Geophysical Research Abstracts, Vol. 7, 07175, 2005
SRef-ID: 1607-7962/gra/EGU05-A-07175

Petrological approach to unravel the meaning of Lu-Hf garnet ages in eclogites

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One of the challenges of geochronology of metamorphic rocks is to relate the ages obtained to the conditions of metamorphism. A major advance in this respect is Lu-Hf geochronology, which allows dating of garnet, a major rock-forming mineral in metamorphic rocks that is very suitable for thermobarometric studies. We apply petrological and geochemical methods to achieve a better understanding of the distribution of Lu and Hf in eclogites. The evolution of this distribution sheds light on the PT-conditions at which the Lu-Hf signature of garnet was acquired.

For a known bulk composition the metamorphic assemblages can be modelled using DOMINO (de Capitani, 1994). The sequences and modes at which garnet and other rock-forming minerals occur can be predicted and distribution coefficients of Lu for a variety of metamorphic minerals then allow us to predict the distribution of Lu in garnet. Assuming the Lu-Hf signature of garnet is fixed during crystallisation (Lapen et al., 2003), this distribution can be used to predict which part of the PT-trajectory is reflected by the ages from the mineral isochrons. Alternatively, if metamorphism occurred at high temperature, Lu-Hf ages may reflect isotopic closure during cooling. The closure temperature of the Lu-Hf system is poorly constrained, but thought to be $>$700 ˚C (Scherer et al., 2000; Lapen et al., 2003).

In addition to Lu-Hf geochronology of mineral separates (Grt, Cpx, Amp) and WR powders, we performed detailed petrological studies on two eclogites from the Central Alps, to characterise their metamorphic evolution. We contrast results from a par-

tially retrogressed eclogite in which garnet is strongly zoned in major elements (Alpe Repiano) with those from an eclogite with homogeneous garnet (Alpe Arami). The trace element distribution in garnet was determined using laser ablation ICP-MS. In the Repiano sample, the distribution of Y and the HREE in garnet mimics Ca and Fe-zoning, with elevated values in the core, and low contents at the rims. In contrast, Hf is homogeneously distributed throughout these garnets. Knowledge of Lu-zoning in garnet allows us to link areas of the garnet with concentrations measured in separates and ages calculated using those separates. We note, however, that separates are mixtures, hence this comparison only indicates whether separates are dominated by core or rim fractions. The occurrence of zoning indicates that Lu-diffusion plays a minor role and therefore, isochrons calculated using different garnet separates likely reflect mixed growth ages.

Garnets that show no zoning in major elements yield nearly flat patterns for all measured trace elements (Alpe Arami). This indicates an overall equilibration of these elements. Lu-Hf geochronology produces an isochron with a 39 Ma age. The complete equilibration of nearly all elements is reflected by the fact that the Sm-Nd age for this rock is the same within error (Becker, 1993). Possible causes for such a homogeneous distribution of elements are: (1) complete metamorphic recrystallisation; (2) slow magmatic crystallisation from a melt; (3) solid state diffusion. Based on a comparison of data for different isotopic systems and the identical age of garnet in the adjacent garnet-peridotite body, we argue that the Lu-Hf and Sm-Nd ages of Alpe Arami are cooling ages, in contrast to the Lu-Hf garnet crystallisation ages of Alpe Repiano.

References:

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