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Systematic distribution of incompatible elements in mantle peridotite

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マントルペリドタイト中の不適合元素分布システムティックス

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We examine the distribution of incompatible elements in Earth’s mantle based on data reported for 20 mantle xenoliths collected from 5 localities worldwide. A structural model combined with an element partitioning model forms the basis for our analyses. The former separates a bulk peridotite into mineral crystal lattices, interfaces (grain and interphase boundaries), and intra- and inter-granular inclusions as sites for incompatible elements. The latter relates the distribution of elements among these sites based on lattice strain theory. By treating both intra- and inter-granular inclusions as a melt-like phase, the combined models successfully reproduce the relative concentrations of incompatible elements among minerals, clean-rock (reconstituted from mineral compositions and mineral mode), and whole-rock. The analyses reveal common signatures in the rocks: (i) Incompatible elements in the crystal lattices of olivine, orthopyroxene (opx) and clinopyroxene (cpx) achieved chemical equilibrium. (ii) Olivine, opx and cpx grains contain similar amounts of an intra-granular, melt-like component possibly in the form of sub-micron inclusions with weight (≈ volume) fractions between $5 \times 10^{-5}$ and $1 \times 10^{-2}$. (iii) All rocks contain an inter-granular melt-like component with a fraction between $10^{-4}$ and $10^{-2}$, well above the amount expected to be stored along interfaces. (iv) Fractions of the inter- and intra-granular components are positively correlated, indicating that they originated from the same process. (v) The inter- and intra-granular melt-like phases are chemically equilibrated with other structural components.

Based on plausible upwelling rates for mantle xenoliths, it is unlikely that the melt-like component formed during ascent. Instead, its ubiquitous appearance, its invisibility to optical microscopy, and its absorption of the incompatible elements in a manner similar to a melt phase even at subsolidus condition, all might be explained by the presence of amorphous silica precipitates such as those observed previously in naturally occurring and experimentally annealed mantle composites.

From the mineral mode, grain size, and mineral plus whole-rock concentrations of incompatible elements, we can ascribe the chemical signatures of xenoliths to achievement of chemical equilibrium at mantle conditions rather than to a consequence of some disequilibrium (metasomatic) effect as has been done previously. Thus, our model makes it possible to determine whether or not a rock is chemically equilibrated in terms of the distribution of incompatible elements or if a metasomatic (disequilibrium) event is required.

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