New Mexico Mineral Symposium

The Sixteenth Annual New Mexico Mineral Symposium was held November 11 and 12, 1995, at New Mexico Institute of Mining and Technology, Socorro. Following are abstracts from talks given at the symposium that concern New Mexico. The numbers in parentheses refer to locations on the map.
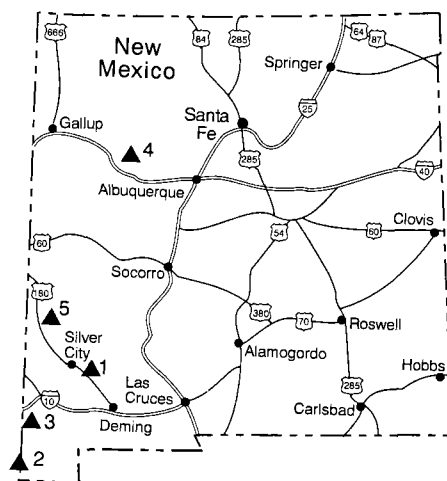
MINERALS AND MINING HISTORY OF THE FIERRO–HANOVER DISTRICT, GRANT COUNTY, NEW MEXICO, by *Robert W. Eveleth,* New Mexico Bureau of Mines and Mineral Resources, Socorro, NM 87801-4796 (1)

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 8½ million short tons. Concurrent with the production has come a long and colorful mining history beginning in ca 1858 with German metallurgist Sofio Hinckle 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.

ORIGIN OF CHALCEDONY NODULES IN RHYOLITE FROM THE PELONCILLO MOUNTAINS, HIDALGO COUNTY, NEW MEXICO, by *Peter J. Modreski,* U.S. Geological Survey, MS 905, Box 25046, Federal Center, Denver, CO 80225-0046 (2)

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, and adjacent Cochise County, Arizona. 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 SiO_2 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 (in prep.).

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*, by *Ramon S. DeMark*, 530 East Arch St., Marquette, MI 49855; and *Paul F. Hlava*, Department 1822, MS-1405, Sandia National Laboratories, Albuquerque, NM 87185-1405 (3)

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 [$(Cu, Fe)_{12}(Sb,As)_4S_{14}$] (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 [$AgBiS_2$] 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 [$Pb_5(AsO_4)_3Cl$], conichalcite [$CaCu(AsO_4)(OH)$], beudantite [$PbFe_3^{3+}(AsO_4)(SO_4)(OH)_6$], agardite-(Y) [$(Y,Ca)Cu_6(AsO_4)_3(OH)_6·3H_2O$] (Williams, 1978, identified the related species mixite), adamite (cuprian) [$(Zn,Cu)_2(AsO_4)(OH)$], olivenite [$Cu_2(AsO_4)(OH)$], and carminite [$(PbFe_2^{3+} (AsO_4)_2(OH)_2$]. 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 subtranslucent. 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 [$(Zn,Cu)_5 (CO_3)_2(OH)_6$]. 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 [$AgBr$] is usually found as individual, 0.5 mm, olive-green crystals perched on crusts of conichalcite. Aurichalcite and rosasite [$(Cu,Zn)_2(CO_3)(OH)_2$] are both found in attractive specimens in a number of areas throughout the mines, always in association with colorless, bladed, hemimorphite [$Zn_4Si_2O_7(OH)_2·H_2O$] 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 [FeS_2] oxidized to goethite [$FeO(OH)$] is common on this dump, and blue botryoidal hemimorphite can be found as well. Plattnerite [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 [$Zn(CO_3)$] along with two single crystals of azurite [$Cu_3(CO_3)_2(OH)_2$] 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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MINERALOGY OF THE TODILTO URANIUM DEPOSITS, GRANTS DISTRICT, NEW MEXICO, by *William R. Berglof*, University of Maryland, Asian Division, Unit 5060 Box 0100, AOP AP 96328-0100; and *Virginia T. McLemore*, New Mexico Bureau of Mines and Mineral Resources, Socorro, NM 87801-4796 (4)

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 häggite 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, $U(SiO_4)_{1-x}(OH)_{4x}$; häggite, $V_2O_2(OH)_3$; paramontroseite, VO_2; fluorite, CaF_2; barite, $BaSO_4$; pyrite, FeS_2; calcite, $CaCO_3$; hematite, Fe_2O_3; galena, PbS; tyuyamunite, $Ca(UO_2)_2(VO_4)_2 \cdot 5–8\frac{1}{2}H_2O$; metatyuyamunite, $Ca(UO_2)_2(VO_4)_2 \cdot 3–5H_2O$; uranophane, $Ca(UO_2)_2(SiO_3 \ OH)_2 \cdot 5H_2O$; schroeckingerite, $NaCa_3UO_2(CO_3)_3 \ SO_4F \cdot 10H_2O$; curite, $Pb_2U_5O_{17}$

$\cdot 4H_2O$; hewettite, $CaV_6O_{16} \cdot 9H_2O$; metahewettite, $CaV_6O_{16} \cdot 3H_2O$; santafeite, $(Mn,Fe,Al,Mg)_8Mn_8(Ca,Sr,Na)_{12} \ (VO_4)_{16}(OH,O)_{20} \cdot 8H_2O$; grantsite, $Na_4CaV_{12} \ O_{32} \cdot 8H_2O$; goldmanite, $Ca_3(V,Fe,Al)_2Si_3O_{12}$.

TELLURIDE OCCURRENCES IN THE FOUR-CORNER STATES, U.S.A., by *Bruce Geller*, Advanced Geologic Services, 700 Vista Lane, Lakewood, CO 80215

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 40 times as many telluride occurrences per square kilometer as Wyoming, and more than 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.

Arizona contains telluride minerals with the broadest chemical diversity in the four-corner states. Most of this diversity is found in the Bisbee district, which contains more than half of Arizona's tellurides. In fact, Bisbee's 18 reported telluride species represent the largest number of telluride species in any depost that the author is aware of in the world. In Colorado, the Jamesown district contains at least 16 unoxidized telluride minerals, which represent 65% of Colorado's telluride mineral varieties. 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 (25), hessite (22), altaite (18), tetradymite (18), sylvanite (16), calaverite (14), and native tellurium (14). Detailed literature examination indicates that altaite, native tellurium, hessite, and tetradymite 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 at

least 43 Te-bearing districts, 24 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 per square kilometer far surpass 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
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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 volcaniclastic rocks, mainly in the Mogollon and Mineral Creek andesite units of Ratté 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 ($Fe_2Te_3O_9\cdot 2H_2O$), mackayite ($FeTe_2O_5(OH)$), sonoraite ($FeTeO_3(OH)\cdot H_2O$), blakeite ($Fe_2(TeO_3)_3$), poughite ($Fe_2(TeO_3)_2(SO_4)\cdot 3H_2O$), and perhaps other, more rare, iron tellurates (rodalquilarite and cuzticite). The district is the type locality for a copper tellurate, rajite ($CuTe_2O_5$). A second copper tellurate, teineite ($CuTeO_3\cdot 2H_2O$), 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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