Short Term Scientific Missions (STSM) Report

Seismic characterization of gas hydrates in the Vøring Basin, offshore Norway

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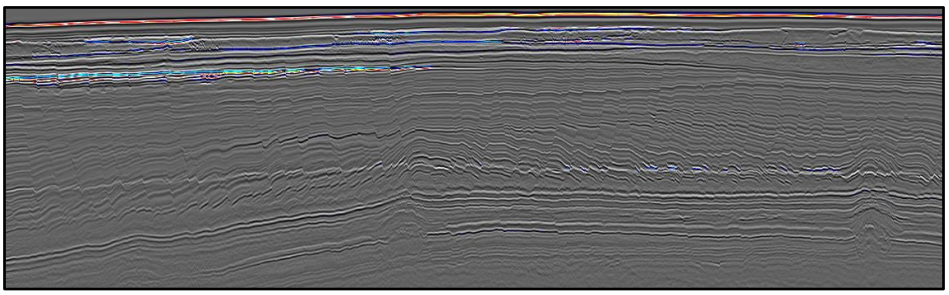
COST Action: ES1405 (MIGRATE)

Host Institution: Centre for Arctic Gas Hydrate, Environment and Climate (CAGE), University of Tromsø, Norway

Duration of STSM: 01.03.2016 - 29.04.2016

Cost STSM Reference number: ECOST-STSM-ES1405-150216-070748



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List of Abbreviations

BSR- Bottom simulating reflector
DBSR - Diagenesis-related bottom simulating reflector
MTD - Mass transport deposit
ER - Enhanced reflection
TWT- Two way time
SS- Storegga slide

1.0 Purpose of the STSM

The presence of submarine gas hydrates in European waters may signify a potential future alternative energy resource. Gas hydrates are ice-like compounds of natural gas (predominantly methane) and water molecules that form under a high pressure and low temperature regime, usually in marine sediments or in permafrost regions (Kvenvolden, 1993; Sloan and Koh, 2007). Previous studies have documented the existence of gas hydrates along the Mid-Norwegian margin (Bünz et al., 2005; Chand et al., 2011; Mienert et al, 1998). However, the nature of gas hydrates in other parts of the Vøring Basin, offshore Norway, still remains elusive, thus presenting an incomplete assessment of its reserves. Therefore, the overarching goal of this STSM was to analyze a newly available seismic reflection dataset in order to detect and map the spatial distribution of gas hydrates in specific areas of the Vøring Basin.

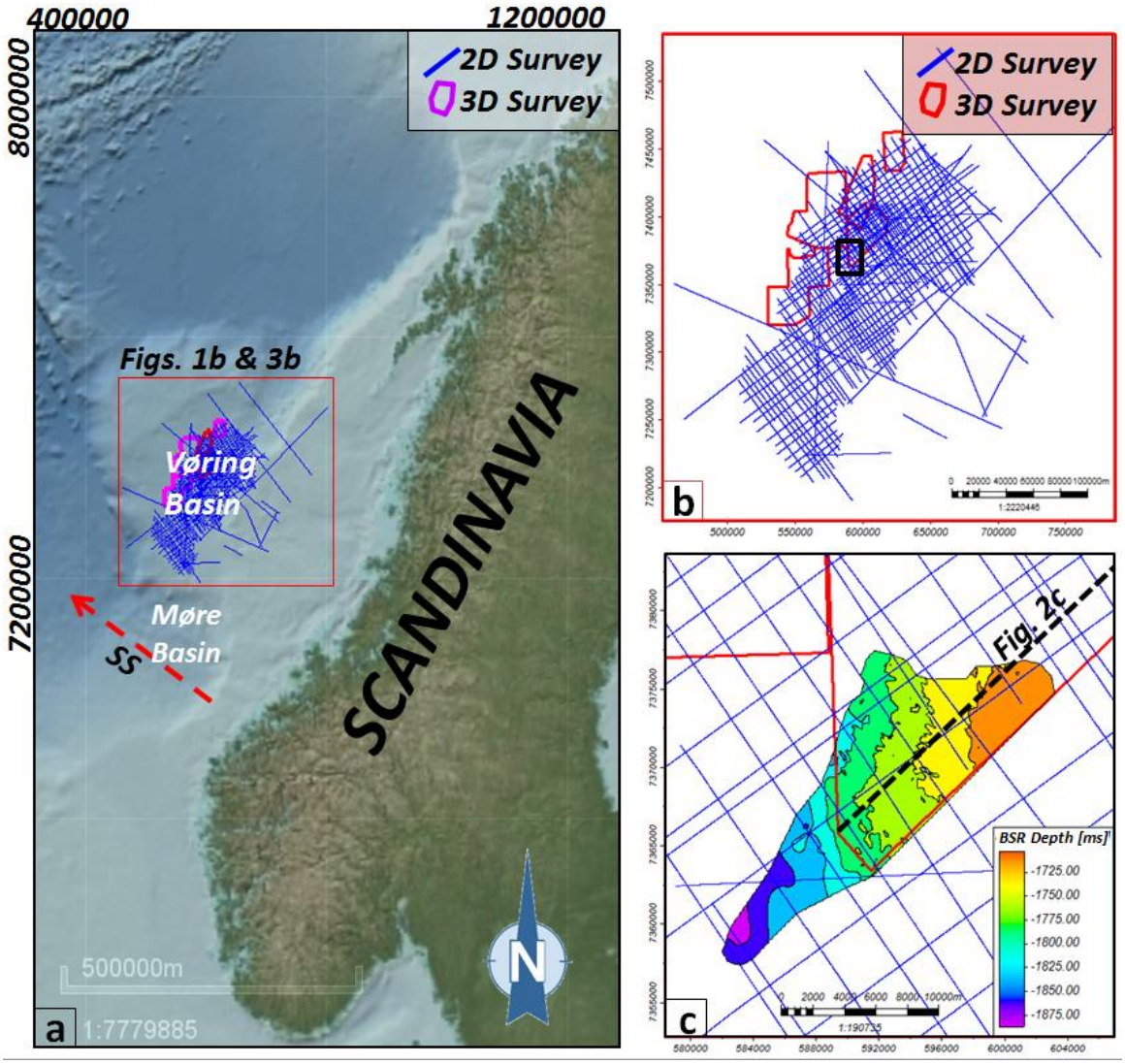

Figure 1. Study Area *(a) Geographical location of the Vøring Basin, offshore Norway. (b) 2D and 3D seismic reflection dataset analyzed in this study, location shown in Figure 1a. (c) Spatial distribution of the gas hydrate related BSR mapped in the study area [25 ms TWT contour interval], location is shown by the black square in Fig. 1b. SS denotes Storegga slide and red dotted arrow indicates the transport direction.*

2.0 Description of the work carried out during the STSM

The work carried out during this STSM at the University of Tromsø entailed; (1) creating a new database based on the amalgamation of the newly available seismic reflection surveys across the Vøring Basin, and (2) seismic interpretation of the database for acoustic evidences diagnostic for the presence of gas hydrates. Five two-dimensional and five three-dimensional time-migrated seismic reflection surveys were loaded into the workstation using the Petrel-E&P Software Platform 2014 to create a unified database (Fig. 1b). The database was analyzed in detail for evidences of gas hydrates, which are usually inferred from the presence of bottom simulating reflectors (BSRs) in seismic profiles. The BSR mimics the seafloor, however is of reverse polarity and high reflection amplitude. This anomaly arises from the contrast in acoustic impedance of hydrates overlying free gas. On the contrary, diagenetic reflectors so-called DBSRs arise from the presence of diagenetic fronts resulting from the transformation of Opal A to Opal CT. Similar to hydrate BSRs, such DBSRs mimics specific paleo-seafloor surfaces. Other evidences of fluid flow within the study area were also mapped (e.g. polygonal fault systems, hydrothermal vents and localized amplitude anomalies) as well as mass transport deposits.

3.0 Description of the main results obtained in the STSM

Analysis of the seismic reflection surveys reveals a prominent high-amplitude, negative polarity reflector which is sub-parallel to the present-day seafloor topography and exhibits a cross-cutting relationship with the host stratigraphy (Fig. 2). This feature was interpreted as a gas hydrate-related BSR (Fig. 2c). The BSR is visible at about ~ 330 ms TWT below the seafloor and is localized at a subsea depth ranging between 1710 and 1880 ms TWT. Moreover, the BSR mapped spatially covers an area of 150 km^2 (Figs. 1c and 2c). Occasionally, the BSR exhibits localized variations in continuity and amplitude strength (see Fig 2c). Localized enhanced amplitude reflections can be imaged beneath the BSR and is interpreted as zones of free gas trapped under the hydrate seal (Fig. 2 c).

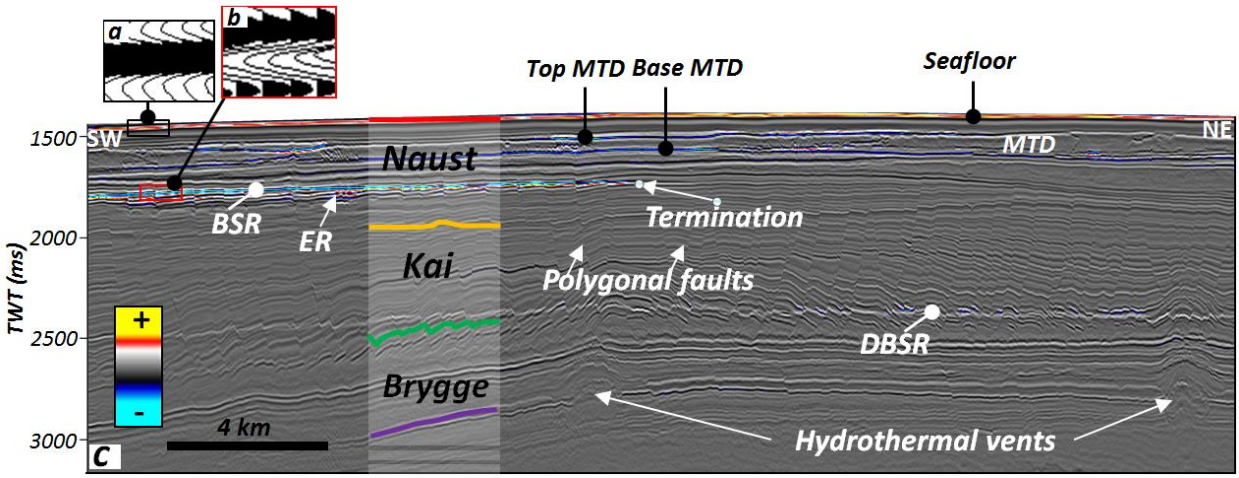

Figure 2. BSR providing evidence for gas hydrate in the Vøring Basin *(a) Top left insert is a wiggle trace of the seafloor, note the opposite polarity when compared to the BSR in Fig.1b. (b) Wiggle trace of the BSR. (a) Seismic section showing the BSR and other fluid flow elements in the study area, location is shown in Fig. 1c. ER denotes enhanced reflection and MTD denotes mass transport deposit.*

The BSR identified in this study developed within the Pliocene-Pleistocene Naust Formation, which consists of sediments deposited in a glacio-marine environment. The Naust Formation has been identified as a favorable host for gas hydrates offshore Norway considering the lithological properties (e.g. Bünz et al., 2003). Possible sources of fluids driving hydrate formation in the study area may be related to deep sources, resulting from thermogenic gas usually associated with hydrothermal vent complexes (Fig. 2c). Otherwise the fluids may be of biogenic origin sourced from the Kia Formation and migrated upwards through feasible layers (Fig. 2c) (e.g. Chand et al., 2011).

4.0 Future collaboration with the host institution

Collaboration with Prof. Stefan Bünz and his research group at the CAGE is still ongoing, and aims at a better understanding of overburden fluid plumbing systems in the Vøring Basin. In addition, during the course of this STSM, mound-like structures were also identified in the shallow overburden arising from subsurface sediment remobilization (Appendix 1). The origin and mechanism behind the evolution of this mounded structure is still under investigation.

5.0 Foreseen publications/articles resulting from the STSM

Two peer-reviewed manuscripts are planned to be written once a full-scale analysis of the hydrates systems and the mounded structures is completed. The papers will be divided into the gas hydrate system description and characterization complemented by a second paper dealing with the origin of the mound-like structures mapped in parts of the Vøring Basin. This would be done in collaboration with the researchers at the CAGE, University of Tromsø.

6.0 Confirmation of the host institution of the successful execution of the STSM

Confirmation will be sent directly by the host.

7.0 Acknowledgement

I am grateful to COST (European Cooperation in Science and Technology) under the framework of ESSEM COST Action ES1405 (MIGRATE) for funding this STSM. I acknowledge Schlumberger for granting Petrel-E&P Software to the University of Tromsø. The dataset analyzed in this report has been graciously made available to the University of Tromsø through the DISKOS Petrobank system. I would like to express my gratitude to my host Prof. Stefan Bünz for providing an enabling working space at the CAGE and for his helpful and stimulating discussions on gas hydrates systems and other sediment remobilization phenomena. Special thanks to Kate Alyse Waghorn for her time and great discussions we had concerning the project. Sunny Singhroha is greatly thanked for helping me settle quickly into Tromsø. I would also like to thank my Ph.D supervisor at the University of Haifa, Dr. Nicolas Waldmann for encouraging me to embark on this STSM and also for providing additional funds to cover my stay in

Tromsø. This report is dedicated in loving memory of my late father Dr. Jonathan Onosivbakpo Eruteya who was also enthusiastic about this scientific mission but sadly passed away before I embarked on it.

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Appendix

Mound-like Structures

Analysis of the database also revealed unique mound-like geomorphological structures (Fig. 3). These mound-like structures are spatially distributed in the northern and southern part of the study area and have varied diameters and a positive relief of up to 150 ms TWT on the present day seafloor (Fig. 3). Internally the mound-like structures are generally chaotic, made of low to moderate amplitude reflections when compared to the continuous reflectors of the surrounding units (Fig. 3a). Initial interpretation suggests a genesis related to the remobilization of fluidized sediments from underlying units.

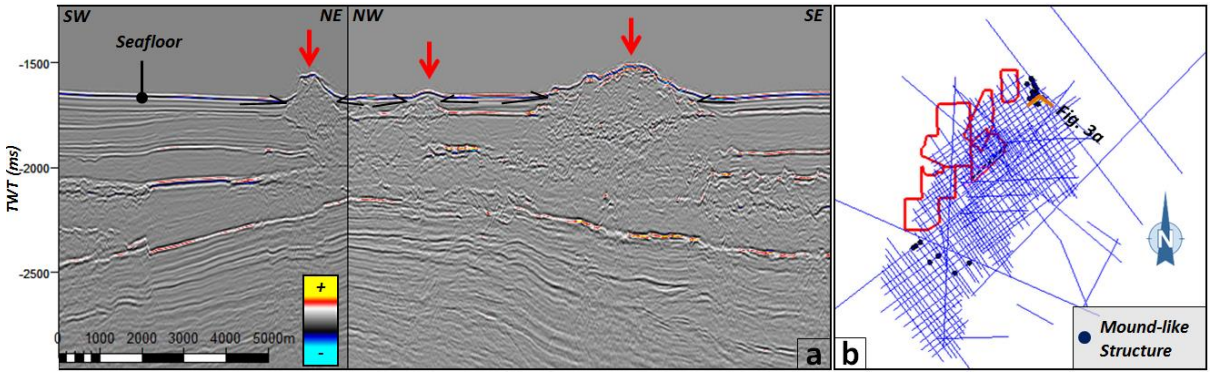

Figure 3. Evidence of large-scale sediment remobilization in the Vøring Basin expressed as mound-like structures*. (a) Seismic profile showing mounded structures indicated by the red arrows, location is shown in Fig. 3b. (b) Location of the mound-like structures mapped in the study area, for geographical location see Figure 1a.*