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Experimental validation of the harmonic average permeability method for layered rocks

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The permeability of rocks has been a central aspect geoscientific studies since the early efforts of Darcy, as the connectivity of pores and fractures control transfer of fluids in the Earth's crust. Permeability increases non-linearly as a function of porosity for a wide range of rocks (e.g. Dasgupta et al., 2000; Klug and Cashman, 1996) – a relationship often described by the Kozeny-Carman relationship by applying a coefficient which is dependent on the dominant conduit geometry controlling the fluid flow, namely connected pores or planar cracks. For a given porosity, permeability can vary widely, even in coherent, relatively homogeneous samples. But how does a laboratory permeability measurement of single rock compare to the fluid flow through layered units, including sedimentary strata, fault zones and volcanic edifices?

Here, we employed laboratory experiments to measure the permeability implications of layering, using a range of sedimentary and extrusive volcanic rock samples with porosities of 3–55 vol. % comprised of both vesicles and micro-cracks. We used a hydrostatic cell to measure the permeability of individual rock cores at effective pressures up to 2.5 MPa, before measuring permeability of pairs of "stratified" samples. We show that rock permeability increases non-linearly with increasing porosity and decreases with increasing effective pressure, and that samples with fracture-dominated porosities are more sensitive to the latter. We also find that permeability of layered rocks is not straightforward, and is acutely controlled by not only the permeability of the individual units, but also by the coupling between the two units and the permeable pathway morphology (channelised versus diffuse flow). We frame these results with regard to the harmonic average permeability method and discuss the implications for layered media.

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