Zircon alteration in Archean orthogneisses: Insights from U-Pb-Hf-O isotopes and trace elements

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In this study we present new results of detailed investigation on zircon populations from several granitoids of Swaziland, which comprises the oldest crust of the Kaapvaal Craton with intrusion ages between 3.66 and 2.70 Ga. Zircons from all granitoids show significant internal variations with respect to their U-Pb ages, REE patterns, and $\delta^{18}O$ (VSMOW) – far beyond analytical uncertainties, but show within error identical initial $^{176}Hf/^{177}Hf$ isotope compositions. These patterns are most pronounced for the oldest granitoids from Swaziland, comprising the 3.66 Ga TTG gneisses from Piggs peak. CL/BSE images reveal clear core-rim relationships for most zircons, but also zircons with complex zoning related to several stages of alteration. Pb-Pb ages of the "magmatic" zircon cores scatter between 3.65 to 3.26 Ga, Th/U = 0.32 to 1.12, $\delta^{18}O$ = 5.4 to 3.4‰. Furthermore, they show steep to moderate chondrite normalized LREE-patterns with a positive slope (La/Sm_N=0.002 to 0.09). In contrast, the "metamorphic" rims commonly show diffuse zoning patterns in CL, and lower Pb-Pb ages (3.28 to 3.20 Ga), Th/U (0.01 to 0.3) and $\delta^{18}O$ (1.3 to 1.7‰), and a negative slopes in LREE patterns (La/Sm_N = 2.8-3.5). Despite these differences, the analyses of all domains yielded identical initial $^{176}Hf/^{177}Hf$ of 0.28040 ± 0.00004 (2 SD). This indicates that all zircon domains (core, rims, alteration zones) were initially formed during magma crystallisation at ca. 3.66 Ga, and that the different domains were differently affected by subsequent alteration processes, causing a reset of the U-Th-Pb system, and dramatic changes of the REE patterns and $\delta^{18}O$, but left the hafnium isotope system unaffected. The low $\delta^{18}O$ of the zircon rims + altered domains (1.5‰) indicate that they probably formed by interaction with hot meteoric water. This interpretation is consistent with the strongly elevated LREE contents. These hydrothermal fluids obviously also altered some of the magmatic cores (5.3-4.1‰), even such which still look pristine in CL images and with concordant U-Pb ages! This observation has clear consequences for the interpretation of the Hadean/Early Archean detrital zircons.

The role of water in the petrogenesis of arc magmas from SW Japan

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Thermometry and hygrometry in SW Japan arc volcanics

We have studied mafic melts from the volcanic centres of Kirishima, Aso, Kuju, Yufu, and Oninomi in Kyushu, and Abu, Menkame, Daisen and Kannabe in Western Honshu. We present results from pyroxene thermometry, 2-pyroxene thermobarometry, and plagioclase hygrometry, extending our published dataset from this region [1]. We show that initial magma water contents vary coherently along the arc, dropping from about 5wt% in Kyushu to about 2wt% in Western Honshu. Water appears to control (a) the average ponding depth of magmas at a given temperature, (b) the equilibrium phase assembleage during lower crustal differentiation and therefore the geochemical evolution of mafic melts towards intermediate (andesitic and adakitic) compositions [1].

SIMS determination of hydrogen in volcanic olivines

To determine H_2O variations directly, we have attempted to measure hydrogen in olivine by SIMS, because melt inclusions in magnesian olivines from this area are generally too small for analysis. Hydrogen concentrations are ubiquitously low (typically < 20 ppm), and in contrast to plagioclase hygrometry data do not vary coherently along the SW Japan arc (Fig. 1). Crystallization modeling suggests that olivine only becomes stable at upper crustal pressures (< 5 kbar) in these magmas, which at that stage all may already have experienced some degassing. We conclude that plagioclase is more suitable than olivine in determining the H_2O content of parental arc magmas, even if olivine melt inclusions are available.

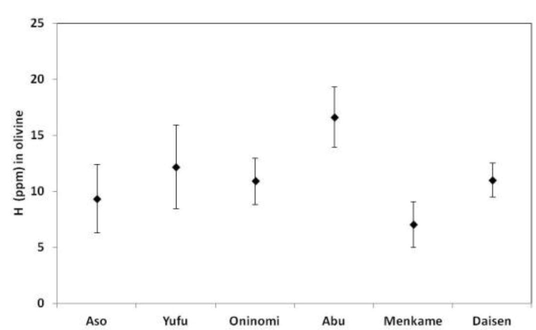

Figure 1: Summary of hydrogen concentrations in volcanic olivines from SW Japan, n ~ 10 for each center.

[1] Zellmer *et al.* (2012) *Geology*, DOI: 10.1130/G32912.1