American Mineralogist, Volume 103, pages 735–741, 2018

Anisotropic growth of olivine during crystallization in basalts from Hawaii: Implications for olivine fabric development

Da-Peng Wen[1], Yong-Feng Wang[1,2,*], Jun-Feng Zhang[1,2], and Zhen-Min Jin[1]

[1]State Key Laboratory of Geological Processes and Mineral Resources, School of Earth Sciences, China University of Geosciences, Wuhan 430074, China

[2]Global Tectonic Center, School of Earth Sciences, China University of Geosciences, Wuhan 430074, China

Abstract

Olivine fabrics are crucial for deciphering anisotropy of many physical properties in the upper mantle, such as seismic velocity and thermal diffusivity. Under circumstances where crystallized mantle rocks do not suffer strong modification from later deformation, olivine fabrics can reflect the results of anisotropic crystal growth and viscous magmatic flow. Currently little is known about the crystallization habits of olivine in nature. Here we report crystallization habits of olivine phenocrysts in two Hawaiian tholeiitic basalts. The low Mg numbers (=$Mg/[Mg+Fe_{total}] \times 100$ atomic ratios; <88.1) of olivine grains suggest that they are crystallized products from the host magma rather than captured ones from peridotite xenoliths. Many olivine grains have non-equidimensional euhedral crystal shapes due to anisotropic crystal growth rates. Electron backscatter diffraction (EBSD) analyses show that of the 115 analyzed olivine grains, 84 grains are oriented with their long axes parallel to the [001] axis, while 24 and 7 grains have their long axes parallel to the [100] axis and the [010] axis, respectively. This growth habit is different from that reported for olivine grown at subsolidus conditions without fluid/melt. Our results imply that olivine will most likely form the AG-type fabric (i.e., a point maximum of the [010] axis normal to the foliation plane, and a girdle distribution of the [100] and the [001] axis in the foliation plane) during crystallization from magma chambers undergoing compaction, and the B-type fabric (i.e., a point maximum of the [010] and the [001] axis normal to the foliation plane and parallel to the lineation, respectively) during pure or simple shear mode magmatic flow, provided that no or weak later plastic deformation is superimposed upon these magmatic fabrics. The AG-type and the B-type olivine fabrics in natural cumulates can be interpreted as results of anisotropic growth of olivine and viscous magmatic flow. Anisotropic olivine growth is expected to strongly affect the fabric development in the upper mantle portion where there is extensive partial melting (e.g., the mantle wedge above subduction zones or the upper mantle beneath the middle ocean ridges) or reactive melt percolation leading to crystallization of olivine at the consumption of pyroxene.

Keywords: Olivine fabric, crystallographic preferred orientation, anisotropic growth, cumulate