MARIA S. MERIAN – Berichte

Deep drilling in the Baffin Bay for marine sediment records of Greenland Ice Sheet collapse during past warm intervals

Cruise No. MSM111

02.09. – 04.10.2022
Reykjavik (Iceland) – St. John´s (Canada)
BAFFDEEP

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1 Cruise Summary

1.1 Summary

The main aim of the cruise was to recover sediments from the Baffin Bay to reconstruct the history of oceanic conditions and terrigenous supply from the Greenland Ice Sheet reaching back to the last time when Greenland was largely ice-free. For this, seafloor drilling to more than 100 m depth with the MeBo-200 drill rig was necessary. The ancillary aims of the cruise were to obtain (i) plankton material for cultivation experiments with planktonic foraminifera, (ii) surface sediment material for calibration of paleoceanographic proxies and environmental DNA, and (iii) longer sediment records to reconstruct environmental conditions since the last ice age. The collected material will enable us to develop and validate new proxies for past environmental conditions and use these to reconstruct the interaction between the ice sheet, sea ice and marine ecosystems in the region. The main working area of the cruise was the continental slope off Disko Bay in depths between 900 and 1800 m. The area was extensively surveyed by multibeam bathymetry and sediment echo sounder profiles, which, together with sediment sampling by multicorer and gravity corer, allowed us to position a total of four MeBo drilling sites. These penetrated between 53 and 126 m below the seafloor and provide two borehole logs of 92 m and 123 m. Additional surface sediments and gravity cores were taken off Iceland, in the Narsaq Sound, Disko Bay and in the Davis Strait. Moreover, filtered seawater, plankton net samples of bulk and individual foraminifera were taken at eight stations along the ship's track between Iceland and South Greenland.

1.2 Zusammenfassung

Das Hauptziel der Expedition MSM111 war die Gewinnung von marinen Sedimenten aus der Baffin Bay, um die zeitliche Entwicklung der Ozeanographie sowie des terrestrischen Eintrages aus dem grönländischen Eisschild bis in die letzte Zeit, als Grönland weitgehend eisfrei war, zu rekonstruieren. Dazu waren Bohrungen bis zu einer Tiefe von >100 m mit dem Bohrgerät MeBo-200 erforderlich. Weitere Ziele der Fahrt waren die Gewinnung von (i) Planktonmaterial für Kultivierungsexperimente mit planktischen Foraminiferen, (ii) Oberflächensedimentmaterial für die Kalibrierung paläozeanographischer Proxies und alter DNA, und (iii) Sedimentkerne, die Aufschluss über die Umweltbedingungen seit der letzten Eiszeit geben. Das Material wird es uns ermöglichen, neue Proxies zu entwickeln und zu validieren und zu nutzen, um die Interaktion zwischen dem Eisschild, dem Meereis und den marinen Ökosystemen in der Region auf verschiedenen Zeitskalen zu rekonstruieren. Das Hauptarbeitsgebiet der Fahrt befand sich am Kontinentalhang vor der Disko Bay, in Tiefen zwischen 900 und 1800 m. Das Gebiet wurde mit Hilfe von Fächerecholot und Sedimentecholotprofilen umfassend vermessen, was uns zusammen mit der Beprobung des Sediments mit Multicorer und Schwerelot die Positionierung von insgesamt vier MeBo-Bohrstellen ermöglichte. Diese drangen zwischen 53 und 126 m in den Meeresboden vor und lieferten zwei Bohrloch-Logs von 92 m und 123 m. Weitere Oberflächensedimente und Schwerelotkerne wurden vor Island, im Narsaq Sound, in der Disko Bay und in der Davisstraße entnommen. Darüber hinaus wurden an acht Stationen entlang der Fahrtroute zwischen Island und Südgrönland gefiltertes Meerwasser sowie Planktonnetzproben von Gesamt- und Einzelforaminiferen entnommen.

2 Participants

2.1 Principal Investigator

Name	Institution
Kucera, Michal, Prof.	MARUM

2.2 Scientific Party

Name	Discipline	Institution
Kučera, Michal, Prof.	Chief Scientist	MARUM
Faust, Johan, Dr.	Marine Geology	MARUM
Meilland, Julie, Dr.	Plankton analysis	MARUM
Siccha, Michael, Dr.	Multi-Plankton-Sampler, CTD	MARUM
Janßen, Anjuly	Marine Geology	MARUM
von Dobeneck, Tilo, Prof.	Geophysics, Geomagnetics	UoB
Morard, Raphaël, Dr.	aDNA	MARUM
Streuff, Katharina, Dr.	Hydroacoustics	UoB
Diekamp, Volker	Gravity Corer	MARUM
Düßmann, Ralf	MeBo	MARUM
Bergenthal, Markus	MeBo lead	MARUM
Linowski, Erik	MeBo	MARUM
Fröhlich, Siefke	MeBo	MARUM
Ahrlich, Frauke	MeBo	MARUM
Schillai, Sophia	MeBo	MARUM
Haider, Dennis	MeBo	MARUM
Kaszemeik, Kai	MeBo	MARUM
Schmidt, Werner	MeBo	MARUM
Detlef, Henrieka, Dr.	Marine Geology	AU
Schulz, Hartmut, Dr.	Multicorer, Gravity Corer	UoT
de Vernal, Anne, Prof.	Palynology	Geotop-UQAM
DMello, Gavin	Hydroacoustics	AWI

2.3 Participating Institutions

MARUM	Center for marine environmental Sciences, Bremen, Germany
AU	Aarhus University, Denmark
UoT	University of Tübingen, Germany
GEOTOP	Université du Québec à Montréal, Canada
AWI	Alfred-Wegener-Institut, Bremerhaven, Germany

Fig. 2.2.1: Scientific party of the MSM111 expedition.

3 Research Program

3.1 Description of the Work Area

The ongoing accelerated melting of Greenland Ice Sheet (GIS) raises concerns about the future of this large meltwater source and its unique environment under further global warming. Indirect evidence from the magnitude of past sea-level high stands and numerical modelling suggests that the GIS was significantly reduced during MIS5 and largely collapsed during MIS11 (Dutton et al., 2015). It is particularly the large-scale collapse during MIS11 (~400 000 years ago) that is a source for concern under projected future climate change scenarios, due to the resulting discharge of large amounts of meltwater to the North Atlantic, sea-level rise, and the establishment of a fundamentally different landscape on Greenland at that time. MIS11 was characterized by insolation-driven long climatic optimum, which resulted in a protracted sea level rise lagging global temperature by ~5 ka and culminating in a sea-level highstand around 400 ka (Milker et al., 2013). At the same time, the emergence of tree pollen in marine sediments off southwest Greenland (de Vernal and Hillaire-Marcel, 2008) and provenance change in glaciogenic debris in the same sediment record (Reyes et al., 2014) indicate a regime shift, consistent with a large-scale ice-sheet collapse. Indeed, sedimentary material recovered from the bottom of boreholes that penetrated throughout the present ice sheet down to bedrock contain plant fossils and ancient DNA indicative of a vegetated Greenland interior (Christ et al., 2021; Willerslev et al., 2007).

Whilst the existence of a collapse of the GIS and vegetation of Greenland at some point in the Quaternary is well established, its exact timing, as well as its chronology relative to global and local climatic forcing are not well constrained, and the recurrence pattern of the ice-free periods is completely unknown (Christ et al., 2021). Existing subglacial sediment records are hard to date and there are no suitable proximal marine records documenting the history of Greenland glaciation. The most dynamic portions of the GIS discharge into the Baffin Bay, but so far, no record has been recovered from this key region to reconstruct the history of the GIS collapse during late Pleistocene warm interglacials. Such record would also allow to investigate phase relationships between ice sheet collapse, local oceanic conditions, and the associated changes to the marine environment, which appear to have played a role of the GIS response to climatic forcing during the last deglaciation. In addition, discharge of the Arctic ice sheets into the Lancaster sound during deglaciations, leaves a distinct mineralogical fingerprint in Baffin Bay sediments (Jackson et al., 2017; Simon et al., 2014). Therefore, marine sediment records from the Baffin Bay should help constrain both the pattern and chronology of GIS collapse, as well as the phase relationship of oceanic change in the Baffin Bay and the collapse of the North American Arctic Ice Sheets.

3.2 Aims of the Cruise

The principle aim of the cruise **was** to recover a continuous sediment sequence from the central Baffin Bay, allowing a reconstruction of the chronology of changing oceanic conditions and terrigenous sediment supply from Greenland and Arctic ice sheets during MIS5 and MIS11. The ancillary aim of the cruise, which **was** follow**ed** to avoid idle time during MeBo maintenance between deployments **was** to obtain plankton and sediment material for calibration of paleoceanographic proxies in the region.

3.3 Agenda of the Cruise

The only investigations of paleoenvironmental change in the Baffin Bay prior to 100 ka are based on micropaleontological studies from ODP Site 645 (Baldauf et al., 1989). However, core recovery was very poor, providing only a discontinuous record across the target interval and the site was drilled in abyssal sediments, resulting in intermittent preservation of carbonate for most of the Quaternary (Aksu, 1983). Based on biostratigraphic data, the Pliocene to Quaternary transition

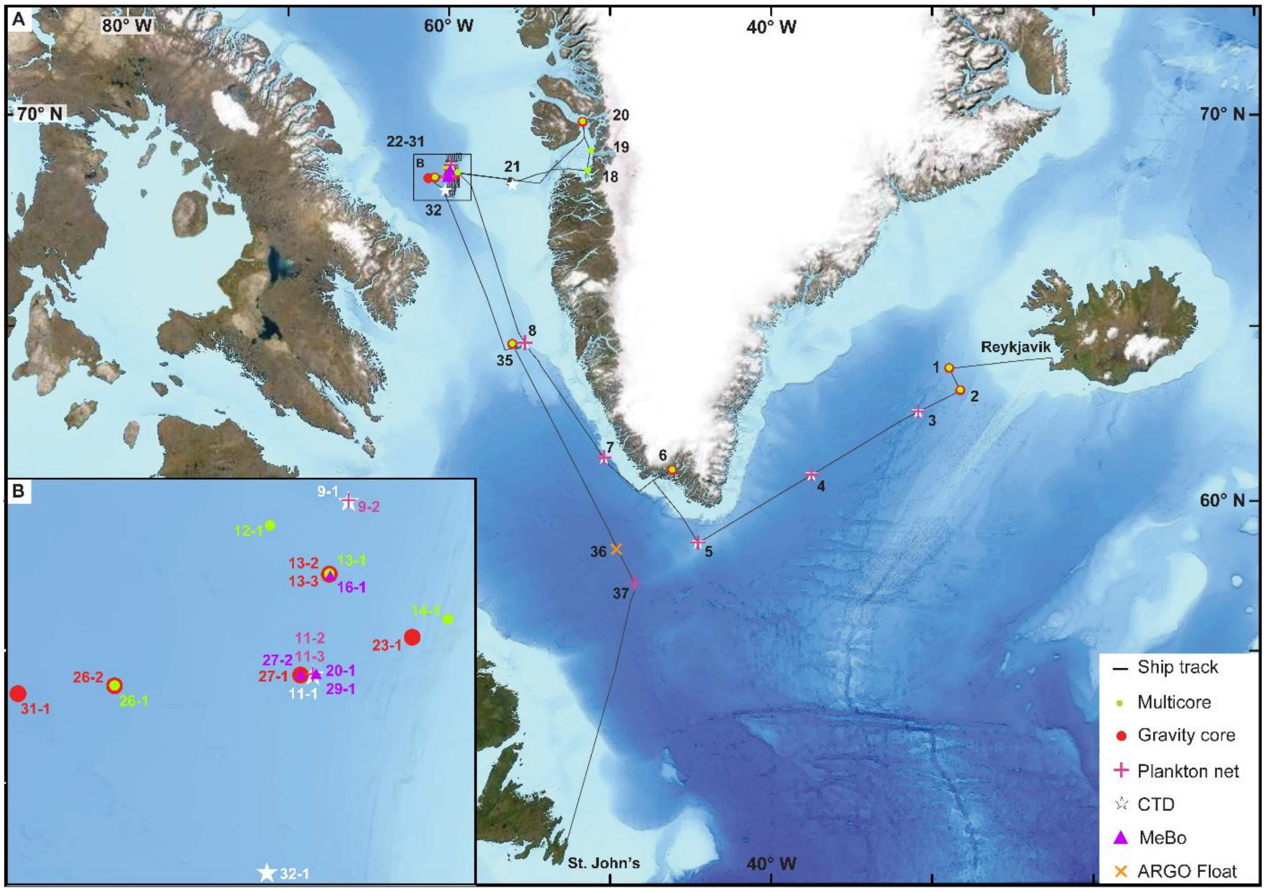

Fig. 3.1 Track chart of *R/V Maria S. Merian* Cruise MSM111. Inlet B) is the operational area of MeBo-200.

could be positioned at about 150 m in the sedimentary sequence. This indicates that it should be possible to obtain a continuous sediment sequence from the Baffin Bay since MIS11 by drilling to a depth of 100 m using the unique capacity of the MeBo-200 drill rig.

Because of the lack of published sedimentary records and high-resolution shallow seismic profiles, drill site selection had to be preceded by extensive hydroacoustic surveys and conventional gravity core sampling. Existing large-scale seismic data indicate stratified deposition in thick wedges, with the youngest large reconfiguration of the sedimentary system dated to the mid Pleistocene transition (Knutz et al., 2011). This transition resulted in the focussing of ice stream towards the present-day troughs, from which we inferred that an appropriate site to record a continuous sedimentary sequence with glaciogenic material would have to be located on the slope of one of the major sediment fans. This guided our decision to focus on the southernmost Disko Bay Fan, at depths of 1500-1000 m, below the iceberg scour limit, yet shallow enough to facilitate carbonate preservation as a substrate for dating and paleoenvironmental reconstruction.

To make the most of the transit to and from the Baffin Bay, and to provide an alternative program in case of bad weather or technical difficulties, the ancillary aim of the cruise was to obtain plankton and sediment material for calibration of palaeoceanographic proxies and reconstruction of oceanic conditions and biotic response since the last ice age. To this end, plankton nets taken along the cruise track were used to obtain plankton samples for analyses of genetic diversity and biotic associations of planktonic foraminifera, and their living cells were collected for cultivation experiments. Moreover, multicorer deployments were used to obtain surface sediments for calibration of organic and inorganic geochemical and micropaleontological proxies and environmental DNA survey. Furthermore, we aimed to collect gravity cores in proximal positions to Greenland to recover a sediment sequence spanning from the last ice age and to the present day, allowing for the reconstruction of environmental conditions and interaction between ice sheet, sea ice and the marine environment.

4 Narrative of the Cruise

After preparing laboratories and instruments, and especially setting up the MeBo-200 drill rig, we were able to leave the port of Reykjavik on 02.09.2022 at 5 pm local time. The intense rain of the last days had calmed down and we could enjoy a beautiful view of the dramatic landscape of Iceland with blue skies. Hydroacoustic data collection started in the evening, after leaving the 12 nm zone, and remained active throughout the cruise, with exception of two visits within the 12 nm zone of Greenland. After completion of the obligatory safety meeting, the scientific program of the cruise started with sediment sampling on the NW flank of the Mid-Atlantic ridge. Here, within the EEZ of Iceland, we collected surface sediments and gravity cores at two positions where our colleagues from the GLOBE Institute in Copenhagen expected to recover suitable sediments to reconstruct the marine environment and ecosystems during the last interglacial. Having collected two multicores and three gravity cores, recovering up to 10 m of sediment, we set sail towards Cape Farewell. Underway we enjoyed spectacular Auroras Borealis and collected planktonic foraminifera from multinet samples for cultivation experiments.

Considering the weather forecast for the Baffin Bay with conditions unfavorable for MeBo deployment, we decided to extend the transit by sampling sediment in the Narsaq Sound. The southernmost tip of Greenland was reached in the early hours of 06.09.2022 and on 07.09.2022, we arrived in the Narsaq Sound via the Ikersuaq Fjord, which proved easily navigable despite numerous icebergs. In the Narsaq Sound, we were able to resample a coring position published by (Norgaard-Pedersen and Mikkelsen, 2009), recovering 11 m of sediment, extending the published record and likely covering the entire Holocene. At the entrance of the Ikersuaq Fjord the ship's Underwater Positioning System (USBL) was calibrated and we resumed our transit to the Baffin Bay, with underway plankton sampling and CTD profiles. Because of the ongoing Covid-19 pandemics, the cruise participants initially had to adhere to mask duty and distancing regulations and were tested daily. Only after five consecutive days of negative test results, these limitations could be lifted.

We passed the Davis Strait and crossed the polar circle at 9 pm local time on 09.09.2022 and arrived in Baffin Bay on 10.09.2022. Strong southerly winds reaching Bft 8 in gusts prevented sediment sampling, but we could carry out an extensive bathymetric survey of the main target area for MeBo drilling in the Danish and Canadian sectors of the continental slope off Disko Bay. The survey continued until 14.09.2022 in the evening, interrupted by one day with multiple deployments of the multi- and gravity corer at prospective MeBo locations. Evaluation of Parasound profiles indicated that the slope between 1100 and 1600 m water depth is built of two sedimentary units. The lower unit consists of parallel reflectors which appear to follow an old topography with ridges perpendicular to the slope. This unit is capped by an unconformity or hiatus, following the outlines if the underlying expressive topography. The upper unit drapes and fills the underlying ridges and basins. Apart from some unconformities at the bottom and changing reflector thickness the drape is remarkably uniform, likely representing the same sedimentary sequence and covers the entire region. Based on the Parasound data and the recovery of a 17 m gravity core, the first MeBo site was positioned to recover a thick sequence of the upper unit and penetrate into the lower unit at about 70 m.

On 14.09.2022 the sea calmed, so the MeBo operation could commence in the evening and drilling began at 2 am the next day. Drilling initially appeared to proceed well and at 6 pm we were closing in on 50 m. However, it transpired that the borehole was experiencing backpressure, which caused sediment to enter the drilling string, preventing the recovery of the core barrel. Despite extensive efforts, the problem could not be solved and the borehole had to be abandoned at 52.9 m bottom depth. It was not possible to obtain a borehole log. The drill rig was recovered successfully on 16.09.2022 after 33 hours of operation. An inspection of the cores revealed variable recovery of a total of 35.2 m of sediment.

The weather forecast announced the arrival of another storm, and the decision was made to carry out a supplementary sampling and survey program in the Disko Bay. Here we recovered surface sediment samples along a S-N transect towards the Vaigat Strait, where an 8 m core from a sedimentary basin with stratified deposits was obtained. Following a survey underway back to the central Baffin Bay, the geological sampling recommenced on 19.09.2022. Another 18 m gravity corer deployment at a place with a less extensive drape of the upper unit penetrated completely, but only recovered 9 m of sediment, indicating the presence of coarse-grained sediment units, which are not conducive to drilling. The second MeBo site was positioned at a place with the best Parasound resolution of the lower unit, and it was decided to flush until 52 m and attempt to drill through the unconformity and reach the lower sedimentary unit. The drilling proceeded well, and the coring depth of 52.5 m was reached overnight. The drilling could continue the next day without incidents but had to be terminated at 94.5 m because the core barrel catcher exhibited a tear. Nonetheless, the last barrel could be recovered, and the borehole could be fully logged with magnetic susceptibility and a spectrum gamma ray probe.

The recovery of the drill rig was successfully completed on 21.09.2022 after 41 hours on the seafloor and the inspection of the core barrels revealed a much better recovery of almost 90%. During the day, whilst the MeBo was refitted, we continued with a survey line into the deeper part of the slope, where a gravity core, preceded by a multicorer sampling, recovered 14 m of sediments covering a substantial part of the upper unit, which was found to thin with depth. The third MeBo deployment could begin only in the evening of the same day and considering the experiences from the second deployment, we decided to occupy a position slightly downslope, with less disturbance at the base of the lower unit, this time coring already from 15 m. Whilst drilling with flushing was successful, the change to coring was not successful, as due to strong back pressure sediment kept entering the drill string. The entire drill string had to be dismantled at 35 m, because of a stuck barrel and another attempt was carried out using the same hole. The back pressure problem remained and having three times switched from coring to flushing, the borehole had to be abandoned at 91.4 m, with a stuck core barrel and no possibility for borehole logging.

After 52 hours of operation at 1472 m, the drill rig was recovered on 24.09.2022 at 7 am. After recovery, we observed that the last core barrel was not in position at the end of the drill string. It appears that after the final drill string segment was added, sediment penetrated back into the open pipe and the core barrel therefore could not reach the desired position. Consequently, the flushing circulation likely did not establish correctly and sediment got into the pipe through the misaligned core barrel, preventing its capture. The core recovery was only 63%. Fortunately, the drill rig itself remained fully operational throughout and could be refitted within 12h, during which we continued with the hydroacoustic survey. The fourth and final deployment of the MeBo-200 drill rig started in the evening. We decided to reoccupy the position of the most successful second deployment, flushing to 87 m. The final deployment proved to be the most successful. The flushing proceeded rapidly, reaching 70 m by the morning of 25.09.2022 and at midnight, when the final depth was reached, the last barrel could be recovered, and the probe was deployed for logging. According to our speculative age model, based on the magnetic susceptibility log of the cores and of the second borehole, we estimated that paleomagnetically datable sediments should be recovered around 115 m. Since the drilling proceeded well and the weather conditions ahead were favourable, we decided to make the most of the available time window and the final borehole reached a sediment depth of 126.3 m.

After its final deployment on our cruise, the drill rig was successfully recovered on 26.09.2022 in the morning, after less than 32 hours in operation. The core recovery was more than 90%, except for the last barrel, which was empty. It appears that the content of the core was lost and filled the drill pipe, such that the logging probe could not extrude from the drill string and therefore only spectrum gamma ray information could be obtained. This had to be measured through the drill string, but a comparison with the log from the second deployment showed excellent agreement in the overlapping part of the drilled sediment sequence. The rest of the day was used for a final attempt to recover the upper sediment unit downslope. Parasound surveys indicated a particularly thin sequence around 1750 m and a final gravity core in the Disko Bay slope area was taken. The corer penetrated to about 16 m, but the liner contained only 8.6 m of sediment, with a conspicuous light hard layer obtained in the core catcher. We then continued with the survey to completely cover features of the upper slope and shelf break until the morning of 28.09.2022, when we departed from the Baffin Bay to our destination port in St. John’s, Canada.

Because of time reserves, on 29.09.2022 we were able to carry out an additional short survey south of the Davis Strait, at the position of the planned IOPD-962 campaign, to drill the Davis Strait Drift Complex. We were able to obtain Parasound long- and cross-profiles of four planned drilling sites and to sample the surface sediment with the multi- and a gravity corer. The obtained data will help our colleagues from the IODP-962 team to better understand the shallow subsurface sediment dynamics and potential sediment instability in the area. The coring was accompanied by the last snowfall of the expedition. Temperatures close to freezing and moist air resulted in sleet and snow showers almost every morning over the last week. With the geology program of the cruise completed at 5.30 pm, we continued our transit to the Labrador Sea, where an ARGO float was deployed on 01.10.2022 at 7 am and on the same day in the afternoon the last plankton sampling took place at the position of the Dalhousie University long-term monitoring station GS04-244-03. The hydroacoustic data collection was finished upon reaching the 12 nm zone of Canada and, after two days of rough seas with waves reaching almost 5 m, we safely arrived in St. John's in the morning of 04.10.2022.

5 Preliminary Results

5.1 Hydroacoustics

(Katharina Streuff, Gavin DMello, Tilo von Dobeneck, Hartmut Schulz, Michael Siccha)

5.1.1 Multibeam bathymetry

Precise knowledge of seabed topography is necessary to understand many marine geological processes. For sparsely surveyed areas, the bathymetry provides the first image of the seafloor, with all its bedforms, forming the basis for the location of subsurface profiling and sampling. Therefore, detailed bathymetric surveys were conducted to extend our knowledge on seabed topography in the studied region and to use the resulting maps for planning of further surveys and geological sampling. In combination with sub-bottom profiler information (chapter 5.1.2), the data formed the basis for the location of gravity core and MeBo-200 drilling sites during the MSM111 expedition.

5.1.1.1 Technical description

During the MSM111 cruise bathymetry and water column data were recorded using the hull-mounted Kongsberg Maritime Simrad EM122 system (the EM712 for shallow waters was only used briefly on the Greenland continental shelf). The EM122 is a deep-water system using two linear transducer arrays that are configured in a Mills Cross alignment. It operates with an acoustic frequency of about 12 kHz with a beam width configuration of 0.5° (Tx) by 1°(Rx) and a maximum fan opening angle of 150°. Per ping the EM122 gains up to 432 soundings (in high density mode) which can be increased to 862 in dual swath mode, when two signals are emitted into the water column simultaneously, with a difference in tilting angle: one slightly tilted forward and the second one backward. This enables a denser bottom coverage which allows for higher survey speeds (Kongsberg Maritime AS, 2011). The technical specifications of the EM122 system are listed in Table 5.1.1.

Table 5.1.1 EM122 technical specifications (Kongsberg Maritime AS, 2011)

Main operational frequency	12 kHz
Angular coverage sector	150°
Number of beams per swath	288
Number of soundings per swath	432 (864 in dual swath mode)
Beam width	0.5° x 1°
Depth range	20 – 11000 m

5.1.1.2 Multibeam data acquisition

Data acquisition was carried out throughout the entire cruise, starting on the 02.09.2022 at 10:45 pm outside the territorial waters of Iceland and ending on the 04.10.2022 07:45 am UTC at the territorial boundary of Canada, near St. John´s. Where possible, the cruise track was planned parallel to existing bathymetric data to optimize data coverage and the surveys were performed to extend already mapped regions. The multibeam surveys were generally carried out at 5 to 6 knots, whereas transit data were acquired at speeds up to 10 knots. During mapping, the fan opening angle was kept between 130° and 140°, resulting in a swath width of about 15 km in 3,500 m water depth. The Ping Mode was set to Auto, which enabled the system to use continuous wave pulses in shallow modes and frequency-modulated pulses in deep modes. Furthermore, high density and dual swath mode were continuously applied.

The Kongsberg SIS (Seafloor Information System) software was used for data acquisition. The software processes and logs the collected data, applies all corrections and defined filters, and ultimately displays the resulting depths on a map. Bathymetric and backscatter data were recorded in Kongsberg raw file *.all format and water column data were stored in *.wcd files.

5.1.1.3 Sound Velocity Profiles

In order to achieve best survey results, sound velocity profiles were updated every few days or whenever artefacts in the data became visible. The profiles were determined either using the onboard CTD (Conductivity, Temperature, Depth; see also chapter 5.3) or an AML sound velocity probe attached to the multicorer. Having reliable sound velocity profiles is essential, as the acoustic signal travels down the water column, from the transducer to the seafloor and back to the surface through several different layers of water masses, each with a different sound velocity. Sound velocity is influenced by density and compressibility, both depending on pressure, temperature and salinity. Wrong or outdated sound velocity profiles thus lead to refraction errors and reduced data quality for bathymetric maps.

Conducting a dedicated local sound velocity cast was several times not possible during transit and the WOA13 Atlas model was used. This is generated using the open-source software Sound Speed Manager developed by NOAA Coast Survey and UNH CCOM/JHC. All profiles were entered into the acquisition software Kongsberg SIS. In total nine CTD measurements, two AML profiles and eight WOA13 model profiles were used for sound velocity corrections during the expedition as shown in Figure 5.1.1 and 5.1.2

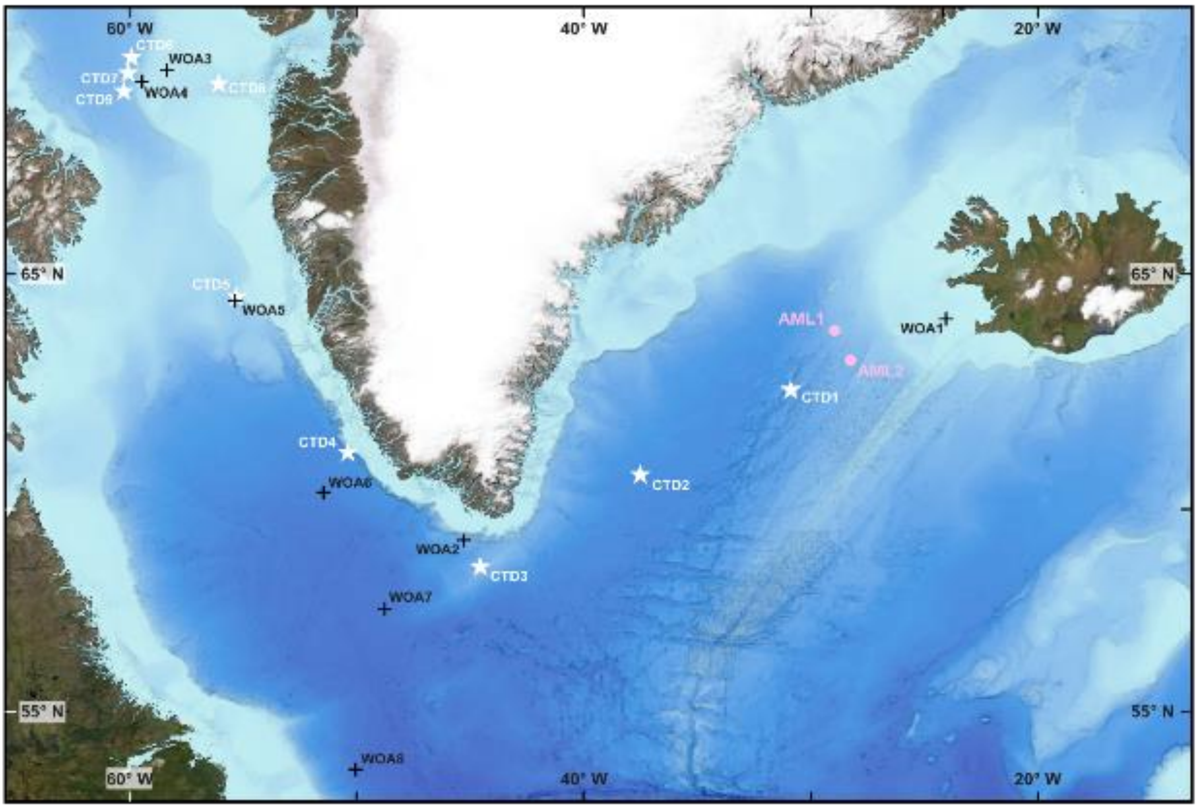

Fig. 5.1.1 Locations of all MSM111 sound velocity profiles, including CTD, AML and WOA13 Atlas data.

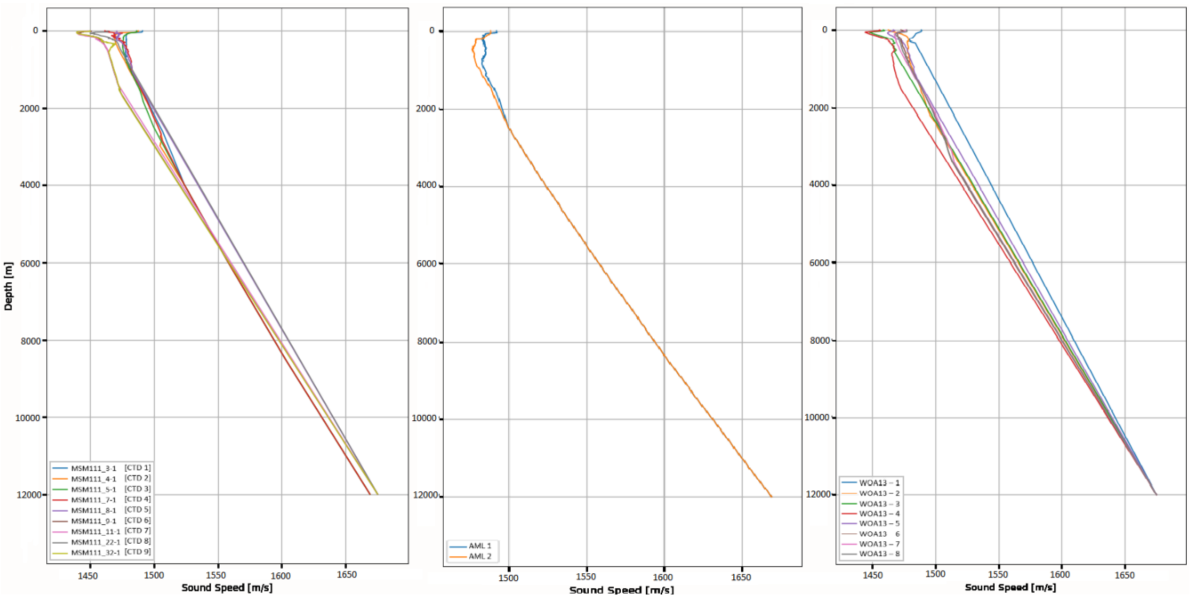

Figure 5.1.2: Sound Velocity profiles of CTD, AML and WOA13. All profiles are virtually extended to 12,000 m water depth for Kongsberg SIS to accept them.

5.1.1.4 Preliminary results

Throughout the MSM111 cruise, echo sounding data were continuously recorded, but only EM122 data were processed from designated surveys. During just over 33 days of recording, a track length of 4,020 nm (7,445 km) was surveyed. The raw data volume of the EM122 including water column data is 71 GB with 1114 separate files for *.all and 1058 *.wcd data type. The recorded water depths ranged between a minimum of 125 m as we approached St. John`s and a maximum of 3997 m in the Labrador Sea. A total of seven bathymetric surveys were conducted to extend our knowledge on seabed topography in the Baffin Bay and to use the resulting maps for station planning purposes, such as for MeBo operations and gravity core sampling. One additional survey was also completed in the Davis Strait to support a future IODP expedition. The maps in Figure 5.1.3 showcase the seven hydrographic surveys conducted. The maps generated from Survey area B (Fig. 5.2.3) were the basis for the MeBo site selection. The total area coverage of this region by the multibeam echosounder is 5,100 km². The water depths vary from 1796 m in the Baffin Basin, to 434 m at the top of the continental slope. The data revealed that the seafloor of eastern Baffin Bay is generally smooth, reminiscent of typical basin-fill sedimentation. Around the continental slope, subtle canyons provide evidence for concentrated down-slope processes. Series of grooves running parallel to the continental slope were observed at depth around 1000 m – these features have been previously interpreted as giant iceberg ploughmarks (Kuijpers et al., 2007).

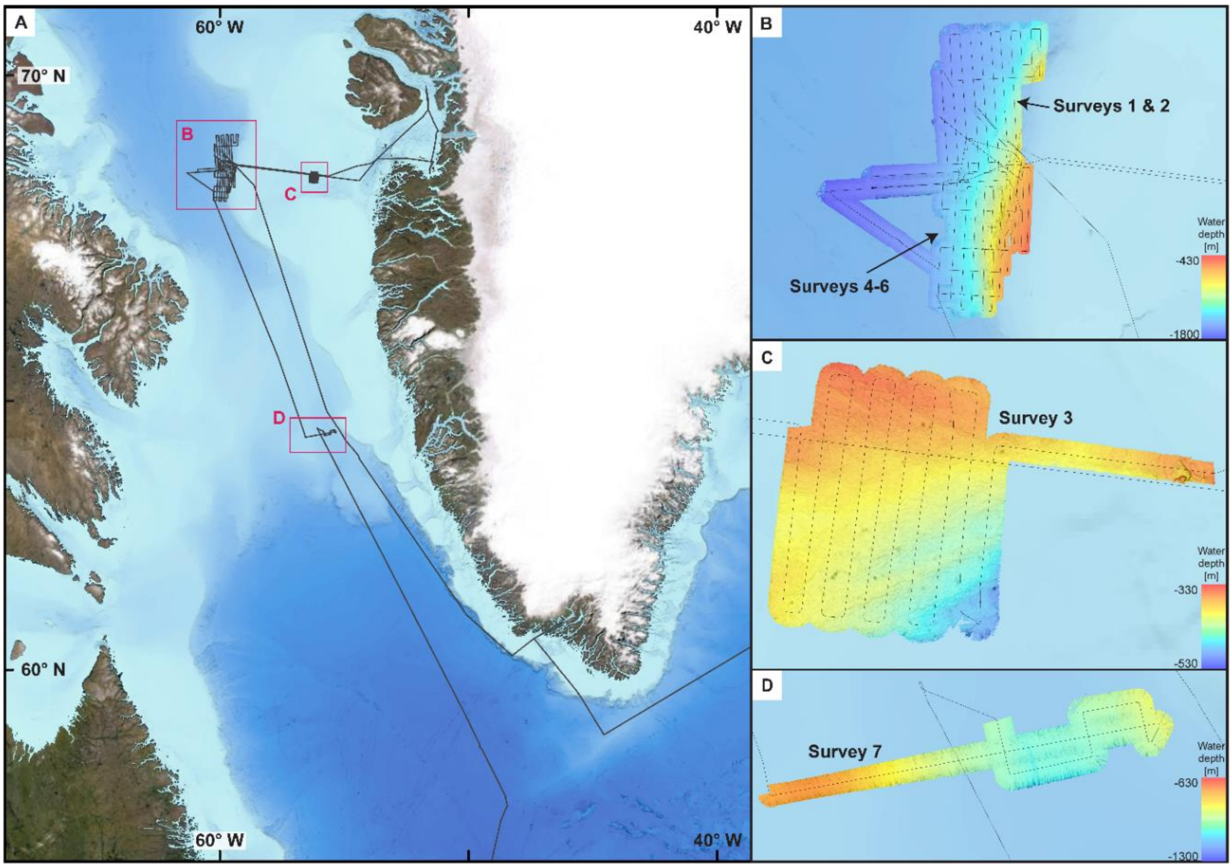

Fig. 5.1.3 Hydrographic surveys illustrating recorded depth values, crucial for MeBo200 and gravity core sampling

As the MeBo operations required maintenance time, a hydrographic survey (Fig. 5.1.3C) was conducted on the continental shelf, between Baffin Bay and Disko Bay. The area covered was 359 km² and took a total 12 hours to map with 40% overlap. The survey was planned adjacent to already existing bathymetry from the Disko Bay Trough and was intended to highlight the seafloor morphology in the shallower regions of the West Greenland continental shelf. It shows a gently dipping terrain from shallower regions with a minimum water depth of 332 m in the north to the flank of a deeper channel associated with Disko Bay Trough at a maximum depth of 527 m in the south. Numerous plough marks as well as pockmarks were observed, also during the transit across the shelf, and attest to the presence of large eroding icebergs and likely fluid flow from the subsurface.

The main purpose of Survey 07 (Fig. 5.1.3D) was the investigation of upper sediment layers using the Parasound system (Chapter 5.1.2) for a future IODP expedition. Simultaneously a bathymetric survey was also completed. The multibeam swath coverage area was 418.98 km². Minimum depth here was 631 m and the maximum depth recorded was 1277 m. The seafloor was observed to be smooth with no distinct morphological features. Interestingly, the area shoals further seawards, thus confirming an area of relatively shallow seafloor in central Baffin Bay, which can also be observed in the General Bathymetric Chart of the Oceans (Fig. 5.1.3A). Small circular features resemble pockmarks and thus hint at the escape of sub-bottom fluids. However, the data have not been processed and the comparably rough weather conditions throughout the survey resulted in numerous artefacts, so this interpretation remains tentative.

5.1.2 Parasound

Sediment echo sounders are used to gather information on the upper ~100 m of the subseafloor geology. Like all echo sounders they use the principle of acoustic wave propagation to identify differences in material properties, such as density and sound velocity, through which lithological changes can be identified in the sediment column. R/V *Maria S. Merian* is equipped with an ATLAS Parasound sediment echo sounder, which, compared to conventional echo sounders, offers an improved lateral and vertical resolution of sedimentary structures within the subsurface. The latter is due to the so-called parametric effect, the interaction between two simultaneously emitted sound waves of finite amplitude, which is caused through the non-linear relationship between density and pressure changes in the water column. Furthermore, when operated at a frequency of 4 kHz, the Parasound echo sounder has an opening angle of 4° compared to 20° for conventional echo sounders. As a result, the instrument interpolates across a footprint of only 7% of the water depth, which is a mere 20% of the area conventional echo sounders integrate over. Accordingly, the imaged data are more accurate and of better quality than those of other sediment echo sounders.

5.1.2.1 Methods

During research cruise MSM111, a total of nearly 900 nautical miles were surveyed using the Parasound system, ~800 of which at a vessel speed of 5 to 5.5 kn to obtain the best possible resolution of the subseafloor stratigraphy. In addition, the sediment echo sounder was running underway during most of the transit, amounting to 3100 nautical miles worth of data. The software programmes ATLAS Parastore and ATLAS Hydromap Control Center were used to determine the settings of the Parasound. During cruise MSM111, the Parasound echo sounder was mainly used with two different frequency signals: PHF (Primary High Frequency, set to 18 kHz) and SLF (Secondary Low Frequency, set to 4 kHz). The PHF signal was recorded in order to resolve the water column to check for flares as indication for gas bubbles and active gas seepage. Conversely, the SLF signal is optimal for resolving the sedimentary characteristics in the sub-bottom at the seafloor, which can be used on the fly for the identification of suitable locations for MeBo and gravity cores, as well as for gathering information on the seafloor stratigraphy. Because the successful deployment of the MeBo as well as the recovery of some gravity cores was the main objective of research cruise MSM111, resolution of the SLF signal was given priority over the PHF signal. Accordingly, the Parasound echo sounder was set to operate in Quasi-Equidistant Transmission mode, which yields better results for the imaging of the subseafloor due to better distribution of more frequent sound impulses in the water column. Throughout the cruise, the data, while being recorded, were displayed in two separate echogram windows using the Atlas Parastore software, where settings can be modified both for the display of the PHF and for the SLF signals. The window length was usually kept at 200 m for both, and the water depth adjusted when appropriate. Tracking of the signal within the window was done manually during most of the surveys, as the resulting data are of superior quality. However, due to lower priority of the data in some cases, the window depth was set to automatic tracking based on the water depth given by the Multibeam systems. This was particularly the case during transits to and from the different research areas as well as for Survey03 on the continental shelf outside of Disko Bay (Fig. 5.1.4).

During cruise MSM111, a total of ~500 GB of Parasound raw data were recorded. Data storage occurred as raw .asd files, which can be replayed in the Parastore software, and pre-processed .ps3 and .sgy files. Due to their superior quality only .ps3 files were used and converted into UTM-corrected envelope .sgy files using the software tool PS32SGY. The resulting output files were imported into SMT The Kingdom Suite v. 2020 for visualisation and on-the-fly interpretation. An overview of the surveys carried out during MSM111 is given in Figure 5.1.4.

5.1.2.2 Preliminary Results

In almost all investigated areas the seafloor was characterised by a very smooth appearance and good penetration, leading to the resolution of the uppermost ~40 m. At some sites penetration even reached beyond 75 m (≈ 100 ms; Fig. 5.1.5). This was especially the case along profiles recorded in Canadian waters on the outer Disko Bay Fan. Here, the acoustic character of the seafloor is defined by smooth, perfectly stratified reflections, imparted by the regular changes between light and dark sediment bodies. The associated acoustic reflectors are continuous over long distances and are characterised by homogenous amplitudes. As the principle of a sediment echo sounder is based on changes in acoustic impedance (density * p-wave velocity), the alternations of reflectors is likely due to regular changes between the deposition of softer, more water-rich sediments, such as hemipelagic muds, and relatively “harder”, more compact and/or water-deprived sediments, such as sands or ice-rafted debris.

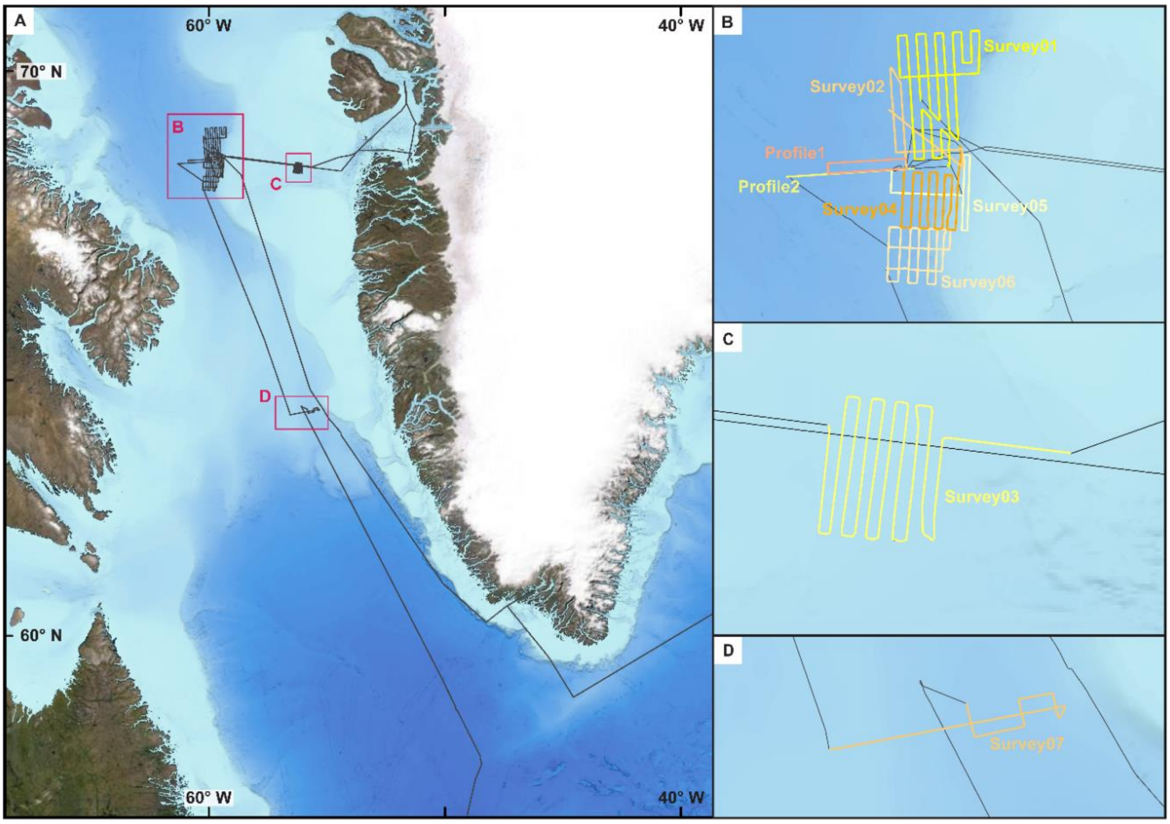

Fig. 5.1.4 Parasound surveys conducted during research cruise MSM111. A) Cruise track north of ~55° N with location of surveyed areas. B) A total of five surveys and two profiles were used to identify suitable coring locations on the outer Disko Fan. C) Survey03 conducted on the continental shelf north of Disko Bay Trough at 10 kn to achieve larger area coverage. D) Survey07 in the Davis Strait as preparation for an upcoming IODP Expedition.

The origin of the sediments in Baffin Bay can only be confirmed once the cores will be opened and analysed. Nevertheless, it can be concluded from the extent and shape of the sedimentary units that the sedimentation on most of the Disko Fan seems to have been uniform both temporally (at least over defined time intervals) and spatially, likely resulting from regional rather than local changes in depositional environments. Underneath the upper stratified unit, recorded only in placed where acoustic focussing facilitated Parasound penetration for more than ~50 m, discordant layering of a second thick package of sediments indicates a regional change in sedimentation regime, tentatively interpreted as an unconformity (Figs. 5.1.5, 5.1.6). Local cut-off of specific reflectors supports this interpretation (Fig. 5.1.5). Stratified and largely (sub-)horizontal reflections throughout most of the study areas likely represent generally calm and low-energy depositional environments as typical for basin sedimentation; however, local lenticular bodies of acoustically semi-transparent and internally massive sediments attest to the occurrence of some mass-transport activity (Fig. 5.1.6). On the continental shelf and slope, sediment cover is thin to absent and often acoustically opaque, giving expression of a harder substrate and steeper inclination. A thin sediment cover on the continental shelf is expected for this region, where an expansive Greenland Ice Sheet likely eroded most sediments deposited prior to the Last Glacial Maximum.

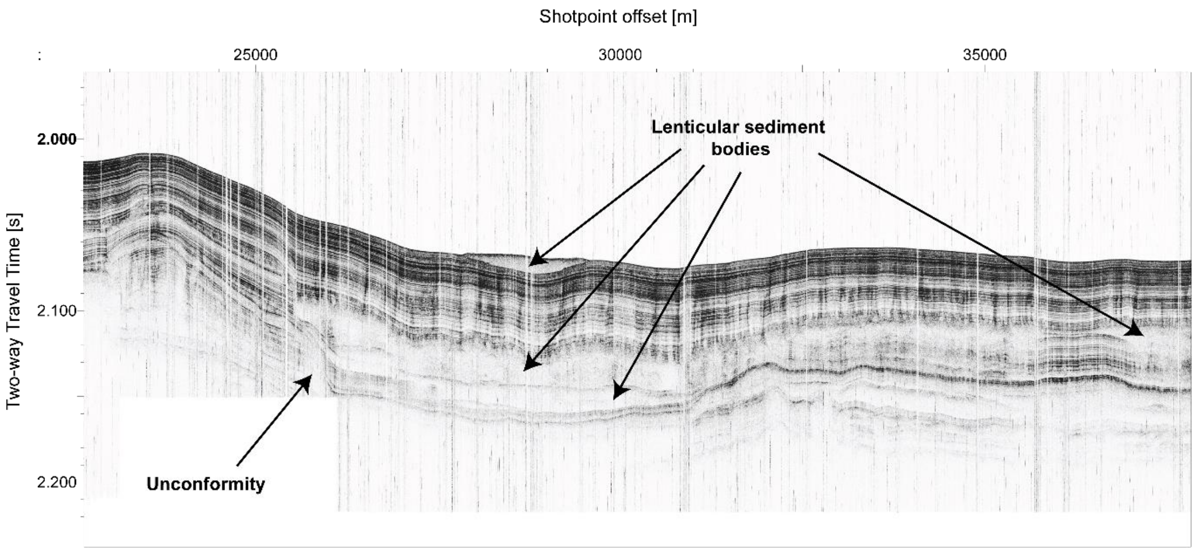

Fig. 5.1.5 Example of the sedimentary subsurface in Baffin Bay. The profile (Survey02) runs from NW (left) to SE (right) and clearly shows the stratified nature of the basin sediments beyond the continental slope. For location of the profile, see Fig. 5.2.1. Note the top sedimentary package, characterised by continuous, opaque reflections above a lower sedimentary package implied by discontinuous reflections of overall weak amplitude.

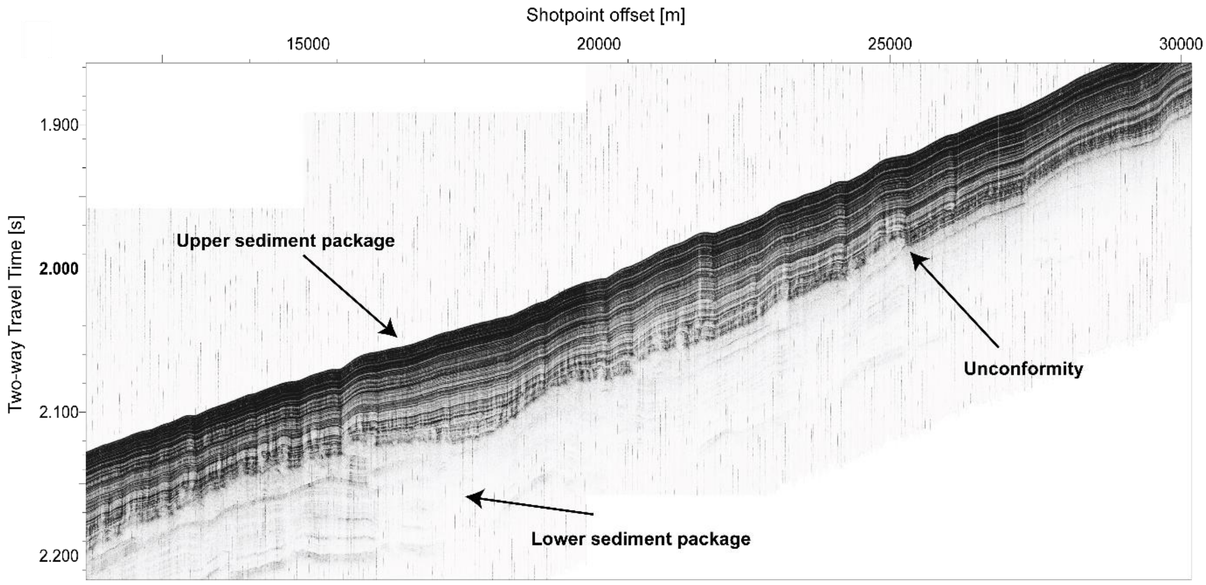

Fig. 5.1.6 Example of lenticular bodies of acoustically transparent, internally massive character, interpreted as mass-flow deposits. The Parasound profile (Survey01) runs from S (left) to N (right). Note the discontinuous nature of reflectors in the subsurface on the left-hand-side (labelled unconformity).

5.2 Hydrography

(Michael Siccha)

5.2.1 On-board CTD with water sampling rosette

The on-board Seabird Electronics (SBE) 911 plus CTD (Conductivity-Temperature-Depth) probe was deployed at nine stations to obtain measurements of temperature, salinity, chlorophyll a and dissolved oxygen in the water column (Fig. 5.2.1). Sound velocity profiles were used for parametrisation of the Kongsberg EM122 during the cruise. At all deployments, the CTD was lowered to a depth of around 10 m above the seafloor. The CTD was equipped with an altimeter, a single fluorescence [WET Labs ECO-AFL/FL, S/N 1755] and redundant oxygen sensors [SBE 43, S/N 0881, S/N 0951] next to its standard configuration of pressure [S/N 0807] and redundant temperature [S/N 4459, S/N 4450] and conductivity [S/N 2939, 2935] sensors. The CTD probe was mounted vertically in the frame of a SBE water sampler rosette with 24 10-L Niskin bottles. All data will be made available on PANGAEA.

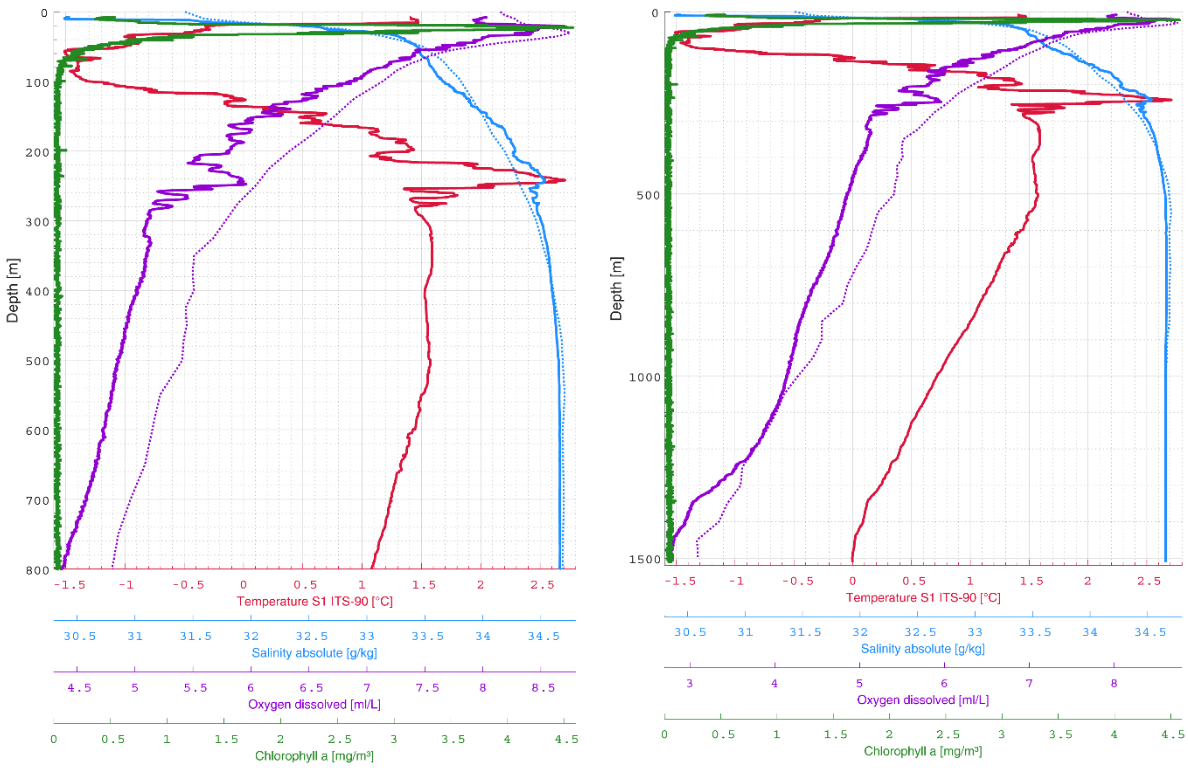

Fig. 5.2.1 Exemplary plot of the CTD data of the northernmost station GeoB25209-1 down to 800 m (left), and full cast depth 1520 m (right). A pronounced chlorophyll maximum centred at 22 m lies below the fresh and warm (30.5 S and 1.5 T) surface water layer, and the cold Arctic water (33.5 S and -1.5 T) is found between 50 and 100 m depth. With increasing depth, it gradually and dynamically mixes with the inflowing warm Atlantic water centred in this cast at 240 m with 2.5 T and 34.5 S. The remaining part of the water column is filled with the Baffin Bay deep water, with an almost constant S of 34.66 and from about 500 m depth monotonically decreasing T down to 0 T at the very bottom.

5.2.1.1 Plankton-sampler-mounted CTD unit

A CTD M90 (Sea and Sun Technologies, Trappenkamp, S/N CTM 979) was mounted on the multi-plankton-sampler (MPS) during all deployments. The instrument measured pressure, temperature, salinity, chlorophyll-a concentration and photosynthetic active radiation at pressure difference intervals of 0.2 decibar. The unit was operating during each MPS deployment, resulting in the recovery of 15 CTD profiles of the upper water column at eight stations.

5.2.2 Argo Float

The Bundesamt für Seeschifffahrt und Hydrographie (BSH) provided the cruise with a single ARGO float (PROVOR CTS4, nke instrumentation, S/N P43244-22DE001) that was to be deployed in the Labrador Sea. It was deployed on 01.10.22 at 9:44 am UTC at 58° 26.38' N, 49° 33.62' W. Measurement parameters were programmed by BSH.

5.3 Water sampling

(Hartmut Schulz)

5.3.1 CTD and multinet plankton filtration

A total of 58 filtrates of 0.3 – 2.0 litres of sea water each were collected at 11 stations (Fig. 5.3.1). For samples taken from CTD rosette, the exact depth intervals were guided by the position of the local subsurface chlorophyll a maximum derived from the CTD profile. Seawater was sampled from below, within the centre, and above the ChlA-peak. Further samples were taken from the bottom layer, as deep as the CTD could be lowered to the seafloor, and at positions of distinct changes in the mid-depth water column. For all samples, salinity (PSU), density (kg/m3), temperature (°C), oxygen (ml/L) and ChlA (µg/L) values were recorded. For samples taken from the 1,7 L-bottles attached to the Multinet, sampling depths were fixed to 500-300, 300-200, 200-100 m, or at 100-80, 80-60, 60-40, 40-20 and 20-0 m. The filtration used Sartorius Polycarbonate Track-Etch membrane filters (47 mm diameter) of 0.22 µm pore size. The filters from the chlorophyll maximum had a faint yellowish colour. The filters will be analysed for phytoplankton composition and abundance with an SEM at the University of Tübingen.

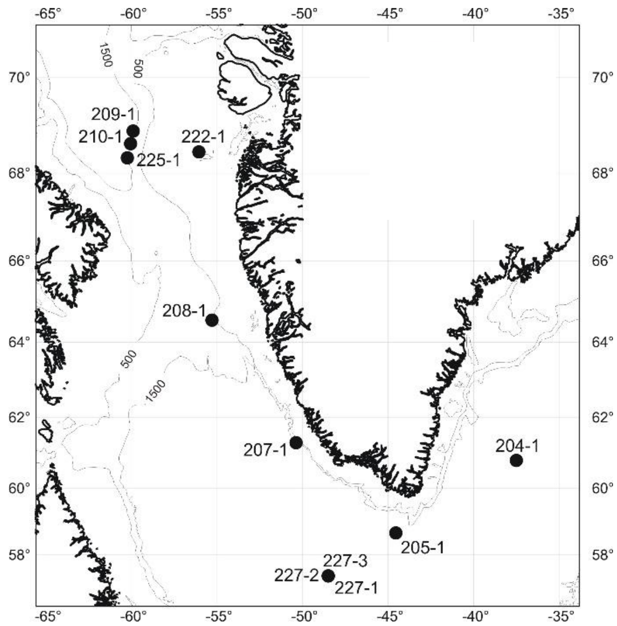

Fig. 5.3.1 MSM111 sampling station for plankton filtrations.

5.4 Plankton sampling and foraminifera cultivation

(Julie Meilland, Raphaël Morard, Michael Siccha, Anjuly Janßen, Johan C. Faust)

5.4.1 Multi-Plankton-Sampler sampling

During the transit to and from drilling area, plankton tow casts were performed at eight stations (Fig. 5.4.1) to collect planktonic foraminifera for culturing experiment and molecular genetic studies. A Hydrobios Multi Plankton Sampler (MPS) Midi was used with an inlet size of 50×50 cm and five individual net bags with a mesh size of 100 µm (Fig. 5.4.2). Slacking and hoisting was done with a rope speed of 0.5 m/s. After each net haul, the net bags were carefully rinsed from outside with sea water from the ship's pump and the cup's mesh cloth was washed and rinsed with filtered sea water. Opening and closing depths of each net were determined from the pressure readings from the pressure sensor of the device and controlled using a custom software script. The software simultaneously recorded parameter readings from the MPS, like opening/closing depth, activation time and sampled volume, as well as selected parameters from the DSHIP, such as

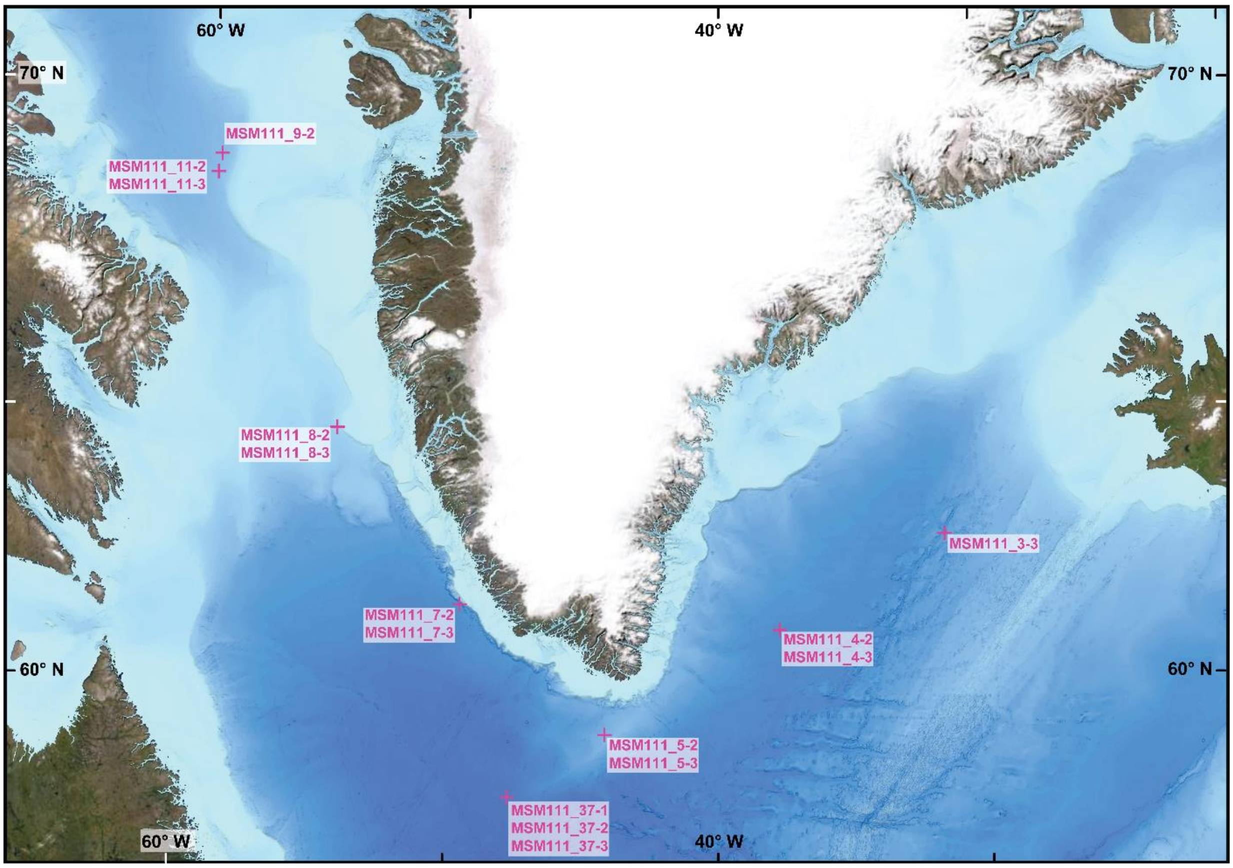

Fig. 5.4.1 All multiple plankton sampler deployments during MSM111, highlighting repeated deployments at the same station, use to obtain material both for culturing experiments and plankton filtration for environmental genomics.

position, wind speed, rope length and rope speed.

The standard sampling plan consisted of two hauls at the same station, with sampling depth intervals of 100 – 80 – 60 – 40 – 20 – 0 m, except for the station GeoB25209 and GeoB25227, where the MPS was deployed to 200 m to specifically target depth intervals for material for culture experiments based on the readings of the CTD and then to 700 m for deeper assemblages. At the station GeoB25209 only a single cast was done because of the weather conditions, making it difficult to deploy and recover the device. A CTD M90 (Sea and Sun Technologies, Trappenkamp, Germany, S/N CTD979) was mounted on the MPS during all deployments and recorded water column properties simultaneously during each cast. Samples obtained from the first haul were used to select specimens for culturing and foraminifera genomics and the samples form the second haul filtered for environmental metabarcoding.

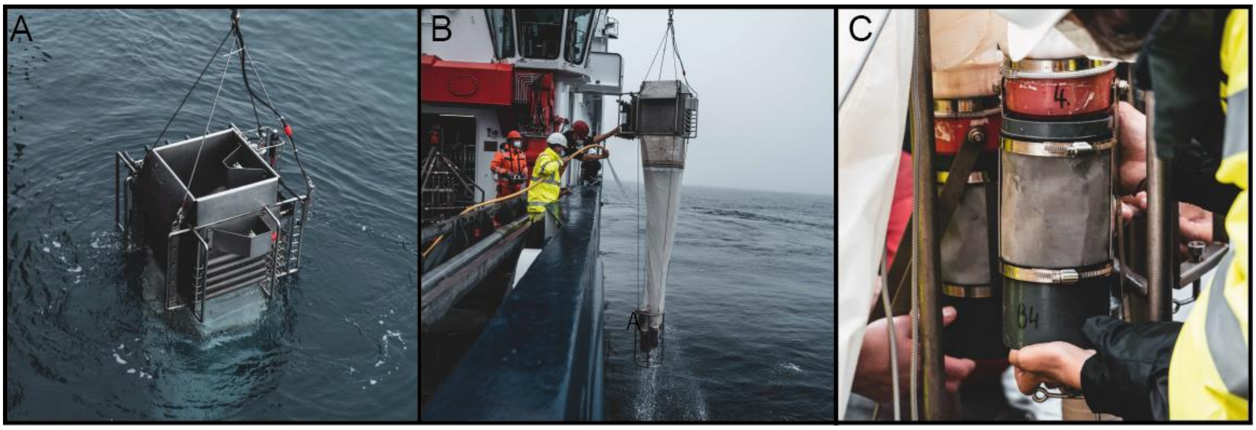

Fig. 5.4.2 A) MPS during hoisting with the upper par outside the water and the net bags and cod ends still I mmerged. B) Rinsing of the nets with pumped sea water to ensure that all plankton particles are collected into the cod ends. C) Cod ends removed from the MPS for sample processing. Photos by *R. Morard*.

5.4.2 Foraminifera culturing

From station GeoB25204 to GeoB25210, specimens of *Neogloboquadrina pachyderma* were picked and placed in culture for asexual reproduction. In station GeoB25204, GeoB25205, GeoB25207 and GeoB25208, in which the surface and subsurface water remained warmer than 8°C, and the target species was rare, specimens for culturing were picked randomly, selected only by the presence of well-developed cytoplasm. At stations GeoB25209 and GeoB25210, where the temperature dropped (below 0°C in the subsurface), *Neogloboquadrina pachyderma* was the only species present, in very large number, allowing for the selection of specimens to be cultivated based on specific criteria (thin shell, bright red cytoplasm, large and round chamber) suspected to characterize specimens reproducing asexually. After their recovery, all specimens were gently rinsed in filtered (0.2 µm) seawater and placed individually in a well of 6-well culture plates. They were kept in filtered seawater in a cold room at 6.5°C with constant light and fed with diatoms cultivated onboard (*Chaetoceros debilis*). All specimens were monitored daily to record their feeding behaviour, rhizopodial activity, and growth (chamber addition, encrustation).

From September 12th to October 1st, asexual reproductive events were observed daily with offspring spawned by a total of 29 *Neogloboquadrina pachyderma* specimens. Once observed, each event was documented, and the offspring was placed in a culture jar of 75 mL filled with filtered seawater. The offspring were fed with four different strains of live diatoms to identify the best-suited one for them and their growth was monitored every other day. By the end of the cruise (October 4th) some offspring had calcified up to 10 chambers in culture and most appeared healthy. All specimens were prepared to be transported to MARUM, Bremen, to establish a perennial culture.

5.4.3 Foraminifera sampling for shotgun sequencing

After selection of foraminifera for culturing, the remaining part of the samples was used to collect large amounts of single specimens to attempt sequencing of their genome. This requires a molecular weight of DNA that cannot be attained with single specimens. Specimens from single species were selected from several depths, individually cleaned with a brush and transferred into a Petri dish with filtered sea water (Fig 5.4.3). Subsequently, the selected specimens were transferred into 1.5 mL Eppendorf tubes, the overlying water was removed using a pipetted and absolute ethanol added to conserve the genetic material. The sealed tubes were stored at -20°C. In total, 7 pools of foraminifera for genome sequencing were collected, 1 for *Globigerinita uvula*, 1 for *Globigerina bulloides*, 1 for *Turborotalita quinqueloba* and 4 for *Neogloboquadrina pachyderma.*

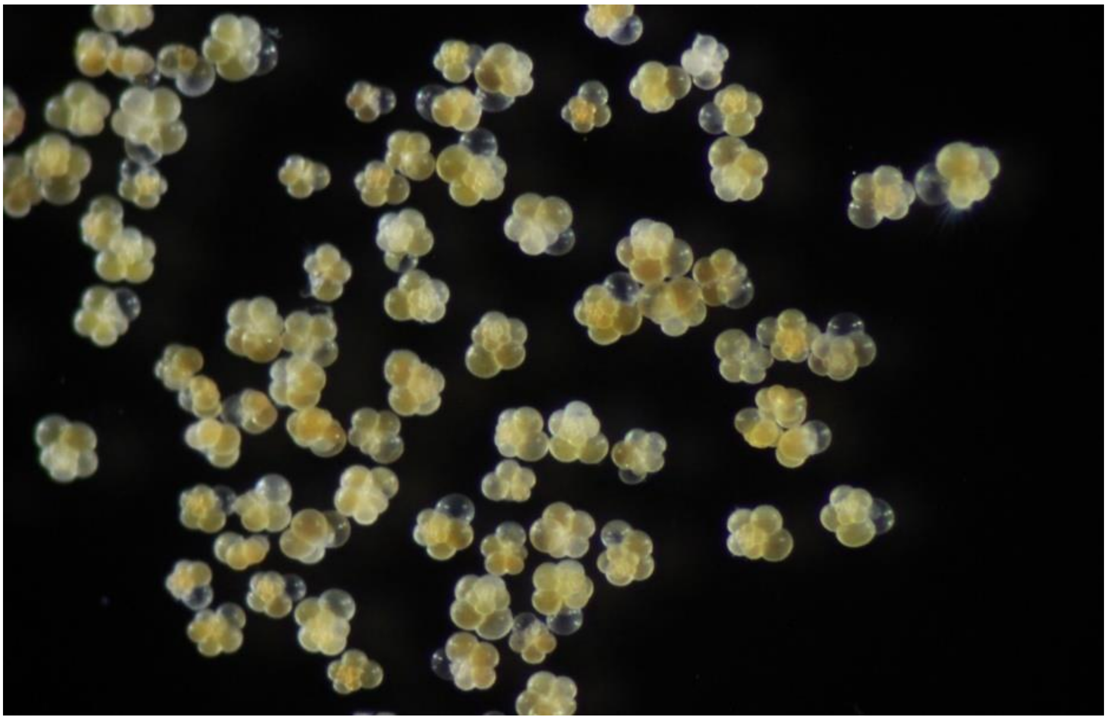

Fig. 5.4.3 Microscope picture of specimens of the species *Turborotalita quinqueloba* selected for genome sequencing.

5.4.4 Plankton filtration for environmental genomics

The filtration system consisted in 3 funnels of 500 mL mounted in series on a filtration ramp and connected to a pump and a vacuum bottle (Figure 5.4.4). Before each collection, every part of the filtration system in contact with the sample were washed using 70% ethanol, 5% bleach and MilliQ water to eliminate potential contaminants. After cleaning, cellulose filtration membranes of 47 mm and 0.2 µm mesh size were placed on the gasket using sterile tweezers and the funnel was screwed on top of it. To obtain samples for filtration, after the dedicated plankton net haul, the cod-ends were recovered and transferred into the chemistry lab. The content of the cod-ends was transfer into a 1 L beaker through a 2 mm sieve to remove large zooplankton particles from the sample (Figure 5.4.4). The mesh of the cod-end was rinsed carefully using a squeezing and spray bottle until all particles were removed and transferred to the beaker. The cod-ends were later cleaned further by ultrasound. The samples were transferred into the funnel (Figure 5.4.4) and the beaker rinsed with filtered seawater to ensure than no planktonic particles remained in the beaker. After the three first samples were ready, the pump was switched on and the samples filtrated through the membrane. After all the seawater was filtered, the inner part of the funnel was rinsed with filtered seawater (0.2 µm) to make sure that no particle stayed attached to it. After that the

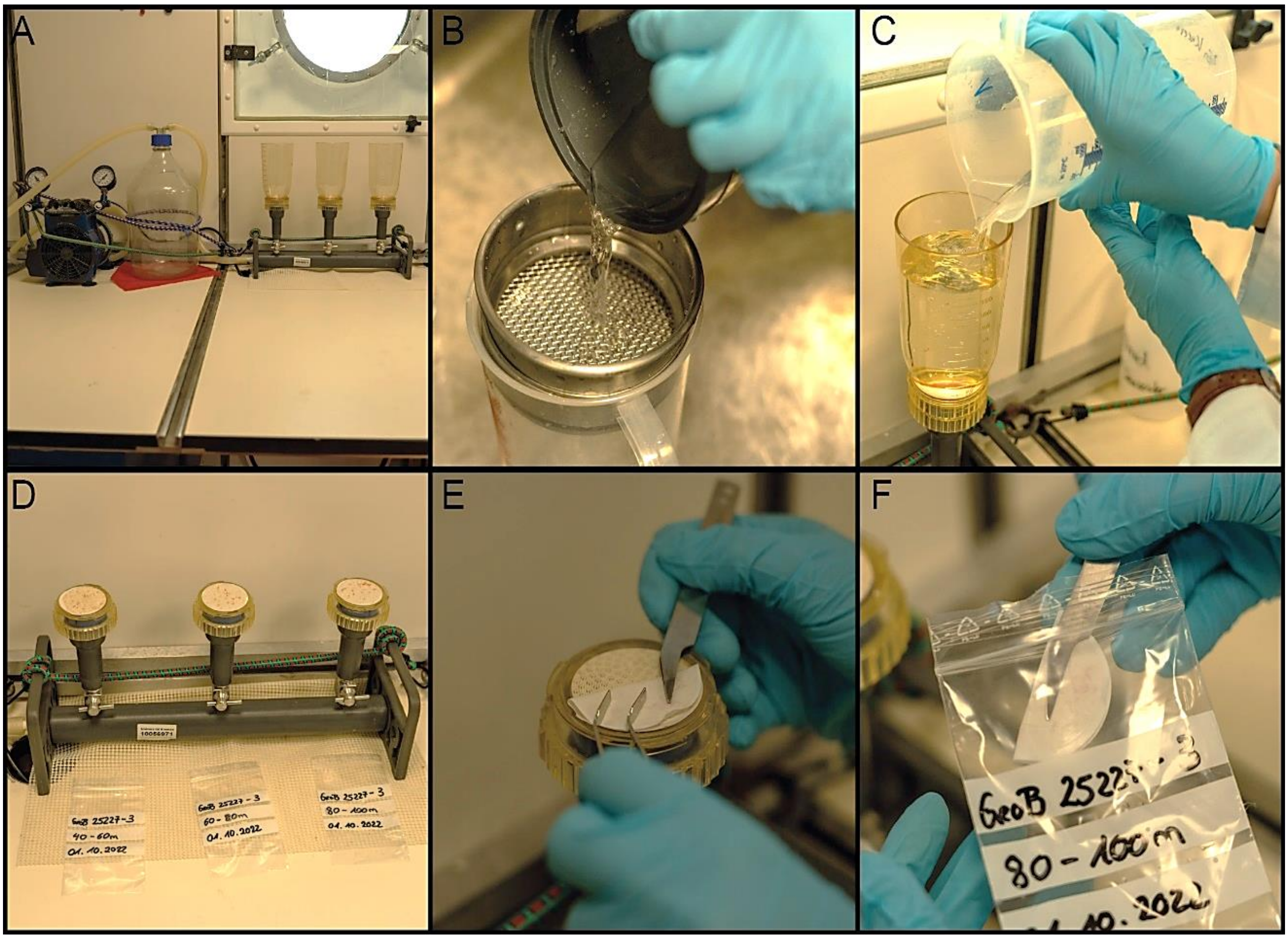

Fig. 5.4.4 Workflow of the filtration for environmental genomics. (A) Filtration rack (B) transferring plankton net cod-end content into a beaker (C) and then for filtration (D) plankton concentrated on the filters (E) folding of a filter (F) storing of the sample before freezing. Photos*: R. Morard*

pump was switched off and the funnels unscrewed (Figure 5.4.4). The filters were removed and folded (Figure 5.4.4) and placed individually into pre labelled sampling bags (Figure 5.4.4). After the three first sample were processed, the filtration system was cleaned, and the two remaining samples were processed following the same procedure. In the case of rich samples, usually from the uppermost layer of the water column, the entire sample could not be processed with a single filter because of material clogging the membrane. In such case, the pump was switched on and then the sample was poured progressively on the filter until it started to be clogged. The pouring was then interrupted, and the filter exchanged. The operation was repeated until the whole sample was processed. For 24 samples, only a single filter was needed and for 11 samples 2 to 6 filters per sample had to be used. Once the last sample was filtered, all the pre-labelled bags were gathered and frozen at -20°C. The entire process always took less than an hour between the recovery of the sample and freezing. A total of 35 samples from 7 stations have been filtered during the cruise (Table 5.4.4).

Table 5.4.4 Sample list of filtered water samples for metabarcoding

Station	Sample Depth (cm)	Station	Sample Depth (cm)
GeoB25203-3	0-20	GeoB25208-3	0-20
GeoB25203-3	20-40	GeoB25208-3	20-40
GeoB25203-3	40-60	GeoB25208-3	40-60
GeoB25203-3	60-80	GeoB25208-3	60-80
GeoB25203-3	80-100	GeoB25208-3	80-100
GeoB25204-3	0-20	GeoB25210-3	0-20
GeoB25204-3	20-40	GeoB25210-3	20-40
GeoB25204-3	40-60	GeoB25210-3	40-60
GeoB25204-3	60-80	GeoB25210-3	60-80
GeoB25204-3	80-100	GeoB25210-3	80-100
GeoB25205-3	0-20	GeoB25227-3	0-20
GeoB25205-3	20-40	GeoB25227-3	20-40
GeoB25205-3	40-60	GeoB25227-3	40-60
GeoB25205-3	60-80	GeoB25227-3	60-80
GeoB25205-3	80-100	GeoB25227-3	80-100
GeoB25207-3	0-20		
GeoB25207-3	20-40		
GeoB25207-3	40-60		
GeoB25207-3	60-80		
GeoB25207-3	80-100		

5.5 Sediment Sampling

5.5.1 Multicorer: Handling and Sampling

(Hartmut Schulz, Henrieka Detlef, Anjuly Janßen, Anne de Vernal, Julie Meilland, Raphaël Morard, Johan C. Faust)

Short sediment cores were taken at eleven stations using a Multicorer (MUC; Fig. 5.5.1). Prior to deployment at each station, the MUC was fitted with eight large (⌀ 9.6 cm) and four smaller coring tubes (⌀ 6.2 cm). At each deployment location, one intact core was required for pore water sampling and six intact cores were required for sediment sampling. As we successfully recovered at least seven intact cores at each deployment, none of the deployments had to be replicated. Following deployment, the MUC was lowered onto the deck, in some cases preceded by manual closing of the bottom shutters (usually without significant loss of sediment). Individual tubes were removed from the MUC by 2-4 scientific team members and transferred into a rack, labelled, and carried into the ship's hangar for further processing. Once MUC cores were transferred into the ship's hangar, apart from cores assigned for pore water sampling, remaining bottom water was decanted from the tubes using a plastic hose.

The multicorer generally recovered up to ~50 cm light grey to reddish-brown, clayey to silty sediment, with variable amounts of gravel with irregular shape and a diameter of up to a few centimetres, likely dropstones, of magmatic or metamorphic origin. Some light-coloured, small calcitic rock fragments were also observed. Multicores GeoB25201-2 and GeoB25202-2 from the upper western slope of the Reykjanes Ridge SW off Iceland contained a significant amount of small basaltic rocks. Remarkable was the recovery of a distinctly reddish-brown (Munsell HUE YR7.5 6/6, yellowish-red dark brown), dm-thick top layer found at station GeoB25212-1.

For all sediment sampling procedures core tubes were transferred onto a core extruder, carefully removing the bottom rubber bung to avoid sediment loss. The sediment content of the core was manually pushed up and extruded until the surface layer was at the level of the sampling tube and then sampled for different purposes.

Fig. 5.5.1 Multicorer arriving back on deck. Photos: *Volker Diekamp.*

aDNA: Depending on the coring success either one small or one large core at each station was used for sedimentary DNA sampling. The surface sediment was sampled with a sterile spatula and isolated into 1.5 mL vials in five replicates. After the surface layer was sampled, the core was gently extruded, and the first two centimetres were transferred into a sampling bag. The core was further extruded for another 2 cm and a metal spatula was inserted at the base of the extruded part, the sediment was lifted and flipped to expose the inner part of the core without touching it (Fig. 5.5.2). Sediment samples were taken form in the inner part of each core using sterile metal spatulas and stored in 1.5 mL vials in three replicates. The extruded sediment was recovered into a sampling bag. The same procedure was repeated in two-centimetre intervals until the end of the core. Sediment samples were stored at -20°C.

Benthic foraminifera: At every MUC station, one core with a diameter of 9.6 cm was sampled to study the benthic foraminifera assemblage. The core was extruded in 0.5 cm intervals for the top 5 cm and at 1 cm intervals for the remaining portion of the core. Samples were taken using two metal spatulas cleaned with freshwater between sampling and transferred to sterile Whirlpak bags. Samples were immediately frozen onboard and stored at -20°C. The top 5 cm of each core was shipped frozen from St John's to the MARUM, while the remaining samples was shipped in a cooling container at 4°C.

Age determination and anthropogenic pollutants: One 9.6 cm diameter core was sampled at every MUC station to be used for dating of the marine sediments using various techniques (e.g. ^{210}Pb) and to study the evolution of anthropogenic pollutants in Arctic marine sediments. Persistent organic pollutants include, for example, compounds previously used as insecticides, polychlorinated biphenyls, and polybrominated diphenyl ethers. For this purpose, all cores were extruded in 0.5 cm intervals at the top 5 cm of each core followed by 1 cm interval for the remaining sediment column. One core at station GeoB25216 was only sampled for the top 10 cm of the core at 0.5 cm resolution. Samples were taken using two metal spatulas (Fig. 5.5.3) cleaned with freshwater between samples and transferred to sterile Whirlpak bags. Subsequently the samples were frozen onboard at -20°C to be shipped frozen from St John's to MARUM.

Fig. 5.5.3 Sampling a MUC using metal spatulas. Photo: *Raphael Morard*.

Inorganic geochemistry and palynology: At each station, two sediment cores were sliced in 1 cm intervals. One for inorganic geochemistry analysis and the other one for palynology investigations. Samples were taken with Perspex plates and transferred into plastic bags. Geochemical samples were stored at -20°C and palynology samples at 4°C.

Organic geochemistry: Organic geochemistry samples were taken with stainless steel plates wearing nitrile gloves to avoid contamination. Samples were taken in 1 cm intervals. At stations where the MUC deployment was followed by a gravity core, the first 5 cm were stored in pre-labelled glass snap top vials covered with aluminium foil. Remaining samples from the rest of the core were transferred into glass petri dishes and wrapped into aluminium foil. At MUC stations only, the remaining core was frozen (-20°C) and pushed out of the core tube, wrapped in aluminium foil and transferred into a plastic bag. All samples for organic geochemistry were stored at -20°C.

Sediment pore water: For pore water sampling, a pre-drilled core tube was transferred into the sink in the ship´s hangar and fixed with bungee cords. Pore water samples were taken with Rhizone samplers attached to 10 mL plastic syringes with wooden spacers to generate under pressure. At the appropriate depths, the cover (tape) of the pre-drilled holes was perforated using a pipette tip, and Rhizones were inserted quickly and carefully. If Rhizones could not be inserted into certain sediment horizons without force (due to the occurrence of rocks), these intervals were not sampled. The pore water sampling order was as follows: Bottom water samples were extracted first (10 mL). Once sufficient bottom water had been sampled, the remaining overlying water was drained by perforating the holes right above the sediment-water interface. Rhizones were inserted in 1 cm intervals down to 10 cm and further in 2 cm intervals down to 20 cm and in 5 cm intervals until the end of the core. Rhizones were left in the core tubes for up to ~2 hours, depending on the efficiency of pore water extraction (very fast in the top layers, much slower in deeper layers). The pore water extracted was split, 4 ml for cation analysis and 6 ml for dissolved carbon analysis. Samples for cation analysis were acidified with nitric acid and stored at 4°C. Samples for dissolved carbon analysis were flash-frozen untreated at -80°C, then transferred to -20°C for transport and storage after the cruise. Equivalent splits were also taken from bottom water samples and treated and stored in the same way as for pore waters.

Although the multicore functioned reliably and all deployments were successful, we observed that the MUC-frame was slightly bent. When standing on deck, one of the six legs did not touch the deck. Therefore, the "coring-head" was not centred in the frame and one to three arms did frequently not close as they hit the frame when the MUC was lifted from the seafloor. During the first deployment, one large tube was lost. During deployment at station GeoB25216-1 (Disko Bay), the EM101 depth profiler falsely indicated a water depth of over 600 m, whereas the true depth was only ~300 m. Therefore, more than 300 m of extra cable length had been released, laying at the seafloor. During the heave, the slack cable likely interfered with the multicore and possibly dragged it on the sea floor for some time. As a result, two arms of the MUC had been damaged, as they had lost the lower lids and their fixations. The lids could be replaced.

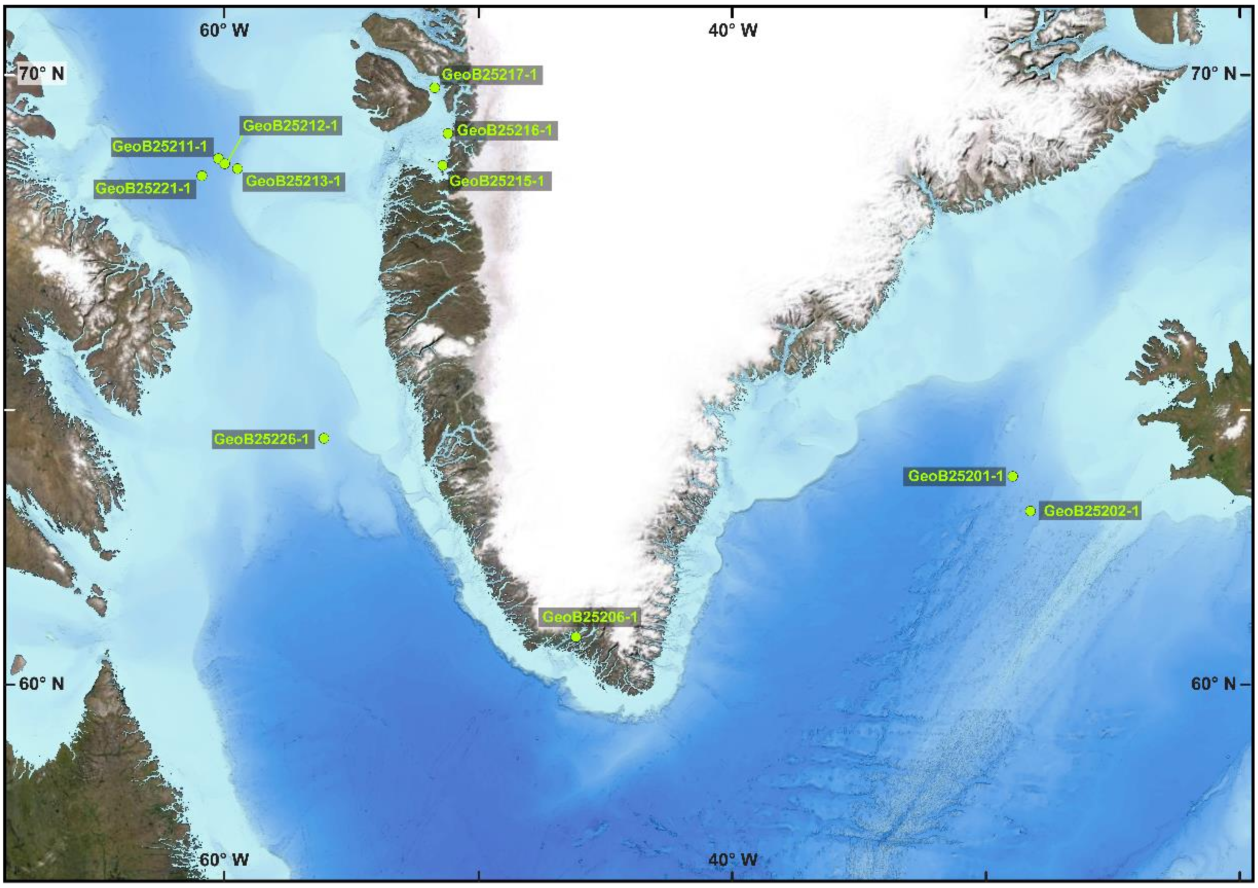

Fig. 5.5.4 MUC sampling locations of the MSM111 expedition.

5.5.2 Gravity Corer: Handling and Sampling

(Hartmut Schulz, Michael Siccha, Michal Kučera, Henrieka Detlef, Johan C. Faust, Volker Diekamp, Anjuly Janßen)

Sedimentary records of late Quaternary paleoenvironmental conditions and of sediment properties in the upper part of the sediment sequence in the Disko Fan were recovered using a gravity corer. The coring locations either followed pre-determined coordinates based on earlier surveys (off Iceland, in Narsaq Sound and in Davis Strait), or their positions were selected during the cruise by evaluation of Parasound profiles. The gravity corer had two tons of head weight and was used in two versions, depending on the sea floor condition and expected recovery. The corer consisted either of two (GC12) or three (GC18) 575 cm-long core barrels with 500 cm-long inner plastic liner segments (diameter of 125x2,5 mm), allowing us to obtain 11,5 m- or 17,25 m-long sediment cores. The entire device was rigged up on deck and was deployed using an outboard cradle (Kernabsatzgestell). After setting out, the gravity core was lowered to the sea floor at 1.0 m/s. Some 100 m to 150 m above the seafloor, the winch was stopped. Recorded tension was between 25,5 kN at 500 m and 34,3 kN at 1650 m. After equilibration of a few minutes, the GC was lowered with a speed between 1.3 and 1.5 m/s until it hit the seafloor, as recorded by lowered rope tension. Upon successful recovery, core liners were removed from the steel tube and the core liner was cut from bottom to top into 1 m sections (Fig. 5.5.5). Core sections were labelled, capped and sealed with tape and transferred to the Multi-Sensor Core Logging (MSCL) system. The cores were then

Fig. 5.5.5 Left: 18 m long gravity corer gets a wash after it arrived on deck. Right: After core liners were removed from the steel tube, they were cut into 1 m sections. Photo: *Johan C. Faust*

stored at 4°C after the MSCL measurement; none of the cores was opened on board. Altogether twelve gravity cores were taken during MSM111, position and sediment recovery are listed in table 5.5.5.

Table 5.5.5 List of gravity cores recovered during the MSM111 expedition.

Station	Date	Time UTC	Lat. N	Long. W	Water Depth (m)	Core Length (cm)	No-Sections
GeoB25201-2	03.09.2022	12:54	63° 52.055'	028° 56.790'	1618	807	9
GeoB25201-3	03.09.2022	16:54	63° 52.059'	028° 56.783'	1617	532	6
GeoB25202-2	03.09.2022	23:27	63° 15.507'	028° 15.063'	1726	1083	12
GeoB25206-2	07.09.2022	11:23	60° 56.205'	046° 09.290'	275	522	6
GeoB25212-2	13.09.2022	14:54	68° 47.620'	059° 59.429'	1505	1159	12
GeoB25212-3	13.09.2022	17:47	68° 47.621'	059° 59.426'	1505	1702	18
GeoB25217-2	17.09.2022	22:50	69° 50.990'	051° 43.197'	622	762	9
GeoB25219-1	19.09.2022	09:12	68° 41.819'	059° 38.404'	1101	912	10
GeoB25221-2	21.09.2022	16:06	68° 37.355'	060° 53.874'	1728	1394	15
GeoB25222-1	21.09.2022	22:21	68° 38.346'	060° 06.714'	1488	1046	13
GeoB25224-1	26.09.2022	20:41	68° 36.627'	061° 18.352'	1768	864	11
GeoB25226-2	29.09.2022	19:01	64° 31.249'	056° 05.141'	906	609	7

5.5.3 Sea floor drill rig MARUM MeBo200

(Markus Bergenthal, Frauke Ahrlich, Ralf Düßmann, Siefke Fröhlich, Dennis Haider, Erik Linowski, Werner Schmidt, Sophia Schillai, Volker Diekamp, Tim Freudenthal)

During *R/V Maria S. Merian* cruise MSM 111, the seafloor drill rig MeBo200 (Fig.5.5.6) was used for retrieving long sediment cores and conducting geophysical borehole logging. This device is a robotic drill that is deployed on the seabed and remotely controlled from the vessel. The complete MeBo200-system, including drill, winch, power unit, launch and recovery system, control unit, as well as workshop and spare drill tools is shipped within seven 20' containers. A steel armoured umbilical with a diameter of 35.5 mm is used to lower the 10-tons heavy device to the seabed where four legs are being armed out to increase the stability of the rig. Copper wires and fibre optic cables within the umbilical are used for energy supply from the vessel and for communication between the MeBo200 and the control unit on the deck of the vessel. The maximum deployment depth in the current configuration is 2700 m.

The mast with the feeding system forms the central part of the drill rig. The drill head provides the required torque and rotary speed for rock drilling and is mounted on a guide carriage that moves up and down the mast with a maximum push force of 5 tons. A water pump provides sea water for flushing the drill string for cooling of the drill bit and for removing drill cuttings. Core barrels and rods are stored on two magazines in the drill rig. We used wire-line push core barrels (HQ) with

Fig. 5.5.6 Sea floor drill rig MARUM-MeBo200 on board *R/V Maria S. Merian* during expedition MSM 111. Photo: *Volker Diekamp*.

55 mm core diameter and – in a few cases – rotary core barrels with 61 mm core diameter. A

special tool for open hole drilling (flushing with the "Vollbohreinheit" VBE) was used for reaching the target depth without coring. The stroke length was 3.5 m. With complete loading of the magazines a maximum drilling and coring length of about 160 m can be reached. Additional tools like the VBE, pressure core barrels, bore hole logging and temperature probes are stored on cost of loading capacity for core barrels. The maximum drilling depth can be increased to more than 200 m by increasing the loading capacity of drill rods on cost of loading capacity for core barrels. One deployment typically takes several days.

During MSM111, the MeBo was deployed four times (Tab. 5.5.1). Unstable borehole conditions typical for formations containing sandy deposits of several meter thickness were challenging for the drilling operations in the investigation area. During a total deployment time of 184 hours, a total of 365 m was drilled. Of the 365 m drill length, 178 m were cored, with an average recovery of 75%.

Push coring was conducted at site GeoB25214 down to 52.9 mbsf until sediment entering into the drill string prevented the recovery of the inner core barrel. The drill string had to be tripped out without the possibility to conduct borehole logging.

The VBE was used at site GeoB25220 for flushing down to a depth of 52.5 mbsf before core drilling was conducted down to a depth of 91.4 mbsf. Most of the core drilling was conducted by push coring with the exception of rotary core drilling between 71.9 and 73.5 mbsf. Borehole logging was conducted during trip out of the drill string.

Table 5.5.6 All MeBo deployments during the expedition MSM111.

Station GeoB No. Drill #	Drilling duration [hrs:min]	Latitude	Longitude	Water depth (m)	Drill depth (cm)	Cored length (cm)	Recovery (cm)	Remarks
25214-1 31	33:17	68°47.549'N	59°59.222'W	1505	5290	5280	3354 64%	High back pressure below 48m pressed sandy sediment inside the drill string and above the core barrel.
25220-1 32	40:46	68°38.460'N	60°02.798'W	1440	9450	4200	3769 90%	Flushed down to 52m, cored to 94.5m, 91m logging with SGR, MagSus and CTD
25222-2 33	52:05	68°38.343'N	60°06.668'W	1472	9140	4560	2861 63%	Partially cored to 52m, drill string recovering and rebuilding with partially coring to 91m.
25223-1 34	31:48	60°38.456'N	60°02.804'W	1440	12630	3850	3384 88%	Flushed down to 87m, cored to 126m, 122m logging with SGR (MagSus and CTD failed).
Total	158				36510	17890	13368 75%	

At site GeoB25222, the VBE was used for flushing down to 13.4 mbsf before starting core drilling down to 35.4 mbsf. Due to a blocked core barrel the drill string was tripped out. Again, the VBE was used to flush down to 52.9 mbsf in the same hole. Drilling proceeded with push coring down to 56.5 m, flushing down to 63.4 mbsf and push coring down to 73.9 m. Finally, a blocked core barrel caused stop of drilling and tripping out of the drill string without the possibility to conduct borehole logging.

Site GeoB25223 was located close to site GeoB25220 and was drilled in order to extend the record. The VBE was used for flushing down to 87.9 mbsf before we proceeded with core drilling. Using 9 push core barrels and 1 rotary core barrel (115.9 – 119.4mbsf) a final drilling depth of 126.4 m was reached. Borehole logging was conducted during trip out of the drill string.

5.5.3.1 Borehole logging

Borehole logging using a tool string with CTD (CTD 48M, Sea and Sun Technologies), Memory Adapter (3105 Logger, Antares Datensysteme GmbH), Spectrum Gamma Ray (1460 Memory SGR, Antares Datensysteme GmbH) and Magnetic Susceptibility (1188 Memory MagSus, Antares Datensysteme GmbH) probe, was conducted at two of the four MeBo200 deployments (Tab. 5.5.1). After reaching the final drill depth and after the recovery of the last drill tool, the drill string is lifted by one 3.5 m rod and the borehole logging tool string is dropped into the drill string. The Memory Adapter together with the CTD lands on the drill bit while the MagSus and SGR stick through the drill bit with the sensors being located below the drill string. The borehole logging tool string is hooked up inside the borehole by tripping out of the drill (logging while tripping). The logging tools collect data of the characteristics of adjacent formation (SGR, MagSus) and borehole fluid (CTD). These data are logged with time. Depth profiles are generated by combining with the information on drill bit depth of the MeBo-system.

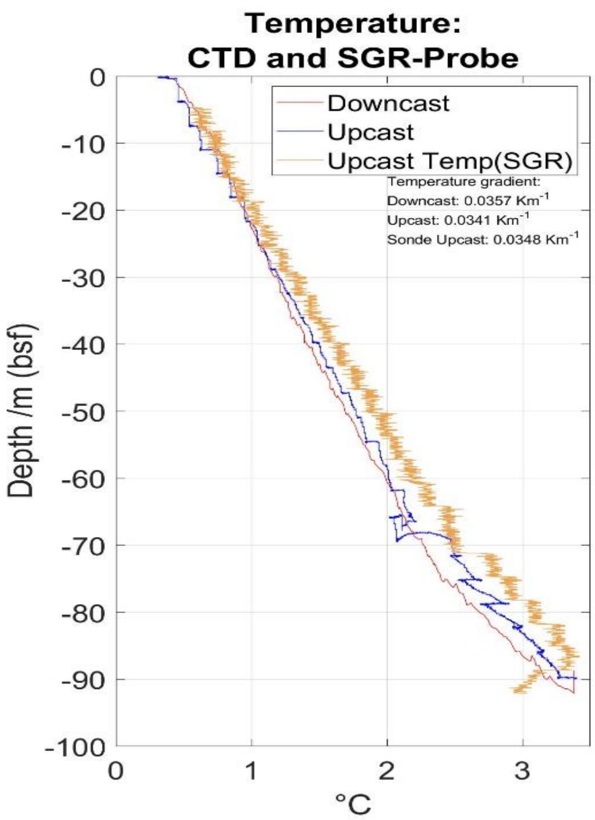

Fig. 5.5.7 Temperature measurements within the borehole at MeBo drilling site GeoB25220

An overview on the collected borehole logging data is shown in table 5.5.2. Since the recovery of the last drill tool was not possible at sites GeoB25214 and GeoB25222, no borehole logging was conducted at these sites. Post processing at site GeoB25223 showed, that the drill bit probably was plugged by sediment such that the SGR and MagSus were located inside the drill string during the entire measurement. While it is possible to conduct an environmental correction (signal attenuation by the drill pipe) for the SGR data (natural gamma ray as well as potassium, thorium and uranium concentration), no formation signal can be seen for the magnetic susceptibility data at this site. Since the tool string did not land on the drill bit the exact sensor distance to the drill bit is not known for this deployment. A good correlation of the SGR data of sites GeoB25220 and GeoB25223 was achieved by applying a -3.7 m shift to the drill bit depth of site GeoB25223.

At MSM111 a CTD was added to the MeBo borehole logging string for the first time. The primary goal was to get a depth reference during the downcast logging. When the final drilling depth is reached and the last core barrel is recovered, the drill string is lifted by one stroke (3.5 m) and the borehole logging tool is dropped into the drill string. The logger lands ten centimetres above the drill bit. For the used combination of SGR and MagSus-Probe, the CTD (M48; Sea and Sun Technologies) was located 1 m above the drill bit while the other sensors were located below the drill bit. During recovery out of the borehole, the logging string is hooked up together with the drill string and measures the geophysical characteristics of the borehole and the adjacent formation (upcast, logging while tripping). Monitoring of the drill bit depth by the MeBo system provides a depth control for the borehole logging data. The pressure sensor of the CTD provides an independent depth control that can be used for the upcast data but also as depth reference for the downcast data while the borehole logging string sinks down inside the drill string after drop in. Next to depth control the CTD provides temperature and conductivity measurements of the borehole fluid. Borehole temperatures increase with depth, indicating a dominant signal reflecting the local geothermal gradient, despite perturbations in caused by the previous drilling action (Fig. 5.5.7) that result from pumping of cold flush water into the bore hole during drilling. Ongoing adaption of the borehole temperatures to undisturbed formation temperature is indicated by slightly higher temperature measurements during the upcast, especially in the lowest part of the borehole. Temperatures monitored by the SGR electronics are even higher due to electric heat generation within the instrument. Irregularities of the shown upcast CTD temperature profile at around 69 m below sea floor (Fig. 5.5.7) may indicate active aquifers or recirculation of flushing fluid in sandy parts of the formation.

Table 5.5.7 Overview of collected borehole logging data: CTD: borehole fluid conductivity, temperature and pressure; SGR: Spectrum Gamma Ray; MagSus: Magnetic Susceptibility.

Station GeoB No. Drill #	**Borehole logging tool Sensor depth range (m)**		
	CTD	**SGR**	**MagSus**
25220-1 32	89.6 - 0	92.1 – 1.3	93.4 – 2.6
25223-1 34	No data	119.9 – 0.8 (3.7 m depth shift applied)	No data

5.5.4 Core Logging

(Tilo von Dobeneck)

All sediment series recovered during the MSM111 cruise by gravity and MeBo 200 drill rig coring were routinely logged with a Multi-Sensor Core Logging (MSCL) system (Fig. 5.5.10), providing two fundamental petrophysical parameter logs at cm-resolution:

- **magnetic volume susceptibility κ**
- **electric resistivity ρ_s [Ωm], reciprocal to electric conductivity σ_s [S/m]**

These physical sediment properties are closely related to lithology, grain-size and porosity and can be rapidly measured by inductive methods even on unopened cores. Shipboard magnetic susceptibility and electric resistivity core logs provide interpretable high-resolution lithostratigraphic information shortly (12-24h) after core retrieval. They can be used for a tentative correlation and age estimates of already collected cores and the planning of subsequent coring operations. These core logs also provide guidance for shore-based prioritization, sampling and investigation strategies.

The **magnetic volume susceptibility κ** can be defined by:

$$\kappa = dM_{ind} / dH,$$

where dH denotes the change of an external (e.g. alternating) magnetic field and dM_{ind} the resulting change in induced magnetization of materials within this field. As both parameters carry the same unit A/m, κ is a dimensionless quantity in the SI unit system. It expresses how susceptible a material is to being magnetized by a (weak) external magnetic field.

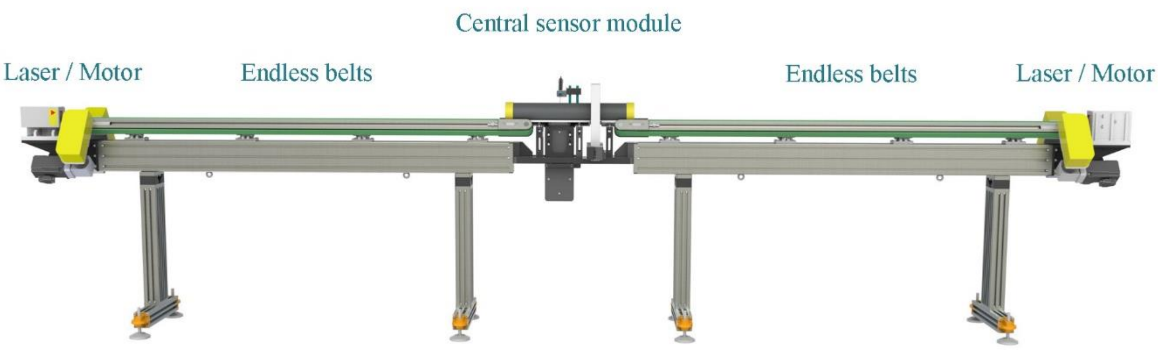

Fig. 5.5.10 CAD drawing of Multi-Sensor Core Logging (MSCL) system consisting of two-sided (endless) conveyor belts, a central sensor module, four drive motors and two laser distance sensors

The magnetic volume susceptibility of marine sediments may vary from lowest possible values of $-15 \cdot 10^{-6}$ SI (pure carbonate and quartz) to several $10.000 \cdot 10^{-6}$ SI (magnetite-rich debris of magmatic rocks). κ is largely determined by fine-grained ferrimagnetic minerals, while paramagnetic minerals like Fe-bearing clays have a lesser influence. Minima in susceptibility can result from biogenic fractions diluting the terrigenous input, from sandy sections with better sorting and higher porosity, or from diagenetic dissolution and alteration of primary iron oxide minerals. Extremely high susceptibility values are indicative of large or numerous magmatic rock clasts such as ice rafted detritus (IRD), volcanic ash (tephra layers), or heavy mineral enrichments (placer formation).

The **electric resistivity** $\boldsymbol{\rho_s}$ (and, reciprocally, **electric conductivity** $\boldsymbol{\sigma_s}$) of marine sediments depend primarily on the porosity $\boldsymbol{\phi}$, pore water resistivity $\boldsymbol{\rho_w}$, and pore-water saturation **S**, which we assume here as complete. Their mutual relation is described by Archie's equation:

$$\boldsymbol{\rho_s / \rho_w = \sigma_w / \sigma_s = k \cdot \phi^{-m}},$$

with cementation exponent **m** (here ~1.4) and tortuosity factor **k** (here ~1.2). The assumed pore water resistivity $\boldsymbol{\rho_w}$ of 0.206 Ωm may be too low for Baffin Bay's high meltwater influx. Resistivity-based sediment porosity estimates can be further transformed to bulk densities assuming a matrix density of 2670 kg/m^3 (quartz) and pore-water density of 1030 kg/m^3.

We present all these estimates in our shipboard core logging data files, but only show conductivity $\boldsymbol{\sigma}$ in the figures - the physically valid result of our measurements. While some sandy cores may have partially lost pore water, in particular at the segment ends, others may contain excess seawater from the coring process. Calibrated, sediment-specific values for **m** and **k** are also not readily available. It is recommended not to take such porosity and density estimates as reliable absolute values, but just as indications of relative change.

5.5.4.1 Methods

The self-developed MARUM MSCL (Fig. 5.5.10) is a mobile fast-track core logging system equipped with *Bartington* susceptibility MS2C loop sensors with 140 mm or 85 mm inner diameter and an elongated *GeoTek* NCR sensor. It features a bidirectional double conveyor belt driven by four optically controlled synchronous motors. The V-shaped conveyor layout ensures optimal axial alignment with flexible core diameters. Laser distance meters at both ends measure the distance to the segment ends instantaneously, which provides a positioning accuracy and segment length determination with less than 1 mm error.

As MSM111 core segments were logged ~3-24h after core recovery. Gravity cores were generally logged with 3.5 s integration time at 1 cm spacing (MEBO cores at 2 cm spacing). Thermal sensor drift was trend-corrected by background measurements before and after each segment log and additionally once or twice in-between depending on segment length. For the necessary NCR calibration, a set of saline solutions at concentrations of 0.35 - 1.75 - 3.5 - 8.75 - 17.5 - 35 g/l was measured daily. Each solution was prepared onboard using 5 l distilled Milli-Q water and a pre-weighed amount of sea salt. These saline solutions were filled into empty core liner sections of the gravity and MEBO cores.

The core segment data were numerically corrected for signal decay within the first and last 14 cm of each segment. Where segments continue, their data were correctly overlapped and added to create seamless susceptibility records. Nevertheless, the resistivity data within the first and last 5 cm of each segment had to be discarded, as they usually showed artifacts of partial pore-water and/or sediment loss (in particular at the core-catcher end).

Electric resistivity was logged with an inductive NCR (non-contact-resistivity) sensor that measures the strength of electromagnetically induced eddy currents in the sediment by their secondary electromagnetic field. Since seawater resistivity is temperature-dependent, all measured values were converted to their 20°C analogues for better comparability. A non-contact infrared thermometer providing real-time temperature was used for that purpose.

5.5.4.3 Shipboard Results

All collected core logging data and first, tentative correlations are presented as downcore plots (Figs. 5.5.11- 5.5.28). They demonstrate that susceptibility and conductivity logs carry independent, partially mirror-symmetric information on sediment composition. These systematic and characteristic signals are thought to result from paleoclimatic changes in sediment provenance and transport. Successive compaction with depth is reflected in systematic downcore conductivity losses, in particular over the first few meters of the cores.

All measured cores share certain common features: High mean susceptibilities of usually 500-$4000 \cdot 10^{-6}$ SI should result from mostly magmatic and hence titanomagnetite-rich source rocks of the Reykjanes Ridge and the Greenlandic Craton. Low-magnetic marine microfossils seem to be subordinate or absent at these high latitude locations. There is no evidence of diagenetic alteration of primary magnetic minerals. Despite their lithogenic, regionally confined sources, most susceptibility logs show large episodic or recurrent signal variations that share similarity with previously investigated records from these regions.

The three cores collected from the western flank of Reykjanes Ridge GeoB25201-2/-3 and GeoB25202-2 (Figs. 5.5.11-5.5.23) have nearly identical large-scale susceptibility variations, partly in phase with conductivity changes. The 5 m long core GeoB25201-3 repeats the upper half of the 8 m long GeoB25202-2 core, which appears to correspond to the top 7.5 m of the 9.3 m long core GeoB25202-2. Their susceptibility patterns resemble published records of North Atlantic IRD layers (e.g. Robinson et al., 1995). Noteworthy, the latest MSM111 core GeoB25226-2 from Davis Strait shows partly similar susceptibility patterns.

The upper ~7 m of the 10.7 m long gravity core GeoB25206-2 (Fig. 5.5.14) from Narsaq Sound near Ikersuaq Fjord in southern Greenland can be easily tied to the well-investigated and dated (7560 C^{14} yrs. BP) 5.5 m long core Ga3-2 by (Norgaard-Pedersen and Mikkelsen, 2009). In contrast, the 7.5 m long core GeoB25217-2 from the Vaigat Strait (Fig. 5.5.18) shows a rather featureless susceptibility pattern with values of $1300\text{-}1700 \cdot 10^{-6}$ SI, indicative of Late Holocene sedimentation.

Six gravity and four MeBo cores taken in the eastern Baffin Bay systematically sampled a confined study area at the slope and foot of a large glacial fan system off Disko Bay. First shipboard Parasound- and log-based cyclostratigraphic analyses indicate the recovery of a nearly complete, up to 125 m thick sedimentary archive of Greenland’s mid- to late Pleistocene climatic evolution (Figs. 5.5.27/28).

While the first, 51 m deep MeBo core GeoB25214-1 taken at 1505 m water depth was partly incomplete due to coring difficulties (Figs. 5.5.17/27), the sediment sequence it recovered appears to have been largely replicated –but at lower sedimentation rate – by the 14 m long gravity core GeoB25221-2 taken at 1728 m depth (Fig. 5.5.19) and the 8.6 m long core GeoB25224-1 taken at 1768 m depth (Fig. 5.5.25). The two deeper MeBo cores GeoB25220-1 (Fig. 5.5.21) and GeoB25223-1 (Fig. 5.5.24) had almost continuous coring success and show ongoing alternations of sediment packages with lower and higher susceptibilities (1000 to $4000 \cdot 10^{-6}$ SI), possibly representing glacial-interglacial cycles. MeBo core GeoB25222-2 is very fragmented (Fig. 113), but records a magnetite- enriched layer of up to $18600 \cdot 10^{-6}$ SI at 68-70 m coring depth, possibly representing an erosional unconformity. The 17 m gravity core GeoB25212-3 from the MeBo site (Fig. 5.5.15) seems to carry a complete high-resolution late Pleistocene sediment record of the last glacial cycle.

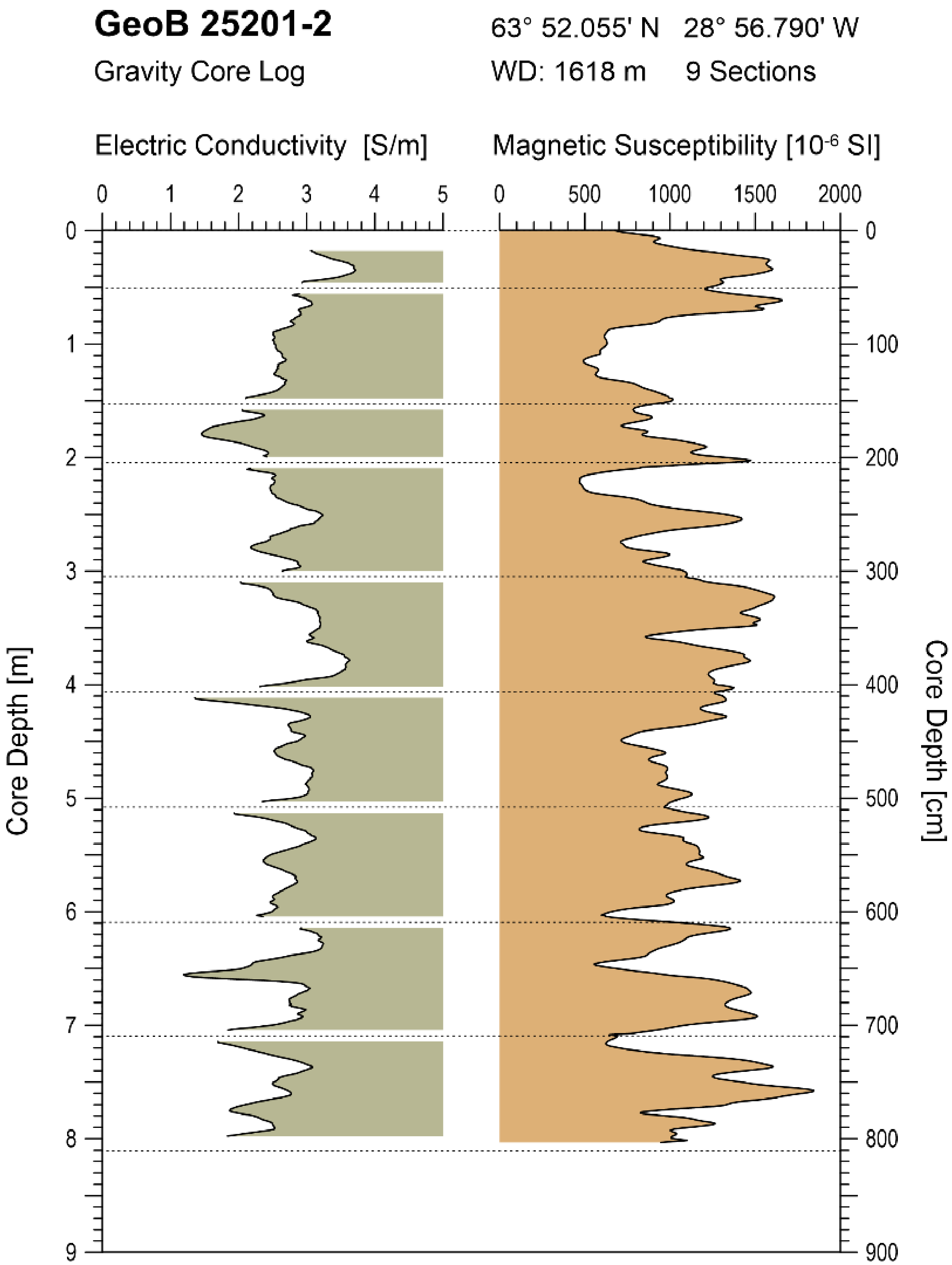

Fig. 5.5.11 Electric conductivity (NCR) and magnetic volume susceptibility core logs of gravity core GeoB 25201-2

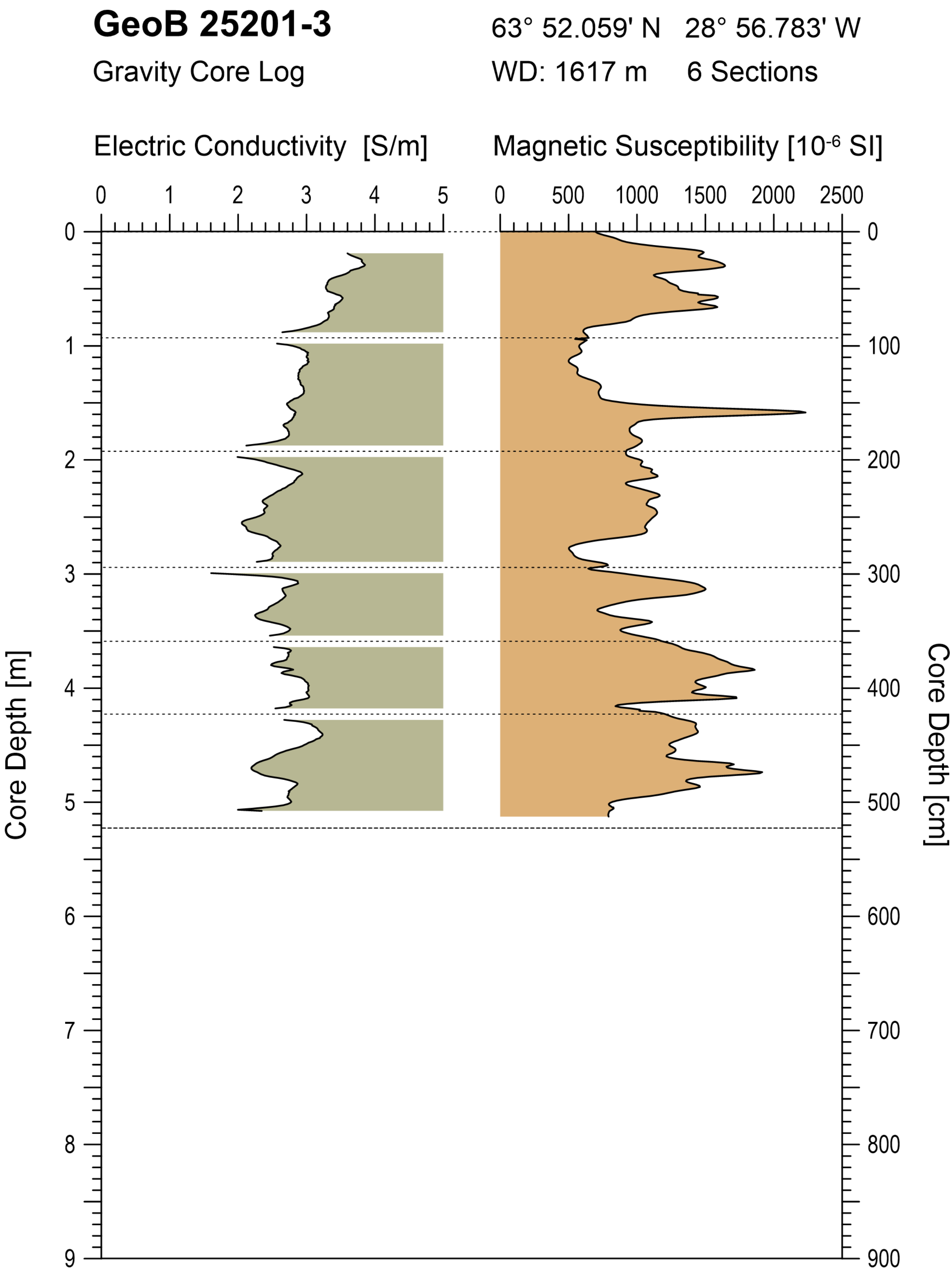

Fig. 5.5.12 Electric conductivity (NCR) and magnetic volume susceptibility core logs of gravity core GeoB 25201-3

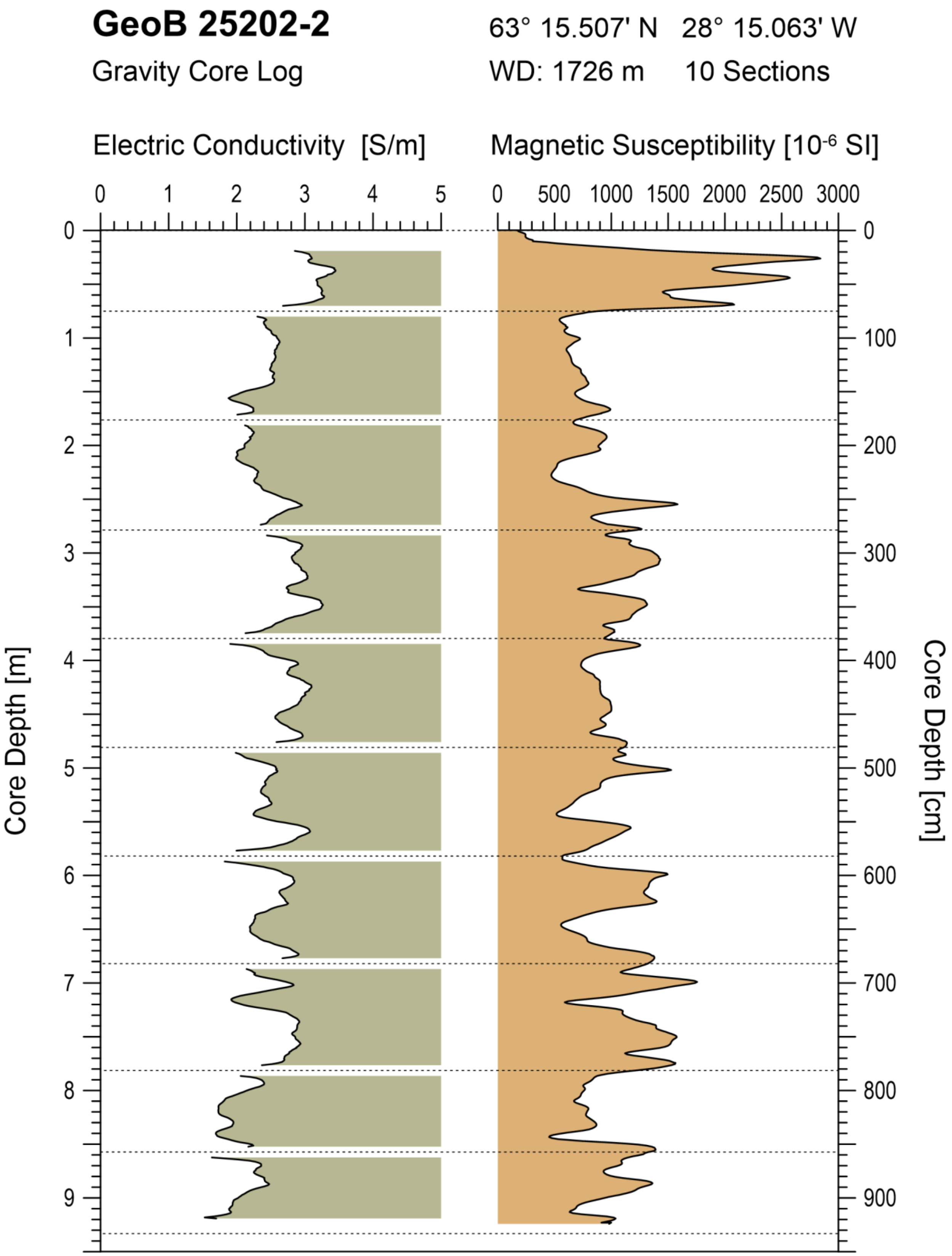

Fig. 5.5.13 Electric conductivity (NCR) and magnetic volume susceptibility core logs of gravity core GeoB 25202-2

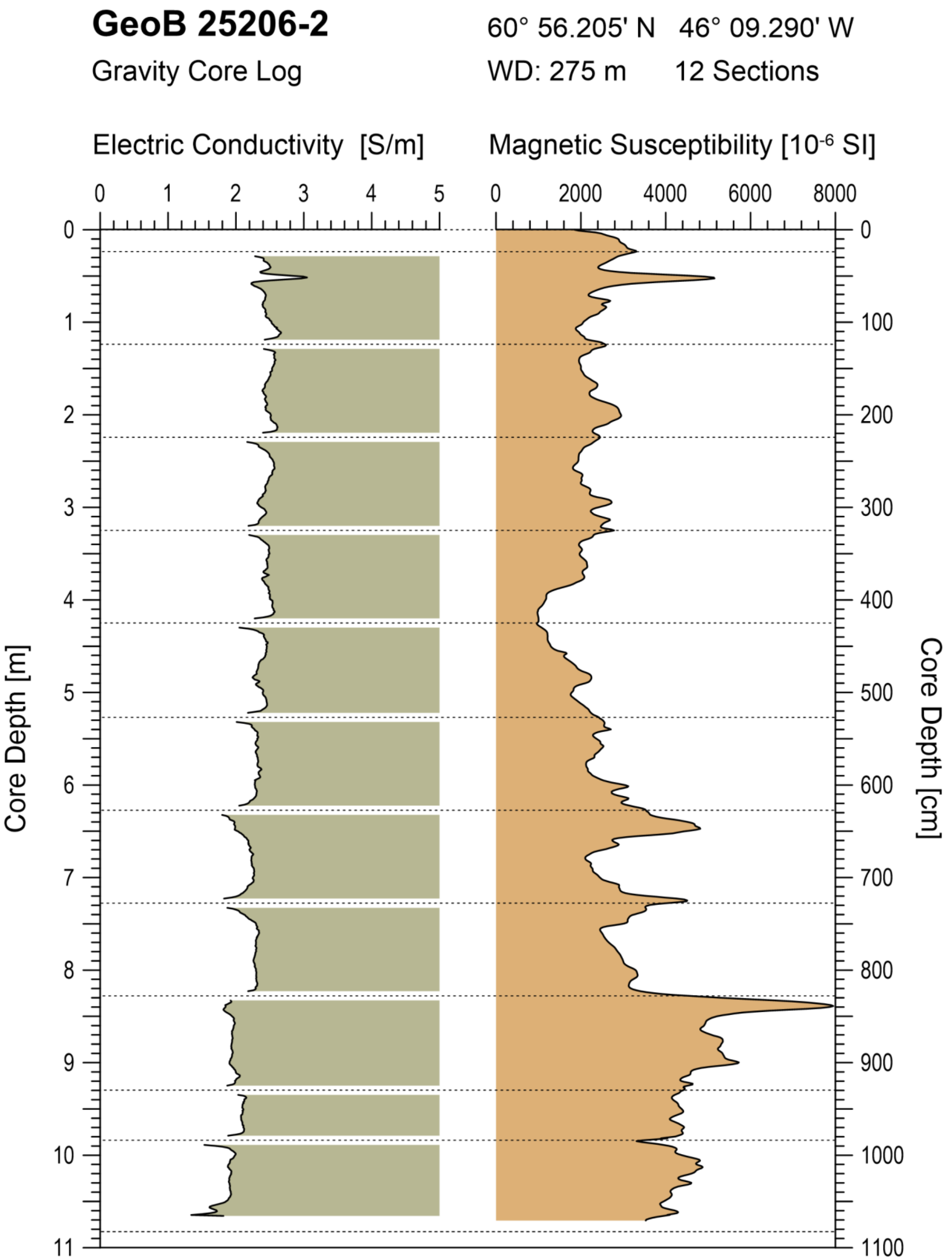

Fig. 5.5.14 Electric conductivity (NCR) and magnetic volume susceptibility core logs of gravity core GeoB 25206-2

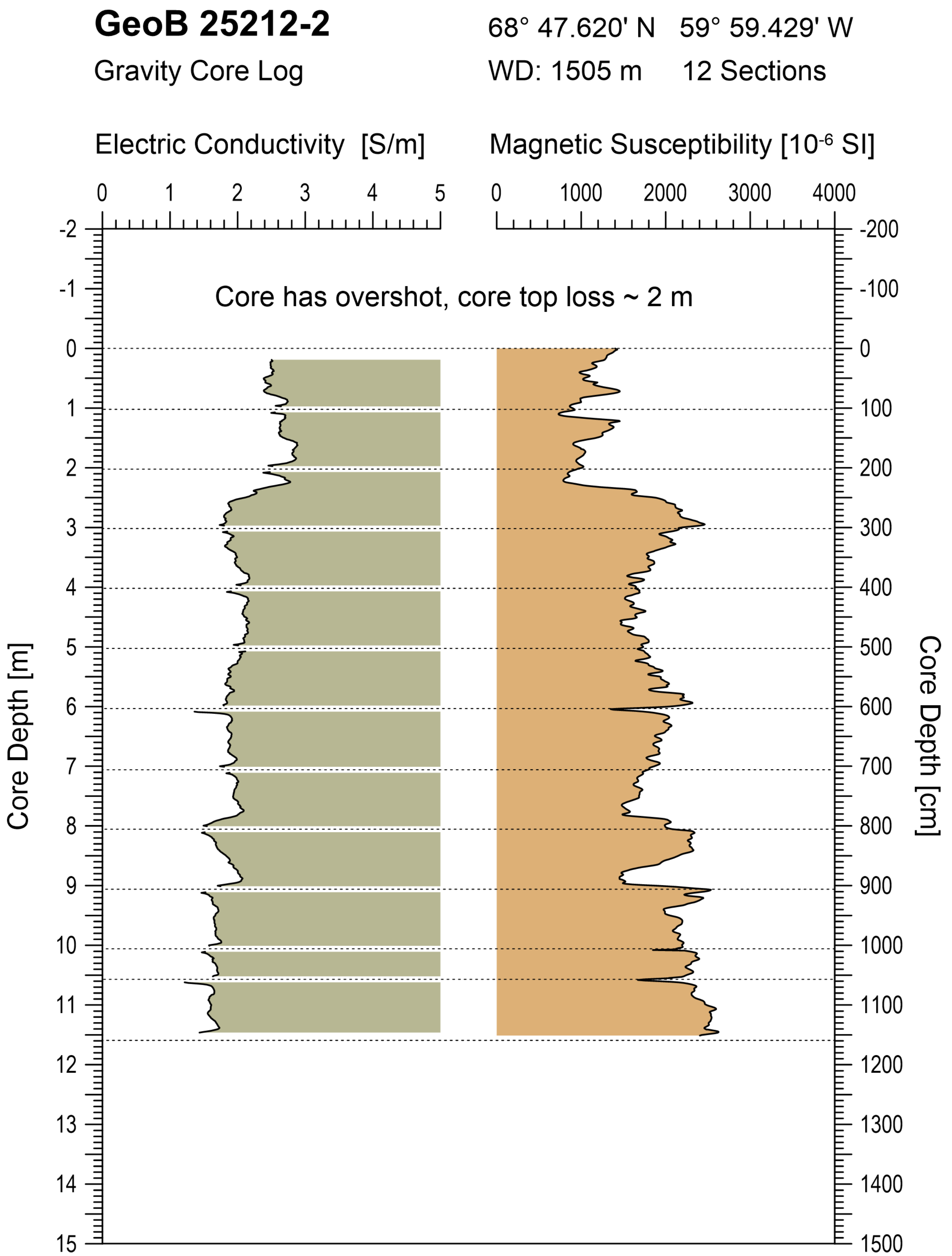

Fig. 5.5.15 Electric conductivity (NCR) and magnetic volume susceptibility core logs of gravity core GeoB 25212-2

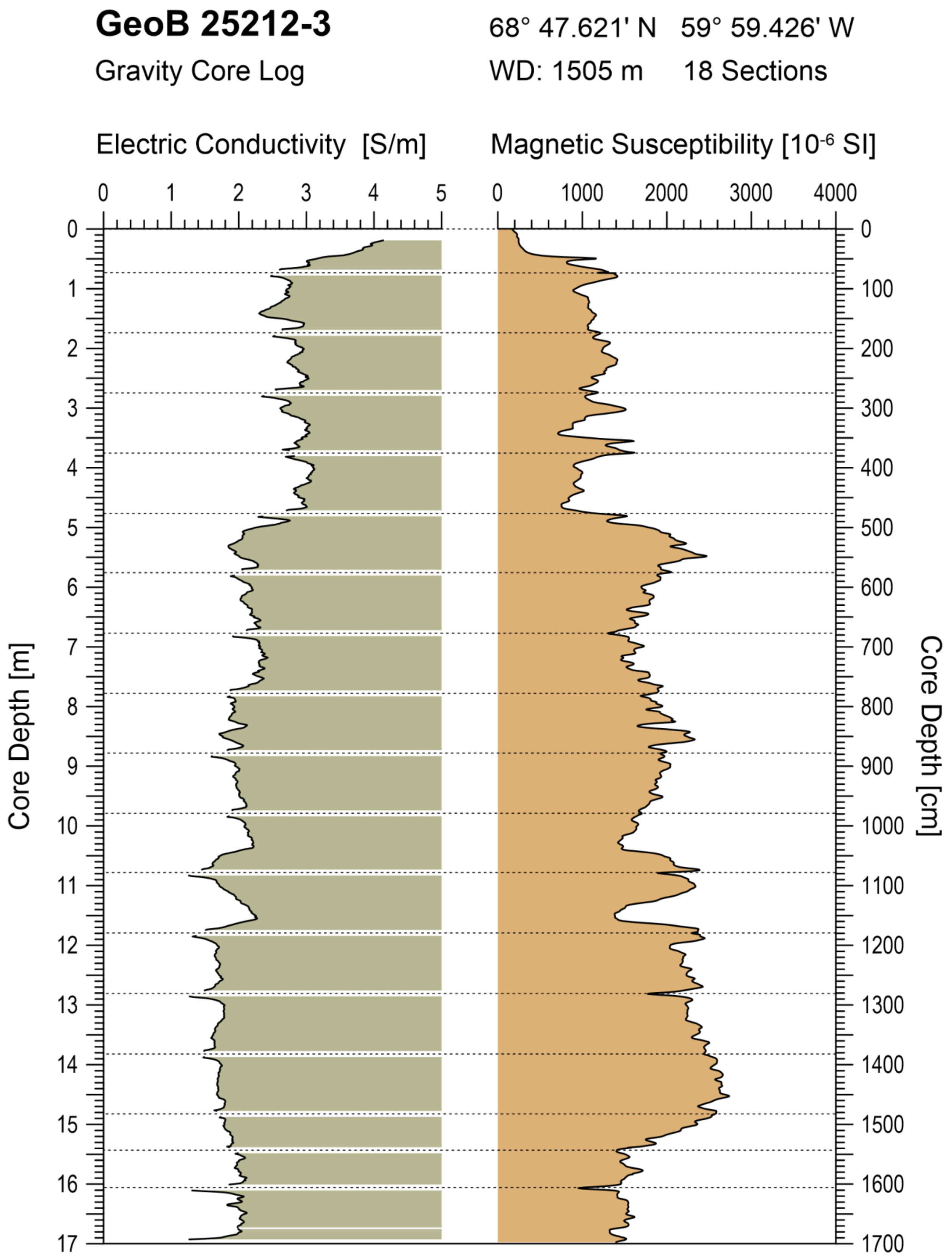

Fig. 5.5.16 Electric conductivity (NCR) and magnetic volume susceptibility core logs of gravity core GeoB 25212-3

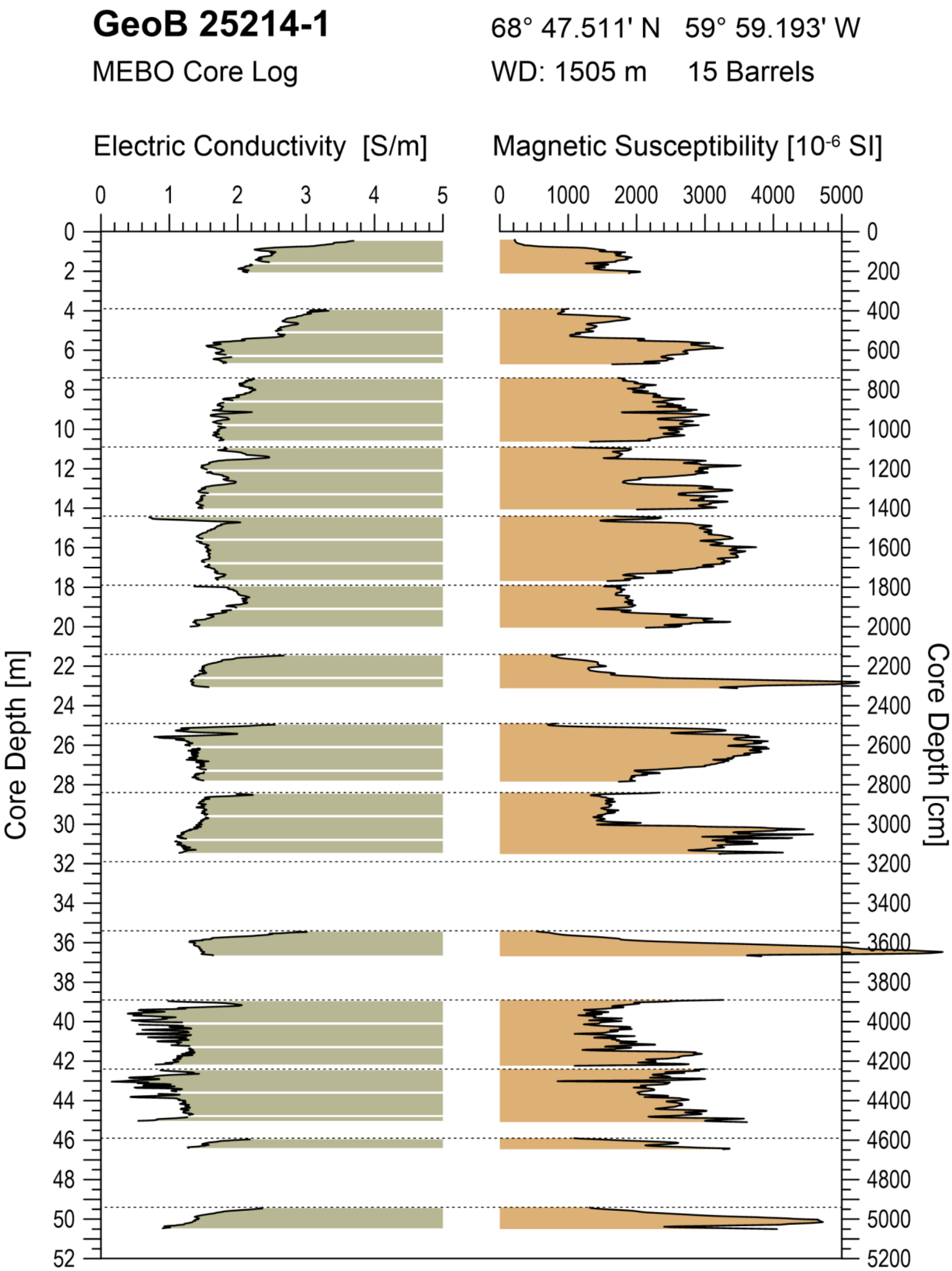

Fig. 5.5.17 Electric conductivity (NCR) and magnetic volume susceptibility core logs of gravity core GeoB 25214-1

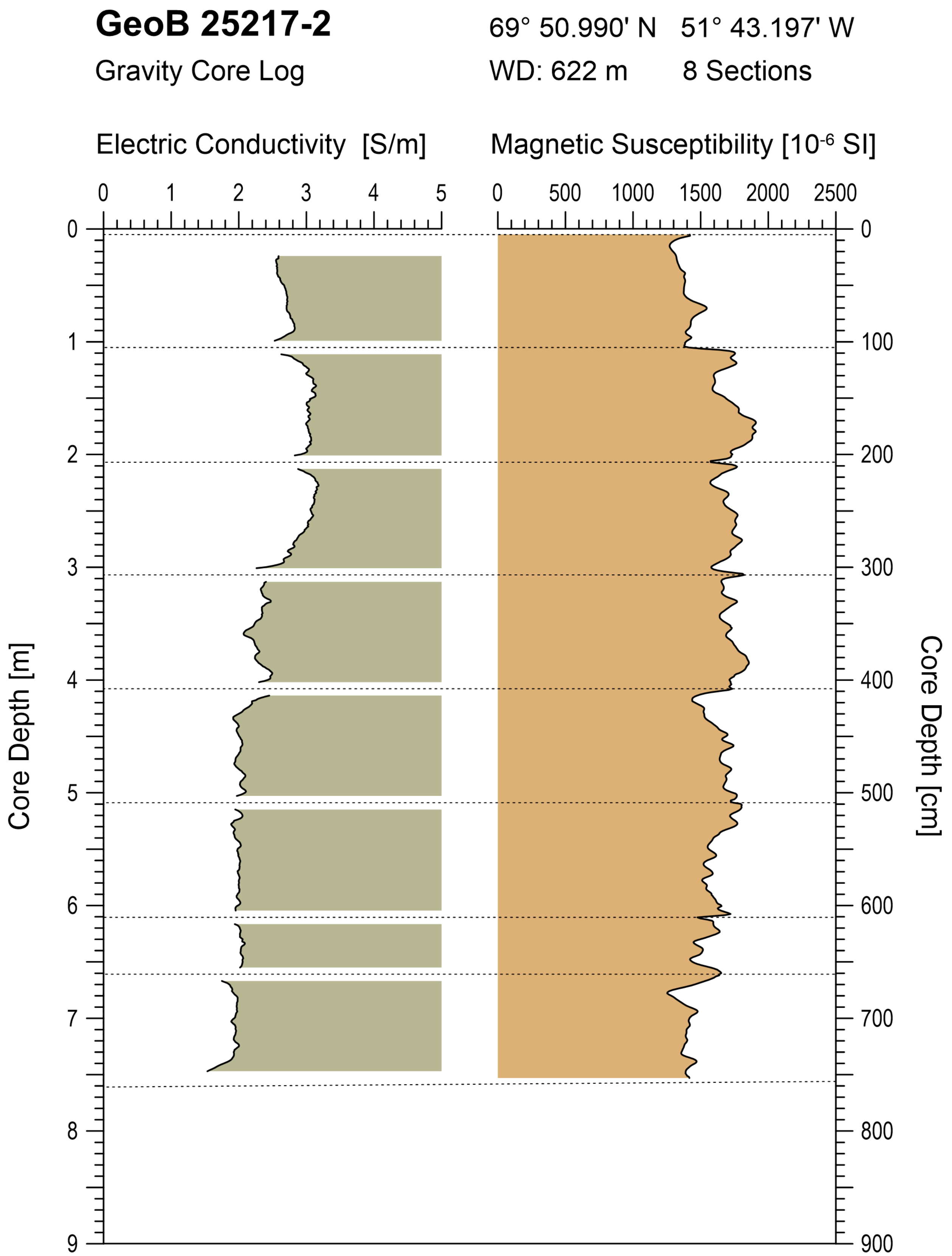

Fig. 5.5.18 Electric conductivity (NCR) and magnetic volume susceptibility core logs of gravity core GeoB 25217-2

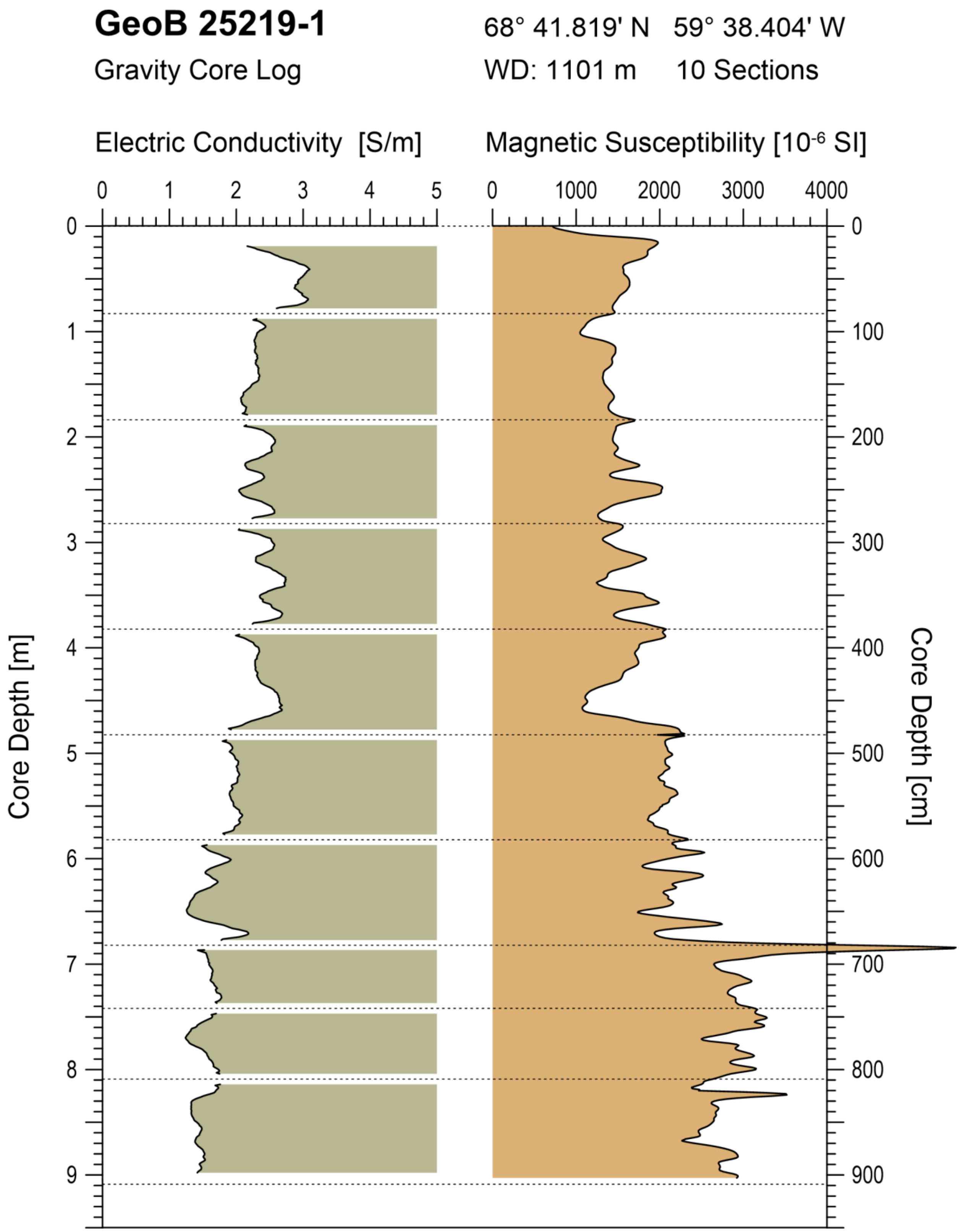

Fig. 5.5.19 Electric conductivity (NCR) and magnetic volume susceptibility core logs of gravity core GeoB 25219-1

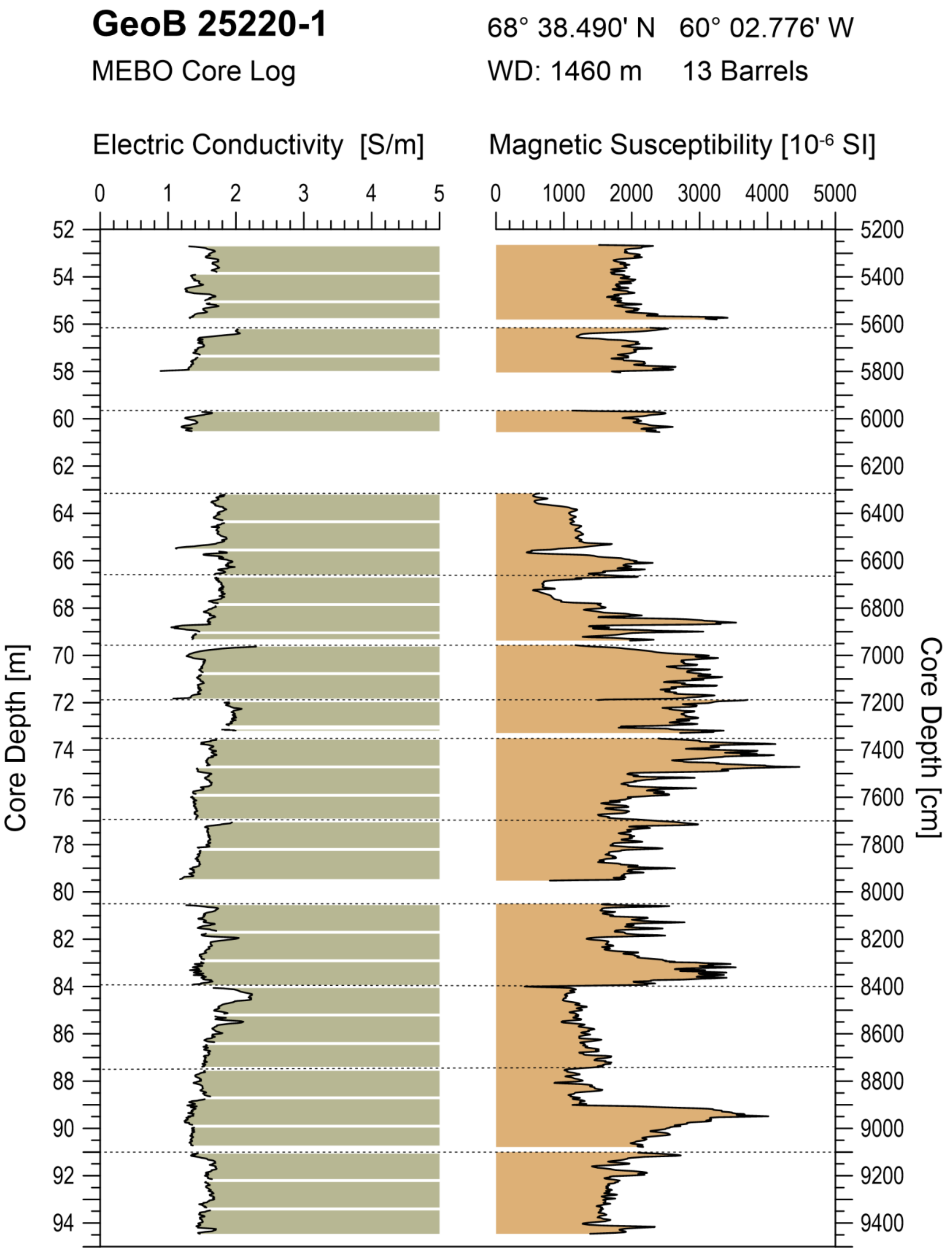

Fig. 5.5.20 Electric conductivity (NCR) and magnetic volume susceptibility core logs of gravity core GeoB 25220-1

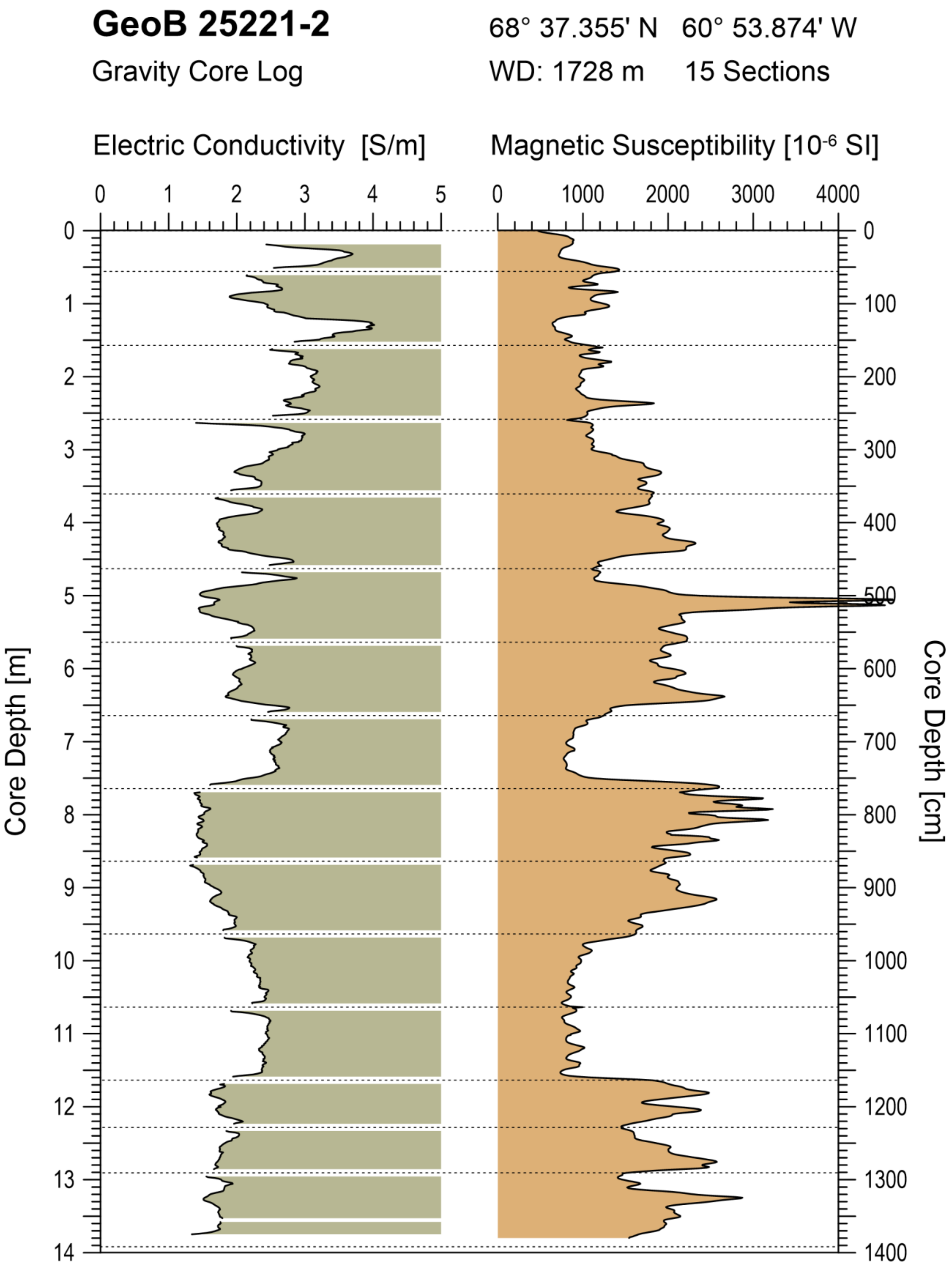

Fig. 5.5.21 Electric conductivity (NCR) and magnetic volume susceptibility core logs of gravity core GeoB 25221-2

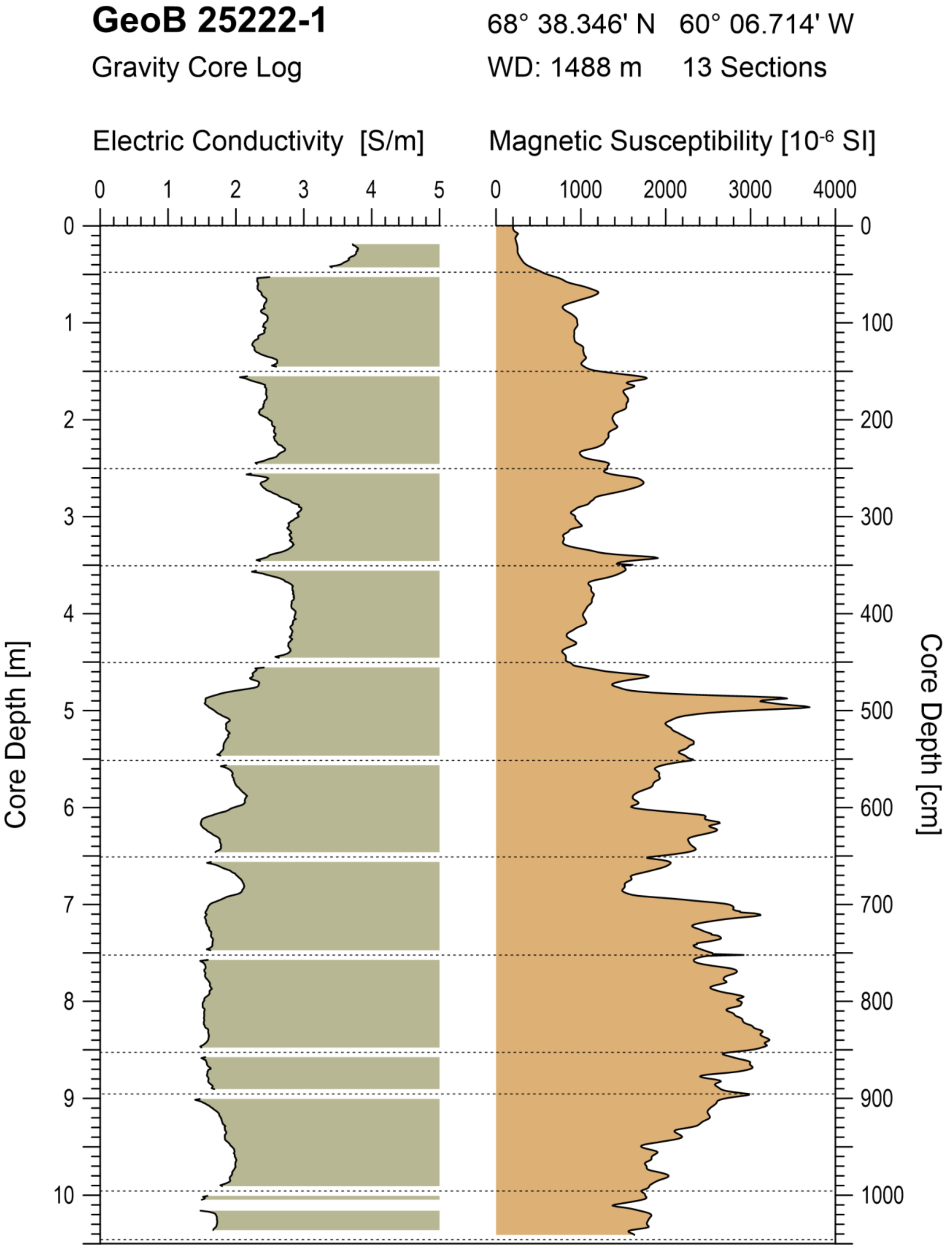

Fig. 5.5.22 Electric conductivity (NCR) and magnetic volume susceptibility core logs of gravity core GeoB 25222-1

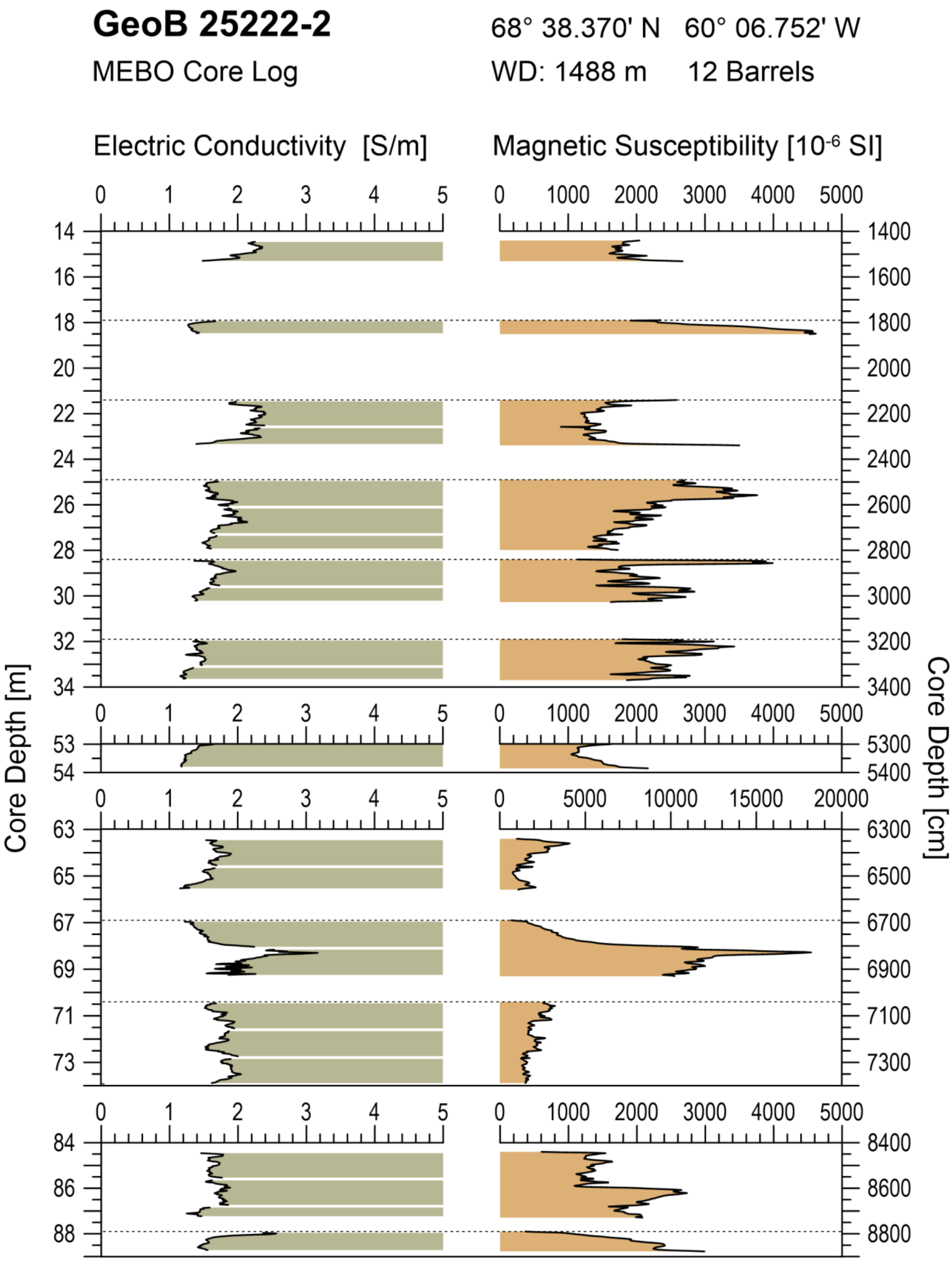

Fig. 5.5.23 Electric conductivity (NCR) and magnetic volume susceptibility core logs of gravity core GeoB 25222-2

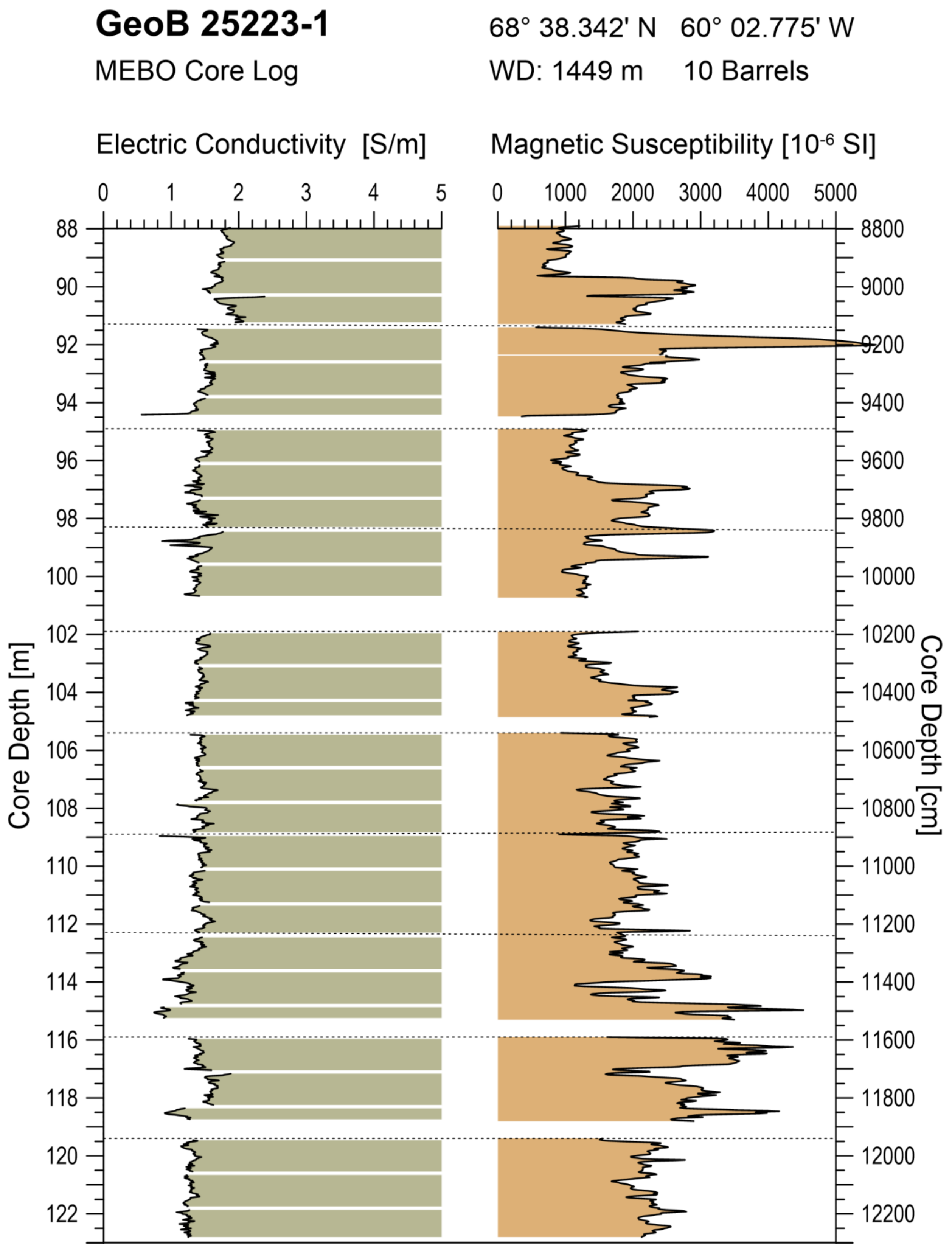

Fig. 5.5.24 Electric conductivity (NCR) and magnetic volume susceptibility core logs of gravity core GeoB 25223-1

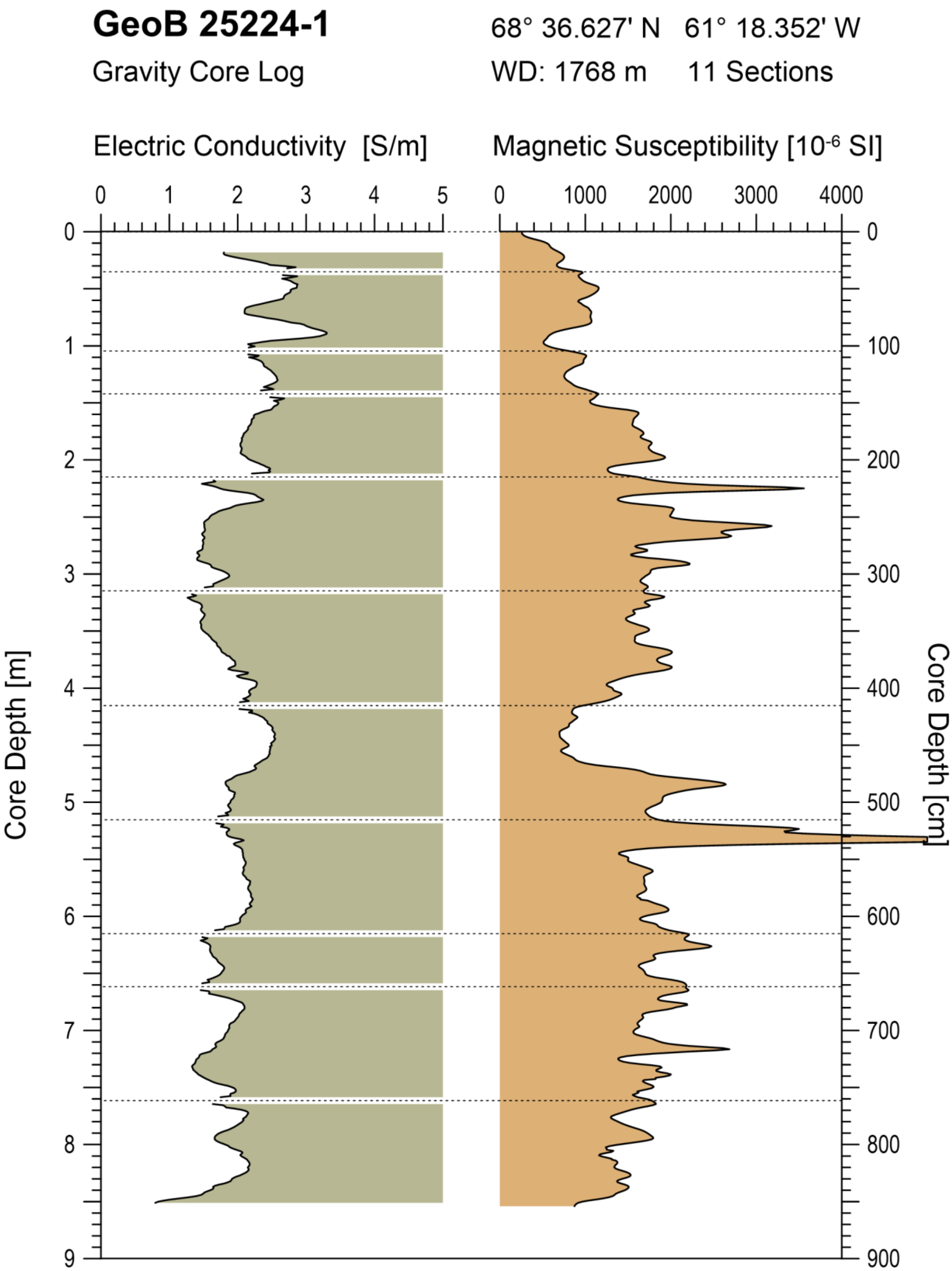

Fig. 5.5.25 Electric conductivity (NCR) and magnetic volume susceptibility core logs of gravity core GeoB 25224-1

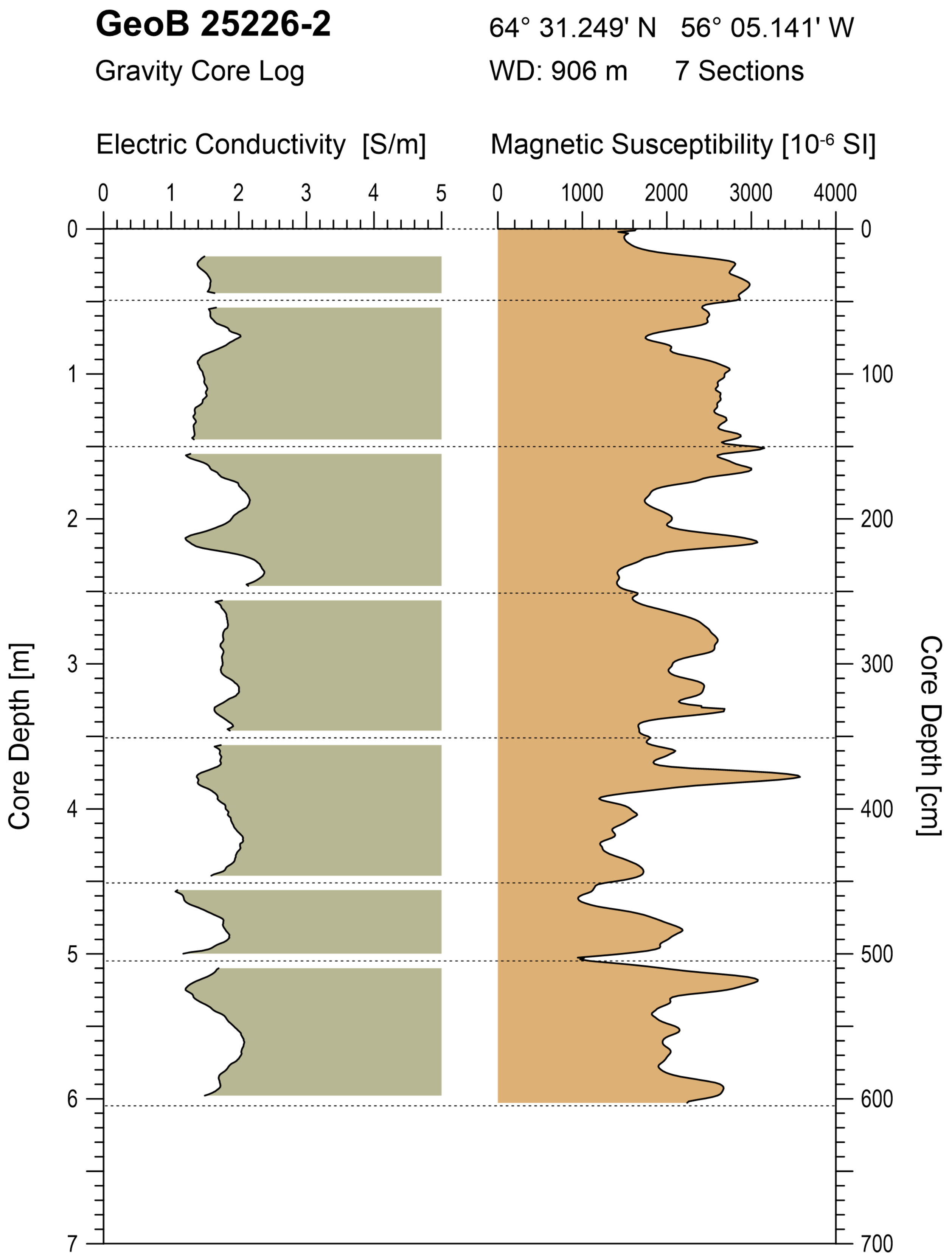

Fig. 5.5.26 Electric conductivity (NCR) and magnetic volume susceptibility core logs of gravity core GeoB 25226-2

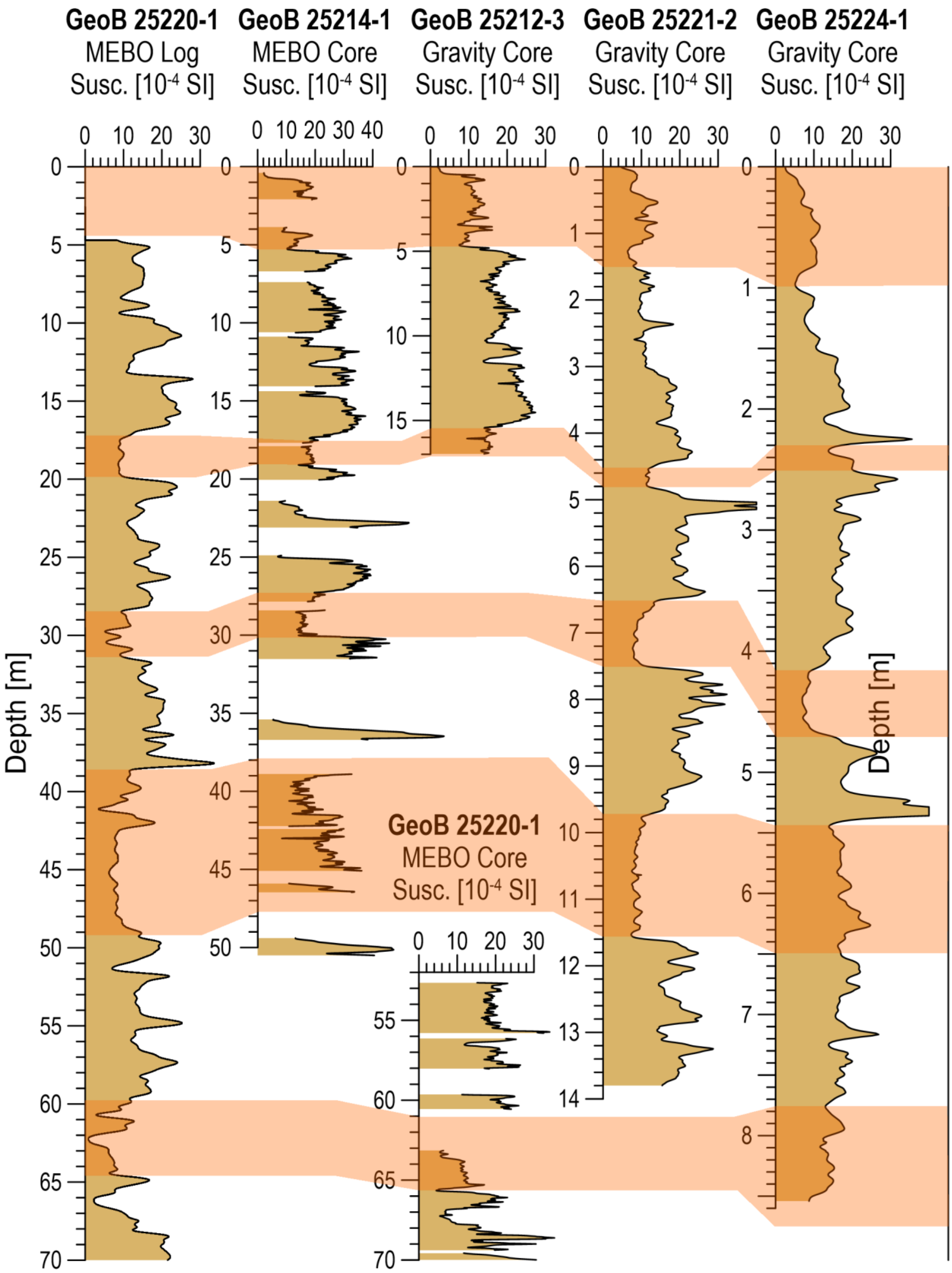

Fig. 5.5.27 Susceptibility-based correlation of Baffin Bay GeoB25220-1 MeBo well log (0-70 m Depth) with selected other MSM111 sediment cores

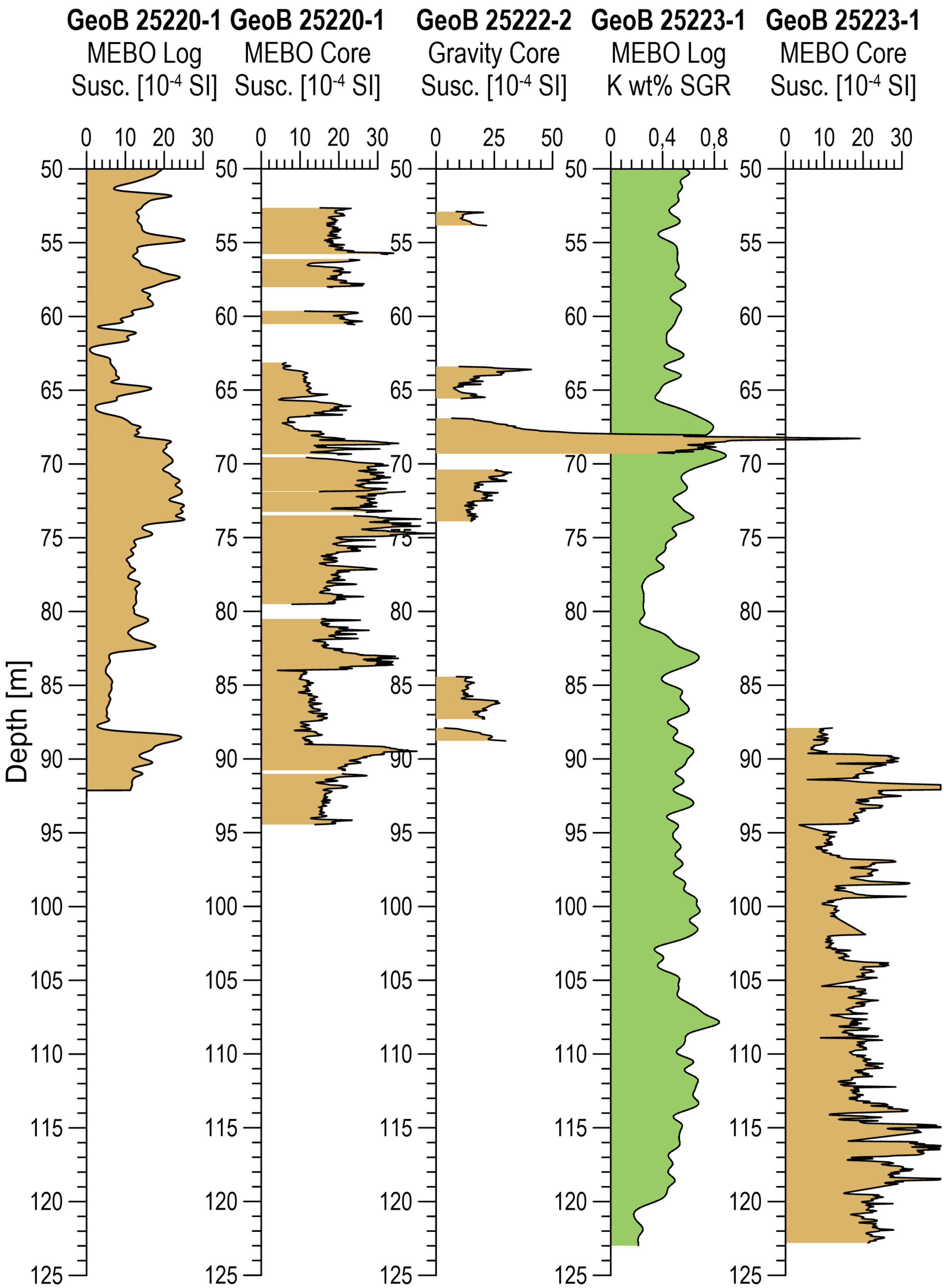

Fig. 5.5.28 Susceptibility-based correlation of Baffin Bay MEBO well log and cores GeoB25220-1, GeoB25222-2 and GeoB25223-1 (50-125 m Depth)

5.5.5 Micropaleontology

(Anne de Vernal and Henrieka Detlef)

5.5.5.1 Sample preparation

Core catchers of gravity and MeBo cores were subsampled to obtain a first estimate on the nature and preservation of the biogenic content of the sediment. A volume of sediment ranging from 5 to 10 cm^3 was processed by immersion in water. The sediment was then wet-sieved on 106 µm and 15 µm mesh sieves. The coarse fraction was dried and examined under binoculars at magnification ranging up to 40X. The low-density particles from the fraction ranging from 15 to 106 µm were mounted in glycerine gel for examination on a microscope at 400X magnification. No chemical treatment was done. The fine fraction was sieved manually. Sonification was done to deflocculate and facilitate the fraction sieved at 15 µm.

5.5.5.2 Results from the coarse fraction (>106 µm)

The residue of the size fraction >106 µm was dried and examined under a binocular for semi-quantitative estimation of the constituent mineral (sand) components and microfossils (Fig. 5.5.29, Tab. 5.5.1). The sand abundance is reported on a scale ranging from 0 (no sand) to 4 (> 5%). In all samples, quartz grains are dominant, but the mineralogy of the grains is generally diverse, including mica and black minerals. In many samples, the sand seems to be well sorted. The occurrence of larger grains of various mineralogical affinities is interpreted and reported as ice-rafted debris (IRD).

The entire fraction >106 µm was scanned for biogenic remains. The occurrences are reported as rare (< 5 specimens), common (5-50) and abundant (> 50 specimens). Among planktonic foraminifera, *Neogloboquadrina pachyderma* is the most common species, virtually exclusive in most samples. Benthic foraminifera assemblages display a variable diversity, with taxa identified at least at the genus level. The most frequently observed taxon is *Elphidium* cf. *excavatum*. The overall preservation of biogenic carbonates is usually mediocre with signs of dissolution and calcite overgrowth on the foraminifer shells. The occasional occurrences of radiolaria, echinoderm spines and ostracods are reported. The occurrence of large diatoms (mostly centric forms) and sponge spicules (mostly monaxones) is also reported. Other remains include pyritized worm tubes (GeoB25223-1-2cc) and plant macrofossils (GeoB25223-7cc).

5.5.5.2 Results from the fine fraction (15-106 µm)

The 15-106 µm fraction is usually larger representing more than 50% of the overall sample. Hence the biogenic material is highly diluted in the silt matrix. In order to concentrate the organic-walled microfossils expected to be found in this size fraction, the fraction was put in suspension and left to settle and a few drops of the liquid above the settled sediment were mounted on slides for microscope observations. The optical properties (light source and magnification) of the inverted microscope were not ideal for the identification of organic material. Moreover, without a mechanic stage, systematic scanning was not possible. Hence, the observations made are qualitative. Also, the occurrence of taxa is significant, but the absence of a taxon cannot be interpreted as significant, as only a very small fraction of the sample was examined.

Several types of organic-walled microfossils were identified (Fig. 5.5.30, Tab. 5.5.2), mostly dinocysts and pollen, in addition to organic linings of foraminifera. Reworked material was also seen. A rare occurrence of ciliates (*Halodinium*) is noted. Diatoms and sponge spicules are common in many samples. One silicoflagellate was also seen. Among the dinocysts, *Islandinium minutum* and *Brigantedinium* spp. are common to abundant in many samples. These heterotrophic taxa suggest phases of high productivity in a seasonal sea ice environment. Pollen grains occur in low numbers in many samples, but are exceptionally abundant in two samples from the last MeBo drill hole (GeoB25223-1-7cc and -9cc). The dominant taxa are *Pinus*, *Picea*, *Betula*, *Alnus* and a high number of tricolpate pollen for which identification will have to be verified. It is of note that, due to coarse sieving and the difficulty to concentrate organic matter, the species diversity of dinocysts and pollen is probably underestimated.

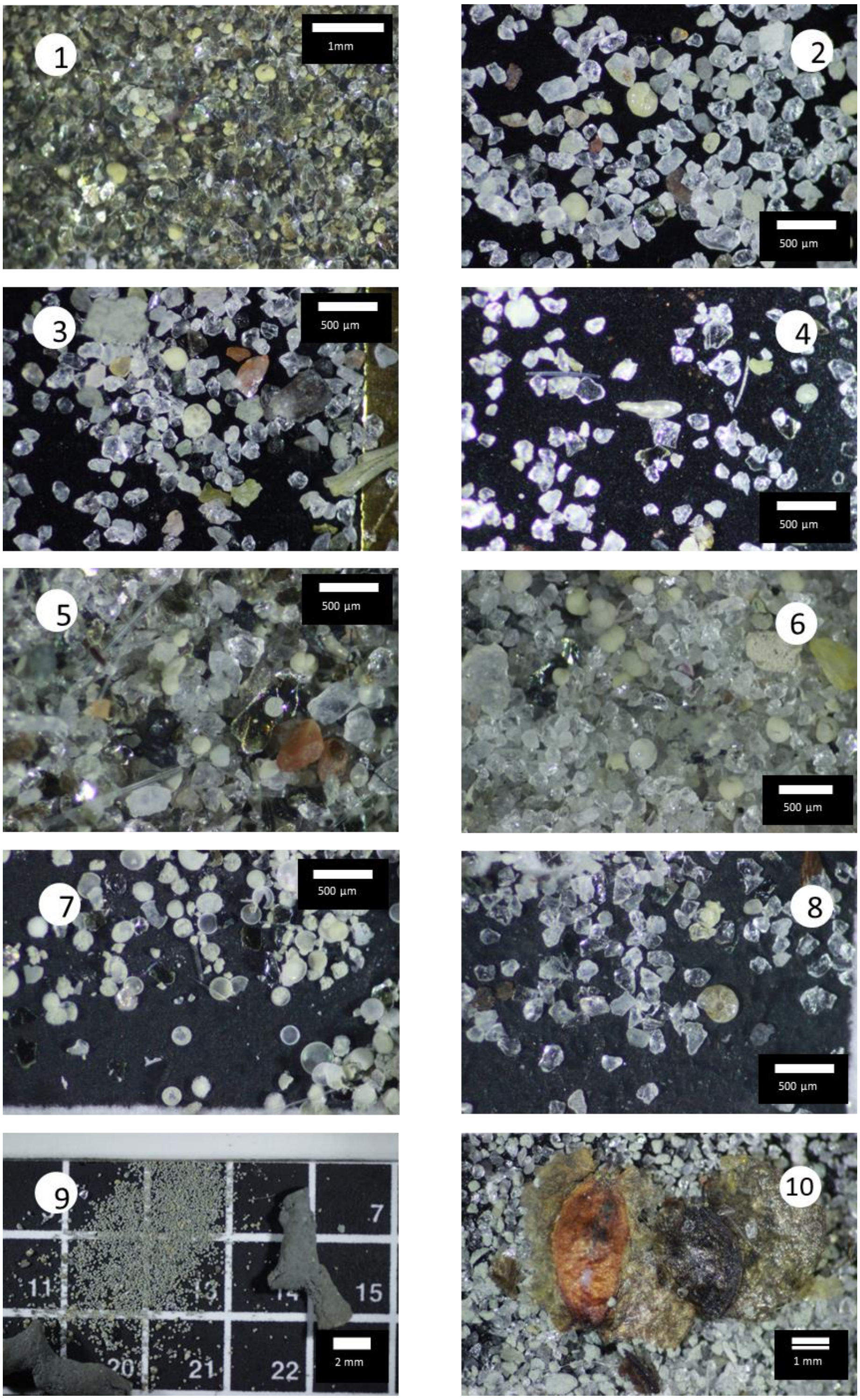

Fig. 5.5.29 Illustration of the >106 µm content in selected core catcher samples. **1.** Sample GeoB25214-1-4cc: Quartz and mica particles with planktonic foraminifera; **2**. Sample GeoB25222-2-20cc: Sand with planktonic and benthic (*Elphidium*) foraminifera; **3.** Sample GeoB25222-2-20cc: Sand including IRD with planktoni and benthic (*Elphidium*) foraminifera, and bryozoa; **4**. Sample GeoB25220-1-3cc: Sand with the benthic foraminifer *Stainforthia* and sponge spicules (monaxones); **5.** Sample GeoB25220-1-3cc: Sand, including IRD, with planktonic foraminifera, sponge spicules and diatoms; **6**. GeoB25214-1-7cc: Sand, including IRD, with planktonic and benthic foraminifera; **7.** GeoB25223-1-6cc: Sand rich in diatoms; **8**. Sample GeoB25220-1-12cc: Sand with the benthic foraminifer *Elphidium*; **9.** Sample GeoB25223-1-2cc: Clayey pellets and lithified worm tube; **10**. Sample GeoB25223-1-7cc: Sand with seeds of *Betula glandulosa* and cf. *Alnus*.

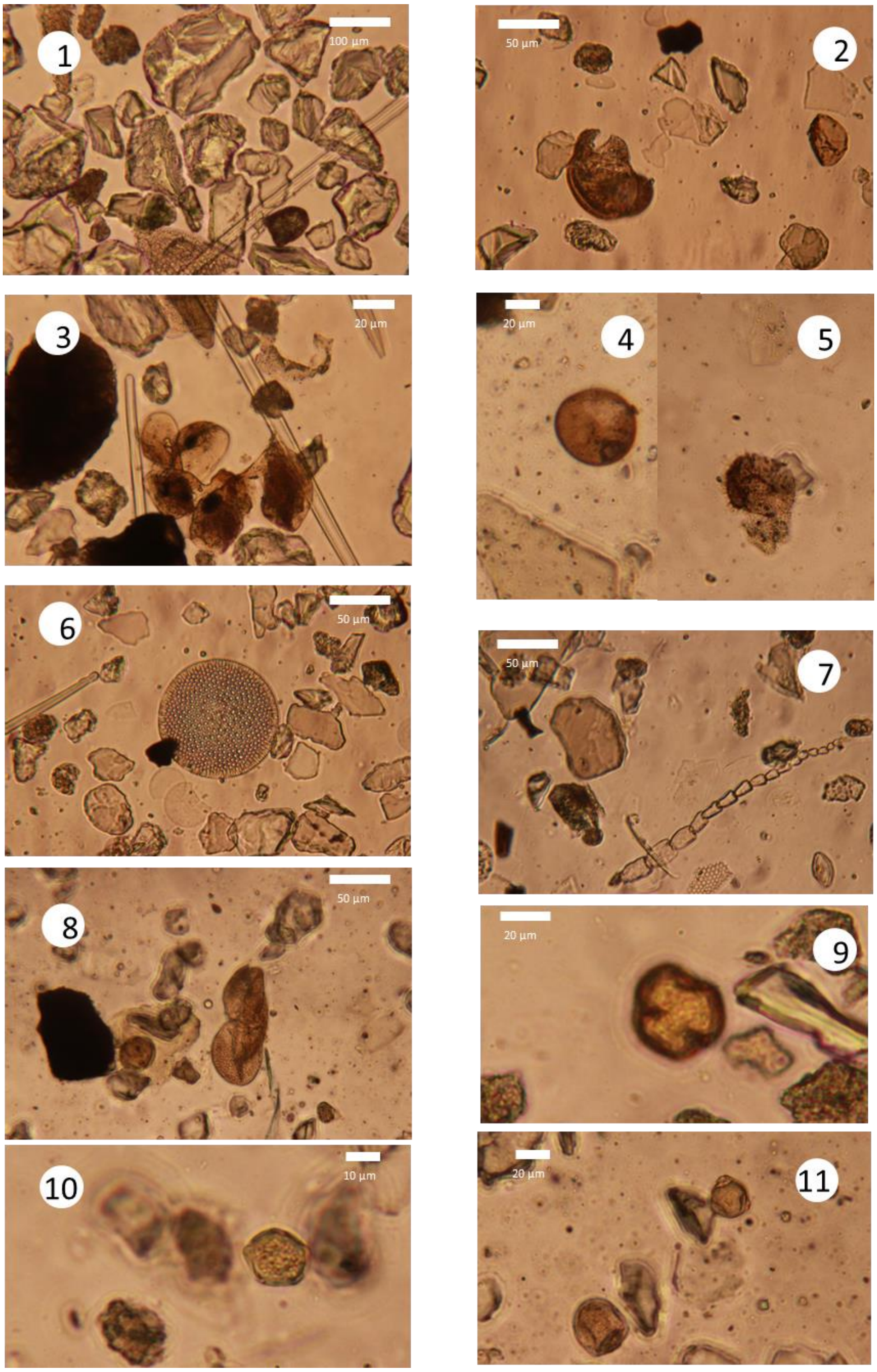

Fig. 5.5.30 Illustration of the 10-106 µm content in selected core catcher samples. **1.** Sample GeoB25220-1-3cc: minerals, sponge spicule and a diatom fragment; **2**. Sample GeoB25220-1-12cc: *Picea* pollen grain and dinocyst (*Brigantedinium* sp.); **3.** Sample GeoB25220-1-3cc: Organic lining of benthic foraminifera, sponge spicules and minerals; **4**.Sample GeoB25222-2-15cc: Close up on *Brigantedinium* (size ~35 µm); **5**. Sample GeoB25222-2-7cc: Close up on *Islandinium minutum* (size ~ 25 µm); **6.** Sample GeoB25220-1-12cc: diatom and sponge spicule; **7**. GeoB25222-1-GC-cc: organic lining of a uniserial benthic foraminifer; **8.** GeoB25223-1-9cc: *Picea* pollen grain ; **9**. Sample GeoB25223-1-7cc: Close up on tricolpate pollen grain (size ~ 25 µm); **10.** Sample GeoB25223-1-7cc: Close up on *Alnus* pollen grain (size ~ 20 µm); **10**. Sample GeoB25223-1-7cc: Pollen grain of *Betula* and Poaceae.

Table 5.5.8 >106 µm fraction. “X” stands for present or rare, “XX” for common, “XXX” for abundant. Reddish shading are carbonate remains and yellow shading are silicate microfossils. Sand occurrence from 0 (nil) to 4 (abundant). Calcium carbonate preservation based on benthic foraminifera morphology: G = good; d = evidence of dissolution; co = calcite overgrowth; p = pyritization.

Coring type	Core ID	Sample volume (cm³)	Sand	IRD	Planktic	Benthic	Carbonate	Ostracods	Echinoderm	Bryozoa	Bivalve	Diatoms	sponge	Radiolaria	Remarks
MeBo hole 1	GeoB25214-1-1														
MeBo hole 1	GeoB25214-1-2														
MeBo hole 1	GeoB25214-1-3	8	1		XX	X	co	X				XX	X		
MeBo hole 1	GeoB25214-1-4	7	2		XXX	XX	co	X	X			XX	XX	X	
MeBo hole 1	GeoB25214-1-5	6	1		XX	X						X	X		
MeBo hole 1	GeoB25214-1-6														
MeBo hole 1	GeoB25214-1-7	8	4	XX	XXX	XX	d	X	X		X				
MeBo hole 1	GeoB25214-1-8	10	1,5		X				X				X		
MeBo hole 1	GeoB25214-1-9	10	4		X										
MeBo hole 1	GeoB25214-1-10														
MeBo hole 1	GeoB25214-1-11	10	4	XX	X		co				X	X			
MeBo hole 1	GeoB25214-1-12	7	1,5		X	X	d, co					XX	XX		
MeBo hole 1	GeoB25214-1-13	10	4		X	X						XX	XX		
MeBo hole 1	GeoB25214-1-14	10	4		XXX	XXX	p					XX			
MeBo hole 1	GeoB25214-1-15														
MeBo hole 2	GeoB25220-1-1														
MeBo hole 2	GeoB25220-1-2	5	2		X								X		
MeBo hole 2	GeoB25220-1-3	5	3		XXX	XXX	g					XX	X	X	
MeBo hole 2	GeoB25220-1-4	5	2		X								X		
MeBo hole 2	GeoB25220-1-5	5	0		X	X	d								
MeBo hole 2	GeoB25220-1-6	5	3	XX	XX										
MeBo hole 2	GeoB25220-1-7	5	0,5		X							X	X		
MeBo hole 2	GeoB25220-1-8	5	2	XX											
MeBo hole 2	GeoB25220-1-9	5	1												
MeBo hole 2	GeoB25220-1-10	5	2,5		XX				X						
MeBo hole 2	GeoB25220-1-11	5	2,5	X	XX	X	co								
MeBo hole 2	GeoB25220-1-12	5	1			XX	d								
MeBo hole 2	GeoB25220-1-13	5	0,5												
MeBo hole 3	GeoB25222-2-1														
MeBo hole 3	GeoB25222-2-2														
MeBo hole 3	GeoB25222-2-3														
MeBo hole 3	GeoB25222-2-4														
MeBo hole 3	GeoB25222-2-5	6	4		XX										
MeBo hole 3	GeoB25222-2-6	5	0,5												
MeBo hole 3	GeoB25222-2-7	5	4		XX								XX		
MeBo hole 3	GeoB25222-2-8	7	4	X	XXX	XX		X	X				XXX		
MeBo hole 3	GeoB25222-2-9														
MeBo hole 3	GeoB25222-2-10	8	4	XXX	XXX	X	G						XX		
MeBo hole 3	GeoB25222-2-11														
MeBo hole 3	GeoB25222-2-12														
MeBo hole 3	GeoB25222-2-13														
MeBo hole 3	GeoB25222-2-14	5	4	XX	XXX	XX	co								
MeBo hole 3	GeoB25222-2-15	5	2		XX	X									
MeBo hole 3	GeoB25222-2-16	5	0								X				
MeBo hole 3	GeoB25222-2-17														
MeBo hole 3	GeoB25222-2-18														
MeBo hole 3	GeoB25222-2-19	5	1,5		XX								X		
MeBo hole 3	GeoB25222-2-20	5	4	XXX	XXX	XX	d	X		X	X				
Mebo hole 4	GeoB25223-1-1														
Mebo hole 4	GeoB25223-1-2	5	1,5	X		XX	d								Worm tube lithified
Mebo hole 4	GeoB25223-1-3	5	1	X	X										
Mebo hole 4	GeoB25223-1-4	5	0,2			XX	d					X			
Mebo hole 4	GeoB25223-1-5	5	0												
Mebo hole 4	GeoB25223-1-6	5	1,5	X	X							XXX	XXX	X	
Mebo hole 4	GeoB25223-1-7	5	1,5	X	X	X	d						X		seeds of *Betula* cf. *glandulosa*
Mebo hole 4	GeoB25223-1-8	5	0,2												
Mebo hole 4	GeoB25223-1-9	5	4	X	X	X	d								
Mebo hole 4	GeoB25223-1-10	5	1,5	XX		X	d					XX	XX		
Mebo hole 4	GeoB25223-1-11	5	0,2			XX	d						X		
Mebo hole 4	GeoB25223-1-12														
Gravity Core	GeoB25219-1cc	5	4		XXX	XX	G	X				XXX			
Gravity Core	GeoB25221-2cc	7	3,5	XX	XX	X	d		X			XXX	XXX	X	
Gravity Core	GeoB25222-1cc	5	1,5		XX	X									
Gravity Core	GeoB25224-1cc	10	4	XXX	X	X	G	X					X		

Table 5.5.9 Content of the 10-106 µm fraction. “X” stands for present or rare, “XX” for common and “XXX” for abundant. The yellowish shading corresponds to silicate microfossils and the greenish shading to organic-walled microfossils.

Coring type	Core ID	Diatoms	sponge spicules	Radiolaria	Silicoflagellate	Organic linings	Dinocyst : *Islandinium minutum*	Dinocyst: *Brigantedinium* spp.	Other dinocysts	Type cyst P	Halodinium	Reworked palynomorphs	Pollen grains
MeBo hole 1	GeoB25214-1-1												
MeBo hole 1	GeoB25214-1-2												
MeBo hole 1	GeoB25214-1-3	X	X			X							
MeBo hole 1	GeoB25214-1-4	XXX	XXX			X	X			X			X
MeBo hole 1	GeoB25214-1-5		X										
MeBo hole 1	GeoB25214-1-6												
MeBo hole 1	GeoB25214-1-7	XX	XX			X						X	
MeBo hole 1	GeoB25214-1-8	XX	X										
MeBo hole 1	GeoB25214-1-9	X	X										
MeBo hole 1	GeoB25214-1-10												
MeBo hole 1	GeoB25214-1-11	XXX	XX			X	X	X				X	
MeBo hole 1	GeoB25214-1-12	XXX	XX				XXX						
MeBo hole 1	GeoB25214-1-13	XXX	XXX				XX						
MeBo hole 1	GeoB25214-1-14		X										
MeBo hole 1	GeoB25214-1-15												
MeBo hole 2	GeoB25220-1-1												
MeBo hole 2	GeoB25220-1-2	XXX	XXX			XX		X		X		X	
MeBo hole 2	GeoB25220-1-3	XXX	XXX			XX	X			X			
MeBo hole 2	GeoB25220-1-4	XXX	XXX			XX							X
MeBo hole 2	GeoB25220-1-5		X				X	X					
MeBo hole 2	GeoB25220-1-6	XX	XX										
MeBo hole 2	GeoB25220-1-7	XX	XX										
MeBo hole 2	GeoB25220-1-8		X										
MeBo hole 2	GeoB25220-1-9	X	XX					X				X	
MeBo hole 2	GeoB25220-1-10	X	XX										
MeBo hole 2	GeoB25220-1-11												
MeBo hole 2	GeoB25220-1-12	XX	XX				X	XX					
MeBo hole 2	GeoB25220-1-13		X										
MeBo hole 3	GeoB25222-2-1												
MeBo hole 3	GeoB25222-2-2												
MeBo hole 3	GeoB25222-2-3												
MeBo hole 3	GeoB25222-2-4												
MeBo hole 3	GeoB25222-2-5	XX	XX			XX	XX			X	X	X	
MeBo hole 3	GeoB25222-2-6		X										
MeBo hole 3	GeoB25222-2-7	XX	XX			XX	XXX	XX		X			
MeBo hole 3	GeoB25222-2-8	XXX	XXX			XX	XXX	XX					
MeBo hole 3	GeoB25222-2-9												
MeBo hole 3	GeoB25222-2-10	XXX	XXX		X	XX	XX	X					
MeBo hole 3	GeoB25222-2-11												
MeBo hole 3	GeoB25222-2-12												
MeBo hole 3	GeoB25222-2-13												
MeBo hole 3	GeoB25222-2-14	X	XX					XX				XX	
MeBo hole 3	GeoB25222-2-15	XX	XX			X	XX	XX					
MeBo hole 3	GeoB25222-2-16	X	X									X	
MeBo hole 3	GeoB25222-2-17												
MeBo hole 3	GeoB25222-2-18												
MeBo hole 3	GeoB25222-2-19	XXX	XXX	X		X	XX	XXX				X	
MeBo hole 3	GeoB25222-2-20	XX	XX					XX				X	
Mebo hole 4	GeoB25223-1-1												
Mebo hole 4	GeoB25223-1-2	XX	XX			X		X	X				
Mebo hole 4	GeoB25223-1-3	X	X					X				X	
Mebo hole 4	GeoB25223-1-4	XX	XX					XX				X	
Mebo hole 4	GeoB25223-1-5	X	X			XX						X	
Mebo hole 4	GeoB25223-1-6	XXX	XXX			X		XXX	XX				
Mebo hole 4	GeoB25223-1-7	XX	XX										XXX
Mebo hole 4	GeoB25223-1-8		X										
Mebo hole 4	GeoB25223-1-9	X										X	AA
Mebo hole 4	GeoB25223-1-10	XX	XX			XX		X					
Mebo hole 4	GeoB25223-1-11	XX	XX										
Mebo hole 4	GeoB25223-1-12												
Gravity Core	GeoB25219-1cc	XX	XX			XX	XXX	X			X		
Gravity Core	GeoB25221-2cc	XXX	XXX			XX	XXX						
Gravity Core	GeoB25222-1cc	XX	XX							X			
Gravity Core	GeoB25224-1cc	X	X				X					X	

6 Ship’s Meteorological Station

There was no meteorologist on board.

7 Station List MSM111

Device key: CTD = shipboard CTD with rosette, EM122 = deep sea multibeam echosounder, EM712 = shallow water multibeam echosounder, FLOAT = ARGO float deployment, GC = gravity corer, MSN = multiple closing plankton net with CTD and water sampler, MUC = multicorer, PS = Parasound, SVP = sound velocity profiler. For all devices, the position and time of deployment from ship is recorded.

Station	GeoB No.	Date and Time [UTC]	Latitude	Longitude	Depth [m]	Device	Comment
MSM111_1-1	25201-1	03.09.2022 11:03	63° 52.048' N	028° 56.819' W	1607	MUC + SVP	
MSM111_1-2	25201-2	03.09.2022 12:22	63° 52,055' N	028° 56.790' W	1607	GC	Core barrel: 12m
MSM111_1-3	25201-3	03.09.2022 16:22	63° 52.060' N	028° 56.784' W	1617	GC	Core barrel: 18m
MSM111_2-1	25202-1	03.09.2022 21:38	63° 15.497' N	028° 15.042' W	1722	MUC + SVP	
MSM111_2-2	25202-2	03.09.2022 22:55	63° 15.507' N	028° 15.063' W	1721	GC	Core barrel: 12m
MSM111_3-1	25203-1	04.09.2022 08:02	62° 39.294' N	030° 52.302' W	2590	CTD	
MSM111_3-2	25203-2	04.09.2022 10:01	62° 39.294' N	030° 52.301' W	2586	MSN	
MSM111_3-3	25203-3	04.09.2022 10:27	62° 39.294' N	030° 52.301' W	2587	MSN	
MSM111_4-1	25204-1	05.09.2022 08:02	60° 48.128' N	037° 30.180' W	2956	CTD	
MSM111_4-2	25204-2	05.09.2022 10:13	60° 48.128' N	037° 30.181' W	2957	MSN	
MSM111_4-3	25204-3	05.09.2022 10:32	60° 48.129' N	037° 30.180' W	2957	MSN	
MSM111_5-1	25205-1	06.09.2022 11:36	58° 40.246' N	044° 33.092' W	1845	CTD	
MSM111_5-2	25205-2	06.09.2022 13:02	58° 40.246' N	044° 33.093' W	1845	MSN	
MSM111_5-3	25205-3	06.09.2022 13:24	58° 40.246' N	044° 33.092' W	1844	MSN	
MSM111_6-1	25206-1	07.09.2022 10:51	60° 56.191' N	046° 09.248' W	275	MUC	
MSM111_6-2	25206-2	07.09.2022 11:16	60° 56.206' N	046° 09.290' W	274	GC	Core barrel: 12m
MSM111_7-1	25207-1	08.09.2022 09:03	61° 18.353' N	050° 23.227' W	2804	CTD	
MSM111_7-2	25207-2	08.09.2022 11:02	61° 18.353' N	050° 23.227' W	2804	MSN	
MSM111_7-3	25207-3	08.09.2022 11:22	61° 18.379' N	050° 23.188' W	2801	MSN	
MSM111_8-1	25208-1	09.09.2022 09:01	64° 33.439' N	055° 17.858' W	768	CTD	

MSM111_8-2	25208-2	09.09.2022 09:49	64° 33.439' N	055° 17.859' W	767	MSN	
MSM111_8-3	25208-3	09.09.2022 10:08	64° 33.439' N	055° 17.860' W	765	MSN	
MSM111_9-1	25209-1	10.09.2022 12:52	68° 54.357' N	059° 54.559' W	1541	CTD	
MSM111_9-2	25209-2	10.09.2022 14:10	68° 54.360' N	059° 54.560' W	1541	MSN	
MSM111_10-2	NA	10.09.2022 14:41	68° 54.416' N	059° 54.352' W	1527	PS	profile start
MSM111_10-1	NA	10.09.2022 14:41	68° 54.416' N	059° 54.352' W	1527	EM122	profile start
MSM111_10-1	NA	12.09.2022 15:44	68° 38.437' N	060° 02.381' W	1442	EM122	profile interrupted
MSM111_10-2	NA	12.09.2022 15:44	68° 38.437' N	060° 02.381' W	1442	PS	profile interrupted
MSM111_10-2	NA	12.09.2022 17:40	68° 38.442' N	060° 03.294' W	1457	PS	profile resumed
MSM111_10-1	NA	12.09.2022 17:40	68° 38.442' N	060° 03.294' W	1457	EM122	profile resumed
MSM111_10-1	NA	13.09.2022 10:48	68° 52.062' N	060° 14.438' W	1625	EM122	profile end
MSM111_10-2	NA	13.09.2022 10:48	68° 52.062' N	060° 14.438' W	1627	PS	profile end
MSM111_11-1	25210-1	12.09.2022 15:57	68° 38.402' N	060° 03.584' W	1458	CTD	
MSM111_11-2	25210-2	12.09.2022 17:06	68° 38.401' N	060° 03.583' W	1453	MSN	
MSM111_11-3	25210-3	12.09.2022 17:21	68° 38.402' N	060° 03.583' W	1457	MSN	
MSM111_12-1	25211-1	13.09.2022 10:54	68° 52.063' N	060° 14.435' W	1628	MUC	
MSM111_13-1	25212-1	13.09.2022 13:05	68° 47.616' N	059° 59.433' W	1505	MUC	
MSM111_13-2	25212-2	13.09.2022 14:19	68° 47.620' N	059° 59.429' W	1505	GC	Core barrel: 12m
MSM111_13-3	25212-3	13.09.2022 17:18	68° 47.621' N	059° 59.424' W	1504	GC	Core barrel: 18m
MSM111_14-1	25213-1	13.09.2022 19:54	68° 43.453' N	059° 29.394' W	868	MUC	
MSM111_15-1	NA	13.09.2022 20:39	68° 43.387' N	059° 29.368' W	868	EM122	profile start
MSM111_15-2	NA	13.09.2022 20:39	68° 43.386' N	059° 29.367' W	870	PS	profile start
MSM111_15-1	NA	14.09.2022 21:26	68° 38.531' N	060° 05.009' W	1468	EM122	profile end
MSM111_15-2	NA	14.09.2022 21:26	68° 38.531' N	060° 05.009' W	1468	PS	profile end
MSM111_16-1	25214-1	14.09.2022 22:54	68° 47.513' N	059° 59.186' W	1506	MeBo	
MSM111_17-2	NA	16.09.2022 17:00	68° 42.798' N	059° 13.108' W	510	PS	profile start
MSM111_17-1	NA	16.09.2022 17:00	68° 42.798' N	059° 13.108' W	510	EM122	profile start
MSM111_17-1	NA	17.09.2022 03:45	68° 29.829' N	054° 24.736' W	319	EM122	profile end

MSM111_17-2	NA	17.09.2022 03:45	68° 29.829' N	054° 24.736' W	319	PS	profile end
MSM111_17-3	NA	16.09.2022 20:09	68° 39.104' N	057° 51.020' W	290	EM712	profile start
MSM111_17-3	NA	16.09.2022 20:54	68° 38.174' N	057° 30.289' W	325	EM712	profile end
MSM111_18-1	25215-1	17.09.2022 10:48	68° 46.201' N	051° 24.599' W	366	MUC	
MSM111_19-1	25216-1	17.09.2022 16:30	69° 13.143' N	051° 12.168' W	303	MUC	
MSM111_20-1	25217-1	17.09.2022 21:53	69° 50.993' N	051° 43.198' W	625	MUC	
MSM111_20-2	25217-2	17.09.2022 22:35	69° 50.990' N	051° 43.198' W	303	GC	Core barrel: 12m
MSM111_21-1	NA	18.09.2022 11:35	68° 33.790' N	055° 38.207' W	347	EM122	profile start
MSM111_21-2	NA	18.09.2022 11:35	68° 33.790' N	055° 38.207' W	347	PS	profile start
MSM111_21-1	NA	18.09.2022 13:14	68° 27.788' N	056° 04.156' W	487	EM122	profile interrupted
MSM111_21-2	NA	18.09.2022 13:15	68° 27.788' N	056° 04.156' W	485	PS	profile interrupted
MSM111_21-1	NA	18.09.2022 13:56	68° 27.789' N	056° 04.158' W	483	EM122	profile resumed
MSM111_21-2	NA	18.09.2022 13:56	68° 27.789' N	056° 04.159' W	486	PS	profile resumed
MSM111_21-2	NA	18.09.2022 23:36	68° 35.607' N	056° 23.407' W	357	PS	profile end
MSM111_21-1	NA	18.09.2022 23:36	68° 35.639' N	056° 23.424' W	355	EM122	profile end
MSM111_22-1	25218-1	18.09.2022 13:20	68° 27.787' N	056° 04.158' W	483	CTD	
MSM111_23-1	25219-1	19.09.2022 08:49	68° 41.819' N	059° 38.404' W	1101	GC	Core barrel: 18m
MSM111_24-1	25220-1	19.09.2022 11:12	68° 38.489' N	060° 02.774' W	1459	MeBo	
MSM111_25-2	NA	21.09.2022 10:27	68° 38.494' N	059° 59.661' W	1421	PS	profile start
MSM111_25-1	NA	21.09.2022 10:27	68° 38.494' N	059° 59.661' W	1421	EM122	profile start
MSM111_25-1	NA	21.09.2022 14:03	68° 37.361' N	060° 53.710' W	1729	EM122	profile interrupted
MSM111_25-2	NA	21.09.2022 14:03	68° 37.361' N	060° 53.710' W	1729	PS	profile interrupted
MSM111_25-2	NA	21.09.2022 16:58	68° 37.390' N	060° 53.722' W	1732	PS	profile resumed
MSM111_25-1	NA	21.09.2022 16:58	68° 37.390' N	060° 53.722' W	1732	EM122	profile resumed
MSM111_25-2	NA	21.09.2022 21:00	68° 38.451' N	060° 03.486' W	1465	PS	profile end
MSM111_25-1	NA	21.09.2022 21:19	68° 38.236' N	060° 11.929' W	1521	EM122	profile end
MSM111_26-1	25221-1	21.09.2022 14:14	68° 37.353' N	060° 53.874' W	1732	MUC	
MSM111_26-2	25221-2	21.09.2022 15:34	68° 37.355' N	060° 53.872' W	1728	GC	Core barrel: 18m

MSM111_27-1	25222-1	21.09.2022 21:51	68° 38.345' N	060° 06.714' W	1486	GC	Core barrel: 18m
MSM111_27-2	25222-2	21.09.2022 23:12	68° 38.366' N	060° 06.743' W	1492	MeBo	
MSM111_28-2	NA	24.09.2022 09:53	68° 38.213' N	060° 12.969' W	1530	PS	profile start
MSM111_28-1	NA	24.09.2022 09:53	68° 38.213' N	060° 12.969' W	1530	EM122	profile start
MSM111_28-1	NA	24.09.2022 22:23	68° 40.280' N	059° 59.645' W	1434	EM122	profile end
MSM111_28-2	NA	24.09.2022 22:23	68° 40.269' N	059° 59.760' W	1436	PS	profile end
MSM111_29-1	25223-1	24.09.2022 22:59	68° 38.434' N	060° 02.758' W	1449	MeBo	
MSM111_30-2	NA	26.09.2022 14:34	68° 38.391' N	060° 02.898' W	1449	PS	profile start
MSM111_30-1	NA	26.09.2022 14:34	68° 38.391' N	060° 02.898' W	1449	EM122	profile start
MSM111_30-2	NA	26.09.2022 19:45	68° 36.447' N	061° 20.349' W	1769	PS	profile end
MSM111_30-1	NA	26.09.2022 19:45	68° 36.447' N	061° 20.349' W	1769	EM122	profile end
MSM111_31-1	25224-1	26.09.2022 20:02	68° 36.629' N	061° 18.352' W	1768	GC	Core barrel: 18m
MSM111_32-1	25225-1	27.09.2022 00:12	68° 20.055' N	060° 15.211' W	1513	CTD	
MSM111_33-1	NA	27.09.2022 01:23	68° 20.057' N	060° 15.210' W	1513	EM122	profile start
MSM111_33-1	NA	28.09.2022 06:48	68° 14.978' N	060° 16.112' W	1533	EM122	profile end
MSM111_33-2	NA	27.09.2022 01:24	68° 20.061' N	060° 15.208' W	1512	PS	profile start
MSM111_33-2	NA	28.09.2022 06:48	68° 14.978' N	060° 16.112' W	1533	PS	profile end
MSM111_34-1	NA	29.09.2022 05:46	64° 22.264' N	056° 33.745' W	727	EM122	profile start
MSM111_34-2	NA	29.09.2022 05:46	64° 22.264' N	056° 33.745' W	727	PS	profile start
MSM111_34-2	NA	29.09.2022 16:54	64° 27.876' N	055° 50.272' W	989	PS	profile end
MSM111_34-1	NA	29.09.2022 16:54	64° 27.876' N	055° 50.272' W	989	EM122	profile end
MSM111_35-1	25226-1	29.09.2022 17:52	64° 31.250' N	056° 05.137' W	905	MUC	
MSM111_35-2	25226-2	29.09.2022 18:42	64° 31.249' N	056° 05.144' W	905	GC	Core barrel: 12m
MSM111_36-1	NA	01.10.2022 10:16	58° 26.425' N	049° 33.088' W	3522	FLOAT	P43244-22DE001
MSM111_37-1	25227-1	01.10.2022 17:09	57° 20.416' N	048° 29.987' W	3421	MSN	
MSM111_37-2	25227-2	01.10.2022 18:18	57° 20.417' N	048° 29.988' W	3423	MSN	
MSM111_37-3	25227-3	01.10.2022 18:45	57° 20.416' N	048° 29.987' W	3423	MSN	

8 Data and Sample Storage and Availability

All samples of planktonic foraminifera from the net hauls are stored and curated at MARUM. Phytoplankton filter samples are stored and curated at the University of Tübingen. All MUC cores have been completely sampled; residues are being processed by the participating groups. with most analyses being destructive. Unused residues of all the above material will be made available upon request 3 years after the cruise. All hydrographic data from the CTD and multinet casts are publicly available on PANGAEA. Sediment porewater samples are curated at MARUM; their analyses are destructive. and residues will not be available. Bathymetry and shallow seismic data are stored at PANGAEA and will be made publicly available after a three-year moratorium. The same three-year moratorium applies to all sediment cores taken during the cruise. which are stored and archived at the MARUM GeoB core repository. and will be then available for sampling following the established material access procedures of the GeoB repository.

Table 8.1 Overview of data and samples availability

Type of data/samples	Database/Repository	Available	Free Access	Contact
Bathymetry	Pangaea	November 2022	November 2025	AWI/Simon Dreutter
PARASOUND	Pangaea	November 2022	November 2025	Katharina Streuff
CTD	Pangaea	November 2022	March 2022	Michael Siccha
CTD-MPS	Pangaea	November 2022	March 2022	Michael Siccha
Thermosalinograph	Pangaea	November 2022	March 2022	Michael Siccha
Phytoplankton filters from CTD	University of Tübingen	November 2022	November 2025	Hartmut Schulz
Zooplankton filters from MPS	MARUM – AG Kucera	November 2022	November 2025	Raphael Morard
Planktonic foraminifera from MPS	MARUM – AG Kucera	November 2022	November 2025	Julie Meilland
MUC samples	Sample residues available from participating groups	December 2022	November 2025	Michal Kucera
Gravity cores	MARUM GeoB core repository	December 2022	November 2025	Vera Bender
MeBo cores	MARUM GeoB core repository	December 2022	November 2025	Vera Bender
Core logging data	Pangaea	November 2022	November 2025	Tilo von Dobeneck
MeBo borehole logging data	Pangaea	November 2022	November 2025	Tim Freudenthal

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All maps in this cruise report were created using the software ESRI ArcGIS and finished using Adobe Illustrator. ArcGIS© and ArcMap™ are the intellectual property of ESRI and are used herein under licence. Basemaps used are the World Imagery Basemap. courtesy of ESRI. and the General Bathymetric Chart of the Ocean. Multibeam data were processed using CARIS Hips as well as QPS Qimera. Parasound software was processed using SMT The Kingdom Suite v. 2020. Funding for Henrieka Detlef was provided by the Danish Council for Independent Research 0135-00165B (GreenShelf) to Marit-Solveig Seidenkrantz. and by the European Union's Horizon 2020 research and innovation program under Grant Agreement No. 869383 (ECOTIP).

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