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Research paper

Hydrocarbons from near-surface sediments of the Barents Sea north of Svalbard – Indication of subsurface hydrocarbon generation?

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ABSTRACT

The Barents Sea is considered as an important target for oil and gas exploration, but the petroleum potential of its shelf and slope regions is unknown. Here we present results of a research cruise to the Northern Hinlopen Margin at the transition to the Southern Nansen Basin and the Eastern Yermak Plateau. Multichannel reflection seismic data acquisition, heat flow measurements, and geochemical analyses of near-surface sediments obtained by gravity coring were conducted to study the northern Barents Sea shelf and the early opening of the Nansen Basin and decipher their petroleum potential. Seismic data indicate high thicknesses of up to ~2000 m of Cenozoic sediments. Heat flow density values in the study area range between 67 and 108 mW/m^2. The sediment samples were analysed for bulk geochemistry and sorbed hydrocarbon gases and for two sites for extractable hydrocarbons. Data from extractable (*n*-alkanes > *n*-C_{25}) and bulk (HI and OI from Rock Eval) organic matter demonstrate predominantly terrigenous organic material, most likely derived from ice-transported allochthonous sediments. None of the sediments revealed substantial amounts of methane in pore waters, arguing against active hydrocarbon seepage in the studied areas. However, thermogenic gases sorbed to the sediment matrix (clay minerals, organic matter and/or carbonates) were found in concentrations of up to 600 ppb (on sediment wet wt. basis). For the samples from the Northern Hinlopen Margin and particularly from the adjacent Nansen Basin, a paleo fluid flow of thermogenic gas is indicated and accompanied by higher *n*-alkanes with a modal, petroleum-like distribution. $\delta^{13}C$ values of methane, ethane and propane and gas compositions point at a mainly marine source rock origin of all studied gases with early oil window maturities of the associated rocks (0.6–0.9%VR). From this data an admixture of Type III derived thermogenic gases is indicated for some of the Yermak Plateau sediments for which also the lowest abundances of sorbed gases (50–100 ppb) were observed. Gas geochemical characteristics in the samples with low gas abundances can partially be explained by an input of gases through ice-transport of allochthonous hydrocarbons, which were bound to mature organic matter. For a site on the Northern Hinlopen Margin NE of Svalbard, right at the southern termination of the Nansen Basin a different situation is indicated. In this area the highest concentrations of sorbed gases most likely derived from sediments with an early-oil window maturity and a marine kerogen Type II-typical isotopic distribution. At this location a pseudo well was constructed from 2D seismic data for reconstruction of thermal and maturity evolution. The simulation results indicate that an Early to Middle Eocene source rock would be in the early oil window since the Early Miocene. A possible source rock here and in the circum-Arctic region could have been formed by *Azolla* algae and other flourishing primary producers.

1. Introduction and geological setting

The Arctic region is one of the major frontier areas for hydrocarbon exploration. While in the European Arctic most of the exploration activity is focused on the Southern Barents Sea, little is known about the Norwegian shelf and slope north of the Svalbard archipelago, between the Yermak Plateau to the west and the Nansen Basin to the north and east (Fig. 1). The presence of sedimentary rocks older than Cenozoic in this study area is unclear.

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While some argue that respective rocks are missing north of Svalbard (Minakov et al., 2012), others argue that locally Paleogene and Mesozoic sediments are present and are superimposed by Neogene deposits in deep basins (Grogan et al., 1999). Although speculative, this includes Late Jurassic and Paleogene (marine) source rocks on the Yermak Plateau (Grogan et al., 1999). Large Quaternary and Cenozoic sedimentary packages are present north of Svalbard, which mostly derive from erosional transport through (i) regional uplift in the area during the Early Cenozoic and subsequently (ii) glacial erosion and relocalisation of massive sediments from southerly located regions (Rasmussen and Fjeldskaar, 1996). It is questionable whether these sediments contain productive hydrocarbon source rocks. Based on their estimated thickness and their potentially underlying Mesozoic sedimentary sequences hydrocarbon generation from deeply buried TOC-rich rocks, however, could be possible (Rasmussen and Fjeldskaar, 1996). Furthermore, Paleozoic sediments might be present between Svalbard and Yermak Plateau, if the underlying basement consists of stretched continental crust (Engen et al., 2008; Geissler and Jokat, 2004). But, the exact thicknesses and composition of these sediments is poorly understood. To date no direct information from drill core samples exists on deep subsurface lithology, thickness, and composition of sediments of the Northern Barents region and Nansen Basin. Therefore indirect methods have to be used to explore for potential petroleum systems. These methods include geophysical surveys, as well as near-surface geochemical prospecting such as detection and analysis of migrated hydrocarbons bound to seabed sediments.

2. Sorbed (bound) gases in marine sediments

Since the pioneering work by Horwitz (e.g., Horvitz (1972) and references therein) near-surface hydrocarbon prospecting has become a frequently used method in hydrocarbon exploration (Abrams, 1996a, b; 2013; Bernard et al., 1976; Horvitz, 1972; Logan et al., 2010; Stahl et al., 1981), especially in frontier areas (Abrams, 2013; Cole et al., 2001; McConell et al., 2008; Polteau et al., 2014).

In offshore regions this involves detection and analysis of oil and gas migrating from the subsurface into the water column in form of macroseepage, as well as the geochemical analysis of hydrocarbons retained in near-surface seabed sediments, which can be indicative for recent (active or passive) or past (micro) seepage. Seabed sediment samples are commonly obtained by gravity coring. They can contain migrated hydrocarbons in form of 1) free gaseous hydrocarbons in the pore space, 2) hydrocarbons dissolved in pore water, 3) hydrocarbons “bound” to the mineral matrix or organic matter by sorption or enclosure e.g. in fluid inclusion in carbonates, and 4) higher molecular weight hydrocarbons which can be extracted from the sedimentary organic matter. Free and dissolved gases are commonly investigated by headspace analysis (Abrams and Dahdah, 2010; Bernard et al., 1978), whereas “sorbed” or “bound” (both terms are in the following used as synonyms) hydrocarbon gases can be released from the sediment by mechanical agitation or milling, as well as by acid treatment (Horvitz, 1972; Knies et al., 2004; Stahl et al., 1981; Whiticar, 2002). Free, dissolved and sorbed gases mostly comprise light hydrocarbons (C_1–C_7) but can also contain permanent gases such as CO_2, N_2 and traces of noble gases. However, the exact mechanisms by which

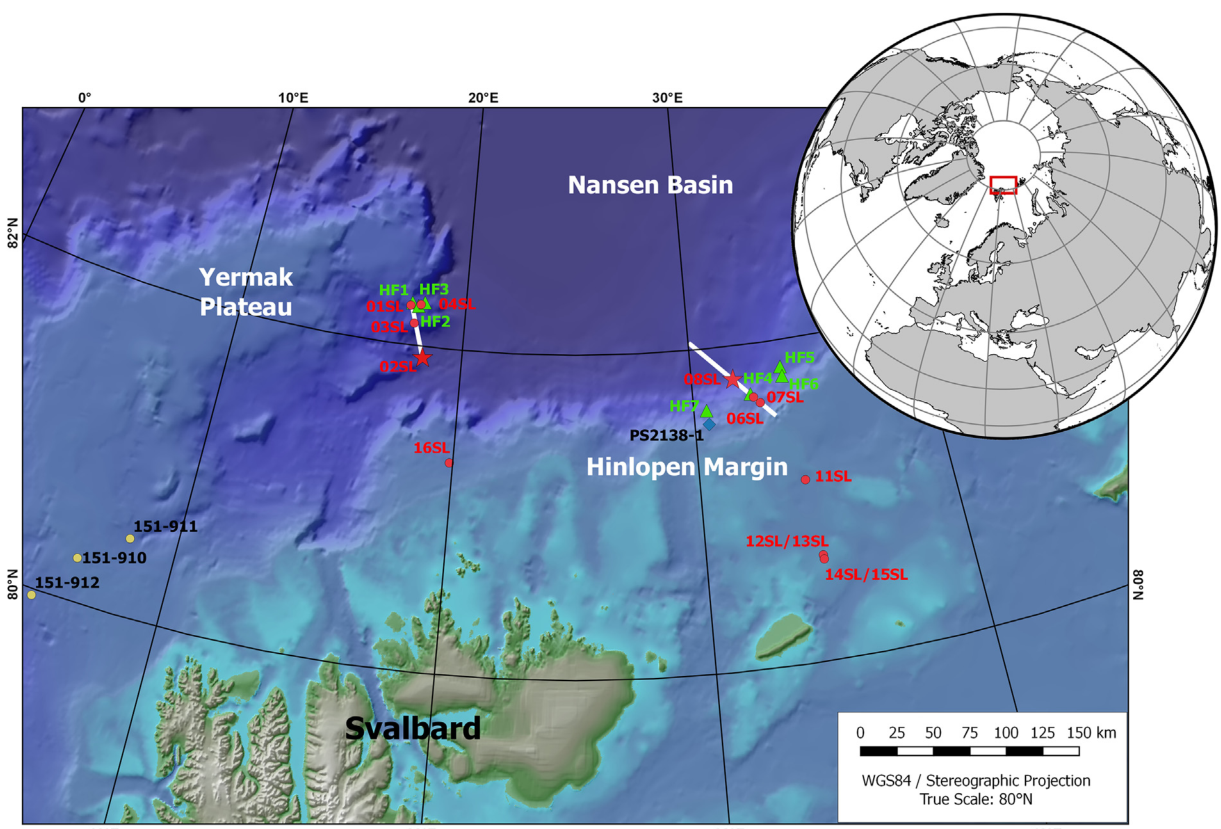

Fig. 1. Sampling sites on the Hinlopen Margin, southern Nansen Basin and at the Yermak Plateau. Red circles indicate locations of gravity cores. Green triangles show locations of heat flow measurements. Yellow circles are locations of ODP sites. PS2138-1 is a core site described in Knies and Stein (1998). White lines show the locations of seismic profiles BGR13-206 (Fig. 5) and BGR13-208 (Fig. 6). Bathymetry is from Jakobsson et al. (2012). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)