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Architecture and sedimentary processes on the mid-Norwegian continental slope: A 2.7 Myr record from extensive seismic evidence

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A B S T R A C T

Quaternary architectural evolution and sedimentary processes on the mid-Norwegian continental slope are investigated using margin-wide three- and two-dimensional seismic datasets. Of ~100,000 km^3 sediments delivered to the mid-Norwegian shelf and slope over the Quaternary, ~75,000 km^3 comprise the slope succession. The structural high of the Vøring Plateau, characterised by initially low (~1–2°) slope gradients and reduced accommodation space, exerted a strong control over the long-term architectural evolution of the margin. Slope sediment fluxes were higher on the Vøring Plateau area, increasing up to ~32 km^3 ka^{-1} during the middle Pleistocene, when fast-flowing ice streams advanced to the palaeo-shelf edge. Resulted in a more rapid slope progradation on the Vøring Plateau, these rates of sediment delivery are high compared to the maximum of ~7 km^3 ka^{-1} in the adjacent sectors of the slope, characterised by steeper slope (~3–5°), more available accommodation space and smaller or no palaeo-ice streams on the adjacent shelves. In addition to the broad-scale architectural evolution, identification of more than 300 buried slope landforms provides an unprecedented level of detailed, process-based palaeoenvironmental reconstruction. Channels dominate the Early Pleistocene record (~2.7–0.8 Ma), during which glacimarine sedimentation on the slope was influenced by dense bottom-water flow and turbidity currents. Morphologic signature of glacigenic debris-flows appear within the Middle-Late Pleistocene (~0.8–0 Ma) succession. Their abundance increases towards Late Pleistocene, marking a decreasing role for channelized turbidity currents and dense water flows. This broad-scale palaeo-environmental shift coincides with the intensification of Northern Hemispheric glaciations, highlighting first-order climate control on the sedimentary processes in high-latitude continental slopes.

1. Introduction

The morphology and sedimentary architecture of glacier-influenced continental slopes are inherently linked to different styles of glaciation and mechanisms of sediment delivery to the slope (e.g., Dowdeswell et al., 1996; Vorren and Laberg, 1997; Taylor et al., 2000; O'Grady and Syvitski, 2002). When ice sheets advance to the shelf edge, sediments are transported down the slope by a range of processes including turbidity currents, debris flows and sediment mass-wasting. In contrast, when ice sheets retreat back across the shelf, the depositional environment on the slope is dominated by slower hemipelagic and contouritic sedimentation (e.g., Ó Cofaigh et al., 2013). In addition, ice sheets are partitioned into fast-flowing ice streams that provide high rates of sediment flux to the adjacent areas of continental slope, whereas the neighbouring sectors of the ice-sheet are slow-flowing and rates of sediment delivery are more limited (e.g., Bentley, 1987; Stokes and Clark, 2001; Mosola and Anderson, 2006; Nygård et al., 2005; Dowdeswell et al., 2006; Ottesen and Dowdeswell, 2009; Klages et al., 2016). As a result, sedimentation on high-latitude slopes exhibits a considerable degree of temporal and spatial variability.

Glacier-influenced sedimentation in high-latitude regions during the last glacial period has been the subject of extensive research, based mainly on swath-bathymetric studies accompanied by shallow acoustic stratigraphy and dated sediment cores from the modern seafloor (e.g., Solheim et al., 1990; Ottesen et al., 2005; Dowdeswell et al., 2007; Rebesco et al., 2011; Rydningen et al., 2013; Ottesen et al., 2016, 2017). The evolution of high-latitude

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slope sedimentation prior to the Last Glacial Maximum (LGM) has been inferred largely from sediment cores (e.g., Svendsen et al., 1992; Domack et al., 1999; Ó Cofaigh et al., 2001; Mosola and Anderson, 2006) and seismic facies analyses using two-dimensional (2D) seismic profiles (e.g., Damuth, 1978; Anderson and Bartek, 1992; Sejrup et al., 1995; Bart and Anderson, 1996; King et al., 1996, 1998; Laberg and Vorren, 2000; Ó Cofaigh et al., 2003; Nygård et al., 2005; Laberg et al., 2012; Batchelor et al., 2013; Ottesen et al., 2014). However, morphological evidence from palaeo-slope surfaces is often very limited because 3D seismic datasets are still relatively scarce from the polar seas and most previous work using 3D seismic evidence has focused on palaeo–shelf morphology (e.g., Rise et al., 2004; Andreassen et al., 2004; Dowdeswell et al., 2006, 2007; Stewart and Lonergan, 2011; Dowdeswell and Ottesen, 2013). A few studies, with limited 3D data coverage, have investigated the slope record in the European North Atlantic (e.g., Nygård et al., 2003; Laberg et al., 2010; Rydningen et al., 2016). Work from the Barents Sea and the northern part of the Norwegian Sea found a general trend for the progressive dominance of debris flows in the slope succession towards the Late Pleistocene (e.g., Laberg et al., 2010; Rydningen et al., 2016).

Multiple blocks of 3D seismic data have now been acquired and become available on the 500-km-long mid-Norwegian continental margin (Fig. 1), providing a unique opportunity to investigate the morphology of buried slope surfaces in great detail. The purpose of this study is to examine the interplay between ice-sheet dynamics, broad-scale architectural evolution and sedimentary processes through the Quaternary, and the resultant degree of spatio-temporal variability on the continental slope along the mid-Norwegian margin. We integrate detailed, process-based

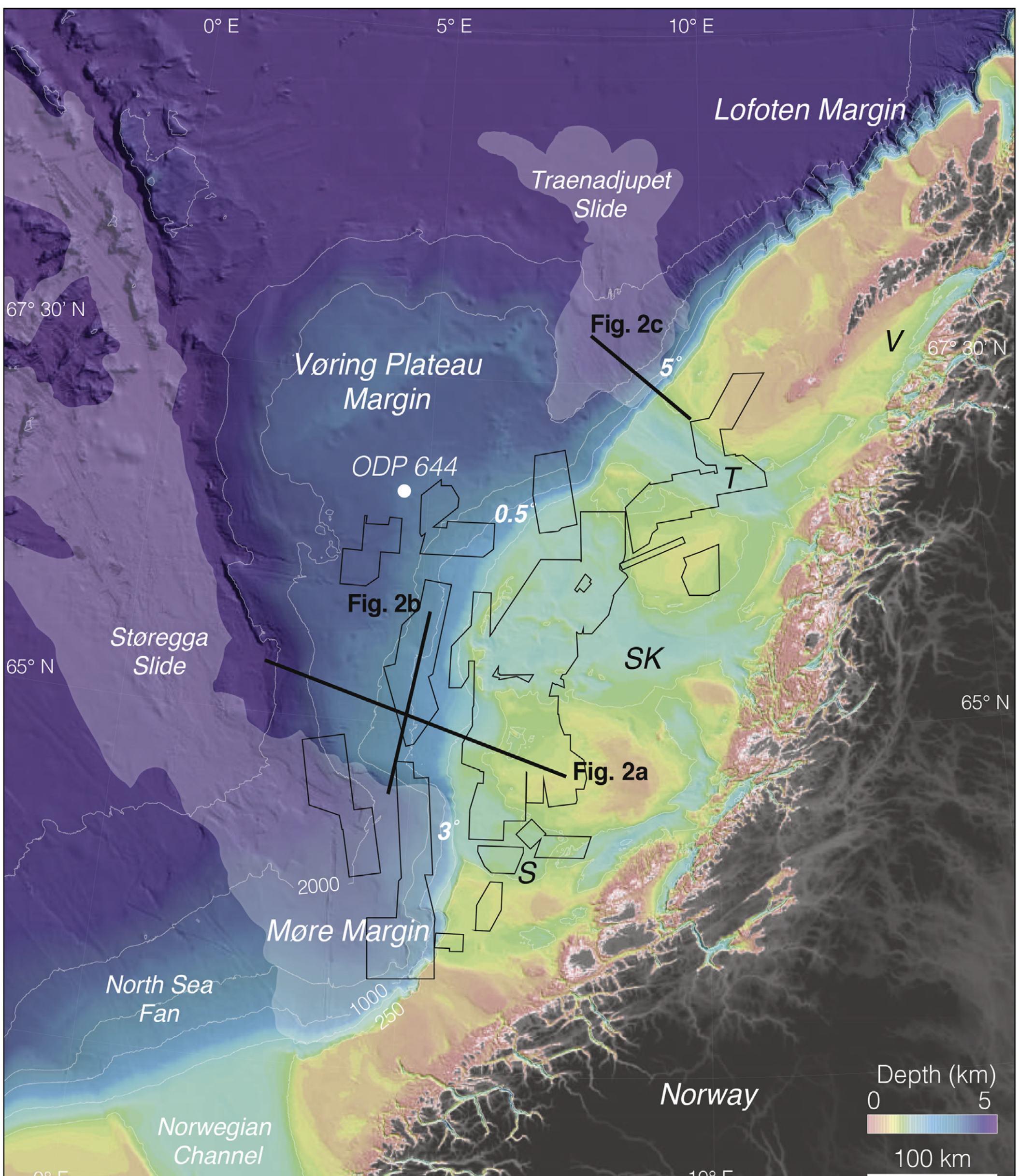

Fig. 1. The mid-Norwegian continental margin. Boxes outlined in black show 3D seismic data coverage. Numbers in bold white give the angle of the modern continental slope. Shallow banks are bounded by major cross-shelf troughs: T-Trænadjupet, SK- Sklinnadjupet, S-Suladjupet, V- Vestfjorden. Semi-transparent white areas outline the major Storegga and Traenadjupet slides (after Bryn et al., 2005).