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Evidence for multi-stage metasomatism of chlorite-amphibole peridotites (Ulten Zone, Italy): Constraints from trace element compositions of hydrous phases

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Abstract

Peridotites from the Ulten Zone (Upper Austroalpine Domain, Central-Eastern Alps, Italy) derive from a mantle wedge environment and record a complex metamorphic history. This study focuses on amphibole–spinel peridotites and chlorite–tremolite peridotites. Chlorite is generally closely intergrown with Cr–spinel, indicating that it grew at the expense of former Al–spinel. No garnet relics or chlorite pseudomorphs after garnet have been found. Moreover, amphibole and chlorite trace element patterns display no fractionation in HREE, suggesting that these chlorite peridotites never equilibrated in the garnet stability field.

On the basis of textures, bulk rock and mineral major and trace element compositions three stages of metasomatism are documented in the mantle rocks. We propose that the earliest stage represents melt impregnation at plagioclase peridotite conditions and is unrelated to subduction. The metasomatism leading to spinel– and chlorite–amphibole peridotites is related to the progressive influx of a fluid with crustal signature, derived from neighbouring subducted continental crust as the mantle wedge peridotites approach the slab. The observation that garnet peridotites and chlorite peridotites, which never equilibrated in the garnet stability field, are hosted within the same gneisses, suggests that slices of mantle wedge peridotite with different *P-T* trajectories can be sampled by subducted and exhumed crust.

Keywords: Chlorite peridotites; Chlorite; Amphibole; Trace elements; Metasomatism; Ulten Zone

1. Introduction

Peridotite boudins enclosed within crustal rocks provide an excellent natural laboratory to study fluid-mediated element transfer in a crust–mantle system at great depth. Of particular interest are garnet peridotites, as a minimum pressure of 1.5 GPa is required to stabilize garnet in lherzolitic compositions (O'Neill, 1981; Robinson and Wood, 1998; Klemme and O'Neill, 2000). The incorporation of garnet peridotites in crustal rocks is a complex problem that is far from being fully understood. Two principal models have been proposed for the incorporation of garnet peridotites in orogenic belts: 1) subduction of oceanic or exhumed subcontinental

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mantle into the garnet peridotite field. Such garnet peridotites often display clear evidence of a prograde metamorphic evolution and are associated with rocks such as rodingites, which clearly formed at shallow conditions (Evans and Trommsdorff, 1978; Trommsdorff et al., 2000); 2) sampling of mantle wedge peridotites by subducted crust followed by exhumation of both. These garnet peridotites preserve evidence of a high-temperature mantle evolution prior to their incorporation into the crust (Brueckner, 1998; Brueckner and Medaris, 2000; Nimis and Morten, 2000). Generally, the country rock gneisses of garnet peridotite lenses do not provide unambiguous evidence for ultra-high pressure metamorphism and hence it is not clear where the peridotites were assembled with the crust.

The Ulten Zone peridotites are one of the best examples of trapped slices of mantle wedge peridotite within continental crust (Morten and Obata, 1990; Nimis and Morten, 2000; Rampone and Morten, 2001; Tumiati et al., 2003; Marocchi et al., 2005; Marocchi, 2006; Scambelluri et al., 2006). In the Ulten Zone numerous small lens-shaped peridotitic bodies are included within high-grade garnet–kyanite gneisses and migmatite basement rocks belonging to the Upper Austroalpine domain (Tonale Nappe). The peridotites represent a portion of the Adria subcontinental mantle wedge, which underwent metasomatic enrichments (i.e. C–O–H fluid influx) during the subduction and likely during the late exhumation of a crustal slab. Seven mineral associations have been described (Morten, 1993; Morten and Trommsdorff, 2003) and related to a complex metamorphic *P*-*T* evolution from high-*T* spinel peridotites to relatively low-*T* garnet peridotites. The transition from spinel peridotites ($P = 1.5$ GPa, $T = 1200$ °C) to garnet (±amphibole)-peridotites associated with an increase in pressure and concomitant cooling ($P = 2.7$ GPa, $T = 850$ °C) has been interpreted as the result of corner flow within the mantle wedge followed by the incorporation of peridotites in a downgoing continental slab (Nimis and Morten, 2000). Within such an evolution, the chlorite–amphibole-bearing peridotites were interpreted by Obata and Morten (1987) as retrogressed garnet peridotite and were as such related to the exhumation of the peridotites (Morten and Trommsdorff, 2003). We have attempted to test this hypothesis with in situ trace element analyses of porphyroblastic minerals.

The main aim of this paper is to investigate in detail the metasomatic imprints recorded in chlorite–amphibole peridotites from the Ulten Zone. Previous studies of trace element characteristics of bulk-rocks and of main mineral phases revealed that the Ulten peridotites underwent multi-stage metasomatic events. An early metasomatic event led to Light Rare Earth Elements (LREE) and some Large Ion Lithophile Element (LILE) enrichment in spinel peridotites and has been interpreted to reflect interaction of subduction related magmas with peridotites at temperatures of ~1200 °C (Scambelluri et al., 2006). Extensive metasomatism at much lower temperatures of ~850 °C but higher pressures of ~2.7 GPa is documented at the transition from anhydrous spinel peridotites to hydrous amphibole–garnet peridotites. This metasomatism is well documented in LILE and LREE enriched amphibole and has been interpreted to reflect the influx of an aqueous fluid related to subducted continental crust (Morten and Obata, 1990; Rampone and Morten, 2001; Scambelluri et al., 2006).

In this study we report bulk rock major and trace element compositions of chlorite–amphibole peridotites and compare them to garnet peridotites to evaluate whether or not these rocks derive from the same protolith and share a common history of metasomatism. In situ trace element patterns of chlorite and amphibole in these peridotites provide constraints on the composition of the fluid phase that was present during exhumation. We compare the trace element composition of such amphiboles with amphiboles formed in equilibrium with garnet, to evaluate whether or not significant changes in fluid composition took place during the retrograde evolution of the peridotites. Furthermore, we will discuss the importance of the new data to better constrain the incorporation of peridotites into the country rock gneisses.

2. Geological setting and sample location

The Ulten Zone (Tonale Nappe, Upper Austroalpine Domain) forms a NNE striking belt, which is about 12 km long and 2–3 km wide. It is bounded to the NW by the Val Clapa Line and to the SE by the Rumo Line (Morten et al., 1976) (Fig. 1). The Ulten Zone is made of massive and foliated garnet–kyanite-bearing granulitic gneisses, migmatites, orthogneisses including small pods of eclogitic metabasites and small bodies of peridotites (Obata and Morten, 1987; Godard et al., 1996). The area has been the subject of several tectono-stratigraphic and petrological works (Morten et al., 2004 and references therein); the reader is referred to the above review paper for a more thorough description.

Most of the peridotite outcrops are lens-shaped bodies (*boudins*) with the major axis generally at least three times as long as the minor one. The peridotitic bodies, a few to ten metres thick and a few tens to hundreds metres long, form a discontinuous horizon between the