



Mode of rifting in magmatic-rich setting: Tectono-magmatic evolution of the Central Afar rift system

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Observation of deep structures related to break-up processes at volcanic passive margins (VPM) is often a troublesome exercise: thick pre- to syn-breakup seaward-dipping reflectors (SDR) usually mask the continent-ocean boundary and hide the syn-rift tectonic structures that accommodate crustal stretching and thinning. Some of the current challenges are about clarifying 1) if tectonic stretching fits the observed thinning and 2) what is the effect of continuous magma supply and re-thickening of the crust during extension from a rheological point of view? The Afar region in Ethiopia is an ideal natural laboratory to address those questions, as it is a highly magmatic rift that is probably close enough to breakup to present some characteristics of VPM. Moreover, the structures related to rifting since Oligocene are out-cropping, onshore and well preserved.

In this contribution, we present new structural field data and lavas (U-Th/He) datings along a cross-section from the Ethiopian Plateau, through the marginal graben down to the Manda-Hararo active rift axis. We mapped continent-ward normal fault array affecting highly tilted trapp series unconformably overlain by tilted Miocene (25-7 Ma) acid series. The main extensional and necking/thinning event took place during the end of this Miocene magmatic episode. It is itself overlain by flat lying Pliocene series, including the Stratoid. Balanced cross-sections of those areas allow us to constrain a surface stretching factor of about 2.1-2.9. Those findings have the following implications:

- High beta factor constrained from field observations is at odd with thinning factor of ~1.3 predicted by seismic and gravimetric studies. We propose that the continental crust in Central Afar has been re-thickened by the emplacement of underplated magma and SDR.
- The deformation in Central Afar appears to be largely distributed through space and time. It has been accommodated in a 200-300 km wide strip being a diffuse incipient plate boundary until the formation of present-day magmatic segments.
- The difference in tectono-magmatic style between Central Afar (distributed extension and thick crust) and Northern Afar, i.e. Erta Ale segment (narrow graben, thin crust) may be explained by the difference of magma volume (extruded & underplated) brought to the crust during extension. Magma supply in Central Afar allows the crust to be stretched without subsequent thinning despite high degree of extension.
- Presence or absence of thinned crust does not necessarily announce break-up. It may occur in both Central and Northern Afar, depending upon a sudden change in magmatic regime. The striking difference between the two tectono-magmatic styles of Central and Northern Afar are probably due to a combination of: 1) magma supply that affects both crustal thickness and rheology, 2) the amount of extension that may be higher in Central Afar, 3) the distance to the magmatic province, and 4) the presence of an early syn-rift transfer/transform between the two segments that might have controlled the distribution of magmatic activity.