

Experimental study of partitioning of minor and rare-earth elements between sodium-bearing majoritic garnet and melt at 8.5 GPa

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This paper summarizes the first results of experimental study of partitioning of minor and rare-earth elements between phases in the system with sodium-bearing (up to 1 wt % Na₂O) majoritic garnet at 8.5 GPa and 1500–1800°C. The studied samples are characterized by significant enrichment of melts in REEs in relation to garnets. All garnets demonstrate increase of the concentrations of HREEs and yttrium, as well as some flattening of partitioning curves with increase of the majoritic component content. Pyroxenes are characterized by much more homogeneous partitioning of minor elements between mineral and melt.

Key words: experiment at high temperatures and pressures, sodium-bearing majoritic garnet, partitioning of minor and rare-earth elements between phases

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Study of partitioning of minor and rare-earth elements between phases in multi-component and multi-phase mantle matter currently arises significant interest of researchers in relation to the possibility of obtaining of reliable information on the processes of the deep Earth geochemical evolution. A special place among these studies is occupied by experimental investigations at high *PT*-parameters performed for aluminosilicate [Klemme *et al.*, 2002; Pertermann *et al.*, 2004], as well as carbonate-silicate diamond-forming [Kuzyura *et al.*, 2010] systems with natural chemistry. Studies of intraphase partitioning of minor and rare-earth elements in the mantle magmatic systems with majoritic garnet are very limited [Draper *et al.*, 2003], which determined our interest to experimental investigation of these elements in the system with participation of Na-bearing majoritic garnet.

As it was demonstrated in [Bobrov *et al.*, 2008], sodium incorporation in majoritic garnet proceeded as the Na₂MgSi₅O₁₂ component (so-called sodium majorite *NaMaj*) and was controlled by the three main factors: pressure, temperature, and melt alkalinity. Based on the previously obtained results, we predicted crystallization of garnets with significant sodium concentrations (up to 1 wt % Na₂O) for sodium-rich started compositions (~40–60 mol % *NaMaj*) at a pressure of 8.5 GPa at the solidus of the pyrope (*Prp*)–*NaMaj* system.

Investigations were performed in the Institute of Experimental Mineralogy (Chernogolovka) on a high-pressure toroidal “anvil-with-hole” apparatus using special cell assemblies with graphite heaters [Bobrov *et al.*, 2008] at a standardized pressure of 8.5 GPa, within the temperature range of 1500–1800°C. The starting composition *Prp*₅₀*NaMaj*₅₀ (mol %) was added by the small (2 wt %) controlled portions of minor and rare-earth elements (Li, Rb, Cs, Ba, Th, U, Ta, Nb, La, Ce, Pb, Pr, Sr, Nd, Zr, Hf, Sm, Eu, Gd, Tb, Dy, Y, Ho, Er, Tm, Yb, Lu, Sc, Zn), mainly as oxides. The run duration depended on temperature and ranged from 30 to 90 min.

Within the whole temperature range of *T* = 1500–1700°C, experimental samples contain the phase association of clinopyroxene + garnet + melt (Fig. 1a), which is changed by the two-phase assemblage of garnet + melt with temperature increase (Fig. 1b). All garnets are homogeneous and characterized by silicon excess over 3.0 f.u. and admixture of sodium. The maximal content of Na₂O

was registered in garnet obtained at 1750°C (Run 2327). The composition of clinopyroxene corresponds to jadeite with a small admixture of enstatite component (up to 4 wt %MgO). Melt is represented by fine-granular quenched aggregate of pyroxene and coesite with a small portion of garnet. The grain sizes in this aggregate slightly varied within the same sample, so that the areas with the smallest grain size were selected for analyses.

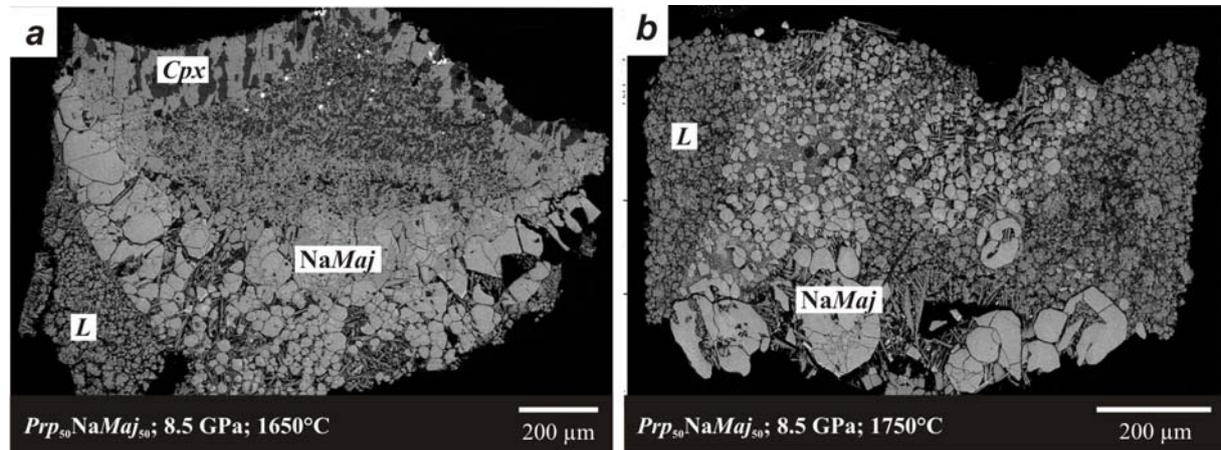


Fig. 1. Back-scattered electron images of textural features of experimental samples obtained in the system $\text{Mg}_3\text{Al}_2\text{Si}_3\text{O}_{12}\text{-Na}_2\text{MgSi}_5\text{O}_{12}$ at 8.5 ГПа.

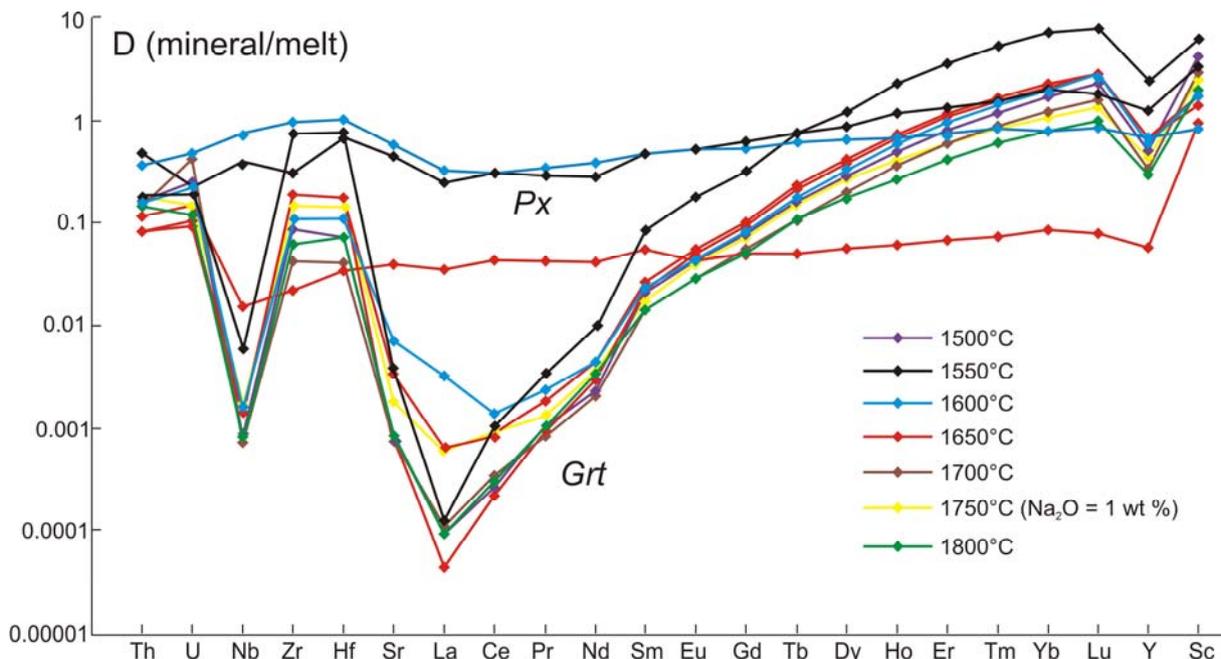


Рис. 2. Partitioning coefficients of minor and rare-earth elements between garnet (*Grt*) and melt and pyroxene (*Px*) and melt in experimental samples depending on temperature.

Samples were investigated on a LA apparatus New Wave UP193FX with ICP-MS Agilent 7500cs in the Laboratory of Analytical Chemistry, Mineralogical Section, Natural History Museum (London, United Kingdom). Synthetic glasses NIST 612 and BCR-2g were applied as standards for calibration of analyses by REEs.

Fig. 2 demonstrates the evolution of partitioning coefficients for minor and rare-earth elements depending on temperature, which, in turn, controls the concentration of sodium in majoritic garnet. The investigated samples are characterized by significant enrichment of melts relatively to garnets in rare-earth elements. Increase of the concentrations of HREEs and Y, as well as some flattening of distribution curves with increase of the concentration of Na-majorite being controlled by the decrease of temperature was observed for all garnets. We should emphasize the higher values of partitioning coefficients for zirconium in comparison with those for hafnium almost for all garnets, except for the most high-temperature ones (1800°C), in which the concentrations of Na_2O do not exceed 0.3–0.4 wt

% Partitioning coefficients for LREEs are comparable with those for less deep garnets. Pyroxenes are characterized by much more homogeneous distribution of minor elements between mineral and melt (Fig. 2).

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