Longevity of cratonic mantle beneath an active rift: Re-Os evidence from xenoliths from the Tanzanian East African Rift

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The Re-Os isotopic system has been applied to dating melt extraction events in peridotites with great success owing to the fact that Re is moderately incompatible during mantle melting, whereas Os is strongly compatible. Melting thus dramatically lowers the Re/Os ratio of residual peridotites and slows the Os isotopic evolution from the time of melting. The elevated Os concentration of the residual mantle material is resistant to subsequent alteration during mantle metasomatism. Estimates of the time of the original melting event can be determined: 1) from Re-Os isochrons, 2) from Re-Os model ages (T_{MA}) -analogous to Nd model ages, or 3) from Re-depletion model ages (T_{RD}). T_{RD} ages assume complete Re extraction during the original melting event therefore the measured $^{187}Os/^{188}Os$ represents the minimum age of melt depletion when compared to the evolution of primitive mantle. In practice, true Re-Os isochrons are rare, owing to the relative mobility of Re during surface weathering and, in the case of xenoliths, Re addition during host-rock reactions. However, other less mobile elements such as Ca, Al or the *HREE* can be used as proxies for Re contents and linear correlations between these elements and $^{187}Os/^{188}Os$ have been used estimate the initial $^{187}Os/^{188}Os$ ratio, hence time of melt extraction (i.e. Reisberg and Lorand, 1995). As melt extraction is generally linked to the timing of lithospheric growth, these ages are used to date lithosphere formation, which for cratonic xenolith suites generally corresponds very well to the age of the overlying crust (Carlson and Irving, 1994; Pearson *et al.*, 1995).

We have applied the Re-Os technique to dating peridotite xenoliths from the Labiat tuff cone, a rift-related Pleistocene olivine melilitite that erupted near the Archaean-Proterozoic boundary of the Tanzanian craton. Peridotites found at Labait span a wide range of compositions and mineralogies (Lee and Rudnick, 1998) and include spinel facies harzburgites and lherzolites, chromite-bearing harzburgites, garnet harzburgites and lherzolites as well as Fe-rich dunites, pyroxenites and glimmerites. P-T estimates for the garnet peridotites fall in a scattered field near a geotherm of ~50 mW/m^2. There is an overall correlation between bulk composition and depth, with more fertile peridotites occurring at deeper levels (Lee and Rudnick, 1998). Trace element compositions show LILE enrichments, similar to cratonic mantle xenoliths elsewhere. Metasomatic overprinting by carbonatites and Fe-rich silicate melts is inferred from petrography and trace element compositions. At least one stage of this metasomatism is rift-related, based on U-Pb dating of Pleistocene metasomatic zircons (Rudnick *et al.*, 1998).

Bulk rock Os concentrations range from a low of 0.42 ppb in the glimmerite to a high of 4.8 ppb in a garnet-free harzburgite, showing a general correlation with fertility: Harzburgites, lherzolites, and the metasomatic rocks (glimmerite and pyroxenite) have the highest, intermediate and lowest the lowest Os concentrations, respectively. Os contents do not correlate with the amount of sulphides optically visible in the samples. Re concentrations range from a low of 0.036 ppb in the glimmerite to a high of 0.404 ppb in a garnet lherzolite. Re contents do not correlate well with fertility. A $^{187}Re/^{188}Os$ *vs* $^{187}Os/^{188}Os$ isochron plot shows only a very poor correlation. Moreover, T_{MA} ages give unreasonable values. Collectively, these observations point to recent Re mobility. It is noteworthy that the garnet lherzolite for which we have petrographic and chemical evidence of overprinting has the highest Re concentration and the highest Re/Os ratio. This suggests that Re addition occurred in some samples immediately before their entrainment in the host melilitite and was associated with Fe-enrichment, but not refertilization (i.e. Ca and Al are not enriched in these samples).

T_{RD} model ages range from 0.33 Ga in a garnet lherzolite to 2.80 Ga in a harzburgite, demonstrating that Archaean-aged lithosphere is preserved beneath Labait. The two cumulate xenoliths have radiogenic $^{187}Os/^{188}Os$ and give future T_{RD} ages. $^{187}Os/^{188}Os$ increases with depth (using T as a proxy for depth) and correlates well with fertility. The intercept on a CaO or Al_2O_3 *vs* $^{187}Os/^{188}Os$ plot, yields ages for the peridotites that are 2.8 and 3.4 Ga respectively. However, neither of these trends pass through the corresponding composition of the primitive upper mantle, thus these ages cannot be used as reliable indicators of lithosphere formation.

The best estimate for the age of the Tanzanian lithosphere is obtained from the $^{187}Os/^{188}Os$ of the abraded chromite separates, which range from 2.9 to 1.3 Ga. These ages should be considered minimum ages since petrographic evidence suggests overgrowths on the chromites and it cannot be certain whether all of the overgrowths were abraded away. We suggest based on a combination of the oldest chromite and whole rock T_{RD} ages that the age of formation of the Tanzanian lithosphere was between 2.9 and 2.5 Ga. The intercept of a line regressed between the garnet-free peridotites and PUM on a CaO or Al_2O_3 *vs* $^{187}Os/^{188}Os$ diagram yields a model age compatible with this age estimate. However, garnet-bearing peridotites plot well above this line and give younger T_{RD} ages. There are three possible interpretations of this: 1) a secular increase in depth of the lithosphere through time, 2) all of the peridotites were formed at approximately the same time, but the deeper garnet-bearing samples experienced Re enrichment sometime after formation, but well before their entrainment in the host basalt, and 3) the deep seated peridotites experienced recent addition of radiogenic Os. We favour the later two interpretations since a) T_{RD} ages of the garnet peridotites are scattered and are not indicative of a single younger melting event, b) Re is compatible in garnet (Righter and Hauri 1997), c) abundant sulphides in some garnet peridotites coupled with deformed textures, suggest recent metasomatic enrichment of these samples (including sulphide addition, and d) the abraded rims of chromites in peridotite that has 400 ky. (U-Pb) zircons (implying recent metasomatism are more radiogenic than the cores, suggesting the incorporation of radiogenic Os during the metasomatic event. The Re-Os results presented here demonstrate that the Archaean lithosphere exists to depth of 160 km beneath the edge of the Tanzanian craton.

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