THE PREMIER KIMBERLITE PIPE, TRANSVAAL, SOUTH AFRICA

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Although excavation started as early as 1903 and despite extensive study, the geology of the Premier Kimberlite pipe is still not fully understood. The complexity of the geology of Premier was realised by Wagner (1914) who recognised twelve varieties of kimberlite and also commented that the differences between the kimberlites were determined by their secondary minerals. Based mainly on the macroscopic appearance of the rocks, there is general agreement among many previous workers on the occurrence of three principal varieties of kimberlite, which are usually referred to as:

(i) Grey or Type 1,

(ii) Brown or Type 2 and

(iii) Black or Type 3.

The present study (in collaboration with R.G. Molyneux, Mine Geologist) confirms that there are differences, including some primary petrographic features, between typical samples of these three main varieties of kimberlite. Despite extensive alteration, primary features are discernible in these kimberlites, but many of them have been overlooked in the past. For example, the occurrence of abundant fine-grained clinopyroxene in the groundmass (Table I) has not previously been reported at Premier. The main petrographic features of the three principal kimberlites are summarised below, in their apparent order of intrusion.

The Brown or Type 2 kimberlite has an inequigranular texture resulting from the presence of abundant olivine pseudomorphs, scattered macrocrysts of various other minerals and xenolithic fragments in a fine-grained matrix. Many of the olivine grains have angular shapes and appear to be broken fragments, but even so the overall morphological characteristics and size distribution of olivine is similar to that typically found in other kimberlites. Besides olivine, macrocrysts of phlogopite, orthopyroxene, ilmenite and rare clinopyroxene occur. Garnet was not observed in any of the hand specimens and thin sections examined. Xenolithic fragments include a large variety of types similar to, but generally smaller than, those present in the Grey kimberlite. The groundmass is dominated by the presence of abundant, very fine-grained diopside needles (0,03 mm in length). Also present are equant microlites of opaque minerals and perovskite and locally fine flakes of phlogopite may also occur. The base to the groundmass consists mainly of secondary clay minerals which are considered to represent altered serpentine. Mineralogically the Type 2 or Brown kimberlite is classified as a diopside kimberlite while texturally it is a tuffisitic kimberlite.

The Grey or Type 1 kimberlite has an inequigranular texture containing abundant and often large xenolithic inclusions which are mostly locally derived country rock including quartzite, norite and shale. Altered ultrabasic inclusions and fragments of kimberlite are occasionally present. Crustal xenocrysts and relatively abundant mantle-derived ilmenite, altered garnet, orthopyroxene, clinopyroxene and phlogopite occur. Olivine pseudomorphs show the two population, morphological differences typical of kimberlites. The groundmass contains fine-grained diopside set in a base of altered serpentine. The groundmass usually displays a well developed segregationary (frequently termed autolithic) texture with the diopside laths concentrated round the coarser components forming sub-spherical, globular segregations. Relatively minor perovskite and opaque spinels have an irregular distribution within the matrix. The interglobular groundmass is considered to have been serpentine, now altered predominantly to clay minerals. The Type 1 kimberlite is classified mineralogically as a diopside - serpentine kimberlite but texturally it is a tuffisitic kimberlite breccia. In the northern and eastern parts of the Type 1 kimberlite extensive alteration masks the primary textures in the groundmass.

The Black or Type 3 kimberlite has an inequigranular texture. It contains abundant olivine pseudomorphs occurring both as anhedral macrocrysts and smaller, euhedral grains in addition to xenolithic material. The groundmass consists of fine-grained (<0,05 mm) diopside and serpentine. Perovskite and opaque minerals also occur and phlogopite may be locally abundant. A poorly developed segregationary texture is evident. Common irregular pool-like segregations have marginal, radially-orientated, laths of diopside projecting inwards to a core of serpentine. The Type 3 kimberlite is mineralogically classified as a diopside - serpentine kimberlite. Crustal xenolithic material, generally with reaction zones plus occasional ultrabasic inclusions and scattered macrocrysts dominated by ilmenite and altered garnet (in addition to olivine) are present. Texturally this kimberlite is classed as a kimberlite breccia transitional to a tuffisitic kimberlite breccia.

Both the Types 2 and 1 kimberlites are considered to be tuffisitic kimberlite breccias because locally derived country rock inclusions lack internal reaction zones and because the groundmass contains extremely fine-grained or microlitic diopside presumed to have crystallized from a vapour condensate. The Type 2 differs from the Type 1 kimberlite in that the groundmass constituents have a uniform rather than a segregationary texture and the ratio of groundmass diopside to serpentine is significantly greater (Table 1). Also the olivine pseudomorphs are more angular.

In the Type 3 kimberlite country rock inclusions macroscopically exhibit distinct reaction zones and groundmass diopside laths are generally twice the size of those found in the Types 1 and 2 kimberlites. These features are consistent with the classification of the rock as a kimberlite breccia, but the microlitic nature of the groundmass suggests that it is transitional to a tuffisitic kimberlite breccia.

It should be noted that the differences between these three kimberlites, particularly for the Types 1 and 2, apply to 'typical' samples and that the overall picture is more complex. A contact between the Types 1 and 2 kimberlite has not yet been accurately defined and it may be mixed or gradational. The contact between Type 1 and 3 can be defined to within approximately one metre. The often described Type 4 or Green kimberlite on petrographic grounds appears to represent an alteration aureole within the Type 1 or Grey kimberlite around the younger Type 3 kimberlite rather than a separate intrusion. The two distinctive intrusions known as the Piebald kimberlites both have numerous, altered, white inclusions. One variety (often termed Pale or Type 3A) appears to be an extensively altered kimberlite with abundant olivine pseudomorphs. Garnet and ilmenite are also present. The other variety (Dark or Type 3B) of so-called kimberlite contains only a few olivine pseudomorphs, but no apparent garnet or ilmenite, in a matrix of magnetite and calcite. This matrix is very similar to the carbonate-rich dykes (Robinson, 1975) which, together with the 'Piebald kimberlites' are radial, late-stage intrusions in the northern part of the pipe.

The extensive alteration and fine-grain size adversely affects a study of the chemistry of most of the primary minerals. A few groundmass clinopyroxene laths, however, have been analysed and the results are given in Table 2. Most of the these laths are too fine for analysis so the results given in Table 2 are mainly derived from the segregation-like pools where they are coarser. Somewhat coarser-grained groundmass clinopyroxene was also analysed from Schuller Pipe, the second largest of Premier's satellites (Table 2).

As a result of alteration, the rocks at Premier are now composed predominantly of secondary minerals. The Type 2 kimberlite is characterized by the occurrence of abundant clay minerals (montmorillonites) and mica. In contrast, the Type 1 kimberlite consists of abundant talc as well as clay minerals. The Type 3 kimberlite is very different with the main constituent being serpentine and no clay minerals being detected. Other unusual alteration features at Premier include the presence of small, spherical crystals of sphene together with fine rods of nickel-sulphide(?) included in olivine pseudomorphs in the Type 3 kimberlite. Garnets in most of the kimberlites are altered to a mineral which has the structure of hydrogrossular but a different and somewhat variable chemistry, mainly due to the substitution of calcium for magnesium (Table 3).

The heavy mineral suite was also examined for many samples at Premier. It is shown that the Type 2 kimberlite contains only a small total heavy mineral fraction with smaller proportions of pyroxene, particularly chrome diopside, and very few garnets when compared with the other kimberlites.

Ilmenites from approximately fifty samples were analysed and they revealed two interesting features. Firstly, some ilmenites from the northern part of the Type 1 and parts of the Type 2 kimberlites have high manganese contents commonly up to 5 wt.% MnO. This unusual feature is considered to be a secondary phenomenon and is discussed in detail by Wyatt (this volume). The unaltered ilmenites have consistent compositions (Table 4), all typical of kimberlites, suggesting that the different varieties of kimberlite are closely related.

The 2 800 garnets recovered from five samples representing the three principal kimberlites were found to have unusual compositions with extremely high TiO_2 (up to 2 wt.%) and Cr_2O_3 (up to 16 wt.%) contents. Most of the garnets are similar to those derived from garnet lherzolites and garnet harzburgites (Danchin, 1979) and megacrysts (Lawless, 1974) at Premier. The unusual chemical characteristics of the Premier garnets were highlighted during statistical analysis of a large number of garnet analyses from the literature (Danchin and Wyatt, this volume). The only garnets that compare with Premier, having TiO_2 contents greater than 1,2 wt.% and relatively high Cr_2O_3, are one garnet from Udachanaya (U.S.S.R.) and a few from some unusual polymict xenoliths found at Bultfontein, South Africa (Lawless, 1978). Low TiO_2 and Cr_2O_3, straw-orange-coloured garnets were not found at Premier but are known at other localities (e.g. Dokolwayo and Jagersfontein, B. Wyatt - personal communication). FeO-rich garnets were not found. Unusual green and purple garnets were recovered in most concentrates, apart from the Type 2 kimberlite. The green garnets have high Cr_2O_3 and high CaO contents (Table 5) and are different from those found at Newlands or Kao (e.g. Clarke and Carswell, 1977). The purple garnets have variable compositions with 10-15 wt.% Cr_2O_3 and 0,1-2 wt.% TiO_2.

In conclusion it has been shown that the three main kimberlites at Premier, on the basis of their mineralogy, are diopside- serpentine- or diopside-kimberlites. Texturally they are tuffisitic kimberlite breccias (Types 1 and 2) or kimberlite breccia (Type 3). Although some primary and secondary features can be used to distinguish between typical samples of Types 1, 2 and 3 kimberlites, it is likely that they are closely related.

Elthon and Ridley (1979) have discussed the mineralogy of one fresh sample of Premier Mine kimberlite. They describe fresh olivine, fresh and abundant phlogopite, carbonate and apatite. No fresh or micaceous kimberlites have otherwise been described from Premier. It seems more likely that this is a pre-1900 sample which was probably derived from Wesselton Mine, then called Premier Mine.

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TABLE 1

MODAL ANALYSES

Kimberlite Type		2	1	3
Sample Number		K1/28	K1/25	BHS510
Xenoliths	Mantle and Crustal	12	13	11
Xenocrysts and Cryptocrysts		2	3	2
Olivineø		44	42	48
Groundmass	clinopyroxene	23	16	16
	serpentine*	12	22	20
	phlogopite	4	2⁻	tr.
	perovskite	1	1	1⁻
	opaques	2	2⁺	2⁻
	other	tr.	tr.	tr.

øpseudomorphed

*mostly altered to clay minerals in Types 2 and 1.

TABLE 2

ANALYSES OF GROUNDMASS CLINOPYROXENE FROM THE TYPE 3 KIMBERLITE (SAMPLES BHS 211) AT PREMIER AND FROM THE SCHULLER SATELLITE PIPE

	Premier							Schuller		
Analysis No.	937	938	943	944	948	55*	947ø	952	954	955
SiO_2	54,66	54,27	53,84	53,92	54,79	54,45	52,76	54,63	53,94	53,87
TiO_2	0,19	0,26	0,88	0,57	0,14	0,46	0,47	0,25	1,08	0,29
Al_2O_3	0,01	0,02	0,06	0,03	n.d.	0,38	0,85	1,22	0,39	0,11
Cr_2O_3	0,12	0,12	0,13	0,12	0,12	0,01	0,20	0,13	0,12	0,12
FeO	2,88	4,80	3,95	4,53	2,69	2,79	3,88	4,54	6,81	5,22
MgO	16,96	15,64	15,52	15,08	16,75	17,43	17,66	15,46	14,12	15,04
MnO	0,10	0,16	0,10	0,12	0,09	0,10	0,07	0,18	0,17	0,21
NiO	n.d.†	0,02	0,02	0,01	0,02	-	0,03	0,02	0,05	0,05
CaO	24,85	23,93	24,05	24,18	24,68	24,79	21,99	21,88	22,90	24,32
Na_2O	0,54	0,98	0,90	0,87	0,49	0,12	0,65	1,63	1,23	0,67
K_2O	0,01	0,01	0,01	0,02	0,01	-	0,07	n.d.	0,01	n.d.
TOTAL	100,33	100,21	99,46	99,45	99,76	100,83	98,64	99,87	100,82	99,89

†n.d. = not detected

* microlite

ø = numerous extremely fine laths (defocused beam)

TABLE 3

ANALYSES OF A PARTIALLY ALTERED GARNET GRAIN FROM TYPE 1 KIMBERLITE

Analysis Number	808	809	810	811
	Core (fresh)	←(altered)		rim →
SiO_2	41,09	31,44	33,46	32,14
TiO_2	0,82	0,07	0,26	0,22
Al_2O_3	17,87	6,74	5,35	4,73
Cr_2O_3	6,74	7,79	7,34	7,23
FeO	6,54	11,83	12,50	14,21
MgO	20,64	19,64	17,25	13,80
MnO	0,29	0,22	0,20	0,22
NiO	0,01	0,10	0,12	0,08
CaO	5,46	7,87	13,01	17,08
Na_2O	0,05	0,47	0,12	0,09
K_2O	n.d.†	0,15	0,19	0,10
TOTAL	99,51	86,32	89,79	89,90

†n.d. = not detected

TABLE 4

AVERAGE ANALYSES OF UNALTERED (NON-MANGANESE) (ILMENITES 50 GRAINS EACH)

	Type 2 PM59D	Type 1 BHS1	Type 3 BHS10
SiO_2	-	-	-
TiO_2	53,78	54,40	53,94
Al_2O_3	0,55	0,44	0,37
Cr_2O_3	1,11	0,81	0,92
FeO	31,06	30,96	31,66
MgO	12,19	12,25	12,29
MnO	0,30	0,31	0,27
CaO	0,03	0,03	0,04
TOTAL	99,03	99,20	99,50

TABLE 5

ANALYSES OF GREEN GARNETS

Kimberlite	Type 1		Type 3	Total range (37 grains)
Sample	285/33/A/2		285/30/B/1	
SiO_2	40,17	40,57	39,64	38,20 - 40,57
TiO_2	0,16	0,23	0,24	0,15 - 0,43
Al_2O_3	14,85	11,69	10,85	9,98 - 14,85
Cr_2O_3	10,43	14,98	15,45	10,32 - 16,25
FeO	6,78	5,82	5,65	5,21 - 8,31
MgO	14,33	15,37	12,96	11,60 - 15,37
MnO	0,29	0,40	0,31	0,29 - 0,52
CaO	12,88	11,44	14,22	11,35 - 15,35
TOTAL	99,89	100,51	99,32	

KIMBERLITE SYMPOSIUM II

Cambridge July 1979