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SEISMIC DATA ACQUISITION IN THE NANSEN BASIN, ARCTIC OCEAN

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ABSTRACT

During the NPD-POLAR-2001 expedition to the Arctic Ocean in the fall of 2001 a multi-channel seismic (MCS) and sonobuoy acquisition program was carried out in the sea ice on the Hinlopen margin north of Svalbard and in the Nansen Basin. For this purpose, specially adapted acquisition and processing techniques were developed, resulting in ~1100 km of 2-D MCS profiles and 50 wide-angle velocity profiles. The data may be interpreted in terms of four main sedimentary units with distinct seismic velocities and reflection character.

INTRODUCTION

The Nansen Basin (Fig. 1) has formed by seafloor spreading along the Gakkel Ridge, the Arctic end-member of the Mid-Atlantic Ridge system, since the late Paleocene (~55 Ma) (Karasik, 1968). Due to perennial sea ice, only a few MCS and wide-angle seismic profiles sample the ocean basin north of 81°N (Duckworth and Baggeroer, 1985; Jokat et al., 1995; Kristoffersen and Husebye, 1985). Following Norway’s ratification of the UN Convention on the Law of the Sea in 1996, the Norwegian Petroleum Directorate (NPD) has initiated a research program to map sediment thickness and the foot-of-slope for the purpose of delineating legal outer shelf boundaries beyond 200 nautical miles. As a part of this program, the NPD and the Universities of Bergen and Oslo conducted a seismic survey aboard the Swedish icebreaker MV Oden in the autumn of 2001. Here, we present some preliminary results.

DATA ACQUISITION AND PROCESSING

Major breakthroughs in seismic exploration of the Nansen Basin have been achieved during the two-ship expeditions ARCTIC-91 (Fütterer, 1992) and AMORE (Thiede and the Shipboard Scientific Party, 2002), where the PFS Polarstern collected seismic data in a trail cut open by another icebreaker ahead. However, such operations are costly and involve inefficient sharing of ship-time between two scientific parties. On the other hand the MV Oden, with its 30 m wide bow, is an adequate platform for simultaneous icebreaking and seismic surveying, provided that the seismic equipment is robust and flexible (Kristoffersen, 1997). Because the trail of open water rapidly closes, the airguns and hydrophone cable have to enter the water in the turbulent zone just behind the ship, where variable speed, bouncing ice and high noise is a challenge to the acquisition. The airguns (2×4 l or 1×20 l) and hydrophone cable (300 m active section, 12 channels) were suspended from a light depressor device which was able to move around ice fragments and effectively kept the airguns and the hydrophone cable separated in the water.

The raw seismic data contain geometrical and noise effects typical for ice-acquired data. Because the vessel had to navigate around pressure ridges and speed varied because of ice resistance, the shotpoint distances are not constant and the traces had to be stacked in 25 m bins along the ship track. Furthermore, trace-to-trace noise variation and delayed ghost effects from the lack of hydrophone cable depth control had to be filtered out. Further processing steps involved geometrical spreading correction, predictive deconvolution and normal move-out correction, stacking, and filtering. The processing significantly reduced ringing of seismic reflections. The sonobuoy profiles were not processed after the geometrical binning.

VELOCITY MODELLING

Of the 60 sonobuoys deployed, 50 had sufficient quality and range (up to 28 km) for reduction. Most profiles contained both refracted arrivals from the top of basement and intra-sedimentary reflections. These arrivals were solved for initial velocities using standard slope-intercept and T²-X² methods assuming 1-D conditions (plane-layers). Then, velocities were combined with interpreted reflector geometries into 2-D velocity models which were modified by ray tracing and traveltime inversion (Zelt and Smith, 1992). By perturbing the final sediment velocities while recording the traveltime and model χ² misfits, we calculated uncertainty in sediment thickness of about ±7%. The 2-D models also show that the original 1-D reduction over-estimates sediment thickness in areas of high basement relief.
Fig. 1. Existing seismic database and new lines of the NPD-POLAR-2001 survey in the Nansen Basin and adjacent shelf. IBCAO bathymetry (Jakobsson et al., 2000), contoured every 0.5 km. AB, Amundsen Basin; AWI, Alfred Wegener Institute for Polar and Marine Research, Bremerhaven, Germany; COT, continent–ocean transition (Engen, 2005); FJL, Franz Josef Land; LR, Lomonosov Ridge; MAGE, Marine Arctic Geological Expedition, Murmansk, Russia; MJR, Morris Jesup Rise; NB, Nansen Basin; NPD, Norwegian Petroleum Directorate; NPI, Norwegian Polar Institute; UIB, University of Bergen, Norway; YP, Yermak Plateau.
Figure 2. Seismic data example and line drawing of the easternmost profile, line NPD-POLAR-15. Four sedimentary units (NB-1–NB-4) overlie oceanic basement. Annotated columns show velocities, in km s\(^{-1}\), sampled from the 2-D velocity model in the sonobuoy deployment positions. CDP, common depth point.
RESULTS
The processing yielded ~1100 km of good-quality MCS data imaging the basement surface and the main sedimentary sequences. The sediment thickness increases both from the Gakkel Ridge to the margins and from west to east, where the sharp basement relief is completely covered (Fig. 2). There is good agreement between the velocity models and the seismic stratigraphy that the sediments can be subdivided, from bottom to top, into four regional units (Fig. 3). The boundaries between units probably correspond to major paleoceanographic events such as the onset of late Cenozoic glacial deposition and the opening of the Fram Strait gateway between the Arctic and North Atlantic oceans (Engen, 2005). Faults cut the sediments from basement to shallow levels, indicating recent tectonism (Fig. 2).

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Fig. 3. Typical seismic reflection character, velocity (V), and thickness (Z) of the four sedimentary units of the Nansen Basin. Top of basement (Bas.) marked by white line; fault by dashed line. Location of section in Figure 2. CDP, common depth point.
