Upper mantle xenoliths from alkali basalts of the Vogelsberg, Germany: implications for mantle upwelling and metasomatism

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Abstract: Alkali basalt-hosted mantle xenoliths of type I (Frey & Prinz, 1978) from the Vogelsberg area (W Germany) cover a compositional range from mildly depleted lherzolites (19 wt.% clinopyroxene) to harzburgites (3 wt.% clinopyroxene), whereas dunites and pyroxenites seem to be extremely rare. Due to partial melting and magma extraction, major and moderately incompatible trace-element compositions of bulk rocks and minerals correlate with the variable modal clinopyroxene abundance, indicating a degree of ~ 30% partial melting for the most depleting harzburgites. Even though these peridotites represent residues of partial melting, some harzburgites show light rare-earth-element enrichment and a Sr-Nd isotopic signature similar to that of the Vogelsberg basanites.

The xenoliths equilibrated in narrow temperature intervals typical for each locality (1125, 1025, and 925 °C), with exception of xenoliths from one outcrop, which reveal a bimodal temperature distribution (1050 and 900 °C). The elevation of the thermal condition above that expected for a stable continental shield appears to be the result of mantle uplift and heating due to magma intrusion. The presence of “spinel-pyroxene-clusters” interpreted as former garnet suggests the rise of asthenospheric mantle into the lithosphere. The peridotite/magma interaction is deduced from Fe-Ti-metasomatism observed in high-temperature xenoliths (1020–1070 °C) considered as parts of thermal aureoles adjacent to local magma conduits.

Key-words: petrology, peridotite xenoliths, mantle upwelling, metasomatism, Vogelsberg, Germany.

Introduction

Petrographic and geochemical studies focussed on alkalic basalts and their mantle inclusions of the Eifel and the Hessian Depression have shown that parts of the upper subcontinental mantle of W and NW Germany were affected by complex partial melting and metasomatic enrichment processes (e.g. Stosch, 1987; Kramm & Wedepohl, 1990). The present investigation was undertaken in order to gain knowledge on the nature of the upper mantle beneath the Vogelsberg (W Germany), which represents, being more than 2500 km² in size, the largest volcanic area of Middle Europe. Geophysical studies have documented the existence of two remarkable anomalies beneath this region. Firstly, long-range seismic refraction data record a disruption of the crust-mantle boundary, which in general lies at a depth of ~ 30 km beneath the surrounding areas (Illies et al., 1979). The Moho is replaced by a well-developed boundary at intermediate depth in the crust (20 km), believed to be the result of mass intrusion from the upper mantle stagnating at the level of the crust-mantle boundary structure (Mechie et al., 1983). Secondly, based on the analysis of teleseismic P-residuals measurements, Raikes & Bonjer (1983) proposed a region of low seismic velocity at a depth < 60 km in the present-day upper mantle structure. This anomalous part of the mantle beneath the Vogelsberg may be hotter than and/or chemically different from its surroundings.

Besides geophysical data, mantle-derived spinel peridotite xenoliths provide direct informa-