$^{40}Ar/^{39}Ar$ Laser Probe Analyses of Clinopyroxene Diamond Inclusions from the Orapa and Mbuyi-Miya Mines.

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The ability of the $^{40}Ar/^{39}Ar$ laser probe system to analyse single clinopyroxene diamond inclusions was first demonstrated by Burgess et al. (1989) and Phillips et al. (1989). Initially, the results obtained from these analyses were interpreted as diamond genesis ages. Subsequently, Burgess et al. (1992) reported more variable results for eclogitic inclusions from Orapa, Jwaneng, Udachnaya and Argyle diamonds – in many cases, the ages measured are intermediate between the time of kimberlite eruption and inferred diamond genesis events. As these analyses were performed on inclusions partially encapsulated by their host diamonds, Burgess et al. (1992) suggested that the intermediate ages were caused by partial loss of argon that had diffused to the diamond/inclusion interface during mantle residence. At the time of kimberlite emplacement, the ambient temperature would decrease below the closure temperature for argon diffusion in clinopyroxene, causing radiogenic argon to then accumulate within the inclusion (Burgess et al., 1992, 1997). These authors advocate laser drilling to buried inclusions (i.e. totally encapsulated by diamond), to release the pre-eruption argon component at the diamond/inclusion interface, with subsequent melting of the inclusion to degas post-intrusion argon. Burgess et al. (1997) suggest that the latter component should yield the age of host magma emplacement, while a combination will give an estimate of the diamond formation event. Burgess et al. (1994, 1997) present some evidence to support the latter contention, while the possibility of obtaining kimberlite eruption ages from clinopyroxene inclusions is investigated further in the current study.

If the model proposed by Burgess et al. (1992, 1997) is correct, then total extraction of clinopyroxene inclusions from their host diamonds should result in loss of all pre-eruption argon. Analysis of the extracted inclusion should then provide a reasonable estimate for the time of kimberlite intrusion. To test this hypothesis, $^{40}Ar/^{39}Ar$ laser probe analyses were carried out on clinopyroxene inclusions from several Jwaneng, Orapa and Mbuyi-Miya diamonds. The two former kimberlites are situated in Botswana, with the latter occurring in the Democratic Republic of Congo (Figure 1).

$^{40}Ar/^{39}Ar$ laser probe experiments on two fragments of a large peridotitic clinopyroxene inclusion from a Jwaneng diamond yielded reproducible ages of 241 ± 4 Ma and 233 ± 6 Ma. The mean result of 239 ± 4 Ma is indistinguishable from that of host kimberlite emplacement - Kinny et al. (1989) reported Rb-Sr mica and U-Pb zircon ages of 250 ± 17 Ma and 235 ± 4 Ma, respectively, for the DK2 and DK7 intrusive in the Jwaneng cluster. In contrast, four pieces of a peridotitic clinopyroxene inclusion, from an Orapa mine diamond, yielded apparent ages ranging from 105 ± 2 Ma to 176 ± 3 Ma. These ages are distinctly older than the ca.90Ma intrusion age determined for the Orapa kimberlite by Davis (1977). Laser step-heating of one fragment produced the old apparent age of 176 ± 3 Ma from the low temperature step and a younger apparent age of 107 ± 1 Ma from the high temperature fusion increment. Analyses of five eclogitic clinopyroxene inclusions from Mbuyi-Miya diamonds also yielded anomalous results, with apparent ages ranging from 106 ± 4 Ma to 801 ± 11 Ma. Two fragments from the same inclusion gave dissimilar apparent ages of 539 ± 9

Ma and 801 ± 11 Ma. The inclusion ages are all significantly older than the inferred time of kimberlite intrusion, estimated at ca.71 Ma by Davis (1977) and 70 ± 1 Ma by Scharer et al. (1997).

The most obvious explanation for the older apparent ages is retention of some pre-eruption argon within the clinopyroxene inclusions. However, the age difference between fragments from the same inclusion indicates that the argon is heterogeneously distributed. Furthermore, the step-heating results suggest that the pre-eruption argon is located in low retention sites and/or at grain/domain boundaries. The current results are, thus, incompatible with a simple model involving diffusion of pre-eruption argon to the diamond/inclusion interface during mantle residence. One possibility is initial diffusion of pre-eruption argon to the diamond interface region, followed by the diffusion of some interface gas back into the inclusion in response to increased argon partial pressures caused by differential expansion during the eruption process. In cases where cracks develop around the inclusion, all pre-eruption argon should accumulate at the interface region. An alternative explanation requires partial break-down of the clinopyroxene during transport to surface, causing considerable reduction in diffusion domains and resulting in partial recoil loss of $^{39}Ar_K$. It must be noted, however, that the experimental studies of Burgess et al. (1992, 1994 and 1997) recorded minimal levels of $^{39}Ar_K$ from initial step-heating and laser drilling steps, which mitigates against the latter model. Vacuum encapsulation experiments could be employed to investigate this option more thoroughly.

The potential for determining kimberlitic emplacement ages from clinopyroxene diamond inclusions has important implications for constraining the sources of alluvial diamond deposits around the world (e.g. Burgess et al., 1998). However, the current study demonstrates that caution must be exercised in the interpretation of $^{40}Ar/^{39}Ar$ laser probe results from extracted or partially encapsulated inclusions. While some inclusions may well yield reliable host kimberlite/lamproite emplacement ages, the partial retention of pre-eruption argon will often lead to an over-estimation of the true result.

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Figure 1. Locality map showing the locations of the Jwaneng, Orapa and Mbuyi-Miya kimberlites.

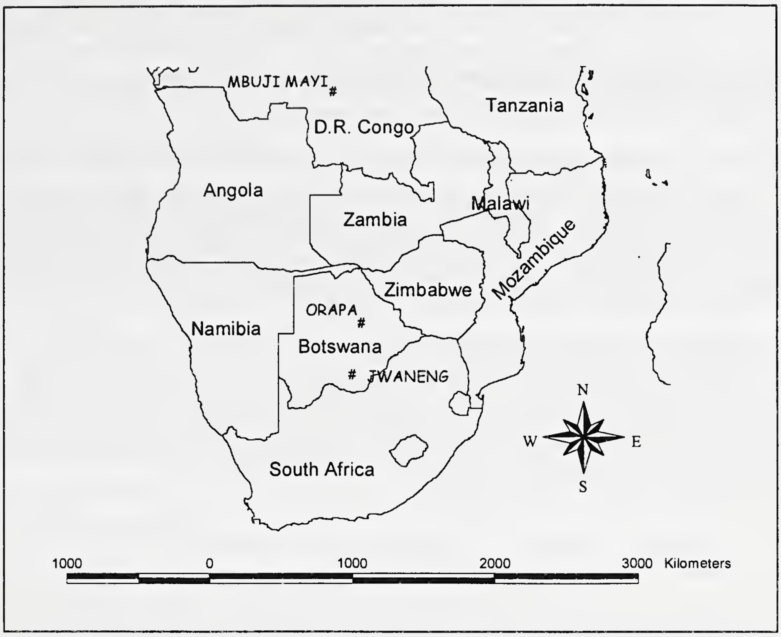

Figure 2. Summary diagram of age results obtained for clinopyroxene inclusions from Jwaneng, Orapa and Mbuyi-Miya diamonds. The vertical bars correspond to the emplacement ages of the kimberlites. The symbols refer to inclusion ages.