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Structure and evolution of a magmatic rift segment close to continental breakup

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The continental-oceanic transition (OCT) at volcanic margins is often associated with large volcanic provinces and with specific tecto/volcanic structures, notably seaward dipping reflectors (SDRs), of which the origin and processes of formation are still debated. The Afar province corresponds to the very last observable stages of continental rifting before breakup. Interestingly, in this area where the continental crust remains $\sim$20 km thick, magmatism and tectonic activity are already clearly expressed in well-individualised rift segments, presenting the morphological characteristics of mature oceanic ridges. The Afar region therefore represents an ideal natural laboratory to study the processes responsible for maintaining magmatic accretion and their links with the distribution of deformation in a pre-breakup context.

We have focussed on the Dabbahu segment that experienced a diking event in 2005 that has been studied in detail. The subsequent tectono-volcanic crisis that lasted 5 years, has provided invaluable information on the mechanisms controlling dyke intrusion, the main process responsible for extension at the scale of a single rifting event. Our investigations focussed on the 1 to 100 kyrs timescales - a key period over which the main morphology of a rift/ridge segment is acquired, but which currently lacks chronological constraints. In order to bridge this gap in temporal evolution, our multidisciplinary approach combines surface exposure dating (3He and 36Cl) of lavas and fault scarps with major & trace element compositions and field/remote sensing mapping of the Dabbahu rift.

Our results show that accretion is maintained by individual magmatic chambers, distributed along the active rift segment. There, we have identified magmatic cycles of 30-40 kyrs duration during which the magmas progressively differentiate, until the magmatic centre is abandoned. These cycles exert a strong control on the building of topography: the tectonic activity is subdued during the active phases of the magma chamber, and are enhanced when the magmatic activity decreases. Our measurements show that the fault scarps have a continuous slip rate along the neo-volcanic zone, between 1-2 mm/yr. We also identify several individual palaeo-tectonic events of metric amplitude (very similar to the 2005 crisis) which suggest that the main process responsible for the building of the axial depression is indeed dike intrusions. This implies that in pre-breakup stages accretion is already organised and maintained by processes similar to those occurring in mature oceanic ridges. The question arises to know if these mechanisms, observed here on the scale of a few tens of kyrs, could be responsible for the creation of SDRs, implying these mechanisms operate on timescales of a few million years.