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Dr. Phillip L. Merritt, Assistant Director
Division of Raw Materials
U. S. Atomic Energy Commission
P. O. Box 30, Ansonia Station
New York 23, New York

Dear Phil:

Transmitted herewith are six copies of TEI-334, "Identification and occurrence of uranium and vanadium minerals from the Colorado Plateaus," by A. D. Weeks and M. E. Thompson, April 1953.

We are asking Mr. Hosted to approve our plan to publish this report as a Circular.

Sincerely yours,

Dwight M. Lemmon
for W. H. Bradley
Chief Geologist

UNCLASSIFIED

Geology and Mineralogy

This document consists of 69 pages.
Series A.

UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

IDENTIFICATION AND OCCURRENCE OF URANIUM AND VANADIUM MINERALS FROM THE COLORADO PLATEAUS*

By

A. D. Weeks and M. E. Thompson

April 1953

Trace Elements Investigations Report 334

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

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by A. D. Weeks and M. E. Thompson

Part I

ABSTRACT

This report, designed to make available to field geologists and others information on identification and occurrence of uranium minerals of the Colorado Plateaus, contains physical properties, X-ray data, and in some instances results of chemical and spectrographic analysis of 24 uranium and 17 vanadium minerals. Also included is a table giving the optical properties of uranium minerals and a list of locations of mines from which the minerals have been identified.

INTRODUCTION

More than 20 uranium and about 20 vanadium minerals have been identified during recent mineralogic studies of uranium ores from the Colorado Plateaus. This work is part of a program undertaken by the Geological Survey on behalf of the Atomic Energy Commission.

Thanks are due many members of the Geological Survey who have worked on one or more phases of the study--including chemical, spectrographic, and X-ray examination as well as collecting of samples. We are grateful to George Switzer of the U. S. National Museum and to Clifford Frondel of Harvard University who kindly loaned type mineral specimens and discussed various problems.

PURPOSE

The purpose of this report is to make available to field geologists and others, who do not have extensive laboratory facilities, present information on the identification and occurrence of the uranium and vanadium minerals of ores from the Plateaus. Distinctive properties of each mineral are listed to encourage and facilitate identification by optical or chemical tests. A combination of data from X-ray powder patterns and spectrographic analyses is useful and efficient for certain minerals, especially if the quantity of mineral is very small, but for many minerals these techniques are not necessary.

MINERAL DATA

The minerals include several new species and many that were rare and incompletely (or inaccurately) described before the recent intensive search for uranium. The data for each mineral include the best available formula, in general from the Glossary of uranium- and thorium-bearing minerals (Frondel and Fleischer, 1952), and crystallographic and physical properties from Dana's System of mineralogy, 7th edition, and from Mineralogy of uranium and thorium minerals (George, 1949). For minerals showing a considerable range of properties, selection has been made to emphasize those noted by the writers for specimens from the Colorado Plateaus. Crystallographic data are reduced to a minimum because such would be used rarely by the field geologist. An exception is crystal habit which may be observed with a binocular microscope, such as the platy habit of the torbernite group and bladed or fibrous habit of uranophane. Chiefly to establish the particular material that is referred to under each species, the d-spacing in Angstrom units is given for several strong lines of the X-ray diffraction powder pattern taken with CuKα radiation. The relative intensity of the lines is indicated by the abbreviations: VS very stong, S strong, M medium, and W weak. The X-ray photographs were taken by E. A. Cisney, and M. E. Thompson.

Relatively few of the uranium and vanadium minerals are too fine grained, too high in refractive index, or too dark for determination of some optical properties. Certain minerals, notably the torbernite group and the carnotite group, dehydrate easily with resultant rise in refractive indices; identification of minerals in these groups by optical properties must be made with considerable care. Table 1 gives the optical properties of uranium minerals.

So many yellow and greenish-yellow uranium minerals as well as a few yellow and greenish-yellow vanadium and copper minerals occur on the Plateaus that color is not a dependable means of identification unless combined with other properties. The color of fluorescence noted here is for minerals observed under ultraviolet light (2537 A) and may differ considerably from the color or degree of fluorescence observed at 3660 A.

For the new and some of the doubtful species, chemical analyses were made by A. M. Sherwood and R. G. Milkey. If no chemical analysis has been made, a spectrographic analysis is given. These are by C. L. Waring, H. W. Worthing, C. S. Annell, J. N. Stich, and K. E. Valentine. Semiquantitative spectrographic analyses (Waring and Annell, 1952) made on 10 mg of sample are given for constituents in the following percentage ranges: more than 10, 1 to 10, 0.1 to 1, 0.01 to 0.1, and 0.001 to 0.01. Qualitative spectrographic analyses (Stich, 1953), made on 1 mg of sample, list the constituent elements as major (more than 10 percent), minor (approximately 1 to 10 percent), and trace (less than 1 percent).

Under Occurrence is noted the primary or secondary nature of each mineral and whether it is found as impregnation, replacement, or coating on fractures and mine walls. Listed also are the commonly associated minerals. Only for a few rare minerals is the name of the person who collected the samples given. Most of the samples were collected by L. B. Riley, L. R. Stieff, T. W. Stern, and the writers; a smaller number by other Survey geologists and by mine operators.

The section headed Identification is based on the writers' experience in identifying these minerals. Minerals that are commonly fine grained, in thin coatings, or admixed with other minerals, as are many from the Plateaus, can be identified satisfactorily in the laboratory using a small amount of material. A 1-mg amount of mineral is sufficient for a spindle for an X-ray powder pattern, and the spindle may then be used for qualitative spectrographic analysis. Some groups of minerals have similar X-ray patterns, as autunite and uranocircite or metatorbernite and metazeunerite, and an additional test is necessary to determine the mineral.

A satisfactory test for uranium may be made by a bead test using a small loop of platinum wire and a flux composed of 45.5 percent by weight of Na_2CO_3, 45.5 percent by weight of K_2CO_3, and 9 percent by weight of NaF and observing with a long wavelength (3650 A) ultraviolet light the fluorescence caused by uranium (Grimaldi and others, 1952). The test is more easily made using a small platinum pan such as the lid of a platinum crucible. The flux should be melted and the blank tested with the ultraviolet light before the mineral grains are added and the flux remelted for the final test. With a little practice one can distinguish between the bright fluorescence of a uranium mineral and the faint fluorescence of slightly uraniferous material such as uraniferous opal. After obtaining a positive test the platinum wire or pan should be washed in hydrochloric acid before making another test.

The test described above may be modified by using a flux composed of nine parts of household baking soda and one part of sodium fluoride (as sold by drug stores for ant poison) and ordinary iron wire. In this case the flux should be fused only a short time to avoid adding iron that causes quenching of the uranium fluorescence. Although a wavelength of 3650 A is best for accurate laboratory work, almost any battery-operated ultraviolet light suitable for prospecting may be used in this field test.

To test for vanadium, dissolve a small portion of the mineral or ore in aqua regia, evaporate to dryness, add as much water as original acid, and then add a few drops of hydrogen peroxide. If vanadium is present the solution will turn orange red. Carnotite or tyuyamunite commonly turns red brown when a drop of concentrated hydrochloric acid is added but this test is not always satisfactory for roscoelite ore.

Localities are listed by mine name and the mining district, as shown on a map by Shoemaker and Luedke (1952). Most mine names are those in use when samples were collected in the summer of 1952, but some are as recorded with samples collected in 1950 and 1951. To help the reader who is not familiar with the mining districts an alphabetical list of mine and locality names is given in table 2 showing the county and state in which each is located. The number of localities is restricted to those from which specimens have been identified by the authors and to the type localities of minerals named from the Plateaus. In addition, a few samples from the sandstone-type deposits at Pumpkin Buttes, Wyo., have been included.

MINERAL ASSOCIATIONS AND DISTRIBUTION OF TYPES OF ORE

Ore from the Plateaus may be classified on the basis of whether uranium is associated with vanadium or with copper and other metals. Each may be subdivided into highly oxidized or relatively unoxidized ore.

Oxidized vanadium-uranium ore (carnotite)

For many years the chief ore mined on the Plateaus was oxidized vanadium-uranium ore from the western Colorado-eastern Utah area, now known as the Uravan mineral belt, and from Temple Mountain on the east side of the San Rafael swell in Utah. The most abundant uranium mineral was carnotite with a smaller amount of tyuyamunite and very little rauvite and uvanite. The most abundant vanadium minerals (aside from the uranyl vanadates) were vanadium hydromica and/or roscoelite and corvusite, with local concentration of hewettite and metahewettite and small amounts of other secondary quinquivalent vanadium minerals: pascoite, hummerite, rossite, metarossite, steigerite, navahoite, fervanite, and the sodium analogue of hewettite--filling fractures or coating joint surfaces and mine walls.

Many of these minerals have been found in mines recently developed at Monument Valley, Ariz. In the Shiprock district, Arizona-New Mexico, and along the north side of the Zuni uplift, N. Mex., tyuyamunite and metatyuyamunite are more abundant than carnotite. Recently several other uranium minerals in small amounts have been found in carnotite ore: schroeckingerite, meta-autunite, metazeunerite, uranophane, and novacekite. Locally, where both copper and vanadium are present, small quantities of volborthite and calciovolborthite occur as at Richardson Basin, Moab district, Utah, and in the Slick Rock district, Colo.

Placerville and Rifle, Colo.--two areas that produced chiefly vanadium with relatively little uranium--have not been given detailed mineralogic study.

The vanadium-to-uranium ratio of the ores ranges from a high ratio of about 30:1 at Placerville and Rifle, Colo., through lower values in the Uravan mineral belt, Colorado-Utah, the Shiprock district, Arizona-New Mexico, Monument Valley, Ariz., the Grants district on the north side of the Zuni uplift, N. Mex., to a ratio of about 1:1 at Temple Mountain in the San Rafael district, Utah. Some differences in relative abundance of minerals in the several areas are due to the variation in V:U ratio. Other differences are due to local conditions such as high calcium content of the sediments in the Shiprock and Grants districts causing local predominance of tyuyamunite. In the Uravan belt the predominance of carnotite seems to be coincident with the area of the Pennsylvanian evaporite basin and may be related to the presence of potassium salts in the Paradox member of the Hermosa formation. Presence of fossil bone may favor local development of autunite. In the Grants district the fluorite associated with ore may be related to fluorite deposits in the center of the Zuni uplift.

Unoxidized vanadium-uranium ore

In the early days of uranium mining on the Plateaus, small concentrations of black minerals included in the carnotite ore were called corvusite-vanoxite ore and thought to be composed chiefly of vanadium oxides.

Recently, as many new mines have been opened, much more black ore high in uranium as well as vanadium has been found wherever ore bodies are protected from oxidation by thick cover, as in the deeper ore bodies in the Long Park area of the Uravan district, or where ore has been exposed very recently by headward erosion of steep canyons, as in Lumsden Canyon, Gateway district, or La Sal Creek, Paradox district. Some small mines have chiefly black ore with very little secondary alteration, and others like Monument No. 2 mine in Monument Valley district, have scattered unoxidized remnants in ore that is chiefly oxidized.

Since 1950 mineralogic study has shown the presence of several important primary uranium and vanadium minerals. The uranium minerals are pitchblende* (identified in 11 mines of uranium-vanadium ore) and a new uranium mineral (identified in 8 mines of uranium-vanadium ore). The new mineral is called coffinite by L. R. Stieff and T. W. Stern who found it in 1951 (report in preparation). The vanadium minerals are montroseite and other trivalent and quadrivalent vanadium oxides (one called doloresite and another lumsdenite by T. W. Stern, report in preparation). Both uranium and vanadium minerals are associated with pyrite, commonly with high rank coalified wood, and traces of copper, lead, cobalt, nickel, molybdenum, and silver. Also present and possibly representing a transition to the oxidized ore are melanovanadite, corvusite and probably fernandinite.

The ore at Temple Mountain in the eastern part of the San Rafael district has been commonly referred to as asphaltite ore because of asphaltic material impregnating the sandstone and carbonaceous material in the ore. However, higher-than-average carbon content does not prevent classifying this ore on the basis of mineral assemblage with the other uranium-vanadium ores. The relatively unoxidized portion of the ore contains pitchblende associated with a hard carbonaceous substance variously described as high rank coal or

*The term pitchblende is used as in Dana, 7th edition, vol. 1, pp. 613-614, for a massive variety of uraninite, with specific gravity lower than 8.5 and thorium absent or less than 1 percent.

polymerized petroleum residue (thucholite ?); also present is pyrite with very small amounts of montroseite and galena.

Oxidized nonvanadiferous uranium ores

In contrast to the carnotite ore, the nonvanadiferous uranium ores are characterized by a wide variety of secondary uranium minerals that include hydrated oxides, carbonates, sulfates, phosphates, arsenates, and silicates. Most of these uranium minerals are yellow, orange, greenish yellow, or green, and microcrystalline or massive. They fill minute fractures in sandstone, conglomerate, or fossil wood and coat joint surfaces and mine walls. In small ore pockets or even in small mines one of these minerals may be abundant, but among them no mineral is as predominant as carnotite is in the oxidized vanadium-uranium ore. In studies to date, the uranium sulfates seem the most abundant.

Copper, the chief associated metal, occurs in many secondary minerals, commonly as malachite, azurite, chalcanthite, antlerite, brochantite, and chrysocolla, and rarely as conichalcite, chalcoalumite, and volborthite. Other metals are present and differ in abundance from one mine to another: iron and manganese in limonite and wad, cobalt in bieberite (commonly dehydrated), sphaerocobaltite, erythrite, or cobaltoan pickeringite, molybdenum in ilsemannite or ferrimolybdite, and traces of lead, zinc, nickel and silver.

Outcrops of these deposits or joint surfaces within a few inches of the cliff face commonly show bright-blue and green copper stain, bright yellow of uranium sulfates or carbonates, pink cobalt bloom, dull-yellow jarosite, white alunite and, in a few places, fluorescent uraniferous opal and allophane. Clay lenses in the ore or nearby are bleached and altered to kaolinite, jarosite, alunite, or gibbsite.

Unoxidized nonvanadiferous ore (pitchblende-copper sulfide)

Since 1949 relatively unoxidized nonvanadiferous uranium ore has been found at a number of places in the west-central part of the Monument uplift, now called the White Canyon mining district, and in scattered localities in the Green River, San Rafael, and Henry Mountains mining districts. Coffinite has been identified at 1 mine and pitchblende at 13 mines in nonvanadiferous ore (in addition to the 8 coffinite and 11 pitchblende localities in vanadiferous ore). As in the case of the black vanadium-uranium ore, some mines have chiefly unoxidized ore and others have unoxidized remnants in ore that is fairly well oxidized.

The best development of relatively unoxidized nonvanadiferous ore is the pitchblende-copper sulfide deposit in which the Happy Jack mine is located at White Canyon, Utah. The ore contains both sooty pitchblende and massive pitchblende that is so pure and of such high specific gravity (9.0) as to justify calling it uraninite. Some of the pitchblende replaces fossil wood and some, in tabular masses, does not show wood structure. It is closely associated with chalcopyrite, pyrite, bornite, chalcocite, sphalerite, and galena and traces of cobalt, nickel, molybdenum, and silver. The abundance of secondary uranium sulfates as efflorescences on the mine walls shows the close relation between pitchblende and the sulfides.

Part II

URANIUM MINERALS

Description of identified minerals

The uranium minerals described in the following pages are those from the Colorado Plateaus that the authors have studied. One species, uvanite, exists only in the type specimen in the U. S. National Museum and no new localities have been found.

Classified according to chemical composition the described minerals are:

Oxides	Uraninite and pitchblende UO_2	
	Becquerelite $2UO_3 \cdot 3H_2O$	
	Fourmarierite $PbU_4O_{13} \cdot 7H_2O$	
Carbonates	Bayleyite $Mg_2(UO_2)(CO_3)_3 \cdot 18H_2O$	
	Schroeckingerite $NaCa_3(UO_2)(CO_3)_3(SO_4)F \cdot 10H_2O$	
	Liebigite $Ca_2U(CO_3)_4 \cdot 10H_2O$ (?)	
	Rabbittite $Ca_3Mg_3(UO_2)_2(CO_3)_6(OH)_4 \cdot 18H_2O$	
Sulfates	Uranopilite $(UO_2)_6(SO_4)(OH)_{10} \cdot 12H_2O$	
	Johannite $Cu(UO_2)_2(SO_4)_2(OH)_2 \cdot 6H_2O$	
	Betazippeite $(UO_2)_2(SO_4)(OH)_2 \cdot 4H_2O$	
Phosphates	Autunite $Ca(UO_2)_2(PO_4)_2 \cdot 10\text{-}12H_2O$	
	Meta-autunite I $Ca(UO_2)_2(PO_4)_2 \cdot 2\frac{1}{2}\text{-}6\frac{1}{2}H_2O$	
	Bassetite $Fe(UO_2)_2(PO_4)_2 \cdot 8H_2O$	
	Torbernite $Cu(UO_2)_2(PO_4)_2 \cdot 8\text{-}12H_2O$	
	Metatorbernite $Cu(UO_2)_2(PO_4)_2 \cdot 8H_2O$	
	Phosphuranylite $Ca_3(UO_2)_5(PO_4)_4(OH)_4 \cdot 2H_2O$ (?)	
Arsenates	Metazeunerite $Cu(UO_2)_2(AsO_4)_2 \cdot 8H_2O$	
	Novacekite $Mg(UO_2)_2(AsO_4)_2 \cdot 8\text{-}10H_2O$	
Vanadates	Carnotite $K_2(UO_2)_2(VO_4)_2 \cdot 1\text{-}3H_2O$	
	Metatyuyamunite $Ca(UO_2)_2(VO_4)_2 \cdot 6\text{-}n$ (?) H_2O	
	Tyuyamunite $Ca(UO_2)_2(VO_4)_2 \cdot n\text{-}12$ (?) H_2O	
	Rauvite $CaO \cdot 2UO_3 \cdot 5V_2O_5 \cdot 16H_2O$ (?)	closely related
	Uvanite $2UO_3 \cdot 3V_2O_5 \cdot 15H_2O$ (?)	
Silicates	Uranophane $Ca(UO_2)_2Si_2O_7 \cdot 6H_2O$	
	Cuprosklodowskite $Cu(UO_2)_2Si_2O_7 \cdot 6H_2O$	

New mineral of uncertain formula	Coffinite, black mineral having X-ray pattern like thorite.
Uranium-bearing materials	Organic material, opal, allophane, limonite, and wad.

Additional minerals from the Colorado Plateaus noted in Atomic Energy Commission reports are schoepite $UO_3 \cdot 2H_2O$, sabugalite $HAl(UO_2)_4(PO_4) \cdot 16H_2O$, sklodowskite $Mg(UO_2)_2Si_2O_7 \cdot 7H_2O$, and beta-uranophane $Ca(UO_2)_2Si_2O_7 \cdot 6H_2O$. Three new uranium carbonates, swartzite $CaMg(UO_2)(CO_3)_3 \cdot 12H_2O$, andersonite $Na_2Ca(UO_2)(CO_3)_3 \cdot 6H_2O$, and bayleyite were described from the Hillside mine, Yavapai County, Ariz., (Axelrod and others, 1951). Bayleyite has been found in a second occurrence in a copper-uranium deposit in White Canyon district, Utah (Stern and Weeks, 1952). Soddyite $(UO_2)_5(SiO_3)_2(OH)_6 \cdot 3H_2O$, is known to occur also in Yavapai County, Ariz. (R. Berman, personal communication). Other minerals that may be found in the Plateaus deposits include uranocircite $Ba(UO_2)_2(PO_4)_2 \cdot 8H_2O$, uranospinite $Ca(UO_2)_2(AsO_4)_2 \cdot 8\text{-}12H_2O$, saléeite $Mg(UO_2)_2(PO_4)_2 \cdot 8\text{-}10H_2O$, and sengierite $Cu(UO_2)(VO_4)(OH) \cdot 4\text{-}5H_2O$ (?).

Several yellow uranium minerals from the Plateaus are still unidentified and some of these are probably new minerals. When work on these is completed descriptions of the new minerals will be given in a second edition of this report.

AUTUNITE
and META-AUTUNITE I

$Ca(UO_2)_2(PO_4)_2 \cdot 10\text{-}12H_2O$
(Meta-autunite I has $2\frac{1}{2}\text{-}6\frac{1}{2}H_2O$)

Crystal system: Tetragonal; ditetragonal-dipyramidal 4/m 2/m 2/m

Habit: Thin tabular {001}. As foliated or scaly aggregates.

Physical properties:

Color: ranges from lemon yellow to pale green. Streak yellowish.
Fluorescence: strong yellow green. Meta-autunite less strong.
Luster: vitreous, pearly on {001}.
Cleavage: {001} perfect, {100} indistinct. Not brittle.
Hardness: $2 - 2\frac{1}{2}$
Specific gravity: 3.1 - 3.2, varying with the water content.
Strongest lines of X-ray powder pattern: VS 8.3, S 3.59, W 1.60 (Meta-autunite I)

Optical properties:

Orientation	n	Pleochroism
X = c	1.553 - ?	Colorless to pale yellow
Y	1.575 - 1.59	Yellow to dark yellow
Z	1.577 - 1.61	Yellow to dark yellow
2V usually 10-30°; r > v strong		Usually anomalously biaxial negative due to loosely held water in both autunite and meta-autunite I

Meta-autunite from Thom claim is biaxial negative, 2V small to medium, nY and nZ equal to 1.603 ± 0.003

Analysis: Qualitative spectrographic analysis of material from Thom claim.

Major	U P
Minor	Ca Si Fe
Trace	Al Co Na As Ni Mg Pb

Occurrence and associated minerals: Coating fracture surfaces of weathered brown sandstone.

Identification: On drying or slight heating autunite passes reversibly to meta-autunite I

Optical properties are quite variable. Use with caution.
X-ray powder pattern. Analysis for Ca necessary to distinguish from uranocircite.

Locality: Thom claim, Thompson district.

BASSETITE $Fe(UO_2)_2(PO_4)_2 \cdot 8H_2O$

Crystal system: Monoclinic, pseudo-orthorhombic

Habit: Scaly, flattened on $\{010\}$.

Physical properties:

Color: yellow
Fluorescence: yellow, weak, variable
Luster: pearly
Cleavage: $\{010\}$ perfect. $\{100\}$ and $\{001\}$ distinct.
Hardness:
Specific gravity: 3.10
Strongest lines of X-ray powder pattern: S 9.4, M 3.48, M 2.19

Optical properties:

Orientation	n (Na)	Pleochroism	
X = b	[~ 1.56]	Pale yellow	Biaxial negative
Y	1.574	Deep yellow	$2V \sim 52^\circ$
$Z \wedge c = 40^\circ$	1.580	Deep yellow	

Analysis: Qualitative spectrographic analysis

Major	U
Minor	P Na Fe
Trace	Al K Ba Si Ca Cu

Occurrence and associated minerals: Secondary coating on mine wall, near the portal.

Identification: X-ray powder pattern.

Locality: Denise No. 1 mine, Green River district.

BAYLEYITE $Mg_2(UO_2)(CO_3)_3 \cdot 18H_2O$

Crystal form: Monoclinic

Habit: Minute prismatic crystals.

Physical properties:

Color: sulfur yellow
Fluorescence: feeble
Luster: vitreous
Cleavage:
Hardness: 2 - $2\frac{1}{2}$
Specific gravity: 2.05
Strongest lines of X-ray powder patterns: S 7.6, S 13.0, M 3.82

Optical properties:

Orientation	n	Pleochroism	
$X \wedge c$ 14°	1.455	Pinkish	
Y	1.490	Pale yellow	Biaxial negative
Z = b	1.500	Pale yellow	
2V = 30°			

Analysis: Semiquantitative spectrographic analysis, in percent, of material from Hideout mine.

> 10	U
1.0-10	Mg Ca (low)
0.1-1.0	Al
0.01-0.1	Si Sr

Occurrence and associated minerals: Found with schroeckingerite and gypsum as a coating on mine wall.

Identification:

Soluble in water. Effervesces in HCl.
Optically distinct. Indices unusually low for a uranium mineral.
Hideout material did not dehydrate in lab, as Arizona material did.

Localities:

Hillside mine, Yavapai County, Arizona, type locality.
Hideout (Tiger) mine, White Canyon district.

BECQUERELITE $2UO_3 \cdot 3H_2O$

Crystal system: Orthorhombic; dipyramidal 2/m 2/m 2/m

Habit: Tabular {001} and elongated [010] . Also massive.

Physical properties:

Color: amber to brownish yellow. Streak yellow.
Fluorescence:
Luster: adamantine, inclining to greasy.
Cleavage: {001} perfect, also {101}
Hardness: 2 - 3
Specific gravity: 5.2
Strongest lines of X-ray powder patterns: S 7.5, M 3.53, M 3.19

Optical properties:

Orientation	n	Pleochroism	
X = c	1.735	Colorless	
Y = b	1.820	Light yellow	Biaxial negative
Z = a	1.830	Dark yellow	
2V = 31°; r > v marked			

Analysis: Qualitative spectrographic analysis of material from Posey mine.

Major	U
Minor	Si
Trace	Cu Fe Mg

Occurrence and associated minerals: Alteration product of pitchblende at Cato Sells. At Posey in high-grade pocket of yellow oxidized ore with cuprosklodowskite.

Identification:

X-ray powder pattern.

Localities:

Posey mine, White Canyon district
Cato Sells mine, Monument Valley district
Monument No. 2 mine, Monument Valley district.

CARNOTITE $K_2(UO_2)_2(VO_4)_2 \cdot 1\text{-}3H_2O$

Crystal system: Monoclinic

Habit: As a powder or as loosely coherent microcrystalline aggregates, some may be compact; disseminated; rarely as crusts of imperfectly platy crystals, flattened $\{001\}$.

Physical properties:

Color: lemon yellow, greenish yellow; at Pumpkin Buttes orange.
Fluorescence: none
Luster: dull or earthy; pearly or silky when coarsely crystalline
Cleavage: $\{001\}$ perfect.
Hardness: soft
Specific gravity: 4 - 5; 4.6 average of 4 measurements on crystalline carnotite.
Strongest lines of X-ray powder patterns: S 6.5, M 3.11, W 3.51

Optical properties:

Orientation	n	Pleochroism	
$X \sim c$	1.750	Nearly colorless	
$Y \wedge a \sim 14^\circ$	1.925-2.06	Canary yellow	Biaxial negative
$Z = b$	1.950-2.08	Canary yellow	
2V $40^\circ - 50^\circ$			

Indices of refraction very with water content

Analysis: Semiquantitative spectrographic analysis, in percent, of material from near Cane Springs Pass, Moab district (USNM 95332)

>10	U V
1 - 10	K
0.1 - 1	Al Ca Na Si
0.01 - 0.1	Ba Sr Fe

Occurrence and associated minerals: Chiefly disseminated in sandstone or locally as small pure masses, especially around petrified or carbonized tree trunks or other vegetal matter. Associated with tyuyamunite, metatyuyamunite, hewettite, rauvite, and corvusite. At Monument No. 2 mine, with pitchblende.

Identification: Carnotite has higher indices of refraction than any other yellow uranium mineral. Carnotite and tyuyamunite turn red-brown when a drop of concentrated HCl is added. Tyuyamunite fuses relatively easily; carnotite is infusible.

Localities: In most of the vanadium-uranium mines of the following districts on the Colorado Plateaus: Thompsons, Gateway, Uravan, Paradox, Bull Canyon, Gypsum Valley, Slick Rock, Moab, Monticello, Monument Valley, Grants, and the Temple Mountain part of the San Rafael district. Also at Pumpkin Buttes, Wyo., and at Craven Canyon, Fall River County, S. Dak.

COFFINITE Formula uncertain*

Crystal system: Tetragonal

Habit: Massive; may show remnants of wood structure.

Physical properties:

Color: black
Fluorescence: none
Luster: adamantine
Cleavage:
Hardness:
Specific gravity: about 3.3 - 3.5
Strongest lines of X-ray powder pattern: S 3.48, Ms 4.62, M 2.64, M 1.80

Optical properties: Opaque. Translucent in very thin fragments.

Analysis: No good analysis is yet available; mineral occurs mixed with carbonaceous material and other black minerals.

Occurrence and associated minerals: Impregnating sandstone and replacing wood; with uraninite, and a low-valence (+3, +4) vanadium oxide (doloresite), and pyrite. Found in mines with protective cover or at the heads of steep canyons where erosion has recently exposed ore. (Coffinite was first found at La Sal No. 2 mine in August 1951 by T. W. Stern and L. R. Stieff, report in preparation; named for R. C. Coffin.)

Identification: X-ray powder pattern and lack of thorium. The X-ray powder pattern is very similar to that of thorite.

Localities:

Arrowhead mine	Gateway dist.	Gray Dawn mine	Paradox dist.
Black Mama mine	Gateway dist.	Wild Steer mine	Bull Canyon dist.
Corvusite mine	Gateway dist.	Little Muriel mine	Slick Rock dist.
La Sal No. 2 mine	Gateway dist.	Denise No. 1 mine	Green River dist.
Matchless mine	Gateway dist.		

*Analyses show up to 61 percent U and varying amounts of Si, As, and V. Coffinite may be analogous to thorite ($ThSiO_4$), i.e., $USiO_4$, with As, V, OH, etc., substituting for Si, or it may be a hydrated oxide. (June 1953).

CUPROSKLODOWSKITE $Cu(UO_2)_2Si_2O_7 \cdot 6H_2O$

Crystal system: Orthorhombic

Habit: Minute prismatic or acicular crystals. Usually grouped in radial clusters, also as thin films and botryoidal crusts.

Physical properties:

Color: pale yellow green; yellow in thin crystal blades.
Fluorescence:
Luster: pearly to dull
Cleavage: {100} and {010}
Hardness: 3 - 4
Specific gravity: 3.5 ±
Strongest lines of X-ray powder pattern: VS 8.1, S 4.08, M 6.1

Optical properties:

Orientation	n	Pleochroism	
X	1.654	Very pale yellowish green	
Y	1.664-1.667	Very pale yellowish green	
Z = c	1.664-1.667	Pale greenish yellow	Biaxial negative

2V small; r > v strong

Analysis: Qualitative spectrographic analysis of material from Posey mine.

Major	U Si
Minor	Cu
Trace	Pb Fe Na

Occurrence and associated minerals: As a fracture coating with brochantite. In a high-grade pocket as thin green veins in massive becquerelite.

Identification: X-ray powder pattern, or spectrographic analysis of a pure sample.

Localities:

Posey mine, White Canyon district

FOURMARIERITE

$PbU_4O_{13} \cdot 7H_2O$

Crystal system: Orthorhombic

Habit: Tabular {001} and usually elongated [010]

Physical properties:

Color: red to golden red; also brown
Fluorescence:
Luster: adamantine
Cleavage: {001} perfect
Hardness: 3 - 4
Specific gravity: 6.0
Strongest lines of X-ray powder pattern: S 3.38, S 3.04, S 1.89

Optical properties:

Orientation	n	Pleochroism	
X = c	1.85	Colorless	
Y = b	1.92	Pale yellow	Biaxial negative
Z = a	1.94	Yellow	

2V large; r > v strong

Analysis: Qualitative spectrographic analysis of material from Lucky Strike No. 2 mine

Major	U
Minor	Pb
Trace	Al Mg Si Fe

Occurrence and associated minerals: As an alteration product of pitchblende, with beta-zippeite.

Identification: Orange-red color and test showing more than 10 percent Pb. X-ray powder pattern.

Localities:

Lucky Strike No. 2 mine, San Rafael district
Monument No. 2 mine, Monument Valley district

JOHANNITE

$Cu(UO_2)_2(SO_4)_2(OH)_2 \cdot 6H_2O$

Crystal system: Triclinic; pinacoidal $\bar{1}$

Habit: Prismatic; as coatings and small spheroidal aggregates of lath-like crystals.

Physical properties:

Color: clear, light green. Streak paler.
Fluorescence: none
Luster: vitreous
Cleavage: {100} good. Not brittle
Hardness: $2 - 2\frac{1}{2}$
Specific gravity: 3.32
Strongest lines of X-ray powder pattern: S 7.8, S 6.2, M 3.88.

Optical properties:

	n	Pleochroism	
X	1.577	Colorless	
Y	1.597	Pale yellow	Biaxial positive
Z	1.616	Greenish yellow	$2V \sim 90^\circ$
$r < v$ strong			

Analysis: Qualitative spectrographic analysis of material from Happy Jack mine.

Major	U
Minor	Cu
Trace	Ca Al Mg Si

Occurrence and associated minerals: As wall or fracture coatings with uranopilite, betazippeite, brochantite, and chalcanthite. Coating pitchblende, chalcopyrite, and covellite.

Identification: Color, and tests for Cu and sulfate. X-ray powder pattern.

Localities:

Happy Jack mine, White Canyon district.
Oyler mine, Henry Mountains district.
Frey No. 4 mine, White Canyon district.

LIEBIGITE $Ca_2U(CO_3)_4 \cdot 10H_2O$*

Crystal system: Orthorhombic

Habit: Crystals equant or short prismatic [001], usually indistinct with rounded edges. Commonly as granular or scaly aggregates and thin crusts; also botryoidal.

Physical properties:

Color: light greenish yellow
Fluorescence: bright light green
Luster: vitreous, slightly pearly on the cleavage
Cleavage: {100}
Hardness: $2\frac{1}{2}$ - 3
Specific gravity: 2.41
Strongest lines of X-ray powder pattern: S 8.7, S 6.8, S 5.4
Effervesces in HCl

Optical properties:

Orientation	n	Pleochroism	
X = a	1.497	Nearly colorless	
Y	1.502	Pale yellowish green	Biaxial positive
Z	1.539	Pale yellowish green	

2V 40°, r > v moderate

Analysis: Qualitative spectrographic analysis of material from Pumpkin Buttes

Major	U Ca
Minor	--
Trace	Al Fe Mg Mn Si

Occurrence and associated minerals:

Secondary coating at Pumpkin Buttes. Noted by D'Arcy George at Lusk, Wyo., perhaps as alteration product of uranophane (George, 1949).

Identification:

Optical properties. (Be careful to distinguish from bayleyite).

Localities:

Pumpkin Buttes, Wyo.
Lusk, Wyo.

*The valence state of U in this mineral is being checked (U.S.G.S.)

NOVACEKITE $Mg(UO_2)_2(AsO_4)_2 \cdot 8\text{-}10H_2O$

Crystal system: Tetragonal (or pseudotetragonal)

Habit: Thin tabular {001} . As foliated or scaly aggregates.

Physical properties:

Color: straw yellow
Fluorescence: pale yellow green
Luster: pearly
Cleavage: {001} perfect
Hardness: $2\frac{1}{2}$
Specific gravity: 3.3
Strongest lines of X-ray powder pattern: VS 10.2, S 3.56, M 5.1

Optical properties:

Orientation	n	
X = c		
Y	1.620-1.623	Biaxial negative
Z	1.620-1.623	
2V 0 - 15°		

Analysis: Semiquantitative spectrographic analysis, in percent, of material from Laguna, Grants district.

Over 10	U Si
1-10	As Al Fe
0.1-1	Mg Ca
0.01-0.1	Ti Sr Ba

Occurrence and associated minerals:

Coating on sandstone

Identification:

Color, fluorescence, and test for arsenate distinguish from all but uranospinite $[Ca(UO_2)_2(AsO_4)_2 \cdot 8\text{-}12H_2O]$
X-ray powder pattern.

Localities:

Laguna, Grants district.
This is the only known occurrence in North America, second in world. (found by T. W. Stern, 1952).

PHOSPHURANYLITE $Ca_3(UO_2)_5(PO_4)_4(OH)_4 \cdot 2H_2O$ (?)

Crystal system: Tetragonal or pseudo-tetragonal

Habit: As earthy or scaly coatings or crusts, also as microscopic rectangular plates and laths.

Physical properties:

Color: deep yellow to golden yellow
Fluorescence:
Luster: pearly
Cleavage: {001} perfect but not easily observed.
Hardness: $2\frac{1}{2}$
Specific gravity:
Strongest lines of X-ray powder pattern: S 7.9, M 5.83, M 3.92, M.2.88

Optical properties: variable

	n	Pleochroism	
X or E	1.660-1.690	Colorless to pale yellow	
Y	1.700-1.718	Golden yellow	Usually biaxial negative
Z or O	1.701-1.718	Golden yellow	
2V usually 5°-20° (up to 35°)		r > v strong	

Analysis: Good analyses lacking due to occurrence admixed with clay.

Occurrence and associated minerals:

Disseminated in sandstone or as coating on fracture.

Identification:

X-ray powder pattern. The optical properties are variable and the mineral is usually too fine grained to exhibit a typical crystal form.

Localities:

North Point - Gonway claim, White Canyon district
Posey mine, White Canyon district
Cobalt No. 2 mine, Thompsons district
Cactus Rat mine, Thompsons district

RABBITTITE $Ca_3Mg_3(UO_2)_2(CO_3)_6(OH)_4 \cdot 18H_2O$

Crystal system: Monoclinic

Habit: Fibrous or finely acicular, in clusters of microscopic crystals; elongated [001].

Physical properties:

Color: pale greenish yellow
Fluorescence: weak
Luster: silky
Cleavage: {001}
Hardness: soft
Specific gravity: approx. 2.5
Strongest lines of X-ray powder pattern: S 8.1, M 11.1, M 4.37

Optical properties:

Orientation	n	
X	1.502 ± 0.005	
Y = b	1.508 ± 0.005	Biaxial positive (?)
$Z \wedge c \sim 15^\circ$	1.525 ± 0.003	2V large

Analysis:

Chemical analysis of material from Lucky Strike No. 2 mine (in percent).
Analyst: A. M. Sherwood

CaO	MgO	UO_3	CO_2	H_2O	Total
10.6	9.2	37.4	17.8	24.5	99.5

Occurrence and associated minerals: Efflorescent coating on mine wall near portal; with gypsum, sphaerocobaltite, bieberite and uranium sulfates.

Identification: Habit, optical properties.

Locality: Lucky Strike No. 2 mine, San Rafael district, Uth
Specimen collected by M. E. Thompson. Named for John C. Rabbitt, Chief, Trace Elements Section, U.S.G.S., 1947-1953.

RAUVITE

$CaO \cdot 2UO_3 \cdot 5V_2O_5 \cdot 16H_2O$ (?)

Crystal system:

Habit: As dense slickensided masses, botryoidal crusts, and filmy coatings commonly showing shrinkage cracks.

Physical properties:

Color: brownish red to purplish black. Sometimes dirty orange yellow, streak yellow brown.
Fluorescence: none
Luster: adamantine to waxy. Variable.
Cleavage: none. Brittle
Hardness: soft
Specific gravity: 2.92 (for analyzed material, Monument No. 2 mine)
Strongest lines of X-ray powder pattern: VS 10.5, M (broad) 2.95, M 3.48, M 3.35.

Optical properties: variable

minutely crystalline
n = 1.89-1.95

Biaxial negative (?)

Analysis: Chemical analysis, in percent, of material from Monument No. 2 mine. ADW-9-51 (A. M. Sherwood, analyst)

UO_3	V_2O_5	V_2O_4	CaO	Al_2O_3	Acid insol.	total H_2O	Total
31.49	48.28	1.44	2.76	0.70	0.61	15.49	100.77

Occurrence and associated minerals:

Probably an alteration product of pitchblende and low valence vanadium oxides; also possibly of tyuyamunite. Association and occurrence as for tyuyamunite; not as common as tyuyamunite.

Identification:

X-ray powder pattern. Rauvite is very fine grained, and extremely variable in physical properties.

Localities:

Corvusite mine, Gateway district
Small Spot mine, Gateway district
Monument No. 2 mine, Monument Valley district
Temple Mountain, San Rafael district
Arrowhead mine, Gateway district
Cactus Rat mine, Thompsons dictrict

SCHROECKINGERITE $NaCa_3(UO_2)(CO_3)_3(SO_4)F\cdot 10H_2O$

Crystal system: Hexagonal ?

Habit: As clusters or globular aggregates of scales flattened {0001}, some with a six-sided outline.

Physical properties:

Color: greenish yellow
Fluorescence: strong, greenish yellow
Luster: weakly vitreous, sometimes pearly on (0001)
Cleavage: {0001} perfect
Hardness: $2\frac{1}{2}$
Specific gravity: 2.51
Strongest lines of X-ray powder pattern: S 7.2, M 4.79, M 2.86.
Soluble in water, effervesces in HCl.

Optical properties:

	n	
O	1.542	Uniaxial (?) negative
E	1.489	

Usually biaxial with small and variable 2V, 0-25°

Analysis: Semiquantitative spectrographic analysis, in percent, of material from Red Desert, Wyo.

Over 10	U Ca
0.1-1	F Na
0.01-0.1	Si Al Sr Zn Fe
0.001-0.01	K Ti Mg

Occurrence and associated minerals:

In a near surface deposit in clay at McCoy group, Thompsons district. As coating on mine wall, with bayleyite, at Hideout mine. As alteration product of pitchblende at Crabapple claim.

Identification: X-ray powder pattern. If coarsely crystalline, six-sided plates distinguish it from the other carbonates.

Localities:

McCoy group, Thompsons district
Crabapple claim, Green River district
Hideout (Tiger) mine, White Canyon district

TORBERNITE
and METATORBERNITE

$Cu(UO_2)_2(PO_4)_2 \cdot 8\text{-}12H_2O$
Metatorbernite has $8H_2O$

(Metatorbernite probably more abundant in nature than torbernite)

Crystal system: Tetragonal; ditetragonal-dipyramidal 4/m 2/m 2/m

Habit: Tablets on {001}; often in rosettes or sheaf-like aggregates of irregularly curved and composite crystals.

Physical properties:

Color: pale green to dark green
Fluorescence: not commonly
Luster: vitreous to subadamantine; pearly on {001}
Cleavage: 001 perfect. Rather brittle
Hardness: $2\frac{1}{2}$
Specific gravity: 3.5 - 3.7 Torbernite = 3.2
Strongest lines of X-ray powder pattern-Metatorbernite: VS 8.7, VS 3.68, M 4.93, M 3.49, M 3.35

Optical properties:

	Metatorbernite	Torbernite	
	n	n	Dichroism
O	1.610-1.628 in white light	1.592	Sky blue
E		1.582	Green
	Uniaxial positive (?)		Uniaxial negative

Anom. inter. colors

Analysis: Qualitative spectrographic analysis of material from Markey No. 3 mine

Major	U
Minor	Cu Na Si P
Trace	Ca Mg As Fe

Occurrence and associated minerals: Crystalline aggregates on sandstone with metazeunerite, pyrite, chalcopyrite, chalcanthite, and alunite.

Identification: Color, crystal form, and absence of arsenic.

Locality: Markey No. 3 mine, White Canyon district

TYUYAMUNITE $Ca(UO_2)_2(VO_4)_2 \cdot nH_2O$
$n = ?-12$

Crystal system: Orthorhombic

Habit: As scales and laths flattened {001} and elongated [100]; as radial aggregates. Commonly massive, compact to cryptocrystalline; also pulverulent.

Physical properties:

Color: yellow, greenish yellow
Fluorescence: none
Luster: of crystals adamantine, pearly on {001}, massive material waxy.
Cleavage: {001} perfect, micaceous. {010} and {100} distinct.
Hardness: about 2
Specific gravity: 3.62 on fully hydrated material
Strongest lines of X-ray powder pattern*: S 9.9, M 4.93, M 3.29, M 3.16

Optical properties:

Orientation	n	Pleochroism	
X = c	1.57 calc.	Nearly colorless	
Y = b	1.805±.002	Pale canary yellow	Biaxial negative
Z = a	1.851±.002	Canary yellow	

2V 42° r < v
The indices increase on dehydration

Analysis: Chemical analysis of material from Small Spot mine, Gateway district. Analyst: R. G. Milkey

CaO	UO_3	V_2O_4	V_2O_5	H_2O	Total
6.03	57.08	0.55	20.31	16.03	100.00

Recalculated to 100 percent, after H_2O determination on fully hydrated sample.

Occurrence and associated minerals:

Disseminated in sandstone. Coating joints and fractures, with meta-tyuyamunite, carnotite, rauvite, corvusite, and hewettite. At Mesa No. 1 mine, Shiprock district, with melanovanadite.

Identification: Tyuyamunite and carnotite can be distinguished from other yellow U-minerals by the presence of vanadium; they will turn red-brown when a drop of concentrated HCl is touched to the mineral. X-ray powder pattern is usually necessary to distinguish from carnotite. When coarsely crystalline may be distinguished optically. Fuses much more easily than carnotite.

Localities: Same as for carnotite. Abundant in Grants and Shiprock districts, with little carnotite.

*Note: Too vigorous grinding of tyuyamunite for a powder pattern destroys

METATYUYAMUNITE

$Ca(UO_2)_2(VO_4)_2 \cdot nH_2O$
$n = 6-?$

Crystal system: Orthorhombic

Habit: Same as tyuyamunite

Physical properties:

Color: yellow, greenish yellow
Fluorescence: none
Luster: adamantine to pearly
Cleavage: {001} perfect, micaceous. {010} and {100} distinct.
Hardness: about 2
Specific gravity: 3.81 - 3.93
3 Strongest lines of X-ray powder patterns: S 8.4, M 4.21, M 3.24, M 3.04

Optical properties:

Orientation	n	
X = c	1.67 calc.	
Y = b	1.835 ± 0.002	Biaxial negative
Z = a	1.865 ± 0.002	
2V = 44°		

Analysis: Qualitative spectrographic material from Eastside mines, Shiprock district

Major	U
Minor	Ca V
Trace	Si Al Fe Mg Pb Nb

Occurrence and associated minerals:

Same as for tyuyamunite. A dehydration product of tyuyamunite, found at or near surface deposits.

Identification:

X-ray powder pattern

Localities:

Same as for tyuyamunite.
Especially abundant near Haystack Mountain and Laguna, Grants district.

URANINITE (Pitchblende) — Ideally UO_2 (commonly contains UO_3)

Crystal system: Isometric; hexoctahedral $4/m\ \bar{3}\ 2/m$ (?)

Habit: Massive. Commonly replaces cellular structure of wood.

Physical properties:

Color: black
Fluorescence: none
Luster: submetallic to pitchlike or greasy, and dull.
Cleavage: fracture uneven to conchoidal. Brittle.
Hardness: 5 - 6
Specific gravity: Uraninite 8-10. Colloform pitchblende <8.5
Strongest lines of X-ray powder pattern: VS 3.14, S 1.65, S 1.93

Optical properties: Usually opaque. Transparent in very thin splinters.

Analysis: Qualitative spectrographic analysis of pitchblende from Juniper claim.

Major	U
Minor	Si Ca
Trace	V Fe Na Mn

Spectrographic analysis of uraninite from Happy Jack shows no element except uranium over 1 percent.

Occurrence and associated minerals: In unoxidized ore in mines located at the heads of steep canyons or under a protective cover. In vanadiferous ore associated with coffinite and low valence vanadium oxides, montroseite, doloresite, etc., and alters to rauvite, carnotite and tyuyamunite and rarely to becquerelite and uranophane. In non-vanadiferous ores, as at Happy Jack mine, with sulfides of Fe, Cu, Pb, Zn, Co, and Ni. Alters to becquerelite, fourmarierite, uranopilite, johannite, betazippeite, schroeckingerite and uranophane.

Identification:

Black, heavy, very radioactive, commonly with yellow alteration products. X-ray powder pattern.

Uraninite (continued):

Localities:

Morrison formation

Grey Dawn mine	Paradox district
Juniper mine	Thompson district
Corvusite mine	Gateway district
Blue Jay claim	Moab district

Shinarump conglomerate

Camp Bird No. 13 mine	San Rafael district
Lucky Strike No. 2 mine	San Rafael district
Marshbank Canyon mine	San Rafael district
Pay Day mine	San Rafael district
Rex No. 2 mine	San Rafael district
Crabapple claim	Green River district
Shinarump No. 1 mine	Green River district
Oyler mine	Henry Mountains district
Frey No. 4 mine	White Canyon district
Happy Jack mine	White Canyon district
Hideout mine	White Canyon district
Markey No. 3 mine	White Canyon district
Notch mine	White Canyon district
White Canyon No. 1 mine	White Canyon district
Cato Sells mine	Monument Valley district
Monument No. 2 mine	Monument Valley district
Skyline mine	Monument Valley district

Others

Haystack Mountain area	Grants district
Placerville, Colo.	Placerville district
Huskon No. 2 claim	Little Colorado district

URANOPHANE

$Ca(UO_2)_2Si_2O_7 \cdot 6H_2O$

Crystal system: Orthorhombic

Habit: Minute prismatic in radiated or stellate aggregates. Commonly massive and very finely fibrous.

Physical properties:

Color: yellow, orange yellow, streak paler
Fluorescence: none
Luster: pearly to greasy
Cleavage: $\{100\}$
Hardness: 2 - 3
Specific gravity: 3.8 - 3.9
Strongest lines of X-ray powder pattern: S 7.9, S 3.95, M 4.82, M 2.98, M 2.92

Optical properties:

Orientation	n	Pleochroism	
X = a	1.642-1.645	Colorless	
Y = b	1.665-1.667	Pale canary yellow	Biaxial negative
Z = c	1.667-1.670	Canary yellow	

2V 32°; r < v marked to extreme

Analysis: Partial chemical analysis by A. M. Sherwood, TWC-1263, material from Lusk, Wyo.

H_2O	SiO_2	CaO	UO_3	Total
13.02	12.66	8.53	65.24	99.45

Occurrence and associated minerals: Disseminated in sandstone at Pumpkin Buttes. At Grants coating limestone. At Cato Sells on pitchblende with becquerelite.

Identification: Index of refraction and absence of Cu distinguish it from cuprosklodowskite.

Localities: Grants district; Cato Sells mine, Monument Valley district. Pumpkin Buttes and Lusk, Wyo.

URANOPILITE $(UO_2)_6(SO_4)(OH)_{10} \cdot 12H_2O$

Crystal system: Probably monoclinic

Habit: As velvety incrustations and globular or reniform masses composed of microscopic needles or laths elongated [001] and flattened {010}

Physical properties:

Color: bright yellow
Fluorescence: bright yellow green
Luster: silky
Cleavage: {010} perfect
Hardness:
Specific gravity: 3.7 - 4.0
Strongest lines of X-ray powder pattern: S 7.1, S 9.1, S 4.23

Optical properties:

Orientation	n	
X	1.623	
$Y \wedge c = 18^{\circ}$	1.625	
Z	1.634	Biaxial positive

2V rather large (Na); 0° for some wavelengths
$r < v$ extreme; also $r > v$

Analysis: Qualitative spectrographic analysis of material from Happy Jack mine

Major	U
Minor	--
Trace	Si Ca Co

Occurrence and associated minerals: Abundant in Happy Jack mine as wall coatings with johannite and betazippeite.

Identification: May be distinguished from zippeite and betazippeite by optical properties. From johannite by test for Cu.

Localities: Happy Jack mine, White Canyon district.

UVANITE* $2UO_3 \cdot 3V_2O_5 \cdot 15H_2O$ (?)

Crystal system: Probably orthorhombic

Habit: As minutely crystalline masses and coatings.

Physical properties:

Color: brownish yellow
Fluorescence: none
Luster:
Cleavage: 2 pinacoidal cleavages
Hardness:
Specific gravity:
Strongest lines of X-ray powder pattern: S 2.96, Mb 5.9, Mb 5.3, M 1.71

Optical properties:

	n	Pleochroism	
X	1.817	Light brown	Biaxial positive
Y	1.879	Dark brown	
Z	2.057	Greenish yellow	
2V = 52°			

Analysis: W. T. Schaller, Analyst

CaO	UO_3	V_2O_5	H_2O	Rem.	Total
1.73	39.60	37.70	18.28	1.69	99.00

Occurrence and associated minerals: Associated with carnotite, rauvite, hewettite, metatorbernite, hyalite and gypsum in asphaltic sandstone at Temple Mountain, San Rafael district.

Identification: X-ray powder pattern (?). May be related to rauvite as an alteration product of tyuyamunite. Poorly defined mineral. Needs further work.

Locality: Temple Mountain, San Rafael district, Utah.

*Data from Dana system, 7th ed., vol. 2, p. 1056, except X-ray powder pattern. No new localities found.

METAZEUNERITE $Cu(UO_2)_2(AsO_4)_2 \cdot 8H_2O$

(fully hydrated zeunerite probably rare in nature)

Crystal system: Tetragonal; ditetragonal dipyramidal 4/m 2/m 2/m

Habit: Tabular {001} and resembling torbernite.

Physical properties:

Color: grass green to emerald green
Fluorescence: yellow green
Luster: vitreous, pearly on {001}
Cleavage: {001} perfect. {100} distinct.
Hardness: 2 - $2\frac{1}{2}$
Specific gravity: 3.6
Strongest lines of X-ray powder pattern: S 8.7, S 3.68, M 5.44, M 4.98

Optical properties:

	n	Dichroism	
O	1.643-1.651	Grass green	Uniaxial negative
E	1.623-1.635	Pale green	

Indices vary with content of zeolitic water.

Analysis: Qualitative spectrographic analysis of mineral from Markey No. 3 mine.

Major	U
Minor	Cu As Si
Trace	Co Fe Na Ca Pb

Occurrence and associated minerals: Coating joints and fracture surfaces.

Identification: Test for Cu and As, with green color, and habit as square plates.

Localities:

Markey No. 3 mine, White Canyon district
Pay Day mine, San Rafael district
Monument No. 2 mine, Monument Valley district

BETAZIPPEITE*

$(UO_2)_2(SO_4)(OH)_2 \cdot 4H_2O$

Crystal system: Monoclinic (?)

Habit: Microscopic crystalline aggregates; rarely in blades or flakes.

Physical properties:

Color: orange yellow
Fluorescence: green
Luster: of aggregates dull to silky
Cleavage: probably {010} perfect
Hardness:
Specific gravity: > 3.2
Strongest lines of X-ray powder pattern: S 7.1, M 3.13, M 3.49

Optical properties:

Orientation	n	Pleochroism
X = b	1.630	Nearly colorless
Y	1.689	Pale yellow to orange yellow
$Z \wedge c = 40^\circ$	1.739	Pale yellow to orange yellow

2V large (80°)
Indices variable — Biaxial negative

Analysis: Chemical analysis of material from Oyler mine
Analyst: A. M. Sherwood

UO_3	SO_3	H_2O	CaO	Total
78.78	10.42	11.20	0.07	100.47

Occurrence and associated minerals: In mines as wall coatings, as joint and fracture coatings. Alone, or with johannite, uranopilite, or pitchblende.

Identification: A sulfate containing no Cu. May be distinguished optically from uranopilite. Distinguished from zippeite by X-ray powder pattern.

Localities:

Happy Jack mine, White Canyon district
Oyler mine, Henry Mountains district
Lucky Strike No. 2 mine, San Rafael district
Sodaroll claim, Green River district

*This name is tentative because zippeite is still poorly defined and we have not proved this to be a polymorph of zippeite.

Table 1.--Optical properties of uranium minerals

<u>Uniaxial positive group</u>

Indices and pleochroism nE	nO	Name and composition	System and habit	Cleavage	Color	Remarks
1.540 Pale yellow	1.520 Colorless	Andersonite $Na_2Ca(UO_2)(CO_3)_3 \cdot 6H_2O$	Hex. R. minute pseudo cubic crystals		Bright yellow green. Fluoresces bright green	Effervesces with HCl
	1.610-1.628	Metatorbernite $Cu(UO_2)_2(PO_4)_2 \cdot 8H_2O$	Tet. Tablets on {001}	{001} perfect	Pale to dark green	

Table 1.--Optical properties of uranium minerals--Continued

Uniaxial negative group

Indices and pleochroism nE	nO	Name and composition	System and habit	Cleavage	Color	Remarks
1.489	1.542	Schroeckingerite $NaCa_3(UO_2)(CO_3)_3(SO_4)F \cdot 10H_2O$	Hex. ?	{0001} perfect	Greenish-yellow. Fluoresces strong greenish yellow	Soluble in H_2O effervesces in HCl
1.559 Colorless	1.574 Pale green-yellow	Saléeite $Mg(UO_2)_2(PO_4)_2 \cdot 8\text{-}10H_2O$	Tet. tablets on {001}	{001} perfect {010} , {110} indistinct	Yellow to lemon yellow	
1.582 Green	1.592 Sky blue	Torbernite $Cu(UO_2)_2(PO_4)_2 \cdot 8\text{-}12H_2O$	Tet. tablets on {001}	{001} perfect	Pale to dark green	
1.623-1.635 Pale green	1.643-1.651 Grass green	Metazeunerite $Cu(UO_2)_2(AsO_4)_2 \cdot 8H_2O$	Tet. tablets on {001}	{001} perfect {100} distinct	Grass green to emerald green	
1.66-1.69 Colorless to pale yellow	1.701-1.718 Golden yellow	Phosphuranylite $Ca_3(UO_2)_5(PO_4)_4(OH)_4 \cdot 2H_2O$	Tet. or pseudo-tet.	{001} perfect; not easily observed	Deep yellow to golden yellow	

Table 1.--Optical properties of uranium minerals--Continued

Biaxial positive group

Indices and composition nX	nY	nZ	Name and composition	2V disp.	Optical orientation	System habit	Cleavage	Color
1.497 Nearly colorless	1.502 Pale yellowish green	1.539 Pale yellowish green	Liebigite $Ca_2U(CO_3)_4 \cdot 10H_2O$	$2V=40^\circ$ $r > v$ moderate	X = a	Orth. equant or short prismatic	{100}	Light greenish yellow
1.502	1.508	1.525	Rabbittite $Ca_3Mg_3(UO_2)_2(CO_3)_6(OH)_4 \cdot 18H_2O$	2V large	Y = b $Z \wedge c \sim 15^\circ$	Mon. acicular	{001}	Pale greenish yellow
1.577 Colorless	1.597 Pale yellow	1.616 Greenish yellow	Johannite $Cu(UO_2)_2(SO_4)_2(OH)_2 \cdot 6H_2O$	$2V \sim 90^\circ$ $r < v$ strong		Tricl. prismatic	{100} good	Clear, light green
1.623	1.625	1.634	Uranopilite $(UO_2)_6(SO_4)(OH)_{10} \cdot 12H_2O$	2V large for Na; 0°-some wave-lengths	$Y \wedge c = 18^\circ$	Mon. (?)	{010} perfect	Bright yellow. Fluoresces bright yellow green
1.817 Light brown	1.879 Dark brown	2.057 Greenish yellow	Uvanite $2UO_3 \cdot 3V_2O_5 \cdot 15H_2O$ (?)	2V 52°		Orth. (?)	Two pina-coidal	Brownish yellow
1.455 Pinkish	1.490 Pale yellow	1.500 Pale yellow	Bayleyite $Mg_2(UO_2)(CO_3)_3 \cdot 18H_2O$	$2V = 30^\circ$	$X \wedge c = 14^\circ$ Z = b	Mon. pris.		Sulfur yellow
1.465 Colorless	1.51 Yellow	1.540 Yellow	Swartzite $CaMg(UO_2)(CO_3)_3 \cdot 12H_2O$	$2V = 40^\circ$ (calc.)		Mon. pris.		Green fluoresces green

Table 1.--Optical properties of uranium minerals--Continued

Biaxial negative group

Indices and pleochroism nX	nY	nZ	Name and composition	2V disp.	Optical orientation	System habit	Cleavage	Color
1.559	1.570	1.570	Saléeite $Mg(UO_2)_2(PO_4)_2 \cdot 8\text{-}10H_2O$	2V = 61° r > v strong		Tetr. square plates	{001} perfect {010} and {110} indistinct	Yellow, lemon yellow
1.56 ± Pale yellow	1.574 Deep yellow	1.580 Deep yellow	Bassetite $Fe(UO_2)_2(PO_4)_2 \cdot 8H_2O$	2V ~ 52°	X = b Z ∧ c = 40°	Mon., pseudo-orth.	{010} perfect	Yellow
1.553 Pale yellow	1.575 Yellow	1.577 Yellow	Autunite $Ca(UO_2)_2(PO_4)_2 \cdot 10\text{-}12H_2O$	2V = 10°-30° r > v strong	X = c	Tetr. square plates	{001} perfect {100} indistinct	Lemon yellow to pale green. Fluoresces yellow green strong.
Indices vary with water content								
	1.603 Yellow	1.603 Yellow	Meta-autunite I $Ca(UO_2)_2(PO_4)_2 \cdot 2\frac{1}{2}\text{-}6\frac{1}{2}H_2O$	2V small to medium	X = c	Tetr.	{001} perfect	Same as autunite
Indices vary with water content								
	1.620-1.623	1.620-1.623	Novacekite $Mg(UO_2)_2(AsO_4)_2 \cdot 8\text{-}10H_2O$	2V = 0°-15°	X = c	Tetr. square plates	{001} perfect	Straw yellow. Fluoresces pale yellow green.
1.654 Very pale greenish yellow	1.664-1.667 Pale greenish yellow	1.664-1.667 Pale greenish yellow	Cuprosklodowskite $Cu(UO_2)_2Si_2O_7 \cdot 6H_2O$	2V small r > v strong	Z = c	Orth.	{100} and {010}	Pale yellow green, yellow in thin flakes.

Table 1.--Optical properties of uranium minerals--Continued

Biaxial negative group

Indices and pleochroism nX	nY	nZ	Name and composition	2V disp.	Optical orientation	System habit	Cleavage	Color
1.642-1.645 Colorless	1.665-1.667 Pale yellow	1.667-1.670 Canary yellow	Uranophane $Ca(UO_2)_2Si_2O_7 \cdot 6H_2O$	2V = 32° r < v marked to extreme	X = a, Y = b, Z = c	Orth. prism.	{100}	Yellow, orange yellow
1.650 Colorless	1.68 Pale greenish yellow	1.710 Greenish yellow	Soddyite $(UO_2)_5(SiO_3)_2(OH)_6 \cdot 3H_2O$	2V near 90° r > v strong	X = a, Y = b, Z = c	Orth. prism.	{010} and {100} ?	Yellow, greenish yellow
1.66-1.67 Colorless	1.67-1.70 Lemon yellow	1.68-1.71 Lemon yellow	Beta-uranophane $Ca(UO_2)_2Si_2O_7 \cdot 6H_2O$	2V = 40°-70° r > v strong	X = b	Mon. acicular	{010} and {100} perfect	Yellow, yellow green
1.630 Nearly colorless	1.689 Pale yellow to orange yellow	1.739 Pale yellow to orange yellow	Betazippeite $(UO_2)_2(SO_4)(OH)_2 \cdot 4H_2O$	2V large (80°)	X = b $Z \wedge c$ = 40°	Mon. (?)	{010} perfect	Orange yellow
1.690 Colorless	1.714 Lemon yellow	1.735 Lemon yellow	Schoepite $UO_3 \cdot 2HO_2$	2V = 89° r > v	X = c, Y = b, Z = a	Orth. tabular {001}	{001} perfect	Sulfur to citron yellow
1.660-1.690 Colorless to pale yellow	1.700-1.718 Golden yellow	1.701-1.718 Golden yellow	Phosphuranylite $Ca_3(UO_2)_5(PO_4)_4(OH)_4 \cdot 2H_2O$ (?)	2V = 5°-20° (35°) r > v strong	X = c	Tet. or pseudo-tet.	{001} perfect	Deep yellow to golden yellow

Table 1.--Optical properties of uranium minerals--Continued

Biaxial negative group

Indices and pleochroism nX	nY	nZ	Name and composition	2V disp.	Optical orientation	System habit	Cleavage	Color
1.57 Calc. nearly colorless	1.805 Pale canary yellow	1.851 Canary yellow	Tyuyamunite $Ca(UO_2)_2(VO_4)_2 \cdot nH_2O$ n=?-12	$2V = 42^\circ$ $r < v$	X = c, Y = b, Z = a	Orth.	{001} perfect {010} {100} distinct	Yellow, greenish yellow
1.735 Colorless	1.820 Light yellow	1.830 Dark yellow	Becquerelite $2UO_3 \cdot 3H_2O$	$2V = 31^\circ$ $r > v$ marked	X = c, Y = b, Z = a	Orth. tabular {001}	{001} perfect also {101}	Amber to brownish yellow
1.67 Calc.	1.835	1.865	Metatyuyamunite $Ca(UO_2)_2(VO_4)_2 \cdot nH_2O$ n=6-?	$2V = 44^\circ$	X = c, Y = b, Z = a	Orth.	{001} perfect {010} {100} distinct	Yellow, greenish yellow
	1.89-1.95		Rauvite $CaO \cdot 2UO_3 \cdot 5V_2O_5 \cdot 16H_2O$ (?)			Minutely crystal-line		Yellow, brownish red
1.85 Colorless	1.92 Pale yellow	1.94 Yellow	Fourmarierite $PbU_4O_{13} \cdot 7H_2O$	2V large $r > v$ strong	X = c, Y = b, Z = a	Orth. tabular {001}	{001} perfect	Red to golden red, brown
1.750 Nearly colorless	1.925-2.06 Canary yellow	1.950-2.08 Canary yellow	Carnotite $K_2(UO_2)_2(VO_4)_2 \cdot 1\text{-}3H_2O$	$2V = 40^\circ$-50°	$X \sim c$, $Y \wedge a \sim 14^\circ$, $Z = b$	Mon.	{001} perfect	Lemon yellow, greenish yellow (orange)

VANADIUM MINERALS

Description of identified minerals (uranyl vanadates under uranium minerals)

The vanadium minerals described in the following pages (except the uranyl vanadates described under uranium minerals) include all those studied by the writers and thought to be valid species from the Colorado Plateaus, including one mineral, fervanite (Hess and Henderson, 1931) for which no new localities have been found.

Classified according to chemical composition the described minerals are:

Oxides	Montroseite $VO(OH)$ or $(V,Fe)O(OH)$
	Navahoite $V_2O_5 \cdot 2\text{-}3H_2O$
	Doloresite probably V^{+3} and V^{+4}, hydrated
	Lumsdenite $V_2O_3 \cdot V_2O_4 \cdot H_2O$
Vanadates	Calciovolborthite $(Cu,Ca)_2(VO_4)(OH)$
	Volborthite $Cu_3(VO_4)_2 \cdot 3H_2O$ (?)
	(Fervanite $Fe_4V_4O_{16} \cdot 5H_2O$) type specimen only
	Steigerite $Al_2(VO_4)_2 \cdot 6\frac{1}{2}H_2O$
	Rossite $CaV_2O_6 \cdot 4H_2O$
	Metarossite $CaV_2O_6 \cdot 2H_2O$
	Pascoite $Ca_2V_6O_{17} \cdot 11H_2O$
	Hummerite $K_2Mg_2V_{10}O_{28} \cdot 16H_2O$
	Melanovanadite $2CaO \cdot 2V_2O_4 \cdot 3V_2O_5 [(H_2O)\ ?]$
	Hewettite $CaV_6O_{16} \cdot 3\text{-}9H_2O$
	Metahewettite $CaV_6O_{16} \cdot 3\text{-}9H_2O$ (?)
	Sodium analogue of hewettite $Na_2V_6O_{16} \cdot 3H_2O$
	Corvusite $V_2O_4 \cdot 6V_2O_5 \cdot nH_2O$ (?) (similar to Fernandinite $CaO \cdot V_2O_4 \cdot 5V_2O_5 \cdot 14H_2O$)
Silicates	Roscoelite $(Al,V)_2(AlSi_3)(K,Na)O_{10}(OH,F)_2$
	Vanadium hydromica

Two species originally described from the Colorado Plateaus, vanoxite (Hess, 1925) and pintadoite (Hess and Schaller, 1914) are omitted. The name vanoxite has been used for a variety of vanadium minerals. The composition of vanoxite had been calculated from a rock analysis of sandstone ore from

Jo Dandy mine, Colo., after deducting quartz, gypsum, tyuyamunite, and limonite. The "type" specimen in the U. S. National Museum came from Wild Steer mine, Colo., and was not analyzed. X-ray powder patterns of this type specimen are similar to those of corvusite and fernandinite. The black crystals observed in thin sections (Hess, 1925, p. 65) probably were montroseite. The description of pintadoite is so incomplete that no more of the mineral can be recognized. No X-ray pattern could be obtained from the National Museum sample of pintadoite which appears as a faint green stain on sandstone.

In 1950 when X-ray powder patterns were made for "standards" of all the vanadium minerals, it was found that corvusite (U. S. Nat. Mus. type specimen) and fernandinite (W. T. Schaller's type specimen) give similar patterns. The chief difference between the minerals seems to be the presence of several percent of calcium in fernandinite and little or none in corvusite.

Another vanadium mineral that may occur on the Plateaus although it has not been identified yet is sincosite $CaV_2O_2(PO_4)_2 \cdot 5H_2O$.

CORVUSITE $V_2O_4 \cdot 6V_2O_5 \cdot nH_2O$ (?)

(Resembles fernandinite $CaO \cdot V_2O_4 \cdot 5V_2O_5 \cdot 14H_2O$)

Crystal system:

Habit: Massive. Very finely crystalline. Slickensided surfaces appear fibrous.

Physical properties:

Color: blue black to greenish black. Weathers brown
Fluorescence: none
Luster: variable
Cleavage: fracture conchoidal
Hardness: $2\frac{1}{2}$ - 3
Specific gravity: 2.82 (?)
Strongest lines of X-ray powder pattern: VS 12.1, M 3.47, W 1.83, VW 1.95

Optical properties: Opaque except on thin edges; biaxial, 2 indices above 1.90, high birefringence.

Analysis: Qualitative spectrographic analysis of X-ray spindle of type material.

Major	V
Minor	Fe
Low minor	Si Al

Occurrence and associated minerals: Impregnating sandstone and siltstone. Masses of relatively pure material are commonly slickensided. May be an alteration product of low valence vanadium oxides. Associated with carnotite, tyuyamunite, rauvite, and hewettite.

Identification: In hand specimen, black, commonly with blue-black iridescence, and greenish streak.
X-ray powder pattern resembles that of fernandinite. (The corvusite-fernandinite problem is being investigated, June 1953).

Localities:

Abundant in mines in Thompsons, Gateway, Uravan, Paradox, Bull Canyon, and Slick Rock districts, in the Temple Mountain part of the San Rafael district, and at Monument No. 2 mine in Monument Valley district.

DOLORESITE (probably V^{+3} and V^{+4}, hydrated)

Crystal system:

Habit: Massive, fibrous, radial aggregates, in veinlets

Physical properties:

Color: nearly black with bronze tint; bronze in polished section
Fluorescence: none
Luster: adamantine
Cleavage: perfect in one direction
Hardness:
Specific gravity: 3.25
Strongest lines of X-ray powder pattern: S 4.72, S 2.47, M 3.83, M 3.17

Optical properties: opaque

Analysis:

Occurrence and associated minerals: Occurs with coffinite and lumsdenite* at La Sal No. 2 mine and with clausthalite and pitchblende at Corvusite mine. (Doloresite was first found by L. R. Stieff and T. W. Stern in August 1951 at La Sal No. 2 mine; named from Dolores Rives; report in preparation.)

Identification: X-ray powder pattern, not as black as montroseite, heavier than melanovanadite.

Localities:

La Sal No. 2 mine, Gateway district
Utex mine, Monticello district
Corvusite mine, Gateway district

*Another new mineral, lumsdenite, was found with doloresite at La Sal No. 2 mine. It is known only from the X-ray powder pattern and single crystal X-ray photographs taken from a few microscopic crystals. The intensities are consistent with an atomic arrangement that contains elements of the montroseite structure and the rutile-type structure of artificial VO_2. It is orthorhombic and its formula is probably $V_2O_3 \cdot V_2O_4 \cdot H_2O$ (personal communication, H. T. Evans, U.S.G.S.). Named from Lumsden group of mines, in which La Sal No. 2 mine is located, at the head of Lumsden Canyon, Colo.

FERVANITE* $Fe_4V_4O_{16} \cdot 5H_2O$

Crystal system: Probably monoclinic

Habit: Parallel fibrous aggregates

Physical properties:

Color: golden brown
Fluorescence:
Luster: brilliant
Cleavage:
Hardness:
Specific gravity:
Strongest lines of X-ray powder pattern (taken with Fe $K\alpha$ radiation):
S 8.83, S 6.44, M 2.92

Optical properties:

	$\underline{n}$	
X	2.186 ± 0.005	
Y	2.222 ± 0.005	Biaxial negative
Z	2.224 ± 0.005	

2V very small

Analysis: Chemical analysis of type material from Gypsum Valley.
E. P. Henderson, analyst.

Fe_2O_3	V_2O_5	$H_2O(-)$	Total
41.89	46.10	12.01	100.00

Recalculated after deducting 9.40 percent insol. and 7.34 percent gypsum.

Occurrence and associated minerals:

Coatings and fracture fillings; with gypsum, metahewettite, carnotite, and various black vanadium minerals.

Identification: Lighter brown color and higher index of refraction than fibrous hewettite.

Localities:

Polar Mesa, Gateway district, and in Gypsum Valley district.

*All data except X-ray powder pattern from Dana, 7th ed., vol. 2, p. 1049. No new occurrences of this mineral found by writers.

HEWETTITE $CaV_6O_{16} \cdot 3\text{-}9H_2O$

Crystal system: Monoclinic*

Habit: As nodular aggregates and coatings of fibers or microscopic needles; elongated {010}

Physical properties:

Color: deep red; less vivid on exposure in dry atmosphere
Fluorescence: none
Luster: silky, adamantine
Cleavage:
Hardness: soft
Specific gravity: 2.55
Strongest lines of X-ray powder pattern: VS 8.2, M 3.06, M 2.29, M 2.20

Optical properties:

Orientation	n	Pleochroism	
X	1.77	Light orange yellow	
Y	2.18	Light orange yellow	
Z = b	2.35-2.4	Dark red	Biaxial negative
2V medium			Indices probably vary according to water content.

Analysis: Chemical analysis of material from Jo Dandy group. Analyst: A. M. Sherwood

SiO_2	Al_2O_3	CaO	MgO	V_2O_4	V_2O_5	SO_3	H_2O	Total
0.46	0.13	6.38	1.61	8.07	73.15	0.01	10.12	99.93

Occurrence and associated minerals:

As coatings and fracture fillings; alteration product of less oxidized vanadium minerals--montroseite, corvusite. Associated with vanadium clay, rauvite, steigerite, navahoite, carnotite, tyuyamunite, etc.

Identification:

Color except from sodium analogue of hewettite. The nature of the difference, if any, between hewettite and metahewettite is not fully understood. The structures of these minerals are being investigated by W. H. Barnes, National Research Council, Canada.

Localities: Jo Dandy mine, Bull Canyon district; Opera Box mine, Bull Canyon district; Matchless mine, Gateway district; Monument No. 2 mine, Monument Valley district.

*Barnes, W. H., and Qurashi, M. M., 1952, p. 414.

METAHEWETTITE $CaV_6O_{16} \cdot 3\text{-}9H_2O$ (?)

Crystal system: Monoclinic*

Habit: As pulverulent masses composed of microscopic tablets or laths, and as parallel or radially fibrous to bladed aggregates or coatings; elongated $\{010\}$.

Physical properties:

Color: deep red; less vivid on exposure in dry atmosphere
Fluorescence: none
Luster: dull to somewhat silky
Cleavage:
Hardness: soft
Specific gravity: 2.51-2.94, varies with water content
Strongest lines of X-ray powder pattern: S 8.1, M 3.08, W 1.80

Optical properties:

Orientation	n(Li)	Pleochroism	
X	1.70	Light orange yellow	
Y	2.10	Deep red	Biaxial negative
Z = b	2.23	Deeper red	Indices probably vary according to water content.
2V 52° calc			

Analysis: Qualitative spectrographic analysis of type material

Major	V
Minor	Si Ca Fe Al
Trace	K Mg Na Nb Ba Pb

Occurrence and associated minerals: In highly oxidized ore; same as for hewettite.

Identification: Color, except from hewettite, and sodium analogue of hewettite. U. S. Nat. Mus. type material gives same X-ray pattern as hewettite.

Locality:

Yellow Cat group and Cactus Rat group, Thompsons district.

*Barnes, W. H., and Qurashi, M. M., 1952, p. 411.

HUMMERITE* $K_2Mg_2V_{10}O_{28} \cdot 16H_2O$

Crystal system: Triclinic

Habit: Finely crystalline aggregates, or massive. Crystals formed by evaporation of water solution are elongated parallel to {001} or tabular parallel to {100}.

Physical properties:

Color: bright orange. Streak yellow
Fluorescence: none
Luster: subadamantine on fresh surface, dulls on exposure.
Cleavage: {010} and {001} distinct. Brittle.
Hardness: about 2
Specific gravity: 2.55
Strongest lines of X-ray powder pattern: VS 8.3, M 9.7, M 2.76, W 7.5

Optical properties:

Orientation	n	
X	1.771 ± 0.003	
Y	1.812 ± 0.003	Biaxial negative
$Z \wedge c = 32^\circ$	1.833 ± 0.003	

$2V = 70^\circ$; dispersion strong $r > v$

Analysis: Chemical analysis of recrystallized material from North Star mine

V_2O_5	V_2O_4	MgO	K_2O	Total H_2O	Total
64.33	1.36	5.44	6.96	21.88	99.97

Occurrence and associated minerals: As vein fillings with columnar structure perpendicular to the vein wall (similar to occurrence of gypsum in seams). Also as granular crusts coating or cementing sandstone, in highly oxidized ore zone.

Associated with hewettite and vanadium clay.

Identification: X-ray powder pattern or spectrographic analysis necessary to distinguish from pascoite.

Localities: Jo Dandy group, Bull Canyon district; North Star mine, Uravan district, Mesa No. 1 mine, Shiprock district and Whitney mine, Uravan district.

*First collected by Stieff, Stern, and Girhard in 1949 from the Hummer workings of Jo Dandy group of mines and studied by Weeks, Cisney, and Sherwood (1950). Named from the first locality.

MELANOVANADITE

$2CaO \cdot 2V_2O_4 \cdot 3V_2O_5$
probably contains H_2O*

Crystal system: Triclinic*

Habit: Velvety, divergent bunches of crystals elongated [001] the prism faces usually rounded or striated.

Physical properties:

Color: black; streak dark reddish brown
Fluorescence: none
Luster: almost submetallic
Cleavage: {010} perfect. Brittle
Hardness: $2\frac{1}{2}$
Specific gravity: commonly less than 3.0
Strongest lines of X-ray powder pattern: VS 8.5, S 4.21, M 2.99

Optical properties:

Orientation	n	Pleochroism	
X	1.73	Light reddish brown	
Y $\wedge$ c 15°	1.96	Deep reddish brown	Biaxial negative
Z	1.98	Dark reddish brown	
2V medium			

Analysis: Qualitative spectrographic analysis of material from Mesa No. 1 mine, Ariz.

Major	V
Minor	Ca Fe
Trace	Si Al Na Mg

Occurrence and associated minerals:

At Mesa No. 1 mine, coarsely crystalline aggregates in clay with marcasite. At Mesa No. 5 mine, impregnating sandstone. At Juniper mine rosettes on fracture in sandstone. In oxidized ore associated with tyuyamunite, pascoite, hummerite, and rossite. The first occurrence of melanovanadite in the U. S. was at Mesa No. 1 mine found by A. Rosenzweig of A.E.C. in 1951.

Identification: Distinguished from montroseite and doloresite by pleochroism and specific gravity.

Localities: Mesa No. 1 mine, Shiprock district, Mesa No. 5 mine, Shiprock district, and Juniper mine, Thompsons district.

*Barnes, W. H., and Qurashi, M. M., 1952, p. 417.

MONTROSEITE* $VO(OH)$ or $(V,Fe)O(OH)$

Crystal system: Orthorhombic, dipyramidal

Habit: Microscopic bladed and prismatic crystals. Also in compact crystalline aggregates.

Physical properties:

Color: black; streak black
Fluorescence: none
Luster: submetallic
Cleavage: perfect parallel $\{100\}$. Brittle
Hardness: soft
Specific gravity: 4.0 meas. 4.1 calc.
Strongest lines of X-ray powder pattern: S 4.29, M 2.65, W 3.39

Optical properties: Opaque (even on thin edges).

Analysis: Partial chemical analysis of 120 mg of material from Bitter Creek mine.

FeO	V_2O_3	V_2O_4	H_2O	Total
8.8	10.5	72.3	5.0	96.6

Occurrence and associated minerals: Occurs in unoxidized, black, uranium-vanadium ore, impregnating sandstone or as relatively pure masses in sandstone, associated with pyrite, barite, and coffinite (?). In oxidized zone alters to corvusite and hewettite.

Identification: X-ray powder pattern. Distinguished from doloresite by blacker color and from melanovanadite by greater density and opacity.

Localities: Bitter Creek mine, Uravan district; Whitney mine, Uravan district; Matchless mine, Gateway district; Juniper mine, Thompsons district; and Rex No. 2 mine, Temple Mountain portion of San Rafael district.

*First collected by Stieff, Stern, and Girhard in 1949 from Bitter Creek mine. Preliminary study by Weeks, Cisney, and Sherwood (1950). Crystal structure study by H. T. Evans in 1952 showed the correct formula to be as given above. Named from Montrose County, Colo., where Bitter Creek mine is located.

NAVAHOITE

$V_2O_5 \cdot 2\text{-}3H_2O$

Crystal system: Monoclinic (?)

Habit: Fibrous, silky

Physical properties:

Color: dark brown; brown streak
Fluorescence: none
Luster: silky
Cleavage: .
Hardness: soft
Specific gravity: 2.56 measured
Strongest lines of X-ray powder pattern: VS 12.1, M 10.7, M 2.91

Optical properties:

Orientation	n	Pleochroism	
X	1.905 ± 0.003	Greenish brown	
Y	~ 2.02	Light greenish brown	
Z parallel to fiber length	> 2.02	Dark brown	Biaxial negative

Analysis: Of sample from Arizona (AW-119-52) A. M. Sherwood, analyst.

V_2O_5	V_2O_4	Fe_2O_3	CaO	SiO_2	H_2O	Total
71.68	3.08	3.58	0.22	1.20	20.3	100.06

Occurrence and associated minerals: Fibrous coating in crescent shape above and below pebbles in conglomerate; cross fibers 1/16 to 1/8 inch long filling fractures in sandstone or siltstone; with rauvite, corvusite, and steigerite.

Identification: Darker brown than hewettite. X-ray powder pattern.

Locality:

Monument No. 2 mine, Arizona, Monument Valley district. Mineral named for Navaho Indian Reservation on which the Monument No. 2 mine is located. First sample collected by A. Rosenzweig, A.E.C., in 1951. Material for chemical analysis and X-ray study collected by A. D. Weeks 1951 and 1952.

PASCOITE $Ca_2V_6O_{17} \cdot 11H_2O$

Crystal system: Triclinic

Habit: As granular crusts, rarely showing minute lath-like crystals with oblique terminations.

Physical properties:

Color: dark red orange to yellow orange
Fluorescence: none
Luster: vitreous to subadamantine
Cleavage: $\{010\}$ distinct. Fracture conchoidal
Hardness: $\sim 2\frac{1}{2}$
Specific gravity: 1.87
Strongest lines of X-ray powder pattern: VS 8.7, M 7.4, W 9.4, W 4.69

Optical properties:

	n	Pleochroism	
X	1.775 ± 0.005	Light cadmium yellow	
Y	1.815 ± 0.005	Cadmium yellow	
Z	1.825 ± 0.005	Orange	Biaxial negative

2V 50°-56°; crossed dispersion strong
Optic plane is $\perp \{010\}$

Analysis: Qualitative spectrographic analysis of mineral from Mesa No. 1 mine, Ariz.

Major	V	Ca		
Minor	Fe			
Trace	Na	Al	Mg	Si

Occurrence and associated minerals: Coating mine walls and open fractures; in oxidized zone; coating montroseite, melanovanadite, and other vanadium minerals.

Identification: X-ray powder pattern or spectrographic analysis necessary to distinguish from hummerite. Orange color and solubility in water distinguish it from all others.

Localities:

Mesa No. 1 mine, Shiprock district; Bitter Creek mine, Uravan district; Mill No. 1 mine, Uravan district; and Corvusite mine, Gateway district.

ROSCOELITE
and VANADIUM HYDROMICA*

$(Al,V)_2(AlSi_3)(K,Na)O_{10}(OH,F)_2$

Crystal system: Monoclinic

Habit: Massive

Physical properties:

Color: green, gray, tan, brown
Fluorescence: none
Luster: pearly
Cleavage: basal
Hardness: soft
Specific gravity:
Strongest lines of X-ray powder pattern: S 10.0, S 3.34, M 4.50, M 2.59

Optical properties:

Transparent if finely divided. Birefringent.

Analysis: Chemical (Fischer et al., 1947, p. 124). Roscoelite from Placerville, Colo.

SiO_2	Al_2O_3	FeO	V_2O_3	MgO	CaO	K_2O	Na_2O	H_2O	Rem.	Total
44.81	18.42	1.58	20.41	0.83	0.20	8.28	0.07	4.40	0.75	99.73
									Less O = F	0.06
										99.67

(Analyst: V. North)

Occurrence and associated minerals: Impregnating sandstone and replacing clay pellets and stringers. Associated with corvusite, hewettite, carnotite, and tyuyamunite.

Identification: Although the X-ray powder pattern distinguishes this pair from other vanadium minerals, commonly it does not distinguish between these two minerals. Also, some "vanadium clay ore" may consist of hydromica with included vanadium oxides. (M. D. Foster, U.S.G.S.)

Localities:

Districts: Gateway, Placerville, Thompsons, Uravan, Paradox, Bull Canyon, Gypsum Valley, and Slick Rock.

*Hydromica contains less potassium and is more hydrated than roscoelite.

ROSSITE $CaV_2O_6 \cdot 4H_2O$

Crystal system: Triclinic

Habit: Glassy lumps surrounded by flaky alteration rims of metarossite.

Physical properties:

Color: yellow
Fluorescence: none
Luster: vitreous to somewhat pearly
Cleavage: {010} good. Brittle.
Hardness: 2 - 3
Specific gravity: 2.45
Strongest lines of X-ray powder pattern: S 7.3, S 6.66, S 3.87

Optical properties:

Orientation	n	Color	
X	1.710		
$Y \wedge b \sim 45^{\circ}$	1.770		Biaxial negative (?)
$Z \sim c$	1.840	Yellow	

2V large; dispersion very strong

Analysis: No new analysis. See Dana VII

Occurrence and associated minerals: Secondary coatings and veinlets, in oxidized zone, with metarossite. USNM samples of rossite described in 1927 have all dehydrated to metarossite. (1950).

Identification: Optical properties, color. Readily soluble in hot water.

Localities:

Originally described by Foshag and Hess from an occurrence at Bull Pen Canyon, Slick Rock district,
Mesa No. 1 mine, Shiprock district.

METAROSSITE $CaV_2O_6 \cdot 2H_2O$

Crystal system:

Habit: Soft and friable, platy to flaky masses in veinlets.

Physical properties:

Color: very light yellow, pale greenish yellow
Fluorescence: none
Luster: more pearly than rossite
Cleavage:
Hardness: soft
Specific gravity:
Strongest lines of X-ray powder pattern: S 5.9, S 5.1, M 3.05

Optical properties:

		n	
X		1.840	
Y	>	1.85	Biaxial positive
Z	>	1.85	

2V large; dispersion strong

Analysis: Qualitative spectrographic analysis of material from Buckhorn claim.

Major	V
Minor	Ca
Trace	Al Si Nb Fe Mg

Occurrence and associated minerals: Same as rossite

Identification: Color, optical properties. Readily soluble in hot water.

Localities:

Buckhorn claim, Slick Rock district
Spring Creek, Brushy Basin, Monticello district

SODIUM ANALOGUE OF HEWETTITE

$Na_2V_6O_{16} \cdot 3H_2O$

Crystal system: Monoclinic

Habit: Bladed or acicular; botryoidal

Physical properties:

Color: deep red; brownish red on exposure
Fluorescence: none
Luster: adamantine, dulls on exposure
Cleavage:
Hardness:
Specific gravity:
Strongest lines of X-ray powder pattern: VS 7.97, S 3.13, S 2.27

Optical properties:

Orientation	n	Pleochroism	
X	approx. 1.8	Yellow	
Y	> 2.0	Orange yellow	Biaxial negative
Z = b	> 2.0	Orange red	2V medium

Analysis: Chemical analysis of material from Cactus Rat incline.
Analyst: A. M. Sherwood

V_2O_4	V_2O_5	Na_2O	K_2O	CaO	Acid insol.	H_2O-	H_2O+	Total
1.56	77.17	9.17	1.35	0.12	0.31	1.83	7.86	99.37

Occurrence and associated minerals: Coating a fracture in the roof of the Cactus Rat incline, with steigerite.

Identification: By color, except from hewettite. By X-ray or spectroscopic analysis from hewettite.

Localities: The first sample was collected by Benjamin Webber from the Thompsons district, during World War II. The second sample was collected by J. Stone in July 1952, from Cactus Rat incline, Thompsons district.

STEIGERITE

$Al_2(VO_4)_2 \cdot 6\frac{1}{2}H_2O$

Crystal system:

Habit: As canary-yellow pulverulent coatings that are variously composed of cryptocrystalline fibrous material resembling chalcedony, gumlike masses, and occasionally flat plates.

Physical properties:

Color: canary yellow
Fluorescence: none
Luster: waxy in compact aggregates
Cleavage:
Hardness:
Specific gravity:
Strongest lines of X-ray powder pattern: S 10.5, S 12.4, W 5.6

Optical properties:

Mean index 1.710 ± 0.005

Analysis: Qualitative spectrographic analysis of material from Cactus Rat incline.

Major	V
Minor	Al Ca
Trace	U Na Fe Si

Occurrence and associated minerals: At Cactus Rat, coatings on highly weathered sandstone, with sodium analogue of hewettite.

Identification: Color and lack of radioactivity.

Locality: Original locality -- north wall of Gypsum Valley, Gypsum Valley district.
Cactus Rat incline, Thompsons district; Monument No. 2 mine, Monument Valley district.

VOLBORTHITE

$Cu_3(VO_4)_2 \cdot 3H_2O$ (?)

Crystal system: Monoclinic (?)

Habit: As scaly, spongy, or fibrous crusts and as rosette-like aggregates; also reticulated. Some as scales with a triangular or hexagonal outline.

Physical properties:

Color: dark olive green to green and yellowish green
Fluorescence: none
Luster: vitreous to pearly on the cleavage
Cleavage: perfect in one direction
Hardness: 3 ½
Specific gravity: 3.5 - 3.8
Strongest lines of X-ray powder pattern: S 7.2, M 2.88, M 2.56, M 2.39, M 1.51

Optical properties:

	n	Color	
X	2.01	Green to	
Y	2.05	greenish yellow	Biaxial positive red
Z	2.10	in transmitted light.	
2V 68° Li, 83° Na; r > v		inclined	Biaxial negative violet

Analysis: Qualitative spectrographic analysis on material from Daggett County, Utah

Major	Cu V Si
Minor	Ba Al
Trace	Ca Mg Nb Fe

Occurrence and associated minerals: Coating joint and fracture surfaces in sandstone, with gypsum.

Identification: The distinction between volborthite and calciovolborthite is not well established. X-ray powder pattern.

Locality:

Radium No. 5 mine, Slick Rock district.

CALCIOVOLBORTHITE $(Cu,Ca)_2(VO_4)(OH)$

Crystal system: Orthorhombic (?)

Habit: As scaly aggregates; also fibrous to dense

Physical properties:

Color: yellow green, olive green
Fluorescence: none
Luster: vitreous to pearly on the cleavage
Cleavage: perfect in one direction
Hardness: $3\frac{1}{2}$
Specific gravity:
Strongest lines of X-ray powder pattern: S 7.2, M 2.88, M 2.56, M 2.39, M 1.51

Optical properties:

	n	Pleochroism	
X	2.00	Brown	Biaxial negative
Y	2.01	Brown	
Z	2.02	Green	

2V large; r > v strong

Occurrence and associated minerals:

Coating on sandstone, with tyuyamunite and conichalcite.

Identification: The distinction between calciovolborthite and volborthite is not well established.

X-ray powder pattern.

Localities:

Richardson Basin, Moab district.

Table 2.--List of mine names showing county and state

Mine or mine group	County	State
Arrowhead mine	Mesa	Colorado
Bitter Creek mine	Montrose	Colorado
Black Mama mine	Mesa	Colorado
Blue Jay claim	San Juan	Utah
Buckhorn claim	San Miguel	Colorado
Cactus Rat group	Grand	Utah
Camp Bird No. 13 mine	Emery	Utah
Cato Sells mine	Apache	Arizona
Cobalt No. 2 mine	Grand	Utah
Corvusite mine	Grand	Utah
Crabapple claim	San Juan	Utah
Craven Canyon	Fall River	South Dakota
Denise No. 1 mine	Emery	Utah
Frey No. 4 mine	San Juan	Utah
Gray Dawn mine	San Juan	Utah
Gypsum Valley	San Miguel	Colorado
Happy Jack mine	San Juan	Utah
Haystack Mountain area	McKinley	New Mexico
Hideout (Tiger) mine	San Juan	Utah
Hillside mine	Yavapai	Arizona
Huskon No. 2 claim	Coconino	Arizona
Jo Dandy mine	Montrose	Colorado
Juniper claim	Grand	Utah
Laguna (area)	Valencia	New Mexico
La Sal No. 2 mine	Mesa	Colorado
Little Muriel	San Miguel	Colorado
Lucky Strike No. 2 mine	Emery	Utah
Lusk	Niobrara	Wyoming
Markey No. 3 mine	San Juan	Utah
Marshbank Canyon mine	Emery	Utah
Matchless mine	Mesa	Colorado
McCoy group	Grand	Utah
Mesa No. 1 mine	Apache	Arizona
Mesa No. 5 mine	Apache	Arizona
Mill No. 1 mine	Montrose	Colorado
Monument No. 2 mine	Apache	Arizona

Table 2.--List of mine names showing county and state--Continued

Mine or mine group	County	State
North Point-Gonway claim	San Juan	Utah
North Star mine	Montrose	Colorado
Notch mine	San Juan	Utah
Opera Box mine	Montrose	Colorado
Oyler mine	Wayne	Utah
Pay Day mine	Emery	Utah
Placerville	San Miguel	Colorado
Polar Mesa	Grand	Utah
Posey mine	San Juan	Utah
Pumpkin Buttes	Campbell	Wyoming
Radium No. 5 mine	San Miguel	Colorado
Rex No. 2 mine	Emery	Utah
Richardson Basin	Grand	Utah
Shinarump No. 1 mine	Grand	Utah
Skyline mine	San Juan	Utah
Small Spot mine	Mesa	Colorado
Sodaroll claim	San Juan	Utah
Spring Creek in Brushy Basin	San Juan	Utah
Temple Mountain	Emery	Utah
Thom claim	Grand	Utah
White Canyon No. 1 mine	San Juan	Utah
Whitney mine	Montrose	Colorado
Wild Steer mine	Montrose	Colorado
Yellow Cat group	Grand	Utah

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