RARE EARTH ELEMENT GEOCHEMISTRY OF KIMBERLITE

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Seven rare earth elements (REE) have been determined in kimberlite (Wesselton) and micaceous kimberlite (Swartruggens) by neutron activation analysis (Table 1). Chondrite normalized REE distribution patterns are essentially linear. Micaceous kimberlites have slightly higher REE abundances and are slightly more fractionated than kimberlites, average La/Yb ratios are 139 and 103 respectively. A small negative Eu anomaly is evident in the micaceous kimberlite data (figure 1). REE whole rock abundances and distribution patterns are considered to reflect the proportions of apatite, perovskite and carbonate present, the weak Eu anomaly being due to the presence of perovskite (Eby 1972).

Although the degree of enrichment of light REE in kimberlite is similar to that observed in oceanic and continental nepheline and melilite bearing basalts (Schilling and Winchester 1969, Hermann 1968) the REE distribution patterns are markedly different and do not support any relation between kimberlites and melilitites as proposed by Frey et al. (1971).

The REE data can be considered in terms of two groups of petrogenetic theories, partial melting and eclogite crystallization.

Partial melting of a garnet lherzolite mantle in which only the low melting point fraction, garnet and clinopyroxene is involved is considered as these phases dominate the alkali and alkaline earth geochemistry of such rocks. Following Gast (1969), REE crystal-liquid distribution coefficients are used to calculate the La/Yb ratios of liquids produced by varying amounts of partial melting. La/Yb ratios of kimberlites and micaceous kimberlites can be produced by 0.7 - 0.9% and 0.3 - 0.4% melting of garnet lherzolite respectively. The liquids produced are however poor in La and Yb relative to the actual abundances found and it is postulated that further processes e.g. crystallization of REE free phases acts to increase the REE abundances without further fractionation of the REE.

The effects of high pressure bimineralic eclogite crystallization from a magma of basaltic composition are analysed using the fractional crystallization models of McIntire (1963) to calculate the La/Yb ratios of residual liquids after the separation of eclogites of differing modal compositions. Fractionation of eclogite (Cpx-50, Gnt-50) will only produce kimberlite if greater than 96% of the liquid has crystallized. Removal of eclogite (Cpx-20, Gnt-80) requires 88-94% crystallization for derivation of kimberlite from tholeiitic parents but only 48-64% crystallization for alkaline olivine basalt parents.La and Yb abundances,as in the partial melting model again do not reach levels found.

The models do not unequivocably point to partial melting or eclogite crystallization as a means of generating the kimberlite REE abundances and distributions. Eclogite crystallization models are however considered to be unlikely on geological grounds,namely,the extensive degree of crystallization reuired,the known distribution,age and mineralogy of eclogite and garnet lherzolite xenoliths in kimberlite,the lack of the minerals of eclogite as inclusions in diamond and the lack of extensive compositional range in kimberlite olivines.The REE geochemistry of kimberlites is thus considered to be the result of partial melting processes.As a consequence of the small volumes of liquid involved it is likely that most kimberlite remains trapped in the mantle.Partial melting processes thus can explain the rarity and small volume of kimberlite.The relation of kimberlites to basaltic volcanism and continental magmatic cycles can be explained in terms of partial melting and the following thermal cycle.Initially an increase in heat flow results in extensive(15%) partial melting of the undepleted mantle to produce basaltic, (tholeiitic) volcanism.Waning of the heat flow results in a smaller degree of partial melting and generation of undersaturated basaltic magmas together with migration downwards of the zone of melting(Ringwood 1969).Finally at the lowest levels of heat flow and greatest depth a small amount of partial melting,one per cent or less forms kimberlitic liquids over a very broad zone.Only those liquids lying in regions where large scale tectonic features penetrate to depth are able to escape.Micaceous kimberlites represent the very last stages of the cycle and they are consequentely rare relative to kimberlite.Kimberlites are not found in oceanic areas as heat flow is too great to allow limited partial melting.

References

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Table 1.Rare earth content of kimberlites(ppm)

	#	La	Ce	Sm	Eu	Tb	Yb	Lu	La/Yb
Wesselton	12	106	239	13.7	3.28	1.21	1.09	0.13	97
	13	90	191	12.7	2.98	1.09	1.01	0.11	82
	14	205	455	28.2	6.57	2.72	2.55	0.28	80
	15	112	265	14.2	4.05	1.49	1.16	0.14	96
	16	209	550	28.2	7.96	3.35	1.71	0.24	137
	17	196	481	26.9	7.42	2.44	1.53	0.39	128
average		153	363	20.6	5.38	2.05	1.48	0.18	103
Swartruggens	3	254	588	24.0	5.68	2.45	2.65	0.28	96
	7	259	439	25.1	4.91	1.96	0.95	0.17	132
	8	238	378	22.9	4.10	1.80	1.24	0.17	192
	9	230	440	21.6	4.36	1.95	1.68	0.13	137
average		245	461	23.4	4.76	2.04	1.63	0.18	139
Monastery	23	97	243	12.6	3.70	1.30	0.99	-	98
Ison Creek	28	114	226	10.3	2.69	0.66	0.68	0.08	168
Somerset I.	29	63	107	5.6	1.28	0.44	0.45	-	140

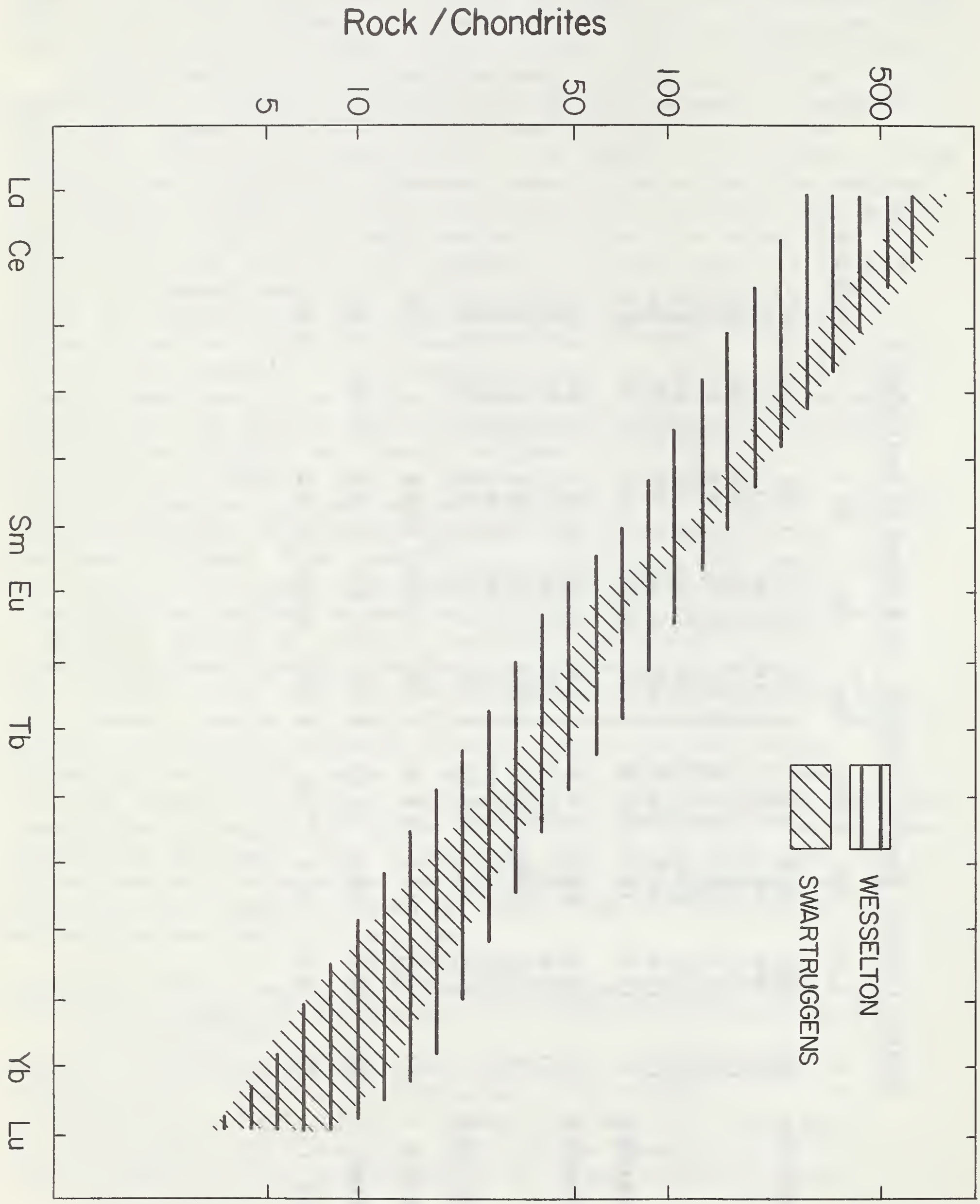

Figure 1. Distribution of REE in kimberlite(Wesselton)
and micaceous kimberlite(Swartruggens).