SOME ASPECTS OF THE GEOCHEMISTRY OF KIMBERLITES FROM THE PREMIER MINE, TRANSVAAL, SOUTH AFRICA

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The Premier kimberlite pipe is unique in relation to other kimberlite occurrences in Southern Africa in that it is the only known Pre-cambrian kimberlite, >1150±15 m.y. (1), whereas all other occurrences are believed to be of Cretaceous age. It is intrusive into a plug of igneous rocks which is related to the well known Bushveld Igneous Complex (1950±150m.y.)

The Premier diatreme is a complex, multiple intrusion in which at least eight different types of kimberlite are macroscopically distinguishable, all containing diamonds in economic quantities. These different types are thought to be derivatives of three major brecciated basaltic kimberlites which are associated with separate intrusive events. In order of intrusion they are: Type 2 Brown→Type 1 Grey→Type 3 Black. Some of these kimberlites contain large numbers of lithic and basic rock fragments generally of Bushveld parentage as well as fragments and rafts of Waterberg quartzite (2).

Representative samples (∿50 kg) of each type were collected at different levels within the mine and where possible, away from mixed contact zones.

Samples were analysed for major and trace elements by X-ray fluorescence, X.R.F. (3), instrumental neutron activation analysis, I.N.A.A. (4) and conventional chemical techniques. The average chemistry for each of the main Premier kimberlite types is presented in Tables 1,2. Data for other kimberlites are included for comparison (Table 1), particularly with respect to the varying degree and type of crustal contamination.

Kimberlites generally contain large numbers of crustal fragments, normally of the country rock into which they intrude (5). Their major element chemistry in particular will therefore reflect such contamination (Table 1), N.B. samples KN275/75 and 1982 with high Mg/(Mg+Fe) are relatively uncontaminated 'kimberlites'. Unless an attempt is made to remove the contribution of the major crustal contaminant (mixing model analysis), interpretation particularly with respect to the genetic relationship of kimberlite from major element chemistry can be misleading.

For example, from the Mg/(Mg+Fe) for Premier kimberlites a genetic differentiation relationship in the order: Black Type 3→Brown Type 2 may be inferred. However this is in disagreement with evidence available for the refractory elements (6) and the REE (Table 2, Fig. 1). Erroneous Fe values are a function of the overall composition and the amount of crustal contamination. This observation is even better illustrated by the kimberlites from the Bellsbank fissure system where contamination is due to high limestone assimilation in the Water Fissure which is definitely the least 'differentiated' of the Bellsbank kimberlites (6). The primitive REE pattern highlights both these observations (Fig. 1). The high amount of crustal contamination in Premier kimberlites is well illustrated by their high SiO_2 content particularly in Type 1 (Table 1). Of all the Premier kimberlites Type 2 Brown has the least variable chemistry indicating that it has not been affected by kimberlite mixing e.g. Type 1 and 2 (2).

Crustal contamination is reflected by:

(a) the inclusion of crustal fragments in the kimberlite magma; such contamination may be estimated by modal analysis (e.g. Type 1 Grey 43%, Type 3 Black 20%) and

(b) the assimilation of crustal material, the amount of which is a function of the temperature of the kimberlite magma, its mode of emplacement and the composition of the crustal contaminant, e.g. it would be more difficult to assimilate basic than acid rocks or sediments.

Experiments on the induced graphitisation around mineral inclusions in Premier diamonds indicate emplacement temperatures from 850^{o}C to 1050^{o}C for Premier kimberlites (7). The higher temperature can probably be associated with the Type 2 Brown which on evidence of its chemistry assimilated some basic rocks of Bushveld parentage.

REE GEOCHEMISTRY (Table 2, 3, Fig. 1).

A comparison of the REE geochemistry of Premier kimberlites with other South African kimberlites indicates that Premier kimberlites:

(a) are basaltic (low REE) and

(b) are derived from relatively undepleted mantle, probably from the same source region. Cr-diopsides, garnets and ilmenites as well as diamonds (9) studied from this source confirm the above observation.

Compared with more differentiated micaceous kimberlites (e.g. OG383, Fig. 1) no Eu anomalies are present in Premier kimberlites. Eu depletion appears to be related to the differentiation of kimberlitic liquids and the crystallisation of phlogopite. The analysis of a 'primitive' phlogopite from a Bultfontein garnet peridotite nodule exhibits a negative Eu anomaly. Such an anomaly may be enhanced by phlogopites crystallising from a differentiating kimberlite magma. It is suggested that phlogopite superimposes its REE chemistry on the more differentiated micaceous kimberlites, which would explain the observed high Eu negative anomaly in Bellsbank Main Fissure kimberlites. These contain from 25-60% phlogopite and up to 6% apatite in the matrix (10).

Ilmenite is at present the only upper mantle mineral which we are aware of, which exhibits a positive Eu pattern. Large amounts of ilmenite fractionation would therefore be necessary to explain the Eu depletion in the more differentiated kimberlites. This is considered to be unlikely, although it has been established that ilmenites of changing composition crystallised from the Premier kimberlite magmas (11).

From the involatile and even volatile geochemistry of Premier kimberlites it appears that Type 2 Grey and Type 3 Black are closely related, the latter being the more differentiated product. However, all Premier kimberlites appear to have originated from the same source of the upper mantle, and since the Type 2 Brown was emplaced first (2), a possible age difference is implied between Type 2 Brown and the other types. This is confirmed by recent Rb/Sr age measurements (Allsopp, pers. comm.).

REFERENCES:

(1) H.L. Allsopp et al, Earth Planet. Sci.Lett. 3, 161 (1967).
(2) Anglo American Corp. of S.A., Ltd. Cons. Geol. Dep. Rep. (1969).
(3) J.P. Willis et al, in Proc. 2nd Lunar Sci. Conf. 2, 1123 (1971).
(4) H.W. Fesq et al, J. Radio-anal. Chem. (in press).
(5) P.A. Wagner, The Diamond Fields of Southern Africa (1971).
(6) E.J.D. Kable et al, Int. Kimberlite Conf. (1973).

TABLE 1 PREMIER AND SELECTED KIMBERLITES FROM SOUTHERN AFRICA - A COMPOSITION COMPARISON

	P/2 (7)+	P/1 (4)	P/3 (4)	KOFFY. (10)	EBEN./W (5)	LESOTHO S4B	B/WF (10)	B/MF (7)	MON. 1870	LESOTHO KN275/75	LESOTHO 1982
SiO_2	44.67	48.46	39.59	40.67	34.92	40.20	25.27	28.80	27.98	32.23	39.19
TiO_2	1.70	1.76	2.10	0.90	0.78	1.70	0.50	0.79	4.22	1.48	0.17
Al_2O_3	4.46	4.12	2.88	5.56	6.61	7.30	1.64	2.47	2.64	1.58	0.14
Cr_2O_3	0.17	0.19	0.21	0.12	0.11	0.67	0.23	0.25	0.14	0.23	0.33
ΣFe_2O_3	8.64	8.52	9.31	7.60	5.21	10.68	4.77	7.92	12.87	9.20	8.37
MnO	0.14	0.15	0.15	0.13	0.08	0.16	0.11	0.33	0.18	0.15	0.09
MgO	22.42	23.04	27.60	23.73	10.87	19.86	10.59	24.95	26.17	31.88	36.46
CaO	6.63	4.46	6.84	3.69	15.85	9.75	26.34	11.66	9.16	6.14	0.21
Na_2O	0.85	0.57	0.33	0.29	0.41	0.67	0.03	0.02	0.61	0.04	0.05
K_2O	1.31	0.74	1.64	0.69	2.09	0.53	0.05	1.00	1.78	0.97	0.01
P_2O_5	0.28	0.18	0.23	0.34	0.30	0.40	0.41	1.33	0.94	0.29	0.14
LOI**	4.89	4.52	7.81	7.92	5.30	6.75	5.97	10.89	7.42	9.00	11.99
H_2O^-	3.01	2.21	0.52	6.81	5.35	2.91	3.93	0.95	0.40	0.83	2.84
CO_2	0.33	0.83	0.36	0.90	11.79	0.37	20.50	7.61	5.83	5.11	2.67
Mg/(Mg+Fe)*	91.1	91.5	92.1	92.5	89.2	88.0	89.8	92.6	88.4	93.2	94.5
PRED. CRUSTAL CONTAMI-NATION	SHALES FELSITE (GABBRO)	QUARTZ-ITE FELSITE (GABBRO)	FELSITE (GABBRO) KIMB. MIXING	SHALE (BASALT)	SHALE (BASALT)	SHALE? GRANITE? (BASALT)	LIME-STONE	LIME-STONE	GABBRO SHALE		
ppm											
Cr	890	1060	1210	690	520		1190	1320			
Ni	870	950	1170	1090	475		1110	1150			
Co	72	73	86	71	40		53	62			
K	10880	6140	13610	5690	17350		390	6490			
Rb	104	51	154	44	80		4	53			
Cs	3.2	2.7	4.5	1.8	3.3		0.4	3.4			
Th	7.1	5.5	5.3	8.6	13.4		13.9	45.8			
U	1.5	0.8	0.8	2.0	1.6		2.5	5.3			
K/Rb	105	120	88	129	217		98	122			
K/Cs	3400	2274	3024	3161	5258		975	1909			
Th/U	4.7	6.9	6.6	4.3	8.4		5.6	8.6			

\+ NUMBER OF SAMPLES ANALYSED

* MOLAR RATIO OF Mg/(Mg+Fe)

LESOTHO KIMBERLITES FROM GURNEY AND EBRAHIM (1973)

S4B - LETSENG-LA-TERAE SATELLITE PIPE
KN275/75 - LEMPHANE MAIN PIPE
1982 - NQECHANE

1870 - MONASTRY PIPE, OFS, RSA.

** LOSS ON IGNITION -CO_2

P/2 - PREMIER TYPE 2 BROWN
P/1 - PREMIER TYPE 1 GREY
P/3 - PREMIER TYPE 3 BLACK
KOFFY. - KOFFYFONTEIN PIPE
EBEN/W - EBENHAEZER WEST PIPE
B/WF - BELLSBANK WATER FISSURE
B/MF - BELLSBANK MAIN FISSURE

(7) J.W. Harris and E.R. Vance, Contr. Mineral. and Petrol. 35, 227 (1972)
(8) I.D. MacGregor, Mineral. Soc. Amer. Spec. Pap. 3, 51 (1970)
(9) H.W. Fesq, D.M. Bibby et al, Int. Kimberlite Conf. (1973)
(10) J.L. Bosch, Trans. Geol. Soc. S.A. 74(2), 75 (1971)
(11) J.J. Gurney et al, Lesotho Kimberlite Vol., ed. P.H. Nixon (1973)
(12) J.J. Gurney and S. Ebrahim, Lesotho Kimberlite Vol., ed. P.H. Nixon (1973)
(13) L.A. Haskin et al, in Origin and Distribution of the Elements, ed. L.H. Ahrens, 889 (1968)

L.A. Haskin et al (1966), in Physics and Chemistry of the Earth, 7, 169
R.H. Mitchell et al (1973), Lesotho Kimberlite Vol., ed. P.H. Nixon

TABLE 2 Sr, Ba AND THE REE IN PREMIER AND SELECTED SOUTH AFRICAN KIMBERLITES AND SOME KIMBERLITE MINERALS

KIMBERLITES		Sr	Ba	La	Ce	Nd	Sm	Eu	Tb	Yb	Lu
PREMIER											
Type 2 Brown	(7)[+]	401	507	38.0	59	< 25	4.8	1.25	0.41	1.1	0.24
Type 1 Grey	(4)	183	211	27.6	49	< 25	3.7	0.95	0.39	0.9	0.14
Type 3 Black	(4)	492	1018	32.2	55	< 25	3.7	1.03	0.49	0.7	0.15
KOFFYFONTEIN GROUP											
KOFFYFONTEIN	(10)	394	229	48.9	102	∿ 35	5.5	1.54	0.83	0.9	0.14
EBENHAEZER West	(5)	350	379	54.9	91	∿ 40	5.7	1.45	0.93	1.0	0.14
East	(5)	603	256	83.9	157	80	8.5	2.17	1.09	0.9	0.14
BELLSBANK GROUP											
WATER FISSURE	(10)	430	128	108	198	70	8.1	2.02	1.00	1.0	0.11
BOBBEJAAN FISSURE	(6)	1230	4720	315	523	152	17.3	4.13	2.02	2.1	0.20
OG 382 HOLLIDAY & DE BRUYN		1120	4900	353	585	150	20.3	4.50	2.33	2.2	0.18
MAIN FISSURE	(3)	1520	2540	293	500	146	16.2	3.79	1.79	1.7	0.16
OG 381 DE BRUYN MINE (BLOW)		715	1890	870	1910	560	104	5.35	9.23	3.7	0.47
OG 383 DE BRUYN MINE		972	1830	1120	2080	780	185	6.44	18.8	4.4	0.52
MULLERSVLEI		1220	3340	174	254	150	15.4	3.49	0.72	1.8	0.22
DU TOITSPAN[•]				200	510	134	11.6	0.28		1.20	0.16
MONASTERY[x]				97	243		12.6	3.70	1.30	0.39	
KIMBERLITE MINERALS											
SOUTH AFRICAN CHROME DIOPSIDE	(16)			7.5	34.0		3.02	0.96	0.52		
PREMIER CHROME DIOPSIDE (AVE)				2.4	18.4		1.44	0.47	0.21		
PREMIER GARNET (AVE)				0.25	0.8		0.91	0.58		3.1	0.44
PREMIER ILMENITE	(100)			(<0.1)			<0.4	0.23			
PHLOGOPITE FROM BULTFONTEIN GARNET PERIDOTITE			310	0.9	15.8		∿0.6	0.15	0.15	<0.10	

• DATA FROM HASKIN ET AL (1965)

x DATA FROM MITCHELL ET AL (1973)

\+ NUMBER OF SAMPLES ANALYSED
ALL ANALYSES EXPRESSED IN PPM

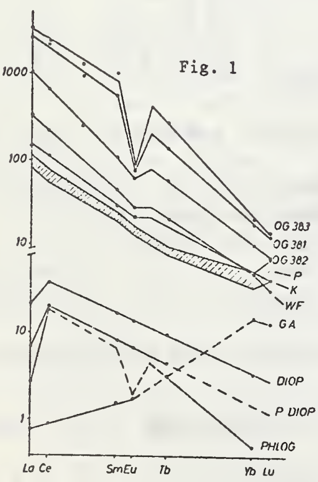

Fig. 1

TABLE 3 : CHONDRITE NORMALISED REE RATIOS

	La/Eu	La/Sm
Chondrite (13)	4.78	1.82
Premier Type 2	6.4	4.3
(P) Type 1	6.1	4.1
Type 3	6.5	4.8
Koffyfontein (K)	6.6	4.9
Bellsbank Water Fissure (WF)	11.2	7.3
OG 382	16.4	9.5
OG 381	34.0	4.6
OG 383	36.4	3.3
Cr-diopside S.A. ave (Diop)	1.6	1.4
Premier Cr-diopside (P.Diop)	1.1	0.9
Premier Garnet (P)	0.1	0.2
Premier Ilmenite	0.1	<0.1
Phlog. (Table 2)	1.3	0.8