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Distribution of elements in the Salt Wash member of the Morrison formation in the Jo Dandy area, Montrose County, Colorado

By William L. Newman and Donald P. Elston

Trace Elements Investigations Report 607

UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

Geology and Mineralogy

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DISTRIBUTION OF ELEMENTS IN THE SALT WASH MEMBER OF THE MORRISON FORMATION IN THE JO DANDY AREA, MONTROSE COUNTY, COLORADO*

By

William L. Newman and Donald P. Elston

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*This report concerns work done on behalf of the Division of Raw Materials of the U. S. Atomic Energy Commission.

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DISTRIBUTION OF ELEMENTS IN THE SALT WASH MEMBER OF THE MORRISON FORMATION IN THE JO DANDY AREA, MONTROSE COUNTY, COLORADO

By William L. Newman and Donald P. Elston

ABSTRACT

A study of the distribution of elements in the Salt Wash member of the Morrison formation of Jurassic age from samples taken in the Jo Dandy area, Montrose County, Colo., was made to determine average chemical compositions of mudstone and sandstone and to determine the magnitude of variations in concentrations of elements within similar rock types. Analytical data were obtained by semiquantitative spectrographic and radiometric methods.

Results of the study show that variations in concentrations of about 20 elements commonly detected by semiquantitative spectrographic analyses of sedimentary rocks are small for a specific rock type; therefore, considerable confidence may be placed upon the average chemical composition derived from the sample populations. In addition, there appears to be no significant relation between chemical composition of mudstone or sandstone and distance from known uranium-vanadium ore or mineralized rock.

Mudstone generally contains greater concentrations of the elements studied than sandstone. The chemical composition of red mudstone is similar to the chemical composition of green mudstone except that red mudstone was found to contain almost twice as much calcium as green mudstone in the Jo Dandy area.

Samples of unoxidized sandstone from the Jo Dandy area contain about twice as much calcium, three times as much strontium, but only about one-half as much zirconium as oxidized sandstone; except for these elements the chemical compositions of both categories of sandstone are similar. Samples of sandstone of the Salt Wash member in the Jo Dandy area contain more potassium, magnesium, vanadium, and nickel than "average sandstone" of the Salt Wash member.

The distribution of bismuth in rocks of the Jo Dandy area suggests that bismuth and perhaps part of the potassium and magnesium found in rocks of the Salt Wash member were either derived from solutions which ascended from the underlying salt- and gypsum-bearing Paradox member or were contained in gypsiferous material of the Paradox member that was incorporated with rocks of the Salt Wash during sedimentation.

INTRODUCTION

In 1954, a chemical study was made of the Salt Wash member of the Morrison formation of Jurassic age in the Jo Dandy area, Montrose County, Colo. (fig. 1). The Jo Dandy area is one of the important uranium-vanadium producing areas of the Colorado Plateau, and within this area sandstone strata in the upper part of the Salt Wash member contain the principal ore deposits.

The chemical study was made to investigate the distribution of elements in the host rocks with emphasis on the pattern of variation as related to the position of known ore bodies, and to determine average concentrations of some of the elements in the major rock types.

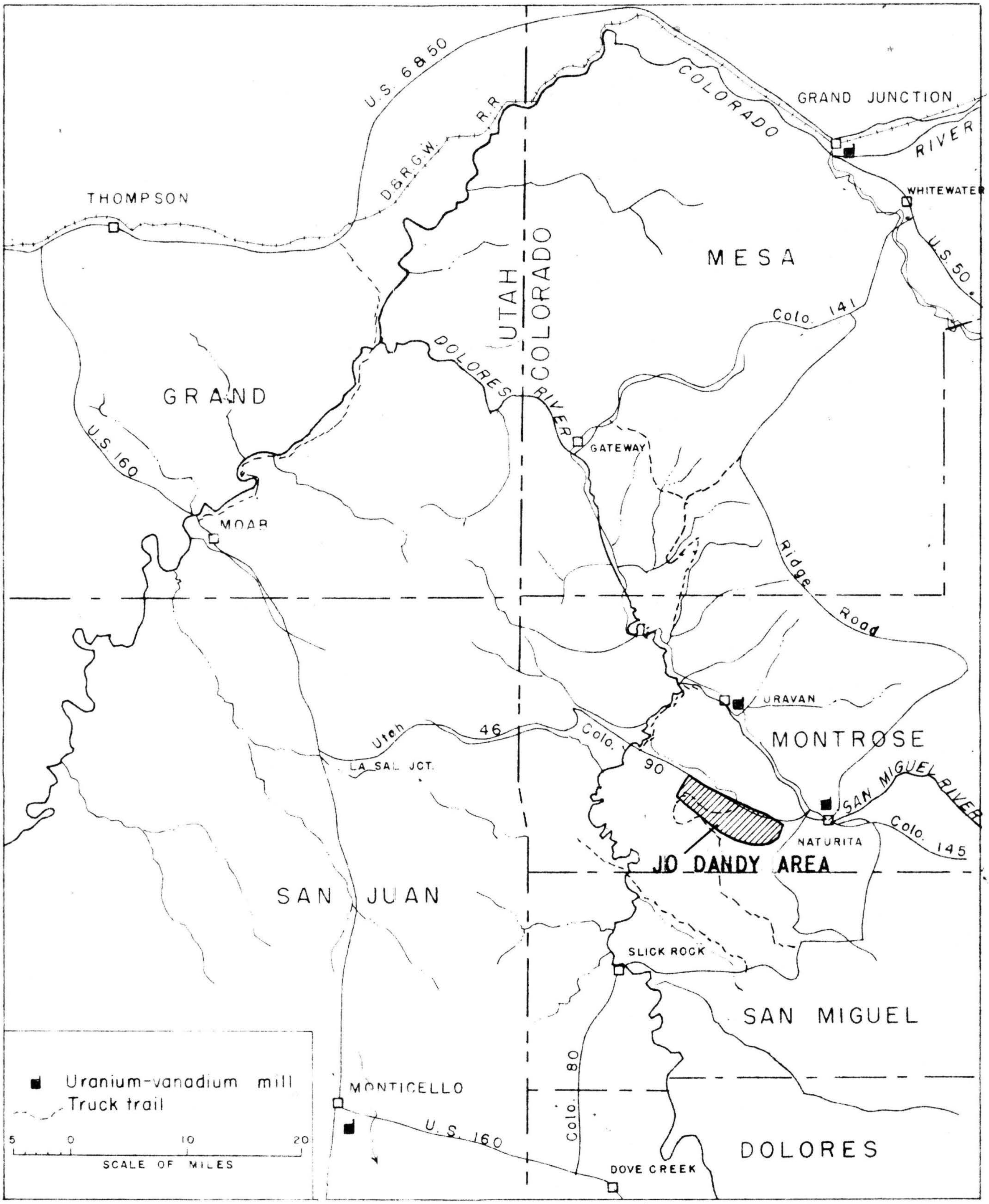


FIGURE 1.--INDEX MAP OF PART OF THE COLORADO PLATEAU SHOWING LOCATION OF THE JO DANDY AREA, MONTROSE COUNTY, COLO.

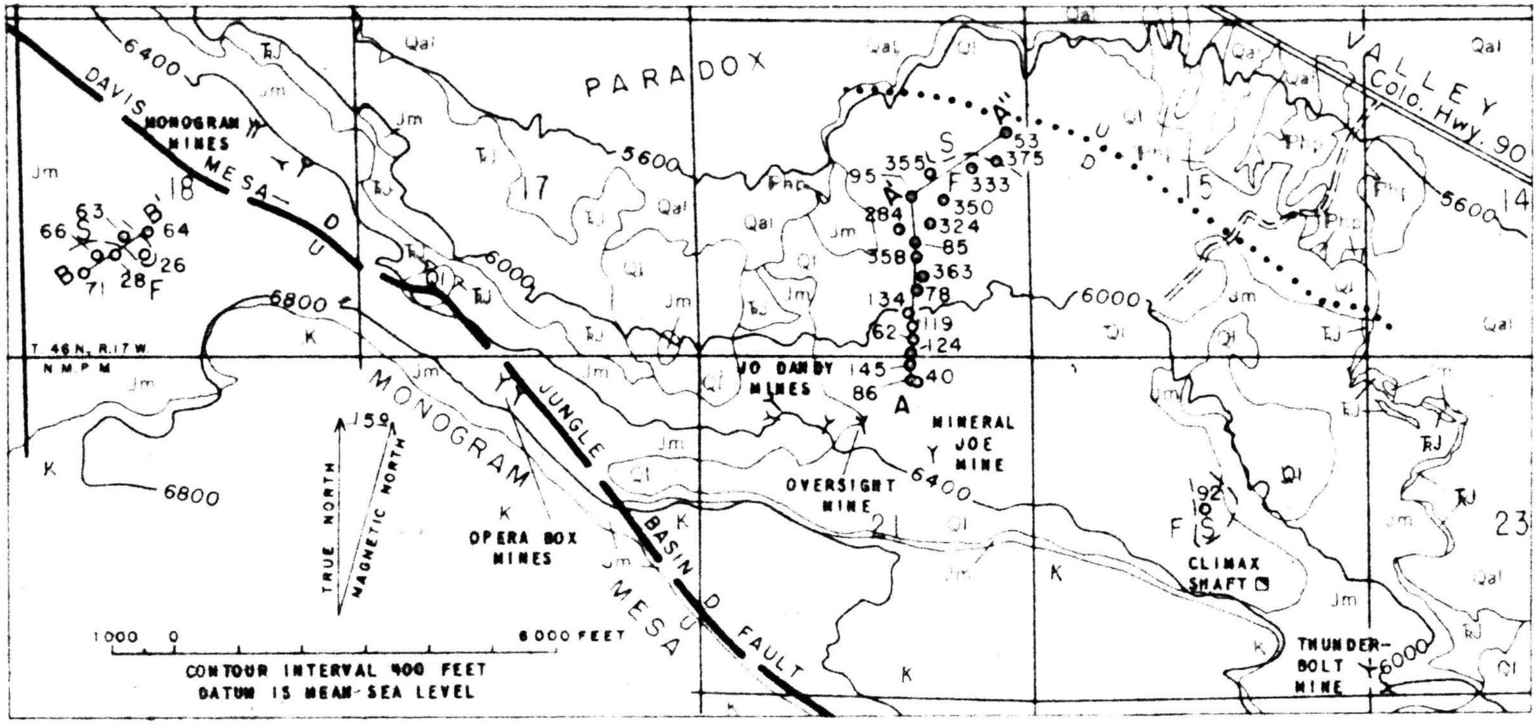
The study was done by the U. S. Geological Survey on behalf of the Division of Raw Materials of the U. S. Atomic Energy Commission, and is based upon the detailed knowledge of the area gained as a result of surface mapping by Cater (1955), and by surface and mine mapping and diamond-drill exploration conducted by the Geological Survey from 1949 to 1956.

Samples, taken mostly from drill cores, were analyzed for chemical constituents and equivalent uranium content in laboratories of the U. S. Geological Survey, Denver, Colo. Semiquantitative spectrographic analyses (Myers, 1954) were done by G. W. Boyes, Jr., and radiometric analyses were done by J. Patton.

GEOLOGIC SETTING

The Jo Dandy area is near the southeastern end of Paradox Valley, Montrose County, Colo. (fig. 2). Paradox Valley is a narrow elongate northwest-trending valley about 20 miles long and 3 to 4 miles wide that has formed as a result of subsidence and removal of strata along the crest or axis of a salt anticline. The core of the anticline consists of plastically deformed salt, gypsum, black shale, sandstone, and limestone of the Paradox member of the Hermosa formation of Pennsylvanian age.

Intrusion of the plastic material of the Paradox member began sometime during deposition of the Cutler formation of Permian age, probably in response to weak compressive forces.



Geology by F. W. Cater, Jr., 1947-48; E. M. Shoemaker, 1948; and D. P. Elston, 1956.

EXPLANATION

Quaternary (Pleistocene and Recent)

- Qal — ALLUVIUM. THIN VENEER ON BENCHES NOT SHOWN
- Ql — LANDSLIDE DEPOSITS

Cretaceous

- K — CRETACEOUS FORMATIONS

Jurassic (Upper Jurassic)

- Jm — MORRISON FORMATION

Jurassic and Triassic

- TRJ — PRE-MORRISON FORMATIONS

Unconformity

Pennsylvanian

- Php — PARADOX MEMBER OF HERMOSA FORMATION

D/U — FAULT (DASHED WHERE APPROXIMATELY LOCATED; DOTTED WHERE CONCEALED; U, UPTHROWN SIDE, D, DOWNTHROWN SIDE. ONLY NORTHERNMOST FAULT AND SOUTHERNMOST FAULT SHOWN)

F / S — BOUNDARY BETWEEN GROUND CLASSED AS FAVORABLE (F) AND GROUND CLASSED AS SEMIFAVORABLE OR UNFAVORABLE (S) FOR ORE. CLASSIFICATION OF GROUND SHOWN ONLY AT AND NEAR SAMPLED HOLES

ADIT

o92 — DIAMOND-DRILL HOLE, (NUMBERS ON DRILL-HOLE STANDPIPES IN FIELD HAVE PREFIX JD)

FIGURE 2.--GENERALIZED GEOLOGIC MAP OF PART OF THE JO DANDY AREA, MONTROSE COUNTY, COLO.

This material ruptured the overlying beds and broke through to the surface at the end of deposition of the Cutler formation (Cater, 1955). From then until Late Jurassic time there was a general, although locally imperfect, isostatic balance between sedimentation on the flanks of the salt structure and upwelling and removal of plastic and soluble materials of the Paradox member along the axis of the structure.

During Late Jurassic time the Morrison and younger formations were deposited across the salt structure. A broad anticline was formed along the trend of the salt structure prior to middle Tertiary time; probably during relaxation of compressive stresses (Cater, 1955), salt flowage was renewed, and normal faults cut the rocks along the crest of the fold. The folding was followed by erosion and, in mid-Tertiary time, by regional uplift, and the crest of the structure was breached. Thick wedges of strata on the flanks of the anticline settled by normal faulting as the plastic material was pressed out from under the sides and ends of the structure and as soluble material was removed. The major part of the settling may have been completed prior to Quaternary time, but minor adjustments continued during parts of the Quaternary and into recent time. Erosion has removed much of the strata from the axial part of the anticline and has left gypsiferous masses of the Paradox member exposed in the valley floor.

The Jo Dandy area includes faulted and unfaulted sedimentary strata between the floor of Paradox Valley on the northeast and the rim of Monogram Mesa on the southwest (fig. 2). Within the Jo Dandy area, in parts of secs. 15, 16, 21, and 22, T. 46 N., R. 17 W., late

Paleozoic and Mesozoic strata, which originally formed part of the southwestern flank of the anticline, have settled differentially with regard to adjacent Permian strata concealed beneath alluvium on the northwest, Mesozoic strata on the south and east, and gypsum of the Paradox member on the north. The differential movement of these strata is caused by foundering of competent rocks in the relatively plastic salt and gypsum core of the anticline. Rocks in this area were mapped as landslide material, and this area is called the Jo Dandy landslide by Elston, Botinelly and Shoemaker (written communication). Strata older than the Morrison formation of Late Jurassic age pinch out from south to north under the landslide. Under the north-central part of the landslide the Morrison formation overlies gypsiferous black mudstone, gray limestone, and gypsum of the Paradox member.

Drilling has shown that strata in the landslide area are cut by a series of normal faults; most of the fault blocks are displaced downward toward the valley with displacements locally in excess of 150 feet. In the landslide area, many of the faults, like those exposed on the valley wall to the west, generally parallel the northwest trend of the valley and are related to formation of the anticlinal structure; in places however, faults related to local differential settling crosscut the northwesterly set. All faults observed in the Jo Dandy area appear to be younger than the ore deposits.

In the Jo Dandy area the Morrison formation, which contains the principal ore-bearing beds, is about 700 feet thick and is divided into two members of about equal thickness. The lower or Salt Wash member consists of broad lenses of sandstone interbedded with reddish-brown and grayish-green mudstone; the upper or Brushy Basin member consists of variegated mudstone, scattered lenses of conglomeratic sandstone, very fine-grained quartzitic sandstone, and thin limestone beds.

The Salt Wash member consists of 3 to 5 prominent layers of sandstone separated by mudstone strata of varying thickness. The uppermost sandstone layer is called the ore-bearing sandstone as it contains all of the productive uranium deposits in the area. The ore-bearing sandstone ranges from a feather edge to about 130 feet in thickness.

Individual sandstone layers in the Salt Wash member consist of a series of lenses which range from about 5 to 60 feet in thickness and from a few hundred to a few thousand feet in length. They are commonly separated by seams of mudstone. Bedding within the lenses or composite sets (McKee and Weir, 1953, p. 383) is varied and ranges from horizontal to steeply dipping crossbeds. The individual sandstone layers near the top and base of the member are prominent and crop out throughout the area. The intermediate layers are less persistent and only locally do all the sandstone layers coalesce or nearly coalesce to form an essentially continuous vertical section of sandstone.

Sandstone of the Salt Wash member is composed dominantly of quartz grains; feldspar and dark minerals are only minor constituents. Mudstone, commonly pale green in color, is present as intergranular material, as flakes, and as thin discontinuous seams.

Mudstone strata that separate the sandstone layers of the Salt Wash member are generally reddish brown, but mudstones adjacent to and within the lower and upper sandstone layers are commonly grayish green. The thickest mudstone and the one most persistent laterally, underlies the ore-bearing sandstone. It is commonly about 75 feet thick.

The distribution of green mudstone coincides with the occurrence of mineralized sandstone in many areas; therefore, the color of mudstone adjacent to sandstone beds has been used as a criterion for the classification of ground as to favorableness for ore (Weir, 1952; McKay, 1955).

The color of sandstone is also used in this respect. Color is due to the presence of iron in the form of sulfides and oxides. Unoxidized sandstone classed as favorable for ore is light gray and contains scattered crystals of pyrite and marcasite. Its oxidized equivalent is generally light to dark brown. In many places oxidized sandstone is given a freckled appearance by discrete brown dots of limonite derived from oxidation of the iron sulfides. Sandstone classed as unfavorable for ore is found both above and below the present water table and ranges from light to dark gray and has a pale-red to dark-red cast. Sulfides are absent. The red color of clays of the Salt Wash was found to be due to the dispersion of minute particles of iron oxide which pigment the clay minerals (Weeks, 1951, p. 12). The pigment of red sandstone is believed to be due to a pervasive coating of anhydrous ferric oxide, probably hematite.

The grain size of sandstone is also used to classify ground. Sandstone classed as favorable for ore generally is fine to medium grained, whereas sandstone classed as semifavorable and unfavorable for ore is commonly very fine grained and silty.

Uranium ore in the Jo Dandy area consists mainly of sandstone impregnated with oxidized and partly oxidized uranium and vanadium minerals, but some unoxidized uranium ore is present. In many places the ore minerals follow the bedding of the host sandstone in detail, but the upper and lower edges of a mineralized layer typically crosscut the larger bedding features at low angles. Within a mineralized layer high-grade concentrations of uranium and vanadium minerals occur in concretionary masses or pods commonly associated with carbonaceous material. Local high-grade concentrations also occur in sandy mudstone pebble carbonaceous trash layers and in traps produced by wedging sandstone beds. Rolls, in which ore boundaries sharply crosscut the sedimentary bedding to form C-shaped figures, have been observed in both unoxidized and oxidized ore, but sharply defined surfaces between ore and barren rock have been observed only in oxidized ore. Diffuse S-shaped rolls, confined to a single bed but crosscutting laminae of the bed, have been observed only in oxidized ore. Field observations suggest that little redistribution of ore minerals occurs during oxidation of uranium-vanadium ore. (D. P. Elston and Theodore Botinelly, written communication).

Individual ore deposits range from about 50 to 2,000 feet in length and from 25 to 500 feet in width. Thicknesses of ore-grade and mineralized rock are locally in excess of 30 feet, but ore layers are commonly 3 to 5 feet thick.

The geology of the Jo Dandy area, summarized above, forms the basis for the chemical study described in the following sections. Data obtained from diamond-drill exploration permitted fairly precise correlations of sandstone and mudstone strata throughout the area. In addition, the drilling provided drill core for chemical analysis. The detailed information concerning the stratigraphy of the Salt Wash member and the position, size, and trend of ore deposits led to the selection of the Jo Dandy area as an ideal place to study the distribution of elements in host rocks of the Salt Wash member.

SAMPLE COLLECTION

Eighty-eight samples of drill core from nine diamond-drill holes were selected for analysis. One or more core samples were taken to represent each major lithologic unit penetrated in each drill hole. The samples were NX-sized (2-1/8 inches in diameter) and averaged 0.3 feet in length.

Core was taken from seven holes that were drilled in the landslide area (figs. 2 and 3). Six of these holes are shown in cross section A-A'-A" (fig. 3). Two of these holes (holes 62 and 78) penetrated ore in the ore-bearing sandstone and one hole (hole 53) penetrated mineralized rock in the Paradox member of the Hermosa formation. Of these 6 holes, 5 holes are in ground classed as favorable for ore, and 1 hole is in ground classed as unfavorable for ore. Core samples were taken from lower strata of the Salt Wash member in 2 of these holes (86 and 53), and core samples were taken from the upper or ore-bearing strata in the remaining 4 holes. The remaining hole (hole 92) sampled in the landslide area (sec. 22, figs. 2 and 3) penetrated ground classed as semifavorable for ore, but ore-bearing ground lies about 700 feet south of this hole.

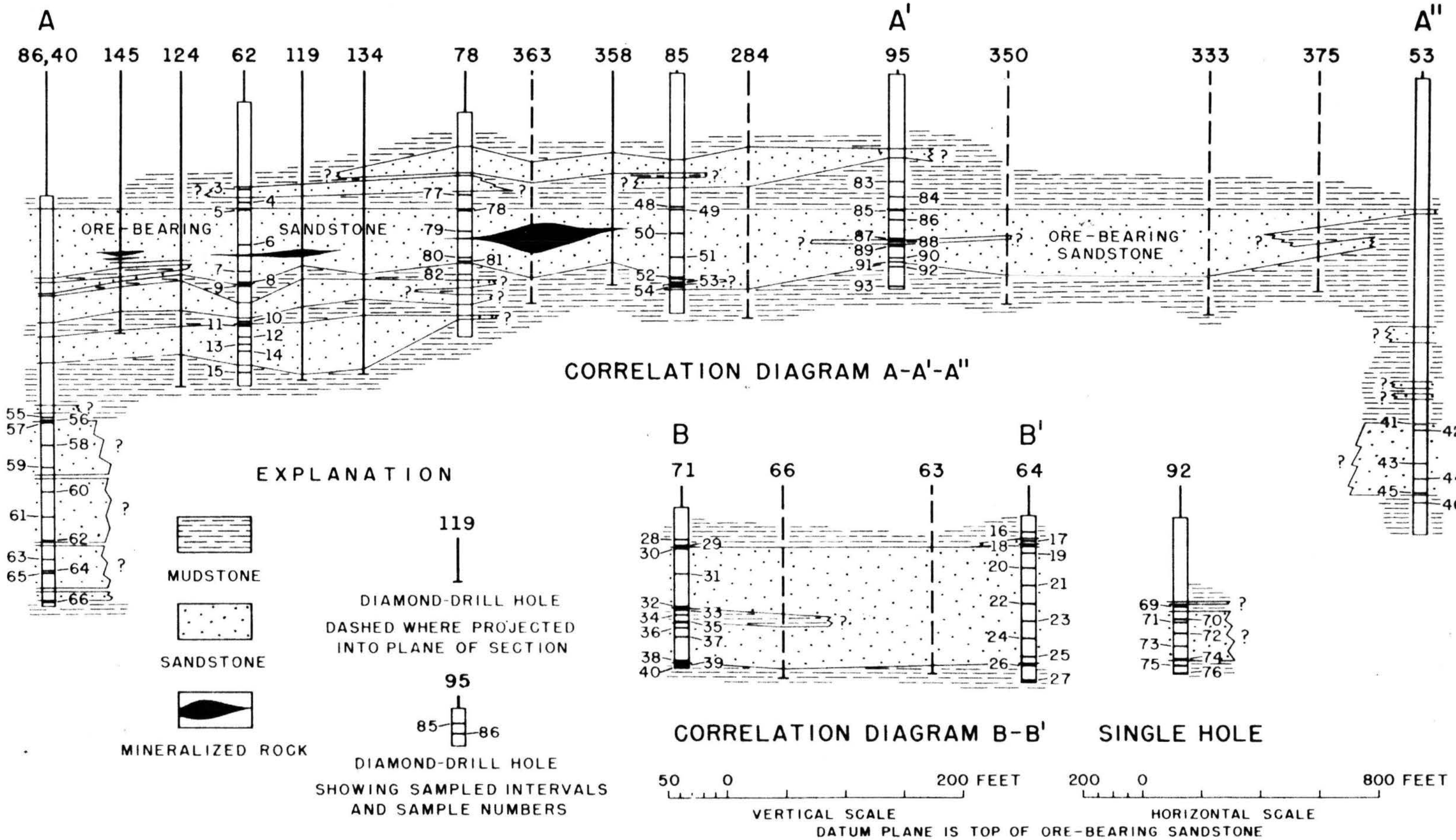


Figure 3.--SCHEMATIC STRATIGRAPHIC CORRELATION DIAGRAMS OF PART OF THE SALT WASH MEMBER OF THE MORRISON FORMATION, JO DANDY AREA, MONTROSE COUNTY, COLO.

Core samples were also taken from two holes drilled in the vicinity of the Monogram mines, about 2 miles west of the landslide area (cross section B-B', holes 71 and 64, figs. 2 and 3). These holes penetrated upper strata of the Salt Wash member classed as favorable for ore; however, these holes straddle a lobe of ground classed as semifavorable for ore. Ground southwest of the semifavorable lobe is classed as favorable for ore but is mostly barren of uranium and vanadium minerals. An ore deposit occurs about 350 feet northeast of section B-B'.

Lithologic data from these nine drill holes were integrated with surrounding drill-hole data to determine the internal stratigraphy of the Salt Wash member. Along the lines of section, lithologic logs of adjacent drill holes have been plotted to demonstrate the additional stratigraphic control, but samples were not taken from these holes.

Datum for the correlation diagrams is the top of the ore-bearing sandstone. About 30 feet of red-brown and gray-green mudstone and very fine-grained sandstone commonly separates the top of the ore-bearing sandstone from the basal sandstone strata of the Brushy Basin member. In places where the basal sparsely conglomeratic sandstone of the Brushy Basin member is channeled into the ore-bearing sandstone, the datum is the contact of these two sandstone units.

In addition to samples of drill core, two samples (samples 1 and 2) of rock gypsum of the Paradox member were collected from outcrops in Paradox Valley, and a specimen of selenite (sample 67, appendices A and C) was taken from a fracture in the Mineral Joe mine. One of the samples of rock gypsum (sample 1, appendices A and C) was collected from a bulldozer cut on the west side of the landslide area (fig 2). The second sample of rock gypsum (sample 2, appendices A and C) was collected about 3 miles west of the intersection of Colorado Highway 90 and the Monogram truck trail. The location of this sample site is not within the area shown on figure 2.

VARIATIONS IN COMPOSITIONS OF HOST ROCKS

Analytical data (Appendix C) were used to determine variations in composition of the two major rock types, sandstone and mudstone, and also to determine variations within each rock type. Variations in concentration of each element were determined by plotting chemical data in their proper sample interval within the graphic log of each drill hole.

Graphic logs of each hole were then plotted to form stratigraphic correlation diagrams (fig. 3).

Silicon

In all samples of sandstone and mudstone the silicon content was greater than 10 percent. The concentration of silicon is too high to be estimated by semiquantitative spectrographic methods, but the arithmetic mean silicon concentration in unmineralized sandstone made during regional studies of the Salt Wash member by W. L. Newman and E. M. Shoemaker was found to be approximately 36 percent (77 percent SiO_2). In samples of gypsum the silicon content ranged from 0.0X percent in a crystal of selenite to 0.X+ percent in a sample of rock gypsum from the Paradox member. See appendix B for explanation of the method used to report spectrographic analyses. The amount of silicon over 0.0X percent may thus be taken as a rough estimate of the amount of extraneous material, such as sandstone and mudstone, that is incorporated with the evaporite of the Paradox member.

Aluminum

The concentrations of aluminum in mudstone range from X.- to X.+ percent, but only three samples of mudstone out of 32 contained less than X. percent. The aluminum content of mudstone in the Jo Dandy area is, therefore, constant. Concentrations of aluminum in sandstone also range from 0.X- to X.+ percent, but only one sample of sandstone contained more than X. percent. Sandstone samples that contain the higher concentrations of aluminum also contain greater amounts of clay that fills interstices or occurs as films, seams, or pellets. The amount of aluminum in sandstone, therefore, is roughly proportional to the amount of clay contained in the sandstone.

Iron

The concentrations of iron in mudstone range from 0.X+ to X. percent. But only two samples of mudstone contained as much as X. percent iron; therefore, the iron content in mudstone is consistent. Sandstone contains concentrations of iron that range from 0.X- to X. percent. One sample of sandstone from hole 71 (sample 37, appendix C) contains disseminated crystals of pyrite. The iron content of this one sample is correspondingly high and contains X.0 percent iron.

Correlative strata of sandstone show very little variation in iron content nor a consistent pattern of concentration with depth. The average iron content in sandstone is close to 0.3 percent (midpoint of the range of 0.X, the most frequently occurring class interval), and the average iron content in mudstone is close to 1.5 percent (midpoint of the range of X.-).

Magnesium

The range in concentrations of magnesium in mudstone is rather a narrow one, extending from 0.X+ to X. percent, whereas the range in concentrations in sandstone is wide, extending from 0.0X to X. percent. Variations in correlative strata are not systematic, however. In some holes (holes 62, 71, 53, and 92, fig. 2), the magnesium content in sandstone increases with depth, whereas in other holes (holes 78, 85 95, and 86, fig. 2) the concentration of magnesium decreases with depth.

Calcium

The calcium content of the Salt Wash member does not vary systematically within correlative lithologic units, nor are there systematic variations in calcium content with depth. The concentrations of calcium in mudstone range from 0.X- to X. percent, whereas the calcium content in sandstone ranges from 0.0X+ to X.+ percent. There appears to be no observable relation between the distribution of calcium in sandstone and the distribution of known ore bodies, but lateral and vertical sample intervals are too widely spaced to show variations which may occur in and close to ore.

Potassium and sodium

The concentrations of potassium in mudstone range from X.- to X. percent, a narrow spread of values. Concentrations of potassium in sandstone show a greater range of values extending from less than trace amounts (about 0.X- percent) to X.- percent. The range in concentrations of sodium in mudstone is from 0.0X+ to 0.X percent, but only one sample of mudstone contained less than 0.X- percent. Concentrations of sodium in sandstone range from trace amounts (about 0.0X- percent) to 0.X percent, but only one sample contained more than 0.X- percent.

The concentrations of potassium throughout the sandstone beds are very similar, both laterally and vertically. This is equally true for the concentrations of sodium. Sandstone in hole 64 (cross section B-B', fig. 3), however, contains somewhat less potassium and sodium than commonly found in sandstone of the Salt Wash member in the Jo Dandy area.

Titanium and zirconium

Concentrations of titanium in mudstone range from 0.0X to 0.X percent, and the range in sandstone is from 0.00X+ to 0.X- percent. Zirconium in mudstone ranges in concentration from 0.00X to 0.0X- percent and in sandstone from 0.00X- to 0.0X- percent. Although the total amount of titanium in the host rocks is somewhat greater than the total amount of zirconium, the two elements show geochemical affinities. Both elements are concentrated in the fine-grained sediments such as mudstones and claystones, and the concentration of one element varies directly with the concentration of the other.

Manganese

Ranges of concentration of manganese in both mudstone and sandstone are very nearly alike, concentrations of manganese in mudstone range from 0.00X to 0.0X+ percent, and the concentrations in sandstone range from 0.00X to 0.0X percent. Variations in manganese content throughout sandstone strata are of small magnitude, although there are indications that manganese tends to be slightly concentrated at the top and bottom of sandstone lenses. Manganese appears to vary directly in concentration with that of calcium. A high positive correlation of calcium with manganese was also observed in a regional study of the distribution of elements in sandstone of the Salt Wash member by W. L. Newman. Manganese may be contained largely in solid solution in calcite.

Barium and strontium

The concentrations of barium in mudstone range from 0.00X+ to 0.0X percent, whereas concentrations in sandstone range from 0.00X+ to 0.X- percent. However, only one sample of sandstone contained more than 0.0X+ percent barium, and that sample (59, hole 86) also contained abundant tiny fractures filled with gypsum and probably barite. The average barium content in mudstone and in sandstone is very similar. Sandstone enclosing an ore body in hole 62 (samples 6 and 7) contains less than the average amounts of barium, and the sample of sandstone nearest ore-grade material in hole 78 (sample 79) also contains less-than-average amounts of barium. In general, the uppermost and lowermost parts of the ore-bearing sandstone appear to contain slightly more barium than the central parts. The variations in concentration are so slight, however, that they are of questionable significance.

Concentrations of strontium in mudstone show only a narrow spread of values that range from 0.00X+ to 0.0X percent, and only one sample contained more than 0.0X- percent strontium. Concentrations of strontium in sandstone, however, show a wide spread of values that range from 0.00X- to 0.0X+ percent, but concentrations of strontium do not show a systematic variation except with the oxidation state of sandstone as described in a subsequent section of the report. Barium and strontium appear to be geochemically related, for, with few exceptions, the concentrations of each element vary coincidentally.

Beryllium and boron

Except for one sample, beryllium occurs in detectable quantities only in mudstone. The one exception is a sample of very fine- to fine-grained sandstone (hole 64, sample 17) taken from a thin lens above the ore-bearing sandstone. This sample contained 0.000X- percent beryllium. Most samples of mudstone contained from trace to 0.000X- percent beryllium, although in a few samples of mudstone beryllium was not detected.

Boron likewise tends to become concentrated in the finer grained sediments. Concentrations in mudstone range from 0.00X- to 0.0X percent, whereas concentrations in sandstone range from below trace amounts (about 0.000X+ percent) to 0.00X percent. No systematic variations in the concentrations of these two elements are indicated by the data.

Vanadium

Concentrations of vanadium in mudstone range from 0.00X to 0.0X percent; whereas concentrations in sandstone range from trace amounts (about 0.000X+ percent) to 0.0X- percent. Concentrations of vanadium are remarkably constant within correlative lithologic units, but vanadium may be slightly more concentrated in sandstones in zones that correlate laterally with mineralized zones. This relationship is particularly apparent in hole 64 in which somewhat higher concentrations of vanadium occur near the base of the ore-bearing sandstone layer. In drill hole 26 a trace of carnotite coating fracture surfaces was found at the same stratigraphic position as the high vanadium values found in hole 64. The concentration of vanadium in sandstones either above or below known ore bodies shows no persistent relations to the ore bodies, however.

Chromium

Concentrations of chromium in mudstone range from 0.00X- to 0.00X+ percent, and in sandstone the concentrations range from 0.000X to 0.00X percent. Thus it is apparent that chromium is concentrated in the fine-grained sediments. Mudstone at the base of the ore-bearing sandstone consistently contains 0.00X percent chromium regardless of color (red or green), as do thin beds of mudstone within the ore-bearing sandstone. Mudstone at the top of the ore-bearing sandstone may contain slightly less chromium than basal mudstone, whereas the basal sandstone layer may contain slightly more chromium than the upper sandstone layer. The distribution of chromium does not appear to be related to the distribution of known ore bodies, however.

Yttrium, ytterbium, gallium, scandium, lanthanum.--

These elements are closely related in their mode of occurrence; each tends to be concentrated in the finer-grained rocks. Yttrium commonly occurs in concentrations above trace amounts only in mudstone which contains from .00X-to .00X percent, but a few samples of oxidized sandstone contained from a trace to .00X- percent. Similarly, ytterbium occurs chiefly in mudstone which contains up to .00X- percent. Most of the samples of mudstone in which ytterbium was detected, however, contained .000X- percent.

The gallium content of mudstone ranges from a trace (about 0.000X+ percent) to 0.00X- percent, but most samples of sandstone contain less-than-trace amounts of gallium. The basal sandstone of the Salt Wash member, cored in hole 53, contained traces of gallium throughout its thickness. Very fine grained and silty sandstones generally contain traces of gallium in other holes studied.

Scandium, like gallium, is detectable only in mudstone and occurs in concentrations that range from a trace (about 0.000X+ percent) to 0.00X- percent. Concentrations of scandium in sandstone are below the threshold of detection of the semiquantitative spectrographic method.

Only trace amounts of lanthanum are found in the mudstones of the Salt Wash member in the Jo Dandy area. If sandstone contains lanthanum, the concentrations of this element are below the threshold of detection by the spectrographic method. Seven samples of green mudstone contained traces of lanthanum; five of these samples were collected from strata at the base of the ore-bearing sandstone lens or in a mudstone split within the ore-bearing sandstone. Three samples of red mudstone contained trace amounts of lanthanum. Two of the three samples were collected from strata overlying the ore-bearing sandstone (sample 28 in hole 71 and sample 18 in hole 63; cross section B-B'), and one sample was taken from the mudstone overlying the basal sandstone layer of the Salt Wash member (sample 55 in hole 86).

Nickel and cobalt

Concentrations of nickel in mudstone range from 0.000X+ to 0.00X- percent, a very narrow spread of values. Concentrations of nickel in sandstone range from less than trace amounts (about 0.000X- percent) to 0.000X+ percent. Concentrations of cobalt in mudstone range from trace amounts (about 0.000X- percent) to 0.00X- percent, whereas concentrations in sandstone range from less than trace amounts to 0.000X+ percent. Both elements are concentrated in mudstone strata and in thin sandstone lenses enclosed by mudstone (holes 62 and 95). A thick sandstone stratum containing mineralized material in hole 62 contains somewhat more nickel and cobalt than correlative units in holes 78 and 85 (cross section A-A'-A"). But except for this occurrence, the sample data show no consistent relationship between the distribution of cobalt and nickel and the distribution of known ore bodies. Cobalt and nickel in host rocks of the Salt Wash member appear to be geochemically similar because the concentrations of one element show an excellent positive correlation with the concentrations of the other.

Copper

The copper content of mudstone ranges from 0.00X- to 0.00X+ percent; in sandstone the copper content ranges from 0.000X to 0.00X percent. The variation in concentrations of copper within correlative units of similar lithology are small. The distribution of copper shows no relationship to the distribution of known ore deposits. There is a tendency for copper to be distributed in a manner similar to that of vanadium, but the two elements do not appear to be distinctly related geochemically.

Lead, molybdenum, and silver

Lead is unquestionably concentrated in mudstone strata of the Salt Wash member of the Morrison formation in the Jo Dandy area. Concentrations range from less than trace amounts (about 0.000X+ percent) to 0.00X+ percent. Most samples of sandstone do not contain sufficient quantities of lead to be detectable by the analytical method used, but thin sandstone lenses below the base of the ore-bearing sandstone consistently contain detectable quantities of lead. The lead content of these thin sandstone lenses is represented by samples 11, 12, and 13 in hole 62, by samples 89 and 90 in hole 95, and by sample 37 in hole 71.

Rocks of the Salt Wash member in the Jo Dandy area generally contain only traces or less of molybdenum and silver. However, two samples in hole 85 (samples 48 and 51) and one sample in hole 86 (sample 65) contained as much as 0.00X- percent molybdenum. The highest concentration of molybdenum (0.0X- percent) was found in a sample of black mudstone underlying the basal sandstone stratum of the Salt Wash member in drill hole 53 (sample 46). This black mudstone was probably derived by weathering in situ of the gypsum and black shale of the Paradox member of the Hermosa formation prior to deposition of the Morrison formation. This particular sample, in addition to containing molybdenum, also contains appreciable amounts of vanadium, copper, lead, boron, gallium, chromium, and a trace of silver. This sample was not included in calculations for the average composition of mudstones of the Salt Wash member. In addition to this one mudstone sample, silver was reported to occur in trace amounts in sample 11, hole 46.

Bismuth

Bismuth is seldom found in sedimentary rocks of the Colorado Plateau in amounts exceeding the spectrographic threshold for that element (about 0.000X+ percent). In the Jo Dandy area, however, bismuth was found in detectable quantities in 6 samples of drill core (samples 3, 5, and 6 in drill hole 62, and samples 17, 23, and 27 in drill hole 64). The quantities of bismuth in these core samples range from a trace to 0.00X percent. Bismuth was also detected in both samples of gypsiferous material of the Paradox member of the Hermosa formation (samples 1 and 2) and from a large crystal of selenite collected from a fracture in the Mineral Joe mine (sample 67). Quantities of bismuth in gypsum range from 0.00X- to 0.00X+ percent.

Equivalent uranium

The radioactivity of unmineralized host rocks of the Salt Wash member of the Jo Dandy area varies with lithology; samples of mudstone and fine-grained rocks are more radioactive than sandstone samples. Mudstones contain from 0.002 percent to 0.007 percent eU, and mudstone (commonly green) directly adjacent to sandstone lenses is more radioactive than mudstone some distance above or below sandstone lenses. Values of eU in sandstone range from less than 0.001 to 0.003 percent; but only one sample of sandstone contained more than 0.002 percent.

AVERAGE CHEMICAL COMPOSITION OF HOST ROCKS

Geometric means representing the average chemical composition of host rocks were calculated for each of the following rock types: red and green mudstone and oxidized and unoxidized sandstone. The average chemical composition of green and red mudstone is shown on table 1. The average chemical composition of oxidized and unoxidized sandstone is shown on table 2. Studies of elements in sedimentary rocks of the Colorado Plateau by W. L. Newman indicate that the frequency distribution of many of the elements is approximately lognormal which supports the findings of Ahrens (1954) that the concentrations of many elements have a lognormal distribution in a specific rock type. For purposes of comparison, the geometric mean is generally the most satisfactory measure of central tendency for lognormal or approximately lognormal distributions because the logarithmic variance of geometric means of small sets of samples drawn from a lognormally distributed population is less than the logarithmic variance of the arithmetic means (the geometric mean is a more efficient or more stable statistic).

Table 1.--Chemical compositions of red and green mudstone from the Salt Wash member of the Morrison formation, Jo Dandy area, Montrose County, Colo. (composition shown in percent).

Element	Red mudstone 1/				Green mudstone 2/			
	G. M. 3/			G. D. 4/	G. M. 3/			G. D. 4/
Si	<10.0			--	<10.0			--
Al	3.4	$\overset{\times}{\div}$	1.53	1.64	4.0	$\overset{\times}{\div}$	1.42	1.67
Fe	1.5	$\overset{\times}{\div}$	1.47	1.56	1.4	$\overset{\times}{\div}$	1.27	1.42
Mg	1.9	$\overset{\times}{\div}$	1.38	1.45	1.7	$\overset{\times}{\div}$	1.42	1.70
Ca	1.9	$\overset{\times}{\div}$	1.52	1.62	0.94	$\overset{\times}{\div}$	1.74	2.28
Na	0.18	$\overset{\times}{\div}$	1.34	1.40	0.19	$\overset{\times}{\div}$	1.28	1.44
K	2.2	$\overset{\times}{\div}$	1.41	1.49	2.4	$\overset{\times}{\div}$	1.29	1.46
Ti	0.10	$\overset{\times}{\div}$	1.55	1.66	0.14	$\overset{\times}{\div}$	1.41	1.66
Zr	0.0072	$\overset{\times}{\div}$	1.66	1.79	0.0090	$\overset{\times}{\div}$	1.48	1.79
Mn	0.026	$\overset{\times}{\div}$	1.49	1.58	0.016	$\overset{\times}{\div}$	1.57	1.96
Ba	0.014	$\overset{\times}{\div}$	1.20	1.24	0.017	$\overset{\times}{\div}$	1.32	1.51
Sr	0.013	$\overset{\times}{\div}$	1.44	1.52	0.015	$\overset{\times}{\div}$	1.00	0
B	0.0036	$\overset{\times}{\div}$	1.73	1.87	0.0040	$\overset{\times}{\div}$	1.42	1.67
Be	<0.0001			--	<0.0001			--
V	0.0057	$\overset{\times}{\div}$	1.86	2.04	0.0083	$\overset{\times}{\div}$	1.62	2.05
Cr	0.0025	$\overset{\times}{\div}$	1.38	1.45	0.0029	$\overset{\times}{\div}$	1.18	1.27
Y	0.0017	$\overset{\times}{\div}$	1.29	1.33	0.0015	$\overset{\times}{\div}$	1.38	1.61
Yb	0.00016	$\overset{\times}{\div}$	1.43	1.51	0.00016	$\overset{\times}{\div}$	1.74	2.28
Ga	0.00057	$\overset{\times}{\div}$	1.97	2.18	0.00077	$\overset{\times}{\div}$	1.69	2.18
Sc	0.0010	$\overset{\times}{\div}$	1.41	1.49	0.0011	$\overset{\times}{\div}$	1.29	1.46
La	<0.002			--	<0.002			--
Ni	0.00097	$\overset{\times}{\div}$	1.41	1.49	0.0011	$\overset{\times}{\div}$	1.30	1.48
Co	0.00057	$\overset{\times}{\div}$	1.34	1.40	0.0044	$\overset{\times}{\div}$	1.08	2.99
Cu	0.0024	$\overset{\times}{\div}$	1.67	1.80	0.0025	$\overset{\times}{\div}$	1.28	1.44
Pb	<0.001			--	<0.001			--
Mo	<0.0005			--	<0.0005			--
Ag	<0.0001			--	<0.0001			--
Bi	<0.001			--	<0.001			--

1/ Chemical composition based on 13 samples.

2/ Chemical composition based on 19 samples.

3/ Geometric mean (percent) showing the 99 percent confidence interval for the population geometric mean. The limits of the confidence interval are determined from student's t distribution (Fisher and Yates, 1953, p. 1 and 40) where t is the deviation (or range of the population mean), in units of estimated standard error. For a normal distribution:

$$\text{confidence interval of the mean} = \pm t \frac{(s)}{\sqrt{n-1}} ;$$

or for a lognormal distribution:

$$\text{confidence interval of G. M.} = \overset{\times}{\div} \text{antilog } t \left[\frac{(\text{Log G. D.})}{\sqrt{n-1}} \right]$$

4/ Geometric deviation or antilog of the log standard deviation.

Table 2.--Chemical compositions of oxidized and unoxidized sandstone of the Salt Wash member of the Morrison formation, Jo Dandy area, Montrose County, Colo., and chemical composition of average sandstone of the Salt Wash member (composition shown in percent).

Element	Oxidized sandstone 1/ G. M. 4/	Oxidized sandstone 1/ G.D. 5/	Unoxidized sandstone 2/ G. M. 4/	Unoxidized sandstone 2/ G.D. 5/	Average sandstone 3/ G. M. 4/	Average sandstone 3/ G.D. 5/
Si	>10.0	--	>10.0	--	>10.0	--
Al	0.78 ×÷ 1.40	2.34	0.35 ×÷ 2.25	1.90	1.2 ×÷ 1.18	1.89
Fe	0.34 ×÷ 1.29	1.91	0.32 ×÷ 2.46	2.04	0.24 ×÷ 1.19	1.91
Mg	0.43 ×÷ 1.53	2.95	0.42 ×÷ 4.33	3.18	0.23 ×÷ 1.33	2.85
Ca	1.8 ×÷ 1.47	2.63	3.5 ×÷ 1.41	1.31	3.3 ×÷ 1.40	3.47
Na	0.062 ×÷ 1.49	2.74	0.046 ×÷ 4.76	3.42	0.089 ×÷ 1.42	3.73
K	0.72 ×÷ 1.43	2.49	0.75 ×÷ 2.62	2.14	<0.37	--
Ti	0.032 ×÷ 1.35	2.14	0.020 ×÷ 2.06	1.77	0.051 ×÷ 1.20	1.96
Zr	0.0046 ×÷ 1.40	2.33	0.0022 ×÷ 2.83	2.27	0.010 ×÷ 1.27	2.4
Mn	0.013 ×÷ 1.40	2.02	0.0091 ×÷ 2.44	2.02	0.022 ×÷ 1.33	2.89
Ba	0.017 ×÷ 1.20	1.57	0.012 ×÷ 2.74	2.21	0.034 ×÷ 1.34	3.00
Sr	0.0063 ×÷ 1.36	2.16	0.024 ×÷ 2.44	2.02	0.0049 ×÷ 1.28	2.5
B	<0.001	--	<0.001	--	<0.001	--
Be	<0.0001	--	<0.0001	--	<0.0001	--
V	0.0040 ×÷ 1.37	2.22	0.0032 ×÷ 2.09	1.79	0.0010 ×÷ 1.32	2.81
Cr	0.00069 ×÷ 1.27	1.84	0.00091 ×÷ 2.06	1.77	0.00066 ×÷ 1.25	2.27
Y	<0.0005	--	<0.0005	--	<0.0005	--
Yb	<0.0001	--	<0.0001	--	<0.0001	--
Ga	<0.0005	--	<0.0005	--	<0.0005	--
Sc	<0.001	--	<0.001	--	<0.001	--
La	<0.002	--	<0.002	--	<0.002	--
Ni	<0.0002	--	<0.0002	--	<0.0002	--
Co	<0.0002	--	<0.0002	--	<0.0002	--
Cu	0.00080 ×÷ 1.26	1.78	0.0015 ×÷ 1.68	1.51	0.0013 ×÷ 1.28	2.49
Pb	<0.001	--	<0.001	--	<0.001	--
Mo	<0.0005	--	<0.0005	--	<0.0005	--
Ag	<0.0001	--	<0.0001	--	<0.0001	--
Bi	<0.001	--	<0.001	--	<0.001	--

1/ Chemical composition based on 47 samples.

2/ Chemical composition based on 8 samples.

3/ Chemical composition based on 96 samples from localities scattered throughout the Colorado Plateau.

4/ Geometric mean (percent) showing the 99 percent confidence interval for the population geometric mean. The limits of the confidence interval are determined from student's _t_ distribution (Fisher and Yates, 1953, p. 1 and 40) where _t_ is the deviation (or range of the population mean) in units of estimated standard error. For a normal distribution:

$$\text{confidence interval of the mean} = \pm t \frac{(s)}{\sqrt{n-1}} ;$$

or for a log normal distribution:

$$\text{confidence interval of G. M.} = \times\!\div \text{ antilog } t \left[\frac{(\text{Log G. D.})}{\sqrt{n-1}} \right]$$

5/ Geometric deviation or antilog of the log standard deviation.

It should be noted that the geometric means given in this report should not be compared directly with published estimates of element abundance which are reported as arithmetic means. The geometric means for all the elements reported are invariably less than the estimated true arithmetic means by an amount that is a function of the log standard deviation.

The composition of green mudstone differs only slightly, and probably not significantly, from the composition of red mudstone. In fact, a comparison of the two color varieties of mudstone shows a remarkable similarity in composition. The concentration of calcium, alone, may indicate a significant difference between red and green mudstone, as red mudstone appears to contain about twice as much calcium as does the green mudstone. However, there is no chemical evidence apparent in the data to establish a spatial relationship between the color of mudstone and mineralized sandstone.

The concentration of many elements depends on the mineral composition of the rock which in turn depends considerably upon the grain size of the rock. This is brought out by a comparison of the average chemical composition of sandstone (table 2) with that of mudstone (table 1) in the Jo Dandy area. Mudstone contains about 5 times more aluminum than sandstone, 3 to 4 times more potassium, titanium, and chromium, up to twice as much vanadium, and about 5 times as much nickel, cobalt, and lead. Mudstone, likewise, contains most of the gallium and most of the rare earths that are found in the Salt Wash member such as scandium, ytterbium, lanthanum, and yttrium. Boron and beryllium are also concentrated in the finer grained rocks.

Unoxidized sandstone samples from the Jo Dandy area contain more calcium, strontium, and copper, and somewhat less aluminum than oxidized sandstone samples, whereas the concentrations of the other elements shown are quite similar in both types of sandstone. Mudstones contain more copper and aluminum than sandstone (compare tables 1 and 2; Rankama and Sahama, 1950, p. 226). Thus sandstones that contain more mudstone should also contain more aluminum and copper. Unoxidized sandstone in the Jo Dandy area, however, contains less aluminum but contains more copper than oxidized sandstone. This suggests that during processes of oxidation some copper is removed from the rocks, and perhaps the aluminum content is increased.

Sandstones of the Salt Wash member in the Jo Dandy area show unmistakable differences in chemical composition when compared with the composition of average sandstone of the Salt Wash member (table 2). The composition of "average" sandstone is based on semiquantitative spectrographic analyses of 96 samples of sandstone from the Salt Wash member collected from outcrops at widely scattered localities on the Colorado Plateau.

Sandstone in the Jo Dandy area contains more potassium, magnesium, vanadium and nickel, and less aluminum, manganese, barium, titanium, and zirconium than average sandstone of the Salt Wash. Unoxidized sandstone in the Jo Dandy area contains about the same amount of calcium as does average sandstone, but the low concentrations of calcium in oxidized sandstone may be the result of a process of solution and redistribution of calcium in areas containing uranium deposits. The oxidation of pyrite and marcasite in sandstone may result in the formation of ferric sulfate and sulfuric acid. In this acid environment some calcium carbonate may be dissolved and redistributed. Thus sulfide-bearing sandstone upon oxidation may become locally depleted in calcium. The abundant gypsum of the unoxidized sandstone is in the form of intergranular flour cement and fracture fillings which have healed the rock. Much of this gypsum may have been derived from exposed evaporite of the Paradox member of the Hermosa formation and incorporated in sediments of the Salt Wash during sedimentation. Some of this gypsum may have formed as a result of the solution of calcium carbonate in the oxidized sandstone and precipitated as intergranular material as a result of combination of Ca^{++} with $SO_4^{=}$ and water. Deformation of the area accompanied by fracturing may have permitted the movement of some gypsum into fractures. Small and generally nonpersistent fractures were probably filled with gypsum in this manner. However, the larger through-going fractures also may have received some gypsum directly from the Paradox member. Field observations show that a gypsiferous, sulfide-bearing sandstone, which contains only sparse amounts of carbonate, changes upon oxidation to a limonitic, locally uncemented sandstone in which only traces of gypsum remain along partly open fractures and through which carbonate cement is erratically distributed.

The greater amounts of potassium and magnesium in sandstone of the Salt Wash member in the Jo Dandy area may be in part derived from the Paradox member. Chemical evidence suggests that bismuth was, in part, derived from the Paradox member; and it seems reasonable to infer that such elements as potassium and magnesium also were in part derived from the Paradox member. Bismuth is seldom, if ever, detected in sedimentary rocks of the Colorado Plateau. In fact, it has never been detected by spectrographic methods in more than 400 samples of sandstone, mudstone, limestone, evaporite, or oil shale from various parts of the Colorado Plateau. Because the occurrence of bismuth in the Jo Dandy area is unique, this element may be considered to be a tracer that links together the materials in which it is found. Bismuth was found in detectable quantities in two samples of gypsum from the Paradox member exposed in Paradox Valley (fig. 2) and was also detected in six samples of drill core taken from the Salt Wash member. Thus bismuth appears either to have been carried upward by a migration of solutions from the salt plug underlying Paradox Valley or carried in gypsiferous detritus that was incorporated with sand and clay during deposition of the Salt Wash member. The fact that bismuth was also detected in a crystal of selenite found in a fracture of the Mineral Joe mine suggests that bismuth is capable of being carried in a sulfate solution.

SUMMARY

The chemical composition of each rock type of the Salt Wash member of the Morrison formation in the Jo Dandy area is remarkably uniform. The chemical composition of red mudstone cannot be distinguished from the chemical composition of green mudstone except for concentrations of calcium. Red mudstone samples contain about twice as much calcium as green mudstone in the area studied. Oxidized sandstone contains somewhat more aluminum, manganese, and zirconium, and about half as much calcium, strontium, and copper, as unoxidized sandstone.

Sandstone of the Jo Dandy area contains less aluminum, barium, zirconium, and manganese, but more potassium, magnesium, vanadium, nickel, and cobalt than average sandstone of the Salt Wash. The unusual amount of bismuth in some samples of host rock in the Jo Dandy area and the occurrence of bismuth in samples of gypsum suggest that bismuth and probably some potassium and magnesium in rocks of the Salt Wash member were derived from the Paradox member of the Hermosa formation.

The persistently high concentrations of vanadium in the host rocks of the Jo Dandy area as compared to the vanadium content of average sandstone of the Salt Wash member suggest that vanadium may be useful as a pathfinder element in geochemical prospecting.

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Appendix A.--Descriptions of samples.

(Described by W. L. Newman and J. D. Vogel)

<u>Outcrop samples</u>

1:	Rock gypsum of Paradox member of the Hermosa formation; cream to white in color, pulverulent; collected from bulldozer cut on west side of landslide area.
2:	Rock gypsum of Paradox member of the Hermosa formation; gray, massive to platy, contorted; collected from outcrop along Colorado Highway 90, 3 miles west of intersection with Monogram truck trail.
67:	Selenite crystal, 2 inches long and half an inch across; collected from fracture in the Mineral Joe mine.

<u>Drill core samples</u>

Salt Wash member

<u>Hole 62</u>

3: Sample interval 203.7 to 204.2 feet	Sandstone reddish-brown, very fine-grained; oxidized, limonite stain and gypsum disseminated on fracture surface, carbonate cement, some interstitial red mudstone.
4: Sample interval 214.5 to 215.0 feet	Mudstone, green, limy, trace of limonite stain.

5: Sample interval 220.0 to 220.5 feet top of upper ore-bearing sandstone unit	Sandstone, gray, very fine- to fine-grained; incipient oxidation, disseminated small patches of limonite with pyrite(?) nuclei; sulfate cement, trace of interstitial green mudstone.
6: Sample interval: 250.0 to 250.5 feet (middle of upper ore-bearing sandstone unit)	Sandstone, gray, fine-grained, unoxidized, tiny pyrite crystals widely disseminated, sulfate cement, some green interstitial mudstone.
7: Sample interval 272.0 to 272.5 feet (upper ore-bearing sandstone unit)	Sandstone, gray, fine-grained, unoxidized, pyrite widely disseminated, sulfate cement; some green interstitial mudstone.
8: Sample interval: 282.5 to 283.0 feet (base of upper ore-bearing sandstone unit)	Sandstone, brown, very fine-grained; oxidized abundant spots and stains of limonite; some green interstitial mudstone.
9: Sample interval: 283.8 to 284.3 feet	Mudstone, green, silty, limy, conspicuous spots of limonite, fractures filled with limonite and gypsum.

10: Sample interval: 315.0 to 315.5 feet	Mudstone, green, sandy, tiny crystals of pyrite widely disseminated, some limonite coating fracture surfaces.
11: Sample interval: 318.1 to 318.6 feet (top of lower ore-bearing unit)	Sandstone, gray, fine-grained, oxidized, prominent speckling of limonite with spots up to 1-1/2 mm. in diameter, siliceous cement, slight amount of interstitial green mudstone, fracture filled with gypsum.
12: Sample interval: 328.0 to 328.5 feet (middle of lower ore-bearing sandstone unit)	Sandstone, pale-brown, very fine- to fine- grained, oxidized, heavy limonite stains in one-fourth inch bands parallel to bedding. Prominent fracture filled with well-developed crystals of gypsum. Some green mudstone as fine grains concentrated along bedding planes.
13: Sample interval: 334.5 to 325.0 feet (base of lower ore-bearing sandstone unit)	Sandstone, brown, fine-grained, oxidized, abundant limonite spotting and staining, slightly cemented by carbonate, some flakes, pellets and seams of yellow-green mudstone.
14: Sample interval: 340.0 to 340.5 feet	Mudstone, green, traces of limonite.
15: Sample interval: 358.0 to 358.5 feet	Mudstone, reddish-brown, trace of manganese stain.

Drill hole 64

16: Sample interval: 54.6 to 55.1 feet	Mudstone, reddish-brown, silty, slightly calcareous.
17: Sample interval: 62.1 to 62.6 feet (top of ore-bearing sandstone unit)	Sandstone, reddish-brown to light-brown, red cast due to red siltstone, very fine- to fine-grained, oxidized, slightly calcareous.
18: Sample interval: 66.6 to 67.1 feet	Mudstone, reddish-brown mottled with green, silty.
19: Sample interval: 72.1 to 72.6 feet (ore-bearing sandstone unit)	Sandstone, pale-red, very fine- and fine-grained, oxidized, friable, limonite as interstitial paint, trace of interstitial green mudstone. Some white altered chert(?).
20: Sample interval: 85.2 to 85.7 feet (ore-bearing sandstone unit)	Sandstone, brown, fine-grained, oxidized, some limonite spotting and staining, sulfate cement, trace of interstitial green mudstone. Abundant white altered chert(?).
21: Sample interval: 100.00 to 100.5 feet (ore-bearing sandstone unit)	Sandstone, pale-brown, fine-grained, oxidized, traces of limonite paint, thin films of green mudstone along bedding surfaces. Abundant white altered chert(?).

22: Sample interval: 115.0 to 115.5 feet (ore-bearing sandstone unit)	Sandstone, brown, fine-grained, oxidized, limonite spotting and staining, sulfate cement, abundant interstitial grains and pellets of green mudstone, abundant white altered chert(?).
23: Sample interval: 130.0 to 130.5 feet (ore-bearing sandstone unit).	Sandstone, pale-brown, medium-grained, oxidized, friable, conspicuous limonite spotting, abundant white altered chert(?).
24: Sample interval: 145.0 to 145.5 feet (ore-bearing sandstone unit)	Sandstone, brown fine- to medium-grained, friable: oxidized, abundant limonite as interstitial paint and stain; trace of yellowish-brown mudstone.
25: Sample interval: 160.0 to 160.5 feet (ore-bearing sandstone unit)	Sandstone, pale-brown, fine-grained, oxidized friable; trace of limonite paint; seams, films and interstitial blebs of green mudstone; abundant white altered chert(?).
26: Sample interval: 167.1 to 167.6 feet	Mudstone, green, silty, limy.
27: Sample interval: 179.6 to 180.1 feet	Mudstone, reddish-brown, silty.

Hole 71

28: Sample interval: 66.7 to 67.2 feet.	Mudstone, reddish-brown.
29: Sample interval: 72.7 to 73.2 feet	Mudstone, grayish-green, very silty; some limonite stain.
30: Sample interval: 74.2 to 74.7 feet (top of upper ore-bearing sandstone unit)	Sandstone, brown, fine-grained, oxidized, abundant spots of limonite, sulfate cement; sparse interstitial green mudstone; fracture filled with gypsum.
31: Sample interval: 95.0 to 95.5 feet (middle of upper ore-bearing sandstone unit)	Sandstone, brown, fine-grained, oxidized, some spots of limonite, sulfate cement, some interstitial green mudstone, abundant white altered chert(?).
32: Sample interval: 123.9 to 124.4 feet (base of upper ore-bearing sandstone unit)	Sandstone, brown, fine-grained, oxidized, abundant spots of limonite; trace of interstitial green mudstone.

33: Sample interval: 126.5 to 127.0 feet	Mudstone, grayish-green, trace of pyrite.
34: Sample interval: 129.8 to 130.3 feet	Mudstone, chocolate-brown.
35: Sample interval: 135.7 to 136.2 feet	Mudstone, grayish-green, silty, calcareous cement.
36: Sample interval: 141.2 to 141.7 feet (top of lower ore-bearing sandstone unit)	Sandstone, pale-brown, fine-grained, quartzitic, oxidized, interstitial limonite, siliceous cement; trace of grayish-green blebs of mudstone; very thin films of gypsum along bedding surfaces.
37: Sample interval: 150.0 to 150.5 feet (middle of lower ore-bearing sandstone unit)	Sandstone, gray, very fine-grained, quartzitic, unoxidized, tiny disseminated crystals of pyrite very abundant but chiefly concentrated along bedding surfaces; seams of fibrous gypsum up to 0.5 mm. thick along bedding surfaces.
38: Sample interval: 169.2 to 169.7 feet (base of lower ore-bearing sandstone unit)	Sandstone, pale-brown, very fine-grained, oxidized, limonite abundant as tiny spots, some interstitial green mudstone.
39: Sample interval: 173.8 to 174.0 feet	Mudstone, grayish-green, mottled with about 20 percent reddish-brown mudstone.

40: Sample interval: 174.0 to 174.2 feet	Mudstone, chocolate-brown, with irregular blebs of gray mudstone up to 3 mm. in diameter.

<u>Hole 53</u>

41: Sample interval: 494.4 to 494.9 (sandstone bed above ore-bearing sandstone unit)	Sandstone, grayish-green, very fine-grained; oxidized, abundant limonite stain; abundant interstitial green mudstone; calcareous cement.
42: Sample interval: 494.4 to 499.9 feet (top of ore-bearing sandstone unit)	Sandstone, brown, very fine-to fine-grained, oxidized, abundant spots of limonite; some interstitial green mudstone.
43: Sample interval: 527.5 to 528.0 (middle of ore-bearing sandstone unit)	Sandstone, brown, fine-grained, oxidized, intense freckling with limonite; friable; trace interstitial green mudstone.
44: Sample interval: 540.0 to 540.5 feet (lower part of ore-bearing unit)	Sandstone, brown, very fine-grained, oxidized, abundant spots and stains of limonite; calcareous cement.

45: Sample interval: 552.5 to 553.0 feet (base of ore-bearing sandstone unit)	Sandstone, pale-brown, very fine-grained; incipient oxidation, sparsely disseminated pyrite clusters up to 1 mm. in diameter with halos of limonite; calcareous cement; blebs and interstitial grains of green mudstone.
46: Sample interval: 560.5 to 561.0 feet	Mudstone, black, carbon probably abundant.

Hole 85

48: Sample interval: 273.0 to 273.5 feet	Mudstone, light-green, heavy limonite stains and concretions.
49: Sample interval: 275.3 to 275.6 feet (top of ore-bearing sandstone unit)	Sandstone, pale-yellow, fine-grained, oxidized, abundant limonite stains, carbonate cement; trace green interstitial mudstone, some disseminated flecks of carbon.
50: Sample interval: 295.8 to 296.1 feet (ore-bearing sandstone unit)	Sandstone, pale-brown, fine-grained; oxidized, slight freckling with limonite; carbonate cement; some white altered chert(?).
51: Sample interval: 315.3 to 315.6 feet (middle of ore-bearing sandstone unit)	Sandstone, brown, fine-grained, oxidized, some spots and stains of limonite, carbonate cement; fractures filled with calcite.

52: Sample interval: 333.1 to 333.4 feet (base of ore-bearing sandstone unit)	Sandstone, brown, fine-grained, oxidized, abundant spots and stains of limonite; carbonate cement; abundant flakes of green mudstone; abundant seams and films of carbon.
53: Sample interval: 337.6 to 337.9 feet.	Mudstone, green.
54: Sample interval: 339.9 to 340.2 feet (sandstone bed below ore-bearing sandstone unit)	Sandstone, pale-brown, very fine-grained; oxidized, abundant spots of limonite; carbonate cement; some flakes of carbon; abundant fractures filled with gypsum; sparse films and interstitial grains of green mudstone.
Hole 86	
55: Sample interval: 270.2 to 270.7 feet	Mudstone, reddish-brown; limonite and manganese stain on fracture surfaces.
56: Sample interval: 271.8 to 272.3 feet	Mudstone, grayish-green, very silty; some limonite stains.
57: Sample interval: 273.4 to 273.9 feet (top of ore-bearing sandstone unit)	Sandstone, brown, fine-grained, oxidized, some spots of limonite, sulfate cement, abundant films and interstitial grains of green mudstone; some flakes of biotite; fractures filled with gypsum.

58: Sample interval: 292.7 to 293.2 feet	Mudstone, grayish-green, very silty.
59: Sample interval: 311.9 to 312.4 feet (ore-bearing sandstone unit)	Sandstone, pale-brown, fine-grained; oxidized, faint speckling with limonite; carbonate cement; trace of interstitial green mudstone, gypsum coating fracture surfaces.
60: Sample interval: 332.8 to 333.2 feet (ore-bearing sandstone unit)	Sandstone, light-gray, very fine-grained, quartzitic; incipient oxidation, traces of pyrite with halos of limonite; siliceous cement; sparse blebs and pods of green mudstone.
61: Sample interval: 354.7 to 355.2 feet (ore-bearing sandstone unit)	Sandstone, gray, fine-grained, quartzitic; unoxidized(?); siliceous cement; several fractures filled with gypsum.
62: Sample interval: 374.7 to 375.2 feet (ore-bearing sandstone unit)	Sandstone, grayish-green, very fine-grained; sulfate cement; fibrous gypsum within vertical fracture; very abundant films, seams, and blebs of green mudstone and interstitial green siltstone.

63: Sample interval: 390.8 to 391.3 feet (ore-bearing sandstone unit)	Sandstone; pale-brown to white, fine-grained; oxidized, faint freckling with limonite.
64: Sample interval: 400.8 to 401.3 feet (base of ore-bearing sandstone unit)	Sandstone, pale-brown, fine-grained; oxidized, sparse limonite, friable; trace of interstitial green mudstone.
65: Sample interval: 401.8 to 402.3 feet	Mudstone, gray, silty; limonite as stains and small concretion.
66: Sample interval: 426.7 to 427.2 feet	Mudstone, reddish-brown, very silty; trace of pyrite; some gypsum.
Hole 92	
69: Sample interval: 181.1 to 181.6 feet	Mudstone, reddish-brown.
70: Sample interval: 192.1 to 192.6 feet (sandstone bed above the ore-bearing sandstone unit)	Sandstone, grayish-green, very fine-grained, unoxidized(?), carbonate cement; abundant films of green mudstone; fracture filled with gypsum.

71: Sample interval: 194.3 to 194.8 feet (sandstone bed above ore-bearing sandstone unit)	Sandstone, yellowish-brown to brown, very fine-grained; oxidized, limonite very abundant; very friable; abundant interstitial mudstone.
72: Sample interval: 203.9 to 204.4 feet (top of ore-bearing sandstone unit)	Sandstone, pale-brown, fine-grained; oxidized, some limonite staining; friable.
73: Sample interval: 215.2 to 215.7 feet (middle of ore-bearing sandstone unit)	Sandstone, pale-brown, fine-grained; oxidized, some limonite staining; carbonate cement; some green mudstone.
74: Sample interval: 225.5 to 226.0 feet (base of ore-bearing sandstone unit)	Sandstone, yellowish-brown, fine-grained, oxidized, some limonite staining; carbonate cement; small fractures filled with calcite; some green mudstone blebs.
75: Sample interval: 230.5 to 231.0 feet	Mudstone, pale-green, silty; traces of carbon and gypsum.

76: Sample interval: 237.5 to 238.0 feet	Mudstone, reddish-brown.

<u>Hole 78</u>

77: Sample interval: 235.2 to 235.7 feet	Mudstone, grayish-green, gypsiferous.
78: Sample interval: 248.1 to 248.6 feet (top of ore-bearing sandstone unit)	Sandstone, light-gray, fine-grained; oxidized, some limonite staining; carbonate cement.
79: Sample interval: 265.7 to 266.2 feet (ore-bearing sandstone unit)	Sandstone, light-gray, fine-grained; oxidized, trace of limonite; friable.
80: Sample interval: 288.2 to 288.7 feet (ore-bearing sandstone unit)	Sandstone, pale-brown, fine-grained; oxidized, trace of limonite; carbonate cement; some interstitial green mudstone.
81: Sample interval: 290.7 to 291.2 feet (ore-bearing sandstone unit)	Sandstone, pale-brown, very fine-grained; oxidized, conspicuous limonite staining; carbonate cement; some interstitial green mudstone.

82: Sample interval: 301.7 to 302.2 feet	Mudstone, green, bentonitic; some thin seams of gypsum.

<u>Hole 95</u>

83: Sample interval: 270.5 to 270.8 feet	Mudstone, reddish-purple with green mottling, limy.
84: Sample interval: 283.4 to 283.7 feet	Mudstone, green; abundant tiny crystals of pyrite.
85: Sample interval: 295.3 to 295.6 feet (top of upper ore-bearing sandstone unit)	Sandstone, brown, fine- to medium-grained; oxidized, limonite staining; friable.
86: Sample interval: 302.8 to 303.1 feet (middle of upper ore-bearing sandstone unit)	Sandstone, brown, fine-grained; oxidized, slight freckling with limonite.
87: Sample interval: 319.7 to 320.0 feet (base of upper ore-bearing sandstone unit)	Sandstone, brown, fine- to medium-grained; oxidized, interstitial limonite; carbonate cement.

88: Sample interval: 321.6 to 321.9 feet	Mudstone, greenish-gray, silty; some limonite.
89: Sample interval: 325.1 to 325.3 feet (top of lower ore- bearing sandstone unit)	Sandstone, brown, very fine-grained; oxidized, abundant spots and stains of limonite; sulfate cement; some interstitial green mudstone.
90: Sample interval 335.1 to 335.3 feet (middle of lower ore- bearing sandstone unit)	Sandstone, brown, very fine-grained; oxidized, abundant limonite stain; abundant interstitial green mudstone.
91: Sample interval: 337.8 to 338.1 feet (base of lower ore- bearing sandstone unit)	Sandstone, brown, fine-grained, poorly sorted; oxidized, some limonite staining; carbonate cement; some pods and blebs of green mudstone.
92: Sample interval: 342.6 to 342.8 feet	Mudstone, green.
93: Sample interval: 361.6 to 342.8 feet	Mudstone, reddish-brown.

Appendix B.--Group number notation used in reporting semiquantitative spectrographic analyses.

As reported by laboratory	Group number	Class interval (percent)	Class midpoint (percent)
XX.	1	10.0 - 100.0	---
X.+	2+	4.6 - 10.0	6.8
X.	2	2.2 - 4.6	3.2
X.-	2-	1.0 - 2.2	1.5
0.X+	3+	0.46 - 1.0	0.68
0.X	3	0.22 - 0.46	0.32
0.X-	3-	0.10 - 0.22	0.15
0.0X+	4+	0.046 - 0.10	0.068
0.0X	4	0.022 - 0.046	0.032
0.0X-	4-	0.010 - 0.022	0.015
0.00X+	5+	0.0046 - 0.010	0.0068
0.00X	5	0.0022 - 0.0046	0.0032
0.00X-	5-	0.0010 - 0.0022	0.0015
0.000X+	6+	0.00046- 0.0010	0.00068
0.000X	6	0.00022- 0.00046	0.00032
0.000X-	6-	0.00010- 0.00022	0.00015

Appendix C.--Semiquantitative spectrographic and radiometric analyses of rocks of the Jo Dandy area, Montrose County, Colo.

Analysts: Spectrographic - G. W. Boyes, Jr., Radiometric - J. Patton.

Source of samples	Field number	Laboratory number	Rock type	Brief description	Elements																													Radio-activity
					Si	Al	Fe	Mg	Ca	Na	K	Ti	Zr	Mn	Ba	Sr	B	Be	Y	Yb	Ga	Sc	La	In	V	Cr	Co	Ni	Cu	Pb	Mo	Ag	Bi	pct. eU
Chip sam-	1	D-88264	gypsum	granular	3+	3-	4+	3-	1	4+	0	4-	Tr	0	5	3-	0	0	0	0	0	0	0	0	5	6+	0	6+	6+	0	0	0	5-	<0.001
ples from	2	D-88265	gypsum	granular	4+	4-	5+	4	1	Tr	0	Tr	Tr	0	5-	3-	0	0	0	0	0	0	0	0	Tr	6	0	0	6	0	0	0	5-	<0.001
outcrop	67	D-88330	gypsum	selenite	4	4	4-	4+	2+	Tr	0	5-	Tr	0	6	4-	0	0	0	0	0	0	0	0	Tr	6	0	0	6+	5-	0	0	5+	0.005
	3	D-88266	sandstone	oxidized	1	2	3+	2-	2	3	2-	3-	5+	4	4	4-	5	0	5-	6-	Tr	Tr	0	0	5	5-	6+	6+	6+	Tr	0	0	Tr	0.002
	4	D-88267	mudstone	green	1	2+	2-	2	2-	3	2	3	4-	4	4-	4-	5	0	5-	6-	5-	5-	0	0	5+	5	6+	6+	5-	Tr	0	0	0	0.004
	5	D-88268	sandstone	unoxidized	1	3	3	4+	2+	4+	3+	4	5-	5	4+	4+	Tr	0	0	0	0	0	0	0	5	6+	Tr	6+	5-	0	0	0	5	0.001
	6	D-88269	sandstone	unoxidized	1	3-	3	3-	2	Tr	3+	4-	5-	5+	5+	4	Tr	0	0	0	0	0	0	0	5+	6+	Tr	6+	5-	0	0	0	5-	<0.001
Core	7	D-88270	sandstone	unoxidized	1	3	3-	3+	2	4+	3+	4	5-	4-	5+	4	0	0	0	0	0	0	0	0	5-	6+	6	6	6+	0	0	0	0	0.001
from	8	D-88272	sandstone	oxidized	1	2-	3+	3+	2	3-	2-	4+	5+	4-	4-	4-	5-	0	Tr	Tr	0	0	0	0	5	6+	6	6	5-	Tr	0	0	0	0.002
drill-	9	D-88271	mudstone	green	1	2	3+	3+	3	3-	2-	3-	4-	5+	4	4-	5	0	5-	5-	Tr	Tr	0	0	5+	5-	6+	6+	5-	Tr	Tr	0	0	0.001
hole	10	D-88273	mudstone	green	2+	2	2-	2	2-	3	2	4+	5+	4	4-	4-	5	0	5-	6-	5-	Tr	0	0	5+	5	6+	5-	5	5-	0	0	0	0.003
62	11	D-88274	sandstone	oxidized	1	3	3-	4+	2	3-	3+	4	5-	5	4-	4	Tr	0	0	0	0	0	0	0	5+	6+	Tr	6	6+	5+	0	Tr	0	<0.001
	12	D-88275	sandstone	oxidized	1	3	3	4+	2	4+	3+	4	5	5+	5+	4	5-	0	0	0	0	0	0	0	5+	6+	6	6	5	Tr	Tr	0	0	0.001
	13	D-88276	sandstone	oxidized	1	3+	3+	3	2	4+	3+	4	5-	4-	4-	4-	5-	0	0	0	Tr	0	0	0	4-	6+	6	6	6+	5-	0	0	0	0.001
	14	D-88277	mudstone	green	1	2+	2-	2-	3	3	2	3	4-	4-	4-	4-	5+	6-	5	-	5-	5-	Tr	0	4	5	6+	5-	5-	Tr	0	0	0	0.004
	15	D-88278	mudstone	red	1	2	2-	2-	2	3	2-	3-	5+	4	4-	4-	5	0	5-	-	Tr	Tr	0	0	4-	5	6+	5-	5-	Tr	0	0	0	0.002
	16	D-88279	mudstone	red	1	2+	2-	2	2-	3-	2	3-	4-	4	4-	4-	5	Tr	5-	6-	Tr	Tr	0	0	4-	5-	6+	6+	6+	5+	0	0	0	0.002
	17	D-88280	sandstone	oxidized	1	2	3+	3+	2-	4+	2-	3-	4-	4-	4	5+	5-	6-	Tr	6-	Tr	0	0	0	5	6+	6	6+	5-	Tr	0	0	Tr	0.001
	18	D-88281	mudstone	red	1	2+	2	2-	2-	3-	2-	3-	4-	4	4-	4-	5	0	5	6	Tr	5-	Tr	0	5+	5-	6+	6+	5	Tr	0	0	0	0.002
	19	D-88282	sandstone	oxidized	1	3+	3-	3-	3	4+	3+	4+	4-	5	4-	5-	Tr	0	Tr	0	0	0	0	0	5	6+	0	0	6+	0	0	0	0	0.001
Core	20	D-88283	sandstone	oxidized	1	3+	3	3+	2-	Tr	3+	4	5+	5+	4	5	Tr	0	0	Tr	0	0	0	0	5	6	Tr	0	6+	0	0	0	0	<0.001
from	21	D-88284	sandstone	oxidized	1	3+	3-	3-	3+	Tr	0	4+	4-	5+	4-	5-	5	0	0	Tr	0	0	0	0	5	6+	Tr	0	6+	0	0	0	0	<0.001
drill-	22	D-88285	sandstone	oxidized	1	2-	3	3+	2-	Tr	0	4	5-	4-	4-	5+	Tr	0	0	Tr	0	0	0	0	5+	6	Tr	Tr	6+	0	0	0	0	<0.001
hole	23	D-88286	sandstone	oxidized	1	3+	3	3-	2-	Tr	0	4	5-	5+	4-	5	Tr	0	0	Tr	0	0	0	0	5+	6	Tr	Tr	6+	0	0	0	Tr	0.001
64	24	D-88287	sandstone	oxidized	1	3+	3+	3-	3-	Tr	0	4	5	5+	4-	5-	Tr	0	0	-	0	0	0	0	4-	6	6+	6	5-	0	0	0	0	0.001
	25	D-88288	sandstone	oxidized	1	2-	3	3+	2-	Tr	0	4	5-	4-	4-	5	5-	0	0	-	0	0	0	0	4-	6+	6	6	5-	0	0	0	0	<0.001
	26	D-88289	mudstone	green	1	2	2-	2	2-	3-	2-	3-	5	4	4-	4-	5	0	5-	-	Tr	5-	0	0	4-	5	6+	5-	5	0	Tr	0	0	0.003
	27	D-88290	mudstone	red	1	2-	2-	2-	2-	3-	2-	4+	5	4	4-	4-	5	Tr	5-	6-	Tr	Tr	0	5+	5	5	6+	6+	5	0	0	0	5-	0.002

Tr = Near threshold (below limit of sensitivity). 0 = Looked for but not detected. - = Not looked for.

Appendix C.--Semiquantitative spectrographic and radiometric analyses of rocks of the Jo Dandy area, Montrose County, Colo.

Analysts: Spectrographic - G. W. Boyes, Jr., Radiometric - J. Patton--Continued.

Source of samples	Field number	Laboratory number	Rock type	Brief description	Elements																													Radio activity
					Si	Al	Fe	Mg	Ca	Na	K	Ti	Zr	Mn	Ba	Sr	B	Be	Y	Yb	Ga	Sc	La	In	V	Cr	Co	Ni	Cu	Pb	Mo	Ag	Bi	pct. eU
	28	D-88291	mudstone	red	1	2+	2	2-	3+	3-	2	3-	4-	4-	4-	4	5+	Tr	5-	6	5-	5-	Tr	Tr	5+	5	6+	5-	5-	Tr	0	0	0	0.003
	29	D-88292	sandstone	oxidized	1	2+	2-	3+	3-	4+	2-	3-	4-	5	4	4-	5	0	5-	6-	Tr	Tr	0	Tr	5	5	6	6+	6+	Tr	0	0	0	0.002
	30	D-88293	sandstone	oxidized	1	3+	3	3-	2-	4+	3+	4	4-	5	4+	5+	Tr	0	0	0	0	0	0	0	Tr	6+	Tr	Tr	6+	0	0	0	0	<0.001
	31	D-88294	sandstone	oxidized	1	3+	3	3+	2-	4+	3+	4	5	4-	4-	5	5-	0	0	0	0	0	0	0	5	6	Tr	Tr	6+	0	0	0	0	0.001
Core	32	D-88295	sandstone	oxidized	1	3	3+	3+	2	4+	3+	4-	5-	4	4	5	0	0	0	0	0	0	0	0	5	6	0	6	5-	0	0	0	0	<0.001
from	33	D-88296	mudstone	green	1	2	2-	2	2-	3-	2	3-	5+	4	4-	4-	5	Tr	5-	6-	5-	5-	0	0	5+	5	6+	6+	5	Tr	0	0	0	0.005
drill-	34	D-88297	mudstone	red	1	2	2-	2-	2-	3-	2	3-	5+	4	4-	4-	5	Tr	5-	6-	5-	5-	0	0	4-	5	6+	5-	5	5	0	0	0	0.003
hole	35	D-88298	mudstone	green	1	2	3+	2-	2-	3-	2-	4+	5+	4	4-	4-	5	0	5-	6-	Tr	Tr	0	0	4-	5	6	6+	5-	Tr	0	0	0	0.001
71	36	D-88299	sandstone	oxidized	1	3	3	3+	2	4+	3+	4	5	4-	4-	4-	0	0	0	0	0	0	0	0	5-	6+	Tr	6	5-	0	0	0	0	<0.001
	37	D-88300	sandstone	unoxidized	1	3-	2-	3	2	Tr	Tr	4-	5-	5+	4-	4-	0	0	0	0	0	0	0	0	5	6+	6	6	5	5-	0	0	0	<0.001
	38	D-88301	sandstone	oxidized	1	3+	3	3+	2-	4+	3+	4	5	4-	4	5	5	0	0	0	0	0	0	0	4-	6+	6	6	6+	0	0	0	0	0.001
	39	D-88302	mudstone	green	1	2	2-	2	3+	3-	2	3	4-	4-	4-	4-	5	Tr	5-	-	5-	5-	Tr	0	4-	5	6+	5-	5	5	0	0	0	0.003
	40	D-88303	mudstone	red	1	2	2-	2	2-	3-	2	3-	4-	4	4-	4-	5	Tr	5-	-	5-	5-	0	0	4-	5	6+	5-	5+	5+	0	0	0	0.002
Core	41	D-88304	sandstone	oxidized	1	3+	3	2-	2	3-	2-	4	5	4	4-	5+	5-	0	0	0	Tr	0	0	0	5	6+	Tr	0	6+	0	0	0	0	0.001
from	42	D-88305	sandstone	oxidized	1	2-	3	2-	2-	4+	2-	4	5+	4-	4-	5+	5-	0	0	0	Tr	0	0	0	5+	6+	Tr	0	6	0	0	0	0	0.001
drill-	43	D-88306	sandstone	oxidized	1	3+	3	2-	2	3-	2-	4	5+	4-	4-	5	Tr	0	0	0	Tr	0	0	0	5+	6+	Tr	0	6	Tr	0	0	0	<0.001
hole	44	D-88307	sandstone	oxidized	1	3+	3	2-	2	3-	2-	4	5+	4	4-	5+	Tr	0	0	0	Tr	0	0	0	5+	5-	0	6+	6+	Tr	0	0	0	0.002
46	45	D-88308	sandstone	unoxidized	1	3+	3	2	2	3-	2-	4	5-	4	4-	5+	5-	0	0	0	Tr	0	0	0	5	5-	0	0	5-	Tr	0	0	0	0.001
	46	D-88309	mudstone	black	1	2	2-	2	2	3-	2	3-	5	4-	5+	4-	4	0	5-	-	5-	Tr	0	0	4	5+	6+	5+	5+	5+	4-	Tr	0	0.006
	48	D-88311	mudstone	green	1	2	2-	3+	3	3-	2	3-	4-	5+	4-	4-	5+	Tr	5-	-	5-	5-	Tr	0	4	5	Tr	5-	5	Tr	5-	0	0	0.005
Core	49	D-88312	sandstone	oxidized	1	2-	3	3	2	4+	2-	4	4-	5+	4-	5+	5	0	Tr	0	0	0	0	0	5+	5-	0	Tr	6	0	0	0	0	0.002
from	50	D-88313	sandstone	oxidized	1	3+	3-	3-	2+	4	3+	4-	5	5+	4-	4-	0	0	0	0	0	0	0	0	5+	6+	0	Tr	6+	0	0	0	0	0.001
drill-	51	D-88314	sandstone	oxidized	1	3	3-	4	2+	4+	3+	4-	5	5+	5+	5+	0	0	0	0	0	0	0	0	5	6+	0	0	6+	0	5-	0	0	0.002
hole	52	D-88315	sandstone	oxidized	1	3	3	4+	2+	4+	3+	4-	5	5+	5+	5+	0	0	0	0	0	0	0	0	5+	5-	0	Tr	5-	0	0	0	0	0.002
85	53	D-88316	mudstone	green	1	2+	2-	2-	2-	3-	2	3-	4-	4-	4-	4-	5+	Tr	5-	-	5-	5-	Tr	-	4-	5	6+	5-	5	Tr	Tr	0	0	0.007
	54	D-88317	sandstone	oxidized	1	3+	3	3-	2	4+	2-	4	5	4-	4-	5+	5-	0	0	0	0	0	0	0	5	6+	0	Tr	6+	0	0	0	0	0.001

Appendix C.--Semiquantitative spectrographic and radiometric analyses of rocks of the Jo Dandy area, Montrose County, Colo.

Analysts: Spectrographic - G. W. Boyes, Jr., Radiometric - J. Patton--Continued.

Source of samples	Field number	Laboratory number	Rock type	Brief description	Si	Al	Fe	Mg	Ca	Na	K	Ti	Zr	Mn	Ba	Sr	B	Be	Y	Yb	Ga	Sc	La	In	V	Cr	Co	Ni	Cu	Pb	Mo	Ag	Bi	Radioactivity pct. eU
Core from drill-hole 86	55	D-88318	mudstone	red	1	2	2-	2-	2-	3	2-	3-	5+	4-	4-	4-	5+	Tr	5	6-	5-	5-	Tr	0	5	5	6+	5-	5	Tr	0	0	0	0.004
	56	D-88319	mudstone	green	1	2	2-	2-	2-	3	2-	3-	4-	4-	4+	4-	5+	Tr	5-	6-	Tr	5-	0	0	5+	5	6+	5-	5	0	0	0	0	0.004
	57	D-88320	sandstone	oxidized	1	3	3	3+	2	4+	3+	4-	5	4-	4-	4-	Tr	0	0	0	0	0	0	0	5+	6+	0	6+	5-	0	0	0	0	0.003
	58	D-88321	mudstone	green	1	2-	3+	2-	2-	3	2-	4+	5+	4-	4-	4-	5	0	5-	6-	Tr	Tr	0	0	5	5	Tr	6+	5-	Tr	0	0	0	0.002
	59	D-88322	sandstone	oxidized	1	3-	3	2-	2	3-	3	5+	5-	4	3-	4-	Tr	0	0	0	0	0	0	0	5-	6+	Tr	Tr	5-	0	0	0	0	<0.001
	60	D-88323	sandstone	unoxidized	1	3	3	3+	2	4+	2-	4-	5-	4-	4-	4	5-	0	0	0	0	0	0	0	5	6+	0	Tr	5-	0	0	0	0	0.001
	61	D-88324	sandstone	unoxidized	1	3+	3-	3	2	4+	3+	5+	5	5+	5+	4	0	0	0	0	0	0	0	0	5-	6+	0	Tr	5-	0	0	0	0	<0.001
	62	D-88325	sandstone	unoxidized	1	3+	3	3+	2	3-	2-	4	4-	5+	5+	4-	Tr	0	0	0	Tr	0	0	0	5+	5	0	6+	5-	0	0	0	0	<0.001
	63	D-88326	sandstone	oxidized	1	3+	3-	3+	2-	4+	2-	4-	5+	4-	4-	5	Tr	0	0	0	0	0	0	0	Tr	6+	0	Tr	6+	0	0	0	0	0.002
	64	D-88327	sandstone	oxidized	1	3	3-	3+	2-	4+	2-	4-	4-	4-	4-	5	Tr	0	0	0	0	0	0	0	Tr	6+	Tr	Tr	6+	Tr	Tr	0	0	0.002
	65	D-88328	mudstone	green	1	2+	2-	2-	3	3-	2	3-	4-	5+	4	4-	4-	Tr	5	6-	5-	5-	Tr	0	5+	5	6+	5-	5	5	5-	0	0	0.006
	66	D-88329	mudstone	red	1	2-	3+	2	2	3-	2-	4	5+	4	4-	5+	5	0	5-	Tr	Tr	Tr	0	0	5	5-	Tr	6+	5-	0	0	0	0	0.002
Core from drill-hole 92	69	D-88332	mudstone	red	1	2	2-	2-	2	3-	2	3-	5+	4-	4-	4-	5+	Tr	5-	6-	5-	5-	0	0	5	5	6+	6+	5	5-	0	0	0	0.002
	70	D-88333	sandstone	oxidized	1	3	3+	2-	2	3	2-	4	5	4	4-	4-	5-	0	Tr	Tr	Tr	0	0	0	5	5	Tr	6+	5-	0	0	0	0	0.002
	71	D-88334	sandstone	oxidized	1	2	2	2-	3+	3	2-	3-	4-	4-	4	4-	5+	Tr	5-	6-	Tr	Tr	0	0	5+	5	6+	6+	5	5-	0	0	0	0.004
	72	D-88335	sandstone	oxidized	1	3+	3	3+	3+	4+	3+	4	4-	5+	4	5	5-	0	0	0	0	0	0	0	5	6+	0	0	6	0	0	0	0	<0.001
	73	D-88336	sandstone	oxidized	1	3	3	2-	2	4+	3+	4-	5	4	4-	5	Tr	0	0	0	0	0	0	0	5	6+	Tr	Tr	6+	0	0	0	0	0.001
	74	D-88337	sandstone	oxidized	1	2-	3+	2-	2	3-	2-	4	5	4	4	5+	5-	0	0	-	0	0	0	0	4-	6+	Tr	Tr	6+	Tr	Tr	0	0	0.003
	75	D-88338	mudstone	green	1	2-	2-	2-	2	3	2-	4+	5	4	4-	4-	5-	0	Tr	Tr	Tr	Tr	0	0	5	5	6+	6+	5	5	0	0	0	0.002
	76	D-88339	mudstone	red	1	2	2-	2-	2	3	2	4+	5+	4-	4-	4-	5	0	5-	6-	Tr	5-	0	0	5	5	6+	5-	5	Tr	0	0	0	0.004

Appendix C.--Semiquantitative spectrographic and radiometric analyses of rocks of the Jo Dandy area, Montrose County, Colo.

Analysts: Spectrographic - G. W. Boyes, Jr., Radiometric - J. Patton--Continued.

Source of samples	Field number	Laboratory number	Rock type	Brief description	Elements																													Radio-activity
					Si	Al	Fe	Mg	Ca	Na	K	Ti	Zr	Mn	Ba	Sr	B	Be	Y	Yb	Ga	Sc	La	In	V	Cr	Co	Ni	Cu	Pb	Mo	Ag	Bi	pct. eU
	77	D-88340	mudstone	green	1	2+	2-	2-	2-	3-	2	3-	4-	4-	4-	4-	5	6-	5	6	5-	5-	0	0	5	5-	6+	6+	5	Tr	0	0	0	0.004
Core	78	D-88341	sandstone	oxidized	1	3+	3	3	2-	4+	3+	4	5	4-	4-	5+	Tr	0	0	0	0	0	0	0	5-	6+	0	0	6+	0	0	0	0	0.001
from	79	D-88342	sandstone	oxidized	1	3	3-	4+	2	4	3+	4-	5-	5+	5+	5	0	0	0	0	0	0	0	0	5	6	0	0	6	0	0	0	0	<0.001
drill-	80	D-88343	sandstone	oxidized	1	3+	3-	4+	2	4+	2-	4-	5	4-	4-	5+	Tr	0	Tr	Tr	0	0	0	0	5	6	0	0	6	Tr	0	0	0	<0.001
hole	81	D-88344	sandstone	oxidized	1	2+	3+	2-	2-	3	2-	3-	4-	4-	4	4-	5	0	5-	-	Tr	Tr	0	0	4-	5-	6+	6+	5-	Tr	Tr	0	0	0.002
78	82	D-88345	mudstone	green	2+	2+	2-	2	2-	3-	2	3-	5+	4-	4-	4-	5	Tr	5-	6-	5-	5-	Tr	0	5+	5	5-	5-	5	Tr	0	0	0	0.004
	83	D-88346	mudstone	red	2+	2	2-	2	2	3-	2-	4+	5	4+	5+	5+	5-	0	5-	6-	Tr	Tr	0	0	5	5-	Tr	6+	5-	0	0	0	-0	0.002
	84	D-88347	mudstone	green	1	2+	2	2-	2-	3-	2	3-	5	4-	4-	4-	5	0	5-	6-	5-	Tr	0	0	5+	5	6+	5-	5	5-	Tr	0	0	0.006
	85	D-88348	sandstone	oxidized	1	3	3	2-	2	4	3+	4-	5-	4	5+	5+	Tr	0	0	0	0	0	0	0	5+	6	Tr	Tr	5-	0	0	0	0	0.002
Core	86	D-88349	sandstone	oxidized	1	3+	3-	3	3+	4+	3+	4-	5+	4-	4-	5-	Tr	0	0	0	0	0	0	0	5-	6	0	0	6	0	0	0	0	<0.001
from	87	D-88350	sandstone	oxidized	1	3+	3	3	2	4+	3+	4-	5-	4	5+	5+	0	0	0	Tr	0	0	0	0	5	6	0	6+	6+	0	0	0	0	0.001
drill-	88	D-88351	mudstone	green	1	2+	2-	3+	3-	3-	2-	3-	4-	5	4-	4-	5+	6-	5-	-	Tr	5-	Tr	0	4-	5	0	6+	5-	5-	Tr	0	0	0.003
hole	89	D-88352	sandstone	oxidized	1	2-	3	3+	2-	4+	2-	4+	5+	4	4	5+	Tr	0	Tr	Tr	0	0	0	0	5-	6+	Tr	6	6+	Tr	Tr	0	0	0.002
95	90	D-88353	sandstone	oxidized	1	2	3+	3	4+	4+	2-	3-	4-	5+	4-	5+	5	0	Tr	6-	Tr	Tr	0	0	5	5-	Tr	6	5-	Tr	Tr	0	0	0.002
	91	D-88354	sandstone	oxidized	1	2-	3	3	2	4+	3+	4	4-	4	4-	5+	5-	0	0	0	0	0	0	0	5	6+	Tr	6	6+	0	0	0	0	0.001
	92	D-88355	mudstone	green	1	2	2-	2-	2-	3-	2	4+	5+	4	4-	4-	5	0	5-	6-	Tr	Tr	0	0	5	5	6+	5-	5	Tr	0	0	0	0.006
	93	D-88356	mudstone	red	1	2	3+	2-	2-	3-	2	4+	5	4	4-	5+	5	0	5-	6-	Tr	Tr	0	0	5	5	Tr	6+	5	Tr	0	0	0	0.002