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Pressure-induced diffusion in natural garnets

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Recent efforts in metamorphic petrology suggest that significant pressure gradients exist on the grain-scale and provide tools for its quantification [1,2]. Here we propose that pressure gradients around coesite inclusions induced diffusion of major elements within garnet crystals upon exhumation. This is based on the fact that the molar mass of garnet endmembers vary between 403 and 497 g/mol, thus up to 23 %.
Whiteschists from the Dora Maira Massive in the Western Alps underwent eclogite facies metamorphism (3.3-4.3 GPa, 720-780 °C) during the Alpine event at 35 Ma [3]. Coesite included in garnet (py0.96gr0.02alm0.02) during the HP stage was partially transformed to quartz during the subsequent, rapid exhumation (from 3.5 to 1 GPa within 2 Ma [4]). Coesite is preserved by maintaining a high pressure on the inclusion wall due to the large volume change of the phase transition. The surface of the host garnet experiences a lower pressure controlled by the exhumation P-T path. This pressure difference should induce diffusion of major elements in the garnet surrounding the inclusion. Element distribution maps show well-defined Fe-rich, Ca-poor halos surrounding the coesite-inclusions. The observed diffusion profiles are in agreement with predictions, assuming a positive ΔP around the inclusions. The results are based on thermodynamic equilibrium calculations assuming heterogeneous pressure [5]. Hence, the observed profiles are interpreted as an equilibrium state reflecting the pressure (stress) distribution within the crystal and can be used as tool to constrain the exhumation path. Understanding the effect of pressure gradients on diffusion and, alternatively, the generation of pressure due to relaxation of chemical gradients by diffusion, is crucial for interpreting P-T-t paths of zoned minerals correctly.

[1] Baumgartner et al. (2010), GSA meeting Denver. [2] Tajčmanová et al. (2014) CMP 32, 195-207. [3] Compagnoni & Rolfo (2003), UHP Metamorphism - EMU notes 5. [4] Rubatto & Hermann (2001), Geology 29, 3-6. [5] Vrijmoed & Podladchikov (submitted).