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Pre-Holocene to recent deglaciation of the Amundsen Sea Embayment, West Antarctica

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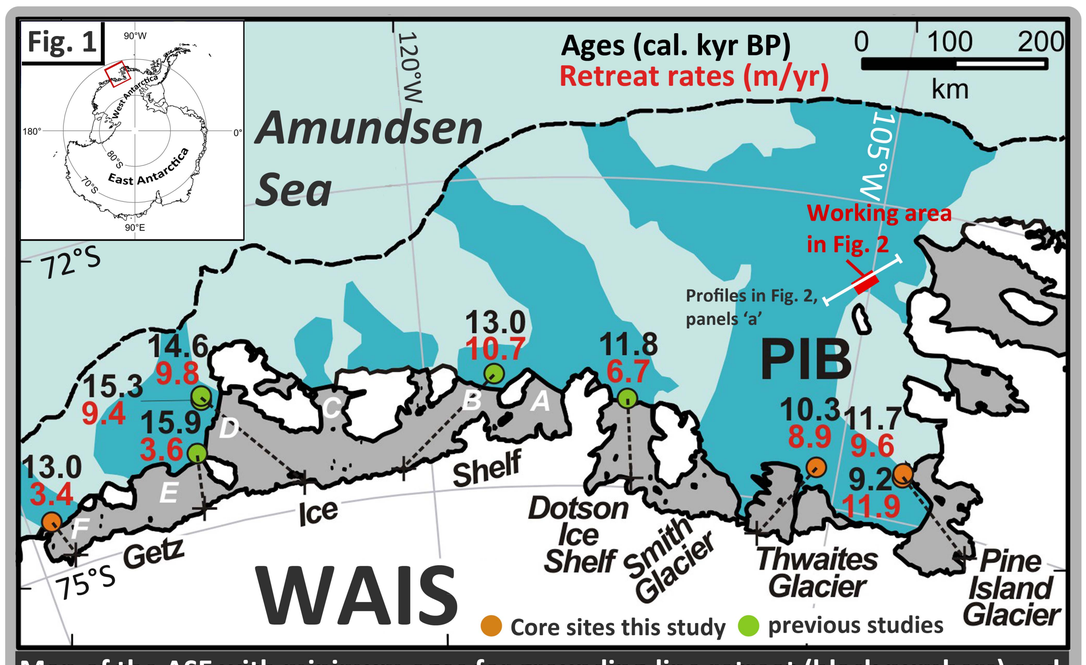
1 Introduction

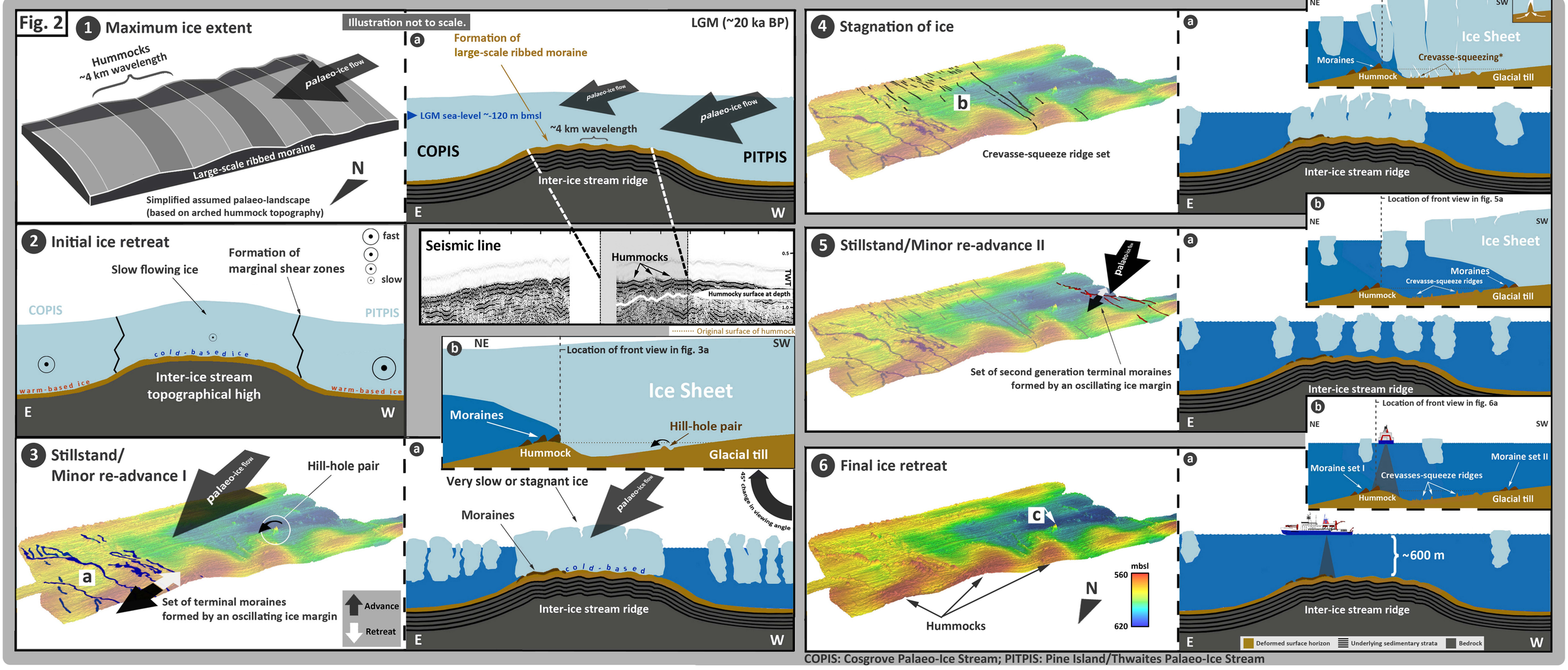
Ice loss from the marine-based, inherently unstable West Antarctic Ice Sheet (WAIS) contributes to the currently observed rise in sea-level and may raise it by up to 3.3-5 metres in the future. Over the last few decades, glaciers draining the WAIS into the Amundsen Sea Embayment (ASE), in particular into Pine Island Bay, have shown thinning, grounding-line retreat and ice-flow acceleration at dramatic rates. These changes are mainly attributed to significant ice-shelf melting by upwelling warm deep water. A critical unknown, limiting our ability to accurately predict future WAIS behaviour, is the poorly constrained long-term context of ice-sheet retreat in the ASE.

Here we present a new pre-Holocene to present chronology for WAIS retreat in Pine Island Bay (PIB) based on radiocarbon dating of marine sediment cores. The dates give evidence that grounded ice had retreated close to its modern-day position by ~10 ka BP. Maximum average retreat rates calculated from the deglaciation ages suggest, that the current rapid WAIS retreat in Pine Island Bay is unprecedented over the last ~10 ka and originates in recent changes in regional climate, ocean circulation or ice-sheet dynamics. However, our data and previously published ages for grounding-line retreat from the wider ASE further demonstrate, that, other than in the Ross Sea, the WAIS did not retreat continuously since the LGM.

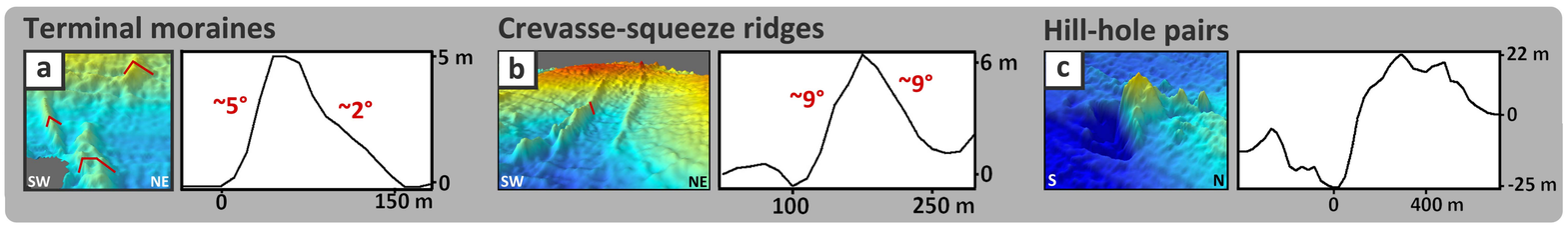
A unique assemblage of glacial morphological features mapped on the eastern ASE shelf suggest a more complex deglacial history, with ice masses slowly flowing and/or stagnating on topographic highs (’Inter-ice stream ridges’) adjacent to main palaeo-ice stream troughs. The incorporation of our results into ice-sheet models will improve predictions of future sea-level rise.



Map of the ASE with minimum ages for grounding-line retreat (black numbers) and maximum rates for grounding line retreat from the core sites to the modern WAIS grounding line (red numbers). Distances of core sites from the present grounding line were measured from the furthest landward grounding line point up-flow from each site (along the trajectories marked by the dotted lines).



COPIS: Cosgrove Palaeo-Ice Stream; PITPIS: Pine Island/Thwaites Palaeo-Ice Stream



Relative chronology of inter-ice stream ridge deglaciation in six phases, (1) Maximum ice extent and conditions of full-glacial flow formed large-scale ribbed moraine, (2) Initial ice retreat, (3) Minor re-advance I, caused deposition of northeastern set of terminal moraines (a) and hill-hole pairs (c), (4) Stagnation of ice, as preserved by extensive fields of crevasse-squeeze ridges (b), (5) Minor re-advance II, caused deposition of southwestern set of terminal moraines (a), (6) Final ice retreat (no disturbance of bedforms north of the SW terminal moraines can be detected). Note that profiles in 1a, 2, 3a, 4a, 5a and 6a are EW-orientated.

2 Results & interpretation

- Radiocarbon dating on biogenic carbonate indicated that the ice on the flanks of the central Pine Island-Thwaites Palaeo-Ice Stream (PITPIS) trough (Fig. 1, eastern orange dots) had already retreated to the inner ASE shelf before the start of the Holocene (~10 ka BP), achieving a configuration close to the modern remarkably early.
- The retreat rates from core sites to the present-day grounding line in PIB are 8.9, 9.6 and 11.9 m/yr (red numbers) → these rates are more than two orders of magnitude lower than the recent grounding-line retreat of Pine Island and Thwaites glaciers (Joughin et al. 2010; Tinto and Bell, 2011).
- The assemblage of features in figure 2 provides a unique insight into the behaviour of ice between ice-stream pathways: i.) Large-scale ribbed moraines, which are first described here for the Antarctic shelf, indicate an initial slow palaeo-ice flow towards ENE. Seismic investigations indicate a continuation of a hummocky topography with depth, thus showing several generations of large-scale ribbed moraines on top of the inter-ice stream ridge between PITPIS and the Cosgrove Palaeo-Ice Stream (COPIS). ii.) Terminal moraines (cf. 3D-view in panel ‘a’) in the northeast and southwest of the working area suggest at least two minor ice re-advances or stillstands, respectively. During these phases slowly flowing ice ripped up subglacial material and deposited it directly downflow resulting in hill-hole pairs (cf. 3D-view in panel ‘c’), iii.) Crevasse-squeeze ridges (cf. 3D-view in panel ‘b’) in the central part reveal phases of ice stagnation. The pristine preservation of bedforms documents that the ice decayed in-situ. The inter-ice stream ridge must have been characterized by slow ice flow over several glacial cycles. Most likely these periods of slow ice flow were followed by ice stagnation as evidenced for the latest glacial cycle by extensive occurence of crevasse-squeeze ridges. The lack of similar bedforms in PITPIS and COPIS indicates that retreats in the troughs and on adjacent inter-ice stream ridges was not uniform.

3 Conclusions

We conclude that the present, rapid deglaciation of the central PIG is driven by recent climatic and/or oceanographic changes rather than being a continued response to past changes. Our data provide the first geological and geophysical constraints on past ice retreat from the coastal vicinity and inter-ice stream areas of a key drainage sector of the WAIS. The data most likely reveal different deglacial modes between the PITPIS trough and its marginal areas. These new information form the critical context for underway and future ice-sheet changes.

References

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