COMPLEMENTARY PETROGRAPHIC AND STRONTIUM-ISOTOPE RATIO-STUDIES OF SOUTH AFRICAN KIMBERLITES

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The Cretaceous kimberlites of South Africa might be expected to have primary Sr^{87}/Sr^{86} ratios comparable with that of the mantle - less than about 0,704. Most kimberlites however have Sr^{87}/Sr^{86} ratios in the range 0,706 - 0,715 (Mitchell and Crocket 1971). These authors consider such ratios to be characteristic. Berg and Allsopp (1972) recently showed that lower ratios of ∿0,704 do occur in kimberlites that are exceptionally fresh, but their study included only three fresh samples. The present work was undertaken to extend the preliminary findings of Berg and Allsopp. A total of 13 fresh kimberlites from many pipes were analysed. Detailed petrographic descriptions of the samples were made and the K, Rb, Sr concentrations and Sr^{87}/Sr^{86} ratios were also measured.

The freshness of the samples was assessed quite independently, i.e. without access to the isotope ratio measurements. The criteria of freshness include relative hardness, degree and appearance of serpentinisation, apparent permeability and porosity, colouration and general geology. These criteria are illustrated by reference to thin sections.

Most of the K, Rb and Sr abundance determinations were made by isotope dilution although XRF was used in some cases. The accuracy obtained was ∿0,5% (isotope dilution) to 5% (XRF) in the kimberlite and wall-rock samples but in the case of water samples (very low abundance) was 10% - 50%. The isotope ratios were measured on unspiked samples. The precision (including the ground-water samples) was ∿ ± 0,0003 (68% confidence limit). The accuracy of the data was established by regular Eimer and Amend standard determinations which gave Sr^{87}/Sr^{86} values ∿0,7081 ± 0,0003. Primary strontium isotope ratios $(Sr^{87}/Sr^{86}{}_{o})$ have been calculated assuming a kimberlite emplacement age of 100 m.y.

RESULTS: Representative data obtained are given in Table 1. The samples considered to be freshest have ratios varying from 0,7039 to 0,7046 which substantiate the previous results of Berg and Allsopp (1972), and which are compatible with the autolith samples ratios reported by Ferguson et al. in a companion paper. There is substantial evidence for assigning a Sr^{87}/Sr^{86} ratio of ∿0,704 to fresh kimberlite. Slightly altered samples give intermediate ratios whilst more altered samples (including those of Mitchell and Crocket (1971), thin sections of which one of us (W.B.) has examined and assessed as being altered), all have higher ratios. Fresh micaceous samples containing small inclusions of granite also had high Sr^{87}/Sr^{86} ratios. Thus the correlation between freshness (in inclusion-free samples) and strontium isotope ratio is seen to be good. In contrast there is no apparent relationship between K, Rb, Sr abundances and K/Rb or Rb/Sr ratios with Sr^{87}/Sr^{86}.

<u>SIGNIFICANCE OF LOW RATIOS</u>: Carbonatites are thought to be genetically related to kimberlites (e.g. Brookins 1970, Dawson 1971). Carbonatites have a high Sr content 1000 ppm - 10,000 ppm (with a mean of ∿3500 ppm) and Sr^{87}/Sr^{86} values of 0,702 - 0,705 are reported by Brookins (1967). Fresh kimberlite Sr^{87}/Sr^{86} ratios obtained in this work lend support to the proposed relationship. The average Sr abundance is considerably lower in kimberlite than in carbonatite, as would be expected if kimberlite is a mixture of carbonatitic material and other mantle rocks (for instance garnet peridotite). Further carbonatite-kimberlite similarities occur in K/Rb ratios which both range from ∿90 - 200.

<u>HIGHER STRONTIUM RATIOS IN AVERAGE KIMBERLITE</u>: There are a number of possible mechanisms for enhancing the strontium isotope ratios of fresh kimberlite.

i) <u>Assimilation: Wall Rock and Mantle derived Xenoliths</u>: Mitchell and Crocket (1971) calculated that bulk assimilation of typical basement material was most unlikely to account for the high Sr^{87}/Sr^{86} values in kimberlite. Similar calculations using data obtained for actual pipe wall rocks support this conclusion. However certain micaceous kimberlites containing small granitic inclusions have high Sr^{87}/Sr^{86} values. The Sr^{87}/Sr^{86} ratios and strontium content of wall-rock are such that they may influence the kimberlite value locally. The mica, if cognetic with fresh kimberlite, would not raise the Sr^{87}/Sr^{86} value. However if the mica is ~~xe~~nolithic being incorporated in ascending kimberlite magma from the breakup of mantle garnet-mica peridotite (Sr^{87}/Sr^{86}_o ∿0.707) & phlogopite (Sr^{87}/Sr^{86} ∿0,710 to 0,714) (ratios as reported by Barrett in a companion paper) then it would be expected to raise the kimberlite ratios. Dawson (1971) advocates such a process and contends that it adequately explains the enhanced kimberlite Sr^{87}/Sr^{86} ratios of typical kimberlite. Both this mechanism and (iii) below could explain the lack of correlation of elemental abundances and ratios with the Sr^{87}/Sr^{86} ratios.

ii) <u>Diffusion</u>: Isotopic exchange by diffusion between kimberlite material and country rock would occur only if high magma temperatures were maintained for long periods (Hart et al). The temperature of kimberlite emplacement (at least at depths currently accessible) is considered to have been low; Brookins (1970) suggests temperatures ∿200°C. That low temperatures are involved is supported by wall rock studies undertaken in this work.

Wall rock studies in this work show that muscovite samples from 0,5 m to 120 m from the pipe contact are colinear on an isochron diagram. The age corresponding to the slope of this line is that of the basement rocks, indicating that no net Rb or Sr concentration nor Sr^{87}/Sr^{86} changes have occurred in these rocks for 2,9 b.y. at these levels. Thus the effect of diffusive processes has been minimal, and low temperatures are implied for pipe emplacement.

iii) Percolating Ground Water: Ion-exchange of Sr between the kimberlite and ground-water was suggested by Berg and Allsopp (1972) as a mechanism whereby the ratio of kimberlite could be raised after pipe emplacement. To assess the possible influence of ground-water, samples of water were collected underground on the mines and from surface in the vicinity of Kimberley. The Sr^{87}/Sr^{86} value of the water was found to be high: 0,712 - 0,720. This, combined with the observation that the freshest kimberlites have the lowest ratios, does support the suggested mechanism. Leaching with cold dilute HCl removed over 80% of the kimberlite Sr. Assuming that this readily soluble component is mainly calcite (and zeolite), it is probable that exchange with ground-water can readily occur and that the ground-water hypothesis is plausible to this extent. The low total strontium content of the waters (0,06 - 1,7 ppm) coupled with the high content in kimberlite (∿1500 ppm) implies a much higher permeability of fresh kimberlite than for average crustal rocks. Whether or not this is so is unknown.

CONCLUSION

The results of this study indicate that ground-water mechanisms alone could account for the high Sr^{87}/Sr^{86} values of typical kimberlite. However incorporation of xenolithic high Sr^{87}/Sr^{86} material (particularly mica) from the mantle into rising kimberlitic magmas could be an important additional process.

Table 1

Some Typical Strontium Isotopic and Elemental Ratios in Kimberlites, Wall Rocks and Ground Waters

Brief Assessment of Samples	Sr Total (ppm)	Sr^{87}/Sr^{86}_o	Rb/Sr	K/Rb
Most fresh	700 to 1900	0,7039 to 0,7046	0,003 to 0,09	120 to 200
Similar to above but slightly altered	1400	0,7058	0,004	120
Mica kimberlite (fresh & serpentinised) and kimberlite containing small granitic inclusions	800 to 1700	0,7062 to 0,7084	0,06 to 0,1	90 to 210
Basement granite - gneiss wall rock	88,0 to 463,0	0,706 to 0,879	0,02 to 1,5	-
Surface and underground Kimberley area waters	0,06 to 1,7	0,712 to 0,720	<0,1	-

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