Conglomeratic sandstone strata at the base of the Brushy Basin member of the Morrison formation as related to uranium-vanadium deposits, southwestern Colorado and southeastern Utah

By D. A. Phoenix

Trace Elements Investigations Report 565

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CONGLOMERATIC SANDSTONE STRATA AT THE BASE OF THE BRUSHY BASIN MEMBER OF THE MORRISON FORMATION AS RELATED TO URANIUM-VANADIUM DEPOSITS, SOUTHWESTERN COLORADO AND SOUTHEASTERN UTAH*

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David A. Phoenix

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CONGLOMERATIC SANDSTONE STRATA AT THE BASE OF THE BRUSHY BASIN MEMBER OF THE MORRISON FORMATION AS RELATED TO URANIUM-VANADIUM DEPOSITS, SOUTHWESTERN COLORADO AND SOUTHEASTERN UTAH

By David A. Phoenix

ABSTRACT

In southwestern Colorado and southeastern Utah strata of conglomeratic sandstone are localized at the base of the Brushy Basin shale member of the Morrison formation of Jurassic age. These strata are discrete lithologic units that contain sedimentary structures oriented in a prevailing easterly direction, they locally rest upon sandstone in the Salt Wash that is ore bearing, and they are believed to cover about one-third of the underlying Salt Wash sandstone member in southwestern Colorado and southeastern Utah. Easterly trending planar cross-stratification- and trough cross-stratification-type bedding and a general westward coarsening of sediments in the strata suggest they are the products of stream aggradation from westerly source areas.

Uranium-vanadium deposits in the uppermost, almost continuous, layer of sandstone of the Salt Wash member have been classified according to their association with the conglomerate strata. Of the 364 deposits that have been studied in the uppermost sandstone layer of the Salt Wash, 29 percent of the total are directly below a conglomeratic sandstone stratum, 61 percent are below their projected trend, 6 percent are beyond the safe limits of projection, and 4 percent are lateral to their margins. Locally, a conglomeratic sandstone stratum may be mineralized. Where this happens, it is usually near clusters of deposits in the uppermost sandstone of the underlying Salt Wash member.

Late Jurassic Morrison ground-water conditions can be postulated to localize uranium-vanadium rich ground water below the conglomerate strata.

INTRODUCTION

An investigation of sedimentary features in a part of the late Jurassic Morrison formation in southwestern Colorado and southeastern Utah was made during the summer of 1949 and later during the summer of 1953. These studies were undertaken by the U. S. Geological Survey on behalf of the Division of Raw Materials of the U. S. Atomic Energy Commission as a part of a larger program aimed at evaluating past and present ground-water conditions in uranium-vanadium host rocks.

The results of a part of this work indicate that uranium-vanadium deposits in the Salt Wash sandstone member of the Jurassic Morrison formation are clustered below lenticular strata of conglomeratic sandstone found near the base of the overlying Brushy Basin shale member of the Morrison formation. This report describes the character and occurrence of conglomeratic sandstone strata near the base of the Brushy Basin member, and their relation to ore deposits in an almost continuous layer of sandstone near the top of the underlying Salt Wash member. The results of this study were obtained from 11 widely scattered mining areas in southwestern Colorado and southeastern Utah (fig. 1).

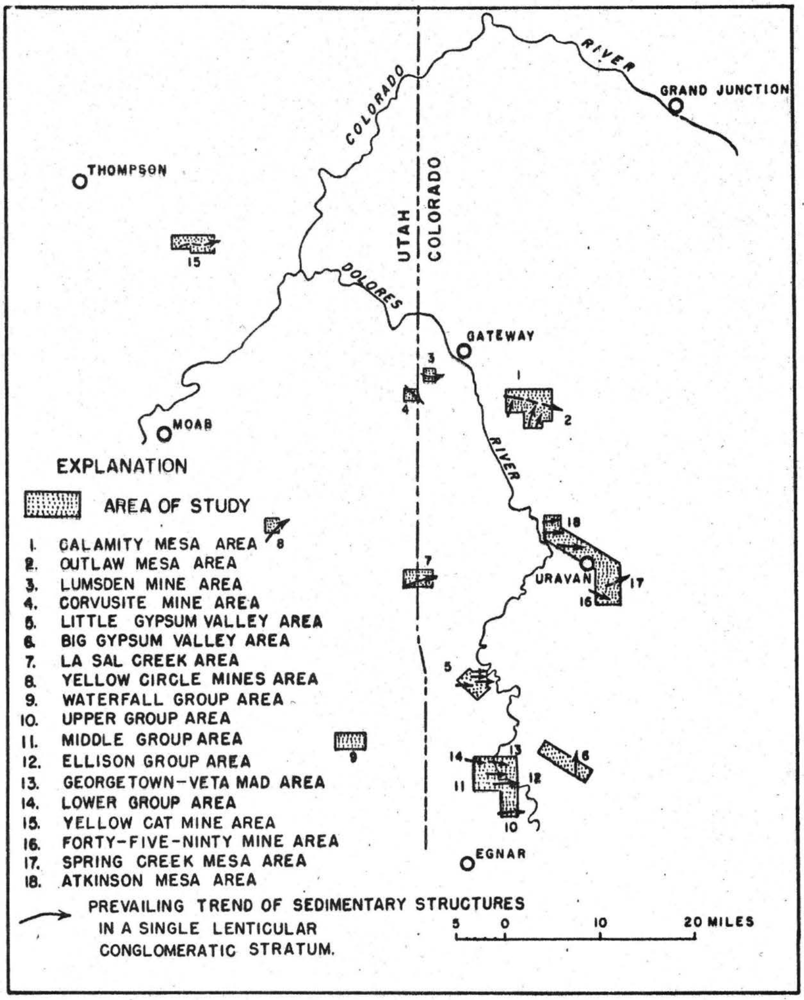

Figure 1. Map of part of the Colorado Plateau showing areas of study, distribution, and trend of conglomerate strata at the base of the Brushy Basin member of the Morrison formation.

METHODS OF STUDY

In southwestern Colorado topographic maps on a scale of 1:24,000 were used as a base for mapping the distribution of conglomeratic sandstone at the base of the Brushy Basin member. Contacts were drawn between these coarse-grained sediments, and siltstone and mudstone above or below. The lithologic character of the almost continuous layer of sandstone near the top of the underlying Salt Wash member was also mapped and studied because it contains most of the ore deposits in the Morrison formation. In southeastern Utah suitable base maps were not available, and the sedimentary relations were studied without the aid of maps.

The orientation of sedimentary structures in the coarse-grained sediments was measured and used to determine the directional trends of sediment transportation. Statistical methods were not employed in the study of sedimentary structures because it was felt that individual measurements in their correct relative position might show systematic changes in orientation that would be masked by statistical methods, and because the writer was in doubt concerning the grouping of elements necessary to a meaningful statistical analyses.

The trend of each sedimentary structure was measured and its location and direction were plotted on the map. The trends were classed as being well defined or poorly defined depending upon their occurrence. Well-defined trends were those that were easy to see and measure, and were substantiated by similar trends in immediately adjacent outcrops. Indistinct and isolated trends were classed as poorly defined. In places where 4 or 5 closely spaced measured trends differed by less than 10° the average measurement was plotted on the map. Where differences in directional trend were greater than 10° over several hundred feet of outcrop, each measurement was plotted in its correct relative position. Sometimes the midportion of a vertical cliff was inacessible to study, and in this case the trends of sedimentary structures were measured only along the base and top of the cliff.

Diamond drilling by the Geological Survey in southwestern Colorado has penetrated the Morrison formation where geologic conditions appear favorable to the extension of known uranium-vanadium deposits or to the existence of hitherto unknown deposits. Systematic geologic logs of core from the Salt Wash member are on record, but the overlying Brushy Basin member has not been logged except in a few places. Where the Brushy Basin member has been described, the logs were examined and, where possible, correlated with the logs of adjacent holes or the outcrop. Geologic logs from the Atkinson Mesa and Spring Creek Mesa areas, Montrose County, Colo. (fig. 1), were used in this study, as were the logs from other areas where they describe the Brushy Basin member. Reports written by the Geological Survey have been used where they describe ore deposits discovered by exploration with the diamond drill.

GENERAL GEOLOGIC RELATIONS

In southwestern Colorado and southeastern Utah uranium-vanadium deposits in the Morrison formation are found in an almost continuous but composite layer of permeable sandstone and relatively impermeable mudstone near the top of the Salt Wash member. The most permeable and likewise most transmissive parts of this layer, sometimes several thousand feet across, are most favorable to the deposits and in these places the deposits often occur in clusters (Phoenix, 1955).

The overlying Brushy Basin member of the Jurassic Morrison formation is composed dominantly of mudstone colored various shades of red or green, but the member also contains discrete lenticular units of conglomeratic sandstone particularly near the base of the member and just above a composite layer of Salt Wash sandstone that is ore bearing. The mudstone in the Brushy Basin member and other fine-grained sediments are covered by talus and landslide debris because they are not resistant to erosion. Nearly everywhere, however, conglomeratic sandstone strata near the base of the member crop out as discontinuous ledges in contrast to the debris-covered slopes above and an almost continuous ledge formed by ore-bearing sandstone in the Salt Wash member below.

UNITS MAPPED

As a distinct phase of Morrison deposition, strata of conglomeratic sandstone are recognized throughout the uranium-vanadium producing region of southwestern Colorado and southeastern Utah, and they are sufficiently prevalent so that the base of the lowermost conglomeratic sandstone is used, when measuring stratigraphic sections, to separate the Brushy Basin member from the underlying Salt Wash member of the Morrison formation (Craig and others, 1955). In many places, however, the strata of conglomeratic sandstone are absent, and the stratigraphic interval they commonly occupy is represented by mudstone. It is for this reason that Cater (1954) says that the mapped contact taken as the base of the lowermost stratum of conglomeratic sandstone is arbitrary in many respects and probably does not mark an identical stratigraphic horizon in all localities.

A stratum as the term is used in this report is a unit of sediments that separates more or less readily from overlying and underlying units. Data presented herein suggest that each stratum represents an accumulation of sediment left within the channel margins of an aggrading stream while that stream was essentially fixed in position. The width of a stratum when referred to is the distance normal to the general trend of its contained sedimentary structures; the length is the dimension parallel to the trend of the sedimentary structures. The mudstone and other fine-grained sediments are believed to represent flood-plain deposits that accumulated under relatively quiet and shallow water conditions. Variations in the fine-grained sediments that usually separate the conglomeratic strata have not been studied.

The units mapped and described in this report are the strata of conglomeratic sandstone that distinguish the base of the Brushy Basin member of the Morrison formation from the underlying Salt Wash member. The conglomeratic strata are distinguished primarily on the basis of contrasting lithology. This is convenient, for in most places the changes in lithology are conspicious and abrupt, usually from bedded sandstone or a coarse conglomerate sandstone to a laminated siltstone or mudstone above and below. In places, however, mudstone between the coarse-grained strata gradually thins laterally, and the contact between conglomeratic strata then becomes a disconformity between strata of similar lithology. The strata of coarse-grained sediments sometimes end abruptly without change in thickness, but most frequently they gradually thin until they are difficult to distinguish between layers of mudstone.

DESCRIPTION OF THE CONGLOMERATIC SANDSTONE STRATA

Lithology

Sediments mapped as conglomeratic sandstone strata often contain all size grades from fine-grained sandstone to pebbles an inch or more in diameter, but strata composed entirely of fine- to medium-grained sandstone and other strata composed almost entirely of conglomerate have been mapped and are considered a part of the same phase of Morrison deposition. The coarse fraction--dominantly pebbles of chert and quartzite--is generally subangular to subrounded and the sand grains are usually rounded to subrounded. In places the sediments are well sorted, particularly near the thinning margins of a stratum, but in the central thicker portions sorting is often poor and pebbles are localized along bedding planes. In contrast, the sandstone at the top of the Salt Wash member is not conglomeratic, is well sorted, and is medium to fine grained throughout. Graded bedding (fig. 2a) is sometimes present in conglomeratic strata more than 100 feet above the contact between the Salt Wash member and Brushy Basin member, but it has not been observed in strata at the base of the Brushy Basin member.

In the Uravan area, Montrose County, Colo. (fig. 1), pebbles in the conglomeratic strata rarely exceed half an inch in diameter and medium-grained sandstone is the dominant rock type. About 30 miles to the west in the Yellow Circle and La Sal Creek mine areas (fig. 1) of northeastern Utah, pebbles 2 inches in diameter have been observed together with clay galls 2 or 3 inches in diameter embedded in coarse sand. A general westward coarsening of the conglomeratic sediments is believed to prevail between these two areas.

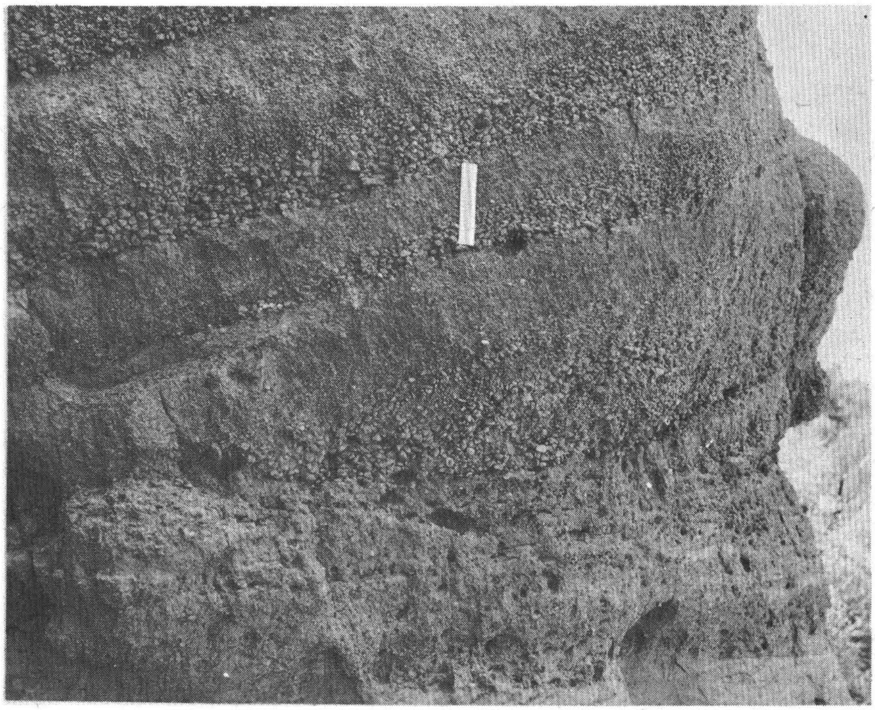

Figure 2a. Combined graded and inclined bedding in conglomeratic sandstone of the Brushy Basin member of the Morrison formation.

In most places the conglomeratic strata are dark brown or reddish due to a high amount of interstitial red mudstone and to iron oxide that either coats the sand grains or is intimately associated with calcite cement. In these sediments the chert pebbles are red or green. Some of the conglomeratic strata, however, are light brown to yellow and the chert pebbles are altered to white or gray so that on the basis of color alone they are difficult to distinguish from strata of light-colored fine- to medium-grained sandstone in the underlying Salt Wash member. Silica overgrowths are abundant on sand grains in both the light- and dark-colored strata, but the sand, though partly cemented with silica, is friable when treated with acid. Commonly carbonate minerals cement the sandstone particularly near the base of a stratum or above and sometimes directly below permeability barriers created by clay films along bedding planes.

Stratigraphic position

The stratigraphic position of the conglomeratic sandstone strata in the lower part of the Brush Basin member is variable with respect to the underlying ore-bearing sandstone layer of the Salt Wash member. In some places the conglomeratic strata rest upon the ore-bearing sandstone layer, but in most places an interval of laminated siltstone or mudstone lies between the conglomeratic strata and ore-bearing sandstone. Above the Gray Daun mine, in the La Sal Creek area (fig. 1) in southeastern Utah, this mudstone interval is about 100 feet thick although in the same mining district and only about 1 mile east above the Vanadium Queen mine, 10 feet of mudstone separates a conglomeratic stratum from underlying fine- to medium-grained Salt Wash sandstone. In the Yellow Cat mine area, 36 miles to the north, a conglomeratic stratum rests upon sandstone that is called Salt Wash. On Calamity Mesa and the nearby Outlaw Mesa, Mesa County, Colo., mudstone between the conglomeratic strata and the ore-bearing sandstone layer is about 30 feet thick although locally conglomeratic strata also rest upon the ore-bearing sandstone layer of the Salt Wash. In the Slick Rock area, San Miguel County, Colo., (areas 10 to 14 on fig. 1), on outcrop the mudstone interval is nowhere greater than 20 feet thick, but in core recovered from diamond-drill holes the mudstone interval is sometimes thicker. Although the time equivalent of a conglomeratic stratum may differ in lithology from place to place, the writer believes that the conditions of deposition resulting in formation of the conglomeratic strata were probably nearly synchronous throughout southwestern Colorado and southeastern Utah, and followed shortly after deposition of the ore-bearing uppermost sandstone layer in the Salt Wash member.

Sedimentary structures

Bedding of various kinds has been recognized in the strata of conglomeratic sandstone. In places a single stratum may contain tabular units of sandstone several feet thick within which the bedding is either horizontal, troughlike, or inclined, or a stratum may contain a prevailing type of sedimentary structure even though it is composed of several distinct tabular units of sand. Only the kinds of bedding for which implications as to origin have been made were distinguished and measured in the field. All the strata contained the planar and trough cross-stratification types of McKee and Weir (1953, p. 387) and McKee and others (1953, p. 24), and in places current lineation (Stokes, 1947).

Although strata composed of sandstone contain trough cross-stratification (fig. 2b), this type of sedimentary structure is most conspicuous where the strata are conglomeratic. In these places pebbles are frequently localized along the bedding planes and emphasize their troughlike appearance.

The appearance in plan view of trough cross-stratification is that of a plunging syncline, the plunging axis of which is taken to be the direction of water movement at the time of deposition. In cross section, at right angles to this axis, beds are symmetrically troughlike. Individual sets of trough cross-stratification sometimes reach 20 feet in width from limb to limb and at their axis occupy 7 or 8 feet of stratigraphic section. Because the limbs of the troughs are usually partly truncated and because their width depends also upon the portion of the trough exposed, it is difficult to make a systematic study of their size. However, in any single stratum where trough cross-stratification is present, there is an apparent prevailing width so that it is uncommon to find wide and deep trough structures in close association with smaller ones. Generally, trough cross-stratification is more abundant in the central thicker parts of the strata where the sediments are conglomeratic although sometimes tabular units of sandstone several feet thick and extending nearly across the entire width of a stratum are trough cross-stratified throughout. In the laboratory this type of structure has been developed through the work of concentrated stream currents accompanied by multiple stages of flow and aggradation (McKee and others, 1953, p. 58).

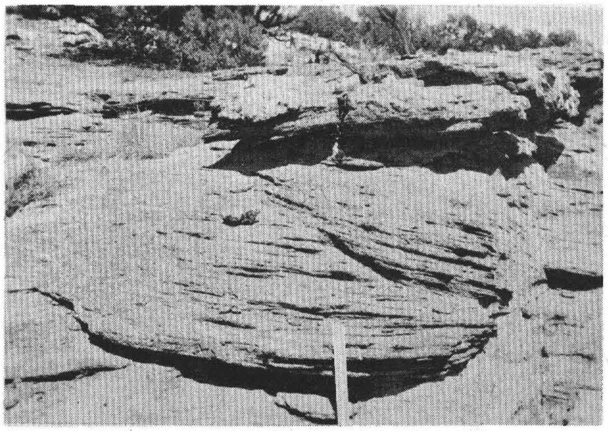

Figure 2b. Trough cross-stratification in a conglomerate stratum of the Brushy Basin member of the Morrison formation.

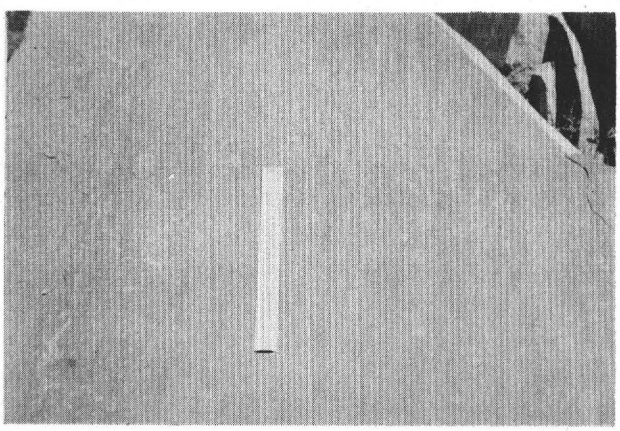

Figure 2c. Current lineation on a bedding plane of sandstone in the Salt Wash member of the Morrison formation.

Planar cross-stratification is not abundant nor is it conspicuous in the conglomerate strata at the base of the Brushy Basin member. Sand that is planar cross-stratified is usually fine grained, the dips of the individual beds are constant in one direction, and each inclined bedding plane terminates in the direction of its dip at a rather sharp angle. The surfaces against which the inclined bedding terminates above and below are planar and usually converge slightly, and they are rarely over a foot or two apart. Bedding may have a similar inclination in a section of rock broken parallel to the axis of trough cross-stratification but in this case, the surface along which the inclined beds terminate is concave. In the laboratory planar cross-stratification similar to that in conglomeratic strata of the Brushy Basin member has been developed in subsequent environments under conditions simulating delta construction (McKee and others, 1953, p. 48-53). The maximum dip direction of cross-stratification is the direction of delta growth and in the field this direction is assumed to be the direction of deposition.

In places where the orientation of the long axis of trough cross-stratification was measured near a measurement of maximum dip direction of planar cross-stratification, the directions were often the same.

Current lineation (fig. 2c) is the term used to describe tiny parallel windrows of sand grains on bedding planes. It is most common in sandstone that is medium or fine grained and is horizontally bedded. Current lineation is believed to be oriented parallel to the direction of stream movement except where it splays outward from a common point. In this case the direction of splay is assumed to be the downstream direction of movememt.

As a rule, current lineation is not common in sediments composing the conglomeratic sandstone strata of the Brushy Basin member although it is sometimes found where a stratum thins and becomes fine grained or near the top of a stratum where bedding is horizontal and the sand is fine grained.

The areas in southwestern Colorado and southeastern Utah in which the conglomerate strata are mapped are shown on figure 1, and the prevailing orientation of the sedimentary structures in each stratum is indicated by a barbed arrow. In some places, as in the Slick Rock area, conglomeratic strata are superimposed and the orientation shown represents a common trend of sedimentary structures in two or more strata. However, where sedimentary structures in superimposed strata diverge in orientation as they do near the Lower Group mines in the Slick Rock area and in the Uravan area (areas 16 -18 on fig. 1) the prevailing orientation of each stratum is shown on the map. Where they systematically change in orientation, the direction of change is shown by a curved arrow.

The prevailing orientation of sedimentary structures is, in the author's opinion, the direction that has been taken by deposition. This direction is, in some places, based on very few measurements, in others it is based upon 20 or 30 measurements. Furthermore, the prevailing trend is based on measurements made at the outcrop. Behind the outcrop, data may lie buried that would considerably alter the prevailing orientation as shown on the map.

The prevailing trend of sedimentary structures in the conglomeratic strata is easterly, as shown on figure 1. Departures from this trend were observed in places due perhaps to irregularities in Morrison topography or to local meanders in stream direction.

Elongation

The elongation of a conglomeratic stratum usually coincides with the prevailing trend of its contained sedimentary structures. Conglomeratic strata have been measured for almost a mile along their length, but they rarely exceed 2,000 feet in width before they grade into or in places terminate abruptly against mudstone. As a general rule strata that exceed 15 feet in thickness and 1,000 feet in width are continuous for at least 3,000 feet in the direction of the trend of their contained sedimentary structures.

On Calamity Mesa and nearby Outlaw Mesa, Mesa County, Colo., the most continuous strata are elongated easterly parallel to the trend of their sedimentary structures and, like beads on a string, they continue for a distance of about 4 miles in an easterly direction. They overlie and nearly parallel an easterly trending belt of ore deposits in the uppermost sandstone layer of the Salt Wash. Outside the limits of the belt of ore deposits on Calamity and Outlaw Mesas the conglomerate strata occur less frequently, they are more lenticular and their trend is generally northeastward. It would appear that during early Brushy Basin time the conglomerate strata above the ore deposits on Calamity and Outlaw Mesas, were deposited along a master streamway that parallels a belt of mineral deposits extending through the Calamity Mesa and Outlaw Mesa areas. Similar conditions may prevail in other parts of southwestern Colorado and southeastern Utah, but they have not been detected by this study.

Frequency of occurrence

The horizontal frequency at which conglomeratic strata appear at the base of the Brushy Basin member varies from place to place and is difficult to measure because their elongation and internal structural trend is often parallel to canyon walls. In the Slick Rock area where the walls of the northerly trending Dolores River Canyon expose easterly trending strata of conglomerate, individual strata are in places more than half a mile apart and are separated laterally by mudstone. In this area they would appear to cover about one-third of the Salt Wash member. In the Atkinson Mesa area, they crop out at intervals of about 1,200 feet, but sedimentary structural trends in at least two of the strata are parallel to the outcrop. Along the southwest side of the Big Gypsum Valley only one well-defined conglomeratic stratum about 1,000 feet wide was found along a 4-mile outcrop of Brushy Basin sediments. Reconnaissance observations in southwestern Colorado and southeastern Utah suggest that not more than one-third and perhaps less of the Salt Wash member is overlain by these strata of conglomerate.

Relation to uranium-vanadium deposits

It has been suggested that uranium-vanadium deposits in the Salt Wash member of the Morrison formation are related to ground-water solutions migrating through the beds, probably soon after the accumulation of the sands (Fischer and Hilpert, 1952, p. 3). If this suggested relation is true, it also seems probable that localization of the metals could have been controlled by ground-water underflow accompanying deposition of sediments younger than those containing the deposits. Because the conglomeratic strata at the base of the Brushy Basin member are believed to have been deposited by streams, it would appear that a more than casual relation should exist between these strata and the ore deposits in the Salt Wash member below.

To test the hypothesis that uranium-vanadium deposits and Morrison ground-water conditions are related, the stratigraphic interval, including the ore-bearing sandstone of the Salt Wash and the lower part of the Brushy Basin member, was in places mapped in detail; and the ore deposits were located and studied with regard to their position in the Salt Wash and their position with respect to conglomeratic strata in the Brushy Basin member. Mine workings were examined in the field to determine the position of ore bodies. In the areas explored by the diamond drill a single deposit was considered to lie within an arbitrary boundary outlining the inferred outer edge of mineralized rock even though several deposits might lie within this boundary. The total number of discrete ore deposits in the areas that were studied may be somewhat less than the actual number present, for mine workings and drill holes commonly explore several closely connected deposits.

Table 1 groups 364 ore deposits in 18 widely scattered mining areas of southwestern Colorado and southeastern Utah into the following three main categories: 1) deposits found below conglomerate strata, 2) deposits below projected trends of conglomerate strata, and 3) deposits showing no obvious relation to conglomerate strata.

In the first category, deposits below conglomerate that are reached by tunnels are separated from deposits that have been discovered by drilling through the conglomerate. Deposits explored by tunneling below the conglomerate are found in most of the mining districts in southwestern Colorado and southeastern Utah. The deposits in this category offer the strongest supporting evidence to bear out the observation that ore deposits underlie conglomerate strata at the base of the Brushy Basin member. There are 101 deposits in this group or 29 percent of the total number.

Deposits in the second main category--those found below projected trends of the conglomerate strata--are found in the top sandstone layer where it is stripped of its Brushy Basin cover, but where conglomerate is preserved in nearby hillsides. To analyze the relation between these deposits and the conglomerate strata, it was assumed that strata exceeding 1,000 feet in width may reasonably be projected for 2,500 feet along the trend of their sedimentary structures. In places where the lateral margin of a conglomerate stratum has been destroyed by erosion, the width of the fragment was arbitrarily increased by one-half the mapped width. These conservative assumptions allow deposits in the top sandstone layer that were probably once overlain by the Brushy Basin member to be included in the analysis. There are 211 deposits in this group or 61 percent of the total number of deposits.

In the third category are included deposits that occur either 1) along the trend of conglomerate strata but beyond the limits of safe projection, or 2) lateral to the marginal pinchout of a conglomerate stratum. Deposits beyond the limit of safe projection of the conglomerate strata are found where the Brushy Basin has been removed from the top sandstone layer of the Salt Wash over broad areas, or where landslide debris obscures geologic relations in the Brushy Basin member. Erosion has largely removed the

Table 1. The relation of uranium-vanadium deposits in the uppermost sandstone layer of the Salt Wash member to overlying conglomeratic strata at the base of the Brushy Basin member of the Morrison formation.

District and mine areas	Deposits below conglomerate strata		Deposits below projected trends of conglomerate strata	Deposits showing no obvious relation to conglomerate strata	Remarks
	Explored by tunnelling	Explored by drilling			
GATEWAY DISTRICT					
Calamity Mesa area	11	17	46	4	Outside limit of projection
Outlaw Mesa area	4	--	56	8	Seven deposits below landslide cover; 1 deposit no drill-core data
Lumsden mine area	2	--	--	--	--
Corvusite mine area	--	--	1	--	--
GYPSUM VALLEY DISTRICT					
Little Gypsum Valley area	9	--	32	10	Outside limit of projection
Big Gypsum Valley area	1	--	--	--	--
MOAB DISTRICT					
La Sal mines area	3	1	--	--	--
Yellow Circle mines area	4	--	1	--	--
MONTICELLO DISTRICT					
Waterfall Group area	--	--	--	13	Landslide cover
SLICK ROCK DISTRICT					
Upper Group area	2	--	13	2	200 feet lateral to marginal pinch-out of conglomerate stratum
Middle Group area	3	--	12	--	--
Ellison Group area	1	3	--	--	--
Veta Mad area	2	--	--	1	350 feet lateral to marginal pinch-out of conglomerate stratum
Lower Group area	--	--	16	3	450 feet lateral to marginal pinch-out of conglomerate stratum
Miscellaneous	2	--	--	--	--
THOMPSON DISTRICT					
Cactus Rat mine area	5	--	1	--	--
URAVAN DISTRICT					
Forty-five-Ninety mine area	8	2	--	--	--
Spring Creek Mesa area	3	7	--	--	--
Atkinson Mesa area	--	11	33	11	Four deposits below edge of conglomerate stratum; 1 deposit 400 feet lateral to marginal pinch-out of conglomerate stratum; 5 deposits within 400 feet of marginal pinch-out of conglomerate stratum
TOTALS	60	41	211	52	

Brushy Basin member in parts of Little Gypsum Valley, whereas in the Waterfall Group area and a small part of the Outlaw Mesa area outcrops of conglomeratic sandstone are obscured by landslide. Thirty-four out of the 52 deposits in this category are thus classified as being out of the limits of geologic observation. The remaining 18 deposits are to the marginal pinchout of conglomerate strata. Four of the 18 were below the edge of a conglomeratic stratum and the rest were mostly within 300 feet laterally of a conglomeratic stratum. These deposits constitute 10 percent of the total number of deposits that were studied in the ore-bearing sandstones.

Exceptions to the suggested relation between ore deposits in the Salt Wash member and conglomeratic strata in the Brushy Basin member have been observed in southwestern Colorado and southeastern Utah. In some places, notably in the Yellow Cat mine area, carnotite deposits are found in strata of Salt Wash sandstone below their usual position near the top of the member. Moreover, one of the deposits in this area is also localized in the conglomeratic strata at the base of the Brushy Basin member. This latter occurrence is not exceptional to the Yellow Cat mine area for the conglomeratic strata are mineralized locally in other areas that have also been notable producers of uranium-vanadium ore from the Salt Wash member. The commonly observed relation between ore deposits in the sandstone of the Salt Wash and conglomeratic strata in the Brushy Basin member is shown on figures 3 and 4.

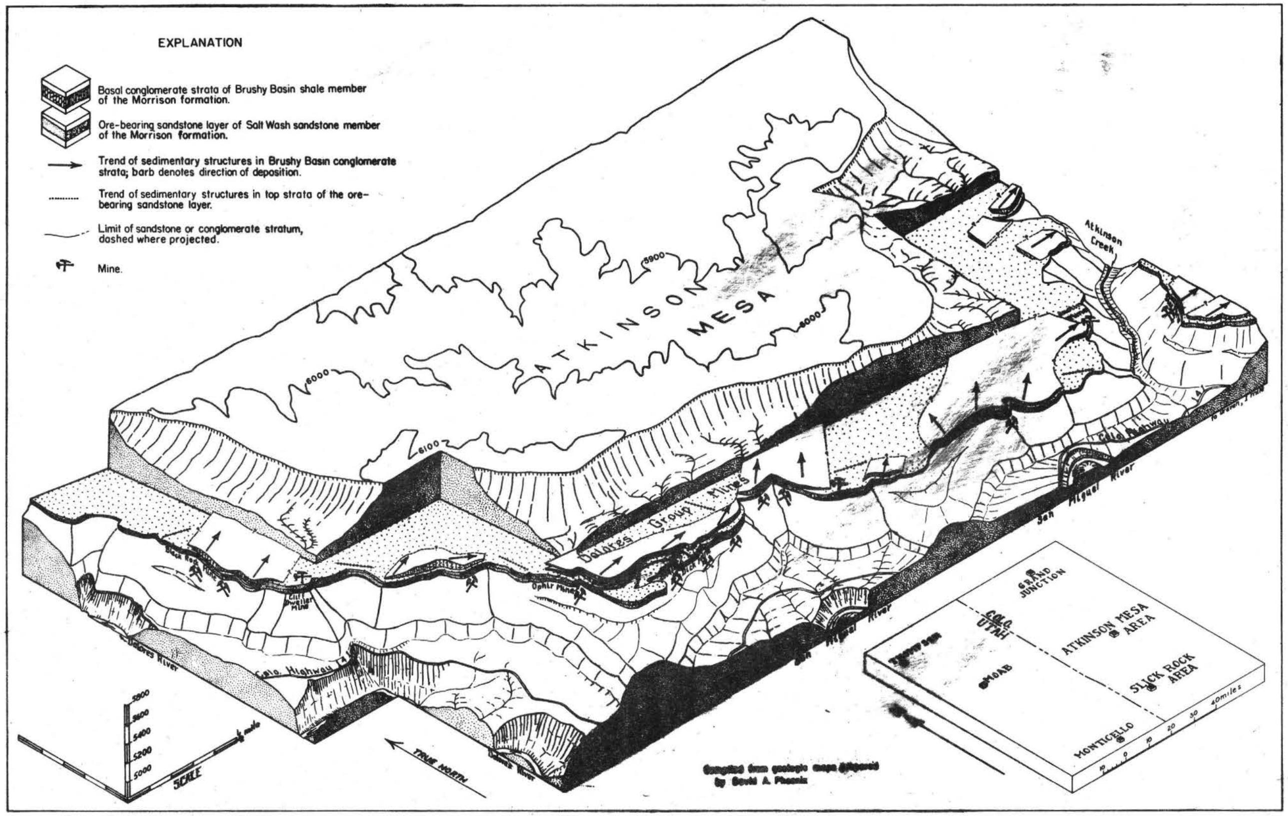

Figure 3. ISOMETRIC DRAWING SHOWING THE RELATION OF URANIUM-VANADIUM MINES IN SANDSTONE OF THE SALT WASH MEMBER TO THE CONGLOMERATE IN THE BRUSHY BASIN MEMBER OF THE MORRISON FORMATION, ATKINSON MESA AREA MONTROSE COUNTY, COLO.

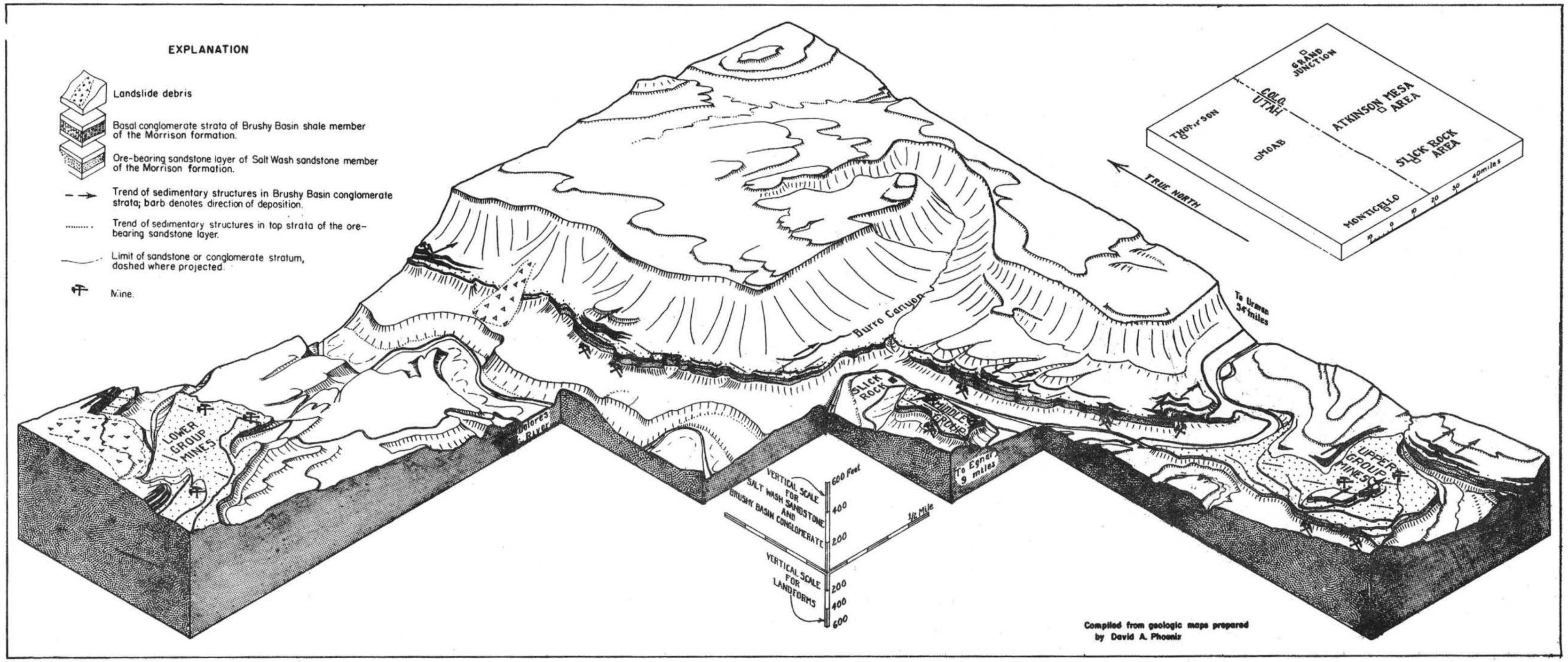

Figure 4. ISOMETRIC DRAWING SHOWING THE RELATION OF THE URANIUM-VANADIUM MINES IN THE SANDSTONE OF THE SALT WASH MEMBER TO THE CONGLOMERATE IN THE BRUSHY BASIN MEMBER OF THE MORRISON FORMATION, SLICK ROCK AREA, SAN MIGUEL COUNTY, COLO.

SUMMARY AND CONCLUSIONS

The geology of the conglomeratic sandstone strata at the base of the Brushy Basin member as it relates to the uranium-vanadium deposits is summarized as follows:

1. Conglomeratic strata at the base of the Brushy Basin member of the Morrison formation and just above an almost continuous layer of fluviatile sandstone near the top of the underlying Salt Wash member are sufficiently widespread to indicate that they constitute a distinct phase of Morrison deposition.

2. Sedimentary structures in the conglomeratic strata including trough cross-stratification, planar cross-stratification, and current lineation indicate the strata were destroyed by streams. The accidents of stream erosion and deposition during Morrison time are believed to have destroyed parts of these strata so that they are now discrete.

3. The pattern of sedimentary structural trends along the outcrop of a single stratum locally indicates a systematic change in orientation such as might be expected if the stream was meandering. However, because the prevailing trend of the sedimentary structures in the strata is easterly and because sediments in the strata coarsen westward, a westerly source for at least the lower portion of the Brushy Basin member is indicated.

4. Sediments in the conglomeratic strata are prevailingly coarser grained than are those in strata of the Salt Wash member and they are less well sorted. The writer believes that these differences in character indicate a departure from depositional conditions prevailing in Salt Wash time toward increased flow velocity. A source area capable of supplying large amounts of chert is also indicated by abundant chert pebbles in the strata.

5. In most places the conglomeratic strata are separated from the underlying top sandstone layer of the Salt Wash by mudstone, but locally, and in the vicinity of uranium deposits they rest directly upon the top sandstone layer. It seems likely that ground-water movement either from or into the underlying Salt Wash sandstone could take place particularly through these "puncture points." The writer believes that the greatest opportunity for movement of this kind was in Morrison time during deposition of the conglomeratic strata, and before the Salt Wash member was covered by a blanket of impervious sediment.

6. Uranium-vanadium deposits in the underlying sandstone layer at the top of the Salt Wash member are clustered below conglomeratic strata in areas where the physical characteristics of the ore-bearing sandstone are also favorable to ore deposits. Although exceptions to this general relation have been observed in some places, they do not eliminate the possibility that ground-water movement during Morrison time controlled emplacement of the uranium-vanadium metals in the Salt Wash sandstone member in southwestern Colorado and southeastern Utah.

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