



Mineralogical notes on the uranium deposits of the Grants and Laguna district, New Mexico

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MINERALOGICAL NOTES ON THE URANIUM DEPOSITS OF THE GRANTS AND LAGUNA DISTRICTS

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INTRODUCTION

In the eleven years since the uranium deposits in the vicinity of Haystack Butte first attracted attention, the Grants and Laguna districts have developed into major uranium-producing areas of the United States. A single deposit in the Laguna district, the Jackpile mine, represents about one-third of the total uranium reserves of New Mexico. In addition to their great economic significance, these deposits have shed considerable light on the geochemistry and mineralogy of uranium deposits in sedimentary rocks. Several new minerals have been discovered in the area, which, though not spectacular, are of considerable scientific interest. The mineral collector may find here outstanding specimens of uraninite and some of its alteration products.

Most of the deposits in the two districts are in Jurassic rocks. Those in the Laguna district are in the sandy facies of the Brushy Basin member of the Morrison formation, and those of the Grants district are in the Westwater Canyon member of the Morrison formation and in the Todilto limestone. Several minor deposits occur in other Jurassic rocks and in the Dakota sandstone. The nature of the host rock, limestone or sandstone, provides a convenient as well as economically significant classification of the ore types. A more fundamental scheme of classification can be established on the basis of the oxidation state of the uranium and vanadium and the ratio of these elements to one another (Weeks and others, 1959), thereby separating the ores into unoxidized and oxidized types. A genetic classification, though very desirable, is as yet impractical, for ten years of intensive research has failed to resolve the question of origin of these deposits.

Todilto limestone ores. The Todilto limestone of the Grants district is typically gray in color and has a distinctly fetid odor. It varies from thin bedded in the lower part to massive in the upper part. The mineralized zones are irregular tabular bodies several feet thick and up to several tens of thousands of square feet in area. Mineralization is generally concentrated in areas of small-scale intraformational folding and faulting. The ores are generally of the unoxidized type, and have been subdivided into uranium, uranium-fluorine (fluorite), and uranium-vanadium ores (Truesdell and Weeks, 1960). This subdivision is not practical in a general discussion, for the ore varies rapidly from one type to another within a single small deposit. Hematite staining of the limestone is common in the higher grade ores. Fracture zones and vugs are commonly coated with oxidized uranium and vanadium minerals.

Sandstone ores of the Grants district. The Poison Canyon deposit is typical of the deposits in the Morrison formation in this district. The ore body is in the Poison Canyon sandstone (local usage), a tongue of the Westwater Canyon member extending into the Brushy Basin member. The deposit is tabular, consisting of several nearly parallel layers as much as 20 feet thick. The greatest concentration of mineralization is near the base of the host unit and directly above thin mudstone beds

within the sandstone. The ore is primarily black and unoxidized with a concentration of oxidized minerals near the surface and along faults which are younger than the deposit. Minor amounts of sulfides, primarily pyrite and marcasite, but containing significant amounts of molybdenum and selenium, are characteristic of this deposit.

Sandstone ores of the Laguna district. The Jackpile deposit is characteristic of deposits in the Laguna district. The host rock is the Jackpile sandstone (local usage) in the upper part of the Brushy Basin member of the Morrison formation. The largest of the ore bodies, the North ore body, consists of two subparallel layers whose total thickness averages 20 feet. The ore body is about 1,300 feet wide and several thousand feet long. In the lower grade parts of the ore layers, and especially in the zone between the two layers, there are concentrations of uranium associated with carbonaceous material in rod-like vertical bodies. The ore is primarily of the unoxidized type, but a wide variety of oxidized minerals is also present.

The Woodrow deposit, about one mile east of the Jackpile mine, is unique in the area, it being the only deposit in a sandstone pipe. Several similar structures are known in the Laguna district but none of them is significantly mineralized. The pipe is nearly vertical, extends to a known depth of 230 feet, and is approximately 35 feet in diameter. The pipe cuts the Brushy Basin member of the Morrison formation and is separated from it by a complex, branching ring fault. The average tenor of the ore is about two percent uranium, the highest concentration being in the upper part of the pipe and along the bounding ring fault. The core of the pipe is essentially barren. The ore minerals are primarily of the unoxidized type, but many secondary minerals are also present, especially near the surface.

THE MAJOR ORE MINERALS

The terms primary and secondary have frequently been used in referring to the minerals of these and other Colorado Plateau uranium deposits. In view of the controversy regarding the origin of the deposits, the terms primary and secondary should be replaced by unoxidized and oxidized, respectively. The oxidized minerals are in fact secondary in a genetic sense in that they are derived from the unoxidized minerals, primarily through the action of ground water. The unoxidized minerals, however, are primary only in the sense that they are the source of material for the oxidized minerals. In the unoxidized ores the uranium is ideally in the tetravalent state and the vanadium is in the trivalent or tetravalent state. In the oxidized ores the uranium is hexavalent, usually as the uranyl (UO_2)⁺ ion, and the vanadium is almost always pentavalent. In general the unoxidized minerals are of the greatest economic importance, but the oxidized minerals are locally important, especially in the Todilto limestone. The great permeability of the sandstones may account for the removal of the highly soluble uranyl ion.

Uraninite. Uraninite or pitchblende is the major unoxidized uranium mineral in the Todilto limestone deposits and is an important constituent of the sandstone ores.

Ideally it has the composition UO_2 , but partial oxidation will have frequently taken place so that the U:O ratio may range from 1:2 to 1:2.6. In none of the ores do we find the cubic crystal habit, the form generally being as small masses, blebs, and seams in the host rock, or as coatings on the sedimentary grains. The mineral is black, has a submetallic to pitchlike luster (limestone ores), or may be dull and earthy (sandstone ores). In the Todilto limestone, the uraninite content may be quite high, and where this is true the limestone may be heavily stained with hematite. The dark streaks of uraninite, often surrounded by yellow oxidation products, in a reddish limestone give the highest grade ores a distinctive, crudely banded appearance. The discovery of uraninite in the Todilto limestone was one of the first reported occurrences of tetravalent uranium in a deposit of the Colorado Plateau type.

Coffinite. The elements zirconium and thorium are found in nature as the orthosilicates zircon (ZrSiO_4) and thorite (ThSiO_4). The chemical similarity of uranium and thorium would lead one to expect a similar uranium silicate. As early as 1953, John W. Gruner noted that some of the asphaltic materials of certain Colorado Plateau uranium ores gave X-ray diffraction patterns that resembled those of zircon. The phase producing the pattern was not isolated and its chemical nature was not ascertained. The problem was pursued by several investigators, and several years later the mineral was isolated and given the name coffinite (Stieff, and others, 1956). As expected, the mineral is a uranous orthosilicate, but the orthosilicate group is in part replaced by hydroxyl ions. The substitution is in the ratio of four hydroxyl ions per orthosilicate, giving a general formula $\text{U}(\text{SiO}_4)_{1-x}(\text{OH})_x$. Coffinite is almost invariably associated with some organic matter, especially asphaltite, which it closely resembles both as to color and luster. For this reason the mineral is often very difficult to recognize. In the Grants and Laguna districts, coffinite is one of the most important ore minerals in the sandstone ores and a minor one in the limestone ores.

Vanadium oxides and hydroxides. In the unoxidized ores the uranium and vanadium occur in separate minerals. The vanadium minerals are black, as are those of uranium, but they are generally somewhat fibrous or bladed in habit. The oxidation state varies from trivalent to tetravalent, both ions being present in some of the minerals. Truesdell and Weeks (1960) have studied the paragenesis of the Todilto limestone ores, and have found that the vanadium mineralization is usually earlier than the uranium mineralization. They found some early vanadium-bearing clay, but most of the unoxidized vanadium is present as the hydroxides and oxides haggite, paramontroseite, and possibly montroseite. Haggite, a new mineral, contains both tri- and tetravalent vanadium and is generally earlier than the uraninite, but may itself be a replacement of montroseite which contains only trivalent vanadium. Paramontroseite contains only tetravalent vanadium and is an alteration product of haggite. The vanadium mineralization of the sandstone ores has not been so thoroughly investigated, but probably involves similar minerals as well as the vanadium mica roscoelite.

The uranyl vanadates. Oxidation of ores containing both uranium and vanadium commonly yields double salts containing the uranyl ion and pentavalent uranium. The most familiar of these minerals are carnotite, tyuyamunite, and metatyuyamunite. Carnotite, a hydrous potassium uranyl vanadate, is known from all ore types in the area,

but is probably not present in sufficient quantities to be important economically. The analogous calcium compounds, tyuyamunite and metatyuyamunite (differing only in the hydration state), are far more important, making up a significant part of the ore in some of the Todilto limestone deposits. All three minerals are bright yellow, powdery or scaly in habit, and form incrustations on the unoxidized minerals or coat fractures and bedding planes in the limestone. When associated with recrystallized calcite they may be found in rather spectacular specimens.

Uranophane. The calcium uranyl silicate, uranophane, is occasionally referred to as an ore mineral in the Todilto limestone deposits. It is probably of only minor economic significance, but the specimens are of such exceptional quality and beauty as to warrant a brief comment. The mineral occurs as rosettes and radiating clusters of bright yellow acicular crystals coating fractures or filling vugs. Vugs several inches in diameter are sometimes completely lined with these radiating clusters. Such specimens are amongst the finest known of this mineral.

NON-URANIUM MINERALS OF SPECIAL INTEREST

Fluorite. Locally the Todilto limestone contains considerable amounts of fluorite. The fluorite is present as small, irregular dark purple grains scattered through the limestone, giving it a speckled appearance. In some cases the concentration of fluorite is so great as to give a uniform dark purple color to the limestone. Truesdell and Weeks (1960) state that uraninite and fluorite are not necessarily associated, being found as separate masses as often as they are intergrown. Lavery and Gross (1956), however, note intimate intergrowths of the two minerals on a microscopic scale. I have observed that all specimens of fluorite which were available to me were radioactive to a degree significantly above background, but that in some instances no uranium mineral could be detected. Microscopically (magnifications of near 1000x), the dark purple color may be seen as very small, intense color patches in a nearly colorless fluorite. The purple color is permanently destroyed on heating for several hours at 500°C. Late-formed veinlets of calcite cutting the fluorite-rich limestones often have microscopic colorless cubes of fluorite at the veinlet wall, apparently in crystallographic continuity with the purple fluorite. These observations suggest to me that the purple color may be due to radiation damage in the fluorite lattice caused by submicroscopic areas of uraninite within the fluorite, with which uraninite is isostructural.

Molybdenum minerals. At the Poison Canyon deposit one often finds specimens of heavily mineralized, black, friable sandstone with a bright blue staining. The stain is caused by the hydrous molybdenum sulfate, ilsemanite. The blue-stained specimens are most common near the surface or in ore which has been lying on the surface for some time. Undoubtedly the ilsemanite is formed by oxidation of sulfide minerals. The molybdenum sulfides jordisite and molybdenite have been found in the ore from this and other localities, but they are not visible to the naked eye.

Selenium minerals. One of the common plants in the vicinity of the Poison Canyon and other deposits in the Morrison formation is *Astragalus pattersoni* or rattle weed. The plants of this genus utilize selenium in their metabolic processes and consequently may be used as "selenium indicator plants". The common association of minor amounts of selenium with uranium in many of the Colorado

Plateau deposits makes possible the use of these plants as prospecting guides. The unoxidized sandstone ores of the Grants district contain small amounts of marcasite and pyrite which have been shown to contain minor amounts of selenium in substitution for the sulfur. Native selenium has been found at several localities in the area (Sun, 1959). The selenium occurs as incrustations consisting of steel-gray, metallic, acicular crystals. Some of the specimens are of exceptionally fine quality.

CHECK LIST OF URANIUM AND VANADIUM MINERALS

Following is a list of minerals containing uranium, vanadium, or both which have been reported from the Grants and Laguna districts. The minerals are grouped according to the oxidation state of the uranium and vanadium, and may accordingly be assigned to the unoxidized or oxidized ore types. Literature references are given for the new and less familiar minerals wherever possible. New minerals for which the Grants district is the type locality, or which were discovered here shortly after the initial discovery at some other locality are underlined. Minerals whose occurrence is questionable are enclosed in parentheses.

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- U⁺⁴ MINERALS
- Uraninite - UO₂ to UO_{2.6}
- Coffinite - U(SiO₄)_{1-x}(OH)_{4x} (Stieff and others, 1956)
- V⁺³ AND V⁺⁴ MINERALS
- Doloresite - 3V₂O₄·4H₂O (Stern and others, 1957)
- Häggite - V₂O₂(OH)₃ (Evans and Mrose, 1958)
- Montroseite - VO(OH) (Weeks and others, 1953)
- Paramontroseite - VO₂ (Evans and Mrose, 1955)
- Roscoelite - K(Al,V)₂(Al,Si₃)O₁₀(OH)₂
- Vanadium clay
- V⁺⁴ - V⁺⁵ MINERALS
- Corvusite - V₂O₄·6V₂O₅·nH₂O
- Grantsite - Na₄CaV₁₂O₃₂·8H₂O
- U⁺⁶ AND V⁺⁵ MINERALS
- Autunite - Ca(UO₂)₂(PO₄)₂·10-12H₂O
- Becquerelite - 2UO₃·3H₂O (Frondel and Cuttitta, 1953)
- Beta-uranophane - (see uranophane)
- Carnotite - K₂(UO₂)₂(VO₄)₂·1-3H₂O (Appleman and Evans, 1957)
- Cuprosklodowskite - possibly a copper analog of uranophane
- Gummite - a mixture of hydrous uranium oxides
- Hewettite - CaV₆O₁₆·9H₂O (Barnes, 1955)
- Johannite - Cu(UO₂)₂(SO₄)₂(OH)₂·6H₂O (Hurlbut, 1950)
- Meta-autunite - Ca(UO₂)₂(PO₄)₂·8H₂O
- Metatyuyamunite - Ca(UO₂)₂(VO₄)₂·3-5H₂O (Stern and others, 1956)
- Novacekite - Mg(UO₂)₂(AsO₄)₂·8-10H₂O (Frondel, 1951)
- Pascoite - Ca₃V₁₀O₂₈·16H₂O
- (Rauvite) - CaO·2UO₃·5V₂O₅·16H₂O
- Rutherfordine - (UO₂)CO₃ (Frondel and Meyrowitz, 1956)
- Saléeite - Mg(UO₂)₂(PO₄)₂·8H₂O (Frondel, 1951)
- Santafeite - Na₂O·3MnO₂·6(Mn,Ca,Sr)O·3(V,As)₂O₅·8H₂O (Sun and Weber, 1957)
- Schroekingierite - NaCa₃(UO₂)(CO₃)₃(SO₄)F·10H₂O (Hurlbut, 1954)
- Sklodowskite - possibly a magnesium analog of uranophane
- Soddyite - (UO₂)₅(SiO₄)₂(OH)₂·5H₂O (Gorman, 1952)
- Tyuyamunite - Ca(UO₂)₂(VO₄)₂·5-8H₂O (Stern and others, 1956)
- Uranophane - Ca(H₃O)₂(UO₂)₂(SiO₄)₂·3H₂O (Smith and others, 1957)
- Uranopilite - (UO₂)₆SO₄(OH)₁₀·12H₂O (Frondel, 1952)
- (Uvanite) - 2UO₃·3V₂O₅·15H₂O
- Weeksite - K₂(UO₂)₂(Si₂O₅)₃·4H₂O (Outerbridge and others, 1960)
- Zippeite - K₄(UO₂)₆(SO₄)₃(OH)₁₀·H₂O

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