



NEW MEXICO MINERAL SYMPOSIUM

November 11 & 12, 1995



NMIMT Campus, Socorro, New Mexico

Welcome to
THE SIXTEENTH ANNUAL
NEW MEXICO MINERAL SYMPOSIUM

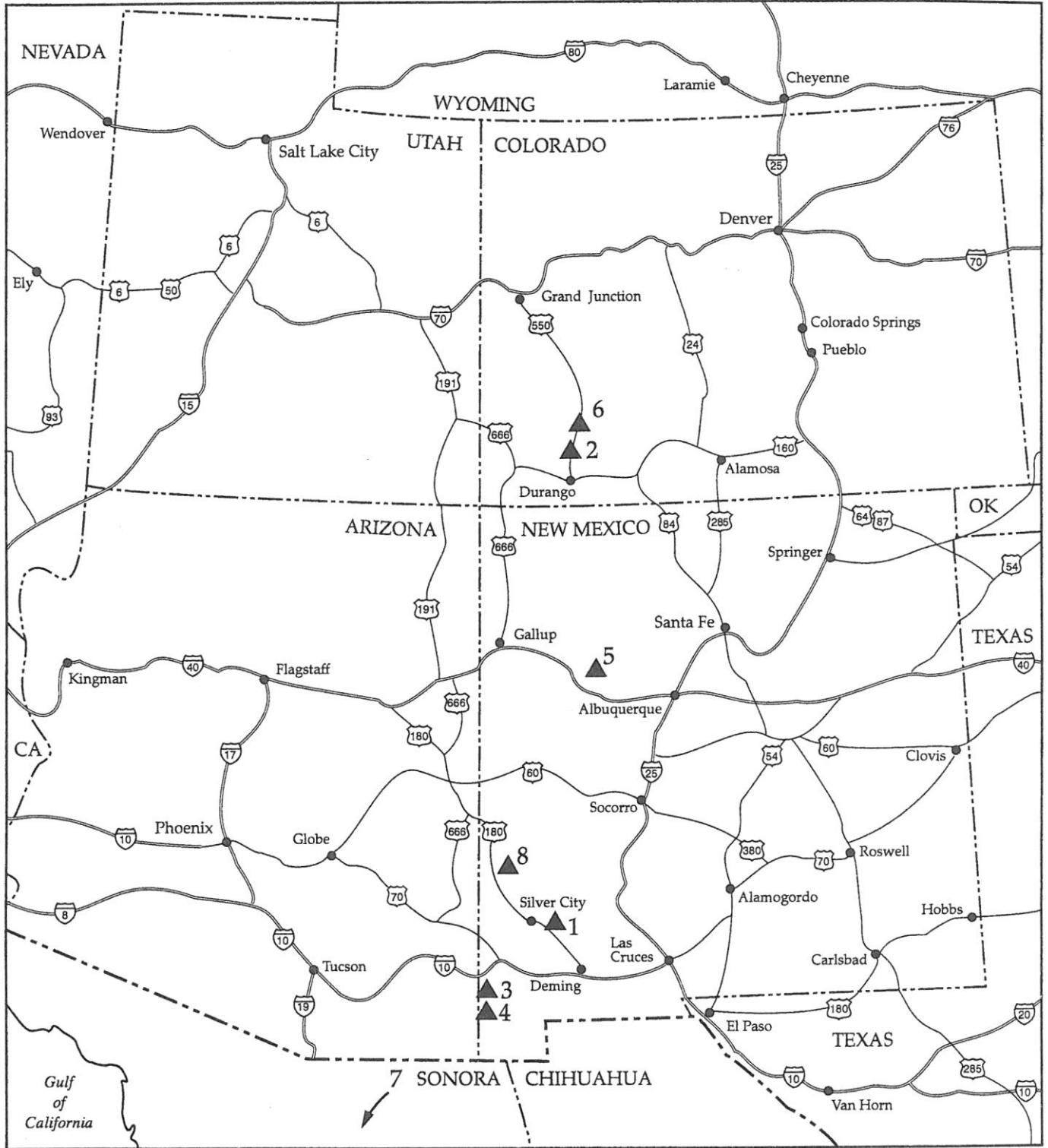
November 11 and 12, 1995

Macey Center Auditorium
New Mexico Institute of Mining and Technology
Socorro, New Mexico

sponsored by
New Mexico Bureau of Mines and Mineral Resources
Albuquerque Gem and Mineral Club
Los Alamos Geological Society
New Mexico Geological Society
Chaparral Rockhounds

The purpose of the New Mexico Mineral Symposium is to bring together for an exchange of ideas both professionals and amateurs interested in mineralogy. The sponsors hope that the Sixteenth New Mexico Mineral Symposium will give both groups a forum to present their cumulative knowledge of mineral occurrences in the state. In addition to the formal papers, informal discussions among mineralogists, geologists, and hobbyists should benefit all.

Cover—MINERALS OF THE FOUR-CORNERS STATES. Scepter quartz from Kingston, New Mexico; rhodochrosite from Silverton, Colorado; topaz from the Thomas Mountains, Utah; and barite from Superior, Arizona represent the four-corners states in the cover design by Teresa Mueller.



Geographic Index Map
 16th New Mexico Mineral Symposium

SCHEDULE

Numbers in parentheses refer to geographic location on map.

Friday, November 10

6:00 pm Informal tailgating and social hour, individual rooms, Super 8 Motel

Saturday, November 11

8:30 am Registration; coffee and donuts

9:30 *Opening remarks*, main auditorium

9:40 (1) *Minerals and mining history of the Fierro-Hanover district, Grant County, New Mexico*—Robert W. Eveleth

10:10 (2) *Secondary lead-copper-zinc minerals from the San Juan Mountains, southwestern Colorado*—Tom Rosemeyer

10:40 Coffee break

11:10 (3) *Origin of chalcedony nodules in rhyolite from the Peloncillo Mountains, Hidalgo County, New Mexico*—Peter Modreski

11:40 (4) *Carminite and other arsenates from Granite Gap, Hidalgo County, New Mexico*—Ramon S. DeMark and Paul F. Hlava

12:00 pm Lunch, Museum tours

2:00 (5) *Mineralogy of the Todilto uranium deposits, Grants district, New Mexico*—William R. Berglof and Virginia T. McLemore

2:30 (6) *The history and minerals of the Grizzly Bear mine, Ouray, Colorado*—Barbara Muntyan

3:00 Coffee break

3:30 (7) *The geology and mineralogy of the Pilares wollastonite deposit, Sonora, Mexico*—Douglas F. Irving and Paul F. Hlava

4:00 (7) *The Romero Mineral Museum*—Dr. Miguel Romero S., featured speaker.

5:30 Sarsaparilla and suds: cocktail hour (with cash bar)

6:30 Dinner at Macey Center followed by a brief presentation by Virgil W. Lueth, "A sneak preview of the new and improved New Mexico Mineral Museum," and an auction to benefit the New Mexico Mineral Symposium.

Sunday, November 12

9:00 am Welcome to second day of symposium and follow-up remarks

9:10 *Telluride occurrences in the four-corners states, USA*—Bruce A. Geller

9:40 (8) *Geology and tellurium minerals of the Lone Pine area, Wilcox district, Catron County, New Mexico*—Virgil W. Lueth, Joan Beyer, and Ronald B. Gibbs

10:10 Coffee break

10:40 *Mining museums of Wales and Scotland*—Dale Wheeler

11:10 *Open forum on minerals in the four-corners states*

12:00 pm Lunch

1:15-3:00 Silent auction, upper lobby, Macey Center, sponsored by the Albuquerque Gem and Mineral Club

**Minerals and mining history of the Fierro-Hanover district,
Grant County, New Mexico**

(Location 1 on index map)

Robert W. Eveleth
New Mexico Bureau of Mines and Mineral Resources

The Fierro-Hanover mining district in Grant County, southwestern New Mexico, is one of the state's more productive mining areas, having seen nearly continuous production of base metals, precious metals, and iron for more than a century.

The entire district is contained within the roughly triangular-shaped features known as the Santa Rita horst, which is sharply bounded on the northwest by the Barringer fault, on the northeast by the Mimbres fault, and less distinctly on the south by the Groundhog and Nancy faults. The intrusion of the Fierro-Hanover granodiorite stock uplifted and fractured the sedimentary rocks in the district. These fractures provided channels through which the mineralizing solutions invaded the limestones and formed the extensive contact-metamorphic and skarn deposits in the Combination, Princess, Kearney, Empire, and Pewabic mines in the southern and central parts of the district and the Union Hill iron deposits and the Continental mine at Fierro in the northern part.

These and other smaller mines have produced a total of more than a billion pounds each of copper and zinc, 50 million pounds of lead, 5 million ounces of silver, and 50,000 ounces of gold. The district is the state's leading producer of iron ore totalling some 8 1/2 million short tons. Concurrent with the production has come a long and colorful mining history beginning in ca 1858 with German metallurgist Sofio Hinkle at the old Hanover mine near present-day Fierro. The richest copper ores, some grading 58% Cu, were produced here until the Civil War.

The Hanover and other mines have produced an abundance of collectible mineral species including quartz, calcite, selenite, magnetite, native copper, and turquoise, as well as wide variety of copper oxides and sulphides. Excellent specimens are still produced occasionally at the currently active Continental mine, the Union Hill iron pits, and until recently, the mines along the Barringer fault north of Fierro.

Secondary lead-copper-zinc minerals from the San Juan Mountains, southwestern Colorado

(Location 2 on index map)

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During the last five years a number of discoveries of secondary lead-copper-zinc minerals have been made in the San Juan Mountains of southwestern Colorado. The minerals generally occur in the upper part of mineralized veins and replacement orebodies that have been oxidized near the surface. The exotic and colorful minerals do not occur in large quantities as in New Mexico and Arizona but do occur as well-crystallized microminerals in the vuggy gossan zone.

In San Juan County, probably the best-known locality for secondary minerals is the Titusville mine at the head of Kendall Gulch at an elevation of 12,920 ft. To date the following secondary minerals have been identified: anglesite, azurite, brochantite, cerussite, chalcoalumite, linarite, malachite, ozarizawaite, posnjakite, serpierite, and smithsonite.

Also in San Juan County, the Bandora mine has produced well-crystallized microcrystals of cerussite, linarite, pyromorphite, and wulfenite.

Moving north to Ouray County, the best locality for secondary minerals are the Senorita, Black Girl, and Slide mines on Carbonate Hill in the Paquin mining district. The primary ore consists of galena and tetrahedrite as replacement orebodies in sedimentary rocks adjacent to steeply dipping mineralized veins. Vugs in the quartz-barite contain beautiful microcrystals of the following minerals: aragonite, anglesite, aurichalcite, azurite, bindheimite, bronchantite, cerussite, cuprite, langite, linarite, malachite, mimetite, pyromorphite, rosasite, silver, smithsonite, and wulfenite.

The Mineral Farm mine, which consists of a number of shafts, declines, and prospect trenches, has produced fine specimens of aurichalcite, azurite, and malachite.

Other small prospects in both counties have produced anglesite, azurite, cerussite, linarite, and malachite.

Origin of chalcedony nodules in rhyolite from the Peloncillo Mountains, Hidalgo County, New Mexico

(Location 3 on index map)

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The origin of agate and chalcedony nodules has always been something of an enigma to mineralogists, as well as to the general public. Although the general concept of their formation has been fairly well understood, the precise details involved in the process of their formation at each particular locality have tended to be more difficult to explain.

A particularly intriguing occurrence of chalcedony nodules has recently been recognized in mid-Tertiary silicic volcanic rocks near the Arizona-New Mexico border in southwestern Hidalgo County, New Mexico. The occurrence is in the vicinity of Clanton Draw and Geronimo Pass, in the Coronado National Forest. The nodules formed within a late Oligocene, high-silica rhyolite lava flow (Rhyolite of Clanton Draw) along the north margin of the Geronimo Trail cauldron (McIntyre, 1988; Erb, 1979; and Charles Bryan, personal communication, 1995).

The chalcedony nodules were recently noticed by Charles Bryan (University of New Mexico) in the course of field work. Ramon S. DeMark and Brian Huntsman learned about the occurrence from Bryan. The nodules range in size from about an inch to 10-12 inches in diameter. They are typically hollow, and only partially fill somewhat angular, irregular-shaped cavities in the host rhyolite. The chalcedony lining making up the nodules is typically from 0.5 to 1 cm thick. Some nodules are flattened or elongated parallel to the direction of flow banding in the rhyolite; others are subspherical. Most nodules are found loose, as "float" pieces, usually still partially attached to pieces of the host rhyolite.

A few occur as loose nodules totally free of rhyolite matrix, and some are seen embedded in rhyolite boulders or outcrops. An unusual feature of the nodules is the way the chalcedony appears to have "oozed" out of the interior surface of the cavity in rhyolite; lobes of chalcedony surround, but usually do not completely close off, the opening of the host cavity. Rarely, completely closed, hollow nodules have weathered out of the rhyolite; some such nodules have thin enough walls and contain a large enough void to float on water.

The chalcedony is fibrous with a radiating microstructure. Fibers are length-fast (elongated perpendicular to the c-axis), as has been reported to be the case for most agate and chalcedony. The color ranges from pale pink to milky-white to colorless; typically, the later-formed material (toward the interior of the rock cavity) is more cloudy. The chalcedony fluoresces bright green under short-wave UV light, typical of hydrous silica containing trace amounts of the uranyl (UO_2^{2+}) ion. The last-formed layers of chalcedony tend to be the most brightly fluorescent, but some of the earliest-formed layers (adjacent to the host rhyolite) also fluoresce brightly. The most cloudy/milky chalcedony usually shows little fluorescence. Fluorescent banding in the layers helps to trace growth patterns in the chalcedony.

Cross-sectioning reveals that the early-formed chalcedony in the interior of the nodules has grown radially from nucleation sites on the rock cavity walls, but later chalcedony growth appears to have progressed outward toward the cavity opening, parallel to the cavity walls. Thin, green-fluorescent chalcedony-filled fractures in the surrounding rhyolite appear to mark pathways by which silica-

bearing water was carried into the cavities. Toward the interior of the cavities, some of the last-formed fibrous chalcedony grades into a layer composed of minute, euhedral drusy quartz, with crystals about 0.5 mm in diameter. Also in places, the outermost layer of chalcedony and drusy quartz is overlain by a surface coating of iron-stained, fibrous, length-slow chalcedony(?) about 0.5 mm thick. Recent studies have shown that much length-slow chalcedony contains moganite (also known in the literature as lucetite), which is a monoclinic SiO₂ polymorph distinct from quartz (Heaney and Post, 1992); XRD confirmation for the presence of moganite in the Hidalgo County chalcedony has not yet been obtained. In some nodules, small patches of glassy, blebby opal (optically isotropic) with a very bright green fluorescence were the last material deposited.

The origins of agate, chalcedony, and geodes have been the subject of increased interest and study in recent years. A major controversy, not yet resolved, has been whether chalcedony forms by precipitation from dilute aqueous solutions that flow through cavities, or by crystallization of a dense, viscous silica gel that fills a cavity as a closed system. Building on the speculations and observations contained in such classic publications as those by Liesegang (1910) and Ross (1941), some very good treatises on the subject have appeared within the past dozen years; for example, Landmesser (1984), Macpherson (1989), and Pabian and Zarins (1994). In addition, an increasing number of papers have applied modern techniques of mineralogy and geochemistry to the study of agate and chalcedony; for example, Fallick and others (1985); Graetsch and others (1985); Wang and Merino (1990); Heaney (1993); and Lueth and Goodell (1995).

Symposium participants are invited to share their own ideas and insights about the origin of agate and chalcedony in the discussion following this presentation, so that together we may try to reach some increased level of understanding of what these nodules are telling us about the deposition of silica within cavities in rhyolite. I would like to particularly acknowledge the advice and unpublished information provided by Charles Bryan, Ramon S. DeMark, and Virgil E. Lueth in preparing this paper.

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Carminite and other arsenates from Granite Gap, Hidalgo County, New Mexico*

(Location 4 on index map)

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Granite Gap is in the central Peloncillo Mountains near the "boot heel" of southwestern New Mexico and was one of the major producers of the San Simon mining district. It can be reached by traveling west on I-10 for 16 mi past Lordsburg to Road Forks then south on U.S. 80 for approximately 11 mi. The mining area is on a hill southeast of the highway and is about one quarter of a mile from the highway. Most of the area is in private ownership as patented claims.

Mining exploration at Granite Gap began about 1880, and there was a great deal of activity at the site in 1904 when it was visited by Lindgren, Graton, and Gordon (1910, p. 330). Extensive production stopped around 1915 although small amounts of ore were shipped until at least 1926 and probably much later as reported by Gillerman (1958, p. 101). The mines were operated for lead and silver with some minor amounts of gold. The ore occurs in hydrothermal veins in Mississippian limestones near or adjacent to Tertiary dikes of a light-colored, fine-grained, quartz monzonite porphyry (Williams, 1978). No contact metamorphic effects were observed in the limestones adjacent to the dikes (Gillerman, 1958; Williams, 1978) although an extensive contact metamorphic aureole does occur around the later, genetically related, main quartz monzonite intrusive (Williams, 1978).

The main workings consist of several shafts and a number of adits, all of which were apparently interconnected at one time. Workings that are currently accessible form a Byzantine series of drifts, declines, stopes, and "dog holes." Mining by "following the ore" is probably responsible for this extreme irregularity of openings and suggests that the ore shoots themselves were highly irregular although they were always near the intrusive dikes.

Arsenic was detected early and was attributed to oxidized tetrahedrite-group minerals [(Cu, Fe)₁₂(Sb,As)₄S₁₄] (Lindgren et al., 1910) although no relict tetrahedrite has been found. Williams (1978) reported a number of arsenate minerals but did not provide specifics of occurrence, associations, and physical descriptions for most of them. He did, however, note the ubiquitous presence of arsenopyrite in unctuous phlogopite surrounding the other sulfides. This material was not detected during this investigation. Williams (1978) determined that the silver in the ore was originally derived from matildite [AgBiS₂] embedded in the galena.

Granite Gap is relatively unknown to mineral collectors with the exception of a small cadre of micromineral enthusiasts. This is probably due to the remoteness of the area plus the paucity of hand-sized specimens. However, it is now revealed to have a significant suite of attractive secondary arsenate minerals plus a number of additional species of interest to mineral collectors. Arsenate species found during this study, in order of abundance, are mimetite [(Pb₅(AsO₄)₃Cl)], conichalcite [CaCu(AsO₄)(OH)], beudantite [PbFe₃³⁺(AsO₄)(SO₄)(OH)₆], agardite-(Y)[Y,Ca]Cu₆(AsO₄)₃(OH)₆ • 3H₂O (Williams, 1978, identified the related species mixite), adamite (cuprian) [(Zn,Cu)₂(AsO₄)(OH)], olivenite [Cu₂(AsO₄)(OH)], and carminite (PbFe₂³⁺(AsO₄)₂(OH)₂). Species identification was accomplished by physical characteristics and electron microprobe analysis. Mimetite color and habit are quite variable. Crystals may be bright canary yellow or completely white, and the habit varies from 1 mm spheres to hexagonal prisms that may terminate with the pinacoid

or branch into "wheat sheaves." Conichalcite is typically grass green and may be individual spheres or mats and crusts of intergrown sheaves. Coverage of some specimens exceeds several square centimeters. Beudantite is found in very small (less than 0.1 mm) crystals that are yellow green to brown and sub-translucent. Agardite-(Y) occurs in greenish-blue, acicular sprays with individual crystals to 0.5 mm. Some crystals are extremely fine whereas others are sufficiently coarse to recognize the hexagonal symmetry. It is found with conichalcite and adamite but is difficult to distinguish from the ubiquitous aurichalcite $[(\text{Zn,Cu})_5(\text{CO}_3)_2(\text{OH})_6]$. Adamite was determined to be cuprian by electron microprobe analysis. Individual, bluish-green, equant crystals about 0.2 mm across are translucent with white patches. Olivenite was determined to be zincian, and the crystals are 0.2 to 0.3 mm and equant. They are lustrous, transparent, and sea-blue green. Carminite occurs as bright, carmine-red sprays less than 0.2 mm across and as drusy crusts with very finely crystalline "blebs" of yellow-green beudantite. A copper arsenate, as yet to be identified, was found as 0.1 mm purple-red octahedra and remains under study.

Bromargyrite $[\text{AgBr}]$ is usually found as individual, 0.5 mm, olive-green crystals perched on crusts of conichalcite. Aurichalcite and rosasite $[(\text{Cu,Zn})_2(\text{CO}_3)(\text{OH})_2]$ are both found in attractive specimens in a number of areas throughout the mines, always in association with colorless, bladed, hemimorphite $[\text{Zn}_4\text{Si}_2\text{O}_7(\text{OH})_2 \cdot \text{H}_2\text{O}]$ crystals. Carminite was found in a single specimen on the dump of an adit high on the northwest side of the Granite Gap hill. This adit and dump were the source of the greatest volume and variety of arsenates. Pyrite $[\text{FeS}_2]$ oxidized to goethite $[\text{FeO}(\text{OH})]$ is common on this dump, and blue botryoidal hemimorphite can be found as well. Plattnerite $[\text{PbO}_2]$ associated with white mimetite and brown beudantite is found in this adit in a small area with difficult access. Willemite in colorless, hexagonal prisms and botryoidal, gray smithsonite $[\text{Zn}(\text{CO}_3)]$ along with two single crystals of azurite $[\text{Cu}_3(\text{CO}_3)_2(\text{OH})_2]$ were found on the dump of the highest adit on the southwest side of the hill.

As the only known New Mexico location for carminite and one of a very few arsenate locations in New Mexico, Granite Gap has added one more interesting chapter to the story of New Mexico minerals although the story is by no means complete.

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*Part of this work was performed at Sandia National Laboratories, operated for the U.S. Department of Energy under contract number DE-AC04-94AL85000.

Mineralogy of the Todilto uranium deposits, Grants district, New Mexico

(Location 5 on index map)

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Uranium minerals in the Grants district were first discovered in the late 1940s in the Todilto Limestone, which has yielded about 2% of the total uranium production from the district. The first uranium minerals discovered and mined were brightly colored yellow minerals. Significant quantities of "black ore" containing uraninite (pitchblende) and coffinite were discovered as mining progressed, sometimes associated with blue-black vanadium oxide minerals, and it became evident that the yellow minerals formed by secondary near-surface oxidation of the black ores. Yellow minerals are rare or absent in the deeper mines. Lead-uranium isotopic dating of uraninite indicates that it formed shortly after the limestone was deposited; the yellow minerals formed at various later times.

Fluorite, barite, and pyrite are the most common accessory minerals in and near the uranium ore. Fluorite occurs in small crystals and fine-grained irregular replacements; known occurrences are roughly coextensive with uranium minerals and are probably not related to fluorite vein deposits in the nearby Zuni district. Uraninite occurs in disseminations and replacements along bedding or irregularly throughout mineralized limestone, and occasionally along fractures. Where uraninite is abundant, the limestone may appear red from associated fine-grained hematite. Microscopic galena crystals are associated with high-grade uraninite; much of the lead in the galena may have been derived from decay of uranium. A few deposits extend into the Entrada Sandstone, immediately below the Todilto, with uraninite filling pore spaces between sand grains. The blue-black vanadium minerals are mainly haggite and paramontroseite and often occur in fractures associated with coarse calcite. The most common yellow mineral in oxidized uranium-vanadium ore is tyuyamunite, the calcium analog of carnotite, which forms in the high-calcium limestone environment. It is abundant in thin but conspicuous coatings on fractures and bedding surfaces in the limestone, and occasionally as platy crystals or in pulverulent masses. Tyuyamunite occurs along with the related lower hydrate metatyuyamunite; the minerals differ in their water content and form reversibly from each other depending on humidity conditions. The yellow uranium silicate uranophane may form where the ore is low in vanadium. It occurs as radiating clusters of acicular crystals on fracture or bedding surfaces and occasionally as thicker felted masses or showy acicular crystals in open spaces. Schroeckingerite is rare in oxidized ore, occurring as light-green platy crystals that fluoresce brilliant yellow green in short-wave ultraviolet radiation.

Other scarce minerals in oxidized or partially oxidized deposits are the lead-uranium oxide curite, the calcium vanadates hewettite and metahewettite, and two new minerals from the Grants district: santafeite, a complex manganese vanadate, and grantsite, a sodium calcium vanadate. Goldmanite, another new mineral, is a vanadium-rich garnet related to andradite and grossularite; it occurs in the Laguna area where a Todilto deposit extending into the Entrada sandstone was intruded by a basaltic igneous sill, forming various calc-silicate metamorphic minerals including andradite-grossularite. Small crystals of goldmanite formed in vanadium-rich parts of the metamorphosed deposit.

Several additional minerals occur in or around the Todilto deposits; their relationship to uranium-vanadium mineralization is not clear. These include small quartz crystals, manganese oxides, and iron oxides resembling limonite. Coarsely crystalline black calcite and paragenetically later white calcite are common in fractures and open spaces. Rare pyrite-coated scalenohedral calcite crystals are also observed. A few other minerals may occur as very minor constituents of the host rocks and possibly of the deposits; some have been reported or tentatively identified in previous work but were not confirmed in this study. The most significant or interesting minerals from the Todilto deposits are: uraninite, UO_2 ; coffinite, $\text{U}(\text{SiO}_4)_{1-3}(\text{OH})_4$; haggite, $\text{V}_2\text{O}_2(\text{OH})_3$; paramontroseite, VO_2 ; fluorite, CaF_2 ; barite, BaSO_4 ; pyrite, FeS_2 ; calcite, CaCO_3 ; hematite, Fe_2O_3 ; galena, PbS ; tyuyamunite, $\text{Ca}(\text{UO}_2)_2(\text{VO}_4)_2 \cdot 5-8\frac{1}{2}\text{H}_2\text{O}$; metatyuyamunite, $\text{Ca}(\text{UO}_2)_2(\text{VO}_4)_2 \cdot 3-5\text{H}_2\text{O}$; uranophane, $\text{Ca}(\text{UO}_2)_2(\text{SiO}_3\text{OH})_2 \cdot 5\text{H}_2\text{O}$; schroekingerite, $\text{NaCa}_3\text{UO}_2(\text{CO}_3)_3\text{SO}_4\text{F} \cdot 10\frac{1}{2}\text{H}_2\text{O}$; curite, $\text{Pb}_2\text{U}_5\text{O}_{17} \cdot 4\text{H}_2\text{O}$; hewettite, $\text{CaV}_6\text{O}_{16} \cdot 9\frac{1}{2}\text{H}_2\text{O}$; metahewettite, $\text{CaV}_6\text{O}_{16} \cdot 3\text{H}_2\text{O}$; santafeite, $(\text{Mn,Fe,Al,Mg})_8\text{Mn}_8(\text{Ca,Sr,Na})_{12}(\text{VO}_4)_{16}(\text{OH},\text{O})_{20} \cdot 8\frac{1}{2}\text{H}_2\text{O}$; grantsite, $\text{Na}_4\text{CaV}_{12}\text{O}_{32} \cdot 8\frac{1}{2}\text{H}_2\text{O}$; goldmanite, $\text{Ca}_3(\text{V,Fe,Al})_2\text{Si}_3\text{O}_{12} \cdot$

The history and minerals of the Grizzly Bear mine, Ouray, Colorado

(Location 6 on index map)

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Located in 1875, a year before Ouray County was carved out of the San Juan territory, the original claims of the Grizzly Bear mine are located up Bear Creek, on the northwest slopes of Engineer Mountain, described by Ransome in USGS Bulletin 182 on the Silverton quadrangle.

The Grizzly Bear mine is a gold-silver mine, having produced almost \$1,000,000 in ore values between 1875 and 1910. Always hampered by the lack of transportation, the mine nevertheless was long-considered a promising property. Nearly every prominent name in Ouray County mining has been associated with the Grizzly Bear mine at one time or another since its early days.

A tremendous amount of money was poured into the development of the Grizzly Bear mine between 1896 and 1900, improving the road up to the mine, building a boarding house, and extending several tunnels on the property hundreds of feet. Unfortunately, the mine went into receivership and was eventually sold to a man named Lars Pilker just after World War I. In the early 1920s, looking for financing to develop the mine, Pilker sold a partial interest to John Zanett. Zanett and his family had come to Ouray just after the end of World War I from the Italian Piedmont by way of New York and Ohio. Over the next half-century, Pilker and Zanett maintained a partnership and a love-hate relationship while trying to develop the Grizzly Bear mine. Both men died before their dream was ever realized. It fell to John Zanett's youngest son, Fred, who had made a considerable fortune in the oil business, to realize his father's dream.

Because transportation had always been the limiting factor in profitably mining the Grizzly Bear, and because building a road up Bear Creek was impossible, proper access to this mine had to be achieved by driving a haulage tunnel either from the south or from the north. In the 1970s, Fred Zanett and associate Caswell Silver thus began acquiring patented mining claims that lay north of the Bear Creek drainage, with the intention of driving a haulage tunnel from the Amphitheatre (the high cirque east of Ouray in which the Forest Service maintains a campground) south toward the old Grizzly Bear workings. An operating company, called Savage Mining Corporation, was formed by the four grandchildren of John Zanett, and work commenced driving the haulage tunnel in 1978, named in honor of their grandfather. After more than a dozen years of work and 8,500 feet of drifting, the John Zanett Tunnel now connects with the historic workings of the Grizzly Bear mine and has been further extended south into new territory along the Grizzly Bear vein system. The mine now includes more than 120 patented and unpatented mining claims.

Even in its early days, the Grizzly Bear mine was known for its rhodochrosite. In a 1910 mine report, mining engineer Chester Ingersoll described the Grizzly Bear vein as "a 'true fissure' with well-defined walls from 15 to 30 inches wide and traceable on the surface for several miles. . The vein filling consists in the main of quartz and rhodonite, a manganese silicate locally termed 'pink quartz,' besides these, quartz crystals and very beautiful crystals of rhodochrosite (a manganese carbonate)." It was certainly unusual for a mining engineer to even bother mentioning gangue minerals, so one may infer that the Grizzly Bear rhodochrosites were most unusual.

While the Zanett Tunnel was being constructed, several zones were encountered that contain rhodochrosite specimens. One zone contained vugs of fern-green quartz crystal plates colored by the inclusion of chlorite. Baby-pink rhodochrosite rhombohedra up to 0.5 inch across were sprinkled on top of the quartz. Farther along the haulage, a large watercourse contained plates up to 12 inches across of white drusy quartz with etched rhodochrosite crystals up to 2 inches on edge perched on the quartz. The rhodochrosite color here ranges from light pink to strawberry pink, but heavy iron staining on the specimens makes determination of the true color often difficult. A few rhombohedra were completely coated by a quartz druse, thus indicating several generations of crystal formation.

The largest rhodochrosite crystal found at the Grizzly Bear mine in modern times is a rhombohedron completely coated by a fine-grained druse of white quartz. Nearly 4 inches on edge, this specimen was collected by Peter Klein, operating partner in the mine, and given to the author as a gift. It came from a large crystal cavity in the Zanett haulage near the site of the refuge station, 6,000 feet from the portal. One corner of the quartz encrustation was removed prior to its presentation to show the underlying rhodochrosite. Although the specimen has been altered by the removal of one small section of the quartz coating, it remains one of the largest and best rhodochrosite crystals to have come out of this or any Ouray County mine.

The mine also contains several zones with pale-green fluorite cuboctahedra to 1 inch on edge, often clusters to 3 inches across, implanted on plates of large milky quartz crystals. In another area of the main haulage, about 6,500 feet in from the portal, the mine owners invited the author to collect some interesting lavender fluorite cubes, somewhat etched, that were up to 1.25 inches on edge. Another zone contains pale-green fluorite cubes with red sphalerite with small rhodochrosite crystals.

Other mineral species found at the Grizzly Bear since 1980 include red, amber, and black sphalerite; small white barite rosettes; brown and cream calcite scalenohedra; small, twinned chalcopyrite; chlorite; galena cubes; tiny hexagonal hematite crystals; gemmy huebnerite; cubic pyrite; massive rhodonite; cinnamon-brown siderite; small tetrahedrite crystals; and silver wires.

Geology and mineralogy of the Pilares wollastonite deposit, Municipality of Hermosillo, Sonora, Mexico*

(Location 7 on index map)

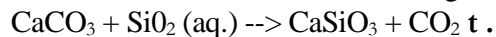
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The Pilares wollastonite deposit is 55 km northwest of Hermosillo, Sonora, Mexico and was first identified in 1981. Cerro Pilares, the most prominent feature in the area, is a mountain rising 300 m out of the flat Sonoran desert and covering about 5 [sq. km](#). Geologic examination has shown that most of this mountain is wollastonitic marble. Current investigations have focused on the westernmost flank of the mountain where several tens of millions of tons of easily accessible, high-quality wollastonite has been identified by geologic mapping and diamond drilling.

The deposit is owned and is being developed by Minera NYCO S.A. de C. V., a wholly-owned subsidiary of NYCO Minerals, Inc. of Willsboro, New York, the world's largest wollastonite producer.

Wollastonite is a white, acicular, calcium metasilicate [CaSiO₃] mineral typically formed in contact metamorphic (dry) and metasomatic (wet) environments where intrusive igneous rocks have come in contact with carbonate rocks. Calcite from the limestone combines with silica carried from the intrusive in hot, aqueous solution to form wollastonite and CO₂ gas by this equation



Its usefulness as an industrial commodity is largely due to its acicularity. Applications for wollastonite include ceramics, brake linings, plastic reinforcement, thermal insulation board, and protective coatings.

The Pilares deposit is a huge, contact metasomatic or skarn deposit formed from the intrusion of a large, Cretaceous, granodiorite stock into a Paleozoic limestone. Remnant beds of thin, pure-white quartzite indicate that some, or even most, of the silica required for the formation of the wollastonite may have been available in the carbonate sequence, and the two rocks would have reacted under the influence of the heat and fluids from the intrusion to form the skarn. A few discontinuous green hornfels beds, ranging from 0.5 to 3 m thick, also occur in the sequence. Wollastonite occurs predominantly as clusters of radiating, white to pale-cream needles, typically ranging from 1 to 2 cm long. The other major mineral in the deposit is medium- to coarse-grained white calcite [CaCO₃]. These two minerals make up 95% of the deposit. Commercial development will occur where wollastonite grades exceed 60% over tens of meters in thickness. Locally, beds 5 to 10 m thick can average 80+ % wollastonite. The deposit is extensively brecciated on a megascale, probably due to the explosive release of CO₂ during formation.

The most common minor mineral in the deposit is pale- to medium-green diopside [CaMgSi₂O₆], which is disseminated throughout the formation. Other minerals include quartz [SiO₂], garnet [Ca₃(Al,Fe^{3±})₂Si₃O₁₂], vesuvianite [Ca₁₀Mg₂Al₄(SiO₄)₅(Si₂O₇)₂(OH)₄], epidote [Ca₂(Fe³⁺,Al)₃(SiO₄)₃(OH)], tremolite [Ca₂Mg₅Si₈O₂₂(OH)₂], orthoclase [KA1Si₃O₈], clinzoisite [Ca₂Al₃(SiO₄)₃(OH)], zeolites [hydrous and hydrated, alkali and alkaline earth, aluminum silicates], and chalcopryite [CuFeS₂].

Acknowledgments—The authors would like to express their gratitude to Minera NYCO S.A. de C. V. because without their cooperation and assistance this presentation could not be given. We also would like to acknowledge the assistance of Prof. Albert M. Kudo of the Department of Earth and Planetary Sciences of the University of New Mexico for his excellent and detailed petrographic studies of selected specimens from the Pilares deposit.

* Part of this work was performed at Sandia National Laboratories, operated for the U.S. Department of Energy under contract number DE-AC04-94AL85000.

The Romero Mineral Museum

(Location 7 on index map)

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Mexico's wealth of mineral resources is very well known, and even after five centuries of continuous mining, it is still considered that less than half her territory has been adequately explored. Mexico has been the world's leader in silver production since Spanish colonial times. During the Paris Exposition last century, it was estimated that 90% of the silver used in Europe at that time had come from Mexico. Mexico remains the world's leading silver producer today and is an important producer of at least 15 other minerals.

Unfortunately, this outstanding industrial development has not been accompanied by extensive historical records regarding the variety of minerals found, especially the hundreds of mineral species found during the early centuries of mining. This is surprising given the fact that the first school of mines was established in Mexico City in 1792 and that the distinguished Spanish-Mexican mineralogist, Andres Manuel del Rio wrote the first Mexican mineralogy book in 1795. (Del Rio is also known for the role he played in the discovery of the element vanadium.)

Geological Institute Bulletins 40 and 41 (National Autonomous University of Mexico.. . UNAM), written by Jose G. Aguilera in 1922, represent the best information about Mexican mineral species and their localities known in his time. In more recent years, William D. Panczner made an effort to tackle an update in his book, "Minerals of Mexico" (1987).

There are scattered mineral collections and some minor museums at certain universities in Mexico, but there is no single mineral collection or museum that preserves any significant number of specimens from the last century or the early part of the present one. Perhaps older museums like the one at the Geological Institute in Mexico City, and at the School of Mines in Guanajuato may still hold some older mineral samples in their basements from this period, but no one really knows.

The Romero mineral collection, which was started in 1970 and evolved into the Romero Mineral Museum by 1978, represents a modest effort to preserve the modern mineralogy and fill the gap regarding older materials. Unfortunately, for the most part it is too late to recover the lost wealth and treasures of the past. This presentation will describe some aspects of the motivation for starting the Romero collection, as well as its structure and development to date.

Telluride occurrences in the four-corner states, U.S.A.

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Tellurium (abbreviated Te) is one of the rarest elements found in the earth's crust, with an average abundance far lower than platinum's. Though rare, telluride minerals (those bearing tellurium) are noted in all 13 mining states in the western U.S., including the four-corner states of Arizona, Colorado, New Mexico, and Utah. For the remainder of this discussion, the term telluride minerals will be restricted to unoxidized species, excluding tellurites and tellurates.

Curiously, certain areas are broadly enriched in telluride minerals such as Colorado, whereas adjacent areas like Wyoming contain few Te-bearing deposits. In fact, Colorado has roughly 38 times as many telluride occurrences per square kilometer as Wyoming, and five times as many per square kilometer as an average western mining state. New Mexico and Utah are examples of typical western mining states in terms of Te occurrences per square kilometer, whereas Arizona contains roughly one third the number of Te occurrences of average western mining states.

In addition, Colorado contains the broadest telluride mineral diversity of the four-corner states. One area, the Boulder County telluride belt, contains at least 16 unoxidized telluride minerals, which represents the largest telluride diversity of any deposit that the author is aware of in the world. In fact, 65% of Colorado's telluride mineral varieties are found in the Boulder Telluride belt alone. In Arizona, the Bisbee district contains over half of that state's telluride minerals. Surprisingly, Utah has the least diverse telluride minerals of the four corner states (perhaps because of inadequate identification techniques), even though it has the typical number of occurrences per square kilometer. Another unexpected result of this investigation is that certain statistical and geologic evidence suggests that Arizona should contain more Te-bearing mining districts than are presently known.

The mineralogy of the telluride minerals in the four-corner states is fairly typical of Te-bearing districts worldwide. The most reported telluride minerals in the region are (in decreasing order of reported district-wide occurrences, with the number of reports in parentheses): petzite (24), hessite (21), altaite (16), sylvanite (16), calaverite (13), native tellurium (13), and tetradyomite (12). Detailed literature examination indicates that altaite, native tellurium, hessite, and tetradyomite are perhaps the most commonly reported telluride minerals worldwide, occurring in a broad range of geologic environments. The presence of petzite, sylvanite, and calaverite in the above list suggests the relative prevalence of Au-tellurides in the four-corner states.

One might infer from above that the general trend is for areas with the most reported Te-bearing minerals to contain the widest diversity in their telluride mineral chemistry. This is basically true. For example, Colorado has 40 Te-bearing districts, 23 reported telluride minerals, and tellurides with more varied chemical elements than other areas in this study. On the other hand, Utah has the least number of verified telluride minerals, hence the least diversity in telluride mineral chemistry.

The tellurides present in the four-corner states are representative of many worldwide hydrothermal systems with low to moderate temperatures of formation. Tellurides were deposited late in the paragenetic sequence of mineralization and are associated with certain Mesozoic/Cenozoic metal-bearing intrusions, in many cases Cu and or Mo alkalic porphyry systems. Tellurides are found either in the porphyries, limestone replacements, skarns, or most commonly in epithermal veins. An entirely different origin is illustrated by the Vulcan deposit near Gunnison, Colorado, which is a

submarine exhalative massive-sulfide deposit of Proterozoic age.

Most of the telluride occurrences in the western U.S. do not occur in distinct belts. Telluride occurrences in Arizona are confined to the far southeast corner of the state except for the Tiger district near the state's center. Colorado's telluride occurrences generally fall within a triangle, with one leg the northeast—southwest-trending Colorado Mineral Belt, another leg trending east from La Plata to an area southeast of Westcliffe (west of Pueblo), and a third leg trending roughly north from Westcliffe to Jamestown, northwest of Boulder. All of New Mexico's telluride occurrences lie in the southwest part of the state except for two districts northeast of Taos. Utah's telluride occurrences are confined to the western half of that state.

Four hypotheses were tested to explain these large-scale distribution patterns. The first concerns the distribution of alkalic rock complexes, with which telluride deposits are known to commonly affiliate (Mutschler et al., 1985). The four-corner states have anomalously high proportions of alkalic intrusions per square kilometer of ground surface, yet they do not uniformly contain above-average numbers of telluride occurrences within their boundaries. The second concerns the timing of peak alkalic igneous activity. In Colorado this occurred 26-76 Ma ago, which is identical to peak alkalic activity in New Mexico and three other western states (Mutschler et al., 1992), yet Colorado's tellurides/km² far surpasses the other four states'. The third hypothesis concerns plate tectonic relations, which do not provide a clear answer. Finally, metal inheritance tied to underlying basement lithology/age was examined and was the most successful of the four hypotheses. Although it cannot yet be proved, the composition of Colorado's basement appears to be the most reasonable explanation for its anomalously high density of telluride occurrences per square kilometer.

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Geology and mineralogy of tellurium mineralization in the Lone Pine mine area, Wilcox district, Catron County, New Mexico

(Location 8 on index map)

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The Lone Pine mine area, in the Wilcox district, Catron County, New Mexico, has been the site of modest mineral production. The district has produced 5 tons of tellurium and less than 100 ounces of gold and silver (1.23 oz. Au and 19.0 oz Ag officially reported). The Wilcox district is also credited with the production of 10,603 tons of fluorite (McAnulty, 1978). Despite the production of metal and fluorite, the area is probably best known for its tellurium minerals. However, very little systematic work on the mineralogy has been attempted prior to this study.

The ore deposits are hosted by Tertiary volcanic and volcanoclastic rocks, mainly in the Mogollon and Mineral Creek andesite units of Ratte et al. (1979). Mineralization tends to be confined to north- and northwest-trending fault zones that were in turn intruded by flow-banded rhyolite dikes. The rhyolites are bleached, silicified, and iron stained, to various degrees. The adjacent volcanic rocks are argillized, locally silicified, and strongly iron stained in places. Previous workers in the district attribute mineralization to late-stage volcanism and buried plutonism related to the development of the ring complex of the Bursum caldera (Oligocene).

Primary mineralization occurs as fracture fillings in veinlets in the silicified flow-banded rhyolite at most prospects. Disseminated mineralization is also present. At the Lone Pine mine, primary mineralization occurs in larger pods in a large zone of silicified flow-banded rhyolite and silicified andesite. Primary mineralization consists of pyrite, fluorite, tellurium, and molybdenum. A precious-metal telluride, krennerite(?), was identified for the first time in the district during this study. A vertical mineralogical zonation is apparent with pyrite stratigraphically lowest grading into pyrite-tellurium assemblage followed by a fluorite-rich zone at the highest elevations. Tellurium mineralization is strongest at the pyrite—fluorite transition zone. Ballmer (1932) reported bismuthinite in the ores, but the mineral was not observed in this study.

As a result of the unique chemistry of tellurium-oxygen molecules and their behavior in the weathering environment, tellurites and tellurates are the most abundant tellurium species in the district. Tellurite and paratellurite (both TeO_2) were observed in the district for the first time, usually growing on native tellurium. In addition, the weathering of pyrite and native tellurium gives rise to a host of iron tellurate minerals including emmonsite ($\text{Fe}_2\text{Te}_3\text{O}_9 \cdot 2\text{H}_2\text{O}$), mackayite ($\text{FeTe}_2\text{O}_5(\text{OH})$), sonoraite ($\text{FeTeO}_3(\text{OH}) \cdot \text{H}_2\text{O}$), blakeite ($\text{Fe}_2(\text{TeO}_3)_3$), poughite ($\text{Fe}_2(\text{TeO}_3)_2(\text{SO}_4) \cdot 3\text{H}_2\text{O}$), and perhaps other, more rare, iron tellurates (rodalquilarite and curticiticite). The district is the type locality for a copper tellurate, rajite (CuTe_2O_5). A second copper tellurate, teineite ($\text{CuTeO}_3 \cdot 2\text{H}_2\text{O}$), was also noted during this study (rajite was reported as a pseudomorph of teineite by Williams, 1972). The presence of copper tellurates in the absence of a primary copper phase is somewhat enigmatic. However, the report of bismuthinite in the district also suggests the potential for a number of bismuth tellurates (smirnite, montanite, and chekhovichite) to be found in the area. There is potential for additional telluride minerals to exist in the district also, including bismuth and other precious metal varieties. Finally, the unique bonding characteristics of tellurates hold promise for the discovery of new tellurate mineral species in the area.

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Mining museums and mining districts of Scotland and Wales

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In a current (Fall 1994) *Visitor's Guide to Scotland and/or Wales*, WHERE TO GO & WHAT TO SEE is listed: "Discover Scotland's highest village, Wanlockhead (higher than any community in the Highlands further north) and also the Scottish Museum of Lead Mining on the breezy slopes nearby." About 200 miles away as the crow flies is the Mining Museum described in the Welch Visitors Guide as the 'California of Wales' exhibition at the Llywernog Mine Historical Site. Both the mining districts and the museums are similar, fantastic, and accessible, plus one sees parts of Scotland and Wales at the same time.

LOCATION—The Leadhills-Wanlockhead mining district is south of Glasgow or Prestwick (nearby airports). It is midway between the A-74 (Carlisle, England to Glasgow, Scotland via Lockerbie to Crawford, then to the southwest) and the road connecting to the A-76 (Prestwick-Dumfries Road). The district is about 45 miles from Glasgow and 30 miles from Prestwick. The Mining Museum is open during the summer, and one needs to call in advance to determine the hours.

The Llywernog Mine Historical Site, in the beautiful Snowdonia mining district, is reached by taking the A-44 east from the coastal town of Aberystwyth via Devils Bridge to Ponterwyd. On a large visitor's map of Wales, Aberystwyth is northwest of Cardiff, which is on the main route from London. The historical site is open daily, Easter to end of September from 10 am to 6 pm. The entire district comprises more than 40 mines within a 50-mile radius. Visitors should purchase *A Glimpse of the Past*, a tourist's guide to industrial trails, slate quarries, mines, mills, railroads, etc., from the Wales Tourist Board. This will give you all the information.

HISTORY—Both the Leadhills-Wanlockhead district of south-central Scotland (reported in *Mineralogical Record*, July-August 1981) and the Llywernog Mine Historical Site, Wales (reported in *Lapidary Journal*, July 1984) were mined for lead, zinc, gold, and silver. The gold at Wanlockhead was recovered from the alluvial gravels during the 1500s, and as many as 300 employees were used during peak production days. The gold from the district was used in both royal crowns and in coinage. The silver content was minor but recoverable.

However, at the Snowdonia district the silver content of the lead was high enough to be not only recoverable but profitable. The nearby Dolgelley gold district produced gold from veins, even in this century, for including in the royal jewelry.

Documented records at the Llywernog Mine Historical Site reveal extensive mining activity from 1740 to 1914. The nearby Cwmystwyth mine was worked intermittently from 1400 to 1939.

The mines in the Leadhills-Wanlockhead district included some 70 veins in an 8-km² area and were in operation as early as 1293 A.D. and intermittently to 1934. The lead miners founded a Reading Society in 1756. The present library, erected in 1850, has 3,000 books from the 17th century to present as well as the original minute books and records of the Society.

GEOLOGY—At both the Leadhills-Wanlockhead and the Snowdonia districts, the country rock is a series of greywackes, mudstones, shales, and cherts of Ordovician age. The mineralized part of the veins is confined to the greywackes and mudstones.

MINERALS—At the Leadhills-Wanlockhead district more than 60 mineral species have been identified. These include: cerussite, anglesite, leadhillite, susannite, lanarkite, caledonite, linarite, and pyromorphite. Earlier, specimens of exceptional quality came from the Susanna and Belton Grain veins. In 1920 operations began on the New Glencrieff vein. This was one of the richest orebodies in the district. At the south end of the vein the top levels were very rich in galena with stringers running for more than 80 meters. At the 300-ft level large quantities of hemimorphite were found. At the 700-ft level enormous quantities of sphalerite were found. The New Glencrieff vein was favored with a deep oxidized zone that extended to a depth of 2,000 ft.

It is reported that the minerals of the Leadhills-Wanlockhead district became so well known to collectors during the 1820s that the Scots Mining Company "had to make a regulation preventing the miners from disposing of specimens to the growing number of collectors!"

From the mines in Wales come at least 24 minerals, and all are to be found at all locations. These include: ankerite, sphalerite (large crystals to 3 inches in size), galena with a high silver content in 1 1/2-inch cubes, copper minerals with malachite being of the soft velvety style among razor-sharp chalcopyrite crystals, devilline, bindheimite, wulfenite, and gold to name a few. The veins are usually wide and deep. At the Van mine one vein of ore was more than 60 feet wide and 2 miles long.

Along with the minerals to be found are numerous opportunities for picture taking of old mine buildings including one, a building that housed a 56-ft diameter waterwheel.

MINING—There are no active mines in mid-Wales (Snowdonia) at this time, and in the Leadhills-Wanlockhead district only the New Glencrieff vein is being worked on a noncommercial basis.