The Cryosphere Discuss.,
https://doi.org/10.5194/tc-2017-134-AC2, 2017

Interactive comment on "Crustal heat production and estimate of terrestrial heat flow in central East Antarctica, with implications for thermal input to the East Antarctic ice sheet" *by* John W. Goodge

J. Goodge

jgoodge@d.umn.edu

Received and published: 10 November 2017

I am grateful to the reviewer for the positive comments and statement about the value of the work.

1. Manuscript revised to address concerns about assumptions used. The author is not aware of any independent estimates of mantle heat flow based on seismic or other data from Antarctica. Publications using seismic velocity structure to invert heat flow (Shapiro and Ritzwoller, 2004; An et al., 2015) consider the lithosphere velocity structure and do not separately treat the mantle contribution to surface heat flow. In absence of specific constraints, an assumption of mantle heat flow based on geologically com-

Printer-friendly version

Discussion paper

parable craton age and thickness is a valid approach.

2. Regarding inclusions of analytical methods, not clear if the reviewer is recommending moving this section to an appendix. Will defer to editor recommendation.

3. It is a good suggestion to consider the potential mobility of U and Th as it relates to their contribution to heat production. As suggested by the reviewer, Table 1 has been modified to list Th/U and K/U ratios. This compilation shows that of the 18 samples presented, only one (10MSA-2.3) has anomalous element ratios. This is shown in plots of Th/U and K/U (provided as a new Figure 3), in which all of the samples show coherent behavior and can be fit to a linear regression. The ratios are also mostly within the ranges compiled in a recent paper by Artemieva et al. (2017). These relationships indicate that, in general, the samples have not experienced fluid-assisted element mobilization as reviewer has in mind. Based on the valid question posed by the reviewer, some specific comments about the element concentrations have been added to the text in Section 4.2 as well as remarks about sample characteristics and isotopic compositions to address these concerns.

To address the specific questions raised in this comment about sample characteristics, the reader is referred to the detailed data presented in Goodge et al. (2017), which includes sample descriptions, petrographic information, geochemical data, cathodoluminescence (CL) images of zircons, and zircon U-Pb and O stable isotope data. This is also noted explicitly in Section 2.

4. Regarding application of two methods to calculate heat production, please refer to author response to similar comment/question by Reviewer 1. Text revised accordingly in Section 4.3.

5. To address a similar concern about 'few new data' that was raised by Reviewer 1, an exhaustive data set on the ages, geochemical compositions, and isotopic behavior of a large suite of igneous rocks was recently published by Goodge et al. (2017, Precambrian Research). To my knowledge, this is the single-most comprehensive such

data set on glacial clasts sampled in Antarctica to date. Unlike the case in central and South Australia, which is well studied from outcrop and industry borehole samples, it is infeasible to expand the current data set without significant additional resources to collect new samples or to conduct the various lab measurements required.

That said, the point raised in this part of the manuscript (original page 7, line 3) is that despite some overlap with the CAHFP, most of the glacial clast samples in this study have values of heat production less than the CAHFP average as cited. Certainly a geological province such as the CAHFP exhibits a range of heat production values, but the mean remains a valid reference point, particularly for a large data set such as noted by the reviewer. This is simply a statement of comparison and at this point does not offer any comment on possible extension of crust like that in the CAHFP into East Antarctica.

It is noteworthy that the paper by McLaren and Powell (2014) discusses granites from the North Australian Craton and is not directly relevant to the discussion concerning the CAHFP.

6. Comparison to examples of heat production and heat flow in other cratons. . . These are all valid criticisms offered by the reviewer, but it represents an unreasonable comparison given that the regions cited are well exposed and well studied by petrologic, geochemical, borehole, and geophysics methods. The text acknowledges (and makes explicit) the various assumptions that are required to use the available dated samples to construct a first-order profile of heat production in central East Antarctica. Likewise, uncertainties in the input parameters are explicitly considered, so it should be clear to a reader that a range in outcomes is to be expected. Certainly the crust in this region contains rock types other than just granite. We can surmise from seismology, aeromagnetics, and locally available outcrop that the East Antarctic craton is a composite of Archean to Neoproterozoic igneous and metamorphic rocks. Seismology indicates the lithosphere is thick, cold and stable. Where exposed, the rocks commonly consist of dense, dehydrated granulites, charnockites, and other gneissic rocks. Granites as

a class have higher concentration of heat-producing elements than other rocks, such that a sampling of granites is likely to skew heat production (and therefore heat flow) to higher values. If anything, the data provided in this study may overestimate thermal conditions at the base of the ice sheet. To address the reviewer concerns, the text in the Introduction and Discussion have been revised to emphasize that rather than a comprehensive top-to-bottom assessment of heat production and heat flow, the data presented here provide a valuable glimpse into the thermal properties of the East Antarctic craton that at this time is otherwise inaccessible.

7. About distribution of heat-producing elements, this is a good point and was considered an implicit idea in the original manuscript, yet should be addressed explicitly. Discussion (Section 5) is revised to emphasize this point.

8. Author prefers to keep the Discussion and Conclusions separate, as they have different purposes. Reviewer's comment about repetition is noted and revisions have been made to both sections in order to improve the presentation.

9. See earlier comments regarding need for additional data. It's not clear what type of modeling is envisioned by this reviewer, but in any case modeling is beyond the scope of this contribution. The goal of this paper is to provide data relevant to ice-sheet modeling that is undertaken by others. Appropriate caveats are included in the revised manuscript.

10. Technical corrections – revised as suggested, including: a) Fig. 2, geographic abbreviations were included in caption. Explanation of sample site abbreviations has been added. b) Table 1. This information is included in Goodge et al. (2017). Age justification beyond the scope of this contribution; refer to citation. Author will provide lithotype and age uncertainty if recommended by the editor, but this will expand Table 1. c) Model of heat production decreasing exponentially with depth is one end member... Absolutely, but it is a commonly assumed model based on a paucity of observations from exposed crustal sections.

Revised figures included with response to Reviewer #1.

Interactive comment on The Cryosphere Discuss., https://doi.org/10.5194/tc-2017-134, 2017.