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Implications of fluid overpressure and fracturing mechanisms in the rift zone of Eastern Iceland from earthquakes and fault slip data

Romain Plateaux (1), Françoise Bergerat (2), Nicole Béthoux (1), Thierry Villemin (3), and Muriel Gerbault (1)

(1) GeoAzur (UMR 6526), CNRS-UNS-OCA-IRD-UPMC, Nice, France (plateaux@geoazur.obs-vlfr.fr/+33 (0)4 93 76 37 66), (2) ISTeP (UMR 7193), CNRS-UPMC, Paris, France, (3) EDYTEM (UMR 5204), CNRS-Université de Savoie, Chambery, France

Comparison of both the eroded off-rift zone left inactive by plate motion and the inner active seismic rift zone allows us to constrain the fracturing mechanics at shallow depths in Eastern Iceland. In the Lagarflot Valley and Eastern fjords (off-rift zone), we measured 423 fault slips including 223 normal faults and 200 strike slip faults, as well as 628 tension fractures (mineralized veins and dykes). Inversion of fault slip data reveals the parallelism of the minimum stress ($\sigma 3$) computed for the normal and for the strike-slip faulting. This similar trend implies a close relationship between these two modes. North of the Vatnajökull, corresponding to the active rift zone (accretion zone), more than 17000 seismic events were recorded by the Icelandic Meteorological Office (IMO) between 2004-2009, especially around the Herðubreið table mountain and both the Herðubreiðarltogl and the Upptyppingar hyaloclastic ridges. Two focal depths were determined at 5km (Herðubreið region) and 15km (Upptyppingar region). Interestingly, the double couple focal mechanisms determined by IMO revealed that more than half of the mechanisms are strike-slip whereas surface deformation expresses rather normal faulting and extensional fractures. Comparison of the mechanics of fracturing between active and off-rift zones reveals (1) an unusual importance of strike-slip regime in such an extensional tectonic context. This can be explained by stress permutations ($\sigma 1/\sigma 2$), and (2) the similarities in terms of stress orientations and type of faulting observed both in the old and present-day rift zones. These features are quite unexpected where only extensional tectonic should prevail. We assume that the seismic events may be generated by rapid deep magma intrusion, also associated to shallower hydrothermal activities. We thus speculate that strike-slip behaviour in the active rift and off-rift zone may be caused by fluid overpressure, maintaining the equality between $\sigma 1$ and $\sigma 2$. Using a Drucker-Prager failure criterion and temperature-dependent power-law creep, we evaluated analytically whether presence of fluid overpressure is a necessary condition to allow stress permutations at failure. Our results suggest that fluid overpressure is likely to reduce the crustal strength sufficiently at high stress shape ratio ($\Phi=(\sigma 2-\sigma 3)/(\sigma 1-\sigma 3)$) to fail at shallow (5km) and deep (15km) depth, despite a high geothermic gradient prevailing in such peculiar thick oceanic crust.