# Kinetics of crystal growth and equilibrium domains in eclogite of the Sesia Zone, Western Alps

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## Thesis abstract

Rock textures and zonings are the consequence of growth processes (element diffusion and interface reaction) steered by the environment in which they grew (pressure, differential stress, temperature, fluid and rock composition). The thesis presented here focuses on three different topics, each of it dealing with aspects of mineral growth processes during subduction, in a high-pressure environment. All studies were conducted in the Sesia Zone of the Western European Alps, Italy.

The first study addresses the crystallography and geochemistry of element incorporation in zoisite, one of the major hydrous minerals found in subduction zone rocks. Elements can be incorporated into a mineral structure only on crystallographic sites that offer enough space for the ion and the overall charge balance has to be maintained. Element concentrations are hence limited. Incorporation of some elements produces complex zoning, including hourglass like patterns, which are the focus of the first contribution. Zoisites from Cima di Bonze (Sesia Zone) show spectacular hourglass zoning defined by Fe-content variations. The hourglass zones have a distinct birefringence and a different extinction angle than the regular part of the zoisite. We show by detailed XRD (X-ray diffraction) and confocal Raman analyses that the high Fe-zones are nevertheless zoisite, and not clinozoisite as one might expect. High resolution TEM (transmission electron microscopy) analyses show planar defects on (100) that can be interpreted as small-scale clinozoisite modules. However, these clinozoisites cannot be interpreted as a distinctive thermodynamic phase and the entire mineral has to be considered as zoisite. The miscibility gap between two zoisites ($X_{ep} = 0.1$ and $X_{ep} = 0.15$) can be then definite at 550 ± 50°C and 14 to 20 Kbar.

Strongly zoned garnets in quartz rich metapelite from the Monte Mucrone area (Sesia Zone) show evolution form 3D mushroom- to atoll structure. The second contribution presents textural investigations, garnet zoning and thermodynamic modeling that demonstrate that atoll garnets are the result of two distinctive growth events. (1) Garnet atoll structure is already formed during a prograde Hercynian path from 525 °C and 6.2 kbar to 640 °C and 9 kbar. It results in an initial poikilitic growth followed by a final idiomorphic growth event. (2) Alpine HP garnet are homogenous (550 °C and 20 kbar) and grew around and also inside the Hercynian garnet. Lack of prograde Alpine garnet and fast growth of the HP garnet is explained by the absence of water during much of the prograde path. Water saturation was only observed towards the end, close towards the peak metamorphic conditions.

Diffusion could be a limiting factor for crystal growth. It has also a great importance in geochronology. HP vein inside the metagranitoide of the Monte Mucrone (~300 Ma) was investigated to determine argon diffusion scales during high-pressure metamorphism. $^{40}Ar/^{39}Ar$ biotite ages profile from the vein toward the metagranodiorite show a diffusion curve: old ages (800 Ma) located close to the vein decrease until homogenous 170-150 Ma ages are obtained, two centimeter away from the vein. Centimeter-scale diffusion occurs with help of a fluid phase marked by high chlorine concentrations. Argon diffusion is reduced to a millimeter scale when free fluid is absent. Very short diffusion distance permits to preserve pre-Alpine ages. The 170-150 Ma ages are considered to be geologic meaningful, probably resulting from the extensional tectonics linked to opening of the Tethian ocean.