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Evolution of Vein Networks and Structural Styles of Fracture-Vein Interaction: Insight into the Crack-Seal Process from 3D-DEM Modelling.

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Observations from natural vein systems suggest that preexisting veins can strongly influence fracture localization and propagation in a rock even in cases where the orientation of the stress field is incompatible with the orientation of the new fracture. We employ 3D discrete element simulations to model the evolution and fracture dynamics of crack seal systems. A sensitivity study has shown that variation of the misorientation angle between the vein and fracture as well as the strength ratio between host rock and vein material results in several “structural styles” of fracture-vein interactions:
Veins which are weaker than the host rock tend to localize fracturing into the vein, even at high misorientation angles. Veins stronger than the host rock cause deflection of the fracture tip along the vein- host rock interface. In some cases fractures are arrested at the interface from weak to stronger material. When fractures are propagating from a stronger to a weaker material, macroscopic bifurcation can occur. Complex interactions are favored by low angle between the vein and the fracture, and by high strength contrast. We propose that these structural styles form the basis for criteria to recognize strength contrasts and stress of crack seal systems in nature.
The influence of fracture-vein interactions on the texture and geometry of crack seal veins and vein networks is studied in multiphase 3D DEM Simulations. After fracturing of the model in layer-parallel extension, open fractures are filled with new material and the cohesion of the model is reestablished before it is fractured again. The crack-seal and crack-jump mechanisms ensue naturally from this workflow as a result of the strength of the vein material relative to the host rock. The models enable the study of more complex crack seal vein networks that evolve under more complex cyclic loading conditions with varying orientation of the principal stresses.