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Constraints on 3D fault and fracture distribution in layered volcanic-volcaniclastic sequences from terrestrial LIDAR datasets: Faroe Islands

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Hydrocarbon reservoirs commonly contain an array of fine-scale structures that control fluid flow in the subsurface, such as polyphase fracture networks and small-scale fault zones. These structures are unresolvable using seismic imaging and therefore outcrop-based studies have been used as analogues to characterize fault and fracture networks and assess their impact on fluid flow in the subsurface. To maximize recovery and enhance production, it is essential to understand the geometry, physical properties, and distribution of these structures in 3D. Here we present field data and terrestrial LIDAR-derived 3D, photo-realistic virtual outcrops of fault zones at a range of displacement scales (0.001- 4.5 m) within a volcaniclastic sand- and basaltic lava unit sequence in the Faroe Islands.

Detailed field observations were used to constrain the virtual outcrop dataset, and a workflow has been developed to build a discrete fracture network (DFN) models in GOCAD® from these datasets. Model construction involves three main stages: (1) Georeferencing and processing of LIDAR datasets; (2) Structural interpretation to discriminate between faults, fractures, veins, and joint planes using CAD software and RiSCAN Pro; and (3) Building a 3D DFN in GOCAD®. To test the validity of this workflow, we focus here on a 4.5 m displacement strike-slip fault zone that displays a complex polymodal fracture network in the inter-layered basalt-volcaniclastic sequence, which is well-constrained by field study.

The DFN models support our initial field-based hypothesis that fault zone geometry varies with increasing displacement through volcaniclastic units. Fracture concentration appears to be greatest in the upper lava unit, decreases into the volcaniclastic sediments, and decreases further into the lower lava unit. This distribution of fractures appears to be related to the width of the fault zone and the amount of fault damage on the outcrop. For instance, the fault zone is thicker in the upper lava unit and therefore fracture concentration is higher, while in the lower lava unit, the fault zone is narrower and thus fracture concentration is also low. Both field observations and the DFN model indicate that the faults and fractures are steeper in the basalts, and shallower in the volcaniclastic sequences, giving a 'stepped' geometry. To assess the nature of sub-seismic fracturing, fracture attributes (connectivity, spacing, length, and orientation) within the model were analysed quantitatively.

Continuing work will integrate the detailed field analysis fully, including 1D and 2D fracture transects, structural logging and mapping as well as microstructural characterisation from collected field samples, to understand the complex nature of fracture networks in inter-layered basalt-volcaniclastic sequences. Fracture attributes, such as the shape, length, aspect ratio, curvature and aperture, will be quantified to provide key parameters for fluid flow simulation. Once these attributes have been assessed, experimental data (porosity and permeability) will be incorporated into the DFN model to constrain the fluid flow potential within these inter-layered volcanic sequences.