DIAMOND-BEARING PERIDOTITE XENOLITHS FROM THE ARGYLE (AK1) PIPE

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A suite of garnet peridotite xenoliths, some carrying diamonds at grades as high as the equivalent of 7.5 ct/tonne, has been recovered from the diamondiferous Argyle AK1 pipe, in northwestern Australia. Many of the xenoliths are altered but relics of most primary phases have enabled estimates of the P-T equilibration history of the xenoliths. Significantly, all fall well within the diamond stability field in the mantle.

The xenoliths, which are rounded and range up to 7 cm diameter, have undergone varying degrees of alteration to talc, serpentine, and/or montmorillonite assemblages. Relict phases indicate that all are coarse textured garnet and chromite-garnet lherzolites and harzburgites containing a primary (P1) assemblage of olivine, enstatite, garnet, $\pm$ diopside $\pm$ rare picrochromite. In all cases the original garnet has been replaced by Al-spinel and Al-pyroxenes together with secondary calcite $\pm$ serpentine $\pm$ phlogopite $\pm$ K-feldspar $\pm$ illite. The Al-spinel and Al-pyroxenes (assemblage P2) typically forms very fine symplectic intergrowths, commonly radially oriented, at the core of the larger former garnets and are enveloped by coarser grained, euhedral to sub-skeletal spinel and pyroxene grains at the rim. Similar reaction coronas on garnets in peridotites from the Lashaine volcano and the Lesotho kimberlites have been described by Reid and Dawson (1972) and Lock and Dawson (1980) who attributed the corona formation to reaction of garnet and olivine to Al-pyroxenes and Al-spinel as a result of re-equilibration within the spinel lherzolite facies. However, in the Argyle nodules no relic garnet remains and the cores of many of the smaller former garnets are totally replaced by secondary silicates. These features, together with the highly irregular outlines of the former garnets and the quench-like form of many of the spinels and pyroxenes forming symplectic intergrowths in the larger former garnets, suggests that formation of the symplectite assemblage may have involved incongruent melting of the garnet followed by quenching of Al-rich spinels and pyroxenes from a melt as proposed by Hunter and Taylor (1982).

The P1 assemblage (Table 1) is characterised by uniformly magnesian compositions with olivine mg$_{91-93}$ and pyroxenes mg$_{92-94}$. The enstatites have exceptionally low Al$_2$O$_3$ (0.5-0.7%) and low CaO (0.8-1.1%), and significant Cr content (Table 1). The clinopyroxenes have high Cr (0.7-1.5% Cr$_2$O$_3$), and low Al$_2$O$_3$ (1.2-1.5%) and Na$_2$O (1%) contents; some contain significant K$_2$O. Ca/(Ca+Mg) ratios lie in the range 0.39-0.42. The picrochromites are extremely magnesian and Cr-rich (Cr/(Cr+Al) = 0.7-0.8). The highly refractory nature of this assemblage is typical of depleted peridotite and consistent with the high Mg/(Mg+Fe) ratios and very low Al$_2$O$_3$, CaO and Na$_2$O contents of their bulk rock compositions (Mg/(Mg+Fe) = 0.92, Al$_2$O$_3$ and CaO 1%, Na$_2$O = 0.03% or less.

In contrast, the P2 assemblage (Table 1) pyroxenes and spinels have high but variable contents of Al$_2$O$_3$ (up to 11% in opx, 10% in cpx). The Al-spinels show a very wide compositional range from more Al-rich cores to more Cr-rich rims (Cr/(Cr+Al) = 0.18-0.66).

Equilibration temperatures have been estimated for coexisting pyroxenes in both assemblages using the Ca solubility geothermometer of Bertrand and Mercier (1985). Pressures for assemblage P1 have been estimated using the garnet-orthopyroxene geobarometer of Nickel and Green (1985) and an assumed garnet composition with X_{Ca} = 0.15, X_{Cr} = 0.25 and Mg/Fe calculated from Fe-Mg partitioning between garnet and olivine (O'Neill and Wood, 1979). Uncertainties introduced by this assumed composition are small (2-3 kb), similar to the uncertainty attached to the geobarometer. Lower Ca and Cr contents will result in higher estimated pressures. Pressures for the P2 assemblage were estimated from the garnet-spinel transition (O'Neill, 1981).

Table 1 : <u>Compositions of Phases in Argyle Xenolith</u> (N24)

	P1			P2		
	ol	opx	cpx	opx	cpx	sp
SiO_2	40.85	57.64	55.34	52.61	48.58	0.08
TiO_2	nd	0.04	0.03	0.10	0.41	0.49
Al_2O_3	nd	0.70	1.26	8.03	9.51	43.59
Cr_2O_3	0.02	0.24	0.87	1.79	2.60	23.74
FeO	8.32	5.08	2.87	5.14	4.23	11.02
MnO	0.14	0.13	0.16	0.24	0.31	0.17
NiO	0.40	0.10	0.10	nd	nd	0.14
MgO	50.64	35.31	20.51	30.95	19.43	20.42
CaO	0.05	1.08	18.16	1.76	15.14	nd
Na_2O	nd	0.16	0.89*	nd	0.16	nd
Total	100.42	100.48	100.19	100.62	100.37	99.65
mg	91.6	92.6	92.7	91.5	91.2	76.8

*K_2O = 0.08%,   nd = not detected
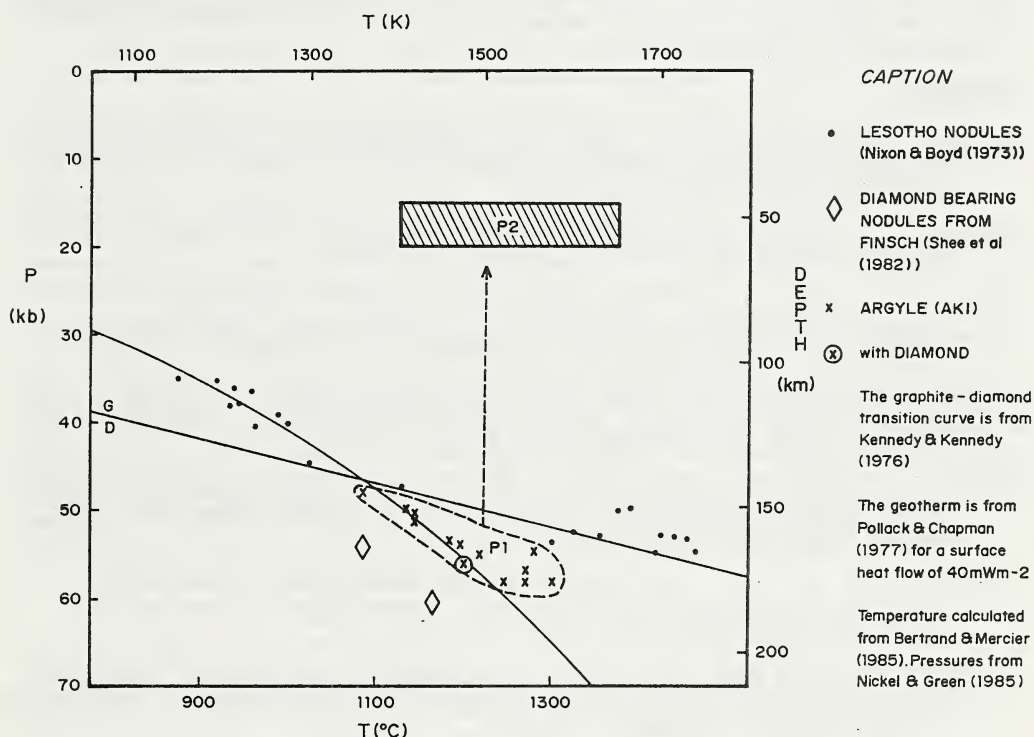
Fig. 1 P-T estimates for Argyle nodules

CAPTION

• LESOTHO NODULES (Nixon & Boyd (1973))

◊ DIAMOND BEARING NODULES FROM FINSCH (Shee et al (1982))

x ARGYLE (AKI)

⊗ with DIAMOND

The graphite – diamond transition curve is from Kennedy & Kennedy (1976)

The geotherm is from Pollack & Chapman (1977) for a surface heat flow of 40mWm-2

Temperature calculated from Bertrand & Mercier (1985). Pressures from Nickel & Green (1985)

    P-T estimates for the Argyle peridotite xenoliths are plotted in Fig. 1 together
with estimates for two diamondiferous garnet lherzolites from the Finsch kimberlite
(Shee et al, 1982) and for sheared and granular garnet lherzolites from the Lesotho
kimberlites (Nixon and Boyd, 1973). The Argyle P1 assemblage and the diamondiferous
Finsch peridotites fall well within the diamond stability field at pressures of 50-60
kb and temperatures of around 1200°C whereas the Lesotho lherzolites form two separate
P-T fields both predominantly within the graphite stability field. Significantly, the
lower termperature Lesotho xenoliths and the diamondiferous peridotites from Argyle and

Finsch all straddle the 40 mW m^{-2} continental (conductive) geotherm of Pollack and Chapman (1977) whereas the hotter Lesotho xenoliths are displaced towards a convective geotherm. Oxygen fugacities have been estimated for the chromite-bearing Argyle xenoliths using the olivine-orthopyroxene-spinel geosensor (O'Neill and Wall, in press) and lie within the wustite field below the magnetite-wustite and enstatite-magnesite-olivine-diamond buffer reactions.

Temperatures estimated for the P2 assemblage are similar to those of P1 whereas pressures are estimated at 20 kb or lower. This suggests that the P1 to P2 assemblage reaction is essentially one of decompression; the P-T estimates for the P2 assemblage lie close to the dry peridotite solidus.

The history of the Argyle xenoliths is therefore inferred to have been: (1) equilibration of refractory garnet lherzolite, depleted by prior melt extraction, well within the diamond stability field under a low geothermal gradient and reducing conditions where microdiamonds formed, (2) entrainment in a hot lamproite host magma, (3) ascent into the spinel peridotite stability field near the dry peridotite solidus causing reaction of garnet with olivine and incongruent (?) melting of the garnet, perhaps aided by metasomatic fluid from the host magma; subsequent quenching produced the Al-rich spinel and pyroxene, and (4) veining and alteration of the primary silicate phases and the inferred glass. The unusual complete elimination of the primary garnet in the xenoliths may reflect higher magmatic temperatures in the lamproite host than typically found in kimberlite.

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