A Re–Os isotopic and petrological study of Namibian peridotites : contrasting petrogenesis and composition of on- and off-craton lithospheric mantle

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Introduction

The processes responsible for the compositional difference between Archaean lithospheric mantle, as characterised by peridotite xenoliths from the Kaapvaal and Siberian cratons, and post-Archaean mantle remain controversial. One reason for this is that most post-Archaean mantle samples are of spinel facies and are often erupted by alkali basalts through relatively young, thin lithosphere undergoing extension. Garnet-facies peridotite xenoliths erupted through Proterozoic crust in the Gibeon area of southern Namibia 70 Ma ago enable direct comparison of mantle lithosphere beneath a tectonically stable off craton area and the lithosphere beneath an adjacent Archaean craton. The peridotite suite from Louwrensia is dominated by low-T, coarse textured garnet lherzolites with subordinate garnet harzburgites and rare spinel-facies peridotites. High-T peridotites are relatively scarce and some have a coarse texture unlike most of those erupted through the Kaapvaal craton.

Pressure-temperature estimates: implications for heat production in continents

The P/T trend defined by the low-temperature (< 1200°C; low-T), coarse textured peridotites from Louwrensia is similar to that for peridotites from kimberlites erupting through the Kaapvaal craton and plots close to a $44 mWm^{-2}$ geotherm. The low-T peridotites are interpreted to represent the cool, non-convecting lithospheric mantle. Equilibration pressures of all the Louwrensia and Gibeon peridotites are exclusively within the graphite stability field, probably reflecting a thinner lithosphere in areas marginal to the craton and consistent with the absence of diamond in the Gibeon kimberlites. Heatflow measurements in Namibia and other Proterozoic areas marginal to the Kaapvaal craton indicate substantially higher heatflow ($60-80\ mWm^{-2}$) than on the craton. The observed similarity of mantle geotherms beneath cratonic and non-cratonic areas in southern Africa implies that heat production in tectonically stable areas of the continents is probably dominated by the continental crust and thus the difference in heat flow between Proterozoic and Archaean areas in southern Africa may be explained by the presence of a thicker crust beneath the Proterozoic areas rather than deflection of heat around thick, cool cratonic keels.

Composition

There is some compositional overlap between the Louwrensia low-T peridotites and those from the Kaapvaal and Siberian cratons but significant differences exist that can be seen from the average compositions presented in Table 1.

The Louwrensia low-T peridotites are compositionally intermediate between Kaapvaal and depleted oceanic peridotites in terms of both their modal mineralogy and Mg#. While olivine and enstatite contents are similar in Namibian and Siberian peridotites the former are more fertile in having higher average diopside and lower Mg#. This can be interpreted in terms of the Archaean Siberian peridotites being residues of higher

TABLE 1. Average modes and olivine Mg# for low-T peridotite xenoliths from the Kaapvaal and Siberian Cratons and the Louwrensia kimberlite, Namibia *vs* Abyssal peridotites. Abyssal peridotite data from Dick and Fisher, 1984

	Olv	Opx	Gar	Cpx	Mg#
Kaapvaal	61.0	31.4	5.8	1.8	0.926
Siberia	74.4	19.2	4.9	1.5	0.926
Louwrensia	70.8	22.5	3.6	3.0	0.918
Abyssal	78.6	12.5	4.5	4.4	0.908

degrees of melting and/or extraction of more Mg-rich magmas. Although a large range of modal enstatite is evident in the Louwrensia peridotites, only one sample contains amounts comparable with the mean of the Kaapvaal samples. Therefore, in contrast to many of the Kaapvaal peridotites, the bulk compositions and modal mineralogy of the Louwrencia peridotites can be achieved by melt extraction from fertile mantle peridotite. This compositional difference between peridotitic lithosphere beneath and adjacent to the craton in southern Africa indicates a fundamental change in the mechanism of lithosphere differentiation on and off-craton.

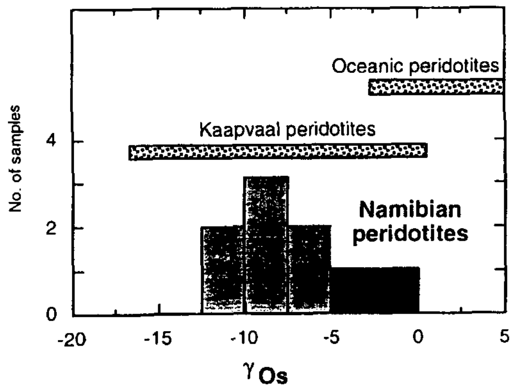

FIG. 1.

Isotopic composition, lithospheric mantle age and crust-mantle relationships

Low-T peridotites from Louwrensia and Gibeon Townlands range in Os isotopic composition from $^{187}Os/^{188}Os$ = 0.1264 to 0.1139 which equate to γOs values of −0.6 to −10.4 at 70 Ma. The lower values are considerably less radiogenic than peridotites from oceanic mantle but overlap the range for cratonic peridotites from the Kaapvaal craton (Fig. 1) and Siberia. The unradiogenic Os isotope compositions of some of the Namibian peridotites require longterm isolation in low Re/Os environments. Assuming that Re/Os was effectively zero at the time of formation (suggested by the very low Re contents of some peridotites, 6ppt), minimum, Re depletion model ages vary from 0.2 to 2.1 Ga. The oldest Re depletion model ages for low-T, coarse peridotites from both Louwrensia and Gibeon Townlands are 2.1 and 2.0 Ga respectively.

The oldest ages for the crust and underlying mantle are the same for the Archaean Kaapvaal and Siberian cratons and the Proterozoic Gibeon area. The age of the crust in the Rehoboth Subprovince is not well defined but estimates of the age of crust formation in basement inliers from zircon and Nd model ages vary from 1.7 to 2.3 Ga.. These estimates of crustal growth in central Namibia thus agree well with the oldest Re depletion ages obtained from the peridotites from 2 kimberlite localities and indicate that both the crust and mantle portions of the lithosphere in this region differentiated in the Early Proterozoic. Several peridotites have Re depletion ages between 1.0 and 1.5 Ga and this may represent post-formation metasomatism or even new mantle additions during the Namaqua thermal event. The correspondence of crustal and mantle ages demonstrates long term crust-mantle coupling over 1000's of km in southern Africa and indicates a stable mechanical boundary layer down to 200 km beneath cratons.