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Fault Void Fills: Reactivation, frictional melting, and coseismic void formation and collapse during ancient earthquakes

Kit Hardman (1), Robert E Holdsworth (1), Edward D Dempsey (2), and Kenneth J McCaffrey (1)

(1) Durham University, Earth Sciences, United Kingdom (kristian.hardman@durham.ac.uk), (2) School of Environmental Sciences, University of Hull, Hull, UK.

Natural fault systems are typically complex, with networks of potentially inter-linked dilational cavities filled with a variety of geological materials. These "fault void fills" are widely recognised in both subsurface cores, and surface exposures; and are thought to exert a significant control on the potential for fluid migration pathways in the brittle upper crust. The geological characterisitics of these fills, such as fill-type, longevity and connectivity, are likely to vary with depth, so by understanding the formation and filling processes at different paleaeodepths we can begin to make predictions about the hydrodynamic properties of upper crustal fault zones, both in the present day and back through geological time.

Here we examine examples of dilational fault void formation and filling from the Lewisian Complex of the NW Highlands which formed at the base of the seismogenic zone, between 10-15km. Contemporaneous interlinked systems of foliation-parallel faults and cross-cutting 'ladder fractures' and fills are well exposed in part of the Canisp Shear Zone (CSZ) at Achmelvich. These so-called 'Late-Laxfordian' brittle structures post-date ductile Proterozoic deformation, responsible for the formation of the NW-SE sub-vertical shear zone (Inverian, Laxfordian, ca. 1.75-2.4 Ga) and pre-date deposition of the overlying Stoer Group ca 1.2Ga. In the CSZ, NW-SE trending sinistral faults reactivate the ductile shear zone fabric, while the contemporaneous N-S dextral-normal ladder fractures cross cut the foliation at high angles and are widely associated with dilatant zones of brecciation and mineralization (the fault voids). Friction melts (pseudotachylites) are generated along the foliation-parallel fractures and locally injected into ladder fracture void spaces. These fissues are albe to remain open due to propping by infilling breccia clasts and mineral fills. The insights gained at Achmelvich identified new mechanisms for tectonic dilational void formation and filling, showing that even at depths close to 15km, fault networks can preserve cm-scale cavities, enabling and actively driving fluid migration through the upper crust.