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Characterization of Glacigenic Debris Flows, Megaslides and Contourites of the North Sea Fan from 3D Seismic Data

Benjamin Bellwald (1), Sverre Planke (1,2,3), Rachel Barrett (4), Christine Batchelor (5), and Reidun Myklebust (6)

(1) Volcanic Basin Petroleum Research AS (VBPR), Oslo, Norway (benjamin@vbpr.no), (2) Centre for Earth Evolution and Dynamics (CEED), University of Oslo, Oslo, Norway, (3) Research Centre for Arctic Petroleum Exploration (ARCEx), UiT The Arctic University of Norway, Tromsø, Norway, (4) Institute of Geophysics, Christian-Albrechts-Universität zu Kiel, Kiel, Germany, (5) Norwegian University of Science and Technology (NTNU), Trondheim, Norway, (6) TGS, Asker, Norway

High-latitude trough mouth fans are high-resolution paleoclimate and ice-sheet monitors, and allow a continuous reconstruction of climate and sedimentary processes active during glacial-interglacial cycles. The North Sea Fan is located on the northern North Sea margin and is built-up by c. 40,000 km3 of sediments dominated by the erosional products of the Norwegian Channel Ice Stream. The aims of this contribution are (i) to characterize the sediments deposited in the North Sea Fan, and (ii) to do a three-dimensional reconstruction of the processes involved into the formation of the North Sea Fan. We use 16,000 km2 of high-resolution processed 3D seismic data collected in 2017 and 2018 from the proximal North Sea Fan. These data allow us to image the shallow subsurface in a resolution of 8 m vertically and 20 m horizontally. Fifteen horizons have been picked with an in-line spacing of 150 m, followed by gridding, horizon attribute extraction, sediment volume calculations, and seismic geomorphological interpretation. Our results show that six sediment packages containing stacked glacigenic debris flows (GDFs) have been deposited at the upper slope of the North Sea Fan. The GDF package related to the last glaciation has a thickness of up to 400 m and is characterized by a homogenous seismic facies intercalated by five continuous high-amplitude reflections, which separate the package into six sub-units. The structure maps of these reflections show multiple sharp, SE-NW-oriented channels with well-developed levees and densely-spaced pockmarks. The GDF deposits have been removed from the upper slope by four megaslides, which are identified as deformed sequences bound by smooth lower and irregular upper surfaces. Negative-amplitude, continuous reflections at the base of the megaslides fade out uphill of the slide headwalls. The topography shaped by these megaslides is infilled by glacimarine deposits identified as low-amplitude, continuous reflections. Continuous reflections with mounded geometries, interpreted as contourites, characterize the deepest part of the fan. The GDF packages show that the Norwegian Channel Ice Stream reached the shelf edge during six marine isotope stages, and that the ice stream oscillated six times during the last glaciation. The up to 400 m thick GDF package related to the last glaciation has been deposited within 4 kyr, which correlates to a sedimentation rate of up to 100 m/kyr, and a sediment flux of 1500 km3/kyr for the study area. Channels identified at multiple levels within the GDF package indicate that the sediment delivery from the Norwegian Channel Ice Stream to the slope was continuous and did not occur in pulses of several decades. Channel-fed levees and debris lobes characterize the paleo-seafloor between the channels. The circular depressions, interpreted as pockmarks, indicate fluid escape events in some intra-channel areas during the deposition of the GDFs. Negative, high-amplitude reflections below the GDFs and megaslides indicate gas-charged sandy bases and show a strong correlation between pre-conditioned glacimarine glide planes and megaslide occurrence. Contourites at the base of the fan indicate different oceanic processes dominating the early Quaternary deposition.