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The development of extension and magmatism in the Red Sea rift of Afar

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Continental breakup and the transition to seafloor spreading is characterized by extensional faulting, thinning of the lithosphere and, at magmatic margins, voluminous intrusive and extrusive magmatism. It is difficult to discriminate between different mechanisms of extension and magmatism at ancient continental margins because the continent–ocean transition is buried beneath thick layers of volcanic and sedimentary rocks and the tectonic activity that characterized breakup has ceased. Instead, the timing of these mechanisms is inferred from theoretical models or from the geological record preserved at the fully developed, ancient rifted margins. Ongoing rifting in the Red Sea rift in Afar offers a unique opportunity to address these problems because it exposes subaerially the transition between continental rifting and seafloor spreading. Here we present evidence from seismicity, InSAR, controlled source seismology, and volcanology for along-rift variations in style of deformation in Afar. We show that although intrusion of magma maintains crustal thickness during the early stages of the continent–ocean transition, subsidence of the rift below sea level, and eruption of voluminous basalt flows, is initiated by late-stage and rapid mechanical deformation of the heavily intruded, weakened plate just before the onset of seafloor spreading. We thus conclude that faulting, stretching and magma intrusion are each important, but at different times during breakup.