

## Ca-RICH SILICATE MELTS DURING FORMATION OF ALKALI-ULTRABASIC CARBONATITE INTRUSIONS

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According to modern concepts, the rocks of alkali-ultrabasic carbonatite intrusions are the derivatives of deepest-level mantle magmas. However the question on the amount of initial magmas taking part in the formation of these complexes is still debatable. The point is that formation of silica-undersaturated Mg-rich pyroxene-olivine and Ca-rich monticellite-melilite rocks entering the composition of these complexes by the way of differentiation of one initial magma in equilibrium conditions seems to be impossible as an increase in the amount of Ca must have been accompanied by an increase in SiO<sub>2</sub>. Therefore, some researchers (Rass, Plechov, 2000) believe that the formation of alkali-ultrabasic carbonatite complexes is participated by two initial silica-undersaturated magmas: Mg-rich ultrabasic and Ca-rich alkalic. At the same time other geologists (Egorov, 1963) assumed a probability of formation of the above-mentioned complexes during differentiation of one mantle-derived magma with a specific alkali-ultrabasic composition enriched in carbon dioxide.

To answer this question, we have studied melt inclusions in the minerals of pyroxenites of the Krestovskaya intrusion (Polar Siberia) composed of olivinites, wehrlites, melilitic and monticellitic rocks, and carbonatites. According to geological observations, pyroxenites formed after the formation of olivinites and wehrlites but prior to the formation of melilitic rocks. We thought that if one initial magma is responsible for the formation of the rock complex of this intrusion, then the minerals of pyroxenites must contain inclusions reflecting the increases in Ca concentrations on the background of the decreasing importance of Mg and preserved deficiency of SiO<sub>2</sub>. If the formation of the intrusion was participated by two initial magmas, then pyroxenite minerals must have melts evolving by the Bowen scheme, i. e., a minor increase in Ca content in them was accompanied by a noticeable growth in SiO<sub>2</sub> concentration.

When studying pyroxenites of the Krestovskaya intrusions, we found primary crystallized silicate inclusions in clinopyroxene and perovskite. The inclusions were distributed throughout mineral grains, in places forming dense accumulations. Their sizes ranged from 20-30 to 1-5 μm. Their shape is commonly rounded but sometimes is irregular or nearly square or elongated. Microprobe analysis of the phase composition clinopyroxene-hosted inclusions indicated: daughter phlogopite, kalsilite, perovskite, magnetite, apatite, and alkali-enriched carbonate phase. Some inclusions contained biotite instead of phlogopite and nepheline instead of kalsilite. Among ore minerals in inclusions we also detected sulfide minerals: djerfisherite and chalcopyrite. The phase composition of inclusions in perovskite was somewhat different: along with phlogopite, kalsilite, apatite and ore minerals they contained clinopyroxene, sphene, and pectolite.

Homogenization of inclusions in clinopyroxene took place at 1310-1200°C, while in perovskite at 1250-1230°C. The composition of homogenized and quenched inclusions from clinopyroxene and perovskite (Table 1) was found to be similar and correspond to that of alkali ultramafic rocks, i. e., it was low-silica, low-alumina, and enriched in alkalis. It contained (wt.%): 33-42 SiO<sub>2</sub>, 2-7 TiO<sub>2</sub>, 6-8 Al<sub>2</sub>O<sub>3</sub>, 7-12 FeO, 0.8-4 Na<sub>2</sub>O, 4-5 K<sub>2</sub>O. It also contained variable amounts of MgO and CaO, which were in reverse proportions with each other, i.e., an increase in one oxide was accompanied by a decrease in the amount of the other. At 18-26 wt.% MgO, the glass contained 8-11 wt.% CaO, while at 12-14 wt.% MgO, 13-14 wt.% CaO was present, i.e. these components occurred in equal amounts. And, finally, at 6-9 wt.% MgO the content of CaO reached 14-20 wt.%. It is interesting that the highest-magnesian compositions (close to ugandite) are typical of the highest-temperature inclusions in clinopyroxene, whereas Ca-enriched (close to turjaite composition) for inclusions in perovskite and inclusions in clinopyroxene with moderate homogenization temperatures. In general, during crystallization of clinopyroxene and formation of pyroxenites, the deficiency of silica in the melt still existed, Ca/Mg ratios and Fe number increased. The importance of Ti, Al, alkalis, sulfur, phosphorus, and, most likely, CO<sub>2</sub> (proceeding from the low sum of analyzed oxides and conserved melts) also grew. The composition of melts evolved from the composition close to ugandites, further to mafurite-katungites up to turjanite-melanonephelinites. Such behavior of the elements fits the scheme of formation of alkali-ultrabasic carbonatite intrusions from one primordial magma. The origin of high-calcium silica-undersaturated melts during the evolutionary transformations of one initial magma should, probably, be related to the presence of elevated concentrations of alkalis and volatile components, mainly carbon dioxide.

The presence of CO<sub>2</sub> in alkali-ultrabasic systems is attributed great importance by researchers. Tomkiew (1962) believes that carbon dioxide can disturb equilibrium crystallization and magma evolution and hinder the formation of Ca-silicates, thereby preserving the deficiency of SiO<sub>2</sub> and increasing Ca potential in magma systems. Moreover, it controls binding of alkali-earth elements into molecules of carbonates to form immiscible silicate-carbonatitic melts. Indeed, when studying melt inclusions in the minerals of melilitic rocks of the Krestovskaya intrusion, at one of crystallization stages of melilite we have found (Panina et al., 2001) carbonate-silicate immiscibility of high-calcium melt (Table 1, ans. 5 a-b; 6 a-b).

**Table 1. Chemical composition of melt inclusions in minerals of clinopyroxenite and melilitolite of the Krestovskaya intrusion, wt%.**

No	n	SiO <sub>2</sub>	TiO <sub>2</sub>	Al <sub>2</sub> O <sub>3</sub>	FeO	MnO	MgO	CaO	Na <sub>2</sub> O	K <sub>2</sub> O	BaO	SrO	P <sub>2</sub> O <sub>5</sub>	Cl	SO <sub>3</sub>	Total
1	5	<b>42,12</b>	2,19	7,51	7,45	0,10	<b>21,47</b>	<b>10,15</b>	0,77	4,24	0,14	0,01	0,80	0,10	0,36	97,41
2	8	<b>41,50</b>	3,05	7,72	8,58	0,09	<b>12,27</b>	<b>15,03</b>	0,88	4,81	0,27	0,04	1,66	0,27	0,63	96,80
3	15	<b>40,26</b>	3,95	8,11	9,62	0,11	<b>8,06</b>	<b>16,14</b>	0,92	5,46	0,35	0,05	2,09	0,13	0,84	96,09
4	2	<b>36,47</b>	12,56	11,11	6,65	0,13	<b>3,82</b>	<b>14,97</b>	4,10	5,09	0,23	0,00	1,51	0,21	0,52	97,37
5a	3	<b>34,41</b>	5,08	6,19	10,87	0,26	<b>6,65</b>	<b>19,10</b>	3,23	6,06	0,42	0,25	2,13	-	0,49	95,14
5b	2	<b>9,85</b>	4,98	1,55	3,02	0,05	<b>1,64</b>	<b>22,81</b>	4,08	12,11	0,26	0,20	0,48	-	4,31	65,30
6a	6	<b>34,19</b>	0,01	3,17	2,01	0,03	<b>10,62</b>	<b>30,76</b>	2,05	1,24	0,17	0,56	0,09	1,24	0,62	86,76
6b	4	<b>9,58</b>	0,04	1,19	0,76	0,02	<b>4,56</b>	<b>21,65</b>	6,10	11,48	0,92	0,22	0,38	3,91	3,50	64,31

Rocks: 1-4 – clinopyroxenite, 5-6 – melilitolite. Host mineral: 1-3 – clinopyroxene; 4-5 – perovskite; 6 – melilite.

Inclusions: 1-4 – homogeneous, 5-6 – inclusions with silicate-carbonate immiscibility: a – silicate fraction, b – carbonate fraction.

n – number of analyses.

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