



Renewed petroleum geological studies onshore West Greenland

*Flemming G. Christiansen, Gregers Dam,
David J. McIntyre, Henrik Nøhr-Hansen,
Gunver K. Pedersen and Martin Sønderholm*

As a consequence of renewed interest in petroleum exploration in West Greenland (e.g. Pulvertaft, 1991; Christiansen & Pulvertaft, 1992; Oil & Gas Journal, 1991; Chalmers & Pulvertaft, in press) the Geological Survey of Greenland (GGU) has begun a new series of petroleum geological investigations of the Upper Cretaceous – Lower Tertiary sediments exposed on Disko, Nūgssuaq and Svartenhuk Halvø (69°–72°N) (Fig. 1). These sediments include the only marine sediments of this age exposed in the entire Labrador Sea – Baffin Bay region, and studies of these are essential for a detailed interpretation of the offshore geology (Chalmers, 1990, 1991; Ottesen, 1991a, b). Field work on the marine succession has been concentrated on three main tasks: detailed sedimentological studies; sampling for palynological and organic geochemical studies; and mapping and structural analysis. In order to gain a detailed knowledge of both early basin development in West Greenland and the three-dimensional architecture of deltas and submarine fans, the petroleum geological studies are being coordinated with ongoing studies of age-equivalent non-marine strata being carried out by the University of Copenhagen, and with several other externally financed projects.

Detailed sedimentological studies

Up until the late 1960s studies on the marine, deltaic and lacustrine sediments in the Cretaceous–Tertiary basin of West Greenland were concentrated mainly on stratigraphy and palaeontology. In the early to mid 1970s investigations focussing on petroleum and coal geology were carried out. This work has been summarised by Henderson *et al.* (1976, 1981). More recently, in 1987, sedimentological studies were initiated on the non-marine Atane Formation on Disko and southern Nūgssuaq (e.g. Pedersen, 1989a, b; Pulvertaft & Chalmers, 1990; Pedersen & Pulvertaft, 1992).

Fig. 1. Geological sketch map showing main outcrops of Cretaceous – Tertiary sediments in West Greenland. 1: Itivdle 2: Ikorfat Fault Zone, 3: Atāta kūa.

Sedimentological fieldwork in the summer of 1991 was concentrated on the fluvio-deltaic Atane Formation and the marine successions partly represented by the Agatdal and Kangilia Formations.

The Atane Formation (Fig. 2) is interpreted as a mid to late Cretaceous delta complex (Henderson *et al.*, 1976; Pulvertaft, 1979; Pedersen, 1989a, b; Pedersen & Midtgaard, 1990; Midtgaard, 1991; Olsen, 1991; Olsen & Pedersen, 1991; Pedersen & Pulvertaft, 1992). On eastern Disko and south-eastern Nūgssuaq the Atane Formation is predominantly non-marine, characterised

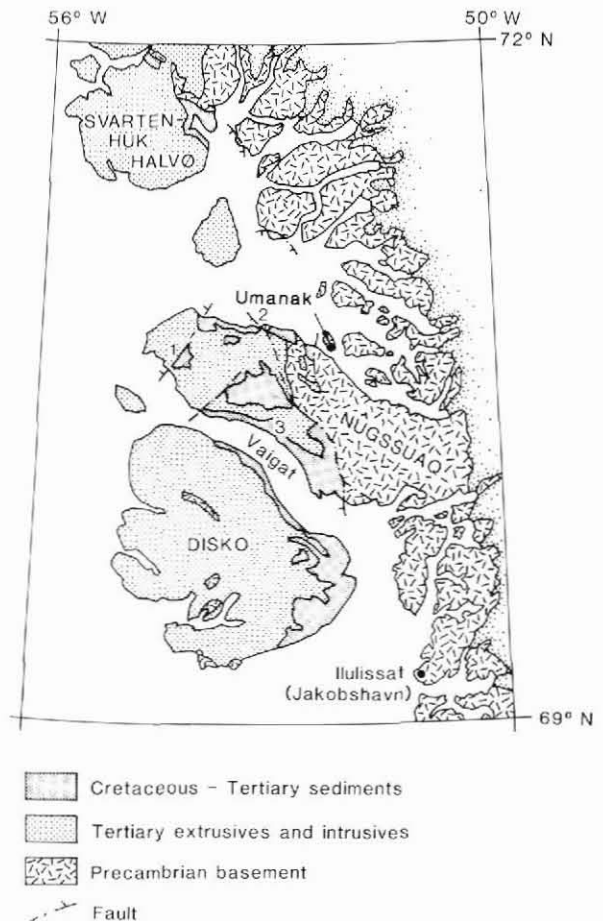




Fig. 2. Thick, coarsening upwards delta front sandstones alternating with delta plain sandstones and shales of the Atane Formation, south coast of Nûgssuaq. Section is approximately 250 m thick.

by distributary channel sand and delta plain shale with coal seams. The degree of marine influence increases towards the north and west where the Atane Formation is characterised by thicker delta front successions showing bioturbation and evidence of marine reworking.

Marine influenced parts of the delta complex are exposed on the north coast of Disko and on southern and central Nûgssuaq. Studies along the southern coast of Nûgssuaq demonstrated a general increase of marine influence towards the north-west. However, the expected parallel trend along the north coast of Disko is not evident. Consequently, detailed interpretations of the palaeogeography of the Atane delta cannot be based solely on sedimentology but must await the results of ongoing biostratigraphical studies.

Marine Cretaceous–Tertiary successions from 300 to more than 2500 m thick are exposed in central and northern Nûgssuaq (Agatdal and Kangilia Formations), in the Itivdle valley on western Nûgssuaq, and on Svarthenuk Halvø (Fig. 1); they are probably stratigraphically partly equivalent (Pulvertaft, 1987). The successions were deposited during a period characterised by repeated fault activity which produced an alternation of shelf mudstones and syntectonic submarine fan sediments.

On central and northern Nûgssuaq submarine fan sediments consist of extraformational cobbles and boulder conglomerates that are associated with major unconformities (Fig. 3). The oldest of these has been shown by finds of ammonites to be Late (latest?) Cretaceous in age, and not Danian as previously supposed.

The conglomerates probably mark main phases of tectonic development of the basin. The fault activity



Fig. 3. Maastrichtian (?) submarine fan cobble and boulder conglomerate from the north coast of Nûgssuaq. The conglomerate sharply overlies black, marine shales and is related possibly to tectonic activity along the Ikorfat Fault Zone. Person for scale.



Deep Late Cretaceous submarine channel infilled by turbiditic sandstones and mudstones. The channel cuts 90 m down into the deltaic deposits of the Atane Formation. South coast of Nūgssuaq at Atâta kûa. Photo: T. C. R. Pulvertaft.

caused rapid erosion of the borderlands and sedimentation of conglomerates and sandstones took place in deep submarine shelf channels fringing the basin.

In the Itivdle valley to the west sediments consist of organic rich slope mudstones alternating with coarse to very coarse-grained submarine fan sandstones (Fig. 4). The sandstones are arranged in 30–100 m thick megacycles, possibly corresponding to major phases of faulting. Tectonic activity caused large-scale slumping on the slope followed by sedimentation of submarine fan sediments. The latter occur in megacycles internally composed of fining-upward cycles a few metres thick deposited from high-density turbidity currents (Fig. 4). These turbidites were probably formed by transformation of slumps or debris flows. If similar sediments have been deposited offshore, they would act as excellent source and reservoir rocks given suitable conditions.

Palynological studies and organic geochemical studies

Systematic palaeontological investigations carried out in West Greenland in the period 1938 to 1968 have been summarised by Henderson *et al.* (1976). A major sampling programme for both palynological and organic geochemical analysis was undertaken in the 1970s in connection with coal and petroleum geological studies (Croxtton, 1976; Hansen 1976; Schiener, 1976; Schiener & Leythaeuser, 1978). Subsequent biostratigraphic and geochemical studies were not fully published, but a discussion of divisions and correlations with recommendations for further studies was given by Pulvertaft (1987).

The present palynological and organic geochemical sampling programme has concentrated on the Upper Cretaceous – Lower Tertiary successions on the north coast of Disko and on Nûgssuaq. On Svartenhuk Halvø only preliminary spot sampling has been carried out. More than 600 samples have been collected in order to evaluate the source rock potential, to carry out palynofacies analysis and to establish a palynomorph zonation that links the terrestrial and littoral facies in the south-east with the deep water facies to the north-west.

Mapping and structural analysis

Four topographic map sheets at scale 1:25 000 with 25 m contour lines, covering the main outcrop areas of the marine sediments on Nûgssuaq, have been prepared by GGU's photogeological laboratory. Preliminary interpretations were followed by detailed mapping and structural analysis in a number of key areas, in order to obtain a background for studies of the relationships

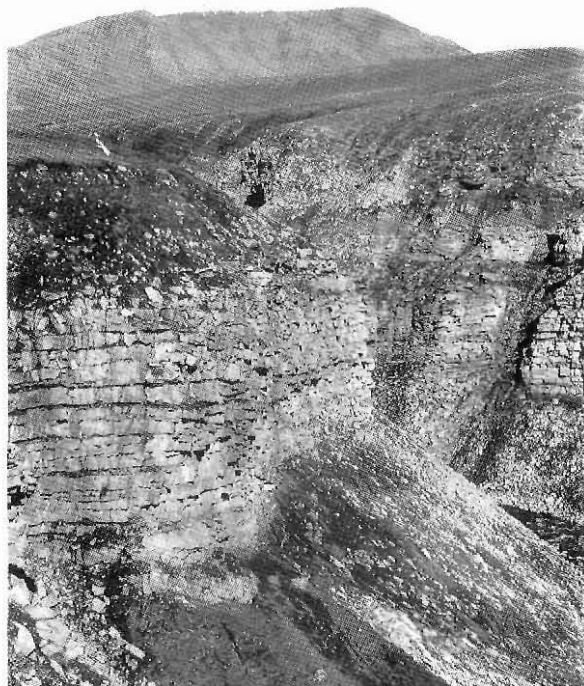


Fig. 4. Syntectonic, coarse-grained submarine fan sandstones exposed in the Itivdle valley. The sandstone interval is approximately 40 m thick.

between tectonic features and sedimentation. The maps have also been used to document the exact location of measured sections and samples, information that has been inadequate or even missing in many of the previous studies of the region.

Sedimentary facies, and hence the distribution of potential source rocks and reservoir rocks, seem to have been strongly influenced by basement topography and tectonic movements. In order to interpret the facies distribution two features on the north coast of Nûgssuaq were studied in particular: the Ikorfat Fault Zone (Fig. 1) and the palaeotopography of the basement prior to sedimentation.

Future work

Sedimentological work will be continued in the area in 1992 and a detailed sampling programme for palynological and organic geochemical studies will be carried out in key areas selected after evaluation of ongoing analytical work. A shallow core drilling campaign is planned for 1992 with the main targets being Cretaceous–Tertiary shales in central Nûgssuaq and Cretaceous shales on the north coast of Nûgssuaq and on Svartenhuk Halvø.

The results of the sedimentological, stratigraphic and

geochemical studies are planned to be integrated within a sequence stratigraphic framework aiming at prediction of the regional distribution of potential reservoir and source rocks.

Acknowledgements. The participation of Henrik Nøhr-Hansen and David J. McIntyre was financed by the Danish Ministry of Energy as part of the project 'Kridtsedimenter, Vestgrønland' (Grant No. EFP 1313/91-0014). The work of Gregers Dam is funded by the Carlsberg Foundation (Grant No. 90-0098/20). The field work of Gunver K. Pedersen was supported by the Danish Natural Science Research Council (Grant No. 11-8949-1).

Morten Dam and Søren Nielsen are thanked for their assistance in the field, Feiko Kalsbeek for his leadership of the Disko Bugt Project and T. C. R. Pulvertaft for his support during the planning of the study.

References

- Chalmers, J. A. 1990: Re-evaluation of the geology of the southern West Greenland shelf – Project VEST SOKKEL. *Rapp. Grønlands geol. Unders.* **148**, 29–32.
- Chalmers, J. A. 1991: New evidence on the structure of the Labrador Sea/Greenland continental margin. *J. geol. Soc. Lond.* **148**, 899–908.
- Chalmers, J. A. & Pulvertaft, T. C. R. in press: The southern West Greenland continental shelf – was petroleum exploration abandoned prematurely?. In Vorren, T. O. (ed.) *Arctic geology and petroleum potential*, . Amsterdam: Elsevier for Norwegian Petroleum Society.
- Christiansen, F. G. & Pulvertaft, T. C. R. 1992: Petroleum-geological activities in 1991: reassessment of areas of earlier exploration, and improvement of information service to industry. *Rapp. Grønlands geol. Unders.* **155** (this report).
- Croxton, C. A. 1976: Sampling of measured sections for palynological and other investigations between 69° and 72°N, central West Greenland. *Rapp. Grønlands geol. Unders.* **80**, 36–39.
- Hansen, J. M. 1976: Microplankton and sedimentological studies in the Nûgssuaq and Disko region, central West Greenland. *Rapp. Grønlands geol. Unders.* **80**, 39–42.
- Henderson, G., Rosenkrantz, A. & Schiener, E. J. 1976: Cretaceous–Tertiary sedimentary rocks of West Greenland. In Escher, A. & Watt, W. S. (ed.) *Geology of Greenland*, 341–362. Copenhagen: Geol. Surv. Greenland.
- Henderson, G., Schiener, E. J., Risum, J. B., Croxton, C. A. & Andersen, B. B. 1981: The West Greenland basin. In Kerr, J. W., Fergusson, A. J. & Machan, L. C. (ed.) *Geology of the North Atlantic borderlands. Mem. Can. Soc. Petrol. Geol.* **7**, 399–428.
- Midtgaard, H. H. 1991: Vertikal og regional faciesfordeling i deltacykler fra Atane Formationen, Øvre Kridt, Vestgrønland – et tidsmæssigt perspektiv. Unpubl. thesis, University of Copenhagen, 88 pp.
- Oil & Gas Journal, 1991: Greenland to gather more exploration data. *Oil & Gas J.* **89**(4), 105–108.
- Olsen, T. 1991: Fluviale distributariekanaler fra Atane Formationen, Øvre Kridt, Pautût, Vestgrønland. Sandlegeme geometri og kanal morfologi. Unpubl. thesis, University of Copenhagen, 108 pp.
- Olsen, T. & Pedersen, G. K. 1991: The occurrence of marine fossils in the Upper Cretaceous deltaic sediments of Pautût, central West Greenland. *Bull. geol. Soc. Denmark* **39**, 111–122.
- Ottesen, T. G. 1991a: A preliminary seismic stratigraphic study of the Paleocene–Eocene section offshore southern West Greenland between 66° and 68°N. *Open File Ser. Grønlands geol. Unders.* **90/1**, 46 pp.
- Ottesen, T. G. 1991b: A preliminary seismic study of part of the pre-Paleocene section offshore southern West Greenland between 66° and 68°N. *Open File Ser. Grønlands geol. Unders.* **91/6**, 28 pp.
- Pedersen, G. K. 1989a: A fluvial-dominated lacustrine delta in a volcanic province, W Greenland. In Whateley, M. K. G. & Pickering, K. T. (ed.) *Deltas: sites and traps for fossil fuels. Spec. Publ. geol. Soc. Lond.* **41**, 139–146.
- Pedersen, G. K. 1989b: Delta plain sequences in the Cretaceous of the West Greenland Basin. *Abstract 10th IAS Regional Meeting, Budapest*, 186–187.
- Pedersen, G. K. & Midtgaard, H. 1990: Spatial distribution of delta plain environments, the Atane Formation, West Greenland. *Abstract 13th Int. Sed. Congr., Nottingham*, 414–415.
- Pedersen, G. K. & Pulvertaft, T. C. R. 1992: The non-marine Cretaceous of the West Greenland basin, onshore West Greenland. *Cret. Res.*
- Pulvertaft, T. C. R. 1979: Lower Cretaceous fluvial-deltaic sediments at Kûk, Nûgssuaq, West Greenland. *Bull. geol. Soc. Denmark* **28**, 57–72.
- Pulvertaft, T. C. R. 1987: Status review of the results of stratigraphical and sedimentological investigations in the Cretaceous–Tertiary of West Greenland, and recommendations for new GGU activity in these fields. Unpubl. intern. GGU rep., 18 pp.
- Pulvertaft, T. C. R. 1991: 1990 – a year of change in hydrocarbon-geological activities at the Geological Survey of Greenland. *Rapp. Grønlands geol. Unders.* **152**, 11–13.
- Pulvertaft, T. C. R. & Chalmers, J. A. 1990: Are there Late Cretaceous unconformities in the onshore outcrops of the West Greenland basin?. *Rapp. Grønlands geol. Unders.* **148**, 75–82.
- Schiener, E. J. 1976: West Greenland coal deposits: distribution and petrography. *Rapp. Grønlands geol. Unders.* **77**, 21 pp.
- Schiener, E. J. & Leythaeuser, D. 1978: Petroleum potential off W. Greenland. *Oil & Gas J.* **76**(40), 223–234.
- F. G. C., G. D., H. N.-H. & M. S., *Geological Survey of Greenland, Copenhagen.*
- D. J. McI., *Institute of Sedimentary and Petroleum Geology, Geological Survey of Canada, 3303-33rd Street N.W., Calgary, Canada T2L 2A7.*
- G. K. P., *Geological Institute, University of Copenhagen, Øster Voldgade 10, DK-1350 Copenhagen K, Denmark*