Fluid flow governed by fault zone architecture, the Alpine Fault, New Zealand

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Fracture pattern within a fault zone controls and records a wide range of crustal processes. However, these fractures usually reflect the complicated history of reactivation, and it is difficult to reveal how the fractures were formed. The Alpine Fault provides a unique opportunity to overcome this problem because the hangingwall uplift rate is very rapid, implying that all fractures in the hangingwall have not experienced the fault reactivation (e.g., Little., et al., 2005).
The DFDP-2B borehole was drilled in late 2014 in the hangingwall of the Alpine Fault and a series of wireline logging was acquired (Sutherland et al., 2015). The orientations of planar structures in the hangingwall of the Alpine Fault were revealed by the analysis of acoustic borehole televiewer (BHTV) logs (Massiot et al., 2017). In this study, fracture pattern near the Alpine Fault was examined based on the orientations of fractures revealed by the BHTV logs. Unfortunately, drillcore samples were not recovered due to technical problems during the drilling.
Fractures were formed or slipped in response to ambient stress. In this study, a technique of stress tensor inversion was applied to the orientations of fractures to characterise the fracture pattern. Reduced stress tensors were inferred with assuming the Wallace-Bott hypothesis based on fault slip data. Different fracture patterns should yield different solutions of reduced stress tensor. However, fracture orientation based on BHTV are not usually complete fault slip data without slip directions, although truncated features in BHTV logs occasionally constrain slip directions. For this reason, we compute stress parameters using the Hough transform method (Yamaji et.al., 2006). We assume that fractures with similar geometries to the Alpine Fault accommodated similar top-to-the-west shear, and that other fractures have reverse fault components.
2244 planar structures were detected in BHTV logs, and 1680 of them can be interpreted as fractures. Stress tensors were determined for groups of fractures within 20 m depth intervals. The analyses in depth intervals shallower than 730 m (measurement depth) yield orientations (trend/plunge) for the maximum and minimum compressive stress axes S1 and S3 of about 120/20 and 020/30 (±30°), respectively and a stress ratio of (S2−S3)/(S1−S3)=0.3−0.4, while those in depth intervals deeper than 730 m yield S1 and S3 axes of about 310/10 and 050/45 (±30°), respectively and a stress ratio of (S2−S3)/(S1−S3)= 0.7. Solution of stress tensor, i.e., fracture pattern, changes at ~730 m depth. The thermal profile measured by distributed temperature sensing (DTS) using a fibre-optic cable indicates that a thermal gradient also changes at ~730 m depth.
The dataset of fractures deeper than 730 m characteristically includes shallowly SE dipping structures. Orientations of these structures correspond to the R_1 shear of the Alpine Fault, which are often developed in fault damage zones. In general, damage zones of fault zones have high permeability compare to the surrounding rocks and fault core (e.g., Cain et al., 1996; Lockner et al., 2009). It can be considered that

rock and fluid advections play key role to account for the thermal profile of DFDP-2B (Sutherland et al., submitted). Therefore, there is a possibility that the deflection in the thermal profile at ~730 m depth corresponds to the boundary of the damage zone of the Alpine Fault. The results of fracture pattern and the thermal profile suggest fluid flow governed by the fault zone architecture of the Alpine Fault.

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