishing this is simply by keeping the organic material below the water table. According to Hinckley (1955), and Chenoweth and Malan (1973), scours in the bottoms of channels are preferred ore sites. Such places are likely to remain beneath the water table more of the time than are shallower parts of the channels (which are more susceptible to drying up), and consequently any organic material in scours is more likely to be preserved. Thus, the preference of uranium ores for scours is consistent with the concept of preserving organic material below the water table as a precursory condition for the formation of uranium deposits. Preservation of the reducing capacity of the organic material is believed to be directly linked to local subsidence.

Gregg and Moore (1955), in their study of the Holbrook area, and Hinckley (1955), in his study of the Cameron area, observed a possible relationship between positive tectonic areas and the locations of the ores. Hinckley (1955) suggested that diversion of the streams in the lower Chinle Formation by the uplift near Cedar Ridge somehow may have influenced the location of the deposits. Thicknesses of the lower Chinle Formation (fig. 1, modified from Stewart and others, 1972), are consistent with the possible presence of an active positive tectonic area near Cedar Ridge during deposition of the Petrified Forest Member. These thicknesses also suggest an active negative tectonic (subsiding) area near Cameron during the deposition of the Petrified Forest Member (fig. 1). In the subsiding area, organic material is more likely to be preserved. Also, by diverting the stream flow, the suggested



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uplift near Cedar Ridge would increase the path length of the streams, thus decreasing the average gradient. Such a decrease in the stream's average gradient would produce a lower energy and a higher water table environment on the upstream side of the rising area. As the water table rises so does the probability of preserving organic material. By preserving organic material, one prerequisite for the formation of the uranium deposits is met. The concentration of uranium deposits near Cameron and the termination of mineralization near Cedar Ridge are in accordance with these suggested tectonic controls. Only the lower part of the Chinle Formation shows changes in thickness related to these tectonics, and only the lower part of the Chinle Formation (especially the lower 20 meters of the Petrified Forest Member) is the host of major deposits.

Figure 1 shows that uranium deposits occur in areas where the Petrified Forest Member is relatively thick. The eastern limit of the area of known concentrations of uranium in the Cameron district may only be due to a lack of exploration. Because of economic considerations, exploration in the Cameron area was limited to depths of about 45 meters. Thus, the apparent center of the subsiding area of Cameron is unexplored, but may indeed be mineralized.

Admittedly there is considerable uncertainty in using the thicknesses of sedimentary units as an indicator of subsidence along with sedimentation. One problem is that the subsurface data in many areas are sparse. Further problems arise because the thickness of the sedimentary units is not only determined by the rate of subsidence along with sedimentation but is also affected by erosional episodes, the intertonguing of units, and, in the case of the Chinle Formation, the variation in the relief of the surface on which the formation was deposited. Also, time markers commonly are not available.

Despite these difficulties, the Petrified Forest Member is indeed thicker in the two areas known to be mineralized than in the surrounding areas, and the reducing capacity of the organic material was preserved in these two areas. The intertonguing of units, erosional episodes, or relief on the depositional surface would not account for the preservation of the organic material; but subsidence along with sedimentation would. Thus the increased thickness of the lower part of the Petrified Forest Member of the Chinle Formation in the mineralized areas is interpreted as being at least in part due to subsidence concomitant with sedimentation.

This concept presents a logical reason for occurrence of uranium in the Cameron and Holbrook-St. Johns areas in the Petrified Forest Member of the Chinle Formation, a unit which is not generally a host for uranium ores. It explains both the geographic and stratigraphic distribution of the ores. Also, the obvious link of the ores to detrital organic material is accounted for and the preference of the ore for scours is consistent with the preferential preservation of organics in such features.

This concept might be applied to other areas in which the preservation of detrital organic material is a prerequisite for the formation of uranium deposits. Subsidence concomitant with sedimentation, however, is not necessarily critical to the formation of all uranium deposits related to detrital organic material. Large accumulations of organic material may resist oxidation simply by virtue of their size. The abundance of nonmineralized silicified wood in the Petrified Forest Member indicates that more than the simple accumulation of organic material was required for the preservation of the reducing capacity of the organic material which was necessary for the formation of the uranium deposits in the Petrified Forest Member.

References

Birdseye, H. E., 1958, Uranium deposits in Northern Arizona: New Mexico Geological Society, 9th Field Conference, p. 161-163.

Chenoweth, W. L., and Malan, R. C., 1973, Uranium deposits of Northeastern Arizona: New Mexico Geological Society, 24th Field Conference, p. 139-149.

Gregg, C. C., and Moore, E. L., 1955, Reconnaissance of the Chinle Formation in Cameron-St. Johns areas, Coconino, Navajo, and Apache counties, Arizona: U. S. Atomic Energy Comm. RME-51, Tech. Inf. Service, Oak Ridge, Tennessee, 15 p.

Hinckley, D. N., 1955, Reconnaissance in the Cameron area, Coconino County, Arizona: U.S. Atomic Energy Comm. RME-81, Tech, Inf. Service, Oak Ridge, Tennessee, 21 p.

Repenning, C. A., Cooley, M. E., and Akers, J. P., 1969, Stratigraphy of the Chinle and Moenkopi Formations, Navajo and Hopi Indian Rservations, Arizona, New Mexico, and Utah: U.S. Geological Survey Professional Paper 521-B, 34 p., 2 pl.

Stewart, J. H., Poole, F. G., and Wilson, R. F., 1972, Stratigraphy and origin of the Chinle Formation and related Upper Triassic strata in the Colorado Plateau region: U.S. Geological Survey Professional Paper 690, 195 p., 5 pl.

Wilson, R. L., 1956, Stratigraphy and economic geology of the Chinle Formation, Northeastern Arizona: Tuscon, Arizona, University of Arizona unpublished Ph.D. thesis, 257 p.