$^{40}Ar/^{39}Ar$ Dating of Kimberlites and Related Rocks: Problems and Solutions

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The determination of accurate emplacement ages for kimberlites and related rocks has important implications for understanding the processes involved in the genesis and intrusion of kimberlitic magmas. As kimberlitic intrusive events are recorded from Eocene to Proterozoic times, they also provide constraints on mantle and crustal geochemical and geodynamic models through time. In turn, this information is utilized in an economic context to focus diamond exploration efforts.

A number of radiometric dating techniques have been applied to kimberlite and related rock geochronology, with varying degrees of success (see reviews by Davis et al., 1996 and Allsopp et al., 1989). The most popular methods are Rb-Sr dating of phlogopite and U-Pb dating of zircon and perovskite. As each of these techniques has certain limitations, it is generally recommended that, where possible, more than one method is used.

Despite the high potassium contents of kimberlites and related rocks, the K-Ar and $^{40}Ar/^{39}Ar$ techniques have not been widely applied to dating emplacement events. This is largely a result of the common presence of excess ^{40}Ar and/or the loss of radiogenic argon (cf. Phillips, 1991; Pearson et al., 1997). Allsopp and Roddick (1984), Smith et al. (1985) and Phillips (1991) have suggested that the most reliable $^{40}Ar/^{39}Ar$ results are obtained from groundmass micas. However, general application of the method has not been demonstrated. Furthermore, matrix phlogopite is rare in some kimberlites and the separation of pure mineral separates for "conventional" $^{40}Ar/^{39}Ar$ analyses can be an arduous task, particularly given the fine grain sizes involved (<200μm).

In the current study, the above problems are addressed through laser probe $^{40}Ar/^{39}Ar$ analyses of groundmass phlogopite from a wide variety of kimberlites and related rocks in southern Africa. The improved spatial resolution of the laser probe allows for the analysis of single groundmass phlogopite grains with grain diameters as small as 50μm. For finer-grained samples, or in cases where phlogopite is rare, grains may be analysed in thin sections. The laser probe obviates the necessity for bulk separates - in most cases, five single phlogopite grains are adequate for determining accurate intrusion ages. The analysis of single grains also serves to identify inherited, xenocrystic, phenocrystic and altered mica grains, which cause problems in bulk analyses. Individual phlogopite grains are step-heated and/or subjected to core-rim laser spot analyses. The reliability of the age data can be assessed through intra- and inter-grain reproducibility of results -- in the current study, most $^{40}Ar/^{39}Ar$ ages are also compared to results from other dating methods.

The localities of the kimberlites and related rocks selected for laser probe $^{40}Ar/^{39}Ar$ dating are shown in figure 1. The list includes the ca.500 Ma Venetia, The Oaks and Colossus kimberlites, which are intruded into the Limpopo Belt and Zimbabwe craton, respectively. The remaining localities comprise Cretaceous/Jurassic intrusives in South Africa, namely, Lace, Voorspoed, Besterskraal, Stieniesrus (Rex mine), 24/K42 (Finsch cluster), Pniel (Aaron's Prospect), Postmas-02 and Vleiplaas (24/PK37). The ca.500 Ma kimberlites are all of Group I affinity. The Vleiplaas occurrence has been classified as transitional between a minette and a diopside-phlogopite lamproite (Tainton, 1992). The remaining localities are classed as Group II kimberlites.

Analytical results are summarised in table 1. It is readily apparent that, where comparisons can be made, the $^{40}Ar/^{39}Ar$ laser probe results are indistinguishable from ages obtained using other techniques. For example, analyses of samples from The Oaks kimberlite yielded a Rb-Sr age of 493 ± 8 Ma, a U-Pb perovskite age of 509 ± 11 Ma and an $^{40}Ar/^{39}Ar$ result of 501 ± 5 Ma. Where other radiometric data are not available, the $^{40}Ar/^{39}Ar$ ages are generally consistent with results from adjacent localities. As an example, kimberlite 24/K42, in the Finsch cluster, produced an $^{40}Ar/^{39}Ar$ age of 119 ± 2 Ma – this result is indistinguishable from a Rb-Sr age of 119 ± 3 Ma, reported for the Finsch kimberlite by Smith et al. (1985).

The current investigation demonstrates that the $^{40}Ar/^{39}Ar$ laser probe technique of analysing single groundmass phlogopite grains offers a reliable method for accurately dating kimberlite and related rock intrusion events. The main advantages of the method are simple sample preparation, rapid analyses, good precision, avoidance of altered, inherited and xenocrystic grains and internal measures of age reliability. Disadvantages of the technique include a restriction to hypabyssal facies kimberlitic material, the rareity of groundmass phlogopite in some kimberlites and a greater susceptibility to alteration, due to the fine grain size. It must be noted, however, that Rb-Sr mica and U-Pb perovskite analyses are also generally limited to hypabyssal facies rocks (cf. Smith et al., 1985). While the $^{40}Ar/^{39}Ar$ laser probe technique provides an internal measure of age reliability, it is still considered complimentary to other isotopic techniques and, where possible, should be used in conjunction with these methods.

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Figure 1. Locality map.

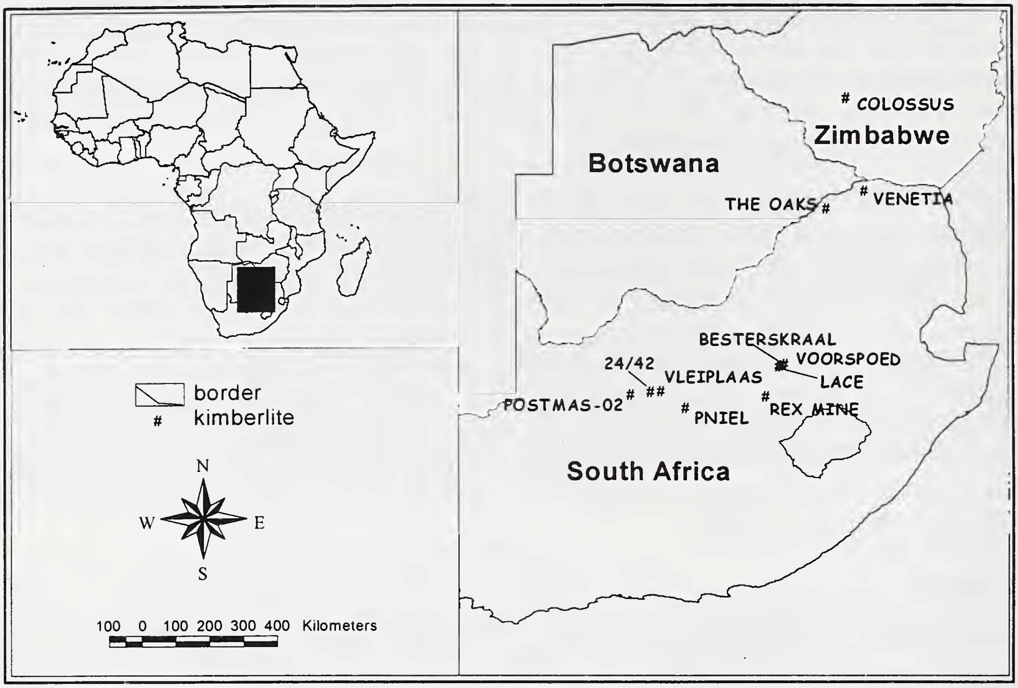

Table 1. Summary of age information for selected kimberlites and related rocks.

LOCALITY	Rb-Sr	U-Pb	$^{40}Ar/^{39}Ar$	References
Venetia	510 ± 16 Ma*		517 ± 6 Ma	*Allsopp et al., 1985a
The Oaks	493 ± 8 Ma	509 ± 11 Ma	501 ± 5 Ma	
Colossus	502 ± 47 Ma*		528 ± 6 Ma	*Allsopp et al., 1985b
Lace			133 ± 3 Ma	
Voorspoed			132 ± 2 Ma	
Besterskraal			135 ± 3 Ma	
Stieniesrus	135 ± 6 Ma		130 - 140 Ma	
24/K42	(119 ± 2 Ma)*		119 ± 2 Ma	*Smith et al., 1985
Pniel			119 ± 1 Ma	
Postmas-02	122 ± 2 Ma		120 ± 2 Ma	
Vleiplaas	120 ± 2 Ma		118 ± 2 Ma	