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PABSTITE FROM THE DARA-i-PIOZ MORAINE (TADJIKISTAN)

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Pabstite was discovered in the moraine of the Dara-i-Pioz glacier (Garmsky district, Tadjikistan) in a leucocratic rock mainly composed of microcline, quartz, and albite. Subordinated minerals are aegirine, titanite, astrophyllite, bafertisite, galena, sphalerite, ilmenite, pyrochlore, fluorite, zircon, fluorapatite, and calcite. Pabstite forms grains and well-faced crystals (0.1-0.5 mm), growing on quartz crystals in small cavities abundant in the rock. Its composition is close to the final member $BaSnSi_3O_9$ in the series pabstite-benitoite. Microprobe analysis has shown: SiO_2 — 37.43; TiO_2 — 0.19; ZrO_2 — 0.16; SnO_2 — 30.05; BaO — 32.41; total 100.24. The empirical formula is $Ba_{1.02}(Sn_{0.96}Ti_{0.01}Zr_{0.01})_{0.98}Si_{3.01}O_9$. Refraction parameters of pabstite are n_o = 1.668(2); n_e = 1.657(2), which is much lower than cited figures for pabstite from the type locality. Strong dependence of pabstite optical properties on titanium contents is shown. The find of pabstite at Dara-i-Pioze is the first find of pabstite in alkaline rocks and, apparently, the second find of this mineral in the world.
2 tables, 3 figures and 13 references.

Pabstite $BaSnSi_3O_9$, the tin analogue of benitoite, was described as a new mineral from Santa Cruz (California, USA), where it was met in cracks of silicified limestones in association with quartz, calcite, tremolite, witherite, phlogopite, diopside, forsterite, taramellite, cassiterite, franckeite, stannite, sphalerite, and galena (Gross *et al.*, 1965). A separate publication (Dunning, Cooper, 1986) is devoted to the mineralogy of the Santa Cruz Quarry. Pabstite was discovered by the author of this paper in a quite different geological setting — in rocks of the Dara-i-Pioz alkaline complex — at laboratory studying of field collections of 1995, which have been made together with A.A.Agakhanov, V.Yu.Karpenko and P.V.Khvorov. Other references to pabstite finds are absent in the accessible literature. Other samples of pabstite, except for those from California, are also absent in the largest mineralogical collections of our country — the Fersman Mineralogical Museum of the Russian Academy of Science and Vernadsky State Geological Museum of the Russian Academy of Science. Apparently, the Santa Cruz Quarry in California was the unique place of finds of this rare mineral until recently.

Occurrence and Mineral Association

Pabstite was discovered in moraine material of the Dara-i-Pioz glacier located within the Upper Dara-i-Pioz alkaline massif (Garmsky district, Tadjikistan). The massif is located near the water-divide in the southern slope of the Alai Range, has a close to ring structure and is composed of biotite and tourmaline granites, aegirine syenites and foyaites. The first data on the massif were received at works of Tadjik-Pamirs expedition of 1932—1936. The Dara-i-Pioz massif mineralogy is covered in a number of publications (Dusmatov, 1968; Dusmatov, 1971; Dusmatov, 1993; Semenov, 1975; Belakovsky, 1991, etc.). Most typical feature of the Dara-i-Pioz massif is an unusual for alkaline massifs enrichment with boron and lithium (Dusmatov *et al.*, 1972) and «dryness» — absence or scarcity of minerals containing water or hydroxils. Mineralogically, this is manifested in the development of boron analogue of albite — reedmergnerite — and availability of numerous rare boron silicates (leucosphenite, stillwellite-(Ce), tienshanite, tajikite, calcibeborosilite-(Y), hyalotekite, etc.), wide distribution of lithium minerals (polylithionite, tainiolite, sogdianite, sugilite, neptunite, etc.). Other elements typical to Dara-i-Pioz and forming own minerals include rare earth elements and yttrium (stillwellite-(Ce), minerals of the tajikite group, kapitsaite-(Y), nordite-(Ce), monazite-(Ce), etc.), beryllium (leucophanite, epididymite, barylite, calcibeborosilite-(Y), hyalotekite, moskvinite, etc.), zirconium (sogdianite, zektzerite, bazirite, zircon, minerals of the eudialite group, etc.), niobium and tantalum (minerals of the pyrochlore group, baotite), thorium and uranium (thorite, turkestanite, uraninite), cesium (cesium-kupletskite, telyushenkoite) and tin [though only one tin mineral was met till now — this is pabstite, increased tin contents were earlier reported in titanite (Reguir *et al.*, 1998; Reguir *et al.*, 1999) and sogdianite (Pautov *et al.*, 2000) from this massif].

From the crystallochemical point of view, a remarkable feature of the Dara-i-Pioz massif is large presence and variety of ring silicates. Minerals of the eudialite group with nine-member rings of oxygen-silica tetrahedrons occur in microcline-reedmergnerite pegmatites and in very original quartz-titanite-aegirine vein rocks. Silicates with six-member rings are represented by minerals of the tourmaline group; the axinite structural type is represented by ferroaxinite, extremely rare at Dara-i-Pioz. Silicates with dual six-member silica-oxygen rings of the milarite group are most various, many of them were first described from this massif – these are first of all sogdianite, which is a rock-forming mineral in some veined rocks, sugilite, darapiozite, dusmatovite, shibkovite, berezanskite. A representative of minerals with four-member silica-oxygen rings at Dara-i-Pioz is baotite, a silicate with dual four-member rings is turkestanite. The benitoite structural type (silicates with three-member silica-oxygen rings) is represented by bazirite and now has supplemented by pabstite. At last, quite recently a mineral with dual three-member rings (a new structural type) was discovered at Dara-i-Pioz – moskvinite.

Pabstite was discovered in medium-coarse grained inequigranular leucocratic rock, mainly composed of microcline, quartz, and albite. Subordinated minerals are aegirine, titanite, astrophyllite and bafertisite forming separate accumulations and lenses, that gives rock spotty, here and there banded texture. Accessory minerals are galena, sphalerite, ilmenite, pyrochlore, fluorite, zircon, fluorapatite, and calcite. The rock bears traces of plastic and fragile deformations expressed in bending of scaly astrophyllite and bafertisite grains, broken grains of microcline, lamellar calcite twins. Small (0.3 – 1 cm) cavities, encrusted with long-columnar transparent and colorless quartz crystals (1 to 5 mm long) with growing on them white spherical aggregates and short prismatic crystals of zircon and rarely single well formed fine crystals of pabstite, are rather abundant in the rock (Fig. 1). Pabstite as irregular grains also occurs and in albite-titanite-quartz-zircon aggregates (Fig. 2), disposed in immediately proximity to above cavities.

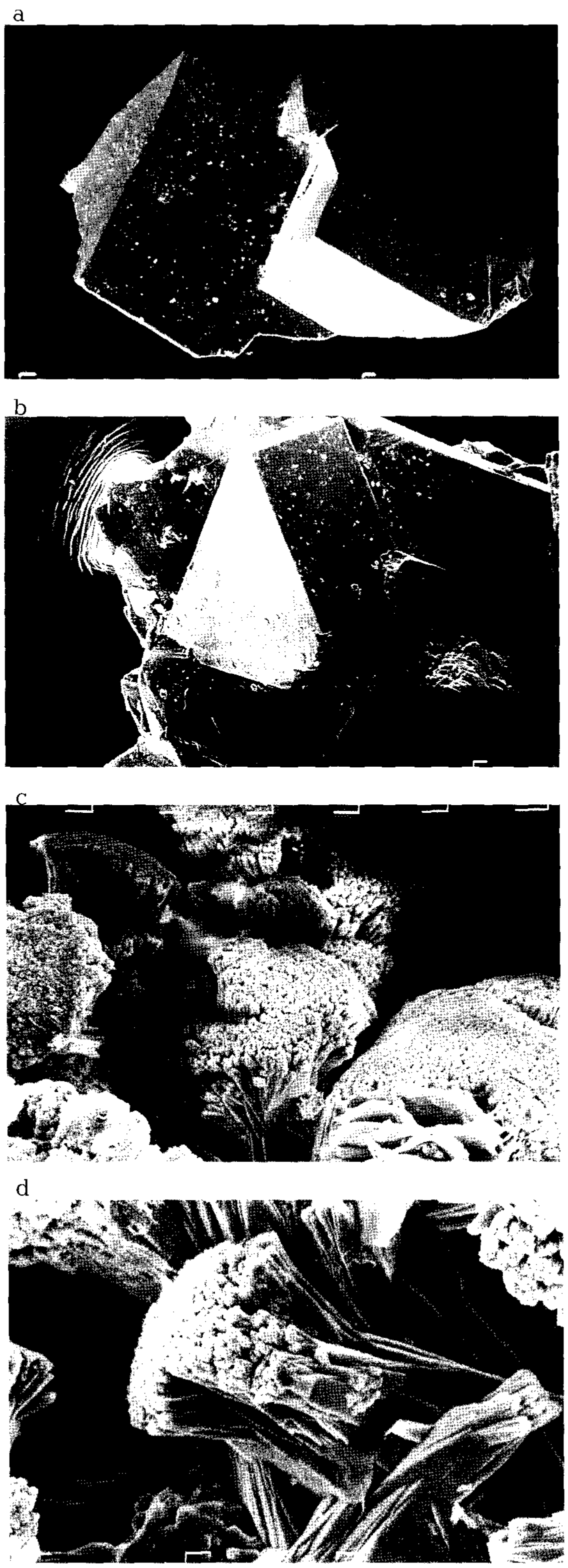

***Fig. 1** a – fragment of pabstite crystal aggregate. In the upper part of image one can see a zircon crystal, x300; b – short prismatic pabstite crystal on quartz, x500; c, d – aggregates of split crystals of zircon from a cavity with pabstite, c – x200, d – x1000. REM-photos*

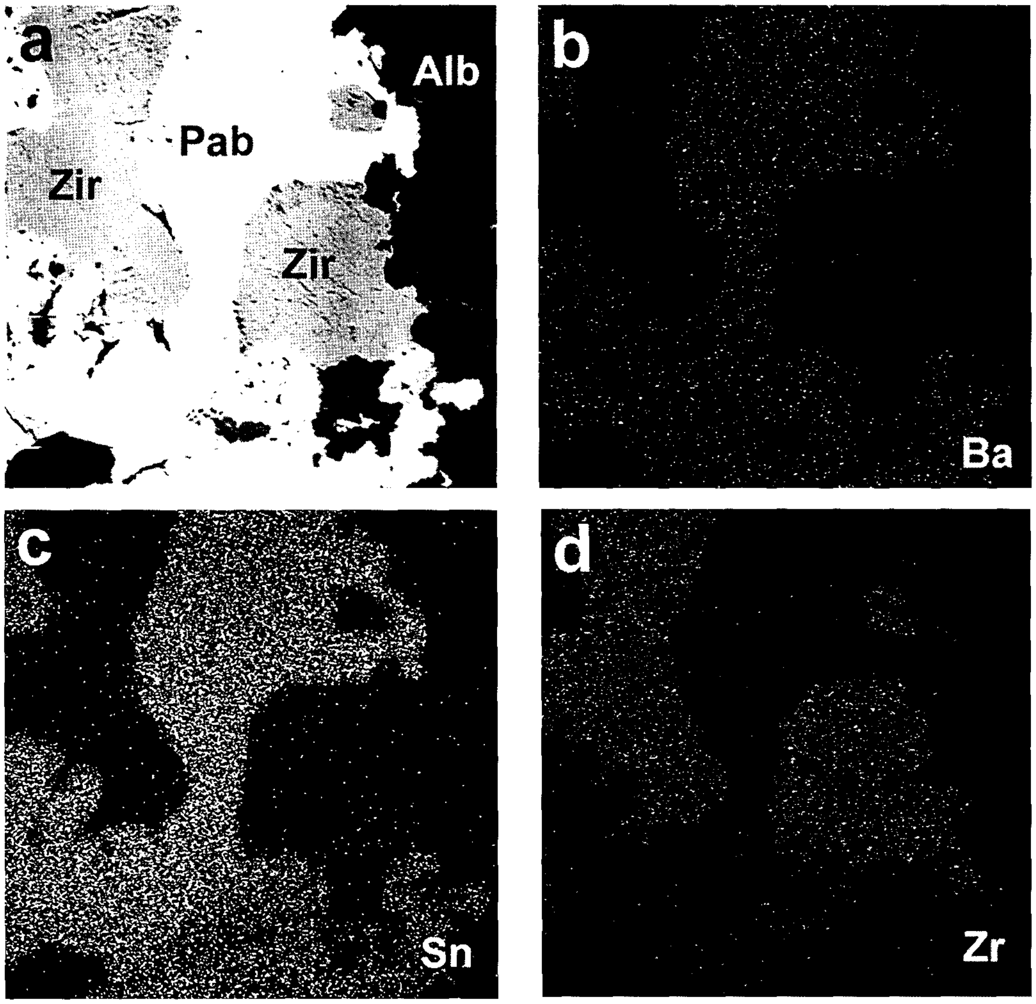

Fig. 2. *An intergrowth of pabstite (Pab) with zircon (Zir) and albite (Alb.) a – COMPO regime; b, c, d – characteristic X-ray radiation of specified elements. Width of the field of vision is 600 microns.*

Physical Properties and Optical Characteristics

Pabstite grains have white color and slightly greasy luster. Cleavage is absent. Mohs hardness is about 6. Crystals of pabstite (0.1 – 0.5 mm) are colorless and transparent, their morphology is well visible in Fig. 1. In shortwave UV light, the mineral shows weak bluish fluorescence. Pabstite is optically uniaxial, negative. The refraction parameters measured on rotating needle are n_o = 1.668(2); n_e = 1.657(2), that is much below the values for pabstite from the type locality. Refraction parameters of pabstite from California on the data of Gross *et al.*, 1965 are n_o = 1.685; n_e = 1.674. Such essential distinctions in optical characteristics are explained by features of chemical composition of the mineral: pabstite from Santa Cruz considerably more enriched with titanium (TiO_2 – 3.8 wt.%) than mineral from Dara-i-Pioz (TiO_2 — 0.08 – 0.42 wt. %) and this has caused its higher refraction parameters. Empirical dependence of refraction parameters on composition in the series pabstite-benitoite is shown in Fig. 3. The deviation from the direct dependence in the field near the final member $BaSnSi_3O_9$ is probably caused by the contribution of small admixture of zirconium into the increase of refraction parameters of pabstite from Dara-i-Pioz.

Table 1. **X-ray powder pattern data for pabstite**

Pabstite, Dara-i-Pioz		Synthetic pabstite, JCPDS 43-0633		
d	I	d	I	hkl
5.81	60	5.83	37	100
4.93	33	4.923	12	002
3.76	100	3.7625	95	102
3.36	90	3.3672	30	110
3.21	10	3.1842	9	111
2.92	28	2.9156	17	200
2.78	53	2.7793	100	112
2.52	5	2.5093	5	202
2.46	20	2.4633	10	004
2.34	3	2.3511	1	113
2.27	2	2.2692	2	104
2.21	5	2.2043	12	210
2.153	3	2.1509	4	211
		2.0117	6	212
1.983	11	1.9880	23	114
		1.9439	14	300
1.887	6	1.8818	13	204
		1.8302	1	213
1.810	8	1.8082	17	302
		1.6832	5	220
1.647	8	1.6421	12	006
1.614	2	1.6172	2	310
1.595	4	1.5928	10	222
		1.5804	4	106
1.541	3	1.5366	8	312
		1.5259	8	304
1.476	5	1.4758	10	116

Table 2. **Chemical composition of pabstite**

Oxide	Dara-i-Pioz, Tadjikistan 1	Santa Cruz, California 2	Theoretical composition 3
SiO_2	37.43	37.7	37.22
TiO_2	0.19	3.8	
ZrO_2	0.16	–	
SnO_2	30.05	24.4	31.12
BaO	32.41	33.2	31.66
Total	100.24	99.1	100.00

Note: *1 — mean of 3 microprobe analyses. Analyst — L.A. Pautov. The empirical formula at calculation for 9 oxygen atoms is* $Ba_{1.02}(Sn_{0.96}Ti_{0.01}Zr_{0.01})_{0.98}Si_{3.01}O_9$*; 2 — microprobe analysis.* $Ba_{1.03}(Sn_{0.77}Ti_{0.23})_{1.00}Si_{2.99}O_9$ *(Gross et al., 1965); 3 —* $BaSnSi_3O_9$

X-ray Data

The pabstite from Dara-i-Pioz was studied by the powder X-ray method on diffractometer DRON-2. Fe-radiation and graphite monochromator were used. Scanning speed of the counter was 1 degree/minute. Quality of received powder pattern could be considered satisfactory, which is caused by small quantity of mineral. Results of X-ray powder pattern calculation in Table 1 show affinity of the investigated mineral to $BaSnSi_3O_9$. It should be noted that the mineral is inconvenient for photographic study because of strong fluorescence under X-rays.

Chemical Composition

The Dara-i-Pioz pabstite chemical composition was studied using X-ray microanalyzer JCXA-50A equipped with energy dispersion spectrometer Link-U and three wave spectrometers. The quantitative analysis was carried out using wave spectrometers at accelerating voltage U = 20 kV, probe current 20 nA and beam diameter 2 microns. Reference samples were benitoite USNM 86539 for Ba, Ti, Si; synthetic SnO_2 – for Sn; synthetic ZrO_2 – on Zr. Calculation of concentrations was made using the ZAF-correction method in the «PUMA» program. Table 2 gives the results of analyses. As noted above, the pabstite from Dara-i-Pioz is closer to the final member $BaSnSi_3O_9$ than the mineral from the first description place. In addition, an insignificant admixture of zirconium is characteristic of the described pabstite.

Conclusions

Pabstite was discovered in a quite different geological setting, than at the reference site. It is the first find of pabstite in alkaline rocks and probably the second find of this mineral in the world. Pabstite is the first actually tin mineral at Dara-i-Pioz.

The Dara-i-Pioz pabstite has the composition close to final member $BaSnSi_3O_9$ in the

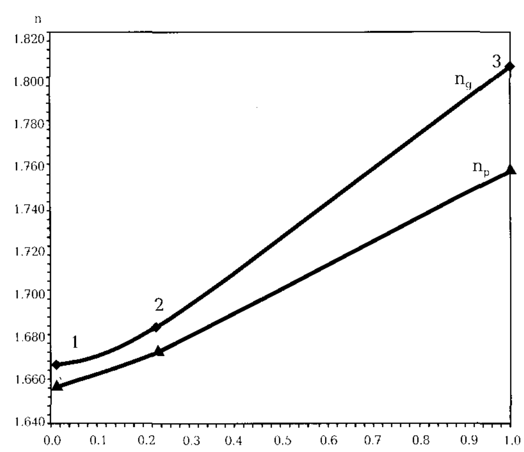

Fig. 3. *Dependence of refraction parameters in pabstite-benitoite series on composition (Ti). 1 — pabstite from Dara-i-Pioz, 2 – pabstite from Santa Cruz (Gross et al., 1965); 3 –* $BaTiSi_3O_9$.

series pabstite-benitoite. The zirconium admixture in Dara-i-Pioz pabstite probably indicates the existence of isomorph system pabstite-benitoite-bazirite.

A strong dependence of pabstite optical properties on the titanium content is shown, the fact to be considered at optical diagnostics of the mineral (pabstite refraction parameters cited in the majority of mineralogical directories refer to the mineral from California and are much higher, than refraction parameters of low-titanium pabstite).

The data on hydrothermal synthesis of $BaSnSi_3O_9$ and $CaSnSi_3O_9$ (Gross *et al.*, 1965; Nekrasov, 1973; Nekrasov, 1976) and mineral associations allow to assume that pabstite crystallization at Dara-i-Pioze occurred at final phases of albitization from alkaline solutions rich in silica and relatively poor in tin at temperature above 300°C. A probable source of Sn^{4+} is tin liberated from Sn-containing sogdianite at its replacement in the phase of its albitization by zektzerite.

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