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Magma Generation During the Continent – Ocean Transition: The Unexpected Role of the Continental Lithospheric Mantle

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The transition from continental rifting to oceanic spreading requires rupture of continental lithosphere. The process by which continental lithosphere thins to permit the eventual formation of oceanic basins remains enigmatic – modern rifted margins, which preserve the evidence of this transition, are typically inaccessible and buried under thick sedimentary accumulations. The Afar Depression, located within the northernmost East African Rift System, provides an opportunity to probe the processes that are active during the terminal phases of continental rifting. Thinning of the continental lithosphere during the terminal rifting phase generates magmatism through decompression melting of the ambient upper mantle, however, the destabilization of enriched lithosphere may also provide a novel mechanism of melt creation. Such a mechanism may be particularly appealing in instances where extension rates and/or plate stretching factors are low. Here we probe the mechanism of melt generation during terminal rifting with a particular focus on assessing the potential contribution of the lithospheric mantle. The primary focus of this study is the Afar Stratoid Series lavas, the most volumetrically significant magmatism in the region. The origin of the Afar Stratoid Series lavas is best simulated by a three-step process: First, upward passage of sub-lithosphere derived melts during the ca. 30 Myrs of magmatism in this region enriches the continental lithospheric mantle. Second, thermobaric destabilization of these enriched regions during progressive lithospheric stretching generates Si-undersaturated melts. Third, interaction of these melts with the surrounding peridotite yields the composition of the Afar Stratoid Series lavas. This model of melt production – without the necessity of elevated mantle potential temperatures or fluxing from a mantle plume – provides an alternative mechanism for magma generation during the continent to ocean transition. We explore the implications of this interpretation in relation to the origin of magmas that form seaward dipping reflectors.