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The behaviour of the extended HFSE group (Nb, Ta, Zr, Hf, W) during the petrogenesis of mafic K-rich lavas: a case study fom the Eastern Mediterranean

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In subduction-related tectonic settings, mafic lavas of the K-rich series (medium-K, high-K and shoshonitic) are considered as the most incompatible element-rich end-members, recording different degrees of sediment flux to their mantle sources via melts, fluids, or supercritical liquids. During partial mantle melting, a relative compatibility sequence of Ba < W < Th < U < Nb < Ta < Zr, Hf has been established by experimental studies [1] and studies on mafic lavas [2], confirming the incompatible behaviour of the HFSE. It has been furthermore shown that in arc lavas even the traditional HFSE (Nb, Ta, Zr, Hf) can be enriched by melt-like slab components to a significant degree, whereas fluid-like components only yield a low mobility for the HFSE [3]. The extended HFS element group is thus a highly valuable tool to monitor source replenishment processes as well as constraining residual mineral assemblages in subduction-related tectonic settings. To study the K-rich endmember of subduction zone lavas, we performed high-precision isotope dilution HFSE (Nb, Ta, Zr, Hf) and W concentration measurements by MC-ICP-MS on well-characterized post-collisional lavas from the Eo-Oligocene Eastern Rhodope province, SE Bulgaria and on mafic calc-alkaline lavas from the Aegean Island arc (Santorini).

Tungsten concentrations in the most K-rich samples (absarokites) reach up to 2.5 ppm at near-chondritic values for Nb/Ta (19.1 – 20.1) whereas HFSE ratios of the other high-K basalts, lie well within the MORB array (Nb/Ta = 12.8 – 15.1 and Zr/Hf = 39.5 – 41.7). Tungsten concentrations in the other K-rich lavas reach values of up to 4 ppm, resulting in W-Th ratios of 0.047 – 0.30, thus covering the range of MORB (0.087 – 0.24; [2], [4]) but ranging to somewhat lower and higher values. The Santorini suite yields W concentrations in the range 170 – 920 ppb at invariant W/Th of 0.060 – 0.074 that are slightly lower than values estimated for MORB. Both suites are furthermore characterized by a selective enrichment of W compared to similarly incompatible lithophile elements like Hf or Ta, reflecting the replenishment of W by sediment-derived subduction components. A sediment-melt-dominated source overprint is evident for Santorini lavas (Ta/W < 1.4), which is also confirmed by correlations of Lu/Hf and Eu/Eu* vs. εHf. The HFSE budget of the Bulgarian K-rich rocks, however, seems to be dominated by partial melting processes of an incompatible element-rich, veined sub-lithospheric mantle source that was replenished by sediment-derived components during Mesozoic-Cenozoic times.

In conclusion, our data comfirms the mobility of W in subduction zones in accordance with previous studies [2], but to a larger magnitude than found in lavas with low K-contents. The enrichment of W is most pronounced in the most K-rich rocks leading to the conclusion that subducted sediments might dominate the geochemical budget of high-K rocks.

[1] McDade et al., 2003; [2] König et al. (2011); [3] Brenan et al., 1994; [4] Babechuk et al., 2010