ULTRAMAFIC XENOLITHS FROM THE PREMIER KIMBERLITE PIPE

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A varied suite of ultramafic xenoliths has recently been recovered from the Pre-Cambrian, Premier kimberlite pipe, South Africa. The suite includes garnet lherzolites, garnet harzburgites, garnet websterites, dunites, pyroxenites and eclogites, as well as chromite peridotites and harzburgites. Discrete nodules, predominantly of garnet, diopside, enstatite and ilmenite were also recovered. Major phase mineral compositions for 108 xenoliths, and bulk chemical compositions for 76 garnet lherzolites and harzburgites are discussed.

The garnet lherzolites can be subdivided into two groups that differ markedly in both texture and mineral chemistry (see Table 1). The first category consists of coarse-equant and coarse-tabular rocks which are believed to have originated at depths of 110 - 170 km. The second group is represented by deformed, extensively recrystallised, garnet-rich lherzolites whose textures vary from porphyroclastic to mosaic-porphyroclastic, that are believed to have been derived from depths of about 200 km. The garnets in the deformed nodules are reddish brown and characterised by unusually high TiO_2 contents (Ave. 1,5 wt%), whereas those in the coarse lherzolites are mauve and titanium-poor (Ave. 0,2 wt%). In the deformed lherzolites the co-existing diopsides, enstatites and olivines are, likewise, enriched in titanium relative to those in the coarse varieties as can be seen from Table 1. Mineralogically and texturally, the Premier garnet lherzolites are, therefore, extremely similar to those from many Late Cretaceous kimberlites in southern Africa, and more specifically to certain suites from northern Lesotho (Nixon and Boyd 1973; Boyd and Nixon 1975). Furthermore, a palaeogeotherm deduced from the Premier garnet lherzolites is very similar to the inflected Late Cretaceous geotherms determined for various pipes in southern Africa (see Boyd and Nixon 1977). A further similarity between the Premier xenoliths and those from northern Lesotho studied by Boyd and Nixon (notably Thaba Putsoa), is the restriction of primary phlogopite and chromite to the coarse (granular) rocks.

Garnet harzburgite inclusions from the Premier suite have been subdivided into three distinct groups on the basis of differences in mineral chemistry and texture (Danchin and Boyd 1977). Mineral data for these rocks are summarised in Table 1. Group I harzburgites have deformed textures and mineral compositions equivalent to those of the deformed garnet lherzolites. Group III harzburgites have coarse-equant textures comparable to the coarse garnet lherzolites. Group II harzburgites are intermediate between these two extremes, particularly with respect to Mg/(Mg + Fe) of the component minerals, the Ca/(Ca + Mg) of the enstatites, and the TiO_2 contents of the garnets and enstatites. Compared to the lherzolite and Group I garnets, those from Group II and III harzburgites are markedly enriched in chromium relative to calcium - several to such an extent that their compositions are equivalent to garnets included in diamond. Temperature-depth estimates for the garnet harzburgites suggest that the deformed Group I varieties equilibrated at depths of approximately 200 km in the mantle, whereas the Group II and Group III harzburgites appear to have equilibrated between 140 and 180 km in the range 1 000^{o} - 1 200^{o}C. The compositional similarities between the garnets in these harzburgites and the most common garnet found as inclusions in diamond suggest that the processes of formation of harzburgite and some diamonds in the mantle are related. The rocks of deepest origin now found as xenoliths in kimberlites are therefore not those in which diamond has most commonl formed.

Average bulk compositions for the Premier garnet lherzolites and harzburgites are given in Table 2 where they can be compared with analyses of equivalent rocks from northern Lesotho (Nixon and Boyd 1973). At Premier, relatively undepleted rocks corresponding in chemical composition to PHN 1611 from Thaba Putsoa, are rare, and the deformed garnet lherzolites show variable degrees of chemical depletion. On average the coarse-garnet lherzolites are more depleted than the deformed varietites, particularly with respect to their FeO_t/FeO_t + MgO ratios (Table 2). Whereas in northern Lesotho, the two groups could be distinguished using their FeO_t/FeO_t + MgO ratios, this is not the case for the Premier lherzolites where values for this ratio overlap markedly. The nature and extent of this overlap is illustrated in Fig. 1 which is a plot of bulk FeO_t/FeO_t + MgO versus Mg/Mg + Fe for each of the major lherzolite and harzburgite minerals. FeO_t/FeO_t + MgO ranges from 13,9 to 20,5 in the deformed lherzolites, and from 12,0 to 17,2 in the coarse lherzolites. Also, it is clear that the harzburgites and lherzolites have equilibrated such that the most fertile, iron-rich garnet lherzolites contain the most iron-rich minerals, and vice versa. It is stressed that no modal combination of minerals from even the most iron-rich, coarse-garnet lherzolite could produce a composition equivalent to PHN 1611.

Bulk Al_2O_3 and CaO in the deformed and coarse-garnet lherzolites also display an overlap as shown in Figs. 2b and 2c, and in this context, it is noteworthy that modal analyses of 16 coarse-garnet lherzolites indicated average garnet and diopside contents of 8 and 6 volume percent respectively, compared to values of 4 and 5 percent for Thaba Putsoa (Nixon and Boyd 1973). It is therefore possible that the coarse Premier garnet lherzolites are somewhat less depleted, notably with respect to CaO, Al_2O_3 and FeO_t/FeO_t + MgO, than those from Cretaceous kimberlites in Lesotho, although additional data from the latter localities are required. The differences between the two localities are subtle, however, and the available data suggests that the depletion of the mantle beneath southern Africa was essentially complete 1 200 million years ago.

The distribution of titanium and potassium in these rocks is problematic. The unique levels of Ti enrichment in minerals comprising the deformed lherzolites and manifested in the bulk data, are shown in Fig. 2d, where a well-developed positive correlation with FeO_t/FeO_t + MgO is illustrated. A similar, but less well-developed pattern of Ti enrichment in xenoliths from the substantially younger Frank Smith kimberlite has been attributed to metasomatic processes by Boyd (1975), however, the complex situation with regard to Ti and K in these rocks would require at least two, quite distinct metasomatic processes to have taken place.

REFERENCES

Boyd, F.R. 1975. De Beers Kimberlite Symposium. Cambridge, U.K. Extended Abstracts.

Boyd, F.R. & Nixon, P.H. 1975. Phys. Chem. Earth. Vol. 9. Pergamon. Eds. Ahrens et al. pp 431-454.

Boyd, F.R. & Nixon, P.H. 1977. Carnegie Inst. Year Book 75. pp 544-545.

Danchin, R.V.D. & Boyd, F.R. 1977. Carnegie Inst. Year Book 75. pp 531-537.

Nixon, P.H. & Boyd, F.R. 1973. Lesotho kimberlites. Maseru, Lesotho National Devel. Corp. Ed. P.H. Nixon. pp 48-56.

Table 1 : SUMMARY OF MEAN COMPOSITIONS OF MINERALS FROM THE GARNET LHERZOLITES AND HARZBURGITES INCLUDED IN THE PREMIER KIMBERLITE

	Mg/(Mg+Fe) Mol. Fraction	TiO_2 wt %	Cr_2O_3 wt %	Na_2O wt %	CaO wt %	Al_2O_3 wt %	K ppm
GARNETS							
A. Lherzolites							
Deformed (35)	0,845	1,15	3,89	0,09	4,86	19,47	-
Coarse (19)	0,846	0,23	4,16	0,04	5,16	20,82	-
B. Harzburgites							
Group I (20)	0,845	1,32	6,72	0,10	5,46	17,17	-
Group II (16)	0,872	0,20	6,73	< 0,03	4,32	18,57	-
Group III (2)	0,888	0,02	7,24	< 0,03	3,81	18,59	-
ENSTATITES							
A. Lherzolites							
Deformed	0,918	0,23	0,31	0,30	1,25	1,01	-
Coarse	0,932	0,05	0,34	0,14	0,43	0,97	-
B. Harzburgites							
Group I	0,924	0,17	0,47	0,31	1,22	0,96	-
Group II	0,936	< 0,03	0,40	0,11	0,80	0,85	-
Group III	0,950	< 0,03	0,54	0,12	0,44	0,90	-
OLIVINES							
A. Lherzolites							
Deformed	0,907	0,03	0,05	-	0,08	0,07	-
Coarse	0,921	< 0,03	0,02	-	0,03	0,03	-
B. Harzburgites							
Group I	0,913	< 0,03	0,07	-	0,05	0,04	-
Group II	0,926	< 0,03	0,06	-	< 0,03	0,04	-
Group III	0,943	< 0,03	0,05	-	< 0,03	0,03	-
DIOPSIDES							
A. Lherzolites							
Deformed	0,907	0,41	1,03	1,71	15,07	2,23	307
Coarse	0,931	0,15	1,85	2,31	19,27	2,94	99

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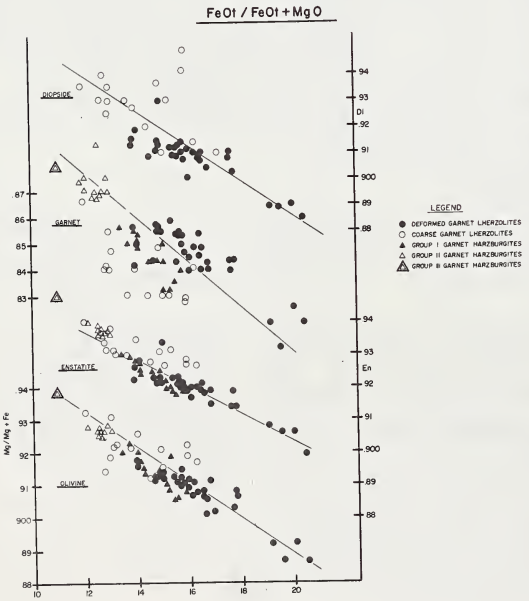

FIG. 1

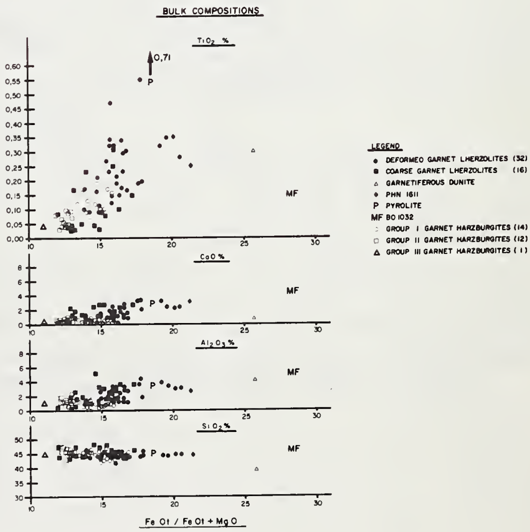

FIG. 2

TABLE 2.

Table 2 : BULK COMPOSITIONS OF GARNET LHERZOLITES AND HARZBURGITES FROM PERMIER COMPARED TO GARNET LHERZOLITES FROM NORTHERN LESOTHO

		Premier "fertile" deformed garnet lherzolites (4)	PHN 1611 Thaba Putsoa	Premier depleted deformed garnet lherzolites (28)	N. Lesotho sheared garnet lherzolites* (5)	Premier coarse garnet lherzolites (16)	N. Lesotho granular garnet lherzolites (4)	Premier Group I harzburgites (16)	Premier Group II harzburgites (11)	Premier Group III harzburgites (1)
SiO_2	SiO_2	44,31	44,60	44,95	43,72	45,83	45,80	44,21	45,55	44,69
TiO_2	TiO_2	0,33	0,25	0,22	0,14	0,11	0,03	0,14	0,07	0,05
Al_2O_3	Al_2O_3	3,40	2,80	1,98	1,65	2,12	0,50	0,87	1,14	1,22
Cr_2O_3	Cr_2O_3	0,34	0,28	0,30	0,21	0,36	0,21	0,25	0,25	0,18
FeO^+	FeO^+	9,46	10,25	7,87	8,24	6,95	6,22	7,76	6,42	5,77
MnO	MnO	0,15	0,13	0,12	0,12	0,14	0,10	0,10	0,09	0,09
MgO	MgO	33,14	37,22	41,98	43,90	41,72	46,06	45,14	44.76	46,26
CaO	CaO	2,59	3,32	1,40	1,57	1,52	0,82	0,42	0,55	0,55
Na_2O	Na_2O	0,13	0,34	0,15	0,19	0,20	0,06	n.d.	0,07	n.d.
K_2O	K_2O	0,18	0,14	0,08	0,03	0,35	0,04	0,02	0,05	0,10
NiO	NiO	0,22	n.d.	0,25	0,23	0,26	0,24	0,29	0,27	0,26
$FeO_t/FeO_t + MgO$		19,6	21,2	15,8	16,0	14,3	12,1	14,7	12,5	11,0

ALL ANALYSES WATER-FREE

* Excluding PHN 1611. + Total iron expressed as FeO.