A CRYSTALLIZATION MODEL FOR PERIDOTITIC DIAMOND INCLUSION SPINELS.

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Spinel, together with olivine, is the most common diamond inclusion in Yakutia[1] and at some southern African occurrences (e.g. Dokolwayo). It has been commonly found to coexist in diamondiferous xenoliths[2] and diamonds with olivine, orthopyroxene, G10 garnets and rarely with diopside, zircon and graphite[1-5]. In both southern Africa and Yakutia similar compositional characteristics have been observed within the spinels (Table 1).

TABLE 1 - DIAMOND INCLUSION SPINELS		
OXIDE (wt%)	YAKUTIA[1] (n=720)	S. AFRICA (n=134)
TiO_2	< 0.7	< 0.7
Al_2O_3	3.5 - 7.5	2.77 - 13.9
Cr_2O_3	62 - 67	57.9 - 68.5
FeO	12 - 19*	4.17 - 16.4
MgO	11 - 15.5	11.1 - 18.7

* Total Fe as FeO

Calculated equilibrium temperatures at 50 kbar for the southern African diamonds with spinel inclusions suggest subsolidus temperatures which is consistent with the temperatures calculated for diamonds from this sub-region containing silicate phases. Calculated fO_2's at 50 kbar suggest oxygen fugacities between WM and IW.

The coexistence of the diamond inclusion-type spinels with G10 garnets suggest a common paragenesis within a subcalcic chromium-rich harzburgitic environment. It is suggested that the key to determining the paragenesis of the spinels lies in establishing the origin of the G10 garnets. In addition to the subsolidus equilibrium temperatures calculated for diamonds containing G10 garnets, the most significant characteristic of these garnets is a depletion in Ti, Fe, Ca, Y, Zr, Ga and Zn which is accompanied by an enrichment in Cr, Mg and LREE's [6]. A model of subsolidus crystallization is proposed.

The extraction of komatiitic or basaltic melts from a chondritic mantle at 2000 °C and 50-70 kbar leaves a dry spinel-harzburgite residue depleted in Ca, Ti, Y, Zr, Ca and Zn, and which is resistant to large scale melting. The olivines in the residue are forsteritic. At these temperatures and pressures the residual orthopyroxenes are Al_2O_3 and Cr_2O_3 enriched with low Al_2O_3/Cr_2O_3 ratios (Cr*, ± 1), Ti and Ca-depleted and contain a significant component

of dissolved garnet. Based on the behaviour of chromium and titanium in silicate melts, the spinels may be Cr_2O_3 (> 55wt%) and TiO_2 (average >.07 wt%) rich. Vertical subduction, driven by the stacking of successive extrusions of komatiites and Archaean ocean floor basalts[7], results in advective thickening. LREE's, alkalis and carbon volatiles fluxing from the base of the descending slab, consisting of an undepleted sub-tectospheric mantle, metasomatises the harzburgitic residue[8]. In the absence of garnet the LREE's will, in preference to olivine and spinel, partition into the residual orthopyroxene. The carbon volatiles remain in solution.

On cooling from 2000 ^{O}C at which the komatiite melts are extracted to a steady state geothermal temperature of 1200 ^{O}C the orthopyroxene exsolves its garnet component. The major element composition of the exsolved garnet will be dependent on the composition of the residual orthopyroxene immediately after the extraction of the komatiite melts. The Cr- and Mg-enriched nature of the unexsolved orthopyroxene will favour the formation of $Mg_3Cr_2Si_3O_{12}$ in the exsolving garnet which, together with the depletion of the FeO, CaO and TiO_2, is consistent with major element compositional characteristics of G10 garnets. The LREE's partition from the orthopyroxenes preferentially into the garnet and consequently enrich the G10's in LREE's.

The exsolution of G10 garnets from residual orthopyroxenes will progressively deplete Al_2O_3 in the pyroxene and the Cr in the exsolving garnet will gradually increase. Although the knorringite molecule in the garnet allows for greater solubility of the Cr in the garnet, the exsolution of spinels will be favoured at low Cr^* in the orthopyroxene. The predicted low Cr^* and TiO_2-depleted composition of the residual komatiite orthopyroxenes will favour the exsolution of TiO_2-poor Cr-rich spinels together with the exsolution of G10 garnets. The presence of both G10 garnets and Cr-rich spinels, depleted in TiO_2, in diamonds, xenoliths and the concentrate of diamondiferous kimberlites is consistent with the model above.

Subcalcic G10 garnets at Dokolwayo have Cr^* > 1.00. The exsolution of these garnets from the residual orthopyroxenes would deplete Al in the residual pyroxene while Cr-enrichment occurs. Spinel exsolving from the orthopyroxene will therefore become increasingly Cr-rich. This may result in zonation patterns within the spinels exhibiting increasing Cr_2O_3 contents from centre to edge. Approximately fifty percent of the Dokolwayo concentrate spinels are compositionally similar to the diamond inclusion spinels and are characterized by TiO_2/Al_2O_3 < 0.2. These spinels commonly exhibit zonation patterns consistent with the model above. It should be noted that the Dokolwayo concentrate spinels with Al_2O_3/TiO_2 > 0.2 show no significant evidence of Cr_2O_3 zoning.

Calculated fO_2 conditions suggest that the dominant carbon volatile species is CH_4. At the reigning T, P and fO_2 conditions diamond crystallizes from the CH_4 either through fractionation or oxidation of CH_4. Mass balancing exercises show that olivine and a small amount of orthopyroxene, depleted of garnet component, also exsolves from original Al,Cr-enriched orthopyroxene. Because diamond crystallization and the process of exsolution occur simultaneously, the

diamonds may occlude the exsolved minerals. The syngenetic relationship between diamonds and their primary inclusions suggests that the processes of exsolution and diamond crystallization occur simultaneously.

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