LOW–Ca GARNET HARZBURGITE XENOLITHS FROM SOUTHERN AFRICA: ABUNDANCE, COMPOSITION, AND BEARING ON THE STRUCTURE AND EVOLUTION OF THE SUBCRATONIC LITHOSPHERE.

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Most natural diamonds probably exist in the upper mantle as members of a low-Ca garnet harzburgite assemblage. Xenoliths of low-Ca garnet harzburgites (with or without diamonds) are purported to be rare, although xenocrysts of low-Ca Cr-pyrope derived from such rocks have been shown to exist in virtually all kimberlites on the Kaapvaal Craton in southern Africa (e.g., Boyd and Gurney, 1982; Gurney, 1985). This has led to suggestions that, relative to other types of mantle xenoliths, low-Ca garnet harzburgites disaggregate more readily upon eruption, yielding xenocrysts of diamond and low-Ca garnet, with few intact low-Ca garnet harzburgite xenoliths surviving (e.g., Boyd and Gurney, 1982; Gurney, 1985). In the present study, xenoliths of low-Ca garnet harzburgite were sought in the Kimberley dumps, and their abundance compared with estimates from garnet xenocryst populations of the Kimberley mines. Investigation of garnet xenocrysts was extended to include 11 additional kimberlites across the Kaapvaal Craton. Note that in similar, earlier studies only Cr-rich purple garnets were analyzed, and thus the data cannot be used to estimate the abundance of low-Ca garnet harzburgites in the upper mantle.

Garnet harzburgites constitute approximately 9% of the mantle xenolith population at Kimberley, (945 nodules studied by Schulze, 1986). As 11 of 45 garnet harzburgites analyzed contain Cr-pyropes with CaO contents lower than those from the Kimberley lherzolite field, approximately 2% of the Kimberley xenolith population is low-Ca garnet harzburgite. If only garnet-bearing xenoliths are considered (41% of the nodule suite), low-Ca garnet harzburgites constitute approximately 5% of the suite. Analysis of 469 garnets from the Wesselton, Du Toit's Pan, and Bultfontein mines yielded an average value of about 5% for low-Ca garnets among the entire garnet population (Table 1). If 41% of Kimberley ultramafic xenoliths are garnet-bearing, the garnet xenocryst data yield a value of 2% low-Ca garnet harzburgite for the mantle sampled by the Kimberley kimberlites.

At the Finsch Mine, low-Ca garnets constitute approximately 6% of the garnet xenocryst population (Table 1). Three low-Ca garnet harzburgites (one diamond-bearing) have been identified in a suite of 104 garnet peridotites at Finsch, approximately 3% of the peridotite population (Gurney, 1985; Skinner, 1986; Viljoen et al., ms in preparation). At both Kimberley and Finsch, therefore, low-Ca garnet harzburgites are present in the xenolith suites in abundances that approximately agree with estimates from the garnet xenocryst population. There is no need to invoke the presence of interstitial magnesite or liquid to cause preferential disaggregation of this type of nodule (e.g., Boyd and Gurney, 1982).

Elsewhere on the Kaapvaal Craton, garnet xenocryst populations yield similarly low values for low-Ca garnet harzburgites, with locally significant exceptions (Table 1). High values for volume abundance of low-Ca garnet harzburgite (as calculated for peridotite-eclogite ratios by Schulze, 1989) exist in the Boshof kimberlite cluster (13% at Blaauwbosch, 21% at Roberts Victor, 34% at New Elands) and at Eendrag (23%) and

Star (27%). At Bobbejaan, Kaalvallei, Lace and Premier values are 3-8%, with an apparently smaller, but uncertain, quantity at Balmoral. In contrast to the present estimate for low-Ca garnet harzburgite abundance at Premier (6%), 19% of the garnet peridotite nodules studied by Danchin (1979) are low-Ca garnet harzburgites. The reason for this difference is unknown. A similarly high abundance (25%) was reported for the xenolith suite at the Zero kimberlite (Shee et al., 1989).

Many of the Kimberley low-Ca garnet harzburgites have zoned garnets, with rims typically enriched in Ca and either enriched or depleted in Cr, relative to cores. Changes are in the direction of garnets in the lherzolite field. All other minerals are homogeneous and magnesian (e.g., Mg/(Mg+Fe) = 0.929 - 0.949 in olivine).

Both Kimberley and Finsch low-Ca garnet harzburgite equilibrated on a steady-state subcontinental geothermal gradient. At Kimberley they are within the range of equilibration of the majority of garnet lherzolites (1000°C, 42 kb to 1150°C, 56 kb), whereas the Finsch low-Ca garnet harzburgites overlap with, but are mostly shallower than, Finsch garnet lherzolites (Skinner, 1986; Viljoen et al., ms in preparation). Similarly, low-Ca garnet harzburgites studied by Boyd and Nixon (1988) apparently equilibrated throughout the subcratonic lithosphere, and not at any specific depth, and all of the examples from the Zero pipe equilibrated in the graphite stability field (Shee et al., 1989). There is thus no evidence for low-Ca garnet harzburgites being concentrated in a "root" to the lithosphere.

Late Ca-metasomatism, similar to that inferred to be the cause of zoning in the Kimberley low-Ca garnet harzburgites, can also be inferred for other localities. Though zoning has not been recognized in the Finsch low-Ca garnet harzburgites, they, and many Finsch garnet xenocrysts (e.g., Group B of Gurney, 1985), are intermediate in composition between garnet lherzolites (>4% CaO) and most garnets in diamonds at Finsch (<2% CaO). Furthermore, at Liqhobong, Dawson et al. (1978) documented a low-Ca garnet harzburgite in which garnet rims are Ca-enriched relative to cores.

In conclusion, low-Ca garnet harzburgites are thought to exist beneath the Kaapvaal craton as small, isolated bodies scattered vertically and horizontally throughout a lherzolite-dominated lithosphere, generally in low volume (3-6%), though locally abundant (to 35%). Subsequent to acquiring their low-Ca signature (and diamonds), Ca was reintroduced into the low-Ca garnet harzburgites on a wide scale, perhaps through diffusive exchange with surrounding garnet lherzolite. Uniformly low-Ti argues against involvement of a silicate melt.

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Table 1. Relative abundances of rock types sampled by kimberlites on the Kaapvaal Craton, in volume percent, as determined from garnet xenocryst populations.

Kimberlite	Rock Type*			
	L	H	W	E
Finsch	94	6	0+	tr+
Bultfontein	93	6	1	tr
Du Toit's Pan	94	6	0	tr
Wesselton	96	3	0	1
Balmoral	99	?#	0	tr
Eendrag	72	23	4	1
Bobbejaan	95	3	0	3
Blaauwbosch	81	13	3	3
New Elands	62	34	0	4
Roberts Victor	61	21	3	16
Star	71	27	0	2
Kaalvallei	89	3	0	8
Lace	83	8	0	10
Premier	91	6	3	0

* Rock type abbreviations: L = lherzolite, H = harzburgite, W = wehrlite, E = eclogite.
+ A value of 0 indicates that garnets from this rock type were not found in the garnet population, tr indicates garnets from this rock type are present in the garnet population, but represent less than one percent by volume.
# Balmoral garnets include some that are marginally, but not clearly, lower in CaO than most of those in the lherzolite field, which is not well defined at this pipe.