MANTLE-DERIVED ARGON COMPONENTS IN PHLOGOPITE FROM SOUTHERN AFRICAN KIMBERLITES

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Application of the 40Ar/39Ar dating technique to kimberlite geochronology often yields discordant spectra with ages that are older than the inferred time of kimberlite emplacement. The anomalously old dates have been attributed to the presence of 'excess' radiogenic argon, incorporated into mineral phases either prior to or during the intrusion of the kimberlite.

Detailed 40Ar/39Ar step-heating analyses have been performed on selected phlogopite samples from kimberlites of known age, to investigate the occurrence and isotopic composition of 'excess' argon components. These studies have also aided in the selection of sample material that is most likely to produce reliable geochronological information.

The Swartruggens Main Fissure, South Africa, is a kimberlite, which contains coarse phlogopite macrocrysts set in a fine-grained mica-rich groundmass. The matrix phlogopite yielded a plateau age of 145±0.3 Ma, which is consistent with previously reported ages, ranging from 142 to 156 Ma (Fig. 1a). In contrast, the phlogopite macrocrysts are characterized by a discordant age spectra, and contain significant amounts of 'excess' radiogenic argon (Fig. 1b). It is suggested that the macrocrysts are xenocrystic, and have entrapped argon prior to crystallization of the kimberlite. Therefore, reliable eruption ages may be obtained on samples from which xenocrystic material can be eliminated. Similar results have been reported by Zartman et al. (1964) and Macintyre and Dawson (1976).

Phillips and Onstott (1986) recognized two distinct 'excess' argon components in phlogopite from the DK-7 kimberlite in southern Botswana. Similar components have since been recognized in phlogopite 'xenocrysts' from other kimberlites and phlogopite-bearing xenoliths. 40Ar/39Ar analyses of phlogopite separated from a garnet lherzolite nodule, from the Premier kimberlite yield ages that are greater than the established intrusion age of 1200 Ma (Allsopp and Kramers, 1977). The step-heating spectrum (Fig. 2) is suggestive of partial loss of 'excess' argon during cooling of the kimberlite.

The various argon components hosted by phlogopite are best distinguished using 36Ar/40Ar versus 39Ar/40Ar correlation diagrams. For the Premier phlogopite, four distinct components are recognized (Fig. 3):

a) 36Ar-rich (atmospheric) contaminating argon, accounting for the high 36Ar/40Ar ratios of the low temperature steps (<800°C). The decrease in the 36Ar/40Ar ratio represents release of this component and increased degassing of radiogenic argon. Construction of a mixing line from the atmospheric ratio (40Ar/36Ar = 295.5) through the low temperature data points intersects the 39Ar/40Ar abscissa at a value corresponding to ±1190 Ma. This is consistent with previously determined Rb-Sr dates. Therefore, despite the presence of 'excess' argon, age estimates may still be achieved, by this method.

b) Radiogenic argon from the decay of 40K subsequent to eruption of the kimberlite.

c) 'Excess' radiogenic-rich argon, resulting in an increase in the 39Ar/40Ar ratio for the intermediate temperature steps (800°- 1100°C).

d) 'Excess' radiogenic-poor argon released at the highest temperatures. The best-fit line through the three highest temperature data points represents a mixing line between decreasing quantities of radiogenic-rich and increasing amounts of radiogenic-poor argon. The intercept on the y-axis yields an 40Ar/36Ar ratio of 365±40.

The origin of the radiogenic-rich 'excess' argon component contained by the phlogopite is unclear. It may represent incomplete degassing of argon produced by in situ K-decay in the mantle, or contamination by a radiogenic-rich argon fluid phase, during residence in the mantle or during emplacement.

The radiogenic-poor 'excess' argon component may be trapped in the hydroxyl sites in phlogopite or in small undetected silicate inclusions (Phillips and Onstott, 1986). Regardless of the specific origin, it is suggested that this component may be representative of ambient argon isotopic compositions in the mantle lithosphere. Similar ratios were obtained on other kimberlitic phlogopites, with a range of values from 278 to 751 (Phillips and Onstott, 1986; and unpubl. data). These ratios are characteristic of an undegassed volatile source in the mantle (Allegre et al., 1983; Hart et al., 1985). As phlogopite is generally considered to be of metasomatic origin, it is suggested that the low 40Ar/36Ar ratios may be indicative of the metasomatising fluids. This implies derivation of the fluids from an undegassed source beneath the southern African lithosphere. Additional analyses on other kimberlite phases are in progress to assess further the validity of the above conclusions.

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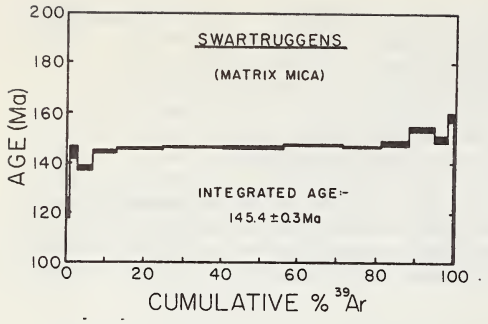

Figure 1a). Apparent age versus %39Ar release for groundmass phlogopite from the Swartruggens Main Fissure. The spectra has a plateau age of 145±0.3 Ma, which is consistent with previous age determinations. The vertical width of the bars represent ±1S.D.

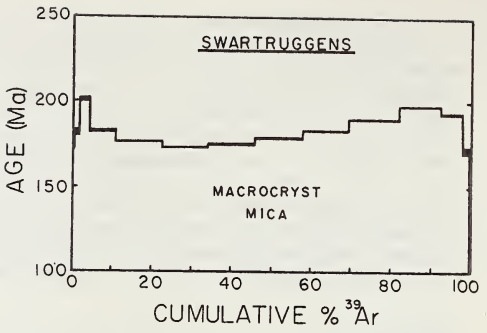

Figure 1b). Apparent age versus %39Ar release for coarse-grained phlogopite 'xenocrysts' from the Swartruggens Main Fissure. The spectra is discordant and the anomalously high ages are indicative of the presence of 'excess' radiogenic argon.

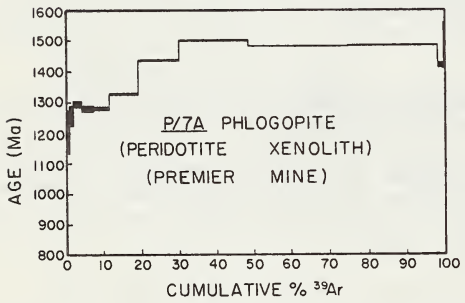

Figure 2. Apparent age versus %39Ar release for phlogopite from a garnet lherzolite nodule from the Premier kimberlite. The general step-wise increase in age with temperature (and %39Ar) is considered to result from partial diffusive loss of 'excess' radiogenic argon during cooling of the kimberlite.

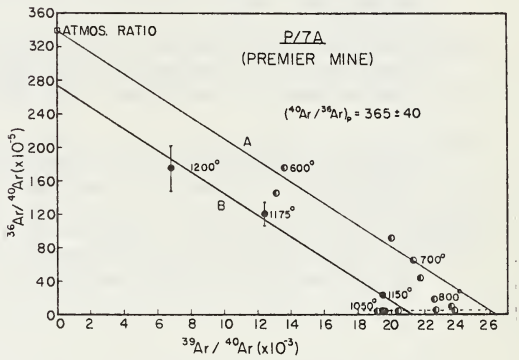

Figure 3. 36Ar/40Ar versus 39Ar/40Ar correlation plot for the Premier phlogopite separate. Line A is interpreted as a 'mixing' line between atmospheric contaminating argon and radiogenic argon. Line B is considered to represent mixing between radiogenic argon and a primitive mantle-derived component having an 40Ar/36Ar ratio of 365±40. The plotted error bars are ±1S.D.