POLYMICT PERIDOTITES FROM THE BULTFONTEIN AND DE BEERS MINES, KIMBERLEY, SOUTH AFRICA

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Introduction

Six nodules have been found amongst the xenoliths of the Bultfontein and De Beers Mines. They have been termed polymict peridotites because they display gross disequilibrium features. The rocks are characterised by the presence of (a) Metasomatic minerals including ilmenite, phlogopite and sulphide phases, and (b) a wide variety of olivines, orthopyroxenes, garnets and clinopyroxenes sometimes as rock clasts. All appear to be of upper mantle origin. The mineral chemistry of four of the polymict nodules has been studied in some detail.

Description and Chemistry of Mineral Components

Olivine bearing clasts within two of the nodules are porphyroclastic, in one laminated disrupted porphyroclastic and in the other disrupted mosaic porphyroclastic using the terminology of Harte (1977). The rock clasts appear to be harzburgites, pyroxenites and lherzolites.

(i) Olivine. The most abundant silicate constituent occurs as phenocrysts and/or porphyroclasts, usually anhedral and displaying undulose extinction. Most grains are partially serpentinised and may have recrystallized to variable extent to produce neoblasts or tabular crystals. Olivine compositions vary from Fo_{86} to Fo_{96}. The higher iron varieties are generally the recrystallized, neoblastic or tabular crystals.

(ii) Orthopyroxene is found as (a) phenocrysts and/or porphyroclasts and as (b) small grains partially or completely enclosing clinopyroxene grains or megacrysts. (a) Clear porphyroclasts seldom exceed 5 mm, are usually anhedral, show good cleavage and straight extinction. Some porphyroclasts are "cloudy" and have been deformed and partially recrystallized. Rare examples have been disrupted and show kink bands. The range of compositions is given in Table 1, which shows the variation in unaltered porphyroclasts and the maximum value for edges of porphyroclasts or for recrystallized grains where either exceeds the unaltered range.

TABLE 1.

Rock No.	JJG 513		BD 2394		BD 2666		JJG 1414	
	Unaltered	Alt.	Unaltered	Alt.	Unaltered	Alt.	Unaltered	Alt
Mg/Mg+Fe	86.8-94.2		88.0-94.0		85.0-95.4		88.3-96.0	
Al_2O_3 wt%	<.01- .91	2.97	.02 -.79	3.21	<.01-.90	1.91	.05 -2.40	2.45
CaO wt%	.02- .62	1.33	.22 -.91	1.21	.25-.70	1.00	.42 -1.69	
Cr_2O_3 wt%	.05- .59	.96	.06 -.58	1.24	.05-.67	1.06	.17 -1.46	
TiO_2 wt%	<.01- .29	.36	.01 -.30	.36	<.01-.29	0.32	.01 - .30	.32

(b) Orthopyroxene around clinopyroxene grains and or within clinopyroxene megacrysts varies in shape, size, orientation and appearance. It is usually associated with phlogopite and finely disseminated opaque minerals, and the manner of its association with clinopyroxene has not been observed in any other clinopyroxenes we have seen. In one small clast in BD 2666, the orthopyroxene forms an optically continuous rim around the clinopyroxene grains but in the other cases the orthopyroxene is randomly oriented in these clasts and megacrysts. The compositions of the orthopyroxenes are extraordinarily variable.

The maximum range for any clast in a particular nodule is given in Table 2.

TABLE 2.

Rock No.		JJG 513	BD 2394	BD 2666	JJG 1414
Mg/Mg+Fe		88.5 -92.3	86.9 -90.6	86.5 -94.2	90.6 -92.3
Al_2O_3	wt%	0.54- 2.85	0.33- 3.35	0.37- 2.01	0.73- 4.23
CaO	wt%	0.33- 1.63	0.57- 1.76	0.27- 2.49	0.59- 1.51
Cr_2O_3	wt%	0.27- 1.68	0.18- 0.71	0.08- 1.50	0.45- 1.88
TiO_2	wt%	<.01- .35	0.13- 0.40	0.01- 0.36	0.12- 0.37

(iii) Garnet. Yellow, orange, red and mauve garnets (occasionally alexandritic) are present in all four specimens and show kelyphitic borders. They are never euhedral and invariably cracked. Most are <5 mm in longest dimension but a garnet in JJG 1414 is approximately 20 mm in diameter. Some garnets are disrupted. The garnets can be broadly classified into three groups: (a) chromian garnets similar to those found as inclusions in diamond and having <3 wt% CaO; (b) harzburgite-lherzolite-websterite chromian garnets with >3 wt% CaO including rare high calcium-high chromium varieties; (c) eclogitic garnets having <1 wt% Cr_2O_3. One low calcium garnet is zoned with respect to CaO, TiO_2 and Cr_2O_3 and some of the lherzolite group garnets are zoned particularly with respect to TiO_2 (from <0.01 to 1.15 wt% on some edges).

(iv) Clinopyroxene occurs in altered megacrysts and small altered clasts in JJG 513 and BD 2394 but only as small clasts in BD 2666 and JJG 1414. It is also found as inclusions in garnets, and olivines and in lherzolite or pyroxenite rock clasts. Orthopyroxene is always associated with the clinopyroxenes in the megacrysts and small clasts.

The compositions of the clinopyroxenes vary both within single clasts and between clasts. Table 3 shows maximum variations for any single clast in a particular nodule.

TABLE 3.

Rock		JJG 513	BD 2394	BD 2666	JJG 1414
Ca/Ca+Mg		41.3 -46.9	46.6 -47.5	44.0 -45.5	43.6 -45.4
Al_2O_3	wt%	0.51- 2.93	0.94- 1.07	1.77- 2.11	1.64- 2.63
Cr_2O_3	wt%	0.44- 2.16	0.50- 0.65	1.08- 1.23	2.46- 2.70
TiO_2	wt%	0.17- 0.49	0.19- 0.21	0.20- 0.34	0.27- 0.44
Na_2O	wt%	0.91- 2.35	1.36- 1.51	1.65- 2.23	2.43- 2.77

(v) Phlogopite is associated with ilmenite veins; as relatively undeformed phenocrysts; as inclusions in ilmenite blebs and also in fine grained mixtures with ilmenite and as alteration products in and around garnets in all four rocks. It also occurs along grain boundaries and around rock clasts. Phlogopite compositions vary considerably with respect to TiO_2 and Cr_2O_3.

(vi) Ilmenite occurs as either blebs (4x3 cm) or as veins (ranging up to 8 x 1.5 cm). The large compositional differences of the ilmenite veins and blebs are illustrated by the variations in chrome content. In BD 2666 Cr_2O_3 ranges from 1 to 4.4 wt% in separate veins and may vary from 2.5 to 3.5 wt% across a vein. In BD 2394 Cr_2O_3 varies from 3.9 to 7.0 wt%. Ilmenites in JJG 1414 show even larger variations in individual veins (1.2 to 7.0 wt% Cr_2O_3). Ilmenite in the orthopyroxene-clinopyroxene association occurs as tiny grains of variable composition. Cr_2O_3 content ranges from 5.3 to 7.7 wt% and in what appears to be a rutile-ilmenite mixture may be as high as 11.2 wt% Cr_2O_3.

(vii) Rutile occurs as rims to ilmenite veins and blebs; as blebs or veins; in an intimate mixture with ilmenite in BD 2394; as tiny orientated platelets in rare orthopyroxene crystals; and associated with serpentine veins and phlogopite; and in the orthopyroxene-clinopyroxene clasts. The Cr_2O_3 content of the rutile rims on ilmenite veins varies from 1.8 to 3.5 wt% with Fe_2O_3

contents of approximately 0.5 wt%. Rutiles in the orthopyroxene-clinopyroxene associations have between 3 and 4 wt% Cr_2O_3 and 0.3 and 1.5 wt% Fe_2O_3, whereas rutiles associated with serpentine have <3 % Cr_2O_3 and <0.27 % Fe_2O_3.

(viii) Chromites have been found as inclusions in olivine, garnet, in a clinopyroxenite rock clast and in the orthopyroxene-clinopyroxene clasts. The different compositions of these chromites is given in Table 4 and a range for those in one of the orthopyroxene-clinopyroxene clasts.

TABLE 4.

	Inclusion in	In Rock clast	Inclusion in Garnet	In opx-cpx clasts
Cr_2O_3 wt%	54.5	>62.	29.5	44.8-54.0
Al_2O_3 wt%	10.5	<1.5	36.4	5.5-10.2
TiO_2 wt%	<0.6	2.0	<0.1	2.51-5.85

(ix) Sulphide phases are associated with ilmenite veins and phlogopites in BD 2666 but in the other rocks are rare and appear to be confined to serpentine veins and around silicate grain boundaries. Pyrrhotite, chalcopyrite, pyrite and pentlandite have been tentatively identified.

(x) Zircon has been found in BD 2666 giving a lead uranium age of 84.5 million years (Davis, 1977).

(xi) Calcite is extremely rare in these nodules and is found in association with serpentine veins and phlogopite.

Conclusions

(a) The compositions of the silicate and metasomatic minerals indicate that they are all probably of upper mantle origin. The ranges of Mg/(Mg+Fe) for olivines and orthopyroxenes suggest that pieces of a wide variety of mantle rocks have been incorporated into these nodules.

(b) The clinopyroxene megacrysts appear to have unmixed on cooling and are considered to have been formed at depth and to have been transported to a lower pressure/temperature environment in the magmatic event mentioned under (d).

(c) The zoning of the peridotitic minerals suggests that they partially re-equilibrated at least with respect to temperature and pressure and to their TiO_2 contents prior to sampling.

(d) The presence of ilmenite and phlogopite and their compositions together with mantle rocks of diverse origin suggests that the event in which the rock formed was a magmatic event crystallizing ilmenite, phlogopite and sulphides and that it was a precursor to the event which finally transported the nodule to surface.

(e) These nodules possibly represent the remnant decarbonated conduit filling related to a kimberlitic event in the upper mantle.

Harte, B. (1977) Rock nomenclature with particular relation to deformation and recrystallization textures in olivine-bearing xenoliths. J. Geol. (in press).