Contributions to the Geology of Uranium 1957

GEOLOGICAL SURVEY BULLETIN 1074

This bulletin was published as separate chapters A–F

UNITED STATES GOVERNMENT PRINTING OFFICE, WASHINGTON : 1963

UNITED STATES DEPARTMENT OF THE INTERIOR

STEWART L. UDALL, *Secretary*

GEOLOGICAL SURVEY

Thomas B. Nolan, *Director*

CONTENTS

[The letters in parentheses preceding the titles are those used to designate the separate chapters]

Mineralogic Classification of Uranium-Vanadium Deposits of the Colorado Plateau

By THEODORE BOTINELLY *and* ALICE D. WEEKS

CONTRIBUTIONS TO THE GEOLOGY OF URANIUM

GEOLOGICAL SURVEY BULLETIN 1074-A

This report concerns work done on behalf of the U. S. Atomic Energy Commission and is published with the permission of the Commission

UNITED STATES GOVERNMENT PRINTING OFFICE, WASHINGTON : 1957

UNITED STATES DEPARTMENT OF THE INTERIOR

FRED A. SEATON, *Secretary*

GEOLOGICAL SURVEY

Thomas B. Nolan, *Director*

For sale by the Superintendent of Documents, U. S. Government Printing Office
Washington 25, D. C. • Price 40 cents (paper cover)

CONTENTS

ILLUSTRATION

428754—57

CONTRIBUTIONS TO THE GEOLOGY OF URANIUM

MINERALOGIC 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. The classification is based on composition and stage of oxidation, and comprises three groups and the oxidized varieties of each.

INTRODUCTION

This report presents some generalized mineralogic data on certain uranium mines and groups of mines on the Colorado Plateau, a classification of the uranium deposits, and a listing of the minerals that may be present in the various types of deposits. The mines plotted on plate 1 were selected to give a geographic spread, to show the larger mines, and to describe some of the variations in mineral and metal content. Not all mines in the area are included.

The uranium deposits of the Colorado Plateau vary widely in mineralogy, but a regularity to the deposits becomes apparent when they are classified on the basis of the elemental composition of the deposit and the amount of oxidation. Thus the mineralogy is the result of the interaction of two factors—the oxidation process and the primary composition of the ores. Symbols on plate 1 show these two factors in the deposits studied.

The 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 communications, 1954). Laboratory work by members of the U. S. Geological Survey has shown the sequence of minerals developed by oxidation of various types of deposits. The results of their work are used in this report to classify the actual deposits. As these deposits are in transitional stages, it will be difficult to classify some of them as being of one specific type.

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.

MINERALOGY

Each deposit can be classified according to the predominant ore minerals present. These ore minerals are either 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 vanadium present as compared to uranium. Where sufficient vanadium is present to fix the uranium in carnotite, other uranium compounds are rare; where vanadium is present in execess, 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 that contain V^{+4} ions) or mixtures of U^{+4} and U^{+6} minerals, or both.

With few exceptions, ore deposits in the Morrison formation have high vanadium-uranium ratios. In contrast, many ore deposits in Triassic rocks have low vanadium-uranium ratios, and in some deposits copper exceeds vanadium.

OXIDATION

Unoxidized and partly oxidized ore is rare in both Triassic and Jurassic deposits. This is probably because most of the mines in the area are shallow. In districts such as Bull Canyon, 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 at 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. Partly oxidized vanadium-uranium deposits show a very narrow transition zone between the two types of ore.

Mineralogic variations 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.

CLASSIFICATION

The ores are classified into 8 types (3 major groups and the oxidized varieties of each) based on the vanadium-uranium ratio and the valence state of the ore metals.

Group 1 consists of ores with high vanadium-uranium ratios (3:1 to 15:1), with 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 2 consists of ores in which amounts of vanadium and uranium are nearly equal (ratios of 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 3 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 +6 and +4 valences of uranium. Partial oxidation of ore from any of these deposits might result in an approximately even mixture of U^{+4} and U^{+6} minerals.

A mineralogic 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 that 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.

Group 1 (V:U=3:1 to 15:1):

Type 1 (high-valent or oxidized ores):

Dominant ore minerals:

Carnotite	Tyuyamunite
Hewettite	Vanadium clay

Minor ore minerals:

High valence	*Middle valence*	*Low valence*
Fervanite	Corvusite	Paramontoseite
Hummerite	Fernandite	Uraninite (with coffinite)
Navajoite	Melanovanadite	
Pascoite	Rauvite	
Rossite		
Sodium vanadate (analogue of hewettite)		

Gangue minerals:

Barite	Iron oxide
Calcite (rare)	Lead carbonates and sulfates
Gypsum	Zinc carbonates and sulfates

Remarks: The ore minerals are red, yellow, and brown.

Type 2 (middle-valent or partly oxidized ores):

Dominant ore minerals:

Corvusite	Rauvite
Doloresite	Vanadium clay
Hewettite	

Minor ore minerals:

High valence	*Middle valence*	*Low valence*
Carnotite	Fernandinite	Paramontroseite
Tyuyamunite	Melanovanadite	Uraninite

Gangue minerals:

Barite	Gypsum
Calcite (rare)	Pyrite and iron oxides

Remarks: These ores are generally black to bluish black, greenish black, and brown.

Type 3 (low-valent or unoxidized ores):

Dominant ore minerals:

Coffinite	Uraninite
Montroseite	

Minor ore minerals:

High valence	*Middle valence*	*Low valence*
Carnotite	Corvusite	Paramontroseite
Tyuyamunite	Fernandinite	
	Melanovanadite	
	Rauvite	

Gangue minerals:

Barite	Galena
Calcite	Nickel
Chalcopyrite	Pyrite
Cobalt, nickel, and arsenic minerals	Sphalerite

Remarks: These ores are generally black; colored only where higher valence oxides have formed.

Group 2 (V : U=3 : 1 to 1 : 2):

Type 1 (high-valent or oxidized ores):

Dominant ore minerals:

Carnotite	Uranyl carbonates, sulfates, and silicates
Tyuyamunite	

Minor ore minerals:

High valence	*Middle valence*	*Low valence*
Hewettite	Corvusite (scarce)	Coffinite
V^{+5} minerals (scarce)	Fernandinite	Montroseite
	Rauvite	Uraninite

Gangue minerals:

Barite	Gypsum
Calcite (rare)	Iron oxides

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

Type 2 (middle-valent or partly oxidized ores);

Dominant ore minerals:

Rauvite

Some V^{+4} minerals such as corvusite, fernandinite, doloresite

Minor ore minerals:

High valence	*Low valence*
Carnotite	Montroseite
Sulfates	Uraninite
Tyuyamunite	
Uranyl carbonates	

Gangue minerals: Pyrite and iron oxides.

Type 3 (low-valent or unoxidized ores):

Dominant ore minerals:

Coffinite	Uraninite
Montroseite	

Minor ore minerals: Intermediate vanadium oxides rare; uranyl compounds probably most conspicuous.

Gangue minerals:

Calcite

Sulfides and arsenides of iron, copper, and lead

Group 3 (uranium associated with minor amounts of other metals):

Type 1 (high-valent ores):

Ore minerals:

Abernathyite	Uranyl carbonates, sulfates, oxides, silicates
Schroeckingerite	
Torbernite	Zeunerite

Gangue minerals:

Allophane	Jarosite
Alunite	Opal
"Cobalt bloom"	Pickeringite
Halotrichite	Secondary copper minerals

Remarks: No middle-valent stage is present in these ores, since uranium is either U^{+4} or U^{+6}. 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. Many of these ore minerals are shades of yellow and green.

Type 2 (low-valent ores):

Ore minerals:

Coffinite

Uraninite (slight oxidation "gummite" or uranium wad may form)

Gangue minerals:

Chalcopyrite	Nickel arsenides
Cobalt	Pyrite
Galena	Sphalerite

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