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DATING PEROVSKITES FROM KIMBERLITES OF THE ALTO PARANAIBA IGNEOUS PROVINCE, BRAZIL: CHALLENGES, STRATEGIES AND GEODYNAMIC IMPLICATIONS

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Introduction

Kimberlites and related rocks are the focus of research and exploration in the Alto Paranaiba Igneous Province (APIP; Brazil) due to their potential correlation with adjacent diamond fields. Obtaining new precise geochronology for the APIP intrusions is fundamental to any attempt to geodynamic understanding of the triggering of the magmatism in the area, and even to the search for controls on diamond deposits. In this work, we explore the challenges and some possible strategies for dating perovskites in kimberlites from the APIP, attempting to provide some clarity on the real contribution of perovskite dating in the APIP geodynamic scenario. The new U-Pb perovskite ages were obtained using recommended protocols for error propagation and data interpretation (e.g., Horstwood et al. 2016).

Samples and Methods

Perovskite is a ubiquitous mineral in all kimberlite, kamafugite and lamproite occurrences of the APIP. For this study, different sets were selected for comparison: (1) perovskites from weathered intrusions, where samples were collected from the saprolite profile (perovskites as heavy resistate minerals): Catalão-1b (CAT-1b), Três Ranchos-55 (TR-55), and Ouvidor-07 (OU-07) intrusions; (2) perovskites (fresh samples) from facies with different degrees of crustal contamination within a single intrusion: Pântano intrusion (PNT; also called Limpeza-18); (3) perovskites (fresh samples) from intrusions outcropping proximally and derived from a similar source: Indaiá-I, Indaiá-II (IND-I and IN-II, also called Perdizes 3a and 3b) and Limeira-I (LIM-I, also called Perdizes 4a) intrusions.

Two analytical methodologies were applied: one determined by *in situ* analyses and other using mineral separates. *In situ* U-Pb perovskite dating using LA-SF-ICP-MS was used in all cases, conducted at the Arctic Resource Lab, University of Alberta (Canada). Also, for samples from IND-I, IN-II and LIM-I, U-Pb ID-TIMS analyses of bulk perovskite separates were performed at the University of Alberta, Canada.

Results and Discussion

Despite the utility of perovskites for U-Pb dating, their significant incorporation of common-Pb is a fundamental limitation on the age resolution of this dating approach, especially for Mesozoic and younger samples (common-Pb of new APIP data: 52-84% for *in situ* analyses, 75-95% for TIMS analyses – Fig. 1). Consequently, the APIP U-Pb ages neither confirm nor discredit previously proposed geodynamic models that invoke age progression (related to the Trindade plume) or distinct magmatic episodes.

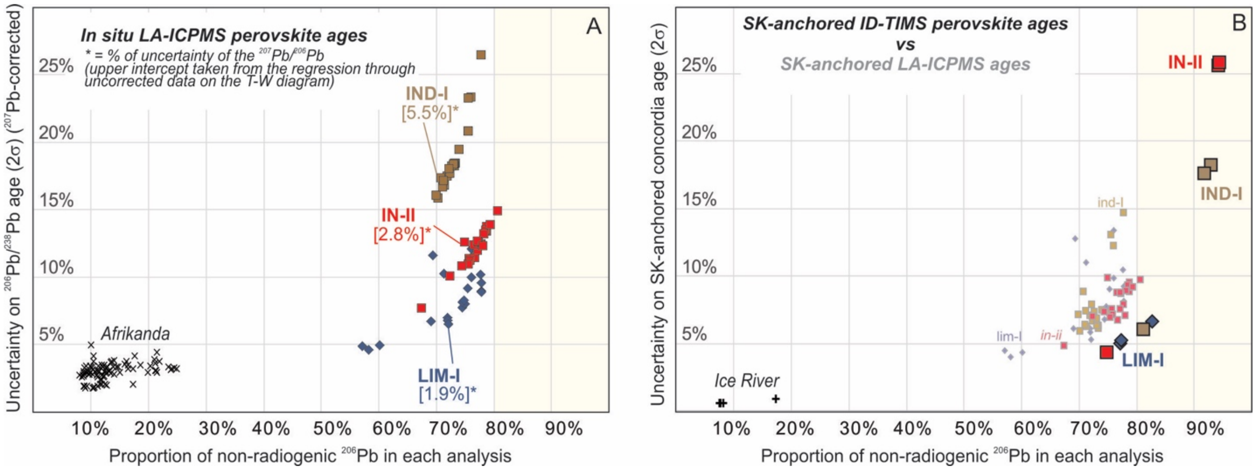

Fig. 1. Influence of non-radiogenic ^{206}Pb on perovskite age uncertainties from LIM-I, IND-I, and IN-II intrusions of APIP. A) A bivariate plot showing the fraction of the non-radiogenic ^{206}Pb versus the variation of $^{206}Pb/^{238}U$ age uncertainty (2σ) of each individual *in situ* perovskite analyses obtained by LA-ICP-MS. The $^{207}Pb/^{206}Pb$ ratio required for the common-Pb correction for each intrusion was obtained from the upper intercept of the unanchored T-W graph. On B) the fraction of the non-radiogenic ^{206}Pb of individual analyses (by LA-ICP-MS, pale colors, smaller symbols) and of perovskite concentrates (ID-TIMS, bright colors) are plotted versus both $^{206}Pb/^{238}U$ individual and ID-TIMS age uncertainties. In this graph, common-Pb correction schemes were obtained using SK-anchoring values. Afrikanda perovskite was used as quality-control standard of LA-ICP-MS analyses and *Ice River* perovskite was used as the quality-control standard analyzed by ID-TIMS.

U-Pb perovskite ages from the APIP kimberlite intrusions studied here are within the wide interval defined by previous geochronological studies (61-98 Ma). Comparing the best ID-TIMS and LA-ICP-MS age results from the same intrusion, and using the same common-Pb correction approach, the LA-ICP-MS data have lower uncertainties. This is largely due to access to a greater spread in common-Pb, which improves regressions and tends to yield older ages (Fig. 2). Unanchored Tera-Wassenburg (T-W) concordia ages are mostly preferred for such perovskites. The SK-anchored T-W regression is used when the data points on the T-W concordia are too clustered to construct a well-defined regression line and/or when the $^{207}Pb/^{206}Pb$ ratios of unanchored T-W concordia are within error of the two-stage Stacey and Kramers (SK; 1975) Pb-isotope evolution model.

Evidence of Pb-loss was found for perovskites collected from weathering profiles (as heavy residual minerals), typical of APIP kimberlite outcrops. This process leads to higher uncertainties in individual analyses, increased data scatter, and consequently higher uncertainties in age estimates, with a tendency toward younger ages. In these situations, after excluding analytical data with evident Pb-loss, a good alternative is to first constrain the $^{207}Pb/^{206}Pb$ from an unanchored T-W regression and compare this value with the SK-model values (Fig. 3). If they are similar, the SK-anchored T-W ages likely provide the best estimate for common-Pb correction. Comparing perovskite ages of fresh kimberlite samples with different degrees of crustal contamination from a single intrusion (PNT), we found an indication of some variability in $^{207}Pb/^{206}Pb$ and $^{238}U/^{206}Pb$ ratios, with a tendency towards older ages and higher uncertainties for more contaminated samples. For almost fresh intrusions with geochemically and isotopically similar mantle sources, related to the same magmatic event and in a close geographic area, we prefer to combine the data in a single unanchored T-W plotting and using the $^{207}Pb/^{206}Pb$ ratio obtained from the upper intercept for common-Pb correction. This approach is preferred especially when $^{207}Pb/^{206}Pb$ from the unanchored T-W is different from that predicted from the SK-model (Fig. 3). In these cases, the difference in estimation of common-Pb values results in age differences > 10 Ma for a single intrusion (see Fig. 2).

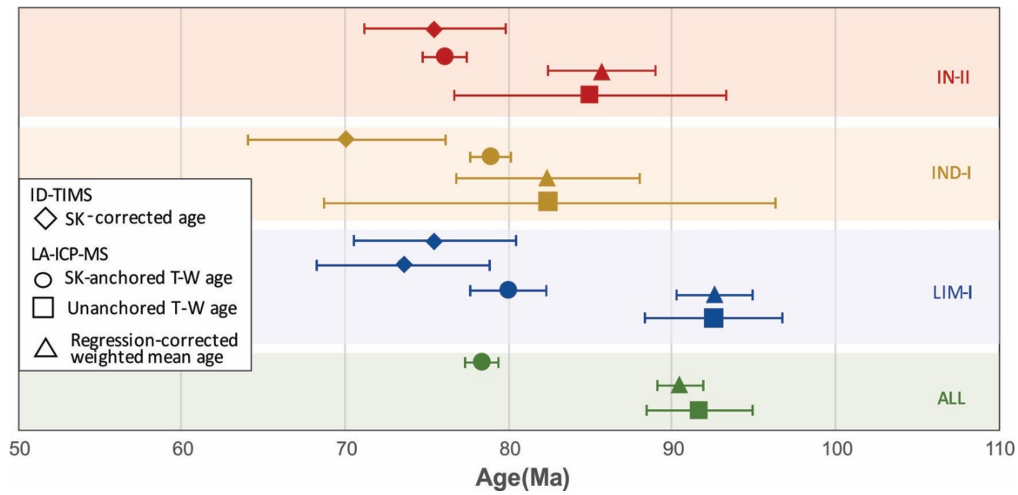

Fig. 2. ID-TIMS vs. LA-ICP-MS perovskite ages for LIM-I, IND-I, and IN-II. Error bars are 2σ.

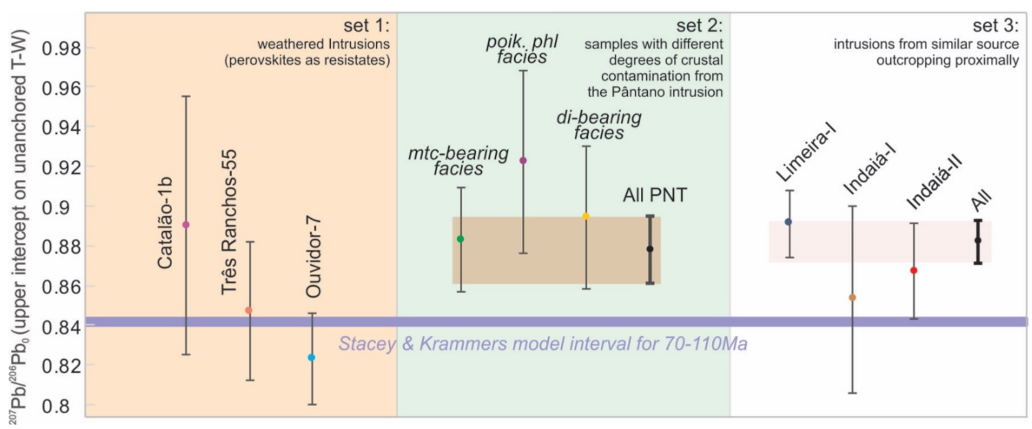

Fig. 3. Values of $^{207}Pb/^{206}Pb$ obtained from the unanchored T-W graphs (upper intercept) for the studied intrusions from APIP. The purple bar is representative of the $^{207}Pb/^{206}Pb_0$ interval calculated according to the Stacey and Kramers (1975) evolution model of Pb for the range of 70-110 Ma.

Despite their high common-Pb, using these strategies, our new perovskite data clearly indicate that APIP magmatism is restricted to Upper Cretaceous times. The initiation of APIP magmatism at ~90 Ma is consistent with a predicted time lag of ~30 Ma after the initial opening of the South Atlantic Ocean and the initial stages of evolution of a stable platform after the Paraná-Etendeka LIP development.

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