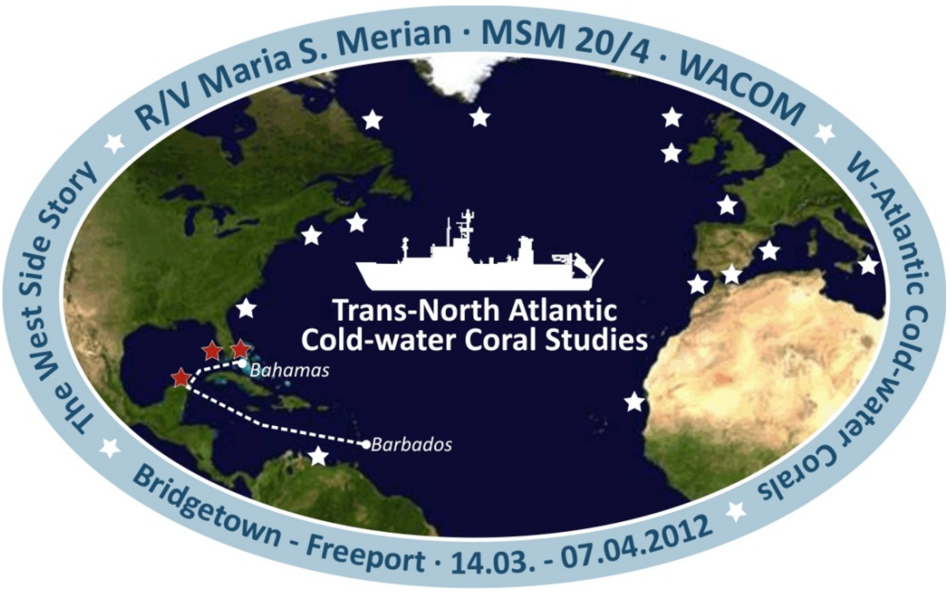
MARIA S. MERIAN-Berichte 20-4

West-Atlantic Cold-Water Coral Ecosystems: The West Side Story

Cruise No. 20, Leg 4

14.3.2012 – 7.4.2012, Bridgetown (Barbados) – Freeport (Bahamas)



Dierk Hebbeln, Claudia Wienberg, Lydia Beuck, Klaus Dehning, Wolf-Christian Dullo, Gregor Eberli, André Freiwald, Silke Glogowski, Thorsten Garlichs, Friedhelm Jansen, Nina Joseph, Marco Klann, Lelia Matos, Nicolas Nowald, Hector Reyes, Götz Ruhland, Marco Taviani, Thomas Wilke, Maik Wilsenack, Paul Wintersteller

Editorial Assistance:
Senatskommission für Ozeanographie der Deutschen Forschungsgemeinschaft
MARUM – Zentrum für Marine Umweltwissenschaften der Universität Bremen

Leitstelle Deutsche Forschungsschiffe
Institut für Meereskunde der Universität Hamburg

2012

Table of Contents Page

1 Summary

Leg MSM 20-4 focussed on the investigation of cold-water coral (CWC) ecosystems in the West Atlantic Ocean (Gulf of Mexico, Florida Straits) with special emphasis on their distribution, appearance, faunal assemblage and vitality under present and past (glacial) conditions. The overarching objective was to identify the main physical and biological factors that are important in controlling CWC occurrence. Based on detailed mapping with the shipboard multibeam echosounder and PARASOUND systems, five working areas were selected for detailed studies: (1) Campeche Bank (NE Yucatan Peninsula), (2) West-Florida Slope, (3) Southwest-Florida Slope, (4) Bimini Slope, and (5) Great Bahama Bank Slope. During 17 dives with the Bremen ROV CHEROKEE (MARUM) a detailed characterisation of the existing facies and fauna was conducted on these selected CWC occurrences. Moreover, a total of 49 CTD profiles were measured comprising single casts and three so-called Yoyo-CTDs with repeated casts over 13 hours covering one complete tidal cycle complemented by bottom water samples at all sites will help to assess the recent environment of the CWC. Finally, a series of grab samples, box cores and gravity cores (total core recovery: ~60 core metres) will enable to study the development of CWC ecosystems in the West Atlantic under changing environmental conditions, e.g., over glacial-interglacial cycles.

The results of the expedition will contribute to the international TRACES initiative (Trans-Atlantic Coral Ecosystem Studies) which aims to compare the coral ecosystems of the West Atlantic with the well-known CWC sites of the East Atlantic with respect to their recent situation and a potential linkage between both occurrences regarding their temporal development during the last glacial-interglacial cycle.

Zusammenfassung

Im Mittelpunkt des Fahrtabschnittes MSM 20-4 stand die Untersuchung von Kaltwasserkorallen (KWK)-Ökosystemen im West-Atlantik (Golf von Mexiko, Florida Straße). Dabei lag das Hauptaugenmerk auf der Erfassung der Verteilung, dem Erscheinungsbild, der Faunenvergesellschaftung und dem Zustand dieser Ökosysteme unter heutigen und vergangenen (glazialen) Bedingungen. Nach eingehender Vermessungen mit den bordeigenen Fächerecholotsystemen und PARASOUND wurden insgesamt fünf Teilarbeitsgebiete für detaillierte Studien ausgewählt: (1) Campeche Bank (NO Yukatan Halbinsel), (2) West-Florida Slope, (3) Southwest-Florida Slope, (4) Bimini Slope und (5) Great Bahama Bank Slope. Im Zuge von 17 Tauchgängen mit dem Bremer ROV CHEROKEE (MARUM) konnten detaillierte Fazies- und Faunen-Charakterisierungen durchgeführt werden. Zusätzlich wurden insgesamt 49 CTD-Profile gemessen (einzelne Messungen und sog. 13 Stunden andauernde JoJo-CTDs) sowie Bodenwasserproben genommen, die helfen werden die heutige Umwelt dieser Ökosysteme zu erfassen. Schließlich werden Greiferproben, Kastengreifer und Schwerelotkerne (Kerngewinn: ~60 m) dazu dienen, die Entwicklung der west-atlantischen KWK über den letzten Glazial-Interglazial-Zyklus zu rekonstruieren und mit Klima-gesteuerten Veränderungen der Umweltbedingungen zu korrelieren.

Die Ergebnisse der Fahrt werden zur internationalen TRACES-Initiative (Trans-Atlantic Coral Ecosystem Studies) beitragen, die zum Ziel hat KWK-Ökosysteme des West-Atlantiks mit den in den letzten Jahren sehr intensiv erforschten Vorkommen des Ost-Atlantiks auf Gemeinsamkeiten zu untersuchen und mögliche Verknüpfungen zwischen beiden atlantischen Systemen zu erfassen.

2 Participants

Name	Discipline	Institution
Hebbeln, Dierk	Marine Geology / Chief Scientist	MARUM
Wienberg, Claudia	Marine Geology	MARUM
Matos Branco, Lelia	Marine Geology	MARUM
Dehning, Klaus	Marine Geology	MARUM
Klann, Marco	Marine Geology	MARUM
Nowald, Nicolas	ROV	MARUM
Ruhland, Götz	ROV	MARUM
Wintersteller, Paul	Marine Geology	MARUM
Freiwald, André	Geobiology	SAM
Beuck, Lydia	Geobiology	SAM
Joseph, Nina	Geobiology	SAM
Wilsenack, Maik	Geobiology	SAM
Dullo, Wolf-Christian	Hydrography	GEOMAR
Glogowski, Silke	Hydrography	GEOMAR
Garlichs, Thorsten	Hydrography	GEOMAR
Jansen, Friedhelm	Meteorology	MPI-HH
Reyes, Hector	Marine Biology	UABCS
Eberli, Gregor	Marine Geology	RSMAS
Taviani, Marco	Marine Biology	ISMAR-CNR
Wilke, Thomas	Journalism	BdW

MARUM	Zentrum für Marine Umweltwissenschaften, Universität Bremen
SAM	Senckenberg am Meer, Wilhelmshaven
GEOMAR	Helmholtz-Zentrum für Ozeanforschung, Kiel
MPI-HH	Max Planck Institut für Meteorologie, Hamburg
UABCS	Universidad Autónoma de Baja California Sur, La Paz, Mexico
RSMAS	Rosenstiel School for Marine Sciences, University of Miami, USA
ISMAR-CNR	Institute of Marine Sciences, National Research Council, Bologna, Italy
BdW	Bild der Wissenschaft, Lübeck

3 Research Program

Cold-water corals (CWC) are the nuclei of unique and important ecosystems of the bathyal zone. The importance of CWC is highlighted in their role in creating biodiversity hotspots, in their worldwide distribution, and in their capability to build large calcareous seabed structures (reefs, mounds) of several kilometres in length and >300 m in height.

Though CWC are widespread on both sides of the North Atlantic Ocean, they have not been studied at a basin-scale. Most research to date has been relatively small-scale and focused on specific sites. Knowledge about potential links between the East and West Atlantic CWC ecosystems is rather limited. Moreover, information about the faunal assemblages as well as the genetic and biogeographical relationship between both provinces is completely lacking. And finally, in particular for the West Atlantic Ocean coral ages (radiocarbon and/or Uranium-series datings) being mandatory for a reconstruction of the development of CWC ecosystems during the last glacial-interglacial-cycle in relation to climate-induced environmental changes are not available so far.

Leg MSM 20-4 aimed to study CWC ecosystems across a transect from the partly enclosed Gulf of Mexico to the "open" West Atlantic Ocean with respect to their distribution, appearance, faunal assemblage and vitality under present and past (glacial) conditions, and to identify the main physical and biological factors that are important in controlling CWC occurrence. The overarching objective was a trans-North Atlantic basin-scale study to compare the West Atlantic CWC occurrences with the well-known CWC ecosystems of the East Atlantic Ocean with respect to their recent situation and a potential linkage between both occurrences regarding their temporal development during the last glacial-interglacial cycle. Thus, for this expedition the following three core questions have been formulated:

1) How divers are CWC as well as the structure and composition of the entire CWC ecosystems in the western Atlantic?
2) How did the CWC ecosystems in the western Atlantic develop under varying climate forcing, as e.g. over the last glacial-interglacial-cycle?
3) Which similarities and/or differences exist between the CWC ecosystems in the western and in the eastern North Atlantic today and during their past long-term development?

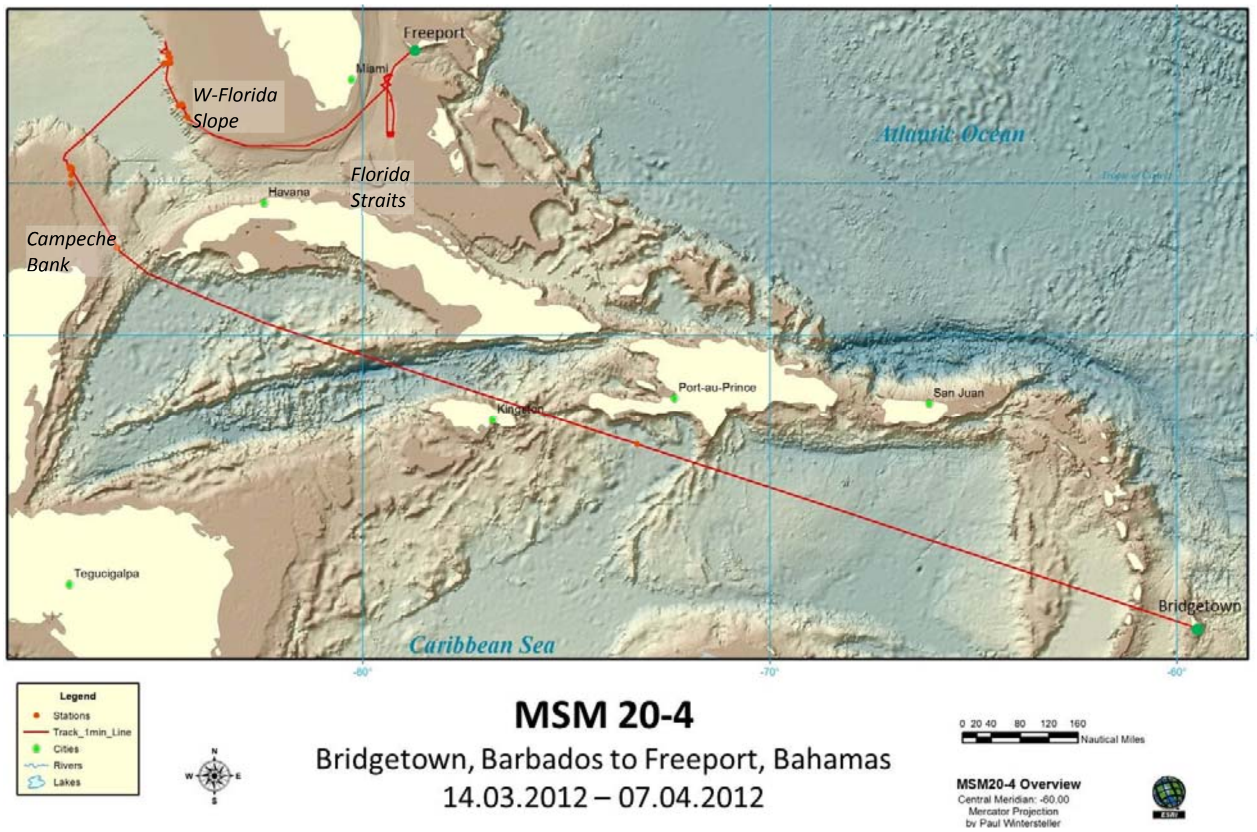


Fig. 3.1 Track chart of R/V MARIA S. MERIAN Cruise MSM 20-4.

To answer these questions various target areas in the western Atlantic have been selected to be investigated during Leg MSM 20-4 (see Fig. 3.1). These comprised "potential" CWC mounds along the Campeche Bank (Yucatan Peninsula) and the West Florida Slope within the Gulf of Mexico, and reported CWC occurrences in the Florida Straits. For all working sites station work started with a detailed hydro-acoustic mapping (multibeam echosounder, PARASOUND; in case appropriate data did not exist for the selected study sites). These data formed the base for planning optimised ROV dives. Extended video surveys with the ROV CHEROKEE were used to characterise the facies and fauna, and even more important here, to identify most suited coring sites. Based on this information, positions have been defined to accomplish a dedicated sampling (gravity cores, box cores, grabs, and water samples) and monitoring (CTD) programme within or in the direct vicinity of the observed CWC ecosystems. During previous expeditions this approach has already been proven to be very successful in sampling CWC material and data of their surrounding environment.

4 Narrative of the Cruise

Sunday, March 11, 2012 and Monday, March 12, 2012 ◊ During the day the R/V MARIA S. MERIAN arrived in Bridgetown (Barbados). A first group of MSM 20-4 scientist visited the vessel to welcome the scientists of the former cruise (MSM 20-3; chief scientist: S. Mulitza, MARUM), to have an exchange with the scientific crew about the equipment to be left on board, and to coordinate the unloading of the two containers send from Bremen to Barbados with additional equipment for cruise MSM 20-4. The next day was spent with the installation of the various laboratories on board, the ROV and other scientific equipment.

Tuesday, March 13, 2012 ◊ In the morning, all 20 scientists and technicians arrived on board the R/V MARIA S. MERIAN. Unfortunately, the departure to the first working area off Mexico, initially scheduled for the 14th of March, had to be postponed for two reasons. Firstly, during the former expedition (MSM 20-3) some severe problems occurred with the multibeam echosounder system (MBES) EM120 making an exchange of some hardware parts necessary. Therefore, a service technician of the KONGSBERG company was send from Oslo (Norway) to Bridgetown (Barbados) to fix the problem. Secondly, the scientists on board were still lacking visa required by the Mexican authorities to work in Mexican waters. Thus, it was necessary to send one scientist to the next Mexican embassy located in Port-of-Spain (Trinidad) for getting the visa for all participants.

Wednesday, March 14, 2012 and Thursday, March 15, 2012 ◊ In the early morning, one of the MSM 20-4 participants was flying to Trinidad to get the visa from the local Mexican embassy. In the meanwhile, it came out that the spare parts necessary to repair the MBES EM120 were sent to Venezuela and had to be re-sent to Barbados. Fortunately, the spare parts arrived on board at lunch time and the KONGSBERG technician could start with the replacement of the spare parts. In the evening, the R/V MARIA S. MERIAN left the port of Bridgetown and anchored in the roadstead off the port. The next day was used for several meetings between the individual scientists and technicians to discuss sampling procedures and gear deployments in detail. Moreover, the KONGSBERG technician finished to repair the MBES EM120 and left the vessel in the afternoon. After dinner, the colleague on duty with getting the visa from Trinidad arrived back on board, and at around 18.30 the vessel started to set sail to the first working area off Mexico (Campeche Bank).

Friday, March 16, 2012 to Tuesday, March, 20 2012 ◊ During our transit we passed ~1,600 nm, thereby crossing the Caribbean Sea from SE to NW. During the five days of transit we used the time for a series of scientific presentations to inform each other about former and on-going studies on CWC on both sides of the Atlantic Ocean carried out by the institutes involved in this cruise (ISMAR-CNR: M. Taviani; RSMAS: G. Eberli; UABCS: H. Reyes Bonilla;

MPI Hamburg: F. Jansen; SaM: A. Freiwald; GEOMAR: C. Dullo; MARUM: D. Hebbeln). In addition, on Sunday we interrupted our transit for ~4 hours to do a test station (GeoB 16301) for the CTD and the ROV CHEROKEE. On Tuesday, the vessel stopped for a second time to deploy the depressor of the ROV in order to test the positioning system POSIDONIA (GeoB 16302).

Wednesday, March 21, 2012 ◊ In the morning, we eventually arrived Mexican waters (Yucatan peninsula) and started station work with a CTD cast down to a water depth of 1,100 m (GeoB 16303). We continued our work with MBES and PARASOUND mapping (GeoB 16304) along the eastern slope of the Campeche Bank heading towards our first "potential" CWC site in water depths of 500-600 m along the NE Campeche Bank. This area was initially mapped in 2009 during R/V METEOR cruise M78-1 (chief scientist: J. Schönfeld, GEOMAR) revealing conspicuous seabed structures up to 40-m-high, which strongly resemble CWC mounds along the NE Atlantic margin, however, any groundtruthing was lacking. Evaluating the origin of these seabed elevations by ROV video observation and sediment sampling was the first target of cruise MSM 20-4. In the evening, we arrived the area, accomplished another CTD cast (GeoB 16305), and continued mapping (GeoB 16306) to get an adequate bathymetric map to plan an ROV dive.

Thursday, March 22, 2012 ◊ During mapping, we discovered 25-m-high NW-SE-elongated seabed structures in water depths between 550 and 600 m along the slope of the Campeche Bank. These structures were the first target for an ROV dive (GeoB 16307). The video observation revealed that these structures are covered by live and dead CWC framework. However, due to strong bottom currents, it was not possible to sample the CWC by the ROV. Nevertheless, after recovery of the ROV, we discovered some live and dead branches of *Lophelia* entangled in the ROV's depressor weight. We continued station work with sediment sampling with the box corer. Whereas two box cores yielded only few sediment with fossil coral framework (GeoB 16308, 16309), a third box corer recovered muddy sediments dispersed by coral rubble (GeoB 16310-1). A gravity core, taken from the same position, was filled over the top (GeoB 16310-2). However, a second attempt with a 12-m-long core barrel yielded a coral-bearing sediment core with a total recovery of 10.60 m (GeoB 16310-3). During the night, we continued mapping (GeoB 16311) in the northern part of the working area and again discovered numerous ridge structures.

Friday, March 23, 2012 ◊ In the morning, we deployed the ROV (GeoB 16312) and observed that all ridge tops are colonised by live CWC, whereas the ridge troughs are dominated by muddy sediments and coral rubble. We selected one ridge structure for sampling with the box and gravity corers (GeoB 16313). One attempt to collect a so-called "off-mound" sediment core (barren of any coral fragments to get a continuous sedimentary record for palaeo-environmental reconstructions) failed (GeoB 16314), a further attempt to obtain such a core was postponed to the next day. A last sampling target for this day was a crater-like structure which has been discovered during mapping eastward of the coral ridges in a water depth of ~620 m. Unfortunately, sampling with the box corer failed (GeoB 16315) as the corer tilted on the seafloor and had to be recovered upside down as the cable of the winch got entangled with the frame of the box corer. However, the deck's crew and technicians together managed to recover the corer safe back on board and the corer revealed just minor damage which could be repaired until the next day. During the night, a so-called Yoyo-CTD was conducted (GeoB 16316) during which the CTD was repeatedly lowered over a period of 13 hours to obtain changes in physical parameters of the water column during a full tidal cycle.

Saturday, March 24, 2012 ◊ We started the day with an ROV dive (GeoB 16317) in the northern, slightly shallower (450-550 m) part of the Campeche area. As during the dives before, we crossed several ridges with very steep flanks. Again, all ridges are covered by abundant dead and live CWC framework whereas the troughs in between the ridges are characterised by strongly bioturbated muddy sediments. Due to some problems with the ROV's electronics we had to abort the dive. On deck, the ROV technicians immediately started to solve the problem and repaired the system before the end of the day. The second half of the day was spent with sediment sampling. One coral-bearing sediment core (GeoB 16318) was collected from the top area of one of the northernmost ridge structures observed during the last ROV dive. In a muddy area in between the observed coral ridges, a box core as well as a gravity corer (recovery: ~8 m) also revealed layers of coral rubble (GeoB 16319). To obtain an off-mound core from this area, we sampled typical drift sediments with a box corer and with a gravity corer with the latter yielding a recovery of 4.3 m (GeoB 16320). In the evening, we again tried to sample the crater-like structure which had already been visited the evening before. This time, we fixed a POSIDONIA transponder above the box corer to sample this structure as accurate as possible. This successful attempt revealed sediments interspersed with abundant fossil CWC framework with partly very thick and large *Lophelia* skeletons (GeoB 16321). The few remaining hours in the area were used to finalise the bathymetric map of the Campeche coral province (GeoB 16322).

Sunday, March 25, 2012 ◊ During the night, we started our transit to the next working area: the West-Florida Slope in the eastern Gulf of Mexico. After dinner, we arrived in the area and started with two CTD casts (GeoB 16323 & 16324) continued by mapping (GeoB 16325).

Monday, March 26, 2012 ◊ In the morning, we started work with an ROV dive (GeoB 16326). We observed massive rocky outcrops which are covered by abundant fossil CWC. After lunch, the dive had to be aborted again due to technical problems with the ROV electronics. Therefore, we continued station work with a series of six grab samples (GeoB 16327-16332) which revealed sandy sediments with few coral rubble and rocks colonised by various organisms. In the evening, we intended to continue our sampling programme with two gravity cores, but due to a serious technical problem with one of the cranes of R/V MARIA S. MERIAN this attempt had to be postponed. Instead, we proceeded mapping of the area (GeoB 16333).

Tuesday, March 27, 2012 ◊ During the next ROV dive (GeoB 16334) we crossed two up to 25-m-high mound-like seabed structures being situated slightly to the south of the previous ROV dive. In water depths between 520 and 490 m their SE flanks are covered by coral rubble becoming more abundant and larger uphill, before in the top areas large colonies of (partly live) *Lophelia* and *Enallopsammia* become abundant being associated with a highly diverse fauna. The NW flanks are characterised by coral rubble, outcrops of carbonate rocks and soft sediments (from their upper to lower flanks). Several attempts to sample these structures with the box corer and with the grab (GeoB 16335-16337) revealed very few coral rubble and sandy sediments. Two gravity cores collected from two other mound-like structures, discovered during mapping in the area, just revealed sandy sediments (GeoB 16338-16339). During the night, a Yoyo-CTD station (GeoB 16340) was conducted in the West-Florida Slope area with repeated casts over 13 hours on the same position covering one tidal cycle.

Wednesday, March 28, 2012 ◊ In the morning station work was continued with an ROV dive (GeoB 16341). As during the two dives before, we observed massive hardgrounds covered with few coral rubble. After recovery of the ROV, we continued with two grab samples (GeoB 16342 & 16343) collected from a small ridge structure, of which one was successful and revealed sandy sediments and coral rubble. Station work along the West-Florida Slope was finished with a CTD cast down to a water depth of 1,000 m water depth (GeoB 16344) before we left the area heading towards our next working area off southwest Florida.

Thursday, March 29, 2012 ◊ We arrived the Southwest-Florida Slope around midnight and started with a CTD cast down to a water depth of ~1,300 m (GeoB 16345) continued by mapping (GeoB 16346). Based on the mapping data, we selected an area for our first ROV dive in this working area (GeoB 16347). On a W-E-transect we crossed extended fields with sandy sediments showing signs of strong bioturbation, outcropping hardgrounds, and fields with boulders. Octocorals and few living *Lophelia* colonise these boulders at their north-western side facing the main current direction. At the easternmost part of the dive, a spectacular steep and terrace-like escarpment of 50 m in height arose showing massive accumulations of coral rubble at the base and being colonised by abundant *Lophelia* and a highly diverse associated fauna. After video observation, four attempts to sample the coral rubble field at the base of the escarpment failed (GeoB 16348). Station work was continued by mapping (GeoB 16349).

Friday, March 30, 2012, to Saturday, March 31, 2012 ◊ Directly after breakfast, we deployed the ROV (GeoB 16350) to survey an area being located slightly further south to the previous dive. We observed extended fields with soft sediments (most probably sand) and fields with rocky outcrops, pebbles, boulders, blocks and crusts. Scleractinian corals were rather scarce in this area, just two times we observed fields with coral rubble, and at one place we found metre-sized colonies of living *Lophelia*. Coring a drift sediment body (north of the area surveyed during the ROV dive) failed as the corer tilted at the seabed (GeoB 16351), most probably because of sandy sediments (as found in the core catcher). We continued sampling with three grabs of which one grab was empty (GeoB 16352), and two revealed rocks (GeoB 16353) and sandy sediments (GeoB 16354). After sampling, we continued mapping to finalise the bathymetric map of the Southwest-Florida Slope (GeoB 16355), before we started our transit to the next working areas off the Bahamas.

Sunday, April 1, 2012 ◊ Before we could start station work in Bahamian waters, we had to clear customs in front of Bimini. This was done by lunchtime. Afterwards, we headed towards the NW of Bimini, where we did a first CTD cast down to a water depth of 760 m (GeoB 16356) continued by a short bathymetric survey (GeoB 16357) to get a preliminary map of the Bimini Slope and to prepare a first ROV dive in this area. We selected an up to 100-m-high mound structure, which resembles a coral mound (tentatively named "Wienberg" mound). During deployment of the ROV, very strong southerly currents forced the vehicle to the north of this structure making it impossible to study it. However, during the dive we crossed some other low relief seabed structures which were partly covered by coral rubble and even a few living corals were observed (GeoB 16358). Afterwards we tried to sample the Wienberg mound. The first gravity core just revealed few coral rubble and lithified sediment in the core catcher (GeoB 16359). Also the second coring attempt partly failed as the core tube bent (GeoB 16360). However, we recovered ~2 m of a coral-bearing core, and even the core top could be recovered as a bulk sample revealing abundant *Lophelia* fragments. During the night, we continued to map the area west of Bimini (GeoB 16361).

Monday, April 2, 2012 ◊ Station work again started with the deployment of the ROV (GeoB 16362). This time we started further upslope and had no problems to reach the seabed as the currents were much weaker compared to the day before. The target of this ROV dive was a series of ridge and mound structures in water depths between 450 and 520 m. We crossed an area with a somehow chaotic morphology with flat plains made up of soft sediments and steep escarpments (up to 15 m high) in between which are colonised by a highly diverse sponge fauna and various soft corals. Coral rubble and live scleractinians are rather scarce. We continued station work with sediment sampling and selected an area that showed a huge package of stratified sediments in the PARASOUND data to collect a so-called off-mound core for palaeoceanographic studies. We started sampling with a grab to make sure that the sediment is suitable to sample it with the gravity corer. As the grab recovered muddy sediments (GeoB 16363-1), we continued with gravity coring. The first attempt with a 6-m-long core barrel over-penetrated (GeoB 16363-2), therefore we deployed a 12-m-long core barrel and recovered impressive 10.3 m of sediment material (GeoB 16363-3). The last sampling target for the day was a mound-like structure in >800 m water depth which had the potential to be a coral mound. However, just 1.6 m of sandy sediments without any coral fragments were recovered (GeoB 16364). During the night, we finished mapping in the area (GeoB 16365) and headed further to the south to our last working area west of the Great Bahama Bank.

Tuesday, April 3, 2012 ◊ During our first ROV dive along the Great Bahama Bank Slope, we crossed conspicuous mound-like seabed structures covered by abundant coral rubble (GeoB 16366). Unfortunately, the dive had to be aborted already after 2 hours of observation again due to technical problems with the ROV. We continued with a CTD cast down to a water depth of 660 m (GeoB 16367). Three positions were selected for sediment sampling where coral rubble was observed during the ROV dive. Two box cores were obtained (GeoB 16367-2, 16368-1) both filled with *Enallopsammia* rubble. Gravity cores taken at the same positions (GeoB 16368-2, 16369) showed limited recoveries with 0.5-2.3 m containing coral fragments. Four further attempts to sample sediments with the box corer from a twin-peaked mound (introduced by Correa et al., 2011) failed due to technical problems with the release of the box corer (GeoB 16370 &16371). Instead, we continued mapping in the area (GeoB 16372) that lasted until the next morning.

Wednesday, 04. April 2012 ◊ This day we started with two subsequent ROV dives crossing two large seabed structures (GeoB 16373 & 16374). During the dives, we observed the following facies from the base to the top of both mounds: coral rubble, dead coral framework, and abundant large live colonies of *Lophelia* and *Madrepora*. One of the observed mounds ("Mount Gay") was selected for sampling. Three box cores collected at its base (GeoB 16375) and at its lower (GeoB 16376) and middle flanks (GeoB 16377) revealed coral rubble embedded in a sandy matrix. Three gravity cores collected at the same (flank) sites (GeoB 16377 & 16378) and at the mound's top (GeoB 16379) showed recoveries between 1.2 and 5.6 m containing coral fragments. Two attempts to collect box cores from the top of the mound failed as the corer did not release due to mechanical problems. The night was again spent with mapping (GeoB 16380).

Thursday, 05. April 2012 ◊ We started the day with another ROV dive (GeoB 16381). As the day before, we crossed two pronounced mound structures which were again covered by abundant coral rubble (*Enallopsammia* and *Lophelia*) whereas live scleractinian corals were rather scarce. Again, one mound was selected for sediment sampling at its top and northern flank. However, box and gravity cores (GeoB 16382) just showed limited sediment recoveries although they contained abundant coral rubble. The coring of the mound's flank (GeoB 16383) even partly failed as the tube bent and just 0.8 m of coral-bearing sediment was recovered, most probably due to the existence of lithified sediment, as found in the core catcher. These observations indicate that the mound structures found off Great Bahama Bank are pre-existing structures overgrown by corals rather than structures build-up by corals. An area situated north of the "coral" mounds and characterised by stratified sediments was selected to obtain an off-mound core for palaeoceanographic studies for this area (GeoB16384). Unfortunately, the core slightly over-penetrated and the top 20-cm of the core were lost. The very last coring attempt during cruise MSM20-4 was dedicated to sample once again site GeoB 16377, but this time equipped with a longer 12-m-long core barrel. However, the attempt to retrieve a very long sediment record from this structure failed and a core with a recovery of only 1.37 m was obtained (GeoB 16385). During the night, the third Yoyo-CTD station was conducted (GeoB 16386) running for 13 hours at the same position.

Friday, April 6, 2012, to Saturday, April 7, 2012 ◊ On Friday morning, the first attempt to dive with the ROV (GeoB 16387) had to be aborted due to strong currents. For a second attempt (GeoB 16388), we chose a starting point further to the south and eventually started our observations as planned at the mound's base running uphill. We observed large fields with coral rubble associated with various live soft corals. The dive ended within an extended field of soft sediments covered by an astonishing huge number of dead large echinoids and bivalve shells. After recovery of the ROV, we finished our work during cruise MSM20-4 with a last bathymetric survey (GeoB 16389) to complete the map for the Great Bahama Bank CWC area. Afterwards, the scientific crew started to de-install the equipment from the laboratories and to load the containers. On Saturday morning, R/V MARIA S. MERIAN arrived in Freeport, where immediately all MSM20-4 containers were unloaded.

It is worth to mention here that during the entire cruise we had almost perfect weather conditions with low winds (<5 Bft) and low swell (<2 m).

5 Methodology and Instrumentation

5.1 Marine Aerosol Network - Microtops II

(Friedhelm Jansen)

The AERONET (**AE**rosol **RO**botic **NET**work) program is a federation of ground-based remote sensing aerosol networks established by NASA and PHOTONS (University Lille) and is greatly expanded by collaborators from national agencies, institutes, universities, individual scientists and partners. The program provides a long-term, continuous and readily accessible public domain database of aerosol optical, microphysical and radiative properties for aerosol research and characterisation, validation of satellite retrievals, and synergism with other databases.

The Maritime Aerosol Network (MAN) component of AERONET provides ship-borne aerosol optical depth measurements from the Microtops II sun photometers. These data provide an alternative to observations from islands as well as establish validation points for satellite and aerosol transport models. Since 2004, these instruments have been deployed periodically on ships of opportunity and research vessels to monitor aerosol properties over the World Oceans.

During cruise MSM 20-4, a handheld sun photometer (Microtops II) for spectral measurements of the direct solar radiation was applied (Fig. 5.1). This Microtops II instrument has five channels at 440, 500, 675, 870, and 936nm to provide information to calculate the columnar aerosol optical depth (AOD), water vapour and Angstrom parameter. The measurements were taken in cloud-free conditions and if possible during times of satellite overpasses of ENVISAT, CALYPSO, CLOUDSAT, AQUA and PARASOL. The collected data

is processed and analysed by NASA and distributed into the network already on a daily base. As expected the weather conditions during this cruise were excellent to perform several cloud-free time series of aerosol properties. The area observed during cruise MSM 20-4 is currently under-sampled, therefore, this contribution is extremely valuable for the MAN project. The links are:
http://aeronet.gsfc.nasa.gov/new_web/maritime_aerosol_network.html
http://aeronet.gsfc.nasa.gov/new_web/cruises_new/Merian_12_0.html
http://aeronet.gsfc.nasa.gov/new_web/KML/Merian_12_0_daily_lev15.kml.

Fig. 5.1
Photograph showing the handheld sun photo-meter for spectral measurements of the direct solar radiation was applied during MSM 20-4.

Overall the data collection was excellent, in total 22 day of measurements. The aerosol optical depth AOD was stable within 0.1-0.2 range at wavelength 500 nm (average ~0.15) which is higher than over typical remote oceanic areas (~0.07). Influence of the continental sources and possible dust transport from Africa might be responsible for that. Spectral dependence (characterized by the Angstrom parameter alpha) varied generally between 0.7 on March 19 and 1.7 on March 27 being on average near 1.0 most of the time. This is an indicative of mainly fine mode aerosol contribution into AOD, however, on a number of occasions when alpha was less than 1.0 indicating the presence of the coarse aerosol fraction was noticeable.

5.2 Underway Hydroacoustics

(Paul Wintersteller, Gregor Eberli)

5.2.1 Attributed sensors (navigation, motion data, sound velocity)

The ship's best determined position was calculated by the SEAPATH 200 Inertial Navigation System (INS). Motion data (roll, pitch, heave) as well as heading and Differential Global Positioning System (DGPS) information was generated by the SEAPATH 200 in combination with the motion reference unit (MRU) 5, and delivered to all hydroacoustic devices applied during MSM20-4. When using a SEAPATH 200 INS, the internal coordinate system contains lever arms between DGPS and the MRU, which is commonly the position of the reference point. This information is important to all devices using the SEAPATH 200 since offsets between transducers and sensors like DGPS or motion sensor refer to the formal center of gravity, the so-called reference point (see Appendix 1 for MSM 20-4 settings of SEAPATH 200). The DGPS failed a couple of times in delivering accurate position for several minutes. On April 2nd, the SEAPATH 200 failed and needed a restart that produced a gap for about 20 minutes. We observed these problems already on former R/V MARIA S. MERIAN cruises within the Gulf of Mexico.

Surface sound velocity (SSV) is usually been taken in real-time with a SSV-probe mounted next to the transducers of the multibeam echosounders (MBES). Due to a malfunction the probe could not be used. SSV as well as sound velocity profiles (SVP) through the water column have been extracted from CTD data.

5.2.2 USBL POSIDONIA

IXSEA's POSIDONIA 6000 is an ultra-short baseline (USBL) underwater navigation that was used during ROV dives and for one of the box corer stations. The moon-pool mounted antennas require a calibration and a proper SVP. Most recent calibrations for the system were done in 2009 (MSM13-4) and 2010 (MSM15-2). Although the SEAPATH 200 is delivering DGPS and motion sensor data, just GPS-information is used for the USBL because POSIDONIA 6000 has its own motion sensor. The motion sensor, IXSEAS OCTANS in a wet pot, is mounted directly above the four antennas. SVP has been updated for every area of investigation or whenever changes in surface sound velocity appear to be higher than 3 m s^{-1} (see Appendix 1 for settings of POSIDONIA during MSM 20-4).

5.2.3 Multibeam Echosounder (MBES)

Seabed mapping during MSM20-4 was performed with two devices, the ship's hull-mounted KONGSBERG EM120 deep-water MBES (12kHz) and the moon-pool mounted KONGSBERG EM1002 that is a shallow- to medium-water MBES (95kHz). The EM120 has a depth range of 20 to 11,000 m, while the depth range of the EM1002 is 2 to 1,000 m but achieves a much higher depth resolution of 2-8 cm, depending on the pulse lengths (0.2-2 ms).

On R/V MARIA S. MERIAN, the EM120's footprint of a single beam is limited to 2° by 2°. The angular coverage sector is up to 150°. EM120 has 191 beams per ping, while the EM1002 has 111 beams per ping. Achievable swath width on a flat bottom is up to 5 times the water depth dependent on the character of the seafloor. The angular coverage sector and beam pointing angles are set to vary automatically with depth according to achievable coverage. This maximizes the number of usable beams. The beam spacing is equidistant to equiangular. All settings applied for the two MBES systems during MSM 20-4 are listed in Appendix 1. For reasonable hydroacoustic recording a proper SVP is essential. Thus, several CTD's were taken during the cruise (see Chapter 5.3). In every survey region at least 1-2 SVP's were calculated based on the SEABIRD CTD measurements (Fig. 5.2). The SVPs have been applied to EM120 and EM1002 right after the data were collected. The SVPs show a wide variability over the entire water column, documenting that the precision of the seabed bathymetry map relies on a SVP in each survey area.

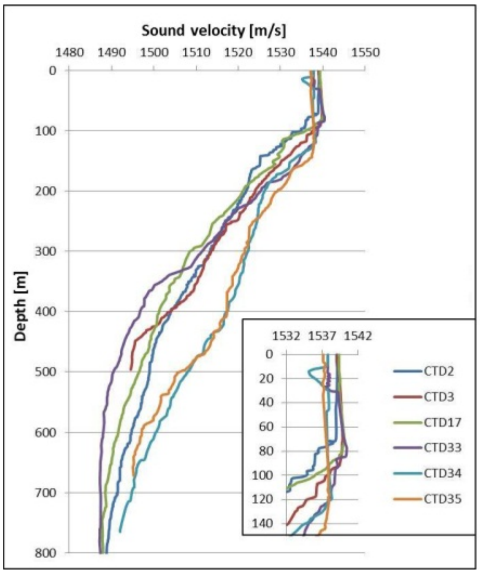


Fig. 5.2
Sound velocity profiles (SVP) calculated from CTD data.

The EM120 delivered reliable data. However, the EM1002 data had less artifacts and a far higher precision in the survey region's water depth range of 400-800 m. The very good results of EM1002 are first and foremost a matter of frequency (95kHz versus 12kHz). In addition, the transducers' semicircular geometry with a radius of 45 cm on the EM1002 has a particular influence regarding the beam-forming. A roll offset error is visible in both MBES. The values are about 0.14 for EM1002 and about 0.21 for EM120. Because there is an uncertainty of about 30% of the mentioned values we expect other offset errors such as pitch or yaw, which will be addressed in the shore-based post processing. The open-source software MB-System version 5.3.1 (Caress & Chaynes, 1996) and GMT version 4.3.1 (Wessel & Smith, 1995) were used for bathymetric data processing, editing and evaluation. ESRI ArcGIS version 10 is inserted to create maps and a sustainable spatial data management.

5.2.4 ATLAS PARASOUND

The ship's hull-mounted sub-bottom profiler ATLAS PARASOUND (type PARASOUND P70, rated for 11,000 metres) utilises the parametric effect to generate a very low secondary frequency signal by emitting two primary signals of higher frequencies. Similar to the MBES measurements, also for the PARASOUND surveys actually measured SVPs were applied for all survey regions.

The equipment failed about 12 times during the cruise. Restarts were usually necessary after station work, regardless whether the system was running during station work or not. The system reacts very sensitive when losing the system depth, even for a short time. On April 2nd, the DGPS failed and had to be restarted. These events are recorded in the MBES/PS event-protocol.

Primary high and secondary low frequencies are recorded as raw-format (*.asd) as well as ps3 and SeGY formats. Every survey region is split into subfolders according to the frequencies (PHF, SLF). SeNT, a program developed by H. Keil (Univ. of Bremen), has been used for post processing (see Appendix 1 for specifications and settings applied to the PARASOUND system during MSM 20-4).

5.2.5 Acoustic Doppler Current Profiler (ADCP)

Data were recorded from the shipboard "Acoustic Doppler Current Profiler" (ADCP), the RDI Ocean Surveyor 75kHz. The system is fully operational and requires minimal operator interference. Data were acquired using the RDI software VMDAS (Vessel-Mount Data Acquisition). The OS 75 operating parameters used during MSM20-4 were 128 depth bins of 5 m bin size. Further settings can be found in the settings file, next to the data. To aid decisions in terms of recovery and deployment of the ROV a water-current prediction was made from the long average plots of 60 minutes (see Appendix 1 for settings of the ADCP during MSM 20-4).

5.3 Hydrography with CTD and Water Sampler

(Christian Dullo, Thorsten Garlichs, Silke Glogowski)

5.3.1 Objectives

The major objective for the Conductivity-Temperature-Depth (CTD) measurements during cruise MSM 20-4 was to determine general water mass characteristics and the influence of physical parameters of water masses bathing (living) CWC in the Strait of Yucatan (Campeche Bank), on the

West- to Southwest-Florida Slope, in the Florida Straits and along the Great Bahama Bank. Moreover, we wanted to get an overview of the variability of water masses in the ultimate vicinity of these CWC habitats in space (locally-regionally) and time (tidal cycles). Bottom water samples were taken at all localities to get an overview of the geochemical characteristics of these water masses. In addition, sound velocity data were provided for hydroacoustic mapping (see chapter 5.2.3).

5.3.2 Sampling and methods

The CTD profiler used during MSM 20-4 was a Seabird "SBE 9 plus" underwater unit and a Seabird "SBE 11plus V2" deck unit. Additionally, it was equipped with two dissolved oxygen sensors, a chlorophyll-a sensor and a Seabird bottle release unit including a rosette water sampler. For the analysis and interpretation of the measurements, the downcast raw data were processed with "SBE Data Processing" software. For the visualisation of the data we used "Ocean Data View (mp-Version 3.3.2)". Measured O_2 values were verified by using the Winkler titration method (Winkler, 1888). We performed single casts, one transect, and three Yoyo-CTDs with repeated casts over 13 hours covering one complete tidal cycle. A total of 49 CTD profiles were measured during the cruise. In addition, we received bottom water samples collected during the ROV dives in close vicinity to living CWC.

5.3.3 Shipboard Analyses

5.3.3.1 Seawater Oxygen Analyses

The measurements of the CTD oxygen sensors were validated on board with water samples by iodometric WINKLER-Titration after Grasshoff (1983). The measurements were performed on all 49 CTD casts. Water samples were taken during upcasts only. When a designated sampler bottle was released, the oxygen sensor readings were noted and later compared to the titration results. Immediately after collection, the water samples were filled into volume-calibrated WINKLER-bottles. Two parallel samples were taken, and we paid particular attention of not having any air in the WINKLER-bottles. The oxygen was fixed with 0.5 cm^3 manganese-II-chloride and 0.5 cm^3 alkaline iodide. Then the bottles were shaken and stored cool for several hours. Before titration, the manganese hydroxide was solved with 1 cm^3 H_2SO4 (9M) and the bottles were shaken again. The samples were each transferred into a 250 ml beaker, where they were titrated with 0.02 M sodium thiosulfate until the solution turned into yellow. After adding 1 cm^3 of zinc iodide solution, the titration was continued until the blue colour of the sample disappeared. The factor of the thiosulfate solution was determined with a standard, which was performed after each CTD station. The oxygen content was calculated from the thiosulfate consumption by using the following standard formula:

$$O2 = (a * f * 0.112 * 103) / (b-1) \text{ [ml/l]}$$

where a is the consumption of thiosulfate solution [ml], b is the volume of the WINKLER bottle [ml], and f is the factor of the thiosulfate solution. A total number of 42 titrations were performed. The oxygen contents range from 5.14 to 2.42 ml/l. The accuracy of our titrations is 0.5%, which is in the range of values reported in the literature (0.06 to 0.89 %; Furuya & Harda, 1995). The two oxygen sensors of the CTD, however, recorded different oxygen contents at shallow depths (<400 m). The comparison of sensor readings and titration results revealed that sensor no.1 indicated completely wrong oxygen values (Fig. 5.3). Therefore, we used only data obtained by sensor no. 2.

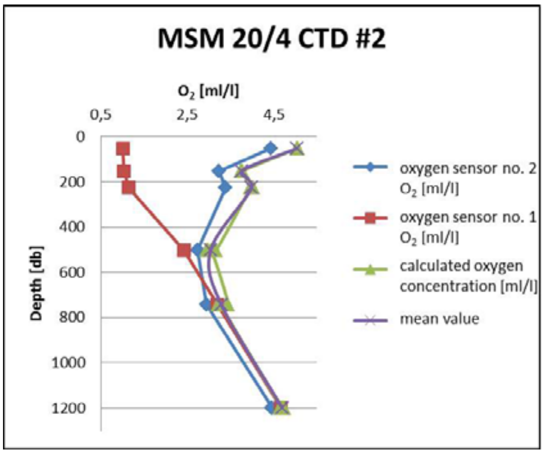


Fig. 5.3
WINKLER calibration of the two oxygen sensors, showing a great offset in shallower water depths between sensor 1 and sensor 2.

5.4 Sediment Sampling Gear and Sample Treatment

(Claudia Wienberg, Dierk Hebbeln, Klaus Dehning, Marco Klann, Maik Wilsenack, Nina Joseph, Lelia Matos, Hector Reyes, Marco Taviani)

5.4.1 Grab Sampler

For qualitative samples of surface sediments and benthic fauna a Van-Veen-type grab sampler was deployed at a total of 20 stations, of which 13 deployments (65%) were successful. The grab samples were photographed and the sediment and faunal composition briefly described. Living fauna was fixed in 95% ethanol or seawater (6-8°C). The entire sample was washed through sieves of 5 mm, 2 mm, 1 mm, and 0.5 mm mesh sizes and dried. The sieving residue meta data were documented on board within the "SaM-Archive" data base. The sieving residue itself will be stored at SaM in Wilhelmshaven, and provided on demand for further taxonomical analyses.

5.4.2 Box Corer

A giant box corer was the main sampling tool for undisturbed surface sediments during R/V MARIA S. MERIAN cruise MSM 20-4. The box corer had a diameter of 50x50 cm and a height of 55 cm. The box corer was deployed at a total of 25 stations, of which 15 deployments were successful (60%), although 6 of them were disturbed or comprised very small samples, thus standard sampling was not possible. Ten deployments did not release or the box was empty. The following standard sub-sampling scheme was conducted on each successfully recovered box core:

a) Rinsing of the super-standing water to sample the living fauna. Water sampling (GEOMAR).
b) Photography and description of the sediment surface and column.
c) Collecting of living fauna and fixation in 95% ethanol or seawater (6-8°C).
d) Surface sediment sampling (0-1 cm; defined volume of 50 cm^3) for further grain size (MARUM) and foraminifera analyses (SaM).
e) Sampling of the sediment column by 2 archive cores (12 cm in diameter) (MARUM, SaM).
f) Sampling of bulk sediments (SaM, RSMAS, UABCS).
g) Sieving of the remaining sediment column over four sieves of 5 mm, 2 mm, 1 mm and 0.5 mm mesh size to collect corals fragments, shells and shell debris. Fragments were dried, living organisms fixed in 95% ethanol or seawater (6-8°C). These samples will be used for component analyses and taxonomic studies. Living CWC fragments will be used for genetic studies (SaM), fossil coral fragments will be used for geochemical (GEOMAR) and dating analyses (MARUM).

h) Documentation of the sieving residue meta data within the "SaM-Archive" data base. The sieving residue itself will be stored at SaM in Wilhelmshaven, and provided on demand for further taxonomical analyses.

5.5.3 Gravity Corer

A gravity corer with a pipe length of 6 or 12 m and a weight of 1.6 tons was applied to recover long sediment sequences. Imprints of the manufacturer along the plastic liners were used to retain the orientation of the core. Once on board, the sediment core was cut into 1-m-sections, closed with caps on both ends and labelled according to a standard scheme (Fig. 5.4).

During MSM20-4, the gravity corer was used at 24 stations (16x equipped with 6-m- and 8x with a 12-m-long core barrel). Seventeen coring attempts were successful (70%) with sediment recoveries between 0.53 and 10.60 m resulting in total core recovery of 61.76 m. One off-mound core (GeoB 16320-2) was opened on board, described and photographed. The remaining off-mound cores (GeoB 16363-3, GeoB 16384-1) and all coral-bearing sediment cores will be opened back in the institute. The latter will be scanned by computer tomography before opening. All sediment cores collected during cruise MSM20-4 will be transported to Bremen and stored in the MARUM core repository at the University of Bremen. The sediment cores will be opened, described, and photo-scanned, and further analyses will be done after the cruise at the home laboratories of the participating institutes.

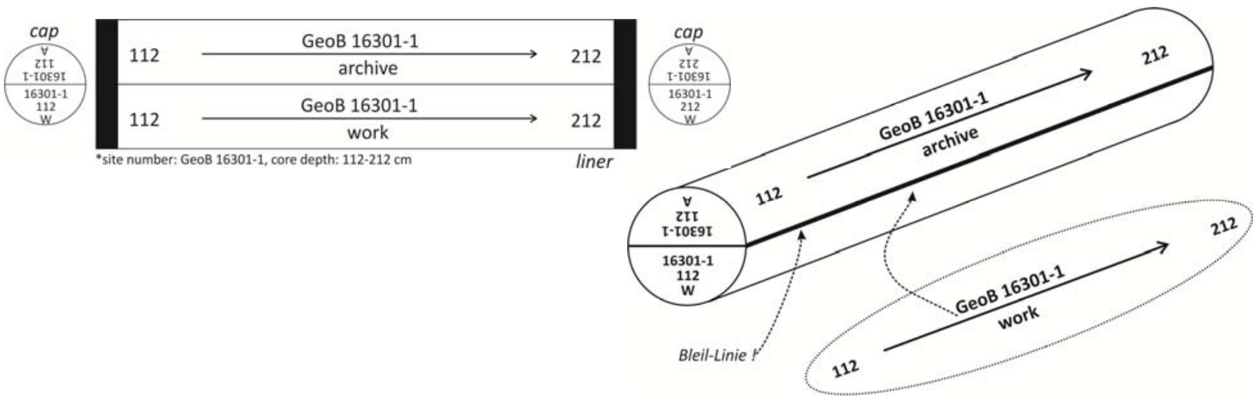


Fig. 5.4 The core segments were closed with caps on both ends and labelled according to a standard scheme for GeoB cores of the MARUM.

5.5. MARUM-CHEROKEE ROV

(ROV-Team: Nico Nowald, Götz Ruhland, Klaus Dehning, Maik Wilsenack, Marco Klann; Observations: André Freiwald, Lydia Beuck, Claudia Wienberg, Dierk Hebbeln)

The MARUM-CHEROKEE is a 1,000 m depth rated, mid-size inspection class ROV, manufactured by Sub-Atlantic, Aberdeen. It is operated by MARUM since 2001 and was adapted and improved for scientific use. The ROV has already been deployed on 24 expeditions with a total of 123 dives.

System description - The ROV system consists of three major components: the vehicle, the winch, and the topside control unit.

Vehicle - Vehicle dimensions are 130 x 90 x 90 cm and the total weight in air is 450 kg. The system is electrically propelled by four axial thrusters and power consumption is around 12 kW. Three 230 VAC dimmable LEDs, provide a total light power of 1500 W. For scientific observation, three cameras are installed on the ROV. The main camera is a Tritech Typhoon

PAL colour zoom camera, mounted on a Pan & Tilt unit. One static DSPL Multisea Cam is overlooking the area directly in front of the ROV, and still images are taken using a KONGSBERG OE-14 5 Megapixel camera, also mounted on the vehicle´s Pan & Tilt unit. The Pan & Tilt unit is additionally equipped with a pair of lasers for size measurements of objects on the seafloor (distance between laser points: 16.5 cm). For obstacle detection, a Tritech Seaking dual frequency sonar is mounted on the port side of the vehicle. It displays an acoustical real time image on the topside sonar PC. The sonar operates at 325/675Hz with a maximum scanning range of 300 m. Navigational devices such as compass, altimeter and depth sensor are parts of the basic sensor package on board the ROV. Two serial links are available on the vehicle in order to connect external sensors. The Hydro-Lek HLK-EH-5 is a non-proportional, 5-function manipulator, powered and controlled by a combined hydraulic pressure pump and 6 station valve pack. Operating pressure is 130 bar and lifting capacity is 25kg. Part of the hydraulic system is the toolbox, which is used for storing samples and/or mounting sampling tools.

Winch - The spooling winch is an MPD, Aberdeen custom design winch, carrying approx. 1000 m umbilical. Overall weight of the winch, including the umbilical, is 1.8t. The supply cable (umbilical) contains 20 electrical conductors providing electrical power and telemetry. One Multimode fibre is used for 4 x video and 4 x RS232 serial channels.

Topside Control Unit (TCU) - The TCU consists of three cases, that are placed in the ship´s laboratory. Two cases are equipped with monitors to display the vehicles camera signals, the navigation and sonar software. The third case is a 19” rack that contains PCs, video recorders, control and monitoring panels.

Deployments - During cruise MSM 20-4, 16 scientific and one test dive were carried out with the MARUM-CHEROKEE ROV. The system was operating in water depths between 500 and 700 m and spent 45 hours on the seafloor for video observation and sampling. During bottom time, videos and minifilm framegrabs of the two main cameras were recorded, resulting in 90 hours of video footage and more than 300,000 single framegrabs. A total of 81 seafloor samples such as living corals and coral rubble were collected with the vehicles manipulator. The still image camera acquired a total of 1,408 high resolution pictures.

6 Preliminary Results by Region

6.1 The North-eastern Slope of the Campeche Bank off the Yucatan Peninsula

6.1.1 Campeche Bank: Overview

(Dierk Hebbeln)

In 1979, a report about findings of CWC from the margin of the Campeche Bank, NW of the Mexican Yucatan peninsula, was published (Cairns, 1979) describing the occurrence of the CWC *Madrepora oculata* based on a single dredge haul. In 2009, R/V METEOR visited this area and discovered conspicuous “mound-like” structures at the seafloor (Hübscher et al. 2010, Schönfeld et al., 2011), that occur in water depths between 500 and 600 m and reach heights of up to 40 m. It has been speculated that these might be CWC mounds, but no groundtruthing was available. This information stimulated the survey conducted during this cruise.

Situated at the edge of the Yucatan Channel, this working area is characterised by high current velocities of up to 3 kn making ROV operations as well as most sampling gear operations a challenging task. Although the manoeuvrability of the ROV was limited while being at the seafloor – as to expect under such vigorous current conditions – high quality video material could be recorded, showing an amazing CWC ecosystem. The detailed MBES mapping reveal that these CWC ecosystems are developed on V-shaped ridges - rather than on mounds - that stretch over several hundreds of metres (Fig. 6.1). The ridges are embedded between a steep slope towards the Campeche Bank in the west and a major drift sediment body in the east (as already described by Hübscher et al., 2010). They follow the main current direction towards the NW. In addition, a second orientation becomes evident with ridges stretching towards the NE. Often both directions are merged thereby forming the V-shaped ridges pointing with the tip to the NW. During the ROV dives, it has been observed that the morphology of these ridges is mostly rather steep with differences between ridge crests and bases of up to 30 m. Living corals occur at the highest parts, followed downslope by a zone of coral rubble and by plain soft sediments in the lower parts of the ridges and in between them. An overview map of the Campeche Bank working area with all the sampling stations is given in Fig. 6.1.

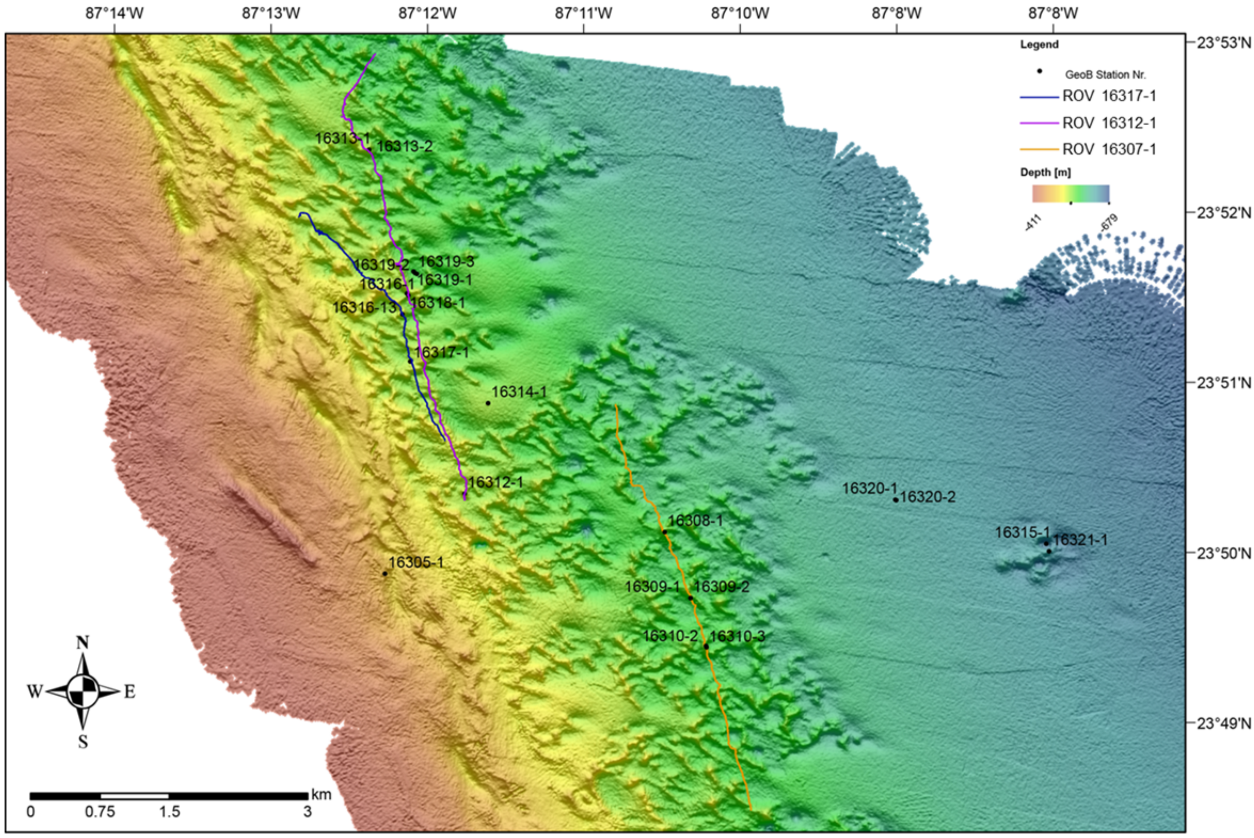


Fig. 6.1 Overview map of the Campeche Bank working area showing all sampling sites and ROV dive tracks (GeoB station Numbers are indicated) conducted during cruise MSM20-4.

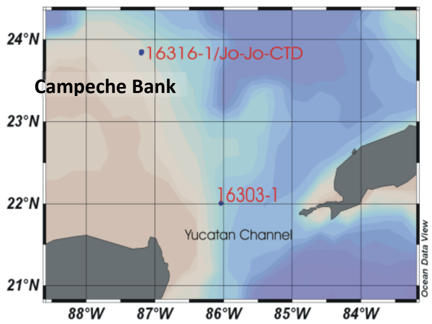
6.1.2. Campeche Bank: The Water Column Structure

(Christian Dullo, Thorsten Garlichs, Silke Glogowski)

In the Yucatan Strait (GeoB 16303), the uppermost 70 m of the water column is characterized by the occurrence of relatively fresh water with salinities less than 35.89. This shallow water mass is called Caribbean Water (CW) and believed to be a mixture of the Amazon and Orinoco River outflow, as well as North Atlantic surface water. A salinity maximum (about 36.9) between 100 to 135 m has been measured and is characteristic for the Subtropical Under Water (SUW). This water mass is formed in the central tropical Atlantic, where evaporation exceeds precipitation. It is found almost in the entire Caribbean region. Further below, around a water depth of 725 m, a salinity minimum of 34.9 is found. It is attributed to the Antarctic Intermediate Water (AAIW) that is characterized by its low salinity and high oxygen-content. (Fig. 6.2)

Living corals on the Campeche Bank were found in water depths around 560 m. The density of the surrounding water mass measures 27.29 kg.m^{-3}, which is 0.06 sigma theta units below the density envelope being characteristic for flourishing *Lophelia* reefs along the East Atlantic margin. It is interesting to note that higher densities occur on the Campeche Bank in shallower depths in comparison to the Yucatan Strait (Fig. 6.2).

A Yoyo-CTD covering a complete tidal cycle was performed on a site with living CWC. The data shows extremely small variations, which mainly occurred in water depth between 200 and 400 m but not in the bottom waters. We believe that the strong currents with speeds up to 170 cm sec^{-1} measured in the Yucatan Strait (Gyory et al. 2005) obscure any tidal signal.



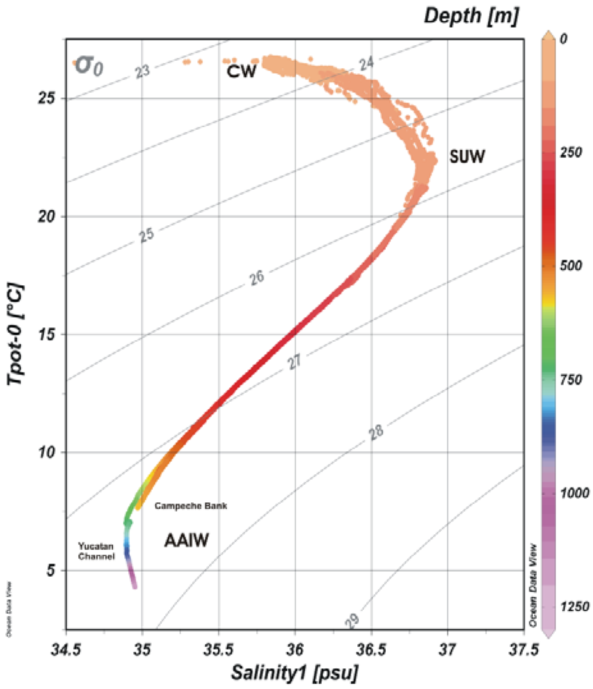


Fig. 6.2
Water mass structure of the Yucatan Channel and NE Campeche Bank. Shown is a Temperature (potential temperature Tpot)-Salinity plot from station GeoB 16316 (Yoyo-CTD) and GeoB 16303 also indicating the density (σ) of the water. CW Caribbean Water, SUW Subtropical Underwater, AAIW Antarctic Intermediate Water.

6.1.3 Campeche Bank: Bathymetry and Sub-Seafloor Structures

(Gregor Eberli, Paul Wintersteller, Dierk Hebbeln)

The Campeche Bank consists of an active shallow-water area and a northern shelf that is the submerged remnant of a larger bank that drowned in the Mid-Cretaceous (Schlager, 1981). The submerged area is bound to the north and east by the Campeche Escarpment (Schlager, 1991). The working area is located on this deep shelf.

While approaching the working area from the Yucatan Straits, bathymetry and sub-bottom profile were recorded in a transect across the submerged shelf. The average water depth of the recorded transect is around 400 m. The sub-bottom profiles display dipping reflections that are often truncated at the water-sediment interface. Similar truncations are also observed further down the section. In some areas the seafloor has a knobby appearance formed by 5-10 m high, coalesced hills that might be low-relief CWC mounds (Fig. 6.3). The 180 km^2 bathymetry map of the working area displays three distinct morphologies (Fig. 6.4). The western portion is a nearly flat area in ~450 m water depth (Fig. 6.4). A distinct edge separates this flat area from a gently sloping surface to the east. The first 3-5 km of the dipping slope east of the edge are covered by 20-40 m high, linear and steep-sided ridges that vary in length between 500-1000 m and trend in two directions; one is from NNE-SSW and the other NNW-SSE. The ridges often start at the same point, producing a series of V-shaped ridge sets. CWC form these ridges and ridge sets (see below). Interspersed between the ridges are smooth sediment bodies of 1-2 km diameter with similar thickness as the ridges (Fig. 6.5). These sediment bodies are steep-sided and often form a moat between the ridges (Fig. 6.6). Further to the east, the ridges give way to the smooth sediment cover that gently dips eastward.

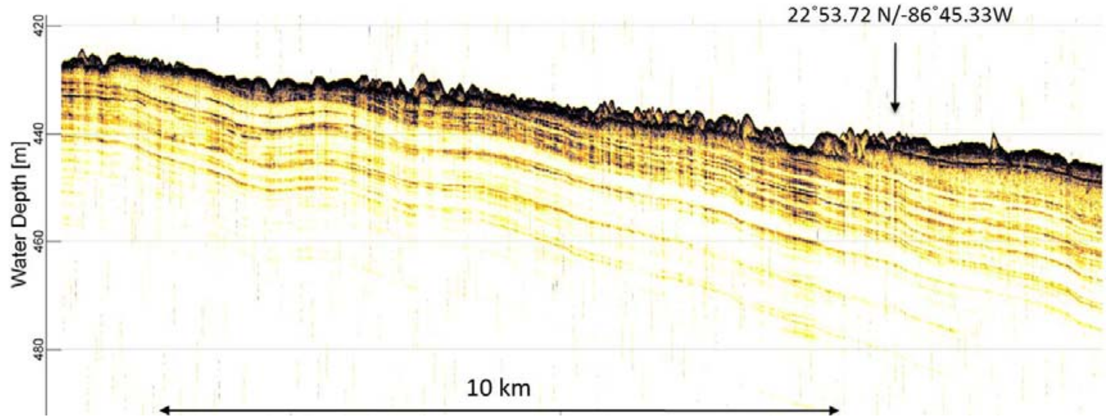


Fig. 6.3 PARASOUND profile across portion of the shelf north of Campeche Bank displaying eastward dipping seismic reflections that are truncated close to the sediment water interface. The unconformity is masked by extensive small transparent mounds.

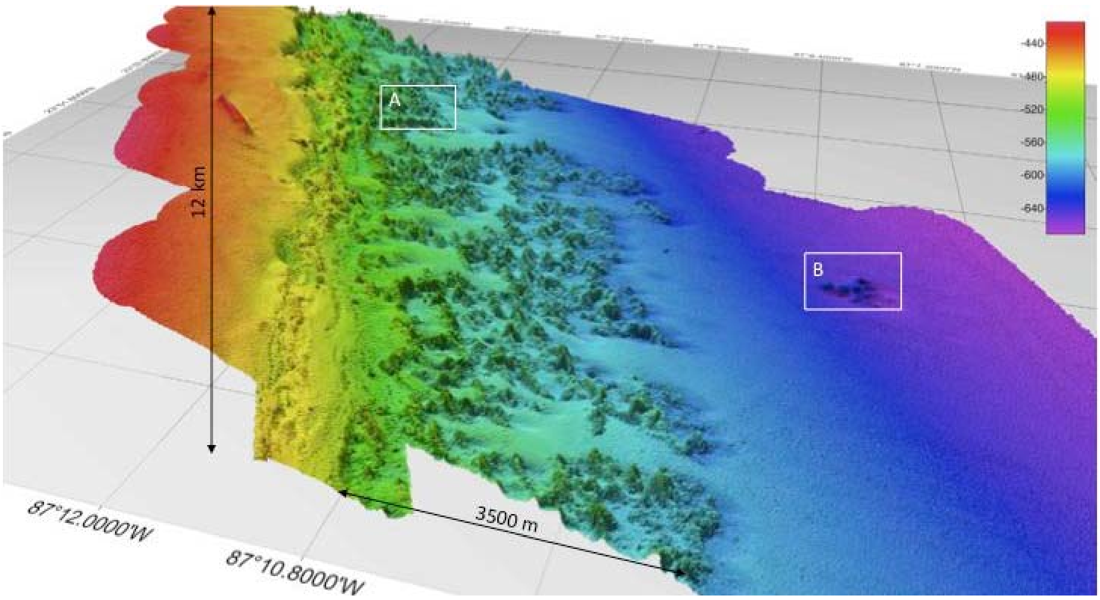


Fig. 6.4 Oblique view (towards the north) of the Campeche Bank working area displaying the near flat submerged shelf and shelf edge with the adjacent slope that is covered by coral mounds and further down-slope by fine-grained sediment. Inset A is a coral ridge location visited by the ROV and sampled. Inset B shows the two holes within the sediment cover that were sampled with the giant box corer.

The PARASOUND data display a different seismic facies for each of the three morphologies (Fig. 6.5). The flat area is characterized by a strong top reflection(s) and a mostly transparent seismic facies below. It reflects the cemented nature of this part of the shelf. The strong reflection can be followed underneath the sediment bodies and the ridges of the sloping area, indicating that it is the base of the coral mounds. The ridges show little to no internal layering and are often transparent. The lack of a strong top reflection indicates little or no cementation of the R/V MARIA S. MERIAN mounds. The mounded external geometry and a series of continuous seismic reflections of sediment bodies between and east of the mounds show characteristics of drift deposits (Hübscher et al., 2010).

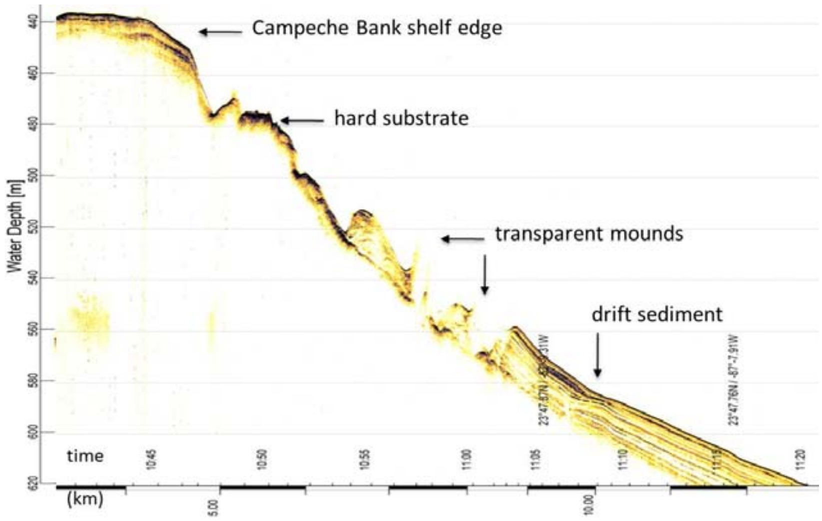


Fig. 6.5
PARASOUND dip profile across the Campeche Bank shelf edge and the adjacent slope illustrating the seismic facies of hard shelf strata, the CWC mounds and the drift sediment.

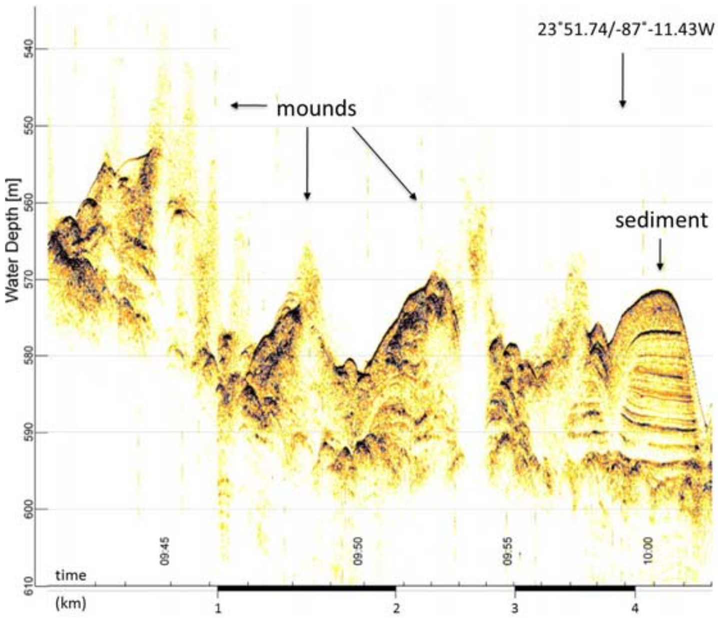


Fig. 6.6
Portion of a PARASOUND strike line through the CWC mound ridges and the interspersed sediment bodies. The mounds are seismically chaotic to transparent. The sediment bodies are also mound-like with steep sides that lead into a moat.

In summary, the seismic and bathymetry data reveal that the investigated CWC mound field on the Campeche Bank has its foundation on a cemented slope of unknown age. It developed between and west of drift deposits. CWC mound growth in the field is bidirectional that result in a series of V-shaped ridge sets. Approximately 50 km^2 of the mound field was mapped but the northern and southern limits are not known.

6.1.4 Campeche Bank: ROV Observations

(André Freiwald, Lydia Beuck, Claudia Wienberg, Dierk Hebbeln, Nico Nowald, Götz Ruhland)

The CWC mounds in this area were selected as the prime target for three ROV dives in this area: GeoB 16307, 16312 and 16317 (Fig. 6.1). These dives revealed that individual mounds gently emerge from the mud-draped seabed and become increasingly denser littered with pale-brown stained coral branches upslope. The coral fragments represent broken branches of *Enallopsammia profunda* colonies, locally admixed with *Lophelia pertusa* fragments (Fig. 6.7a). Dislocated *Enallopsammia* colonies, partly alive in the upper 10 cm of the colony, drape the midslope flanks of the mounds (Fig. 6.7b).

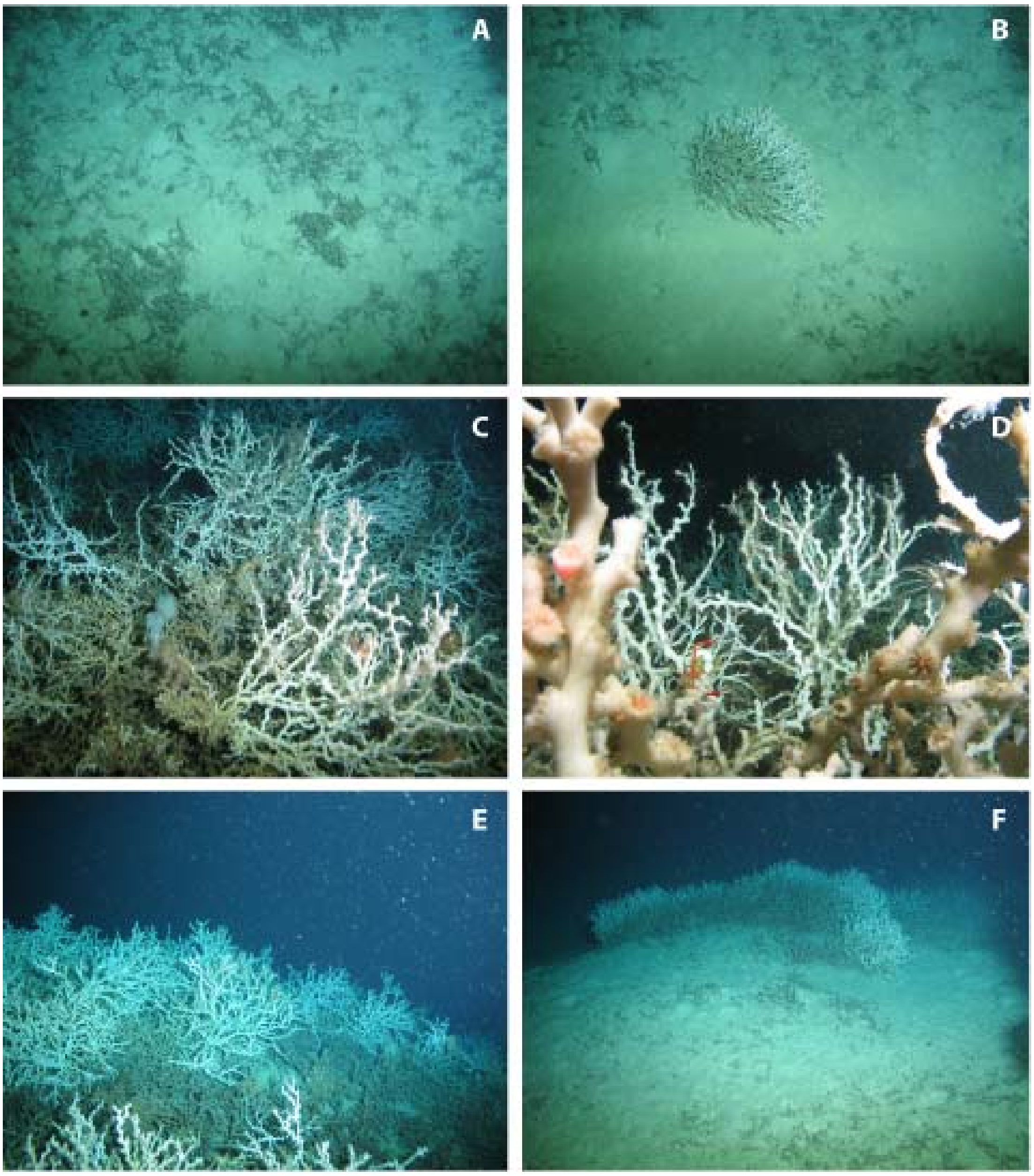


Fig. 6.7 **A** Lower mound flank with dispersed fragments of *E. profunda*. **B** Displaced but still alive colony of *E. profunda*. **C-E** Mound tops with a characteristic dense colonization of *L. pertusa* forma *brachycephala*. Note the hexactinellid sponges in **C**. **F** Arcuate *E. profunda* thicket on a low-relief mound or sediment drift body.

Colonies of *E. profunda* merge to dense thickets but they hardly form rigid frameworks as their branches grow in all directions and secondary fusion with adjacent branches was not observed. This open-spaced growth habit (Fig. 6.8a) facilitates the disintegration of individual branches into saltstick-like fragments. The near summit areas and the summits of the mounds are dominated by *L. pertusa* (Fig. 6.7c-e). The coral thicket framework can attain heights of up to 0.5 m and the living zone of the colonies is 20-30 cm thick (Fig. 6.8b).

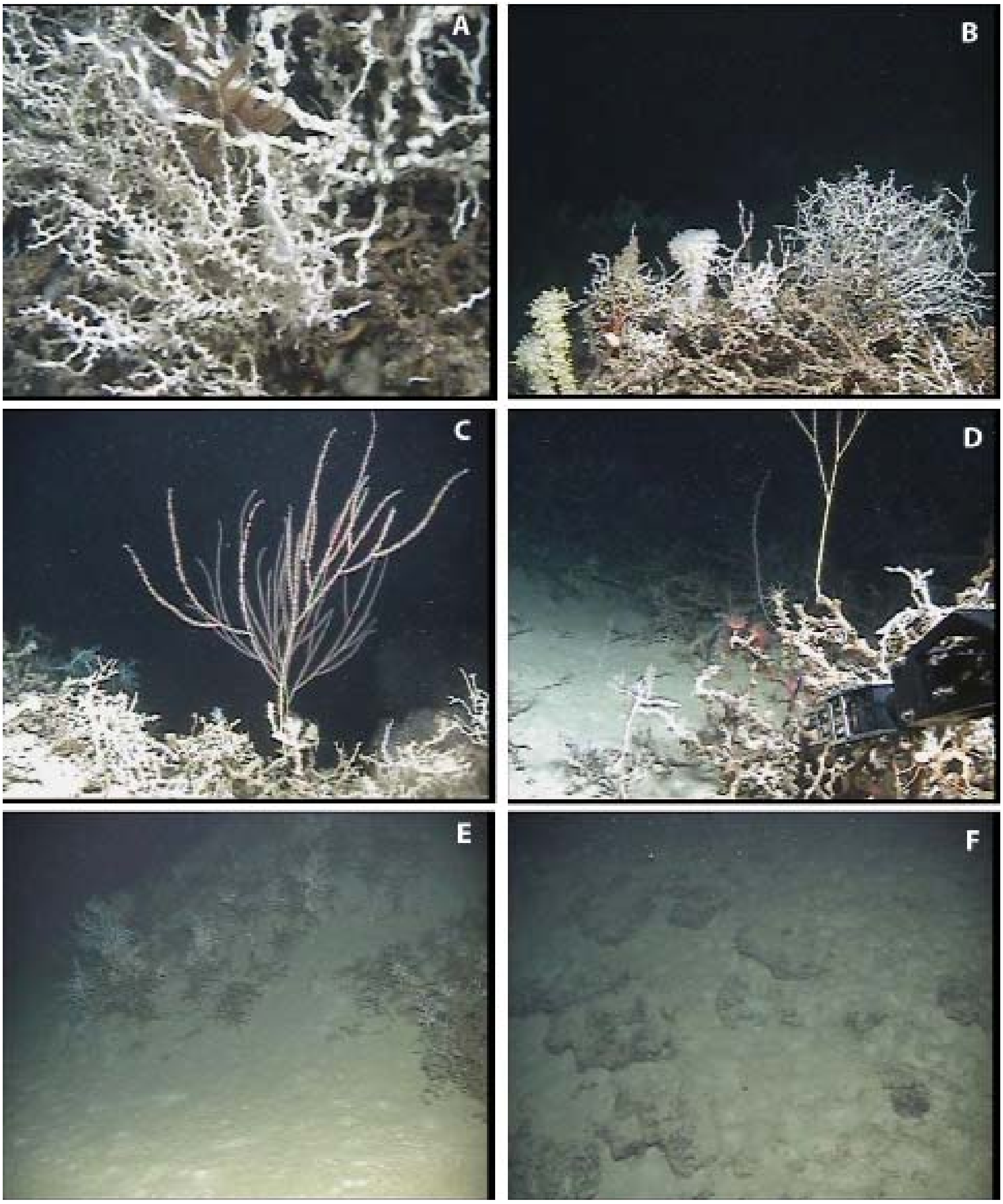


Fig. 6.8 **A** Ensemble of the fragile *E. profunda* and the *brachycephala* morphotype of *L. pertusa*. **B** Live and dead coral framework with *Aphrocallistes* sp. and *E. picta*. **C** Colony of the common isidid coral. **D** Sampling of a dead isidid stem with dead *Lophelia* framework. **E** Sudden facies change from the flat mud plain to the steeply inclined coral mound facies. **F** Outcropping carbonate crusts on the lower current-exposed flank of a coral mound.

Mobile organisms use the living zone as an elevated feeding area to have a better access to the by-passing plankton food. Organisms following this strategy are stalkless crinoids (see Fig. 6.8a), the squat lobster *Eumunida picta* (Fig. 6.8b) and *Bathynectes longispina*. *Gracilechinus* sp. again was observed as a common grazer on living corals. Preferably on the mound tops, the dead and exposed coral framework is colonized by *Aphrocallistes* sp. (Fig. 6.8b) and several other sponges. Locally, isidid colonies use the same niche (Fig. 6.8c-d).

As for *E. profunda* also *L. pertusa* shows an open-spaced growth habit. The branches are thickly calcified with individual corallite lengths of 2.5-3.5 cm, a morphotype for which the term *brachycephala* (Fig. 6.8a) was introduced by Cairns (1979) and which is characteristic for – at least – the northern Gulf of Mexico (Brooke & Young 2009). Some low-relief mounds are colonized by arcuate galleries of *E. profunda* colonies (Fig. 6.7f). It is possible that these structures represent sedimentary drift bodies which formed leeward of larger coral mounds and the coral took advantage of the antecedent topography to settle on their preferred elevated positions. The slope inclination of the rhomboid-shaped coral mounds is with 35 to 45° relatively steep (Fig. 6.8e). One coral mound flank shows exhumed carbonate crusts with irregular upper and lower surfaces (Fig. 6.8f). All in all, the seabed facies and coral habitats resemble those from the previous dive. The coral mounds locally show a series of furrows and coral-covered ridges on top of the mound flanks (Fig. 6.9a).

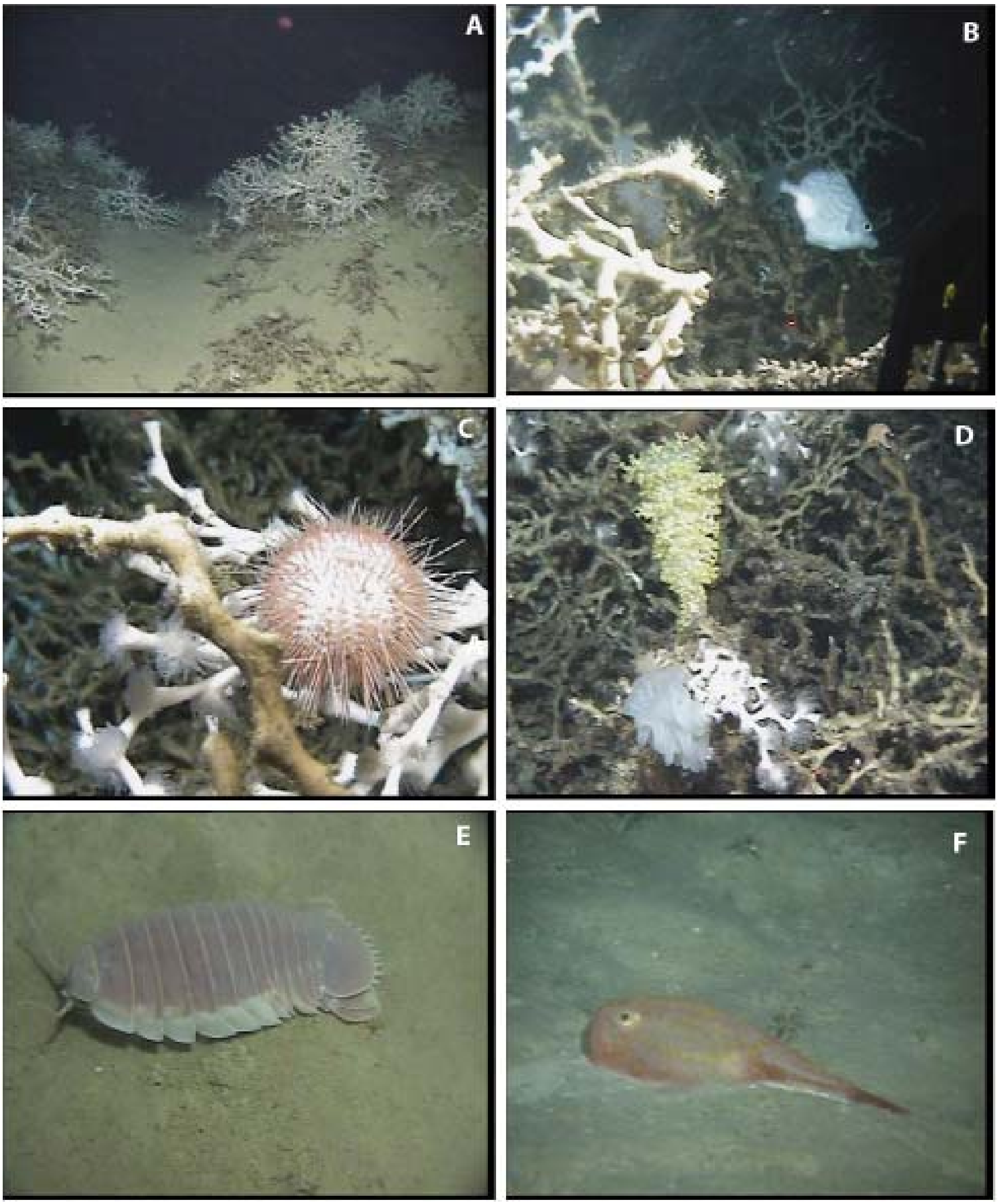


Fig. 6.9 **A** View on a ridge-and-furrow system on the flanks of some coral mounds. **B** Perciform fish swimming between the coral colonies. **C** Grazing of living corals by *Gracilechinus* sp. **D** *Aphrocallistes* sp. infested by a yellow actiniarian. **E** Large isopod (17 cm long) on the mud plain. **F** *Chaunax suttkusi* lying on the mud seabed.

The coral-associated community is quite diverse in the smaller macrofauna scale. We observed several species of hexactinellid sponges, including *Aphrocallistes* sp. and many terebratulid brachiopods attached to the dead coral framework. We encountered many *Aphrocallistes* sp. that are densely colonized by a yellow actiniarian (Fig. 6.9d). Such a hexactinellid sponge-actiniaria interaction has been observed in the Rockall Bank and Porcupine Bank coral mounds as well. In places, isidid octocorals occur in small groups near the summit of some MSCs. Gorgonian corals are extremely rare. Other cnidarians are hydroids, actinoscyphid fly-trap anemones, isidid bamboo corals and solitary scleractinian corals. Bryozoans form a major component of the attached fauna. Crustose anemones seem to compete successfully with living *L. pertusa*. The motile coral community consists of squat lobsters (among them *Eumunida picta and Bathynectes longispina*), sea urchins (*Gracilechinus* sp., *Cidaris* sp.), asteroids (rare) and crinoids (rare). Grazing of living corals by *Gracilechinus* sp. is also a common biologic interaction in this dive area (Fig. 6.9c). The corallivore muricid *Coralliophila richardi* was found and sampled in situ grazing on the biofilm underneath the coral tissue zone. Only few fishes were encountered within or close to the coral framework, among them a bythidid, a red-coloured fish and a spiny eel. More common in the coral framework are *Helicolenus dactylopterus* and *Nettenchelys exoria*. Perciform fishes, probably belonging to the Caproidae swim around some coral colonies (Fig. 6.9b). Apparently, only few tube-forming eunicids were detected or collected in the coral habitat. This is in great contrast to the NE Atlantic coral sites. The seabed between the mounds is made of bioturbated muddy sand rich in pelagic components such as planktonic foraminifers and pteropods. The fine-grained deposits are mottled by tube-forming polychaete fields, by large astrorhizid foraminifers and by various sorts of crustacean burrows. Lebensspuren, probably of gastropods are common in places. Of particular interest is the observation of an about 18-cm-long isopod that tries to escape from the ROV (Fig. 6.9e). Cerianthids (different species), pennatulaceans and stalked hexactinellid sponges stick out of the mud seabed as suspension-feeder (Fig. 6.10b). Amongst the fishes, *Laemonema* sp., *Chaunax suttkusi* (Fig. 6.9d), *Nezumia* sp., a Rajidae (Fig. 6.10a) and other yet not identified species were frequently encountered lying on the seabed or swimming close over it.

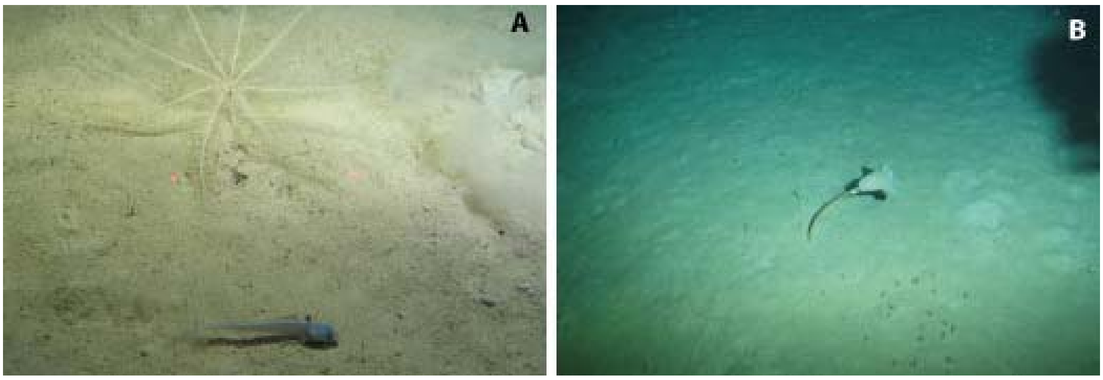


Fig. 6.10 **A** Sandy mud with an unstalked crinoid and *Nezumia* sp. **B** A stalked hextactinellid sponge safeguarded by a decapod crab.

6.1.5 Campeche Bank: Sediment Sampling

(Claudia Wienberg, Dierk Hebbeln, Nina Joseph, Lelia Matos, Hector Reyes, Marco Taviani, Klaus Dehning, Marco Klann, Maik Wilsenack)

The individual box cores collected from the CWC mounds and ridges largely consist of olive-brownish-greyish pteropod foraminiferal ooze and abundant CWC fragments (GeoB 16308-16310, 16313). The live fauna found in these box cores comprises crinoids, polychaetes, sponges, bryozoans, barnacles (attached to corals), brachiopods, echinoids, hydroids, foraminifera, and decapods. The fossil remnants comprise scaphopods, pteropods, gastropods, and bivalves. Two off-mound box cores (GeoB 16319, 16320) revealed a similar overall sediment composition (pteropod foraminiferal ooze), however, with a much reduced living and fossil fauna.

A peculiar feature detected on the detailed bathymetric map was a set of two "crater-like" structures slightly deeper than the belt of CWC mounds (Fig. 6.4). Due to the almost perfect circular structure of the central depressions of these structures encircled by a rim it has been speculated that they might represent a kind of seep structure. However, detailed PARASOUND imaging revealed that layered sediments continue beneath these structures and that they do not have any roots. POSIDONIA-controlled box core sampling of one of the central depressions (GeoB 16321) revealed a common regional hemipelagic sediment matrix with abundant CWC fragments. The observation that these fragments are the most abraded encountered in this region, might imply that these structures represent fossil CWC mounds, possibly related to a lower sea level in the past. Detailed descriptions of all box cores collected are given in Appendix 2.

For reconstructing the long-term development of CWC in the Campeche Bank area, three gravity cores were taken from the ridges with all of them containing abundant CWC fragments. The first site (GeoB 16310) was sampled twice as the first attempt with a 6-m-long core barrel suffered from significant over-penetration. During a second attempt using a 12-m-long core barrel a 10.6-m-long record was recovered. Two other cores resulted in 2.5-m (GeoB 16313) and 4.7-m-long (GeoB 16318) records of coral-bearing sediments. It needs to be noted that core GeoB 16313 penetrated much deeper into the sediment. However, regarding the rope tension record it appeared that a large part of the core has been lost when the corer was pulled out of the sea floor, probably because the sediment column disrupted beneath a semi-lithified horizon, which forms the lowest part of the retrieved record. Overall, the mounds along the Campeche Bank appear to represent typical coral mounds formed by CWC fragments embedded in a matrix of hemipelagic sediments.

In addition, three so-called off-mound cores were taken to retrieve undisturbed palaeoceano-graphic records to reconstruct regional palaeo-environmental changes in the past that might have controlled CWC development. The first site (GeoB 16319) was chosen in a “pool” between coral ridges. There a 7.9-m-long core was collected, however, which also contained individual layers of coral rubble. The second off-mound site (GeoB 16320) was located on the sediment drift just downslope of the coral ridges. The 4.4 m record revealed a rather fine grained white to light gray sediment matrix, mixed with varying amounts of foraminifera.

6.2 The West-Florida Slope

6.2.1 The West-Florida Slope: Overview

(Dierk Hebbeln)

For the West-Florida slope the existence of fossil CWC build-ups in water depths of ~500 m has been described by Newton et al. (1987), although their conclusion is based on one single dredge haul showing abundant fossil CWC fragments but no living specimens. During R/V METEOR cruise M78-1, a TV-sledge survey also revealed the occurrence of living CWC growing on a rocky surface, probably resulting from a major landslide (Hübscher et al., 2010).The MBES bathymetry map established during cruise MSM 20-4 revealed a number of mound and ridge structures in the area with heights of 10-20 m (Fig. 6.11). Similar to the TV-sledge observations by Hübscher et al. (2010), the ROV observations accomplished during cruise MSM20-4 revealed that (partly massive) carbonate rocks form a major element of these structures (see e.g. Fig. 6.16). The entire area lies beneath a major escarpment 50-70 m in height (similar to the situation off Yucatan) and it appears that at least some of these seabed structures are related to major landslides possibly originating from the escarpment. This interpretation is supported by PARASOUND data indicating the continuation of layered sediments beneath these structures.

Also on these structures vital CWC ecosystem were common. Not a single observed structure was barren of living CWC. At all visited sites these were accompanied by substantial amounts of coral rubble. Again, the living CWC ecosystem was always concentrated on the highest parts of the individual structures. Between the individual structures the mostly rather plain seabed was composed of rather coarse, sandy sediments. However, towards the major escarpment the CWC vanished although seemingly well suited living conditions exist there, especially along the exposed rocky escarpment. An overview about this working area with all sampling stations is given in Fig. 6.11.

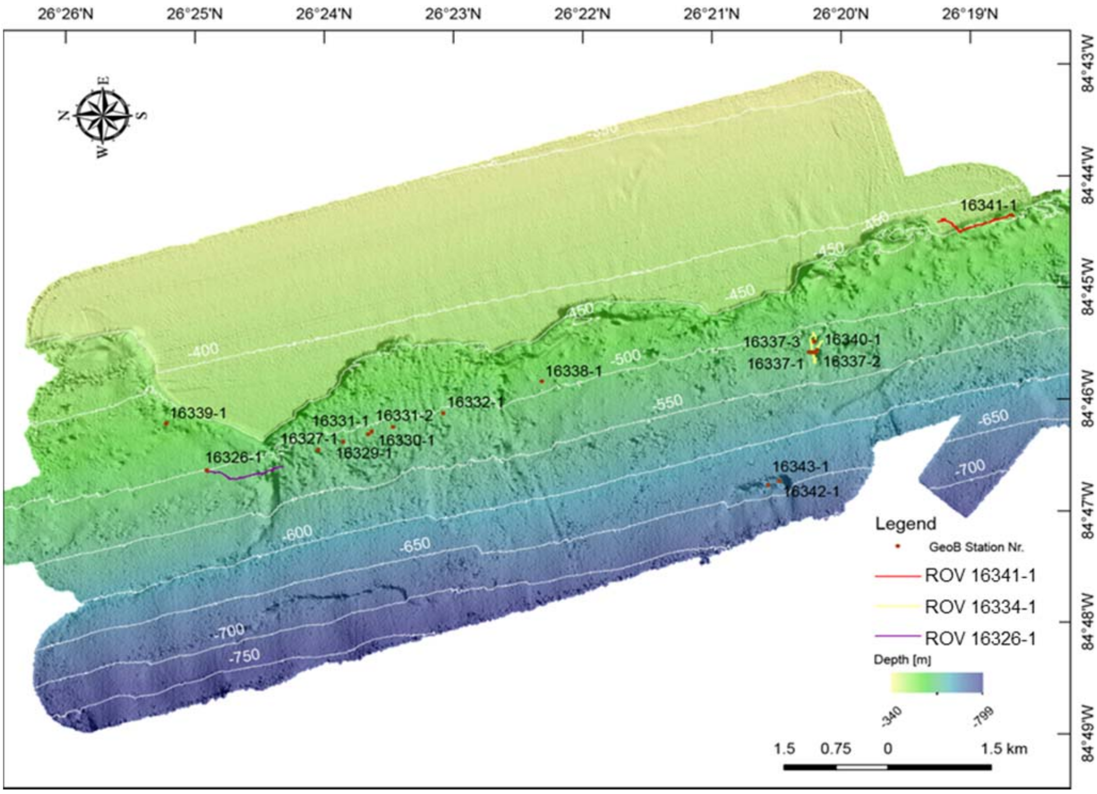
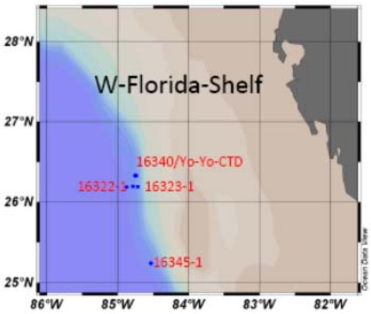


Fig. 6.11 Overview map of the West-Florida Slope working area showing all sampling sites and ROV dive tracks (GeoB station numbers are indicated) conducted during cruise MSM20-4. Slightly dipping flat strata at approximately 550 m water are eroded off along a rugged cliff of approximately 70 m height. West of the cliff the morphology steepens and in the inclined slope steep canyons run perpendicular to the shelf edge towards the Florida Escarpment further down slope.

6.2.2. The West-Florida Slope: The Water Column Structure

(Christian Dullo, Thorsten Garlichs, Silke Glogowski)

Off West-Florida the uppermost part of the water column down to 80 m comprises the shallow water mass of the Florida Shelf Surface Water (FSSW) with the lowest salinities around 34.14 shallower than 50-60 m. This water mass is characterised and influenced by the occurrence of relatively fresh water inflow of the Mississippi Water. Below 84 m (GeoB16322) salinities increase indicating the onset of the Subtropical Underwater (SUW). In a water depth of 110-120 m, a small step in reduced salinities of lowest 36.44 is found. This feature was described as a result of shelf break processes (He & Weissberg, 2003). The salinity maximum in the water column from 120-160 m ranges between 36.72 and 36.87 and is characteristic for the Subtropical Underwater (SUW) which reaches up north into the Gulf of Mexico. At water depths of 620-700 m, a salinity minimum of 34.90 is found. This is attributed to the Antarctic Intermediate Water (AAIW) that is characterised by its low salinity, its higher oxygen content, and its relatively cool temperature (Fig. 6.12).



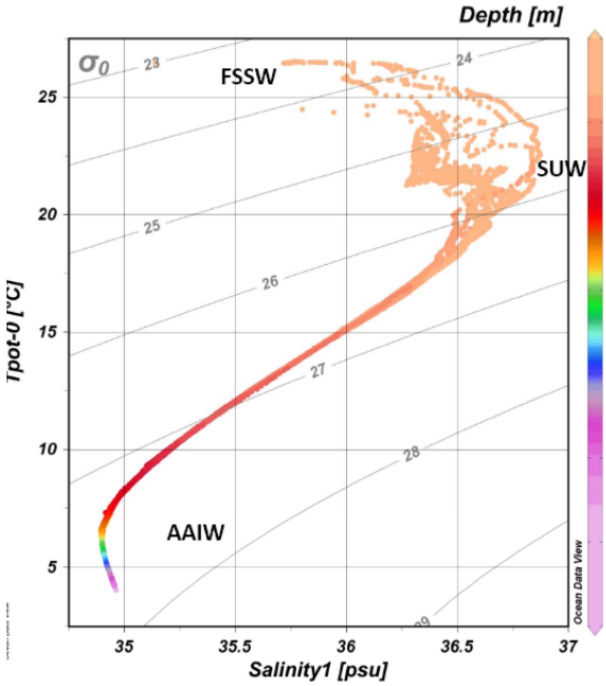


Fig. 6.12
Water mass structure of the West- and SW-Florida Slope. Shown is a Temperature (potential temperature Tpot)-Salinity plot also indicating the density (σ) of the water from stations GeoB 16340 (Yoyo-CTD), 16322, and 16323 off West-Florida, and stations GeoB 16344 and 16345 off SW-Florida. FSSW Florida Shelf Surface Water, SUW Subtropical Underwater, AAIW Antarctic Intermediate Water.

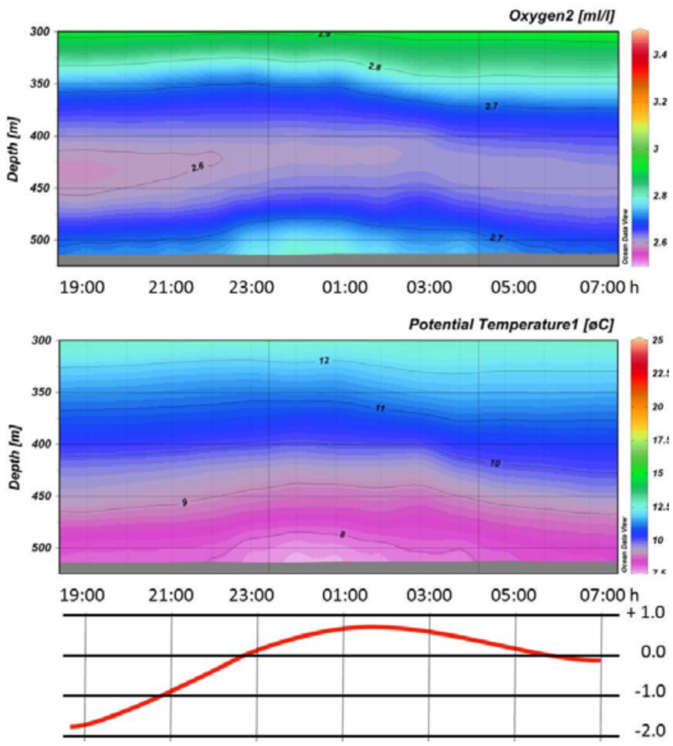


Fig. 6.13
Station GeoB 16340 Yoyo-CTD from 27. 3. to 28. 3.2012. All times are in EDT = UTC +5. At this locality the reduced temperatures during „high tide“ are clearly shown. Also we observed the increased oxygen value right through the deeper oxygen-rich water of SUW and the AAIW. The tidal cycle indicated in the lowest graph refers to Gasparilla, Florida.

Additionally, on the West-Florida Slope we performed a Yoyo-CTD on the site of living CWC (GeoB 16340) with repeated casts over 13 hours on the same position covering one tidal cycle from low tide to low tide. The tides off West-Florida exhibit an asymmetrical pattern. The results show distinct variations in almost all physical parameters (Fig. 6.13). We present variations in oxygen (ml/l) and potential temperature (°C) indicating cooler and better oxygenated waters during high tide between 23:00 and 3:00 EDT = UTC + 5.

6.2.3 The West-Florida Slope: Bathymetry and Sub-Seafloor Structures

(Gregor Eberli, Paul Wintersteller, Dierk Hebbeln)

The two working areas off Florida are situated on the horizontally layered but broken shelf edge of the Florida Shelf between the steep canyons that lead to the Florida Escarpment. The Florida Escarpment forms an impressive 3,000 m high near vertical cliff that exposes Cretaceous and Tertiary strata (Paull et al., 1990). The escarpment developed from a steep platform margin and the corrosive forces of brines seeping out of the base that dissolve the overlying strata, which causes margin collapse and retreat (Corso et al., 1988; Paull et al., 1984). Adjacent to these brine seeps faunal communities exist that are similar to vent communities (Paull et al., 1991).

The West-Florida working area was selected from coordinates provided on a map by Newton et al. (1987). It is located in ~450-600 m water depth just east of upwards narrowing canyons leading into more flat-laying strata. In many places these strata broke off and slid down over the escarpment leaving behind long, irregular cliffs of 50-70 m height (Figure 6.11).

In front of the cliff steep-sided, high-relief features are observed, which produce diffraction hyperbolas on the PARASOUND data. Pockets of soft sediment are interspersed between these high-relief features and sediment often covers the top of the cliffs (Fig. 6.14). This seismic image is reminiscent of the coral ridges and sediment bodies on the Campeche Bank slope. However, ROV observations revealed that these features are boulders and rocks occasionally colonised by corals, sponges and other marine life.

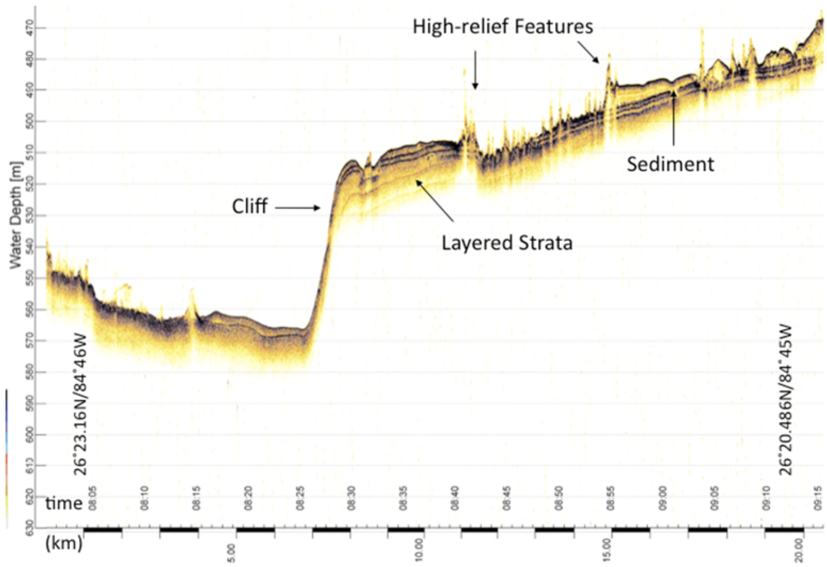


Fig. 6.14
PARASOUND line across the cliff in the West-Florida working area. The near-vertical cliff cuts into layered strata of unknown age. The high-relief features with diffraction hyperbolas above and in front of the cliff are boulders and rocks.

In search for coral mounds an exploratory survey to the northern boundary of the permit area was conducted along the 500 m contour. After stepping up over a cliff of 50 m, the seascape along the contour was smooth and the spikes besides the centre line of the EM120 multibeam data combined with the PARASOUND reflection pattern indicate a soft sediment cover.

Consequently the course was deviated to the west towards the escarpment but again the bathymetry map displayed no mound structures but an impressive canyon above the escarpment. As a result the area surrounding the first coral findings were mapped in detail.

During the transect to the second working area, which was approximately 100 km south, Multibeam and PARASOUND sub-bottom profiler data were collected. They document a seascape of cliffs and canyons and little sediment cover (Fig. 6.15). The cliffs have a similar morphological expression as the one in the northern working area with irregular edges and heights around 50+ m. They occur on several levels of the strata, indicating a repeated erosional process at the edge of the Florida shelf.

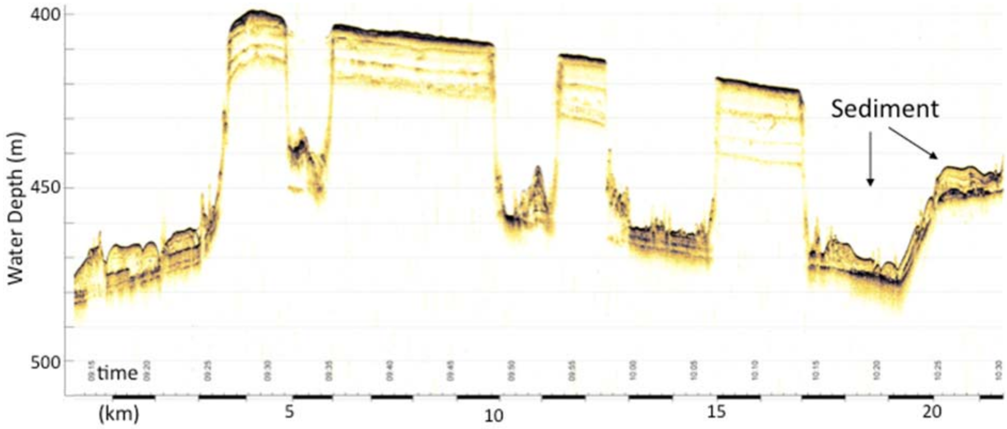


Fig. 6.15 PARASOUND profile through the rugged area off West-Florida. The layered strata of the Florida shelf is eroded off by slope failure that leaves behind steep-sided remnants. Boulder and rocks accumulate next the vertical cliffs and modern sediment is perched on some of the ledges.

6.2.4 The West-Florida Slope: ROV Observations

(André Freiwald, Lydia Beuck, Claudia Wienberg, Dierk Hebbeln, Nico Nowald, Götz Ruhland)

Numerous 5 to 10-m-high elevations and E-W-facing ridges stretch perpendicular from a 40-m-high escarpment (as e.g. seen in Fig. 6.14), suggesting downward transport of rocks and boulders from the hanging wall of the escarpment (see Fig. 6.11). Two ROV dives focussedg on these elevations in front of the escarpment at 520-500 m depth (GeoB 16326, 16334), whereas dive GeoB 16341 investigated the escarpment itself (Fig. 6.11).

The seabed beneath the escarpment is covered by a mixture of muddy to pure sand. The soft sediment is intensely bioturbated by fish and crustacean burrows. Locally, areas of weakly rippled sand with pteropod accumulations in the ripple troughs are present. The sediment-dwelling community consists of ceriantids, solitary scleractinian corals and denser patches of astrorhizid foraminifer threads. Remains of seagrass are present but in low proportions. The benthic mobile fauna consists of galatheid crustaceans, *Chaceon fenneri* and several shrimp species. The demersal fish community encountered comprise of *Polymixia lowei, Prionotus* sp., *Ophichthus* sp. (Fig. 6.16a), *Merluccius* sp., *Chaunax suttkusi* and a rajiid. The rugged seabed topography seen in the PARASOUND data (Fig. 6.14 and 6.15) is made of boulder fields consisting of several types of carbonate rocks such as arenaceous foraminifer packstones. Apparently, the boulders derive from the upslope escarpment and most likely represent a major slope failure. The seabed between the 5 to 10-m-high boulder ridges consists of sand and the corresponding soft bottom community as described above. The boulder substrate is utilised by larger hormatid anemones (Fig. 6.16b), stylasterids (Fig. 6.16b), several antipatharian species (incl. the spiral curled *Stichopathes* sp (Fig. 6.16b). White gorgonians (probably *Eunicella* sp.) and the characteristic *Plumarella* sp. are also present (Fig. 6.16c). Sponges are quite diverse but mostly with small and often thin crustose growth forms. Most prominent is *Aphrocallistes* sp., often fouled by the yellow actiniarian (Fig. 6.16d). Dead *Lophelia* framework and small rubble areas start at 512 m water depth and on the top of the boulder ridges occasional large *L. pertusa* framework with a living fringe can be seen (Fig. 6.16e). *Helicolenus dactylopterus* shows a preference for the boulder fields.

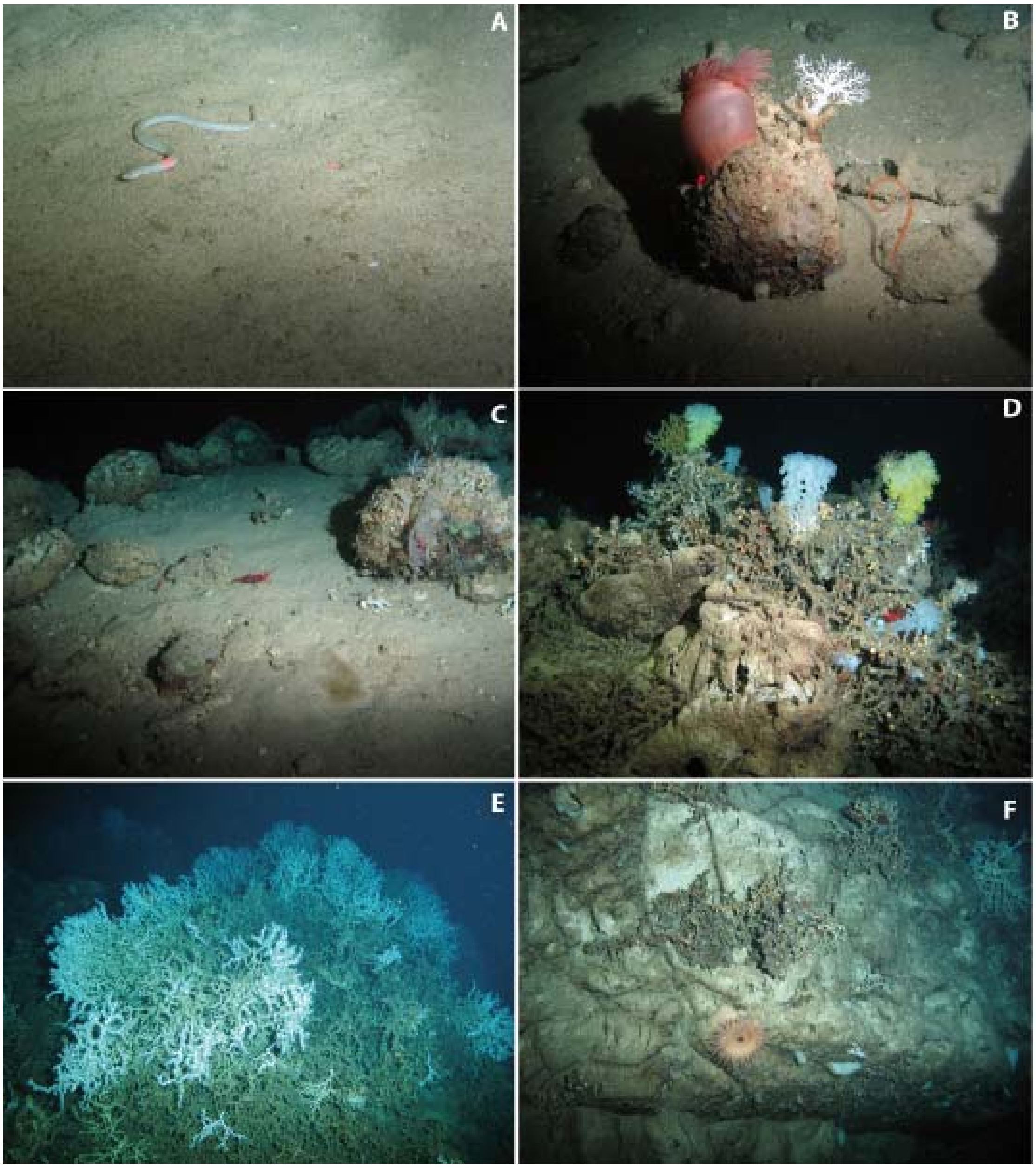


Fig. 6.16 **A** The snake eel *Ophichthus* sp. on the bioturbated sand facies. **B** Characteristic colonization of hard substrate in the boulder facies by anemones, stylasterids and *Stichopathes* sp. whip corals and white *Eunicella* sp. gorgonians. **C** Wider view on the strewn boulder facies with locally dense epilithic colonization. **D** An *in situ* dead *Lophelia* framework is utilized as habitat for a diverse community with *Aphrocallistes* sp., gorgonians (*Acanthogorgia* sp., *Eunicella* sp.) and solitary corals (orange spots) as the most prominent ones. **E** Huge *L. pertusa* framework with a living fringe of corals. **F** Outcropping rocks with ledges and overhangs are colonized by *L. pertusa,* sponges and hormatid anemones.

Closer to the big escarpment larger rock outcrops with stratified sedimentary units occur. The vertical rock walls show scattered colonies of live and dead *L. pertusa* and sponges (Fig. 6.16f). Some of these boulders of carbonate origin show signs of dissolution and intense bioerosion. Over larger areas, the seabed is diagenetically hardened with boulders strewn over it (Fig. 6.17a). The topographic highs turned out to be displaced boulder fields or olisthostromes densely overlain by coral rubble and dead coral framework (Fig. 6.17b, e-f).

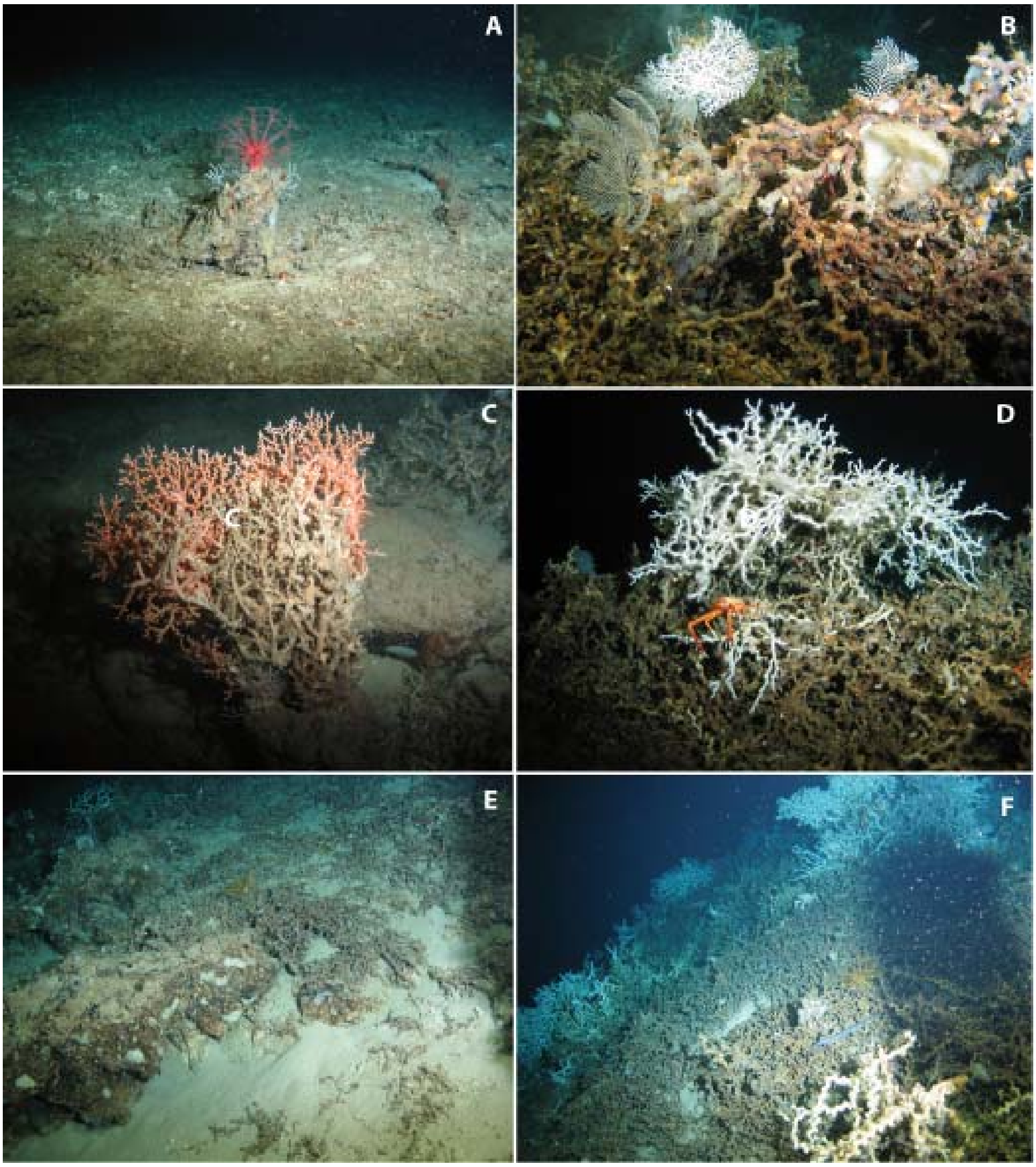


Fig. 6.17 **A** Carbonate hardground with a carbonate boulder on top. The boulder is colonized by *Anthomastus* sp. (red) and by the white *Eunicella* sp. colonies. **B** Dense colonization of dead *Lophelia* framework by sponges, *Bathypsammia* sp. (orange), the feathery *Plumarella* sp. and by a *Stylaster* sp. colony. **C** The single living *E. profunda* colony encountered on this dive. The four collected coralliophilids derive from this stock. **D** The fragile and open-spaced growth form of *L. pertusa* with *E. picta* resting on it. **E** Base of a 10-m-high topographic elevation with outcropping crusts, boulders or rocks as basement which are covered by coral rubble or framework. **F** Towards the top the proportion of living corals increases towards the current-exposed flanks. Note *Nettenchelys exoria* hiding in the coral framework.

Towards the summits of each elevation and the current exposed north-western flanks living corals became increasingly present. The majority of the living colonies are made up by *L. pertusa* with both morphotypes, the thickly calcified and the fragile one (Fig. 6.17d, f). One *E. profunda* colony with reddish tissue was discovered (Fig. 6.17c). This colony contains four coralliophilid gastropods, one *Coralliophila richardi* and three large *Coralliophila* sp. The sessile megafauna consist of *Anthomastus* sp. (Fig. 6.17a), *Eunicella* sp. (Fig. 6.17a), *Stylaster* sp. (Fig. 6.17b), *Plumarella* sp. (Fig. 6.17b), sponges, and several antipatharian species. The most common solitary coral is a *Bathypsammia* (Fig. 6.17b). In almost every case observed, the large *Leiopathes* sp. colonies house a pair of *Bellottia*-type fishes. The mobile fauna consists of sea urchins, goniasterid starfisches, crinoids, ophiurids, *Chaceon fenneri, Eumunida picta*, galatheids. The escarpment itself shows stratified rock outcrops and is terraced due to the different competence of rock properties. Interestingly no major settlement of *Lophelia* or *Enallopsammia* was detected on the escarpment, nor on the flat plateau-like shelf edge platform on top. All in all, the CWC have not developed a self-sustained topographic relief as seen on the Campeche Bank. Instead, the corals are present as part of the common hardsubstrate fringing community on boulders and rocks.

6.2.5 The West-Florida Slope: Sediment Sampling

(Claudia Wienberg, Dierk Hebbeln, Nina Joseph, Lelia Matos, Hector Reyes, Marco Taviani, Klaus Dehning, Marco Klann, Maik Wilsenack)

As the West-Florida Slope working area represents a merely erosive setting it was rather difficult to get appropriate sampling material by conventional instruments. The living CWC ecosystems are located on slumped material that was mainly made up by carbonate rocks (possibly Miocene in age). Six grab sampler were deployed along a PARASOUND transect indicating several sea floor elevations (GeoB 16327-16332). Except of site GeoB 16331, where a few rocky pebbles with some living fauna (solitary corals, ophiurids, serpulids, and sponges) were collected, the remaining grab samples were made up of foraminiferal sand containing occasional live fauna (crustaceans, isopods, polychaetes, and ophiurids) and foraminiferal and pteropod shells.

Two attempts to obtain box cores from a coral rubble field observed during an ROV dive resulted in only one sample (GeoB 16335) containing occasional coral rubble with two different types of sediment: (a) foraminiferal sand, and (b) white nannoplankton ooze that probably underlies a thin veneer of the sandy sediment. Two other grab samples from a coral rubble site detected during an ROV dive also revealed foraminiferal sand with some coral rubble (GeoB 16336, 16337). Especially at the second site a rich live fauna was recovered comprising octocorals, echinoids, ophiurids, sponges, barnacles, polychaetes, and decapod crabs. A final grab sample was taken from a small ridge in ~620 m water depth (GeoB 16342). Collecting some coral rubble in a foraminiferal sand matrix, this grab extended the regional depth window for the occurrence of coral rubble. Detailed descriptions of all box cores and grab samples collected are given in Appendices A2 and A3.

As no build-ups formed by CWC exist in this area, gravity coring was restricted to two drift sediment bodies to obtain off-mound cores. At the first site (GeoB 16338) the sediments consist of sand which resulted in a rather limited recovery of 1.2 m. At the second site (GeoB 16339) the situation was similar with only a bulk sediment sample having been recovered (see description in Appendix 4). These data underline the erosive nature of the sedimentary setting in this region.

6.3 The Southwest-Florida Slope

6.3.1 The Southwest-Florida Slope: Overview

(Dierk Hebbeln)

Although no previous information on the occurrence of CWC existed for the Southwest-Florida Slope working area, the overall setting appeared to be promising. Comparable to the northerly West-Florida site this area is also characterised by rocky landslide deposits. Surprisingly, the overall density of benthic live was rather low compared to the other working areas. Nevertheless, during two ROV dives few small-scaled "oases" with abundant live CWC were discovered surrounded by abundant coral rubble. Why the occurrence of live CWC is limited to few distinct small patches although the environmental conditions are seemingly very similar in much more extended areas is still an open question. An overview map of the working area showing all sampling stations is given in Figs. 6.18 and 6.19.

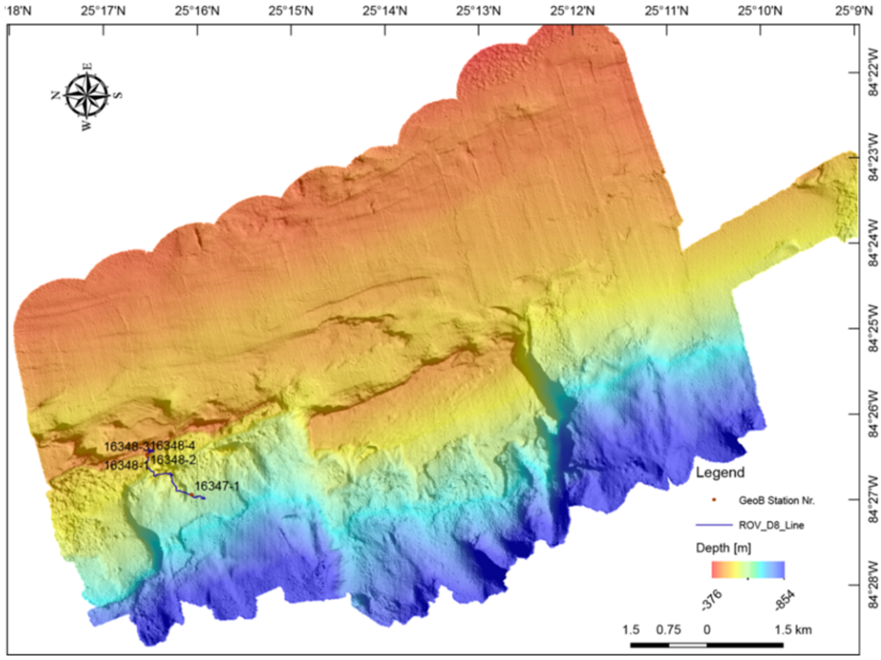


Fig. 6.18
Overview map of the northern part of the Southwest-Florida Slope working area showing all sampling sites (GeoB station numbers are indicated) and the track of ROV dive GeoB 16347-1conducted during cruise MSM20-4. Note the conspicuous main tabular erosional remnant.

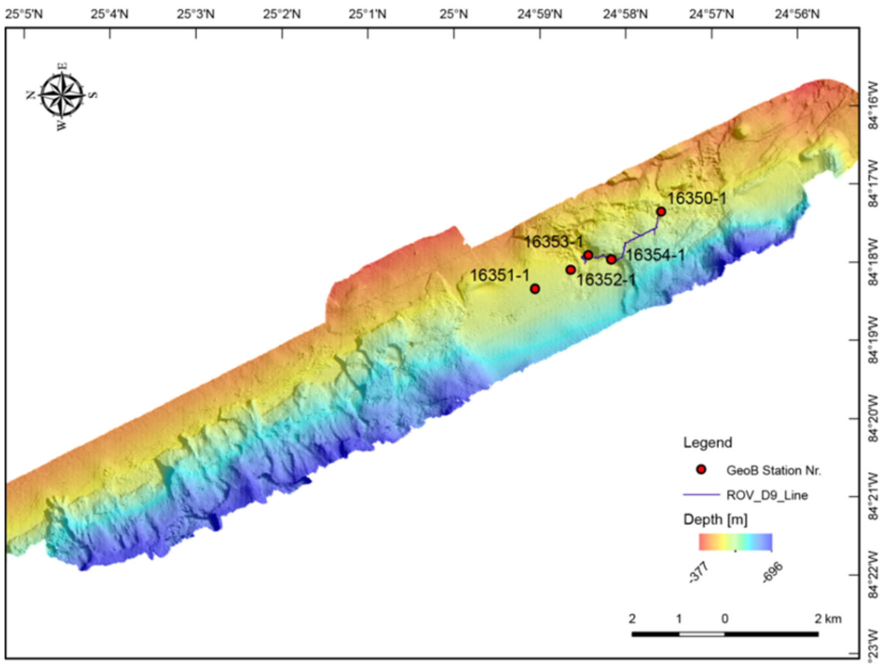


Fig. 6.19
Overview map of the southern part of the Southwest-Florida Slope area showing all sampling sites (GeoB station numbers are indicated) and the track of ROV dive GeoB 16350-1 conducted during cruise MSM20-4. A series of cliffs at several stratigraphic levels occur above steep canyons that lead down to the escarpment.

6.3.2. The Southwest-Florida Slope: The Water Column Structure

(Christian Dullo, Thorsten Garlichs, Silke Glogowski)

Only one CTD cast (GeoB16345) has been conducted in the Southwest-Florida Slope region. The results are very similar to those obtained further north in the West-Florida Slope working area (see chapter 6.2.2). The northern stations exhibit slightly cooler surface water temperatures in contrast to station GeoB16345-1 (Fig. 6.12). Below 84 m (GeoB16322-1) and 87 m (GeoB16345-1) respectively, salinities indicate the onset of the Subtropical Underwater (SUW). Further below in the water column there is no difference between these working areas.

6.3.3 The Southwest-Florida Slope: Bathymetry and Sub-Seafloor Structures

(Gregor Eberli, Paul Wintersteller, Dierk Hebbeln)

Still working within the reach of the Florida escarpment (see chapter 6.2.3), two sites were visited in the Southwest-Florida Slope working area. Both are in the morphologic setting characterised by cliffs in water depths ranging from 500-600 m. Compared to the West-Florida Slope, these southern areas are situated closer to the steep slope and canyons, and the cliff-dissected strata is more rugged with multiple cliffs. The northern site is located near a tabular, erosional remnant that is about 5 x 4 km that is surrounded on all sides by a 50-m-high cliff. A narrow cliff north of the remnant was inspected by the ROV and documented living CWC (Fig. 6.18). The second site is situated 16 km further to the south and comprises a north trending cliff that runs oblique to the margin (Fig. 6.19).

6.3.4 The Southwest-Florida Slope: ROV Observations

(André Freiwald, Lydia Beuck, Claudia Wienberg, Dierk Hebbeln, Nico Nowald, Götz Ruhland)

The slope studied off Southwest-Florida shows seabed features typical for a carbonate platform affected by a former karstic environment and being object to downslope mass wasting transport (Figs. 6.18 and 6.19). Over a distance of less than 3 km, the slope descends from 380 to about 850 m. Two ROV dives (GeoB 16347, 16350) were carried out in depths between 577 and 464 m, where “mound-like” structures with heights of up to 10 m are present.

The ROV dives showed relatively coarse arenaceous sand areas, locally becoming finer grained. The mobile sediment is heavily bioturbated by fish and crustaceans. Upslope carbonate boulders and half-buried rock slabs increasingly dominate the seabed character. Close-ups of these carbonate rocks show intense dissolution and bioerosion patterns (Fig. 6.20a) and it may well be that these carbonates represent fossil hardgrounds. The "mound-like" structures turned out to be elongated piles of rounded to sub-rounded boulders which strongly resemble rockfall deposits in the mountains (Fig. 6.20b-c). Despite the great availability of suitable hard substrates for sessile organisms, the colonisation density is rather low. Few octocorals (incl. gorgonians and the soft coral *Anthomastus agassizi*), antipatharians and sponges occur, but most boulder surfaces remain unexploited by the megafauna. As in the previous study site off West-Florida, no CWC mounds or other major build-ups formed by CWC were detected. Few patches of dead and live *Lophelia* were detected in 532 to 493 m water depth (Fig. 6.20c), thus concentrate at the 500 m depth level. The carbonate escarpment is terraced and shows larger caves and overhangs and the flattened slope regions are covered by a several cm-thick crust that is structured by shrinkage cracks (Fig. 6.20d).

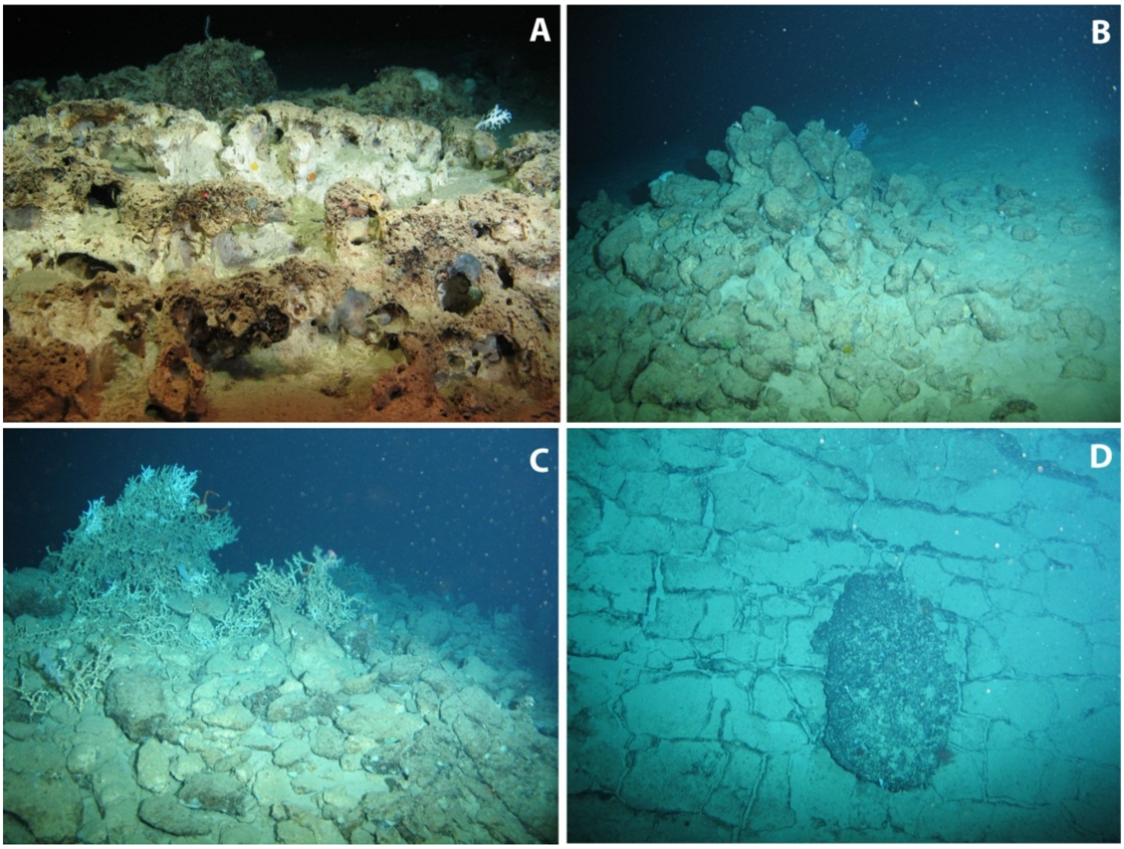


Fig. 6.20 **A** Carbonate rock alterated by dissolution and bioerosion. **B** Overview on a boulder pile representing a rockfall. **C** The same but colonized by *L. pertusa*. **D** Carbonate crusts structured by shrinkage cracks with a displaced rocky slab from further upslope.

6.3.5 The Southwest-Florida Slope: Sediment Sampling

(Claudia Wienberg, Dierk Hebbeln, Nina Joseph, Lelia Matos, Hector Reyes, Marco Taviani, Klaus Dehning, Marco Klann, Maik Wilsenack)

Being still in an area largely characterised by slumped rocks, the possibilities of successful sampling off Southwest-Florida were rather limited. During ROV observation at the first northern study area only one field with abundant coral rubble was detected. Subsequently, this site was selected for sampling using the grab sampler being the only appropriate sampling device in such rugged terrain. However, due to rather strong currents and a target area of only a few tens of square metres in size all four attempts at site GeoB 16348 resulted in limited sampling material. Only few carbonate rocks and small coral fragments, and some sandy sediment was collected.

The following day revealed similar results: three attempts to get grab samples from the southern site off Southwest-Florida yielded only two stones colonised by some live fauna (GeoB 16353) accompanied by sandy sediments and one single coral fragment (GeoB 16354). Detailed descriptions of all grab samples collected are given in Appendix 3.

The MBES and PARASOUND data indicated one region off Southwest-Florida that appeared to be a drift sediment body. One attempt to obtain a gravity core from this area failed (GeoB 16351) as the core barrel could not penetrate the sediments and toppled over - most likely because of a rather hard seabed surface.

6.4 The Bimini Slope

6.4.1 The Bimini Slope: Overview

(Dierk Hebbeln)

The two working areas studied in Bahamian waters during cruise MSM20-4 are situated on the western slope of the Great Bahama Bank with the northern Bimini Slope being part of it. In this region, bathymetric surveys have already been conducted in 2005 by our US partners with an Autonomous Underwater Vehicle (Grasmueck et al. 2006; Correa et al., 2011) and in 2010 by the French R/V LE SUROIT (Mulder et al., in press). Both mapping campaigns revealed a huge amount of mound-like structures at the sea floor (Mulder et al., in press). In addition, CWC have been frequently encountered along this margin (e.g. Correa et al., 2011). Consequently, especially for the area WNW from Bimini, these structures have been interpreted as "coral mounds" (G. Eberli, pers. comm.), however, any groundtruthing was lacking so far.

An ROV dive conducted along the Bimini Slope (GeoB 16358; see Fig. 6.21) revealed that bare rocks form an integral part of these mounds. Therefore, the available bathymetric information of the Great Bahama Bank Slope area can also be interpreted as a large slump area with the observed rocks being (parts of) olisthostromes. Nevertheless, during ROV observations occasional live CWC colonies were detected to colonise these rocky hard substrates. It appeared that their fossil remains partly accumulated to typical "CWC mound sediments" – fine hemipelagic sediments with abundant coral rubble. Indeed, from an ~100-m-high structure, tentatively termed "Wienberg mound", a >2-m-long typical "coral mound" record containing abundant *Lophelia* fragments could be retrieved. Further upslope an additional "mound-field" was studied during a second ROV dive (GeoB 16362). There, a similar setting dominated by slumped rocks was found colonised by a vital sponge-dominated fauna, whereas occasional CWC were detected in water depths of ~480 m. An overview map of this working area showing all sampling stations is given in Fig. 6.21.

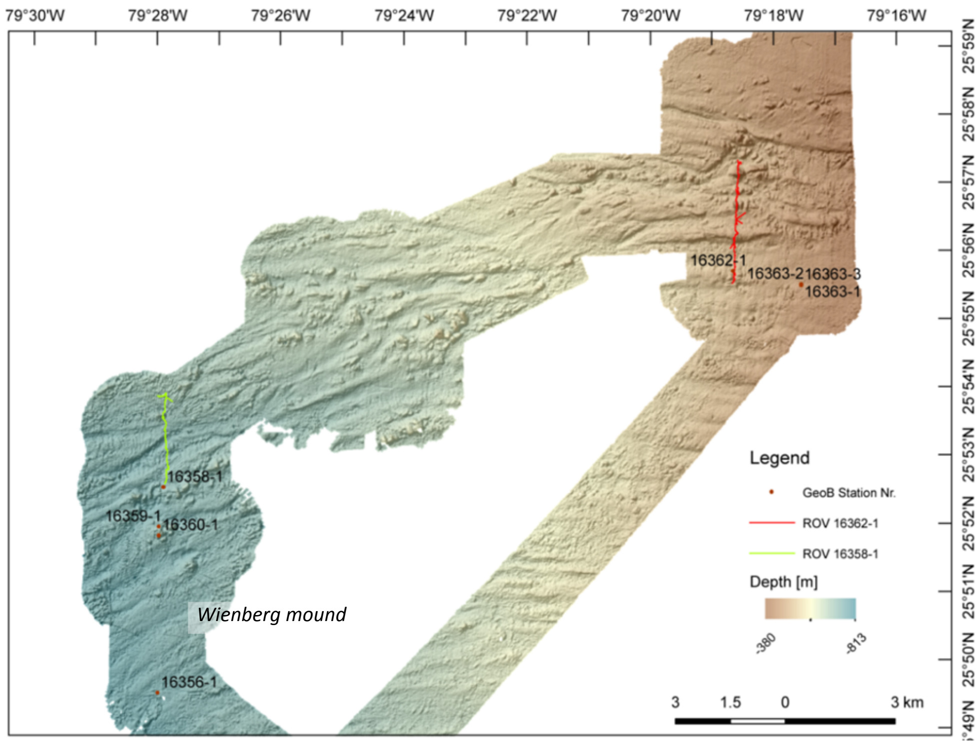


Fig. 6.21 Overview map of the Bimini Slope working area showing all sampling sites (GeoB station numbers are indicated) and ROV dive tracks conducted during cruise MSM20-4.

6.4.2. The Bimini Slope: The Water Column Structure

(Christian Dullo, Silke Glogowski, Thorsten Garlichs)

Off Bimini only one CTD station was performed (GeoB 16356). The upper 70 m of the water column are obtained by Florida Current Surface Water (FCSW) with the lowest salinities around 36.14 in water depth of 70 m (see Fig. 6.26). Here, the FCSW is typically influenced by the Antilles Current. Below 152 m follows the Subtropical Underwater (SUW; salinity: 36.90). Decreasing salinities towards the deep (minimum salinity in 748 m water depth: 34.94) mark the lower portion of the SUW that is already influenced by the Antarctic Intermediate Water (AAIW), although this water mass was not clearly identified in this station. For a comparison with the following CTD station in the next working area slightly further south, the Great Bahama Bank area, see chapter 6.5.2.

6.4.3 The Bimini Slope: Bathymetry and Sub-Seafloor Structures

(Gregor Eberli, Paul Wintersteller, Dierk Hebbeln)

The modern slope of the western Great Bahama Bank (incl. the northern Bimini Slope) is the last one of a series of prograding clinoforms that advanced the platform margin more than 25 km towards the west during the last 12 Myr (Eberli & Ginsburg, 1987; Anselmetti et al., 2000). The modern slope receives large amounts of fine-grained sediment with up to 90 m accumulation during the Holocene (Wilber et al., 1990) but the older strata also contain abundant calcareous turbidites and slump units (Betzler et al., 1999). The recently obtained MBES bathymetry map of Mulder et al. (in press) documents that large-scale slope failures and mass transport complexes occur along the modern carbonate slope. During cruise MSM20-4 it could be demonstrated that these erosional products are the core of the numerous mound structures observed in the MBES data and formerly be interpreted as CWC mounds. Two ROV dives along the Bimini Slope revealed that these mounds are sparsely covered by CWC or even nearly barren of any CWC colonisation and that these mounds (at least most of them) are most probably not formed by coral fragments and hemipelagic sediments (see chapter 6.5).

North of Bimini the slope is dissected by a series of shallow canyons that originate in a 30-km-long array of scars at the upper slope in a water depth of ~450 m (Fig 6.22). The canyons run west down slope and bend slightly to the south. Numerous mound structures with heights of >100 m were found at the canyons' mouth and along the canyons' flanks. Three different sites were defined for detailed studies within this 30x30-km-sized Bimini Slope region (Fig. 6.22). The first site is located close the toe-of-slope including a 100-m-high mound named "Wienberg mound". The second area is characterised by a cluster of mounds at the confluence of three canyons and is situated in the middle of the entire canyon system. However, this site was not investigated by sampling as ROV dives in sites 1 and 3 revealed that the mounds as large boulders with scarce or no coral coverage. The third site comprises the upper end of the canyons below the erosional scar.

The MBES bathymetry map acquired on board R/V MARIA S. MERIAN illustrates the slope with its large anastomosing canyon system in great detail (Fig. 6.21). The canyons are bi-furcating and at the lower slope they bend to the south. Large mounded features of the "Mulder map" (Fig. 6.22) are here recognizable as blocks and boulders. The entire system seems to have very little fine-grained off-bank transported sediment that is smothering mounded features further south (Correa et al., 2011). This lack of layered sediments is also documented by the PARASOUND profiles (an example from site 2 is shown in Fig. 6.23; see Fig. 6.22 for location).

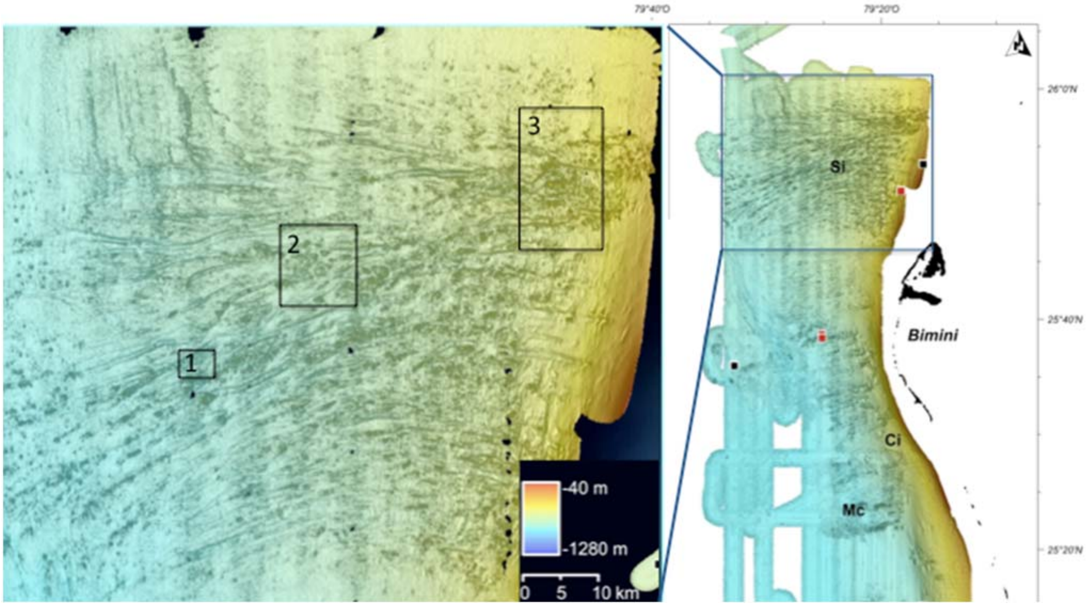


Fig. 6.22 Overview bathymetry map of the Bimini slope working area modified from Mulder et al. (in press) displaying the channels and numerous mounds along the Bimini Slope. ROV dives and sampling were solely conducted in sites 1 and 3.

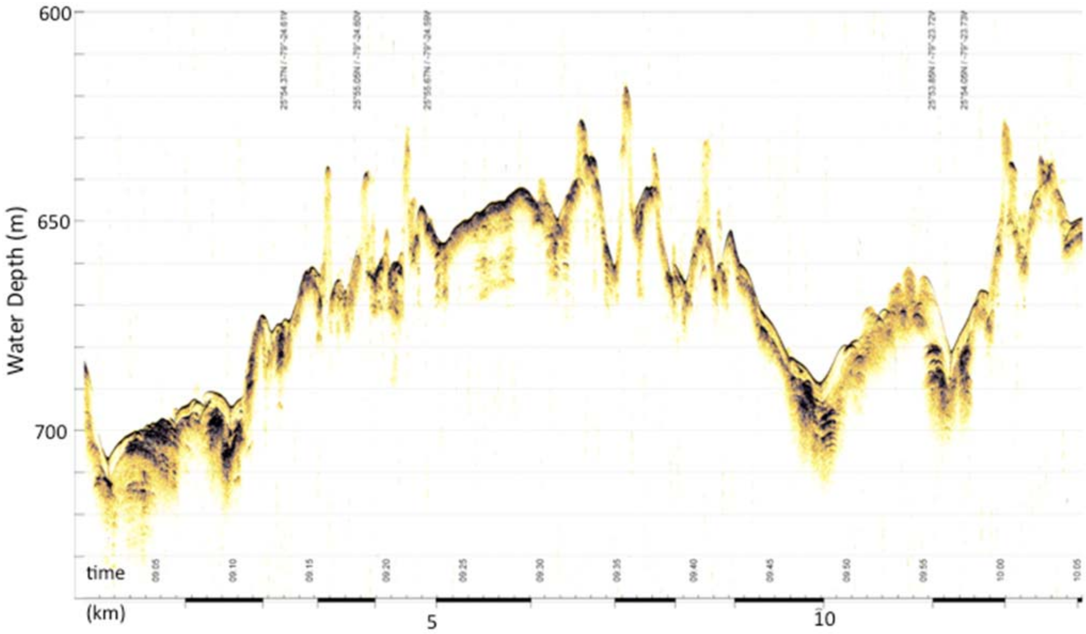


Fig. 6.23 PARASOUND profile in the middle slope site 2 off north Bimini (see Fig. 6.22) displaying numerous steep-sided mounds on the rocky channelised slope.

6.4.4 The Bimini Slope: ROV Observations

(André Freiwald, Lydia Beuck, Claudia Wienberg, Dierk Hebbeln, Nico Nowald, Götz Ruhland)

The study site off Bimini is located at the confluence of a canyon system higher upslope and the multibeam map shows evidence of slope failures and mass transport but also for some mounds which were supposed to be coral mounds (Fig. 6.21). Two ROV dives have been conducted off Bimini. ROV dive GeoB 16358 went over seabed accentuated by low-relief slope failure deposits in 753-697 m water depth. The track of ROV dive GeoB 16362 was directed higher upslope in 527-439 m and crossed several prominent ridge and “mound” structures (Fig. 6.21). The ROV dive GeoB 16358 went over a series of low-relief NE-SW striking mass transported sedimentary bodies and it became evident that these structures are distal expressions of slope failure processes. More prominent ridge-like bodies were pierced with larger, m-sized carbonate rocks which locally provide substrate for larger *Lophelia* and *Enallopsammia* colonies (Fig. 6.24a). The strong bottom current regime created impressive moats at the base of these displaced rock slabs (Fig. 6.24b-c). The general flat seabed shows a high variability from pteropod-ooze, sometimes forming dunes and larger ripples to indurated cemented crusts littered with fossil coral rubble, dispersed live *Lophelia* and other colonial corals and sponges (Fig. 6.24d). Other prominent members of the megafauna were stylasterids (Fig. 6.24c), gorgonians, isidids, and antipatharians.

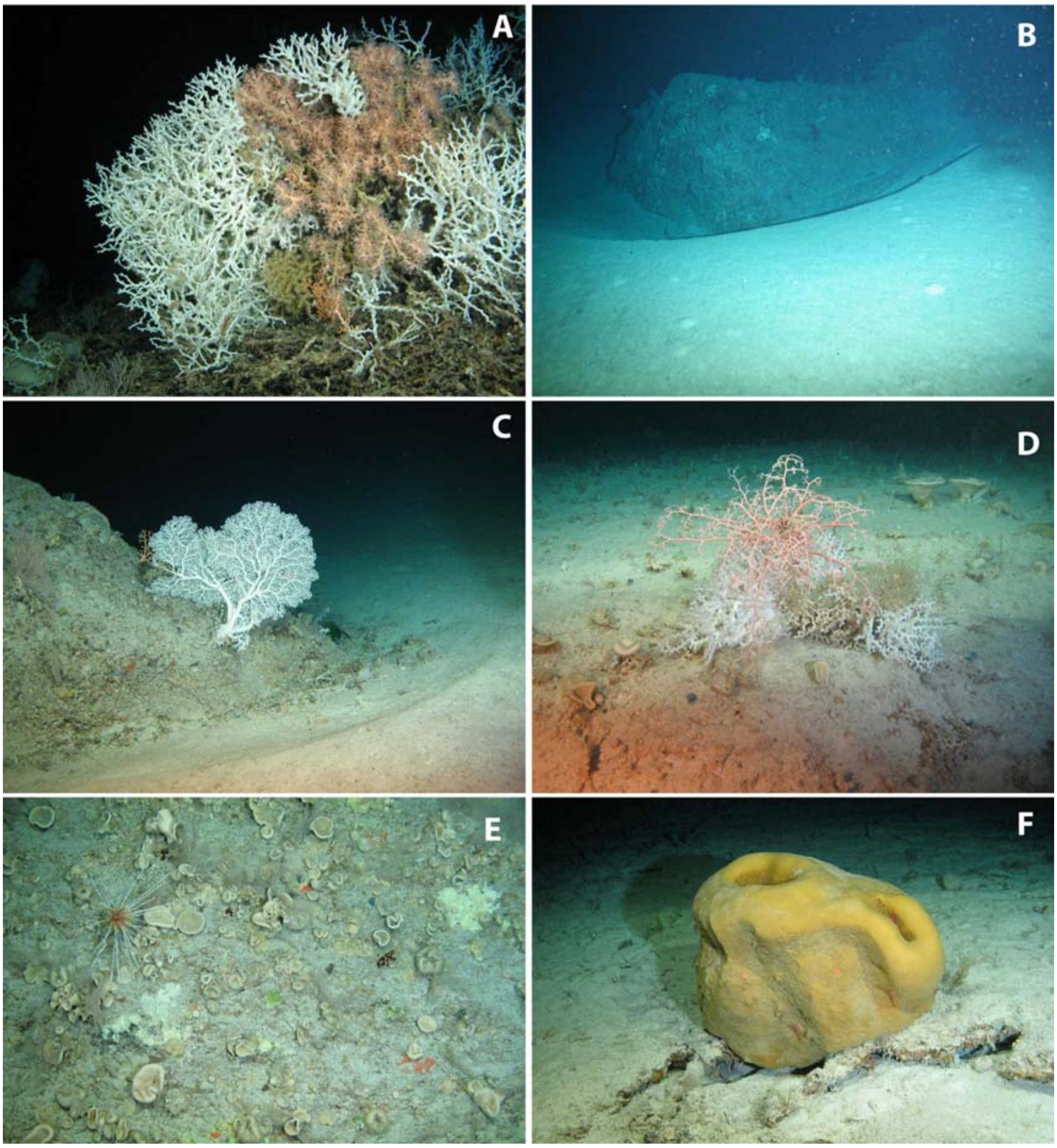


Fig. 6.24 **A** Colony of *L. pertusa* competing with encrusting octocorals. **B** Displaced carbonate slab with current-generated moat. **C** Detail of the same slab showing the moat and a larger stylasterid colony. **D** Indurated seabed provides habitat for sponges and dispersed *Enallopsammia* and *Lophelia* colonies. Note the gorgonocephalid brittle star. **E** Current-exposed flank of a displaced rock with dense aggregation of cup-shaped sponges. **F** Indurated crusts stabilize the mobile fine-grained carbonate ooze and serves a substrate for sponges.

The ROV dive GeoB 16362 was laid out in a more upslope position compared to the previous one. Several mounded structures were crossed during this dive and the multibeam bathymetry indicated that these mounds were elements of E-W striking 0.5-1-km-long ridges. Groundtruthing with ROV yielded evidence that none of the mound-like structures are coral carbonate mounds but instead, these ridges are impressive mass transported sediment bodies packed with olistoliths in places. Living scleractinian colonies were sparse while dead coral rubble is more common in places (Fig. 6.24d and f). The most prominent elements of the megafauna are masses of probably lithistid sponges (Fig. 6.24e) on the current exposed parts of displaced rocks. The edges of these current-exposed elevations show dense aggregations of octocoral colonies aligned against the current to effectively filter plankton organisms. Very prominent are cemented crusts on the seabed surface acting as substrate for a diverse community (Fig. 6.24f).

6.4.5 The Bimini Slope: Sediment Sampling

(Claudia Wienberg, Dierk Hebbeln, Nina Joseph, Lelia Matos, Hector Reyes, Marco Taviani, Klaus Dehning, Marco Klann, Maik Wilsenack)

Due to the rocky nature of the mound settings, no box coring was conducted in the Bimini Slope area. In addition, as the strong currents mostly did not allow to use the grab sampler, only one grab sample from an off-mound setting was retrieved. In this off-mound setting, a white nannofossil-foraminifera-pteropod ooze with ponded sea grass leaves was recovered (GeoB 16363, see Appendix 3). At the same site a gravity corer equipped with a 6-m-long core barrel suffered from over-penetration, whereas a second attempt with a 12-m-long core barrel yielded a recovery of 10.3 m. Beside the off-mound site, three potential CWC sites were selected for gravity coring. Two attempts were performed at "Wienberg mound". The first corer lowered to the lower northern flank penetrated well into the sediment (GeoB 16359). However, the inner plastic core barrel was blocked by a piece of lithified carbonaceous sediment resulting in a rather disappointing core recovery of one small piece of this lithified sediment and very few coral fragments. The second corer hit the middle southern flank of "Wienberg mound". Although the core barrel bent, this coring attempt was quite successful as >2 m of coral-bearing sediments could be recovered (GeoB 16360; see Appendix 4). A final gravity core was collected from the deeper part (830 m water depth) of the Florida Straits where roughly N-S trending ridges were considered as potential CWC sites. Here, a 1.6-m-long sediment core with no obvious coral content was collected (GeoB 16364). However, only the analyses at the home laboratory will finally reveal if this core indeed contains no coral fragments.

6.5 The Slope of the Great Bahama Bank

6.5.1 Great Bahama Bank Overview

(Dierk Hebbeln)

Up to 50-m-high mound-like structures in the Great Bahma Bank area were documented in seismic lines by Anselmetti et al. (2000). These structures seem to be rooted on a seismic sequence boundary that has been dated to ~0.6 Myr indicating that the structures had their onset during the Middle Pleistocene to Holocene (Eberli et al., 2002). A recent study revealed a general lack of correlation between prevailing bottom current direction and mound morphology as well as current strength and mound size Correa et al., 2011), which is in contrast to findings from the NE Atlantic, where "real" CWC mounds show a clear current-controlled growth pattern. However, ROV dives carried out during MSM 20-4 (Fig. 6.25) showed that also in this area the mound-like seabed structures largely originate from slump-related rocks. Though, coring results reveal that these rocks are at least covered by 1-2 m of coral-bearing sediments.

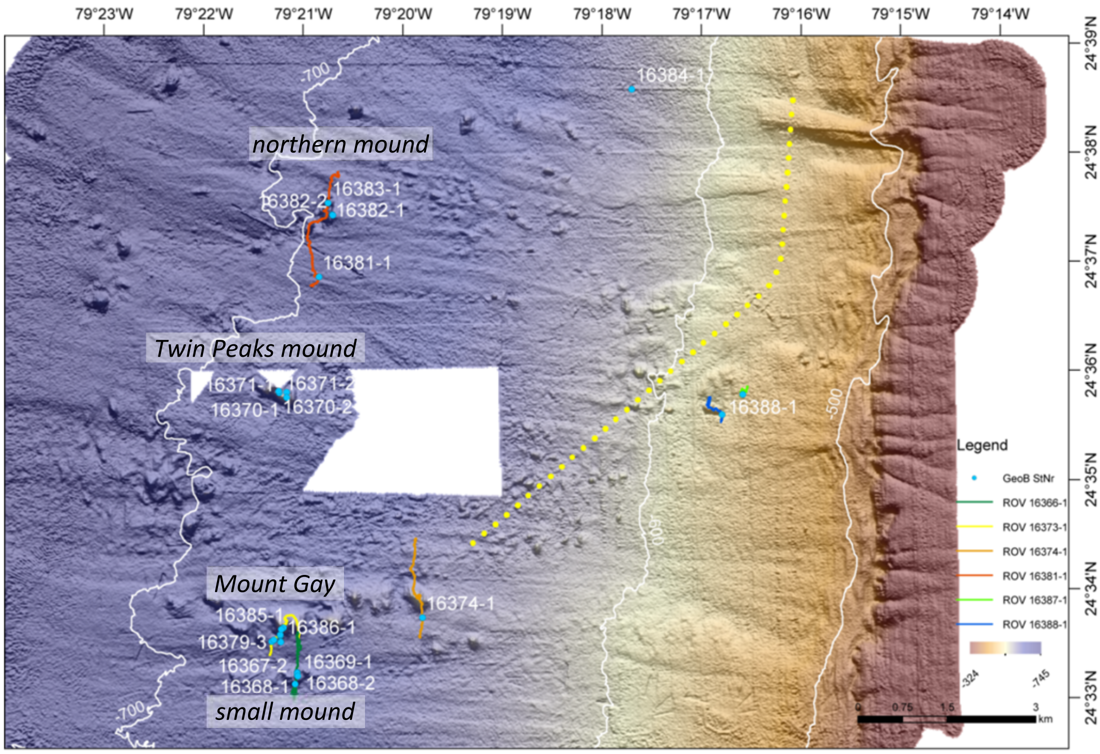


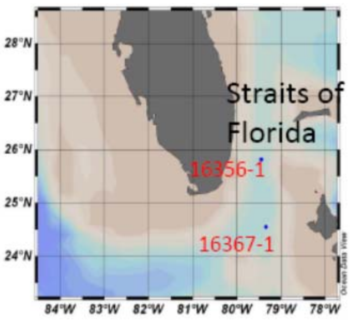
Fig. 6.25 Overview of the Great Bahama Bank working area showing all sampling sites (GeoB station numbers are indicated) and ROV dive tracks conducted during cruise MSM20-4. The map displays mound structures in a field of slightly divergent ridges and depressions that are reminiscent of a flow pattern. To the west a scar of 50 m in height separates this area from a soft sediment slope (in ochre) with regularly spaced furrows. The yellow line gives the position of the PARASOUND profile shown in Fig. 6.27.

Therefore, it is assumed that the mound structures found along the Great Bahama Bank most likely result from slump deposits exhibiting a rocky core that defines the overall morphology and explains the lack of correlation between mound orientation/size and bottom current regime (see above). Interestingly, also the inter-mound areas, although having a largely smooth appearance in the MBES data, are often covered by metre-sized boulders. Strong bottom currents are indicated by e.g. gravel pavements and current ripples. Hemipelagic mud was only found in sediment samples collected from the mound structures where those fine-grained sediments have been deposited in between the fossil coral framework. The ROV observations revealed that the occurrence of living CWC (i.e. CWC ecosystems) is today limited to a water depth of <630 m. However, mounds whose tops arise to water depths of ~650 m are covered by huge amounts of coral rubble indicating suitable living conditions also in these depths for the past. An overview map of this working area showing all sampling stations is given in Fig. 6.25.

6.5.2. Great Bahama Bank The Water Column Structure

(Christian Dullo, Thorsten Garlichs, Silke Glogowski)

Two CTD stations we performed in the Great Bahama Bank working area: a standard CTD station (GeoB 16367) and a Yoyo-CTD station (GeoB 16387). The water column structure here is quite similar to the previous working area in the north, the Bimini Slope (GeoB 16356). The uppermost part of the water column comprises the shallow water mass of the Florida Current Surface Water (FCSW). At the Bimini Slope station this water mass is identified by the lowest salinities of ~36.14 in a water depth of 70 m and at the southern Great Bahama Bank station by 36.18 in 56 m water depth. This water mass is characterised and influenced by the occurrence of the inflow of the Antilles Current.



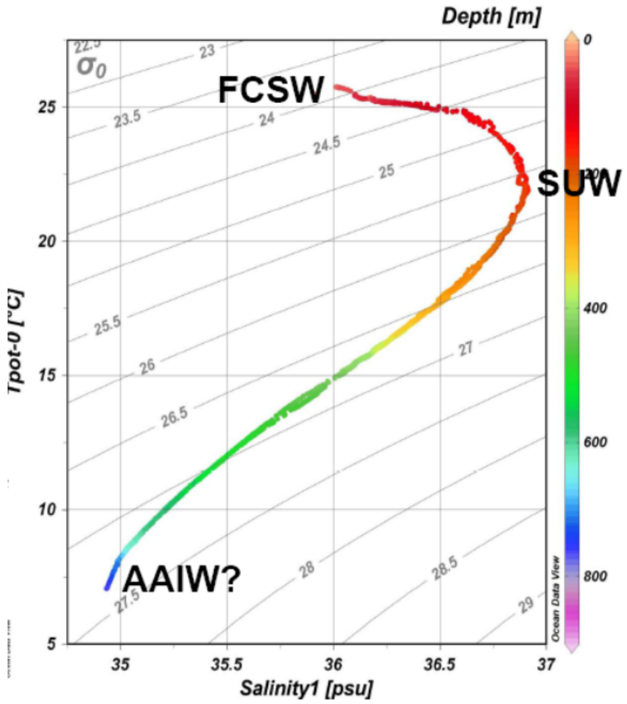


Fig. 6.2
Water mass structure of the Bimini Slope (GeoB 16356) and off the Great Bahama Bank (GeoB 16367) in the Straits of Florida. Shown is a Temperature (potential temperature Tpot)-Salinity plot also indicating the density (σ) of the water from these stations. FCSW Florida Current Surface Water, SUW Subtropical Underwater, AAIW Antarctic Intermediate Water.

The onset of the Subtropical Underwater (SUW) occurs in 152 m water depth at the Bimini Slope (36.90) and in 175 m depth (36.90) at the southern Great Bahama Bank station. The minimum salinities have been measured between in 748 m (34.94) at the Bimini Slope station and in 673 m (35.01) at the southern station. The reduction in salinity indicates the lower part of Subtropical Under Water (SUW). This indicates the influence of the Antarctic Intermediate Water (AAIW), which has not been definitely identified. The lower SUW is characterized by this low salinity, higher oxygen content, and relatively cool temperatures (Fig. 6.26).

During ROV operations substantial amounts of living CWC in the Great Bahama Bank area were only found in water depths shallower than ~630 m. In contrast, along the Bimini Slope living CWC were also observed as deep as ~720 m. The isopycnal of 27.0 kg m^{-3} occurs at the Bimini Slope in a water depth of 535 m while it is slightly shallower off the Great Bahama Bank in a water depth of 515 m. It is interesting to note that the isopycnal of the 27.0 kg m^{-3} occurs in deeper water depths within the Straits of Florida in comparison to the West-Florida Slope (27 kg m^{-3} in 349 m water depth).

Additionally, we performed a Yoyo-CTD about 1 nm north of GeoB16367 comprising 14 casts. With the Yoyo-CTD no dynamics in oxygen content were observed. Throughout the tidal cycle studied, the oxygen values remained constant at 2.66 ml/l. Only slight differences occurred in the bottom temperature with 9.21°C during high tide and 8.96°C during low tide and in salinity respectively (35.06 low tide; 35.26 high tide).

6.5.3 Great Bahama Bank Bathymetry and Sub-Seafloor Structures

(Gregor Eberli, Paul Wintersteller, Dierk Hebbeln)

The Great Bahama Bank working area is located about 100 km south of the Bimini Slope area and includes "AUV Site 1" introduced by Correa et al. (2011). The mound structures in this area are located on and in between a series of low relief ridges that have a divergent pattern (Fig. 6.25). The mounds are highly variable in size and orientation. The ridges end up slope (to the east) at a 50 m high step in the slope that can be followed over 10s of kilometres. In contrast to the Bimini slope area, this working area often exhibits a soft sediment cover (Fig. 6.27).

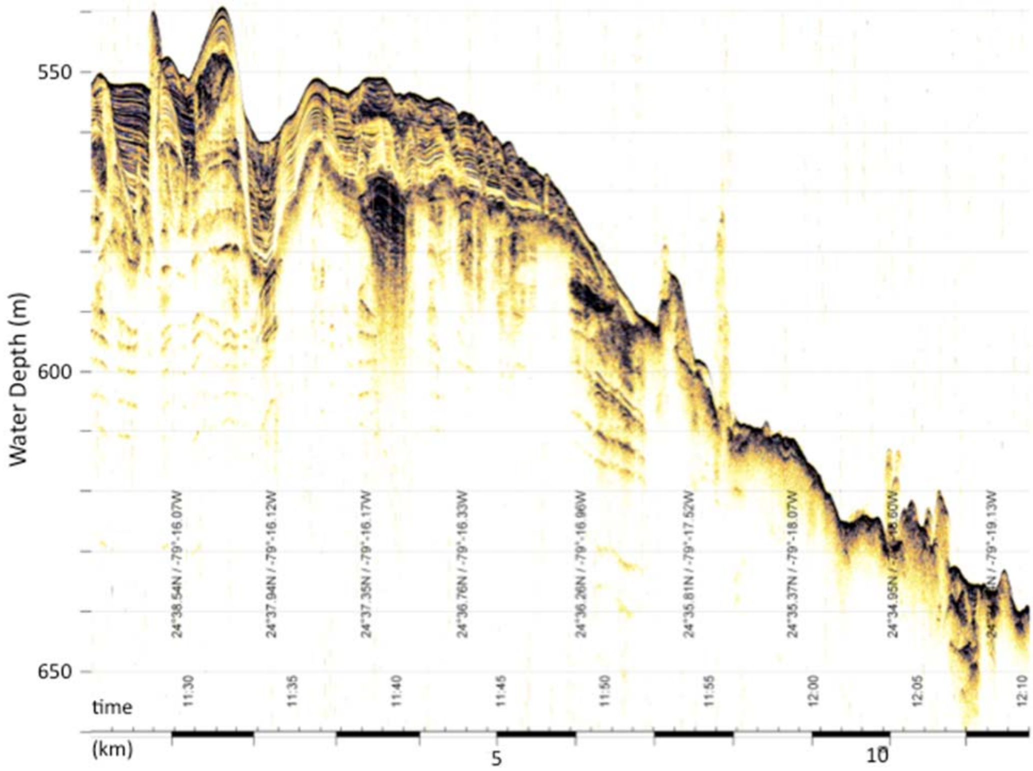


Fig. 6.27 PARASOUND profile in the upslope position of the Bimini slope working area displaying the dual system of layered fine-grained sediment partly covering the steep mounds and the hard surface with solitary individual mounds that are transparent and have diffraction hyperbolas.

As a result many of the mounds in this area have a moat at their base. Nevertheless the distribution of the mounds is reminiscent of a boulder field that is partly buried by finer-grained sediment. The depressions in between have a striation perpendicular to the up slope scare while the sediments are aligned in a N-S direction. This indicates a decoupled depositional process of the coarse and fine sediments. The coarse fraction is clearly related to down slope mass gravity flows, while the fine-grained portion is deposited as a contourite.

6.5.4 Great Bahama Bank ROV Observations

(André Freiwald, Lydia Beuck, Claudia Wienberg, Dierk Hebbeln, Nico Nowald, Götz Ruhland)

Groundtruthing along the slope west of the Great Bahama Bank was performed with six ROV dives (Fig. 6.25), most of them in the deeper mound area between 700-600 m (GeoB 16366, 16373, 16374, 16381). Two dives surveyed the shallower ridge apron closer to the escarpment, where an isolated mound pierces out (GeoB 16387, 16388). The emphasis was on deciphering the origin of the large mound structures which are common in the 700-600 m depth interval. The flat seabed between the mounds is muddy to sandy while indurated crusts are only developed locally (Fig. 6.28d). Approaching the individual mounds encountered here from the southern, current-exposed flank shows an intense presence of coral rubble and dead if not fossil coral framework dominated by *Lophelia, Enallopsammia* and *Madrepora* (Fig. 6.28a-b).

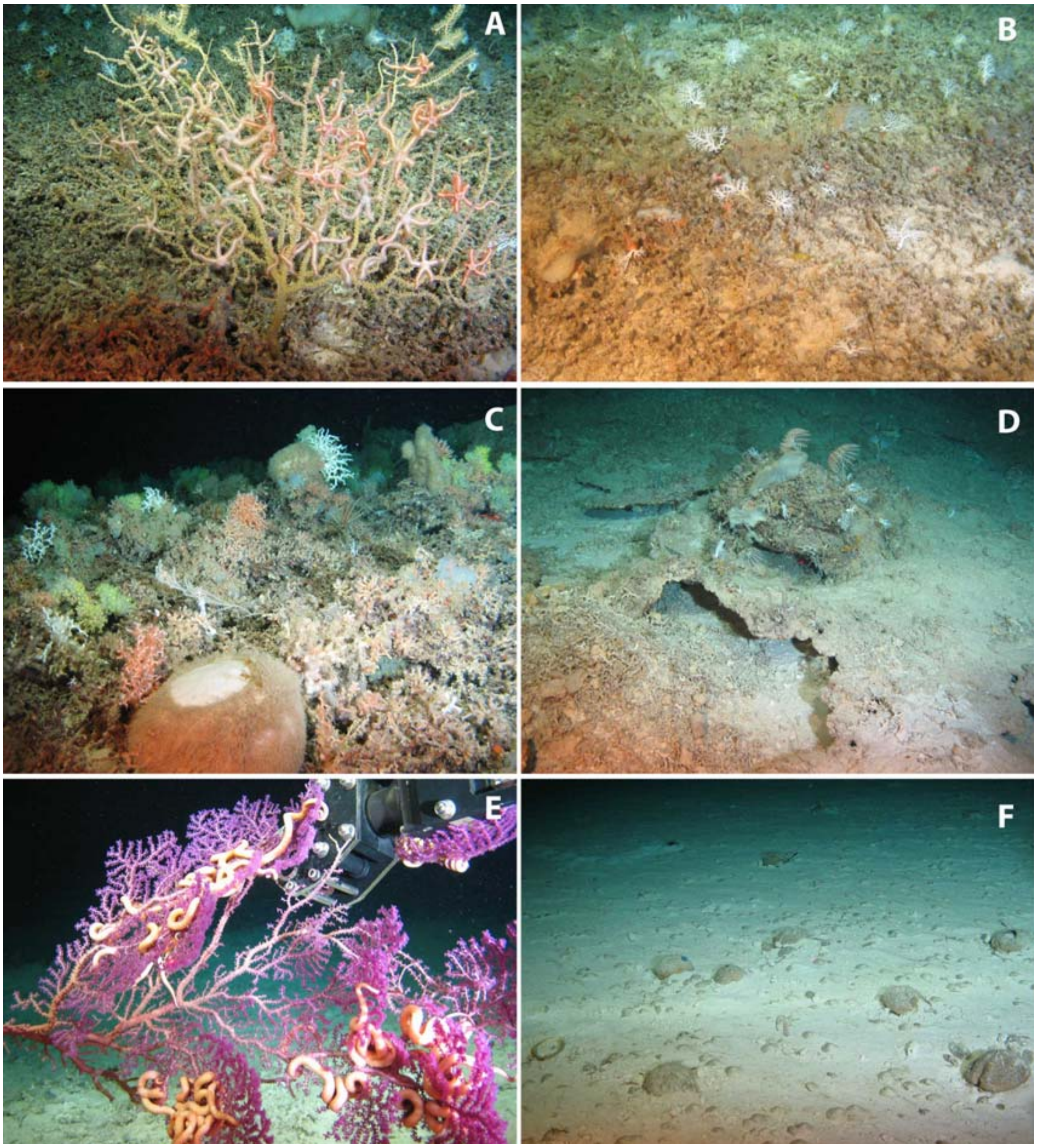


Fig. 6.28 **A** Gorgonian on dead coral framework being under pressure by a brittle star aggregation. **B** Small stylasterid colonies on coral rubble. C Vivid and diverse community on top of a mound with corals and sponges. D Cemented and underwashed crusts. **E** Purple octocoral grazed by large euryalid brittle stars. **F** Graveyard of irregular sea urchins and bivalves.

Particularly near the current-exposed mound bases, displaced rock slabs were visible. These slabs are the results of slope failures and rockfalls from the escarpment further upslope and may form the ecologic foundation to stimulate the framework-constructing corals to settle. Towards the summits of the mounds, the density and thickness of the dead and living coral framework becomes more intense. In the dead framework and rubble habitats, larger colonies of gorgonians (Fig. 6.28a) and stylasterid meadows prevail (Fig. 6.28b). The summits, especially when exposed to the current, harbour impressive coral thickets and large accumulations of *Aphrocallistes,* astrophorid sponges (Fig. 6.28c) and several species of stalked crinoids. The low-relief ridged and almost flattened off-mound seabed shows locally cemented crusts (Fig. 6.28d) which might be outwashed, weak ripple areas of calcareous ooze and sand but also boulder fields. The latter serve as substrate for purple octorals (Fig. 6.28e) and large antipatharian colonies, again each one housing a pair of bellotid fishes. Interestingly, in this region the CWC showed a distinct, though temporarily variable, depth zonation. During ROV dives GeoB 16373 ("Mount Gay") and 16374 "flourishing" coral gardens (Fig. 6.28c) have been observed on the visited mound summits in depths shallower than 610-620 m. In contrast, during ROV dive GeoB 16381 the summit of the visited mound only reached up as high as 650 m and it was entirely covered by huge amounts of dead coral framework. This observation clearly points to a temporal development of the CWC distribution in this region.

Also the two ROV dives higher up on the slope (GeoB 16387, 16388) over the flanks of an isolated mound in 586-547 m depth shows no coral mound but instead a displaced olistolith that is draped locally by coral framework. On ROV dive GeoB 16388 several graveyards with masses of sea urchin coronas and masses of bivalve shells were encountered at the base of the mounded structure (Fig. 6.28f). Among the collected shells, lucinid bivalves have been identified which may indicate seepage in this area. Other indications for seepage (of whatever origin) were noted on dive GeoB 16374 at 626 m water depth, when we spotted flurry water passing by.

It is most likely the case that a two-fold history explains the presence of clustered and often E-W aligned mounds: first the slope failure and mass transport of rock slabs from the platform perpendicular to the slope (E-W), second, the post-failure colonisation and mound growth by corals. This also would explain the highly variable mound morphology of individual mounds which are not current controlled but primarily controlled in their shape by the random accumulation of displaced rock slabs.

6.5.5 Great Bahama Bank Sediment Sampling

(Claudia Wienberg, Dierk Hebbeln, Nina Joseph, Lelia Matos, Hector Reyes, Marco Taviani, Klaus Dehning, Marco Klann, Maik Wilsenack)

Three mound structures were successfully sampled in the Great Bahama Bank region, all belonging to the deep mound area between 700-600 m water depth observed during various ROV dives (GeoB 16366, 16373, 16374, 16381). The first southernmost sampling site of this area comprised a rather small mound structure (situated slightly south of Mount Gay, see Fig. 6.25). Two box cores collected from 660 m (GeoB 16367) and from 667 m (GeoB 16368) water depth revealed quite different recoveries. Whereas GeoB 16367 consisted of *Enallopsammia* rubble within a light grey muddy foraminifera-pteropod matrix, GeoB 16368 was made up by a pale brown foraminifera-pteropod ooze with very few coral fragments. Both cores contained scarce to no living fauna.

Slightly to the north, we selected one larger mound structure for intense sampling (Mount Gay, 79°21.25'W, 24°33.60'N; Fig. 6.25). This mound was sampled with a series of box cores and gravity cores (see below) covering its base, lower and middle slopes, and its top. The mound base (GeoB 16375) and the lower slope (GeoB 16376) consisted of a pale brown muddy sediment, whereby only the box core from the mound base contained a larger amount of coral rubble. No obvious living macrofauna was recognized. The mid-slope core (GeoB 16377) was washed out, however, some pale brown muddy sediment remained in the box. This was accompanied by some coral rubble and some live fauna: *Aphrocallistes* settled by anemones, an ophiurid and even a piece of living *L. pertusa*. According to the ROV data of dive GeoB 16381, the northernmost mound sampled in this area (see Fig. 6.25) was covered by abundant coral rubble, but was lacking any living CWC ecosystems. Box core GeoB 16382, collected from its top plateau, revealed *Enallopsammia*-dominated coral rubble embedded in a pale brown muddy sediment matrix accompanied by a diverse living fauna (crinoids, ophiurids, echinoids, decapod crabs, octocorals, polychaetes, sponges and anemones). Detailed descriptions of all box corers collected are given in Appendix 2.

Gravity coring focused on the same mound structures. Two gravity cores collected from the southernmost small mound structure showed recoveries of 2.3 m (GeoB 16369, same position as box corer GeoB 16367) with coral rubble at its surface and 0.5 m (GeoB 16368) completely filled with coral rubble. Gravity cores collected from Mount Gay revealed an overall good recovery. Only the core from the lower slope (GeoB 16378) resulted in a “banana”, nevertheless it contained 1.3 m of abundant coral rubble. The two cores collected from the mid-slope (GeoB 16377) and the top of the mound (GeoB 16379) recovered more than 5 m of coral rubble within a hemipelagic sediment matrix. Actually, site GeoB 16377 yielded a maximum core length of 5.7 m obtained with a 6-m-long core barrel. A second attempt with a 12-m-long core barrel at the same site (GeoB 16385) unfortunately failed and yielded only a short record (1.3 m). The two cores collected from the northernmost mound yielded short records of coral-bearing sediments with a recovery of 1.1 m (GeoB 16382) and 0.8 m (GeoB 16383), respectively. Both gravity cores penetrated easily through the sediments, however, failed to penetrate deeper most probably due to an overall sediment thickness of less than 1.5 m that drape this mound.

Overall, gravity coring on the Great Bahama Bank mounds gave the impression that the rocky outcrops, observed during ROV dives and assumed to form the core of these mounds, are in most places only covered by a rather thin (<2 m) drape of sediments interspersed with coral rubble. Only on Mount Gay two longer records were recovered pointing to a locally thicker sediment coverage.

The final sampling target of the Great Bahama Bank region was an off-mound site to establish a palaeoceanographic framework for the long-term CWC development in this region. As the PARASOUND data indicated the lack of a sediment cover for the inter-mound areas, an off-mound core could only be collected slightly upslope where at ~630 m water depth first drift sediment bodies occur. Here, a core with a length of 5.7 m was recovered (GeoB 16384) consisting of an almost white foraminiferal-nannofossil ooze. However, this core suffered from a slight over-penetration and the loss of the uppermost ~30 cm of the sediment column.

7 Station List MSM20-4

Station No.		**Device**	**Date** (2012)	**Time** (UTC)	**Latitude** (°N)	**Longitude** (°W)	**Water Depth** (m)	**Reco-very** (m)	**Remarks**
GeoB	**MSM20**								
Caribbean Sea									
16301-1		CTD+WS	18.03.	17:10	17°26.382	73°15.403	4000		test station
16301-2		ROV	18.03.	18:02	17°26.474	73°15.342	4000		test dive#1 down to 200m
16302-1		ROV	20.03.	17:05	22°12.888	82°11.684	3603		POSIDONIA test down to 200m water depth
Yucatan/Campeche Bank									
16303-1	089-1	CTD+WS	21.03.	14:59	22°00.980	86°02.952	1246		
16304-1	090-1	MBES+PS	21.03.	16:26	21°59.540	86°09.430	1000		
		end	22.03.	05:18	23°50.090	87°12.320	510		
16305-1	091-1	CTD+WS	22.03.	05:21	23°49.875	87°12.271	506		

Station No.		**Device**	**Date** (2012)	**Time** (UTC)	**Latitude** (°N)	**Longitude** (°W)	**Water Depth** (m)	**Reco-very** (m)	**Remarks**
GeoB	**MSM20**								
16306-1	092-1	MBES+PS	22.03.	06:37	23°52.371	87°13.865	532		
		end	22.03.	11:49	23°51.160	87°07.590	649		
16307-1	093-1	ROV	22.03.	13:51	23°40.829	87°10.031	547		dive #2, 1 sample; strong currents
		end	22.03.	16:20	23°50.485	87°10.714	577		
16308-1	094-1	BC	22.03.	18:02	23°50.121	87°10.484	565	<0.05	few sediment with fossil corals
16309-1	095-1	BC	22.03.	20:03	23°49.731	87°10.319	578	<0.05	few coral fragments
16309-2	095-2	BC	22.03.	20:38	23°49.732	87°10.319	580	./.	not released
16310-1	096-1	BC	22.03.	22:18	23°29.443	87°10.217	566	0.32	coral rubble
16310-2	096-2	GC (6m)	22.03.	23:07	23°49.443	87°10.217	565	5.01	coral-bearing core; over-penetrated, top lost(~2m)
16310-3	096-3	GC (12m)	23.03.	01:04	23°49.450	87°10.220	573	10.60	coral-bearing core
16311-1	097-1	MBES+PS	23.03.	02:04	23°42.280	87°09.900	589		
		end	23.03.	12:10	23°49.300	87°09.910	587		
16312-1	098-1	ROV	23.03.	14:31	23°50.345	87°11.761	523		dive #3, 5 samples
		end	23.03.	18:31	23°52.519	87°12.485	531		
16313-1	099-1	BC	23.03.	18:49	23°52.367	87°12.373	525	0.31	coral rubble
16313-2	099-2	GC (12m)	23.03.	19:34	23°52.365	87°12.373	553	2.51	coral-bearing core; coral fragments and lithified sediments at the core base
16314-1	100-1	GC (12m)	23.03.	20:52	23°50.876	87°11.612	544	./.	empty
16315-1	101-1	BC	23.03.	22:09	23°50.052	87°08.044	652	./.	box corer tilted
16316-1	102-1	CTD+WS	24.03.	00:20	23°51.510	87°12.120	576		Yoyo-CTD for 12 hours; water sampling
16316-2	102-2	CTD+WS	24.03.	01:12	23°51.650	87°12.120	570		
16316-3	102-3	CTD+WS	24.03.	02:09	23°51.730	87°12.130	566		
16316-4	102-4	CTD+WS	24.03.	03:08	23°51.730	87°12.130	571		
16316-5	102-5	CTD+WS	24.03.	04:01	23°51.720	87°12.130	559		
16316-6	102-6	CTD+WS	24.03.	05:02	23°51.770	87°12.130	573		
16316-7	102-7	CTD+WS	24.03.	05:57	23°51.650	87°12.150	546		
16316-8	102-8	CTD+WS	24.03.	07:00	23°51.740	87°12.130	565		coral framework in the CTD frame
16316-9	102-9	CTD+WS	24.03.	07:58	23°51.700	87°12.150	560		
16316-10	102-10	CTD+WS	24.03.	09:00	23°51.810	87°12.120	560		
16316-11	102-11	CTD+WS	24.03.	10:04	23°51.850	87°12.130	564		
16316-12	102-12	CTD+WS	24.03.	11:01	23°51.520	87°12.120	563		
16316-13	102-13	CTD+WS	24.03.	12:01	23°51.520	87°12.130	558		
16317-1	103-1	ROV	24.03.	13:37	23°51.120	87°12.110	542		dive #4, 1 sample; dive aborted, technical problems
		end	24.03.	15:02	23°51.770	87°12.530	555		
16318-1	104-1	GC (12m)	24.03.	16:58	23°51.399	87°12.160	556	4.73	coral-bearing core
16319-1	105-1	BC	24.03.	18:06	23°51.649	87°12.088	579	./.	not released
16319-2	105-2	BC	24.03.	18:46	23°51.636	87°12.069	578	0.42	coral rubble
16319-3	105-3	GC (12m)	24.03.	19:30	23°51.642	87°12.080	579	7.95	some layers with coral fragments
16320-1	106-1	BC	24.03.	20:41	23°50.309	87°09.009	625	0.40	drift sediment
16320-2	106-2	GC (12m)	24.03.	21:28	23°50.305	87°09.003	626	4.39	off-mound core, drift sediment body
16321-1	107-1	BC	25.03.	00:22	23°50.009	87°08.027	640	0.41	abundant coral fragments
16322-1	108-1	MBES+PS	25.03.	01:04	23°50.160	87°08.030	643		
		end	25.03.	04:02	24°01.420	87°20.630	529		
West-Florida Slope									
16323-1	109-1	CTD+WS	25.03.	23:52	26°11.756	84°52.908	1514		
16324-1	110-1	CTD+WS	26.03.	02:17	26°11.914	84°43.550	527		
16325-1	111-1	MBES+PS	26.03.	02:47	26°11.900	84°43.550	527		
		end	26.03.	11:09	26°20.250	84°44.220	386		
16326-1	112-1	ROV	26.03.	13:39	26°24.910	84°46.646	501		dive #5, 5 samples; dive aborted, technical problems
		end	26.03.	16:45	26°24.428	84°46.643	497		
16327-1	113-1	Grab	26.03.	18:18	26°24.047	84°46.456	501	bulk	sandy sediments

Station No.		Device	Date (2012)	Time (UTC)	Latitude (°N)	Longitude (°W)	Water Depth (m)	Recovery (m)	Remarks
GeoB	MSM20								
16328-1	114-1	Grab	26.03.	19:08	26°23.852	84°46.390	515	bulk	sandy sediments
16329-1	115-1	Grab	26.03.	19:56	26°23.657	84.46.323	513	bulk	sandy sediments
16330-1	116-1	Grab	26.03.	20:50	26°23.467	84°46.256	512	bulk	sandy sediments
16331-1	117-1	Grab	26.03.	21:44	26°23.631	84°46.296	510	bulk	few carbonatic rocks, sponges, *Anthomastos*
16331-2	117-2	Grab	26.03.	22:24	26°23.630	84°46.296	510	bulk	rocks with antipatharian
16332-1	118-1	Grab	26.03.	23:23	26°23.077	84°46.129	506	bulk	sandy sediments
16333-1	119-1	MBES+PS	27.03.	03:06	26°26.238	84°47.089	509		
		end	27.03.	12:21	26°20.140	84°45.530	518		
16334-1	120-1	ROV	27.03.	13:19	26°20.177	84°45.564	519		dive #6, 6 samples
		end	27.03.	15:26	26°20.195	84°45.492	508		
16335-1	121-1	BC	27.03.	16:38	26°20.197	84°45.590	509	./.	not released
16335-2	121-2	BC	27.03.	17:07	26°20.196	84°45.589	508	bulk	few sediment, coral rubble
16336-1	122-1	Grab	27.03.	18:09	26°20.206	84°45.488	498	bulk	few coral rubble
16337-1	123-1	Grab	27.03.	18:52	26°20.223	84°45.588	508	./.	not released
16337-2	123-2	Grab	27.03.	19:26	26°20.222	84°45.588	507	bulk	coral rubble
16337-3	123-3	BC	27.03.	20:13	26°20.244	84°45.588	509	bulk	very few coral rubble
16338-1	124-1	GC (6m)	27.03.	21:16	26°22.314	84°45.850	480	1.21	sandy sediments
16339-1	125-1	GC (6m)	27.03.	22:26	26°25.225	84°46.225	500	bulk	sandy sediments
16340-1	126-1	CTD+WS	27.03.	23:58	26°20.193	84°45.587	519		Yoyo-CTD for 12 hours; water sampling
16340-2	126-2	CTD+WS	28.03.	00:58	26°20.194	84°45.588	520		
16340-3	126-3	CTD+WS	28.03.	01:58	26°20.184	84°45.587	521		
16340-4	126-4	CTD+WS	28.03.	02:57	26°20.194	84°45.587	520		
16340-5	126-5	CTD+WS	28.03.	03:58	26°20.195	84°45.587	521		
16340-6	126-6	CTD+WS	28.03.	04:49	26°20.195	84°45.588	521		
16340-7	126-7	CTD+WS	28.03.	05:57	26°20.197	84°45.588	520		
16340-8	126-8	CTD+WS	28.03.	06:57	26°20.194	84°45.586	520		
16340-9	126-9	CTD+WS	28.03.	07:49	26°20.193	84°45.588	520		
16340-10	126-10	CTD+WS	28.03.	08:58	26°20.198	84°45.587	520		
16340-11	126-11	CTD+WS	28.03.	10:04	26°20.194	84°45.588	520		
16340-12	126-12	CTD+WS	28.03.	10:58	26°20.194	84°45.588	520		
16340-13	126-13	CTD+WS	28.03.	11:58	26°20.193	84°45.589	520		
16341-1	127-1	ROV	28.03.	13:28	26°18.673	84°44.359	449		dive #7, 5 samples
		end	28.03.	16:13	26°19.218	84°44.388	409		
16342-1	128-1	Grab	28.03.	17:34	26°20.475	84°46.742	629	bulk	sand and coral rubble
16343-1	129-1	Grab	28.03.	18:28	26°20.559	84°46.775	631	./.	empty
16344-1	130-1	CTD+WS	28.03.	21:28	26°12.012	84°47.305	1002		
Southwest-Florida Slope									
16345-1	131-1	CTD+WS	29.03.	04:52	25°14.991	84°32.017	1274		
16346-1	132-1	MBES+PS	29.03.	06:06	25°14.999	84°31.997	510		
		end	29.03.	11:54	25°13.724	84°26.098	545		
16347-1	133-1	ROV	29.03.	13:13	25°16.060	84°26.951	568		dive #8; 10 samples
		end	29.03.	18:13	25°16.513	84°26.413	429		
16348-1	134-1	Grab	29.03.	19:09	25°16.529	84°26.491	413	bulk	two rocks (~10 cm in diameter)
16348-2	134-2	Grab	29.03.	19:43	25°16.529	84°26.489	413	bulk	very few small coral rubble
16348-3	134-3	Grab	29.03.	20:25	25°16.533	84°26.485	411	bulk	very few sand and very few small coral rubble
16348-4	134-4	Grab	29.03.	21:02	25°16.531	84°26.477	411	./.	empty
16349-1	135-1	MBES+PS	29.03.	21:37	25°16.370	84°26.661	502		
		end	30.03.	12:39	24°57.600	84°17.350	500		
16350-1	136-1	ROV	30.03.	13:08	24°57.581	84°17.359	487		dive #9, 7 samples
		end	30.03.	18:20	24°58.517	84°17.932	472		
16351-1	137-1	GC (6m)	30.03.	19:30	24°59.051	84°18.342	478	./.	empty, some sand in the core catcher
16352-1	138-1	Grab	30.03.	20:24	24°58.636	84°18.102	468	./.	empty, a bit of sand

Station No. GeoB	MSM20	Device	Date (2012)	Time (UTC)	Latitude (°N)	Longitude (°W)	Water Depth (m)	Reco-very (m)	Remarks
16353-1	139-1	Grab	30.03.	21:14	24°58.428	84°17.916	458	bulk	rocks (20x30 cm)
16354-1	140-1	Grab	30.03.	22:08	24°58.163	84°17.972	471	bulk	sandy sediments
16355-1	141-1	MBES+PS	30.03.	22:50	24°58.741	84°17.522	462		
		end	31.03.	01:01	25°56.400	84°16.920	463		
Bimini Slope									
16356-1	142-1	CTD+WS	01.04.	17:35	25°49.500	79°27.999	766		
16357-1	143-1	MBES+PS	01.04.	18:14	25°49.500	79°28.000	766		
		end	01.04.	19:17	25°51.950	79°27.300	744		
16356-1	142-1	CTD+WS	01.04.	17:35	25°49.500	79°27.999	766		
16357-1	143-1	MBES+PS	01.04.	18:14	25°49.500	79°28.000	766		
		end	01.04.	19:17	25°51.950	79°27.300	744		
16358-1	144-1	ROV	01.04.	21:38	25°52.520	79°27.905	750		dive #10, no samples; strong currents!
		end	01.04.	23:18	25°53.685	79°27.885	695		
16359-1	145-1	GC (6m)	02.04.	00:48	25°51.940	79°27.974	734	bulk	few corals and lithified sediment in core catcher (Wienberg mound)
16360-1	146-1	GC (6m)	02.04.	01:41	25°51.810	79°27.972	700	2.00	coral-bearing core; core bent, top disturbed (Wienberg mound)
16361-1	147-1	MBES+PS	02.04.	02:12	25°51.930	79°28.424	747		
		end	02.04.	11:33	25°58.680	79°17.180	430		
16362-1	148-1	ROV	02.04.	13:15	25°55.690	79°18.642	514		dive #11, 16 samples
		end	02.04.	18:27	25°57.244	79°18.579	520		
16363-1	149-1	Grab	02.04.	19:37	25°55.492	79°17.542	465	bulk	slightly sandy mud
16363-2	149-2	GC (6m)	02.04.	20:21	25°55.493	79°17.542	465	5.69	off-mound core, over-penetration, top is lost (~30-40 cm)
16363-3	149-3	GC (12m)	02.04.	21:39	25°55.490	79°17.540	465	10.27	off-mound core
16364-1	151-1	GC (6m)	03.04.	01:21	25°42.931	79°32.356	830	1.60	sandy sediments
16365-1	152-1	MBES+PS	03.04.	01:47	25°43.269	79°32.309	834		
		end	03.04.	12:38	24°33.000	79°21.050	663		
Great Bahama Bank Slope									
16366-1	153-1	ROV	03.04.	14:03	24°33.120	79°21.081	673		dive #12, 5 samples; dive aborted due to technical problems
		end	03.04.	15:54	24°33.559	79°21.060	648		
16367-1	154-1	CTD+WS	03.04.	17:16	24°33.194	79°21.059	661		
16367-2	154-2	BC	03.04.	17:58	24°33.193	79°21.058	660	0.29	*Enallopsammia* rubble, mud
16368-1	155-1	BC	03.04.	18:47	24°33.227	79°21.062	663	0.47	*Enallopsammia* rubble, mud
16368-2	155-2	GC (6m)	03.04.	19:40	24°33.214	79°21.060	661	0.53	coral-bearing core
16369-1	156-1	GC (6m)	03.04.	20:32	24°33.193	79°21.058	660	2.29	same position as 16367, corals at the top
16370-1	157-1	BC	03.04.	21:57	24°35.791	79°21.241	629	./.	not released (Twin Peaks)
16370-2	157-2	BC	03.04.	23:01	24°35.806	79°21.248	636	./.	not released (Twin Peaks)
16371-1	158-1	BC	03.04.	23:59	24°35.799	79°21.170	619	./.	not released (Twin Peaks)
16371-2	158-2	BC	04.04.	00:40	24°35.748	79°21.170	608	./.	empty (Twin Peaks)
16372-1	159-1	MBES+PS	04.04.	01:10	24°35.758	79°21.191	615		
		end	04.04.	12:18	24°33.340	79°21.330	685		
16373-1	160-1	ROV	04.04.	13:01	24°33.511	79°21.316	682		dive #13, 3 samples
		end	04.04.	14:18	24°34.749	79°21.139	610		
16374-1	160-5	ROV	04.04.	15:53	24°33.730	79°19.804	654		dive #14, 6 samples
		end	04.04.	17:54	24°34.376	79°19.876	660		
16375-1	161-1	BC	04.04.	19:09	24°33.524	79°21.297	677	bulk	foraminifera-pteropod sand with coral rubble (Mount Gay base)
16376-1	162-1	BC	04.04.	19:56	24°33.564	79°21.230	673	0.21	abundant, large *Lophelia* rubble (Mount Gay flank)

Station No.		Device	Date (2012)	Time (UTC)	Latitude (°N)	Longitude (°W)	Water Depth (m)	Reco-very (m)	Remarks
GeoB	MSM20								
16377-1	163-1	BC	04.04.	20:41	24°33.624	79°21.212	641	bulk	few coral fragments, live *Aphrocallistes*
16377-2	163-2	GC (6m)	04.04.	21:27	24°33.625	79°21.212	635	5.65	coral-bearing core; same position as 16385 (Mount Gay flank)
16378-1	164-1	GC (6m)	04.04.	22:34	24°33.570	79°21.231	673	1.24	coral-bearing core; same position as 16376, tube bent, *Lophelia* fragments in the weight of the corer
16379-1	165-1	GC (6m)	04.04.	23:56	24°33.638	79°21.199	634	5.01	coral-bearing core; top (~20cm) as bulk sample (Mount Gay top)
16379-2	165-2	BC	05.04.	00:54	24°33.636	79°21.200	622	./.	not released
16379-3	165-3	BC	05.04.	01:28	24°33.636	79°21.200	623	./.	not released
16380-1	166-1	MBES+PS	05.04.	02:14	24°33.491	79°21.125	676		
		end	05.04.	11:00	24°37.105	79°21.029	687		
16381-1	167-1	ROV	05.04.	13:09	24°36.855	79°20.845	695		dive #15, 7 samples
		end	05.04.	16:20	24°37.771	79°20.719	694		
16382-1	168-1	BC	05.04.	17:40	24°37.425	79°20.711	658	0.28	coral rubble
16382-2	168-2	GC (6m)	05.04.	18:26	24°37.424	79°20.702	663	1.09	coral-bearing core
16383-1	169-1	GC (6m)	05.04.	19:21	24°37.536	79°20.750	669	0.78	coral-bearing core; tube bent, lithified sediment at the base
16384-1	170-1	GC (6m)	05.04.	20:25	24°38.580	79°17.698	633	5.73	off-mound core; over-pene-trated, top is lost (~20cm)
16385-1	171-1	GC (12m)	05.04.	22:09	24°33.620	79°21.220	655	1.32	coral-bearing core; same position as
16386-1	172-1	CTD+WS	05.04.	23:01	24°33.507	79°21.225	678		Yoyo-CTD for 12 hours; water sampling
16386-2	172-2	CTD+WS	06.04.	00:01	24°33.508	79°21.225	679		
16386-3	172-3	CTD+WS	06.04.	01:00	24°33.508	79°21.224	678		
16386-4	172-4	CTD+WS	06.04.	02:00	24°33.507	79°21.225	678		
16386-5	172-5	CTD+WS	06.04.	03:00	24°33.508	79°21.224	678		
16386-6	172-6	CTD+WS	06.04.	04:01	24°33.508	79°21.225	678		
16386-7	172-7	CTD+WS	06.04.	05:01	24°33.508	79°21.225	677		
16386-8	172-8	CTD+WS	06.04.	06:00	24°33.506	79°21.224	678		
16386-9	172-9	CTD+WS	06.04.	07:00	24°33.509	79°21.224	678		
16386-10	172-10	CTD+WS	06.04.	07:59	24°33.506	79°21.226	678		
16386-11	172-11	CTD+WS	06.04.	09:00	24°33.505	79°21.226	678		
16386-12	172-12	CTD+WS	06.04.	10:00	24°33.507	79°21.224	678		
16386-13	172-13	CTD+WS	06.04.	10:59	24°33.506	79°21.226	678		
16386-14	172-14	CTD+WS	06.04.	12:00	24°33.505	79°21.227	678		
16387-1	173-1	ROV	06.04.	13:45	24°35.780	79°16.583	560		dive #16, no samples; aborted, strong currents
		end	06.04.	14:03	24°35.737	79°16.605	561		
16388-1	173-2	ROV	06.04.	15:17	24°35.593	79°16.790	572		dive #17, 5 samples
		end	06.04.	16:44	24°35.705	79°16.933	583		
16389-1	174-1	MBES+PS	06.04.	18:18	24°35.712	79°17.942	613		
		end	06.04.	19:47	24°36.020	79°21.564	691		

MBES+PS: Multibeam Echosounder (EM120 & 1002), PARASOUND
CTD+WS: CTD and rosette water sampler
BC: 50*50 cm box corer
GC: Gravity corer equipped with either 6-m or 12-m-long core barrel
Grab: Van-Veen-type grab sampler
ROV: Remotely Operated Vehicle

8 Data and Sample Storage and Availability

A Cruise Summary Report (CSR) was compiled and submitted to DOD (Deutsches Ozeanographisches Datenzentrum), BSH (Bundesamt für Seeschiffahrt und Hydrographie), Hamburg, immediately after the cruise. A final station list was transferred to PANGAEA. The cruise was performed within the Exclusive Economic Zones of Mexico, the USA and the Bahamas. No formal request for data was made by the respective authorities, except a sample sharing request from Mexico and the request for final cruise reports from Mexico and the USA.

All data will be transferred to the PANGAEA database as soon as they are available and quality checked, generally within 2-3 years (by June 2015), depending on data type and progress of sample analysis. The following compilation names the scientists who are responsible for access to the different data and sample sets.

Aerosol data - The collected data is processed and analysed by NASA and distributed into a network freely available via http://aeronet.gsfc.nasa.gov/new_web/maritime_aerosol_network.html or http://aeronet.gsfc.nasa.gov/new_web/cruises_new/Merian_12_0.html.

Hydrography - CTD data are held at the GEOMAR (Kiel) and will be analysed by the group of Prof. Dr. C. Dullo.

Hydroacoustics - MBES (EM 120 & EM 1002), PARASOUND and ADCP data are held at MARUM (Bremen) (Prof. Dr. D. Hebbeln, P. Wintersteller). A copy of these data sets was given to the University of Miami (USA) (Prof. Dr. G. Eberli). In addition, the MBES data were forwarded to the BSH.

Zoobenthos - Samples and data are held at Senckenberg am Meer (Wilhelmshaven) (Prof. Dr. A. Freiwald) and will be analysed in cooperation with the DZMB (Deutsches Zentrum für Marine Biodiversitätsforschung, Wilhelmshaven).

Sediments – All sediment cores and samples will be stored at the MARUM core repository in Bremen (Prof. Dr. D. Hebbeln, Dr. C. Wienberg).

Seafloor imaging - Photo and video footage obtained by the ROV are held at the MARUM in Bremen (Dr. C. Wienberg) and at Senckenberg am Meer in Wilhelmshaven (Dr. L. Beuck).

9 Acknowledgements

The Scientific Shipboard Party aboard R/V MARIA S. MERIAN cruise MSM 20-4 gratefully acknowledges the friendly and professional cooperation and very efficient technical assistance of Captain Friedhelm von Staa, his officers and crew who substantially contributed to the overall scientific success of this cruise. Greatly acknowledged are the efforts from the German Diplomatique Corps in the German Embassies in Mexico City and in Port of Spain, in the German Honorary Consulates in Bridgetown and in Nassau and in the Foreign Office in Berlin. Finally we thank the German Science Foundation (DFG) for providing ship time on R/V MARIA S. MERIAN to investigate the CWC ecosystems off Yucatan and around Florida.

10 References

Anselmetti, F.S., Eberli, G.P. and Ding, Z.D., 2000. From the Great Bahama Bank into the Straits of Florida: A margin architecture controlled by sea-level fluctuations and ocean currents. Geol. Soc. Am. Bull., 112, 829–844.

Betzler, C., Reijmer J.J. G, Bernet, K., Eberli, G.P, Anselmetti, F.S. (1999) Sedimentary patterns and geometries of the Bahamian outer carbonate ramp (Miocene and lower Pliocene, Great Bahama Bank). Sedimentology 46, 1127-1145.

Brooke, S., Young, C.M., 2009. *In situ* measurement of survival and growth of *Lophelia pertusa* in the northern Gulf of Mexico. Mar. Ecol. Prog. Ser. 397,153-161

Caress, D. W., Chayes, D. N., 1996. Improved processing of Hydrosweep DS Multibeam Data on the R/V Maurice Ewing. Mar. Geophys. Res. 18, 631-650.

Cairns, S., 1979. The deep-water Scleractinia of the Caribbean Sea and adjacent waters. Stud Fauna Curaçao 57, 1-341.

Correa, T. B.S., Grasmueck, M., Eberli, G.P., Reed, J., Verwer, K., Purkis, S., 2011. Variability of Cold-Water Coral Mounds in a High Sediment Input and Tidal Current Regime, Straits of Florida. Sedimentology, on line, 1 – 27, doi:10.1111/j.1365-3091.2011.01306.x

Corso, W., Buffler, R.T., Austin, J.A., 1988. Erosion of the Southern Florida Escarpment. In: Bally, A.W. (Ed.), AAPG Atlas of Seismic Stratigraphy, 2, AAPG Studies in Geology 27, pp. 149-151.

Eberli, G.P., Anselmetti, F.S., Kroon, D., Sato, T., Wright, J.D., 2002. The chronostratigraphic significance of seismic reflections along the Bahamas transect. Mar. Geol. 185, 1–17.

Eberli, G.P., Ginsburg, R.N., 1987. Segmentation and coalescence of Cenozoic carbonate platforms, northwestern Great Bahama Bank. Geology 15, 75-79.

Furuya, K., Harada, K., 1995. An automated precise Winkler titration for determining dissolved oxygen on board ship. Journal of Oceanography 51, 375-383.

Grasmueck, M., Eberli, G.P., Viggiano, D.A., Correa, T., Rathwell, G., Luo J., 2006. Autonomous underwater vehicle (AUV) mapping reveals coral mound distribution, morphology, and oceanography in deep water of the Straits of Florida. Geophys. Res. Lett. 33, L23616, doi:10.1029/2006GL027734.

Grasshoff, K., 1983. Determination of oxygen. In: Grasshoff, K., Ehrhardt. M., Kremling, K. (Eds.), Methods of seawater analysis. Verlag Chemie Weinheim, New York, pp. 61-72.

Gyory, J., Mariano, A.J., Ryan, E.H., 2005. "The Yucatan Current" Ocean Surface Currents. World wide web article, accessed March 2005. Available on-line at: http://oceancurrents.rsmas.miami.edu/caribbean/yucatan.html

He, R., Weissberg, R.H., 2003. A Loop Current intrusion case study on the West Florida Shelf. Journal of Physical Oceanography 33, 465-477.

Hübscher, C., Dullo, C., Flögel, S., Titschak, J., Schönfeld, J., 2010. Contourite drift evolution and related coral growth in the eastern Gulf of Mexico and its gateways. Int. J. Earth Sci. (Geol. Rundsch.) 99, S191–S206.

Mulder, T, Ducassou, E., Eberli, G.P., Hanquiez, V., Gonthier, Kindler, P., Fournier, F., Leonifde, P., Billeaud, I., Marsset, B., E., Reijmer, J.J.G., Bondu, C., Joussiaume, R., Pakiades, M., 2012. Morphology and sedimentary processes along a carbonate slope. Example of the Great Bahama Bank. In press, Geology.

Newton, C.R., Mullins, H.T., Gardulski, A.F., Hine, A.C., Dix, G.R., 1987. Coral mounds on the West Florida slope: Unanswered questions regarding the development of deep-water banks. Palaios 2, 359-367.

Paull, C.K., Hecker, B., Commeau, R., Freeman-Lynde, R., Neumann, A.C., Corso, W., Golubic, S., Hook, J., Sikes, E., Curray J., 1984. Biological communities at the Florida Escarpment resemble hydrothermal vent taxa. Science 226, 965-967.

Paull, C.K., Chanton, J., Martens, C., Fullagar, P., Neumann, A.C., Coston, J, 1991. Seawater circulation through the flank of the Florida Platform: evidence and implications. Mar. Geol. 102, 265-279.

Paull, C.K., Freeman-Lynde, R., Bralower, T., Gardemal, J., Neumann, A.C., D'Argenio, B., Marsella, E., 1990. Geology of the strata exposed on the Florida Escarpment. Mar. Geol. 91, 177-194.

Schlager, W., 1981. The paradox of drowned reefs and carbonate platforms. Geol. Soc. Amer. Bull. 92, 197-211.

Schlager, W., 1991. Depositional bias and environmental change - important factors in sequence stratigraphy. Sed. Geol. 70, 109-130.

Schönfeld et al., 2011. Surface and Intermediate Water hydrography, planktonic and benthic biota in the Caribbean Sea – Climate, Bio and Geosphere linkages (OPOKA). Cruise Report of R/V METEOR cruise M78-1 (http://www.dfg-ozean.de/en/berichte/fs_meteor/m_78/).

Wessel, P., Smith W.H.F., 1998. New, improved version of Generic Mapping Tools released, EOS Trans. Amer. Geophys. U. 79 (47), 579.

Wilber, R.J., Milliman, J.D., Halley, R.B. 1990. Accumulation of bank-top sediment on the western slope of Great Bahama Bank: Rapid progradation of a carbonate megabank. Geology 18, 970-974.