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Comment: Radiocarbon deglaciation chronology of the Thunder Bay, Ontario area and implications for ice sheet retreat patterns

Lowell et al. (2009) put forth a hypothesis for the cause of the Moorehead low stand of Lake Agassiz during the Younger Dryas cold event (~12.9–11.5 ka) that differs from the conventional explanation involving eastward routing of the lake to the St. Lawrence River (Broecker et al., 1989). Based on their minimum limiting radiocarbon dated reconstruction of ice-margin retreat from the area of the Lake Agassiz eastern outlet and similar reconstructions for the southern (Fisher and Lowell, 2006; Fisher et al., 2008) and northern (Fisher et al., 2009) outlets, they suggest that Lake Agassiz had no outlets during the Younger Dryas with an outlet opening only after the end of the Younger Dryas. Lowell et al. (2009) thus attribute the Moorehead low stand either to drainage beneath the Laurentide Ice Sheet (LIS) or to enhanced evaporation that had to exceed water inputs from precipitation across the Lake Agassiz drainage basin and meltwater from the LIS.

With regard to their argument for subglacial drainage, Lowell et al. (2009) state that “glaciology identifies possible routes that would drain the basin,” but unfortunately they do not elaborate on how glaciology identifies these routes, where these routes are, or where the water might have gone. To our knowledge, drainage beneath the ice sheet is untenable and unsupported by field evidence: the surface slope of the LIS at this time would have developed a hydraulic gradient that forced water to drain into the lake (i.e., Clarke et al., 2004), a direction that is clearly shown by the numerous eskers in the region (Sado et al., 1994).

With regard to their water-balance argument, the rate of evaporation that would have been required to stabilize Lake Agassiz during this low phase would have been unrealistically high. Based on previous climate modeling and analysis of the LIS hydrology (Kutzbach et al., 1998; Licciardi et al., 1999), a reasonable estimate of the combined volume of net moisture and meltwater discharge into the lake is ~2200 km^3 yr^{-1}. This volume of water, distributed over the surface area of the early Moorhead phase of Lake Agassiz (117,000 km^2) (Leverington et al., 2000), would have required a minimum evaporation rate of ~18.8 m yr^{-1} in order to maintain the lake at the Moorhead size. During the late Moorehead phase (185,000 km^2) (Leverington et al., 2000), the rate would have been reduced to ~11.9 m yr^{-1}. For perspective, the annual evaporation rate for the Dead Sea is 1.1–1.2 m (Lensky et al., 2005) and 0.4 m for Lake Ontario (Quinn, 1979). Additionally, in a coupled lake-climate simulation of Lake Agassiz (Hostetler et al., 2000), the mean-annual evaporation rate of the lake is 0.2 m. The lake simulation was constrained by geologic evidence that suggests that water temperature of Lake Agassiz may not have exceeded ~5 °C, indicating that substantial solar heating was expended in melting ice and heating cold meltwater. Even if our estimate of the freshwater input to the lake is too high, to achieve a realistic evaporation rate (<1 m yr^{-1}) would require water input rates to the lake to be <190 km^3 yr^{-1}, a value well outside the limits of any reasonable water input rate. Based on this analysis, we believe the only explanation for maintaining the lake at the Moorehead low stand is by active drainage through an outlet lower than the southern outlet.

We note that sole use of minimum limiting radiocarbon dates will by default produce nothing but a history of ice-margin retreat. In this vein, Lowell et al. (2009) neglect several publications that suggest a more complex ice-margin retreat history than their simple one developed from minimum limiting radiocarbon dates. Flower et al. (2004) use δ^{18}O of seawater (δ^{18}O$_{sw}$) records from the Gulf of Mexico to argue that discharge through the southern outlet (i.e., Mississippi River) abruptly decreased at the start of the Younger Dryas, suggesting abandonment of this outlet several hundred years earlier than the date suggested by Lowell et al. (2009); Fisher and Lowell (2006); Fisher et al. (2008). Furthermore, Carlson et al. (2007) showed that after accounting for the competing effect of temperature on foraminifera δ^{18}O, there is a significant decrease in δ^{18}O$_{sw}$ in the St. Lawrence estuary at the start of the Younger Dryas, indicating that freshwater was routed from the southern outlet to the eastern outlet. Four additional independent geochemical runoff tracers confirm the routing of Lake Agassiz discharge through the St. Lawrence estuary at the start of the Younger Dryas (Carlson et al., 2007), in agreement with earlier reconstructions (Broecker et al., 1989; Licciardi et al., 1999; Clark et al., 2001).

Finally, Lowell et al. (2009) neglect previous work by Lowell et al. (1999), which dated a readvance of the Lake Superior Lobe across Lake Superior at the end of the Younger Dryas. Lowell et al. (1999) argued that this readvance was contemporaneous along much of the southern LIS extending to eastern Quebec (St. Narcisse Moraine) (LaSalle and Elson, 1975; LaSalle and Shilts, 1993). Given that the majority of the southern LIS readvanced during the Younger Dryas (Lowell et al., 1999), we question the assumption of Lowell et al. (2009) that no readvance occurred just west of Lake Superior, as has been suggested by Teller et al. (2005) and mapped by Clayton (1984). We thus conclude that Lake Agassiz freshwater was routed eastward at the start of the Younger Dryas, in agreement with the original hypothesized forcing of this event (Johnson and McClure, 1976; Rooth, 1982).

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References

Broecker, W.S., Kennett, J.P., Flower, B.P., Teller, J.T., Trumbore, S., Bonani, G., Wolfli, W., 1989. Routing of meltwater from the Laurentide Ice Sheet during the Younger Dryas cold episode. Nature 341, 318–321.

Carlson, A.E., Clark, P.U., Haley, B.A., Klinkhammer, G.P., Simmons, K., Brook, E.J., Meissner, K.J., 2007. Geochemical proxies of North American freshwater routing during the Younger Dryas cold event. Proceedings of the National Academy of Sciences 104, 6556–6561.

Clark, P.U., Marshall, S.J., Clarke, G.K.C., Hostetler, S.W., Licciardi, J.M., Teller, J.T., 2001. Freshwater forcing of abrupt climate change during the last glaciation. Science 293, 283–287.

Clarke, G.K.C., Leverington, D.W., Teller, J.T., Dyke, A.S., 2004. Paleohydraulics of the last outburst flood from glacial Lake Agassiz and the 8200 BP cold event. Quaternary Science Reviews 23, 389–407.

Clayton, L., 1984. Pleistocene geology of the Superior Region, Wisconsin. In: Information Circular, 46. Wisconsin Geological and Natural History Survey, Madison, WI, pp. 1–40.

Fisher, T.G., Lowell, T.V., 2006. Questioning the age of the Moorehead Phase in the glacial Lake Agassiz basin. Quaternary Science Reviews 25, 2688–2691.

Fisher, T.G., Waterson, N., Lowell, T.V., Hajdas, I., 2009. Deglaciation ages and meltwater routing in the Fort McMurray region, northeastern Alberta and northwestern Saskatchewan, Canada. Quaternary Science Reviews 28. doi:10.1016/j.quascirev.2009.02.003.

Fisher, T.G., Yansa, C.H., Lowell, T.V., Lepper, K., Hajdas, I., Ashworth, A., 2008. The chronology, climate, and confusion of the Moorehead Phase of glacial Lake Agassiz: new results from the Ojata Beach, North Dakota. Quaternary Science Reviews 27, 1124–1135.

Flower, B.P., Hastings, D.W., Hill, H.W., Quinn, T.M., 2004. Phasing of deglacial warming and Laurentide Ice Sheet meltwater in the Gulf of Mexico. Geology 32, 597–600.

Hostetler, S.W., Bartlein, P.J., Clark, P.U., Small, E.E., Solomon, A.M., 2000. Simulated influences of Lake Aggasiz on the climate of central North America 11,000 years ago. Nature 405, 334–337.

Johnson, R.G., McClure, B.T., 1976. A model for Northern Hemisphere continental ice sheet variation. Quaternary Research 6, 325–353.

Kutzbach, J., Gallimore, R., Harrison, S., Behling, P., Selin, R., Laarif, F., 1998. Climate and biome simulations for the past 21,000 years. Quaternary Science Reviews 17, 473–506.

LaSalle, P., Elson, J.A., 1975. Emplacement of the St. Narcisse moraine as a climatic event in eastern Canada. Quaternary Research 5, 621–625.

LaSalle, P., Shilts, W.W., 1993. Younger Dryas-age readvance of Laurentide ice into the Champlain Sea. Boreas 22, 25–37.

Lensky, N.G., Dvorkin, Y., Lyakhovsky, V., Gertman, I., Gavrieli, I., 2005. Water, salt and energy balances of the Dead Sea. Water Resources Research 41, W12418. doi:10.1029/2005WR004084.

Leverington, D.W., Mann, J.D., Teller, J.T., 2000. Changes in the bathymetry and volume of glacial Lake Agassiz between 11,000 and 9300 ^{14}C yr B.P. Quaternary Research 54, 174–181.

Licciardi, J.M., Teller, J.T., Clark, P.U., 1999. Freshwater routing by the Laurentide ice sheet during the last deglaciation. In: Clark, P.U., Webb, R.S., Keigwin, L.D. (Eds.), Mechanisms of Global Climate Change at Millennial Time Scales. Geophysical Monthly Series, No. 112. American Geophysical Union, pp. 177–201.

Lowell, T.V., Fisher, T.G., Hajdas, I., Glover, K., Loope, H., Henry, T., 2009. Radiocarbon deglaciation chronology of the Thunder Bay, Ontario area and implications for ice sheet retreat patterns. Quaternary Science Reviews 28. doi:10.1016/j.quascirev.2009.02.025.

Lowell, T.V., Larson, G.J., Hughes, J.D., Denton, G.H., 1999. Age verification of the Lake Gribben forest bed and the Younger Dryas advance of the Laurentide Ice Sheet. Canadian Journal of Earth Sciences 36, 383–393.

Quinn, F.H., 1979. An improved aerodynamic evaporation technique for large lakes with application to the International Field Year for the Great Lakes. Water Resources Research 15, 935–940.

Rooth, C., 1982. Hydrology and ocean circulation. Progress in Oceanography 11, 131–149.

Sado, E.V., Fullerton, D.S., Goebel, J.E., Ringrose, S.M., 1994. Quaternary Geologic Map of the Lake Nipigon 4° × 6° Quadrangle, United States and Canada. U.S. Geological Survey, Report: I-1420 (NM-16). U.S. Geological Survey, Reston, VA. 1 sheet.

Teller, J.T., Boyd, M., Yang, Z., Kor, P.S.G., Fard, A.M., 2005. Alternative routing of Lake Agassiz overflow during the Younger Dryas: new dates, paleotopography, and a re-evaluation. Quaternary Science Reviews 24, 1890–1905.

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