Forum Reply

doi:10.1130/G38239Y.1

Differentiated impact melt sheets may be a potential source of Hadean detrital zircon

Gavin G. Kenny[1], Martin J. Whitehouse[2] and Balz S. Kamber[1]
[1]Department of Geology, School of Natural Sciences, Trinity College Dublin, Dublin 2, Ireland
[2]Department of Geosciences, Swedish Museum of Natural History, 104 05 Stockholm, Sweden

We recently reported the results of the first ever ion microprobe study of Ti contents, and corresponding Ti-in-zircon crystallization temperatures (T_{zir}^{xtln}), of zircon from throughout the stratigraphy of a differentiated impact melt sheet (Kenny et al., 2016). We appreciate the discussion points presented by Wielicki et al. (2016), and this opportunity to further clarify the aims and conclusions of our study.

From our data for the Sudbury impact melt sheet, Ontario, Canada, we concluded that: (1) earlier Ti-in-zircon data from the melt sheet obtained by laser ablation–inductively coupled plasma–mass spectrometry (LA-ICPMS; Darling et al., 2009) are higher than our secondary ion mass spectrometry (SIMS) data and this is likely due to analytical issues associated with LA-ICPMS, such as downhole fractionation; (2) our new SIMS data show a trend from higher Ti contents, and corresponding T_{zir}^{xtln}, in zircons from the basal norite to much lower values (down to 1.2 ± 0.1 ppm Ti) in the overlying felsic products of differentiation, known as the granophyre; (3) the strong differentiation of the impact melt sheet, which is likely necessary to achieve such low Ti contents in zircon, may be related to the subaqueous nature of the impact crater and the insulating effects of the anomalously thick overlying crater fill; and (4) our new SIMS Ti and T_{zir}^{xtln} values for the Sudbury impact melt sheet fully overlap with the range of values observed in detrital Hadean zircons.

In their Comment, Wielicki et al. used a particular statistical method (p-values for Kolmogorov-Smirnov tests) for comparing the Ti distribution of detrital Hadean zircons with variants of our impact melt sheet zircon dataset (12 analyzed samples) combined with previously published data for two samples from the high-temperature norite at Sudbury, two samples from the Morokweng impact melt sheet, and a single sample from the Manicouagan crater. Notwithstanding concerns that p-values are a "poor measure of dissimilarity between samples" due to the large effect that sample size has on their outcome (Vermeesch, 2013, p. 145), we are not surprised at Wielicki et al.'s conclusion that the distribution of Ti contents in zircon sampled from younger impact melts are not statistically identical to the Hadean detrital zircon record. It is important to state that it was never our aim to quantitatively predict the exact yield and distribution of zircon Ti values from the Sudbury melt sheet. Any serious attempt at modeling the possible detrital zircon yield from the Sudbury impact structure would not only require knowledge of the relative contribution of each lithology to total zircon delivery into a hypothetical detrital system, but also those from affected footwall and basin fill lithologies. We question whether the sparse data from two other impact craters are any more representative of impact melt sheet zircon yields.

Moreover, it is not clear to us that the Hadean detrital zircon population lends itself to statistical comparison. Most Hadean grains are from a very limited number of locations in Western Australia, and this preservational bias makes it impossible to assess how representative the recovered grains are of all zircon that would have existed at the time. This is further complicated by the >1 Ga time gap between crystallization and final deposition, during which the grains experienced multiple stages of protracted growth and thermal reworking (e.g., Nelson et al., 2000) and sedimentary transport (as evidenced by sedimentary rounding). Wielicki et al.'s assertion that higher-temperature zircons fundamentally have lower U and Th contents and are thus more likely to survive sedimentary transport is not supported by our observation (Fig. 1) that there is no correlation between U or Th and Ti contents in impact melt sheet zircon at Sudbury.

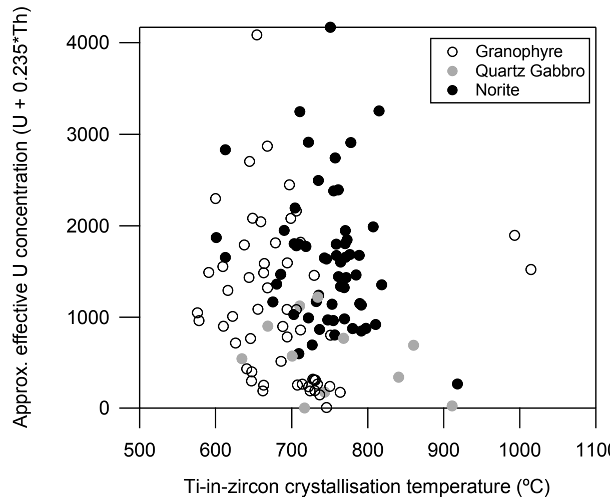

Figure 1. Effective U content versus T_{zir}^{xtln} in zircons from Sudbury.

Regardless of the precise details of the impact bombardment distribution on the early Earth (e.g., Morbidelli et al., 2012), it is beyond doubt that impact melting was a major process of crustal reworking in the Hadean and Eoarchean. Vast differentiated impact melt sheets were therefore a dominant feature of the Hadean-Eoarchean surface no matter whether the Earth operated as a single-plate or multi-plate planet. The key discovery from our study is that differentiation of large impact melt sheets can produce zircon with the full range of Ti contents observed in the Hadean detrital dataset. For this reason, we believe that citing relatively low Ti contents in Hadean detrital zircon as evidence against a melt sheet origin is no longer warranted.

REFERENCES CITED

Darling, J. R., Storey, C. D., and Hawkesworth, C. J., 2009, Impact melt sheet zircons and their implications for the Hadean crust: Geology, v. 37, p. 927–930, doi:10.1130/g30251a.1.

Kenny, G. G., Whitehouse, M. J., and Kamber, B. S., 2016, Differentiated impact melt sheets may be a potential source of Hadean detrital zircon: Geology, v. 44, p. 435–438, doi:10.1130/G37898.1.

Morbidelli, A., Marchi, S., Bottke, W. F., and Kring, D. A., 2012, A sawtooth-like timeline for the first billion years of lunar bombardment: Earth and Planetary Science Letters, v. 355–356, p. 144151, doi:10.1016/j.epsl.2012.07.037.

Nelson, D. R., Robinson, B. W., and Myers, J. S., 2000, Complex geological histories extending for ≥4.0 Ga deciphered from xenocryst zircon microstructures: Earth and Planetary Science Letters, v. 181, p. 89–102, doi:10.1016/S0012-821X(00)00186-2.

Vermeesch, P., 2013, Multi-sample comparison of detrital age distributions: Chemical Geology, v. 341, p. 140–146, doi:10.1016/j.chemgeo.2013.01.010.

Wielicki, M. M., Harrison, T. M., Schmitt, A. K., Boehnke, P., and Bell, E. A., 2016, Differentiated impact melt sheets may be a potential source of Hadean detrital zircon: Comment: Geology, v. 44, p. e398, doi:10.1130/G38135C.1.