

Early Miocene glaciation in the Amundsen Sea, Southern Pacific: A study of the distribution of sedimentary sequences

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Abstract: *The distribution and internal architecture of seismostratigraphic sequences observed on the Antarctic continental slope and rise are results of sediment transport and deposition by bottom currents and ice sheets. Low energy input of detritus via a palaeo-delta originating in an area of the Amundsen Sea shelf and deposition of this material on the continental rise under sea ice coverage (60-21 Ma) was followed by glacial erosion in the hinterland of this part of West Antarctica (21-14.1 Ma), resulting in a larger depocentre and an increase in mass transport deposits. A higher sediment supply along a broad front with a focus via two palaeo-ice stream troughs resulted from a polythermal ice sheet. In the eastern Amundsen Sea rise the glaciogenic debris was shaped into levee-drifts by a re-circulating bottom current. A reduced sediment accumulation in the deep-sea subsequent indicates a reduced sediment supply probably in response to a colder and drier ice sheet (14.1-4 Ma). A dynamic ice sheet since 4 Ma delivered material offshore mainly via Abbott Trough and Pine Island Trough West. Interaction of this glaciogenic detritus with a west-setting bottom current resulted in the continued formation of levee-drifts in the eastern and central Amundsen Sea.*

Key words: *West Antarctic Ice Sheet, sedimentary sequences, sediment drifts, bottom water circulation, glacial development*

INTRODUCTION

Because of modern global warming and their possible contribution to sea level rise and flooding of low lying coastal areas both Antarctic and Greenland ice sheets have moved into the focus of public and scientific interest. Research has concentrated on short-term dynamics of the ice sheets in order to understand their vulnerability to a changing climate by collecting multi-disciplinary data. Little has been known about the long-term development especially of the West Antarctic Ice Sheet (WAIS), which as a marine based ice sheet generally reacts more sensitively to both atmospheric and oceanic warming than the largely terrestrial East Antarctic Ice Sheet. Information on the early phase of WAIS formation and the Cainozoic glacial history in the greater Amundsen Sea is scarce. A cold Antarctic Counter Current has bathed the Amundsen Sea implying a cold climate for that area during the Paleogene. Uenzelmann-Neben and Gohl (2012) presented indications for a pre-Miocene sea-ice cover in the Amundsen Sea based on the study of sedimentary features imaged by seismic reflection data. We here add to the discussion of the transition from pre-glacial to glacial deposition in the Cainozoic by analysing depositional patterns and the distribution of the sedimentary units.

RESULTS

Palaeo-seafloor highs and depocentres will be presented and discussed. Shape and location of a depocentre relative to the continental slope and older depocentres reveal the loci of major sediment

accumulation and allow conclusions about transport pathways and processes. A depocentre oriented parallel to the slope is interpreted to document primarily along-slope sediment transport, while a depocentre perpendicular to the slope is interpreted to indicate down-slope sediment transport. Accumulation rates computed for the depocentres are combined with observations of the occurrence of sedimentary features in the study area, such as sediment drifts and mass transport deposits (mtd), that have been reported previously (Uenzelmann-Neben and Gohl, 2012).

The top of the basement shows a high in the area of the Marie Byrd Seamounts (MBS). This high extends slightly NE-wards. The deepest basement is observed between Pine Island Trough West (PITW) and Abbott Trough (AT). Above the basement, 4 sequences are characterized, ASR-1 to ASR-IV, from older to younger. Unit ASR-I shows a broad depocentre (> 2000 m) parallel to the continental slope, which does not extend far into the ocean. The thickest parts of the depocentre (> 2500 m) can be observed a) continent-wards of the MBS in front of the Dotson-Getz Trough (DGT), b) between PITW and PITE, and c) in front of AT. The base of unit ASR-II also shows a high in the MBS area. This high is smaller than the one observed for the basement. We observe an extension towards the SE (to the slope offshore from PITW) rather than towards the NE. The deepest part of the horizon is located in the NE of the area of investigation with two smaller troughs seaward of PITW. Unit ASR-II again shows a broad depocentre (500 m) parallel to the continental slope, which extends further into the ocean than unit ASR-I's depocentre. The thickest parts of the depocentre (> 750 m) can be observed a) in the NE offshore from PITE, b) in three

locations in front of PITW and further to the W, and c) in front of AT. Two of the three thick depocentres have been deposited in up to 250 m deep troughs but the westernmost depocentre directly indicates an increased sediment input. The foci of the depocentres have shifted relative to those of unit ASR-I except the one in front of AT.

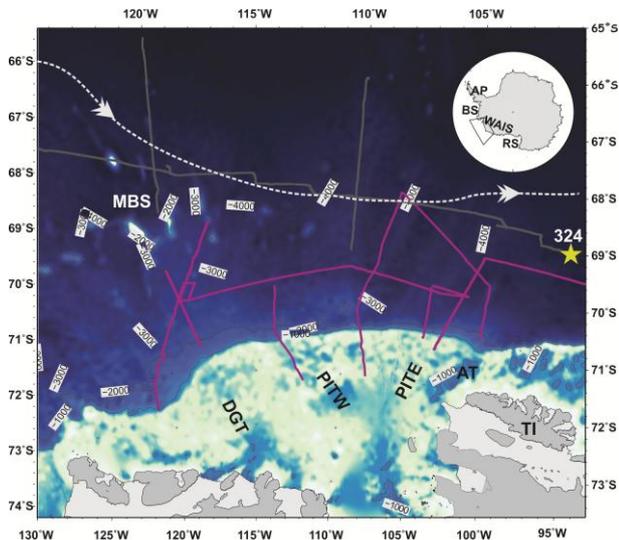


FIGURE 1. Bathymetric map of the Amundsen Sea (Nitsche et al., 2007). The seismic line locations are shown in purple (AWI) and grey (JNOC), the yellow star refers to the location of DSDP Leg 35 Site 324 (Shipboard_Scientific_Party, 1976). The light grey dashed line shows the approximate path of AABW (Orsi et al., 1999). AT = Abbot Trough, DGT = Dotson Getz Trough, MBS = Marie Byrd seamount area, PITE = Pine Island Trough East, PITW = Pine Island Trough West, TI = Thurston Island. Insert map shows the area presented. AP = Antarctic Peninsula, BS = Bellingshausen Sea, RS = Ross Sea, WAIS = West Antarctic Ice Sheet. Modified from Uenzelmann-Neben and Gohl (2014).

The MBS area appears still elevated at the base of unit ASR-III but is less pronounced. The shallowest part is found closer towards the continental slope. Similar to the base of ASR-II that of ASR-III lies relatively deep in the NE. For unit ASR-III we observe two depocentres (500 m) that coincide with locations where ASR-II had been thickest: a) in front and slightly west of PITW, and b) in front and slightly west of AT. Depocentre a) is parallel to the shelf break and the continental slope, while depocentre b) is oriented perpendicular to shelf break and continental slope. For the base of unit ASR-IV we observe a broad high, which extends eastwards from the MBS and is oriented parallel to the shelf break. The NE is characterised by a deep lying base of ASR-IV, which is less pronounced and deepens towards the deep sea. Unit ASR-IV shows depocentres only in the eastern part of the study area, where they cover about the same areas as the depocentres in unit ASR-III. Three depocentres are located between AT and PITW and are oriented perpendicular to the continental slope. The thickest parts (> 500 m) are found on the continental slope.

CONCLUSIONS

Via the analysis of seismic reflection data from the continental slope and rise (Figure 1) and the study of

thicknesses and depocentres of four sedimentary units we reconstructed sediment input (pathways and hence source areas on the shelf, amount) and sediment transport processes and inferred climatic and oceanographic changes. The oldest unit ASR-I (> 21 Ma) shows a narrow depocentre parallel to the continental slope interpreted to represent low energy input. A focus in deposition near 106°W was attributed to sediment supply through a palaeo-delta, which later became PITE. Sediment drifts observed in the elevated MBS area indicate an active water mass with a density between that of today's AABW and LCDW. This points towards a significant sea ice cover but not full glacial conditions for the period before 21 Ma.

For unit ASR-II (21-14.1 Ma) a strong increase in sediment input documented by a larger and thicker depocentre is interpreted as evidence for glacial conditions in West Antarctica already during the Early Miocene. Warming as the result of the MMCO resulted in a wet-based ice sheet and led to a higher sediment supply, which was supplied from the shelf along a broad front but with a main pathway through PITE and AT. Most of the material was transported onto the eastern Amundsen Sea rise where it was shaped into levee-drifts by a re-circulating bottom current. Unit ASR-III (14.1-4 Ma) is characterised by two smaller depocentres seaward of AT and PITW and reduced sedimentation rates. The onset of stronger cooling after 14 Ma resulted in a cooler and dryer based ice sheet leading to less glacial erosion and less material input.

A dynamic ice sheet since 4 Ma characterised by growth and decay during cold and warm phases, respectively, is documented by a strong increase in sedimentation rates with material dominantly being supplied to the rise via AT and PITW. The pulsed glaciogenic debris input from the shelf interacted with a west-setting bottom current on the rise resulting in the continued formation of levee-drifts in the eastern and central Amundsen Sea.

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