

Residence of *REE* in low-temperature eclogites from Ligurian Alps, north western Italy: the role of accessory minerals

R. Tribuzio
R. Vannucci
P. Bottazzi
L. Ottolini

Dipartimento di Scienze della Terra, Università di Pavia, via
Abbiategrosso 209, Pavia, Italy
Centro di Studio per la Cristalloghica e la Cristallografia,
C.N.R., via Abbiategrosso 209, Pavia, Italy

Introduction

The ophiolites of Ligurian Alps were subjected to pervasive re-equilibration under low-temperature eclogite facies conditions, as a result of a subduction event probably of Cretaceous-Eocene age (Ernst, 1976). Eclogitized Fe-Ti-gabbros developed the bimineralic assemblage of omphacite and Fe-rich garnet, with coronitic to mylonitic textures caused by stress gradient during synmetamorphic deformation. The involvement of fluids during eclogite facies metamorphism, probably related to the breakdown of hydrous minerals developed during the preceding ocean-floor metamorphism, is testified by the local occurrence of garnet (\pm omphacite \pm rutile) veins.

In coronitic eclogites, high pressure clinopyroxenes have different *REE* compositions which reflect the original distribution of the major igneous minerals (Messiga *et al.*, 1994). Clinopyroxenes from mylonitic eclogites show homogeneous *REE* compositions, due to the enlargement of reaction domains into the shear zones. The eclogitic clinopyroxenes, as well as garnets, invariably show a marked *LREE*-depletion (Fig. 1), stronger than that of igneous diopside relics from coronitic eclogites which have $La_N/Sm_N \approx 0.2$. In order to unravel the *REE* redistribution during the eclogite facies metamorphism, accessory apatites and allanites from an eclogite sample were analyzed using a Cameca IMS 4F ion microprobe.

Results

The studied eclogite is deformed and consist of omphacite porphyroclasts, pseudomorphs after igneous diopsides, in a fine grained matrix of omphacite and garnet. Apatite occurs ($\approx 3\%$ by volume) in thin discontinuous layers, associated to elongated rutile and minor ilmenite. Orange Fe-rich allanite occurs as a micro-accessory ($< 50 \mu m$) within both omphacites and garnets; the

modal percentage is lower than 1%. Other accessory phases are quartz and Fe-sulphides.

Apatites display high *REE* contents ($\approx 10^3 \times C1$); their pattern is characterized by slight *MREE*-enrichment and negative Eu anomaly (Fig. 1). Allanites have extremely high amounts of *LREE* ($\approx 10^5 \times C1$; Fig. 1), with a slight Nd-

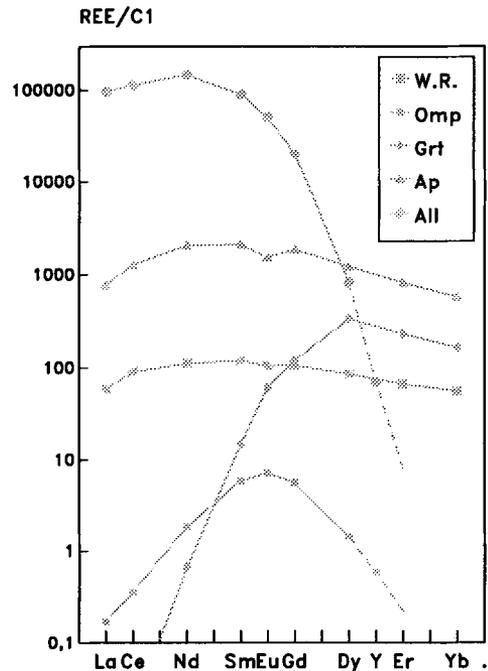


FIG. 1. Chondrite-normalized *REE* patterns for minerals and whole rock of an eclogitized Fe-Ti-gabbro. Mineral analyses by means of SIMS technique. Apatite and allanite compositions are the average of three spot analyses; omphacite and garnet (Messiga *et al.*, 1994) are the average of five and six spot analyses, respectively. In omphacite and allanite, Y has been considered as corresponding to Ho, on the basis of charge and ionic radius. Whole rock by inductively coupled plasma emission spectroscopy.

enrichment over the neighbouring *REE* and an abrupt *HREE*-depletion. Garnets show a strong *HREE*-enrichment relative to *LREE*, with a marked outward *HREE* decrease within a single grain (Messiga *et al.*, 1994). Omphacites have low *REE* amounts: their bell-shaped *REE* pattern is related to the coexistence with allanite and garnet, which preferably incorporate *LREE* and *HREE*, respectively. The *REE* signals in rutile are not detectable with the ion microprobe.

Discussion

Literature data refer to apatites and allanites from terranes with high to intermediate *dT/dP* gradients and generally show steadily decreasing *REE* patterns from La to *HREE* (e.g., Lipin and McKay, 1989). In contrast, our data indicate a slight *MREE*-enrichment in apatites and a maximum value at Nd in allanites. These differences could be related to crystal-chemical constraints. The size of the crystallographic sites which incorporate the *REE* in both apatite and allanite presumably decreases with decreasing *dT/dP* gradients. This would favour the incorporation of *REE* with smaller ionic radius, i.e. Nd relative to La and Ce.

Mass balance calculations, based on mineral modes, indicate that *LREE* are almost entirely incorporated into allanite and apatite. *MREE* are partitioned among the different minerals, but the omphacite contribution to the whole rock is invariably lower than 5%. Calculations for *HREE* are affected by large uncertainty related to the strong zoning in garnets, but indicate that *HREE* reside in garnet (c. 75%) and apatite. The omphacite contribution to the total whole rock *REE* budget is extremely subordinate (c. 1%).

The eclogite protolith could contain significant amounts of accessory apatite, whereas allanite must have developed during the eclogite metamorphism. Allanite probably concentrated the *LREE* once retained by the major igneous minerals, i.e. plagioclase and diopside. Part of the *LREE* in allanite could have been released by igneous apatites, due to re-equilibration under eclogite facies conditions. The crystallization of allanite could be related to the presence of a syneclogitic hydrous fluid phase, in which *LREE* are preferably partitioned relative to clinopyroxene and garnet (see the experimental data of Mysen, 1983). This agrees with the finding of monazites as daughter crystals of aqueous fluid inclusions in eclogitized Fe-Ti-gabbros of Monviso (western Alps; Philippot and Selverstone, 1991).

The redistribution of *REE* in subduction-related eclogites is strongly controlled by accessory minerals. The stability of these phases is therefore of fundamental importance in modeling the metasomatic effects of a subducting slab on the overlying mantle wedge.

References

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