12TH INTERNATIONAL KIMBERLITE CONFERENCE
30 YEARS OF DIAMONDS IN CANADA
8-12 July 2024 • Yellowknife

12th International Kimberlite Conference Extended Abstract No. 12IKC-184, 2024

Secular variation in kimberlite formation: the variable connection to LLSVPs

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The distribution of kimberlites over the North American continent is puzzling, as kimberlites are found not only on thick Archean cratons, but also on thinner and younger Proterozoic terranes. In order to test in more detail the hypothesis that kimberlites are created by upwellings initiating along the edges of large low shear velocity provinces (LLSVPs) (Giuliani et al. 2021), we backtrack the location of the kimberlites found over the North American continent, i.e., we compute the position of the lithospheric plate at the time when the kimberlites were emplaced. We use the GPlates software and new rotation poles that allow us to go back 1,000 Myr in time (Merdith et al., 2019).

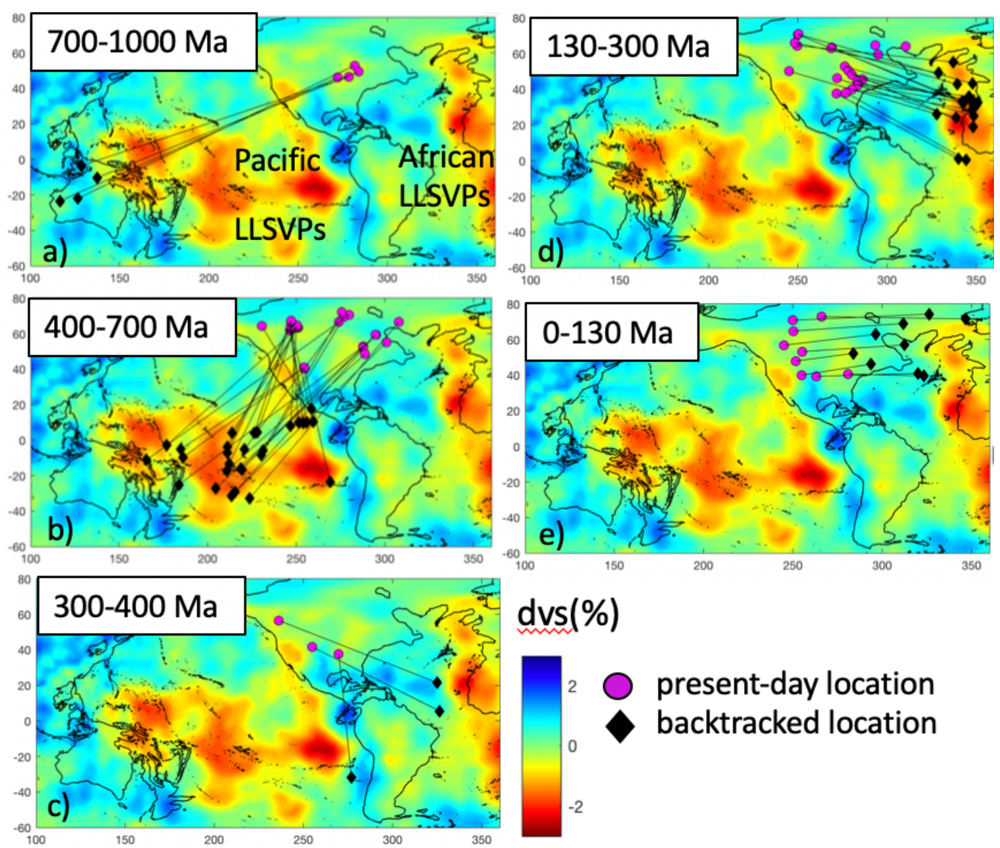

Figure 1: Depth cross-section across the Savani tomography model at depth ~2800 km (Auer et al., 2014), showing the LLSVP locations (regions in red, associated with negative seismic velocity anomalies, dvs). The present-day and backtracked locations of kimberlites are displayed by purple circles and black diamonds, respectively. We use the kimberlite database published by Tappe et al. (2018), and we backtrack the kimberlite locations using the GPlates software and the rotation poles by Merdith et al. (2021). Panels a-e show the reconstruction for different time periods

We show that most kimberlites (87.5%) emplaced within the North American continent during the period 1000 to 130 Ma have been generated along the margins of LLSVPs (Figure 1). We also show a temporal evolution of the emplacement processes. The oldest kimberlites, with ages between 700 and 400 Ma, were emplaced above the margins of the Pacific LLSVP (Figure 2b); kimberlites with ages between 300 and 130 Ma were emplaced at the margins of the African/Atlantic LLSVP (Figure 2d). This has important implications regarding the origin and dynamics of LLSVPs. One of the main questions about them being: "are LLSVPs passive features, easily swept away by mantle convection or do they play an essential role in creating and stabilizing global mantle flow (McNamara, 2019)? " Our results support the latter.

More importantly, we show that the 300-400 Ma period is a quiet period, during which few kimberlites were emplaced within North America (Figure 2c). This period occurs when the North American plate drifted from the Pacific LLSVP to the African/Atlantic LLSVP. Tappe et al. (2018) noticed that kimberlite magmatism is not continuous but rather composed of quiet periods, followed by periods of enhanced magmatism, which, according to these authors correspond to periods of continent assembly and breakup. In this case, the emplacement of kimberlites is a "successful drainage event", facilitated by tectonic triggers. However, our results suggest the mantle plays an active role, as most of kimberlite are emplaced over LLSVPs.

The youngest kimberlites in North America (ages <130 Ma) appear to have no association with an LLSVP and, instead, may be the product of edge-driven convection processes (EDC) (Adam et al., 2023). EDC can be induced where lithosphere transitions from thick to thin. This setup creates decompression melting, which may account for kimberlites and/or other types of volcanic emplacements (e.g., King and Anderson, 1998; Kjarsgaard et al., 2017; Kempton et al., 2019). We investigate the relationship between the base of the lithosphere, extracted from the CAM2016 model (Priestley et al., 2018) and the present-day location of kimberlites younger than 130 Ma. We show that they are emplaced along the margins of cratons (Figure 2). EDC may have then played an important role in their emplacement.

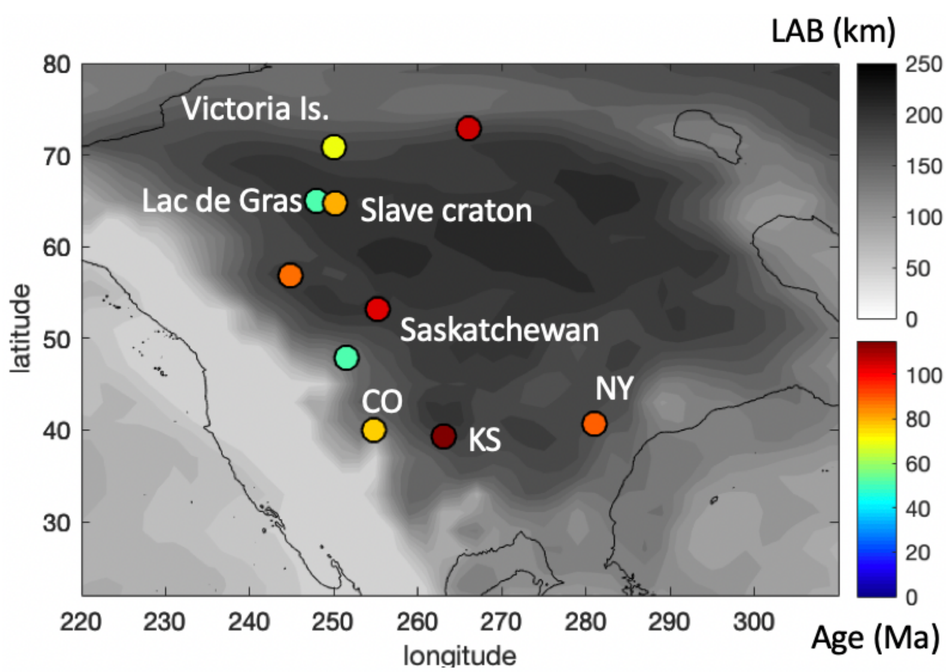

Figure 2: Lithosphere-Asthenosphere Boundary (LAB), (data from Priestley et al., 2019) and the age and locations of kimberlites younger than 130 Ma (data from Tappe et al., 2018).

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