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A Geochronological Perspective on the Geodynamic Models of Kimberlite and Lamproite Magmatism in Kansas

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Introduction

In eastern Kansas, twelve kimberlites and two lamproites comprise the southernmost section of the north-south trending Mid-Cretaceous 'corridor' of alkaline igneous rocks within central North America. At least four different geodynamic models have been proposed to explain the formation of this ~5000 km stretch of alkaline magmatism including (i) association with mantle plumes, (ii) subduction of the Farallon plate, (iii) association with a large low shear velocity province (LLSVP), and (iv) edge-driven convection (EDC). Each of these models has spatial-temporal constraints that provide a basis for assessing their applicability to kimberlite and lamproite petrogenesis in Kansas.

Blackburn et al. (2008) previously reported emplacement ages for five of the Kansas kimberlites of 110-85 Ma and attributed a younger age of ~65 Ma to a later hydrothermal reheating event. K-Ar geochronology on three phlogopite separates from the Kansas lamproites (Zartman et al., 1967) suggests they fall within that range, with ages of ~94-91Ma after recalculation with updated decay constants following Bohike et al. (2005) and Renne et al. (2011) via *Ar*AR software (Mercer and Hodges, 2016). Given the limited data available, it has been difficult to robustly assess the temporal relationship between the kimberlites and lamproites in Kansas.

This study presents new in-situ U-Pb perovskite geochronology on the Hills Pond and Rose Dome lamproites, along with the Tuttle and Bala kimberlites in order to better constrain their emplacement ages. Perovskite was chosen as the target phase for analysis as it is one of the few primary phases common to both rock types that has survived the observed pervasive alteration.

Petrology

Kansas kimberlites are porphyritic with olivine and pyroxene phenocrysts that have been extensively altered to serpentine and calcite, set in a fine-grained serpentine and calcite matrix. Tuttle is a micaceous volcaniclastic kimberlite (Brookins, 1970; Blackburn et al., 2008), characterized by abundant anhedral olivine pseudomorphs, country rock xenoliths, and melt-bearing pyroclasts. The Bala kimberlite is notably denser, less brecciated, and mica is restricted to the groundmass (Brookins, 1970; Blackburn et al., 2008). It also displays two petrographic textures: (i) texture A, which is defined by abundant altered pyroxene phenocrysts in a serpentine and calcite matrix; and (ii) texture B, which consists of zones rich in serpentinized olivine within a slightly more calcite-rich matrix. Hills Pond and Rose Dome are porphyritic madupitic lamproites consisting primarily of olivine, diopside, poikilitic phlogopite ± richterite.

Perovskite is observed at each locality. The Bala perovskites tend to be large (30-150 µm), brown, cubo-octohedral crystals, whereas the Tuttle perovskites are smaller (5-25 µm), pale grey to light brown, concentratedly zoned cubic crystals. Perovskites in the lamproites are largely anhedral, exhibiting a range in color (i.e., red, brown, brown-green, and cream), size (5-800 µm), and zonation (oscillatory and sector).

Geochronology

Perovskites from the Tuttle kimberlite yield a U-Pb age of 105.6 ± 1.9 Ma, consistent with the 106.6 ± 1.0 Ma Rb-Sr phlogopite and clinopyroxene age of Blackburn et al. (2008). In contrast, perovskites from the Bala kimberlite yield two age populations at 59.6 ± 7.4 Ma and 81.7 ± 8.6 Ma (Fig. 1). Blackburn et al. (2008) also determined two distinct ages for this kimberlite. The younger perovskite age is within uncertainty of the 64.3 ± 7.5 Ma (U-Th)/He apatite age from Blackburn et al. (2008), whereas their older age of 103.0 ± 7.5 Ma, based on (U-Th)/He in magnetite, is > 20 m.y. older than the older perovskite population.

The lamproite perovskites contain higher proportions of common Pb than those in kimberlite. To minimize uncertainty, all U-Pb LA-ICP-MS analyses were combined on a per locality and analytical session basis. Despite the range of petrographic attributes exhibited by lamproite perovskites, the results suggest single age populations for each locality. The Hills Pond perovskites yield an age of 86.9 ± 3.5 Ma (MSWD=1.1, n=274); whereas the Rose Dome perovskites yield an age of 97.1 ± 12.6 Ma (MSWD= 0.74, n=344). Both ages are within error of the recalculated phlogopite K-Ar age range of 92-93 ± 5 Ma for Hills Pond and 90 ± 4 Ma for Rose Dome (Zartman et al. 1967).

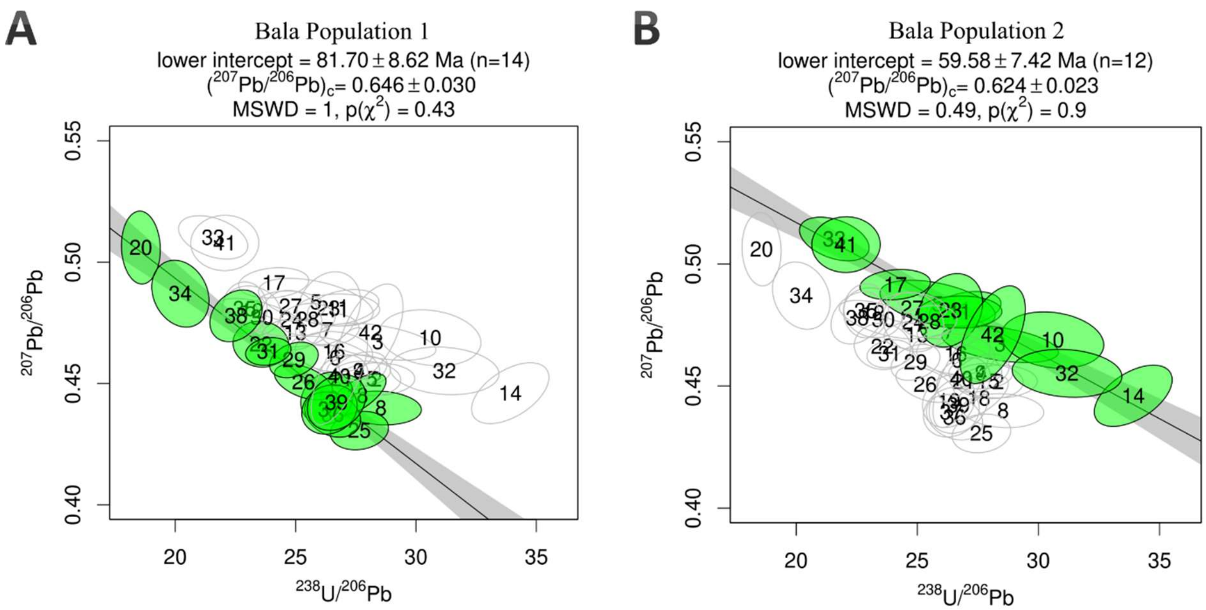

Figure 1: Tera-Wasserburg plots showing the two perovskite populations in the Bala kimberlite (analysis spot numbers indicated). Only the green filled ellipses represent U-Pb data used in each age calculations. Error ellipses are 2σ.

Discussion/Conclusions

Our in-situ analytical approach reveals a relationship between petrographic texture and age for the Bala kimberlite. Thus, in contrast to the interpretation of Blackburn et al. (2008), the younger age is not due to hydrothermal reheating but rather evidence for kimberlitic magmatism recurring within the same pipe for at least 22 m.y. Overall, magmatism within the Kansas kimberlite and lamproite fields spanned ~46 and 11 m.y., respectively, with lamproite magmatism initiating ~8 m.y. after the onset of kimberlite magmatism.

Our new spatial-temporal constraints allow us to assess the applicability of each geodynamic model to the Kansas kimberlites and lamproites. The mantle plume model can be readily discarded, given the protracted period over which magmatism occurred within a limited spatial area. Models involving subduction of the Farallon plate are improbable as reconstructions show that the leading edge of the plate was 1200 km too far west to supply slab-derived fluids to their mantle source region (Kjaarsgaard et al., 2017). A correlation between the edges of LLSVPs and the reconstructed locations of many kimberlites has been shown (Torsvik et al., 2014; Lee, 2023). However, when backtracking the locations of the Kansas kimberlites and lamproites to their minimum and maximum U-Pb ages (105 and 60 Ma), there is no correlation with an LLSVP. Kjardsgard et al. (2017) observed that most kimberlites within the Mid-Cretaceous corridor occur near regions of attenuated lithosphere. Indeed, the CAM2016 model for the lithosphere-asthenosphere boundary (LAB) (Priestley et al., 2018), confirms that the Kansas kimberlites and lamproites occur within the American Midwest Transition (Foster et al., 2014). The transition in LAB thickness, coupled with the thermal insulation provided by the North American craton, could lead to the generation of EDC cells, producing small degrees of partial melting to ascend from the mantle (Kjardsgard et al., 2017). Our geochronological data are most consistent with an EDC model for the origin of the Kansas kimberlites and lamproites and may also explain the presence of other Mid-Cretaceous alkaline magmatism across the region.

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