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A detailed investigation of post-crystallization O-isotope exchange in highly damaged U-rich low-$\delta^{18}O$ Paleoproterozoic zircon via combination of bulk, in-situ measurements, and high-precision U-Pb geochronology

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Low-$\delta^{18}O$ magmatic-hydrothermal systems form via exchange reactions between silicate rocks and local meteoric precipitation. Since the exchanged rocks record the isotope composition of precipitation, such systems of the Precambrian age represent a novel quantitative archive of near-surface conditions. Here we focus on the application of O-isotope geochemistry and U-Pb geochronology of zircon that crystallized near-contemporaneously with the O-isotope exchange. In this presentation, we show new data on a zircon extracted from a low-$\delta^{18}O$ hydrothermally altered rock of a Neoarchean system (Keivy Complex, Kola Craton) that has bulk $\delta^{18}O$ value of -9 ‰. Triple O-isotope approach indicates that meteoric waters had the initial $\delta^{18}O$ of ca. -18 ‰. The in-situ O-isotope measurements of zircon from the most exchanged lithologies conducted by a secondary ion mass spectrometer reveal domains with $\delta^{18}O$ as low as -8 ‰, while bulk fluorination measurements of multi-crystal aliquots yield values between -6 and -4 ‰. A positive correlation between the $^{16}OH/^{16}O$ ratio and $^{18}O/^{16}O$ measured by SIMS allows to constrain the lowest values $\delta^{18}O$ = -8 ‰ to the most preserved domains. Cathodoluminescence and electron microprobe measurements reveal the highly damaged textures of this zircon and mobilization of trace elements (Y, Hf, Yb). The U and Th concentrations of these damaged zircon reach 4000 ppm indicating that a significant radioactive damage had accumulated over time explaining the highly variable O-isotope values measured in situ and in bulk.

To understand the nature and timing of secondary O-isotope exchange, multiple zircon crystals were subjected to annealing, stepwise chemical abrasion and subsequent high-precision ID-TIMS dating. The resultant analyses are discordant, yielding the upper intercept date of 1784.5±0.5 Ma, which is close in time to the locally established metamorphic events. The discordance notably correlates with the measured $^{16}OH/^{16}O$ and $^{18}O/^{16}O$ values in situ. That indicates that the increase in the $^{16}OH/^{16}O$ and $^{18}O/^{16}O$ values trace the Pb-loss from the damaged domains. The crystals with the lowest $^{16}OH/^{16}O$ and $^{18}O/^{16}O$ yield over-concordant dates (a.k.a. negatively discordant) documenting a potential counter part of the Pb-loss/U-gain. This is the first documented evidence of secondary O-isotope exchange that is traced by high-precision U-Pb ages.