

ELEMENT AND ISOTOPIC ZONING IN NATURAL ALPINE QUARTZ

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Abstract

Stable isotope geochemistry is used to help resolve a large number of geological questions. In order to do this, it is essential to understand the different mechanisms that govern isotopic fractionation processes between different phases and to identify the conditions required to reach equilibrium fractionation. However, at low temperatures, these processes are poorly constrained and many factors can induce differential partitioning of the isotopes between sectors of a mineral species and the fluid during mineral growth. This can result in so-called 'sector zoning' of a mineral species.

The aim of this thesis is to evaluate the occurrence of sector zoning of the oxygen isotopes and trace elements in natural α -quartz crystals and to identify the reasons for such zoning. The implications for the fluid-mineral interactions are studied in the context of the Alpine metamorphism. The approach chosen has focused on examining the crystal structure, cathodoluminescence appearance (CL), and on relating elemental (e.g. Li, Na, Al, P, K, Ca, Ge, Ti, Fe) to stable oxygen isotope compositions between and along different growth sectors. Low temperature quartz samples were selected from Alpine veins in different localities, where growth conditions have already been well constrained. The mineralogy as well as the isotopic compositions of the host rocks were also investigated, in order to interpret the variations obtained between the different growth stages in the framework of fluid-rock interaction during Alpine metamorphism.

Depending on the growth conditions, most of the studied quartz is strongly zoned in CL, and it reveals corresponding zonations in the trace element content (e.g. growth zoning). Aluminium, substituting for Si in the lattice, was found in concentrations up to 1000's ppma, and its distribution is strongly related to Li and H and to a lesser extent, to Ge. Elemental sector zoning is evident from the distribution of these three elements since they exhibit differences in their respective concentrations between faces for distinct growth zones, with prismatic faces having the lowest Al contents. Quartz from veins in magmatic rocks, for example, tend to have lower Al concentrations and similar concentrations of Li and Ti suggesting also a contribution of these elements from the host rock. The relationship between Al and Li is still correlated. Only Alpine crystals grown at higher temperatures (~400°C) without any CL zoning feature are free of these impurities and do not show such zoning characteristics.

Differences in the $\delta_{18}\text{O}$ values were measured between different faces principally in the Al-enriched growth zones or stages. These results were confirmed by the means of two different methods (*in situ* / non *in situ*). However, it was determined that the Al concentrations do not affect significantly oxygen isotope fractionations at 300°C. The results altogether suggest that the presence of sector zoning in quartz crystals is real, but not universal, and henceforth should be taken into consideration for any use of these systems. The occurrence of disequilibrium partitioning has been enhanced and is possibly related to kinetic processes as well as structural effects that do not affect similarly trace element incorporation and isotopic fractionation.

In situ measurements also revealed fine scale $\delta_{18}\text{O}$ zonations along growth paths that are useful to constrain fluid-rock interactions during Alpine metamorphism. Variations in the $\delta_{18}\text{O}$ values present along growth vectors indicate changes in the fluid composition and origin. Association with oxygen isotope composition of the host rock allows for the deduction of interactions between rocks, veins and consequently fluids, as well as fluid regimes.