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Opening-displacement variations in rock fractures

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The opening-displacement (aperture) of rock fractures, when measured along their lengths (strike dimensions) commonly shows irregular variations. This applies, for example, to many mineral veins, ranging in strike dimensions from a few tens of centimetres to many metres. But it applies equally well to large tension fractures and normal faults ranging in strike dimensions from a few hundred metres to many kilometres. For all the fractures, the opening-displacement variations are too large to be explained in terms of inaccuracy in the measurements. Some of the fractures may have reached their present apertures through a single tectonic event, whereas for others the observed apertures are the cumulative results of many tectonic events.

Here we present field data on fracture-aperture variations, as well as new numerical and analytical models to explain these data. The numerical models indicate that any variation in Young's modulus (rock stiffness) along the fracture path, even if the applied loading is constant, results in variation in opening-displacement. This is particularly noticeable in fractures in subvertical sections that dissect mechanical layers with different stiffnesses. For a fluid-driven fracture, for example, the induced tensile stresses ahead of the fracture tip, and thus the eventual opening-displacements, depend strongly on the stiffnesses of the mechanical layers.

When a fracture is subject to constant fluid internal overpressure or a constant external driving stress, its opening-displacement profile becomes that of an ellipse. Here over-

pressure is defined as the difference between the total fluid pressure inside the fracture and the stress acting perpendicular to the fracture walls. Similarly, driving stress is defined as the difference between the remote applied (tensile or shear) stress and the residual strength (tensile or shear) on the fracture surface after opening or sliding. Any variation in stiffness along the fracture height (dip dimension) or fracture length (strike dimension) results in variation in overpressure (for a fluid-driven fracture) or driving stress (for a tension fracture or a fault). And these variations are reflected in the displacement profile of the fracture. For example, when the overpressure variation is given by Fourier cosine series, the opening-displacement, as well as the local displacement and stress fields around the facture, can be calculated. Here we present the results of such calculations and compare them with the field results for the type of fractures indicated above. The results show that this analytical method is very flexible and can be used to model abrupt overpressure and driving-stress variations in vertical and lateral sections for fractures of various sizes and types. The results contribute to our understanding of fracture development in heterogeneous anisotropic rocks masses and crustal segments in general, with implications for fractured reservoirs, seismogenic faulting, and earthquake geology.