NEW DATA ON THE ACCESSORY MINERALS OF THE SEMENINSKAYA PIT OF THE ADUY PEGMATITE FIELD (URALS)

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Composition and forms of separations of two specimens of "euxenite" from the collections of A.E. Fersman (from the funds of the Fersman Mineralogical Museum, RAS) found to be samarskite-(Y) as well as new findings of samarskite-(Y), ferro- and manganocolumbite, monazite-(Ce), gahnite and spessartine from quartz-albite aggregates of chamber granitic pegmatite from the Semeninskaya pit have been investigated. Samarskite grains are partly replaced by fersmite, and in zones of alteration contain silica (probably opal).
2 tables, 5 figures, 7 references.
Keywords: granitic pegmatites, former collections, composition of accessory minerals, rare earths, evolution of composition.

Among the other mines of the Central Aduy pegmatite field on the territory of the modern Rezhevsky state nature-mineralogical reserve Semeninskaya pit is famous by its history of foundation (probably in the second half of the XIX century), survey and taking of aquamarine, heliodor, smoky quartz and amethyst. It was colorfully described in several publications (Fersman, 1962; Emlin *et al.*, 2002; Malikov *et al.*, 2007, etc.).

Vein of granitic pegmatite striking in 30 – 50° of NE direction and stretching during 125 m with a 8 – 12 m thickness (up to 0.5 – 1 m in its thinning part) is traced up to the depth of 39 m by two shafts (Fig. 1) and during 80 m down the dip by boreholes of exploration drilling. Granitic graphic pegmatite of the vein is distinguished by relatively thick inner zone (up to 1 – 4 m) of coarse-grained albite with muscovite, microcline, quartz, and accessory minerals.

After their attendance of the mine in 1912 – 1913 A.E. Fersman and B.A. Lindener passed several specimens with "euxenite" to the Mineralogical Museum of the Russian Academy of Sciences. In the same time the owner of the mine M. Belykh at the instance of A.E. Fersman organized the revision of the mine dumps (Malikov *et al.*, 2007) in order to search for accessory minerals. Alongside with berill, A.E. Fersman noted magnetite, spessartine, euxenite, and monazite in the vein. According to the results of the geological-exploration works of the Isetsky geological-exploration party in 1977 – 1980, accessory minerals rarely occurred in the graphic quartz-two-feldspar zone of the vein, but more frequent (and in more large separations) they were found in boundary part between the block two-feldspar zone and zone of coarse-grained albite as well as in cavities within the albitic zone (according to the data of M.B. Arinshtein; see Emlin *et al.*, 2002). We have not found publications concerning the composition of these minerals except our data about monazite (Popova *et al.*, 2007). We have also found ferro- and manganocolumbite, samarskite-(Y), gahnite, and fluorapatite in aggregates with albite and quartz in the mine dumps. Below we give the results of investigation of some minerals (also including "euxenite" of the specimens № 21934 and № 21935 from the funds of the Fersman Mineralogical Museum (FMM). Unfortunately, we could not affirm the presence of this mineral. Separations of "euxenite" proved to be samarskite-(Y). Macrodiagnostics of these minerals is not so simple; samarskite in spalls is frequently similar with euxenite and polycrase seemingly.

Samarskite-(Y) from the specimens of FMM occurs as brown-black and black-brown grains up to 1 sm in size forming ingrowths in albite with specific reddening around them (Fig. 2a). The grain from the specimen № 21934 is brown-black and contains ingrowths of albite and microinclusions of monazite-(Ce) near its margin. Composition of samarskite-(Y) mostly consists of Nb, Fe, Y, sum of *TR* equals to 10.54 wt.%. It also contains few Ti that differ it from euxenite and reveal its similarity with samarskite-(Y). Its empirical formula is well calculated to typical formulas ABO_4 (Table 1, analysis 1): $(Fe_{0.38}Y_{0.28}REE_{0.16}U_{0.12}Th_{0.02})_{0.96}(Nb_{0.85}Ti_{0.10}Ta_{0.09})_{1.04}O_{3.87}$.

Some deficit of oxygen appears to be due to partial hydrous alteration of metamict mineral. Samarskite is partially altered. Debye powder pattern of the grain calcined up to 1000°C contains the following main lines (*d/n*, Å; *I*): 3.99 (9); 3.16 (10); 3.01 (9); 2.48 (9); 1.883 (8); 1.825 (9); 1.561 (7) (analyst E.D. Zenovich; analysed at: URS-2.0, RKD-57.3 mm, Fe-anode). These lines are most close to X-ray pattern of the altered

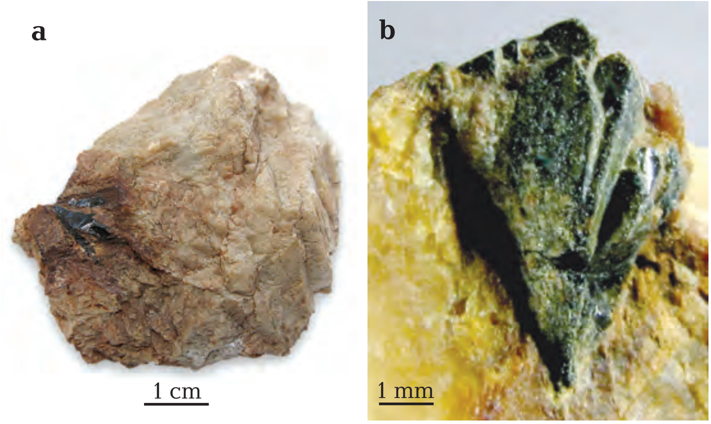


Fig. 1. Headframe of the shaft on the Semeninskaya vein, 2009. (Photo by O.L. Buslovskaya).

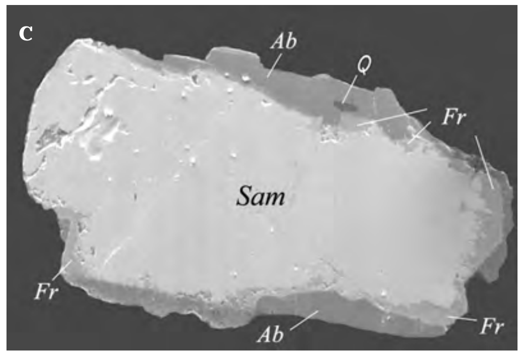


Fig. 2. Samarskite-(Y) in albite (a) and albite-quartz aggregate (b, c). a — specimen № 21934 from FMM (photo by V.Y. Karpenko); b, c — specimen Г1 (b — photo by V.A. Gubin; c — photo by V.A. Kotlyarov; BSE image. Sam — samarskite-(Y), Fr — fersmite (predominating among the products of alteration), Ab — albite, Q — quartz.

Table 1. **Composition of samarskite and pseudomorphs upon it in the Semeninskaya pit from the Aduy**

№ an.	1		2		3		4	5
	wt.%	apfu	wt.%	apfu	wt.%	apfu	wt.%	apfu
TiO_2	2.81	0.10	3.88	0.14	3.20	0.11	9.50	7.94
FeO	9.80	0.38	8.34	0.33	8.55	0.34	7.10	5.83
MnO	–	–	–	–	–	–	0.17	1.41
CaO	–	–	–	–	–	–	4.92	4.71
Nb_2O_5	40.55	0.85	39.64	0.85	38.60	0.82	38.07	47.40
Ta_2O_5	6.94	0.09	8.28	0.11	7.39	0.09	21.15	12.85
Y_2O_3	11.40	0.28	11.24	0.28	11.92	0.30	–	1.46
Ce_2O_3	–	–	–	–	–	–	1.45	0.85
Nd_2O_3	0.88	0.01	1.15	0.02	0.88	0.01	0.72	0.56
Sm_2O_3	1.33	0.02	1.25	0.02	1.49	0.02	–	0.17
Eu_2O_3	0.78	0.01	0.81	0.01	0.79	0.01	–	–
Gd_2O_3	2.68	0.04	2.70	0.04	2.61	0.04	–	0.10
Dy_2O_3	2.25	0.04	2.56	0.04	2.19	0.03	–	–
Tb_2O_3	0.61	0.01	0.83	0.01	0.50	0.01	–	–
Yb_2O_3	2.01	0.03	2.17	0.03	1.80	0.03	–	–
ThO_2	2.12	0.02	2.17	0.02	1.95	0.02	7.70	5.57
UO_2	11.58	0.12	8.76	0.09	14.45	0.15	2.50	2.90
Total	95.84	2.00	93.78	2.00	96.32	2.00	93.28	91.75
	TR = 10.54	O = 3.87	*TR* = 11.47	O = 3.92	*TR* = 10.26	O = 3.89	*TR* = 2.17	*TR* = 1.68
n	4		3		6		5	2

Note: Analyses 1–3 –samarskite-(Y): 1 — specimen № 21934 FMM, 2 — specimen № 21935 FMM, 3 — specimen Г1; analyses 4, 5 — fersmite pseudomorph replacing samarskite-(Y), specimen Г1. Average concentrations are shown (n — number of analyses) according to the data of microprobe analysis (REMMA-202M with energy-dispersion spectrometer Link LZ-5, analyst V.A. Kotlyarov; JXA-733 with wave-dispersion spectrometers, analyst E.I. Churin).

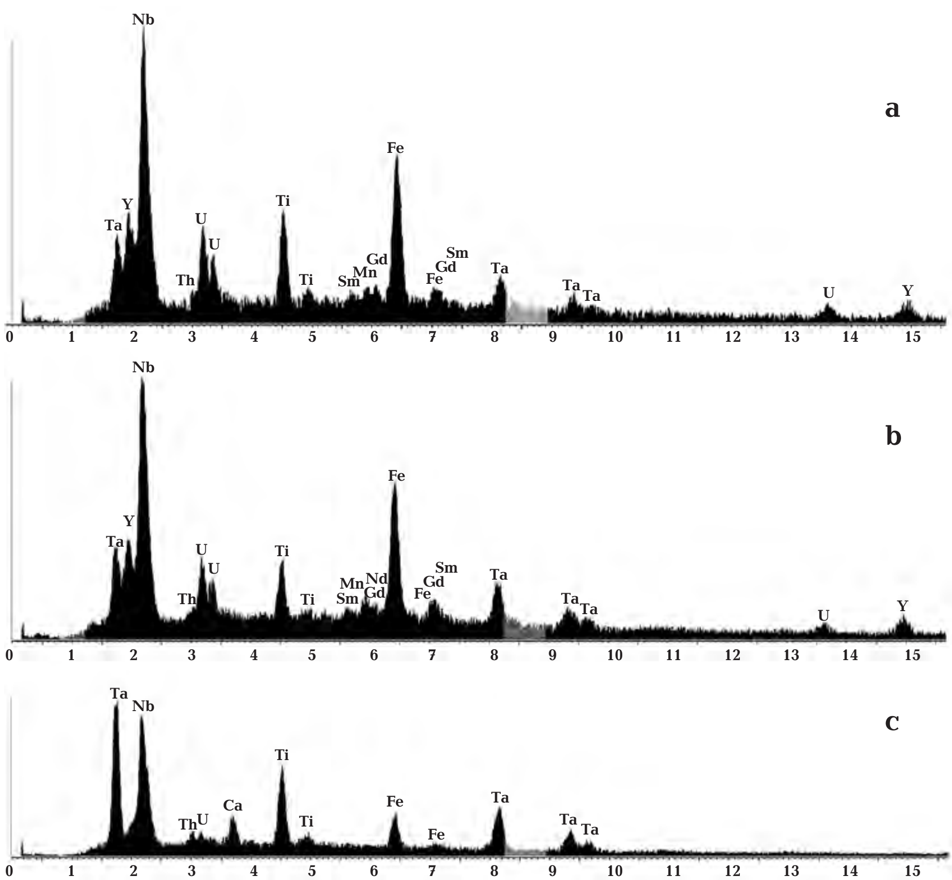
Table 2. **Composition of monazite-(Ce) from the Semeninskaya pit (wt.%)**

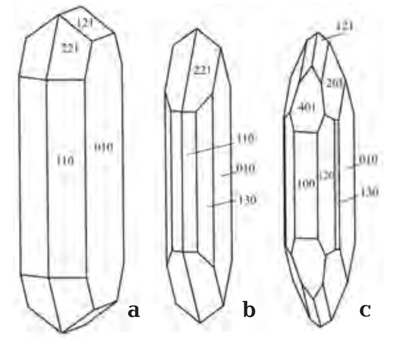
№ an.	Grain	Site	SiO_2	P_2O_5	CaO	La_2O_3	Ce_2O_3	Pr_2O_3	Nd_2O_3	Sm_2O_3	Gd_2O_3	ThO_2	UO_2	Total
1	1	center	–	27.97	–	3.67	21.28	3.79	17.07	17.20	6.03	2.07	–	99.08
2		center	0.11	27.79	0.05	2.85	20.14	5.68	16.16	16.56	7.90	2.48	0.20	99.91
3		margin	–	27.99	–	3.54	20.54	3.39	16.80	18.19	6.66	2.12	–	99.23
4		margin	0.34	27.57	–	2.86	20.36	5.83	16.22	16.25	7.18	2.66	0.34	99.59
5	2	center	1.31	26.59	0.16	5.81	28.39	4.24	16.55	6.70	1.85	5.87	1.28	99.17
6		center	2.17	25.51	0.08	5.59	29.42	6.37	16.97	7.00	–	6.91	–	100.02
7		margin	1.62	26.72.	0.11	5.38	28.47	6.02	17.31	7.36	–	6.55	–	99.54

№ an.	Site	Empirical formulas (based on 2 cations)
1	center	$(Ce_{0.32}Nd_{0.25}Sm_{0.24}Gd_{0.08}La_{0.06}Pr_{0.06}Th_{0.02})_{1.03}P_{0.97}O_{3.98}$
3	margin	$(Ce_{0.31}Nd_{0.25}Sm_{0.26}Gd_{0.09}La_{0.05}Pr_{0.05}Th_{0.02})_{1.03}P_{0.97}O_{3.98}$
5	center	$(Ce_{0.43}Nd_{0.24}Sm_{0.10}La_{0.09}Pr_{0.06}Th_{0.05}Gd_{0.02}Ca_{0.01}Y_{0.01}U_{0.01})_{1.02}(P_{0.93}Si_{0.05})_{0.98}O_{3.99}$
7	margin	$(Ce_{0.43}Nd_{0.25}Sm_{0.10}Pr_{0.09}La_{0.08}Th_{0.06})_{1.01}(P_{0.92}Si_{0.06})_{0.98}O_{3.99}$

Note: Analyses 1, 3, 7 – microprobe analyzer JXA-733 Superprobe (analyst E.I. Churin), (analyses 1, 3 are proceeded with the help of energy-dispersion spectrometer INCA, analysis 7 – with the help of wave-dispersion spectrometers); analyses 2, 4–6 – REMMA-202M with energy-dispersion spectrometer Link LZ-5 (analyst V.A. Kotlyarov); sum of the analysis 5 includes 0.42 wt.% of Y_2O_3. Dash – not detected.

Fig. 3. Energy-dispersion spectra of samarskite-(Y) (a, b) and replacing it fersmite (c):
a – specimen № 21934 FMM; b, c – specimen Г1.





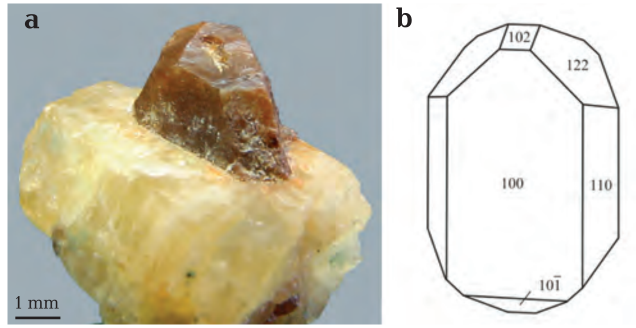


Fig. 4. Form of ferrocolumbite crystals from the Semeninskaya vein.
Fig. 5. Monazite-(Ce) from the Semeninskaya vein: a — monazite in yellow beryl from albite (photo by V.A. Gubin), b — idealized form of crystal.

samarskite (samarskite altered) from the data base JCPDS.

Samarskite-(Y) from the other specimens of FMM (№ 21935) is black-brown in color and also contains microinclusions of albite near its margins. During the microprobe investigations it was established that only central part of the grain relatively not altered. Its composition differs from the former specimen by lower amounts of Fe and U oxides and by higher amounts of Ti, Ta and rare earths. Its empirical formula $(Fe_{0.33}Y_{0.28}\mathit{REE}_{0.17}U_{0.09}Th_{0.02})_{0.89}(Nb_{0.85}Ti_{0.14}Ta_{0.11})_{1.10}O_{3.92}$ (Table 1, analysis 2).

In 1975 V.A. Gubin has found in albite-quartz aggregate fan-shaped joint of elongated tabular brown-black small crystals of samarskite-(Y) 6 mm in size with the following habitus forms: {100}, {010} and {011} (Fig. 2b). According to its composition, it is close to the specimens from FMM with a little higher concentration of UO_2 (Table 1, analysis 3); its formula $(Fe_{0.34}Y_{0.30}\mathit{REE}_{0.17}U_{0.15}Th_{0.02})_{0.98}(Nb_{0.82}Ti_{0.11}Ta_{0.09})_{1.02}O_{3.89}$.

The mineral that partly replaces crystals and grains of samarskite-(Y) from their periphery (Fig. 2c) is characterized by relatively high concentrations of CaO (up to 3 — 5 wt.%) and practically does not contain yttrium and rare earth elements of its group. Amounts of Ti, Ta and Th are twice or thrice higher than in samarskite-(Y) but U concentration is low (Fig. 3, table 1, analyses 4 — 5). Due to the presence of microrelicts of samarskite, we could not obtain its satisfactory analyses. Both varieties distinguished by the Fe, Nb and Ta ratio are very close in their composition to the ferrous fersmite. Their calculated formulas are as follows: $(Fe_{0.40}Ca_{0.35}Th_{0.12}\mathit{REE}_{0.06}U_{0.04}Mn_{0.01})_{0.98}(Nb_{1.16}Ti_{0.48}Ta_{0.39})_{2.03}O_{6.0}$ (analysis 4) и $(Ca_{0.33}Fe_{0.32}Mn_{0.08}Th_{0.08}Y_{0.05}U_{0.04}\mathit{REE}_{0.03})_{0.93}(Nb_{1.42}Ti_{0.40}Ta_{0.23})_{2.05}O_{6.04}$ (analysis 5). Several reflections of Debye powder pattern of the calcined grain of the altered samarskite correspond to fersmite. Except for assumed fersmite, in sites of the samarskite alteration during the analysis we have found micrograins of manganocolumbite, monazite-(Ce), and zircon. In a number of analyses there is increased concentration of SiO_2 (up to 3 — 15 %), probably due to hypergene opal or microinclusions of albite.

Manganocolumbite from the inclusion in the altered samarskite (fersmite) has a following composition (wt.%): FeO 9.30; MnO 12.94; Nb_2O_5 70.41; Ta_2O_5 3.01; TiO_2 2.42; WO_3 0.21; UO_2 1.47; total 99.76 (admixture of U, probably, it is caused by surrounding minerals — samarskite-(Y) and fersmite). Analysis is calculated to the following formula: $(Mn_{0.62}Fe_{0.44})_{1.06}(Nb_{1.81}Ti_{0.10}Ta_{0.05})_{1.96}O_{5.96}$.

High-manganese ferrocolumbite in the aggregate of albite with yellow beryl, quartz and muscovite was found by V.A. Gubin in 1969 in the form of plates fragments of coarse crystals (2.6 mm wide). It also occurs in schlich of the shaft dump. Its larger grains (2 — 5 mm) have elongated-tabular shape with the ratio $c : b = 3$ and facets {110}, {010}, {221}, {021}. Its smaller grains (1 mm and less) are more elongated with the ratio $c : b = 4$ and appearance of facets of additional prisms {120}, {130}, {401}, {261} and pinacoid {100} (Fig. 4). Its composition (wt.%): FeO 10.71; MnO 9.56; Nb_2O_5 69.52; Ta_2O_5 8.19; TiO_2 1.96; total 99.94 (conditions of recording: REMMA-202M, equipped with Link LZ-5 energy dispersion spectrometer, analyst V.A. Kotlyarov); empirical formula $(Fe_{0.51}Mn_{0.47})_{0.98}(Nb_{1.81}Ta_{0.13}Ti_{0.08})_{2.02}O_6$.

In the pegmatite vein Puzyr` (380 m to the north of the Semeninskaya pit) ferrocolumbite similar in composition occurs in graphic pegmatite and high-ferrous manganocolumbite occurs in the block zone (Emlin *et al.*, 2002). In the Yuzhnaya mine high-ferrous manganocolumbite is described in topazes from druse cavities. In the block zone occurs ferrocolumbite with significantly lower (two times or more) concentrations of Mn and Ta (Shagalov *et al.*, 2004).

Monazite-(Ce) is found as ingrowths of partly faceted red-brown grains up to 4–25 mm in size in albite and yellowish translucent beryl (from cavity in albite). Monazite crystals have tabular shape (Fig. 5). This monazite (Table 2, analyses 1–4) is distinguished from the monazites of other veins of the Aduy field by highest concentrations Nd and Sm and lowest – Th (Popova *et al.*, 2007); micrograin of the monazite-(Ce) enriched in Nd and Sm is found also in samarskite-(Y) from the specimen № 21934 FMM. Other type of monazite-(Ce) crystals (elongated-tabular yellow-brown, probably from the block zone of pegmatite) is characterized by lower concentration of Sm_2O_3 (6–7 wt.%), more high – Ce_2O_3 and ThO_2 (Table 2, analyses 5–7) and is closer in composition to the monazites from the block zone of the Yuzhnaya pegmatite vein (Vakhrusheva *et al.*, 2004) and muscovite-quartz-albite zone of the Telephonka vein (Popova, Churin, 2009).

Gahnite in quartz-albite aggregate is found in the form of green-black and dark blue-green crystals and grains (up to 2–5 mm and larger) with parts of habitus facets {111}, {110} (narrow), regularly with predominant induction surfaces with albite and quartz. ZnO content in it is about 33 wt.%, calculated formula is as follows: $(Zn_{0.72}Fe_{0.24}Mn_{0.03})_{0.99}Al_{2.01}O_4$. According to their form and composition, they are similar to gahnite crystals from quartz-albite zone of the Telephonka pegmatite (Emlin *et al.*, 2002). Orange-red spessartine contains about 61% of Mn-endmember (16–17 wt.% of FeO), and red-orange variety from albite contains 77% of Mn-endmember (10–11 wt.% of FeO).

New data on the accessory minerals of the Semeninskaya pit confirm its individuality (marked by A.E. Fersman due to its thick albite zone of the vein). Specimens of "euxenite" from the collections of A.E. Fersman investigated by us are proved to be samarskite-(Y) partly replaced by fersmite and microinclusions of other minerals. Columbites evolutionated in composition from earlier ferruginous to late manganese that is typical of many veins of granitic pegmatites from different regions. Irrespective of Sm_2O_3 concentration in monazites of different veins from the Aduy field, share of Sm in composition of monazite-(Ce) grew during its crystallization.

The data given in the article show expediency of revision of mineralogy of many other veins of the ancient mines and deposits of the last years, especially in rich mineralogical collections of museums.

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