

KOSTOVITE, A GOLD-COPPER TELLURIDE
FROM BULGARIA¹

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ABSTRACT

Kostovite, a new mineral with the formula AuCuTe_4 , was found in the copper ore deposit of Chelopech, Bulgaria, in association with tennantite, chalcopyrite, pyrite, native tellurium, native gold, tellurides and other minerals.

Kostovite forms small grains and short veinlets in tennantite and chalcopyrite. The mineral has a low hardness (about 2–2.5, Mohs). Cleavage distinct in one direction. In reflected light the mineral is creamy white, strongly anisotropic, with high reflectivity (R_p 48.4–54.9%, R_g 50.1–60.1%). Fine polysynthetic lamellae are characteristic.

The x-ray powder diagram of kostovite is similar to those of calaverite and sylvanite.

The name is for Professor Ivan Kostov, Bulgarian mineralogist.

INTRODUCTION

During the microscopic studies of the gold- and tellurium-bearing copper ores from the deposit of Chelopech, Bulgaria, small grains of a mineral have been observed, which by optical properties strongly resembles sylvanite. More detailed investigations of the chemical composition and properties of the mineral showed that it is an independent species, which was named kostovite in honor of Professor Ivan Kostov, Bulgarian mineralogist.

PHYSICAL AND OPTICAL PROPERTIES

Kostovite occurs as isometric to slightly elongated grains, 0.02 to 0.05 mm in diameter, whose outlines in polished sections are usually polygonal, seldom rounded. They are found either as individual grains enclosed in the other ore-forming minerals, or as aggregates. Crystals have not been found. Characteristic for all grains is a fine lamellar twinning (Figs. 1, 2). The width of the twinning lamellae varies from 0.0001 to 0.02 mm.

The mineral is soft and brittle. With a Hanemann's indentor a microhardness of 35–43 kg/mm^2 was determined, which corresponds approximately to 2.0–2.5, Mohs. Kostovite has a distinct cleavage in one direction, observed when scratched by needle. In polished section the cleavage is not discernable. It is non-magnetic. Its color is grayish white, its luster—metallic. No change of color or luster is observed when exposed for a long time to air.

In reflected light kostovite is creamy white with distinct pleochroism,

¹ Approved by the Commission on New Minerals and Mineral Names, International Mineralogical Association.

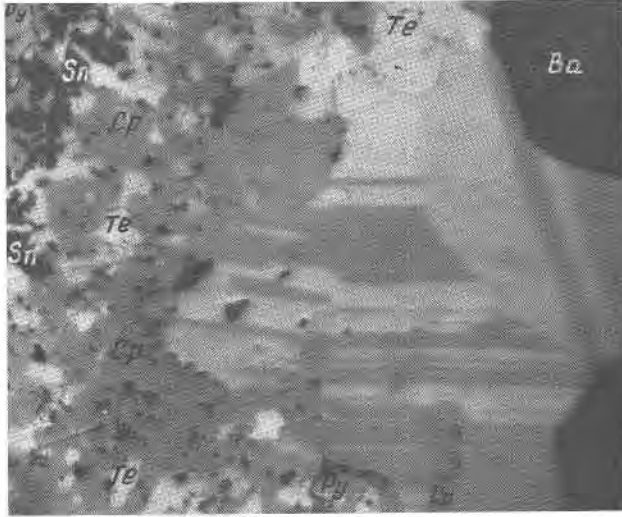


FIG. 1. Granular aggregate of kostovite with distinct pleochroism surrounded by native tellurium (Te), chalcocopyrite (Cp), pyrite (Py), pinkish brown isostannite (Sn), and barite (Ba). Without analyzer. Immersion. $\times 1000$.

accentuated by the twinning and becoming stronger in immersion (Fig. 1). The color changes from light creamy white (lighter) to light creamy brownish (darker). In oil the colors change in a similar manner. Kostovite is perceptibly more creamy than native tellurium. The reflectivity of the

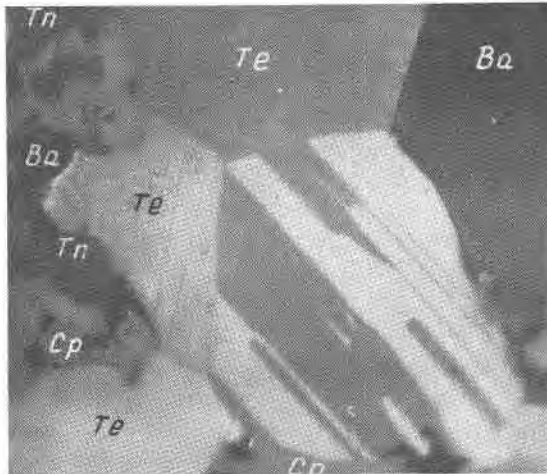


FIG. 2. Twinned grain of kostovite surrounded by native tellurium (Te), chalcocopyrite (Cp), tennantite (Tn), and barite (Ba). Crossed Polars. Immersion. $\times 1000$.

TABLE 1. REFLECTIVITY OF KOSTOVITE IN AIR

$\lambda m\mu$	Rg%	Rp%
433	50.1	49.3
469	53.7	49.7
482	55.2	52.1
518	56.4	52.7
559	60.1	54.9
589	57.9	53.0
624	57.0	52.5
668	55.2	49.3
691	53.3	48.4

mineral is high. In Table 1 are shown the results from measurements of the reflectivity of kostovite with the aid of an apparatus with a photo-multiplier of the Bernstein system. Under crossed polars the mineral is strongly anisotropic, with clear color effects in pinkish grayish brown, yellowish gray, brownish gray and reddish hues.

Kostovite polishes very well. Its relief is lower than those of tennantite, chalcopyrite and native tellurium. Tests with HNO_3 (1:1), HCl (1:1), KCN , KOH , HgCl_2 , and FeCl_3 are negative.

In reflected light kostovite is very similar to sylvanite. It differs from the latter by its lower reflectivity and negative tests with all standard reagents.

CHEMICAL COMPOSITION

The composition of the mineral was determined using electron-probe α -ray microanalyzer JXA-3. The results are presented in Table 2. The determinations were carried out using pure metals and calaverite as standards. The electron beam accelerating voltage was 25 kV and the

TABLE 2. ELECTRON-MICROPROBE ANALYSIS OF KOSTOVITE

	Wt. %		Atomic ratios	Formula on basis of Te=4.0000
	Orig.	Recalc.		
Au	25.2	24.97	0.1267	$\text{Au}_{0.97}\text{Ag}_{0.03}\text{Cu}_{0.92}\text{Te}_4$ or AuCuTe_4
Ag	0.4	0.40	0.0037	
Cu	7.7	7.63	0.1201	
Te	67.6	67.00	0.5250	
Total	100.9	100.00		

Analyst: V. V. Lidder.

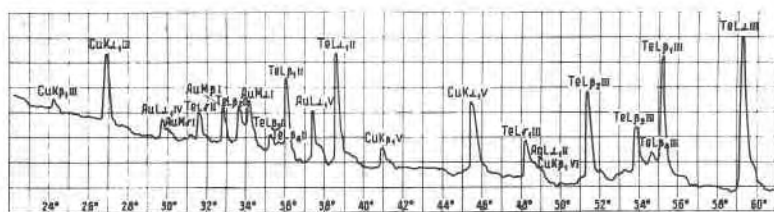


FIG. 3. X-ray spectrogram of kostovite. Mica analyzer, Logarithmic vertical scale.

incident beam was normal to the polished surface of the specimen. The x -rays were collected in a direction at 15° to the surface. The results so obtained are corrected for absorption of the x -rays and for the effect of differences in atomic numbers between specimen and standard. Three analyses of different grains were made using various standards. The results from the three measurements showed but little difference. The deviation of the three measurements from their average are for Au—0.4, for Cu—5.5, for Te—3.0%. Corrections were made on the average figures obtained for each element.

The chemical composition of the mineral corresponds closely to the formula AuCuTe_4 , the small amount of silver probably replacing the gold atoms. An impression about the chemical composition of the mineral can be obtained from Fig. 3, representing the recorded x -ray spectrogram and from Fig. 4, showing the curves of the mass concentration distribution of the elements. The curves are observed on the scanning of the micro-analyzer in x -rays characteristic for each of the elements during the radiation of the specimen along a line traversing a grain of the mineral.

X-RAY INVESTIGATIONS

An x -ray powder diagram was obtained from a few micrograms of the mineral turned into a spherule of 0.3 mm in diameter by using rubber

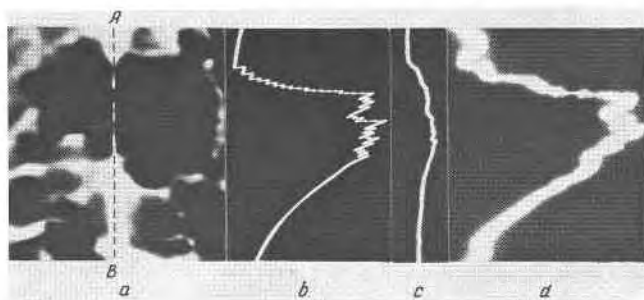


FIG. 4. Absorbed electron scanning image of kostovite (black) (a) and curves of the mass concentration distribution of elements: $\text{AuL}\alpha_1$ (b), $\text{CuK}\alpha_1$ (c) and $\text{TeL}\alpha_1$ (d) along the line AB. $\times 600$.

paste according to the method offered by Hiemstra (1956) and improved by Ghenkin and Korolev (1961). Several *x*-ray powder diagrams with similar *d*-values but bearing some lines of native tellurium were obtained from different other samples. In Table 3 are shown the results of the calculations of two *x*-ray diagrams of kostovite, one of them representing the pure sample, the other one with minor quantities of native tellurium. The presence of other admixed minerals (*e.g.*, chalcopyrite) is excluded.

An *x*-ray powder diagram of kostovite is very specific, but similar to those of sylvanite and calaverite, which allows the assumption that the new mineral is monoclinic. The *x*-ray diagrams cannot be indexed in the cubic, tetragonal, and hexagonal systems. The small dimensions of the grains and their fine polysynthetic twinning did not allow a more detailed structural investigation.

OCCURRENCE AND PARAGENESIS

The deposit of Chelopech in which the mineral was found is a copper one, but it contains lead-zinc ore and barite as well. The ore bodies are represented by irregular replacements of Upper Cretaceous propylitized andesites, andesitic tuffs and breccias, along sub-meridional fault zones. The chief ore minerals are pyrite, chalcopyrite, tennantite, enargite, luzonite, bornite, galena and sphalerite, irregularly distributed. In small amounts are found famatinite, digenite, chalcocite, idaite, marcasite, native gold, native tellurium, altaite, tellurobismuthite, sylvanite, tetradymite, nagyagite, schirmerite, wittichenite, bismuthinite, colusite, isostannite, renierite, eucairite and gallite. Non-ore minerals are quartz, barite, sericite, epidote, kaolinite, gypsum, fluorite and celadonite.

There is a distinct horizontal and vertical zoning in the distribution of the ores: copper ore is found in the deeper levels, lead-zinc ore above and aside it. Uppermost is a barite zone locally enriched in fluorite. Within the copper zone, chalcopyrite-tennantite association gives place at depth first to luzonite-enargite association with famatinite and then, locally, to pyrite-bornite with digenite, chalcocite and covellite. Pyrite is ubiquitous but tends to be present in greater quantities in the deeper levels.

The zonal distribution of the different associations in the ores of Chelopech is similar to the zoning described for Butte, Montana (Sales and Meyer, 1949).

Kostovite is found only in the zone of chalcopyrite-tennantite in association with pyrite, chalcopyrite, tennantite, native tellurium, tellurobismuthite, nagyagite, sylvanite, altaite, schirmerite, native gold, sphalerite, pinkish brown isostannite and colusite. Persistent is its association with native tellurium, with which it forms mutual intergrowths. Kostovite and native tellurium commonly occur as short, fine veinlets in tennantite and chalcopyrite (Fig. 5), which, together with observed relation-

TABLE 3. X-RAY POWDER DIFFRACTION DATA FOR KOSTOVITE, CALAVERITE, AND SYLVANITE

Kostovite, Chelopech, Bulgaria		Kostovite, Chelopech, Bulgaria		Calaverite, (Berry and Thompson, 1962)		Sylvanite, (Berry and Thompson, 1962)	
I	d Å	I	d Å	I	d Å	I	d Å
—	—	3	7.09	—	—	0.5	7.38
2	5.10	5	5.03	1	5.04	1	5.10
—	—	1	4.42	—	—	0.5	4.53
1	4.15	1	4.15	—	—	—	—
2	3.94	3	3.94	—	—	1	3.99
—	—	—	—	0.5	3.77	1	3.83
—	—	1	3.57	—	—	—	—
3	(3.35)	5	(3.36)	—	—	—	—
2	(3.28)	5	(3.24)*	—	—	0.5	3.16
10	3.04	10	3.03	10	3.02	10	3.05
6	2.94	6	2.93	3	2.93	2	2.98
—	—	2	2.83	—	—	—	—
1	2.44	1	2.44	—	—	0.5	2.48
—	—	1	2.36*	—	—	0.5	2.40
1	(2.32)	2	(2.30)	—	—	—	—
2	2.22	4	2.23*	4	2.20	3	2.25
8	2.10	9	2.10	8	2.09	5	2.15
4	2.05	3	2.04	2	2.06	1	2.12
—	—	1	1.992	1	2.01	1	2.09
2	1.947	3	1.941	2	1.941	3	1.989
1	1.863	2	1.857	0.5	1.845	1	1.841
1	1.836	2	1.836	—	—	—	—
—	—	—	—	0.5	1.791	2	1.797
2	1.767	3	1.767	3	1.758	0.5	1.755
1	1.728	2	1.728	—	—	1	1.719
3	1.674	4	1.678	3	1.689	—	—
1	1.619	3	1.629	—	—	0.5	1.647
—	—	1	1.579	—	—	0.5	1.575
2	1.535	3	1.538	1	1.542	—	—
3	1.510	4	1.512	3	1.506	2	1.523
—	—	—	—	—	—	0.5	1.497
—	—	—	—	1	1.463	0.5	1.471
—	—	—	—	0.5	1.435	1	1.419
—	—	1	1.405	—	—	1	1.415
1	1.386	1	1.386	2	1.382	1	1.365
1	1.337	3	1.339	3	1.341	1	1.347
—	—	2	1.324	3	1.315	0.5	1.323
2	1.307	4	1.307	—	—	—	—
1	1.253	3	1.261	2	1.251	0.5	1.277
—	—	—	—	0.5	1.230	0.5	1.237
—	—	1	1.223	0.5	1.214	1	1.222
2	1.197	3	1.198	4	1.198	1	1.193
3	1.190	4	1.190	—	—	—	—
—	—	—	—	0.5	1.163	—	—
—	—	—	—	—	—	0.5	1.139
—	—	1	1.109	0.5	1.097	—	—
—	—	2	1.079	1	1.0836	0.5	1.087

Intensities by visual estimate. Calibrating substance: silicon. Camera RKD (2R 57.3 mm), 35 kV, 16 mA. Unfiltered Fe radiation. In brackets lines of β -radiation. *-d-values corresponding to those of native tellurium, viz.: 3.23(10), 2.36(4), and 2.23(3) (Berry and Thompson, 1962).

TABLE 3—(continued)

Kostovite, Chelopech, Bulgaria		Kostovite, Chelopech, Bulgaria		Calaverite, (Berry and Thompson, 1962)		Sylvanite, (Berry and Thompson, 1962)	
I	d Å	I	d Å	I	d Å	I	d Å
1	1.071	2	1.075	1	1.073		—
	—	1	1.050	2	1.051	0.5	1.052
	—	1	1.029	2	1.031	1	1.023
	—		—	2	1.005	0.5	1.002
	—		—	3	0.977		—
	—		—	2	0.952		—
	—		—	0.5	0.937		—
	—		—	0.5	0.922		—
	—		—	4	0.891		—
	—		—	1	0.860		—
	—		—	1	0.846		—
	—		—	1	0.821		—
	—		—	1	0.814		—
	—		—	1	0.810		—
	—		—	1	0.791		—
	—		—	1	0.777		—

ships among the other minerals, suggests that kostovite is one of the latest minerals to form.

CONCLUSIONS

The independence of kostovite as a mineral species is secured both by its chemical composition and x -ray data. In the literature at hand, there is no information for compounds in the system Au-Cu-Te, so that kostovite is perhaps not only a new mineral but also the first known compound

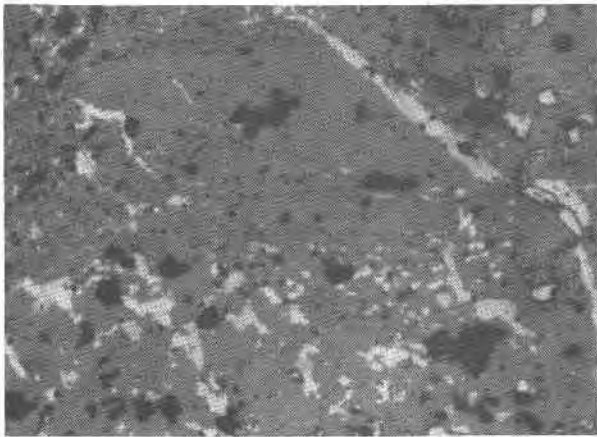


FIG. 5. Veinlets of kostovite and native tellurium in tennantite, without polars in air. $\times 200$.

in the mentioned ternary system. The mineral occurs unfortunately in very scant quantities and in grains unsuitable for more detailed structural and other investigations. Attempts for its synthesis should be made in the near future.

Samples of kostovite are kept in the mineralogical collections of the Geological Institute of the Bulgarian Academy of Sciences and at the University of Sofia, as well as in the Mineralogical Museum of the Academy of Sciences of the USSR and the Mineragraphic Laboratory of IGEM (Institute of Geology of the Ore Deposits, Petrography, Mineralogy and Geochemistry) in Moscow.

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REFERENCES

- BERRY, L. G. AND R. M. THOMPSON (1962) *X*-ray powder data for ore minerals. *Geol. Soc. Am. Mem.* **85**.
- GHENKIN, A. D. AND N. V. KOROLEV (1961) On methods for determination of small grains of minerals in ores. *Geol. Rudnikh Mestorozhdenii*, **5** (in Russian).
- HIEMSTRA, S. A. (1956) An easy method to obtain *x*-ray diffraction patterns of material. *Am. Mineral.* **41**, 519-521.
- SALES, R. H. AND C. MEYER (1949) Results from preliminary studies of vein formation at Butte, Montana. *Econ. Geol.*, **44**, 465-484.

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