ABSTRACT BOOK

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Can we use seismic facies as a proxy for past ice sheet regimes?

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Abstract

Based on integrated analyses of seismic and borehole data from the Antarctic continental shelf and rise in the offshore area of the Wilkes Subglacial Basin, we identify two major turning points in the evolution of the East Antarctic Ice Sheet: the early Miocene and the middle Pliocene, marked by the establishment and subsequent deactivation of a prominent channel-levee system on the continental rise. Our observations support the hypothesis that ice volume increased nonlinearly with climate before and during the Miocene Climatic Optimum (17–14.8 Ma), the warmest period of the Neogene, due to high snowfall under humid climatic conditions, with abundant moisture supplied to a more terrestrial landmass, prior to extensive erosion and overdeepening of Antarctica's continental shelves. The deactivation of the channel-levee system, indicated by the progressive infilling of channels on the continental rise and the deposition of steeply dipping foreset beds at the shelf margin, occurred at about 3.3 Ma, just before the end of the Pliocene Warm Period (4.5–3.0 Ma), and marks the transition to the present polar regime. The late Miocene and the early to middle Pliocene are characterised by a distinctive high-amplitude seismic facies, which is the signature of alternating terrigenous and diatom-rich layers, representing glacial and interglacial periods. This facies characterises the upper part of the channel system and may serve as a significant environmental and stratigraphic marker elsewhere along the Antarctic continental margin.

Disciplines and sessions

Geosciences: S12: Reconstructing past Antarctic Ice-Sheet Dynamics to Inform Future Projections

Can we use seismic facies as a proxy for past ice sheet regimes?

We have identified a particular **high-amplitude seismic package (HASP)** that marks the transition to a less erosive and less dynamic EAIS by the middle Pliocene at regional scale We encourage the community to verify whether this seismic facies can be recognized elsewhere and used as a stratigraphic markers in Antarctica.

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A seismic proxy identifying the transition to an ice sheet polar regime from the sedimentary sequence on the George V Land continental margin (Antarctica)

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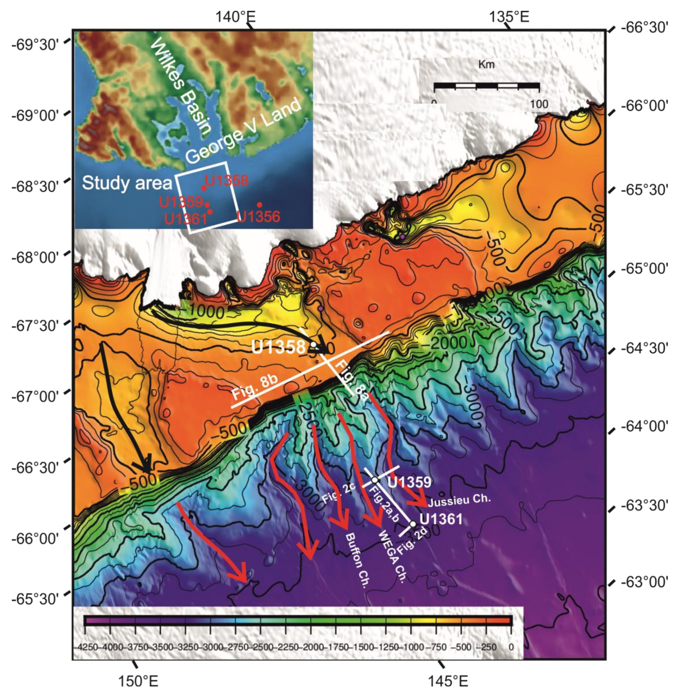
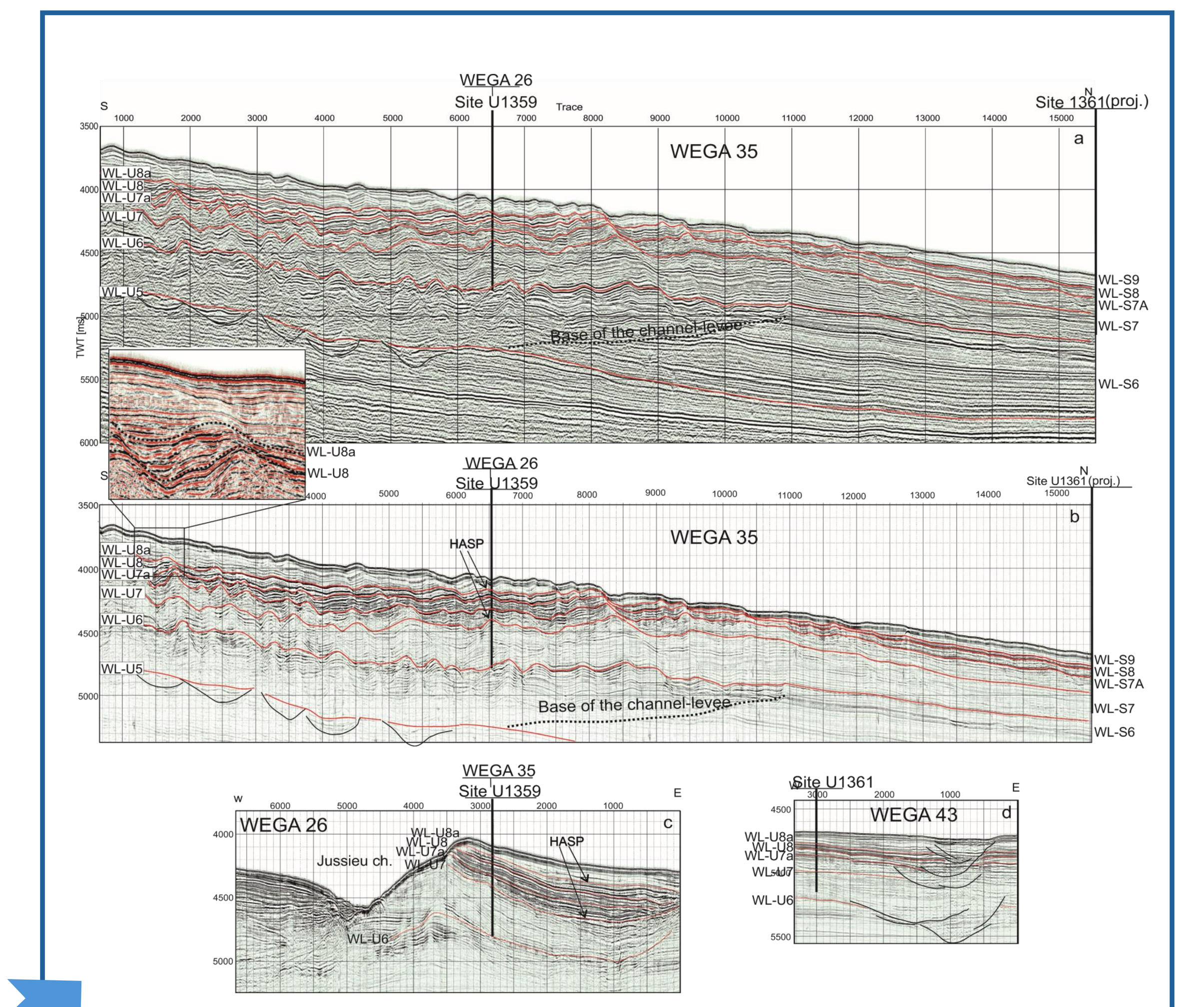
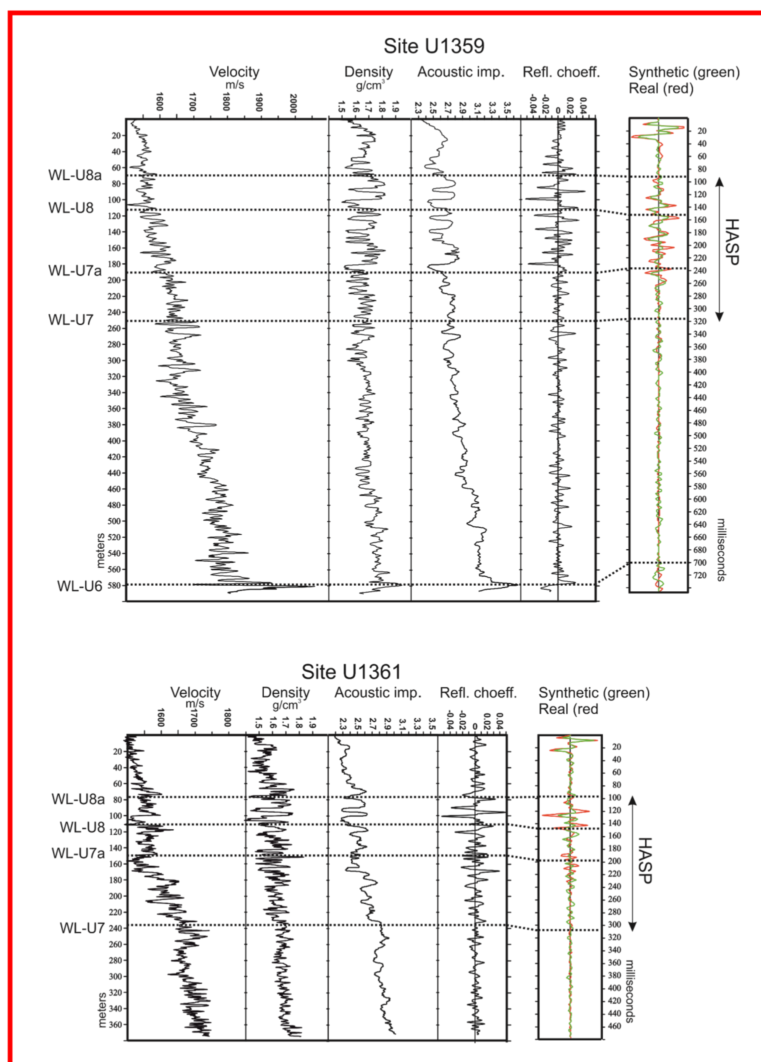


With an ice volume of 3–4 m sea level equivalent, the Wilkes Subglacial Basin (WSB) is the largest low-lying East Antarctic basin and a critical area for the stability of the East Antarctic Ice Sheet (EAIS). Due to the landward deepening of the basement beneath the ice sheet, the WSB is sensitive to marine ice sheet instability triggered by warm water intrusion from the Southern Ocean (Aitken et al., 2014; Fogwill et al.,2014; Pritchard et al., 2012; Greenbaum et al., 2015; Morlighem et al., 2020). Satellite data show ice mass changes in the last decades, however, predicting future behavior of the WSB is prevented by poor direct and long term observations. Past WSB ice sheet response to previous climate warming are required to understand how near is the next threshold crossing.
The area off George V Land preserves a record of sediment derived from the WSB, which is thought to be regulated largely by shifting ice sheet dynamics through time (Cook et al., 2013; Patterson et al., 2014; Golledge et al., 2021). In this paper we integrate seismic and IODP data from the continental shelf and the rise off George V Land and propose a model for the Neogene long-term glacial history of the WSB identifying times when the ice sheet changed its status at regional scale.

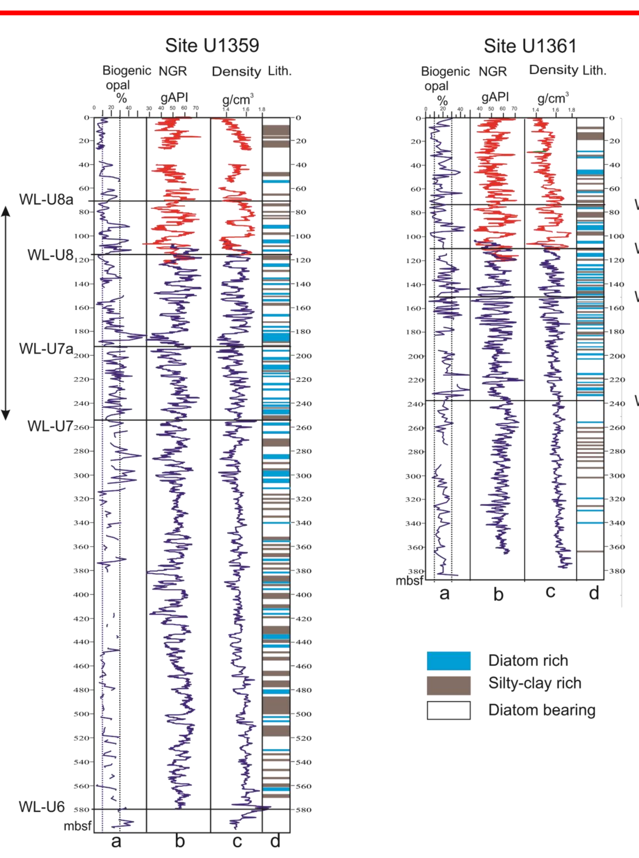


Seismic profile through IODP sites U1359 and U1361. The seismic section in the upper panel (a) is from a standard processing with window balancing to better represent the base of the channel-levee system and the sediment wave field. Reprocessed line in true amplitude to highlight the High Amplitude Seismic Package (Gei et al., 2024), are shown in panel (b), (c), and (d). Panel (b) is the same line of panel (a) while (c) and (d) are perpendicular to (b).

The late Miocene, and the early to middle Pliocene seismic sequences in the continental rise of the Wilkes Subglacial Basin margin are characterized by a particular terrigenous facies (**high-amplitude seismic package HASP**, between the seismic unconformities WL-U7 (9 Ma) and WL-U8a (3.3 Ma) that is the signature of alternating terrigenous and diatom-rich layers, representing glacial and interglacial periods.



Velocity and density logs for Sites U1359 and U1361, derived from the integration of wire and core log data. The high variability of the acoustic impedance and reflection coefficients, consistent with the HASP, depends mainly on the high variability of the density log. The synthetic trace (green seismogram) was obtained by convolving the reflection coefficient with the wavelet extracted from the seafloor and shows a remarkable similarity with the real trace (red seismogram).

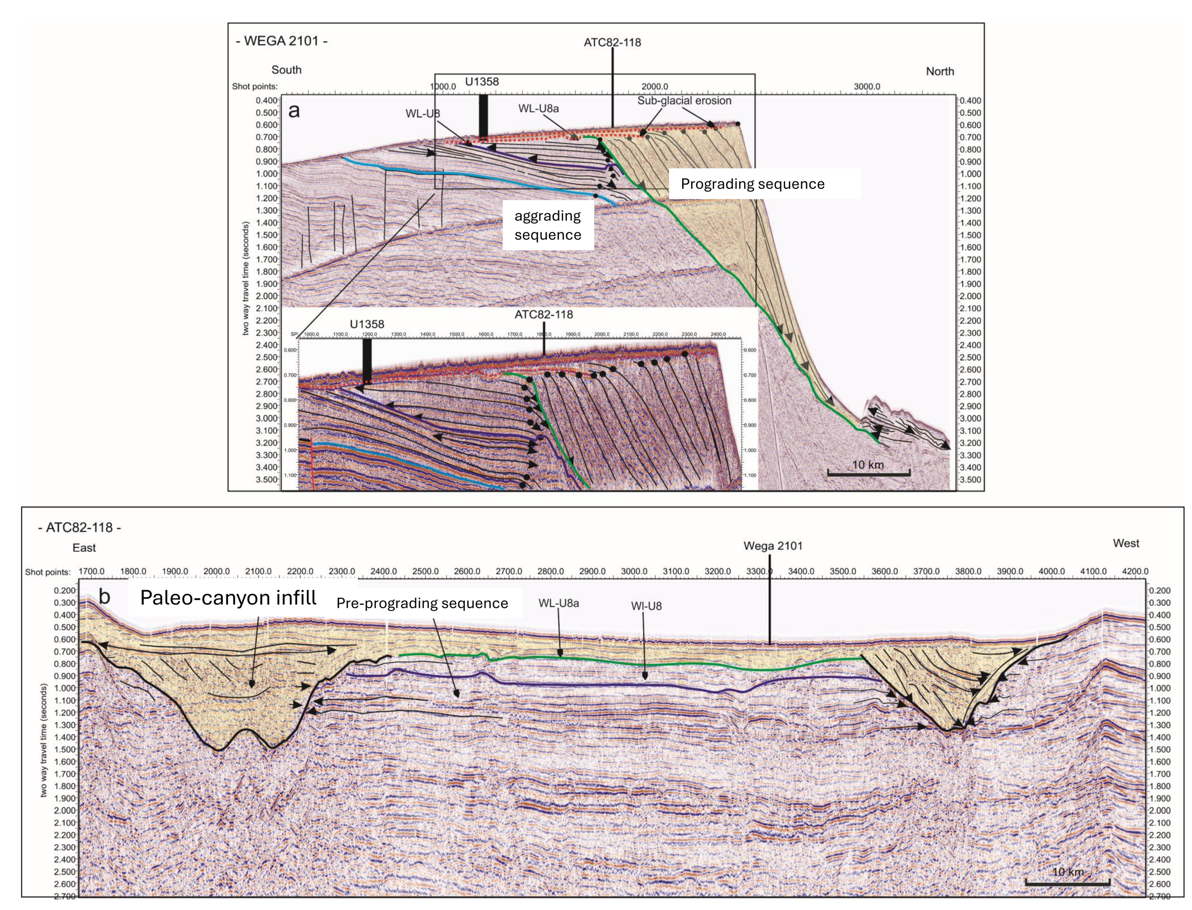


IODP Exp 318 Sites U1359 and U1361

- Biogenic opal,
- NGR: natural gamma ray
- Density logs from wireline and core measurements
- Lithology log indicating the diatom content

In red the data from WRMSL, blue from wireline logs.
Dashed vertical lines delimitate the diatom rich (>30 %) and diatom poor (<10 %) fields.

In the **HASP,** the diatom content during interglacial periods is persistently higher and shows greater variability, which, together with the variability of the IRD, indicates **large environmental fluctuations** probably related to the advance of the ice sheet and subsequent massive calving of the ice during deglacials and long sea-ice-free periods during interglacials (Cook et al., 2013; Patterson et al., 2014; Bertram et al., 2018). In this case, the seismic facies appear to be an indirect indication of the glacial dynamics of the marine-based ice sheet in the WSB.

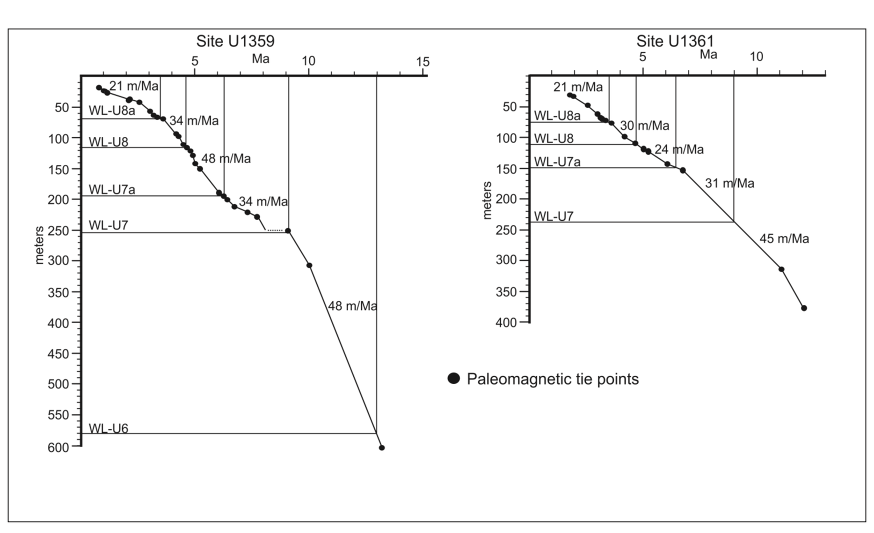


The shelf margin sequences geometry change

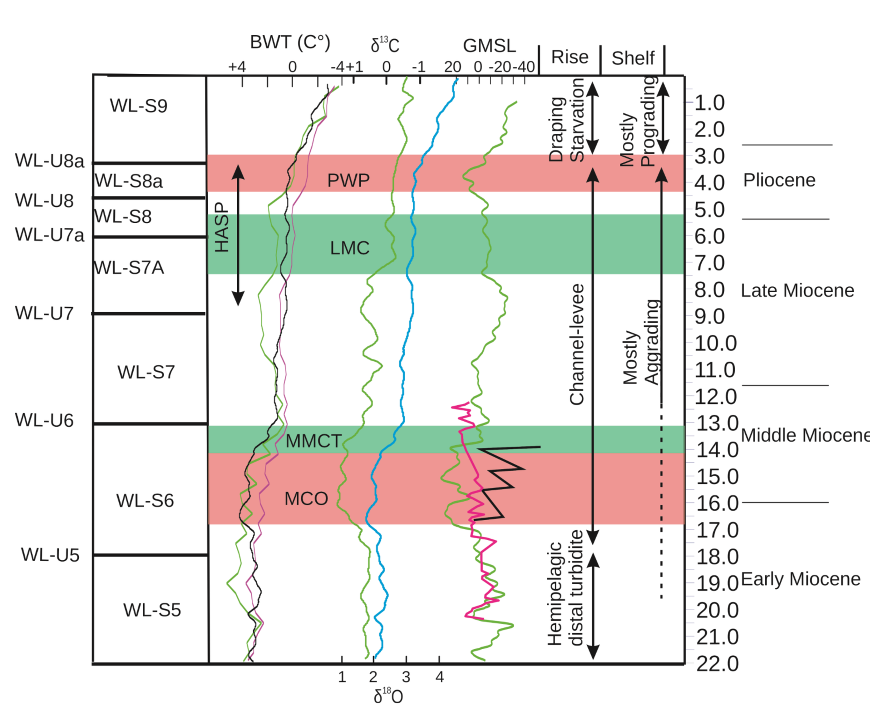
The geometry of the margin changed significantly from aggrading to prograding by the middle Pliocene, after the deposition of the HASP

The seismic line WEGA-21 perpendicular to the margin shows paleoshelf edge position (black dots) marking the evolution from mostly aggrading to mostly prograding sequences since the middle Pliocene (age is from IODP site U1358, Tauxe et al., 2014).
Dashed red lines show erosional surfaces produced by glacial advances up to the shelf

Seismic line ATC82–118 parallel to the shelf margin show the infill of paleo-canyons that formed during the Neogene and were buried by the advancing shelf margin with prograding seismic sequence, after the middle Pliocene



Depositional rates and temporal assessment of seismic unconformities at Sites U1359 and U1361, based on the Paleomagnetic tie points of Tauxe et al. (2012).
Deviating from Tauxe et al. (2012), we introduce a non-depositional hiatus at WL-U7 for Site U1359.
The age of unconformity WL-U7 is ca. 9 Ma after using a new velocity model for converting depth from two way time seconds to meters



Temperature from Westerhold et al. (2020), (black) and Cramer et al. (2011) Eq. 7a (green) and Eq. 7b (magenta), sea level curves from Miller et al., 2020 (green), Kominz et al., 2016 (magenta); John et al., 2011 (black).

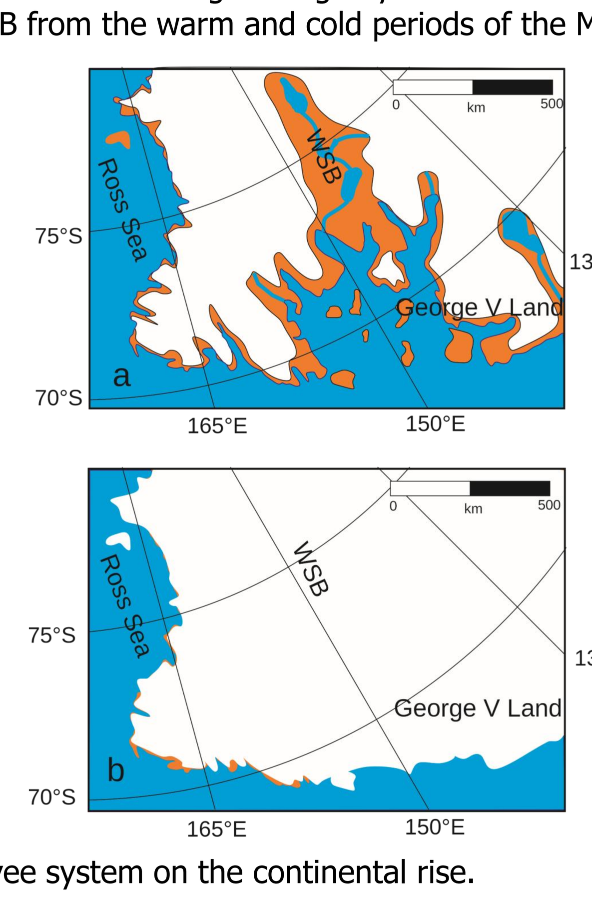
HASP is between WL-U7 (9 Ma) and WL-U8a (3.3 Ma)

During this period, relative sea-level fluctuations, deep-sea benthic δ18O and δ13C curves and seafloor temperatures indicate periodic growth and decay of the Antarctic ice sheet, as the Northern Hemisphere ice sheets were not yet fully developed (Westerhold et al., 2020).

The HASP time interval spans two important climatic periods: the Late Miocene Cooling (LMC) and the Pliocene Warm Period (PWP)

HASP can be considered representative of the geological record deposited during the transition to the present-day polar regime that emerged at the end of the warm PWP.

Schematic model showing the high dynamic behavior of the EAIS in the WSB from the warm and cold periods of the MCO.



based on the bedrock topography from Paxman et al., 2020.

We recognize two major turning points in the evolution of the East Antarctic Ice Sheet: in the early Miocene and middle Pliocene, defined by the establishment and deactivation of a noticeable channel-levee system on the continental rise.

Our observation supports the hypothesis that ice volume increased nonlinearly with climate before and during the Miocene Climatic Optimum (17–14.8 Ma), the warmest period of the Neogene, prior to extensive erosion and overdeepening of Antarctica's continental shelves.

The deactivation of the channel-levee system, evidenced by the progressive filling of the channels on the continental rise and the deposition of steeply dipping foreset beds at the shelf margin, occurred at about 3.3 Ma, just before the end of the Pliocene Warm Period (4.5–3.0 Ma), and represents a regional-scale transition to the present polar regime.

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Acknowledgments
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