Metasomatic hide and seek: origins of the Roberts Victor eclogites, South Africa

Huang, J-x[1,2*], Greau, Y.[1], Griffin, W.L.[1] & O'Reilly, S.Y.[1]
[1]GEMOC, Macquarie University, Sydney, Australia
([*]jhuang@els.mq.edu.au)
[2]School of Earth Sciences and Resources, China University of Geosciences, Beijing, China

Eclogite is an important minor constituent of subcontinental lithospheric mantle (SCLM) (1-3 vol%) and a clear picture of its origin will help us to understand the origin of the ancient SCLM. Extensive studies of these rocks have generated two contradictory hypotheses about their origin; one regards the eclogites as deep-seated magmatic rocks, while the other regards them as components of subducted oceanic slabs. Xenolithic eclogites from Roberts Victor kimberlite (South Africa) have been studied to constrain their origin.

The Roberts Victor eclogites can be divided into two types based on differences in microstructure and mineral composition. Type II eclogites have low Na in gnt and low K in cpx, while Type I has high values. Type II eclogites are generally fresh and show equilibrated microstructures. Rutile exsolution in gnt and cpx, and gnt exsolution in cpx, are only found in Type II. Type I eclogites, in contrast, are texturally not in equilibrium, and have many fluid inclusions. Only Type I eclogites contain diamond, graphite, sulfides and apparently-primary phlogopite.

All the minerals are homogeneous within each sample. Reconstructed whole-rock compositions show that Type I eclogites are richer in Mg, K, Rb, Sr, LREE and LILE than Type II. P-T estimates indicate Type II eclogites are distributed from 170-200 km depth, but Type I are strongly concentrated in a layer at 180-190 km depth, just beneath lithosphere-asthenosphere boundary. However the abundance of Type II is low, about 6-8% of Type I.

Sr, Nd and Hf isotopes of gnt and cpx were analyzed in clean small grains after acid-leaching. The Nd-Hf data for Type I eclogites define two-point isochron ages (Sm-Nd 100±21 Ma; Lu-Hf 133±17 Ma) that are identical to the kimberlite eruption age (128 Ma). Lu-Hf isochron ages for Type II eclogites (1354±9 Ma) may suggest a connection to the Namaqua-Natal Orogenic Belt to the south of Kaapvaal Craton. These differences suggest that Type II eclogites have retained their initial isotopic compositions whereas the isotopic systems of Type I eclogites were actively re-equilibrating at the time of kimberlite eruption. This is also consistent with the petrographic and mineralogical evidence of fluid metasomatism in Type I eclogites. Sr, Nd and Hf isotopic ratios at the time of kimberlite eruption also show marked differences between Type II and Type I; $^{87}Sr/^{86}Sr$ is 0.7060-0.7064 in Type I and 0.7013-0.7030 in Type II. O- isotope ratios are also different. Type II eclogites have $\delta^{18}O < 4.3‰$ and those of Type I have mantle values (ca 5.4) or higher.

These data and observations suggest that Type I eclogites were being actively metasomatized slightly prior the kimberlite eruption. Inter-element correlations suggest that the metasomatism was adding Mg, K, S, Rb, Sr, C (diamonds), LREE and LILE. Some samples (the present Type II eclogites) from the same depth range appear to have escaped this process and preserved their original characteristics.

The calculated fluid in equilibrium with Type I eclogitic gnt and cpx is LREE-enriched and shows trace-element patterns similar to those of fibrous diamonds and carbonatitic/kimberlitic melts. The Sr- and Nd-isotope values are also consistent with reaction between Type II eclogites and diamond forming fluid to form Type I eclogites. Type II eclogites therefore are the key samples for studying the origin of this eclogite suite, since they may represent the protoliths. Type I, in contrast, are heavily metasomatised rocks, and retain little evidence of their primary origin.