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Common-lead corrected U-Pb age dating of perovskite by laser ablation – magnetic sectorfield ICP-MS

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Introduction

Perovskite is a magmatic phase in mantle-derived mafic and ultramafic rocks that are commonly associated with diamond occurences, such as kimberlites, lamphrophyres, carbonatites and alkaline igneous rocks. Because perovskite appears to not record inheritance and is amenable to U-Pb dating, it is a very useful mineral for dating the age of emplacement of kimberlites and associated rocks. Because the emplacement age of kimberlitic rocks can vary considerably within a single cluster (Heaman et al., 2004) and the abundance of diamonds can vary down to the scale of separate intrusive events within individual composite bodies (e.g. Berryman et al., 2004) the determination of emplacement ages of kimberlitic rocks is an important tool in diamond prospecting.

Conventionally, U-Pb dating is achieved using isotope dilution (ID-TIMS) or ion-probe (SHRIMP) techniques, which are time- and cost-intensive. The potential of the rapid and inexpensive laser ablation ICP-MS technique for U-Pb dating of perovskite has recently been demonstrated by Cox and Wilton (2006). The main obstacle for obtaining accurate and precise U-Pb age dates from perovskite by laser ablation techniques based on quadrupole ICP-MS instruments is the large amount of common lead that is incorporated into perovskite and the associated difficulty to perform accurate common lead corrections due to the high mercury blanks of the gases (i.e. Ar and He) used in LA-ICP-MS. We therefore investigated the benefits (very high sensitivity, very low dark noise and a large linear dynamic range) of single collector magnetic sectorfield ICP-MS (SF-ICP-MS) instruments for U-Pb dating of perovskite by laser ablation.

Sample description and methodology

Perovskites from two kimberlites from Garnet Lake, Søndre Strømfjord, SW Greenland (Hutchison, 2008, *this volume*), and Midternæs, about 15 km north of the Pyramidefjeld Igneous Complex, SSW Greenland (Emeleus and Andrews, 1975), have been separated.

The kimberlites from Garnet Lake are known to be an abundant source of diamonds (Hutchison et al., 2005). Multigrain aliquots of both perovskite separates were U-Pb dated by ID-TIMS, yielding emplacement ages of 568±11 Ma for the Garnet Lake kimberlite and 151±2 Ma (two sigma) for the Pyramidefjeld kimberlite. After embedding in epoxy, grinding and polishing, multiple perovskite grains from both samples have been dated *in-situ* with high spatial resolution (spot analysis using a 30 µm beam diameter) by laser ablation using a ThermoFinnigan Element2 SF-ICP-MS coupled to a NewWave UP 213 laser system.

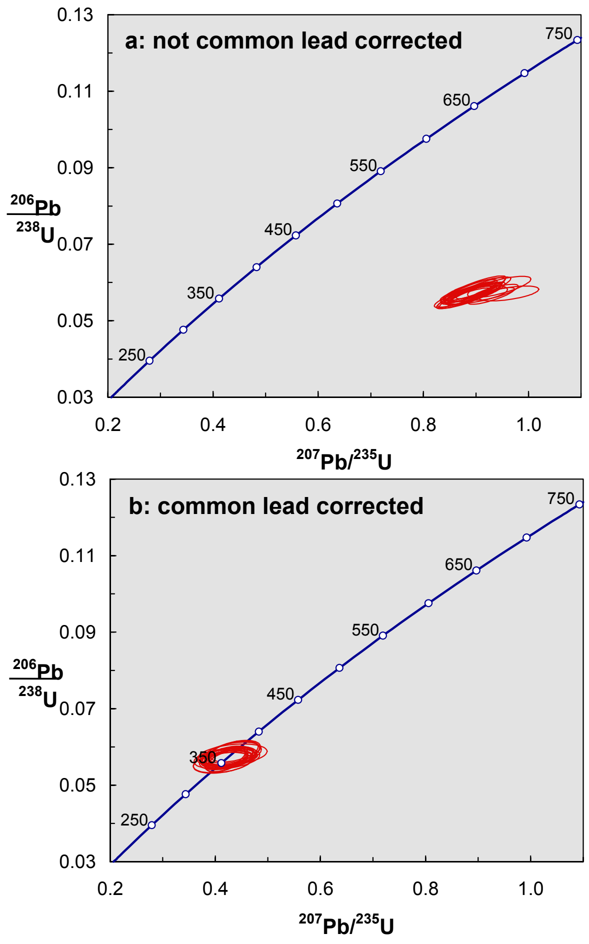

Fig. 1 Effect of common Pb correction on U-Pb age data for the Ice River perovskite. Data-point error ellipses are 2σ.

A common Pb correction was applied using the interference and background corrected ^{204}Pb signal intensity in combination with a model Pb composition (Stacey and Kramers, 1975). The effectiveness of the correction is shown in Fig. 2 for 21 analyses of the Ice River perovskite (see below). A general description of the analytical methodology is provided by Frei et al. (2006) and Frei and Gerdes (2008).

Results

Ice River perovskite

Throughout this study perovskite from the Ice River alkaline complex, southeastern British Columbia (Currie, 1975), was used as a secondary standard in order to evaluate the accuracy of the measurements.

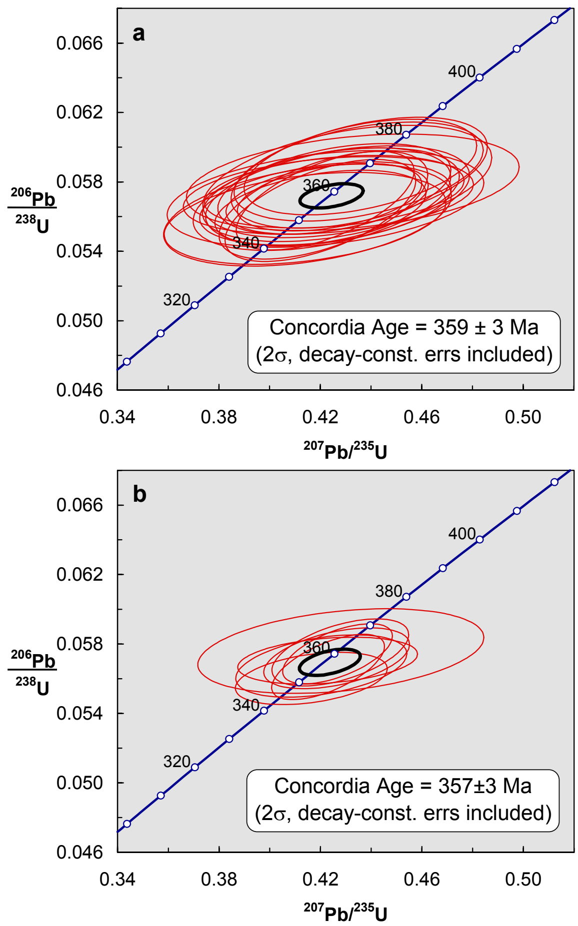

Fig. 2 Wetherill concordia diagrams illustrating the results for 21 (a) and 8 (b) U-Pb measurements of the Ice River perovskite by LA-SF-ICP-MS during two individual analytical sessions. Data-point error ellipses are 2σ.

Multiple in-situ measurements of the Ice River perovskite in two different analytical sessions yielded concordia ages of 359±3Ma (Fig. 1a) and 357±3 Ma (Fig. 1b) after correction for common lead. These results are in excellent agreement with the ID-TIMS ages of 356 Ma for the Ice River perovskite determined by ID-TIMS on an aliquot from the same grain separate used in this study (Heaman, 2007, *pers. comm.*) and the ages of 356 to 372 Ma reported for the emplacement of the Ice River complex by Parrish et al. (1987).

Garnet Lake perovskite

In total nineteen perovskite grains extracted from the Garnet Lake kimberlite have been employed for *in-situ* U-Pb analysis. After correction for common Pb the measurements yielded a concordia age of 566±5 Ma, which is in excellent agreement with the age of 568±11 Ma obtained by ID-TIMS (Fig. 3).

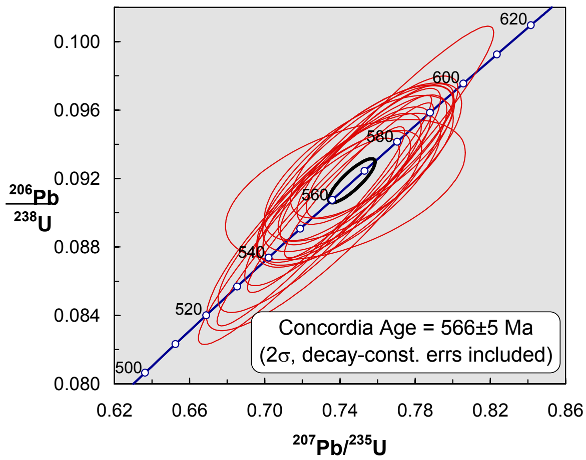

Fig. 3 Wetherill concordia diagram illustrating the results for 19 U-Pb measurements of perovskite extracted from the Garnet Lake kimberlite by LA-SF-ICP-MS. Data-point error ellipses are 2σ.

Midternæs perovskite

The comparably young age (Jurassic) and, consequently, the associated very low Pb contents in perovskites from Midternæs (with average Pb contents around 1 ppm) resulted in large uncertainties associated with the common Pb correction. Hence no concordia age could be obtained.

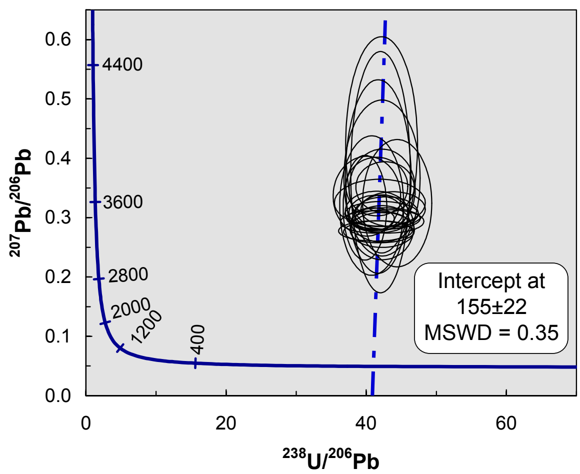

Fig. 4 Tera-Wasserburg plot with regression for 26 U-Pb analysis of perovskite from Midternæs. Data-point error ellipses are 2σ.

A Tera-Wasserburg plot (Fig. 4) reveals an array of points above concordia defining an apparent common

Pb discordia line yielding a common Pb anchored regression intercept age of 155±23 Ma, which is in very good agreement with the weighted average $^{206}Pb/^{238}U$ age of 151.2±1.5 Ma determined by ID-TIMS, but has a comparably large error. Therefore, the $^{206}Pb/^{238}U$ ages determined by laser ablation analysis are considered as the most reliable age estimation. The weighted average of all 26 common lead corrected $^{206}Pb/^{238}U$ age determinations yield an age of 152±3 Ma (Fig. 5) which is in excellent agreement with the ID-TIMS age.

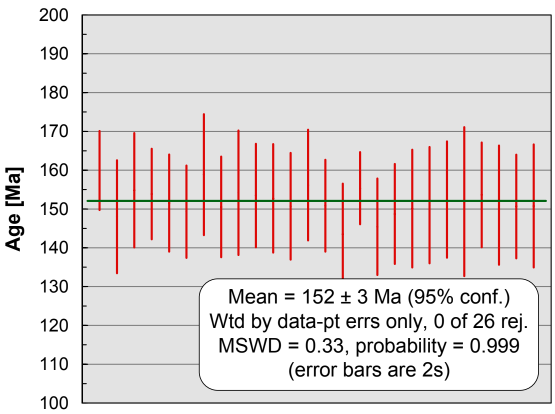

Fig. 5 Weighted mean of $^{206}Pb/^{238}U$ ages of perovskite from Midternæs obtained by in-situ LA-SF-ICP-MS analysis.

Conclusions

In order to assess the accuracy and precision of *in-situ* U-Pb age dating of perovskite by common Pb corrected LA-SF-ICP-MS, we have analysed perovskites from three locations in Canada (Ice River alkaline complex) and Greenland (Garnet Lake and Midternæs) that have previously been dated by ID-TIMS. For all analysed samples, the results obtained by LA-SF-ICP-MS are within error indistinguishable from the results obtained by ID-TIMS. The precision of the U-Pb ages obtained for perovskite from Garnet Lake and Midternæs compares favourably with the precision of ID-TIMS. We therefore conclude that LA-SF-ICP-MS is a fast and inexpensive method for precise and accurate common Pb corrected U-Pb dating of perovskite. The comparably small beam diameter (30 µm) and the depth resolution of only about 20 µm allows U-Pb age dating of perovskite *in-situ* in polished rock slabs (Hutchison and Frei, 2008, *this volume*) and hence constitutes a powerful new tool for diamond exploration.

Acknowledgements

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