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Hf-Zr anomalies in clinopyroxene from spinel peridotite mantle xenoliths from Europe

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Extreme depletion in Hf and Zr in clinopyroxenes from the northern part of the French Massif Central was first reported by Downes et al (2003). New LA-ICPMS analyses of clinopyroxenes from a variety of spinel peridotite mantle xenoliths from localities throughout Europe have revealed unusual and conspicuously strong negative anomalies in Zr and Hf relative to the adjacent REE Sm and Nd in mantle-normalised trace element diagrams. Most of the samples showing this anomaly are from Neogene alkaline basalts in the Massif Central and the Polish Sudetes (Figs. 1 and 2).

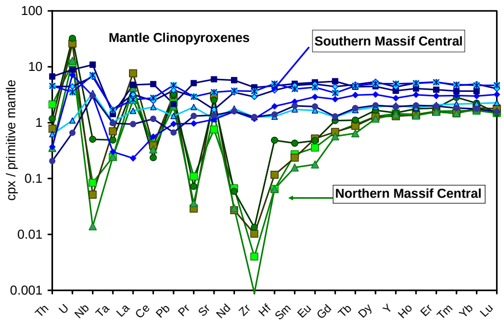

Figure 1 LA-ICPMS data for clinopyroxene in mantle xenoliths from the Northern Massif Central show extreme Zr-Hf-depletion compared with those of the Southern Massif Central(de Vries, unpub data)

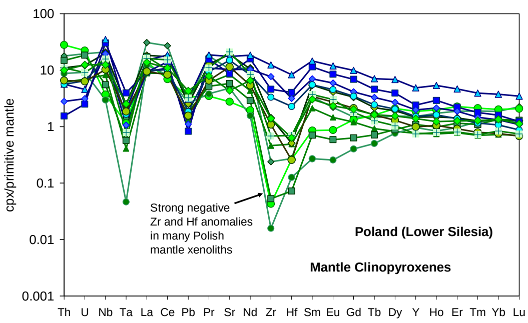

Figure 2. Data for clinopyroxenes from some mantle xenoliths from Neogene volcanics, Polish Sudete show similar Zr-Hd depletions, but not as strong as in the Massif Central (de Vries, unpub data).

Figure 3 shows further examples of similar Zr-Hf-depleted clinopyroxenes in have been found in mantle spinel peridotite xenoliths from Mte Vulture and Sicily in southern Italy. A search of the literature has revealed that such strong Zr-Hf anomalies (and high Lu/Hf ratios) are uncommon worldwide, although other examples are found in xenoliths from the Bearpaw Mts of Montana and Tok in Siberia (Fig. 3).

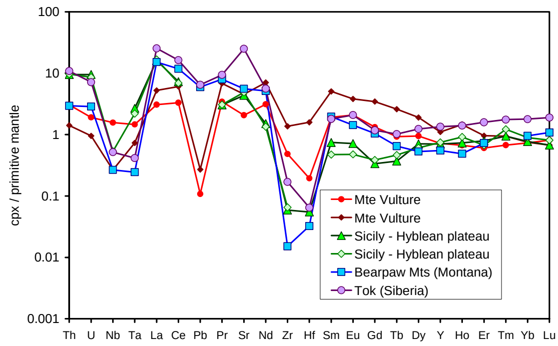

Figure 3. Examples of Zr-Hf-depleted clinopyroxenes from mantle xenoliths from Mte Vulture Italy - Downes et al., 2002; Sicily - Perinelli et al., 200; the Bearpaw Mts (Wyoming craton - Downes et al., 2004) and Tok (Siberia - Ionov et al 2006). Again, none of these examples are as strongly depleted as the Massif Central samples.

The effect of the low Hf contents (typically <0.1 ppm Hf) is to produce extremely high Lu/Hf ratios (typically Lu/Hf > 1) as shown in Fig. 4.

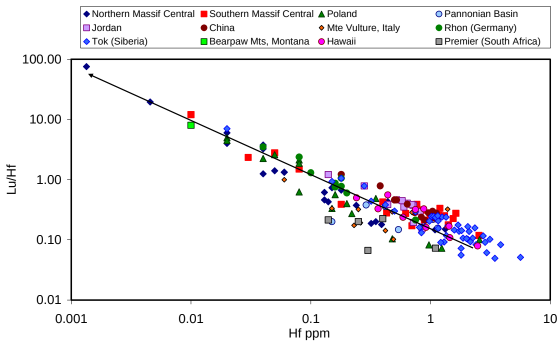

Figure 4 Mantle xenoliths from a few localities worldwide show extreme Hf-depletion and consequent high Lu/Hf ratios similar to those of the Southern Massif Central. Note logarithmic scales on both axes. Arrow indicates increasing extent of partial melting.

The cause of the depletion in Zr and Hf is unclear, although the Massif Central peridotites which show such depletions have generally experienced extensive partial melting (e.g. up to 30%) in the spinel peridotite stability field.

Over geological time these high Lu/Hf ratios will lead to extremely radiogenic ε_{Hf} values. In the example of the northern French Massif Central (Fig. 5), such xenoliths show ultra-radiogenic Hf isotope ratios (ε_{Hf} values range from +40 to +2600).

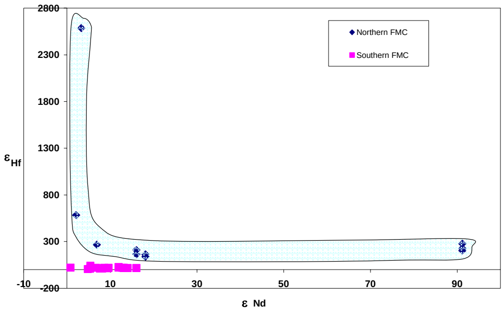

Figure 5. Hf-Nd isotope data for clinopyroxenes from mantle peridotite xenoliths from French Massif Central show differences between northern and southern regions (Wittig et al., 2007).

Thus, as shown in Fig. 6, in the northern Massif Central ε_{Hf} values in clinopyroxenes from mantle peridotite xenoliths are much more strongly decoupled from ε_{Nd} values compared with, for example, xenoliths from the oceanic lithosphere (e.g., Hawaii) or cratonic mantle. They appear to be extreme examples of mantle that is strongly radiogenic in Hf isotopes. Only rare xenoliths from Jordan and one from Hawaii show ε_{Hf} values of >100, although unpublished data for peridotites from Beni Bousera and Kaapvaal may have similarly extreme values (Pearson et al., 2003).

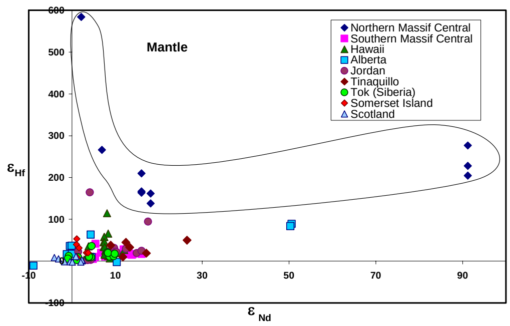

Figure 6. Hf-Nd isotope data for clinopyroxenes from mantle xenoliths from other regions worldwide (Jordan – Shaw et al., 2007; Alberta – Aulbach et al., 2004; Hawaii – Bizmis et al., 2007; Tinaquillo (whole rock) – Choi et al., 2007; Tok – Ionov et al., 2006b; Somerset Island (Canada) – Schmidberger et al., 2001, 2002; Scotland – Bonadiman et al., 2008), compared with data from Massif Central peridotite xenoliths (Wittig et al., 2007).

Clinopyroxenes with high Lu/Hf ratios are amenable to Lu-Hf isotopic age dating (Wittig et al., 2006). Hf model ages and $^{176}Hf/^{177}Hf$-$^{176}Lu/^{177}Hf$ systematics of xenoliths from the northern French Massif Central (Fig. 7) indicate that depletion occurred in the mantle beneath this region in Variscan times (360Ma). This depletion may have been caused by extensive melting in a subduction-related environment (mantle wedge).

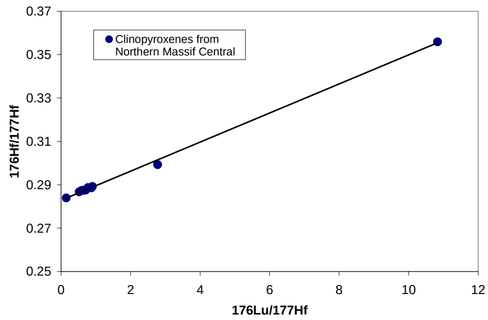

Figure 7. Lu-Hf data for clinopyroxenes from the Northern Massif Central, showing a reference isochron of 360 Ma, interpreted as age of mantle depletion (data from Wittig et al., 2006).

Since the volcanic fields of the Massif Central, Polish Sudetes and Rhon are all situated on the northern margin of the Variscan orogen, it is possible that the mantle beneath these regions experienced a similar extreme depletion event, perhaps related to supra-subduction zone processes. Tok (SE Siberia) and the Bearpaw Mts (W USA) are both in cratonic settings but are situated above regions of recent deep subduction, which may have been the cause of extreme depletion due to partial melting.

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