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Olivine zoning in high-Mg basalts of the Shiveluch volcano (Kamchatka)

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Shiveluch volcano located in northern Kamchatka erupted mainly high-Mg andesites during Holocene times. However, tephrochronologists found two Holocene tephra layers that are unusual for this volcano: a high-Mg middle-K basalts with an age of 7600 yr BP and high-Mg high-K basalt with an age of 3600 yr BP [Volynets et al, 1997]. The proximal outcrops for these two tephra deposits were discovered just recently [Churikova et al., 2010; Gorbach & Portnyagin, 2011]. Our study of olivines from the high-Mg basalts documents unusual Mg-Fe zonation [Gordeychik et al., 2016]: Inner cores of olivines from both eruptions show Fo87-92, falling to the rim to Fo75-85. In the outer cores of both basalt tephra, forsterite decreases linearly abruptly changing to a steeper gradient towards the rim. Electron microprobe element maps reveal the complex and highly unusual zoning features of these olivines.

The inner cores of the olivines of 7600 yr BP tephra have bell-shaped distributions for forsterite and nickel. The maximum forsterite in their core can be up to Fo92, decreasing outward to the outer core to Fo86. At the same time, the trace elements in the inner core remain constant. Such element distribution is consistent with diffusion of Fe, Mg, and Ni in the initially uniform high Mg cores after the phenocrysts were changed to non-equilibrium in a less mafic melt. The shape of the inner cores suggests partial dissolution after magma mixing. The interfaces between the inner and outer cores are marked by abundant melt/fluid inclusions. The inner cores were overgrown by olivine with Fo90 when the crystals moved to the high-Mg melt. As result some olivine grains have the maximum forsterite values in the outer core. The specific feature of the olivine outer cores from basalt of the 7600 yr BP tephra eruption are concentric zones with higher values of Ca, Cr, Al, P. One of the crystals has five distinct growth zones with high Cr concentrations. The width of these zones can be only a few microns and thus such zones are often missed in typical quantitative point measurements in microprobe profiles.

Inner cores of olivines from the 3600 yr BP tephra are uniform in forsterite and nickel. However, Al and Ca element distribution maps show in inner cores higher concentrations with rather smooth contours. This suggests that initially the olivines were formed from high-Al and high-Ca melt, then were dissolved and the overgrowth zonation has been smoothed out due to faster Mg-Fe diffusion. Only Ca and Al with low diffusivity were conserved. The concentric zones with higher element concentrations are not so well expressed in olivines from the 3600 yr BP tephra, but some distinct growth zones are also shown in Ca, Cr, and P.

Information extraction and decoding of the elemental maps allow seeing highly complex growth-dissolution-diffusion history of magma mixing processes prior to eruption. This research was supported by RFBR-DFG grant # 16-55-12040.