

# Petroleum geological activities in West Greenland in 1999

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Renewed interest in petroleum exploration in West Greenland led to grants of licences for the Fylla area operated by Statoil in 1996 and the Sisimiut-West area operated by Phillips Petroleum in 1998 (Fig. 1). The first exploration well on one of the spectacular structures in the Fylla area will be drilled in the year 2000. The new exploration strategy is now in place, and a licensing round offshore West Greenland will be held in the year 2001; see details in the *Ghexis Newsletter* (Ghexis 1999) or the Bureau of Minerals and Petroleum's homepage: [www.bmp.gl](http://www.bmp.gl).

With the strategy in place and everybody expectantly waiting for the first well in the Fylla area, activities in 1999 were concentrated very much on follow-up and preparation for the coming licensing round. The focus of field work in central West Greenland moved north to the Svartenhuk Halvø region. Compared to the Disko–Nuussuaq region, the outcrops of Cretaceous–Palaeogene sediments on Svartenhuk Halvø and nearby islands are minor in both number and size, but nevertheless very important for interpretation of the evolution of the Nuussuaq Basin. It was particularly important to study a number of marine channel deposits and their possible correlation with similar deposits on Nuussuaq. Furthermore 'oil hunting' continued as a necessary follow-up of several interesting finds of oil staining in basalts on Ubekendt Ejland and the south coast of Svartenhuk Halvø in the summer of 1997 (Christiansen *et al.* 1998), and also in order to delineate the northern boundary of the seep province.

In the offshore areas a number of interpretation projects were initiated in order to have the best possible assessment of exploration potential ready before the opening of the coming licensing round. The oil industry continued its work under the two existing licences and exclusive seismic data were acquired both within the Sisimiut-West and the Fylla licence areas (Fig. 1). On completing their programmes the seismic vessel continued work in the region and acquired 2800 km of non-exclusive data.

## Svartenhuk Halvø region

In the summer of 1999 Svartenhuk Halvø and surrounding islands were the scene of continued field studies. The work included stratigraphic, sedimentological and structural studies of the Cretaceous–Paleocene sediments and overlying volcanics, and a systematic search for oil seeps and impregnations. This region is less accessible than Nuussuaq and the last oil-related campaigns were in 1992, 1994 and 1995: in 1992, field work and shallow drilling (Christiansen 1993; Christiansen *et al.* 1994), in 1994 acquisition of a seismic line as preparation for drilling (Christiansen *et al.* 1995), and in 1995 drilling of the Umiivik-1 well (Bate & Christiansen 1996; Dam *et al.* 1998).

Eight geologists carried out the field work in 1999 during six weeks in July–August. A chartered vessel *Maja S* was used throughout this period for mobilisation and transportation while helicopters (Ecureuil AS 350 and Bell 212) were chartered for three days.

## *Sedimentology and palynological field work*

The aim of this field work was to complete the sedimentological and palynological studies of the Cretaceous–Paleocene succession in central West Greenland. Previous published work on the sediments in the Svartenhuk Halvø region is mainly limited to the results of the mapping campaigns in 1962–1963 and 1980 by the Geological Survey of Greenland (cf. Andreasen 1981; Henderson & Pulvertaft 1987; Larsen & Pulvertaft in press) and industry reports (Ehman *et al.* 1976). More recently, palynological results from the Upper Cretaceous succession in the region have been published by Nøhr-Hansen (1996) and Dam *et al.* (1998).

The outcrops of Cretaceous–Paleocene sediments in the Svartenhuk Halvø region are limited to small ravines which rarely show continual sections thicker than 50 m.

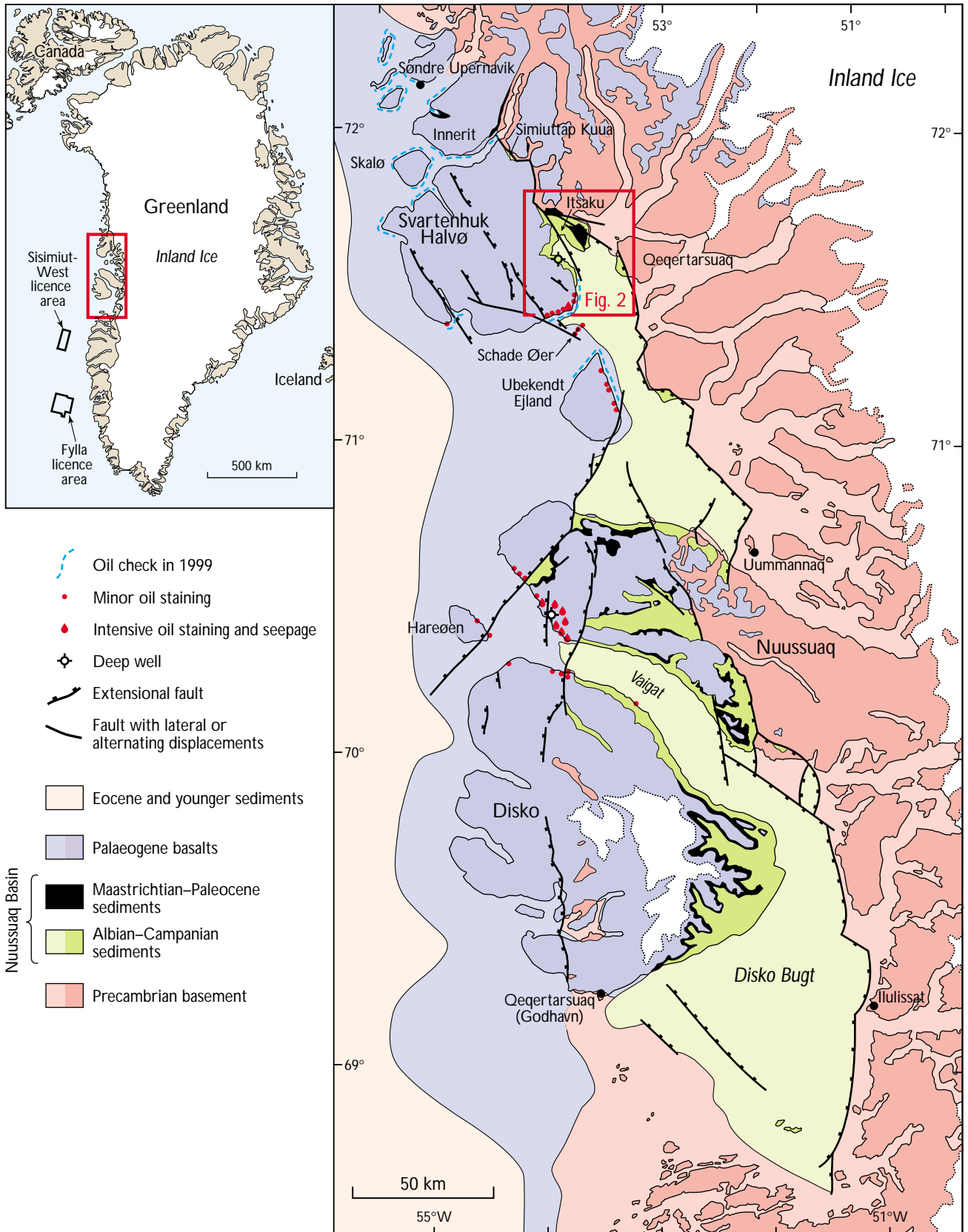


Fig. 1. Simplified geological map of the Disko – Nuussuaq – Svartenhuk Halvø region showing the onshore and offshore geology and place names together with distribution of localities with oil staining and seepage. The locations of the Fylla and Sisimiut-West license areas are shown on the small map. **Blank** areas on Disko are ice.

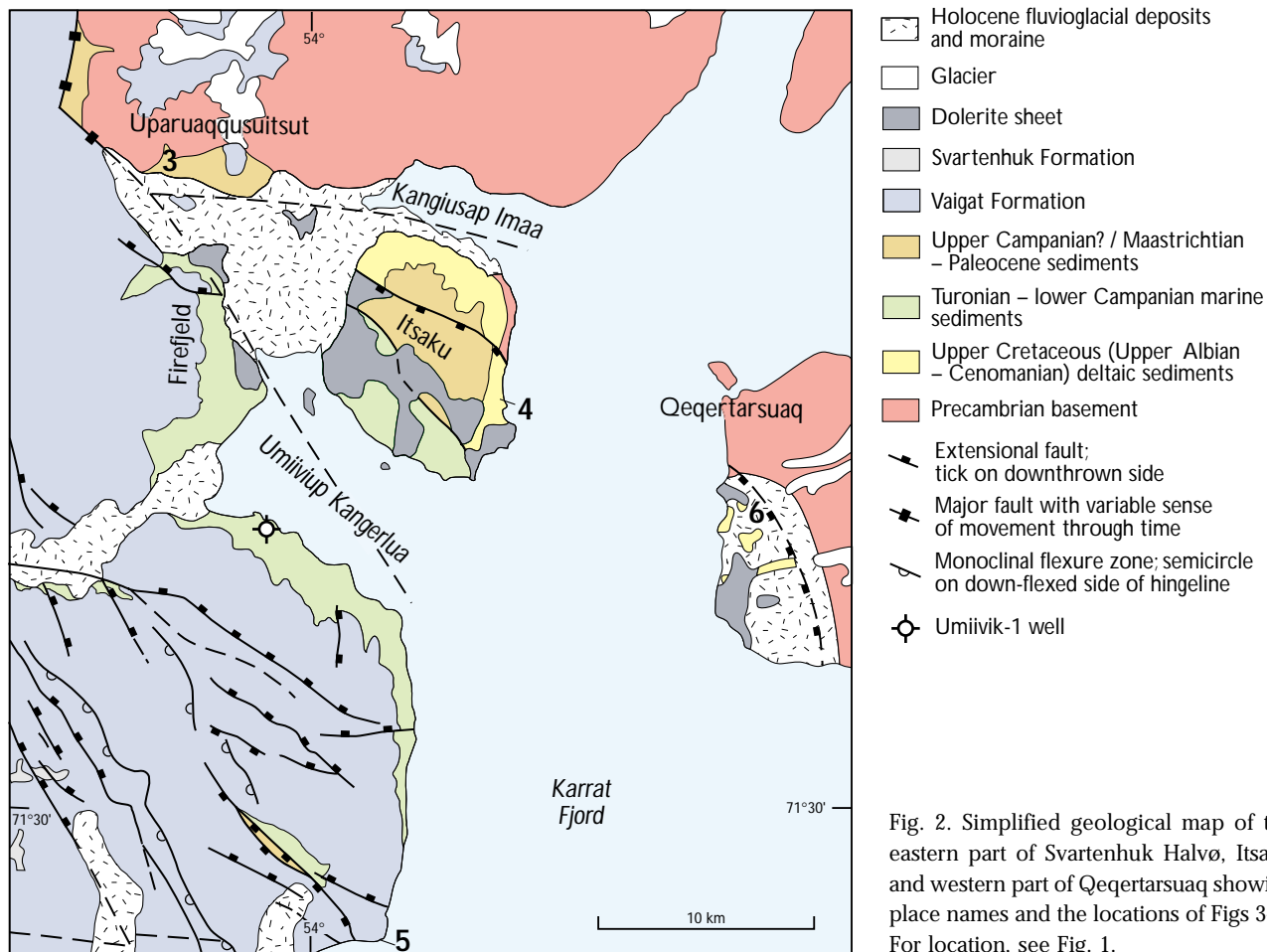


Fig. 2. Simplified geological map of the eastern part of Svartenhuk Halvø, Itsaku and western part of Qeqertarsuaq showing place names and the locations of Figs 3–6. For location, see Fig. 1.

Localities were visited in 1999 at Firefield, Itsaku, Qeqertarsuaq, Simiuttap Kuua and Uparuaqqusuitsut (Figs 1, 2).

At Uparuaqqusuitsut a major valley complex is incised into the underlying basement. The incised-valley fill consists of several hundred metres of thick Paleocene marine conglomerates and mudstones (Fig. 3). Incision is probably related to a major early Paleocene tectonic event that also has been recognised in the Nuussuaq region (cf. Dam & Sønderholm 1998). At Firefield, lower Paleocene conglomerates unconformably overlie marine mudstones of Cretaceous age. This unconformity is probably related to an early Paleocene tectonic event, which may be the same as that recognised at Uparuaqqusuitsut.

At Itsaku, Upper Cretaceous sediments onlap the basement. These sediments are composed of deltaic mudstones and sandstones arranged in coarsening-upwards cycles similar to those described from the Atane Formation in the Disko–Nuussuaq region (cf. Pedersen & Pulvertaft 1992). The Upper Cretaceous sediments are separated from overlying marine sediments

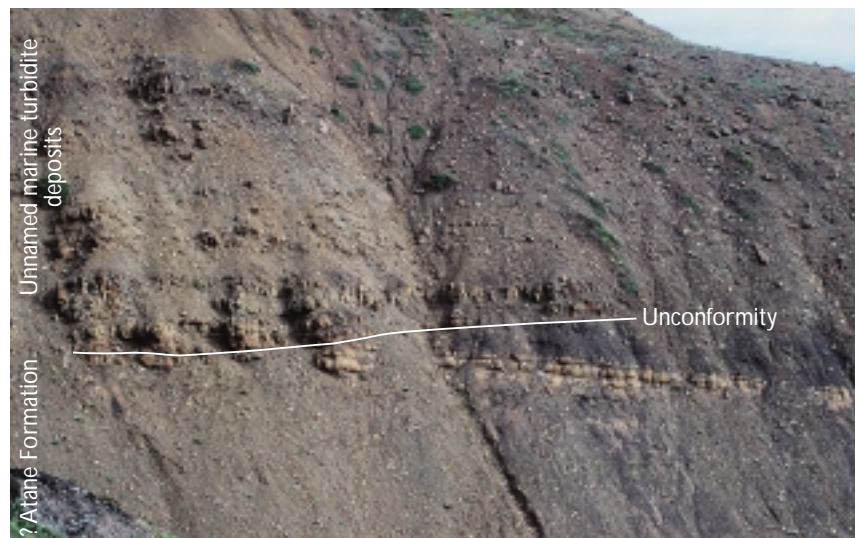
by an angular unconformity (Fig. 4). This unconformity may be correlated with either an early Campanian unconformity recently recognised in central Nuussuaq (Dam *et al.* in press), or a late Maastrichtian – early Paleocene unconformity recognised on Nuussuaq (Dam *et al.* 1999). A more detailed dating of these events must await future palynological studies. Detailed palynological sampling was carried out at all localities. However, many mudstone successions on Svartenhuk Halvø are intruded by thick sills, and it is expected that the intense heating from these sills may have altered the organic material which will make recognition of palynomorphs difficult or impossible in many samples. The successions at Firefield, Itsaku and Simiuttap Kuua were sampled in order to date the uppermost Cretaceous and lower Paleocene sediments, the ages of which have never been palynologically documented.

The deposits at Qeqertarsuaq consist of fluvial sandstones referred to the informal 'Upernavik Næs Formation' (Ødum & Koch 1955). Palaeocurrent directions are generally towards the north-east. The entire

Fig. 3. Incised-valley complex of Paleocene conglomerates and mudstones cut into the Precambrian basement at Uparuaqqsuitsut, northern Svartenhuk Halvø. Person (in circle) for scale. For location, see Fig. 2.



Fig. 4. Unconformity separating Upper Cretaceous deltaic deposits (?Atane Formation) from overlying undated marine turbidite deposits. Height of the section is approximately 40 m. For location, see Fig. 2.



sedimentary succession on Qeqertarsuaq was logged and sampled for palynological and geochemical analysis.

### *Seep studies*

There is no doubt that the discovery of seeping oil and many oil impregnations in volcanic rocks in the Disko – Svartenhuk Halvø region has had a profound positive impact on the evaluation of West Greenland as a petroleum province. Since the first discovery on western Nuussuaq in 1992 (Christiansen 1993; Christiansen *et al.* 1996), the area where oil has been found in sufficient amounts and quality for detailed analytical studies has greatly expanded from a few metres along the beach to an area of several thousand square kilometres covering northern Disko, Hareøen, most of western Nuussuaq and most recently also Ubekendt Ejland

and Svartenhuk Halvø (Fig. 1). Geochemical studies have indicated not just one but several oil-prone source rocks (cf. Bojesen-Koefoed *et al.* 1999); some of these seem to be of local importance only, while others are inferred to have a regional distribution throughout West Greenland including the offshore basins.

'Oil hunting' was continued in 1999 and extended into the northern part of the region, especially with the aim of defining the northern limit of the area with known seepage and oil impregnation and to make a detailed follow-up in the neighbourhood of the few localities on Ubekendt Ejland, Schade Øer and Svartenhuk Halvø where oil impregnations were discovered in 1997 (Christiansen *et al.* 1998).

The south and west coasts of Svartenhuk Halvø and adjacent islands were systematically checked for any signs of petroleum leakage. All well-exposed coastal out-



Fig. 5. Locality at the south-east corner of Svartenhuk Halvø with oil impregnation along a dyke contact. Host rocks are volcanics of the Vaigat Formation. Person stands at the best oil showing in the Svartenhuk Halvø region. For location, see Fig. 2.

crops were checked carefully while passing slowly in a rubber dinghy. Many landings were made to check for smell or visual observation of oil, especially in the vicinity of dykes, faults, fractures, mineralised and other coloured zones (Figs 1, 5). Despite this intense search, it was not possible to document traces of oil on the islands close to Søndre Upernavik, or on Skalø, Innerit and the west coast of Svartenhuk Halvø. In the northern part of this area the lavas are almost horizontal and without dykes, presumably due to underlying shallow basement. On Skalø and the westernmost part of Svartenhuk Halvø the lavas display moderate to strong dips and are often cross-cut by dykes, faults and fractures. Although there seem to be possible conduits for migration/leakage of hydrocarbons to the surface, no examples of oil impregnations were found. It is not clear whether this lack of hydrocarbons is caused by

the great thickness of the volcanic succession here or a lack of minerals capable of trapping hydrocarbon inclusions, or is due to a lack of mature oil-prone source rocks in the subsurface.

On the westernmost part of the south coast of Svartenhuk Halvø only one locality (out of 17 investigated) was found with a distinct petroliferous smell from carbonate veins. Farther east (close to the south-eastern corner of Svartenhuk Halvø) many localities (> 10) with traces of oil were discovered and sampled (Fig. 1). One of these localities has clearly visible oil along a dyke contact (Fig. 5). Previously sampled oil localities on Schade Øer were revisited without any new discoveries. Six new localities with distinct oil impregnation were discovered on the east coast of Ubekendt Ejland, whereas search on the west coast did not give any success, probably because the basalts are weathered and outcrops are poor, and there is very high thermal alteration towards the south.

Encouraged by the discovery of seeping oil in Cretaceous sediments on Disko in 1997, time was also used on a systematic search in the sediments on Svartenhuk Halvø, especially on Itsaku and Qeqertarsuaq, both areas where bitumen has previously been reported. On Itsaku minor bitumen was found but it is strongly thermally degraded. On Qeqertarsuaq, the classic locality of Henderson (1969) was revisited; this locality lies in a downthrown block c. 1 km west of the main fault (Fig. 6). Minor amounts of bitumen were found, possibly enough for detailed analysis, but this bitumen seems to have been generated locally from plant remains in the conglomerate.

### *Palaeomagnetic sampling*

Sampling for palaeomagnetism was an integrated part of the field campaigns in West Greenland in 1994 and 1996 (Christiansen *et al.* 1995, 1997). Subsequent analysis has documented a geomagnetic pole shift and provided a high-resolution record of the palaeointensity variations around this transition (Riisager & Abrahamsen 1999, 2000). Moreover, magnetostratigraphy and palaeosecular variation studies have proved effective for high-precision geochronology and stratigraphic-structural correlation of volcanic units (Riisager *et al.* 1999; Riisager & Abrahamsen 1999).

The 1999 palaeomagnetic field programme covered areas and/or parts of the stratigraphic column that had not been previously sampled: on Svartenhuk Halvø the Paleocene Vaigat Formation, on Ubekendt Ejland the Eocene Erqua Formation, on westernmost Nuussuaq

Fig. 6. Bitumen-impregnated brecciated sandstone from the classical locality of Henderson (1969) on Qeqertarsuaq. Person for scale. For location, see Fig. 2.



the Eocene Kanisut Member and on Hareøen the Eocene Talerua Member (Fig. 1). Furthermore, a few samples of Neogene–Quaternary sediments were collected on Hareøen. This new collection will be particularly valuable in linking together different parts of the West Greenland onshore volcanic region that are otherwise not easy to correlate. The extensive sampling of the Vaigat Formation (60 lava flows), Kanisut Member (22 lava flows) and the Talerua Member (19 lava flows) will provide three new well-defined palaeomagnetic poles and a large data set for palaeosecular variation estimates. Finally, the magnetic polarity data will be useful in geochronological studies of age and periodicity of the West Greenland volcanism.

## Offshore West Greenland

Acquisition of seismic data continued offshore West Greenland in the summer of 1999. The seismic company GECO-Prakla acquired proprietary seismic data (totalling approx. 1700 km) within the Fylla licence area for the Statoil group and within the Sisimiut-West licence area for the Phillips group using the seismic survey vessel *Professor Polshkov*. Afterwards, the same seismic vessel shot a regional non-exclusive survey (approx. 2800 km) for another seismic company TGS-NOPEC.

The Survey continued studies on seismic and well data from offshore West Greenland. Interpretation of the seismic data from the basalt area west of Disko continued and this study was extended to Canadian waters by a Survey geophysicist spending six months at the

Atlantic Geoscience Centre of the Geological Survey of Canada in Halifax, Nova Scotia. As a preparation for the coming licensing round in 2001, a number of new interpretation projects were started in order to reassess the exploration potential off central West Greenland. These projects include interpretation (both structural and stratigraphic) of the many seismic data sets acquired in recent years, reprocessing and reinterpretation of selected older data in combination with reanalysis (lithostratigraphic, biostratigraphic and organic geochemical) of material from the five offshore wells, basin modelling, and description of new play types, leads and prospects combined with ranking of blocks. The initial reports from these studies will be confidential but the data and results will be used for promotion and eventually for publication (cf. Skaarup *et al.* 2000).

A preliminary geohazard study was also carried out in 1999; this project aimed mainly at establishing a systematic data base for studying various potential geohazard features of the continental margin between 60°N and 72°N. The project was set up as a desk-top study, i.e. a study of existing archive material, and a systematic data base has been established consisting of more than 45 000 km of multi- and single-channel seismic data, data from five exploration wells and 63 gravity cores.

The gravity cores derive from a site survey in the Fylla licence area, and detailed sedimentological and stratigraphical studies have been carried out on selected cores. These studies showed that the dominant seabed in the Fylla licence area is a diamicton, and that there is little variation throughout the area.

Interpretation of the seismic data, particularly the multichannel seismic data loaded on the workstation,

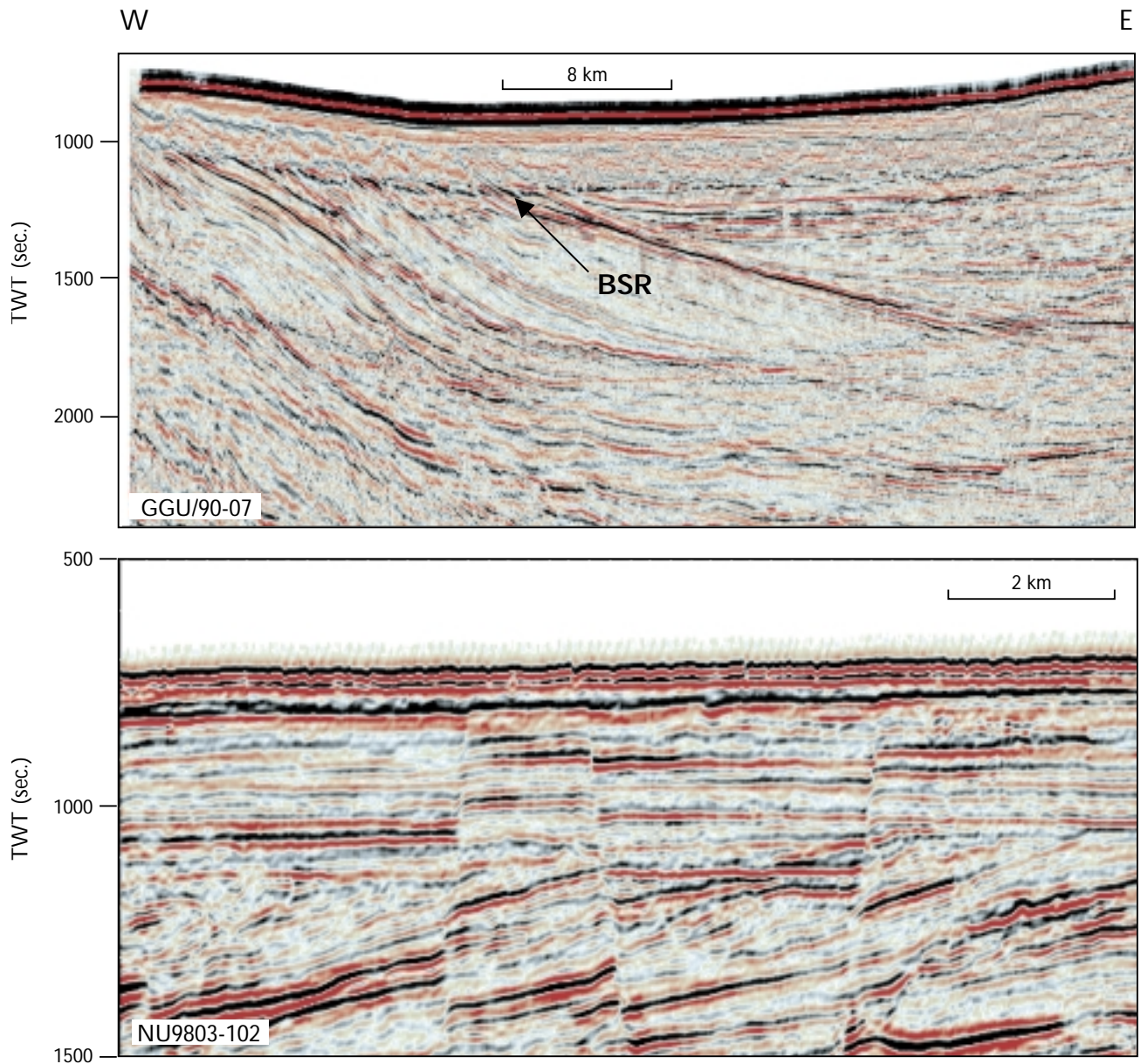


Fig. 7. Seismic lines, offshore West Greenland. **Above:** A bottom simulating reflector (**BSR**) observed in the offshore basin area between 65°N and 67°N. BSR's may indicate the presence of gas hydrates within the sediments. Line GGU/90-70. **Below:** Near-seabed faults observed on seismic line north-west of Disko. Faults propagating at or near the seabed could indicate that the area is liable to sediment failures. The seismic line, NU9803-102, is reproduced with permission of the company Nunaoil.

shows a variety of potential geohazard features on the seabed (e.g. current and glacial related bedforms, faults, mass flow deposits, seabed instability), and sub-seabed (e.g. gas hydrates, shallow gas, diapirism; Fig. 7). The amount and character of possible geohazard-related issues identified by this study show that further work is required to improve our knowledge of the area. It is hoped that later projects will allow the more detailed interpretation and mapping necessary to contribute actively to the safety and environmental aspects of future exploration and development the area.

### *Sequence stratigraphy of the Palaeogene sediments*

A project financed by the Danish government's Energy Research Programme (EFP) was initiated in 1999 to study the sequence stratigraphy of the Palaeogene sediments offshore southern West Greenland. By the end of the year, a total of 28 seismic sequences had been defined, i.e. units that are bounded above and below by unconformities. Many of these sequences are local and may consist of delta or fan lobes of limited lateral

extent. Only about a third of the sequences could be tied to the wells, but there is a reasonably consistent correlation between the seismic interpretation and the biostratigraphy of Nøhr-Hansen (1998).

In order to refine the biostratigraphic zonation of Toxwenius (1986) and extend the dinoflagellate cyst stratigraphy of Nøhr-Hansen (1998), dinoflagellate cysts from the Nukik-2 well have been re-examined in detail and more samples from Nukik-2 and selected intervals from the Hellefisk-1, Kangamiut-1 and Nukik-1 wells (all drilled 1976–77) will be studied in 2000. A nanofossil analysis was also carried out on material from the Nukik-2 well, and in addition microfossils from selected intervals in the wells Kangamiut-1, Nukik-1 and Nukik-2 have been studied in detail.

In 2000 the work will be continued by completing the lithostratigraphic and biostratigraphic analysis of the wells, and by describing the seismic facies of the seismic sequences. The biostratigraphy will be used to date the seismic sequences and the lithostratigraphy will be used to calibrate the seismic facies. These studies will then be integrated to produce a sequence stratigraphic analysis of the sediments.

## Future Survey studies

A general high level of activity with many ongoing and new studies can be expected in West Greenland in the near future, although detailed planning will be highly dependent on the outcome of the first exploration well in the Fylla area planned for 2000 and the subsequent licensing round.

Field work in the Disko – Nuussuaq – Svartenhuk Halvø region is expected to be limited, and a considerable effort will be made to conclude and summarise the onshore studies from the 1990s. This work will concentrate on biostratigraphy and sedimentology (Dam *et al.* in press) and in due course lead to a new depositional model and a new lithostratigraphy (G. Dam & G.K. Pedersen, work in progress). Studies of Cretaceous–Palaeogene source rocks and oils continue (e.g. Nytoft *et al.* 2000).

New offshore activities are, however, planned in the Nuussuaq Basin. As part of EFP-99 project *Structure and hydrocarbon potential of the Nuussuaq Basin: acquisition and interpretation of high-resolution multichannel seismic data*, new seismic data will be acquired in the waters around Nuussuaq and Ubekendt Ejland using the research vessel *Dana*. Seismic data previously acquired in the fjords south and north of Nuussuaq combined

with gravity modelling have greatly improved the general understanding of the structure of the basin (Chalmers 1998; Chalmers *et al.* 1999). The new EFP project aims to improve understanding of the shallow structure of the Nuussuaq Basin by providing a denser data coverage than exists at present. The new data will also have direct implications for the evaluation of the hydrocarbon potential of the onshore areas. Because of ice conditions and the relatively large water depths, a short seismic streamer will be used. As preparation for the seismic programme *Maja S* recorded several echo sounding lines south and east of Svartenhuk Halvø in 1999.

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