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Geodetic observations of simultaneous rift-scale magma inflow in multiple sills in the Central Afar rift

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During plate spreading, large volumes of magma can be extracted from the upper mantle and intrude the crust. Geophysical and geochemical studies at active magmatic rifts and passive margins show that crustal intrusions mainly occur in the form of transient sill-like bodies. The sills pond at various crustal levels, potentially feeding shallower plumbing systems, dike intrusions and surface eruptions. Trans-crustal magma migration and intrusion thus have a key role in controlling extension, strain localization and subsidence during rifting. However, a clear understanding of the mechanisms of sill intrusion, their connection to upper mantle processes, as well as the spatial and temporal response of the sills to a new arrival of magma is still limited by the paucity of direct observations. In this study, we provide one of the few direct InSAR observation of rift-scale deformation caused by magma inflow from the upper mantle to multiple crustal sills in the Central Afar (CA) rift.

We used InSAR time-series from 255 ESA Sentinel-1 interferograms during 2014-2021 and combined them with available GNSS measurement to retrieve the 3D velocity field and the temporal evolution of surface deformation in CA. We observed four uplift patterns with rates of ~5 mm/yr, that we inverted using four inflating Okada tensile dislocation sources (sills). Our best-fit model shows four sills elongated in a NW-SE direction, similar to the rift trend, and opening rates ranging between 16 and 44 mm/yr. The sills are located at various crustal depths but mainly in the mid-to-lower crust, following the thinning of the crust imaged seismically in CA. Cross-correlation of time-series also show that the uplift above the four sills starts simultaneously in December 2016 and continue until March 2021.

We interpreted the simultaneous inflation of four distant sills as the result of a shared pressurization event caused by an episodic magma inflow from a common source in the upper mantle. Our results show that magma supply from the mantle beneath continental rifts is episodic, and occurs across large spatial scales but short temporal scales over which deep crustal magma

ponding takes place. Such process could explain how the thick intruded crust common at magma-rich rifted margins is created and could help in understanding the long-term dynamics of rifting episodes and volcanism.