METEOR-CRUISE M65/2

DAKAR – LAS PALMAS, 04.07.2005- 26.07.2005

Short Cruise Report

Participants

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NOC	National Oceanographic Centre, Southampton, UK

Research Objectives

The continental margin off Northwest Africa is largely shaped by a complex interplay of sediment transport processes directed both downslope and along-slope. Where and how sediment 1) is exported from the shelf, 2) is deposited on the continental slope or 3) reaches the deep-sea basin depends on a wide variety of relevant factors such as seabed morphology, climate, sea level fluctuations, slope stability, oceanographic regime, and sediment sources. Main target of Meteor-Cruise M65/2 is to develop sedimentary and evolutionary models for the sedimentation dynamics off NW-Africa and to establish quantitative sediment budgets in relation to climate controlled variable sediment supply. The investigations are carried out in the framework of the DFG Research Center 'Ocean Margins' at the University Bremen.

Sedimentation processes off Mauritania were studied during Meteor-Cruise M58/1 in 2005. The data clearly show that even at the arid, presumably sediment-starved, continental margin off Mauritania with the Sahara in its hinterland, sediment transport operates with different rates and styles, including a significant transfer of land-derived terrigenous and hemipelagic sediments to the deep sea. During Meteor-Cruise M65/2 the investigations of sediment transport processes were expanded to the subtropical areas off Senegal and The Gambia, where large amounts of sediments were delivered by numerous rivers. Main scientific targets in this area are:

- To investigate morphological structures, sedimentary deposits, and pathways of gravity driven sediment transport on the continental slope in a subtropical area.
- To develop a model, which describes the transport dynamics of the sediments from shallow water into the deep sea and which will extend the existing models for the tropical aspect.

One of the most unexpected results of Meteor-Cruise M58/1 was the discovery of a spectacular meandering slope channel off Cap Timiris at ~19°45'N. The canyon was surveyed by us for ~215km from the shelf edge to ~3000m water depth. To further study the formation and evolution of the canyon, we continued our investigations especially at the shelf edge and at the distal part of the canyon. The specific aims are:

- To study the geometry, age, and sediment sources of the fluvial system, which relicts are preserved on the shelf.
- To analyze the sediment transport pathways from the shelf to the distal canyon at the continental rise

Another working area is located in the central upwelling zone off Cap Blanc with the objective of studying the seasonal and interannual variability of the particle flux. Additionally the dinoflagellate cyst distribution in surface sediments and surface waters as well as the isotopic composition of Thoracosphaera heimii cysts were studied in all working areas

Narrative of the cruise

The main group of the scientific party arrived in Dakar on July 2nd in the evening. All containers were already stored on Meteor and July 3rd was used for setting up the equipment. We left the port of Dakar as scheduled on July 4th at noon heading west. The scientific crew of Meteor-Cruise M65/2 included 24 scientists from the DFG Research Center Ocean Margins and the Department of Geosciences at Bremen University, one scientist each from National Oceanographic Centre, Southampton (UK), Wesleyan University (US), and Mohammed-V Agdal University (Rabbat, Morocco), as well as a technician from the German Weather Service, and a Senegalese Observer.

As we did not receive permission for the waters of Guinea Bissau, which was one of our proposed main working areas, we decided to concentrate our work off the coast of Senegal and The Gambia for the first half of the cruise. After leaving the 3-mile-zone we started the scientific work at 13:25h on July 4th by switching on the hydroacoustic systems Parasound and Hydrosweep in order to search for a first sediment sampling station. On our first profile we crossed a small slump in 1500m water depth. At ~2000m water depth we changed our course to the south following the 2000m contour. On this profile we had our first crossing of Dakar Canyon, which is ~350m deep and 5km wide at this location. We decided to have our first station (GeoB9601) immediately north of Dakar Canyon, where we used a water sampler, a multicorer, and a gravity-corer. The 740cm-long gravity core shows undisturbed hemipelagic sediments throughout the core.

Thereafter, we deployed the multichannel seismics. Recording of seismic data started on July 5th at 2:38h along a profile running south parallel to the coastline in ~2000m water depth as far as we were allowed to go without entering the waters of Guinea-Bissau. On our way we crossed a slump in direct vicinity of Dakar canyon but most parts of the profile show well-stratified sediments without any indications of large scale downslope sediment-transport. Even off the Gambia-River with its supposed large fluvial sediment input we neither see indications for significant sediment transport on the open slope nor in a submarine channel. A number of small diapers and submarine canyons (including Diola and Mandingo canyons) were imaged further to the south. On July 6th early in the morning we changed course to the west and ran two profiles downslope up to ~4000m water depth. On these profiles we passed a very powerful cloud cluster with very heavy rain showers and a thunderstorm, which was accompanied by gusts of Beaufort 12 (up to 70kts). This cloud cluster developed during its way to the Caribbean Sea to the Hurricane Emily. Luckily the heavy gusts were short and seismic profiling was not interrupted. While the margin off southern Senegal is relatively stable up to a water depth of ~3000m, several deposits of mass wasting events were imaged seaward of the diapers imaged before in water depths >3000m. However, these deposits are too thick for sampling; hence, we turned to the north and collected an additional seismic profile across Diola Canyon in ~4000m water depth, which is only ~70m deep at this location. After crossing the canyon we retrieved the seismic gear and cored the northern levee of the canyon (Station GeoB9602). A 483cm-long gravity core shows a number of turbidites intercalated in hemipelagic sediments. The attempt to recover a core from the canyon thalweg was not successful (Station GeoB9603).

The seismic and bathymetric data indicate that the locations of the canyons off southern Senegal are structurally controlled and that the depth of the canyons is quickly decreasing with increasing distance from the coast. This indicates that these canyons are not of key importance for downslope sediment transport but we speculate that sediments delivered by the Gambia River and the numerous smaller rivers further south might be transported on the shelf to the north and than enter the wide and deep Dakar Canyon. Hence, we decided to concentrate our efforts for the next week on Dakar Canyon.

We deployed the seismics on July 7th early in the morning and ran a profile back from the area off southern Senegal to Dakar-Canyon along the 3500m-contour. In contrast to the parallel profile further upslope the lower margin shows clear indication for large scale mass wasting. Very thick transparent units were imaged along large parts of this line. We crossed Dakar Canyon with the seismic system in ~3600m water depth on July 8th ~00:30h and continued the seismic survey with additional crossings of the canyon further upslope until July 9th around noon. In 3600 m water depth the canyon is incised into hemipelagic sediments for ~150m. The incision depth increases to >400m further upslope. The course of the canyon is relatively straight and several terraces were imaged at the canyon flanks. Average canyon width is 3-4km. The canyon floor is almost flat but usually shows a small V-shaped depression indicating young sediment transport through the canyon. The upper most part of the canyon shows a complex pattern with some smaller tributaries and older buried canyons.

Coring around Dakar Canyon started on July 9th in the afternoon. We started with coring a slide mass located close to the canyon. Station GeoB9604 was located inside the slide mass (831cm recovery), Station 9605 north of the slide mass (790cm recovery), and Station

GeoB9606 (951cm recovery) was located a little bit further downslope where the Parasound records show thicker slide deposits.
The night was used for collecting additional bathymetric data of the canyon and coring was continued on July 10th at 08:00h with a transect across the canyon. The first core (GeoB9607) was taken at the thalweg of the canyon. As we expected sandy sediments at the thalweg, we decided to use a 3-m-long core barrel, which overpenetrated into the sediments up to the top of the weight. Therefore we used a 12-m long core barrel for the second try and we recovered a 784cm-long very interesting core. The uppermost section of the core (~50cm) shows undisturbed hemipelagic sediments; from there on the frequency and the thickness of turbidites increase, which are overlying a thick slump deposit. The uppermost undisturbed sediments probably represent the Holocene indicating that no significant sediment transport through the canyon occurred in the Holocene, but the canyon was active during Pleistocene times. Thereafter, we took a core on the northern levee (GeoB9608, 908cm recovery), which only showed thin mud turbidites, while some sandy turbidites were found in a 542cm-long core (GeoB9609) on a terrace of the canyon.
The night was used for collecting additional bathymetric data especially of the lower canyon, which were the basis for selecting additional seismic profiles. Seismic profiling started on July 11th ~10.00h with a profile across the distal canyon in >4000m water depth. The canyon is almost absent on this profile and only some remnants of a levee were identified. Additional seismic profiles show that the canyon is getting shallower very quickly at water depth >3800m. The reason for the sudden decrease of canyon depth is a large slide mass south of the canyon, which filled and therefore destroyed the distal part of the canyon. The last seismic profile of the distal canyon was completed on July 12th at 06:00h and the day was used for taking cores of distal Dakar Canyon. Station GeoB9610 was taken at the thalweg ~60km downslope of the transect described above This core is only 254cm long but again shows a number of turbidites with a coarse grained sandy base. Another 50km downslope two additional cores were taken at the thalweg (GeoB9611) and on the northern levee (GeoB9612), which are 147cm and 878cm long, respectively. Both cores show similar features as described before. The set of three cores of the thalweg of the canyon might allow correlating the individual turbidites between the stations.
The following night was used for collecting additional seismic profiles of the slide, which destroyed the distal canyon. The width of the slide might be >100km. A 30-50m high headwall can be easily identified on several profiles in water depths around 3500m. This is unusually deep for a large mass wasting event. As we identified additional slide deposits in water depth >3000m and slope gradients <0.5° further to the south, slides in great water depth might to be more important than previously estimated.
On July 13th we tried to core the slide (Station GeoB9613) at a location where the cover seems to be thin. A 6-m-long core overpenetrated into the sediments up to the top of the weight; with the following 12-m-core barrel we recovered 980cm of sediments. A first visual inspection suggested that we did not reach the slide, though we cannot exclude that we hit a relatively intact slide block. The rest of the day was used for two additional gravity-cores (Stations GeoB9614 and 9615). One station was located at a depression of the slide which seems to be filled with turbidites and the second core was in the prolongation of Dakar Canyon. Both cores show a large number of turbidites suggesting that the confined flows travelling downslope in Dakar Canyon spread over a large area further downslope once they canyon was destroyed by the slide described above.
On July 14th at 02:16 we completed our work off Senegal and started our transit to Cap Timiris Canyon off Mauritania. For the first part of the transit we chose a northerly course along 19°W longitude. This track allowed us to extend existing hydroacoustic data collected during Meteor-Cruise M58/1 to greater water depth. On this transit we crossed a number of interesting seafloor structures, such as numerous canyons (some of them with exceptionally

well developed terraces) and the distal Mauritania Slide Complex. The width of the youngest debris flow of this slide complex is ~30km in 3500m water depth, while its thickness exceeds 20m. The southern and the northern edge of the debris flow are clearly identified on the Parasound records as depositional boundaries.
At 18°12'N, 19°00'W we changed course to NE and headed for the source area of Cap Timiris Canyon. Cap Timiris Canyon was discovered by us during Meteor-Cruise M58/1. The Cap Timiris Canyon runs westwards from the shelf break to a depth of at least 4000 m and is ~500 km long. The dominantly V-shaped and deeply entrenched canyon exhibits many fluvial features including dendritic, meander, and braiding patterns, a cut-off loop and terraces, and is presently incising. We ascribe canyon origin to an ancient river system in the adjacent presently arid Sahara Desert that breached the shelf during a Plio/Pleistocene sea level lowstand and delivered sediment directly into the slope area. To further prove this hypothesis we collected additional seismic data and took sediment cores in the head region of the canyon.
On July 15th at 17:00h we started a Parasound survey of the shelf, thereby also crossing a structure north of the head region of the canyon, which was previously interpreted as mud belt. The following morning was used for taking 5 giant box corers and a number of water samples (Stations GeoB9616-9620) in an area of a sediment wedge and an erosive feature identified on the Parasound records. The giant box corers mainly contained fine sand and numerous shells and shell fragments. As we also wanted to recover longer cores from the shelf we took a 3m-long Kastenlot (Station GeoB9618) but unfortunately the Kastenlot bent caused by a massive layer of shells in ~1.5m subbottom depth.
On July 16th in the evening we started to collect seismic data of the proximal part of the canyon from the shelf up to ~1500m water depth. The new seismic data show numerous V- and U-shaped canyons up to 500m deep but also some buried channels and erosional unconformities. This data will help to reconstruct the evolution of the proximal canyon. The seismic gear was recovered on July 17th around noon. Thereafter one additional station (GeoB9621) for sediment and water sampling was chosen on the shelf in the area of the mud belt. A 6m-long core-barrel was filled to the top with a homogenous fine sand including shell fragments and hence contradicting the existence of a mud belt in this area.
The next core (GeoB9622, 10.8m recovery) was taken in 2880m water depth in a cut off loop identified during Meteor-Cruise M58/1. As for all cores pore water was extracted using rhizomes immediately after the core was on deck. The pore water profile shows that the upper 4m of sediments slid less than 20 years ago. Additionally the increasing hydrogen sulphide smell with increasing sediment depth indicates the decay of organic matter under the condition of sulphate reduction. We assume the existence of organic rich clays in deeper layers, which were transported through the canyon from the high production area at the shelf break. The fact that only a relatively small portion of the clay is deposited in the cut off loop demonstrates the importance of transfer of organic rich matter through the canyon into the deep sea.
Thereafter (18.07 in the morning), we continued the bathymetric survey of Cap Timiris Canyon by following the canyon with a single Hydrosweep profile. The prolongation of the area mapped during Meteor-Cruise M58/1 shows a small section with a tortuous meander pattern but most of the canyon is relatively straight and has a north-westerly direction. Unfortunately, the wind increased to force 7 resulting in a poor quality of the Hydrosweep data. Therefore, we decided to stop the Hydrosweep survey and to collect some seismic lines crossing the canyons instead. Seismic profiling started on July 18th at 21:00h. The seismic data show a deeply incised canyon with well developed terraces and right-hand levees but ~500km off the shelf break the depth of the canyons decreases suddenly and the canyon shows some distributaries. We retrieved the seismic gear on July 20th at 4.00h and took four gravity cores across the canyon and a distributary. Core GeoB9623 was located on a well developed broad terrace ~50m above the canyon floor. The core bent but we recovered a 2-m-

long section showing several turbidites covered by ~20cm of hemipelagic sediments. The thickest turbidite has a coarse grained base consisting of sands and shell fragments. The only possible source area of this turbidite is the shelf demonstrating that coarse grained sediments are transported through the canyon into the deep sea. The 11.33m-long core GeoB9624 is located on the well developed northern levee. This core shows numerous overspill turbidites intercalated in hemipelagic sediments. This core will allow to reconstruct major phases of active sediment transport through the canyon. The attempt to recover a core from the canyon thalweg (Station GeoB9625) failed and the core was empty, but another core (Station GeoB9626) was successfully taken in one of the small distributaries. This 4m-long core shows numerous turbidites indicating that the distributaries are also important pathways for turbidity currents.

During the night from July 20th to July 21st we collected some additional Parasound lines with the aim to analyze the sudden change of the canyon depth and the depositional pattern. The idea that the Canyon was destroyed by the 170ka-old Cap Blanc Slide was not approved by our new data. They clearly show that the slide terminates on the levees and no slide material is found in the canyon itself. The termination of the slide on the levees gives a minimum age of 170ka for the canyon but the occurrence of levee sediments beneath the slide indicates a significant older age of the canyon. July 21st was used for two additional stations. Station GeoB9627 was taken in the most distal part of the canyon and the 3.12m-long core contains numerous turbidites. Station GeoB9628 was located in the area of the Cap Blanc Slide. The 10.68m-long core is characterized by hemipelagic sediments on top of a massive debrite. This station was also used for a test run of the particle camera up to a depth of 1000m.

The last two days of the scientific program were mainly used to exchange two moorings off Cap Blanc. Work at the mooring station CB ~200nm off Cap Blanc started on July 22nd at 04:00h with a run of the particle camera up to 2000m depth. The mooring CB15 consisting of two sediment traps and one current meter was released at 07:15h. The top buoy was sighted at 07:45h but due to an unfavourable current situation it took until 09:42h to get the top buoy on deck. The mooring was fully recovered at 12:22h. The mooring was in a good condition and the sediment traps and the current meters worked continuously since their deployment in April 2004. Deployment of mooring CB16 with the same design as the recovered mooring started at 14:30h. The time between recovery of the old mooring and deployment of the new mooring was used for a 2000m deep CTD station. The top buoy of the new mooring dived down at 17:49h. The night was used for the transit to mooring station CBi ~80nm to the east. The operation at this station was identical as described above, i.e. a run of the particle camera, a CTD run, and the exchange of mooring CBi2 with CBi3. The top buoy of mooring CBi3 dived on July 23rd at 14:37h. Immediately afterwards we started our transit to Las Palmas. On our way we collected some Parasound data of the headwall region of the Saharan Debris Flow. The second leg of Meteor-Cruise M65/2 ended on July 26th at 07:00h with the arrival in Las Palmas, Spain.

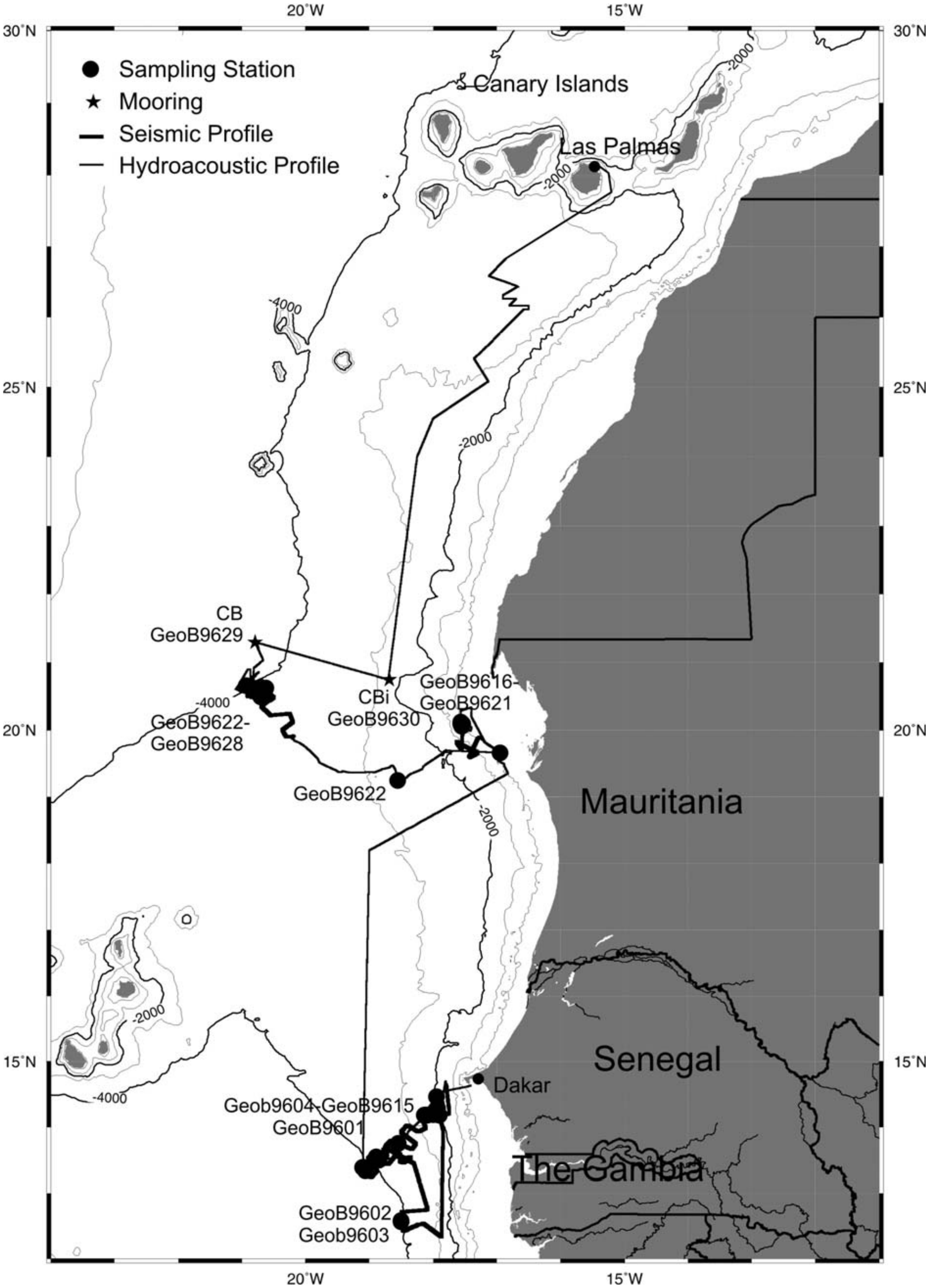

Fig. 1: Track of RV Meteor-Cruise M65/2.