Pre-Cretaceous prospectivity of the outer Møre and Vøring basins constrained by new 3D seismic data

Ben Manton[1], Sverre Planke[1,2], Dmitii Zastrozhnov[1,2], Mohamed Mansour Abdelmalak[1], Dwarika Maharjan[1], John M. Millett[1], Stephane Polteau[1], Jan Inge Faleide[2], Laurent Gernigon[3], Reidun Myklebust[4] Bent E. Kjølhamar[4]

[1]Volcanic Basin Petroleum Research (VBPR) AS, Oslo Science Park, Gaustadalléen 21, N-0349 Oslo, ben@vbpr.no

[2]Centre for Earth Evolution and Dynamics (CEED), University of Oslo, Sem Sælands vei 1, N-0371 Oslo, Norway

[3]NGU, Trondheim, Norway

[4]TGS, Lensmannslia 4, N-1386 Asker

The outer Møre and Vøring basins offshore mid-Norway are vast underexplored areas. By integrating interpretation of new seismic 3D data, as well as regional 2D, 2Dcubed, and potential field data, we identify new targets for future hydrocarbon exploration. Here we present an integrated interpretation of the crustal structure across the Møre Basin indicating that the Cretaceous infill of the basin thins towards the western margin. The thinning of upper Cretaceous sequences suggests that lower Cretaceous and Jurassic plays could be viable in the western parts of the basins. Imaging of the outer margin is complicated by the presence of Paleogene volcanic complexes. However, well-defined sub-basalt reflections are interpreted as shallow lower Cretaceous and Jurassic strata within the newly defined Kolga High. This structure has a four-way closure of about 90 km2. As of yet, no such plays have not been proven by drilling, nonetheless West of Shetland sub-basalt drilling has locally proven successful (e.g., Rosebank). Seafloor sampling along the outer Vøring Margin and on the Jan Mayen microcontinent further corroborates the interpretation of shallow Mesozoic rocks below the marginal highs.

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Introduction

The outer Møre and Vøring basins represent vast, underexplored areas on the mid-Norwegian continental margin (Figure 1). Limited drilling over the past two decades has led to gas discoveries in the Paleocene and upper Cretaceous intervals in the region (e.g. Tulipan, 6302/6-1; Gro, 6603/12-1; Stetind, 6605/8-1), including the newly developed Aasta Hansteen field in the northern Vøring Basin. Lower Cretaceous and Jurassic sequences have been targeted by several wells (e.g. Dalsnuten, 6603/5-1), however these wells have been unsuccessful in reaching the older strata.

The Møre Basin, located between the Vøring and Faroe-Shetland basins, is a deep sedimentary basin with a thick Cretaceous fill (~8 km). The basin formed following extension since the collapse of the Caledonian Orogeny, as a result of severe stretching and thinning during the Late Jurassic-Early Cretaceous. The last major stretching event occurred during the Late Cretaceous-Paleocene. Continental breakup commenced during the earliest Eocene (~55 Ma) and resulted in voluminous extrusive and intrusive igneous activity within the Møre Basin, as well as the potential development of a magmatic lower crustal body.

All discoveries in the outer Møre and Vøring basins occur in widespread deep water sandstone reservoirs. These units are interpreted to be sourced both from the western Norwegian and eastern Greenlandic and Jan Mayen continental landmasses. Within the Cretaceous there have been issues regarding the permeability of reservoirs, however, regions close to the continent-ocean transition may have a greater potential for high quality proximal sands sourced from the Greenland and Jan Mayen landmasses prior to break-up time (Figure 2).

The aim of this paper is to document the presence of potential Lower Cretaceous and Jurassic sequences at rather shallow depths in the outer Vøring and Møre basins. Jurassic intervals are of great interest due to the prolific discoveries on the Halten and Dønna terraces and within the North Sea. To enable further exploration of the outer Møre Basin, TGS is in the process of acquiring a pair of seismic surveys covering 40,000 km^2 during the summers of 2017 and 2018 (Figure 1). The AM17 surveys highlight potential Cretaceous and Paleocene targets and enable imaging of promising units interpreted to be pre-Cretaceous in age.

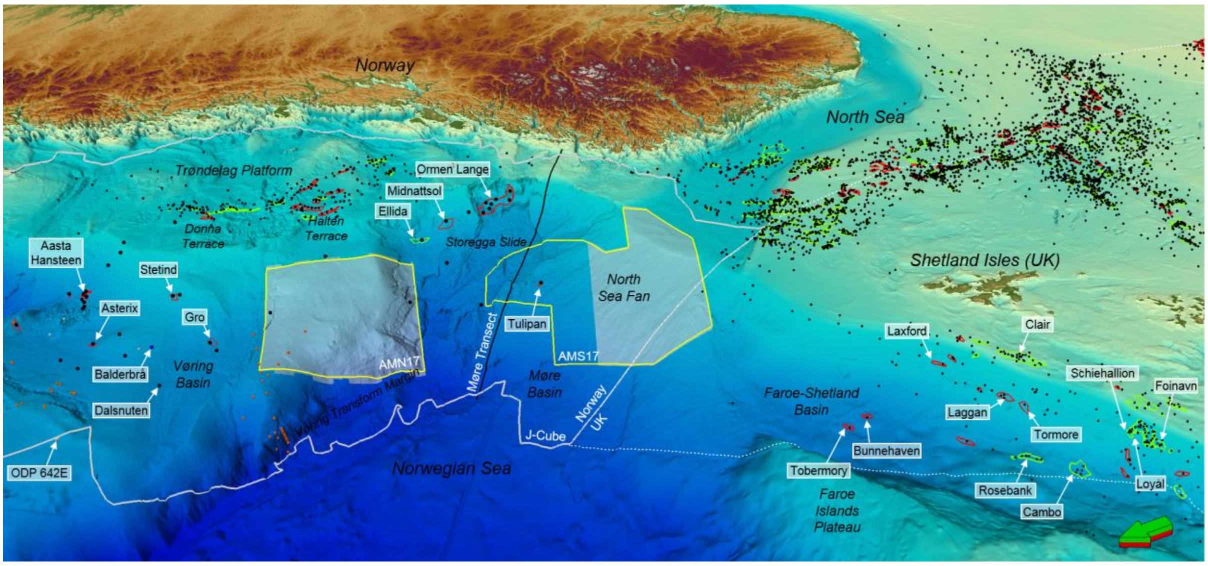

Figure 1 *Location of the study area. The two seismic surveys (AMN17 and AMS17) are outlined with fast-track processed data areas shaded. Outline of J-Cube volume made using regional 2D and some embedded 3Ds is labelled. Exploration boreholes are marked in black, scientific boreholes in grey, seabed sampling sites in orange, and proposed well (Balderbrå) in navy. Fields and selected discoveries are outlined and color coded as oil (green) and gas (red). The Møre Transect is shown in Figure 3.*

Methods

The main database for this project consists of an extensive grid of regional 2D seismic profiles in the Vøring and Møre basins, a 2Dcubed volume (J-Cube) generated using regional 2D and some embedded 3D cubes, and fast-track processed AMN17 and AMS17 3D cubes. In addition, high-pass filtered gravity and magnetic data, bathymetric data, well data, seabed sampling data, and cultural data were available (Figure 1). The data were jointly interpreted using Petrel, DUG and Kingdom Suite software. Key Cenozoic and Mesozoic horizons have been picked and tied to exploration boreholes. The interpretation was corroborated using the integrated seismic-gravity-magnetic (SGM) method, and subsequently depth converted.

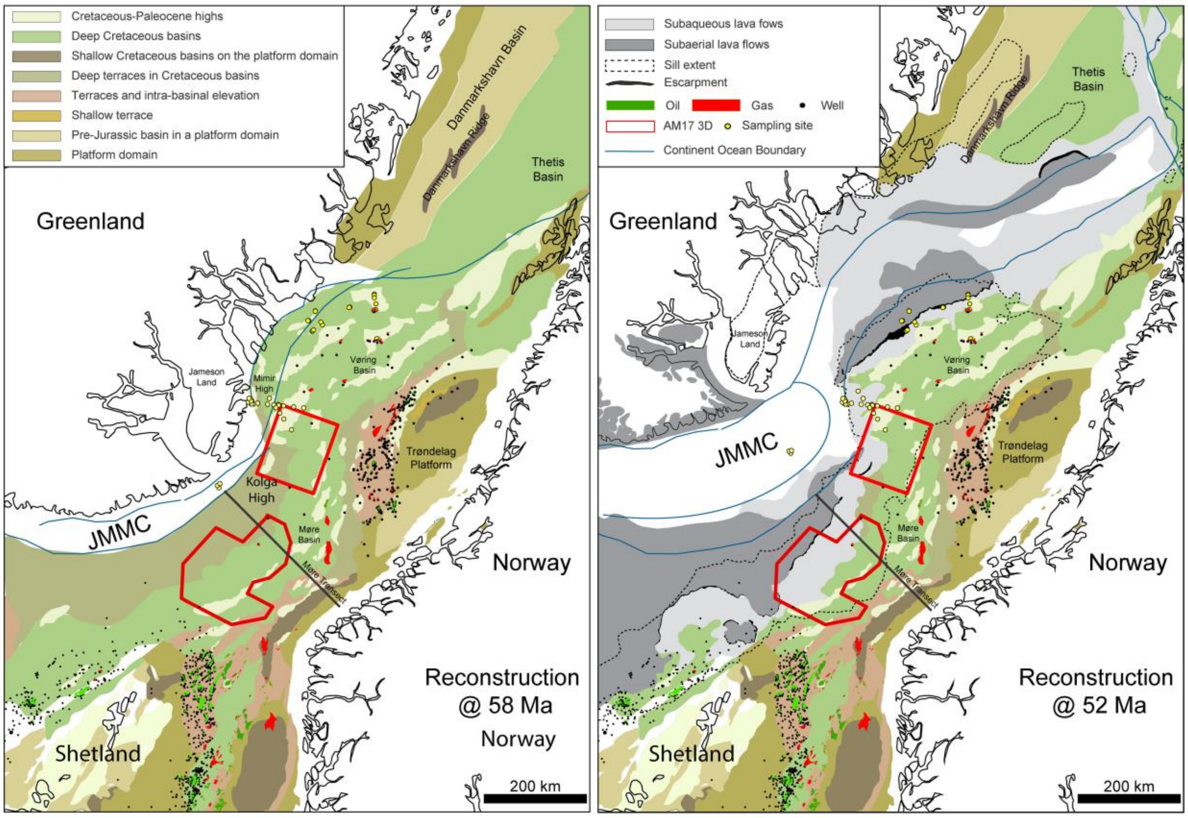

Figure 2 *New structural map and paleogeographic reconstruction of the mid-Norwegian margin before (58 Ma) and after the continental breakup (52 Ma). JMMC: Jan Mayen Microcontinent.*

Regional Møre Margin Transect

A regional profile across the northern Møre Basin has been interpreted based on integrated seismic-gravity-magnetic interpretation method. It shows that the Cretaceous fill thins and shallows towards the newly defined Møre Marginal Plateau (Gernigon et al., 2015; Theissen-Krah et al., 2017) which is located close to the ocean-continent boundary (Figures 2 and 3). The Møre Marginal Plateau may represent a shallow continental block (sub-platform) that existed prior to continental breakup and could be then linked with the Jan Mayen Microcontinent which was initially part of the outer Møre Basin (Theissen-Krah et al., 2017). The Jan Mayen microcontinent is known to have an active Jurassic petroleum system based on seafloor sampling data. Within the Møre Marginal Plateau our interpretation suggests the presence pre-Cretaceous (Jurassic?) sedimentary sequences at a relatively shallow depth that are reachable by exploration boreholes (Figure 3). This interpretation is in agreement with potential field modelling and the interpreted pre-drift configuration (Figure 2; Gernigon et al., 2015; Theissen-Krah et al., 2017).

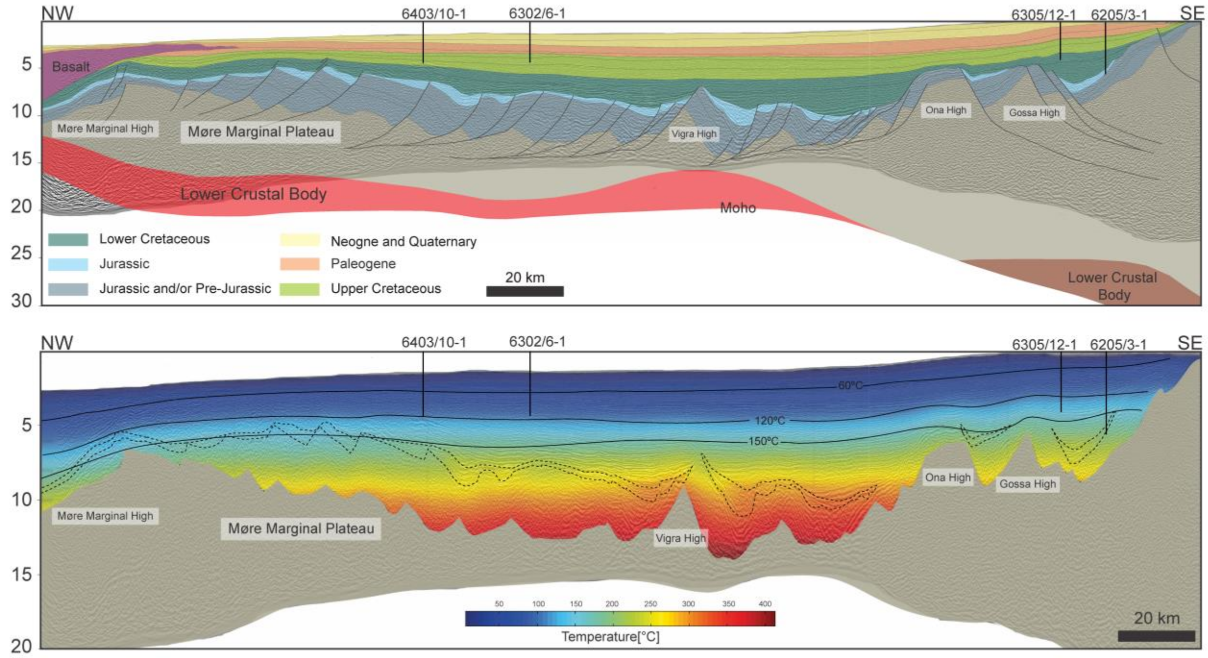

Figure 3 *Interpreted seismic reflection profile in depth across the Møre Margin showing the crustal structure and the sedimentary basin. Jurassic and pre-Jurassic strata are interpreted along the profile and shallows towards the Møre Marginal plateau. The thermal modelling for the transect suggests that Jurassic sequences are within the oil/gas windows on the Møre Marginal Plateau (modified from Theissen-Krah et al., 2017). See Figures 1 and 2 for profile location. Seismic data courtesy of TGS.*

Kolga High

In the outer part of the Jan Mayen Corridor we define the Kolga High, a new structural element which is interpreted as a shallow pre-Cretaceous fault block beneath lava flows and Cretaceous-Paleocene sediments. The Kolga High is identified in both 3D data as well as 2D profiles and corresponds to a positive gravity anomaly (Figure 4). The high has a NW-SE trend and appears to deepen in all directions suggesting it is a significant untested closure (Figure 5). The closure is approximately 11 km long and 8 km wide and its crest is approximately 1.2 s below the seabed, indicating that it can be reached by drilling.

To the south of the Kolga High there are shallower reflections which terminate at the high (Figure 4). These reflections are likely to indicate relatively significant changes in lithology such asunconformities or faults. This could suggest a variety of lithological units above the southern Kolga High, the ages of which are currently uncertain. Furthermore, we suggest that the Kolga High could be a common structure with the Mimir High (presently situated at the Vøring Transform Margin – Figure 2) which was shifted along the Jan Mayen Fracture Zone since the Late Cretaceous. The seafloor sampling along the Mimir High found evidence of reworked Jurassic fossils in Late Cretaceous-Early Eocene sediments. These sediments were likely eroded from the neighboring pre-Cretaceous highs during that time. Therefore, this can be an indication of the presence of Jurassic sediments in the Kolga High.

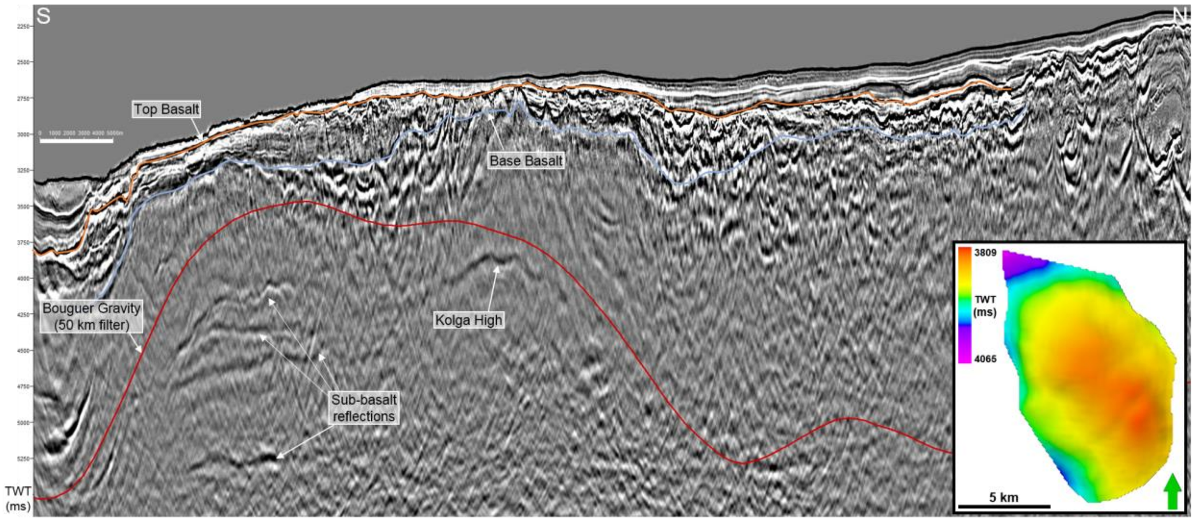

Figure 4 *Reflections interpreted as the sub-basalt Kolga High in the AMN17 fast-track data. The reflections correspond to a Bouguer gravity anomaly (50-km high-pass filtered), suggesting that the reflections correspond to relatively shallow units of Pre-Cretaceous age which are denser than the Cretaceous succession. Numerous reflections are observed suggesting a varied lithological package. Correlating these units away from the high is difficult because of imaging problems in the fast-track data. Inset: TWT map of the Kolga High horizon. Data courtesy of TGS.*

Conclusion

The outer Vøring and Møre basins remain under-explored. By taking an integrated approach, interpreting seismic and potential field data, new potential targets for hydrocarbon exploration such as the Kolga High are identified. These structures may contain prospective lower Cretaceous and Jurassic targets.

References

Gernigon, L., Blischke, A., Nasuti, A. and Sand, M. [2015]. Conjugate volcanic rifted margins, sea-floor spreading and microcontinent: insights from new high-resolution aeromagnetic surveys in the Norway Basin. *Tectonics* **34** (5), 907-933.

Theissen-Krah, S., Zastrozhnov, D., Abdelmalak, M.M., Schmid, D.W., Faleide, J.I. and Gernigon, L. [2017]. Tectonic evolution and extension at the Møre Margin–Offshore mid-Norway. *Tectonophysics* **721**, 227-238.