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Complex eyed pockmarks associated with submarine groundwater discharge in gaseous muddy sediments

Eckernförde Bay, SW Baltic Sea

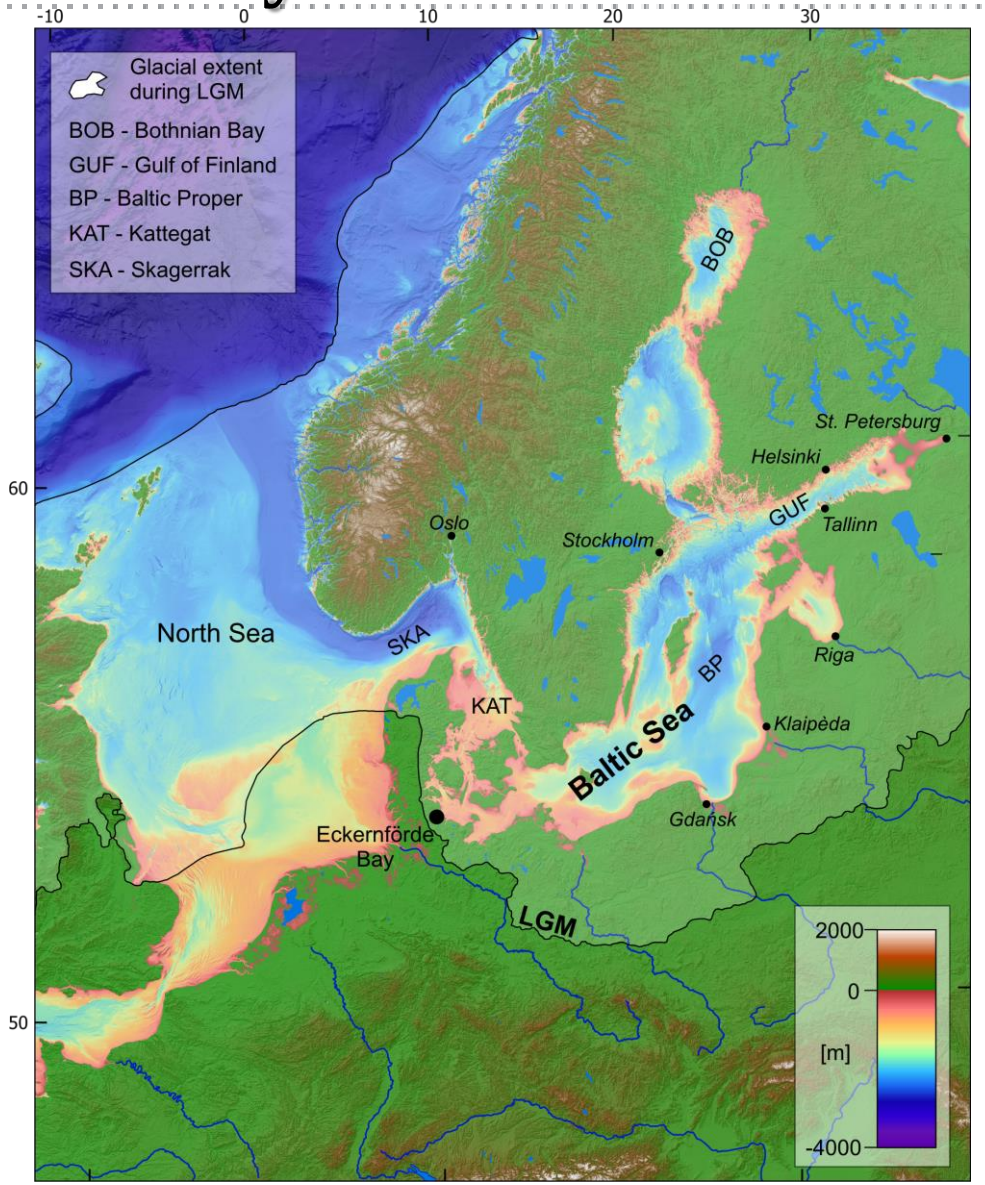
Aim

Find acoustic indications for submarine groundwater discharge (SGD)

Investigate geomorphological characteristics of SGD

Better constrain fluids involved in pockmark formation

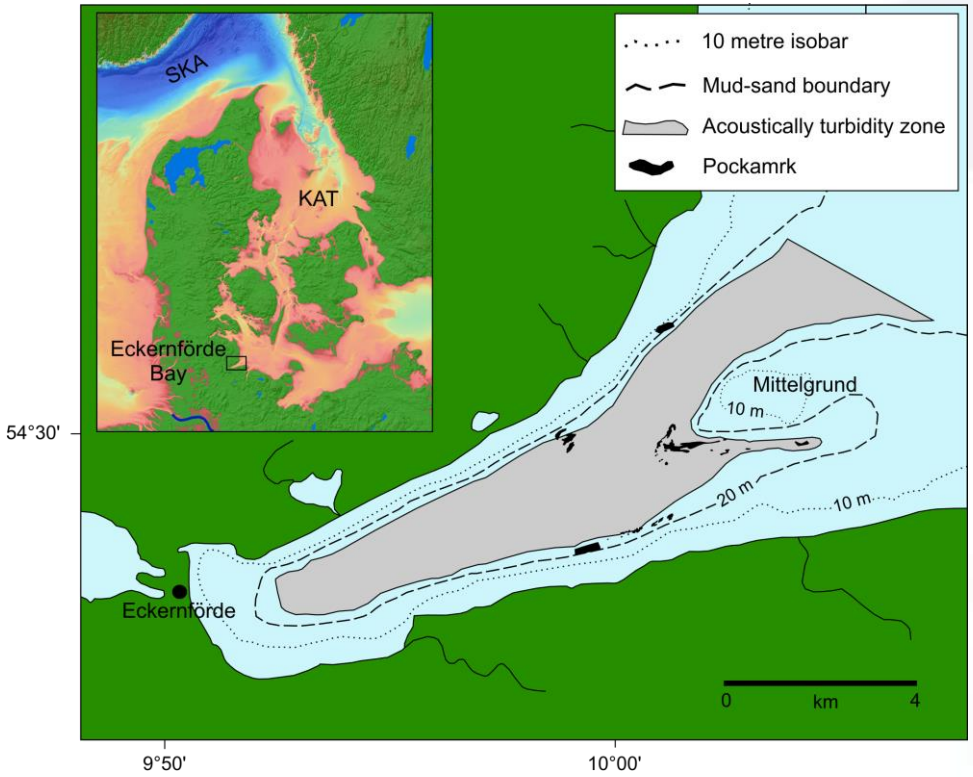
Study Site



Overview of the Baltic Sea area with the glacial extent during the last glacial maximum (DEM was supplied by GEBCO compilation group (2019), Glacial extent after Ehlers et al. (2011)).

Eckernförde Bay (Germany)

- Fjord shaped by Weichselian glaciation ~13,000 yr BP
- Mainly Holocene mud with microbial gaseous sediments below 1-3 m
- Known groundwater and gas seepage site
- Several pockmarks form due to gas and/or groundwater seepage
- Water column is generally well stratified with low saline surface water



Overview of Eckernförde Bay showing the extent of the acoustic turbidity zone and the distribution of pockmarks (modified from (Whiticar, 2002))

Results

Multibeam Bathymetry

- Reveals complex internal morphology
- Mounds and Intra-pockmark

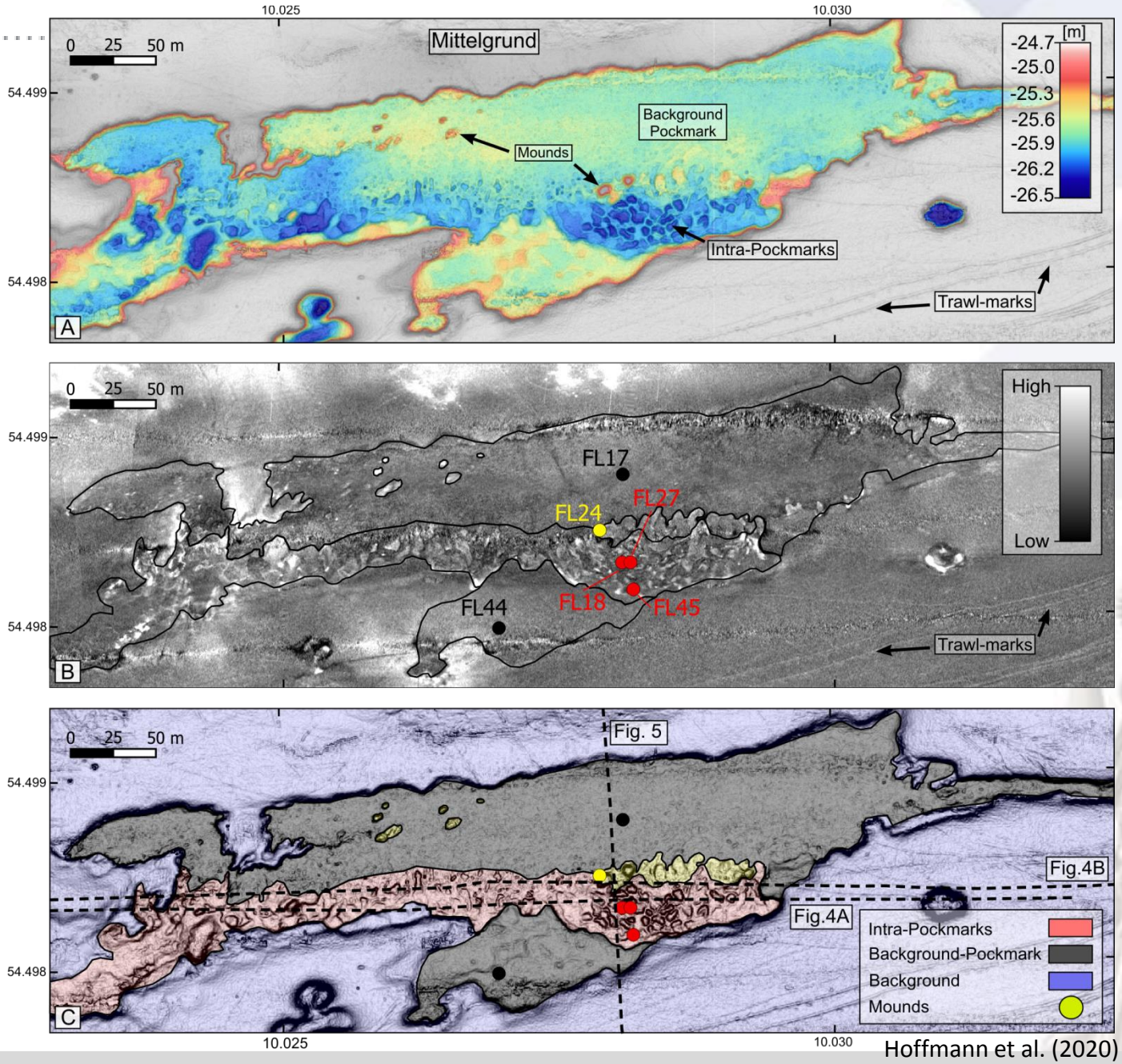
300 kHz Multibeam Backscatter

- Backscattering strength correlates with morphology

- **Sediment Cores** Labelled FL##

Multibeam Classification

- We distinguished three regimes according to the morphology and backscatter strength

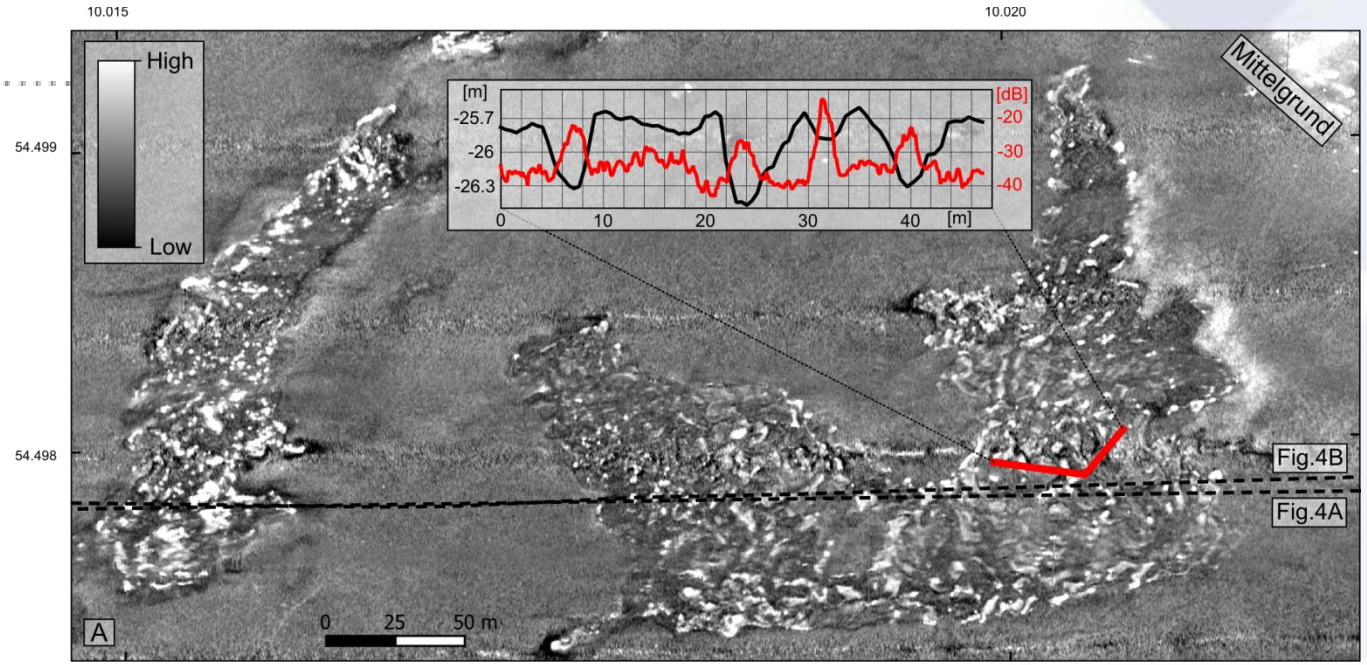


Hoffmann et al. (2020)

Results

300 kHz Multibeam Backscatter 2014

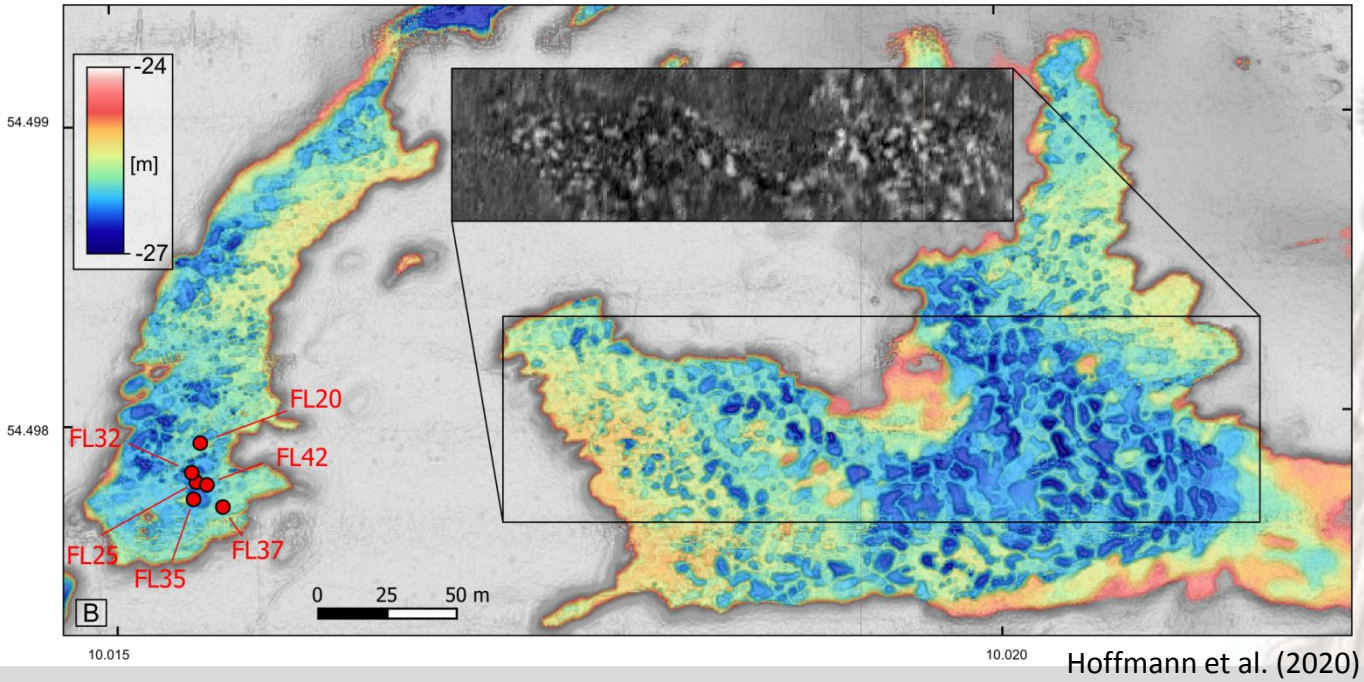
- Highest backscatter strength from the bottom of the Intra-Pockmarks



Multibeam Bathymetry

- Bathymetry showing the intra pockmark morphology

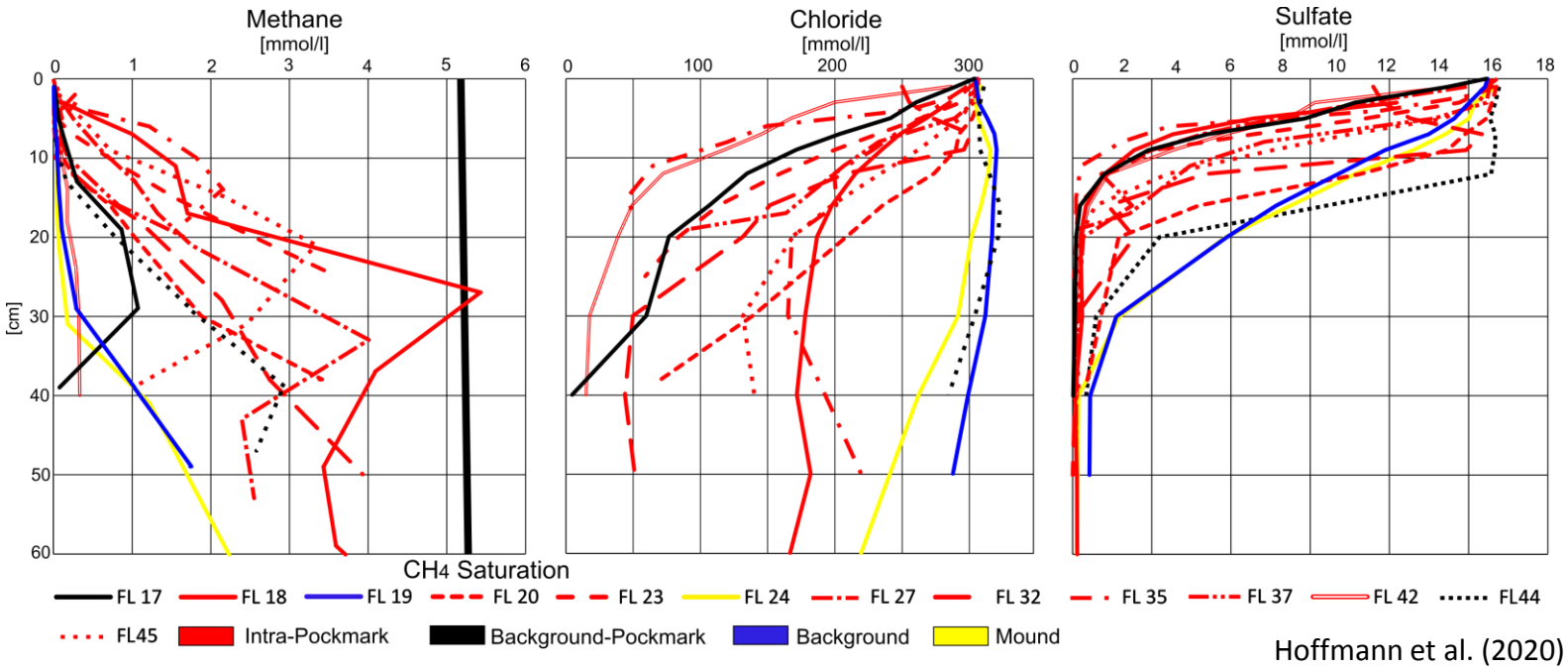
- Inlet shows backscatter from a cruise in **2019** with the same pattern as in 2014.



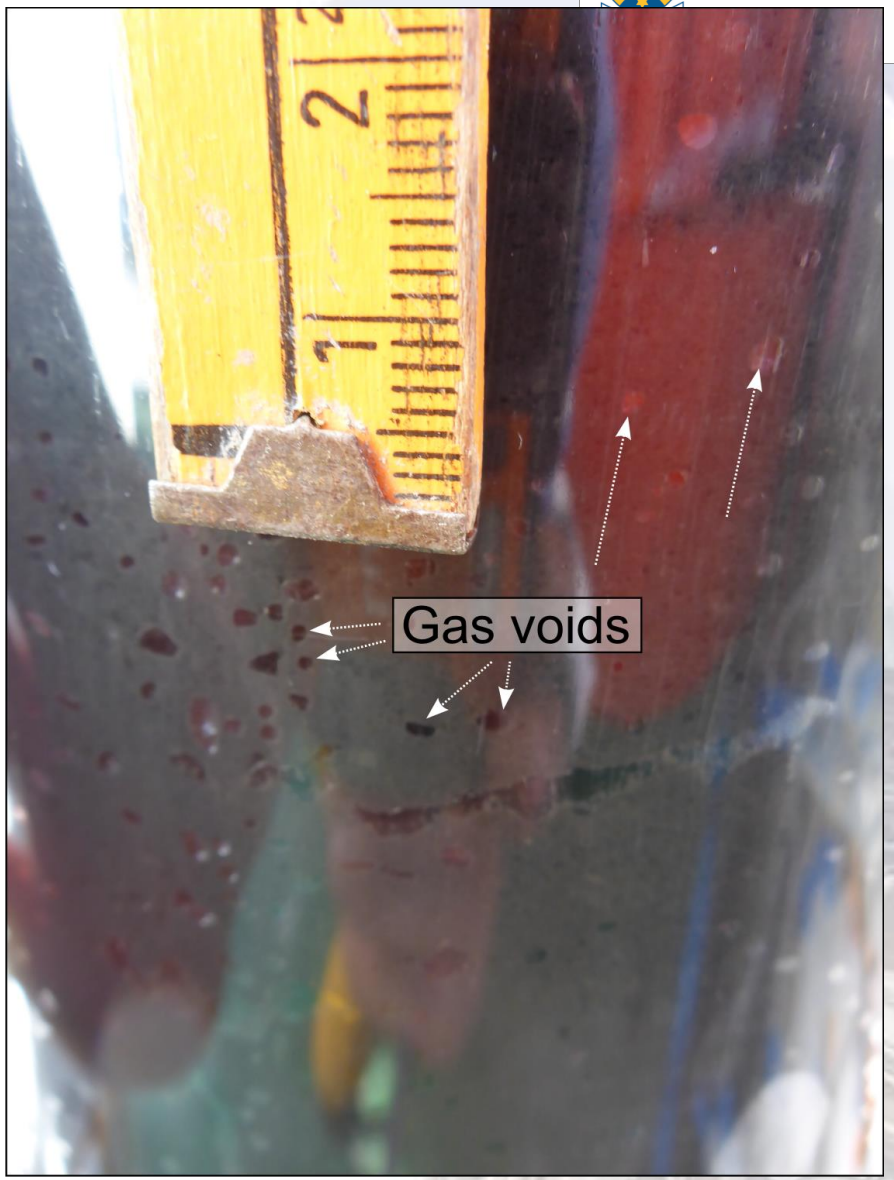
Hoffmann et al. (2020)

Results

Porewater Geochemistry



Hoffmann et al. (2020)

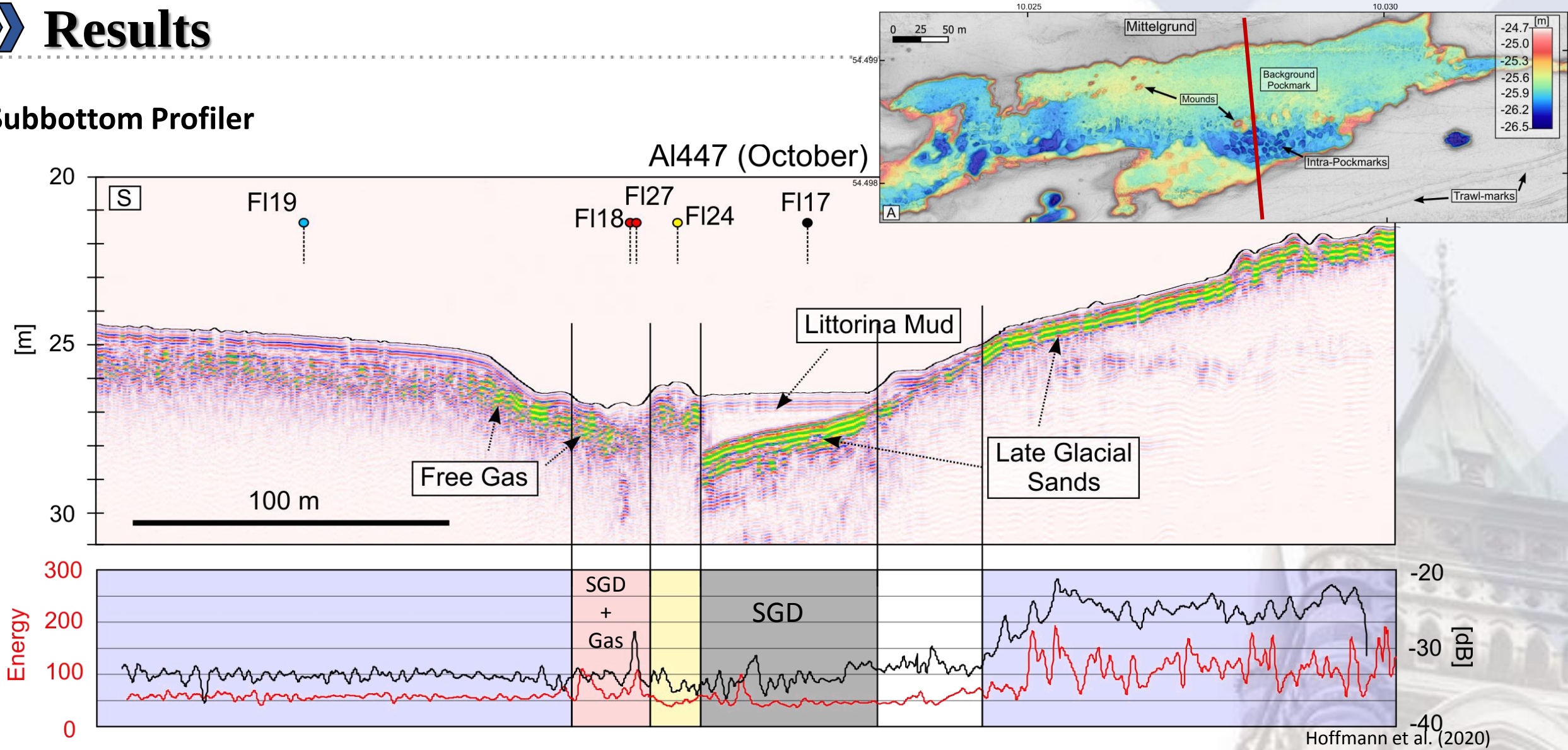


Core FL18

- **Enhanced Methane concentrations in intra-pockmarks**
- **High methane correlates with low chloride**

Results

Subbottom Profiler

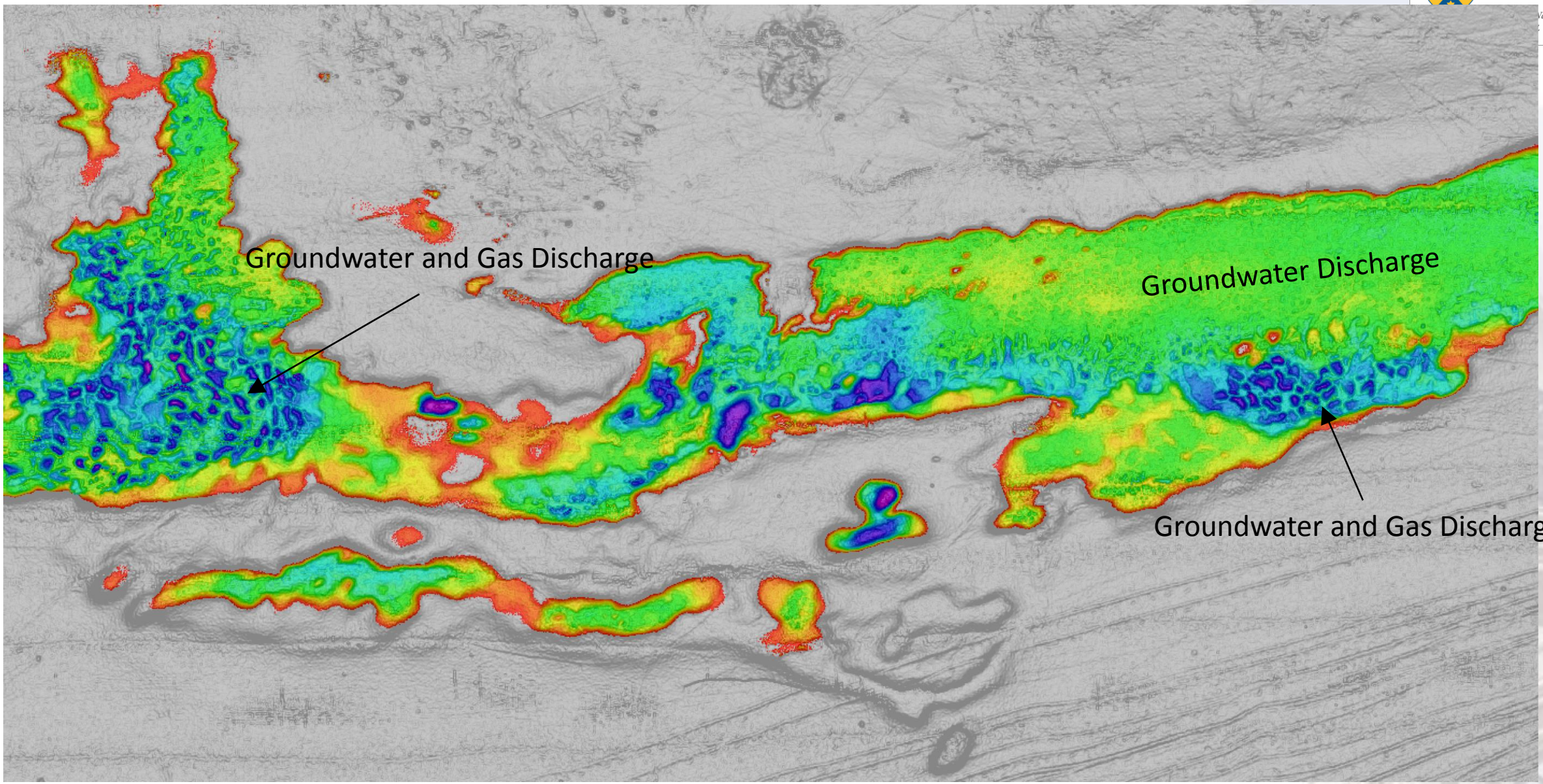


Hoffmann et al. (2020)

TOP: Late Glacial Sands of Mittelgrund extend beneath the pockmark. Once Littorina Mud reaches a thickness of ~1m free gas forms causing acoustic turbidity

BOTTOM: **Subbottom profiler energy** of the upper 50 cm and multibeam **backscatter strength** correlate

Conclusions



Conclusions

Submarine Groundwater Discharge

- Enhances upward migration of gas bubbles to the seafloor
- Supresses sulfate diffusion into the sediment
- Brings the sulfate-methane transition zone (SMTZ) closer to the seafloor

Therefore, even with a 400 kHz multibeam, we can accurately map shallow gas in the sediment **in areas of SGD**

We discovered a new form of eyed pockmarks associated with gas and SGD

Groundwater seems to be the main driving force in pockmark formation since free gas is not present throughout the pockmark

Gas seems to enhance erosion and contributes to intra-pockmark formation but not the background-pockmark

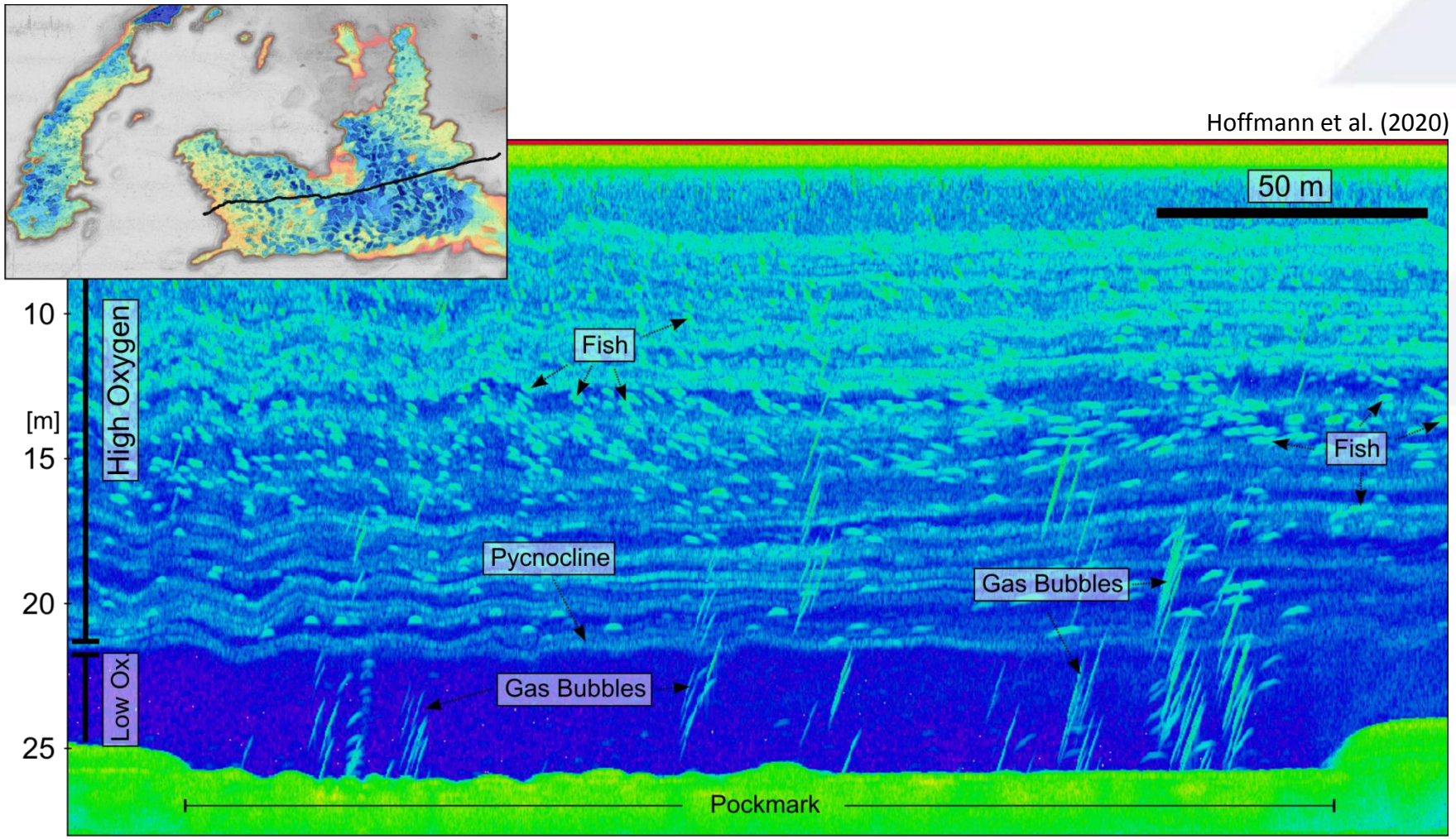
Seasonal variations of gas occurrence do not occur in regions of SGD. Gas constantly resides in the shallow sediments in regions of SGD.

Since gaseous muddy sediments are a common global phenomenon, our study highlights the importance of investigating how SGD and shallow gas interact close to the seafloor.

Results

Water Column Imaging

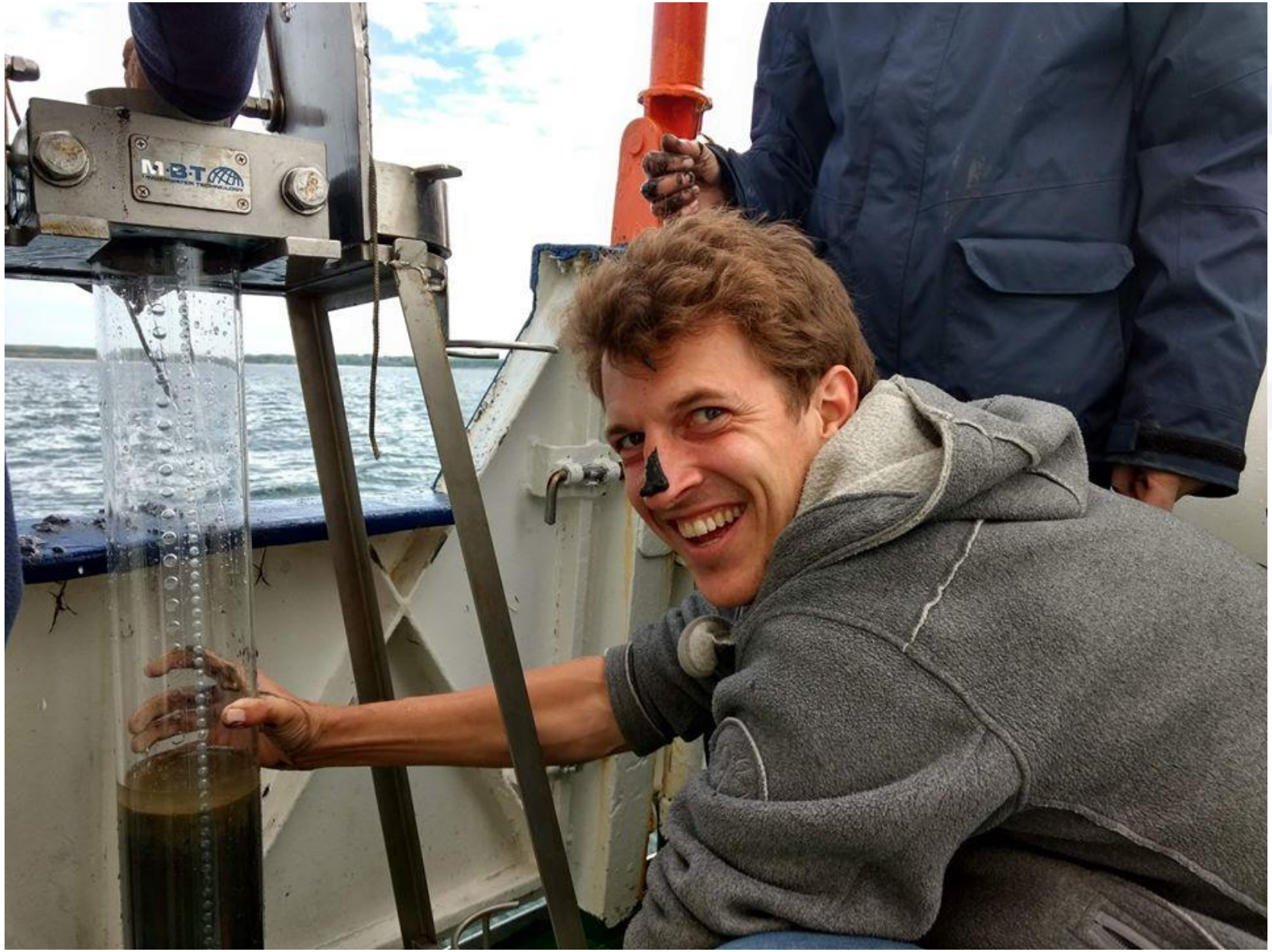
Hoffmann et al. (2020)



WCI investigations from single and multibeam data shows gas bubbles inside and outside the pockmarks

Locally continuous pycnoclines are not affected by groundwater discharge

Results



References

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Whiticar, M. J. (2002). Diagenetic relationships of methanogenesis, nutrients, acoustic turbidity, pockmarks and freshwater seepages in Eckernförde Bay. *Marine Geology*, *182*(1–2), 29–53. https://doi.org/10.1016/S0025-3227(01)00227-4