A surprisingly large marine ice cap at Heard Island during the Last Glacial Maximum?

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Summary A new compilation of bathymetric surveys surrounding Heard Island, near 53°00' S, 73°30' E, appears to show geomorphic evidence that the island and surrounding submarine plateau were covered by a 100-km-wide tidewater ice cap at some time in the past. If this ice cap existed, it presumably did so at the last glacial maximum when relative sea level was lower than present. Even so, it would have been grounded in at least 180 m of water and therefore must have been several hundred meters thick.

Citation: Balco, G. (2007). A surprisingly large marine ice cap at Heard Island during the Last Glacial Maximum? in Antarctica: A Keystone in a Changing World – Online Proceedings of the 10th ISAES X, edited by A.K. Cooper and C.R. Raymond et al., USGS Open-File Report 2007-1047, Extended Abstract 147, 4 p.

Introduction

The glacial history of the scattered islands in the Southern Ocean is a potentially important source of information about paleoclimate and paleoceanography in a region where massive environmental changes must have occurred, but few if any records of these changes exist. The most striking feature of these islands from the perspective of past and present glacier change is that those south of the prominent climate and oceanographic gradient at the Antarctic Polar Front are almost entirely glaciated at present; those north of the Antarctic Polar Front are largely unglaciated now but show clear evidence of past glaciation. Thus, the extent of glaciation of these islands and the timing of ice retreat are presumably closely linked to Southern Ocean oceanography, and understanding this could yield important information about past oceanographic changes (e.g., Hall, 2004). This glacial history is little known, as these islands have been rarely visited by glacial geologists, and even less frequently studied in any detail. A new compilation of bathymetric data around Heard Island, however, provides a glimpse into this little-known story. Here we briefly describe the data set and point out the apparent evidence for significantly expanded glaciation that it reveals.

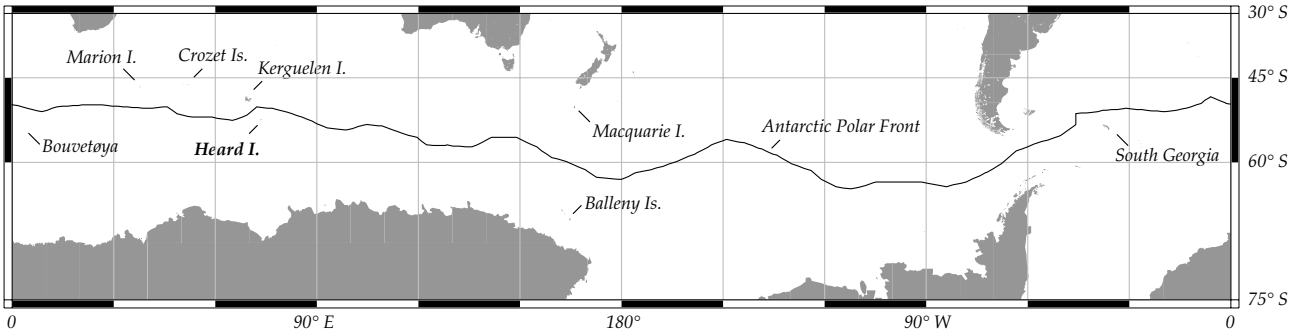

Figure 1. The islands of the Southern Ocean. The mean location of the Antarctic Polar Front is from Moore et al. (1999).

Heard Island

Heard Island is an Australian territory located near 53°00' S, 73°30' E (Figures 1,2). The land exposed above sea level at present consists of a prominent volcano called Big Ben, which is nearly entirely glaciated. Kiernan and McConnell (1999) describe the geomorphology of the island in detail. The present glaciers extend nearly to sea level. Heard Island and its much larger neighbor to the north, Kerguelen Island, are the small subaerially exposed portions of the much larger Kerguelen Plateau, a prominent physiographic feature of the Southern Ocean. Much of the Kerguelen Plateau that surrounds both Kerguelen and Heard Islands lies in water depths less than several hundred meters. Given the evidence that Kerguelen Island has been entirely covered by ice to well outside its present shoreline in the past (Hall, 2004), this presents the possibility that, at times of low sea level during glacial maxima, ice caps significantly larger than the present size of the islands could have existed.

The new bathymetric compilation

In 2005, Mike Sexton of Geoscience Australia and the Australian Antarctic Division compiled existing bathymetric

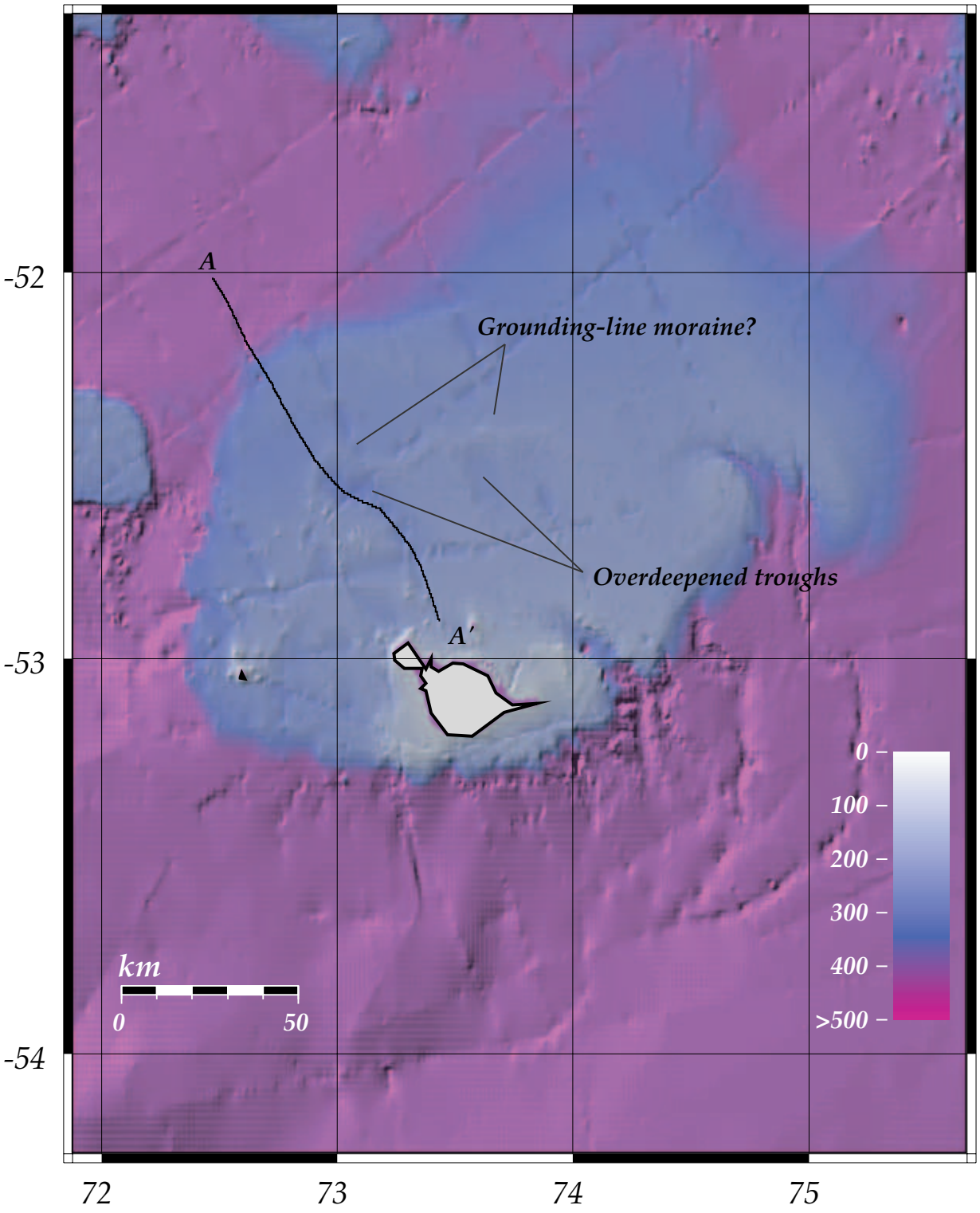

Figure 2. Color shaded-relief image of the bathymetry surrounding Heard Island. The color scale has been compressed to highlight the shallow-water areas: at the edges of the plateau, the seafloor rapidly drops to several thousand meters below sea level, which is not obvious from this presentation. A bathymetric profile along the line A-A' is shown in Figure 3.

surveys for the Heard Island region, and combined them with a large amount of new data generated by Australian fishing vessels. The resulting bathymetric map is significantly improved over previously available charts, especially in areas of shallow water and complex terrain where presumably there is good fishing. Figure 2 shows a subset of the new data set centered around Heard Island. The data sources and gridding procedure are documented in Sexton (2005).

Discussion: evidence for glaciation

The bathymetric map reveals two geomorphic features that suggest extensive glaciation of the shelf surrounding Heard Island. First, a linear ridge is approximately concentric with, and 50-80 km north of, the northern shoreline of the island. This ridge is up to 50 m high and its top is at 150-230 m water depth. Second, there are at least two elongate, overdeepened troughs immediately landward of and perpendicular to this ridge. Although these features are only roughly defined by the bathymetric grid, each is crossed by many individual fathometer tracklines; thus, they do not appear to be artifacts of the gridding process.

This combination of features strongly suggests that they were formed by glaciation. The overdeepened linear troughs are strongly diagnostic of formation by glacial erosion, as few other erosional processes are capable of eroding overdeepened basins. Furthermore, a bathymetric profile that follows the axis of the largest overdeepened trough (Figure 3) and crosses the ridge at its distal end suggests that the ridge is wedge-shaped, steeper on its seaward than on its landward face. This asymmetry is characteristic of 'till tongues' or morainal wedges formed at glacier grounding lines, and the size and shape of this feature are similar to those of grounding zone wedges observed on the continental shelf around the Antarctic Peninsula (e.g., Heroy and Anderson, 2005). Thus, these features may record a significantly expanded ice cap on Heard Island, that extended more than 50 km from the present shoreline onto the adjacent continental shelf.

If these features do record a significantly larger ice cap, it seems most likely that this ice cap would have been present during the last glacial maximum, when relative sea level would have been ca. 125 m lower than present. If sea level lay 125 m below present, the deepest part of the elongated trough highlighted in Figures 2 and 3, which is apparently near 300 m below sea level now, would still have been ca. 180 m below sea level. The top of the inferred grounding line moraine complex shown in Figure 3 would have been ca. 120 m below sea level. Thus, if the ice cap was present at the LGM, it must have been ca. 135 m thick at its margin, which, in turn, would require that it be several hundred meters thick at its center.

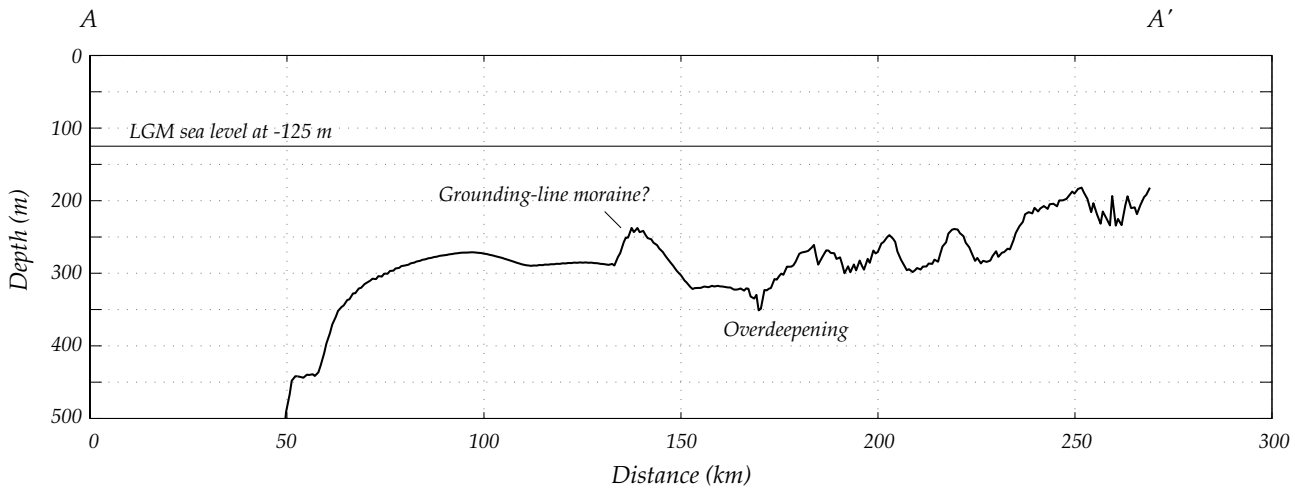

Figure 3. Bathymetric profile down the axis of the prominent elongated trough, crossing the suggested grounding line moraine complex. The location is shown on Figure 2. The data in the overdeepened region are noisy due to crossings of fathometer lines from varying data sources that appear to have been inconsistently processed; this can be seen by comparing Figures 2 and 3.

At present, a minority of the glaciers on Heard Island actually reach tidewater, and none is grounded in a significant depth of water. Thus, for a large ice cap to extend well out onto the shelf and be grounded in ca. 120 m of water would require either that snow accumulation was significantly greater, or that ice loss by calving was less effective than present. The latter might be favored by an increased occurrence of sea ice in this area and thus a reduction in wave energy, or by colder temperatures that would reduce the availability of surface meltwater.

Summary

Obviously the foregoing observations present rather more questions than they actually answer, starting with the question of whether or not the geomorphic features noted above actually have anything to do with glaciation. However, they suggest a strong scientific justification for deploying multibeam bathymetric survey or sidescan sonar equipment on future ship transits in this region, to better evaluate whether or not these features truly represent the grounding line of a surprisingly large ice cap. In particular, detailed bathymetry of the region between our proposed grounding line moraine and the present coastline would show whether or not paleoshorelines exist at depths less than 125 m, and thus whether deglaciation preceded or postdated relative sea level rise.

Acknowledgements. Mike Sexton of Geoscience Australia very graciously provided the Heard Island bathymetric data. The present author was not involved in compiling this data set and takes no credit for the work. The foregoing observations on the glacial-geologic significance of the bathymetric data, on the other hand, are solely the opinion of the present author, who has no connection to Geoscience Australia or the Australian Antarctic Division. Thus, nothing here should be taken to imply their approval or disapproval of these observations. D. Blankenship supervised editing of this abstract.

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