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Mapping of massively dilatant faults in Iceland using UAV-SfM and TLS

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Massively dilatant faults (MDF) are an expression of extensional faults in cohesive rocks close to the Earth's surface. MDF form major pathways for fluids such as oil, water or magma and therefore are of interest e.g. for hydrocarbon exploration, geothermal energy supply or geohazard assessment. Even though MDF are common, their structure at depth as well as their revolution remains poorly understood. To contribute to the understanding of the geometry and development of MDF, we map and digitally visualize faults along the Mid-Atlantic Ridge in Iceland, where exceptional outcrop conditions allow for characterizing MDF geometries at high resolution.

Data acquisition focused on the Northern and Western Rift Zones. The Northern Rift Zone, including the well-known fissure swarms of the Krafla volcano, offers MDF outcrops formed during extension perpendicular to rift direction that are filled with rubble, aeolian sediments, water, ice or cooled lava flows. Eruptive fissures as well as faults with offsets in the scale of several meters can be directly accessed. The Western Rift Zone, containing several fissure swarms on the Reykjanes Peninsula, offers MDF at different scales under the influence of oblique rifting. MDF with unfilled cavities deeper than 20 m are exposed. Further N-E, Thingvellir allows for easy access to large scale MDF with apparent opening widths more than 50 m and apparent vertical displacement of more than 35 m.

Using different unmanned aerial vehicles (UAVs), we captured several sets of frontally and sideways overlapping photographs along the fault-traces and the surrounding areas. With these photosets ranging from hundreds up to thousands images, 3D point clouds and digital elevation models were produced using Structure from Motion (SfM) technology. To enhance the datasets in terms of point cloud density in areas where the conditions prevented the usage of UAVs, we took further measurements with a terrestrial laserscanner (TLS). Geotags in the images and GPS measurements of the TLS allow for the georeferencing of the created 3D point clouds. Measurements on the faults such as strike, dip, heave, throw and length can then be taken within the 3D point cloud. First results show the large variability of geometries along the fault strike, including e.g. antithetic fractures, relay ramps, breached relays or tilted blocks.

Our high-resolution data set enables us to quantitatively characterize the respective features, as well as their distribution along the fault strike. These results may be compared with analogue or numerical models of MDF and other areas featuring MDF, for instance the East African Rift or volcanic areas, such as the Hawaiian hotspot or the Campi Flegrei, Italy.