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Climate of the Past Discussions

Interactive comment on "Laurentide Ice Sheet basal temperatures at the Last Glacial Cycle as inferred from borehole data" *by* C. Pickler et al.

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Response to comments by J.A.M. Majorowicz

We thank the reviewer for his thoughtful and constructive comments. He raises a valid point that the temperature depth profiles are affected by the vertical variations in heat production and that these variations should be properly accounted for before inverting the profiles for ground surface temperature history. This point is certainly valid but the importance of the correction depends on whether the heat production is high and shows systematic variations with depth.

1) The above reported examples show that without a precise knowledge of HP(z) it is impossible to deduct cause of heat flow variations with depth, otherwise interpreted entirely as a result of surface climate change. Pickler et al., (2015) fail to show any evidence of HP (z) variability.

The reviewer is correct in insisting that we should have provided more information on the heat production at the different sites. Detailed information had been published in several papers on heat flow in the Canadian Shield (e.g. Jaupart et al., 2014; Phaneuf and Mareschal, 2014). We shall summarize this information in the revised manuscript. Accounting for heat production (HP) with depth (z) is required in sites with very high heat production. The example provided by the reviewer concerns a hole drilled in granite, which usually has high production, and, sometimes shows systematic variations with depth (e.g. Förster and Förster, 2000). In this case, one should definitely try and account for $HP(z)$. However, the rocks for most of the sites that we are using in this study have lower heat production than granites. For example, the Sept-Iles intrusion is a complex of gabbro, which for all practical purposes has negligible heat production ($<$0.2) producing less than 0.5over 2km. Variations in the heat production with depth are a second order correction and can safely be neglected. Many of the other sites (Val d'Or, Matagami, Flin-Flon) have relatively low heat production ($\approx$0.5) with a total contribution of $<$1.0over 2000m (Mareschal et al., 1989, 1999b; Jaupart et al., 2014). Moreover, the lithology consists of alternating layers of mafic and felsic lava flows and intrusives. In other words the variations in heat production with depth can be seen as random fluctuations over small depth scale. In that case, the mean heat production can reasonably account for the vertical variations in heat flux. This is not the situation for the sites in the Sudbury region where the vertical layering of the basin is well documented. Most of the holes are drilled

near the margin of the structure reaching to the base of the Sudbury igneous complex (SIC). The composition of the SIC indeed shows vertical variations in composition with granophyre and felsic norite on top and more mafic norite at the base (Phaneuf and Mareschal, 2014, e.g.,). Following the reviewer's recommendation, we will discuss $HP(z)$ at the Sudbury sites. So far comparison between different sites shows little correlation between the amplitude of the variations in heat flux and the variations in composition across the drillholes.

2) In the wells they examine, also thermal conductivity measured on core samples are few. There is no sufficient data to determine HP (z) as no spectral logs reported.

As a general principle, we have always favoured high quality thermal conductivity measurements using relatively large samples to measure the property of the bulk rock (Perry et al., 2006, see the discussion in). Each thermal conductivity value, which is the result of 5 measurements, represents the thermal conductivity of the bulk rock unaffected by small heterogeneities. Despite the lack of spectral logs, we can estimate variations in heat production with depth based on the detailed lithological logs used to select the core samples from all lithologies.
We also want to point out that the reviewer's estimates for the temperature at the base of the Laurentide ice sheet during the last glacial maximum are not significantly different from ours. We thank the reviewer for pointing out the ambiguity in the description of the thermal conductivity and heat production measurements and we will clarify this in the revised manuscript.

References

Jaupart, C., Mareschal, J., Bouquerel, H., and Phaneuf, C.: The building and stabilization of an Archean Craton in the Superior Province, Canada, from a heat flow perspective, Journal of Geophysical Research: Solid Earth, 119, 9130–9155, 2014.

Förster, A., and Förster, H.-J. 2000. Crustal composition and mantle heat flow: Implications from surface heat flow and radiogenic heat production in the Variscan Erzgebirge (Germany). *J. Geophys. Res. (Solid Earth)*, **105**, 27917–27938.

Mareschal, JC and Pinet, C and Gariépy, C and Jaupart, C and Bienfait, G and Coletta, G Dalla and Jolivet, J and Lapointe, R: New heat flow density and radiogenic heat production data in the Canadian Shield and the Québec Appalachians, Canadian Journal of Earth Sciences, 26,4, 845–852, 1989.

Mareschal, J.-C., Rolandone, F., and Bienfait, G.: Heat flow variations in a deep borehole near Sept-Iles, Québec, Canada: Paleoclimatic interpretation and implications for regional heat flow estimates, Geophysical Research Letters, 26, 2049–2052, doi:10.1029/1999GL900489, 1999b.

Perry, H., Mareschal, J. C., and Jaupart, C.: Enhanced crustal geo-neutrino production near the Sudbury Neutrino Observatory, Ontario, Canada, Earth and Planetary Science Letters, 288, 301–308, 2009.

Perry, H. K. C., Jaupart, C., Mareschal, J. C., and Bienfait, G. 2006. Crustal Heat Production in the Superior Province, Canadian Shield, and in North America inferred from Heat Flow Data. *J. Geophys. Res. (Solid Earth)*, **111**, B04401.

Phaneuf C, Mareschal JC (2014) Estimating concentrations of heat producing elements in the crust near the Sudbury Neutrino Observatory, Ontario, Canada. Tectonophys 622:135–144, doi:10.1016/j.tecto.2014.03.001

Rolandone, F., Jaupart, C., Mareschal, J., Gariépy, C., Bienfait, G., Carbonne, C., and Lapointe, R.: Surface heat flow, crustal temperatures and mantle heat flow in the Proterozoic Trans-Hudson Orogen, Canadian Shield, Journal of Geophysical Research: Solid Earth, 107, 2371, 2002.

Rolandone, F., Mareschal, J., Jaupart, C., Gosselin, C., Bienfait, G., and Lapointe, R.: Heat flow in the western Superior Province of the Canadian Shield, Geophysical Research Letters, 30, 2003a.