The relationship between metasomatism and oxidation state in the lithospheric mantle: an example from the Massif Central, France

Mantle peridotites brought to the surface by Tertiary and Quaternary volcanism in the French Massif Central provide an unique view into the underlying subcontinental lithospheric mantle (SCLM), including its oxidation state. In addition to the modal addition of amphibole or clinopyroxene in some xenoliths, most samples have undergone a cryptic metasomatism as revealed by major and trace element compositions of clinopyroxene. These data are combined with calculations of the oxidation state, as expressed as oxygen fugacity (fO_2), based upon the equilibrium between spinel, olivine and orthopyroxene in order to understand more about the metasomatic processes that occurred in the SCLM.

Four major groups have been identified from their REE signatures (groups A, B, C and D). Groups A and B are less affected by metasomatism whilst groups C and D experienced stronger metasomatic overprints, as recorded by enrichments in LREE, MREE and other elements like Sr, Zr or Hf. These signatures occur regionally as well as locally. In some cases, the signatures reflect different positions from the source within a reactive flow regime. Two mantle domains have been identified based upon differences in geochemistry, texture and oxidation state, which can be related to different histories involving partial melt extraction and metasomatic interactions. Northern domain clinopyroxenes stand out by their “tick-shaped” REE patterns, which suggest metasomatism by subduction-related fluids. These fluids were also oxidizing.

A few samples from both northern and southern domains are equally strongly oxidized, but have other characteristics like very low Ti/Eu and superchondritic Zr/Hf ratios, reflecting localized carbonatite metasomatism. Other samples with higher Ti/Eu and ~chondritic Zr/Hf ratios are consistent with silicate melt metasomatism and record more modest oxidation states. Amphibole occurs only in traces in a few samples and the lack of any notable trace element or redox signature related to its occurrence suggests that this phase formed from small amounts of dilute H_2O-rich fluids that led to only minor hydration of the mantle assemblage. The signatures of some samples reveal overprinting by more than one type of metasomatic agent.