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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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Pickler et al., (2015) reported post-glacial ground surface temperature histories in eastern and central Canada based on inversion of temperature vs. depth profiles in deep boreholes. Their inversion of the nearly 3,000 m deep borehole at Flin Flon, MB, shows a relatively flat temperature history from 10,000 ka to present, and they report that the maximum temperature attained during that time was 5.64 C. Data from Environment Canada show the mean annual temperature at Flin Flon, MB for the past century is 2.73 C. Thus their result indicates that post-glacial warming at Flin Flon was less than 2 ?C. This result agrees with the finding of Sass et al., (1971) based on direct models of the temperature profile. However, neither inversion nor direct modeling of a temperature profile can discriminate the effect of changes of several degrees lasting thousands of years. I show here how that applies to the Flin Flon borehole and propose that similar analyses would enhance our understanding of the post-glacial climate of North America.

Climate reconstructions of the post-glacial period in Manitoba based on sedimentological analyses (Teller and Last, 1979) and temperature reconstructions based on pollen analyses at Riding Mountain, MB led Ritchie (1983) to propose a four-stage post glacial climate history for the northern Lake Agassiz basin as follows: 13,000 – 10,000 ka was cool with temperatures of 5 C to 10 C. 10,000 – 6500 ka was warm and dry with temperatures of 15C to 17 C. 6500-3000 ka was warm and wet with temperatures similar to the previous period. 2500 ka the modern climate was established.

Ritchie's (1983) pollen analysis was presented as a 23-point temperature history for the summer months (MJJA) during the past 12,500 years, and I have used the data to model subsurface temperatures assuming 1:1 tracking of air and ground temperatures. This is a reasonable assumption as GST and SAT may differ by a couple of degrees, but heat exchange between the air and ground maintains trends in parallel. I digitized and expanded the 23 points into a 2,500 point temperature history with each point representing 5 years (Figure 1). The MJJA temperatures were scaled to annual temperatures using 115 years of monthly temperature data from North Dakota Climate Zone 2 which lies along the MB-ND border, 200 km south of Riding Mountain, MB. The average MJJA temperature for ND Zone 2 is 16.77 C and the mean annual temperature is 3.34 C. The scaled temperatures were used as a surface temperature time series in a 2-D heat conduction model of the subsurface. Thermal properties of the subsurface model (Table 1) were adopted from Sass et. al., 1971 and Lachenbruch and Bunker, 1971.

The results of the model (Figure 2) show that although warming was greater than 4 C for the time period 6500 to 2500 ka, the change to modern temperatures virtually straightened the warming signal in the temperature profile. Unless southern Manitoba underwent a completely different warming trend than northern Manitoba, it appears

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that no deep well in the region would show post-glacial warming effects.Âă The model results agree with the findings of Pickler et. al., (2015) on the basal temperature of the ice sheet.

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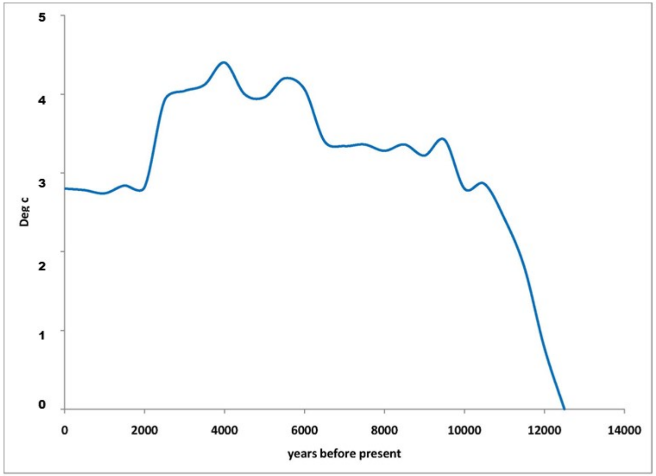

Fig. 1. Smoothed MJJA temperature record for Riding Mountain, MB based on pollen analysis. Modified from Ritchie, 1983)

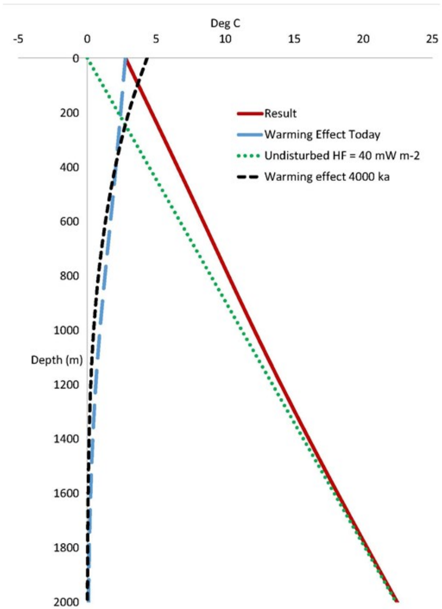

Fig. 2. Subsurface temperature model results based on the surface temperature depicted in Figure 1. The dotted green line shows an undisturbed temperature profile with heat flow at 40 mW m-2. The long- dash

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Depth interval (m)	Gradient K km^{-1}	Conductivity W m^{-1} K^{-1}	Heat Production µW m^{-3}	Heat Flow mW m^{-2}
152- 610	12	3.35	1.17	39
610-1356	11	3.46	1.06	39
1356-1920	12	3.51	1.00	44
1920-2301	14	2.85	0.95	41
2301-2865	16	2.58	0.88	40

Fig. 3. Table 1. Thermal properties of the subsurface temperature model

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