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Cyclical stress drop and stress switching during brittle faulting on a shallow megathrust field analogue (Northern Apennines, Italy).

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One of the most compelling evidences that megathrust subduction interfaces are weak (e.g. Duarte et al., 2015), is the devastating 2011 Tohoku-Oki megaquake, whereby the megathrust accomplished a nearly complete stress drop (Hasegawa et al., 2011; Brodsky et al., 2017) and a co-seismic switching of the maximum and minimum stress orientations (Hasegawa et al., 2012).
We studied the calcite veins of an exhumed thrust fault coming from the base of the Sestola Vidiciatico Tectonic Unit shear zone (SVU, Northern Apennines of Italy), interpreted as a field analogue of the shallow portion of subduction megathrusts (Tmax [U+0334] 100°-150° C) (Vannucchi et al., 2008). Observed crosscutting relationships suggest a cyclical formation of incompatible deformation features: extensional veins exploiting pre-existent cleavage planes at low-angle to the thrust, the main low-angle thrust faults associated with mixed hybrid-shear and implosion-breccia type veins and high-angle extension veins coupled with thrust-parallel pressure solution cleavage (Mittempergher et al., 2018).
To characterize the type of fluids involved, we measured trace elements and Rare Earth Elements (REEs) concentrations by laser ablation-inductively coupled plasma-mass spectrometry (LA-ICPMS) in calcite veins and their wall rock, finding marked difference between REE patterns of extension and shear veins, suggesting different sources of fluid for each type of vein. In particular, a strongly positive Eu2+ anomaly recorded exclusively in the shear veins can derive from an exotic fluid, different in redox conditions and likely higher in temperature. To the contrary, extension veins REE patterns point out for a very local fluid circuit and source.
All these microstructural and geochemical features suggest a cyclical shifting of the principal $\sigma 1$ and $\sigma 3$ stresses through time. This was controlled by interrelated changes in permeability, fluid pressure and composition and easily achieved thanks to the low differential stress, which represented a necessary condition for extension and hybrid veins formation.

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