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GEOLOGIC GUIDES TO CARNOTITE DEPOSITS ON THE COLORADO PLATEAU

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Geologic guides to carnotite deposits on the Colorado Plateau

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R. P. Fischer and Doris Blackman

Abstract

The carnotite deposits of the Colorado Plateau appear to have been localized by geologic structures resulting from sedimentary conditions rather than from regional deformation. They are thought to have accumulated from ground-water solutions shortly after the ore-bearing beds were deposited. Even though many problems regarding the origin of the carnotite deposits cannot be satisfactorily explained, some of the geologic features with which ore is commonly associated are useful guides in ore-finding. The relations of these features to ore are summarized as a preliminary statement of the results of studies being made by the U. S. Geological Survey.

Most of the carnotite deposits are in the Morrison formation of Jurassic age. The ore generally impregnates sandstone, but some of the fossil plant material in the ore-bearing beds is richly mineralized. Many of the deposits are in or near the thicker, central parts of sandstone lenses. Beds of sandstone less than about 20 feet thick rarely contain sizeable ore deposits. In places the ore-bearing sandstone lenses are well defined, but most are broad and poorly defined. Where observations can be made, trends of the lenses can be recognized by a study of bedding and the orientation of fossil logs, but because the lenses are discontinuous, their trends cannot be projected very far. The sandstone

in the central parts of the lenses is dominantly medium-grained, medium- to thick-bedded or irregularly bedded, and moderately clean, though some mudstone in the form of grains, pebbles, and small lenses is common. In the vicinity of ore deposits the sandstone is predominantly yellow-brown, and some of the mudstone associated with the sandstone is altered from red to gray, whereas away from the deposits some of the sandstone has a reddish cast, and the mudstone is unaltered. As a working hypothesis, it is assumed that these color changes resulted from circulating solutions, perhaps the ore-bearing solutions themselves. Carbonaceous matter is abundant in and near ore bodies, suggesting that it might have influenced the chemical conditions that favored precipitation of the ore metals.

Statistical relations between several of these geologic features and the proximity to ore deposits are given. The data presented were obtained from a study of diamond-drill core, outcrops, and mine workings. Where enough data are available to express these relations as mathematical averages, some appear to show systematic variations. At least the averages seem to confirm the validity of these features as guides to ore. On the other hand, variations at single points of observation are so extreme that these relations must be used with caution. In general the relations are so subtle that knowledge based on experience is essential in guiding exploration.

Introduction

The carnotite deposits of the Colorado Plateau have many interesting geologic features, some of which are essentially unique among metal deposits. They also present peculiar problems regarding origin, localization, and ore-finding. This paper deals mainly with the geologic features that are useful in guiding exploration. The general character of the deposits and the problems relating to origin are only briefly reviewed.

General geology

The carnotite deposits have a wide geographic distribution (fig. 1). Practically all of them are restricted to the Shinarump conglomerate of Triassic age and the Entrada and Morrison formations of Jurassic age. In most areas or mining districts the deposits are largely or wholly confined to a single stratigraphic zone in one of these formations. Neither the distribution of the deposits in general nor the character of individual deposits seems to be genetically related to or influenced by igneous intrusion, hydrothermal activity, or regional deformation.

The ore mainly impregnates sandstone, but some of the fossil plant material in the ore-bearing beds is richly mineralized. Average ore contains about 0.25 percent U_3O_8 and 2 percent V_2O_5. The ore bodies are irregularly tabular masses, at most only a few feet thick. They lie nearly parallel to the sandstone bedding but do not follow the beds in detail. They range in size from those containing only a few tons of ore to those containing many thousand tons; most of the deposits contain only a few hundred tons or less. Although the deposits have a spotty distribution, most of them are clustered in relatively small, poorly defined areas. The larger areas between these clusters contain only few scattered deposits, most of which are small.

Origin

The distribution of the deposits and the habits of the ore show a relation to lithologic features which may indicate an influence on the movement and chemical composition of ground waters in the ore-bearing beds at the time the ore was deposited, or at least before regional deformation disrupted the continuity of these beds. It is suggested, therefore, that the deposits formed from ground-water solutions shortly after the ore-bearing beds accumulated. The ore minerals were probably precipitated as a result of slight changes in the composition of the ore-bearing solutions.

Guides to ore

Even though many problems regarding the origin of the deposits and the localization of ore remain to be solved, some of the geologic features with which ore is commonly associated, and which therefore are presumed to have been favorable for ore deposition, are useful guides to ore-finding. These features at least aid in eliminating unfavorable ground where prospecting would be less productive or fruitless. The guides to ore, as well as some of the habits of the ore are described briefly; they are now being used by the Geological Survey in guiding diamond-drill exploration. It should be noted that most of these features are subtle and should be evaluated as a group in appraising the ground being prospected, that no single one is sufficiently well defined to be used alone, and that some can be observed only at the outcrop or in mine workings, whereas others can also be observed in diamond-drill core.

The following description, as well as most of the work being done by the Geological Survey, applies particularly to the deposits in the Morrison formation.

The sandstone beds in the Morrison which contain the ore deposits are lenticular and in places as much as 60 feet thick. They are interbedded with mudstone. The sands were deposited in channels and on flood plains of streams that meandered broadly across a surface of low relief and grade. Most of the carnotite deposits seem to occur in or near the thicker, central parts of the lenses; the portions of the sands that occupy bends in the channels seem to be particularly favorable for deposits in some areas. In places the channel sands form well-defined lenses, some only a few hundred feet across, and these can be recognized at the outcrop or in cross-sections through drill holes. Other channels are broad and poorly defined. The trend of the channel sands commonly can be determined by observations of bedding and by the orientation of fossil logs. In places the channels can be projected and followed, though caution must be used in projection, for some of the channel sands seem to fray out along their course and others are cut off by later channels trending in other directions.

The sandstone in the central parts of the channels is dominantly medium-grained, medium- to thick-bedded or irregularly bedded, and moderately clean, though some mudstone in the form of grains, pebbles, and small lenses is present in many places. Beds of sandstone less than about 20 feet thick, which might have been deposited in small or short-lived channels or on flood plains bordering the main channels, rarely contain sizeable ore deposits. Such sandstone is dominantly fine-grained, thin-bedded, and either clean or argillaceous.

As a working hypothesis to explain the observed associations of the deposits to the channel sands, it is assumed that ground waters moving along the beds generally would follow the central parts of the sandstone lenses due to the effect of greater thickness and permeability. Even so, the route of ground waters moving along discontinuous lenses would be devious and in places might be controlled by other factors that might not be recognizable. The deposits are thought to have been localized where chemical conditions effected precipitation of ore minerals, perhaps in the environment of decaying organic matter such as the fossil plant material found with the deposits.

In the vicinity of ore deposits, the sandstone beds and associated mudstone have characteristic colors that probably express the effect of circulating solutions. The ore-bearing sandstone is dominantly pale to light yellow-brown and speckled with small spots of limonite stain. Sandstone that is whitish to pale yellow-brown or that which is reddish-brown contains few deposits and most of them are small.

The mudstone that is interbedded with this sandstone, as well as the grains, pebbles, and lenses of mudstone within the sandstone, is dominantly red, which is believed to have been its original color. Near ore deposits, however, the mudstone within the ore-bearing sandstone and the upper few inches to few feet of mudstone beneath the ore-bearing sandstone are altered to gray or yellowish gray. In places the mudstone immediately above the ore-bearing sandstone is altered also. Though the character and cause of this color change are not clearly understood, the presence of considerable altered mudstone in the ore-bearing sandstone and immediately above and below it is probably the most useful guide in recognizing ground favorable for ore deposits.

The intensity or amount of alteration, as shown by the change in color of the mudstone from red to gray, decreases outward from the ore deposits. This cross-section (fig. 2) shows a good example of the relationahip of ore and altered mudstone. It also shows the ore deposits in what is presumed to be the central or thicker part of the sandstone lens.

This table (fig. 3) shows the average thickness of the altered mudstone beneath ore deposits and in a series of 100-foot wide zones outward from the deposits. It is compiled from logs of 564 holes drilled in the Calamity group of claims, an area about 2,500 feet wide and 8,000 feet long. The altered mudstone averages 3.4 feet thick in the 177 holes that cut ore deposits; it averages 1.85 feet thick in 225 holes in the zone 0 to 100 feet outward from the deposits; 1.3 feet thick in the 79 holes 100 to 200 feet outward; 0.8 feet thick in 48 holes 200 to 300 feet outward; and in the remainder of the holes 0.6 feet thick in the zone 300 to 400 feet outward.

It would seem that enough data are available here to demonstrate statistically the decreasing thickness of altered mudstone outward from the deposits. Similar relations are found elsewhere.

On the other hand, variations in the intensity or amount of alteration locally, at such single points of observation as individual drill holes, are so extreme that the relationship of alteration to ore must be used cautiously as a guide in ore-finding.

Figure 2

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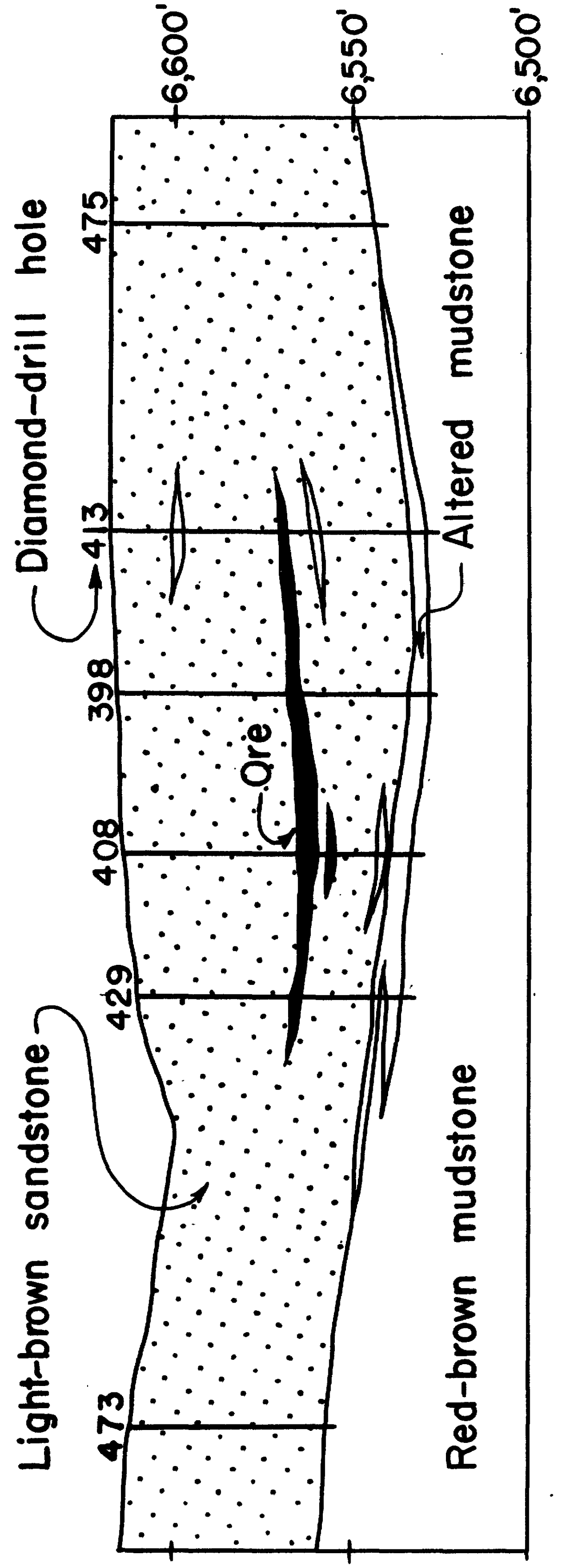


Geologic section through diamond-drill holes on Calamity No. 17 claim showing sandstone and mudstone relations to ore.

0 50 100 Feet

Figure 3

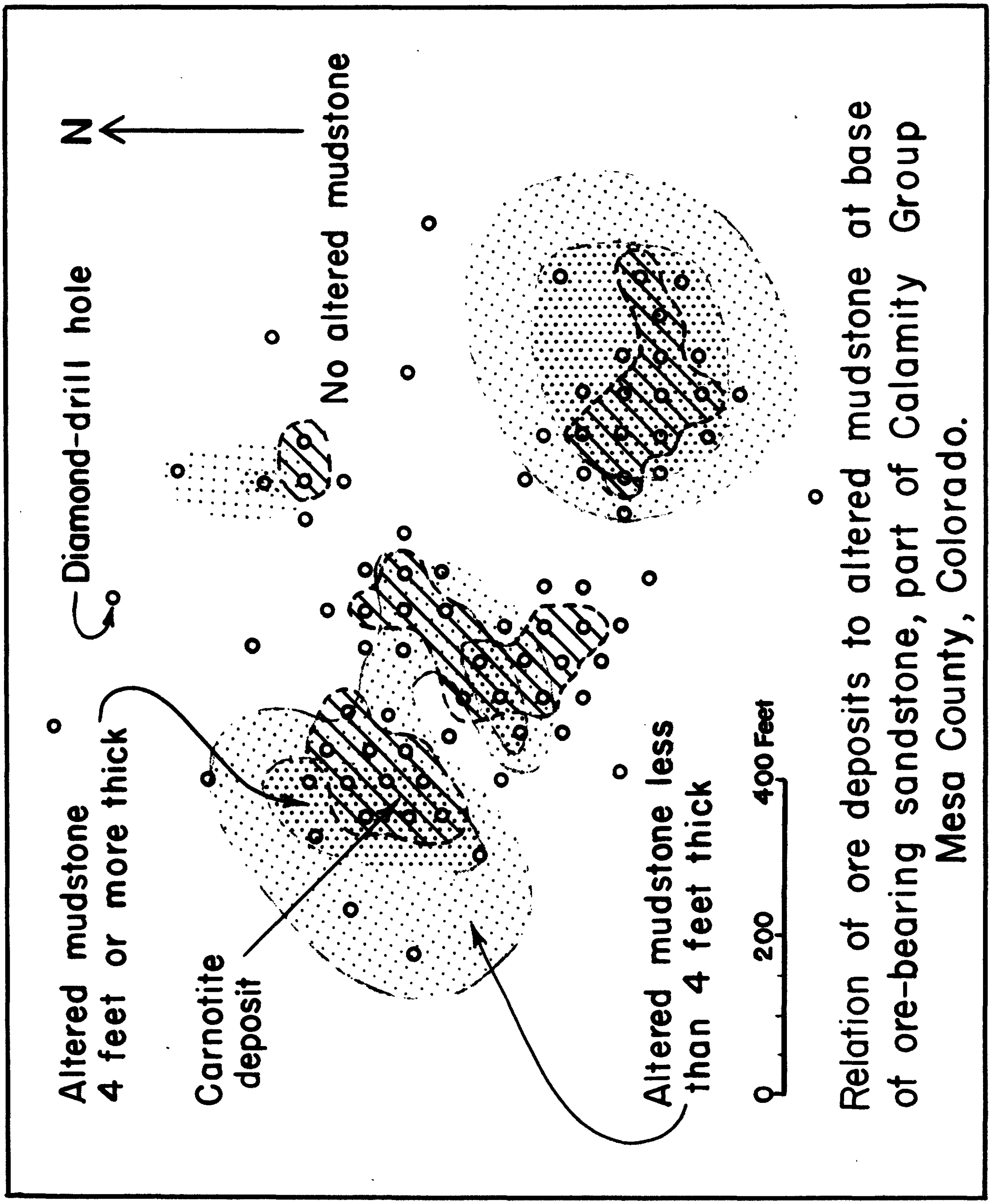
Average thickness of altered mudstone
at base of ore-bearing sandstone
Calamity group, Mesa County, Colorado

Zones beneath and outward from ore deposits	Number of drill holes in zone	Average thickness in feet
Beneath	177	3.4
0-100 feet outward	225	1.85
100-200 " "	79	1.3
200-300 " "	48	0.8
300-400 " "	35	0.6

This map (fig. 4) shows the relation of ore deposits to the alteration in mudstone at the base of the ore-bearing sandstone in part of the Calamity group of claims. Note that some of the drill holes in ore cut no altered mudstone, whereas some of the barren holes cut altered mudstone at least 4 feet thick. Even so, the ore and altered mudstone are closely related in space.

Carbonaceous matter derived from fossil plant material in the ore-bearing sandstone is more abundant in and near ore deposits than in ground away from ore deposits, as shown in this table (fig. 5). Of the 177 drill holes that cut ore deposits in the Calamity area, 69 of them, or 39 percent cut abundant carbonaceous matter, whereas only 49 of the 387 holes in barren sandstone, representing only 13 percent of those holes, cut abundant carbonaceous matter. Just what relationship, if any, the carbonaceous matter had to ore localization is not clear. Perhaps the metals were precipitated in the environment of decaying plant remains; almost certainly the carbonaceous matter did not directly cause precipitation of the ore minerals, for much of the plant remains near ore is barren.

Figure 4



Relation of ore deposits to altered mudstone at base of ore-bearing sandstone, part of Calamity Group Mesa County, Colorado.

FIGURE 5

Relative abundance of carbonaceous matter
in ore-bearing sandstone,
Calamity group, Mesa County, Colorado

Position	Number of drill holes	Holes cutting abundant carbonaceous matter: Number	Holes cutting abundant carbonaceous matter: Percentage
In ore deposits	177	69	39
0-400 feet outward from ore deposits	387	49	13

Conclusion

In conclusion it may be well to summarize the guides to ore now used on the Colorado Plateau and to mention briefly how our exploratory work is guided by them. The ore guides are:

(1) The known areal distribution of the sandy part of the Morrison formation and to less extent the Entrada sandstone and the Shinarump conglomerate.

(2) The location and trend of the thicker, central parts of sandstone lenses.

(3) A characteristic, medium-grained, pale-yellow to light-brown sandstone with which carnotite ore is invariably associated.

(4) Areas where the mudstone has been altered from fresh red to yellowish-gray or gray.

(5) The thicker parts of altered mudstone.

(6) An abundance of fossil logs and other carbonaceous material.

These indications of ore are applied in connection with exploratory drilling, which is planned and carried on in three stages. In the first stage a pattern of widely spaced holes is drilled for geologic information. Examination of the core from these holes and evaluation of the features shown therein that are guides to ore assist in the classification of ground into areas relatively favorable for ore and areas relatively unfavorable. In the favorable areas additional holes are drilled in a more closely spaced pattern. In this, the second stage, ore deposits may be discovered, or if no ore is found, the relative favorability of the drilled areas is reappraised. Where ore is discovered or where strong evidence of the existence of mineralized rock is suspected, a third set of holes is drilled. These actually outline the ore-bearing areas and trace the extension of ore from the discovery holes.

This method of approach, pattern drilling for geologic information and the use of guide features developed thereby in selecting areas for further drilling, has been moderately successful. It is felt that in the future ultimate success will depend on an increased understanding of the causes of ore deposition and on the ability to translate these causes into guides to ore that may be used successfully in the search for carnotite deposits.