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Predicting the Internal Structure of Fault Zones in Basalt and its Effect on Along Fault-Fluid Flow

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Interest in the architecture of fault zones in sedimentary rocks has intensified over recent years, in particular because faults play an important role in hydrocarbon migration. Although most hydrocarbon reservoirs are found in sedimentary basins there are also hydrocarbon plays within igneous rocks, with some 30% of these contained in basalt. Additionally, basalt is a potential carbon dioxide storage option, as chemical reactions between CO2 and mafic minerals can cause carbonates to precipitate, locking CO2 in a solid phase. To understand and predict how fluid moves through a fault zone, it is necessary to understand the processes and the mechanics involved in faulting. These processes include initiation and growth of a fault, generation of fault rocks within the fault zone, and subsequent evolution of fault rocks with increased slip. It is therefore key to study the internal structure of faults in igneous rocks to be able to understand the controls on, and make predictions of, fluid flow throughout the fault system.

Extensive studies have been carried out on faults in sedimentary rocks and some work has been done on faults in granites and gneisses, but little work has focused on the evolution of faults in extrusive igneous rocks, including basalt. Whilst previous studies have modeled the growth and propagation of surface faults in basalt in geological young regions, our study focuses on the evolution of faults formed at depths of >1km in well established basalt sequences. Our aim is to describe the processes through which fault rocks are generated, and how fault architecture evolves through space and time. Field work in Scotland and Iceland has provided data for a new model of fault evolution in basalt, and we present our preliminary results here. As a fault grows by fracture linkage and propagation, fracture-bound breccia zones are formed. With increasing movement, fractures develop into slip surfaces, and fracture bound breccia zones are further deformed into micro breccias and cataclasites forming the core material. Gouge formation is dependant on shear localization and host rock variation (i.e. weaker mechanical units and sedimentary horizons) which can control fault width. Micro- and meso-scale fracturing in the footwall and hanging wall creates coarse protobreccia which later is consumed by the fault. The damage zone is dominated by fractures with no large component of shear. This evolution is documented from faults of cm- to m- scaled fault zones, further work aims to examine faults with larger offsets.