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Probing the age and temperature of rifting in Afar

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Rifting along the southern part of the Red Sea margin in NE Africa (leading to formation of Afar) has been closely associated with magmatic activity since the initiation of extension at around $\sim 25\,\mathrm{Ma}$. Numerous active volcanoes are currently found along rift zones here and magma intrusion into the crust has potentially accommodated significant amounts of extension. This extensive present-day volcanism has been linked to elevated mantle temperature, perhaps due to a thermal plume, or as a consequence of passive flow in the mantle beneath the extending lithosphere. Geochemical evidence for basaltic lavas erupted in Afar have been used to suggest that mantle temperatures are in the range 1370 to $1490\,^{\circ}\mathrm{C}$, and that the region is currently experiencing late stage rifting. Analysis of changes in shear wave seismic velocities and relative travel time tomography suggests mantle temperatures are within a similar range, yet the region has greater similarities to a young spreading centre. The range in potential temperature estimates is however very large, with different implications for the volcanic history of the region and hence timing of break-up.

Rather than focusing a single observable, we use a relatively straight forward model of extension and decompression melting to predict the seismic-velocity and attenuation structure of the asthenosphere and lithosphere, synthetic receiver functions as a result of this seismic structure, crustal thickness as a result of decompression and finally the melt composition. From this combined study we find that melt composition and seismic structure are dependent on both temperature and time. If mantle potential temperature is $1350\,^{\circ}\mathrm{C}$ then both the seismic structure and melt composition can be matched if the duration of extension is more than 30 Myr. However this is longer than the estimated duration of extension from plate reconstructions, and given the low rate of extension in Afar, this cold model only generates up to 5 km of igneous crust. If mantle potential temperature is $1450\,^{\circ}\mathrm{C}$ then both the seismic structure and melt composition can be matched after 22 Myr of extension. Furthermore, igneous crustal thickness is in excess of 10 km. Therefore, the most simple explanation is that Afar is a developing continental rift zone where melting is enhanced by a warm mantle.