Cruise report FK Littorina LIT/1905

(14.05.2019 – 17.05.2019)

Geochemical and hydroacoustic analyses of internal pockmark structures in the Eckernförde Bay and their relation to submarine groundwater discharge

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In Cooperation with University of Otago (New Zealand)

This cruise presents a joint research activity between the two BONUS projects SEAMOUNT and ECOMAP supported by a DAAD grant (Funding programme/-ID: Research Grants - Short-Term Grants, 2019 (57440917)), in collaboration with the University of Otago and GEOMAR. Thereby we bring together the expertise of geochemical analyses of groundwater discharge by SEAMOUNT, and the hydroacoustic expertise available in ECOMAP to support an ongoing PhD work at University of Otago (New Zealand).

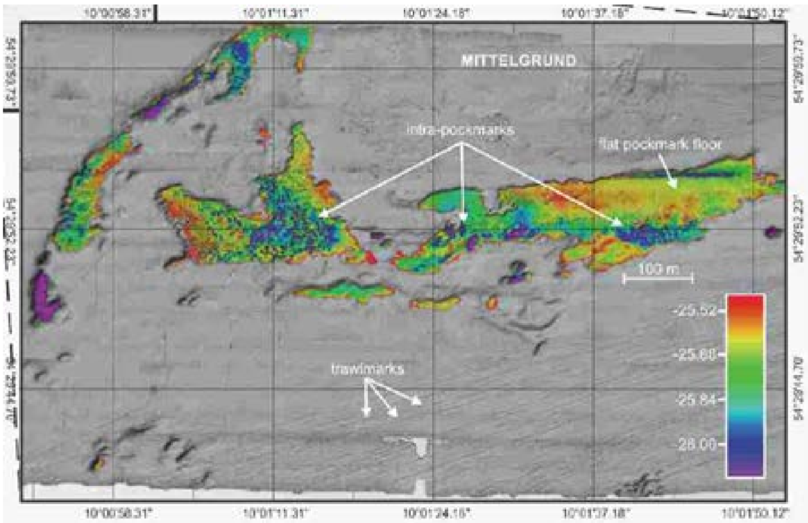

Fig. 1: Overview map and microbathymetry gathered with 300 kHz in 2014 (Schneider von Deimling, 2015) showing the intra-pockmarks, figure taken from Lohrberg et al. (2019).

We targeted the Eckernförde Bay 'Mittelgrund' pockmarks at 25 m water depth. Eckernförde Bay is a typical post-glacial sedimentary basin with high organic carbon inputs and sedimentation rates. As a consequence the muddy sediments host shallow gas in most areas of the Bay, where Holocene mud exceeds a critical thickness.

Our main area of interest is located at the south westerly slope of the outcropping glacial till Mittelgrund. The 2 m deep pockmarks of hundreds of meters extent are known since decades and associated with submarine groundwater discharge (Whiticar & Werner 1982). Circular depressions of only 0.2 m depth and only a few meters wide were reported inside the pockmarks by high resolution multibeam bathymetry gathered during the cruise AL447 in 2014 (Schneider von Deimling, 2015). We term the circular depression inside the known pockmarks 'intrapockmarks' hereafter (Fig. 1). Those were also found to show exceptionally high backscatter which we interpreted as additional indicator for active groundwater discharge with hitherto unknown physical reasons.

The second working area was located at the north coast of Eckernförde Bay to evaluate if acoustic anomalies found during ALKOR 514 correlate with groundwater discharge.

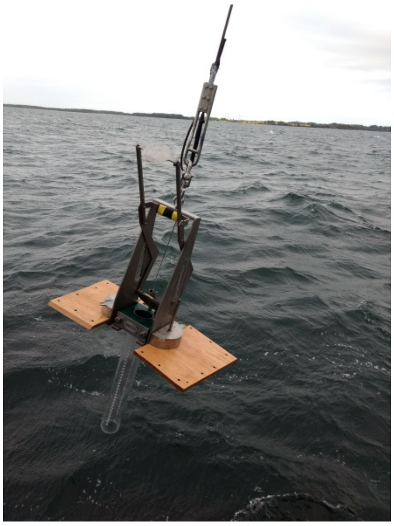

Fig. 2: Deployment of the Frahmlot. We adapted the device with 'snowshoes' to support the release mechanism and to gather cores from extremely soft seabed.

From the acoustic pre-survey we selected three morphological domains labeled in Fig. 1: (a) *intrapockmarks* (b) inside the large pockmark at the *flat pockmark floor*, and (c) *background*, taken south of the pockmark next to the 5 cm deep *trawl marks*. The domains were sampled with the Frahmlot coring device (Fig. 2) to later gather concentration profiles of methane and chlorine as indicators for seepage, shallow gas, and groundwater discharge. For most accurate positioning of the vessel and the core locations we used a Stonex S9i GNSS receiver to track satellite signals from GPS, GLONASS, BEIDOU and GALILEO. Real Time Kinematic (RTK) corrections were received from the ascos (AXIO-NET GmbH) satellite reference service with a Vodafone sim card (D2 net). This ensures an accuracy of several cm laterally in Eckernförde Bay. The lateral offsets from the GNSS receiver to the two cranes used for coring operations were measured manually and are displayed in Fig. 3. The heading of the vessel was recorded with the inertial navigation unit Codaoctopus F180. The vessel was maneuvering in a manner to minimize potential drift of the cable and the coring device. With the cable going down vertically it was possible to sample the intrapockmarks at 25 m water depth even if there diameter is smaller than the vessels positioning accuracy.

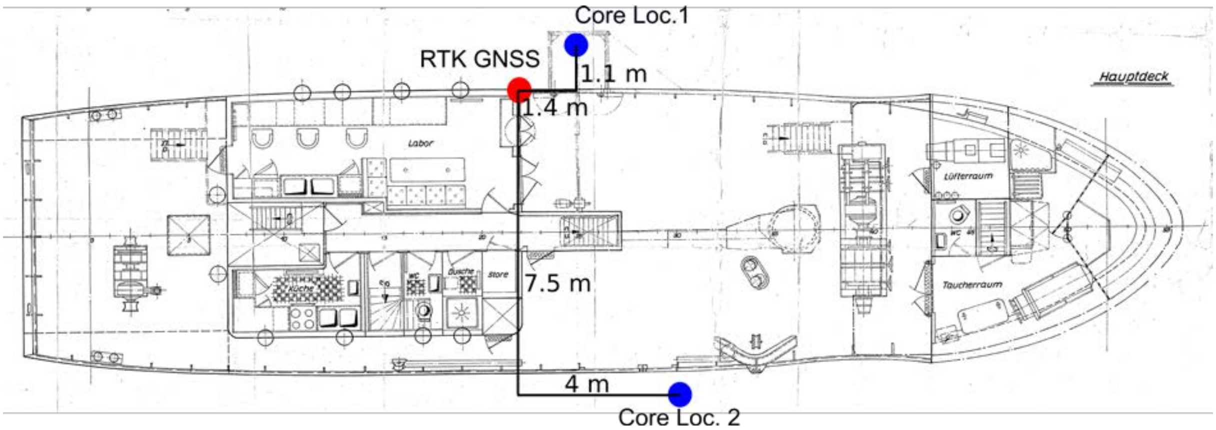

Fig. 3: Scetch of the RV Littorina with assigned offets between the RTK GNSS receiver (red) and the two core locations used (blue)

Overall we explored 52 stations with 19 cores taken and a core recovery between 20 and 60 cm. The cores were immediately sampled to later determine porewater chlorine, CH_4 concentration, and porosity profiles. Lab results will later allow to allocate the porewater profiles with the three acoustic domains (*a-c*) possibly linked with groundwater discharge intensities. The uncorrected GPS locations for the Frahm-Lot cores, Grab samples and CTD locations are plotted in Fig 4.

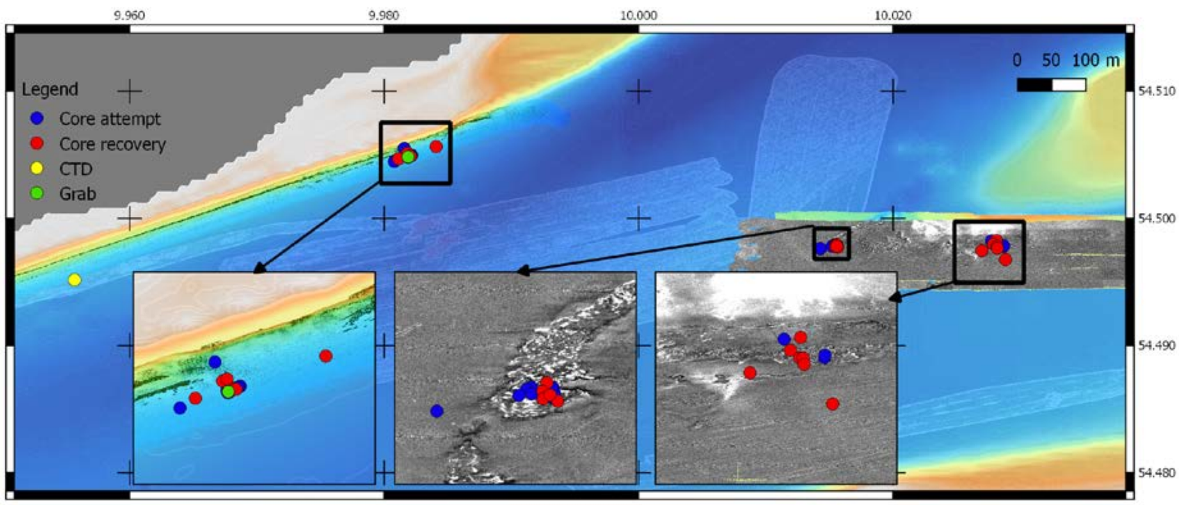

Fig 4: Overview map of working stations in Eckernförde Bay.

Fig. 5: Frahmlot core sample analyses with Rhizones for porewater extraction and cut syringes for sediment sampling.

Most cores showed an oxygenated, brownish, fluffy layer of approximately 1 cm thickness. Remnants of macrobenthic life such as a few tubeworms and signs of carbon sinks like rotten leaves of seagrass and settled organic particles as soft mud could be identified. Below the upper layer the cores turned grey and dark grey. Some cores developed free gas bubbles in the sticky mud after recovery that could be visually observed at the core liner wall. Most cores revealed a strong hydrogen sulphide smell and we interpreted the substrate to be a *Sapropel*. At the intrapockmarks we recovered cores with exceptional low stiffness and black color, they behaved almost like a fluid, and thus part of the core was lost during recovery because sediment was flowing out of the core liner. In none of the cores a more resistant substrate was found at the surface that could have explained the high backscatter reported before. The sediment composition within the intrapockmarks is in contrast to what was reported at other pockmarks sites, where grain sizes are often coarser due to the exhalation of fine grain sediments and removal by near-bottom flows (e.g., Virtasalo et al., 2019). We hypothesize that the lack of strong near-bottom flows at the Mittelgrund could lead to the establishment of a rather permanent layer of (re-)suspended fine grained matter above active groundwater seeps.

Finally, we re-surveyed the pockmarks with the multibeam to validate the bathymetric finding shown in Fig. 1, and run a combined CTD/Camera survey across the pockmark. The unprocessed multibeam data across the pockmark survey area are displayed in Fig. 6. The seabed showed a brownish color and was characterized by many white patches of a decimeter to meter scale. Possibly the white patches represent *Beggiatoa sp.* bacterial mats that are known to feed on hydrogen sulphide (Fig. 7). It remains to be investigated if the bacterial mats might have caused the acoustic anomalies.

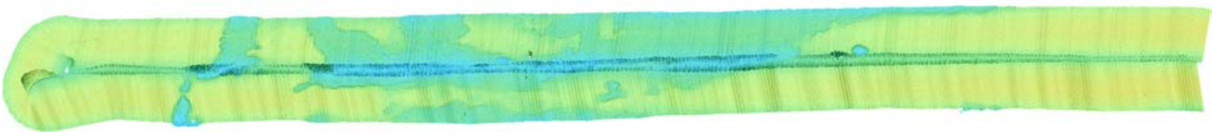

Fig. 6: Uncorrected mutibeam survey across the pockmarks, recorded during bad weather.

Fig. 8: Video shot from our towed CTD/camera device showing white patches in the pockmark, possibly presenting Beggiatoa bacterial mats.

Cruise narrative

Tuesday the cruise started as scheduled 07:30 in the port of Kiel. We rigged up our gear comprising the porewater geochemical sampling devices, the Frahmlot for sediment coring, a Van-Veen grab for surface sampling. We installed a Stonex S9i GNSS receiver RTK GPS on portside next to the deployment frame of Littorina. Then we sailed to Eckenförde Bay and started with our sampling. We also sailed some hydroacoustics profiles to acquire bathymetric data at the northcoast of Eckernförde. A CTD was run and sound velocity profiles derived for the multibeam surveying. The CTD data show offsets and the data need to be re-calculated after proper calibration of the CTD.

Wednesday We proceeded with the sediment sampling next to Mittelgrund. In between some multibeam surveying was performed. A camera tow track was conducted together with the CTD.

Thursday We proceeded with the sediment sampling next to Mittelgrund. The Frahmlot was adapted with snow shoes. Later in the day we had to switch to the crane for deployment starboard, which has to be considered in regard to the RTK-GPS portside geometry change. In between some multibeam surveying was performed. A CTD was run and sound velocity profiles derived for the multibeam surveying. A camera tow track was conducted together with the CTD. Given the upcoming stormy conditions from northeast we had to abandon the cruise Thursday afternoon.

Friday Unloading the equipment

Fig. 9: Cruise participants from left to right: Mats Ippach (GEOMAR), Jasper Hoffmann (University Otago), Jens Schneider von Deimling (CAU), Jan Schröder (CAU), Gareth Crutchley (GEOMAR), Andrew Gorman (University Otago).

Methods

Seabeam 1000 180 kHz mit Codaoctopus F185 IMU (onboard)

Van-Veen Grab (CAU)

Frahm-Lot (GEOMAR) with porewater and sediment sampling

Sea & Sun CTD (GEOMAR)

Camera GoPRO Hero3+ (CAU)

Stonex S9i GNSS receiver (CAU)

References

Whiticar, M.J., Werner, F., 1981. Pockmarks: Submarine vents of natural gas or freshwater seeps? Geo-Mar. Lett. 1, 193-199.

Virtasalo, J. J., Schröder, J. F., Luoma, S., Majaniemi, J., Mursu, J., & Scholten, J. (2019). Submarine groundwater discharge site in the First Salpausselkä ice-marginal formation, south Finland. Solid Earth, 10(2), 405-423.

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tationsnumm	it (UTC) On bott	eraetenumm	Location	LONG	LAT	Heading	Comments
14.5							
1	08:36:30	MBES01	Mound	9.996167	54.507333		No valid CTD in files - Last line is calibration line
2	11:00:00	CTD1	Mound	9.955667	54.495167		
3	11:21:00	BG1	Mound	9.98188	54.504835		schlick oben- leicht sandiger boden unten - starker geruch
4	11:44:01	FL1	Mound	9.98079	54.504465		Schlick - fluffy layer - Falsche position daher nicht beprobt
5	11:54:50	FL2	Mound	9.981848	54.50487		Leerer kern
6	12:05:55	FL3	Mound	9.9815816	4.50550233		Nur ~5 cm recovery - nicht beprobt - mehr gewichte fuer naesten kern (2)
7	13:13:02	FL4	Mound	9.982041	54.5049166		nur wenige cm recovery - nicht beprobt - sehr schlickiger boden - mehr gewichte fuer naechsten kern (3)
8	12:20:55	FL5	Mound	9.981873	54.504808		arm hat nicht ausgeloest - sediment rutscht aus dem rohr raus - nicht beprobt
9	12:30:34	FL6	Mound	9.981933	54.5048433		arm hat nicht ausgeloest - kern war voll - sediment rutscht raus - nicht beprobt
10	12:47:00	FL7	Mound	9.98200	54.5048833		Kern halbvoll - an deck aus rohr gerutscht - nicht beprobt - Wide wird gewechselt - weniger gewicht (2)
11	12:59:59	FL8	Mound	9.9821516	54.504958		kern an deck aus rohr gerutsch - nicht beprobt - mehr gewicht (3)
12	13:07:00	FL9	Mound	9.9818733	54.504951		arm hat nicht ausgeloest
13	13:13:00	FL10	Mound	9.982111	54.504933		arm hat nicht ausgeloest
14	13:22:22	FL11	Mound	9.982021	54.504905		kern beprobt - leicht durchmischte wassersaeule - ~ 10cm
15	13:44:00	FL12	Mound	9.9817533	54.5050733		kern beprobt - leicht durchmischte wassersaeule - ~ 10cm
16	13:59:51	FL13	Mound	9.981851	54.505121		probt - saubere wassersaele - brauner fluffy layer - leicht sandig am boden ~ 10cm - Bilder von tubeworm und fadenalgen in Kamera (genommen 15.5. 8:00 local time)
17	14:14:28	FL14	Mound	9.98113833	54.504685		kern beprobt - klare wasserseaele - schwarzer fluffy layer on top - leicht sandig am boden - background kern
18	14:34:00	MBES02	Mound	9.97767	54.504031	15:30:00	MBES survey mit aktuellem schallprofil -
19	16:44:34	FL15	Mound	9.9820566	4.50488667		kern beprobt - klare wasserseaele - sandig am boden
20	17:04:45	FL16	Mound	9.984085	4.50563833		Bester kern :) lang sauberes wasser laminierung - background kern
15.05.19							
21	06:33:46	FL17	Pockmark	10.028105	54.498262		„background kern in pockmark background - langer kern, fluffy oben , grau unten , schwartz dazwischen
22	06:59:49	FL18	Pockmark	10.0280868	4.49779729		Drift survey ueber intra pockmark (RTK genauigkeit) - Langer kern - fluffy layer on top
23	07:14:03	FL19	Pockmark	10.0288309	4.49675686		Background kern ausserhalb des pockmarks - RTK
24	09:19:48	FL20	Pockmark	10.0155232	4.4979526	29.56	~10 grad neigung im kabel zum kern/ Langer kern, truebe wasserseaule
25	10:54:03	FL21	Pockmark	10.0156110	4.49776503		grad neigung im Kabel zum kern - Nicht beprobt - eindrintiefe zu hoch - sediment zu weich - arm nicht ausgeloese - vermutlich keinen wiederstand vom sediment
26	11:31:12	FL22	Pockmark	10.0154855	4.49783666		Nicht beprobt - eindrintiefe zu hoch - sediment zu weich - arm nicht ausgeloese - vermutlich keinen wiederstand vom sediment
27	11:50:59	FL23	Pockmark	10.0154982	4.4978259	334.68	high backscatter target westliches pockmark, kern beim entnehmen leicht raus gerutscht, jens hat verkackt;)
28	13:07:31	FL24	Pockmark	10.0278765	54.497969	308.61??	Mound ueber intra pockmark - drift survey - langer kern - saubere wasserseule
29	14:15:04	FL25	Pockmark	10.0286449	54.4978		Arm nicht ausgeloest, mit einem gewicht durch geschossen, zu viel kern - keine probe
30		FL26	Pockmark	10.0286600	4.49785656		ohne gewicht, arm nicht ausgeloest - kern war voll aber ist raus gerutscht
31	14:33:14	FL27	Pockmark	10.0281631	4.4977970	73.86	Intra pockmark - guter kern - beprobt
32	'14:47:04	CTD2/Gopro1	Pockmark				
33	16:15:20	FL28	Pockmark	10.0155916	4.49789667		high backscatter target westliches pockmark, ohne gewichte - arm nicht ausgeloest - sediment zu weich - framlot ist komplett eingesackt
34	16:28:04	FL29	Pockmark	10.0155550	4.49786833		high backscatter target westliches pockmark, ohne gewichte - arm nicht ausgeloest - sediment zu weich - framlot ist komplett eingesackt
16.05.19							
35	06:16:40	FL30	Pockmark	10.0156071	4.49783818		high backscatter target westliches pockmark, sediment zu weich, ohne gewichte , arm nicht ausgeloest
36	06:24:14	FL31	Pockmark	10.0155556	4.49779340		high backscatter target westliches pockmark, sediment zu weich, ein gewicht , arm nicht ausgeloest, eventuell zu viel drift,
37	06:33:18	FL32	Pockmark	10.0154736	4.4978566	45.05	eschossen zu viel sediment kern leicht raus gerutscht bei bergung, kern wird trotzdem gesampelt, oberkante vom seiment wahrscheinlich nicht wahre oberkante
38	07:03:04	FL33	Pockmark	10.0153475	4.49790190		
39	07:15:00	FL34	Pockmark	10.015295	54.497878		
40	07:21:24	FL35	Pockmark	10.0154817	4.49777051		
41	07:48:45	FL36	Pockmark	10.0153517	4.49782656		
42	07:54:27	FL37	Pockmark	10.0156442	4.49774403		
43	08:56:00	MBES03	Pockmark				Ab jetzt korrektes Schiffsparameterfile Lit1905.ship geladen, vorheriges Konfiguration war falsch und mit starkem induziertem Heave
44	10:18:15	FL38	Pockmark	10.0155552	4.49782088		
45	10:28:47	FL39	Pockmark	10.0155781	4.49788084		im high backscatter patch
46	10:49:29	FL40	Pockmark	10.0152069	4.49780972		backscatter patch am kran backboard - mit schneeschuhen
47	10:51:50	FL41	background	10.0142772	4.49763026		ausserhalb pockmark am kran backboard - mit schneeschuhen
48	10:57:16	FL42	Pockmark	10.0155568	4.49781678		pockmark background kra
49	11:28:45	F43	ckmark backgrou	10.0277295	4.49822178		Empty - kran
50	11:35:47	F44	ckmark backgrou	10.0269608	54.497459	44.09	Southwest of previous/planned pockmark ;position - kran
51	12:41:07	FL45	Intrapockmark	10.028185	54.497654	4.39	Sorry: GPS panel wasn't displayed, use cross on image. Guter kern
52	'13:30:00	CTD3/Gopro2	Pockmark				