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New Mexico Geology, v. 38, n. 1 pp. 17-23, Online ISSN: 2837-6420.

<https://doi.org/10.58799/NMG-v38n1.17>

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Tellurium Minerals in New Mexico

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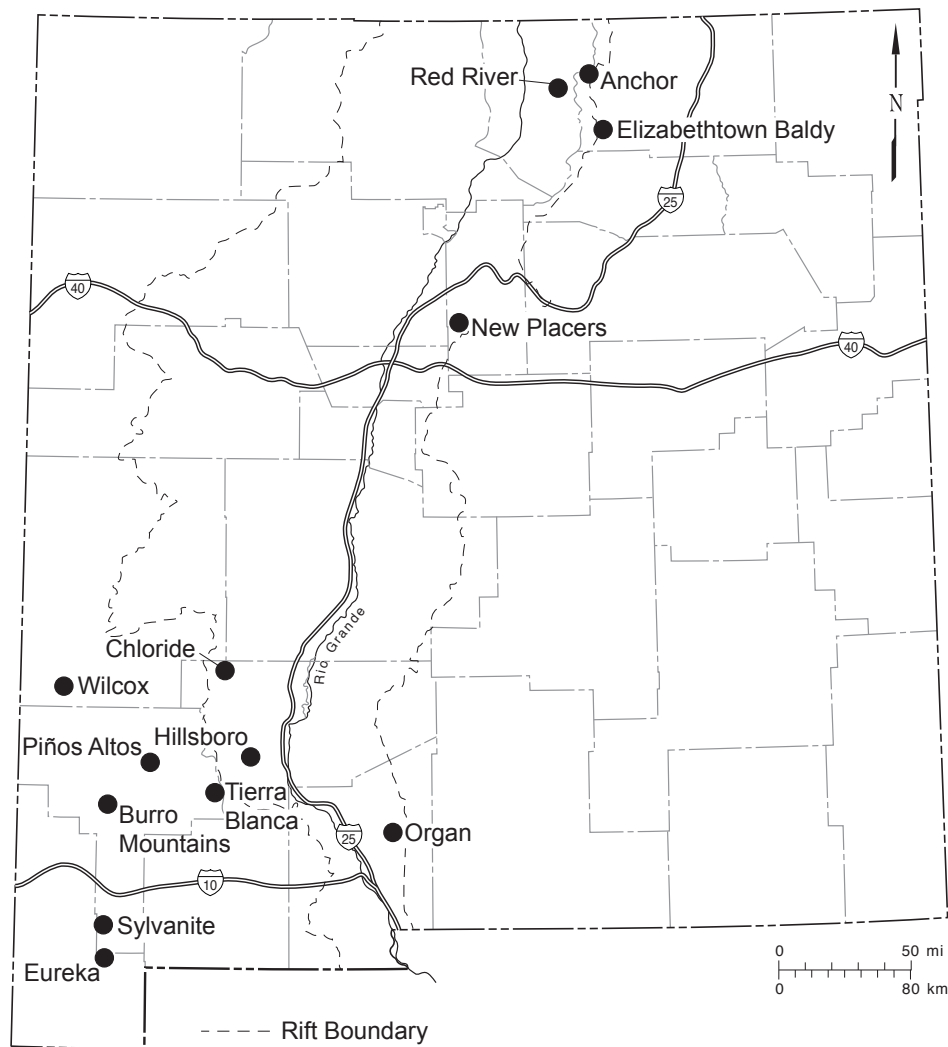


Figure 1. Map of reported tellurium mineral occurrences in New Mexico. County boundaries in gray.

Tellurium (Te) is an element of paradoxes. It is one of the most abundant heavy elements in the cosmos (Zemann and Leutwein, 1978), with “heavy” defined as having an atomic number >40 . But it is exceedingly rare in the earth’s crust, where its abundance is approximately 0.005 ppm (Jović, 1999), and reliable values have never been reported in seawater (Cohen, 1984). This is probably due to the fact that Te readily forms metal hydrides and most of the element was lost to space during the Earth’s formation (Jović, 1999). In terrestrial environments, it behaves as a chalcophile element and has a strong affinity for the noble elements, transition metals, and sulfur (with whom it shares the same column in the periodic table of the elements). Tellurium is most abundant in low temperature hydrothermal systems, where it precipitates in the latter phases of activity (Jović, 1999). Interestingly, the element is found in anomalously high concentration in coal and some plants (especially certain food plants), although it is not abundant in soil (Cohen, 1984), and it

is among the most abundant trace elements in the human body (Schroeder et al., 1967). This last paradox has not yet been adequately resolved.

All tellurium minerals are rare in nature and their associated mineral deposits are usually small. The tellurium minerals themselves are often microscopic, observed under high power in petrographic microscopes or electron microprobes. Macroscopic examples are thus prized by collectors, especially when found in crystalline forms. This short paper compliments the lead article in this volume (Tellurium Resources in New Mexico, by Virginia McLemore) by expounding on the various tellurium minerals reported in New Mexico.

Tellurium minerals have been reported from 14 mining districts in the state, from the Red River area in the north to the boot heel region in the southwest. This distribution roughly follows the distribution of ore deposits along the margins of the Rio Grande rift (Fig. 1). The total number of tellurium mineral species is relatively small (Table 1), with

TABLE 1. Reported tellurium mineral localities in New Mexico (from Northrup, 1996, except where noted).

County	Mining District	Reported Tellurium Minerals
Bernalillo	“La Luz area”	Tellurium
Catron	Wilcox	Tellurium, Tellurobismutite, Tetradyomite, Emmonsite, Mackayite Rajite, Poughite ¹ , Tellurite ¹ , Paratellurite ¹ , Teinite(?) ¹ , Cuzticite(?) ¹
Colfax	Elizabethtown-Baldy	Tetradyomite
Dona Ana	Organ	Altaite, Hessite, Montanite(?), Petzite, Rickardite, Sylvanite, Tetradyomite, Tellurium, Weissite(?)
Grant	Eureka Burro Mountains Pinos Altos	Tetradyomite Tellurium, Tetradyomite Tetradyomite
Hidalgo	Sylvanite	Hessite, Tellurium, Tellurobismuthite
Santa Fe	New Placers	Tetradyomite*
Sierra	Chloride Hillsboro Tierra Blanca	Calaverite, Nagyagite(?), Sylvanite, Tellurium Tellurium(?), Tetradyomite Calaverite, Hessite, Petzite, Sylvanite, Tellurium?
Taos	Anchor Red River	Calaverite, petzite Calaverite, petzite

¹ Lueth et al., 1996

(?) unconfirmed by chemical or structural methods

* new report – NMBGMR Museum No. 12907

only 18 recorded in Northrup (1996) and three additional noted by Lueth et al. (1996). In many districts, however, the identity of the reported tellurium mineral may be suspect and subject to change. The Organ district in Doña Ana County (fig. 3 of McLemore, this volume) has the most diverse assemblage of telluride minerals in New Mexico, which have been reported from four individual mines.

Although generally very rare in New Mexico, native tellurium (Te) is notable in two mineral deposits. The first known report of tellurium metal is from the Lone Pine mine in the Wilcox district, Catron County, New Mexico (Table 1; Fig. 2). Tellurium was reported as early as 1904 by



Figure 2. Photograph of native tellurium from the Lone Pine mine. Note the hackly habit and bright white color with high reflectivity. Specimen is 4 cm across, NMBGMR Mineral Museum No. 11394.

Jones (1904). Ballmer (1932) later described the occurrence in some geologic detail. Masses of native tellurium were mined in the early 1960s by Minnesota Mining and Manufacturing, and number of high quality specimens from this locality can be found in private collections and museums around the country.

The other locality with notable native tellurium is the Hilltop mine in the Organ Mountains. Here, Dunham (1935) first described masses of native tellurium associated with the lead telluride called altaite [PbTe]. Collector and study specimens from the Hilltop mine have been sold since the 1930s by a number of specimen dealers. Altaite was the predominant telluride in most samples, but later analysis of the material revealed a greater abundance of native Te than originally noted (Lueth et al., 1988; Lueth and Goodell, 1991). Their studies noted that the altaite tarnishes to a cream white color while the native tellurium develops a sky blue tarnish with time, helping to discriminate between the minerals (Fig. 3). This blue tarnished native tellurium has often been confused with the copper tellurides rickardite [Cu₇Te₅] or weissite [Cu_{2-x}Te] that have been reported from the Rickardite mine (Lueth, et al., 1988). In addition to tetradyomite and altaite, other tellurides reported from the district, listed in order of decreasing occurrence, include hessite [Ag₂Te], rickardite [Cu₇Te₅], weissite [Cu_{2-x}Te], and tellurobismuthite [Bi₂Te₃].

The most common occurrence for tellurium is as telluride minerals. More than 50 telluride minerals are known world-wide, where tellurium is generally combined with silver, gold, copper, lead, iron and bismuth. Precious metal tellurides are rarely reported in New Mexico and, when described, are highly suspect since very few examples are extant. Northrup (1996) reported four possible

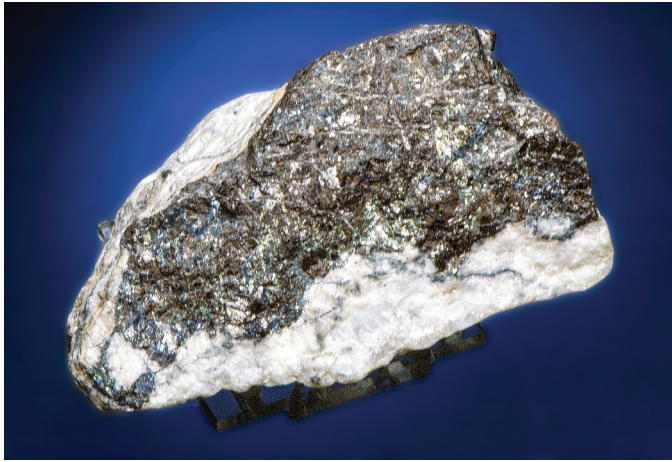


Figure 3. Altaite (cream to white metallic) and native tellurium (blue tarnished metallic) in sphalerite and galena on marble from the Hilltop mine, Organ district. Specimen is 7 cm in length. Former Herfurth collection, NMBGMR Museum No. 18893.

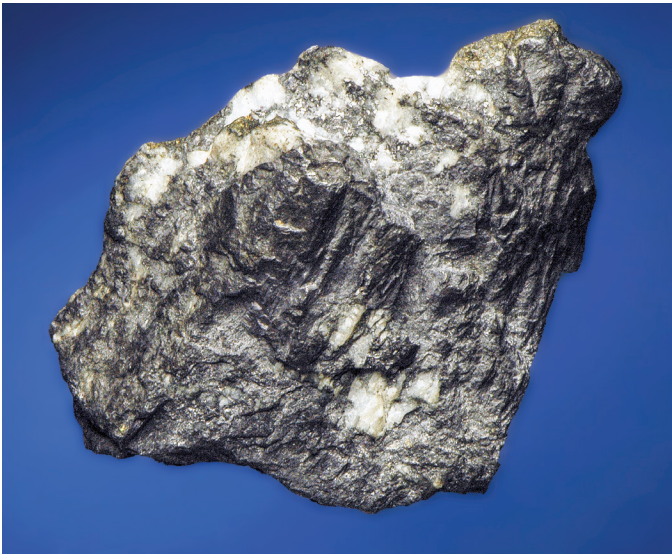


Figure 4. Petzite and quartz specimen from the Tierra Blanca district, Sierra County. Specimen is 4 cm tall. NMBGMR Museum No. 18466, Gift of Gary and Priscilla Young.

occurrences of calaverite $[AuTe_2]$, two each from Taos and Sierra counties, but even he doubted the authenticity of the reports. A single specimen (Fig. 4) of Petzite $[Au, Ag_2Te]$ is in the collection of the New Mexico Bureau of Geology and Mineral Resources Mineral Museum from the Tierra Blanca district in Sierra County. Petzite was also reported from the Little Buck mine in the Organ Mountains (Dunham, 1935), but no specimens are known to exist.

The most common telluride mineral in New Mexico is tetradymite, a bismuth tellurosulfide $[Bi_2Te_2S]$. It is often associated with gold deposits and is reported from the Baldy district (Colfax County), Organ district (Doña Ana County), New Placers (Santa Fe County), and erroneously in the Sylvanite district (Hidalgo County). It is very abundant at the Memphis mine (Organ district), where museum quality specimens were recovered during the days of active mining (Fig. 5). The stope containing the tetradymite was backfilled, however, as the ores resulted in a penalty for bismuth when shipped to the

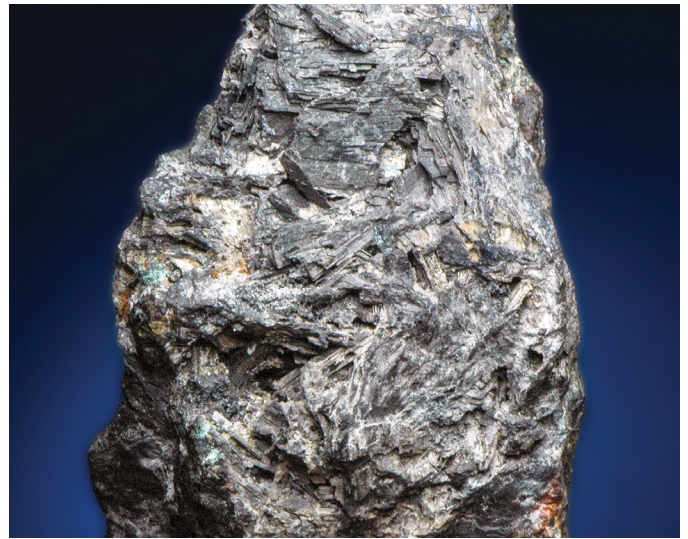


Figure 5. Mass of bladed and striated tetradymite crystals from the Memphis mine, Organ district. NMBGMR Museum No. 3454. The catalog number of this specimen dates to the reestablishment of the mineral museum after the 1928 fire. The specimen may have come directly from K.C. Dunham, who completed NMBMMR Bulletin 11 in 1935, or L.B. Bentley, who was the assayer at Organ and owned the claims at the time.

smelter (Dunham, 1935). Specimens of the material can still be located on the dumps of the mine.

Misidentification is a hallmark of many tellurium minerals. As a classic example, the Sylvanite district received its name from the mistaken identification of Sylvanite $[(Au, Ag)_2Te_4]$. Rather than being the gold-silver telluride, later researchers reported the material to be a micromixture of gold, acanthite $[Ag_2S]$, and tetradymite (Short and Henderson, 1926). Laskey (1947), based on the work of Short and Henderson, suggested the mineral was actually tellurobismuthite $[Bi_2Te_3]$ containing native gold and acanthite. tetradymite was initially reported from the Wilcox district but later found to be a mixture of tellurium and bismuthinite (Crawford, 1937), although recent studies have reconfirmed the presence of Tetradymite (Lueth et al., 1996).

Given that tetradymite is the most common telluride mineral in New Mexico, one might wonder why there is such a paucity of gold tellurides in New Mexico when elsewhere gold is often reported with tetradymite (e.g., Boulder district in Colorado). In the Organ district, examination of the mineral paragenesis reveals that gold often precipitates early in the mineralization sequence and tetradymite precipitates later. By the time tellurium activity increases to precipitate gold telluride, the gold has already left the system via precipitation of the native metal (Fig. 6; Lueth, 1998).

An interesting mineralogical feature of tellurium is the subequal number of telluride to tellurate species. The tellurides occur in primary hypogene deposits, whereas tellurates are found in secondary supergene deposits. The stoichiometry and composition of secondary tellurium minerals closely follows those of the primary types. This is due to the details of the coordination chemistry of tellurium. In tellurides, metal atoms are surrounded by six Te atoms; this creates a distorted octahedron when connected together, resulting in sheet structures. The sheets are repeated in Te oxide minerals, but oxygen occupies the corners of a trigonal bipyramid and one corner is unoccupied (Fig. 7). Two natural polymorphs of TeO_2

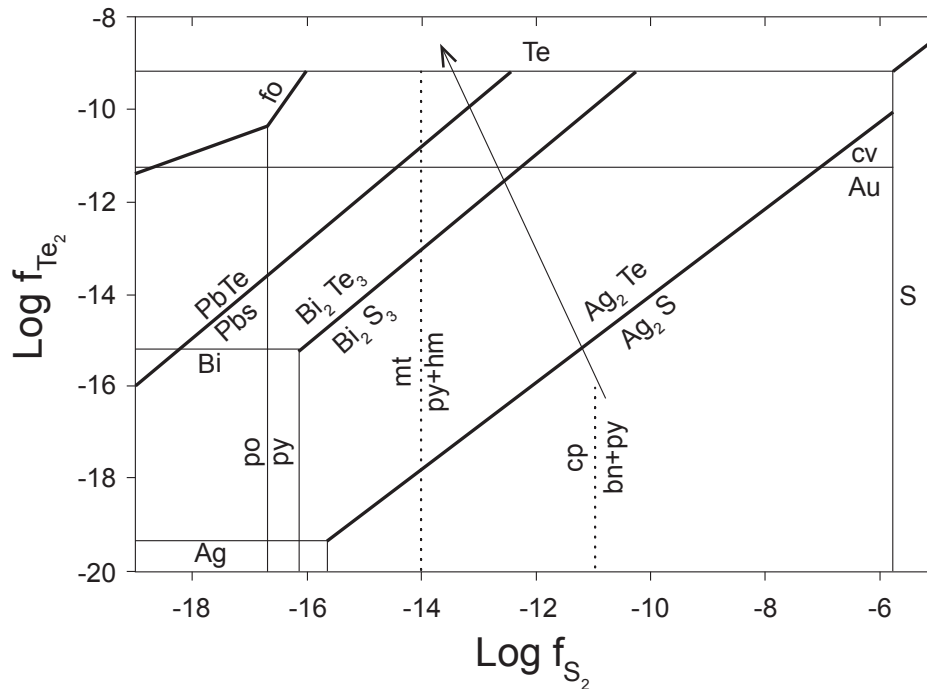


Figure 6. Relative variations in Te_2 and S_2 fugacities with respect to selected telluride-sulfide-oxide equilibria at 200°C , similar to the mineralogies and fluid inclusion temperatures reported by Lueth (1998) at the Organ district. The arrow represents the interpreted trend of ore fluid evolution (Lueth, 1998). Phase equilibria calculated from data by Afifi et al., (1988). Abbreviations: bn = bornite, cp = chalcopyrite, cv = calaverite, fo = frohbergite, hm = hematite, mt = magnetite, po = pyrrotite, py = pyrite.

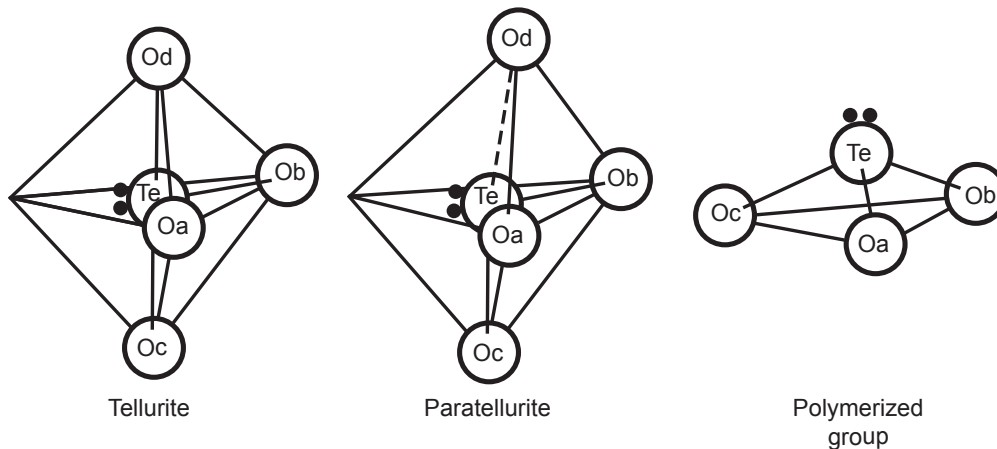


Figure 7. Oxygen coordination around Te^{4+} . Dark dots represent lone electron pairs. Figure modified from Zemmann and Leutwein (1978).

exist due to subtle differences in oxygen coordination. If bonding occurs at the corners, the orthorhombic tellurite structure is present (Figs. 8). If bonding occurs along the edges, resulting in distortion of the apical oxygen, the tetragonal paratellurite structure is favored (Fig. 9). A structure of the tellurates consist of polymerized groups, coordinated around three oxygens, that can form around other transition metals leading to an additional set of tellurium oxides having orthorhombic structure (Fig. 7). The presence of lone electron pairs in all of these structures (dark dots on Fig. 7) allows for a number of cations to bond with these Te oxide polyhedrons, resulting in a wide range of secondary metal-tellurium oxides.

Secondary Te minerals are relatively rare, however, because the native element and many tellurides are stable

in the weathering environment. Only in zones of high oxidation potential and acid leaching (gossan zones) is tellurium mobile as HTeO_3^- (Fig. 10). Tellurium mobility only occurs in the near-surface weathering zones of ore deposits characterized by abundant oxides, including pyrite and other sulfides. Accordingly, secondary Te-oxides are geologically young and near the surface, making their preservation unlikely over geologic time.

Secondary tellurium oxides are predominantly limited to one deposit in New Mexico, the Lone Pine mine. At this locality, pyrite and tellurium dominate the ore mineralogy, and a very diverse suite of tellurium oxide minerals occur in oxidized quartz-tellurium-gold veins. It is the type locality (Williams, 1979) for the mineral Rajite $[\text{CuTe}_2\text{O}_5]$ (Fig. 11) and possibly one of the ten worldwide occurrences

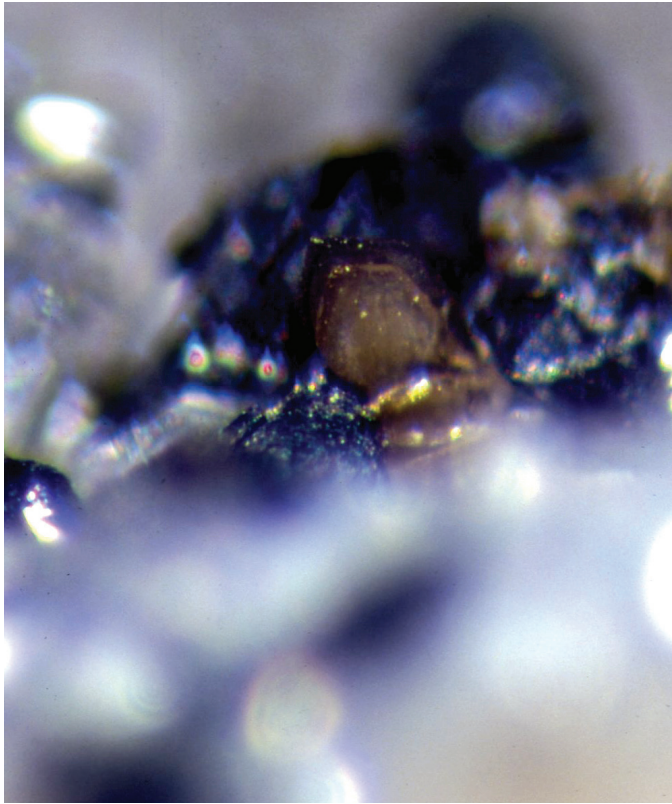


Figure 8. Tellurite (brown) on tellurium from the Lone Pine mine, Catron County. Crystal is approximately 0.5 mm across.



Figure 9. Paratellurite (yellow) on quartz from the Lone Pine mine, Catron County. Individual crystals are 1 mm across.

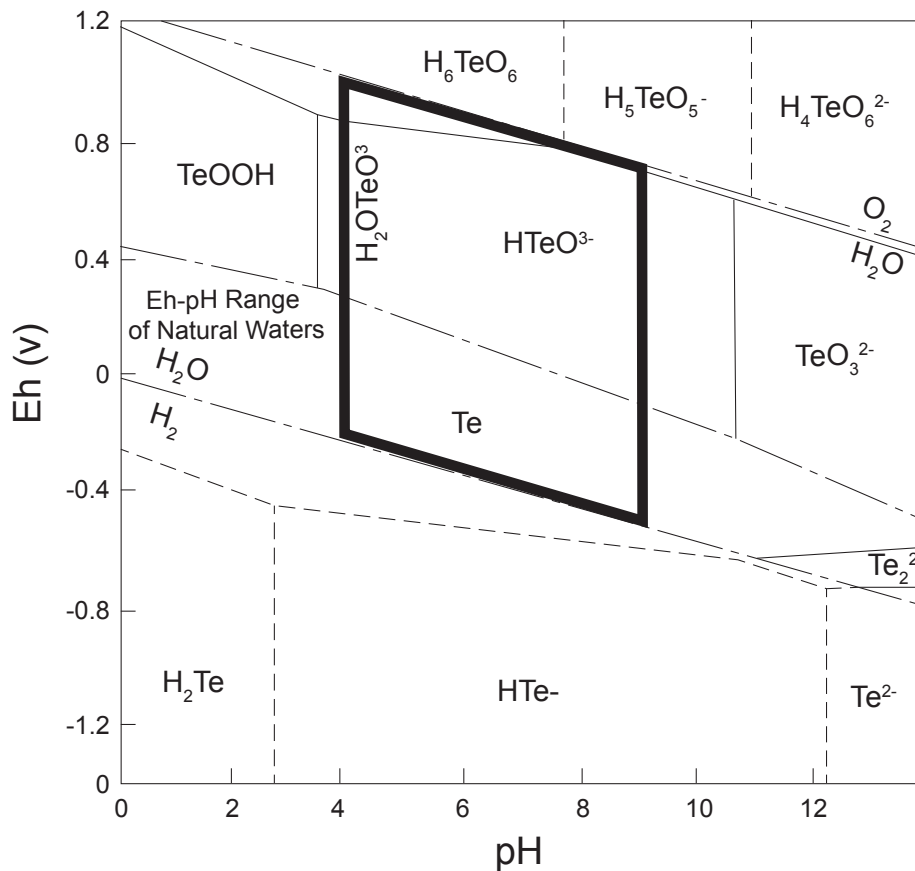


Figure 10. Stability of various tellurium species with relation to Eh and pH at $\Sigma Te = 10^{-7}$ at 25°C and 1 atmosphere. The dark box represents the Eh-pH boundaries of natural waters. Diagram based on data from Dyachkova and Khodakorskiy (1968).

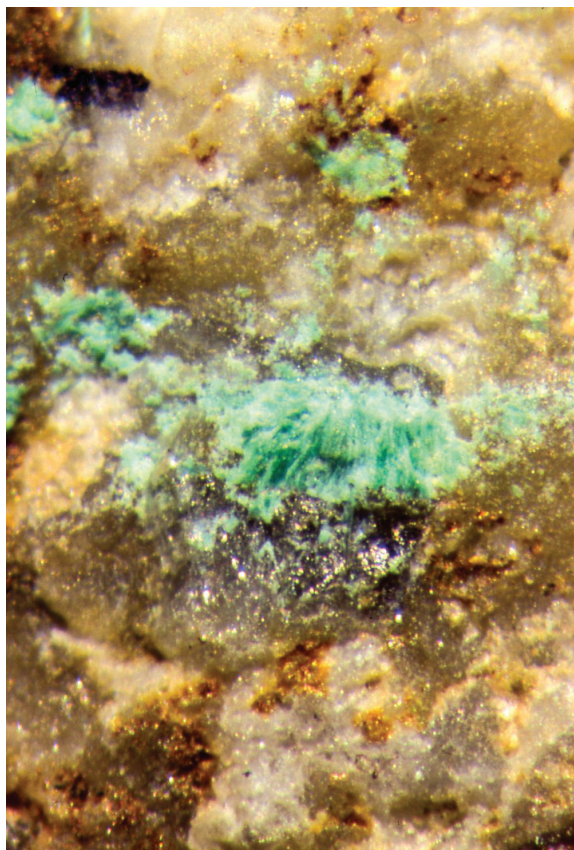


Figure 11. Rajite (bluish green) with native tellurium from the Lone Pine mine area, Catron County. Long dimension of the rajite grain is 1 mm.

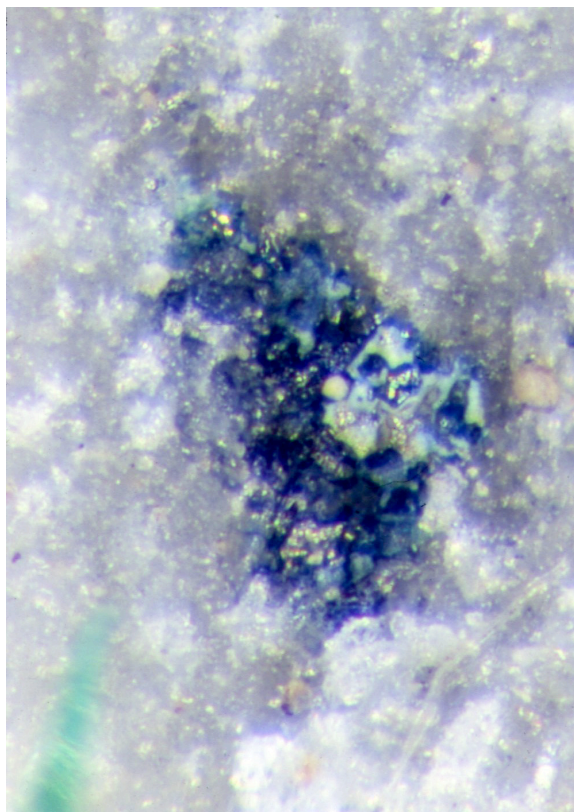


Figure 12. Teineite(?) (blue) on tetradymite with native tellurium from the Lone Pine mine area, Catron County. Tellurium minerals approximately 1 mm wide in quartz.

of Teineite [$\text{CuTeO}_3 \cdot 2\text{H}_2\text{O}$] (Fig. 12). The most abundant tellurate at this locality is Mackayite [$\text{FeTe}_2\text{O}_5(\text{OH})$], often occurring with Emmonsite [$\text{Fe}_2\text{Te}_3\text{O}_6 \cdot 2\text{H}_2\text{O}$] (Fig. 13). Blakeite [$\text{Fe}_2(\text{TeO}_3)_3$] and Poughite [$\text{Fe}_2(\text{TeO}_3)_2(\text{SO}_4) \cdot 3\text{H}_2\text{O}$] (Fig. 14) are also rarely found in gossan material on the surface. The polymorphs of tellurium oxide, tellurite (Gillerman, 1964) and paratellurite, are also observed in vugs with quartz and tetradymite. Cuzticiticite [$(\text{FeTe})_6 \cdot 3\text{H}_2\text{O}$] has been tentatively identified based on morphology alone (Fig. 15), with exceedingly small crystals and volume of material making positive identification difficult. At this locality, pyrite and tellurium dominate the ore mineralogy, resulting in a relatively simple oxide assemblage.

The simple oxide assemblage at the Lone Pine mine precludes formation of a more exotic secondary tellurium mineralogy. Other tellurium occurrences in New Mexico in weathered polymetallic deposits may hold promise for a more diverse suite of tellurates. Perhaps the oxide zones at the Memphis mine (Organ district, Fig. 1.), which has an unconfirmed report of Montanite (?) [$\text{Bi}_2\text{Te}^{+6}\text{O}_6 \cdot 2\text{H}_2\text{O}$], and at San Pedro (New Placers district, Fig. 1) may hold promise for a larger number of species to be found in New Mexico. But the collector will have to have a keen eye and perhaps some sophisticated instrumentation!

Acknowledgments

Ronald Gibbs and Joan Beyers escorted the author to the Lone Pine mine the first time and provided some of the specimens for photomicrographs. Kelsey McNamara, Virginia McLemore, and Dan Koning reviewed the manuscript and provided a number of constructive suggestions.

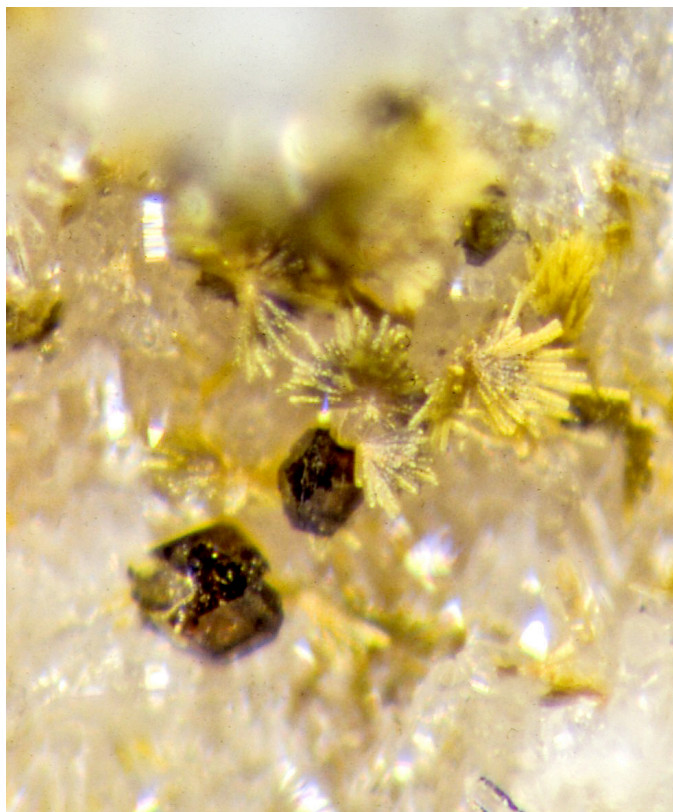


Figure 13. Mackayite (dark green crystals) and Emmonsite (lime green blocky needles) from the Lone Pine mine area, Catron County. Largest crystals are 0.25 mm across.

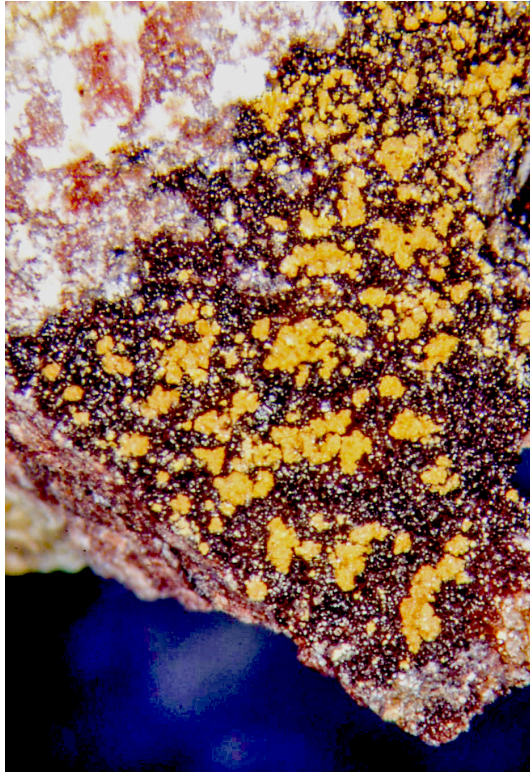


Figure 14. Poughite (yellow) on Blakeite (brown) from the Lone Pine mine area, Catron County. Field of view is 5 mm.

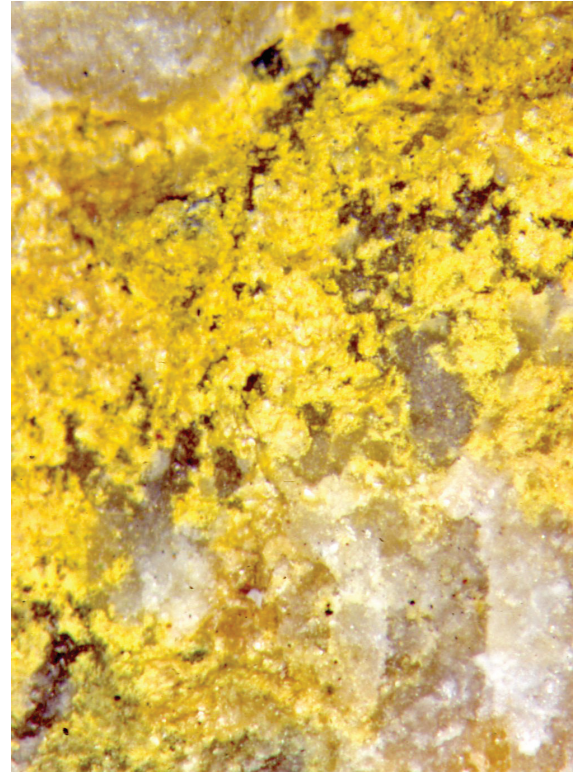


Figure 15. Cuzticitic(?) on quartz from the Lone Pine mine area, Catron County. Field of view is 5 mm.

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