Dating the lithospheric mantle: in situ Re-Os technique

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The in situ Re-Os isotope analysis of mantle sulfides was recently developed, and has rapidly become the most powerful method available for dating mantle events. The method, which uses multi-collector ICPMS laser microprobe (LAM-MC-ICPMS) has a great advantage over conventional Re-Os analysis because it analyses single sulfide grains, and preserves the microstructural context necessary for interpretation of the analytical data. Another advantage is that each analysis takes a few minutes, without the need for the difficult and time-consuming separation of the sulfides and micro-chemical extraction of Os. The best precision for the in situ Os isotope technique is obtained from sulfides with > 40 ppm Os and > 100 μm in size. The work carried out so far shows that the LAM-MC-ICPMS technique can provide Os-isotope analyses of individual sulfide grains with precision and accuracy comparable to whole-rock analyses using Carius tube digestion and N-TIMS analysis, provided the grains contain > 40 ppm Os.

Using LAM-ICPMS analyses of sulfides in mantle-derived peridotites, Alard et al. (2000) showed that sulfides enclosed in primary silicate minerals typically have high Os and Ir contents (> 100,000 x PM) and low Pd/Ir ratios (Pd/Ir < 0.5), whereas interstitial sulfides have low Os and Ir contents and high Pd/Ir ratios (up to 1000). Both types of sulfide commonly occur in the same sample. The silicate-enclosed sulfides are thought to represent the residues of partial melting, and the intersitial sulfides the crystallisation products of sulfide-bearing metasomatic fluids.

Grains with lower Os contents yield data with lower precision, but the precious analyses demonstrated that these data still provide valuable information on the movement of Os within the lithosphere. It was also confirmed that sulfides enclosed in silicates preserve significantly less radiogenic Os isotopic compositions than interstitial sulfides. Whole-rock Os-isotope compositions will generally reflect the proportions of these different types of sulfides, and this casts doubt on the significance of many published "depletion ages". However, analysis of sulfides enclosed in primary silicates can produce more realistic estimates of depletion ages in the lithospheric mantle. These data will allow more detailed correlation between events in the mantle and the overlying crust, and a better understanding of Earth's dynamics.

Analysis of fragments of mantle rocks brought up by Miocene intra-plate basalts on the Penghu Islands in the Taiwan Strait has been carried out by this novel high-precision in situ techniques for the Re-Os isotopic ratios. The Os isotope compositions of sulfides in the spinel peridotites reveal the presence of Proterozoic subcontinental lithospheric mantle (SCLM) beneath the highly extended southeast margin of the South China Block (SCB).

Despite the recent Os disturbance, both T_{MA} model ages for individual sulfides and model ages estimated from the initial $^{187}Os/^{188}Os$ ratios of Re-Os mixing lines require that some volumes of the SCLM formed prior to 2.3-1.9 Ga. Eleven sulfides with low $^{187}Re/^{188}Os$ ratios (0.017~0.073), yield similar peak T_{MA} and T_{RD} age patterns. Three peak ages (1.8, 1.4 and 0.9 Ga) with the earliest phase (2.3 Ga) from the most pristine sulfides in the region define that some parts of lithospheric mantle had formed since late Paleo-Proterozoic time. These sulfide age data indicate that at least part of the SCLM beneath the thinned margin of the SCB is as old as some crust in its interior. Later major events in the SCLM may be recorded by T_{RD} model ages, which are consistent with the range of Nd and Hf model ages of overlying crust on the SCB (Chen and Jahn, 1998; Griffin et al., 2002). Notably, the 0.9 Ga event recorded by the Os model age is consistent with age of the proposed mantle plume that led to the breakup of Rodinia (Li et al., 1999) and may represent the first isotopic evidence from the lithospheric mantle for this event. Therefore, in situ sulfide Os ages may actually date metasomatic events in the SCLM, related to mantle thermal events that also affected the crust.