Evolution of the lithospheric mantle beneath the Kerguelen Archipelago: formation of heterogeneities in a plume environment

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The Earth's mantle behaves as a viscous fluid over geologic timescales. The variation and amplitude of mantle geochemical heterogeneities reflect the efficiency of heat and mass transfer processes as well as the composition of entrained components. Mantle plumes, such as the Kerguelen plume in the Southern Indian Ocean, represent the main mechanism for entrainment in the mantle. The study of mantle xenoliths associated with Kerguelen hotspot volcanism can provide important constraints on melt extraction and migration processes, and sources of mantle heterogeneities. The Kerguelen plume is remarkable among mantle plumes because its voluminous volcanic activity is long lived (at least 115 myr) and occurred in diverse geotectonic environments related to the spreading of the Indian Ocean. Xenoliths outcrop exclusively in the youngest and most alkaline lavas of the Kerguelen Archipelago, which lies on the northern part of the oceanic Kerguelen Plateau and represents the last 38 myr of the plume's volcanic activity.

Variable trace element abundances in Kerguelen xenoliths (Southeast Province): investigation of the scale and degree of mantle geochemical heterogeneity

Trace element abundances in Kerguelen peridotite xenoliths (dunite, protogranular harzburgite, poikilitic harzburgite and lherzolite) show large variability within single samples, within sample localities and throughout the archipelago (e.g. data for the Southeast Province (Mattielli *et al.*, 1996) compared with those for the Courbet Peninsula (Hassler and Shimizu, 1998)), reflecting the extension and the diversity of metasomatic processes in the upper mantle. The residual mantle peridotites have interacted with at least two types of metasomatic melts: (1) an alkaline basaltic melt evidenced in a lherzolite xenolith; (2) a carbonatitic melt that produced new clinopyroxene grains and secondary wehrlitic assemblages in dunite and harzburgites. Extremely variable and high incompatible element contents in clinopyroxenes (Mattielli *et al.*, 1996) result from porous flow percolation associated with chromatographic fractionation of this carbonatitic melt through peridotite mantle matrix. Trace element heterogeneities observed on cm-scales in harzburgites could not have survived for a long period of time at mantle temperatures, suggesting that carbonatitic melt invasion occurred relatively shortly before the eruption of the host lava with their xenoliths. The last event to affect the metasomatized xenoliths was the entrapment of cogenetic silicate and carbonate melt-fluid inclusions. Schiano *et al.* (1994) showed that this last injection occurred in the upper mantle (minimum trapping pressure for all types of inclusions is 12.5 kbars at 1250°C), prior to or synchronous with peridotite deformation, probably related to upwelling of Kerguelen plume materials. The similar trace element patterns of melt inclusions and clinopyroxenes in harzburgites suggest that inclusions and clinopyroxenes may be produced from the same metasomatic melts which have interacted with the Kerguelen xenoliths at different stages of their evolution.

Os, Sr, Nd and Pb isotope systematics: investigation of the origin of geochemical heterogeneity related to the Kerguelen plume.

Isotopic data of the Kerguelen peridotite xenoliths (from the Southeast Province) place constraints on sources of lithospheric peridotite matrix and metasomatic melts migrating through the mantle. This approach also provides some insights into the effects of melt extraction and metasomatism on Re and Os in peridotites. During interaction with the metasomatic melts, the initial Sr, Nd and Pb isotopic compositions of the peridotite xenoliths were modified; the current isotopic characteristics of the xenoliths reflect the isotopic signature of the source of metasomatic melts. Metasomatized lherzolite and harzburgite have Sr, Nd and Pb isotopic compositions (Mattielli *et al.*, 1996) as enriched as those of the recent alkaline lavas from the Kerguelen Archipelago. Given those recent lavas have isotopic characteristics of the Kerguelen plume (Weis *et al.*, 1993), we infer that the alkaline basaltic and carbonatitic metasomatic melts are both related to the alkaline magmatism produced by the Kerguelen plume. The Os analyses were performed on two Kerguelen harzburgites which recorded extensive and variable degrees of interaction with the carbonatitic melt. Predicted high Re/Os and high Re abundances in carbonatitic melts (e.g. Re/Os = 6130 and Re = 0.4 ppb), combined with extremely low Re concentrations in residual peridotites suggest that Os isotopic signature of residual peridotites is susceptible to contamination by carbonatitic metasomatism within the mantle. However, there is no evidence for Os isotopic compositions disturbed by such metasomatism in Kerguelen mantle xenoliths (Hassler and Shimizu, 1998). In addition, ^{187}Os is inferred to be relatively insensitive to mantle metasomatic processes because Os is a compatible element during partial melting of peridotite. Our results show relatively unradiogenic Os isotopic compositions for the protogranular harzburgite ($^{187}Os/^{188}Os$ = 0.1193 $\pm$ 2) and the poikilitic harzburgite ($^{187}Os/^{188}Os$ = 0.1203 $\pm$ 1), consistent with the results of Hassler and Shimizu (1998) on xenoliths from the Courbet Peninsula. Following the model of Walker *et al.* (1989), the Re-depletion model ages for those harzburgites are respectively 1.30 Ga and 1.15 Ga. Despite the paucity of Os isotopic data for oceanic mantle xenoliths, the Kerguelen oceanic environment is the only one which presents mantle xenoliths with such unradiogenic Os isotopic compositions (Hassler and Shimizu, 1998).

A single dunite xenolith (carefully acid-leached), out of 30 analysed samples, has the most enriched Sr, Nd and Pb isotopic composition yet measured for any lava, pluton or anhydrous xenolith from the Kerguelen Archipelago (Mattielli *et al.*, 1996). The most plausible interpretation is that those isotopic characteristics, supported by high values in $(La/Ta)_p$ and $^{207}Pb/^{204}Pb$, reflect the influence of a component derived from continental crust. However, leached clinopyroxene separates of this dunite show lower $^{87}Sr/^{86}Sr$ and higher $^{143}Nd/^{144}Nd$ values, typical of the Kerguelen plume isotopic signature. This sample displays a relatively radiogenic Os isotopic composition ($^{187}Os/^{188}Os$ = 0.1288 $\pm$ 2), included within the range of Os compositions measured for the Ocean Island basalts. We propose therefore that some Gondwanan lithosphere material was incorporated into the mantle beneath Kerguelen probably during the breakup of Gondwanaland, and mixed with plume-derived material. Consistent with the previous studies on plutonic and volcanic rocks from the Kerguelen Archipelago (Weis *et al.*, 1993; Yang *et al.*, 1998), our results show this continental component is minor in volume and sporadic in location.

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