Petroleum geological activities in West Greenland in 2001

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Greenland petroleum geological activities at the Geological Survey of Denmark and Greenland (GEUS) during 2001 were focused mainly on the preparation of the 2002 licensing round offshore West Greenland. Promotion of the exploration opportunities in the licensing round area between 63° and 68°N has played an important role together with launching of new seismic and geological projects. Critical evaluation of the results from the Qulleq-1 well drilled in 2000 has continued in this context.

The Statoil group relinquished the eastern subarea of the Fylla licence at the end of April 2000, making all the Qulleq-1 data available for promotion purposes (see Christiansen *et al.* 2001a). The entire remaining area was relinquished by the end of the year. However, as part of outstanding working commitments, the Statoil group acquired approximately 1000 km of new seismic data, mainly from the western part of the licence area. These data have proven to be of great interest for companies evaluating West Greenland (see below). The Phillips group relinquished the entire Sisimiut-West licence area by the end of the year, without entering the next phase of exploration which called for a firm commitment well.

The seismic company TGS-NOPEC extended its activities from 1999 and 2000 with the acquisition of two regional non-exclusive surveys, GreenCan2001 and Green2001. The first is a regional joint-venture programme between TGS-NOPEC and the Bureau of Minerals and Petroleum (BMP), Government of Greenland; the second is a conventional speculative survey, mainly in the northern open-door area (see below).

Several Survey projects relevant to petroleum exploration in West Greenland were finalised in 2001. A study of the Palaeogene succession, combining seismic sequence stratigraphy, sedimentological reinterpretation of petrophysical logs, new biostratigraphy and facies analysis in a sequence stratigraphic framework, is summarised in a paper by Dalhoff *et al.* (2002, this volume). A seismic study of the Palaeogene volcanic rocks from the region west of Disko is also summarised in a separate paper in this volume (Skaarup 2002). Furthermore, a study of potential geohazards in West Greenland, that included a systematic interpretation and mapping of the Neogene succession, was completed (see below).

Two important petroleum geological projects were initiated at GEUS in 2001. One concerns biostratigraphic correlation of the offshore wells from West Greenland and the shelf offshore Labrador, Canada; the other is a regional correlation study of mid-Cretaceous source rocks and oils from West Greenland and North America (see below).

The 2002 licensing round

The 2002 licensing round offshore West Greenland covers the entire area between 63°N and 68°N and thus includes the former Fylla and Sisimiut-West licensing areas. A major effort promoting the petroleum exploration potential has been carried out by BMP in close co-operation with GEUS, the Greenland–Danish national oil company Nunaoil and the owners of major seismic surveys (principally TGS-NOPEC). Numerous presentations on the geology of West Greenland have been given during 2001 at petroleum-related meetings and conferences (Bojesen-Koefoed *et al.* 2001a; Chalmers & Oakey 2001; Chalmers *et al.* 2001a; Christiansen *et al.* 2001b; Dam *et al.* 2001; Middleton *et al.* 2001; Oakey & Chalmers 2001; Rasmussen & Sheldon 2001; Sønderholm *et al.* 2001). Presentations have also been given to a large number of companies both at their own offices in Europe, Canada and the United States and at the Survey's headquarters in Copenhagen.

All relevant information relating to petroleum exploration in West Greenland has been made available on the internet on a newly developed portal: GhexisOnline (www.geus.dk/ghexis). On this site, information on the West Greenland licensing round, geology (including prospectivity, source rocks and maturity, and play types), available data types (well data, seismic data, source rock data, cultural data, etc.), operational conditions, exploration history and relevant literature can be found, together with online versions of the GHEXIS Newsletter.

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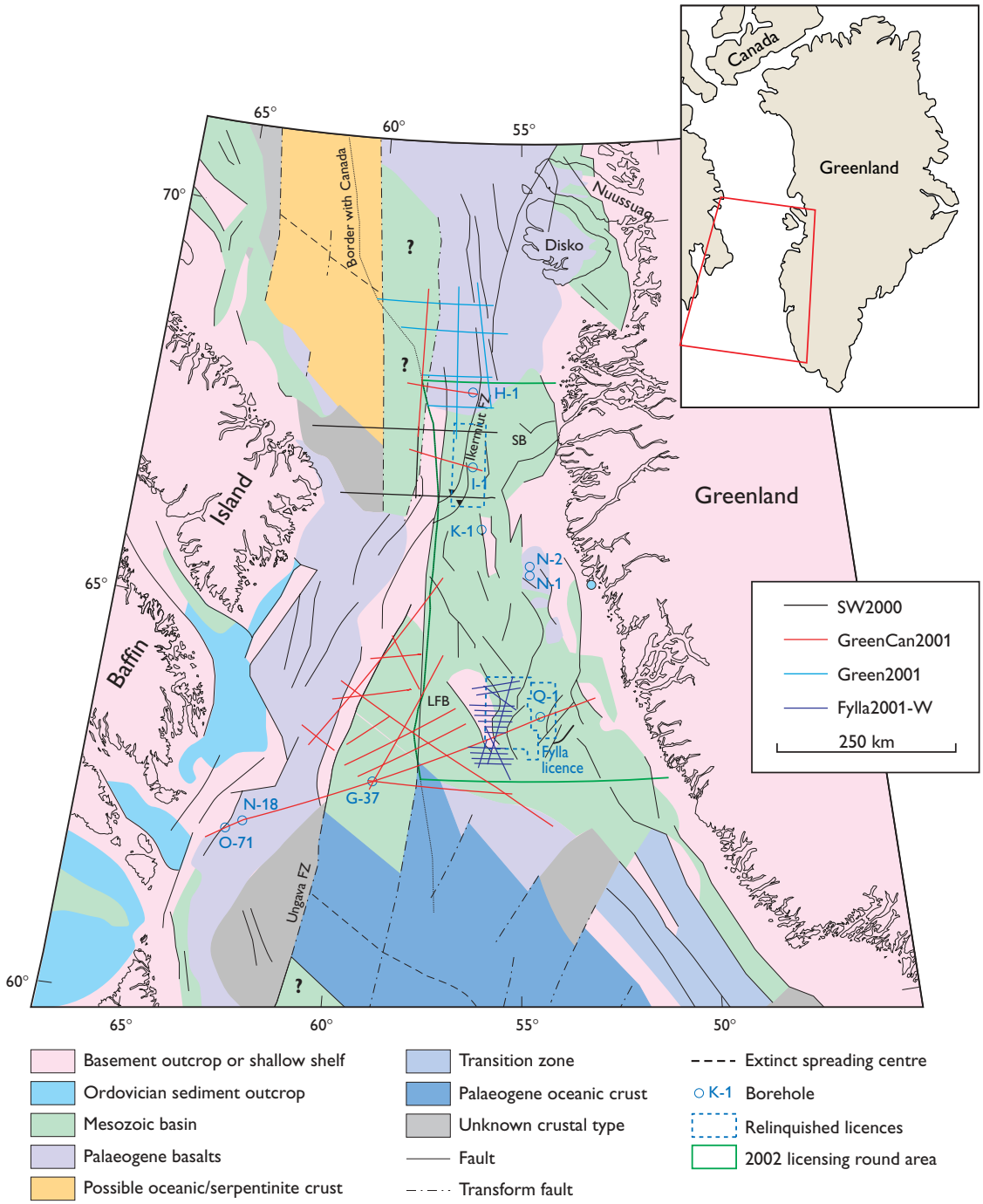

Fig. 1. Map of West Greenland showing main structural elements, sedimentary basins and position of seismic surveys mentioned in text. **SB**: Sisimiut Basin, **LFB**: Lady Franklin Basin, **FZ**: Fault Zone. Two offshore licences were relinquished in 2001: the Fylla licence (Statoil Group) to the south and the Sisimiut-West licence (Phillips Group) to the north.

Seismic acquisition during summer 2001 – the search for the deep basins in the boundary zone between Canada and Greenland

The development of the continental margins of the Labrador Sea is still relatively poorly known due to a limited seismic and geophysical database. The literature and data have recently been reviewed in detail by Chalmers & Pulvertaft (2001). A plate-tectonic reconstruction project has also been initiated in a collaboration between GEUS and the Geological Survey of Canada to increase the geotectonic knowledge of the region (Chalmers & Oakey 2001; Oakey & Chalmers 2001).

In the year 2000, TGS-NOPEC acquired some high-quality seismic lines along the Ungava Fault Zone in the vicinity of the Greenland–Canada border (the SW2000 survey; Fig. 1). These data, in combination with re-processed satellite gravity data, indicate that deep sedimentary basins that earlier had been recognised in the Sisimiut Basin are more extensive than previously believed (Chalmers *et al.* 2001b; Christiansen *et al.* 2001a). Better mapping of the distribution and internal features of these sedimentary basins may have a significant influence on petroleum exploration concepts in the region. Source rocks older than those already known from the Paleocene, and inferred mid-Cretaceous, may be present in a system of basins along the boundary zone between Greenland and Canada. This is expected to lead to completely new exploration models, both within the deep basins themselves and, due to the possibility of long-distance migration, in the surrounding shallower basin areas.

In order to follow the deeper basins along the Ungava Fault Zone northwards and to outline and study potential kitchens for petroleum generation in the Lady Franklin Basin, the GreenCan2001 survey was acquired during summer 2001 (Fig. 1). A tie-line connecting the Greenland Qulleq-1 well and the Canadian Gjoa G-37, Ralegh N-18 and Hekja O-71 wells was acquired (Fig. 1). This line is important both for tectonic reconstructions and for biostratigraphic/organic geochemical correlations. The survey, which is a regional joint-venture project between TGS-NOPEC and BMP, with GEUS as technical advisor, resulted in a total of 2829 km of seismic data; of these, 1213 km were acquired in Greenland waters and 1616 km in Canadian waters (Fig. 1).

In addition, TGS-NOPEC acquired the Green2001 survey in the northern open-door area (Fig. 1). This survey was designed to follow possible deep basinal trends from the Ungava Fault Zone towards the oil seep region of Disko–Nuussuaq (Christiansen *et al.* 2000). In total, 904 km of seismic data were acquired.

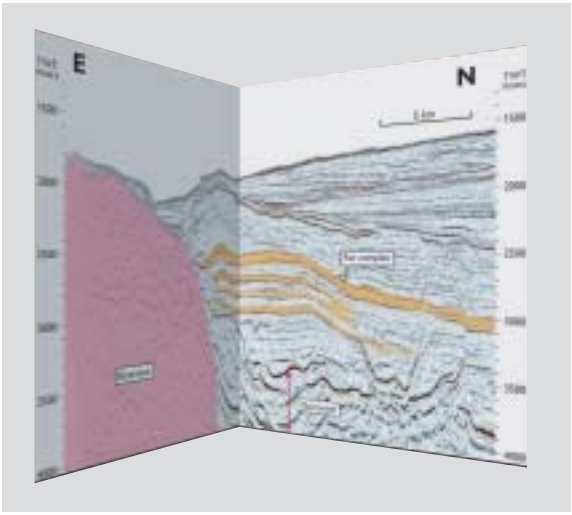

Fig. 2. Seismic lines from the Fylla2001-W survey showing closures at several levels in the Cretaceous succession, primarily as roll-overs formed by later compression along the main Fylla fault.

Seismic acquisition in the western Fylla area

In order to fulfil the remaining work obligations in the Fylla licence, the Statoil group acquired 948 km of seismic data, mainly in the western part of the licence (Fylla2001-W survey; Fig. 1). Although there are some problems in correlating the Cretaceous seismic units across the main Fylla fault, there are good indications from maturity modelling that the inferred Cenomanian–Turonian source rock is thermally mature in this area (Christiansen *et al.* 2001a, fig. 7). The survey was mainly designed to map leads and prospects, either comparable to the Santonian reservoir sandstones known from the Qulleq-1 well, or to contemporaneous or younger hanging-wall and basin floor fans just west of the main Fylla fault. A preliminary inspection of data demonstrates closures at several levels in the Cretaceous succession, primarily as roll-overs formed by later compression along the main Fylla fault (Fig. 2).

With the relinquishment of the Fylla licence, this area is open for licensing in the coming round. A large and modern database is now available which provides opportunities of mapping very large leads and prospects.

The results from the Qulleq-1 well demonstrate the presence of good seals and reservoir rocks and a significant untested up-dip potential (see Christiansen *et al.* 2001a). The main risk, until deeper stratigraphic successions have been penetrated by drilling, is still verification of the presence of good oil-prone source rocks and, in some areas, also thermal maturity.

Geohazard study

During 2001, a study of possible geohazards offshore West Greenland was completed at GEUS in preparation for the 2002 licensing round. Apart from mapping seabed and sub-seabed geohazard features, the post mid-Eocene succession was mapped for the first time using the most important seismic units of regional to semi-regional scale integrated with existing biostratigraphic and well-log data. The mapped seabed geohazard features include bathymetry, gradient, channels, canyons and iceberg ploughmarks, seabed reflector amplitude anomalies, hard bottom and possible 'bottom simulating reflectors' (BSRs), mass flow deposits and current-related features. Sub-seabed features include buried channels and canyons, buried mass flow deposits, diapiric features and dewatering fractures (Fig. 3).

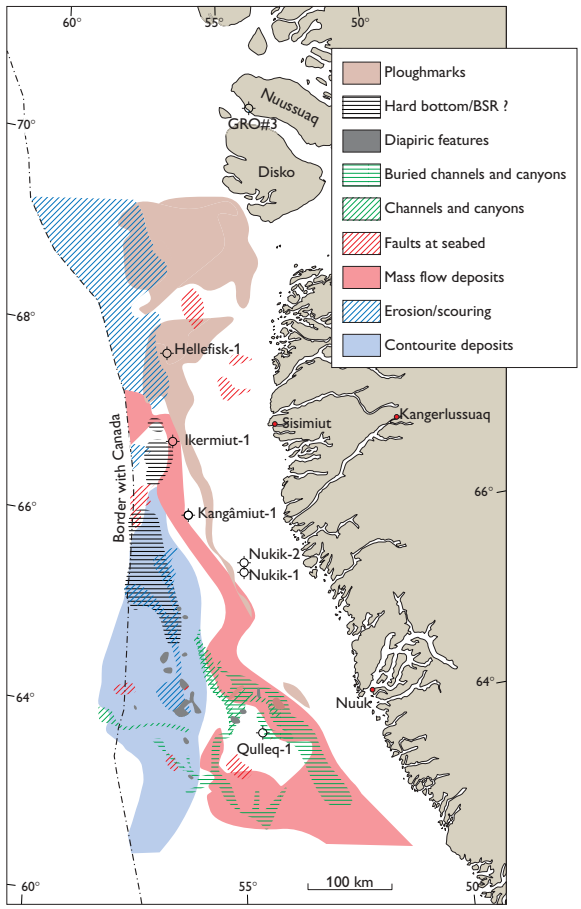

Fig. 3. Map showing compilation of possible geohazard features offshore West Greenland (see text for further details). **BSR**: bottom simulating reflector.

New stratigraphic and source rock studies

Two studies relevant for petroleum exploration were initiated at the Survey in 2001: (1) a biostratigraphic correlation study between West Greenland and Canada, and (2) an organic geochemical project on mid-Cretaceous source rocks and oils throughout the United States and Canada in comparison with West Greenland.

The aim of the first project is to present a biostratigraphic correlation of the West Greenland wells, especially Ikermiut-1 and Qulleq-1 where Cretaceous sediments are present (Nøhr-Hansen 1998; Nøhr-Hansen *et al.* 2000), with selected Canadian wells on the Baffin Island and Labrador shelves (Gjoa G-37, Ralegh N-18, Hekja O-71, Skolp E-07 and Ogmund E-72).

The aim of the second project is to analyse and describe marine oil-prone source rocks deposited during the Cenomanian–Turonian anoxic event (e.g. Schlanger & Jenkyns 1976; Hallam 1987), but also during other periods in the Cretaceous and Palaeogene (especially in the Aptian–Albian and in the Paleocene) in order to erect models for source rock deposition and prediction. The project focuses on a comparison of source rocks and oils in West Greenland with the Arctic basins in Canada and Alaska, the east coast basins of Canada and the United States and basins from the Cretaceous Western Interior Seaway (central Canada and the United States). The provincialism of the fauna and flora of the source rock units will also be addressed in order to test palaeogeographic, palaeo-oceanographic and palaeoclimatic models for the region. In particular, possible seaway connections in Cretaceous time from central West Greenland towards the north (Sverdrup Basin and other Arctic basins), west (Canadian Interior) and south (Atlantic basins) are important for source rock models.

Other petroleum geological work

Although the main focus in 2001 was on the West Greenland 2002 licensing round, field work was also carried out in East Greenland. A project on the post-basaltic, Palaeogene and Neogene sediments in central East Greenland was initiated (Larsen *et al.* 2002, this volume; Nøhr-Hansen & Piasecki 2002, this volume). These sediments have received renewed interest as a result of the recent exploration activities around the Faeroe Islands. Lithostratigraphy, biostratigraphy and sequence stratigraphy studies will provide further insights into basin evolution and uplift history of the northern North Atlantic during Palaeogene time.

After almost 10 years of intensive field work in the Disko–Nuussuaq region in West Greenland, many results important for the evaluation of the exploration potential of the offshore areas are emerging. Although field work was completed in 1999 (Christiansen *et al.* 2000), several studies have been published in 2001, including those on organic geochemistry of coals (Bojesen-Koefoed *et al.* 2001b), sequence stratigraphy (Dam *et al.* 2001), taxonomy (Nøhr-Hansen & Heilmann-Clausen 2001; Nøhr-Hansen *et al.* in press) and discussions of the tectonic history (Chalmers & Pulvertaft 2001). The last of the planned 1:100 000 geological maps of the region was also printed in 2001 (Pedersen *et al.* 2001). Many other studies of basin history, sedimentological and structural models, lithostratigraphy, organic geochemistry of seeps, etc. are in progress.

Acknowledgements

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