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Crack - seal veins - what we learnt since the seminal work of John Ramsay

Janos L. Urai (1) and Paul D. Bons (2)

(1) Structural Geology, Tectonics and Geomechanics, RWTH Aachen University, Germany (j.urai@ged.rwth-aachen.de, (2) Institute for Geosciences, Eberhard Karls University Tübingen, Germany

In the nineteen-eighties, John Ramsay and co-workers have laid the basis for much of our current understanding of tectonic veins, by proposing that tectonic veins accrete in many small increments of cracking and sealing, making the link to cyclic stress and fluid pressure cycles and the earthquake cycle, and by proposing that fibrous veins track the opening trajectory, which has created a toolbox to analyse progressive deformation in rocks. They recognised syntaxial and antitaxial veins, which grow depending on the composition of the wall rock and the vein. Following on these seminal contributions, advances in analysing the microstructure and chemical signature in crack-seal veins made a lot of progress, facilitated by the rapid increase in micro analytical tools like cathodeluminescence and EBSD. Initial modelling of crystal growth in crack- seal veins provided an explanation of how crystals become fibrous without being deformed and explained how fibres sometimes do and sometimes don't follow the opening trajectory. This was followed by numerical models of crystal growth to study the development of crystal facets after larger crack increments, and experimental study of the sealing dynamics of syntaxial veins. These models were initially kinematic, using the ELLE microdynamic simulation package, and more recently incorporating the physics of the growing interface using the Phase Field method, which now allows 3D simulation of both syntaxial and antitaxial veins and can simultaneously compute the evolving permeability of the crack using Lattice Boltzmann techniques. Parallel to these developments we developed an understanding of the strength of the vein cement, and, using Discrete Element Techniques, explored the effects of differences of the strength of the vein and its adhesion to the wall rock on fracture patterns in crack-seal systems in changing stress fields. This presentation will review these developments, showing how the ideas of John Ramsay inspired follow up work leading to a much better understanding of the complex feedback systems between fracture growth, crystal growth and fluid flow in crack-seal systems.