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Modeling dike-fault interactions in continental rifts on geological time scales

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Normal faulting in continental rifts creates pronounced relief which evolves over time. At the same time, many rifts are marked by decompression melting and the ascent of magma that intrudes into the brittle crust in the form of dikes and sills and that extrudes along volcanic fields. It is clear that magmatic intrusions and normal faulting interact in magmatic rifts such as the Kenya Rift, the Main Ethiopian Rift, the Afar triple junction, and in the Icelandic plate boundary. However, the interplay between tectonic and magmatic processes, the evolving topography and the rift-related stress field, as well as the impact of these processes on dike-fault interactions remains difficult to isolate from observations.

Previous modeling studies of time-dependent magma-tectonic interactions in extensional tectonic settings fell into one of two categories: (1) simple models where diking is represented by a prescribed fixed rectangular zone of horizontal divergence (e.g., Buck et al., 2005), (2) complex setups where magma ascent is represented by porous flow and fluid-driven fracture (e.g., Li et al. 2023). While the former approach can be applied to model of tens of millions of years of dike injection along spreading ridges, the simplicity prevents applications to continental rifts where magmatism manifests over broad areas. The latter approach allows to study the evolution of individual dikes, but its computational costs prevent application to lithospheric-scale rifts over geological times scales.

Here, we propose a numerical workflow that can be categorized as a model of intermediate complexity. We nucleate the dikes at the brittle/ductile transition above magma-forming regions. The dikes are then propagated perpendicular to the minimum compressive stress, similar to the approach of Maccaferri et al. (2014), until they reach their freezing depth or the surface. In this presentation, we show how we have approached this problem and how we implemented it in the open-source community geodynamics model ASPECT. We show how the generated dikes are being focused in specific regions, and how the dilation and heat injection during magma intrusion through dikes influence the long-term rifting evolution.

References:

Buck, W. Roger, Luc L. Lavier, and Alexei N. B. Poliakov. "Modes of Faulting at Mid-Ocean Ridges." Nature 434, no. 7034 (April 2005): 719–23. https://doi.org/10.1038/nature03358.

Li, Yuan, Adina E Pusok, Timothy Davis, Dave A May, and Richard F Katz. "Continuum Approximation of Dyking with a Theory for Poro-Viscoelastic–Viscoplastic Deformation." Geophysical Journal International 234, no. 3 (September 1, 2023): 2007–31. https://doi.org/10.1093/gji/ggad173.

Maccaferri, Francesco, Eleonora Rivalta, Derek Keir, and Valerio Acocella. "Off-Rift Volcanism in Rift Zones Determined by Crustal Unloading." Nature Geoscience 7, no. 4 (April 2014): 297–300. https://doi.org/10.1038/ngeo2110.