Fluid-assisted healing of micro-cracks in fault damage zones

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Abstract

Micro-cracks in damage fault zones can heal through diffusive mass transfer, driven by differences in chemical potential due to surface curvature, and whose rates are controlled by temperature and pressure. In the absence of saturating fluids, cracks can only heal if faces are in contact. Thus, fluid circulation, in damage zones, can cause local temperature changes, accelerate ions migration and assist healing processes. In this work, we use a coupled fluid flow, heat transfer and crack healing model to investigate the role of hot fluid migration, along the Alpine fault in New Zealand, in healing and reshaping its damage zone structure. The drilling project through the Alpine fault in New Zealand revealed two important things: i) high geothermal gradient (125degC/km) within 50m from fault core and relatively lower geothermal gradient (60degC/km) at distances far from the core and ii) a 20-40m chemically altered zone, with reduced permeability, adjacent to the fault slipping zone, while the highest permeability was measured in regions 100m further from the fault core. Thus, the damage zone immediately adjacent to the fault core is not the interval with the highest permeability. This is dissimilar to previous studies, of fault damage zones, that find clear decays in permeability with increasing distance from the fault core. Our simulation results, during the actual inter-seismic period, show that the unusual permeability structure of the Alpine fault zone is due to healing by diffusive mass transfer, favored by the high geothermal gradients and fluid migration. The fluid flow, driven by topological gradient, requires a high permeability anisotropy, in the fault zone, to localize the alteration in a region of 20-40m. The resulting 20-40m altered zone acts as a barrier, where pressure builds up and changes the fault thermal and hydro conditions and might facilitate its slip. In this case, it is necessary to incorporate permeability evolution to better simulate the seismic cycles of this fault.

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