

## Ktenasite from Creede, Colorado

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### Abstract

The rare sulfate mineral ktenasite,  $(\text{Cu,Zn})_3\text{SO}_4(\text{OH})_4 \cdot 2\text{H}_2\text{O}$ , has been found coating chalcopyrite and sphalerite crystals from the Commodore Mine, Creede, Colorado. The type locality is Laurium, Greece.

Ktenasite, a rare Cu–Zn sulfate, has been found by us in a small number of specimens from the Commodore Mine, Creede, Colorado. It was originally described from the Kamaresa Mine, Laurium, Greece by Kokkoros (1950); we are aware of no other locality reported in the literature. Several years ago, however, a private mineral collector, Mr. A. Eadie, informed us that he had obtained a small specimen of ktenasite from a locality in Norway. We have verified the identification of the Norwegian material but have no additional information about the occurrence other than the locality (given below).

At Creede, ktenasite occurs as blue-green, generally flattened prismatic crystals up to  $60\mu\text{m}$  (mostly smaller), encrusting large chalcopyrite and sphalerite crystals. In some specimens ktenasite encrusts only chalcopyrite, leaving adjacent sphalerites uncovered. Associated accessory minerals are prismatic rose-quartz crystals, prismatic colorless quartz crystals, galena, anglesite, and white powdery coatings of goslarite. Several clay minerals are present as coatings on some sulfide crystals and in cavities.

At the type locality, Kokkoros reported a paragenesis that included smithsonite, serpierite, and glaucokerinite. Platy crystals of ktenasite up to  $1\text{mm}$  across occur there.

The Norwegian specimen contains platy crystals,  $<100\mu\text{m}$ , on sphalerite, with small crystals of gypsum. The locality is given as Glomsrudkollen, Modum, near Drammen, in southern Norway.

The composition of the Creede ktenasite was obtained by electron microprobe analysis. Because the mineral is exceedingly soft and of low thermal stability, the lowest possible beam currents caused some vaporization of the specimen. By opening the beam to  $10\text{--}20\mu\text{m}$  and counting for short periods on different spots, the results given in Table 1 were obtained. The results agree fairly well with the analysis of Kokkoros (1950) with, however, a different Zn-to-Cu ratio. Because of the difficulties in analysis, relative errors in our analysis are probably no better than  $\pm 10$  percent of the amounts present.

Table 2 gives the X-ray powder diffraction data obtained for the Creede material, comparing it with the pattern given by Kokkoros and a pattern made from the Norwegian material. Berry (1974, p. 349) noted that the powder pattern could not be satisfactorily indexed on the basis of the cell parameters determined by Kokkoros, and down-rated the quality of the Powder Diffraction File card (#13-309) to a "o" status. We note that the powder-diffraction data were obtained from a secondary source, a compilation by Mikheev, rather than Kokkoros' original paper. In Kokkoros' work the powder pattern was obtained with unfiltered Cu radiation. Apparently, Mikheev listed all the observed peaks without noting that  $\text{CuK}\beta$  peaks would be present. Some of the difficulty in indexing the pattern must be due to this. We find at least two significant peaks in the forward reflection region that cannot be indexed; all of these

Table 1. Analyses of two ktenasites

	Creede, Colorado (this work)	Laurium, Greece (Kokkoros, 1950)
	wt. %	wt. %
CuO	12.4	32.44
ZnO	48.0	28.14
SO <sub>3</sub>	22.0	19.92
H <sub>2</sub> O	17.6 (by difference)	19.50
Sum	100.0	100.00
Zn/Zn+Cu	0.79	0.46
CuO : ZnO : SO <sub>3</sub> : H <sub>2</sub> O		CuO : ZnO : SO <sub>3</sub> : H <sub>2</sub> O
0.57:2.15 : 1 : 3.56		1.64:1.39 : 1 : 4.35

are in the correct 2-theta positions to be CuKβ peaks of two prominent reflections. These peaks were not seen on patterns made with filtered radiation of the Creede and Norwegian materials. In addition, there is apparently an error in the Mikheev compilation, which gives the first reflection as 12.9A. Berry could not index this major peak. In Kokkoros' original table, however, this peak is 11.9A. This peak is indexed satisfactorily as (002). Also, since this peak is broad in all three patterns, the broadness could be due to the (100) peak at 11.1A.

The patterns given in Table 1 can be indexed satisfactorily using the cell parameters determined by Kokkoros (1950). There is not perfect correspondence between the three patterns. The most obvious difference is the peak at 7.2A (and 7.1A) for the Laurium and Creede specimens, respectively. It does not occur for the Norwegian specimen, and it cannot be satisfactorily indexed. It is, however, the strongest peak in the pattern for the mineral langite, a sulfate mineral of similar chemistry. It is possible that minor langite occurs intergrown with the ktenasite from these localities.

The occurrence of ktenasite at Creede suggests it may actually be a widespread accessory mineral in Cu-Zn-Pb deposits, where it is easily mistaken for smithsonite, or even chrysocolla.

**Note added in proof**

The authors are very embarrassed to have missed the paper by G. Raade *et al.* giving a full description of the ktenasite from Norway (*Mineral. Mag.*, 41, 65-71, 1977), along with full X-ray data. Thus, this report on the Creede occurrence is the third documented report in the literature.

**Acknowledgments**

We thank Mr. Art Eadie of Taft, California for bringing to our attention the Norwegian occurrence of ktenasite and for providing

Table 2. X-ray powder diffraction data for three ktenasites. Indices calculated using the cell parameters determined by Kokkoros (1950): a = 11.16, b = 6.11, c = 23.74A, β = 95°35'; space group P2<sub>1</sub>/c. Powder data obtained by film methods on 114.6mm diameter camera; d spacings in A units; intensities visual estimates; Ni-filtered Cu radiation. In addition, the Laurium pattern has four more lines to 0.9181A, and the Norwegian pattern has eight more lines to 0.9188A.

Laurium			Creede		Norway		hkl
(Kokkoros, 1950)	d (I)		d (I)		d (I)		
11.9 (100)			11.72 (100)		11.5 (100)		002
7.2 (30)			7.17 (40)				**
6.46 (40)*							
5.87 (90)			5.85 (90)		5.86 (90)		004, 101
5.37 (40)***							
4.85 (90)			4.84 (80)		4.81 (80)		013, 202
4.27 (20)			4.24 (30)		4.24 (30)		014, 204
4.10 (30)			4.11 (50)		4.08 (50)		210, 211
3.93 (70)			3.91 (70)		3.92 (80)		006
			3.83 (30)		3.85 (30)		204
3.74 (60)			3.75 (50)		3.73 (70)		015
3.53 (90)							213
3.39 (30)			3.36 (20)		3.35 (30)		007
3.21 (30)			3.20 (20)		3.20 (20)		215
3.05 (60)			3.05 (10)		3.06 (30)		020
2.95 (60)			2.94 (80)		2.95 (90)		022, 008
2.74 (100)			2.76 (50)		2.77 (50)		402, 123
2.70 (40)			2.70 (70)		2.67 (60)		220, 221
			2.66 (20)		2.64 (60)		221, 402
			2.62 (20)				222
2.58 (60)			2.59 (70)		2.57 (80)		222
2.53 (60)			2.52 (20)		2.52 (20)		208
2.42 (60)			2.48 (10)		2.42 (60)		404
2.38 (60)			2.40 (80)		2.37 (70)		224
2.32 (60)							218
2.28 (30)			2.29 (40)		2.28 (40)		322, 225
2.21 (20)							308
					2.17 (30)		226
2.15 (60)			2.15 (80)		2.14 (50)		324, 219
2.11 (60)			2.12 (20)		2.12 (20)		028
2.04 (60)			2.05 (20)		2.05 (30)		420, 227
			2.00 (10)		2.02 (10)		504, 512
			1.957 (10)		1.952 (10)		423
1.941 (60)							417
			1.920 (50)		1.928 (30)		034
					1.911 (30)		230
1.888 (30)							134
1.831 (30)			1.834 (10)		1.826 (20)		135, 229
			1.794 (10)		1.798 (10)		136
			1.759 (20)				333
1.743 (20)							236
			1.732 (10)		1.737 (20)		137
1.704 (90)					1.709 (30)		137
			1.678 (20)		1.680 (30)		524
1.639 (10B)					1.634 (30)		428
1.575 (10B)			1.584 (30)		1.587 (40)		622
			1.564 (10)				429
					1.550 (10)		337
1.530 (50)			1.535 (30)		1.536 (40)		710
			1.502 (10)		1.503 (10B)		142
1.495 (50)							338
1.478 (10)			1.481 (10)		1.473 (40B)		240
1.435 (10)			1.443 (10)		1.434 (10)		145
1.412 (50)							340
			1.405 (10)		1.406 (10)		146
							716
1.379 (20)			1.375 (10B)		1.387 (10)		147
1.359 (20)			1.351 (20B)		1.355 (20)		148
1.344 (50)							811, 708
			1.325 (10)		1.330 (40)		443
							814
			1.296 (10)				446
1.254 (30)			1.256 (10)		1.284 (10B)		541
			1.202 (20)		1.250 (30)		153, 911
1.185 (30)			1.184 (10)				252, 904
							155
					1.173 (10)		354
					1.145 (10B)		828
1.108 (10)			1.101 (10)		1.126 (10)		454, 159
					1.107 (10)		357
					1.087 (10)		551
1.074 (30)			1.076 (10)		1.073 (10)		

\*CuKβ peak of 101

\*\*Impurity of Langite

\*\*\*CuKβ peak of 013

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