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Deformation history of mantle peridotites decoded from chemical and textural patterns in pyroxenes

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Al and Ca contents in pyroxenes have been used as useful geothermobarometers for peridotites because of their different dependences on P and T, particularly in the garnet and plagioclase stability fields. The geothermobarometry is often problematic because of complicated kinetic processes in adjustment of the mineral composition in response to P-T changes and deformation (P-T-d history). However, the disturbance caused by kinetic processes provides rich information on the P-T-d history of mantle rocks. The modification of Al and Ca contents in pyroxenes during P-T changes occurs by two main mechanisms: (i) diffusive exchange of their components with or net mass transfer to/from the surrounding minerals and (ii) exsolution of other phases, such as pyroxenes and garnet, within crystals. Both mechanisms usually result in primarily concentric Al and Ca distribution patterns in crystal grains with some effects of crystallographic anisotropy. Deformation affects kinetic processes through the creation of fast diffusion paths inside the crystal such as localized high concentration of dislocations and tilt/twisted boundaries and even formation of new grain boundaries by recrystallization. It could result in non-concentric or striped Al and Ca distribution patterns, which potentially record coupling/decoupling of deformation with P-T changes. On these bases, the combined examination of the crystallographic orientation and the distributions of Al and Ca content in pyroxene crystals provides a powerful tool to unravel the P-T-d history of mantle rocks.

On the basis of this concept, orthopyroxene megacrysts as large as one to a few cm from Pyrenean peridotite massifs (Fabries et al., 1991) were examined with EPMA and FE-SEM attached with EBSD system to estimate their P-T-d history. The megacrysts are in a garnet websterite near the host peridotite from Bestiac, a thin websterite in spinel peridotite from Sem, and a spinel websterite in contact with spinel peridotite from Lherz massifs. Megacrysts were examined because they record the prolonged P-T-d history up to the higher temperature approaching the solidus and/or the higher pressure and temperature approaching the depth of derivation in the mantle.

The orthopyroxene megacrysts from the Pyrenean peridotites and pyroxenites have wide core region rich in exsolution lamellae of clinopyroxene, garnet, or spinel, which are absent in the marginal zone. The cores have high averaged Al and Ca content including lamellae than the outermost rim with or without a marginal high. These concentric features suggest overall cooling at various pressures depending on the mineral assemblage. Overlapping with such concentric variation, striped disturbances accompanied with distortion of lamellae and tilt boundaries are noticed particularly in the marginal zone of the megacrysts. Such stripes are nearly parallel to (001) and rich in Al with or without Ca enrichment as high concentration of clinopyroxene lamellae. In detail, the most of lamellae are asymmetric featuring gradual increase in Al from one side towards the high followed by rapid decrease on the other side. When the Ca enrichment overlaps with the Al high, clinopyroxene lamellae are mostly restricted on the Al-rich side. The location of tilt boundary almost coincides with the Al high, but is often shifted to the Al-poor side by a few to 10 microns. These features of striped zoning in the marginal zone indicate that the tilt boundaries were in motion during Al (and Ca) enrichment in orthopyroxene, probably corresponding to a short heating. Combined this with the overall Al and Ca zoning, it is inferred that deformation and P-T change were coupled in the latest stage of cooling of Pyrenean peridotite massifs.

Keywords: deformation history, mantle, pyroxene, chemical heterogeneity, subgrain/suboundary