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Constraints on ice volume changes of the WAIS and Ross Ice Shelf since the LGM based on cosmogenic exposure ages in the Darwin-Hatherton glacial system of the Transantarctic Mountains

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Quantitative assessment of the spatial and temporal scale of ice volume change of the West Antarctic ice sheet (WAIS) and Ross Ice Shelf since the last glacial maximum (LGM) ~20 ka is essential to accurately predict ice sheet response to current and future climate change. Although global sea level rose by approximately 120 metres since the LGM, the contribution of polar ice sheets is uncertain and the timing of any such contribution is controversial. Mackintosh et al (2007) suggest that sectors of the EAIS, similar to those studied at Framnes Mountains where the ice sheet slowly calves at coastal margins, have made marginal contributions to global sea-level rise between 13 and 7 ka. In contrast, Stone et al (2003) document continuing WAIS decay during the mid-late Holocene, raising the question of what was the response of the WAIS since LGM and into the Holocene. Terrestrial evidence is restricted to sparse coastal oasis and ice free mountains which archive limits of former ice advances. Mountain ranges flanking the Darwin-Hatherton glaciers exhibit well-defined moraines, weathering signatures, boulder rich plateaus and glacial tills, which preserve the evidence of advance and retreat of the ice sheet during previous glacial cycles. Previous studies suggest a WAIS at the LGM in this location to be at least 1,000 meters thicker than today.

As part of the New Zealand Latitudinal Gradient Project along the Transantarctic, we collected samples for cosmogenic exposure dating at a) Lake Wellman area bordering the Hatherton Glacier, (b) Roadend Nunatak at the confluence of the Darwin and Hatherton glaciers and (c) Diamond Hill which is positioned at the intersection of the Ross Ice Shelf and Darwin Glacier outlet. While the technique of exposure dating is very successful in mid-latitude alpine glacier systems, it is more challenging in polar ice-sheet regions due to the prevalence of cold-based ice over-riding events and absence of outwash processes which removes glacially transported debris.

Our glacial geomorphic survey from ice sheet contact edge (~850 masl) to mountain peak at 1600 masl together with a suite of 10Be and 26Al exposure ages, documents a pre-LGM ice volume at least 800 meters thicker than current ice levels which was established at least 2 million years ago. However a complex history of exposure and re-exposure of the ice free regions in this area is seen in accordance with advance and retreat of the ice sheets that feeds into the Darwin –Hatherton system. A cluster of mid-altitude boulders, located below a prominent moraine feature mapped previously as demarcating the LGM ice advance limits, have exposure ages ranging from 30 to 40 ka. Exposure ages for boulders just above the ice contact range from 1to 19 ka and allow an estimate of inheritance. Hence, we conclude that LGM ice volume was not as large as previously estimated and actually little different from what is observed today. These results raise rather serious questions about the implications of a reduced WAIS at the LGM, its effect on the development of the Ross Ice Shelf, and how the Antarctic ice sheets respond to global warming.

J. O. Stone et al., Science v299, 99 (2003).
A. Mackintosh, D. White, D. Fink, D. Gore et al, Geology, v 35; 551–554 (2007).