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Palaeo-ice streams in the Amundsen Sea sector of the West Antarctic Ice Sheet during the last glacial period: flow dynamics, retreat histories, and geological controls

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The potentially unstable parts of the West Antarctic Ice Sheet contain enough water to raise global sea levels by ∼3.3 metres were it to be discharged rapidly into the oceans. Of this, approximately one third is frozen into the ice within the Amundsen Sea sector, which is considered one of the most vulnerable drainage systems in the ice sheet today. Recent dynamic thinning and grounding-line recession in the Amundsen Sea's glaciers have suggested the sector may be on the verge of a rapid phase of ice retreat, but it is unclear whether current changes are unprecedented or simply reflect a short-term deviation from the ice sheet's long-term retreat trajectory. To test this hypothesis it is necessary to establish the maximum extent of ice during the last glaciation, the timing and pattern of its subsequent retreat, and the controls on the dynamics of past flow.

Here, multibeam swath bathymetry, sub-bottom profiler, and sediment core data are used to establish constraints on the flow and retreat history of major palaeo-ice streams that carried the combined discharge from two parts of the Amundsen Sea sector: (1) the area now occupied by the Pine Island and Thwaites glacier basins, in the east; and (2) the region of the Dotson-Getz ice shelves, in the west.

Sets of highly-elongated bedforms show that, at the Last Glacial Maximum, major palaeo-ice streams flowed along several prominent cross-shelf troughs. In the east the grounding line advanced to within ∼68 km of, and probably reached the shelf edge, while in the west ice covered the entire middle shelf, and we assume reached the shelf break also. For the Pine Island-Thwaites Ice Stream, minimum ice-thickness is estimated at 715 m on the outer shelf, and we estimate a minimum ice discharge of ∼108 km^3 yr^{-1} assuming velocities similar to today's Pine Island Glacier (∼2.5 km yr^{-1}). Additional bedforms observed in a trough northwest of Pine Island Bay are interpreted to have formed via diachronous ice-flows across the outer shelf, and demonstrate switching ice-stream behaviour. In the west, mapping of bedforms shows an equally dynamic ice sheet with a shelf geomorphology imprinted by multiple phases of ice flow indicating a complex former ice-basal regime. In addition, the pattern and geometry of bedforms imply strong geological controls upon both the relict bed signature, and the processes facilitating fast-flow within the ancient ice sheet.

The style of ice-retreat in the Pine Island-Thwaites system is evident in five mapped grounding zone wedges, which suggest episodic deglaciation characterised by halts in grounding-line migration up-trough. Stillstands occurred in association with changes in ice-bed gradient, and phases of inferred rapid retreat correlate to higher bed-slopes, supporting theoretical studies that show bed geometry as a control on ice-margin recession. A new, detailed radiocarbon chronological dataset for the Dotson-Getz system generally supports a stepped deglaciation of the Amundsen Sea Embayment, highlighting variable rates of ice retreat through the Late Quaternary-to-Holocene with increased rates of retreat across deep inner shelf basins. However, maximum rates of retreat from the Holocene to the present day are found to be orders of magnitude lower than late 20th Century grounding-line recession of Pine Island Glacier, suggesting that present rapid deglaciation of the sector is driven by recent effects rather than being a continued response to past changes.