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# GEOLOGY OF THE RAINY DAY URANIUM MINE

# GARFIELD COUNTY, UTAH*

By

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# GEOLOGY OF THE RAINY DAY URANIUM MINE, GARFIELD COUNTY, UTAH

By Edward S. Davidson

## ABSTRACT

The Rainy Day mine in the Circle Cliffs area, Utah, is developed on a long slender pod of uranium ore. Ore is localized in siltstone of the Moenkopi formation of Triassic age, on the south edge of a channel about 3,300 feet wide by 40 feet deep that is filled with sandstone of the Shinarump member of the Chinle formation of Triassic age. Shale of the Chinle rests directly on siltstone of the Moenkopi on either side of the channel. The pod of ore is of moderately high grade, measures $1\frac{1}{2}$ by 4 feet in cross section, and is continuous for a mined distance of more than 1,800 feet. Sphalerite, chalcopyrite, pyrite, marcasite, and galena are associated with a black uranium mineral, which is probably uraninite. Semiquantitative spectrographic analyses show that lead, copper, nickel, cobalt, silver, molybdenum, zinc, yttrium, and ytterbium increase proportionately with uranium; the increase suggests that these metals were introduced by the ore-forming fluid.

The deposit is on the east flank of the northwest-trending Circle Cliffs anticline. No major faults are near the mine, nor were any through-going joints noted in the deposit. Efforts to correlate the localization of the deposit with minor structures were unsuccessful.

# INTRODUCTION

The Rainy Day uranium mine is in the eastern part of the Circle Cliffs area, about 45 miles southwest of Hanksville, Utah (fig. 1). The mine was opened in the spring of 1954 and was operated more or less continuously until the fall of 1955. It was reopened in the spring of 1956, and was operated on a small scale during 1956 and 1957.

The deposit is unusual in that it is not more than 4 square feet in cross section, yet it is continuous for over 1,800 feet along its strike. The uranium ore is localized in siltstone and mudstone of the Moenkopi formation of Triassic age, on the south side of a channel filled with sandstone. This is in contrast to most "channel type" uranium deposits in rocks of Triassic age, which are localized in the channel-filling sandstone.

This report describes the relation of the uranium deposit to the local geology and presents several ore and subore analyses which show similarities between this deposit and those in the Shinarump and Moss Back members of the Chinle formation of Triassic age.

Field work was done in the summers of 1954 and 1955 in connection with the geologic mapping of the Circle Cliffs area by the U. S. Geological Survey on behalf of the Division of Raw Materials of the U. S. Atomic Energy Commission. All geologic contacts were mapped in the field on a topographic base map at a scale of 1 inch equal to 2,000 feet and with a 40-foot contour interval. The writer was ably assisted in the field by Louis D. Carswell and David A. Brew of the U. S. Geological Survey.

GENERAL GEOLOGY

The Circle Cliffs is a breached anticline; rocks of Permian and Triassic age floor the interior, which is about 10 by 30 miles across and which is rimmed by cliffs of resistant sandstone of Triassic and Jurassic age. Reports describing the geology of the area are those by Gregory and Moore (1931), Hunt (1953), and Steed (1954). The following is a brief résumé.

The oldest rock exposed in the vicinity of the Rainy Day mine is of Permian age and is sandstone with medium- and large-scale crossbeds. The base of this sandstone is not exposed, but 105 feet of it crops out in a canyon a few miles south of the Rainy Day mine. The sandstone is correlated with the Coconino sandstone by Gregory and Moore (1931, p. 45) and with the White Rim member of the Cutler formation by Steed (1954, p. 100-101).

A white to light-yellow flat-bedded sandstone overlies the cross-bedded sandstone. Fine-grained friable white sandstone and dolomite-cemented light-yellow sandstone are the main constituents although a few sandy dolomite beds are present. This sandstone ranges from 50 to 75 feet in thickness and was probably included in the Kaibab limestone by previous workers (Gregory and Moore, 1931; Hunt, 1953; Steed, 1954). The top of this sandstone was used for structural control in the vicinity of the Rainy Day mine (fig. 2).

The Kaibab limestone of Permian age conformably overlies the flat-bedded sandstone. The formation consists of light yellowish-white dolomite in beds ranging from 1 to 4 feet thick. The top of the Kaibab is an erosional surface. In most places the formation is about 45 feet thick, but in a few places the Kaibab has been completely removed by erosion.

The Moenkopi formation of Early and Middle(?) Triassic age is composed mainly of sandstone, siltstone, and mudstone, but some dolomitic units form the base of the formation and several persistent dolomitic(?) siltstone beds occur near the top of the formation. The Moenkopi is dominantly reddish brown. The lower part of the formation, however, weathers gray or light yellow in the central and eastern parts of the Circle Cliffs; the fresh rock in these places is petroliferous and is gray or black. Also, the upper few feet of the Moenkopi, where overlain by the Shinarump member of the Chinle formation, is locally dark to light gray, weathering on the outcrop to light yellow. The gray color, according to Keller and Schultz (1955), is caused mainly by reduction of the ferric iron in the red siltstone to ferrous iron, a process that may be due to chemicals included in ground water. Data presented later in this report indicate that the color change, in the Rainy Day mine area at least, is also accompanied by a decrease in amount of iron present in the gray rock. This formation ranges from 475 to 525 feet in thickness.

The Chinle formation of Late Triassic age is divided into several members in the Circle Cliffs area. The lowest member, the Shinarump (Stewart, 1957), is described in detail below. The other members, which are not described in detail, are composed of varicolored red, gray, and purple bentonitic and nonbentonitic mudstone, siltstone, and sandstone and minor limestone; they range in combined thickness from 600 to 700 feet.

The Shinarump member is a fine- to medium-grained white feldspathic sandstone with some interbedded gray micaceous mudstone. It is commonly 40 to 60 feet thick in most of the Circle Cliffs area and may be considerably thicker where it fills Triassic stream channels cut in the underlying Moenkopi formation. In the vicinity of the Rainy Day mine, the Shinarump is mostly absent. It crops out in very small areas in the eastern part of the area shown on figure 2 and occurs on isolated mesas in the western part. The two outcrops in the eastern part of the area are interpreted as deposits in two stream channels. The northernmost of these channels, along which the Rainy Day deposit is localized, is 3,000 to 3,400 feet wide, and the sandstone is not more than 40 feet thick. Most of this thickness is gained at the expense of the Moenkopi formation although in the outcrop on the cliff there appears to be some buildup of sandstone over the central part of the channel. The sandstone deposit to the south fills a channel that is only about 1,200 feet wide, but here the sandstone is almost 100 feet thick. Uranium and copper minerals are localized near the contact of the Shinarump member and Moenkopi formation in both channel deposits, but exploration in parts of these channel deposits has not disclosed any uranium ore except that in the Rainy Day mine.

The Wingate sandstone of Late Triassic age is a light-orange fine-grained well-sorted sandstone. This sandstone is 230 to 350 feet thick and forms a cliff that caps the escarpment for which the Circle Cliffs is named. The contact between the Wingate sandstone and the Chinle formation is disconformable but with negligible relief.

The Rainy Day mine is on the eastern flank of the Circle Cliffs anticline. The anticline trends N. 30° to 35° W., and pitches southeast in the southern part of the area shown on figure 2 and to the northwest in the northern part; maximum pitch is $1\frac{1}{2}°$ to 2°. On the northeastern side of the anticline, dips in the central part of the anticline increase gradually to 15°; dips on the flank increase abruptly from 15° to 50°. Beds near the mine dip about 12° northeast. The structural surface illustrated on figure 2 is represented by lines drawn through points of equal elevation on the top of the sandstone that underlies the Kaibab limestone. North and east of the mine, this sandstone is not exposed and the contours below about 5,200 feet are projected from the base of the Wingate sandstone. This projection is supported by three complete and two partial measured sections and was constructed by assuming that the folding is of the parallel type, so that stratigraphic thickness remains constant downdip.

## RAINY DAY DEPOSIT

The Rainy Day mine was opened on the northwest end of a long slender pod of the uranium ore $1\frac{1}{2}$ feet by 4 feet wide by 1,800 feet in length. The main drift, which followed the ore pod, trends about N. 70° W. at the westernmost end of the mine, and about N. 85° W. in the eastern end of the mine and slopes about 9° southeast (fig. 3). Several exploratory crosscuts and inclines have been driven to the northeast into the sandstone of the Shinarump member of the Chinle formation and along the Shinarump and Moenkopi contact, but encountered no additional ore, although the siltstone of the Moenkopi formation directly underlying the contact is noticeably more radioactive than normal. Exploration of other parts of the channel has found no rock of commercial grade, but high radioactivity and copper staining are evident in the siltstone of the Moenkopi near the contact with the Shinarump. Locally, abundant pyrite is found in the lower foot or so of the Shinarump.

## Habit of deposit

The channel is asymmetric in cross section and curves gently to the north in plan view. The north side of the channel has a gentle slope which resembles the slip off slopes found on the banks of present day streams; the south side of the channel is steep, locally undercut, and is marked by a series of abrupt slope changes that are probably former stream banks. The ore pod is localized near the top of one of these small banks. The southern edge of the channel, where the Shinarump member of the Chinle formation pinches out, is probably parallel to, and not more than 50 feet south of the ore pod. The sandstone filling the channel is not more than 40 feet thick, and most of this thickness is gained at the expense of the Moenkopi formation (fig. 3, section of incline), although on the outcrop there appears to be some buildup of sandstone over the central part of the channel. Crossbed measurements indicate that the sandstone was deposited by a stream that flowed from southeast to northwest.

The Moenkopi in the mine ranges from a mudstone to a siltstone. Quartz, kaolinite, and mica grains, coated with iron oxide, are the main constituents. This rock, normally red, is gray in a 6- to 10-foot zone under the contact with the Shinarump member and the Moenkopi formation, but this altered zone is not significantly thicker near the mine than in other places at the contact. A small amount of pyrite occurs in the altered zone, diminishing in quantity toward the contact with unaltered red siltstone. The red siltstone contains no pyrite. The total iron content of the gray rock ranges from 1 to 3 percent, and total iron in red siltstone ranges from 3 to 7 percent. The iron removed from the gray rock probably was redeposited in the overlying pyritic sandstone, as pointed out below. Asphaltic material, not soluble in xylol or benzene, is present in the gray siltstone of the Moenkopi formation in the Rainy Day mine, and it may have had some influence on ore deposition.

The sandstone filling the channel is medium to fine grained and contains abundant gray mudstone seams and lenses and carbonaceous material. Quartz, about 1 percent mica, and up to 25 percent kaolinite and altered feldspar are the main rock-forming minerals. The base of the sandstone is locally conglomeratic, especially in the mine, containing pebbles of quartz, quartzite, and chert, and fragments of siltstone and carbonaceous material. Much of the carbonaceous material is partly replaced by pyrite and marcasite. The sediment filling the channel is generally slightly petroliferous and, locally, is nearly saturated with a brown to black asphaltic material which dissolves easily in xylol or benzene.

Overlying the channel-filling sandstone with a gradational and intertonguing contact is the Monitor Butte member of the Chinle formation. This unit consists of bentonitic gray to gray-green mudstone and siltstone interbedded with discontinuous lenses of arkosic fine- to medium-grained gray sandstone. This normally gray-green rock is altered to shades of yellow and blue near the north edge of the Rainy Day channel. The alteration probably involves only a change in amount and composition of iron minerals. No unusual radioactivity has been noted in association with this alteration.

The uranium ore is localized near the top of a streambank cut in the siltstone of the Moenkopi formation. This pod of ore, illustrated in cross section in figure 4, is lens shaped, measuring about 1½ feet in thickness and 4 feet in width. Locally the host rock is crumpled and sheared, especially at the top of the bank; more commonly it is not noticeably sheared or disturbed. This crumpling is attributed to partial caving during cutting and filling of the channel. The ore pod was localized in the top of the bank at the northwest end of the deposit, but in the southeast end it is more commonly found a foot or two below the top of the bank in essentially undisturbed rock. The ore has been continuous and uniform in grade for its entire mined length of more than 1,800 feet, 1,100 feet of which was mapped and is shown in figures 3 and 4. Grab samples taken from the central part of the ore pod contain from 1 to 4 percent uranium. The grade decreases gradually away from the center of the pod but drops off abruptly at the contact with the Shinarump member of the Chinle formation. Generally, the Shinarump does not contain minable concentrations of ore, but the operator reports that locally very small patches of sandstone in contact with the ore pod have a high count. Away from the ore pod, the Moenkopi is slightly radioactive along its contact with the Shinarump, and this radioactivity diminishes as the distance from the ore body increases.

The ore mineral is isotropic, gray under reflected light, and may be seen only under very high magnification. It is considered to be uraninite. The uraninite fills interstices and microscopic fractures and replaces parts of the siltstone and mudstone of the Moenkopi formation. It is also localized along bedding planes. Chalcopyrite, sphalerite, pyrite, marcasite, and galena, in approximately that order of relative abundance, are associated with the uraninite. No molybdenum minerals were identified in thin or polished sections, but ilsemannite can be seen on the exposed surface of rock near ore, and spectrographic analyses show as much as 2 percent molybdenum.

Directly overlying the ore, in the Shinarump member, is a fairly continuous zone containing abundant pyrite and marcasite (figs. 3 and 4). Local concentrations of molybdenum, indicated by development of ilsemannite on mine walls, also occur in this zone. The total iron content in the zone ranges from 3 to 7 percent. This is in marked contrast to the amount of iron occuring in the overlying nonpyritic sandstone, which contains only about 1 percent total iron. The iron in the pyrite zone probably was leached out of the gray siltstone which contains 1 to 3 percent iron, or less than half that of the parent red siltstone, but whether by ore solution, or other waters at a time not related to ore deposition, is a matter for conjecture. The zone containing pyrite and marcasite ranges up to 4 feet in thickness and, merging with the pyrite in the gray siltstone of the Moenkopi, forms an imperfect pyritic envelope or halo around the ore pod (fig. 4, especially section D-D').

## Chemical changes due to uranium introduction

Semiquantitative and chemical analyses were made of eight grab samples taken from the Rainy Day channel. A graph of the analyses is presented on figure 5. These samples show that several elements, notably copper, zinc, nickel, and lead, increase as the grade of uranium increases.

The relative positions of the samples are shown diagrammatically on figure 5. All of the samples are from the Moenkopi formation; one, RD21a, is unaltered red siltstone; the others are from gray siltstone. Of these, RD2, RD101, RD102, and RD17 are ore samples. RD22b, RM4, and RM3 are only very weakly mineralized. Both RD21a and RD22b are slightly more dolomitic than the other samples. Samples RM3 and RM4 were collected from the prospect at the north edge of the Rainy Day channel (fig. 2); all other samples are from the Rainy Day mine (figs. 3 and 4).

The samples are arbitrarily positioned in figure 5, so that uranium increases from left to right. Ytterbium, yttrium, copper, nickel, cobalt, lead, silver, molybdenum, and zinc show a 10-fold or greater increase, from barren rock to uranium ore, similar to that of uranium. The author believes this correspondence indicates that these elements were introduced with, and roughly in proportion to uranium; if this is true they were carried by the ore-forming solutions and were concentrated in the deposit during the ore-forming period. If the slightly greater original dolomite content of RD21a and RD22b is taken into account and the lowest and highest amounts of the elements considered, gallium and calcium also show a 10-fold increase corresponding roughly to that of uranium; but, because of the erratic nature of the gallium curve and the likely fluctuation of amounts of calcium due to ground-water removal or deposition of dolomite since ore emplacement, their correspondence may not be significant. The chemical trend of samples RM3 and RM4 from the north side of the channel closely follow the chemical trend of the samples from the Rainy Day mine. The location of the samples suggest that the ore solutions which formed the Rainy Day deposit probably traversed the entire channel sandstone deposit, but formed minable concentrations of uranium only at the southern edge in the Moenkopi formation.

Analyses of unmineralized sandstone and uranium-ore sandstone samples from the Shinarump and Moss Back members of the Chinle formation, collected from the entire Colorado Plateau, show that samples from ore deposits have a 10-fold or greater increase from barren rock to uranium ore, in vanadium, cobalt, nickel, copper, zinc, yttrium, molybdenum, and lead (William L. Newman, oral communication, 1957). Thus, except for the lack of an increase in vanadium and an increase in silver and ytterbium, the ore at the Rainy Day mine from the Moenkopi formation has nearly the same suite of added or "extrinsic" elements as ore bodies in sandstone of the Shinarump and Moss Back members of the Chinle formation.

These samples point up an ore guide that has already been used by prospectors, especially with regard to copper staining in the Circle Cliffs area; that is--channel sandstones showing enrichment in the elements associated with uranium are more favorable for prospecting than sandstones showing no enrichment at all, no matter how favorable the channel fill looks otherwise.

Possible structural localization of the ore body

As pointed out above, the deposit is localized on the eastern flank of the Circle Cliffs anticline, near where the rate of change of dip increases rapidly. In the mine the localization of ore is not controlled by through-going large fractures or joints and probably is controlled only to a minor extent by fractures caused by slumping during cutting of the channel. The structure surface near the mine is not smooth but is quite irregular, having several bumps and hollows. Several maps which eliminated the regional structure and isolated the minor structures were constructed, in line with general principles outlined by Dobrin (1952), Griffin (1949), and Nettleton (1942). The deposit is located almost on the center of a saddle formed by the intersection of a northwest-trending low and a northeast-trending high. The structural relief above and below the generalized regional structural surface was on the order of 200 to 300 feet. The correlation between the minor structures and the deposit does not suggest an obvious ore control. The ore body does not appear to be controlled by the present regional structure. It is almost impossible to say whether or not an earlier structure or an early stage of the present regional structure, now masked, is responsible for the localization of the ore body.

## CONCLUSIONS

The Rainy Day deposit is localized in siltstone to mudstone in contrast to most other **minable** deposits in Triassic rocks which are in much more permeable rock--generally sandstone. In addition, the siltstone has only small amounts of asphaltic material, whereas the sandstone has moderate to abundant amounts of asphaltic and charcoally material. The cause of the peculiar localization is unknown. It seems most likely that the sandstone filling the channel provided the main conduit for the ore solutions since the mudstone above and the siltstone below the sandstone are much less permeable than the sandstone deposit in the channel. The chemical similarity of the samples from the north edge of the channel to those from the Rainy Day deposit supports this contention. Yet, essentially none of the sandstone in the channel deposit, nor any of the abundant carbonaceous or asphaltic material in the sandstone is mineralized with uranium.

Ore textures indicate the ore minerals are later in age than the host rock; it is probable that this deposit is approximately the same age as other Colorado Plateau ores which, according to Stieff and others (1953), are 71 to 82 million years old, based on $Pb^{206}/U^{238}$ and $Pb^{207}/U^{235}$ ratios. Thus the deposit was probably emplaced during the latter part of the Cretaceous period. The folding of the Circle Cliffs structure has involved Upper Cretaceous rocks, and the Wasatch formation of early Eocene age truncates the structure to the north and west. The regional structure, therefore, probably ranges from Late Cretaceous to early Eocene in age. Hence, ore deposition may have preceded or occurred approximately at the same time as the main structural deformation. The flow of ore solutions may have been controlled by an early development of the regional structure, later masked by more vigorous folding; efforts to isolate such an early structure proved fruitless.

Possible sources of ore solutions, ably discussed in considerable detail by Gruner and others (1953), Gruner (1956), Fischer (1950), and McKelvey and others (1955), seem limited to ground water or hydrothermal sources or perhaps a combination of the two. The intense alteration of the Chinle formation at the northern edge of the channel and the mineral assemblage in the deposit seem to favor a hydrothermal source, yet the bleaching and even the typical "hydrothermal minerals," chalcopyrite, galena, and sphalerite, may have originated from more or less cool ground(?) waters. Chemical evidence does not eliminate either source. The direction of solution transport, which might be helpful in ascertaining source directions, is not at all clear from the structural picture, nor are techniques for determining the direction of ore solution flow (Gross, 1956) applicable, mainly because of the small size of the deposit.

Semiquantitative spectrographic analyses of rock directly underlying a channel in the Circle Cliffs area would be valuable in locating places higher-than-normal in copper, silver, molybdenum, and zinc content. These channels, on evidence submitted here, are more favorable places for prospecting than places where there is no enrichment of these critical elements. This technique might also apply in other regions of the Colorado Plateau.

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