EUROFLEETS Cruise Summary Report

Cold-water coral ecosystems from the Moira Mounds (NE Atlantic): affinities and differences with modern and Pleistocene Mediterranean counterparts.

RV Belgica, Cruise No. 2012/16
EUROFLEETS – CWC Moira

June 2-7, 2012, Cork (Ireland) - Galway (Ireland)

Silvia Spezzaferri, Agostina Vertino and the E-CWC Moira cruise scientific party

2012

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1 Summary

The EUROFLEETS Belgica 2012/16 cruise (CWC-Moira cruise) was performed from the 2nd to the 7th of June 2012 in the Moira Mound (MM) area (Belgica Mound Province, NE Atlantic; Fig. 1.1) on board of the R/V Belgica. The goal of this cruise was to collect seafloor and seawater samples for a better understanding of the mechanisms triggering the nucleation of cold-water coral mounds. Moreover it was aimed to characterize NE Atlantic CWC bio-sedimentary facies in order to compare them with modern and fossil Mediterranean counterparts and to collect biological samples for taxonomic analysis and CWC mound biodiversity assessment.

The MMs surveyed and sampled during this cruise are small morphological structures (up to 50 m in diameter) colonized by cold-water corals. Due to the very small size of the mounds, sampling locations were selected on the basis of previously acquired georeferenced ROV videos (Wheeler et al 2011b).

During the CWC-Moira cruise a total of 35 box-cores were collected at mound and intermound locations in two main regions of the down-slope area *sensu* Wheeler et al. (2011). All samples were photographed, described and sieved on board and subsampled for further land-based taxonomic and sedimentological analyses. Moreover 18 CTD vertical profiles were performed along N-S and E-W transects (Fig. xxx), 26 seawater samples were collected for pH measurements and stable isotope analyses and, at one mound location ("Twin Mounds"; Fig. 1.2), a yo-yo CTD was carried out.

The bio-sedimentary facies observed in the collected box-corers can be grouped in three main categories: 1. Coral Frame and Coral Rubble (CF-CR); 2. Sand and Dropstones (SD); 3. Sand and Biogeinc Gravel (S-BG). The CF-CR facies group was generally found on the mound tops and in some cases included live frame-building scleractinians (*Madrepora oculata* and *Lophelia pertusa*) whereas both the SD and S-BG facies were mostly collected in the intermound areas. Interestingly, the coarse sandy surface of some samples (S-BG facies) showed micro ripples with wave length up to 3 cm. All exposed coral branches devoid of soft tissue were intensely colonised by a diverse epifauna (dominantly hydrozoans, sponges, octocorals, foraminifera and agglutinant polychaetes) and infesting endofauna. Epizoans were common also on dropstone surfaces but less diverse (mostly foraminiferans, hydrozoans and encrusting polychaetes) and more loosely distributed than on corals. It is worth remarking that the bioclastic gravel which characterizes the surface of almost all collected cores, both in the mound and intermound areas, is dominated by coral and echinoid fragments.

1.1 Working area: Moira Mounds

The Moira Mounds (MM) are small-scale mounded features located in the cold-water coral Belgica Mound Province on the eastern margin of the Porcupine Seabight (Fig. 1.1). Hundreds of these features occur in water depth between 900 and 1080 m (Huvenne et al., 2005; Foubert et al. 2011; Wheeler et al., 2011). They are clearly defined morphological structures, with slope gradients of about 15–20°, diameters up to 40-50 m and height up to 10 m. These mounds can be isolated or grouped in clusters or swarms (Kozachenko, 2005; Wheeler et al., 2005, 2011a).

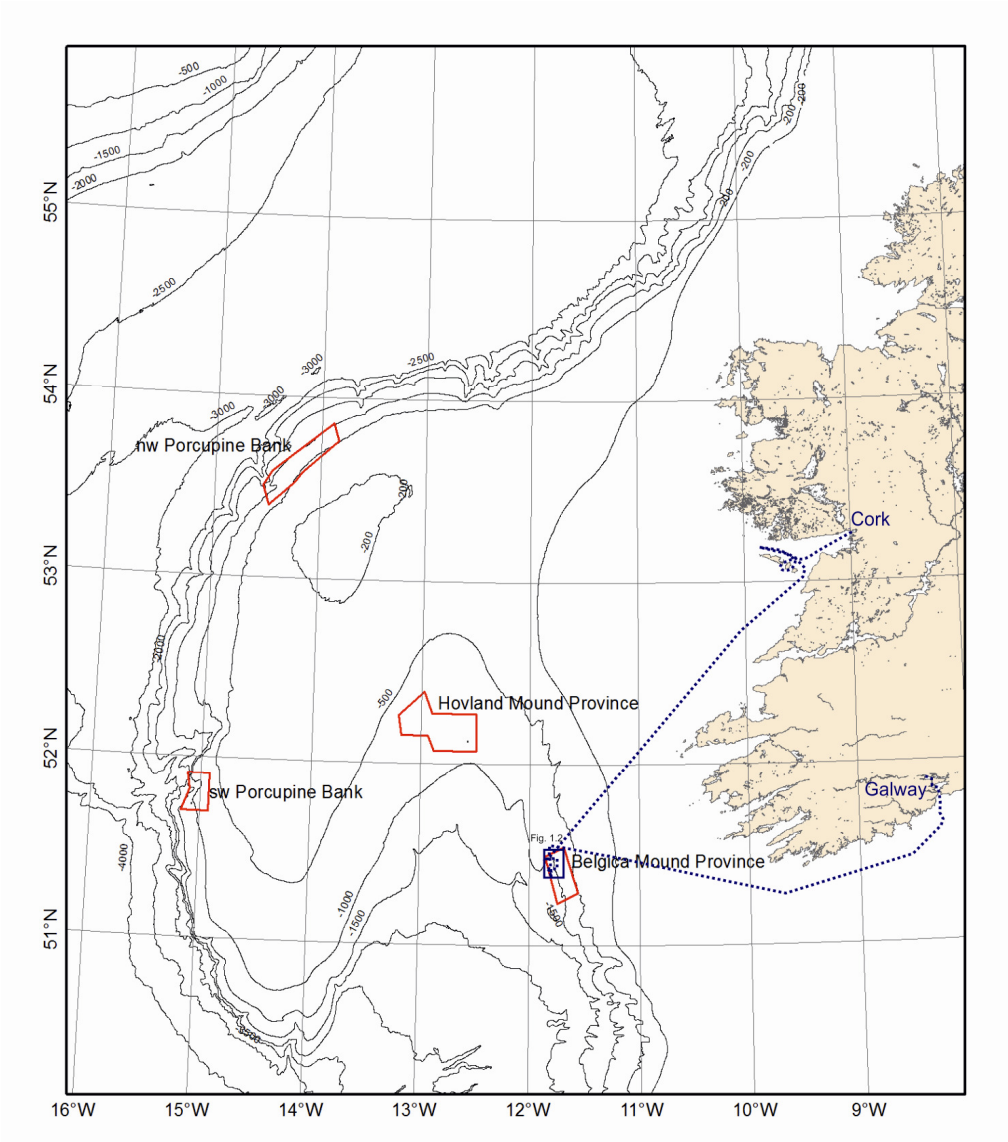

Fig. 1.1 Map of the Porcupine Seabight with location of the Belgica Mound Province where the small Moira Mounds occur. In red the Irish Special Areas of Conservation (SAC), in blue the working area (Fig. 1.2) and the position track of R/V BELGICA, Cruise 2012/16. Bathymetric contours are derived from the Irish National Seabed Survey Data © Geological Survey of Ireland.

The working area of the RV Belgica 2012/16 cruise is located in the Moira Mound mid- and down-slope regions described by Wheeler et al. (2011a) and includes part of the Belgica Province SAC (Special Area of Conservation) (Fig. 1.2).

On the basis of side-scan sonar imagery and georeferenced video (Wheeler et al, 2011a, b), two main areas were selected for box-coring (Figs 1.2). In “Area 1” the MM appear densely distributed and mostly N-S oriented whereas in “Area 2” they are more scattered and predominantly NNW-SSE oriented.

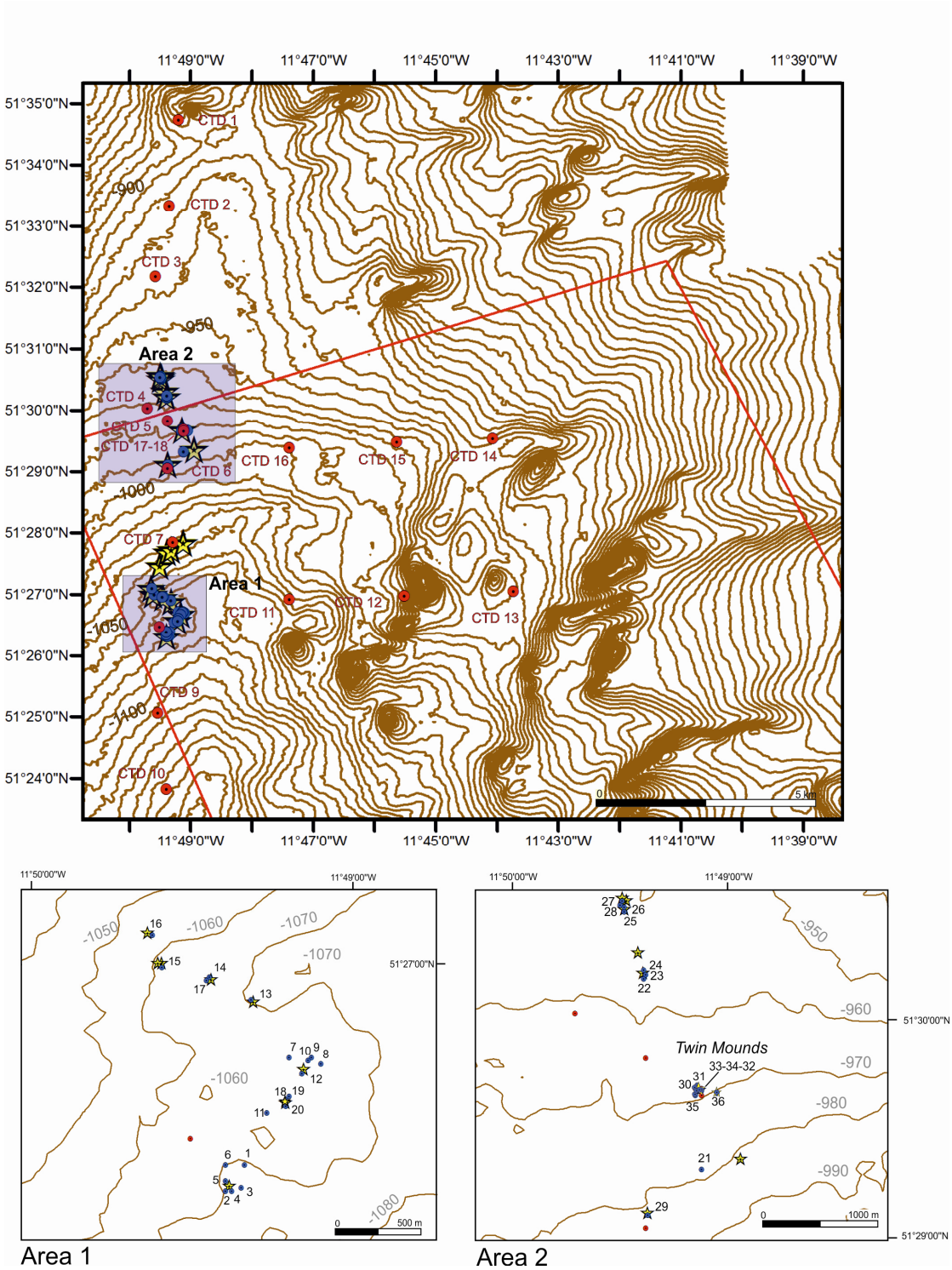

Fig. 1.2 Working area of R/V BELGICA, Cruise 2012/16, with location of CTD (red) and box-corer (blue) stations. Dashed red line: Irish Special Area of Conservation (SAC). Yellow stars: locations of the mound tops visualised during the VENTuRe cruise ROV survey (Wheeler et al. 2011b).

2 Research Programme and Objectives

In the last two decades the discovery of cold-water coral (CWC) ecosystems and mounds especially along the European Atlantic margins has added a new dimension to the concept of carbonate factories as a complementary counterpart to fossil and warm-water carbonate (Roberts *et al.*, 2006). The discovery of extensive provinces of giant and small carbonate mounds in the modern ocean fuels the interest towards comparative studies between recent and ancient analogues. It also opens new perspectives in our understanding of the diversity and variability of carbonate mound systems in the recent world as the key to unravel the diversity of mound settings, morphologies and characteristics in deeper time.

One of the fundamental questions about CWC mounds concerns the *driving forces* behind their start-up, growth and demise (Freiwald *et al.*, 2004). Nearly two decades of research on CWC mounds along the Irish margin have illustrated a dominant oceanographic control in the life cycle of these mounds (Dorschel *et al.*, 2005; Mienis *et al.*, 2007; Huvenne *et al.*, 2009; Thierens *et al.*, 2010). Life, growth and demise of scleractinian coral reef is controlled by a variability of physical, chemical and biological parameters (temperature, salinity, density, pressure, oxygen availability and currents, (Roberts *et al.*, 2006); nutrient supply and availability of fresh labile organic matter (Davies *et al.,* 2009). It is presently known that the CWC ecosystems are "hot-spots" for marine life and host many other organisms (such as e.g., foraminifera, scleratinian corals, sponges, hydrozoans, molluscs, bryozoans, echinoderms, polychaetes, crustaceans, fishes) with a biodiversity comparable to that of their warm water analogues (e.g., Fosså and Mortensen, 1998; Rogers, 1999; Fosså et al., 2000; Freiwald et al., 2004. Costello et al., 2005; Henry and Roberts, 2007; Neulinger et al., 2008; Schrötter et al., 2009; Margreth et al., 2009; Schoenfeld et al. 2011).

Nevertheless, several questions remain open regarding the initial nucleation of CWCs and their transition from open skeletal frameworks towards large mounds. Furthermore, still little is known about the role of the full spectrum of Biosphere actors in these processes as well as in their fossil counterparts.

Thanks to the FP7 Eurofleets programme we were able to bring together, in a sampling campaign, senior and junior scientists (including Master and Bachelor students) from the research fields of modern and ancient carbonate mound systems to answer the open questions related to CWC mound initial nucleation. The sampling activity was focused on the small-scale Moira Mounds because these morphological features (1) had been previously interpreted as possible early stage of giant coral mounds and (2) were already acoustically and video surveyed during previous cruises (Wheeler et al. 2011 a,b)

The main objectives of the cruise were:

- To collect seafloor and seawater samples to characterize the Moira Mound CWC habitats and, above all, their biomineralized benthic facies (BBF). These facies, formed by calcifying organisms, have the potential to fossilize and represent an important tool to study benthic community variations through time.

- To collect suitable seafloor samples (box-cores) to carry out a comparative study between NE Atlantic and Mediterranean CWC benthic habitats and facies.

- To increase our knowledge on CWC ecosystem biodiversity by performing taxonomic (genetic when possible) analysis of all collected organisms.

Last but not least, a central aim of the EUROFLEETS Belgica cruise No. 2012/16 cruise was to provide a practical ship-based training for young scientists and students. This goal was fully accomplished since 9 of the 15 members of the scientific crew were students (5 PhD's, 2 Master's, 2 Bachelor's) who enthusiastically and effectively participated in all activities carried out on board.

3 Narrative of the Cruise

(All times are given in UTC time. All coordinates in WGS84)

Saturday 2nd June, 2012
The RV Belgica left Cork at 6h30 in the morning. During the transit a science meeting was held to highlight the cruise goal and the sampling strategies. Specific tasks were shared out amongst the scientific team members; sub-teams were formed and day- and night- shifts defined.
Weather forecasts indicated relatively fair weather in the Porcupine Basin at least for the first 2 days. A worsening of weather conditions was expected for the third and fourth day.
The sampling sites (coral mounds) were located at about 150 nautical miles from Cork and the first site (51°34.8' N, 11° 49.0'W) was reached at around 21h30. CTD operations started at 22h10.

Sunday 3rd June, 2012
CTD operations lasted until 6h00: CTD casts were taken along a N-S transect (from 51°34.8'N, 11° 49.0'W to 51°23.8', 11°48.7'W) and water samples were collected as close as possible to the sea floor of five selected coral mounds.
USBL-guided box-coring started at 7h30 and proceeded all day long at water depth ranging from 950 and 1100 m. Weather conditions were still fair and the last box-core reached the deck at 19h52. In total the box-corer was deployed 10 times and only ones returned empty. Sampling was performed both on- and off- mounds collecting the following main facies: coral rubble, coral frames (including live slceractinians and gorgonians), sand and dropstones, sand and biogenic fragments. Rotating teams processed the samples continuously, following routine steps: describing, photographing, subsampling, sieving, storing.
CTD casts and water sampling started at 20h20 along a N-S transect (from 51°29.0'N, 11°49.4'W to 51°23.7'N, 11°49.5'W). Five sites were profiled and water samples per site were taken as close as possible to the seafloor.

Monday 4th June, 2012
CTD operations ended around 06h00. Weather conditions were still good and we transited to the next sampling site. USBL-guided box coring started at 07h12 and ended at 18h27. Ten box cores were successfully collected between 970 and 1064 water depth, both on- and off-mound: live and dead corals, sand and dropstones were sampled. Rotating teams processed the samples continuously following routine steps over all night.
After a short transit and since 19h26 the CTD was lowered in three locations along a E-W transect (from 51°26.9'N, 11°47.3'W to 51°27.0'N, 11°43.6'W). At each site water was sampled as close as possible to the seafloor.

Tuesday 5th June, 2012
CTD casts and water samples were taken from three locations along a E-W transect (from 51°29.5'N, 11°43.6'W to 51°29.3'N, 11°47.4'W) until 06h00.
After transit to the next station, box-coring started at 07h34 and continued till 18h53. Further ten box-cores were successfully collected at a water depth range of 930-980 m. Almost all cores contained coral fragments and some of them live colonial and solitary scleractinians. Samples were routinely processed by the scientific teams on shift.
At 19h30 water sampling started at a selected coral mound site: ten samples were collected along the water column, at intervals of around 100 meters, from the sea surface to the mound seafloor. Immediately after, yo-yo CTD started at the same location.

Wednesday 6th June, 2012
Yo-yo CTD ended around 6h00 and the ship transited to the next box-corer station. A problem with the ship's hydraulic system delayed box-coring operations which started at 09h00 and continued till 15h40. After the successful collection of six box-cores, due to incoming bad weather and upon suggestion of the Commander, the chief scientists decided to stop sampling operations in order to process and safely store all cores before worsening of meteorological conditions.
Transit to Galway commenced at 15h50.

Thursday 7th June, 2012
Weather conditions worsened rapidly during the morning. The ship took shelter in the lee of the Aran islands and the scientific team continued processing, analysing and storing the samples collected in the previous days.
The ship docked in Galway at around 19h10.

4 Preliminary Results

4.1 Computer logged navigational, oceanographic and meteorological data

(J. Backers, G. Gennari, L. Naudts, A. Savini, C. Stalder, A. Vertino)

4.1.1 Data Acquisition System

ODASIII data acquisition and processing system

A Hewlett Packard HP rx2660 workstation with 64 serial interfaces was used to acquire the meteorological, hydrological and navigational data at a 10 seconds interval.

All input devices are connected through RS232 type interfaces to the HP rx2660 Itanium computer. The data acquisition software collects the sensor data and delivers this raw data to the data processing software implemented on the same system. This real-time data processing software converts the raw data from the different input devices into physical units, performs quality control of the data and stores the data in an Informix relational database.

The data presentation software is based on a Client Server model. The oceanographic data in the Informix database on the UNIX workstation are obtained on a personal computer through a 10/100/1000 Mbps local area network. These personal computer presentation units are installed in the labs, in the computer room, in the cabins and on

the bridge and are accessible by all scientists on board for the production of real-time listings, graphs and track plots.

4.1.2 Navigation

Data from the following navigational instruments connected to the ship born computer system were logged by the Oceanographic Data Acquisition System "ODASIII" :

* Thales Navigation Aquarius LRK DGPS positioning system with an accuracy of 2 m in the working area.
* Furuno GP90 DGPS positioning system with an accuracy of ca. 3 m.
* Anshutz STD20 gyro compass.
* Consilium SAL 860T doppler speed log.
* Seatex MRU-5 motion sensor.
* Kongsberg EA400 scientific echosounder.

Bathymetric data from the Moira-mounds area were acquired using Kongsberg EA 400 multi-frequency (33, 38 and 220 KHz) single-beam echo-sounder (SBES), hull-mounted on the RV Belgica and integrated with Thales Aquarius-02 DGPS receiver. The EA400 was equipped with 3 transducers (33, 38 and 210 kHz); the 38 kHz transducer had a depth range of ca. 3000 m in good weather conditions. The data of the EA400 echosounder are corrected for the heave by the MRU-5.

Though focused navigation lines were not acquired, the low-frequency (33 and 38 kHz) EA400-transducers data logging was constantly active to check the location and the acoustic proprieties of the mounds during the sampling operations and CTD casts. The morphology of coral-mounds was indeed well imaged by low-frequency (33 and 38 kHz) EA400 SBES data, as shown in Fig. 4.1.1.

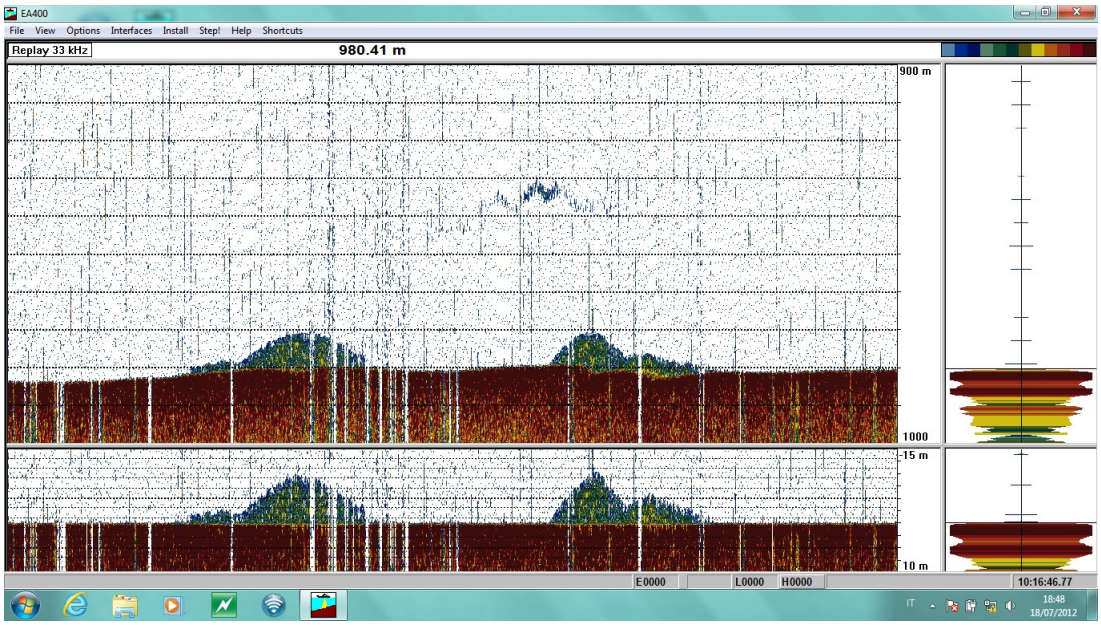

Fig. 4.1.1 Screenshot of the SIMRAD EA400 33kHz echosounder, illustrating the morphology and the associated acoustic signature of two coral-mounds from the Moira-mounds area.

4.1.3 Sea surface oceanographic measurements

The sea surface temperature was measured continuously with the remote temperature sensor of the Sea-Bird SBE21 thermosalinograph as well as with a Sea-Bird SBE38 temperature sensor, both installed at the inlet of the non-toxic seawater circuit which starts at the bow of the vessel. The Sea-Bird SBE21 thermosalinograph, installed in the wet lab, was also connected to the non-toxic seawater circuit. The salinity was measured continuously using a personal computer with a dedicated software package from Sea-Bird. The processed data were continuously (every 6 sec.) transmitted to the HP rx2660 data acquisition computer.

The Autonomous Underway Measurement System (AUMS) is installed on board the Belgica in 2011 and during this cruise it allowed the measurement of the following parameters:

Parameter	Trade	Model	Range + Units	Time interval
Turbidity	Endress+Hauser	2 * CUS41	0 – 2000 FTU	1 s
			0 – 10000 FTU	1 s
Turbidity	Campbell	OBS3+	0 – 4000 FTU	1 s
Oxygen	Aanderaa	3835 optode	0 – 30 mg/l	2 s
pH	Meinsberg	AGA 140	0 – 12 pH	1 s
Chlorophyll	TriOS	MicroFlu-chl	0 – 100 µg/l	1 s
Blue Algae	TriOS	MicroFlu-blue	0 – 100 µg/l	1 s
CDOM	TriOS	MicroFlu-CDOM	0 – 200 µg/l	1 s
Salinity	Sea-Bird	SBE45	0 – 40 PSU	1 s
pCO2	SubCtech	MK2	0 – 20000 µAtm	1 s
Fluorescence	Turner Designs	10AU	0 - 500	1 s
NO3,NH3,PO4,	Systea	3 * MicroMac1000	0 – 500 ppb	1 h
SiO2,			0 – 8000 ppb	
NO2			0 – 150 ppb	

Table 4.1.1 AUMS parameter specifications.

4.1.4 CTD vertical profiles

CTD vertical profiles were taken with the Sea-Bird SBE09*plus* CTD profiler integrated with the Sea-Bird carousel water sampling system SBE32. The specifications of this CTD profiling system are given in table 3.

Parameter	Units	Range	Accuracy (guaranteed)
Depth	m	0 → 3000	0.1 % of full scale range
Temperature	°C	-5 → +35	0.01 °C / 6 months
Conductivity	S/m	0 → 6	0.001 S / m / month
Dis. Oxygen	µmol/kg	0 → 600	5 µmol / kg / day
Backscatterance (OBS)	FTU	0 → 200	2.5 % of full scale range

Table 4.1.2 Sea-Bird SBE09*plus* specifications.

The Sea-Bird SBE09*plus* CTD system measured the depth of the sensor package (water temperature, conductivity, turbidity and dissolved oxygen) at a rate of 24 samples per second. This data was averaged in the Sea-Bird deck unit over a 0.5 sec. time interval and the Sea-Bird software (SeasaveV7) was used for the data presentation and post processing.

A total of 24 CTD vertical profiles was performed (Fig. 1.2; Tab. 7.1): 10 along a N-S transect, 6 along two E-W transects and 6 during a "yo-yo deployment" at one selected mound station ("Twin Mound A"). The yo-yo deployment consisted of continuous CTD lowering and raising for a c. 8 hours period to trace tidal fluctuations. The processed CTD profiles show a similar patterns though some differences can be highlighted. In each cast, it is evident an abrupt decline in temperature in the upper 100 m, from around 13°C (at the sea surface) to 11°C. Temperature slowly and continuously decreases between 100 and 500-600 m and more swiftly down to 950-1000 m where it reaches a value of around 9°C. Between 1000 and 1100 m an abrupt change abates the temperature below 8.5° C. Temperature and dissolved oxygen show a perfect inverse correlation in all examined profiles, all along the column water. The salinity trend is more variable than the temperature and oxygen ones in the 24 collected vertical profiles. Nevertheless, an abrupt salinity increase from the surface to around 50 m depth is common to all CTD casts. Below 100 m depth the salinity (presumably of the North Atlantic Central Water, NACW) shows a relatively uniform distribution down to a minimum value at around 700-800 m. However, between 400 and 500 m depth, the slope of the salinity curve declines in almost all profiles. Below 700-800 m the salinity starts rising, most probably due to the influence of the Mediterranean Outflow Water (MOW), reaching a peak between 1000 and 1050 m. At higher depths the PSU value drops again showing a high correlation with the abrupt temperature decrease. Interestingly, during the yo-yo deployment at the Twin Mound A (CTD 18), tide-controlled variations were detected in the measured parameters and particular evident in the salinity curve (Fig. 4.1.2).

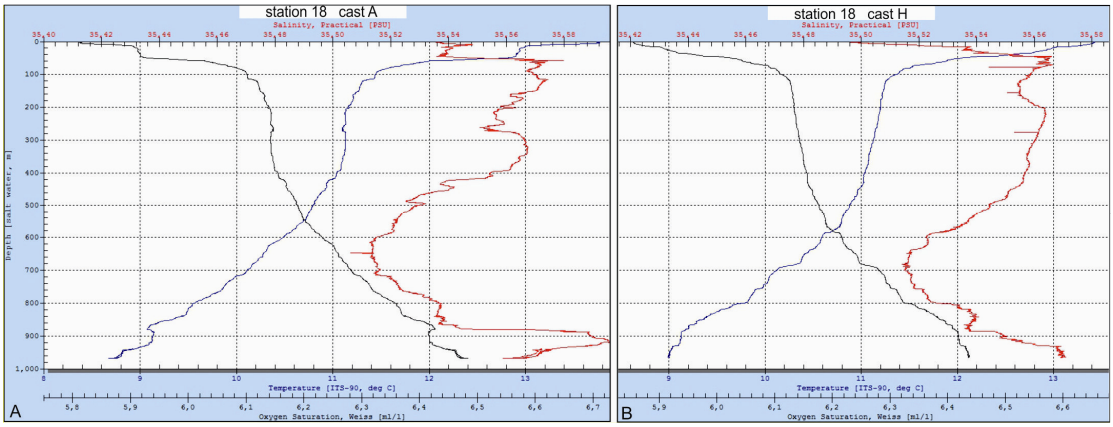

Fig. 4.1.2 CTD downcast profiles ("Twin Mound A", CTD 18 A, H).

4.1.5 Meteorological measurements

The following parameters were measured by the Friedrichs meteorological station :

- wind speed (2 sensors)
- wind direction (2 sensors)
- air temperature wet and dry
- atmospheric pressure (2 sensors)
- solar radiation (2 sensors)
- PAR

4.2 Seafloor Sampling (Box-coring)

(A. Vertino, S. Spezzaferri, A.M. Addamo, V. Baratti, G. Gennari, L. Naudts, A. Savini, and Shipboard Scientific Party)

For geo-biological studies 35 seafloor samples were collected both in on-mound and intermound sites by means of a NIOZ-type box-corer (Appendices 1, 2, 3; Fig. 4.2.1). Only one deployed box-corer (BC 09) returned empty due to operational problems.

4.2.1 Sampling and subsampling procedures

The sampling sites shown in Fig. 1.2 were selected on the basis of geo-referenced ROV video snapshots and video footage. Due to the small size of the mounds, precise subsea-positioning of the box-corer was determined by using a GAPS system. This Global Acoustic Positioning System is a portable Ultra Short Base Line (USBL) with integrated Inertial Navigation System (INS) and Global Positioning System (GPS). The GAPS was deployed from the starboard side using a temporary installed pole and a transponder was fixed on the box-corer frame (Fig. 4.2.2 A). During deployments, communication was maintained between the boatswain at the winch, the scientists at the GAPS acquisition system and the commanding officer on the bridge, the latter got a direct video feed to assure meter-scale positioning of the ship and the box-corer (Fig. 4.2.2 B). The box-corer was positioned at around 25 m above the seafloor until the

precise position was obtained and then immediately released to take the sediment samples.

Fig. 4.2.1 Box-corer recovery.

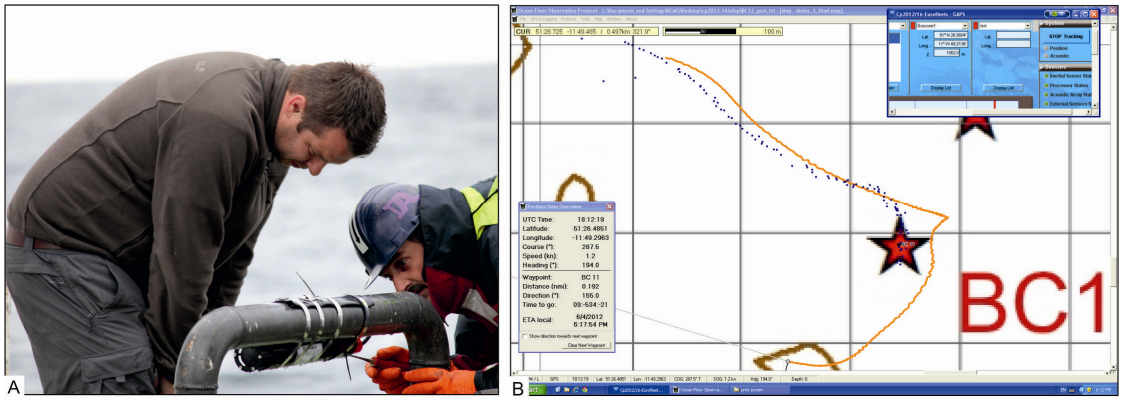

Fig. 4.2.2 A. Fixing the GAPS transponder on the box-corer frame. B. Screenshot showing the target site (red star), the ship track (orange line) and the GAPS signal (blue dots) during the box-corer deployment.

On recovery of the gear, the seawater was delicately drained out and the core surface was photographed and described (Fig. 4.2.3 A-B). Immediately after, subsampling was performed as follows:

<u>Macrofauna</u>

Epibenthic organisms were collected in order to study the coral associated fauna and perform molecular analysis. To ensure the DNA was kept in good condition, caught samples were stored in seawater (Fig. 4.2.3 C) in the cold room. Afterwards, representative specimens of each phylum/class/order were separately collected and

preserved in pure ethanol into falcon tubes. Some frames of corals with associated fauna were also entirely preserved in absolute ethanol.

Fig. 4.2.3 Procedure followed when the box-corer sample was on deck. A. Photographing the sediment surface. B. Describing. C. Collecting live macrofauna and immersing it in cold seawater (in the figure a dead coral frame colonised by live endo- and epifauna). D. Subsampling the box-core using 2 to 3 liners.

Microfauna (benthic foraminifera and ostracod assemblages)

Samples for microfauna were processed on board following the protocol established by the Foraminiferal Biomonitoring Working Group (FOBIMO) in June 2011 (Schoenfeld et al., in press.). The protocol includes: sampling from 0 to 1 cm below the sediment surface. Sample size determined by a tube with 8 cm inner diameter. A pure ethanol solution with Bengal Rose (2 grams per liter) was used as preservative. Samples will need a staining time of at least 14 days.

Paleontology and Sedimentology

At least two subcores of around 10 cm in diameter and 20 to 50 cm in length were collected for each box-core (Fig. 4.2.3 D) and stored in the cold room. They will be further processed (x-ray scanned, longitudinally cut, described and subsampled) in land-based laboratories. The rest of the core sediment was divided into three main portions (surface, medium and lower part) and sieved on board through 2 mm, 1 mm, 0.5 mm, 0.2 mm mesh sieves (Fig. 4.2.4 A-B) with exception of around 10% which was sieved through a 63µm mesh. Sieved samples were (1) dried in the drying oven at around 50-60°C, (2) sorted and preliminarily analysed by the naked eye and under the microscope and (3) labelled and stored in plastic boxes and bags.

Fig. 4.2.4 A. Sieving box-core samples. B. Sieved sediments in the wet laboratory.

4.2.2 Bio-Sedimentary Facies

On the surface of the 35 collected box-cores several biosedimentary facies were recognized. However, taking into account their prominent features, three main facies groups can be described as follows:

CORAL FRAME AND CORAL RUBBLE (CF-CR)

Area 1: BC 04, 5, 14, 18.
Area 2: BC 21, 22, 24, 25, 26, 27, 31, 32.

The CF-CR facies group is characterized by the dominance of frame-building corals (*Lophelia pertusa, Madrepora oculata, Desmophyllym dianthus*) and subordinate sandy to muddy sandy sediment(Appendix 1).
Exposed coral branches are mostly dead, bioeroded and variably stained with brownish Fe/Mn oxides. Coral skeletons may form very robust frames, dominated by the species *L. pertusa*, (BC 05, 14, 22, 26, 31, 32; Appendices 1-3) or appear as loose colonial fragments from few cm up to 15 cm long (BC 4, 21, 24, 25; Appendices 1-2). Dead scleractinian frames and fragments are locally colonised by live *Madrepora* (Fig. 4.2.5 A-B; E) and *Lophelia* (Fig. 4.2.5 B-D; G) coralla which, in the collected samples (BC 05, 18, 21, 22, 25, 26, 28, 31, 32, Appendices 1-3), do not exceed 15 cm in height and show much more slender branches than the fossil ones. Generally *Lophelia* corallites show the typical flared shape (Fig. 4.2.5 C), but in some samples may display a swollen aspect (Fig. 4.2.5 D) comparable to the one observed in specimens

from the neighbouring Galway Mound (Beuck et al, 2007). In some samples live solitary scleractinians, *D. dianthus* (Fig. 4.2.5 L; Appendices 1-3: BC 05, 25, 28, 31, 33) and *Caryophyllia sarsiae* (BC 05), were found associated to the colonial species. The tissue-barren scleractinian skeletons can be infested by abundant macro- and microscopic endo- and epizoans. The former consist mainly of boring sponges, polychaetes and the actinian *Fagesia* sp. (Fig. 4.2.6 A-B). Among the sessile epizoans diverse hydrozoans dominate (including rare and tiny colonies of the skeletonised species *Pliobothrus symmetricus*; Fig. Fig. 4.2.5 F-I), followed by foraminifera, sponges (Fig. 4.2.5 E; locally very common and large *Aprocallistes bocagei*), gorgonians (Fig. 4.2.5 M), actinians (Fig. 4.2.6 C), zoantharians, agglutinant polychaetes and serpulids, bryozoans (mostly Cyclostome erect colonies), bivalves (e.g., *Delectopecten vitreus*, *Chlamys sulcata*, *Asperarca nodulosa scabra*), brachiopods (*Terebratulina* sp., Fig. 4.2.6 A; *Neocrania anomala*), very tiny stalked crinoids (Fig. 4.2.6 D), echinoderms (*Psolus* sp.; Fig. 4.2.6 E), cirripedes (*Verruca stroemia*; Fig. 4.2.6 F). The vagile fauna of all samples is dominated by Ophiuroidea (Figs. 4.2.5 E; 4.2.6 G), rather common are also polychaetes (belonging to taxa that are typically associated with corals, e.g. *Eunice* sp. and *Lumbrineris*) and tiny gastropods such as *Amphissa acutecostata* (Fig. 4.2.6 H) and *Alvania cimicoides*.

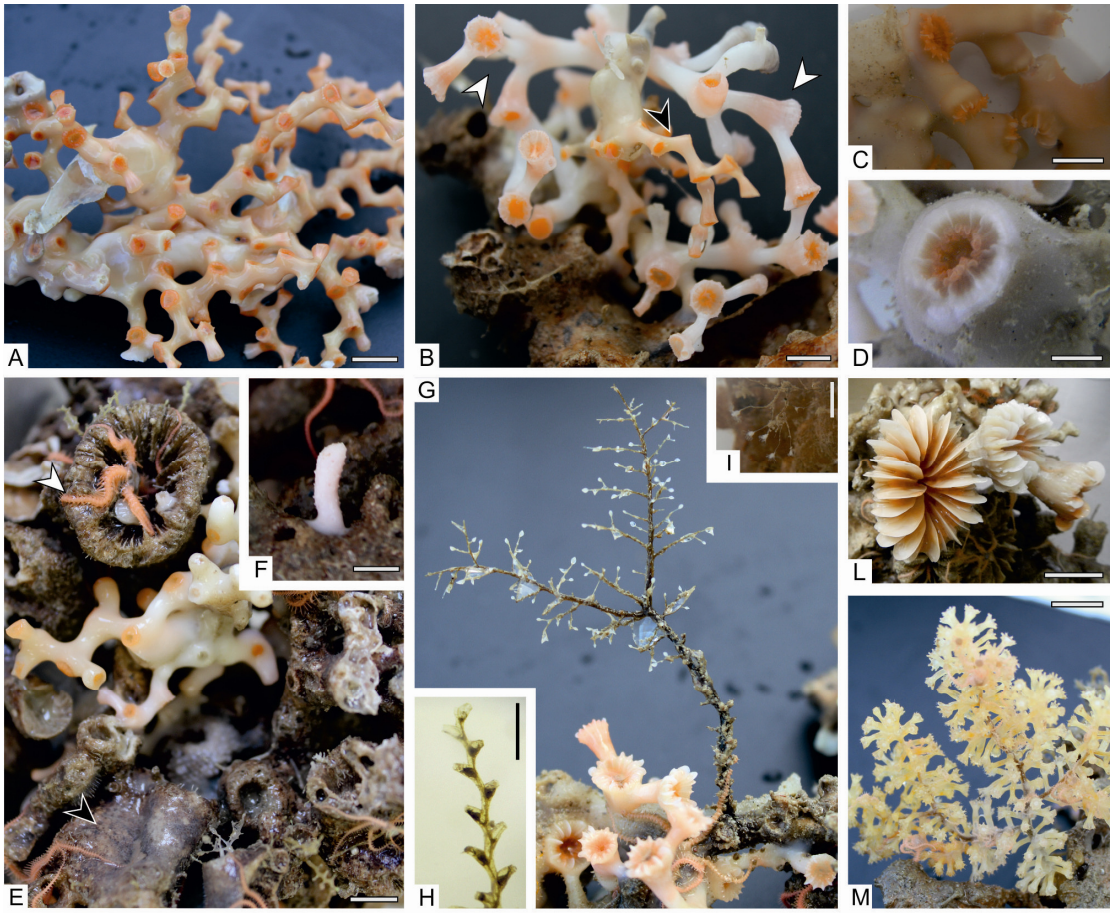

Fig. 4.2.5 A-M: Coral Rubble and Coral Frame Facies (CR-CF). A. Small colony of the frame-building scleractinian *Madrepora oculata*. B. Small colonies of the frame-building scleractinians *Lophelia pertusa* (white arrow) and *M. oculata* (black arrow). C-D: *Lophelia* corallites; flared (C) and swollen (D) morphotypes. E. Dead and black-coated scleractinian frame colonised by live epifauna; note a tiny *Madrepora* colony (in the centre), encrusting sponges (black arrow), hydroids, brachiopods, ophiuroids (white arrow). F-I: Hydrozoans; note a very small branch of the stylasterid *Pliobothrus symmetricus* (F) and a live *Lophelia* colony at the base of the hydroid colony figured in G. L: Live *Desmophyllum dianthus*. M: Tiny gorgonian colony. Scale bar: 2 cm (D, M); 1cm (A, B, C, E, F, G, I), 0.5 cm (H, L).

Remarkably, a large gastropod (*Calliostoma* sp.; Fig. 4.2.6 I), typical of Pleistocene cold-water coral outcrops from the Mediterranean, was found in sample BC 31.
The sandy to muddy sediment in between and within the coral branches is rich of a gravely bioclastic component produced by the accumulation of skeletonised organisms living on the coral branches and by the deposition of planktonic fauna, such as pteropods and foraminifera.

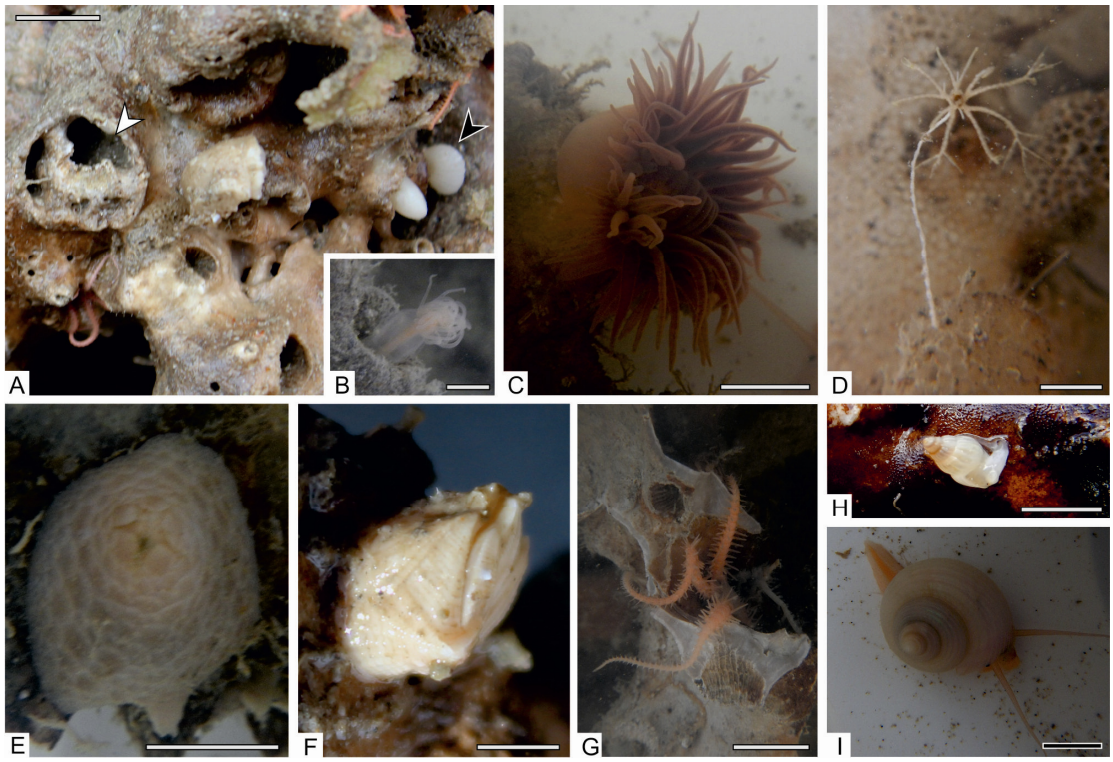

Fig. 4.2.6 A-I. Coral Rubble and Coral Frame Facies (CR-CF). A. Bioeroded and dark-coated coral frame showing cavities created by boring sponges (white arrow) and several epizoans among which the brachiopod *Terebratulina retusa* (black arrow). B. Boring actinian (*Fagesia* sp.). C: Actinian. D. Tiny stalked crinoid on the sponge *Aprocallistes bocagei*. E. Sessile echinoderm (*Psolus* sp.). F. The cirriped *Verruca stroemia*. G-I: Vagile fauna: an ophiuroid within a coral branch hole (G); the gastropods *Amphissa acutecostata* (H) and *Calliostoma* sp.. Scale bar: 1cm (A, E, F, G, I), 0.5 cm (B, C, D, H).

SAND AND DROPSTONES (SD)

Area 1: BC 01, 02 (transitional to BG); BC 06 (transitional to S); BC 07, 15, 19.
Area 2: BC 29, 30 (transitional to S); BC 35 (sandy mud); BC 36.

This facies group is characterized by sandy to muddy sandy sediments and heterometric dropstones (from 1-2 cm up to 13 cm in maximum diameter), from densely (Fig. 4.2.7 A-B) to loosely (Fig. 4.2.7 C) distributed on the soft sediment. Dropstones are mostly colonised by hydrozoans, agglutinant polychaetes, foraminifera and secondarily by bryozoans and rare chitons. On the surface of the sandy sediments mm- to cm-sized biogenic fragments are generally common and locally abundant, mostly characterized by cirriped and echinoid plates, gastropods, bivalves and dentaliids. In the mm fraction, *Madrepora* and *Lophelia* fragments, as well as echinoid spines, can be rather abundant. In some samples the muddy component has high percentage (BC 06) or is predominant (BC 35) and dropstones decrease in size and number (BC 02, 06, 35). In BC 02 the associated bioclastic gravel is particularly abundant and includes small (from mm to a couple of cm in length) and abraded fragments of scleractinian corals. Indeed, the samples BC 02 and BC 06 exhibit

intermediate features between the SD (Sand and Dropstone) and the S-BG (Sand and Biogenic Gravel) facies, respectively.

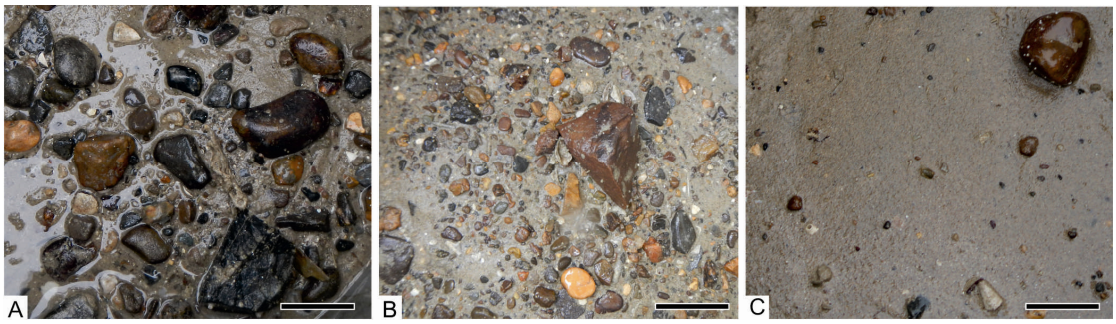

Fig. 4.2.7 A-C: Sand and Dropstone Facies (SD). From densely packed (A-B) to loose dropstones (C) on the sandy surface of box-core samples. Scale bar: 2 cm.

SAND AND BIOGENIC GRAVEL (S-BG)

Area 1: BC 08, 10, 16 (rippled sand); BC 11; 16 (transitional to CR); BC 17
Area 2: BC 23 (biogenic gravel); BC 28 (transitional to CR); BC 34

This facies group includes all samples whose surface is dominated by sandy to muddy-sandy sediment (Fig. 4.2.8 A-B) and/or by bioclastic gravel (Fig. 4.2.8 C-E). However, it comprises also samples showing transitional features, such as BC 16 and 28, to the coral rubble facies: rather large fragments of corals, in particular *Madrepora* branch fragments up to 15 cm in extension (Fig. 4.2.8 B). Interestingly, in "area 1", three samples (BC 08, 10, 16) dominated by coarse sand show evident micro ripple structures up to 3 cm in wave length (Fig. 4.2.8 A; Appendix 1). In particular, in BC 08 the sediment is well sorted and the gravely biogenic fraction appears to be aligned along a main direction. Instead, BC 17 and 34 do not show peculiar sedimentary features but biogenic gravel spread on the sediment surface. The mm-sized bioclastic fraction of the sediments belonging to the S-BG facies is normally dominated by echinoid spines and presents rather common *Cidaris* plates, benthic molluscs (typical of both hard and soft substrates), otolithes and coral fragments. Sample BC 23 differs from the other ones for its more abundant coarser bioclastic fraction (Fig. 4.2.8 C) which is mostly composed of coral fragments (from mm-sized to over 5 cm in size; (Fig. 4.2.8 D), cirriped plates, echinoderm plates/spines and molluscs (pteropods, benthic gastropods and bivalves).

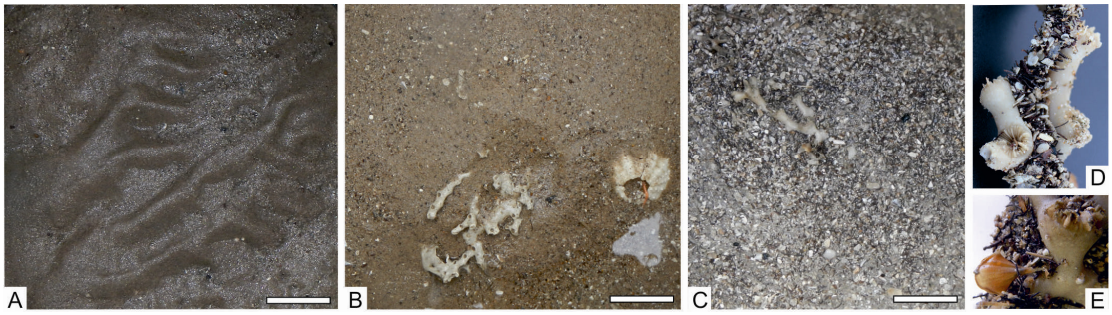

Fig. 4.2.8 A-E. Sand and Biogenic Gravel Facies (S-BG). A. Rippled sandy surface. B. Sandy surface with fragments of *Madrepora oculata* and an entire echinoid shell (transitional aspect between S-BG and CR (coral rubble) facies). C. Biogenic gravel facies. D-E. Details of C showing an agglutinant polychaete encrusting a dead *Lophelia* branch. Scale bar of A, B, C: 2 cm.

It is worth remarking that in this sample it was observed a peculiar agglutinant polychaete tube (Fig. 4.2.8 D), encrusting a large *Lophelia* fragment, made of all available carbonate fragments and black elongated elements of dubious origin (Fig. 4.2.8 E).

4.3 Seawater Sampling

(C. Stalder, G. Gennari, J. Backers and Shipboard Scientific Party)

During the cruise the CTD-rosette sampler (Fig. 4.2.9 A) was equipped with 12 (10 L) Niskin bottles. For each CTD cast, at least one Niskin bottle was fired for sampling bottom seawater. On the average samples were collected at 5 to 10 m above the seafloor. However at the station ECWC 48, corresponding to the top of the Moira "Twin Mound A" (Fig. 1.2), sampling was performed throughout the complete water column by firing Niskin bottles at a 100 m depth interval. Water samples for carbon and oxygen stable isotopes measurements were taken from Niskin bottles immediately after rosette arrival on deck (Fig. 4.2.9 BA). Samples were collected in 100 ml glass bottles minimizing gas exchange with atmosphere. Glass bottles were rinsed by overflowing with sample seawater three times. Seawater was then slowly poured in the glass vials with a flexible draining tube (Tygon tubing) reaching the bottom of the bottle. With a precision pipette a fixed amount (150 µl) of seawater was then removed from the glass bottles in order to inject properly the needed chemical ($HgCl_2$). About 200 µl $HgCl_2$ were added to poison the samples in order to prevent any further bacterial activity. The $HgCl_2$ reagent used during the cruise consisted of 50 ml MilliQ-H_2O and 3,7 g of mercury chloride and was stored in a low profile dispenser calibrated at 200 µl. Glass bottles were then sealed with airtight stoppers and crimps and stored at + 4°C for onshore analysis.

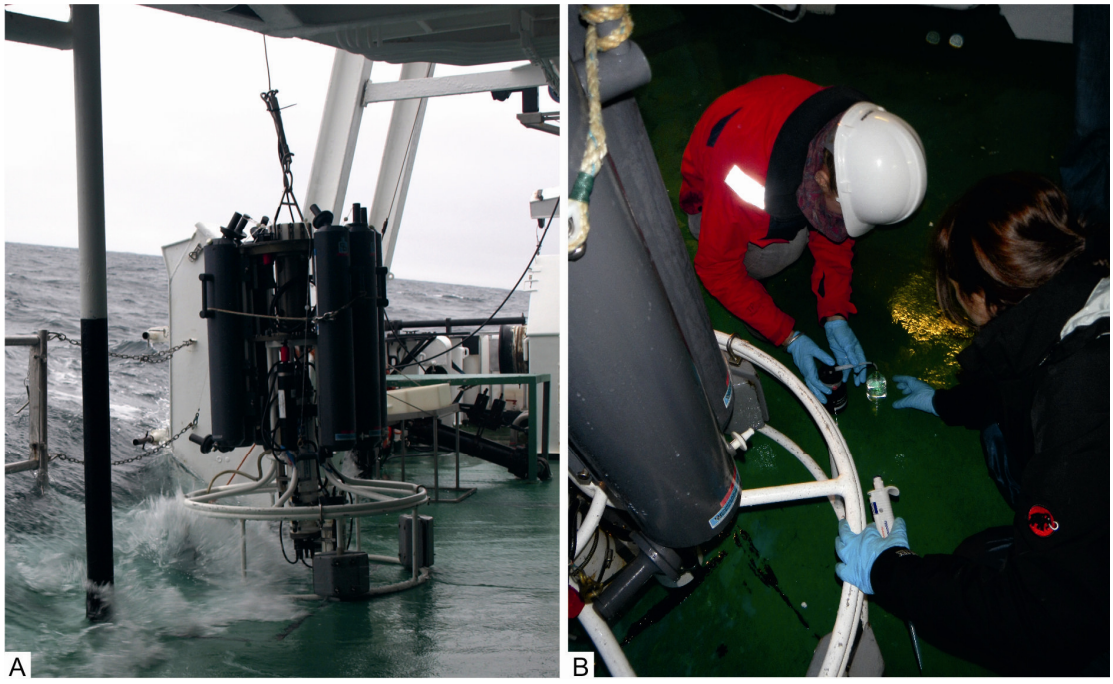

Fig. 4.2.9 A. CTD-Rosette sampler. B. Collecting seawater samples.

Water samples for pH were systematically collected for each CTD cast after the sampling of the stable isotopes samples. Samples were taken using 125 ml Nalgene

bottles and Tygon tubings. The Nalgene bottles and their caps were first rinsed with sample seawater. Then samples were collected and analysed onboard with an Ecoscan pH 5 (Eutech Instruments) pH-meter. This pH-meter was initially calibrated using two standardized buffer solution (pH 4 and pH 7). No water sample for pH was stored on board.

5 Data and Sample Storage / Availability

ODASIII continuous measurement data is stored at MUMM-OST, accessible by BMDC. Contact person : Joan Backers (Joan.Backers@mumm.ac.be)

The ship's station list and all metadata from sampling and shipboard observations are currently stored at the University of Milano-Bicocca and the University of Fribourg. For more information, contact Agostina Vertino (agostina.vertino@unimib.it) and Silvia Spezzaferri (silvia.spezzaferri@unifr.ch). This data, together with further scientific data retrieved from shore-based analyses, will be submitted to the PANGAEA database either upon publication or with password protection by the individual P.I.s as soon as the data is available and quality-assessed.
Molecular data will be deposited in globally accessible databases such as GenBank.

All sediment and faunal samples are currently stored at the University College of Cork, under the supervision of Dr. Andy Wheeler (co-proponent of the EUROFLEET CWC-Moira cruise programme). However we plan to distribute them among the following institutions for sedimentological and taxonomic analyses: University of Fribourg, Department of Geosciences, Fribourg, Switzerland; University of Milano-Bicocca, Milan, Italy; Museo Nacional Ciencias Naturales, Madrid, Spain; University of Catania, Catania, Italy; University, Heriot-Watt University, Edinburgh, United Kingdom.

Through the association with the ESF COCARDE-ERN research network (**www.esf.org/cocarde** or **www.cocarde.eu**), the data collected during this cruise will be object of multidisciplinary and international researches.

6 Participants

The 15 participants were from six European institutions (University of Fribourg Switzerland, University of Milano-Bicocca, Italy, University of Cork, Ireland, Museo Nacional Ciencias Naturales, Madrid, Spain University of Granada, Spain, MUMM, Belgium): five senior scientists, one Post-Doc scientist, five PhD students, two Master Students and two Bachelor students.

This cruise on the RV Belgica represented a unique opportunity for some Master and PhD students especially from Switzerland, a land locked country, to get in touch with the oceanographic research under a true ―*floating university* spirit. During the cruise, the students have learned how to acquire and process box-cores, multicores and CTD samples. The shifts during ship time have been organized to rotate the specific tasks for everyone. Therefore students had the opportunity to learn in turn the different sampling techniques. In particular, Osvaldo Camozzi will compile his Bachelor work on the cruise report and on the preliminary results.

No.	Name	Gender	Affiliation	On-board tasks
1	Silvia Spezzaferri	F	UF	Leading scientific activities
2	Agostina Vertino	F	UMB	Leading scientific activities
3	Anna Maria Addamo	F	MNCN	Collection and storage of live macrofauna
4	Joan Backers	M	MUMM	CTD deployment and data processing; Technical support
5	Valentina Baratti	F	UMB	Sediment and water sampling
6	Monica Constandache	F	UF	Sediment and water sampling
7	Osvaldo Camozzi	M	UF	Sediment and water sampling
8	Akram El KAteb	M	UF	Sediment and water sampling
9	Giordana Gennari	F	UG	Sediment and water sampling
10	Lea Leuzinger	F	UCC	Sediment and water sampling
11	Marian McGrath	F	UCC	Sediment and water sampling
12	Sarah Kate Mc Hugh	F	UCC	Sediment and water sampling
13	Lieven Naudts	M	MUMM	Sampling location (USBL); Technical support
14	Alessandra Savini	F	UMB	Hydroacoustic monitoring; Sediment and water sampling
15	Claudio Stalder	M	UF	Sediment and water sampling

Tab. 6.1 List of participants. UF: University of Fribourg, Department of Geosciences, Fribourg, Switzerland; UMB: University of Milano-Bicocca, Milan, Italy; UCC: University College Cork, Cork, Ireland; MNCN: Museo Nacional Ciencias Naturales, Madrid, Spain; UG: University of Granada, Granada, Spain; MUMM: Management Unit of the North Sea Mathematical Models, Oostende, Belgium.

7 Station List

Station No.	Date	Time	Latitude	Longitude	Water Depth	Gear	Remarks:
	2012	[UTC]	[°N]	[°W]	[m]		
E-CWC-1	6.02	22:43	51°34.73	11°49.20	919	ROS/CTD	CTD01: up and down cast; water sample close to the seafloor for pH measurement and $\delta^{18}O$ / $\delta^{13}C$ analysis
E-CWC-2	6.03	0:37	51°33.33	11°49.35	914	ROS/CTD	CTD02: up and down cast; water sample close to the seafloor for pH measurement and $\delta^{18}O$ / $\delta^{13}C$ analysis and $\delta^{18}O$ / $\delta^{13}C$ analysis
E-CWC-3	6.03	2:22	51°32.17	11°49.58	926	ROS/CTD	CTD03: up and down cast; water sample close to the seafloor for pH measurement and $\delta^{18}O$ / $\delta^{13}C$ analysis
E-CWC-4	6.03	4:16	51°30.03	11°49.71	936	ROS/CTD	CTD04: up and down cast; water sample close to the seafloor for pH measurement and $\delta^{18}O$ / $\delta^{13}C$ analysis
E-CWC-5	6.03	5:30	51°29.82	11°49.38	965	ROS/CTD	CTD05: up and down cast; water sample close to the seafloor for pH measurement and $\delta^{18}O$ / $\delta^{13}C$ analysis
E-CWC-6	6.03	7:56	51°26.38	11°49.34	1057	BC	BC01: SD facies. Subsamples: forams (sea surface); 2 liners. Fauna preserved 50% and 100% ETOH
E-CWC-7	6.03	8:59	51°26.30	11°49.40	1060	BC	BC02: SD/BG facies. Subsamples: 2 liners
E-CWC-8	6.03	9:45	51°26.31	11°49.35	1065	BC	BC03: S/CR facies. Subsamples: forams (sea surface); 2 liners
E-CWC-9	6.03	10:28	51°26.30	11°49.38	1062	BC	BC04: CR/S-BG facies. 3 bulk samples (upper, middle, lower portion). Fauna preserved 100% ETOH
E-CWC-10	6.03	12:53	51°26.33	11°49.40	1069	BC	BC05: S facies (ripples). Subsamples: forams (sea surface); 2 liners (1 without surface). Fauna preserved 70% and 100% ETOH
E-CWC-11	6.03	13:44	51°26.38	11°49.40	1038	BC	BC06: SD/S facies. Almost empty (c. 15 cm thick). Two bulk subsamples (upper, lower portion).
E-CWC-12	6.03	16:26	51°26.71	11°49.20	969	BC	BC07: SD facies. Subsamples: 2 liners
E-CWC-13	6.03	17:56	51°26.69	11°49.10	960	BC	BC08: S (ripples) Subsamples: 2 liners
E-CWC-14	6.03	18:37	51°26.71	11°49.13	970	BC	BC09: Empty
E-CWC-15	6.03	19:27	51°26.70	11°49.14	970	BC	BC10: S facies (ripples). Subsamples: 2 liners
E-CWC-16	6.03	21:08	51°29.04	11°49.38	978	ROS/CTD	CTD06: up and down cast; water sample close to the seafloor for pH measurement and $\delta^{18}O$ / $\delta^{13}C$ analysis
E-CWC-17	6.03	22:45	51°27.84	11°49.30	1023	ROS/CTD	CTD07: up and down cast; water sample close to the seafloor for pH measurement and $\delta^{18}O$ / $\delta^{13}C$ analysis

Station No.	Date	Time	Latitude	Longitude	Water Depth	Gear	Remarks:
E-CWC-18	6.04	0:29	51°26.46	11°49.51	1058	ROS/CTD	CTD08: up and down cast; water sample close to the seafloor for pH measurement and $\delta^{18}O$ / $\delta^{13}C$ analysis
E-CWC-19	6.04	2:31	51°25.06	11°49.54	1112	ROS/CTD	CTD09: up and down cast; water sample close to the seafloor for pH measurement and $\delta^{18}O$ / $\delta^{13}C$ analysis
E-CWC-20	6.04	4:04	51°23.82	11°49.40	1128	ROS/CTD	CTD10: up and down cast; water sample close to the seafloor for pH measurement and $\delta^{18}O$ / $\delta^{13}C$ analysis
E-CWC-21	6.04	7:34	51°26.54	11°49.27	1054	BC	BC11: S/BG facies. Subsamples: 2 liners
E-CWC-22	6.04	8:37	51°26.66	11°49.16	1062	BC	BC12: SD facies. Subsamples: forams (sea surface); 3 liners. Fauna preserved 100% ETOH
E-CWC-23	6.04	9:37	51°26.89	11°49.32	1062	BC	BC13: S-BG facies. Subsamples: liners
E-CWC-24	6.04	10:36	51°26.96	11°49.45	1064	BC	BC14: CF-CR facies. Almost empty. Bulk subsample. Fauna preserved 100% ETOH
E-CWC-25	6.04	12:58	51°26.99	11°49.60	1062	BC	BC15: SD facies. Subsamples: 2 for forams (sea surface); 2 liners; bulk samples. Fauna preserved 100% ETOH
E-CWC-26	6.04	14:13	51°27.09	11°49.63	1056	BC	BC16: S-BG/CR facies. Subsamples: 2 liners. Fauna preserved 100% ETOH
E-CWC-27	6.04	15:23	51°26.95	11°49.46	1057	BC	BC17: S facies. Subsamples: 2 for forams (sea surface); 2 liners
E-CWC-28	6.04	16:23	51°26.58	11°49.21	1058	BC	BC18: single piece of coral frame. Fauna preserved 100% ETOH
E-CWC-29	6.04	17:29	51°26.59	11°49.20	1057	BC	BC19: SD facies. Subsamples: forams (sea surface); 2 liners
E-CWC-30	6.04	18:12	51°26.56	11°49.21	1062	BC	BC20: S facies (ripples). Subsamples: 2 for forams (sea surface); 2 liners
E-CWC-31	6.04	19:54	51°26.91	11°47.39	1028	ROS/CTD	CTD11: up and down cast; water sample close to the seafloor for pH measurement and $\delta^{18}O$ / $\delta^{13}C$ analysis
E-CWC-32	6.04	21:39	51°26.97	11°45.52	929	ROS/CTD	CTD12: up and down cast; water sample close to the seafloor for pH measurement and $\delta^{18}O$ / $\delta^{13}C$ analysis
E-CWC-33	6.04	23:37	51°27.04	11°43.74	1096	ROS/CTD	CTD13: up and down cast; water sample close to the seafloor for pH measurement and $\delta^{18}O$ / $\delta^{13}C$ analysis
E-CWC-34	6.05	1:40	51°29.53	11°44.07	914	ROS/CTD	CTD14: up and down cast; water sample close to the seafloor for pH measurement and $\delta^{18}O$ / $\delta^{13}C$ analysis
E-CWC-35	6.05	3:40	51°29.47	11°45.64	954	ROS/CTD	CTD15: up and down cast; water sample close to the seafloor for pH measurement and $\delta^{18}O$ / $\delta^{13}C$ analysis

Station No.	Date	Time	Latitude	Longitude	Water Depth	Gear	Remarks:
E-CWC-36	6.05	5:17	51°29.38	11°47.39	979	ROS/CTD	CTD16: up and down cast; water sample close to the seafloor for pH measurement and $\delta^{18}O$ / $\delta^{13}C$ analysis
E-CWC-37	6.05	8:09	51°29.31	11°49.12	980	BC	BC21: CR facies. Subsamples: forams (sea surface); 3 liners. Fauna preserved 50% and 100% ETOH
E-CWC-38	6.05	9:14	51°30.19	11°49.39	952	BC	BC22: CF/CR facies. Little sediment collected. 1 bulk subsample in ethanol 100%
E-CWC-39	6.05	10:42	51°30.21	11°49.38	951	BC	BC23: BG facies. Subsamples: 2 for forams (sea surface); 2 liners
E-CWC-40	6.05	12:32	51°30.23	11°49.39	942	BC	BC24: CR/CF facies. Little sediment collected. Sieved on board. Fauna preserved 100% ETOH
E-CWC-41	6.05	13:29	51°30.50	11°49.48	933	BC	BC25: CR/CF facies. Subsamples: 2 liners; 1 surface bulk sample (ethanol 100%). Fauna preserved 100% ETOH
E-CWC-42	6.05	14:15	51°30.52	11°49.48	949	BC	BC26: CR/CF facies. Little sediment collected. Fauna preserved 100% ETOH
E-CWC-43	6.05	15:08	51°30.55	11°49.49	952	BC	BC27: CR/CF facies. Little sediment collected. Fauna preserved 100% ETOH
E-CWC-44	6.05	15:55	51°30.53	11°49.50	949	BC	BC28: S/CR facies. Subsamples: 1 for forams (sea surface); 2 liners. Fauna preserved 100% ETOH
E-CWC-45	6.05	17:39	51°29.10	11°49.37	983	BC	BC29: SD facies. Subsamples: 1 for forams (sea surface); 2 liners. Fauna preserved 80% ETOH
E-CWC-46	6.05	18:39	51°29.68	11°49.15	960	BC	BC30: SD/S facies. Subsamples: 1 for forams (sea surface); 2 liners. Fauna preserved 100% ETOH
E-CWC-47	6.05	19:48	51°29.68	11°49.12	969	ROS/CTD	CTD17 (Twin Mound): up and down cast; 10 samples along the water column at 100 m interval for pH measurement and $\delta^{18}O$ / $\delta^{13}C$ analysis
E-CWC-48	6.05/ 06	21:46 - 5:20	51°29.65	11°49.12	969	ROS/CTD	CTD18 (Twin Mound): Yo Yo deployment (8 up and down casts)
E-CWC-49	6.06	9:41	51°29.69	11°49.14	962	BC	BC31: CF/CR facies. Little sediment collected. Subsamples: 1 for forams (sea surface); bulk sample 100% ETOH
E-CWC-50	6.06	10:32	51°29.67	11°49.12	972	BC	BC32: CF/CR facies. Little sediment collected. Subsamples: 1 for forams (sea surface); fauna 100% ETOH
E-CWC-51	6.06	12:34	51°29.67	11°49.14	962	BC	BC33: S/CR facies. Little sediment collected. Subsamples: 2 bulk sample 50% ETOH; fauna 100% ETOH

Station No.	Date	Time	Latitude	Longitude	Water Depth	Gear	Remarks:
E-CWC-52	6.06	13:31	51°29.67	11°49.13	975	BC	BC34: BC17: S-BG facies. Subsamples: 1 for forams (sea surface); 3 liners; fauna 100% ETOH
E-CWC-53	6.06	14:23	51°29.65	11°49.15	966	BC	BC35: S facies (sandy mud). Subsamples: 1 for forams (sea surface); 2 liners
E-CWC-54	6.06	15:21	51°29.66	11°49.05	970	BC	BC36: SD facies (sandy mud). Subsamples: 1 for forams (sea surface); 2 liners.

Tab. 7.1 Station list. Coordinates, depth and time refer to the gear at bottom. ROS/CTD: Rosette/Conductivity Temperature Depth system; BC: Box-corer.

8 Acknowledgements

Andy Wheeler (co-proponent of the RV Belgica Cruise 2012/16 project) and Boris Dorschel are warmly welcome for providing bathymetric and video data of the surveyed Moira Mound area. Andy Wheeler, the Geological Survey of Ireland and the Irish Marine Institute are further acknowledged for their crucial logistic support.
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APPENDIX 1 (Box-corer 1-13; Area 1)

APPENDIX 2 (Box-corer 14-25; Areas 1 and 2 (BC 21-25)

APPENDIX 3 (Box-corer 26-36; Area 2)