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Combining ROV-based acoustic data and underwater photogrammetry to characterize Hakon Mosby Mud Volcano (Barents Sea) cold seep systems

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Cold-seeps have a unique geo-ecological significance in the deep-sea environment. They impact the variability of present-day submarine sedimentary environments, affecting the evolution of the landscape over time and creating a variety of submarine landforms, one of which is Mud Volcanoes (MVs). MVs form due to mud, fluids, and gas extrusion, mainly methane, from deeper sedimentary layers. These natural gas seepage systems could significantly affect climate change and the global carbon cycle. We present a comprehensive method that combines ROV-based multibeam mapping and underwater photogrammetry to enhance the understanding of the physical relationships between geomorphic units characterizing the Hakon Mosby Mud Volcano (HMMV) and the distribution of associated habitats.

HMMV is indeed characterized by high thermal and geochemical gradients from its centre to the margins, resulting in a clear zonation of chemosynthetic communities. Our approach integrates multi-resolutions and multi-sources data acquired using a work-class ROV. The ROV-based microbathymetry data helped to identify the different types of fine-scale submarine landforms in the central part of HMMV. This revealed three distinct geomorphic units, with the central hummocky region being the most complex. ROV images were analyzed using a defined structure from motion workflow to study this area further, producing millimetric resolution 2D and 3D models. Object-Based Image Analysis (OBIA), applied on orthomosaics, allowed us to obtain a fine classification of main benthic communities covering a total area of 940m2, including the active seepage area of the hummocky rim. Four major substrate types were identified in these regions: uncovered mud, bacterial mats high-density, bacterial mats low- density, sediments and tubeworms. Their relationship with terrain morphology and seepage activity were investigated at different spatial scales, contributing to a deeper understanding the ecological functioning of cold seep ecosystems in MVs.

The proposed workflow and innovative processing techniques could serve as a model for future

studies on cold-seep systems. These investigations aim to clarify the extent to which geomorphic, biogeochemical, and ecological processes occurring in extreme environments are inherently linked and marked by the spatial patterns found in associated habitats and sedimentary environments.