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Role of cold, dense water in the development of submarine canyon morphology

Jenny Gales (1), Michele Rebesco (2), Laura De Santis (2), Fabrizio Zgur (2), Andrea Bergamasco (3), Sookwan Kim (4), Elisabetta Olivo (2), Florence Colleoni (2), Daniela Accettella (2), Vedrana Kovacevic (2), Yanguang Liu (5), Christian Florindo-Lopez (6), Rob McKay (7), Denise Kulhanek (8), Maxine King (1), and the IODP Expedition 374 Scientists

(1) Biological and Marine Sciences, University of Plymouth, Plymouth (Jenny.gales@plymouth.ac.uk), (2) OGS, Borgo Grotta Gigante 42/C, 34010 Sgonico (TS), Italy, (3) ISMAR, CNR, Castello 2738/F, 30122 Venezia, Italy , (4) KOPRI, 26 Songdomirae-ro, Yeonsu-gu, Incheon 21990, South Korea , (5) FIO, Xianxialing Road 6, Laoshan District, Qingdao 266061, China , (6) National Oceanography Centre, European Way, Southampton, SO14 3ZH, UK, (7) Antarctic Research Centre, Victoria University of Wellington, PO Box 600, Wellington 6140, New Zealand, (8) International Ocean Discovery Program, Texas A&M University, 1000 Discovery Drive, College Station, Texas 77845-9547, USA

The rate of ice loss from the West Antarctic Ice Sheet has increased during the last few decades with global implications for large-scale effects to ocean and atmospheric circulation and sea level rise. One major change is in dense water production and regime around Antarctica. Dense water masses, formed during sea-ice production, flow down-slope and ventilate the deep ocean and eventually feed the global thermohaline circulation. Constraining the signature of these flows on the seafloor therefore provides huge potential in understanding how ocean circulation has changed in the past, for example, when climatic conditions resembled ‘worst-case’ future climatic scenarios and may provide important clues as to how they may change in the future; and what effects this may have on ice retreat and sea-level rise. Here, we present a multidisciplinary dataset collected over the last two years from the Hillary Canyon, Ross Sea, Antarctica, in one of the greatest regions of cold, dense water export in the world. Data includes multibeam bathymetric, single-channel seismic, sub-bottom profiler and oceanographic data collected during the EUROFLEETS-funded ANTSSS expedition on OGS Explora (January 2017); and sedimentological and petrophysical data from boreholes drilled during the International Ocean Discovery Program Expedition 374 (January 2018). These new data show deeply incised gully and channel systems feeding the canyon head at the mouth of the Glomar Challenger Basin. Single-channel seismic data from the shelf edge show that the gullies likely evolved over multiple glacial cycles, filling and reforming with subsequent glacial advances. A distinct lack of gullies and channels are observed on the western side of the canyon, where oceanographic data collected over a five-day mesoscale experiment in 1997-98 (Bergamasco et al., 2002) and during a 2-week ADCP, XBT and CTD survey in 2017 show sustained high-velocity cold, dense bottom currents reaching velocities of 1 m/s. Through integrating these datasets, we show that the absence of gullies and channels where sustained bottom currents are observed in modern times, suggests that gullies are not likely to be formed by the density driven currents under modern-day conditions. Instead we suggest that gully erosion is related to processes influenced by the presence of ice grounded near the shelf edge during previous glaciations. We propose that climatic cycles drive canyon-head processes with significant gully erosion dominated by down-slope, turbidity-driven, sediment density flows during and following glacial conditions.