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

Eckernförde Bay, SW Baltic Sea
Find acoustic indications for submarine groundwater discharge (SGD)

Investigate geomorphological characteristics of SGD

Better constrain fluids involved in pockmark formation
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
Results

Multibeam Bathymetry
• Reveals complex internal morphology
• Mounds and Intra-pockmark

300 kHz Multibeam Backscatter
• Backscattering strength correlates with morphology
• Sediment Cores Labeled FL##

Multibeam Classification
• We distinguished three regimes according to the morphology and backscatter strength

Hoffmann et al. (2020)
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.
Results

Porewater Geochemistry

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

Submarine Groundwater Discharge
• Enhances upward migration of gas bubbles to the seafloor
• Suppresses 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.
WCI investigations from single and multibeam data show gas bubbles inside and outside the pockmarks.

**Locally continuous pycnoclines are not affected by groundwater discharge**

Hoffmann et al. (2020)
Results
References


