



Metasomatic reaction phenomena from entrainment to cooling on the surface: evidence from mantle peridotite xenoliths from Moesian Platform

Метасоматични реакционни явления от заграбването до застиването на повърхността: доказателства от мантийни перидотитови ксенолити от Мизийската платформа

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Introduction

Variations in the chemical composition of ultramafic xenoliths brought to the surface by alkaline and, rarely, by supra-subduction magmas, are thought to reflect chemical heterogeneity in the lithosphere. In many studies it is assumed that the effect of interaction between xenoliths and host basalt is minimal, and thus bulk and cryptic metasomatism of the xenoliths are generally attributed to processes that occurred in the upper mantle, prior to their incorporation into the host magma. The major debate has therefore been about the nature of the metasomatising agents: CO₂ ± H₂O fluid (Kempton, 1987; Ionov et al., 1994); migrating small-fraction melts either of alkaline (Menzies et al., 1985; Zangana et al., 1998) or carbonate composition enriched in volatile components (Sciano, Clocchiatti, 1994; Yaxley et al., 1998). However, other studies (e.g. Shaw, Edgar, 1997; Klügel, 1998, 2001; Shaw et al., 2006) have shown that mantle xenoliths may react with their host melts, causing effects which are very difficult to distinguish from the supposed metasomatism occurring in the mantle. According to Klügel (1998), xenolith-host reaction may take place over years to decades in the mantle reservoirs or during residence in a crustal chamber. Scambelluri et al. (2009) suggested that modification can start immediately before and/or during xenolith entrainment in the host alkali basalts. Experimental work by Shaw and Dingwell (2008) explored the possibility of textural modifications of xenoliths during magma cooling at the Earth's surface, however, they concluded that most changes occur during the transport of xenoliths. To date, there is no detailed study on the possible modification of mantle xenoliths close or at Earth's surface conditions.

The most appropriate objects for such a study would be large magmatic bodies with different rates of crystallization, e.g. lava flows, sills, domes or dikes. The rationale of collecting samples from both the quickly cooled outer part and the slowly crystallized interior of such bodies is that it may enable us to distinguish the role of transformation of xenoliths during transport and cooling on, or close to, the surface.

Results

We present the first detailed study of mineralogical and chemical modifications of peridotite xenoliths during magma transport and cooling at the Earth's surface. Three large Miocene basanite domes from the Moesian Platform, North Bulgaria, contain abundant spinel peridotite xenoliths. The xenoliths exhibit different degrees of mineralogical and chemical interaction with their host which strongly depend on their position in the dome structure. Protogranular spinel lherzolite xenoliths from the fine-grained brecciated carapace of the domes show very thin fine-grained reaction rims around orthopyroxene and thin diffusion zones around spinel and olivine. The reactions are limited mostly to the contact of the xenoliths. Modeling of concentration profiles of xenolith's olivine suggest very short residence time of 1–3 days in the lavas and, therefore, rapid ascent rate at velocities around 0.5–1.5 km/h. Clinopyroxene from the xenoliths is always strongly depleted in LREE and Sr and have DMM Nd-values isotopic characteristics. Xenoliths from the interior of the domes are much more strongly affected by the host basanites. This is recorded in the wider reaction rims around orthopyroxene leading up to their entire consumption, transformation of spinel into chromite,

and Fe-Mg diffusion profiles in olivine up to 400 μm long. Calculations from the olivine diffusion profiles indicate interdiffusion time up to 200 days. Times obtained from Ca concentrations from the carapace and interior are from 8 to more than 700 days, respectively. Clinopyroxene is variably enriched in LREE and Sr, from several times with respect to the depleted xenoliths to complete equilibration with the host basanites. Their Sr and Nd isotopic compositions are also similar to the host basanites. Porphyroclastic xenoliths exhibit the strongest reaction phenomena facilitated by infiltrated melt, particularly in the dome interior.

Conclusions

Our study demonstrates that chemical and mineral modification, although starting at the time of entrain-

ment of xenoliths at mantle depths, was completed mostly during their emplacement on the surface. We also show that residence of xenoliths in thick domes, dikes and lava flows will result in partial or total resetting of their Sr and Nd isotopic systems. The strong modification of the chemistry of xenoliths by interaction with the host alkaline magma explains the high Sr and LREE contents and isotopic similarity of the enriched European xenoliths with the European asthenospheric reservoir compared to peridotite massifs.

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