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URANIUM ENRICHMENT IN THE LITHOSPHERIC MANTLE: EVIDENCE FROM FRENCH MASSIF CENTRAL

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ABSTRACT

Several studies have reported trace-element data showing that mantle xenoliths from world-wide localities are selectively enriched in uranium (±lead, ±strontium) relative to other incompatible trace elements; these samples show prominent U spikes on primitive mantle-normalized diagrams (e.g., Jochum et al., 1989; Ionov et al., 1995). Most often, the authors have considered these enrichments as "secondary" features related to post-eruption contamination, or weathering. At first sight, this hypothesis is supported by the existence of U spikes in xenoliths that are otherwise devoid of any trace of modal or cryptic mantle metasomatism. Except for the U positive anomaly (±Pb, ±Sr), these samples have a trace-element signature typical of depleted MORB mantle (DMM).

Our ICP-MS study of 31 peridotites representative of mantle xenoliths from Massif Central (France) confirms the widespread character of U enrichment in these rocks. 25 xenoliths have $(U/Th)_N$ (= primitive mantle-normalized ratio) and $(U/La)_N > 1$, among which 7 have $(U/Th)_N$ in the range 10 - 100 and $(U/La)_N$ in the range 5 - 20. However, our results are at variance with previous works in suggesting a "primary" (mantle) origin for the U spike. Evidence is twofold: (1) trace-element variations in whole rocks indicate that the U spike is overprinted by cryptic mantle metasomatism - i.e., overall enrichment of large ion lithophile elements (LILEs) - and (2) acid-leached minerals are enriched in U and account for whole-rock budget. Olivine analyses indicate that fluid-derived inclusions trapped in minerals are a significant host for U. Together with experimental data, this suggests that U enrichment is related to the migration of volatile-rich fluids/melts through the upper mantle. Positive correlations between U/Th, Pb/Ce and Sr/Ce indicate that this process was also responsible for Pb and Sr enrichments.

Two hypothesis may be envisaged for the origin of U-, Pb- and Sr-enriched fluids/melts. They could either be derived from subducted oceanic lithosphere (e.g., during the Variscan orogeny), or they may represent volatile-rich small melt fractions, residual after incomplete solidification of asthenospheric melts at the base of the lithosphere (in the Tertiary). The latter alternative is strongly supported by the existence of negative U anomalies in high-temperature (≥ 1200°C) xenoliths considered to represent the base of the lithospheric mantle eroded by uprising asthenosphere (Xu et al., 1998). In this scheme, the development of the U spike in lithospheric peridotites does not require an U-enriched source. As shown with a numerical simulation, it would simply result from selective transport of U (±Pb, ±Sr) by volatile-rich, uprising melts.

A significant implication of this study is that the lithospheric mantle beneath Massif Central is characterized, on overall, by much higher U/Th ratios than both primitive Earth's mantle and present-day convective mantle. Judging from the number of published data reporting U spikes in mantle xenoliths from various localities, this may also be true for large volumes of subcontinental lithosphere. If time-integrated, the trace-element signature of lithospheric peridotites may significantly contribute to the isotopic heterogeneity of the mantle.

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