A Comparison of Geochronology Methods Applied to Kimberlites and Related Rocks from the Karelian Craton, Finland

David Phillips[1], Darwin Zhong[1], Erin L. Matchan[1], Roland Maas[1], Henrietta Farr[1], Hugh O'Brien[2] and Andrea Giuliani[1]

[1]*The University of Melbourne, Parkville, Australia, dphillip@unimelb.edu.au.*
[2]*Geological Survey of Finland, Bentonimiehenkuja, Finland, hugh.obrien@gtk.fi.*

Introduction

A range of geochronology techniques have been applied to kimberlites and related rocks, including the Rb-Sr phlogopite, U-Pb perovskite, U-Pb zircon, $^{40}Ar/^{39}Ar$ phlogopite and Fission Track apatite methods. These approaches all have specific advantages and disadvantages, with the Rb-Sr phlogopite and U-Pb perovskite methods being the most commonly used for kimberlite geochronology.

In this study, we compare the Rb-Sr phlogopite, U-Pb perovskite and $^{40}Ar/^{39}Ar$ phlogopite/kinoshitalite dating methods, applied to kimberlites and orangeites from the Karelian craton, Finland. This region includes the Kaavi-Kuopio Group I kimberlite province, located along the southwestern margin of the craton, the Kuusamo Group I kimberlites in the north-central part of the craton, and orangeites and related alkaline rocks of the Lentiira-Kuhmo-Kostomuksha area in the centre of the craton straddling the eastern Finland – Russia border.

Previous Work

Previously published $^{206}U/^{238}Pb$ perovskite ages for the Kuusamo Group I Kattaisenvaara and Kalettomanpuro kimberlites are 759 ± 15 Ma and 756.8 ± 2.1 Ma, respectively (O'Brien and Bradley 2008). $^{206}U/^{238}Pb$ perovskite results for the Kaavi-Kuopia kimberlites give an age range of 589 – 626 Ma (O'Brien et al. 2005). $^{40}Ar/^{39}Ar$ analyses of phlogopite from the Seitaperä (Pipe 16, two samples) and Lentiira orangeites (Lentiira-Kuhmo cluster) yielded weighted mean ages of 1202 ± 3 Ma, 1199 ± 3 Ma and 1204 ± 4 Ma, respectively (O'Brien et al. 2007). These results are broadly similar to Rb-Sr data reported for orangeite samples from the Kostomuksha cluster (Belyatsii et al. 1997; Nikitina et al. 1999), which give a recalculated age of 1232 ± 10 Ma (2σ; MSWD = 35) (O'Brien et al. 2007).

Methods

Handpicked phlogopite and kinoshitalite micas were washed in water, 2M HCl, and dissolved in HF-HNO_3. Sample solutions were equilibrated with a ^{85}Rb-^{84}Sr tracer, with Rb and Sr extracted on Eichrom Sr resin and cation resin columns. Isotopic analyses were carried out on a Nu Plasma MC-ICPMS (University of Melbourne). $^{87}Rb/^{86}Sr$ ratios determined by isotope dilution have an external precision of ±0.5% (2σ). Isochron ages were calculated using the ISOPLOT software from the Berkeley Geochronology Centre (www.bgc.org.au). The decay constant of ^{87}Rb is 1.397E-11/yr.

Phlogopite and kinoshitalite grains were irradiated in the Oregon State University reactor, together with the monitor Fish Canyon Tuff sanidine (28.126 Ma; Phillips et al. 2017). Single grain $^{40}Ar/^{39}Ar$ step-heating analyses were conducted on a multi-collector ARGUSVI mass spectrometer (University of Melbourne). Ages were calculated using the atmospheric ration of 298.56 ± 0.31 (Lee et al. 2016) and the decay constants of Steiger and Jäger (1977). Plateau ages were calculated using ISOPLOT.

Results

Rb-Sr and $^{40}Ar/^{39}Ar$ analyses of phlogopite and kinoshitalite from representative samples of Kuusamo kimberlites produced indistinguishable ages of 747 ± 4 Ma and 747.8 ± 1.0 Ma (2σ), respectively (Figs. 1, 2), broadly similar to previous U-Pb perovskite results from the same localities.

Rb-Sr analysis of three leach aliquots from a Kostomoksha orangeite dyke (KOS OL) give an isochron age of 1180 ± 5 Ma (Fig. 1). $^{40}Ar/^{39}Ar$ analyses of single phlogopite grains from the same sample produced slightly discordant age spectra, with most ages in the range 1200 – 1210 Ma. $^{40}Ar/^{39}Ar$ analyes of phlogopite from other orangeites in the nearby Lentiira-Kuhmo cluster produced more consistent results, although only one sample produced a plateau age – 1204.4 ± 1.2 Ma (2σ) (Fig. 3). No perovskite was recovered from the orangeite localities.

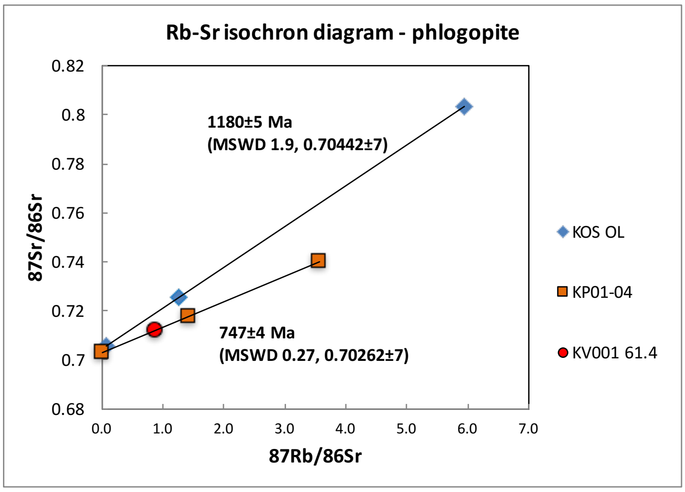

Figure 1. Rb-Sr isochron plots for leached separates of kinoshitalite from two Kusammo Group I kimberlite (Kalettomanpuro - sample KP01-04; Kattaisenvara – sample KV001-61.4m; orange and red symbols, respectively) and from a Kostomoksha orangeite (sample Kos-Ol; blue symbols). (uncertainties are ±2σ).

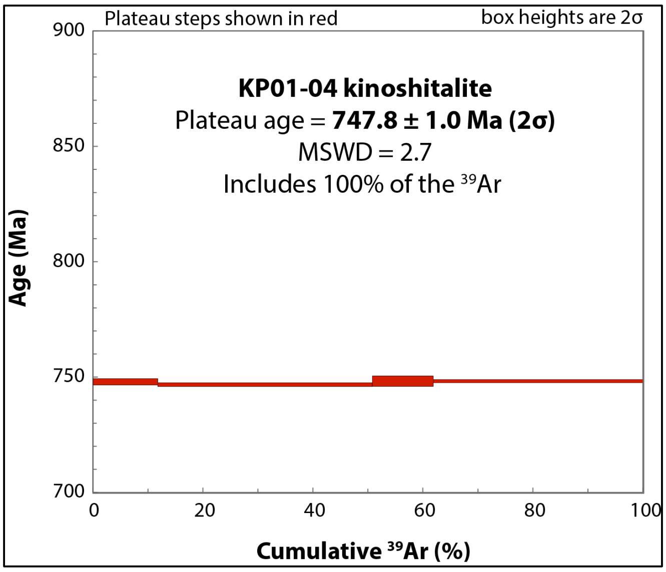

Figure 2. $^{40}Ar/^{39}Ar$ step-heating age spectrum for kinoshitalite extracted from the Kalettomanpuro Group I kimberlite (sample KP01-04), Kuusamo cluster. This sample shows a plateau age of 747.8 ± 1.0 Ma (2σ).

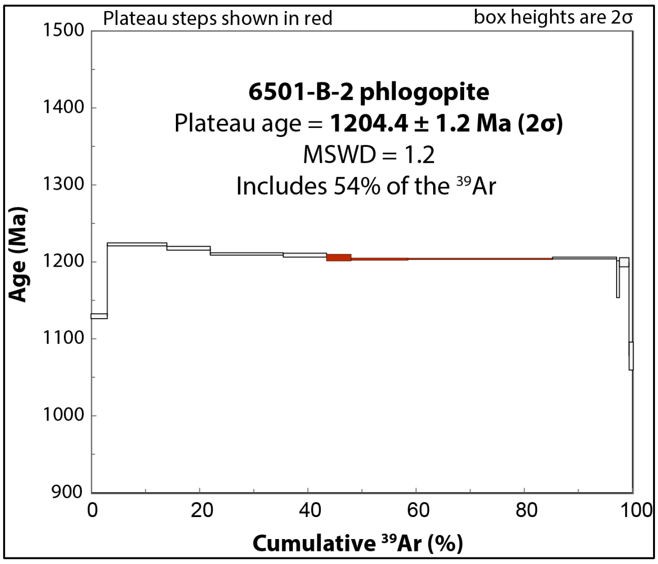

Figure 2. $^{40}Ar/^{39}Ar$ step-heating age spectrum for phlogopite extracted from the Seitaperä orangeite intrusion in the Kuhmo region (sample 6501-B-2). This age spectrum shows discordance in the low temperature steps, with the higher temperature steps yielding an plateau age of 1204.4 ± 1.2 Ma (2σ).

Discussion

The concordance of the Rb-Sr and $^{40}Ar/^{39}Ar$ results (748 Ma) obtained on the Kuusamo kimberlite samples provides confidence in the age of these localities. However the results are distinctly younger than the most precise $^{238}U/^{206}Pb$ perovskite age reported for the Kuusamo cluster Kalettomanpuro kimberlite (756.8 ± 2.1 Ma; O'Brien and Bradley, 2008). In contrast, the Rb-Sr and $^{40}Ar/^{39}Ar$ ages reported for the Lentiira-Kuhmo-Kostomuksha orangeites are less consistent, with Rb-Sr ages (1180 ± 5 Ma, 1232 ± 10 Ma) bracketing $^{40}Ar/^{39}Ar$ results (1200 – 1210 Ma). Unfortunately, U-Pb perovskite data could not be obtained from these localities. Although the current results provide the most precise estimates for the time of kimberlite/orangeite magmatism in Finland, this study illustrates the importance of using multiple geochronology methods for precise and accurate determination of kimberlite and orangeite emplacement events.

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