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Mafic intrusive rocks from the Paranja-Etendeka large igneous province - insights into sub-surface magmatic processes and consequences on the thermal state of the lithosphere

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Mafic continental intraplate magmatism contributes to the bulk chemical composition of the crust and affects the thermal state of the lithosphere. In case of large igneous provinces, where large volumes of magma erupt within short times, this contribution might be significant and accompanied by local heating and weakening of the crust. The latter, in turn, might affect or trigger continental breakup. The extent of crustal heating, however, depends on the size and geometry of the magmatic plumbing system, and the temperature, residence time and volume of magmas in it.

In this study we present mineral and whole-rock geochemical and petrological data from different types of gabbros from Western Namibia, which represent a deeper crustal section of a magmatic plumbing system that fed the Paranja-Etendeka LIP ~132 Ma ago. Major- and trace element systematics and thermodynamic modelling suggest that the parental magma(s) developed from a tholeiitic picritic melt with high MgO (~18wt%) at a liquidus temperature of ~1525°C (3 GPa), corresponding to a mantle potential temperature of 1455-1470°C. This is higher than estimates for the upper convecting mantle (1280-1340°C), but in agreement with values assigned to the Tristan mantle plume head upon impacting the Gondwana lithosphere. The primary picritic magma formed within the plume by ~14% partial melting, possibly from a mixture of entrained upper mantle and plume mantle, and crystallized at least 10% olivine en route to the surface prior to emplacement and gabbro formation. Clinopyroxene and whole-rock trace element and Sr-Hf-Nd isotope data are inconsistent with gabbro formation by pure fractional crystallization from a common magma, but indicate chemically distinct magmatic pulses and concomitant assimilation of Pan-African continental crust during solidification.

Our observations favour significant residence times of larger volumes of very hot mafic magmas within the Paranja-Etendeka crust, possibly in multiple stacked magma chambers as suggested by geophysical data, and thus argue for an intense heat exchange between the plumbing system and ambient lithosphere and crust. It is suggested that this heat exchange had an impact on lithospheric strength and thus may have supported rift initiation.