A DIAMOND GRAPHITE ECLOGITE FROM THE ROBERTS VICTOR MINE

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HRV247, an eclogite from the Roberts Victor kimberlite pipe displays the primary assemblage garnet, clinopyroxene, graphite, diamond, pyrrhotite, rutile and possibly phlogopite.   The rock is believed to have formed as a cumulate from partial melting of peridotite mantle.   The well defined crystal shape of graphite is good evidence that this phase grew in a liquid medium.

Compositions of the garnet and clinopyroxene were determined (Table I). Garnet rims were found to be pyrope rich relative to cores.   Garnets at one end (A) of the nodule were found to be pyrope rich relative to the other (F2), (Figure 1).   Clinopyroxene rims were found to be diopside rich relative to cores and similarly clinopyroxenes in A were found to be diopside rich relative to F2.   The nodule therefore evolves from jadeite-grossular compositions in F2 toward diopside-pyrope compositions in A.   F2 is the bottom of the nodule, A the top.

The $\ln X_D$ for Fe/Mg distribution between garnet and coexisting clinopyroxene (Raheim and Green, 1974) of F2 is near to 1.4 while A has values close to 1.2.

Graphite is concentrated in F2 and diamond in A (Robinson, 1977).   The carbon content of the nodule is approximately .15wt%.

The features outlined above may be explained if portion F2 formed at P,T within the graphite stability field while A formed at P,T within the diamond stability field.   These conditions are illustrated in Figure 2 and indicate that a path of increasing pressure (and increasing temperature) must be followed. Pressure increase can be caused by a sinking magma (considered unlikely) or by increasing gas overpressure.   This latter possibility cannot be discounted. However, the compositional variation in the silicates is described by a model of magma mixing, and the possible genesis of diamond will be incorporated into this model.

Magma mixing has been invoked to explain rapid compositional variations in several group II eclogites (e.g. HRV15, Hatton & Gurney, 1977a).   It is envisaged that continued partial melting of garnet lherzolite produces successively more magnesian liquids at correspondingly higher temperatures (Mysen & Kushiro, 1976) and that these liquids are continuously intruded into and mixed in a magma chamber at higher levels.   The compositional variation in HRV247 is on the scale of centimetres.   In a large magma body hundreds of metres thick, magma compositional variation will be reflected over correspondingly large distances (metres) in the cumulates.   The small scale of variation in HRV247 suggests that the coexisting magma was only metres thick.

Heat loss from a magma chamber is expected to be most rapid at the top wall. The warm cumulate crystal pile will ensure a slower rate of heat loss from the bottom of the magma chamber.   Thus a heat profile through this body will reveal a cold upper portion, a hot centre and a warm lower portion.

A possible source of carbon is calcium carbonate.   This consideration is prompted by the presence in a sulphide eclogite WM7, of small calcium carbonate (60wt%CaO) blebs on the margin of sulphide.   On reaction with the silicate magma at least some dissociation of $CaCO_3$ will occur by reaction of the type $CaCO_3 = Ca^{++} + O^{--} + CO_2$.   Some conversion of CO_2 to diamond or graphite might

occur depending on the fO_2 of the silicate magma. fO_2 of mantle material may be approximated by the iron wustite buffer (Sato pers. comm. to Huggins et al. 1976). P,T conditions under which fO_2 (IW) equals fO_2 defined by the graphite -CO-CO_2 buffer have been obtained by solution of equations given by Heubner (1971), and are diagramatically represented in Figure 2. At pressures above this curve CO_2 is stable relative to graphite, if fO_2 if defined by the iron-wustite buffer. In the presence of H_2O, P_{CO_2} will usually be less than P total, and the curve fO_2 (IW) = fO_2 (G-C-CO_2) will lie at higher temperature for a given pressure. Nevertheless, taking the equations at face value, at pressures below about 45kb carbon dioxide will be reduced to graphite, and to diamond at lower temperatures. If it is assumed that magma from which the diamond-graphite eclogite crystallises was initially at temperatures near $1100^{\circ}C$, and a pressure of 42kb then with heat loss diamond will crystallise adjacent to the cold upper wall (T $1020^{\circ}C$) while graphite will be stable near the warm bottom wall of the magma chamber. Garnet and clinopyroxene crystallise with diamond near the upper wall but on settling through the hot central portion are largely resorbed, while less reactive diamond shows only limited resorption. The small scale of the magma chamber allows significant concentrations of diamond to reach the bottom of the magma. Thus graphite settles first together with early low temperature cumulates, and diamond occurs together with later, higher temperature cumulates. Two zones of nucleation are proposed - the top and bottom walls of the magma chamber. The garnet inclusion in garnet 5 (table 1) may have crystallised at the upper wall of the magma chamber.

The model discussed above attempts to explain the coexistence of diamond and graphite in a particular eclogite, but if small volumes of magma are common in the mantle, the model may have wider application. Nucleation of graphite in the diamond stability field, rapid cooling of magma, the effects of other volatiles and of high gas overpressures are alternative processes which will allow coexistence of diamond and graphite in an eclogite nodule.

References

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Figure Legends

Fig. 1. Ca-Mg-Fe plot of clinopyroxenes (near Ca_{50}) and garnets in HRV247. Upper arrow indicates compositions in garnet 5. Lower arrow indicates garnet inclusion in garnet 5.

Fig. 2. P,T plot with range in K_D ratios of rock; theoretical diamond-graphite equilibrium curve; curve in P,T space along which oxygen fugacity of the graphite, carbon monoxide, carbon dioxide buffer is equal to the oxygen fugacity defined by the iron-wustite buffer; and a possible P,T path followed during evolution of HRV247.

Table 1.

Garnet compositions in HRV247

| | Portion A | | Portion F | | Garnet 5 | | |
	Centre	Edge	Centre	Edge	Garnet inclusion	Centre	Edge
SiO_2	41.6	41.6	40.6	40.6	41.5	41.3	41.4
TiO_2	.27	.22	.38	.32	.36	.30	.27
Al_2O_3	23.6	23.6	23.0	23.2	23.3	23.3	23.4
Cr_2O_3	.06	.06	.05	.09	.10	.05	.05
FeO	10.4	10.4	11.8	12.2	11.1	10.6	10.6
MnO	.26	.26	.22	.23	.33	.22	.24
MgO	16.7	17.1	13.9	14.2	17.8	15.9	16.3
CaO	7.45	6.80	9.80	9.25	5.34	8.04	7.55
Na_2O	.09	.10	.11	.12	.06	.09	.08
K_2O							
Total	100.4	100.1	99.9	100.2	99.9	99.8	99.9
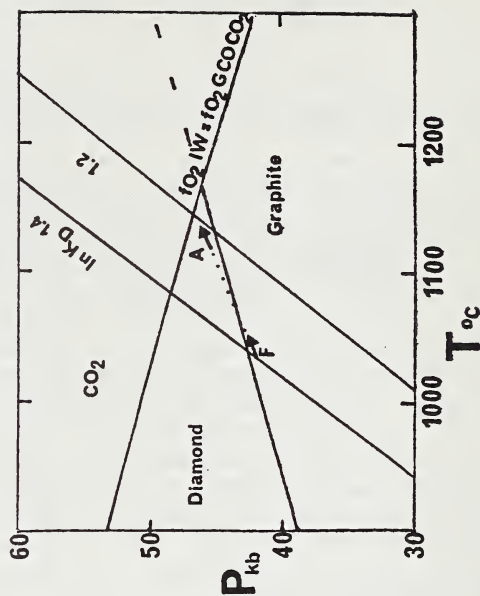
Clinopyroxene compositions

| | Portion A | | Portion F | |
	Centre	Edge	Centre	Edge
SiO_2	55.0	55.4	55.2	55.5
TiO_2	.24	.26	.31	.29
Al_2O_3	5.13	5.15	7.80	7.76
Cr_2O_3	.07	.08	.07	.07
FeO	2.51	2.49	2.61	2.62
MnO	.03	.04	.05	.01
MgO	14.8	14.8	12.6	12.6
CaO	19.2	19.3	17.5	17.3
Na_2O	3.01	2.91	4.65	4.57
K_2O	.05	.06	.06	.06
Total	100.0	100.5	100.3	100.8

Figure 1.

Figure 2.