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0.1 Alteration halos along tensile cracks in natural rocks - fluid infiltration into the permeable damage zone

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A process zone with inelastic deformation develops around the propagating tip of the macroscopic fracture during faulting and dyke propagation. Within the process zone local failure by both crystal plastic deformation and microcracking may occur concomitantly, driven by the high stress concentration. The advancing process zone at a tip of the propagating crack leaves a wake of damage to both sides of the fracture surface. The width of this wake is controlled by the diameter of the process zone. In many natural rocks, where the fractures formed at elevated temperatures, this damage zone is well visible in the field due to conspicuous alteration driven by the infiltration of a fluid phase. The alteration halos appear internally homogeneous and have sharp boundaries. The main fracture is widened and filled with minerals precipitated from the fluid phase, forming a vein.

On the microscopic scale, the original nature of the damage is blurred by mineral reactions, mainly hydration reactions in an open system, and healing of microcracks, both being controlled by fluid infiltration into the zone with transient high crack permeability.

The microcrack density measured in specific minerals is found to be a bell-shaped function of distance from the main fracture. Within the damage zone it is about one order of magnitude higher compared to the background value beyond, and decays over a short distance at the boundary of the macroscopically visible alteration halo.

Analysis of a large number of tensile cracks with conspicuous alteration halos shows that the width of the damage zone is correlated with the width of the open main fracture (i.e. the central vein). For well defined alteration halos in igneous rocks, the ratio is similar to 10. In contrast to faults [1], for tensile cracks the damage is created at a single instant and not expected to undergo later modification. The width of the alteration halo is defined by the radius of the process zone at the instant of passage of the crack tip. For one specific fracture event in a given rock at given environmental conditions, i.e. temperature and confining pressure, the diameter of the process zone depends on the fracture toughness value [2]. The systematic relation between the width of the main fracture and the width of the flanking damage zone implies that the final opening width of the fracture is already pre-determined at the stage of crack propagation. This may also hold for the presumably correlated [3] length of the cracks. Notably, such characteristics are expected to apply to artificial hydrofractures, as created in hot dry rock geothermal reservoirs, with the extent and microcrack density of the damage zone (representing the specific fluid-rock interface) probably controlling the fluid rock interaction, which may be crucial for the lifetime of the heat exchanger.

[1] Vermilye and Scholz 1998

[2] Engvik et al. 2005

[3] Vermilye and Scholz 1995