Geology and Mineralogy

UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

MINERALOGICAL CLASSIFICATION OF URANIUM-VANADIUM DEPOSITS OF THE COLORADO PLATEAU*

By

Theodore Botinelly and Alice D. Weeks

January 1957

Trace Elements Memorandum Report 1011

This preliminary report is distributed without editorial and technical review for conformity with official standards and nomenclature. It is not for public inspection or quotation.

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

USGS - TEM-1011

GEOLOGY AND MINERALOGY

Distribution	No. of copies
Atomic Energy Commission, Washington	2
Division of Raw Materials, Albuquerque	1
Division of Raw Materials, Austin	1
Division of Raw Materials, Casper	1
Division of Raw Materials, Denver	1
Division of Raw Materials, Ishpeming	1
Division of Raw Materials, Phoenix	1
Division of Raw Materials, Rapid City	1
Division of Raw Materials, Salt Lake City	1
Division of Raw Materials, Spokane	1
Division of Raw Materials, Washington	3
Exploration Division, Grand Junction Operations Office	6
Grand Junction Operations Office	1
Technical Information Service Extension, Oak Ridge	6
U. S. Geological Survey:	
Fuels Branch, Washington	1
Geochemistry and Petrology Branch, Washington	2
Geophysics Branch, Washington	1
Mineral Classification Branch, Washington	2
Mineral Deposits Branch, Washington	2
P. C. Bateman, Menlo Park	1
A. L. Brokaw, Grand Junction	2
N. M. Denson, Denver	1
V. L. Freeman, College	1
R. L. Griggs, Albuquerque	1
W. R. Keefer, Laramie	1
M. R. Klepper, Spokane	1
L. R. Page, Washington	1
P. K. Sims, Denver	1
Q. D. Singewald, Beltsville	1
A. E. Weissenborn, Spokane	1
TEPCO, Denver	2
TEPCO, RPS, Washington, (including master)	2
	51

CONTENTS

ILLUSTRATION

MINERALOGICAL CLASSIFICATION OF URANIUM-VANADIUM DEPOSITS OF THE COLORADO PLATEAU

By Theodore Botinelly and Alice D. Weeks

ABSTRACT

The uranium deposits of the Colorado Plateau contain suites of minerals that are the result of different stages of oxidation of deposits with different elemental composition. A classification based on composition and stage of oxidation is presented.

INTRODUCTION

The uranium deposits of the Colorado Plateau vary widely in mineralogy, but there is a regularity to the deposits that becomes apparent when they are classified on the basis of the elemental composition of the deposit and the amount of oxidation.

Laboratory work by the U. S. Geological Survey has shown the sequence of minerals developed by oxidation of various types of deposits. This report attempts to use these results to classify the actual deposits. The gradations between the different types of deposits are transitional and any classification will necessarily have cases that fall on the borderlines.

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

BASIS OF CLASSIFICATION

This report presents a mineralogical classification of some of the mines and groups of mines of the Colorado Plateau. The mines shown on figure 1 were selected to give a geographic spread, to show the larger mines, and to show some of the variations in mineral and metal content in different mines. Not all mines or groups of mines are shown.

The purpose of this report is to present some generalized mineralogical data on certain mines and groups of mines, to present a classification of the uranium deposits of the Colorado Plateau, to show what minerals may be present in the various types of uranium deposits, and to arouse the interest of the field geologists in the study of the effects of oxidation on these ore deposits.

This classification is based on a concept of progressive oxidation of ore deposits that contain uranium and vanadium or other accessory metals. This concept of oxidation was originally proposed by Alice D. Weeks and Robert M. Garrels (oral communication, 1954).

Each deposit is classified according to the predominant ore minerals present. These ore minerals are either the primary oxides and silicates or have been formed from these minerals by oxidation. In those deposits that are completely oxidized the mineralogy is controlled by the amount of

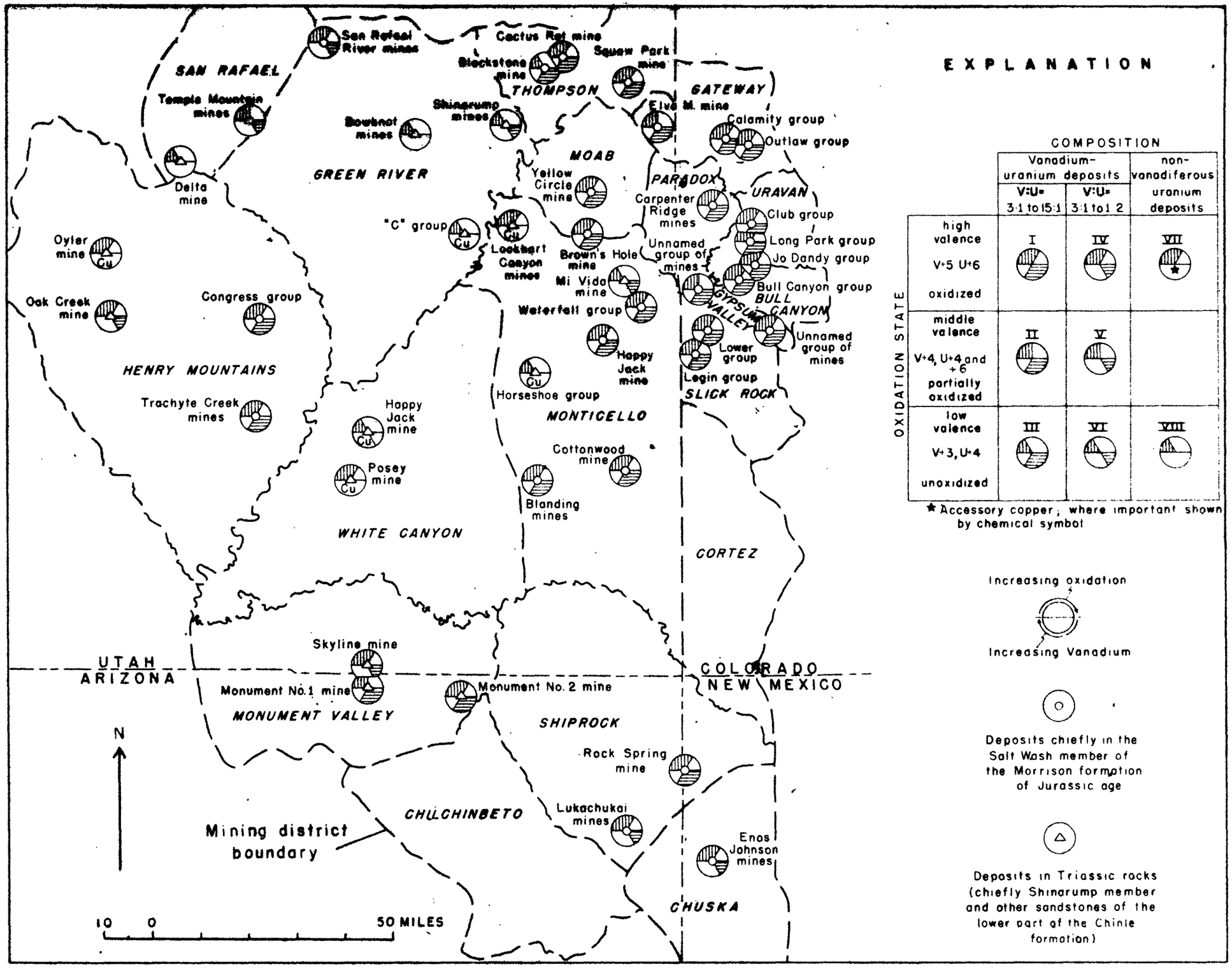

Figure 1.--MINERALOGICAL CLASSIFICATION MAP OF SOME URANIUM-VANADIUM DEPOSITS OF PART OF THE COLORADO PLATEAU.

vanadium present compared to uranium. Where sufficient vanadium is present to fix the uranium in carnotite, other uranium compounds are rare. Where vanadium is present in excess, other vanadate minerals are formed; where insufficient vanadium is present to fix all the uranium in carnotite, uranyl compounds other than vanadates are formed.

In some deposits oxidation has not progressed far enough to form carnotite or other high-valence minerals; these deposits contain "intermediate" minerals (minerals which contain V^{+4} ions) or mixtures of U^{+4} and U^{+6} minerals, or both. (Partially oxidized vanadium-uranium deposits are rare, and deposits which have both oxidized and unoxidized ore show a very narrow transition zone between the two.) Thus the mineralogy may be thought of as the result of the interaction of two factors, the oxidation process and the primary composition of the ores. The symbols on figure 1 are an attempt to show these two factors.

Unoxidized and partially oxidized ore is rare in deposits in both Triassic and Jurassic rocks. This rarity probably is due to the great preponderance of shallow mines in the Plateau area. In districts, such as the Bull Canyon district, where most of the mines are in oxidized ore, unoxidized deposits may also be present. Some mines are in oxidized ore near the surface and in unoxidized ore in the deeper part, such as the JJ mine in the Bull Canyon district. Pockets of unoxidized material may be present in oxidized deposits; these are usually associated with carbonaceous material.

Figure 1 shows that variations in the mineralogy in the deposits in the Salt Wash member of the Morrison formation are more likely to be due to variations in the amount of oxidation than to variations in the vanadium-uranium ratio. With few exceptions, ore deposits in the Morrison formation

have high V:U ratios. In contrast, many ore deposits in Triassic rocks have a low V:U ratio, and in some deposits copper exceeds vanadium.

The ores have been classified into eight types (3 major groups and the oxidized varieties of each) based on V:U ratio and the valence state of the ore metals.

Group I consists of ores with high vanadium-uranium ratios (V:U = 3:1 to 15:1)--a large excess of vanadium over the amount needed to form carnotite or tyuyamunite. This group is characterized by large amounts of vanadium minerals.

Group II consists of ores in which amounts of vanadium and uranium are nearly equal (V:U = 3:1 to 1:2). In this group there is only a slight excess of vanadium over that needed to form carnotite and tyuyamunite. Vanadium minerals are not predominant and unoxidized ore is not conspicuous.

Group III consists of ore containing uranium and little or no vanadium; other metals are present usually as minor constituents of the ore. The mineralogy of these ores is widely variable. Only two oxidation stages are present, corresponding to the two valences of uranium U^{+6} and U^{+4}. Partial oxidation of ore from any of these deposits might result in an approximately even mixture of U^{+4} and U^{+6} minerals.

A mineralogical description of the eight types of ores is given below. The minerals listed are those that are known to occur in deposits of these types. However, not all of the minerals listed necessarily occur in any single deposit. The minerals listed as "dominant ore minerals" are those uranium and vanadium minerals that make up the bulk of the ore and are diagnostic for the type of ore. The other minerals listed are those that may be present but are not diagnostic of the oxidation stage. The minerals are classed according to the valence state of the uranium and vanadium.

Types of ore

Group I

Type I V:U=3:1 to 15:1

High-valent or highly oxidized ores

Dominant ore minerals	Carnotite, tyuyamunite, vanadium-clay, hewettite
Vanadium-uranium minerals present in minor amounts	
High-valent	Pascoite, hummerite, rossite, navajoite, steigerite, fervanite, sodium vanadate (analogue of hewettite)
Middle-valent	Fernandinite, corvusite, rauvite, melanovanadite
Low-valent	Uraninite (with coffinite), paramontroseite
Gangue minerals	Iron oxide, gypsum, barite, calcite (rare), zinc and lead carbonates and sulfates.

Remarks: The ore minerals are red, yellow and brown. Some middle- and low-valent minerals may be present.

Type II V:U = 3:1 to 15:1

Middle-valent ores

Dominant ore minerals	Corvusite, hewettite, doloresite, vanadium-clay, rauvite
Vanadium-uranium minerals present in minor amounts	
High-valent	Carnotite, tyuyamunite
Middle-valent	Melanovanadite, fernandinite
Low-valent	Uraninite, paramontroseite
Gangue minerals	Pyrite and iron oxides, barite, rare calcite, gypsum

Remarks: These ores are generally off-shades of black to bluish black, greenish black, and brown.

Type III V:U = 3:1 to 15:1

Low-valent ores

Dominant ore minerals	Coffinite, uraninite, montroseite
Vanadium-uranium minerals present in minor amounts	
High-valent	Carnotite, tyuyamunite
Middle-valent	Corvusite, rauvite, fernandinite, melanovanadite
Low-valent	Paramontroseite
Gangue minerals	Galena, pyrite, sphalerite, chalcopyrite, cobalt, nickel, arsenic minerals, calcite, barite

Remarks: These ores are black, colored only where higher-valence oxides have formed.

Group II

Type IV V:U = 3:1 to 1:2

In general, the mineralogy of these ores is similar to the ores in the 3:1 to 15:1 group. There is less vanadium in excess over that needed to form carnotite and tyuyamunite and as a consequence fewer vanadium-oxide minerals form.

High-valent ores

Dominant ore minerals	Carnotite, tyuyamunite, and uranyl carbonates, sulfates, and silicates
Vanadium-uranium minerals present in minor amounts	
High-valent	Scarce V^{+5} minerals, hewettite
Middle-valent	Scarce corvusite, fernandinite, rauvite
Low-valent	Uraninite, coffinite, montroseite
Gangue minerals	Iron oxides, gypsum, barite, calcite (rare)

Type V V:U= 3:1 to 1:2

Middle-valent ores

Dominant ore minerals	Rauvite, some V^{+4} minerals such as corvusite, fernandinite, doloresite

Vanadium-uranium minerals present in minor amounts

High-valent	Carnotite, tyuyamunite, uranyl carbonates, sulfates
Low-valent	Uraninite, montroseite
Gangue minerals	Pyrite and iron oxides

Type VI V:U=3:1 to 1:2

Low-valent ores

Dominant ore minerals	Uraninite, montroseite, coffinite

Vanadium-uranium minerals present in minor amounts

	Intermediate vanadium oxides rare; uranyl compounds probably most conspicuous
Gangue minerals	Sulfides and arsenides of iron, copper, and lead; calcite

Group III

Type VII Uranium associated with minor amounts of other metals

No middle-valent stage is present in these ores because uranium is either U^{+4} or U^{+6}.

High-valent ores

Ore minerals	Uranyl carbonates, sulfates, oxides, silicates, schroeckingerite, torbernite, zeunerite, abernathyite
Gangue minerals	"Cobalt bloom," halotrichite, pickeringite, secondary copper minerals, jarosite, alunite, allophane, opal

Remarks: The mineralogy may vary from place to place in the deposit. Deposits with a predominant minor metal, such as copper, contain suites of uranyl compounds containing the minor metal. Ore minerals are often shades of yellow and green.

Type VIII Uranium associated with minor amounts of other metals

Low-valent ores

Ore minerals	Uraninite, coffinite (with slight oxidation "gummite" or uranium wad may form)
Gangue minerals	Pyrite, sphalerite, galena, chalcopyrite, cobalt, nickel arsenides

Remarks: Ores are black with red, green, and yellow minerals where oxidized.