Geophysical Research Abstracts
Vol. 15, EGU2013-8882, 2013
EGU General Assembly 2013

Faulting Mode Characterization using fault attributes : Example of a nascent oceanic rift the Manda-Hararo rift in Afar (Ethiopia)

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The Manda-Hararo rift segment, located in the Afar depression, underwent a major dyke injection of 65 km long in September 2005, that initiated a rifting episode. From June 2006 to May 2010, 13 other successive dykes were intruded and monitored using InSAR and seismic surveys. Aside from its recent activity, the Manda-Hararo rift architecture shows some particularities which distinguish the segment North of the central magma chamber from the rest of the rift. This Northern segment shows a change of strike of the rift axis and of the overlying faults, as well as a marked asymmetry featured by high no-conjugated west-dipping scarps. These observations led to wonder how the Northern part of this rift has been integrated into the long-term evolution of the whole rift, and whether its deformation mode and fault growth processes might be influenced by the Dabbahu volcano. To address such questions, we focus our analysis on the scaling laws applied to the fault attributes such as fault length, fault scarps or spacing between adjacent faults.

This study is based on a fault mapping which was done using optical images (SPOT and, QUICKBIRD images) together with SAR interferograms and coherence images. This map is divided into three regions to isolate the different sources of deformation : the Northern segment close to the Dabbahu volcano, the central one where the main magma reservoir is located and dyke intrusions occurred, and finally the southernmost one coinciding with the segment end.
A first stage in determining the scaling law, and consequently the growth mode, consists in characterizing the displacement (Dmax) versus length (L) relationship. With our whole dataset and the different groups of segments defined previously, we observe a scattering suggesting no clear evidence for a linear trend associated with self-similar processes. A possible explanation for such observation in addition to the sampling issue would be a distributed mode of deformation (Soliva et al. 2008).
Next, for each of these three regions, we determine the distribution law and discuss them in terms of fault growth processes and the possible role of the fragile thickness as a limiting factor. The center and southern regions tend to a gamma law (Davy 1993), unlike the Northern part where an exponential law seems to be more appropriate. Such observation in the Northern part of the rift mean that faulting would be distributed and scale dependent, when the central and southern parts would be characterized by a faulting mode closer from the transition localized-distributed. The analysis of scaling laws applied to fault attributes is also discussed in terms of inward-outward dipping faults and compared to the oceanic ridge models (Carbotte et al. 1990).
These observations suggest a similar and more advanced stage of evolution for the Central and Southern part of the segment, unlike the Northern segment, which shows a less localized deformation. Indeed, the preferential zone of intrusion of the Northern segment seems to be able to laterally jump over time, as illustrated by the unexpected path taken by the September 2005 intrusion.