New compilation of the Amundsen Sea continental shelf bathymetry

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Summary The Amundsen Sea continental shelf is one of the remotest areas of coastal Antarctica, and was relatively unexplored until the 1980s. Over the last two decades, however, oceanographic and geological interest has led to several cruises, one result of which is that there is now sufficient bathymetric data to compile a fairly detailed regional map of the Amundsen continental shelf. We have combined the available multibeam and single beam bathymetry data from this region and created a new regional bathymetric map of the Amundsen Sea continental shelf and slope. After editing the individual data sets we used a natural neighbor algorithm to interpolate between the existing data and create a grid at 5 km raster resolution. The most prominent regional feature is a series of separate trough systems along the inner shelf, which are aligned with present glaciers, separated by shallower ridges, and shoaling seaward.

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Introduction

The Amundsen Sea continental shelf is located between 100° and 135°W, south of 71°S, along the margin of the Marie Byrd Land sector of the West Antarctic Ice Sheet (WAIS). As one of the more remote Antarctic coastlines, with a nearly perennial sea ice cover and little if any bottom water formation, it remained largely unexplored until the 1980s and maps of the area had gaps or have been misleading. Interest in the region increased with the 1994 discovery that the ice shelf at the terminus of the Pine Island Glacier was melting orders of magnitude faster than the Ross and Filchner-Ronne Ice Shelves (Hellmer et al., 1998; Jacobs et al., 1996), accompanied by thinning and grounding line retreat (Rignot and Jacobs, 2002) The thinning appears to be driven by 'warm' Circumpolar Deep Water (CDW) that floods deeper areas of the Amundsen Sea continental shelf. Subsequent investigations have revealed high melt rates for other Amundsen Sea ice shelves, thinning and increased velocities of tributary glaciers, and decreasing ice surface elevations of the adjacent WAIS drainage basins (Rignot and Thomas, 2002; Wingham et al., 1998). Such findings have revived longstanding concerns about ice sheet stability in this sector (Hughes, 1973).

Much of the rapid melting occurs within deep troughs on the inner shelf, presumably cut when the ice streams of larger ice sheets were grounded on the present sea floor (Evans et al., 2006; Lowe and Anderson, 2002). As these features now extend beneath the small Amundsen Sea ice shelves, it is important to understand what controls CDW access to the troughs, along with their characteristics and connections to the shelf break. A better description of the continental shelf bathymetry will become a key element in improved models of ocean circulation, ocean-ice interactions and ice sheet behavior, and for reconstructions of paleo-ice flow (Evans et al., 2006; Kellogg and Kellogg, 1987; Larter et al., 2007; Lowe and Anderson, 2002).

While several previous studies of Amundsen Sea bathymetry provided significant new insights, most have been restricted to local areas covered by single cruises. The aggregated tracks of several expeditions, including recent cruises on the RRS James Clark Ross and RV Polarstern in 2006 and the Nathaniel B Palmer in 2007, have now been compiled into a regional chart that provides an overview of the regional bathymetric setting and its geological, oceanographic and glaciological implications.

Data compilation

Multibeam swath-mapping on several recent expeditions has significantly improved our knowledge of bathymetric features on and along the Amundsen Sea continental shelf. Here we integrate those data and add other available bathymetric and geophysical measurements to create a new regional map of this sector of the continental margin. Our sources include single-beam and multi-beam bathymetry available through the NSF-funded Antarctic Multibeam synthesis database, soundings from earlier cruises in the GEODAS database (National Geophysical Data Center), and measurements from James Clark Ross cruises JR84 and JR141, Polarstern cruises ANT-XI/3, ANT-XII/4, ANT-XVIII/5a, and ANT-XXIII/4, and NB Palmer cruise 07-02. To connect the bathymetry to the adjacent land and ice-covered areas we used the new airborne-geophysical data collected as part of the AGASEA and UK Basal Balance mission (Holt et al., 2006; Vaughan et al., 2006) and the older BEDMAP data set outside of the AGASEA coverage (Lythe et al., 2000).

We generated and loaded the swath bathymetry, AGASEA, and BEDMAP as point data together with the single soundings into a geographic information system (ArcGIS). Then we went through several iterations of creating a new bathymetry grid with 1000 m resolution, identifying suspicious bathymetric features, and editing. Finally, we used a natural neighbor gridding routine to create the final bathymetry grids with 5000 m cell size.

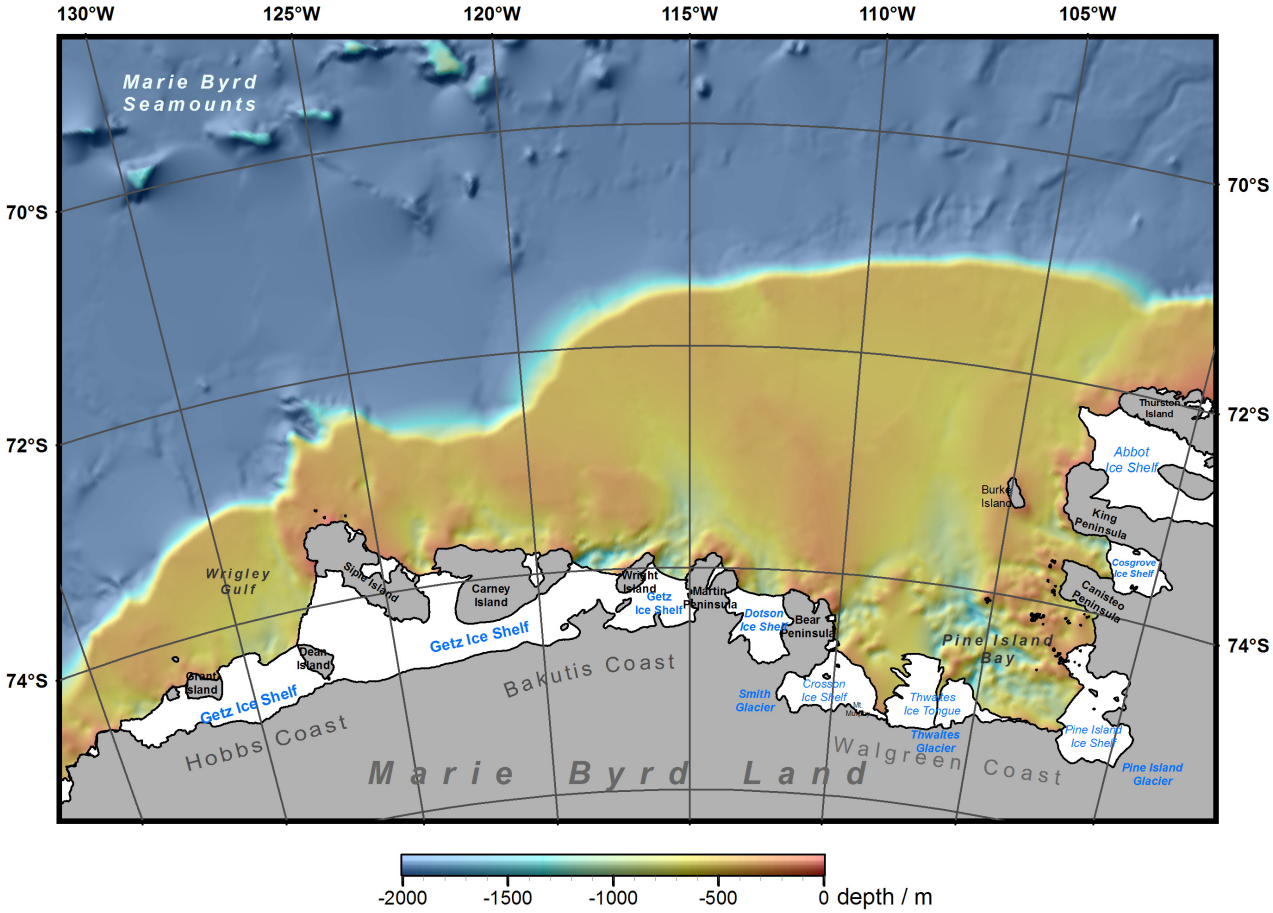

Figure 1. Bathymetry of the Amundsen Sea based on data available through March 2007. The coastline, ice shelves, and grounding lines are based on the Antarctic Digital Database 4.1, but have been modified to fit more accurate MODIS satellite image. The sub-ice topography is based on AGASEA/BBAS and BEDMAP datasets.

Results

Figure 1 shows a map of the resulting grid. Although the data set still has major gaps, the shelf break and the main structures of the shelf between 100°W and ~135°W are clearly defined. The Amundsen Sea shelf is characterized by a series of deep troughs on the inner shelf that gradually shoal towards the outer shelf. Several of these troughs merge on the mid shelf to form larger systems with two systems dominating the broader eastern shelf. The one in Pine Island Bay combines troughs that originate from the Pine Island, Thwaites, and Smith Glaciers. A second system includes troughs from the Dotson and western Getz ice shelves. Maximum depths in both systems exceed 1600 m. Several smaller troughs and related systems are found near Cosgrove Ice Shelf, and off Carney Island and the central and western Getz Ice Shelf fronts. Detailed bathymetry shows morphological features including mega-scale glacial lineations and drumlins that indicate that these troughs where occupied by paleo-icestreams.

The trough systems appear to connect to major depression on the outer shelf and could provide access of warmer CDW onto the shelf. However, except for one of the minor trough system west of Siple Island, where the connection is well established, gaps in the present data hinder final confirmation of a deep connection.

The general morphology of the continental slope and rise is comparable to other parts of the Antarctic continental margins. The slope ranges from 2° – 5° with parts of the upper slope being dissected by gullies (Dowdeswell et al., 2006; Lowe and Anderson, 2002). More detailed multibeam coverage of both the slope and shelf is needed to

definitively relate gullies, depressions, lineations, troughs and paleo-ice streams in all parts of the continental margin. An exception of the general slope morphology is located north of Siple Island (125°W – 127°W), where the slope is interrupted by a large SE – NW oriented ridge at depths of 1-3 km. This ridge itself is incised by steep canyons. Its shape and water depth preclude glacial links, but its proximity to the Mt. Siple volcano and Marie Byrd Seamounts suggests a tectonic origin and possible shaping by slumping and erosional processes.

Summary

The availability of new swath bathymetry data from large parts of the Amundsen Sea and continental shelf has enabled us to create a new bathymetric map of the region. The new data compilation shows the existence and organization of major trough and ridge systems on the inner shelf. The merging of disparate data sets for this area, much of which is typically covered by perennial ice, should aid the understanding of past glacier flow and present ocean circulation. It provides guidance for future expeditions, and identifies areas where additional data are needed.

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References

Dowdeswell, J.A., Evans, J., O´Cofaigh, C. and Anderson, J.B., 2006. Morphology and sedimentary processes on the continental slope off Pine Island Bay, Amundson Sea, West Antarctica. Geological Society of America Bulletin, 118: 606–619.

Evans, J., Dowdeswell, J.A., O Cofaigh, C., Benham, T.J. and Anderson, J.B., 2006. Extent and dynamics of the West Antarctic Ice Sheet on the outer continental shelf of Pine Island Bay during the last glaciation. Marine Geology, 230: 53-72.

Hellmer, H.H., Jacobs, S.S. and Jenkins, A., 1998. Oceanic Erosion of a Floating Antarctic Glacier in the Amundsen Sea. In: S.S. Jacobs and R. Weiss (Editors), Ocean, Ice, and Atmosphere: Interactions at the Antarctic Continental Margin Antarctic Research Series. American Geophysical Union, Washington, D.C., pp. 83-99.

Holt, J.W., Blankenship, D.D., Morse, D.L., Young, D.A., Peters, M.E., Kempf, S.D., Richter, T.G., Vaughan, D.G. and Corr, H.F.J., 2006. New boundary conditions for the West Antarctic Ice Sheet: Subglacial topography of the Thwaites and Smith glacier catchments. Geophysical Research Letters, 33.

Hughes, T., 1973. Is West Antarctic Ice-Sheet Disintegrating? Journal of Geophysical Research, 78: 7884-7910.

Jacobs, S.S., Hellmer, H.H. and Jenkins, A., 1996. Antarctic ice sheet melting in the Southeast Pacific. Geophysical Research Letters, 23: 957-960.

Kellogg, T.B. and Kellogg, D.E., 1987. Recent glacial history and rapid ice stream retreat in the Amundsen Sea. J. Geophys. Res., 92: 8859-8864

Larter, R.D., Gohl, K., Hillenbrand, C.D., Kuhn, G., Deen, T.J., Dietrich, R., Eagles, G., Johnson, J.S., Livermore, R.A., Nitsche, F.O., Pudsey, C.J., Schenke, H.W., Smith, J.A., Udintsev, G. and Uenzelmann-Neben, G., 2007. West Antarctic Ice Sheet Change Since the Last Glacial Period. Eos Trans. AGU, 88: 189–196.

Lowe, A.L. and Anderson, J.B., 2002. Reconstruction of the West Antarctic Ice Sheet in Pine Island Bay during the Last Glacial Maximum and its subsequent retreat history. Quaternary Science Reviews, 21: 1879-1897.

Lythe, M.B., Vaughan, D.G. and the BEDMAP Consortium, 2000. BEDMAP - bed topography of the Antarctic. 1:10,000,000 scale map, BAS (Misc) 9. British Antarctic Survey, Cambridge.

Rignot, E. and Jacobs, S.S., 2002. Rapid Bottom Melting Widespread near Antarctic Ice Sheet Grounding Lines. Science, 296: 2020-2023.

Rignot, E. and Thomas, R.H., 2002. Mass balance of polar ice sheets. Science, 297: 1502-1506.

Vaughan, D.G., Corr, H.F.J., Ferraccioli, F., Frearson, N., O'Hare, A., Mach, D., Holt, J.W., Blankenship, D.D., Morse, D.L. and Young, D.A., 2006. New boundary conditions for the West Antarctic Ice Sheet: Subglacial topography beneath Pine Island Glacier. Geophysical Research Letters, 33.

Wingham, D.J., Ridout, A.J., Scharroo, R., Arthern, R.J. and Shum, C.K., 1998. Antarctic elevation change from 1992 to 1996. Science, 282: 456-458.