Natural Methane Seepage and Fluid Migration Pathways in the Tampen Slide: Insights from Structural and Seismic Analysis

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Abstract

Natural methane seepage systems in the northern North Sea provide important insights into how submarine landslides, faults, and glaciogenic sediments interact to control fluid migration and seafloor venting. During a recent WELLFATE scientific cruise, we investigated methane seepages in the Norwegian Trench at a water depth of ~375 m.

The seepages are concentrated along the upper headwall of the Tampen Slide (age ~ 71–120 ka before present), including one site where a methane-rich mud flow was observed. This occurrence illustrates how buried slide deposits and overlying glaciogenic sediments can act together to govern fluid migration pathways.

Seismic data reveal a fault beneath the upper headwall that cuts through clinoforms below the slide mass and merges with the upper slide wall. This fault likely serves as a vertical migration pathway, linking deeper gas-charged zones to the seabed. The chaotic slide mass, characterized by negative seismic anomalies, suggests the presence of trapped gas within slurry-like deposits generated during mass failure. We propose that during clinoform development, gas accumulated within sand-rich intervals. The subsequent collapse of the slide mass likely sealed these gas pockets, burying them beneath contorted sediments and glaciogenic overburden. Over time, the deposition of additional glacial sediments, particularly during the Late Weichselian (Last Glacial Maximum), contributed to overpressure buildup. Fault activity further facilitated fluid expulsion, with fluids migrating upward along fault planes and the slide wall. The observed methane-rich mud flow is likely a surface expression of deeper, overpressured zones releasing fluids through fracture networks.

Near the deeper main headwall of the slide, we also identified three mound-like features associated with negative seismic anomalies. One of the largest has an elliptical geometry with a major axis of ~1700 m and a minor axis of ~1100 m. These features are interpreted as remnants of a buried ancient mud-volcano system. Although the deeper system now appears inactive due to thick overburden, it may have indirectly contributed by supplying fluids to the overlying clinoforms. The clinoforms, which display bright spots suggestive of gas presence, outcrop at the upper regional unconformity and may help sustain ongoing seepages by recharging very shallow subsurface strata.

Overall, our findings indicate a strong linkage between ancient and modern fluid migration systems, driven by overpressure, structural weaknesses, and glaciogenic sedimentation.

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