RE-OS ISOTOPE EVIDENCE FOR LATE ARCHAEAN STABILISATION OF A THICK LITHOSPHERIC MANTLE KEEL BENEATH THE KIRKLAND LAKE AREA, SUPERIOR PROVINCE, CANADA. FURTHER EVIDENCE FOR LONG-TERM CRUST-MANTLE COUPLING.

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The age of lithospheric mantle underlying cratons and its relationship to the overlying crust remain a major goal in the study of crust-mantle evolution. Crustal ages are widely documented in many areas, particularly in the Superior Province of the Canadian Shield but we have very little information on the nature and age of the underlying mantle. Using measurements of seismic anisotropy defined by shear-wave splitting, Silver & Chan (Silver and Chan, 1988) found seismically distinct mantle lithosphere beneath the Superior Province and the Canadian Shield in general to depths of 200 km. Furthermore, these experiments showed that the anisotropy preserved in the mantle lithosphere at depth correlated in many cases with the dominant geological fabric in the crustal rocks and implies that the fabric and thus age of the mantle lithosphere is at least that of the last major orogenic event affecting the crustal rocks, i.e., the Kenoran Orogeny, 2.73 to 2.65 Ga (Goodwin, 1991). Lack of samples from the lithospheric mantle beneath this region has hitherto prevented this model being tested.

Recently, Meyer et. al. (1994) described a suite of 10 small, <10 cm, peridotite xenoliths from a drill core through the C-14 kimberlitic tuffisitic breccia in the Kirkland Lake area, N. Ontario. The xenoliths are coarse grained (≤ 6mm) and two display porphyroclastic textures. Most xenoliths are coarse granular lherzolites ± garnet. mg numbers of olivines vary between 91 and 92 (Meyer et al., 1994), i.e., the xenoliths are depleted in basaltic elements relative to Bulk Earth. Garnets in the xenoliths are of the chrome-pyrope variety and are Ca-saturated in that they plot within the lherzolite field defined by Sobolev et al. (1973). A low proportion of concentrate garnets (<10%) fall within the sub-calcic garnet field (Meyer et al., 1994). Thermobarometrically derived equilibration conditions for the peridotites plot between the 40 to 44 mWm^{-2} reference geotherms depending on the formulation used and most of the xenoliths appear to have been derived from the diamond stability field (Meyer et al., 1994). Derivation of the xenoliths from within the diamond stability field is supported by the subeconomic occurrence of diamond the C-14 kimberlite (Meyer et al., 1994). Thus, the samples appear to be fragments of the deep lithospheric mantle "keel" identified by Silver and Chan (1988). The data appear consistent with equilibration conditions derived from other peridotite cratonic xenolith suites e.g., those from the Kaapvaal craton (Finnerty and Boyd, 1987).

The xenoliths recovered from drill core by Meyer et. al. (1994) were too small for representative bulk analyses and most were severely altered. However, recent successful applications of the Re-Os isotope system in estimating lithospheric mantle formation ages (Carlson and Irving, 1994; Pearson et al., 1994; Pearson *et al.*, in press; Pearson et al., 1995a; Reisberg et al., 1991; Walker et al., 1989) prompted us to analyse three of the most amenable samples in order to estimate their age. Normal application of the Re-Os isotope system to estimating the age of peridotite suites involves analysing 20 or so xenoliths to reveal the likely full range of ages. Obviously this study is limited in this regard because of the previously mentioned sampling problems. Three xenolith samples were sawn from the drill cores and any adhering kimberlite removed. Powders were prepared in a small alumina ball mill and were dissolved in Carius Tubes

(Shirey and Walker, 1994) to ensure spike-sample equilibration . The results are presented in Table 1.

Table 1: Os isotopic analyses of peridotite xenoliths from the Kirkland Lake area. Ages and γ_{Os} values are calculated relative to the mantle evolution curve given by Walker et al. (1994). The age estimations are minimums in that they are calculated assuming Re/Os = 0, i.e., all Re was removed during the initial melting event.

Sample	Os ppb	$^{187}Os/^{188}Os$	γ_{Os}	Minimum age, Ga
22002	2.58	0.12046 ± 40	-5.2	1.1
22003	6.00	0.11761 ± 14	-7.5	1.5
22006	2.02	0.11054 ± 14	-13:0	2.6

Unfortunately, Re concentrations have not been determined. γ_{Os} values range from -5.2 to -13.0, the later value being considerably less radiogenic than any samples of oceanic lithosphere or mantle beneath young orogenic areas thus far measured. The unradiogenic Os isotope composition of 22006 is within the range of other peridotite xenoliths erupted in the cratons (average γ_{Os} for Kaapvaal peridotites ~-10, Pearson et. al., in press). Thus, from mineral compositions, equilibration conditions and Os isotope systematics the Kirkland Lake xenoliths are similar to other mantle beneath cratons.

Estimating the likely age of the cratonic mantle beneath this part of the Superior Province region is not straightforward with just 3 samples. Two samples give *minimum* Re depletion ages of 1.1 and 1.5 Ga whereas 22006 gives a minimum age of 2.6 Ga. The small size of these xenoliths makes it highly probable that they have experienced Re addition from the host kimberlite. U/Pb analyses of perovskites from an unspecified Kirkland Lake kimberlite dyke yielded an emplacement age of 158 ± 2 Ma (Heaman, 1989). If the C-14 intrusion is of a similar age then radiogenic Os in-growth in the peridotites since kimberlite emplacement will lower the calculated ages. This means that the values given in Table 1 are probable underestimates of the "minimum" age by about 0.1 Ga if they have even average cratonic peridotite Re contents. If a Re content of 50 ppt is assumed for 22006, comparable to that expected for Kaapvaal peridotite, or massif peridotite with a similar mg number this results in a Re-Os model age of 3.2 Ga. This is a possible age for this sample and thus the lithospheric mantle in this region. Although 3.2 Ga is within the range of crustal ages reported for the Superior Province (Goodwin, 1991), it is considerably older than the age of the crust in the extensive Abitibi granitoid-greenstone belt (2.73 to 2.67 Ga, Corfu et. al., 1989) into which the Kirkland Lake kimberlites intrude. In fact the 2.6 ± 0.3 Ga (likely 2.7 Ga) minimum Re depletion age for the peridotite xenolith (22006, Table 1) overlaps this major period of crust building and greenstone belt formation in the Abitibi Belt.

Previous Re-Os isotope studies of xenolith suites from the Kaapvaal, Siberian and Wyoming cratons (Carlson et al., 1994; Pearson et al., in press; Pearson et al., 1995a; Pearson et al., 1995b; Walker et al., 1989) have concluded that formation of lithospheric mantle keels overlaps the period of major crust building. This notion is further supported by the coincidence of 2.1 Ga Re depletion ages in peridotites from Namibian kimberlites and the stabilisation of regional crust in southern Namibia at 2.1 Ga (Pearson et al., 1994). Although caution should be exercised in the interpretation of the 3 Kirkland Lake xenoliths studied here, it is possible that the lithospheric mantle keel beneath this part of the Superior Province formed contemporaneously with the Abitibi crustal units. Certainly, the finding of a peridotite xenolith of at least Late Archaean/Early Proterozoic age indicates that the crust and mantle have been coupled over Ga time scales, to depths in excess of 150 km, confirming the hypothesis of Silver and Chan (1988) based on seismic studies.

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