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Olivine from aillikites in the Tarim large igneous province as a window into mantle metasomatism and multi-stage magma evolution

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Abstract

Aillikites are carbonate-rich ultramafic lamprophyres, and although they are volumetrically minor components of large igneous province (LIP), these rocks provide important clues to melting and metasomatism in the deep mantle domain during the initial stages of LIPs. In this study, we investigate the Wajilitag "kimberlites" in the northwestern part of the Tarim LIP that we redefine as hypabyssal aillikites based on the following features: (1) micro-phenocrystic clinopyroxene and Ti-rich andradite garnet occurring in abundance in the carbonate-rich matrix; (2) Cr-spinel exhibiting typical Fe-Ti enrichment trend also known as titanomagnetite trend; and (3) olivine showing dominantly low Mg values (Fo < 90). To constrain the magma source and evolution, the major, minor, and trace element abundance in olivine grains from these rocks were analyzed using electron microprobe and laser ablation-inductively coupled plasma-mass spectrometry. Olivine in the aillikites occurs as two textural types: (1) groundmass olivines, as sub-rounded grains in matrix, and (2) macrocrysts, as euhedral-anhedral crystals in nodules. The groundmass olivines show varying Mg ($Fo_{89–80}$) with high-Ni (1606–3418 ppm) and Mn (1424–2860 ppm) and low-Ca (571–896 ppm) contents. In contrast, the macrocrysts exhibit a restricted Fo range but a wide range in Ni and Mn. The former occurs as phenocrysts, whereas the latter are cognate cumulates that formed from earlier, evolved aillikite melt. The two olivine populations can be further divided into sub-groups, indicating a multi-stage crystallization history of the aillikite melt. The crystallization temperatures of groundmass olivines and macrocrysts in dunite nodules as computed from the spinel-olivine thermometers are 1005–1136 and 906–1041 °C, respectively. The coupled enrichment of Ca and Ti and lack of correlation between Ni and Sc and Co in the olivine grains suggest a carbonate-silicate metasomatized mantle source. Moreover, the high 100·Mn/Fe (average 1.67) at high Ni (up to 3418 ppm), overlapping with OIB olivine, and the 100·Ni/Mg (~1) of primitive Mg-Ni-rich groundmass olivines suggest a mixed source that involved phlogopite- and carbonate-rich metasomatic veins within mantle peridotite.

Keywords: Trace elements, LA-ICP-MS, olivine, aillikites, carbonate-phlogopite metasomatism, Tarim large igneous province