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The interaction between deformation and hydration: Physico-chemical alteration and replacement of naturally deformed olivine

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Deformation and fluid-mediated reactions are essentially interrelated and thus it is crucial to understand the mechanisms that govern the interaction between them. Natural olivine grains frequently display microstructural evidence of plastic deformation, such as the alignment of planar arrays of dislocations forming subgrain boundaries. We have examined deformed olivine from ophiolitic metaperidotites in Norway to investigate the influence of intragranular microtextures created by deformation on fluid-mediated replacement reactions. Optical and scanning electron microscopy show a striped chemical zoning parallel to the typical olivine kink banding and the optical undulose extinction. Fe-enriched and Fe-depleted zoning are found that have distinct, parallel spacing across the olivine grains. The most pronounced striped zoning is found to spread out from serpentine needles that cut into the olivine. Focused ion beam sample preparation technique and transmission electron microscopy reveal that the striped chemical zoning is associated with (100)ol subgrain boundaries composed of edge dislocations that are formed during plastic deformation. Nanometer-sized serpentine clusters are found at subgrain boundaries associated with the Fe-depleted zoning. The replacement of olivine by serpentine originating at these subgrain boundaries indicates that they can act as pathways for fluid infiltration. However, subgrain boundaries associated with Fe-enriched zoning show no evidence for olivine replacement by serpentine. From the striped zoning and serpentine replacement we infer that (100)ol subgrain boundaries, the locus of edge dislocation piling, potentially channels fluid entry, as has also been recently suggested by Boudier et al. (in press). In conjunction with the zoning, the investigated olivine grains have a tendency to develop preferentially orientated parting, mimicking a well developed cleavage. Electron backscatter diffraction (EBSD) reveals a complex orientation relationship between the parting formation and the replacement process. Olivine grains have the textural appearance of a single grain but are divided into highly misorientated domains. However, the parting propagates throughout the seemingly single olivine grain despite the large misorientation of the domains. Grains showing parting are surrounded by olivine that is replaced by serpentine with the typical mesh texture. Backscattered electron imaging from scanning electron microscopy showed that the formation of the preferred orientated parting is closely related to the replacement of olivine by elongated diopside grains orientated parallel to the parting. Our observations indicate that the plastic deformation of olivine has the potential to channel the entry of fluids. This would have an important influence on the homogeneity of fluid infiltration and hence the hydration of olivine to form serpentine. Therefore, fluid infiltration and the resulting mineral replacement reactions are strongly dependent on the plastic deformation of olivine prior to replacement.

References:

Boudier et al. (in press), J. Petrol.