Marine and Petroleum Geology 28 (2011) 1350–1363

Contents lists available at ScienceDirect

Marine and Petroleum Geology

journal homepage: www.elsevier.com/locate/marpetgeo

Stratigraphic development of the south Vøring margin (Mid-Norway) since early Cenozoic time and its influence on subsurface fluid flow

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ARTICLE INFO

Article history:
Received 15 June 2010
Received in revised form
9 November 2010
Accepted 9 January 2011
Available online 15 January 2011

Keywords:
Norwegian margin
Gas hydrate
BSR
Fluid flow
Stratigraphy

ABSTRACT

The Cenozoic seismic stratigraphy and geological development of the south Vøring margin are analyzed to understand their relation to fluid flow and margin stability. The regional stratigraphy and palaeomorphology of the Møre and Vøring basins indicate gradual changes in depositional environment and tectonic compression between 55 Ma to 2.8 Ma during Brygge and Kai periods, and abrupt changes associated with glacial/interglacial cycles from last 2.8 Ma during Naust period. These changes resulted in deposition of various types of sediments and led to processes such as polygonal faulting and dewatering, inter-fingering of contouritic, stratified and glacigenic sediments, and margin progradation.

A gas hydrate related bottom simulating reflector (BSR) occurs at Nyegga and within the central Vøring Basin while pockmarks are observed at Nyegga only. Diagentic reflectors due to Opal A - Opal CT conversion (DBSRs) occur along a wider area beyond the shelf edge. The DBSRs are located in oozes within the Kai and late Brygge Formations. The gas hydrate BSR occurrence is concentrated above Eocene depocenters in hemipelagic and contouritic sediments deposited during Late Plio-Pleistocene. The BSR overlies polygonal faults and DBSRs but are confined to the slope of anticlines indicating its formation being related to fluid pathways from methanogenic rocks through focused fluid flow. Microbial gas production in Kai, Brygge and deeper formations may have supplied the gas for gas hydrate formation. Fluid expulsion due to DBSR formation and polygonal faulting in oozes may have created overpressure development in permeable layers belonging to the overlying Naust Formation. Slide headwalls are also located close to the anticlines in the study area, implying that over pressured oozes and focussed fluid flow may have been important in creating weak surfaces in the overlying Naust sediments, promoting conditions for failures to occur.

1. Introduction

Subsurface fluid flow, gas hydrates, pockmarks, slides and their association with subsurface structural and geological features are often subjects of debate. In this paper we analyze these topics based on seismic interpretation carried out in the GANS-project (Gas Hydrates on the Norway-Barents Sea-Svalbard margin). One of the goals of this project has been to improve the understanding of the Cenozoic geological development of the Vøring and Møre basins, off Mid-Norway, and to relate glide planes, polygonal faulting, diagenetic reflectors, pockmarks and their coexistence with gas hydrate related bottom simulating reflector (BSR) to the stratigraphic framework.

The BSR in the Nyegga area was first identified by Bugge (1983) and later extended and mapped by others (Bugge et al., 1988; Mienert et al., 1998; Andreassen et al., 2000; Bünz et al., 2003) (Fig. 1). The BSR is confined to the Naust Formation, and is not observed where the Gas Hydrate Stability Zone (GHSZ) crosscuts the Kai Formation (Bünz et al., 2003). The BSR is also limited to the region outside the Naust S glacial debris unit (Fig. 1) (Bünz et al., 2003). The diagenetic reflectors observed in the Vøring Basin area are related to the conversion of Opal A to Opal CT (hereafter referred as DBSRs) in siliceous oozes (Einsele, 1992, p. 792). Multiple occurrences of DBSRs have previously been mapped widely in the Vøring Basin even beyond the Vøring Escarpment (Berndt et al., 2003) (Fig. 1).

Polygonal faults are observed in the lower Naust, Kai and upper Brygge Formations (Berndt et al., 2003). These faults are mainly confined to the basinal parts of the Vøring and Møre basins and are reported to occur further east of the DBSR (Berndt et al., 2003). A large number of pockmarks are mapped in the Nyegga area. These features are observed above the north-eastern part of the identified BSR and occur mainly southwest of the Naust S glacial debris wedge

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doi:10.1016/j.marpetgeo.2011.01.005

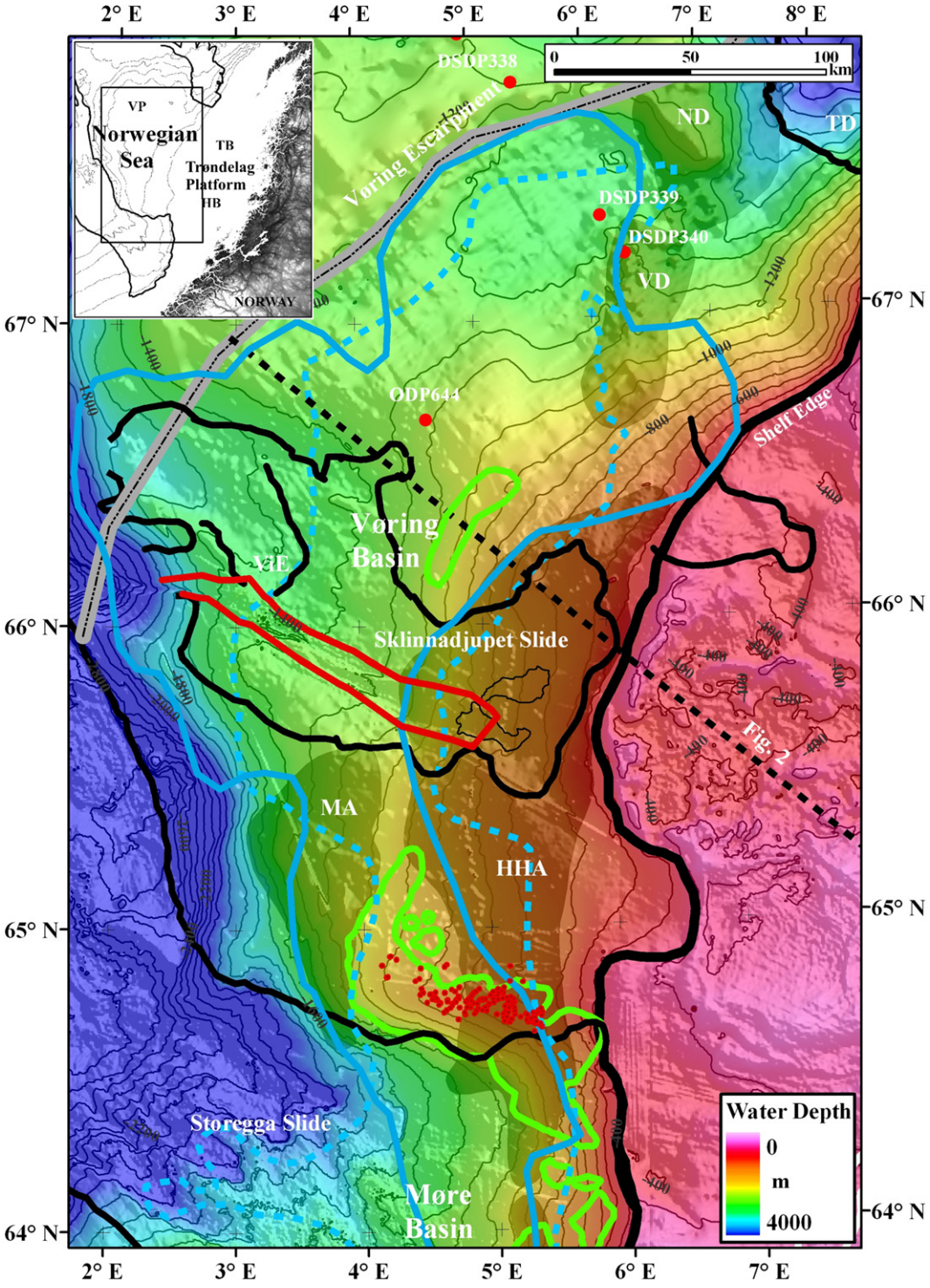

Figure 1. Shaded relief bathymetry of the Study area showing the locations of the two prominent Cenozoic anticline structures, the Helland-Hansen Arch (HHA) and the Modgunn Arch (MA). Also shown are the locations of other smaller anticlines such as Naglfar Dome (ND) and Vema Dome (VD), pockmarks (red dots), shelf edge (thick black line), Vøring Escarpment, slides, Vigrid Escarpment (ViE), Vigrid ridges (red polygon), polygonal faults (dashed blue line), DBSR (blue line), evacuation craters (thin black polygons) and location of the regional seismo-geological section given in Fig. 2. Inset figure, Vøring Plateau (VP), Halten Banken (HB), Træna Banken (TB). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article).

(Bouriak et al., 2000; Bünz et al., 2003; Hjelstuen et al., 2010). Numerous chimney-like structures cut through the BSR with their origin traced to the top of the polygonal faults (Berndt et al., 2003; Hustoft et al., 2009a). Bünz et al. (2003) related their location to a transition zone between gas hydrate occurrences and glacigenic sediments. No pockmarks are reported north of Nyegga even not in areas of high polygonal faulting which Berndt et al. (2003) attributed to diffused fluid flow.

Ridge-like structures, named the Vigrid diapirs by Hjelstuen et al. (1997), are reported from the south western part of the