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Constraints on the dynamics of pockmarks in the SW Barents Sea: Evidence from gravity coring and high-resolution, shallow seismic profiles

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ABSTRACT

Newly acquired sediment cores and high-resolution seismic lines were studied in order to constrain the timing and mechanism of pockmark formation in the Loppa High area in the southwestern Barents Sea. The evolution of the pockmarks after their formation was also investigated, together with the possibility that they are currently active features. The cores retrieved within the pockmarks lack a layer of ice-rafted debris and an overlying sequence of laminated glaciomarine sediments that were deposited on the undisturbed seafloor at the inception of the Bølling interstadial (~15 cal kyr BP). The pockmarks are suggested to have formed in that period, probably due to climate change-induced destabilisation of methane hydrates and the subsequent release of free gas. The depressions deepened as a result of reduced sedimentation above active seeps. The pockmark cores contain a series of gravel-rich layers, which are attributed to the winnowing of sediment during episodic fluid venting activity. The seismic images reveal little disturbance of the most ancient sediments underneath the pockmarks, indicating that the pockmark chimneys are localised features and were not imaged. The Holocene marine sediment cover in the pockmarks is thinner than on the surrounding seafloor, indicating relatively low sedimentation rates inside the depressions. The gas seepage may thus have been active until the recent past, although no indications of present-day methane flux were found.

1. Introduction

Pockmarks are common expressions of focused fluid flow through the seabed. They appear as circular to elongated depressions in the seafloor, with steep flanks and a relatively flat bottom (Hovland and Judd, 1988; Judd and Hovland, 2009). They range in size from less than 1 m to hundreds of metres and can be up to 45 m deep, but are typically 20–50 m across with depths of 2–10 m. These depressions form in areas where a thick cover of soft, fine-grained sediments with low permeability acts as a recording medium. Fluids causing their formation are usually seeping hydrocarbons, mainly methane of biogenic or thermogenic source (Solheim and Elverhøi, 1985; Vaular et al., 2010), although other fluids may be responsible, such as groundwater (Khandriche and Werner, 1995) or pore water released due to compaction (Harrington, 1985). Pockmarks were first identified in the late 1960s on the Scotian Shelf, offshore the Atlantic coast of Canada (King and MacLean, 1970), and are now reported worldwide in a variety of contexts: nearshore, continental shelf and slope, deep ocean, and even in lakes (Hovland and Judd, 1988; Judd and Hovland, 2009).

Pockmarks have received attention for several reasons. First, they provide an indirect indication of present or past migration of hydrocarbons from underlying reservoirs (Hovland and Judd, 1988; Judd and Hovland, 2009). Their widespread occurrence along continental margins, moreover, suggests that massive quantities of methane, a potent greenhouse gas, may have been released through the seafloor, potentially affecting the global climate (Judd et al., 2002). Knowledge on the spatio-temporal behaviour of pockmarks can also be crucial for the assessment of geohazards for offshore installations (Hovland et al., 2002). In addition, they are remarkable seabed features for the greater diversity and abundance of life that they host (Webb et al., 2009a).

The time of formation of pockmarks is often poorly constrained and their dynamics is largely unknown. It is debated whether pockmarks are currently active, i.e. fluids are seeping at the present day, even episodically. A detailed stratigraphic study based on the analysis of sediment cores and shallow seismic data is necessary in order to gain insight into the past and present dynamics of pockmarks. Most studies, however, are limited to the interpretation of bathymetry, sidescan sonar and/or deep seismic data.

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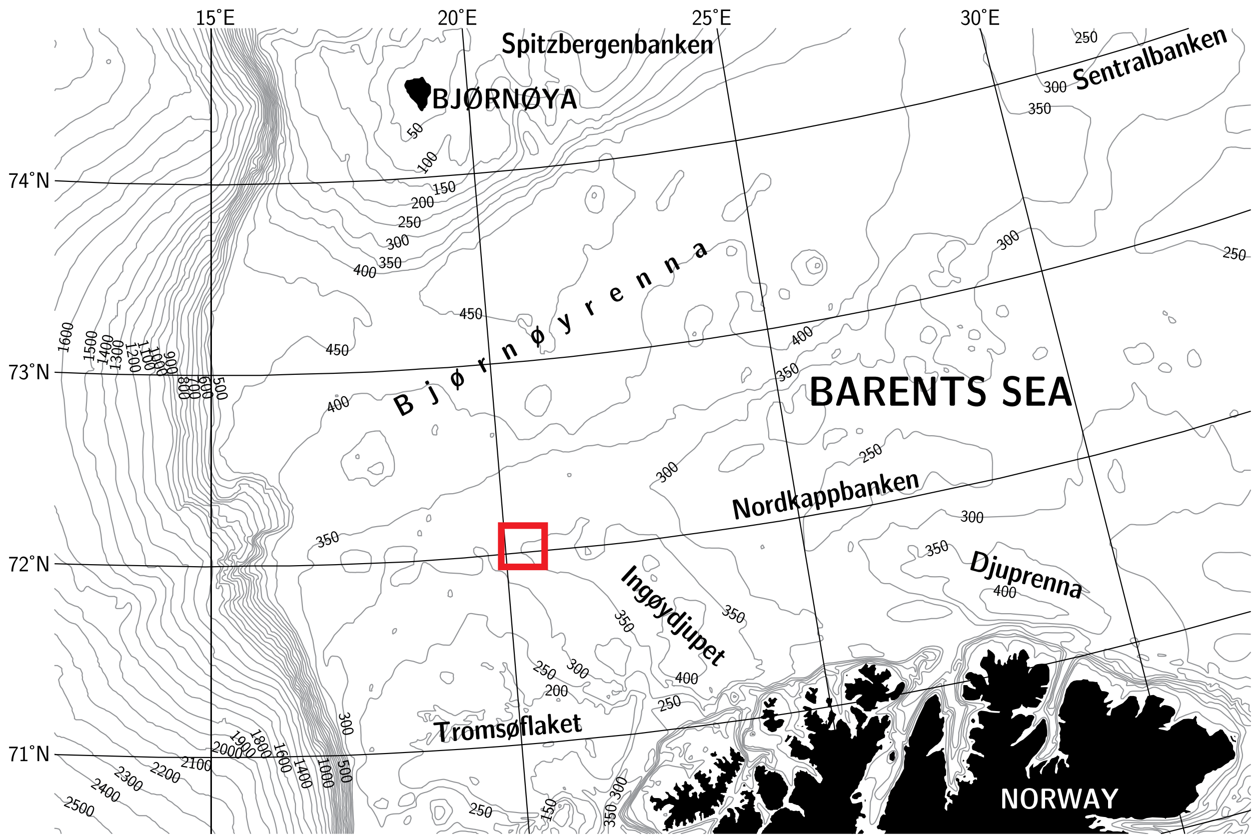

Fig. 1. Regional bathymetry of the SW Barents Sea showing the location of the main troughs and banks (Andreassen et al., 2008). The red rectangle indicates the Ingøydjupet–Loppa High–Ringvassøy Loppa Fault Complex area, where the study area is located. Bathymetry acquired by the Norwegian Hydrographic Service.

The Barents Sea features a large variety of pockmarks in terms of size and distribution (Solheim and Elverhøi, 1985, 1993; Lammers et al., 1995; Long et al., 1998; Ostanin et al., 2013). The most frequently occurring of these seabed depressions are less than 3 m deep, and are contained in fields with densities of hundreds of pockmarks per square kilometre (Chand et al., 2009, 2012). Although the formation mechanism is generally believed to be gas expulsion (e.g. Chand et al., 2012; Nickel et al., 2012; Ostanin et al., 2013), the timing and subsequent dynamics of fluid flow have never been investigated in detail. It is the aim of this paper to (1) constrain the time of formation of the pockmarks,

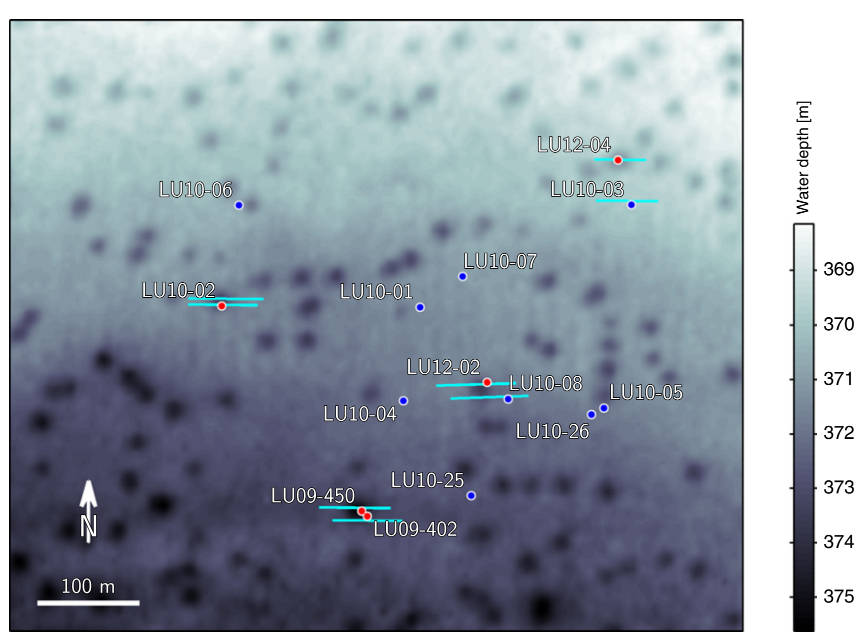

Fig. 2. Bathymetry of the study area showing the coring sites (red dots indicate pockmark cores and blue dots reference cores) and the locations of the seismic lines (cyan lines). See Fig. 1 for approximate location in the SW Barents Sea. Perspective views of the studied pockmarks are shown in Fig. 3. Multibeam bathymetry acquired by the Norwegian Defence Research Establishment.