Cruise Report

Belgica 05/12

CADIPOR II

Gulf of Cadiz, off Larache, Morocco

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Willem Versteeg

& the CADIPOR II shipboard scientific party

RCMG

Renard Centre of Marine Geology

Ghent University, Belgium

May 17 - May 27, 2005

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1. Cruise reference

Belgica 05/12
Cádiz (ES) – Cádiz (ES)
17.05.2005 - 27.05.2005

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2. Framework and objectives

2.1 Framework

The geophysical and sedimentological research programme of the Belgica cruise 2005/12 frames into several international and national projects:

- **FWO project GeNesis (2003-2006) : Gent - NEBROC II Associated project on the Genesis of Mounds**

  Research project on the genesis of large carbonate mounds and their precursor phenomena, in particular those possibly related to methane seeps and authigenic carbonate crust formation, with due emphasis on microbial mediation processes.

- **ESF EUROCORES EUROMARGINS (2003-2006) project MOUNDFORCE**

  Study of the forcing factors controlling mound genesis and growth.

- **EU FP5 RTN EURODOM (2002-2006)**

  The research activities of this European Research and Training Network (RTN) are (1) the assessment of submarine continental slope stability and (2) the investigation of the distribution, composition, functioning and significance of deep-water carbonate mounds and reefs. In the meantime possible relationships between both subjects are investigated. The role of the RCMG in this project is mainly linked with the second topic.

- **EC FP6 IP HERMES (2006-2008)**

  Hotspot ecosystem research on the margins of European Seas. RCMG focuses on geosphere controls on ecosystem hotspots in mound provinces and on the dynamic interaction between slope sedimentary processes, carbonate mounds and coral banks.

- **ESF EUROCORES EUROMARGINS (2003-2006) project MVSeis**

  This project investigates the deep crustal structure, the sedimentary section and sediment dynamics, the tectonic control and the detailed geometry of the fluid escape pathways in an area of active mud volcanism in the Gulf of Cadiz

- **Ph.D. projects of the Flemish IWT and FWO**

2.2 Objectives

The discovery of the giant mud volcanoes and deep-sea coral reefs offshore Larache on the Moroccan continental margin (CADIPOR cruise 2002, Fig. 1)) has led to the initiation of several European projects (ESF Euromargins, EU FP6) and international campaigns in this area (R/V Sonne, Marion Dufresne, Logachev, Pelagia). Cadipor II is consolidating the Belgian project dynamics in this exceptional area (projects GeNesis, MoundForce, MVSeis, HERMES) and is expanding the research towards closely related and promising sectors, with a new technology.

The project will be executed in cooperation with the University Mohammed V Rabat-Agdal and partners of the European projects MoundForce, MVSeis, EURODOM and HERMES.

This campaign will focus on the following topics:

- creation of a densely spaced framework of high-resolution seismic profiles over the Pen Duick escarpment, a possible cradle of young carbonate mounds. Other targets are Vernadsky and Renard Ridge.
- extension of the multibeam and seismic survey of CADIPOR (2002) towards the south, with the intention of mapping new and uncharted mud volcanoes
- sampling carbonate mounds and carbonate crusts
- video-imagery of the Pen Duick escarpment
- 2-ship AVO seismic experiment, in cooperation with R/V Pelagia (Royal NIOZ)

3. Departure and arrival of the cruise

Departure: Cádiz (ES)	17.05.2005, at 08.30h.	Belgica 05/12
Arrival: Cádiz (ES)	27.05.2005, at 15.00h.	

4. Working area

Two main working areas have been surveyed during this campaign (Fig. 2):

1. **Area A** (Fig. 3): Study with RCMG single-channel surface sparker. This area has been surveyed intensively with multibeam during the CADIPOR I campaign. Seismic profiles have been acquired over the Pen Duick escarpment, Vernadsky Ridge and Adamastor mud volcano. Special attention has been paid to the proposed IODP drill sites MOMA 01, 02, 03 and 04. Sites 03 and 04 were subject of an AVO-CMP seismic experiment in cooperation with the Royal NIOZ vessel R/V Pelagia. They also provided CTD data for our multibeam survey and boxcores were acquired on three sites previously cored with the R/V Marion Dufresne CASQ cores. The proposed IODP sites and other prominent features were subject of a video survey and were sampled with a Hamon grab.
2. **Area B** (Fig. 4): This area is centered on two sidescan sonar lines acquired by R/V Professor Logachev, with the Meknes mud volcano as most prominent feature. They were subject to a combined multibeam/seismic survey and some video lines.

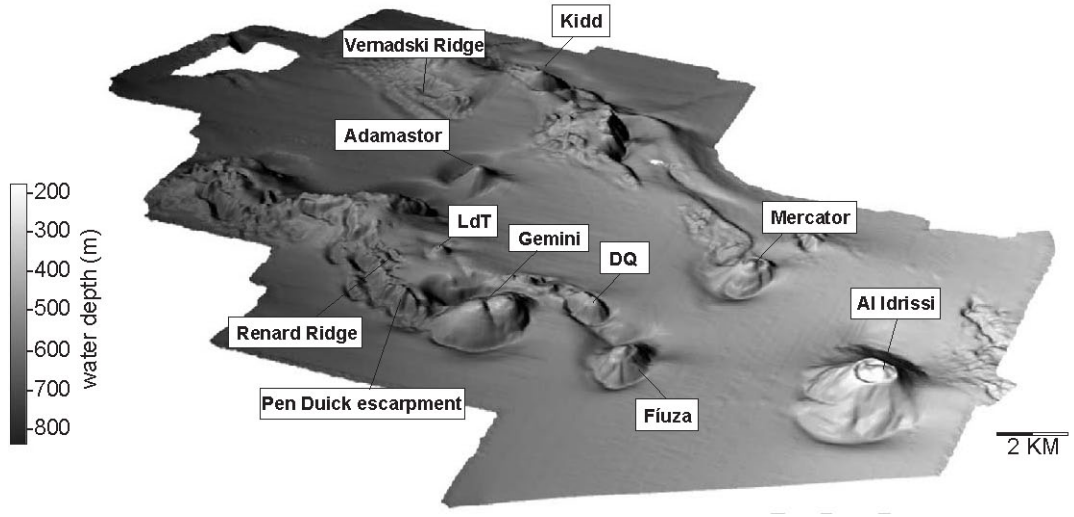


Figure 1: *Morphology of the Al Arraiche mud volcano field, discovered during the CADIPOR 2002 campaign (Van Rensbergen* et al., 2005)

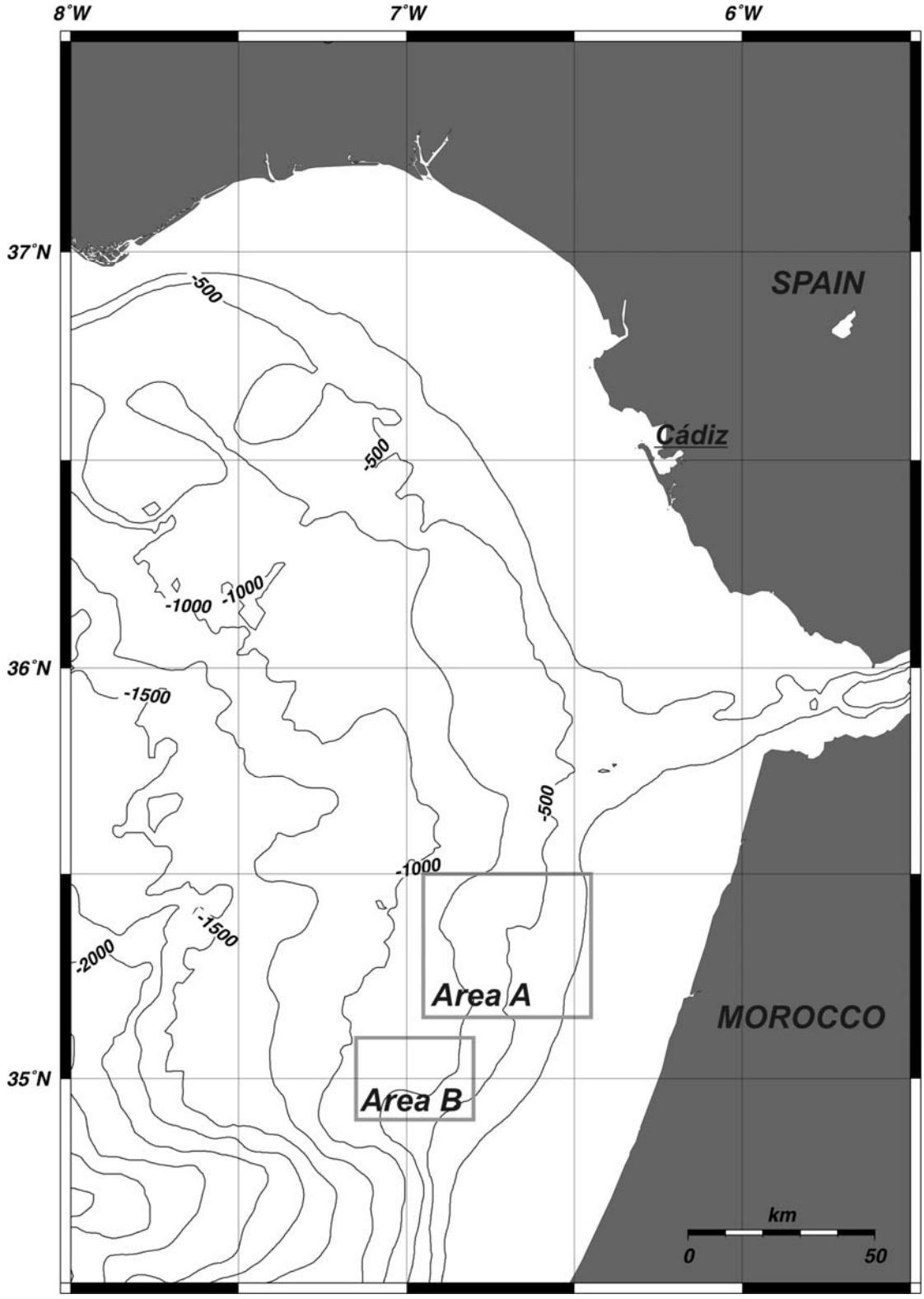


Figure 2: *Map of the CADIPOR II study area, offshore Larache in the Gulf of Cadiz.*

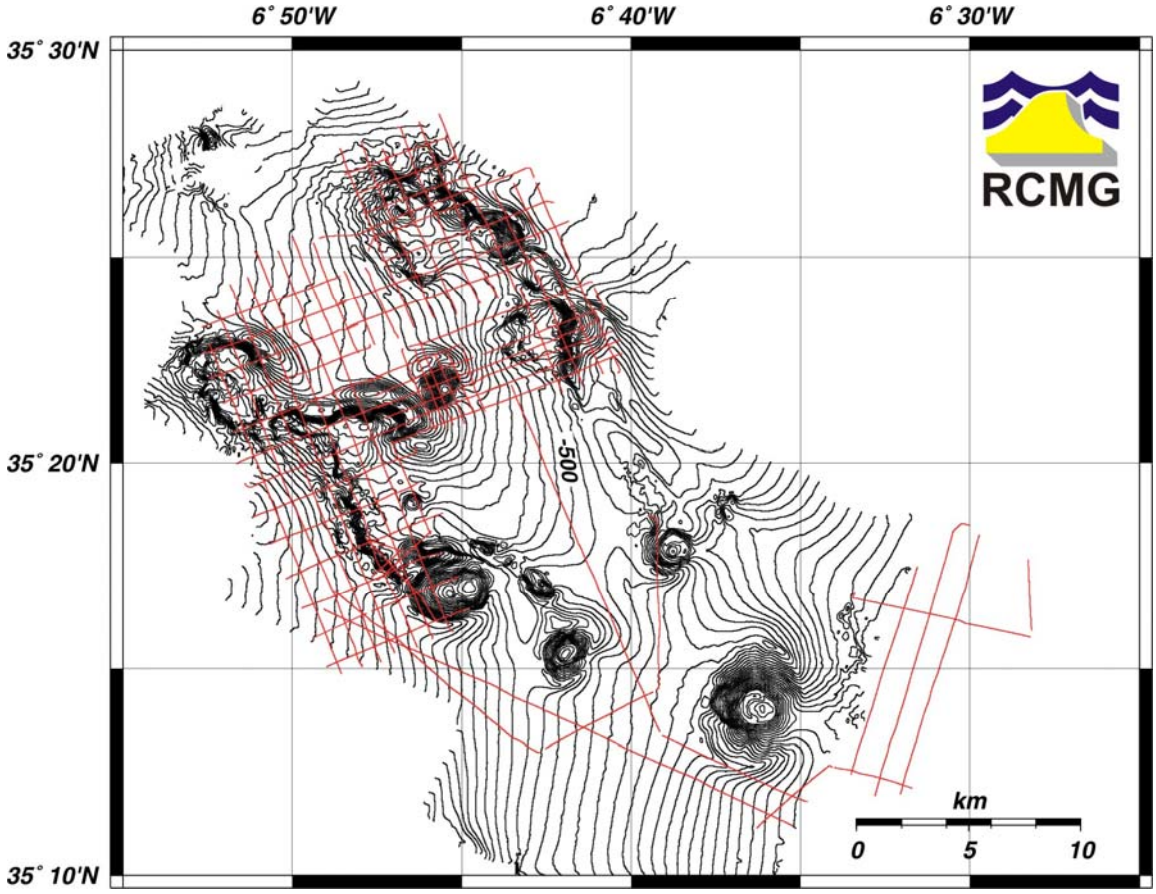


Figure 3: *Seismic profiles acquired in area A during the CADIPOR II campaign, more details are shown in figures 5, 6 and 7.*

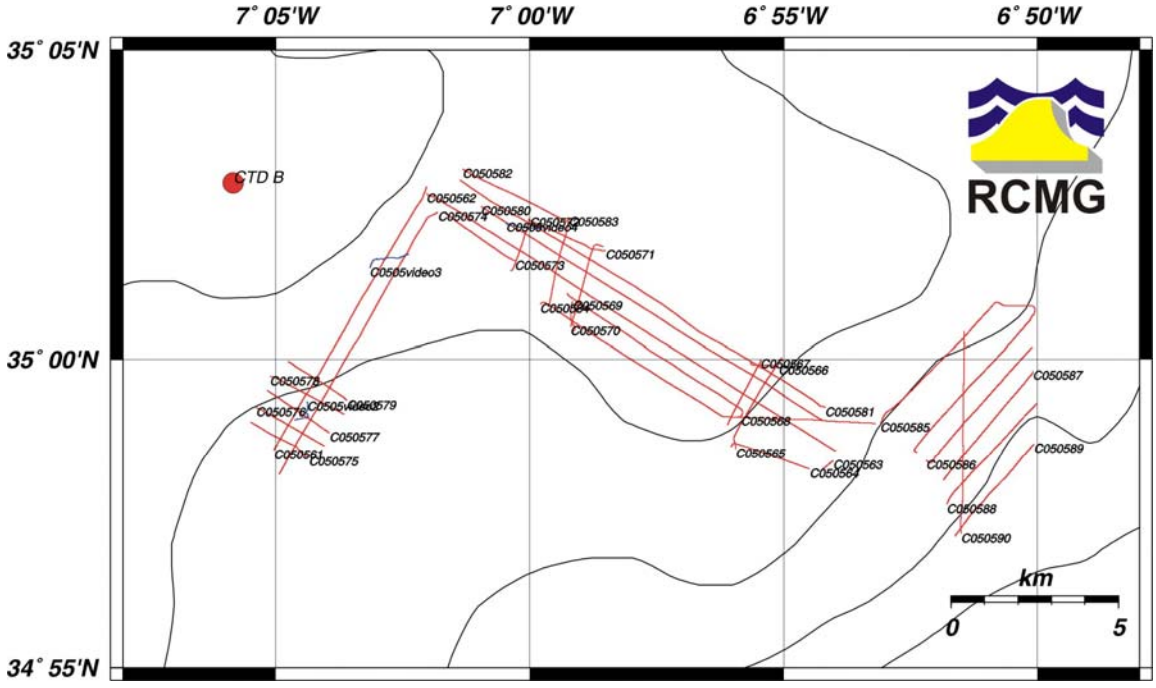


Figure 4: *Seismic profiles, CTD-cast and video lines acquired in area B during the CADIPOR II campaign.*

4.1 Coordination at Sea

Co-chief scientists:	VAN ROOIJ, David & VERSTEEG, Wim
	Renard Centre of Marine Geology (RCMG),
	Ghent University, Belgium

4.2 Scientific staff

Dr. David VAN ROOIJ	UGent, RCMG,
Willem VERSTEEG	UGent, RCMG,
Anneleen FOUBERT (21/05-27/05)	UGent, RCMG,
Dr. ir. Veerle HUVENNE (21/05-27/05)	NOCS (UK),
Ilham BOUIMETARHAN	Université Mohammed V Rabat-Agdal (Morocco),
Julie REVEILLAUD	UGent, RCMG,
Ing. Jeroen VERCRUYSSE	UGent, RCMG,
Ing. Koen DE RYCKER	UGent, RCMG,
Davy DEPREITER	UGent, RCMG,
Peter STAELENS	UGent, RCMG,
Pieter PROVOOST	UGent, RCMG, Marelac student,
Nele GEMOETS	UGent, RCMG, Marelac student,
Eva DE BOEVER	UGent, RCMG, Marelac student,

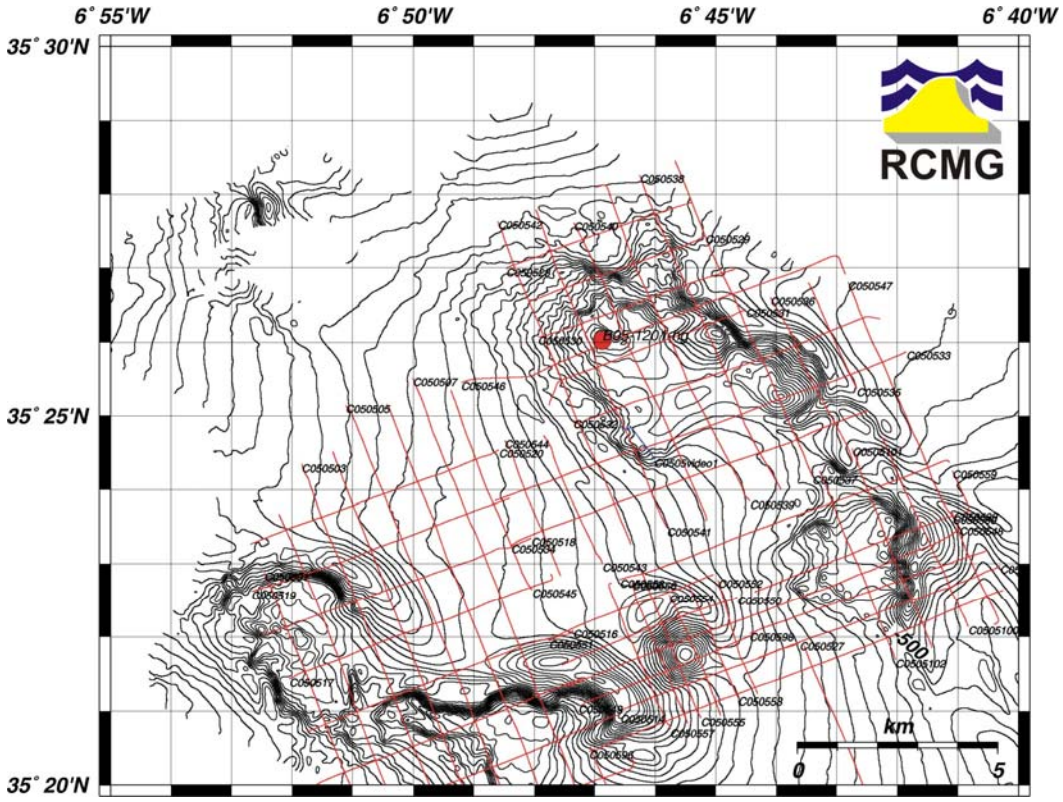


Figure 5: *Detailed map of seismic profiles and Hamon grab positions in the NW sector of area A.*

4.3 Operations

4.3.1 Seismic survey

Most of the seismic profiles are single channel surface sparker lines, acquired with a SIG sparker source (120 electrodes). The sparker was triggered every 2 s reaching 400-500J energy. The sampling frequency was set at 8 kHz and a record length of 1800 ms TWT was used. The velocity of the ship during surface sparker seismics was tried to be maintained at about 3 knots.

For the 2-ship experiments, the Belgica each time sailed a line 100 m north of the drill sites of interest, while the R/V Pelagia sails in opposite direction 100 m south of a line (Fig. 8). The positioning of these sites (AVO-03A and AVO-04A) is shown in figures 6 and 7. Both ships maintain a speed of 2 knots (course over ground, GPS). R/V Pelagia triggers the seismic source (4 TI SG-I sleeve guns at 10, 20 and 2 x 40 cu inch at 110 bar) every 12 s (MOMA-04A) or 9 s (MOMA-03A) and radios this over using a radio link. The main recording took place on the Belgica, using the single channel surface streamer. The sampling frequency was respectively set at 1 and 2 kHz with a record length of 11 and 7 s TWT. During the experiment, R/V Pelagia also recorded the reflection seismics with a multichannel streamer.

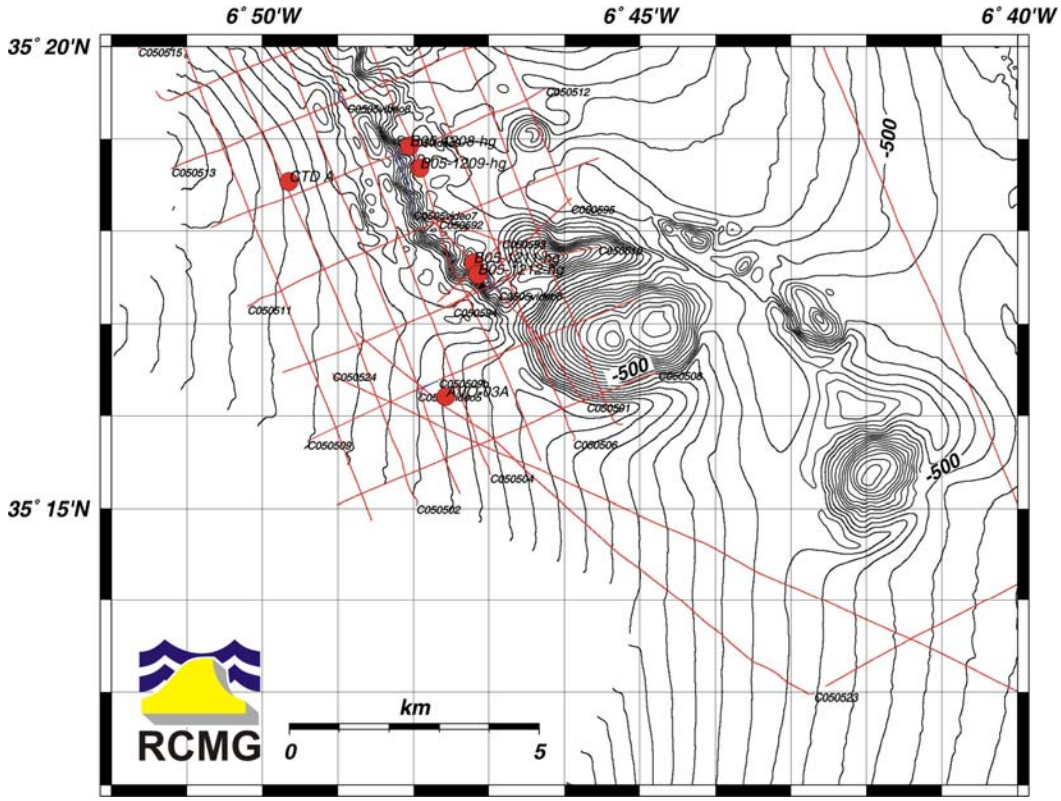


Figure 6: *Detailed map of seismic profiles, CTD, video lines Hamon grab positions in the SW sector of area A.*

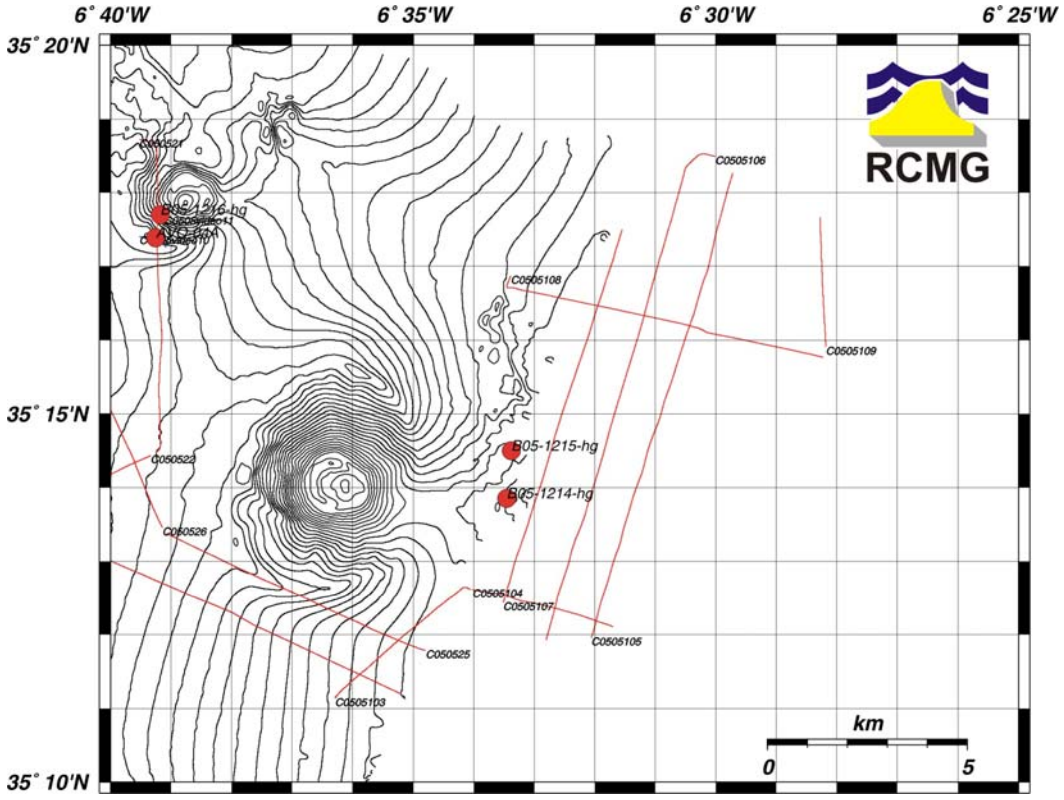


Figure 7: *Detailed map of seismic profiles, video lines and Hamon grab positions in the SW sector of area A.*

Figure 8: *Meeting of R/V Belgica with R/V Pelagia (Royal NIOZ) for the AVO experiment.*

4.3.2 CTD measurements

In order to obtain an up to date sound velocity profile in the multibeam survey areas, CTD casts were taken and the temperature and salinity information was converted to sound speed values using the formula of Chen-Millero (Chen Ch.-T. & Millero, F.J. Speed of sound in seawater at high pressures //JASA.-1977.-Vol. 62.-No 5.-P. 1129-1135.)

The first CTD cast was obtained through collaboration with the R/V Pelagia (Figs. 3, 9a). The system used on this ship is the SBE9, and the data were collected in study area A (35° 18.54 N, 6° 49.65 W). The recording of the data was controlled with the software SEASAVE. The resulting data were saved in a binary file (.dat), and the configuration settings were saved in *64pe237mt2005-01001.con*. The binary data were converted to ASCII using the program *SBEDataprocessing_Win32*. Only the downcast data were chosen, and the information was binned in 2 m intervals. Besides sound velocity, also temperature, salinity and turbidity values were saved for further reference and for characterization of the physical environment in the study areas. The CTD cast was limited to ca. 700 m depth, and in order to obtain a full-depth sound velocity profile, this new cast was combined with the sound velocity data used during the first CADIPOR cruise in 2002. Hence the upper 232 m of the profile (including the very strong thermocline present in this area in May 2005) was taken from the new cast, and the data below 234 m was copied from the old cast. The sound velocity profile obtained this way was stored in the file *svpascii.asvp*.

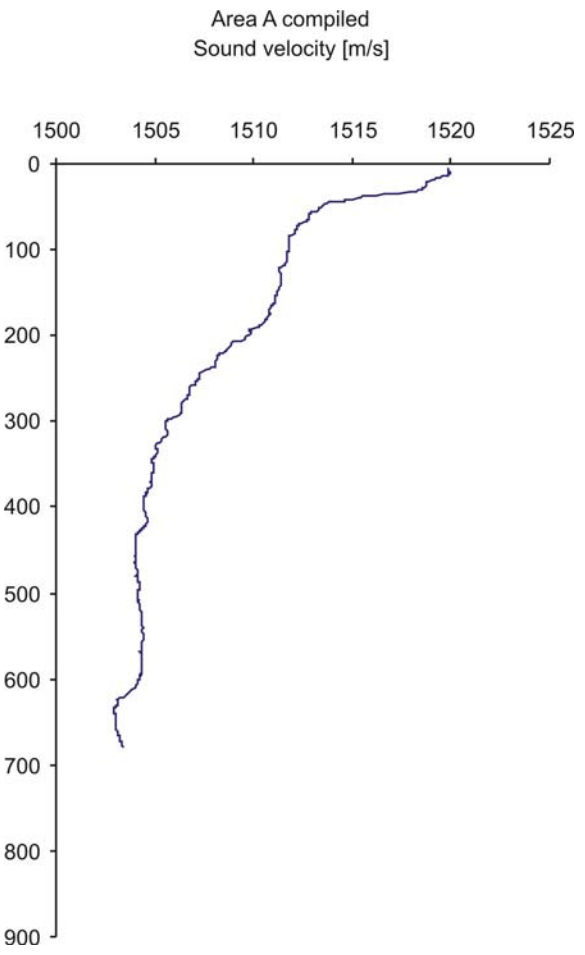


Figure 9a: *combined sound velocity profile with data acquired by R/V Pelagia (courtesy of Dr. Henk de Haas, Royal NIOZ) and the data obtained during the CADIPOR campaign in 2002.*

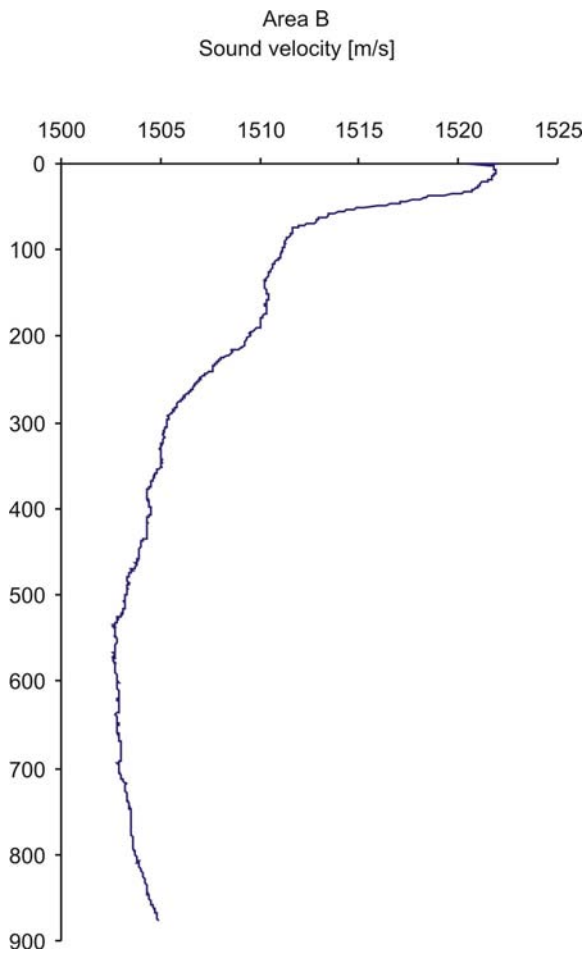


Figure 9b: *Sound velocity profile acquired NW of Area B using the CTD of the RCMG video frame.*

A second CTD profile (Figs. 4, 9b, 10) was taken on 23/05/05 west of area B, in order to maximize accuracy in the data collection in this area too (35°02.8552N, 7°05.8393W). In this case the instrument used was the CTD mounted as standard equipment on the RCMG video frame. The data were recorded with the program *Datalogger* and converted using *MATLAB* routines and the *Ocean Data View* software (pressure to depth conversion). The CTD recording was continued to a depth of 887 m, and below this the sound velocity was extrapolated as a constant value to create a sound velocity profile down to more than 1000 m. The final sound velocity profile was stored in the file *cadiporb2.asvp*.

Further CTD measurements were acquired during the different video surveys. Recording was carried out with a MATLAB routine, developed by Peter Staelens (RCMG).

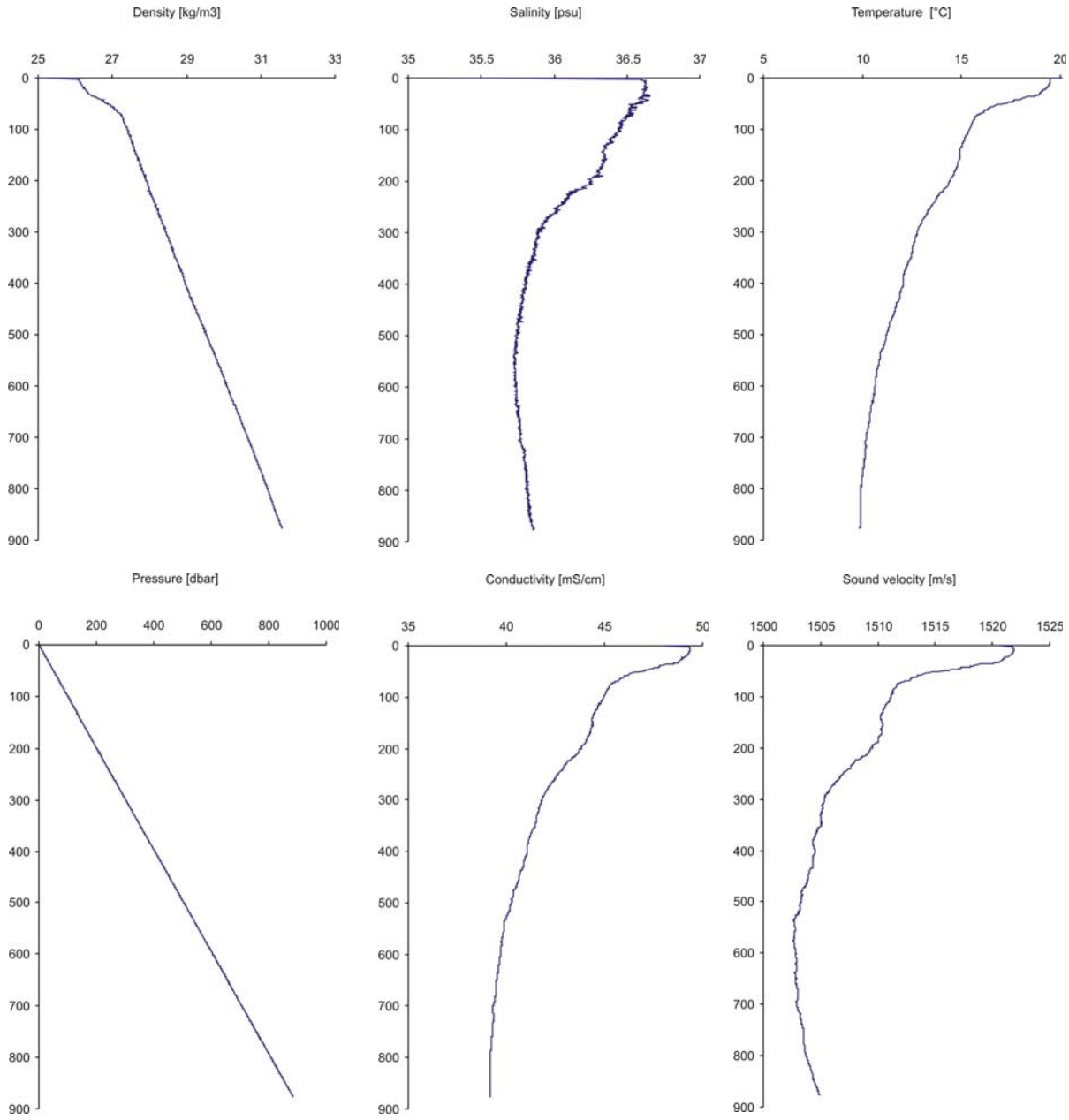


Figure 10: *CTD data obtained NW of area B with the RCMG video frame with density, salinity, temperature, pressure, conductivity and sound velocity.*

4.3.3 Multibeam survey

The multibeam echosounder used during the CADIPOR2 cruise is the Simrad E1002 system from the Ministry of Economical Affairs, installed permanently on the Belgica. Standard procedures were chosen for its application.

Before leaving the port of Cadiz, the draft of the ship was measured at four locations, resulting in the average value of 5.15 m. This value was entered in the settings of the multibeam system. However, after this measurement, extra water was loaded into the ship, resulting in a new draft of 5.42 m. This new value will have to be entered during post-processing.

Once arrived at a study site, the sound absorption coefficient in the water was calculated from the temperature and salinity of the surface water. No pH measurement was carried out, but an average value of 8 was entered in the formulas. A CTD cast was taken for the estimation of the sound velocity, as described above.

INPUT PARAMETERS :		ABSORPTION COEFFICIENT :	
ONLY THE RED FIELDS NEED TO BE ADJUSTED !			
DATE	*2005-05-22 19:47*		
SOUND SPEED C in m/s =	1519.80	α in dB/km (T > 20°C)	32.69637658
			34.96224243
SEA WATER TEMPERATURE, T in °C =	18.75	α in dB/km (T < = 20°C)	31.30916682
SEA WATER SALINITY, S in ppt =	36.3384		33.4218606
SEA WATER pH, pH =	8		
		RATIO (α1/α2) x 100	106.7478441
WATER DEPTH in km =	0.6	α1 - 98 KHz	33.4218606
		α2 - 93 KHz	31.30916682
FREQUENCY in KHz, *f*	93		
	98		

Figure 11: *Input parameters for the multibeam calibration*

At the beginning of the first survey (area b) a roll and pitch calibration was carried out. Therefore 2 tracks were sailed in opposite direction, followed by one perpendicular to it. The roll had to be adjusted by -0.446 degrees, the pitch by -0.50 degrees. It was chosen to record all possible parameters; position, backscatter image…

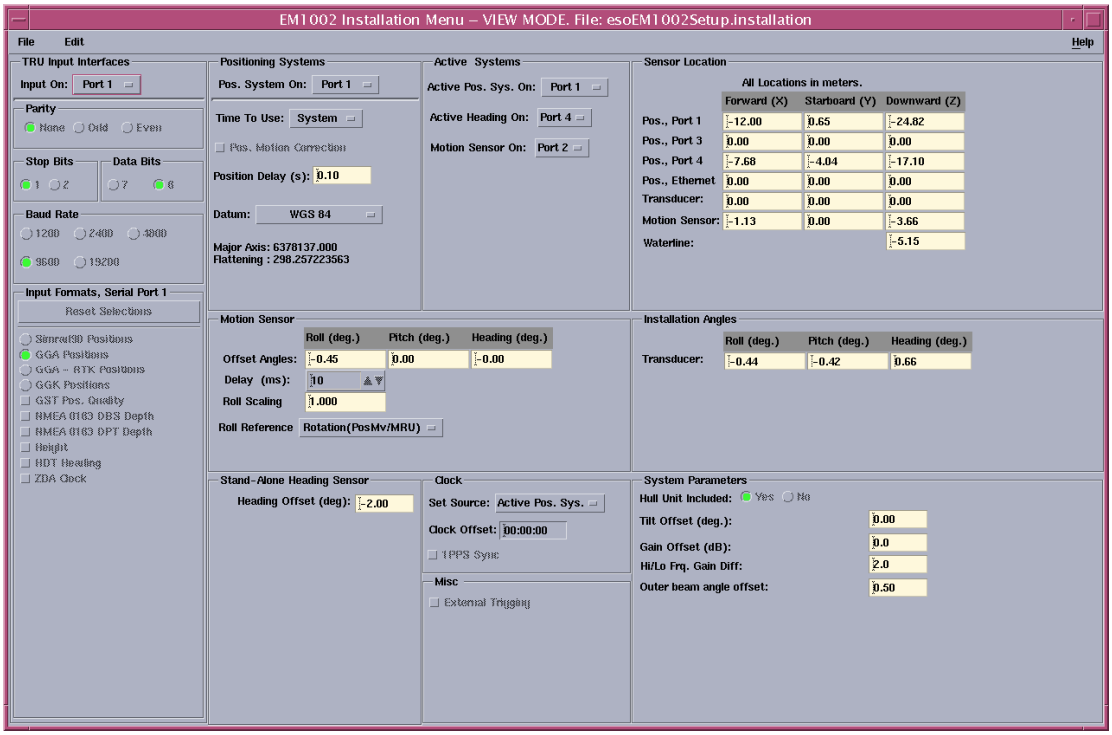


Figure 12: *Screenshot of the multibeam input parameters concerning motion sensors and roll/pitch calibration.*

During the actual surveys we aimed at keeping a 10% overlap between the consecutive swaths. This resulted in a line spacing ranging from ca. 500 to 700 m (swaths of

2x300 to 2x450 m). For most of the time the system was switched to the automatic detection of the appropriate working mode (shallow, medium or deep). Only in a few cases (e.g. bottom detection at the beginning of a line) the system was forced in the deep mode. The beam angles were generally chosen quite narrow (20 to 30°), in order to focus the acoustic energy towards the relatively large depth below the vessel. The beam spacing was chosen as 'in between' (between equi-angle and equi-distant), to optimise the backscatter recording. A spike filter of weak to medium strength was switched on, after reports from the MUMM about regular occurrences unwanted spikes in the data.

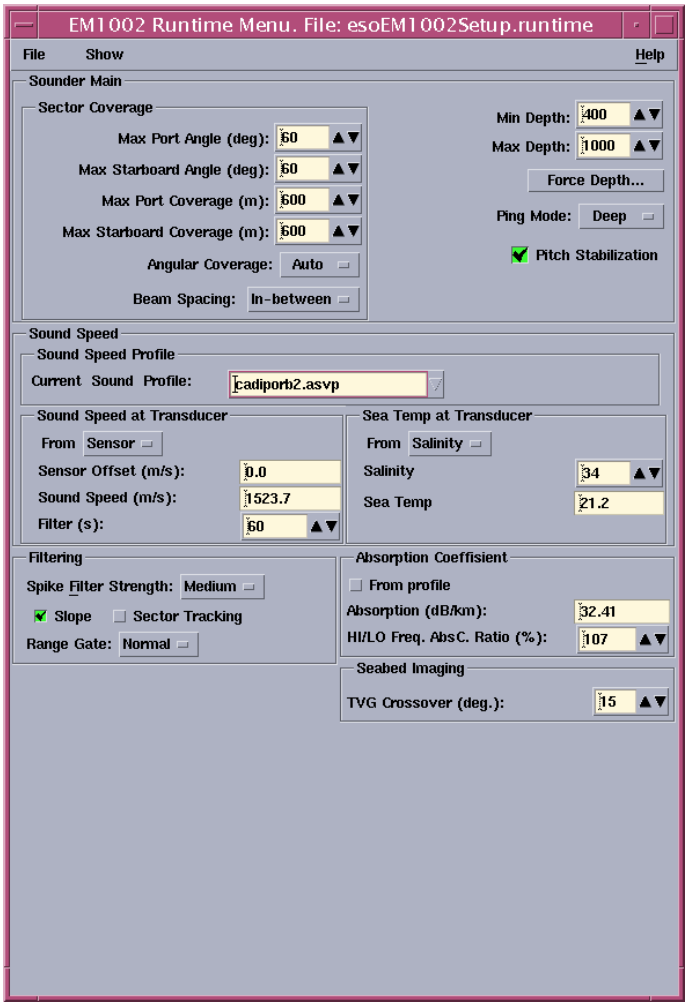


Figure 13: *Screenshot of the multibeam input parameters concerning sound velocity and filtering.*

During the multibeam surveys, it was tried to keep the vessel speed to 8 kn. Especially for lines going from east to west this was often not possible, due to the currents and sea state during the first days of multibeam surveying. A reduced speed of 7 or 6 kn had to be used in order to increase the data quality, but even then the data collected with headings ranging from ca. 200 to 320 show much more noise and reduced quality. Part of

the multibeam survey was recorded during seismic profiling, while sailing at a speed of ca. 3 kn.

At regular intervals (during turns or during other operations) the data were gridded on 20x20 m grids, such that they could be used for the planning of further activities.

At the end of the survey, all the data were backed up on DVD (both the raw data files and the proc files). The tape drive on board of the Belgica needed to be cleaned and could not be used during the survey. However, upon arrival in Zeebruges, this problem will be tackled and the data will be saved on tape as well.

In general, two main areas were subject to a multibeam survey. Initially, it was planned to map entire area B (Fig. 14), but due to a lack of time and a not ideal sea state, a more selected area, previously covered with TTR sidescan sonar data was mapped in combination with seismic profiling. In Area A, additional multibeam lines were acquired east of El Idrisi mud volcano (Fig. 15).

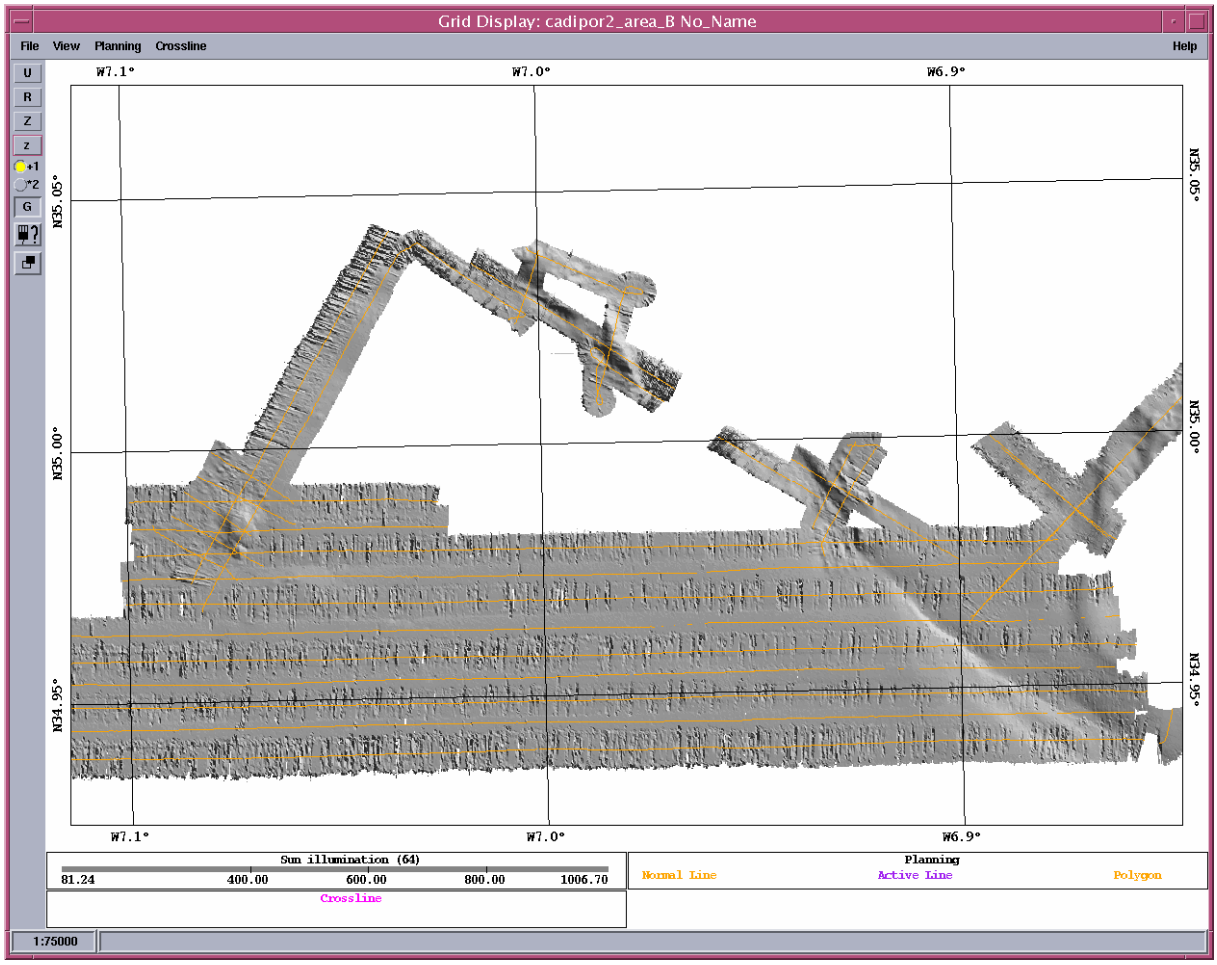


Figure 14: *Screenshot of the multibeam coverage in Area B. The initial grid has an E-W orientation, while the TTR sidescan sonar imagery has a NNE-SSW (Meknes MV) and NW-SE orientation.*

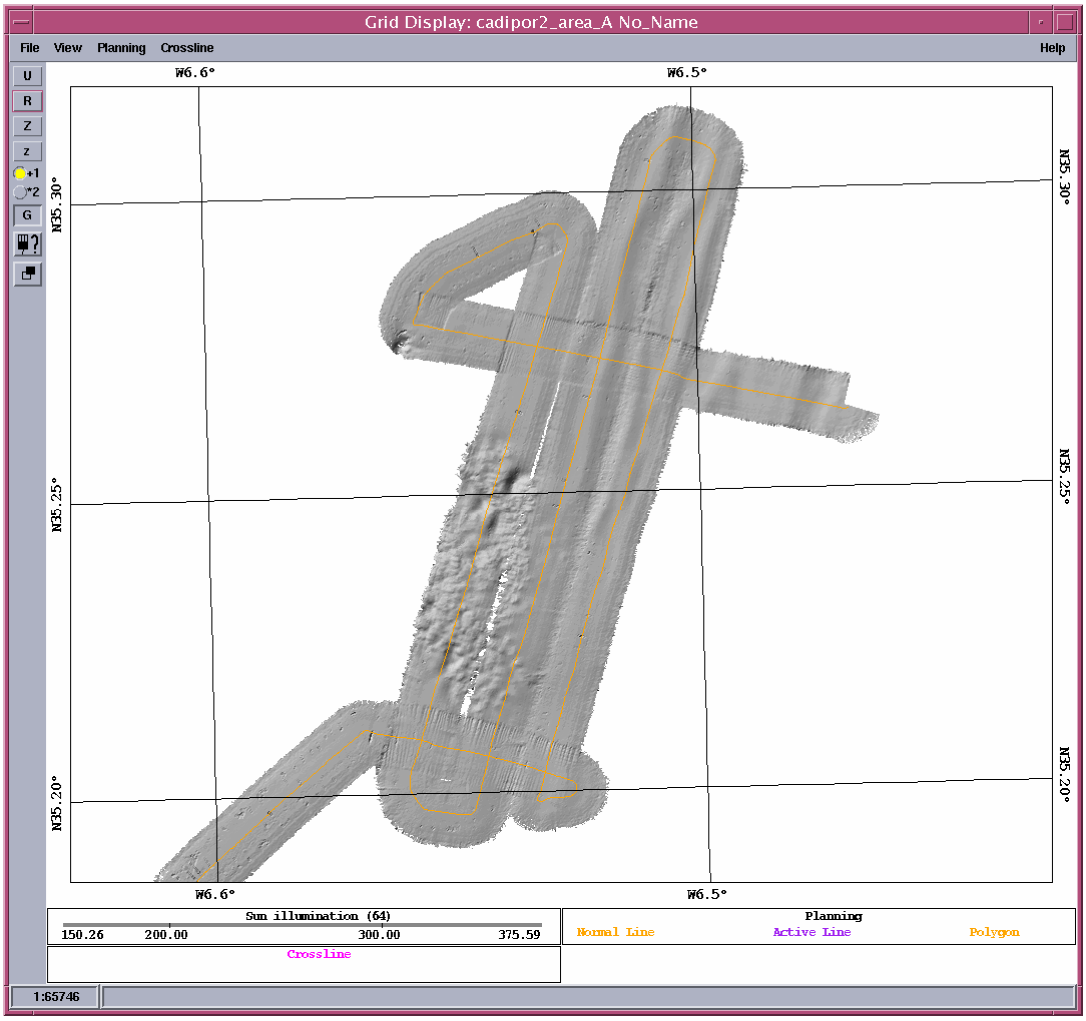


Figure 15: *Screenshot of the multibeam coverage in Area A, directly east of the CADIPOR 2002 grid, within the vicinity of El Idrisi mud volcano.*

4.3.4 Video survey

For the video survey, the frame (Fig. 16) was launched from the aft deck with the Belgica A-frame and the deck remote control up to a water depth of 400 m, after checking water depth. For the actual survey, the winch control was transferred to the survey area on the bridge where the operator has visual observation with the navigator camera. Both camera footage, navigator and inspector, is recorded. During operations, ship time and camera time is recorded as reference. A first video dive was performed with electric ship propulsion, whereas following dives were performed on diesel propulsion, giving less electric disturbance. During the survey, the ship remained near-stationary or gently drifted along a predetermined track at a speed of 0.5 knots. Transit between two nearby sites was done on a speed of 2 knots with the frame at a safe depth (200 m above sea floor). A total of 11 sites were visited (Table 1, figs. 17, 18)

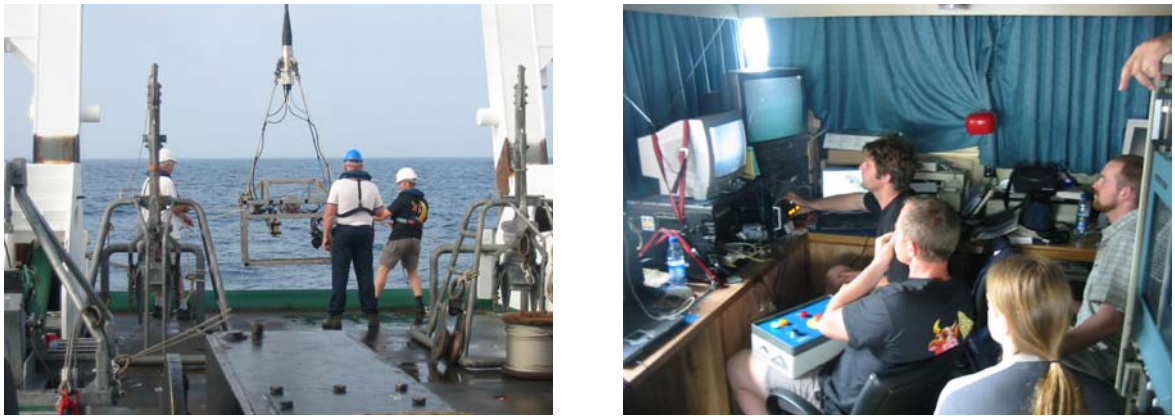


Figure 16: *Video operations. On the left side, the video frame is launched with navigator camera on the left side and inspector camera on the right side. The picture on the right, shows the bridge configuration with the two camera displays, navigation computer, remote winch control and observers.*

Name	***Area***	***Start track***		***End track***	
		Time	*Depth (m)*	*Time*	*Depth (m)*
C0505video1	South flank of Vernadsky ridge	10:19	500	11:34	551
C0505video2	Meknes mud volcano	12:13	748	13:43	740
C0505video3	2.5 nm NE of Meknes MV, mounded area	15:32	808	16:23	801
C0505video4	Ridge-like area 4.4 nm NE of Meknes MV	17:18	813	18:00	732
C0505video5	Site MOMA-03A	11:07	656	11:25	652
C0505video6	Sites MOMA-01A & 02A	12:07	596	13:21	510
C0505video7	Lower flank of Pen Duick escarpment	14:03	578	15:56	637
C0505video8	Presumed mounds 0.8 nm NW of Pen Duick escarpment	16:32	633	16:53	634
C0505video9	Upper flank of Pen Duick escarpment	17:36	582	18:22	540
C0505video10	Site MOMA-04A	19:40	493	20:10	492
C0505video11	Site MOMA-04A bis	20:41	416	20:59	400

Table 1: *Overview of video lines with area description, as well as time and depth at the start and end of the tracks.*

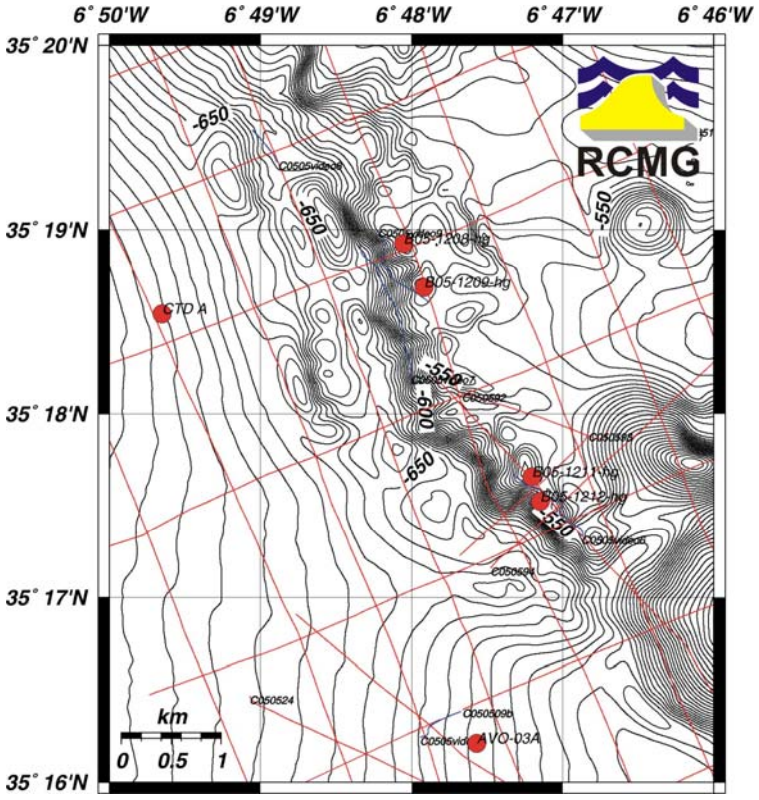


Figure 17: *Detailed map the Pen Duick escarpment, illustrating the video tracks, grab and AVO stations.*

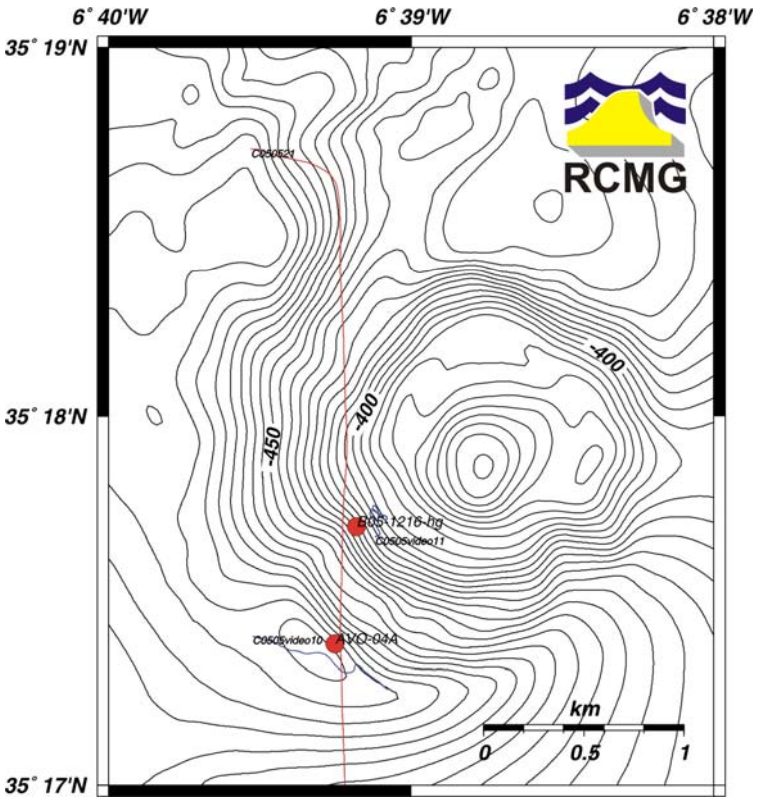


Figure 18: *Detailed map of Mercator MV, illustrating the video tracks, grab and AVO stations.*

4.3.5 Operational Report

It is worth noting that the time used in this cruise report and on the seismic survey sheets is the Belgian Summer time (BRAVO TIME = UTC+2hours). Multibeam files were acquired in GMT time.

Saturday 14.05.2005

18:00 Arrival of a part of the scientific team in Cádiz, Zona Franca (David Van Rooij, Koen De Rycker, Jeroen Vercruysse, Davy Depreiter, Peter Staelens and Julie Réveillaud).

19:00 Official reception on board R/V Belgica with the Belgian consul and some Belgian and Spanish guests.

Sunday 15.05.2005

10:00 Testing of all optical connections of the RCMG and MUMM equipment. Connection and testing of the shipboard CTD.

12:00 Visit of the Belgian aquaculture R&D company CADITEC (upon invitation of the managing director), located a few kilometres outside Cádiz, in Puerto Real. After the visit, the science crew had a day off.

18:00 Arrival of Willem Versteeg

Monday 16.05.2005

08:30 Unpacking all RCMG material out of the cargo and installation and preliminary testing of seismic and video equipment. Writing of software necessary for the control of the depth monitoring of the video equipment and the processing of deep CTD data. Setup of the video frame and testing of the camera movements.

10:00 Arrival of Ilham Bouimetarhan

13:00 Arrival of Eva De Boever

15:00 During the tests of the camera movements, power failures were discovered so zooming did not work. The power supply and routes were changed to solve this problem.

19:00 Arrival of Jean-Pierre Henriet

19:30 Arrival of Nele Gemoets

20:15 Arrival of the Belgian Consul for the province of Cádiz. Reception and dinner with the commander, boatswain and chief scientists.

Tuesday 17.05.2005

Meteo: Clear weather with a gentle breeze of 6-7 beaufort, weakening to 3-4 beaufort. In the afternoon, a gentle swell (1-1.5m) was present in the study area.

08:30 Final briefing with Jean-Pierre Henriet, who will not participate in the campaign. Departure of R/V Belgica from the Cádiz harbour towards Area A, offshore Larache.
09:00 Safety briefing by LDV Jean-Pol George
15:30 Slowing down of vessel to obtain a stable position. Science meeting in the wardroom with a briefing of the scientific objectives, study areas and schedules. This meeting was attended by all scientists, the CO and XO of R/V Belgica
16:00 Final approach to study Area A, switching from diesel to electric propulsion
16:30 Sparker and streamer in the water and testing of equipment on test line. Problems with the streamer, which is lying to deep in the water. The problem was solved by removing water that entered the streamer cable.
16:58 Start of line C050501, heading 160° (av. speed 3 knots)
17:05 Problems with the acquisition (filtering). The pre-amplification and the bandpass-filter was turned off.
19:36 End of line C050501
20:13 Start of line C050502, heading 335° (av. speed 3 knots). The record length was increased to 1.8 s.
21:35 Small interruption due to radio emission
23:15 End of line C050502
23:33 Start of line C050503, heading 160° (av. speed 2.5 knots)

Wednesday 18.05.2005

Meteo: Clear, warm weather with 3-4 beaufort NE wind, increasing to 5-6. Gentle Atlantic swell.

03:08 End of line C050503
03:23 Start of line C050504, heading 345° (av. speed 3 knots)
06:42 End of line C050504
07:02 Start of line C050505, heading 160° (av. speed 3 knots)
08:30 Seatec deep-sea cable was connected to the A-frame wheel and further testing of the video equipment.
10:10 End of line C050505
10:31 Start of line C050506, heading 296° (av. speed 2.73 knots)
10:40 Ship out of course, restart line C050506
10:48 Second start of line C050506, heading 340° (av. speed 3 knots)
14:08 End of line C050506
14:31 Start of line C050507, heading 160° (av. speed 3 knots)
17:40 End of line C050507, end of SSE-NNW lines, preparing for ENE-WSW lines
18:05 Start of line C050508, heading 247° (av. speed 3.1 knots)
19:13 End of line C050508
19:33 Start of line C050509, heading 65° (av. speed 2.9 knots)

20:03 Delph system stopped recording line C050509, start of a new line C050509b, same heading and speed.
20:53 End of line C050509b
21:15 Start of line C050510, heading 257° (av. speed 3.5 knots)
22:11 End of line C050510
22:38 Start of line C050511, heading 66° (av. speed 2.6 knots)

Thursday 19.05.2005

Meteo: Clear, warm weather with 5-6 beaufort NE wind, decreasing to 5 in the afternoon. Gentle Atlantic swell.

00:12 End of line C050511
00:35 Start of line C050512, heading 249° (av. speed 3 knots)
01:52 End of line C050512
02:25 Start of line C050513, heading 67° (av. speed 1.8 knots)
04:41 End of line C050513
04:56 Start of line C050514, heading 250° (av. speed 3 knots)
06:21 End of line C050514
06:33 Start of line C050515, heading 68° (av. speed 2.6 knots)
08:12 End of line C050515
08:29 Start of line C050516, heading 248° (av. speed 4.5 knots)
09:19 End of line C050516
09:35 Start of line C050517, heading 70° (av. speed 2.4 knots)
11:07 End of line C050517, clipping of sparker electrodes
11:18 Start of line C050518, heading 245° (av. speed 4.5 knots)
12:10 End of line C050518
12:21 Start of line C050519, heading 70° (av. speed 3 knots)
13:30 End of line C050519
13:35 Start of line C050520, heading 248° (av. speed 3 knots)
15:05 End of line C050520, switch from electric to diesel propulsion, transit to additional lines at the SE limit of area A
16:26 Switch from diesel to electric propulsion, start of line C050521, heading 180° (av. speed 3 knots)
16:56 Passing over proposed IODP drill site MOMA-04A
17:55 End of line C050521
17:57 Start of line C050522, heading 243° (av. speed 3 knots)
18:49 End of line C050522
18:50 Start of line C050523, heading 310° (av. speed 3 knots)
20:43 Passing over proposed IODP drill site MOMA-03A
21:03 End of line C050523, clipping of sparker electrodes

21:21 Start of line C050524, heading 115° (av. speed 3 knots)

Friday 20.05.2005

Meteo: Clear but slightly clouded, warm weather with 4 beaufort NE wind, decreasing towards the afternoon. Gentle Atlantic swell.

01:32 End of line C050524
01:50 Start of line C050525, heading 296° (av. speed 3.3 knots)
03:00 End of line C050525
03:02 Start of line C050526, heading 330° (av. speed 2.8 knots)
06:12 End of line C050526
06:14 Start of line C050527, heading 250° (av. speed 3 knots)
07:11 End of line C050527, end of seismic survey and transit towards Vernadsky 1 site for video survey (propulsion remains electric)
08:00 Begin of video operations C0505video1, Belgica stays stationary on site. Moving frame and winch cable to the A-frame.
09:00 Connection frame and cables. Technical problems were met in the remote winch control, solved by the ships electrician.
09:45 Water depth of the site is 600 m, inspector cable of 4 m is installed under the frame
09:52 Winching down video frame to a depth of 500 m. Software displaying CTD data, altimeter and navigation data works properly, except altimeter reading look doubtful
10:19 Sea floor is reached, first observations yield a flat, bioturbated muddy sea floor with sporadic clasts and some small fish
10:30 Image breaks down, although CTD and altimeter work, winching up to safe depth of 500 m, advancing ship 0.5 nm up track
10:51 Second video survey site is reached, winching down video frame
10:57 Sea floor is reached; muddy sea floor, some clasts, possibly isolated dead corals, shrimps, “whipped” corals, anemones…
11:20 Sea floor is gently touched, camera malfunctioning
11:34 Winching up video frame for inspection
12:50 In attention for the results of the video inspection, a small seismic network will be surveyed over the Vernadsky Ridge. Start of line C050528, heading 70° (av. speed 3 knots)
13:43 End of line C050528
13:54 Start of line C050529, heading 250° (av. speed 3.2 knots)
14:42 End of line C050529
14:54 Start of line C050530, heading 70° (av. speed 3 knots)
15:15 Cameras of the video frame are functioning, although salt water is found into the connection bottle, damaging some electronic devices. A possible intrusion source can

be the entry of the deep-sea streamer. Reparations will be carried out to get the video frame operational by 0900h

15:51 End of line C050530
16:05 Start of line C050531, heading 250° (av. speed 3.1 knots)
17:05 End of line C050531
17:15 Start of line C050532, heading 69° (av. speed 3 knots)
18:34 End of line C050532
18:49 Start of line C050533, heading 250° (av. speed 3 knots)
20:47 End of line C050533
20:58 Start of line C050534, heading 70° (av. speed 2.9 knots)
22:00 First (radio)contact with R/V Pelagia
22:44 End of line C050534, trimming sparker electrodes
22:58 Start of line C050535, heading 333° (av. speed 3.3 knots)
23:23 End of line C050535
23:31 Start of line C050536, heading 150° (av. speed 4 knots)

Saturday 21.05.2005

Meteo: Clear but slightly clouded, warm weather with 3-4 beaufort slight NE wind, increasing to 5 in the afternoon. Gentle Atlantic swell.

00:04 End of line C050536
00:15 Start of line C050537, heading 336° (av. speed 2.8 knots)
01:47 End of line C050537
02:02 Start of line C050538, heading 157° (av. speed 3 knots)
03:35 End of line C050538
03:48 Start of line C050539, heading 330° (av. speed 3 knots)
05:20 End of line C050539
05:35 Start of line C050540, heading 155° (av. speed 3.5 knots)
06:58 End of line C050540
07:13 Start of line C050541, heading 340° (av. speed 3 knots)
08:30 Radio contact with Dr. Henk de Haas, chief scientist on board R/V Pelagia, discussing schedule for upcoming days, organisation of 2-ship experiment and transfer of scientific personnel
08:46 End of line C050541, temporary end of seismic survey
08:49 Preparation for test of the deeptow bottle to ensure it is waterproof
08:56 Empty video frame is put in the water, winching down to 500 m
09:10 500 m depth reached, winching up
09:25 Video frame on board, start of new seismic survey
09:32 Streamer is too deep in the water, venting
09:38 Start of line C050542, heading 155° (av. speed 3 knots)

10:05 Still water is found in the bottle, further tests will be scheduled to make it waterproof
11:12 End of line C050542, preparation for second test of the bottle
11:17 Video frame in the water (depth 620 m), winching down
11:32 500 m in the water, winching up
11:37 Video frame on board, heading for new seismic profile track
12:05 Start of line C050543, heading 335° (av. speed 3.5 knots)
12:10 Bottle was checked and proven waterproof, preparation for new video dive on Vernadsky Ridge
12:43 End of line C050543
12:56 Start of line C050544, heading 160° (av. speed 3.5 knots)
13:27 End of line C050544
13:35 Final test of the cameras prior to the dive; too much noise on the imagery, restoring pan & tilt function (which has been eliminated earlier on the day)
13:41 Start of line C050545, heading 336° (av. speed 3.0 knots)
14:42 End of line C050545
14:45 Start of line C050546, heading 70° (av. speed 3 knots)
16:35 End of line C050546
16:39 Start of line C050547, heading 155° (av. speed 3 knots)
17:57 End of line C050547
18:00 Start of line C050548, heading 245° (av. speed 3 knots)
19:00 Video imagery works; stand-by for suitable weather conditions (5 beaufort)
20:00 End of line C050548
20:20 Start of line C050549, heading 68° (av. speed 3.1 knots)
21:07 End of line C050549
21:24 Start of line C050550, heading 245° (av. speed 3.5 knots)
22:07 End of line C050550
22:17 Start of line C050551, heading 66° (av. speed 4 knots)
22:54 End of line C050551
22:56 Start of line C050552, heading 165° (av. speed 4 knots)
23:18 End of line C050552, clipping of sparker electrodes
23:27 Start of line C050553, heading 335° (av. speed 2.8 knots)
24:00 End of line C050553

Sunday 22.05.2005

Meteo: Clear but slightly clouded, gentle weather with 5-6 beaufort NE wind. Moderate Atlantic swell. In the afternoon, very clear and warm weather with 4 beaufort wind.

00:08 Start of line C050554, heading 155° (av. speed 4.6 knots)
00:30 End of line C050554
00:37 Start of line C050555, heading 335° (av. speed 2.9 knots)

01:25 End of line C050555

01:32 Start of line C050556, heading 165° (av. speed 3.5 knots)

02:10 End of line C050556

02:18 Start of line C050557, heading 330° (av. speed 2.2 knots)

03:06 End of line C050557

03:11 Start of line C050558, heading 70° (av. speed 3 knots)

04:50 End of line C050558

04:52 Start of line C050559, heading 160° (av. speed 3 knots)

05:02 End of line C050559

05:08 Start of line C050560, heading 250° (av. speed 3 knots)

06:00 End of line C050560, end of seismic survey, transit to site MOMA-04A, electric propulsion remains active

08:00 Rendez-vous with R/V Pelagia, which has come alongside. Zodiac malfunctioning and due to difference in ship-time (Belgica B-time, Pelagia Lissabon time), the transfer is postponed to 0900.

09:00 Transfer of Anneleen Foubert, Veerle Huvenne, Henk de Haas (chief scientist Pelagia) and first officer of the Pelagia

10:00 Scientific meeting discussing practical issues of 2 ship experiment. Further communication involving time between Belgica and Pelagia will happen in GMT-time

12:30 Radio trigger link is confirmed (over a distance 3.8 nm), preparations start on board of R/V Pelagia (set-up seismic source en trigger)

14:46 Streamer of the Belgica are in the water, also the sleeve guns and streamer of the Pelagia (distance 1.6 nm)

14:52 Positioning problem of Pelagia and test shots (frequency 12 sec)

15:02 Start experiment over site MOMA-04 (heading 114°, av. speed 2 knots COG), passage ships on 35°17,384N and 6°39,250'W (position Belgica, offset with Pelagia is approximately 200 meters)

15:56 Loss of trigger contact, distance between Belgica and Pelagia is 2.3 nm. Streamer is put on deck, switch to diesel propulsion for transit to site MOMA-03A

17:10 Switch to electric propulsion, positioning for second experiment

17:13 Streamer in water, navigating to centre point MOMA-03A, shot frequency Pelagia every 9 sec

17:28 Difference in heading Pelagia and Belgica, adjustment course.

17:36 Start experiment over site MOMA-03A (heading 116°, av. speed 2 knots COG), passage ships on 35°16,211N and 6°47,566'W (position Belgica, offset with Pelagia is approximately 200 meters)

18:20 Stop of experiment at a distance of 2.73 nm between both ships. Streamer is put on deck, course is set for Area B at slow speed (due to BBQ on front deck)

21:00 Start full transit to Area B on diesel propulsion

22:37 Start of multibeam calibration line, heading 223° (av. speed 6 knots)

23:15 End of multibeam calibration line

23:19 Start of multibeam calibration line, heading 36° (av. speed 6 knots)

Monday 23.05.2005

Meteo: Clear and warm weather with 4-5 beaufort NE wind. Moderate Atlantic swell.

00:23 End of calibration lines, start of multibeam line heading 142° (av. speed 6 knots)

01:18 Start of multibeam line heading 270° (av. speed 6 knots)

03:13 Start of multibeam line heading 90° (av. speed 8 knots)

04:56 Start of multibeam line heading 270° (av. speed 6 knots)

06:47 Start of multibeam line heading 90° (av. speed 8 knots)

08:37 Start of multibeam line heading 270° (av. speed 6 knots)

08:42 Short electric black-out of R/V Belgica, restart logging system, making loop to restart new line

09:05 Restart of multibeam line heading 270° (av. speed 6 knots)

10:45 Start of multibeam line heading 90° (av. speed 8 knots)

12:34 Start of multibeam line heading 270° (av. speed 6 knots)

14:21 Start of multibeam line heading 90° (av. speed 8 knots)

15:47 Start of multibeam line heading 270° (av. speed 6 knots)

17:29 Start of multibeam line heading 90° (av. speed 8 knots)

18:07 Start of multibeam line heading 270° (av. speed 6 knots)

18:30 End of multibeam survey for CTD sampling with video frame and backup of acquired data

18:45 Malfunctioning of multibeam retraction into the vessel

19:05 Multibeam restored. Start transit towards CTD point

19:31 Arrival on CTD point 35°02,8552 N 7°05,8393 W

19:41 Tests cameras successful, video frame is put overboard

20:10 885 m water depth is reached, winching up

20:41 Video frame is back on board

20:45 Start transit towards start point of simultaneous multibeam/seismic survey

21:27 Arrival on start point, switch from diesel to electric propulsion. Multibeam is launched

21:30 Seismic equipment is put in the water, acquisition problems

21:37 Start of multibeam line heading 20°

21:40 Start of line C050561, heading 30° (av. speed 2.8 knots)

23:35 End of line C050561

23:42 Start of line C050562, heading 122° (av. speed 3.2 knots)

Tuesday 24.05.2005

Meteo: Clear and warm weather with 3-4 beaufort NE wind, decreasing to 1-2 beaufort in the afternoon. Gentle Atlantic swell.

00:00 Start of multibeam line heading 116°
00:43 End of multibeam line because the water depth is beyond the detection limit
01:12 Start of multibeam line heading 111°
01:55 End of line C050562
01:57 Start of line C050563, heading 226° (av. speed 3.7 knots)
02:02 End of line C050563
02:06 Start of line C050564, heading 286° (av. speed 3.3 knots)
02:26 End of line C050564
02:33 Start of line C050565, heading 30° (av. speed 2.9 knots)
02:35 Start of multibeam line heading 350°
03:07 End of line C050565
03:13 Start of multibeam line heading 275°, start of line C050566, heading 265° (av. speed 3 knots)
03:20 End of line C050566
03:26 Start of line C050567, heading 200° (av. speed 3.1 knots)
03:28 Start of multibeam line heading 200°
03:42 End of line C050567
03:49 Start of line C050568, heading 302° (av. speed 3.6 knots)
03:56 Start of multibeam line heading 306°
04:22 End of multibeam line due to bad quality
04:58 End of line C050568
05:07 Start of line C050569, heading 189° (av. speed 2.8 knots)
05:08 Start of multibeam line heading 34°
05:15 End of line C050569
05:19 Start of line C050570, heading 17° (av. speed 2.5 knots)
05:49 End of line C050570
05:51 Start of line C050571, heading 290° (av. speed 2.8 knots)
06:08 Start of multibeam line heading 304°
06:17 End of line C050571
06:28 Start of line C050572, heading 194° (av. speed 3.2 knots)
06:29 Start of multibeam line heading 185°
06:44 End of line C050572
06:47 Start of multibeam line heading 313°
06:55 Start of line C050573, heading 295° (av. speed 3 knots)
07:22 End of line C050573
07:25 Start of multibeam line heading 208°

07:26 Start of line C050574, heading 237° (av. speed 3 knots)
08:59 End of line C050574
09:14 Start of line C050575, heading 295° (av. speed 4 knots)
09:17 Start of multibeam line heading 225°
09:31 End of line C050575
09:39 Start of line C050576, heading 120° (av. speed 3.8 knots)
09:40 Start of multibeam line heading 45°
09:58 End of line C050576
10:06 Start of line C050577, heading 309° (av. speed 4 knots)
10:11 Start of multibeam line heading 225°
10:23 End of line C050577
10:29 Start of line C050578, heading 116° (av. speed 3.6 knots)
10:33 Start of multibeam line heading 45°
10:51 End of line C050578
10:57 Start of line C050579, heading 310° (av. speed 3.9 knots)
10:59 Start of multibeam line heading 225°
11:15 End of line C050579
11:21 End of simultaneous multibeam and seismic survey, switch to diesel propulsion for video survey on Meknes mud volcano
11:47 Positioning video dive point C0505video2, on the north flank of Meknes mud volcano
11:48 Winching down video frame
12:13 Seafloor is reached at 748 m water depth, gentle course south (0.5 knots)
13:43 End of C0505video2, winching up to 600 m water depth for transit to next site
15:27 Start of survey C0505video3, 2 nm north of Meknes M.V. in a small mounded area, winching frame down
15:32 Seafloor is reached at 808 m water depth, gentle course 90° (0.5 knots)
16:23 End of C0505video3, winching up to 600 m water depth for transit to next site
17:09 Start of survey C0505video4, 1.6 nm east of previous site on a dome-like feature
17:18 Seafloor is reached at 813 m water depth, gentle course 110° (0.5 knots)
18:00 End of C0505video4, winching up video frame
18:30 Video frame on deck, transit to simultaneous multibeam/seismic survey site (switch to electric propulsion).
19:05 Start of line C050580, heading 122° (av. speed 3 knots)
19:07 Start of multibeam line heading 110°
21:28 End of line C050580
21:37 Start of multibeam line heading 310°
21:33 Start of line C050581, heading 305° (av. speed 3.8 knots)
23:22 End of line C050581
23:27 Start of line C050582, heading 120° (av. speed 3.8 knots)
23:28 Start of multibeam line heading 110°

23:57 End of line C050582

Wednesday 25.05.2005

Meteo: Slightly clouded (clear in the afternoon) and warm weather with 3-4 beaufort NE wind. Smooth Atlantic swell.

00:06 Start of line C050583, heading 190° (av. speed 3.5 knots)
00:08 Start of multibeam line heading 180°
00:30 End of line C050583
00:38 Start of line C050584, heading 123° (av. speed 3.3 knots)
00:43 Start of multibeam line heading 110°
01:45 Start of multibeam line heading 90°
02:31 End of line C050584
02:34 Start of multibeam line heading 45°
02:35 Start of line C050585, heading 45° (av. speed 3.4 knots)
03:29 Start of multibeam line heading 220°
04:27 End of line C050585
04:29 Start of multibeam line heading 45°
04:31 Start of line C050586, heading 45° (av. speed 3 knots)
05:22 End of line C050586
05:29 Start of multibeam line heading 215°
05:31 Start of line C050587, heading 220° (av. speed 3 knots)
06:20 End of line C050587
06:29 Start of multibeam line heading 54°
06:31 Start of line C050588, heading 40° (av. speed 3 knots)
07:29 Start of multibeam line heading 221°
07:30 End of line C050588
07:31 Start of line C050589, heading 220° (av. speed 3.2 knots)
08:09 End of line C050589
08:13 End of multibeam survey
08:14 Start of line C050590, heading 0° (av. speed 4 knots)
09:01 End of line C050590, switch to diesel propulsion, transit to Area A
10:41 Arrival in Area A, site MOMA-04 for survey C0505video5 at a water depth of 656 m
10:45 Frame in the water
11:01 Seafloor is reached at 656 m
11:25 End of C0505video5, transit to next site with frame up to a water depth of 400 m
12:07 Start of survey C0505video6 at a water depth of 596 m, over sites MOMA-01 and 02
13:21 End of line C0505video6, transit to next site with frame winched up to 300 m
14:03 Start of survey C0505video7 at a water depth of 578 to 637 m, along the foot of the Pen Duick escarpment

15:00 Rendez-vous with R/V Pelagia, for transfer of radiolink material and visit by the commandant and Wim Versteeg

15:56 End of survey C0505video7, transit to next site with frame winched up to 400 m

16:31 Start of survey C0505video8 at a water depth of 633 m, in an area where previously recorded seismic profiles of this campaign suggested the presence of small mounds

16:55 End of survey C0505video8, transit to next site with frame winched up to 400 m

17:36 Start of survey C0505video9 at a water depth of 582 m, on the upper slope of Pen Duick escarpment

18:22 End of survey C0505video9, winching up the frame up to deck for long transit to Mercator mud volcano. During the winching up, the deepsea cable was cleant with fresh water

19:40 Start of survey C0505video10 at a water depth of 493 m on site MOMA-04, the lower flank of Mercator mud volcano

20:10 End of survey C0505video10. Wrong coordinates were given for this survey, correct coordinates were recalculated, and a course was set (frame up to 250 m) to the new survey point (35°17.7299'N and 6°39.0944'W).

20:41 Start of survey C0505video11 at a water depth of 416 m

21:00 End of survey C0505video11, transit to sites MOMA-01 and 02 for new seismic survey.

21:56 Start of line C050591, heading 318° (av. speed 4.4 knots)

22:34 End of line C050591

22:40 Start of line C050592, heading 102° (av. speed 3.4 knots)

22:53 End of line C050592

22:56 Start of line C050593, heading 217° (av. speed 4.4 knots)

23:09 End of line C050593

23:18 Start of line C050594, heading 45° (av. speed 4.0 knots)

23:44 End of line C050594

23:50 Start of line C050595, heading 336° (av. speed 3.9 knots)

Thursday 26.05.2005

Meteo: Slightly clouded (clear in the afternoon) and warm weather with 2-3 beaufort NE wind. No swell (at last).

00:23 End of line C050595

00:30 Start of line C050596, heading 69° (av. speed 4.4 knots)

01:53 End of line C050596

02:03 Start of line C050597, heading 250° (av. speed 4.0 knots)

02:55 End of line C050597

03:05 Start of line C050598, heading 69° (av. speed 4.2 knots)

03:52 End of line C050598

04:12 Start of line C050599, heading 146° (av. speed 3.4 knots)
04:40 End of line C050599
04:48 Start of line C0505100, heading 330° (av. speed 3.3 knots)
05:38 End of line C0505100
05:52 Start of line C0505101, heading 160° (av. speed 3.2 knots)
06:46 End of line C0505101
06:55 Start of line C0505102, heading 333° (av. speed 3.2 knots)
07:47 End of line C0505102, transit for first sampling site
08:00 Preparation for sampling with the Hamon grab
09:05 On station for sampling site 01
09:08 Technical problem, no cable length and tension on the deck control of the winch. The winch will be operated on deck by the boatswain, while the length and tension will be communicated by the chief scientist from the bridge
09:39 Sampling site 01
09:35 Hamon grab reaches sea floor (504 m bsl) at 35°26.056'N and 6°46.858'W
09:43 Hamon grab out of water, is not closed, second attempt after fine-tuning of sampling procedure
09:58 Hamon grab reaches sea floor (489 m bsl) at 35°26.066'N and 6°46.863'W
10:04 Hamon grab out of water, is not closed again, fine-tuning of trigger, third attempt of sampling procedure
10:17 Hamon grab reaches sea floor (499 m bsl) at 35°26.029'N and 6°46.877'W
10:24 **B05-1201-hg** on deck, successful sample, transit to sampling site 02
10:50 Hamon grab reaches sea floor (550 m bsl) at 35°24.537'N and 6°46.255'W
10:56 Hamon grab out of water, is not closed, second attempt
11:05 Hamon grab reaches sea floor (535 m bsl) at 35°24.607'N and 6°46.181'W
11:20 Hamon grab out of water, is not closed, sample **B05-1202-hg** has failed, transit to sampling site 03
12:09 Hamon grab reaches sea floor (610 m bsl) at 35°22.054'N and 6°51.688'W
11:20 Hamon grab out of water, is not closed, second attempt
12:25 Hamon grab reaches sea floor (600 m bsl) at 35°22.153'N and 6°51.460'W
12:32 Hamon grab out of water, is not closed, sample **B05-1203-hg** has failed. Sampling sites 04, 05, 07 and 13 are cancelled. Transit to site 06
13:22 Hamon grab reaches sea floor (570 m bsl) at 35°18.499'N and 6°48.084'W
13:29 Hamon grab out of water, is not closed, second attempt cannot proceed because R/V Pelagia is too close to the sampling point. Failure of **B05-1206-hg**. Transit to site 08
13:56 Hamon grab reaches sea floor (550 m bsl) at 35°18.922'N and 6°48.056'W
14:05 **B05-1208-hg** on deck, successful sample, transit to sampling site 09
14:42 Hamon grab reaches sea floor (546 m bsl) at 35°18.686'N and 6°47.917'W
14:51 **B05-1209-hg** on deck, successful sample, transit to sampling site 10
15:28 Hamon grab reaches sea floor (560 m bsl) at 35°17.776'N and 6°47.057'W

15:35 Hamon grab out of water, is not closed, second attempt
15:28 Hamon grab reaches sea floor (550 m bsl) at 35°17.818'N and 6°47.077'W
15:51 Hamon grab out of water, is not closed, sample **B05-1210-hg** has failed. Transit to site 11
16:22 Hamon grab reaches sea floor (550 m bsl) at 35°17.660'N and 6°47.200'W
16:31 **B05-1211-hg** on deck, successful sample, transit to sampling site 12
17:04 Hamon grab reaches sea floor (550 m bsl) at 35°17.528'N and 6°47.150'W
17:14 **B05-1212-hg** on deck, successful sample, transit to sampling site 14
18:37 Hamon grab reaches sea floor (295 m bsl) at 35°13.934'N and 6°33.567'W
18:44 Hamon grab out of water, is not closed, second attempt
18:46 Hamon grab reaches sea floor (280 m bsl) at 35°13.859'N and 6°33.456'W
18:52 **B05-1214-hg** on deck, successful sample, transit to sampling site 15
19:26 Hamon grab reaches sea floor (302 m bsl) at 35°14.500'N and 6°33.378'W
19:31 **B05-1215-hg** on deck, successful sample, transit to sampling site 16
20:18 Hamon grab reaches sea floor (410 m bsl) at 35°17.738'N and 6°39.187'W
20:25 Hamon grab out of water, is not closed, second attempt
20:29 Hamon grab reaches sea floor (414 m bsl) at 35°17.702'N and 6°39.182'W
20:36 **B05-1216-hg** on deck, successful sample, transit for seismic survey
21:34 Start of multibeam line heading 54°
21:38 Start of line C0505103, heading 50° (av. speed 4.5 knots)
22:10 End of line C0505103, start of line C0505104, heading 107° (av. speed 4.4 knots)
22:34 Start of multibeam line heading 14°
22:37 End of line C0505104
22:48 Start of line C0505105, heading 21° (av. speed 3.5 knots)

Friday 27.05.2005

Meteo: Clear and warm weather with 1-2 beaufort NE wind. No swell.

00:22 End of line C0505105
00:38 Start of line C0505106, heading 198° (av. speed 3.3 knots)
02:24 End of line C0505106
02:49 Start of line C0505107, heading 20° (av. speed 3 knots)
04:33 End of line C0505107 (fishing boat is lying on position)
05:12 Start of line C0505108, heading 100° (av. speed 3.1 knots)
05:34 Start of multibeam line heading 108°
06:04 Start of multibeam line heading 120°
06:37 End of line C0505108
06:39 End of multibeam survey
06:41 Start of line C0505109, heading 0° (av. speed 3.6 knots)

07:11 End of line C0505109, end of seismic survey, end of campaign. Start transit to Cádiz.

09:00 Breaking off set-up of seismic and video equipment. Cleaning of material (fresh water) and backing up all seismic and multibeam data

15:00 Arrival of R/V Belgica in Cádiz harbour

15:30 Packing off all equipment and stowing it away within the cargo area. Cleaning of the wetlab

16:30 All operations are finished, leave for the entire crew

19:00 Departure of Nele Gemoets

Saturday 28.05.2005

12:00 Cleaning of all rooms, departure of Ilham Bouimetarhan

14:00 Settling of shipboard accounts, inspection of all rooms and labs

15:00 Departure of entire shipboard scientific party

4.4 Geological investigations: preliminary results

The location of the morphologic features in the study area is indicated in figure 1.

4.4.1 Pen Duick escarpment & Renard Ridge

The first set of seismic lines consisted of 7 NW-SE and 13 SW-NE lines in a perpendicular grid over the Renard Ridge. Profiles C050501 to 07 image the depocentre S and N of the Renard ridge and the transition to the ridge, consisting of outcropping eroded acoustic basement. In the sediment drift deposits, some small normal faults are observed, associated to a change of subbottom slope (C050502, shotpoint 2000). At this location, slight acoustic attenuation is present, with small blanked discrete bodies of about 10 ms TWT in height (C050502, sp 2000-3300). These bodies are confined between distinct reflections and might represent small buried mounds, gas pockets or dewatering effects. Profile C050503 shows more blanking at the fault location, but less clear mounded bodies.

Profile C050504 (sp 1000-4300) demonstrate that the ridges have a complex structure. Also Gemini mud volcano (MV) is partly imaged again. In profile C050505 (sp 5000) a large mudflow west of the MV is visible. Profile C050506 images the MV body with stacked outflow lenses visible at sp 200. Profile C050508 to 20 provide crosslines to this grid and image the Gemini MV (C050508 & 09), the Pen Duick Escarpment (C050510 - 12) and further north over the Ridge (C050513 -20).

Additional lines over Gemini MV and PDE (Profiles C050591-94), Lazarillo de Tormes MV (C050595) were acquired during the last day of this campaign.

4.4.2 Additional profiles

The purpose of profiles C050521-23 is to establish a connection between existing profiles and the location of the proposed IODP 673-Pre Atlantic Mound Drilling II: Morocco Margin (MOMA) sites. The section displays continuous, parallel reflections and therefore will be very useful for correlation of previous grids. Profile C050524 makes a good connection between previous grids over Al Idrisi MV and Gemini MV. Profile C050525 and 26 make good connections towards the area west of Mercator MV. Profile C050527 is a short line near Adamastor MV.

Profile C050521 images the side of the Mercator mud volcano in a N-S direction, again displaying the H-event reflector (base of gas hydrate stability zone) and very clear mud flows at the sides. Further south small faults and enhanced reflections (C050522) are present.

4.4.3 Vernadsky Ridge, Kidd MV & Adamastor MV

Profiles C050528 to 60 record the structure of the Vernadsky ridge in a set of perpendicular seismic lines. Profiles C050528 to 34 run in a SW-NE direction over the Vernadsky Ridge. Profiles C050532 to 33 image the Kidd MV. Profiles C050535 to 45 were

acquired in a NW-SE orientation over the northern part of the Vernadsky ridge and also west of the ridge in order to provide connections with the grid over Renard Ridge. The seismic lines show a similar complex geometry as at the Renard Ridge site, with possible diapiric updoming, many diffractions, ... Profiles C050546 to 47 complete the northern grid.

A few miles southward, a perpendicular grid is covered over the Adamastor MV and the structure at the NE side of it, featuring a steep cliff. Adamastor MV displays stacked outflow lenses (e.g. C050549 and C050555), which will be useful for correlation with other mud volcanoes. Profile C050556 displays reflections in the mud volcano body, which are here thought to be sedimentary drapes deposited during times of no activity. Profile C050558 to 60 record the cliff structure.

Additional lines over Adamastor MV and Vernadsky Ridge (Profiles C050596-102) were acquired during the last day of this campaign.

4.4.4 Area B: Meknes MV

The seismic quality is lower than previous profiles due to a seastate 5. Multibeam acquisition is done at the same time. Profile C050561 images the Meknes MV and the area north of it. The small mounded features north of Meknes MV, are not well visible on the seismic data. The raw data does not reveal clear mud flow lenses around the mud volcano. Profile C050562 covers two ridge- or mound-like structures east of Meknes mud volcano. Profiles C050564 and 65 are perpendicular lines and reveal the ridge-like morphology, comparable to the ridges in area A. Several lines are shot over the structures in the north revealing a complex, faulted morphology. Profile C050574 is parallel to profile C050561, at its eastern side. Profiles C050575 and 79 are crosslines intended to reveal the 3D structure of the Meknes mud volcano.

After a day of video imaging, seismics, simultaneous with multibeam bathymetry, is continued in area B. Due to the very good weather, the seismic data is of excellent quality. Profiles C050580 and 81 run over the two mounded structures again, displaying two ridge-like anticlines, divided by a deep subsidence basin. Profile C050582 shows many mounded features north of one of the dome structures.

Profiles C050585 to 90 are shot in an NE-SW direction east of the easternmost dome since possibly interesting structures and alienations were observed on the multibeam bathymetry during calibration. Complex ridge structures and covering sedimentary units are imaged, featuring highly dynamic deposition systems with alternating deposition and erosion, overlying a widespread regional erosive unconformity. Profile C050591 crosscuts these lines for correlation purposes.

4.4.5 Area A: East of Al Idrisi MV

As a last part of the seismic survey, additional lines were acquired east of El Idrisi mud volcano in order to get a better understanding of the eastward propagation of the ridge

underneath the mud volcano (Profiles C0505103-109). Simultaneously, the area was covered with multibeam bathymetry.Unexpectedly, mounded features were observed in the area, above the faulted crest of the anticlinal ridge.

4.5 Sedimentological investigations

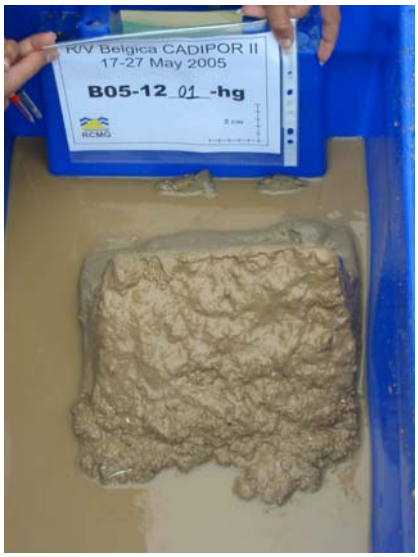
The sampled sites are shown on figures 5, 6 and 7. As mentioned in the operational report, some sampling sites were cancelled or the coring failed. Here, only the successful Hamon grab samples are shown. This campaign probably was the first time this tool was used in deep-water environments (Fig. 19). A comparison between the water depth on multibeam or sonar and the length of the cable when the grab hits the sea floor yields a minimal difference, suggesting the grab is heavy enough to descend straight to the sea floor and is not deviated by currents. Only the trigger of the grab is a sensitive point and was adapted to respond very quickly. For all safety, approximately 20 m cable extra was added after the seafloor was reached. After recovery, the bulk sample was photographed and described, respectively followed by sampling for microbiology, sedimentology and biology. A recapitulative list of grabs is given in table 2.

Figure 19: *Hamon grab operations on board R/V Belgica.*

Core number	***Latitude***	***Longitude***	***Water Depth***	***Recovery length/width***	***Remarks***
B05-1201-hg	35°26.029'N	6°46.877'W	499 m	47 / 30 cm	Top mud volcano
B05-1208-hg	35°18.922'N	6°48.056'W	550 m	40 / 24 cm	Top mound PDE
B05-1209-hg	35°18.686'N	6°47.917'W	546 m	28 /23 cm	Top mound PDE
B05-1211-hg	35°17.660'N	6°47.200'W	550 m	40 / 20 cm	MOMA-02A
B05-1212-hg	35°17.528'N	6°47.150'W	550 m	40 /20 cm	Between MOMA-01A and MOMA-02A
B05-1214-hg	35°13.859'N	6°33.456'W	280 m	35 / 21 cm	East of Al Idrisi
B05-1215-hg	35°14.500'N	6°33.378'W	302 m	44 / 22 cm	East of Al Idrisi
B05-1216-hg	35°17.702'N	6°39.182'W	414 m	Low recovery	Flank of Al Idrisi (seep site)

Table 2: *List of obtained Hamon grabs and relevant data*

4.5.1 B05-1201-hg (499 m bsl)



This first grab was taken on the top of a supposed mud volcano at the northwestern edge of the Vernadsky Ridge. The sediment is a brownish sandy, soupy clay with clasts (siltstone), a few coral fragments and biogenic fragment, scaphopods,…). Downwards, a transition towards greyish sandy to silty, compacter clays is visible.

Sedimentological subsamples consist of **1** bag with bulk sediment and **1** bag with clasts. For microbiology, **3** times 1.5 ml sample was fixed in 4% paraformaldehyde PBS, then washed in ethanol PBS and stored at -20°C. **1** 45 ml sample was stored directly at -20°C. **No** live or washed out biological samples were taken.

Hamon grab sample B05-1201-hg: *Washed out clasts from mud volcano*

4.5.2 B05-1208-hg (550 m bsl)

This sample was taken on the top of a mound on Pen Duick escarpment. The sediment is a brownish sandy to silty clay with a lot of coral fragments (abundant *Desmophyllum* fragments) and small biogenic fragments (spikes of echinoderms, gastropods, sponge spiculae,…).

Sedimentological subsamples consist of **1** bag with bulk sediment from the top layer and **1** bag of bulk sediment from the bottom layer. For microbiology, **3** times 1.5 ml sample was fixed in 4% paraformaldehyde PBS, then washed in ethanol PBS and stored at -20°C. **1** 45 ml sample was stored directly at -20°C. **2** bagged boxes with

washed out biological samples were taken, but **no** live biological samples.

4.5.3 B05-1209-hg (546 m bsl)

This sample was also taken on the top of a mound on Pen Duick escarpment. The upper 10 cm are dominated by brownish sandy clays with dead, partly oxidized coral fragments (*Lophelia pertusa, Madrepora oculata*) and smaller biogenic fragments (bivalve fragments, sponge spiculae, sea urchin needles). Transition to greyish, compact silty clay at 7 cm depth.

Sedimentological subsamples consist of **1** bag with bulk sediment from the top layer and **1** bag of bulk sediment from the bottom layer. For microbiology, **3** times 1.5 ml sample was fixed in 4% paraformaldehyde PBS, then washed in ethanol PBS and stored at -20°C. **1** 45 ml sample was stored directly at -20°C. **7** bagged boxes with washed out biological samples were taken, and **1** bucket with live biological samples, the latter fixed in 8% formaldehyde.

4.5.4 B05-1211-hg (550 m bsl)

This sample was targeted at the proposed IODP site MOMA-02A. The upper 2 cm consist of soupy, brownish, sandy clay with dead coral fragments going over in greyish sandy clays with dead coral and biogenic fragments.

Sedimentological subsamples consist of **1** bag with bulk sediment from the top layer, **1** bag of bulk sediment from the bottom layer and **1** small bag with washed clasts. For microbiology, **3** times 1.5 ml sample was fixed in 4% paraformaldehyde PBS, then washed in ethanol PBS and stored at -20°C. **1** 45 ml sample was stored directly at -20°C. **6** bagged boxes with washed out biological samples were taken, and **1** bucket with live biological samples, the latter fixed in 8% formaldehyde.

4.5.5 B05-1212-hg (550 m bsl)

This sample was taken between sites MOMA-01A and 02A on Pen Duick escarpment. Brownish, sandy clays are found over the entire length of the grab with a high amount of dead coral fragments (large solitary fragments of *Desmophyllum* up to a length of 7 cm) and biogenic fragments. Live soft corals were observed on the surface. Small oxidized nodules were present between the sandy clays.

Sedimentological subsamples consist of **1** bag with bulk sediment from the top layer and **1** bag of bulk sediment from the bottom layer. For microbiology, **3** times 1.5 ml sample was fixed in 4% paraformaldehyde PBS, then washed in ethanol PBS and stored at -20°C. **1** 45 ml sample was stored directly at -20°C. **6** bagged boxes with washed out biological samples were taken, and **1** bucket with live biological samples, the latter fixed in 8% formaldehyde.

4.5.6 B05-1214-hg (280 m bsl)

This sample is located east of Al Idrisi mud volcano, on small, mound-like features observed on CADIPOR 2 multibeam imagery. The upper 5 cm contain brownish, oxidized silty clays (finer material than observed in the other grabs) with a lot of dead coral fragments (mainly *Lophelia pertusa* and *Madrepora occulata*). Underneath this interval, greyish, silty, stiff clays are present with small coral fragments.

Sedimentological subsamples consist of **1** bag with bulk sediment from the top layer and **1** bag of bulk sediment from the bottom layer. For microbiology, **3** times 1.5 ml sample was fixed in 4% paraformaldehyde PBS, then washed in ethanol PBS and stored at -20°C. **1** 45 ml sample was stored directly at -20°C. **6** bagged boxes with washed out biological samples were taken, and **1** bucket with live biological samples, the latter fixed in 8% formaldehyde.

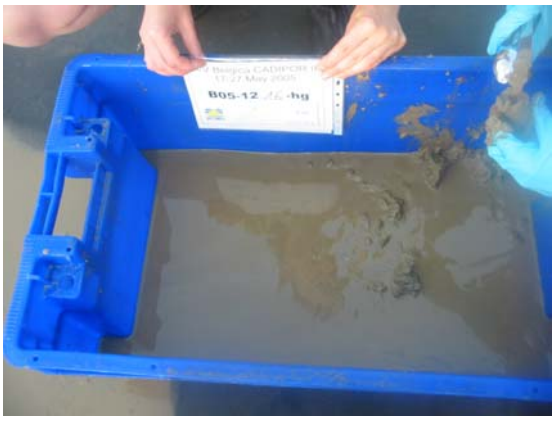
***Hamon grab sample B05-1214-hg**: dead coral fragment (Madrepora occulata)*

4.5.7 B05-1215-hg (302 m bsl)

As B05-1214-hg, this sample is located as well east of Al Idrisi mud volcano. The upper 4 cm contain brownish silty, soupy clay with a lot of dead coral fragments and other biogenic fragments (bivalves, gastropods, echinoderm fragments,...). Below, a greyish compact, silty clay is found with small coral fragments.

Sedimentological subsamples consist of **1** bag with bulk sediment from the top layer and **1** bag of bulk sediment from the bottom layer. For microbiology, **3** times 1.5 ml sample was fixed in 4% paraformaldehyde PBS, then washed in ethanol PBS and stored at -20°C. **1** 45 ml sample was stored directly at -20°C. **6** bagged boxes with washed out biological samples were taken, but **no** live biological samples.

4.5.8 B05-1216-hg (414 m bsl)



This last grab sample was targeted at the flank of Al Idrisi mud volcano, at the location of a supposed seepage site, as suggested by video imagery. The recovery was rather low and yielded very soupy brownish silt with some bivalve fragments.

Sedimentological subsamples only consist of **1** bag with bulk sediment from the top layer. For microbiology, **3** times 1.5 ml sample was fixed in 4% paraformaldehyde PBS, then washed in ethanol PBS and stored at -20°C. **1** 45 ml sample was stored directly at -20°C. **No** live or washed out biological samples were taken.

5. Data storage

During the Belgica 05/12 campaign, 109 seismic lines were acquired over approximately 1120 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). Multibeam data is backed up on DVD and tape : including both the 'raw' and 'proc' data folders.

11 video lines were acquired near Pen Duick escarpment and over the proposed IODP MOMA sites. This video data (inspector as navigator footage) is stored on mini-DV tapes. The geophysical and CTD data are stored at the RCMG on DVD, as well as some video extracts. For more information about the seismic, multibeam, video and sedimentological data, please contact

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