

## Experimental phase relation in lamprophyric magmas from Agardag dike complex, Russia

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Alkali basalts and lamprophyres (camptonites) from Agardag complex (Tuva, Russia) are characterized by the presence of inclusions, globules and lenses of leucocratic rocks. The rocks have sharp contacts and features typical for ductile deformations. There are two hypotheses on their origin: (1) liquid immiscibility, (2) crystal differentiation and mingling [1]. An experimental study was conducted to investigate phase relations and liquid line of descent in hydrous lamprophyre and to clarify to which extent liquid immiscibility is possible in alkali-rich magmatic system.

The starting material was prepared from natural rocks of Agardag (in wt %): 48.14 (SiO<sub>2</sub>), 2.70 (TiO<sub>2</sub>), 17.39 (Al<sub>2</sub>O<sub>3</sub>), 10.87 (FeO<sup>tot</sup>), 0.28 (MnO), 3.93 (MgO), 7.77 (CaO), 4.57 (Na<sub>2</sub>O), 3.65 (K<sub>2</sub>O), 0.70 (P<sub>2</sub>O<sub>5</sub>). Crystallization experiments were performed in an internally heated pressure vessel at 300 MPa, in the temperature range 950 to 1100°C under fluid-saturated conditions at logfO<sub>2</sub> varied from NNO to NNO+3 (Ni/NiO buffer). The water activity of the experimental charges was varied by adding a fluid composed of a mixture of H<sub>2</sub>O and CO<sub>2</sub>. Experimental melts were coexisted with magnetite and apatite in the range of all studied temperatures and fluid compositions. With temperature decrease below 1050°C and for the range of water mole fraction in the fluid (XH<sub>2</sub>O) from 0.4 to 1 magnetite was followed by the crystallization of amphibole. At XH<sub>2</sub>O<0.4 amphibole was not stable, and magnetite was followed by clinopyroxene and plagioclase. In H<sub>2</sub>O-rich experiments (XH<sub>2</sub>O>0.6) the crystallization sequence was amphibole+clinopyroxene+plagioclase+phlogopite.

Liquid immiscibility was not experimentally reproduced. In general the residual glasses demonstrate gradual change in composition from lamprophyre towards syenite, indicating that syenitic rocks could be produced by crystal differentiation. However compared to natural syenitic rocks, experimental glasses were enriched in K<sub>2</sub>O, presumably due to the late crystallization of phlogopite in experiments.

[1] Panina *et al.* (1992) *Russian Geol Geophys* **33**, 98-104.

## Mantle-atmosphere interaction through time

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The distribution of siderophile elements in the Earth indicates an earliest stage of reduced silicate mantle. By contrast, the geochemistry of Archean komatiites [1, 2] as well as the lack of positive Ce anomalies in Hadean zircon [3] show that the mantle soon became more oxidized.

Notwithstanding the monotonous mantle fO<sub>2</sub> evolution since at least 3.5 Ga, mantle geochemistry contains a fascinating record of interaction with the atmosphere. This starts with the observation that modern depleted mantle has a Th/U ratio much lower than chondrite, requiring preferential addition of U to the mantle. The time-integrated Th/U of depleted mantle is significantly higher (ca. 3.4), as recorded by the <sup>208</sup>Pb/<sup>206</sup>Pb ratio of N-MORB, which requires that U addition is a relatively recent phenomenon. Indeed, Nb/Th and Nb/U ratios of Precambrian depleted mantle melts pinpoint the beginning of U recycling to between 2.5 and 2.0 Ga [4], thereby dating the Great Oxidation Event (GOE).

In contrast to the flat evolution of fO<sub>2</sub> in the mantle, the potential upper mantle temperature has varied considerably and this has had a tremendous impact on the composition of the atmospheric gases. In the Archean, very hot mantle domains underwent extensive melting, producing thick mafic-ultramafic plateaux that must have emerged from the sea. The existence of high-Mg basaltic land that was frequently resurfaced with new lavas provided nutrients to the sea, including, in particular, Ni. Once the mantle cooled, and komatiite plateaux disappeared at ca. 2.6 Ga, the Ni supply to the ocean collapsed. This may have triggered a collapse in methanogens, drastically curtailing reduction of free oxygen by methane, ultimately causing the GOE [5]. The presence of short-lived ultramafic plateaux also provided sufficient rock surface to draw down CO<sub>2</sub> from the early atmosphere. It therefore appears that the onset of global atmospheric oxidation and the regulation of the Earth surface temperature were in no small part driven by mantle temperature but not mantle fO<sub>2</sub>.

[1] Canil (1997) *Nature* **389** 842-845. [2] Berry *et al.* (2008) *Nature* **455** 960-963. [3] Whitehouse & Kamber (2002) *EPSL* **204** 333-346. [4] Collerson & Kamber (1999) *Science* **283** 1519-1522. [5] Konhauser *et al.* (2009) *Nature* **in press**.