

Kimberlite and the chemical state of the Earth's deep interior

Ichiro Kaneoka[1]

[1] ERI, Univ. Tokyo

<http://www.eri.u-tokyo.ac.jp/>

Kimberlite contains abundant mantle xenoliths including diamonds, suggesting it to be derived from the depth of more than 150km. It is characterized to contain relatively abundant volatile elements such as H₂O and CO₂, resulting in forming phlogopites though it is classified as an ultrabasic rock. It has been found only in the continental area so far and most of them have extruded through cratons. Since their extruded areas are so limited, they have often been treated as anomalous occurrences and not always regarded as a significant indicator to show the signature of the Earth's deep interior. However, judging from their isotope ratios, chemical compositions and their special occurrences in total, it seems to keep significant information on the chemical state of the Earth's deep interior and we should keep more attention to kimberlite.

In the Nd-Sr isotope diagram, kimberlites are classified in two groups based on their initial isotopic ratios when they erupted. Group I kimberlites have values close to the Bulk Earth, which is assumed to correspond to values of undifferentiated materials estimated from Nd isotopes of meteorites. On the other hand, Group II kimberlites have values which might have been affected from the enriched components such as continental materials (Smith, 1983). These groups are also identified in the Pb isotope diagram and Group I kimberlites have closer values to that of the undifferentiated material. In the REE pattern normalized to the meteorite values, however, kimberlites show patterns of sharp enrichment in light REE probably occurred during the formation of kimberlite magmas. Although volatile elements such as H₂O, CO₂ and halogens might be also enriched during this process, the estimated original contents of such volatile elements are more abundant compared to those of the upper mantle materials and the source materials of kimberlites are considered to be enriched in volatile elements.

On the other hand, platinum group elements (PGEs) are also relatively enriched in kimberlites. Especially Os and Ir are more enriched in kimberlites with more than one order of the magnitude compared to MORBs and OIBs (e.g., Evans and Chai, 1997). Furthermore, chondrite normalized PGE patterns show more flat trend compared to those of MORB and OIB, suggesting a possibility that PGEs in kimberlites have been transported to the surface without large fractionation (e.g., Ballhaus, 1995). PGEs are siderophile elements. Hence when magmas are formed due to the partial melting of mantle materials, it is expected that such PGEs are generally left in the residue. On the other hand, REEs and volatile elements are incompatible elements and enriched in the melt phase. Kimberlites include both PGEs and incompatible elements abundantly, which are generally enriched in opposite phases during magma formation. Hence, the chemical environments of kimberlites are considered to be quite different from those of MORB and OIB during magma formation, which has not yet been clarified so far.

As a possibility to produce the observed trend for kimberlite magma, it is expected that the occurrence of S might play an important role, since the chemical compositions of kimberlite magma suggest less oxidized environment of magma formation compared to those for normal igneous rocks. Hence it is significant to clarify the origin of S observed in kimberlites. In addition, it has been reported that some inclusions in diamonds might be derived from the lower mantle (e.g., Harte and Harris, 1994). Furthermore, it has been argued that sites of kimberlite extrusion might have been related to hot spots. These observations suggest a possibility that signatures observed in kimberlites might reflect the chemical state of the lower mantle to some extent, which shall be also reflected in noble gas isotopic ratios.