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Late Quaternary ice-sheet extent & dynamics on the continental margin of the Bellingshausen Sea as reconstructed from marine geophysical evidence

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1. Abstract

Multibeam swath bathymetric & TOPAS sub-bottom profiler data show that during the last glacial cycle the West Antarctic Ice Sheet (WAIS) drained to the continental shelf edge of the Bellingshausen Sea through a 150 km wide, bathymetric trough (Fig. 1) as a grounded, fast-flowing, ice stream. The drainage basin feeding this ice-sheet outlet would probably have encompassed parts of southern Alexander Island, south-western Palmer Land & the Bryan Coast of Ellsworth Land, with an area of about 300,000 km². On the inner continental shelf streamlined bedrock & drumlins mapped by swath bathymetry (Figs. 2 & 3) show that the ice stream was fed by convergent ice flow draining from Eltanin Bay & bays immediately to the east, as well as by ice draining the Antarctic Peninsula Ice Sheet through the Ronne Entrance. Drumlins evolve downflow into mega-scale glacial lineations formed in an acoustically transparent till unit in the outer shelf trough (Figs. 3 & 4). Grounding-zone wedges on the inner and mid-shelf (Fig. 5) record stillstands of the ice-sheet margin during deglaciation & imply a staggered pattern of retreat.

Geophysical data were also acquired from the upper & middle continental slope along 385 km of the Bellingshausen Sea margin between 88°21'W & 78°07'W. Below about 1000 m water depth the contours exhibit a distinct bulge-shape (Fig. 6). This pattern is limited to the area directly in front of the trough mouth & is interpreted as a trough-mouth fan. TOPAS sub-bottom profiler records from the fan show acoustically-transparent lenses of sediment (Fig. 6) which are interpreted as debris flow deposits recording downslope remobilisation of glacial debris from an ice-sheet positioned at, or close to, the shelf edge.

Mega-scale glacial lineations & the large trough-mouth fan indicate the former presence of an ice stream in Belgica Trough. Ice stream formation was controlled by a combination of topography & subglacial geology. These new data indicate an extensive WAIS at the last glacial maximum (LGM) on the southern Bellingshausen margin, which likely advanced to the continental shelf edge. In conjunction with existing ice-sheet reconstructions from further to the south & north, this implies that ice sheet configuration during the LGM along the Antarctic Peninsula, Bellingshausen Sea & Amundsen Sea margins was characterised by fast-flowing ice streams which drained the WAIS & Antarctic Peninsula Ice Sheet through cross-shelf bathymetric troughs, reaching the continental shelf edge.

2. Location

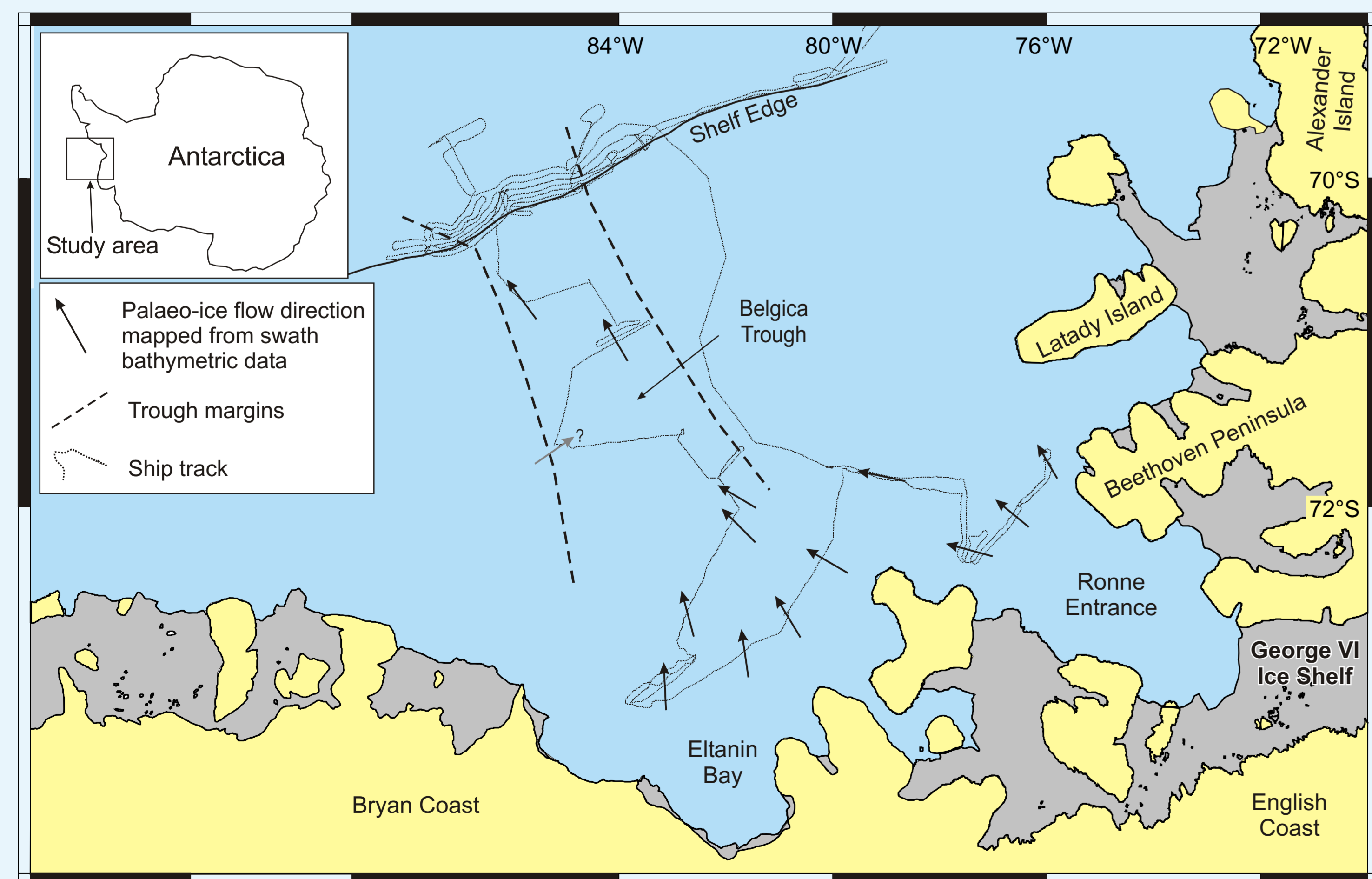


Fig. 1. Location map showing ship track, margins of Belgica Trough & palaeo-ice flow directions mapped from the orientation of streamlined subglacial bedforms. Note bifurcation of flow emanating from the Ronne Entrance & flow convergence into Belgica Trough.

3. Ronne Entrance

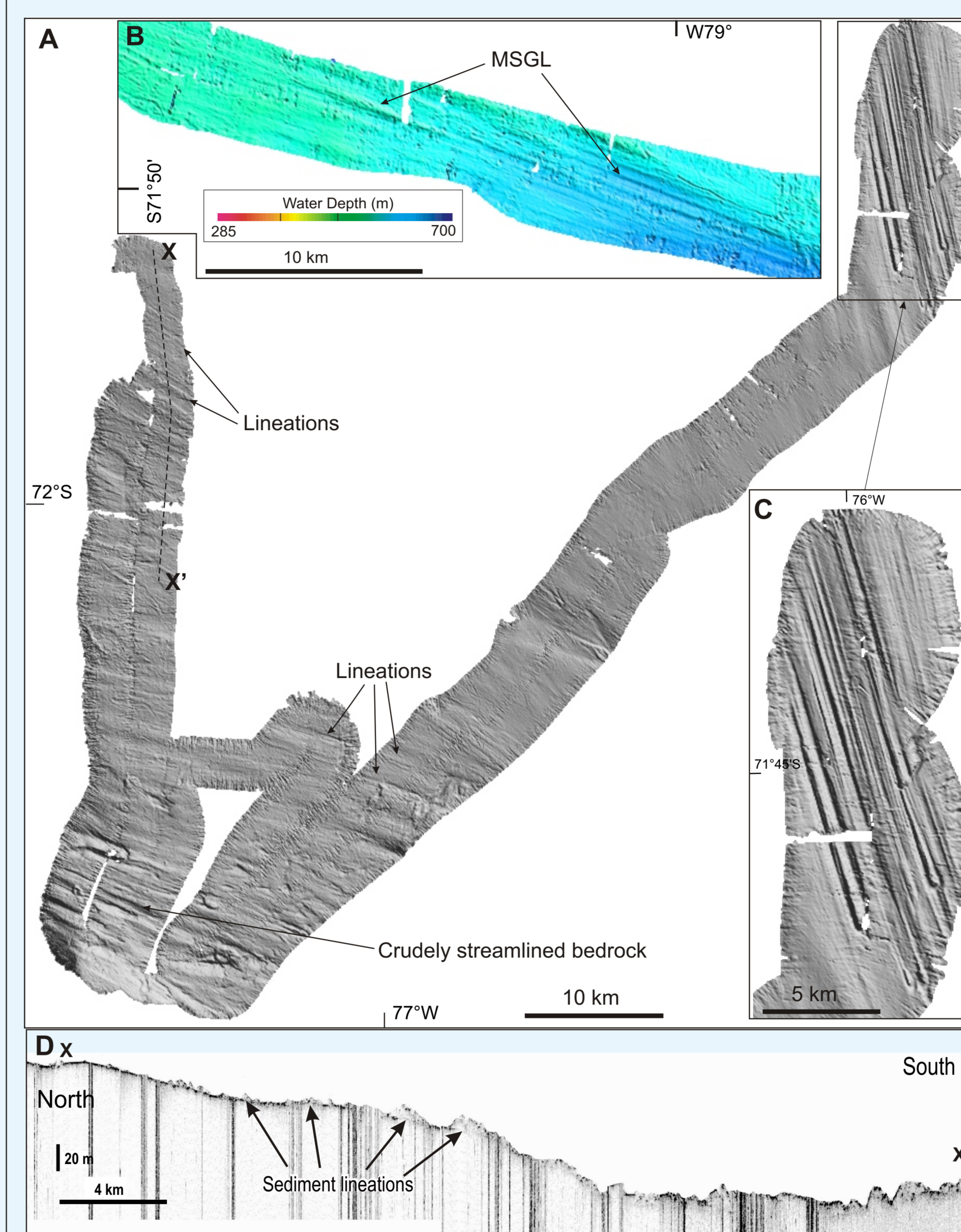


Fig. 2. Geophysical records of palaeo-ice sheet flow from the Ronne Entrance. (A) EM120 (12 kHz) multibeam swath bathymetry, shaded relief image of the sea floor at the mouth of the Ronne Entrance. Note the 2 sets of streamlined bedforms recording WNW flow towards Belgica Trough & NNW flow. The WNW set is formed predominantly in bedrock. (B) Mega-scale glacial lineations (MSGL) formed in sediment in water depths of 570-620 m. The MSGL record WNW ice flow from the Ronne Entrance towards the continental shelf edge. (C) Drumlins & lineations recording NNW ice flow from the Ronne Entrance towards the continental shelf edge. (D) TOPAS sub-bottom profiler record of lineations recording WNW ice flow from the Ronne Entrance. Location of profile X-X' is shown in 2A. The lineations form ridges composed of acoustically-transparent sediment sitting above a strong sub-bottom reflector.

4. Eltanin Bay

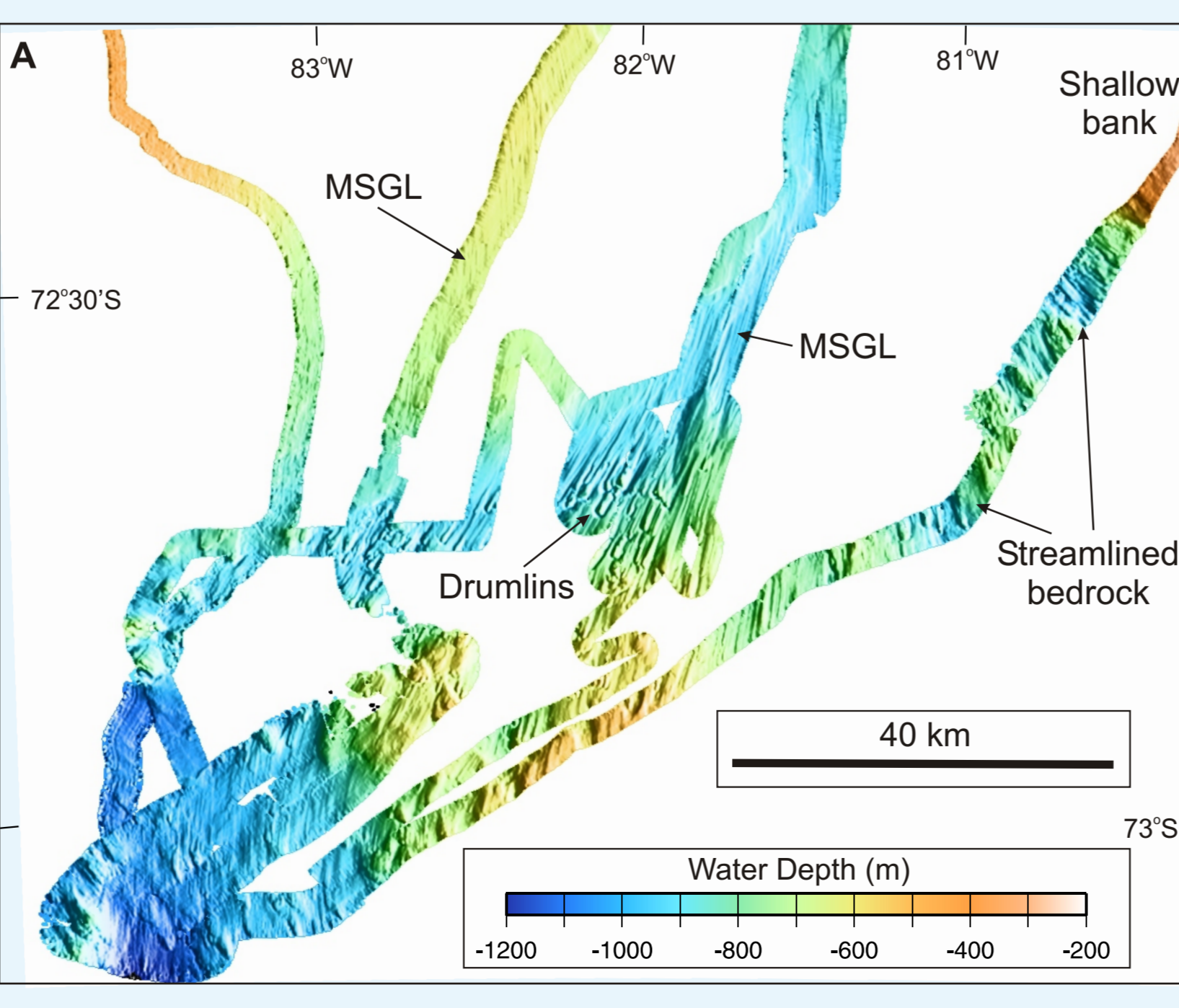


Fig. 3. Multibeam swath bathymetry (colour draped, shaded relief) image of streamlined subglacial bedforms, Eltanin Bay. The orientation of the bedforms indicates flow convergence into the head of Belgica Trough. The multibeam data is a combination of EM120 (12KHz) data obtained during the present study & SeaBeam 2100 (12 kHz) data (after Wellner et al., 2001).

5. Belgica Trough

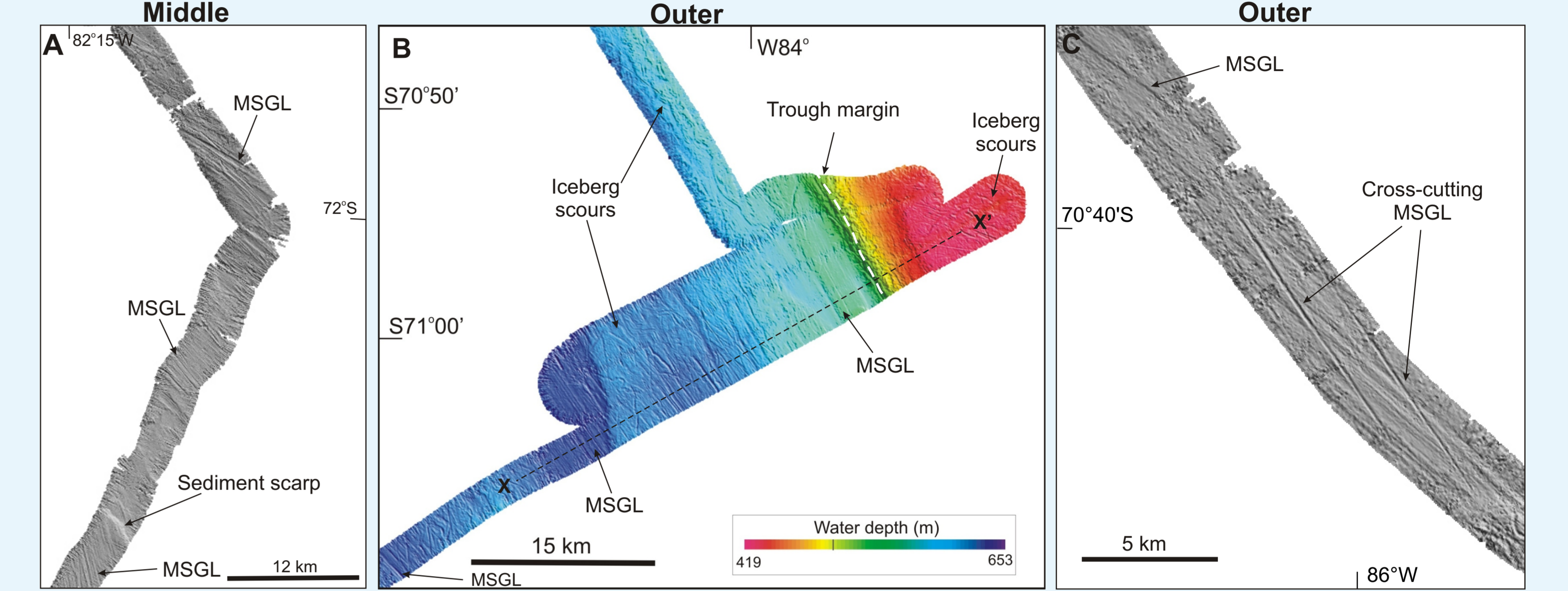


Fig. 4. Geophysical records (EM120 swath bathymetry & TOPAS sub-bottom profiler) of submarine landforms & shallow acoustic stratigraphy, Belgica Trough. (A) Mega-scale glacial lineations (MSGL) in water depths of ~700 m on the mid-shelf. Note the sediment scarp. This forms the NE end of the TOPAS transect "X-X'" in Figure 5B & is interpreted as the edge of a grounding-zone wedge. (B) Colour draped, shaded relief image of MSGL. The MSGL are obliterated downflow by iceberg ploughmarks. Transect X-X' is shown in Fig. 4D. (C) Cross-cutting MSGL in the outer shelf trough. (D) TOPAS record of shallow acoustic stratigraphy in outer Belgica Trough. The location of the profile "X-X'" is shown in Fig. 4B. The MSGL are formed in an acoustically transparent sediment unit which overlies a prominent sub-bottom reflector.

6. Grounding-Zone Wedges

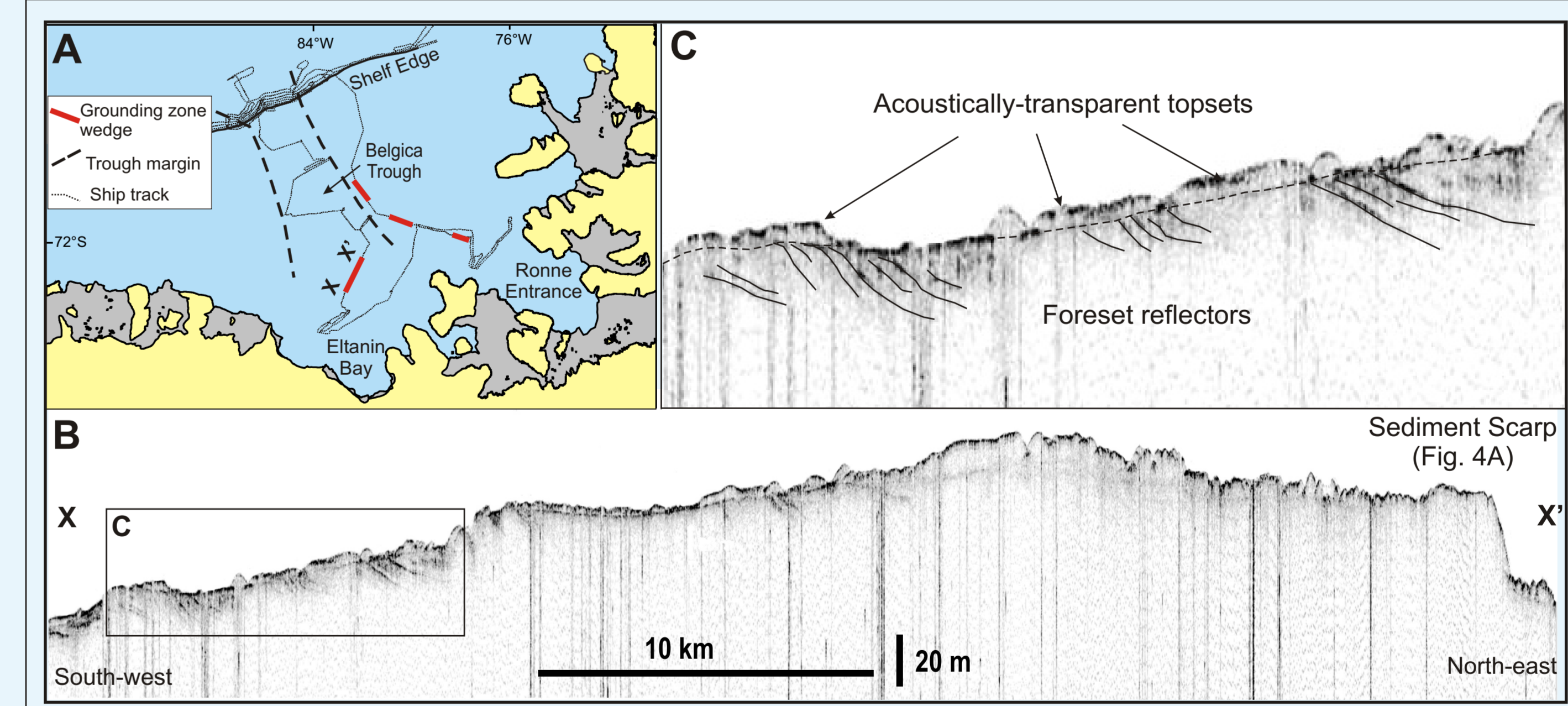


Fig. 5. Grounding-zone wedges (GZW) in the study area. (A) Location of GZW. (B) GZW in Belgica Trough. Note the dipping foreset reflectors that are truncated by the gently dipping overlying reflector; the capping acoustically transparent sediment unit (topsets); & the wedge-shaped geometry of the GZW with an abrupt & steep distal face. (C) Blow up of topsets & foresets.

7. Continental Slope

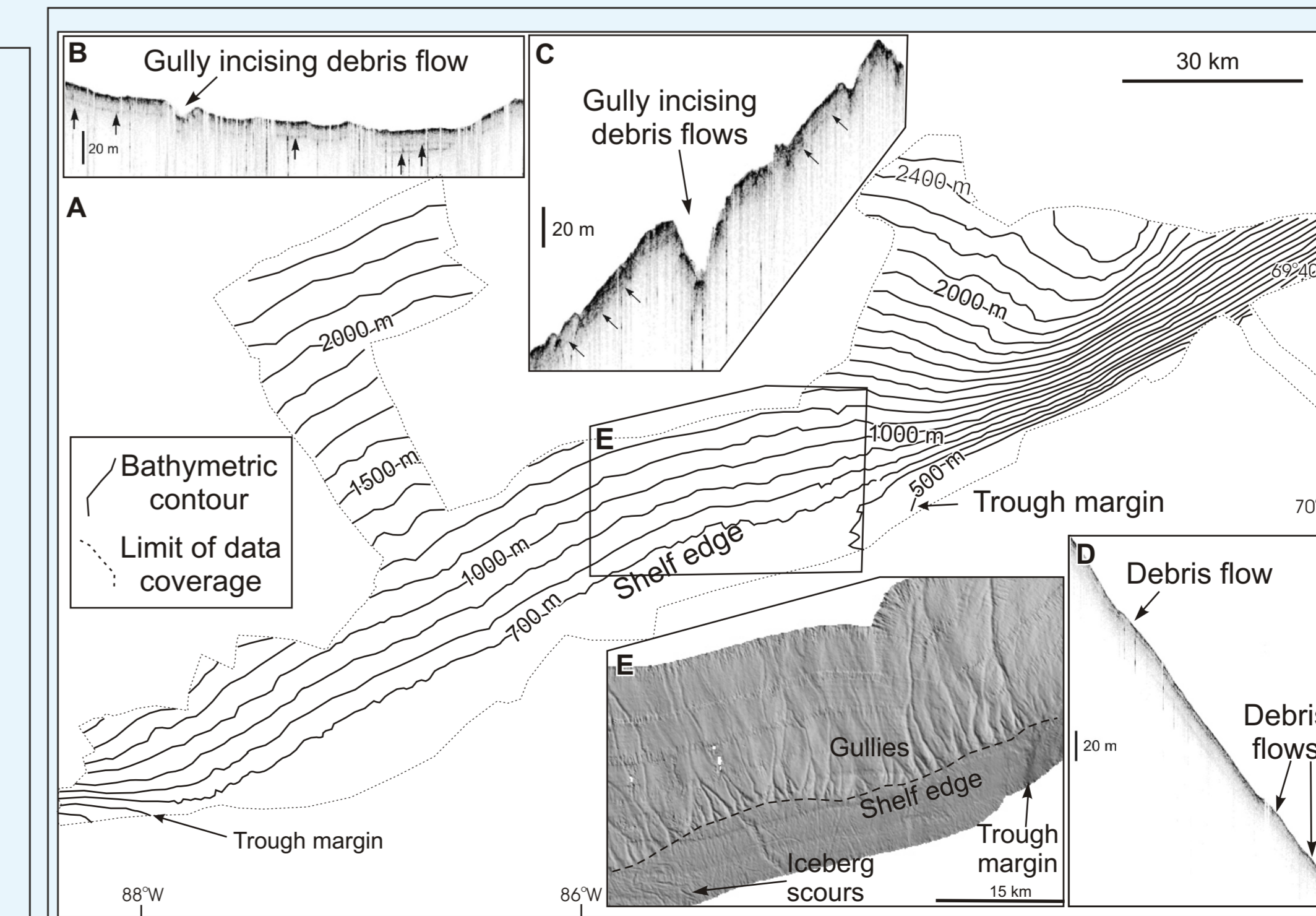


Fig. 6. Bathymetric and acoustic data from the continental slope in front of Belgica Trough. (A) Bathymetry. (B) Across-slope TOPAS sub-bottom profiler record of acoustically-transparent sediment units interpreted as debris flows (bases of flows arrowed). (C) Downslope TOPAS record of debris flows (bases of flows arrowed) incised by a 20 m+ deep gully. (D) Downslope TOPAS record of acoustically-transparent sediment lenses interpreted as debris flows. (E) EM120 multibeam swath bathymetry shaded-relief image of the upper continental slope in front of Belgica Trough. Note gullies eroded into the slope. Gullies commence at the shelf edge but in some cases cut back into the shelf. They extend downslope for up to 40 km & incise the debris flows imaged on TOPAS. The gullies are inferred to have formed by turbidity current activity during ice stream retreat from the shelf edge, following debris flow delivery.

Acknowledgements
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