Swinging gate or Saloon doors: Do we need a new model of Ross Sea deglaciation?

Robert P. Ackert Jr.
Department of Earth and Planetary Science, Harvard University, Cambridge MA 02138

Knowledge of the history of the marine-based West Antarctic Ice Sheet (WAIS) is important due to its potential instability in the face of global warming. With an ice volume equivalent ~5m of sea level, even partial collapse could have disastrous consequences along the World's coasts. New data from the WAIS interior are stimulating reappraisal of established WAIS reconstructions and models of grounding line retreat. In particular, models that simulate stable isotope and thinning data from the Siple Dome ice core indicate that surprisingly low surface elevations (~1000 m) persisted there during the last glacial maximum (LGM)(Price et al., 2007; Waddington et al., 2005). In addition, data from near the head of the Mercer Ice Stream, close to the WAIS divide, indicate maximum ice elevations were <125 m above the present surface and occurred as late as the early Holocene. These new data challenge the traditional view of WAIS expansion in the Ross Embayment. Rather than a relatively thick ice sheet sourced largely in West Antarctica, with ice streams similar in length to those of today (Denton and Hughes, 2002), a much thinner ice sheet, with a significant contribution from East Antarctica (Licht et al., 2005) and low slope ice streams extending across the Ross Embayment (Parizek and Alley, 2004), seems more plausible.

This alternative WAIS reconstruction calls for re-examination of deglaciation models. Rather than a "swinging gate", hinged on Roosevelt Island (Figure 1a)(Conway et al., 1999), grounding line retreat may have been characterized by a calving embayment centered over the Eastern Basin in the central Ross Sea, with retreat more normal to flow lines originating from both outlet glaciers of the EAIS flowing through the Transantarctic Mountains and from Marie Byrd Land (Figure 1b). Three lines of circumstantial evidence support a "saloon door" model with early formation of a calving bay in the central Ross Sea.

First, it is consistent with broadly limiting ^{14}C dates on tills and overlying glacial marine sediment in the Ross Sea, given the inherent uncertainty in the large, poorly constrained corrections for old organic carbon. Secondly, ice recession from maximum positions on the west coast of McMurdo Sound was underway by ~14.5 ka (Hall et al., 2000) indicating that the WAIS lobe in McMurdo Sound began thinning ~4500 years prior to final deglaciation (unloading) at ~9 ka. Price et al. (2007) find thinning began at Siple dome as early as ~14 ka. Given the inherent lag in ice sheet response, it seems likely that significant thinning due to grounding line retreat began prior to 14 ka. Third, relative sea level (RSL) curves obtained from raised beaches on the Scott Coast have an exponential form, consistent with the final unloading of grounded ice occurring between 8 and 9 ka (Hall and Denton, 2000; Hall et al., 2004). However, the highest raised beaches are only ~21 m above sea level, suggest ice thickness of only ~100 m. In contrast, the actual ice thickness, as indicated by the elevation of Ross Sea drift was ~400 m. This apparent inconsistency results from the persistence of an ice shelf following retreat of the grounding line that prevented the formation of raised beaches (Hall et al., 2004; Stuiver et al., 1981). The implication is that >70 m of rebound (~300 m of thinning) occurred between 14.5 and 9 ka.

This "saloon door" style of retreat in turn has potentially large implications for the interpretations of grounding line retreat rates based existing chronologic data along the Victoria Land coast. For example, tying existing glacial chronologies to the swinging gate model, Conway et al. (1999) concluded that most of the grounding line recession from the LGM position near Coulman Island to Ross Island occurred during the early to mid Holocene, in the absence of substantial sea level or climate forcing (Figure 1a). Consequently, they inferred that grounding line retreat from Ross Island to the Siple Coast occurred even more recently, may well be ongoing, and that grounding line retreat could continue even in the absence of further external forcing. However, if ice retreat instead followed a calving bay centered in the Ross embayment (Figure 1b), deglaciation could have begun earlier, initiated by sea level and temperature forcing. The chronologic constraints utilized by Conway et al. (1999) would instead record only the final deglaciation of grounded ice that lingered along the Victoria Land and Marie Byrd Land coasts after the grounding line had passed by in the central Ross Embayment. These alternatives have significantly different implications for the sensitivity of the WAIS to climate change.

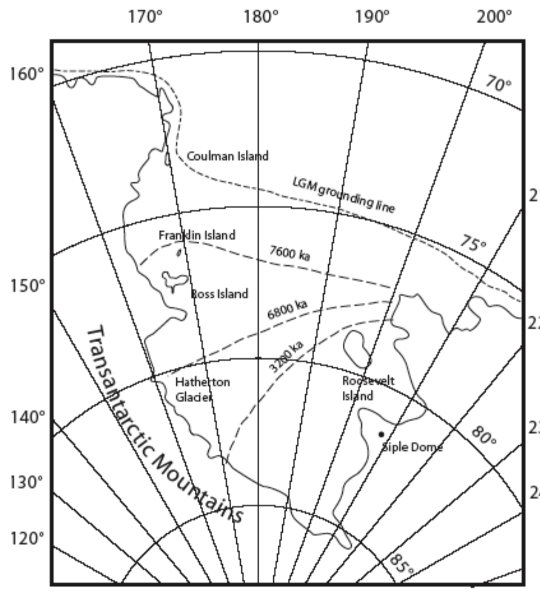

Figure 1a) Cartoon depicting the *swinging gate* mode of Ross Sea deglaciation (modified from Conway et al., 1999). The dashed line represents the location of the grounding line. Note that grounding line retreat occurs fastest along the deep troughs fronting the TAM, perhaps aided by higher ablation rates due to katabatic winds (Stuiver et al., 1981).

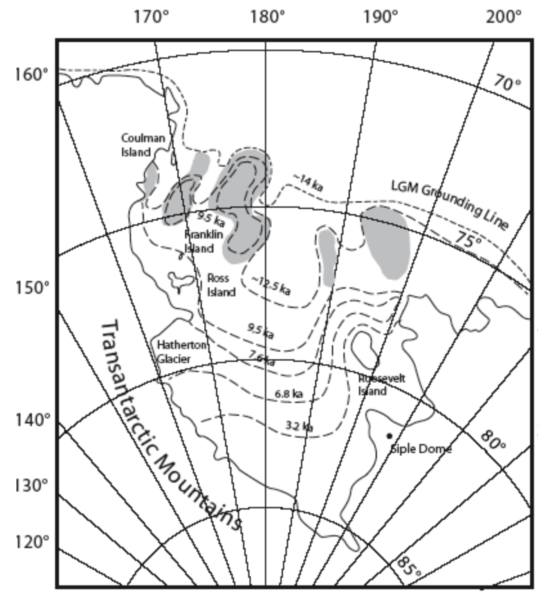

Figure 1b) Cartoon depicting the *saloon door* mode of Ross Sea deglaciation suggested by interior WAIS elevation data, and composition of Ross Sea sediments. The LGM and ~12.5 ka grounding line positions (dashed line) are based on the mapping in the Ross Sea that indicates streaming ice in troughs and divergent flow from banks (Shipp et al., 1999). Shallow banks marked in gray.

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