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

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Peter U. Clark
Department of Geosciences, Oregon State University, Corvallis, Oregon 97331, USA

Boundaries along valley or mountain slopes separating fresh, largely unweathered glacial deposits or bedrock below from more highly weathered deposits or bedrock above (weathering zones) have long been used to constrain vertical ice limits in Scandinavia (Dahl, 1966) and the Canadian Arctic (Ives, 1957; Boyer and Pheasant, 1974). The concept of constraining vertical ice limits was challenged by an alternative hypothesis in which the weathering zones mark a thermal boundary between erosive warm-based ice and non-erosive cold-based ice (Sugden and Watts, 1977; Denton and Hughes, 1981). This issue remained largely unresolved, however, until direct evidence for the age of the weathering zones first became available in the 1990s and 2000s: cosmogenic nuclide (CN) ages now provide conclusive evidence that the upper, more weathered surfaces were covered by cold-based, largely non-erosive ice at the Last Glacial Maximum (LGM) (Davis et al., 2006; Phillips et al., 2006; Goehring et al., 2008). Recent CN dating from Antarctica also shows that highly weathered surfaces were preserved beneath cold-based ice during the last glaciation (Stone et al., 2003; Sugden et al., 2005; Strasky et al., 2009; Di Nicola et al., 2009).

Bentley et al. (2010) argue that a moraine dated by CN to ca. 15 ka represents the maximum LGM surface reached by the West Antarctic Ice Sheet in the Weddell Sea drainage, because it separates a lower, less-weathered zone from a higher, more-weathered zone. From this interpretation, they conclude that the LGM ice sheet in this region was at most 480 m thicker than present, indicating little contribution by this sector of the ice sheet to global sea-level rise, including meltwater pulse 1a (mwp-1a) ca. 14.5 ka. Bentley et al. point to two other lines of evidence in support of thinner ice, including an unpublished ice-core record and two CN ages on bedrock from the Shackleton Range that, at the same time, "cannot rule out the possibility that the mountain has been covered intermittently for short periods by cold-based ice" (Fogwill et al., 2004, p. 267).

Given what we now know about weathering zones elsewhere, it is surprising that Bentley et al. do not consider the alternative hypothesis that thicker, cold-based LGM ice may have covered the upper, more highly weathered, surface prior to 15 ka, perhaps up to the well-defined erosional trimline mapped by Denton et al. (1992), and that the moraine mapped by Bentley et al. (2010) represents a recessional phase following some amount of ice-sheet thinning after the LGM. In fact, Bentley et al. refer to four CN ages (ranging from 41 ± 3 to 67 ± 5 ka) in an unpublished abstract by Todd et al. (2004) "from sites…above our mapped limit" that, given the likelihood of TCN inheritance in these samples (e.g., Bentley et al., 2010), provide plausible support for thicker LGM ice in this region. Under this scenario, ice-sheet thinning to the ca. 15 ka moraine may have represented a more substantial contribution to sea level, including mwp-1a.

Similar studies from West Antarctica (Ackert et al., 1999, 2007) also conclude that thicker LGM ice did not exist, because of weathered surfaces above limits dated by CN. Given the preponderance of evidence for cold-based LGM ice covering highly weathered surfaces elsewhere in Antarctica and in the Northern Hemisphere, however, the use of such surfaces alone to infer ice limits remains unconstrained. On the other hand, those cases where CN ages have established cold-based conditions provide an important thermodynamic constraint for ice-sheet models (Stone et al., 2003; Sugden et al., 2005; Strasky et al., 2009; Di Nicola et al., 2009).

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