Geochemical and acoustic evidence for the occurrence of methane in sediments of the Polish sector of the southern Baltic Sea*

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Abstract

This paper presents the results of geochemical and acoustic investigations of sediments in the Polish sector of the southern Baltic Sea. Its objective was to

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indicate areas of gas bubble formation and the occurrence of methane. Over 3000 nautical miles of transects were recorded using a variety of hydroacoustic instruments, and five coring points were selected for further analyses of pore waters (CH_4, SO_4^{2-}, H_2S, NH_4^+, total alkalinity) and sediments (grain size distribution, C_{org}, N_{tot}, LOI and WC). Gas turned out to be present at shallow depths in different forms such as recent and buried pockmarks, and gas-saturated sediments (including gas pockets and seepages). It was found that methane was widespread in the sediments of the study area, both in the surface sediments, e.g. in the vicinity of the Hel Peninsula or in the central Gulf of Gdańsk, and in deeper sediment layers, e.g. in the Gdańsk Deep and the Słupsk Furrow. Chemical analysis showed that as a result of the rapid decomposition of organic matter, sulphates were depleted in the top 20 cm layer of sediments and that methane was produced at relatively shallow depths (in some areas even at depths of 20–30 cm bsf) compared to other regions of the Baltic, reaching concentrations of >6 mmol l^{-1} in the 30–40 cm layer below the sediment surface. The sulphate-methane transition zone (SMTZ) was 4–37 cm thick and was situated in the uppermost 50 cm of the sediments.

1. Introduction

The occurrence of methane in the marine sediments of shallow seas is closely associated with organic matter decomposition and is governed by various biological and geochemical processes (Claypool & Kaplan 1974, Davis 1992, Reeburgh 1996). The organic-rich sediments of coastal regions play an important role in the global methane cycle, which is important in the context of the greenhouse effect and global warming.

The southern Baltic Sea receives a large input of organic matter, mainly due to the constant supply from the Polish Rivers Vistula and Oder/Odra (Łysiak-Pastuszak et al. 2004), as well as intensive primary production in the water column during the warm months (Witek et al. 1997), as demonstrated by frequent algal blooms. Seasonal changes of water temperature and salinity, variable weather conditions, freshwater runoff and limited exchange with ocean waters (Brink & Robinson 2005) give rise to a distinct stratification in the deeper parts of the southern Baltic, which, together with the large supply of organic matter, result in seasonally occurring hypoxic or even anoxic conditions in the near-bottom waters (Łysiak-Pastuszak & Drgas 2004, Hansson et al. 2011). In view of this, an investigation into the extent to which methane occurs in the marine sediments of this region is called for.

Methane can be produced by non-biological thermogenic processes deep in the sea bed or by microbial organic matter decomposition in the muddy sediments of coastal productive environments (Barnes & Goldberg 1976, Claypool & Kvenvolden 1983). During the mineralization process in organic-rich sediments, electron acceptors (O_2, NO_3^-, Fe^{3+}, Mn^{4+}, SO_4^{2-}) are successively depleted. Once sulphates are no longer available, methane