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Surface expression, spatial distribution and temporal propagation of the faulting and fissuring in the Thingvellir Fissure Swarm, Iceland

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Iceland brings exceptional opportunity for analysing faulting and fissuring (tension fractures), especially revealing fresh structural patterns in active fissure swarms. All these fissures swarms belong to the Icelandic Rift Zone which is the subaerial part of the Mid-Atlantic Ridge. The post-glacial fracture systems of the Thingvellir rift segment of the West Volcanic Zone and the interaction with Holocene lava flow overlapping have been analysed in detail. This study aims at providing a model for formation and growth of faulting at the divergent plate boundary in Iceland.

We mapped 5390 fractures in order to realise (i) a precise structural map, (ii) a representative analysis of fault length distribution and (iii) some statistical calculations in terms of fault length/number growth rates from Holocene to recent time. Mapping and 3-D geometrical analysis of faults and fissures were based on use of photogrammetric techniques (classical aerial photographs and photographs taken from a helicopter), on GPS positioning at ground control points and on validation from geological field work. The strike of fractures belongs to the azimuthal range N15°E - N60°E, with N42°E as average strike. The fracture lengths range from 3 m to 1,780 m, with 84 m as average length. The vertical throw distribution along 52 faults with a precision around 0.5–1 m. Most of these faults have symmetric serrated fault-displacement profiles; however some of them have profiles offset to the north or south. The offset varies from 2 m to 34 m and the average offset is about 10 m. Fault vertical offset as a function of the age of the affected lava flows are presented too. Finally, from the study of 70 transverse topographic profiles and the fault offset analysis, we propose a propagation model for Holocene fissure development, partly controlled by Pleistocene tectonic inheritance. Our model takes into special account alternating volcanic events and faulting. The analysis of the transverse profiles allowed identification of three profil-types: (i) smooth slope, (ii) typical monocline at the foot of a fault scarp, (iii) pronounced open fissure commonly associated with a monocline. We present growth fault models for two contrasting situations, highlighting the limitations in the analysis of fault offsets based on topography. Our model suggests that large voids are present along the fault beneath the surface of the lava flows. They are expected to be few and narrow at great depths where simple shear dominates along the inclined fault, but numerous and wide in the shallowest portion of the fault zone where tension prevails across nearly vertical fissures. Because of lava flow accumulation during the rift extension, estimating the amount of extension based on the present-day morphology would have led to severe under-evaluation.