

**Extremely Cs-rich mineral-forming media in pegmatites and ongonites**IGOR S. PERETYAZHKO<sup>1</sup>, VICTOR YE. ZAGORSKY<sup>1</sup>, SERGEY Z. SMIRNOV<sup>2</sup> & ELENA. A. TSAREVA<sup>1</sup><sup>1</sup> Institute of Geochemistry (Russian Academy of Science, Siberian branch), Favorsky St., 1a, Irkutsk, Russia, pgmigor@igc.irk.ru,<sup>2</sup> Institute of Geology and Mineralogy (Russian Academy of Science, Siberian branch), Novosibirsk, Russia, ssmr@uiggm.nsc.ru**ABSTRACT***The data on inclusions of extremely Cs-rich mineral-forming media in minerals of pegmatites and ongonites are resulted.***Keywords:** Cs, melt, melt-like gel, inclusion, pegmatite, ongonite.**INTRODUCTION**

Chemical properties of Cs determine its ability to be accumulated in the late differentiated portions of aluminosilicate melts. Rhyolite glasses contain often 200-800 ppm, sometimes up to 4000 ppm Cs. In igneous rocks Cs is concentrated mainly in micas and feldspars, but its major mineral, pollucite is formed in pegmatites only. Inclusions of mineral-forming media, containing up to 5.2 wt% Cs<sub>2</sub>O are discovered in miarolitic pegmatites of the Malkhan field in Siberia (Smirnov et al., 2003; Peretyazhko et al., 2004a). Cs-rich silicate melt inclusions (MIs) are found in pegmatites of Ehrenfriedersdorf (1.59±0.22 wt% Cs<sub>2</sub>O, Thomas et al., 2003) and Kola Peninsula (3.67±0.36wt% Cs<sub>2</sub>O, Badanina et al., 2005). New data on composition of extremely Cs-rich inclusions trapped by minerals in miarolitic pegmatites of Siberia and SW Pamirs, as well as in ongonites of the Ary-Bulak massif (Eastern Transbaikalia) are presented below.

**INCLUSIONS OF “MELT-LIKE GELS” IN PEGMATITES**

Some unusual inclusions resembling in appearance silicate MIs were found in quartz from miaroles in pegmatite veins Oktyabrskaya and Mokhovaya of the Malkhan field, as well as in vein Vezdarinskaya at SW Pamirs. They are filled with crystalline aggregate and contain small amount of aqueous solution. However they occur among numerous fluid inclusions in the growth zones of quartz crystals formed in the miaroles at the hydrothermal stage. Most inclusions are completely re-melted when heated up to 650°C at 3 kbar during 4 days. The data obtained by EPMA and SIMS analyses of homogeneous glasses of such inclusions are shown in Table 1. The glasses have relatively low contents of Si and Al, very high H<sub>2</sub>O and B, highly dispersed Cs, Ta, Nb, Be, Li, F, Zr, Hf, U and Th. When exposed in air, quenched glasses in inclusions are dehydrated. The comparison of thermometric and analytical data with experimental study of the systems Na<sub>2</sub>O-B<sub>2</sub>O<sub>3</sub>-SiO<sub>2</sub>-H<sub>2</sub>O (Smirnov et al., 2005) and NaF-H<sub>3</sub>BO<sub>3</sub>-SiO<sub>2</sub>-H<sub>2</sub>O (Peretyazhko et al., 2005) suggest that the contents of these inclusions represent hydrosilicate liquid with composition and properties resembling hydrous silica gel. Earlier these media were named “melt-like gels” (Peretyazhko et al., 2004b). The gel nature of such liquids is very important for understanding the element fractionation in the course of magmatic-hydrothermal transition in the granite-pegmatite systems that are potentially enriched in B, F, Cs, Li, Be, Ta, Nb, Sn, W and other rare elements.

**TABLE 1.**

	I	II	III
	1	16	8
N <sub>EMPA</sub> , wt%			
SiO <sub>2</sub>	71.98	58.89-66.81	62.13-68.18
Al <sub>2</sub> O <sub>3</sub>	11.8	11.21-13.67	11.97-14.29
FeO	0.02	bld-0.06	bld-0.06
MnO	0.05	bld-0.09	0.01-0.40
MgO	0.06	bld-0.07	bld
CaO	bdl	bld-0.22	0.22-0.32
Na <sub>2</sub> O	2.23	1.63-3.78	0.55-1.36
K <sub>2</sub> O	0.55	1.72-5.06	2.05-3.43
Rb <sub>2</sub> O	0.02	0.03-0.21	0.09-0.17
<b>Cs<sub>2</sub>O</b>	<b>5.53</b>	<b>2.33-6.40</b>	<b>1.0-2.41</b>
<b>F</b>	<b>0.03</b>	<b>2.12-3.01</b>	<b>0.07-1.50</b>
ASI	1.88	1.06-1.80	1.95-2.51
N <sub>SIMS</sub> , ppm	1	6	6
<b>H<sub>2</sub>O</b> , wt%	<b>5.77</b>	<b>3.34-9.40</b>	<b>4.8-18.6</b>
<b>B<sub>2</sub>O<sub>3</sub></b> , wt%	<b>0.81</b>	<b>1.22-4.11</b>	<b>3.79-5.18</b>
Rb	147	565-999	852-1516
Ba	1.8	0.4-7.7	1.3-9.4
Sr	1.5	1.4-6.4	1.4-3.6
Be	1.9	5.7-424	120-604
Li	1.5	4.7-7	8.5-42.6
Ta	0.1	78-390	291-499
Nb	0.1	29-200	21-68
Zr	0.1	1.8-11.3	2.3-17.9
Hf	bdl	1-6.9	2.5-8.0
U	bdl	0.1-2.3	5.8-12.0
Th	bdl	0.1-5.7	5.6-10.4

I-Mokhovaya, II- Oktyabrskaya, III-Vezdarinskaya. bdl- below detection limit. N- number of analyses. ASI- molar ratio Al<sub>2</sub>O<sub>3</sub>/(Na<sub>2</sub>O+K<sub>2</sub>O+CaO+Cs<sub>2</sub>O+Rb<sub>2</sub>O).

**MELT INCLUSIONS IN ONGONITES**

Melt inclusions glasses containing 0.5-17.5 wt% Cs<sub>2</sub>O are discovered for the first time in ongonites of the Ary-Bulak massif (Peretyazhko et al., 2006; 2007). These MIs occur in both early and late zones of the quartz phenocrysts separately or together with usual low Cs silicate MIs and fluid inclusions. MIs showing the extreme Cs enrichment contain semitransparent or transparent residual glasses and large shrinkage bubbles. Some of them contain Na-sanidine and mica crystalline phases. Cs-rich MIs do not homogenize on heating up to 1050°C. According to EMPA Cs is distributed uniformly within residual and quenched glasses of MIs. SEM EDS and SIMS analyses of some Cs-rich glasses are shown in Table 2. Glasses from 16 MIs, including 3 glasses with extremely high Cs, are determined by SIMS. All glasses are enriched in B, Be, Li, Rb, Nb, Ta and depleted in Ba and Sr. Element concentrations in all

MIs glasses typically show high dispersion (ppm): B 122-1942, Be 16-179, Li 73-1233, Rb 630-2705, Nb 70-180, Ta 11-46, Ba 0.1-18, Sr 0.3-8.

TABLE 2.

N <sub>SEM EDS</sub>	4	7	14	3	3
SiO <sub>2</sub>	58.55	69.15	63.02	59.03	53.35
Al <sub>2</sub> O <sub>3</sub>	18.80	12.79	16.15	18.24	16.83
FeO	bdl	0.19	0.41	Bdl	bdl
Na <sub>2</sub> O	5.68	3.73	4.49	5.49	4.43
K <sub>2</sub> O	4.76	3.04	3.38	3.93	0.52
<b>Cs<sub>2</sub>O</b>	<b>4.10</b>	<b>7.33</b>	<b>7.18</b>	<b>6.55</b>	<b>17.51</b>
Rb <sub>2</sub> O	1.91*	0.55*	0.50*	3.47	
Li <sub>2</sub> O*	0.19	0.13	0.17		
<b>B<sub>2</sub>O<sub>3</sub>*</b>	<b>0.25</b>	<b>0.31</b>	<b>0.46</b>		
Cl	0.60	bdl	0.16	0.32	bdl
<b>F</b>	<b>5.78</b>	<b>3.75</b>	<b>5.15</b>	<b>6.70</b>	<b>14.13</b>
<b>H<sub>2</sub>O*</b>	<b>0.61</b>	<b>0.64</b>	<b>0.62</b>		
Σ <sub>(-O=F2)</sub>	98.67	100.02	99.48	100.84	100.80
ASI	1.10	1.03	1.16	1.04	1.19

\* SIMS analyses, blank- not determined. ASI- molar ratio Al<sub>2</sub>O<sub>3</sub>/(Na<sub>2</sub>O+K<sub>2</sub>O+Cs<sub>2</sub>O+Rb<sub>2</sub>O). N- number of analyses. CaO<0.2 wt% in all analyses.

Usual MIs contain 113-564 ppm Cs and 1.5-7 wt% H<sub>2</sub>O whereas H<sub>2</sub>O contents in the Cs-rich ones (>0.5 wt% Cs) are essentially lower (~0.6 wt% H<sub>2</sub>O). Data on thermometry, behavior under heating and composition of MIs reveal that Cs-rich melts have unusually high viscosity and low H<sub>2</sub>O content.

Some deductions follow from the available data. H<sub>2</sub>O- and F-rich ongonite melt of the Ary-Bulak was enriched in Cs, B, Be, Li, Rb, Nb and Ta. Strong dispersion of Cs contents in the MIs may be explained by heterogeneity of the ongonite melt in the course of phenocryst crystallization. At this stage rare small “drops” of extremely Cs-rich melts immiscibly existed within ongonite melt. Importantly, these drops are more viscous and more “dry” than the surrounding melt. There is no correlation between Cs and Si, Al, Na, K, Rb and F in residual and quenched glasses of MIs. In most cases, the molar ratio ASI is close to 1. This suggests predominantly “feldspar” ratio of Al and alkalis in extremely Cs-rich melts. Na predominates significantly over K in glass with 17.5 wt% Cs<sub>2</sub>O. In the process of melt crystallization Cs is consumed by feldspars and micas. Cs enrichment in groundmass of ongonites in comparison to the whole rock composition and data on distribution coefficients of Cs ( $D^{Cs}$ ) reveal that it accumulated at the final stage of the Ary-Bulak massif crystallization. Possibly some Cs was redistributed between melt and fluid phases. Analysis of data on Cs distribution in rocks and glasses of MIs with regard to  $D^{Cs}_{crystal/melt}$ ,  $D^{Cs}_{fluid/melt}$  and the crystallization degree of the massif is not consistent with the fractional crystallization model (Peretyazhko et al., 2007). It is necessary to use other models, for instance, crystallization of chemically heterogeneous melts with the availability of fluid flow draining through magmatic chamber.

## CONCLUSIONS

Although formation of extremely Cs-rich media (melts and/or melt-like gels) is not well understood yet, they are suggested to be a result of chemical heterogenization processes in acid rare-metal melts. Some most probable modes of heterogenization of pegmatite melts were discussed earlier (Zagorsky & Peretyazhko, 2006). They are as follow: a) formation of chemically zonal columns in melt as a result of fluid-melt interaction in metamagmatic regime when fluid drainages through magma (“metasomatism” in magma by analogy with metasomatism in hard medium); b) liquation; c) formation of clusters (protomatrices of crystalline phases in melt) in above-liquidus conditions; d) formation of the latest silicate liquids of the gel nature at magmatic-hydrothermal transition in pegmatite-forming processes. This list of possible heterogenization modes of acid melts may be extended. Besides, it is important to emphasize the geochemical affinity of Cs with F and B in the processes of acid aluminosilicate melts evolution. In addition to pegmatites and ongonites, inclusions of extremely Cs-rich mineral-forming media may be expected in minerals from other plutonic and volcanic rocks enriched in rare-elements and Cs.

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