Remote sensing and in-situ studies of West Antarctic paleo-ice sheet beds: Implications for West Antarctic Ice Sheet dynamics during the late Quaternary

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Abstract
One of the largest uncertainties highlighted in the last IPCC report is future sea level rise in response to polar ice-sheet melting. The behavior of the West Antarctic Ice Sheet (WAIS) is of particular interest because the WAIS is mainly marine based and therefore could be potentially unstable. A complete collapse of the WAIS would raise global sea level by ~5.4 m. The risk of a future collapse of the WAIS could be estimated more precisely if, we understand the causes of accelerated ice flow and ice-sheet thinning (as is observed in the Amundsen Sea sector of the WAIS today) could be improved. These deglaciations are likely to depend heavily on conditions at the ice-bed. The inaccessibility of modern ice sheet beds, however, hampers in situ studies significantly. As a consequence, subglacial processes can only be insufficiently integrated into current ice sheet and climate models. An alternative method to investigate subglacial processes is remote sensing of the interface of the bed of the WAIS, which is exposed on the West Antarctic shelf. It's study gives important clues about mechanisms and modes of ice-sheet retreat following the last glacial maximum (LGM). Here, we investigate multi-beam swath bathymetry data, PARASOUND acoustic sub-bottom profiles and sediment cores collected during RV Polarstern cruise ANT-XIV/3 (10/2010-04/2010) from the West Antarctic continental shelf. Here we present initial results from Pine Island Bay (Amundsen Sea) that include multi-beam swath-bathymetry images, PARASOUND sub-bottom profiles and lithological data of sedimentary sequences collected from a previously unsurveyed area north of Burke Island. The seabed is characterized by unique pro-glacial landforms, which have not been reported from the West Antarctic shelf before. We present a preliminary interpretation of our data set and discuss possible implications for post-LGM ice-sheet retreat in the Amundsen Sea sector of the WAIS.

Regional setting & methods
East of 110°W, the Amundsen Sea Embayment’s (ASE) bathymetry is characterized by four >40-km-wide troughs. The most extensive one is the Pine Island Trough with a width of approximately 40 km and a longitudinal extension from 75°S to 72°S. Three distinctive glacial drains into the inner PUB, Pine Island-, Thwaites- and Smith Glaciers. The area around Burke Island is situated between the Pine Island paleo-ice stream trough and an over-deepened part in Ferrar Bay to the east. Here we investigate an area north of Burke Island at ~105°W, 72°5’W (Fig. a). Multi-beam echo-sounding data were collected on RV Polarstern expedition ANT-XIV/3 in early 2010. An Atlas Hydrosweep DS-2 system with 155 kHz was applied. Beam raypaths and seabed depths were calculated in near real time using sound velocity profiles derived from CTD casts on the same cruise. Parametric sub-bottom echo sounder profiles were collected simultaneously to the multi-beam swath bathymetry survey, using an Atlas PARASOUND system (secondary frequency of 5.5 kHz). PARASOUND profiles display the sub-surface at a very high resolution (up to ~1 m vertically), to as much as 10-30 m below sea floor. Sediment coring was also undertaken to obtain detailed information about the characteristics of the sea-floor sediments. The sedimentological analyses for both cores (PS75/233-1 [55.9 m] and PS75/234-1 [83.8 m]) focused on determining of the physical properties (P-wave velocities, magnetic susceptibility), shear strength measurements, determination of the water content and Grain ice analyses of the coarse fraction (63 μm - 2mm and >2 mm-fractions). The P-wave velocity data derived from a GEOFLEX multisensor core logger were measured on the whole cores while still aboard RV Polarstern. Magnetic susceptibility was additionally measured on split cores with a GEOFLEX F-point sensor. Finally Line scan images and X-ray photographs were obtained to further refine lithological units and deeper structural changes. Here we present data for core PS75/234-1 [58.0 m] and PS75/233-1 [55.9 m].

Visible features & preliminary interpretation
Figures 5 & 6 depict clearly the set of diverse morphological features present in the working area. Two sets of parallel ridges: • parallel and undulated ridges in the north and south • parallel but linear ridges in the central part Hummocky structures with an approximate wavelength of 4 km wavelengths along the whole west-north side: the isolated upheavals in the southwestern part suggest that these features continue NE- and SWwards. Distinctive depressions in the central south-western part with remarkable elevations on their northeastern sides. A clear undulating sub-bottom reflector is visible on several PARASOUND profiles (two shown here; Fig. b and c).

Conclusions & future work
As we have shown, the area N of Burke Island is characterized by some unique pro- and sub-glacial morphological features, which have never been described on the Antarctic Peninsula before. Through the exploration of the bathymetric high depressions, and the observation of the polished ice surface, we should be able to get an idea of the paleo ice flow behaviour in matters of velocities and reliabilities. Most likely we could find features, which are associated or even connected to almost stagnant ice flow in this area, which could mean that the melting ice sheet there was more durable than surrounding ice streams. To validate this, our future work will focus on searching for an additional ice core, setting the scene of the paleo ice flow history, etc. to deliver suitable basic data for potential ice-flow models of the area.

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