**In Situ Stress and Structural Permeability**

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### Structural Permeability

The development of structural permeability is critical to subsurface fluid flow where primary porosities are low. For example, a single fracture 0.25 mm wide has the same effective permeability as 188 m of unfractured rock with a matrix permeability of 10 mD.

Our approach to predicting the occurrence of structural permeability is based on 'Sibsonian' fracture meshes. Field evidence suggests that mesh structures, comprising shear fractures, and/or hybrid extensional/shear, and/or purely extensional fractures, and/or stylolites form conduits for subsurface fluid flow. Note that extensional fracture modes can only form in the absence of suitably oriented, cohesionless faults. If such faults exist, their shear reactivation precludes extensional fractures developing.

The extent to which structural permeability has developed within the contemporary, or within a palaeo-stress field must be assessed. In the latter case, the extent to which the fractures are stress-sensitive should be assessed. If pre-existing, stress-insensitive fractures control permeability, in situ stress data are not of primary significance. However, if fractures are stress-sensitive, or if structural permeability has developed within the contemporary stress field, in situ stress data can be used to help predict the type and orientation of hydraulically-significant mesh structures.

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**Examples of tensile fracturing at the macro-, meso- and micro-scale respectively.** (a) Shale dyke in Brunei. (b) Gypsum veins in Mercia Mudstone, Watchet Harbour, SW England (Cosgrove, 1995). Vein fibres indicating dilational opening. (c) Photomicrograph of tensile vein with crossed polar. Vein fibres indicating dilational opening.

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The conditions for the three brittle failure modes can be represented in terms of differential stress ($\sigma_{1} - \sigma_{3}$), and the effective vertical stress ($\sigma_{v} = \sigma_{n} - \Delta P$). With increasing tensile strength ($T$), the failure line moves further away from the line representing reshear of an optimally oriented, cohesionless fault. For each value of tensile strength there is a transition with increasing $\sigma_{v}$ from pure extension fracturing through extensional-shear to compressional-shear failure. For a heterogeneous rock mass with a range of tensile strengths, mixed-mode brittle failure can lead to the development of structural permeability meshes (Sibson, 1996).

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**Schematic illustration of a structural permeability mesh comprising of interlinked shear, extensional-shear and tensile fractures.** Diagram represents an extensional normal fault stress regime when upright, a compressional thrust fault regime when viewed sideways, and a strike-slip regime in plan view.

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**Structural permeability mesh with infillings of calcite and bitumen, observed in interbedded dolostones, limestone, siliceous shales and mudstones of the Monterey Formation, Arroyo Burro Beach, Santa Barbara (pocket knife indicates scale).**

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**Structural permeability stereonet illustrating the relative likelihood of fracture formation/reactivation in terms of $\Delta P$, incorporating all modes of brittle failure.** Lower hemisphere projection, all points plotted as poles to planes.