American Mineralogist, Volume 105, pages 803–819, 2020

Decoupled water and iron enrichments in the cratonic mantle: A study on peridotite xenoliths from Tok, SE Siberian Craton

Luc S. Doucet[1,2,*,†], Yongjiang Xu[3], Delphine Klaessens[2,4], Hejiu Hui[3], Dmitri A. Ionov[5,6], and Nadine Mattielli[2]

[1]Earth Dynamics Research Group, The Institute for Geoscience Research (TIGeR), Curtin University, Western Australia 6845, Australia
[2]Laboratoire G-Time, Département Géosciences, Environnement et Société, Université Libre de Bruxelles, 1050 Brussels, Belgium
[3]State Key Laboratory for Mineral Deposits Research & Lunar and Planetary Science Institute, School of Earth Sciences and Engineering, Nanjing University, Nanjing 210023, China
[4]CRPG, UMR 7358 CNRS—Université de Lorraine, 54501 Vandœuvre-lès-Nancy, France
[5]Géosciences Montpellier, UMR-CNRS 5243, Université de Montpellier, 34095 Montpellier, France
[6]Guangzhou Institute of Geochemistry, Chinese Academy of Sciences, 510640 Guangzhou, China

Abstract

Water and iron are believed to be key constituents controlling the strength and density of the lithosphere and, therefore, play a crucial role in the long-term stability of cratons. On the other hand, metasomatism can modify the water and iron abundances in the mantle and possibly triggers thermo-mechanical erosion of cratonic keels. Whether local or large scale processes control water distribution in cratonic mantle remains unclear, calling for further investigation. Spinel peridotite xenoliths in alkali basalts of the Cenozoic Tok volcanic field sampled the lithospheric mantle beneath the southeastern margin of the Siberian Craton. The absence of garnet-bearing peridotite among the xenoliths, together with voluminous eruptions of basaltic magma, suggests that the craton margin, in contrast to the central part, lost its deep keel. The Tok peridotites experienced extensive and complex metasomatic reworking by evolved, Ca-Fe-rich liquids that transformed refractory harzburgite to lherzolite and wehrlite. We used polarized Fourier transform infrared spectroscopy (FTIR) to obtain water content in olivine, orthopyroxene (Opx), and clinopyroxene (Cpx) of 14 Tok xenoliths. Olivine, with a water content of 0–3 ppm H_2O, was severely degassed, probably during emplacement and cooling of the host lava flow. Orthopyroxene (49–106 ppm H_2O) and clinopyroxene (97–300 ppm H_2O) are in equilibrium. The cores of the pyroxene grains, unlike olivine, experienced no water loss due to dehydration or addition attributable to interaction with the host magma. The water contents of Opx and Cpx are similar to those from the Kaapvaal, Tanzania, and North China cratons, but the Tok Opx has less water than previously studied Opx from the central Siberian craton (Udachnaya, 28–301 ppm; average 138 ppm). Melting models suggest that the water contents of Tok peridotites are higher than in melting residues, and argue for a post-melting (metasomatic) origin.

Moreover, the water contents in Opx and Cpx of Tok peridotites are decoupled from iron enrichments or other indicators of melt metasomatism (e.g., CaO and P_2O_5). Such decoupling is not seen in the Udachnaya and Kaapvaal peridotites but is similar to observations on Tanzanian peridotites. Our data suggest that iron enrichments in the southeastern Siberian craton mantle preceded water enrichment. Pervasive and large-scale, iron enrichment in the lithospheric mantle may strongly increase its density and initiate a thermo-magmatic erosion. By contrast, the distribution of water in xenoliths is relatively "recent" and was controlled by local metasomatic processes that operate shortly before the volcanic eruption. Hence, water abundances in minerals of Tok mantle xenoliths appear to represent a snapshot of water in the vicinity of the xenolith source regions.

Keywords: Peridotite, water, lithospheric mantle, stability, FTIR; Volatile Elements in Differentiated Planetary Interiors