Single-grain $^{238}U/^{235}U$ Measurements in Early Earth Zircons

F.L.H. TISSOT[1,2], M. IBANEZ-MEJIA[3], P. BOEHNKE[4], N. DAUPHAS[4], D. MCGEE[1], T.L. GROVE[1], T.M. HARRISON[5]

[1]Dept. of EAPS, MIT, Cambridge, MA 02139, USA.
[2]The Isotoparium, California Institute of Technology, Pasadena, CA 91125, USA (tissot@caltech.edu)
[3]Dept. of Earth and Environmental Sciences, University of Rochester, Rochester, NY 14627, USA
[4]Dept. of the Geophysical Sciences, The University of Chicago, Chicago, IL 60637, USA.
[5]Dept. of Earth, Planetary, and Space Sciences, University of California, Los Angeles, CA 90077, USA.

Hadean zircons are the only lithic witnesses of the first ~500 Myr of Earth's crust evolution. As these zircons are detrital, each grain has a potentially unique story to tell about its formation conditions. Here, we report the first high-precision U isotope data of single-zircon grains, using 31 Jack Hills grains and 3 reference zircon localities (FC-1, R33, Temora). This work is motivated by the possibility that Oklo-type natural reactors were more prevalent in the Hadean [1], that zircon $^{238}U/^{235}U$ could reflect the conditions, extent, and/or nature of crystallization [2], and how single-zircon $^{238}U/^{235}U$ variations may influence the precision and accuracy of high-precision U-Pb and Pb-Pb dating [3].

Single Hadean zircon show resolvable $\delta^{238}U$ variations between -0.60 and -0.12 permil (‰). This range is centered on the chondritic and bulk continental crust value, arguing against (i) a widespread existence of Oklo-type reactors in the Hadean and (ii) any contribution of U from sources with excess ^{238}U (*e.g.*, mineralized ore sediments), consistent with the reducing conditions implied by the small Ce anomalies of many Hadean zircon. These variations are more plausibly explained by vibrational isotope effects than by nuclear field shift during magmatic differentiation, and suggest preferential removal of ^{235}U from the melt into zircons, and/or other accessory phases, during fractional crystallization.

We show that single-zircon $^{238}U/^{235}U$ measurements can be performed with precisions of ±0.04 to ±0.25 ‰ on the small sample loads relevant to high-precision U-Pb and Pb-Pb geochronological studies. This will make it possible to (i) improve both the precision and accuracy of U-Pb and Pb-Pb chronology, (ii) properly investigate the contributions of intermediate daughter product disequilibrium to U-Pb dates discordance, as well as (iii) re-evaluate the accuracy of U decay constants.

[1] Draganic et al. (1983) *Prec. Res.* 20, 283-298. [2] Tissot et al. (2017) *GCA* 213, 593-617. [3] Tissot & Dauphas (2015) *GCA* 167, 113-143