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The Afar region as an analogue of mature oceanic ridges: a model for slow spreading centres?

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The Afar depression (Ethiopia) is organised along magmatic rift segments which morphologically resemble oceanic ridges. The segmentation in individual magmatic rift segments results from interactions between dyke injection and volcanism, as observed in mature oceanic ridges. Therefore the Afar region represents an ideal natural and subaerial analogue laboratory to study the evolution of rift/ridge morphology as a response to volcanic and tectonic influences.We focussed on the Dabbahu rift segment which experienced in 2005 a well-documented rifting event. This tectono-volcanic crisis provided invaluable information via the direct observation of a sequence of dyke intrusions. However, over timescales of 1 to 100 kyrs - a key period over which the main morphology of a rift/ridge segment is acquired - chronological constraints are very scarce. In order to address the lack of data on these timescales, a multidisciplinary study of the Dabbahu rift has combined surface exposure dating (3He and 36Cl) of lavas and fault scarp with major & trace element compositions and field/remote sensing mapping. Over three field campaigns, we investigated the Northern and central parts of the rift, from its western shoulders to the axial valley, allowing the long-term interplay between tectonic and magmatic processes to be deciphered (Medynski et al., 2013; Medynski et al. 2014a,b submitted). Based on this subaerial example of an active magmatic rift segment, we propose a model for the acquisition of slow spreading oceanic ridge morphology, where topography building is tightly tied to magma budget and location. Over a period of $\sim$100 ka, magmatic accretion is maintained by successive intrusions of dikes that spread from the various magma chambers distributed along the rift, and which also provoke a local topographic response. The main topographic development is not continuous, but rather is linked to the degree of differentiation of these reservoirs. Our data show that magma chambers function in cycles of 30-40 kyrs duration, corresponding to the time necessary to differentiate a single batch of magma. These cycles strongly impact the rift morphology acquisition. First, during phases of high magmatic activity, the pre-existing topography is erased by intense fissure volcanism. During these magmatic phases, tectonic activity is subdued with little movement recorded on the faults. Second, when the batch of magma begins do differentiate, volcanic activity decreases and dikes are more likely trapped within the crust, allowing the tectonic activity to be expressed at the surface and enhancing the development of the axial depression. The position of the magmatic reservoirs is also a key parameter concerning the locus of the rift valley. In Afar, we highlighted the lateral variability of these reservoirs' position, which can deviate by 10-15 km away from the current rift axis location; a result that was also confirmed by magneto-telluric techniques (Dessisa et al. 2013). It underlines the unfocussed character of the magmatic plumbing system, which contributes to the lateral dispersion of the deformation and to the instability of the rift axis on timescales of a few tens of kyrs.