

Can lamprophyres in LIPs constrain upper mantle plume dynamics?

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Volatile-rich basanitic melts giving rise to camptonite lamprophyre swarms in the Orkney Islands (Scotland, U.K.) have been dated by mantle xenocrystic zircon and autocrystic zircon from differentiated melt using CA-ID-TIMS U-Pb geochronology. The results show that melt generation in the mantle, recorded by xenocrystic zircons, and emplacement, recorded by autocrystic zircon in a fractionated sannaitic dike, occurred within 5 m.y. The melt-generation zone of the lamprophyres has been modelled to be >90 km depth and the zircons show Hf-isotopic evidence for the mixing of two suprachondritic sources, the most positive ϵ_{Hf} -values interpreted to represent influxing asthenospheric mantle. The xenocrystic nature of the zircons from the camptonite and the majority from the sannaitic is evidenced by texture, trace element chemistry, high Ti-in-zircon crystallisation temperatures, and for camptonites, by the highly zircon-undersaturated nature of the melts.

The Orkney dike swarm has been associated with the Skagerrak-centred large igneous province (SCLIP [1]). The main stage of the SCLIP is dated to c. 300 Ma [2], and xenocrystic zircons in the Orkney camptonite dikes formed up to 7 m.y. prior to the main stage of the LIP. The formation of mantle zircons are likely linked to the first partial melting event associated with elevated mantle temperature due to plume-lithosphere interaction. This places absolute time constraints on upper mantle plume dynamics as a function of mantle potential temperatures (T_p) during different stages of a LIP, ultimately determined by the plume ascent velocity in the upper mantle. We use the modelled T_p at the lamprophyre melt generating stage and compare it to the T_p of mantle melting during the main LIP volcanism stage ($T_p > 1500^\circ\text{C}$, occurring at shallower depths < 50 km; [3]), to evaluate models estimating the plume ascent in the upper mantle. Hence, identifying and precisely dating lamprophyre magmas preceding basalt volcanism in LIPs globally provide new constraints to test models of upper mantle plume dynamics when combined with thermal models for plume-ambient mantle interaction.

[1]Lundmark, Gabrielsen & Brown (2011), J. Geol. Soc. 168, 6, 1233–1236.

[2]Corfu & Larsen (2020), Lithos 376-377, 105755.

[3]Hole & Millett (2016), J. Petrol. 57, 2, 417–436.