Present-day current activity in an inactive canyon-channel system: the Gollum Channel System offshore southwest Ireland.

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ABSTRACT

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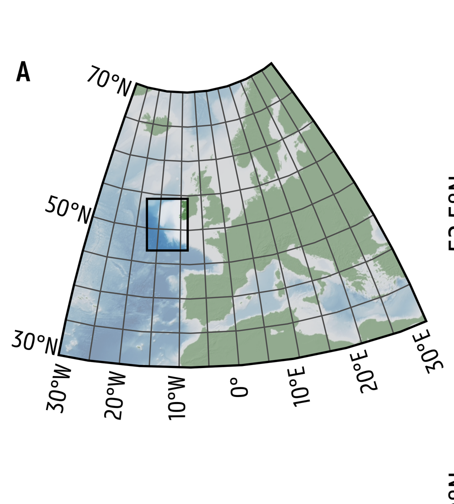
1 – Background

The Gollum Channel System (GCS) is a large-scale submarine canyon-channel system situated offshore southwest Ireland on the Northeast Atlantic margin (Fig. 1). As a land-detached system, the GCS is considered inactive since the Last Glacial Maximum, when the British-Irish Ice Sheet extended onto the Celtic Sea Shelf (Wheeler et al., 2003), but newly acquired geophysical seafloor and shallow subsurface data do suggest recent activity. Only recently has canyon-channel research started challenging the highstand-dormant paradigm for land-detached systems (Heijnen et al., 2022). The aim of this research is to test the (in)activity hypothesis in the GCS and in doing so, improve the understanding of which processes are presently active in these systems and in what capacity.



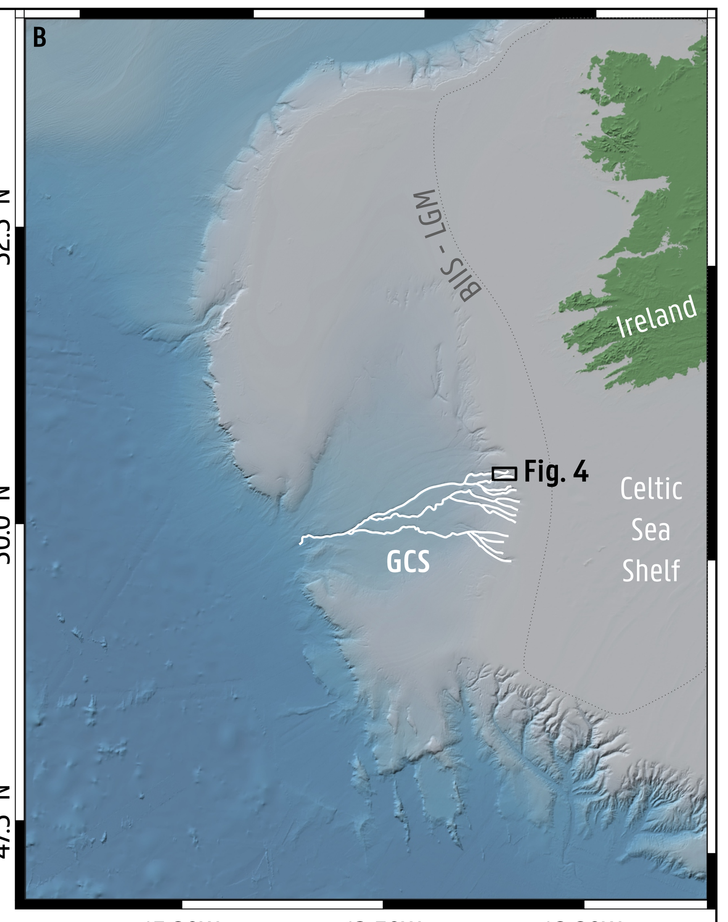


Fig. 1. (A) Overview map showing the location of Ireland on the Northeast Atlantic margin and the location of B is shown as a black rectangle. (B) Map showing the location of the Gollum Channel System (GCS) offshore southwest Ireland. Also indicated as a dotted line is the extent of the British-Irish Ice Sheet (BIIS) at the Last Glacial Maximum (LGM). The location of Fig. 4 is indicated with a black box.

2 – Methods

This study is based on bathymetry, side-scan sonar (SSS) and monochrome image data collected in the two northernmost channels of the GCS (Bilbo Channel and Frodo Channel) using an autonomous underwater vehicle (AUV). Additionally, a time series of current meter data was recorded using a mooring in the northernmost channel of the system.

AUV - Three dives were performed using the Teledyne Gavia AUV Barabas (Fig. 2) from the Flanders Marine Institute (VLIZ). Good-quality positioning was ensured through ultra-short baseline acoustic communication between the mother vessel and the AUV. The AUV was fitted with a side-scan sonar module capable of simultaneously acquiring swath bathymetry through interferometry (Klein 3500). Images were provided by the monochrome camera in the nose of the AUV.

Mooring - The mooring sat underwater at a depth of 900 m for 325 days between June 2005 (Julian day 166) and May 2006 (Julian Day 126). It was located on the floor of Bilbo Channel (Fig. 4) and had one current meter at 8 m above the seafloor (Fig. 3) providing a measurement every 30 minutes. Due to biofouling, the current data are accurate only until December 2005. Therefore, current data from mid-December (Julian day 351) until the end of the measuring period are omitted from the analyses.

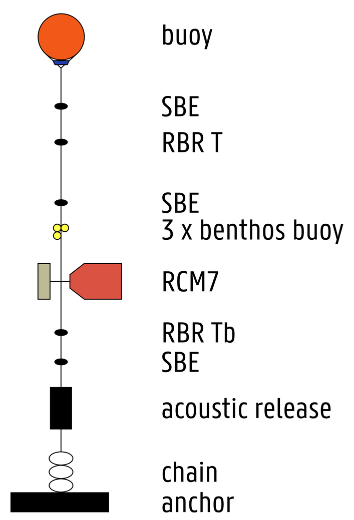


Fig. 3. Sketch of the mooring setup used in this study. RCM7 = Anderaa current meter, RBR Tb/T = Brancker turbidity/temperature sensor, SBE = Seabird Microcat.

Fig. 2. Picture of a Teledyne AUV of the same type (Gavia) as the one that was used in this study. Picture courtesy of Teledyne Marine.

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3 – Results and Interpretation

Bottom currents create megaripples and coral habitats

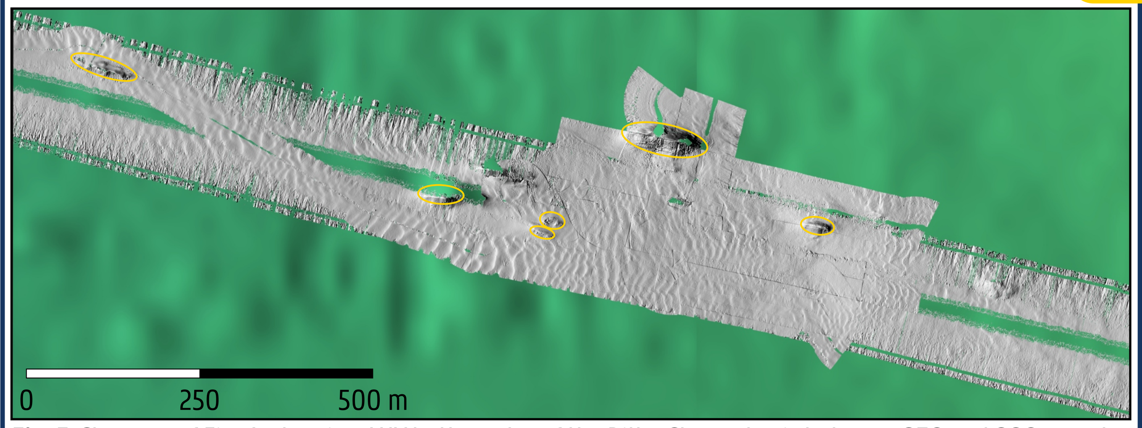


Fig. 5. Close-up of Fig. 4 showing AUV bathymetry of the Bilbo Channel axis between 830 and 880 m water depth. A field of megaripples is visible, as well as cold-water coral patches circled in yellow.

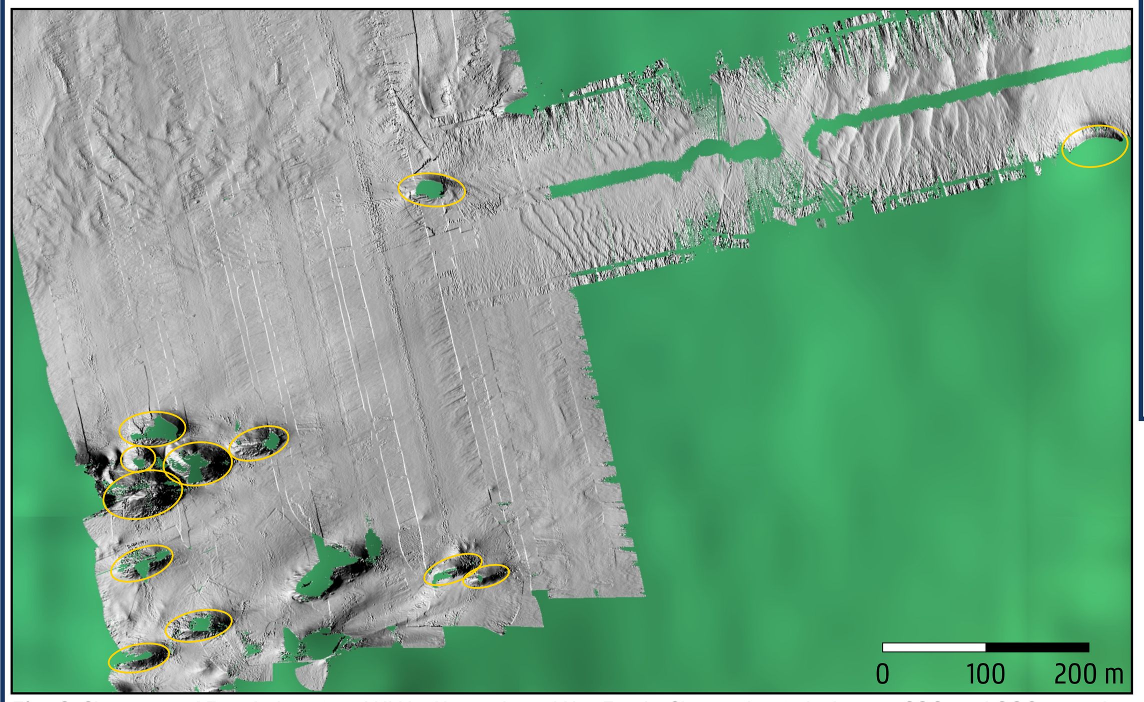


Fig. 6. Close-up of Fig. 4 showing AUV bathymetry of the Frodo Channel axis between 820 and 880 m water depth. A field of megaripples is visible, as well as cold-water coral patches circled in yellow.

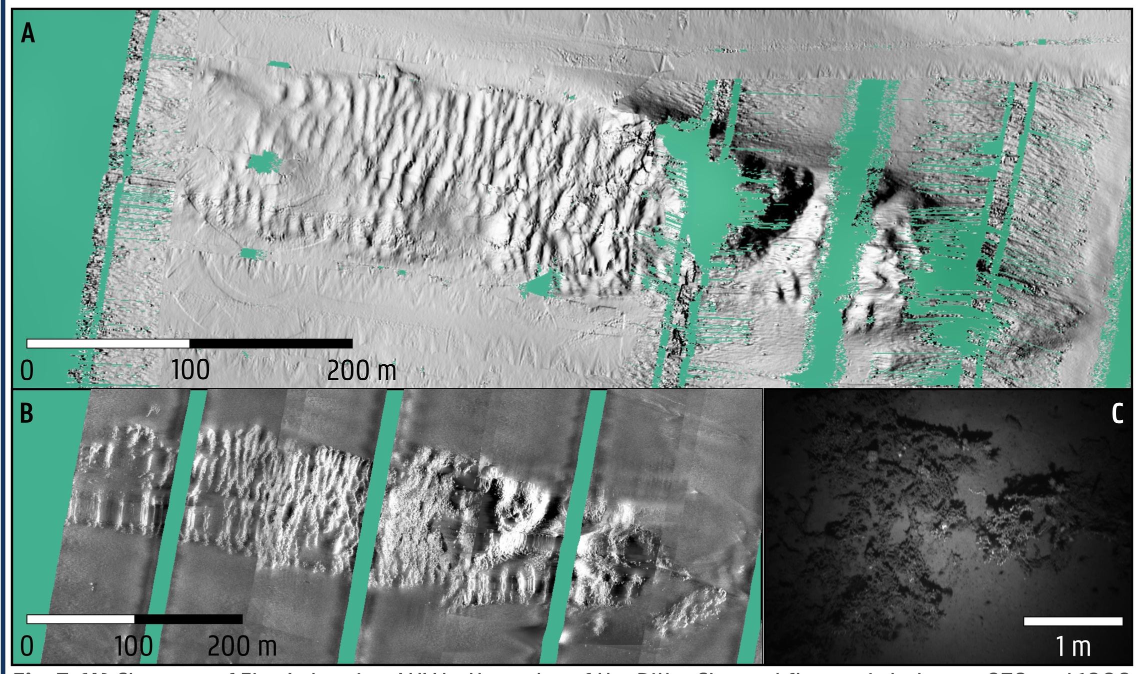


Fig. 7. (A) Close-up of Fig. 4 showing AUV bathymetry of the Bilbo Channel floor axis between 970 and 1000 m water depth. Cold-water corals can be seen forming linear structures. (B) SSS view of the same area (C) Monochrome image of the cold-water corals.

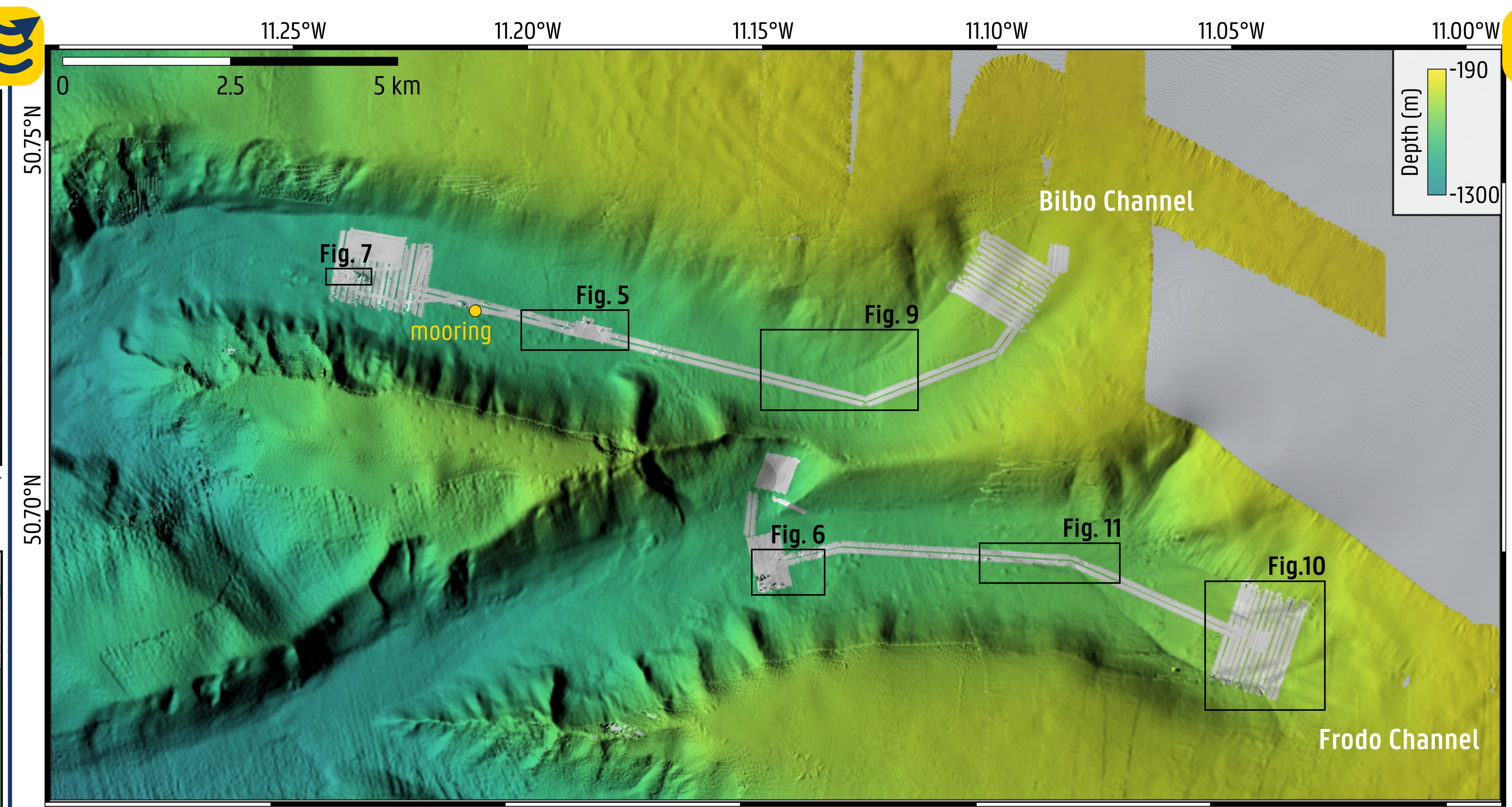


Fig. 4. Bathymetry map of the study area: the upper reaches of Bilbo Channel and Frodo Channel. The coloured bathymetry data was acquired during several surveys using Kongsberg EM304 and EM302 systems. The grey areas are covered by AUV bathymetry and SSS data. The location of the mooring in Bilbo Channel is indicated as a yellow dot. The locations of the close-up figures (Figs. 5-11) are indicated as black rectangles.

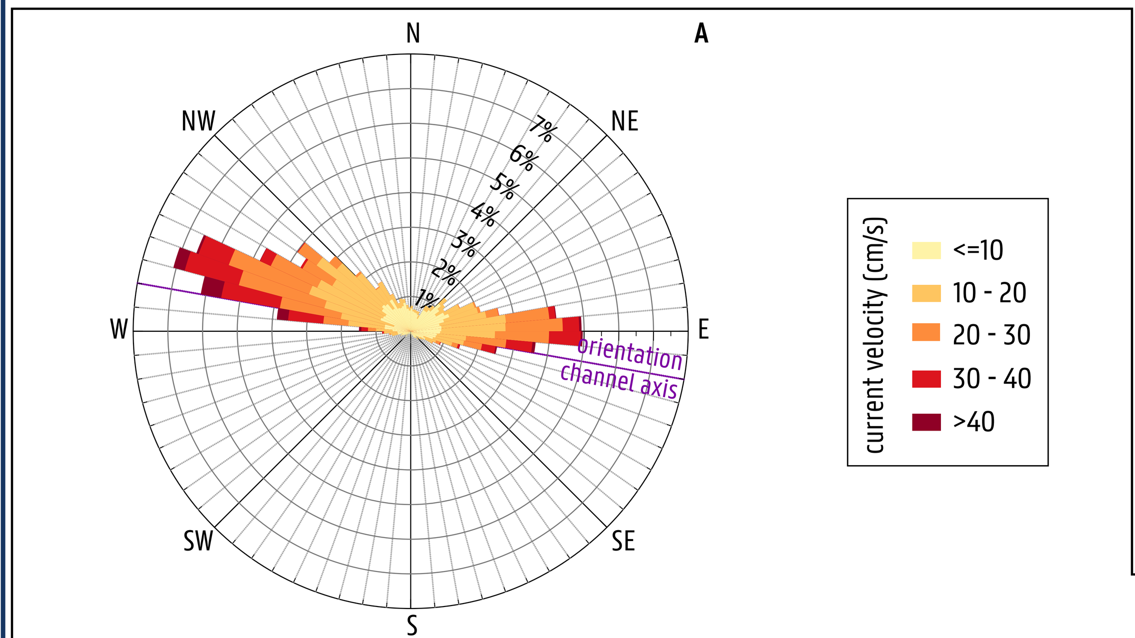
- **Wavy bedforms** are identified at 840-885 m and 750-850 m water depth in Bilbo (Fig. 5) and Frodo (Fig. 6) channels, respectively. Based on their dimensions (Table 1), they are characterized as megaripples (van Dijk et al., 2020). The megaripples have a straight to sinuous shape and bifurcated crests have developed in some sections of the ripple fields.
- Patches of **cold-water corals** are identified at 840-1000 m and 680-840 m water depth in Bilbo and Frodo Channel, respectively (Figs. 5, 6, 11). They are several meters high and wide, 10-20 m long, and elongated along the channel axes. The largest of the patches is c. 30 m high, > 100 m wide, c. 600 m long, and contains corals that are lined up in an across-axis orientation (Fig. 7).
- The mooring data (Verweirder et al., 2021) show **tidal bottom currents** in Bilbo Channel, with a dominance of the M_2 component (principal lunar semidiurnal; 12.42 h period). The average instantaneous current velocity is 15.1 cm/s (range 1.1-53.7 cm/s) and the currents are strongly oriented along the channel axis (E-WNW; Fig. 8A).

The N-S orientation of the megaripples in both channels and perpendicularly oriented (E-WNW) bottom currents suggest formation of the ripples by the tidal bottom currents. The measured flow velocities (15.1 cm/s average) compare with other studies where megaripples have been observed (Bellec et al., 2019), but are a bit lower than the average flow velocities for the formation of dunes or sandwaves (0.3-0.75 m/s) that were described by Stow et al. (2009).

These bottom currents are also thought to be responsible for creating favourable conditions for settling and growth of the corals observed in the channel axes.

channel	wavelength (m)	waveheight (cm)	orientation
Bilbo	15.8 (6.4-31.3)	23 (4-67)	N-S
Frodo	10.4 (4.8-18.6)	21 (3-58)	N-S/NNW-SSE

Table 1. Dimensions of the megaripples [avg (min-max)].



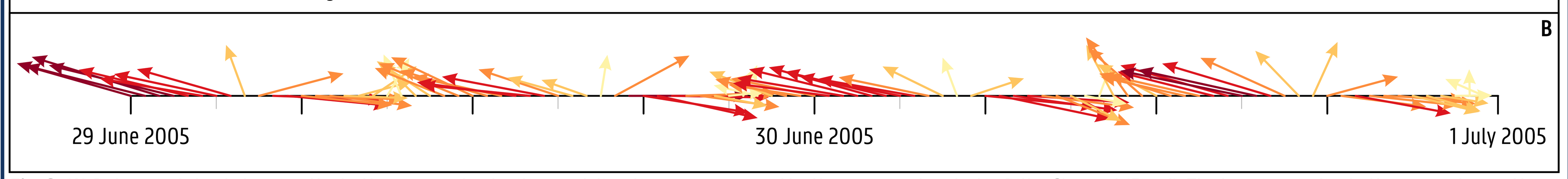


Fig. 8. (A) Polar wind chart showing the bottom current velocities and directions as measured by the mooring located in Bilbo Channel (Fig. 4). The bar sizes indicate the percentage of time the current flowed in the given direction, and the colours indicate the current velocity. (B) Vector diagram showing a representative time series of current velocities and directions.

Downslope activity is present but minimal

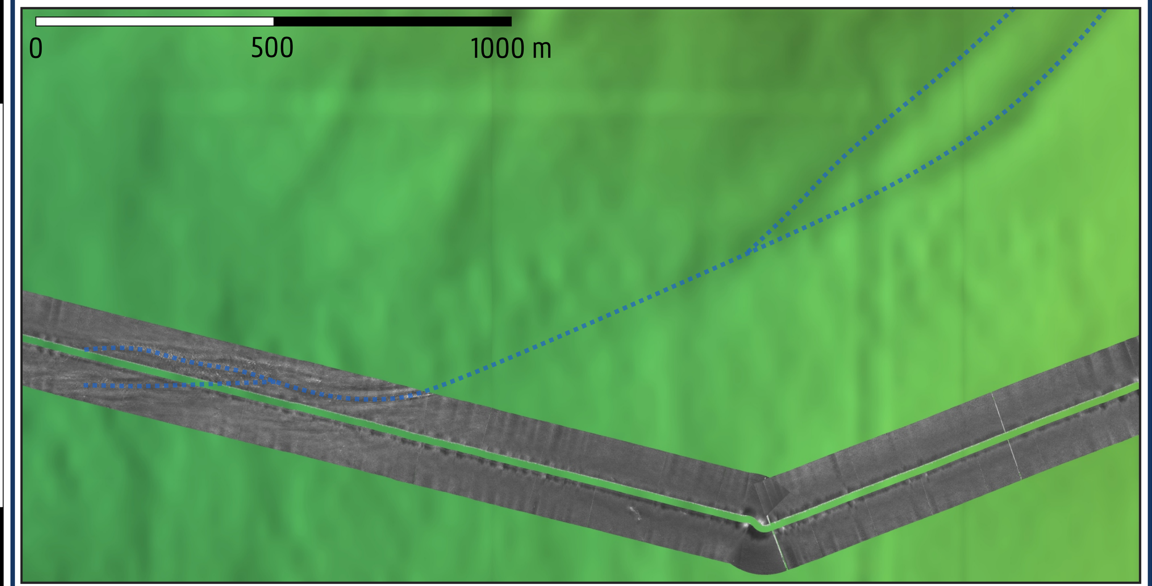


Fig. 9. Close-up map of Fig. 4 showing the Bilbo Channel flank and axis between 600 and 750 m water depth. Gullies are indicated as blue dotted lines.

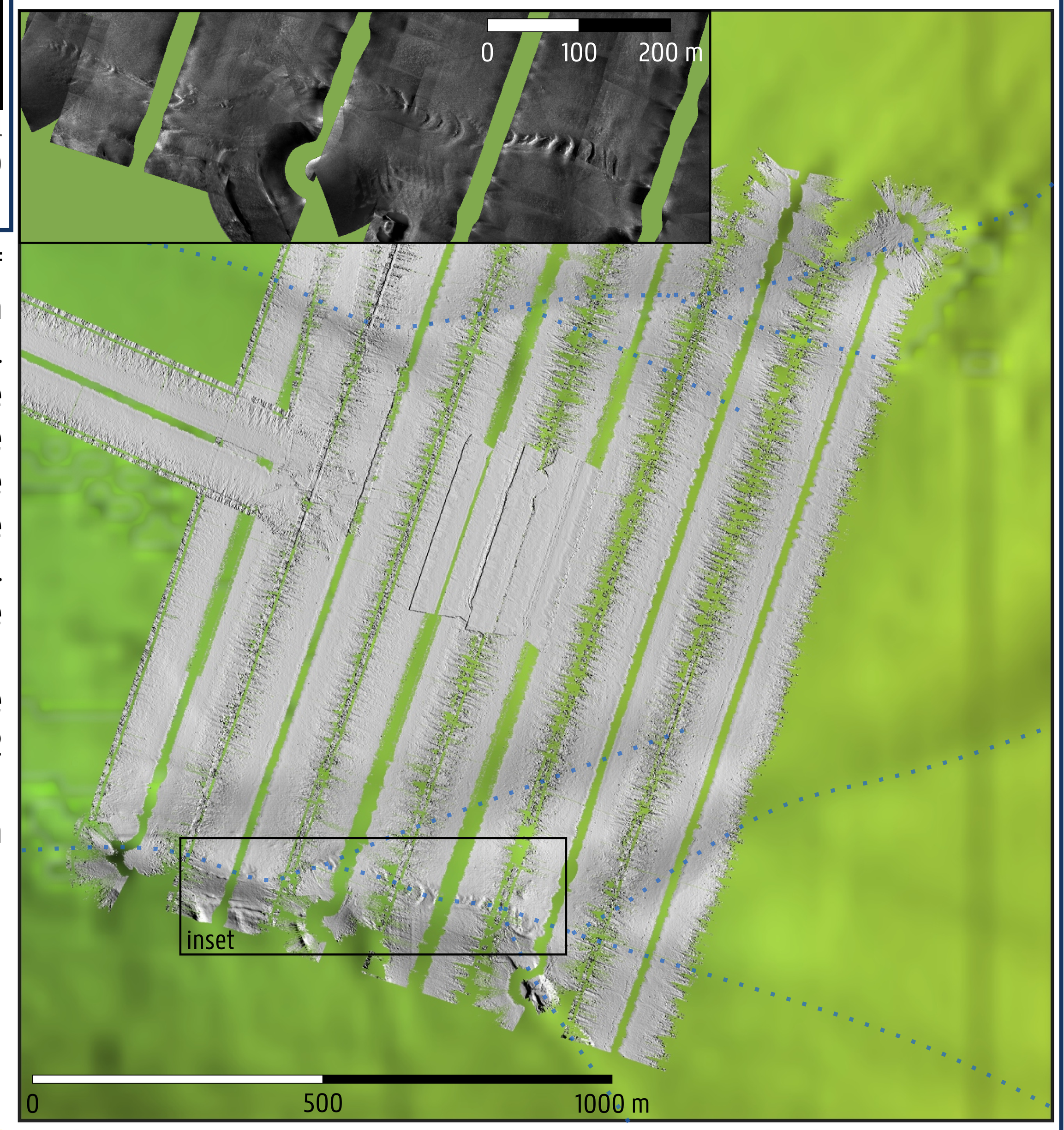


Fig. 10. Close-up of Fig. 4 showing AUV bathymetry of the Frodo Channel head (430-550 m water depth). Gullies are indicated as blue dotted lines. The inset shows barchan dunes in one of the gullies in de SSS data.

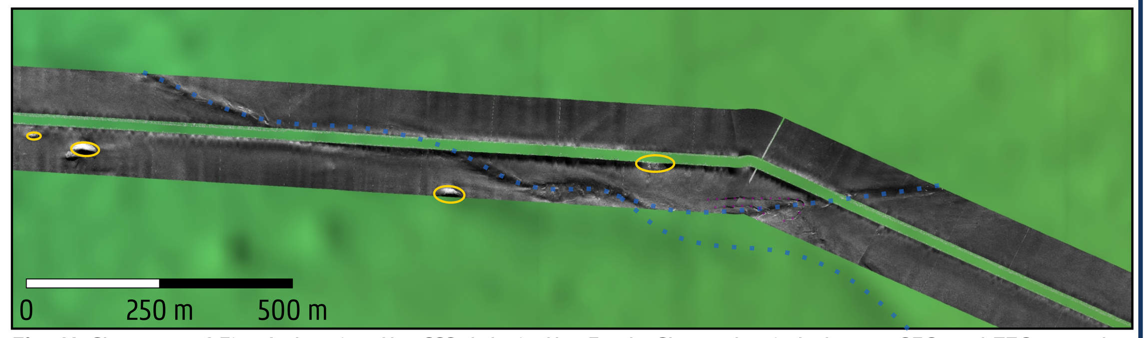


Fig. 11. Close-up of Fig. 4 showing the SSS data in the Frodo Channel axis between 650 and 730 m water depth. Gullies are indicated as blue dotted lines. Patches of cold-water corals are circled in yellow. Two scarps in one of the gully axes is indicated as purple dotted lines.

- Down-channel oriented **gullies** originate in the heads of both channels (Figs. 9-11). They are most pronounced in Frodo Channel, where they form a dendritic network (Fig. 10). They are 10-25 m deep, 100-200 m wide, and are identified down to water depths of about 750 m. Some gullies are recognized as areas of higher reflectivity in the SSS data (Fig. 11), indicating an increased roughness of the seabed there compared to the surrounding channel floor. Others have a SSS signature that is similar to the surrounding seabed.
- A series of **barchan dunes** is present within one of the gullies at the head of Frodo Channel (Fig. 10). They are 1-2 m high and have wavelengths of 10 to 15 m.
- Two **scarps** are visible in the axis of one of the gullies in Frodo Channel (Fig. 11): one is 2 m high, the other 1 m.

Barchan dunes are generally associated with average flow velocities of 0.6-1.2 m/s (Stow et al., 2009). Here, their orientation and location within a gully, along with the presence of the scarps in a gully further downslope, suggests recent activity of downslope nature. Due to the spatial limits of the datasets, it is difficult to establish whether these downslope flows originate from processes on the shelf or flank failures in the channel head area. Other gullies do not display similar features and have SSS characteristics similar to the surrounding seafloor, which is interpreted as a sign of recent inactivity and burial by hemipelagic sediments.

4 – Conclusions

The main active process in the two northernmost channels of the Gollum Channel System are **bottom currents** that

- are strongly tidally modulated, oriented along-axis, and have average velocities of 15 cm/s;
- create megaripples;
- create a habitat for cold-water corals.

Downslope flows exist but are a minor process confined to a couple of gullies in the channel head area. They

- create the gullies they use as pathways;
- create barchan dunes and scarps within the gullies;
- are generated by mechanisms that are unclear at present.

Bellec, V. K., Bøe, R., Bjarnadóttir, L. R., Albretsen, J., Dolan, M., Chand, S., Thorsnes, T., Jakobsen, F. W., Nixon, C., Plassen, L., Jensen, H., Baeten, N., Olsen, H., and Elvenes, S. (2019). Sandbanks, sandwaves and megaripples on Spitsbergenbanken, Barents Sea. Mar. Geol. 416, 105998.
Heijnen, M. S., Mienis, F., Gates, A. R., Bett, B. J., Hall, R. A., Hunt, J., Kane, I. A., Pebody, C., Huvenne, V. A. I., Soutter, E. L., and Clare, M. A. (2022). Challenging the highstand-dormant paradigm for land-detached submarine canyons. Nat. Commun. 13, 1–11.
Stow, D. A. V., Hernández-Molina, F. J., Llave, E., Sayago-Gil, M., Díaz del Río, V., and Branson, A. (2009). Bedform-velocity matrix: The estimation of bottom current velocity from bedform observations. Geology 37, 327-330.
van Dijk, T. A., Best, J., and Baas, A. C. (2020). Subaqueous and subaerial depositional bedforms. In: Encyclopedia of Geology: Volume 1-6, Second Edition. (Eds. Alderton, D. and Elias, S. A.), pp 771-786. Elsevier.
Verweirder, L., Van Rooij, D., White, M., Van Landeghem, K., Bossée, K., and Georgiopoulou, A. (2021). Combined control of bottom and turbidity currents on the origin and evolution of channel systems, examples from the Porcupine Seabight. Mar. Geol. 442, 106639.
Wheeler, A. J., Kenyon, N. H., Ivanov, M. K., Beyer, A., Cronin, B. T., McDonnell, A., Schenke, H. W., Akhmetzhanov, A. M., Satur, N., and Zaragosi, S. (2003). Canyon Heads and Channel Architecture of the Gollum Channel, Porcupine Seabight. In: European Margin Sediment Dynamics. (Eds. Mienert, J. and Weaver, P.), pp 183-186. Springer, Berlin, Heidelberg.

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