2011 CSPG CSEG CWLS Convention

The NE Greenland Shelf: Full Crustal Imaging of Salt Tectonics and the Wandel Sea Mobile Belt

Richard C. Whittaker*
GeoArctic Ltd, Calgary, Alberta, Canada
rwhittaker@geoarctic.com

Menno G. Dinkelman
ION Geophysical-GX Technology, Houston, TX, USA.
menno.dinkelman@iongeo.com

P. A. Emmet and J. W. Granath
Consultants to ION Geophysical-GX Technology, Houston, TX, USA.

Summary

A new deep long-offset seismic survey was shot in the summer of 2010 on the northern part of the NE Greenland Shelf using specialized new technology for acquiring data in first-year ice covered areas. These new seismic techniques have resulted in data being acquired over 250 km farther north than any other industry seismic data on the margin. The new survey adds significantly to our knowledge of the structure and geology of the region and reveals a highly complex margin. Evidence for strike slip faulting and inversion on the seismic data supports earlier model based interpretations for the area to be affected by strike slip motion related to the De Geer Megashear region and is the offshore extension to the Wandel Sea Mobile Belt. The presence of a salt basin is confirmed by the seismic data and the salt diapirism can now be confirmed to extend to 80°N, farther north than in previous interpretations. The data also provide valuable new information on the deep crustal structure of the margin. The early results of the interpretation of the new data have important implications for the general understanding of the Mesozoic – Cenozoic development of the intra-continental De Geer Megashear region between North Greenland and Eurasia.

Introduction

A new reconnaissance deep, long-offset seismic reflection programme was acquired in 2009 and 2010 in northeast Greenland (the NE GreenlandSPAN Phase I and II surveys) (Figure 1). The current Phase I and II data extend north of the Jan Mayen Fracture Zone (72°N) to the Hovgaard Fracture Zone (81.5° N) and a Phase III is planned for 2011, primarily as infill acquisition. The Phase II survey was acquired north of the Northeast Greenland Volcanic Province, including an area that previously had little or no seismic coverage in the northern part of the Danmarkshavn Basin, and the eastern extension of the Wandel Sea Mobile Belt on the northeast margin of the shelf. The NE Greenland Shelf is the conjugate margin to the Lofoten and Vøring Margins of Mid-Norway and it lay south of the Barents Shelf prior to break up.

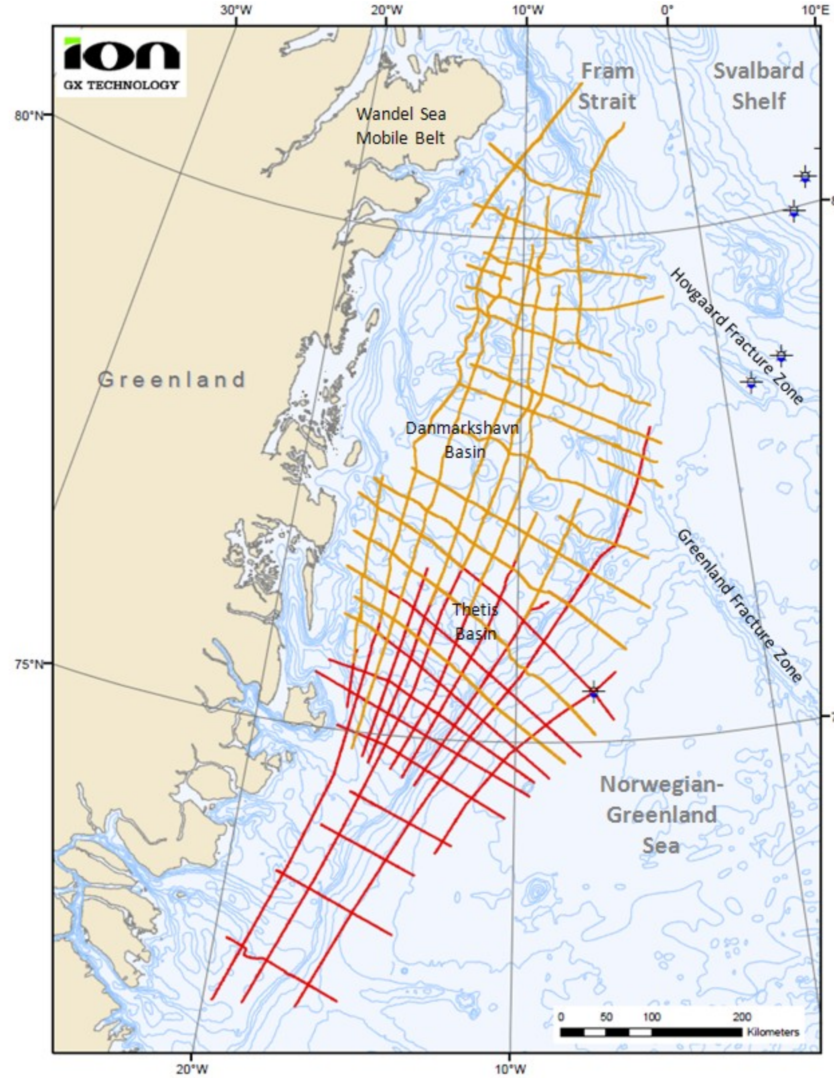

Figure 1: The NE GreenlandSPAN seismic survey (Phase I in red, Phase II in orange).
The location of ODP wells, prominent fracture zones and structural features are also shown.

Due to the extreme ice conditions relatively little was previously known about the northern and eastern parts of the margin. This results in considerable uncertainty in the existing structural and tectonic models for the area which rely on extrapolation from onshore geology and sparse reconnaissance seismic data. The onshore part of the NE Greenland shelf is dominated by Late Cretaceous–Palaeogene strike-slip faults of the Wandel Sea Mobile Belt (Håkansson and Stemmerik, 1989). Existing models generally consider the margin to have undergone strike-slip movements and transtension as a result of Late Mesozoic–Cenozoic right-lateral shear (e.g. Håkansson and Pedersen, 2001; Engen et al, 2008).

Seismic data acquired in the southern and central part of the NE Greenland Shelf in the 1990s identified a large basin characterized by salt tectonics (the Danmarkshavn Basin) and an offshore basin (the Thetis Basin) with no apparent salt movement (Hamann et al, 2005). The salt is inferred to be of Late Carboniferous–earliest Permian age, by comparison to the Nordkapp Basin in the Norwegian Barents Sea and thus age-equivalent to the lower part of the carbonate succession in North Greenland. Salt deposition is characterized by transition from carbonate-dominated successions, over structural highs and stable platforms, to salt in more rapidly subsiding basins.

Seafloor spreading in the Eurasia Basin and the Norwegian– Greenland Sea was established by earliest Eocene times as Greenland and North America separated from Eurasia. The two ocean basins were linked by the right-lateral De Geer Megashear region (Harland, 1969) comprising a NW-SE trending transform zone that includes the northern part of the NE Greenland Shelf, off western Svalbard and the sheared Hornsund and Senja margins offset by a rifted segment including the Vestbakken Volcanic Province on the Barents Sea margin. Plate tectonic reconstructions of the Fram Strait region between Svalbard and Greenland show that the relative plate motion between Greenland and Eurasia changed from right-lateral shear to oblique divergence at Chron 13 times (33.3 Ma; earliest Oligocene). The sheared margin was rifted and broken up obliquely as relative plate motions between Greenland and Eurasia changed from transform to divergent (Engen et al, 2008). It has therefore been suggested that dextral transcurrent motions continued to affect the NE Greenland Shelf at least until the earliest Oligocene (Døssing et al., 2008).

Data Acquisition and Processing

Earlier attempts to acquire seismic data in the area have been hampered by heavy ice coverage. This was overcome by uitlizing a proprietary streamer and deployment technology to acquire data below the pack ice. In addition, an icebreaker was used to clear first-year ice for the primary acquisition vessel. As a result, data could be acquired in a relatively regular grid (Figure 1) in areas otherwise either not covered or only sparsely covered by earlier academic surveys, allowing the seismic program to remain focused on geologic targets.

Acquisition parameters included a 25 m shot interval, 12.5 m group interval and maximum offset of 9000 m. The record length was 18 sec, and the data were processed to pre-stack time (PSTM) images of 16 sec and pre-stack depth (PSDM) images of 40 km record length. Pre-stack depth migrated (PSDM) seismic lines are used for the interpretation which was tested iteratively against gravity and magnetic modeling.

Interpretation

Several of the seismic lines extend across the Continent Ocean Transition (COT) on the northern and eastern margins of the NE Greenland Shelf. The long-offset and deep tow seismic data images show intra- and sub-basalt reflectors on the volcanic margin where Seaward Dipping Reflectors (SDRs) are interpreted. The margin north of the Greenland Fracture Zone is relatively free of volcanics and low angle listric faulting is related to the present-day divergent margin. A high-amplitude deep crustal event is seen at about 15 km along the outer margin which is possibly related to a lower crustal reflector described on the Norwegian margin, and has been attributed to be associated with crustal underplating.

The data show a thick sedimentary sequence in the Danmarkshavn and Thetis Basins which is at least 9 km thick. Both basins are interpreted to include a thick Mesozoic section. Seismic and gravity data show that the Danmarkshavn Basin extends northwards to over 80°N, being at least 500 km long. It widens from less than 50 km in the south to more than 100 km in the north. Older Palaeozoic sediments are also thought to be present in the Danmarkshavn Basin and subcrop along the Danmarkshavn Ridge which forms a prominent structural high separating the two basins. The Koldewey Platform defines the western margin of the basin. The Danmarkshavn Basin is a large, very deep sedimentary basin, characterized by salt tectonics in the central and northern parts. Numerous unconformities along the basin margins indicate repeated tectonic activity throughout the basin history. The central part of the basin is characterized by major salt diapirism from 77°N to over 80°N. In the northern part of the basin many salt diapirs have penetrated nearly to the seafloor. Turtle structures are interpreted and the rim-synclines filled rapidly with sediments as the structures collapsed due to salt withdrawal.

Faulted anticlines, inversion structures, and complex zones of faulting are interpreted north of the Greenland Fracture Zone and along the outer part of the shelf. These are interpreted to be strike slip and transtension features associated with the Wandel Sea Mobile Belt.

Conclusions

The new seismic data add significant information about the structuring of the ice-covered offshore and reveal the presence of a highly complex margin. The presence of strike-slip faulting and inversion interpreted on the seismic data supports earlier model-based interpretations that the area has been affected by strike-slip motion related to the De Geer Megashear region and is the offshore extension to the Wandel Sea Mobile Belt. The presence of a significant salt basin is confirmed by the seismic data and the salt diapirism can now be confirmed to extend to 80°N, farther north than previous interpretations. The new data also provide valuable new information on the deep crustal structure of the margin. The results of the interpretation of the new data have important implications for the general understanding of the Mesozoic–Cenozoic development of the intra-continental De Geer Megashear region between North Greenland and Eurasia. A revised structural model for the development of the region can be used to develop plate models and palaeogeographic interpretations which, in turn, can be used to predict source and reservoir deposits.

Acknowledgements

The authors would like to thanks ION / GX technology for giving permission to publish this paper. The NE GreenlandSPAN surveys are carried out by ION Geophysical as part of its worldwide BasinSPAN programme (http://www.iongeo.com/Data_Libraries/Spans/).

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