Sediment dynamics and destabilization of continental margins: Predicting shelf and slope instability under a changing climate

Supervisory Team

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Project Description

The increase in energy demand has pushed the E&P industry toward new frontiers that carry with them implicitly higher socio-environmental risk. In deep and ultra-deep water targets it is requisite to identify the sources and triggers of surface and subsurface natural hazards and to place them in a spatial and temporal framework. Gravity driven processes, seabed instabilities, pore pressure phenomena and seismicity are (often linked) marine geohazards that may compromise sea-floor engineering. A detailed characterization of their distribution and occurrence is fundamental when planning submarine developments in those challenging environments. For new and long-term installations, in particular, the evaluation of the potential impact of future climate changes on the current geohazard scenario is of critical importance, and the determination of past events that occurred in similar environmental conditions to that observed today is key to the potential geohazard assessment.

The Quaternary evolution of the North Atlantic continental margins has been primarily driven by the impact of high-frequency glacio-eustatic oscillations on depositional systems. Changes in sea level, sedimentation rates, strength of oceanographic currents, bottom water temperature and dynamics of ice sheets promoted contrasting scenarios during glacial and interglacial periods that led to the generation of different sources of continental margin instability, including huge submarine landslides (Bryn et al., 2005). The modern physiography of the North Sea and North Atlantic margins offshore UK and Norway shows a combination of glacial features and recent sediment accumulations, reflecting the advance and retreat of the Fennoscandian ice sheet (Nielsen et al., 2009; Huuse and Lykke-Andersen, 2000) and British-Irish ice sheet (Bradwell et al., 2008). High sediment accumulation rates coupled with climate dynamics generated different sources of marine geohazards, including shallow-gas accumulations, gas hydrate dissociation, current-induced scour, mud diapirism/volcanism, pockmark formation, tilting and seismicity associated with glacial/de-glacial isostatic adjustments.

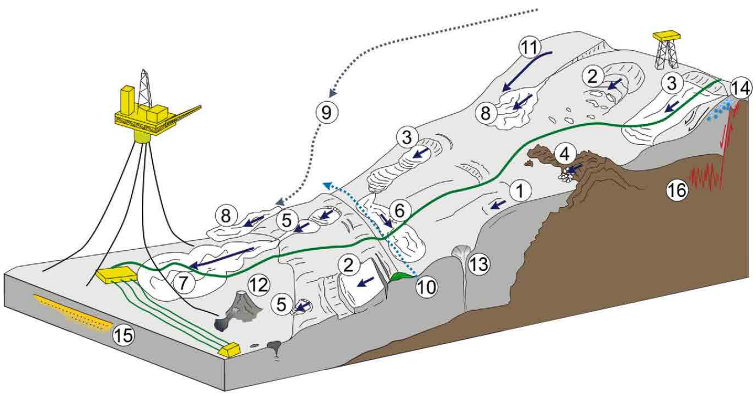

Fig. 1 - Schematic representation of main offshore geohazards: 1- creep; 2- translational slide; 3- rotational slide; 4- debris avalanche; 5- debris flow; 6- liquefied/fluidized flow; 7- high density turbidity current; 8- low density turbidity current; 9- hyperpycnal flow; 10- along contour flow; 11- laminar flow; 12- mud diapirism and volcanism; 13- fluid venting and pockmarks; 14- gas hydrates or free gas accumulations; 16- overpressured sand layer; 16- seismic loading. Modified from Thomas et al., 2010.

This project will investigate environmental conditions and geological processes that may generate natural hazards affecting the sea floor along the Eastern margin of the North Atlantic Ocean, defining their occurrence through time (glacial vs interglacial periods) and delineating areas likely to become vulnerable during future climate change. Particular effort will be dedicated to quantifying the volume of gas-hydrates stored along the margin (Bünz and Mienert, 2004), aiming to define areas that could be potentially affected by gas-hydrate dissociation and, consequently, by seabed instability (Maslin et al., 2010).

The results obtained from the analysis of acoustic data will be integrated with relevant field observations of submarine landslides and gas-charged sediments, which could include, for example, sites around North Atlantic, Arctic and Argentina.

Data: 2D and 3D seismic data, velocity and offset reflectivity volumes, multibeam bathymetry, sediment samples (industry and DSDP/ODP/IODP boreholes, data from site surveys).

Approach: The characterization of the North Atlantic margin and the definition of potential sources of hazard will be achieved in five steps: 1 - Definition of the processes that shaped the sea floor during the Quaternary and led to the modern physiography of the North Sea and Norwegian Sea; 2 - Identification and mapping of surface and subsurface geomorphic features and related deposits that may affect the stability of the margin; 3 - Identification and mapping of gas-charged sediment; 4 - Development of a GIS-based hazard map of the sea floor; 5 - Evaluation of the occurrence and location of future potential geohazards.

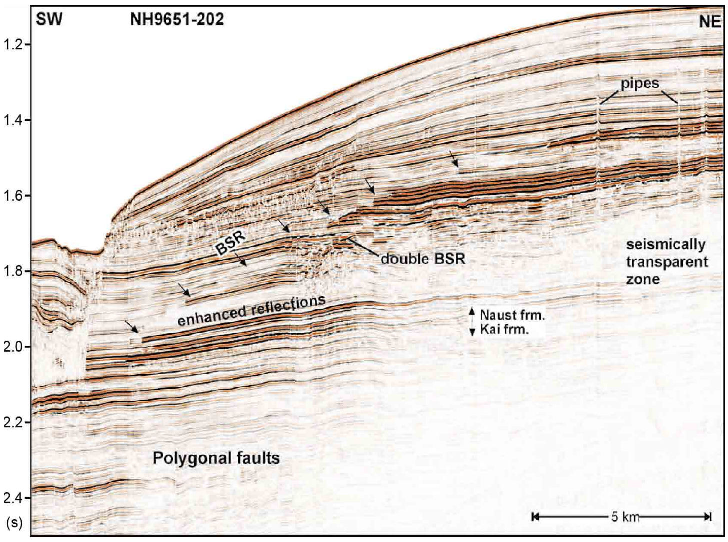

Fig. 2 - Time-migrated seismic section from the northern flank of the Storegga Slide (mid-Norwegian margin) showing accumulation of gas hydrates (highlighted by Bottom Simulating Reflectors - BSR) and gas chimneys. Modified from Bünz and Mienert, 2004.

CDT Research Themes: "Exploitation of Challenging Evironments" (70%), "Environmental Impact and Regulation" (30%).

Major scientific outcomes: Increase our knowledge of glacially-influenced depositional systems, improve the understanding of the geohazard scenario in the North Sea and North Atlantic margins, quantify the role of gas-hydrate dissociation for sea floor instability under a changing climate.

Research context: The student will join the strong and dynamic scientific communities of the Basin Fill Group and Glaciology Group of the University of Aberdeen, the Site Investigation Team of BP, and the Basin Studies and Petroleum Geoscience Group of University of Manchester.

Student profile: A 1st or high 2:1 degree in Geoscience. Industry or academic research experience will be an advantage, particularly offshore data acquisition and analysis. Experience with GIS and/or geotechnical analysis would be highly beneficial.

Career routes: The student will gain expertise in the use of industry-standard seismic interpretation and mapping software to assess the risk of geological hazards to drilling operation and subsea installation. Future career paths may include the Oil and Gas industry, offshore site investigations, and academia.

References

Bradwell, T., Stoker, M.A., Golledge, N.R., et al. 2008. The northern sector of the last British Ice Sheet: maximum extent and demise. Earth Science Reviews, 88, 207-226. 10.1016/j.earscirev.2008.01.008

Bryn, P., Berg, K., Forsberg, C.F., Solheim, A., Kvalstad, T.J. 2005. Explaining the Storegga Slide. Marine and Petroleum Geology 22, 11-19.

Bünz, S., Mienert, J. 2004. Acoustic imaging of gas hydrate and free gas at the Storegga Slide. Journal of Geophysical Research B04102.

Huuse, M., Lykke-Andersen, H., 2000. Overdeepened Quaternary valleys in the eastern Danish North Sea: morphology and origin. Quaternary Science Reviews 19, 1233-1253.

Maslin, M., Owen, M., Betts, R., Day, S., Dunkley Jones, T., Ridgwell, A., 2010. Gas hydrates: past and future geohazards. Phil. Trans. R. Soc. 368, 2369-2393.

Thomas, S., Hooper, J., Clare, M. 2010. Constraining Geohazards to the Past: Impact Assessment of Submarine Mass Movements on Seabed Developments. In. Mosher, D.C. et al. (Eds.), Submarine Mass Movements and Their Consequences. Advances in Natural and Tehnological Hazards Research 28, Springer.

Nielsen, S.B., Gallagher, K., Leighton, C. et al. 2009. The evolution of the western Scandinavian topography: a review of Neogene uplift versus the ICE (isostacy-climate-erosion) hyphotesis. Journal of Geodynamics 47, 72-95.

Further Information

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