Seal integrity for hydrogen geostorage in depleted gas reservoirs of Taranaki, New Zealand

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Objectives

- Fracture geometries and properties. Identify faults and fractures in key seal rocks. Investigate their variability in orientations, dimensions, density, width, aperture and fill for different rock types and structural settings.
- Fracture dilation and reactivation (geomechanics). Quantify stress orientations and magnitudes. Examine caprock/seal pressures required to open fracture and promote hydrogen (H_2) migration.
- Fracture modelling. Develop Discrete Fracture Network (DFN) model to investigate possible fluid flow pathways through fracture networks.

Methodology

Data	Quality control	Feature identification	Data processing	Model input parameters
Wireline Image logs (FMI) Core Surface analogues	Tool performance Depth matching 'Stick and pull' Image normalisation	Conductive fractures Resistive fractures Borehole breakout Drilling induced fractures Faults & fractures Bedding	Stress orientation Stress magnitudes Fracture aperture Fracture orientation Fracture density Fault zone architecture	Stress orientation Stress magnitudes Fracture aperture Fracture orientation Fracture density Fault zone architecture

Grey = physical datasets

Future work

- Orientate fracture and fault planes within the *in-situ* stress field to calculate applied normal force.
- Recreate *in-situ* normal stress for different fracture properties under constant normal load direct shear tests. Calculate friction angle.
- Determine which fracture and fault populations are critically stressed and likely to reactivate during H_2 injection/withdrawal scenarios (Figure 6).
- Create DFN vmodels that approximate fracture & fault distributions in the seal, showing critically stressed fracture populations as potentially enhanced fluid flow pathways.
- Use fracture models to assist reservoir scale simulations (Figure 7).

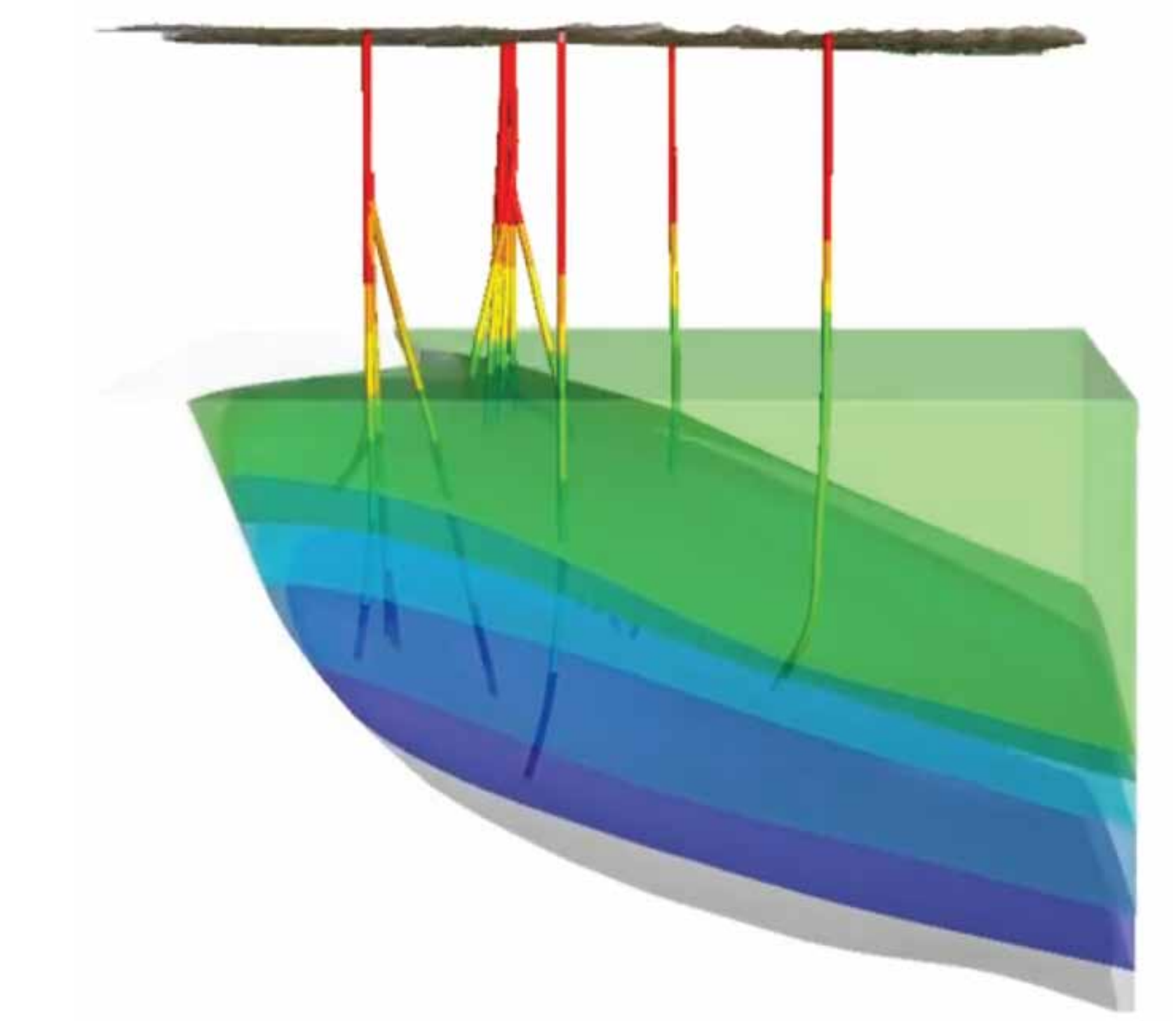


Figure 7: Leapfrog model showing stratigraphy, structure and location of wells in the Ahuroa field, Taranaki, New Zealand. The model is used in conjunction with a DuMux reservoir model to simulate hydrogen injection and withdrawal cycles, please see Parker et al. EGU presentation (2024).

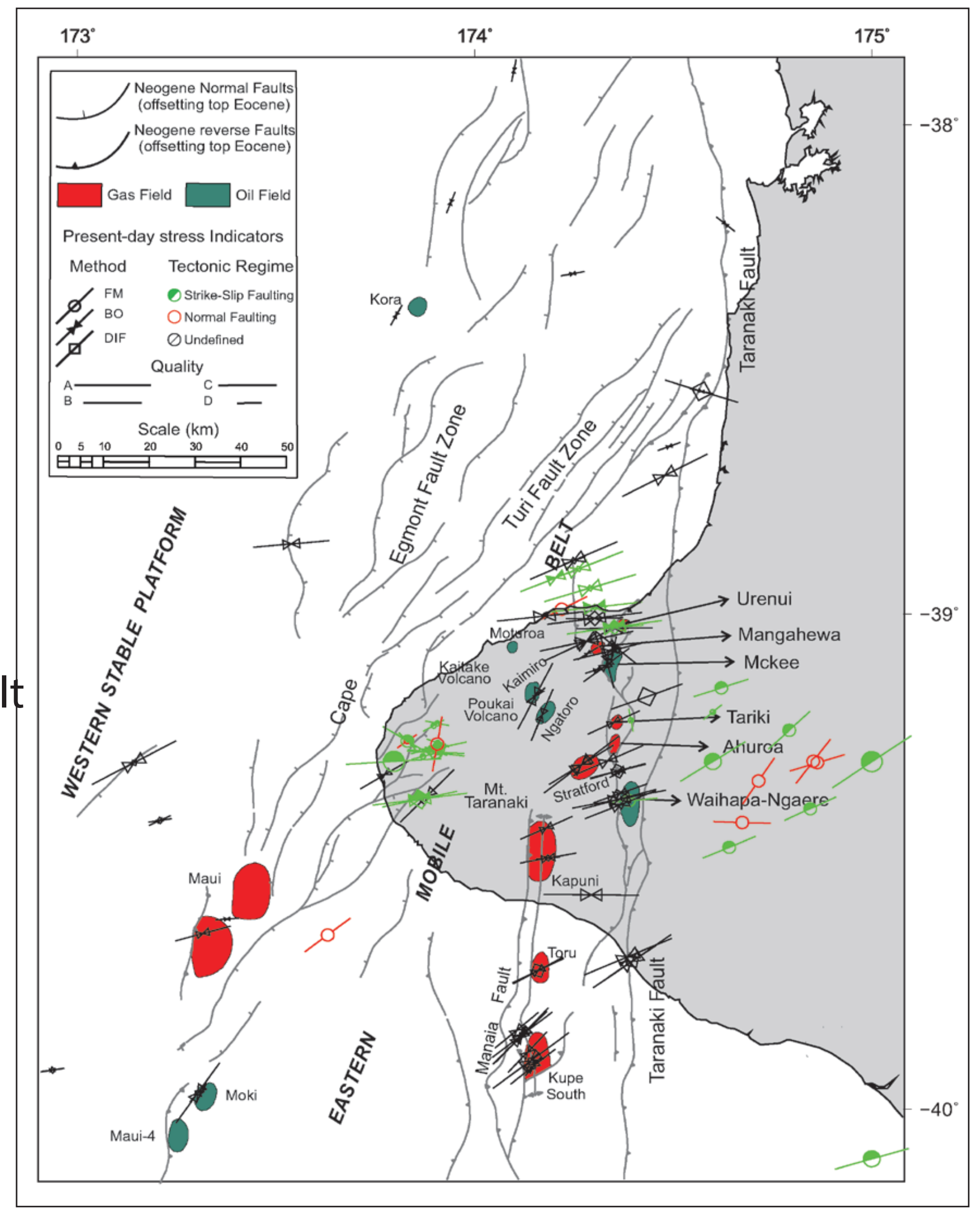


Figure 5: Present day stress map of Taranaki region, New Zealand [1].

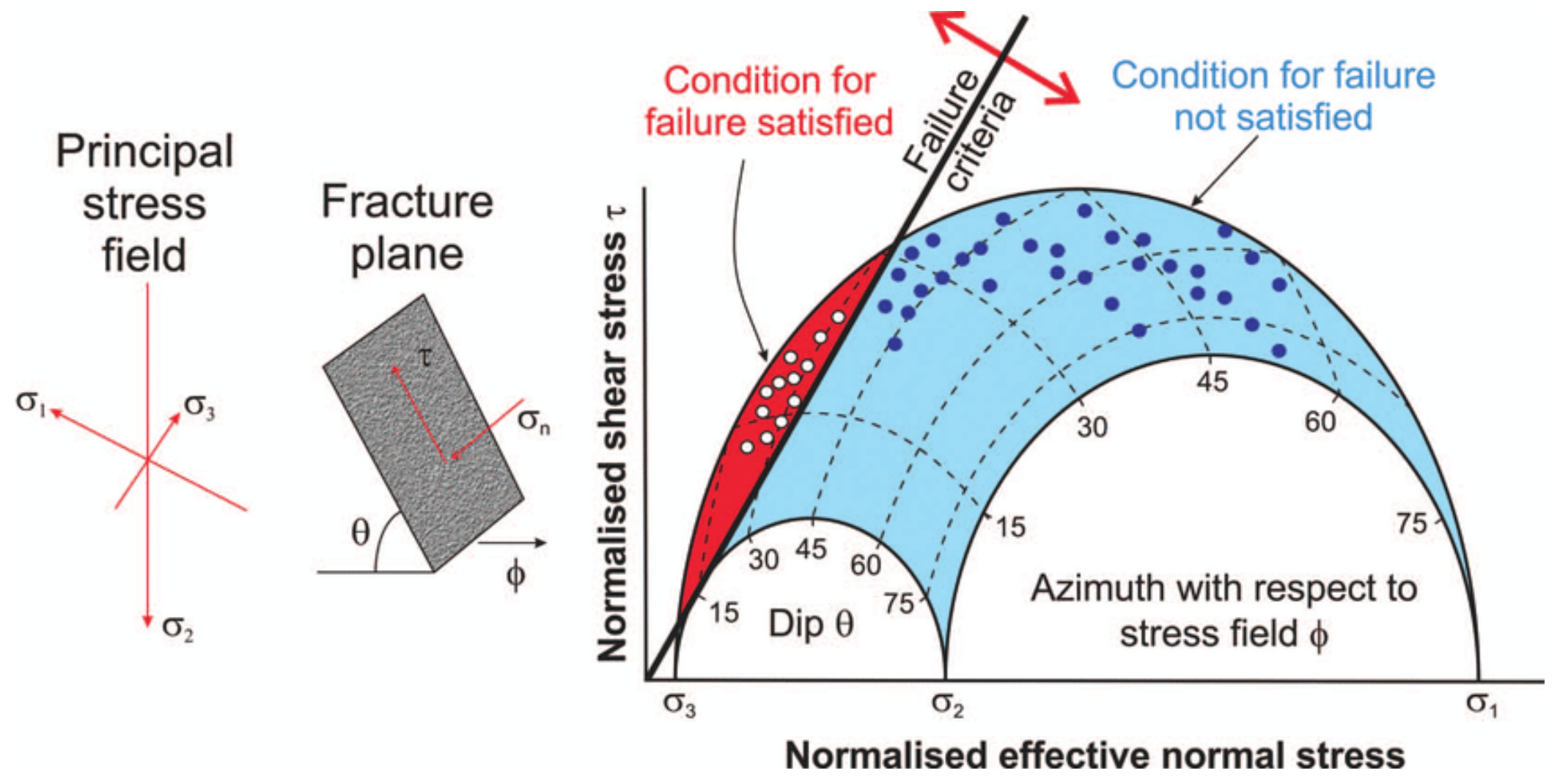


Figure 6: Diagrammatic representation of the critical stress hypothesis where failure of fractures can be predicted given fracture properties and orientation within the principal in-situ stress feild [2].

Analysis

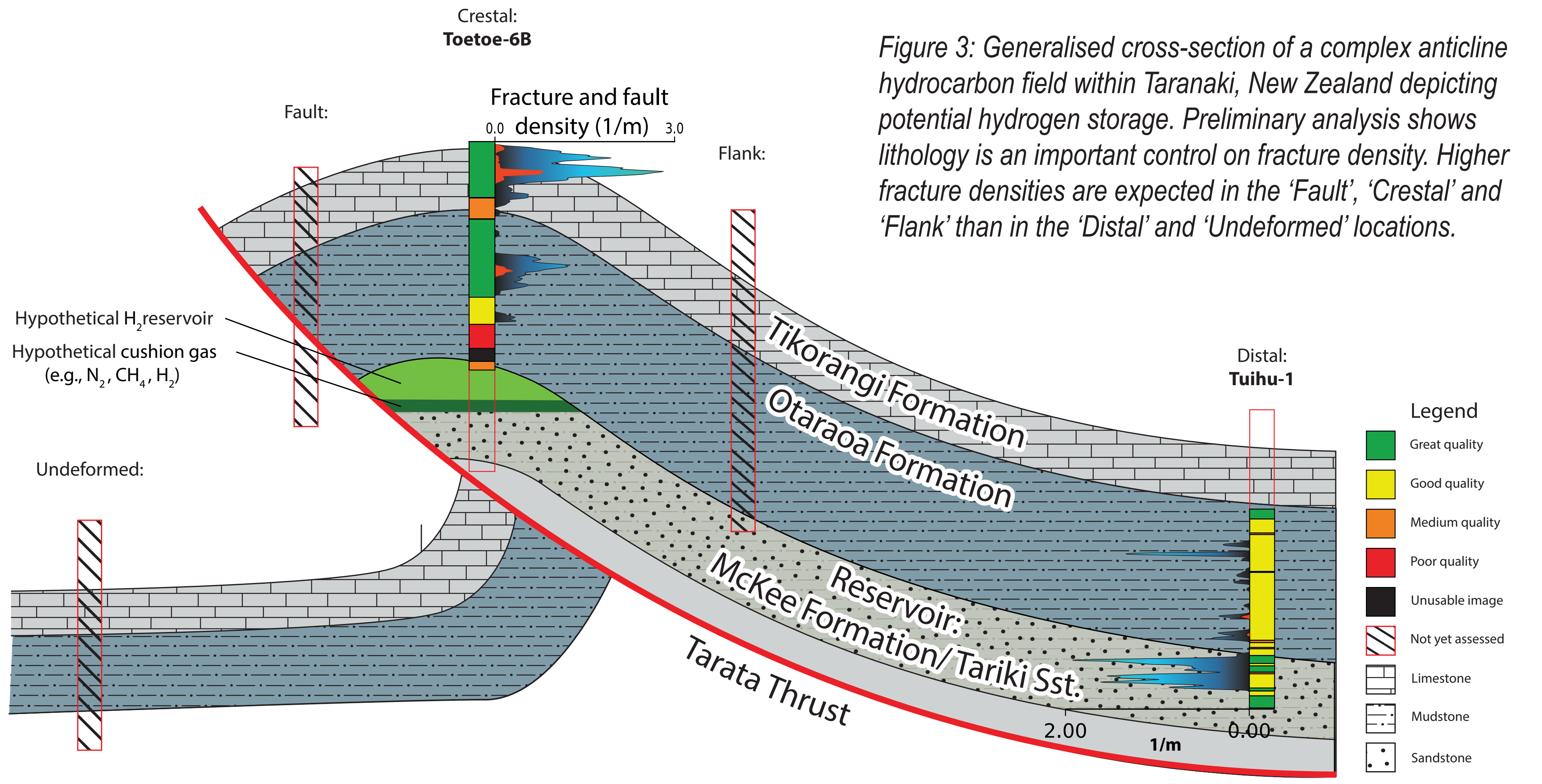
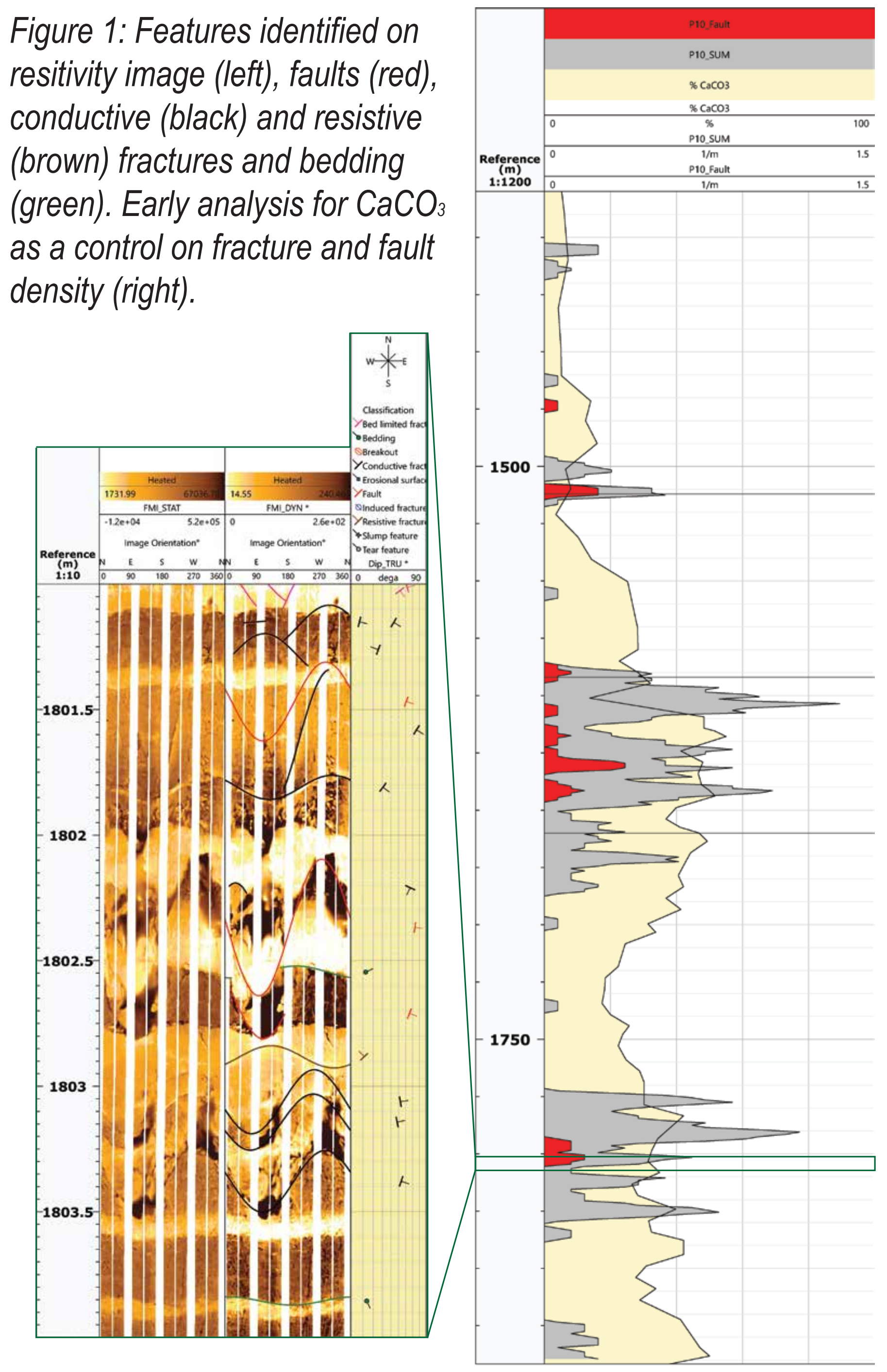


Figure 3: Generalised cross-section of a complex anticline hydrocarbon field within Taranaki, New Zealand depicting potential hydrogen storage. Preliminary analysis shows lithology is an important control on fracture density. Higher fracture densities are expected in the 'Fault', 'Crestal' and 'Flank' than in the 'Distal' and 'Undeformed' locations.

Figure 1: Features identified on resistivity image (left), faults (red), conductive (black) and resistive (brown) fractures and bedding (green). Early analysis for $CaCO_3$ as a control on fracture and fault density (right).



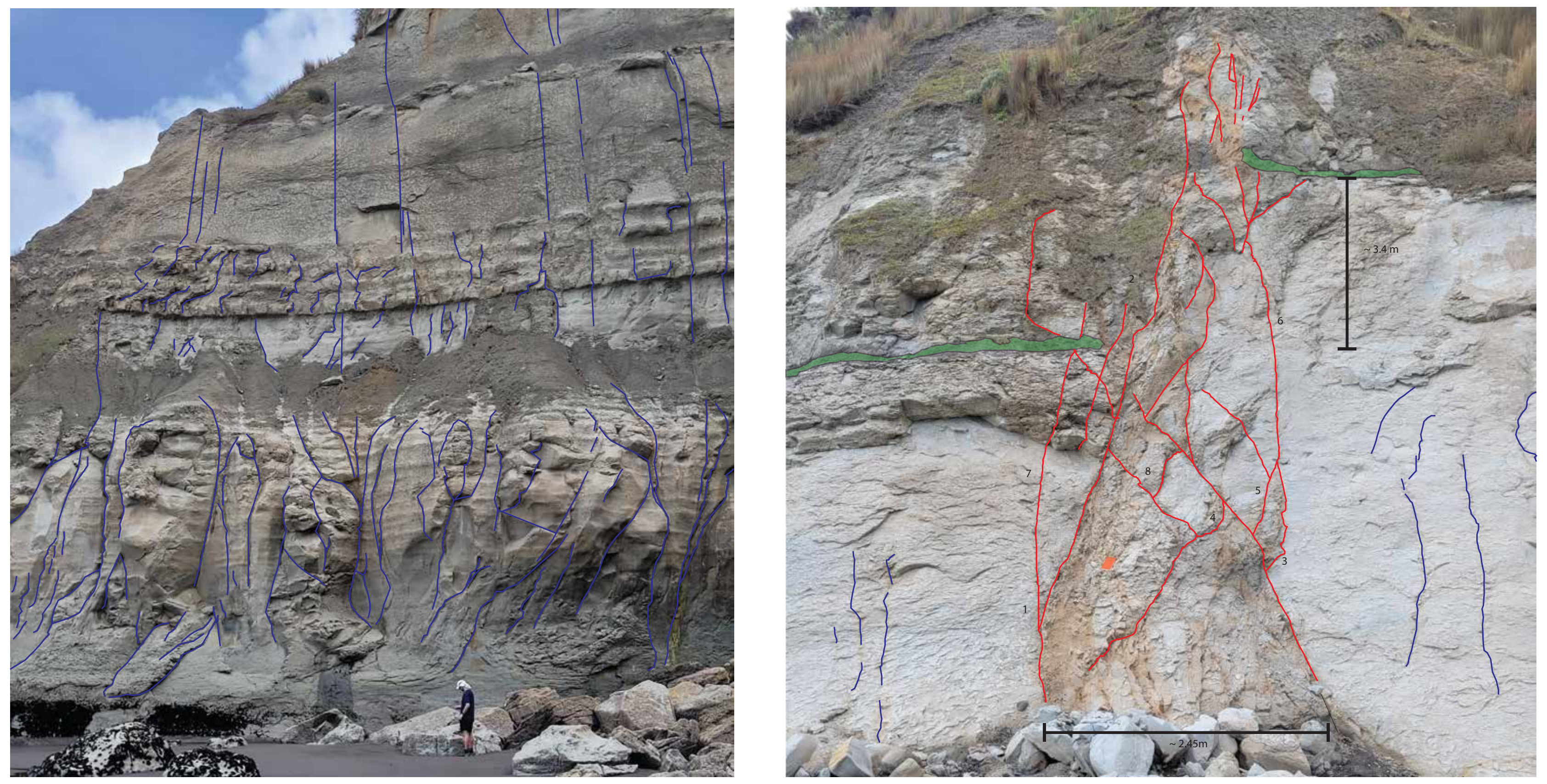
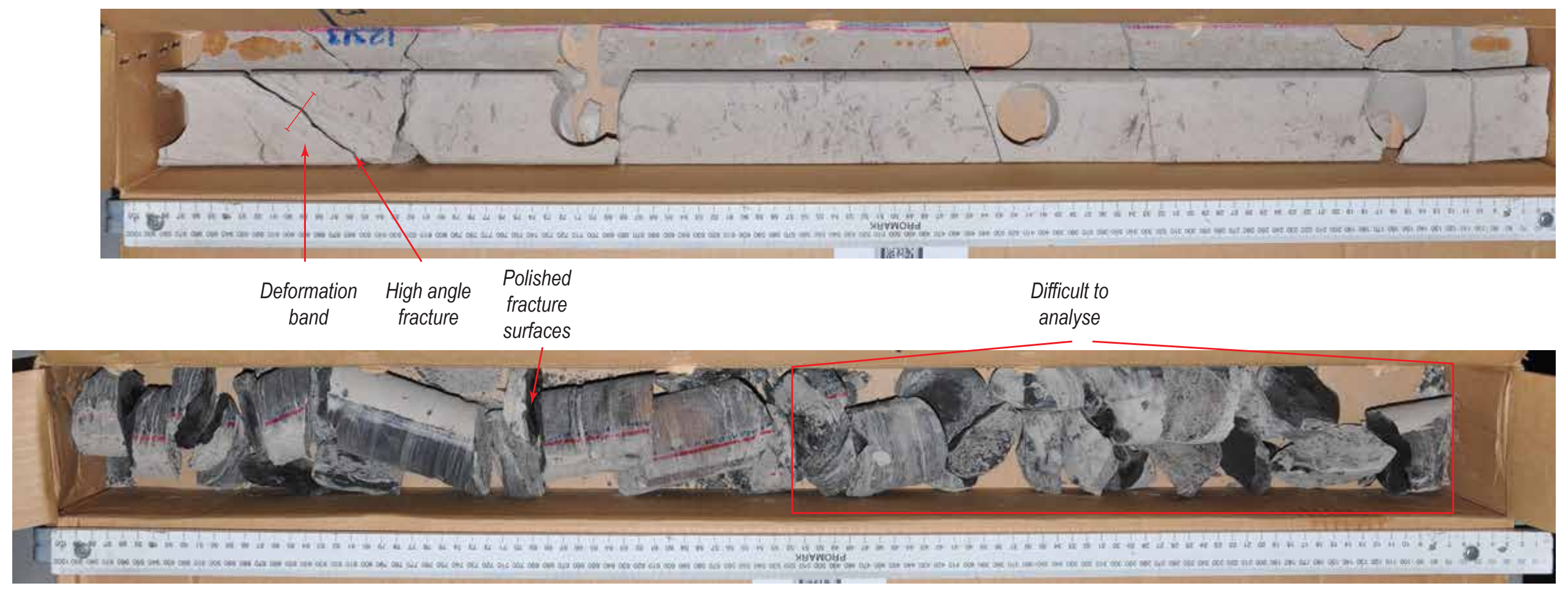


Figure 4: Analagous surface outcrop examples of sub-vertical joints with joint spacing and continuity controlled by bedding (left) and fault architecture (right). Bedding (green), faults and associated fractures (red), and background fracturing (blue) are highlighted. Complex architecture with intense damage zone, similarities to Figure 1.

Figure 2 below: Cores from prospective reservoir (top) and seal (bottom) units. Note difference in fracture properties, abundance and architecture.



References:
[1] Rajabi, M., Ziegler, M., Tingay, M., Heidbach, O., & Reynolds, S. (2016). Contemporary tectonic stress pattern of the Taranaki Basin, New Zealand. Journal of Geophysical Research: Solid Earth, 121(8), 6053-6070.
[2] Sathar, S., Reeves, H. J., Cuss, R. J., & Harrington, J. F. (2012). The role of stress history on the flow of fluids through fractures. Mineralogical magazine, 76(8), 3165-3177.