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SUBSURFACE STRATIGRAPHY OF THE MORRISON FORMATION IN THE MOUNT TAYLOR AREA AND ITS RELATION TO URANIUM ORE GENESIS

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INTRODUCTION

This article is an outgrowth of a subsurface stratigraphic study of the Morrison Formation present near San Mateo, New Mexico, on properties being explored and developed by Gulf Mineral Resources Company (fig. 1). This project was undertaken as part of a M.S. thesis project for the University of New Mexico. The principal aim of this study has been to carry out detailed stratigraphic correlation through the use of electric logs, core analysis and thin section analysis in order to define the paleoenvironments of the Jurassic Morrison Formation in the Ambrosia Lake and Mount Taylor areas and to determine what roles these environments have played in uranium ore genesis.

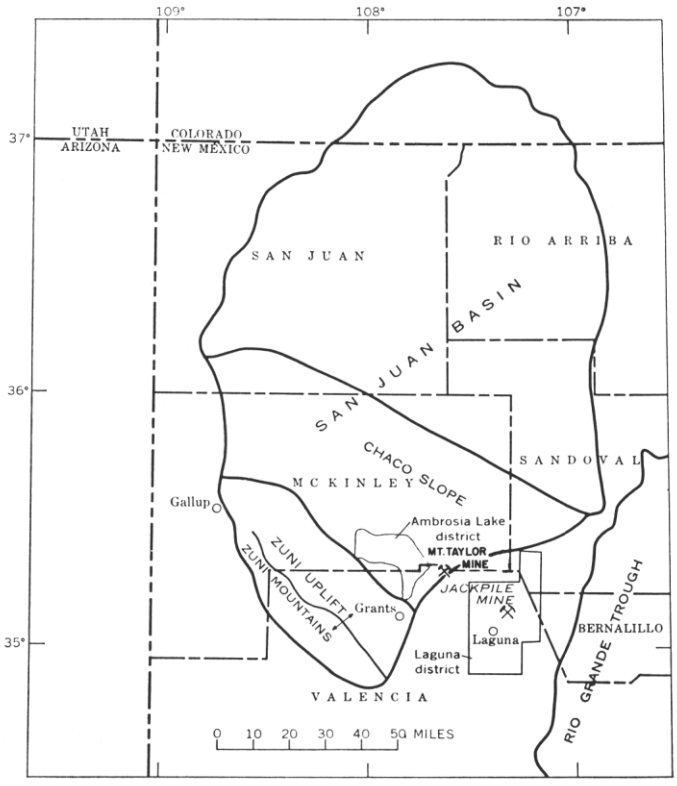


Figure 1. Location of the Ambrosia Lake district and the Mount Taylor mine, west-central New Mexico (modified from Santos, 1970).

STRATIGRAPHY OF THE HOST ROCKS

General Background

Sandstone-type uranium deposits in the United States occur in about 140 stratigraphic units representing nearly every period in the geologic record (Fince, 1967). Of these, the most prolific producers were deposited in fluvial environments.

The deposits of the Grants mineral belt and Mount Taylor are found in the Late Jurassic Morrison Formation, which is composed of fluvial sandstone lenses that are interbedded with mudstone (Cadigan, 1959; Santos, 1970). Many of the sandstone beds are arkosic, and some of the mudstone beds contain clay minerals derived from volcanic ash. The streams that deposited the host sandstones are generally assumed to have flowed to the east and northeast from the ancestral Mogollon highland into a depositional basin (Cadigan, 1959; Santos, 1970; Flesch, 1974a).

Morrison Formation

The Morrison Formation was named by Cross (1894) for exposures near the town of Morrison in east-central Colorado. It has been recognized over most of the western interior of the United States, and its age, relationships and correlation have been the object of considerable discussion. A summary of the development of Morrison nomenclature is offered by Imlay (1952), Flesch (1974a) and Sears and others (1974).

Much of the present study has been devoted to a subsurface analysis of the geometrics and lithologies of the Morrison in the Mount Taylor area. This was carried out by the analysis of detailed core descriptions, thin section studies and geometric analysis through cross-sectioning of the lithosomes that constitute the Morrison Formation. Data for this cross-sectional analysis were gathered from a suite of electric logs that measured gamma-ray, self-potential and resistivity characteristics of Morrison stratigraphy. Where logs of deviated or whipstocked holes were used, measured formation thicknesses were trigonmetrically corrected to true formation thicknesses.

The Morrison is divided into three mappable members in the Mount Taylor area. From oldest to youngest these are the Recapture, Westwater Canyon and Brushy Basin members. On the basis of lithology, fossils and geometry, the members are interpreted as fluvial and all intertongue (fig. 2) with overlying and underlying units. Therefore, the contacts delimiting the stratigraphic range of each member are arbitrary (Harshbarger and others, 1957), but lithologic differences and weathering properties provide a basis for their differentiation.

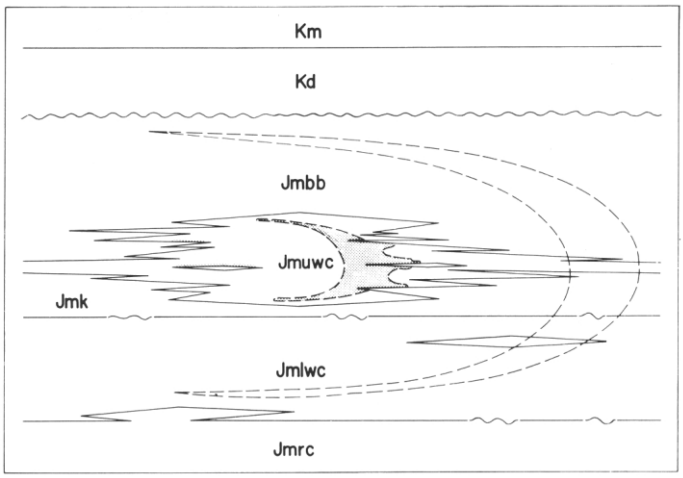


Figure 2. Generalized cross section of Morrison stratigraphy in the Mount Taylor area. The total section shown is approximately 300 feet; total width of section is approximately 1.5 miles. North is to the right. Mineralization distributions are superimposed. Ore zones are cross-hatched. The symbols on this figure refer to the following units of the Morrison Formation: (Jmrc) Recapture Member; (Jmlwc) lower Westwater Canyon lithosome; (Jmk) "K shale"; (Jmuwc) upper Westwater Canyon lithosome; and (Jmbb) the Brushy Basin Member. Other units shown are: (Kd) Dakota Sandstone; and (Km) Mancos Shale.

Recapture Member

The Recapture Member is an interstratified sandstone and shaly mudstone (Gregory, 1938), commonly pale reddish brown to grayish pink and consisting chiefly of fine- to medium-grained quartz sand. Large amounts of coarse-grained conglomeratic material, including appreciable amounts of granitic materials, are present in northeastern Arizona, an area which presumably served as provenance for the southern San Juan Basin. The Sandstone units are lenticular and have low-angle trough and wedge-planar crossbedding similar to that in the Salt Wash Member (Harshbarger and others, 1957). Eolian beds are locally interbedded with those of fluvial origin and become dominant near the southern San Juan Basin.

The mudstones of the Recapture are dark reddish brown and greenish gray, are lenticularly bedded and constitute nearly 85 percent of the member (Gregory, 1938). From limited data, this seems to be true in the Mount Taylor area.

No commnet can be made regarding the lower contact of the Recapture Member in the Mount Taylor area owing to insufficient data. The Recapture intertongues with the overlying Westwater Canyon Member, although variations in the thickness of the Westwater, especially of its lower part, indicate that this contact may be locally unconformable (Riese, 1977; Green, 1975).

Westwater Canyon Member

The Westwater Canyon Member consists of a series of white to greenish-yellow, coarse- to medium-grained sandstones (Gregory, 1938). In the Mount Taylor area, the Westwater Canyon is composed of complexly interbedded pebble conglomerates, sandstones and mudstones. These lithologies are variously colored throughout the section in shades of gray, black and green to grayish yellow green. The sands constitute by far the greatest portion of the section; 70-80 percent of the sands consist of subangular to rounded quartz. Orthoclase, plagioclase feldspar and lithic fragments make up the remainder. The silts and pebble conglomerates are similarly composed, but the mudstones are locally made up almost entirely of clay minerals.

In the Mount Taylor area, the Westwater Canyon Member exhibits a characteristic shaly bed that is referred to as the "K" shale in the Grants mineral belt (fig. 2). It is present throughout the area of study and apparently prohibits any connection of the lower Westwater Canyon lithosome (Jmlwc) with the upper Westwater Canyon lithosome (Jmuwc). It is identical in appearance to the Brushy Basin Member and may correlate with the "shale' between the "b" and "c" sands (local usage) of the Ambrosia Lake district.

The Westwater Canyon Member intertongues with, grades into, and unconformably adjoins both the underlying Recapture and the overlying Brushy Basin members throughout the southern San Juan Basin. These relations are all expressed in the subsurface geometry of the Mount Taylor area as well.

Brushy Basin Member

The Brushy Basin Member is the uppermost member of the Morrison Formation (Gregory, 1938). In the Grants mineral belt it is composed of a sequence of fine- to very fine-grained sands, siltstones and mudstones which grade into one another, although disconformities are locally distinguishable. Colors range from shades of gray and green to grayish brown. The mudstones and siltstones constitute the greatest part of the section, although sands very similar to those attributed to the Westwater Canyon may also be found in the sequences.

The Brushy Basin Member intertongues with, grades into, and unconformably overlies the Westwater Canyon Member. Its contact with the overlying Dakota Sandstone (Cretaceous) is a well-documented unconformity in the Mount Taylor area and over most of the Colorado Plateau as well (Gregory, 1938; Harshbarger and others, 1957; Peterson, 1972).

Depositional Environments of the Morrison Formation

The depositional environments of the Morrison Formation have been outlined by many of the authors already cited. Hilpert (1963, p. 14) had an excellent summary of the views held by many working in the district:

> *"Studies of the lithologies and sedimentary structures of the Morrison by Craig et al. (19551 indicate that the sediments were largely derived from a landmass in east-central Arizona and west-central New Mexico and were deposited by an aggrading system of northeastward flowing streams. The sediments of the Brushy Basin Member were probably deposited in a mixed lacustrine and fluvial environment in which the fluvial material probably came largely from the Mogollon Highland to the south (Harshbarger et al., 1957). The bentonitic claystone is interpreted to be a derivative of volcanic ash." (Craig et al., 1955).*

These conclusions were previously stated by Silver (1948) and have been more recently expounded by Peterson (1972, p. 186):

> *"The continental beds of the Morrison Formation were deposited essentially as a region-wide blanket of variable lithology on the sea floor plain which emerged after the final marine Jurassic cycle of deposition" (Swift).*

Flesch (1974a) also agreed with these findings but indicated

the need for caution pending correlation of the extensive outcrop studies with subsurface studies.

Figure 2 is a generalization of a large number of cross sections constructed through the study area. Note the distinct lens-like development in the upper Westwater Canyon sands (Jmuwc), which in an isometric diagram might look very similar to the meander-belt deposits illustrated in Figure 3. The Morrison Formation, specifically the Westwater Canyon Member, was probably not deposited as a purely meandering stream belt; the specific fluvial environments of deposition of the various Morrison lithosomes were discussed by Flesch (1974b) in a detailed fashion that cannot be duplicated here because of a lack of samples. Nor is the sand thick depicted in Figure 2 representative of the filling of a single mega-channel. This would be unlikely. This sand thick probably represents a lithosome that was deposited by a succession of streams during the course of Morrison deposition. The lithosomes on either side represent areas that were flood plains during this same time.

Constraints on the lateral development of this stream system were probably imposed by small-scale topographic relief present in the area during Morrison deposition. This relief may have been nothing more significant than that which bounds the present-day Rio Salado of west-central New Mexico along much of its length.

Alternately, it may have owed its development to structural flexing during continued subsidence of the San Juan Basin (Saucier, 1975). Because the contact of the Westwater Canyon and Recapture members shows no structural distortion, we feel that this topography is probably due to normal geomorphic development of the area and not to structural flexing.

Further evidence for the presence of this paleotopography is found in the variations in thickness of the section bounded by the top of the "K" shale and the top of the Brushy Basin Member. Recognizing that this last contact is unconformable, but assuming for the sake of argument that this surface is planar and parallel to the underlying stratigraphy, the designated stratigraphic section thins laterally away from the thicks in the sand bodies, thus delimiting the valley of interest, and then locally begins to thicken again to the north, suggesting that a second valley parallels the one which is illustrated in this section.

Morrison deposition, at least in the Mount Taylor area, is not simply a collection of northeasterly coalescing streams and alluvial fans. Rather, this pattern was broken by the southeasterly flowing channel system just described. This channel system was fed by the northeasterly and easterly flowing streams whose directions of flow are so well documented in the already mentioned outcrop studies. This stream system could not have reached the base level offered by the sea if its course had continued to the southeast, because the Jurassic seas of Swift age had transgressed the western interior of the United States from the north (Peterson, 1972). This stream must therefore have eventually turned north, probably in the area of the Laguna-Paguate district, as indicated by the greater than 50 percent sand lithofacies bulge present in north-central New Mexico (Peterson, 1972, fig. 8).

STRATIGRAPHIC ORE CONTROLS

The uranium deposits in the Ambrosia Lake and Mount Taylor areas have for many years been recognized as associated with the fluvial paleoenvironments preserved in the Jurassic Morrison Formation. These relationships have been summarized very well by Fischer (1974). The environments of deposition and mineralization visualized by Fischer (1974), and by most workers in the district, involve a system of generally northeasterly flowing streams that drained a highland to the southwest. The uranium was provided by leaching of source rocks in the provenance and depositional areas—either granitic intrusive materials that were being unroofed at the time of deposition and which provided much of the uranium material deposited in the Westwater Member of the Morrison, or tuffaceous volcanic material in the overlying and interfingering Brushy Basin Member. The leaching solutions then

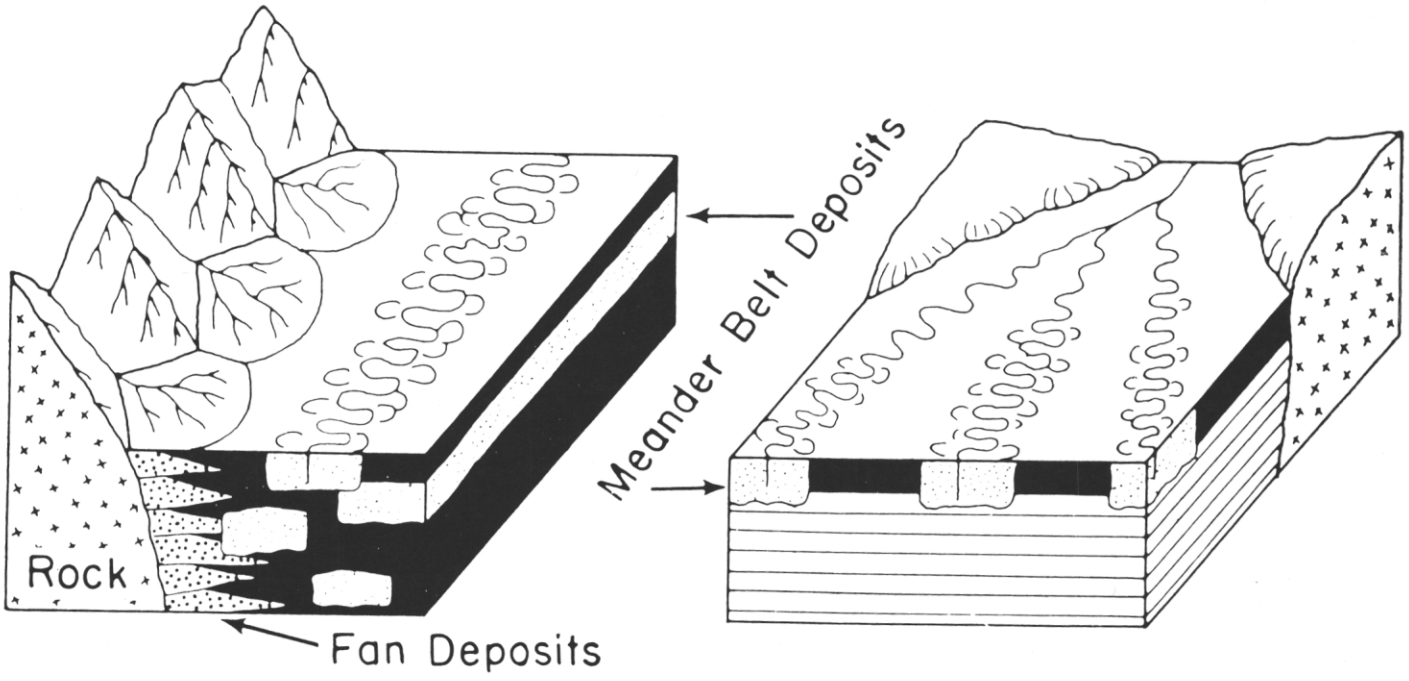


Figure 3. Idealized alluvial sand patterns (from Pettijohn and others, 1973).

moved down dip to areas with chemically reducing environments, where the uranium was then reduced and precipitated from solution, usually in and owing to local accumulations of carbonaceous material.

This concept of depositional and mineralization environments fails to explain the elongate southeast-northwest nature of the deposits; one normally might expect a Uravan-type of distribution (C. T. Smith, personal communication) with the ore bodies parallel to the stream-flow directions, in this case a northeasterly direction.

In Figure 2, the upper Westwater Canyon has been noted to have a crudely lenticular outline, which is locally quite thick in the center and diminishes in thickness to the north and south as the member lenses out and interfingers with the mudstones and siltstones of the Brushy Basin. We believe that this stratigraphic geometry does not represent a system of northeasterly flowing streams, but rather a southeasterly trending valley. Through this valley flowed a complex system of braided and meandering streams, which through time deposited a sand lithosome similar in cross-sectional appearance to a single stream deposit.

A second significant characteristic of the Ambrosia Lake area is the repetition of ore deposits in a direction parallel to the strike of the structure in the area—northwest-southeast. This distribution is also present in the Mount Taylor area and is interpreted to represent frequency of meander in the stream system just described. More specifically, a series of point bar deposits would account for the distribution noted. These areas are places where the sands of the Westwater Canyon intertongue most freely with the muds of the Brushy Basin. Where these muds contain high concentrations of clay minerals, these too may serve as collecting sites for the uranium. This tendency is best shown in what are interpreted to be shale lenses in the centers of channels. These areas are often barren of any carbonaceous materials that could have aided precipitation, and therefore the uranium found here is present solely through precipitation by clay minerals.

Although the Brushy Basin Member of the Morrison Formation is not composed entirely of clay minerals, but rather of clay size materials, there are sufficient clay minerals in the member to have effectively sealed it with respect to fluvial migration early in the diagenetic process. Hostetler and Garrels (1962) considered the tuffaceous materials in the Brushy Basin to be the source of the uranium in the deposits and suggested that this material was leached very soon after deposition and moved into more permeable materials. Their model requires that the leach solutions be squeezed from the enveloping mudstones into permeable sand channels along which they could then migrate to locations of precipitation and concentration.

A diagrammatic representation of the distribution of anomalous background values of the gamma radiation in the Morrison is superimposed on the stratigraphy in Figure 2. Notice the resemblance to a C-shaped roll and how this roll transgresses lithologic boundaries. This distribution, as well as the thorium trace element geochemical data discussed in another paper in this volume, suggests a model that uses the host formations as source rocks for the uranium as well. Leaching took place during deposition and early diagenesis. As compaction began, these leach solutions were squeezed from the muds and migrated down dip as the mega-roll we see frozen in this figure. As compaction continued, the mudstones lost most of their permeability; but the stream channels, which were filled with sands, remained relatively open and permeable and allowed ore material to accumulate.

CONCLUSIONS

The principal aim of this study has been to carry out detailed stratigraphic correlation through the use of electric logs, core analysis and thin section analysis in order to define the paleoenvironments of the Jurassic Morrison Formation in the Ambrosia Lake and Mount Taylor areas and to determine what roles these environments have played in uranium ore genesis. With regard to the environments, this study shows that the Morrison streams of Westwater time drained to the southeast and not to the northeast as suggested by previous workers. We suggest that this interpretation was not made earlier because the subsurface data base used in this study was not available.

The ore deposits in the Mount Taylor area are preferentially located with respect to point bar deposits in the fluvial systems of the Westwater Canyon Member. Both carbonaceous materials and clay minerals appear to have had some role in precipitation. The interaction between the two remains a question to be answered by future research in the area.

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