Scientific Report of AMBER subproject WP B.4

Identification and quantification of submarine groundwater discharge

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The major aim of subproject WP B.4 was the identification of submarine ground water discharge (SGD) at selected sites in the southern Baltic Sea (Fig.1). The major research area formed the Puck Bay, southern Baltic Sea (north Poland). In addition, sampling campaigns have been carried out at a site of ground water efflux close to Meschendorf (Germany) as well as in the Oder lagoon in cooperation with the WP B.3. Field sampling was conducted between years 2009 and 2011 at Hel Peninsula (7 sampling campaigns), in the Oder lagoon in 2010 (1 sampling campaign), and at Meschendorf in 2011 (3 sampling campaigns). Following successful ex-situ and in-situ SGD site identification, a quantification of near-shore SGD rates was estimated with Lee-type seepage meters (Hel Peninsula). A small arithmetic overflow was applied to a discrete ground water seep at the shore line close to Meschendorf.

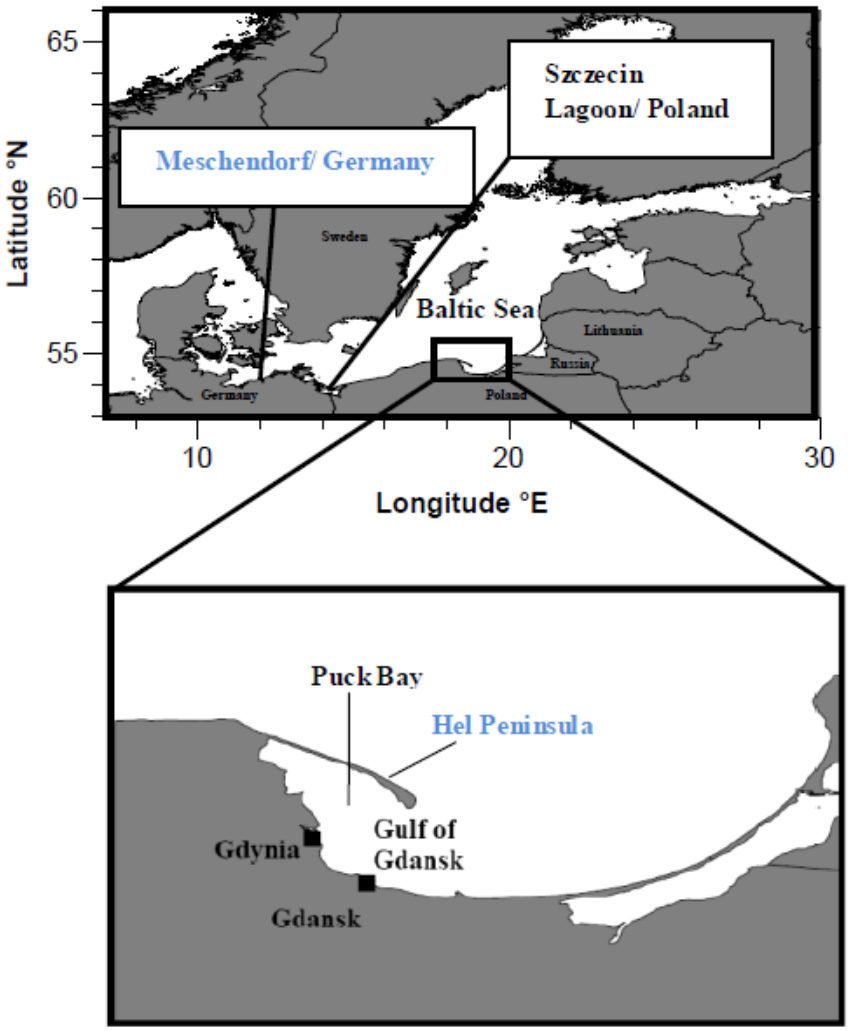
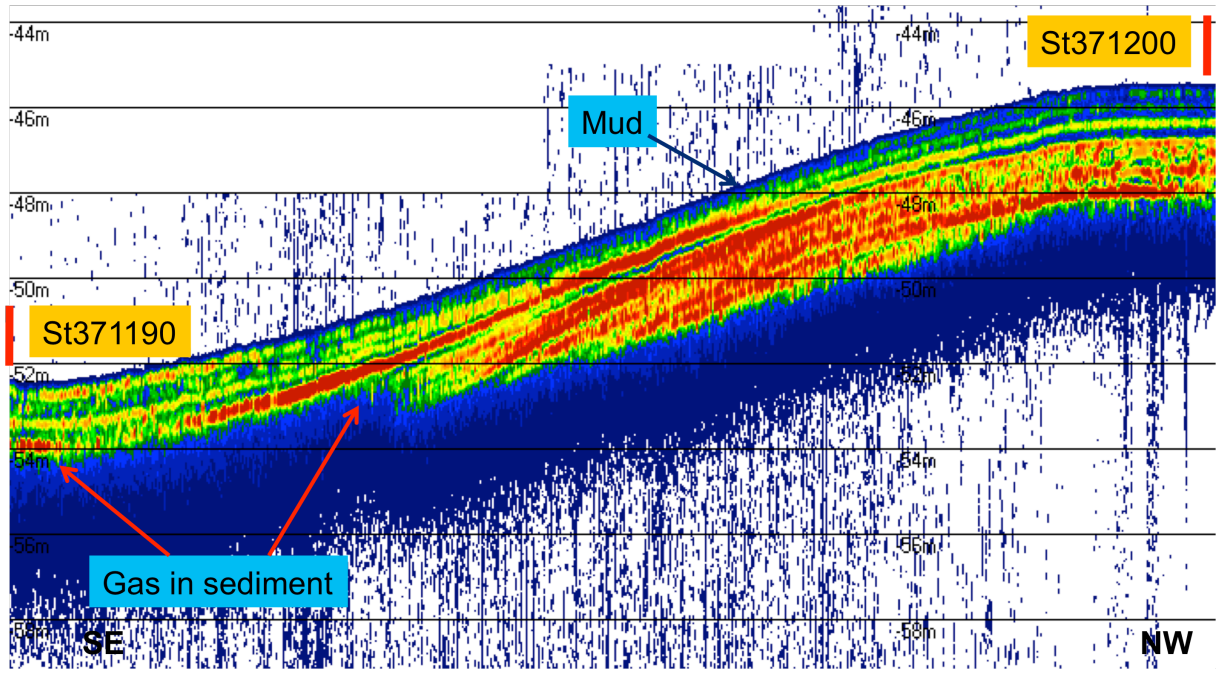


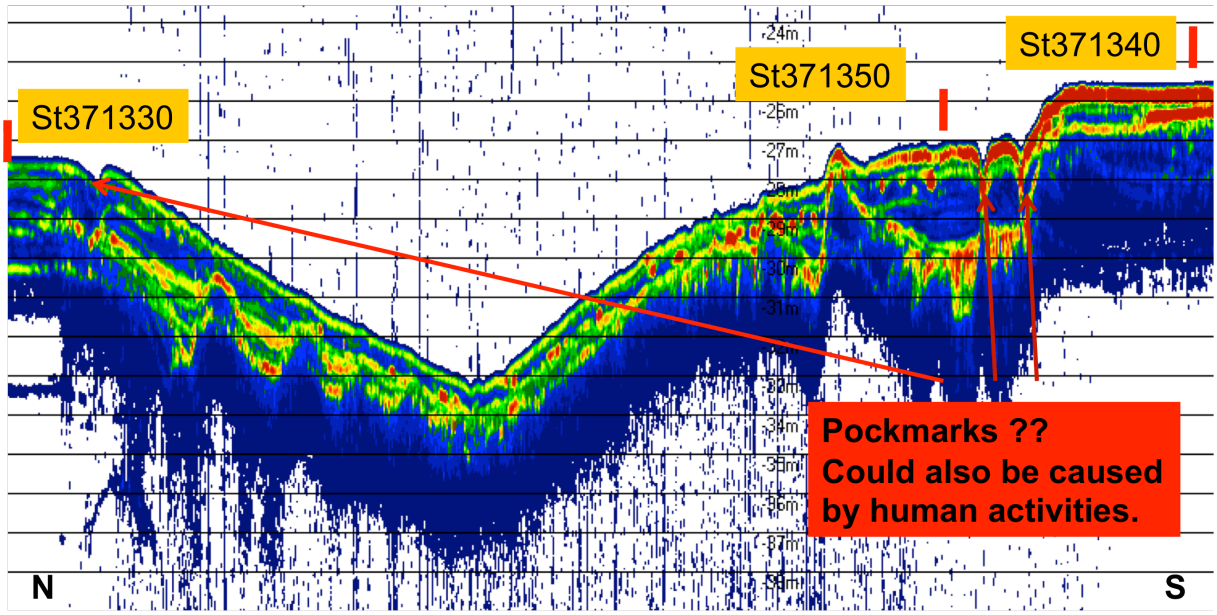
Figure 1: Map with positions of the main study area investigated by WP B.4 in the western Bay of Gdansk and the sampling areas at Meschendorf and the Oder lagoon, all located in the southern Baltic Sea area.

In year 2009, a research cruise with the research vessel “Professor A. Penck” was carried out to identify regions of groundwater impact on surface sediments and the water column of Puck Bay. On a continuous transect between Warnemünde and the Puck Bay, acoustic sub-bottom profiling was performed and measurements of methane, Radon-isotopes, salinity and temperature in the water column were carried out to screen for possible local SGD (methane in coastal environments is one potential indicator for SGD). No clear indications for ground water seeps were found in acoustic profiles and tentative chemical measurements during the

transit from Warnemünde to and from Puck Bay. Within the Puck Bay vertical profiles through the water column were measured by CTD profiling and a multicoring device was applied to retrieve short sediment cores from the central part of the Bay for pore water analyses and further geochemical characterization of potential SGD. A number of shallow sedimentary structures (e.g. pock mark-like) were identified in the central part of the Puck Bay (Fig.2) that may have been caused by strong and focused SGD, but also an anthropogenic origin cannot be ruled out. The deeper part of Puck Bay is covered by gas charged muds (Fig.2). It is very likely that the gas originates from methanogenesis below the sulfate-bearing zone.



a)



b)

Figure 2: Acoustic mapping of Puck Bay surface sediment to find pockmark structures for WP B.4. (Endler & Nickel, unpublished). IOW multicoring stations are indicated by red bars.
a) Acoustic image of NE border basin sediments outer part.
b) Acoustic image of sea bottom sediments at the SW Puck Bay slope.

CTD profiles, in particular salinity variations, as well as increasing Rn counts and CH_4 (Fig.3) concentrations at depth confirm the influence of SGD on the Puck Bay water column.

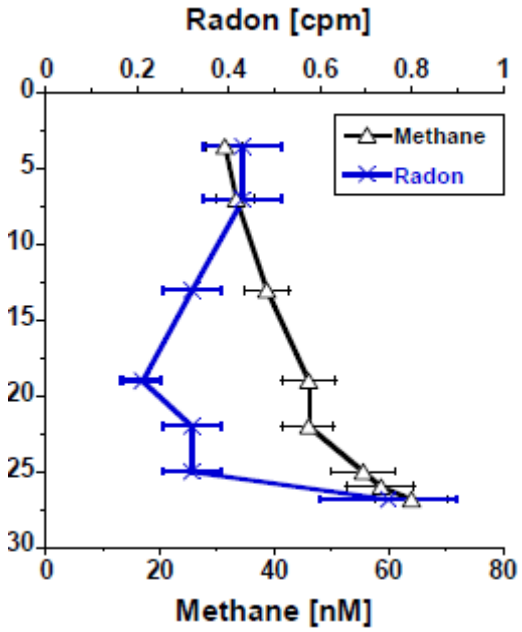


Figure 3: A vertical profile of Rn activity and methane concentrations in the water column of Puck Bay measured during research cruise with RV Prof. Penck for WP B.4. (Vogler, Gentz et al., unpublished). Y-axis indicates water depth in m.

Close to the beach line of Hel Peninsula (Fig.1), an area with nearshore seepage was identified, first by our polish colleagues due to the escape of methane gas bubbles to the water column. Further investigations applied pore water lances, to measure vertical profiles of dissolved constituents and benthic chambers to follow the time dependent changes of dissolved species. Hydrogeochemical and isotope results clearly indicate the seepage of fresh ground waters from underlying aquifers (see WP B.5), that had been enriched in dissolved methane due to decomposition of organic matter, likely in Quaternary sediments. Sediments affected by SGD were characterized for grain size distribution and permeability on a seasonal base to derive an estimate for possible controls of SGD by sedimentological changes. A mapping with benthic temperature-profilers and pore-water lances led us to define the main seepage area and the benthic gradients caused by advective mixing of brackish pore waters with upward migrating fresh ground water. Time-dependent applications of benthic Lee-type seepage-meters allowed to estimate seepage rates of up to 187 L m^{-2} d^{-1} (2009-2010; Kotwiki et al., unpublished). These rates are much higher than a previous estimate for the whole area of the Puck Bay (Piekarek-Jankowska, 1994). This is due to the seep-type nature of these areas with intense SGD from the sands. A more diffusive efflux from the muddy surface sediments in the central Bay is expected. Muddy surface sediments in the central part of Puck Bay are actually found to be affected by SGD based on vertical profiles of dissolved constituents in short sediment cores obtained by multicoring devices. The gradients were much less pronounced compared to the nearshore sandy sites. The water depth and muddy character of the sediments in the central Bay leads to a more diffusive character of SGD and did not allow efflux measurements during the cruise. A distinct signature for ground water contributions was not observed during the cruise in the Oder lagoon.

Another seep-type ground water efflux was investigated near Meschendorf during three campaigns in 2011. Groundwater entered the surface of the beach and drained after a flow of several meters on the sandy surface back to underground passage were it mixed with brackish pore water. This mixture becomes SGD at lower depths. Rate measurements at the iron-rich seep gave a normalized estimate of about 250 L m^{-2} h^{-1}. A further investigation of SGD in this area is ongoing.

Results from the WP B.4 have already been presented on the BONUS conferences and several international conferences (e.g., Vogler et al., 2010, 2011). Two manuscripts are in preparation that will be submitted to international scientific journals in until the end of year 2011.

All meta data sets from the sampling campaigns are published on the AMBER project homepage.

References:

Piekarek-Jankowska H., 1994, *Zatoka Pucka jako obszar drenażu wód podziemnych*, Wyd. UG, p. 104, (in Polish)

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