Geophysical Research Abstracts
Vol. 18, EGU2016-15572, 2016
EGU General Assembly 2016

Magmatic cycles pace tectonic and morphological expression of rifting (Afar depression, Ethiopia)

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Dyking and faulting at mid-oceanic ridges are concentrated in narrow axial volcanic zones due to focussing of both melt distribution and tectonic strain along the plate boundary. Due to the predominantly submarine location of oceanic ridges, the interplay between these processes remain poorly constrained in time and space. In this study, we use the Dabbahu-Manda Hararo (DMH) magmatic rift segment (MRS) (Afar, Ethiopia) to answers the long debated chicken-egg question about magmatic and tectonic processes in extensive context: which on comes first, and how those two processes interplay to finally form oceanic ridges? The DMH MRS is an oceanic ridge analogue and here we present quantitative slip rates on major and minor normal fault scarps for the past 40 kyr in the vicinity of a recent (September 2005) dike intrusion. Our data show that the long-term-vertical slip rates of faults that ruptured in 2005 are too low to explain the present rift topography and that the 2005 strain distribution is not the main stress accommodating mechanism in the DMH segment. Instead, we show that the axial valley topography is created by enhanced slip rates which occur only when the amount of magma available in magma reservoirs is limited, thus preventing dykes from reaching the surface. Our results suggest that development of the axial valley topography is regulated by the magma reservoir lifetime and, thus, to the magmatic cycles of replenishment/differentiation (< 100 ky).

This implies that in the DMH rift system (with a magma supply typical of an intermediate spreading centre), significant topography of the axial rift valley is transient, and is expressed only when magma available in the reservoirs decreases. The absence of tilting on the rift margins over the last 200 kyr also suggests that amagmatic accommodation of extension is not required over this time period. Extension instead is accommodated by dykes injected laterally from multiple ephemeral reservoirs located along the DMH segment. This suggests that, in such magmatic rifts/accretion centers, the location and development of narrow axial valleys is fundamentally controlled by the spatial and temporal interplay between the various magmatic reservoirs, and that tectonic activity is subaerially expressed only as a result of the decrease of magmatic activity.