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3D anatomy of a composite shale smear: along-strike variations of fault zone architecture of a normal fault in poorly lithified sediments, Miri (Malaysia)

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Shale smearing has long been recognized as one of the key mechanisms for membrane fault sealing. The study site in Miri offers unprecedented 3D along-strike and sub-vertical exposure of a composite shale smear fault architecture. We use this site as a natural laboratory to investigate the linkage of multiple smaller smears into a composite smear and to quantify the risk of discontinuities in the smear, allowing potential leakage across the fault.

The hydraulic behaviour of faults at depth plays an important role in the exploration and production of hydrocarbons, storage of CO_2 and other subsurface engineering applications. Whether a fault acts as a conduit, barrier or combined conduit-barrier to fluid flow is strongly determined by the internal fault zone architecture and by the properties of the fault rocks.

The object of this study is normal fault (20-50 m offset) cutting poorly consolidated deltaic sand-clay sediments of the Baram Delta. The continuity within the fault zone of a single clay smear originating from a 20-30 cm thick footwall bed can be traced up to 2.5 m down-dip (twelve times its thickness) and up to 7 m along-strike. Sand smears, on the other hand, extend for a maximum distance that is double the sand bed thickness.

The fault core is composed of dark, foliated clay and elongated sand lenses. Key observations are related to the along-strike thickness (1 cm - 60 cm) and clay content (<5% - 90%) variability of the fault core. Eight areas that could represent potential cross-fault pathways have been identified over the 56 m of exposed fault. Six of these are due to the thinning of the clay-rich fault core to less than 2 cm, while in the other two areas the clay gouge is interrupted, resulting in sand-on-sand juxtaposition. Microstructural analysis of the samples collected in Miri show particulate flow as the dominant deformation mechanism, combined with minor cataclasis and growth of authigenic clays.

When upscaling this fault architecture to the size of reservoir simulator grid cells, using the average core thickness of the fault (17 cm) would poorly represent the true hydraulic properties of the fault.