Geology of Carnotite-Bearing Sandstone in the Uravan and Gateway Districts, Montrose and Mesa Counties, Colorado, and Grand County, Utah

By
E. J. McKay

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GEOLOGICAL SURVEY

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E. J. McKay

January 1953

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GEOLOGY OF CARNOTITE-BEARING SANDSTONE IN THE URAVAN AND GATEWAY DISTRICTS, MONTROSE AND MESA COUNTIES, COLORADO, AND GRAND COUNTY, UTAH*

By E. J. McKay

ABSTRACT

Most of the carnotite deposits in the Uravan and Gateway mining districts are in the persistent upper sandstone stratum of the Salt Wash sandstone member of the Morrison formation.

Areas in which this stratum is predominantly lenticular have been delimited from areas in which this stratum is predominantly nonlenticular. Ground most favorable for carnotite deposits is in areas of lenticular sandstone where the stratum is underlain by green-gray altered mudstone.

Ore is localized in scour-and-fill bedded sandstones within favorable areas of lenticular sandstone.

Regional control of the movement of ore-bearing solutions in the persistent ore-bearing sandstone stratum is indicated by:

1. A concave arcuate belt of partly altered mudstone transitional between areas of unaltered mudstone to the west and areas of altered mudstone to the east.
2. An increase in size, grade, and number of ore deposits from areas of partly altered to altered mudstone.

INTRODUCTION

Carnotite deposits in sandstone beds of the Morrison formation are widely distributed in southwestern Colorado and the adjoining parts of Utah, Arizona, and New Mexico. Some of the more productive areas in Colorado have been studied and drilled intensively by the Geological Survey. This work, much of which has been done on the behalf of the Atomic Energy Commission, has resulted in the recognition that several lithologic features of the ore-bearing beds can be useful in guiding exploration and in appraising the favorableness for ore deposits. Those features that can be readily observed in drill core, and their application in exploration have been described by Weir (1952), and they are briefly mentioned in this report. They are particularly useful in guiding diamond drilling, as they have somewhat limited distribution and offer relatively small-scale targets. This report describes other features, that can be observed better at the outcrop and can be used as large-scale guides.

In 1950 a special detailed study was made of the ore-bearing sandstone and associated beds in the Uravan and Gateway districts, Montrose and Mesa Counties, Colorado, and the adjoining part of Grand County, Utah (fig. 1). The purpose of the work was to determine the gross lithologic characteristics of these beds, both in the vicinity of and away from carnotite deposits, in order to evaluate certain geologic features as ore guides, as an aid in planning exploration and appraising large areas from the standpoint of favorableness for ore deposits. The pertinent results of this work--predictions of ground favorable and unfavorable for ore--were summarized in a preliminary report (McKay, 1951). These predictions have been largely substantiated by a small amount of wide-spaced drilling done subsequently by the Geological Survey, and as a result, additional drilling originally planned has been abandoned and considerable footage saved.

In the Uravan and Gateway districts, the general character of the bedding in the ore-bearing sandstone and amount of alteration in associated mudstones, and the relation of these to each other, are the features most useful as large-scale guides. This report describes these features and their distribution, as well as other significant geologic characteristics of the ore-bearing sandstone. It also describes briefly some of the

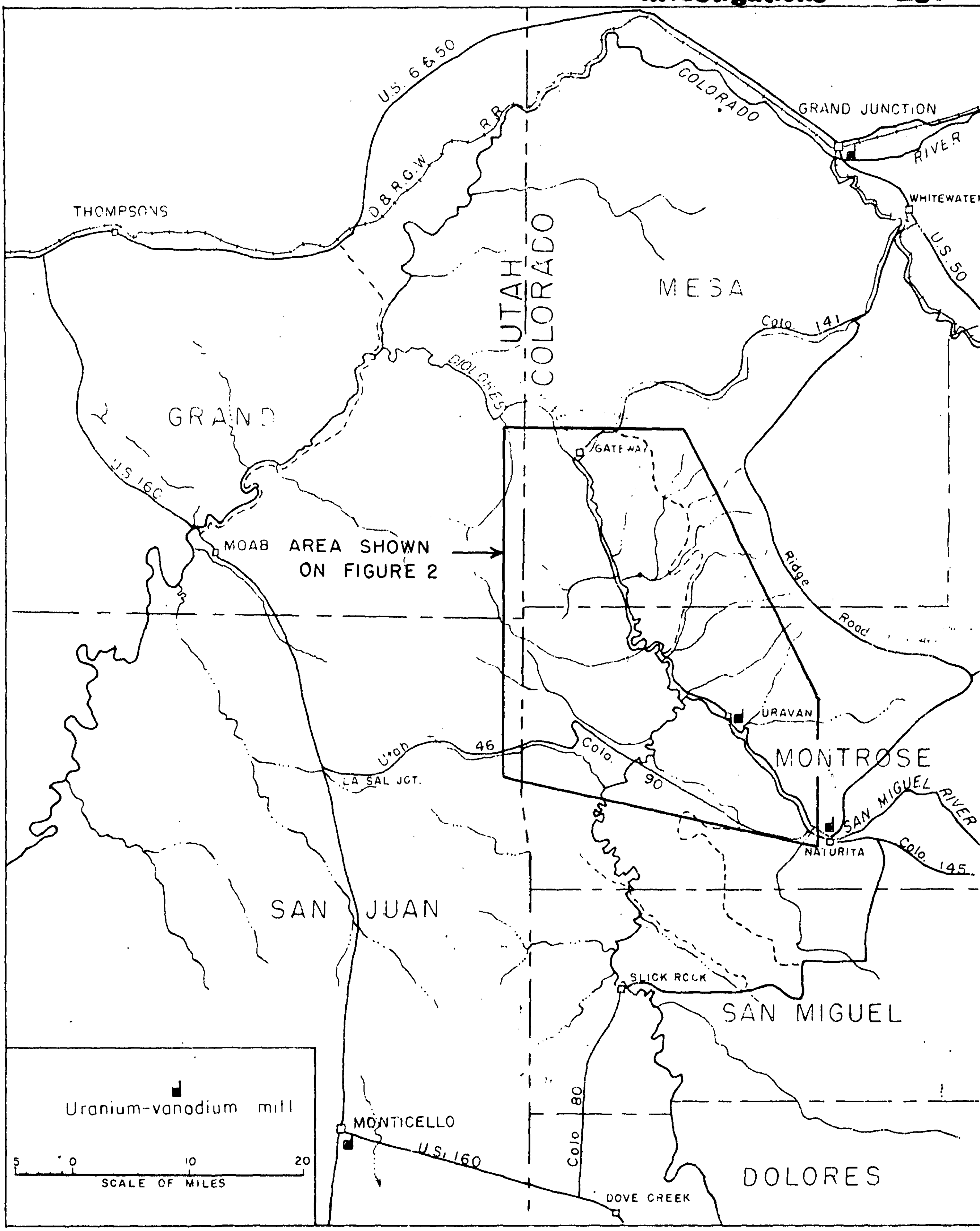

FIGURE 1.--INDEX MAP OF PART OF THE COLORADO PLATEAU SHOWING URAVAN AND GATEWAY DISTRICTS, MONTROSE AND MESA COUNTIES, COLORADO, AND GRAND COUNTY, UTAH

broad geologic relations that may have influenced regional localization of ore deposition. As a result of this work, plus different studies by other geologists, it may be necessary to revise some of the previous ideas regarding the origin of the carnotite deposits, and this study in particular might also necessitate modifying the concept of the Uravan mineral belt, as presented by Fischer and Hilpert (1952).

GEOLOGY

Geologic setting

The Uravan and Gateway mining districts lie in a broad, shallow syncline between the northwest-trending Uncompahgre Plateau on the northeast and the northwest-trending Paradox Valley and Sinbad Valley anticlines on the southwest. The area is a deeply dissected, rugged highland ranging from 5,500 to 7,000 feet in altitude. Rocks ranging from Permian to Cretaceous in age are exposed. The ore-bearing Morrison formation of Upper Jurassic age is about 700 feet thick and is composed of two members, the Brushy Basin shale member and the underlying Salt Wash sandstone member. Carnotite deposits are found mostly in the Salt Wash sandstone member.

Salt Wash sandstone member

The Salt Wash sandstone member is about 300 feet thick and is composed of about equal parts of sandstone and mudstone strata. On fresh exposures, the sandstone ranges from white to gray, yellow, and reddish-brown. Limonite occurs in places as specks in the sandstone; limonite diffusion bands are prominent in some exposures of light-colored sandstone. The sandstone is composed dominantly of fine- to medium-grained clear quartz with minor amounts of white and pink chert, clear feldspar, and interstitial clay. The quartz grains are subrounded to rounded and are well sorted, though in a few places, the textural range is from fine to coarse. Chert grains are angular and their modal diameter is larger than the modal diameter of the quartz grains. Calcite is the principal cementing material. Fossil logs composed of hydrocarbons, silica, limonite, calcite, dolomite, and carnotite occur in places.

The sandstones of the Salt Wash member are broadly lenticular. The lenses are thicker and more numerous and form fairly continuous sandstone strata near the top and at the base of the member (plate 1a). Scour-and-fill-type bedding is present in places (plate 1b).

A mudstone sequence with interbedded sandstone lenses lies between the upper and lower sandstone strata. Mudstone also occurs in the sandstone strata as thin lenses, films, and reworked fragments ranging from pebble to cobble size. The mudstone strata are dominantly red and are composed largely of argillaceous material in which are mixed minor amounts of fine to medium quartz grains and other minerals of silt size or slightly larger. Fossil logs and remnants of vegetal material are almost absent in these strata. Over wide areas red mudstone has been altered to green-gray within and immediately beneath the upper Salt Wash sandstone stratum. Altered green-gray mudstone is also found locally beneath the lower Salt Wash sandstone stratum and beneath individual sandstone lenses in mudstone strata.

Ore-bearing sandstone

The upper sandstone stratum, the ore-bearing sandstone, ranges from 15 to 80 feet in thickness. In places this stratum is rather thinly and evenly bedded (plate 1c); the beds range from 1 to several feet in thickness. In most places, however, the stratum is composed of several broad irregularly bedded lenses that range from a feather-edge to 60 feet in thickness and from several hundred to several thousand feet in horizontal extent (plate 1a). These lenses are separated in many places by mudstone lenses that range from a fraction of an inch to 20 feet in thickness.

Scour-and-fill-type bedding is common in areas of lenticular sandstone but rare in areas of nonlenticular sandstone. The scour-and-fill-type bedding forms thick, narrow sandstone lenses interbedded with thin discontinuous mudstone lenses and mudstone-pebble and -cobble conglomerate. Fragments and masses of replaced woody material are abundant in many of these scour-and-fill-type beds. Material in these beds is generally poorly sorted. Scour-and-fill sandstone in some places occupies the entire stratigraphic interval of the ore-bearing sandstone, whereas in most places only part of the interval is so occupied.

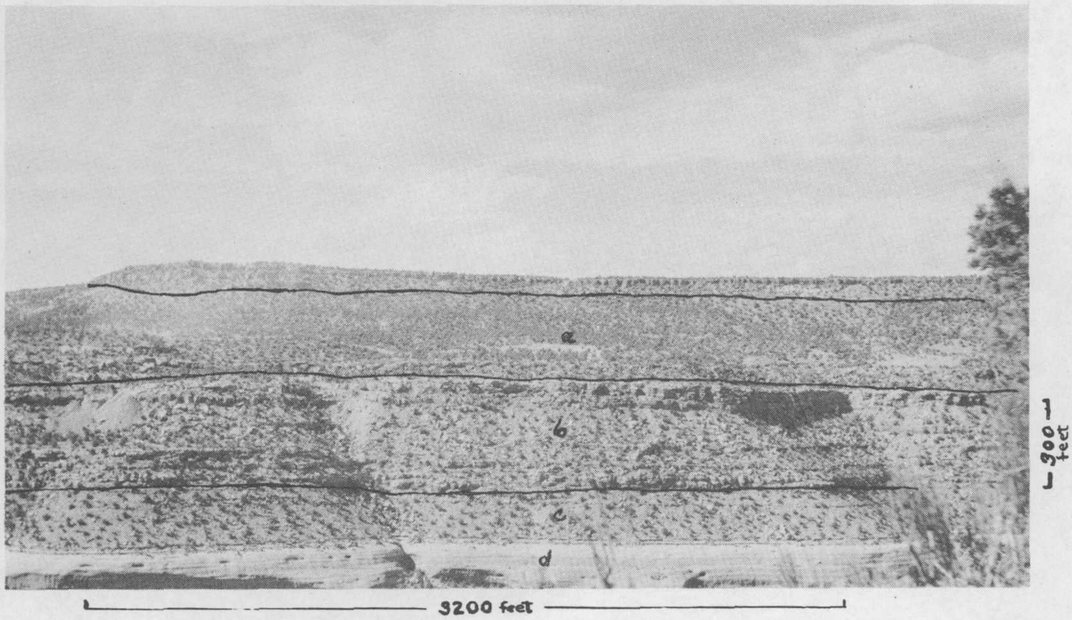

Plate 1a. --Salt Wash sandstone member of Morrison formation (b), overlain by Brushy Basin shale member (a), underlain by Summerville formation (c) and the Entrada sandstone (d). Caprock of mesa is Lower Cretaceous Burro Canyon formation. (Picture taken looking toward Dolores Group of mines.)

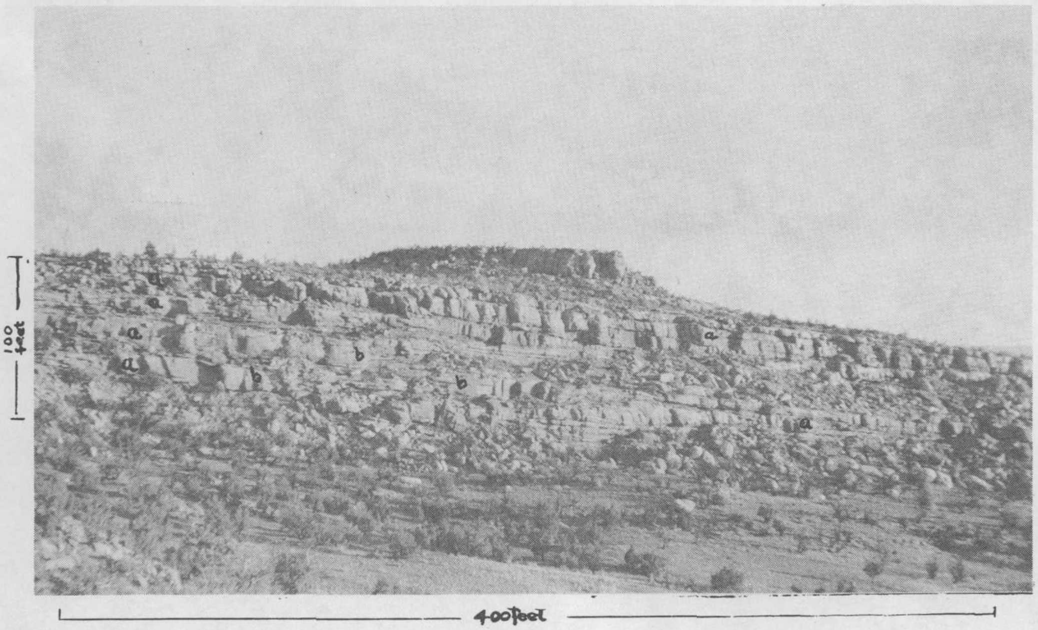

Plate 1b. --Lenticular upper Salt Wash sandstone stratum composed of scour-and-fill sandstone lenses (a), which interfinger at (b). (Picture taken looking toward east side of Club Mesa.)

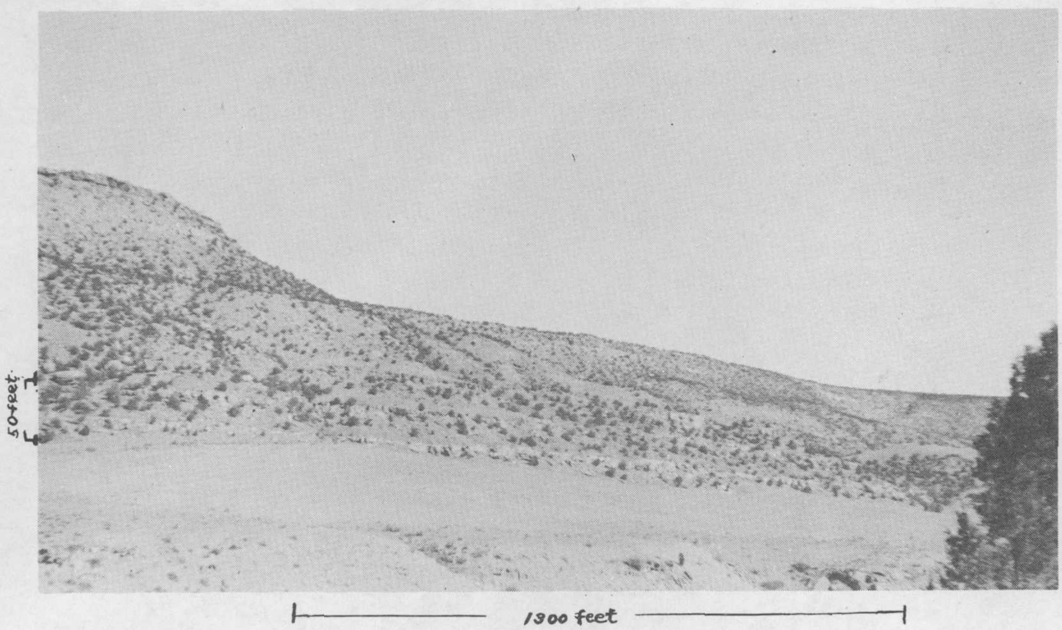

Plate 1c. --Dominantly nonlenticular upper Salt Wash sandstone stratum showing thin flat beds. (Picture taken looking east of the San Miguel River, 5 miles southeast of Uravan, Colorado.)

In places, the ore-bearing sandstone has filled channels cut in the underlying mudstone, but the depth of these channels rarely exceeds 10 feet. Sandstones filling these channels generally contain more reworked interstitial and conglomeratic mudstone and fossil woody material than the scour-and-fill structures within the ore-bearing sandstone.

The relatively slight scouring indicated at the contact between the upper sandstone stratum and the underlying mudstone over most of the area, together with relatively little redeposited pebble and cobble aggregates of mudstone in the sandstone, indicate a pre-ore-bearing sandstone terrain of low relief and gradient. Relatively clean clay and thin limestone beds near or at the top of the mudstone stratum suggest local ponding just prior to or simultaneous with initial stages of deposition of the ore-bearing sandstone. In places, however, the basal 2 or 3 feet of the sandstone contains much reworked clay and lime. The sandstone lenses within the ore-bearing sandstone stratum were deposited by numerous aggrading northeastward flowing streams, which appear to have formed a braided system rather than a dendritic system. Levee structures have not been recognized; conditions of intermittent flooding and aggradation were probably such that levees, if present, were low-lying and continually broken and destroyed by shifting stream channels. Fossil plant material was not seen in place; most of the plant fragments were probably rafted into the positions they now occupy.

Sedimentary-trend directions of sandstone lenses are indicated by the orientation of cross-bedding, current lineation, and ripple marks. These orientations may be widely dispersed in direction but generally are confined to a single quadrant. Trend directions are more erratic in scour-and-fill bedding structures than in other areas of dominantly lenticular sandstone and are relatively consistent in areas of dominantly nonlenticular sandstone. Figure 2 shows the average sedimentary trend of the more prominent sandstone lenses in the ore-bearing sandstone.

GEOLOGIC GUIDES TO ORE DEPOSITS

The following geologic features, compiled from drill-core data, have been shown by Weir (1952) to be useful small-scale guides in diamond-drill exploration for carnotite ore in the Morrison in southwestern Colorado:

1. The ore-bearing sandstone is 40 feet thick or more in the vicinity of ore deposits.

2. The ore-bearing sandstone near ore deposits is dominantly light brown, whereas away from ore deposits the sandstone has a reddish cast.

3. The mudstone in and immediately below the ore-bearing sandstone is altered from red to green-gray in the vicinity of ore deposits, whereas away from ore the amount of alteration decreases.

4. Carbonized woody material is more abundant in the sandstone near ore deposits than away from deposits.

In addition to these features which can be observed in diamond-drill core, geologists have observed that the ore deposits occur mainly in lenticular sandstone strata.

The following observations have resulted from this outcrop study of the Salt Wash sandstone member in the Uravan district:

1. The sandstones of the Salt Wash sandstone member are dominantly lenticular and lithologically similar. The sedimentary structures have a dominant northeasterly trend, though locally the trend diverges as much as 45° from the average (fig. 2).

2. Green-gray mudstone beneath the persistent upper and lower Salt Wash sandstone strata is continuous on the outcrops.

3. Scour-and-fill structures, fossil woody material, and extensive green-gray mudstone occur together in the middle and lower Salt Wash sandstone, but only in the upper Salt Wash sandstone are these features associated with the ore deposits.

4. The green-gray mudstone ranges in thickness from 6 to 18 inches beneath the lenticular upper Salt Wash sandstone.

5. The underlying green-gray mudstone is as much as 5 feet thick below channel-fill sandstone structures of the Salt Wash sandstone.

The size of the ore bodies was found to be related to the thickness of the ore-bearing sandstone stratum. Sandstones 15 to 35 feet thick contain small deposits of ore, whereas the thicker sandstones contain both small and large deposits. The most readily visible examples of the association of ore deposits with scour-and-fill sandstones can be seen in the Red Fox, Fortyfive Ninty, and Tramp mines, the Cue Ball and J. B. No. 1 mines in the Julian Group, the Grass Roots mine in the Wright Group, and the Little Dick and Ophir mines in the Dolores Group (fig. 2). Although structure of the sandstone is not entirely exposed at any one of these mines, a composite of exposed sedimentary structures indicates that the ore-bearing sandstone is composed of several sandstone lenses that on small scale roughly resemble different-sized elongated serving platters with thin margins thickening to a relatively narrow, blunt keel parallel to the long axis of the platters. In long dimension these platters are generally oriented within 45° of one another. Some of these platter-like sandstone lenses are tilted slightly from one another so that underlying and adjacent lenses are beveled and scoured. Larger-scale scour-and-fill structures occur where the thicker part of these lenses have filled scours in the underlying sand lens. Projection of these thicker sedimentary structures behind the outcrop is uncertain because of the unpredictable extent and varied trend of superimposed lenses within the ore-bearing sandstone strata. Field observations suggest, however, that the various scour-and-fill structures in an area are causally related to one another and reflect the shifting of the braided streams that deposited the sands; therefore, the clusters of scour-and-fill structures are elongated in the direction of sedimentary trend.

DISTRIBUTION OF LARGE-SCALE ORE GUIDES

The coincidence of two geologic features in favorable ground became apparent as the areal scope of field work increased away from the Uravan district. These features or guides are: (1) the character of the sandstone bedding, and (2) the intensity of alteration of the mudstone immediately beneath the ore-bearing sandstone. Other guides such as thickness and color of sandstone or presence of carbonaceous material were found to be related but mostly incidental to bedding and alteration. Symbols representing areas where the sandstone is dominantly lenticular or dominantly nonlenticular and where the top of the underlying mudstone is continuously altered, partly altered, or unaltered are shown on figure 2. Symbols representing types of bedding are overlain by colors representing degree of mudstone alteration.

Southeast of Red Fox mine area

Southeast of the Red Fox mine area (fig. 2), the lenticular character of the Salt Wash sandstone changes gradually in a distance of a few miles to one that is dominantly nonlenticular and thin-bedded. These sandstone layers are light brown or gray, in a few places reddish-brown, uniformly fine-grained, hard, and conspicuously limy. The upper Salt Wash sandstone stratum is composed of several thin, persistent sandstone lenses 1 to 10 feet thick. The total thickness of the stratum ranges from 15 to 25 feet and in only a few places exceeds 30 feet. Scour-and-fill structures in the upper sandstone stratum occur in only a few places and are small and poorly developed. Sedimentary structure trends of various sandstone lenses rarely vary more than 20° from an average northeasterly direction. Green-gray mudstone beneath the upper Salt Wash sandstone is persistent, but only in the vicinity of seeps and springs is it more than 6 inches thick. Fossil woody material is present but not as abundant as in the Uravan area.

Northwest of Uravan

Northwest of Uravan the ore-bearing sandstone is thick and lenticular. Green-gray mudstone within, as well as beneath, the ore-bearing sandstone decreases in thickness and degree of alteration northwestward from the Dolores Group of mines to Mesa Creek (fig. 2). Beneath the lenticular sandstones at the Dolores Group the green-gray mudstone is generally 6 to 18 inches thick, whereas beneath scour-and-fill sandstones it is 1 to 5 feet thick. In the interval between the Dolores Group and Mesa Creek the mudstone is partly altered and ranges from thin film to 6 inches thick beneath lenticular sandstones and 1 to 3 feet beneath scour-and-fill bedded sandstones. This partly altered mudstone commonly has a mottled appearance or consists of alternately banded red and green-gray mudstone. Likewise, a transition from green-gray to red mudstone occurs in the northwest end of Atkinson Mesa. Here the thin green-gray mudstone is no longer continuous. Partly altered, discontinuous patches of mottled and alternately banded red and green-gray mudstones occur beneath the upper Salt Wash sandstone stratum. On the north side of Mesa Creek and the southwest side of Blue Mesa the mudstone at the base of the upper Salt Wash sandstone is dominantly red, and in only a few places are found thin discontinuous streaks and films of green-gray mudstone.

The transition in color of mudstone is accompanied by changes in color of the interstitial clays in the overlying sandstone. In the Dolores Group area, lenticular as well as scour-and-fill sandstone is predominantly light brown. In the transition area, an increasing proportion of lenticular sandstone is reddish-brown, whereas the scour-and-fill sandstones are light brown. In the area of red mudstone, both lenticular and scour-and-fill sandstones are reddish-brown.

Northeast of Uravan

The Salt Wash sandstone is not exposed between Uravan and Blue Basin. Between Blue Basin and Mesa Creek the ore-bearing sandstone is lenticular, but it has a greater range in thickness and is less continuous than that on the west side of Atkinson and Blue Mesas. Partly altered mudstone underlies exposures of ore-bearing sandstone in the area between Blue Basin and Mesa Creek. A transitional area was recognized, but whether the transition was to more favorable or less favorable ground could not be determined.

A comparison of sedimentary features in the upper Salt Wash sandstone between the unfavorable Blue Mesa and the favorable Uravan areas suggests the need for careful evaluation of ore guides. The trends of the lenticular sandstones are alike in the two areas. Fossil vegetal material is more abundant in scour-and-fill sandstones than in the surrounding sandstone in both areas. Light-colored sandstones underlain by altered green-gray mudstone in the Uravan area contain some mineralized logs, whereas none of the logs are mineralized in the reddish-brown sandstone underlain by red mudstone on Blue Mesa. Limonite-speck stain occurs in the upper sandstone stratum in both areas, but limonite diffusion bands were observed only in the Uravan area.

The significance of locally thick altered mudstone zones can be misinterpreted because in some places this alteration is not associated with favorable ground. Green-gray mudstone is locally thicker in the vicinity of water seeps in the Uravan area. A water seep near the base of the upper Salt Wash sandstone in a cutbank above the North Fork of Mesa Creek has effected a color change in the sandstone from reddish-brown to gray and has changed the underlying mudstone from red to green-gray in a zone about 3 feet thick and about 30 feet wide. An altered mudstone and sandstone zone about 200 feet wide occurs in the upper Salt Wash sandstone on the southwest side of Blue Mesa, where it is associated with a fault belonging to the Roc Creek fault system. The alteration along this fault may be due to present-day water seepage or to older solutions, perhaps solutions responsible for ore deposition.

North and east of Blue Mesa

Alteration increases from the periphery of Blue Mesa to the north and east, as well as to the south. The northeastern part of Blue Mesa and a belt through the central parts of Outlaw and Calamity Mesas are areas of partly altered mudstone that are transitional in a northerly direction from an area of unaltered to an area of altered mudstone. The area of altered mudstone includes the northern half of Outlaw and Calamity Mesas and all of Tenderfoot Mesa.

Green-gray mudstone, 1 to 5 feet thick, underlies the ore-bearing sandstone in the northern part of Outlaw Mesa and on the north-central part of Calamity Mesa. Green-gray mudstone is persistent on the northern part of Calamity Mesa and all of Tenderfoot Mesa but in few places is it as much as 12 inches thick.

Sedimentary structures and lithology of the ore-bearing sandstone on Outlaw Mesa and the central part of Calamity Mesa are similar to those in the Uravan area, whereas on the northern part of Calamity Mesa and on Tenderfoot Mesa the upper Salt Wash sandstone is persistent, dominantly nonlenticular, and is rarely more than 30 feet thick. This nonlenticular sandstone is light brown, fine- to medium-grained, and friable. Sedimentary trends change from east of the northeastern end of Blue Mesa to northeast on the northern part of Outlaw Mesa to north on the central and northern parts of Calamity Mesa and on Flattop Mesa (fig. 2). On Tenderfoot Mesa trends are dominantly to the east though locally they vary 20°.

Northwest of Blue Mesa

In Flattop Mesa the upper sandstone is reddish brown, persistent, lenticular, and more than 50 feet thick. It is underlain by red mudstone except along the northwestern side of the mesa where the upper 3 feet of the mudstone is green-gray and the sandstone is light brown. The change from red to green-gray mudstone occurs in an interval of about 300 feet along the outcrop. The area of green-gray mudstone underlies an outcrop of scour-and-fill sandstone, whereas red mudstone underlies similar sandstone structures exposed at other places on the mesa.

On Beaver Mesa the ore-bearing sandstone is not persistent but where present is highly lenticular and, in places, unusually thick. The sandstone is generally reddish-brown, friable, and seems to contain more fossil wood material than the upper Salt Wash sandstone studied elsewhere. Limonite and manganese oxide diffusion banding in the sandstone also seems to be more abundant on Beaver and Flattop Mesas. The top of the mudstone underlying the ore-bearing sandstone on Beaver Mesa is red except in the immediate vicinity of ore deposits. No transition is apparent between areas of unaltered and altered mudstone.

LOCALIZATION AND CONTROL OF ORE DEPOSITS

The largest and richest known deposits in the Uravan and Gateway districts are in the vicinity of Long Park and Club Mesa at Uravan, the northern part of Outlaw Mesa, and the central part of Calamity Mesa. These deposits are restricted stratigraphically to the upper Salt Wash sandstone stratum. The sandstones composing this stratum in these areas are dominantly lenticular and the top of the underlying mudstone is persistently altered. Smaller and more stratigraphically scattered deposits, some of which are rich, though others are lower than average grade, are present in areas where only one of these two geologic features is well developed. For example, on Beaver and Flattop Mesas the sandstone is dominantly lenticular, but altered mudstone is found only in the immediate vicinity of carnotite deposits, whereas on Tenderfoot Mesa, although alteration is persistent at the top of the mudstone the sandstone is dominantly nonlenticular and contains little ore. In the transition zone between areas of persistent alteration and areas of little or no alteration, as on the north end of Blue Mesa, east of Mesa Creek in Mesa County, and on the western side of Atkinson Mesa, the deposits also appear to be small and scattered.

Drilling has shown that ore bodies occur in elongated clusters, the long axes of which are normal to the belt of mineralization and parallel to the sedimentary trend (Fischer and Hilpert, 1952). Individual ore bodies, however, may or may not be elongated parallel to the sedimentary trend. No consistent interval between deposits could be seen in outcrop or on maps of deposits compiled from drilling data. Also, no consistent pattern of size, number, or spacing of ore bodies is apparent from one cluster to another. Ore deposits are erratically grouped together in an elongated pattern probably because complex scour-and-fill sandstone structures localized ore deposition; consequently the pattern of ore deposits reflects the complexities of distribution of the scour-and-fill structures.

It has been generally conceded that carnotite or its unoxidized parent minerals were deposited by laterally migrating solutions. The present water-carrying capacity of the upper Salt Wash sandstone indicates that the permeability and transmissability of the beds is relatively high. There is evidence to suggest that the upper Salt Wash sandstone, which is overlain by impermeable mudstone of the Brushy Basin member, is limited in its function as an aquifer by the small volume of water available in recharge areas rather than the physical nature of the sandstone. For example, one of the most favorable upper Salt Wash sandstone recharge areas is on the flank of the Uncompahgre Plateau between Blue Basin and Mesa Creek. The discharge in seeps, and recently in drill holes down-dip from this area, is much greater than the discharge elsewhere.

Thus, the upper Salt Wash sandstone stratum can be likened to an aquifer within which are broad and thick lenticular sandstones of simple structure and lithology which allow the passage of a relatively large volume of circulating solutions. In contrast, the scour-and-fill sandstone structures within the aquifer are composed of interbedded sandstones and mudstones of complex structure and mixed lithology which would tend to inhibit movement of solutions and might provide the locus for carnotite deposition. The ore shows a selectivity for only part of the less uniformly permeable sandstone in most places. The unpredictable nature of this selectivity is probably due to the concentration, volume, and pH of the ore-bearing solutions and the reaction of the solutions with clay minerals in the mudstone.

The capacity of the upper Salt Wash sandstone stratum to transmit ore-bearing solutions before the period of canyon-cutting on the Colorado Plateau may be reflected by the areal distribution of red and green-gray mudstone and the association of mineralization with the latter. Assuming the areal pattern of alteration to have remained unchanged since ore deposition, the pattern of alteration suggests a regional control. Whether ore deposition was controlled by early Brushy Basin or Tertiary regional structures is subject to different interpretations based on inconclusive field evidence.

ORIGIN OF ORE DEPOSITS

Coffin (1921), Hess (1933), and Fischer and Hilpert (1952) have defined belts of mineralization in southwestern Colorado, and from detailed studies believed the geologic relations are best interpreted as the result of circulating ground waters leaching and redepositing uranium-vanadium minerals soon after deposition of the Salt Wash.

Geologic history of the Colorado Plateau is marked by repeated folding, uplift, normal faulting, pre-Tertiary salt intrusion, and, during Tertiary and Pleistocene time, igneous intrusion (Hunt, 1946). Fractures transecting ore bodies in the Uravan and Gateway districts indicate that ore deposits were emplaced before the last period of faulting in late Tertiary time.

Recent work by Stieff and Stern (1951) on age determinations of ore minerals in hypogene hydrothermal veins in the Front Range, in fault-controlled deposits and in sediments of Triassic and Jurassic age on the Colorado Plateau, indicates a common, probably early Tertiary age for all these deposits.

A genetic relation between fault-controlled hypogene deposits and normal disseminated carnotite deposits has not been observed in the upper Salt Wash sandstone. Copper-uranium deposits occur in the lower Salt Wash sandstone in and adjacent to faults, small fractures, and joints that are part of the Roc Creek fault system, (fig. 2). The spatial relation between these deposits and those in the upper Salt Wash sandstone in the area between Roc Creek and the junction of the San Miguel and Dolores Rivers suggests that a genetic relation may exist.

Relative thickness of the Salt Wash and Brushy Basin members as drawn in a diagrammatic section (fig. 2a) through the Uravan and Gateway districts shows no apparent controlling relation to the areal pattern of altered mudstone. On the other hand, the movement of ore-bearing solutions, as recorded by alteration features, has a pattern which regionally can be more nearly related to a Tertiary igneous epicenter under the La Sal Mountains area.

CONCLUSIONS

Observed relations in the Uravan and Gateway districts have strongly suggested that large blocks of ground, favorable for exploration, occur only where the ore-bearing sandstone is dominantly lenticular, and where the upper part of the underlying mudstone is persistently altered. These observations focused attention on the southeastern half of Atkinson Mesa and the northwestern half of Spring Creek Mesa, where drilling by the Geological Survey has been successful in outlining favorable ground. The prediction that little favorable ground would be found in the Blue Basin-Mesa Creek area, Blue Mesa and Tenderfoot Mesa areas, and the evidence on which it was based, have been firmly established by subsequent exploratory drilling. Less favorable areas containing small patches of favorable ground may be found on Beaver Mesa, between the Lumsden Group and the Corvusite mine. This part of Beaver Mesa might be considered for exploration at some future date.

Detailed studies and mapping of the type undertaken in the Uravan and Gateway districts, may be done in other areas being considered for exploration such as Slick Rock, Gypsum Valley and West Paradox.

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