Henriksen, N. & Jepsen, H. F. 1985: Precambrian crystalline basement at the head of Victoria Fjord, North Greenland. *Rapp. Grønlands geol. Unders.* **126,** 11–16.

Higgins, A. K., Friderichsen, J. D. & Soper, N. J. 1981: The North Greenland fold belt between central Johannes V. Jensen Land and eastern Nansen Land. *Rapp. Grønlands geol. Unders.* **106,** 35–45.

Hurst, J. M. 1980: Silurian stratigraphy and facies distribution in Washington Land and western Hall Land, North Greenland. *Bull. Grønlands geol. Unders.* **138,** 95 pp.

Jakobsen, U. H. & Steenfelt, A. 1985: Zinc mineralisation at Navarana Fjord, central North Greenland. *Rapp. Grønlands geol. Unders.* **126,** 105–109.

Larsen, P.-H. & Escher, J. C. 1985: The Silurian turbidite sequence of the Peary Land Group between Newman Bugt and Victoria Fjord, western North Greenland. *Rapp. Grønlands geol. Unders.* **126,** 47–67.

Peel, J. S. & Wright, S. C. 1985: Cambrian platform stratigraphy in the Warming Land – Freuchen Land region, North Greenland. *Rapp. Grønlands geol. Unders.* **126,** 17–24.

Soper, N. J. & Higgins, A. K. 1985: Thin-skinned structures at the basin-shelf transition in North Greenland. *Rapp. Grønlands geol. Unders.* **126,** 87–94.

Steenfelt, A. 1985: Reconnaissance scale geochemical survey in central and western North Greenland. Preliminary results concerning zinc and barium. *Rapp. Grønlands geol. Unders.* **126,** 95–104.

Source rock investigations and shallow core drilling in central and western North Greenland – project 'Nordolie'

F. G. Christiansen, O. Nykjær and H. Nøhr-Hansen

The aim of project 'Nordolie' (Christiansen & Rolle, 1985) is to study the distribution and maturity of potential hydrocarbon source rocks in central and western North Greenland.

A first broad reconnaissance and examination of most lithostratigraphic units throughout the region in 1984, followed by organic geochemical and palynofacies analyses, showed that some intervals in the Cambrian shelf sequence and in the Cambrian to Silurian trough sequence are sufficiently rich in organic matter to be considered as potential source rocks (Christiansen *et al.*, 1985). The Cambrian and Ordovician trough sequence is thermally postmature with respect to hydrocarbon generation in the whole area. Consequently the second and final field programme within the project (1985) concentrated on the Cambrian shelf sequence (especially the Henson Gletscher Formation in the Brønlund Fjord Group) and the Silurian slope to trough sequence (Lafayette Bugt Formation and Wulff Land Formation).

The main purpose of the 1985 work was to make a detailed study of these units combining field work and shallow core drilling. The samples and cores provide the basis for later detailed maturity studies and a quantitative evaluation of source rock quality and volume. As in 1984, the 1985 field season was fully integrated with the geological mapping programme in the region (Henriksen, this report).

The field work was carried out by a team of two geologists and a drilling team with three technicians (John Boserup, Anders Clausen, Jørgen Bojesen-Koefoed) and a drill site geologist. The three geologists alternated often in order to obtain continuity in the programme and furthermore six of the total 14 camps were located at the drill sites (fig. 1).

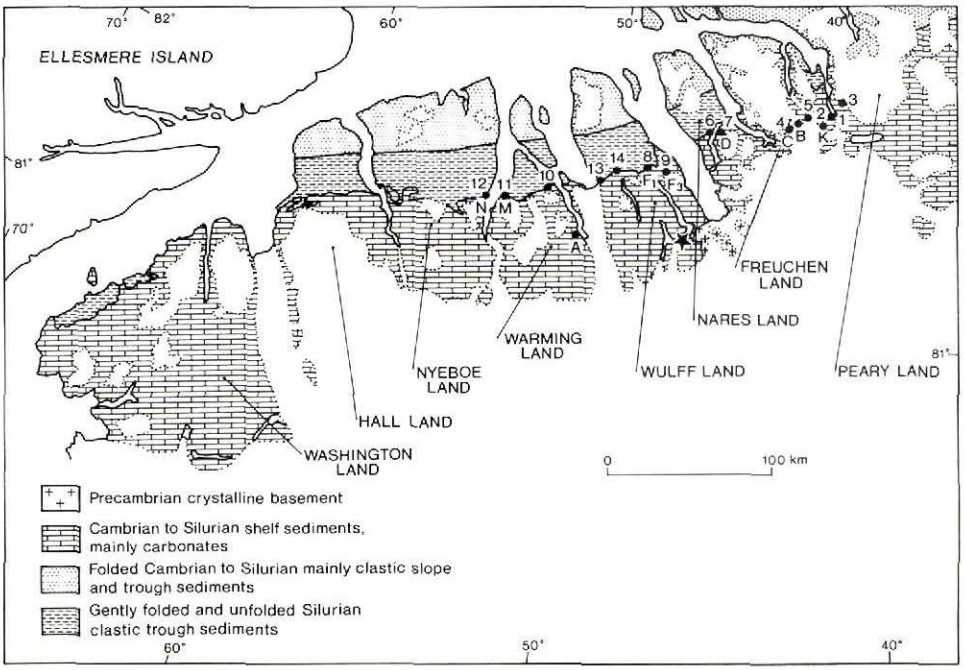

Fig. 1. Camps (numbers) and drill sites (letters) during the 1985 field season. The oil seep is indicated with a star. Based on Dawes (1976).

The drilling programme

The drilling unit (fig. 2) was assembled by J. Boserup and A. Clausen at the Geological Survey of Greenland and had previously been employed in Jameson Land (Surlyk, 1983; Surlyk *et al.*, 1984). With a Bell Jet Ranger helicopter four sling loads and four cabin loads are usually necessary to move the drill and camp equipment plus four persons (total *c.* 2000 kg). Long distance camp moves were often performed by combined Twin Otter – helicopter operations.

Thirteen holes were drilled to various depths, e.g. a maximum 40 m (Tables 1 and 2). Approximately 345 m were drilled and except for the uppermost metres in the active layer or overburden the recovery was almost 100%. All cores are described at the drill site on a scale 1:50 or 1:100 and most holes were logged by gamma ray. These values show good correlation with hand measured gamma ray logs of nearby exposures.

There were some limitations in the choice of drill sites, especially in the Henson Gletscher Formation. Many of the shaly source rocks can only be reached after penetration of thick overburden or cliff-forming beds of dolomite conglomerate. The need for continuous water supply and helicopter landing sites excluded the use of some well-exposed geological sections.

The first hole (A), located a few kilometres north of the base camp, was drilled mainly to test the equipment under the strong permafrost conditions, and the cored Ordovician dolomites are expected to have a very low content of organic matter. The five following holes

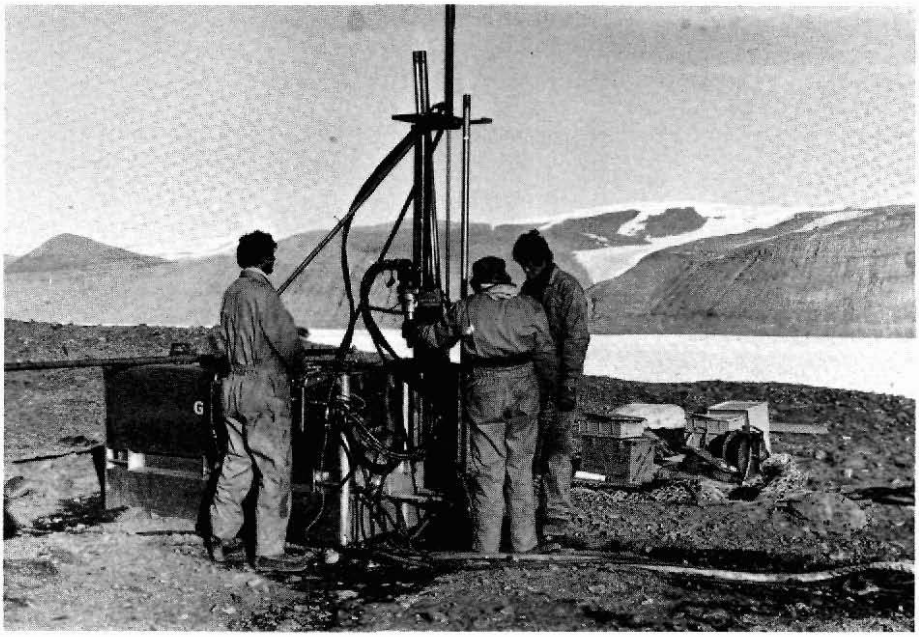

Fig. 2. Drilling on the N1 site.

(K, C1, C2, B1 and B2) at three localities were all drilled in the Cambrian sequence (Table 1). The greenish shale from the Buen Formation at K is not of source rock quality. The four holes in the Henson Gletscher Formation are very interesting. C2 penetrates most of the lower sequence of dolomite and lime mudstone which is considered to be the best Cambrian source rock in the area. C1, B1 and B2 are from the middle and upper part of the formation with bitumen impregnated sandstone and dolomite.

The last seven holes are in slope facies shales outcropping along the Silurian shelf/trough margin (Table 1). D penetrates the lower organic-rich part of the Thors Fjord Member and F2 and N2 are from the most organic-rich part of the Lafayette Bugt Formation. F1 is from interlayered limestone, conglomerate and shale of the Lafayette Bugt Formation where it onlaps the carbonate shelf sequence. F3 and N1 represent the thicker but less organic-rich shales and siltstones of the Wulff Land Formation.

The drilling programme was accomplished as scheduled despite major technical challenges. The main engine seized at the second locality because of a factory defect, and the programme was delayed one week. The strong permafrost created serious problems and many metres of drill rods were lost. Temperature measurements in five of the holes show that the freezing point is reached 20 to 40 minutes after termination of hot water circulation and the temperature stabilizes between −11°C and −14°C within a couple of days (Table 2).

Henson Gletscher Formation

The Henson Gletscher Formation (Ineson & Peel, in press) is exposed in the southern part of Freuchen Land and in the south-eastern part of Peary Land (fig. 1). In addition to the four drill holes in the formation, 16 more or less complete sections have been sampled. The total thickness varies between 40 and more than 150 m and the formation can be divided into

Table 1. Geological description of the different drill sites

Drill site		Region	Lithostratigraphy	Main lithology
A	318001	Warming Land	Steensby Gletscher Fm	Dolomite
K	318002	Freuchen land	Upper Buen Fm	Green shale
C_1^*	318003	Freuchen land	Base Sydpasset Fm Upper Henson Glet. Fm	Dolomite grainstone and conglomerate
C_2^*	318004	Freuchen Land	Lower Henson Glet. Fm Top Aftenstjernesø Fm	Lime and dolomite mudstone
B_1	318005	Freuchen Land	Upper Henson Glet. Fm	Limestone and sandstone
B_2	318006	Freuchen Land	Upper Henson Glet. Fm	Limestone and sandstone
D	318007	Nares Land	Thors Fjord Mb Top Aleqatsiaq Fjord Fm	Black shale
F_1	318008	Wulff Land	Lower Lafayette Bugt Fm Top Aleqatsiaq Fjord Fm	Black limestone and shale
F_2	318009	Wulff Land	Lafayette Bugt Fm	Black shale
F_3	318010	Wulff Land	Wulff Land Fm	Silty shale
M	318011	Warming Land	Undiff. Quaternary (Lafayette Bugt Fm)	Gravel
N_1	318012	Nyeboe Land	Wulff Land Fm	Silty shale
N_2	318013	Nyeboe Land	Lafayette Bugt Fm	Black shale and limestone

three main depositional facies: a lower carbonate sequence, a central clastic sequence, and an upper carbonate sequence. The lower carbonate sequence has good source rock intervals throughout the area whereas the upper carbonates are only occasionally rich in organic matter. The clastic sequence and the upper carbonates are potential reservoirs and migration conduits with a close spatial relation to the source rocks. The common presence of bitumen-impregnated sandstones and bitumen-filled vugs and veins of dolospar in the carbonates (fig. 3) suggests that significant hydrocarbon generation has already occurred, and that most areas might be mature to postmature.

Table 2. Technical details of the drilling at each site

Drill	site	Period	Depth (m)	Drill time	Temp/depth
A	318001	27.6– 1.7	28.70	~12½ h	–
K	318002	1.7– 6.7	19.61	~8½ h	–
C_1^*	318003	6.7–15.7	23.90	~15½ h	–
C_2^*	318004	15.7–18.7	34.80	~15½ h	< – 10°C/10 m
B_1	318005	18.7–21.7	11.78	~10 h	–
B_2	318006	21.7–24.7	12.03	~ 5 h	–
D	318007	24.7–27.7	39.66	~13½ h	–
F_1	318008	27.7–30.7	30.90	~10½ h	– 14°C/29
F_2	318009	30.7– 2.8	39.71	~10½ h	–
F_3	318010	2.8– 7.8	30.38	~13 h	– 11°C/15
M	318011	7.8– 9.8	5.71	~ 7 h	–
N_1	318012	9.8–13.8	28.87	~14 h	– 14°C/12
N_2	318013	13.8–17.8	40.02	~13 h	– 13°C/20

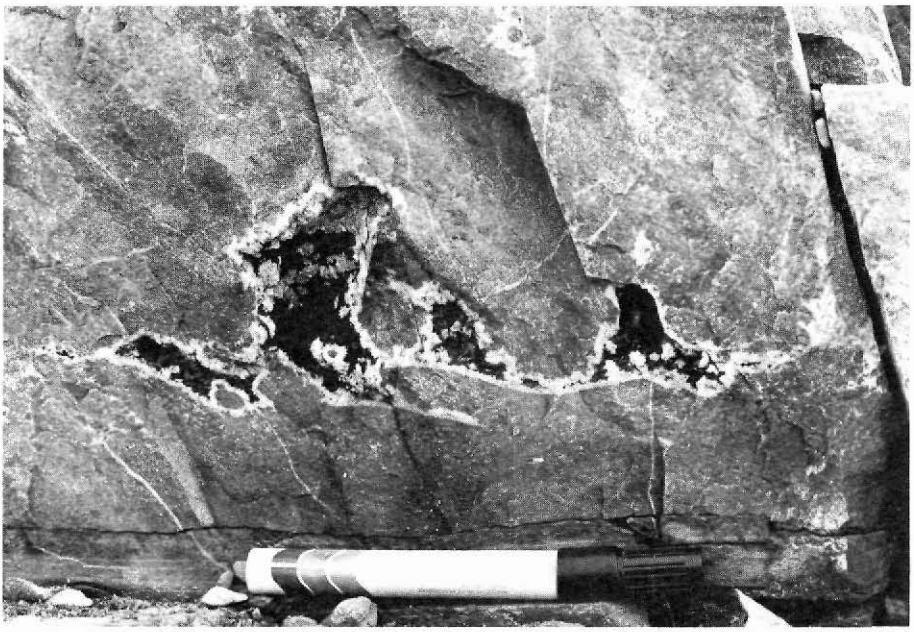

Fig. 3. Bitumen filled dolospar vugs and veins in a dolomite grainstone at the C1 drillsite.

Lafayette Bugt Formation and Wulff Land Formation

The Lafayette Bugt Formation and the Wulff Land Formation (Hurst & Surlyk, 1982) which outcrop along the Silurian shelf/trough margin, have been examined from Hall Land in the south-west to Freuchen Land in the north-east. Organic-rich shale and lime mudstone are common in this zone but both the facies development and the thickness are highly variable. In addition to the seven drill holes through these slope shales, more than 20 sections have been studied in detail. The organic rich shales have been traced and sampled with a close spacing in a longitudinal profile along the margin in order to refine the maturity study presented by Christiansen *et al.* (1985).

In many places in the region there is evidence of hydrocarbon generation in the sequence. Impressive bitumen fillings have been observed in calcirudite (coral fragments) and in corals in shaly debris flow in Wulff Land, Warming Land and Nyeboe Land. Black coatings and fracture fillings of presumed bituminous origin are common in many calcarenites and calcirudites.

Seep in Portfjeld Formation breccia

The impressive seep (fig. 4), discovered earlier this summer by H. F. Jepsen and J. B. Jørgensen, was visited late in the season. Bitumen-impregnated sandstone and dolomite from the Buen Formation and the Ryder Gletscher Group have previously been mentioned in southern Wulff and Warming Land (Christiansen *et al.*, 1985) but no potential source rock is known to occur horizontally closer than 50 km away.

Fig. 4. Seepage of asphaltic material from veins and cracks in dolomite. See fig. 1 for location.

The tar or asphaltic material in the seep shows evidence of flow, supposedly on hot summer days. It is related to cracks and veins of dolospar in a large algal laminated dolomite block in the Portfjeld breccia, which is situated less than 100 m above the contact to the basement gneisses.

The occurrence of the seep can be interpreted either as staining from a large scale migration to a now eroded reservoir, as tar along the margin of a postmature basin, or alternatively as evidence of oil trapped stratigraphically by a tar seal (Moore, 1984).

Preliminary geochemical analysis with gas chromatography and mass spectrometry (P. Østfeldt, personal communication, 1985) shows that the material is strongly degraded by evaporation and bacterial activity. There is, however, no evidence of thermal alteration.

Laboratory studies

The main objective of the planned laboratory programme is to obtain data for detailed modelling of both the present and the past generation potential of the Cambrian and the Silurian source rock sequences. The preliminary maturity variation given by Christiansen *et al.* (1985) will be refined by closer spacing of analysed samples and by more sophisticated methods (gas chromatography, mass spectrometry, isotopic composition). Quantitative aspects of hydrocarbon generation will be studied using unweathered and statistically representative material from the cores. Priority will also be given to a study of the bitumen and asphaltic material. The types of bitumen which occur close to known source rocks and the widespread bitumen staining or seepage in the southern part of the region will be compared.

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References

Christiansen, F. G., Nøhr-Hansen, H., Rolle, F. & Wrang, P. 1985: Preliminary analysis of the hydrocarbon source rock potential of central and western North Greenland. *Rapp. Grønlands geol. Unders.* **126,** 109–120.

Christiansen, F. G. & Rolle, F. 1985: Project 'Nordolie': hydrocarbon source rock investigations in central North Greenland. *Rapp. Grønlands geol. Unders.* **125,** 17–21.

Dawes, P. R. 1976: Precambrian to Tertiary of northern Greenland. *In* Escher, A. & Watt, W. S. (edit.) *Geology of Greenland,* 248–303. Copenhagen: Geol. Surv. Greenland.

Hurst, J. M. & Surlyk, F. 1982: Stratigraphy of the Silurian turbidite sequence of North Greenland. *Bull. Grønlands geol. Unders.* **145,** 121 pp.

Ineson, J. R. & Peel, J. S. in press: Cambrian shelf stratigraphy of the Peary Land region, central North Greenland. *Bull. Grønlands geol. Unders.*

Moore, L. V. 1984: Significance, classification of asphaltic material in petroleum exploration. *Oil Gas J.* **82**(41), 109–112.

Surlyk, F. 1983: Source rock sampling, stratigraphical and sedimentological studies in the Upper Palaeozoic of the Jameson Land basin, East Greenland. *Rapp. Grønlands geol. Unders.* **115,** 88–93.

Surlyk, F., Hurst, J. M., Marcussen, C., Piasecki, S., Rolle, F., Scholle, P. A., Stemmerik, L. & Thomsen, E. 1984: Oil geological studies in the Jameson Land basin, East Greenland. *Rapp. Grønlands geol. Unders.* **120,** 85–90

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