

Fracture propagation driven by crystal growth and the role of interfacial fluid chemistry

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Crystals that grow confined in pores and cracks may exert a force on their surroundings and thereby drive crack propagation in rocks and other materials. Of particular importance for engineering and cultural heritage is the degradation of building stones due to salt crystallization. The opening of fractures due to crystal growth may also open new pathways for transport of reactive fluids and therefore serve to accelerate the rate of advancement of weathering or replacement fronts.

In order for a growing crystal to actively displace the walls of the confining pore, there must be a liquid film present between the crystal face and the surface of the pore. This film acts as the transport pathway for growth units to the crystal face. The normal stress between the crystal face and the confining wall is transmitted through the disjoining pressure in the liquid film, and the maximum stress which can be exerted is determined by the fluid chemistry and surface properties. The same confined fluid is also present at the crack tip, where it plays a large role in determining the fracture threshold and velocity at low tensile stresses [1,2].

We use a theoretical model of crystal growth in an idealized crack geometry to study how the kinetics of crystal growth and crack propagation are coupled through the confined fluid and the stress in the surrounding bulk solid [3]. The rate of initial crack propagation is found to be limited by subcritical crack growth, while crystal growth becomes the rate limiting step when the crack has grown to sufficient length. The cross-over length is determined by crystal and crack tip kinetics, fluid supersaturation and elastic properties of the surrounding material.

[1] Røyne *et al.* (2011) *J. Geophys. Res.* **116**, B04204 [2] Rostom *et al.* (2012) *Tectonophysics* **583**, 68-75 [3] Røyne *et al.* (2011) *EPL* **96**, 24003

Integration of U-Pb dating, trace elements and oxygen isotopes at the microscale

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The U-Pb chronology of metamorphic events has greatly benefited from the high spatial resolution achievable with microbeam techniques that allows to date individual growth zones in accessory phases. The capability to retrieve trace elements and isotopic information at the same scale has allowed relating ages to metamorphic processes. With the newly developed capacity to analyse oxygen isotopes at the same scale as U-Pb ages, the application of this method to metamorphic fluid-rock interaction is particularly exciting.

The robustness of zircon makes it a prime candidate for retrieving the oxygen composition of pre-metamorphic history. Zircon in high pressure rocks of the Western Alps show different degrees of metamorphic recrystallization. Their age and oxygen composition constrain the timing of fluid circulation and offer insight into its origin and degree of fluid-rock interaction.

Monazite is particularly promising as monitor and timer of fluid-rock interaction as experimental and field studies have shown that monazite readily recrystallizes in the presence of fluids. Analytical protocols and standards have been developed for in-situ oxygen analysis of monazite using the SHRIMP ion microprobe. Accurate measurements require an additional correction for matrix effect due to the variable composition of monazite. This effect is found to be proportional to the Th content of monazite and produces a shift of circa in $\delta^{18}\text{O}$ of 1‰ every 10 wt% of Th. Oxygen isotopes combined with trace element analysis to relate monazite to major mineral offer new opportunities for monazite geochronology in metamorphic rocks.

Allanite preserves multiple growth zones and retains its U-Pb age up to temperatures of at least 700°C. Geochronology of allanite requires adequate corrections for initial Pb composition, particularly for metamorphic domains formed in sub-solidus conditions. For ion microprobe data, robust results are obtained with Th-Pb isochrons. Even in allanite with high amounts of initial Pb (60-95%) isochrons return reasonably accurate and robust ages. Oxygen isotope analysis of allanite is still hampered by significant matrix effects for which a correction scheme is work in progress.