

## **Greenland - The New Arctic Hot Spot?\***

**Martin Damsø Bruun<sup>1</sup>, Gregers Dam<sup>1</sup>, Niels-Erik Hamann<sup>1</sup>,  
and Martin Sønderholm<sup>1</sup>**

Search and Discovery Article #10353 (2011)

Posted September 12, 2011

\*Adapted from article published in AAPG European Region Newsletter, March 2011

([http://europe.aapg.org/wp-content/uploads/2010/12/AAPG\\_Newsletter-March\\_2011-Final.pdf](http://europe.aapg.org/wp-content/uploads/2010/12/AAPG_Newsletter-March_2011-Final.pdf)).

Appreciation is expressed to AAPG European Region Council, Jeremy Richardson, Director, David R. Cook, President, their Editorial Board, Karen Wagner, Chief Editor and coordinator of Exploration Country Focus.

<sup>1</sup>DONG Energy Exploration and Production, Agern Allé 24-26, 2970 Hørsholm, Denmark

### **Introduction**

Despite the fact that the Arctic regions present major technical and environmental challenges to the petroleum industry, their potential as one of the last real frontier regions in the world has spurred a significant increase in exploration interest, especially during the past decade. This is also true for Greenland, where the USGS Circum-Arctic Resource Appraisal has suggested a large yet-to-find potential for the offshore basins of both West and East Greenland ([Table 1](#)).

Hydrocarbon exploration in Greenland has occurred in three phases. During the first phase, that started in the mid-1970s, five wells were drilled offshore southern West Greenland ([Figure 1](#)). All wells were declared dry at that time but nevertheless provided some indications of a working petroleum system.

The second exploration phase was initiated in the early 1990s with extensive public acquisition of seismic data and onshore field work for analogue studies (Dam et al., 2009). The finds of widespread oil seeps onshore West Greenland changed the perception of West Greenland being gas prone only, to an understanding that oil could also serve as an exploration target. Five exploration licenses were granted, and during this phase an onshore exploration well was drilled in the Nuussuaq Basin (GRO#3), and an offshore well was drilled 150 km west of Nuuk (Qulleq-1; Pegrum et al., 2001).

These wells were plugged and abandoned, but gave important new stratigraphic knowledge that encouraged further exploration both offshore southern West Greenland and farther to the north in the Davis Strait and Baffin Bay areas.

The third phase was initiated in 2007 with the granting of seven licenses offshore central West Greenland and four offshore southern Greenland ([Figure 1](#)). Work is still ongoing and in 2010 Cairn Energy drilled three new wells, and four are planned to be drilled in 2011. In 2010, two wells were plugged and abandoned, with the discovery of thin gas-filled sands, but at sub-commercial levels.

With the award of seven new licenses in the Baffin Bay area in late 2010 to seven major and medium-sized E&P companies and with a view to licensing rounds in 2012 and 2013 off northeastern Greenland, the interest for exploration in Greenland has now increased to unprecedented levels.

## **Basin Overview**

### **West Greenland**

The sedimentary basins offshore West Greenland belong to a complex of basins that were established in the Late Jurassic to Early Cretaceous, extending from the Labrador Sea in the south to Melville Bay in the north ([Figure 1](#); e.g., Chalmers and Pulvertaft 2001; Dam et al., 2009).

These up-to 10-12 km deep basins appear basically to share the same tectonostratigraphic evolution with two major rift phases during the Early Cretaceous and the Late Cretaceous - Early Palaeocene. The region is dominated by rotated fault blocks where large structural and stratigraphic pinch-out plays can be mapped ([Figure 2](#)).

World-class outcrops in the Nuussuaq Basin onshore central West Greenland provide further details on basin evolution, plays and hydrocarbon systems, and oil seeps suggest presence of regionally distributed mid-Cretaceous and Palaeocene source rocks ([Figure 3](#); see Dam et al., 2009 for exhaustive literature listing).

Although underexplored, five plays are proven on the Labrador Shelf forming the conjugate margin to South-West Greenland, but only one of these has been tested in West Greenland. The technical success in the Canadian Hopedale Basin is 33% and the USGS yet-to-find estimate for the West Greenland - Canada basins is in the order of 17 BBOE ([Table 1](#)). This illustrates the potential of these plays in the Greenland-Canada basins.

The seismic database in West Greenland is relatively extensive and now more than 100,000 km of post-1990 vintage data is available as open-file data from GEUS (Geological Survey of Denmark and Greenland) and as spec. data from TGS-NOPEC.

The physical conditions in the Greenland waters are variable, but less severe than for the Canadian side. Sea ice is restricted to first-year ice and large icebergs are only locally abundant and their presence manageable.

## Greenland Sea - NE Greenland

The onshore areas of East Greenland and North-East Greenland are geologically relatively well known. Numerous papers have been published since the 1970s describing these world class rift basin exposures ([Figure 4](#)) and their petroleum geological significance. The sedimentary succession in these areas form well established analogues to the Mesozoic rift succession offshore Mid-Norway and the late Palaeozoic succession of the Barents Sea (e.g., Håkansson and Stemmerik 1989; Surlyk 1990, 2003; Larsen et al., 2001, and many others).

The offshore area is, however, an unexplored frontier area and is one of the last "white spots" in world ([Figure 1](#)). This is mainly due to the constant drifting multi-year pack-ice and icebergs along East Greenland. Thus, the North-East Greenland shelf suffers from large geological uncertainty, extreme technical challenges and associated high-operating costs. Acquisition of multichannel reflection seismic data on the East Greenland shelf started in the late 1970s, in the beginning mainly focused in the area south of 75°N latitude. During the last two decades the northern part of the shelf has also been covered by data acquired by the so-called KANUMAS Group (a group of companies having a preferential position in North-East Greenland), TGS-NOPEC and ION-GXT. Despite the severe ice conditions in the region, the seismic data now form a relatively regular open grid with a line spacing of 25-40 km. No exploration wells have been drilled offshore eastern Greenland to date.

The most comprehensive overview of the major structures and the Late Palaeozoic–Neogene evolution offshore North-East Greenland is given by Hamann et al. (2005) and Tsikalas et al. (2005) based partly on proprietary regional seismic data acquired as part of the KANUMAS Project.

The East Greenland shelf forms the pre-Palaeocene conjugated margin to the well known and prolific Norwegian continental shelf, and is probably underlain by more than 14 km of Devonian through Holocene sedimentary rocks. Many of the working play systems offshore West Norway and the Barents Sea can also be expected to be found on the North-East Greenland shelf.

The sparse seismic data suggest potential large traps in the Danmarkshavn Basin and along the Danmarkshavn Ridge that is dominated by extensional structures ([Figure 5](#)). Prospective inversion structures of Tertiary age may be present along the western margin of the South Danmarkshavn Basin and more seismic data will probably reveal more in the future.

Four high-quality source rock intervals have been identified onshore East Greenland, and their presence suggests the possibility of a world-class petroleum province in the offshore area. The recent assessment carried out by USGS indicates that northeastern Greenland may be a major future petroleum province ([Table 1](#)). If the mean estimate of 31 BBOE were discovered and proven, this huge area would rank 19th out of the world's 500 known petroleum provinces.

This year the Greenland Authorities have invited companies to apply for hydrocarbon exploration and exploitation licenses. The first licensing round will be a pre-round, to accommodate the preferential position of the KANUMAS Group in 2012, followed by an ordinary round in 2013.

## North Greenland

The Wandel Sea off northeastern Greenland is characterized by intense strike-slip tectonics, and no seismic data exist in the region (Døssing et al., 2010, and references therein). Onshore sedimentary exposures in North Greenland are few. The USGS has assessed that the yet-to-find for this area is roughly 3 BBOE ([Table 1](#)).

## Conclusions

Greenland offers a huge exploration potential in a well regulated exploration regime with the possibility of both short- and long-term exploration opportunities. The current drilling campaign in West Greenland and the world class onshore sedimentary exposures offer insight into an attractive offshore geological setting in both Baffin Bay and East Greenland that are still waiting to be tested. Tremendous technical challenges lie ahead in terms of data acquisition and drilling in these harsh waters, but according to the USGS, the reward could be very substantial.

## References

- Bird, K.J., R.R. Charpentier, D.L. Gautier, D.W. Houseknecht, T.R. Klett, J.K. Pitman, T.E. Moore, C.J. Schenk, M.E. Tennyson, and C.J. Wandrey, 2008, Circum-Arctic resource appraisal; estimates of undiscovered oil and gas north of the Arctic circle: U.S. Geological Survey Fact Sheet 2008-3049, 4 p.
- Chalmers, J.A., and T.C.R. Pulvertaft, 2001, Development of the continental margins of the Labrador Sea: a review, *in* R.C.L. Wilson, R.B. Whitmarsh, B. Rayor, and N. Froitzheim, (eds.), Non-volcanic rifting of continental margins: A comparison of evidence from land and sea: Geological Society (London) Special Publication 187, p. 77–105.
- Dam, G., G.K. Pedersen, M. Sønderholm, H. Midtgaard, L.M. Larsen, H. Nøhr-Hansen, and A.K. Pedersen, 2009, Lithostratigraphy of the Cretaceous-Palaeocene Nuussuaq Group, Nuussuaq Basin, West Greenland: Geological Survey of Denmark and Greenland Bulletin 19, 171 p.
- Døssing, A., L. Stemmrik, T. Dahl-Jensen, and V. Schlindwein, 2010, Segmentation of the eastern North Greenland oblique-shear-margin regional plate tectonic implications: Earth and Planetary Science Letters, v. 292, p. 239-253.
- Håkansson, E., and L. Stemmerik, 1989, Wandel Sea Basin - A new synthesis of the Late Paleozoic to Tertiary accumulation in North Greenland: Geology, v. 17, p. 683-686.

Hamann, N.E., T.C. Wittaker, L. and Stemmerik, 2005, Geological development of the Northeast Greenland shelf, *in* A.G. Doré, and B.A. Vining, (eds.), *Petroleum Geology: North-West Europe and Global Perspectives - Proceedings of the 6th Petroleum Geology Conference*: Geological Society (London), p. 887-902.

Henriksen, N., 2008, *Geological History of Greenland*: Geological Survey of Denmark and Greenland, Copenhagen, 272 p.

Larsen, M., T. Nedkvitne, and S. Olaussen, 2001, Lower Cretaceous (Barremian-Albian) deltaic and shallow marine sandstones in North-East Greenland - sedimentology, sequence stratigraphy and regional implications, *in* O.J. Martinsen, and T. Dreyer, (eds.), *Sedimentary Environments offshore Norway - Paleozoic to Recent*: NPF Special Publication 10, p. 259-278.

Pegrum, R.M., T. Ødegård, K. Bonde, and N.E. Hamann, 2001, Exploration in the Fylla area, SW Greenland (abstract): VNIGRI/AAPG Regional Conference, St. Petersburg, Russia, 7 p.  
<http://www.geus.dk/ghexis/pdf/pegum.pdf>

Surlyk, F., 1990, Mid-Mesozoic syn-rift turbidite systems: Controls and predictions, *in* J.C. Collinson, (ed.), *Correlation in Hydrocarbon Exploration*: Norwegian Petroleum Society, p. 231-241.

Surlyk, F., 2003, The Jurassic of East Greenland: A sedimentary record of thermal subsidence, onset and culmination of rifting, *in* J.R. Ineson, and F. Surlyk, (eds.), *The Jurassic of Denmark and Greenland*: Geological Survey of Denmark and Greenland Bulletin 1, p. 659-722.

Tsikalas, F., J.I. Faleide, O. Eldholm, and J. Wilson, 2005, Late Mesozoic-Cenozoic structural and stratigraphic correlations between the conjugate mid-Norway and NE Greenland continental margins, *in* A.G. Dore, and B.A. Vining, (eds.), *Petroleum Geology: North-West Europe and Global Perspectives*: Proceedings of the 6th Petroleum Geology Conference, p. 887-902.

Whittaker, R.C., N.E. Hamann, and T.C.R. Pulvertaft, 1997, A new frontier province offshore northwest Greenland: Structure, basin development, and petroleum potential of the Melville Bay area: *AAPG Bulletin*, v. 81/6, p. 978-998.

Province	Oil (MMBO)	Total Gas (BCFG)	NGL (MMBNGL)	BOE (MMBOE)
East Greenland Rift Basins	8902.13	86180.06	8121.57	31387.04
West Greenland - East Canada	7274.4	51818.016	1152.59	17063.35
North Greenland Sheared Margin	1349.8	10207.24	273.09	3324.09

Table 1. Yet-to- find potential of the Greenland offshore basins (from Bird et al., 2008).



Figure 1. Simplified geological map of Greenland with offshore basins. Slightly modified from Henriksen (2008). Published with permission from GEUS.



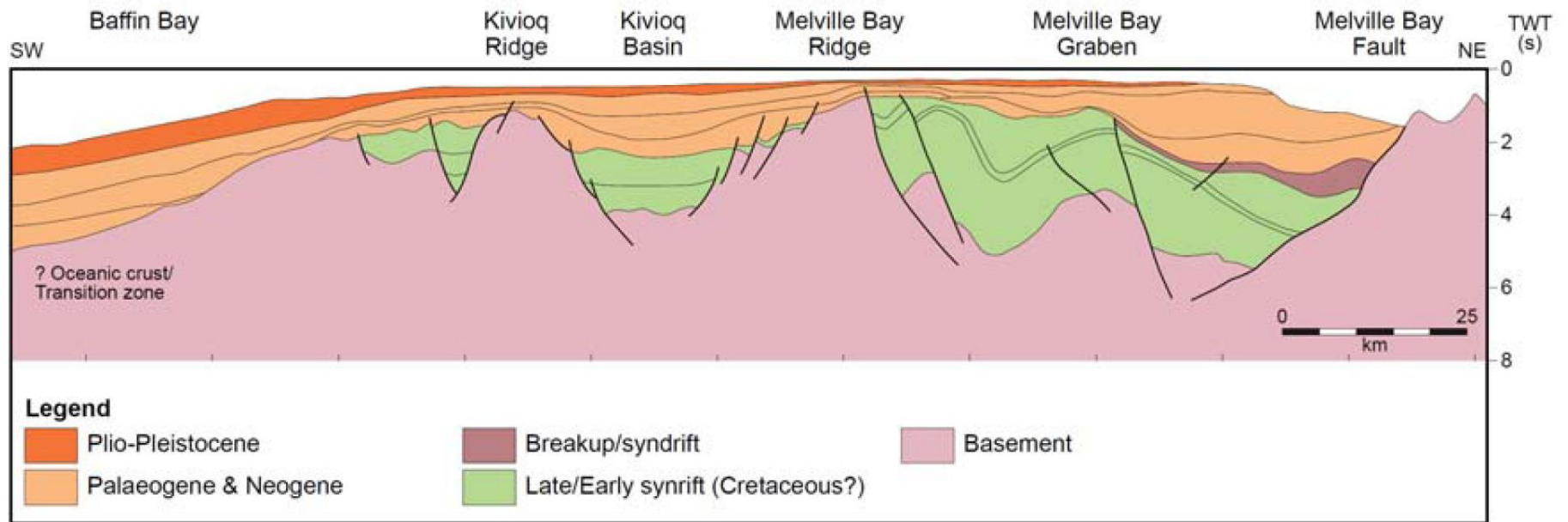


Figure 2. Geosection of the Melville Bay area showing large-scale extensional structures overprinted by Palaeocene inversion. From Whittaker et al. (1997).





Figure 3. Onshore exposure of Upper Cretaceous fluvio-deltaic sandstones with a major 200-m deep Lower Palaeocene incised valley system in the Nuussuaq Basin providing evidence for large-scale sand deposition in the offshore areas of West Greenland. Photo: Martin Sønderholm, DONG Energy.



Figure 4. Stacked shoreface sandstones exposed at Mt. Pelion in northern Jameson Land. The Middle Jurassic Pelion Formation is an analogue to the prolific Garn Formation of the Mid-Norwegian shelf. Height of vertical cliff-face is approximately 150 m. Photo: Michael Larsen, DONG Energy.

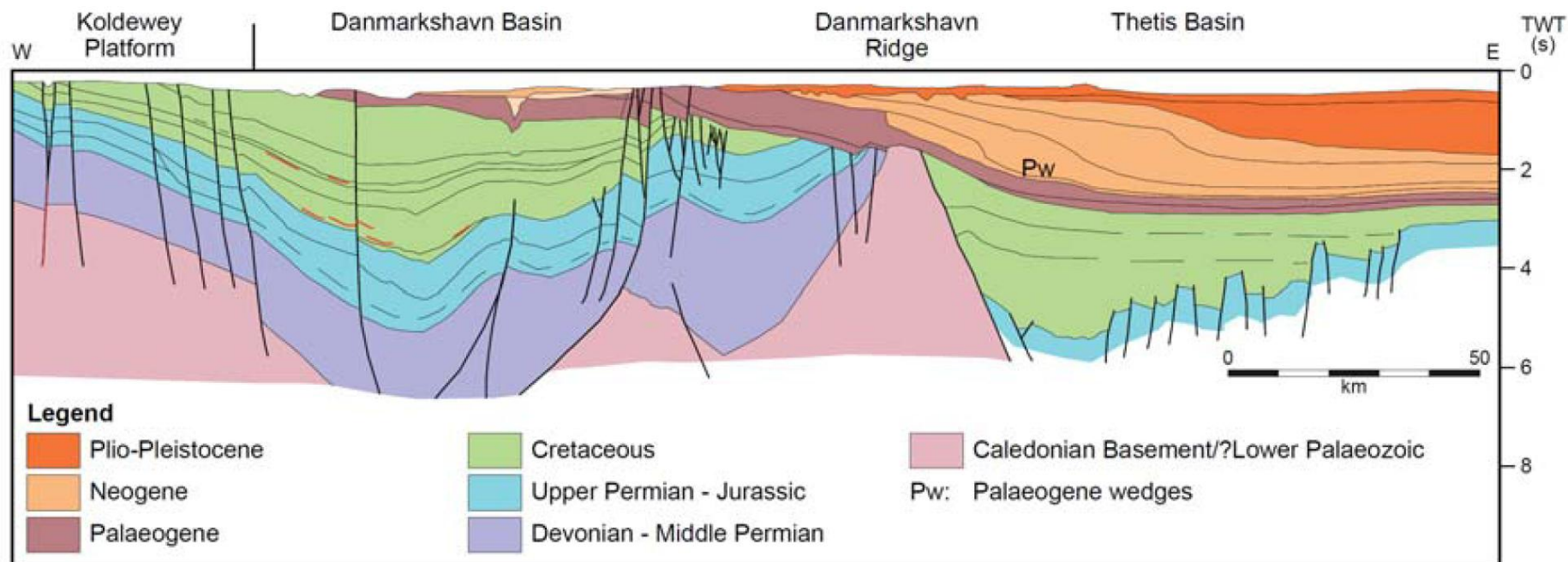


Figure 5. Geosection of the North-East Greenland Shelf (north of 75 °N) based on KANUMAS seismic data, illustrating the very different development of the inner and the outer shelf. From Hamann et al. (2005).