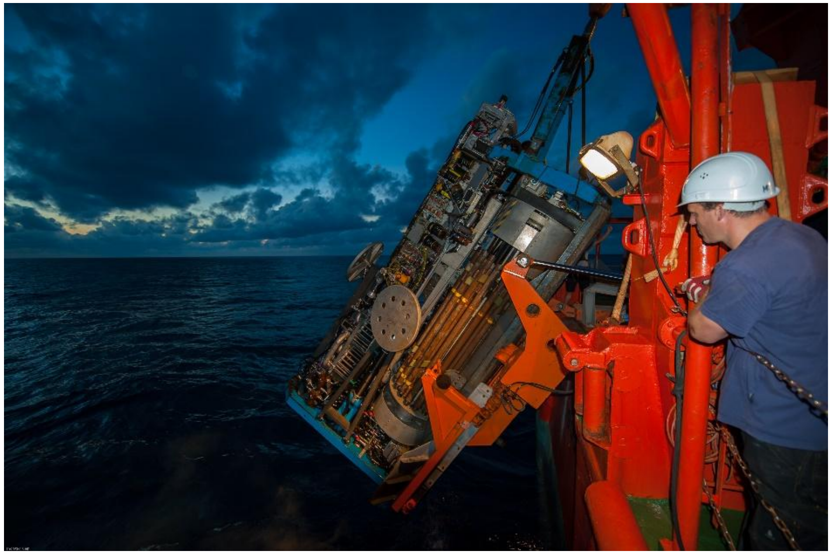
The Sea Floor Drill Rigs MARUM-MeBo

T. Freudenthal

Foto: T. Klein; MARUM-MeBo70 on the ice-breaking research vessel POLARSTERN in the Amundsen Sea Embayment during expedition PS104

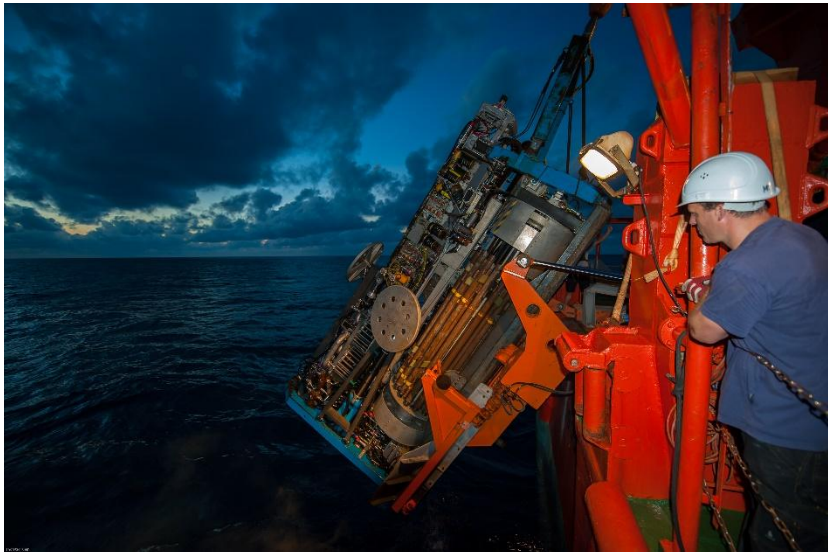
The MARUM-MeBo drilling systems

MARUM-MeBo70	MARUM-MeBo200
	

MeBo: Meeresboden-Bohrgerät
Robotic drill for getting cores from soft sediments and hard rocks deployed on the sea bed, remotely powered and controled from the vessel

2000 m	Deployment depth	2700 m
70 m	Drilling depth	200 m
10 t	Weight in air	10 t
Fits into 20‘ cont.	size	Transp. as 20‘ cont.

MeBo deployment statistics 2005 - 2023

MARUM-MeBo70		MARUM-MeBo200
		
2008 (2005)	• Start of operation (conventional coring)	2014
22	• Number of expeditions	6
189	• Number of deployments	41
80.85 m	• Maximum drilling depth	147.4 m
4229 m	• Total drilling length	2619 m
67%	• Average core recovery	68%

Concept of MeBo

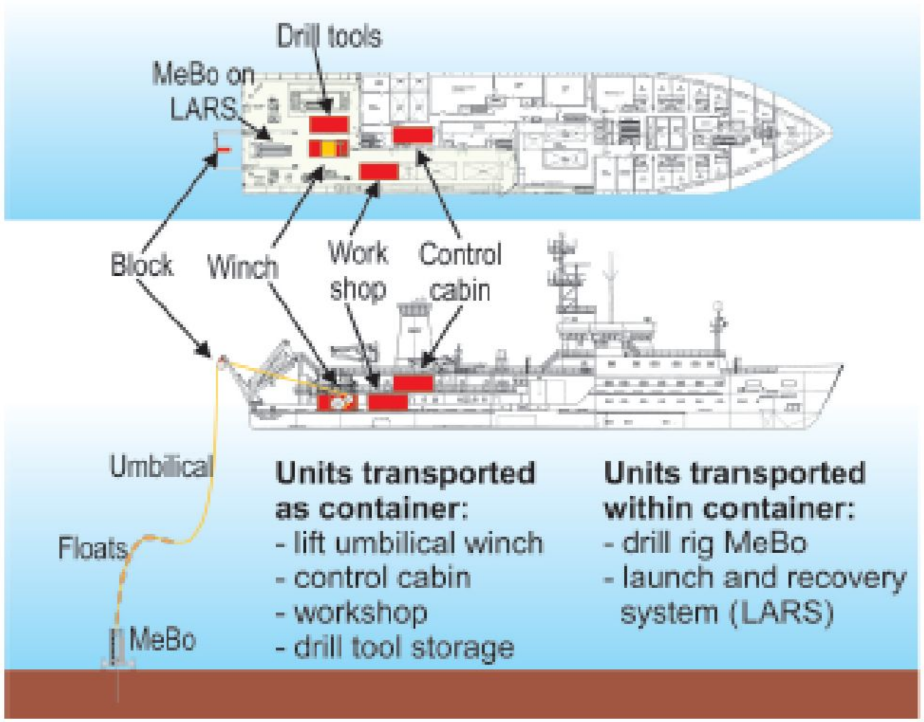


Fig. 1. Typical operational setup for a remote-controlled drill rig that is lowered to the sea floor. As an example, the sea floor drill rig MeBo and the research vessel *Maria S. Merian* is shown.

- **Umbilical is used to lower the drill rig to the sea floor**
- **Umbilical is used for energy supply and remote control from the vessel**
- **Transport of the system within 20' shipping containers, that are mounted on the working deck of the research vessel**

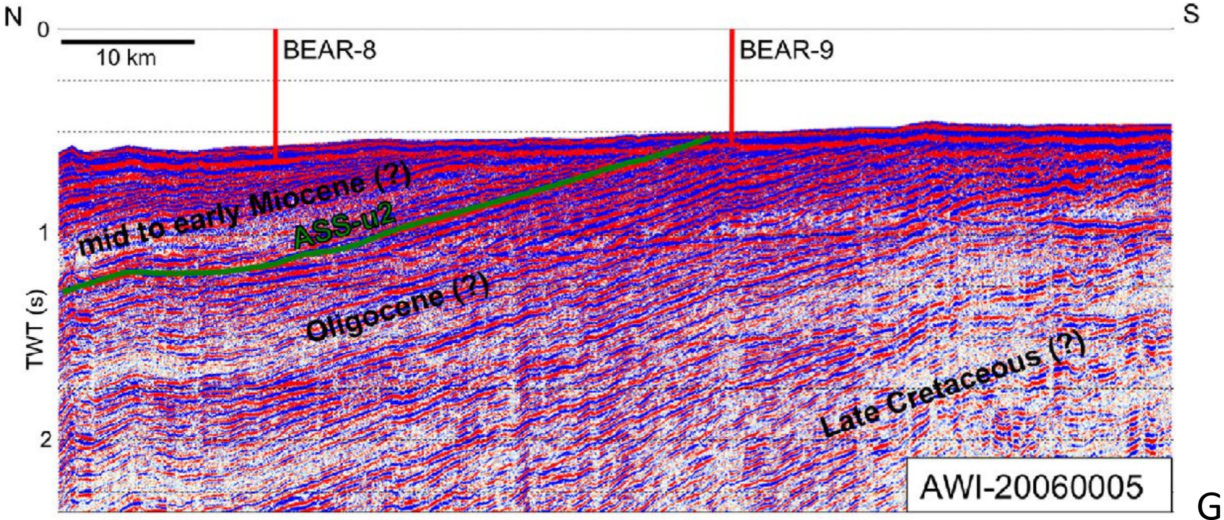
Freudenthal and Wefer, 2013

- **Since 2008: use of H-size wire line coring technique**
- **Since 2010: development of bore hole logging and testing capability**
  Sensors: SGR, Dual Induction, Acoustic, Magnetic Susceptibility, Temperature, CPT
- **Since 2012: Installation of Circulation Obviation Retrofit Kits (CORK)**

Shallow drilling (up to 200 mbsf) with sea bed drill rigs

Operational features:

- **Drilling from a stable platform at the sea bed is prerequisite for high core quality**
- **Combination of open hole and core drilling is possible**
- **Multiple hole drilling is conducted when a continuous record is needed**
- **Transect drilling in dipping strata allows for collecting cores with a range of different ages**



Gohl et al. 2017

Figure 5. Seismic record from the middle shelf of the western ASE shows dipping older shelf sequence with a presumed stratigraphic age and unconformity ASS-u2 from Gohl et al. (2013). The Parasound records on top show some of the dipping layer boundaries of the sequence overlain by a thin glacial and postglacial drape at drill sites BEAR-8 and BEAR-9. The vertical axes in both record types are two-way traveltime (TWT).

Scientific Applications of MARUM-MeBo:
Hard rock drilling on the Antarctic continental shelf

Article

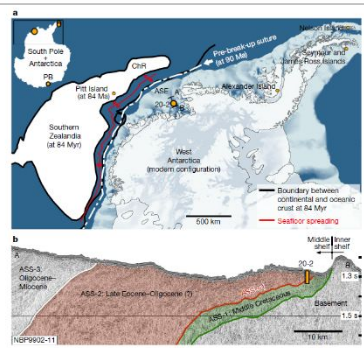


Fig. 1 | Setting of MARUM-MeBo70 drill site PS104_20-2 on the ASE shelf. **a**, The present-day location of West Antarctica is shown in relation to the reconstructed boundary between continental and oceanic crust at 84 Ma (refs. [31,32]) (thick black lines). The pre-break up suture (dashed white line) indicates the position of the reconstructed Zealandian and West Antarctic continental and oceanic crust before initial break-up starting at ~90 Ma (ref. [31]). Orange circles mark the locations of other outcrops of mid-Cretaceous sedimentary strata[13–17]. **b**, Seismic reflection profile NBP9902-11[21] (A–B) crossing drill site PS104_20-2. The orange bar indicates the drilled core length. The profile position is indicated in **a**. The drill hole penetrated Amundsen Sea shelf unconformity ASS-u1, which separates seismic units ASS-1 and ASS-2 (ref. [20]). The interpretation of seismostratigraphic units and unconformities is based on both previous work[24] and this study. Pitt Island belongs to the Chatham Island group of New Zealand. PB, Prydz Bay; ChR, Chatham Rise. Shelf bathymetry and sub-ice topography data derive from refs. [54,55].

Article

Temperate rainforests near the South Pole during peak Cretaceous warmth

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Johann P. Klages[1], Ulrich Salzmann[2], Torsten Bickert[3], Claus-Dieter Hillenbrand[4], Karsten Gohl[1], Gerhard Kuhn[1], Steven M. Bohaty[5], Jürgen Titschack[3,6], Juliane Müller[1,3,7], Thomas Frederichs[3,7], Thorsten Bauersachs[8], Werner Ehrmann[9], Tina van de Flierdt[10], Patric Simões Pereira[10,14], Robert D. Larter[4], Gerrit Lohmann[1,3,11], Igor Niezgodzki[1,12], Gabriele Uenzelmann-Neben[1], Maximilian Zundel[7], Cornelia Spiegel[7], Chris Mark[13,15], David Chew[13], Jane E. Francis[4], Gernot Nehrke[1], Florian Schwarz[2], James A. Smith[4], Tim Freudenthal[3], Oliver Esper[1], Heiko Pälike[3,7], Thomas A. Ronge[1], Ricarda Dziadek[1] & the Science Team of Expedition PS104*

- First drilling ever in the Amundsen Sea embayment
- Drilling of transects on dipping strata allowed sampling of different time windows documenting the West Antarctic glaciation history
- Oldest strata drilled from upper Cretaceous

MeBo drilling was required since

- **Glacial diamictons and older sedimentary rocks were not suitable for gravity coring**
- **MeBo was deployed from ice breaking vessel due to ice conditions**

Scientific Applications of MARUM-MeBo: Coring cold water coral mounds down to the base

Quaternary Science Reviews 293 (2022) 107723

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Contents lists available at ScienceDirect

Quaternary Science Reviews

journal homepage: www.elsevier.com/locate/quascirev

Cold-water coral mounds in the western Mediterranean Sea: New insights into their initiation and development since the Mid-Pleistocene in response to changes of African hydroclimate

C. Wienberg [a,*], T. Krengel [b], N. Frank [b], H. Wang [a,c], D. Van Rooij [d], D. Hebbeln [a]

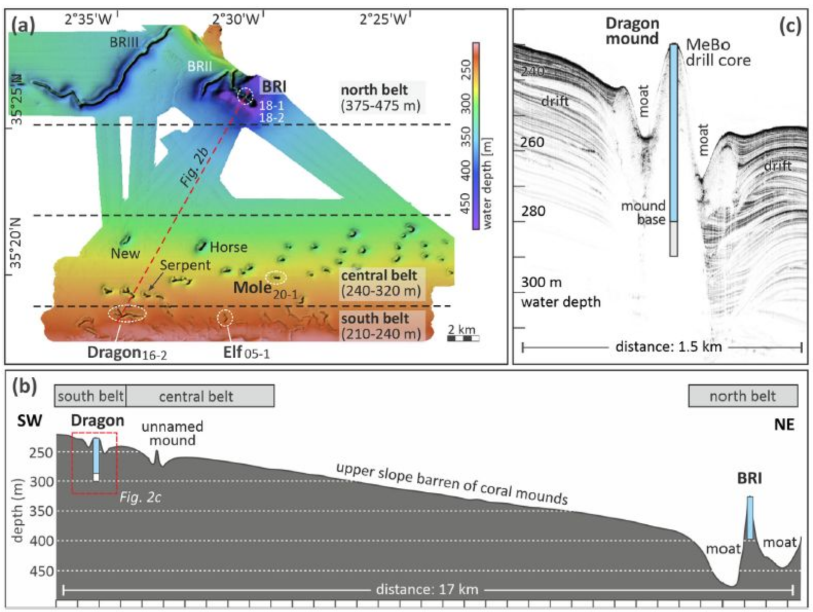


Fig. 2. The East Melilla cold-water coral mound province. (**a**) Shaded-relief map showing the East Melilla coral mounds/ridges, which are grouped into three belts (modified after Hebbeln 2019). The location of MeBo drill sites on top of Brittlestar ridge I (BRI) and Dragon mound, and gravity cores collected from BRI, Mole and Elf mounds are indicated by dotted circles (core-IDs: GeoB181xx-x). The dashed red line indicates the position of the altitude profile shown in Fig. 2b. (**b**) Altitude profile crossing the MeBo drill sites on top of the shallow Dragon mound in the SW and of the steep and large BRI in the NE. The dashed red box indicates the drill site on Dragon mound shown in detail in Fig. 2c. (**c**) Sub-bottom profile showing the Dragon mound surrounded by moats and drift sediments. The position of the MeBo core penetrating the mound base is indicated (blue: coral-bearing sediments, white: coral-barren sediments). (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

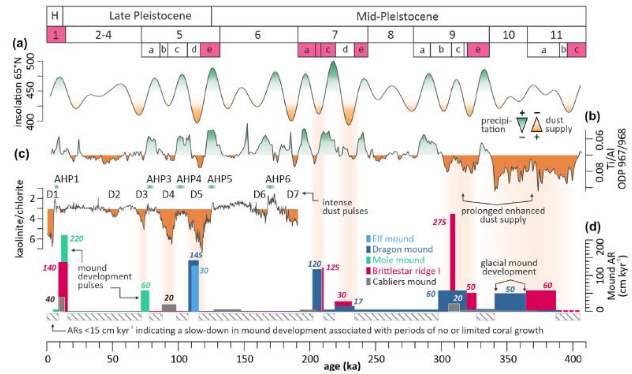


Fig. 4. (**a**) Summer (21 June) insolation curve for 65°N (Laskar et al. 2004). Insolation maxima (green peaks) indicated times of intensified African monsoon precipitation (e.g., Grant et al. 2017), insolation minima (orange peaks) indicate times of enhanced dust supply from the Sahara and northern Africa (e.g., Ehrmann et al. 2017; Sabatier et al. 2020). (**b**) Ti/Al ratio of the composite ODP 967/968 record (Levantine Basin). The Ti/Al in the sediments at these ODP sites is considered to be determined by two major sources, the Nile river suspended matter (depleted in titanium) and windblown dust (enriched in titanium). The Ti/Al changes are therefore linked to monsoonal-induced humidity changes in central to northern Africa (Ziegler et al. 2010; Konijnendijk et al. 2014). (**c**) Influx of clay-sized Saharan dust to the Mediterranean Sea as expressed by the kaolinite/chlorite ratios in a sediment core collected off the Libyan coast. Intense dust pulses (orange peaks) following African Humid Periods (AHP) are labelled D1-D7 (Ehrmann and Schmiedl 2021). Dust pulses D3–D5 coincided with pronounced mound development pulses during the last interglacial. (**d**) Mound aggradation rates (ARs) calculated for the East Melilla mounds and one Cabliers mound (MD13-3469G, water depth: 417 m; Corbera et al. 2021). ARs of > 15 cm kyr^{-1} (and up to 220 cm kyr^{-1}) are interpreted to represent periods of enhanced mound development, while ARs of < 15 cm kyr^{-1} correspond to times without or limited coral growth that led to a slow-down or stagnation in mound development (AR threshold according to Frank et al. 2009). (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

- Cold water coral mounds were cored down to the mound base
- The onset of mound growth occured in the Mid-Pleistocene
- Mound growth in the Western Mediterranean Sea showed a remarkebly coherent pattern with precession driven changes in African hydroclimate

MeBo drilling was required since

- **Deep drilling with MeBo allowed to reach the base of the mound**

Scientific Applications of MARUM-MeBo: Gas hydrate dissociation off Svalbard


nature COMMUNICATIONS

ARTICLE

DOI: 10.1038/s41467-017-02550-9 OPEN

Gas hydrate dissociation off Svalbard induced by isostatic rebound rather than global warming

Klaus Wallmann[1], M. Riedel[1], W.L. Hong[2,3], H. Patton[3], A. Hubbard[3,4], T. Pape[5], C.W. Hsu[5], C. Schmidt[1], J.E. Johnson[6], M.E. Torres[7], K. Andreassen[3], C. Berndt[1] & G. Bohrmann[5]

NATURE COMMUNICATIONS | (2018)9:83 | DOI: 10.1038/s41467-017-02550-9 | www.nature.com/naturecommunications

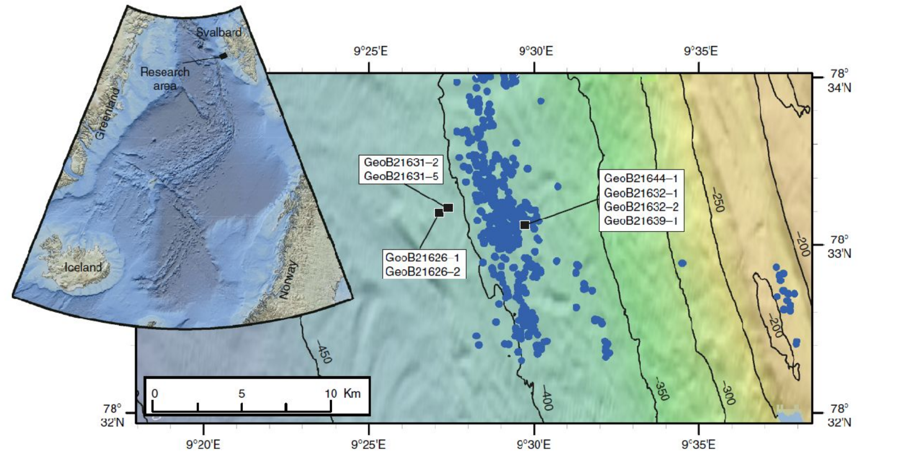
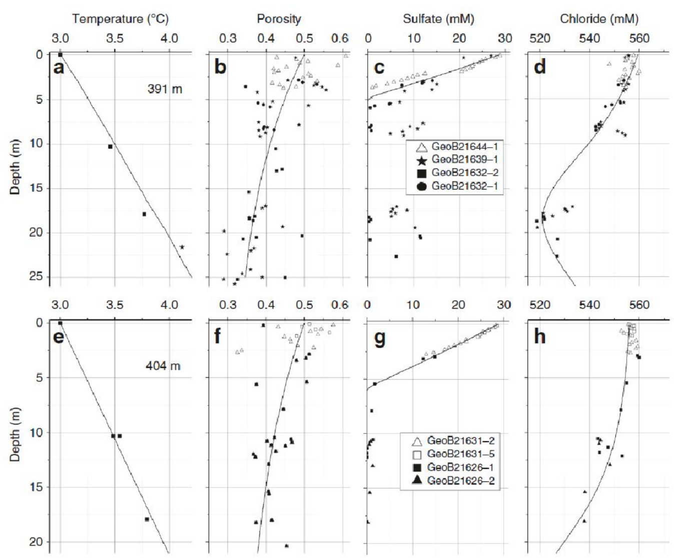


Fig. 1 Location of coring sites and gas flares. Gas flares (blue dots) were identified during a previous cruise[11]. Locations are listed in Supplementary Table 1

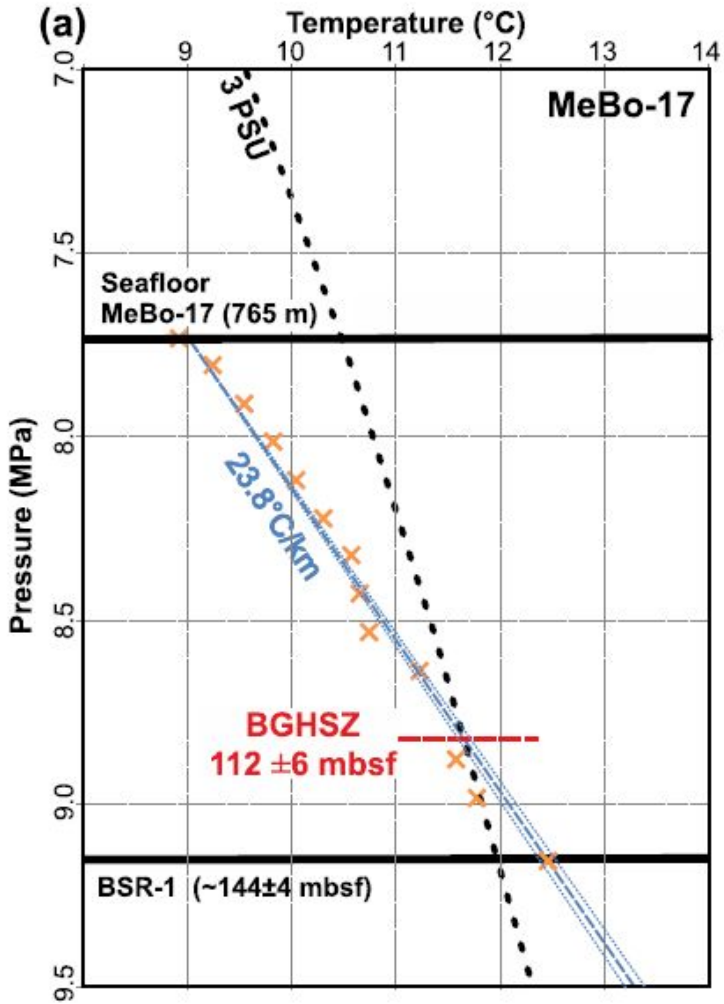


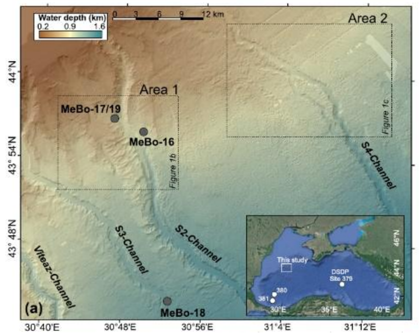
- Porewater salinity anomalies indicate dissociation of gas hydrates
- Temperature gradients were used to identify gas hydrate stability zone

MeBo drilling was required since

- **Glacial diamictons were not suitable for gravity coring**
- **Drilling through and sampling of authigenic carbonates**
- **Base of gas hydrate stability zone within the reach of MeBo**

Scientific Applications of MARUM-MeBo: Temperature gradient and gas hydrate stability zone at the Danube Deep Sea Fan





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In-situ borehole temperature measurements confirm dynamics of the gas hydrate stability zone at the upper Danube deep sea fan, Black Sea

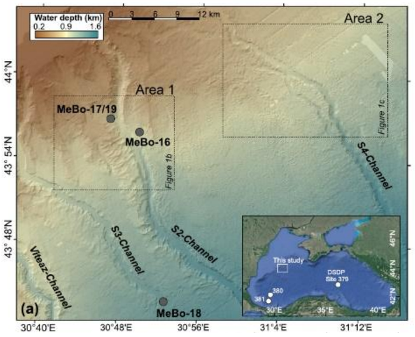
Michael Riedel [a,*], Tim Freudenthal [b], Jörg Bialas [a], Cord Papenberg [a], Matthias Haeckel [a], Markus Bergenthal [b], Thomas Pape [b,c], Gerhard Bohrmann [b,c]

- A formation temperature profile down to 144 mbsf was aquired
- Base of gas hydrate stability zone (BGHSZ) is located about 30 m above the occurence of free gas indicated by the bottom simulating reflector (BSR)

MeBo drilling was required since

- **Bottom seismic reflector is beyond the reach of gravity/piston corer and typical heat flow probes**

Scientific Applications of MARUM-MeBo: Core Log Seismic Integration at the Danube Deep Sea Fan



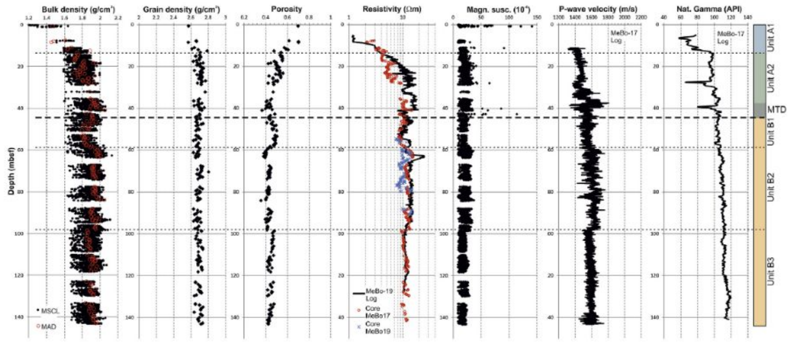


Fig. 10. Physical properties for Site MeBo-17 (GeoB22605) and Site MeBo-19 (GeoB22620): Core-based bulk density, grain density, porosity, electrical resistivity (core-based values are corrected for in situ conditions), and magnetic susceptibility are shown. P-wave velocity and natural gamma radiation are for Site MeBo-17, electrical resistivity is from Site MeBo-19, ~40 south of Site MeBo-17. Lithologic units for Site MeBo-17 are shown as vertical column on the right-hand side.

Marine and Petroleum Geology 114 (2020) 104192

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Research paper

Physical properties and core-log seismic integration from drilling at the Danube deep-sea fan, Black Sea

M. Riedel[a,*], T. Freudenthal[b], M. Bergenthal[b], M. Haeckel[a], K. Wallmann[a], E. Spangenberg[c], J. Bialas[a], G. Bohrmann[b,d]

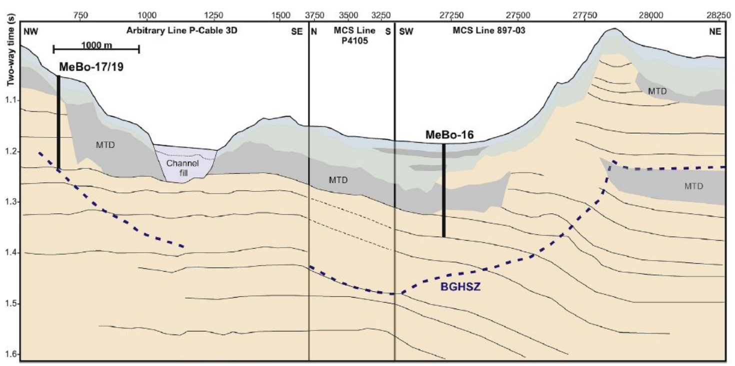


Fig. 15. Regional stratigraphy and line-drawing from seismic display of Fig. 3 around MeBo drill sites and the S2 channel. Drilling at Site MeBo-16 intersected an older sequence of stratigraphic Unit B (old levee complex) than at Site MeBo-17/19. Also, the upper sediments (stratigraphic Units A1 and A2) are intersected by several mass transport deposits (MTDs). The base of the (sl) methane gas hydrate stability zone (BGHSZ) is shown by the blue dashed line. (For interpretation of the references to color in this figure legend, the reader is referred to the Web version of this article.)

- Cores and borehole logging data were collected at three sites down to >140 m
- By combination of core data, bore hole logging data and seismic profiles the stratigraphy and architecture of a channel/levee-complex within the Danube Sea Fan was reconstructed

MeBo drilling was required since

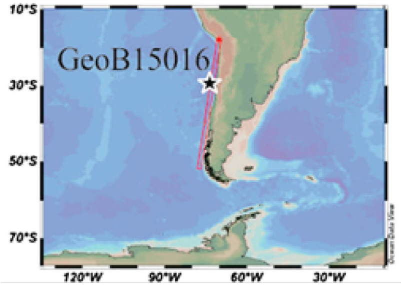
- **MeBo borehole logging provides continuous in-situ data of geophysical properties**

Scientific Applications of MARUM-MeBo: Paleoenvironmental reconstructions by drilling marine sediments

PALEOCEANOGRAPHY, VOL. 28, 1–12, doi:10.1002/palo.20047, 2013

Changes in the advection of Antarctic Intermediate Water to the northern Chilean coast during the last 970 kyr

G. Martínez-Méndez,[1] D. Hebbeln,[1] M. Mohtadi,[1] F. Lamy,[2] R. De Pol-Holz,[3] D. Reyes-Macaya,[3] and T. Freudenthal[1]



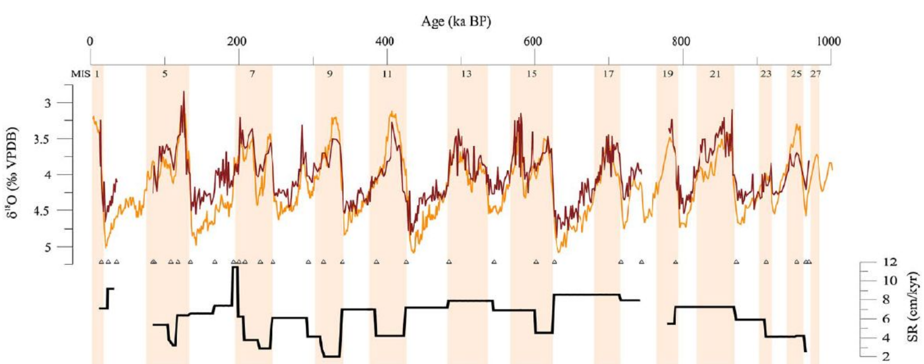


Figure 3. Age model for site GeoB15016. The age model was derived by linking the benthic $\delta^{18}O$ records (brown) of MeBo core GeoB15016 and of the gravity core GeoB15005-1 (corresponding to the period from 33 to 8 ka) to the LR04 global benthic $\delta^{18}O$ stack of *Lisiecki and Raymo* [2005] (orange). Gaps in the site GeoB15016 $\delta^{18}O$ record indicate intervals missing due to reduced sediment recovery in the respective sections. White triangles indicate the tie points used for the correlation of this site to the LR04 stack. The resulting sedimentation rates (SR in cm/kyr) for site GeoB15016 are illustrated by the bold black line. Vertical shading highlights interglacial Marine Isotope Stages (MIS) indicated at the top.

- 70 m long nearly continuous sedimentary sequence was obtained by double hole drilling in 957 m water depth off northern Chile
- Sedimentary record contains 1 million years of changes in intermediate water mass characteristics in the south eastern Paciific

MeBo drilling was required since

- **longer cores compared to gravity cores allow sampling of much older sediments and investigation of longer time scales**

Take home messages

- Nearly 20 years of experience with MeBo technology
- Sea bed drills bridge the gap between conventional sea bed sampling from multi purpose research vessels and the services of drill ships
- Sea bed drilling is not only coring. The borehole can be used for testing, logging and long term observations
- Sampling strategy and project design have to be adapted to the technology

Foto: T. Klein