IN REPLY REFER TO:

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
WASHINGTON 25, D.C.

AUG 12 1953

AEC-50/4

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,

[Signature]

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
<table>
<thead>
<tr>
<th>Distribution (Series A)</th>
<th>No. of copies</th>
</tr>
</thead>
<tbody>
<tr>
<td>American Cyanamid Company, Winchester</td>
<td>1</td>
</tr>
<tr>
<td>Argonne National Laboratory</td>
<td>1</td>
</tr>
<tr>
<td>Atomic Energy Commission, Washington</td>
<td>2</td>
</tr>
<tr>
<td>Battelle Memorial Institute, Columbus</td>
<td>1</td>
</tr>
<tr>
<td>Carbide and Carbon Chemicals Company, Y-12 Area</td>
<td>1</td>
</tr>
<tr>
<td>Division of Raw Materials, Butte</td>
<td>1</td>
</tr>
<tr>
<td>Division of Raw Materials, Denver</td>
<td>1</td>
</tr>
<tr>
<td>Division of Raw Materials, Grants</td>
<td>1</td>
</tr>
<tr>
<td>Division of Raw Materials, Hot Springs</td>
<td>1</td>
</tr>
<tr>
<td>Division of Raw Materials, New York</td>
<td>6</td>
</tr>
<tr>
<td>Division of Raw Materials, Richfield</td>
<td>1</td>
</tr>
<tr>
<td>Division of Raw Materials, Salt Lake City</td>
<td>1</td>
</tr>
<tr>
<td>Division of Raw Materials, Washington</td>
<td>3</td>
</tr>
<tr>
<td>Division of Research, Washington</td>
<td>1</td>
</tr>
<tr>
<td>Dow Chemical Company, Pittsburgh</td>
<td>1</td>
</tr>
<tr>
<td>Exploration Division, Grand Junction Operations Office</td>
<td>6</td>
</tr>
<tr>
<td>Grand Junction Operations Office</td>
<td>2</td>
</tr>
<tr>
<td>Technical Information Service, Oak Ridge</td>
<td>6</td>
</tr>
<tr>
<td>Tennessee Valley Authority, Wilson Dam</td>
<td>1</td>
</tr>
<tr>
<td>U. S. Geological Survey:</td>
<td></td>
</tr>
<tr>
<td>Alaskan Geology Branch, Washington</td>
<td>1</td>
</tr>
<tr>
<td>Fuels Branch, Washington</td>
<td>6</td>
</tr>
<tr>
<td>Geochemistry and Petrology Branch, Washington</td>
<td>30</td>
</tr>
<tr>
<td>Geophysics Branch, Washington</td>
<td>1</td>
</tr>
<tr>
<td>Mineral Deposits Branch, Washington</td>
<td>3</td>
</tr>
<tr>
<td>E. H. Bailey, San Francisco</td>
<td>1</td>
</tr>
<tr>
<td>J. R. Cooper, Denver</td>
<td>1</td>
</tr>
<tr>
<td>N. M. Denson, Denver</td>
<td>2</td>
</tr>
<tr>
<td>C. E. Dutton, Madison</td>
<td>1</td>
</tr>
<tr>
<td>R. P. Fischer, Grand Junction</td>
<td>20</td>
</tr>
<tr>
<td>L. S. Gardner, Albuquerque</td>
<td>3</td>
</tr>
<tr>
<td>C. B. Hunt, Plant City</td>
<td>1</td>
</tr>
<tr>
<td>M. R. Klepper, Washington</td>
<td>1</td>
</tr>
<tr>
<td>A. H. Koschmann, Denver</td>
<td>1</td>
</tr>
<tr>
<td>R. A. Laurence, Knoxville</td>
<td>1</td>
</tr>
<tr>
<td>D. M. Lemmon, Washington</td>
<td>1</td>
</tr>
<tr>
<td>J. D. Love, Laramie</td>
<td>1</td>
</tr>
<tr>
<td>L. R. Page, Denver</td>
<td>20</td>
</tr>
<tr>
<td>R. J. Roberts, Salt Lake City</td>
<td>1</td>
</tr>
<tr>
<td>Q. D. Singewald, Beltsville</td>
<td>1</td>
</tr>
<tr>
<td>J. F. Smith, Jr., Denver</td>
<td>1</td>
</tr>
<tr>
<td>R. W. Swanson, Spokane</td>
<td>1</td>
</tr>
<tr>
<td>A. E. Weissenborn, Spokane</td>
<td>1</td>
</tr>
<tr>
<td>W. P. Williams, Joplin</td>
<td>1</td>
</tr>
<tr>
<td>TEPCO, Washington:</td>
<td></td>
</tr>
<tr>
<td>Resource Compilation Section</td>
<td>5</td>
</tr>
<tr>
<td>Reports Processing Section</td>
<td>5</td>
</tr>
<tr>
<td>(Including master)</td>
<td></td>
</tr>
</tbody>
</table>

149
## CONTENTS

### Part I

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abstract</td>
<td>5</td>
</tr>
<tr>
<td>Introduction</td>
<td>5</td>
</tr>
<tr>
<td>Purpose</td>
<td>6</td>
</tr>
<tr>
<td>Mineral data</td>
<td>6</td>
</tr>
<tr>
<td>Mineral associations and distribution of types of ore</td>
<td>10</td>
</tr>
<tr>
<td>Oxidized vanadium-uranium ores (carnotite)</td>
<td></td>
</tr>
<tr>
<td>Unoxidized vanadium-uranium ores</td>
<td>11</td>
</tr>
<tr>
<td>Oxidized nonvanadiferous uranium ores</td>
<td>13</td>
</tr>
<tr>
<td>Unoxidized nonvanadiferous ore (pitchblende-copper sulfide)</td>
<td>14</td>
</tr>
</tbody>
</table>

### Part II

<table>
<thead>
<tr>
<th>Uranium minerals</th>
<th>15</th>
</tr>
</thead>
<tbody>
<tr>
<td>Description of identified minerals</td>
<td>15</td>
</tr>
<tr>
<td>Autunite and meta-autunite</td>
<td>17</td>
</tr>
<tr>
<td>Bassetite</td>
<td>18</td>
</tr>
<tr>
<td>Bayleyite</td>
<td>19</td>
</tr>
<tr>
<td>Becquerelite</td>
<td>20</td>
</tr>
<tr>
<td>Carnotite</td>
<td>21</td>
</tr>
<tr>
<td>Coffinite</td>
<td>22</td>
</tr>
<tr>
<td>Cuprosklodowskite</td>
<td>23</td>
</tr>
<tr>
<td>Fourmarierite</td>
<td>24</td>
</tr>
<tr>
<td>Johannite</td>
<td>25</td>
</tr>
<tr>
<td>Liebigite</td>
<td>26</td>
</tr>
<tr>
<td>Novacekite</td>
<td>27</td>
</tr>
<tr>
<td>Phosphuranylite</td>
<td>28</td>
</tr>
<tr>
<td>Rabbittite</td>
<td>29</td>
</tr>
<tr>
<td>Rauvite</td>
<td>30</td>
</tr>
<tr>
<td>Schroedergerite</td>
<td>31</td>
</tr>
<tr>
<td>Torbernite and metatorbernite</td>
<td>32</td>
</tr>
<tr>
<td>Tyuyamunite</td>
<td>33</td>
</tr>
<tr>
<td>Metatyuyamunite</td>
<td>34</td>
</tr>
<tr>
<td>Uraninite (pitchblende)</td>
<td>35</td>
</tr>
<tr>
<td>Uranophane</td>
<td>37</td>
</tr>
<tr>
<td>Uranopilite</td>
<td>38</td>
</tr>
<tr>
<td>Uvanite</td>
<td>39</td>
</tr>
<tr>
<td>Metazeunerite</td>
<td>40</td>
</tr>
<tr>
<td>Betazippeite</td>
<td>41</td>
</tr>
</tbody>
</table>

| Vanadium minerals                                                     | 48   |
| Description of identified minerals (uranyl vanadates under uranium minerals) | 48   |
| Corvusite                                                            | 50   |
| Doloresite and lumsdenite                                            | 51   |
| Fervanite                                                            | 52   |
| Hewettite                                                            | 53   |
Part II Vanadium minerals (Continued)

- Metahewettite ..................................... 54
- Hummerite ........................................... 55
- Melanovanadite ...................................... 56
- Montroseite .......................................... 57
- Navahoite ............................................. 58
- Pascoite ................................................ 59
- Roscoelite and vanadium hydromica .............. 60
- Rossite ................................................ 61
- Metarossite .......................................... 62
- Sodium analogue of hewettite ..................... 63
- Steigerite ............................................. 64
- Volborthite ........................................... 65
- Calciowolborthite ................................... 66

Literature cited ....................................... 69
Unpublished reports .................................. 69

TABLES

Table 1. Optical properties of uranium minerals .......... 42-48

2. List of mine names showing county and state ... 67-68
IDENTIFICATION AND OCCURRENCE OF URANIUM AND VANADIUM MINERALS FROM THE COLORADO PLATEAUS

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 strong, 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 carnitite 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 Å) and may differ considerably from the color or degree of fluorescence observed at 3660 Å.

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 metabearthite, 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 Na₂CO₃, 45.5 percent by weight of K₂CO₃, and 9 percent by weight of NaF and observing with a long wavelength (3650 Å) 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 quinivalent 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: Schroekingerite, 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, chalcoalbumite, 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 illemannite or ferrimolybdate, 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.
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:

<table>
<thead>
<tr>
<th>Oxides</th>
<th>Carbonates</th>
<th>Sulfates</th>
<th>Phosphates</th>
<th>Arsenates</th>
<th>Vanadates</th>
<th>Silicates</th>
</tr>
</thead>
<tbody>
<tr>
<td>Uraninite and pitchblende $UO_2$</td>
<td>Bayleyite $Mg_2(UO_2)(CO_3)_3\cdot18H_2O$</td>
<td>Uranopilite $(UO_2)<em>6(SO_4)(OH)</em>{10-12}H_2O$</td>
<td>Autunite $Ca(UO_2)_2(PO_4)_2\cdot10-12H_2O$</td>
<td>Metazeunerite $Cu(UO_2)_2(AsO_4)_2\cdot8H_2O$</td>
<td>Carnotite $K_2(UO_2)_2(VO_4)_2\cdot1-3H_2O$</td>
<td>Uranophane $Ca(UO_2)_2Si_2O_7\cdot6H_2O$</td>
</tr>
<tr>
<td>Becquerelite $2UO_3\cdot3H_2O$</td>
<td>Becquerelite $2UO_3\cdot3H_2O$</td>
<td>Johannisite $Cu(UO_2)_2(SO_4)_2(OH)_2\cdot6H_2O$</td>
<td>Meta-autunite I $Ca(UO_2)_2(PO_4)_2\cdot2\frac{2}{3}-6H_2O$</td>
<td>Novacekite $Mg(UO_2)_2(AsO_4)_2\cdot8-10H_2O$</td>
<td>Metatyuyamunite $Ca(UO_2)_2(VO_4)_2\cdot6-n\ (?)H_2O$</td>
<td>Cuprosklodowskite $Cu(UO_2)_2Si_2O_7\cdot6H_2O$</td>
</tr>
<tr>
<td>Fourmarierite $PbU_4O_{13}\cdot7H_2O$</td>
<td>Schroeckingerite $NaCa_3(UO_2)(CO_3)_3(SO_4)\cdot4L0H_2O$</td>
<td>Betazippeite $(UO_2)_2(SO_4)(OH)_2\cdot4H_2O$</td>
<td>Basselite $Fe(UO_2)_2(PO_4)_2\cdot8H_2O$</td>
<td>Phosphuranylite $Ca_3(UO_2)_5(PO_4)_4(OH)_4\cdot2H_2O\ (?)$</td>
<td>Tyuyamunite $Ca(UO_2)_2(VO_4)_2\cdot9-n\ (?)H_2O$</td>
<td></td>
</tr>
</tbody>
</table>
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$_3$•2H$_2$O, sabugalite HAl(UO$_2$)$_4$(PO$_4$)$_4$•16H$_2$O, sklodowskite Mg(UO$_2$)$_2$Si$_2$O$_7$•7H$_2$O, and beta-uranophane Ca(UO$_2$)$_2$Si$_2$O$_7$•6H$_2$O.

Three new uranium carbonates, swartzite CaMg(UO$_2$)(CO$_3$)$_3$•12H$_2$O, andersonite Na$_2$Ca(UO$_2$)(CO$_3$)$_3$•6H$_2$O, 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)$_8$•3H$_2$O, is known to occur also in Yavapai County, Ariz. (R. Berman, personal communication).

Other minerals that may be found include uranocircite Ba(UO$_2$)$_2$(PO$_4$)$_2$•8H$_2$O, uranospinitie Ca(UO$_2$)$_2$(AsO$_4$)$_2$•8-12H$_2$O, saléite Mg(UO$_2$)$_2$(PO$_4$)$_2$•8-10H$_2$O, and sengierite Cu(UO$_2$)(VO$_4$)(OH)$_4$•5H$_2$O (?).

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

Ca(UO$_2$)$_2$(PO$_4$)$_2$·10-12H$_2$O

and META-AUTUNITE I

(Meta-autunite I has $2\frac{1}{2}$-6$\frac{1}{2}$H$_2$O)

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 $[001]$.
- 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:

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

Meta-autunite from Thom claim is biaxial negative, 2V small to medium, $n_Y$ and $n_Z$ 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.
BASSETTITE

\[ \text{Fe(} \text{UO}_2\text{)}_2(\text{PO}_4)_2 \cdot 8\text{H}_2\text{O} \]

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:

<table>
<thead>
<tr>
<th>Orientation</th>
<th>(n) (Na)</th>
<th>Pleochroism</th>
</tr>
</thead>
<tbody>
<tr>
<td>(X = b)</td>
<td>(\sim 1.56)</td>
<td>Pale yellow, Biaxial negative</td>
</tr>
<tr>
<td>(Y)</td>
<td>1.574</td>
<td>Deep yellow</td>
</tr>
<tr>
<td>(Z \wedge c = 40^\circ)</td>
<td>1.580</td>
<td>Deep yellow</td>
</tr>
</tbody>
</table>

**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**

\[ \text{Mg}_2(\text{UO}_2)(\text{CO}_3)_3 \cdot 18\text{H}_2\text{O} \]

Crystal form: Monoclinic

Habit: Minute prismatic crystals.

Physical properties:

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

Optical properties:

<table>
<thead>
<tr>
<th>Orientation</th>
<th>n</th>
<th>Pleochroism</th>
</tr>
</thead>
<tbody>
<tr>
<td>X ( \wedge c ) 14°</td>
<td>1.455</td>
<td>Pinkish</td>
</tr>
<tr>
<td>Y</td>
<td>1.490</td>
<td>Pale yellow</td>
</tr>
<tr>
<td>Z = b</td>
<td>1.500</td>
<td>Pale yellow</td>
</tr>
<tr>
<td>2V = 30°</td>
<td></td>
<td>Biaxial negative</td>
</tr>
</tbody>
</table>

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

- > 10 \( \text{U} \)
- 1.0-10 \( \text{Mg Ca (low)} \)
- 0.1-1.0 \( \text{Al} \)
- 0.01-0.1 \( \text{Si Sr} \)

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

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:

<table>
<thead>
<tr>
<th>Orientation</th>
<th>n</th>
<th>Pleochroism</th>
</tr>
</thead>
<tbody>
<tr>
<td>X = c</td>
<td>1.735</td>
<td>Colorless</td>
</tr>
<tr>
<td>Y = b</td>
<td>1.820</td>
<td>Light yellow</td>
</tr>
<tr>
<td>Z = a</td>
<td>1.830</td>
<td>Dark yellow</td>
</tr>
<tr>
<td>2V = 31°; r &gt; v marked</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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.
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:

<table>
<thead>
<tr>
<th>Orientation</th>
<th>n</th>
<th>Pleochroism</th>
</tr>
</thead>
<tbody>
<tr>
<td>X ~ c</td>
<td>1.750</td>
<td>Nearly colorless</td>
</tr>
<tr>
<td>Y (\wedge a) ~ 14°</td>
<td>1.925-2.06</td>
<td>Canary yellow  Biaxial negative</td>
</tr>
<tr>
<td>Z = b</td>
<td>1.950-2.08</td>
<td>Canary yellow</td>
</tr>
<tr>
<td>2(\psi) 40° - 50°</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Indices of refraction vary with water content

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

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

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

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

*Analyses show up to 61 percent U and varying amounts of Si, As, and V. Coffinite may be analogous to thorite (ThSiO₄), i.e., USiO₄, with As, V, OH, etc., substituting for Si, or it may be a hydrated oxide. (June 1953).
CUPROSKLODOWSKITE

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 - ¼
- Specific gravity: 3.5 ±
- Strongest lines of X-ray powder pattern: VS 8.1, S 4.08, M 6.1

Optical properties:

<table>
<thead>
<tr>
<th>Orientation</th>
<th>n</th>
<th>Pleochroism</th>
</tr>
</thead>
<tbody>
<tr>
<td>X</td>
<td>1.654</td>
<td>Very pale yellowish green</td>
</tr>
<tr>
<td>Y</td>
<td>1.664–1.667</td>
<td>Very pale yellowish green</td>
</tr>
<tr>
<td>Z = c</td>
<td>1.664–1.667</td>
<td>Pale greenish yellow</td>
</tr>
<tr>
<td>2V small; r &gt; v strong</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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  \( \text{PbU}_4\text{O}_{13} \cdot \text{H}_2\text{O} \)

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: \( 338, 304, 189 \)

Optical properties:

<table>
<thead>
<tr>
<th>Orientation</th>
<th>( n )</th>
<th>Pleochroism</th>
</tr>
</thead>
<tbody>
<tr>
<td>X = c</td>
<td>1.85</td>
<td>Colorless</td>
</tr>
<tr>
<td>Y = b</td>
<td>1.92</td>
<td>Pale yellow Biaxial negative</td>
</tr>
<tr>
<td>Z = a</td>
<td>1.94</td>
<td>Yellow</td>
</tr>
</tbody>
</table>

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

Crystal system: Triclinic; pinacoidal 1

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

Physical properties:

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:

<table>
<thead>
<tr>
<th>n</th>
<th>Pleochroism</th>
</tr>
</thead>
<tbody>
<tr>
<td>X</td>
<td>1.577 Colorless</td>
</tr>
<tr>
<td>Y</td>
<td>1.597 Pale yellow</td>
</tr>
<tr>
<td>Z</td>
<td>1.616 Greenish yellow</td>
</tr>
<tr>
<td>r &lt; v</td>
<td>strong</td>
</tr>
</tbody>
</table>

2V \(\sim 90^\circ\)

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 $\text{Ca}_2\text{U}$(CO$_3$)$_4\cdot 10\text{H}_2\text{O}$

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:

<table>
<thead>
<tr>
<th>Orientation</th>
<th>n</th>
<th>Pleochroism</th>
</tr>
</thead>
<tbody>
<tr>
<td>X = a</td>
<td>1.497</td>
<td>Nearly colorless</td>
</tr>
<tr>
<td>Y</td>
<td>1.502</td>
<td>Pale yellowish green  Biaxial positive</td>
</tr>
<tr>
<td>Z</td>
<td>1.539</td>
<td>Pale yellowish green</td>
</tr>
<tr>
<td>2V 40°, r &gt; v</td>
<td>moderate</td>
<td></td>
</tr>
</tbody>
</table>

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(UO₂)₂(AsO₄)₂·8-10H₂O

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 ½
- Specific gravity: 3.3
- Strongest lines of X-ray powder pattern: VS 10.2, S 3.56, M 5.1

Optical properties:

<table>
<thead>
<tr>
<th>Orientation</th>
<th>n</th>
</tr>
</thead>
<tbody>
<tr>
<td>X = c</td>
<td>1.620-1.623</td>
</tr>
</tbody>
</table>
| 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 uranospinete [Ca(UO₂)₂(AsO₄)₂·8-12H₂O] 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

\[ \text{Ca}_3(\text{UO}_2)_5(\text{PO}_4)_4(\text{OH})_4\cdot2\text{H}_2\text{O} \]

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 ½
- Specific gravity:
- Strongest lines of X-ray powder pattern: S 7.9, M 5.83, M 3.92, M 2.88

Optical properties: variable

<table>
<thead>
<tr>
<th>(n)</th>
<th>Pleochroism</th>
</tr>
</thead>
<tbody>
<tr>
<td>X or E</td>
<td>1.660-1.690</td>
</tr>
<tr>
<td>Y</td>
<td>1.700-1.718</td>
</tr>
<tr>
<td>Z or O</td>
<td>1.701-1.718</td>
</tr>
<tr>
<td>2V usually</td>
<td>5°-20° (up to 35°)</td>
</tr>
</tbody>
</table>

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:

<table>
<thead>
<tr>
<th>Orientation</th>
<th>n</th>
</tr>
</thead>
<tbody>
<tr>
<td>X</td>
<td>1.502±0.005</td>
</tr>
<tr>
<td>Y = b</td>
<td>1.508±0.005</td>
</tr>
<tr>
<td>Z (\wedge) c (\sim) 15°</td>
<td>1.525±0.003</td>
</tr>
</tbody>
</table>

Biaxial positive (?)

2V large

Analysis:

Chemical analysis of material from Lucky Strike No. 2 mine (in percent).

<p>| | | | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>CaO</td>
<td>MgO</td>
<td>UO₃</td>
<td>CO₂</td>
<td>H₂O</td>
<td>Total</td>
</tr>
<tr>
<td>10.6</td>
<td>9.2</td>
<td>37.4</td>
<td>17.8</td>
<td>24.5</td>
<td>99.5</td>
</tr>
</tbody>
</table>

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
RAUVITE  

$\text{Ca}_0 \cdot 2\text{UO}_3 \cdot 5\text{V}_2\text{O}_5 \cdot 16\text{H}_2\text{O}$ (?)

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: $\text{VS} 10.5$, $\text{M}$ (broad) 2.95, $\text{M} 3.48$, $\text{M} 3.35$.

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)

<table>
<thead>
<tr>
<th>Element</th>
<th>UO$_3$</th>
<th>V$_2$O$_5$</th>
<th>V$_2$O$_4$</th>
<th>CaO</th>
<th>Al$_2$O$_3$</th>
<th>Acid insol.</th>
<th>total H$_2$O</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>31.49</td>
<td>48.28</td>
<td>1.44</td>
<td>2.76</td>
<td>0.70</td>
<td>0.61</td>
<td>15.49</td>
<td>100.77</td>
</tr>
</tbody>
</table>

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 district
SCROECKINGERITE

\[ \text{NaCa}_3(\text{UO}_2)(\text{CO}_3)_3(\text{SO}_4)\text{F} \cdot 10\text{H}_2\text{O} \]

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: 2½
Specific gravity: 2.51
Strongest lines of X-ray powder pattern: \( S \text{ 7.2}, \text{ M 4.79}, \text{ M 2.86} \), Soluble in water, effervesces in HCl.

Optical properties:

\[ \begin{array}{cc}
\text{E} & 1.489 \\
\text{Uniaxial (?) negative} \\
\text{Usually biaxial with small and variable } 2V, 0-25^\circ
\end{array} \]

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

<table>
<thead>
<tr>
<th>Element</th>
<th>Over 10</th>
<th>0.1-1</th>
<th>0.01-0.1</th>
<th>0.001-0.01</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \text{U} )</td>
<td>( \text{Ca} )</td>
<td>( \text{F} )</td>
<td>( \text{Si Al Sr Zn Fe} )</td>
<td>( \text{K Ti Mg} )</td>
</tr>
</tbody>
</table>

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$_4$)$_2$·8·12H$_2$O

Metatorbernite has 8H$_2$O

(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 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:

<table>
<thead>
<tr>
<th></th>
<th>Metatorbernite</th>
<th>Torbernite</th>
<th>Dichroism</th>
</tr>
</thead>
<tbody>
<tr>
<td>$n$</td>
<td>1.610-1.628</td>
<td>1.592</td>
<td>Sky blue</td>
</tr>
<tr>
<td>in white light</td>
<td></td>
<td>1.582</td>
<td>Green</td>
</tr>
<tr>
<td>E</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Uniaxial positive (?)

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

$\text{Ca(}\text{UO}_2\text{)}_2\text{(V}_4\text{O}_8\text{)}_2\text{.nH}_2\text{O}$

$n = ?-12$

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.
Cleavages: $\{001\}$ 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
$2V \{42^0\}$  $r < v$
The indices increase on dehydration

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

<table>
<thead>
<tr>
<th></th>
<th>CaO</th>
<th>UO$_3$</th>
<th>V$_2$O$_4$</th>
<th>V$_2$O$_5$</th>
<th>H$_2$O</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Value</td>
<td>6.03</td>
<td>57.08</td>
<td>0.55</td>
<td>20.31</td>
<td>16.03</td>
<td>100.00</td>
</tr>
</tbody>
</table>

Recalculated to 100 percent, after H$_2$O 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

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

\[X = c \quad 1.67 \text{ calc.}\]
\[Y = b \quad 1.835 \pm 0.002\]
\[Z = a \quad 1.865 \pm 0.002\]
\[2V = 44^\circ\]

Biaxial negative

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 UO₂  
(commonly contains UO₃)

Crystal system: Isometric; hexoctahedral 4/m 3 2/m (?)


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.

<table>
<thead>
<tr>
<th>Major</th>
<th>U</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minor</td>
<td>Si Ca</td>
</tr>
<tr>
<td>Trace</td>
<td>V Fe Na Mn</td>
</tr>
</tbody>
</table>

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, carnitite 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
- Juniper mine
- Corvusite mine
- Blue Jay claim

**Shinarump conglomerate**
- Camp Bird No. 13 mine
- Lucky Strike No. 2 mine
- Marshbank Canyon mine
- Pay Day mine
- Rex No. 2 mine
- Crabapple claim
- Shinarump No. 1 mine
- Oyler mine
- Frey No. 4 mine
- Happy Jack mine
- Hideout mine
- Markey No. 3 mine
- Notch mine
- White Canyon No. 1 mine
- Cato Sells mine
- Monument No. 2 mine
- Skyline mine

**Others**
- Haystack Mountain area
- Placerville, Colo.
- Huskon No. 2 claim

San Rafael district
San Rafael district
San Rafael district
San Rafael district
Green River district
Green River district
Henry Mountains district
White Canyon district
White Canyon district
White Canyon district
White Canyon district
White Canyon district
White Canyon district
Monument Valley district
Monument Valley district
Monument Valley district
Grants district
Placerville district
Little Colorado district
URANOPHANE

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:

<table>
<thead>
<tr>
<th>Orientation</th>
<th>n</th>
<th>Pleochroism</th>
</tr>
</thead>
<tbody>
<tr>
<td>X = a</td>
<td>1.642-</td>
<td>Colorless</td>
</tr>
<tr>
<td></td>
<td>1.645</td>
<td></td>
</tr>
<tr>
<td>Y = b</td>
<td>1.665-</td>
<td>Pale canary yellow</td>
</tr>
<tr>
<td></td>
<td>1.667</td>
<td>Biaxial negative</td>
</tr>
<tr>
<td>Z = c</td>
<td>1.667-</td>
<td>Canary yellow</td>
</tr>
<tr>
<td></td>
<td>1.670</td>
<td></td>
</tr>
</tbody>
</table>

2V 32°; r < v marked to extreme

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

<table>
<thead>
<tr>
<th></th>
<th>H₂O</th>
<th>SiO₂</th>
<th>CaO</th>
<th>UO₃</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>13.02</td>
<td>12.66</td>
<td>8.53</td>
<td>65.24</td>
<td>99.45</td>
</tr>
</tbody>
</table>

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:

<table>
<thead>
<tr>
<th>Orientation</th>
<th>n</th>
</tr>
</thead>
<tbody>
<tr>
<td>X</td>
<td>1.623</td>
</tr>
<tr>
<td>Y ( \times c = 18^\circ )</td>
<td>1.625</td>
</tr>
<tr>
<td>Z</td>
<td>1.634</td>
</tr>
</tbody>
</table>

- 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*  

$2\text{UO}_3 \cdot 3\text{V}_2\text{O}_5 \cdot 15\text{H}_2\text{O}$ (?)  

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, $M_b$ 5.9, $M_b$ 5.3, $M$ 1.71  

Optical properties:  

\begin{tabular}{|c|c|c|}
\hline
$n$ & Pleochroism &  \\
\hline
X & 1.817 & Light brown  \\
Y & 1.879 & Dark brown  \\
Z & 2.057 & Greenish yellow  \\
2V & 52° &  \\
\hline
\end{tabular}  

Biaxial positive  

Analysis: W. T. Schaller, Analyst  

\begin{tabular}{|c|c|c|c|c|c|}
\hline
& CaO & UO$_3$ & V$_2$O$_5$ & H$_2$O & Rem. & Total  \\
\hline
CaO & 1.73 & 39.60 & 37.70 & 18.28 & 1.69 & 99.00  \\
\hline
\end{tabular}  

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

\[ \text{Cu(UO}_2\text{)}_2(\text{AsO}_4\text{)}_2 \cdot 8\text{H}_2\text{O} \]

(fully hydrated zeunerite probably rare in nature)

Crystal system: Tetragonal; ditetragonal dipyramidal \( \frac{4}{m} \frac{2}{m} \frac{2}{m} \)

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:

<table>
<thead>
<tr>
<th></th>
<th>( n )</th>
<th>( \Delta n )</th>
<th>Dichroism</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>1.643-1.651</td>
<td>Grass green</td>
<td>Uniaxial negative</td>
</tr>
<tr>
<td>E</td>
<td>1.623-1.635</td>
<td>Pale green</td>
<td></td>
</tr>
</tbody>
</table>

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
RETZIPPEITE* \((\text{UO}_2)_2(\text{SO}_4)(\text{OH})_2 \cdot 4\text{H}_2\text{O}\)

Crystal system: Monoclinic (T)

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:

<table>
<thead>
<tr>
<th>Orientation</th>
<th>n</th>
<th>Pleochroism</th>
</tr>
</thead>
<tbody>
<tr>
<td>X = b</td>
<td>1.630</td>
<td>Nearly colorless</td>
</tr>
<tr>
<td>Y</td>
<td>1.689</td>
<td>Pale yellow to orange yellow</td>
</tr>
<tr>
<td>Z (\wedge c) = 40^\circ</td>
<td>1.739</td>
<td>Pale yellow to orange yellow</td>
</tr>
<tr>
<td>2V large (82^\circ)</td>
<td></td>
<td>Biaxial negative</td>
</tr>
</tbody>
</table>

Indices variable

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

<table>
<thead>
<tr>
<th>Element</th>
<th>Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>UO(_3)</td>
<td>78.78</td>
</tr>
<tr>
<td>SO(_3)</td>
<td>10.42</td>
</tr>
<tr>
<td>H(_2)O</td>
<td>11.20</td>
</tr>
<tr>
<td>CaO</td>
<td>0.07</td>
</tr>
<tr>
<td>Total</td>
<td>100.47</td>
</tr>
</tbody>
</table>

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

**Uniaxial positive group**

<table>
<thead>
<tr>
<th>Indices and pleochroism</th>
<th>Name and composition</th>
<th>System and habit</th>
<th>Cleavage</th>
<th>Color</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>nE 1.540 Pale yellow</td>
<td>Andersonite</td>
<td>Hex. R.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Na₂Ca(UO₂)(CO₃)₅·₆H₂O</td>
<td>minute pseudo</td>
<td></td>
<td></td>
<td>Bright yellow Effervesces with green. Fluoresces bright green</td>
</tr>
<tr>
<td></td>
<td></td>
<td>cubic crystals</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>n₀ 1.520 Colorless</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Tet.</td>
<td>{001} perfect</td>
<td></td>
<td></td>
<td>Pale to dark green</td>
</tr>
<tr>
<td></td>
<td>Metatorbernite</td>
<td>Tablets on</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Cu(UO₂)₂(PO₄)₂·₆H₂O</td>
<td>{001}</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Table 1. -- Optical properties of uranium minerals -- Continued

<table>
<thead>
<tr>
<th>Indices and pleochroism</th>
<th>Name and composition</th>
<th>System and habit</th>
<th>Cleavage</th>
<th>Color</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>nE</td>
<td>nO</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.489</td>
<td>1.542</td>
<td>Schroeckingerite</td>
<td>Hex. ?</td>
<td>[001]</td>
<td>Greenish-yellow. Fluoresces strong greenish yellow Soluble in H₂O effervesces in HCl</td>
</tr>
<tr>
<td>1.559</td>
<td>1.574</td>
<td>Saleeite</td>
<td>Tet.</td>
<td>[001]</td>
<td>Yellow to lemon to yellow</td>
</tr>
<tr>
<td>Colorless, Pale green-yellow</td>
<td>Mg(UO₂)₂(PO₄)₂·8·H₂O</td>
<td>tablets on {001}</td>
<td>perfect</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.582</td>
<td>1.592</td>
<td>Torbernite</td>
<td>Tet.</td>
<td>[001]</td>
<td>Pale to dark green</td>
</tr>
<tr>
<td>Green, Sky blue</td>
<td>Cu(UO₂)₂(PO₄)₂·8·H₂O</td>
<td>tablets on {001}</td>
<td>perfect</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.623-1.635</td>
<td>1.643-1.651</td>
<td>Metazeunerite</td>
<td>Tet. or</td>
<td>[001]</td>
<td>Grass green to emerald green</td>
</tr>
<tr>
<td>Pale green, Grass green</td>
<td>Cu(UO₂)₂(AsO₄)₂·8·H₂O</td>
<td>tablets on {001}</td>
<td>perfect</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.66-1.69</td>
<td>1.701</td>
<td>Phosphuranylite</td>
<td>Tet. or</td>
<td>[001]</td>
<td>Deep yellow to golden yellow</td>
</tr>
<tr>
<td>Colorless, to pale yellow</td>
<td>Ca₃(UO₂)₅(PO₄)₄(OH)₄·2H₂O</td>
<td>pseudo-tet.</td>
<td>perfect; not easily observed</td>
<td></td>
<td></td>
</tr>
<tr>
<td>nX</td>
<td>Indices and composition</td>
<td>Name and composition</td>
<td>2V disp.</td>
<td>Optical orientation</td>
<td>System habit</td>
</tr>
<tr>
<td>-----</td>
<td>-------------------------</td>
<td>-------------------------------------------</td>
<td>----------</td>
<td>---------------------</td>
<td>----------------------</td>
</tr>
<tr>
<td>1.497</td>
<td>1.502  1.539</td>
<td>Liebigite (\text{Ca}_2\text{U(CO}_3\text{)}_4\cdot\text{10H}_2\text{O})</td>
<td>2V=40°</td>
<td>X = a</td>
<td>Orth. equant or short prismatic</td>
</tr>
<tr>
<td>1.502</td>
<td>1.508  1.525</td>
<td>Rabbittite (\text{Ca}_3\text{Mg}_3(\text{UO}_2)_2(\text{CO}_3)_6(\text{OH})_4\cdot\text{18H}_2\text{O}).</td>
<td>2V large</td>
<td>Y = b</td>
<td>Mon. acicular</td>
</tr>
<tr>
<td>1.577</td>
<td>1.597  1.616</td>
<td>Johannite (\text{Cu(\text{UO}_2)}_2(\text{SO}_4)_2(\text{OH})_2\cdot\text{6H}_2\text{O})</td>
<td>2V &lt; 90°</td>
<td>r &lt; v</td>
<td>Tric. prismatic</td>
</tr>
<tr>
<td>1.623</td>
<td>1.625  1.634</td>
<td>Uranopilite (\text{UO}_2)_6(\text{SO}<em>4)_{(\text{OH})</em>{10}\cdot\text{12H}_2\text{O}).</td>
<td>2V large for Na; 0°-some wavelengths</td>
<td>Y &amp; c = 18°</td>
<td>Mon. (?) {010} perfect</td>
</tr>
<tr>
<td>1.817</td>
<td>1.879  2.057</td>
<td>Uvanite (\text{2UO}_3\cdot\text{3V}_2\text{O}_5\cdot\text{15H}_2\text{O})</td>
<td>2V 52°</td>
<td>Orth. (?) Two pinacoidal</td>
<td></td>
</tr>
<tr>
<td>1.455</td>
<td>1.490  1.500</td>
<td>Bayleyite (\text{Mg}_2(\text{UO}_2)\text{(CO}_3\text{)}_3\cdot\text{18H}_2\text{O})</td>
<td>2V = 30°</td>
<td>X &amp; c = 140°</td>
<td>Mon. pris.</td>
</tr>
<tr>
<td>1.465</td>
<td>1.51   1.540</td>
<td>Swartzite (\text{CaMg(\text{UO}_2)}_2(\text{CO}_3\text{)}_3\cdot\text{12H}_2\text{O})</td>
<td>2V = 40°</td>
<td>Mon. pris.</td>
<td></td>
</tr>
</tbody>
</table>
### Table 1: Optical properties of uranium minerals—Continued

#### Biaxial negative group

<table>
<thead>
<tr>
<th>Indices and pleochroism</th>
<th>Name and composition</th>
<th>2V disp.</th>
<th>Optical orientation</th>
<th>System habit</th>
<th>Cleavage</th>
<th>Color</th>
</tr>
</thead>
<tbody>
<tr>
<td>nX 1.559 nY 1.570 nZ 1.570</td>
<td>Saléeite Mg(UO₂)₂(PO₄)₂·8·10H₂O</td>
<td>2V = 61°</td>
<td>Tetr.</td>
<td>{001} perfect</td>
<td>Yellow, lemon</td>
<td></td>
</tr>
<tr>
<td>1.56 + Pale yellow Deep yellow</td>
<td>Bassetite Fe(UO₂)₂(PO₄)₂·8H₂O</td>
<td>2V = 52°</td>
<td>Mon.</td>
<td>{010} perfect</td>
<td>Yellow</td>
<td></td>
</tr>
<tr>
<td>1.553 Pale Yellow Yellow</td>
<td>Autunite Ca(UO₂)₂(PO₄)₂·10-12H₂O</td>
<td>2V = 10°-30°</td>
<td>Tetr.</td>
<td>{001} perfect</td>
<td>Lemon yellow to pale green. Fluoresces yellow green strong.</td>
<td></td>
</tr>
<tr>
<td>1.603 Yellow Yellow</td>
<td>Meta-autunite I Ca(UO₂)₂(PO₄)₂·2½·6H₂O</td>
<td>2V small to medium</td>
<td>Tetr.</td>
<td>{001} perfect</td>
<td>Same as autunite</td>
<td></td>
</tr>
<tr>
<td>1.620-1.623 1.620-1.623</td>
<td>Novacekite Mg(UO₂)₂(AsO₄)₂·8·10H₂O</td>
<td>2V = 0°-15°</td>
<td>Tetr.</td>
<td>{001} perfect</td>
<td>Straw yellow. Fluoresces pale yellow green.</td>
<td></td>
</tr>
<tr>
<td>1.654-1.664 Very pale greenish yellow</td>
<td>Cuprosklodowskite Cu(UO₂)₂Si₂O₇·6H₂O</td>
<td>2V small</td>
<td>Orth.</td>
<td>{100} and {010}</td>
<td>Pale yellow green, yellow in thin flakes.</td>
<td></td>
</tr>
</tbody>
</table>
Table 1.--Optical properties of uranium minerals--Continued

<table>
<thead>
<tr>
<th>Indices and pleochroism</th>
<th>Name and composition</th>
<th>2V disp.</th>
<th>Optical orientation</th>
<th>System habit</th>
<th>Cleavage</th>
<th>Color</th>
</tr>
</thead>
<tbody>
<tr>
<td>nX</td>
<td>nY</td>
<td>nZ</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.642-</td>
<td>1.665-</td>
<td>1.667-</td>
<td>Uranophane</td>
<td>2V = 32°</td>
<td>X = a,</td>
<td>Orth.</td>
</tr>
<tr>
<td>1.645</td>
<td>1.667-</td>
<td>1.670-</td>
<td>Ca(UO₂)₂Si₂O₇•6H₂O</td>
<td>r &lt; v</td>
<td>Y = b,</td>
<td>prism.</td>
</tr>
<tr>
<td>Colorless</td>
<td>Pale</td>
<td>Canary yellow</td>
<td>marked to extreme</td>
<td>Z = c</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.650</td>
<td>1.68</td>
<td>1.710-</td>
<td>Soddyite</td>
<td>2V near 90°</td>
<td>X = a,</td>
<td>Orth.</td>
</tr>
<tr>
<td>Colorless</td>
<td>Pale</td>
<td>Greenish yellow</td>
<td>X = b,</td>
<td>Y = b,</td>
<td>Z = c</td>
<td></td>
</tr>
<tr>
<td>1.66-</td>
<td>1.67</td>
<td>1.70</td>
<td>Beta-uranophane</td>
<td>2V = 40°-</td>
<td>X = b</td>
<td>Orth.</td>
</tr>
<tr>
<td>1.67</td>
<td></td>
<td>1.71</td>
<td>Ca(UO₂)₂Si₂O₇•6H₂O</td>
<td>70°</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Colorless</td>
<td>Lemon</td>
<td>Lemon yellow</td>
<td>r &gt; v,</td>
<td>strong</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.630</td>
<td>1.689</td>
<td>1.739-</td>
<td>Betazippeite</td>
<td>2V large (80°)</td>
<td>X = b</td>
<td>Mon.</td>
</tr>
<tr>
<td>Nearly colorless</td>
<td>Pale</td>
<td>Pale yellow to orange yellow</td>
<td>Z A c = 40°</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.690</td>
<td>1.714</td>
<td>1.735-</td>
<td>Schoepite</td>
<td>2V = 89°</td>
<td>X = c,</td>
<td>Orth.</td>
</tr>
<tr>
<td>Colorless</td>
<td>Lemon</td>
<td>Lemon yellow</td>
<td>r &gt; v,</td>
<td>Y = b,</td>
<td>Z = a</td>
<td></td>
</tr>
<tr>
<td>1.660-</td>
<td>1.700-</td>
<td>1.701-</td>
<td>Phosphuranyllite</td>
<td>2V = 5°-</td>
<td>X = c</td>
<td>Tet. or</td>
</tr>
<tr>
<td>1.690</td>
<td>1.718</td>
<td>1.718-</td>
<td>Ca₃(UO₂)₅(PO₄)₄(OH)₄•2H₂O (?)</td>
<td>20°</td>
<td></td>
<td>pseudo-</td>
</tr>
<tr>
<td>Colorless</td>
<td>Golden</td>
<td>Golden yellow</td>
<td>r &gt; v,</td>
<td>strong</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Table 1.--Optical properties of uranium minerals--Continued

**Biaxial negative group**

<table>
<thead>
<tr>
<th>Indices and pleochroism</th>
<th>Name and composition</th>
<th>2V disp.</th>
<th>Optical orientation</th>
<th>System habit</th>
<th>Cleavage</th>
<th>Color</th>
</tr>
</thead>
<tbody>
<tr>
<td>nX</td>
<td>nY</td>
<td>nZ</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.57</td>
<td>1.805</td>
<td>1.851</td>
<td>Tyuyamunite</td>
<td>Ca(UO₂)₂(VO₄)₂·nH₂O</td>
<td>2V = 42°</td>
<td>X = c, Y = b, Z = a</td>
</tr>
<tr>
<td>nearly colorless</td>
<td>Pale</td>
<td>Canary</td>
<td>yellow</td>
<td>r &lt; v</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.735</td>
<td>1.820</td>
<td>1.830</td>
<td>Becquerelite</td>
<td>2UO₃·3H₂O</td>
<td>2V = 31°</td>
<td>X = c, Y = b, Z = a</td>
</tr>
<tr>
<td>Colorless</td>
<td>Light</td>
<td>Dark</td>
<td>yellow</td>
<td>r &gt; v</td>
<td>marked</td>
<td></td>
</tr>
<tr>
<td>1.67</td>
<td>1.835</td>
<td>1.865</td>
<td>Metatyuyamunite</td>
<td>Ca(UO₂)₂(VO₄)₂·nH₂O</td>
<td>2V = 44°</td>
<td>X = c, Y = b, Z = a</td>
</tr>
<tr>
<td>Calc.</td>
<td></td>
<td></td>
<td>n=6-?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.85-</td>
<td>1.89-</td>
<td>1.95</td>
<td>Rauvite</td>
<td>Ca₀·2UO₃·5V₂O₅·16H₂O (?)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.85</td>
<td>1.92</td>
<td>1.94</td>
<td>Fourmarierite</td>
<td>PbU₄O₁₃·7H₂O</td>
<td>2V large</td>
<td>X = c, Y = b, Z = a</td>
</tr>
<tr>
<td>Colorless</td>
<td>Pale</td>
<td>Yellow</td>
<td></td>
<td>r &gt; v</td>
<td>strong</td>
<td></td>
</tr>
<tr>
<td>1.750</td>
<td>1.925-</td>
<td>1.950-</td>
<td>Carnotite</td>
<td>K₂(UO₂)₂(VO₄)₂·1·3H₂O</td>
<td>2V = 40°</td>
<td>X ~ c, Y ~ 14°, Z = b</td>
</tr>
<tr>
<td>Nearly colorless</td>
<td>Canary</td>
<td>Canary</td>
<td>yellow</td>
<td>50°</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
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 $\text{VO(OH)}$ or $(\text{V,Fe})\text{O(OH)}$
- Navahoite $\text{V}_2\text{O}_5 \cdot 2-3\text{H}_2\text{O}$
- Doloresite probably $\text{V}^3$ and $\text{V}^4$, hydrated
- Lumsdenite $\text{V}_2\text{O}_3 \cdot \text{V}_2\text{O}_4 \cdot \text{H}_2\text{O}$

**Vanadates**
- Calciovolborthite $(\text{Cu,Ca})_2 (\text{VO}_4)(\text{OH})$
- Volborthite $\text{Cu}_3(\text{VO}_4)_2 \cdot 3\text{H}_2\text{O}$ (?)
- (Fervanite $\text{Fe}_4\text{V}_4\text{O}_{16} \cdot 5\text{H}_2\text{O}$) type specimen only
- Steigerite $\text{Al}_2(\text{VO}_4)_2 \cdot 6\text{H}_2\text{O}$
- Rossite $\text{CaV}_2\text{O}_3 \cdot 4\text{H}_2\text{O}$
- Metarossite $\text{CaV}_2\text{O}_3 \cdot 2\text{H}_2\text{O}$
- Pascoite $\text{Ca}_2\text{V}_6\text{O}_{17} \cdot 11\text{H}_2\text{O}$
- Hummerite $\text{K}_2\text{Mg}_2\text{V}_{10}\text{O}_{28} \cdot 16\text{H}_2\text{O}$
- Melanovanadite $2\text{CaO} \cdot 2\text{V}_2\text{O}_4 \cdot 3\text{V}_2\text{O}_5 \left[ (\text{H}_2\text{O}) ? \right]$
- Hewettite $\text{CaV}_6\text{O}_{16} \cdot 3\text{H}_2\text{O}$
- Metahewettite $\text{CaV}_6\text{O}_{16} \cdot 3\text{H}_2\text{O}$ (?)
- Sodium analogue of hewettite $\text{Na}_2\text{V}_6\text{O}_{16} \cdot 3\text{H}_2\text{O}$
- Corvusite $\text{V}_2\text{O}_4 \cdot 6\text{V}_2\text{O}_5 \cdot \text{nH}_2\text{O}$ (?) (similar to Fernandinite $\text{CaO} \cdot \text{V}_2\text{O}_4 \cdot 5\text{V}_2\text{O}_5 \cdot 14\text{H}_2\text{O}$)

**Silicates**
- Roscoelite $(\text{Al,V})_2(\text{AlSi}_3)(\text{K,Na})\text{O}_{10}(\text{OH,F})_2$
- 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 $\text{CaV}_2\text{O}_2(\text{PO}_4)_2\cdot5\text{H}_2\text{O}$. 
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:


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.

<table>
<thead>
<tr>
<th>Major</th>
<th>V</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minor</td>
<td>Fe</td>
</tr>
<tr>
<td>Low minor</td>
<td>Si Al</td>
</tr>
</tbody>
</table>

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 clausenthalite 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.
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 Kα radiation): S 8.83, S 6.44, M 2.92

Optical properties:

\[
\begin{align*}
    n & \\
    X & 2.186 \pm 0.005 \\
    Y & 2.222 \pm 0.005 \\
    Z & 2.224 \pm 0.005 \\
    2V & \text{very small}
\end{align*}
\]

Biaxial negative

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

\[
\begin{align*}
    \text{Fe}_2\text{O}_3 & \quad \text{V}_2\text{O}_5 & \quad \text{H}_2\text{O}(-) & \quad \text{Total} \\
    41.89 & \quad 46.10 & \quad 12.01 & \quad 100.00
\end{align*}
\]

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

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:

<table>
<thead>
<tr>
<th>Orientation</th>
<th>n</th>
<th>Pleochroism</th>
</tr>
</thead>
<tbody>
<tr>
<td>X</td>
<td>1.77</td>
<td>Light orange yellow</td>
</tr>
<tr>
<td>Y</td>
<td>2.18</td>
<td>Light orange yellow</td>
</tr>
<tr>
<td>Z = b</td>
<td>2.35-2.4</td>
<td>Dark red</td>
</tr>
<tr>
<td>2V medium</td>
<td></td>
<td>Biaxial negative Indices probably vary according to water content.</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>SiO₂</th>
<th>Al₂O₃</th>
<th>CaO</th>
<th>MgO</th>
<th>V₂O₄</th>
<th>V₂O₅</th>
<th>SO₃</th>
<th>H₂O</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.46</td>
<td>0.13</td>
<td>6.38</td>
<td>1.61</td>
<td>8.07</td>
<td>73.15</td>
<td>0.01</td>
<td>10.12</td>
<td>99.93</td>
</tr>
</tbody>
</table>

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.

METAHEWETTITE

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:

<table>
<thead>
<tr>
<th>Orientation</th>
<th>n(Li)</th>
<th>Pleochroism</th>
</tr>
</thead>
<tbody>
<tr>
<td>X</td>
<td>1.70</td>
<td>Light orange yellow</td>
</tr>
<tr>
<td>Y</td>
<td>2.10</td>
<td>Deep red Biaxial negative</td>
</tr>
<tr>
<td>Z = b</td>
<td>2.23</td>
<td>Deeper red Indices probably vary according to water content</td>
</tr>
<tr>
<td>2V 52° calc</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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.

HUMMERITE*  

\[ \text{K}_2\text{Mg}_2\text{V}_{10}\text{O}_{28} \cdot 16\text{H}_2\text{O} \]

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:

\[
\begin{array}{ccc}
\text{Orientation} & \text{n} \\
\text{X} & 1.771 \pm 0.003 \\
\text{Y} & 1.812 \pm 0.003 \\
\text{Z} \wedge c = 32^\circ & 1.833 \pm 0.003 \\
2V = 70^\circ; \text{dispersion strong } r > v \\
\end{array}
\]

**Biaxial negative**

Analysis: Chemical analysis of recrystallized material from North Star mine

<p>| | | | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>( \text{V}_2\text{O}_5 )</td>
<td>( \text{V}_2\text{O}_4 )</td>
<td>( \text{MgO} )</td>
<td>( \text{K}_2\text{O} )</td>
<td>Total ( \text{H}_2\text{O} )</td>
<td>Total</td>
</tr>
<tr>
<td>64.33</td>
<td>1.36</td>
<td>5.44</td>
<td>6.96</td>
<td>21.88</td>
<td>99.97</td>
</tr>
</tbody>
</table>

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 zones.

- 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.

MELANOVANADITE  

2CaO \cdot 2V_{2}O_{4} \cdot 3V_{2}O_{5}  

probably contains H_{2}O*  

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:  

<table>
<thead>
<tr>
<th>Orientation</th>
<th>n</th>
<th>Pleochroism</th>
</tr>
</thead>
<tbody>
<tr>
<td>X</td>
<td>1.73</td>
<td>Light reddish brown</td>
</tr>
<tr>
<td>Y \wedge c</td>
<td>1.96</td>
<td>Deep reddish brown</td>
</tr>
<tr>
<td>Z</td>
<td>1.98</td>
<td>Dark reddish brown</td>
</tr>
<tr>
<td>2V medium</td>
<td></td>
<td>Biaxial negative</td>
</tr>
</tbody>
</table>

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.  

MONTEROSITE*  

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.  

<table>
<thead>
<tr>
<th></th>
<th>FeO</th>
<th>V₂O₃</th>
<th>V₂O₄</th>
<th>H₂O</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>8.8</td>
<td>10.5</td>
<td>72.3</td>
<td>5.0</td>
<td>96.6</td>
</tr>
</tbody>
</table>

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.
NAVAHOTITE

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:

<table>
<thead>
<tr>
<th>Orientation</th>
<th>n</th>
<th>Pleochroism</th>
</tr>
</thead>
<tbody>
<tr>
<td>X</td>
<td>1.905 ± 0.003</td>
<td>Greenish brown</td>
</tr>
<tr>
<td>Y</td>
<td>~ 2.02</td>
<td>Light greenish brown</td>
</tr>
<tr>
<td>Z parallel to fiber &gt; 2.02</td>
<td>Dark brown</td>
<td>Biaxial negative</td>
</tr>
</tbody>
</table>


<p>| | | | | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>V_2O_5</td>
<td>71.68</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>V_2O_4</td>
<td>3.08</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fe_2O_3</td>
<td>3.58</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CaO</td>
<td>0.22</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SiO_2</td>
<td>1.20</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>H_2O</td>
<td>20.3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>100.06</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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, corrusite, 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**

\[ \text{Ca}_2\text{V}_8\text{O}_{17}\cdot 11\text{H}_2\text{O} \]

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:

<table>
<thead>
<tr>
<th></th>
<th>n</th>
<th>Pleochroism</th>
</tr>
</thead>
<tbody>
<tr>
<td>X</td>
<td>1.775 ± 0.005</td>
<td>Light cadmium yellow</td>
</tr>
<tr>
<td>Y</td>
<td>1.815 ± 0.005</td>
<td>Cadmium yellow</td>
</tr>
<tr>
<td>Z</td>
<td>1.825 ± 0.005</td>
<td>Orange</td>
</tr>
</tbody>
</table>

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.
ROSCEOELITE and VANADIUM HYDROMICA

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.

<table>
<thead>
<tr>
<th>SiO₂</th>
<th>Al₂O₃</th>
<th>FeO</th>
<th>V₂O₅</th>
<th>MgO</th>
<th>CaO</th>
<th>K₂O</th>
<th>Na₂O</th>
<th>H₂O</th>
<th>Rem.</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>44.81</td>
<td>18.42</td>
<td>1.58</td>
<td>20.41</td>
<td>0.83</td>
<td>0.20</td>
<td>8.28</td>
<td>0.07</td>
<td>4.40</td>
<td>0.75</td>
<td>99.73</td>
</tr>
</tbody>
</table>

(Analyst: V. North)

Less O = F 0.06

99.67

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

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:

<table>
<thead>
<tr>
<th>Orientation</th>
<th>n</th>
<th>Color</th>
</tr>
</thead>
<tbody>
<tr>
<td>X</td>
<td>1.710</td>
<td></td>
</tr>
<tr>
<td>Y &amp; b \sim 45\degree</td>
<td>1.770</td>
<td>Biaxial negative (?)</td>
</tr>
<tr>
<td>Z \sim c</td>
<td>1.840</td>
<td>Yellow</td>
</tr>
</tbody>
</table>

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 Poshag and Hess from an occurrence at Bull Pen Canyon, Slick Rock district, Mesa No. 1 mine, Shiprock district.
METAROSSITE \( \text{CaV}_2\text{O}_6 \cdot 2\text{H}_2\text{O} \)

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:

\[
\begin{array}{c|c|c}
\text{n} & \text{X} & 1.840 \\
\text{Y} & > 1.85 & \text{Biaxial positive} \\
\text{Z} & > 1.85 & \\

2V & \text{large; dispersion strong} & \\
\end{array}
\]

Analysis: Qualitative spectrographic analysis of material from Buckhorn claim.

Major \( V \)
Minor \( \text{Ca} \)
Trace \( \text{Al Si Nb Fe Mg} \)

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

$\text{Na}_2\text{V}_3\text{O}_8\cdot3\text{H}_2\text{O}$

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:

<table>
<thead>
<tr>
<th>Orientation</th>
<th>n</th>
<th>Pleochroism</th>
</tr>
</thead>
<tbody>
<tr>
<td>X</td>
<td>approx. 1.8</td>
<td>Yellow</td>
</tr>
<tr>
<td>Y</td>
<td>&gt; 2.0</td>
<td>Orange yellow</td>
</tr>
<tr>
<td>Z = b</td>
<td>&gt; 2.0</td>
<td>Orange red</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>$\text{V}_2\text{O}_4$</th>
<th>$\text{V}_2\text{O}_5$</th>
<th>$\text{Na}_2\text{O}$</th>
<th>$\text{K}_2\text{O}$</th>
<th>$\text{CaO}$</th>
<th>Acid insol.</th>
<th>$\text{H}_2\text{O}^-$</th>
<th>$\text{H}_2\text{O}^+$</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.56</td>
<td>77.17</td>
<td>9.17</td>
<td>1.35</td>
<td>0.12</td>
<td>0.31</td>
<td>1.83</td>
<td>7.96</td>
<td>99.37</td>
</tr>
</tbody>
</table>

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 Thompstones district, during World War II. The second sample was collected by J. Stone in July 1952, from Cactus Rat incline, Thompstones district.
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 $1.710 \pm 0.005$

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.
VOIBORTHITE

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

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: $3 \frac{1}{2}$
- 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:

<table>
<thead>
<tr>
<th>n</th>
<th>Color</th>
</tr>
</thead>
<tbody>
<tr>
<td>X</td>
<td>2.01 Green to greenish yellow</td>
</tr>
<tr>
<td>Y</td>
<td>2.05 Biaxial positive red</td>
</tr>
<tr>
<td>Z</td>
<td>2.10 in transmitted light.</td>
</tr>
<tr>
<td>$2V$</td>
<td>$68^\circ Li, 83^\circ Na$; $r &gt; v$ inclined</td>
</tr>
</tbody>
</table>

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

\[(\text{Cu,Ca})_2(\text{VO}_4)(\text{OH})_3\]

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:

\[
\begin{array}{ccc}
X & 2.00 & \text{Brown} \\
Y & 2.01 & \text{Brown} \\
Z & 2.02 & \text{Green} \\
2V & \text{large; } r > v & \text{strong}
\end{array}
\]

Biaxial negative

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

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

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


George, d'Arcy, 1949, Mineralogy of uranium and thorium minerals: RMO-563.


UNPUBLISHED REPORTS
