More than ten years of successful operation of the MARUM-MeBo sea bed drilling technology: Highlights of recent scientific drilling campaigns

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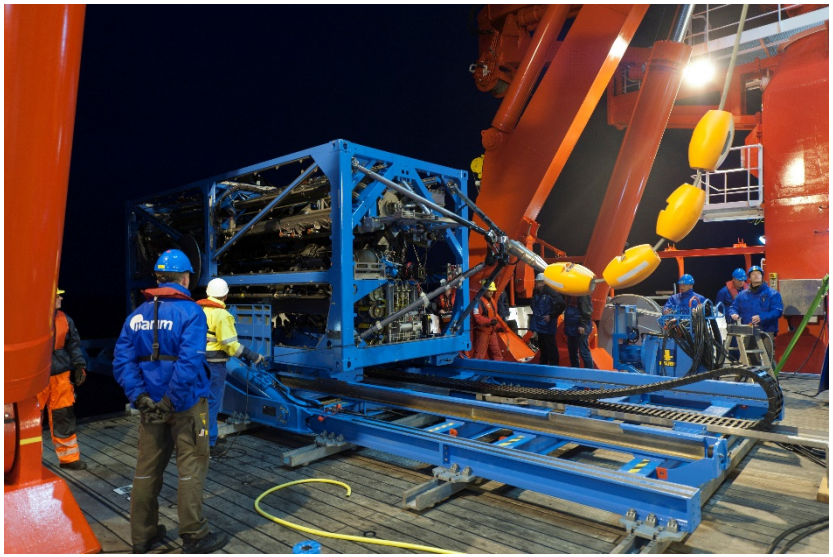
Foto: T. Klein; MARUM-MeBo70 on the ice-breaking research vessel POLARSTERN in the Amundsen Sea Embayment during expedition PS104

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.

Concept of MeBo

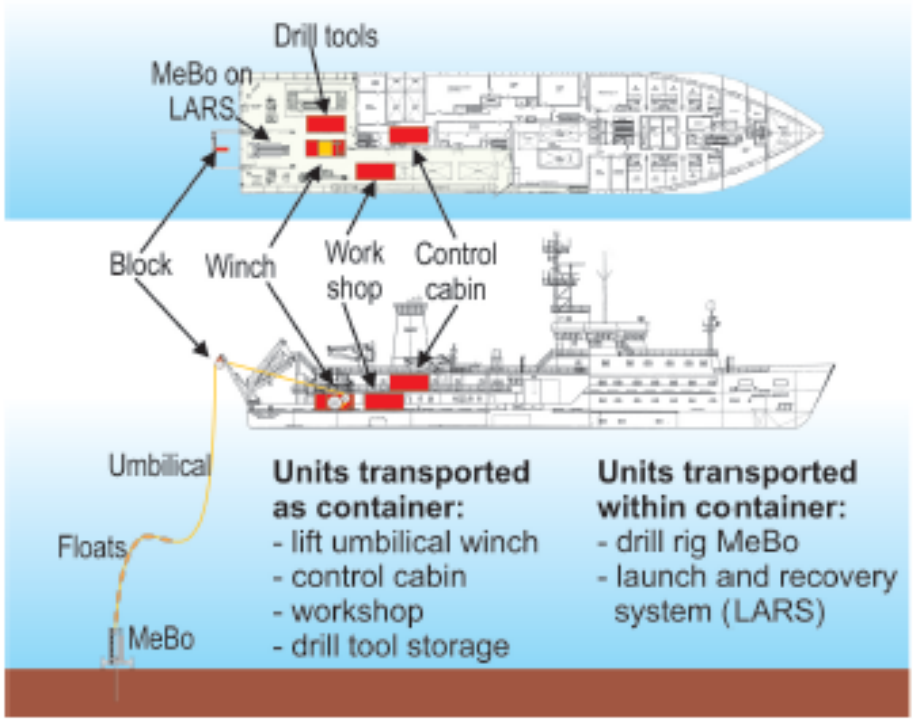


Fig. 1. Typical operational setup for a remote-controlled drill rig that is lowered to the sea floor. As an example, the sea floor drill rig MeBo and the research vessel *Maria S. Merian* is shown.

- **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**

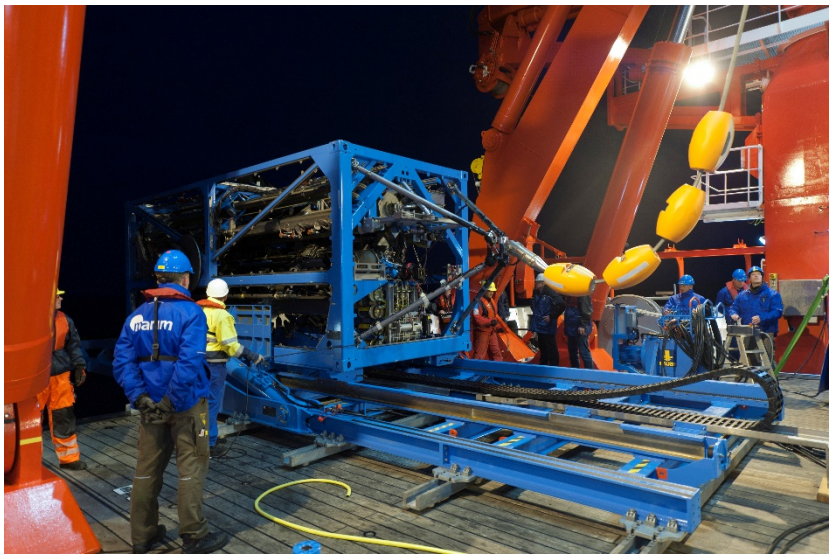
Freudenthal and Wefer, 2013

- **Since 2008: use of H-size wire line coring technique**
- **Drill tools are stored on two magazines on the drill rig**
- **2010-2016: development of bore hole logging capability;**
  Sensors: SGR, Dual Induction, Acoustic, Magnetic Susceptibility, Temperature

MeBo Deployment statistics 2008 - 2019

MARUM-MeBo70

MARUM-MeBo200



2008 (2005)	• Start of operation (conventional coring)	2014
17	• Number of expeditions	4
154	• Number of deployments	30
80.85 m	• Maximum drilling depth	147.4 m
3711 m	• Total drilling length	1808 m
67%	• Average core recovery	72%

Highlight 1: expedition PS104 (chief scientist: K. Gohl)

MARUM-MeBo70 drilling from the ice breaking vessel POLARSTERN on the West Antarctic shelf

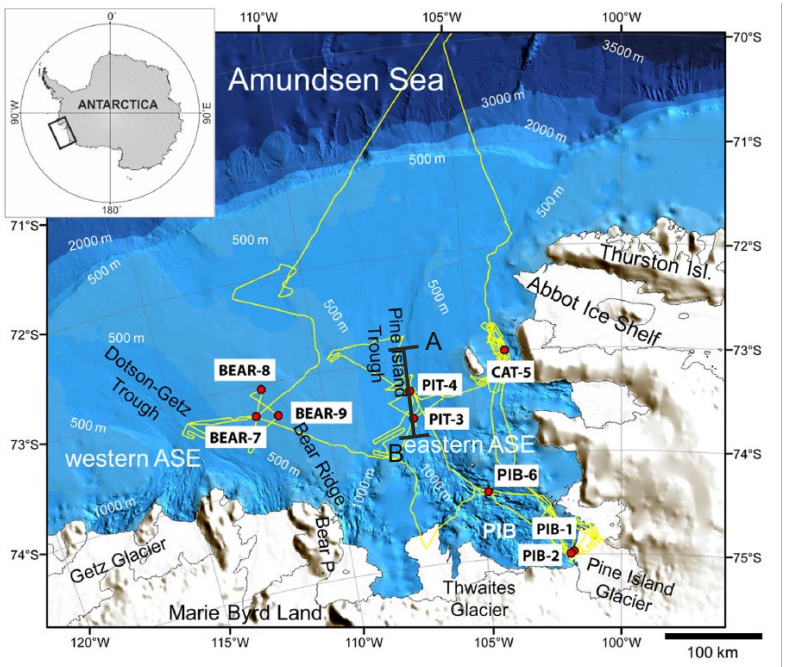
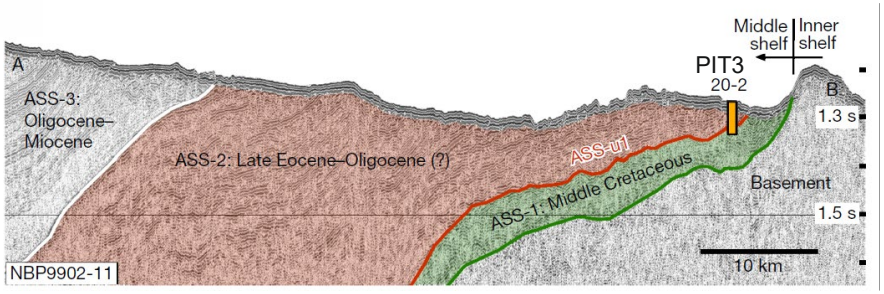


Figure 1. Bathymetric map of the Amundsen Sea Embayment (ASE), West Antarctica, with labeled MeBo70 drill sites (red dots) of expedition PS104. Yellow lines mark the ship track. Bathymetry is from the International Bathymetric Chart of the Southern Ocean (IBCSO) Version 1.0 (Arndt et al., 2013). PIB = Pine Island Bay.

Gohl et al. 2017

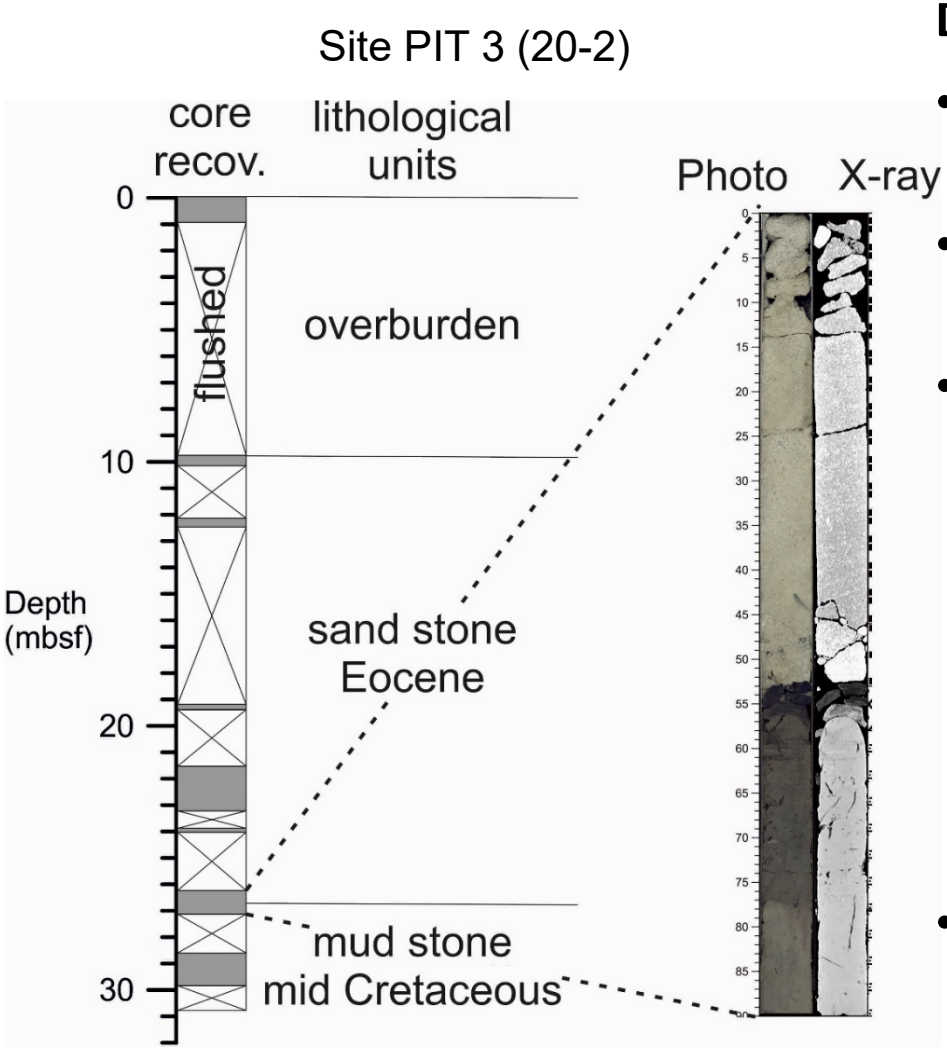


Klages et al. 2020

- **Research Goal: „Recovery of sediments for the study of the West Antarctic preglacial environment and ist transition into the glacially dominated domain“** (Gohl et al., 2017)
- **Research area is difficult to access due to remoteness, sea ice and icebergs**
- **Drilling strategy: drilling through last glacial till into dipping strata of older shelf sequences of previously undetermined composition and ages**
- **Polarstern expedition PS104 was the first drilling campaign in the Amundsen Sea Embayment**

Highlight 1: expedition PS104 (chief scientist:K. Gohl)

MARUM-MeBo70 drilling from the ice breaking vessel POLARSTERN on the West Antarctic shelf



Drilling results:

- **Eleven deployments of MARUM-MeBo70 at 9 sites**
- **162 m were drilled with an average core recovery of 38%**
- **Several deployments had to be aborted due to approaching icebergs**

- **Drilling highlight: recovery of a pollen-rich soil of Middle Cretaceous age at deployment PS104 20-2 (site PIT 3)**

Highlight 1: expedition PS104 (chief scientist:K. Gohl)

MARUM-MeBo70 drilling from the ice breaking vessel POLARSTERN on the West Antarctic shelf

Publication Klages et al. 2020, Temperate rainforests near the South Pole during peak Cretaceous warmth, Nature 580, 81-86 based on results of investigation of MeBo cores at PIT3:

- **About 90 Mio years ago a temperate coastal rainforest grew at a paleolatitude of 82°S**
- **This indication of an unexpected warm climate can only be reproduced by climate models with extremely high CO_2 concentrations of 1120 to 1630 ppm**

For more details: See Klages et al. https://presentations.copernicus.org/EGU2020/EGU2020-242_presentation.pdf

Highlight 2: expedition MSM57 (chief scientist: G. Bohrmann)

MSM57: MARUM-MeBo70 drilling and temperature probing in the Arctic Ocean off Svalbard

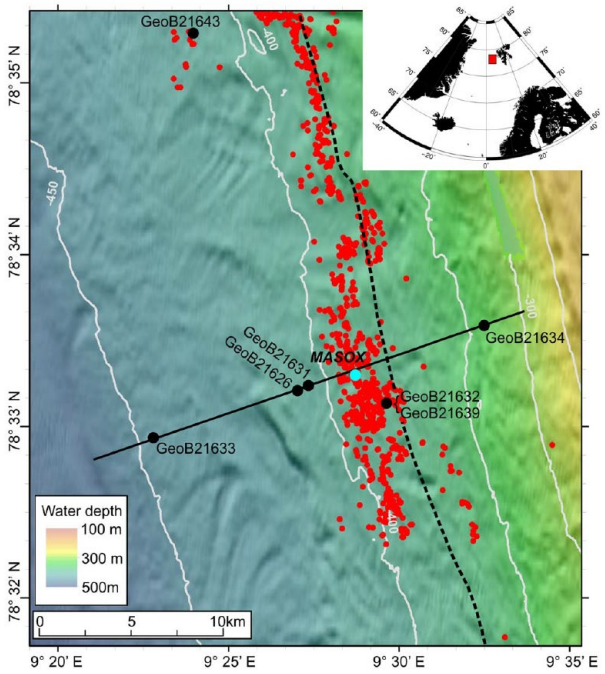


Figure 1. Location of study region in the Fram Strait (inset) and bathymetric map of study region (compiled from numerous cruises, details see Acknowledgments) at the upper continental margin slope west of Prins Karls Forland. MeBo drill holes at six sites occupied during MSM57 are shown as black dots (see Table 1 for details). Gas emission sites (red circles) were taken from Sahling et al. (2014). Solid black line is location of seismic data shown in Figure 2. Blue dot indicates location of the long-term observatory site MASOX (Berndt et al., 2014). The black dashed line is the approximate location of the theoretical maximum extent of the sI gas hydrate stability zone as constrained from the temperature data and modelling applied for the time of the MSM57 expedition (see Table 2 for details).

Riedel et al. 2017

Drilling strategy:

- drilling a depth transect across the area of frequent gas venting
- Conducting *in situ* temperature measurements with MeBo70 for characterising the gas hydrate stability field

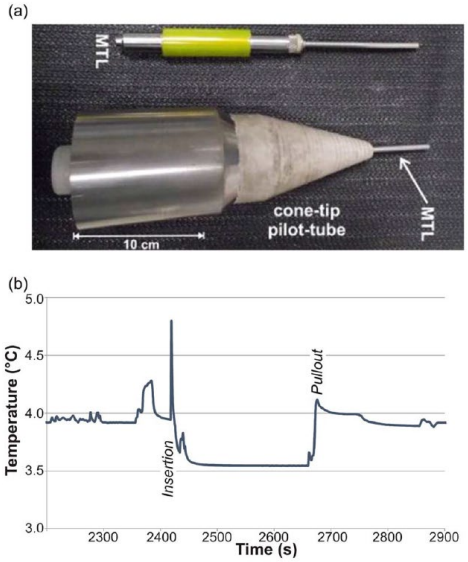


Figure 3. (a) Image of the MTL inside a pilot tube (lower) and the MTL itself (upper). (b) Example of a temperature record from Station GeoB21643-1 at a depth of 12.1 m below seafloor (mbsf). (For calculated sediment temperatures see also Table 1).

Riedel et al. 2017

Goal of research expedition MSM57:

- Investigate gas hydrate distribution and dissociation at the continental margin off Svalbard

Highlight 2: expedition MSM57 (chief scientist: G. Bohrmann)

MSM57: MARUM-MeBo70 drilling and temperature probing in the Arctic Ocean off Svalbard

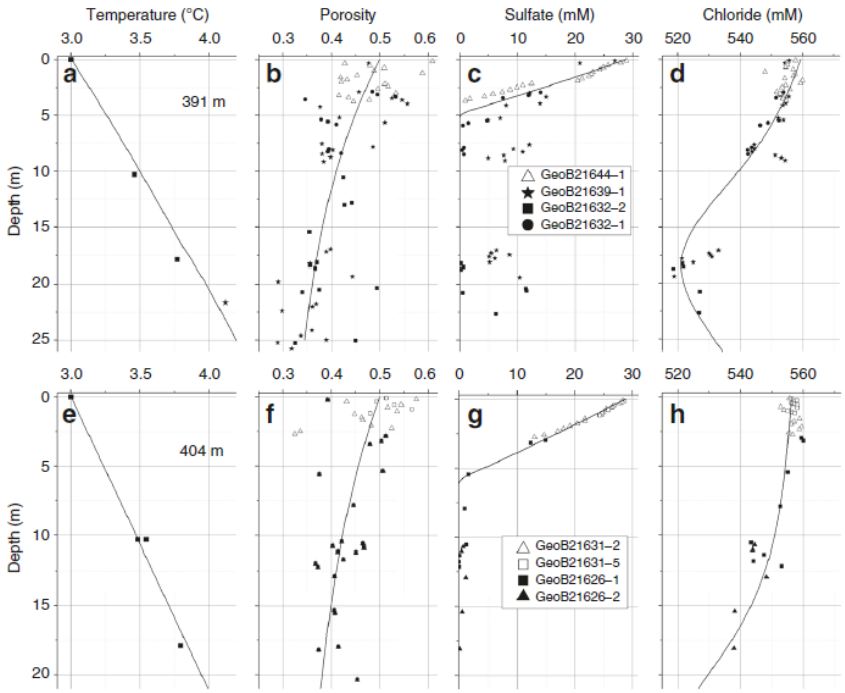
nature COMMUNICATIONS

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]



Wallmann et al. 2018

Publications Wallmann et al. 2018 and Riedel et al. 2017 based on results of MeBo drilling on MSM57:

- **Temperature measurements were combined with geophysical characteristics and porewater analyses on the cores**
- **Chloride anomalies indicate zones of gas hydrate dissociation.**
- **Observations are best explained by a response of the gas hydrate stability field on postglacial isostatic rebound**

Highlight 3: expedition M142 (chief scientist: G. Bohrmann)

MARUM-MeBo200 drilling and bore hole logging at the Danube deep sea fan

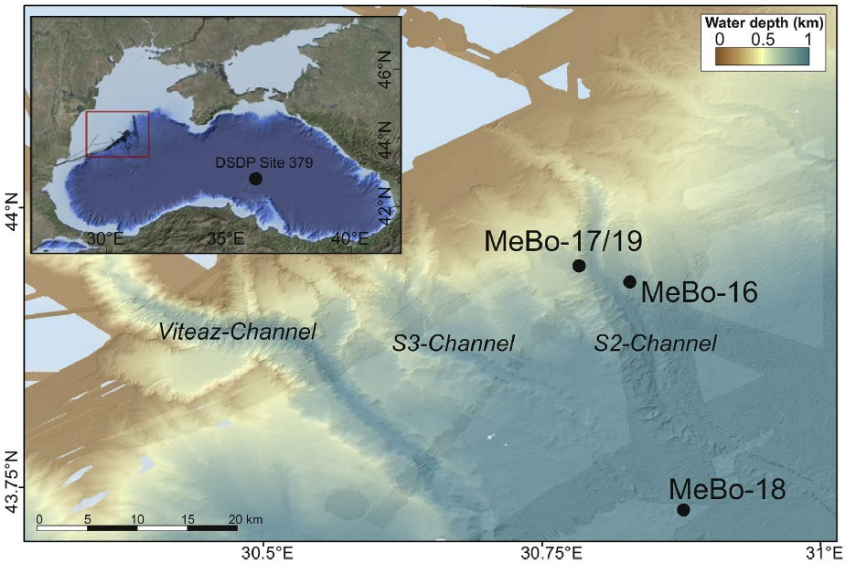


Fig. 1. Map of study region in the Black Sea, targeted during Expedition M142. Inset shows region of the entire Black Sea and location of drill site 379 during DSDP Leg 42b.

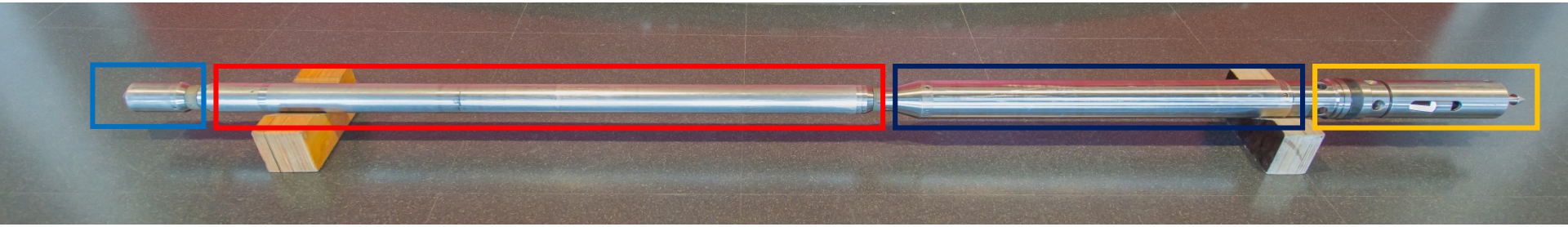
Riedel et al. 2020

Research Goal:

- Investigate gas hydrate distribution at the Danube Deep Sea Fan in the Black Sea

Methods:

- Core drilling down to the base of the gas hydrate stability zone (BGHSZ)
- Borehole logging with Acoustic, Dual Induction and Spectrum Gamma Ray probes



Coupling Adapter | Spectrum Gamma Ray Probe | Memory Logger | Latch System

Highlight 3: expedition M142 (chief scientist: G. Bohrmann)

MARUM-MeBo200 drilling and bore hole logging at the Danube deep sea fan

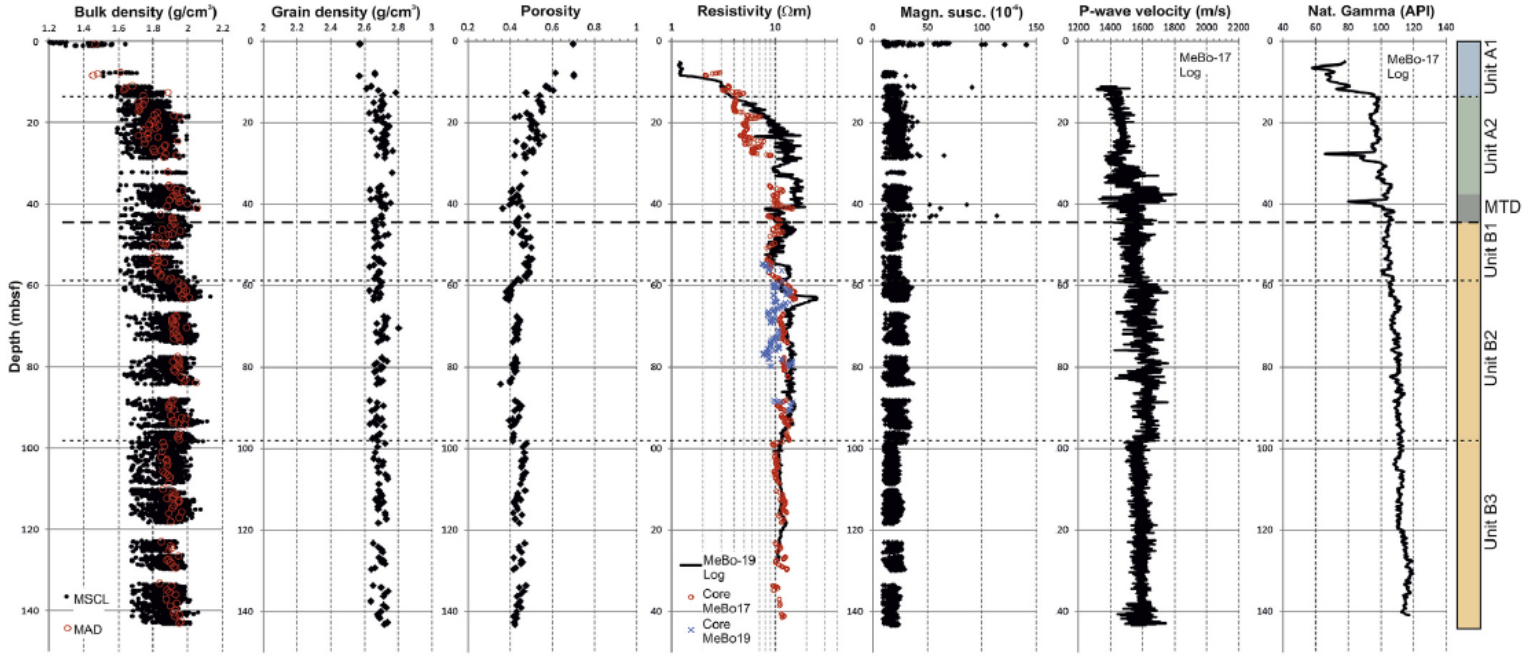


Fig. 10. Physical properties for Site MeBo-17 (GeoB22605) and Site MeBo-19 (GeoB22620): Core-based bulk density, grain density, porosity, electrical resistivity (core-based values are corrected for in situ conditions), and magnetic susceptibility are shown. P-wave velocity and natural gamma radiation 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.

Riedel et al. 2020

Drilling results:

- **4 deployments of MARUM-MeBo200 at 3 sites; 444 m drilled with 82% core recovery, deepest drilling down to 147 mbsf**
- **Borehole logging was conducted in the unconsolidated sediments during trip out of the drill string with the probes located below the drill string**

Highlight 3: expedition M142 (chief scientist: G. Bohrmann)

MARUM-MeBo200 drilling and bore hole logging at the Danube deep sea fan

Marine and Petroleum Geology 114 (2020) 104192

Contents lists available at ScienceDirect

Marine and Petroleum Geology

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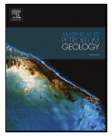

Research paper

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]

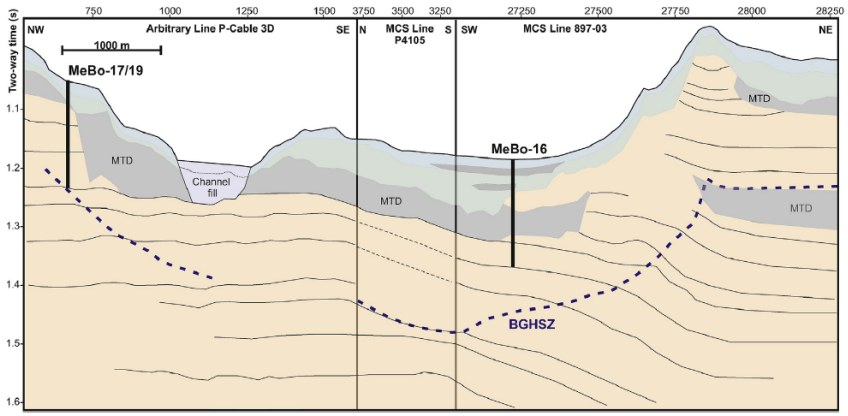

Fig. 15. Regional stratigraphy and line-drawing from seismic display of Fig. 3 around MeBo drill sites and the S2 channel. Drilling at Site MeBo-16 intersected an older sequence of stratigraphic Unit B (old levee complex) than at Site MeBo-17/19. Also, the upper sediments (stratigraphic Units A1 and A2) are intersected by several mass transport deposits (MTDs). The base of the (sI) 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.)

Riedel et al. 2020

Publication Riedel et al. 2020 based on results of MeBo drilling on M142:

- **Seismics, core derived sedimentological and geophysical data, and bore hole logging data were used for a Core Log Seismic Integration approach**
- **Within the channel-levee complex investigated, the seismic reflecting charateristics of the sedimentary units are mostly driven by changes in density/porosity**
- **Free gas was observed below the seismic indicated base of gas hydrate stability zone (BGHSZ) but no indication of gas hydrates was found above**

Take home messages

Since the upgrade of the MARUM-MeBo70 for the use of the wireline coring technique in 2008, we collected more than 10 years of operational experience with MeBo70 and 5 years with MeBo200

Three expeditions – all conducted in 2017 – exemplify the strengths of the MeBo sea bed drilling technology:

- **Sea bed drill rigs are effective for research projects that can be adressed by shallow drillings in the range of a few to 200 m below sea floor (e.g transect drilling)**
- **Sea bed drill rigs can be operated in remote areas difficult to access**
- **Temperature probing and borehole logging add to the coring capabilities of sea bed drill rigs**
- **The logging tools are located below the drill bit and hooked up inside the bore hole while tripping out the drill string. Using the logging while tripping technology, borehole logging can be conducted also in (shallow) unconsolidated sediments that bear the risk of a borehole collaps**

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