Geochemistry of high-temperature garnet peridotite complexes from Lower Austria (Southern Bohemian Massif): Crustal signatures in the lower lithosphere

H. Becker

Max-Planck-Institut für Chemie, Abt. Geochemie,
Postfach 3060, 55020 Mainz, Germany.

Introduction

Garnet bearing high-temperature peridotite massifs are rare probes of the lower lithospheric mantle. These peridotite complexes may yield insights to understand processes affecting and modifying the lower lithosphere. However this is contingent on an understanding of cooling history, tectonic setting and exhumation process of such rocks. Here I report major, trace element and isotope data obtained from garnet peridotites, pyroxenites, megacrysts and a related calcsilicate rock suite from

Lower Austria. These rocks were once equilibrated at conditions of the lower lithosphere and show extreme variations in trace element and isotopic compositions.

Petrology, cooling history and tectonic setting

High-temperature peridotite complexes from Lower Austria (southern Bohemian massif) form lensoid bodies enclosed in Hercynian high-pressure granulites. Peridotites consist of mostly sheared garnet lherzolites and harzburgites, spinel-garnet and spinel harzburgites, and they contain concordant garnet pyroxenite layers (garnet websterites and clinopyroxenites). Modally zoned pyroxenites consist of high- temperature (~1400°C) orthopyroxene megacryst layers at the contact to the host harzburgite, and a sequence of garnet websterite to garnet clinopyroxenite and garnetite (70 vol. % cumulus garnet) to the center of the layer. Clinopyroxene megacrysts occur as partially to completely recrystallized lenses in harzburgite. Garnet megacryst aggregates (> 90 vol. % garnet; clinopyroxene, apatite, ilmenite) are rare. New petrological evidence indicates that cooling from $T > 1400°C$ (megacryst compositions and garnet exsolution from pyroxenes) proceeded to 1100–1200°C near-isobarically in the lower lithosphere (P = 3–3.5 GPa). Cooling was followed by near-isothermal decompression from 3–3.5 GPa to 1.5–2 GPa at 1000–1200°C (Carswell, 1991; Becker, in prep.) and further cooling in the spinel lherzolite stability field. New age data and a reevaluation of existing geological and geochronological data indicates formation of the pyroxenite layers and subsequent decompression in a mid-upper Devonian marginal basin tectonic setting. Final exhumation was due to the lower Carboniferous collision of the Baltic plate and Gondwana.

Geochemistry

Peridotites represent residues of ~5% to >20% degree of fractional melting of fertile spinel peridotite mantle but some have $(La/Sm)_n > 1$ and excess orthopyroxene contents indicative of a multi-stage history. Selective *LREE* reenrichment of the peridotites is due to melt percolation and mineral dissolution-precipitation processes whereas bulk *REE* enrichment in some peculiar peridotites is related to late mechanical interaction with pyroxenites as a result of the exhumation process. Peridotites sampled at some distance from pyroxenites have isotopic compositions typical for the depleted mantle ($^{87}Sr/^{86}Sr$ = 0.7021–0.7033, ε_{Nd} (335 Ma) = +5 to +12).

The cumulus origin of most garnet pyroxenites and megacrysts is evident from their strong depletion in K, Rb, and Ba, their modal variability and the zoned structure of some pyroxenites. Pyroxenites with high MgO (HMg) and high-temperature pyroxene megacrysts formed from melts that are genetically related. These rocks have negative Eu anomalies, show *LREE* enrichment in minerals and bulk rocks (*LREE, HREE* 0.5–20 × chondrites), $^{87}Sr/^{86}Sr$ of 0.7080–0.7089 and ε_{Nd} (335 Ma) of −2.3 to −4.8 (clinopyroxenes and garnets). In normalized element concentration diagrams HMg pyroxenites and megacrysts show negative Ta, P and Ti anomalies. Equilibrium melt compositions calculated from the cumulate compositions have very high *LREE* abundances (La_n = 300–600 × chondrites) and show strong *LREE* fractionation (La/Smn = 11–83). On the basis of these features and possible Ti saturation in the melts (tiny rutile inclusions in cumulus garnets) I suggest that these melts were of carbonatitic-melilitic or similar but more primitive composition. Low Ti-solubilities in CO_2-rich melts result in Ti-phase fractionation at high *P*, and this explains negative Ti- and Ta anomalies of melts and pyroxene-garnet cumulates.

Some pyroxenites that have lower MgO (LMg) contents may also be genetically related to the HMg goup, i. e. the melts had similar trace element and isotope characteristics, but others are not. The latter include Al-rich garnet-kyanite clinopyroxenites with positive Eu, Sr, and Ba anomalies, high Na contents, strong *LREE* and *HREE* depletion (0.7–2 × chondrites) and $^{87}Sr/^{86}Sr$ of 0.7036 and ε_{Nd} (335 Ma) of +2.5. These rocks probably represent high-pressure equivalents of subducted plagioclase cumulates. Other LMg pyroxenites, including garnet megacryst aggregates, show inherited *HREE* depletion (as do their equilibrium melts) and less radiogenic $^{87}Sr/^{86}Sr$ (< 0.706) than HMg pyroxenites. Some pyroxenites have low *LREE* abundances (1.2–3 × chondrites), no Eu anomaly and low $^{87}Sr/^{86}Sr$ (<0.704) and ε_{Nd} (+4.6 to −1.1 at 335 Ma). The melts in equilibrium with these rocks must have been derived from material with low time integrated Rb/Sr and Sm/Nd ratios like this might be the case in subducted oceanic basalts which lost their Rb during the subduction process.

Evidence for sediment subduction

The combination of high $^{87}Sr/^{86}Sr$, low ε_{Nd} (335 Ma), and negative Eu anomalies of HMg pyroxenites and megacrysts can be explained if their parent melts were derived from subducted upper crustal rocks such as sediments or granites. High equilibration temperatures (1200–1400°C) and pressures (3–3.5 GPa) of peridotites and pyroxenites indicate that these melts probably came from the underlying asthenosphere. Subduction of sediments is also indicated by a high-pressure, high-temperature calcsilicate marble with enclosed pyroxenites (Becker and Altherr 1992). These rocks tend to have somewhat higher $^{87}Sr/^{86}Sr$ and lower ε_{Nd} than HMg pyroxenites and also show negative Eu anomalies. Sphene and rutile bearing pyroxenites enclosed in the marble are weakly LILE depleted, but strongly depleted in *LREE, MREE,* Sr and P (positive Nb-Ta-Zr-Hf-Ti anomalies) and contain more Fe and Ca but much less Mg than pyroxenites enclosed in peridotites. Pyroxenites enclosed in the calcsilicate marble may represent residues of partial melting or fluid extraction in the eclogite facies. Trace element and isotope compositions of Lower Austrian pyroxenites and related melts are consistent with having formed in a convergent plate margin tectonic setting (marginal basin) as indicated from regional geology. Isotope disequilibrium across modally zoned pyroxenite layers indicates that these pyroxenites cannot have had a residence time longer than 15 Ma in the lower lithospheric mantle at temperatures > 1100°C.

References

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