Forum

Deglacial history of the West Antarctic Ice Sheet in the Weddell Sea embayment: Constraints on past ice volume change: REPLY

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Michael J. Bentley[1], David E. Sugden[2], Christopher J. Fogwill[3], Anne M. Le Brocq[3], Alun L. Hubbard[4], Tibor J. Dunai[5], and Stewart P.H.T. Freeman[6]

[1]*Department of Geography, University of Durham, South Road, Durham DH1 3LE, UK*

[2]*School of GeoSciences, University of Edinburgh, Drummond Street, Edinburgh EH9 8XP, UK*

[3]*Geography, College of Life and Environmental Sciences, University of Exeter, Rennes Drive, Exeter EX4 4RJ, UK*

[4]*Institute of Geography and Earth Sciences, Aberystwyth University, Aberystwyth, Ceredigion SY23 3DB, UK*

[5]*Institut für Geologie und Mineralogie, Universität zu Köln, Zülpicher Str. 49 b, D-50674 Köln, Germany*

[6]*Scottish Universities Environmental Research Centre, Scottish Enterprise Technology Park, East Kilbride G75 0QF, UK*

We welcome Clark's (2011) interest in our deglacial history of the Ellsworth Mountains, West Antarctica. The essence of his Comment is to ask why we did not consider an alternative interpretation that the ice sheet limit we dated represents a recessional position during the end of the last glacial cycle, rather than its maximum position. In this alternative model, the limit would have formed during thinning from an earlier and thicker cold-based ice sheet. Below we outline the reasoning behind our suggestion that the dated limit is a maximum position and why the recessional model appears less likely to have occurred. Before doing so, we should note clearly that we do agree that ice *has* been above the altitude of the limit, but it is the age of this thicker ice sheet that we disagree upon (Bentley et al., 2010).

First, we noted in the paper the strong weathering contrast between clasts below and above the limit. Clark provides an excellent summary of the debate in the Arctic regarding the presence of fresh glacial material deposited over weathered, older surfaces. Indeed, the same situation also occurs in the Sarnoff Mountains of Marie Byrd Land, West Antarctica (Sugden et al., 2005). One key difference between the Ellsworth work and the Arctic work to which Clark refers is that we found no fresh erratics above the limit. This is in spite of looking for fresh erratics at all altitudes, including above the 480 m limit because we initially suspected that the higher Denton et al. (1992) trimline was the Last Glacial Maximum (LGM) limit (Bentley and Anderson, 1998). Furthermore, the erratics we dated above the limit, and those dated by Todd et al. (2004) all gave old ages, substantially predating the global LGM, contrasting to the Arctic where cosmogenic nuclide (CN) ages of erratics showed the presence of younger over-riding ice (e.g., Davis et al., 2006; Briner et al., 2006). In the Ellsworth Mountains, those samples with paired Al and Be analysis showed continuous exposure for several 100 k.y.

Second, from our understanding of depositional regime, we suggest it is unlikely that a thicker ice sheet could have existed without leaving a significant drift deposit. As with many other Antarctic locations (e.g., Todd et al., 2010), the majority of moraines in this part of the Ellsworth Mountains are currently deposited from supraglacial debris on marginal blue ice areas (Fogwill et al., 2011). Given mean annual temperatures (~−30 °C) at these locations, marginal ice sheet thicknesses of only tens to a few hundreds of meters, and ice sheet flow patterns past numerous source areas for supraglacial material, it seems likely that supraglacial deposition has persisted as the dominant mechanism. Yet Clark's hypothesis would require an abrupt shift from a no- or sparse-deposition regime to one of extensive supraglacial deposition, in order to form the extensive drift layer as the ice sheet thinned to our mapped limit.

Clark makes a wider comment about the potential for thicker ice in two other areas of Antarctica where geomorphology and CN work have been used to infer former ice sheet limits. Other studies (e.g., Todd et al., 2010) have defined maximum ice sheet elevations in West Antarctica from ice-marginal locations similar to ours, where supraglacial deposition is dominant, where there are abrupt drift limits, and where workers are cognisant of the cold-based ice debate. As in the Ellsworths, no young erratics have yet been found above the inferred LGM limits.

Clark's Comment raises the difficulty of interpreting negative evidence. We cannot rule out a short-lived thickening of the ice, but without some evidence of its existence in the form of fresh erratics or glacial geomorphology, and without some explanation of the contrast in drift deposition, we find the most parsimonious explanation to be that the mapped limit represents the maximum limit. The future discovery of any younger (post-LGM) ages in the zone above the trimline would invalidate our hypothesis, but as yet such erratics have not been found despite extensive searching in a range of locations.

In summary, we cannot rule out Clark's interpretation, but in the absence of evidence for a thicker ice sheet during the LGM, the simplest explanation supported by the data available is that the limit marks the LGM extent of the ice sheet.

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