URANIUM DEPOSITS IN SANDSTONES OF MARGINAL MARINE ORIGIN

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ABSTRACT

Uranium deposits are now known to occur on the Colorado Plateau in sandstones deposited in a marine or a nearshore terrestrial environment. This is in contrast to the wholly continental origin of the highly productive Morrison formation of Jurassic age and Chinle and Shinarump formations of Triassic age. The shoreline sandstones originated as beach and fluvial deposits which commonly intertongue with shales and carbonaceous beds of marine and paludal origin.

Uranium is known in the marine Curtis formation of Jurassic age and also in several marine and terrestrial sandstones related to the Late Cretaceous sea. Occurrences are associated with local changes of facies, accumulations of carbonaceous material, or both. All are within or near regions of post-Cretaceous tectonic disturbances.

The potential production of uranium from the shoreline sandstones on the Plateau is not known; to date only a small tonnage of marginal grade has been mined. It is only recently that commercial uranium deposits have been discovered in rock of this origin, and an increasing number of discoveries is being made.

INTRODUCTION

Nearly 90 percent of the uranium ore produced on the Colorado Plateau has come from fluvial sandstones, represented chiefly by members of the Morrison and Chinle formations and by the Shinarump conglomerate. However, uranium also occurs on the Plateau in units that originated in marine, littoral marine, and coastal plain environments. Some of these are beach sandstones, others are fluviomarine sandstones, lagoonal deposits of mudstone, carbonaceous shale, and coal. All of these are related to transgression and regression of the strand line.

Shoreline sandstones have at many places the same lithologic and sedimentary features generally associated with uranium in the highly productive fluvial sandstones: shales or mudstones interbedded with sandstone in an approximate 1 to 2 or 1 to 3 ratio; carbonized plant matter; light-tan or gray color rather than the prevailing reddish; and feldspar or mica. The uranium occurrences are generally clustered on or near positive tectonic structures, but their genetic relation to these is yet to be proven.

The known uranium occurrences in sandstones of shoreline origin are shown in figure 153. These are in two general groups on the Plateau; the first is in the Curtis formation of Jurassic age (at Skull Creek, Moffat County, Colo.), which accumulated in a sea that invaded the northern part of the Colorado Plateau.

The second group is in sandstones of Late Cretaceous age deposited along the shore of a sea that extended

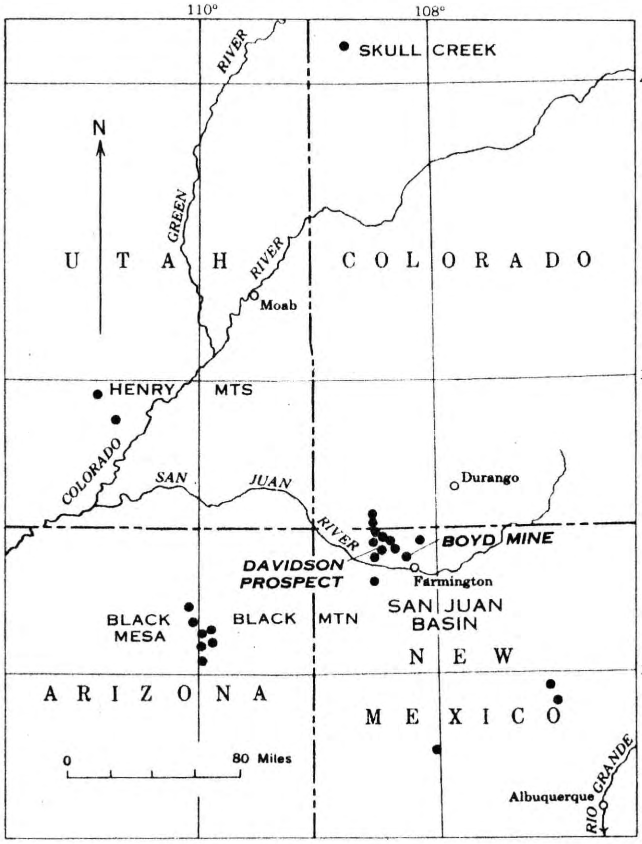

FIGURE 153.—Map of Colorado Plateau showing uranium occurrences in the Curtis formation of Jurassic age and sandstones of Late Cretaceous age.

northwestward across the Plateau from the Gulf of Mexico. Uranium occurs in the Toreva formation of the Mesaverde group on Black Mesa, northeastern Arizona. In the San Juan Basin of northwestern New Mexico uranium occurs in the Dakota sandstone, in the Menefee and the Hosta tongue of the Point Lookout formations of the Mesaverde group, in the Pictured Cliffs sandstone, and in the Fruitland formation. Uranium is also reported in the Ferron and Emery sandstone members of the Mancos shale in southeastern Utah.

URANIUM IN THE CURTIS FORMATION

Uranium occurs in the Curtis formation at Skull Creek, Moffat County, Colo. A few hundred tons have been mined during the past 50 years, first for radium, later for vanadium, and currently for uranium.

The Curtis formation, which accumulated as a near-shore marine deposit in the Jurassic sea that advanced over the northern part of the Colorado Plateau from the north or northwest (Baker, Dane, and Reeside, 1936), is composed of conglomerate, sandstone, limestone, and shale containing Upper Jurassic fossils. The Curtis, which may reach a thickness of 200 feet, is predominantly a thinly laminated, very fine grained sandstone.

The ore deposits (McDougald, 1955) are at the base of the Curtis, which overlies the eolian Entrada sandstone. The basal part of the Curtis is water-laid ripple-marked thin-bedded sandstone ranging in thickness from 6 to 36 inches, and grades upward into fossiliferous marine sandstone. The ore zone is considered to be a marginal marine facies.

The deposits are tabular, 1 or 2 feet thick, and generally contain less than 100 tons of carnotite ore disseminated in sandstone. Associated with the carnotite are other vanadium, iron, and copper minerals, together with varying amounts of organic material. The uranium content of the deposits is generally low, but at places there are concentrations of as much as 7 percent U_3O_8.

The Skull Creek deposits are on the south flank of the east-trending Skull Creek anticline. Locally, cross folding has resulted in erratic changes in strike and dip and has developed many small fracture zones, some of which show a few inches displacement. In one deposit fractures appear to have influenced the deposition of ore.

URANIUM IN SANDSTONES OF LATE CRETACEOUS AGE

During Late Cretaceous time a section of rocks about 5,000 feet thick was deposited in the Colorado Plateau region near the western edge of a geosynclinal sea that extended across the region from the Gulf of Mexico into Alberta, Canada (Pike, 1947; Sears, Hunt, and Hendricks, 1941). This sea is believed to have been separated from highlands to the west by a broad coastal plain. As marine waters transgressed and regressed during Late Cretaceous time, the coastline oscillated from west to east many times (Pike, 1947; Silver, 1951). These changing environments are reflected in the intertonguing of marine, littoral marine, swamp, and terrestrial deposits of shale, carbonaceous material, and sandstones (fig. 154). Terrestrial deposits are mostly to the southwest and marine deposits to the northeast.

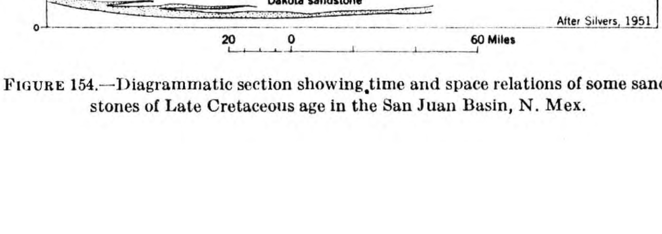

FIGURE 154.—Diagrammatic section showing time and space relations of some sandstones of Late Cretaceous age in the San Juan Basin, N. Mex.

The Dakota sandstone, of Early (?) and Late Cretaceous age, unconformably overlies Lower Cretaceous and Jurassic rocks throughout the Plateau except where it has been removed by erosion. The Dakota is overlain by thick marine shales and interbedded with tongues of sandstone and thinner carbonaceous deposits. Most of the sandstone units are members of the widespread Mesaverde group. In the southeastern part of the Plateau the Mesaverde and overlying Lewis shale are overlain by the Pictured Cliffs sandstone, the Fruitland formation, and later sediments which mark the final retreat of the Late Cretaceous sea from the region and the transition from marine through littoral marine to continental environments.

Uranium occurs in a single sandstone formation of the Upper Cretaceous on Black Mesa, Ariz., and in several formations in the San Juan Basin, N. Mex.; other deposits are reported in Cretaceous rocks in the Henry Mountains, Utah. Uranium also occurs in carbonaceous shale and coal of Late Cretaceous age (Gabelman, 1956).

BLACK MESA DEPOSITS

Black Mesa is a topographically high and structurally low area in the middle of the Navajo Indian Reservation, Apache and Navajo Counties, Ariz. (fig. 153).

Regional structure.—Black Mesa basin is a saucerlike depression tilted to the southwest. Northwest-trending anticlines, synclines, and monoclines, superimposed on this structure (fig. 155) tend to bifurcate. They are probably post-Cretaceous (Kelley, 1955).

Although figure 155 indicates uniform structure, the greatest deformation occurs in the northeast part of the mesa. The asymmetrical Black Mountain anticline, with a steep northeast flank, has the greatest structural relief in the Black Mesa area.

The principal joint set is parallel to the axes of the structures; another set is perpendicular and a third set oblique to the structural axes. A normal fault 100 feet long and having a 20-foot vertical displacement occurs in the Black Mountain-Yale Point area. No relation of joints or faults to uranium deposition is apparent.

Stratigraphy and sedimentation.—On Black Mesa the Toreva formation (Repenning, C. A., oral communication) of the lower part of the Mesaverde group is divided into three members: an upper thin littoral marine quartzose sandstone, a middle thin carbonaceous shale, and a lower, thick, ore-bearing arkosic sandstone resting on Mancos shale.

The basal unit of the lower member is a beach-type sandstone, 10 to 15 feet thick, which grades upward into a 250- to 350-foot arkosic sandstone interbedded with carbonaceous siltstones and mudstones.

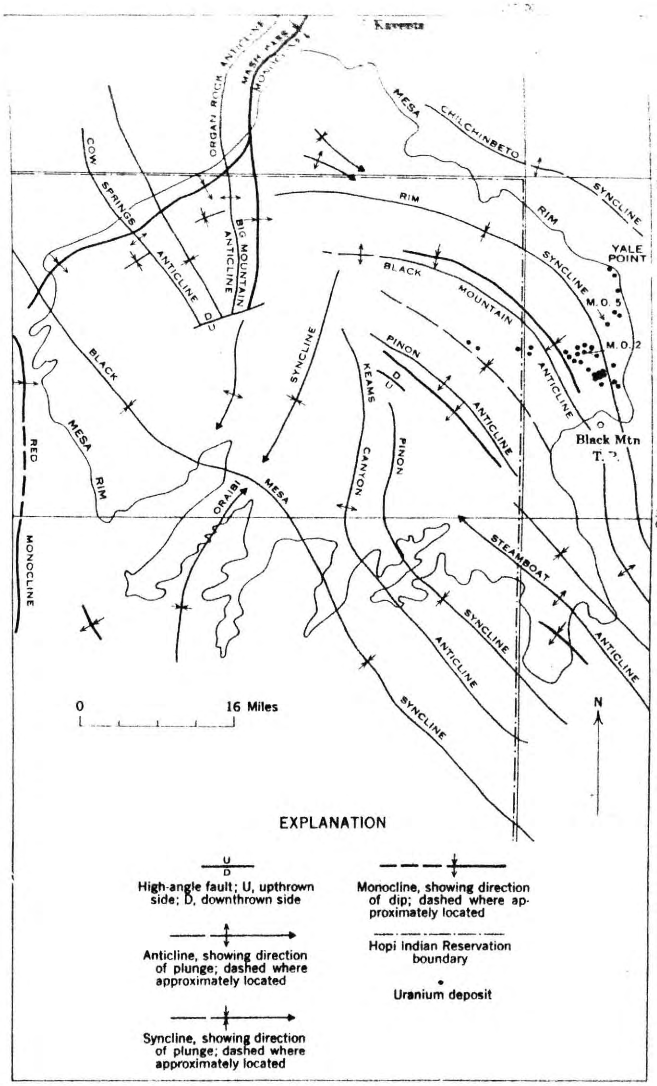

FIGURE 155.—Tectonic structure of Black Mesa, Navajo County, Ariz.

The arkosic member is a light-gray to buff cross-bedded sandstone consisting chiefly of subangular fine- to coarse-grained quartz and unweathered feldspar grains, and contains minor amounts of amphibole, magnetite, zircon, rutile, garnet epidote, apatite, ilmenite, tourmaline, and biotite. This mineral suite strongly suggests a crystalline source nearby.

Economic geology.—Uranium deposits occur on Black Mesa in areas where the structural relief of the superimposed flexures is most pronounced. Radiometric and geologic reconnaissance, made in areas where no local tectonic structures exist, revealed no commercial deposits of uranium. A concentration of deposits does occur on the steeper, more sharply flexed, northeast flank of the Black Mountain anticline (fig. 155).

All known uranium occurrences are in the light-tan or brown to light-gray 35- to 50-foot zone of quartzose lenses at the top of the arkasic member of the Toreva formation. Tongues of carbonaceous siltstone and mudstone occur within this zone. The deposits are about 20 feet long, 5 to 10 feet wide, and 0.5 to 2.5 feet thick. Present petrographic studies are too inconclusive to explain why the uranium is restricted to this single zone, although it is noted that ore-bearing sandstone contains no feldspar.

Paleostream directions in the ore-bearing zone were determined by studies of cross stratification. According to Stokes (1953), uranium is most likely to exist where paleostream directions change. Chemical assays of samples taken along the rim and a radiometric survey on top of the mesa indicate increased uranium content in areas of ancient channels and changes in paleostream directions (figs. 156 and 157). Recent mining

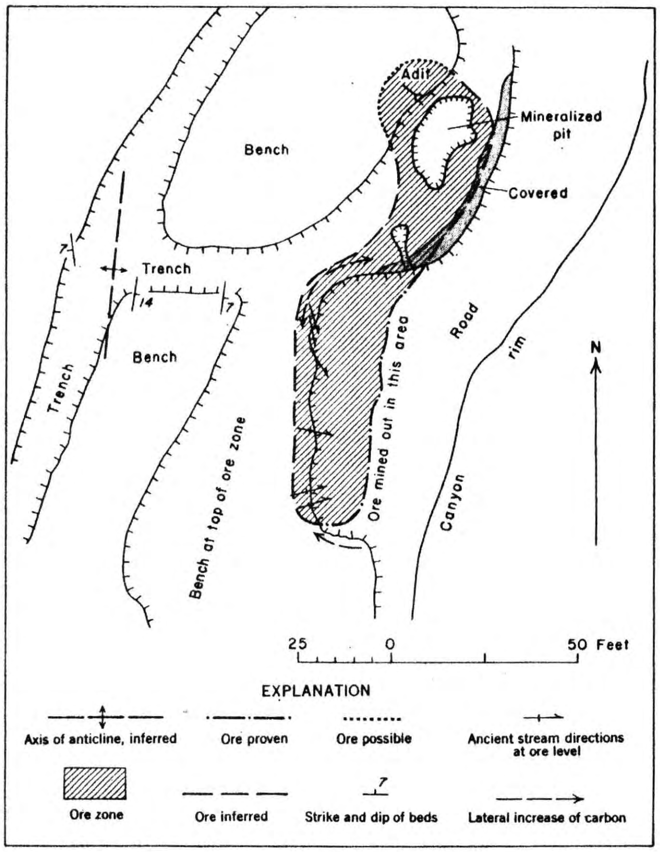

FIGURE 156.—Mineralized outcrop no. 5, Black Mesa, Navajo County, Ariz.

has uncovered a promising deposit in the Yale Point area where uranium lies within an ancient channel or "festoon" (Stokes, 1953).

Mineralogy.—Without exception, the uranium minerals are secondary and either carnotite or tyuyamunite. No unoxidized minerals have been reported but they may occur under deeper cover. The vanadium assemblage accompanying the uranium vanadates is composed

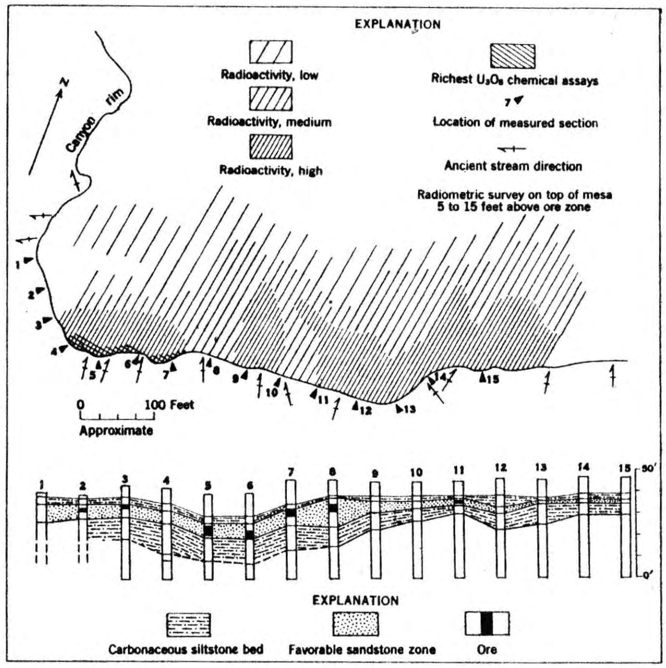

FIGURE 157.—Radioactivity, paleostream direction, and sections of mineralized outcrop no. 2, Black Mesa, Navajo County, Ariz.

of vanadium-bearing clay minerals, metahewettite, and melanovanadite.

The bulk of the host-rock mineral assemblage is composed of quartz in the form of subangular sand grains. The amount of calcium carbonate cement is low, averaging between 0.50 and 0.75 percent for the entire area. The remainder of the host rock consists of the following in varying minor amounts: hematite, goethite, jarosite, pyrite, feldspar, rutile, ilmenite, tourmaline, topaz, zircon, garnet, biotite, magnetite, and epidote.

Paragenesis indicated from petrographic analyses of samples taken from several outcrops shows that the uranium minerals replaced the original cement. The carnotite or tyuyamunite is later than the vanadium-bearing clay and replaced the carbonaceous material. The ore is postlithification (E. B. Gross, written communication).

SAN JUAN BASIN DEPOSITS

The San Juan Basin, a region of several thousand square miles in northwestern New Mexico and southwestern Colorado, is rimmed by Upper Cretaceous rocks. In its middle there is an extensive exposure of lower Eocene sandstone and shale.

Before 1955 two uranium occurrences (the Boyd deposits in the Fruitland formation and the Davidson prospect in the Menefee formation) were known in the northern part of the San Juan Basin. Early in 1955 an airborne radiometric survey by the Atomic Energy Commission detected several radioactive deposits at outcrops of the Point Lookout and the Pictured Cliffs sandstones. These are similar to the Boyd and Davidson deposits in that they are all on or near the Hogback monocline, a major structure of the area, and are associated with carbonaceous material.

The Boyd deposit is in a tuffaceous sandstone of the Fruitland formation on a mesa 12 miles northwest of Farmington, N. Mex. About 40 tons of ore containing 0.15 to 0.20 percent U_3O_8 have been mined from a sharply defined light-pink zone at the base of the tuffaceous sandstone. Just above the ore zone is 1 foot of gray sandstone that grades upward into barren buff-colored, tuffaceous sandstone. Beneath the ore there is a thin zone of gray sandstone; this in turn is separated from a 1-foot bed of mudstone and sandstone containing carbonaceous fragments and marine (or brackish water?) gastropods by a sharp, scoured contact. Bentonitic and tuffaceous beds underlie the fossiliferous unit. The uranium mineral is too fine to be readily identified.

The ore, exposed in an area of about 25 by 50 feet in an open pit, is from 3 inches to 36 inches thick. The ore body occupies a shallow depression scoured into the subjacent, tuffaceous sediments. It is on the flank of the Hogback monocline in beds dipping 12° SE. The pink color of the ore unit is due to iron oxide.

The Davidson occurrence is in the Menefee formation of the Mesaverde group, about 9 miles east of Ship Rock, N. Mex., where the stratigraphic sequence from top to bottom is:

	Feet
Coal	4
Sandstone and coal	2 to 3
Sandstone, uranium-bearing, dark gray-green	1 to 2
Sandstone, light-gray	Not measured

The gray-green uranium-bearing sandstone consists of iron-stained fine-grained quartz sandstone containing mica, feldspar, clay, tiny flecks of hydrocarbon, and a few grains of an unidentified pink mineral. The uranium minerals have not been identified. Pyrite and calcium carbonate concretions are abundant just above and below the mineralized zone. No ore has been shipped from this deposit. Surface material contains less than 0.10 percent U_3O_8.

Carnotite occurs in sandstone lenses associated with carbonaceous material in the Dakota sandstone (Gabelman, 1956) and in the Hosta tongue of the Point Lookout sandstone of the Mesaverde group (Vine, Bachman, Read, and Moore, 1953) in the southern part of the San Juan Basin.

SUMMARY

Production of uranium from marginal marine sandstone has been minor in comparison with production from fluvial sandstones. Two of the features considered favorable for the occurrence of uranium deposits in the fluvial Morrison formation (Weir, 1952) are also considered favorable for deposits in marginal marine sandstone: Color is altered from red to brown or light gray in the vicinity of ore deposits, and ore deposits occur near concentrations of carbonized plant fossils. Other favorable features are ancient stream channels, a littoral zone of deposition, and local folding.

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