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A quantitative geomorphological approach to constraining the volcanic and tectonic evolution of the active Dabbahu rift segment, Afar, Ethiopia.

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In the Afar depression (Ethiopia), extension is organised along rift segments that morphologically resemble oceanic rifts. Segmentation results from interactions between dyke injection and volcanism, as observed during the well-documented 2005 rifting event on the Dabbahu rift segment. This tectono-volcanic crisis was observed in detail via remote sensing techniques, providing invaluable information on the present-day tectonic - magmatic interplay during a sequence of dyke intrusions. However, lack of data remains on timescales of 1 to 100 kyr, the period over which the main morphology of the rift is acquired.

The Dabbahu rift segment represents an ideal natural laboratory to study the evolution of rift morphology as a response to volcanic and tectonic influences. We use cosmogenic nuclides (3He and 36Cl) to determine the ages of young (<100 kyr) lava flows and to date the initiation and movement of fault scarps, which cut the lavas. Where possible, we analysed vertical profiles along fault scarps, in an attempt to distinguish individual tectonic events that offset the scarp, estimate their amplitudes and date the recurrence intervals. These geochronological constraints, combined with major & trace element compositions, field mapping and digital mapping (Landsat, ASTER and SPOT imagery), provide valuable insights on the magmatic and tectonic history of the segment.

The results show that over the last 100 ka, the northern part of the Dabbahu segment was supplied by at least two different magma reservoirs, which can be identified from their distinctive chemistries. The main reservoir is located beneath Dabbahu volcano at the northern tip of the rift segment, and has been supplied with magma for at least 72 ka. The second reservoir is located further south on the rift axis and corresponds to the current mid-segment magma chamber, which was responsible for the 2005 rifting episode.
Two magmatic cycles linked to the Dabbahu magma chamber were recorded, lasting 20-30 kyr each. They correspond to periods of high magma supply rate (from 72 to 58 ka) and lower magma supply rate (from 51 to 22 ka). Initiation of the main rift faults was dated at around 35 ka in this portion of the segment, coeval with the decrease in magma supply to the reservoir below Dabbahu volcano. On the long term, we identified a difference in slip rate regimes on major and minor scarps ($\sim$1-2 mm/yr compared to $\sim$0.2 mm/yr respectively). It was possible to establish the recurrence time and the amplitude of tectonic events on a single scarp: the scarp was created by a series of seismic slip events of the order of 1 metre with a recurrence time varying from 6 to 12 kyrs.
On the other side of the rift, close to the mid-segment magma chamber, the relief is lower and topographic development was initiated around 29 ka.