DANMARKS OG GRØNLANDS GEOLOGISKE UNDERSØGELSE RAPPORT 2018/4

Well completion report: Ravn Pynt-1 fully cored borehole, Store Koldewey, Northeast Greenland

Contribution to Petroleum Geological Studies Services and Data in East and Northeast Greenland

Gunver K. Pedersen & Jørgen A. Bojesen-Koefoed

GEOLOGICAL SURVEY OF DENMARK AND GREENLAND
MINISTRY OF ENVIRONMENT AND ENERGY

G E U S

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Confidential report

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DANISH MINISTRY OF ENERGY, UTILITIES AND CLIMATE

G E U S

1. General information

1.1 Borehole data

Country	Greenland / Denmark
Borehole number	GGU 517009
Borehole name	Ravn Pynt-1
Area	Northeast Greenland, Ravn Pynt, Store Koldewey
Operator	GEUS
Drilling operator	GEUS

Borehole Location

Altitude:	108 m above mean sea level.
Coordinates WGS 84:	76º 08.455´N, 18º 32.745´W

Drill rig	Sandvik DE 130
Drilling contractor	GEUS
Casing diameter	64/57 mm,
Casing depth	Casing 64/57 mm to 95,5m
Borehole diameter	56 mm
Core diameter	42 mm
Total depth	116.4 m
Core recovery	95%
Status	Abandoned, open hole

Logistic history:

Transportation of rig and crew to drill site at Jurakløft	July 24th–28th 2017
Establishment of field camp and drilling rig	July 27th–30th 2017
Spud, Ravn Pynt-1	July 30th 2017
Drilling completed	August 2nd 2017
Drill rig transported to Daneborg, Wollaston Forland	August 3rd – 4th 2017
Effective drilling	4 days
Total days on drill location	10 days

1.2 Borehole summary

The Ravn Pynt-1, GGU 517009, fully cored borehole was drilled to test the succession of Middle Jurassic sandstones exposed in southern Store Koldewey. The borehole was drilled during the summer of 2017 at Ravn Pynt ("Pynt" = small promontory/cape, "nose"), southern Store Koldewey (Figs 1, 2).

The borehole was drilled by GEUS as part of the ongoing GEUS-industry collaboration "Petroleum Geological Studies, Services and Data in East and Northeast Greenland", however, with participation exclusively by companies holding an exploration license offshore Northeast Greenland. Hence, the borehole was drilled on behalf of a consortium including three groups holding licenses for exploration offshore Northeast Greenland, represented by the operating companies Chevron, and ENI.

The objective was to test the Middle Jurassic sandstone succession exposed in southern Store Koldewey, represented by the Pelion Formation (Surlyk 2003 and references therein), in order to obtain data on the petroleum reservoir properties of this unit, which is expected to be present in the offhore license areas as well.

The Ravn Pynt-1 borehole was spudded on July 30th 2017 and completed on August 2nd 2017 at a total depth of 116.4 m, at which depth drilling had to be suspended since technical problems and the nature of the formation precluded further drilling. The borehole was planned to reach a depth of more than 150 m, which, however, proved impossible to reach. The total core recovery was slightly less than 95%.

The borehole was abandoned as an open hole.

For technical reasons borehole logging in the field was not attempted.

Fig. 1. Overview map of Northeast Greenland. Yellow star: Basecamp in Daneborg. Red star: Drill-site Jurakøft-1, 2 boreholes. Blue star: Drill site Ravn Pynt-1 borehole. Orange triangle: fuel depot at Twinotter strip near Haystack.Red frame: detailed map, Fig. 2.

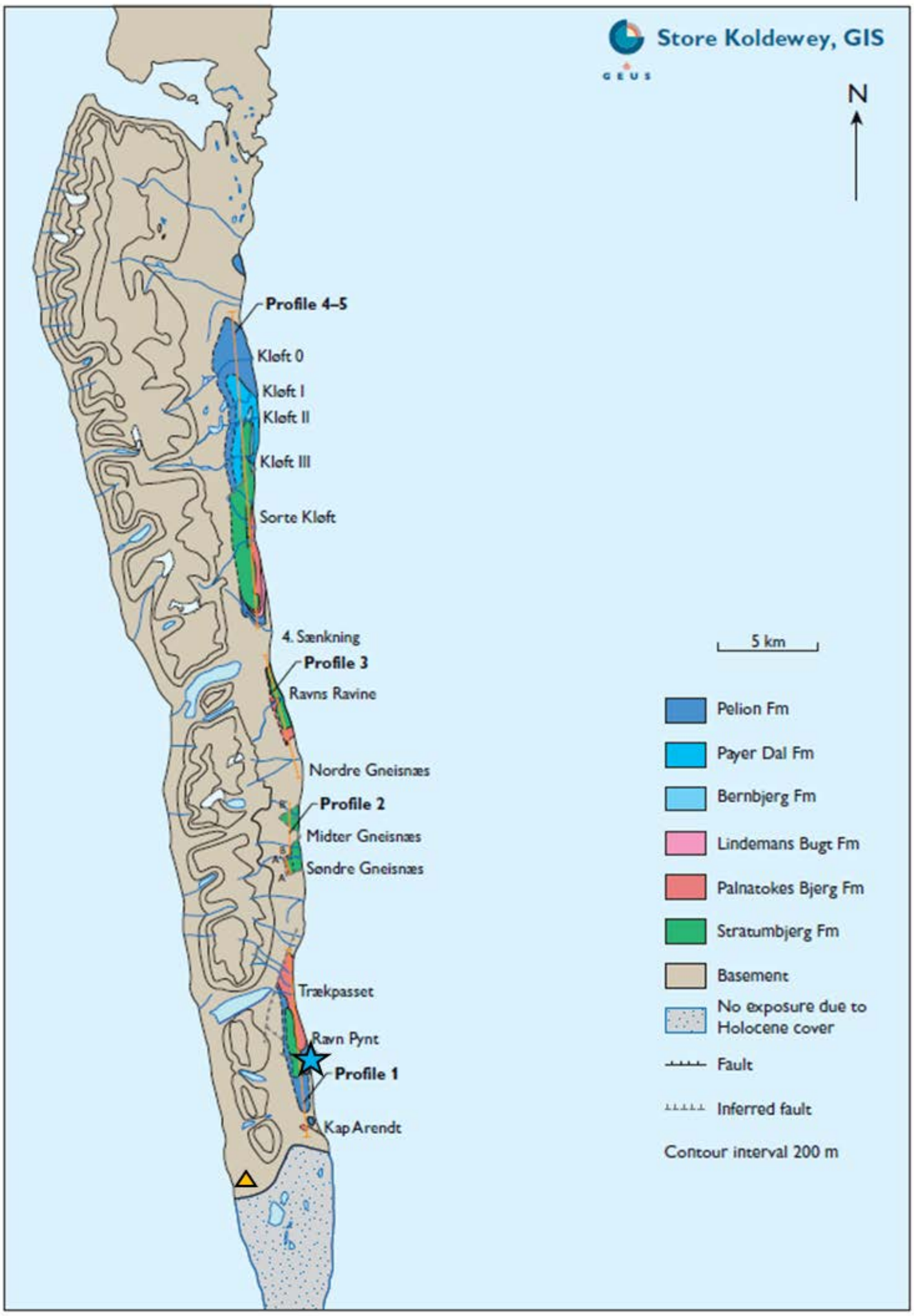

Fig. 2 Geological map of Store Koldewey (from Piasecki et al 2012). Blue star: Drill-site Ravn Pynt-1 borehole. Orange triangle: Twinotter strip used for demobilisation.

2. Drilling operations

Drilling team:

Driller Jan Varup

Driller Tonny Arndt

Driller’s assistant Kathrine Hedegaard

Driller’s assistant Kristine Balslev Jørgensen Fasting

Driller’s assistant Christopher Trinder Nielsen

Driller’s assistant Rune Hende

Assistant (and expedition leader) Jørgen A. Bojesen-Koefoed

Logistics were handled by GEUS.

Helicopter from Air Greenland (Eurocopter AS-350B3) was chartered for a full field season.

Drilling was carried out by a Sandvik DE 130 wire line rig, with inner and outer casing diameter of 57 mm and 67 mm, respectively. The borehole diameter is 56 mm, whereas the core diameter is 42 mm. Core barrels are 1.5m and 3m long.

Most field equipment, helicopter fuel and the drill rig was transported late summer 2016 by ship to Daneborg at Wollaston Foreland, the headquarters of the Sirius dog sledge Patrol. Equipment was left in sealed containers, to be opened when operations were initiated during the summer of 2017. Daneborg served as basecamp for the field campaign, which included both shallow borehole drilling and traditional fieldwork.

Rig, equipment and personnel were mobilised directly from the previous drill site at JuraklØft (Wollaston Forland) by helicopter to the drill site at 76º 08.455´N, 18º 32.745´W, 108 m above sea level (Figs 1, 2). Due to the long distances and heavy sling loads, mobilisation took place in several stages using the Twinotter strip at Haystack as fuel depot and reloading station. In addition, due to limited helicopter capacity, partly caused by constant, strong catabatic winds, drilling was carried out with less manpower than usual, leaving two persons behind at the previous drill site.

The objective was to test the Middle Jurassic Pelion Formation sandstones exposed at Ravn Pynt, in order to carry out analyses of petroleum reservoir properties of the unit. A secondary objective was to penetrate the “base-Cretaceous unconformity” (BCU), which can be observed in the area as a Cretaceous-age valley-incision into the Middle Jurassic succession, filled with Lower Cretaceous mudstones of the Stratumbjerg Formation (Figs 3, 4, 5).

Placing the borehole on a narrow ridge protruding towards the East from the coastal cliffs seemed to allow both objectives to be fulfilled. However, the ridge proved much too narrow to accommodate the drill rig, and an alternative drill site further to the west had to be chosen. This was placed on a narrow ridge protruding towards the East between two gullies, and outcrops on the East-facing front of the ridge prognosed a succession including a few metres of overburden followed by a few metres of Barremian shale, before encountering the Pelion Formation. This drill site was thus expected also to allow penetration of the BCU.

The Ravn Pynt-1 borehole was spudded on Sunday, July 30th at 1200, location 76º 08.455´N, 18º 32.745´W, 108 m above sea level. Water was pumped to a reservoir by the rig from a creek situated approximately 1.2 km to the NW.

Eventually, despite a distance of less than 50 metres between the outcrops and the drill site, no Stratumbjerg Formation mudstones were encountered, the overburden resting directly on the Pelion Formation sandstones. Hence, the BCU represented by Cretaceous shale on Jurassic sands was not penetrated. The Pelion Formation proved to consist of alternations between highly indurated sandstones, and perfectly soft and unlithified sands. The nature of the deposit was highly challenging for core drilling, and casing to great depth was necessary.

At 0530 a.m. on Tuesday, August 1st, permafrost caused the drill stem to become stuck in the hole just before commencing the 95-98 m run. Re-establishing circulation was impossible, but after 4 hours of flushing with hot water, the casing could be rotated. Casing was then drilled from 79.1 m to 95.5 m, thereby releasing the drill stem and core-barrel, which was pulled out of the hole. All drill rods were then checked for damage arising from the violent attempts to release the drill stem and from the process of drilling casing around the immobile drill stem. A considerable length of drill stem had to be discarded. Shortly before midnight, drilling resumed, initially drilling/melting ice in the hole.

Drilling of the Ravn Pynt-1 borehole was eventually terminated shortly after 0400 a.m. on Wednesday August 2nd with a frozen and unrecoverable drill stem. The total depth reached was 116.4 metres, and except for the overburden, core recovery was close to 100% with excellent quality core, even in unconsolidated portions of the succession. TD was roughly 8 metres below sea level, and a significant proportion of the penetrated succession is unknown. Given the extremely complicated drilling conditions, this result is satisfactory, despite the planned depth of >150 m was not realised.

The drill stem broke close to the base of the borehole, allowing most of it to be recovered. Logging of the hole was deemed too risky and was not attempted.

Demobilisation started later on the same day by lifting equipment and personnel by helicopter to a Twinotter-strip approximately 7 kilometres SW of the drill site (Fig. 2), from where everything was carried by Twinotter (chartered from Norlandair, Akureyri, Iceland) to Daneborg, allowing demobilisation to be complete by Friday, August 4th

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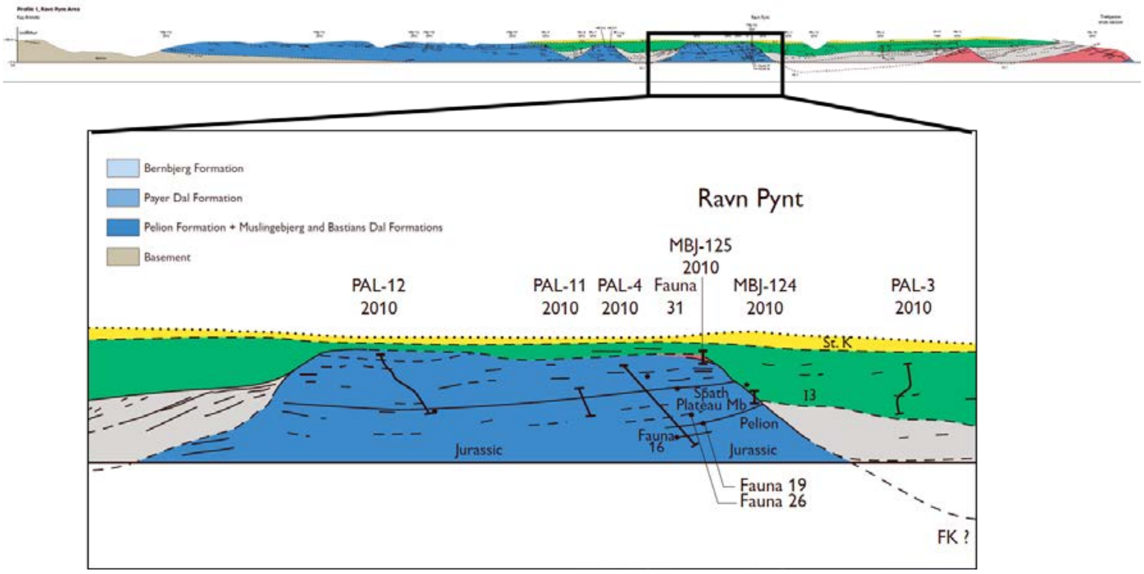

Fig. 3 Simplified profile of the study area (from Piasecki et al. 2012). The Middle Jurassic rests on Caledonian basement and is unconformably overlain by Lower Cretaceous marine mudstones of the Stratumbjerg Formation. Where documented, the contact between the Middle Jurassic and the overlying Lower Cretaceous successions is highly irregular and steeply inclined. For legend, see fig. 2.

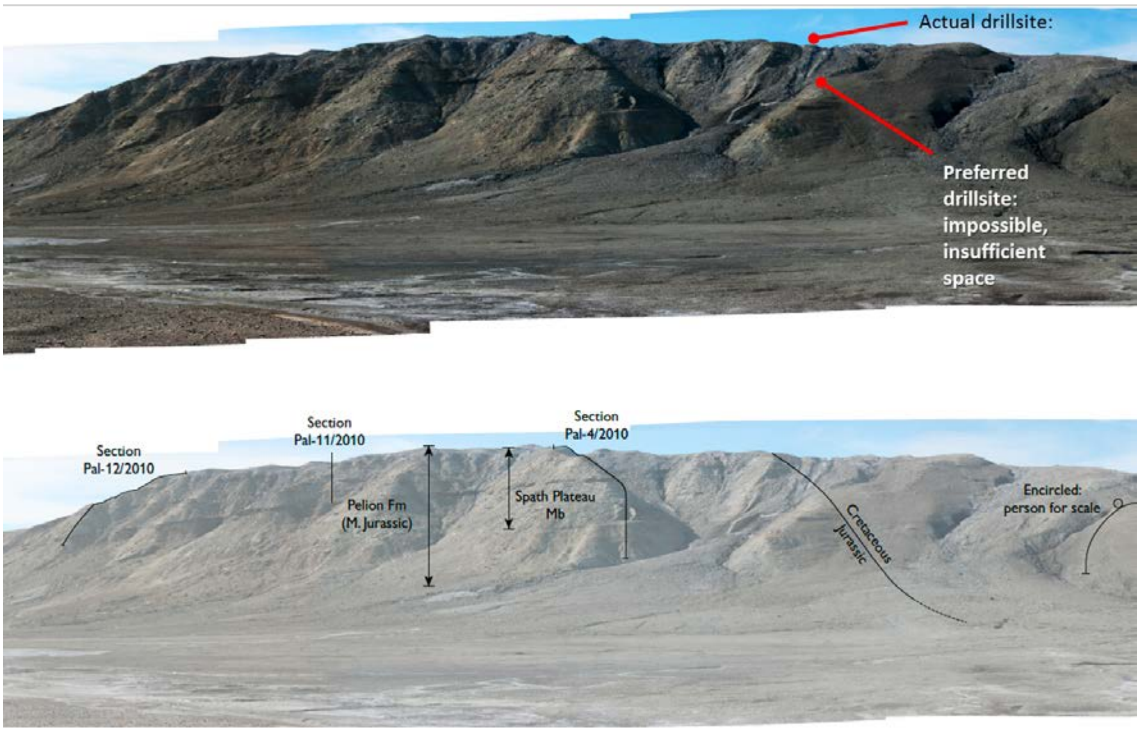

Fig. 4. Drill site viewed from the NE towards the SW. Upper part: view of the exposures showing both the preferred drill sitre, which proved unsuitable, and the actual drillsite located higher and slightly more westerly. Lower part: dimmed image showing geological units, the steeply inclined BCU and the position of profiles reported in Piasecki et al. (2012). (Photomosaic by Peter Alsen).

Fig. 5 The preferred drill site would have been a few metres left of the hammer, which is placed at the BCU (also marked by white line). However, the narrow ridge was unable to accommodate the drill rig. (Photo by Peter Alsen).

Fig. 6. Drill site after drilling resumed around midnight on August 2nd 2017. View towards the NE.

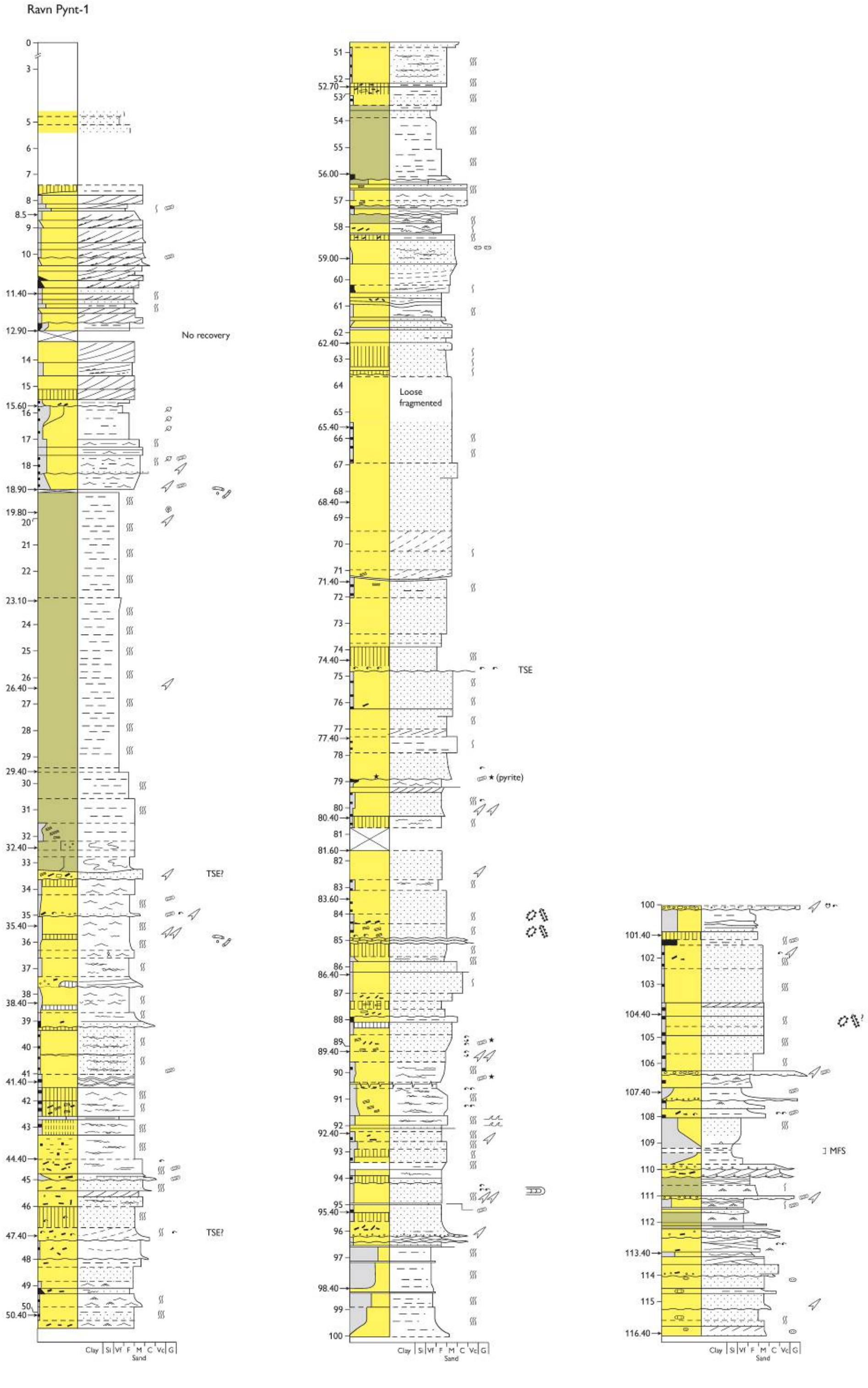

Fig. 7. Sedimentary log of the drilled succession. Minor adjustments may be added to the final version of the log. Legend, see fig 8.

Fig 8. Legend for sedimentary log

3. Geology

Lithostratigraphy of Store Koldewey (Table 1):

			Lithostratigraphy		Main depositional environment
Cretaceous	Lower	Barremian, upper	Stratumbjerg Fm		Upper slope channel?
			Sorte Kløft Fm		Marine slope w gravity flows (sst)
		Barremian, Lower	Palnatokes Bjerg Fm		
		Hauterivian		Ravn Pynt Mb	
		Valanginian			Slope channel
				Midter Gneisnes Mb	Debris flows in slope channel
		Ryazanian	Lindemans Bugt Fm		Marine slope w gravity flows (sst)
		Volgian, middle-upper			
		Volgian, lowermost	Bernbjerg Fm		
Jurassic	Upper	Kimmeridgian, upper			
		Kimmeridgian, lower	Payer Dal Fm		
		Oxfordian, upper			
		Oxfordian, lower			
	Mid	Callovian	Pelion Fm	Spath Plateau Mb	
		Bathonian		undivided	

Table 1. The table is based on the chapter “Depositional evolution of Store Koldewey” by Hovikoski, Bjerager & Piasecki (2012) in Piasecki et al. (2012).

The Middle Jurassic succession at Store Koldewey is referred to the Pelion Formation of Surlyk (2003). The Pelion Fm comprises a lower part, of Bathonian age, which is not referred to members, and an upper part referred to the Spath Plateau Member of Callovian age (Vosgerau et al. 2004; Piasecki et al. 2004). The lower boundary of the Spath Plateau Member is tentatively located at c. 30 m in the Ravn Pynt-1 core. The final identification of the boundary awaits the results of the biostratigraphic analysis. The Spath Plateau Mb. overlies an erosional unconformity, which covers a longer period at Ravn Kløft than in outcrops further south (Piasecki et al 2004: their Fig. 3).
The Upper Jurassic succession on Store Koldewey is Oxfordian – Kimmeridgian, and is referred to the Payer Dal Formation of Alsgaard et al. (2003). It is overlain by the upper Kimmeridgian Bernbjerg Formation (Piasecki et al. 2004: figs: 5, 6).

3.1 Description of lithology

The Ravn Pynt-1 core recovered a 116.4 m thick succession, representing the upper part of the Pelion Formation. The uppermost c. 30 m are referred to the Spath Plateau Member, outlined in blue in Table 2. The succession below is referred to the undivided, lower part of the Pelion Fm. The base of the Pelion Formation was not reached. Five lithologies are distinguished in the preliminary description pf the core. Three of these, the medium-grained sandstone; the heterolithic, fine-grained sandstone; and the bioturbated muddy sandstone recur several times through the core, as shown in Table 2. Two lithologies, laminated mudstone and muddy sandstone are restricted to single intervals. Brief descriptions of the lithologies are found below. The trace fossil assemblage awaits a more detailed examination. The lithological description starts from the top of the core.

Strata		**Lithology**	**Depth (m)**	**Thickness (m)**
Pelion Fm	SP Mb	Medium-grained, well-sorted, friable sandstone. Locally interbedded with the fine-grained heterolithic sandstone	5–15.6 m	c. 49 m
			47.5–52.7 m	
			58.5–79.5m	
			83–88 m	
			102.5–107 m	
			113.5–116.4 m	
	SP Mb	Heterolithic fine-grained sandstone with moderate to strong bioturbation. Locally interbedded with the medium-grained sandstone, or the bioturbated very fine-grained sandstone	15.6–18.9 m	c. 30 m
			29.5–43.3 m	
			52.7–53.5 m	
			60.7–63.6 m	
			79.4–83 m	
			88–94 m	
			101.3–102.4	
	SP Mb	Bioturbated, very fine-grained muddy sandstone. Locally interbedded with the fine-grained heterolithic sandstone	18.9–29.5 m	c. 26 m
			53.5–58.5 m	
			74–74.8 m	
			89.5–92 m	
			96.5–101.3 m	
			107–108 m	
		Laminated and weakly laminated mudstone	108–109.7 m	c. 2 m
		Medium-grained, muddy sandstone	43.3–47.5 m	c. 4 m

Table 2. Five lithologies characterize the Ravn Pynt-1 core at St. Koldewey. The Spath Plateau Member is indicated in blue. The lower c. 30 m of the member constitute the upper part of the core. The dominant lithology is the medium-grained, well-sorted, friable sandstone, with a cumulative thickness of c. 49 m.

Medium-grained, well-sorted, friable sandstone
5–15.6 m, and deeper intervals in Ravn Pynt-1 (Table 2)

Greyish brown sandstone, cross-bedded, medium- to coarse-grained, well-sorted with few trace fossils, including *Ophiomorpha* isp. Coal- and mud-clasts occur locally. The sandstone is generally friable, but includes cemented intervals, which may represent concre-

tions. The sandstone may have been deposited in a fairly high-energy environment possibly within the middle to upper shoreface.
Comparable sandstones occur at greater depth in the Ravn Pynt-1 core.

Heterolithic, fine-grained sandstone with moderate to strong bioturbation of the Pelion Fm
15.6–18.9 m, and deeper intervals in Ravn Pynt-1 (Table 2)
The heterolithic sandstone is fine-grained and contains small amounts of mudstone as mud-drapes and mud-clasts. The sand is well-sorted, and the sandstone is locally cemented. The sandstone is moderately bioturbated, the trace fossils awaits further study. Fragments of belemnites and coalified wood occur locally.
The belemnites indicate a marine environment, and the heterolithic sandstone suggests deposition at depths around wave-base. The core shows examples of transitions between the heterolithic fine-grained sandstone and the medium- to coarse-grained, well-sorted sandstone (described above) or transitions to the very fine-grained muddy sandstone (described below).
Comparable sandstones occur at greater depth in the Ravn Pynt-1 core.

Bioturbated, very fine-grained muddy sandstone
18.9–32 m, and deeper intervals in Ravn Pynt-1 (Table 2)
This sandstone is brownish grey and very fine-grained, locally silty. The sandstone is thoroughly bioturbated, and physical sedimentary structures are not preserved. An overall fining-upwards trend is seen from 21–32 m and an upwards coarsening trend characterize the upper part of the interval and continues into the heterolithic fine-grained sandstone (21–16 m). Similar trends are seen in the interval 52.7–56 m.
Comparable sandstones occur at greater depth in the Ravn Pynt-1 core.

Bioturbated, very fine-grained muddy sandstone.
18.9–30.5 m, and deeper intervals
Medium grey, very fine-grained sandstone to siltstone, which is strongly bioturbated. The trace fossils have not yet been examined, but they resemble traces, which have been interpreted as produced by deposit feeders. In some intervals (56–58.5 m; 110.3–112.3 m), the very fine-grained sandstone is interbedded with sharp-based, graded somewhat coarser sandstone beds, which tentatively are interpreted as storm sand layers. This suggests that the muddy, very fine-grained sandstone was deposited at depths between fair-weather wave-base and storm wave-base.

Laminated and weakly laminated mudstone
108–109.7 m
The dark grey, mudstone is restricted to a single occurrence. The mudstone is laminated or weakly laminated, and locally sand-streaked. It is tentatively interpreted as deposied below storm wave-base in a shelf environment, and the mudstone may possibly contain a maximum flooding surface.

Medium-grained, muddy sandstone
43.3–47.5 m

Grey, “dirty”, medium-grained sandstone, which appears to have a muddy matrix and scattered mud-clasts. This lithology appears to be restricted to one interval. The type and amount of matrix is not yet documented.

Figs 9 through 25 (this and following pages) show photos of cores. The photos were taken at the drill site, and core-depths are preliminary, related to markers used as datums for measurements, which may occasionally cause a small apparent overlap of cores. Slight revisions of depths will take place during later core description and laboratory handling of the cores.

Fig. 9. Core photo from drill site. Box 1: 3.10 – 12.83 m

Fig. 10. Core photo from drill site. Box 2: 12.90 – 19.80 m

Fig. 11. Core photo from drill site. Box 3: 19.85 – 26.61 m

Fig. 12. Core photo from drill site. Box 4: 26.52 – 33.42 m

Fig. 13. Core photo from drill site. Box 5: 33.50 – 40.40 m

Fig. 14. Core photo from drill site. Box 6: 40.49 – 47.20 m

Fig. 15. Core photo from drill site. Box 7: 47.28 – 54.08 m

Fig. 16. Core photo from drill site. Box 8: 54.12 – 60.52 m

Fig. 17. Core photo from drill site. Box 9: 60.65 – 67.48 m

Fig. 18. Core photo from drill site. Box 10: 67.43 – 74.27 m

Fig. 19. Core photo from drill site. Box 11: 74.15 – 81.77 m

Fig. 20. Core photo from drill site. Box 12: 81.76 – 88.40 m

Fig. 21. Core photo from drill site. Box 13: 88.46 – 95.22 m

Fig. 22. Core photo from drill site. Box 14: 95.22 – 101.99 m

Fig. 23. Core photo from drill site. Box 15: 101.99 – 108.80 m

Fig. 24. Core photo from drill site. Box 16: 108.84 – 115.36 m


Fig. 25. Core photo from drill site. Box 16: 115.41 – 116.40 m

4. Further analyses

- Detailed sedimentological analysis and core description
- High resolution photography in both UV and white light
- Core scanning to produce a spectral GR-log
- Biostratigraphic dating
- Systematic porosity and permeability analysis
- Diagenesis analyses

Data from such studies will be included in the final reporting.

5. References

Alsgaard, P.C., Felt, V.L., Vosgerau, H. & Surlyk, F. 2003 : The Jurassic of Kuhn Ø, North-East Greenland. Geological Survey of Denmark and Greenland Bulletin 1, 865–892.

Piasecki, S., Alsen, P., Anthonsen, K. Bjerager, M., Bojesen-Koefoed, J.A., Fyhn, MBW, Japsen, P., Hovikoski, J., Kjøller, C., Morigi, C., Nielsen, L.H., Nøhr-Hansen, H., Sheldon, E., Wiebel, R. & Kazerouni, A.M. 2012: The geology of Store Koldewey, North-East Greenland, 76° - 76.45°N Implications for offshore petroleum geology. GEUS rapport 2012/33 20pp. *Confidential report and GIS compilation available to companies participating in the GEUS-industry collaboration project "Petroleum studies, services and data in East and Northeast Greenland"*

Piasecki, S., Callomon, J.H. & Stemmerik, L. 2004: Jurassic dinoflagellate cyst stratigraphy of Store Koldewey, North-East Greenland. Geological Survey of Denmark and Greenland Bulletin 5, 99–112.

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

Vosgerau, H., Larsen, M., Piasecki, S. & Therkelsen, J. 2004 : A new Middle-Upper Jurassic succession on Hold with Hope, North-East Greenland. Geological Survey of Denmark and Greenland Bulletin 5, 51–71.