A QUENCH ORTHOPYROXENE-ILMENITE XENOLITH FROM KIMBERLITE - EVIDENCE FOR TI-RICH LIQUID IN THE UPPER MANTLE

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Textural, mineralogical and experimental studies have been made on a currently unique non-equilibrated, pyroxene-ilmenite nodule (BD 2027) from the kimberlite of the Weltvreden Mine, S. Africa. The xenolith comprises mainly acicular high-Ti bronzite (terminology of Stephens and Dawson, 1977) irregularly intergrown with magnesian ilmenite in macro-spherulites and comb-layered units; some macrospherulites are nucleated upon larger equidimensional crystals of high-Ti bronzite. These phases are compositionally similar to phases in orthopyroxene/ilmenite nodules from Monastery (Boyd, 1971; this work) and Frank Smith (Frick, 1973) except for slightly higher Al_2O_3, Cr_2O_3 and Mg/(Mg+Fe); the main difference is in the acicular morphologically of the opx in the Weltvreden specimen. Representative analyses are given in Table 1. Relatively coarse, much less abundant clinopyroxene in regular intergrowths with ilmenite occur only in the vicinity of late-stage pegmatitic patches; compared with previously reported analyses of clinopyroxene in lamellar clinopyroxene/ilmenite intergrowths (summary by Gurney et al. 1973), the pyroxene is more calcic, lower in Cr_2O_3, Al_2O_3, and Na_2O, and most closely resemble clinopyroxenes in MARID-suite nodules (Dawson and Smith, 1977). The nodule is cut by a 0.5cm vein of more iron-rich magnesium ilmenite. Other phases are rare high-Ti pyrope and titanian phlogopite, the latter occupying interstices between acicular orthopyroxene, but also occurring most abundantly as larger bent crystals in the pegmatitic patches, together with coarse serpentinized olivines, calcite, apatite and ilmenite. Also present are small patches of very fine-grained calcite, serpentine, ilmenite phlogopite and diopside, (together resembling a kimberlite groundmass assemblage (Dawson et al. 1978)), which are interpreted as the final products of essentially "closed" crystallization of the presumed high-titanium liquid. We propose a complex cooling history for the rock. Initial crystallization of garnet and orthopyroxene, was followed by rapid similtaneous crystallization of ilmenite and acicular high Ti-bronzite. The phases in the pegmatitic and kimberlitic patches were the last to crystallize under high fH_2O and fCO_2 conditions. Pyroxene-ilmenite geothermometry (F.C. Bishop pers. comm.) suggests temperatures of 1020 ± 40° for opx-il intergrowths, and 910 ± 30°C (at 30 kbrs) for cpx-ilmenite intergrowths, thereby confirming the textural evidence for at least two stages of crystallization.

Experimental work on the bulk rock, (containing the pegmatitic calcite, serpentine and phlogopite areas, in addition to the highly refractory px-il areas), attempted to establish the crystallization sequence and to simulate the unusual texture of the opx-il intergrowths. The solidus at 20 kb was 1200°C, rising to 1230°C at 30 kb. Olivine was the liquidus phase from 5-30 kb, and the ilmenite-out curve coincided with the beginning of melting. Olivine reacted with liquid to give enstatite. The range of simultaneous crystallisation of enstatite and ilmenite increased from 180°C at 20 kb to 260°C at 30 kbrs. Bulk-rock melted at 20 kb and held at the solidus temperature for 10 minutes before quenching produced fine acicular intergrowths of opx and ilmenite, strongly resembling the texture of the original rock.

The acicular opx-ilmenite crystallization stage of the natural rock is interpreted as due to rapid co-precipitation of opx and ilmenite from an undercooled, supersaturated Ti-rich liquid in an upper mantle vein or dyke. Coarser intergrowths described previously are possibly derived from upper-mantle pegmatites - the textural differences perhaps being a reflection of the volatile content at the time of injection. These conclusions are in agreement with theories that pyroxene-ilmenite intergrowths result from cooling of Ti-rich liquids (e.g. Wyatt, 1977) rather than by exsolution from earlier high-pressure phases.

References

Boyd (1971) Carn. Inst. Wash. Yk. 70, 134. Dawson & Smith (1977) GCA 41, 309. Dawson, Smith & Hervig (1978) Neu. Jahrb. Min.. Frick (1973) Trans. G. Soc. S. Afr. 76, 195. Gurney, Fesq & Kable (1973) *in* Lesotho Kimberlites, Nixon ed., Lesotho Dev. Corpn., 238. Stephens & Dawson (1977) J. Geol. 85, 433. Wyatt (1977) Contr. Min. Pet. 61, 1.

Table 1. Representative analyses of phases in BD 2027

	1	2	3	4	5	6	7
SiO_2	56.16	0	51.94	0.15	0	41.74	40.11
TiO_2	0.37	53.00	2.66	54.05	48.52	1.62	5.14
Al_2O_3	1.57	0.37	1.32	0.05	0.60	21.70	11.65
Cr_2O_3	0.12	0.72	-	0.36	0.89	0.08	0.15
FeO	7.96	33.72	3.70	34.72	41.24	11.00	6.58
MnO	0.19	0.27	0.07	0.59	0.20	0.27	0.05
MgO	32.00	11.08	15.89	9.19	10.20	20.56	20.41
NiO	0.20	0.07	-	-	-	-	0.04
CaO	1.07	-	23.48	0.1	-	3.22	-
Na_2O	0.27	-	0.62	-	-	0.12	0.26
K_2O	n.d.	-	-	-	-	-	9.73
Total	99.9	99.3	99.7	99.3	101.7	100.7	94.1

1 Opx; 2 Ilm intergrown with 1; 3 Cpx; 4 Ilm intergrown with 3; 5 Ilm in vein; 6 Garnet; 7 Ti-phlogopite in pegmatitic patch.