Geophysical Research Abstracts, Vol. 7, 01787, 2005
SRef-ID: 1607-7962/gra/EGU05-A-01787

Insight into the volatile budget of subduction zones using garnet growth zonation patterns from high- and ultra-high pressure rocks

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Chemical growth zonation patterns in metamorphic garnets contain information about the pressure and temperature conditions as well as about the chemical properties of the surrounding rock matrix during metamorphism. This is because the composition of garnet depends on pressure (P), temperature (T) and also on the chemical composition (X) of the matrix in equilibrium with the mineral surface. During metamorphism the bulk chemistry of the host rock changes progressively due to fractional mineral crystallisation and fluid fractionation. Thus, changing volatile contents of the host rock during the metamorphic evolution may be recorded in the garnet growth zonation pattern. Because cation diffusion in garnet is sufficiently slow to preserve compositional differences within a grain, the interpretation of the zonation patterns yields insight into the fluid evolution during metamorphism. Nevertheless, the interpretation of the zonation patterns using conventional thermodynamic equilibrium calculations is inadequate, because once fractional crystallisation during metamorphism is considered, the equilibrium among the phases in the system is a path-dependent function and can only be determined using thermodynamic forward modelling.

We investigated garnet zonation patterns in continentally derived subduction related high pressure rocks of the Western Alpine Sesia-Lanzo zone for 32 sample localities. To gain insight into the crystallisation history of the investigated garnets, we compared the observed garnet zonation patterns with those obtained from thermodynamic forward modelling that considers fractional garnet crystallisation and water fractionation. This revealed three different groups of zonation patterns with a spatial relationship between the shapes of the zonation patterns and sample localities. The compari-

son between modelled and observed garnet zonation patterns shows that the different zonation patterns are caused by differences in the water content, as well as by different devolatilisation-reactions in the subducted rocks during metamorphism. Zonation patterns of garnets from water-saturated host rocks show a typical prograde chemical zonation with steadily increasing pyrope content and increasing X Mg together with a bell shaped spessartine pattern. In contrast, garnets from water-undersaturated rocks have more complex zonation patterns with a characteristic intermediate decrease in pyrope and X Mg. In some cases garnets with an abrupt compositional change between core and rim, possibly the result of water-undersaturation prior to HP metamorphism, can be found in the central part of the Sesia-Lanzo zone.

The water content as well as the devolatilisation behaviour of the subducted slab during burial has significant influence on the physical properties of the subducted rocks. Due to enhanced garnet crystallisation water-undersaturated rocks become denser than their water-saturated pendants during burial, facilitating the subduction of continental material. Although water bearing phases such as phengite and epidote are stable up to eclogite facies conditions in these rocks, dehydration reactions during subduction are lacking in water-undersaturated rocks up to the transition to the eclogite facies. The lack of significant dehydration during subduction explains the preservation of the chemical properties of the fluids incorporated in the hydrous phases, a feature often observed in HP and UHP rocks, and enables the recycling of primary fluids into the mantle.

Our results show that the interpretation of the garnet growth zonation patterns from high- and ultra-high-pressure rocks gives insight into the water content of the host rock and devolatilisation reactions during burial and therefore enables one to quantify the volatile budget in subduction zones.