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The development of extension and magmatism during continent-ocean transition: evidence from Ethiopia

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The geological record at rifts and margins worldwide often reveals along-strike variations in volumes of extruded and intruded igneous rocks. These variations may be the result of asthenospheric heterogeneity, variations in rate and timing of extension. Preexisting plate architecture and/or the evolving kinematics of extension during breakup may also influence magmatism strongly. The Ethiopian and Afar Rift systems provide an excellent opportunity to address these issues since they expose, along strike, several sectors of ongoing, asynchronous rift development from embryonic continental rifting in the south to incipient oceanic spreading in the north. A consensus has now emerged from a variety of disciplines in Ethiopia that a considerable proportion of extension in Ethiopia is accommodated by focused dyke intrusion in narrow axial zones, without marked crustal (and plate?) thinning. These "magmatic segments" may mark the final breakup boundary and location of an incipient oceanic spreading centre. However, observations of markedly thinned crust and a pulse in Quaternary-Recent basaltic volcanism within the Danakil Depression have recently been cited as evidence that an abrupt, late stage of localised plate stretching may instead mark the final stages of continent-ocean transition (Bastow & Keir, 2011). We explore this hypothesis using recently-acquired seismic reflection data and accompanying borehole geological constraints from Danakil. Thick sequences of evaporites have been deposited in an asymmetric basin, whose subsidence has been controlled primarily by a major, east dipping normal fault. Surprisingly, no significant magmatism is observed in the upper $\sim$1000m. Age constraints on a potash-bearing sequence presently being mined in the basin point towards rapid basin infill in the last several tens-to-hundreds of thousands of years. Basin formation cannot be easily attributed to the effects of magmata intrusion. Instead, an abrupt, localised, late-stage, plate-stretching phase marks the final stages of breakup, prior to the onset of seafloor spreading. It is unclear whether the stretching is due to heating and weakening of the plate by protracted dyke intrusion, or whether strong flanking lithosphere of the Nubian plateau and the Danakil micro-plate control the focusing. Regardless, the magmatic locus of strain, developed during the final stages of breakup, may not necessarily represent the final break-up boundary and ultimate spreading centre location.