Formation of Na/Ca – F/Cl salt melts in the pantellerites magmas, Island Pantelleria, Itali

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In the last decades, increasing evidence has appeared for the occurrence of immiscible chloride melts in natural magmatic systems. In contrast, findings of fluoride melts are still very rare (Andreeva et al., 2007), although experimental evidence indicates the existence of a wide silicate-fluoride liquid immiscibility field (e.g. Gramenitskiy et al., 2005; Dolejs & Baker, 2007). We report new data on the formation of Na/Ca-F/Cl melts in the pantellerites of the Island of Pantelleria, Italy (samples were provided by V. Kovalenko). Previously, immiscible chloride melts were reported from groundmass glasses and melt inclusions in these rocks (Solovova et al., 1991; Lowerstern, 1994). Melt inclusions were studied in anorthoclase phenocrysts from the pantellerites using a Linkam TS-1500 heating stage and electron and ion microprobes.

Silicate melt inclusions contain daughter crystals of anorthoclase, glass, fine-grained multiphase salt globules and H_2O-bearing low-density vapour, in which liquid water was occasionally observed. The composition of salt melt globules are NaCl-CaF_2±NaF and show only minor admixtures of Mg and Fe and never Al. Two groups of globules are clearly distinguished: (1) NaCl-CaF_2 and (2) NaF-NaCl-CaF_2 with variable Cl/F proportions. Globules of these two types may coexist in a single inclusion, although they were never observed in direct contact.

Upon heating, the salt phases were completely melted between 500 and 800 °C (Figure 1). The salt melt gradually dissolved in the silicate melt and completely disappeared at 850 to 1020 °C. The complete homogenization of the melt inclusions with the dissolution of daughter anorthoclase and vapour bubbles was attained at 1020–1080 °C. Rapid quenching (~2 s to 100 °C) produced homogeneous glasses in the inclusions, whereas cooling at rates of 1-20 °C/min resulted in the reappearance of salt globules embedded in silicate glass.

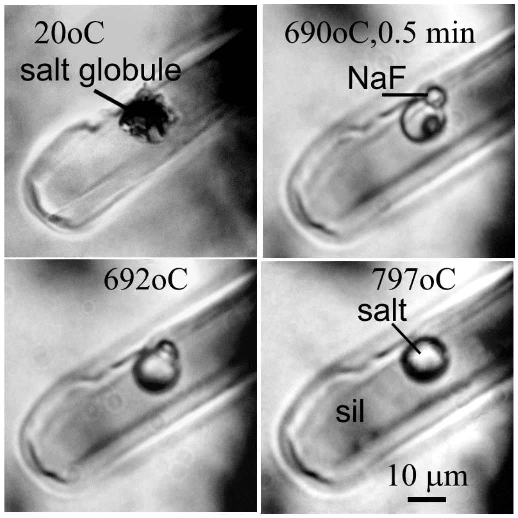

Fig. 1. Micrographs of the behaviour of the silicate glass + salt globule inclusion during heating. sil – silicate and salt – salt melts.

The homogeneous melt of inclusions contained up to 72 mass% SiO_2 and up to 10 mass% Na_2O + K_2O (Na/K mol. up to 2). Average concentration of $Fe_2O_{3\ tot}$ is 7.4 mass%. These melts are rich in F (up to 0.6 mass%), Cl (up to 1.2 mass%) and H_2O (0.3 - 0.93 mass%). SIMS analysis revealed high contents of Zr (up to 4300 ppm), Nb (up to 1400 ppm), and Hf (up to 67 ppm), but only minor Ba (70–740 ppm) and Sr (4.5–38 ppm). NaCl-CaF_2±NaF salt melt is characterized by maximum concentrations of Ba and Sr (intraplate continental settings, Figure 2). NaCl-CaF_2 salt melt with minimum concentrations of Ba and Sr is typical for acid igneous rocks of island arcs and active continental margins.

Residual silicate melts coexisting with salt globules and daughter anorthoclase are very distinguished from the homogeneous melt of inclusions. A main features of these melts are 1) the sharp increase of (Na+K)/Al ratios (up to 14) and 2) reduction of Al_2O_3 concentration (up to 1 mass%) while increasing Fe_2O_3 concentration (up to 18 mass%) (Figure 3). Residual silicate melts contain up to 1.3 mass% F, and 2.1 mass% Cl that can be considered as the limit of saturation.

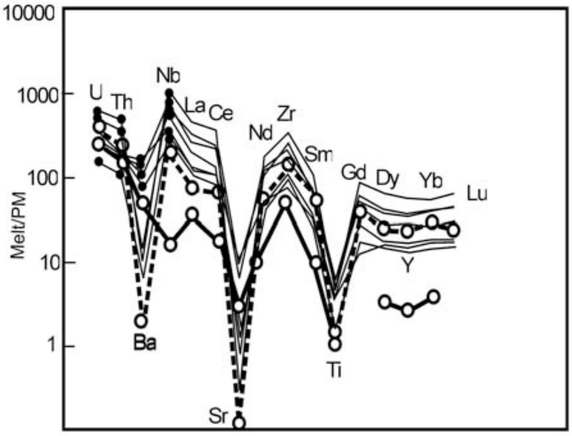

Fig. 2. Primitive mantle-normalized trace-element patterns of homogeneous melt inclusions: thin lines - glasses of inclusions, thick dotted line – the peralkaline silicic melts of intraplate continental settings and thick solid line - island arcs and active continental margins (Kovalenko et al., 2009).

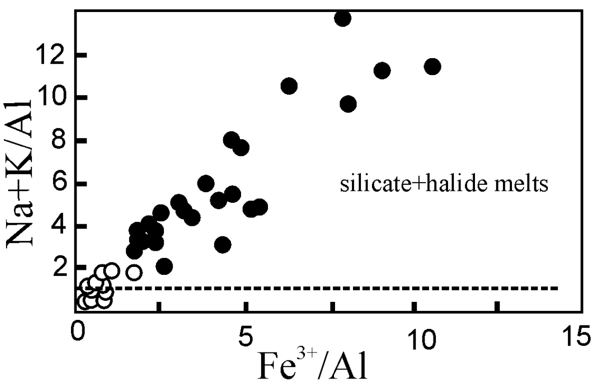

Fig. 3. Correlations of the Al=(Na+K)/Al ratio with the Fe^{3+}/Al ratio in the homogeneous (open circles) and residual (solid circles) melt inclusions.

The relationships between the two halide melts remain obscure. The NaCl-NaF-CaF_2 system shows no liquid immiscibility field (e.g. Sydykov et al., 2004), but the additional components (H_2O, SiO_2, Al_2O_3, Fe_2O_3, etc.) may affect phase relationships. This problem is a topic of future studies. Our investigation showed that fluoride–chloride melts may separate from peralkaline silicic melts containing about 2.1 mass% Cl and 1 mass% F at temperatures about 1000°C. The SIMS analysis of fluoride globules indicated that NaF-NaCl-CaF_2 melts are strongly enriched in incompatible trace elements relative with the coexisting silicate melts.

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