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REE distribution, mobilization and fractionation in the coesite-bearing 'pyrope quartzite' and related rocks of the Dora-Maira Massif, Western Alps

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Abstract: Rare earth element (REE) concentrations of ultrahigh-pressure (UH*P*) metamorphic rocks from the Dora-Maira Massif as well as of their granitic country rocks were investigated to evaluate their primary relationships. Additionally, retrograde derivatives of these rocks and mineral separates of pyrope, phengite, and monazite from 'pyrope quartzite' were analyzed to study the REE fractionation behaviour and mobilization conditions. Comparative REE studies were performed on leucophyllite from the Eastern Alps that had formed along shear zones in granite gneiss, and whiteschist of evaporitic origin from Afghanistan.

While the 'pyrope quartzite' rocks typically show flat chondrite-normalized REE patterns, their retrograde products are distinctly depleted in heavy REEs (HREEs). The REE distribution patterns of all granitic country-rock gneiss, phengite schist- and garnet-jadeite-quartz-layer intercalations within 'pyrope quartzite' are nearly identical, whereas the 'pyrope quartzite' shows variations in total REE contents. Nevertheless, all 'pyrope quartzite' spectra are parallel to each other and follow those of the surrounding orthogneiss. The whole suite of rock types is characterized by a distinct negative europium anomaly typical for differentiated material of the continental crust. Pyrope shows an enrichment of the HREEs. During the retrograde breakdown of pyrope to a chlorite-bearing assemblage, these elements became mobilized and were partly removed. As a result, the HREEs in these altered rocks are depleted. Monazite shows an enrichment of all, especially light, REEs, whereas in phengite only the light REEs (LREEs) La, Ce, and Nd were detected.

The metasomatically formed 'pyrope quartzite' still preserves its original crustal REE pattern in spite of the strong major- and minor-element changes during the prograde stage. The REEs, which were incorporated into garnet and monazite, behaved immobile. However, during slight retrograde fluid infiltration the REEs may become partly mobilized. This contrasting mobilization behaviour is related to the fractionation of the REEs into newly growing phases.

The original crustal REE distribution spectrum of 'pyrope quartzite' maintained during Mg-metasomatism is not diagnostic for a specific protolith, thus fitting the REE distributions of both, the Afghanistan whiteschists and the leucophyllite samples as well.

Key-words: Dora-Maira, 'pyrope quartzite', whiteschist, UHP, mobility of REEs, metasomatism.

1. Introduction

Advances in understanding the geochemistry of the rare earth elements (REE) have primarily been used to study the evolution of igneous rocks, lower crustal processes, and sedimentary provenance. Metamorphic rocks have received much less attention in regard to their total REE content, the mineral hosts of REE, and questions of REE mobility during metamorphism (Grauch, 1989).

The coesite-bearing unit with its ultrahigh-pressure (UH*P*) rocks is part of a metamorphic nappe system located in the southern part of the Dora-Maira Massif, Western Alps (*e.g.*, Chopin, 1984; Chopin *et al.*, 1991; Compagnoni *et al.*, 1994). Especially the unique 'pyrope quartzite' of that unit is of particular interest, since it is highly enriched in Mg, and depleted in Fe, Ca, and Na (Schertl & Schreyer, 2008). The term ''whiteschist'', introduced by Schreyer (1973, 1974) for a rock type characterized by a talc + kyanite-bearing mineral assemblage, is also quite often synonymously used there for the 'pyrope quartzite'. Based on extensive petrological and geochronological work (*e.g.*, Chopin, 1987; Schertl *et al.*, 1991; Tilton *et al.*, 1991; Gebauer *et al.*, 1997; Simon *et al.*, 1997; Compagnoni & Hirajima, 2001; Hermann, 2003; Groppo *et al.*, 2006; for further references see Schertl & Schreyer,

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