

# ILAB-SPARC Cruise Report

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August 25 to October 2, 2018

**Chief Scientist:** Prof. Satish C. Singh (IPGP)

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## Summary

ILAB-SPARC, Imagining of the Lithosphere-Asthenosphere Boundary across St Paul, Romanche and Chain Fracture Zones, is part of the Trans-Atlantic Imaging of the LAB (TransAtlanticILAB) project, funded by the European Research Council, to image oceanic lithosphere down to its base. The first experiment, deep seismic imaging took place in 2015 on board the Schlumberger Seismic Vessel, Western Trident, collecting 2750 km of ultra-deep seismic reflection data. In 2017, an 1100-km long refraction profile (LITHOS), coincident with a part of the seismic reflection profile, was acquired on board the German R/V Maria S Merian, with the OBS spacing varying from 10 to 20 km.

The ILAB-SPARC experiment took place on board the French R/V Pourquoi Pas from July 26 to October 2, 2018, with the port of calls at Mindelo, Cape Verde. Two seismic refraction profiles were acquired. (1) ILAB-SP Profile 1 is a N-S profile, 850 km long with 50 OBS deployed along 700 km at 14.28 km, crossing the great fracture zones, namely St Paul and Chain, and Romanche Transform fault, coincident with the seismic reflection profile. The age contrast across St Paul is 70 Ma to 40 Ma that across Romanche is 40 Ma to 7 Ma, and across Chain is 10 Ma to 26 Ma. The profile also crossed a propagator in the south. (2) ILAB-SP Profile 2 is 785-km long in E-W direction, with 35 OBS deployed at 17.2 km over 585 km coincident with the reflection profile, running parallel to the Chain Fracture zone in the south, crossing the Mid-Atlantic Ridge, covering the 26 Ma lithosphere on the South American plate to the MAR and then up to 5 Ma lithosphere on the South African plate. The energy source consisted of two sub-arrays each carrying 8 air guns, with a total volume of 4950 cubic inch, towed at 10 m water depth. The shot interval was 300 m. A 6-km long streamer containing 960 channels at 6.25 m recorded all the shots. It was deployed at 12 m. A total of 5,450 of shots were fired during the experiment. On the OBS shot record, one can observe the first arrivals up to 700 km along Profile 1, and reflections up to 400 km offset along Profile 2.

A short OBS profile, 56 km long with an OBS spacing of 14 km, was shot at the transition of the fracture zone and transform fault. The shooting line was 150 km. The shot interval was 75 m, recorded by the streamer deployed at 15 m. Three more crossing profiles, one within the MAR, and two crossing a push-up ridge in the Chain Transform zone were also shot. One can observed layer 2B arrivals at farthest offsets. These profiles were connected with transit profiles.

Coincident gravity, magnetic, 3.5 kHz echo sounder and multi-beam bathymetry data were also acquired. The data acquisition started soon after we left the Cape Verde EEZ until we arrived back again on 30<sup>th</sup> September.

It was a very successful experiment.

## 1. Introduction

The ILAB-SPARC is a part of the TransAtlanticILAB project to image the base down to the base of oceanic lithosphere across Atlantic Ocean, from the ridge axis at 0 Ma to 75 Ma Oceanic lithosphere.

### ***TransAtlanticILAB Project:***

The TransAtlanticILAB (Trans-Atlantic Imaging of the Lithosphere-Asthenosphere Boundary) is an ambitious project to image the lithosphere-asthenosphere boundary starting from the Mid-Atlantic Ridge at 0 age to the margin of Africa up to 100 Ma oceanic lithosphere in a systematic way using different geophysical methods at the same location. There are four elements to the project: (1) Seismic reflection, (2) Seismic refraction, (3) Teleseismic study using broadband OBS, and (4) Conductivity study using magnetotelluric method.

The equatorial Atlantic region was chosen for study as it contains large fracture zones that maintain their azimuths over more than 2000 km, and between which 2D profiles could be shot as straight lines to survey lithosphere aged 0 to 75 Ma. The MAR axis in this area is offset by a set of closely-spaced large-offset ( $> 300$  km) transform faults: from north to south, the St. Paul, Romanche and Chain Transform faults. The Romanche is the largest of these fracture zones (FZ), with a total offset of  $\sim 900$  km; its topographic signature can be traced from the African to the South American shelves. The St. Paul FZ located  $\sim 180$  km to the north has an offset of  $\sim 600$  km and the Chain FZ located  $\sim 180$  km to the south has an offset of  $\sim 300$  km. These FZ reflect an indentation in the Pangea break-up pattern and the corresponding portions of the equatorial continental margins (e.g. Ghana-Ivory Coast) are classified as transform margins. Each of these FZ displays a strong topographic signature, with a deep transform valley bordered by prominent transverse ridges and hosting right-lateral strike-slip earthquakes. Although these equatorial FZ represent some of the longest continuous tectonic features on our planet, little is known about their deep structure and properties of the active strike-slip fault zone. Large-offset transforms may have profound effects on the thermal conditions and dynamics of mantle upwelling, the melting regime, the melt budget and the compositions of melt erupted along mid-ocean ridges. The role and significance of large-offset oceanic transform faults go well beyond solid-Earth dynamics: anomalously uplifted transverse ridges such as those encountered along the Romanche FZ may have had an important effect on the paleocirculation between the North and South Atlantic; also, transverse ridges might have served as land bridges between South America and Africa and facilitated faunal migrations well after the opening of the equatorial Atlantic Ocean.

### ***Scientific Objectives***

The global scientific objectives of the TransAtlanticILAB project are:

1. Image the oceanic lithosphere and the LAB systematically, from zero to 75 Ma of age, using a combination of seismic reflection, refraction, receiver function, surface wave and magnetotelluric methods across the Atlantic Ocean along a 2D profile – this would provide images of the LAB at different scales and allow to distinguish among different models of the LAB.
2. Image the possible presence of melt lenses in the mantle beneath the mid-ocean ridge, and develop a model of melt generation and migration towards the surface
3. Quantify ageing of the oceanic crust and upper mantle as it moves away from the spreading centre.
4. Image possible deep penetrating faults and their distribution as the lithosphere cools and subsides with age away from the ridge axis.
5. Quantify and model the hydration process of the oceanic lithosphere with age.

Four experiments were performed in the last four years:

**(a) TransAtlanticILAB reflection experiment:** The seismic reflection survey was carried out aboard the vessel M/V Western Trident during March-April 2015 using the WesternGeco IsoMetrix\* technology.

The TransAtlanticILab experiment utilized a 12-km long IsoMetrix streamer deployed at 30 m water depth. The energy source was a 10,170 cubic inch air-gun array comprised of 6 sub-arrays with 8 guns each, deployed at 15 m depth, targeting very low frequency output. To increase the low frequency content and have a broadband source, the sub-array spacing was increased to 12 m instead of conventional 8 m spacing. The multi-component towed-streamer system recorded both total pressure and particle acceleration vectors. The shot interval varied from 50 m to 75 m, and consequently the record length from 20 s to 30 s, depending upon the target depth along the profile.

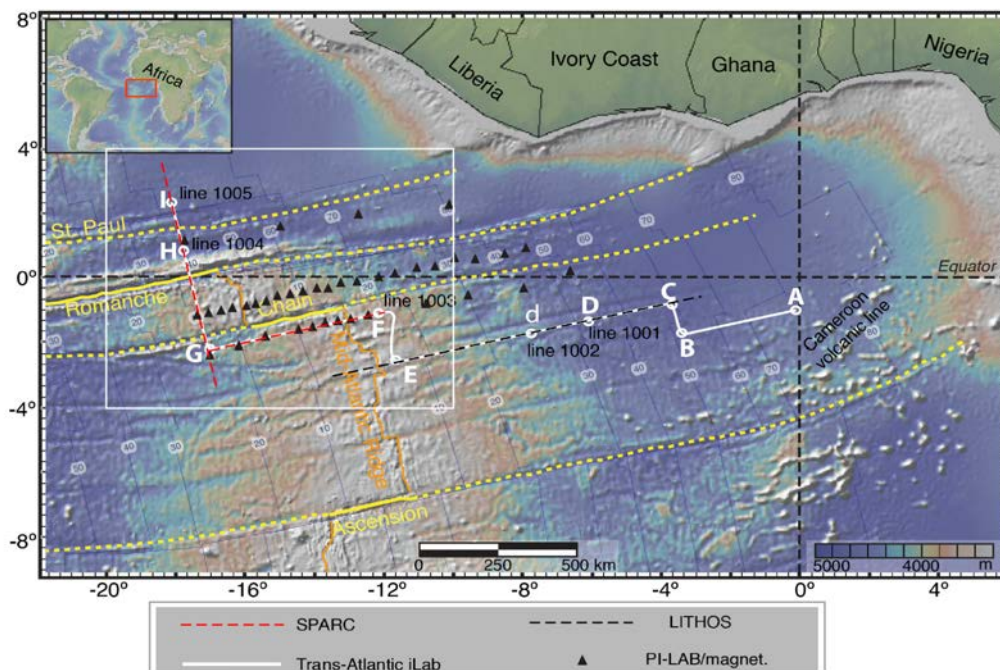


Figure 1.1: Trans-Atlantic ILAB Experiment location: Seismic Reflection Profiles – ABCDEFGHI. LITHOS Refraction Profile: White and black dashed line. PILAB: Black triangles. ILAB-SPARC Refraction Profiles: Red and white dashed lines. Fracture zones: Yellow dashed lines. MAR: Brown lines. The number indicates the age of the lithosphere.

We had planned to acquire two profiles: one 2000 km long E-W profile south of the Chain FZ and one N-S profile crossing the Chain and St. Paul FZ and Romanche Transform. However, due to the United Nation Law of Sea the countries have claimed up to 350 miles from their continental shelf (instead of the earlier 200 miles Exclusive Economy Zone), and hence permits from neighbouring Sub-Saharan African countries would have been required prior to data acquisition, which was not possible due to the limited time. This restriction had two consequences: (1) the maximum age of the lithosphere that could be imaged was reduced from 100 Ma to 75 Ma and (2) two extra turns were acquired to remain within international waters (Figure 1.1).

A total of 2,775 km of deep seismic reflection data was acquired starting from Greenwich Meridian at 1° S, at about 75 Ma plate age (Figure 1.1). A composite profile was shot in nearly E-W direction as three segments (AB, CE, FG), with the third one (FG) crossing the MAR at 1.3° S (zero-age lithosphere). Thus our data span 0-75 Ma of the oceanic lithosphere on the African

Plate. Profile FG extends for approximately 500 km west of the MAR axis, imaging 0-25 Ma lithosphere on the South American Plate. It connects with a N-S profile (profile GI) that traverses Chain FZ, Romanche Transform and St Paul FZ.

IsoMetrix data require special processing, and WesternGeco provided an in-field geophysics team to perform initial preconditioning of the raw measurements into total pressure (P), plus vertical (Az) and horizontal (Ay) pressure gradients, at 3.125 m receiver intervals. A key objective of the project was to extract usable frequency content down to 1.5 Hz, and hence care was taken during the noise removal process to preserve low frequencies. The pressure and vertical gradient data were combined to remove the effect of the receiver-side ghost. Since the seafloor is very rugose across the survey area, wavefield scattering is a key issue, as well as the related multiples. Thus, the removal of scattered noise and multiples is essential for extraction of the weak signals from the mantle and LAB at 50-70 km depth. Figure 1.2 is an on board brute stack seismic image showing possible reflections from the mantle at 18-22 s two-way travel time (50-70 km), which was a very encouraging preliminary result.

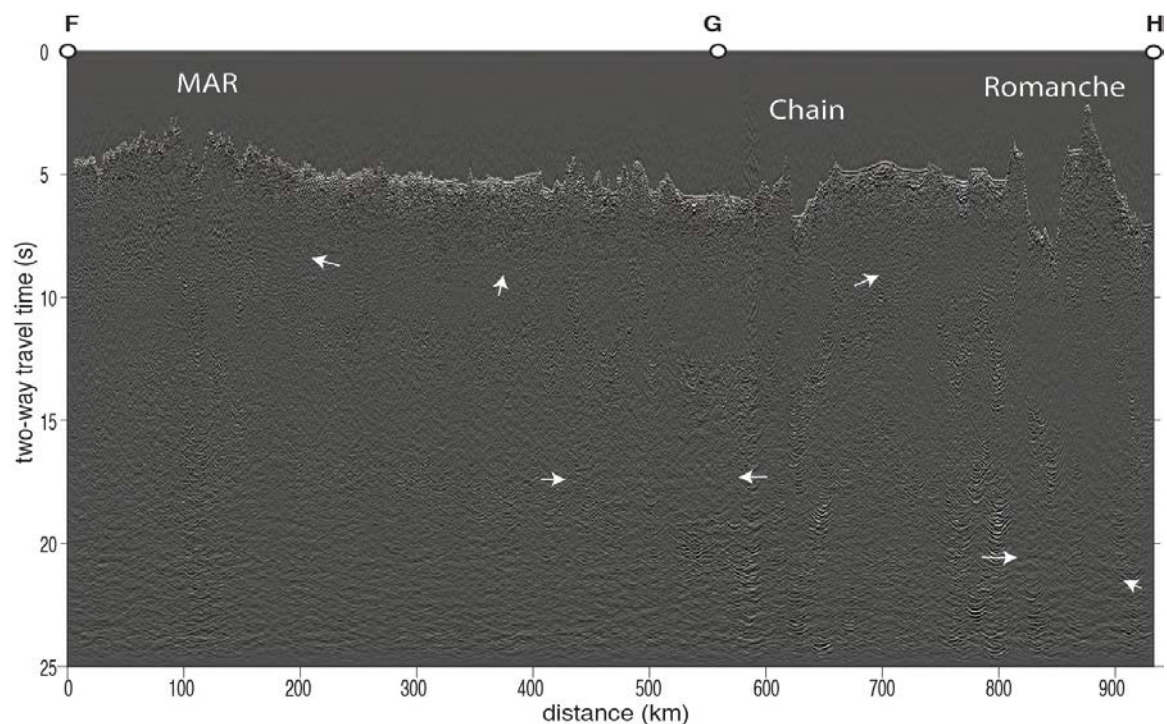
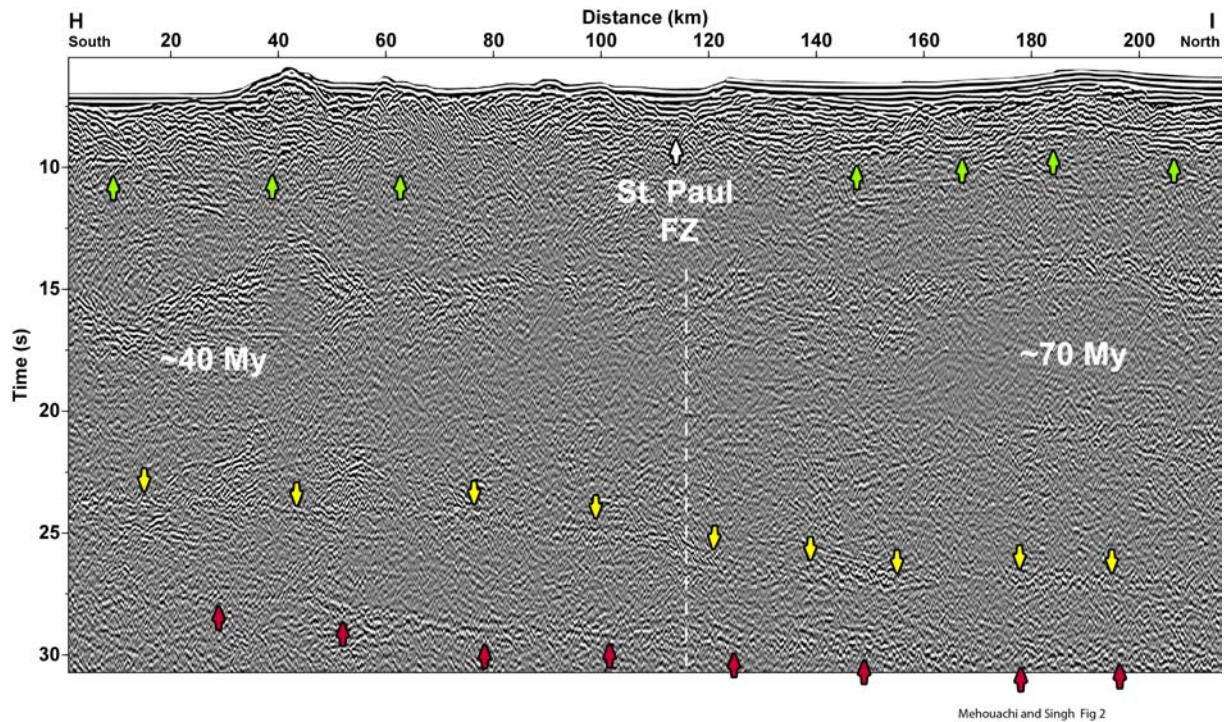


Figure 1.2: Brute stack seismic reflection image from the TransAtlanticILAB deep seismic survey (E-W profiles FG followed by N-S profile GH). MAR: Mid-Atlantic Ridge axis. Crossing of St Paul FZ is not shown on this image. At the Chain FZ crossing, young, shallow side is visible on the right and old, deep side on the left. At the Romanche TF crossing, a deep transform valley is imaged flanked by prominent transverse ridges.

Figure 1.3 shows the final seismic reflection image across the St Paul Fracture zone along profile HI. Here one can clearly observe two reflections; top one from 23 s in the south deepening to 27 s in the north and the lower one starting at 27 s in the south deepening to 30 s in the north. Mehouachi and Singh (2018) suggest that these reflections correspond to the top and bottom of a melt channel at the base of the lithosphere. They find that the top corresponds to a 1260° C isotherm and the bottom to 1355° C isotherm, requiring the presence of water in the melt channel. The depth of the LAB increases with age whereas the thickness of the channel decreases with age. Mehouachi and Singh (2018) found that although the water concentration increases with age, the total amount of water remains constant with age, suggesting that the water enters



the channel at the ridge axis (Figure 1.4).

Figure 1.3: Deep Seismic reflection across St Paul Fracture Zone showing Moho (green arrows) and deep mantle reflections (yellow and red arrows) (From Mehouachi and Singh, 2018).

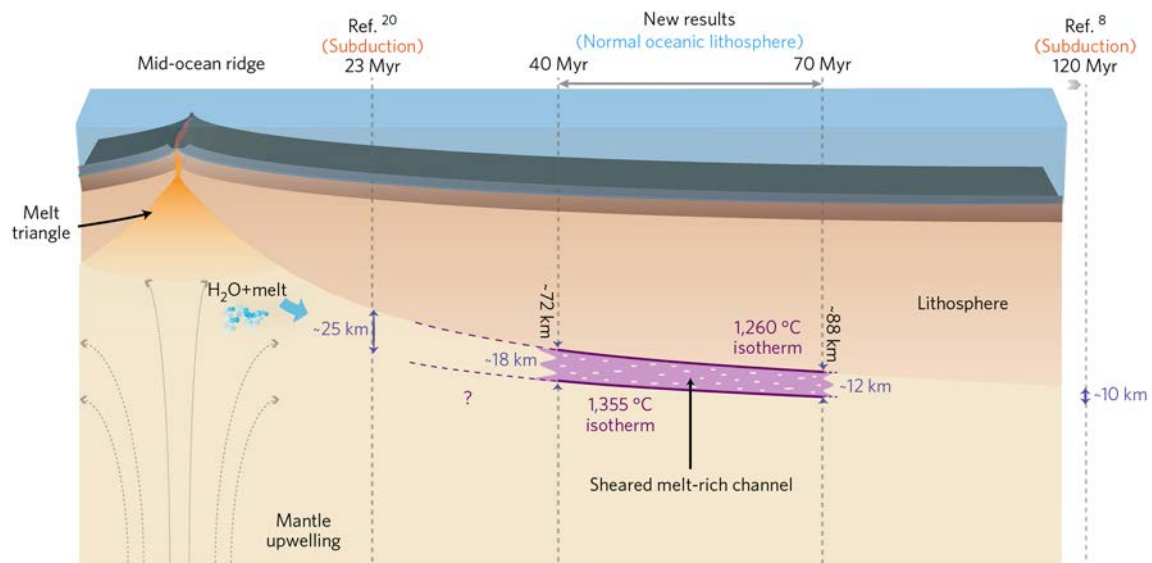


Figure 1.4: Schematic diagram showing the water-rich melt channel at the base of the lithosphere (From Mehouachi and Singh, 2018).

Other part of the data are being processing and will be published in the near future.

**(b) Passive Imaging of the Lithosphere-Asthenosphere Boundary (PI-LAB/Magnet)**

The active source part of the experiment is complemented by the deployment of broadband seismometers (BBOBS) and magnetotelluric (MT) instruments. In 2016, 39 four-component BBOBS and 39 MT (Scripps) were deployed for about 12 months north of the E-W trending profile CE, coincident with profile FG and GH, covering 0-40 Ma of oceanic lithosphere. This passive deployment is located slightly north of our main wide-angle reflection-refraction profile CE.

Overall the cruise was very successful, 37 ocean bottom seismometers and 38 ocean bottom magnetotelluric instruments were recovered. The mapping of the western end of the Chain Fracture zone compliments the survey done on the eastern side during the deployment cruise. The survey over Romanche will provide insight into earthquake rupture dynamics and tectonics of the region. Overall the seismic and magnetotelluric data from the seafloor combined with the shipboard surveys will allow us to better understand oceanic lithosphere and the defining mechanism of the plate. The array geometry (Figure 1.1) is optimized to allow effective 3-D surface and body wave studies to be performed to image the 3-D structure around the fracture zones in addition to lithospheric thickening with age. The main objectives of the broadband seismic study are to determine the 3D S-wave velocity down to 300 km and receiver function images of the LAB across 0 to 40 Ma of the oceanic lithosphere at a resolution never achieved before. These results will allow us to answer the following questions: (1) How does the depth of the LAB vary with the age of the lithosphere? (2) What is the difference between LAB depths determined by three seismic methods? (3) How thick is the LAB? (4) Which model of the formation of LAB is valid? These results will complement active source seismic results, particularly information on S-waves, which are more sensitive to the presence of fluid, such as melt.

The 39 (38 recovered) ocean bottom broadband MT instruments, designed and built by Scripps, use low noise/low impedance silver chloride electrodes and electric field amplifiers to measure the horizontal electric field on 10 m long dipoles. Horizontal magnetic fields are measured using low power/low weight induction coil magnetometers. An electronic magnetic compass/tiltmeter records the instrument's orientation on the seafloor. A stray-line buoy system allows for rapid recovery of the instrument, containing flashing LEDs for night recoveries and a miniature GPS unit that transmits real time position to the ship via a wireless modem.

The main objective of the MT study is to determine the resistivity of the upper 100–200 km of the oceanic mantle in 2D and 3D. These results would allow us to answer the following questions:

(1) How does the temperature of the asthenosphere vary with the age of the lithosphere? The electrical conductivity of mantle rocks is a fairly well understood phenomenon, with the electrical conductivity of sub-solidus olivine increasing by over an order of magnitude as temperature increases from 1000° C to 1200° C (e.g. Constable, 2006).

(2) How does the hydration of the lithosphere vary with age? Thus, if the LAB is expressed as a hydration boundary, conductivity will be enhanced over that of dry olivine and variation with age will provide insight as to variation in water content.

(3) What is the extent and distribution of melt in the mantle as a function of age? Basaltic melt is several orders of magnitude more conductive than sub-solidus peridotite, and even small fractions of melt will increase mantle conductivity more than is possible by increasing the temperature or hydration of mantle minerals. Furthermore, there is evidence from both seismic studies and MT soundings that melt entrained at the LAB will be associated with an anisotropic fabric, which can often be detected by MT studies.

(4) How does the depth of the LAB vary with age? The MT method is particularly sensitive to the depth of conductive layers, and so assuming the LAB is associated with an increased conductivity, either as a result of increased temperature, increased water content, or the presence of melt, its depth will be well resolved by the MT data.

The deployment will take place from March 1 to 25, 2016 on board the R/V Langseth. The recovery was done between February 28 and April 2, 2017. The recovery surveys also included multibeam swath bathymetry, gravity, and magnetics.

### ***(C) 2D Wide-angle Reflection-Refraction survey along E-W profile (LITHOS experiment):***

In order to determine velocity along the E-W reflection profile, seventy-one ocean bottom seismometers (IFREMER+GEOMAR) at ~10–20 km spacing were deployed along profile CE on board the German Research Vessel Maria S. Merian from 14 November to 21 December, 2017. This profile is 1096 km long. Starting from the west side, it crossed the Mid-Atlantic Ridge

(MAR) axis so that crustal and magmatic structure of the MAR could be studied whereas the eastern part of the profile lies at 50 Ma. We also acquired heat flow data using Villinger heat flow instruments (Villinger et al., 2002), complementing the seismic reflection and refraction study. One can observe first arrivals up to 140 km offsets. Sometimes, we also observe some mantle reflections on the data after a careful analysis.

The energy source was 5900 cubic inch air guns containing two sub-arrays with 8 guns in each array. The shot interval was 3.5 minutes. The vessel speed varied from 4-5 knots, with a shot interval of 400 m.

The main objective of this work is to determine velocity down to 30 km depth. Below this depth, we shall use the velocity determined using seismological studies. Using these results, we should be able to answer the following scientific questions: (1) How does the LAB depth vary with age? (2) What happens to the oceanic lithosphere as it moves away from the ridge axis? (3) How does serpentinisation change due cracks produced by the cooling of the lithosphere? (4) What is the effect of hydration as the lithosphere cools? (5) Are there large frozen melt bodies in the cooled lithospheres?

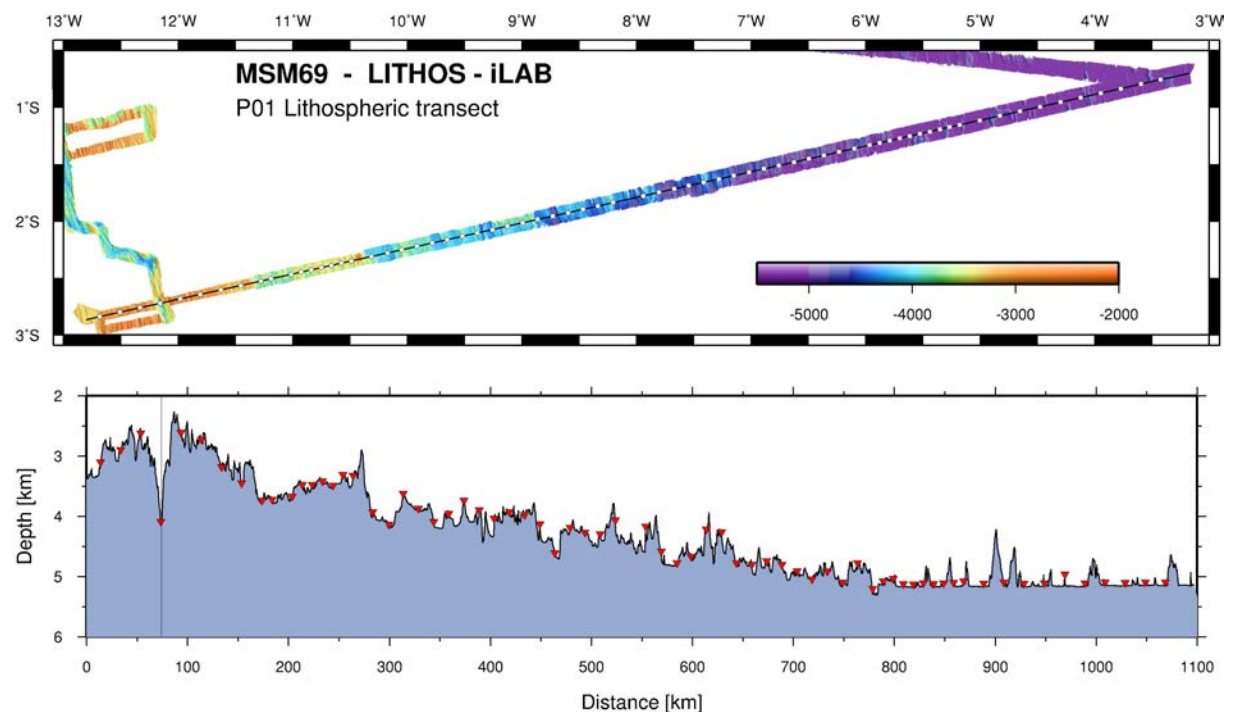


Figure 1.5: Seismic refraction profile from the LITHOS cruise. White dots and red triangles indicate the OBS positions. One can see negative bathymetry slope between 160 and 260 km distance range, suggesting a possible presence of a ridge jump.

At the end of the survey, we acquired bathymetry along the ridge axis and 12 km east of the deep seismic profile. Finally, we deployed 14 OBS along St Paul Fracture Zone and acquired seismic refraction data.

These data are being analysed at IPG Paris and Geomar.

***(d) Imaging of the Lithosphere-Asthenosphere Boundary across St Paul, Romanche and Chain Fracture zones (ILAB-SPARC):***

The last data collection component of the TransAtlanticILAB project is the ILAB-SPARC experiment (this experiment), during which we acquired seismic refraction (OBS) data along

IsoMetrix seismic reflection profiles FG (580 km) and GI (520 km of reflection data). The French R/V Pourquoi Pas was used for the survey from August 26 to October 2, 2018.

The N-S profile was extended to 700 km along which 50 OBS at 14.2 km interval were deployed. The shooting line was extended by 50 km in the south and 100 km in the north. On the E-W profile, we deployed 35 OBS over 585 km long profile at 17.2 km interval, while extending the shooting by 100 km on either side of the profile. The shot consisted of two sub-arrays with 8 guns on each arrays, producing a total volume of 4990 cubic inch. The shot interval was 300 m and the vessel speed varied from 3.2 to 4.5 knots. Bathymetry, 3.5 kHz echo-sounder, gravity and magnetic data were also acquired.

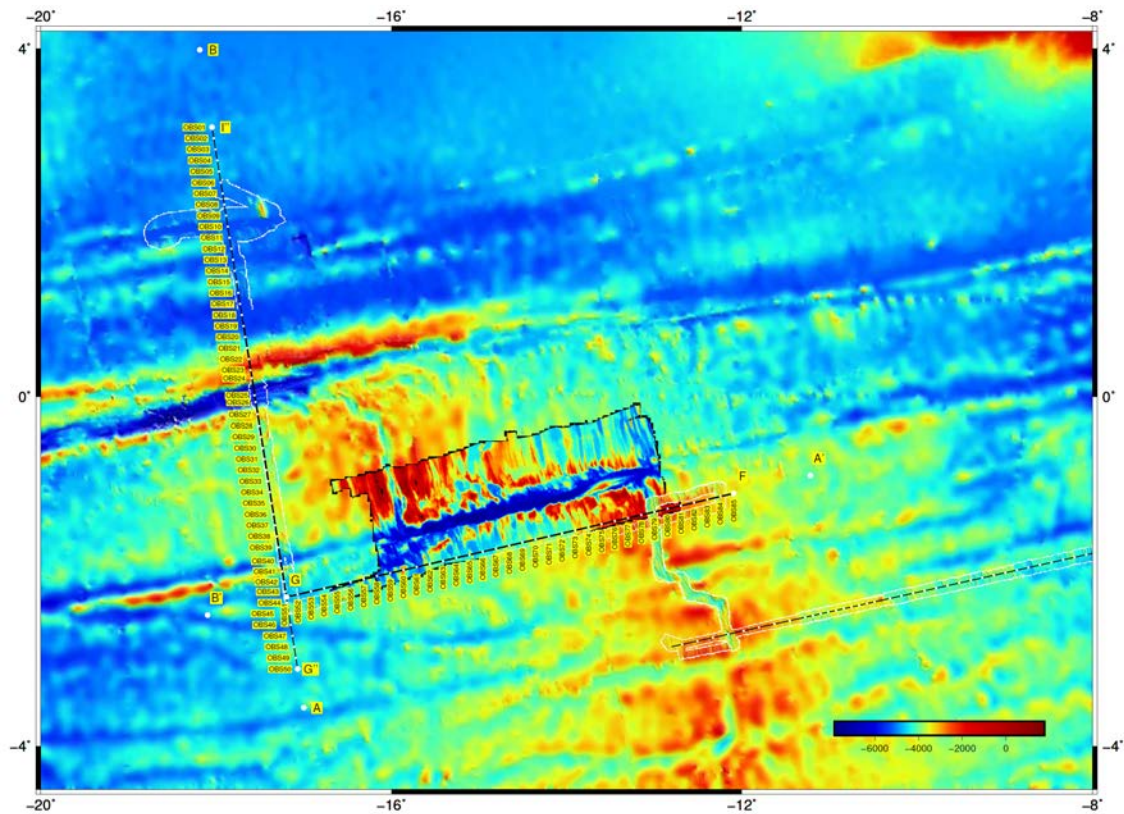


Figure 1.6: ILAB-SPARC refraction profiles. Yellow dots indicate the location of OBS.

In this report, we detail different aspect of data acquisition and on board processing.

## 2. ILAB-PARC Team

	Name	Function	Organisation
1	Singh, Satish	Chief Scientist	IPGP Paris
2	Marjanovic, Milena	Post-Doc	IPGP Paris
3	Gomez, Laura	Post-Doc	Geomar Kiel
4	Laurencin, Muriel	Post-Doc	IPGP Paris
5	Gregory, Emma	PHD / Post-Doc	Durham / IPGP Paris
6	Vaddineni, Venkata	PhD-Student	IPGP Paris
7	Grove, Kevin	Student	Geomar

			Kiel
8	Filbrandt, Christian	Student	Geomar Kiel
9	Guyavarch, Pierre	OBS Technician	Ifremer Brest
10	Pelleau, Pascal	OBS Technician	Ifremer Brest
	<b>MMO-Team</b>		
11	Suardi, Alessandra	MMO	Cohabys / Adera
12	Wyss, Virginie	MMO	Cohabys / Adera
	<b>Seismic Team</b>		
13	Morvan, Laurence	Electronician	Genavir
14	Guiomar, Stephane	Technician	Genavir
15	Kergoat, Yohann	Electronician	Genavir
16	Le Beuz, Gilles	Streamer Technician	Genavir
17	Viollette, Guillaume	Electronic Engineer	Genavir
18	Masson, Nicolas	Airgun Engineer	Genavir
19	Apprioul, David	Engineer	Genavir
20	Lancou, Kevin	Electronic Engineer	Genavir
21	Le Philippe, Jean Luc	Engineer	Genavir
22	Morvan, Nicolas	Engineer	Genavir
23	Goas, Erwan	Electronician	Genavir
	<b>Crew List</b>		
24	Moimeaux, Philippe	Master / Captain	Genavir
25	Herault, Vicky	Chief Mate	Genavir
26	Martin, Pauline	Mate	Genavir
26	Golain, Morgane	Mate	Genavir
28	Samson, Jeanne	Cadet	Genavir
29	Dehame, Sandra	Cadet	Genavir
30	Le Roy, Patrick	Chief Engineer	Genavir
31	Clodic, Francois	2nd Engineer	Genavir
32	Meral, Jean	3rd Engineer	Genavir
33	Fourcade, Perrine	Dual Purpose Officer	Genavir
34	Delourme, Cedric	Electro Officer	Genavir
35	Cadiou, Luc	Electro Officer's Assistant	Genavir
36	Cambuzat, Benoit	Doctor	Genavir
37	Gillier, Arnaud	Boatswain	Genavir
38	Le Bousse, Fernand	Able Seaman	Genavir
39	Quinton, Frederic	Able Seaman	Genavir
40	Le Boulicaut, Raynald	Ordinary Seaman	Genavir

41	Delarue, Jean-Charles	Ordinary Seaman	Genavir
42	Le Roy, Nicholas	Ordinary Seaman	Genavir
43	Le Bourdiec, Eric	Ordinary Seaman	Genavir
44	Morais, Adrien	Ordinary Seaman	Genavir
45	Autret, Joris	Ordinary Seaman	Genavir
46	Cavillon, Pierre Andre	Motorman	Genavir
47	Baillobay, Regis	Electrician	Genavir
48	Quere, Valentin	Greaser	Genavir
49	Maussion, Thierry	Electrician	Genavir
50	Lucas, Lou	Cleaner	Genavir
51	Charlemein, Pierre	Chief Cook	Genavir
52	Ferron, Fabrice	2nd Cook	Genavir
53	Bourgeois, Yoan	Cook's Assistant	Genavir
54	Gobourg, Reynald	Chief Steward	Genavir
55	Morvan, Sybille	2nd Steward	Genavir

### 3. Daily Report

*24 August:* We left early in the morning, arrived in Lisbon, and found the Laura GOMEZ could not join the flight to Cape Verde as her flight was delayed. She was re-booked for a flight on 25<sup>th</sup> August. We arrived in Cape Verde, picked up by the agent and driven to the hotel. It was a relaxing afternoon.

*25 August:* We were picked by the agent at 10 AM, and boarded the vessel around 11 AM, got organised in our cabins, met for lunch and then spend about 3:30 hours discussing the survey design in the conference room with the science team. The idea was to assess all the existing data and information from the previous ILAB cruises, and reorganise the OBS deployment in the absence of 15 Geomar OBS. After that we had a pleasant evening.

*26 August:* Early in the morning, we learned that Erwan Guillon, head of the MMO Team, missed the flight. After discussion with Captain, we decided to depart at 3 PM with only two MMO on board. We had another science discussion once the vessel was on the route. We finally agreed to reduce the length of N-S line to 700 km, deploy 50 OBS along the profile, starting from new point I'', finish the line and then deploy 35 OBS on the E-S profile and shoot that profile. We agreed to have a shot interval of 200 m, vessel speed of 3 kt, with OBS spacing of 14 km on the N-S profile and 16 km on the E-W profile. We had the security briefing for an hour and half.

*27 August:* We visited the vessel to get orientation, visited the OBS lab etc. An XBT was deployed at 6:45 PM, which went down to 2100 m and we started bathymetry data at 7:15 PM along with 3.5 KHz. We found the beam was not symmetric, possibly due to tilt of the vessel by 1 degree, which was fixed soon. The 3.5 KHz data are not very good.

*28 August:* We realised that the poor quality of 3.5 KHz data is due the synchronization of multibeam and eco sounder and hence we decided to make them independent, which improved the 3.5 KHz data significantly, but introduced a bit of noise in the multibeam data, which could be cleaned up during the processing. We prepared OBS locations, and found that profile should be 670 km long with OBS spacing of 13.6 km. During the briefing we learned that Genavir would not be able to acquire data at 3 knots but at 4.5 knots, which means we would have to shoot at every 300 m.

*29 August:* All is going well. I sent an email to IFREMER Brest requesting to find a solution of acquiring data 3 knots. They responded back saying it would be difficult. We continue transit to the first OBS deployment. We decided to have a briefing every day at 4 PM in the science room. At 4:30 PM, Satish presented ILAB-SPARC experiment to the equipage.

*30 August:* We arrived at the first OBS site I'' at 4 AM local time, and started deploying the OBS. It took about 50 minutes for each OBS deployment with an OBS spacing for 14.36 km. The OBS team is very efficient, and all is going well. We got the news from IFREMER recommending a vessel speed of 4 knots.

*31 August:* All is going well. We completed the OBS deployment at 5:45 PM and then started a transit line up to 50 km the last OBS, 12 km further west, parallel to the main profile. Started deploying streamer at around 9 PM, and then deployed guns. We have to wait for sunlight for MMO pre-watch before start shooting.

*September 1:* At 6 AM we saw some dolphins within 500 m of the vessel, but soon they moved away. The pre-watch started at 6:10 until 7:10. We started ramp-up at 7:10 but there was problem, so it was delayed by 30 minutes. Once all the guns were on, we found that first gun on the starboard side was not working. We decided to pull the line and fix the problem. We redeployed the line around 10:30 AM, but found that two more guns were not working. We then decided to pull the line again, and repaired, and started to circle. The guns were again in the water at 3:30 PM, and we started acquisition around 3:45 PM, while the steamer was still not straight.

*September 2:* Early in the morning we found that two of guns are firing at 4-6 ms before and after the fix time. After the discussion, we decided to shut off the two the guns, with a total volume of only 4150 cubic inch, and wait for another one to pose problems, and then pull them off and fix the problem. All the guns are working.

*September 3:* All went well all day. We crossed the Chain Fracture zone. The vessel speed remained low, 3-3.4 knots all day. Milena gave a presentation in the conference room on her on 3D FWI work, which was well received.

*September 4:* Early in the morning, we found that there was a problem with starboard guns, and then it came back; we lost three shots. At 11:30 AM we found that one of the gun on starboard side stopped firing and so we decided to repair the guns. We first took all the port guns out, fix them and redeployed. We then took starboard guns and fix then and redeployed. While testing we found that gun 4 is not firing. Given the risk involved in bringing the guns up, we decided to continue with one gun less (320 cubic inch). We arrive at the profile around 9 PM local time.

*September 5:* All has gone well today. The current is behind us so the vessel speed is high, 4.5 knots. At the end of the day, we found that one of the starboard gun did not fire a couple of times, then it got fixed.

*September 6:* We found at 4:15 AM that the tension of streamer was 2 tons, and then all the birds beyond 13 did not respond, connection lost. There must be some thing that is caught in the streamer. We immediately decided to stop shooting, circle and start recovering airguns first, completing at 7:30 AM and then the streamer. We did find a fish attraction device (FAD), up to 14 m long, near the bird 14, which has tore the streamer, which means we could not use that section. We replaced that section and then redeployed streamer by 1:30 PM. Then we deployed the guns completing at 3:15 PM. We found that the GPS of the port gun array was not responding, and hence decided to pull it in and check it. We found that cable was broken. We also found that there was some problem with one of the compressor.

We replaced the cable and redeployed. We also decided to start ramp-up to make sure that we have one side of the array is working before the sunset. After several phone calls and discussion

with MMO, we started ramping up at 5:51 PM. In the mean time, we replaced the cable and re-deployed the guns. By 6:21 PM, we had re-deployed the guns and completed the ramp-up for both sub-arrays. We then discovered that two of the port side guns did not fire, and one on the starboard side is not synchronising. We then decided to pull the port side array and replace the guns, and re-deployed them by 9 PM, and start shooting at 9:30 PM. We turned toward the profile at 10:30 PM. We decided to postpone Laura's talk for Friday.

*September 7:* All went well today. Only one of the gun's hydrophone is not producing good signal. At 8:30 PM we found that there is fishing device at 500 m east of the profile, drifting eastward. At 10:00 PM, it had drifted by 1.7 km from the profile. We did not know if this was fish attraction device or fishing net connected to other two devices present on the either side of the profile. We first decided to bring the streamer at 8 m in order to avoid being caught by the net. However, at midnight, we found a floating fish attraction device 50 m from the vessel, without any GPS, and hence decided to lower the streamer to 30 m depth. Nothing happened, but it was an intense moment both in the lab and on the bridge. Laura gave her talk at 6 PM.

*September 8:* We completed the profile at 5:30 AM, and did noise recording of 30 shots at 30 s interval, and started turning at 5:40 AM. Started recovering the guns at 7 AM, and completed by 8 AM. Then started recovering the streamers until 12:30 PM. We acquired a 12 km of swath east of the profile during transit, arrived at the first OBS at 3:50 PM, and recovered the first OBS at 6:30 PM. It took some time to get the first OBS, but it took an average of two hours per OBS.

*September 9:* OBS recovery continues and by 4 PM local time, we had recovered 13 OBS. The data quality is good, and the source signature is excellent. We are continuing with a recovery rate of 2 hours per OBS.

*September 10:* We had some difficulty with the OBS on the northern flank of Romanche; it did not get released during the first time and hence have to wait for an hour. It came finally. By 4 PM, we had recovered 25 OBS, with 2 hr/OBS. The data quality is excellent. We could see the first arrivals up to 500 km and some reflections from the mantle. We also discussed a possible contingency plan, in case we have some extra time. If we have more than 5 days, then we should acquire OBS profile to study transition from transform to fracture zone and also some seismic reflection profiles across these zones, over a compressional ridge within the Chain Transform fault.

*11 September:* All is going well. We have recovered 25 OBS by 4 PM local time. One OBS did not get released first time, so have to wait for an hour as it was in shallow water and on the northern slope of the Romanche Transform.

*12 September:* All has gone well. We recovered the 50<sup>th</sup> OBS at 5:30 AM local time. We acquired bathymetry data west of the profile during transit, and arrived at 11:15 AM at the 51<sup>st</sup> OBS. It took about one hour per OBS to deploy.

*13 September:* All is going well. We deployed 85<sup>th</sup> OBS at 7 PM local time, and transited to the end of profile, arriving at 11 PM. We started deploying the streamer. On OBS 45, we could observe arrivals up to 700 km. There was a citing of pilot whales. Muriel gave a presentation at 6 PM.

*14 September:* We had difficulty with the section around 4<sup>th</sup> bird, and found there was some electrical problem, so replaced with another section and completed the streamer deployment at 4:30 AM local time. Then we deployed airguns by 5:30 AM, and started Pre-watch at 5:30 AM. At 6:32 AM, we started ramp-up, which completed at 6:32 AM. But we found that the one of the gun, 520 cubic inch, did not fire. So we decided to bring the starboard side sub-array, and fix it. It took longer to re-deploy the starboard guns. Finally we started shooting at 10:15 AM. At 11:00 AM, we found one of the gun (520 cubic inch) on the port side did not fire, so we turned it off.

The length of the profile is 585 km. We have 35 OBS at 17.2 km interval. We have extended shooting profile by 100 km on either side to get mantle arrivals up to 685 km within the OBS window of 585 km. We had fire drill at 4:15 PM.

*15 September:* All has gone well. By 4 PM, we had crossed 80<sup>th</sup> OBS. If all goes well, we should complete the profile on the 19<sup>th</sup> September, around lunchtime. There was an earthquake of Mw=4.7 this morning at 4:30 GMT at the junction of the Chain TF and MAR. There are several earthquakes recorded by the OBS prior to shooting.

*16 September:* All has been going on well until this morning at 2 AM. I was awoken to review the guns firing more than 1.5 ms from the firing time. After reviewing the situation, I extended the limit to 2 ms. In the morning, we found that gun timing error between 1.5-1.9 ms was 4.3% so we decided to continue shooting with same the configuration. At 11 AM, we found that the error on three guns were more than 2 ms, so decided to bring the port side array and fix it. There was a very strong wind (23 knots) and hence the vessel has to be facing the wind. We also had some possibility of airguns entangling with the streamer. Finally, got the array on board at 1 PM, replaced three guns and redeployed at 3:15 PM, and start testing. We found that we still have a long way to go, we decided to fix the starboard side gun as well. Finally, we deployed the starboard guns at 6:40 PM. All guns are working, but we are about 6 hours from the start of the profile at 11 PM.

Today was Laura's birthday. Students had prepared a game of card using photographs on board and the different actions. We celebrated her birthday with a drink at 4:15 PM after the daily briefing at 4 PM.

*17 September:* One of the gun started having time error of 1.5-1.9 ms in the morning, but we decided to keep it as the error statistics was small. At 3:10 PM, it started having larger errors and hence we turned it off (320 cubic inch). All went well after that.

*18 September:* All was going well until 8:30 AM, when we found many fish buoy around our profile. We were obliged to deviate by 6 miles from the profile, and it took three hours to return back on the profile. Emma gave a talk at 6 PM.

*19 September:* At around 2 AM in the morning, the air release system had some problem, not letting the pressure to increase to 2000 psi, but was fixed quickly. One of the starboard side guns (520 cubic inch) started having time error, but later stabilized. We completed the profile at 10:15 PM, and then did some noise test for 10 minutes, and then turned to SE direction to recover guns and streamer.

*20 September:* We recovered the guns around 1:30 AM, and the streamer by 5:30 AM. We have five hours transit to the first OBS, but acquired bathymetry data parallel to the main profile. The first OBS came on board at 11:35 AM, the second at 1:40 PM and third at 3:35 Pm. This OBS did not get released the first time so was delayed by 30 minutes. It was a shopping day from Coop at 4:14 PM, and talk by Guillaume Viollette gave a talk on seismic equipment at 6 PM.

*21 September:* All has gone well so far with OBS recovery every two hours, except OBS 56 that took three hours. The 70<sup>th</sup> OBS recovered.

*22 September:* All went well, except OBS 80, which did not get released the first time because it was hidden behind a ridge. Finally recovered the 85<sup>th</sup> OBS at 7:35 PM, local time. Then we transit to the first deployment along the Chain Transform-Fracture zone profile.

*23 September:* We arrived at the 86<sup>th</sup> OBS at 12:30 AM, and deployed it. It took three hours to deploy all the OBSs. We decided to turn in SE direction from OBS 90 to deploy the streamer. We started deploying the streamer at 3:45 AM and completed at 6:45 AM, and started deploying the

gun that completed at 7:40. In the mean time, we started pre-watch at 6:40 AM, and completed at 7:40 AM. We decided to do 10 minutes of noise record, and started ramp up at 7:50 and completed at 8:20 AM. We continued along the profile and turned on a N-S profile (E-F) within the ridge axis going through the ridge-transform-fracture zone junction. We arrived at the profile around 10 AM. All the guns are working at full strength. We have deployed the streamer at 15 m and recording for 25 s. We might be imaging some reflection in the crust around 2 s below the seafloor.

*24 September:* All has been going well. Airguns are at their full strength. There was a fire incident with one of the compressor at 6:15 AM, which was quickly controlled. At 3:45 PM, we had some problem with one of the compressor, which was quickly fixed. Given that we have time, we have decided to extend the E-S profile by 20 km further west to cover the whole of the push-up ridge and shoot two more orthogonal profiles crossing through the push-up ridge, one at the centre and the other going through OBS 90.

*25 September:* All has been going, but we had one of the guns (320 cubic inch) giving time error so we turn it off. Later in the morning, another gun, 520 cubic inch, start giving timing error, so we turn it off as well. Given that OBS will be on surface at 2:30 tomorrow, we decided to stop shooting at 9 PM, but increased the speed to 5 knots to cover as much of the profile. We managed to complete a significant part of the third profile, crossing the push-ridge. We performed noise recording for 10 minutes and then start turning to SE direction. We started recovering guns at 10:30 PM and completed at 00:30 AM.

*26 September:* We started recovering streamer at 00:35 and completed at 3:35 AM. We then approached the OBS 90 for release and recovered it at 5:19 AM. The OBS 86 was recovered at 11:45 AM, earlier than expected. We did some test of instruments and left for Mindelo at 12:15 PM.

We decided have only day watch, from 6 AM to 10 PM so that people could get used to sleep in the night and work during the day. We had a pot at 6:30 PM for the end of the cruise.

*27 September:* All have been going well. We crossed the Romanche Fracture zone and then St Paul. The Romanche FZ does not have much of the bathymetry as but the St Paul has the same bathymetric feature as along the profile. There were some compressional features in the vicinity of St Paul FZ, similar to what has been observed further west, suggesting that the deformation extends far away from the ridge axis along the St Paul FZ.

*28 September:* We are in transit.

*29 September:* We remain in transit. Along the profile, we had a seamount that rises less 1000 m, and the observer did not notice and hence did not change the scale of recording, and hence we have gap in bathymetry along the seamount. At the end of the day we noticed that 3.5 kHz image was not good, which could be due to strong seafloor. We had the Equator crossing ceremony followed, Pot and BBQ. We enter the Cape Verde EEZ and hence all the data acquisition is turned off.

*30 September:* We are entering the zone of Cape Verde.

*1 October:* We arrived at the port at 8:30 AM

## **4. Seismic Equipment**

### **4.1. Source**

Genavir acquired simultaneously a new airgun system (Figure 4.1) with a new software of controls, *Gunlink* for source. An array of 16 guns arranged in two strings, 8 in each (Figure 4.2).

For each side, the 8 guns are arranged in 5 clusters either with a 2 Ggun of 150, 250, 320 in<sup>3</sup> or with a Ggun of 520 in<sup>3</sup> (Figure 4.3). The 16 guns were shooting representing a volume of 4990 in<sup>3</sup> at 140 Bars. This represents an hourly consumption of 320 m<sup>3</sup> of air. This configuration does not have any spare, therefore, in the case of gun failure, the shooting has to stop. For the ILAB-SPARC survey, if the volume fired is less than 89% of the total volume, the acquisition will be stopped, a turn will begin and one of the strings will be brought on board for reparation. The guns were at a theoretical depth of 10 m.



Figure 4.1 Air gun sub-arrays installed on the NO Pourquoi Pas?

Depth sensors and hydrophones were placed on source array, which enables a control on depth and firing in real time during the acquisition. For each cluster, there is a hydrophone, which measures the near field signature. These signatures are stored for each shot point in the auxiliary traces of the SEG-D file. Auxiliary traces 1 to 5 correspond to source on portside, for cluster 1 to 5 and auxiliary traces 6 to 10 correspond to traces on starboard side for cluster 6 to 10. The first control is made by the Genavir engineers in real time during the acquisition (Figure 4.4). All guns were synchronized on the maximum peak. If the delay of one of the guns is more than 1 ms (for ILAB-SP1) and 2 ms (for ILAB-SP2), the gun is stopped. Indeed, the goal is to have a minimum delay in order to have the maximum amplitude of propagation.

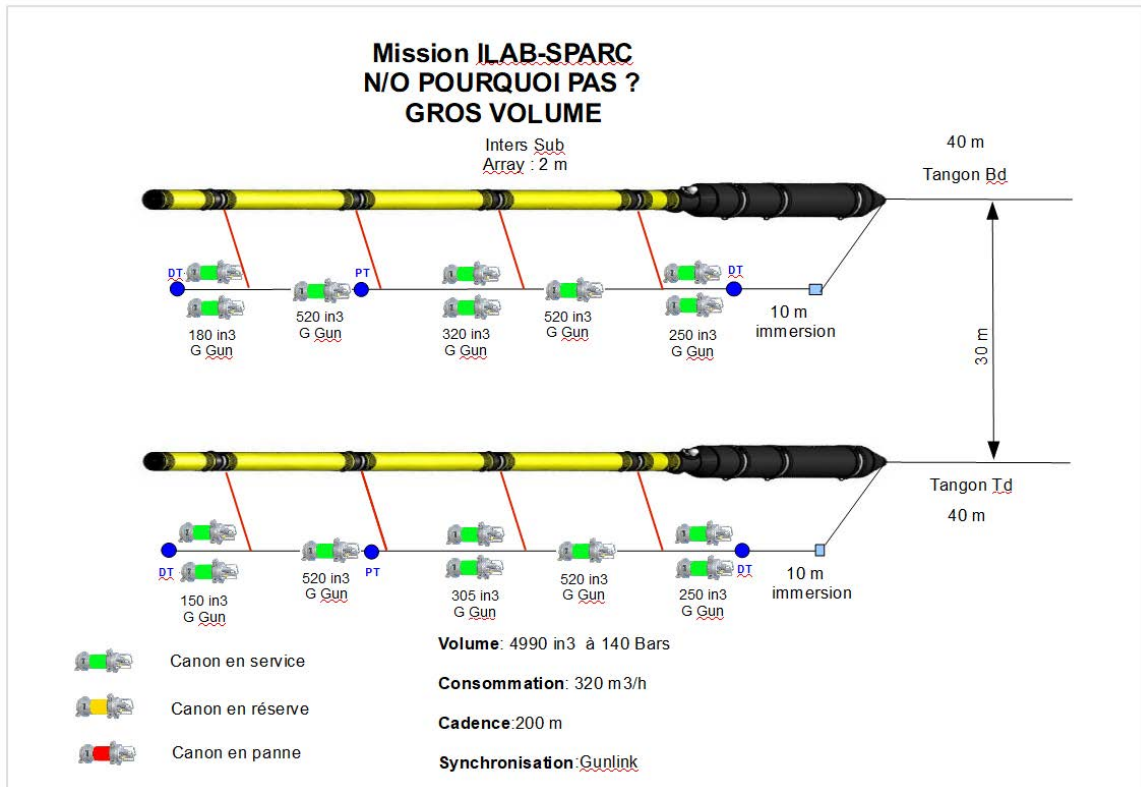


Figure 4.2: The ILAB-SPARC airgun configuration. Two sub-arrays each containing 8 guns. The sub-array separation is 30 m.

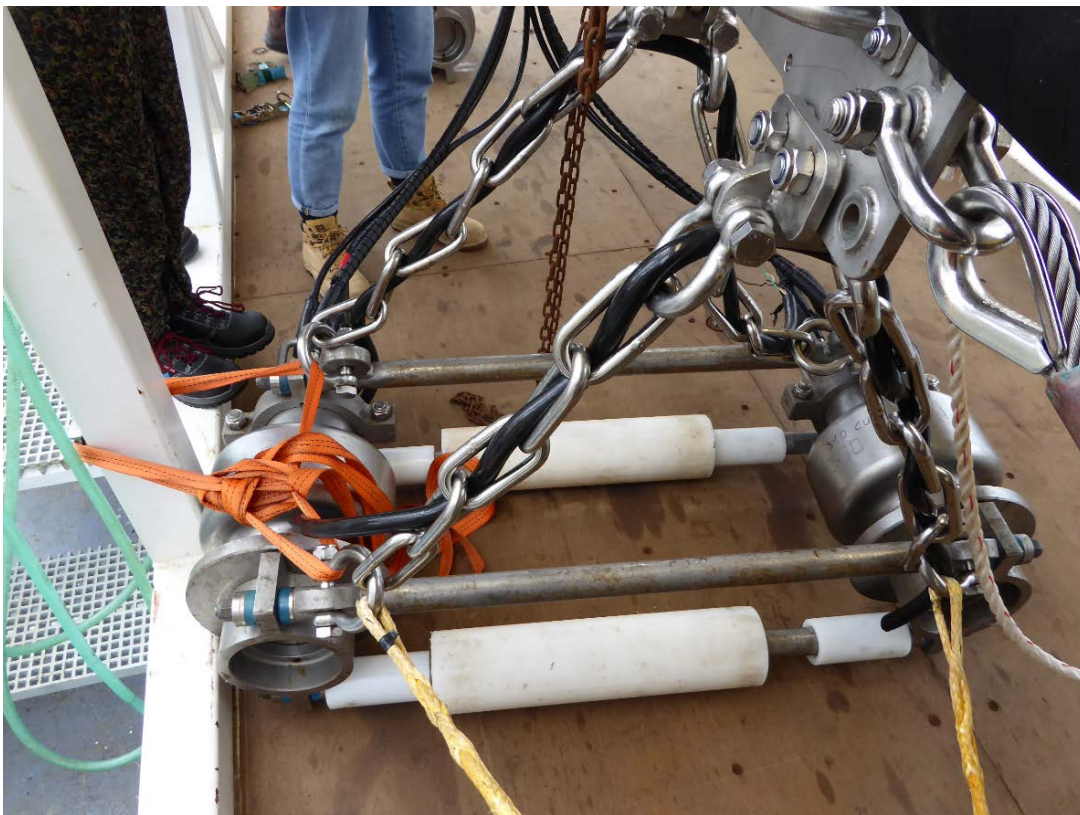


Figure 4.3 Air gun cluster.

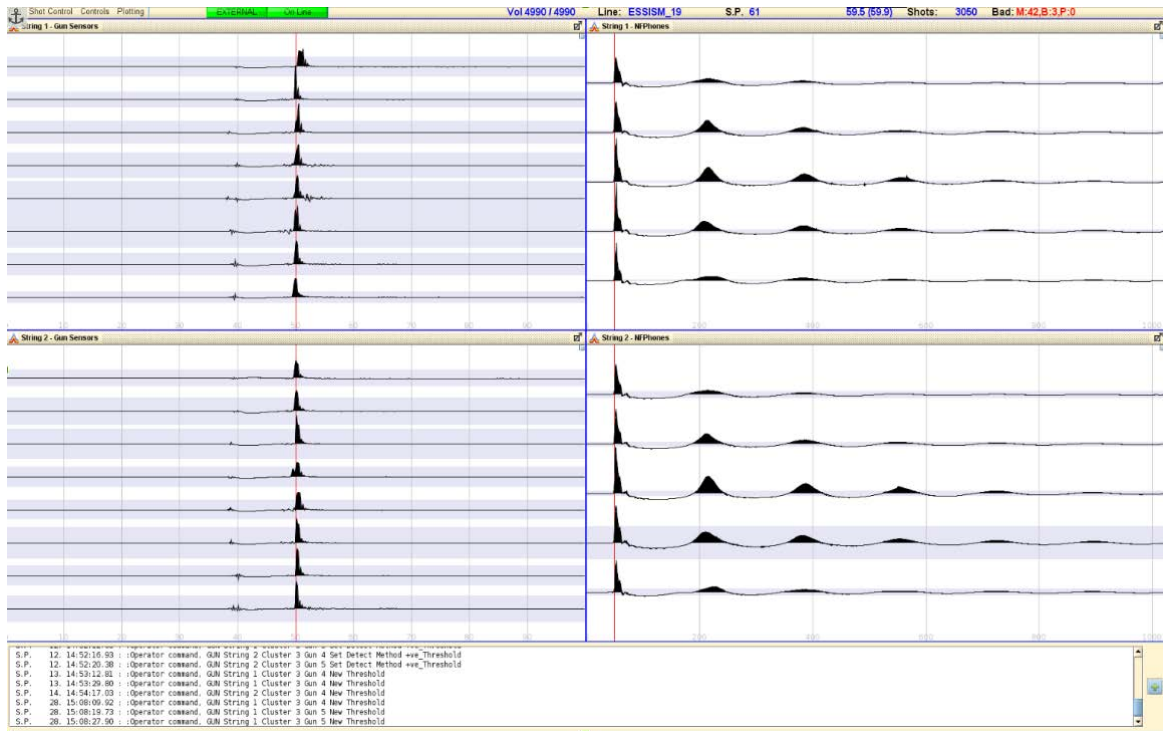


Figure 4.4: Left: Synchronisation of airguns, right: hydrophone recording of each guns.

## 4.2. Streamer

The complete and detailed configuration of the streamer is displayed in Figure 4.5. The streamer is divided into two and tidy on reel (Figure 6). First offset with respect to source is 147 m, trace interval is 6.25 m with a total of 960 traces, with the last offset of 6141 m. The total length of the streamer is 6 km. Each section is composed of 4 hydrophones arranged by 24 groups per section. The streamer was towed to a depth of 12 m for the first part of the acquisition (ILAB\_SP01-02) and 15 m for the second part (ILAB\_SP03 to 10). It was controlled by 21 birds (Figure 4.6). GPS position of boat, tail buoy (Figure 4.6) and birds depth and inclination are all controlled by GENAVIR engineer in real time and recorded in the SEG-D headers. The geometry information necessary to reconstruct the geometry of the source is displayed on Figure 4.7. Behind the tail buoy a magnetometer was also towed (Figure 4.5).

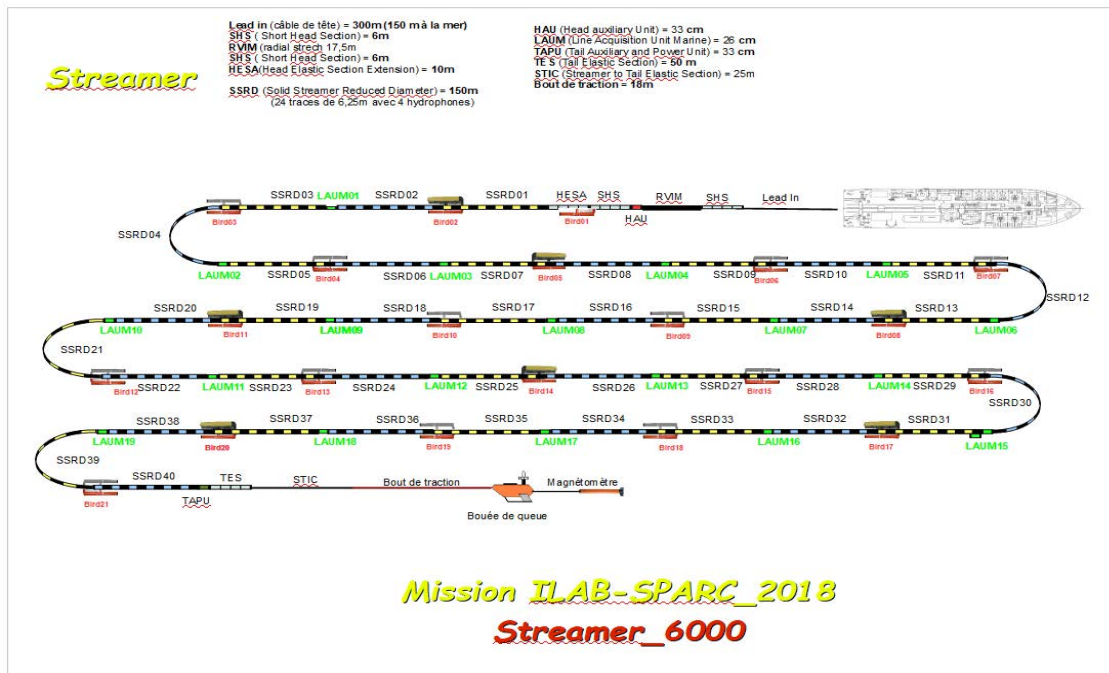


Figure 4.5: Streamer configuration.

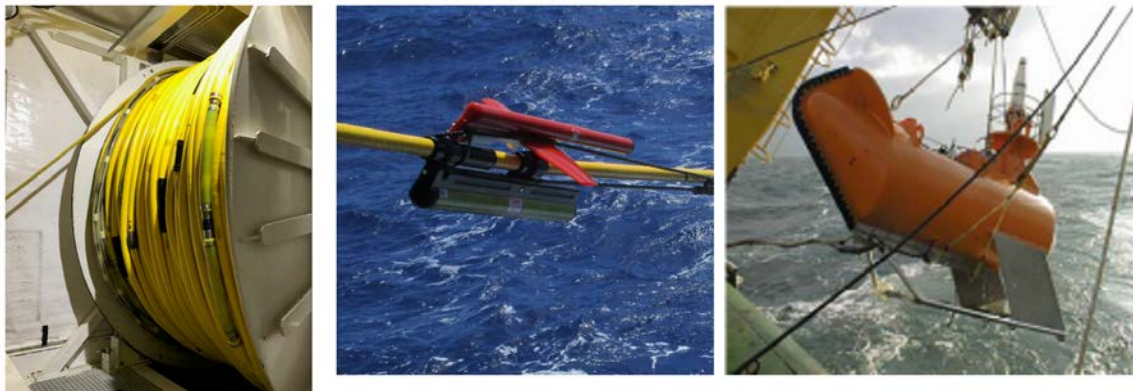


Figure 4.6: Streamer reel (left), bird (centre) and the tail buoy (right).

**SURVEY DESIGN - SMT GEOMETRY** RESET DEFAULT

---

**STARBOARD SIDE**

**STREAMER**

Number of traces:

Trace distance:  m

Dist. centre first trace:  m

Total payed out length:  m

Head passive section:  m

Tail passive section length:  m

# Active SSAS (150 m):

Towing Point dx:  m

Towing Point dy:  m

Tail Buoy GPS:

**DEPTH CONTROLLERS**

(Distance from the center of 1st trace)  #

Bird 1	<input type="text" value="-5.7"/> m	Bird 8	<input type="text" value="1922.5"/> m	Bird 15	<input type="text" value="4024.3"/> m
Bird 2	<input type="text" value="121"/> m	Bird 9	<input type="text" value="2222.8"/> m	Bird 16	<input type="text" value="4324.5"/> m
Bird 3	<input type="text" value="421.3"/> m	Bird 10	<input type="text" value="2523"/> m	Bird 17	<input type="text" value="4624.8"/> m
Bird 4	<input type="text" value="721.5"/> m	Bird 11	<input type="text" value="2823.3"/> m	Bird 18	<input type="text" value="4925"/> m
Bird 5	<input type="text" value="1021.8"/> m	Bird 12	<input type="text" value="3123.5"/> m	Bird 19	<input type="text" value="5225.3"/> m
Bird 6	<input type="text" value="1322"/> m	Bird 13	<input type="text" value="3423.8"/> m	Bird 20	<input type="text" value="5525.5"/> m
Bird 7	<input type="text" value="1622.3"/> m	Bird 14	<input type="text" value="3724"/> m	Bird 21	<input type="text" value="5748.9"/> m

**SOURCES**

**Starboard Source**

Towing Point dx:  m

Towing Point dy:  m

Source cable payed out:  m

GPS source:

Offset (centre array - GPS):  m

**Port Side Source**

Towing Point dx:  m

Towing Point dy:  m

Source cable payed out:  m

GPS source:

Offset (centre array - GPS):  m

**Source - Traces offset**

min:  m max:  m

**VESSEL GPS**

Raw GPS  ECOS: integrated

dx:  m dx:  m

dy:  m dy:  m

Figure 4.7: Gun and streamer control panel.

### 4.3 OBS

During the survey, the OBSs from IFREMER were deployed (Figure 4.8). It is MicroOBS with three 4.5-10 Hz geophones and one 2 Hz hydrophone. It records P and S wave up to 24 days. These OBSs can be deployed to a depth of 6000 m. Electronics, releaser and batteries were housed in 72 cm glass-sphere. The recording unit consisted of 24-bits Sercel France data logger. The OBS have an acoustic receptor controllable from the surface, which mechanically release the OBS when it received the signal. Flashlight and a radio signal help for the recovering on the surface. Figure 4.9 shows more details of OBS.



Figure 4.8: IFREMER OBS during different stages of deployment.

SPECIFICATIONS			
<b>Weight</b>	<b>in air</b>	<b>in water</b>	
MicrOBS	36 kg	-12.5 kg	
MicrOBS + Dead Weight	64 kg	11.5 kg	
<b>Sensors</b>	<b>Hydrophone</b>	<b>Geophone</b>	
Configuration	1 channel	3 axis	
Low frequency cut-off	2 Hz (-3dB)		
Natural frequency		4.5 Hz	10 Hz
Sensitivity	-160 dB ref 1V/ $\mu$ Pa	32 V/m/s	22.8 V/m/s
<b>Batteries</b>	Rechargeable Li-Ion 15V/40Ah		
Type	Rechargeable Li-Ion 15V/40Ah		
Autonomy	8 days idle + 24 days acquisition		
<b>Memory</b>	Compact Flash Card - 8 GB (Optional 16 GB)		
Type	Compact Flash Card - 8 GB (Optional 16 GB)		
Autonomy	24 days (@2 ms SR)		
Operating depth	6000 m maximum		
<b>Dimensions</b>	base 550 x 550 mm		
	height 720 mm		
	dead weight size (cross shape) 800 x 800 mm		
<b>Data Logger</b>	Seismic channel 4		
	A/D converter (seismic channel) 24 bits		
	Sampling frequency 25 to 1000 Hz		
	Bandwidth DC to 0.40 x sampling frequency		
	Gain preamplifier Hydrophone : 0 to 36 dB step 6 dB Geophone : 20 to 56 dB step 6 dB		
	Dynamic range 120 dB		
	Synchronization interface DCF77 (from GPS)		
	Configuration interface RS 232 (9600,1,1)		
	Date & Time stamped data Yes		
<b>Signal</b>	Localization radio signal VHF radio beacon (156.625 MHz)		

Figure 4.9. Detailed specification of the IFREMER OBS.

## 5. OBS Data Acquisition and Processing

Ifremer's OBSs are equipped with four recording channels. Electronics, releaser and batteries were housed in 17-inch glass sphere. The recording unit consisted of 24-bits Sercel France data logger. The hydrophone was a HTI-90-U from High Tech Inc. and a 4.5 Hz geophone. Active source data were sampled at 250 Hz. The OBSs were synchronized to GPS-derived UTC time before deployment and after recovery the data were corrected for clock drift prior to conversion to SAC format.

During the survey 85 Ifremer's MicrOBSs were used to acquire data along two profiles: ILAB-SPARC\_01 (profile I''G'' in Figure 5.1) and Line ILAB\_SPARC\_02 (profile FG in Figure 5.1). In addition to these two main profiles, we also acquired one additional OBS line, ILAB\_SPARC-05, deploying 5 OBSs within the eastern corner of the Chain Transform Fault/Fracture Zone.

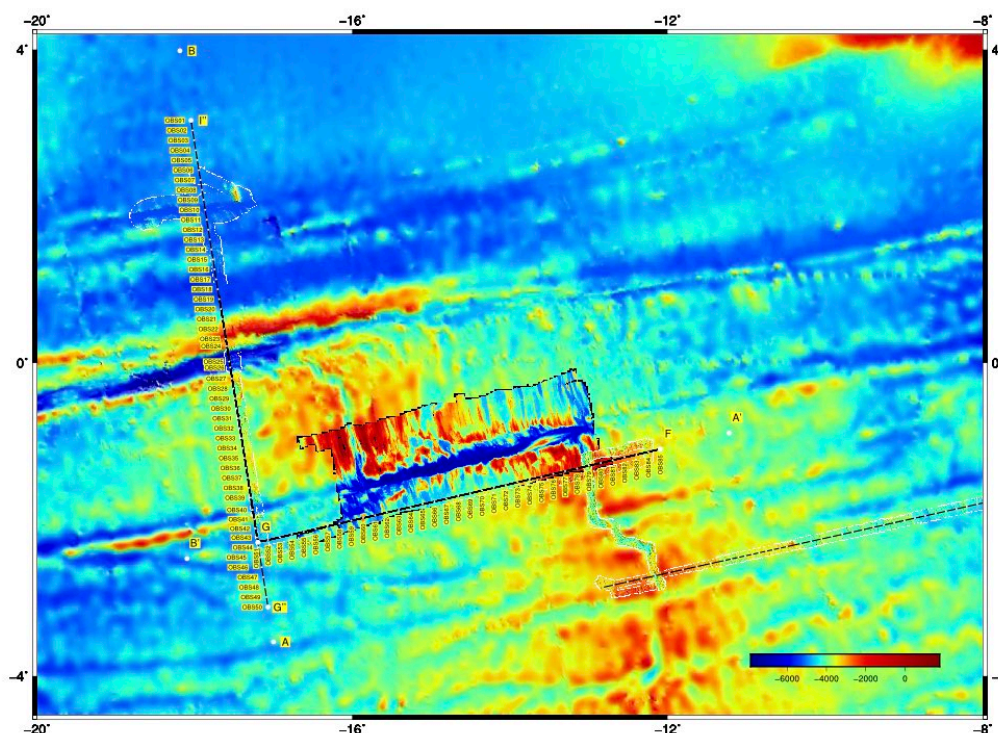


Figure 5.1 - Location of the 85 OBSs deployed along the two main profiles ILAB-SPPARC\_01 (I''G'') and ILAB-SPPARC\_01 (FG).

### 5.1 Line ILAB-SPARC-01

Deployment -The line ILAB-SPARC-01 is ~700 km long, extending from 18°02'49.78''W/3°05'46.18''N (I'') to 17°04'12''W/3°07'12''S (G''), with the general trend N-S, and 171° azimuth (Figure 5.1). The line crosses the St. Paul and Chain Fracture Zones, and Romanche Transform Fault. The depth of the seafloor along this profile varies significantly from <2000 m to >6000 m, which was a challenge when designing the OBS deployment locations (Figure 5.2). The line is collocated with the multi-channel seismic line I'G' collected during the ILAB-TRansAtlantic survey in 2015.

The first OBS along the Line ILAB-SPARC\_01 was deployed on August 30th at 5:07 UTC time (Table 5.1, provided at the end of this chapter). Along the line the OBS were deployed at equidistant locations, d=14.2 km. The exceptions are the OBSs 23-26 where the distance varied from 8.6 to 22.3 km (Table 5.1). This distance change is introduced to avoid the deepest portion of the Romanche Transform Fault (TF). Within the Romanche TF the maximum depth exceeds 6000 m (Figure 5.2) for which the Ifremer's OBS are not attested. Another change in OBSs distance is introduced for the OBSs 39-42. The distance varied from 12.8-17.5 km, and it was introduced to avoid steep southern wall of the Chain Fracture Zone (Figure 5.2). The last OBS was deployed on August 31st at 18:36 UTC time.

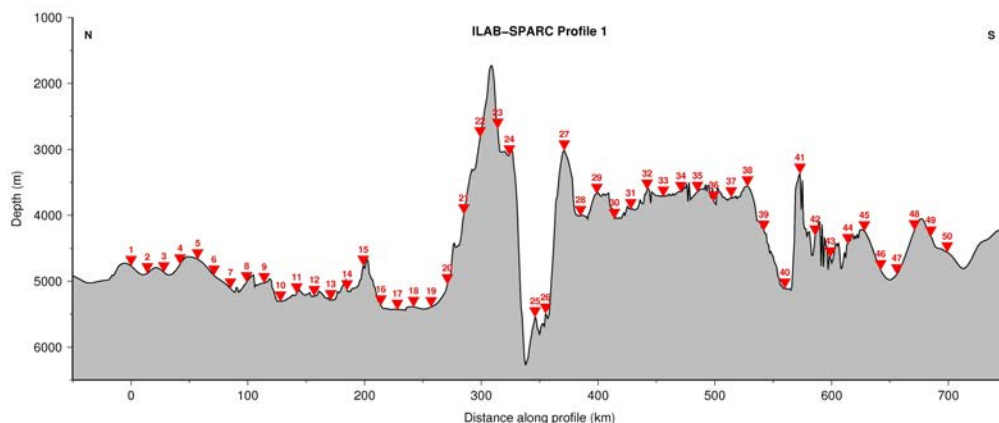


Figure 5.2 - Bathymetry profile along the line ILAB-SPARC\_01 with the location of 50 OBSs (from 1 to 50). The locations of OBSs are marked in red triangles.

Shooting - The onset of the shooting profile is at point A (17°W/3°33'50.4''S) which is ~50 km south of the southernmost point of the line ILAB-SPARC\_01 (Figure 5.1). The first shot was recorded on September 1st at 16:43. The shooting continued to the point B, which is ~100 km north of the northernmost point I'' (18°11'09.6''W/3°59'13.2N). The last shot was recorded on September 8th at 6:30, with the last 10 min dedicated to noise recording. The shot interval was kept at 300 m with the vessel ground speed varying between 2.9 to 4.4 knots. The total number of shots along this line is 2867.

Recovery - The OBS recovery started on September 8th at 18:43 and ended on September 12th at 6:29 (Table 5.1). The recovery time for OBSs varied from 60-120 min, depending on the water depth.

### 5.2 Line ILAB-SPARC-02

Deployment - The line ILAB-SPARC-02 is ~585 km long and extends from 17°13'12''W/2°17'56.4''S (G) to 12°05'42''W/1°06'14.4''S (F), with the general trend E-W and 77° azimuth (Figure 5.1). The line crosses the Mid-Atlantic Ridge and samples the axis from 0-25

Ma on the American and 0-5 Ma on the African plate. The line is collocated with the multi-channel seismic line FG collected during the ILAB-TransAtlantic survey in 2015.

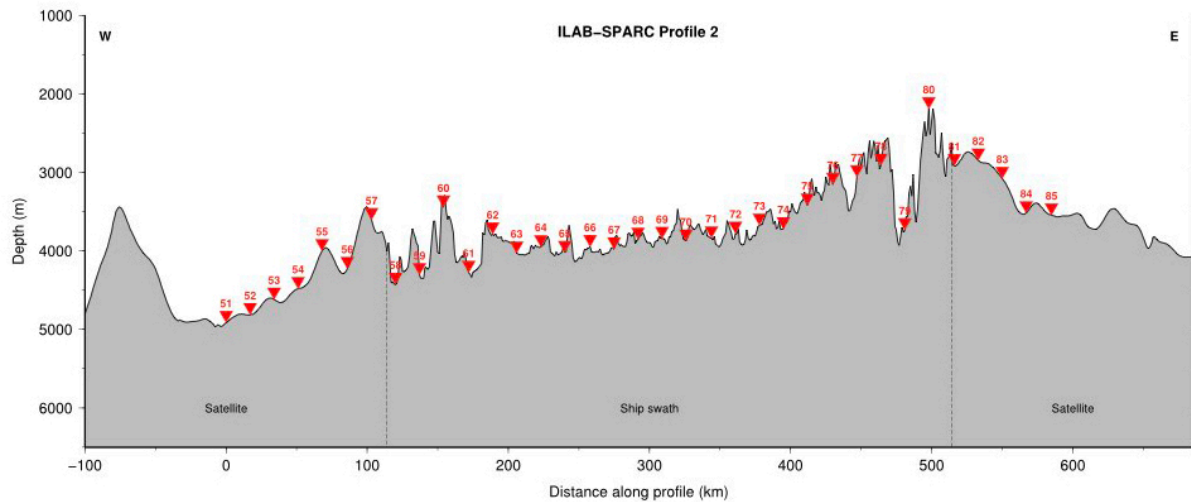


Figure 5.3 - Bathymetry profile along the line ILAB-SPARC\_02 with the location of 35 OBSs (from 51-85) that were deployed. The locations of OBSs are marked in red triangles.

The first OBS along the Line ILAB-SPARC\_02 was deployed on September 12th at 12:13 UTC time (Table 5.2 which is provided at the end of this chapter). Along the line the OBS were deployed at equidistant locations,  $d=17.2$  km (Figure 5.3). The distance was kept constant along the line. The last OBS was deployed on September 13th at 19:28 UTC time.

Shooting - The onset of the shooting profile is at point A' ( $11^{\circ}13'08.4W/0^{\circ}53'56.4'S$ ) which is  $\sim 100$  km east of the easternmost point of the line ILAB-SPARC\_02 (Figure 5.1). The first shot was recorded on September 14th at 11:22. The shooting continued to the point B', which is  $\sim 100$  km west of the westernmost point G ( $18^{\circ}06'32.4W/2^{\circ}30'28.8S$ ), allowing to image a maximum offsets of 695 km. The last shot was recorded on September 8th at 6:30, with the last 10 min dedicated to noise recording. The shooting was done at 300 m distance, with the ground vessel speed varying from 3.1 to 4.4 knots. The total number of shots recorded along this line is 2672.

Recovery - The OBS recovery started on September 20th at 12:50 (UTC) and ended on September 22nd at 20:41 (Table 5.2). The recovery time for OBSs varied from 1.5 h to 2.5 hours.

### 5.3 Line ILAB-SPARC-05

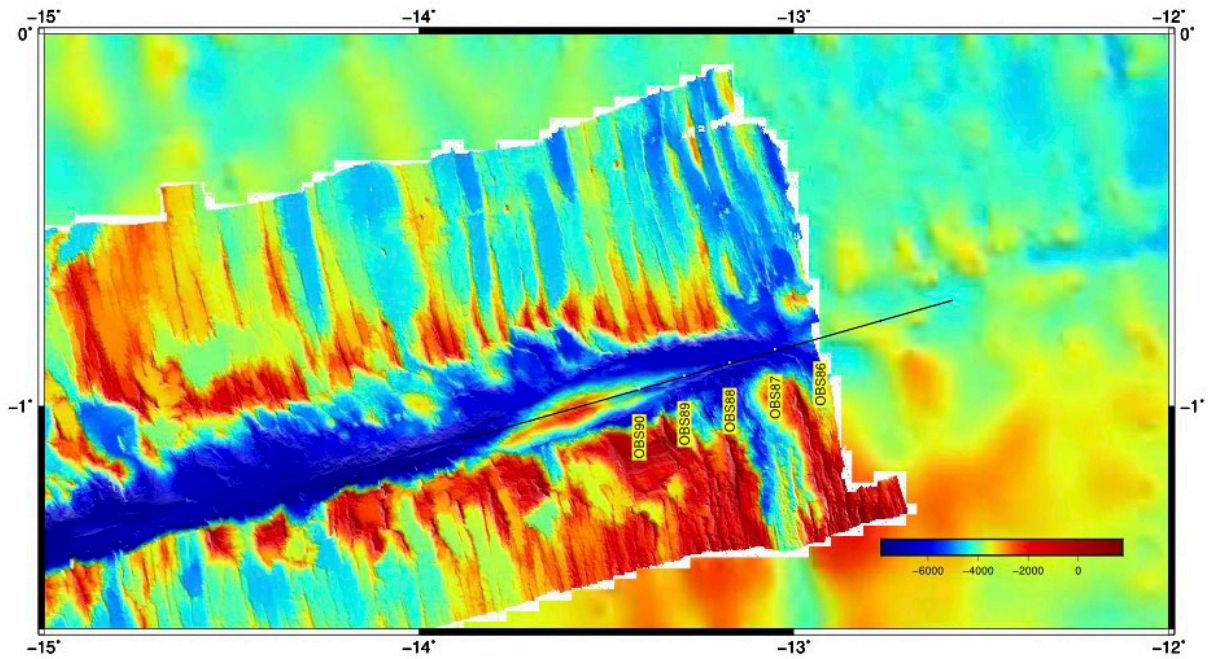


Figure 5.4 - Location of the 5 OBSs deployed along the profile within the Chain Transform Fault/Fracture Zone.

**Deployment** - The line ILAB-SPARC-05 is ~152 km long and extends from 12°55.834'W/00°48.742'S (OBS86) to 13°24.83W/00°57.250S (OBS90), with the general trend SW-NE and 260° azimuth (Figure 5.4). The line is located within the Chain, at the transition between Transform Fault and Fracture Zone. It samples a push-up ridge-like structure, the origin of which is puzzling. The bathymetry profile, with the location of the OBS is shown in Figure 5.5. The main objective of collecting the data along this line is to look at the variations in crustal structure as it transitions from transform fault to fracture zone.

The first OBS (86) was deployed on September 23rd at 1:28 UTC time, and the last one, OBS 90 was deployed on September 23rd at 4:31 UTC. The spacing between OBSs is 14 km. Details on date, time and deployment position can be found in Table 5.3.

**Shooting** - The onset of the shooting profile is at point C (13°53.152W/01°05.561S) which is ~55 km east of the OBS 86 (Figure 5.4). The first shot was recorded on September 24th at 6:30. The shooting continued to the point D, which is ~35 km west of the OBS 90 (12°34.575W/0°42.992S). The last shot was recorded on September 25th at 1:55. The shooting was done at 75 m distance, with the ground vessel speed varying from 3.7 to 4.5 knots. The total number of shots recorded along this line is 2023. These OBSs also received shots from the crossing MCS profiles, thus the total number of shots, including the ones shot along the MCS lines is 5359.

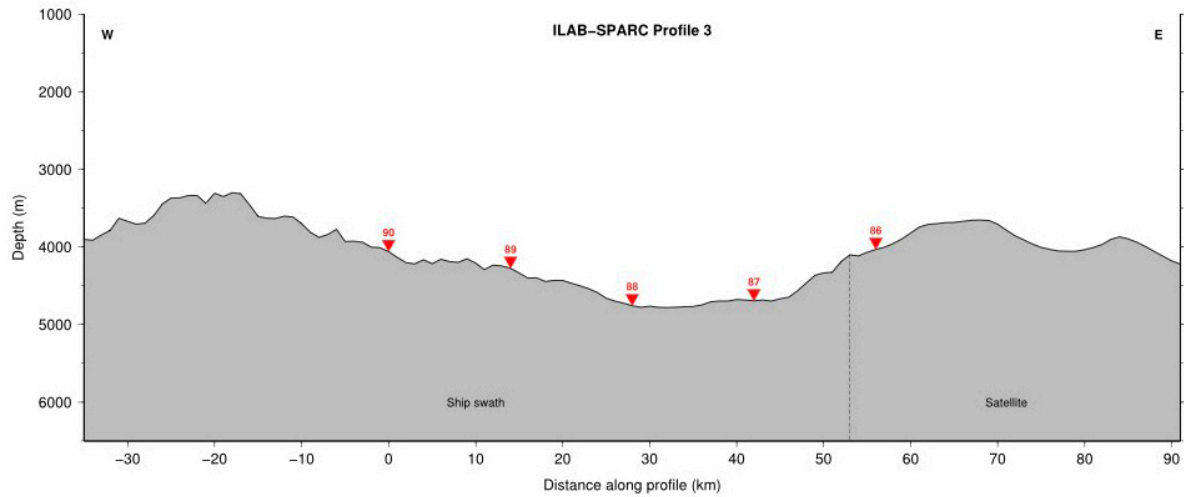


Figure 5.5 - Bathymetry profile along the line ILAB-SPARC\_05 with the location of 5 OBSs (from 86-90) that were deployed. The locations of OBSs are marked in red triangles.

Recovery - The OBS recovery started on September 20th at 12:50 (UTC) and ended on September 26th at 20:41 (Table 5.2). The recovery time for OBSs varied from 1.5 h to 2.5 hours.

Line ILAB-SPARC\_01

OBS number	OBS deployment							OBS Recovery				
	date	time	lat	long	distance between OBSs	water depth (m)	NOTES	date	time	lat	long	NOTES
1	30/08/2018	5:07	03°05.725N	18°02.785W	14.279	4861		09/09/2018	18:43	03°05.997N	18°02.794W	
2	30/08/2018	5:50	02°58.508N	18°01.388W	14.279	4953		08/09/2018	20:33	02°58.340N	18°01.810W	
3	30/08/2018	6:38	02°50.563N	18°00.437W	14.279	4919		08/09/2018	22:10	02°50.373N	18°00.509W	
4	30/08/2018	7:27	02°42.918N	17°59.908W	14.279	4820		08/09/2018	23:55	02°42.974N	17°59.240W	
5	30/08/2018	8:15	02°35.315N	17°58.034W	14.279	4712		09/09/2018	01:42	02°35.489N	17°58.137W	
6	30/08/2018	9:05	02°28.162N	17°56.211W	14.279	4955		09/09/2018	03:30	02°27.825N	17°56.985W	
7	30/08/2018	9:54	02°19.947N	17°55.605W	14.279	5072		09/09/2018	05:15	02°20.159N	17°55.355W	
8	30/08/2018	10:42	02°14.464N	17°54.425W	14.279	5088	XBT T7_0009 at 10:44	09/09/2018	07:14	02°12.598N	17°54.607W	
9	30/08/2018	11:30	02°04.798N	17°53.219W	14.279	5018	crossing St Paul at 10:56	09/09/2018	09:01	02°04.994N	17°53.141W	
10	30/08/2018	12:19	01°57.251N	17°52.052W	14.279	5308	in St. Paul	09/09/2018	10:46	01°57.297N	17°51.931W	
11	30/08/2018	13:07	01°49.65N	17°50.822W	14.279	5149		09/09/2018	12:48	01°49.795N	17°50.875W	
12	30/08/2018	13:56	01°42.028N	17°49.644	14.279	5217		09/09/2018	14:39	01°41.879N	17°49.659W	
13	30/08/2018	14:45	01°34.42N	17°48.47W	14.279	5279		09/09/2018	16:31	01°34.345N	17°48.565W	
14	30/08/2018	15:34	01°26.82N	17°47.264W	14.279	5148	XBT T_00010 at 15:58	09/09/2018	18:25	01°29.980N	17°47.406W	
15	30/08/2018	16:21	01°19.2N	17°46.06W	14.279	4811		09/09/2018	20:00	01°19.449N	17°46.355W	
16	30/08/2018	17:07	01°12.062N	17°44.927W	14.279	5337		09/09/2018	21:48	01°11.767N	17°45.130W	
17	30/08/2018	17:55	01°04.183N	17°43.706W	14.279	5424		09/09/2018	23:30	01°03.949N	17°43.936W	
18	30/08/2018	18:41	00°56.520N	17°42.501W	14.279	5421		10/09/2018	01:30	00°56.650N	17°42.848W	
19	30/08/2018	19:28	00°48.903N	17°41.300W	14.279	5341		10/09/2018	03:24	00°48.817N	17°41.679W	
20	30/08/2018	20:15	00°41.866N	17°39.705W	14.279	5120		10/09/2018	05:38	00°41.717N	17°40.858W	
21	30/08/2018	21:02	00°33.501N	17°38.870W	14.279	4008	Going over northern ridge of Romanche	10/09/2018	07:11	00°33.692N	17°39.308W	
22	30/08/2018	21:48	00°25.880N	17°37.660W	14.279	2808		10/09/2018	09:06	00°26.038N	17°37.938W	
23	30/08/2018	22:35	00°18.289N	17°36.495W	10.359	2659		10/09/2018	10:45	00°18.298N	17°36.811W	
24	30/08/2018	23:09	00°12.772N	17°35.641W	22.273	3099	XBT T5_00011	10/09/2018	12:06	00°12.810N	17°35.904W	
25	31/08/2018	00:16	00°00.879N	17°33.114W	8.612	5543	Crossing the Equator at 00:25	10/09/2018	14:01	00°00.860N	17°33.834W	Crossing the Equator
26	31/08/2018	00:45	00°03.699S	17°33.053W	15.874	5463		10/09/2018	16:00	00°03.576S	17°33.330W	
27	31/08/2018	01:36	00°12.166S	17°31.718W	14.279	2872		10/09/2018	17:22	00°12.099S	17°31.950W	
28	31/08/2018	02:20	00°19.773S	17°30.490W	14.279	4005		10/09/2018	18:55	00°19.369S	17°30.344W	
29	31/08/2018	03:06	00°27.367S	17°29.335W	14.279	3642		10/09/2018	20:17	00°27.230S	17°29.555W	
30	31/08/2018	03:51	00°34.997S	17°28.117W	14.279	4023		10/09/2018	21:45	00°34.823S	17°28.238W	
31	31/08/2018	04:37	00°42.585S	17°26.939W	14.279	3903		10/09/2018	23:07	00°42.585S	17°27.048W	
32	31/08/2018	5:21	00°50.225S	17°25.753W	14.279	3646		11/09/2018	00:38	00°50.219S	17°25.908W	
33	31/08/2018	6:05	00°57.587S	17°24.575W	14.279	3703		11/09/2018	02:17	00°57.839S	17°24.720W	
34	31/08/2018	6:47	01°05.202S	17°23.832W	14.279	3633		11/09/2018	03:48	01°05.471S	17°23.540W	
35	31/08/2018	07:30	01°12.775S	17°22.187W	14.279	3435		11/09/2018	05:24	01°12.981S	17°22.461W	

OBS number	OBS deployment							OBS Recovery				
	date	time	lat	long	distance between OBSs	water depth (m)	NOTES	date	time	lat	long	NOTES
36	31/08/2018	8:12	01°20.689S	17°20.956W	14,279	3599		11/09/2018	06:51	01°20.636S	17°21.150W	
37	31/08/2018	08:54	01°28.287S	17°19.759W	14,279	3737		11/09/2018	08:11	01°28.203S	17°20.006W	
38	31/08/2018	09:34	01°35.895S	17°18.571W	14,279	3452		11/09/2018	09:29	01°35.820S	17°18.659W	
39	31/08/2018	10:14	01°43.491S	17°17.396W	17,468	4243		11/09/2018	10:59	01°43.452S	17°17.382W	
40	31/08/2018	11:10	01°52.815S	17°15.889W	13,509	5118		11/09/2018	13:16	01°52.917S	17°15.760W	
41	31/08/2018	11:53	02°00.025S	17°14.814W	13,345	3874		11/09/2018	15:17	01°59.928S	17°14.785W	
42	31/08/2018	12:35	02°07.111S	17°13.592W	12,797	4222		11/09/2018	16:47	02°06.967S	17°13.564W	
43	31/08/2018	13:17	02°13.956S	17°12.575W	14,279	1710		11/09/2018	18:37	02°13.809S	17°12.800W	
44	31/08/2018	14:01	02°21.540S	17°11.370W	14,279	4412		11/09/2018	20:45	02°21.251S	17°11.310W	
45	31/08/2018	14:47	02°29.161S	17°10.180W	14,279	4412		11/09/2018	22:07	02°29.014S	17°09.986W	
46	31/08/2018	15:32	02°36.785S	17°09.010W	14,279	4892		11/09/2018	23:48	02°36.691S	17°08.787W	
47	31/08/2018	16:17	02°44.392S	17°07.793W	14,279	5013	XBT 14 at 16:36	12/09/2018	01:55	02°44.287S	17°07.573W	
48	31/08/2018	17:03	02°51.995S	17°06.590W	14,279	4370		12/09/2018	03:27	02°51.858S	17°06.421W	
49	31/08/2018	17:49	02°59.457S	17°05.411W	14,279	4568		12/09/2018	05:05	02°59.508S	17°05.291W	
50	31/08/2018	18:36	03°06.920S	17°04.233W	0,000	4516		12/09/2018	06:29	03°07.160S	17°04.249W	

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OBS number	OBS deployment							OBS Recovery				
	date	time	lat	long	distance between OBSs	water depth (m)	NOTES	date	time	lat	long	NOTES
51	12/09/2018	12:13	02°17.918S	17°13.203W	17,206	4800		20/09/2018	12:50	2°17.903S	17°13.202W	
52	12/09/2018	13:09	02°15.810S	17°04.153W	17,206	4475		20/09/2018	14:24	2°15.778S	17°04.181W	
53	12/09/2018	14:04	02°13.701S	16°55.112W	17,206	4417		20/09/2018	16:32	2°13.650S	16°55.162W	
54	12/09/2018	14:59	02°11.630S	16°46.550W	17,206	4479		20/09/2018	18:14	2°11.526S	16°40.037W	
55	12/09/2018	15:54	02°09.518S	16°37.007W	17,206	4042		20/09/2018	19:59	2°09.444S	16°37.124W	
56	12/09/2018	16:50	02°07.405S	16°27.936W	17,206	4387		20/09/2018	21:36	2°07.289S	16°28.134W	
57	12/09/2018	17:45	02°05.341S	16°18.865W	17,206	3872		21/09/2018	00:05	2°05.180S	16°18.048	
58	12/09/2018	18:40	02°03.220S	16°09.852W	17,206	4408		21/09/2018	01:38	2°03.092S	16°10.097W	
59	12/09/2018	19:35	02°01.120S	16°00.790W	17,206	4465		21/09/2018	04:01	2°00.935S	16°01.040W	
60	12/09/2018	20:30	01°59.013S	15°51.757W	17,206	3302		21/09/2018	06:00	1°58.627S	15°50.506W	
61	12/09/2018	21:27	01°56.902S	15°42.720W	17,206	4282		21/09/2018	07:41	1°56.839S	15°42.781W	
62	12/09/2018	22:23	01°54.785S	15°33.643W	17,206	3821		21/09/2018	09:44	1°54.724S	15°33.695W	
63	12/09/2018	23:18	01°52.634S	15°24.457W	17,206	4053		21/09/2018	11:11	1°52.541S	15°24.167W	
64	13/09/2018	00:13	01°50.600S	15°15.613W	17,206	3951		21/09/2018	12:32	1°50.465S	15°15.699W	
65	13/09/2018	01:13	01°48.481S	15°06.503W	17,206	4031		21/09/2018	13:56	1°48.478S	15°06.765W	
66	13/09/2018	02:06	01°46.377S	14°57.463W	17,206	3975		21/09/2018	15:58	1°46.237S	14°57.752W	
67	13/09/2018	02:59	01°44.277S	14°48.426W	17,206	3981		21/09/2018	17:26	1°44.037S	14°48.694W	
68	13/09/2018	03:53	01°42.163S	14°39.385W	17,206	3820		21/09/2018	19:02	1°42.526S	14°39.544W	
69	13/09/2018	04:48	01°40.056S	14°30.342W	17,206	3856		21/09/2018	20:25	1°39.908S	14°30.538W	
70	13/09/2018	05:41	01°37.978S	14°21.276W	17,206	3823		21/09/2018	21:50	1°37.770S	14°21.514W	
71	13/09/2018	06:36	01°35.818S	14°12.249	17,206	3841		21/09/2018	22:21	1°35.753S	14°12.484W	
72	13/09/2018	07:31	01°33.729S	14°03.253W	17,206	3780		22/9/2018	00:52	1°33.634S	14°03.443W	
73	13/09/2018	08:27	01°31.600S	13°54.167W	17,206	3682	XBT 19 at 09:00	22/09/2018	02:37	1°31.516S	13°54.436W	
74	13/09/2018	09:21	01°29.517S	13°45.112W	17,206	3657		22/09/2018	04:17	1°29.516S	13°45.209W	
75	13/09/2018	10:18	01°27.408S	13°36.085W	17,206	3361		22/09/2018	05:43	1°27.337S	13°36.215W	
76	13/09/2018	11:04	01°25.409S	13°27.629W	17,206	3012		22/09/2018	07:18	1°25.176S	13°27.060W	
77	13/09/2018	12:05	01°23.179S	13°18.120W	17,206	3012		22/09/2018	08:34	1°23.035	13°17.992W	
78	13/09/2018	13:04	01°21.053S	13°08.943W	17,206	2870	XBT 20 at 13:50	22/09/2018	09:43	1°20.992S	13°08.900W	
79	13/09/2018	13:58	01°18.918S	12°51.891W	17,206	3721		22/09/2018	11:11	1°18.930S	12°59.878W	
80	13/09/2018	14:52	01°16.804S	12°50.850W	17,206	2520		22/09/2018	12:58	1°16.138S	12°50.877W	
81	13/09/2018	15:45	01°14.680S	12°41.809W	17,206	2682		22/09/2018	14:47	1°14.531S	12°41.375W	
82	13/09/2018	16:39	01°12.562S	12°32.735W	17,206	2739		22/09/2018	16:30	1°12.384S	12°32.167W	
83	13/09/2018	17:32	01°10.439S	12°23.718W	17,206	3127		22/09/2018	18:05	1°10.353S	12°23.365W	
84	13/09/2018	18:26	01°08.369S	12°14.669W	17,206	3329		22/09/2018	19:19	1°08.394S	12°14.794W	
85	13/09/2018	19:28	01°06.184S	12°05.679W	17,206	3349	XBT 21 at 21:40	22/09/2018	20:41	1°06.270S	12°05.696W	

ILAB-SPARC\_05

OBS number	OBS deployment							OBS Recovery				
	date	time	lat	long	distance between OBSs	water depth (m)	NOTES	date	time	lat	long	NOTES
86	23/09/2018	01:28	00°48.742S	12°55.834W	14	3856		26/09/2018	12:41	00°48.792S	12°55.592W	Last OBS recovered
87	23/09/2018	2:13	00°50.903S	13°03.069W	14	4696		26/09/2018	11:15	00°50.873S	13°02.906W	
88	23/09/2018	2:59	00°53.022S	13°10.318W	14	4753	XBT T7_00022 at 2:37	26/09/2018	9:43	00°53.020S	13°10.151W	
89	23/09/2018	3:45	00°55.147S	13°17.569W	14	4261		26/09/2018	8:08	00°55.088S	13°17.549W	
90	23/09/2018	4:31	00°57.250S	13°24.83W	14	4055		26/09/2018	6:19	00°57.196S	13°24.859W	

## ILAB-SPARC

### 5.4 OBS Data Processing:

The data from the data-logger in the MicroOBS is converted to .SAC format for all the four components i.e., hydrophone, vertical and two horizontal components. These .sac files are usually a continuous recording of the ground motion by the OBS from the time of deployment till the recovery unless a start and end time are programmed in to the OBS before deployment. Using the `Mcc_process` software provided by IFREMER, the shot navigation file, a .dec file and the .sac file is cut in to individual traces at various shot times and merged in to a SEG-Y file.

The navigation file (.nav) is of the following format delimited by a whitespace:  
Shot number, dd/mm/yyyy, Shot time, Shot Latitude, Shot Longitude

The OBS file (.dec) is of the following format delimited by a whitespace:

Name of the survey, First shot number, Last shot number, Shot delay, Air gun depth, OBS depth, OBS latitude, OBS longitude, the time interval in seconds to cut for each shot

The SEG-Y file that is obtained from the above software does not contain the offset header information. The offset is calculated for each trace using the OBS and shot co-ordinates and then added to the header of the SEG-Y file using sushw command in Seismic Unix.

The OBS data is filtered between 3 and 20 Hz using Seismic Unix and Predictive deconvolution is applied to the data by generating the source wavelet from minimum and maximum lag obtained by the auto correlation of the data. Offset gain has been applied to the data to improve Signal-to-Noise ratio at the far offsets. The data is plotted with a reduction velocity of 8km/s.

#### 5.4 OBS Data file summary

##### ***ILAB-SPAR-01:***

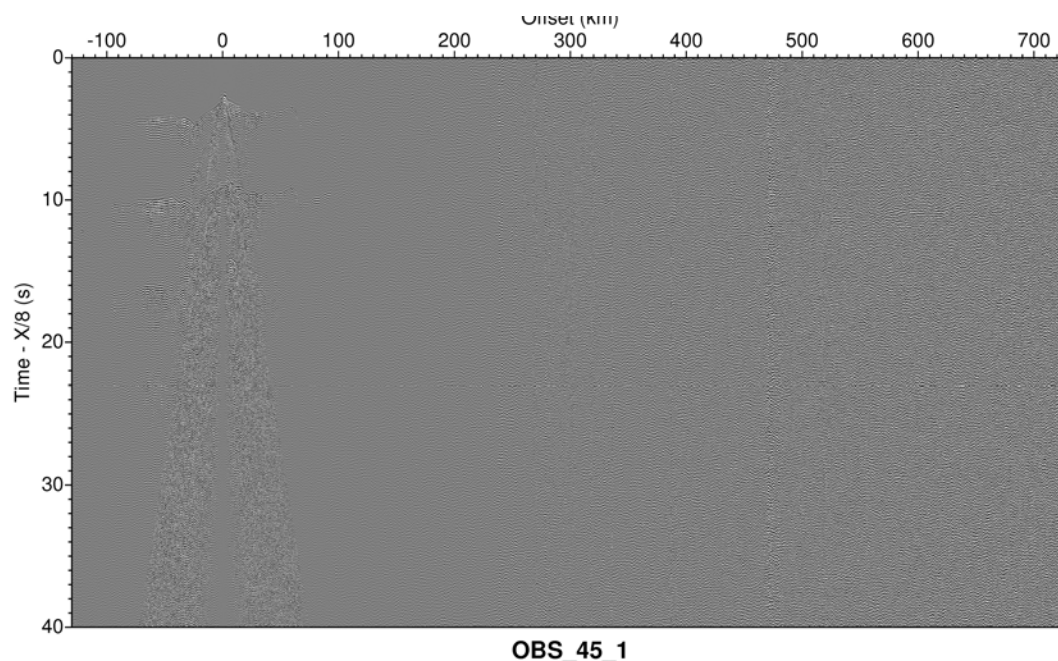


Fig 5.6: Hydrophone component of OBS45 with Pn arrivals up to 730 km

We have deployed 50 IFREMER MicroOBS along 858 km long profile crossing the St.Paul fracture zone, Romanche transform fault and Chain fracture zone running along the deep seismic reflection profile. The OBS are spaced at a constant distance of 14.2 km all along the profile. A total of 2867 shots were fired in equal distance with 300 m shot spacing. The average vessel speed was around 3.8 knots. An example of OBS45 is shown in the Fig 5.6.

*OBS01:* This was the northern most OBS on the profile. The shot line was extended 100 km further north of this OBS. The OBS lies at shot position 2532 and water depth is 4768 m. The water wave arrival is at 3.2s. There are Pn arrivals until 100 km on the North and up to 200 km on the south. The arrivals on the vertical component are rather weak. We see P-S converted waves on the horizontal component clearly up to 200 km to the south.

*OBS02:* This OBS lies the shot position 2485 and water depth is 4873 m. The water wave arrival is at 3.2s. We see Pn arrivals up to 200 km clearly in the south and 70 km in the north both in the hydrophone and vertical component. We see P-S converted waves on the horizontal component

clearly up to 200 km to the south. S-waves are much stronger on the horizontal components up to 200 km to the south and 100 km to the North.

*OBS03:* This OBS lies at the shot position is 2437 and water depth is 4872 m. The water wave arrival is at 3.2s. We see Pn arrivals up to 150 km clearly in the south and 100 km in the north in the hydrophone. Multiples are much stronger in the hydrophone component up to 200 km. PmP can be followed up to 70 km on both sides. Pn arrivals can be followed till 200 km to the south in the vertical component. The arrivals on horizontal X component are weak whereas we see some energy in the horizontal Y component up to 600 km offset which is P-S converted energy.

*OBS04:* This OBS lies at the shot position 2389 where the water depth is 4717 m. The water wave arrival is at 3.15s. We see Pn arrivals up to 150 km in the south and 40 km in the north. In the multiple Pn arrivals can be followed till 145 km to the north. PmP can be followed up to 30 km on both sides. Pn arrivals are similar to hydrophone on the vertical component. The P-S converted arrivals on horizontal X component are up to 200 km offset to the south and 100 km to the north. S-waves are stronger on this component and can be followed until 200 km to the south and 150 km to the north.

*OBS05:* This OBS lies at the shot position is 2342 where water depth is 4666 m. The water wave arrival is at 3.11s. We see Pn arrivals up to 60 km in the south and 100 km to the north in the hydrophone. There is some dipping energy in the multiple between 20 to 40 km to the south, which could be a reflection. In the vertical component, Pn arrivals are until 50 km to the south and 40 km to the north. There are S-wave arrivals until 60 km to the north and 30 km to the south. Horizontal components are weak and noisy.

*OBS06:* This OBS lies at the shot position is 2294 where water depth is 4972 m. The water wave arrival is at 3.31s. There are Pn arrivals up to 200 km in the south and 170 km in the north in the hydrophone. There is a dipping arrival between 20 – 40 km offset to the south which could be a reflection and which was seen on the previous OBS. This OBS did not record vertical and horizontal components.

*OBS07:* The shot number at this OBS is 2247 and water depth is 5075 m. The water wave arrival is at 3.38s. There are Pn arrivals up to 130 km in the south and 60 km in the north both in the hydrophone and vertical component. The P-S converted arrivals on horizontal X component are very strong and can be followed up to 450 km to the south and 190 km to the north. S-waves can be seen up to 160 km offset to the south and 130 km to the north. Also we see a strong dipping event between 170 km to 100 km in the north in the multiple on this channel. S – waves on horizontal – y component can be followed until 170 km to the south and 190 km to the north. There are some P-S converted arrivals at 450 km offset to the south.

*OBS08:* The shot number at this OBS is 2199 and water depth is 4986 m. The water wave arrival is at 3.32s. We see Pn arrivals up to 100 km clearly in the south and up to 200 km in the north both in the hydrophone and vertical component. The P-S converted arrivals on horizontal X component can be followed up to 500 km to the south and 200 km to the north. S-waves can be seen up to 170 km to the south and 200 km to the north. Horizontal – y component is similar to x component but much weaker.

*OBS09:* The shot number for this OBS is 2152 and water depth is 5022 m. The water wave arrival is at 3.35s. We see Pn arrivals up to 100 km clearly in the south and 220 km to the north in the hydrophone. Vertical component is similar to hydrophone but with P-S converted arrivals and much weaker arrivals. The P-S arrivals on horizontal X component are stronger on the north till 220 km and till 120 km to the south. The multiples are much stronger to the south up to 300 km. In the horizontal – y component, we see P-S arrivals are up to 220 km to the north and 480 km to the south. Multiples can be seen up to 300 km to the south.

*OBS10:* The shot number for this OBS is 2103 and water depth is 5299 m. The water wave arrival is at 3.53s. We see Pn arrivals up to 130 km clearly in the south and 230 km in the north in the hydrophone. Multiples are similar but much stronger. Vertical component is similar to the hydrophone. The arrivals on horizontal X component are similar to vertical component and S-waves are much stronger to the north until 230 km. On Y component, we have P-S arrivals until 230 km to the north and arrivals from south are very weak and not visible. Multiples are stronger to the north. There is some dipping energy between 100 km and 150 km to the south and this could be a reflection.

*OBS11:* This OBS lies at the shot position 2056 where water depth is 5152 m. The water wave arrival is at 3.44s. We see Pn arrivals up to 120 km clearly in the south and 130 km in the north in the hydrophone. Pn arrivals can be followed till 200 km to the north and 130 km to the south S – waves can be followed up to 250 km on the north and 80 km to the south on the vertical component. PmP can be followed up to 70 km on both sides. The arrivals on horizontal components are weak except for S -waves.

*OBS12:* The shot number at this OBS is 2008 and water depth is 5225 m. The water wave arrival is at 3.48s. We see Pn arrivals up to 100 km clearly in the south and 200 km in the north in the hydrophone. Multiples are much stronger in the hydrophone component up to 220 km in the south. Vertical component is very noisy on this OBS. The arrivals on horizontal X component are seen to the south till 230 km, till the location of Romanche. We see two parallel arrivals, one of which could be the Pn and other being P-S converted arrival. Horizontal – y component is noisy.

*OBS13:* The shot number for this OBS is 1960 and water depth is 5286 m. The water wave arrival is at 3.52s. We see Pn arrivals up to 220 km clearly in the south and 230 km in the north in the hydrophone. PmP arrivals are much stronger on this channel up to 60 km to the south and 50 km to the north. We see some energy in the multiples until 400 km to the south. Pn arrivals are weaker on the vertical component. We see P-S arrivals on horizontal X component till 350 km to the south and 230 km to the north. Y component is weak.

*OBS14:* The shot number for this OBS is 1913 and water depth is 5153 m. The water wave arrival is at 3.44s. We see Pn arrivals up to 220 km clearly in the south and 200 km in the north in the hydrophone. PmP arrivals are up to 50 km to the south and 60 km to the north. Vertical component is noisy. There are P-S arrivals till 330 km south and 170 km to the north in x component. Y component is similar but noisy.

*OBS15:* This OBS lies at the shot position is 1865 where water depth is 4808 m. The water wave arrival is at 3.21s. We see Pn arrivals up to 200 km clearly in the south and 230 km in the north in the hydrophone. Vertical component is similar to the hydrophone. X component is noisy. We see S- waves up to 250 km to the north in y component.

*OBS16:* This OBS lies at the shot position is 1818 where water depth is 5377 m. The water wave arrival is at 3.59s. We see Pn arrivals up to 430 km clearly in the south and 200 km in the north in the hydrophone. PmP arrivals are up to 70 km to the south and 60 km to the north. Pn arrivals are up to 220 km on both sides on the vertical component. X and Y components are similar to hydrophone.

*OBS17:* The shot number for this OBS is 1770 and water depth is 5427 m. The water wave arrival is at 3.62s. We see Pn arrivals up to 170 km clearly in the south and 100 km in the north in the hydrophone. Vertical component is noisy. X component is noisy whereas in y component we have P-S arrivals up to 200 km to the north and 60 km to the south. Multiples are much stronger and we have arrivals up to 200 km to the south and 330 km to the north.

*OBS18:* The shot number for this OBS is 1723 and water depth is 5391 m. The water wave arrival is at 3.59s. We see Pn arrivals up to 400 km clearly in the south and 220 km in the north in the

hydrophone. Vertical component is much stronger than the hydrophone and has continuous Pn and P-S arrivals up to 400 km to the south and 250 km to the north. Multiples are weaker on this channel. Both horizontal components are stronger in P-S arrivals similar to vertical component.

*OBS19:* The shot number for this OBS is 1675 and water depth is 5391 m. The water wave arrival is at 3.59s. We see Pn arrivals up to 320 km clearly in the south and 360 km in the north in the hydrophone. Multiples are stronger to the north and weaker to the south. We see some secondary arrivals between 150 and 250 km to the north, which could be a reflection. Vertical and x components are noisy. In y component we have P-S arrivals until 150 km to the south and 200 km to the north.

*OBS20:* OBS 20 is at the bottom part of the start of northern flank of Romanche Transform fault. The shot position is 1627 and water depth is 5022 m. The water wave arrival is at 3.35s. In the hydrophone, we see Pn arrivals up to 370 km to the south and 120 km to the north. There is some energy at long offsets of up to 400 km to the north but buried in the noise. Surprisingly multiples are rather weak on the hydrophone. PmP can be followed up to 80 km on the North side. On the vertical component, the SNR is weak but there are signs of Pn arrivals up to 350 km to the South. There are no visible arrivals on the horizontal components.

*OBS21:* OBS 21 is located on the northern flank of Romanche where the slope is very high. The shot position is 1580 and water depth is rather shallow at 3933 m. The water wave arrival is at 2.62s. In the hydrophone, we see Pn arrivals up to 100 km to the south and 140 km to the north, much less than the preceding OBS due to the scattering of the slope. PmP can be followed up to 90 km to the North. In the vertical component, P arrivals are very weak but S arrivals are particularly strong up to 150 km to the North. The horizontal components are very weak.

*OBS22:* OBS 22 is located on the top part of the northern flank of Romanche where the slope is very high. The shot position is 1532 and water depth is very shallow at 2760 m. The water wave arrival is at 1.84 s. In the hydrophone, we see Pn arrivals up to 160 km to the south and only 50 km to the north due to the slope of Romanche. There are arrivals starting from 170 km offset to the south but shifted from the Pn by 1-1.5 sec. This may be a local effect as we see it on all the OBS south of the same shot number. In the vertical component, Pn arrivals are weak but can be seen up to the same offset as in the hydrophone i.e., up to 140 km to the south and 50 km to the north. The horizontal components are very weak.

*OBS23:* OBS 23 is located on the top most part of the northern flank of Romanche where the slope is very high. The shot position is 1485 and water depth is the shallowest at 2705 m. The water wave arrival is at 1.8 s. In the hydrophone, we see Pn arrivals only up to 20 km to the south due to the slope and up to 120 km to the north. Surprisingly, there is some strong energy at 410 km offset to the north at the end of shooting profile. Multiples are rather weak. All other components are very weak.

*OBS24:* OBS 24 is located on a flat part of the northern flank of Romanche. The shot position is 1451 and water depth is the shallowest at 3064 m. The water wave arrival is at 2.04 s. In the hydrophone, we see Pn arrivals only up to 380 km to the south and only up to 30 km to the north due to the slope of Romanche. There is a shift of 1-1.5 s at around 100 km offset to the south as observed on all the preceding OBS. All other components are very weak.

*OBS25:* OBS 25 is located in the deep trench of Romanche. The shot position is 1376 and water depth is the deepest in the profile at 5548 m. The water wave arrival is at 3.7 s. This OBS is placed in such a way to avoid the deepest part of Romanche as IFREMER OBS are not designed to be deployed beyond 6000 m water depth. Hence the spacing between the previous OBS is larger than the usual at 22 km instead of 14.2 km. We see arrivals up to 400 km on either side and very strong multiples, because of very deep waters. We also see some dipping energy south around 100-150 km offset. There is a strong energy just before the multiples around 50-60 km

offset. The 1-1.5 sec shift in the Pn arrivals to the south is very clear on this OBS. In the vertical component, we see Pn arrivals only up to 60 km to the south and up to 110 km to the north but rather weak. Horizontal – X component is bad. Horizontal – Y component has P-S converted arrivals up to 100 km on both sides and also some energy at 450 km offset to the North. S-wave arrivals can be followed up to 150 km offset to the North.

*OBS 26:* OBS 26 is also located in the deep trench of Romanche. The shot position is 1348 and water depth is the deeper at 5469 m. The water wave arrival is at 3.65 s. In the Hydrophone component, we have Pn arrivals up to 100 km to the south and can be followed continuously up to 460 km on the North. We see some energy in the multiples till 300 km to the south. Around 50 km offset on both sides, there are arrivals just above the multiples. In the vertical component, arrivals to the south are weak but can be followed till 200 km to the north. In both horizontal components, we see continuous arrivals till 200 km to the north and around 110 km to the south and faint arrivals till 450 km north.

*OBS27:* OBS 27 is located on the southern flank of Romanche with high slope on either side. The shot position is 1295 and water depth is shallower at 3022 m. The water wave arrival is at 2.01 s. Due to the location of this OBS on top of the flank, the arrivals on the hydrophone component are very weak due to the sudden slope on either sides but we see faint energy until 230 km to the north and 40 km to the south on the hydrophone. All other components are also very weak.

*OBS28:* OBS 28 is located on relatively flat part south of Romanche Transform fault. The shot position is 1247 and water depth is 4009 m. The water wave arrival is at 2.67 s. In the hydrophone component, Pn arrivals are seen up to 70 km to the south and 230 km to the north. Whereas multiples are stronger in the north with arrivals up to 450 km. Pn arrivals are up to 70 km in the south and 200 km to the north in vertical component. In both horizontal components, first arrivals are similar to the hydrophone component i.e., up to 70 km to the south and 200 km to the north. Multiples are much stronger as in the horizontal components up to 470 km to the north and 200 km to the south.

*OBS 29:* OBS 29 is located on relatively flat part south of Romanche Transform fault. The shot position is 1199 and water depth is 3644 m. The water wave arrival is at 2.43 s. In the hydrophone component, Pn arrivals are seen up to 90 km to the south and 190 km to the north. The multiples are similar to the first arrivals with some arrivals seen at 400 km offset to the north. In the vertical component P arrivals are similar to hydrophone but with S wave arrivals till 100 km to the south. In both horizontal components, we see P-S converted waves and strong S-waves till 100 km to the south and 200 km to the north.

*OBS 30:* OBS 30 is located south of Romanche Transform fault. The shot position is 1152 and water depth is 4036 m. The water wave arrival is at 2.69 s. In the hydrophone component, Pn arrivals can be followed up to 70 km to the south and 170 km to the north. Multiples are weaker than the first arrivals. Vertical component is rather weak. In both horizontal components, P arrivals are weak but S-waves can be followed until 100 km to the south and 200 km to the north.

*OBS31:* OBS 31 is located south of Romanche Transform fault. The shot position is 1104 and water depth is 3907 m. The water wave arrival is at 2.61 s. In both hydrophone and vertical components, Pn arrivals can be followed only up to 50 km to the south and 70 km to the north. Surprisingly, in horizontal - x component, P-S converted arrivals can be followed until 60 km to the south and until 530 km to the north though they are weak. Multiples are stronger in the south till 250 km. S-wave arrivals are until 250 km to the north. In horizontal – y component, first arrivals are weaker and multiples are similar to the other horizontal component.

*OBS32:* OBS32 is in between Romanche and Chain in a relatively flat part of the profile. The shot position is 1056 and water depth is 3650 m. The water wave arrival is at 2.43 s. in the hydrophone component we see Pn arrivals till 40 km to the south and 200 km to the north. We see

strong PmP till 50 km to the south. Also we observe 1.5 s shift in the Pn arrivals very clearly in this OBS at 40 km offset, which was observed in previous OBS also. Vertical component is rather weak. Horizontal – x component is also weak whereas horizontal – y component has first arrivals till 230 km and multiples can be followed till 500 km.

*OBS 33:* OBS33 is in between Romanche and Chain in a relatively flat part of the profile. The shot position is 1009 and water depth is 3699 m. The water wave arrival is at 2.47 s. The hydrophone has Pn arrivals up to 35 km in the south and 70 km in the north. We observe the same shift in Pn as in the previous OBS and also the PmP arrivals. Vertical component is weak. In both horizontal components, we see Pn arrivals similar to the hydrophone component but weaker.

*OBS34:* OBS34 is in between Romanche and Chain in a relatively flat part of the profile. The shot position is 961 and water depth is 3627 m. The water wave arrival is at 2.42 s. The hydrophone has Pn arrivals up to 35 km in the south and 70 km in the north. Vertical component is weak. There are strong S-wave arrivals till 50 km to the south and 30 km to the north in both horizontal components.

*OBS35:* OBS35 is in between Romanche and Chain in a relatively flat part of the profile. The shot position is 913 and water depth is 3618 m. The water wave arrival is at 2.41 s. The hydrophone has Pn arrivals up to 50 km in the south and 50 km in the north. All other components have arrivals till 35 km to the south and 50 km to the north.

*OBS36:* OBS36 is close to Chain fracture zone in a relatively flat part of the profile. The shot position is 866 and water depth is 3618 m. The water wave arrival is at 2.41 s. we see Pn arrivals up to 90 km to the south and 60 km to the north. We see some dipping energy to the north of this OBS between 30 and 60 km. On other components we only see arrivals up to 40 km on either side. This may be because of the close proximity of the OBS to chain fracture zone.

*OBS 37:* OBS37 is close to Chain fracture zone in a relatively flat part of the profile. The shot position is 818 and water depth is 3731 m. The water wave arrival is at 2.49 s. We see Pn arrivals up to 40 km to the south and 50 km to the north. PmP arrivals can be seen up to 50 km to the south and 60 km to the North. Surprisingly, we see Pn arrivals till 500 km to the north on the vertical component in both first arrivals and multiples. There are arrivals also in the horizontal components till 500 km to the north.

*OBS38:* OBS38 is on the northern flank of Chain fracture zone. The shot position is 770 and water depth is 3546 m. The water wave arrival is at 2.36 s. We see Pn arrivals up to 110 km to the south and 50 km to the north. PmP arrivals can be seen up to 70 km to the north. There are very faint Pn arrivals till 400 km offset to the north. On all other components, we see Pn arrivals only until 50 km on either side of the OBS.

*OBS 39:* OBS39 is on the northern flank of Chain fracture zone on the sloping towards south. The shot position is 723 and water depth is 4269 m. The water wave arrival is at 2.85 s. We see Pn arrivals up to 120 km to the south and 45 km to the north. There are PmP arrivals up to 60 km to the north and we see some dipping energy between 90 to 100 km twice with 2 seconds interval south of the OBS in the multiple. The first arrivals on the vertical component are very weak but we see some energy in the multiple between 300 and 600 km. The horizontal components are very weak and we do not see any arrivals.

*OBS 40:* OBS40 is in the deepest part of Chain fracture zone. The shot position is 665 and water depth is 5118 m. The water wave arrival is at 3.41 s. We see Pn arrivals up to 80 km to the south and 60 km to the north. The multiples are strong and we see some dipping energy between 70 and 90 km to the south and Pn arrivals till 600 km though they are not strong. Vertical component is very weak. The horizontal components are also very weak, yet we see faint arrivals in the multiples of the x component.

*OBS 41:* OBS41 is on the top most part of the southern flank of Chain fracture zone. The shot position is 619 and water depth is 3879 m. The water wave arrival is at 2.59 s. We see Pn arrivals up to 70 km to the south and 600 km to the north. Multiples are weak on the northern side but stronger on the southern side up to 75 km. We see some dipping energy at around 50 to 70 km south of the OBS in the multiples. Vertical component is very weak but there are signs of Pn arrivals at offsets up to 550 km. The horizontal components are very weak, may be because of the location of the OBS on the top part of the flank of the Chain fracture zone.

*OBS42:* OBS42 is south of Chain fracture zone. The shot position is 575 and water depth is 4241 m. The water wave arrival is at 2.83 s. We see Pn arrivals up to 65 km to the south and 600 km to the north. The Pn arrivals are very strong on this OBS as it is located on much more older crust as compared to the previous OBS. Multiples are similar to the first arrival. Vertical and horizontal components are rather noisy except for S-wave arrivals till 100 km to the north and 60 km to the south in the vertical component.

*OBS 43:* OBS43 is south of Chain fracture zone. The shot position is 532 and water depth is 4719 m. The water wave arrival is at 3.15 s. We see Pn arrivals up to 80 km to the south and 600 km to the north but very weak at far offsets. We see some arrivals to the south of the OBS in the multiple, which we do not see in the first arrival. It could be a PmP arrival from the mantle but which is very weak in the first arrival. Vertical component is very noisy. There are some arrivals in the horizontal components until around 600 km but the channels are too noisy.

*OBS 44:* OBS44 is south of Chain fracture zone. The shot position is 485 and water depth is 4437 m. The water wave arrival is at 2.96 s. We see Pn arrivals up to 80 km on either sides. We see S - wave arrivals on both vertical and horizontal – y components until 100 km. Horizontal – x component is very weak and we do not see any arrival on this channel.

*OBS 45:* OBS45 is south of Chain fracture zone. The shot position is 437 and water depth is 4246 m. The water wave arrival is at 2.83 s. We see Pn arrivals up to 130 km to the south and 730 km to the north. This OBS has by far the best SNR at far offsets of up to 730 km in the whole profile. Vertical component is rather weak. But horizontal – X component has very strong P-S converted arrivals until 730 km, which is till the end of the profile. Horizontal – y component is very noisy and we do not see any signal in this channel.

*OBS 46:* OBS46 is south of Chain fracture zone and is located in the trench of the propagator. The shot position is 389 and water depth is 4846 m. The water wave arrival is at 3.23 s. We see strong Pn arrivals up to 80 km to the south and 110 km to the north. We can see some Pn arrivals in the multiple until 600 km but very faint and weak. Vertical component is very weak and noisy. Horizontal components are noisy too but some faint arrivals are buried in the noise at far offsets. This OBS is too noisy, may be because of its presence in the propagator.

*OBS 47:* OBS47 is south of Chain fracture zone and is located in the trench of the propagator. The shot position is 342 and water depth is 4869 m. The water wave arrival is at 3.25 s. We see strong Pn arrivals up to 70 km to the south and 60 km to the north. All other channels are very noisy in this OBS.

*OBS 48:* OBS48 is south of Chain fracture zone and is located on the southern flank of the propagator. The shot position is 294 and water depth is 4218 m. The water wave arrival is at 2.81 s. Pn arrivals are seen up to 50 km on either sides. PmP can be followed up to 60 km. All other channels are very noisy and no signal can be seen at all. This may be due to the location of the OBS on the southern side of the propagator.

*OBS 49:* OBS49 is south of the propagator. The shot position is 246 and water depth is 4327 m. The water wave arrival is at 2.88 s. Pn arrivals are seen up to 70 km on either side of the OBS in

the hydrophone component. Vertical component is very noisy. Horizontal components have P-S converted arrivals until 50 km to the south and 70 km to the north. Horizontal – x component has some arrivals at 650 km to the north but very faint.

*OBS 50:* OBS50 is south of the propagator and is the last OBS in this profile. The shot position is 199 and water depth is 4569 m. The water wave arrival is at 3.05 s. Pn arrivals are seen up to 70 km on the south and 80 km to the north in the hydrophone channel and vertical component. Both the horizontal components have P-S converted arrivals till 60 km to the south and 80 km to the north.

### ***ILAB-SPARC-02***

We have deployed 35 IFREMER MicroOBS along 791 km long profile running across the ridge-axis from 26 Ma till 0 Ma and then to 5 Ma to the east of the ridge axis. The OBS are spaced at a constant distance of 17.2 km all along the profile. A total of 2672 shots were fired in equal distance with 300 m shot spacing. The average vessel speed was around 3.8 knots. An example of a receiver gather for OBS 53 is shown in the Fig.5.7.

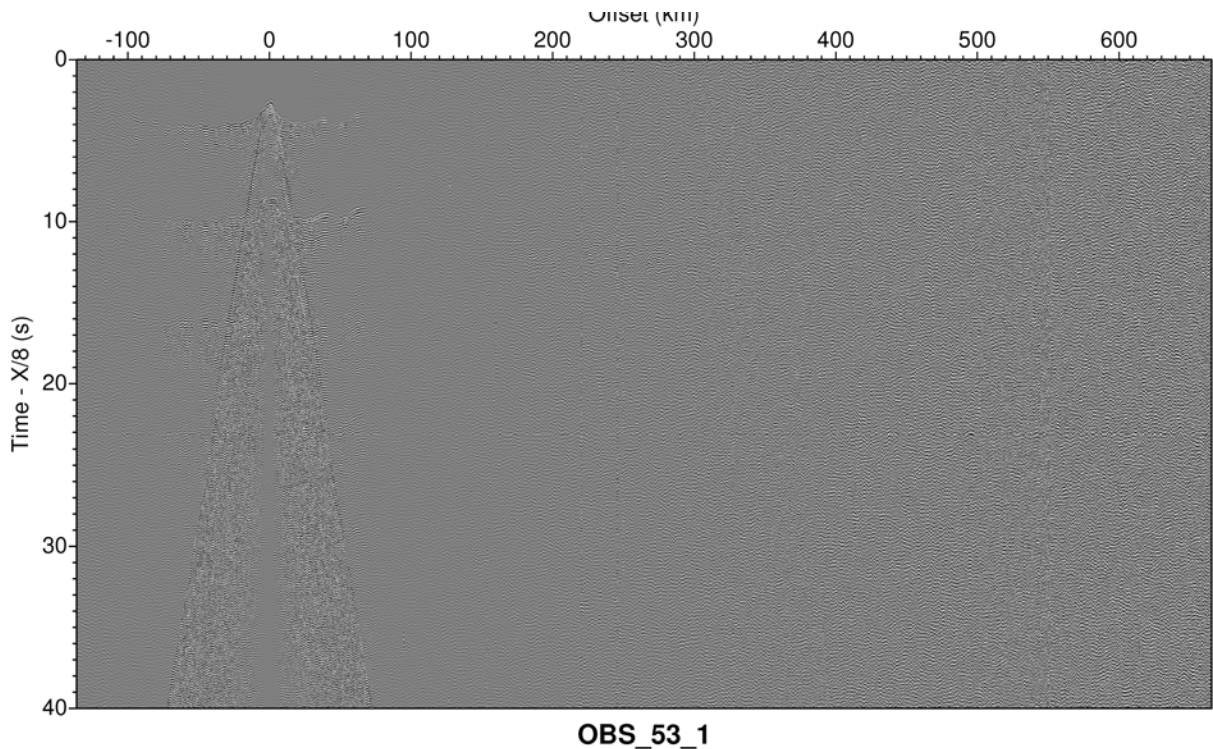


Fig. 5.7: Hydrophone component of OBS53 with reflection arrival between 150 and 300 km

*OBS 51:* OBS51 is the westernmost OBS in this profile. The shot position is 2333 and water depth is 4914 m. The water wave arrival is at 3.28 s. We see Pn arrivals up to 100 km on both sides of the OBS. There is a reflection arrival to the east between 250 km to 400 km offset, which is 150 km long and could be from 60 – 80 km deep. This reflection could be from the LAB or G' discontinuity in the mantle. PmP arrivals are strong till 40 km to the west and 30 km to the east. The vertical component is similar to the hydrophone but without the reflection energy. Both horizontal components are noisy except for S – wave arrivals till 100 km to the east.

*OBS52:* The shot position is 2276 and water depth is 4811 m. The water wave arrival is at 3.21 s. We see Pn arrivals up to 120 km to the west and 80 km to the east. The reflection event seen in

the previous OBS is absent on this OBS due to noise. Vertical component is noisy but we see S-wave arrivals till 100 km to the west. X component does not have any data. Y component has P-S arrivals till 100 km to the west and some reflection energy between 300 and 400 km to the east.

*OBS 53:* The shot position is 2218 and water depth is 4623 m. The water wave arrival is at 3.08 s. We see Pn arrivals up to 120 km to the west and 90 km to the east. PmP arrivals are seen on both sides at near offsets. The reflection arrival seen on OBS51 is seen again on this OBS to the east between 160 km to 310 km offset. This implies that the reflection event is changing with the position of the OBS and hence it is from the fixed boundary in depth. This arrival is more stronger in the multiple than the first arrival. There could be a secondary reflection event after the main reflection but needs more processing to find it. Vertical component is noisy but see the first arrivals till 80 km on both sides. Horizontal components do not have any data.

*OBS54:* The shot position is 2161 and water depth is 4479 m. The water wave arrival is at 2.99 s. We see Pn arrivals up to 120 km to the west and 90 km to the east. PmP arrivals are seen on both sides till 35 km. Multiples have better SNR. Vertical component is similar to hydrophone but more noisy. In horizontal components, we can follow the S-wave arrivals until 170 km to the east.

*OBS55:* The shot position is 2104 and water depth is 3984 m. The water wave arrival is at 2.66 s. We see Pn arrivals up to 100 km to the west and 120 km to the east. There are strong S – wave arrivals between 25-35 km to the east. Vertical component is similar to the hydrophone. X component has no data. Y component has strong S -wave arrivals up to 200 km to the east and 50 km to the west.

*OBS56:* The shot position is 2047 and water depth is 4236 m. The water wave arrival is at 2.82 s. We see Pn arrivals up to 120 km on both sides. PmP can be seen up to 100 km to the east and 80 km to the west. We see a reflection arrival to the east from 170 km till 310 km more strongly in the multiple. Vertical component has Pn arrivals until 70 km to the west and 60 km to the east. X component has no data. Y component has strong S – wave arrivals until 230 km to the east and 60 km to the west.

*OBS57:* OBS 57 is on a local peak in the bathymetry. The shot position is 1989 and water depth is 3595 m. The water wave arrival is at 2.4 s. We see Pn arrivals up to 75 km to the west and 90 km to the east. Vertical component is noisy but Pn arrivals can be followed until 80 km to the west and 90 km to the east. There is no data on the horizontal components.

*OBS58:* The shot position is 1932 and water depth is 4422 m. The water wave arrival is at 2.95 s. We see Pn arrivals up to 80 km to the west and 130 km to the east. On the vertical component we see Pn arrivals until 60 km to the west and 100 km to the east. There are strong S-wave arrivals until 200 km to the east. On both horizontal components, we see S-waves until 180 km to the east. We see some dipping energy from 200 – 300 km to the east, which could be a reflection.

*OBS59:* The shot position is 1875 and water depth is 4439 m. The water wave arrival is at 2.96 s. We see Pn arrivals up to 100 km to the west and 170 km to the east. We again see the reflection arrival very clearly on this OBS starting from around 160 km to the east till 320 km. There seems to be two reflections again which needs more processing to confirm. On the vertical component, there are Pn arrivals until 80 km to the west and 40 km to the east. There is reflection energy starting from 140 km to the east till 250 km. X component has no data. Y component has P-S arrivals until 80 km to the west and 100 km to the east. Strangely we see very strong reflection/dipping energy in the multiple starting from 100 km to the east till 280 km. We also see a dipping energy to the west from 170 km till 240 km. This channel needs more processing as there are multiple reflection arrivals on either sides.

*OBS60:* The shot position is 1820 and water depth is 3290 m. The water wave arrival is at 2.19 s. We see Pn arrivals up to 100 km on both sides. PmP is seen very clearly up to 80 km to the east

and 40 km to the west. Multiple is stronger to the west. Vertical component is noisy with Pn arrivals up to 40 km to the west and 60 km to the east. Both horizontal components are noisy but have dipping arrivals as seen in the previous OBS.

*OBS61:* The shot position is 1727 and water depth is 4286 m. The water wave arrival is at 2.86 s. We see Pn arrivals up to 120 km on either side. PmP can be followed until 80 km on both sides. There are reflection arrivals between 170 and 250 km to the east. On vertical component we see S-waves until 120 km to the west and 100 km to the east. We see reflection energy on both sides but needs more processing to improve SNR. X component has S -wave arrivals till 170 km to the west and 110 km to the east. We see dipping energy/reflections similar to the previous OBS. Y component has no data.

*OBS62:* The shot position is 1671 and water depth is 3806 m. The water wave arrival is at 2.54 s. We see Pn arrivals up to 100 km to the west and 80 km to the east. In vertical component, Pn arrivals are up to 80 km to west and 50 km to the east. We see dipping energy in the multiple between 120 km to 250 km to the east. X component is noisy and does not have any data. Y component is similar to the vertical component and has reflection energy from 100 to 250 km to the east and 150 to 200 km to the west on the multiple.

*OBS63:* The shot position is 1614 and water depth is 4037 m. The water wave arrival is at 2.69 s. We see Pn arrivals up to 100 km on both sides. PmP is very clear to the east up to 100 km to the east. We see dipping energy to the east from 120 km till 220 km, which could be the same reflection on all the previous OBS. On vertical component, S-waves are stronger to the west till 200 km and 100 km to the east. X component is noisy and has no data. Y component is similar to vertical component and has reflection energy from 130 km to 230 km to the east.

*OBS64:* The shot position is 1556 and water depth is 3935 m. The water wave arrival is at 2.62 s. We see Pn arrivals up to 110 km to the west and 80 km to the east. PmP arrivals are up to 70 km to the east and 60 km to the west. Vertical component is weak and has Pn arrivals only up to 40 km to the west and 50 km to the east. X component has P-S arrivals up to 100 km on both sides, Y component has up to 60 km on both sides. Both components have reflection energy around 150 km till 230 km.

*OBS65:* The shot position is 1499 and water depth is 4008 m. The water wave arrival is at 2.67 s. We see Pn arrivals up to 50 km to the west and 80 km to the east. In the vertical component, there is a clear reflection arrival from 80 km to 230 km. X and Y components are noisy and have no data.

*OBS66:* The shot position is 1442 and water depth is 3960 m. The water wave arrival is at 2.64 s. We see Pn arrivals up to 80 km to the west and 130 km to the east. S – waves can be seen up to 130 km to the east. On the vertical component, there are Pn arrivals up to 50 km on both sides but mostly noisy. X component is noisy and has no data. We have S – wave arrivals up to 160 km to the east and 80 km to the west. We see some energy in the multiple at around 200 km to the west.

*OBS67:* The shot position is 1384 and water depth is 3944 m. The water wave arrival is at 2.63 s. We see Pn arrivals up to 90 km to the west and 140 km to the east. PmP arrivals are stronger on this channel up to 60 km on both sides. In multiples there are some arrivals at 170 km to the west. Vertical and x-component are more ringy and noisy. Y-component has no data.

*OBS68:* The shot position is 1327 and water depth is 3813 m. The water wave arrival is at 2.54 s. We see Pn arrivals up to 100 km to the west and 110 km to the east. Vertical component is noisy at far offsets and arrivals only up to 50 km on both sides. Horizontal components are similar and ringy. S-wave arrivals can be seen up to 130 km and some reflection arrivals between 80 km and 150 km to the east. Also multiples are much stronger to the west till 200 km to the west.

*OBS69:* The shot position is 1269 and water depth is 3846 m. The water wave arrival is at 2.56 s. We see Pn arrivals up to 70 km to the west and 90 km to the east. PmP can be seen up to 50 km on both sides. Vertical component is similar to the hydrophone with S waves up to 110 km to the east and 100 km to the west. Horizontal components are ringy and have reflection energy between 60 and 160 km to the east.

*OBS70:* The shot position is 1212 and water depth is 3825 m. The water wave arrival is at 2.55 s. We see Pn arrivals up to 80 km to the west and 60 km to the east. PmP arrivals are stronger up to 60 km on both sides. Multiples are stronger to the west until 120 km. Vertical component is noisy at far offsets but has arrivals up to 40 km on either sides. Horizontal components are ringy but have S wave components up to 120 km to the east and Pn arrivals till 300 km to the west in the multiples. There are some reflection events from 70 km till 130 km to the east.

*OBS71:* The shot position is 1155 and water depth is 3834 m. The water wave arrival is at 2.56 s. We see Pn arrivals up to 50 km on both sides. This channel is more noisy at far offsets compared to other OBS in this profile. There are PmP arrivals up to 50 km on both sides. Vertical component is similar to the hydrophone. P-S arrivals are up to 90 km to the west and 50 km to the east on the horizontal components. S waves can be seen up to 100 km to the east. There is some far offset energy in the multiples to the west.

*OBS72:* The shot position is 1097 and water depth is 3775 m. The water wave arrival is at 2.52 s. We see Pn arrivals up to 80 km to the west and 40 km to the east on hydrophone component. Otherwise this channel is weak. Vertical component is similar to the hydrophone but more noisy. Both the horizontal components are similar and ringy with S -wave arrivals up to 100 km to the east.

*OBS73:* The shot position is 1040 and water depth is 3678 m. The water wave arrival is at 2.45 s. We see Pn arrivals up to 120 km to the west and 90 km to the east on the hydrophone. PmP can be followed up to 50 km on both sides. Vertical component has Pn arrivals up to 80 km to the west and 60 km to the east. Horizontal components are noisy but P-S arrivals can be seen up to 400 km to the west and 50 km to the east on x component and 490 km to the west and 90 km to the east on the y component.

*OBS74:* The shot position is 982 and water depth is 3654 m. The water wave arrival is at 2.44 s. We see Pn arrivals up to 200 km to the west and 80 km to the east. Vertical component is noisy and has Pn arrivals only until 40 km on both sides. Horizontal components have no data.

*OBS75:* The shot position is 925 and water depth is 3350 m. The water wave arrival is at 2.23 s. We see Pn arrivals up to 200 km to the west and 80 km to the east. Vertical component has Pn arrivals until 200 km to the west and 60 km to the east. Horizontal components are noisy but P-S arrivals can be seen up to 200 km to the west on the multiples.

*OBS76:* The shot position is 867 and water depth is 3160 m. The water wave arrival is at 2.11 s. We see Pn arrivals up to 180 km to the west and 60 km to the east. PmP can be clearly seen up to 70 km to the west and 60 km to the east. Vertical component is more ringy and noisy but multiples have P-S arrivals up to 200 km to the west. X component has no data. Y component is more ringy but has energy in the multiples to the west until 200 km.

*OBS77:* The shot position is 810 and water depth is 3044 m. The water wave arrival is at 2.03 s. We see Pn arrivals up to 80 km to the west and 100 km to the east. Vertical component is noisy and has arrivals only up to 40 km on both sides. Horizontal components are similar to the vertical component.

*OBS78:* OBS 78 is on the western flank of the ridge axis. The shot position is 753 and water depth is 2869 m. The water wave arrival is at 1.91 s. We see Pn arrivals up to 50 km to the west

and 100 km to the east on the hydrophone. All other components have no data at all. This may be due to the scattering of the energy near the ridge axis due to rough sea floor.

*OBS79*: OBS 79 is exactly located on the ridge axis. The shot position is 695 and water depth is 3717 m. The water wave arrival is at 2.48 s. We see Pn arrivals up to 40 km to the west and 80 km to the east. PmP can be followed until 50 km to the west and 40 km to the east. Vertical component is noisy and has faint arrivals up to 40 km on either sides. X component has very faint arrivals and more noisy. Y component has no data.

*OBS80*: OBS 80 is located on the eastern flank of the ridge axis. The shot position is 638 and water depth is 2505 m. The water wave arrival is at 1.67 s. We see Pn arrivals up to 60 km to the west and 50 km to the east on the hydrophone. Vertical component has arrivals up to 40 km to the west and 50 km to the east but no data at far offsets. X component has P-S arrivals only up to 30 km on both sides. Y component has no data.

*OBS81*: The shot position is 580 and water depth is 2929 m. The water wave arrival is at 1.95 s. We see Pn arrivals up to 70 km to the west and 90 km to the east on the hydrophone. Vertical component is more ringy and noisy, nonetheless we see arrivals up to 50 km on either sides. Horizontal components have no data. This is due to the energy being scattered near the ridge axis.

*OBS82*: The shot position is 523 and water depth is 2855 m. The water wave arrival is at 1.9 s. We see Pn arrivals up to 60 km to the west and 80 km to the east. PmP arrivals can be seen up to 60 km to the east. Multiples have more energy to the west up to 90 km to the west. All other components have no data.

*OBS83*: The shot position is 466 and water depth is 3092 m. The water wave arrival is at 2.06 s. We see Pn arrivals up to 90 km to the west and 60 km to the east. PmP arrivals can be seen up to 70 km to the east and 40 km to the west. Vertical component is similar to the hydrophone. Horizontal components have arrivals up to 80 km to the west and 60 km to the east. Far offsets are more noisy.

*OBS84*: The shot position is 408 and water depth is 3334 m. The water wave arrival is at 2.22 s. We see Pn arrivals up to 60 km on either sides on hydrophone. PmP arrivals can be seen up to 50 km on either sides. Vertical component has only arrivals up to 40 km on both sides. Horizontal components are similar to the vertical component and more ringy and noisy.

*OBS85*: This is the last OBS in this profile and the easternmost. The shot position is 351 and water depth is 3542 m. The water wave arrival is at 2.36 s. We see Pn arrivals up to 80 km to the west and 60 km to the east. PmP arrivals can be seen up to 60 km to the west and 70 km to the east. Vertical component has Pn arrivals till 80 km to the west and 50 km to the east. X component has P-S arrivals up to 60 km to the west and 50 km to the east. Y component has no data.

### ***ILAB\_SPARC-03***

We have deployed 5 IFREMER MicrOBS along 151 km long profile running along the Chain transform fault and fracture zone. This profile is carried out to study the crustal variation from the transform fault to the fracture zone. The OBS are spaced at a constant distance of 14 km all along the profile. A total of 2023 shots were fired in equal distance with 80 m shot spacing. The average vessel speed was around 3.8 knots. An example of a receiver gather for OBS 90 is shown in the Fig. 5.8.

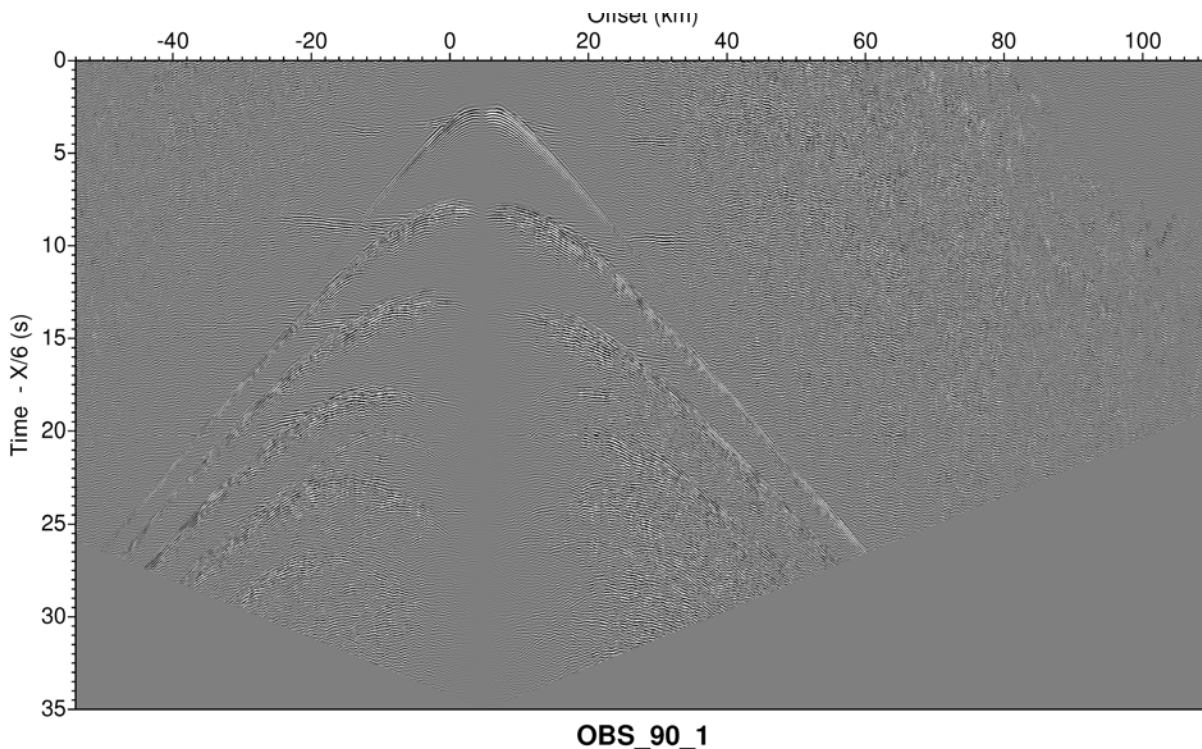


Fig 5.8: Hydrophone component of OBS90

*OBS86*: This is the easternmost OBS on this profile and is located on the fracture zone. The shot position is 545 and water depth is 4058 m. The water wave arrival is at 2.71 s. We see Pn arrivals up to 22 km to the west and 44 km to the east. PmP arrivals can be clearly seen to the east. Arrivals from the west are weaker. Multiples are much stronger than the first arrivals. Vertical component is similar to the hydrophone but more noisy. Horizontal components are more ringy and SNR is too low.

*OBS87*: This OBS is on the fracture zone. The shot position is 732 and water depth is 4274 m. The water wave arrival is at 2.85 s. We see Pn arrivals up to 30 km to the west and 40 km to the east. The arrivals at far offsets are masked by the water wave arrivals from previous shots. All other components are similar to the hydrophone and more noisy.

*OBS88*: This OBS is adjacent to the ridge axis and is located on the transform fault region of Chain. The shot position is 919 and water depth is 4755 m. The water wave arrival is at 3.17 s. We see Pn arrivals up to 22 km to the west and 36 km to the east. Vertical component is similar to the hydrophone. Horizontal components are very noisy have no arrivals.

*OBS89*: This OBS is on the Chain transform fault. The shot position is 1106 and water depth is 4695 m. The water wave arrival is at 3.13 s. We see Pn arrivals up to 30 km to the west and 24 km to the east. Vertical component is ringy and similar to hydrophone. Horizontal components are noisy.

*OBS90*: This is the westernmost OBS in this profile. The shot position is 1293 and water depth is 4031 m. The water wave arrival is at 2.69 s. We see Pn arrivals up to 42 km to the west and 28 km to the east. Vertical component is stronger on this OBS and has Pn arrivals up to 30 km to the west and 38 km to the east. We see a shadow zone on both hydrophone and vertical component

on this OBS between 10 km to 18 km on either sides of this OBS. X component is similar to the vertical channel. Y component is more noisy.

Notations used for the table below:

- All offsets are in kilometers
- M indicates the arrivals in multiples for the corresponding first-arrivals.
- / indicates faint arrivals at far offsets

**ILAB-SPARC PROFILE - 1**

OBS	Hydrophone		Vertical		Horizontal - X		Horizontal - Y		S arrivals Max. offset (N/S)
OBS01	100	200	60	130	100	200	60	200	100/200
OBS02	70	200	70	200	120	200	120	200	100/200
OBS03	100	150	70	200	-	-	90	600	70/200
OBS04	40/M145	150	40	150	100	200	-	-	150/200
OBS05	100	60	40	50	30	30	40	30	60/30
OBS06	170	200	-	-	-	-	-	-	-
OBS07	60	130	60	130	190	450	190	450	190/170
OBS08	200	100	200	100	200	500	200	150/450	200/170
OBS09	220	100	220	100	220	120/M300	220	480	220/130
OBS10	230	130	230	130	230	130	230	M240	230/120
OBS11	130	120	200	130	200	100	200	120	250/150
OBS12	200	100/M220	40	40	40	230	40	50	30/70
OBS13	230	220/M400	200	90	230	350	250	40/M220	220/100
OBS14	200	220	70	80	170	330	280	210	260/100
OBS15	230	200	230	200	-	-	70/M250	100	250/30
OBS16	200	430	220	220	300	430	300	370	100/100
OBS17	100	170	40	40	100	60	200/M330	60/M200	100/40
OBS18	220	400	250	400	250	400	250	400	160/100
OBS19	360	320	115	50	50	30/M250	200	150	140/140
OBS20	400	370	40	350	-	-	-	-	40/30
OBS21	140	100	50	30	30	20	30	20	150/50

OBS	Hydrophone		Vertical		Horizontal - X		Horizontal - Y		S arrivals Max. offset (N/S)
	Pn North	Pn South	Pn North	Pn South	P-S North	P-S South	P-S North	P-S South	
OBS22	50	160	50	150	40	300	-	-	50/40
OBS23	120/410	20	-	-	-	-	-	-	30/0
OBS24	30	380	30	70/M200	30	M250	-	-	40/20
OBS25	400	400	110	60	-	-	100	100	100/50
OBS26	460	100/M300	200	100	200/450	110	200/450	110	200/100
OBS27	230	40	-	-	-	-	-	-	-
OBS28	230/M450	70	200	70	200/M470	70/M200	200/M470	70/M200	180/100
OBS29	190/M400	90	190	90	200	100	200	100	200/100
OBS30	170	70	120	60	120/M200	60	120	60	200/100
OBS31	70	50	70	50	530	60/M250	40/M460	40/M270	250/70
OBS32	200	40	60	40	150/M200	50	230/M500	50	100/70
OBS33	70	35	70	35	70	35	70	35	25/50
OBS34	70	35	35	50	35	45	30	30	30/50
OBS35	50	50	50	35	50	35	50	35	50/50
OBS36	60	90	40	40	40	40	40	40	50/40
OBS37	50	40	500	50/M70	500	30	500	40	60/30
OBS38	50/500	110	50	50	50	50	50	50	60/30
OBS39	45	120	30/M600	40	-	-	-	-	30/10
OBS40	600	80	30	30/M70	50	30/M70	45	25/M70	60/10
OBS41	600	70	550	40/M370	55	10	-	-	70/20
OBS42	600	65	70	60	50	60	25	15	100/60
OBS43	600	80	20	30	20/600	40	20/600	40	100/30

OBS	Hydrophone		Vertical		Horizontal - X		Horizontal - Y		S arrivals Max. offset (N/S)
	Pn North	Pn South	Pn North	Pn South	P-S North	P-S South	P-S North	P-S South	
OBS44	80	80	50	80	-	-	80	80	120/100
OBS45	730	130	100	90	730	100	30	30	110/100
OBS46	110/M600	80	50	50	40	70	30	M80	30/70
OBS47	60	70	40	60	40	40	-	-	50/40
OBS48	50	50	-	-	20	20	-	-	-
OBS49	70	70	70	50	70/650	50	70	50	60/40
OBS50	80	70	80	70	80	60	80	60	80/50

**ILAB-SPARC PROFILE - 2**

OBS	Hydrophone		Vertical		Horizontal - X		Horizontal - Y		S arrivals Max. offset (E/W)
	Pn East	Pn West	Pn East	Pn West	P-S East	P-S West	P-S East	P-S West	
OBS51	100	100	100	100	50	60	50	60	110/40
OBS52	80	120	30	90	-	-	50	100	80/100
OBS53	90	120	80	80	-	-	-	-	70/20
OBS54	90	120	90	120	50	90	50	80	110/40
OBS55	120	100	120	100	-	-	60	80	200/50
OBS56	120	120	60	70	-	-	100	60	230/60
OBS57	90	75	90	80	-	-	-	-	80/30
OBS58	130	80	100	60	180	70	70	100/M300	180/100
OBS59	170	100	40	80	-	-	100	80	300/110
OBS60	100	100	60	40	50	40	50	30	70/40
OBS61	120	120	50	100	100	120	-	-	110/170
OBS62	80	100	50	80	-	-	50	80	50/150
OBS63	100	100	100/M210	90	-	-	90	90	100/200
OBS64	80	110	50	40	100	100	60	60	110/30
OBS65	80	50	60	50	-	-	-	-	110/60
OBS66	130	80	50	50	-	-	70	70	160/80
OBS67	140	90	130	90	90	70	-	-	70/70
OBS68	110	100	50	50	90/M200	90/M300	130	100	130/130
OBS69	90	70	90	70	70/M150	110	70	70	110/100
OBS70	60	80/M120	40	40	50	80/M380	50	80/M350	120/60
OBS71	50	50	50	90	60	100/M350	50	100	100/70

OBS	Hydrophone		Vertical		Horizontal - X		Horizontal - Y		S arrivals Max. offset (E/W)
	Pn East	Pn West	Pn East	Pn West	P-S East	P-S West	P-S East	P-S West	
OBS72	40	80	40	80	40	30/M100	40	40	100/60
OBS73	90	120	60	80	50	400	90	490	110/120
OBS74	80	200	40	40	-	-	-	-	50/50
OBS75	80	200	60	200	60	60/M200	60	100/M200	60/100
OBS76	60	180	40	70/M200	-	-	40	60/M200	50/70
OBS77	100	80	40	40	40	40	40	40	40/50
OBS78	100	50	-	-	-	-	-	-	-
OBS79	80	40	40	40	20	40	-	-	-
OBS80	50	60	50	40	30	30	-	-	30/20
OBS81	90	70	50	50	-	-	-	-	40/40
OBS82	80	60/M90	-	-	-	-	-	-	-
OBS83	60	90	60	90	60	80	60	80	70/40
OBS84	60	60	40	40	40	40	40	40	60/60
OBS85	60	80	50	80	50	60	-	-	80/50

### ILAB-SPARC PROFILE 3

OBS	Hydrophone		Vertical		Horizontal - X		Horizontal - Y	
	Pn East	Pn West	Pn East	Pn West	P-S East	P-S West	P-S East	P-S West
OBS86	44	22	44	22	24	16	40	12
OBS87	40	30	40	30	18	20	-	20
OBS88	36	22	36	22	-	-	-	-
OBS89	24	30	24	30	16	20	16	18
OBS90	28	42	38	30	28	30	24	22

## 6. Seismic reflection Acquisition and Processing

Two seismic reflection lines acquired during ILAB SPARC (ILAB\_SP01 and ILAB\_SP02) survey are coincident to wide-angle seismic lines (Figure 6.1). The acquisition parameters of these two lines were designed for deep imaging and in particular for the lithosphere-asthenosphere boundary. Shots are every 300 m for a speed of ~4 knots (~145 s). We sampled the data every 2 ms for a record of 30 s. The streamer was deployed at a 12 m water depth.

Reflection seismic data were also acquired near the Mid-Atlantic Ridge and across the Chain FZ, ILAB\_SP03, ILAB\_SP04, ILAB\_SP05, ILAB\_SP06, ILAB\_SP07, ILAB\_SP08, ILAB\_SP09, ILAB\_SP10 (Figure 6.2). Shots are every 75 m (~35 s) for a speed from 4 to 5 knots. We sampled every 2 ms for 25 s recording. ILAB\_SP05 is coincident to a line with 5 OBSs. The streamer along this line was deployed at 15 m depth.

The seismic processing of the whole dataset was carried out using IFREMER's SolidCQ software, version 3.01. More details for each line are given below. The paragraph 6.2 gives in details the step of processing.

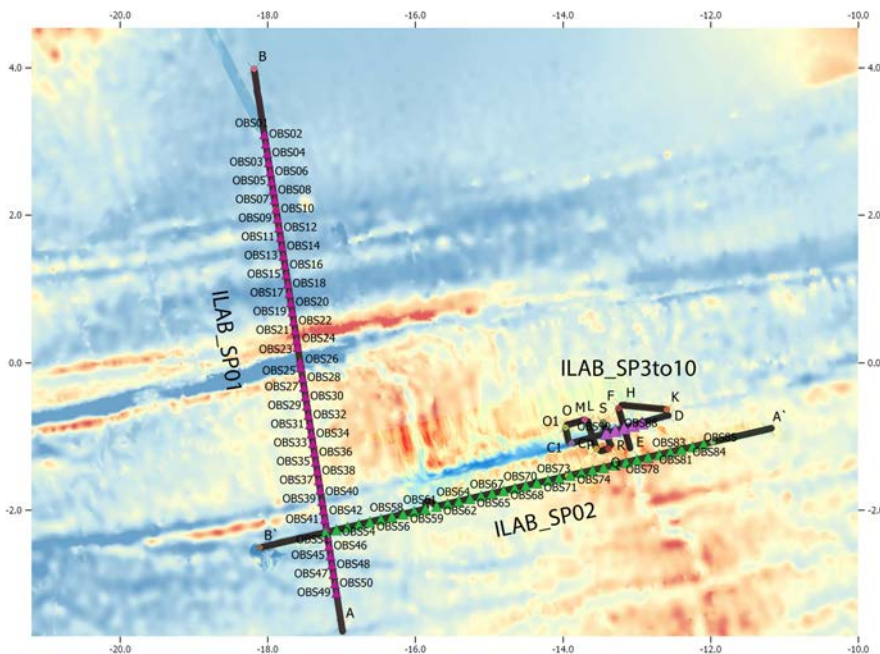


Figure 6.1 Map of the MCS profiles ILAB-SP01 to ILAB-SP10 and the location of OBSs (triangle).

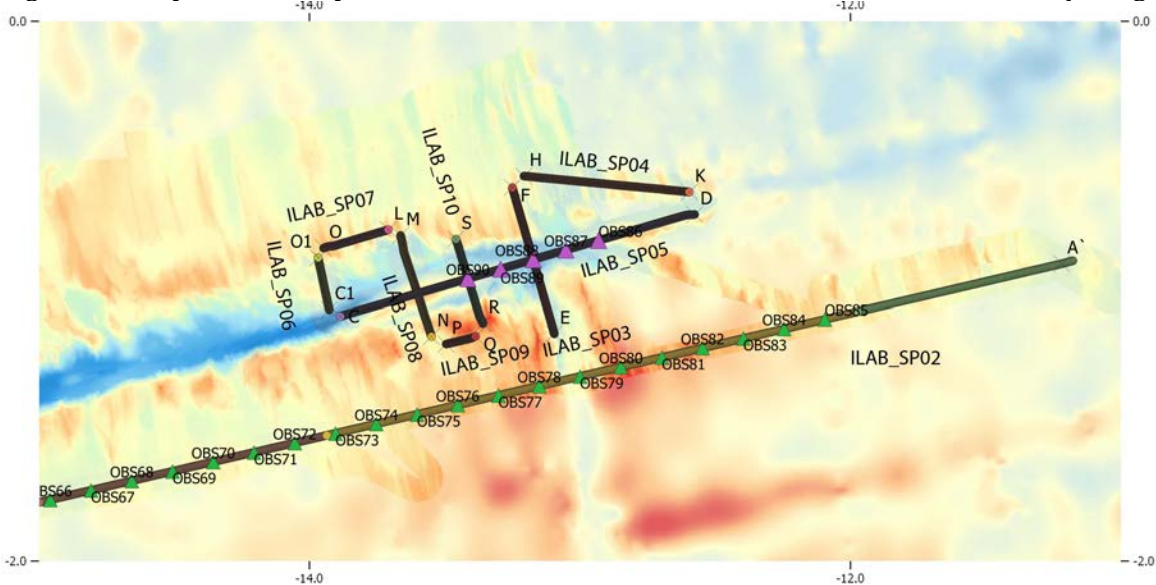


Figure 6.2: Location of profiles ILAB-SP03 to ILAB-SP10. The triangles indicate the OBS locations.

## 6.1. Acquisition

### 6.1.1. Profile ILAB\_SP01

ILAB\_SP01 is a north-south line and crosses the fracture zones St Paul, Romanche, Chain and a propagator in the south. The line is 850-km-long. The seismic survey duration was between 01/09/2018 to 04/09/2018. It begins at W016°59.180 / S03°38.772 and finished at W018°11.157 / N03°59.191. This line is cut in 3 sublimes: ILAB\_SP1.01, ILAB\_SP1.02, ILAB\_SP1.03. Guns reparation was done at the end of subline ILAB\_SP1.01 and we stopped at the end of subline ILAB\_SP1.02 because of a FAD catching (Figure 6.1.1). More details of the acquisition are given in Annexes.



Figure 6.1.1 14-m long FAD caught by the streamer, damaging one segment of the streamer.

### 6.1.2. Profile ILAB\_SP02

ILAB\_SP02 is an east-west line and crosses the Mid Atlantic Ridge. The line is 787-km-long. The seismic survey duration was between 14/09/2018 to 15/09/2018. The line is cut in 3 sublimes: ILAB\_SP2.01, ILAB\_SP2.02, ILAB\_SP2.03 (details in Annexes). There was a problem with the naming of the shot that is why we changed the name from ILAB\_SP2.01 to ILAB\_SP2.02. In Ecos the shot number 1 is called 2. But there is no problem for number of shot in segd file. The gun reparation was done between ILAB\_SP2.02 and ILAB\_SP2.03. The ILAB\_SP2.03 have a deviation from the line because of the presence of FAD along the profile. There was a problem with guns and the software; The software said that the guns had not fired but looking at the source signal it seemed that the gun had been shooting. See operator log file for details.

### 6.1.3. Profile ILAB\_SP03

ILAB\_SP03 is a N-S profile, which is in the Mid Atlantic Ridge and crosses the Chain FZ junction. The line is 62-km-long. The seismic acquisition (details in Annexes) was between 23/09/2018 at 11 AM until 23/09/2018 at 19:08 PM. It begins at E (W13°5.653/ S1°9.428) and finishes at F (W13°14.937 / S0°36.977). For the processing we cut the turn and we begin the processing from shot 61 at W13°06.29461 / S01°07.08784 to shot 836 at W13°14.93721 / S0°36.9773.

### 6.1.4. Profile ILAB\_SP04

ILAB\_SP04 is a NW-SE transit profile oblique to the oceanic fabric. The line is 68-km-long. The seismic acquisition was between 23/09/2018 at 8:06 PM until 24/09/2018 at 4:16 AM (Figure 6.2). It begins at H (W13°12.373 / N0°34.437) and finishes at K (W12°35.747 / S0°37.976). For the processing we cut the turn and we begin the processing from shot 100 at W13°08.38163 / S00°34.83006 to shot 911 at W12°35.74749 / S00°37.976.

### 6.1.5. Profile ILAB\_SP05

ILAB\_SP05 is an ENE-WSW profile inside the Chain FZ. The line is 152-km-long. The seismic acquisition was between 24/09/2018 at 05:58 AM until 25/09/2018 at 1:54 AM. It begins at D (W12°34.575 / 0°42.992) and finishes at C (W13°53.152/S1°5.561). For the acquisition we cut the turn and we begin the process at shot 60 at W12°36.955 / S00°43.254 up to shot 2023 at W13°53.036 / S01°05.524.

Science	QC	SegD file_number of shots	suppression of shots	long /lat first shot for processing	long /lat last shot
ILAB SP1 01	profile001	1-350	1-28 (end of turn)	W016°59.1791 / S03°38.77214	W017°08.00193 / S02°43.02145
ILAB SP1 01	profile002	351-700	none	W017°08,02693 / S02°42.86131	W017°16.79452 / S 01°47,11463
ILAB SP1 01	profile003	701-1050	none	W017°16.81832 / S01° 46.95448	W017°25.58078 / S00°51.20808
ILAB SP1 01	profile004	1051-1390	none but the shot 1328 is very noisy	W17°25.60378 / S00°51.04759	W017°34.10832 / N00°03,10769
ILAB SP1 02	profile005	1-350	none	W17°33.06136 / S 00°03.62649	W17°41.86704 / N00°52.44718
ILAB SP1 02	profile006	351-803	From 798 to 803 beginning of the turn	W017°41.89455 / S 00°52.60685	W017°53.38992 / N02°04,86823
ILAB SP1 03	profile007	11-350	1-10 turn	W017°53.44440 / N02°06.11120	W018°01.93443 / N03°00.28064
ILAB SP1 03	profile008	351-719	none	W18°01.96165 / N03°00.44014	W018°11.15705 / N03°59.19061
ILAB SP2 01	profil009	1-305	1-17 turn, because of beginning of profile	W011°10.59512 / S00°53.27173	W11°58.47742 / S01°04.53816
ILAB SP2 02	profil010	1-350	none	W11°58.63388 / S01°4,57828	W12°53.60938 / S01°17.41408
ILAB SP2 02	profil011	351-747	none	W012°53.76671 / S01°17045159	W013°56.14463 / S01°32.00911
ILAB SP2 03	profil012	1 – 350	1-20 turn	W13°48.08853 / S01°30.12902	W 14°39.92953 / S01°42.24478
ILAB SP2 03	profil013	351-737		W14°40.08719 / S01°42.28051	W15°40.92744 / S01°56,39361
ILAB SP2 03	profil014	737-866		W015°40.92744 / 01°56.39361	W15°56.15139 / S02°0.02441
ILAB SP2 03	profil015	867-1200		W 15°56.31258 / S02°00.05830	W016°49.04440 / S02°12.35327
ILAB SP2 03	profil016	1200-1691		W16°49.04440 / S2°12.35327	W18°6.48348 / S2°30,43539
ILAB SP03	profil017	61-836	1-60 in turn	W13°06.29461 / S01°07.08784	W13°14.93721 / S0°36.9773
ILAB SP04	profil018	1-911	1-99 in turn	W13°12.37253 / S00°34.43704	W12°35.74749 / S00°37,97600
ILAB SP05	profil019	60-2020	1-59 in turn ; 2021-2023 very noisy	W12°36.95521 / S00°43.25432	W13°53.03620 / S01°05.52397
ILAB SP06	profil020	30-262	1-29 in turn	W13°55.852 / S01°02.983	W13°58.066 / S00°52.606
ILAB SP07	profil021	90-270	1-89 in turn	W13°53.344 / S00°49.594	W13°42.459 / S0°46.366

ILAB_SP08	profil022	90-580	1-89 in turn	W13°39.043 / S0°51.172	W13°32.888 / S1°10.0301
ILAB_SP09	profil023	giration, line not important			
ILAB_SP10	profil024	80-477	1-79	W13°22.668 / S01°22.668	W13°27.363 / S00°48.797

Table 6.2.1: Summary of the Seismic Profiles: ILAB-SP01 to ILAB-SP10.

#### 6.1.6. Profile ILAB\_SP06

ILAB\_SP06 is a N-S transit profile north of the Chain FZ. The line is 23-km-long. The seismic acquisition was between 25/09/2018 at 2:40 AM until 25/09/2018 at 5:16 AM. It begins at C1 (W13°55.585 / S1°4.131) and finishes at C2 (W13°58.066 / S0°52.606). For the acquisition we cut the turn and we begin the processing at shot 30 at W13°55.852 / S01°02.983 to shot 292 at W13°58.066 / S00°52.606.

#### 6.1.7. Profile ILAB\_SP07

ILAB\_SP07 is an ENE-WSW transit profile north of the Chain FZ crossing the oceanic structures. The line is 30-km-long. The seismic acquisition was between 25/09/2018 at 5:56 am until 25/09/2018 at 9:01 am. It begins at O (W13°56.843 / S0°50.471) and finishes at L (W13°42.459 / S0°46.366). For the acquisition we cut the turn and we begin the processing shot 90 at W13°53.344 / S00°49.594 up to shot 370 W13°42.459 / S0°46.366.

#### 6.1.8. Profile ILAB\_SP08

ILAB\_SP08 is a NNW-SSE profile crossing the Chain FZ and a high bathymetric structure bounded by faults. (cf bathymetry) The line is 45-km-long. The seismic acquisition was between 25/09/2018 at 9:45 AM until 25/09/2018 at 3:00 PM. It begins at C1 (W13°55.585 / S1°4.131) and finishes at C2 (W13°58.066 / S0°52.606). For the acquisition we cut the turn and we begin the processing shot 90 at W13°39.043 / S0°51.172 up to shot 580 at W13°32.888 / S1°10.0301.

#### 6.1.9 Profile ILAB\_SP09

ILAB\_SP09 is a transit line. It begins at P (W13°29.638 / S1°11.032) and finishes at Q (W13°23.119 / S1°9.954) (Figure 27). This line is very short and was not processed.

#### 6.1.9. Profile ILAB\_SP10

ILAB\_SP10 is a NNW-SSE profile crossing the Chain FZ and the eastward of the push-up ridge bounded by faults. (cf bathymetry) The line is 35-km-long. The seismic acquisition was between 25/09/2018 at 5:52 PM until the 25/09/2018 at 10 PM. It begins at R (W13°21.481 / S1°7.142) and finishes at S (W13°27.363 / S0°48.797). For the acquisition we cut the turn and we begin the processing shot 80 at W13°22.668 / S01°22.668 up to shot 477 at W13°27.363 / S00°48.797.

### 6.2. Processing (Solid QC)

The seismic processing of the whole dataset was carried out using IFREMER's SolidCQ software, version 3.01. SolidQC allows to perform navigation QC and processing, merging SEG-D shot point data with processed navigation, CMP binning, and basic seismic reflection processing (stacking with a constant velocity function and a constant velocity migration).

Below is the summary of seismic profiles.

The table sums up the different parameters of processing and the next paragraphs explained in details of the process using SolidQC.

Quality noise analysis				Comments	Failures													
coverage	sedation picking (done or not)	CHP export (done or not)	Noise average (dB)		last shot	Volume (m3)	Config	comment on sources	num of traces	Average depth	Comment on immersion birds	heading	Bottom speed (ft/s)	surface speed (ft/s)	suppression of traces	filter used	bin	number of bin
40	done	done	2.9	38.68	8.00132 / 1.02145	4890	16 guns	some problems of delay for some guns, important delay around shot 250-300 // problems sur les autorisations, inversion du signal pour le 1, 3, 6, 8. On a peut être 52	960	12m	the bird 1 is at 12m, it is normal and is not on the first section	351	3.2/2.4	4.2	none	5.125Hz	12.5m	795
40	done	done	5.7	37	7.9432 / 5.11463	4470	15 guns 14	delay problem so we stop 2 guns, we are at 11 m less of the maximum volume	960	12m	the bird 1 is at 12m, it is normal and is not on the first section	254 / 295	3.8 (first 100 shots) 3.1 (for the rest)	4.2 / 4.5	none	5.125Hz	12.5m	957
40	done	done	3.9	37	1.20878 / 4.10832 / 3.10769	4475	14	14 but some problems of guns, a ligine don't fired (problems sur la en des canon / stop acquisition)	960	12 m	the bird 1 is at 12m, it is normal and is not on the first section	390 * (problem of surface heading for this 960,963)	3/2.8	4.5/4	none	5.125Hz	12.5m	950
40	done	done	4.1	37	1.86704 / 2.47718	4475	14	problem since the beginning of one of the guns	960	12 m	14m for the first bird	351 *	3.5/4	4/4.5	none	5.125Hz	12.5m	934
40	done	done	4.1	38	3.28892 / 1.89823	4470	15	two shots with a problem with one gun, but it don't begin again	960	12 m	some birds at 14 m, at the end around 9m > problem with the streamer	351 *	3.5/4	4	none	5.125Hz	12.5m	9510
40	done	done	2.8	33	1.93443 / 2.38054	4470	15	3 shots (42, 44, 49 with problem of guns ) only 8 guns firing	960	12 m	14m for the first bird	264 / 260 *	4/4.5	4/4.5	none	5.125Hz	12.5m	10889
40	done	done	3.2	34	1.15705 / 3.19051	4470	15		960	12 m	14m for the first bird, presence of a 2000 streamer up to 9m and then 30m between shots 880-920	390 *	3.8/4	4/4.2	none	5.125Hz	12.5m	9309
40	done	done	2.2	40	1.67742 / 1.52915	4470	15	shots which seems to not be firing - 68, 81, 147, 159, 280, 333, 349	960	12 m	16m & 14m for bird 1 & 2	295 *	3.7	4	none	5.125Hz	12.5m	7129
40	done	done	3.3	40	1.60938 / 7.14108	4470	15	problem on shot 13, 52, 56, 700, 101, 149, 152, 165, 175, 185, 225. Gunlink software says that half of the sources have not fired, but data say the contrary, it's a problem of installation, all these shots were fired	960	12 m	16m & 14m for bird 1 & 2	295 *	3.4	4	none	5.125Hz	12.5m	8615
40	done	done	3	39	5.14463 / 2.00911	4470	15	2 stops on badly/very acquisition	960	12 m	16m & 14m for bird 1 & 2	295 *	3.6 / 3.2	4/4.2	none	5.125Hz	12.5m	9715
40	done	done	2.8	39	3.82931 / 1.24478	4990	16 guns		960	12 m	14 m for bird 1	295 *	3.6 / 3.2	4/4.2	none	5.125Hz	12.5m	9136
40	done	done	2.4	39	5.39361 / 1.92744 / 1.15139 / 1.02441	4670	15 / 16	15 guns, by again with 16 guns but one have a lot of delay	960	12 m	14 m for bird 1	295 *	3.6	4	none	5.125Hz	12.5m	9500
40	done	done	2.9	39	9.04410 / 3.35297	4670	15	stop of one of the guns because of many delay	960	12 m	14 m for bird 1	n turn	4.3/2.4	4.2/2.4	none	5.125Hz	12.5m	2559
40	done	done	2.9	39	9.04410 / 3.35297	4670	15	Volume field = 4150 for Shot 1175 / problems of precision on guns between shot 1175 and 1190 / gun 12 with a lot of delay, and more since the shot 1170	960	12 m	14 m for bird 1	295 *	4 (pic to 5 between shots 902-918)	4 (pic to 5 between shots 902-918)	none	5.125Hz	12.5m	8261
40	done	done	2.7	39	48248 / 42639	4670		problem shot 1679	960	12 m	14 m for bird 1	295 *	4/4.2	4/2/4	none	5.125Hz	12.5m	12028
150	done	done	11.7	31	1.93721 / 5.3773	4890	16		960	15m		344 *	4.5/4	5/4.5	none		4860	
150	done	done	3.8	38	1.71749 / 1.27600	4890	16		960	15m		96 *	4/1.4	4.5	none	5.125Hz	12.5m	5104
150	done	done	6.4	33	1.02820 / 5.52597	4890 / 4670	16/15/14	stop of guns because of important time delay	960	15m	12 & 13 m for birds 1 & 2	297 *	4/4.2	4/4/4.8	none	5.125Hz	12.5m	11989
150	done	done	7.4	31	18.006 / 52.606	4150	14		960	15m	12 & 13 m for birds 1 & 2	348 *	4/4.5	5/5.2	none	5.125Hz	12.5m	1775
150	done	done	4.6	34	12.489 / 5.286	4150	14		960	15m		74 *	4.8	4.8	none	5.125Hz	12.5m	1923
150	done	done	6.3	36	12.888 / 2.0201	4150	14		960	15m	16 & 17m for birds 1 & 2	162 *	3.8	4.6	none	5.125Hz	12.5m	2163
150	done	done	8.4	31	77.263 / 45.197	4150	14		960	15m	14 & 13 m for birds 1 & 2	342 *	4.8	5.4	none	5.125Hz	12.5m	2811

			Quality noise analysis		
coverage	subbottom picking (done or not)	CMB export (done or not)	Noise average (microsec)	S/N average (dB)	Comments
40	done	done	2.9	38dB	presence of noise very visible for the entire section
40	done	done	5.7	37	important count : during of the streamer
40	done	done	3.9	37	
40	done	done	4.1	27	
40	done	done	4.1	38	
40	done	done	2.8	33	problem bathymetry around shot 248-250
40	done	done	3.2	34	
40					
40	done	done	2.3	40	Trace 1 very noisy
40	done	done	3	39	2 stops on bathymetry acquisition
40	done	done	2.5	39	noisy shot 724,730
40	done	done	2.4	39	Big Turn because of FAD
40	done	done			important noise between shot 906 and 905
40	done	done	2.7	39	
150	done	done	11.7	31	
150	done	done	3.8	38	
150	done	done	6.4	33	
150	done	done	7.4	31	we cut the maximum of the turn
150	done	done	4.6	34	
150	done	done	6.3	35	
150	done	done	8.4	31	

Figure 6.2.1 Details of seismic data processing and division of profiles in sub-profiles.

### 6.2.1 data storage and subdivision of profiles into segments

Raw seismic data in SEG2 format were stored in Data(D:) > Data\_SEG2 > ILAB\_SPARC > 2d > profil\*\*\*, where \*\*\* indicates the three-digit profile number, or in our case, segment number within our long profiles.

Profiles of ILAB\_SP01 and ILAB\_SP02 are cut into different segments. In general, segment size was fixed to 350 shots, representing 105 km along the track. Segment numbers ranged from 1 to 16 for the whole cruise with 8 segments per profile. The lines ILAB\_SP03, 04, 05, 06, 07, 08, 09, 10 were processed entirely and named profil017 to profil024 (see table 6.1-1, **Error! Reference source not found.**, **Error! Reference source not found.** and **Error! Reference source not found.**).

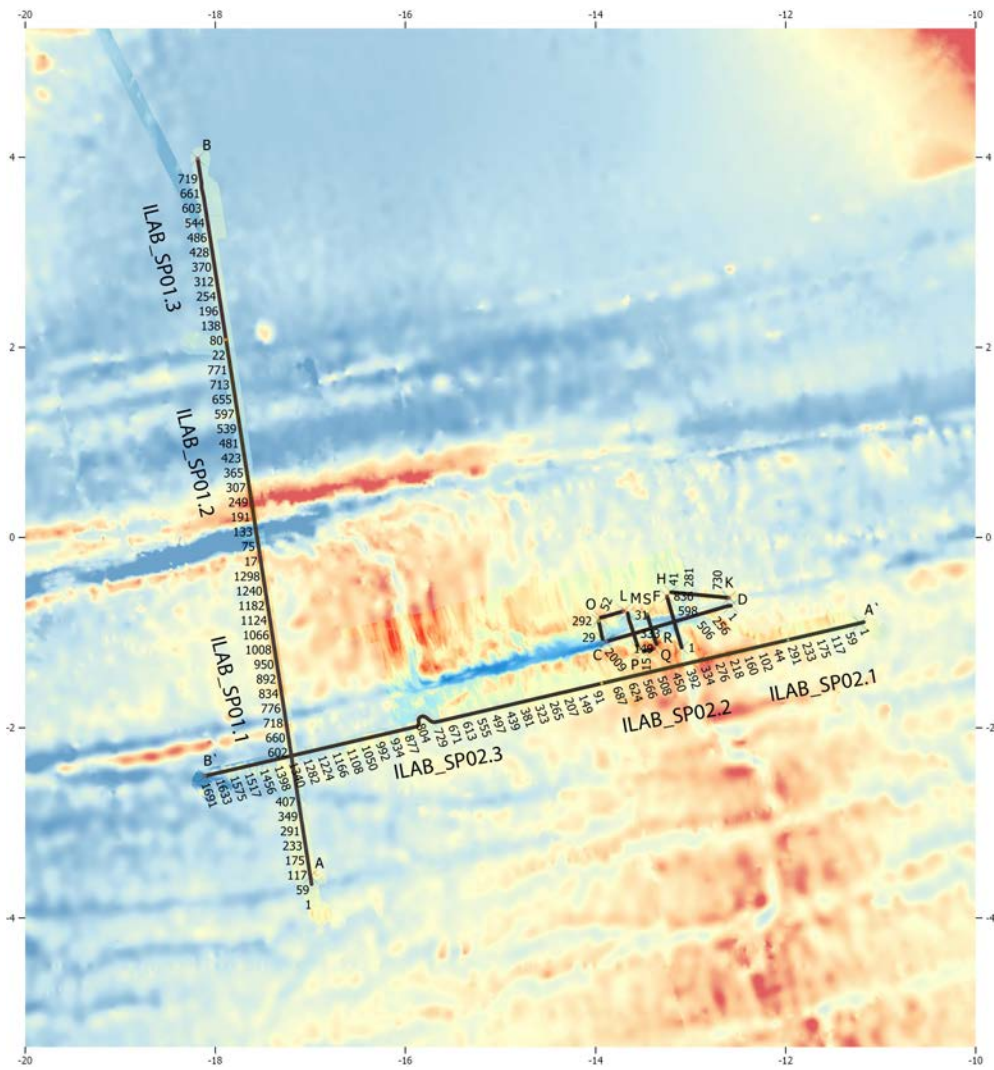


Figure 6.2.1-2. Locations of processed profiles sub-profiles for the seismic profiles ILAB-SP01 and ILAB-SP01 and ILAB-SP02.

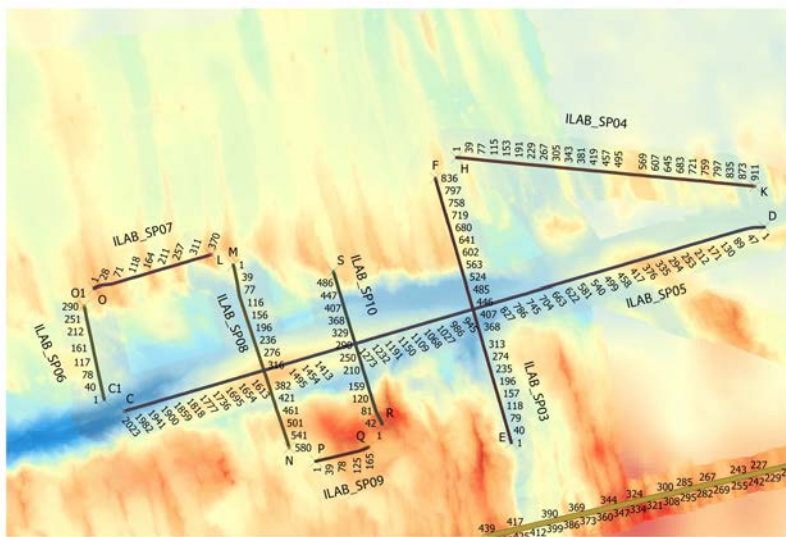


Figure 6.2.1-3: The processed seismic profiles (renamed).

### 6.2.3 Processing with SolidQC

The SolidQC work directory for the cruise was located on Data(D:) > SolidQC > Study > ILAB SPARC, with subdirectories automatically created by the software, named: auxi, export, migration, nav, picking, posit, prepro, sn, snap, stack, and survey.

There are three main menus and associated sub-menus that need to be executed sequentially:

SURVEY: Create/Select survey

NAVIGATION: Extract nav from SEGD; Display raw data; Process raw data; Source/receiver positions

SEISMIC: SEGD signal QC; Processing; Post-processing; Signal&noise

SURVEY

Create/Select survey. For the survey definition, we used parameters adapted to the towing configuration of the Pourquoi Pas (**Error! Reference source not found.**).

**STREAMER**

Number of traces	960
Trace distance	6.25 m
Dist. centre first trace	201.125 m
Total payed out length	6290 m
Head passive section	198 m
Tail passive section length	92 m
# Active SSAS (150 m)	40
Towing Point dx	0 m
Towing Point dy	-39.8 m
Tail Buoy GPS	1

**DEPTH CONTROLLERS**

Bird	Distance (m)	Bird	Distance (m)	Bird	Distance (m)
1	-5.7	8	1922.5	16	4324.5
2	121	9	2222.8	17	4624.8
3	421.3	10	2523	18	4925
4	721.5	11	2823.3	19	5225.3
5	1021.8	12	3123.5	20	5525.5
6	1322	13	3423.8	21	5748.9
7	1622.3	14	3724		

**SOURCES**

**Starboard Source**

Towing Point dx	15 m
Towing Point dy	-33.7 m
Source cable payed out	60 m
GPS source	2
Offset (centre array - GPS)	3 m

**Port Side Source**

Towing Point dx	-15 m
Towing Point dy	-33.7 m
Source cable payed out	60 m
GPS source	3
Offset (centre array - GPS)	3 m

**Source - Traces offset**

min	147 m	max	6141 m
-----	-------	-----	--------

**VESSEL GPS**

Raw GPS dx	0.5 m	Raw GPS dx	
Raw GPS dy	24.5 m	Raw GPS dy	

Figure 6.2.2-1: Seismic survey parameters for the ILAB-SPARC survey.

### NAVIGATION

1. Extract Nav from SEGD. Navigation information is extracted from the SEGD headers for all the shot points in a given profil\*\*\* directory, with the possibility to exclude problematic shot points.
2. Display Raw Data. Navigation information is displayed as a function of shot number (hence time): clock, vessel, latitude, longitude, bird depth, bird heading, bird wing angle, tail buoy GPS, or as a combined plot (lon/lat). Additional information can be examined as well: magnetometer data, gun pressure, gun depth.
3. Process Raw Data. Filtering (smoothing) is performed and manual editing is possible, for instance to remove an unrealistic excursion along the profile.
4. Source/Receiver positions. Source and receiver positions are created for each shot point, according to the survey file, processed ship position, tail buoy position and bird wing angles. The suite of reconstructed streamer positions can be QC-ed visually by means of a movie playing each shot one after the other.

### SEISMIC

1. SEGD signal QC. This includes SEGD shot gather display (with band-pass and F-K filtering available and spectrum calculation) (Figure 6.2.2-2, Figure 6.2.2-3) and traces visualization (Figure 6.2.2-4), auxiliary trace

display (including individual time break hydrophone data) (Figure 6.2.2-5 and Figure 6.2.2-6), and single-trace section display.

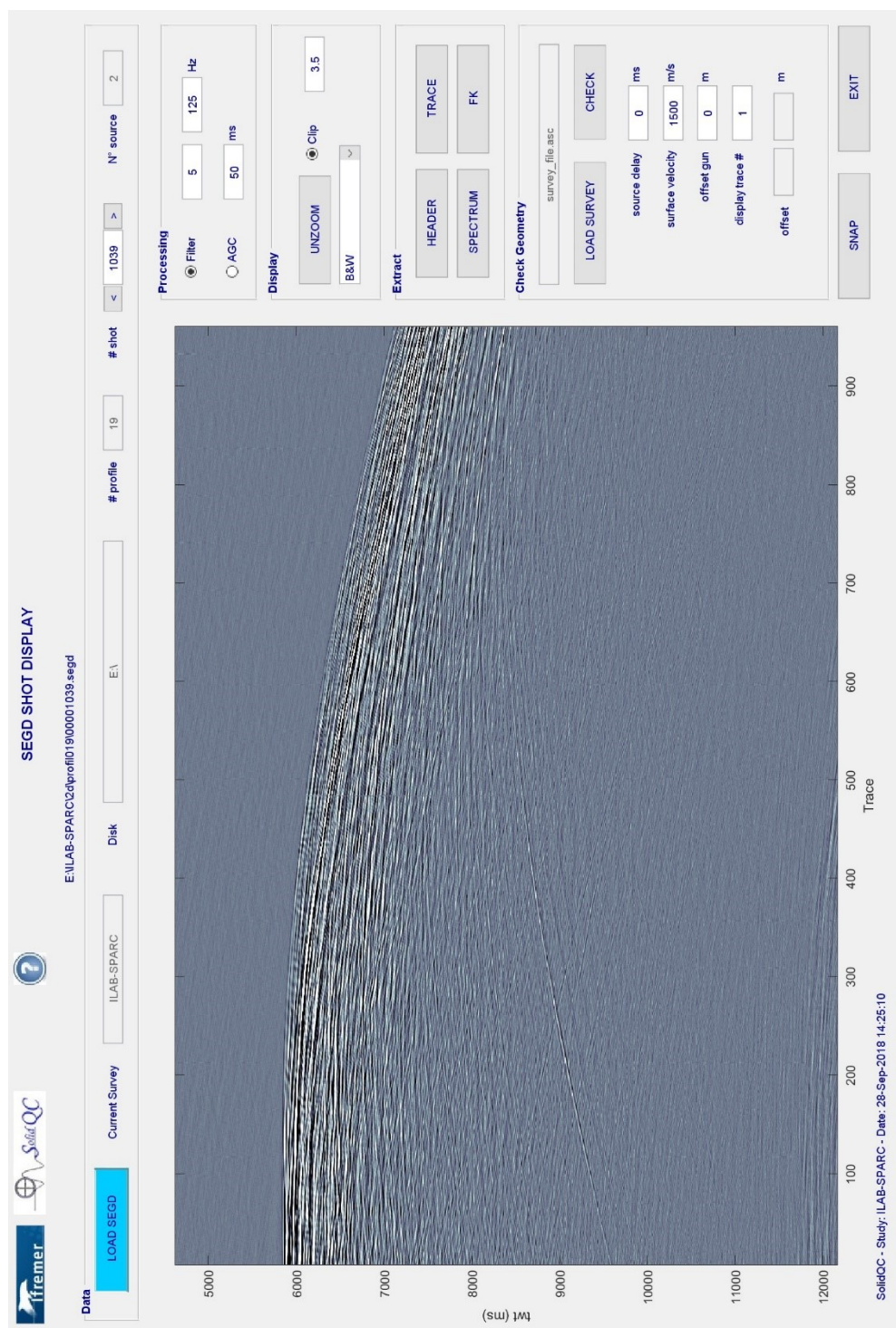


Figure 6.2.2-2: Example of shot gather (1039) for Profil019 (ILAB-SP05).

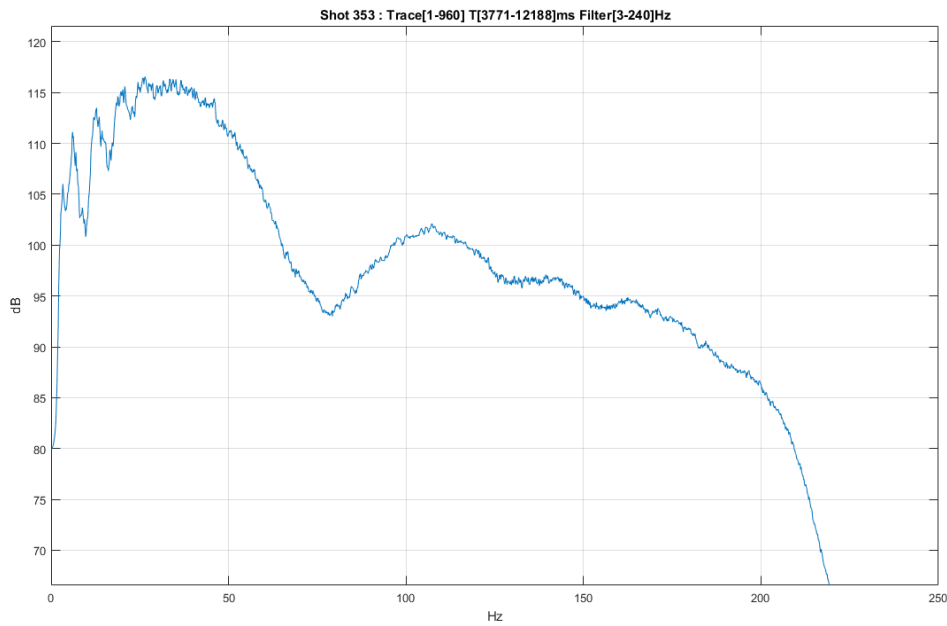


Figure 6.2.2-3 Frequency spectrum for shot 353 Profil019 (ILAB-SP05), showing the notch at 83 Hz and peak at 41 Hz.

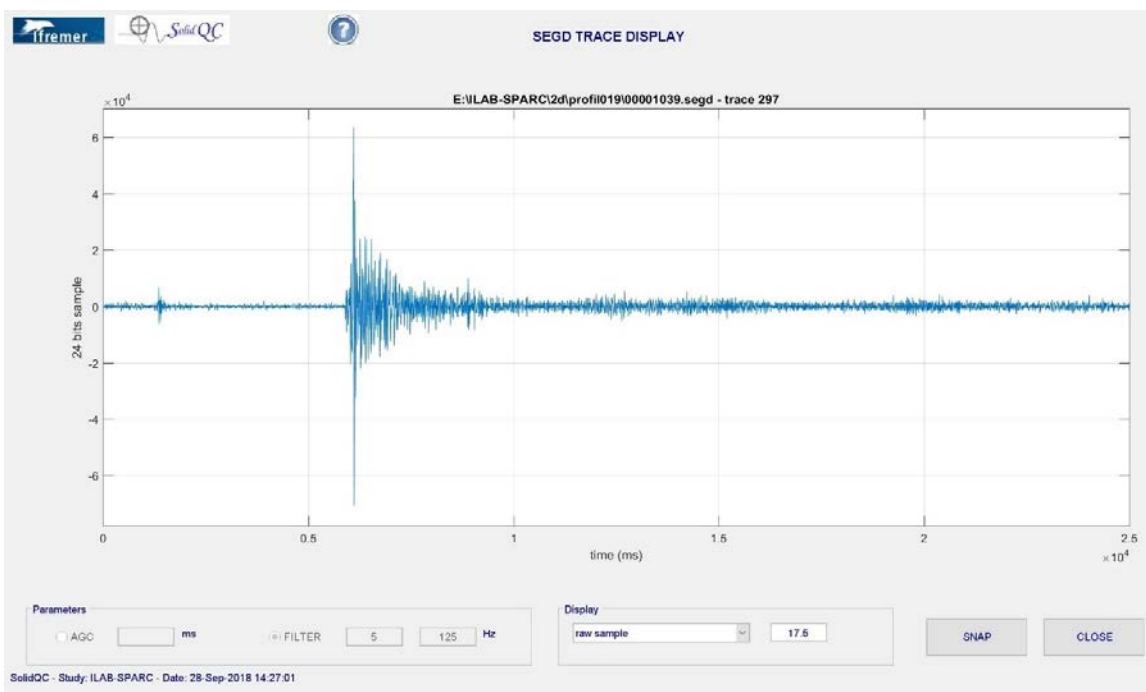


Figure 6.2.2-4 Example of a trace 297 from shot 1039 Profil019 (ILAB-SP05).

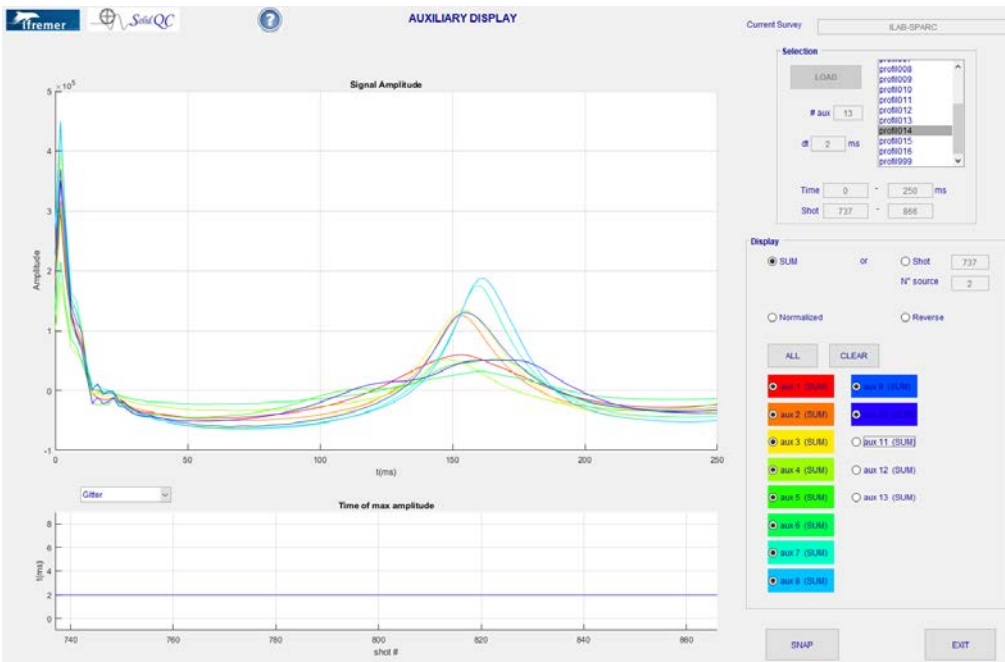


Figure 6.2.2-5 Signal of hydrophones for different guns.

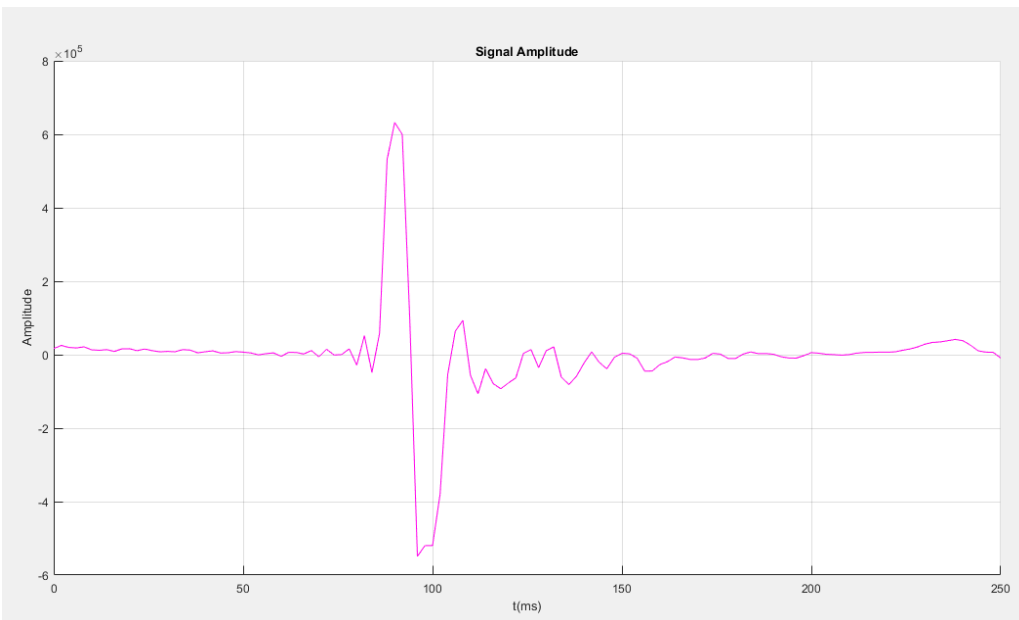


Figure 6.2.2-6 Final source signal.

2. Processing. The first step of the Processing menu is SEG-D to SEG-Y conversion with positioning information added to trace headers. With this new configuration, we don't need to take account the source delay. This data conversion step generates SEG-Y files that can be loaded into other seismic data processing software, and are used by SolidQC for subsequent processing steps.

The segy data are saved in big endian.

Prior to NMO and stack, CMP binning is performed. Using source-receiver positions read from the SEG-Y headers, and an inline bin size (CMP spacing) specified by the user, a bin file is then created by SolidQC and stored in the posit > binning directory. The natural CMP spacing for our survey is 3.125 m.

For ILAB\_SP01 and 02 the nominal fold is  $960 \cdot 6.25 / (2 \cdot 300) = 10$ . We choose to bin the data at 12.5 m CMP interval for onboard stacking. Thus, in 12.5 m wide bins, nominal fold is  $10 \cdot 4 = 40$ .

For ILAB\_SP03 to 10 the nominal fold is  $960 \cdot 6.25 / (2 \cdot 75) = 40$ . We choose to bin the data at 12.5 m CMP interval for on board stacking. Thus, in 12.5 m wide bins, nominal fold is  $40 \cdot 4 = 160$ .

SolidQC inline CMP bin numbers start at 1 for each suite of shots under consideration (profile segment). After creation of the bin file, a fold plot appears, as fold (exact fold according to the 3D bin grid) vs CMP bin number. Statistics (mean fold, max fold) are automatically calculated.

SolidQC allows to apply NMO and stack using either a constant velocity or a constant gradient function hung from the seafloor. We applied a 1500m/s constant velocity for NMO correction. We also test a 2200 m/s constant velocity or a gradient of 200m/s/s for lines ILAB\_SP01, ILAB\_SP02 in order to image the Moho. But we don't see it. For ILAB\_SP03, 04, 05, 06, 07, 08, 09, 10 we applied a 1500m/s constant velocity. For some lines we applied different velocity in order to see some reflection at depth. But in general we don't see any deep reflectors. It will be necessary to process them with a better velocity law.

Stretch muting is applied according to a percentage provided by the user; we kept the default value of 50%. A band-pass filter is required: we chose 5-125 Hz pass band. Then, we applied a migration at water velocity.

Stacks and migrated sections were examined using the Display SEG Y window available in the Post Processing menu. Similarly as for shot gather data export, the segy data were exported in big endian.

3. Post Processing. As part of Post-processing, SolidQC allows to export positioning information to ascii and UKOAA P1/90 formats. We exported source and receiver lat/lon, CMP bin lat/lon, and P1/90 files for each profile segment.

The P1/90 files will be useful for loading the processed navigation into other processing software and re-merging with the SEG D shot point data in the frame of a new bin grid geometry. Note that one P1/90 file was exported for each segment, and there are currently no P1/90 files available for whole profiles. However, it should be possible to concatenate the blocks of source-receiver positions of individual P1/90 files to generate one file per profile.

### 6.3. Data file summary

In the backup MCS data were saved in the directory MCS\_ILAB:

- SEG D :
  - ILAB-SPARC
    - Bruits: noise test realized during the cruise
    - Documents: configuration of source, streamer and real time report for each lines
    - ILAB\_SP01.1 to ILAB\_SP10.1: segd for each lines
  - TEST: some test segd
  - NAV: all ecos files, each shots and navigation is recorded by day.
  
- ILAB-SPARC > 2d:
  - Profil001 to 0024 : organization of each profile for the processing. See the table for the correspondence between profil\*\*\* and the number of the line.
  - Save : segd remove for the processing. It is shots during turns.
  - Ilab\_sparc profile: table with all information of the processing
- SolidQC > Study > ILAB-SPARC:
  - Auxil : auxiliary data
  - Cube
  - Export: binning and shots position of each lines
  - Fold
  - Migration: final segy
  - Nav: process, raw and ukoaa files



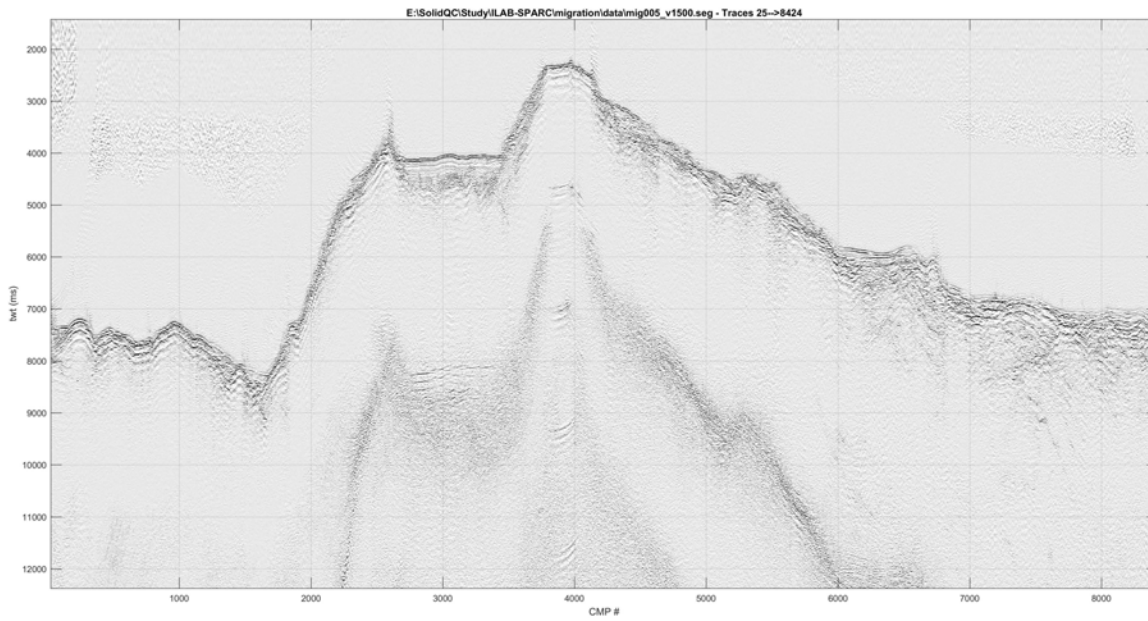


Figure 6.4.2 Profil005 (ILAB\_SP01.2) at the northern part of the Romanche Transform Fault.

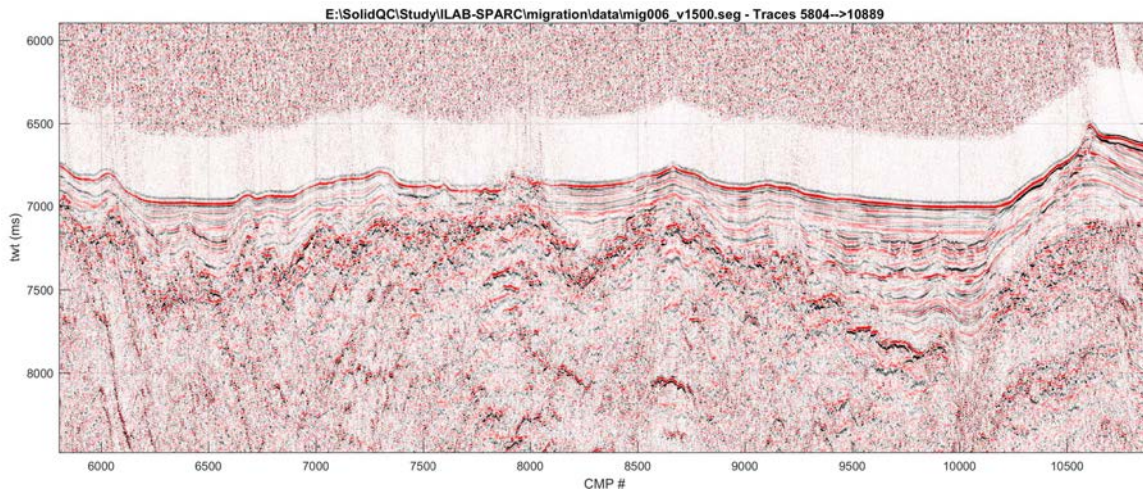


Figure 6.4.3 Profile006 (ILAB\_SP\_01.3) across the St Paul FZ. One can observe older extensional deformation followed by large-scale compressional deformation, possibly linked to the deformation associated with the plate organization 10 Ma.

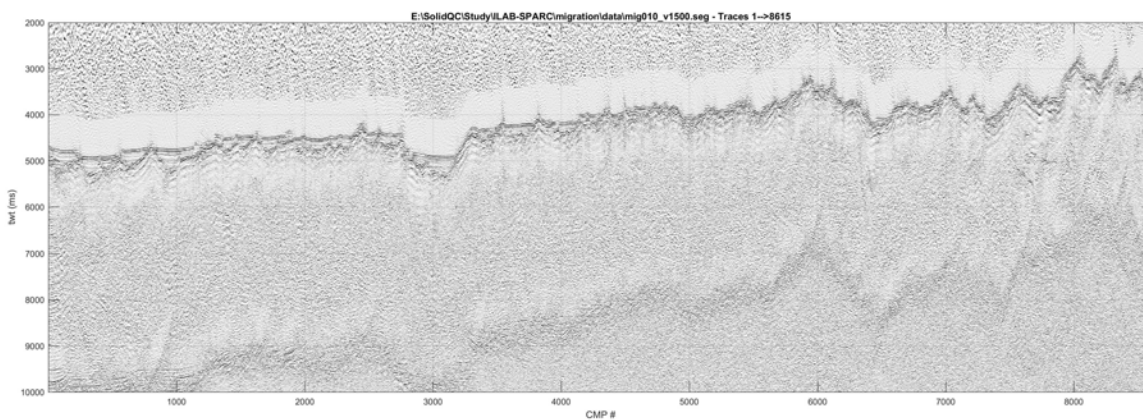


Figure 6.4.4 Profile010 (ILAB\_SP02.2) over the oceanic crust north of the Chain FZ.

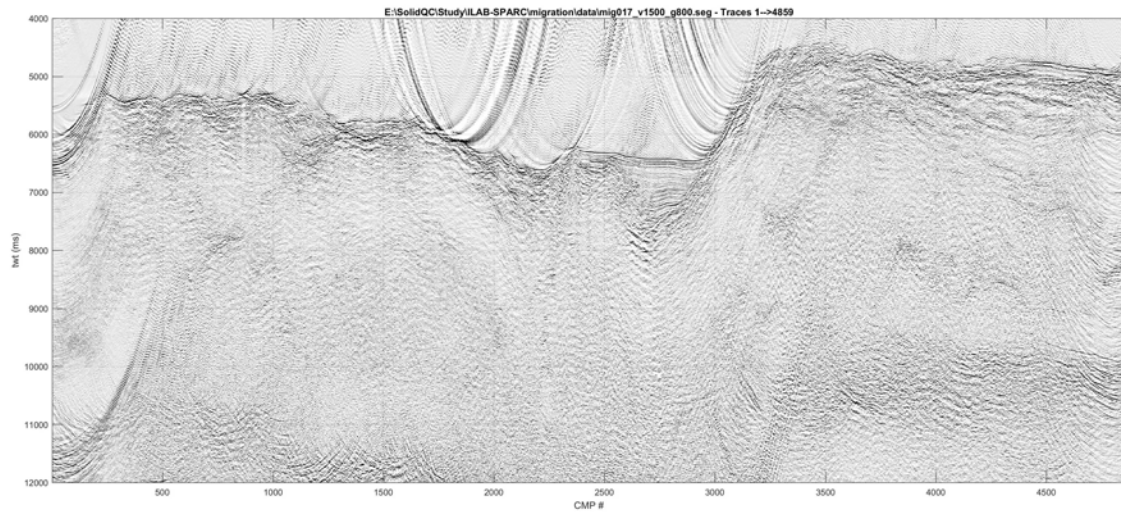


Figure 6.4.5 Profil017 (ILAB\_SP\_03) along the MAR and Chain TF-FZ junction showing a small compressive feature.

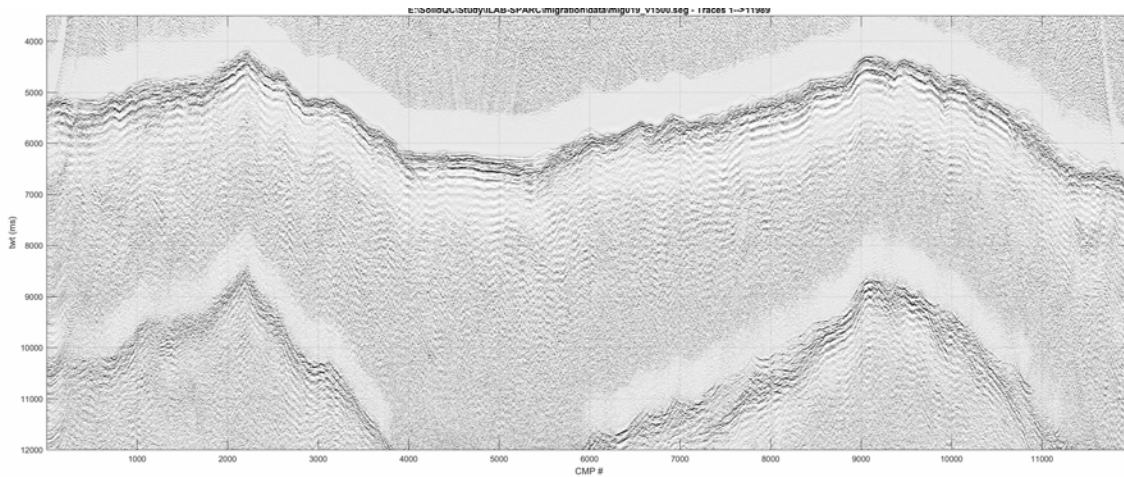


Figure 6.4.6 Profil019 (ILAB\_SP\_05) along the Chain FZ-TF going over the compressive ridge in the center.

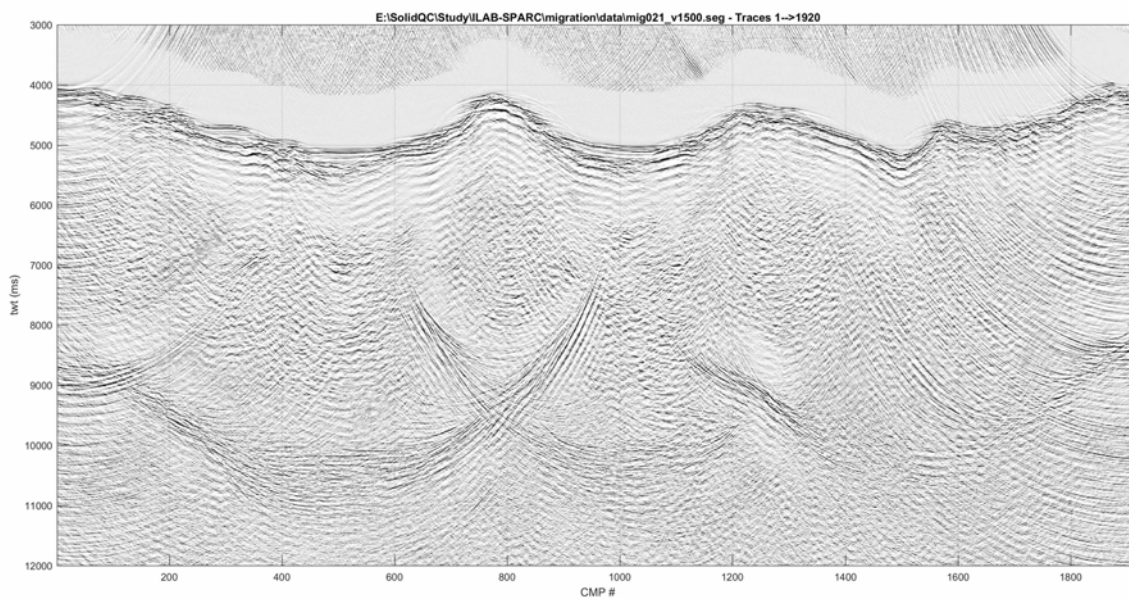


Figure 6.4.7 Profil021 (ILAB\_SP\_08) crossing the Chain Transform Fault.

## 7. Bathymetry

### 7.1. Data acquisition

Seafloor bathymetric data have been acquired using a Reson Seabat 7150 12/24 kHz deep water system, operated at 12 kHz (for depth from 100 m up to 12000 m). This sounder is designed to perform seabed mapping with high resolution and accuracy to a maximum depth. The main technical specifications of the Reson 7150 are listed in Table 7.1.

	<b>7150 LF mode (low frequency)</b>	<b>7150 HF mode (high frequency)</b>	<b>7111</b>
<b>Operating frequencies</b>	<b>12 kHz</b>	<b>24 kHz</b>	<b>100 kHz</b>
<b>measurements</b>	Bathymetry, sidescan imagery, water column		
<b>Max depth</b>	12000 m (*)	5000 m (*)	800 m (*)
<b>Swath width</b>	5 times the water depth (*) 16 km max (*)	5 times the water depth (*) 8 km max (*)	6 times the water depth (*) 1500 m max (*)
<b>Rx beams</b>	880 equidistant		301 equidistant
<b>Beams resolution</b>	1 x 1°	0.5 x 0.5°	1.5 x 1.5°
<b>Motion compensation</b>	roll / pitch		pitch
<b>Transmission</b>	multiplexing (x4)		singleping
<b>Signal shape</b>	CW		CW
<b>Reception</b>	A/D conversion : 6 kHz / 12 bits Gain compensation : TVG law (2AR+BlogR+G) adjusted by the operator		
<b>Sonar arrays</b>	Tx 12 kHz : L = 8 m Tx 24 kHz : L = 8 m Rx 12/24 kHz : L = 8 m		Tx : L = 0.6 m Rx : Ø = 0.6 m
<b>Acquisition software</b>	PDS 2000		PDS2000

(\*) depends on the survey conditions: noise level, bottom type, water temperature and salinity.

Table 7.1: Main specifications of the Reson 7150 and 7111 (not used in this survey as it is designed for shallow waters) multibeam echosounders.

Operation of the Reson 7150 is monitored and controlled from PC-Science room on R/V Pourquoi Pas?. The software PDS2000 has been used for acquisition, allowing real time quality control and access to the system sensors. Data are stored on hard drive on the workstation and regularly copied to network workstations. A new file is generated every 30 minutes of acquisition. Watch-keepers and GENAVIR marine crew are responsible for monitoring and maintaining an error free operation.

The Reson 1750 is mounted on a gondola, attached to the hull of the R/V Pourquoi Pas?. Other data used in the bathymetry data processing are:

- Navigation: Cinna / DGPS: Pourquoi pas ? is equipped with a CNav3050 GNSS receiver. This system uses the CNav-C PPP (Precise Point Positioning) correction service that provides a submeter accuracy anywhere in the world. Navigation data is normally provided by CINNA software (NMEA GGA message – 1 Hz). Mercator WGS84 projection has been used, being S 0° 0' the latitude of the preserved scale and W 15° 0' the origin longitude meridian.
- Attitude (roll, pitch, heading, heave): Phins II. Phins is located in gravimeter room, close to vessel COG. A spare Phins is located in sonar room, close to the sonar arrays. Theoretical accuracy is ~5cm (5% of the heave). Attitude data is provided to PDS 2000 on a serial line (binary SimradEM message – 100 Hz).
- Sound velocity profile: XBT launches. Sound velocity are generally calculated from XBT launches ( $T=f(\text{depth})$ ), which are combined with the Levitus data base in order to obtain full ocean SV profiles. This process is done by Ifremer Doris software. All the XBT used during this survey are listed at section 3.4: XBT data. The maximum depth of measurement was ~2000 m.
- Surface sound velocity it is provided either by the SBE21 thermosalinograph (data is acquired by Techsas software and sound velocity is transmitted to PDS by ethernet), or by the SVP-70 soundvelocitymeter (sound velocity is transmitted by serial link).

## 7.2. Data processing

We used CARAIBES software (Version 5.0) for bathymetric data processing and map generation on board.

The raw data output from the Reson 1750 are “.s7k” format. These files are converted to “.mbg” files (raw data that can be read by CARAIBES) and are extracted the navigation files in “.nvi” format (Fig. 7.1).

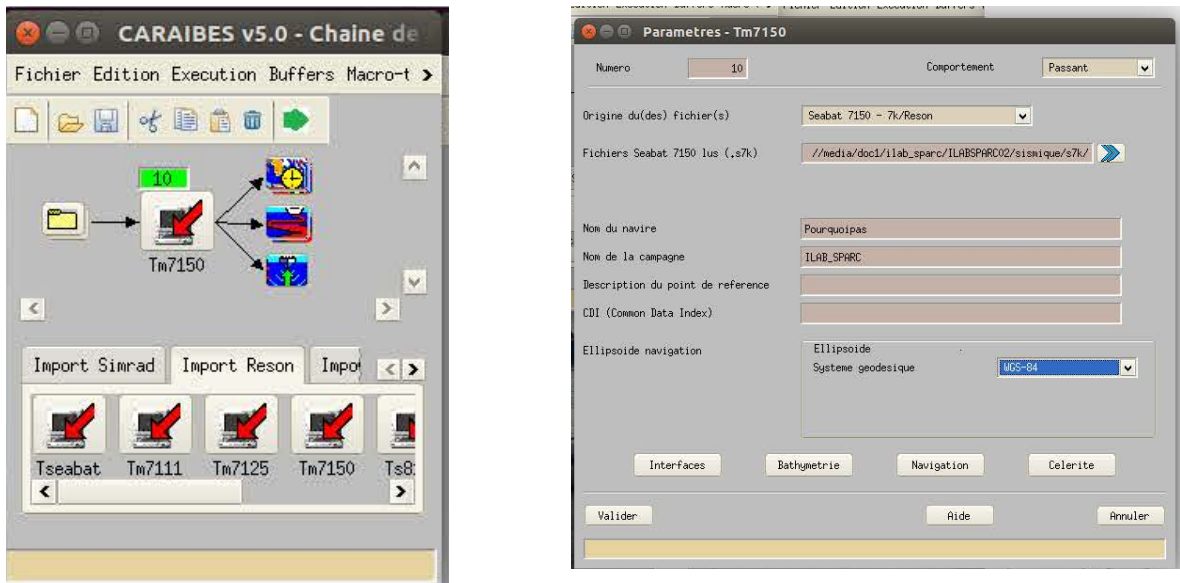


Fig. 7.1: Reading and importing parameters of the raw bathymetric data to software CARAIBES V5.0.

The raw data are then filtered by the filter module FilTri (Fig. 7.2).

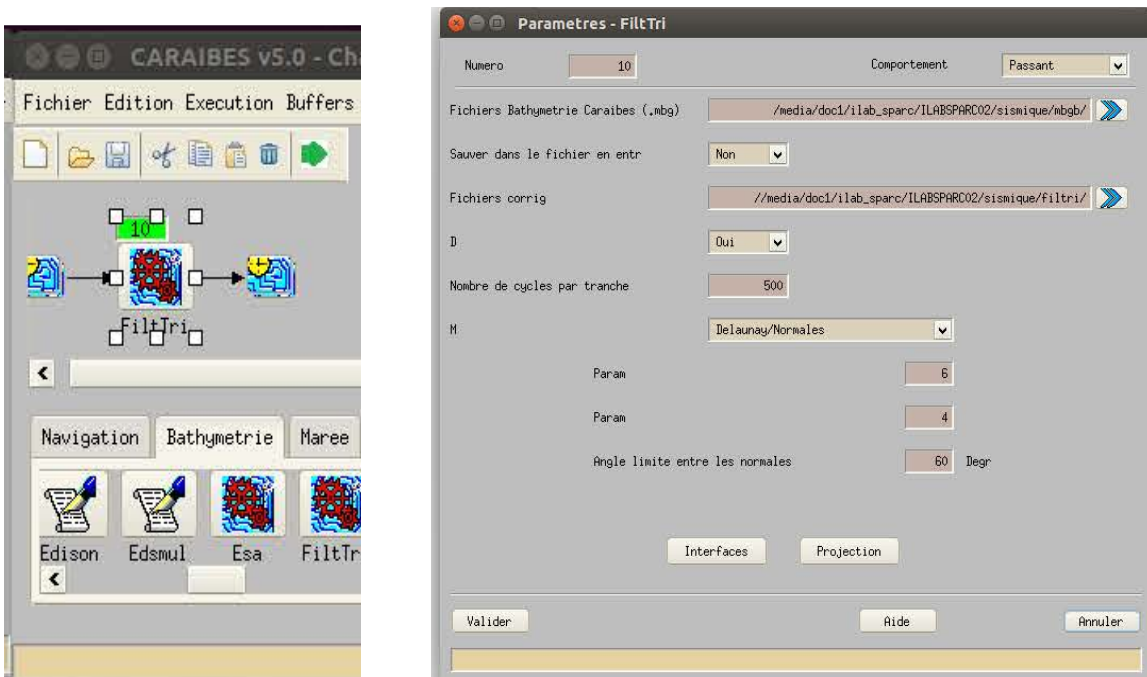


Fig. 7.2: FilTri filtering module, and parameters applied.

Afterwards, the data is processed manually to eliminate the remaining bad probes with the module Odicce (Fig. 7.3).

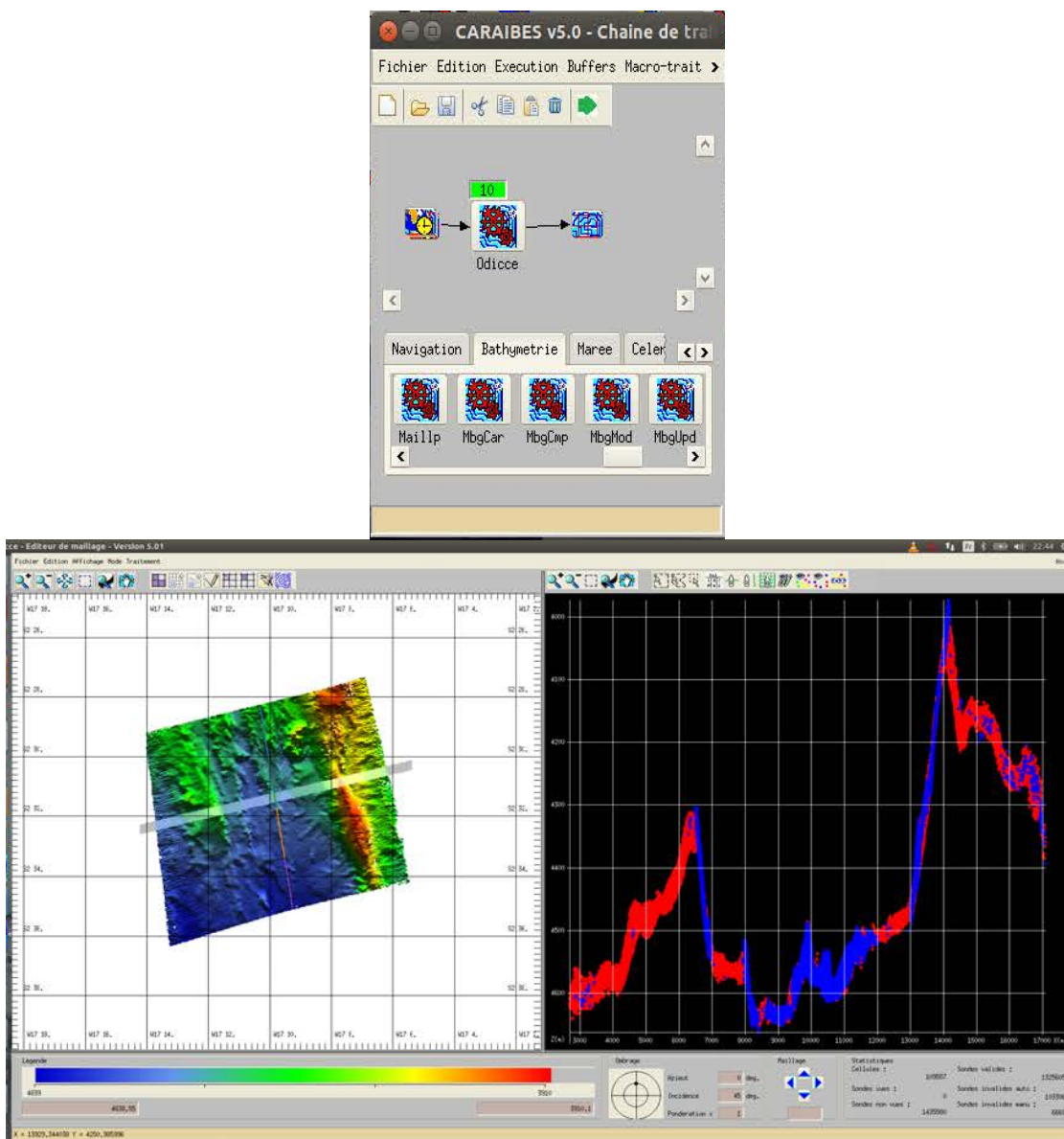


Fig. 7.3: Odicce module and interactive window used for manual filtering.

Finally, the output map is created in “.mnt” format using the Mailla module (Fig. 7.4)

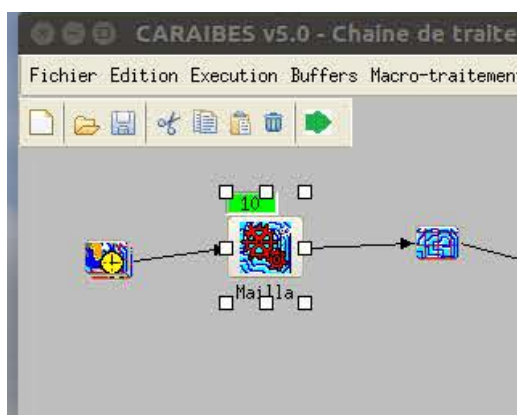


Fig. 7.4: Mailla module.

3D views have been generated using View3D module.

#### 7.2.1. Other information about the on-board processing

Some data of the first pass at 12 knots were used to complete the final map, instead of the transition at 5 knots. On the 15/09/2018, data quality during the 5 knots pass is not so good due to the rough sea condition. Files from 20180915\_110754 to 20180915\_173754 (acquired at ~5 knots) were replaced by 20180913\_123752 to 20180913\_160752 (acquired at ~12 knots).

### 7.3. Data File Summary

Bathymetry data acquisition started soon after we left the Cape Verde EEZ (on 27.08.2018 at 20:16 UTC, 12° 01.398 N 22° 39.830 W). At a water depth of 5000 m, the seafloor coverage was 17 km. During the cruise, a total of ~5.600 km of bathymetry were acquired.

For the ILABSPARC 01 and 02 profiles, there are two passes with acquisition of multibeam data: The first sweep was during OBS deployment at 12 knots, and the second was while shooting the profiles, at a speed lower than 5 knots. In general, the quality of the data acquired at low speed is better (see 2.1. for additional information).

#### 7.3.1. Storage of data

One folder per profile has been created: ILABSPARC01 (corresponds to the seismic profile 01), ILABSPARC02 (corresponds to the seismic profile 02), ILABSPARC03to10 (corresponds to the seismic profiles 03 to 10) and TRANSIT\_ALLER, TRANSIT\_RETOUR.

- Raw data (.s7k): ILABSPARC / EQUIPMENTS / RESON7150 / DATA / CARTOGRAPHY

File name: YYYYMMDD\_HHMMSS\_PP\_7150\_12kHz.s7k, where YYYYMMDD is Date (Year, Month and Date) and HHMMSS is the time.

- Processed data: ILABSPARC / REPLAY / BATHY\_IMAGERIE

Different files format and contain:

- mbgn: .mbg cleaned
- mbginused: .mbg not used because already passed on this zone
- nvi: navigation files
- nviinused: nvi not used
- mnt: final map mesh at 50m
- ps: picture

#### 7.3.2. Bathymetric profiles acquired during this cruise

Five main profiles have been acquired: Transit profile to the study area (Fig. 7.5), ILABSPARC01 (Fig. 7.6, 7.7, 7.8, 7.9 and 7.10), ILABSPARC02 (Fig. 7.11 and 7.12), ILABSPARC03to10 (Fig. 7.13 and 7.14) and Transit profile back to Cape Verde.

A general view of the acquired data together with some examples is shown below:

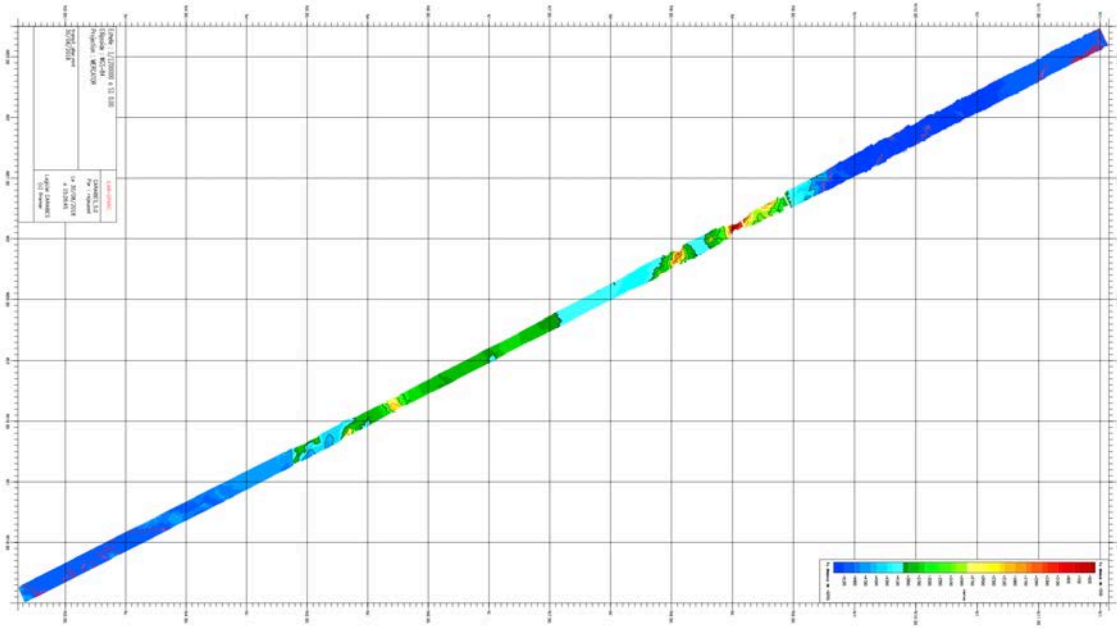


Fig. 7.5: Transit profile from Mindelo to the study area.

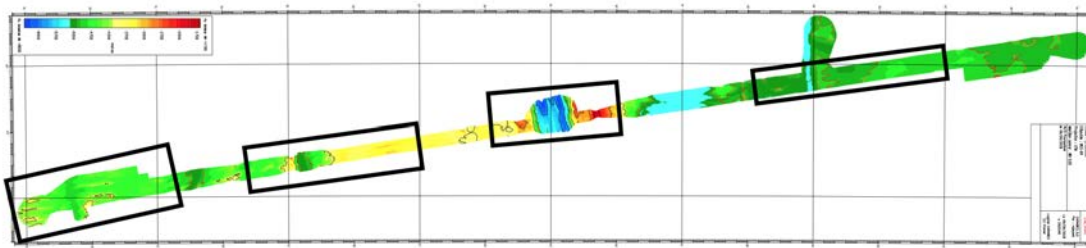


Fig. 7.6: Profile ILABSPARC01. This profile cuts, from north to south, the St. Paul (Fig. 7.7), Romanche (Fig. 7.8) and Chain (Fig. 7.9) fractures zones, and the propagator (Fig. 7.10) at the southern segment. Location of the detailed figures is depicted by black rectangles.

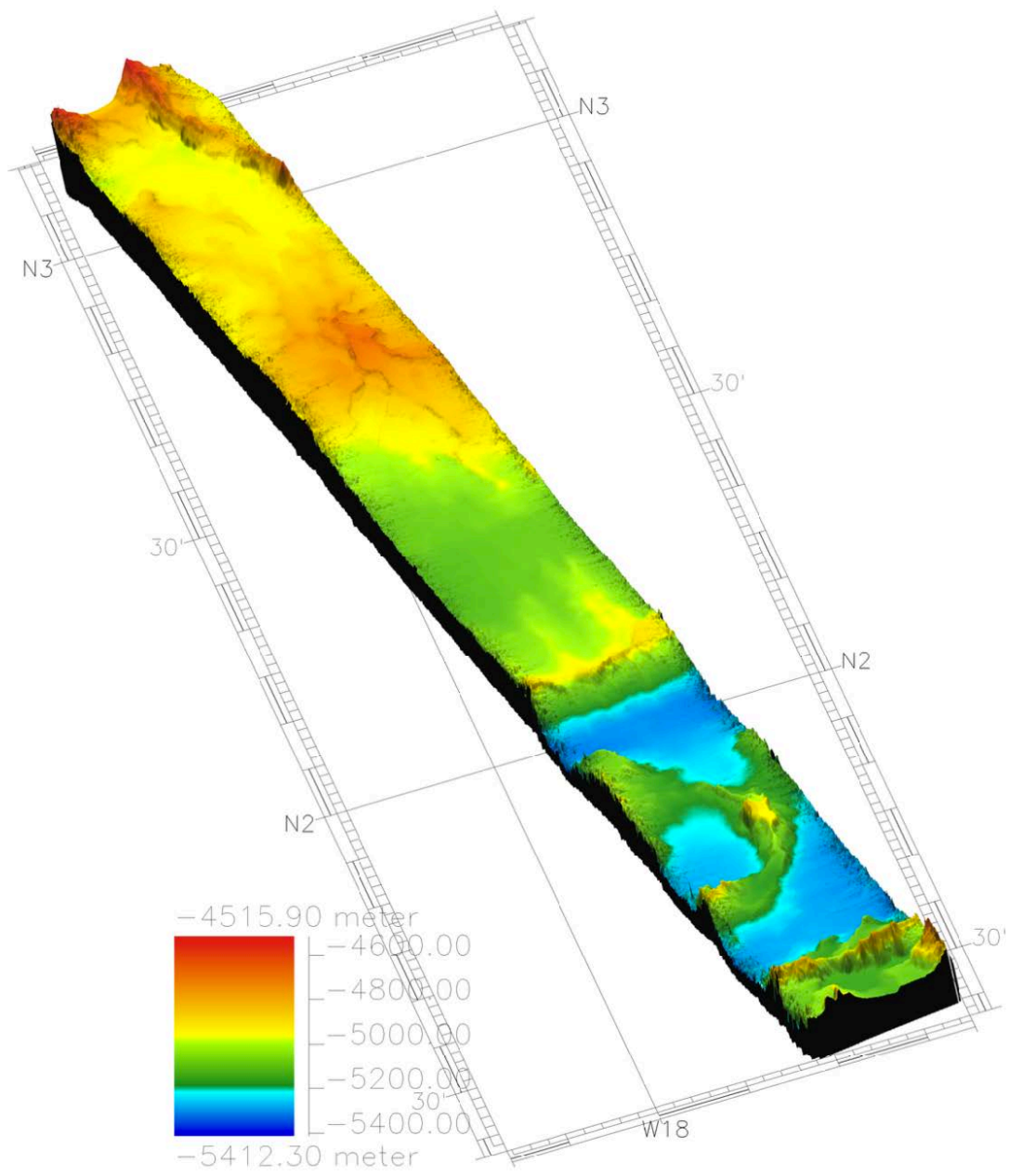


Fig. 7.7: Close-up of the St. Paul fracture zone area.

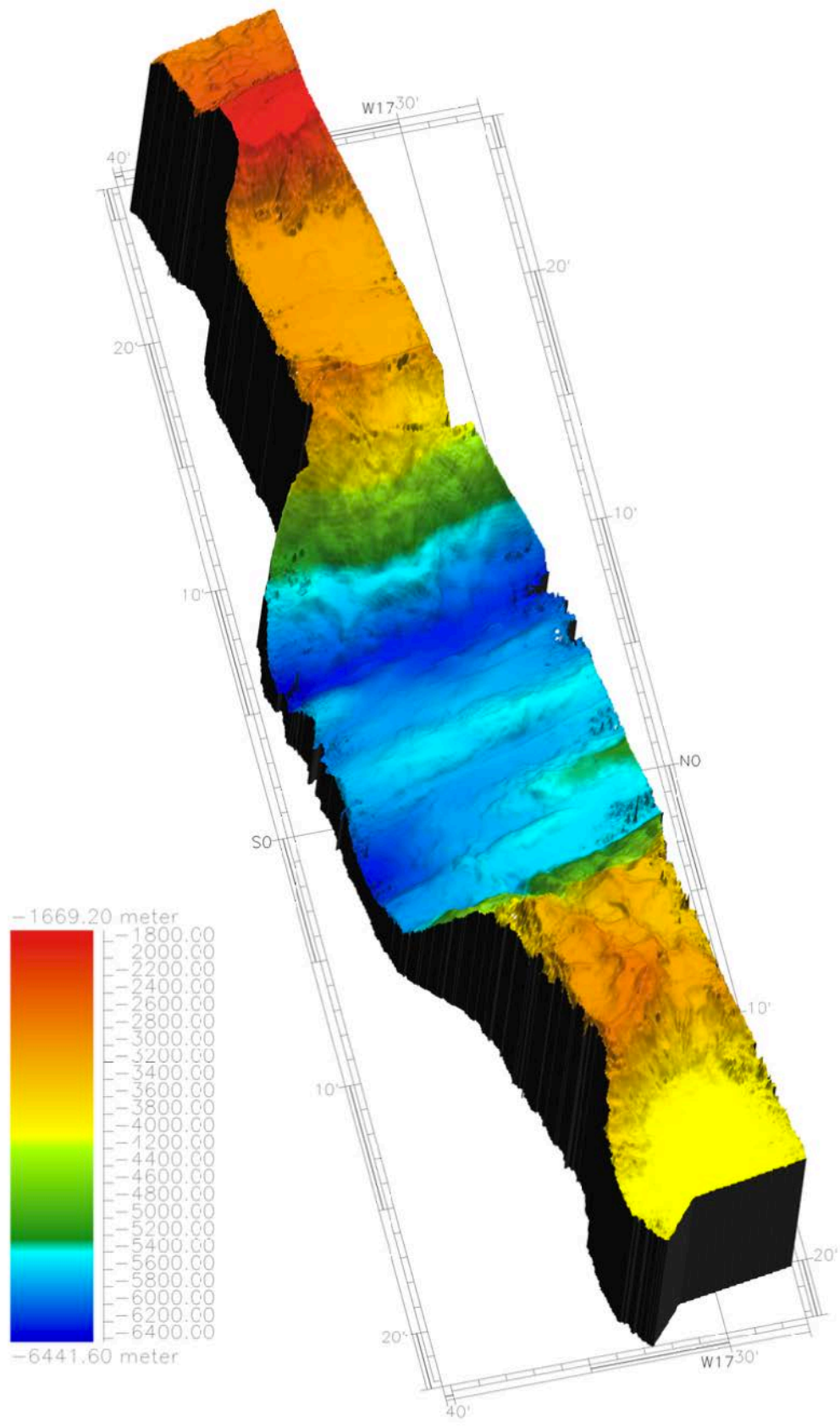


Fig. 7.8: Close-up of the Romanche transform area.

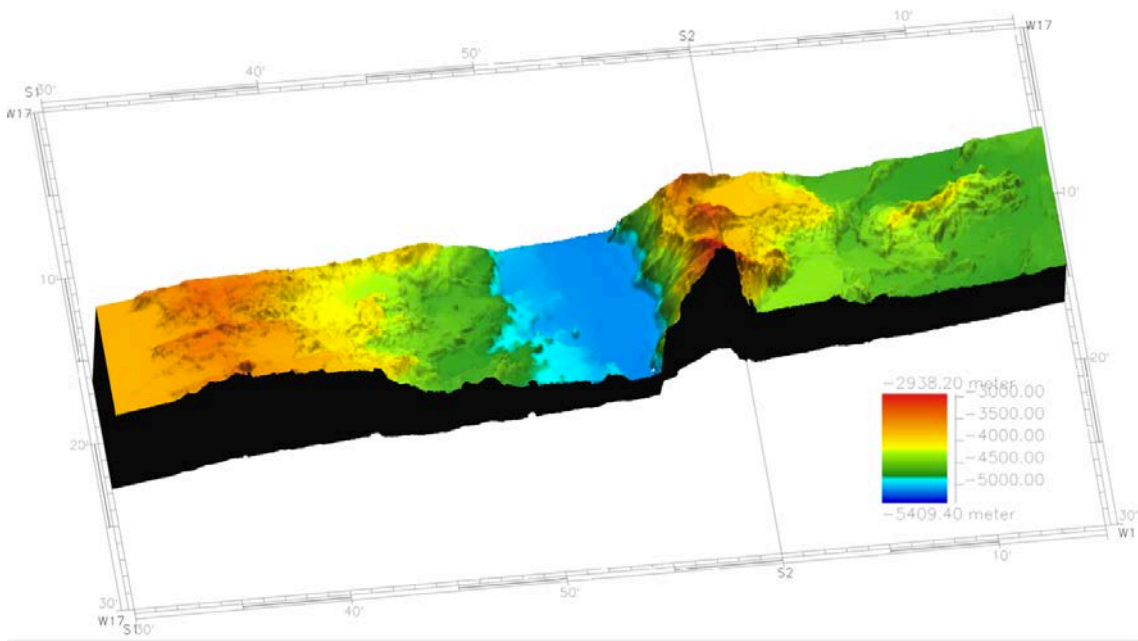


Fig. 7.9: Close-up of the Chain fracture zone area.

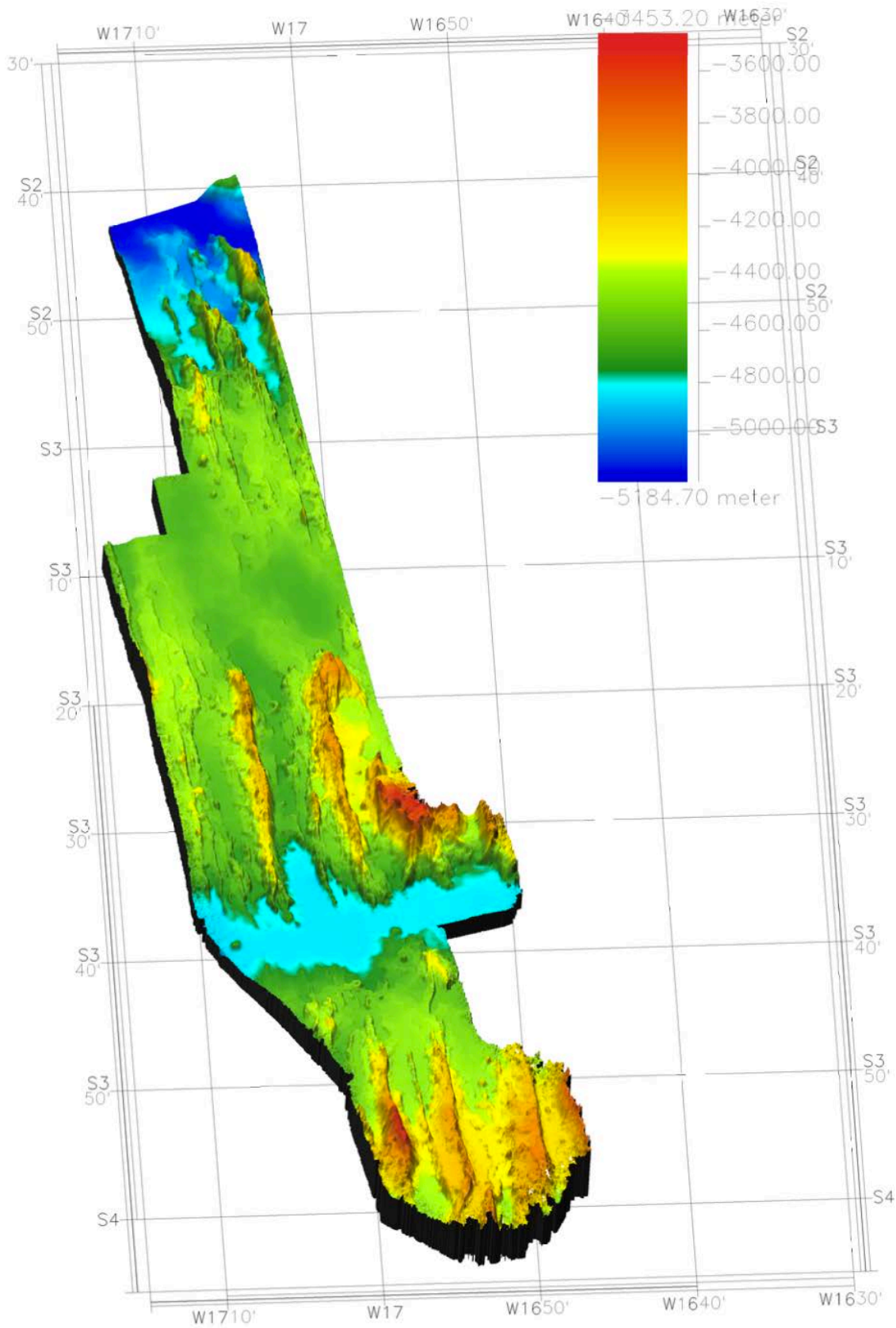


Fig. 7.10: Close-up of the propagator area in the south.

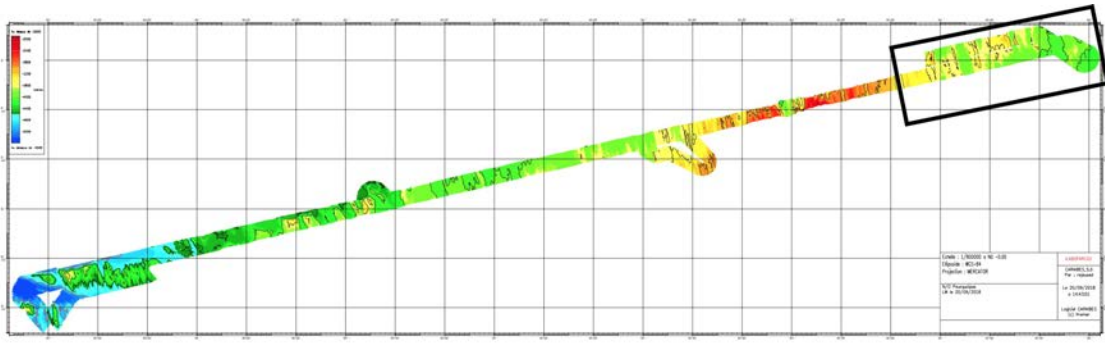


Fig. 7.11: ILABSPARC02 profile. A close-up of the ridge axis region is shown in figure 7.12.

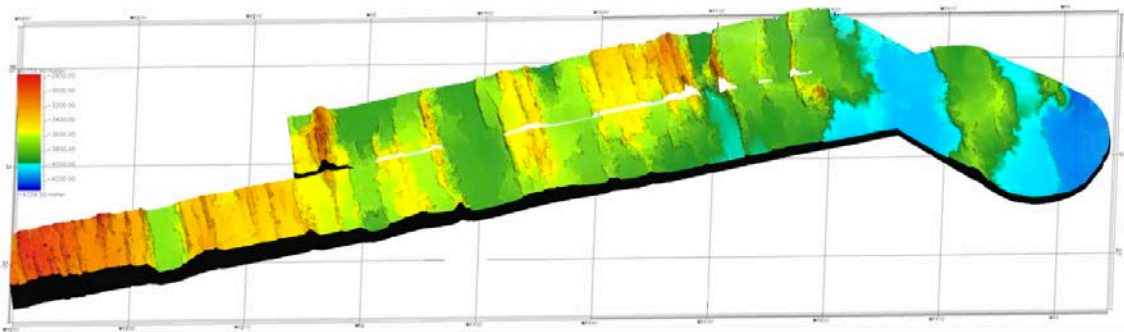


Fig. 7.12: Close-up of the east of the ridge axis area.

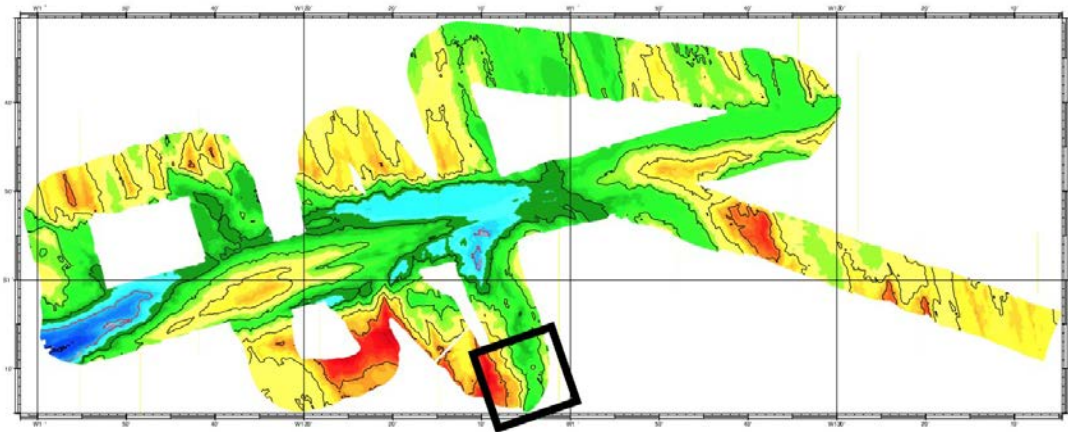


Fig. 7.13: ILABSPARC03to10 profile. A detailed view of the volcanoes found in the southern section (see black rectangle) is shown in figure 7.14.

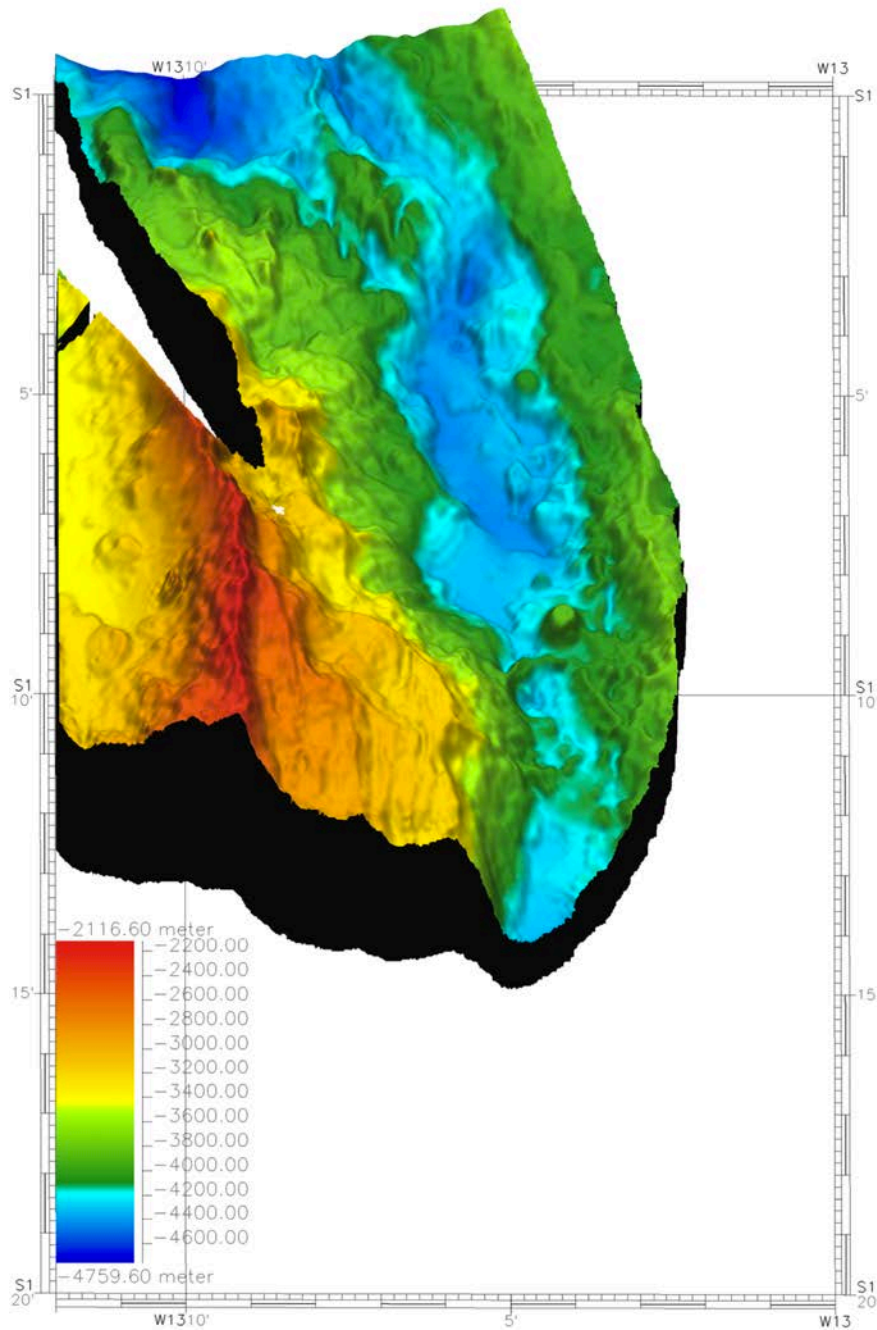


Fig. 7.14: Close-up of the volcanoes imaged in profile ILABSPARC03to10.

### 7.3.3. XBT data

A total of 28 XBT were deployed. Only XBT12 was bad. The maximum water depth reached has been 2131 m. Table 7.2 shows a summary of all the XBT launched. Figure 7.15 shows the position of these XBT during the survey on a bathymetric map, and Figure 7.16 shows the velocity data recovered by the XBT.

Profil Hydrologie			Thermo (3)		Celerimètre (4)	Sonde (m) (5)	RESON 7150		POSITION		...	Commentaires
Date/Heure	Type de Profil (1)	Fichier (2)	Temp (°C)	Celerite (m/s)	Celerité (m/s)		Date/Heure de Transfert du Profil	Fichier (7)	LAT	LONG		
27/08/2018 19:54	XBT	T5_00001	28,7	1543,7	1543,1	4960	20:15	T5_00001	1284.436 N	22441.370W		2131m
28/08/2018 0:59	XBT	T5_00002	28,8	1543,7	1543	5090	1:10	T5_00002	11715.786N	22215.934W		à 12n05 1273m
28/08/2018 12:00	XBT	T5_00003	28,2	1542,6	1542,2	4170	12:00	T5_00003	9932.309N	21921.766W		1350m
28/08/2018 18:35	XBT	T7_00004	27,8	1541,3	1540,6	1815	18:40	T7_00004	8931.618N	20950.140W		933m
28/08/2018 21:33	XBT	T7_00005	27,5	1540,7	1540,5	4215	21:41	T7_00005	894.789N	20936.160W		925m
29/08/2018 9:13	XBT	T7_00006	27,5	1540,6	1540,8	3625	8:00	T7_00006	6918.986N	19941.271W		938m
29/08/2018 23:34	XBT	T7_00007	27,6	1541	1541,2	5000	23:43	T7_00007	470.044N	18930.356W		900m
30/08/2018 4:50	XBT	T7_00008	27,37	1540,5	1539,8	4817	4:58	T7_00008	397.099N	1893.520W		900m
30/08/2018 10:44	XBT	T7_00009	26,4	1538,5	1538,8	5100	10:52	T7_00009	2912.350N	17954.346W		916m
30/08/2018 15:59	XBT	T7_00010	25,8	1537,3	1536,5	5000	15:11	T7_00010	1922.879N	17946.646W		950m
30/08/2018 23:15	XBT	T5_00011	25,1	1535,8	1536,0	3100	23:28	T5_00011	0812.335N	17935.575W		1500m
31/08/2018 0:00	XBT	T7_00012										échec cause ligne de pêche
31/08/2018 0:00	XBT	T7_00013	24,9	1535,3	1535,5	3700	9:25	T7_00013	1833.0195	17919.017W		
31/08/2018 16:36	XBT	T7_00014	25,5	1536,6	1536	4999	16:49	T7_00014	2947.5695	1797.285W		900m
01/09/2018 1:17	XBT	T7_00015	25,1	1535,3	1534,9	4465	1:30	T5_00015	3938.827N	1891.418W		
08/09/2018 14:25	XBT	T5_00016	27,8	1541,1	1540,5	5005	14:36	T5_00016	3948.1875	16958476W		582m
12/09/2018 8:58	XBT	T7_00017	25,6	1537	1537,1	4900	9:09	T7_00017	2953.1645	17913.083W		920m "leg2"
12/09/2018 21:38	XBT	T7_00018	25,5	1536,7	1536	4350	21:38	T7_00018	1956.5255	15941.199W		900m
13/09/2018 9:01	XBT	T7_00019	25,2	1536,1	1535,5	3650	9:07	T7_00019	1930.2265	13948.252W		900m
13/09/2018 13:49	XBT	T7_00020	25,5	1536,7	1536,1	3846	14:03	T7_00020	1919.1815	1390.986W		955m
13/09/2018 21:40	XBT	T7_00021	25,5	1536,7	1536,1	3750	21:46	T7_00021	0955.5965	11948.506W		917m
22/09/2018 21h47	XBT	T7_00022	25,2	1536,3	1535,7	3350	21:54	T7_00022	192.3725	12916.676W		930m "leg3"
23/09/2018 2:37	XBT	T7_00023	25,6	1536,2	1535,6	4750	2:52	T7_00023	0952.0125	1396.878W		
26/09/2018 13:52	XBT	T7_00024	25,7	1537,2	1536,6	3850		T7_00024	0946.5685	12957.289W		915m
26/09/2018 23:19	XBT	T7_00025	26,73	1539,10	1538,5	4394		T7_00025	0926.300N	1491.582W		916m
27/09/2018 10:41	XBT	T7_00026	27,8	1541,1	1540,5	4820	10:48	T7_00026	2937.578N	15918.572W		915m
27/09/2018 21:30	XBT	T7_00027	27,8	1540,7	1540,1	5000	21:39	T7_00027	4821.155N	16930.393W		958m
27/09/2018 23:13	XBT	T7_00028	27,8	1540,7	1540	5000	23h22	T7_00028	4837.181N	16841.481W		911m

Table 7.2: XBT summary.

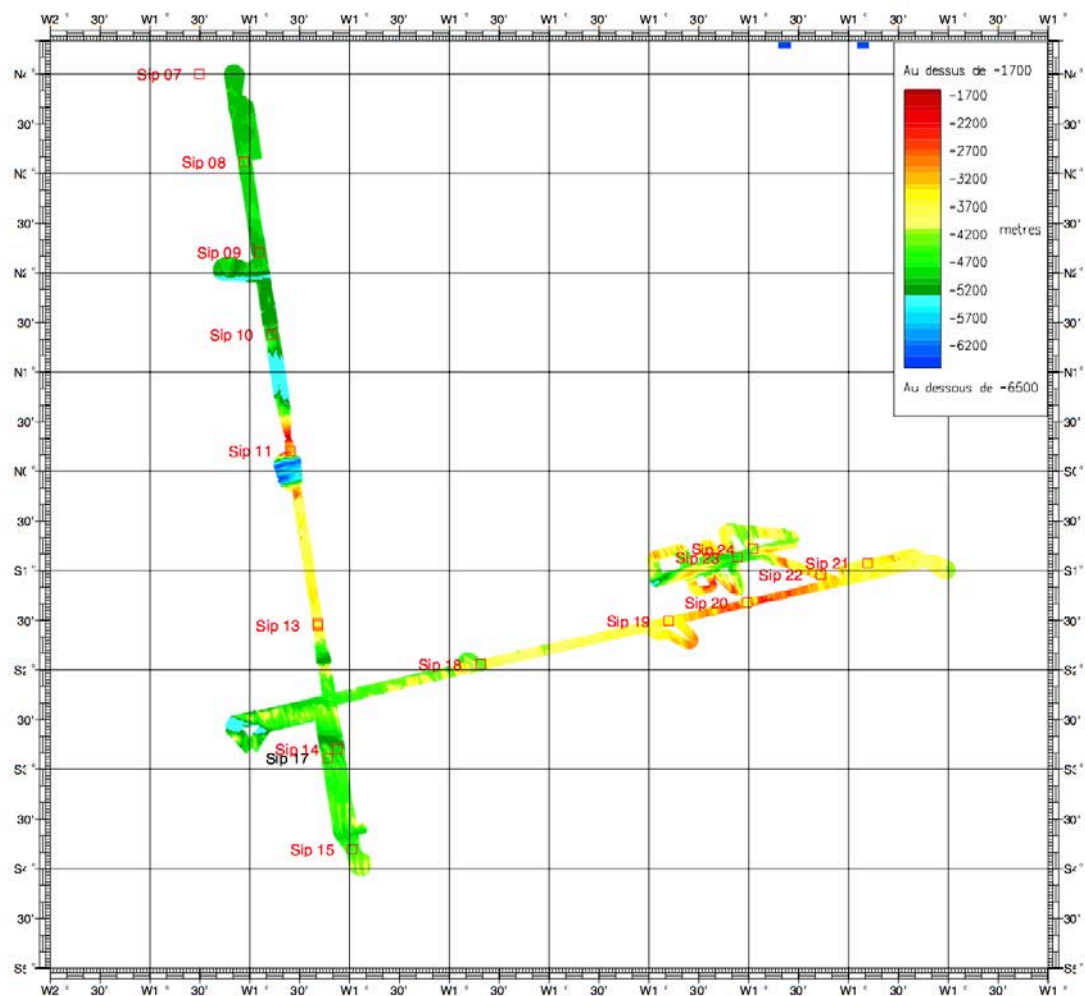


Fig. 7.15: XBT map along profiles ILABSPARC01, ILABSPARC02 and ILABSPARC02to10.

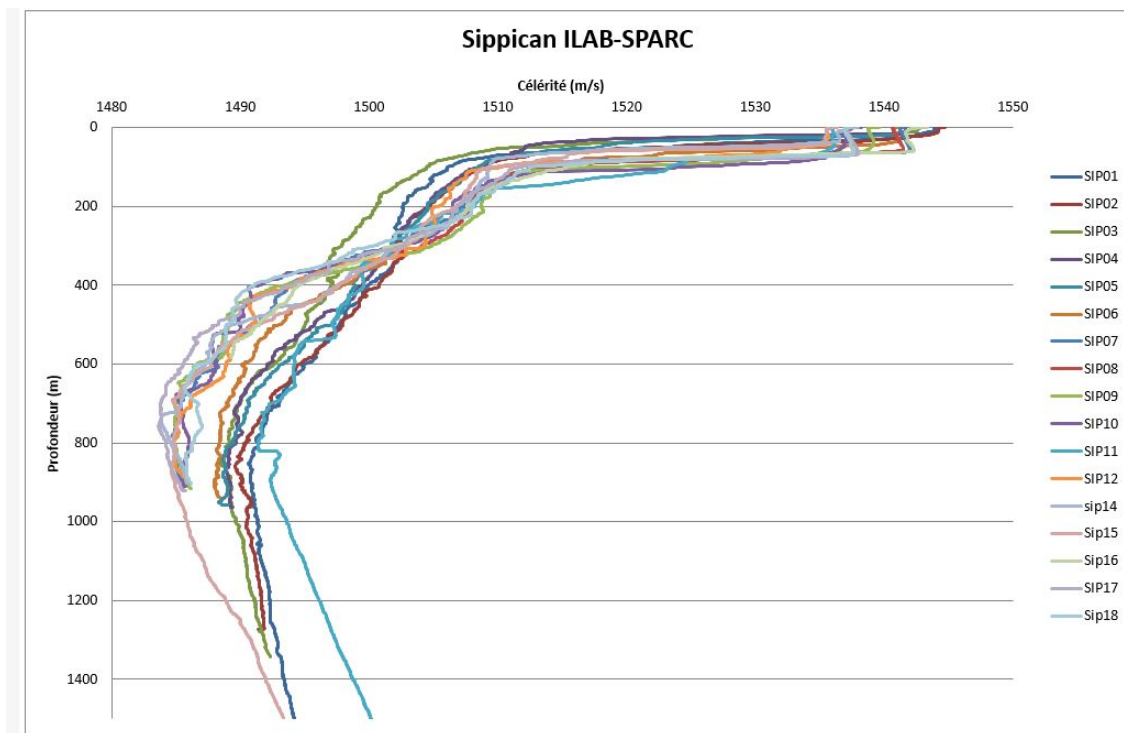


Fig. 7.16: Velocity curves obtained from the 27 XBT used during this survey.

## 8. Sub-bottom profiler (PARASOUND)

### 8.1 DATA ACQUISITION

*System/Equipment information:* The sub-bottom profiler installed on the NO Pourquoi Pas is a IXBLUE PWM 4 kVA sediment sounder. The antenna of the sounder is composed of 7 transducers (type Tonpilz from Ixsea), fixed to the gondole on the hull of the ship. The transducers emit the source signal and receive the response from the subsurface, and communicate with the PWM IXBLUE electronic unit, which adapts the outgoing signal, switches from emitting to receiving mode, and applies a pre-amplification to the recorded signal. The Logiciel SUBOP system (from Ifremer) installed on a PC onboard communicates with the electronic unit, and controls the parameters of acquisition, alongside applying the digital-analogue conversions. This system also receives the navigation information from the ship's GPS, bathymetry from the multibeam echosounder, ship's attitude information (pitch, roll, heave etc.), and acoustic synchronisation information, alongside producing a real-time QC display, and writing out the data. The system is capable of producing a source at 210 dB, with a maximum penetration of ~100 m and vertical resolution of ~30 cm.

*Acquisition timetable:* The sub-bottom profiler system began recording at the same time as the multibeam bathymetry, with the two systems in the in-sync mode, on 27/08/2018 at 20:16 UTC, beginning with SUBOP profile PP0001. The system was struggling to produce images of the seabed and sediments despite the likely presence of relatively flat topography and a thick sediment sequence. At 09:44 UTC on 28/08/18 the sub-bottom profiler and multibeam systems were changed to out-of-sync mode to test whether this improved the SUBOP recording without producing interference with the multibeam data (SUBOP profile was changed to PP0002 at this point). This produced a marked improvement with the profiler now clearly imaging the seabed and sediments, and produced no significant interference with the multibeam data, thus for the remainder of the cruise the systems were run in out-of-sync mode.

The profiler was run constantly for the remainder of the cruise except during OBS recovery to prevent interference with the acoustic release signal to the OBSs, between 17:30 08/09/2018 – 06:35 12/09/2018 (between profiles PP0013 and PP0014), 11:12 20/09/2018 – 21:08 22/09/2018 (between profiles PP0022 and PP0023), and 04:35 26/09/2018 – 13:51 26/09/2018 (between profiles PP0037 and PP0038).

Data acquisition ended ~1 day out of Mindelo on the return transit on 29/09/2018 at 20:08 UTC.

The profile number was changed either when a new line was started, or when a change occurred in the acquisition system (e.g. a problem occurred and was rectified). A total of 38 profiles were recorded during the cruise (locations shown in Figure 8.1).

*Source signal:* The sounder produced a linear chirp between 1500 and 6500 Hz, with a length of 80 ms, at 100% amplitude emission level (Figure 8.2). The minimum ping interval was set to 800 ms, with the actual interval dependent on the water depth, normally ~1 s. During transit, at an average speed of 10 kn, this gave an average distance between pings of 5-6 m. During seismic shooting, at an average speed of 3.8 kn, this gave an average distance between pings of ~2 m.

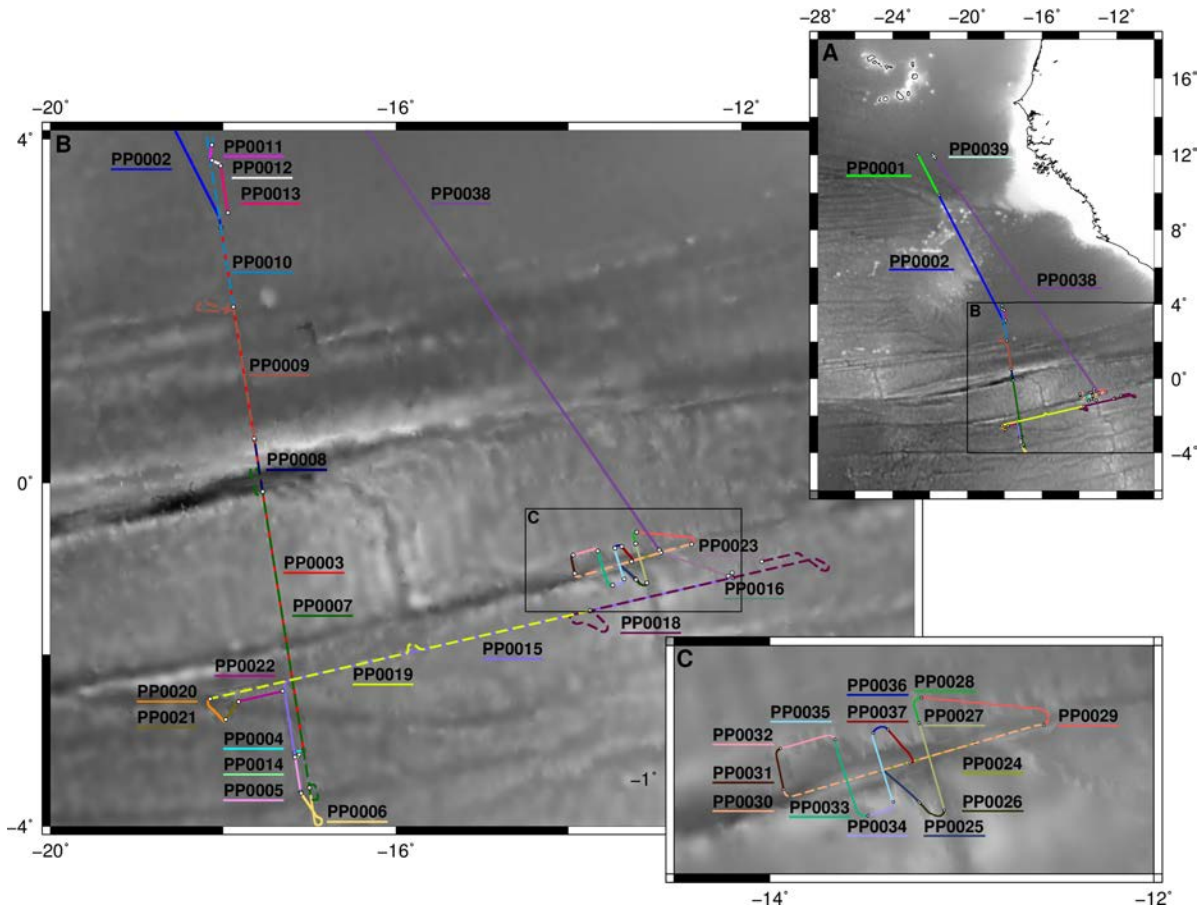


Figure 8.1: Acquisition maps of the SUBOP profiles. A: the entire study area including transit profiles also showing the location of map B. B: the main study area also showing the location of map C. C: the contingency time study area. For more details about each profile, see the Data File Summary table below.

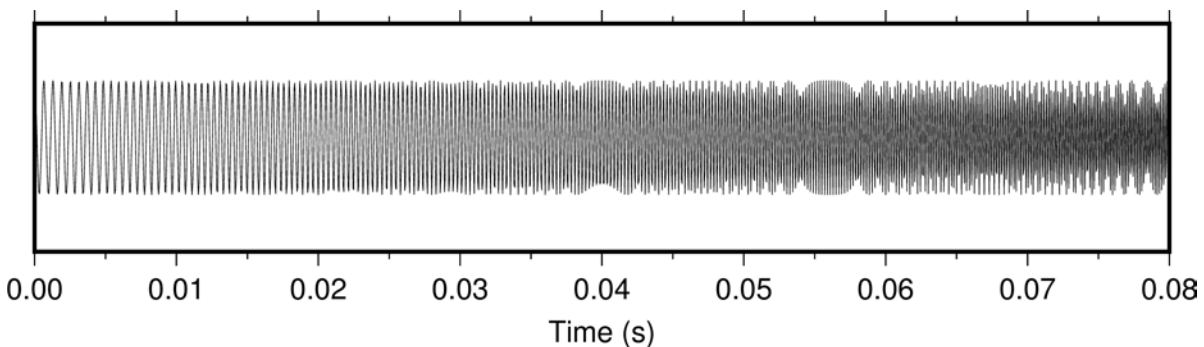


Figure 8.2: Source chirp signal used in the survey. The frequency varies from 1500 to 6500 Hz and the signal time is 80 ms.

*Recording and QC:* The sampling interval during recording was set to 0.05 ms (= 50 $\mu$ s), equivalent to a sampling frequency of 20,000 Hz, giving a Nyquist frequency of 10,000 Hz. Each trace contains 6001

samples, giving a trace length of 300 ms. The 300 ms recording window was automatically adjusted based on the water depth provided by the multibeam system and an adjustable water column velocity (varied manually from 1500-1520 m/s), in order to capture the seabed and sediment arrivals from each ping. Thus, the ‘start time’, or ‘recording delay’, for each trace varies according to the bathymetry. During recording, the sounder system applied a linear preamplification gain of 19 dB. Data QC is performed through the SUBOP acquisition program on the onboard PC, which processes and displays the data in real-time.

*Output files:* The acquisition system outputs the raw data in classic SEG Y format; consisting of textual (3200 bytes in ASCII format) and binary (400 bytes) file headers, a 240 byte header for each trace, and data in float32, big-endian format. A new file is created every 52.4 Mb, and file naming follows the convention <profile>\_D<date>\_T<time>.SEG, e.g. file PP0009\_D20180906\_T045720.SEG is along profile PP0009 and begins on the 06/09/2018 at 04:57:20 UTC.

Acquisition parameters (source information, sampling interval etc.) and parameters from the receiver system (trace number, seabed depth at source/receiver positions etc.) are written into the trace headers. A description of the output files and full list of the header values is included in the Appendix (in French). Some key trace header fields are:

- sy, sx, gy, gx (bytes 73-76, 77-80, 81-84, 85-88, long integer int32) are the source longitude and latitude, and receiver longitude and latitude for the ping, given in degrees, minutes and decimal seconds DDDMMSSs;
- delrt (bytes 109-110, short integer int16) is the recording delay time in ms (i.e. the start time of each trace), which changes according to the seabed depth.
- unassigned header (bytes 233-234, short integer int16) is the millisecond component of the ping time, in milliseconds. The year/day/hour/minute/second components of the ping time are given in the standard header fields;
- unassigned header (bytes 235-238, long integer int32) is the correction in  $\mu$ s for the movement of the ship, calculated from the heave, pitch, roll, and shot and receiver positions.

Alongside the SEG Y data, the acquisition system also outputs a NETCDF file containing ship data and ship attributes: time, heading, roll, pitch and heave. It creates a new file for each day, or if the file reaches a threshold size. The naming convention for the NETCDF file is <data><time>-shipattitude-ATT\_SUBOP.att, e.g. file 20180830055005-shipattitude-ATT\_SUBOP.att started recording on the 30/08/2018 at 05:50:05.

## 8.2 PROCESSING

The data are output in raw SEG Y format, with no processing sequence applied (Figure 8.3a). To produce a final image of the seabed and sediment section, a processing sequence was developed using Seismic Unix, following both a sequence used on the 2017 MIRAGE survey, and the processing applied within the SUBOP acquisition software to produce the QC display.

1. Read and clean the segy file [segypread, segyclean]. To prevent the unassigned headers from being overwritten by SU, these were remapped to unused standard header fields.
2. Correct for changes in recording delay time, so each trace within the file has a consistent start and end time [sushift].
3. Ensure trace number increases monotonically from 1 in output file [sushw].
4. Apply correction for ship movement (see Figures 8.3b, 8.3c for the effect of this correction). As the correction is in microseconds and SU expects the static time shift in milliseconds, the sampling time is multiplied by 1000 [sushw] before applying the shift [suchw, sustatic], and restored to its original value afterwards [sushw].
5. Apply spherical divergence correction [sugain].
6. Bandpass filter at 1000, 1500, 6500, 7000 Hz to remove energy outside frequency band of interest [sufilter].
7. Time shift to correct for delay introduced by the correlation step below [sushw, sustatic].
8. Generate source signal, using the given source parameters of the chirp [suviibro].
9. Correlate with the source signature [suxcor].
10. Bandpass filter at 1000, 1500, 4500, 6000 Hz [sufilter].

11. Calculate trace envelope instantaneous amplitude [suenv].

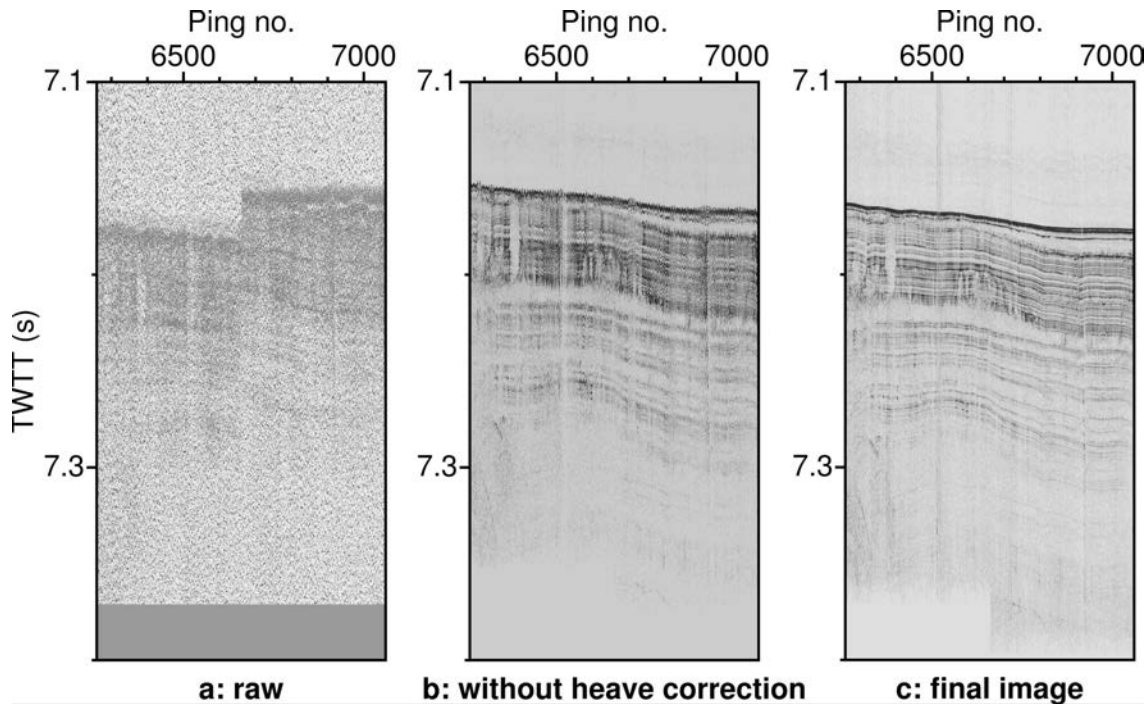


Figure 8.3: Examples of different stages of processing. a: raw data with recording time shifts uncorrected; b: all processing applied apart from correction for ship heave/movement, causing high frequency distortion on horizons; c: fully processed final image.

A few more cosmetic steps are applied before plotting.

12. An AGC [sugain].
13. A small trace mix [sumix].
14. Produce data plot [supsimage] (Figure 8.3c).

*PRELIMINARY RESULTS:* Where there are sediments, the sub-bottom profiler data quality is very high (e.g. Figures 8.4-8.6), with over 100 m of penetration and a high lateral resolution due to the small spacing between pings of 1-6 m. As expected, young, unsedimented crust and extreme topography such as the Romanche transform zone result in diffractions, scattering of the energy and a poor image of the seafloor. The final processed images of the sediments clearly show different sedimentary horizons and packages, and different periods of deformation including both normal and thrust faulting (Figures 8.5 & 8.6).

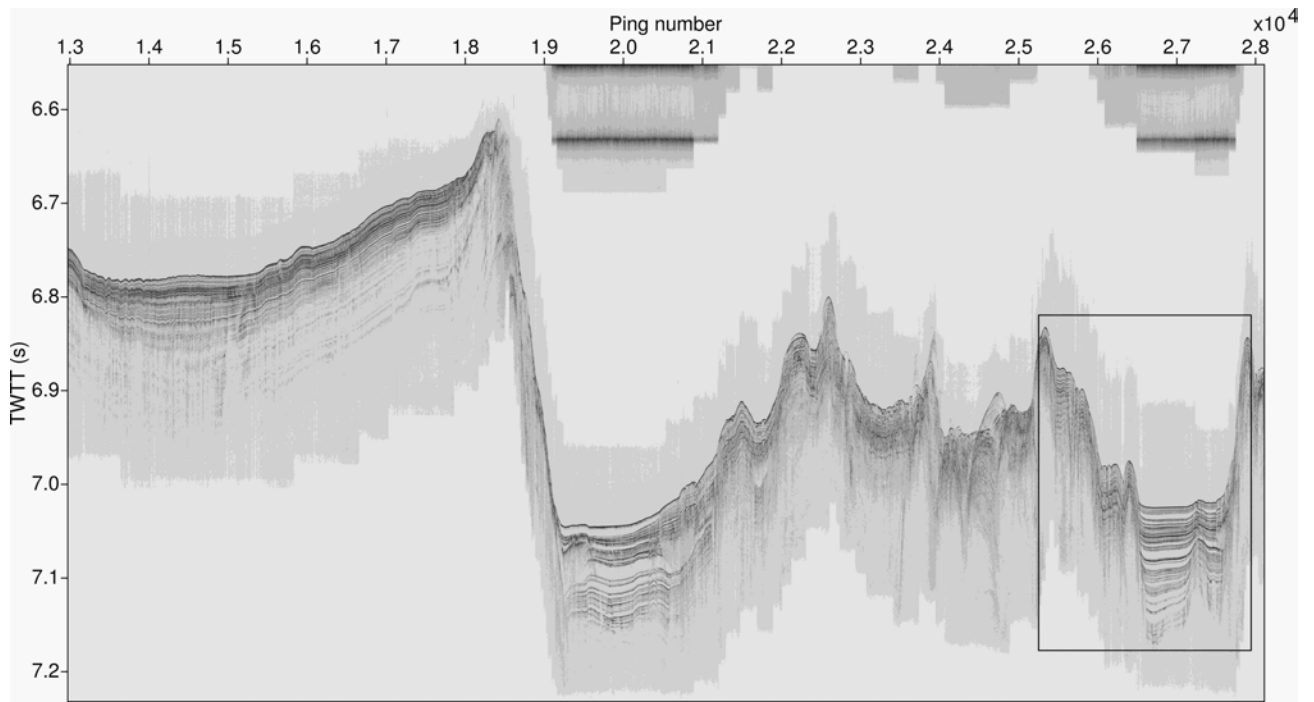


Figure 8.4: St Paul fracture zone from North to South side from PP0003.

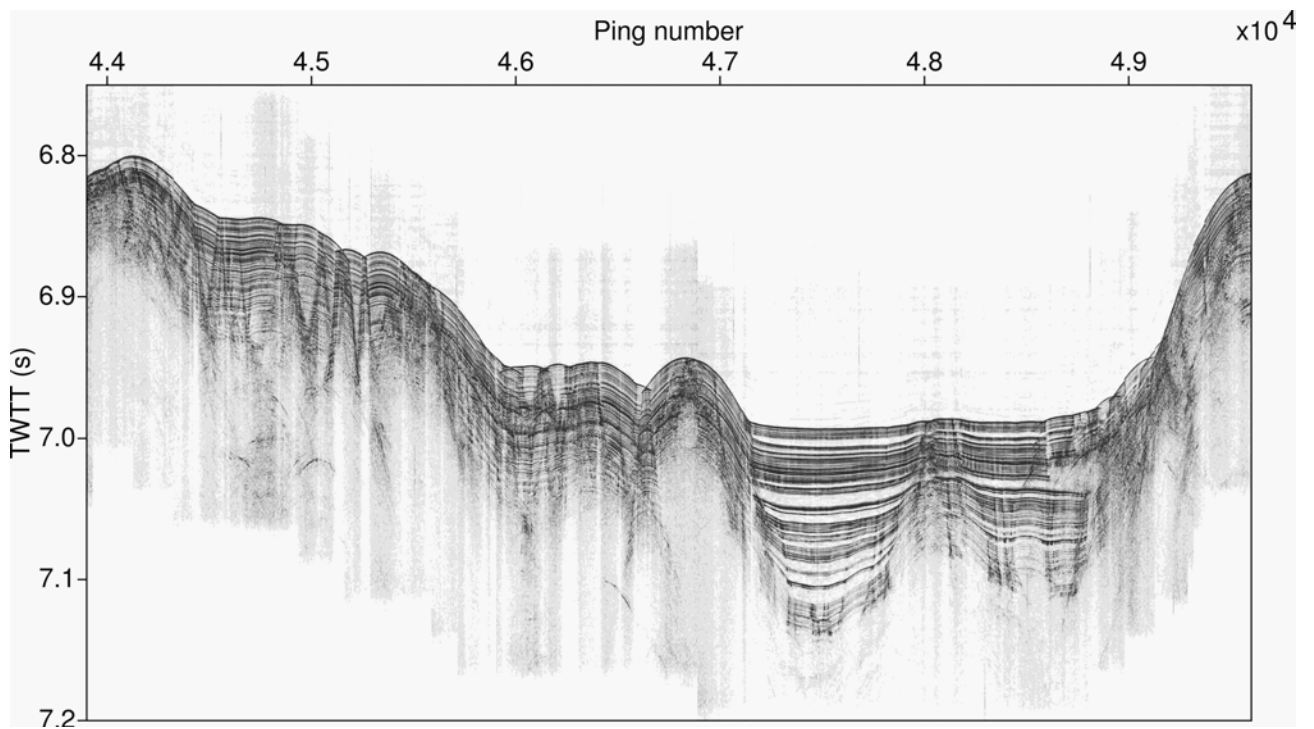


Figure 8.5: Sediment ponding within the St Paul fracture zone from profile PP0009, showing compressive structures. Location is shown by box in Figure 8.4.

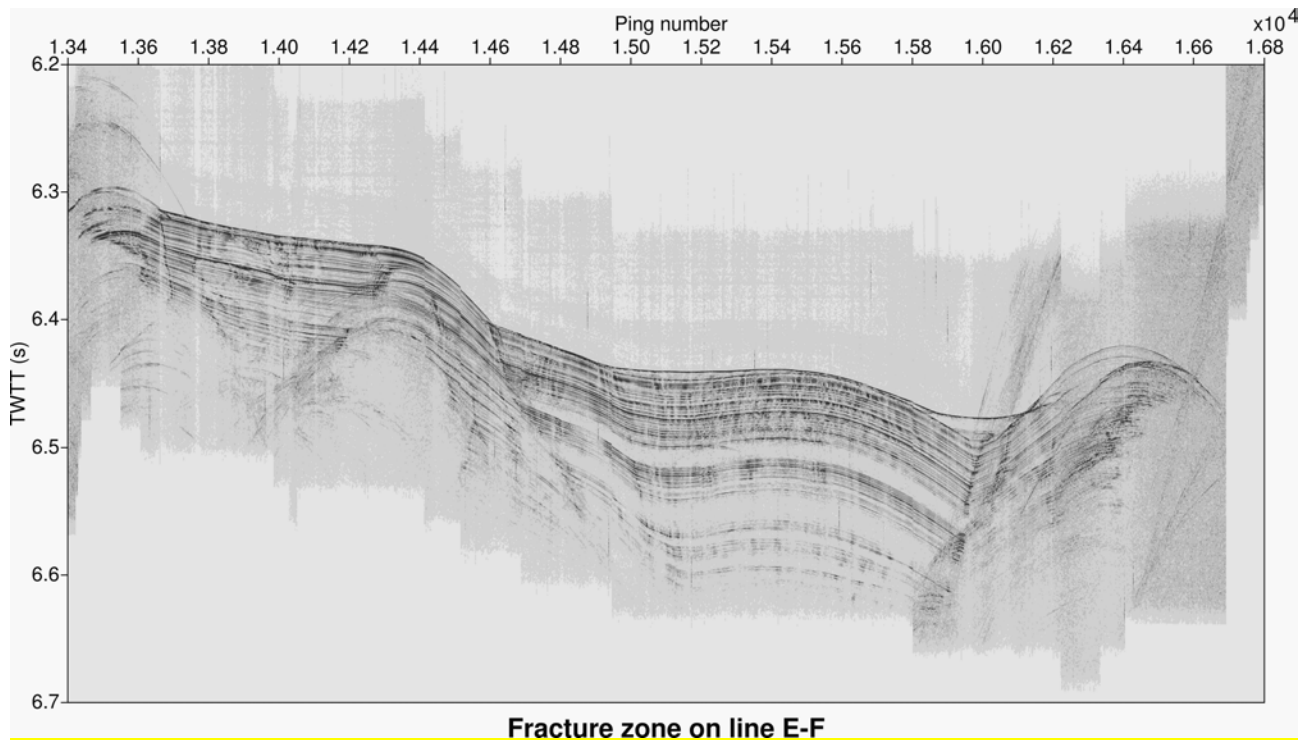


Figure 8.6: Sediments in Chain transform fault from profile PP0027, close to the eastern ridge-transform intersection and just east of the large push-up ridge, showing active and old faults.

### 8.3 DATA FILE SUMMARY

The following table contains the details of each sub-bottom profiler profile.

Profile	Start julian day and time	End julian day and time	Start longitude	Start latitude	End longitude	End latitude	Length (km)	No. of files	Ping rate (s) and distance (m)	
PP0001	239 20:16:36	240 09:42:32	22.665500 W	12.026200 N	21.536200 W	9.870020 N	269.5	2	18.5 103.3	Outgoing quality EM122
PP0002	240 09:44:28	242 05:49:41	21.533600 W	9.865010 N	18.027200 W	2.970190 N	858.9	70	1.1 5.7	Outgoing good as
PP0003	242 05:49:59	243 18:36:35	18.027100 W	2.969960 N	17.070000 W	3.120190 S	685.5	54	1.1 6.0	ILAB-5 deployment Roman
PP0004	243 18:36:51	243 19:16:53	17.070100 W	3.120390 S	17.176900 W	3.145020 S	12.2	2	1.1 5.5	Transition deployment Chain.
PP0005	243 19:17:05	243 21:42:56	17.176700 W	3.145620 S	17.104200 W	3.604040 S	51.6	4	1.1 6.6	Transition deployment Chain.
PP0006	243 21:48:10	244 11:48:52	17.099000 W	3.618180 S	17.001600 W	3.553920 S	13.0	22	1.1 0.3	Stream deployment shooting
PP0007	244 11:49:34	247 20:48:55	17.001700 W	3.553210 S	17.542900 W	0.100967 S	388.6	129	1.1 1.4	Gun report SPARC second crossing
PP0008	247 20:49:29	248 03:50:20	17.543000 W	0.100278 S	17.638700 W	0.497900 N	67.4	15	0.8 2.2	ILAB-5 (shooting Roman after 06 into hea
PP0009	248 07:00:49	250 00:29:00	17.640900 W	0.511939 N	17.882900 W	2.046980 N	172.8	58	1.2 1.4	ILAB-5 (shooting and stream crossing
PP0010	250 00:29:22	251 09:06:28	17.882900 W	2.047480 N	18.132100 W	3.935400 N	211.7	48	1.2 2.1	ILAB-5 (shooting turn and St Paul
PP0011	251 09:06:44	251 13:33:35	18.132100 W	3.935200 N	18.132100 W	3.753760 N	20.2	7	1.2 1.5	Stream Paul.
PP0012	251 13:33:43	251 14:10:57	18.131800 W	3.753580 N	18.030800 W	3.691830 N	13.1	1	1.2 6.8	Transition
PP0013	251 14:11:03	251 17:15:55	18.030700 W	3.691530 N	17.945300 W	3.143970 N	61.6	5	1.2 6.5	Transition Switch

Profile	Start julian day and time	End julian day and time	Start longitude	Start latitude	End longitude	End latitude	Length (km)	No. of files	Ping rate (s) and distance (m)	
PP0014	255 06:57:22	255 07:23:48	17.120500 W	3.167410 S	17.170500 W	3.198010 S	6.5	1	1.1 4.5	Transit
PP0015	255 07:23:58	256 19:17:26	17.170600 W	3.197470 S	12.093800 W	1.103500 S	610.2	56	1.1 5.1	Transit profile south of ridge a
PP0016	256 19:17:50	256 19:50:04	12.093400 W	1.103480 S	12.108100 W	1.046770 S	6.5	1	0.9 3.2	Transit
PP0017	<i>Profile 17 doesn't exist.</i>									
PP0018	256 21:54:10	259 23:50:39	11.763600 W	0.915708 S	13.752900 W	1.490820 S	230.2	127	1.0 0.8	ILAB-5 (shooting crossin
PP0019	259 23:51:06	262 23:43:39	13.753300 W	1.490940 S	18.151100 W	2.518270 S	501.9	118	1.0 2.0	ILAB-5 (shooting south o
PP0020	262 23:44:06	263 06:52:24	18.151600 W	2.518460 S	17.971400 W	2.758390 S	33.4	10	1.2 1.6	Transit
PP0021	263 06:52:38	263 8:15:56	17.971100 W	2.757810 S	17.823100 W	2.551630 S	28.2	2	1.4 7.7	Transit
PP0022	263 08:16:07	263 11:12:05	17.822600 W	2.551420 S	17.311600 W	2.427310 S	58.4	4	1.3 7.2	Transit Switch
PP0023	265 21:05:13	266 01:30:40	12.153600 W	1.085310 S	12.933000 W	0.813031 S	91.8	8	1.0 6.0	Transit Chain I
PP0024	266 01:30:47	266 04:36:18	12.933200 W	0.813106 S	13.413000 W	0.952975 S	55.6	5	1.1 5.6	ILAB-5 deploy transform
PP0025	266 04:36:25	266 08:35:20	13.413000 W	0.953019 S	13.227000 W	1.119240 S	27.7	7	1.0 1.9	Gun an oblique push-up TF.
PP0026	266 08:42:49	266 10:53:53	13.219900 W	1.126620 S	13.093500 W	1.166030 S	14.7	4	1.2 2.2	Turn to of Char
PP0027	266 10:54:07	266 17:43:44	13.093500 W	1.165800 S	13.222700 W	0.709500 S	52.7	11	1.1 2.3	ILAB-5 (shooting crossin
PP0028	266 17:45:47	266 20:02:26	13.223400 W	0.707250 S	13.211000 W	0.574136 S	14.9	5	0.9 1.6	ILAB-5 (shooting turn, no

Profile	Start julian day and time	End julian day and time	Start longitude	Start latitude	End longitude	End latitude	Length (km)	No. of files	Ping rate (s) and distance (m)	
PP0029	266 20:02:36	267 05:56:03	13.210800 W	0.574111 S	12.574300 W	0.716253 S	72.5	17	1.0 2.1	ILAB-5 (shootin turn, ob Chain.
PP0030	267 05:56:15	268 02:52:21	12.574500 W	0.716286 S	13.929800 W	1.054830 S	155.3	34	1.0 2.1	ILAB-5 (shootin Chain a ridge..
PP0031	268 02:52:35	268 05:56:56	13.929800 W	1.054540 S	13.946900 W	0.840942 S	23.8	5	1.0 2.2	ILAB-5 (shootin north o
PP0032	268 05:57:16	268 9:45:37	13.946600 W	0.840778 S	13.663000 W	0.793639 S	32.0	7	1.0 2.4	ILAB-5 (shootin north o
PP0033	268 09:45:50	268 15:54:15	13.662900 W	0.793897 S	13.490200 W	1.193800 S	48.4	11	1.0 2.2	ILAB-5 (shootin crossin ridge.
PP0034	268 15:54:23	268 17:52:00	13.490000 W	1.193760 S	13.357700 W	1.120320 S	16.8	4	1.0 2.3	ILAB-5 (shootin south o
PP0035	268 17:52:06	268 22:42:43	13.357700 W	1.120170 S	13.463400 W	0.760406 S	41.7	8	1.1 2.5	ILAB-5 (shootin crossin
PP0036	268 22:42:53	268 23:55:17	13.463300 W	0.760194 S	13.385700 W	0.741533 S	8.9	3	0.9 1.9	Turn, n
PP0037	268 23:55:25	269 04:51:13	13.385600 W	0.741628 S	13.270900 W	0.916894 S	23.3	8	1.1 1.4	Gun an north o
PP0038	269 13:51:07	272 18:43:02	12.951900 W	0.780669 S	21.719900 W	11.80790 0 N	1687.7	111	1.2 7.1	Return Roman
PP0039	272 18:43:54	272 20:08:06	21.721400 W	11.810100 N	21.869900 W	12.02040 0 N	28.4	3	1.2 6.5	Return

## 9. Earthquakes

### 9.1 BACKGROUND

Due to their nature as active plate boundaries, mid-ocean ridges and their connecting transform faults commonly generate earthquakes. The dominant stresses at each boundary type result in a predominance of extensional earthquakes at mid-ocean ridges, and strike-slip mechanisms at transforms. Earthquakes are consistently observed in the study area (Figure 9.1), mostly with magnitudes of 4 – 5, but larger events can also occur, such as a Mw 7.0 event in the Romanche transform zone in 1994 (McGuire et al., 1996). Analysis by Abercrombie and Ekstrom (2001) shows that deeper events occur within the Romanche than the Chain transform, likely due to differences in temperature structure as the Romanche offsets older and colder lithosphere than Chain, and the depth of seismic slip on transforms is limited by the 600°C isotherm. Previous studies of the area also found evidence for compression in the transforms: in St Paul transform reverse-faulting earthquakes have been observed near St. Peter and St. Paul islets (Wolfe et al., 1993), which consist of mylonitised peridotite and are thought to have formed over the past 10 Ma due to transpressive stresses uplifting and exhuming mantle material (Maia et al., 2016). Bathymetric maps of Chain transform reveal several features which could be positive flower structures formed by transpression due to offsets in the main strike-slip fault (Harmon et al., in press). Seismic reflection and sub-bottom profiler images of the sediments from this study show recently active compressive structures in Chain and Romanche transforms, and St. Paul fracture zone (Chapters 6 and 8), and a micro-earthquake study using OBS data could reveal if these structures have associated seismic activity. Fracture zones, the remnants of old transform faults, are thought to be inactive and no longer deforming and thus, aseismic. However, a few smaller events in the global catalogue appear to occur in the Chain transform fault east of the ridge-transform intersection (Figure 9.1), and studies of micro-earthquakes recorded by OBSs may reveal more events.

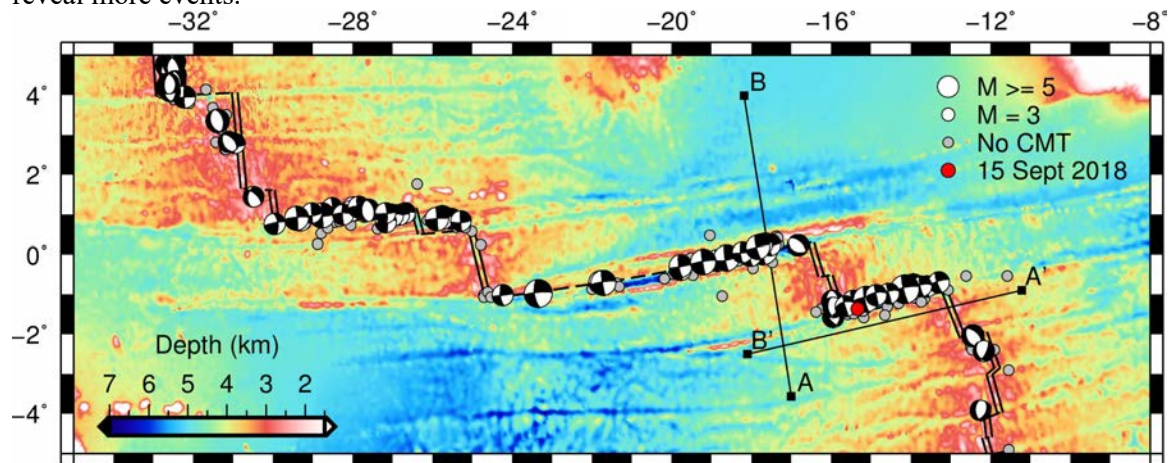


Figure 9.1: Earthquakes within the main study region during 2016-2018. Focal mechanisms are from the Harvard Centroid Moment Tensor (CMT) database and grey circles are events from the USGS global earthquake database with no entry in the Harvard CMT database. The red circle represents the 15<sup>th</sup> September Mb 4.5 earthquake. ILAB-SPARC profiles 1 and 2 are shown by lines A-B and A'-B', respectively. Plate boundaries are from Bird (2003): double lines=MAR, dashed lines=transform zones.

### 9.2 OBSERVATIONS

During the cruise, numerous earthquakes occurred in the study area which were recorded by the OBSs. They were identified and distinguished from airgun shots by their long signal duration, clearly separated P, S, and surface wave arrivals, and extended coda. Only one identified event, in the Chain transform zone on the 15<sup>th</sup> September at 04:29 UTC, was recorded by the International Seismographic Network and so the remainder do not appear in either the USGS or Harvard CMT global earthquake databases. A systematic study to identify all the earthquakes recorded on all OBS has not yet taken place, instead below are several examples of recorded events.

#### *Local earthquakes*

Numerous earthquakes were observed in the study area which were not of high enough magnitude to be recorded by the global earthquake databases, although were significant enough to be recorded by more than one OBS (e.g. Figure 9.2).

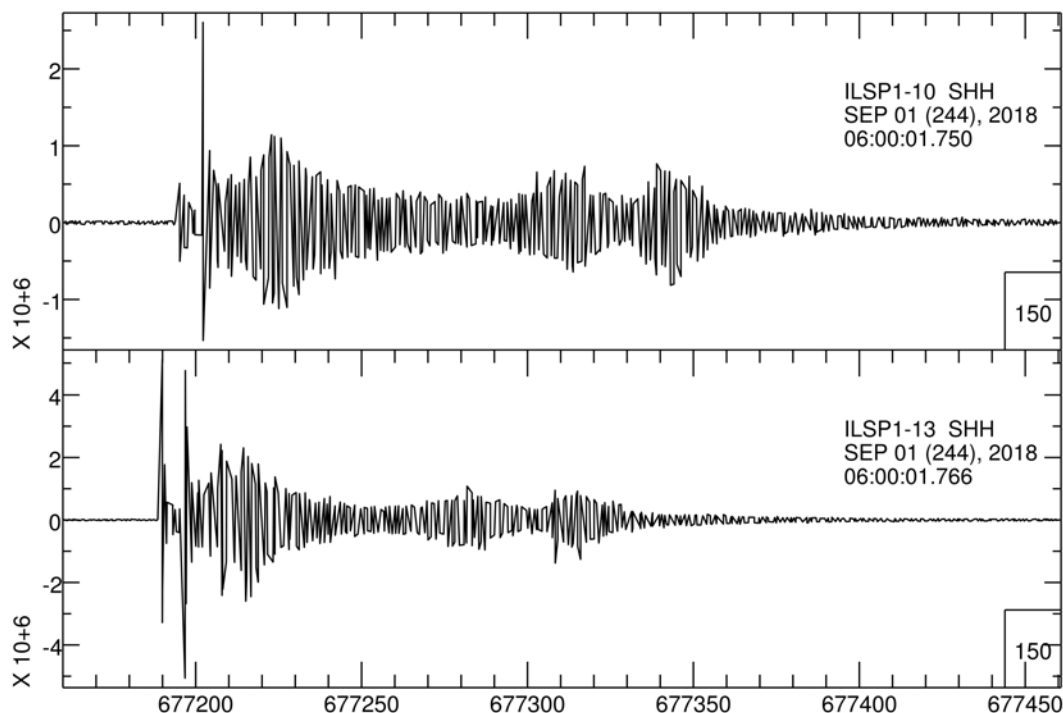


Figure 9.2: Earthquake on 9<sup>th</sup> September at approx. 02:06 UTC, shown here on the hydrophone channel of OBSs ILSP1-10 and ILSP1-13. Likely to have occurred in the Romanche.

#### *15<sup>th</sup> September M 4.5 event*

On 15<sup>th</sup> September at 04:29 the USGS global earthquake database recorded a Mb 4.5 event, which was also recorded by the OBS deployed along ILSP-2 (Figure 9.3). Foreshocks to this event can also be found in the OBS data.

#### *Event seen on MCS*

On 25<sup>th</sup> September at the end of shooting profile ILAB-SPARC 5 within the Chain transform zone, an anomalous shot gather was observed from the MCS data with a high amplitude event occurring before the seabed reflection. Further analysis showed that the signal from this event was characteristic of an earthquake. The same event is also observed in the OBS data (Figure 9.4).

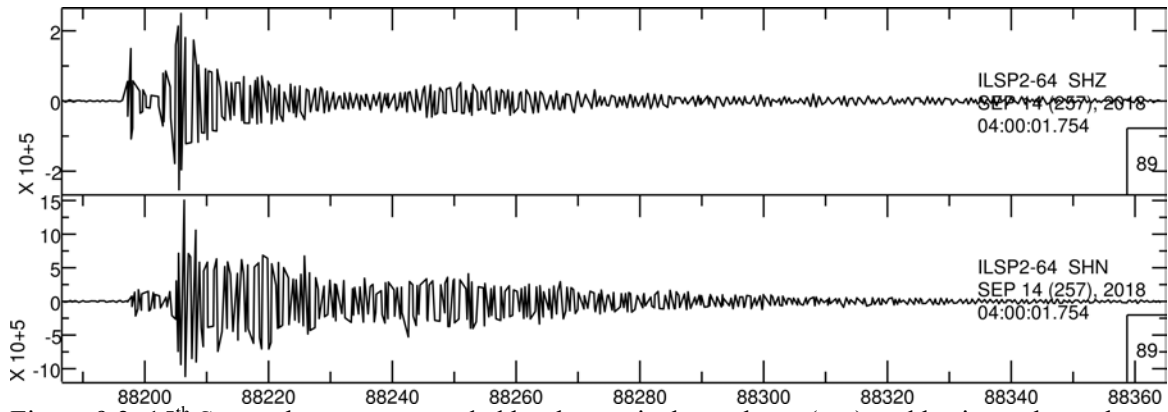


Figure 9.3: 15<sup>th</sup> September event recorded by the vertical geophone (top) and horizontal geophone (bottom) of OBS ILSP2-64.

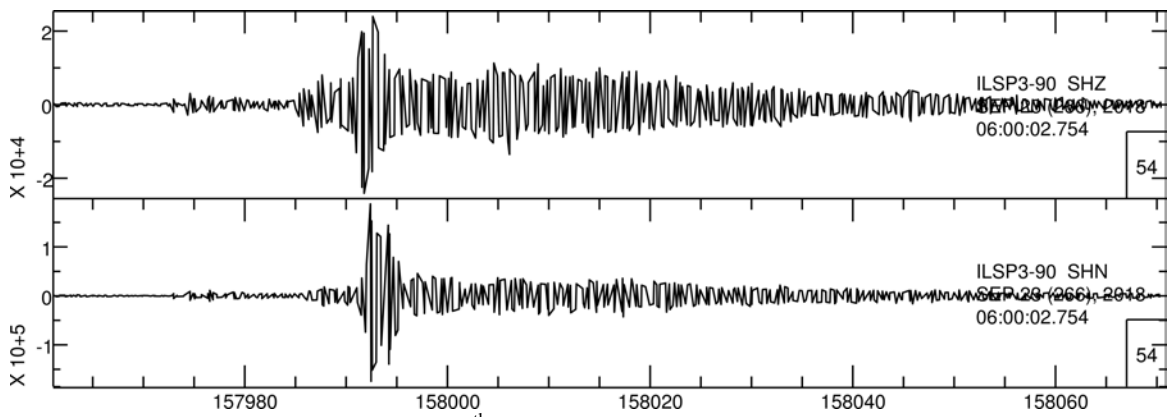


Figure 9.4: Earthquake occurring on 25<sup>th</sup> September at approx. 01:53 UTC, shown here on the vertical (top) and horizontal (bottom) geophones of OBS ILSP3-90.

## 10. Marine Gravity

The gravimeter KSS31(Bodenseewerk) was operated throughout the cruise with the first set of gravity ties made in Mindelo (Cape Verde) on August 24th (Figure 10.1).

Gravity data were converted from NavCDF (the conversion is done using Ifremer' software), merged with navigation and exported as two ascii files (one containing recorded data from August 26th until September 25th, and the other one from September 26th until September 29th; the latter file includes only sampling during the transit to Cape Verde). The information on the available data (e.g. Bouger anomaly, Free-Air Anomaly etc.) is indicated in the header of each file.

**Rattachement du Gravimètre Bodenseewerk KSS31** rattachement N° **139**

S/N capteur: 010 S/N plate-forme: 031 porteur: N/O Pourquoi pas ?

date: **24-Aug-18** échale: **MINDELO - Poste 3** Lat: **16°53.35N**  
mission: **TRBRMIN** observateurs: **GB** Long: **024°59.90W** longitudes

**Observations:**  
Bateau au QP4 (Td à quai)

Position: N 16° 53.3558 W 024° 59.9012 Cap: 185°

Quai (C/P): CQ = **P** Quai = Pie  
H. eau à Z: H = **2.20** m prendre la

**Station de référence**  
nom: **Mindelto Poste 3 Bollard 4**  
N°:  
syst. réf.:  
Gréf = **978730.51** mGal  
correction IGSN/1:  
Gréf IGSN/1: **978730.51** mGal

**Dérive du gravimètre portable**

mesure N°	quai 1	station	quai 2	quai 1	station	quai 2
1	3439.054	3439.340	3439.073			
2	3439.053	3439.341	3439.067			
3	3439.049	3439.341	3439.072			
4	3439.053	3439.342	3439.062			
5	3439.052	3439.341	3439.072			
6	3439.052	3439.341	3439.071			
7						
8						
9						
10						

h. deb: 15:07:15 15:19:34 15:30:29  
h. fin: 15:15:01 15:27:04 15:37:58  
h. moy: 15:11 15:23 15:34

K Scintrex KW = 1  
Type: Scintrex CG5  
N° Série: 080340042

mo. capteur: **3439.052 3439.341 3439.073** unité capteur  
val. en mGal: **3439.052 3439.341 3439.073** mGal  
écart type: **0,00 0,00 0,00** mGal

dérive du Scintrex: (G2-G1)/(t2-t1)  
DW = **0,054** mGal/h

**Gravité rapportée au navire**  
G abs. au quai (Gréf-G2-G0-DHx(t-R)): Gquai = **9730.232070552** mGal  
correction de hauteur (CDH): CH = **0.418** mGal  
G abs. rapporté au navire (Gquai + CH): Gnav = **978730.650** mGal  
GV relative lu sur le KSS31 (moyenne 10 min): GV = **-1364.11** mGal  
Grav-Du.KinetKinet = **880284.756**

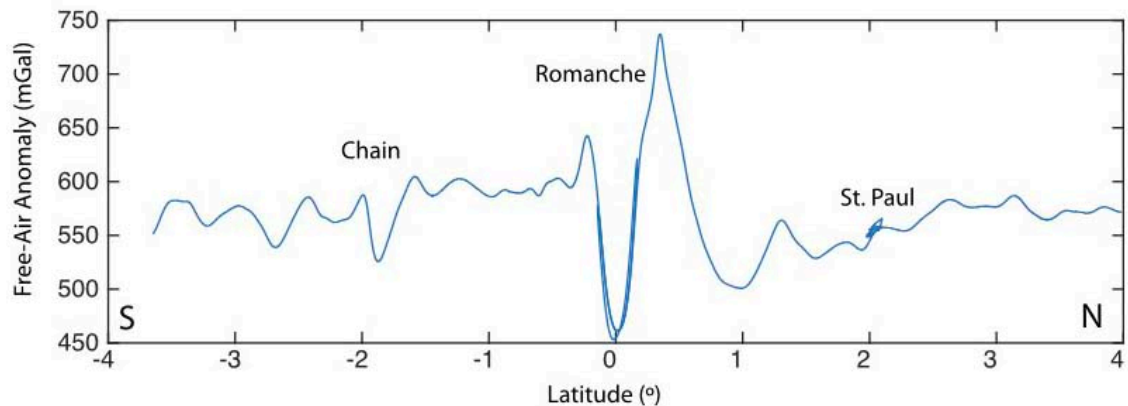
**Dérive du KSS31**  
Dérive KSS31 ((Gnav-(GV+CK))-(Gnav0-GV0))  
Correction de coefficient = (Gnav-Du.KinetKinet) / (Grav0-GV0.KinetKinet)  
Ck = **0**  
D = **-0,384** mGal  
Dm = **-0,135** mGal/mois  
Dl = **-0,004** mGal/jour

Rattachement précédent  
date: **29-May-18**  
échelle: **Reydsjokk**  
Grav0: **982267.72** mGal  
GV: **2172.58** mGal

1

**Figure 10.1-** Information about the gravity tie(s) taken in Mindelo on August 24th, at the start of the survey.

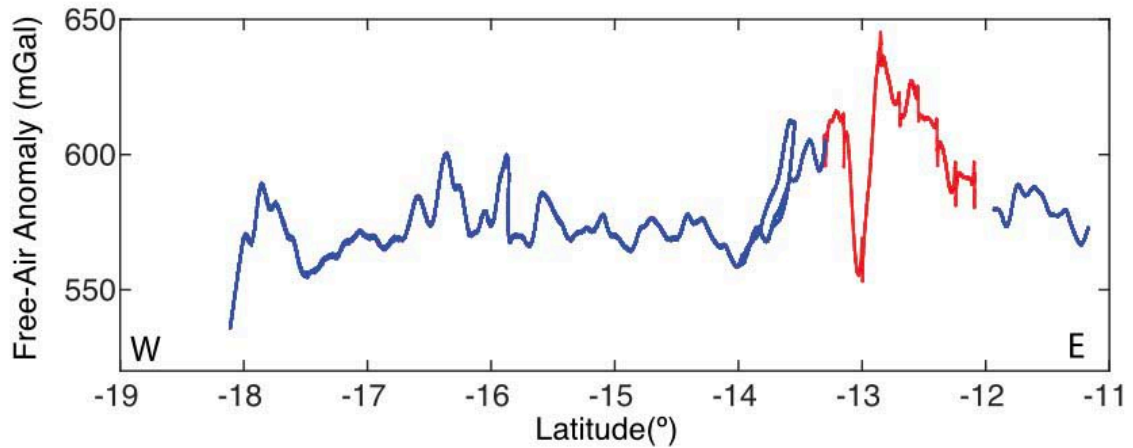
Profiles, collected along ILAB-SPARC-01, ILAB-SPARC-02 and ILAB-SPARC 05 are shown as examples in Figure 10.2, 10.3 and 10.4, respectively. The signal in Free-Air Anomaly follows the bathymetry in all three cases.



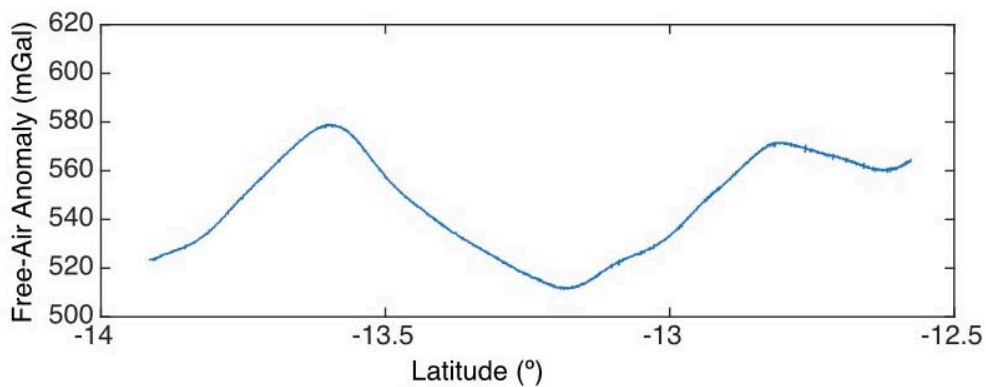
**Figure 10.2** - Example of Free-Air Anomaly profile recorded along the line ILAB-SPARC\_01 with the main geologic features identified; Chain Fracture Zone, Romanche Transform Fault and St. Paul Fracture Zone. The anomaly follows the bathymetry. The overlap in the gravity signal within the Romanche Transform Fault represents the data collected during the turn due to gun repair.

For the profile ILAB-SPARC\_02 a file recorded on September 15th was not possible to merge with the navigation and thus there is a gap for the gravity profile recorded along the shooting line (Figure 10.4). Unfortunately, the gap was produced during the time when we were crossing the ridge axis. As the gravity was also recorded during the OBS deployment (September 12th until

September 13th), we were able to recover the most of the missing data (note the red line in Figure 10.3). The outliers in the profile recorded during the OBS deployment are due to the speed reduction when deploying OBSs.



**Figure 10.3** - Example of Free-Air Anomaly profile extracted along the line ILAB-SPARC\_02. Blue line is the gravity anomaly profile recorded during the shooting, and the red line represents the profile recorded during the OBS deployment along the line. The loop west of the gap is corresponding to the deviation from the profile due to gun repair.



**Figure 10.4** - Example of Free-Air Anomaly profile extracted along the line ILAB-SPARC\_05.

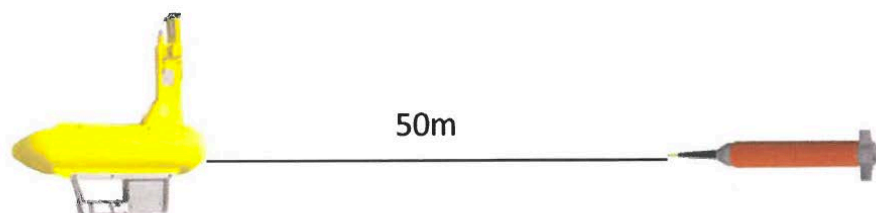
The anomaly shown along the ILAB-SPARC\_05 profile corresponds to the topography of the intra-transform ridge-like feature within Chain Transform Fault.

All the data with navigation merged are backed up, together with documentation files (pdf that shows specifications of the gravimeter, values for tie points, etc.).

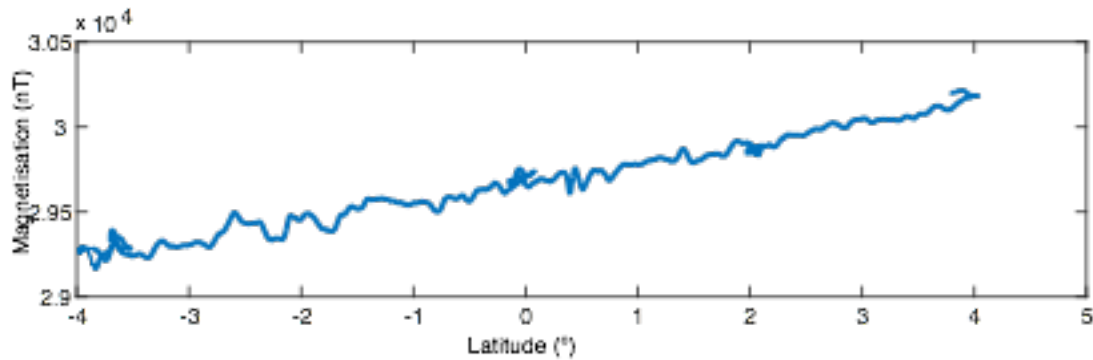
At the arrival to Mindelo another set of gravity ties was taken on **October XX (Figure 10.5)**.

## 11. Marine Magnetic

The magnetometer (SeaSPY) was operated only during the MCS data acquisition, as the instrument is attached to the streamer, ~50 m from the tail buoy (Figure 11.1).



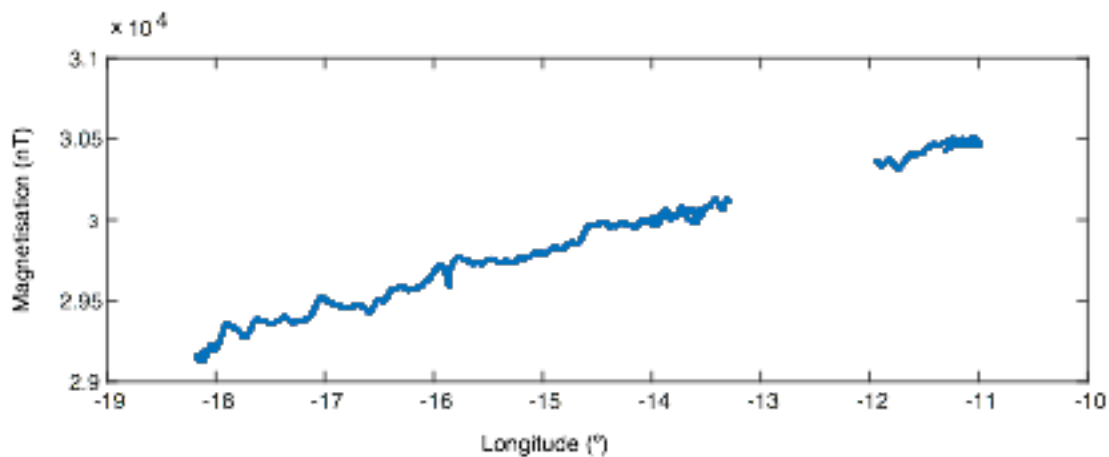
**Figure 11.1** - Illustration of magnetometer position with respect to the tail buoy.



**Figure 11.2** - Example of magnetic data profile recorded along the line ILAB-SPARC\_01.

The magnetic data are recorded in nT units. The raw data were converted from NetCDF format, merged with navigation, and exported in ascii format. Examples of magnetic profiles recorded along the lines: ILAB-SPARC\_01, ILAB-SPARC\_02 and ILAB-SPARC\_05 are shown in Figure 11.2, 11.3 and 11.4, respectively.

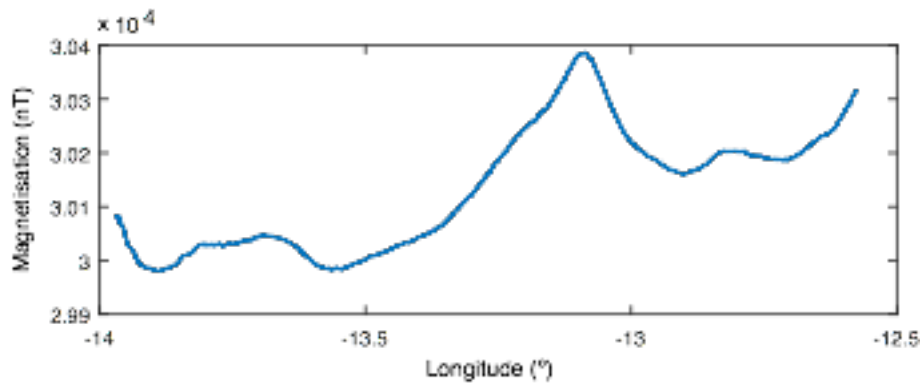
Similarly, to the gravity, there are problems with the file recorded on September 15th.



**Figure 11.3** -Example of magnetic data profile recorded along the line ILAB-SPARC\_02. Note the gap that was introduced due to the problems with the file recorded on September 15th.

Unfortunately, this resulted in data gap around the Mid-Atlantic Ridge (Figure 11.3). However, we backed up the raw file and perhaps with more investigation, the data information could potentially be recovered.

All the data with navigation merged are backed up, together with documentation file (pdf that shows specifications of the magnetometer).



**Figure 11.4** -Example of magnetic data profile recorded along the line ILAB-SPARC\_05.

It has to be emphasized that all of the magnetization data needs to be corrected for the location of the magnetometer and feathering of the streamer.

### **Acknowledgements**

ILAB-SPARC Team would like to thank Captain Philippe Moimeaux, and Gilles Le Beuz and, Nicolas Masson of for seismic and guns, respectively, all of R/V Pourquoi Pas? crews for their enormous helps and assistances. Their dedication and professionalism were instrumental both to the success of the experiments and enchanting shipboard life during the cruise. This project is funded by the European Research Council Advanced Grant to Satish Singh.

## **APPENDIX**

Observer notes