Would the lithosphere lie about its age? In situ Re-Os reveals all!

W.L. GRIFFIN[1,2], S.Y. O'REILLY[1], N.J. PEARSON[1], S. GRAHAM[1] & K.L. WANG[1]

1. GEMOC ARC Key Centre, Dept. of Earth and Planetary Sciences, Macquarie University, NSW 2109
2. CSIRO Exploration and Mining, North Ryde, NSW 2116

Abstract: Whole-rock Re-Os analysis of mantle-derived xenoliths has provided fundamental information on the age of the subcontinental lithospheric mantle (SCLM). However, detailed studies have shown that the PGE and Re-Os systematics of such rocks are controlled by sulfide phases, and that most (all?) samples contain >1 generation of sulfides of different ages. The whole-rock model ages therefore are likely to represent mixtures, rather than the timing of specific mantle events. Fortunately, in situ analysis of Re-Os in single sulfide grains by LAM-MC-ICPMS now allows the recognition of discreet events in mantle peridotites, and a better understanding of the limitations of whole-rock analysis.

In situ analyses of sulfides in spinel peridotite xenoliths from basalts show either positive or negative slopes in Re-Os isochron plots, reflecting mixing between possible primary sulfide populations and fluids with suprachondritic $^{187}Os/^{188}Os$, probably derived from older silicates. Similar mixing lines are defined by multiple sulfide inclusions in single olivine macrocrysts from the Udachnaya kimberlite (Siberia). Whole-rock data for such samples may give model ages either >0 or <0, depending on the distribution of sulfide populations, but none of the ages are meaningful. Minimum ages for these samples are given by the TRD model ages of sulfides with the least radiogenic Os, or by the zero intercept of mixing lines with positive slopes.

Whole-rock analyses of 15 peridotite xenoliths from kimberlites in the Kaapvaal Craton, South Africa range from <0 to 2.75 Ga, with a concentration between 2.4 -2.6 Ga, as found in numerous other studies of xenoliths from this region. The oldest model ages are significantly younger than the oldest crust exposed in the Kaapvaal craton, and this "age conundrum" has led to suggestions that the SCLM was emplaced beneath the crust long after its initial formation.

Peridotites (15 from the the Western Terrane (Finsch, Kimberley, Jagersfontein), 10 from the Southeastern Terrane (N. Lesotho)) were serially sectioned to reveal sulfide phases. Each sample contains several generations of sulfides with widely varying Os contents, Re/Os and $^{187}Os/^{188}Os$. Where both whole-rock and in situ data are available, the sulfide data enclose the whole-rock data, and the TRD model age of whole-rock sample typically is younger than the maximum sulfide TRD by 0.3-1.5 Ga.

Comparison with rock compositions indicates that sulfide introduction accompanied Fe-(±Al, Ca, Cr) metasomatism by asthenosphere-derived silicate melts and fluids. Fluids with high $^{187}Os/^{188}Os$, inherited from the asthenosphere or scavenged from older silicates, have reacted with pre-existing sulfides, lowering their TRD. This process is most prominent toward the base of the lithospheric mantle, and it gradually obliterates the record of the earliest events in each rock.

The TMA ages of sulfides with $^{187}Re/^{188}Os$ <0.08, which are least likely to have been disturbed by reaction with fluids, show major peaks equivalent to the oldest crustal ages in each terrane (Western Terrane, 2.9-3.2 Ga; Southeastern Terrane, 3.0-3.6 Ga), and there thus is no "age conundrum." Other age peaks correlate with the timing of major crustal events, including the suturing of terranes (2.65 -2.75 Ga), and later rifting/collision (1.8-2.2 Ga) events. The sulfide ages push the minimum age of lithosphere stabilisation beneath the Kaapvaal craton back further than indicated by the whole-rock model ages; the bulk of the SCLM formed prior to 3 Ga, and the major Late Archean crustal magmatic events only modified the older SCLM.

The in situ analysis of sulfides in mantle peridotites opens the way to a more detailed understanding of the formation and modification of the SCLM, and the relationship of these processes to events in the crust. Whole-rock Re-Os ages on mantle peridotites should only be regarded as minimum ages, and their use in geodynamic models should be treated warily.