Cruise Report

Belgica 09/14b

Genesis 2 "Pen Duick"

Gulf of Cadiz

Lies De Mol, Ana Hilário, Stéphanie Larmagnat, Jean-Pierre Henriet

& the R/V Belgica 09/14b shipboard scientific party

RCMG

Renard Centre of Marine Geology

Ghent University, Belgium

May 18 – May 27, 2009

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1. Cruise schedule & staff

1.1 Schedule

Departure: Cadiz (ES)	18.05.2009, at 09.00h.
Arrival: Vigo (ES)	27.05.2009, at 11.00h.

Belgica 09/14b

1.2 Coordination

Chief scientist:	Prof. Dr. Jean-Pierre HENRIET Renard Centre of Marine Geology (RCMG), Ghent University, Belgium
Co-chief scientist:	Lies DE MOL

1.3 Scientific staff

Prof. Dr. Jean-Pierre HENRIET	UGent, RCMG
Lies DE MOL	UGent, RCMG
Willem VERSTEEG	UGent, RCMG
Matthias BAEYE	UGent, RCMG
Stéphanie LARMAGNAT	ULaval, Canada
Dr. Ana HILARIO	UAveiro, Portugal
Clara RODRIGUES	UAveiro, Portugal
Mohamed El Amine HAZIM	URabat, Morocco
Ing. Dries BOONE	UGent, RCMG
Ing. Koen DE RYCKER	UGent, RCMG

2. Framework and objectives

2.1 Framework

The research programme of the Belgica cruise 2009/14b frames into several international and national projects. They all build upon achievements of previous projects such as FWO Genesis, EC FP6 HERMES, ESF EuroDIVERSITY MiCROSYSTEMS...

- **EC FP7 Integrated Project HERMIONE**

  HERMIONE is the ecological follow-up of the EC FP6 IP HERMES project and stand for "*Hotspot Ecosystem Research and Man's Impact on European Seas*". Together with its 38 partners, it will focus on ecosystem research along key sites on the European margin. It will try to investigate the dimensions, distribution and interconnection of deep-sea ecosystems, as well as to understand the influence of climate change, anthropogenic impact and large-scale episodic events (hydrologic or geologic). The results of this project will be directly coupled to the EU policy (among others).

- **ESF EuroDEEP project CHEMECO**

  The CHEMECO project is formed by an international consortium of research teams that aim at a multidisciplinary study of colonisation processes in European deep-waters. The selected sites located in the Atlantic Ocean and in Mediterrannean and Nordic seas, will illustrate different reducing environments (cold seeps and hydrothermal vents) associated with diverse geological settings and have been the focus of geological and ecological surveys in the past. With this multi-site approach we will examine the factors that govern the establishment of metazoan communities in different deep-sea reducing habitats with particular attention to bivalve and tubeworm symbiotic species that often dominate the biomass of vents and seeps.

- **NSERC project 'Early diagenesis of deep-water coral mounds, Atlantic Ocean'**

  The Canadian participation to this cruise is part of the project entitled 'Early diagenesis of deep-water coral mounds, Atlantic Ocean' that relies on research funds provided by the Natural Sciences and Engineering Research Council of Canada (NSERC) in the frame of the Special Research Opportunity (SRO) Program. This research project intends to sample and analyze modern, deep-water coral mounds that are in the stage of biological,

physical and chemical degradation and that pass vertically-down into a suboxic to anoxic diagenetic environment.

- **PhD project of L. De Mol (IWT-Vlaanderen): "Mound-4D: an ROV supported study of the 4D architecture of carbonate mounds"**

  The aim of this research is a detailed study of the 4D architecture of carbonate mounds based on ROV footage, side-scan sonar data, boxcores and gravity cores:

  1. Study of the characteristics of individual coral plates, including the spatial (3D) characteristics of the plates, their present colonization and the sedimentological and (micro)biological processes within these plates,
  2. 4D study of carbonate mounds by having a look at the organization and migrations of coral plates in space and geological time.

  The main topic are the cold-water coral mounds in the El Arraiche mud volcano field in the Gulf of Cadiz but we will also have a look at the cold-water corals in the Gulf of Biscay.

2.2 Objectives

The cold-water coral carbonate mounds in the El Arraiche mud volcano field on the Moroccan continental margin were discovered by the RCMG during the R/V Belgica CADIPOR cruise in 2002. Since then, a lot of data has been obtained in that region, resulting in an IODP proposal (673-Full) for drilling the coral mounds on Pen Duick Escarpment. Within the framework of the ESF MiCROSYSTEMS, ESF CHEMECO and EC-FP7 HERMIONE projects, these study area will be surveyed using high-resolution reflection seismics in order to obtain a stratigraphic framework and the ROV 'Genesis' will be deployed to carry out detailed mapping. Also the hydrography and sediment dynamics of the area will be studied with respect to the steering of the present ecosystems.

This campaign will focus on the following objectives within the study area:

1. ***High-resolution seismic profiling:*** investigation of the stratigraphic framework and the sedimentary environment.
2. ***ROV operations:*** visual observations of deep-water ecosystems for habitat and environmental mapping.
3. ***Seabed sampling:*** boxcore sampling of the ROV-investigated sites.

During the transit from Pen Duick Escarpment to Vigo, an experiment of the Marine Biology Section (Ghent University) will be deployed in the region of Cabo Ortegal. The coordinates will be determined after the multibeam survey during campaign 14a. This experiment will be picked up again during campaign 14c.

The cruise will be executed in cooperation with the University of Aveiro (Portugal), the Laval University (Quebec, Canada), the University of Geneva (Switzerland) and the Mohamed V University of Rabat (Morocco). A short overview of the objectives of each research group is given below.

(1) University of Aveiro (Portugal)

The aim of the participants from the University of Aveiro (Portugal) is to recover one set of the colonization devices deployed in previous cruises on the Mercator, Meknes and Darwin mud volcanoes as part of the ESF EuroDIVERSITY CHEMECO project. Each set is composed of three colonization devices loaded with different types of substrate: carbonate, wood and alfalfa. After recovery the different substrates will be fixed following specific protocols for the study of the microbial film and the taxonomic and trophic characterization

of colonizing metazoan analyses. The ROV Genesis will be used to recover the colonization devices and also to video survey the deployment sites.

(2) Laval University (Canada)

During this Belgica cruise, sampling boxcores from the Gulf of Cadiz will be the opportunity to document in their natural context the deep-water coral mounds and their early diagenesis. Biological, inorganic and organic material will be collected in a systematic manner to document the diversity of early diagenetic phenomena. Immediately after sampling, samples will be biologically fixed applying a solution of glutaraldehyde, sodium cacodylate and marine water. Later on, samples will be transferred in multiple steps towards a storage solution of 70 % ethanol. The aim is to concentrate on the coral rubble facies and their associated cryptic community (e.g. sponges). Back in Canada, all samples will serve for the preparation of histological thin sections (using a Microtome) or for SEM (critical point-dried samples) in the Geology department at Laval University. In addition to the sediment samples, water samples will be collected either from the sediment (pore-water) using rhizons or directly into the sponge canals network using gas-tight syringes. The samples will be stored in 10 ml amber glass vials, filled to the top using nanopure water and sealed. Water samples will be analyzed for their content of fluorescent dissolved organic matter using Excitation Emission matrix (EEM) spectroscopy in the Biology department at Laval University.

(3) University of Geneva (Switzerland)

The 'Molecular phylogeny of protists and invertebrates' lab of the Department of Zoology and Animal Biology is working on the molecular phylogeny of foraminifers. They try to collect as many species as they can to complete the database on the foram distribution and diversity, and compare them with species from other oceans. In order to do this, a molecular environmental approach will be used, allowing to see species which cannot be detected with classical methods. Right now, not a single data on foraminifers from this part of the Atlantic Ocean is available. The newly obtained samples will be included in a global study on forams and other eukaryote distributions.

3. Working area

The working area of campaign 09/14b is located on the NW Moroccan continental margin in the Gulf of Cadiz (Figure 1), offshore the city of Larache. The area, El Arraiche mud volcano field, is characterized by a number of submarine mud volcanoes of variable dimensions and large submarine seafloor ridges. Depths in the working area vary between between 350 and 1150 m.

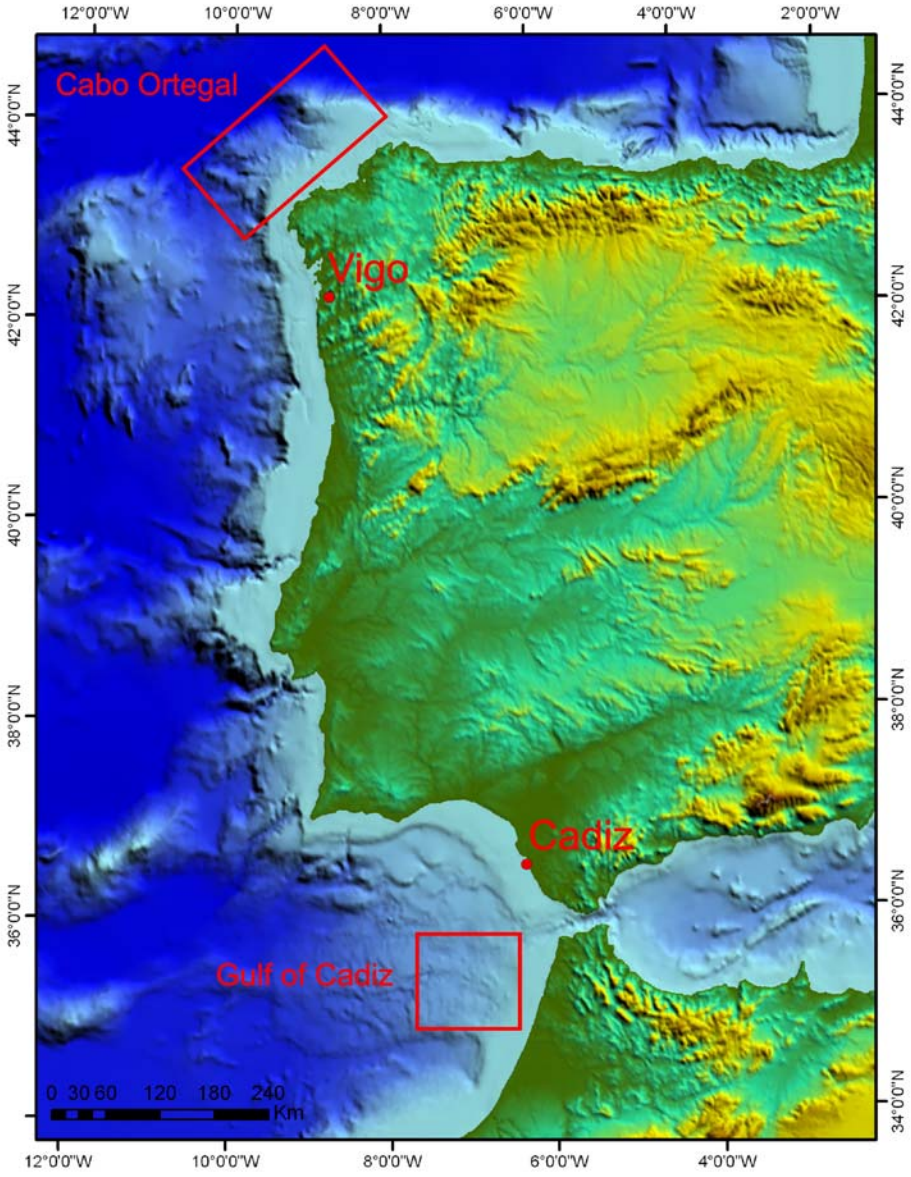

Figure 1: *Working area in the Gulf of Cadiz (main study area) and Cabo Ortegal (deployment of the MarBio experiment) (GEBCO bathymetry).*

The seafloor ridges are structural features, called Renard Ridge and Vernadsky Ridge, and are fault-related and/or diaparic structures that extend in a northwest direction from the

shelf edge towards deeper water, creating a topography with height differences of more than 100 m at some locations. At different sites on these ridges, small mounded features were discovered in the past which appeared to be carbonate mounds, biogenic build-ups consisting of a coral framework filled with sediments. The best studied area so far is the Pen Duick Escarpment, on which a whole range of carbonate mounds occur. The largest specimen is about 60 m high.

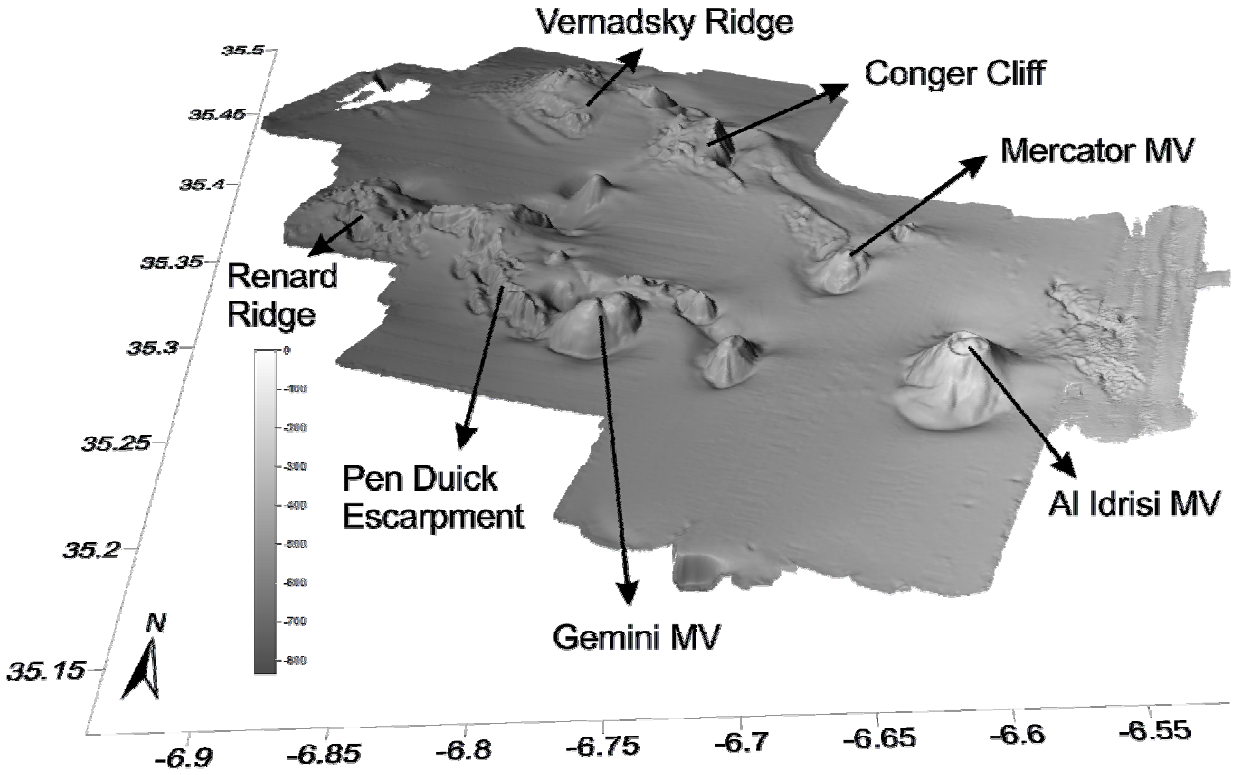

***Figure 2**: The El Arraiche mud volcano field in the Gulf of Cadiz.*

4. Operations

4.1 Overview of activities

4.1.1 Seismic survey

About 305 kilometers of high-resolution single channel seismic data (Figure 3) were collected (62 2D lines) in the study area with a SIG sparker source (120 electrodes). The sparker was triggered every 2 s reaching 500 J energy. The sampling frequency was set at 8 kHz and a record length of 2500 ms TWT was used. The velocity of the ship during seismic work was about 4 knots. During this work, R/V Belgica operated on electrical engines for noise reduction.

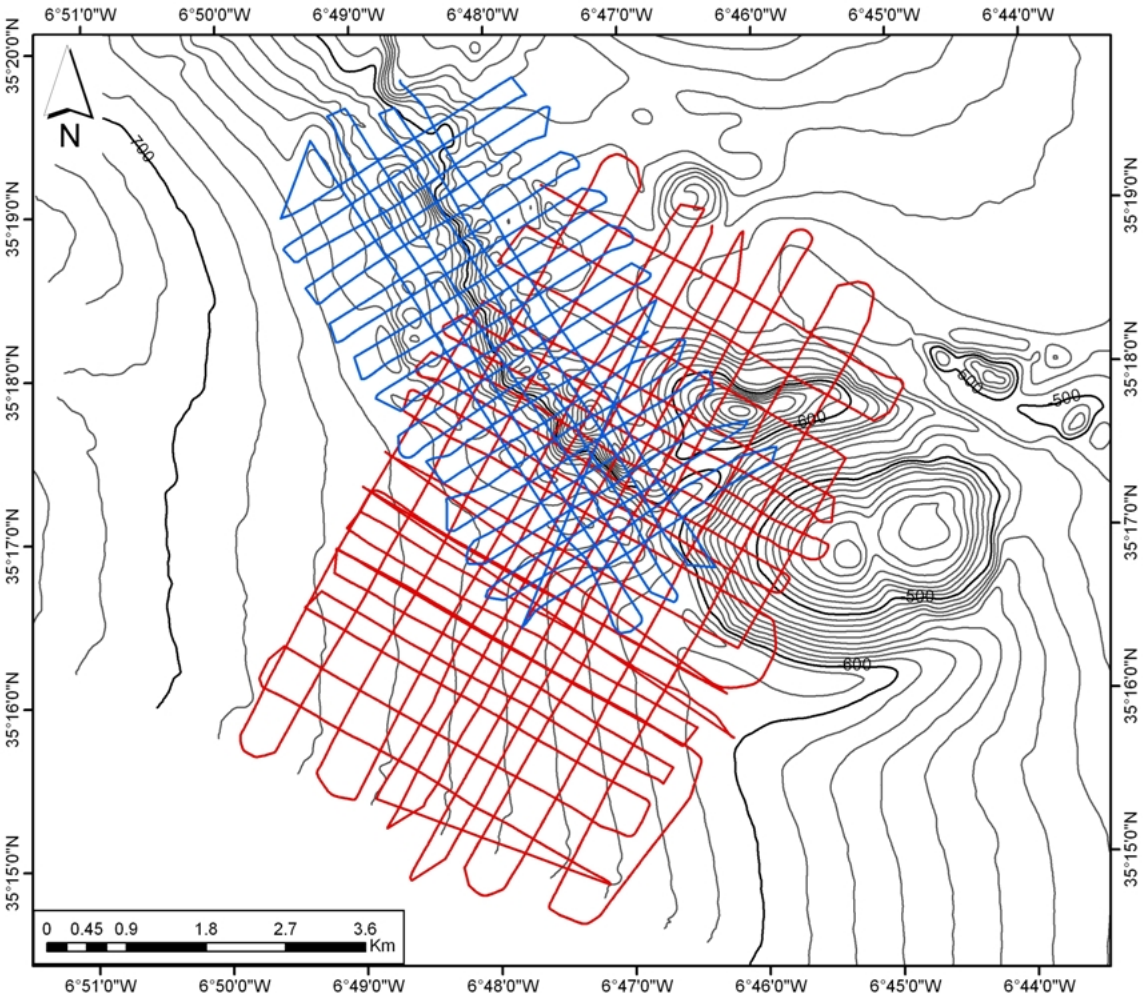

Figure 3: *2D seismic navigation (red: IODP sites, blue: Pen Duick sites) (WGS84).*

4.1.2 ROV survey

The RCMG acquired a Sub-Atlantic Cherokee-type ROV "Genesis", with TMS and shipboard winch. This winch hosts a reinforced cable of 1600 m which can bring the TMS and ROV to a safe depth prior to ROV launch (with a maximum tether of 120 m). The winch cable is connected to a pilot control interface which was installed in the laboratory container. This encompasses the physical control of the ROV and its instruments, as well as the observation (and navigation cameras). 4 cameras and 1 still camera were active: one on the TMS (ROV launch & re-entry control), a backward looking within the ROV (for TMS re-entry and tether inspection) and the two forward-looking black & white and colour (with overlay) cameras. An overlay on the screen with navigation control information could be put on an arbitrary camera display. The main sampling tool on the ROV is the controlled grab arm and a deployable tray in which samples can be stored. The ROV also contains a depth control, an altimeter and a side-looking sonar for detection of seabed objects.

Positioning of the TMS and ROV was done through the GAPS positioning system (IXSEA). This Global Acoustic Positioning System, GAPS, is a portable Ultra Short Base Line (USBL) with integrated Inertial Navigation System (INS) and Global Positioning System (GPS). The GAPS was deployed at the side and a transponder fixed on the TMS and on the ROV, resulting in the position of the Belgica, TMS and ROV. Navigation from the GAPS software is stored in raw format. During the deployments, the ship's, TMS and ROV navigation was also recorded through the OFOP software (J. Greinert, Royal NIOZ, The Netherlands).

During ROV survey, the control is performed by the pilot and the PI scientist (scientist, co-pilot/navigator), assisted by another shipboard scientist and contact with the bridge is held. Propulsion of the ship remained diesel which enables to handle the ship in a very controlled manner, even though dynamic positioning is not available.

Figure 4: *Pictures demonstrating the ROV deployment and operational environment.*

4.1.3 Seafloor sampling: boxcores

Based on the ROV survey we were able to select different locations on the three mounds (Alpha, Beta and Gamma) for boxcore sampling. For every boxcore, samples from different locations have been taken for the purpose of sedimentological analyses. Some pieces of dead coral rubble have been collected for U/Th dating (in cooperation with Norbert Frank, LSCE, Gif-sur-Yvette, France). Living species were collected and stored on formol/ethanol by A. Hilàrio and C. Rodrigues (U. Aveiro) for morphologic studies. Sponge specimens were collected and stored on ethanol upon request by J. Reveillaud (UGent, Marine Biology Section) for phylogenetic/genomic studies.

For each boxcore, the transponder of the TMS was installed on the boxcore so that a more accurate position was obtained.

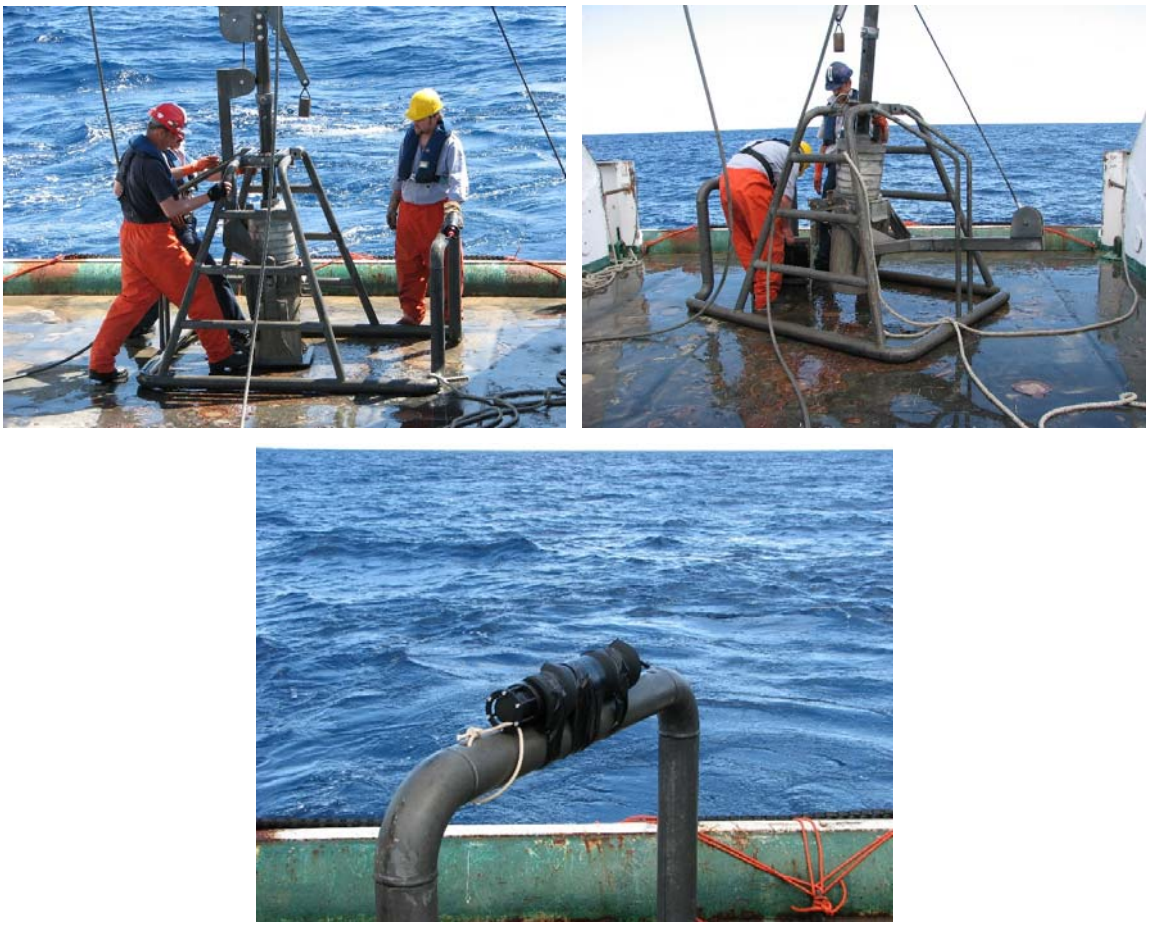

***Figure 5**: Pictures of the boxcore with transponder.*

4.1.4 University of Aveiro (Portugal)

The CHEMECO project is formed by an international consortium of research teams that aim at a multidisciplinary study of colonisation processes in European deep-waters. The selected sites located in the Atlantic Ocean and in Mediterrannean and Nordic seas, will illustrate different reducing environments (cold seeps and hydrothermal vents) associated with diverse geological settings and have been the focus of geological and ecological surveys in the past. With this multi-site approach we will examine the factors that govern the establishment of metazoan communities in different deep-sea reducing habitats with particular attention to bivalve and tubeworm symbiotic species that often dominate the biomass of vents and seeps. Our specific interests rely on the establishment of pioneer microbial communities, the recruitment of metazoan larvae, the development of symbioses and their importance in the biodiversity and trophic structure of newly-established communities. Another aspect of this project is to assess the impact of symbiotic metazoan colonisation on chemical exchanges and biogeochemical processes. We propose to address these aims through a unique combination of site surveys, replicate colonization experiments of mineral and organic substrates and in situ chemical monitoring.

During this cruise the aim of the participants from the University of Aveiro (Portugal) was to recover one set of colonization devices deployed in previous cruises on the Mercator, Meknes and Darwin mud volcanoes (Table 1), and to video survey the deployment sites using the ROV Genesis.

Each colonization set, composed of three devices loaded with different types of substrate (carbonate, wood and alfalfa) was recovered in a single dive in which each device was brought to the surface in an individual box (Figure 6). Each device was photographed and fixed following specific protocols for the study of the microbial film and the taxonomic and trophic characterization of colonizing metazoans. These analyses will be carried in the University of Aveiro (Portugal), University of Azores (Portugal), University of Pierre and Marie Curie (Paris, France) and University of Provence (Marseille, France).

The results of the CHEMECO project will provide knowledge on the ability of symbiotic organisms to re-colonize after disturbance. As the anthropic pressure on deep-sea ecosystems is increasing, particularly for sites associated with oil and mineral resources such as cold seeps and hydrothermal vents, the need to further understand the factors that ensure the sustainability of these poorly known ecosystems is crucial. The proposed experiments can, additionally, be seen as a preliminary step toward the implementation of

in situ experimentation platforms in the context of long-term deep-sea observatory sites (eg: ESONET, MOMAR).

Mud Volcano	*Latitude*	*Longitude*	*Depth (m)*	*Deployment date*	*Recovery dive*
Mercator	35°17.916' N	6°38.709' W	354	May 2007	B09-01
Meknes	34°59.090' N	7°04.410' W	698	March 2008	B09-03
Darwin	35°23.523' N	7°11.513' W	1110	May 2007	B09-02

Table 1: *Location and deployment date of the colonization devices recovered during the cruise.*

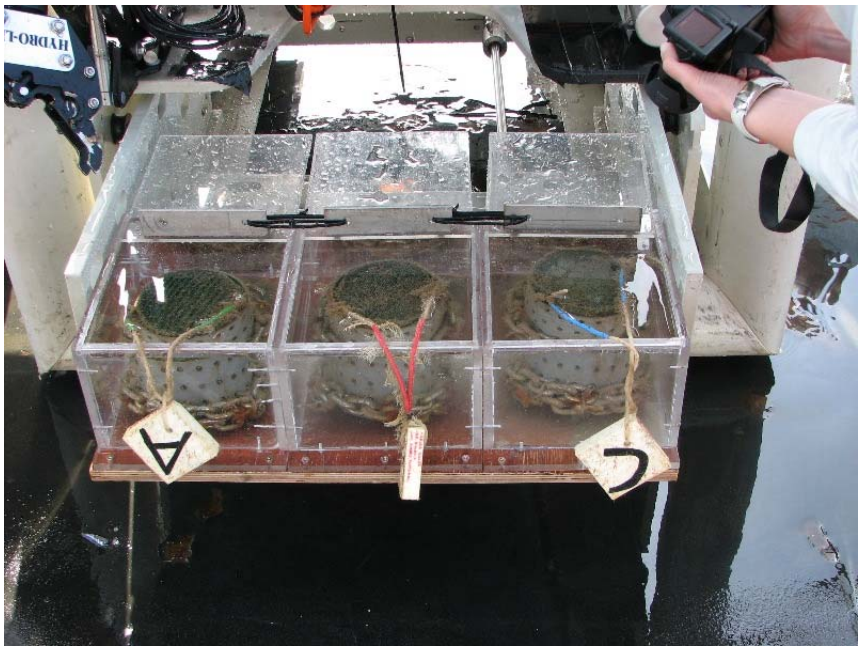

Figure 6*: Set of colonization devices recovered from the Mercator mud volcano.*

4.1.5 Laval University (Canada)

Introduction

The Canadian participation to Belgica 09/14b cruise is part of the project entitled "Early diagenesis of deep-water coral mounds, Atlantic Ocean" that relies on research funds provided by the Natural Sciences and Engineering Research Council of Canada (NSERC) in the frame of the Special Research Opportunity (SRO) Program. This research project intends to sample and analyze modern, deep-water coral mounds that are in the stage of biological, physical and chemical degradation and that pass vertically-down into a suboxic to anoxic diagenetic environment. Specifically, we are looking for organomineralization process (*sensu* Trichet and Defarge, 1995) that might take place within cryptic space of coarse coral rubble facies. Such facies is well developed at Pen Duick carbonate mounds located on top of the Pen-Duick escarpment (PDE), Atlantic Ocean, off Morocco, in water depths of 500 to 600 metres (Templer et al., 2007).

In 2008, our participation to MD169 campaign, within the framework of the ESF MiCROSYSTEMS project, was our first attempt to sample these coral rubble facies in the PDE area. Nevertheless, for technical reason we were not able to sample these coral «graveyards» facies (gravity-coring not suitable to sample the sediment-water interface). However, our first results of this first cruise show that the methods apply well to document the histology and pore water FDOM chemistry of Atlantic coral mounds. Furthermore, pore-water FDOM analyses on the Gamma mound revealed that interstitial fluid expected to produce calcifying colloids are present whereas the substrates for calcification are lacking.

During Belgica 09/14b cruise, ROV deployments on Alpha, Beta and Gamma mounds within the PDE were the opportunity to realize direct observations of deep-water ecosystems looking for well developed «coral graveyards». Indeed, our main focus was to select the most promising sites for seabed sampling using boxcores.

Sampling

Sediment sampling was performed from the boxcores on Alpha, Beta and Gamma mound (B09-1401-bc, B09-1402-bc, B09-1404-bc, B09-1405-bc, B09-1406-bc and B09-1408-bc). Additional coral and sponge samples were taken using the controlled grab arm of the Sub-Atlantic Cherokee-type ROV «Genesis» during dives B09-06 and B09-07 (Beta mound). A total of 15 sediment and biological samples was collected, all of which will serve for the preparation of histological thin sections. For this purpose, the samples were biologically fixed applying a solution of glutaraldehyde, sodium cacodylate and marine water. The samples were fixed on board ship for 24 hours. Later the samples were transferred in multiple steps towards a storage solution of 70 % ethanol (respectively into

30%, 50% and 70%). Additional sediment samples were collected and fixed using a solution of formaldehyde (University of Aveiro, Portugal) for the preparation of SEM samples applying critical point-dried method.

Marine water samples were collected during ROV Genesis dive B09-07 (Beta mound) to give us a reference value of bottom marine water chemistry.

Pore-water samples were collected from boxcores on Alpha, Beta and Gamma mounds (B09-1401-bc, B09-1402-bc, B09-1404-bc, B09-1405-bc, B09-1406-bc and B09-1408-bc) using rhizons (Seedberg et al., 2005). For each boxcore, pore water samples were collected from the uppermost sediment layer (water-sediment interface). From a few boxcores, pore water samples were also taken deeper down in the sediment column (around 30 to 40 cm depth). The samples were stored in 10 ml amber glass vials, filled to the top and sealed. These pore-water samples will be analyzed for their content of fluorescent dissolved organic matter using Excitation Emission matrix (EEM) spectroscopy in W. Vincent lab, biology department at University Laval. In addition, aliquots were acidified using a solution of HCl (1N) and hermetically closed to avoid sulphate production via sulphide oxidation during sample storage. These samples will be used further analysis of sulfate, sulfide and chloride contents using Ion chromatography in the Geology department at Laval University.

Both sediment and pore-water samples were taken on deck, within an hour after box-core retrieval.

Methods

- **Integrated petrography**

At Laval University, the sediment samples will be stored refrigerated at 4-6°C in 70% ethanol. Prior to further treatment the dehydration process must be completed to 99% ethanol. For scanning electron microscopy (SEM) samples will be critical point dried and place in an oven at 40°C. For microscopy the dehydrated sample will be kept unstained and stained with methylene blue or azur-II/methylene blue. Embedding is in LR White resin. Samples will be cut into slices of 20 to 50 µm thickness using a Leica saw microtome (Leica 1600 SP). Both optical methods will provide details of the histology, the micro-organismic contributions and the relationships between particles, living and non-living organic tissue.

- **Fluorescence spectroscopy**

Pore water samples will be analysed for their FDOM fraction applying three-dimensional excitation-emission matrix (EEM) fluorescence spectroscopy. Analyses and interpretations will be performed applying the common quantification and qualification of fluorescence peak patterns present in natural waters (Parlanti et al., 2000; Burdige et al.,

2004). These analyses will serve to discuss the biological activity and the freshness of FDOM in interstitial fluids.

- **Ion chromatography**

The aliquot of acidified pore-water samples will be analysed for their content in SO_4^{2-} and Clusing a Dionex DX-100 ion chromatograph (Ion Pac AS4A-SC column; 1.8 mM Na_2CO_3 and 1.7 mM $NaHCO_3$ as eluant).

References

Burdige, Kline, Chen, 2004. Fluorescent dissolved organic matter in marine sediment pore waters. Marine Chemistry, 89, 289-311.

Parlanti, Wörz, Geoffroy, Lamotte, 2000. Dissolved organic matter fluorescence spectroscopy as a tool to estimate biological activity in a coastal zone submitted to anthropogenic inputs. Organic Geochemistry 31, 1765-1781.

Seeberg-Elverfeldt, J., Schlüter, M., Feseker T., Kölling, M., 2005. Rhizon sampling of porewaters near the sediment-water interface of aquatic systems. Limnol. Oceanogr., Methods 3, 361–371.

Templer, S.P., Maignien, L., McKenzie, J.A., Henriet, J. P., Vasconcelos, C., 2007, The Pen Duick Escarpment off Morocco: A promising biogeochemically active carbonate mound laboratory (MiCROSYSTEMS). Geophysical Resarch Abstracts, v. 9.

Trichet, J., Défarge, C., 1995. Non-biologically–supported organomineralization: Institut Océanographique de Monaco, Bulletin, numéro spéciale 14, p. 203–236.

4.2 Operational Report

It is worth noting that the time used in this cruise report is the Belgian Summer time (BRAVO TIME = UTC + 2 hours). On the ROV logsheets UTC time was used.

Friday 15.05.2009

18:00 Arrival of Willem Versteeg, Dries Boone and Lies De Mol.
19:00 Reception on board of the Belgica.
19:45 Arrival of Stéphanie Larmagnat.

Saturday 16.05.2009

08:30 Start ROV installation.
19:00 Arrival of Ana Hilário and Clara Rodrigues.
20:00 Arrival of Mohamed El Amine Hazim.

Sunday 17.05.2009

08:30 Continue ROV installation.
10:30 Meeting with the Portuguese scientists, Jean-Pierre Henriet and Lies De Mol.

Monday 18.05.2009

08:30 Briefing with the crew, Jean-Pierre Henriet and Lies De Mol.
09:00 Departure of R/V Belgica from the harbour of Cadiz.
09:30 Safety briefing.
09:45 'Abandon ship' exercise.
16:30 Arrival at Mercator mud volcano for the first ROV dive.
19:00 Dive cancelled due to problems with the baskets for the TRAC's on the ROV.
22:15 Start transit to Pen Duick Escarpment for seismics on the IODP sites.
23:00 Arrival at IODP seismics.
23:19 Start of line C090501, heading 207° (av. speed 4.2 knots).

Tuesday 19.05.2009

00:00 Continue seismic operations.

00:14 End of line C090501.
00:33 Start of line C090502, heading 34° (av. speed 4.1 knots).
01:20 End of line C090502.
01:27 Start of line C090503, heading 209° (av. speed 4.2 knots).
02:24 End of line C090503.
02:31 Start of line C090504, heading 34° (av. speed 4.2 knots).
03:24 End of line C090504.
03:27 Start of line C090505, heading 212° (av. speed 4.4 knots).
04:30 End of line C090505.
04:32 Start of line C090506, heading 29° (av. speed 4.2 knots).
05:30 End of line C090506.
05:45 Start of line C090507, heading 210° (av. speed 4.4 knots).
06:30 End of line C090507.
06:32 Start of line C090508, heading 300° (av. speed 3.5 knots). Transit to Mercator site.
07:35 End of line C090508.
08:00 Arrival at Mercator mud volcano.
09:10 ROV in the water for dive B09-01 for the recovery of three TRAC's.
10:45 ROV on deck. Start transit to Darwin site.
13:00 Arrival at Darwin mud volcano.
14:30 ROV in the water for dive B09-02 for the recovery of three TRAC's.
17:40 ROV on deck.
21:00 Start transit to Pen Duick Escarpment to continue seismics on the IODP sites.
23:10 Start of seismics.
23:12 Start of line C090509, heading 110° (av. speed 4.3 knots).
23:45 End of line C090509.
23:49 Start of line C090510, heading 304° (av. speed 3.1 knots).

Wednesday 20.05.2009

00:00 Continue seismic operations.
00:35 End of line C090510.
00:36 Start of line C090511, heading 120° (av. speed 4.4 knots).
01:13 End of line C090511.
01:16 Start of line C090512, heading 310° (av. speed 3.0 knots).
02:04 End of line C090512.
02:06 Start of line C090513, heading 113° (av. speed 4.2 knots).
02:45 End of line C090513.
02:46 Start of line C090514, heading 303° (av. speed 3.0 knots).
03:28 End of line C090514.
03:31 Start of line C090515, heading 124° (av. speed 4.2 knots).

04:00 End of line C090515.
04:05 Start of line C090516, heading 295° (av. speed 3.6 knots).
04:55 End of line C090516.
05:00 End of seismics. Start transit to Meknes site.
07:45 Arrival at Meknes mud volcano.
08:40 ROV in the water for dive B09-03 for the recovery of three TRAC's.
09:50 Technical problem with the cable of the ROV.
10:20 ROV on deck.
12:00 Start transit to Pen Duick Alpha mound.
14:30 ROV in the water for dive B09-04.
15:25 Cable is damaged.
16:30 ROV on deck.
20:20 Start of seismics on the IODP sites.
20:28 Start of line C090517, heading 310° (av. speed 3.5 knots).
21:12 End of line C090517.
21:18 Start of line C090518, heading 112° (av. speed 4.1 knots).
21:53 End of line C090518.
22:01 Start of line C090519, heading 305° (av. speed 4.0 knots).
22:38 End of line C090519.
22:44 Start of line C090520, heading 114° (av. speed 3.5 knots).
23:22 End of line C090520.
23:26 Start of line C090521, heading 305° (av. speed 4.0 knots).

Thursday 21.05.2009

00:00 Continue seismic operations.
00:03 End of line C090521.
00:09 Start of line C090522, heading 115° (4.0 knots).
00:45 End of line C090522.
00:49 Start of line C090523, heading 290° (3.5 knots).
01:27 End of line C090523.
01:30 Start of line C090524, heading 123° (4.0 knots).
02:10 End of line C090524.
02:37 Start of line C090525, heading 38° (4.2 knots).
03:32 End of line C090525.
03:38 Start of line C090526, heading 209° (3.8 knots).
04:40 End of line C090526.
04:42 Start of line C090527, heading 31° (4.4 knots).
05:32 End of line C090527.
05:34 Start of line C090528, heading 214° (4.0 knots).

06:43 End of line C090528.
06:45 Start of line C090529, heading 31° (3.0 knots).
07:12 End of line C090529.
07:14 Start of line C090530, heading 129° (4.5 knots).
07:41 End of line C090530.
07:50 End of seismics. Start transit to Pen Duick Alpha mound.
08:41 ROV in the water for dive B09-05.
09:47 ROV on deck. Start transit to Pen Duick Beta mound.
10:00 ROV in the water for dive B09-06.
12:15 Technical problem with the cable of the ROV.
13:06 ROV on deck.
17:15 Start of seismics.
17:33 Start of line C090531, heading 118° (av. speed 4.3 knots).
18:01 End of line C090531.
18:22 Start of line C090532, heading 307° (av. speed 3.6 knots).
19:04 End of line C090532.
19:10 Start of line C090533, heading 120° (av. speed 4.0 knots).
19:39 End of line C090533.
19:41 Start of line C090534, heading 300° (av. speed 3.7 knots).
20:22 End of line C090534.
20:38 Start of line C090535, heading 145° (av. speed 4.4 knots).
21:24 End of line C090535.
21:33 Start of line C090536, heading 331° (av. speed 4.1 knots).
22:17 End of line C090536.
22:27 Start of line C090537, heading 148° (av. speed 4.4 knots).
23:04 End of line C090537.
23:15 Start of line C090538, no heading and speed information.

Friday 22.05.2009

00:00 Continue seismic operations. End of line C090538.
00:03 Start of line C090539, heading 150° (av. speed 4.4 knots).
00:54 End of line C090539.
00:56 Start of line C090540, heading 330° (av. speed 4.1 knots).
01:40 End of line C090540.
01:59 Start of line C090541, heading 70° (av. speed 4.3 knots).
02:20 End of line C090541.
02:25 Start of line C090542, heading 233° (av. speed 4.3 knots).
02:49 End of line C090542.
02:52 Start of line C090543, heading 70° (av. speed 4.1 knots).

03:15 End of line C090543.
03:21 Start of line C090544, heading 233° (av. speed 4.2 knots).
03:45 End of line C090544.
03:49 Start of line C090545, heading 70° (av. speed 4.0 knots).
04:09 End of line C090545.
04:11 Start of line C090546, heading 237° (av. speed 4.0 knots).
04:40 End of line C090546.
04:43 Start of line C090547, heading 65° (av. speed 4.0 knots).
05:04 End of line C090547.
05:06 Start of line C090548, heading 236° (av. speed 4.4 knots).
05:34 End of line C090548.
05:38 Start of line C090549, heading 60° (av. speed 4.3 knots).
05:59 End of line C090549.
06:02 Start of line C090550, heading 235° (av. speed 4.2 knots).
06:30 End of line C090550.
06:34 Start of line C090551, heading 60° (av. speed 4.2 knots).
06:54 End of line C090551.
06:57 Start of line C090552, heading 240° (av. speed 4.0 knots).
07:22 End of line C090552.
07:25 Start of line C090553, heading 63° (av. speed 4.5 knots).
07:47 End of line C090553.
08:00 End of seismics. Start transit to Pen Duick Beta mound.
08:50 ROV in the water for dive B09-07.
10:40 ROV on deck.
11:20 ROV in the water for dive B09-08.
13:45 ROV on deck. Start transit to Pen Duick Gamma mound.
14:30 ROV in the water for dive B09-09.
16:25 ROV on deck. Start transit to Pen Duick Alpha mound.
16:50 ROV in the water for dive B09-10.
17:57 Technical problem with the cable of the ROV.
18:45 ROV on deck. Start transit to continue seismic operations on Pen Duick site.
21:15 Start of seismics.
21:23 Start of line C090554, heading 50° (av. speed 4.0 knots).
21:49 End of line C090554.
21:52 Start of line C090555, heading 240° (av. speed 4.1 knots).
22:20 End of line C090555.
22:24 Start of line C090556, heading 62° (av. speed 3.5 knots).
22:51 End of line C090556.
22:55 Start of line C090557, heading 245° (av. speed 3.8 knots).
23:21 End of line C090557.

23:23 Start of line C090558, heading 60° (av. speed 4.1 knots).
23:50 End of line C090558.
23:53 Start of line C090559, heading 245° (av. speed 3.8 knots).

Saturday 23.05.2009

00:00 Continue seismics.
00:21 End of line C090559.
00:27 Start of line C090560, heading 60° (av. speed 4.2 knots).
00:45 End of line C090560.
00:54 Start of line C090561, heading 240° (av. speed 4.0 knots).
01:20 End of line C090561.
01:26 Start of line C090562, heading 70° (av. speed 4.0 knots).
01:46 End of line C090562.
02:00 End of seismics.
08:00 Preparing boxcore operations. Start transit to Beta mound.
08:55 Boxcore in the water.
09:21 B09-1401-bc at the bottom: 35°17.734'N - 6°47.272'W (526 m).
09:30 Boxcore on deck.
10:22 Boxcore in the water.
10:38 B09-1402-bc at the bottom: 35°17.7832'N – 6°47.2600'W (528 m).
10:45 Boxcore on deck.
11:23 Boxcore in the water.
11:36 B09-1403-bc at the bottom: 35°17.6700'N – 6°47.2434'W (517 m).
11:44 Boxcore on deck.
13:04 Boxcore in the water.
13:16 B09-1404-bc at the bottom: 35°17.6838'N – 6°47.2818'W (524 m).
13:23 On deck.
13:40 Start transit to Gamma mound.
14:14 Boxcore in the water.
14:23 B09-1405-bc at the bottom: 35°18.8742'N – 6°48.0757'W (551 m).
14:31 Boxcore on deck.
15:18 Boxcore in the water.
15:34 B09-1406-bc at the bottom: 35°17.5035'N – 6°47.0641'W (530 m).
15:42 Boxcore on deck.
16:20 Boxcore in the water.
17:00 B09-1407-bc at the bottom: 35°17.5045'N – 6°47.0784'W (531 m).
17:09 Boxcore on deck.
17:16 Boxcore in the water.
17:55 B09-1408-bc at the bottom: 35°17.5015'N – 6°47.0500'W (533 m).

18:03 Boxcore on deck.
18:42 Boxcore in the water.
19:07 B09-1409-bc at the bottom: 35°17.4948'N – 6°47.0556'W (532 m).
19:16 Boxcore on deck.
20:00 End of boxcoring operations.
21:30 Start transit to Cabo Ortegal.

Sunday 24.05.2009

00:00 Continue transit to Cabo Ortegal.

Monday 25.05.2009

00:00 Continue transit to Cabo Ortegal.

Tuesday 26.05.2009

06:45 Arrival at the study area. Preparing ROV for deployment of the MarBio experiment.
10:00 Too much swell so the dive is delayed. Start transit for multibeam operations.
11:00 Start multibeam.
11:03 Start of multibeam line 1, heading 0°.
11:55 End of multibeam line 1.
12:09 Start of multibeam line 2, heading 0°.
12:51 End of multibeam line 2.
13:14 Start of multibeam line 3, heading 0°.
13:19 End of multibeam line 3.
13:27 Start of multibeam line 4, heading 90°.
14:23 End of multibeam line 4.
14:30 End of multibeam operations. Start transit to the deployment area.
15:00 Arrival at the deployment area. Dive is cancelled due to the swell.
16:00 Start transit to Vigo.

Wednesday 27.05.2009

11:00 Arrival at Vigo.

5. Geological investigations: preliminary results

5.1 High-resolution 2D seismics

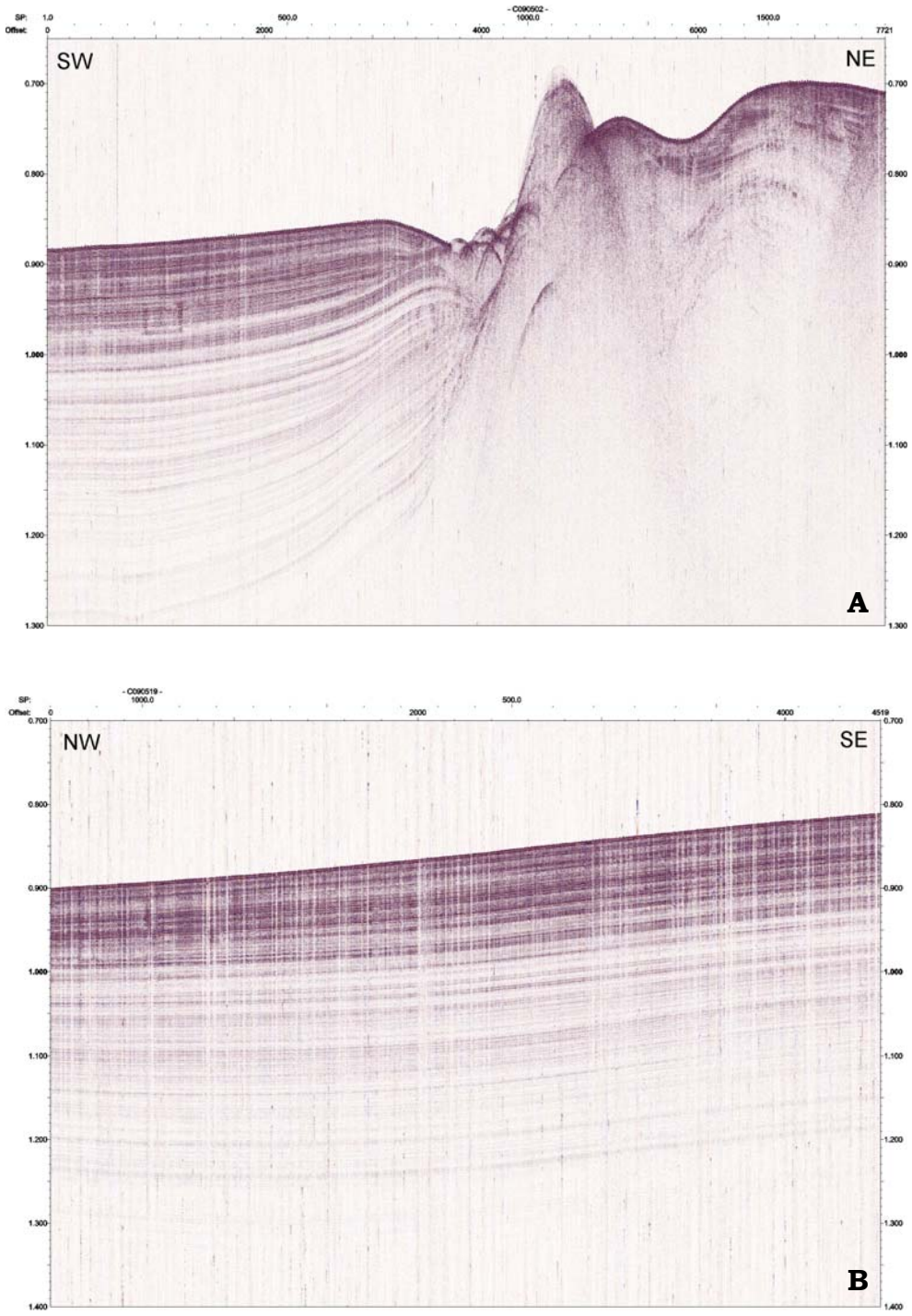

Figure 7: *Example of two seismic profiles on the IODP sites:*
A. *C090502 is a SW-NE profile that covers both IODP sites,* ***B.*** *C090519 is a NW-SE profile on the off-mound site (SP = shotpoints, Offset = distance in meters, vertical scale in seconds TWT).*

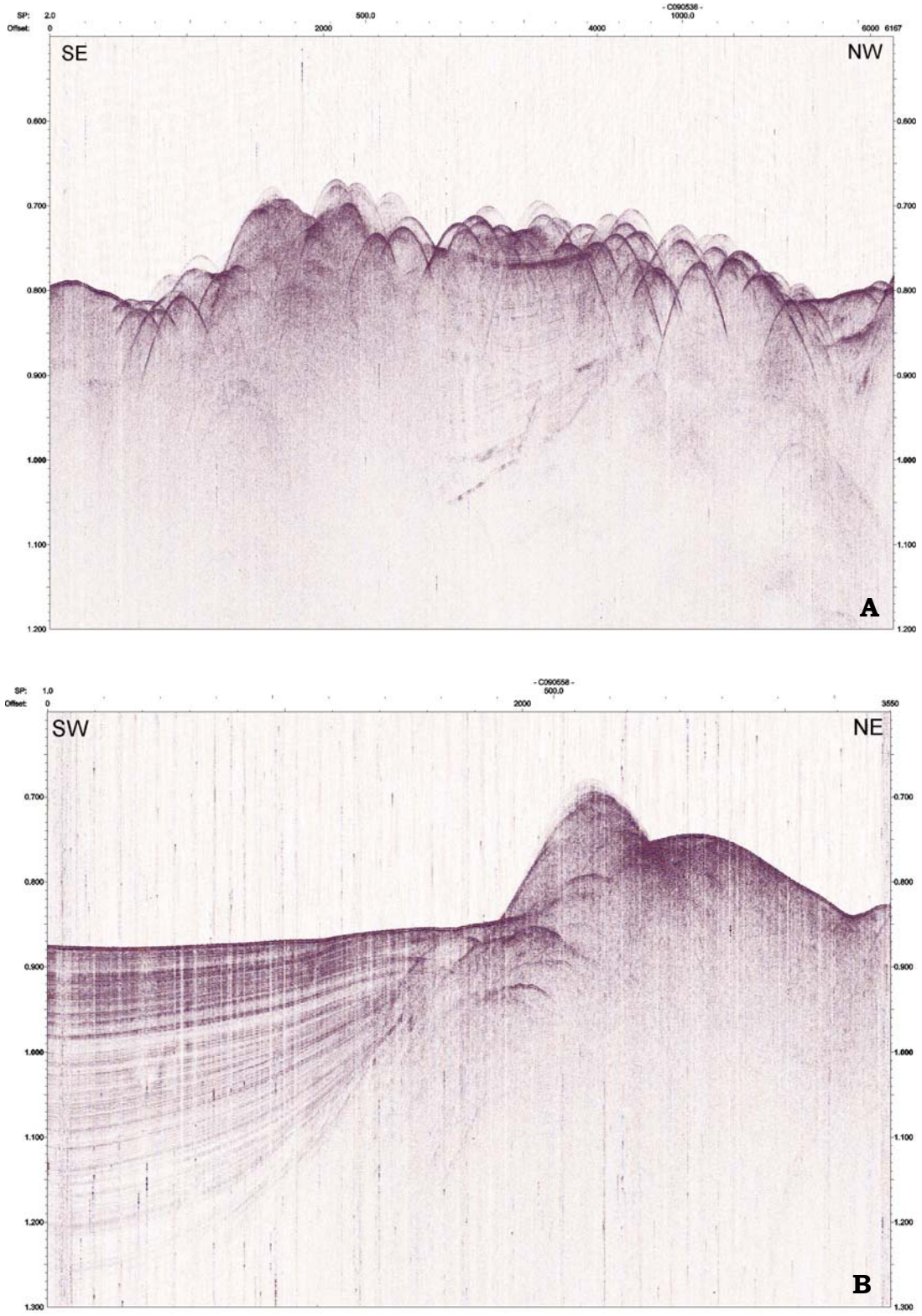

Figure 8: *Example of two seismic profiles on Pen Duick Escarpment:*
A. *C090536 is a SE-NW profile along Pen Duick Escarpment,* ***B.*** *C090558 is a SW-NE profile across Pen Duick Escarpment (SP = shotpoints, Offset = distance in meters, vertical scale in seconds TWT).*

5.2 ROV observations

The locations of the 10 ROV dives are shown on figure 9. Some preliminary remarks about the ROV observations are made here. A full analysis of the video data will be done in a later stage. A recapitulative list of the ROV dives is given in table 2.

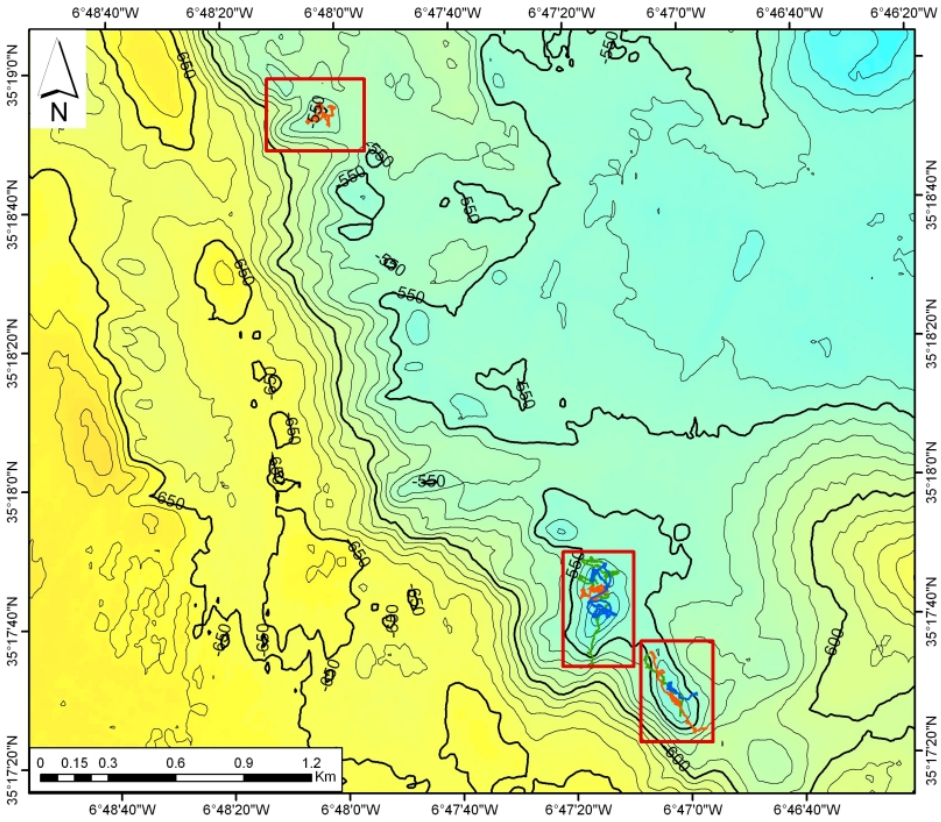

Figure 9: *Location of the ROV dives.*

Name	***Area***	***Start track***		***End track***	
		Time	*Depth*	*Time*	*Depth*
B09-01	Mercator mud volcano	07:39:11	355 m	08:32:46	353 m
B09-02	Darwin mud volcano	13:06:24	1116 m	14:55:16	1120 m
B09-03	Meknes mud volcano	07:07:58	699 m	07:54:42	694 m
B09-04	Pen Duick Alpha mound	12:54:59	540 m	13:22:18	531 m
B09-05	Pen Duick Alpha mound	07:01:27	570 m	07:40:38	530 m
B09-06	Pen Duick Beta mound	08:13:51	512 m	10:22:14	480 m
B09-07	Pen Duick Beta mound	07:05:16	526 m	08:26:45	520 m
B09-08	Pen Duick Beta mound	10:01:11	533 m	11:24:11	548 m
B09-09	Pen Duick Gamma mound	13:11:08	554 m	14:04:56	544 m
B09-10	Pen Duick Alpha mound	15:36:43	552 m	15:58:20	530 m

Table 2: *Names, locations and operational data of the ROV Genesis dives. Time in UTC.*

ROV dive 01

Date: 31/05/2008

Location: Mercator mud volcano

Description: The aim of dive B09-01 is to recover three colonization devices for the University of Aveiro. The TRACs were found about 10 m northwest of the given coordinates.

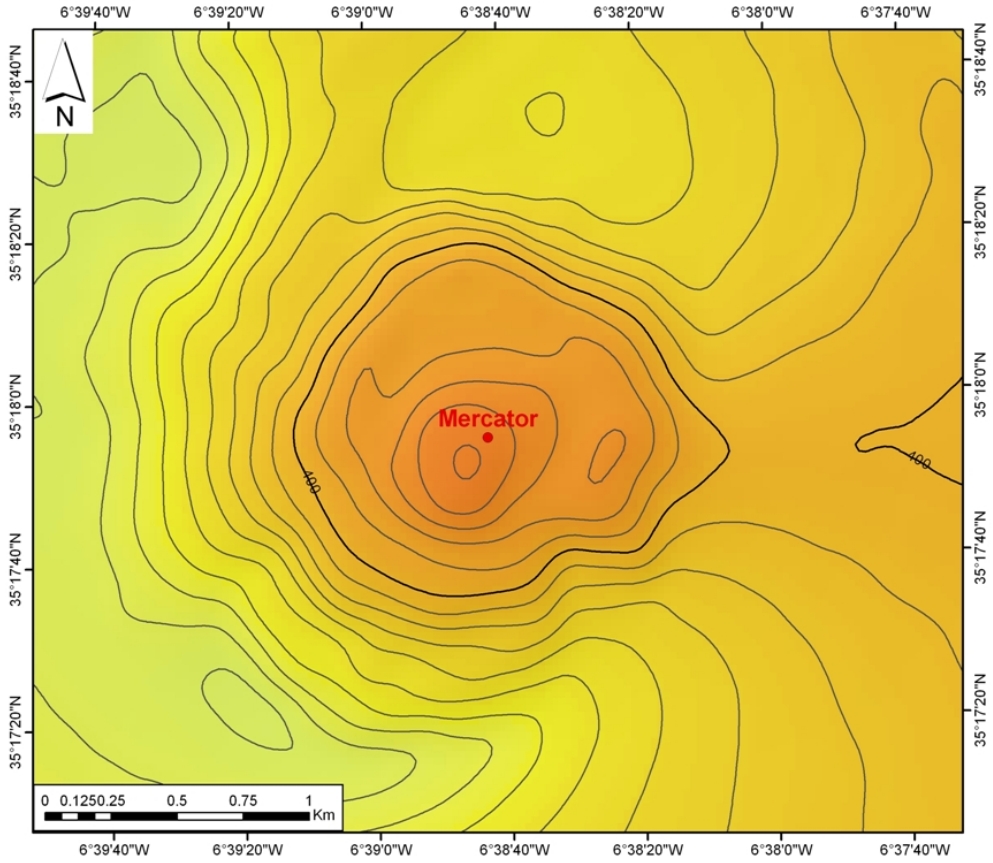

Figure 10: *Map ROV dive 01.*

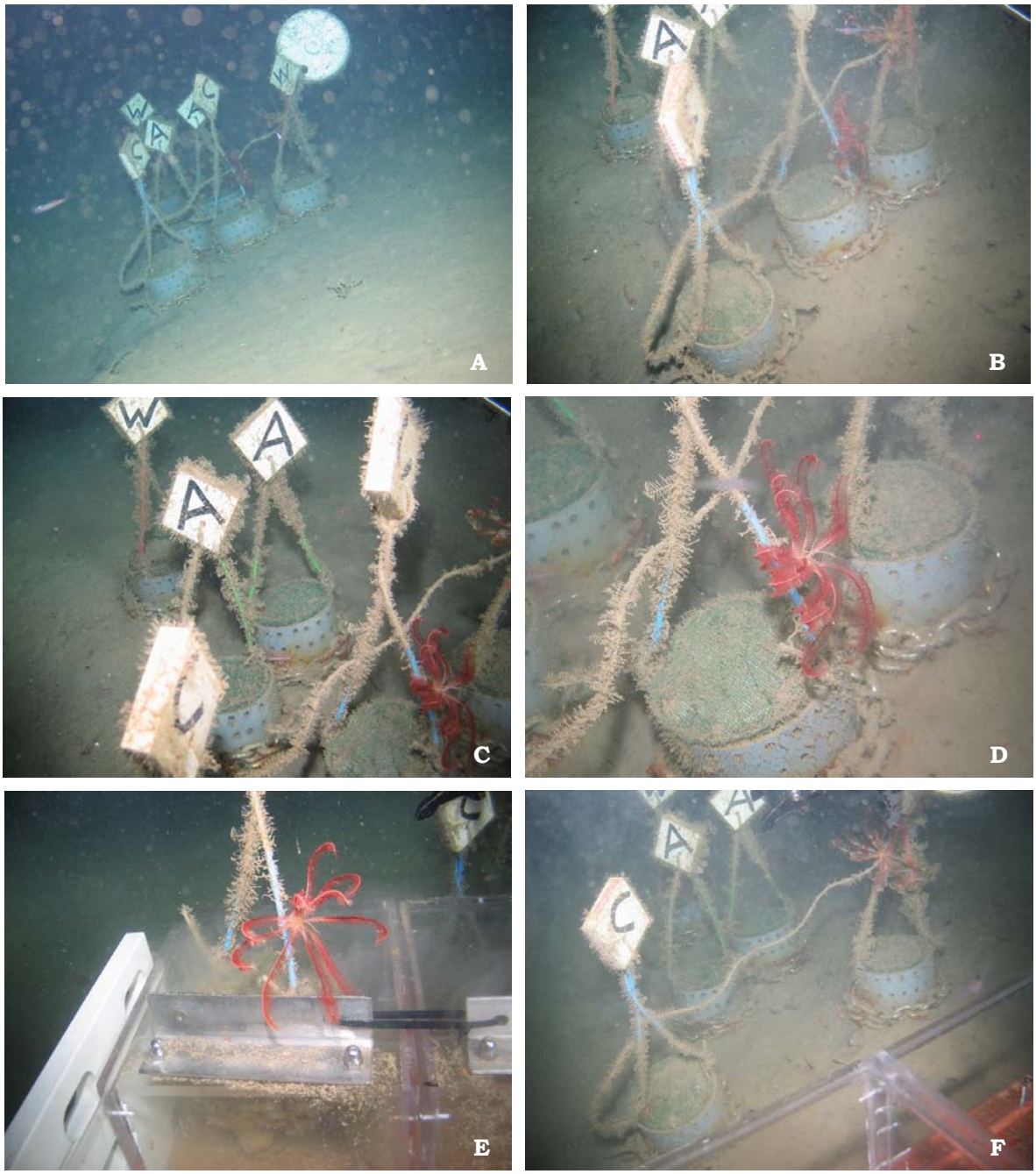

Figure 11: *Pictures of ROV dive 01:* ***A-B.*** *Set of colonization devices.* ***C-D.*** *Zoom on the TRACs with a red crinoids on one of them.* ***E.*** *Recovery of one of the TRACs.* ***F.*** *View after recovery.*

ROV dive 02

Date: 01/06/2008

Location: Darwin mud volcano

Description: The aim of dive B09-02 is to recover three colonization devices for the University of Aveiro. The TRACs were found about 10 m east of the given coordinates.

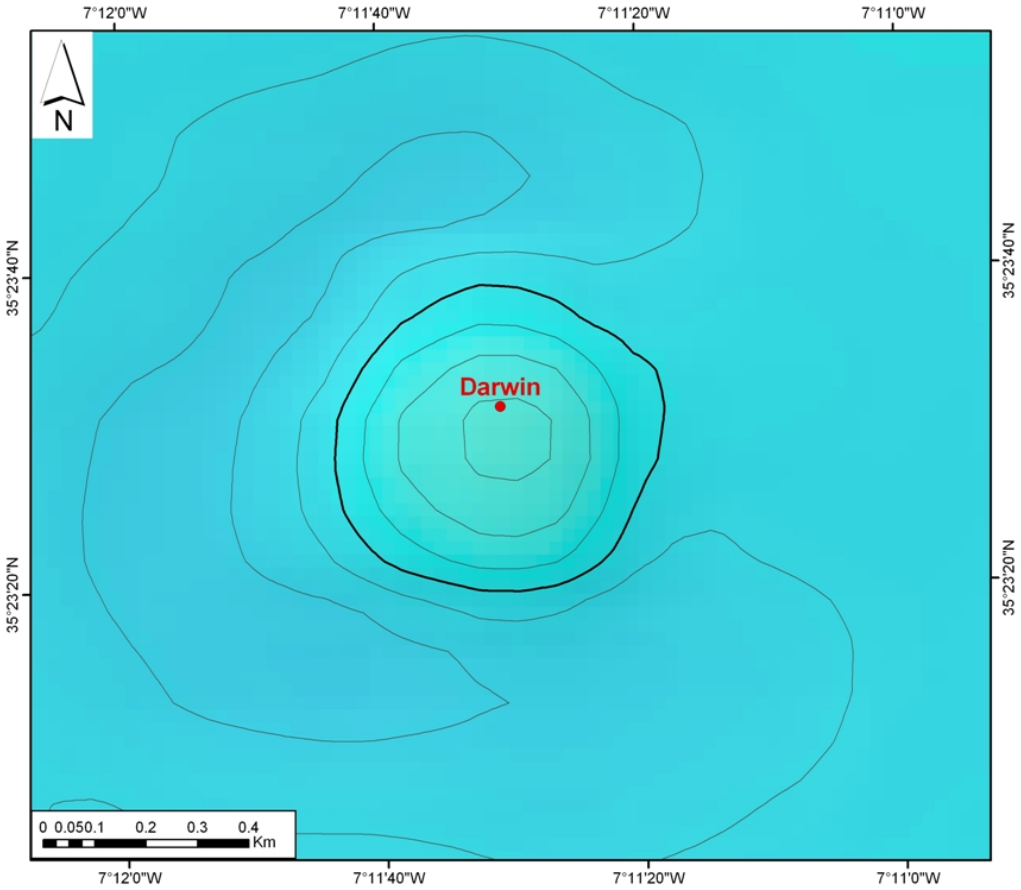

Figure 12: *Map ROV dive 02.*

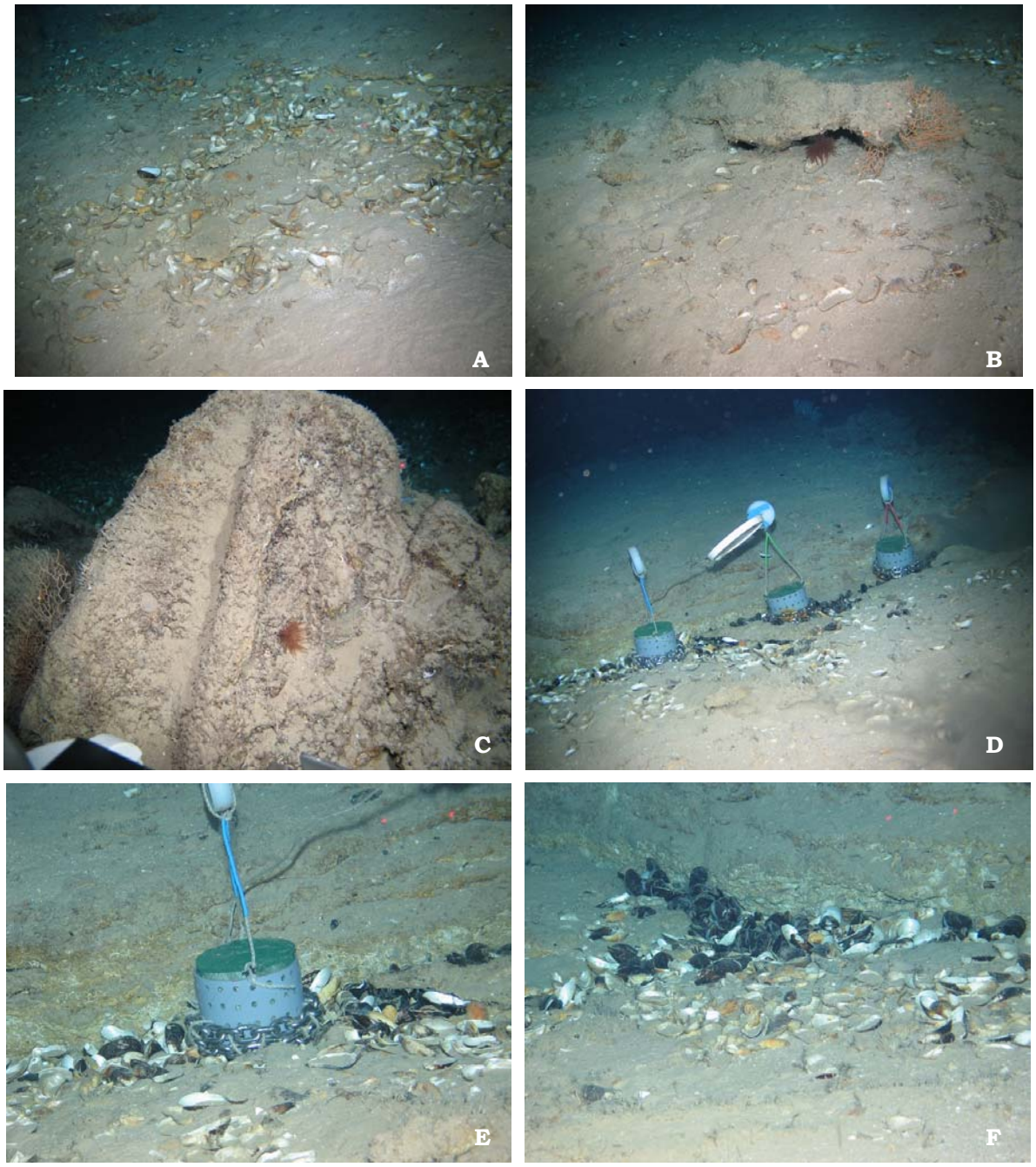

Figure 13: *Pictures of ROV dive 02:* ***A-C.*** *Pictures of the surroundings of the TRACs.* ***D.*** *Set of colonization devices.* ***E.*** *Zoom on one of the TRACs.* ***F.*** *A clump of living Bathymodiolus sp. mussels.*

ROV dive 03

Date: 02/06/2008

Location: Meknes mud volcano

Description: The aim of dive B09-03 is to recover three colonization devices for the University of Aveiro. The TRACs were found about 35 m northwest of the given coordinates.

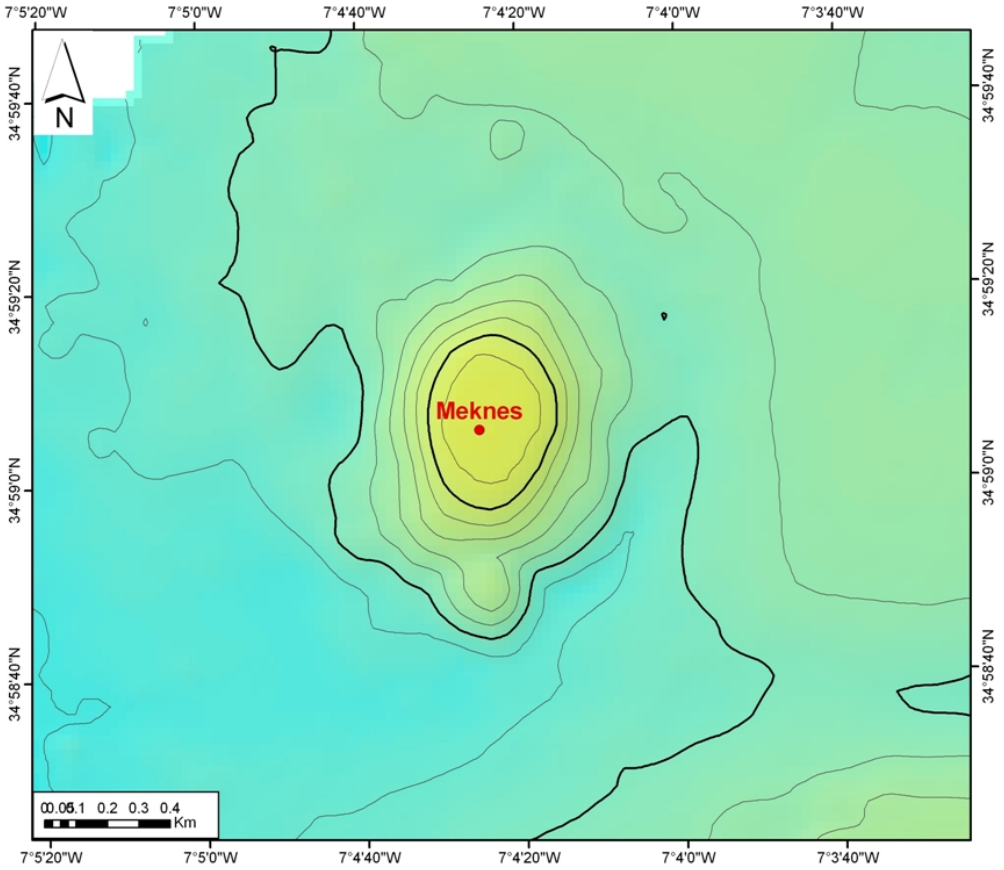

Figure 14: *Map ROV dive 03.*

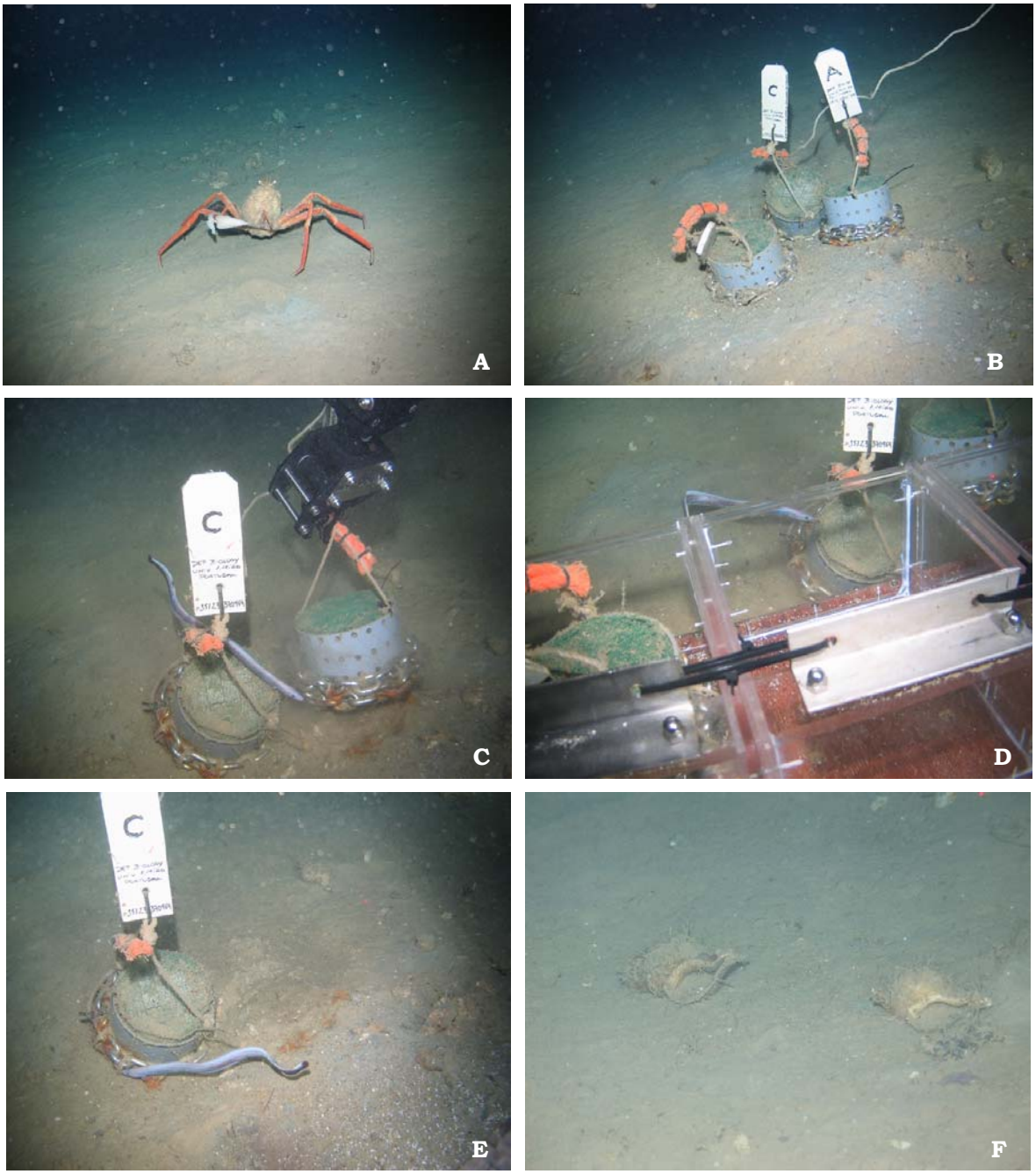

Figure 15: *Pictures of ROV dive 03.* ***A.*** *Crab with a sponge.* ***B.*** *Set of colonization devices.* ***C-D.*** *Recovery of the TRACs.* ***E.*** *Zoom on one of the TRACs.*

ROV dive 04

Date: 20/05/2009

Location: Alpha mound

Description: During this short dive on Pen Duick Escarpment an E-W transect was made along the slope of Alpha mound. Reaching the top of the mound a lot of rocks and boulders were observed. Unfortunately, the cable got stuck behind one of the rocks and it was damaged for over a distance of 40 m.

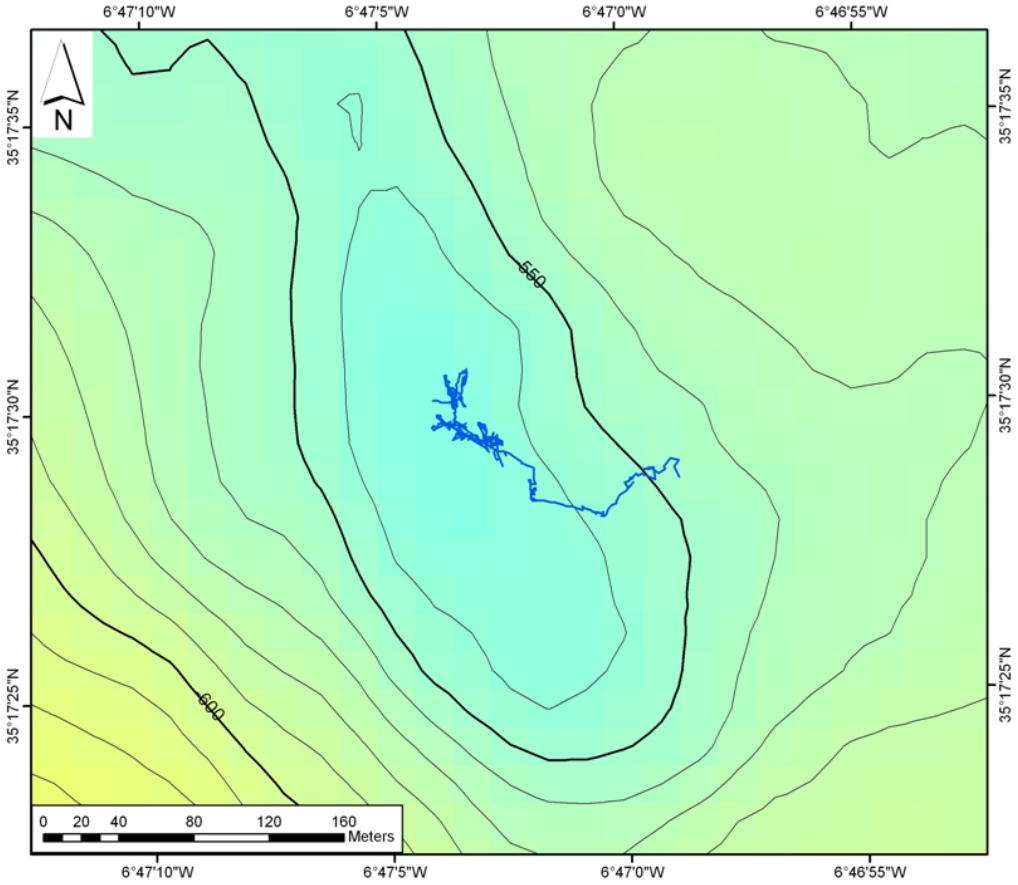

Figure 16: *Map ROV dive 04.*

ROV dive 05

Date: 21/05/2009

Location: Alpha mound

Description: During dive B09-05 a N-S transect was made on Alpha mound, observing soft sediment with a patchy distribution of dead corals covered with crinoids.

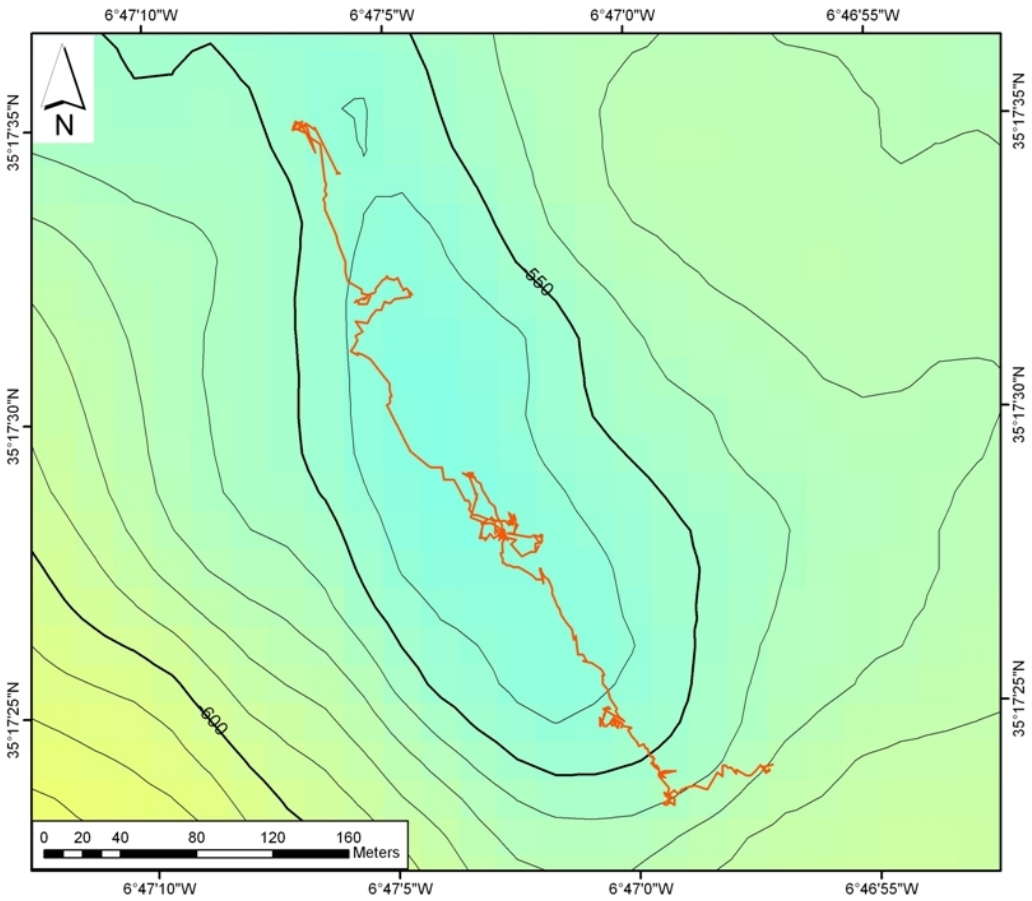

Figure 17: *Map ROV dive 05.*

Figure 18: *Pictures of ROV dive 05.*

ROV dive 06

Date: 21/05/2009

Location: Beta mound

Description: During dive B09-06 the two mound tops of Beta mound were observed where we noticed an alternation between less and more coral rubble. Again most of the dead corals were covered with crinoids.

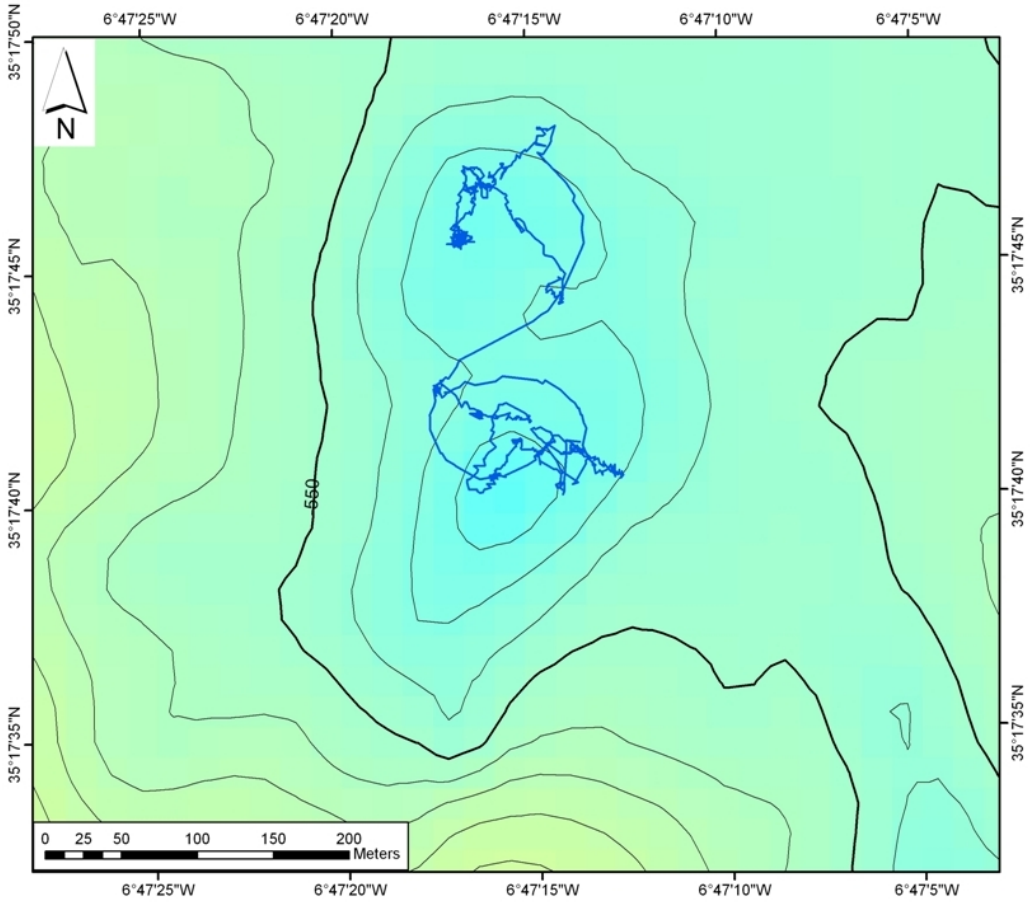

Figure 19: *Map ROV dive 06.*

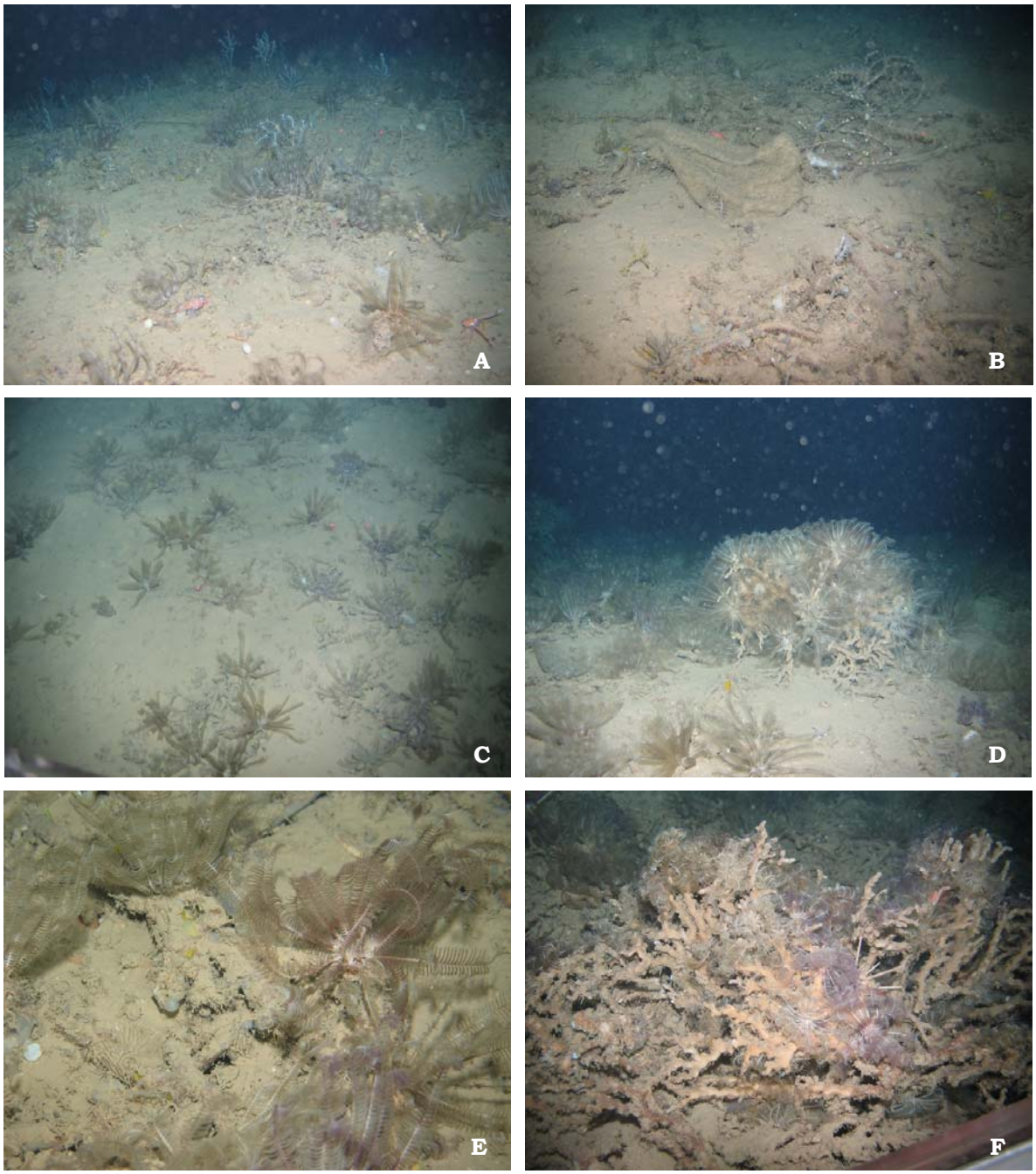

Figure 20: *Pictures of ROV dive 06.*

ROV dive 07

Date: 22/05/2009

Location: Beta mound

Description: During dive 07 the area in between the mound tops on Beta mound was surveyed. Again we found a few boulders and coral rubble covered with crinoids. One big sponge was sampled by the ROV and stored on formol/ethanol for further analysis.

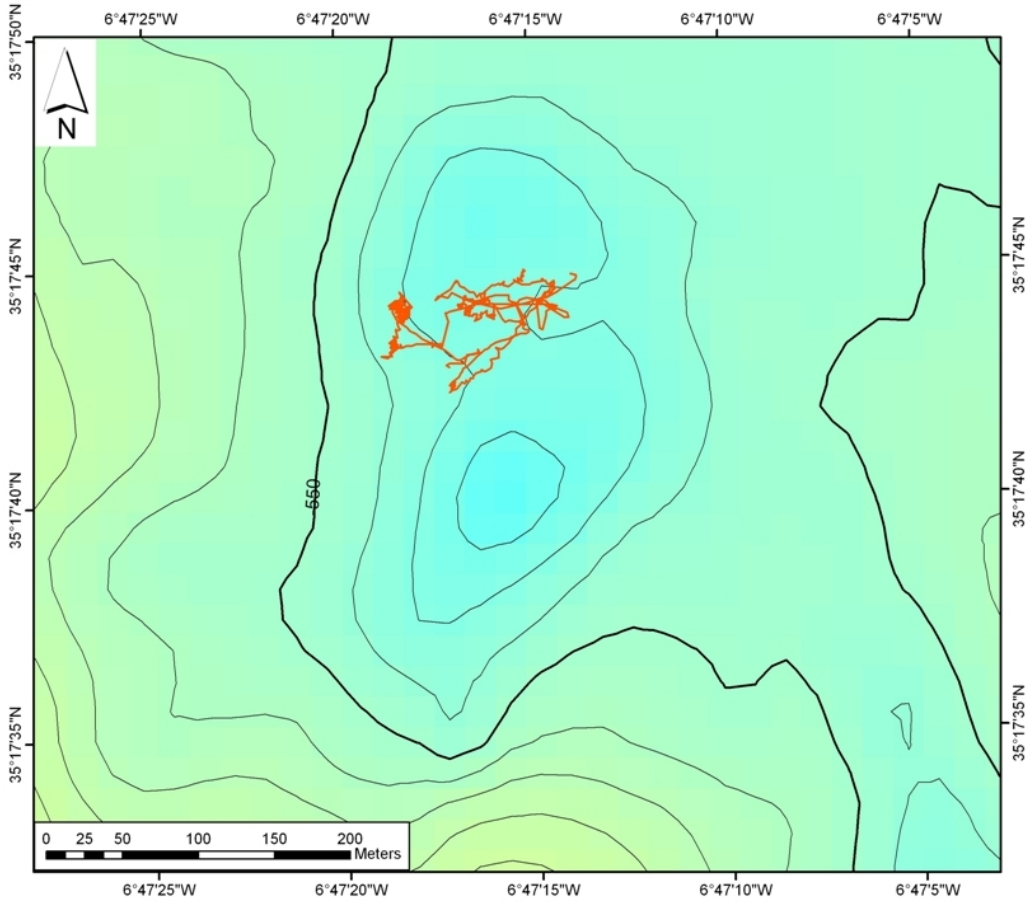

Figure 21: *Map ROV dive 07.*

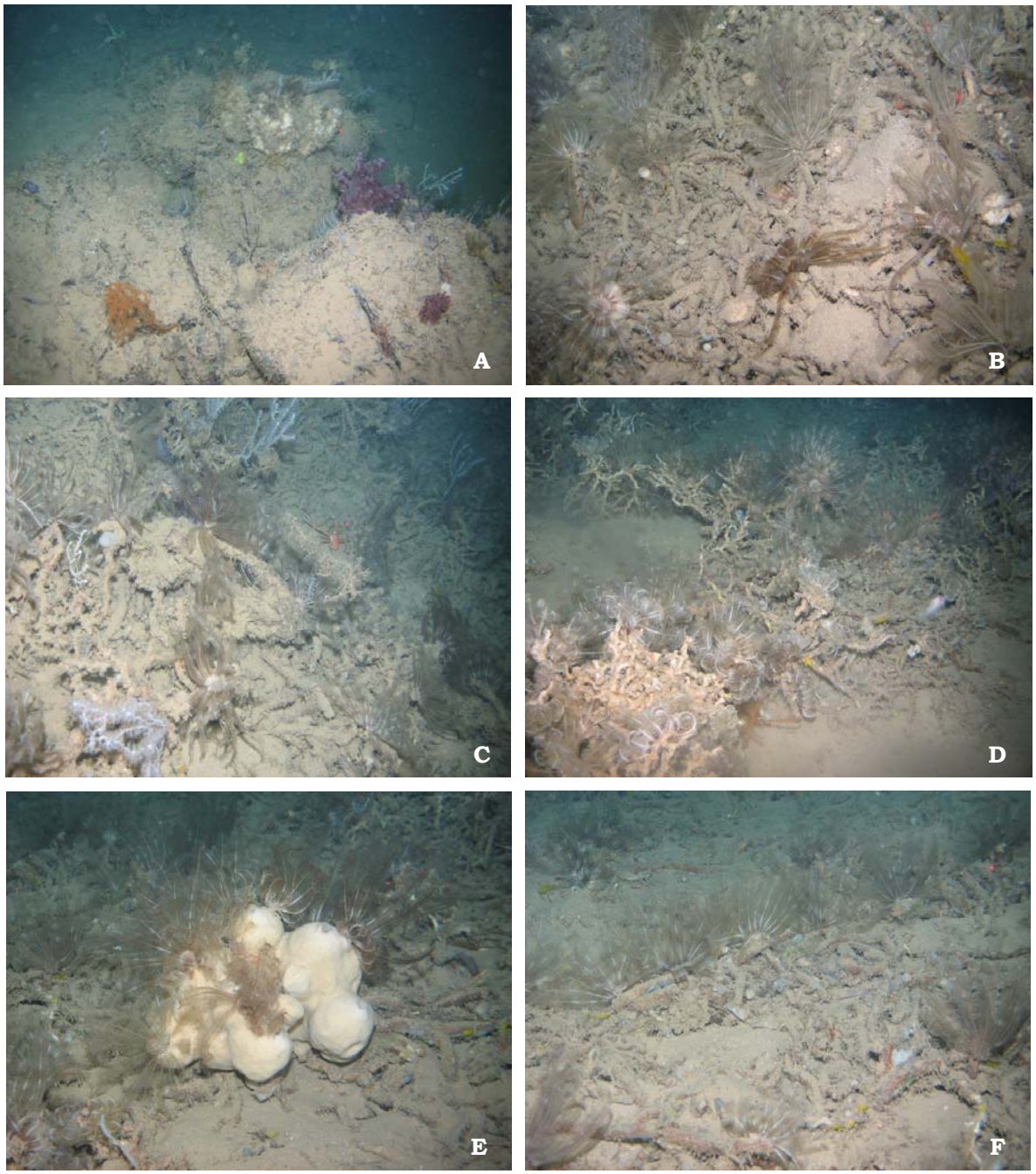

Figure 22: *Pictures of ROV dive 07.*

ROV dive 08

Date: 22/05/2009

Location: Beta mound

Description: During dive B09-08 an N-S transect was made on Beta mound. An alternation between soft sediment with and without coral rubble was observed.

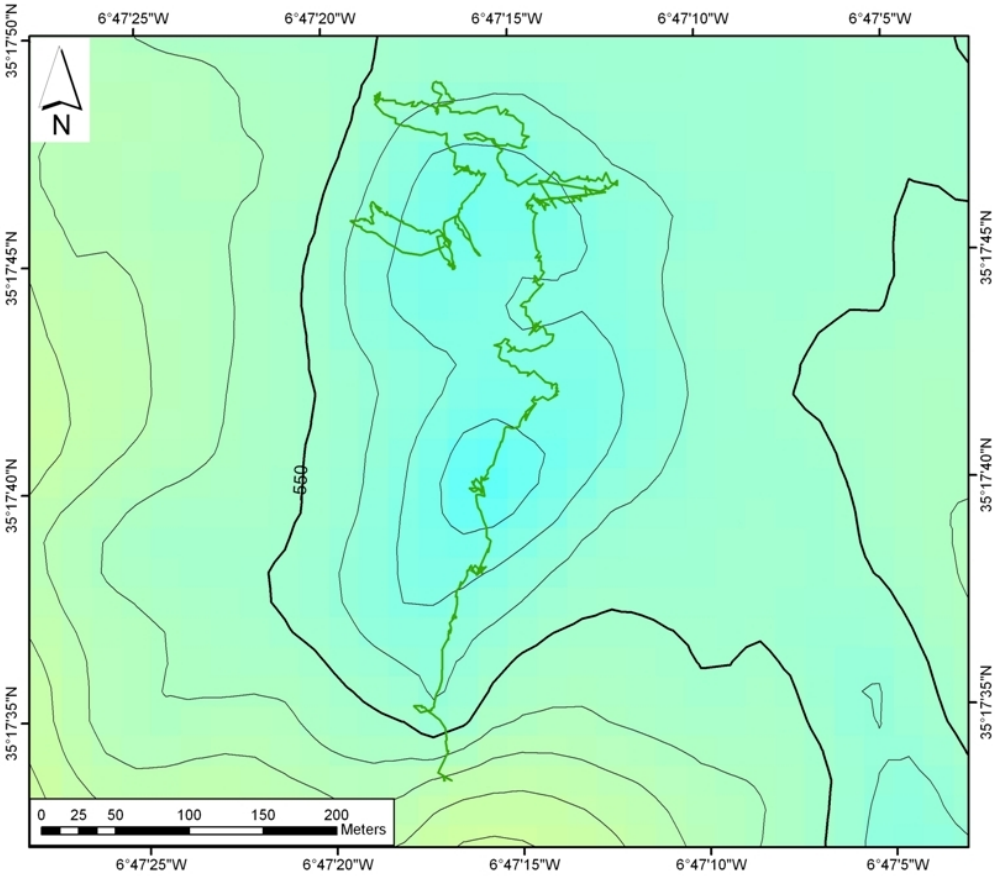

Figure 23: *Map ROV dive 08.*

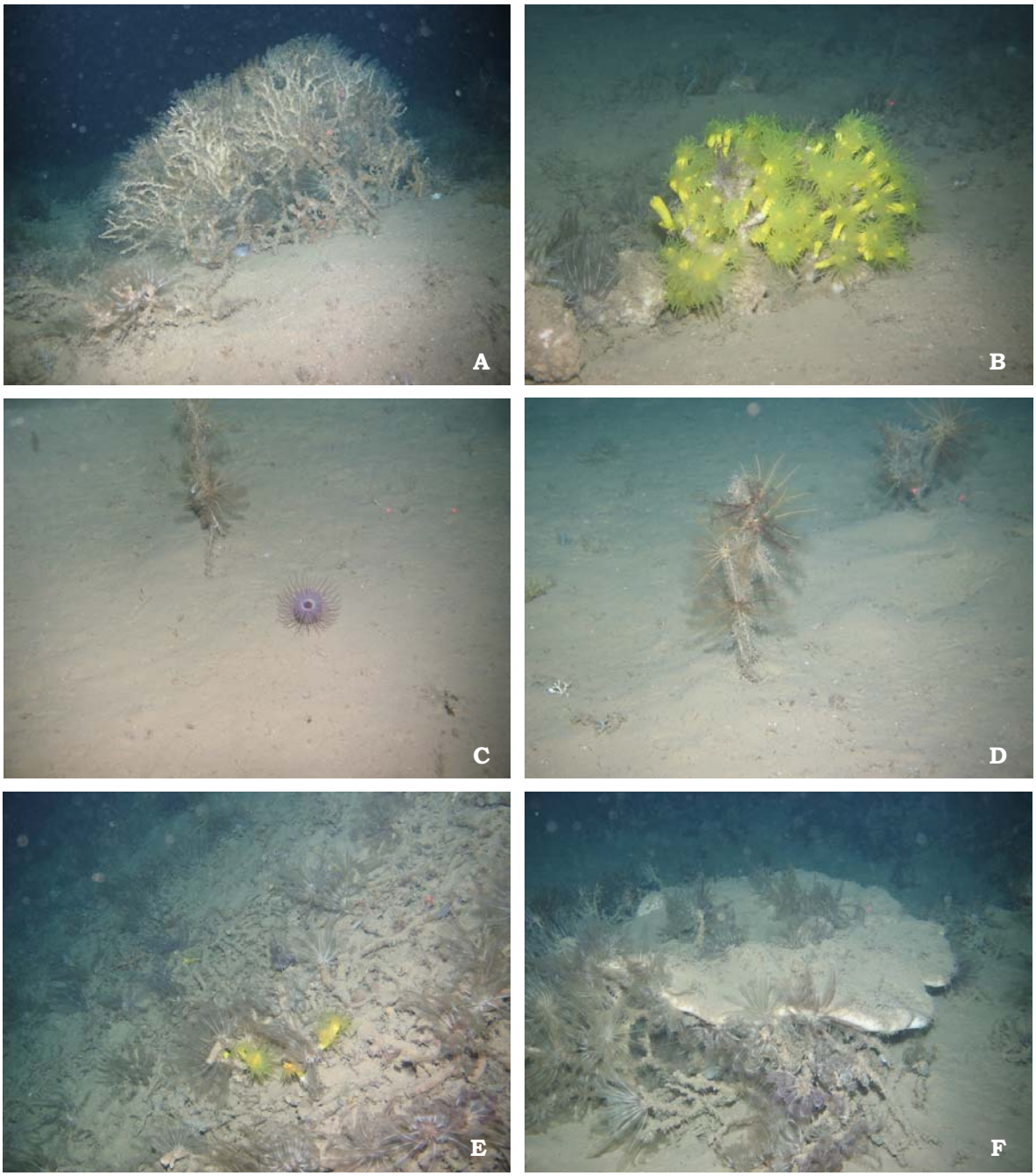

Figure 24: *Pictures of ROV dive 08.*

ROV dive 09

Date: 22/05/2009

Location: Gamma mound

Description: During dive 09 the top of Gamma mound was targeted. Again coral rubble was observed with mostly crinoids on top of them. Also big sponges were found.

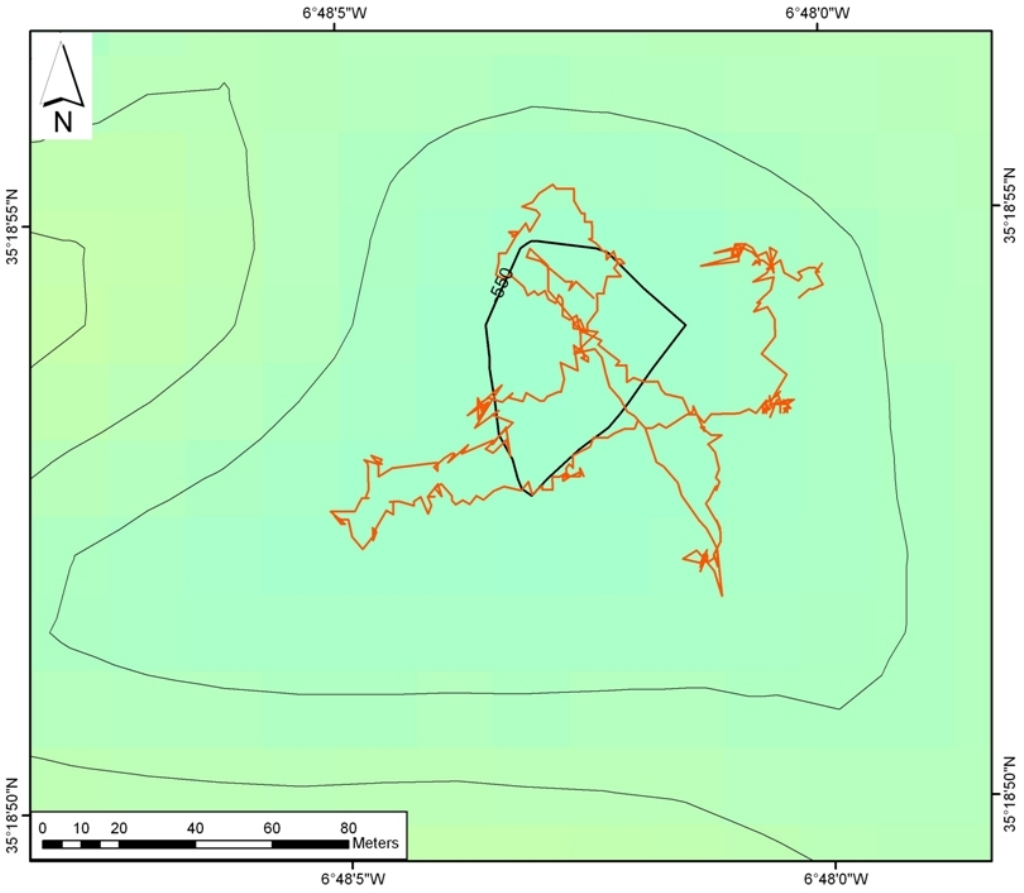

Figure 25: *Map ROV dive 09.*

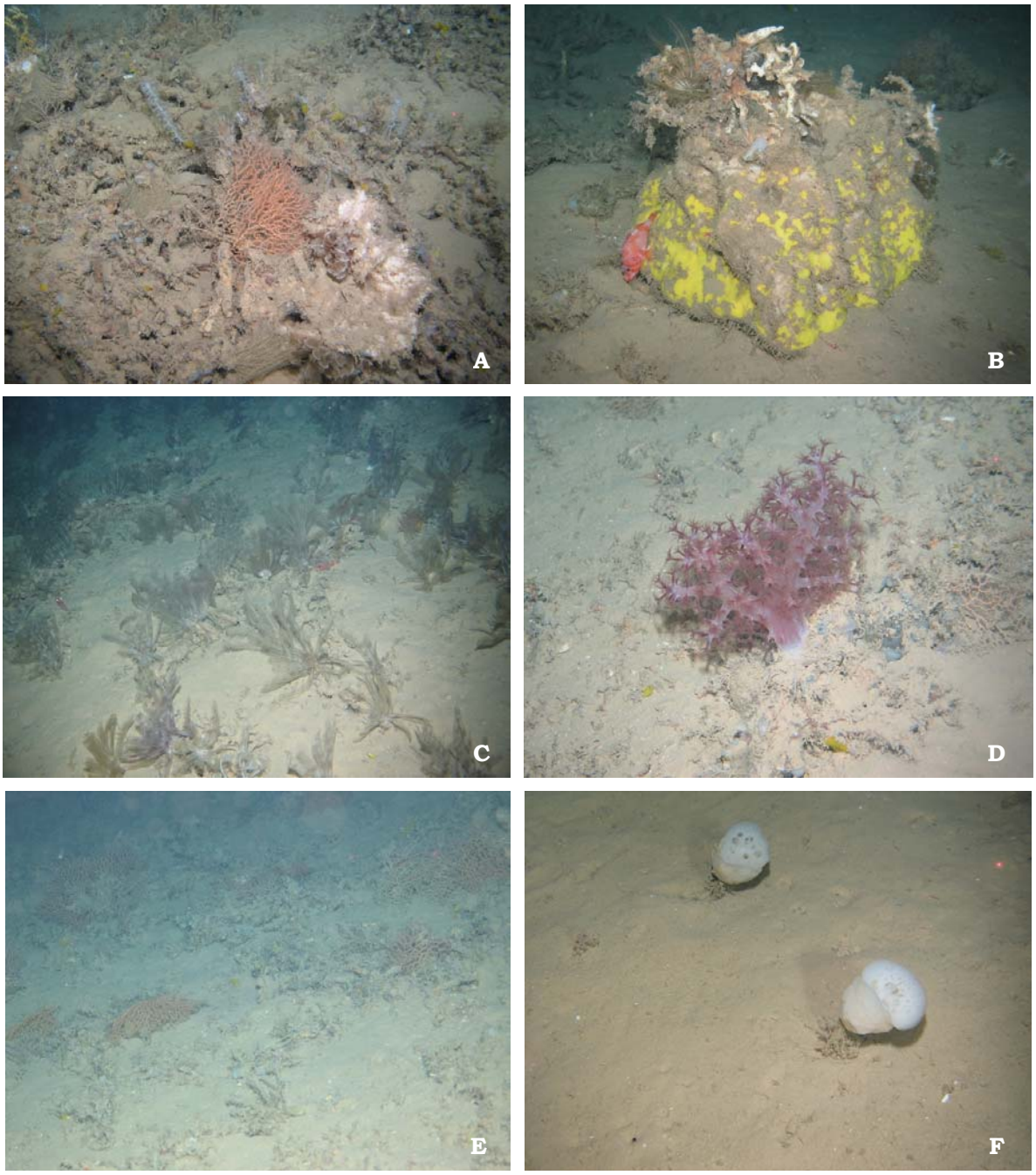

Figure 26: *Pictures of ROV dive 09.*

ROV dive 10

Date: 22/05/2009

Location: Alpha mound

Description: During dive B09-10 a second N-S transect was made on Alpha mound. Like in dive 04 a lot of boulders and rocks (probably carbonate slabs) were observed, also colonized by crinoids.

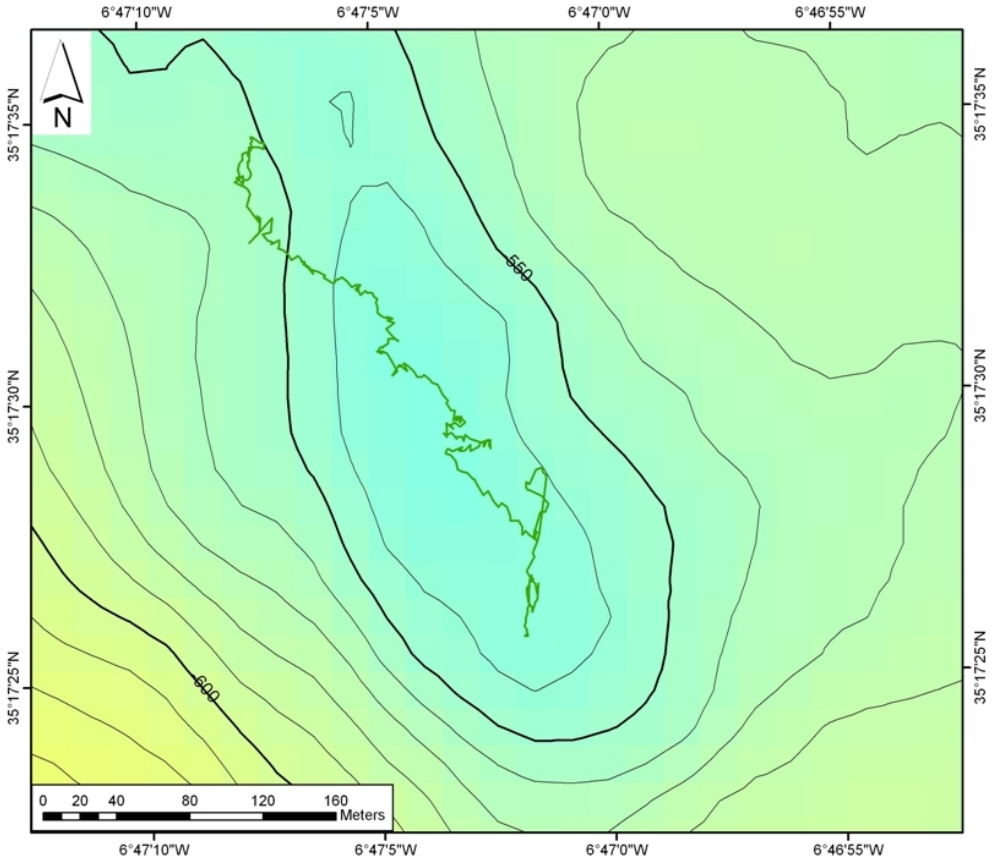

Figure 27: *Map ROV dive 10.*

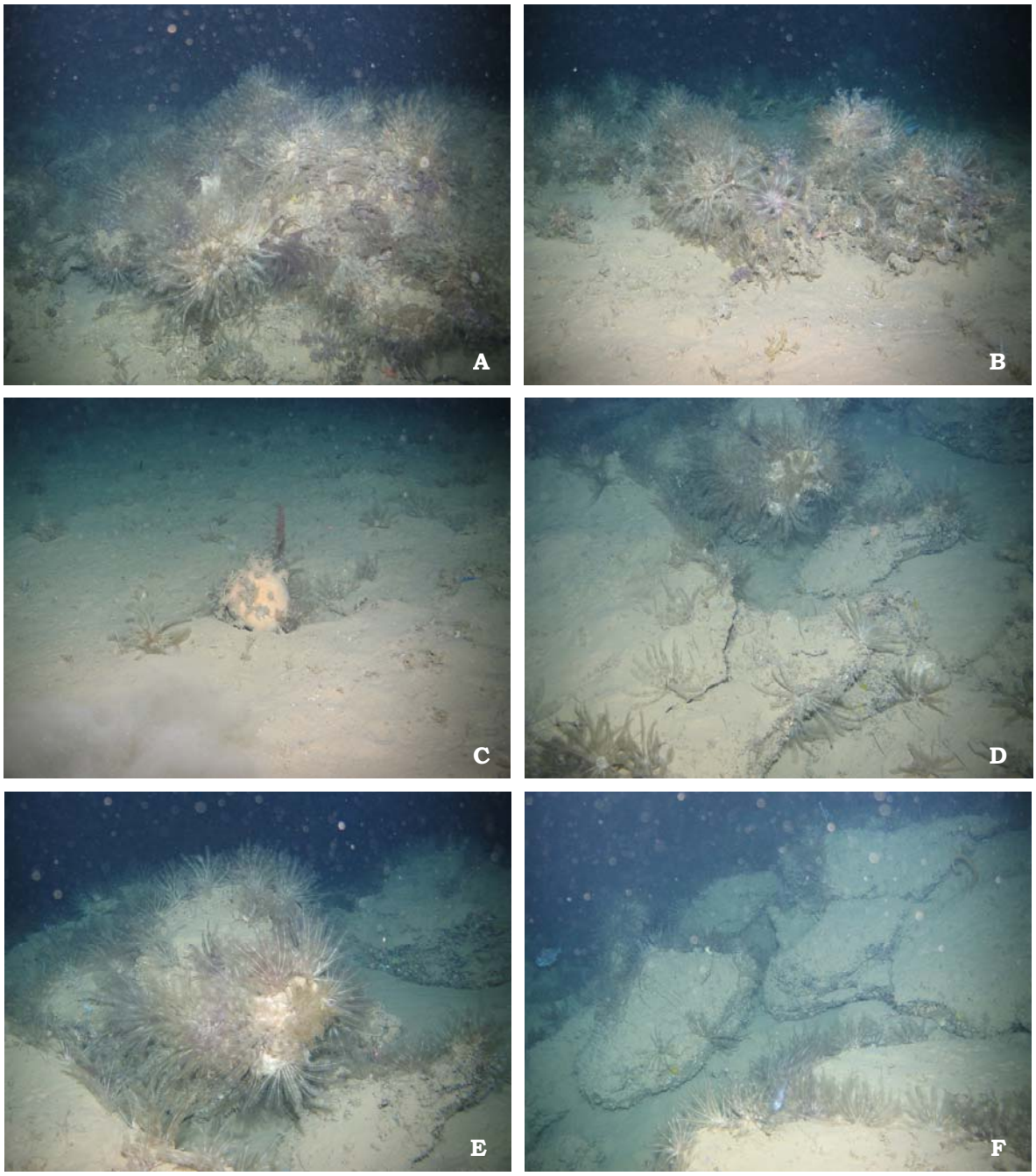

Figure 28: *Pictures of ROV dive 10.*

5.3 Boxcore sampling

The sampled sites are shown on figure 29. After recovery, the bulk sample was photographed and described, respectively followed by sampling for microbiology, sedimentology and geochemistry. A recapitulative list of boxcores is given in table 3.

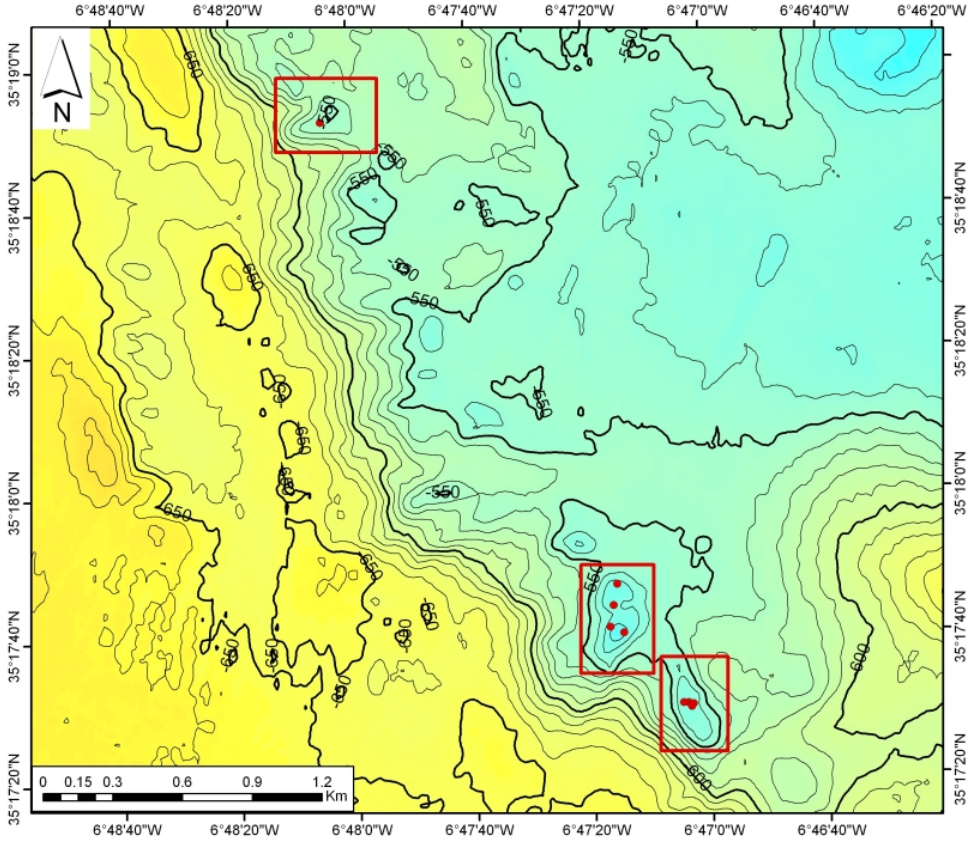

Figure 29: *Multibeam map with boxcore locations.*

Core number	*Location*	*Latitude*	*Longitude*	*Water Depth*	*Recovery*
B09-1401-bc	Alpha mound	35°17.734' N	6°47.272' W	526 m	13 cm
B09-1402-bc	Alpha mound	35°17.783' N	6°47.260' W	528 m	5-20 cm
B09-1403-bc	Alpha mound	35°17.670' N	6°47.243' W	517 m	0 cm
B09-1404-bc	Alpha mound	35°17.684' N	6°47.282' W	524 m	30 cm
B09-1405-bc	Gamma mound	35°18.874' N	6°48.076' W	551 m	33 cm
B09-1406-bc	Beta mound	35°17.504' N	6°47.064' W	530 m	25-35 cm
B09-1407-bc	Beta mound	35°17.505'N	6°47.178'W	531 m	38-47 cm
B09-1408-bc	Beta mound	35°17.502'N	6°47.050'W	533 m	38 cm
B09-1409-bc	Beta mound	35°17.495'N	6°47.056'W	532 m	40 cm

Table 3: *List of obtained boxcores and relevant data.*

B09-1401-bc (526 m bsl)

Description surface:
The surface is covered with big coral fragments, mostly Dendrophyllia.

Description vertical transect:
0-13 cm: Pale brown (10YR6/3) fine sand with coral rubble, mostly Dendrophyllia.

B09-1402-bc (528 m bsl)

Description surface:
Pale brown (10YR6/3) silt to fine sand with a few coral fragments (Dendrophyllia).

Description vertical transect:
0-20 cm: Pale brown (10YR6/3) silt to fine sand with coral rubble, mostly Dendrophyllia.

B09-1403-bc (517 m bsl)

Empty

B09-1404-bc (524 m bsl)

Description surface:
We observed light olive brown (2.5Y5/4) silt to fine sand with coral fragments of mostly Dendrophyllia.

Description vertical transect:
0-15 cm: Light olive brown (2.5Y5/4) silt to fine sand with coral rubble (Dendrophyllia, Desmophyllum and Lophelia), mostly crushed fragments and only a few big pieces.
15-30 cm: Colour change to greyish brown (2.5Y5/2). Coral fragments of Dendrophyllia, Lophelia and Desmophyllum (both big pieces and crushed fragments) are still present.

B09-1405-bc (551 m bsl)

Description surface:
Light olive brown (2.5Y5/4) silt to fine sand with coral fragments.

Description vertical transect:
0-27 cm: Light olive brown (2.5Y5/4) silt to fine sand with big Lophelia pieces.
27-30 cm: Colour changes to grey.

B09-1406-bc (530 m bsl)

Description surface:
Light olive brown (2.5Y5/4) silt with a few coral fragments.

Description vertical transect:
0-35 cm: Light olive brown (2.5Y5/4) silt with big Lophelia pieces.

B09-1407-bc (531 m bsl)

Description surface:
Dark yellowish brown (10YR4/4) silt. No corals were observed at the surface.

Description vertical transect:
0-10 cm: Dark yellowish brown (10YR4/4) silt, no corals.
10-25 cm: Dark yellowish brown (10YR4/4) silt with big Dendrophyllia pieces.
25-47 cm: Greyish brown (10YR5/2) clay to silt with big Dendrophyllia pieces.

B09-1408-bc (533 m bsl)

Description surface:
Dark yellowish brown (10YR4/4) silt with coral fragments, mostly Dendrophyllia.

Description vertical transect:
0-23 cm: Dark yellowish brown (10YR4/4) silt with coral fragments: Dendrophyllia, a few Lophelia and 1 Desmophyllum.
23-38 cm: Pale brown (10YR6/3) silt with big Lophelia pieces.

B09-1409-bc (532 m bsl)

Description surface:
Dark yellowish brown (10YR4/4) silt without coral fragments.

Description vertical transect:
0-15 cm: Dark yellowish brown (10YR4/4) silt, no corals.
Corals, big pieces and crushed fragments of Dendrophyllia, occur at a depth of 5-10 cm.
In the middle part the coral fragments become smaller and small stones were found.
15-40 cm: colour change to grey (7.5Y5/1) with coral fragments (Dendrophyllia, Lophelia and Desmophyllum). First signs of dissolution of the corals are observed.

Figure 30: *Pictures of all boxcores.*

6. Data storage

During the Belgica 09/14b campaign, 62 seismic lines were acquired over approximately 305 km. All lines were recorded in ELICS format and were converted in a SegY-Motorola format with associated navigation files (these are text files containing shot point, longitude, latitude, date and time).

A total of 10 ROV dives were performed. The ROV imagery (forward looking colour camera with/without overlay, black/white camera and rear camera) was recorded on DV tapes through Professional-DV recorders.

All data are stored at RCMG. For more information about the seismic, multibeam, video and sedimentological data, please contact

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