

# ON THE DISCOVERY OF ROOSEVELTITE, PREISINGERITE, TRÖEGERITE, AND ZEUNERITE IN Bi-As-Cu-U-MINERALIZATION FROM THE ORANZHEVOYE ORE FIELD, VERKHNE-KALGANINSKY MASSIF, MAGADAN REGION, RUSSIA

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New data on bismuth, arsenic, uranium and copper minerals (rooseveltite, preisingerite, zeunerite, and tröegerite) obtained with the help of an optical microscope and scanning electron microscope equipped with a Link detector are represented in the article. The minerals were established within Bi-As-Cu-U-mineralization at the Oranzhevoye ore field of the Verkhne-Kalganinsky massif in sulfide-quartz, arsenopyrite-quartz and sulfide-quartz-chlorite veinlets that intersect andesites. The following secondary minerals: scorodite, rooseveltite and preisingerite replace arsenopyrite, bismuthinite, tetradymite, and native bismuth. Uranium minerals – zeunerite and tröegerite – also associate with these minerals. Roosevelite and preisingerite are established in Russia for the first time. Character of occurrence of rooseveltite and preisingerite indicates that they formed during low-temperature metasomatic (hydrothermal) processes. The established association – arsenopyrite, pyrrhotite, chalkopyrite, and minerals of bismuth (bismuthinite and native bismuth, rooseveltite and preisingerite), tellurium (tetradymite), tin (stannite), gold and silver (tellurides, akantite, native silver) – allowed to attribute this mineralization to the gold-polyarsulfide-quartz formation.

6 figures, 2 tables, 16 references.

Keywords: rooseveltite, preisingerite, zeunerite, tröegerite, Verkhne-Kalganinsky massif, Oranzhevoye ore field, Bi-As-Cu-U-mineralization.

## Introduction

Oranzhevoye ore field of the Verkhne-Kalganinsky massif has received its name due to the bright colour anomaly connected with vast and intensive contact-metamorphic and metasomatic alterations of rocks composing it. According to the analytical researches, the area of the Oranzhevoye ore field is characterized by the sporadic increased contents of gold and silver. The increased contents of useful components are observed in formations of the following two types: 1) in arsenopyrite-sericite-scorodite-quartz nests in fault zones (size of nests vary from 0.1 up to 1 m) and in the veins of the "crust" shape with uplifted contents (according to the data by L.I. Rtishcheva – up to 58 ppm of gold and 2 kg/ton of silver; according to our data – up to 25 ppm of gold and 100 ppm of silver); 2) in separate arsenopyrite-muscovite-quartz veinlets (1–5 ppm of gold and silver). In addition, development of Bi-As-Cu-U-mineralization at this ore field occurs. Within this mineralization, several minerals have been established that earlier in Russia have not been recorded.

As the studying of polished sections with the help of an optical microscope and electron microscope equipped with a Link detector has

shown, arsenopyrite, chalkopyrite and pyrrhotite were the most widespread ore minerals. In addition, minerals of bismuth (bismuthinite and native bismuth, rooseveltite, preisingerite), tellurium (tetradymite), tin (stannite), gold (established only according to the gross chemical analysis of rocks) and silver (akantite and tellurides) are also established here. The association of minerals established allows to attribute the revealed mineralization to the gold-polyarsulfide-quartz (connected with intrusions) formation. Arsenopyrite, bismuthinite, tetradymite, and native bismuth are replaced by secondary minerals: scorodite, rooseveltite  $\text{BiAsO}_4$  and preisingerite  $\text{Bi}_3\text{O}(\text{OH})(\text{AsO}_4)_2$ . Tröegerite  $(\text{UO}_2)_3(\text{AsO}_4)_2 \cdot 12\text{H}_2\text{O} (?)$  and zeunerite  $\text{Cu}(\text{UO}_2)_2(\text{AsO}_4)_2 \cdot 12\text{H}_2\text{O}$  also occur in the same association (Soboleva, Pudovkina, 1957),  $\text{Cu}(\text{UO}_2)_2(\text{AsO}_4)_2 \cdot 10 - 16\text{H}_2\text{O}$  (Frondele, 1951). As for this ore field, these minerals are discovered for the first time. Roosevelite and preisingerite are established for the first time in Russia.

Rooseveltite is an isostructural mineral to monazite. Extremely fine size of this mineral does not allow to obtain X-ray diffraction pattern of the phase established by us. But we conditionally name it as rooseveltite, because of the fact that tetra-rooseveltite is much more rare phase in nature and from the greater degree of

probability of detection rooseveltite exactly, and also because of low-temperature genesis of this mineral. After 1946, rooseveltite was established in several deposits of the world with a complex Fe-Bi-Cu-Zn-Pb-Au-As-S-mineralization. As a rule, it was established in their hydrated zone. For the first time it was discovered in Bolivia at the Potosi deposit (Palache *et al.*, 1951), and then in Germany (Walenta, 1992; Roberts *et al.*, 2001). Rooseveltite was later described from the following several deposits: in Uzbekistan (Chatkal sky ridge, Nizhneaktashsky deposit) (Minerals of Uzbekistan, 1976), in Argentina (Bedlivy *et al.*, 1972; Minlka, 2002), Spain (Schnorrer, 2000), Greece (Sejkora, 1994; Sejkora *et al.*, 2006; Šrein *et al.*, 2008), Australia (Rankin *et al.*, 2002), Portugal and Great Britain. In the majority of the listed cases, as well as in the Oranzhevoye ore field, rooseveltite associates with preisingerite.

Troegerite and zeunerite were firstly described as secondary minerals of oxidation zones of the uranium and uranium-arsenate deposits in Germany in 1871 and 1872, respectively (Weisbach, 1871; Weisbach, 1872). Since then they have been discovered in numerous deposits of Europe (in Austria, Italy, France, Great Britain, Portugal, Spain, and Sweden), and also in Canada, USA, Argentina, Chile, Mexico, Japan, China, Iran, and Africa. Zeunerite and troegerite are also described in Russia (deposits Severnoye, Chukotka; Lastochka, Khabarovsk territory; Korolevskoye-Chasovoye, Transbaikalia) (Chernikov *et al.*, 1997). Zeunerite is a widespread mineral, and troegerite occurs rarely.

### Occurrences of rooseveltite, preisingerite, zeunerite and troegerite in the Oranzhevoye ore field

The most significant occurrences of rooseveltite and preisingerite are established in the sulphide-quartz and sulphide-quartz-chlorite veinlets intersecting andesites in the right board of the Oranzhevaya river, arsenopyrite-

quartz veinlets in the left board of the Obydennaya river, and in arsenopyrite-muscovite-quartz veinlet (3 cm in thickness) intersecting metamorphosed hornfels rock in the right board of the Chalym stream. The main sulphide mineral in these veinlets is partly fragmented and cataclased arsenopyrite. In the presented article we shall stop more in detail on the most characteristic occurrences of rooseveltite and preisingerite.

In the first case (Oranzhevaya river) rooseveltite is established in the arsenopyrite-quartz – chlorite veinlet with a breccia texture and a layered fabric. Detrital part is presented by large aggregates of arsenopyrite. Rooseveltite forms aggregates of thin-lamellar individuals or earthy accumulations of prismatic or isometric forms, dirty-grey coloured among the chlorite-quartz main part of the veinlet. Size of the aggregates reaches 0.1 – 0.2 mm. Radiating and thin branching veinlets of rooseveltite are characteristic for aggregates of rooseveltite in this sample (Fig. 1). The character rooseveltite aggregates – their spatial association to the cracks, radiating from its large accumulation thin veinlets, also located closer to thinner cracks – specifies its formation, probably, during late low-temperature (hydrothermal) metasomatic processes.

Rooseveltite is also established in the fragment of substantially arsenopyritic (with quartz) cataclased vein with a massive structure (Oranzhevaya river). Pyrrhotite and intergrowths of chalkopyrite and stannite are observed in the intergranular space of the cataclased and corroded aggregates of arsenopyrite and pyrite. Scorodite develops along the cracks in arsenopyrite grains. Feathering cracks are observed in the veinlet's exocontact. Along these cracks, chains of micron size drop-like sulphosalt are observed (precisely not identified). Rooseveltite develops mostly along bismuthinite (Fig. 2), sometimes along arsenopyrite and, as a rule, is in close intergrowth with preisingerite. In addition, branching microveinlets of these minerals (thickness – 0.0n mm) occur in quartz. Pyr-

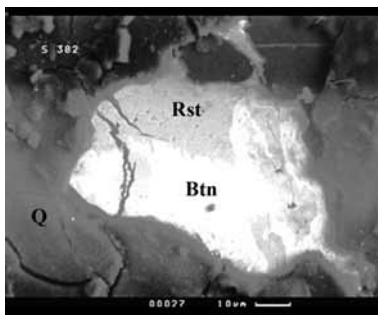
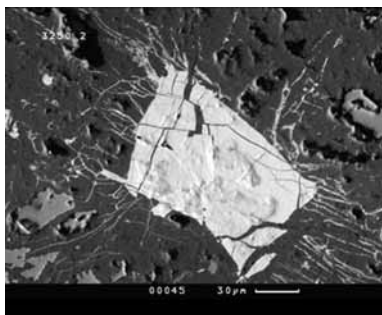


Fig. 1. Platy crystal of rooseveltite (white) among chlorite (dark grey) in association with scorodite (light grey). Oranzhevaya river (BSE).

Fig. 2. Rooseveltite (Rst) developing along bismuthinite (Btn) among quartz grains, Oranzhevaya river (BSE).

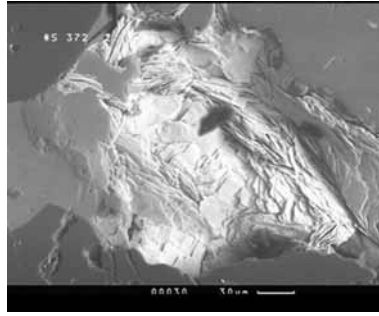
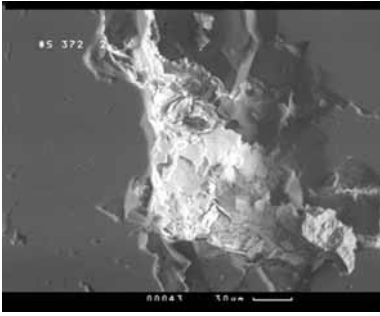


Fig. 3. Aggregate of platy crystals of zeunerite (white) in a cataclastic crack in quartz, Oranzhevaya river (BSE).

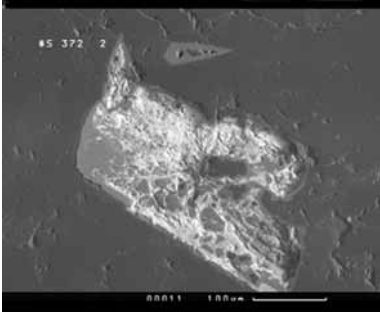


Fig. 4. Zeunerite (white) intergrowing with arsenopyrite (light grey) in a crack of a quartz grain (BSE).

Fig. 5. Zeunerite (white) developing along arsenopyrite (light grey) on a joint of quartz grains (BSE).

Fig. 6. Aggregate of troegerite platy crystals (white) in a crack of the quartz grain, Oranzhevaya river (BSE).

rhotite is replaced by marcasite-pyrite aggregate. The size of rooseveltite aggregates varies from the 0.0n up to 0.1–0.2 mm. According to the character of its aggregates and relationship with earlier minerals of arsenic and bismuth, rooseveltite and preisingerite are later minerals and, probably, the products of low-temperature metasomatic transformation of the specified minerals.

Tröegerite and zeunerite are established in the same sample. Zeunerite forms aggregates of fine thin-lamellar individs of yellowish colour in cracks of quartz grains or on their joint (Fig. 3–5). Length of individs does not exceed 30 microns (thickness of plates – from 0.0n up to 1–2 microns), size of aggregates – about 300–400 microns. As a rule, it is tightly associated with arsenopyrite or replaces it (Fig. 5). Tröegerite forms aggregates of lamellar individs similar in the morphology with zeunerite. Its aggregates are more finely and do not exceed 60–80 microns and are observed in the quartz grain cracks (Fig. 6). As well as rooseveltite and preisingerite, zeunerite and tröegerite are, probably, later-hydrothermal phases.

Rooseveltite develops on minerals of bismuth in quartz veinlets intersecting andesites that expose in the boards of the Chalyms river. Aggregates of bismuth minerals are associated to the cracks of cataclase in quartz. Intergrowths of tetradymite and native bismuth (about 0.3 mm in size) are established in this occurrence.

Rooseveltite is also established in the occurrence on the left board of the Obyden-naya river in area of a watershed with one of its small tributaries, in deluvium. The samples are represented by sericite-calcite-quartz nests (up to 5 cm in diameter) in fragments of quartz – arsenopyrite vein with a twisting-banded structure from the crumpling zone. The rock has a green shade of colour because of the replacement of arsenopyrite by scorodite. Rare relic impregnation of chalcopyrite, arsenopyrite, galenite, and ilmenite is observed. Rooseveltite and scorodite develop in cavities remaining from the earlier, completely leached, minerals. Fine aggregates of native silver occur in small cavities in galenite.

## Chemical composition

As a whole, the composition of rooseveltite and preisingerite is very close to the theoretical composition of these minerals (Table 1). It is interesting to note for rooseveltite established in the chlorite-arsenopyrite veinlet observed in the right board of the Oranzhevaya river, that it is characterized by an unusual to this mineral significant content of lead – from 3 up to 6% (Table 1, analyses 1–8). Substantial differences from the theoretical composition are not established for its other samples (Table 1).

Chemical compositions of tröegerite and zeunerite also practically do not differ from the theoretical formulas. Significant impurity of

Table 1. Chemical composition of rooseveltite and preisingerite from the Oranzhevoye ore field, wt. %

Mineral № an.	Rooseveltite Pb-containing								Properly rooseveltite					Preisingerite				
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
FeO	1.49	0.84	0.57	0.69	3.31	0.70	0.86	1.42	0.67	1.57	0.61	1.06	0.93	<b>0.00</b>	0.44	0.63	0.65	<b>0.00</b>
CuO	0.05	0.12	0.06	0.00	0.22	0.00	0.00	0.00	0.07	0.10	0.06	0.10	0.00	<b>0.00</b>	0.14	0.18	0.19	<b>0.00</b>
NiO	0.13	0.08	0.02	0.08	0.06	0.06	0.00	0.14	0.08	0.00	0.00	0.00	0.06	<b>0.00</b>	0.06	0.05	0.05	<b>0.00</b>
CoO	0.16	0.06	0.00	0.07	0.00	0.00	0.00	0.00	0.04	0.04	0.00	0.00	0.07	<b>0.00</b>	0.00	0.00	0.00	<b>0.00</b>
ZnO	0.22	0.30	0.10	0.09	0.08	0.00	0.06	0.00	0.00	0.00	0.00	0.00	0.00	<b>0.00</b>	0.00	0.28	0.28	<b>0.00</b>
SO <sub>3</sub>	1.81	1.09	0.57	0.75	1.01	0.72	0.57	0.67	0.54	0.61	0.88	0.61	0.82	<b>0.00</b>	0.00	0.26	0.00	<b>0.00</b>
As <sub>2</sub> O <sub>3</sub>	29.00	29.55	30.01	30.14	31.61	29.85	29.87	30.91	30.70	30.79	30.20	31.87	31.18	<b>33.03</b>	23.35	23.96	24.51	<b>24.51</b>
SeO <sub>3</sub>	0.45	0.39	0.51	0.00	0.84	0.30	0.64	0.47	0.00	0.04	0.00	0.00	0.17	<b>0.00</b>	0.37	0.26	0.46	<b>0.00</b>
TeO <sub>3</sub>	0.40	1.08	0.76	0.84	1.06	0.57	1.09	0.60	0.12	0.00	0.00	0.29	0.00	<b>0.00</b>	0.00	0.01	0.00	<b>0.00</b>
Sb <sub>2</sub> O <sub>3</sub>	0.21	0.56	0.53	0.20	0.48	0.02	0.43	0.19	0.31	0.26	0.17	0.40	0.15	<b>0.00</b>	0.00	0.00	0.00	<b>0.00</b>
Bi <sub>2</sub> O <sub>3</sub>	59.78	59.88	57.17	60.09	56.74	60.08	58.59	57.23	64.66	63.42	66.30	62.67	64.19	<b>66.97</b>	74.66	73.16	72.83	<b>74.53</b>
PbO	4.02	3.32	6.43	3.78	3.84	4.53	5.68	5.32	0.00	0.00	0.00	0.00	0.00	<b>0.00</b>	0.00	0.00	0.00	<b>0.00</b>
<b>Total</b>	<b>97.72</b>	<b>97.26</b>	<b>96.72</b>	<b>96.72</b>	<b>99.25</b>	<b>96.84</b>	<b>97.80</b>	<b>96.96</b>	<b>97.19</b>	<b>96.84</b>	<b>98.23</b>	<b>97.00</b>	<b>97.57</b>	<b>100.00</b>	<b>99.03</b>	<b>98.80</b>	<b>98.98</b>	<b>99.04</b>
Quantity of atoms in formula calculation onto the cation sum: 2 – for rooseveltite and 5 – for preisingerite)																		
Fe	0.07	0.04	0.03	0.03	0.15	0.03	0.04	0.07	0.03	0.08	0.03	0.05	0.04	<b>0.00</b>	0.06	0.08	0.08	<b>0.00</b>
Cu	0.00	0.01	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	<b>0.00</b>	0.02	0.02	0.02	<b>0.00</b>
Ni	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	<b>0.00</b>	0.01	0.01	0.01	<b>0.00</b>
Co	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	<b>0.00</b>	0.00	0.00	0.00	<b>0.00</b>
Zn	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	<b>0.00</b>	0.00	0.03	0.03	<b>0.00</b>
S	0.08	0.05	0.02	0.03	0.04	0.03	0.03	0.03	0.02	0.03	0.04	0.03	0.04	<b>0.00</b>	0.00	0.03	0.00	<b>0.00</b>
As	0.86	0.89	0.92	0.93	0.89	0.92	0.91	0.93	0.94	0.93	0.92	0.96	0.94	<b>1.00</b>	1.91	1.92	1.96	<b>2.00</b>
Se	0.01	0.01	0.01	0.00	0.02	0.01	0.02	0.01	0.00	0.00	0.00	0.00	0.00	<b>0.00</b>	0.03	0.02	0.03	<b>0.00</b>
Te	0.01	0.02	0.02	0.02	0.02	0.01	0.02	0.01	0.00	0.00	0.00	0.01	0.00	<b>0.00</b>	0.00	0.00	0.00	<b>0.00</b>
Sb	0.01	0.02	0.02	0.01	0.01	0.00	0.01	0.01	0.01	0.01	0.00	0.01	0.00	<b>0.00</b>	0.00	0.00	0.00	<b>0.00</b>
Bi	0.88	0.89	0.87	0.91	0.79	0.92	0.88	0.85	0.98	0.95	1.00	0.94	0.96	<b>1.00</b>	2.98	2.89	2.87	<b>3.00</b>
Pb	0.06	0.05	0.10	0.06	0.06	0.07	0.09	0.08	0.00	0.00	0.00	0.00	0.00	<b>0.00</b>	0.00	0.00	0.00	<b>0.00</b>

Note. Rather low total value of rooseveltite analyses due to the quality of its polishing and its association, in some cases, with cavities in arsenopyrite. The most characteristic chemical compositions of the minerals are chosen from the complete data base (properly rooseveltite – more than 20 analyses, Pb-containing rooseveltite – 15 analyses). Analysis 14 – theoretical composition of rooseveltite, analysis 18 – theoretical composition of preisingerite.

iron in zeunerite, probably, inherited from arsenopyrite (it occurs in cracks and intergrowth with this mineral) is its characteristic feature (Table 2).

## Conclusion

As a result of the researches carried out, the character of the complex Bi-As-U-mineralization belonging to the gold-polysulphide-quartz formation of the Oranzhevoye ore field is investigated. This mineralization is established in the indicator ore formations exposing on the earths surface and presumably bedding above the latent ore bodies as rather thin (0.2–2 m) metasomatic nests and veinlets intersecting intrusive rocks and hornfels. These formations are mainly composed of arsenopyrite-quartz-sericite mineralization. Chalcopyrite, pyrite and galenite, minerals of tellurium (tetradymite), bismuth (bismuthinite, native bismuth, rooseveltite, preisingerite), tin (stannite), silver (native silver, akanthite and tellurides of silver), uranium and uranium-copper arsenates

(tröegerite, zeunerite) are established as accessory minerals. Gold as independent mineral phase is not observed by us (it is traced only according to the chemical analysis). It is possible to characterize the mineralization of the investigated object as polystadial imposed mineralization of the mixed type – As-Ag-Au and Ag-Fe-Bi-As-Cu-U-sulphide.

Mineralogical studying of the Oranzhevoye ore field of the Verkhne-Kalganinsky massif has allowed – for the first time in Russia – to establish two low-temperature mineral of bismuth: rooseveltite and preisingerite. Both minerals are characterized by chemical composition close to the described in other deposits of the world (Bedlivy *et al.*, 1971, etc.). In addition, the variety of rooseveltite enriched in lead (Pb-containing rooseveltite from occurrences in the board of the Oranzhevaya river) was found. It is possible to consider polymorphic this feature of the Oranzhevoye ore field – a substantial impurity of lead (3–6.5 wt.%). Its nature, however, still demands additional investigation.

**Table 2. Chemical composition of zeunerite and tröegerite from the Oranzhevoye ore field, wt.%**

Mineral № an.	Tröegerite				Zeunerite		
	1	2	3	4	5	6	7
FeO	0.15	<b>0.00</b>	1.01	0.64	0.78	1.25	<b>0.00</b>
CuO	0.00	<b>0.00</b>	6.25	7.42	6.34	6.21	<b>7.49</b>
NiO	0.00	<b>0.00</b>	0.05	0.00	0.01	0.00	<b>0.00</b>
CoO	0.19	<b>0.00</b>	0.18	0.14	0.11	0.00	<b>0.00</b>
ZnO	0.04	<b>0.00</b>	0.00	0.00	0.00	0.00	<b>0.00</b>
SO <sub>3</sub>	0.32	<b>0.00</b>	0.09	0.05	0.00	0.04	<b>0.00</b>
As <sub>2</sub> O <sub>5</sub>	19.42	<b>17.63</b>	17.67	18.21	17.48	20.38	<b>21.65</b>
SeO <sub>3</sub>	0.42	<b>0.00</b>	0.58	1.18	0.00	0.00	<b>0.00</b>
TeO <sub>3</sub>	0.00	<b>0.00</b>	0.24	0.00	0.00	0.00	<b>0.00</b>
Sb <sub>2</sub> O <sub>3</sub>	0.07	<b>0.00</b>	0.49	0.44	0.82	0.30	<b>0.00</b>
Bi <sub>2</sub> O <sub>3</sub>	0.09	<b>0.00</b>	0.00	0.00	0.00	0.00	<b>0.00</b>
UO <sub>2</sub>	58.61	<b>65.81</b>	53.07	51.79	54.39	50.76	<b>50.87</b>
Total	79.30	<b>83.44</b>	79.64	79.87	79.93	78.95	<b>80.01</b>
Quantity of atoms in formula (calculation onto the sum of cations equal to 5)							
Fe	0.03	<b>0.00</b>	0.15	0.10	0.12	0.19	<b>0.00</b>
Cu	0.00	<b>0.00</b>	0.86	1.00	0.88	0.84	<b>1.00</b>
Ni	0.00	<b>0.00</b>	0.01	0.00	0.00	0.00	<b>0.00</b>
Co	0.03	<b>0.00</b>	0.03	0.02	0.02	0.00	<b>0.00</b>
Zn	0.01	<b>0.00</b>	0.00	0.00	0.00	0.00	<b>0.00</b>
S	0.05	<b>0.00</b>	0.01	0.01	0.00	0.01	<b>0.00</b>
As	2.12	<b>1.93</b>	1.68	1.69	1.68	1.91	<b>2.00</b>
Se	0.04	<b>0.00</b>	0.05	0.10	0.00	0.00	<b>0.00</b>
Te	0.00	<b>0.00</b>	0.02	0.00	0.00	0.00	<b>0.00</b>
Sb	0.01	<b>0.00</b>	0.04	0.04	0.07	0.03	<b>0.00</b>
Bi	0.00	<b>0.00</b>	0.00	0.00	0.00	0.00	<b>0.00</b>
U	2.72	<b>3.07</b>	2.15	2.05	2.23	2.03	<b>2.00</b>

Note. Analysis 2 – theoretical composition of tröegerite without H<sub>2</sub>O, analysis 7 – theoretical composition of zeunerite without H<sub>2</sub>O.

## References

- Bedlivy D., Llambiac E.J., Astarloa J.F.H. Rooseveltit von San Francisco de los Andes und Cerro Negro de la Aguadita, San Juan, Argentinien // *Tschermaks Mineralogische und Petrographische*. **1972**. Bd. 17. S. 65–75 (in Spanish).
- Chernikov A.A., Pekov I.V., Minina E.L. To the history of studying of uranium minerals by domestic researchers // *Zapiski VMO*. **1997**. Vol. 4. P. 111–128 (in Russian).
- Fron del J.W. Studies of uranium minerals (VII): Zeunerite // *Amer. Min.* **1951**. Vol. 36. N. 3–4. P. 249–256.
- Minerals of Uzbekistan. \ Ed.: S.T. Badalov. Vol. III. Tashkent: "Fan" UzSSR. **1976**. 374 p. (in Russian).
- Minlka K. de Brodtkorb. Las Especies Minerales de la Republica Argentina. Vol. 1. Elementes, sulphides and sulphosalts. **2002**. 385 s. (in Spanish).
- Palache C., Berman H., & Frondel C. The system of mineralogy of James Dwight Dana and Edward Salisbury Dana, Yale University 1837–1892. **1951**. Vol. II. 697 p.
- Rankin J., Lawrence L., Sharpe J.L., Williams P. Rare secondary bismuth, tungsten and molybdenum minerals from Elsmore. New England district of new South Wales // *Austral. J. Minerals*. **2002**. Vol. 8. P. 55–60.
- Roberts A.C., Burns P.C., Gault R.A., et al. Paganoite, NiBi<sup>3+</sup>As<sup>5+</sup>O<sub>5</sub>, a new mineral from Johanngeorgenstadt, Saxony, Germany: Description and crystal structure // *European Journal of Mineralogy*. **2001**. Vol. 13. P. 167–175.
- Schnorrer G. Die Minerale der ehemaligen Grube Espuela de San Miguel bei Villanueva de Cordoba, Prov. // *Cordoba in Spanien. Der Aufschluss*. **2000**. Vol. 51. S. 211–222 (in German).
- Sejkora J. Minerály ložiska Moldava v Krušných horách // *Bulletin Mineralogicko-petrografického oddělení Národního muzea v Praze*. **1994**. roc. 2. P. 110–116 (in Czech language).
- Sejkora J., Ondruš P., Fikar M., Veselovsky F., Mach Z., Gabašová A., Skoda R., Beran P. Supergene minerals at the Huber stock and Schnöd stock deposits, Krásno ore District, the Slavkovsky les area, Czech Republic // *Journal of the Czech Geological Society*. **2006**. Vol. 51. P. 57–101 (in Czech language).
- Soboleva M.V., Pudovkina I.A. Uranium minerals. Handbook. Moscow.: GNTI. **1957**. 408 p. (in Russian).
- Šrein V. Zlatonosná mineralizace v okolí Horské Kvildy na Šumavě, Česká republika // *Bulletin mineralogicko-petrografického oddělení Národního muzea v Praze*. **2008**. Vol. 16. 2. P. 153–176 (in Czech language).
- Walenta K. Die Mineralien des Schwarzwaldes. Munchen: Chr.Weise Verlag, **1992**. 336 s. (in German).
- Weisbach A. Vorläufige Mittheilung [Über Tröegerit und Walpurgin] // *Neues Jahrbuch für Mineralogie, Geologie und Paläontologie*. **1871**. Bd. 24. S. 869–870 (in German).
- Weisbach A. Mittheilungen an Professor H.B. Geinitz, Freiberg 9. Februar // *Neues Jahrbuch für Mineralogie*. **1872**. Bd. 9. S. 206–208 (in German).