Core Surprise: Characterising the Internal Structure of an Ancient Plate Boundary Fault in Scotland

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Abstract

Knowledge of the structure and rheology of large, earthquake-hosting plate boundary faults is lacking as they are normally poorly exposed or difficult to find on the surface. Recently, several drilling projects have been undertaken to explore the internal structure of active plate boundary fault zones at depth to understand how this constrains seismic slip behaviour. All of these projects highlight the presence and importance of clay-rich rocks within the fault core in controlling slip behaviour along these large faults.

The Highland Boundary fault (HBF) in Scotland, provides a rare opportunity to study the internal fault architecture of a well-exposed along-strike section of an ancient plate boundary fault. The HBF extends for over 240 km, however, is only well-exposed along a 560 m section at Stonehaven. Here, serpentinite juxtaposes quartzofeldspathic crustal rocks, a common feature at many plate boundaries (e.g., sections of the San Andreas fault and Alpine fault, New Zealand). We collected six across-fault transects aiming to capture the internal structure of the HBF and its along-strike variability. Within the fault core we discover four mechanically and chemically distinct clay-rich units, which have sharp contacts. Despite evidence of internal strain within the clay-rich fault rocks, relatively intact clasts of wall rock and microfossils are preserved. From mineralogical observations it can be interpreted that the clay-rich rocks along this section of the HBF, formed through fluid-assisted, shear-enhanced chemical reactions between wall rocks of contrasting chemistry. Our field evidence also demonstrates that plate boundary faults can be structurally variable along strike at various scales. The total thickness of the fault core varies from 3 to 10.7 m over an along strike distance of 560 m. Not every unit is laterally continuous along strike, and each unit varies in thickness.

We compare our observations with studies on other plate boundary systems. For example, the HBF has analogous thickness and mineralogy to drill core recovered from the San Andreas fault. Highly variable fault core structures and related properties such as mineralogy, may exert significant control on earthquake rupture and slip behaviour at large plate boundaries.

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