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Zircon solubility in supercritical $KAlSi_3O_8$-H_2O fluids: Implications for HFSE mobility in subduction zones

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Zirconium was traditionally considered as fluid-immobile element in subduction zones, which is supported by the extremely low solubility of zircon in aqueous fluids ...(Bernini et al., 2013). However, the ubiquitous presence of zircon as vein minerals in high-pressure to ultrahigh-pressure eclogitic rocks makes this paradigm no longer tenable.

The common coexistence of zircon and alkali-bearing alumino-silicates motivates experimental study on zircon solubility in $KAlSi_3O_8 \pm Al_2O_3 \pm K$-$H_2O$ supercritical fluids at 800-1000° and 2-6Gpa pressure and temperature using piston cylinder and multi-anvil. Experimental data indicate that ZrO_2 concentrations at zircon saturation range from 66 ppm at 2 Gpa, 900 ˚C, 53.89wt% H_2O and Al/K=1 to 10061 ppm at 2Gpa, 1000 ˚C, 33.58 wt% H_2O and Al/K=0.6. Zircon solubility shows a positive dependence on solute contents in the supercritical fluids, which suggests the solubility is controlled by access to energetically favorable Zr-coordination environments in the K-Al-Si polymers. At 1000˚C, 2Gpa and ∼30wt% H_2O ZrO_2concentrations decrease continuously from 10061 ppm at Al/K=0.6 to 443 ppm at Al/K=1.1. At 2Gpa and fixed H_2O contents, ZrO_2concentrations at 1000˚C are 2-3 times greater than those at 900˚C. The effect pressure on zircon solubility is hardly independently evaluated due to incongruent dissolution of $KAlSi_3O_8$ at 4-6 Gpa, which results in solute deviating from $KAlSi_3O_8$composition. Therefore, zircon solubility is governed primarily by fluids composition and temperature, and to a lesser extent by pressure. Compared to dilute aqueous fluids, solute-rich supercritical fluids are effective agents to transfer HFSE in subduction zones. However, supercritical fluids are unlikely to directly transfer HFSE to arc-magma source regions because they would separate into aqueous fluids and hydrous melts at slab-mantle interface in response to changes in pressure, temperature and whole rock chemical compositions ...(Chen et al., 2018). Hydrous melts would interact with ultramafic host rocks, during which zircons were precipitated, whereas aqueous fluids continued to ascend to locus of arc-magmas and induced mantle melting. Zirconium concentrations in primitive arc basalt are systematic higher than those in MORB, which indicates such aqueous fluids are able to enrich arc-magma source regions with respect to zirconium. Therefore, in spite of the nature of fluids (aqueous fluids, hydrous melts, or supercritical fluids), zirconium could be mobile in subduction zones.

.Bernini, D., Audétat, A., Dolejš, D. and Keppler, H. (2013) Zircon solubility in aqueous fluids at high temperatures and pressures. Geochimica et Cosmochimica Acta 119, 178-187.

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