

## Beshtauite, $(\text{NH}_4)_2(\text{UO}_2)(\text{SO}_4)_2 \cdot 2\text{H}_2\text{O}$ , a new mineral from Mount Beshtau, Northern Caucasus, Russia

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### ABSTRACT

A new mineral beshtauite,  $(\text{NH}_4)_2(\text{UO}_2)(\text{SO}_4)_2 \cdot 2\text{H}_2\text{O}$ , was found in the oxidation zone of the Beshtau uranium deposit, Mount Beshtau, Stavropol region, Northern Caucasus, Russia, and named after the locality. It is associated with rozenite, gypsum, lemontovite, and older marcasite, pyrite, halloysite, and opal. Beshtauite occurs as well-shaped short-prismatic crystals up to  $0.1 \times 0.15 \times 0.2$  mm, their clusters and crusts up to 0.5 mm across growing on marcasite. Beshtauite is transparent, light green. The luster is vitreous. The mineral fluoresces strongly yellow-green under both short- and long-wave UV irradiation. It is brittle. The Mohs hardness is ca. 2. Cleavage was not observed.  $D_{\text{calc}}$  is  $3.046 \text{ g/cm}^3$ . Beshtauite is optically biaxial (+),  $\alpha = 1.566(3)$ ,  $\beta = 1.566(3)$ ,  $\gamma = 1.592(3)$ ,  $2V_{\text{meas}} < 10^\circ$ . The chemical composition (wt%, electron microprobe data,  $\text{H}_2\text{O}$  by difference) is:  $(\text{NH}_4)_2\text{O}$  10.33,  $\text{UO}_3$  53.21,  $\text{SO}_3$  29.40,  $\text{H}_2\text{O}_{\text{calc}}$  7.06, total 100.00. Content of  $(\text{NH}_4)_2\text{O}$  was calculated from measured nitrogen content: 5.56 wt% N. The empirical formula, calculated on the basis of 12 O apfu, is  $(\text{NH}_4)_{2.12}\text{U}_{0.99}\text{S}_{1.96}\text{O}_{9.91}(\text{H}_2\text{O})_{2.09}$ . Beshtauite is monoclinic,  $P2_1/c$ ,  $a = 7.7360(8)$ ,  $b = 7.3712(5)$ ,  $c = 20.856(2) \text{ \AA}$ ,  $\beta = 102.123(8)^\circ$ ,  $V = 1162.76(19) \text{ \AA}^3$ ,  $Z = 4$  (from single-crystal X-ray diffraction data). The strongest reflections of the X-ray powder pattern [ $d$  ( $\text{Å}$ ),  $l(hkl)$ ] are: 6.86, 100(011, 10 $\bar{2}$ ); 5.997, 19(012); 5.558, 15(102); 5.307, 36(11 $\bar{1}$ , 110); 5.005, 35(013, 11 $\bar{2}$ ); 3.410, 38(114, 20 $\bar{4}$ , 10 $\bar{6}$ ); 3.081, 24(016); 2.881, 20(106, 123). The crystal structure was solved by direct methods and refined on the basis of 2677 independent reflections with  $I > 4\sigma(I)$  to  $R_1 = 0.093$ . The structure is based upon  $[\text{UO}_2(\text{SO}_4)_2(\text{H}_2\text{O})]^{2-}$  layers consisting of corner-sharing  $\text{UO}_6(\text{H}_2\text{O})$  pentagonal bipyramids and  $\text{SO}_4$  tetrahedra. The layers are coplanar to  $(\bar{1}02)$  and are linked via hydrogen bonding that involve interlayer  $\text{NH}_4^+$  ions and  $\text{H}_2\text{O}$  molecules. Beshtauite is important indicator mineral: its presence can be considered as an evidence of transportation of  $\text{U}^{6+}$  in nature in forms of mobile complexes of uranyl cation with ammonia or polyamines.

**Keywords:** Beshtauite, new mineral, ammonium uranyl sulfate, crystal structure, oxidation zone, Beshtau, Northern Caucasus