JUANITAITE

A NEW MINERAL FROM GOLD HILL, UTAH

Anthony R. Kampf
Mineral Sciences Section
Los Angeles County Museum of Natural History
900 Exposition Boulevard
Los Angeles, California 90007

William S. Wise
Department of Geological Sciences
University of California
Santa Barbara, California 93106

George R. Rossman
Division of Geological and Planetary Sciences
California Institute of Technology
Pasadena, California 91125

ABSTRACT

Juanitaite, $(Cu,Ca,Fe)_{10}Bi(AsO_4)_4(OH)_{11}\cdot 2H_2O$, is a new mineral from the Gold Hill mine, Tooele County, Utah. The name is for Juanita Curtis who found the mineral. Juanitaite occurs at one occurrence as square crystal plates with rounded corners in sheaf-like subparallel aggregates and rosettes associated with conichalcite and mixite, scattered over fracture surfaces on limonitic matrix, and in another occurrence with connellite, tyrolite and azurite on quartz. The mineral formed from the oxidation of tennantite in quartz veins.

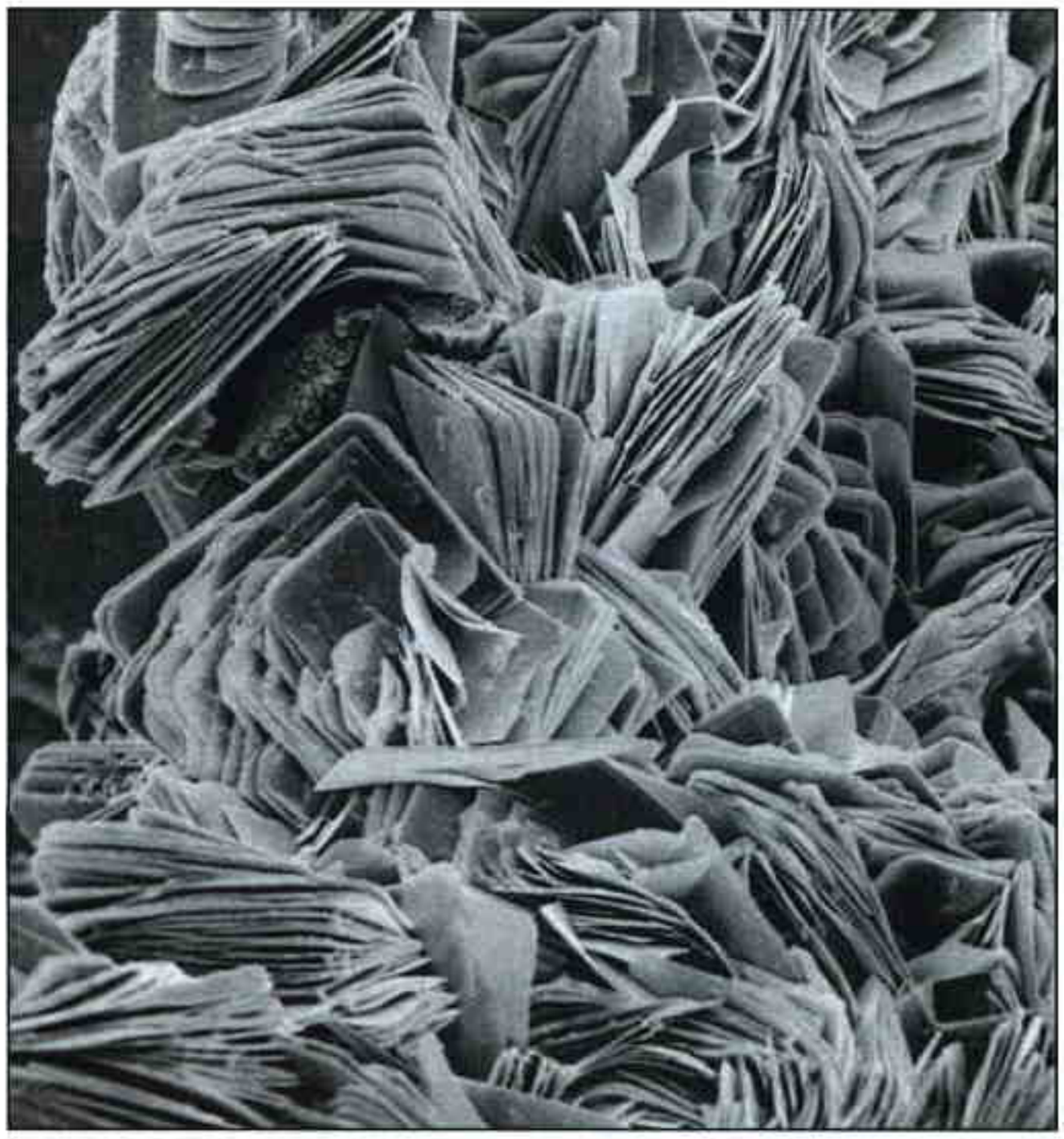
Juanitaite is olive-green to grass-green with a pale greenish yellow streak and resinous to dull luster. It is translucent and non-fluorescent. Crystals are tabular on {001} and also exhibit the forms {110} and {310}. Twinning was not observed. Plates are flexible, but not elastic. Cleavage is perfect on {001} and {110} and good on {100}. Fracture was not observed. The specific gravity measured by sink-float in Clerici solution is 3.61(5) g/cm^3. The calculated density is 3.56 g/cm^3. Crystals are uniaxial (–), ω 1.785(5), ε 1.705(5) (white light), but subparallel aggregates yield an anomalous biaxial figure ($2V \cong 20°$). No dispersion was observed. Pleochroism: O = olive-brown, E = olive-green.

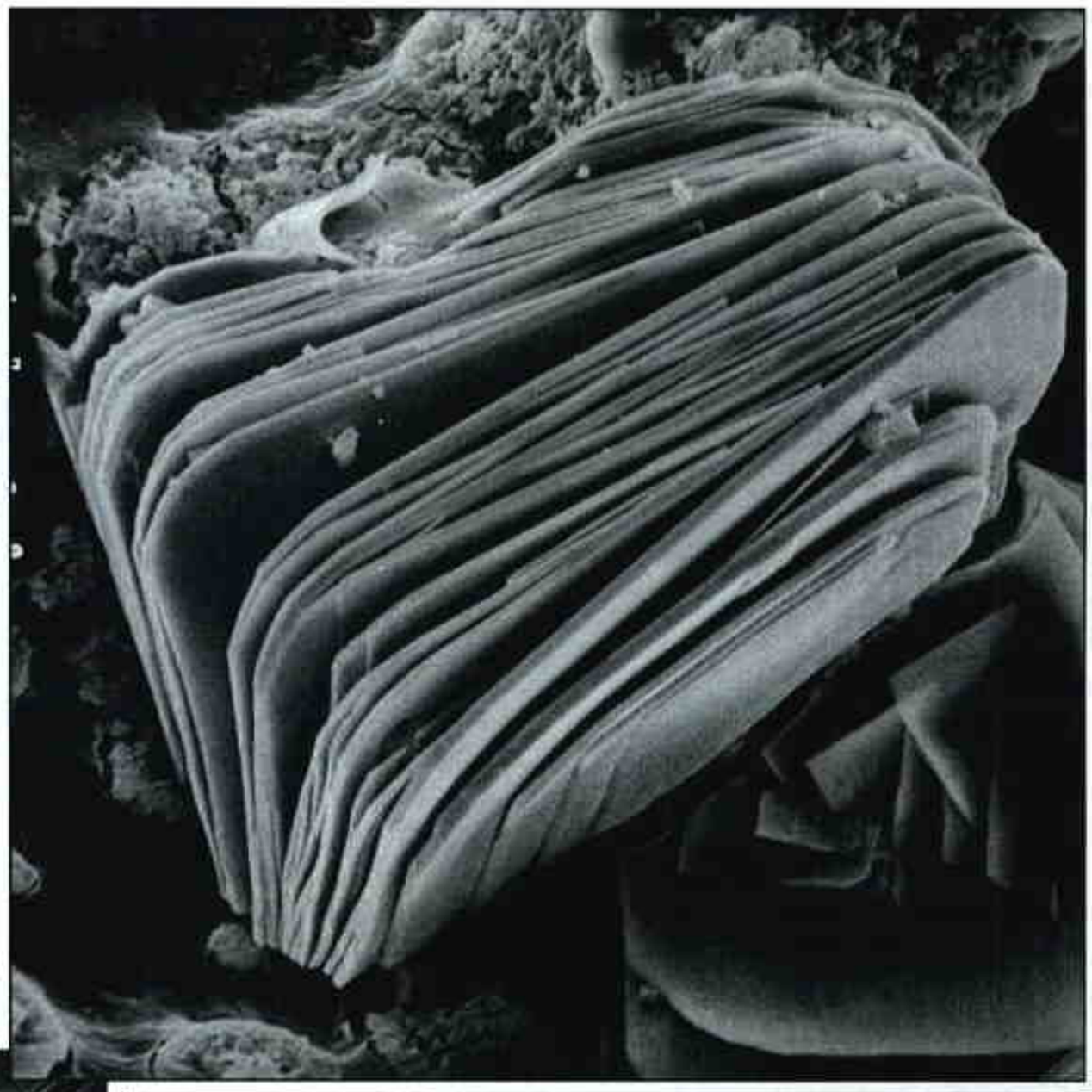
Juanitaite is tetragonal, space group $P4_2/nnm$, a = 9.961(3), c = 29.19(2) Å, V = 2896(2) Å^3, Z = 4. EMP analyses provided: CaO 8.64, FeO 2.32, CuO 35.97, Bi_2O_3 14.82, As_2O_5 29.35, H_2O (8.90) (by difference), total (100.00) weight %. Water was confirmed by IR. Juanitaite has a close chemical relationship with mixite, $Cu_6Bi(AsO_4)_3(OH)_6\cdot 3H_2O$. The six strongest powder diffraction lines are [d(Å)(I)(hkl)] 14.6(100)(002), 7.04(50)(110), 6.34(70)(112), 5.07(50)(114), 3.146(60)(310,303), 2.535(50)(228).

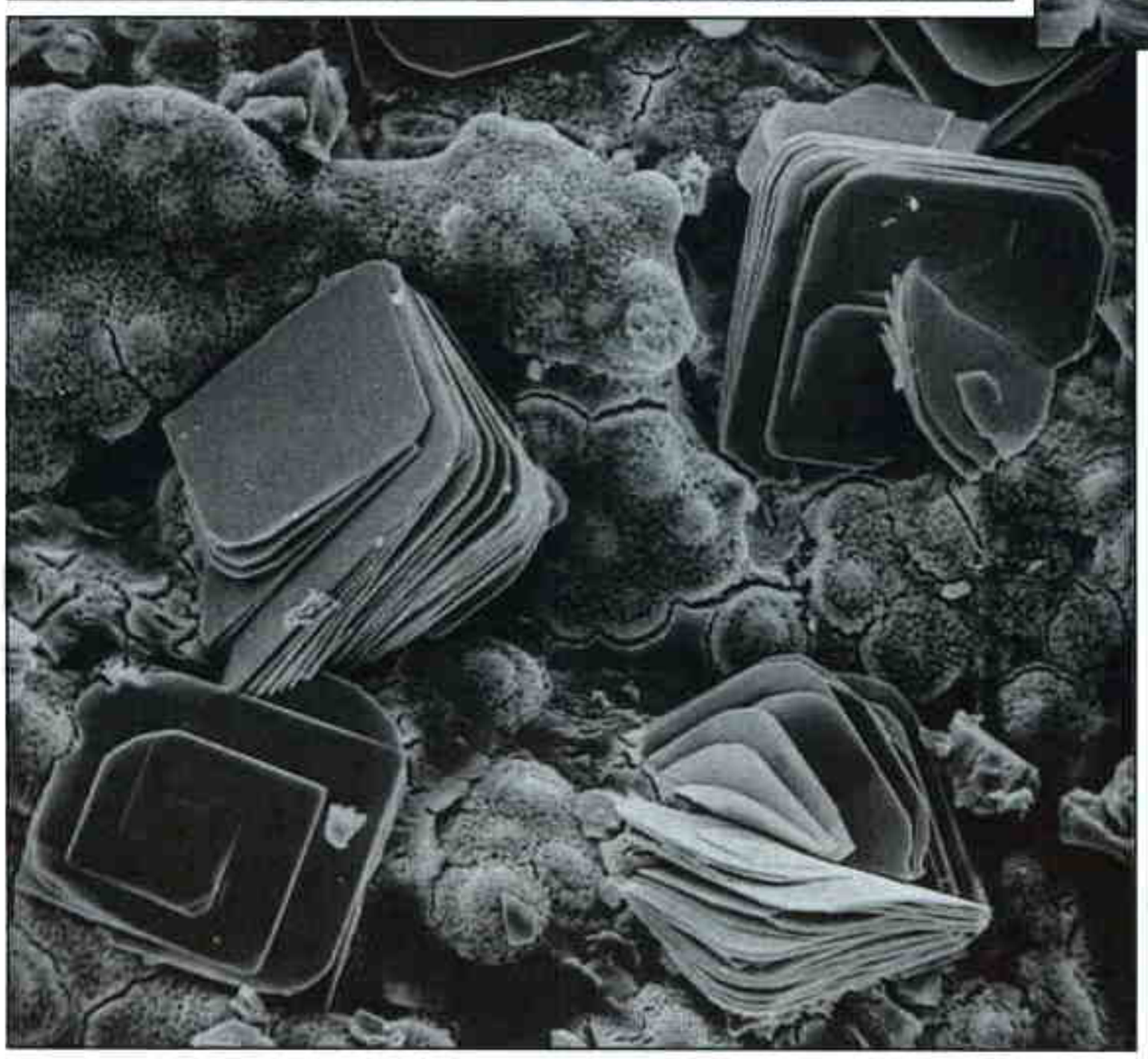
INTRODUCTION

In September of 1971, a group of four collectors, Juanita and Charles (Bob) Curtis, Wayne Leicht and Fred Croad, visited the Gold Hill mine. On the dump immediately west of the 30-foot level adit (see Kokinos and Wise, 1993, Fig. 2), they noticed weathered fragments of limonitic gossan bearing a green mineral that they took for malachite (but which was later determined to be mixite). Juanita noticed native gold in the matrix, which spurred Wayne and Bob to venture through a crawl hole into the shallow inclined adit. Here they found similar material in place in the walls. They collected approximately two flats of this material.

A couple of weeks later, while examining the material more closely, Juanita noticed dark spots resembling pepper scattered on many of the specimens. Under the microscope she observed these to be clusters of olive-green plates with bronzy reflections. They didn't match anything that she had seen before from Gold Hill, so she sent them to one of the authors (WSW) for identification. X-ray powder diffraction and chemical analysis indicated that the mineral







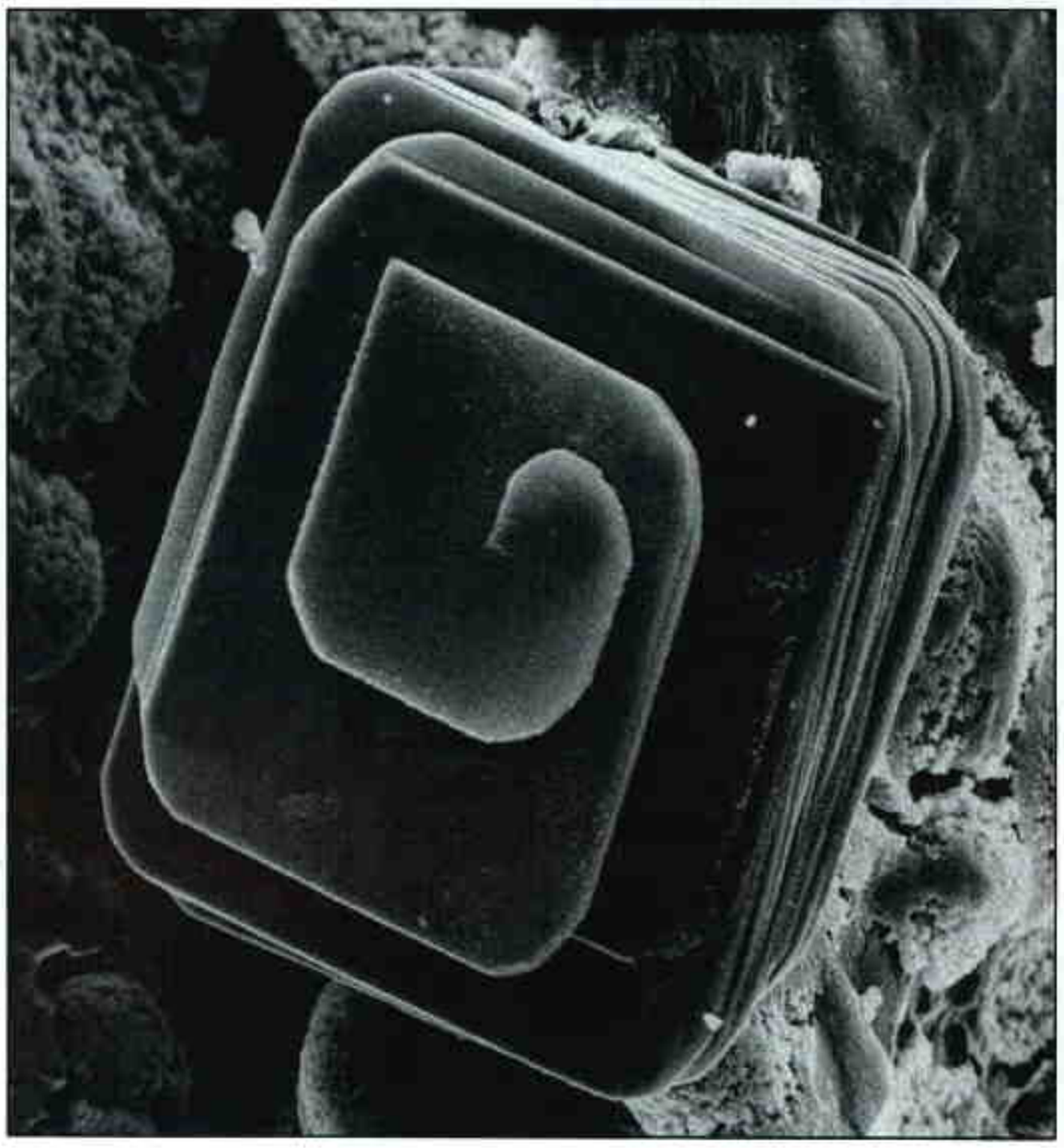


Figure 1. (top) **Dense surface coating of sheaf-like subparallel aggregates and rosettes of juanitaite plates; field of view is approximately 125 µm.**

Figure 2. (bottom) **Several groups of diverging juanitaite plates, about 35 µm across.**

Figure 3. (top) **A sheaf-like subparallel aggregate of juanitaite plates, about 35 µm across.**

Figure 4. (bottom) **Stack of juanitaite plates, about 30 µm across, showing spiral growth on {001}. Note that each rounded corner is composed of two faces that are estimated to correspond to the form {310}.**

was new, but it was not until recently that crystals of sufficient quality to complete the description were located in the original material.

The new mineral is named "juanitaite" for Juanita Curtis. This name was chosen rather than "curtisite" because the latter was originally applied to a mineral described in 1926, which in 1975 was determined to be a mixture of hydrocarbons. The mineral and name have been approved by the Commission on New Minerals and Mineral Names, IMA. Specimens LACMNH #45266 and #45267 are designated as cotypes and are deposited in the collection of the Los Angeles County Museum of Natural History.

OCCURRENCE

The Gold Hill mine in western Tooele County, Utah, is well known to collectors for its vast array of well-crystallized secondary zinc, iron, lead, copper and bismuth arsenate minerals. Kokinos and Wise (1993) reported on the mineralogy of the deposit and referred to juanitaite as an "unnamed Cu-Bi arsenate." The juanitaite from the 30-foot level is found coating surfaces and filling thin fractures in gossan. It is associated with Ca-rich mixite, conichalcite, chrysocolla, azurite, gold and quartz. In the early 1990's, juanitaite was found by Les Cubit in quartz veins underground on the 150-foot level. Here it forms fine-grained coatings on cavity walls and is associated with connellite, tyrolite and azurite.

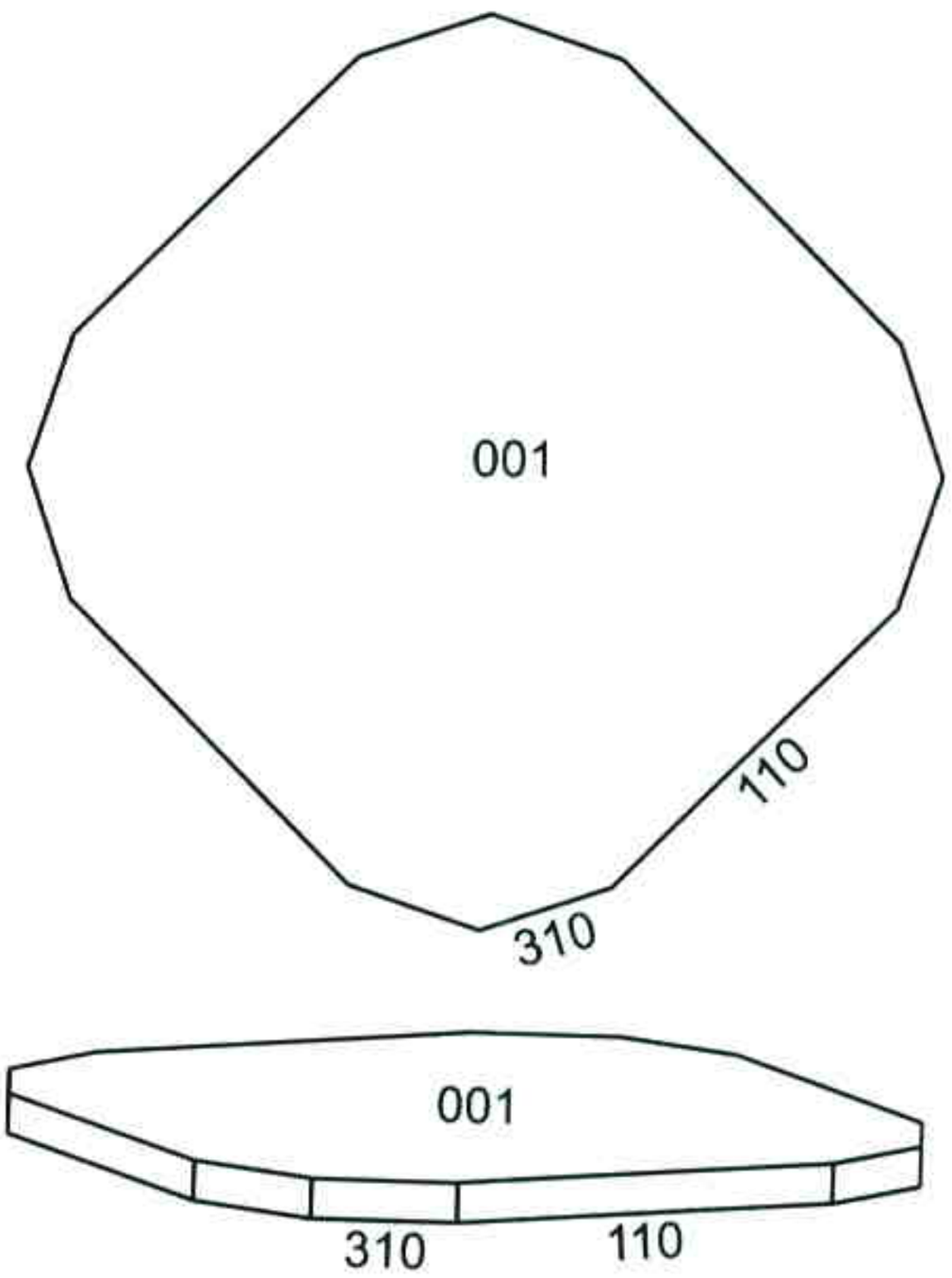


Figure 5. **Crystal drawings of juanitaite: above: looking down the *c* axis; and below: clinographic projection.**

PHYSICAL and OPTICAL PROPERTIES

Juanitaite crystals are square crystal plates (25 to 150 micrometers across and 1 micrometer thick) with rounded corners. Sheaf-like subparallel aggregates and rosettes of juanitaite plates are scattered over fracture surfaces. Crystals are tabular on {001} and are bounded by the forms {110} and {310}; the latter were estimated from SEM images. No twinning was observed.

The color of juanitaite is olive-green to grass-green and the streak is pale greenish yellow. Reflections from the {001} faces often appear bronzy. No fluorescence under ultraviolet light was detected. The luster is resinous to dull. Crystals are very soft, with Mohs hardness estimated at about 1. Crystals are flexible, but not elastic. No fracture was observed. The specific gravity measured by sink-float in Clerici solution is 3.61(5). The calculated density is 3.56 g/cm^3.

Juanitaite is uniaxial negative, but subparallel aggregates yield an anomalous biaxial figure with $2V \cong 20°$. The indices of refraction measured in white light are ω 1.785(5) and ε 1.705(5). No dispersion was observed. Pleochroism: O = olive-brown, E = olive-green.

CHEMICAL COMPOSITION

Seven chemical analyses were carried out by means of an electron microprobe using the following standards: clinoclase for Cu and As, hematite for Fe, Bi metal for Bi and wollastonite for Ca. Because of the paucity of material and the sparse distribution of the small, thin plates, it was impossible to separate a sufficient quantity of pure material for determination of water; however, the presence of water in juanitaite is supported by infrared spectroscopy (see below). In the analysis presented here, water is calculated by difference.

The mean analytical results (and ranges) are: CaO 8.64 (8.51–8.80), FeO 2.32 (1.46–2,44), CuO 35.97 (35.36–36.87), Bi_2O_3 14.82 (13.76–14.99), As_2O_5 29.35 (28.85–31.11), H_2O (8.90), total (100.00) weight %. The empirical formula (based on O = 29) is: $(Cu_{7.03}Ca_{2.39}Fe_{0.50})_{\Sigma 9.92}Bi_{0.99}(AsO_4)_{3.97}(OH)_{10.90}\cdot 2.22H_2O$ and the ideal formula is $(Cu,Ca,Fe)_{10}Bi(AsO_4)_4(OH)_{11}\cdot 2H_2O$. The ideal formula (with Cu:Ca:Fe = 7.09:2.41:0.50) requires: CaO 8.65, FeO 2.30, CuO 36.09, Bi_2O_3 14.91, As_2O_5 29.41, H_2O 8.65, total 100.00 weight %. Juanitaite is soluble in weak acids.

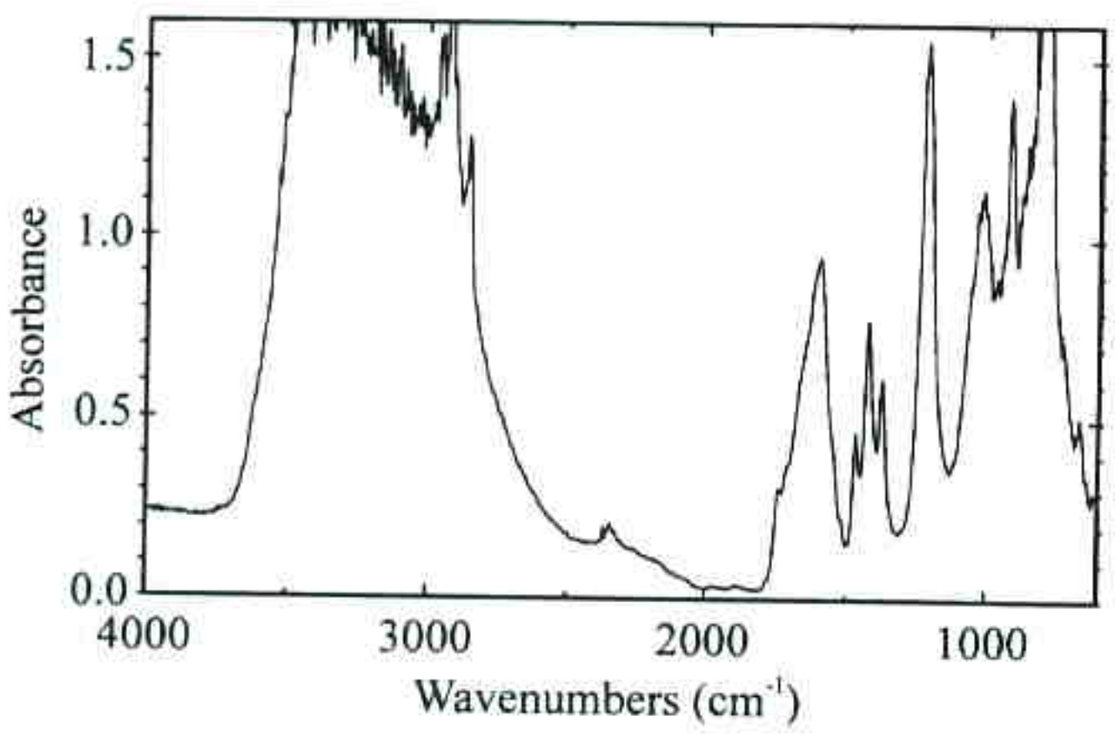


Figure 6. **Infrared absorption spectrum of juanitaite.**

INFRARED SPECTROSCOPY

Infrared absorption spectroscopy was conducted on an approximately 0.01 mm thick single juanitaite flake using an infrared microscope. An unpolarized spectrum was recorded at room temperature with light propagating down the *c*-axis. The presence of H_2O in juanitaite is supported by the IR spectrum. Absorption bands at 3440 cm^{-1} and 1600 cm^{-1} are assignable to H_2O. The lack of a band specifically corresponding to OH may be due to masking of that band by the very large band at 3440 and/or to extensive hydrogen bonding between and among OH and H_2O. The amount of absorbance attributable to H_2O is consistent with the weight % H_2O calculated by difference. The juanitaite spectrum is very similar in general features to the mixite spectrum reported by Miletich *et al.* (1997).

X-RAY DIFFRACTION STUDY

A single-crystal X-ray precession study using MoKα radiation showed juanitaite to be tetragonal, space group $P4_2/nnm$, a = 9.961(3), c = 29.19(2) Å, V = 2896(2) Å^3, Z = 4. The cell parameters were refined from the powder diffraction data using all uniquely indexed lines between 4.50 and 1.70 Å with intensities $\geq$5. The powder diffraction data are provided in Table 1. The small size, thinness, softness and flexibility of the plates, and their occurrence in sheaves, make the selection of a single crystal suitable for atomic structure determination impossible.

Table 1. **X-ray powder diffraction data for juanitaite.**

I	$d_{meas.}$	$d_{calc.}$	*hkl*
100	14.6	14.595	*002*
10	9.4	9.427	101
50	7.04	7.043	110
70	6.34	6.343	112
50	5.07	5.068	114
5	4.405	4.404	211
10	4.258	4.261	212
25	4.112	4.114	204
5	4.006	4.003	116
5	*3.646*	3.649	*008*
40	3.518	3.522	220
40	3.494	3.496	221
15	3.425	3.423	222
5	3.285	3.285	216
5	3.235	3.240	118
60	3.146	3.150, 3.142	310, 303
10	3.079	3.079	312
<5	2.917	2.919	0•0•10
40	2.855	2.853	226
30b	2.761	2.750, 2.772	321, 315
5	2.718	2.714	322
30	2.657	2.658	323
5	2.603	2.597	307
50	2.535	2.534	228
20	2.491	2.490	400
20	2.456	2.455	402
30	2.391	2.402, 2.386	326, 229
10	2.321	2.318	332
10	2.250	2.247	2•2•10
10	2.236	2.235	334
10	2.143	2.141	3•1•10
5	2.119	2.114	336
<5	2.057	2.057	408
<5	2.001	2.006	3•2•10
30	1.956	1.954	510
5	1.946	1.949	511
5	1.929	1.936	512
10	1.897	1.895	4•0•10
10	1.856	1.853	515
5	1.817	1.813	516
5	1.789	1.793	524
10	1.762	1.761, 1.758	440, 441
25	1.746	1.748	442
15	1.718	1.712, 1.722	444, 518
5	1.704	1.708	530
<5	1.684		
<5	1.653		
20	1.602		
<5	1.577		
20	1.548		
5	1.526		
25	1.502		
20	1.474		
10	1.450		
5	1.430		
15	1.409		
5	1.386		
5	1.374		
5	1.352		
10	1.349		

(Recorded with CuKa radiation using a 114.6 mm diameter Gandolfi camera.)

STRUCTURAL CONSIDERATIONS

Chemically *juanitaite is most closely allied to mixite*, $Cu_6Bi(AsO_4)_3(OH)_6 \cdot 3H_2O$. Minerals of similar chemistry that occur in intimate association, as do juanitaite and mixite, often possess similar structural components. Miletich *et al.* (1997) noted that the basic structural units in mixite are infinite chains of edge-sharing CuO_5 square pyramids. These chains are aligned parallel to the *c*-axis of mixite. The cell of juanitaite does not seem capable of accommodating such a chain. Although the *c*-axis of juanitaite (29.19 Å) is almost exactly five times the length of the *c*-axis of *mixite (5.913 Å), that would suggest a chain with* ten square pyramids in each unit cell repeated along *c*, which is inconsistent with the space group symmetry of juanitaite. Other orientations of edge-sharing or, for that matter, corner-sharing chains of CuO_5 square pyramids also appear inconsistent with the juanitaite cell.

The empirical formula of juanitaite provides another structural quandary. If Cu is accommodated in square pyramidal (5-coordinated) sites in juanitaite as it is in mixite, where do Ca and Fe go? It is unlikely that either could be accommodated in significant *quantity in a square pyramidal site* and it is unusual for Ca and Fe to share the same site. The ideal formula could be written $Ca_{10}Fe_2Cu_{28}Bi_4(AsO_4)_{16}(OH)_{44} \cdot 8H_2O$, *reflecting the contents of the* unit cell ($Z = 1$), with Ca, Fe and Cu segregated into separate sites. However, apportioning cations between hypothetical structural sites must, by necessity, take space group special position multiplicities and symmetries into consideration. This ideal formula requires that Fe exist at a site with 2-fold multiplicity. The only such site in space group $P4_2/nnm$ has site symmetry $\bar{4}2m$, which is not consistent with the octahedral (6-fold) coordination typical for Fe^{2+}. This, of course, assumes full site occupancies, which need not be the case. *Fe could statistically half occupy a site with 4-fold* multiplicity. In space group $P4_2/nnm$ such sites have *mm*, 2/*m* or 222 symmetry, all of which are compatible with octahedral coordination about the Fe.

PARAGENESIS

Kokinos and Wise (1993) noted that the orebody of the Gold Hill deposit was emplaced in three stages, each with a different set of primary minerals. Oxidation of each set yielded a different suite of secondary minerals. Juanitaite is found in the suite designated as the *copper arsenate and sulfate assemblage*, which originated from the oxidation of tennantite, chalcopyrite and pyrite and consequent fluid remobilization of ions. The contributors to the constituents of the secondary minerals found in this assemblage include the groundwater (carbonate and chloride), limestone host rock (calcium and carbonate), tennantite (Cu, Bi, arsenate and sulfate), chalcopyrite (Cu, Fe and sulfate) and pyrite (Fe and sulfate). Specific associations, such as juanitaite-mixite-conichalcite or juanitaite-connellite-tyrolite-azurite, are attributed to unique local cation and/or anion concentrations.

ACKNOWLEDGMENTS

We wish to very gratefully acknowledge Juanita Curtis, not only for providing specimens of the new mineral and details concerning its occurrence, but also for her many years of dedicated service to the amateur and professional mineralogical community.

Juanita Curtis

REFERENCES

KOKINOS, M., and WISE, W. S. (1993) Famous mineral localities: the Gold Hill mine, Tooele County, Utah. *Mineralogical Record*, **24**, 11–22.

MILETICH, R., ZEMANN, J., and NOWAK, M. (1997) Reversible hydration in synthetic mixite, $BiCu_6(OH)_6(AsO_4)_3 \cdot nH_2O$ ($n \leq 3$): hydration kinetics and crystal chemistry. *Physics and Chemistry of Minerals*, **24**, 411–422.