THE SIGNIFICANCE OF THE INTER-ELEMENT RELATIONSHIP OF SOME REFRACTORY ELEMENTS IN SOUTH AFRICAN KIMBERLITES

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The interpretation of the geochemistry of kimberlites is complicated by country rock contamination, as exemplified by the variation of major element chemistry (1), the loss of volatiles on emplacement and the mobility of some elements during secondary processes(2). For these reasons those elements which are least likely to be affected, viz. the refractories: Ti, Sc, Y, Zr, Hf, Nb and Ta, were analyzed in 59 basaltic and micaceous kimberlites. These kimberlites represent different ages, modes of emplacement (pipe, blow, fissure), various degrees of weathering and country rock contamination (e.g. quartzite, gabbro, shale sedimentary carbonate). The kimberlite occurrences investigated include:

(a) the Premier pipe near Pretoria which is the only known kimberlite of Precambrian age (3),
(b) Koffyfontein and Ebenhaezer (near Koffiefontein, O.F.S.) and
(c) the kimberlite dykes on the farm Bellsbank (N.N.W. of Barkly West, C.P.)

The kimberlites from Premier, Koffyfontein and Ebenhaezer have been described as basaltic (4); on Bellsbank both basaltic and micaceous kimberlites were emplaced along existing parallel fissures (5).

X-ray fluorescence spectrography (X.R.F.) was used for the determination of Ti, Zr, Nb and Y while Sc, Hf and Ta were determined by instrumental neutron activation analysis (I.N.A.A.). Full details of the methods and standards used have been described elsewhere (6, 7, 8). Analytical precision for Ti, Sc, Y, Zr, Nb and Ta is better than 3%; Hf has an upper limit of 10%.

Average values for element concentrations and some inter-element relationships are presented in Table 1, together with data for Mullersvlei, (near Theunissen, O.F.S.) and Du Toitspan, Kimberley, C.P.

In general, the basaltic kimberlites have lower concentrations of Sc, Y, Zr, Hf and Nb than the micaceous kimberlites. In the particular case of Bellsbank, all elements, including Ti and Ta have lower concentrations in the basaltic kimberlite (Water Fissure). The Premier kimberlites are characterized by high Ti contents which are at least a factor of two greater than the kimberlites of the Koffyfontein group and Bellsbank. These differences are also reflected by the Ti/Zr, Ti/Nb, Nb/Ta and Hf/Ta ratios.

The Bellsbank fissures provide an ideal opportunity for studying the relationship between the basaltic and micaceous kimberlites. From the inter-element relationships (Fig. 1a) it appears that the basaltic Water Fissure is genetically related to the micaceous Bobbejaan and Main Fissures which represent more "differentiated" kimberlites. Further evidence supporting this interpretation is provided by the

TABLE 1: ELEMENT CONCENTRATIONS* AND INTER-ELEMENT RELATIONSHIPS IN SELECTED SOUTH AFRICAN KIMBERLITES

		Ti	Sc	Y	Zr	Hf	Nb	Ta	Ti/Zr	Ti/Nb	Zr/Nb	Hf/Ta	Zr/Hf	Nb/Ta
PREMIER														
Brown Kimberlite	(7)+	10210	11.4	10	105	2.6	74	12.1	97	137	1.4	0.25	41	7.0
Grey Kimberlite	(4)	10540	8.8	8	118	2.9	54	6.5	90	194	2.2	0.44	41	8.3
Black Kimberlite	(4)	12610	9.5	5	96	2.0	71	8.0	133	178	1.4	0.25	49	8.9
KOFFYFONTEIN GROUP														
KOFFYFONTEIN	(10)	5420	10.6	13	118	2.7	50	3.1	46	111	2.4	0.88	43	16
EBENHAEZER East	(5)	4980	9.9	15	141	3.1	82	4.2	35	61	1.7	0.73	46	19
West	(5)	4880	9.4	16	130	3.1	43	2.6	39	114	3.0	1.2	42	17
BELLSBANK														
WATER FISSURE	(10)	2980	8.8	9	140	3.0	41	1.9	22	72	3.4	1.6	48	23
BOBBEJAAN FISSURE														
Bobbejaan Mine	(2)	4020	19.4	18	267	6.1	173	9.3	15	23	1.5	0.66	44	19
Dancarl Mine	(3)	3540	16.6	20	263	6.1	158	7.8	14	22	1.7	0.78	43	21
Holliday & de Bruyn Mine	(1)	4680	23.4	19	344	7.7	201	11.3	14	23	1.7	0.68	45	18
MAIN FISSURE														
De Bruyn Mine	(3)	5380	23.4	17	343	7.7	188	9,6	16	29	1,8	0.80	45	20
Martin & de Bruyn Mine	(1)	3780	15.6	257	272	6.7	136	8.4	14	28	2.0	0.80	41	16
Blows along Main Fissure	(3)	4440	17.7	18	284	6.0	132	7.3	16	35	2.2	0.83	47	18
MULLERSVLEI	(1)	7010	23.4	18	304	6.8	105	6.6	23	67	2.9	1.0	45	16
DU TOITSPAN	(1)			10	218		101				2.2			

* Element concentrations expressed as ppm

\+ Number of samples analyzed

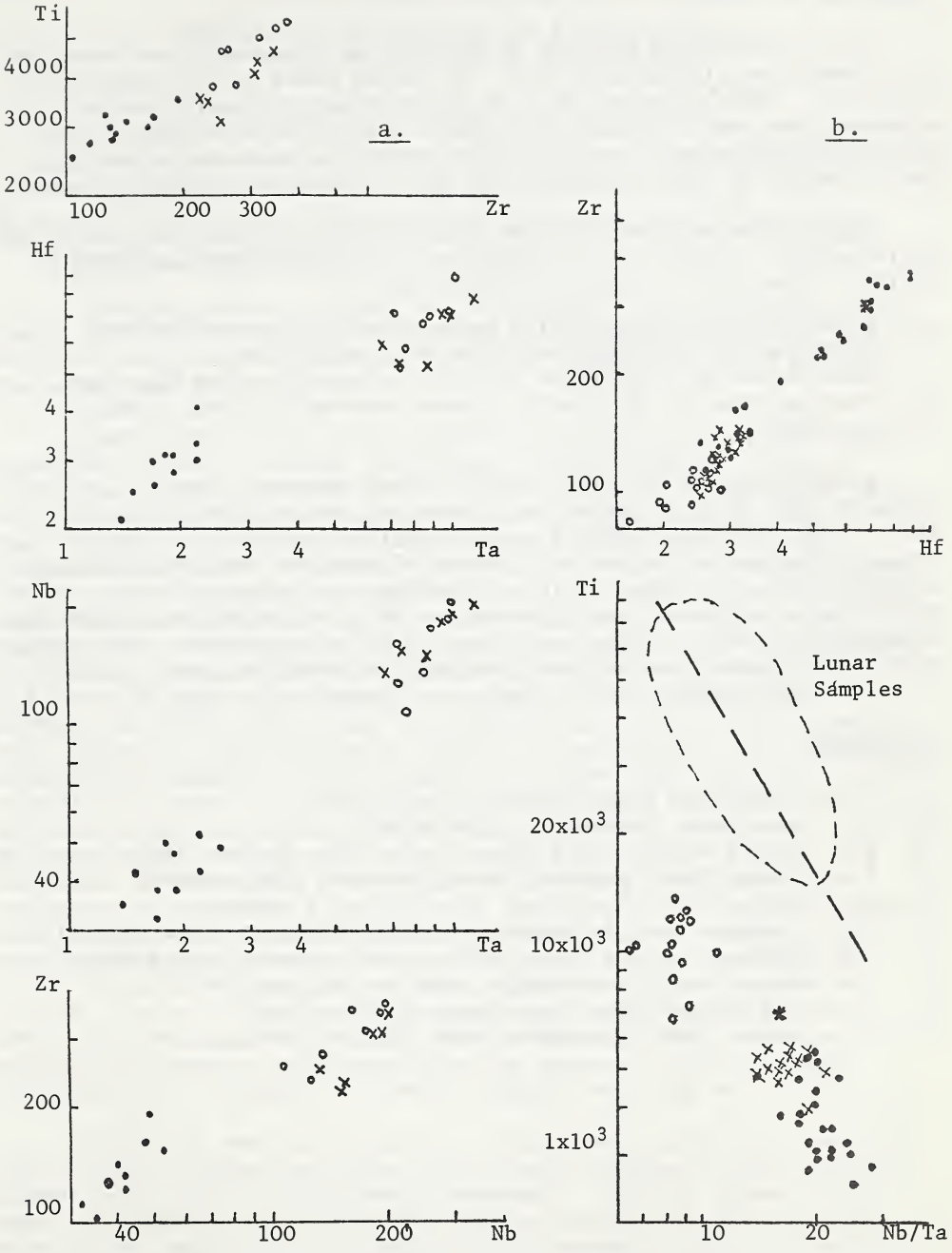

FIGURE 1: Some inter-element relationships in S.A. Kimberlites

(a) Bellsbank : . Water
Fissures x Bobbejaan
o Main

(b) Bellsbank .
Koffyfontein x
Mullersvlei *
Premier o

Concentrations expressed as ppm

light REE enrichments in the micaceous kimberlites (1).

It is significant that the Zr/Hf ratio is reasonably consistent for all kimberlites studied here (N.B. Hf values based on 14.0 ppm GSP-1) (Fig. 1b). This suggests that, as Zr and Hf are strongly coherent elements, the source regions from which these kimberlites were originally derived have been constant (with respect to these two elements) over a period of time extending from the Pre-cambrian to the Cretaceous.

High Ti contents in the Premier kimberlites are associated with low Nb/Ta ratios. In the case of Koffyfontein and Bellsbank the inverse applies. From this it may be inferred that

(a) kimberlites are derived from upper mantle regions which have undergone different degrees of partial melting or
(b) kimberlites have undergone different crystallization histories.

Attention is drawn to the similar trends observed in lunar samples (Fig. 1b) (9).

Although the Zr/Nb ratio exhibits fractionation, there is a remarkable similarity in the ratio between the various kimberlites (1.3 - 3.4). Lesotho kimberlites have similar ratios (10). This suggests that Zr and Nb are not grossly affected by early fractional crystallization processes. The crystallization/accumulation of perovskite in differentiated kimberlites (e.g. Bellsbank, Main/Bobbejaan Fissures) may result in the enrichment of Nb relative to Zr. The range of Zr/Nb in kimberlites is less than that recorded for garnet lherzolites from Bultfontein (2 - 6) and oceanic basalts (4 - 40) (6).

REFERENCES:

(1) H.W. Fesq et al, Int. Kimberlite Conf. (1973)
(2) G.W. Berg, Amer. Mineral 53, 1336 (1968)
(3) H.L. Allsopp et al, Earth Planet. Sci. Lett. 3, 161 (1967)
(4) P.A. Wagner, The Diamond Fields of Southern Africa (1971)
(5) J.L. Bosch, Trans. Geol. Soc. S.A. 74(2), 75 (1971)
(6) E.J.D. Kable et al, in Marion and Prince Edward Islands, 78(1971)
(7) J.P. Willis et al, in Proc. 2nd Lunar Sci. Conf. 2, 1123 (1971)
(8) H.W. Fesq et al, J. Radioanal. Chem. (to be publ.)
(9) Proc. 2nd and 3rd Lunar Sci. Conf. (1971, 1972)
(10) J.B. Dawson, Bull. Geol. Soc. Amer. 73, 545 (1962).