POTASSIUM, THORIUM AND URANIUM IN SOME KIMBERLITES FROM SOUTH AFRICA

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Samples Analysed: The samples of kimberlite analysed were, for the most part, collected in situ in the present day underground workings of the mines. The samples from Newlands Mine, Koffiefontein Mine and samples KRV 12 and KRV 13 from Roberts Victor Mine were collected from mine dumps where they may have lain for a considerable time. The majority of the samples were collected by G.W.Berg who is conducting a detailed petrological and mineralogical and geochemical study of the same suite of rocks (Ph.D. Thesis). Data already published can be found in Gurney and Berg (1970) and Berg and Allsopp (1972).

Analytical Method: Potassium, thorium and uranium were determined by gamma spectroscopy as described by Cherry et al. (1970).

Results: The individual determinations together with the statistical precision (calculated from counting statistics) and the Th/U, Th/K and U/K ratios of each sample are presented in Gurney (1968). Average Th, U and K values for the kimberlites from each locality, average Th/U ratios and the ranges of these are presented in Table I.

Discussion: Thorium and uranium increase in concentration during normal magmatic differentiation, but cannot substitute for the highly charged abundant cations such as Si^{4+}, Al^{3+}, Fe^{3+} and Ti^{4+} because of the larger siz of the thorium and uranium ions. Thorium and uranium only occur in very small amounts in the abundant silicate minerals therefore, and both elements are substantially concentrated in accessory minerals, and, in the case of extrusive rocks, in glass. In addition, it has been shown (Hurley and Fairbairn, 1957) that a phase containing thorium and uranium may develop along grain boundaries. This was demonstrated to be the case for an eclogite from the Delegate Pipe, New South Wales, by Kleeman and Lovering (1967). Lambert and Heier (1968) postulate that Th and U are absorbed on to biotite surfaces during progressive regional metamorphism of granulite facies rocks, offering yet another possible site for the accommodation of these elements into many rocks.

The thorium/uranium ratios of most rock types cluster around the value of 3.7 used by some authors as a crustal average. A close coherence of thorium and uranium can be said to exist (Adams et al., 1959) and this would be expected on the basis of the similar properties of the thorium and uranium ions. For a given suite of rocks there are sometimes trends within the general coherence, but the significance of these is difficult to assess. It is not clear from existing data whether the Th/U ratio tends to change with differentiation or not. The position is complicated because uranium is easily oxidised to the U^{6+} uranyl ion which is stable and soluble and concentrates in residual solutions. It is further complicated by evidence that thorium and uranium are redistributed by hydrothermal fluids and by leaching of uranium during weathering.

Heier and Rogers (1963) noted that potassium tended to increase with differentiation in a similar way to uranium and thorium and that the ratios Th/U, U/K and Th/K also tended to increase. They noted that basaltic and granitic rocks have, on the average, distinctly different U/K and Th/K ratios.

Turekian and Wedepohl (1961) give a value of 0.001 ppm uranium as typical for an ultrabasic rock, but this is derived from an analysis of one dunite. Their value of 0.004 ppm thorium was obtained by assuming a Th/U ratio of 4. The potassium content of ultrabasic rocks is low, usually less than 500 ppm.

The average values obtained in this work on kimberlites are very high by comparison. Potassium values in South African kimberlite are well established, but the values for uranium (up to 7.1 ppm) and thorium (up to 58 ppm) are new data. These high values for all three elements confirm the extremely differentiated nature of the kimberlite magma.

The absolute abundance level of the three elements studied is higher in the micaceous kimberlites than for the basaltic varieties. This may simply be related to the fact that the basaltic varieties, found chiefly in the pipe occurrences, have lost volatiles to the atmosphere during emplacement, or alternatively the micaceous kimberlites have undergone a greater degree of differentiation. In practical terms, the high concentrations of radioactive elements in the micaceous kimberlite may be detectable instrumentally in areas where the country rock has contrastingly low natural radioactivity, such as the Drakensberg lavas. Natural radioactivity is known to turn diamonds green, for instance in the gold-bearing conglomerates of the Wits system. Especially high values for the radioactive elements are reported here for the Roberts Victor and Bellsbank kimberlite occurrences. Diamonds from these two localities are characterised by having a greenish tinge. It is suggested that this may have been created by the natural radioactivity of the kimberlite in which they are found.

The average Th/U ratios of the basaltic kimberlites (8) cluster closely around 5 (see Table I). The average Th/U ratios of the micaceous kimberlites (4) are all distinctly higher (6.9 - 9.3), a feature which may again be related to differentiation. The U/K and Th/K ratios are high, generally higher than those given by Heier and Rogers for granitic rocks ($U/K \times 10^4 = 1.3$; $Th/K \times 10^4 = 5.0$).

Eclogite and peridotite xenoliths are found in kimberlite and are studied extensively. It has already been conclusively shown that these inclusions have been contaminated by the introduction of potassium, rubidium and cesium from the host kimberlite (Gurney et al., 1966; Berg, 1968; Gurney and Berg, 1970; Erlank, 1970). The high concentrations of thorium and uranium in kimberlite and the close geochemical association of these elements with potassium are very strong reasons for expecting a similar introduction of thorium and uranium to have occurred into the inclusions.

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TABLE I

AVERAGE VALUES OF THE THORIUM, URANIUM AND POTASSIUM DETERMINATIONS FOR EACH OCCURRENCE

Name of Mine	Locality	*Kimberlite Type	No. of Samples	Thorium ppm	Range of Thorium	Uranium ppm	Range of Uranium	Potassium %	Range of Potassium	Th/U	Range of Th/U
Bultfontein	Kimberley, Cape	Basaltic	13	12.5	7–18	2.7	1.6–4.4	1.62	1.1–2.1	4.7	3.5–5.4
Du Toits Pan	Kimberley, Cape	Basaltic	3	10.8	10–11	2.2	2.1–2.2	0.95	0.6–1.3	4.9	4.8–5.1
De Beers	Kimberley, Cape	Basaltic	4	14.2	8–22	3.1	1.8–5.0	0.98	0.3–1.3	4.6	4.3–5.0
Wesselton	Kimberley, Cape	Basaltic	5	9.0	7–11	1.7	1.4–2.0	1.77	1.5–2.0	5.4	4.7–6.2
Jagersfontein	Jagersfontein, O.F.S.	Basaltic	10	13.2	9–21	2.7	1.1–4.0	1.61	0.7–2.2	4.8	3.8–6.1
Koffiefontein	Koffiefontein, O.F.S.	Basaltic	4	18.1	16–20	3.3	2.7–4.0	1.01	0.3–1.3	5.4	4.7–6.1
Monastery	Marquard, O.F.S.	Basaltic	1	13.5	-	2.6	-	1.01	-	5.1	-
Wessels Sill	Lochard, Rhodesia	Basaltic	3	22.1	20–24	4.6	3.9–5.2	0.84	0.7–1.0	4.8	4.0–6.6
Roberts Victor	Boshof, O.F.S.	Micaceous	8	43.7	30–54	5.1	4.0–7.1	3.34	1.8–4.7	8.5	5.7–10.7
Southern Fissures	Boshof, O.F.S.	Micaceous	2	24.2	23–25	3.5	2.8–4.2	2.34	2.1–2.5	6.9	9.7–11.1
Newlands	Barkly West, Cape	Micaceous	6	33.8	23–38	3.8	2.5–4.4	1.15	0.9–1.5	9.0	7.9–9.7
Bellsbank	Barkly West, Cape	Micaceous	1	57.9	-	6.2	-	1.37	-	9.3	-

* Classification after Wagner (1914).