Forum Comment

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Zircon (U-Th)/He thermochronology reveals pre-Great Unconformity paleotopography in the Grand Canyon region, USA

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Peak et al. (2021) concluded that their ZHe data revealed differences between eastern (EGC) and western (WGC) Grand Canyon regions in 1255–500 Ma basement cooling/exhumation such that the Grand Canyon Supergoup was not deposited in western Grand Canyon. Here, we agree that WGC and EGC had different 1255–500 Ma cooling histories, but we disagree that the ZHe data preclude deposition of the Grand Canyon Supergroup in WGC. Instead, a scenario of structurally controlled Unkar and Chuar Group deposition and magmatism across a wide region, including parts of WGC, is equally viable for the available thermochronometry, and is more viable geologically (Howard, 1991; Dehler et al., 2017; Mulder et al., 2017;).

Figure 1 compares Peak et al.'s preferred WGC HeFTy time-temperature path (pink) with a new QTQt model (http://www.iearth.org.au/codes/QTQt/) constructed from all their western Grand Canyon ZHe data. We also superimpose a K-spar multiple diffusion domain (MDD) model (yellow) from basement just below the sub-Tapeats Great Unconformity in the tilted Gold Butte block that restores to a pre-17 Ma position ~50 km northwest of their westernmost sample, and that likely had a similar thermal history as WGC (Karlstrom et al., 2010; Fitzgerald and Malusà, 2019). The ZHe QTQt model and the K-spar MDD models independently suggest that basement was being cooled from 250 to 200 °C in WGC at the same time (1250–1100 Ma) that basement was near the surface and being buried by ~2 km of Unkar Group in EGC. The MDD model shows crustal residence at ~200–150 °C from 1100 to 800 Ma and a second cooling pulse between Chuar (775–723 Ma) and Tonto (520–500 Ma) Group time, notably after Chuar deposition in EGC. Peak et al.'s HeFTy model differs markedly and was dependent on the choice of specific constraint boxes; the K-spar data suggest that a constraint box in Peak et al.'s figures 3A and 3B would be needed to allow for long-term residence at 250–150 °C from 1100–800 Ma. This time-temperature range is crucial because it is hot enough to reset ZHe dates and anneal damage and excludes the need to have only cooling (exhumation) in WGC. The multiple cooling pulses in all the models support the hypothesis that "many unconformities make one 'Great Unconformity'" (Karlstrom and Timmons, 2013), but the combined data do not support the assumption that WGC and EGC basement samples were at the same crustal level at 1255 Ma (Peak et al., 2021, their figure 4A). Fault and shear zone segmentation in both EGC and WGC likely caused differential cooling, but large displacement across the northeast-trending Sinyala fault seems unlikely as it is a <4-m-displacement Neogene fault with no known ancestry, whereas Unkar- and Chuar-age basin-bounding structures are northwest- and north-striking, respectively. Using combined data sets, Grand Canyon presents an ideal setting to continue to test the sensitivity of the deep-time zircon (U-Th)/He (ZHe) thermochronometer for resolving differential cooling, in different fault blocks, between 1300 and 500 Ma, to create the composite Great Unconformity.

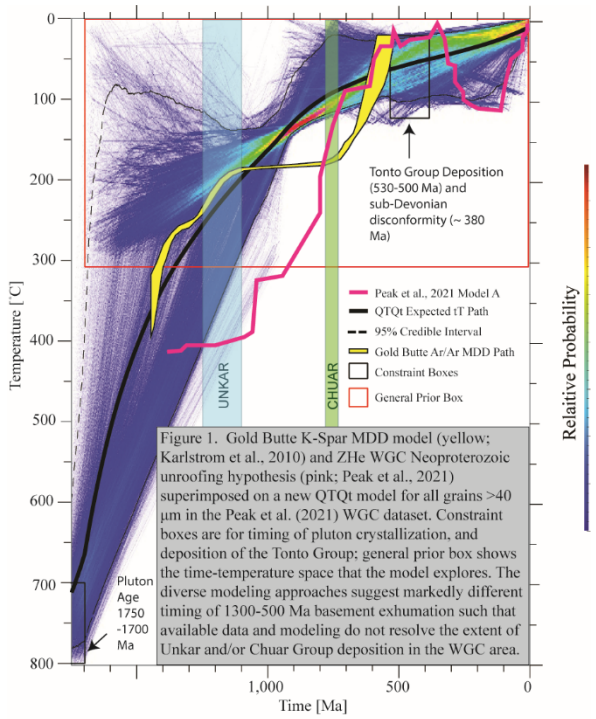

Figure 1. Gold Butte K-Spar MDD model (yellow; Karlstrom et al., 2010) and ZHe WGC Neoproterozoic unroofing hypothesis (pink; Peak et al., 2021) superimposed on a new QTQt model for all grains >40 µm in the Peak et al. (2021) WGC dataset. Constraint boxes are for timing of pluton crystallization, and deposition of the Tonto Group; general prior box shows the time-temperature space that the model explores. The diverse modeling approaches suggest markedly different timing of 1300-500 Ma basement exhumation such that available data and modeling do not resolve the extent of Unkar and/or Chuar Group deposition in the WGC area.

REFERENCES CITED

Dehler, C., Gehrels, G., Porter, S., Heizler, M., Karlstrom, K.E., Cox, G., Crossey, L.C., and Timmons, J.M., 2017, Synthesis of the 780–740 Ma Chuar, Uinta Mountain, and Pahrump groups (ChUMP), western USA: Implications for Laurentia-wide cratonic marine basins: Geological Society of America Bulletin, v. 129, p. 607–624, https://doi.org/10.1130/B31532.1.

Fitzgerald, P.G., and Malusà, M.G., 2019, Concept of the exhumed partial annealing (retention) zone and age-elevation profiles in thermochronology, *in* Malusà, M.G., and Fitzgerald, P.G., eds., Fission-Track Thermochronology and Its Application to Geology: Springer International Publishing, p. 165–189, https://doi.org/10.1007/978-3-319-89421-8_9.

Howard, K.A., 1991, Intrusion of horizontal dikes: Tectonic significance of middle Proterozoic diabase sheets widespread in the upper crust of the southwestern United States: Journal of Geophysical Research, v. 96, p. 12461–12478, https://doi.org/10.1029/91JB00112.

Karlstrom, K.E., Heizler, M., and Quigley, M.C., 2010, Structure and $^{40}Ar/^{39}Ar$ K-feldspar thermal history of the Gold Butte block: Reevaluation of the tilted crustal section model, *in* Umhoefer, P.J., et al., eds., Miocene Tectonics of the Lake Mead Region, Central Basin and Range: Geological Society of America Special Paper 463, p. 331–352, https://doi.org/10.1130/2010.2463(15).

Karlstrom, K.E., and Timmons, J.M., 2013, Many unconformities make one "Great Unconformity", *in* Timmons, J.M., and Karlstrom, K.E., eds., Grand Canyon Geology: 2 Billion Years of Earth History: Geological Society of America Special Paper 489, p. 73–80, https://doi.org/10.1130/2012.2489(04).

Mulder, J.A., Karlstrom, K.E., Fletcher, K., Heizler, M.T., Timmons, J.M., Crossey, L.J., Gehrels, G.E., and Pecha, M., 2017, The syn-orogenic sedimentary record of the Grenville Orogeny in southwest Laurentia: Precambrian Research, v. 294, p. 33–52, https://doi.org/10.1016/j.precamres.2017.03.006.

Peak, B.A., Flowers, R.M., Macdonald, F.A., and Cottle, J.M., 2021, Zircon (U-Th)/He thermochronology reveals pre-Great Unconformity paleotopography in the Grand Canyon, USA: Geology, v. 49, p. 1462–1466, https://doi.org/10.1130/G49116.1.