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Discussion

Comment on "New Ar–Ar ages of southern Indian kimberlites and a lamproite and their geochemical evolution" by Osborne et al. [Precambrian Res. 189 (2011) 91–103]

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ABSTRACT

Osborne et al. (2011; Precambrian Res. 189, 91–103) report new $^{40}Ar/^{39}Ar$ age results for two kimberlites (Muligiripalle pipe 5 and Tummatapalle pipe 13) and one lamproite (Pochampalle), from the Archaean Dharwar craton in southern India. Previous studies indicate that kimberlites and related rocks are highly susceptible to extraneous argon contamination, leading to anomalously old ages; although reliable $^{40}Ar/^{39}Ar$ ages can be obtained from step-heating analyses of groundmass phlogopite grains. Osborne et al. (2011) carried out single-step $^{40}Ar/^{39}Ar$ fusion analyses on phlogopite phenocrysts and xenocrysts. This approach is not favoured, because it does not allow identification of argon loss/gain effects, thus complicating data interpretation and reducing confidence in the reliability of the reported ages. In particular, it is suggested that the Pochampalle lamproite was emplaced <1400 Ma ago, rather than ca.1500 Ma, as suggested by Osborne et al. (2011). It is recommended that $^{40}Ar/^{39}Ar$ geochronology of kimberlite and lamproites include step-heating analyses of matrix phlogopite grains, with anomalous or contentious results verified using other dating methods.

1. Introduction

India hosts a number of historically important kimberlite and lamproite occurrences. In addition, many new kimberlites and lamproites have been discovered in recent years as a result of expanded diamond exploration activities. Most Indian kimberlites and lamproites are of Mesoproterozoic age; however, an improved geochronology framework is required to better constrain kimberlite and lamproite genesis models and to focus diamond prospecting efforts.

Kimberlites and related rocks can be difficult to date accurately, due to a high susceptibility for alteration and an abundance of entrained mantle and crustal material. The most widely used techniques for dating these rocks include the Rb–Sr phlogopite, U–Pb zircon and U–Pb perovskite methods. The K–Ar and $^{40}Ar/^{39}Ar$ dating methods can also provide useful age information; provided that samples are carefully chosen to avoid alteration affects and rigorous experimental procedures are employed to test for the common presence of extraneous argon (e.g. Phillips et al., 1998, 1999).

Osborne et al. (2011) report new $^{40}Ar/^{39}Ar$ age results for two kimberlites and one lamproite, from the Archaean Dharwar craton, southern India. The two kimberlites (Muligiripalle pipe 5 and Tummatapalle pipe 13) belong to the Wajrakarur kimberlite field, whereas the lamproite (Pochampalle) is associated with the Krishna lamproite field. Osborne et al. (2011) claim 'high precision' emplacement ages of 1113 ± 3 Ma, 1105 ± 12 Ma and ~ 1500 Ma for the Muligiripalle, Tummatapalle and Pochampalle occurrences, respectively (uncertainties reported at the 2σ level).

In this discussion, I evaluate the $^{40}Ar/^{39}Ar$ results of Osborne et al. (2011), present an alternative interpretation of the Pochampalle data, comment on the source(s) of extraneous argon, and describe methods to improve the precision and accuracy of kimberlite and lamproite age data.

2. Sample characterisation

Careful sample selection and characterisation is key to interpreting isotopic results and obtaining reliable ages for kimberlites and related rocks. These issues are particularly important for $^{40}Ar/^{39}Ar$ geochronology, because prior investigations have shown that phlogopite phenocrysts and xenocrysts typically contain variable amounts of extraneous argon, whereas unaltered, matrix phlogopite grains are usually devoid of extraneous argon and yield the best age results (Allsopp and Roddick, 1984; Phillips, 1991; Phillips et al., 1998, 1999).

Osborne et al. (2011) provide useful photomicrographs of the phlogopite-bearing samples selected for their study; however, petrographic descriptions and mica compositional data are lacking.

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The photomicrographs of the two kimberlite samples appear to show unaltered, euhedral to subhedral mica grains hosting inclusions of finer groundmass minerals (Fig. 3a and b of Osborne et al. (2011)); these features are typical of groundmass or phenocrystic phlogopite. In contrast, the Pochampalle lamproite sample contains large, subhedral mica macrocrysts set in a fine-grained matrix (Fig. 3c of Osborne et al. (2011)). The macrocrysts appear to be devoid of groundmass phases, indicating that they are either early-formed phlogopite phenocrysts or xenocrysts.

3. Analytical methods and $^{40}Ar/^{39}Ar$ data reporting

As noted above, previous studies of kimberlites have demonstrated that the most reliable $^{40}Ar/^{39}Ar$ ages are obtained from step-heating analyses of unaltered, matrix phlogopite grains (Allsopp and Roddick, 1984; Phillips, 1991; Phillips et al., 1998, 1999). Step-heating analyses are important for evaluating the presence of extraneous argon, and/or argon loss effects caused by alteration or later thermal events.

The above approach was not followed by Osborne et al. (2011); instead, these authors carried out single grain $^{40}Ar/^{39}Ar$ fusion analyses (equivalent to K–Ar analyses) of phlogopite phenocrysts and xenocrysts. The latter method reduces the chances of identifying extraneous argon or argon loss effects, which in turn complicates data interpretation and raises questions regarding the reliability of the reported age results.

One of the keys to obtaining high precision $^{40}Ar/^{39}Ar$ ages is precise and accurate measurement of ^{36}Ar amounts. However, a number of analyses reported by Osborne et al. (2011; data repository tables) show negative ^{36}Ar results, which are propagated through the age equation, thus giving slightly older ages (up to 6.8%, but mostly <0.5% older), than if the atmospheric correction were not applied. Reasons for the negative ^{36}Ar values and justification of this calculation protocol are not provided.

Note also that several laser spot and traverse analyses (sample POCg) shown in Fig. 4 of Osborne et al. (2011) are not listed in the data repository table or are mislabeled. In addition, *J*-values are not reported in Table 3, contrary to statements in the text.

4. The Wajrakarur kimberlites

Osborne et al. (2011) present fusion (infra-red laser) and in situ (UV) laser spot analyses of single phlogopite grains from the Muligiripalle and Tummatapalle kimberlites. Fusion ages (n = 18), from the Muligiripalle pipe 5 sample, range from 1088 ± 5 to 1149 ± 21 Ma, (Fig. 1) with a calculated weighted mean age of 1113 ± 3 Ma (MSWD = 0.96; excluding the youngest age of 1088 Ma). Fusion analyses of phlogopite grains (n = 10) from the Tummatapalle sample produced ages varying from 1098 ± 16 to 1138 ± 29 Ma, and a mean result of 1105 ± 12 (MSWD = 0.24).

These results are reasonably concordant and in general agreement with Rb–Sr ages reported previously for the Wajrakarur and Narayanpet kimberlites (1085 ± 14 Ma to 1102 ± 23 Ma; Kumar et al., 1993, 2001, 2007). However, it is noteworthy that the mean Rb–Sr age of 1092 ± 3 Ma (MSWD = 0.45; n = 8) is statistically younger than the mean $^{40}Ar/^{39}Ar$ age for the Muligiripalle sample, a discrepancy that is exacerbated if the more recent decay constant and fluence monitor values of Renne et al. (2010) are used. It is possible that the use of single-step analyses, and the relatively large uncertainties associated with many analyses (up to 5.3%), mask subtle argon loss or argon gain (extraneous argon) effects. Step-heating analyses of individual grains or, (less ideally) composites of several grains, would have provided further insight on this issue.

5. The Krishna lamproites

Previous age information on the Krishna Lamproite Field (KLF) is limited to Rb–Sr and K–Ar phlogopite ages of 1224 ± 14 Ma (Kumar et al., 2001) and 1384 ± 18 Ma (Chalapathi Rao et al., 1996), respectively, for the Ramannapeta lamproite. In the nearby Cuddapah basin, the Chelima lamproite has reported ages ranging from 1354 ± 17 Ma (Rb–Sr; Kumar et al., 2001) to 1418 ± 8 Ma ($^{40}Ar/^{39}Ar$; Chalapathi Rao et al., 1999), whereas the nearby Zangamarajupalle lamproite has a Rb–Sr age of ~1090 Ma (Kumar et al., 2001). In all cases, the K–Ar or $^{40}Ar/^{39}Ar$ ages are distinctly older than the Rb–Sr results, suggesting the ubiquitous presence of extraneous argon contamination.

Osborne et al. (2011) analysed several phlogopite grains from the Pochampalle lamproite using two methods. Single grain fusion analyses yielded highly variable ages, ranging from 1408 ± 5 to 1614 ± 8 Ma (n = 6), (Fig. 2) which is consistent with the presence of extraneous ^{40}Ar. UV laser spot analyses and grain margin traverses were then carried out, to refine intra-grain spatial age distributions, which yielded ages ranging from a minimum of 1480 ± 35 along the margin of one mica grain, to a maximum of 1698 ± 30 Ma in the core of another grain.

In this case, Osborne et al. (2011) ascribed geological significance to the grain margin ages and concluded that the Pochampalle

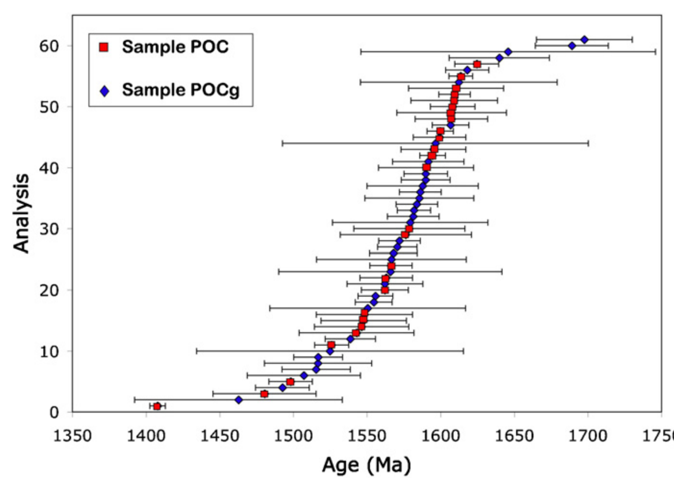

Fig. 1. Summary of $^{40}Ar/^{39}Ar$ age results reported for fusion analyses of single phlogopite grains from the Muligiripalle (pipe 5) and Tummatapalle (pipe 13) kimberlites by Osborne et al. (2011).

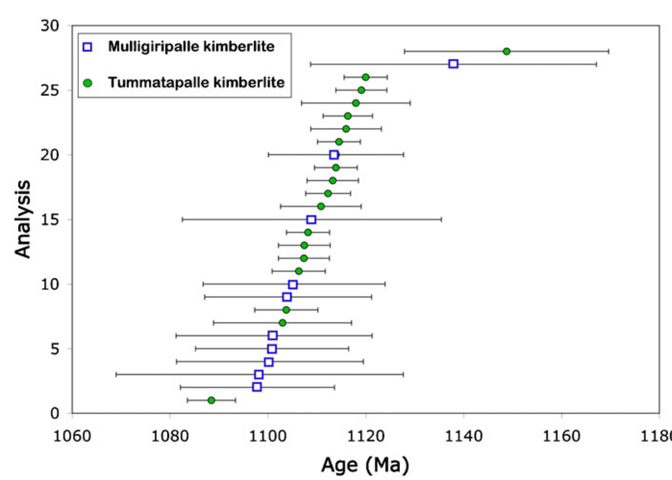

Fig. 2. Summary of all available $^{40}Ar/^{39}Ar$ age results reported for phlogopite grains from the Pochampalle lamproite (samples POC and POCg) by Osborne et al. (2011).