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The permeability of fracture intersections in basalt

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Fluid transport within low porosity rocks in the Earths crust is primarily controlled by fracture permeability developed by brittle deformation processes. Field and numerical studies consistently show that the maximum permeability correlates with the direction of greatest fracture connectivity, generally corresponding to the orientation at which fractures intersect. Thus, the dominant permeability has been associated with fracture intersections. However, the transport properties of fracture intersections and quantifying their enhancement on permeability has received surprisingly little attention. Furthermore, how higher permeabilities are maintained at depth under conditions of increasing confining pressures where fracture apertures are expected to close remains a subject of debate. Here we produced an axial fracture intersection using a Brazilian test apparatus on samples of the low porosity (*ca.* 4%) Seljadur basalt (SB), Iceland, with a measured intact rock permeability of $1x10^{-19}m^2$ (Nara et al., 2011, Perez-Flores et al., 2017). Each sample was subjected to two separate tensile loadings at 90 degrees to each other, in order to create two approximately perpendicular axial fracture planes with a single axial intersection. Samples were then pleased in a hydrostatic permeameter, where we measured the permeability at increasing effective pressures in order to look at the pressure dependence of permeability in intersecting fractures. We compare permeability measurements to that of samples with 1) a single axial macrofracture, and 2) three unconnected axial macrofractures. We observe that intersection permeability is between one and two orders of magnitude larger than single fracture permeability. Additionally, the intersections shows a significantly lower pressure sensitivity; relatively high permeabilities are maintained at increasingly higher effective pressures (30 to 90 MPa), where intersection permeability is consistently two orders of magnitude greater than single and triple fracture permeability (approximately $1x10^{-15}m^2$to $1x10^{-17}m^2$). This confirms that fracture intersections are significantly harder to close at higher effective pressures, suggesting that they might play a critical role in maintaining permeability at intermediate to deeper crustal levels. These results may significantly improve the understanding on the development of permeability with brittle deformation as fractures form, coalesce and intersect, and on the intersections capability of maintaining permeability under increasing effective pressures.