

METEOR-Berichte

***Biogeochemistry and methane hydrates of the Black Sea;
Oceanography of the Mediterranean; Shelf sedimentation and cold
water carbonates***

Cruise No. M84/1

February 09 – February 22, 2011
Valletta (Malta) – Istanbul (Turkey)



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M. Elvert, E. Gagen, T. Goldhammer, V. Heuer, K.-U. Hinrichs,
B.P. Koch, C. Lazar, Y.-S. Lin, J. Lipp, T. Meador, S. Pape, C. Peters,
J. Schmal, F. Schmidt, J. Schröder, A. Teske, J. Wendt, L. Wörmer,
M. Yoshinaga, C. Zhu, E. Knuth, A. Gogou, A. Schön**

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MARUM – Zentrum für Marine Umweltwissenschaften der Universität Bremen

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1.1 Summary / Kurzfassung

Central objective of this expedition was the sampling of sediment and suspended particulate material from locations with extremely different environmental conditions. These samples will be used to constrain factors that influence the distribution of benthic archaea in marine sediments and thus determine their role in the marine carbon cycle. Five locations with a broad spectrum of environmental conditions were selected in the Mediterranean, Marmara and Black Seas based on published data. Therefore, site survey was not necessary and all ship time could be used for the deployment of the four different sampling devices, which we had available (gravity corer, multicorer, CTD rosette, in-situ pumps). Due to the shortness of the leg, only few sedimentological and geochemical investigations could be conducted on board directly. In contrast, great effort was made for preparation and storage of subsamples for the planned analysis and experiments in the home laboratories that will employ a great variety of complex methods. Taking the very ambitious schedule into account, with two stops at anchor for

(dis)embarkations, three transfers through very busy straits, more than 2.100 nm transit and extensive sampling programs at five locations, it has to be stated that the cruise was extremely successful. The recovered number of very promising samples has exceeded our initial expectations and constitutes an excellent basis for future scientific studies.

Zentrales Ziel dieser Expedition war es Sediment- und Suspensionsproben von Standorten mit extrem unterschiedlichen Milieubedingungen zu gewinnen. An diesem Material sollen jene Faktoren ermittelt werden, die die Verteilung benthischer Archaeen in marinen Sedimenten maßgeblich beeinflussen und somit deren Rolle im marinen Kohlenstoffkreislauf bestimmen. Zu diesem Zweck wurden im Vorfeld fünf Lokationen im zentralen und östlichen Mittelmeer, im Marmara Meer und im Schwarzen Meer ausgesucht, die ein sehr breites Spektrum an Umweltbedingungen abdecken. Profildfahrten zur Stationsuche waren somit nicht erforderlich. Die gesamte Zeit konnte auf Einsätze der vier zur Verfügung stehenden Probennahmesysteme verwendet werden (Schwerelot, Multicorer, CTD-Kranswasserschöpfer, In-situ Pumpen). Aufgrund der Kürze des Fahrtabschnitts konnten nur wenige sedimentologische und geochemische Untersuchungen direkt an Bord durchgeführt werden. Viel Zeit war für die aufwendige Präparation und Verpackung von Teilproben für die geplanten vielfältigen und methodisch komplexen Analysen und Experimente in den Heimlaboren notwendig. In Anbetracht des sehr ehrgeizigen Zeitplans, mit zwei Stops auf Reede zur Ein-/Ausbootung von Teilnehmern, dem dreifachen Passieren vielbefahrener Meerengen, mehr als 2.100 nm Transitstrecke und umfangreichen Arbeiten an den fünf Lokationen, muss die Reise als extrem erfolgreich bezeichnet werden. Die große Menge vielversprechenden Probenmaterials hat unsere Erwartungen weit übertroffen und stellt eine exzellente Grundlage für künftige wissenschaftliche Studien dar.

1.2 Participants

Table 1.1 List of scientific party

Name	Discipline	Institution
Zabel, Matthias, PD Dr.	chief scientist	MARUM
Aiello, Ivano, Dr.	Sedimentology	ML
Becker, Kevin, MSc-stud.	organic geochemistry	GeoB
Braun, Stefan, MSc-stud.	organic geochemistry	GeoB
Broda, Nadine, MSc-stud	organic geochemistry	GeoB
Dibke, C., MSc-stud.	organic geochemistry	GeoB
Elvert, Marcus, Dr.	organic geochemistry	GeoB / MARUM
Gagen, Emma, Dr.	microbiology	UR
Goldhammer, Tobias, Dr.	inorganic geochemistry	MARUM
Heuer, Verena, Dr.	organic geochemistry	GeoB / MARUM
Hinrichs, Kai-Uwe, Prof. Dr.	organic geochemistry	GeoB / MARUM
Koch, Boris, Prof. Dr.	organic geochemistry	AWI
Lazar, Cassandre, Dr.	microbiology	UNC
Lin, Yu-Shih, Dr.	organic geochemistry	MARUM
Lipp, Julius, Dr.	organic geochemistry	GeoB / MARUM
Meador, Travis, Dr.	organic geochemistry	MARUM
Pape, Silvana, techn.	inorganic geochemistry	MARUM
Peters, Carl, MSc- stud.	organic geochemistry	GeoB
Schmal, Jessica, techn.	organic geochemistry	GeoB / MARUM
Schmidt, Frauke, Dr.	organic geochemistry	GeoB / MARUM
Schön, Andreas, artist	special guest	
Schröder, Jan, PhD-stud.	organic geochemistry	GeoB
Teske, Andreas, Prof. Dr.	microbiology	UNC
Wendt, Jenny, techn.	inorganic geochemistry	GeoB
Wörmer, Lars, PhD-stud.	organic geochemistry	GeoB / MARUM
Yoshinaga, Marcos, Dr.	organic geochemistry	GeoB / MARUM
Zhu, Charlie, Dr.	organic geochemistry	MARUM
Knuth, Edmund, Dr.	Meteorology	DWD
Gogou, Alexandra, Dr.	observer/org. biogeochemistry	HCMR

Participating Institutions

AWI	Alfred Wegener Institute for Polar- and Marine Research, Stilleweg 2, D 30655 Hannover, Germany	www.awi-bremerhaven.de
DWD	Deutscher Wetterdienst, Geschäftsfeld Seeschiffahrt, Bernhard-Nocht-Str. 76, D 20359 Hamburg, Germany	www.dwd.de
GeoB	Dept. of Geosciences, Bremen University Klagenfurter Str., D 28359 Bremen, Germany	www.geo.uni-bremen.de
HCMR	Hellenic Centre for Marine Research, 46.7 km Athens-Sounion Av., 19013 Anavyssos, Greece	www.hcmr.gr

MARUM	Centre for Marine Environmental Sciences Leobener Str., D 28359 Bremen, Germany	www.marum.de
UNC	University of North Carolina at Chapel Hill, Dept. of Marine Sciences, Chapman Hall 351, CB 3300, Chapel Hill, NC 27599, USA	www.marine.unc.edu
UR	Institute for Microbiology, University Regensburg, Universitätsstraße 31, D 93053 Regensburg, Germany	www.biologie.uni-regensburg.de



Fig. 1.1 Scientific party on M84/1

1.3 Research Program

(K.-U. Hinrichs, M. Zabel)

METEOR Expedition M84/1 DARCSEAS (Feb 09-22, 2011) recovered sediments, water samples and suspended particulate matter from five sites in the Mediterranean Sea, Marmara Sea, and Black Sea. The goals of the cruise were intimately linked, but not limited, to the project DARCLIFE (*'Deep subsurface archaea: carbon cycle, life strategies, and role in sedimentary ecosystems'*) funded by the European Research Council (04/2010 – 3/2015), in which the majority of the cruise participants collaborate. This project investigates the distribution, composition, and processes of sub-seafloor microbial communities with a particular emphasis on *benthic archaea*. Archaea are a poorly understood domain of life. They have long been considered to be exotics that only occur in extreme environments like hot springs and salt lakes but are nowadays increasingly recognized as globally abundant organisms that mediate important processes controlling greenhouse gases and nutrients. In sub-seafloor sediments, the so-called *benthic archaea* have a cosmopolitan distribution, make up a significant - if not dominant - portion of life, and consist of numerous novel phylogenetic lineages that are at present uncultured. The large abundance of archaea in the deep sub-seafloor might be related to their unique ability to cope with extreme energy starvation, and their presumed ability to degrade

complex recalcitrant organic residues highlights their relevance for the carbon cycle and as potential targets for biotechnology. With DARCLIFE we have initiated a project to study *benthic archaea*, their carbon cycle and life strategies in the sub-seafloor. We seek to understand the geochemical and (paleo)environmental factors controlling the distribution, composition and processes of sub-seafloor microbial communities along with the accompanying biosphere-geosphere interactions. We ultimately aim to better understand the role of archaea in the Earth system and the fundamental properties of life at minimum energy. Central to our research strategy is the information encoded in structural and isotopic properties of sedimentary membrane lipids from *benthic archaea*. With metagenomic analysis we aim to establish a phylogenetic framework and to gain insights on potential metabolism. With in-depth geochemical examinations of the habitat we seek to elucidate processes that are mediated by *benthic archaea* in situ. In order to develop the full potential of lipids as proxies for studying nearly inaccessible microbial life, we grow model archaea under a set of environmental conditions and examine the impact on cellular lipid distributions. Our research approach involves the examination of *benthic archaea* in a global range of diverse sedimentary environments. The expedition DARCSEAS is the first concerted step toward this direction as it aims to capture the largest possible range of contrasting biogeochemical and depositional conditions in the Mediterranean Sea and adjacent basins.

In the Eastern Mediterranean the Urania Basin (Station GeoB 15101) and Discovery Basin (Station GeoB 15102) West off Crete represent two deep basins which only recently filled with highly saline, anoxic brines of different salinity and salt composition, thus creating extreme conditions for life. South of Cyprus Station GeoB 15103 targets a highly oligotrophic area where organic-lean coccolith oozes are intercalated with organic-rich sapropels. These sapropels may act as bioreactors in otherwise biologically largely inactive sediments. Station GeoB 15104 in the Marmara Sea is largely composed of clay-rich coccolith oozes and an organic rich sapropel layer, while Station GeoB 15105 at the southeastern slope of the Black Sea is situated in anoxic waters and comprises the succession of modern coccolith oozes, the early Holocene sapropel, and the late Pleistocene brackish mud. Taken together these sites cover sediments with largely varying inputs of organic matter, salinities, sedimentation rates, and depositional and paleoenvironmental regimes. Our sampling strategy was designed to generate a comprehensive set of geochemical and microbiological data that capture the chemical environment as well as the composition and processes of microbial communities in the sub-seafloor. It included: (a) sedimentologic description of recovered cores; (b) geochemical characterization of sediment pore-waters with respect to nutrients, electron acceptors and donors, and water-soluble organic metabolites; (c) quantification and molecular characterization of particulate and dissolved organic matter; (d) characterization of microbial communities by coupled lipid biomarker/DNA-based approaches and cultivation. In addition, we collected water samples and suspended particulate matter at the two brine basins and in the Black Sea in order to characterize the modern marine chemistry and composition of oceanic microbial communities and their linkage to their sedimentary counterparts. Moreover, excellent existing background information on the lithostratigraphy at stations GeoB 15103-15105 will enable us to study the late Quaternary paleoenvironmental conditions on a North-South transect from the southern Eastern Mediterranean to the Black Sea. The combination of biogeochemical, microbiological and paleoenvironmental data provides opportunities for examining the relationships between

subsurface microbial life and paleoenvironmental conditions at time of deposition. For example, we will compare early Holocene sapropel layers that were deposited simultaneously in three different oceanic basins.

1.4 Narrative of the Cruise (V. Heuer, M. Zabel)

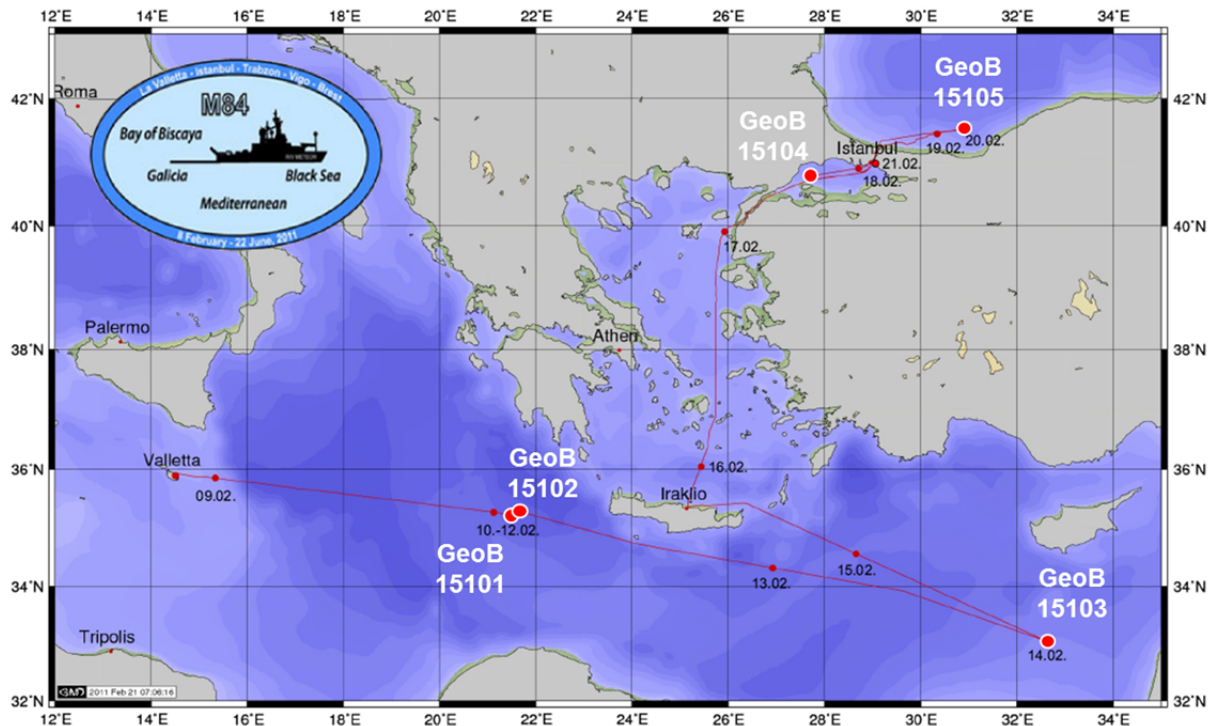


Fig. 1.2 Working area with cruise trajectory and sampling sites.

The expedition started 09:00 am on Wednesday, 09 February with leaving the port of Valletta (Malta). The scientific crew of 27 persons was completed by Dr. Alexandra Gogou, the Greek observer and well known colleague from the Hellenic Centre for Marine Research, and Andreas Schön, an artist and special guest on this cruise leg. After a transit of about 350 nm we arrived at the first station, GeoB 15101, in the Urania Basin in the afternoon of February 10. First samples were taken from the water column by using the CTD rosette sampler of the ship. As to be expected, a distinct change in salinity could be observed at around 3460 m water depth. At this location, an active mud volcano has been described in the literature. A thick layer of fluid mud could be sampled, but hampered also the deployment of our instruments for sediment sampling, gravity corer and multicorer. Station work was finished in the early evening of February 11. After only about 1 hour transit time we arrived at station GeoB 15102 in the Discovery Basin. Again, a huge amount of water column and sediment samples could be obtained. The transit to the third sampling site, located in the central eastern Mediterranean Sea, started in the afternoon of February 12 after about 48 hours of continuously intense work. As planned before, we took only sediment samples at site GeoB15103. With the gravity corer the uppermost sequence of sapropel layers could be sampled. Before passing the Aegean Sea, the Greek observer and an engineer of Kongsberg were disembarked in the harbor entrance of Heraklion (Crete). In turn, an inspector of the shipping company Laeisz embarked. After passing the Dardanelles without delay

we arrived at Istanbul in the morning of February 18. Despite an official announcement, the wait for the Turkish observers was more than 4 hours. So, we arrived at station GeoB 15104 in the Marmara Sea only at 6 pm. Again all instruments for sampling could be used successfully. In the morning of February 19 we passed the Bosphorus Strait and arrived at our last sampling site GeoB 15105 in the late afternoon. After finishing the very extensive scientific program in the early evening of the 20th February, the cruise ended one day later in the harbor of Istanbul after more than 2.100 nm transit and 28 mostly successful deployments of sampling devices at 5 locations in the Mediterranean Sea, the Marmara Sea, and the Black Sea.

1.5 Preliminary Results

1.5.1 Sampling Strategy

(V. Heuer)

At all sites, our sampling strategy was designed to generate a comprehensive set of geochemical and microbiological data. We sampled the sub-seafloor using a gravity corer (GC) set for 12 m long cores. In order to investigate small scale spatial heterogeneities, the gravity corer was deployed 2-3 times per site. We sampled surface sediments using a multicorer (MUC) equipped with 12 cores suited to retrieve the upper meter of sediment with an intact sediment/water interface. In addition, we investigated the water column and collected water samples and suspended particulate matter in the two brine basins (GeoB 15101 and GeoB 15102) and in the Black Sea (GeoB 15101) using a CTD-rosette with 24 Niskin bottles and a tool string with four in situ pumps (ISP).

Gravity cores were processed in the following way: (1) Immediately after recovery, the 12 m long cores were cut into one meter long sections, sampled for gas analysis at the freshly cut section ends, sealed with end caps, measured for curatorial purposes, labeled and moved to a cool room (+4°C) for storage and further processing. In general, the initial processing of gravity cores at room temperature (ca. 20°C) was finished within one hour. (2) Next, for analyses of redox-sensitive inorganic compounds, anaerobic pore-water samples were withdrawn from the closed sections of the gravity cores using rhizon suction samplers and evacuated syringes. The rhizon samplers were inserted into the sediment through small holes which were drilled into the core liner every 20-25 cm, following a pre-defined sampling scheme for all cores. The rhizons were allowed to collect pore-water samples for 1-2 hours. (3) Following rhizon sampling, small sampling ports were cut into the closed core liners for additional anaerobic probing of fresh sediment. Sampling ports were located adjacent to the rhizon sampling ports but a distance of ca. 5 cm was kept in order to avoid artifacts from the pore-water sampling process. Samples were collected for gas analysis cultivation of *benthic archaea* and the freshly cut sampling ports were used to insert electrodes for the direct measurement of pH values and redox potential. Gas sampling yielded a set of four or five individual samples for (a) shipboard and (b) shore based analysis of dissolved hydrogen, (c) shipboard quantitative and (d) shore based stable carbon isotopic analysis of hydrocarbon gases, and (e) analysis of methyl substrates. (4) When the gas-sensitive sampling was finished, core sections were cut lengthwise into halves. One half was moved back to the geology lab for visual core description, petrographic analysis of smear slides, scanning of magnetic susceptibility and color reflectance, and was further processed at room temperature. The other half was covered with foil and stored in the cool room. (5) Based on the

lithological core description and shipboard gas analysis, depth intervals were identified for an intensely coordinated geochemical and microbiological sampling program. Since our research approach requires relatively large samples, we sampled depth intervals stretching over 10-20 cm. We were particularly interested in resolving contrasting geochemical or lithological intervals, for example microbially relevant redox gradients (observed in shipboard hydrogen and methane data), or contrasting Sapropel/coccolith ooze sequences. Samples were taken simultaneously from the same depth intervals in both core halves in the geology lab and in the cold lab. The former was sampled for cell counts, metagenomic analysis of microbial diversity, structural and isotopic analysis of sedimentary microbial membrane lipids, molecular analysis of solid-phase bound organic matter and elemental and isotopic analysis of bulk sedimentary carbon and nitrogen. From the latter pore-water was sampled for quantitative and isotopic analysis of organic metabolites (using a pore-water press) and for molecular analysis of dissolved organic matter (DOM) (using rhizon samplers). In addition, solid phase samples were taken from the center of the cold core half and preserved under nitrogen atmosphere for shore-based incubation experiments. (6) This standard program was supplemented with additional samples at selected sites. In particular, samples for ^{14}C -dating of biomarkers and dissolved inorganic carbon were taken at Sites GeoB 15104 and GeoB 15105; solid phase samples for sulfur speciation were taken at Site GeoB 15104; and solid phase samples for activity measurements on end-acting hydrolases were taken at Sites GeoB 15103-15105. In general, all sampling was finished within less than 24 hours after core retrieval.

The 12 MUC cores were labeled A-M and in general distributed in the following way: Cores A and B were equipped with pre-drilled ports for anaerobic rhizon sampling of pore-waters from intact sediment cores and were used for inorganic pore-water analysis and quantitative and molecular analysis of DOM, respectively. Core C was used for lithological core description. Core D was sampled for gas analysis and the remaining sediment was combined with Cores E, F, and G to generate large volume samples for metagenomic analysis of microbial diversity, structural and isotopic analysis of sedimentary membrane lipids, molecular analysis of solid-phase bound organic matter and elemental and isotopic analysis of bulk sedimentary carbon and nitrogen. Cores H, I, and K were used to preserve live sediments for shore-based incubation experiments. Cores L and M were taken as back-up cores in cases of incomplete core recovery and were sampled for additional shore-based studies when MUC deployments returned 12 full cores. Pore-water samples for inorganic and organic analysis were rhizoned at room temperature and $+4^\circ\text{C}$, respectively. All other cores were either sampled immediately after recovery on the work-deck or stored at $+4^\circ\text{C}$ for processing.

The CTD-Rosette was equipped with sensors for conductivity, temperature, density, oxygen and fluorescence and with 24 niskin bottles. Six different types of samples were taken from the niskin bottles: (1) 20 mL of water were filtered ($0.2\ \mu\text{m}$ syringe micro filter) and analyzed for inorganic nutrients on board; (2) 50 mL of water were filtered through glass fiber filters and stored at -20°C for quantitative analysis of dissolved organic carbon (DOC); (3) 35 mL of water were filtered and stored frozen for shore based quantitative and stable carbon isotopic analysis of organic metabolites; (4) 150 mL of water were taken in glass or PTFE bottles and stored at $+4^\circ\text{C}$ or -20°C , respectively, for shore-based analysis of methylated organic compounds; (5) 2 L of water were passed through solid phase extraction cartridges on board for shore based molecular

analysis of DOM; (6) 8 L of water were filtered and filters stored for shore-based microbiological investigations.

Deployment of in-situ pumps (ISP) returned samples of particulate matter on glass fiber filters through which up to 846 liters of sea water had been pumped during the deployment. The tool string was equipped with four ISPs to sample four individual depths with one deployment. Our aim during the cruise was to sample particular organic carbon (POC) for the molecular and carbon isotopic characterization of microbial intact membrane polar lipids in target interfaces related to salinity and/or dissolved oxygen concentration.

Table 1.2 Overview on the number of samples taken during M84/1. For more details see text.

GeoB No.	Gear	Gas analysis	Cultivation of archaea	Inorganic (pore-) water analysis	Organic (pore-) water analysis	Molecular analysis of DOM	Cells counts, metagenomics, intact polar lipids, TOC	Live samples
15101-1	CTD	-	-	24	24	4	5	-
15101-2	ISP	-	-	-	-	-	4	-
15101-3	MC	-	-	-	-	-	-	-
15101-4	MC	2 x 4	2	-	-	1	2	-
15101-5	GC	-	-	-	-	-	-	-
15101-6	CTD	24	10	24	24	-	24	-
15101-7	GC	15 x 5	1	18	9	4	7	2
15102-1	GC	11 x 5	1	5	13	-	10	-
15102-2	CTD	-	-	24	24	3	6	-
15102-3	ISP	-	-	-	-	-	4	-
15102-4	MC	11 x 5	3	-	-	3	25	6
15102-5	GC	18 x 5	3	18	10	9	10	6
15103-1	GC	28 x 4	-	28	24	17	24	3
15103-2	GC	28 x 4	12	29	18	13	18	8
15103-3	MC	13 x 4	-	16	-	3	16	5
15104-1	MC	13 x 5	-	-	-	3	27	5
15104-2	GC	29 x 4	21	28	15	13	14	5
15104-3	GC	28 x 5	-	28	12	12	12	1
15104-4	GC	-	-	-	-	-	-	-
15105-1	GC	29 x 5	-	29	16	-	16	-
15105-2	GC	33 x 4	24	33	18	10	18	8
15105-3	GC	-	-	-	-	-	-	-
15105-4	MC	12 x 5	1	-	-	4	24	2
15105-5	CTD	-	1	24	24	4	4	-
15105-6	ISP	-	-	-	-	-	4	-
15105-7	ISP	-	-	-	-	-	4	-
15105-8	ISP	-	-	-	-	-	4	-
15105-9	ISP	-	-	-	-	-	4	-
Total		1241	79	328	231	104	286	51

1.5.2 Sampling with the CTD-Rosette

(C. Dibke, B.P. Koch, C. Lazar, T. Meador, A. Teske)

Three stations were sampled with the CTD water rosette (GeoB 15101, GeoB 15102, GeoB 15105). Several water masses at the first two stations were identifiable in the water column above the brine lakes. Preliminary identification of water masses are as follows: (1) a surface mixed layer of relatively low salinity consisting of a mixture of Atlantic, Levantine, and Cretan Sea waters down to ~80 to 100 m; (2) a subsurface salinity maximum (~39.15) at 370 m and 180 m in the Urania and Discovery Stations (GeoB 15101 and GeoB 15102, respectively), which defined the Cretan Intermediate Water or a mixture of this water mass with Levantine

Intermediate Water; (3) a thin lens of water exhibited local salinity and O₂ minima at ~ 600 m at the Urania Station, which may represent the Transitional Mediterranean Water; this layer was not obvious at the Discovery station; (4) water column minima for salinity and O₂ were observed in the bathypelagic layer (~1000 m) at both stations, which may represent a mixture of multiple generations Eastern Mediterranean Deep Water formed in the Northern Adriatic Sea and Transitional Mediterranean Water; and finally (5) the deep salinity and O₂ maxima likely identifying the Cretan Deep Water.

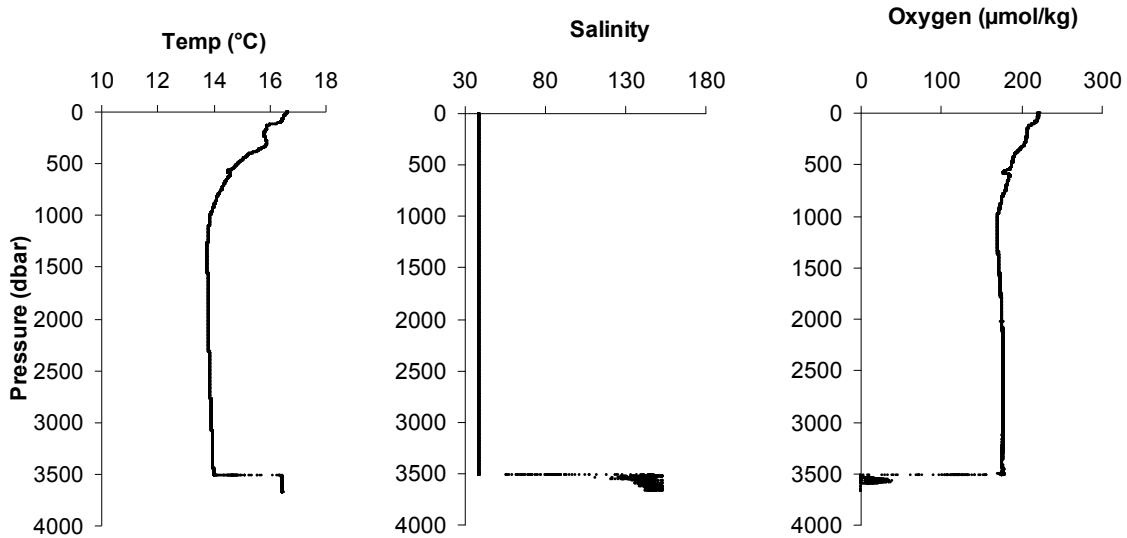


Fig. 1.3 CTD data of station GeoB 15101 (Urania Basin).

At the bottom of station GeoB 15101 a highly saline brine (salinity ~150 psu; Fig. 1.3; Appendix: Tables A1, A2) with high gas content (H₂S) was sampled. The thickness of this brine layer was ~138 m (without reaching ground). Within few minutes in the chemocline the oxygen and conductivity (salinity, density) sensors did not produce reliable values anymore.



Fig. 1.4 Samples from the water rosette at station GeoB 15101-6. Samples 8-21 (downcast) and 23-24 (upcast) contained suspended mud.

Water bottles were closed during the upcast at selected depths, primarily targeting brine water and the brine/water column interface. Oxygen and conductivity sensors began to report more reliable values shortly after exiting the brine pool.

During the second cast (GeoB 15101-6) the bottom water was sampled during the downcast (except bottles 23 and 23; Fig. 1.4). All sensors apart from the pressure sensor were detached during this cast which reached a maximum water depth which was ~80 m below the water depth values provided by the ships instruments. The water bottles 8-24 contained a liquid mud which was much warmer than the overlying water column.

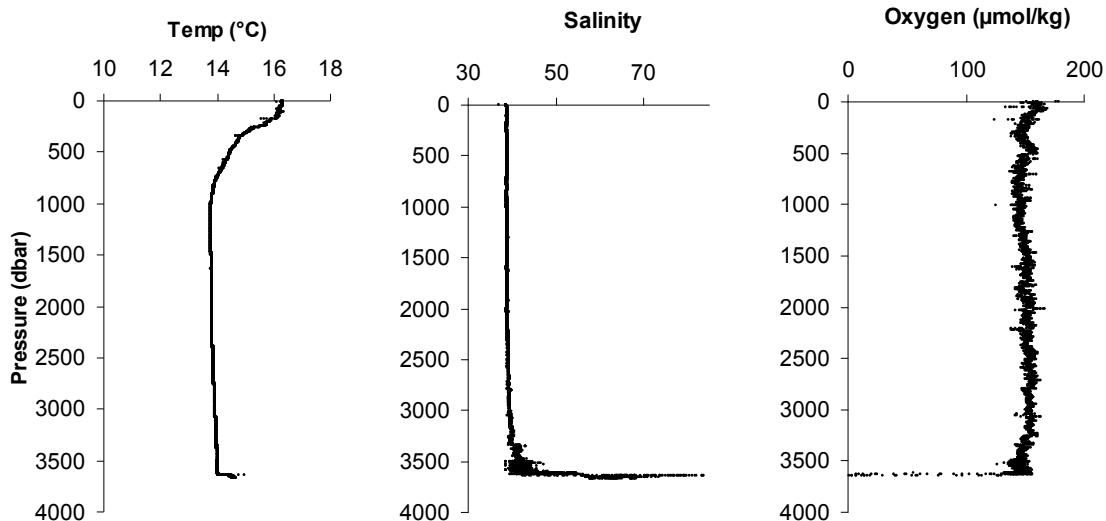


Fig. 1.5 CTD data of station GeoB 15102 (Discovery Basin).

Station GeoB 15102 also showed a brine layer (3581 m water depth of 24 m thickness; Fig. 1.5, Appendix: Table A3), which was sampled in high resolution (samples every 2 m), up to 20 m above the interface. The brine showed an oily consistency which probably led to a repeat failure of the oxygen and conductivity (salinity, density) sensor.

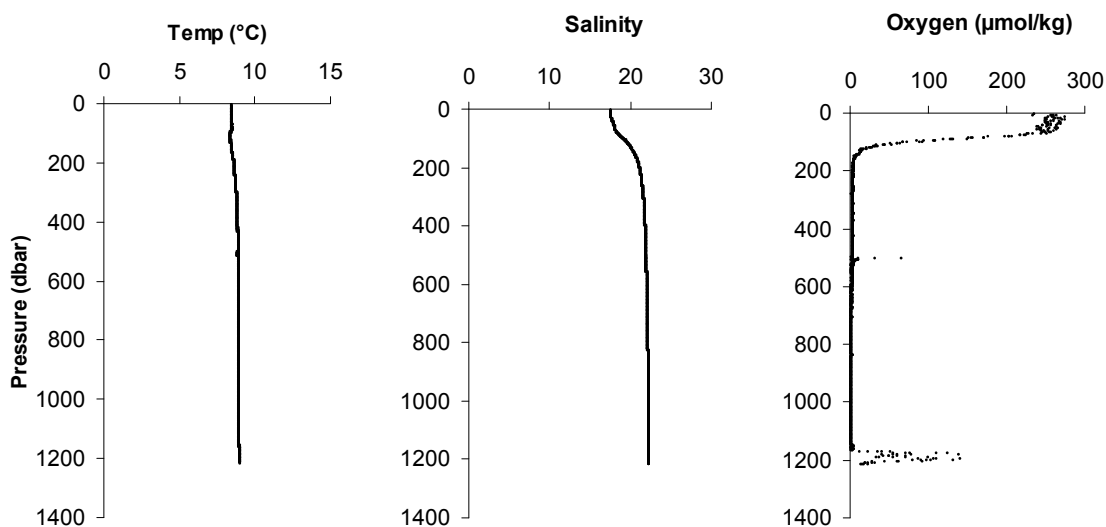


Fig. 1.6 CTD data of station GeoB 15105 (Black Sea).

The chemocline at station GeoB 15105 reached from 80-130 m water depth (Fig. 1.6; Appendix: Table A4). Again, in and below the chemocline the oxygen sensor did not produce reliable values. The variability of the O₂ sensor was also dependent on rope speed and wave action. Measured water depth (ground signal & altimeter) was 1214 m which was ~50 m less than the data from the ships echo sounder (1263 m).

1.5.3 Sampling with the In-situ Pumps

(L. Wörmer, M. Yoshinaga, C. Zhu)

By filtering material at selected depths, studies have shown that certain microbial communities are concentrated at specific depths generally associated with oceans stratification, e.g. Archaea at the chemocline in the water column of the Black Sea (Schubotz et al., 2009). Our aim during the cruise was to sample POC for the molecular and carbon isotopic characterization of microbial intact membrane polar lipids in target interfaces related to salinity and/or dissolved oxygen concentration. We performed six deployments (Appendix: Table A5), being the first two at the two saline basins (GeoB 15101 and GeoB 15102) and the last four in the Black Sea (GeoB 15105) using a high resolution sampling scheme throughout the oxic-anoxic transition of the water column.

1.5.4 Visual Core Description, Smear Slide Analysis, and Physical Properties

(I. Aiello, S. Braun, C. Dibke, J. Schröder, M. Zabel)

Introduction

Combined, lithologic and physical property analyses provided the basis for understanding the geologic characteristics of the cores that were collected during expedition M84/1. Petrographic analysis of smear slides was performed on representative samples to establish the composition and the sources of the sediment particles, and the combination of visual description, magnetic susceptibility and color reflectance was used to describe down core changes in sedimentation and to identify key intervals including sapropel and volcanic ash layers.

Methods

Sediment analyses of smear slides were examined with a transmitted-light petrographic microscope equipped with a standard eyepiece micrometer. Biogenic and mineral components were identified and their percentage abundances were visually estimated under petrographic microscope using Rothwell (1989).

Magnetic susceptibility (MS) was measured with the Bartington Instruments MS2 system using a high resolution surface scanning sensor. The frequency at which the MS sensor operates is 621 Hz. The output of the magnetic susceptibility sensors was set to SI units. Magnetic susceptibility is a measure of the degree to which a material can be magnetized by an external magnetic field. It provides information on the magnetic composition of the sediment that commonly can be related to mineralogical composition (e.g., terrigenous versus biogenic materials) and diagenetic overprinting.

Color reflectance (CR) was measured on the surface of the split core every 1 cm. The surface of the core was covered with saran wrap to avoid contamination of the spectrophotometer lens. The Gretag Macbeth spectrophotometer recorded counts approximately every 10 nm in the range 380 to 730 nm. Spectral data were related to color in a cylindrical coordinate system using the

tristimulus values $L^*a^*b^*$ (Commission Internationale d'Eclairage (CIE), 1986), where the axis of the cylinder, L^* , is the total light reflected or luminosity (a^*) is redness and (b^*) yellowness. Sediment lithology, color, structures, accessories, disturbances and other observations were recorded on visual core description sheets. Annotated graphical descriptions of each core, so-called “barrel sheets”, summarize the data collected. When possible, color was qualitatively described using the Munsell Soil Color Charts (Munsell Color Company, 1994), which provide corresponding hue, value, and chroma data.

Site GeoB 15101 Urania Basin

Multicore (GeoB 15101-3) was analyzed for sedimentology and physical properties, while a gravity core (GeoB 15101-7) was analyzed only for sedimentology. The multicore GeoB 15101-3 was 54 cm long, the top 20 cm were soupy (water rich) and only the bottom 6 cm were firm. The gravity core GeoB 15101-7 was 4.5 m long and the upper 80 cm were very soupy. The firmness of the sediment increased down section and the sediment at the very bottom of the core was stiff.

Both the multicore and the gravity core are composed of a homogenous, dark gray (GLEY1 4/N) to gray (GLEY1 4/N) fine silt characterized by very low magnetic susceptibility. The petrographic analysis on samples collected at all depths intervals in both the multicore and gravity core showed that the dark gray silt is mainly composed of a mix of micro-carbonates and coccoliths (~35% each) and secondarily by clay (~15%), siliciclastic material (~10%) and opaques (~5%). The micro-carbonates are sub-spherical to elongated particles ranging in size between 10 μm to more than 20 μm . It is not clear whether these particles are *in situ* authigenic precipitates or the product of dissolution of calcareous tests (e.g. foraminifers) and further analyses are necessary. The siliciclastic particles (mainly fine sand to very fine silt) include: subangular to subrounded quartz and feldspar fragments (well sorted mainly silt size), subrounded, brownish unidentified minerals (fine sand), and various elongated micas.

The lithologic and sedimentologic characteristics of the Urania Basin sediments indicate pelagic deposition in oligotrophic conditions only marginally influenced by input from terrigenous sources. The homogeneity of the cores, both lithologic and sedimentologic, and the presence of ‘soupy’ intervals all suggest high disturbance and potential reworking of the majority of the sediment.

Site GeoB 15102 Discovery Basin

Gravity cores GeoB 15102-1 and GeoB 15102-5 were analyzed for sedimentology and physical properties (MS and CR; Fig. 1.8). Gravity core GeoB 15102-1 was 262 cm, and core GeoB 15102-5 was 432 cm long.

The sediments at Site GeoB 15102 are very heterogeneous and characterized by prominent color variations (colors range from black to brown to gray), different types of sedimentary structures (soft sediment deformation, lamination and banding and trace fossils), and precipitates of gypsum and other authigenic minerals that can form crystals and nodules ranging from a few mm to more than 10cm (Figs. 1.7 and 1.8). The most common sedimentary component at this site is homogenous to laminated coccolith ooze (~5 μm to 10 μm) that can occur mixed with various amounts of secondary components including clay, micro-carbonates, foraminifers, volcanic ash and framboidal pyrite. Downcore color changes of the coccolith ooze reflect changes in the relative amount of secondary components in the sediment. For instance, light

gray, low- a^* and low-MS sediments are made almost entirely by coccoliths, while reddish brown high a^* and high-MS sediments are composed of a subequal mix of coccoliths and clay (Fig. 1.7). Components that are generally secondary in the bulk coccolith ooze sediment can occur concentrated in discrete laminae or bands characterized by prominent color changes including foraminifer sand and graded ash (Fig. 1.8D), and black sulfide-rich laminae and mottles (Fig. 1.8C).

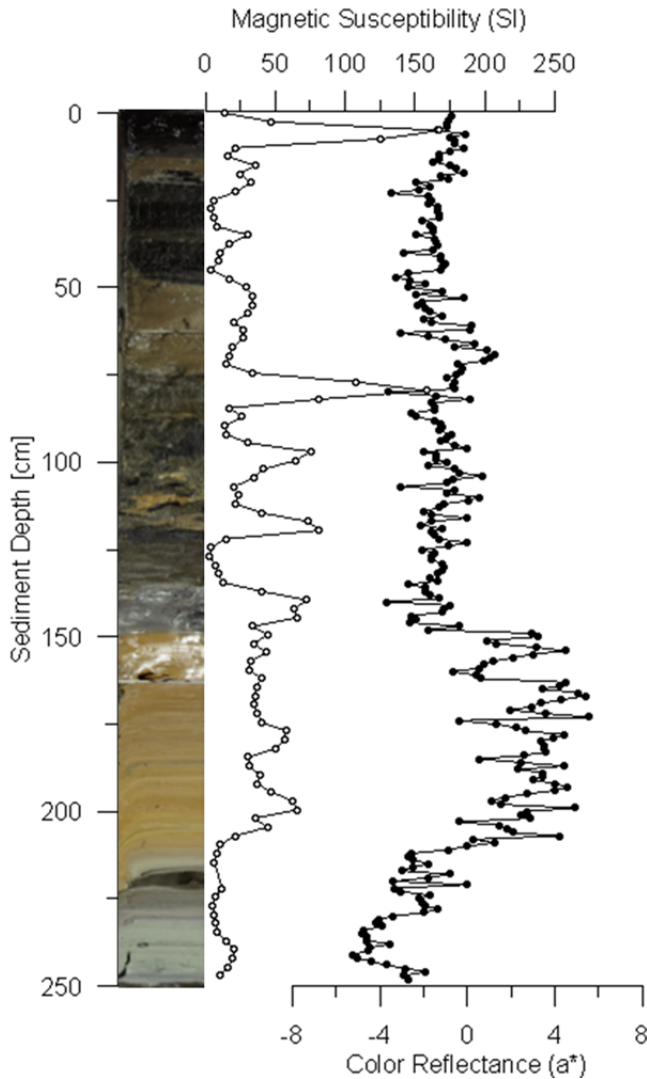


Fig. 1.7 Photo-mosaic, magnetic susceptibility and color reflectance for core GeoB 15102-1, Discovery Basin.

The second most prominent lithology at the site occurs mainly in the upper 50 cm of both gravity cores and is a black, organic-rich diatom and coccolith ooze mixed with large volumes (>50% sediment) of cm-size gypsum crystals (Fig. 1.8E). A third lithology occurs in two discrete gray layers in the upper 50 cm of the cores and in a black layer near the bottom of core GeoB 15102-1 where a large cubic, transparent crystal of unknown composition was also found (Fig. 1.8F). These layers are composed of a silicoflagellates- and radiolarian-rich diatom clay, composition that matches the description of sapropels observed at the same site by Wallmann et al. (2002).

The abovementioned interval of sediment deformation (between 70 and 150 cm for gravity core GeoB 15102-1 in Fig. 1.7) is about 70 cm thicker in gravity core GeoB 15102-5. This marked lateral difference between adjacent sub-seafloor area accounts for local re-sedimentation

probably triggered by tectonic activity of the accretionary wedge which is the main structural feature of the region.

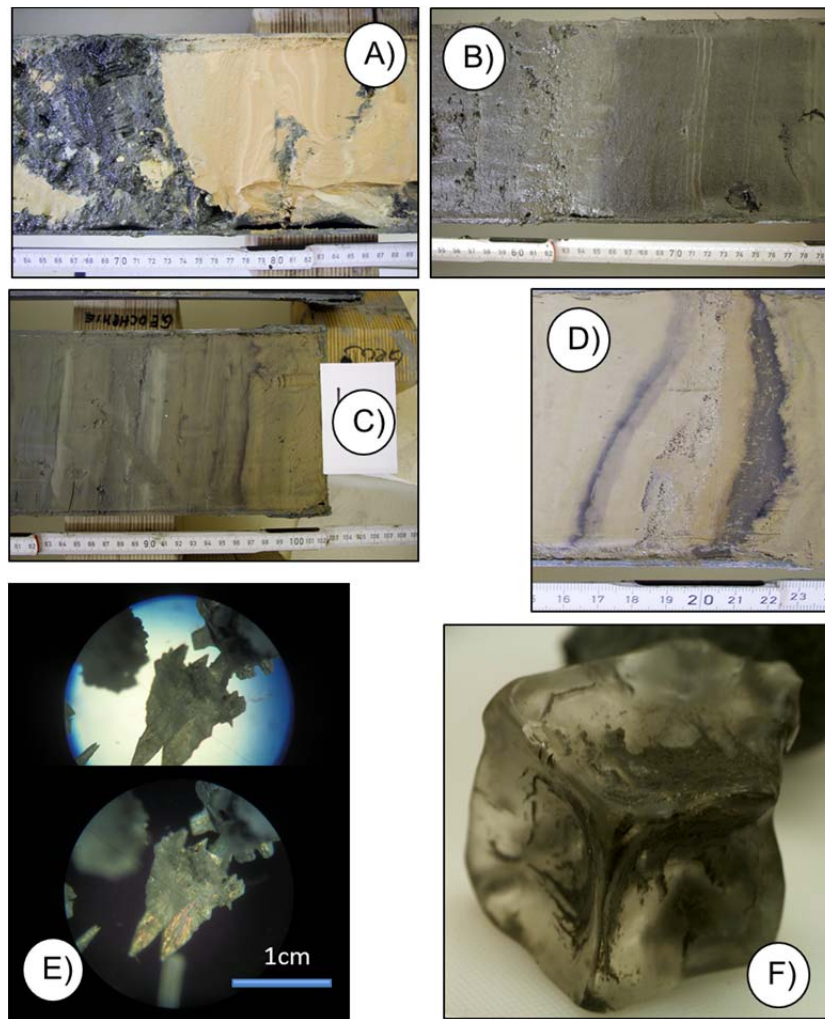


Fig. 1.8 Examples of sedimentary structures and authigenic precipitates at Site GeoB 15102. A) soft sediment deformation; B) lamination and banding; C) Trace fossils and lamination; D) Graded ash layer and foraminifer sand; E) Gypsum (petrographic microphotograph, transmitted (top) and cross-polarized light (bottom)); F) Large cubic crystal of unknown composition (photo size ~4 cm).

Site GeoB 15103 South of Cyprus

Gravity cores GeoB 15103-1 and GeoB 15103-2 were analyzed for sedimentology and physical properties (MS and CR; Fig. 1.9). Gravity core GeoB 15103-1 was 690 cm, and core GeoB 15103-2 was 698 cm long.

Four main lithologies alternate throughout the core and they can be visually identified by different colors, sedimentary structures (lamination, trace fossils), CR and MS values and, petrographic composition (Fig. 1.9):

(1) Reddish to dark reddish brown (5YR 5/3), micro-carbonate-bearing clay-rich coccolith ooze. Reddish coccolith ooze is present mainly in the upper two sections between 0 and 160 cm. This lithology, which has intermediate MS values, correlates to positive peaks of the color reflectance parameter a^* (2) Olive brown (2.5Y 4/3) coccolith clay which has low L^* and low MS values; (3) Gray (2.5Y 6/1) to light gray (2.5Y 8/1) coccolith ooze with variable amounts of

foraminifers and siliciclastic material; (4) Black (Gley1 2.5/N), organic-rich brown clay (sapropel) characterized by very low MS and L*.

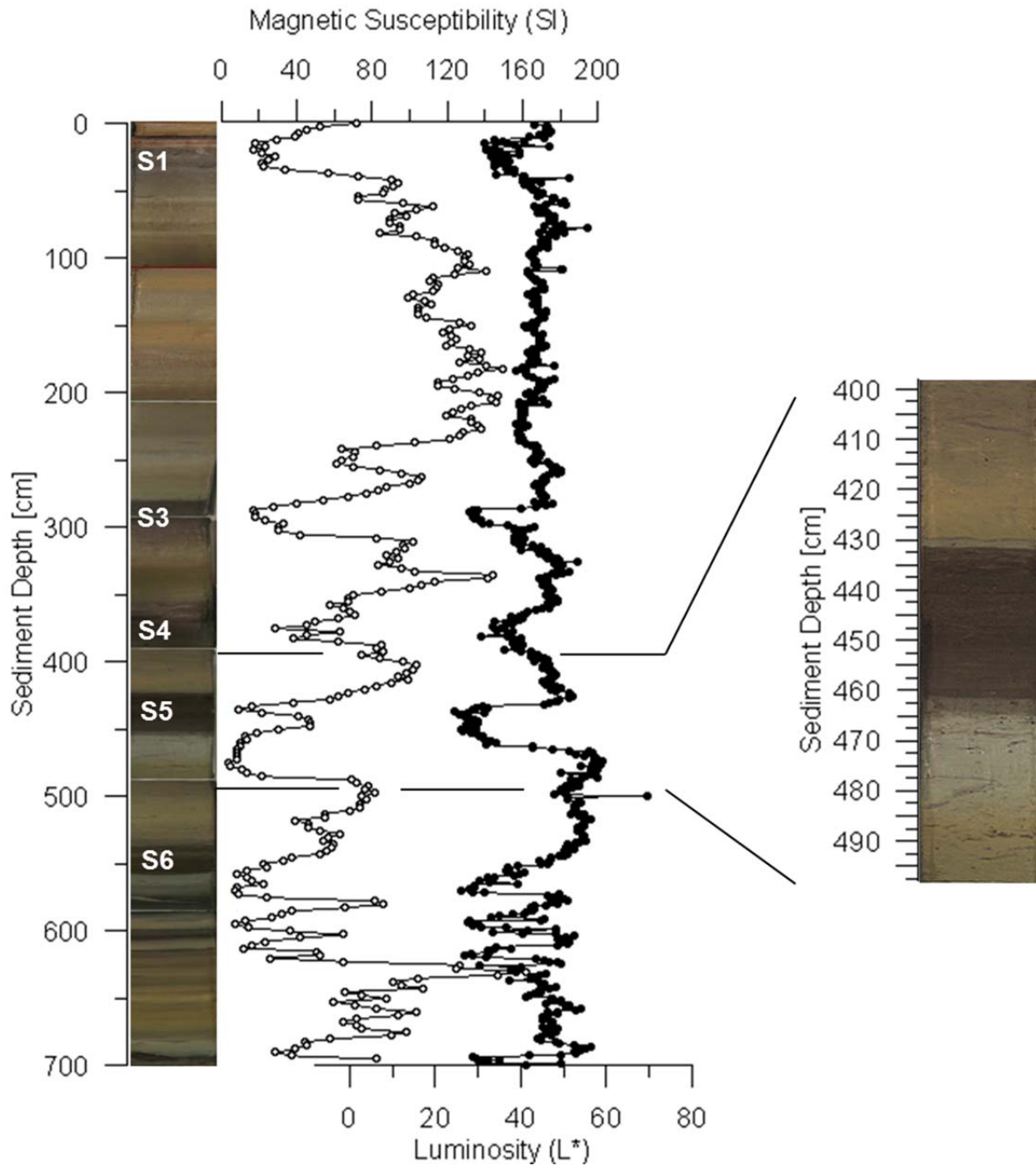


Fig. 1.9 Photo-mosaic, magnetic susceptibility (red) and Luminosity (L*; blue) for core GeoB 15103-2, South of Cyprus; right: detail of the interval between 398 and 498 cm in core GeoB 15103-2 showing an upper pale brown coccolith clay, a middle black sapropel layer, and a bottom gray coccolith ooze.

Five main black sapropel layers have been identified and based on their sizes and relative position in the core they have been tentatively correlated with the sapropel layers identified by Calvert and Fontugne (2001).

Both whole and fragmented pteropoda shells, 3-5 mm in diameter were found in several parts of the core but particularly in the interval between 398 and 498 cm.

Site GeoB 15104 Marmara Sea

Gravity cores GeoB 15104-2 and GeoB 15104-4 were analyzed for sedimentology and physical properties (CR; Fig. 10). Gravity core GeoB 15104-2 was 704cm, and core GeoB 15104-4 was 653 cm long.

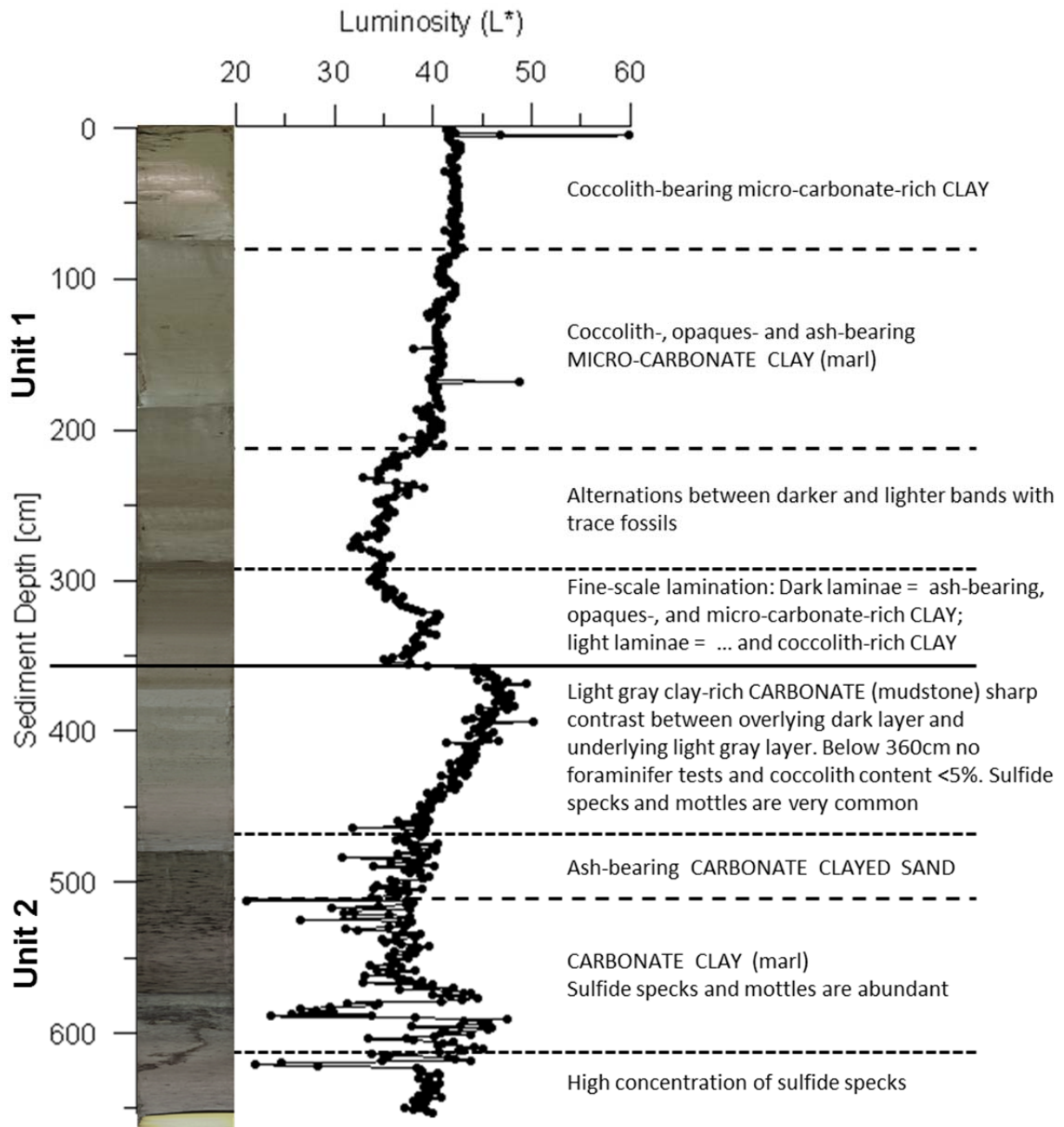
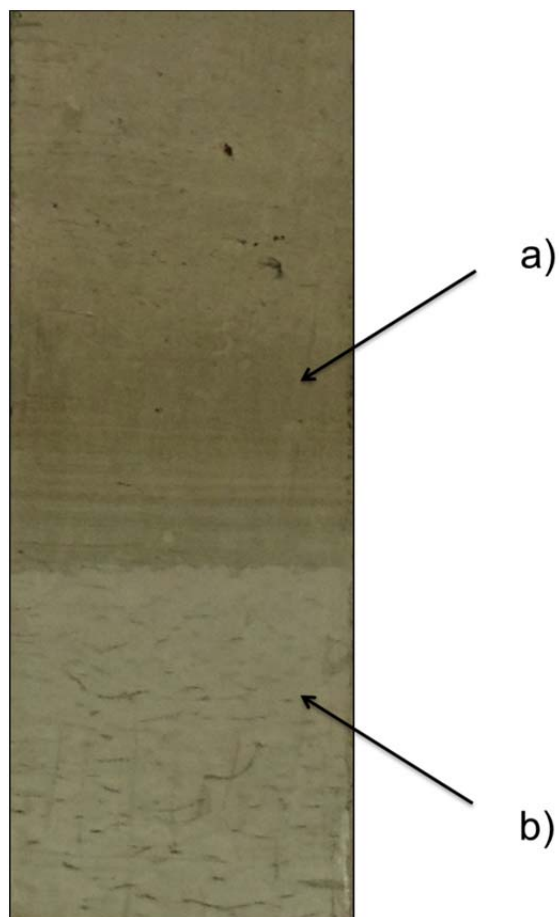


Fig. 1.10 Photo-mosaic, and color reflectance for core GeoB 15104-4, Marmara Sea.

The sediments at this site show lithologic variability at different scales ranging from millimeters to meters. The main lithologies are clay, marl and carbonate mudstone (a subequal mixture of clay and carbonate), which can occur mixed with various proportions of ash, siliciclastic particles, coccoliths and opaque minerals (mainly sulfides).



In the upper part of the sediment column (Unit 1 in Fig. 1.10) clay is the major sedimentary component (always >50%), and is particularly abundant below ~210 cm, where it assumes a brownish color probably due to an increase in organic carbon content and a decrease in silt-sized carbonate particles (potential sapropel layer). Coccoliths are relatively abundant (~10%) while they become more rare in the underlying unit. The interval between 210 cm and the top of Unit 2 at ~350 cm can be divided into two parts: an upper layer (~210 to 290 cm) where brown and light brown several-cm thick bands containing trace fossils alternate, and a lower layer which is darker brown and shows fine-scale (mm to less than cm) lamination (Fig. 1.11).

Fig. 1.10 Transition between the laminated bottom of Unit 1 (a) and homogenous light gray top of Unit 2 (b) in core GeoB 15104-2.

Marls and in particular carbonate mudstone are the most common lithology in the bottom Unit 2. Carbonate rich sediments (mudstones) are very abundant in the light gray layer the marks the top of this unit. Unlike the upper Unit 1, Unit 2 does not contain foraminifer tests and poorly preserved coccoliths (probably re-sedimented) occur often in trace amounts. An interval characterized by a mix of clay, silt-sized carbonates and sand-size siliciclastic particles occur between ~460 and 500 cm. Although sulfide specks are common throughout the unit, they are particularly concentrated in the darker interval between ~480 and 620 cm (Fig. 1.9). A large (10 cm long and ~3 cm thick) sulfide crust was found between 580 and 590 cm in core GeoB 15104-4. A black layer composed of ash mixed with silt-sized carbonate clasts and clay was found in the core catcher of core GeoB 15102-6.

Site GeoB 15105 Black Sea

Gravity core GeoB 15105-3 was analyzed for sedimentology and physical properties (CR; Fig. 1.11). Gravity core GeoB 15105-3 was 875 cm long.

The core shows two distinct parts: an upper part (Unit 1, 0 to 448 cm) which is gray to light brown to olive brown characterized by very-fine-scale-lamination with laminae ranging in thickness between less than 1 mm to 1 cm; a lower party (Unit 2, 448 to 875 cm) that is light gray to black and homogenous (Fig. 1.11). Within the two units, further changes in lithology and sedimentary structures can be identified.

The laminated sediments of Unit 1 (equivalent to elsewhere described stratigraphic Units I+II; e.g. Kwiecien et al. 2008) include several sedimentary components such as clay, silt-size carbonates (including acicular aragonite), siliciclastic material (including lithic fragments), ash,

opaque minerals (mainly framboidal pyrite), diatom frustules (both pennate and centric), coccoliths and silicoflagellates. Clay is the major sedimentary component and in smear slide it can appear either clear or dark brown as in the interval between ~375 and 448 cm (potential sapropel layer; Fig. 1.11). Three main lamina types can be recognized, although the typology of laminae present in the core can be more complex than identified during the core description. (1) Homogenous bands are the thickest lamina type (between 5 and 10 mm), are light brown and composed of a sub-equal mix between diatom frustules, silt-sized carbonates and brown clay (Fig. 1.12a); (2) light-colored laminae (usually light olive but also white) (Fig. 1.12b) and (3) dark-colored laminae (dark brown) (Fig. 1.12c). A white, coarser (silt to sand size) lamina composed of volcanic shards has been detected at 337 cm.

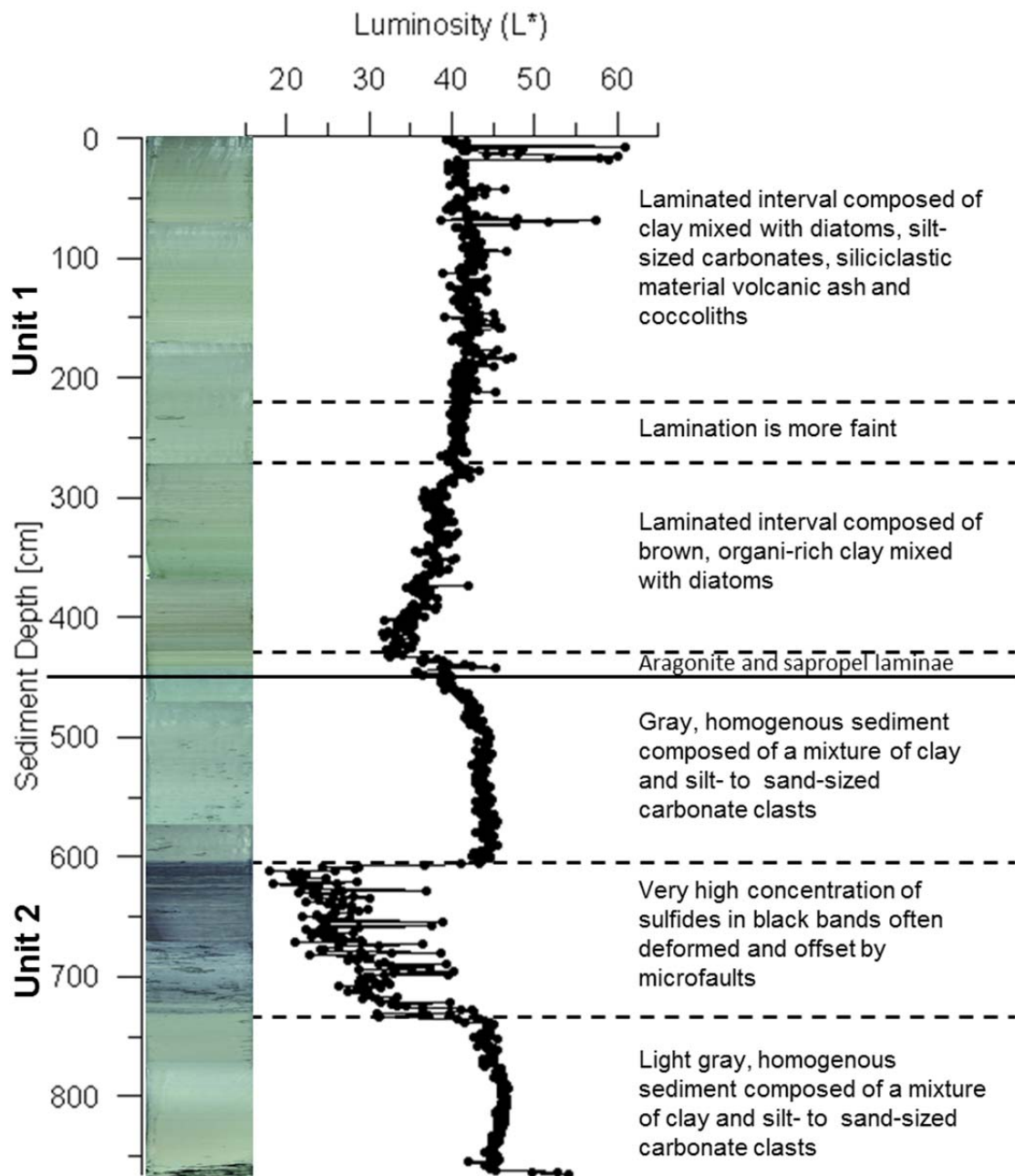


Fig. 1.11 Photo-mosaic, and color reflectance for core GeoB 15105-3, Black Sea.

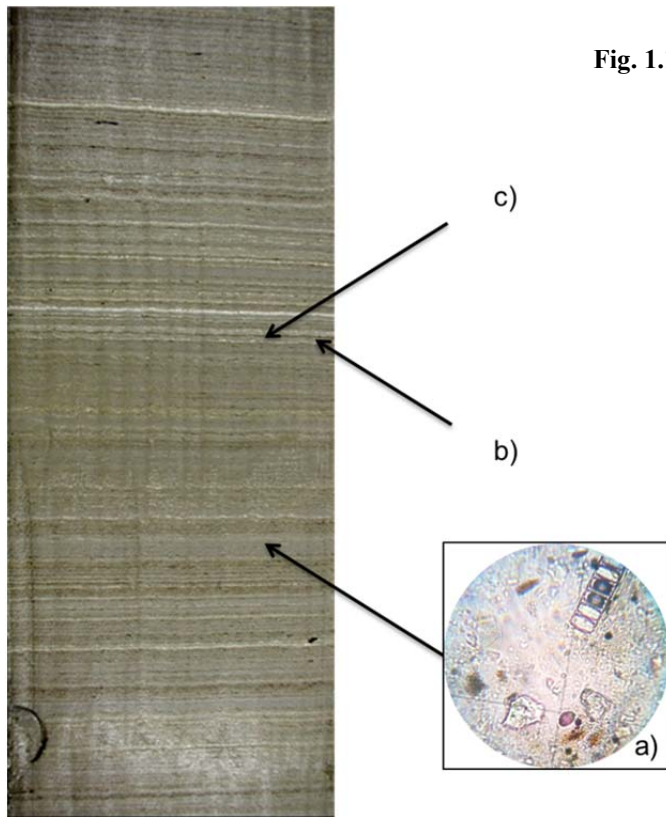


Fig. 1.12 Examples of lamina types in core GeoB 15105-3 (Black Sea). a) Homogenous band (microphotograph shows brown clay, centric diatoms, and sub-angular clasts of silt-sized carbonate; field of view $\sim 500 \mu\text{m}$); b) light lamina; c) dark lamina.

The bottom of Unit 1, between the bottom of an organic rich, laminated (sapropel) layer (between ~ 275 and 435 cm) and the top of Unit 2 is marked by a 14 cm thick interval characterized by a brighter color and prominently white laminae alternated with brown laminae (Figs. 1.11, 1.13). The white laminae are composed mainly by acicular crystals of aragonite (Fig. 1.13a) while the brown laminae are mainly composed of brown clay as in the sapropel interval above. The boundary with Unit 2 is sharp.

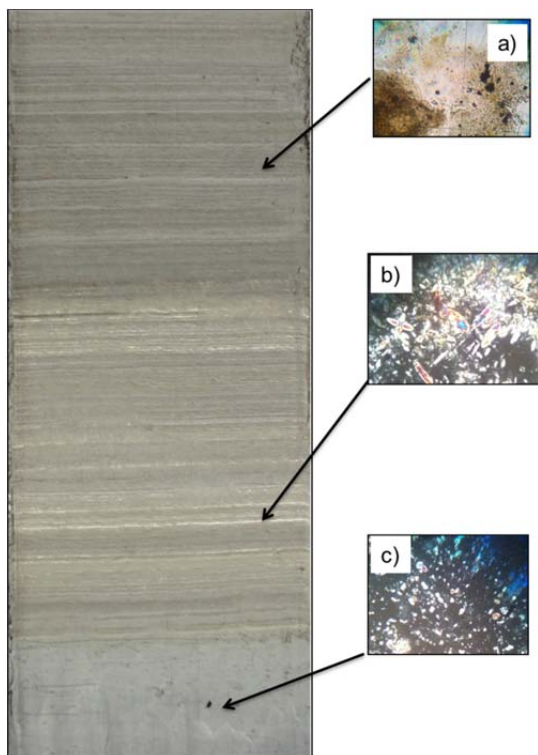


Fig. 1.13 Transition between laminated Unit 1 and homogenous light gray Unit 2 in core GeoB 15105-3; core photograph and microphotographs (field of view $\sim 500 \mu\text{m}$) (Black Sea). a) Microphotograph of dark brown laminated (sapropel) layer; b) Microphotograph of white acicular aragonite lamina; c) Microphotograph of light gray marl showing abundant silt-size carbonate clasts.

The main sedimentary components of Unit 2 are clay and silt- to sand-sized carbonate clasts which occur often in subequal proportion (marl). Secondary components include siliciclastic particles, ash, and (reworked) coccoliths. Intact fossils of gastropods were also found especially between ~470 and 570 cm. Opaque minerals (mainly sulfides) are also very abundant and they can constitute a very large fraction of the sediment in the dark banded intervals (some of the bands show offsets along microfaults and hummock-like structures) such as the portion between 600 and 735 cm (Fig. 1.11). A few hours after splitting, the black coloration of the sulfide rich layer changed into a lighter dark gray color as a result of the oxidation (the luminosity L^* values of the layer were about two times higher after oxidation).

1.5.5 Sediment Pore Water and Seawater Analysis

(T. Goldhammer, V. Heuer, B.P. Koch, Y.-S. Lin, F. Schmidt, S. Pape, J. Wendt)

Introduction

We seek to understand the geochemical and (paleo)environmental factors controlling the distribution, composition and processes of sub-seafloor microbial communities along with the accompanying biosphere-geosphere interactions. The main objectives of the sediment porewater sampling program were the acquisition of detailed down core profiles of (1) inorganic pore water constituents to describe the sedimentary chemical environment with respect to redox zonation and mineralization processes, (2) molecular composition of DOM to gain information about the preservation and remineralization of organic matter, and (3) low-molecular-weight organic compounds that act as central intermediates or terminal products in many metabolic processes. Each objective required a separate sampling protocol but sampling was closely coordinated in order to generate a comprehensive data set (see 1.5.1 Sampling Strategy). Pore water samples were recovered from sediment cores at all sites. In the two brine basins (GeoB 15101 and GeoB 15102) and in the Black Sea (GeoB 15101) we also investigated the water column. We collected water samples using a CTD-rosette equipped with 24 niskin bottles and used the same coordinated sampling protocol as for pore water sampling.

Inorganic Pore Water Chemistry: Objectives

The focus of the Inorganic Geochemistry Group was the geochemical characterization of the diverse benthic and sedimentary environments encountered at the five stations. Our aim was to retrieve detailed chemical information on signature compounds that are sensitive to microbial turnover as well as on species that are considered non-reactive and suitable as conservative tracers of transport processes. Our approach embraces nutrient chemistry, (trace) metal chemistry, standard anion and cation analyses, and *ex situ* electrode measurements. We took a total of 391 single pore-water samples in high depth resolution, corresponding solid phase samples in intermediate depth resolution (161 samples) and occasionally large volume sediment samples for further onshore experiments and analyses (32 samples).

Inorganic Pore Water Chemistry: Sampling Methods

Water column samples (10 to 20 mL) were directly filtered from the Niskin bottle (0.2 μm syringe micro filter) after the recovery of the CTD-equipped rosette. Pore water samples were taken from closed MUC cores and gravity cores and through rhizon micro suction samplers (5 cm length, 0.2 μm porous polymer).

MUC cores were kept upright in a laboratory sink and sampled immediately after recovery at laboratory temperature ($\sim 20^{\circ}\text{C}$). Rhizon samplers were carefully inserted through sampling holes every centimeter in the upper 10 and every 2 to 4 cm down to the bottom. Three way Luer-lock stopcocks were connected to the adapters of the rhizons for proper closing and simultaneous connection of two syringes. First, a 10 mL syringe was attached, evacuated and kept open with a spacer. After the first 0.5 mL was sampled, it was discarded through the stopcock and vacuum was reapplied. After 1 mL was sampled, the pore water was transferred into 1 mL disposable syringes using the three-way stopcock, sealed with a cap, and instantly analyzed for dissolved iron (see below). The syringes were then left connected to the rhizons until about 8 mL of pore water had been retrieved, which took about 10 to 20 min (Fig. 1.14). At stations GeoB 15102, GeoB 15103 and GeoB 15104, live surface sediment samples for onshore incubation experiments were collected from a parallel multi-core. We extruded the sediment in slices of 5 cm using an upright piston and collected them in 150 mL plastic cups.



Fig. 1.14. Rhizon pore water sampling from multi-core GeoB15103-3.

Pore water samples from gravity cores were taken from closed cores in the ship's cool room at 4°C . There, sampling holes were drilled into the core-liner and pore water was extracted in a depth resolution of approximately 25 cm using the rhizon technique described above. Sediment samples from gravity cores were taken after pore water extraction by cutting sampling windows into the liner close to the rhizon sampling points. A volume of 2 to 4 mL of bulk sediment was obtained with an open 5 mL syringe. The syringe was capped and subsequently used as sample container. The samples were immediately frozen at -80°C .

Inorganic Pore water Chemistry: Onboard analyses and sample conservation

Dissolved iron (Fe^{2+}) was measured photometrically (Hach Lange DR 5000 photometer) at a wavelength of 565 nm (Collins et al., 1959). An iron sensitive color complex was formed by adding 1 mL of plain sample to 50 μL of a ferrospectral reagent (Merck Chemicals) in disposable polystyrene cuvettes. In case of high iron concentrations, the original sample was diluted with oxygen free artificial seawater to match the respective calibration range.

Dissolved phosphate (PO_4^{3-}) was quantified photometrically (Hach Lange DR 5000 photometer) using the classic molybdenum blue method (Murphy and Riley, 1962). About 1 mL of sample was mixed with 50 μL of an ammonium molybdate solution in a disposable polystyrene cuvette, and spiked with 50 μL of an ascorbic acid solution. The phosphomolybdate complex was thus reduced to molybdenum blue and determined at a wavelength of 820 nm.

Dissolved ammonium (NH_4^+) was detected onboard with a flow injection, PTFE tape gas separator technique after (Hall and Aller, 1992). About 200 to 300 μL of plain sample were injected into a 100 μL loop of a Rheodyne valve and mixed with an alkaline solution (0.01 M NaOH + 0.2 M sodium citrate) to form gaseous NH_3 that passes a PTFE membrane and causes a conductivity signal in a receiving acid solution (0.001 M HCl). The resulting conductivity was determined using a temperature compensated conductivity meter (Amber Scientific 1056) with a micro flow-through cell (Amber Scientific 529) and recorded on a strip chart recorder.

Electric conductivity was measured directly using a temperature compensated conductivity meter (Amber Scientific 1056) with a micro flow-through cell (Amber Scientific 529).

pH was measured with microelectrodes (WTW Sentix SP, WTW GmbH) in fluid samples and in bulk sediments, along with sediment sampling from the gravity cores.

Redox potential (E_h) was measured with electrodes (Hamilton Redox special, Hamilton Inc.) directly in the sediment, along with sediment sampling and pH measurement from the gravity cores.

Sample conservation: Solid sediment samples for elemental analysis, determination of iron and phosphate mineral phases and organic matter quality were immediately frozen at $-80\text{ }^\circ\text{C}$. Beside the water aliquots used in onboard analyses, we collected the following sample splits for onshore laboratory analyses: 40 μL of sample diluted with 3960 μL for anion analysis, 1 mL of sample diluted with 9 mL of 1% HNO_3 for cation analysis, 1.8 mL of sample preserved with zinc acetate solution for DIC analysis, and 0.5 to 1.5 mL of sample preserved with zinc acetate for sulfide determination. The remaining original sample was kept without addition of preservatives. An overview of samples and analyses is given in Table 1.3.

Inorganic Pore Water Chemistry: Selected preliminary onboard results

Water column at station GeoB 15101 (Urania Basin)—We were particularly interested in the distribution of important chemical species across a water column profile that crossed the interface between “normal” seawater and the brine pool that overlies the seafloor of the Urania Basin. According to our expectation, we found a sharp increase in electric conductivity across a very sharp chemocline at around 3500 m water depth, analog to the data transmitted from the CTD sensor array. This zone of conductivity increase was restricted to a few meters (3469 to 3471 m water depth). Dissolved iron (Fe^{2+}) was absent in all samples retrieved from the rosette hydrocast. The availability of nutrients (NH_4^+ , PO_4^{3-}) was negligible in the ‘normal’ water column, and strongly enhanced in the highly saline brine. Concentrations of NH_4^+ and

PO_4^{3-} were close to zero in the water column and increased up to $2300 \mu\text{mol L}^{-1}$ (NH_4^+) and $14 \mu\text{mol L}^{-1}$ (PO_4^{3-}), sharply across the chemocline (Fig. 1.15).

Table 1.3 Samples and parameters measured onboard and onshore in samples of water column hydrocasts (ROS), pore water and sediments from multi-cores (MUC) and gravity cores (GC)

Station GeoB No.	Onboard data					Lab data				
	Fluid samples					Fluid samples				Bulk sediment
	Fe^{2+}	PO_4^{3-}	NH_4^+	pH	Eh	HS^-	DIC	Anions	Cations	Elements
15101	ROS MUC	ROS MUC GC	ROS MUC GC	ROS MUC GC	ROS MUC GC	ROS MUC GC	ROS MUC GC	ROS MUC GC	ROS MUC GC	GC
15102	ROS MUC GC	ROS MUC GC	ROS MUC GC	ROS MUC GC	ROS MUC GC	ROS MUC GC	ROS MUC GC	ROS MUC GC	ROS MUC GC	MUC GC
15103	ROS MUC GC	ROS MUC GC	ROS MUC GC	ROS MUC GC	ROS MUC GC	ROS MUC GC	ROS MUC GC	ROS MUC GC	ROS MUC GC	MUC GC
15104	ROS MUC GC	ROS MUC GC	ROS MUC GC	ROS MUC GC	ROS MUC GC	ROS MUC GC	ROS MUC GC	ROS MUC GC	ROS MUC GC	MUC GC
15105	ROS MUC GC	ROS MUC GC	ROS MUC GC	ROS MUC GC	ROS MUC GC	ROS MUC GC	ROS MUC GC	ROS MUC GC	ROS MUC GC	GC

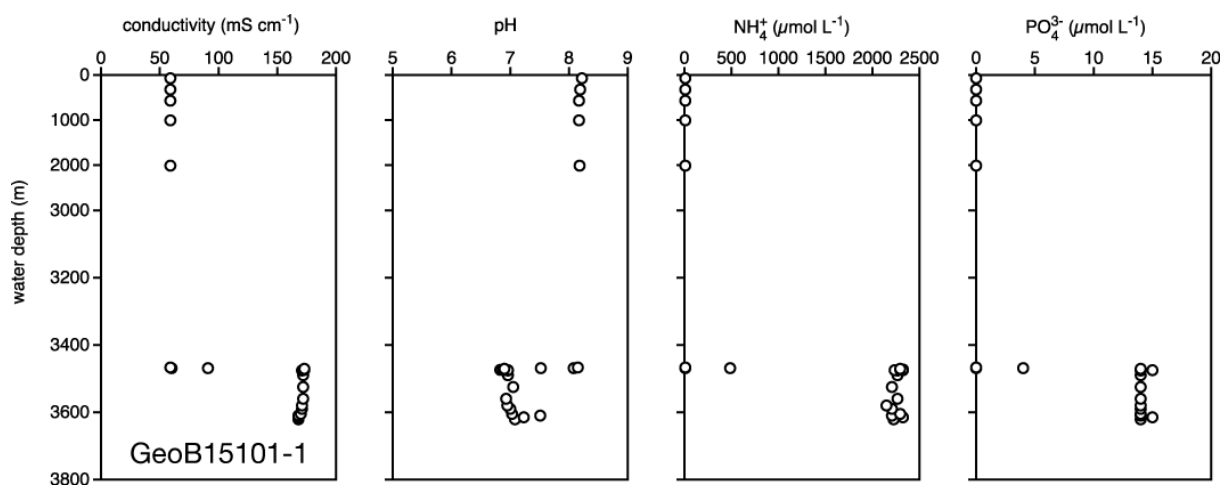


Fig. 1.15 Profiles from water samples of hydrocast GeoB15101-1. From left to right: electric conductivity, pH, concentrations of dissolved ammonium (NH_4^+) and phosphate (PO_4^{3-}). Note that the depth resolution of the y-axis changes at 3000 m.

Molecular characterization of dissolved organic matter (DOM)

DOM in deep ocean sediments contains important information about the preservation and remineralization of organic matter. Organic matter preservation is strongly dependent on the chemical composition and the resistance or susceptibility to microbial decomposition. Therefore, knowledge about the composition and structures of DOM in sediment pore waters allows insights into the types of compounds utilized by benthic archaea. We sampled sediment pore waters in order to apply Fourier Transform Ion Cyclotron Resonance Mass Spectrometry (FT-

ICR-MS) which recently has delivered first extensive molecular insights into the poly-disperse and complex nature of this material (Schmidt et al., 2009).

Pore waters in a volume of 20 to 50 ml were extracted with rhizons (0.1 μm pore size) from selected sediment depths of MUC and gravity cores at all stations. Additionally, three to four representative water column samples were taken from the CTD rosette at stations GeoB 15101, GeoB 15102 and GeoB 15105. All samples were acidified to pH 2 with hydrochloric acid in a glove bag (nitrogen atmosphere) in order to prevent oxidative decay of samples from reductive sediments. Solid phase extraction (SPE) was carried out for the enrichment and desalting of DOM on pre-cleaned SPE cartridges (PPL bond elut, 200 mg sorbent, Varian). Afterwards, DOM was eluted with 0.5 ml methanol and stored under nitrogen atmosphere in combusted glass vials at -20°C .

In total, we extracted 93 pore water and additionally 11 water column samples. Aliquots were taken from the original sample and the SPE extract for measurements of DOC concentrations. Moreover, corresponding solid phase samples were taken and stored at -20°C . All parameters will be measured after the cruise in the laboratories.

Water-soluble organic metabolites

In order to investigate microbial life in the deep subsurface we aim to decipher information encoded in low-molecular-weight organic compounds in pore waters that act as central intermediates or terminal products in metabolic processes. We are particularly interested in the distribution, abundance, and isotopic composition of volatile fatty acids such as acetate and took samples for shore-based analysis (Heuer et al., 2006, 2009). For the interpretation of compound-specific data additional information on bulk parameters are crucial and lead us to take samples for bulk analysis of contents and stable carbon isotopic ratios of total organic carbon (TOC) and dissolved inorganic carbon (DIC). Sampling focused on pore waters from gravity cores but also included brine samples retrieved from the water column by CTD-rosette deployments.

Pore waters were extracted from gravity cores by hydraulic press in the following way: Bulk sediment samples were taken from the lengthwise split core sections in lengthwise direction in order to integrate samples over depth intervals of 10-20 cm as lined out in the lithology based coordinated sampling plan. Sediment samples were filled in Teflon squeezers equipped with regenerated cellulose filters (Whatman, RC58, 0.2 μm , \emptyset 100 mm). In order to extrude pore waters, pressure was applied and gradually increased to 4 bar using a high pressure nitrogen tank. Pore water samples were collected in pre-combusted glass vials and split into a 1.4 mL fraction for stable carbon isotope analysis of DIC (stored with minimal headspace in 2 mL vials at -20°C) and into a 5 mL fraction for quantitative and stable carbon isotopic analysis of water soluble organic metabolites (stored in 7 mL vials at -20°C). Pore water sampling was carried out in a cool lab at $+4^{\circ}\text{C}$ and was in general finished within 24 hours after core retrieval. Water samples from CTD-deployments were filtered through glass fiber filters and ca. 35 mL of water was stored frozen in pre-combusted glass vials for shore based analysis. In total, we extracted 135 pore water samples and took additionally 96 water column samples.

1.5.6 Gas Analysis

(K. Becker, N. Broda, M. Elvert, Y.-S. Lin, J. Schmal)

Objectives

The major goal of gas analysis and sampling in this cruise is to investigate concentrations and/or carbon isotopic compositions of three types of volatile compounds: (a) CH₄ and higher hydrocarbon gases (C₁ to C₆), (b) molecular hydrogen (H₂), and (c) methylated substrates, e.g. methyl amines, methyl sulfides or methanol. Compounds of type *a* provide information with regard to the hydrocarbon gas origin. A full analysis of C₁ to C₆ hydrocarbons allows the calculation of C₁/C₂₊ ratios, which can be used for identification of biogenic or thermogenic sources (Whiticar, 1999). This approach will be supported by home-based carbon isotopic measurements of these compounds in order to gain a deeper understanding of hydrocarbon gas cycling. Direct shipboard CH₄ analysis serves as a tool to rapidly screen the sediment for the depth of the sulfate-methane transition zone (SMTZ) and to guide the subsequent sampling strategy for research projects focusing on this important geochemical zone.

Molecular hydrogen (compound type *b*) is a key metabolite in anoxic environments. It is produced and consumed by a wide variety of microorganisms during the decomposition of organic matter. Concentrations of H₂ in sediments are thought to reflect the predominant terminal electron accepting processes and bioenergetics of the microbial ecosystem *in situ* (e.g., Hoehler et al., 1998). Compound types *c* (methylated carbon substrates) are one of the less understood volatile carbon components in marine sediments. They are non-competitive substrates for methanogens in sulfate-rich environments and previous studies demonstrated the presence of methylotrophic methanogens in seafloor brine pools (Joye et al., 2009) and subseafloor sediments (Yoshioka et al., 2010). Because *in situ* concentrations and production and consumption pathways of methylated compounds remain unclear, we aim to carefully investigate concentrations and, if possible, carbon isotopic compositions in sediment material retrieved from the brine pools and other locations during M84-1.

Methods of Sampling

MUC cores were processed on deck immediately after core retrieval. The sediment was extruded from the core by measured increments and the freshly exposed sediment surface was sampled. For gas analyses, a subsample set of 2-10 mL sediment was collected by cut-off plastic syringes, transferred to gas-tight vials and sealed according to the procedures described below. The depth resolution was about every four centimeter.

In the case of gravity cores, syringe samples for gas analysis were first taken in the Geolab when the core was cut into 1 m long segments. Samples were taken from each freshly cut segment base. In order to improve the depth resolution, additional samples were taken at a later time, usually within 24 h, from intact segments that were stored in a cold room at 4°C. Sampling ports (ca. 3 cm-wide bands) were cut into the core liner and syringe samples were retrieved from the freshly exposed sediments.

Gas Analysis

C₁ to C₆ Hydrocarbon gases – Concentrations of dissolved C₁ to C₆ hydrocarbon gases were determined according to previously reported protocols (Kvenvolden, 1986; D'Hondt et al., 2003): 2-3 mL of wet sediment were enclosed in a gas-tight 22 ml glass vial with a Teflon

septum and heated for 20 min at 60°C. After heating, 100-500 µL sub-samples were taken from the headspace gas with a gas-tight syringe and analyzed on board by gas chromatography-flame ionization detection (GC-FID). The GC-FID was calibrated on a daily basis using hydrocarbon gas standards (Scotty). Based on the partial pressure of the gases in the headspace and the headspace volume, the total amount of released hydrocarbon gases was quantified and normalized to the pore water volume of the extracted sediment sample, using the sample volume and corresponding porosity data of the solid phase sample that will be measured on shore. For a first interpretation, all sediment data presented in this report are based on an assumed sediment porosity of 0.7, except for water column samples (porosity of 1). Another set of subsamples was stored in gas-tight 22-ml glass vials with 5 mL NaOH at 4°C for shore-based carbon isotopic analysis.

H₂ – Concentrations of dissolved H₂ were determined using two different protocols, the headspace equilibration technique published in Hoehler et al. (1998) and an extraction-based method described in Lin (2009). To prepare samples for the extraction-based method, a sediment sample of 4-6 mL was extruded into a 22-mL headspace vial, which was immediately filled with NaCl solution to the top, sealed with a thin gray chlorobutyl stopper (VWR International LLC.), and crimp capped. The concentrations of NaCl were 35% for the brine pool sites GeoB 15101 and GeoB 15102 and 3.5% for the other stations. In the vial, a headspace was created by displacing 5-7 mL of the aqueous phase with an equal volume of H₂-free N₂ gas (the bypass gas out of the H₂ analyzer, Peak Performer I). Once the headspace reached the intended volume, the gas-in needle was removed first, and the overpressure in the vial was allowed to escape through the liquid-out needle. The expelled liquid was collected in a syringe and the volume which corresponds to the generated headspace was recorded. The vial was then vortexed, turned upside-down, and allowed to sit for 20 min at 4°C to let H₂ diffuse out of the interstitial water and equilibrate with the headspace. For H₂ analysis, the headspace gas was displaced into a N₂-flushed plastic syringe by injecting into the vial the same volume of NaCl solution. The concentration of H₂ in headspace gases was analyzed on board by gas chromatography with mercury oxide detection using a Peak Performer 1 (Peak Laboratories, LLC, USA). The instrument was calibrated with a 10 ppm H₂ primary standard (Air Liquide, Germany) on a daily basis.

To prepare samples for the headspace equilibration technique, a sediment sample of 2-3 mL was extruded into a 12-mL headspace vial, immediately sealed with a thick black butyl stopper, crimp capped, and flushed with N₂ (purity = 99.999%) for at least 1 min. Samples were stored at 4°C for shore-based incubation, where H₂ concentrations in the headspace gas will be analyzed every 1-3 days until a steady-state concentration is reached. To avoid evacuating the headspace by repeated removal of headspace gas, 1 mL of H₂-free N₂ will be injected into the headspace immediately after the removal of headspace gas to ensure a constant gas pressure.

Methylated substrates – Samples of ~10 mL sediment for methylated carbon substrate analysis were stored in 40 mL glass vials with Teflon septa at -20°C. The samples will be measured on shore using a purge-and-trap unit linked to a gas chromatograph with different detectors (mass spectrometer, flame photometric detectors and/or nitrogen phosphorus detector).

Onboard Results

C₁ to C₆ Hydrocarbon gases – Methane profiles in the duplicate cores, when present, match well to those of the first cores in most cases. The two brine pools (Urania and Discovery Basin) show distinct differences in the concentrations of hydrocarbon gases (Fig. 1.16). In the Urania Basin (Site GeoB 15101), brine waters are rich in methane (200-700 μM ; Fig. 1.17), and ethane was also detected at a level of 2-10 μM . The surface sediments contain also high concentrations of methane (1-2 mM), and the distribution of methane scatters throughout the sediment column, suggesting the presence of active fluid transport from below. The C_1/C_2 ratios are in the range from 3-6 for the brine waters and sediments, in accordance to gases of thermogenic origin. In contrast, methane concentrations in the Discovery Basin (Site GeoB 15102) are much lower, showing a maximum of only $\sim 75 \mu\text{M}$ in the upper 4.5 m of sediments. Despite the low methane concentrations, ethane was constantly present, and C_1/C_2 ratios increase from 50 at the surface sediment to 400 at 4.5 mbsf. No samples from the water column of the Discovery Basin were taken for analysis of hydrocarbon gases.

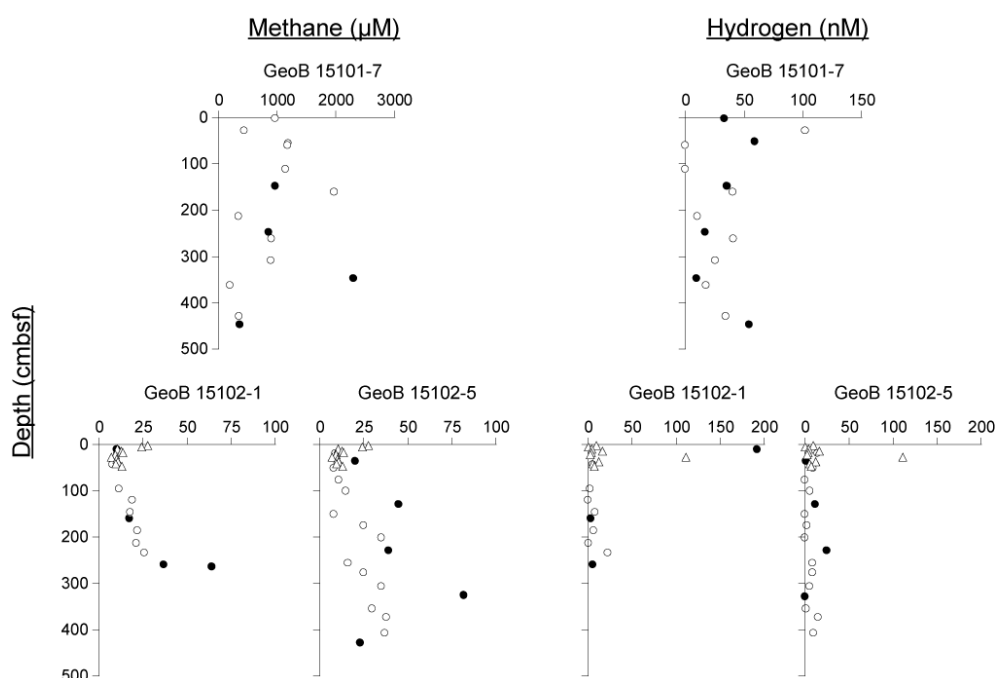


Fig. 1.16 Methane and hydrogen concentrations at Sites GeoB 15101 (Urania Basin) and 15102 (Discovery Basin). Solid dots: samples taken at the bottom of core segments; open dots: samples taken in the cold room; triangles: samples from MUC cores.

No higher hydrocarbon gases were detected in the sediment from the other three stations. At Site GeoB 15103 in the eastern Mediterranean Sea and GeoB 15104 in the Marmara Sea, methane concentrations are low ($<4 \mu\text{M}$; Fig. 1.18). In contrast, sediments from the southwest Black Sea contain abundant methane, reaching $>10 \text{ mM}$ at around 400 cmbfs. The SMTZ locates roughly at 100 cmbfs. Due to strong degassing during storage in the cold room, methane concentrations determined 12 hours later were much lower than those measured from samples at the bottom of segments taken right after core retrieval.

H₂ – The downcore distribution of H_2 in the duplicate cores are roughly comparable to each other. In general, there was no clear correlation between the extracted H_2 concentrations and the inferred geochemical zones, but there were some similarities among the H_2 profiles obtained

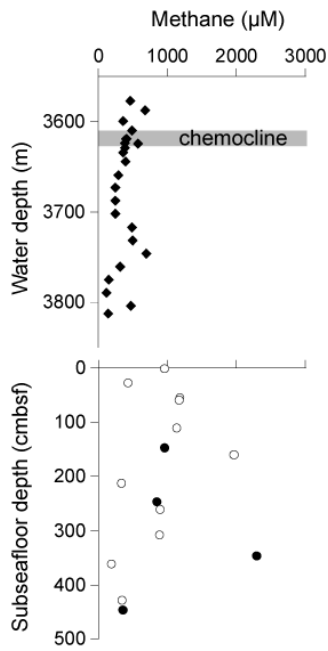


Fig. 1.17 Methane concentrations in the water column and sediments at Site GeoB 15101 (Urania Basin). Diamonds: samples taken from the CTD rosettes; solid dots: samples taken at the bottom of core segments; open dots: samples taken in the cold room.

from some stations (Figs. 1.16 and 1.18). At Sites GeoB 15101, 15102, and 15104, H_2 concentrations were lower in the uppermost sediment, exhibited a maximum of 100-200 nM at a shallow depth of c. 20-30 cmbsf, and decreased again to levels lower than 50 nM. In contrast, at Sites GeoB 15103 and GeoB 15105, we did not observe such a shallow subsurface maximum. At Site GeoB 15103, H_2 profiles show substantial scattering with poor comparability between duplicate cores. At Site GeoB 15105, H_2 measurements on samples taken at the bottom of core segments depict maximal values at 400-500 cmbsf. However, such a pattern was poorly reproduced by measurements on samples taken from the cold room, probably due to the degassing effect. Our data suggest that immediate sampling of gas samples is essential for proper quantification of both methane and H_2 in methane-rich sediments.

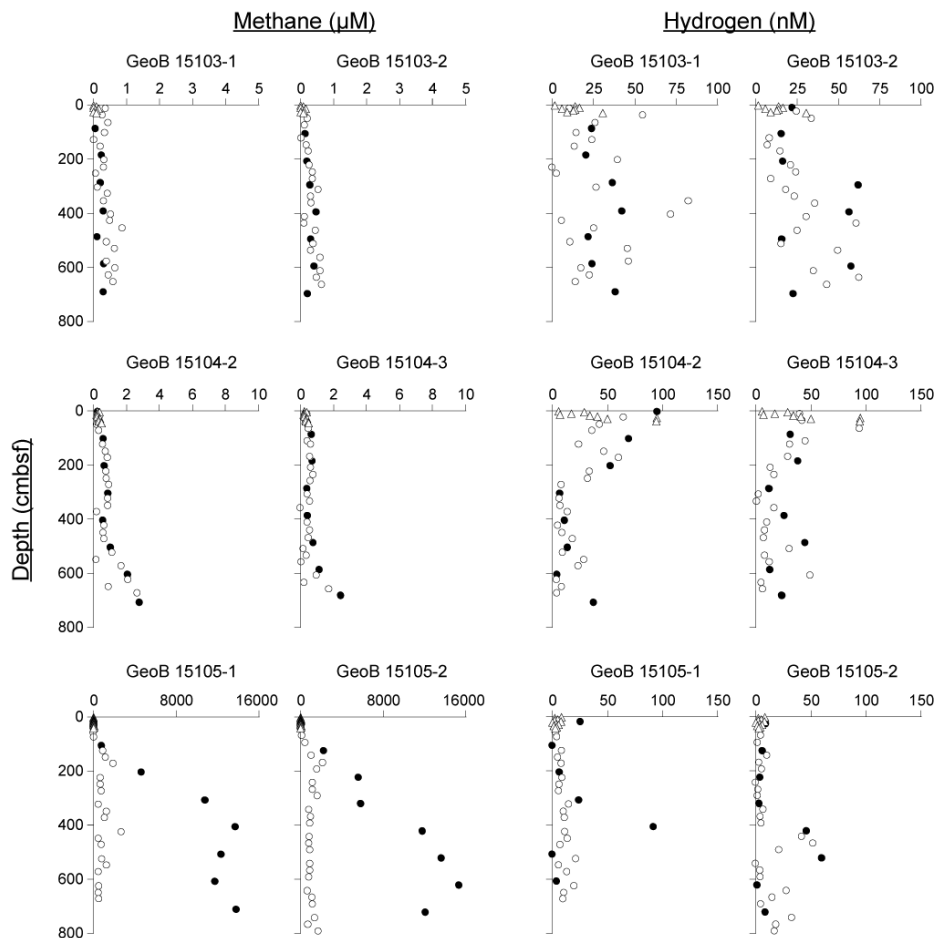


Fig. 1.18 Methane and hydrogen concentrations at Sites GeoB 15103 (eastern Mediterranean Sea), GeoB 15104 (Marmara Sea), and GeoB 15105 (Black Sea). Solid dots: samples taken at the bottom of core segments; open dots: samples taken in the cold room; triangles: samples from MUC cores.

1.5.7 Microbiology

(E. Gagen, K.-U. Hinrichs, C. Lazar, J. Lipp, J. Schröder, A. Teske, M. Yoshinaga)

The center piece of this expedition was the retrieval of suitable samples for shore-based studies in which we aim to elucidate how the distribution, composition and processes of subseafloor microbial communities are controlled by geochemical and (paleo)environmental factors. The investigation of microbial communities will encompass cell counts, metagenomic analysis of microbial diversity, structural and isotopic analysis of sedimentary microbial membrane lipids, and cultivation. The characterization of the sedimentary environment includes (a) molecular analysis of solid-phase bound organic matter and DOM and elemental and isotopic analysis of bulk sedimentary carbon and nitrogen that will provide information about the sources, preservation and remineralization of organic matter, (b) pore-water analysis of inorganic and organic pore water constituents that serve as nutrients, electron-acceptors, central intermediates or terminal products in metabolic processes and will provide valuable information on biogeochemical processes, and (c) the geological characterization of the sediments that will inform us about the paleoenvironmental context of sediment deposition. Sampling for the various investigations was closely coordinated and has been described above (1.5.1 Sampling Strategy).

Sampling methods

For DAPI cell counts, 0.5 ml sediment samples were taken with syringes, fixed in 1% PBS-buffered paraformaldehyde, washed in ethanol/PBS buffer, and returned to UNC-Chapel Hill for epifluorescence cell counting. For molecular analysis including metagenomic analysis, membrane lipid analysis and molecular analysis of solid-phase bound organic matter a combined sample (ca. 150 to 300 mL) was taken from ca. 10 – 20 cm long sediment horizons of interest and immediately frozen at -80°C. Samples were shipped to the University of Bremen where they will be homogenized in a liquid nitrogen cooled sediment grinding mill with adjustable grain size, with the goal of obtaining, for each sediment horizon, a homogenized sample of reproducible composition for all combined solid phase analyses.

DAPI Cell Counts

DAPI cell counts will be performed to quantify the number of all microbial cells that contain double-stranded DNA. The fluorochrome DAPI reacts with DNA by intercalation into the stacked basepairs within the double helix. Under UV excitation light in epifluorescence microscopy, DAPI-stained cells reveal a distinct blue fluorescence and can be counted on a per ml basis. DAPI cell counts deliver the 100% baseline for cell number quantification and comparisons with other approaches that target specific populations like Fluorescence in-situ hybridization (FISH) or quantitative polymerase chain reaction (q-PCR); they can be combined with FISH to visualize microbial cells with group-specific 16S rRNA-targeted gene probes (see Teske et al., 2009).

Metagenomic analysis of microbial diversity

A homogenized sediment sample of ca. 50 ml will be subjected to DNA and RNA extraction using specially optimized protocols that optimize recovery while at the same time minimize PCR inhibition (Lloyd et al., 2010a); the combination is essential for successful PCR amplification, whole-genome amplification, and q-PCR from often DNA-limited subsurface sediments.

Subsequently, bacterial and archaeal marker genes that are part of the most basic genetic equipment of every living cell, the slowly evolving small-subunit ribosomal RNA genes, will be PCR-amplified for the following processing pathways:

1) *Classical 16S PCR and clone libraries*. First, near-complete gene copies for clone library construction, sequencing, and taxonomic/phylogenetic analysis will be obtained using suitable PCR primers that capture almost the complete 16S rRNA gene for bacteria and archaea (Teske et al., 2002). This procedure is essential for phylogenetic identification and placement of novel bacterial or archaeal lineages for which no precedent exists – a common occurrence in extreme subsurface environments (Teske and Sørensen, 2008), and also evident for hypersaline basins (Van der Wielen et al., 2005; Edgcomb et al., 2009).

2) *Pyrosequencing of 16S rRNA gene fragments*. Second, short PCR fragments will be generated for V6-tag pyrosequencing analysis, a high-throughout pathway that yields two-to-three orders of magnitude higher sequence throughput than classical clone libraries (Sogin et al., 2006), with reduced taxonomic resolution on the subphylum level, sometimes on genus- and family level. The method depends critically on a good reference sequence database, and works optimally when full-length 16S rRNA gene sequences are available for reliable identification of novel “unknowns” that remain otherwise unresolved or misidentified (see Lloyd et al., 2010b for examples).

3) *Metagenomic Pyrosequencing*. The third pathway of gene analysis does not single out specific genes, but shears the complete DNA extracted from an environmental sample into short fragments of suitable size for pyrosequencing. This metagenomic approach produces a wide variety of randomized, fragmented gene sequences that remain, to 10 or 15% of all fragments, identifiable by comparison to standard genomic databases (GenBank, CAMERA); the technique is useful for the subsurface, and can identify metabolic functionality in complex subsurface microbial communities (Biddle et al., 2008), and detect correlations of functional gene classes (or the lack thereof) to geochemical key parameters, for example methane or ammonia pore water concentration (Teske and Biddle, 2008; Biddle et al., 2011).

Structural and Isotopic Analysis of Sedimentary Microbial Membrane Lipids

Intact membrane polar lipids (IPLs) are indicative of biomass from active subsurface prokaryotes. IPL analysis leads to general taxonomic information on the active sedimentary community and simultaneous semi-quantification of both archaeal and bacterial lipids, which can be used for estimation of extant biomass (Lipp et al., 2008). In addition, comparison of carbon isotopic values of IPLs with $\delta^{13}\text{C}$ of other carbon pools such as methane, DIC, and total organic carbon will provide a first indication of microbial metabolism and the carbon source used for building biomass (Biddle et al., 2006). We will analyze IPLs using high-performance liquid chromatography/electrospray ionization multistage mass spectrometry following the protocols described in Sturt et al. (2004), Biddle et al. (2006), and Schubotz et al. (2009). Isotopic characterization of individual IPL groups can be achieved using preparative high-performance liquid chromatography followed by isotope ratio monitoring mass spectrometry (Biddle et al., 2006).

Molecular Analysis of Solid-Phase Bound Organic Matter

Given the complex mass spectra that demand substantial efforts of data mining and processing, FT-ICR-MS analysis of solid-phase bound organic matter will be performed on only a small set of samples. DOM will be extracted from the solid phase sample by aqueous soxhlet extraction and subsequently analyzed as described above (1.5.5 Sediment Pore-water and Seawater Analysis). Isotopic analysis of bulk sedimentary carbon will be performed using isotope ratio monitoring mass spectrometry coupled to an elemental analyzer (Biddle et al., 2006).

Cultivations

Sediment samples were also taken for later cultivation and enrichment of benthic Archaea. Samples were collected as soon as possible after core opening to minimize exposure to oxygen and where possible, sampling was done in the cold room. For gravity cores, 10mL sediment samples were collected every 25 cm and pooled, providing an integrated combination of microbial communities, to afford the best chance of success in enriching (and later isolating) novel Archaea with presently unknown metabolic requirements. Larger volume samples (up to 250 mL) were also collected from multicores and specific locations within the gravity cores (e.g., sapropel layers) to provide enough material for multiple cultivation strategies. Sterile spoons or syringes were used to transfer sediment from cores into glass bottles which were sealed with gas-tight stoppers. The headspace gas of the bottles was immediately replaced with N₂ before samples were stored at 4°C.

Cultivation of presently uncultured Archaea from these sediments will be performed at the Lehrstuhl für Mikrobiologie, Universität of Regensburg. Enrichment strategies will target Archaea with a heterotrophic lifestyle (Biddle et al., 2006) (e.g. enrichment on organic substrates or recalcitrant substrates), or Archaea that may be adapted to life under extreme conditions (e.g. nutrient limiting conditions, energy stress) (Valentine, 2007) as well as enrichment of presently known Archaeal phenotypes (e.g. methanogenesis, ammonia oxidation).

Similar large volume samples were collected from multi-cores for stable isotope labelling experiments to be performed at MARUM, seeking to identify microbial activity by the uptake and incorporation of ¹³C and ²H labelled substrates into archaeal and bacterial intact polar lipids. Overlying bottom water was also collected and stored at 4°C, which will be used to make sediment slurry solutions to perform stable isotope incubations in the laboratory.

1.6 Ship's Meteorological Station

(E. Knuth)

On the 9th of February FS METEOR left the harbour Valetta on Malta at 09:00 MEZ. Under weak high pressure the weather was fine with weak northwesterly winds experiencing. The high (1026 hPa) across the Balearic Islands dominated the weather to the first spot of the research area (320 nm). With the help of the large high pressure area the station work was conducted within a northwesterly airflow at first. Later the FS METEOR experienced easterly winds shifting westerly to northwesterly on the 11./12. Calm seastate conditions resulted in the good outcome of the scientific work.

The first spot located to the south of Cyprus was reached on the 14.02. early. Under the influence of high pressure system northwesterly to westerly winds were experienced. Late on the 14.02. a low across Libya moved northeast and cloudiness in the working area increased. The

transit to Heraklion was accompanied by the low while it was already located to the south of Crete. During the night 14.02./15.02. we experienced southwesterly to southerly winds with force 4 to 5 with occasional showers. On the morning the passage of the front was associated with strong showers and thunderstorms. As winds shifted quickly northeast almost clear sky followed. On the night 15th/16th the wind increased 6 to 7, with local gusts about 8. With lots of showers associated the wind backed northwesterly. During day time the wind decreased further to 3 to 4, with further backing to the southwest to south to follow. The cold front of a low to the east of Crete moved across the cruising area und brought on the night 16th/17th southeasterly winds about force 5 Bft. Clouds increased with mainly dry conditions persisting.

On the 18.02. close to Istanbul a weak high pressure ridge maintained weak easterly winds. During the day some high clouds developed with the wind increasing to 4 to 5 Bft. On the night to the 19th at times 6 Bft were experienced. Later on the weather was dominated by an elongated low pressure trough stretching from the Caspian Sea across the Black Sea into the Balkan area. This trough slowly shifted south. Therefore in the area of operation (Black sea) mainly easterly to northeasterly winds with 4 to 5 force at first, later 6 to 7 Bft were experienced. The seastate on the station was measured from 2 to 3 m. Later the elongated trough moved slowly to the east causing the wind to decrease to 4 to 5 Bft and shifting more to northerly directions.

On the night 20th/21th a high across Scandinavia moved to Westrussia. The associated ridge extended in the cruising area of the FS METEOR. On the way to Istanbul a ridge of a high dominated the weather with calm conditions and winds of force 2 to 4 Bft. Later on the 21th FS Meteor reached the final destination in Istanbul.

1.7 Station List M84/1

(M. Zabel)

Table 1.4 Station list M84/1

Station No.	GeoB No.	Date (2011) dd.mm	Time (UTC)	Lat [N]	Long [E]	Water Depth [m]	Gear	max. rope tension [kN]
ME841/107-1	15101-1	10.02	15:41	35°13,87'	21°28,31'	3599*	CTD	---
ME841/108-1	15101-2	10.02	20:42	35°13,87'	21°28,30'	3600*	ISP	---
ME841/109-1	15101-3	11.02	03:09	35°13,87'	21°28,30'	3599*	MC	47,3
ME841/110-1	15101-4	11.02	06:14	35°13,87'	21°28,30'	3599*	MC	58,7
ME841/111-1	15101-5	11.02	09:46	35°13,88'	21°28,31'	3603*	GC	67,7
ME841/112-1	15101-6	11.02	12:52	35°13,87'	21°28,30'	3602*	CTD	---
ME841/113-1	15101-7	11.02	15:46	35°13,87'	21°28,30'	3602*	GC	67,5
ME841/114-1	15102-1	11.02	20:21	35°16,43'	21°41,50'	3615	GC	66,2
ME841/115-1	15102-2	11.02	23:18	35°16,43'	21°41,50'	3615	CTD	---
ME841/116-1	15102-3	12.02	03:18	35°16,43'	21°41,50'	3615	ISP	---
ME841/117-1	15102-4	12.02	09:48	35°16,43'	21°41,50'	3615	MC	48
ME841/118-1	15102-5	12.02	12:40	35°16,43'	21°41,50'	3624	GC	65,3
ME841/119-1	15103-1	14.02	12:50	33°02,00'	32°38,00'	1424	GC	48,7
ME841/120-1	15103-2	14.02	15:03	33°01,65'	32°37,80'	1367	GC	40,8
ME841/121-1	15103-3	14.02	16:35	33°01,65'	32°37,80'	1366	MC	30,3
ME841/122-1	15104-1	18.02	16:08	40°47,97'	27°43,49'	606	MC	18,0
ME841/123-1	15104-2	18.02	17:14	40°47,97'	27°43,49'	600	GC	36,1
ME841/124-1	15104-3	18.02	18:08	40°47,97'	27°43,49'	600	GC	34,2
ME841/125-1	15104-4	18.02	19:01	40°47,98'	27°43,49'	601	GC	35,9
ME841/126-1	15105-1	19.02	16:02	41°31,70'	30°53,07'	1268	GC	50,9
ME841/127-1	15105-2	19.02	17:26	41°31,71'	30°53,07'	1266	GC	40,8
ME841/128-1	15105-3	19.02	18:51	41°31,70'	30°53,10'	1267	GC	43,9
ME841/129-1	15105-4	19.02	20:07	41°31,70'	30°53,09'	1266	MC	21,6
ME841/130-1	15105-5	19.02	21:58	41°31,70'	30°53,10'	1264	CTD	---
ME841/131-1	15105-6	19.02	23:45	41°31,70'	30°53,10'	1266	ISP	---
ME841/132-1	15105-7	20.02	05:53	41°31,70'	30°53,10'	1263	ISP	---
ME841/133-1	15105-8	20.02	11:38	41°31,69'	30°53,09'	1227	ISP	---
ME841/134-1	15105-9	20.02	17:00	41°31,70'	30°53,10'	1231	ISP	---

* apparent depth! Surface of the fluid mud

1.8 Data and Sample Storage and Availability

All metadata were delivered to the PANGAEA World Data Center MARE and to the BSH (CSR). The ship station list is published together with the SCR on the homepage of the control station METEOR. Reference geological cores are stored in the MARUM core repository, these and the other geological samples have obtained GeoB ID numbers in addition to the PANGAEA event labels.

1.9 Acknowledgements

The overall successful course of this expedition needs to be attributed to the friendly cooperation and very efficient technical assistance of Captain Michael Schneider, his officers and crew. No matter in which area, we always were attentively cared for. It was always obvious that all people on board worked on a common task. For this we would like to thank everybody involved, last but not least also the Leitstelle METEOR Hamburg. We would like to cordially thank Götz Ruhland (MARUM/Bremen University), Klaus Bohn (LPL Projects + Logistics GmbH) and their teams for professional support of expedition logistics.

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