Campagne SMARTIES/ SMARTIES Cruise

(**S**mooth regions at the **M**id-**A**tlantic **R**idge **T**ransform-**I**ntersections under **E**xtreme thermal gradient**S**)

Cruise report

NO “Pourquoi Pas?”
13/07/2019 – 23/08/2019 – Mindelo-Mindelo, Cape Verde

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Scientific rationale and cruise objectives

The objective of SMARTIES (**S**mooth regions at the **M**id-**A**tlantic **R**idge **T**ransform-**I**ntersections under **E**xtreme thermal gradient**S**) was to explore the axis of the Mid-Atlantic ridge (MAR) at the intersection with the Romanche transform fault (Figure 1), the longest in the Atlantic (950 km and ~50 My of axial and age offsets), and specifically the southeast ridge-transform intersection (RTI). Large-offset transforms, or mega-transforms, induce extreme cooling at the edge of axial ridge segments due to the associated enhanced age contrast and peculiar tectonics. The Equatorial Atlantic hosts several mega transforms, where the interactions between low mantle potential temperatures and large lithospheric age contrast with melt production are poorly understood. The nature of the asthenospheric mantle at this location as well as the cold edge effect induced by the Romanche due to the lithospheric age contrast, result in a portion of the ridge axis where the partial melting rates are exceptionally low (Bonatti et al., 2001). The study area therefore corresponds a strong temperature gradient which results in a passage from a magmatic area to an area where the mantle is exposed at the ocean floor, in the vicinity of the transform. These mantle outcrop areas, very different from the OCCs commonly observed at the MAR axis, are extremely rare and so far, observed only at ultra-slow ridges (e.g. , Indian Southwest ridge, SWIR), at much lower spreading rates.

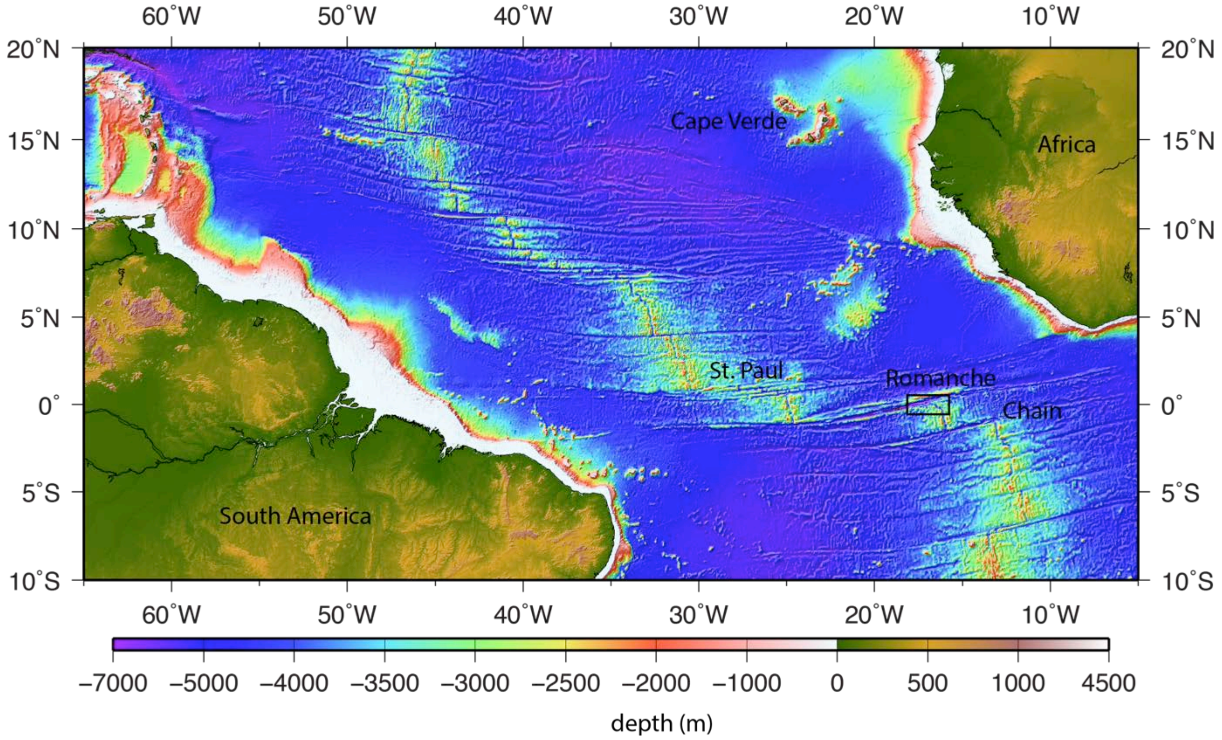

Figure 1. General bathymetry (from satellite data) of the Equatorial Atlantic. The SMARTIES area corresponds to the rectangle.

The cruise is part of a larger international project to study the long offset complex multi-fault transforms of the Equatorial Atlantic. This project follows the COLMEIA cruise (PI M. Maia, CNRS-UBO, France, Co-PI S. Sichel, UFF, Brazil, 2013) which obtained bathymetric and geophysical data, as well as rock samples on the St. Paul's multi-transform system.

SMARTIES targeted the longest transform oceanic fault in the Atlantic, the Romanche, studied in the 1990s by the team of E. Bonatti from Bologna-WHOI. The cruise strategy (Figure 2) was mainly based on surface mapping with the ship's echosounder to improve the quality of the available bathymetry data, as well as gravity and magnetics, on performing 25 Nautile dives in several locations along the eastern part of the transform fault valley and walls, the ridge-transform intersection and the ridge axis, and the deployment of 19 OBSs (broadband and short period) for the length of the cruise (five weeks on the target area) in a cooperation with the ILAB project (S. Singh, IPGP).

During the cruise we improved the mapping of the region in order to recognize the boundaries of the SSF domain and its persistence through time. We explored in detail the change in deformation patterns on selected targets already identified from available bathymetric data. The detailed study consisted on the acquisition of a surface bathymetry with the largest possible resolution (about 30 m using a very low ship velocity -5 knots – and high overlap) over the main targets and dives with the Nautile to acquire samples, high-resolution images (bathymetry and video/photographs) of the structures as well as near bottom magnetic profiles. The images allow a detailed mapping of the fault and of the deformation patterns of different parts of the RTI, where we observed different, or contrasting, tetonic styles. The sampling strategy targeted the study of rock compositions and rheological properties, with particular attention to the serpentinization process. The integrated study of rock characteristics and of geophysical surveys allows tackling the interactions between magmatism and tectonics. Direct observations and sampling also help to understand the nature of the peculiar alkaline, water-rich, magmatism observed in the region.

One of the objectives of the cruise was to improve our understanding of the thermal regime at complex transform domains. As part of the cruise, we were interested on potential hydrothermal activity associated to the large mantle serpentinite exposures and its impact on the chemical and heat transfers from the seafloor to the hydrosphere in a poorly-known region. During the dives, a particular attention was given to finding signals of hydrothermal activity. Traces of such activity were observed on dive #24 and the area was fully explored during dive #25.

The OBS experiment was a major asset for the project. The purpose of the deployment was to record seismicity and micro-seismicity in the study area. The expected results of this deployment are diverse, for example, the location of the most active zones and therefore of the ridge axis, in particular in the portion close to the transform fault or the geometry and functioning of the active faults at depth and the depth of water penetration into the lithosphere. Our study area presents a strong gradient in the temperature of the mantle and the lithosphere and the depth distribution of the seismicity can give us information on the depth of the isotherms of 500-600° C (brittle area) and therefore the maximum depth of serpentinization (Grevemeyer et al., 2013).
18 OBSs were safely retrieved.

REFERENCES

Grevemeyer, I., Reston, T. J., & Moeller, S. (2013). Microseismicity of the Mid‐Atlantic Ridge at 7° S‐8° 15′ S and at the Logatchev Massif oceanic core complex at 14° 40′ N‐14° 50′ N. Geochemistry, Geophysics, Geosystems, 14(9), 3532-3554.

Bonatti, E., Brunelli, D., Fabretti, P., Ligi, M., Portaro, R. A., & Seyler, M. (2001). Steady-state creation of crust-free lithosphere at cold spots in mid-ocean ridges. Geology, 29(11), 979-982.

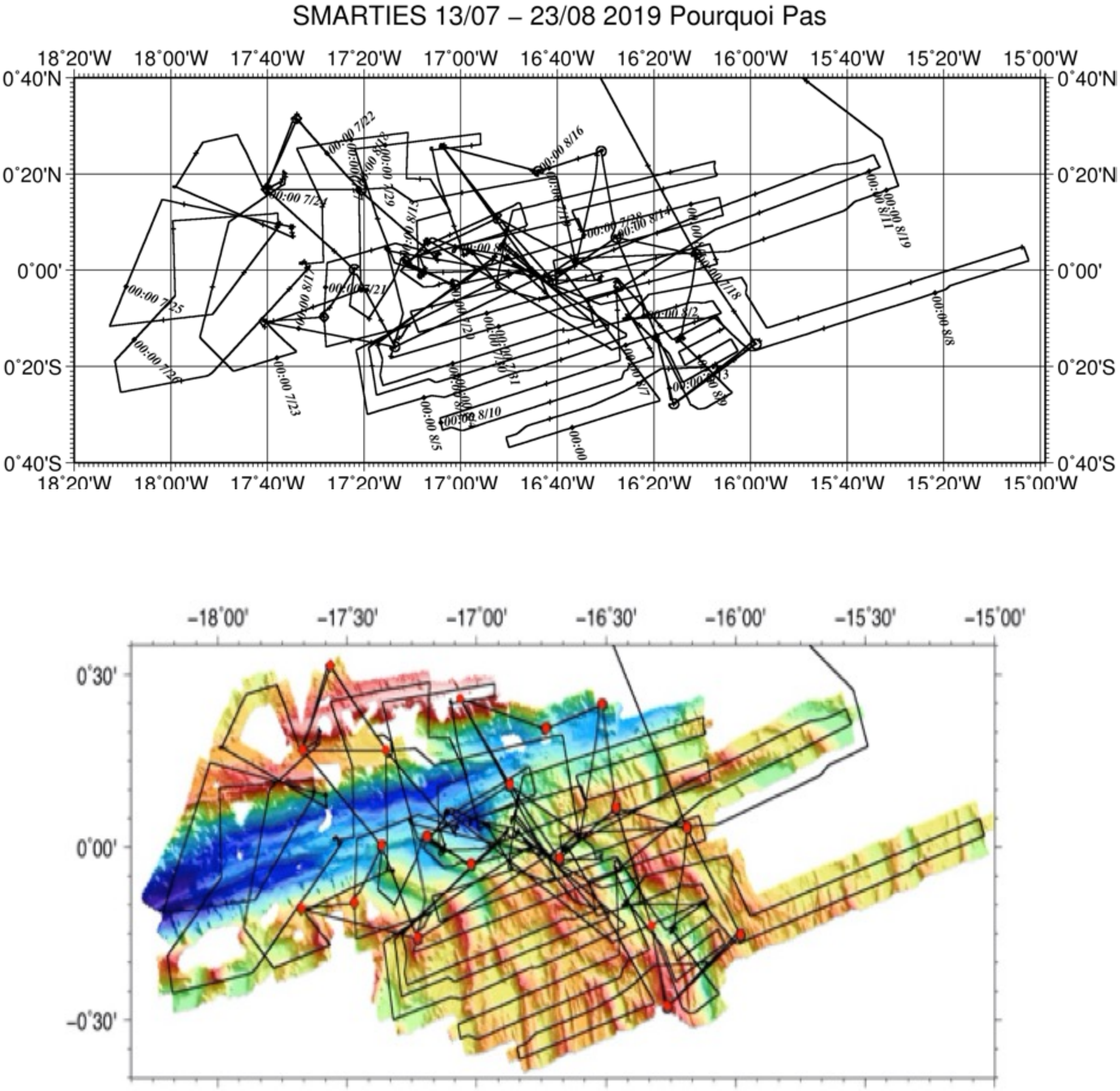

Figure 2. Top. Navigation of the SMARTIES cruise. Bottom. General bathymetry of the area (SMARTIES and ILAB data) showing the ship routes (black lines) and the location of the OBSs (in red, missing OBS in orange).

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Surface Geophysics

- **Bathymetry and backscatter data**
- **Surface Magnetic data**
- **Gravity data**

Bathymetry and backscatter

Multibeam bathymetry echosounder

Multibeam bathymetry and backscatter data were collected during all the SMARTIES cruise on the tracks outside the Cape Verde Exclusive Economic Zone.

During the cruise, the R/V *Pourquoi Pas?* RESON 7150 hull-mounted multibeam echosounder was well suited for surveys of seafloor deeper than ~2000 m. The echosounder has two main configurations for deep survey areas:

Conf.1: 12 kHz soundings, 880 beams, 140° opening, offers wider swaths but with a lower cross-track resolution and longer time between pings

Conf.2: 12 kHz soundings, 630 beams, 120° opening, offers narrower swaths, with a slightly higher cross-track resolution and a shorter time between pings.

During the SMARTIES cruise the highest resolution was necessary, so Configuration 2 was adopted. The speed vessel was chosen between 10 knots on "regular" tracks, and 5 knots on some tracks aimed to survey areas where a higher resolution bathymetry was required.

On some of the tracks where enough redundancy from previous tracks was expected, we collected the water column signal to identify thermal or physical anomalies in the water column.

Data processing

2.1. SMARTIES dataset

During the whole SMARTIES cruise an operator from IFREMER was in charge of cleaning the swath bathymetry. He used the Swath Editor tool from the GLOBE software to produce cleaned bathymetry files (.mbg format, compatible with GLOBE and MB-System softwares) from the raw .s7k RESON files.

The IFREMER Operator also produced the bathymetric contoured maps compatible with the navigation system of the Nautile submersible. These could help prepare the Nautile dives, and were used during the dives as a bathymetric reference. The generation of these maps was fairly time consuming and required old versions of software. Hopefully the compatibility between maping systems in GLOBE and the Nautile navigation system will be improved in the near future.

2.2. Previous dataset - ILAB-SPARC data

During the SMARTIES cruise we had access to a 50m-resolution grid of the 2018 *R/V Pourquoi Pas?* ILAB-SPARC bathymetry data in our survey area. Postcruise, we had access also to the cleaned swath bathymetry in .mbg format with the full data set in the SMARTIES survey area.

2.3. Older data - Romanche data compilation from Marco Ligi

Before the SMARTIES and ILAB-SPARC cruises, a series of multibeam bathymetry surveys or transits covered the Romanche area. These data were compiled by Marco Ligi, Univ. Bologna, who provided us with a 150 m-resolution grid. In particular, some Russo-Italian data sets are not available in the public domain, and were included in this compilation.

Grids and maps

3.1. Grid resolution

We produced a 150 m-resolution grid of the whole eastern Romanche area combining the Italian bathymetry compilation, the ILAB-SPARC data and the SMARTIES data.

We tested the highest resolution possible for the study areas where dives were performed. These areas were typically covered by at least one swath collected at 5 knots, and one or several swaths collected at 10 knots. We could choose a resolution of 20 meters in these areas, and a resolution of 50 meters in the rest of the SMARTIES survey. The high-resolution grids include only SMARTIES and ILAB-SPARC data, for which the navigation and processing is of highest quality.

3.2. Maps

The SMARTIES cruise allowed to map the eastern part of the Romanche transform fault (TF) to 18°15'W, and the Mid-Atlantic Ridge (MAR) axis just south of the transform fault. The maps allow a tectonic and volcanic interpretation of the seafloor morphology near the intersection between the Romanche TF and the MAR.

Backscatter imagery

Backscatter imagery data are part of the multibeam bathymetry dataset. The data were processed with the Sonarscope software.

From the raw data .s7k files, in Sonarscope:

- Survey processing -> Geometric transformation -> PingBeam -> Latlon -> Reflectivity from snippets 100%

This tool generates 2 images: reflectivity and Tx angles

Clicking (right) on the color scale in reflecctivity image opens the image histogram and allows to enhance the image.

File -> Export -> Images exports images in various formats, including one compatible with GLOBE.

The backscatter swaths have higher values near the nadir, so that images including all tracks are disrupted by this effect. We chose to process only one or 2 swaths at a time, to produce images with a minimal nadir effect. The choice of files to include may be done by representing the navigation in Sonarscope.

These images are especially useful to show the recent faults and the contrast between volcanic terrains of different ages.

Surface Magnetic data

Magnetic data acquisition

The Marine Magnetics SeaSpy magnetometer provides measurements of the intensity of the Earth's magnetic field. It is usually towed behind the research vessel, at a distance of about three times the length of the ship to avoid signal noise. During the SMARTIES cruise, magnetic data were collected along 122 profiles (three during the transit phases and 119 in the SMARTIES working area) with the sensor towed 250 m behind the ship, and with a sampling step t = 1 s.

Preliminary shipboard magnetic data processing and results

Magnetic data are provided in the format *date, time, intensity value*, so that onboard preliminary processing consists in: (i) merging the magnetic data with the vessel navigation, (ii) clean the data from the high-frequency noise and outliers, using a quadratic regression with window equal to 50s, and (iii) computing magnetic anomaly values by making use of the International Geomagnetic Reference Field (IGRF), version 12. Magnetic anomalies in the SMARTIES working area, without sensor-ship distance corrections, are in the range of -300 and 300 nT and are reported in Figure 3. As an example of preliminary shipboard data processing and results, the magnetic data along the profile n. 22 (see Figure 3 for the location) are reported in Figure 4.

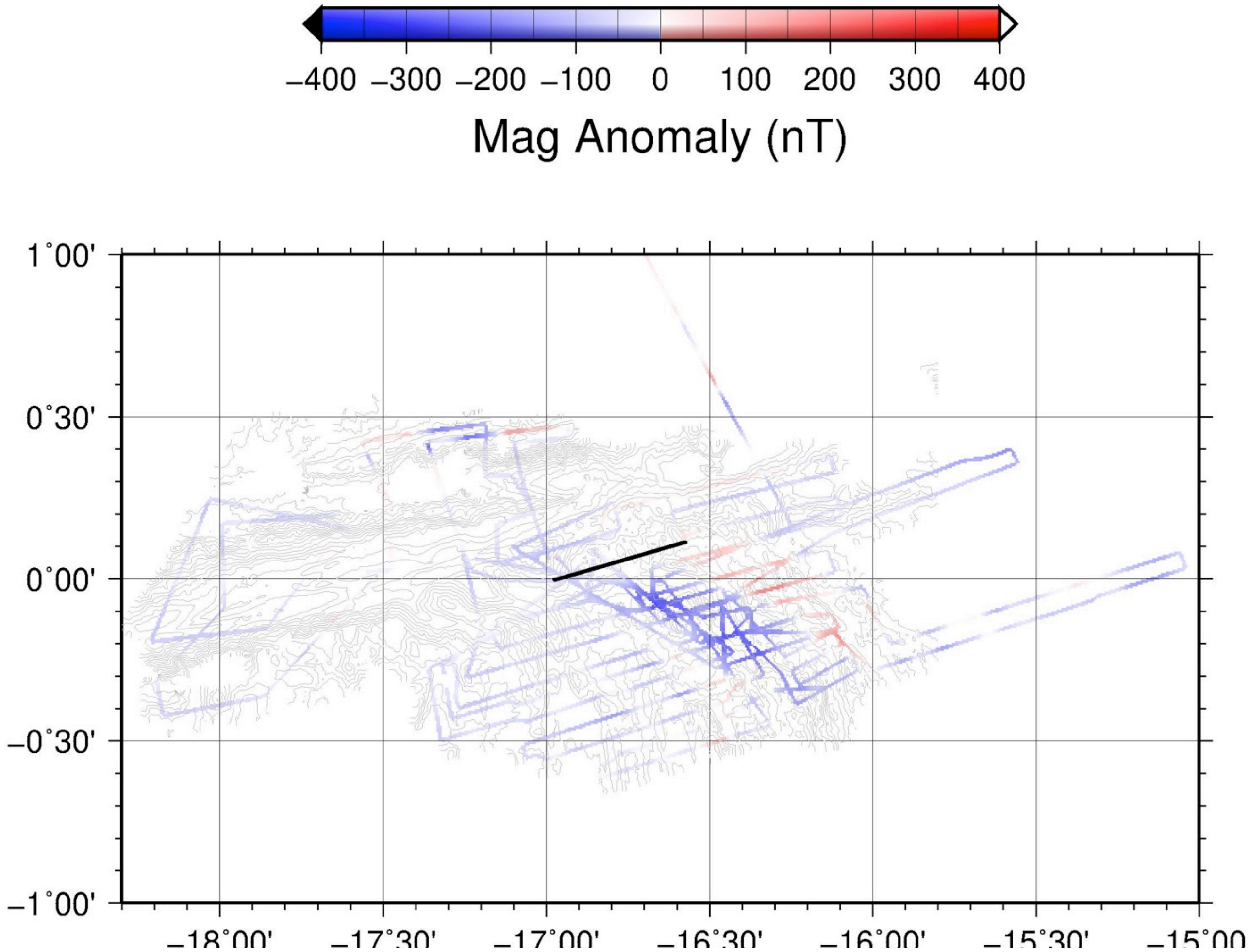


Figure 3. Preliminary magnetic anomaly results along the 122 SMARTIES magnetic profiles. The solid black line shows the location of the profile n. 22, whereas the thin grey contours are the newly acquired high-resolution bathymetry (300 m spacing). Colored grid spacing corresponds to 300 m, with interpolation search radius equal to 1 km.

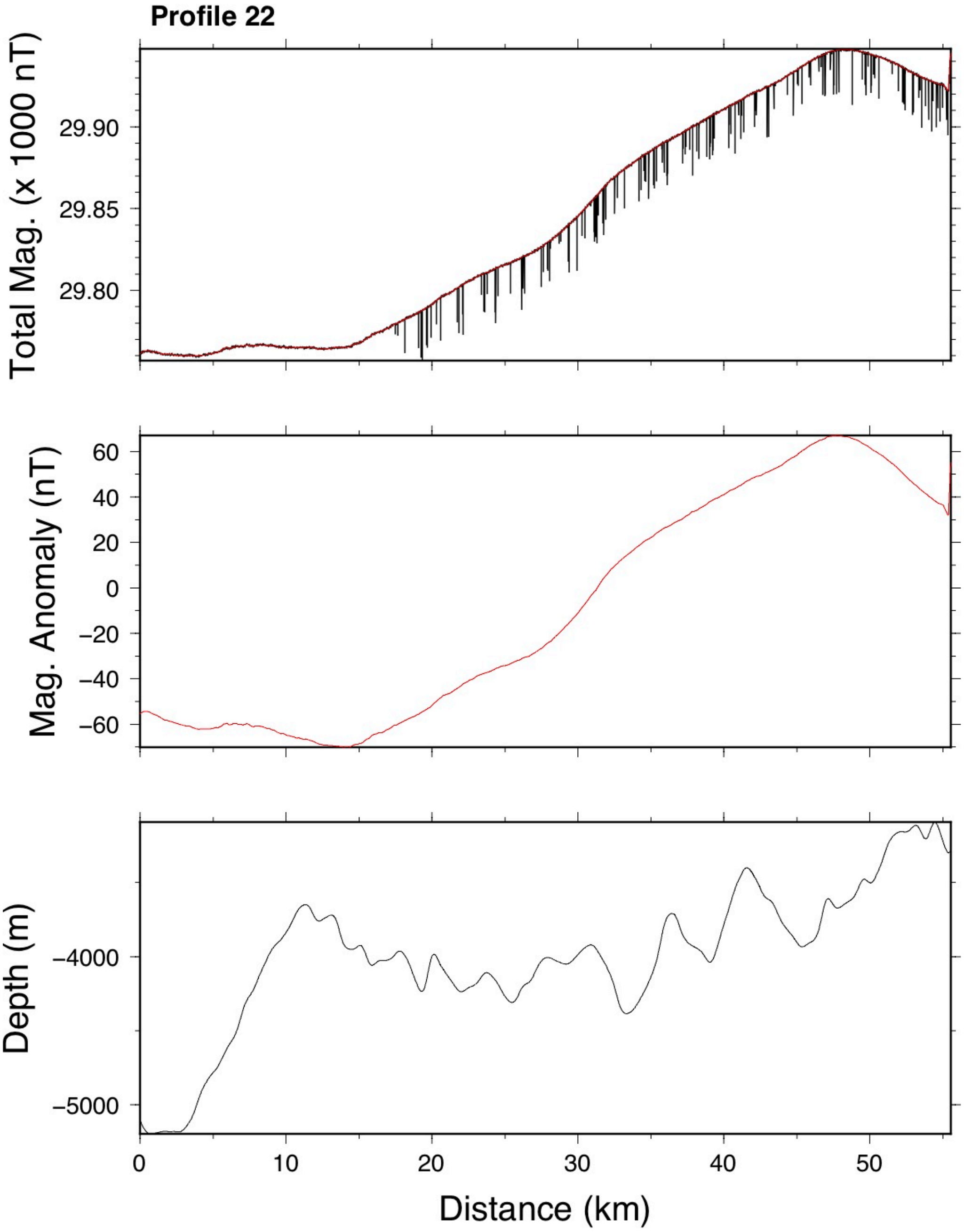


Figure 4. Magnetic data along the profile n. 22 (see Figure 1 for the location). Upper panel: total magnetic field (black line) and filtered one (red line). Middle panel: magnetic anomaly computed using the IGRF-12 (red line). Lower panel: bathymetric section along profile n. 22 (black line).

Gravity data

Gravimetric data acquisitions

Gravimetric data were continuously collected with the onboard KSS32M-1 gravimeter. In the SMARTIES working area, 172 gravimetric profiles have been recorded, with a sampling step $t = 1$ s.

Preliminary shipboard gravimetric data processing and results

Gravimetric data are provided in the format *date, time, relative gravity*, so that onboard preliminary processing consists in: (i) merging the gravimetric data with the vessel navigation, (ii) computing the normal field, the Eotvos correction and the Free Air Anomaly (FAA), taking into account the ship speed and heading, at every measurement location. Free air anomalies in the SMARTIES working area are in the range of -160 and 230 mGal and are reported in Figure 5. As an example of preliminary shipboard data processing and results, the FAA anomalies along the profile n. 22 (see Figure 3 for the location) are compared with satellite-derived ones and are reported in Figure 6.

Additional shipboard gravimetric data processing consists in the integration of newly acquired SMARTIES gravimetric data with the satellite-derived free air grid (https://www.ngdc.noaa.gov, Sandwell et al., 2014), useful to compute Mantle Bouguer Anomaly (MBA, Figure 7) with the Parker method, by taking into account corrections of topographic effects and of a hypothetical Moho depth (i.e., 5 km). Then, using Thermal Gravity Mantle Anomaly (TGMA) corrections (Figure 8) derived from the mantle thermal structure of the area (Ligi et al. 2008 and reference therein), the Residual Mantle Bouguer Anomaly (RMBA) is computed and reported in Figure 9. Finally, crustal thickness variations (CTK) with respect to a theorical oceanic crust of 5 km were computed following the downward continuation methods (e.g., Phipps Morgan and Blackman, 1993 and reference therein). Corrections for sedimentary coverage are not applied in the previous steps of shipboard gravimetric data processing.

REFERENCES

Ligi, M, M. Cuffaro, F. Chierici, A. Calafato (2008), Three-dimensional passive mantle flow beneath mid-ocean ridges: an analytical approach Geophysical Journal International, 175, 783-805.

Parker, R. L. 1972 The Rapid Calculation of Potential Anomalies, Geophys. J. R. astr. SOC., 31, 447455.

Sandwell, D. T., Müller, R. D., Smith, W. H. F., Garcia, E. and Francis, R. 2014. New global marine gravity model from Cryo-Sat-2 and jason-1 reveals buried tectonic structure. Science, Vol. 346, 6205, pp. 65-67, doi: 10.1126/science.1258213.

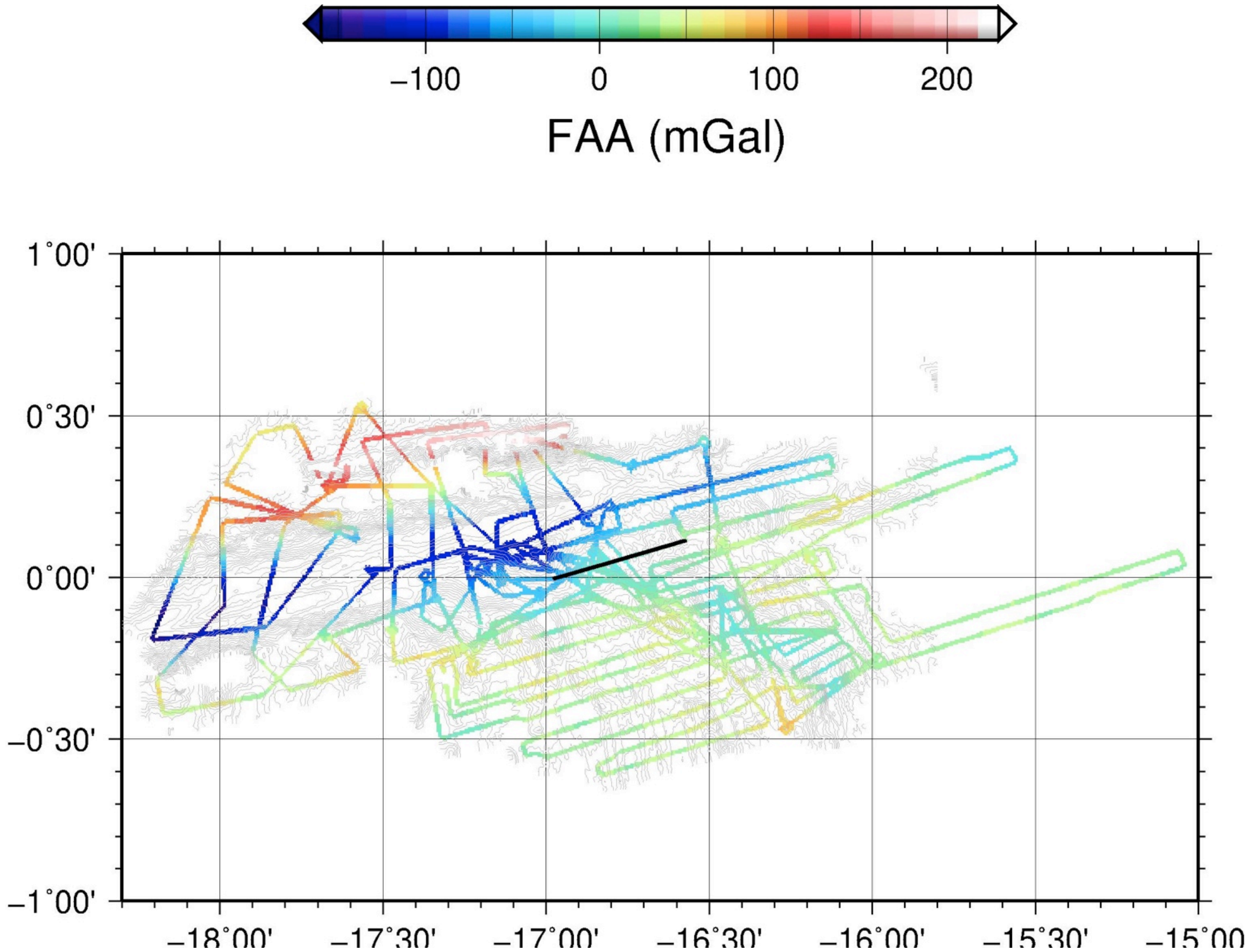


Figure 5. Preliminary gravity results along the 172 SMARTIES gravimetric profiles. The solid black line shows the location of the profile n. 22, whereas the thin grey contours are the newly acquired high-resolution bathymetry (300 m spacing). Colored grid spacing corresponds to 300 m, with interpolation search radius equal to 1 km.

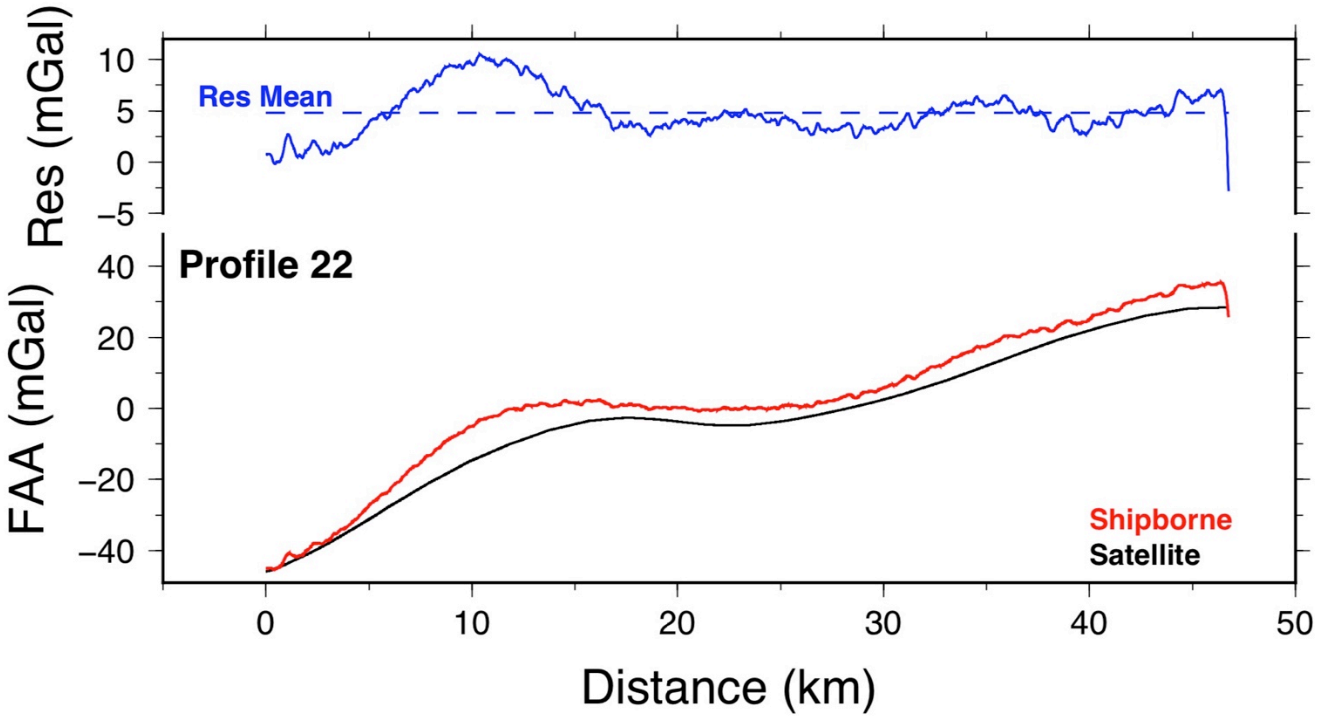


Figure 6. Lower panel: comparisons between the SMARTIES FAA shipborne gravity (red line) and satellite-derived one (black line) along the selected profile n. 22 (see location in Figure 3). Upper panel: computed pointwise difference (Res, blue line) between shipborne and satellite-derived gravity values, showing a mismatch range of 10 mGal, with a Res Mean value (dashed blue line) equal to 4.9 mGal.

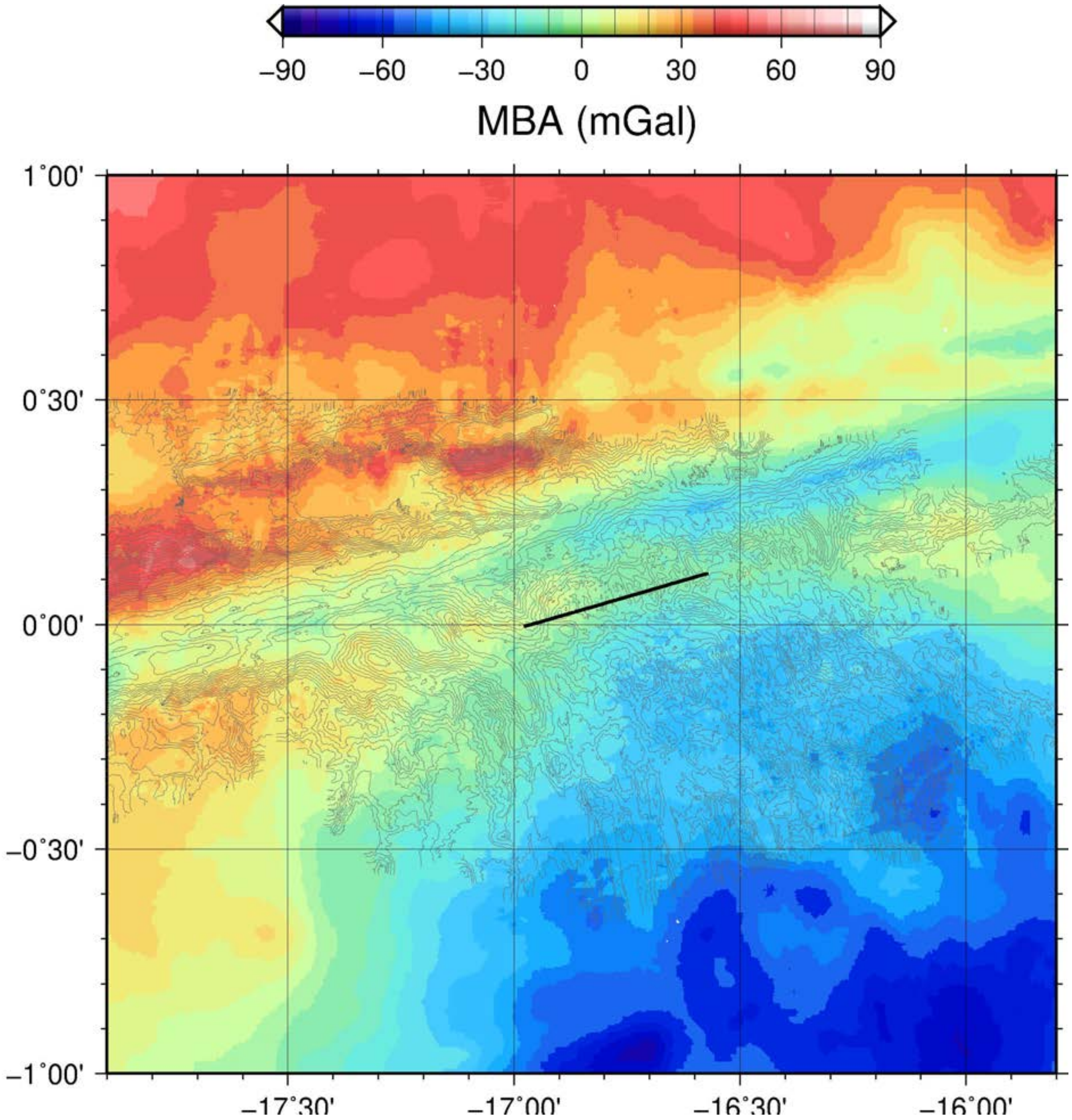


Figure 7. Mantle Bouger Anomaly (MBA) of the SMARTIES working area integrated with satellite-derived gravity. The solid black line shows the location of the profile n. 22, whereas the thin grey contours are the newly acquired high-resolution bathymetry (300 m spacing). Colored grid spacing corresponds to 300 m.

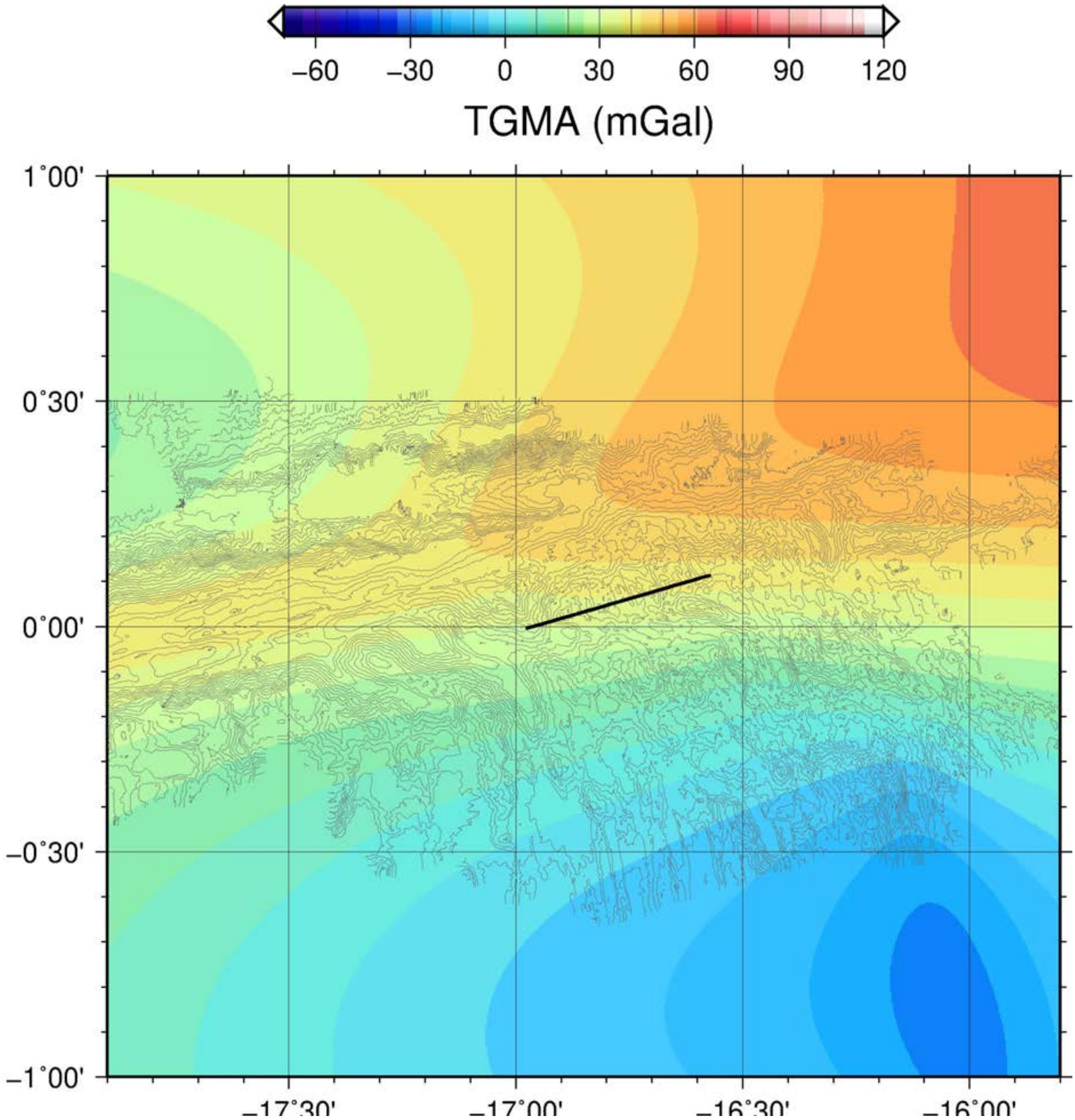


Figure 8. Thermal Gravity Mantle Anomaly (TGMA) of the SMARTIES working area integrated with satellite-derived gravity. The solid black line shows the location of the profile n. 22, whereas the thin grey contours are the newly acquired high-resolution bathymetry (300 m spacing). Colored grid spacing corresponds to 300 m.

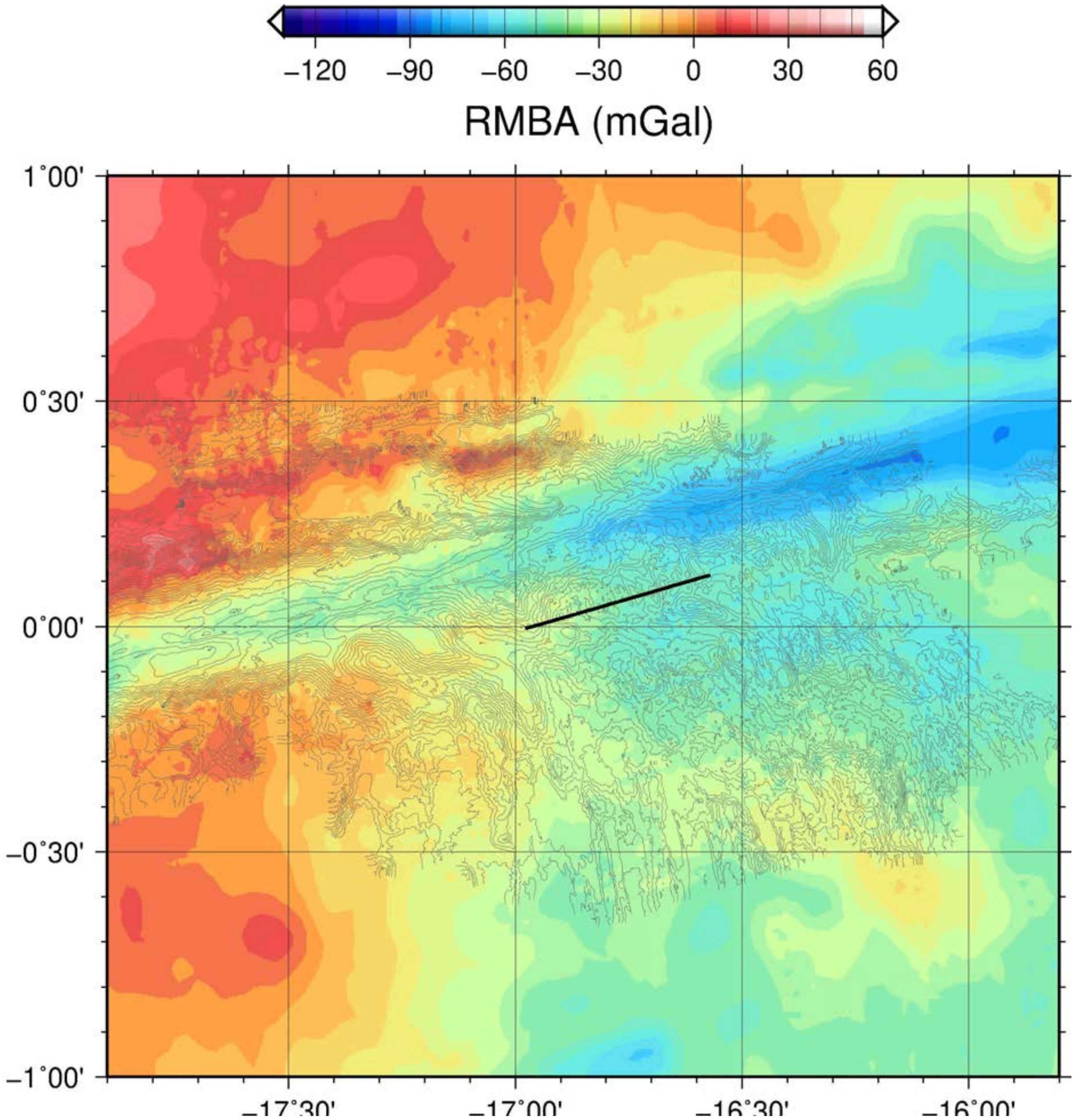
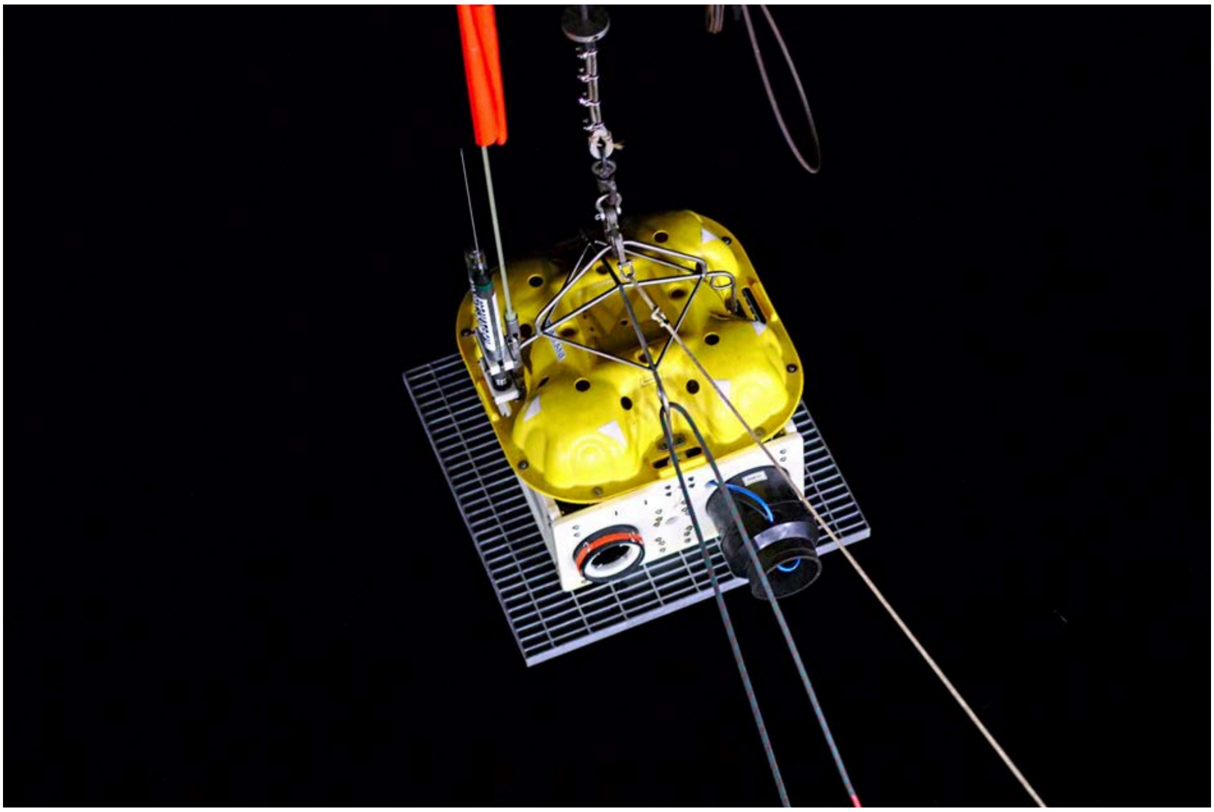


Figure 9. Residual Mantle Bouger Anomaly (RMBA) of the SMARTIES working area integrated with satellite-derived gravity. The solid black line shows the location of the profile n. 22, whereas the thin grey contours are the newly acquired high-resolution bathymetry (300 m spacing). Colored grid spacing corresponds to 300 m.

OBS deployment



Night deployment

OBS deployment

Scientific objectives

The ocean-bottom seismograph (OBS) experiment formed part of a collaboration between SMARTIES and the TRANSATLANTIC-ILAB project, led by Prof. Satish Singh at IPGP. The ILAB project is aiming to characterise the oceanic lithosphere and image the lithosphere-asthenosphere boundary from 0 Ma at the MAR to ~75 Ma near the African continental shelf, and across major transform faults/fracture zones Romanche, Chain and St Paul. Three previous cruises in 2015, 2017 and 2018 collected several profiles of active-source seismic reflection and refraction data, as well as heat-flow, multibeam bathymetry, and potential field data, to try and map the base of the lithosphere and understand its physical and thermal structure. http://www.ipgp.fr/~marjanovic/ILAB/ILAB/Trans-Atlantic_iLAB.html

The goal of this passive OBS experiment is to record the seismicity of the eastern Romanche Transform Fault and its intersection with the MAR over a period of 3-4 weeks. Being able to map the microseismicity of this area will contribute to several scientific questions:

- The depth of the earthquakes will help to constrain the base of the lithosphere and its thermal gradient (e.g. Schlindwein & Schmid, 2016), and how the thermal regime changes across transform faults and may influence spreading dynamics (e.g. Abercrombie & Ekstrom, 2001; Behn et al., 2004; Roland et al., 2010; Ligi et al., 2011).
- This ridge-transform intersection (RTI) is complex with several small ridge jumps and a wide zone of unusual tectonics and deformation with both extension and uplift. Locations and focal mechanisms of the earthquakes can help to locate the current ridge axis and understand how the RTI is deforming.
- At this segment of the MAR, 'normal-mode' magmatic spreading evolves into amagmatic 'smooth-seafloor'-type spreading close to the transform fault. We can see if there is a change in the seismicity which may indicate either melt migration, tectonic stretching or detachment faulting at different parts of the ridge axis.
- Transform faults may produce slow-slip events (McGuire et al., 1996) and have varying seismicity along strike depending on changes in composition and fracturing (Roland et al., 2012; Froment et al., 2014). Combining the observed seismicity with high-resolution bathymetric mapping, tomographic velocity models and the submersible mapping and rock sampling by the Nautile will produce an integrated analysis of the controls on oceanic strike-slip faulting.

An array of 19 OBSs were deployed to cover the Romanche-MAR RTI, the northernmost part of the southern MAR segment, and the eastern part of the Romanche TF, extending westwards to the ILAB seismic survey profile (Fig. 11). Instruments were positioned to achieve the most regular coverage possible whilst avoiding steep slopes and depths greater than 5000 m (the maximum depth rating of the OBSs), with an average spacing of ~30 km.

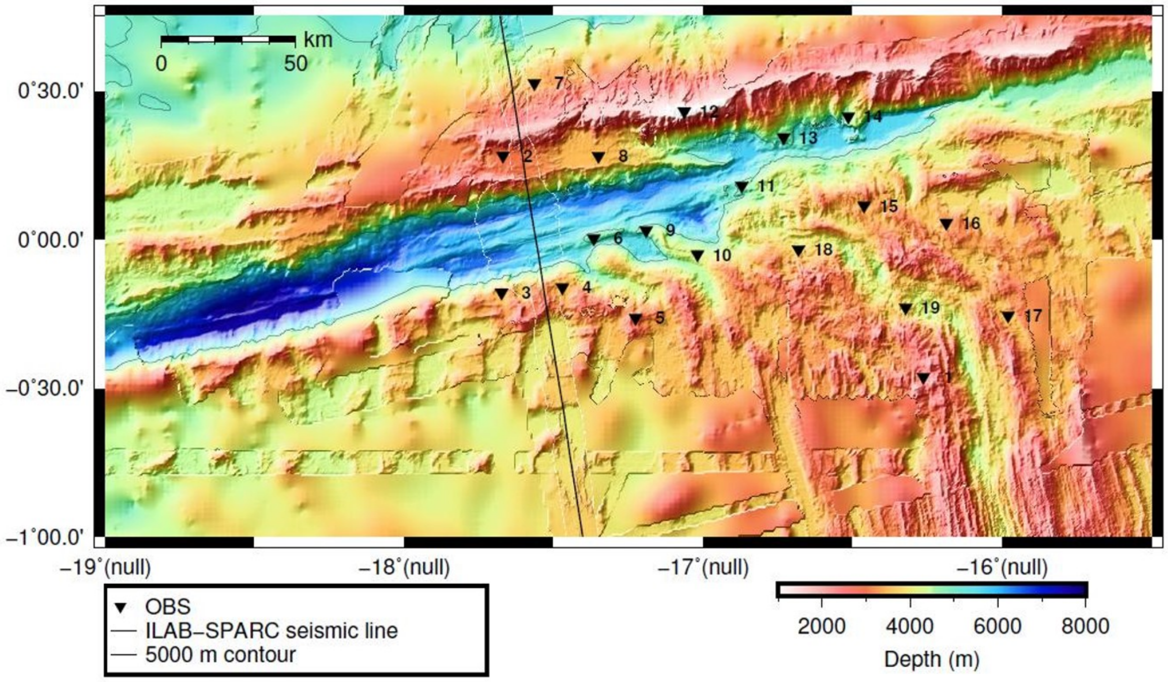


Figure 11. Map of OBS deployment positions

OBS equipment

The 19 OBS instruments comprised four short-period OBS from IPGP/INSU in Paris (Fig. 12) and 15 short-period OBS from UTM-CSIC in Barcelona (Fig. 13). All OBS were equipped with a hydrophone and 3-component geophone. All hydrophones (UTM and IPGP) were High Tech@ HTI-90-U; and all geophones Sercel's L28 – 3 components. Four UTM data loggers (powered by alkaline batteries) were L-Cheapo 4x4-type, 11 were Abalones-type, and the IPGP data loggers (powered by lithium batteries) were L-Cheapo 2000-type (Table 1). Data were recorded onto either a flash card (UTM) or hard disk (IPGP). The sampling rate was set to either 200 Hz (UTM) or 62.5 Hz (IPGP). For the UTM instruments, channels 0-2 correspond to the geophones (0=X, 1=Y, 2=Z), and had a gain of 64 applied, and channel 3 is the hydrophone, which had a gain of 16. For the IPGP instruments, channel 0 is the hydrophone, with a gain of 16, and channels 1-3 are the geophones (1=X, 2=Y, 3=Z), and had a gain of 128. All OBS were synchronised to GPS-derived UTM time before deployment and after recovery and the data corrected for clock drift during conversion to MINISEED (.msd) format.

To communicate and send commands to the acoustic system of each OBS, both UTM and IPGP use an ITC-Gavial 3013 transducer and an Edgetech 8011A deck box, which emits at 12 Hz and receives at 11 or 13 Hz. The transducer is deployed on a cable over the side of the ship, which must be brought to a stop to prevent the transducer being pulled back towards the ship's propellers. To save time stopping the ship and to enable communication with the OBSs while steaming, compatibility between the deck unit and the ship's hull-mounted transducer was tested. However, due to the different programming systems this would only be able to send ranging pings and not the full enable, disable and burn commands to the OBS. Two transducers can be mounted in the hull at once, thus we installed one of the UTM transducers into the second place for the majority of the deployments, and for the last few recoveries. It was not possible to have the transducer installed for all of the deployments and recoveries as the Nautile's transducer needed to be installed in the hull during the diving periods to enable communication between the ship and the submersible.

Acoustic release test

OBS deployment was preceded by a dip test of the acoustic releases of each instrument, conducted on 7th July. The release tubes were loaded into a rosette, lowered to ~4000 m depth, and tested one-by-one using an overboard transducer. The ship's acoustic systems (ADCP, multibeam swath, sub-bottom profiler etc) and the ship's thrusters had to be turned off to enable good communication. All UTM acoustic releases responded well and it was confirmed that the hull-mounted UTM transducer was functioning. Initially, communication failed with the IPGP acoustic releasers. After trying different transducers and frequencies, communication was established and all acoustic releases responded well. It is not clear what the initial problem was, though perhaps there was some short-lived noise coming from the ship which temporarily blocked the communication. The total time for the acoustic testing was ~7 hours, including the deployment and recovery of the rosette.

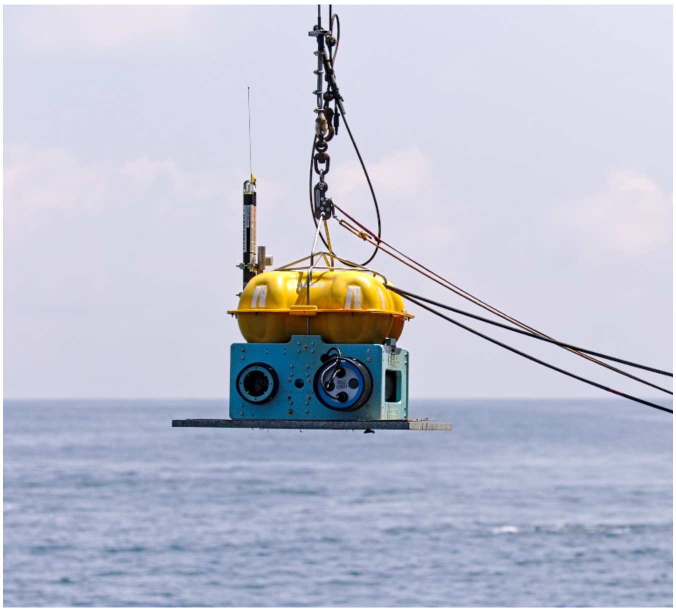


Figure 13: IPGP OBS during deployment. Photo: C. Hamelin.

Figure 12: UTM OBS prepared for deployment. Photo: G. Ceuleneer.

OBS deployments

At the beginning of the cruise we discussed whether to deploy the OBS by dropping from the ship, or alternatively to lower the instruments to the seabed using a winch. The latter option would provide a more accurate location for the instrument and remove the need to triangulate the OBS after deployment. However, it was calculated that this method would take significantly more time and it was thus discarded. The first 15 instruments were deployed (Fig. 12) in sequence from 17th July to the 19th July, with the final four OBS deployed during the nights of the 21st and 22nd July between Nautile dives. The ship remained on station and instruments were tracked by ranging commands until they reached the seabed. The descent rate was approximately 60 m/min for the UTM OBS and 55 m/min for the IPGP OBS.

Loss of communication with OBS SM08

Communication was lost with OBS SM08 during its descent (below ~600 m depth) and was not able to be re-established, despite trying with different transducers and deck units, at different positions on a circle 0.5 nm from the OBS, and remaining on site for 2.5 hours. One of the GENAVIR electronic technicians reported seeing some noise on the multibeam bathymetry display, which shows noise in the water column in real time even when the sounder is switched off. This noise was present even when not trying to ping to the instrument, and the technician suspected it was constant pinging coming from the OBS. However, we have no record of this noise or estimation of its frequency, so this cannot be confirmed. A return to the site was made during the night of the 23rd/24th July to try and re-establish communication with the OBS. Half an hour was spent at the site trying different methods of communication at two different locations, but this was unsuccessful. No noise in the water column was seen during the return to the instrument.

Triangulation

After each deployment a triangulation exercise was conducted to be able to re-locate the instruments to their seabed position (Russell et al., 2019; Figures in Appendix). After ranging the instrument directly overhead, the ship drove ¾ of a circle around the instrument at a speed of 6 knots and with a circle radius of 1 nm, and ranging commands were sent to the OBS every few minutes. When using the overboard transducer (for OBSs SM04, 03, 02, 07 and 08) the ship stopped at the four cardinal points on the circle to range the instrument. Once the exercise was complete, the disable command was sent to the OBS. The average time for the triangulation survey with the hull-mounted transducer was ~1 hour, and with the overboard transducer varied from 1h20 to 2h.

Due to communication problems during the descent of the OBS at site SM01, (the instrument struggled to range after it reached a depth of ~3300 m, and then stopped ranging completely) the radius for the triangulation survey was reduced to 0.5 nm. After trying different transducers, communication was re-established after changing the deck unit, and the triangulation survey was completed with no further issues.

At the end of the triangulation exercise at Site SM18, the OBS was not responding to range or the disable command, likely due to topography blocking the acoustic signals. After heading back to the OBS deployment position, communication worked again from 0.5 nm and the instrument was disabled.

The triangulation survey file for the OBS at Site SM02 was not saved correctly. Luckily this was realised and the survey was re-conducted one day later during the night of the 23rd /24th July, between Nautile dives. During the original survey, ranging didn't work from the eastern cardinal point, so the ranging positions were re-adjusted for the second survey.

Figure 14: UTM's Emergency Recovery Beacon (ERB)
prepared for deployment with anchor weight.

OBS recoveries

OBS recovery began the night of the 12th August, between Nautile dives. This was earlier than originally planned in order to try and save one full day of time, to prevent the loss of a planned dive in case the Nautile required another day for repairs. Nine OBS were recovered during the three nights from the 12th to the 14th, with the remaining nine recovered in sequence after the dive on the 15th August. Recovery finished at 00:30 on the 18th August, allowing time for an extra Nautile dive that day. The average time on site for each recovery was 2h20. During the recoveries before the 15th August Nautile dive, the overboard transducer was used. The Nautile transducer was swapped with the UTM transducer immediately after the dive and the remaining recoveries were conducted using the hull-mounted transducer.

For the first recovery (OBS SM17), the ship stopped 3 nm from the OBS to try and release the OBS at a distance, to save time waiting for the OBS to rise. However, we couldn't receive a response from the instrument. We tried again on the point and found that the OBS was already rising and had heard the release command from the initial position. The remaining OBSs recovered whilst using the overboard transducer were released at the OBS position, to ensure that communication worked and to prevent the loss of time from stopping the ship at 3 nm. OBSs were then tracked during their ascent until appearing on the sea surface. The average rise speed was 45 m/min for the UTM OBSs and 35 m/min for the IPGP OBSs.

When using the hull-mounted transducer, enable and release commands were sent from ~5 nm away from the instrument until a response was received from the OBS and it could be confirmed that it was rising.
Recovery of OBS 15

After releasing OBS 15, its calculated rise speed was 30 m/min, much slower than the expected 45 m/min for a UTM OBS. The technician's suspected that the data logger tube may have been flooded and filled with water, weighing the instrument down. When the OBS reached the surface, it was riding very low in the water. After recovered onto the ship, it was found that the logger tube had indeed flooded and contained a significant amount of water. All of the electronics inside were water damaged, and it was not possible to download any data from the flash card as it was unreadable. It is not clear why the tube flooded – the technicians confirmed that it had been properly vacuumed and all o-rings were in place. As the OBS descended at a normal speed after deployment, it is likely that the flooding took place after the instrument reached the seabed.

Recovery attempt of OBS 8

The recovery attempt of OBS 8 began at 17:07 on 17th August, when communication attempts began whilst 5.5 nm away from the OBS position using the hull-mounted transducer. Enable and burn commands were then sent every 15 minutes (each burn cycle lasts a maximum of 15 minutes), whilst the ship drove in a spiral at a speed of 6 knots around the OBS to try communication from all different azimuths. The OBS position was reached at 19:22, where communication using the overboard transducer, different deck units and at different frequencies was also attempted.

As no response had been received from the OBS, the UTM Emergency Recovery Beacon (ERB) was deployed at 20:06 (Fig. 14). The ERB is a transducer which was pre-programmed to send the burn command of the OBS every 8 minutes. This was lowered on a winch to a depth of 3200 m to improve the strength of the acoustic signal to the OBS (the seabed at the site was at 3500 m). The ERB reached its maximum depth at 21:38, began to be recovered at 22:03 and was back on board at 23:01. The ship remained on the OBS position for 2.5 hours after the recovery of the ERB began, to ensure that the OBS would be spotted if it had been released and rose to the surface, including if it had an unusually slow rising speed. The ship left the site at 00:30 on the 18th August with still no communication received from the OBS, after a total time of 7 hours and 23 minutes. Combined with previous return to OBS 8 on the 23rd July and the original triangulation attempt, more than 10 hours were spent attempting to communicate with the instrument.

Equipment performance

In general, all OBS recorded good quality data suitable for identifying seismic events (e.g. Figs. 15 & 16), although some components had poor data. From the UTM instruments, three (SM01, SM14, SM10) had either very noisy or unusable data on the X-geophone component, and one each had noisy data on the Z-geophone component (SM17) and hydrophone component (SM16). In general, the hydrophone component on all instruments looks very noisy, likely due to the higher noise experienced by this channel when compared to the geophones, resulting in a lower signal-noise ratio. A quick QC of the IPGP instruments suggests all channels recorded usable data, although again the hydrophone component is noisy.

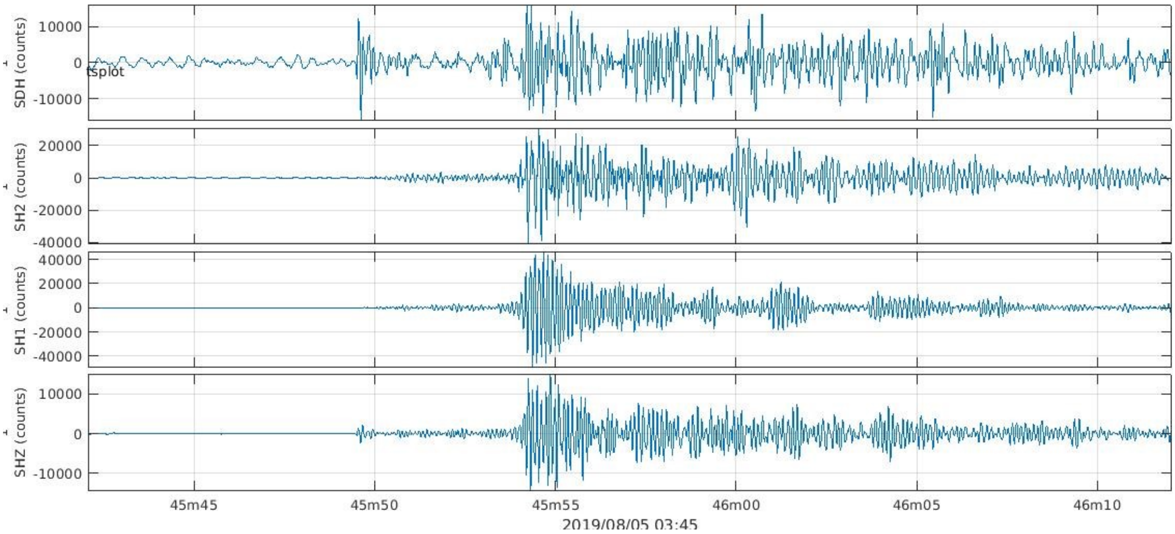


Figure 15: Local earthquake recorded by SM03 on 05/08/2019 at approx. 03:45.

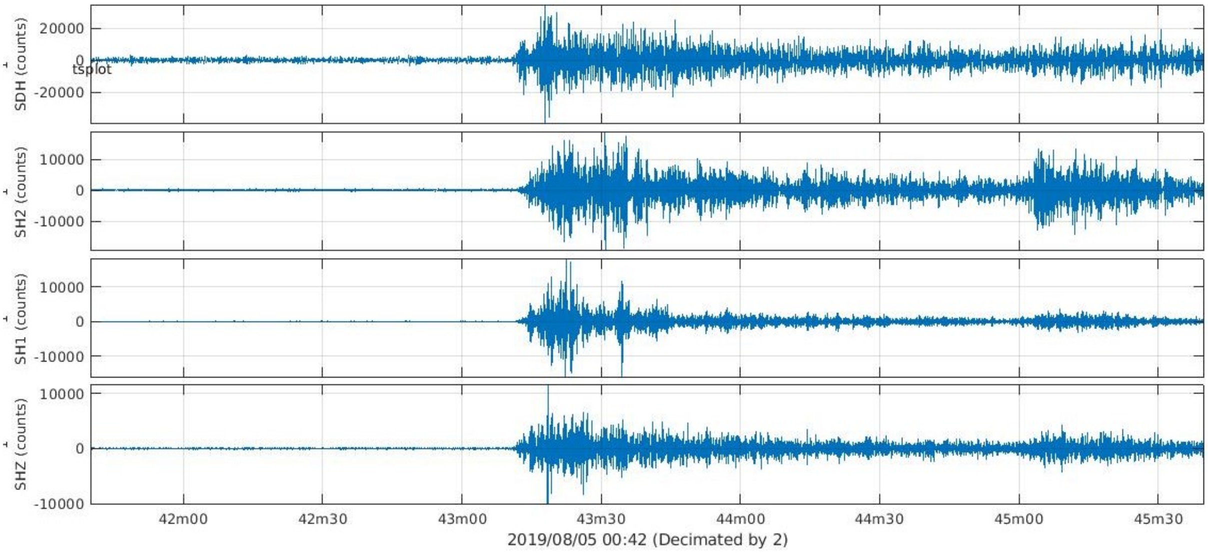


Figure 16: Large (Mw 5.8) earthquake which occurred on St Paul transform fault on 05/08/2019 at approx. 00:40, recorded by SM03.

Tables

Deployment and recovery times and locations

OBS Site	Dropping time and positions					Recovery time and positions				Relocated positions (prelim.)	
	Date	Time UTC	Longitude	Latitude	Depth (m)	Date	Time UTC	Longitude	Latitude	Longitude	Latitude
SM01	18/07/2019	08:43	-16.2642	-0.46319	2594	12/08/2019	23:39	-16.2667	-0.4500	-16.2639	-0.4634
SM02	22/07/2019	06:08	-17.6704	0.279967	3016	17/08/2019	11:48	-17.6778	0.2800	-17.6672	0.2802
SM03	23/07/2019	01:27	-17.6748	-0.1798	3534	17/08/2019	02:41	-17.6796	-0.17982	-17.6747	-0.1800
SM04	20/07/2019	20:17	-17.4715	-0.16272	3506	17/08/2019	05:41	-17.4812	-0.1556	-17.4694	-0.1621
SM05	20/07/2019	12:52	-17.2265	-0.26491	2874	16/08/2019	22:26	-17.2309	-0.2643	-17.2254	-0.265
SM06	20/07/2019	08:35	-17.3666	0.002478	4925	17/08/2019	08:32	-17.3721	0.0071	-17.3669	0.0033
SM07	22/07/2019	01:14	-17.5653	0.523642	3475	17/08/2019	14:43	-17.5712	0.5246	-17.5643	0.5235

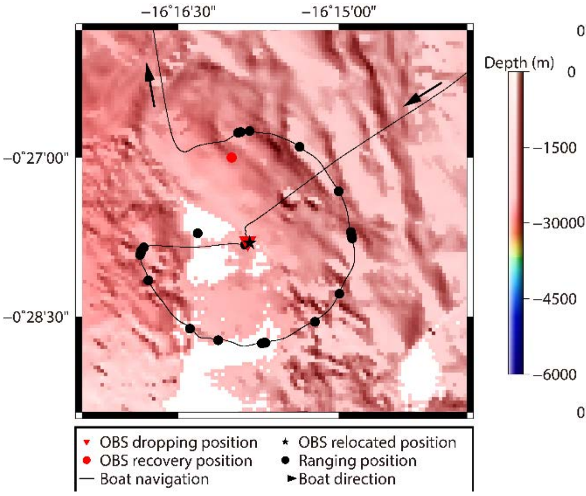
SM08	21/07/2019	20:31	-17.3508	0.279469	3519	-	-	-	-	-	-
SM09	20/07/2019	01:19	-17.1916	0.029198	4784	15/08/2019	01:23	-17.1968	0.0276	-17.1908	0.0297
SM10	19/07/2019	21:50	-17.0202	-0.05161	4317	15/08/2019	04:56	-17.034	-0.0577	-17.0199	-0.0512
SM11	19/07/2019	08:06	-16.8714	0.179552	4836	14/08/2019	21:32	-16.8781	0.1793	-16.8716	0.1800
SM12	19/07/2019	05:13	-17.0639	0.429683	922	15/08/2019	21:30	-17.0695	0.4292	-17.0636	0.4302
SM13	19/07/2019	00:27	-16.7315	0.342141	4866	16/08/2019	02:01	-16.7344	0.3412	-16.7307	0.3422
SM14	18/07/2019	20:34	-16.5151	0.411895	4814	16/08/2019	05:02	-16.5082	0.4146	-16.5151	0.4118
SM15	18/07/2019	16:41	-16.4625	0.112516	3508	14/08/2019	01:40	-16.4723	0.1091	-16.4621	0.1132
SM16	17/07/2019	23:27	-16.1876	0.054287	3280	13/08/2019	21:29	-16.1958	0.0532	-16.1864	0.0543
SM17	18/07/2019	04:10	-15.9807	-0.25659	3496	12/08/2019	20:28	-15.9854	-0.2562	-15.9804	-0.2567
SM18	19/07/2019	12:23	-16.6813	-0.03482	3729	14/08/2019	05:19	-16.6942	-0.0396	-16.6794	-0.0347
SM19	18/07/2019	12:21	-16.3234	-0.22987	3724	13/08/2019	03:15	-16.3311	-0.2316	-16.3212	-0.2305

Post-recovery GPS-to-instrument clock synchronisation

OBS Site	**Type**	**Data logger type**	**Data logger number**	**Recovery time synchronisation**		
				Sync time (GPS)	**Sync time (OBS)**	**Drift (ms)**
SM01	UTM	LC4x4	013	224:23:57:00	224:23:57:00.0983986	98.399
SM02	UTM	Abalones	011	229:12:02:00	229:12:01:59.9691256	-30.874
SM03	IPGP	LC2000	09	229:03:08:44.9964	229:03:08:45	3.6
SM04	UTM	Abalones	007	229:06:03:00	229:06:02:59.9935661	-6.434
SM05	IPGP	LC2000	04	228:22:38:15.1835	228:22:38:15	-183.5
SM06	UTM	Abalones	001	229:08:45:00	229:08:44:59.9795660	-20.434
SM07	UTM	Abalones	012	229:14:57:00	229:14:56:59.9210259	-78.974
SM08	UTM	Abalones	009	-	-	-
SM09	UTM	Abalones	010	227:01:38:00	227:01:37:59.5410290	-458.897
SM10	UTM	Abalones	005	227:05:15.00	227:05:14:59.9573459	-42.654
SM11	UTM	Abalones	006	226:22:50:00	226:22:49:59.9605406	-39.459
SM12	UTM	Abalones	003	227:21:48:00	227:21:48:00.0363369	36.337
SM13	UTM	Abalones	008	228:02:14:00	228:02:13:59.9437989	-56.201
SM14	UTM	Abalones	004	228:06:04:00	228:06:04:00.2194481	219.448
SM15	UTM	LC4x4	015	-	-	-
SM16	UTM	LC4x4	014	225:21:51:00	225:21:51:00.024668	24.668
SM17	UTM	LC4x4	017	224:20:44:00	224:20:44:00.0198460	19.846
SM18	IPGP	LC2000	03	226:05:43:09.8796	226:05:43:10	120.4
SM19	IPGP	LC2000	01	225:03:42:09.9989	225:03:42:10	1.1

Individual OBS position and triangulation maps

SM01



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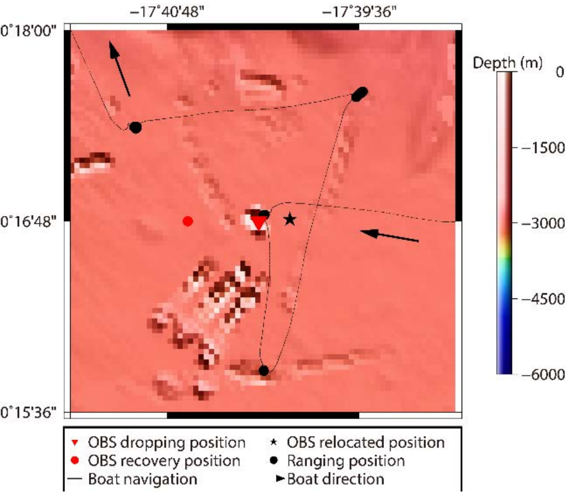
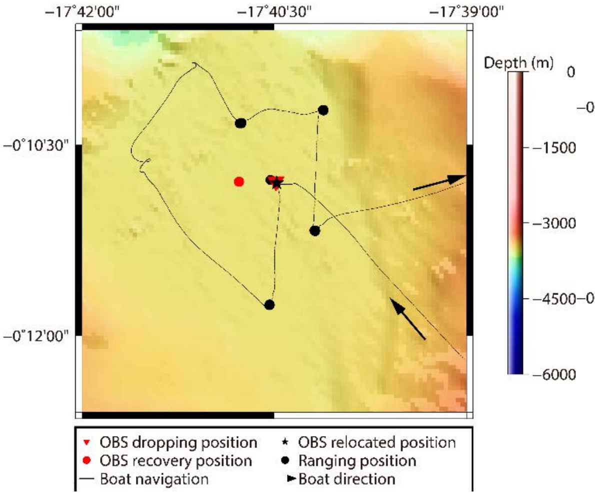
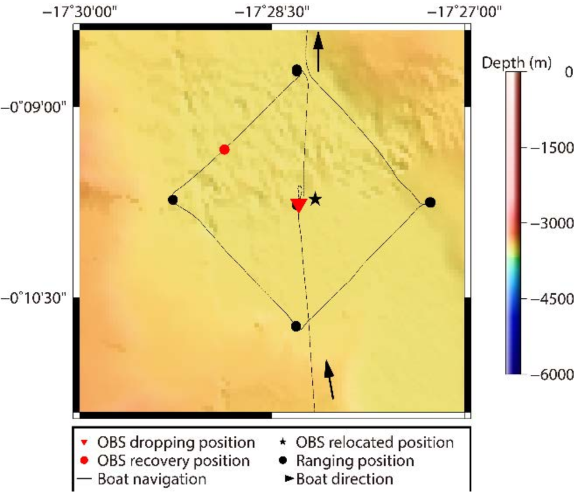


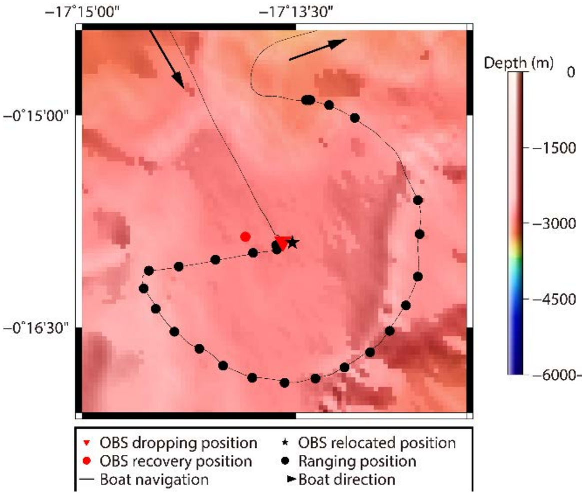
SM03



SM04



SM05



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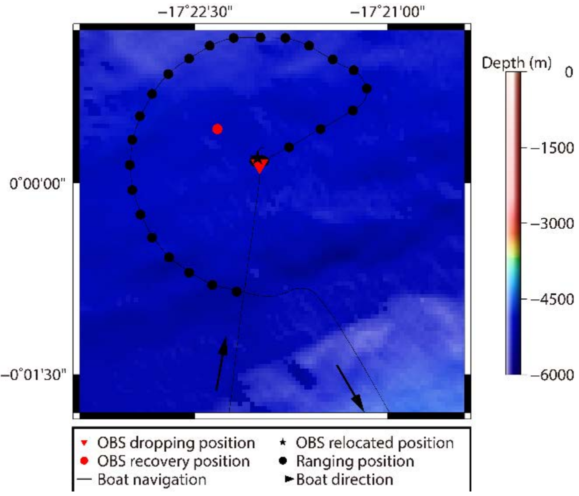
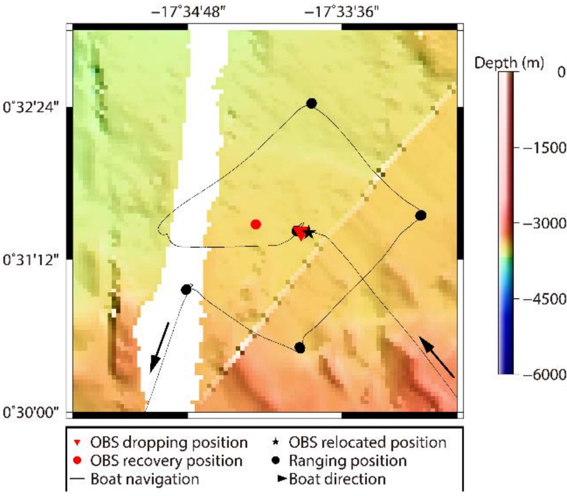
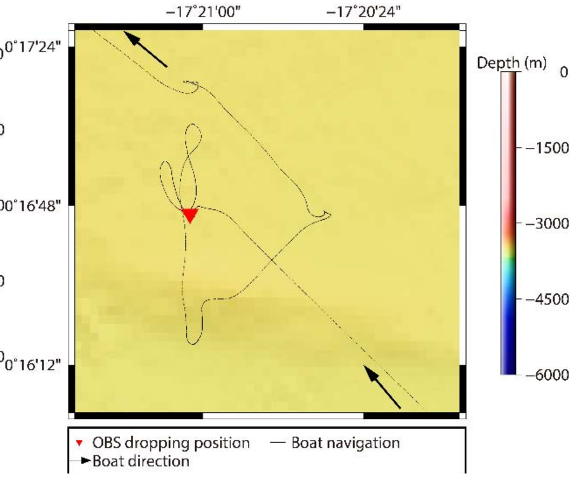


SM07



SM08



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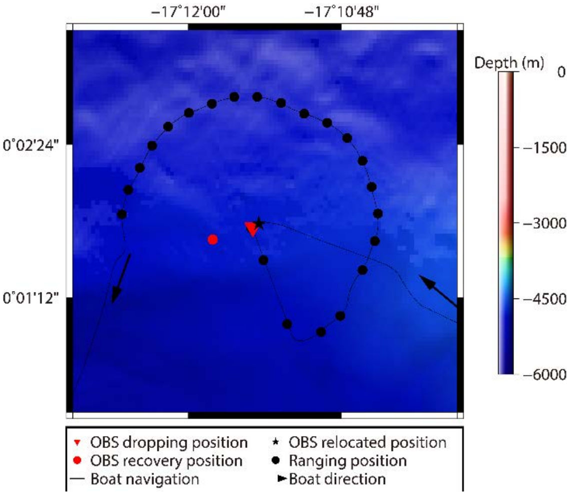

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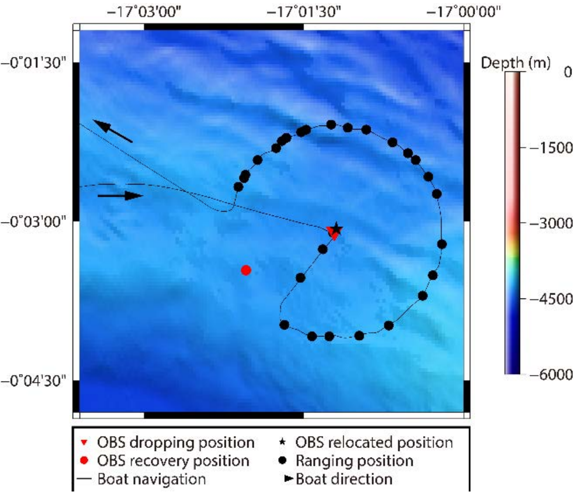
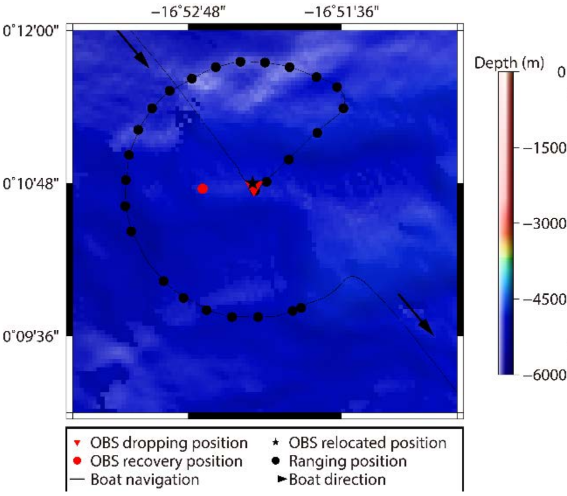


SM11



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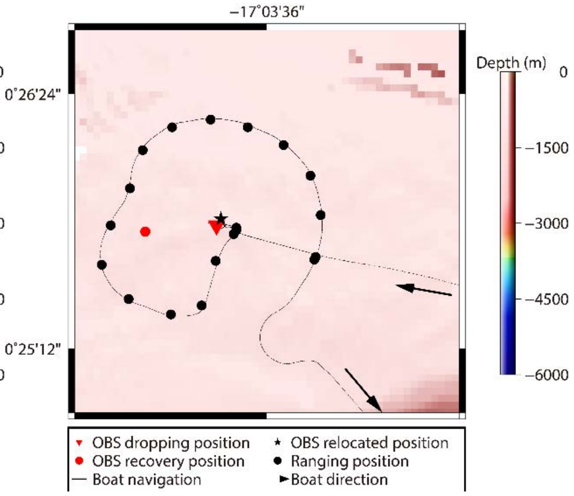

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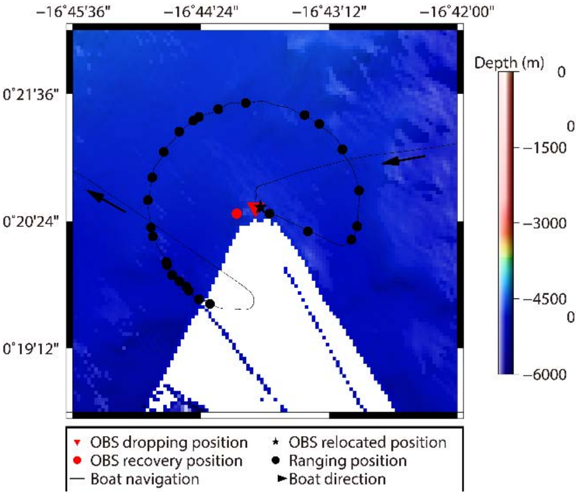

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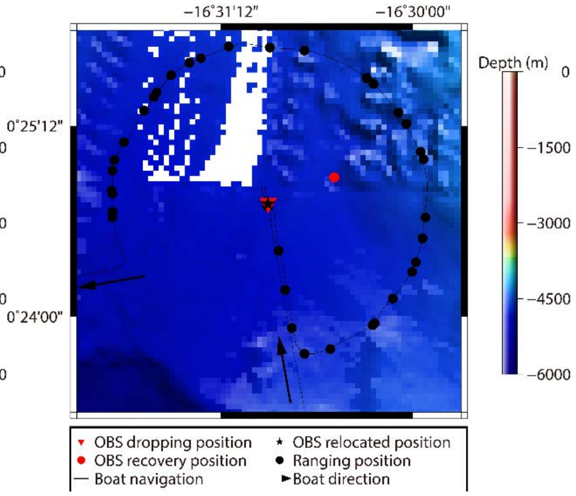
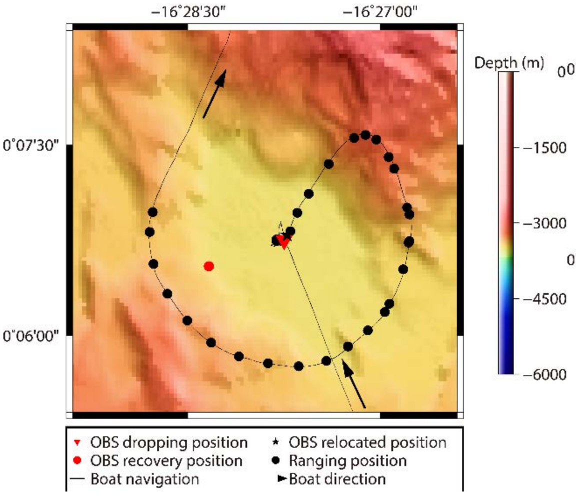
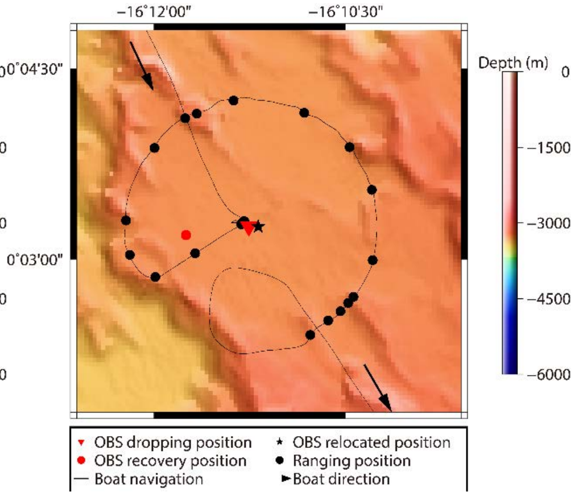


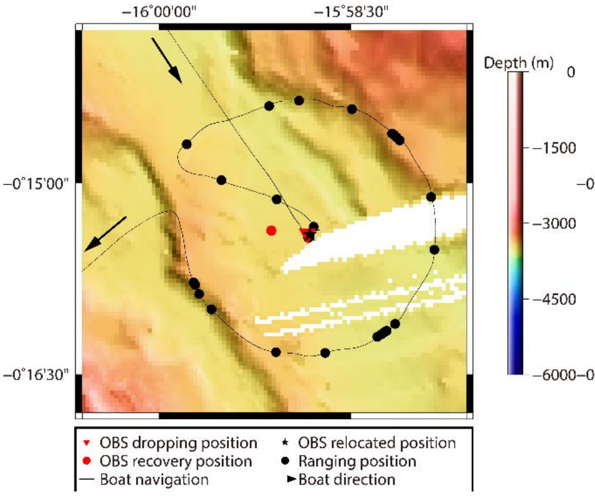
SM15



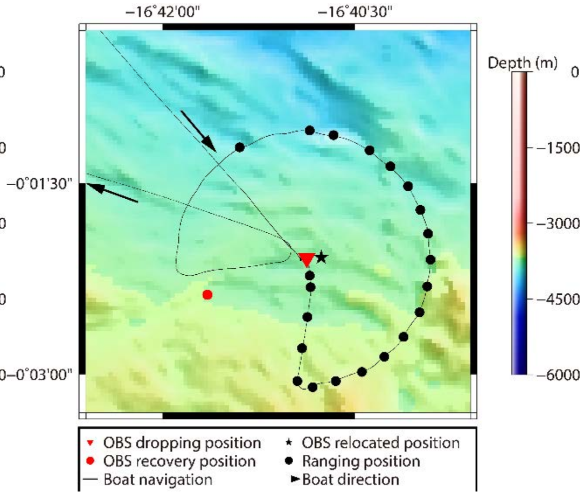
SM16



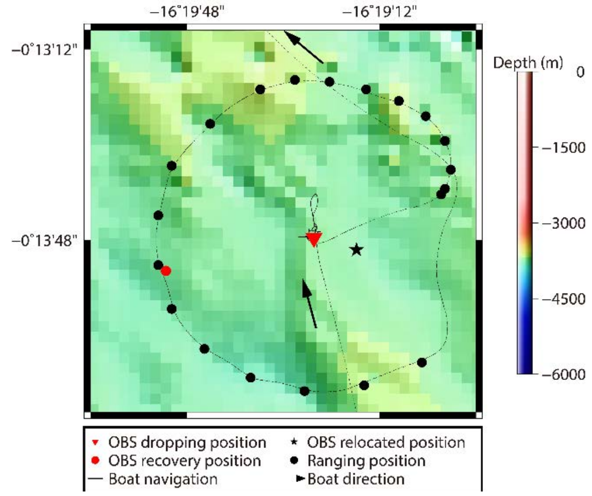
SM17



SM18



SM19



REFERENCES

Abercrombie, R.E., and Ekström, G., 2001, Earthquake slip on oceanic transform faults: Nature, v. 410, p. 74–77, doi: 10.1038/35065064.

Behn, M.D., Boettcher, M.S., and Hirth, G., 2007, Thermal structure of oceanic transform faults: Geology, v. 35, p. 307, doi: 10.1130/G23112A.1.

Froment, B., McGuire, J.J., van der Hilst, R.D., Gouédard, P., Roland, E.C., Zhang, H., and Collins, J.A., 2014, Imaging along-strike variations in mechanical properties of the Gofar transform fault, East Pacific Rise: Journal of Geophysical Research: Solid Earth, v. 119, p. 7175–7194, doi: 10.1002/2014JB011270.

Ligi, M., Bonatti, E., Brunelli, D., Cipriani, A., and Ottolini, L., 2011, Water in Mid Ocean Ridge Basalts: Some Like it Hot, Some Like it Cold, *in* Marine Research at CNR, p. 671–690.

McGuire, J.J., Ihmlé, P.F., and Jordan, T.H., 1996, Time-domain observations of a slow precursor to the 1994 Romanche Transform earthquake: Science, v. 274, p. 82–85, doi: 10.1126/science.274.5284.82.

Roland, E., Behn, M.D., and Hirth, G., 2010, Thermal-mechanical behavior of oceanic transform faults: Implications for the spatial distribution of seismicity: Geochemistry, Geophysics, Geosystems, v. 11, p. n/a-n/a, doi: 10.1029/2010GC003034.

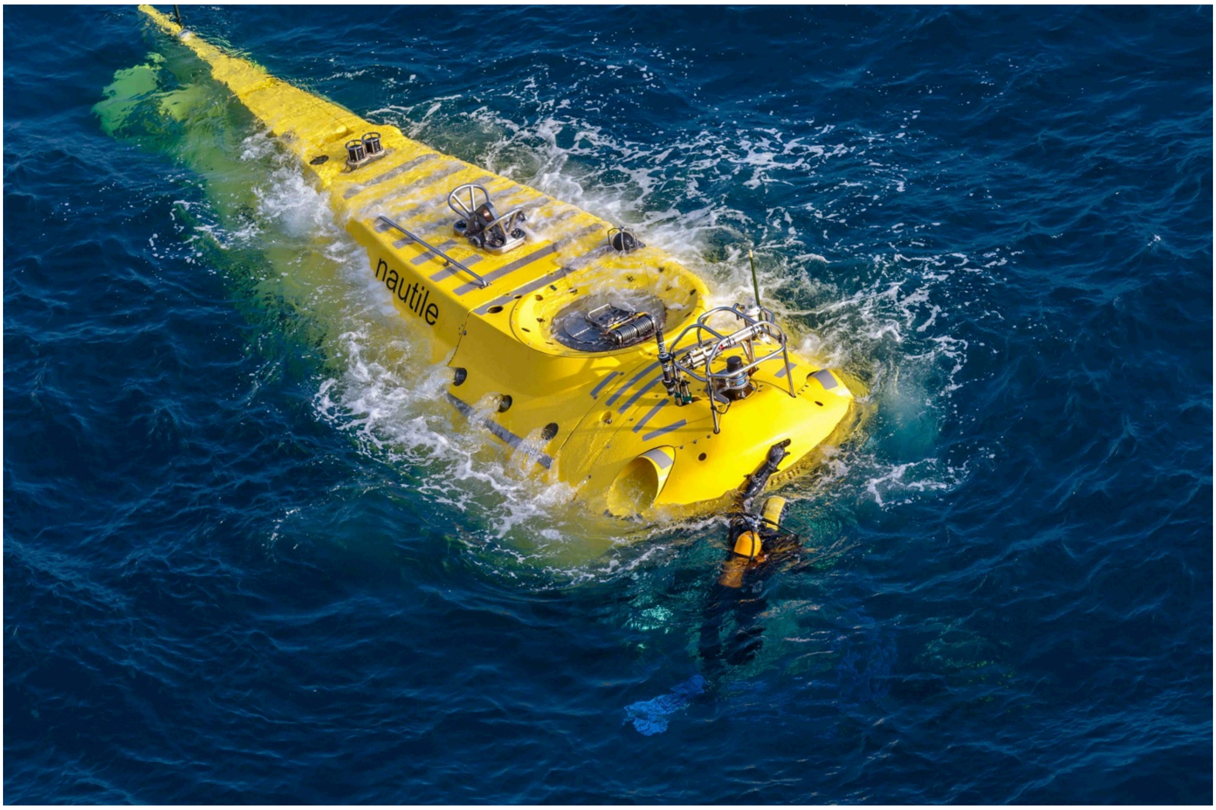
Roland, E., Lizarralde, D., McGuire, J.J., and Collins, J.A., 2012, Seismic velocity constraints on the material properties that control earthquake behavior at the Quebrada-Discovery-Gofar transform faults, East Pacific Rise: Journal of Geophysical Research: Solid Earth, v. 117, p. n/a-n/a, doi: 10.1029/2012JB009422.

Russell, J.B., Eilon, Z., and Mosher, S.G., 2019, OBSrange: A New Tool for the Precise Remote Location of Ocean-Bottom Seismometers: Seismological Research Letters, v. 90, p. 1627–1641, doi: 10.1785/0220180336.

Schlindwein, V., and Schmid, F., 2016, Mid-ocean-ridge seismicity reveals extreme types of ocean lithosphere: Nature, v. 535, p. 276–279, doi: 10.1038/nature18277.

Nautile dives

- Nautile dives and samples
- Nautile dives and samples
- Magnetic data acquisition



Nautile dives

During SMARTIES, the Nautile performed 25 dives at different locations of the study area. Three dives (#2, #4 and #5) were carried on along a transect across the north wall of the Romanche transform fault, roughly following a seismic line acquired during the ILAB experiment. These dives had the objective of establishing a geological section comparable to the seismic results. Three other dives (#6, #10 and #15) were carried on across the transform fault line at different locations, the last one on the western part of the nodal basin.

Eight dives (#1, #3, #7, #8, #9, #11, #12 and #14) targeted the study of the off axis reliefs along the southern wall of the transform fault and the eastern flank of the ridge-transform intersection, along what appears to be a large faulted core complex.

The ridge axis was surveyed by nine dives, from its northern part, just south of the large core complex to its southern part, where the ridge axis displays a spreading perpendicular orientation. The dives along the axial domain are #13, #16, #17, #18, #19, #20, #21, #22 and #23.

Finally, the two last dives of the cruise surveyed a large peridotite hill on the eastern flank of the ridge axial domain, where traces of hydrothermal activity were found (#24 & #25).

The dives allowed recovering about 2.2 tons of rock samples and more than 130 hours of video and photographic recordings. Of the 25 dives 18 acquired magnetic data near the ocean floor.

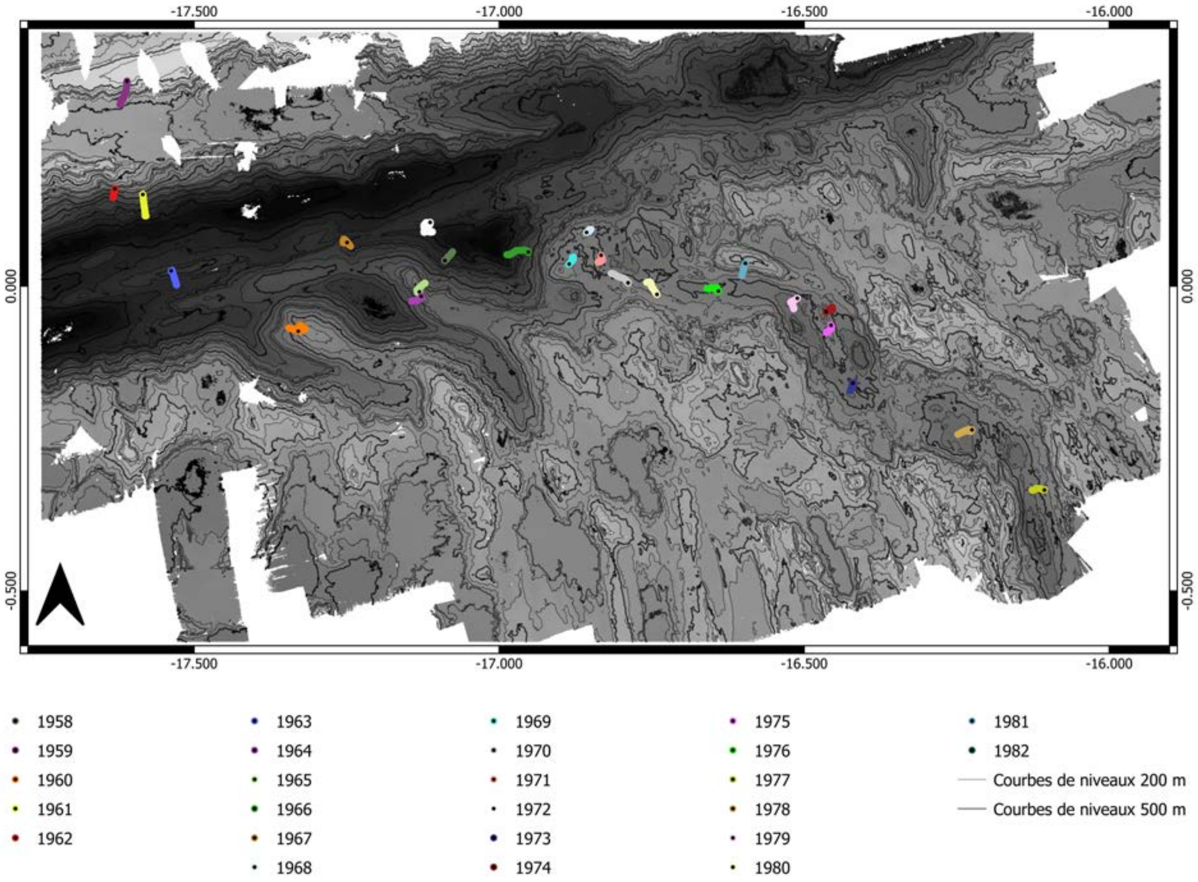
The dives went very well and the Nautile performance was exceptional. The extreme depths to wich the submersible was repeatedly exposed during the cruise required a few technical interventions, with short interruptions of the diving sequence (31/07, 01/08, 07/08). As these technical breaks were planned in the cruise schedule, all the targets were explored and we were able to add two more dives to the initially scheduled 23.

The following tables (taken from the technical report) summarize the details of each dive of the cruise.

Number of dives :	25
Average duration :	8:41:48
Cummulated time:	217:25:0
Average time on bottom :	5:20:50
Cummulated time on bottom :	133:41:0
Average depth of the submersible :	4564 m
Maximal depth of the submersible :	6028 m
Cummulated distance :	82.6 km

Dive number	Dates	Maximal immersion	Distance	Dive duration	Time on bottom
1958/32/1	21/07/2019	6011 m	2.3 km	09:26:00	05:02:00
1959/33/2	22/07/2019	2950 m	4.5 km	07:20:00	05:23:00
1960/34/3	23/07/2019	4177 m	5.6 km	08:03:00	05:02:00
1961/35/4	24/07/2019	5660 m	3.9 km	10:03:00	05:50:00
1962/36/5	25/07/2019	4886 m	1.4 km	09:15:00	05:54:00
1963/37/6	26/07/2019	5770 m	3.1 km	09:50:00	05:01:00
1964/38/7	27/07/2019	4866 m	2.6 km	08:27:00	05:05:00
1965/39/8	28/07/2019	4572 m	3.75 km	08:38:00	05:18:00
1966/40/9	29/07/2019	6028 m	4.3 km	09:33:00	05:08:00
1967/41/10	30/07/2019	5600 m	3.6 km	08:43:00	05:39:00
1968/42/11	02/08/2019	4074 m	1.9 km	08:50:00	05:44:00
1969/43/12	03/08/2019	3955 m	2 km	08:32:00	05:33:00
1970/44/13	04/08/2019	4109 m	4.5 km	08:06:00	05:03:00
1971/45/14	05/08/2019	4210 m	2.3 km	08:13:00	05:04:00
1972/46/15	06/08/2019	6005 m	5.8 km	09:48:00	05:23:00
1973/47/16	08/08/2019	4210 m	2.58 km	08:38:00	05:35:00
1974/48/17	09/08/2019	3900 m	2.7 km	08:05:00	05:07:00
1975/49/18	10/08/2019	3919 m	2.08 km	08:30:00	05:23:00
1976/50/19	11/08/2019	4128 m	3.9 km	08:36:00	05:33:00
1977/51/20	12/08/2019	4230 m	2.9 km	08:40:00	05:35:00
1978/52/21	13/08/2019	4318 m	3.6 km	08:47:00	05:08:00
1979/53/22	14/08/2019	4330 m	3.3 km	08:44:00	05:33:00
1980/54/23	15/08/2019	4000 m	4 km	09:08:00	05:35:00
1981/55/24	16/08/2019	4100 m	2.7 km	07:42:00	05:03:00
1982/56/25	18/08/2019	4100 m	3.3 km	07:48:00	05:00:00

Maps of the dive locations



Dive list

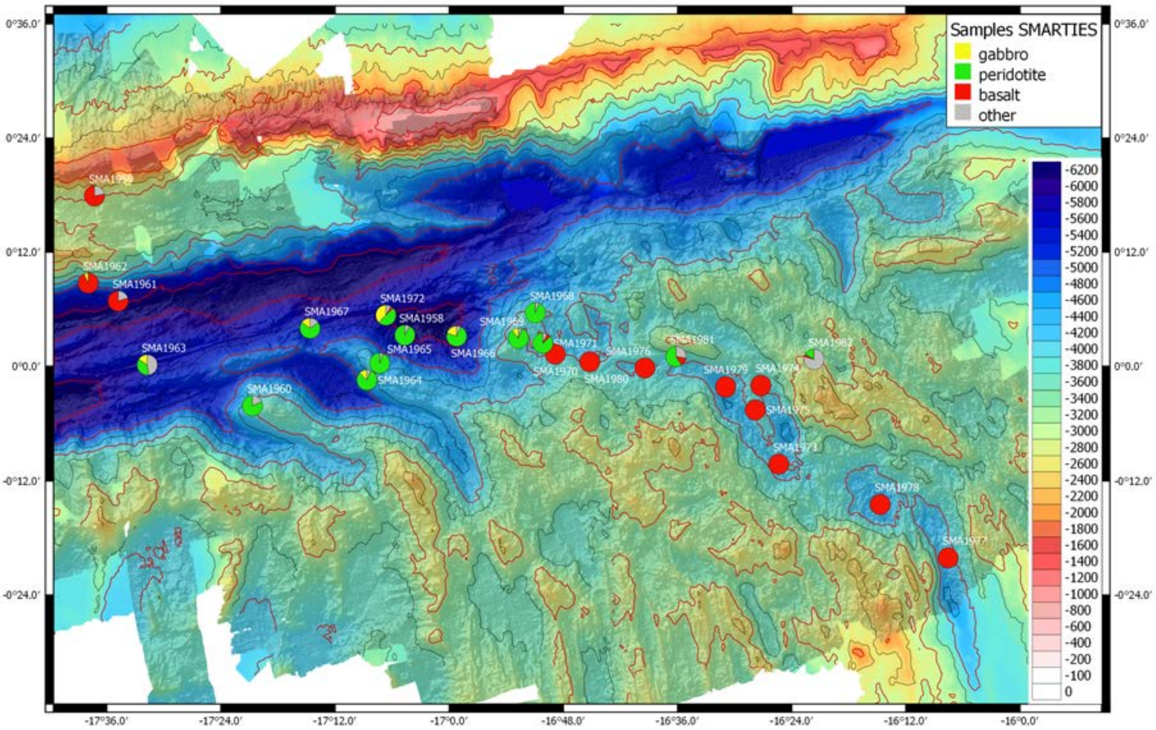
Dive number	Date	Diver	Start longitude	Start latitude
SM-1	21/07/2019	Marcia MAIA	17°04’34.9011”W	0°03’23.0658”N
SM-2	22/07/2019	Lena VERHOEST	17°37’17.2752”W	0°17’52.9201”N
SM-3	23/07/2019	Anne BRIAIS	17°20’41.1937”W	0°04’05.8235”S
SM-4	24/07/2019	Sidonie REVILLON	17°34’43.3411”W	0°06’55.42.50”N
SM-5	25/07/2019	Azam SOLTANMOHAMMADI	17°37’57.5846”W	0°08’47.9108”N
SM-6	26/07/2019	Mary-Alix KACZMAREK	17°31’46.2849”W	0°00’11.7350”N
SM-7	27/07/2019	Rim JBARA	17°08’37.7021”W	0°01’28.0282”S
SM-8	28/07/2019	Georges CEULENEER	17°07’17.0071”W	0°00’16.8805”N
SM-9	29/07/2019	Daniele BRUNELLI	16°59’14.8836”W	0°03’06.4860”N
SM-10	30/07/2019	Anna CIPRIANI	17°14’37.2846”W	0°03’57.2706”N
SM-11	02/08/2019	Bérengère MOUGEL	16°51’24.1499”W	0°05’17.5179’N
SM-12	03/08/2019	Monique SEYLER	16°52’46.7699”W	0°02’51.6978”N
SM-13	04/08/2019	Cédric HAMELIN	16°48’59.4566’W	0°01’14.9800”N
SM-14	05/08/2019	Mary-Alix KACZMAREK	16°50’17.9744”W	0°02’22.4416”N
SM-15	06/08/2019	Marcia MAIA	17°06’48.9427”W	0°05’19.2988”N
SM-16	08/08/2019	Anne BRIAIS	16°25’28.9827”W	0°10’17.2493”S
SM-17	09/08/2019	Sidonie REVILLON	16°27’50.8561”W	0°02’29.8961”S
SM-18	10/08/2019	Anna CIPRIANI	16°27’49.1680”W	0°04’33.9809”S
SM-19	11/08/2019	Bérengère MOUGEL	16°39’33.1476”W	0°00’13.4289”S
SM-20	12/08/2019	Cédric HAMELIN	16°07’35.3985”W	0°20’03.8835”S
SM-21	13/08/2019	Monique SEYLER	16°14’53.8338”W	0°14’34.8840”S
SM-22	14/08/2019	Daniele BRUNELLI	16°31’01.9085”W	0°02’13.5583”S
SM-23	15/08/2019	Azam SOLTANMOHAMMADI	16°45’29.4128”W	0°00’22.6652”N
SM-24	16/08/2019	Georges CEULENEER	16°36’07.6075”W	0°01’00.4496”N
SM-25	18/08/2019	Marcia MAIA	16°36’07.1041”W	0°01’16.1161”N

Rock samples

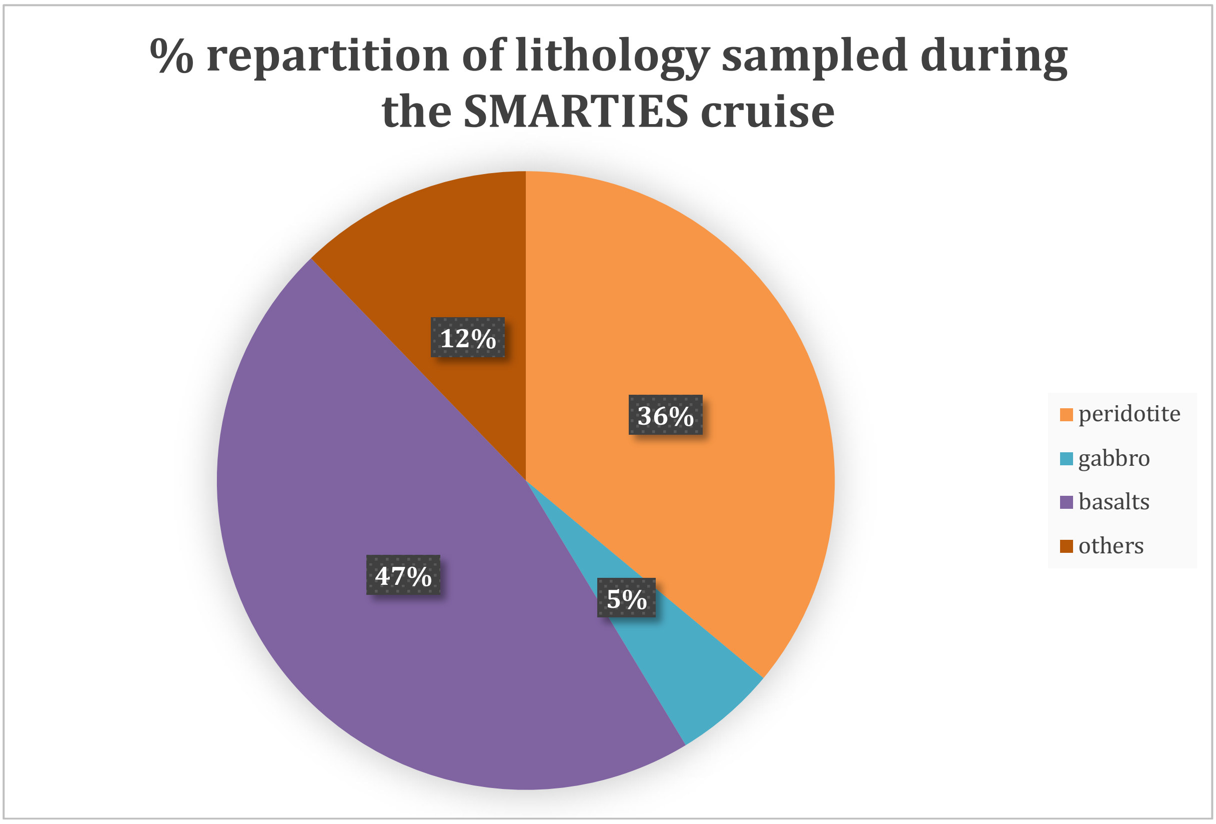
During the cruise, all samples were described, photographed and referenced with an IGSN to be stored in the database of the CNRS-INSU for marine samples. The samples are stored in the rock sample bank in Brest, IUEM.

All sample reports were made on board by the teams in charge of the sampling and are grouped here. Additional data are stored for the moment in Brest and in Modena. These are the detailed photographs of the samples as well as the table with the IGSN of each sample. Whenever possible, thin sections were made on board using the CNRS-INSU equipment and used to help the description and preliminary analyses of the samples. Descriptions of these thin sections are also stored in Brest and Modena.

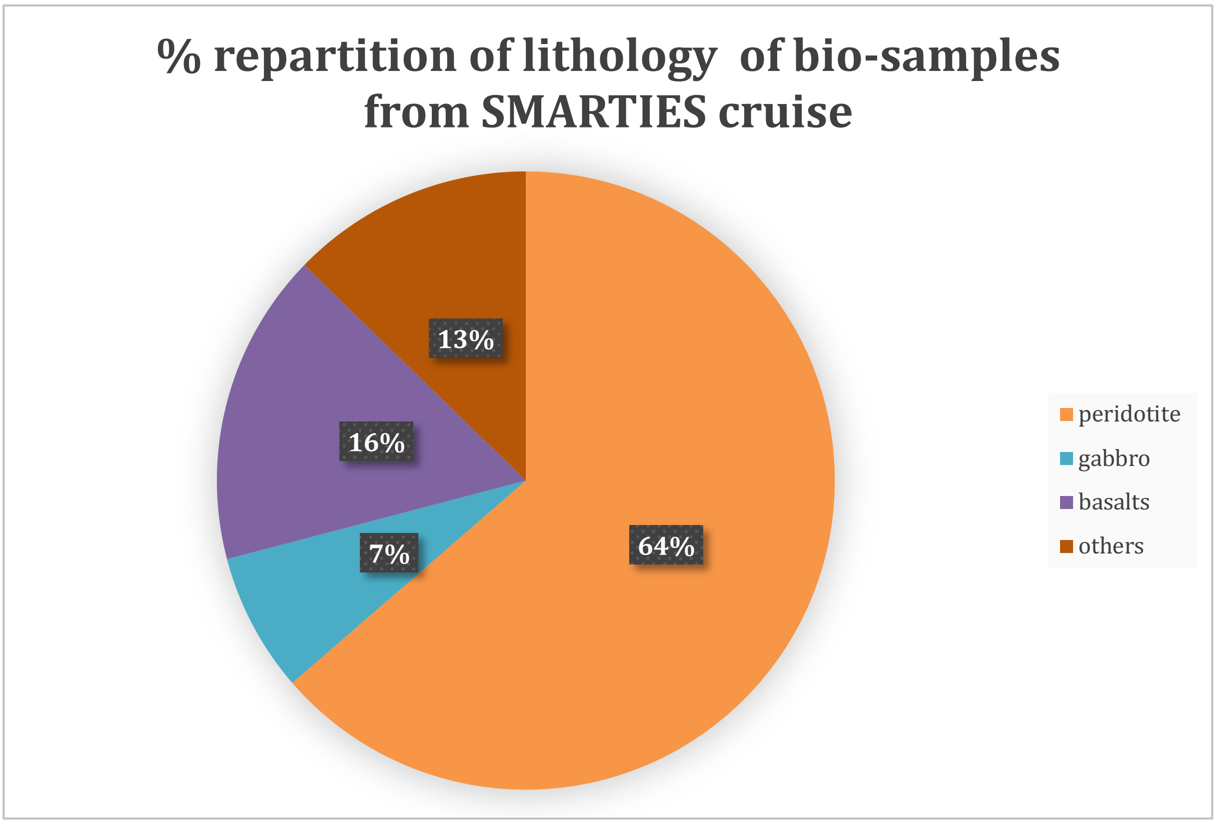
The map below shows the geographical repartition of the samples retrieved during the dives.



Below, the pie diagram represents the percent of the different lithologies sampled during the cruise.



During the cruise, some samples were taken to be used for organic components research. The pie diagram below shows the percent of the lithologies of the samples selected for these studies. The samples were treated separately and isolated to prevent contamination.



Magnetic data acquisition

During the scientific cruise SMARTIES along the Mid-Atlantic Ridge Transform-Intersections in the Atlantic Ocean, high-resolution magnetic data have been acquired using the deep-sea submersible Nautile of the Ifremer.

The magnetometer has been tested on the ship and it worked properly. The times of the data logger and of the laptop on board of the Nautile have been set carefully according to the UTC time. The magnetometer sensor, the data logger, and the laptop used to record the data have been installed on the Nautile during the transit phase from Mindelo (Cape Verde) to the study area. The laptop has been connected with the data logger in order to have a copy of the data at the end of each dive.

During the cruise, 25 dives have been made with the Nautile submersible. The magnetometer worked properly for most of the dives and 18 dives have recorded high-resolution magnetic data. Unfortunately, for 6 dives the magnetometer did not work properly, probably due to cable connections troubles. The first dive, which has been a test dive for the Nautile at a depth greater than 6000 m, has recorded magnetic data during the descent and the ascent phases, but only two hours during the phase at the sea floor. Note that for dive “Smarties-1976-19” the laptop did not record any data. The data have been recovered from the data logger.

The dives with the magnetic data are the following:

- Dive Smarties-1958-01 (21 July 2019). Only two hours have been recorded during this dive
- Dive Smarties-1959-02 (22 July 2019)
- Dive Smarties-1960-03 (23 July 2019)
- Dive Smarties-1961-04 (24 July 2019)
- Dive Smarties-1962-05 (25 July 2019)
- Dive Smarties-1964-07 (27 July 2019)
- Dive Smarties-1965-08 (28 July 2019)

- Dive Smarties-1966-09 (29 July 2019)
- Dive Smarties-1968-11 (02 August 2019)
- Dive Smarties-1970-13 (04 August 2019)
- Dive Smarties-1972-15 (06 August 2019)
- Dive Smarties-1975-18 (10 August 2019)
- Dive Smarties-1976-19 (11 August 2019)
- Dive Smarties-1977-20 (12 August 2019)
- Dive Smarties-1978-21 (13 August 2019)
- Dive Smarties-1979-22 (14 August 2019)
- Dive Smarties-1980-23 (15 August 2019)
- Dive Smarties-1981-24 (16 August 2019)
- Dive Smarties-1982-25 (16 August 2019)

The dives without magnetometer data are the following:

- Dive Smarties-1963-06 (26 July 2019)
- Dive Smarties-1967-10 (30 July 2019)
- Dive Smarties-1969-12 (03 August 2019)
- Dive Smarties-1971-14 (05 August 2019)
- Dive Smarties-1973-16 (08 August 2019)
- Dive Smarties-1974-17 (09 August 2019)

Brief description of the magnetic data and maintenances

We report here the information related to the magnetic data acquired during the dives and technical maintenances carried out during the cruise.
Notes that the time is reported always in UTC time (hh:mm:ss format).

- **Dive Smarties-1958-01 (21 July 2019)**

13 files have been recorded. The data start from 07:58:08 to 12:37:50 (first 12 files). The laptop has been restarted at 16:33:07 and data have been acquired from 16:33:07 till 16:52:48.

__OPERATION:__ *The laptop crashed several times during the diving. Once on board, the battery has been replaced and the time on the laptop has been set again.*

- **Dive Smarties-1959-02 (22 July 2019)**

The data have been recorded continuously in 8 files. The acquisition started at 09:54 and ended at 16:50

- **Dive Smarties-1960-03 (23 July 2019)**

The data have been recorded continuously in 8 files. The acquisition started at 09:07 and ended at 16:56.

- **Dive Smarties-1961-04 (24 July 2019)**

The data have been recorded continuously in 10 files. The acquisition started at 07:40 and ended at 16:57.

- **Dive Smarties-1962-05 (25 July 2019)**

The data have been recorded continuously in 9 files. The acquisition started at 08:14 and ended at 16:52.

__OPERATION:__ *A check of the magnetometer has been made in the early morning of 27th July. Water has been found within the cable connections, in particular for the cable connecting the laptop. The data logger should have worked properly during the dive, but the data are not good since the Nautile dove without retracting the arms.*

- **Dive Smarties-1964-07 (27 July 2019)**

The first file (time 06:00) is a test to confirm that everything works properly.

The data have been recorded continuously in 9 files. The acquisition started at 07:57 and ended at 15:44.

- **Dive Smarties-1965-08 (28 July 2019)**

The first file (07:46:46) is a test to confirm that everything works properly.

The data have been recorded continuously in 9 files. The acquisition started at 08:54:36 and ended at 16:52:31.

- **Dive Smarties-1966-09 (29 July 2019)**

The data have been recorded continuously in 10 files. The acquisition started at 07:35:11and ended at 16:28:34.

__OPERATION:__ *After Dive 10 (30th July 2019) the time of the laptop has been synchronized with the GPS time*

- **Dive Smarties-1968-11 (02 August 2019)**

The first file (06:35:57) is a test to confirm that everything works properly.

The data have been recorded in 9 files. The acquisition started at 08:03:01 and ended at 16:54:27.

- **Dive Smarties-1970-13 (04 August 2019)**

The first file (07:37:23) is a test to confirm that everything works properly.

The data have been recorded in 8 files. The acquisition started at 09:13:23 and ended at 16:10:31.

__OPERATION:__ *After the Dive 1969-12, the data logger has been removed from Nautile and all the cables have been properly cleaned and dried. In the morning of the 4th August, we test the data logger and it was working properly. A shift has been noted respect the GPS data. A new synchronization has been made*

After Dive 12 (03RD August 2019) the time of the laptop has been synchronized with the GPS time. The laptop was ***41min 40sec late***

- **Dive Smarties-1972-15 (06 August 2019)**

The first file (06:18:34) is a test to confirm that everything works properly.

The data have been recorded in 10 files. The acquisition started at 07:57:14and ended at 16:05:32.

- **Dive Smarties-1975-18 (10 August 2019)**

The data have been recorded in 11 files. The acquisition started at 06:47:28 and ended at 16:05:39.

- **Dive Smarties-1976-19 (11 August 2019)**

Note that the laptop did not record any data. The data from this dive have been taken from the data logger the day after the last dive.

The data have been recorded in 10 files. The acquisition started at 06:40:16 and ended at 17:00:00.

- **Dive Smarties-1977-20 (12 August 2019)**

The data have been recorded in 10 files. The acquisition started at 07:11:49 and ended at 16:58:15.

- **Dive Smarties-1978-21 (13 August 2019)**

The data have been recorded in 10 files. The acquisition started at 07:23:13 and ended at 16:03:02.

Dive Smarties-1979-22 (14 August 2019)

The data have been recorded in 10 files. The acquisition started at 07:10:46 and ended at 16:29:23.

Dive Smarties-1980-23 (15 August 2019)

The data have been recorded in 9 files. The acquisition started at 07:18:43 and ended at 15:41:58.

Dive Smarties-1981-24 (16 August 2019)

NOTE: The Nautile had a problem with one arm. It was impossible to retract it. From 12:00 UTC, Nautile dives with this arm opened. They tried to have few loops during the ascent phase for the new calibration of the Nautile.

The data have been recorded in 9 files. The acquisition started at 07:39:55 and ended at 15:26:40.

Dive Smarties-1982-25 (16 August 2019)

The data have been recorded in 8 files. The acquisition started at 07:07:08 and ended at 14:49:32.

Final remarks:

At the end of the cruise the time of the laptop was 25 secs in advance compared to the UTC time.

Data logger: At the end of the cruise the data have been downloaded from the data logger (SD CARD 1 and 2). The data logger was 1min and 21 secs in advanced respect to the UTC time.