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Stairway fracture architecture in laminated to finely stratified rocks

Matteo Maggi, Paola Cianfarra, and Francesco Salvini
Università degli Studi Roma Tre, Dipartimento di Scienze, Roma, Italy (matteo.maggi@uniroma3.it)

In this work we present the result of a study dealing on the architecture of fractures in laminated rocks, where they develop accordingly to a stairway architecture. On a section perpendicular to the sedimentary layering/structure intersection, this architecture consists of stepping fracture segments running parallel to the lamination/layering (LaP) connected by ramp segments (R) cutting across the laminations. The presence of lamination produces an anisotropy that deviates the average fracture propagation. The presence of LaP segments strongly influences the fracture induced permeability in these rocks by increasing connectivity. These fractures are formed by either the coalescence of individual fractures (representing the ramp segments) or as the result of a single propagating fracture. Stairway fractures are likely to form during syn-diagenetic conditions. Depending on the original lamination dip, a component of rock sliding may trigger or enhance the fracturing process.
The architecture of stairway fractures is parameterized by the L/R ratio (the ratio between the lengths of the Ramp and LaP segments), the original lamination dip, and the cut-off angle (the angle between the ramp segment of the fracture and the lamination), in turn depending from the stress regime. Successive tilting may tilt the original lamination dip. In this view, the cut-off angle results a particularly suited parameter being related to the interplay between the rheology of the layers and the stress conditions at failure.
A physical model of stairway fractures has been developed considering the effect of the rheological contrast between the layer and the intra-layer infilling, the fluid overpressure and the overburden. The model has been successfully applied to laminated rocks outcrops. The rheological parameters needed to match the observed geometry were obtained using a Montecarlo approach. The obtained rheological parameters are comparable with those presented in the literature and justify the LaP/Ramp proposed model. Two distinct behaviors were found and quantified depending on the original lamination/layers dip. Fluid pressure plays an important role in the development of the LaP segments.
Resulting model may be applied to model fracture-induced permeability in laminated fluid reservoirs.