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CRUISE REPORT

GRACE PROJECT (Geo-hazaRds Along the CEuta canyon)

RV Belgica, Cruise No. 2022/11,

28/04/2022 - 11/05/2022, Algeciras (SPAIN) – Algeciras (SPAIN)

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1 Summary

The GRACE cruise was carried out from 28/04/2022 to 11/05/2022 onboard the *R/V Belgica* (RBINS-OD Nature, Belgium), departing and returning to the Port of Algeciras (Spain). The GRACE cruise shared ship time with the SEAQUAKE cruise. Out of the total of 14 days of ship time granted, 11 days corresponded to the GRACE Project and 3 days corresponded to the SEAQUAKE Project. The GRACE study area was located on the westernmost Mediterranean Morocco margin, including the continental slope and basin physiographic provinces, and not surveying the shelf to avoid sailing waters in current conflict between Spain and Morocco.

The GRACE cruise aimed to study the geological risks associated to the Ceuta Canyon and its adjacent areas. The Ceuta Canyon is a large-scale downslope feature at the westernmost end of the Mediterranean Morocco margin. Its location is tectonically controlled, and seems to be related to onshore active structures. Its head (located close to the coast) and its eastern margin are affected by arcuate-shaped scars, and in addition the area is deeply influenced by vigorous bottom currents that cause erosion on its margins and the rapid growth of the adjacent Ceuta Drift. This complex context raises concerns regarding the high exposure of coastal populations and key infrastructures to geohazards. For that reason, the GRACE cruise tackled the task of gathering the necessary data to evaluate such geohazards with a multidisciplinary approach, focusing on the sedimentary processes, chrono-stratigraphy, oceanography. Last, the incorporation of an AUV allowed obtaining knowledge of the submarine features with unprecedented precision, providing higher resolution datasets than those achieved from surface vessels with traditional techniques.

-The sedimentary processes will be studied based on the multibeam, Sparker (Fig. 1), TOPAS, AUV data and sediment cores.

-The chrono-stratigraphy will be mostly studied based on the Sparker and TOPAS data.

-The oceanography will be studied based on the CTD, hull-mounted ADCP, and moored ADCP (Fig. 1).

-Additional information on the biological communities present in the study area, whose cyclic growth pattern is also affected by the paleoclimatic and paleoceanographic variations, will be provided by the AUV, Sparker and TOPAS profiles.

This cruise means a key advance in the knowledge of major features such as the Ceuta Canyon and the adjacent Ceuta Drift, as well as on the analysis of their associated geohazards, and the results obtained will allow a safer planning and management of coastal and submarine infrastructures, and of biological communities.

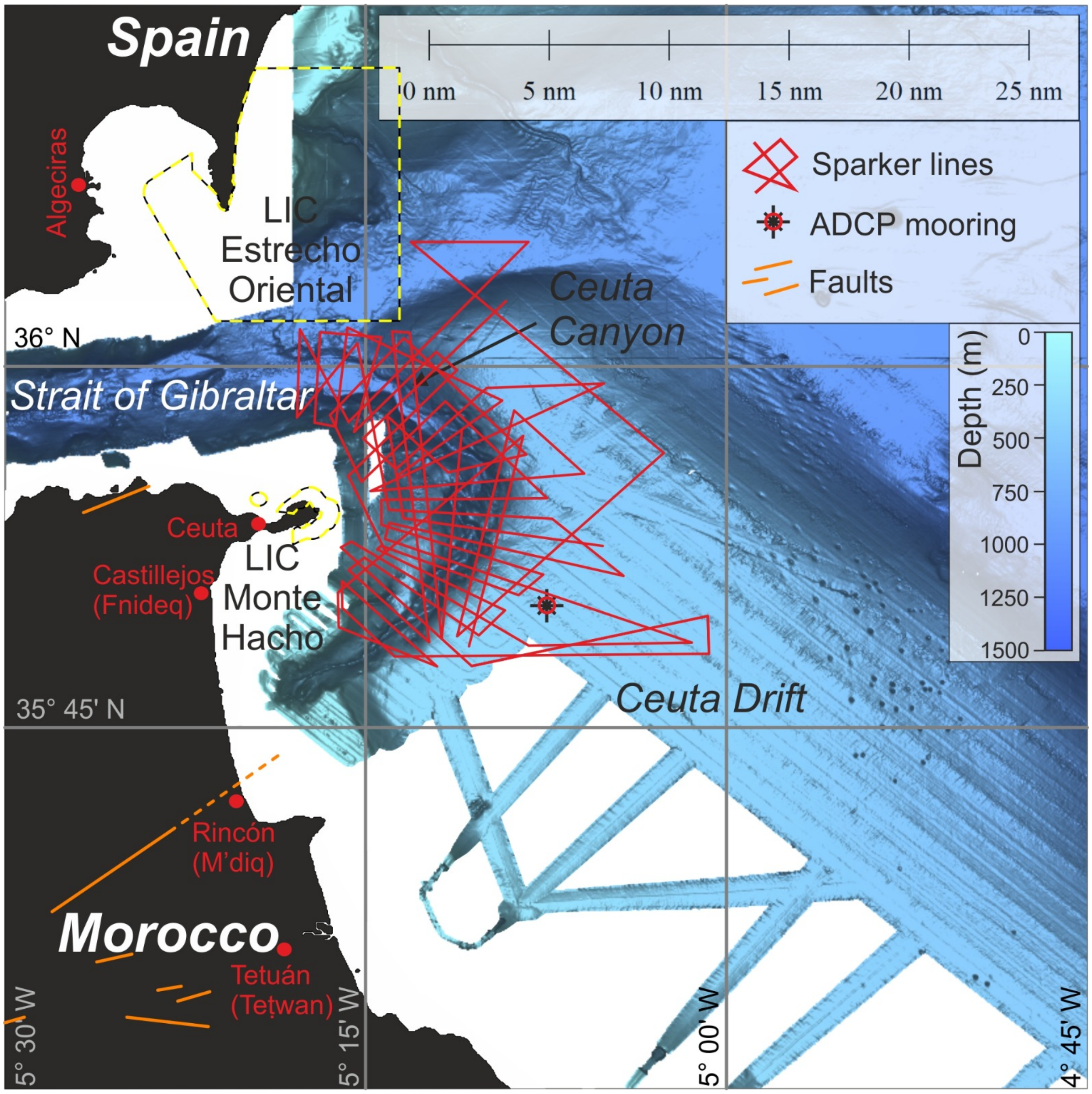

Fig. 1 Working area and Sparker track chart of R/V Bélgica Cruise 2022/11. Bathymetry from the CONTOURIBER Project (*Published in* Somoza et al., 2012).

2 Research Programme/Objectives

The GRACE cruise pursued two main objectives: a) to better understand the Ceuta Canyon, including its origins, influence of tectonic features, and chronostratigraphy of the deposits, and b) the study of potential hazardous geological and oceanographic processes occurring in the Ceuta Canyon and adjacent areas. These two main objectives were broken down into specific scientific questions:

Objective A: origins, development and chronology of the Ceuta Canyon

a) Is the origin and current location of the Ceuta Canyon related to the Onsar fault? *

b) How was the Plio-Quaternary evolution of the Ceuta Canyon and its tributaries? How was the interplay between the Ceuta Canyon and Drift in the past?

c) Have the downslope processes influenced the Ceuta Canyon incision and the meandering of the thalweg in the past?

d) Are there any cyclic patterns dismantling the canyon head and eastern sidewall? Are these cyclic patterns related to glacioeustatic sea-level changes? *

Objective B: hazardous geological and oceanographic processes

e) Is the Onsar fault a relevant risk factor? *

f) Are slide scars on the canyon rims active today? Do they present a great risk to nearby populations? Which are the diagnostic criteria?

g) How is the Atlantic Jet affecting the morphology? Are internal waves detected in the study area? Are they a relevant triggering factor?

h) Which of the possible mechanisms (slope oversteepening, seismicity, internal waves...) prevails triggering the downslope processes?

Additional questions

j) Do the bioconstructions located besides the canyon head contain relevant information to reconstruct the past evolution of the Ceuta Canyon? Are they forming singular vulnerable ecosystems? Are sediment instabilities endangering the bioconstructions?

k) Do new interpretations fit within previously published sedimentary and oceanographic models? Which are the implications of these results? Can they be extrapolated to other margins with coexisting alongslope and downslope features?

* Unfortunately, the lack of sailing permits into Moroccan waters greatly affected the possibility of obtaining data of the canyon head to fully answer these questions, which will be nonetheless tackled with the currently available information.

3 Narrative of the Cruise

(time in GMT)

28/04/2022

- 6:00 - Departure from the Port of Algeciras towards the mooring station
- 7:00 - Safety training provided by the Captain at the Meeting Room.
- 8:00 – The MMOs start their first shift
- 08:00 – 12:30 – Preparation of the ADCP mooring line on deck.
  TECHNICAL ISSUES: Part of the material corresponded to a different mooring line. The assemblage of the ADCP on the buoy was slightly modified to achieve a solid grip and a better orientation of the ceramic plates by placing two packing rings in between the clamp and the connection at the buoy's frame.
- 13:30 – ADCP mooring maneuver (35.834743ºN / 5.124762ºW).
  The buoy's frame was tied up with a rope and a liberator hook. The weight was placed in the wáter, and once the entire mooring line was in good position, the buoy was freed from the rope and the entire mooring line descended to the seafloor. Clean maneuver.
- 14:00 – Full test with AUV (release, descent, acquisition)
- 16:00 - Training for the day-to-day use of the various acousting sounders installed onboard the RV Bélgica (EK80, TOPAS, multibeam echosounders).
- 16:30 - Recovery of the AUV. Test successful.
- 17:20 – Calibration of the CTD rosette
- 18:00 – CTD01 profile (35.8068333ºN / 5.17766667ºW). The Morocco authorities repeatedly request the RV Belgica not to enter into their waters.
- 19:00 - Tuning of all the acoustic sounders (EK80, TOPAS, multibeam).
  TECHNICAL ISSUES: The multibeam and TOPAS echosounders can't work simultaneously due to interferences. Given that a mid-resolution multibeam grid is available, priority in acquisition is given to TOPAS, so the multibeam is shut down. In addition, due to the insistence of the Moroccan authorities, the Sparker lines are modified even before their start to avoid navigation on the continental shelf, which are waters in conflict between Spain and Morocco.
- 19:00 - Tuning of all Sparker systems. Navigation in circles around the starting point.
  TECHNICAL ISSUES: The sparker can't fire, so the power supply is changed. Not knowing the duration of the repair, multibeam lines are planned in the meantime along the upper part of the Ceuta canyon, as a backup plan. A second Sparker test is performed on route to the first multibeam line. The test is successful, so the start of multibeam lines is aborted and the vessel returns to the start of the first Sparker line.
- 19:26 – Start Of Line (SOL) GRACE01 (TOPAS) and A01 (Sparker), about 200 m west of the line. The vessel slowly fixes its course until reaching the line.

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- 00:00 - End Of Line (EOL) GRACE01 (TOPAS), slightly out of line for transit to the next line.
- 00:02 - SOL GRACE02 (TOPAS).
- 00:04 - EOL A01/SOL A02 (Sparker).
- 02:29 - EOL GRACE02 (TOPAS).
- 02:32 - SOL GRACE03 (TOPAS).
- 02:37 - EOL A02 /SOL A03 (Sparker).
- 02:56 - TECHNICAL ISSUES: The EK80 loses the seafloor "at 400 m deep" and the TOPAS shows the we are currently at 85 m depth, but seems to be recording the water column. We force the depth into the EK80 and the problem is solved.
- 02:59 - EOL A03 (Sparker) / SOL A04 (Sparker). EOL GRACE03 / SOL GRACE04 (TOPAS).
- 03:55 - EOL GRACE04 TOPAS. The vessel made the turn on the inside of the angle made by the two lines and some features that were being imaged on the platform were lost.
- 03:58 SOL GRACE05 TOPAS. The beginning of the line was not recorded due to the turn of the vessel.
- 04:05 EOL A04/SOL A05 SPARKER. The change of the line was done a little bit late.
- 04:20 TECHNICAL ISSUES: GRACE05 (TOPAS). Problems with the depth, the system indicates only 4 m deep (which is not posible at the axis of the canyon), and then suddenly jumped to 1000 m. The depth of the system was manually forced to 300 m (which was the depth indicated bu the EK80. Once stable, the settings of the depth were set back to authomatic and went once again to 1000 m deep. The team had to return to manual settings.

- 04:57 – In a flat, not-so-relevant area, the TOPAS team tried once again to go back to automatic settings. At the beginning it went to 500 m, but slowly went to the actual depth of the seafloor, at 160 m deep.
- 05:04 – EOL A05 / SOL A06 (Sparker).
- 05:06 – EOL GRACE05 / SOL GRACE06 (TOPAS).
- 05:13 – EOL A06/SOL A07 (Sparker) (There was another problema with the turn of the vessel and the new line 7 should still be line 6)
- 05:24 – EOL A07/SOL A07b (Sparker).
- 05:26 – EOL GRACE06 / SOL GRACE07 (TOPAS).
- 05:34 – Still experiencing problems with the automatic detection of the seafloor on the TOPAS. These problems are explained to David, the technician of the vessel, who is about to start his shift. The technician switches to manual.
- 05:36 - The technician switched the system back to automatic because in manual everything seems to work fine. The seafloor jumps suddenly to 800 m. After agreeing that there are problems with the automatic detection of the seafloor, he switched back to manual. Depth stays blocked at 150 m due to an internal error. The technician switched once again to automatic and back to manual and the system is able to detect the seafloor once again.
- 05:42 - EK80 is stable at a good depth and one last attempt to switch to automatic is done. The depth of the TOPAS jumps to 1250 m, so the team returns to manual settings.
- 05:45 – The technician suspects that there is a second synchrony problem between the sounders (on top of the interference that prevents to use TOPAS and Multibeam at the same time). The TOPAS pulse affects the EK80, that registers way too much noise and can't find the seafloor. Since the EK80 feeds the location of the seafloor to the TOPAS, she can't find the seafloor in automatic settings.
- 05:47 - The technician lowers the energy of the TOPAS pulse to 39.8% to see if the EK80 can find the seafloor with less noise. It does not work, so the TOPAS goes back to 100% energy settings.
- 06:11 - EOL A07b/SOL A08 (Sparker).
- 06:14 - EOL GRACE07 / SOL GRACE08 (TOPAS).
- 07:10 - EOL A8 (Sparker).
- 07:30 - EOL GRACE08 / SOL transit to AUV1 -TRANSAUV1- (TOPAS).
- 08:30 - EOL TRANSAUV01 (TOPAS).
- 09:30 - CTD02 to obtain a sound velocity profile (35.9048333ºN / 5.15383333ºW).
- 12:30 - AUV on the water. (35º 55.381'N 5º 9.1462'W).
- 13:00 - AUV back to surface (emergency stop due to a technical problem). It is sent back down without requiring to go on deck. The AUV resumes her work.
- 13:30 - AUV back to surface. Emergency stop.
- 15:30 - AUV is on deck to carry out a change of batteries.
- 16:22 - AUV back to water
- 17:00 - The AUV navigates correctly above the seafloor. Start of maneuvers to record a CTD in the meantime (CTD03 - 35.9096667ºN / 5.15666667ºW).
- 17:55 - CTD03 back onboard
- 19:09 - Dolphins near the prow (35º54.571'N / 5º9.398'W)
- 19:29 - AUV back onboard (35º54.538'N / 5º 9.375'W)
- 20:09 – SOL Transit to GRACE 08B (TRAGRACE8B - TOPAS).
- 20:56 – EOL TRAGRACE8B / SOL GRACE 8B (TOPAS).
- 20:57 – SOL A08B (Sparker).
- 22:39 – EOL GRACE 8B (TOPAS).
- 22:40 – EOL A08B / SOL A09 (Sparker).
- 22:55 – TECHNICALL ISSUES: Connection problem with the Sparker system.
- 22:41 – SOL GRACE 09 (TOPAS).
- 23:00 – EOL GRACE 09 (TOPAS) and EOL A09 / SOL A010 (Sparker).
- 23:02 – SOL GRACE 10 (TOPAS).

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- 01:04 – EOL GRACE 10 (TOPAS).
- 01:05 – EOL A10 / SOL A011 (Sparker).
- 01:06 – SOL GRACE 11 (TOPAS).
- 02:45 – EOL GRACE11 / SOL GRACE12 (TOPAS) and EOL A11 / SOL A12 (Sparker).
- 02:52 – EOL A12 / SOL A13 (Sparker).
- 02:53 – EOL GRACE 12 / SOL GRACE 13 (TOPAS).

- 04:59 – EOL GRACE 13 / SOL GRACE14 (TOPAS) and EOL A13 / SOL A14 (Sparker).
- 06:14 – EOL GRACE14 (TOPAS) due to the presence of dolphins close to the vessel.
- 06:15 – EOL A14 (Sparker) due to the presence of dolphins close to the vessel. Change of course towards AUV DIVE02
- 06:26 – SOL TRANS AUV2 (TOPAS). Preparation of AUV during transit.
- 07:30 – Arrival to AUV2 mother position.
- 07:42 – SOL TRANS AUV2 (TOPAS).
- 08:15 – AUV in the water.
- 09:46 – CTD 04 (35.897ºN / 5.1555ºW) - Later we learned that doing a CTD during the AUV dive affected the navigation of the AUV, and we stopped using the time during AUV dives for CTDs.
- 12:56 – AUV back on deck. Battery swap.
- 13.42 – AUV diving once again
- 17.11 – Start AUV recovery maneuver (very quick, at 17.14 the AUV is on deck). The analysis of the data reveals coral-like structures.
- 17:28 – Start of the maneuver to recover Gravity Core 01 (35º53.3342' N / 5º10.5667' W). Since it is the very first time that the sediment core recovery system is used onboard the vessel, it is decided to only use the 1 m trigger core as the main core (thus, using the trigger as a small-sized gravity core) so all the personnel on deck can start to get used to using the system.
- 17:48 – Gravity core GRACE GC-01 at the bottom of the seafloor (Depth: 646 m)
- 18:00 – End of maneuver to recover the gravity core GRACE GC-01. (Penetration: 110 cm; Sections: 1/1). Full success.
- 18:00 – Start of maneuver to record CTD 05 (35.8888333 ºN / 5.17616667 ºW)
- 18:49 – CTD 05 back on deck.
- 19:00 - SOL transit to GRACE15 (TOPAS).
- 20:36 - EOL transit to GRACE15. SOL GRACE 15 (TOPAS) and SOL A15 (Sparker).
- 23:17 - EOL GRACE 15 (TOPAS).
- 23:18 - SOL GRACE 16 (TOPAS) and EOL A15 / SOL A16 (Sparker).
- 23:28 - EOL GRACE 16 (TOPAS).
- 23:29 - EOL A16 / SOL A17 (Sparker).
- 23:30 - SOL GRACE 17 (TOPAS).

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- 01:19 - EOL A17 / SOL A18 (Sparker).
- 01:20 - EOL GRACE 17 (TOPAS).
- 01:23 - SOL GRACE 18 (TOPAS).
- 01:45 - EOL GRACE18 (TOPAS).
- 02:03 - EOL A18 / SOL A19 (Sparker).
- 02:04 - SOL GRACE19 (TOPAS).
- 03:28 - EOL GRACE19 / SOL GRACE20 (TOPAS) and EOL A19 / SOL A20 (Sparker).
- 05:07 - EOL GRACE20 / SOL GRACE21 (TOPAS).
- 05:08 - EOL A20 / SOL A21 (Sparker).
- 05:59 - EOL A21 / SOL A22 (Sparker) and EOL GRACE21 / SOL GRACE22 (TOPAS) – TECHNICAL ISSUES: The seafloor is lost on the TOPAS profiles.
- 06:15 – Early EOL A22 (Sparker) due to the presence of dolphins in the vicinity.
- 06:50 – The Sparker line A22 is resumed once the dolphins are gone. SOL A22B (Sparker).
- 07:12 - EOL A22B (Sparker). Change of recording parameters in Sparker (shooting interval 2 s).
- 07:13 - EOL GRACE22 (TOPAS).
- 07:15 - SOL A23 (Sparker) and SOL GRACE23 (TOPAS).
- 08:06 - EOL GRACE23 and SOL transit to AUV3 (TOPAS). The AUV is prepared during the transit.
- 08:10 - EOL A23 (Sparker).
- 09:07 - EOL TRANSIT AUV3 (TOPAS).
- 09:27 - Start of AUV deployment maneuver for AUV dive 3 (mother position: 35º58.10002' N / 5º 10.8997' W)
- 09:40 – Start of AUV dive3
- 15:35 - AUV back onboard for battery swap
- 16:33 - AUV back on the water
- 17.30 - AUV back bordo. End of AUV DIVE3
- 19:03 - Start of CTD06 (35.987606ºN / 5.258445ºW)

- 19:50 - CTD06 back onboard.
- 20:45 – The TOPAS is not working. Krongsberg is contacted, the team awaits for answers. Given that we can't use the TOPAS, we will switch on the multibeam echosounder.
- 20:47 - SOL A24 (Sparker).
- 22:30 - SOL LMB25 MULTIBEAM (the recording starts when Sparker line A24 is about halfway).
- 23:12 - EOL A24 / SOL A25 Sparker (change of acquisition parameters: shooting rate 1.5 s, recording length 1.4 s).

02/05/2022

- 00:05 - EOL A25 / SOL A26 (Sparker). The weather is bad and the vessel drifts far away from the planned line.
- 00:09 - EOL LMB25 / SOL LMB26 (Multibeam).
- 03:07 - EOL A26 / SOL A27 (Sparker), and EOL LMB26 (Multibeam). Problem with Multibeam acquisition.
- 03:10 – The multibeam system is restored and it seems to work fine. SOL LMB27 (Multibeam).
- 03:50 – Acquisition problems with Sparker.
- 04:19 – The source of the problem with the Sparker system seems to be the power supply unit (CSP700). It seems to work fine, but it stops after a while. Test with different acquisition parameters.
- 04:53 – Still with problems. The sparker centipede and the power supply (CSP600) are changed.
- 05:02 - SOL A27_002 (Sparker).
- 05:45 - EOL LMB27 (Multibeam).
- 05:51 - SOL LMB28 (Multibeam).
- 05:52 - EOL A27_002 / SOL A28 (Sparker).
- 06:30 - EOL A28 SPARKER. The planned Sparker line is not finished yet, but Sparker is cut short due to the worsening weather. The day will be dedicated to the acquisition of high-resolution multibeam lines along the canyon axis (the multibeam lines that were planned on the first night as a backup plan).
- 06:38 - EOL LMB28 and SOL TRANSCTD7 (Multibeam).
- 07:10 - EOL TRANSCTD7 (Multibeam). The multibeam record is stopped by mid-transit towards the CTD position 07. The TOPAS is being fixed, and a few tests will be carried out during the rest of the transit.
- 8:02 – CTD 07 is lowered to the water (35.964541ºN / 5.214523ºW)
- 8:53 – CTD 07 back onboard.
- 09:13 - SOL TRANS LMB01 (Multibeam).
- 10:06 - EOL TRANS LMB01 (Multibeam).
- 10:26 - SOL LMB01 (Multibeam).
- 10:42 - EOL LMB01 (Multibeam).
- 10:49 - SOL LMB02 (Multibeam).
- 11:13 - EOL LMB02 (Multibeam).
- 11:19 - SOL LMB03 (Multibeam).
- 12:37 - EOL LMB03 (Multibeam).
- 12:46 - SOL LMB04 (Multibeam).
- 14:29 - EOL LMB04 (Multibeam).
- 14:35 - SOL LMB05 (Multibeam).
- 14:50 – During the afternoon various tests are carried out to check the power supplies of the Sparker system, as well as all the connection cables.
- 15:43 - EOL LMB05 (Multibeam).
- 15:48 - SOL LMB06 (Multibeam). The vessel drifts away from the planned course.
- 15:56 – The vessel is back to its course.
- 16:39 - EOL LMB06 / SOL LMB07 (Multibeam).
- 17:08 - EOL LMB07 (Multibeam).
- 17:13 - SOL LMB08 (Multibeam).
- 18:38 - EOL LMB08 / SOL LMB09 (Multibeam).
- 19:27 – The vessel stops at the CTD 08 planned position (35.8601667ºN / 5.1895ºW).
- 19:31 - EOL LMB09 (Multibeam).
- 19:32 – Start of CTD 08 (35.8601667ºN / 5.1895ºW).
- 20:18 – End of maneuver to record CTD 08.
- 20:42 - SOL LMB09-B (Multibeam).
- 21:37 - EOL LMB09-B / SOL LMB10 (Multibeam).
- 23:03 - EOL LMB10 (Multibeam).
- 23:09 - SOL LMB11 (Multibeam).

03/05/2022

- 00:23 - EOL LMB11 (Multibeam).
- START OF SEAQUAKE OPERATIONS FOR DAY 03/05/2022, to work with both shallow and deep multibeam echosounders. The data of the SEAQUAKE CTDs are also included in this record due to their shared use for calibrating the multibeam echosounder for both the GRACE and the SEAQUAKE projects.
- 11:58 CTD 09a - SQ (35º 57,46'N / 5º 12,23'W). The operation is aborted due to the extremelly strong current, that threatens to break the cable. The vessel moves to a more sheltered location.
- 14:15 CTD-09b - SQ (35º 56' 02.9338"N / 5º 10' 21.7353"W). The operation is once again aborted due to the extremely strong current. The hull-mounted ADCP data is checked to better understand the current conditions and the signal of a very stron internal wave is clearly visible on screen.
- 14:40 – END OF SEAQUAKE OPERATIONS FOR DAY 03/05/2022
- 14:40 – New recorded TOPAS tests while sailing towards the next AUV dive.
- 20:25 – SOL GRACE 24 (TOPAS).
- 22:29 – EOL GRACE 24 (TOPAS).
- 22:30 – SOL GRACE 25 (TOPAS).
- 23:20 – EOL GRACE 25 (TOPAS).
- 23:22 – SOL GRACE 26 (TOPAS).
- 16:02 – AUV in the water at the same position of AUV dive 02, but with the Grasshopper camera, to try to discern if the coral mounds detected in previous dives are alive or just relict features.
- 18:32 AUV back onboard.
- Core GRACE GC-02 (35º53.276'; -5º9.522') – First attempt unsuccessful.
- 19:22 – Start of the second attempt to recover Core GRACE GC-02 (35º53.276'; -5º9.522').
- 19:28 – The Gravity core is at the seafloor (Depth: 492 m).
- 19:40 – End of maneuver for GRACE GC-02. Not much sediment is recovered, two plastic bags are filled with the top (about 10-15 cm of recovery) and bottom (core catcher) sediment.
- 20:34 - SOL A28B (Sparker) (the line that was left unfinished is resumed).
- 22:30 - EOL A28B / SOL A29 (Sparker).
- 23:20 - EOL A29 / SOL A30 (Sparker).

04/05/2022

- 01:07 - EOL A30 / SOL A31 (Sparker).
- 01:11 - EOL GRACE26 / SOL GRACE27 (TOPAS).
- 02:58 - EOL A31 / SOL A32 (Sparker).
- 03:03 - EOL GRACE27 / SOL GRACE28 (TOPAS).
- 03:04 - EOL A32 / SOL A32B (Sparker).
- 04:03 - EOL A32B / SOL A33 (Sparker).
- 04:04 - EOL GRACE28 / SOL GRACE29 (TOPAS).
- 05:15 - EOL A33 / SOL A34 (Sparker). There are once again problems with the power supply of the Sparker system after starting the new line.
- 05:19 - EOL GRACE29 / SOL GRACE30 (TOPAS).
- 05:25 - Change of the power supply of the Sparker, to CSP600. SOL A34b
- 05:40 - The Sparker seems to work properly once again. EOL A34b / SOL A35 (Sparker).
- 05:41 - EOL GRACE30 / SOL GRACE31 (TOPAS).
- 07:27 - EOL A35 (Sparker) and EOL GRACE31 (TOPAS).
- 07:29 - SOL TRANS to AUV04 (TOPAS).
- 08:26 - EOL TRANS to AUV04 (TOPAS).
- 10:00 - AUV in the water.
- 14:04 - AUV back onboard.
- 14:27 - SOL transtit to PC01 LMB with (Multibeam).
- 14:47 - EOL TRANS PC01LMB (MULTIBEAM).
- 14:57 - Start of maneuver for GRACE PC-01 (35º56.897'N; 5º8.0455'W)
- 15:33 - The piston core system touches bottom (Depth: 508 m).
- 16:49 – End of maneuver for GRACE PC-01 (196 cm recovery, 2 sections + trigger core)
- 18:25 - START OF SEAQUAKE OPERATIONS FOR DAY 04/05/2022, using both the shallow and deep multibeam echosounders.

05/05/2022

- 04:30 End of SEAQUAKE OPERATIONS
- 04:30 - SOL transit to AUV8 (recording with MULTIBEAM).
- 05:55 - EOL TRA-LMB-AUV8 (Multibeam). Arrival to AUV8 mother position.
- 06:50 - Start of AUV8 dive on a rocky outcrop at the upper sector of the canyon.
- 09:18 (aprox.) - AUV back onboard.
- 11:03 - Start of maneuver to recover the piston core GRACE PC-02 (35º52.8696'N/ 5º9.074'W)
- 11:30 - GRACE PC-02 touches bottom (Depth: 463 m)
- 12:11 - GRACE PC-02 is on deck (251 cm penetration; 3 sections + trigger).
- 14:17 – Start of maneuver for core GRACE PC-03 (replica of PC-02, for geotechnical analysis) (35º52.8698'N; 5º9.07431'W)
- 14:45 – Bottom (Depth: 464 m).
- 15:20 - End of maneuver for core GRACE PC-03 (261 cm of penetration; 3 sectionc + trigger).
- 16:45 – Same position as AUV8, second dive with the Grasshopper camera (after battery swap) to check on a different benthic community.
- 17:00 - AUV is still at the surface. There is bad communication link with the vessel.
- 17:12 - AUV back on deck to fix comms.
- 17:35 - AUV back on the water for a quick and short dive (it must be recovered while there is still some light, before 21:30 local time, 19:30 GMT).
- 19:25 - AUV back on deck.
- 20:04 - START OF SEAQUAKE OPERATIONS, using TOPAS.
- 23:17 - Problems due to the abundance of tiny boats not properly signaled and without radio.

06/05/2022

- 20:23 - END OF SEAQUAKE OPERATIONS, using TOPAS and AUV.
- 20:23 - SOL transit GRACE32 (TOPAS). TECHNICAL ISSUES: Depth detection is once again not working at all… TOPAS does not update it and EK80 provides almost random values.
- 20:46 - SOL transit A36 (Sparker).
- 22:28 - EOL transit A36 / SOL A36 (Sparker).
- 22:30 - EOL transit GRACE32 / SOL GRACE32 (TOPAS).

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- 00:56 - EOL GRACE32 (TOPAS).
- 01:00 - SOL GRACE33 (TOPAS) and EOL A36 / SOL A37 (Sparker).
- 02:27 - EOL A37 / SOL A38 (Sparker).
- 02:28 - EOL GRACE33 / SOL GRACE34 (TOPAS).
- 02:57 - EOL GRACE34 / SOL GRACE35 (TOPAS) and EOL A38 / SOL A39 (Sparker).
- 03:37 - EOL A39 / SOL A40 (Sparker).
- 03:49 - A new interference appears on the TOPAS data. The team calls to David, the technician.
- 04:03 - After a few tests, the technician reboots the TOPAS a couple of times and the interference (serious enough to mask all the data) remains. EOL GRACE35 TOPAS, and end of all TOPAS recording.
- 05:15 – Problems with the Sparker once again.
- 05:19 - EOL A40 (Sparker). The technician switches once again the power supply (CSP600), but the system keeps failing.
- 05:33 - SOL A40_002 (Sparker).
- 05:35 – EOL A40_002/ SOL A40_003. Short test lines. Suddenly there is a warning coming from the bridge that we must transit to AUV position.
- 05:39 - EOL A40_003 (Sparker) with the system already on deck.
- 05:40 – TRANSIT TO SEAQUAKE AUV POSITION.
- 14:56 – During its second dive the AUV makes an emergency exit and is back on deck. There is a huge problem with the propeller, and there is no replacement onboard. End of all operations with AUV. Without AUV and TOPAS, the SEAQUAKE team has no other chance but to keep working with (Multibeam).
- 16:26 - CTD 10 -SQ (35.9093333ºN / 5.1825ºW).
- 19:45 END OF SEAQUAKE OPERATIONS (07/05/2022). Start transit to Sparker line A41
- 21:03 EOL transit to A41 / SOL SPK-41 (Multibeam).
- 21:04 SOL A41 (Sparker).
- 21:51 EOL SPK-41 / SOL SPK-42 (Multibeam).
- 21:52 EOL A41 / SOL A42 (Sparker).
- 22:29 EOL A42 / SOL A43 (Sparker).

- 22:30 EOL SPK-42 / SOL SPK-43 (Multibeam).
- 23:32 EOL SPK-43 / SOL SPK-44 (Multibeam).
- 23:33 EOL A43 / SOL A44 (Sparker).

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- 00:52 - EOL A44 / SOL A45 (Sparker).
- 00:57 - EOL SPK-44 / SOL SPK-45 (Multibeam).
- 02:22 - EOL SPK-45 / SOL SPK-46 (Multibeam). Problems with the adjustement of the sound velocity profile on the Multibeam echosounder.
- 02:27 - EOL A45 / SOL A46 (Sparker).
- 02:37 - EOL SPK-46 / SOL SPK-47 MULTIBEAM and EOL A46 / SOL A47 (Sparker).
- 03:45 - EOL SPK-47 / SOL SPK-48 MULTIBEAM and EOL A47 / SOL A48 (Sparker).
- 03:59 - EOL SPK-48 / SOL SPK-49 (Multibeam).
- 04:01 - EOL A48 / SOL A49 (Sparker).
- 05:01 - EOL SPK-49 + turn (Multibeam).
- 05:04 - SOL SPK-50 (Multibeam).
- 05:05 - EOL A49 / SOL A50 SPARKER
- 07:35 - EOL A50 (Sparker).
- 05:37 - EOL SPK-50 and transit to GC03 still recording with the (Multibeam).
- 07:00 - EOL TRAN-GC03 (Multibeam).
- 07:14 - Gravity corer GRACE – GC03 in water (35º 58.32'N / 5º 9.6484'W)
- 07:55 - Corer on the sea surface, all the sediment (aprox. 3 m) is lost during the recovery maneuver due to a failure of the core catcher. Second attempt with 2 core catchers.
- 08:00 - Gravity corer GRACE GC-03 back in the water (35º 58.32' N / 5º 9.6497' W)
- 08:35 - The gravity corer touches bottom. Depth: 553
- 08:47 - Recovery of core GRACE GC-03 (35º 58.3205' N / -5º 9.6500' W) (241 cm of penetration; 3 sections).
- 09:21 Core GRACE GC-04. Replica of core GC-03 (35º 58.3203' N; -5º 9.6515' W). Core to the water.
- 09:31 Core GRACE GC-04 hits bottom; depth: 553 m.
- 09:42 - Core GRACE GC-04 back on deck. Recovery: 226 cm; 2 sections.
  TECHNICAL ISSUES: After the loss of another gravity core once it was back up, it is decided to use piston corer once again, despite the relatively low penetration (equivalent to that of the gravity core) and much slower maneuvers. Switching the system back to piston corer configuration takes a few hours.
- 13:40 - Start of Core GRACE PC-04 (35º52.4288'; -5º12.3522').
- 14:09 - Core GRACE PC-04 hits bottom. Depth: 450 m.
- 14:48 - Core GRACE PC-04 back on deck. TECHNICAL ISSUES: BENT SHAFT (a.k.a. “banana”). 99 cm of recovery, 1 section + trigger.
- 16:01 - Core GRACE PC-05 starts descending (35º56.0703'; -5º10.3616').
- 16:30 - Core GRACE PC-05 hits bottom. Depth: 761 m.
- 17:07 - Core GRACE PC-05 is back on deck. Recovery: 251 cm (2 sections).
- 17:29 - CTD 11 starts its descent (35º 56.4614' N / 5º 10.0892' W).
- 18:14 - CTD 11 back onboard.
- 19:10 - SOL SPK-51 MULTIBEAM
- 19:38 - SOL A51 (Sparker).
  TECHNICAL ISSUES: The acquisition software of the Sparker starts showing a mistake, adding more delay that it was actually required and making “jumps” on the record. Fortunatey it’s something that can easily be fixed after some processing.
- 20:41 - EOL A51 / SOL A52 (Sparker).
- 22:16 - EOL A52 / SOL A53 (Sparker).
- 22:17 - EOL SPK-51 / SOL SPK-52 (Multibeam).
- 23:21 - EOL A53 / SOL A54 (Sparker).
- 23:22 - EOL SPK-52 / SOL SPK-53 (Multibeam).
- 23:35 - EOL A54 / SOL A55 (Sparker).
- 23:36 - EOL SPK-53 / SOL SPK-54 MULTIBEAM

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- 00:31 - EOL SPK-54 / SOL SPK-55 (Multibeam).
- 00:32 - EOL A55 / SOL A56 (Sparker).
- 01:02 - EOL SPK-55 / SOL SPK-56 (Multibeam) and EOL A56 / SOL A57 (Sparker).

- 01:59 - EOL A57 / SOL A58 (Sparker).
- 02:00 - EOL SPK-56 / SOL SPK-57 (Multibeam).
- 02:51 - EOL SPK-57 / SOL SPK-58 (Multibeam) and EOL A58 / SOL A59 (Sparker).
- 03:02 - EOL SPK-58 / SOL SPK-59 (Multibeam) and EOL A59 / SOL A60 (Sparker).
- 04:05 - EOL SPK-59 / SOL SPK-60 (Multibeam) and EOL A60 / SOL A61 (Sparker).
- 04:44 - EOL SPK-60 / SOL SPK-61 (Multibeam).
- 04:45 - EOL A61 / SOL A62 (Sparker).
- 04:59 – EOL A62 (Sparker) because the Sparker stops working. Koen, the technician switches the power supply to CSP600.
- 05:07 - SOL 62_002 (Sparker).
- 05:37 - EOL 62_002 (Sparker). Sparker out of the water. Transit to recovery point of ADCP (recording with Multibeam TRANS-ADCP). The ADCP is recovered due to the concerns of the technician due to the weather forecast suggesting wind will be coming.
- 06:01 - EOL TRANS-ADCP (Multibeam).
- 06:46 –ADCP back onboard in a very quick and clean maneuver.
- 08:30 - Core GRACE PC-06 (35º51.5445'; -5º11.4122') starts its descent.
- 09:07 - Core GRACE PC-06 hits bottom (Depth: 587 m)
- 09:42 - Core GRACE PC-06 is back on deck (recovery: 410 cm; 4 sections).
- 11:24 – Start of Core GRACE PC-07 (35º54.22'; -5º12.09')
- 11:46 - Core GRACE PC-07 hits bottom. Depth: 533 m.
- 12:30 - Core GRACE PC-07 is on deck. TECHNICAL ISSUES: BENT SHAFT (a.k.a. “banana”). 47 cm of recovery, 1 section.
- 14:00 - Start of Core GRACE PC-08 (35º56.8974'; -5º8.0447').
- 14:28 - Core GRACE PC-08 hits bottom (Depth: 497 m)
- 15:15 Core GRACE PC-08 is on deck. (235 cm of recovery, 2 sections).
- 16:41 – Start of descent for core GRACE PC-09 (replica of PC08) (35º 56.9026' N / 5º 8.0539'W)
- 17:03 - Core GRACE PC-09. Bottom. Depth: 497 m;
- 17:36 - Core GRACE PC-09 is back on deck. (Recovery: 242 cm; 2 sections)
- 19:00 – CTD12
- 21:02 - SOL A62B (Sparker).
- 21:10 - EOL A62B / SOL A63 (Sparker).
- 21:12 - SOL SPK-63 (Multibeam).
- 21:30 - EOL A63 / SOL A64 (Sparker).
- 21:32 - EOL SPK-63 SOL SPK-64 (Multibeam).
- 22:44 - EOL A64 / SOL A65 (Sparker).
- 22:45 - EOL SPK-64 SOL SPK-65 (Multibeam).
- 22:56 - EOL SPK-65 SOL SPK-66 (Multibeam) and EOL A65 / SOL A66 (Sparker).
- 23:57 - EOL A66 / SOL A67 (Sparker).
- 23:58 - EOL SPK-66 SOL SPK-67 (Multibeam).

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- 03:21 - EOL LMB-67 SOL LMB-68 (Multibeam).
- 03:23 - EOL A67 / SOL A68 (Sparker).
- 03:27 - EOL LMB-68 SOL LMB-69 (Multibeam).
- 03:29 - EOL A68 / SOL A69 (Sparker).
- 06:30 - EOL A69 / SOL A70 (Sparker). A loop will be made to cover a hole in the multibeam data due to the huge inwards gyre of the vessel.
- 07:04 - EOL LMB-69 SOL LMB-70 (Multibeam).
- 07:06 - EOL A70 / SOL A70B (Sparker).
- 08:16 - EOL LMB-70 (Multibeam).
- 09:23 - EOL A70B (Sparker).
- 09:30 - Sparker back onboard. END OF ALL SPARKER OPERATIONS.
- 11:15 - Start of Core GRACE PC-10 (35º59.0349'; -5º10.865')
- 11:39 - Core GRACE PC-10 hits bottom. Depth: 570.7 m.
- 12:01 - Core GRACE PC-10 back on deck. Recovery: 224 cm; 2 sections)
- 13:01 - Start transit to SEAQUAKE CTD location. The main activity will be (Multibeam).
- 14:23 - CTD 13 - SQ starts its descent 35º 54.7052' // -5º 11.2711'
- 15:10 - CTD 13 - SQ back onboard

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- 07:03 - CTD 14 – SQ (35.8693333 ºN / 5.11933333 ºW)
- 13:30 – END OF SEAQUAKE OPERATIONS.
- 13:30 - Quick Multibeam E-W lines for the GRACE team to have better data on a few features imaged at the northern end of the study area, almost on our way to the port.
- 16:00 – End of all scientific operations. Start transit to the Port of Algeciras.
- 17:00 – Vessel at the Port station
- 18:30 – Vessel back on Algeciras dock.

4 Preliminary Results

4.1 – CTD data

A total of 13 CTD profiles were successfully recorded. These CTD profiles were recorded both at the axis of the canyon, the eastern wall, and the uppermost Ceuta Drift (Fig. 2). The CTD profile 9 was unsuccessful due to the strong current at the time caused by an incoming internal wave. Three of these CTDs were recorded during SEAQUAKE working time.

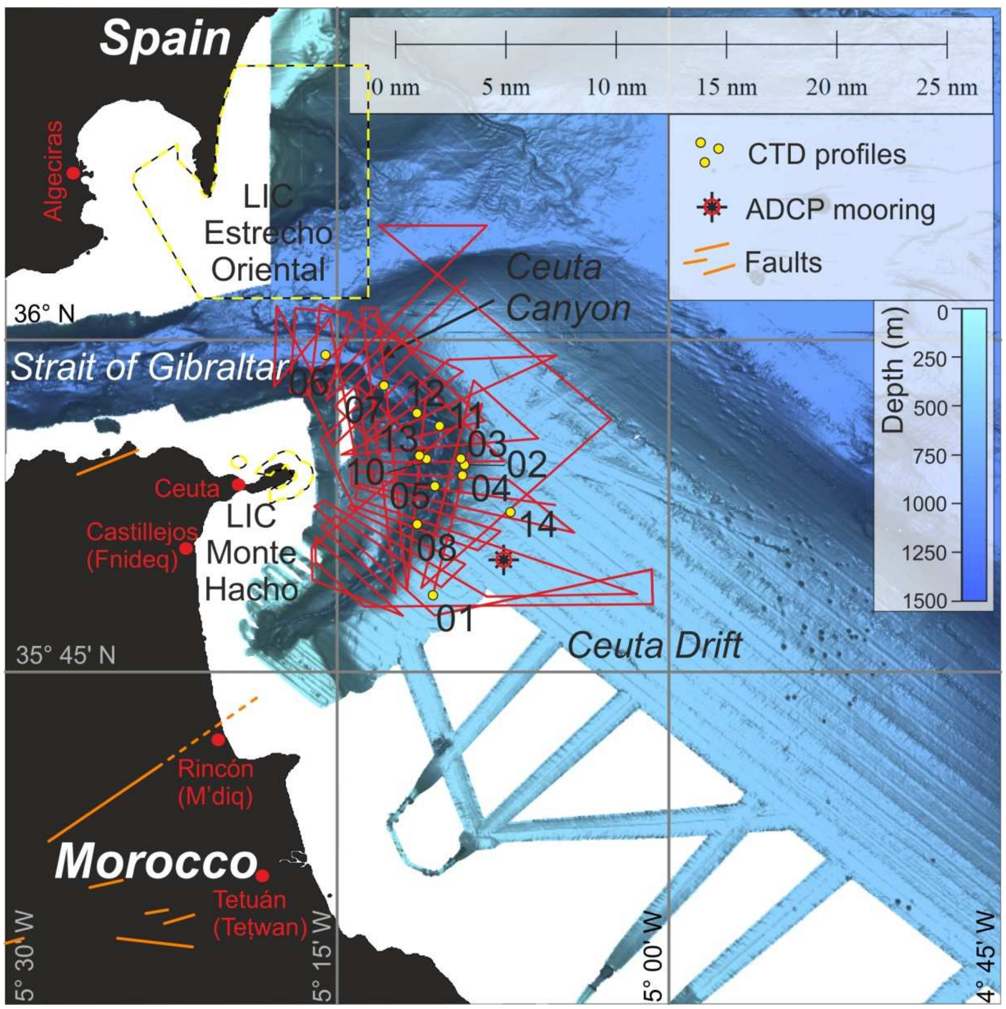


Fig. 2 Location of the recorded CTD profiles. Bathymetry from the CONTOURIBER Project (*Published in* *Somoza et al., 2012*).

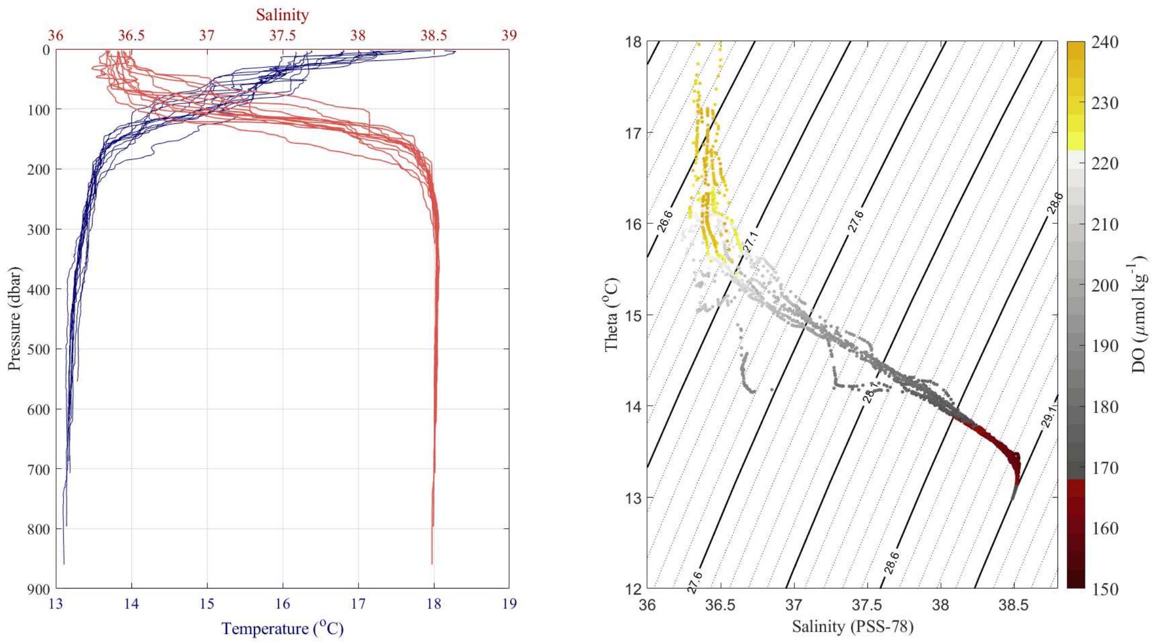


Fig. 3 A) CTD temperature and salinity data of the 13 successful CTD profiles; B) T/S graphic of the CTD profiles, highlighting in yellow the Atlantic Waters and in red the Mediterranean Waters.

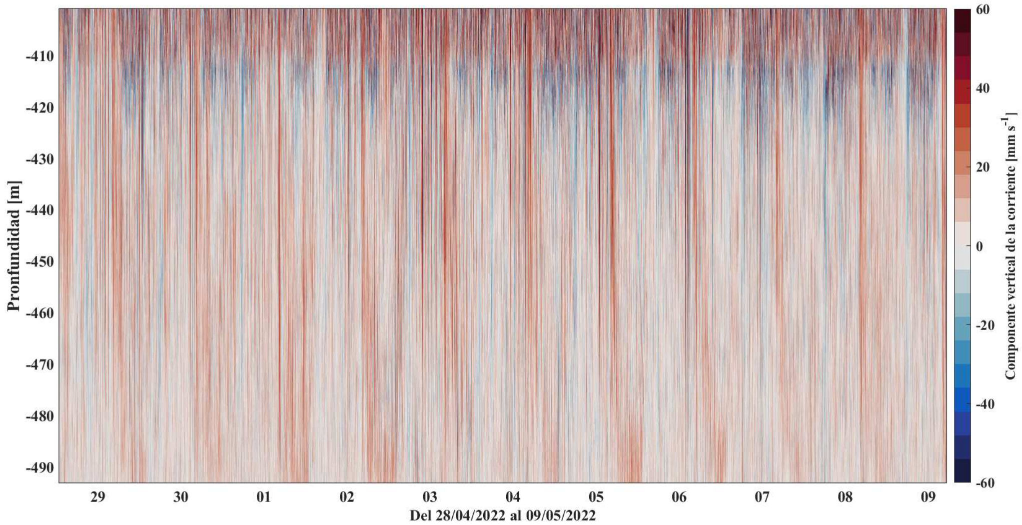
The halocline (salinity) is present between 50 and 200 m water depth (Fig. 3a). On the opposite, the termocline appears from the surface to 200 m water depth (Fig. 3a). The uppermost water mass consist of incoming Atlantic Waters (Fig. 3a). Between 50 and 200 m water depth, the mixing layer is present (Fig. 3a). Below, the dominant water mass is Mediterranean Dense Water flowing towards the Strait of Gibraltar (Millot, 2009) (Fig. 3a).

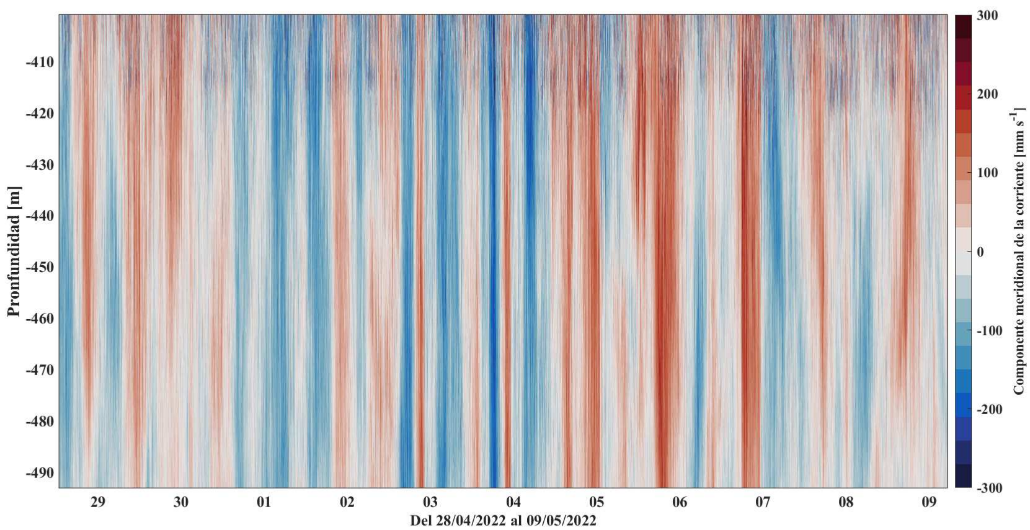
4.2 - Current meter data

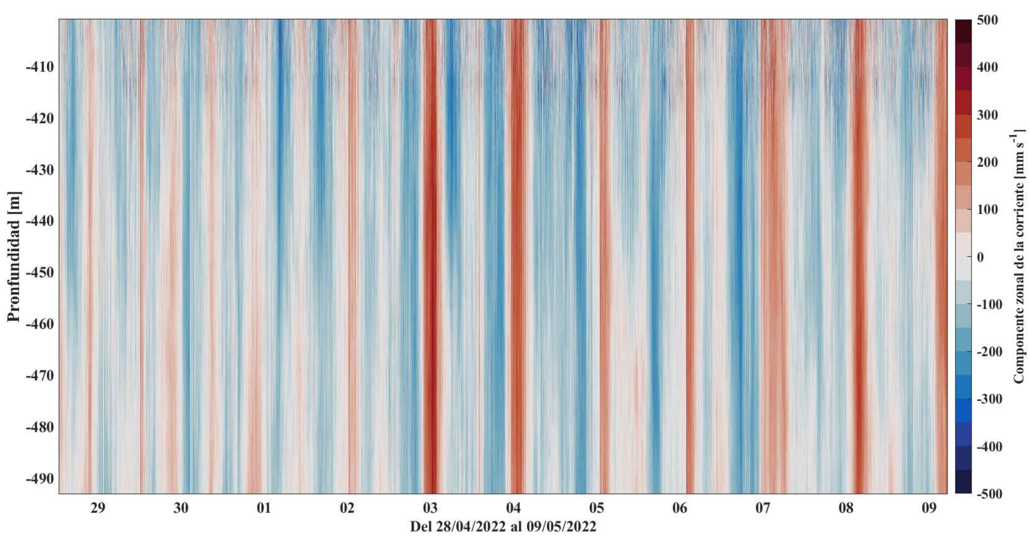
4.2.1. Moored ADCP

The moored current meter has revealed strong zonal and meridional changes in the velocity of the current, of up to 50 cm/s, with a semidiurnal tidal frequency but with a very strong diurnal component (Fig. 4). The vertical changes are less relevant, but still show the string tidal ciclicity. The strength of the current above the seafloor was surprisingly high (Fig. 5), given that in spring tide the current must be even stronger. The data also confirms the influence of internal waves over the Morocco margin, and their possible influence as trigger mechanisms for sediment mass movement.

Fig. 4 (below) A) vertical component of the current, reaching up to 6 cm/s; B) Meridional component of the current, reaching up to 30 cm/s. C) Zonal component of the current, reaching up to 50 cm/s.


Pronfundidad [m]
-410
-420
-430
-440
-450
-460
-470
-480
-490
29 30 01 02 03 04 05 06 07 08 09
Del 28/04/2022 al 09/05/2022
Componente vertical de la corriente [mm s-1]
60 40 20 0 -20 -40 -60


Pronfundidad [m]
-410
-420
-430
-440
-450
-460
-470
-480
-490
29 30 01 02 03 04 05 06 07 08 09
Del 28/04/2022 al 09/05/2022
Componente meridional de la corriente [mm s-1]
300 200 100 0 -100 -200 -300


Pronfundidad [m]
-410
-420
-430
-440
-450
-460
-470
-480
-490
29 30 01 02 03 04 05 06 07 08 09
Del 28/04/2022 al 09/05/2022
Componente zonal de la corriente [mm s-1]
500 400 300 200 100 0 -100 -200 -300 -400 -500

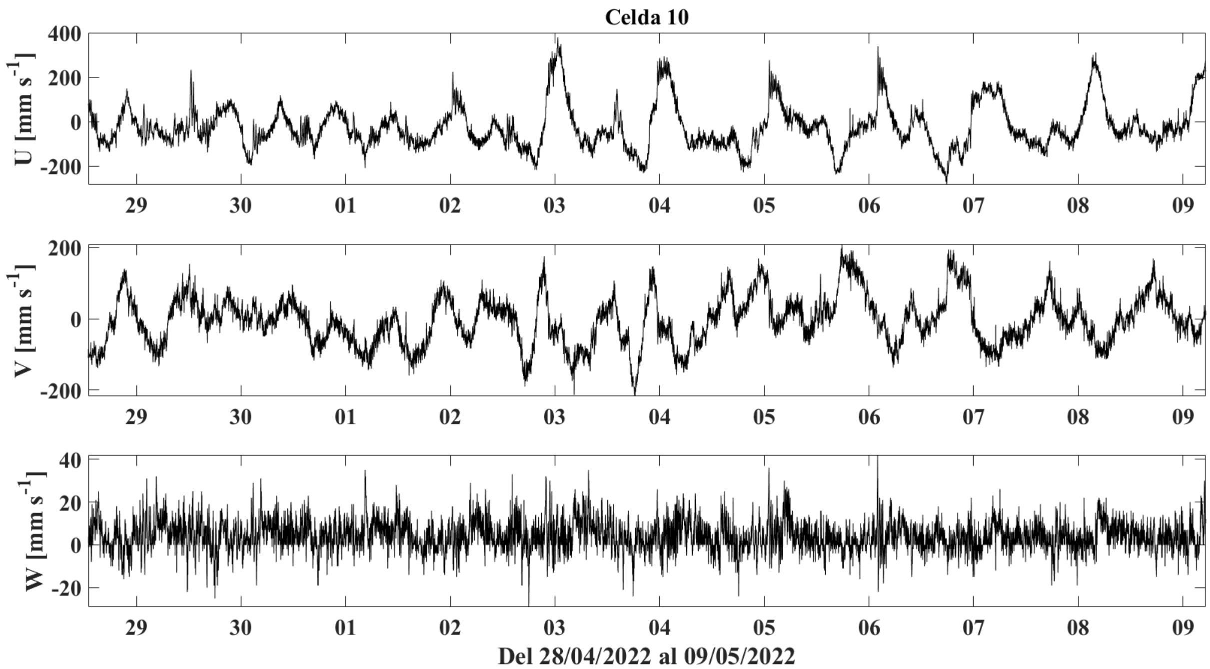


Fig. 5 A) Data of the current velocity about 12 metres above the seafloor, reaching velocities capable of mobilixing and transporting the sediment.

4.2.2. Hull-mounted ADCP

The hull-mounted ADCP data is still being processed, given that a record of a vessel that sails at different speeds and suddenly halts due to its arrival to a sampling location is more difficult to image and properly place. Still, the data was extremely handy to determine the cause of the failure of 2 CTD profiles the 3rd of May, which consisted of a very strong internal wave.

4.3. Multi-beam Echosounder Kongsberg EM304

The multibeam echosounder data was recorded both following planned lines with the aim of imaging in high resolution specific structures or areas (i.e., the entire canyon axis), and as opportunistic data after the TOPAS sub-bottom profiler could no longer operate, during navigation and while acquiring Sparker lines. In the first case, the overlap between different lines was over 100%, with an aperture angle of up to 65º, and navigation velocities between 4 and 5 knots to obtain good resolution data. In the second case, the velocity could vary depending of the activity (4-5 knots if the data was recovered during Sparker acquisition, and up to 6,5 knots if the data was recorded during navigation between different stations.

The data was processed onboard using the software Caris HIPS & SIPS v.11. As a result, a first general bathymetric map was obtained. The new bathymetric data (5 m resolution) (Fig. 6) largely improved the previously available bathymetry (30 m resolution), allowing to image in high resolution structures that were only fuzzy before. Among these structures, the furrows sculpted by the strong currents and entering into the Ceuta Canyon and harboring what appeared to be a group of coral mounds stand out (Fig. 7).

Future re-processing of the areas with higher overlap and lower navigation velocity will provide even higher-resolution maps (1-2 m resolution) of the canyon axis, as well as the erosive/sedimentary structures located north of the Ceuta Drift, along the exit path of the deepest Mediterranean Waters.

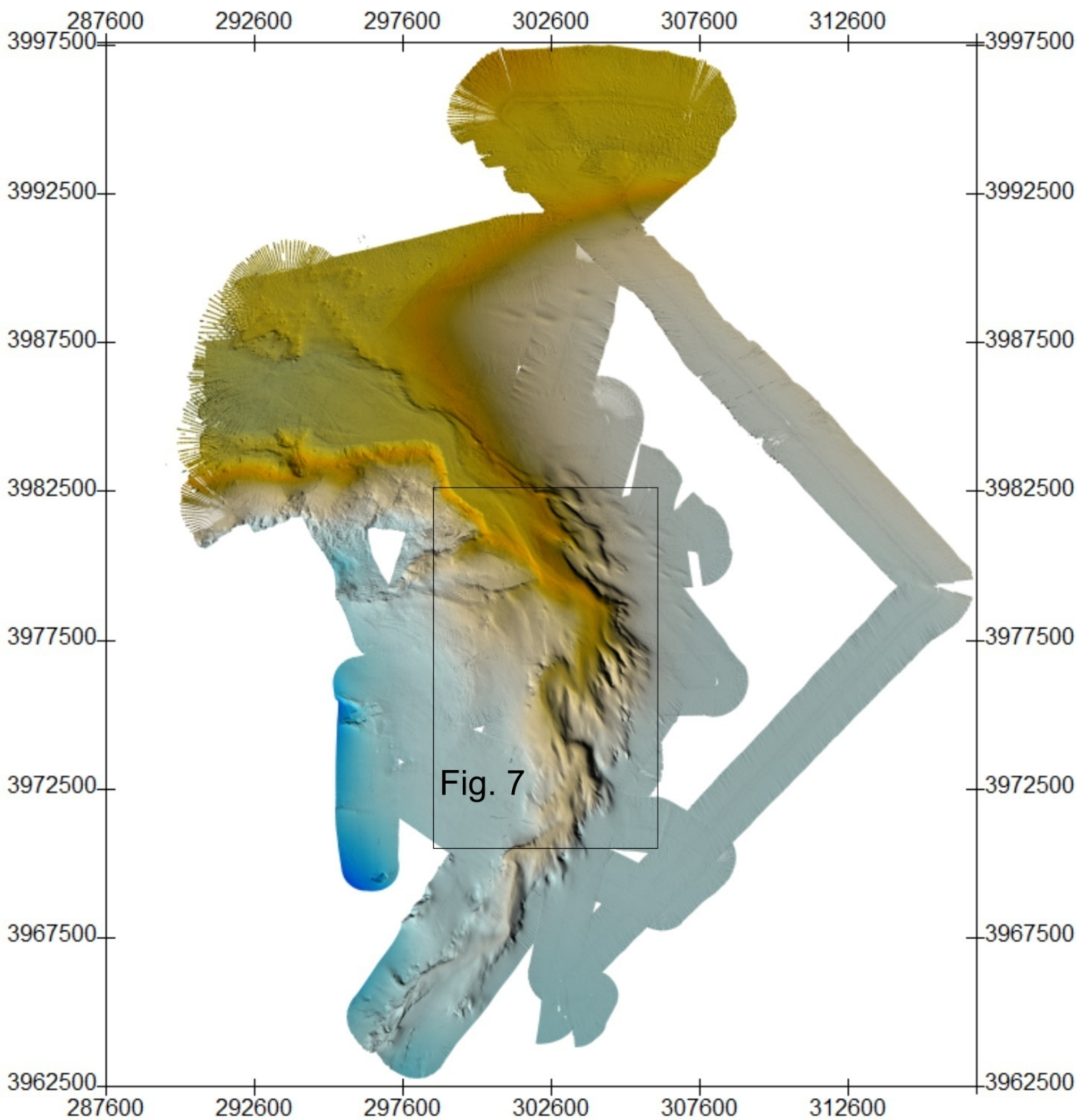


Fig. 6 New preliminary multibeam map with 5 m resolution obtained after a first processing using CARIS HIPS & SIPS during the GRACE cruise.

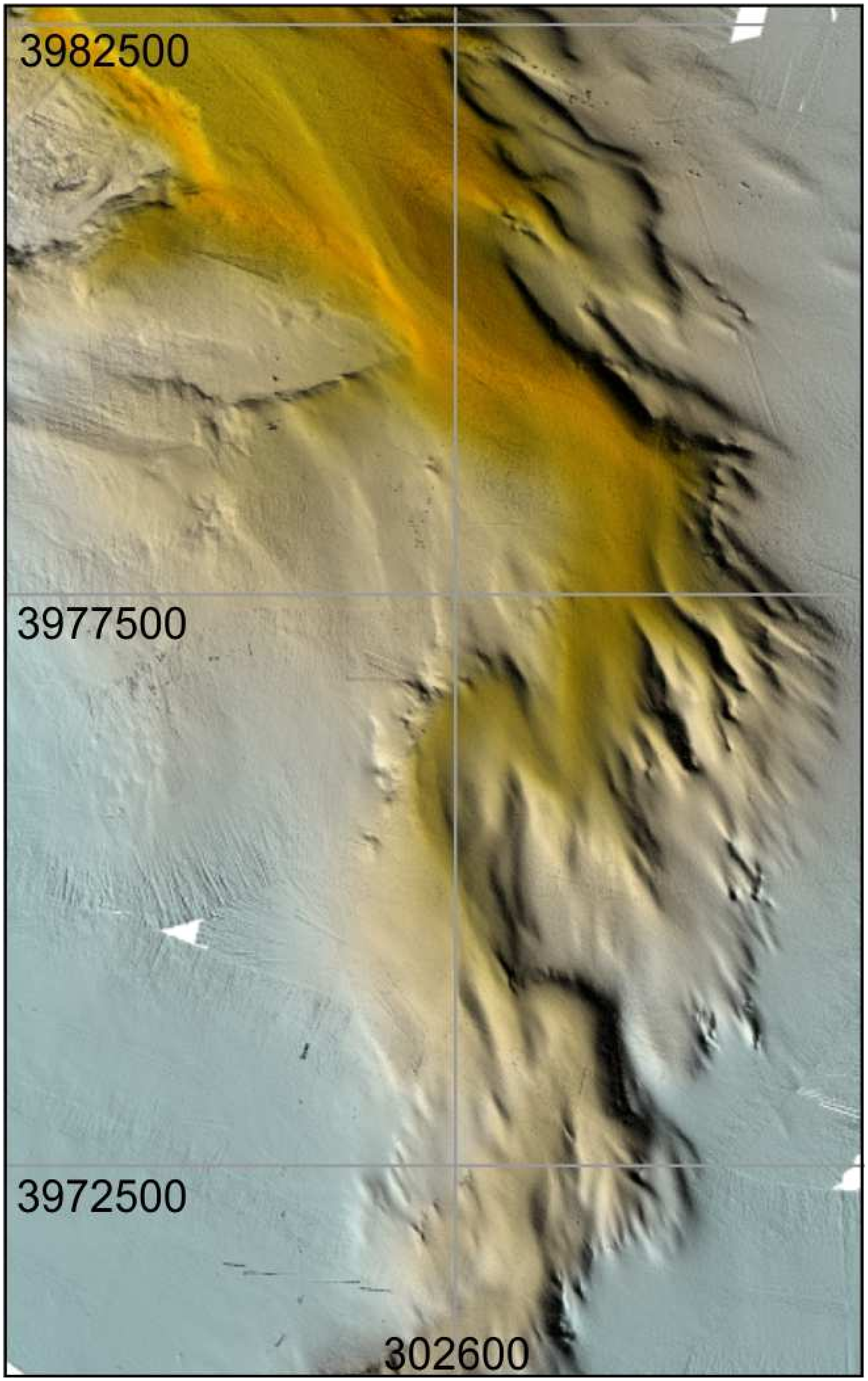


Fig. 7 Zoom of the central sector of the canyon, where furrows sculpted by the strong currents as well as possible coral mounds stand out.

4.4. Seismic reflection systems

4.4.1. Pinger sub-bottom profiler (TOPAS PS18 System)

The TOPAS system had synchronicity problems with the Kongsberg EM304 multibeam echosounder. For that reason, the TOPAS was given priority at the beginning of the cruise. The TOPAS system, however, broke down twice during the course of the cruise, and could not be fixed again due to the lack of additional spare parts onboard. The two periods in which the system could work properly allowed nonetheless obtaining a general high-resolution overview of the uppermost sedimentary cover.

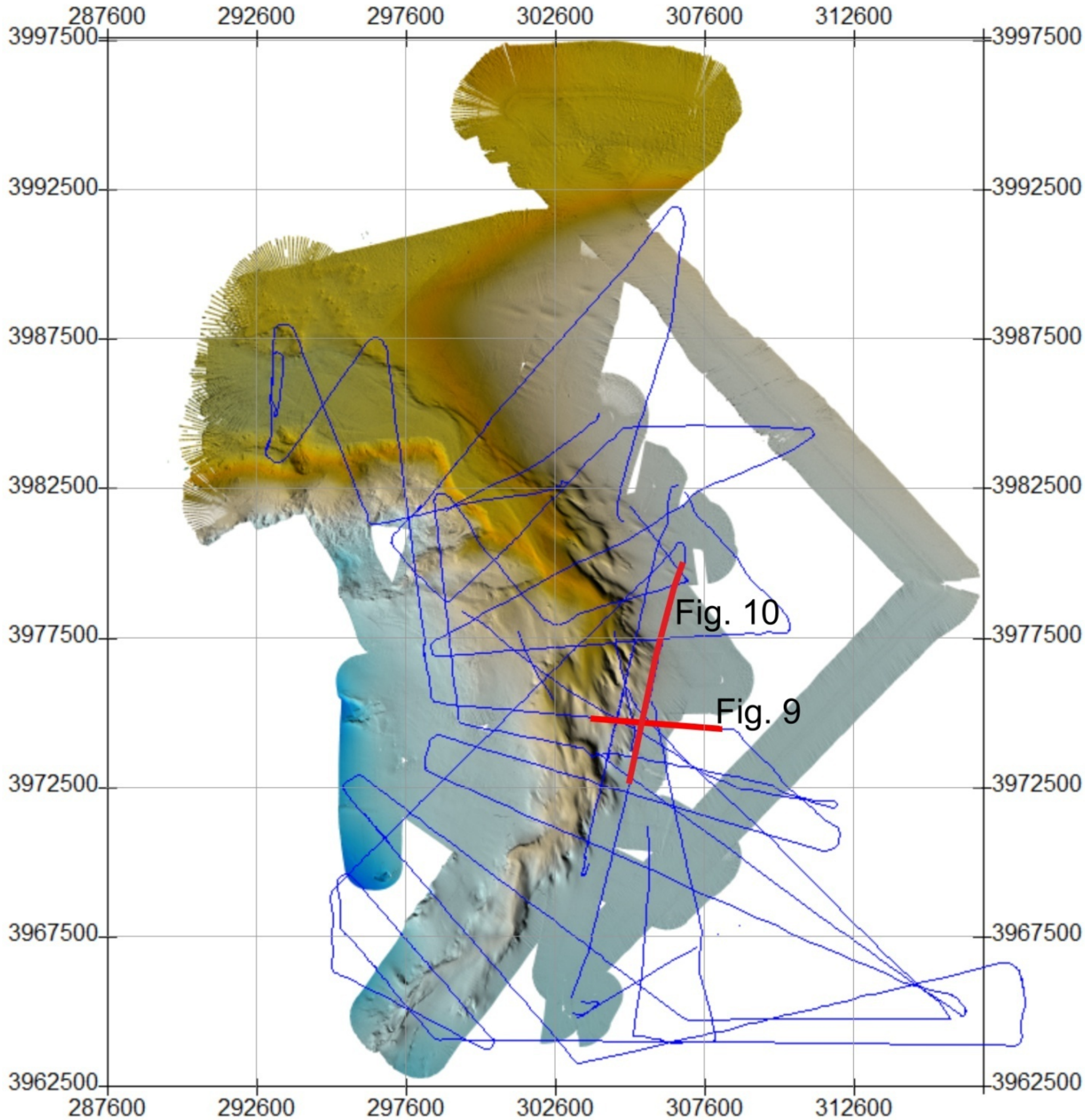


Fig. 8 Overview of the TOPAS high-resolution profiles recorded during the GRACE working time.

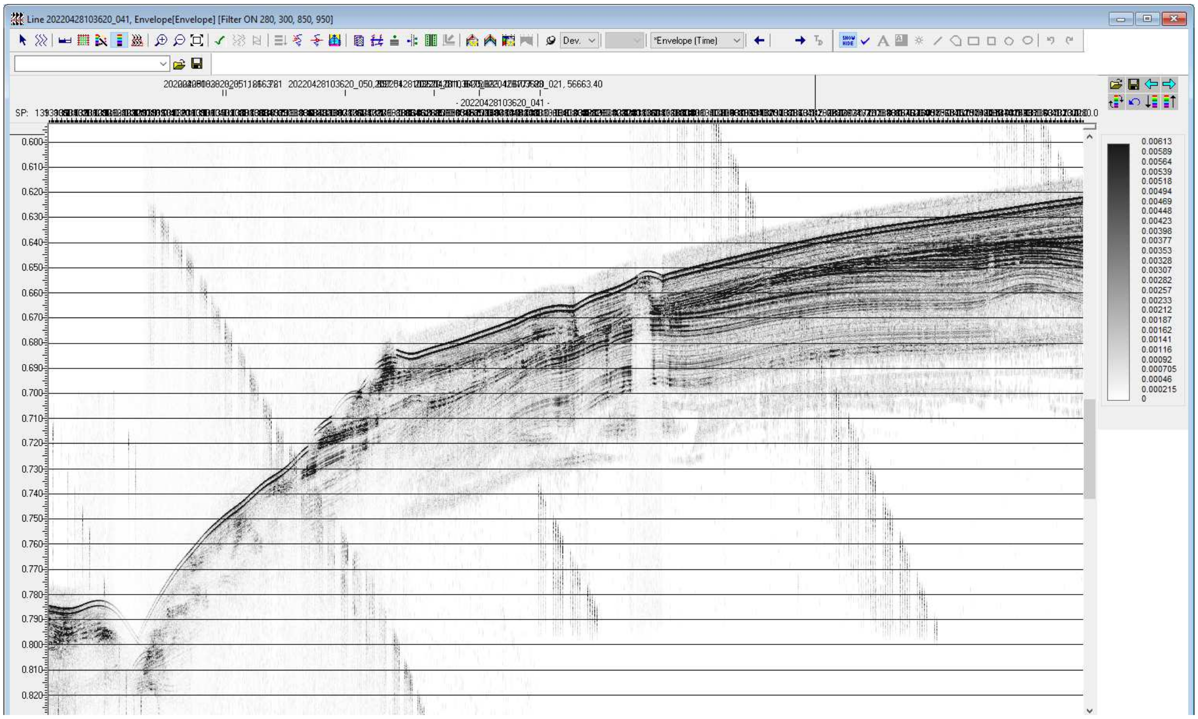


Fig. 9 TOPAS acoustic profile roughly perpendicular to the canyon axis, showing one of the reliefs observed at the eastern axis of the canyon and profiding further evidence of their nature as coral mounds.

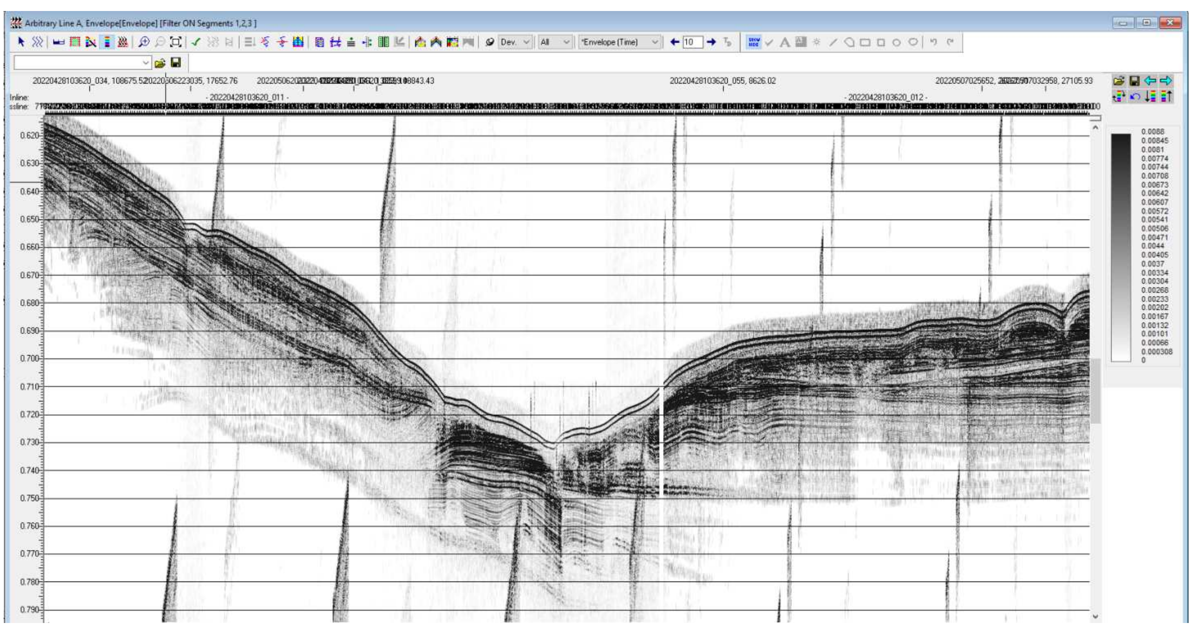


Fig. 10 TOPAS acoustic profile roughly paralel to the canyon axis, showing one of the areas where the previous bethymetry hinted to sediment slides. The profile indicates that sediment slides have indeed occured in the past.

4.4.2. Sparker single-channel system

The Sparker seismic profiles were considered as key data to understand the characteristics and evolution of the Ceuta Canyon, and to map the different interacting sedimentary systems. The Sparker system was composed of a multi-tip SIG ELC820, and the source varied during the course of the cruise from Applied Acoustics CSP600 to CSP700. The area was scanned by the Marine Mammal Observers before the start of operations, to ensure that no cetaceans were in the vicinity, and the operations were paused if cetaceans were observed too close to the vessel or if their behavior showed any signs of distress.

Up to 70 seismic profiles were recorded during the course of the cruise, crossing perpendicularly the Ceuta Canyon along its course and allowing a pseudo-3D view of its structure, erosive scars, palaeo-canyons, etc.

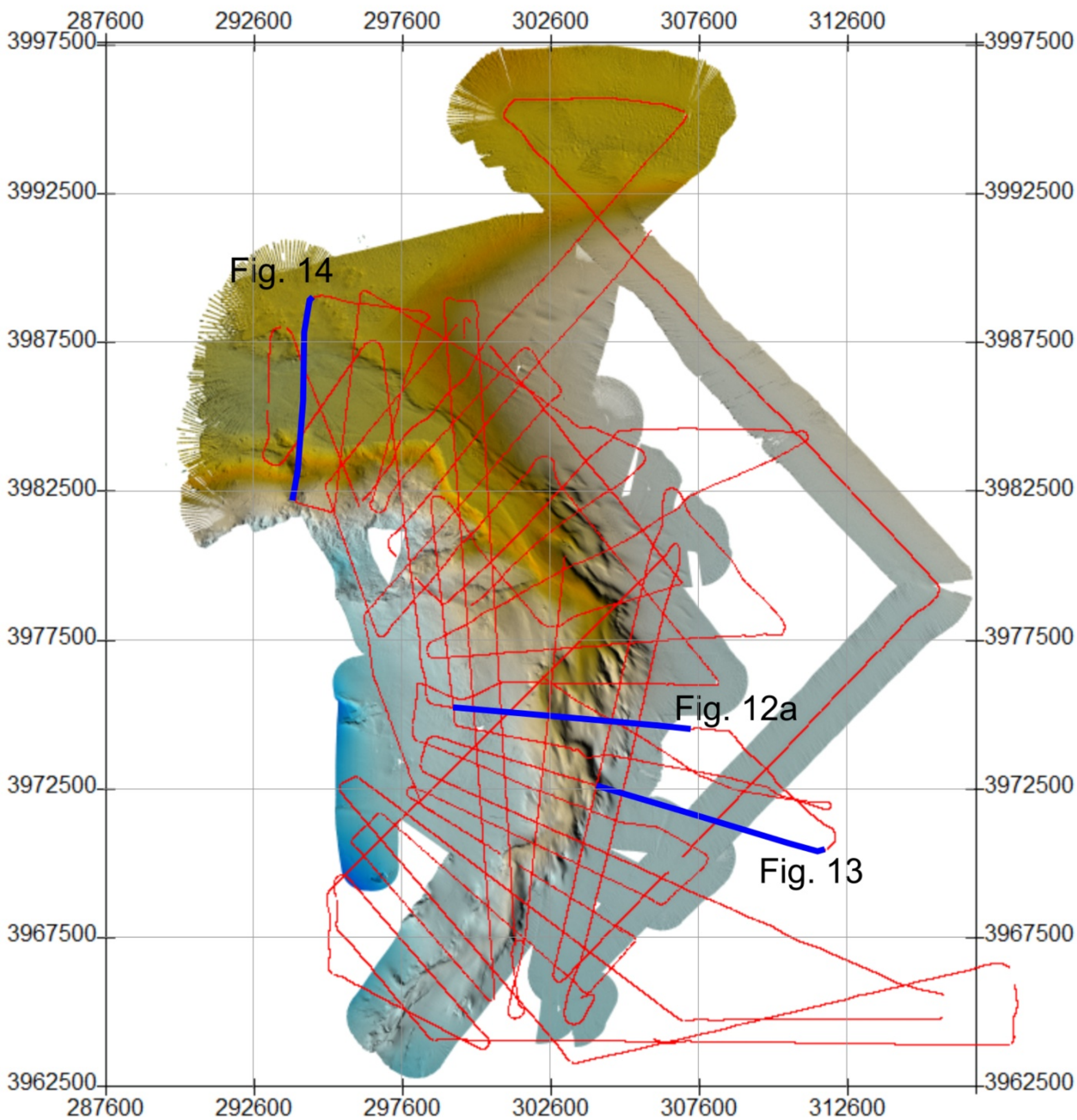


Fig. 11 Overview of the Sparker single-channel seismic profiles recorded during the cruise.

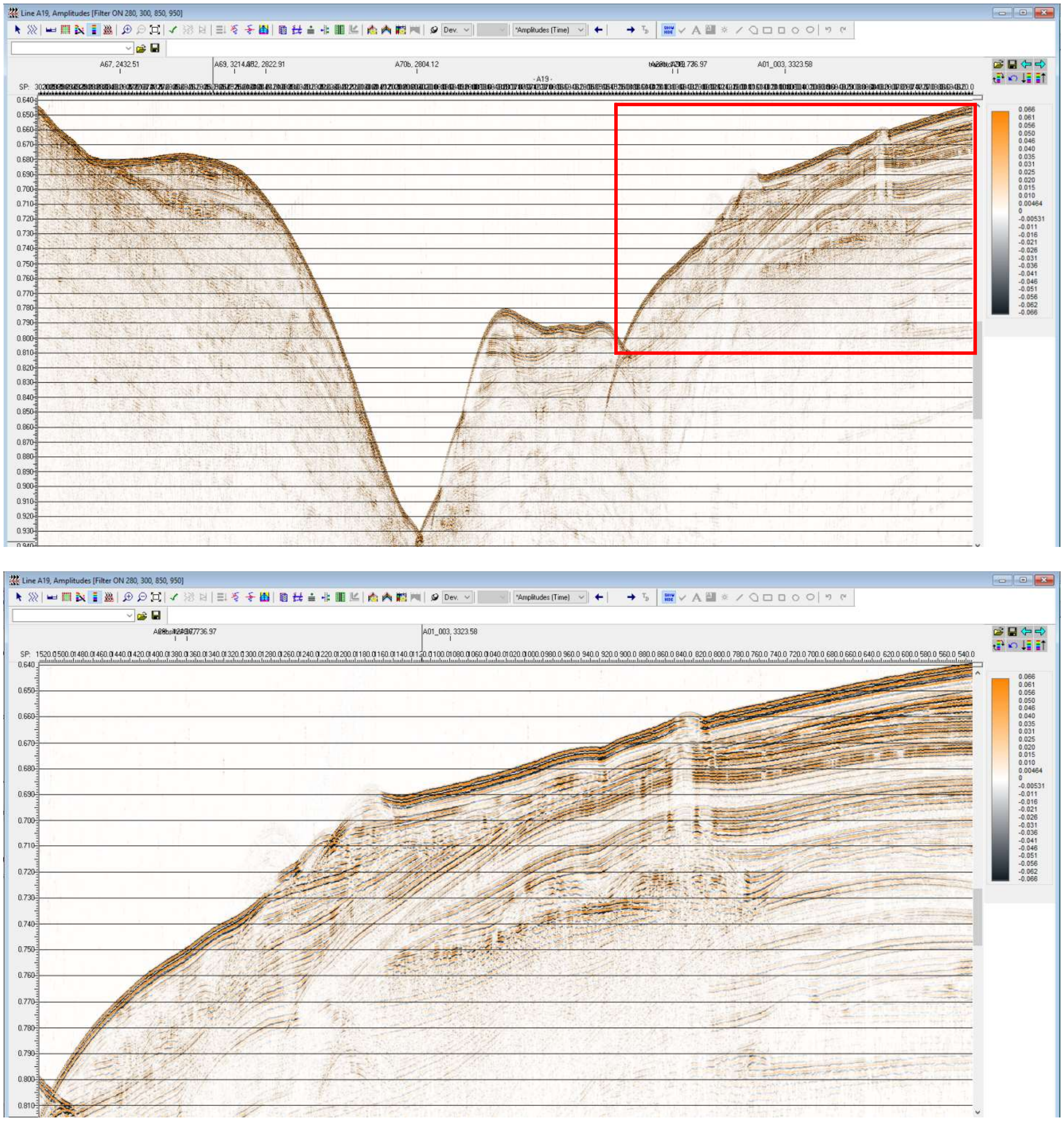


Fig. 12 **A)** Cross-section of the Ceuta Canyon, showing aterraced plastered drift on the left (western side of the canyon) and possible coral mounds to the right (eastern side of the canyon). **B)** Detail of the possible coral mounds (both at the current seafloor and buried within the sediment); theSparker line overlaps Fig. 9 (TOPAS), providing information of the same structure with different resolutions.

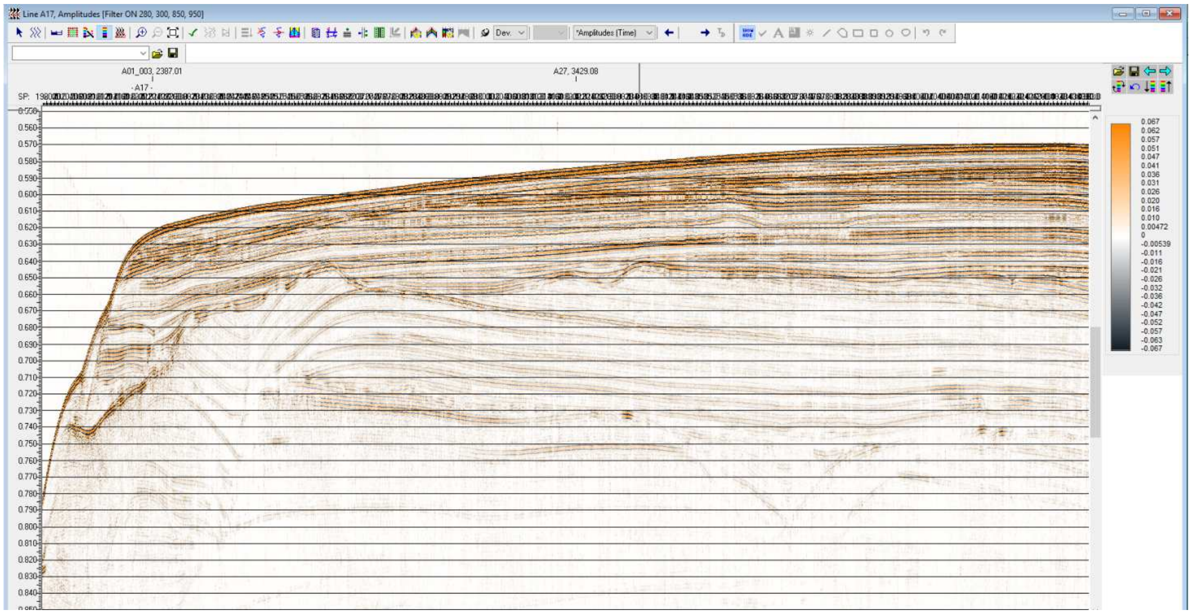


Fig. 13 Cross-section of two palaeo-tributaries to the Ceuta Canyon, located below highly erosive unconformity.

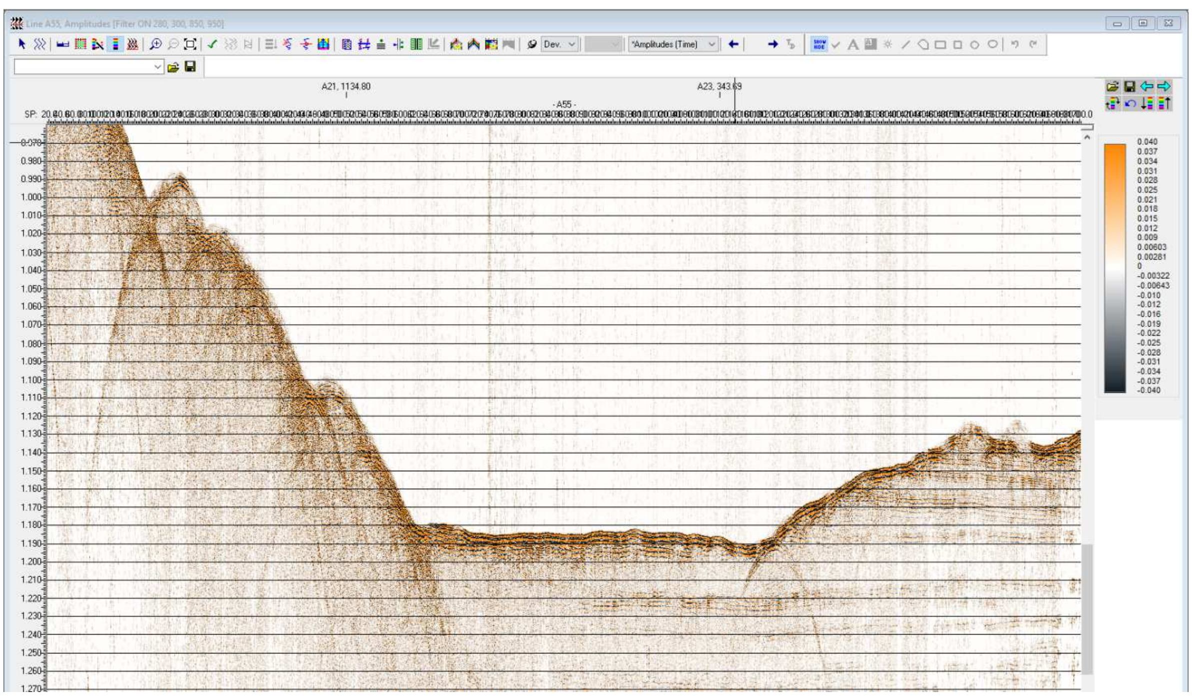


Fig. 14 Bedforms and thalweg at the distal end of the Ceuta Canyon.

4.5 Automated Underwater Vehicle – AUB Barabas (VLIZ)

During the course of the cruise, the AUV Barabas carried out 10 dives for the GRACE Project (Fig. 15):

-Two dives in target area 1 (AUV 1.1, in green; AUV 1.2, in magenta).

-Two dives in the last part of target area 1, the entire target area 2, and a notch of target area 7 (AUV 2.1, in orange; and AUV 2.2, in yellow).

-Two dives in target area 3 and part of target area 4 (AUV 3.1, in apricot; and AUV 3.2, in sky blue).

-One dive with the GAVIA grasshopper camera in target area 2 (AUV 4, in black/lilac).

-One more dive to complete target area 4 (AUV 5).

-Two dives in the vicinity of target area 8, whose location was modified due to the high slopes (AUV 6.1, with the SSS, in red; AUV 6.2, with the GAVIA grasshopper camera, in navy blue).

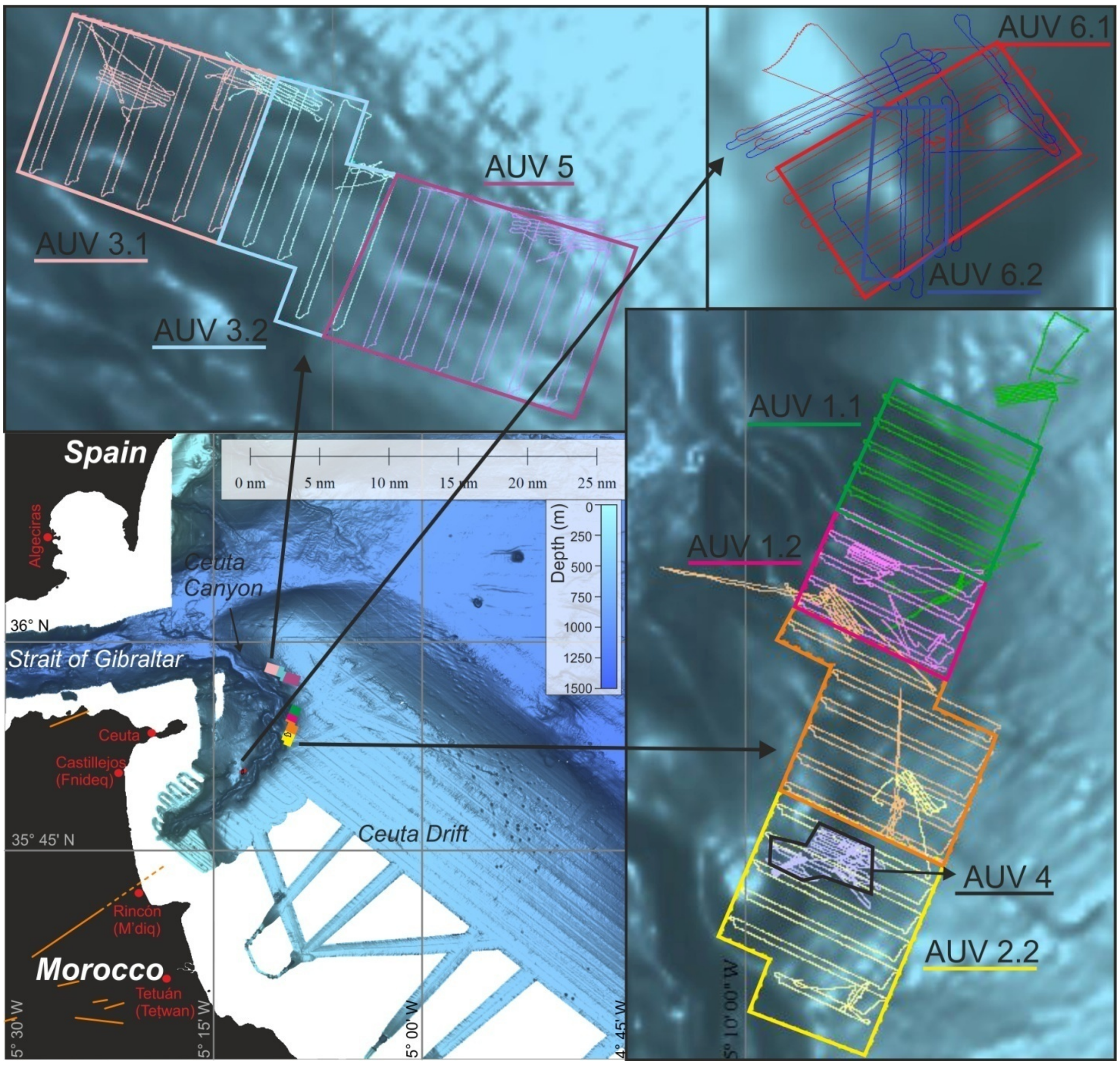


Fig. 15 Location and tracks of the 10 AUV dives carried out for the GRACE Project during the course of the cruise. Of all the dives, 8 were carried out using the side scan sonar with long range, and 2 using the GAVIS Grassgopper camera (AUV 4 and AUV 6.2).

4.5.1. Side-scan sonar

The side scan sonar data was recorded at 100 Hz. The data was loaded on the software SonarWiz 7, and a project was created to visualize and process the data. The tracks were calculated to obtain 100% coverage, including the nadir of the AUV. The raw data (Fig. 16) contained certain artifacts that were removed or diminished during the processing (Fig. 17).

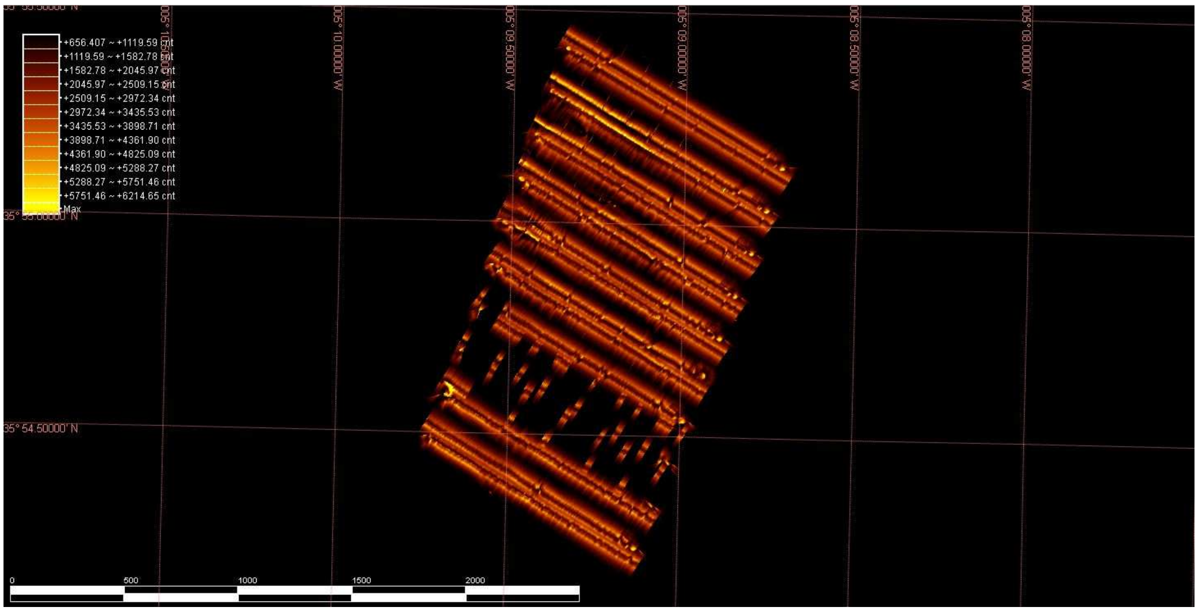


Fig. 16 Unprocessed data of the target area 1 (AUV dives 1.1 and 1.2). See figure 15 for location.

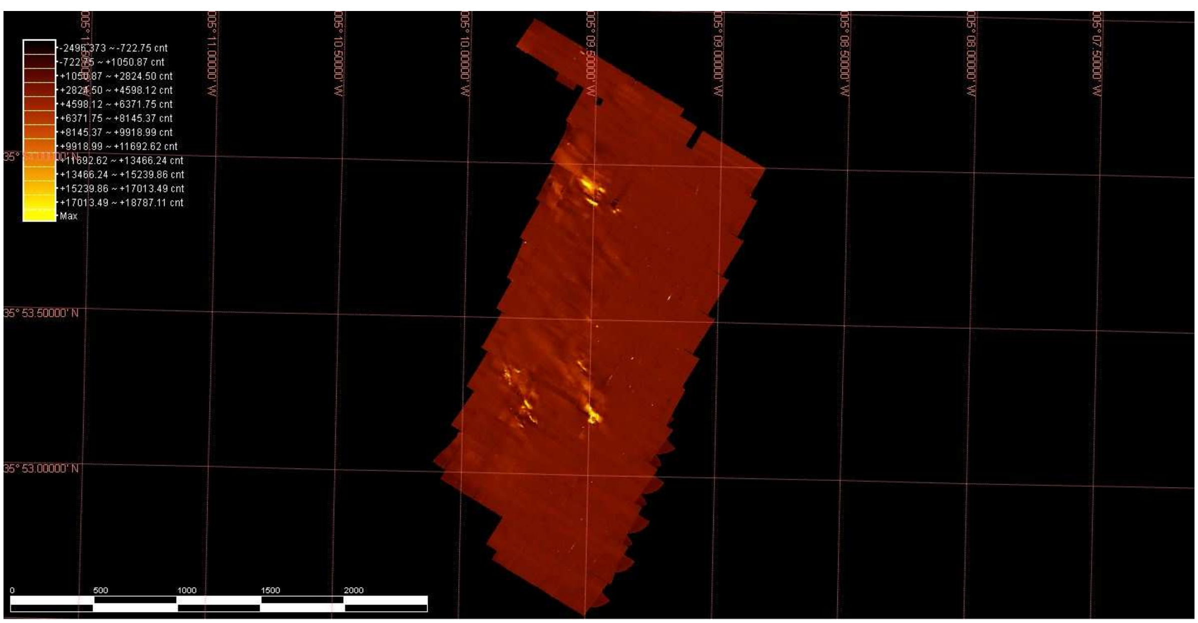


Fig. 17 First processing of the data recorded on target area 2 (AUV dives 2.1 and 2.2). See figure 15 for location. The possible coral mounds are imaged in this mosaic. The reflectivity strongly suggests that the mounds have a rocky nature. A close-up on the mounds also reveals that the rocky mounds have an uneven, irregular texture.

A processed navigation file has been generated for the position and attitude recorded at 100 Hz) (Fig. 18). To achieve this, bugs on the original manufacturer's software have been detected and solved by the VLIZ technicians. Injecting the improved navigation into the sonar data files apply numerous corrections to the positioning of the vehicle, and removes part of the artifacts present in the data. This work is still in process, but has improved significantly the sonar data mosaic.

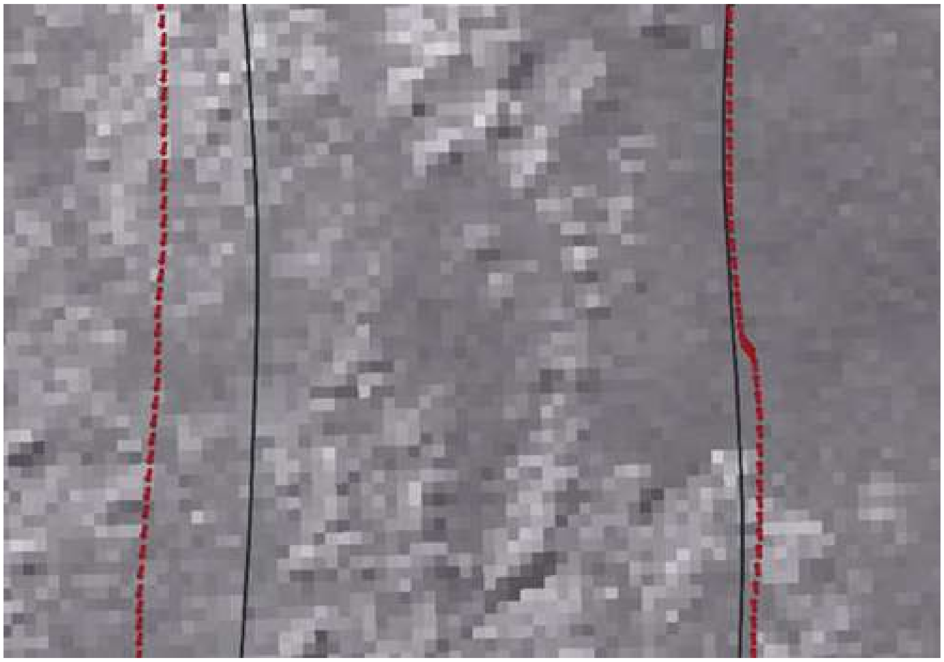


Fig. 18 Example of the differences between the raw navigation of the AUV (dashed line in red), and the processed navigation (solid line in black). The maximum distance between the raw and the processed navigation in this capture is of 2.6 m.

4.5.2. Interferometric bathymetry

The return signal of the sonar data can be processed to obtain a bathymetric surface. In order to achieve this, the work of the VLIZ team in solving the bugs on the manufacturer software and injecting the processed navigation (Fig. 18) has been crucial. Despite the presence of some gaps in the data, the result is a 1m resolution map at 500 m deep (Fig. 19). The rocky mounds stand out, aligned with NNW-SSE trend with the scours in the canyon eastern wall (Fig. 19).

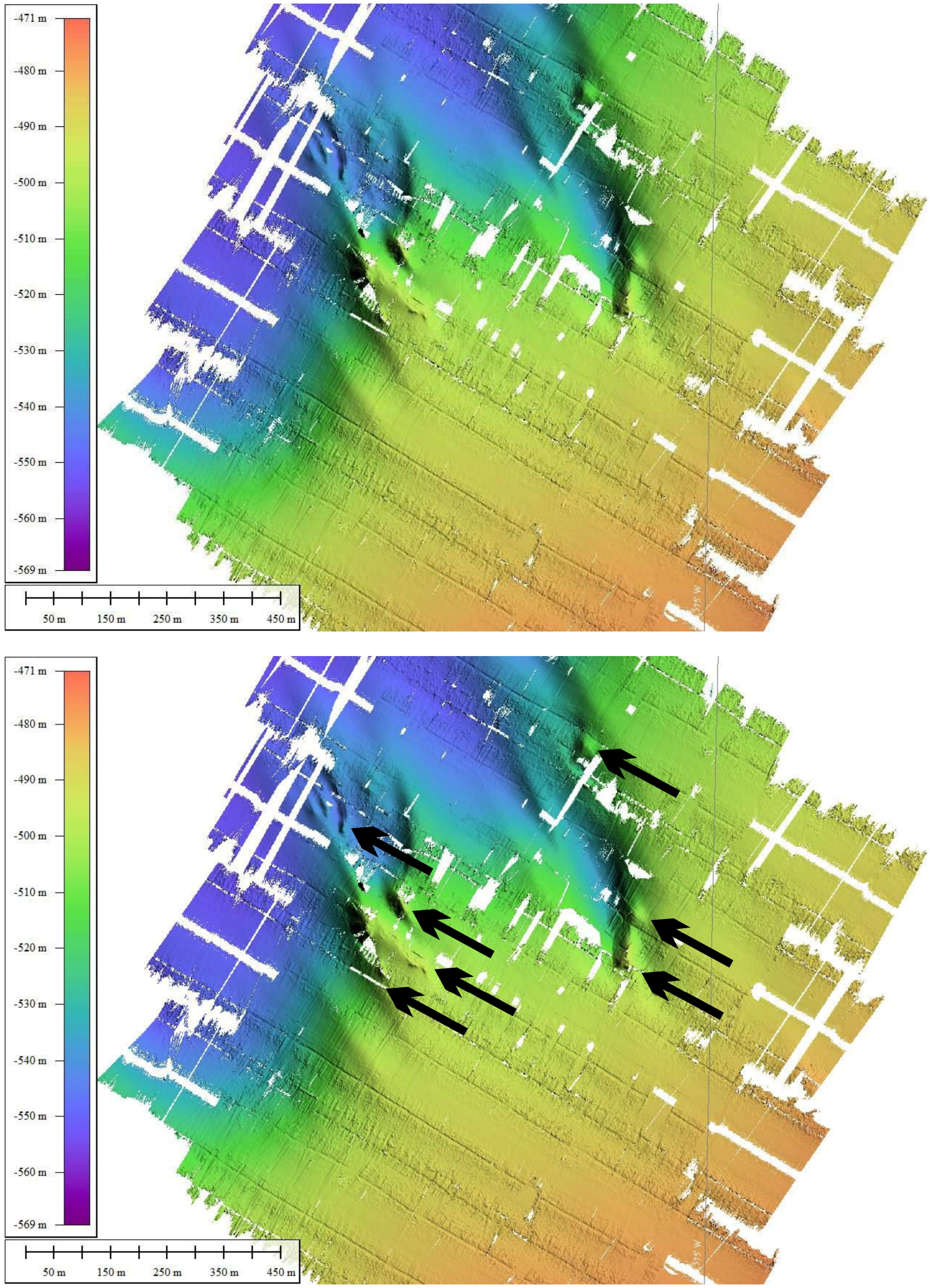


Fig. 19 **A)** Capture of the interferometric bathymetry map obtained by the VLIZ team in target area 2 (AUV dives 2.1 and 2.2), based on the side scan sonar data. B) The coral mounds detected in the area are highlighted for clarity.

4.5.3. Submarine camera

Two different areas were imaged using the GAVIA grasshopper camera: the rocky mounds in target area 2 (AUV dive 4), and a rounded outcrop located at the upper Ceuta Canyon, in target area 8 (AUV dive 6.2).

The seabed photography record resulting from AUV dive 4 confirmed not only the coralliferous nature of the mounds east of the Ceuta Canyon, but also demonstrated that these were living communities (Fig. 20), possibly constituting "reservoir communities" (Camp et al., 2017) that are very small during unfavorable conditions and bloom into large communities during favorable periods, depending on the sea level, water conditions (oxygen, temperature, salinity) and speed of the current. Corals, gorgonians, sponges, crabs, sea urchins and even large chimera fishes were observed during this dive (Fig. 20).

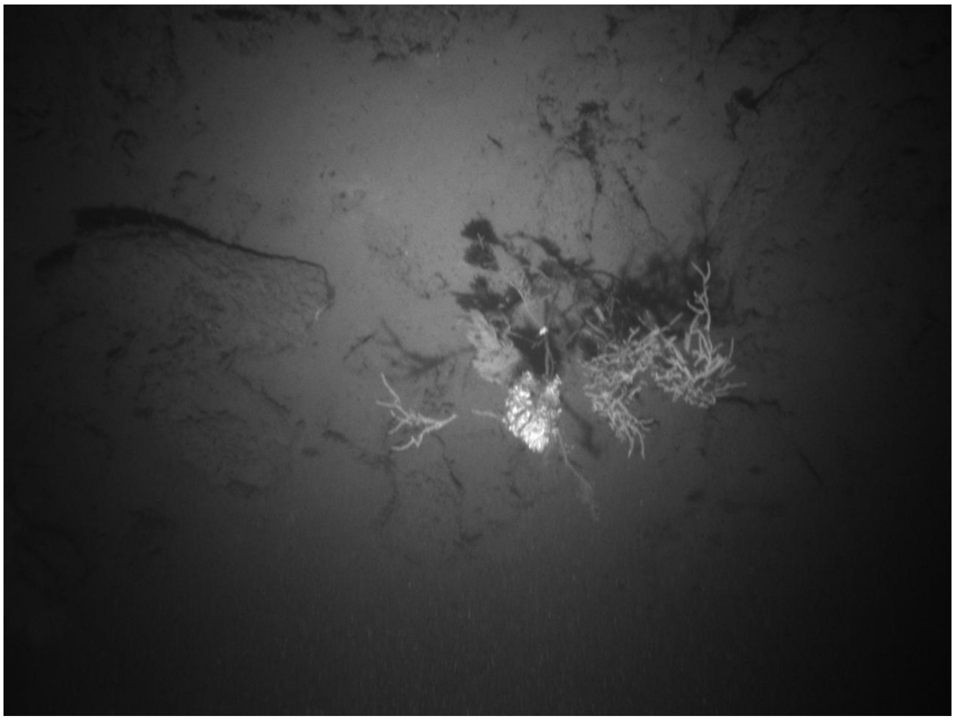
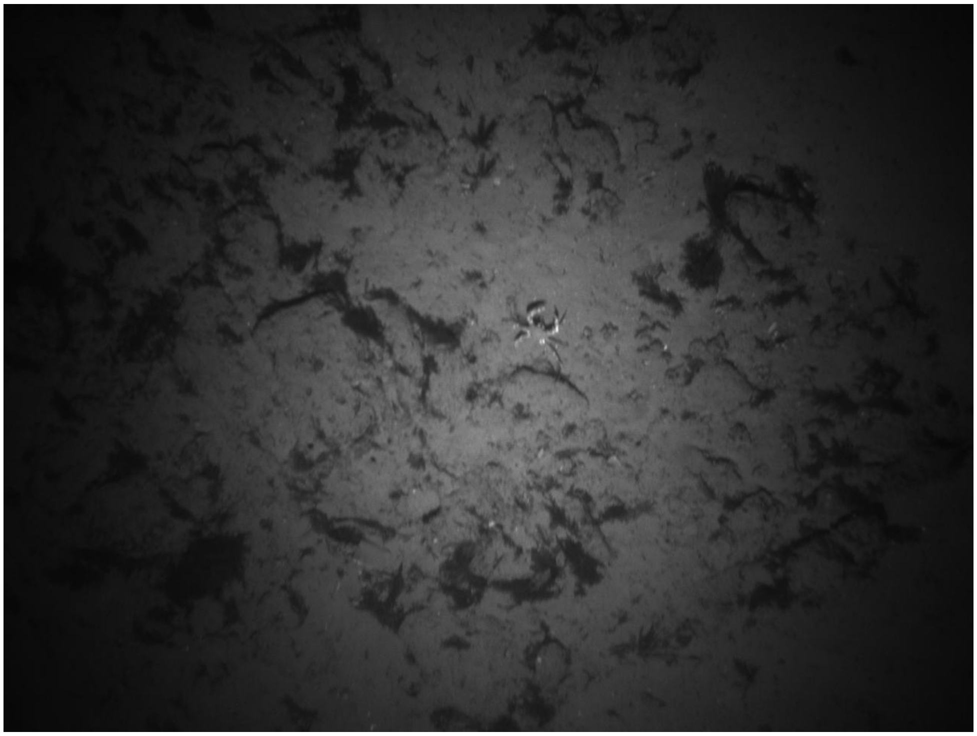
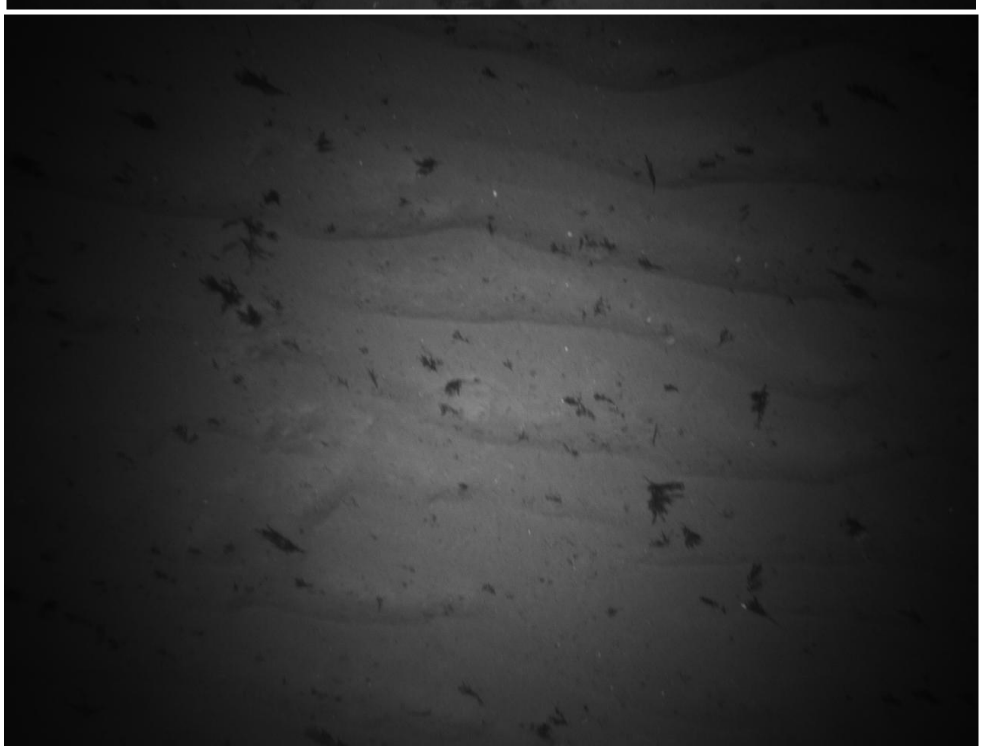


Fig. 20 Images obtained with the GAVIA grasshoper camera, showing a living community thriving anchored on dead corals and coral rubble. The different images correspond to the three largest mounds imaged by the AUV during Dive 02, and were recorded during AUV dive 04.

The seabed photography record resulting from AUV dive 6.2, located in a much shallower environment and closer to the coast, reveals a very different ecosystem. The benthic community is composed of soft species capable of bending with the current (Fig. 21) and anchored on rocky outcrops and on rock covered with sand, with fishes and crabs (Fig. 21). There are evidences of a strong hydrodynamic regime in the form of sand ripples, as well as abundant marine litter (Fig. 21).





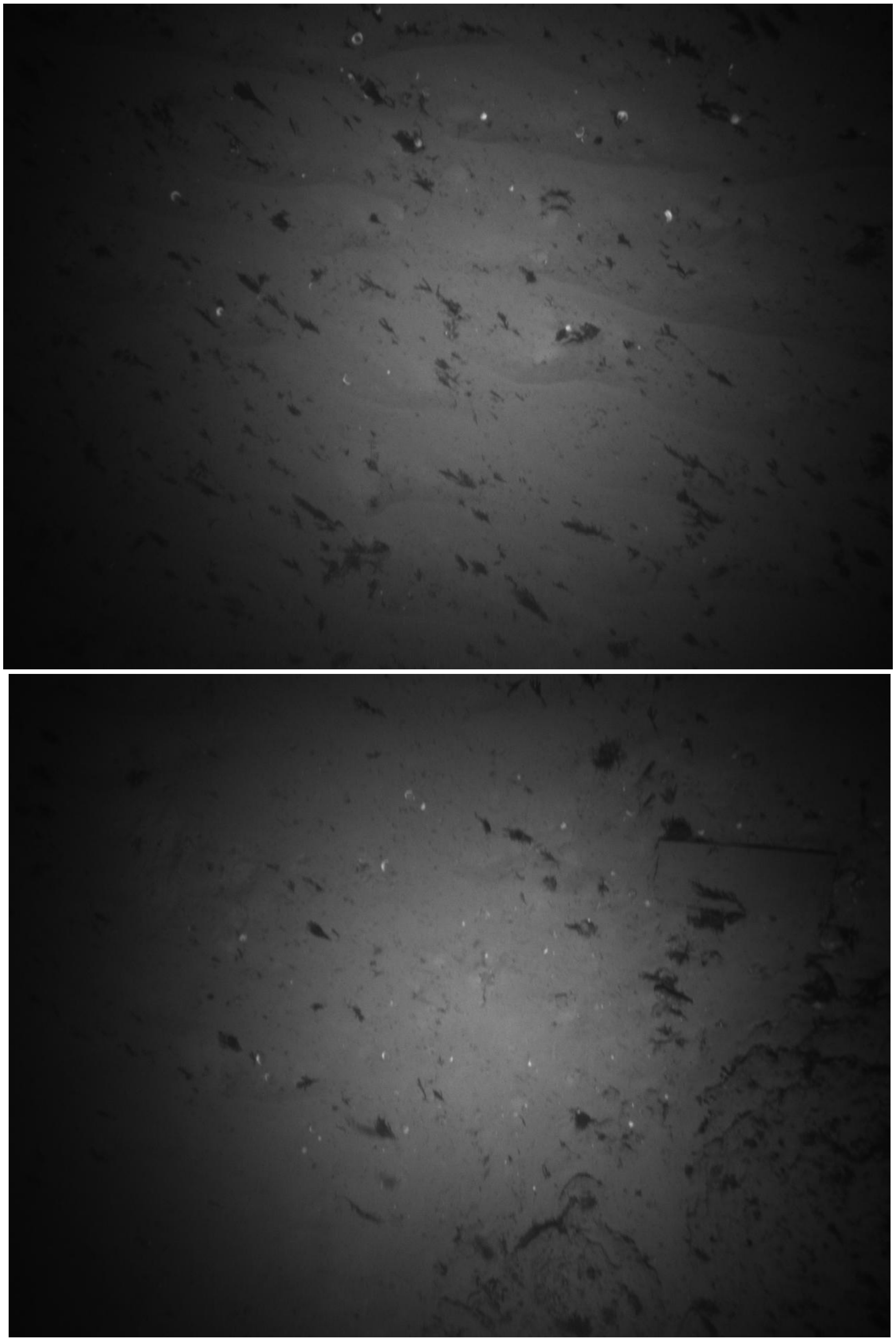


Fig. 21 Images obtained with the GAVIA grasshoper camera during AUV dive 6.2, showing A) a rocky outcrop with abundant living organisms; B) sand ripples; C) sand ripples with sessile fauna bent in the direction of the current; D) example of marine litter, consisting of a rectangular weight typically used in fisheries.

The raw (uncorrected) navigation files have been matched by the VLIZ team with the timestamps on the photos to generate a CSV containing an interpolated position of each photo (Fig. 22). In the near future, the corrected navigation files will be matched with the photos to create a corrected photo mosaic.

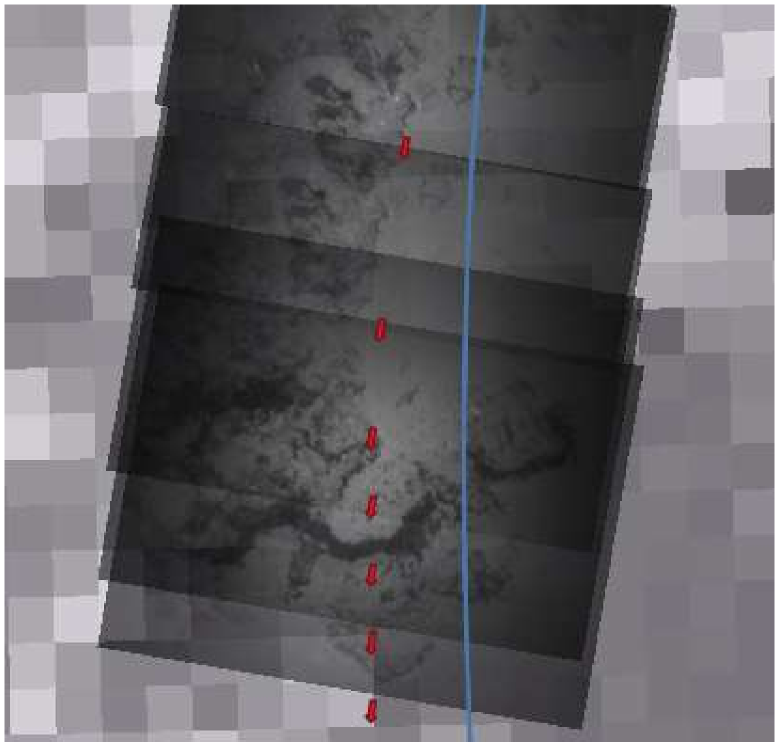


Fig. 22 Example of a photo mosaic built using images recorded with the GAVIA grasshoper camera during AUV during Dive 02. The red arrows indicate the location of an image based on the uncorrected navigation files, with the tip of the arrow pointing the heading. The blue line shows the processed and corrected navigation line, where the images should be placed.

4.6. Sediment sampling using gravity and piston corers

14 sediment cores were recovered in 10 different sampling locations (Fig. 23). Four of these sediment samples were obtained using the sampling system in gravity core mode (either using only the trigger, as a first test for the first sediment sample recovery ever made onboard of the vessel, or using the main system without the piston). This proved to be a very fast maneuver, but with a high rate of sediment loss. The other 10 sediment samples were recovered using the piston core system.

The longest sample was recovered at the canyon axis (PC-06, with 410 cm) (Fig. 23, Table 1). The cores PC-04 and PC-07 (pierced on the western side of the canyon, on a terraced plastered drift) contained a surprisingly high amount of sand, coarse sand and bioclasts (Table 1). Last, cores PC-03, GC-04, PC-04, PC-08 and PC-10 were waxed to carry out geotechnical analyses (Table 1).

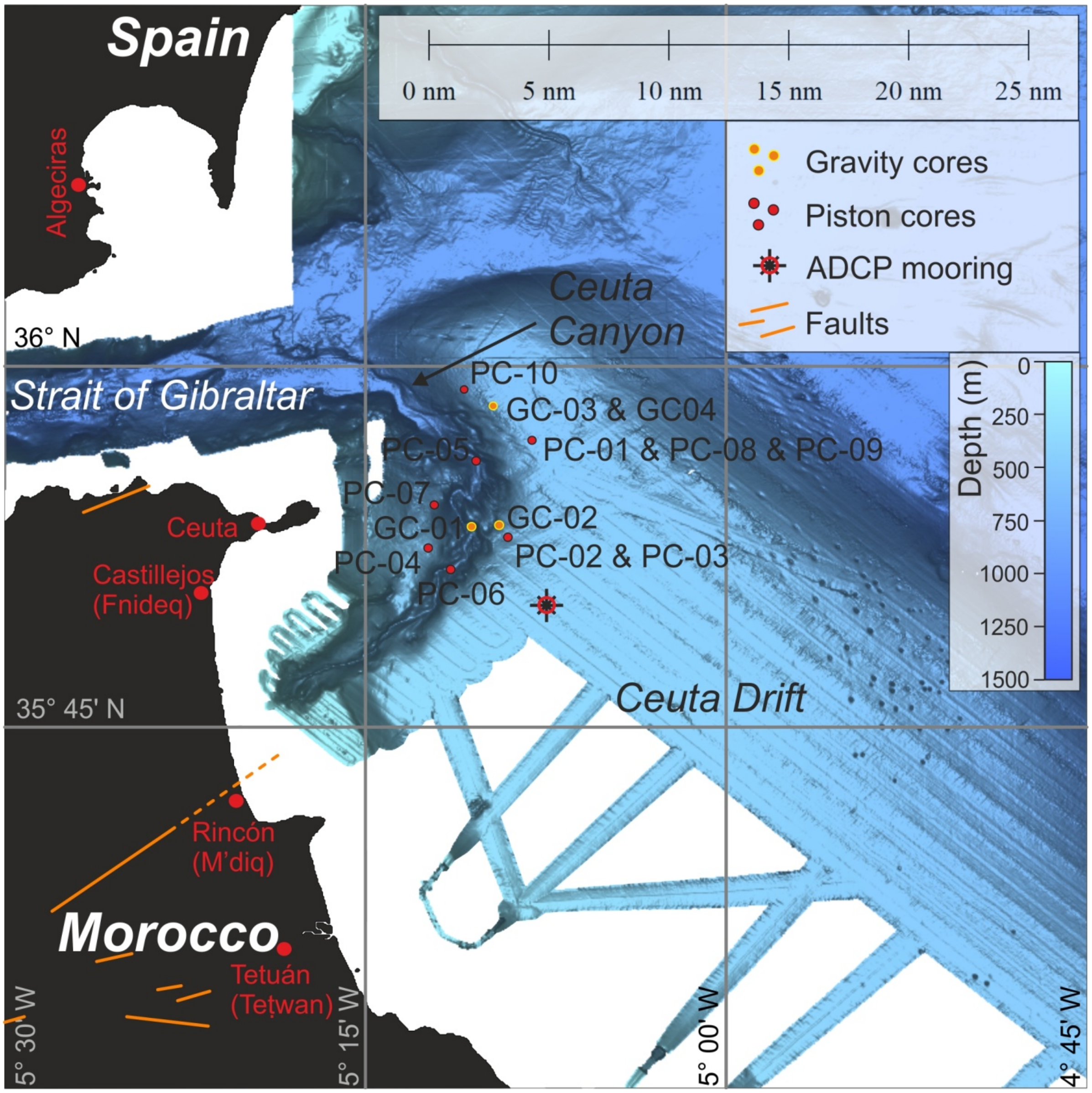


Fig. 23 Location of the 14 sediment cores recovered during the GRACE cruise. Piston cores are marked in red and gravity cores are marked in orange. Sediment core replicas were recovered in three sampling locations, to allow a more detailed granulometry and chemical analysis parallel to the geotechnical analyses.

Core	*Location (Lat/Lon)*	*Location (description)*	*Depth (m)*	*Recovery*	*Top*	*Bottom*	*Comments*
GC-01	35.888607ºN 5.175854ºW	Canyon axis (middle)	646	1 section, 110 cm	Muddy sediment	Muddy sediment	The trigger was used as a gravity core
GC-02	35.889543ºN 5.156877ºW	Eastern flank, southern sector. Rubble in between the	496	only a few cm + the content of the core catcher	-	-	The first attempt was null

		coral mounds		(stored in zip bags)			
PC-01	35.94829ºN 5.134108ºW	Eastern flank, northern sector	504	2 sections, 196 cm. Trigger 96 cm.	Hemipelagic brown mud	Sandy mud	The cable was entangled and the piston system could not be released
PC-02	35.881282ºN 5.15068ºW	Eastern flank, southern sector.	472	3 sections, 251 cm. Trigger 80 cm	Hemipelagic	Greenish mud	-
PC-03	35.881282ºN 5.15068ºW	Eastern flank, southern sector.	472	3 sections, 261 cm. Trigger 80 cm	Hemipelagic mud with few forams	Muddy sand	Replica of PC-02. Waxed for geotechnical analysis
GC-03	35.97216ºN 5.160872ºW	Eastern flank, northern sector.	537	3 sections, 241 cm	-	-	-
GC-04	35.97216ºN 5.160872ºW	Eastern flank, northern sector.	537	2 sections, 220 cm	-	-	Replica of GC-03. Waxed for geotechnical analysis
PC-04	35.873807ºN 5.205899ºW	Western plastered drift	547	1 section, 99 cm. Trigger 23 cm.	Brown sandy mud with forams and organic matter	Dark grey muddy sand with bioclasts	Bent shaft. Waxed for geotechnical analysis
PC-05	35.934148ºN 5.172704ºW	Canyon axis (low)	771	2 sections, 251 cm. Trigger 115 cm	Brown hemipelagic mud	Grey sandy mud	-
PC-06	35.859039 ºN 5.190282 ºW	Canyon axis (up)	595	4 sections, 410 cm. Trigger 79 cm	-	-	-
PC-07	35.903736 ºN 5.201599 ºW	Western plastered drift	543	1 section, 47 cm. Trigger 43 cm	Coarse muddy sand with bioclasts	Coarse muddy sand with bioclasts	Bent shaft
PC-08	35.94829 ºN 5.134108 ºW	Eastern flank, northern sector	504	2 sections, 235 cm. Trigger 99 cm.	Hemipelagic mud	Sandy mud/grey muddy sand	Replica of PC-01 and PC-09. Waxed for geotechnical analysis
PC-09	35.94829 ºN 5.134108 ºW	Eastern flank, northern sector	504	2 sections, 242 cm. Trigger 96 cm	Hemipelagic mud	Grey muddy sand	Replica of PC-01 and PC-08
PC-10	35.983928 ºN 5.181093 ºW	Eastern flank, northern sector	580	2 sections, 224 cm. Trigger 92 cm.	Lumpy mud with brown hemipelagic mud, grayish mud, black organic matter	Grey sandy mud	Waxed for geotechnical analysis

Table 01 Data of the 14 sediment cores recovered during the GRACE cruise.

4.7. Cetaceans and other relevant species

During the course of the cruise two MMO trainees noted the presence of cetaceans and their behavior, in order to stop the activities in the case that there was any risk of collision or the noise might disturb the cetaceans. Most of the sightings were either of common dolphin (*Delphinus delphis*) or striped dolphin (*Stenella coeruleoalba*) (Fig. 24), with a few additional sightings of pilot whale (*Globicephala melas*), ocean sunfish (*Mola mola*), sea turtle (undetermined species) and possibly a sperm whale (*Physeter macrocephalus*).

Fig. 24 Striped dolphin sighted on 29/04/2022.

5 Data and Sample Storage / Availability

All the data recorded during the GRACE project will endure a 2-year embargo, so the data will not be publicly available in freely accessible databases such as SeaDataNet until the 12th May of 2024.

The raw multimeam, TOPAS and Sparker data is stored at the ICM-CSIC (Barcelona, Spain) and at the IEO-CSIC (Cádiz, Spain). The team of the University of Ghent has also loaded the raw Sparker data on their institutional database, but not made publicly available yet. After a first processing, a Kingdom Suite project has been built. This project has been made available to all the teams involved in the GRACE project (including onboard and remote participants), so currently exists at least one copy of these data in each institution.

The sediment cores have been stored at the ICM-CSIC core depository (Barcelona, Spain). The waxed core replicas are in the process of being moved to the storage of University of Salamanca (Salamanca, Spain) for their analysis.

One copy of the oceanographic data (moored ADCP, hull-mounted ADCP, CTD) is held at IEO-CSIC (Cádiz, Spain), and another at University of Cádiz (Campus Puerto Real, Spain), where the team of oceanographers working on the data is rooted.

Last, the raw AUV data is stored at the IEO-CSIC (Cádiz, Spain), the ICM-CSIC (Barcelona, Spain), and at the VLIZ (Oostend, Belgium), where it is currently being reprocessed.

6 Participants

The coexistence of the GRACE and SEAQUAKE teams onboard of the same vessel resulted in the support of the SEAQUAKE team during GRACE activities, and viceversa. For that reason, the SEAQUAKE team has been included in the list of onboard participants (Table 02).

No.	Name	Early career (Y/N)	Gender	Affiliation	On-board tasks
1	Lieven Naudts	N	M	RBINS-OD NATURE	Coordinator GRACE & SEAQUAKE Projects
2	Nick Eloot	N	M		Technical support for multibeam, and TOPAS, as well as for gravity/piston core acquisition
3	Carmen Juan *	N	F	IEO-CSIC	CHIEF SCIENTIST. Planning of all activities. Surveillance of Sparker, TOPAS, multibeam, sediment core recovery
4	Nieves López-González*	N	F		Chief of the 4-8h shift. Surveillance of Sparker, TOPAS, multibeam, sediment core recovery
5	David Casas *	N	M	ICM-CSIC	Chief of the 12-4h shift. Surveillance of Sparker, TOPAS, multibeam, sediment core recovery
6	Ferran Estrada *	N	M		Chief of the 8-12h shift. Surveillance of Sparker, TOPAS, multibeam, sediment core recovery. Multibeam processing, creation of Sparker and TOPAS KS Projects.
7	Sara Martínez Loriente**	N	F		Surveillance of Sparker, TOPAS, multibeam, sediment core recovery
8	Ariadna Canari Bordoy **	Y	F		Surveillance of Sparker, TOPAS, multibeam, sediment core recovery
9	Maria Azpiroz *	N	F	Arquimea RC	Surveillance of Sparker, TOPAS, multibeam, sediment core recovery
10	Koen De Rycker *	M	M	UGent	Sparker technician
11	Alice Matossian *	Y	F		Assistant to Sparker maneuvers. Surveillance of Sparker, TOPAS, multibeam, sediment core recovery
12	Clara Beda *	Y	F	U. La Sapienza	Surveillance of Sparker, TOPAS, multibeam, sediment core recovery
13	Juan A. Jimenez Rincon *	Y	M	UCA	CTD work, Hull-mounted ADCP, moored ADCP. Surveillance of Sparker, TOPAS, multibeam.
14	Elizabeth Blazquez Gómez *	N	F		Surveillance of Sparker, TOPAS, multibeam, sediment core recovery

15	Patricia Soriano Tineo *	Y	F		MMO trainee
16	Angel Rafael Domínguez Bustos *	Y	M		MMO trainee
17	Fred Fourie	N	M	VLIZ	AUV technician
18	Kobus Langedock	N	M	VLIZ	AUV technician

Table 02 List of onboard participants of the GRACE cruise

*Participants funded by EUROFLEETS+ GRACE Project

**Participants funded by EUROFLEETS+ SEAQUAKE Project

RBINS-OD NATURE Royal Belgian Institute of Natural Sciences - Operational Directorate Natural Environment (Brussels, Belgium)

IEO-CSIC Instituto Español de Oceanografía – Consejo Superior de Investigaciones Científicas (Málaga and Cádiz headquarters, Spain)

ICM-CSIC Institut de Ciències del Mar - Consejo Superior de Investigaciones Científicas (Barcelona, Spain)

Arquimea RC Arquimea Research Centre (Santa Cruz de Tenerife, Spain)

UGent Ghent University (Ghent, Belgium)

U. La Sapienza Sapienza Università di Roma (Rome, Italy)

UCA Universidad de Cádiz (Cádiz, Spain)

VLIZ Vlaams Instituut voor de Zee (Ostend, Belgium)

7 Station List

The stations are here considered as locations where a punctual sample was recovered. In this category, we consider the moored ADCP, the CTD casts, as well as all the sediment samples (gravity and piston cores) (Table 03).

Station No.	Date	Time	Latitude	Longitude	Water Depth	Gear	Remarks/Recovery
	2022	[GMT]	[°N]	[°W]	[m]		
01	28.04	13:30	35.834743	5.124762	402	ADCP mooring	Deployment
02	28.04	18:00	35.8068333	5.17766667	359	CTD	CTD 01
03	29.04	09:30	35.9048333	5.15383333	550	CTD	CTD 02
04	29.04	17:30	35.9096667	5.15666667	592	CTD	CTD 03
05	30.04	09:46	35.897	5.1555	516.5	CTD	CTD 04
06	30.04	17:48	35.888607	5.175854	646	Gravity Core	GC01 (1 section, 110

							cm)
07	30.04	18:00	35.8888333	5.17616667	661	CTD	CTD 05
08	01.05	19:03	35.9876667	5.2585	876	CTD	CTD 06
09	02.05	08:02	35.9645	5.2145	831	CTD	CTD 07
10	02.05	19:32	35.8601667	5.1895	595	CTD	CTD 08
11	03.05	11:58	35.9576667	5.20383333	825	CTD	*CTD 09a - SQ (ABORTED)*
12	03.05	14:15	35.9341667	5.17266667	771	CTD	*CTD 09b - SQ (ABORTED)*
13	03.05	19:28	35.889543	5.156877	496	Gravity core	GC02 (0 sections, top and bottom stored in zip bags)
14	04.05	15:33	35.94829	5.134108	504	Piston core	PC01 (2 sections, 196 cm)
15	05.05	11:30	35.881282	5.15068	472	Piston core	PC02 (3 sections, 251 cm)
16	06.05	14:45	35.881282	5.15068	472	Piston core	PC03 (3 sections, 261 cm)
17	07.05	16:26	35.9093333	5.1825	704	CTD	*CTD 10 - SQ*
18	08.05	08:35	35.97216	5.160872	537	Gravity core	GC03 (3 sections, 241 cm)
19	08.05	09:31	35.97216	5.160872	537	Gravity core	GC04 (2 sections, 220 cm)
20	08.05	14:09	35.873807	5.205899	547	Piston core	PC04 (1 section, 99 cm)
21	08.05	16:30	35.934148	5.172704	771	Piston core	PC05 (2 sections, 251 cm)
22	08.05	17:29	35.9355	5.172	771	CTD	CTD 11 (aprox. same location as CTD 09b)
23	09.05	06:46	35.834743	5.124762	402	ADCP mooring	Recovery
24	09.05	09:07	35.859039	5.190282	595	Piston core	PC06 (4 sections, 410 cm)
25	09.05	11:46	35.903736	5.201599	543	Piston core	PC07 (1 section, 47 cm)
26	09.05	14:28	35.94829	5.134108	504	Piston core	PC08 (2 sections, 235 cm)
27	09.05	17:03	35.94829	5.134108	504	Piston core	PC09 (2 sections, 242 cm)
28	09.05	19:00	35.9438333	5.18966667	795	CTD	CTD 12
29	10.05	11:39	35.983928	5.181093	580	Piston core	PC10 (2 sections, 224 cm)
30	10.05	14:23	35.9118333	5.18783333	716	CTD	*CTD 13 - SQ*
31	11.05	07:03	35.8693333	5.11933333	436	CTD	*CTD 14 - SQ*

Table 03 List of stations carried out during the GRACE cruise

8 Acknowledgements

The entire GRACE team (both onboard and remote participants) would like to express our most sincere recognition **to the entire crew of the RV Belgica**, who are excellent professionals and also were extremely kind and helpful during the cruise. In addition, we would like to thank the participants of **RBINS-OD NATURE (Lieven Naudts and Nick Eloot)**, as well as the technicians of the AUV Barabas belonging to the **VLIZ (Kobus Langedock and Fred Fourie)**, who have been our close colleagues during these two weeks. Many other people contributed to make this cruise such a success (advising us, providing contacts, suggesting solutions…), among which **all the people working for Eurofleets+** deserve a special thanks.

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