Geophysical Research Abstracts
Vol. 20, EGU2018-12714, 2018
EGU General Assembly 2018

Influence of obliquity on the geometry of massively dilatant faults – insights from scaled analogue models

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Many normal faults have an oblique displacement component. These are often bound to large-scale tectonic processes, such as transfer zones at rifts (e.g. Iceland or East African Rift). Especially at rift zones, in brittle rocks such as basalts massively dilatant faults (MDF) form. These are major fluid pathways and thus important in applications such as geothermal energy production. The effect of obliquity on dilatant faults both at the surface and at depth is not well known. Additionally, assessing obliquity of faults in brittle rocks at the surface is sometimes difficult as clear markers are often lacking. This raises the question if we can use surface structures to estimate the amount of obliquity of individual faults and predict the subsurface structure.

We approach this problem with scaled analogue models using well controlled hemihydrate powder and mixtures of powder and sand as modeling material in a sandbox with adjustable basement fault obliquity (0°, 15°, 30°, 45°, 60°, 75°, 90°). We run experiment series with 10 and 20 cm thickness using pure hemihydrate powder and sand-powder mix for all obliquities and recorded photos from top and oblique view. Using photogrammetric 3D models, we document the final stage of the experiments and investigate the structure of fault planes.

Results show a variation of initial fractures, similar to what is known from shear mode faults, in that the density of Riedel shears increases with increasing obliquity. However, with increasing displacement the differences between experiments becomes more and more obscured and it is less clear if the fault is driven by a high or low obliquity basement fault. We differentiate three classes of obliquity with distinct differences: (1) No obliquity (0°) shows typically no Riedel shears; (2) intermediate obliquity (<60°) where Riedel shears are common; (3) high obliquity (>60°) with dominant Riedel shears and ultimately no opening component at 90°.

Some observable parameters are affected by obliquity. Graben width shows no clear trend throughout the no- and intermediate obliquity domains but decreases systematically in the high obliquity domain. Dilatancy of the faults decreases continuously with increasing obliquity, which is a geometric consequence of the reduced opening component. Similarly, the number of tilted blocks decreases linearly with increasing obliquity, whereas the size of tilted blocks shows a less clear trend. Interestingly some first order geometric properties of the faults such as the sinuosity show no correlation with obliquity.

Excavated fault planes indicate dilatancy up to great depths, upscaled to the range of 400-800 m in nature in the full range of obliquities. Connectivity decreases with increasing obliquity because at high angles dilatancy is focused on releasing bends of the fault trace (or pull-aparts).