Towards understanding the mechanisms and quantifying the rates of crack growth in rocks

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Cracks govern physical and chemical degradation of natural and artificial materials. In particular, sub-critical crack (SCC) growth in rocks is reckoned to be a significant controlling factor in landscape evolution (Eppes et al. 2018). In order to fully appreciate the role of SCC in geomorphology, we need to understand its causal mechanisms on relevant spatial scales, e.g., intrinsic vs. extrinsic stresses at the crack tip, and understand crack evolution over relevant geological time scales.

To address these issues, we are currently testing the hypothesis that SCC growth is influenced by the presence of atomic scale metastable states at the crack tip. Such metastable states are created by exposure of a rock to ambient ionising radiation (alpha, beta, gamma and cosmic rays) over geological time scales and this exposure results in trapping of electrons or holes at the crystallographic defects. The metastable states, e.g. in feldspar or quartz, can exist for millions of years at about 20 ºC; however, exposure to visible light photons at the crack tip can destroy the metastable states in seconds to days depending on the available light flux. We reckon that the destruction of such metastable states at the crack tip could potentially release the stored lattice energy in the form of phonons (Blaise & Le Gressus 2018) and thus lead to crack tip propagation. This idea is being tested by inter-comparing the sub-critical crack tip velocities in gamma irradiated and non-irradiated ceramics (Figure 1a) and rock materials.

Some of us are also developing a method for constraining the timing of crack propagation by applying the principle of luminescence surface exposure dating (Sohbati et al. 2012); specifically, we map the aforementioned metastable states in feldspar mineral using infra-red stimulated luminescence or photoluminescence (IRSL and IRPL, respectively) (Prasad et al. 2017). We find that a luminescence bleaching front develops parallel to the crack surface due to daylight exposure (Figure 1b), and the positon of this front changes with time. With appropriate calibration, it is possible to translate the distance between the bleaching font and the crack wall in terms of the timing of crack opening.

Here we will present some preliminary results on both these aspects on some ideal/well constrained materials.

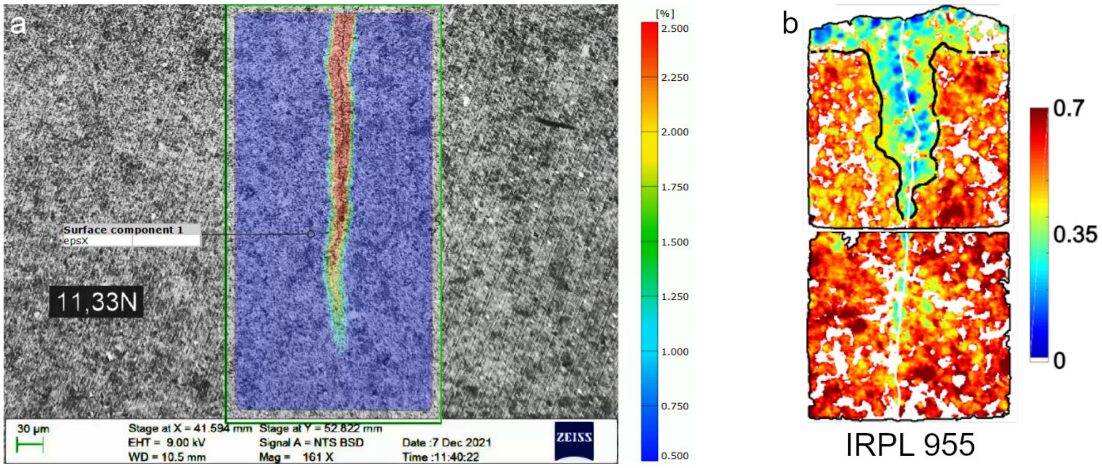

Figure 1. (a) Observation of sub-critical crack growth in Al2O3 ceramics under scanning electron microscope. (b) IRPL map showing the disposition of filled traps (red) and empty traps (blue) around the crack in a naturally exposed boulder. Trap emptying (or the destruction of the metastable states) has occurred due to daylight exposure through the crack surface. The black curve traces the boundary between filled and empty traps, which moves away from the crack as a function of time.

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