DANMARKS OG GRØNLANDS GEOLOGISKE UNDERSØGELSE RAPPORT 2018/40

Description of cored sections in three wells located in the Visund area: 34/8-9S, 34/8-A-33H and 34/8-A-1H

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DANISH MINISTRY OF ENERGY, UTILITIES AND CLIMATE

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GEUS

Contents

1 Abstract

The present study is carried out for NPD in order to unravel the depositional setting of linsoidal to sigmoidal units formed in front of a huge Quarternary progradational wedge. Cored sections from three wells, 34/8-9S, 34/8-A-33H and 34/8-A-1H, located in the Visund area, northern North Sea, are described. Four facies have been identified: Facies 1 organic-rich silty mudstone, Facies 2 calcareous clayey siltstone, Facies 3 calcareous sandstone and Facies 4 contorted conglomerate. The cored sections all represent deep water contourites. A 3 m section 34/8-9S is interpreted as debris-flow or, alternatively, may be interpreted as an injectite.

2 Introduction

The present study is carried out by GEUS for the Petroleum Directorate of Norway. The purpose was to describe cored sections of the Quaternary succession in block 34/8. The cored sections are from the three wells 34/8-9S, 34/8-A-33H and 34/8-A-1H respectively (Fig. 1).

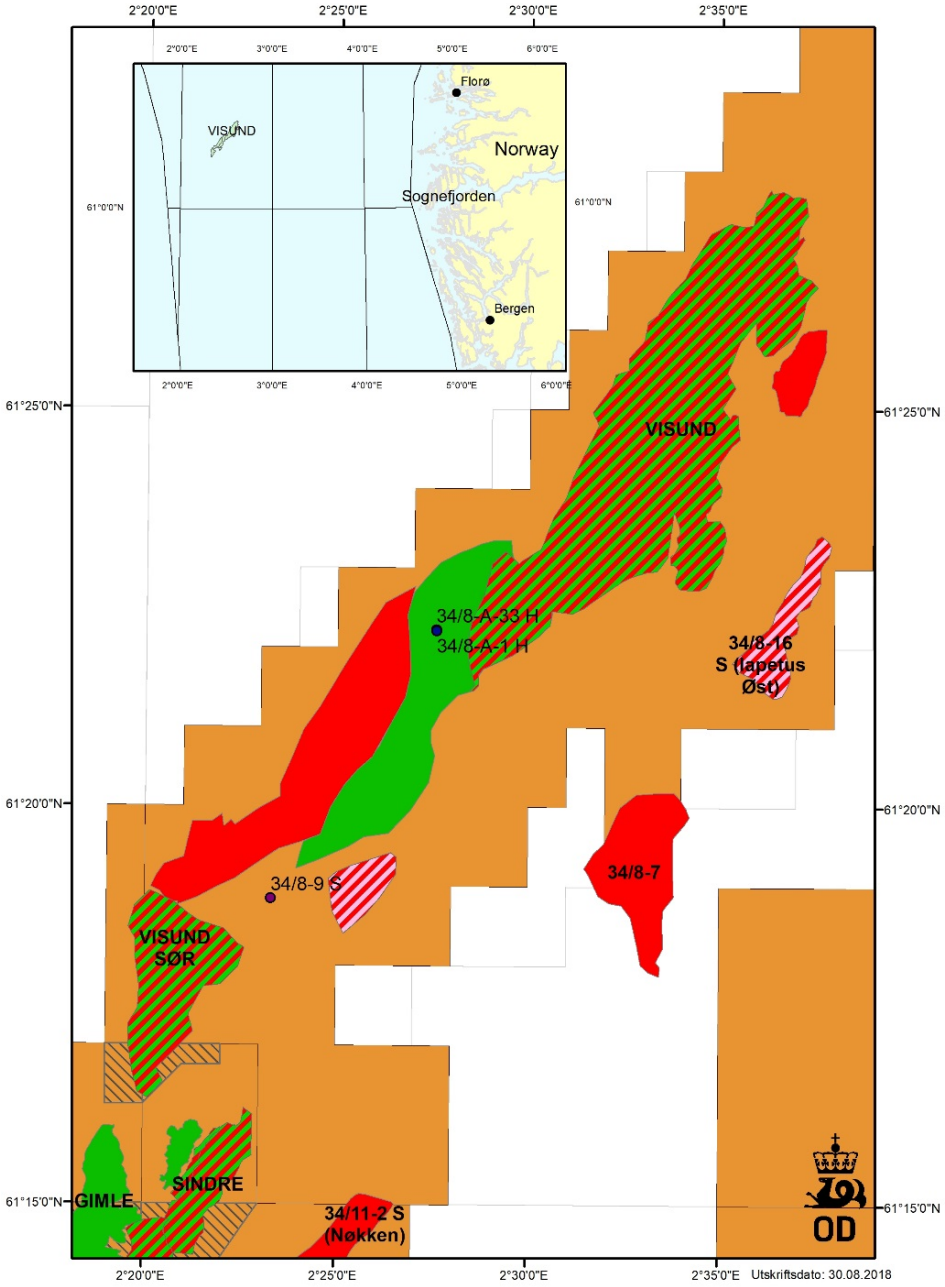

Fig. 1: Map of the Visund Field area showing the location of the studied wells.

3 Geological Setting

The studied successions were deposited on the northern North Sea shelf during the Quaternary. The water depth, inferred from the height of the clinoformal package was in the order of several 100's m (Batchelor et al. 2017). The area is strongly influenced by ocean current systems, e.g., at present, the warm north-east-flowing Norwegian Current flows in the upper water masses and the colder Norwegian Sea Bottom Water occupies the deeper water masses (e.g., Turrell et al. 1999; Masson 2001). Initial expansion of the Scandinavian Ice Sheet commenced during the early Quaternary. This resulted in infilling of the northern North Sea by glacigenic debris-flows alternating with contourites (Batchelor et al. 2017)

4 Facies description

The succession covered by the three wells is subdivided into four facies: Facies 1 organic-rich silty mudstone, Facies 2 calcareous clayey siltstone, Facies 3 calcareous sandstone and Facies 4 contorted conglomerate.

Facies 1 organic-rich, silty mudstone

Description: Dark brown, organic-rich, silty mudstone with reddish color in some intervals (weathering of pyrite; Fig. 2). The lower boundary is irregular due to bioturbation probably by *Planolites*. The upper boundary is gradational as indicated by a color shift from dark brown to greenish and finally greenish gray.

Interpretation: The silty mudstone was deposited in a low energy and low oxygenated depositional environment. The uniform grain size and nature suggest deposition from suspension. However, due to bioturbation it is interpreted that some oxygen was present at the sea bottom. From the height of a clinoformal wedge overlying the facies, a depositional water depth of several 100's m is interpreted to have persisted in the area during deposition (Batchelor et al. 2017).

Facies 2 calcareous clayey siltstone

Description: Greenish gray, calcareous clayey siltstone. At some levels more reddish in color. The facies is totally bioturbated, but discrete trace fossils of *Planolites* and *Thalassinoides* occur (Fig. 3). Lignite is common and at some levels concentration of lignite is seen. Clasts from 1 mm to a few cm are common (Fig. 4). Facies 2 grades upward into Facies 3.

Interpretation: The facies was deposited in a low energy, oxygenated environment. Similar to facies 1, the height of a clinoformal wedge overlying the facies, indicates a depositional water depth of up to 1 km. The close association with facies 3 indicates that facies 2 forms part of a contourite system. The facies correspond to facies C1 of the contourite facies model (e.g., Rodriguez-Tovar & Hernandez-Molina 2018). The isolated clasts found in the succession are interpreted as dropped vertically from icebergs.

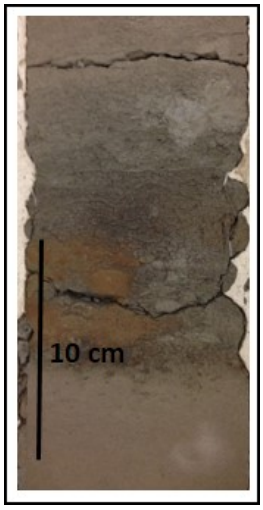

Fig. 2: Facies 1, mudstone.

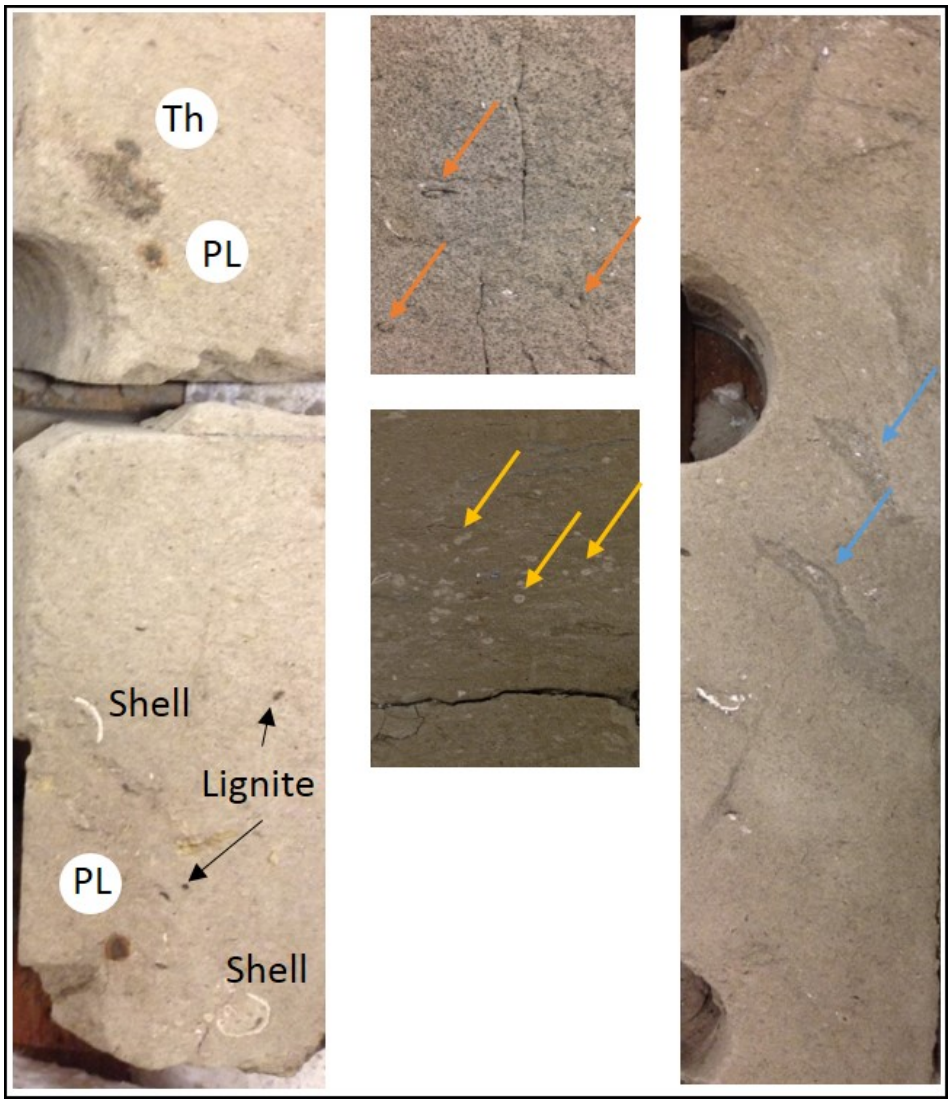

Fig. 3: Trace fossils identified in the studied section. PL; Planolites and Th; *Thalassinoides. Note discrete trace fossils indicated by orange, yellow and blue arrows.*

Fig. 4: Photo of the contourite facies with dropstones (arrows). The core is 10 cm wide.

Facies 3 calcareous sandstone

Description: Greenish gray, mica-rich, calcareous very fine to fine-grained sandstone showing a gradual increase in grain size (revers grading) which in turn is followed by a decrease in grain size (normal grading, Fig. 5). Some cored sections only show either normal grading or inverse grading in connection with missing cored sections (Fig. 6, 7, 8 and 9). Bioturbation is 100 %, however, discrete trace fossils can occur (Fig. 3). Subtle lamination and concentrations of well sorted foraminifera (Tor Eidvin et al. 2013) may occur (e.g., Fig. 6). Clast from 1 mm to 0.5 cm are common, a single clast up to 9 cm has been found.

Interpretation: The general arrangement in coarsening-upwards and/or fining-upwards cycles strongly indicated deposition by waxing and waning currents typical for contourites (Stow & Faugeres 2008). Primary structures formed by current activity were post-depositionaly destroyed by borrowing. Only at one level, weak lamination has been observed, which support deposition from a current. A level consisting of well-sorted foraminifera clearly indicates

deposition from bottom current activity. The continuous and homogeneous bioturbation is typical for contourites (Rodriguez-Tovar & Hernandez-Molina 2018), e.g. turbidites are typically bioturbated from the top. The facies corresponds to facies C2 and C4, respectively, of the contourite facies model (e.g., Rodriguez-Tovar & Hernandez-Molina 2018). The isolated clasts found in the succession are interpreted as dropped vertically from icebergs.

Facies 4 contorted conglomerate

Description: Greenish gray, clayey siltstone showing contorted bedding. Irregular, red colored clay clasts, up to 7 cm in size occurs (Fig. 10).

Interpretation: This facies, which shows contorted bedding and contain clay clasts, was probably deposited by mass flows generated on the clinoformal succession deposited on top of the contourites. Mass flow is renown from the area and are quite common in the Naust Formation (Batchelor et al. 2017). However, given the common occurrences of drop stones in facies 2 and 3, one would expect some siliciclastic clasts incorporated in a mass flow formed at the toe of a prograding Naust Formation. This has not been observed in the studied section. Alternatively, the contorted section was formed by injection of underlying deposits and thus represent an injectite.

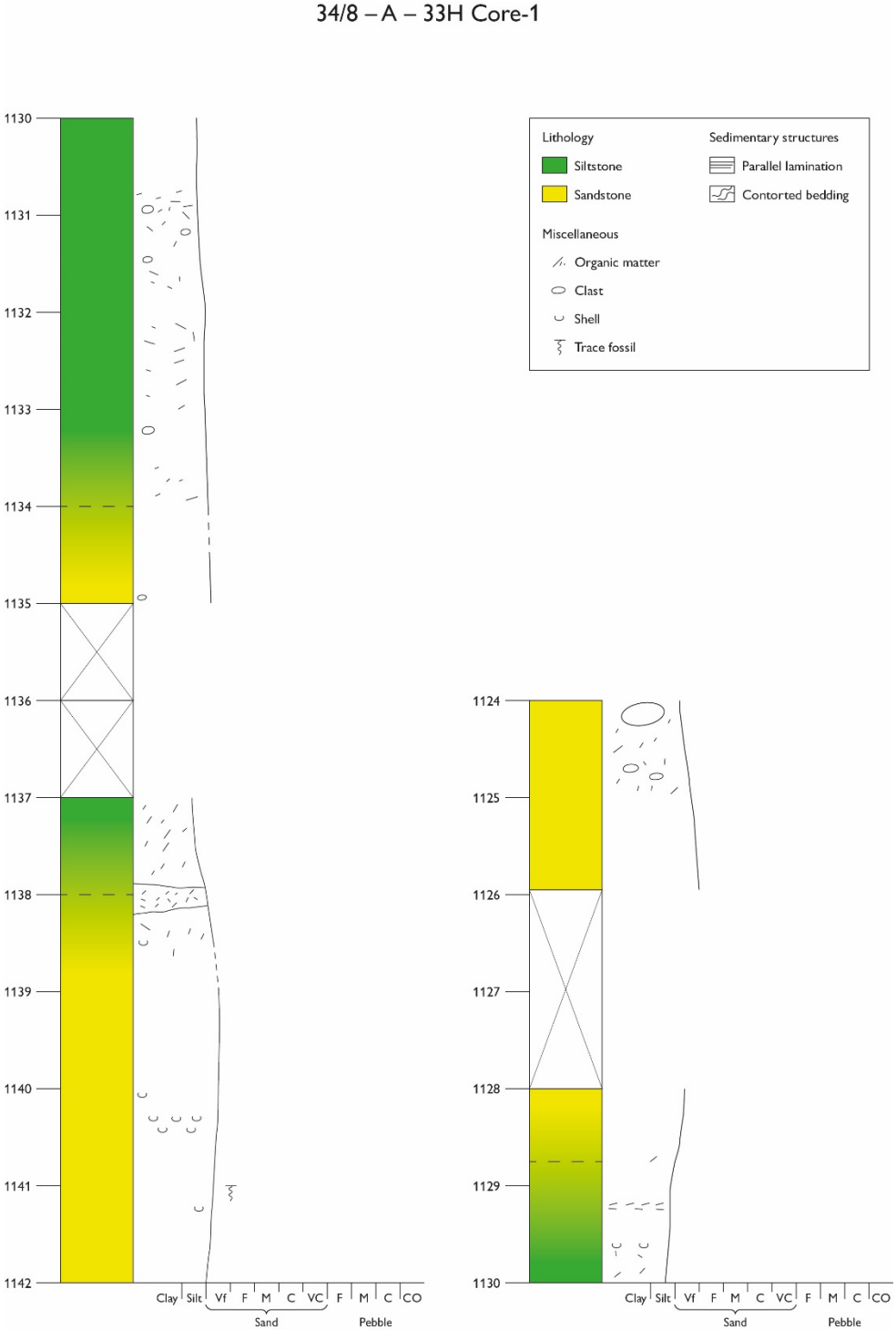

Fig. 5: Cored log of 34/8-A-33H, core 1. Note the characteristic coarsening and fining upward trends of the section. The missing sections are probably sand-rich sections.

Fig. 6: Cored log of 34/8-A-1H, core 1. Note the corsening upward trend of the section and parallel lamination.

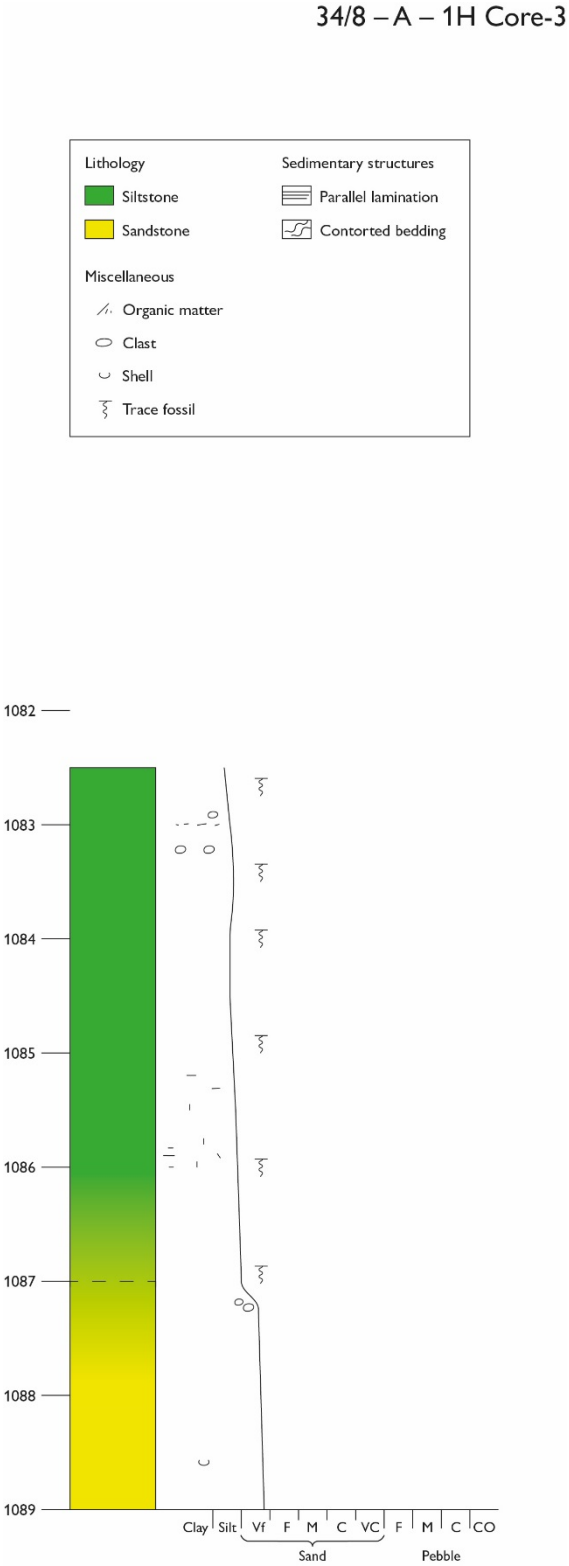

Fig. 7: Cored log of 34/8-A-1H, core 3. Note the fining upward trend of the section. Discrete trace fossils are common in the upper part (see also figure 3).

Fig. 8: Cored log of 34/8-A-1H, core 5. Note the fining upward trend of the section.

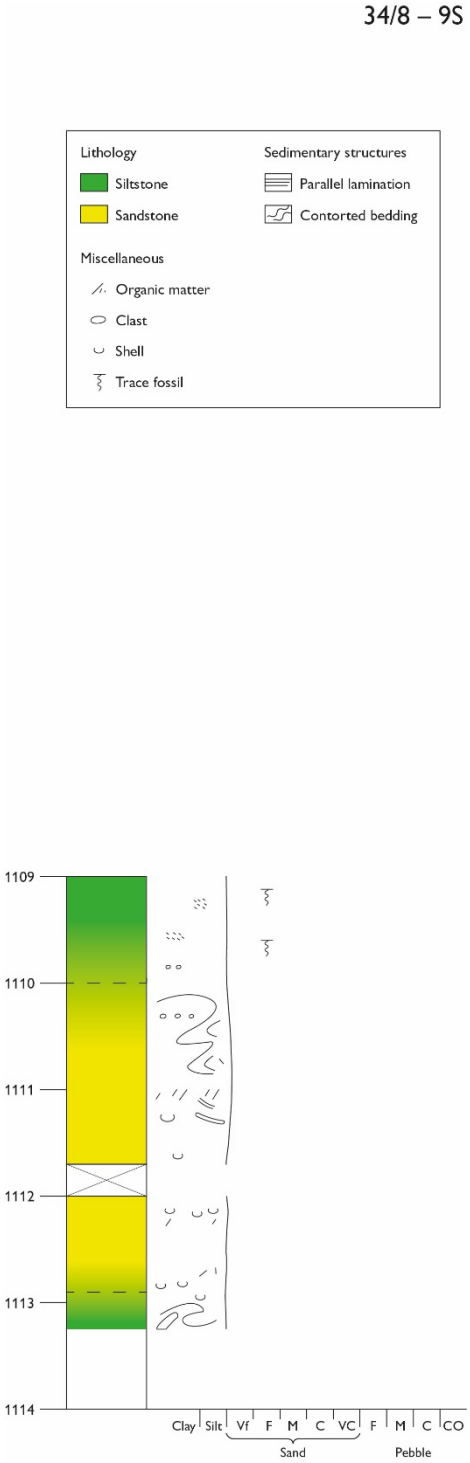

Fig. 9: Cored log of 34/8 – 9S. Contored bedding is seen at two levels. Note the clay clasts at 1111 m (see also figure 10).

Fig. 10: Contorted bedding from 34/8 – 9S. Note the clay clasts in the upper part of the section.

5 Discussion

The nature of facies 2 and 3, showing a gradational increase in grain size followed by decreasing grain size, is typical for contourites (Gonthier et al. 1984; Stow & Faugeres 2008). The changes in grain size indicate waxing and waning of bottom currents. In well 34/8-A-33H core-1 (Fig. 5) 2 m of section is missing at 1126 – 1128 m and 1135 – 1137 m respectively. The missing interval is between a coarsening upwards and a fining upwards successions. It is most likely that the missing section is a sand-rich interval and consequently has a low core recovery. This part may thus represent the most coarse-grained portion of a contourite (facies C3, e.g., Rodriguez-Tovar & Hernandez-Molina 2018) and truly show the negatively – positively gradation of the succession characteristic for contourites.

The occurrence of well-sorted foraminifera as observed by Tor Eidvin et al. (2013) clearly indicates current activity in the area and thus strongly support the interpretation of contourite deposits. The identified trace fossils *Planolites* and *Thalassinoides* are also typical for contourites (Rodriguez-Tovar & Hernandez-Molina 2018).

6 Conclusions

The cored sedimentary sections are all interpreted as deep water (several 100's m) deposits. This is based on the position of the studied sections in front of several 100 m's high clinoformal marine package.

The characteristic coarsening – fining upward pattern of the studied sections clearly indicate deposition of a contourite succession.

A section penetrated in 34/8 -9S is interpreted as a muddy debris flow or alternatively represents a thin injectite.

7 References

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