DANMARKS OG GRØNLANDS GEOLOGISKE UNDERSØGELSE RAPPORT 2010/5

Rødryggen-1 core Well, GGU 517101, Wollaston Forland, North-East Greenland: Completion Report

Henrik Vosgerau, Jørgen Bojesen-Koefoed, John Boserup

GEOLOGICAL SURVEY OF DENMARK AND GREENLAND
MINISTRY OF ENVIRONMENT AND ENERGY

GEUS

DANMARKS OG GRØNLANDS GEOLOGISKE UNDERSØGELSE RAPPORT 2010/5

Rødryggen-1 core Well, GGU 517101, Wollaston Forland, North-East Greenland: Completion Report

Henrik Vosgerau, Jørgen Bojesen-Koefoed, John Boserup

Confidential report

Copy No.

Released 01-07-2025

GEOLOGICAL SURVEY OF DENMARK AND GREENLAND
MINISTRY OF CLIMATE END ENERGY

GEUS

1. General information

1.1 Borehole data

Country	Greenland / Denmark
Borehole number	GGU 517101
Borehole name	Rødryggen-1
Area	North-East Greenland, Wollaston Forland
Operator	GEUS
Drilling operator	GEUS

Borehole Location	
Altitude:	110 m above mean sea level.
Coordinates WGS 84:	Latitude: 74°32.561´ N, Longitude: 19°50.924´ W
UTM Zone:	27W 0401666 N - 7852249 E

Drill rig	Sandvik DE 130
Drilling contractor	GEUS
Casing diameter	64/57 mm
Casing depth	15.8 m
Borehole diameter	56 mm
Core diameter	42 mm
Total depth	234.5 m
Core recovery	99%
Status	Abandoned open hole, top of casing closed with a steel cap.

Logistic history:

Drilling crew arriving in East Greenland, Daneborg	July 24th 2009
Transportation of rig and crew to drillsite at Rødryggen	July 27th – July 29th 2009
Establishment of field camp and drilling rig	July 27th - August 2th 2009
Spud	August 3th 2009
Drilling completed	August 14th 2009
Drill rig back at Constable Pynt	August 16th 2009
Effective drilling	11 days
Total days on drill location	22 days

1.2 Borehole summary

Rødryggen-1, GGU 517101, was drilled during the summer of 2009 in northern Wollaston Forland approximately 30 km northeast of the Daneborg military station. Rødryggen-1 is the second corehole in an onshore drilling program in East and North-East Greenland that started in 2008 with the drilling of the Blokelv corehole in central Jameson Land. The drilling program is part of collaboration between GEUS and a number of oil companies regarding Petroleum Geological Studies, Services and Data in East and North-East Greenland. Fieldwork and drilling was financed by GEUS. Subsequent analytical analytical work is financed by sponsoring companies. A more detailed description together with all analytical results will be delivered to sponsoring companies in the end of 2010.

The primary objective was to core the Upper Jurassic Bernbjerg Formation of the Hall Bredning Group to obtain fresh unweathered and continuous samples for investigations of source rock potential and detailed stratigraphic extent on this mudstone succession.

The Rødryggen-1 borehole was spudded on August 3th 2008 and completed on August 14th 2009 at a total depth of 234.5 m. The core recovery was 99%. The core diameter is 42 mm and cores are stored in 36 core boxes of c. 25 kg each, with a total weight of c. 880 kg. The borehole was abandoned open hole with casing down to 15.8 m. The casing is cemented and closed at the top.

Logging in the field included a total gamma log from terrain surface and down to 213 m. This was later supplemented with a total gamma log and a density log from 193 – 234.5 m measured in the core-lab at GEUS.

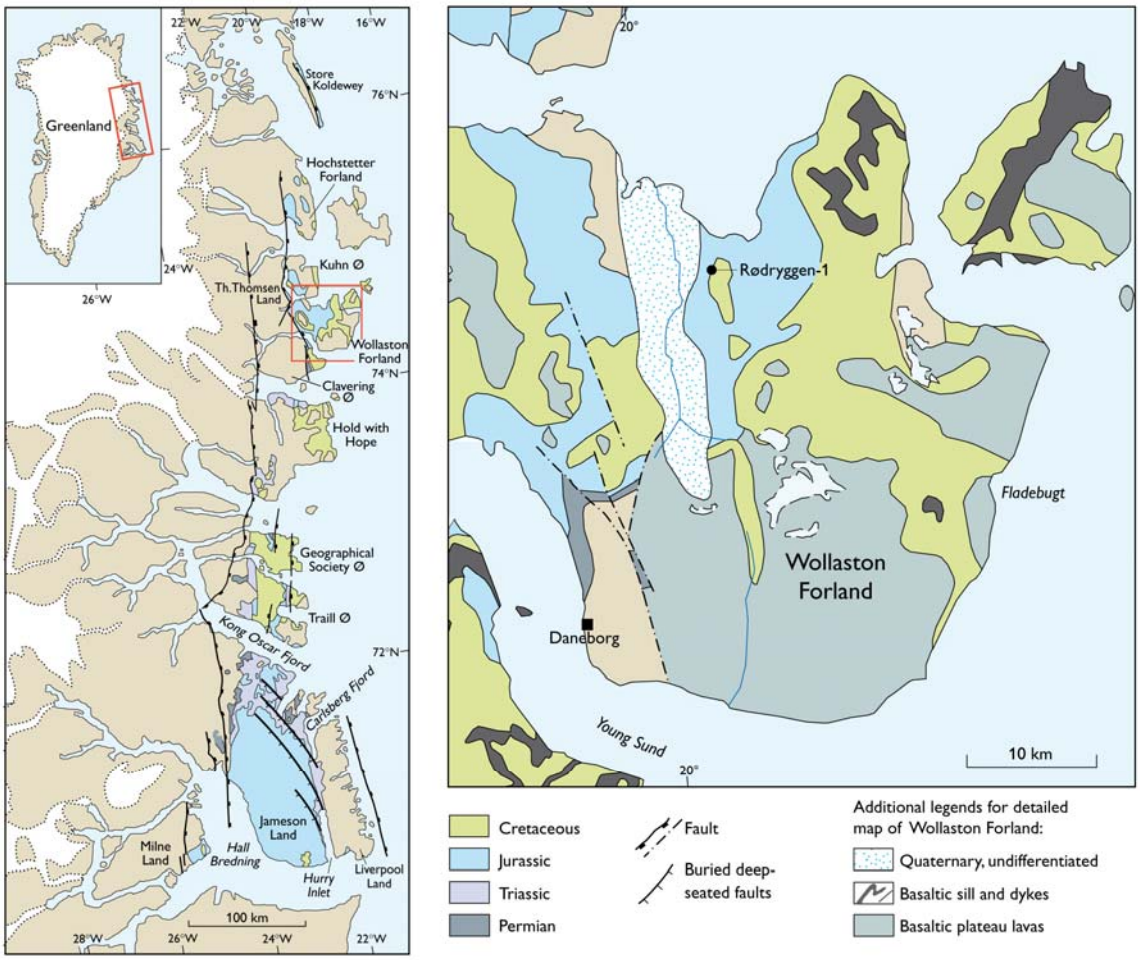

Figure 1.1. Map of East Greenland showing the Permian–Cretaceous outcrops and major faults. The detailed map of Wollaston Forland, with the location of the Rødryggen-1 bore-hole marked, also includes Quaternary deposits and basaltic sills, dykes and plateau lava outcrops. Map of East Greenland based on Surlyk (2003).

2. Drilling operation:

The drilling camp personal:

Senior Researcher Henrik Vosgerau, GEUS
Senior technician John Boserup, GEUS
Catering (Laboratory technician) Annette Ryge, GEUS
Driller Peter Turner, Turner Drilling
Driller assistant Andreas Frandsen, student

Logistics were handled by POLOG
Helicopter from Air Greenland was chartered for a full field season.

Drilling was carried out by a Sandvik DW 130 wire line rig, with an inner and outer casing diameter of 57 mm and 64 mm, respectively. Core barrels are 1.5 and 3 m long. The bore-hole diameter is 56 mm, whereas the core diameter is 42 mm.
The drill rig equipment was shipped by boat from Denmark to Iceland. From Iceland it was flown with a Dash 8 to Constable Pynt in Greenland and from there with Twin Otter plane to Daneborg at Wollaston Foreland, the headquarters of the Sirius dogsledge Patrol. The former weather station at Daneborg acted as GEUS main base for the logistic coordination of the drilling team and the field team's operating in the region. From Daneborg the drill rig parts were brought to the Rødryggen drill site (Figs. 2.1, 2.2) with helicopter slings, a distance of c. 30 km. The helicopter was a Eurocopter AS-350 which has a max sling load of 1.3–1.4 tons.

Mobilisation of the drill rig and camp took 7 days and the effective drilling took 11 days (Fig. 2.3, Appendix A). The mobilisation and drilling operation was delayed considerably due to bad weather conditions. Casing was drilled to 15.8 m. Demobilisation and down-hole logging took 5 days.

Water for drilling was supplied from the nearest river at about 250 m lateral distance and 50 m vertical distance by a diesel-driven water pump through inflatable hoses into a 5000 l basin. Permafrost was present from a few decimetres below terrain surface and down to about 100 m.

Figure 2.1. The drill camp at Rødryggen, Wollaston Forland.

Figure 2.2. Assembling the drilling rig.

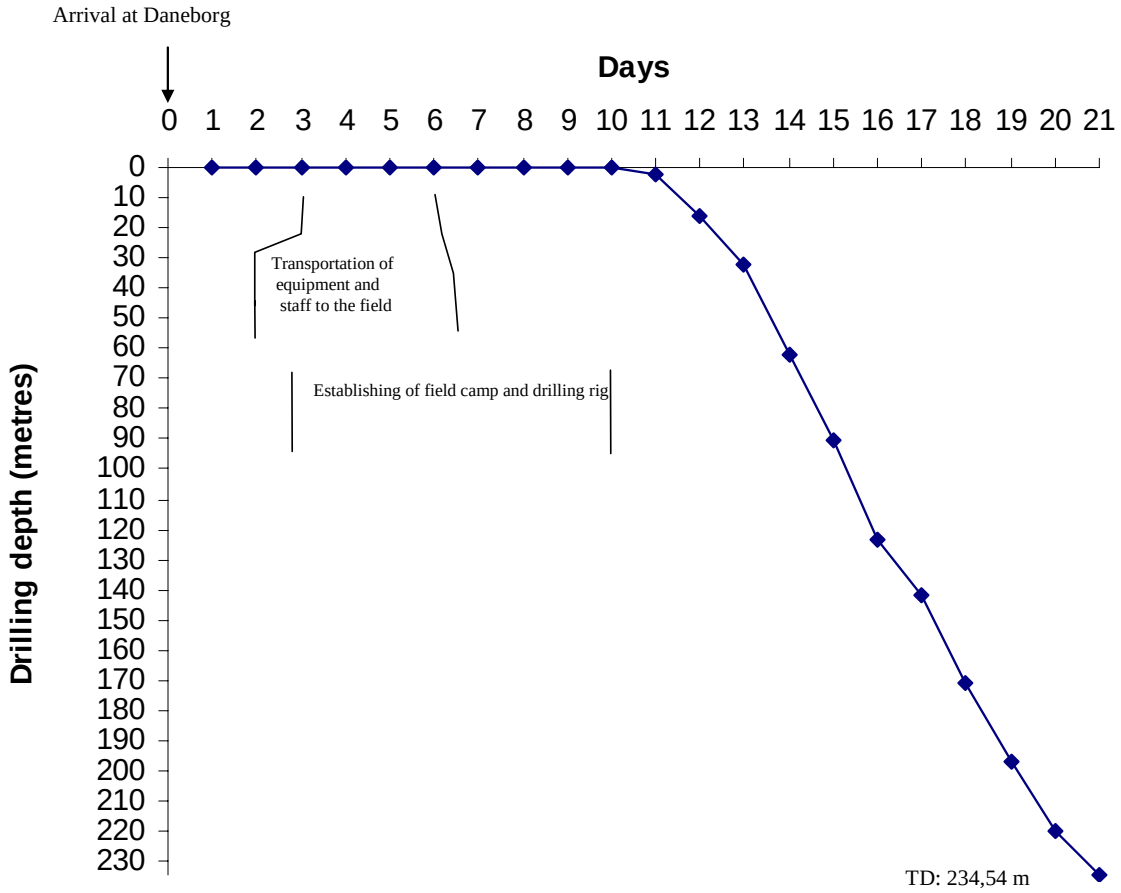

Figure 2.3. Progress chart; obtained drilling depth after the arrival at Daneborg (day 0) and until TD (day 21). The first three days at Daneborg went with making the old weather station inhabitable as well as preparing the drilling equipment. Note that subsequent time for down-hole logging and demobilisation is not included in the figure (see appendix A).

3. Geological and geophysical data

The Rødryggen-1 borehole is located on the western side of Rødryggen ("red ridge") which is an elongated hill or ridge conspicuously situated at the eastern margin of Storsletten, Wollaston Forland. Rødryggen consists of dark mudstones of the Upper Jurassic–Lower Cretaceous Bernbjerg Formation overlain by light grey or yellowish mudstones of the Lower Cretaceous Albrecht Bugt Member followed by red mudstones of the Lower Cretaceous Rødryggen Member which in turn is overlain by the "Mid Cretaceous sandy shale sequence" *sensu* Nøhr-Hansen (1993). The drill camp was situated at a small plateau formed by the uppermost part of the Albrecht Bugt Member (Fig. 3.1).

3.1 Objectives

The target of the drilling was the Upper Jurassic Bernbjerg Formation. The thickness of the formation is unknown at the drill site and nowhere is the formation exposed in its full original thickness, which is estimated to have been approximately 600 m (Maync 1947, Surlyk 1977). The purpose of the drilling was to acquire fresh unweathered and continuous samples for investigations of the source rock potential of the mudstones by applying modern source rock analysis and to obtain samples for detailed stratigraphic information on the mudstones.

3.2 Results

The Rødryggen-1 core recovered bioturbated, greyish mudstones of the Albrecht Bugt Member from 0–24.4 m and dark grey to black mudstones with rare, very fine-grained sandstone beds of the Bernbjerg Formation from 24.4 – 234.5 m (TD) (Figs. 3.2, 3.3). The base of the Bernbjerg Formation was not reached.

3.3 Coring

Conventional coring was performed from terrain surface to TD at 234.5 m. The core recovery was 99% with a very high quality of core material.

3.4 Sampling programme on drill site

A total of 70 whole core samples for gas analyses were collected immediately from the base of the recovered core for every 3 m in average. Samples have lengths up to about 10 cm and they were stored in sealed metal cans.

Samples, collected for preliminary Rock-Eval/TOC screening and biostratigraphic age identification based on dinoflagellates, include mudstone samples from the upper and lower part of the cored Albrect Bugt Member at 1.1 m (517101-1) and 24.1 m (517101-3), respectively; and mudstone samples from the uppermost and lowermost part of the cored Bernbjerg Formation at 25.0 m (517101-5), 27.0 m (517101-7) and 234.4 m (517101-75), respectively.

A sample of possible bitumen stained calcite crystals within a fracture was collected at 187.5 m (517101-60).

One surface sample of weathered mudstone (Albrecht Bugt Member) was collected at the drill site (0 m drilling / 110 m a.s.l.).

3.5 Logging

Logging of the Rødryggen-1 borehole was initiated immediately after the drilling was completed. A total gamma ray log and conductivity log was planned. However, due to problems with the winch only a total gamma ray log down to 209 m was obtained. After the return of the core to Copenhagen total gamma ray logging supplemented by density logging was carried out in the core-lab at GEUS on the lower part of the core (190 – TD) in order to obtain a complete gamma ray log, representative for the entire drilled succession. The merged gamma ray log and the log measured in the field are shown in Figure 3.4 together with the gamma ray log and density log measured in the core-lab.

The transition from the Bernbjerg Formation to the overlying Albrecht Bugt Member at 24.4 m is clearly seen by a considerably decrease in the gamma ray signal (Fig. 3.4). Peaks of low gamma ray signals in the Bernbjerg Formation correspond to very fine-grained sandstone beds or sandy mudstone intervals, in general less than 0.6 m thick, in the formation. Overall the gamma ray signal increases upwards in the cored Bernbjerg Formation and is particularly high in the top part.

3.6 Biostratigraphy of the cored succession

The Albrecht Bugt Member is exposed in outcrops next to the drill site and these have been intensively sampled for ammonites in previous studies (Alsen 2006). The ammonite data indicate lower Valanginian for the drilled part of the Albrecht Bugt Member.

The Bernbjerg Formation ranges from the Upper Oxfordian to the Lower Volgian on Wollaston Forland, but the upper portions of the formation have everywhere been removed by pre-Valanginian erosion (Surlyk 1977).

The core revealed ammonite fragments at several depths and these will, together with mudstone core samples taken for dinoflagellates analysis, form the basis for a biostratigraphic dating of the core.

3.7 Lithology

The Rødryggen-1 core covers two lithostratigraphic units:

Albrecht Bugt Member (Palnatokes Bjerg Formation) 0–24.4 m.
Lower Cretaceous

MUDSTONE, light grey – grey, laminated, moderate to strongly bioturbated, abundant shell fragments, Buchia bivalves, belemnites, locally pyritized burrows and small fractures, calcareous.

Bernbjerg Formation 24.4 –234.5 m (Total Depth).
Upper Jurassic

Overall homogeneous mudstone succession which locally contains thin beds, laminae or lenses of very fine- or fine-grained sandstone.

MUDSTONE, dark grey – black, in a few places slightly sandy, organic rich, indistinct laminated (but core breaks up along smooth laminae surfaces), locally fragments of ammonites, belemnites and coalified plant material, in places pyritized laminae and possibly *Chondrites* sp. burrows, high-angle fractures are common, in places calcite cemented or with slickensides. Laminae or lenses of very fine or fine-grained sandstone are most common in the lower part of the cored succession where they locally show climbing ripple cross-lamination and form symmetrical ripples organised as bundles. Sandstone beds are scarce and mainly

occur in the lower part of the cored succession. They consist of muddy, very fine-grained sandstones that are greyish in colour and weakly laminated in places. The sandstone beds are less than 0.6 m thick except for a sandstone bed at 175 m which is 1.6 m thick. The contact to under- and overlying mudstone is either sharp or gradational. In a few places the lower boundary is strongly undulating with the underlying mudstone intruding the sandstone. Fractures within sandstone beds are calcite cemented, in some places showing distinct calcite crystal growth into fracture cavities.

3.8 Bitumen

The deep black-colour of ”dogtooth” calcite precipitated along a fracture at a depth of 187.5 m may indicate bitumen-staining (Fig. 3.5). However, no distinct petroliferous odour was detected, and the presence of bitumen has yet to be analytically confirmed.

Five samples for Rock-Eval/TOC screening analysis were collected from the core at the wellsite with the objective of obtaining a first impression of the petroleum source potential of the penetrated mudstone-succession. The results are listed in Table 3.1. The uppermost two samples represent the Cretaceous Albrechts Bugt Member, whereas the lower three samples represent the Upper Jurassic – (?) Lower Cretaceous Bernbjerg Formation (equivalent of the Kimmeridge Clay Formation *sensu lato*).

Based on these preliminary results the Albrechts Bugt Member mudstones are poor in organic carbon and do not possess petroleum source potential. Conversely, the Bernbjerg Formation mudstones are rich in organic carbon and suphur, show high pyrolysis yields and may be classified as rich oilprone petroleum source rocks (Figs. 3.6, 3.7). Moreover, in keeping with the pattern observed in Kimmeridge Formation equivalent deposits elsewhere in the North Atlantic realm, the mudstones seem to show higher Hydrogen Indices (HI) in the upper part of the succession than in the lower part. The petroleum potential of the Bernbjerg Formation mudstones appears much better than expected from earlier analysis of outcrop samples, probably due to the absence of weathering of the core samples. Confirmation of these initial results awaits the outcome of the full analytical programme planned.

Sample	Depth, base (m)	TOC (%)	TC (%)	TS (%)	Tmax (°C)	S1 (mg/g)	S2 (mg/g)	HI	PI	PC
517001-1	1,1	0,05	6,53	1,80	418	0,00		0	0,00	0,00
517001-3	24,1	0,22	1,13	2,26	422	0,01	0,02	9	0,33	0,00
517001-5	25,0	3,43	3,54	4,05	425	0,41	12,97	379	0,03	1,11
517001-7	27,0	4,45	4,30	4,29	423	0,80	19,46	437	0,04	1,68
517001-75	234,4	6,53	6,59	2,76	431	1,44	15,76	241	0,08	1,43

Table 3.1. Rock-Eval/TOC screening data. Shaded: Albrechts Bugt Member samples, unshaded: Bernbjerg Formation samples

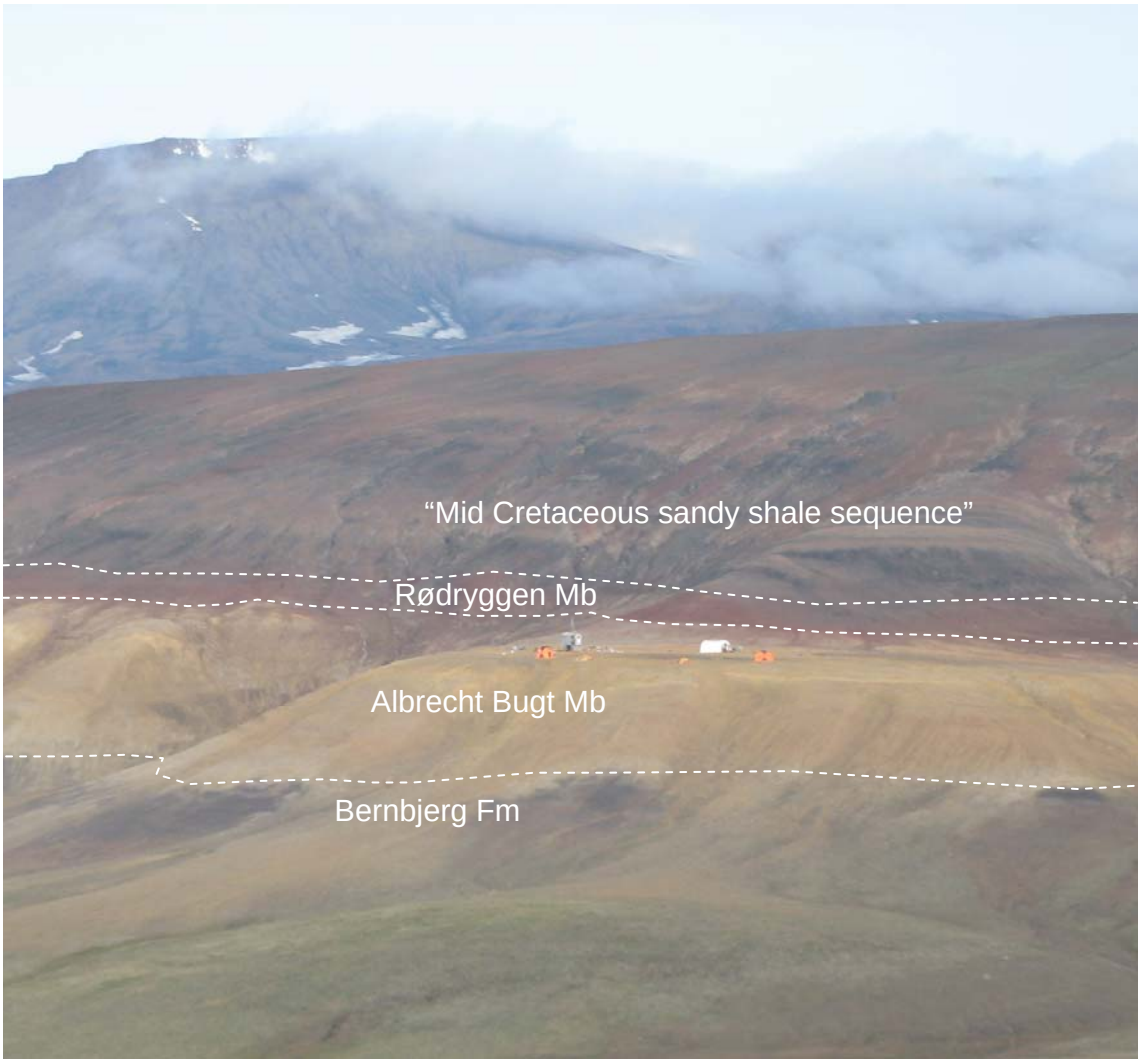

Figure 3.1. Lithostratigraphy at the drill site. The target for the drilling was the Upper Jurassic, dark mudstones of the Bernbjerg Formation. The drill camp is situated at a small plateau formed by the uppermost part of the Lower Cretaceous Albrecht Bugt Member. The Albrecht Member is overlain by the Lower Cretaceous Rødryggen Member with its distinct red color in the field followed by the “Mid Cretaceous sandy shale sequence” *sensu* Nøhr-Hansen (1993).

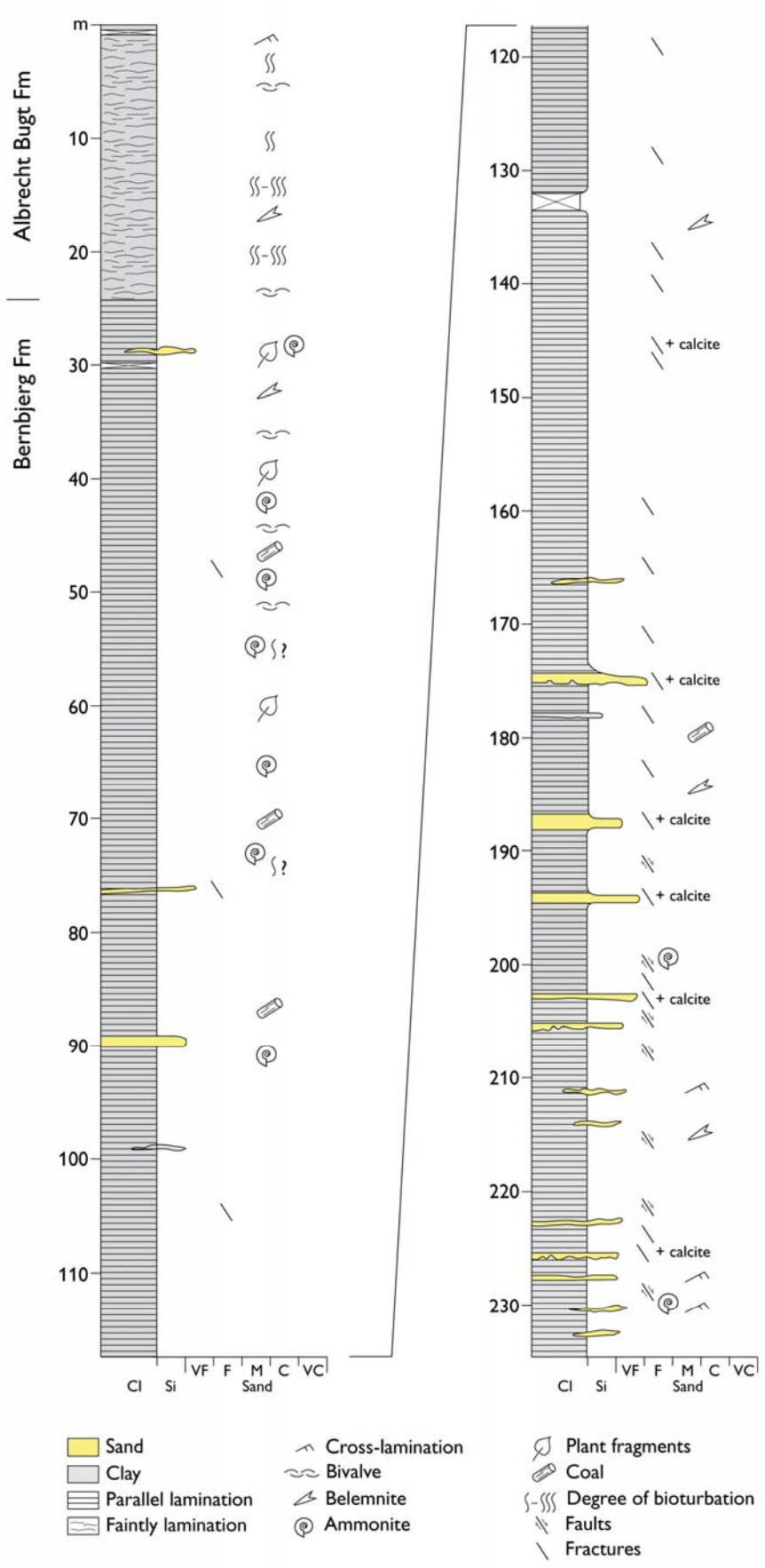

Figure 3.2. Lithological log of the Rødryggen-1 core.

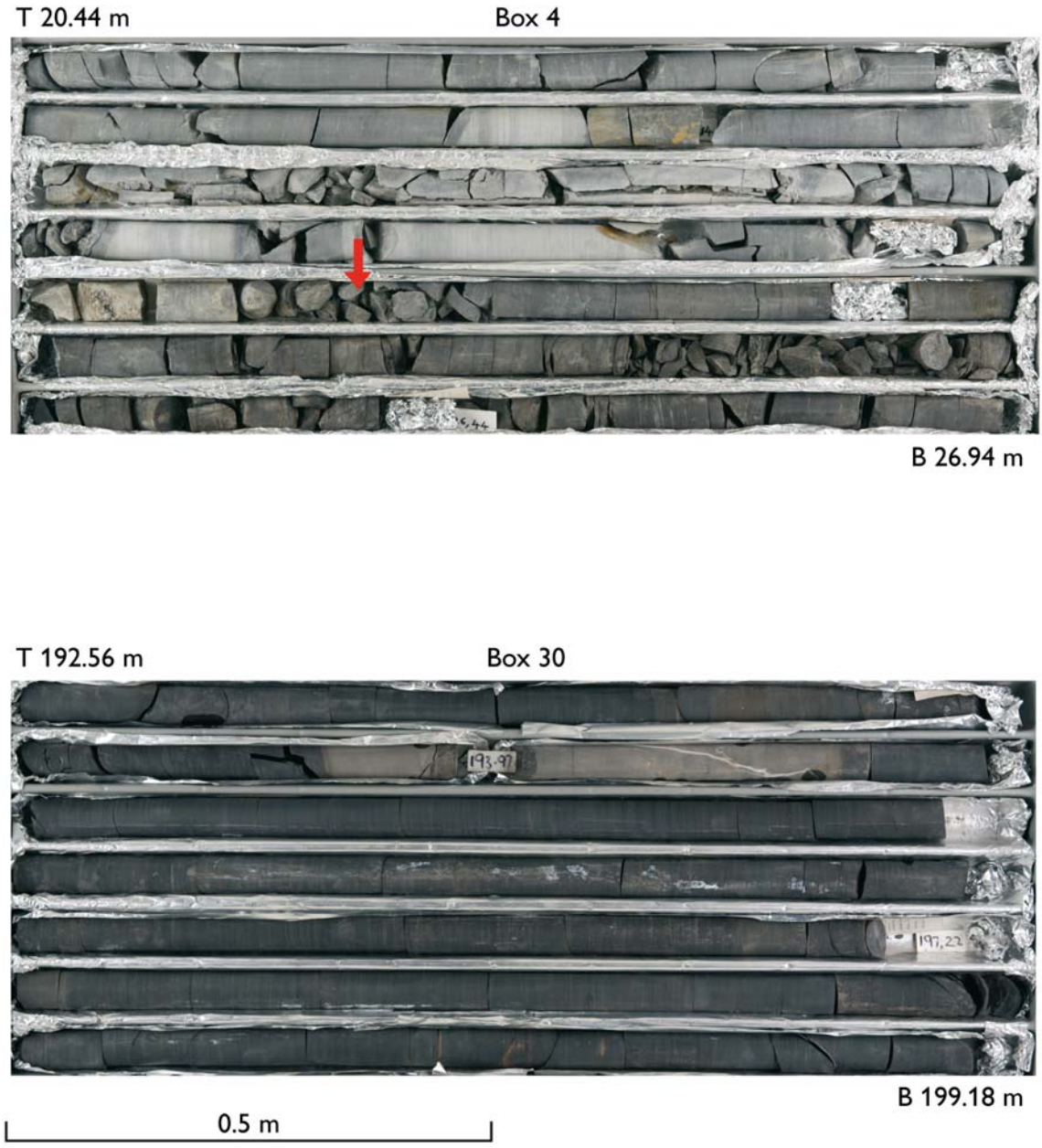

Figure 3.3. Core photographs of boxes 4 and 30. Box 4: Arrow points towards the boundary at 24.4 m between grey mudstones of the Albrecht Bugt Member and underlying dark grey or black mudstones of the Bernbjerg Formation. Box 30: Black organic rich mudstones of the Bernbjerg Formation containing a dark grey, very fine-grained sandstone bed which is c. 0.5 m thick. Note the calcite cemented fracture within the sandstone bed.

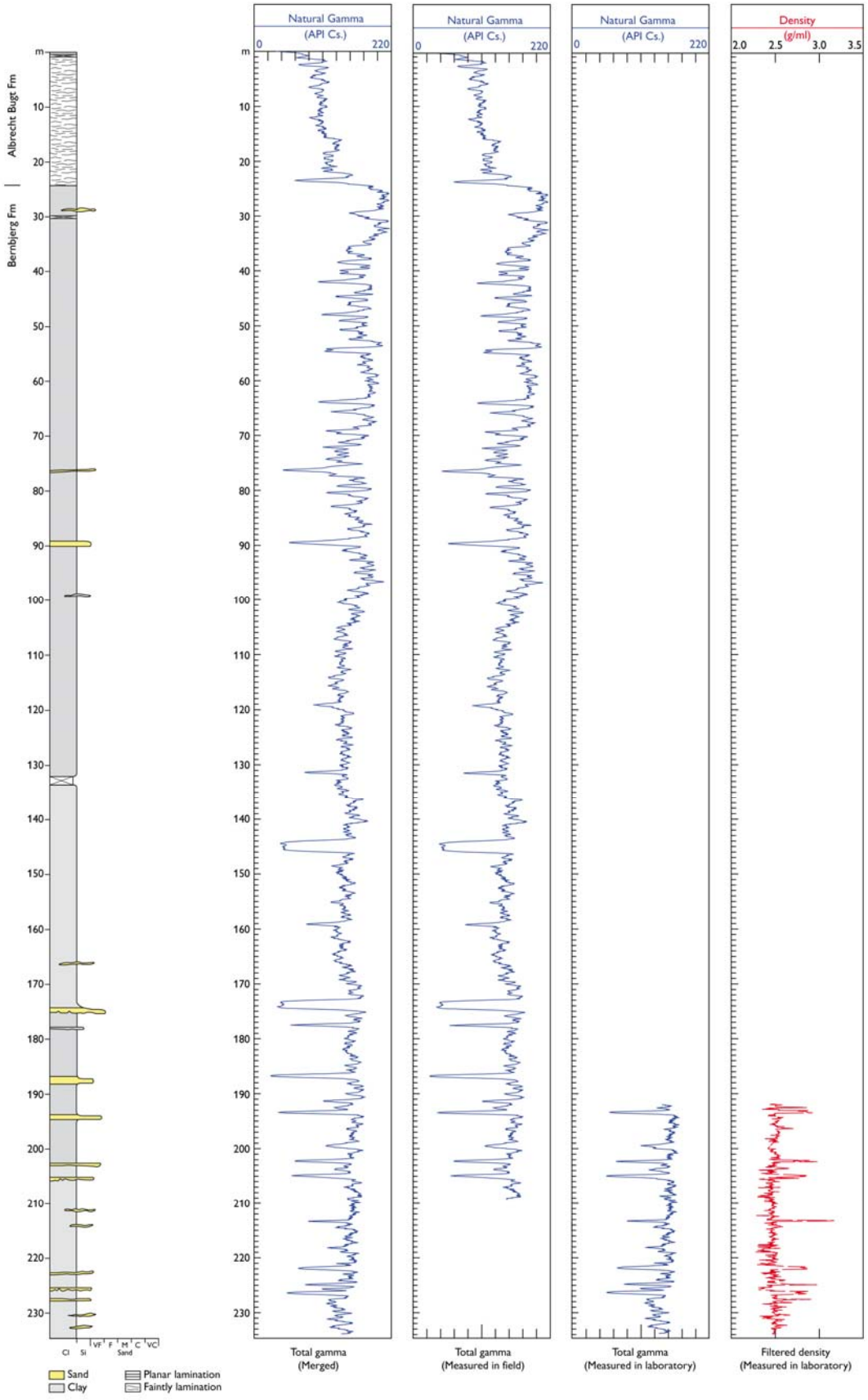

Figure 3.4. Gamma Ray logs (composite, measured in the field and in the laboratory) and density log together with lithology of the Rødryggen-1 well.

Figure 3.5. Possible bitumen stains on the surfaces of calcite crystals within a fracture cavity in a dark grey sandstone bed at 187.5 m.

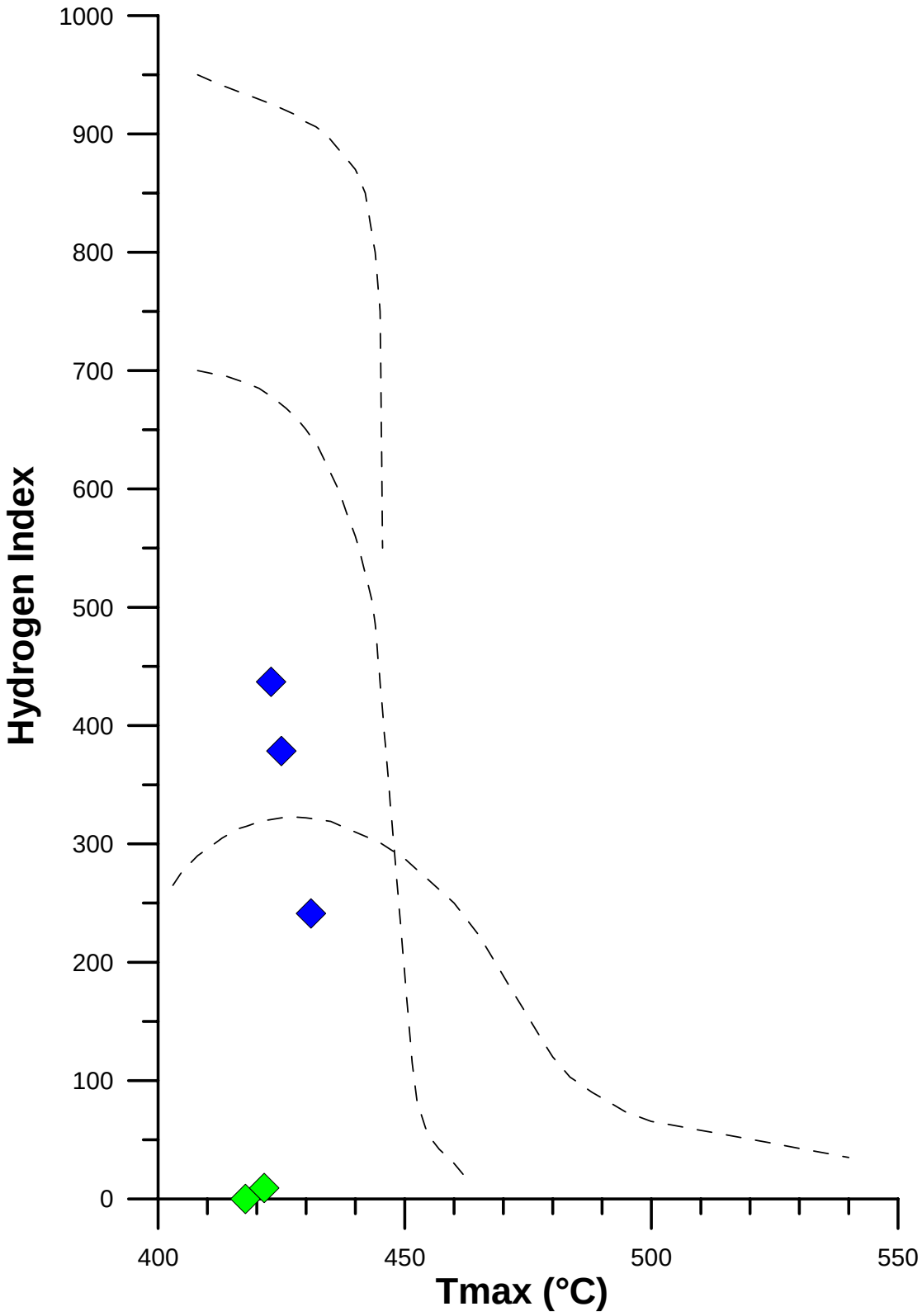

Figure 3.6. Green symbols: Albrechts Bugt Member samples, blue symbols: Bernbjerg Formation samples.

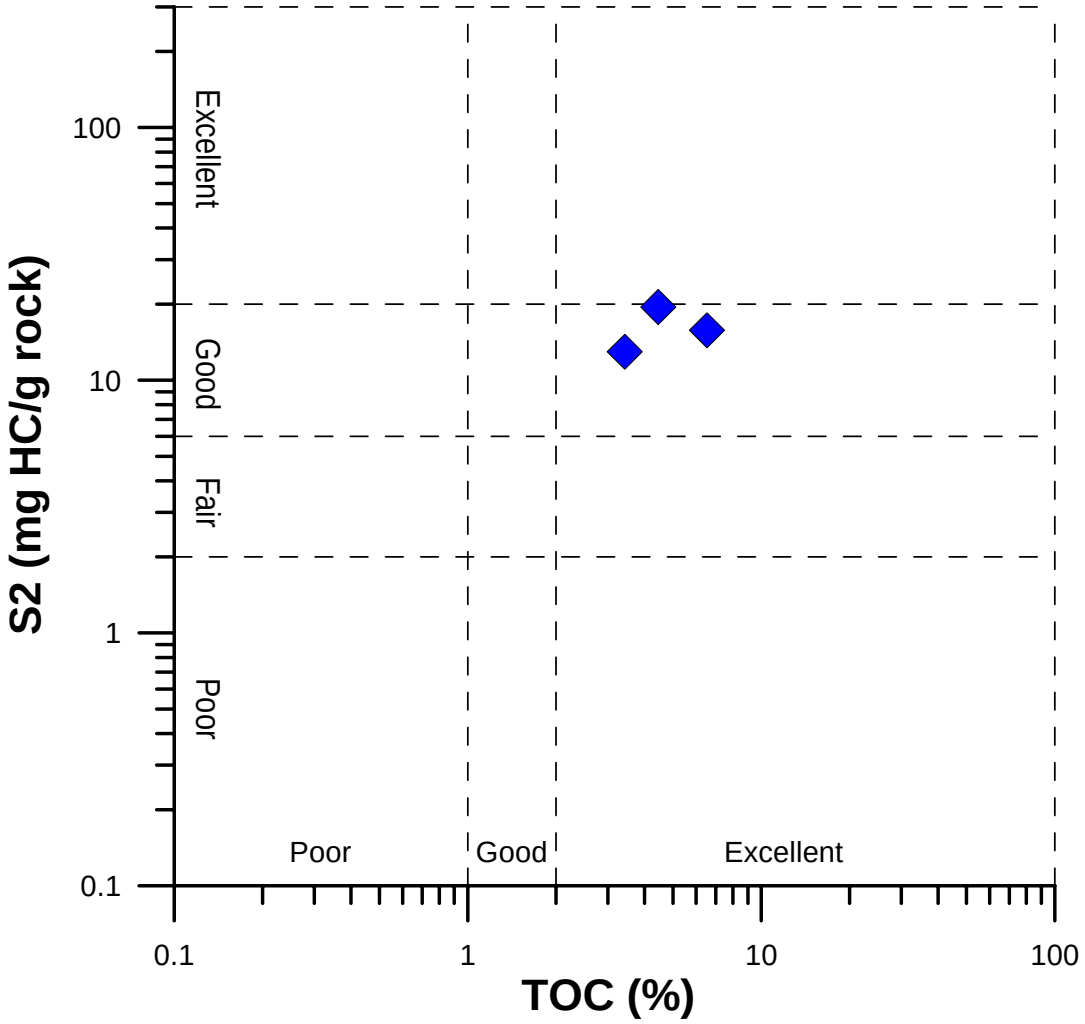

Figure 3.7. Blue symbols: Bernbjerg Formation samples. Albrecths Bugt Member samples show no petroleum potential and fall outside of limits of the plot.

References

Alsen, P. 2006: The Early Cretaceous (Late Ryazanian - Early Hauterivian) ammonite fauna of North-East Greenland: taxonomy, biostratigraphy, and biogeography. Fossils & Strata 53, 229 pp.

Maync, W. 1947: Stratigraphie der Jurabildungen Ostgrönlands zwischen Hochstetter bugten (75˚ N.) und dem Kejser Frantz Josepth Fjord (73˚ N.). Meddelelser om Grønland 132 (2), 223 pp.

Nøhr-Hansen, H. 1993: Dinoflagellate cyst stratigraphy of the Barremian to Albian, Lower Cretaceous, North-East Greenland. Grønlands Geologiske Undersøgelser Bulletin 166, 177 pp.

Surlyk, F. 2003: The Jurassic of East Greenland: a sedimentary record of thermal subsidence, onset and culmination of rifting. Geological Survey of Denmark and Greenland Bulletin 1, 659-722.

Surlyk, F. 1977: Stratigraphy, tectonics and palaeogeography of the Jurassic sediments of the area north of Kong Oscars Fjord, East Greenland. Bulletin Grønlands Geologiske Undersøgelse 123, 56 pp.

APPENDIX

Appendix A: Daily drilling log/report

Appendix B: Rødryggen-1, GGU 517101, Core Box Depths.

Appendix A: Daily drilling report

Date	Cored	Remarks
27/7-2/8 2009		Flying out crew and equipment from Daneborg to Rødryggen drill site. Establishment of drill rig and camp.
3/8-2009	2.3 m	Drilling 0–2.3 m with 77% core recovery.
4/8-2009	13.5 m	Drilling of casing 0–15.8 m. Coring 2.3–15.8 m with 100% core recovery. Cementation of casing with concrete.
5/8-2009	16.2 m	Drilling 15.8-32.0 m with 97% core recovery.
6/8-2009	30.3 m	Drilling 32.0–62.3 m with 100% core recovery.
7/8-2009	28.5 m	Drilling 62.3–90.8 m with 100% core recovery.
8/8-2009	32.9 m	Drilling 90.8–123.7 m with 100% core recovery.
9/8-2009	17.9 m	Drilling 123.7–141.6 m with 92% core recovery.
10/8-2009	29.5 m	Drilling 141.6–171.1 m with 100% core recovery.
11/8-2009	26.1 m	Drilling 171.1–197.2 m with 100% core recovery.
12/8-2009	23.1 m	Drilling 197.2–220.3 m with 100% core recovery. Sling of core barrels and core boxes.
13/8-2009	14.2 m	Drilling 220.3–TD 234.5 m with 99% core recovery.
13/8-17/8 2009		Gamma logging, dismantling drill rig and camp, flying equipment and crew back to Daneborg.

Appendix B: Rødryggen-1, GGU 517101, Core box depths.

Box	Top Depth/m	Bottom Depth/m	Core length in box/m
Box 1	0	7.30	6.34
Box 2	7.30	13.82	6.52
Box 3	13.82	20.44	6.62
Box 4	20.44	26.94	6.50
Box 5	26.94	33.94	6.56
Box 6	33.94	40.56	6.62
Box 7	40.56	46.80	6.24
Box 8	46.80	53.28	6.48
Box 9	53.28	59.81	6.53
Box 10	59.81	66.16	6.35
Box 11	66.16	72.95	6.79
Box 12	72.95	79.68	6.73
Box 13	79.68	86.35	6.67
Box 14	86.35	93.04	6.69
Box 15	93.04	99.69	6.65
Box 16	99.69	105.37	5.68
Box 17	105.37	111.94	5.67
Box 18	111.94	118.73	6.79
Box 19	118.73	125.64	6.91
Box 20	125.64	133.54	6.49
Box 21	133.54	140.20	6.66
Box 22	140.20	146.53	6.33
Box 23	146.53	152.97	6.44
Box 24	152.97	159.62	6.65
Box 25	159.62	166.16	6.54
Box 26	166.16	172.74	6.58
Box 27	172.74	179.26	6.52
Box 28	179.26	185.91	6.65
Box 29	185.91	192.56	6.65
Box 30	192.56	199.18	6.62
Box 31	199.18	205.46	6.28
Box 32	205.46	211.97	6.51
Box 33	211.97	218.59	6.62
Box 34	218.59	225.00	6.41
Box 35	225.00	231.55	6.47
Box 36	231.55	234.54	2.99