DANMARKS OG GRØNLANDS GEOLOGISKE UNDERSØGELSE RAPPORT 2016/70

Pituffik Titanium Project: Results of 2016 Fieldwork

Near-shore sub-bottom profiling

Lars-Georg Rödel, Jørn Bo Jensen & Samuel Weatherley

GEOLOGICAL SURVEY OF DENMARK AND GREENLAND
DANISH MINISTRY OF ENERGY, UTILITIES AND CLIMATE

G E U S

DANMARKS OG GRØNLANDS GEOLOGISKE UNDERSØGELSE RAPPORT 2016/70

Pituffik Titanium Project: Results of 2016 Fieldwork

Near-shore sub-bottom profiling

Lars-Georg Rödel, Jørn Bo Jensen & Samuel Weatherley

GEOLOGICAL SURVEY OF DENMARK AND GREENLAND
DANISH MINISTRY OF ENERGY,UTILITIES AND CLIMATE

G E U S

1. **Summary** **4**

2. **Introduction** **5**

3. **Survey** **7**

3.1 Sediment echo-sounder mapping 7
3.1.1 Timeframe 7
3.1.2 Instrument spread 7

4. **Bathymetry** **10**

4.1 Bathymetry area 1a Mourisaq region 10
4.2 Bathymetry area 2a Iterlak region 11

5. **Acoustic soft sediment mapping with SES 2000** **13**

5.1 Potential black sand resources in area 1a based on the SES2000 data 14
5.2 Potential black sand resources in area 2a based on the SES2000 data 16

6. **Conclusions** **20**

7. **References** **21**

8. **Digital data delivery** **22**

1. Summary

A SES 2000 sediment echo sounding survey was carried out in August 2016.

The survey continued the 2015 mapping with additional shallow bathymetry in the Mourisaq area, as well as mapped soft sediment thickness in nearshore shallow basins.

The mapped basins show soft sediments in thickness of 0 to 2.5m.

The high resolution SES2000 profiles give detailed information of the uppermost few meters of the seabed. Future studies should aim to correlate this new geophysical data with existing vibrocore data.

At water depths of more than 10m, the detailed SES2000 profiles reveals substantial reworking of the seabed sediments caused by iceberg ploughing.

2. Introduction

In August 2015 a combined echo sounding, C-boom and grab sample survey was conducted in the Thule Fjord Moriusaq area, with the aim to map potential offshore heavy mineral sand deposits.

Models of relative sea level change in the Pituffik district (Flemming & Lambeck, 2004) indicate that the postglacial sea level evolved from a highstand at 13,000 years BP to a lowstand at 7000 years BP, and was followed by transgression to the present situation. On the basis of the study of Flemming & Lambeck (2004), results from the 2015 survey were interpreted to show highstand, lowstand and transgressive units. In this model, sandy facies in shallow water together with the lowstand and transgressive seismic units are potential heavy mineral black sand resources. The model predicts that the relative sea level was not at any point lower than approximately -20 m below the present sea level. Therefore heavy mineral sands are not expected to be present at depths greater than -30 m below lowest astronomical tide. It is emphasised, however, that the present understanding of the relative sea level change is model-based, and requires testing by sediment coring to sufficiently deep depths.

In sections of the survey area where the water depth is greater than approximately 20 m, heavy contortion by iceberg ploughing was observed in the seismic profiles. The 2015 survey is reported in GEUS Report 2015/74.

Figure 1. Location of Moriusaq, North West of Thule Airbase. Blue box indicated the region of field activities in 2016.

In 2016 a minor offshore sediment profiling survey was conducted with a scope of work to extend the survey done by boomer profiling in the previous year as close to the shore as possible in selected areas.

Selection of equipment was done by the following criteria:

- Able to be pole mounted to ensure safe navigation close to the shore
- Simple enough to be run from a zodiac or similar and to be mobilised in less than a day
- Highest possible weight to depth ratio to ensure maximum penetration

The choice was a parametric sub bottom profiler from Innomar in Germany.

This report describes the results of the Innomar SES 2000 standard survey. The survey was divided into 3 subareas that were selected for nearshore sediment echosounding (Figure 2). In area 1a the near coastal shallow areas around Moriusaq was mapped. In area 2a, the shallowest area outside Iterlak Delta was surveyed, and in area 1b the survey was conduced along a cross-basin line.

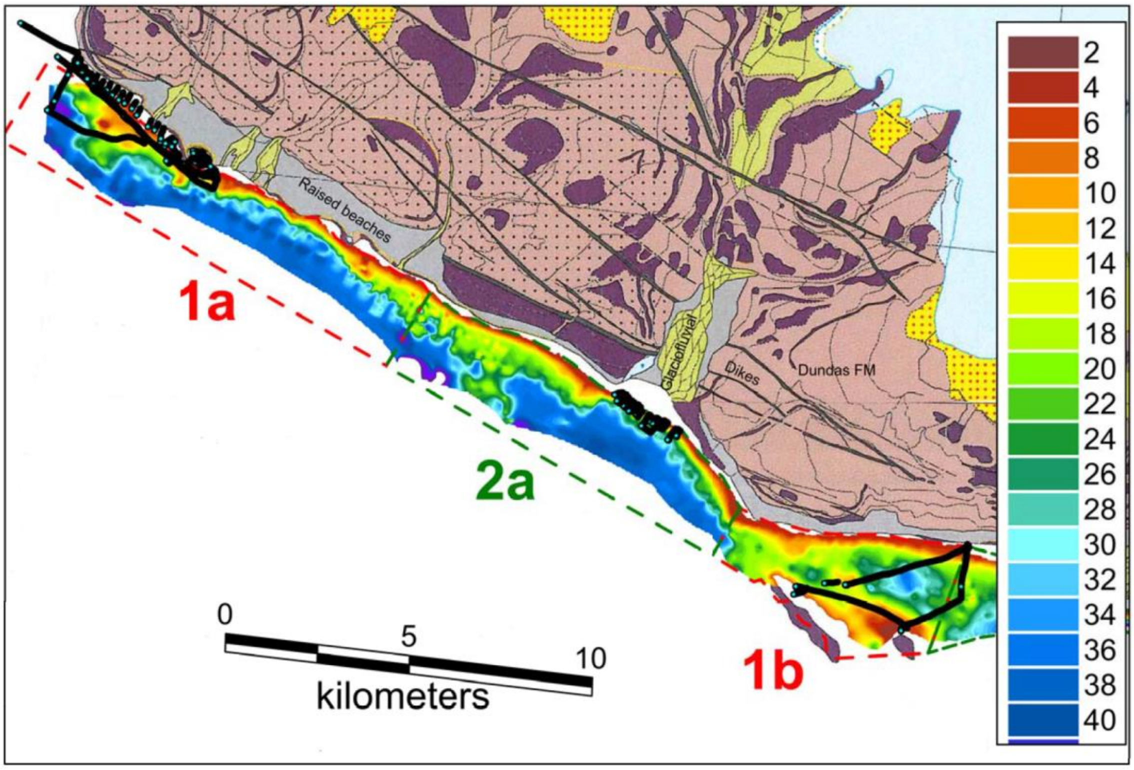

Figure 2. The survey areas 1a, 1b and 2a with the 2015 bathymetry map and location of 2016 Survey track lines of SES 2000 sediment echo sounder data, UTM zone 19 wgs84.

3. Survey

3.1 Sediment echo-sounder mapping

The survey was carried out by GEUS as part of the fieldwork program in the period 27/07/16 – 23/08/16.

The time schedule for the survey included 4 days of surveying and 1 day of mobilisation and demobilisation. A team from GEUS who have extensive experience with similar equipment conducted the survey.

3.1.1 Timeframe

The technician/surveyor also worked on the vibrocoring and GPS mapping aspects of the field campaign. The sediment echosounding survey started after the Georadar survey was finalized.

The Georadar stopped on the 10th August and the responsible geologist Peter Roll from GEUS Denmark went home. The geologist helping out with the georadar took over the position of vibrocoring and the technician from GEUS started the survey.

The mobilizing of the sub bottom profiling setup was performed during a period of bad weather that made vibrocoring impossible. The mobilization was done on Kisaq while anchoring at Iterlak on the 8th August and set of test lines were made before retrieving the mob boat and resuming vibrocoring.

The survey was finalized in 4 days with one day of downtime due to heavy fog. The demob was done immediately after, because the same technician was responsible for the DGPS measurements of the auger drilling and digging of trenches.

3.1.2 Instrument spread

- Innomar ses 2000 standard, rented and shipped from manufacturer Innomar in Germany.
- C-Nav3050 GPS for navigation was brought from the GEUS instrument pool.
- 2 laptops, one running seiswin for controlling and recording the sub bottom profiler, one for running the navigation and run line control on the survey program Sonarwiz 6.
- All the electronics were placed in a waterproof enclosure in the front of the boat.
- The Innomar transducer was mounted on the Mob boat from Kisaq rather than the original choice – the GEUS zodiac, the reason being better safety features and better handling.

- The pole was brought from home along with a universal bracket, this was not needed, and the pole was mounted around the steering console, amidships with excellent stability.
- The setup was powered with a Honda i20 generator and protected with a 1000w UPS.

Figure 3. The Mob boat with electronics in the yellow crate. Transducer pole mounted with the GPS antenna on top.

Figure 4. The helmsman and data acquisition computers.

The data delivery comprised

- Map of run lines
- Raw data from Innomar in 2 formats, the ses file and the raw file, the latter containing the full envelope.
- The interpreted geophysical data representing the areas of soft seabed vs. rock.

Raw data files were converted to standard seismic SGY format with navigation in UTM WGS84 Zone 19. The processed bathymetry exported as .csv files in local grid coordinates.

4. Bathymetry

The SES2000 sediment echo sounder was also used to make bathymetrical measurements. This instrument has the capacity to provide depth data with an accuracy of centimetres. The echo sounder operates with 33 kHz. Editing of the echo sounder data was done with the NaviPac-software packet NaviEdit.

Tidal effects were corrected for using the tidal table for Greenlandic waters produced by the Danish Meterological Institute (DMI). The results of the bathymetry mapping are illustrated in figure 10. All bathymetrical measurements are reported to Lowest Astronomical Tide.

4.1 Bathymetry area 1a Mourisaq region

In the north-western part of area 1a a narrow shallow zone has been investigated between the coastline and the 2016 survey as well as inside the Mouriusaq Bay (Figure 5).

The bathymetry mapping was conducted in water as shallow as 0.5 m. Detailed bathymetric information is presented in Figure 6.

A shallow sill (<1m depth) is present at the entrance to Mouriusaq Bay. The shallow zone of <5m water depth in general extends only a few hundred meters out from the coastline. Slight misfits in the two data sets can be seen by examining the 10 m depth contours. This is a consequence of a different density of data in the two datasets.

Figure 5. Survey lines of SES 2000 collected in 2016 in the Mourisaq region. Contourlines of the 2015 survey is shown.

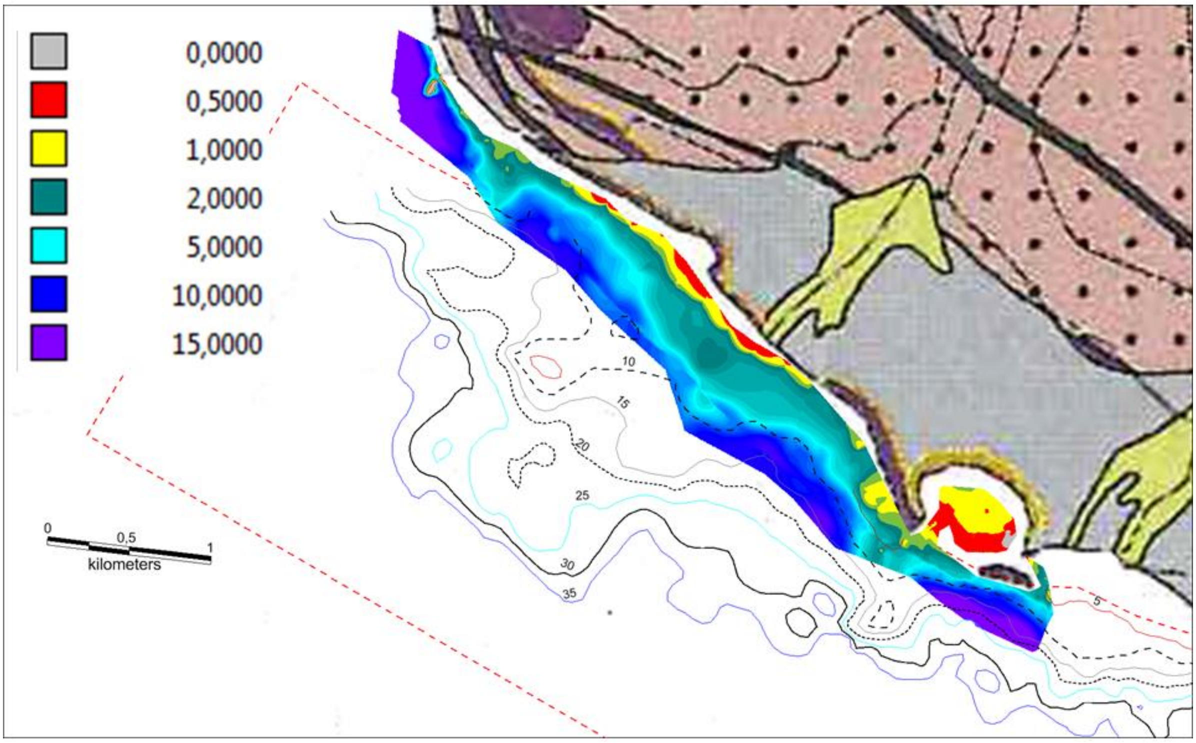

Figure 6. Bathymetry of the Mourisaq region. Colours show bathymetry in metres. Contour lines show results of the 2015 bathymetry survey in metres.

4.2 Bathymetry area 2a Iterlak region

Figure 7 shows survey lines for bathymetric mapping in the shallow marine part of Iterlak Delta. The bathymetric map in Figure 8 shows a very steep delta front with increasing depths of 0.5 – 10 m within a distance of about 200m.

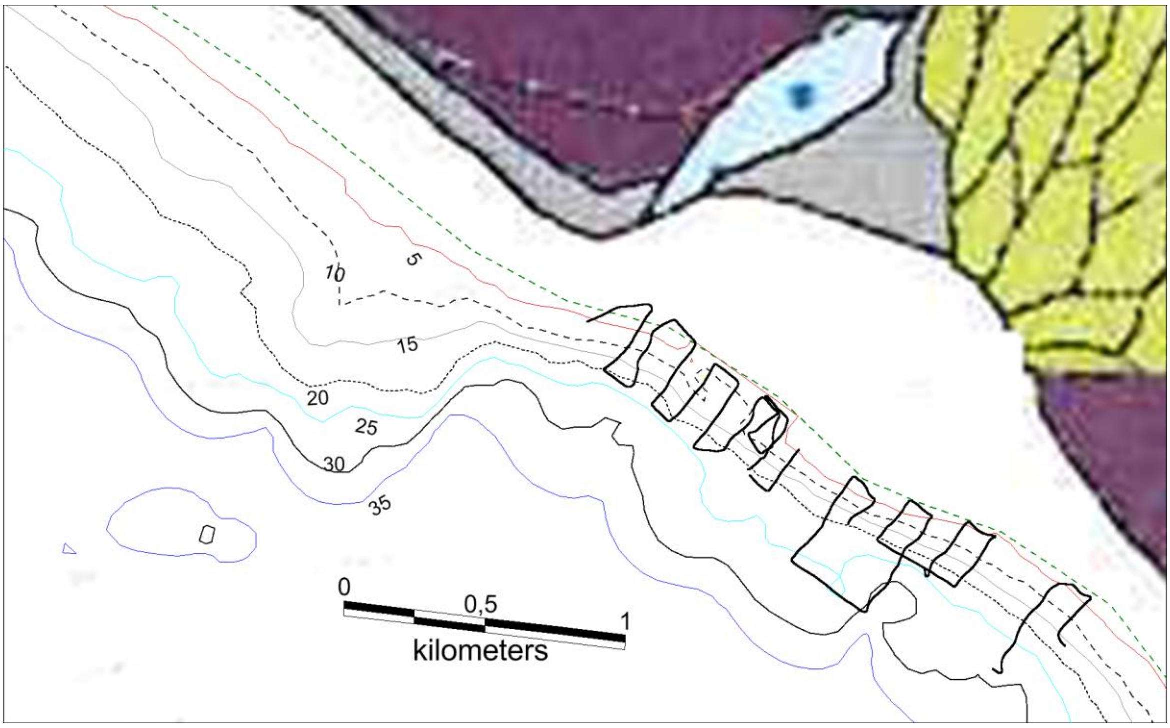

Figure 7. Survey lines of SES 2000 collected in 2016 in the Iterlak region. Contour lines show results of the 2015 bathymetry survey in metres.

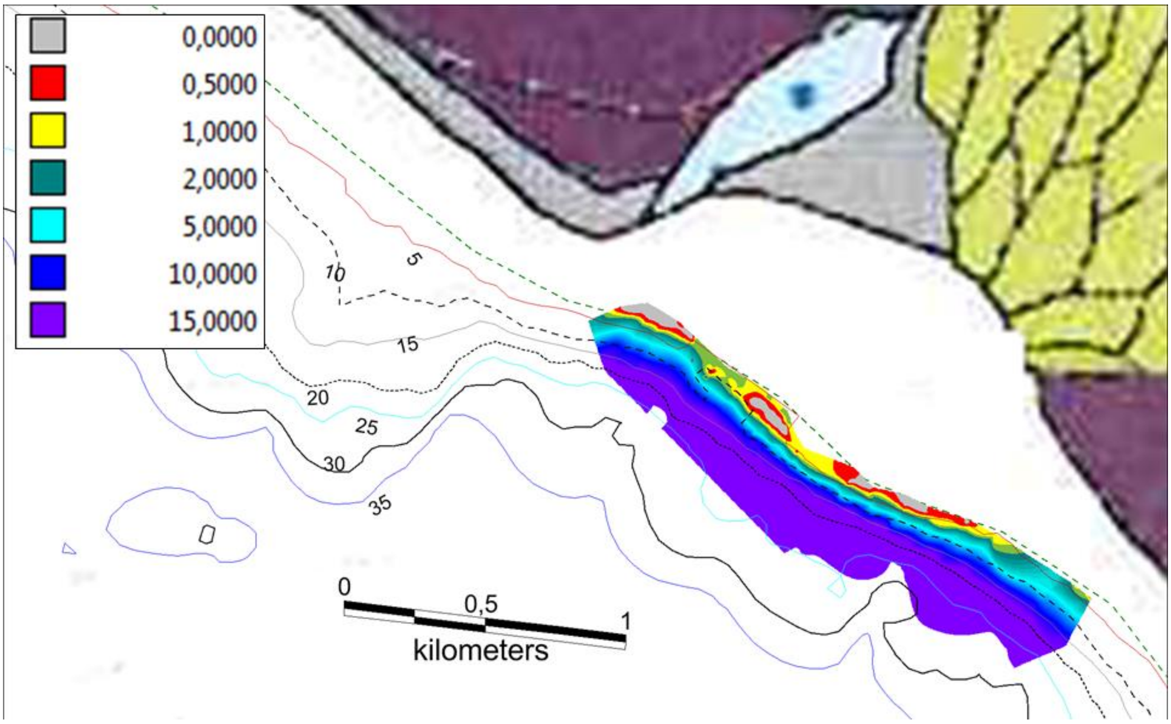

Figure 8. Bathymetry of the Iterlak region. Contourlines of the 2015 survey is shown. All depths are reported in metres.

5. Acoustic soft sediment mapping with SES 2000

The sediment echo sounder mapping was made in order to map the near coastal thickness and distribution of potential offshore heavy mineral sand deposits in very shallow water. The survey was designed to overlap with the 2015 boomer surveyed area (Figure 2).

- The SES 2000 Raw data format files were converted to standard seismic SGY files. The files were loaded into GEOGRAPHIX interpretation software and the seabed and the soft sediment bottom reflector were digitised.
- The difference between the two reflectors was calculated for all the lines and a .csv file was produced containing navigation and thickness of soft sediments.
- The soft sediment thickness file was imported in MapInfo GIS and thickness grids were produced in Vertical Mapper.

In total, 6 minor potential soft sediment shallow areas were located in area 1a and 2a with a clustering outside Moriusaq and Iterlak delta (Figure 9).

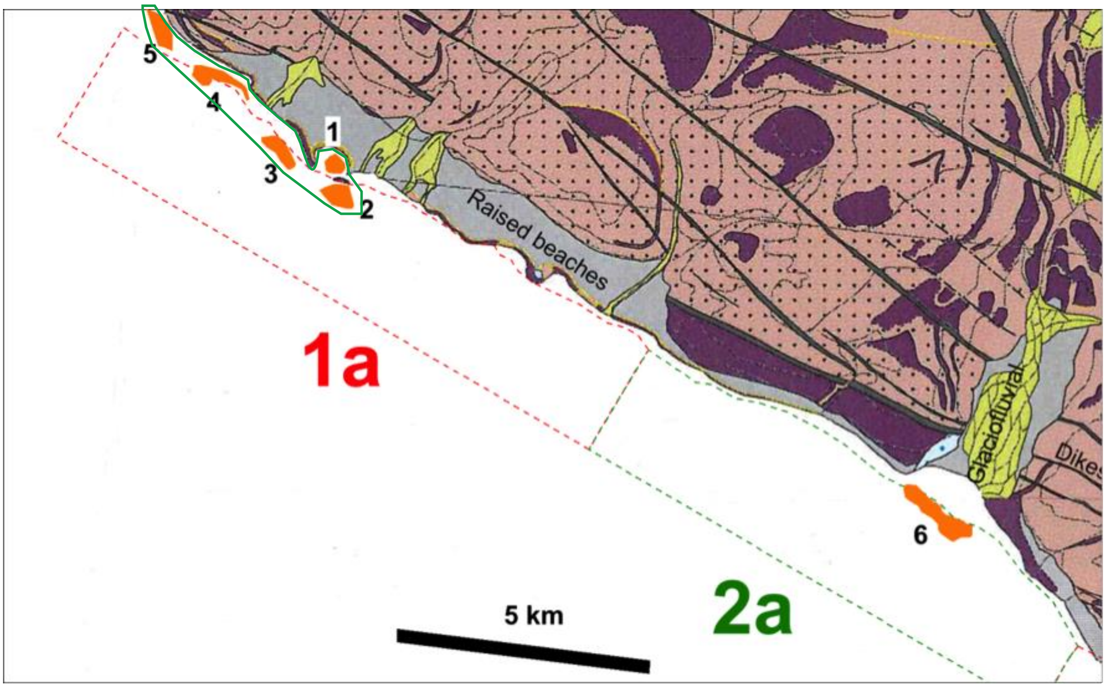

Figure 9. Location of 6 (orange) soft sediment areas mapped by SES 2000. Green line shows the approximate outline of the survey area.

The SES 2000 mapped areas partly covers already Boomer mapped areas from 2015 and shallow areas closer to the coastline (Figure 10).

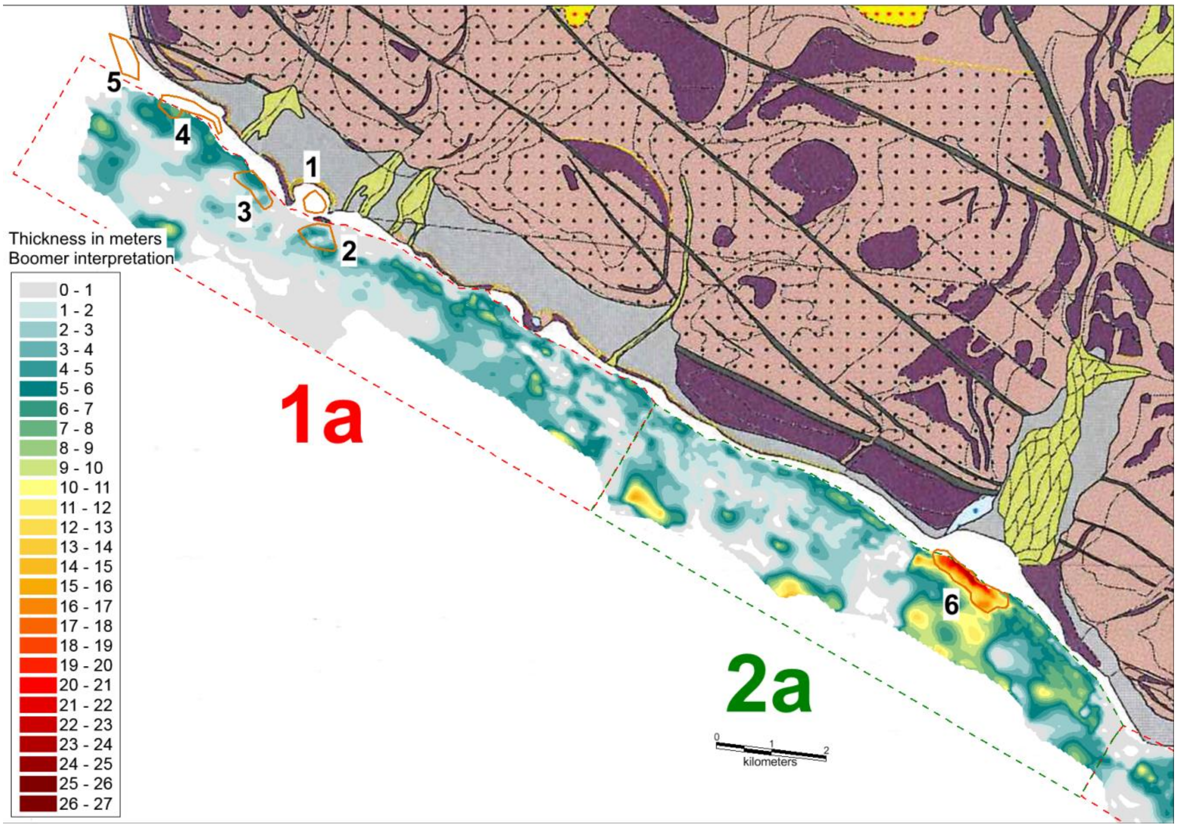

Figure 10. Location of 6 soft sediment areas (orange polygons) mapped by SES 2000, on top of the 2015 thickness map on basis of interpretation of Boomer seismic data.

5.1 Potential black sand resources in area 1a based on the SES2000 data

In the near coastal shallow areas around and inside Mourisaq Bay, 5 areas with thin soft sediment coverage between 0 and 2m in thickness were observed. These areas are presented in Figure 11.

Comparison with the 2015 boomer thickness mapping shows that, where the datasets overlap, soft sediment is found in the same areas, but with greater penetration in the boomer survey (figures 10, 11).

In addition comparison with the bathymetry map (Figure 6) shows that Mourisaq Bay acts as a small sediment trap (Figures 11 and 12). Soft sediments is also present in shallow pocket shaped basins at water depths of more than 10m (Figures 11 and 13). The very uneven surface of the soft sediment surface at water depths of more than 10m, points on the possible iceberg ploughing effect.

The soft sediment top layer (Figs. 12 and 13) covers a hard bottom layer that cannot be penetrated by the sediment echo sounder. The hard bottom layer may be sedimentary bedrock but it can also include hard sands that cannot be penetrated by this high frequency system.

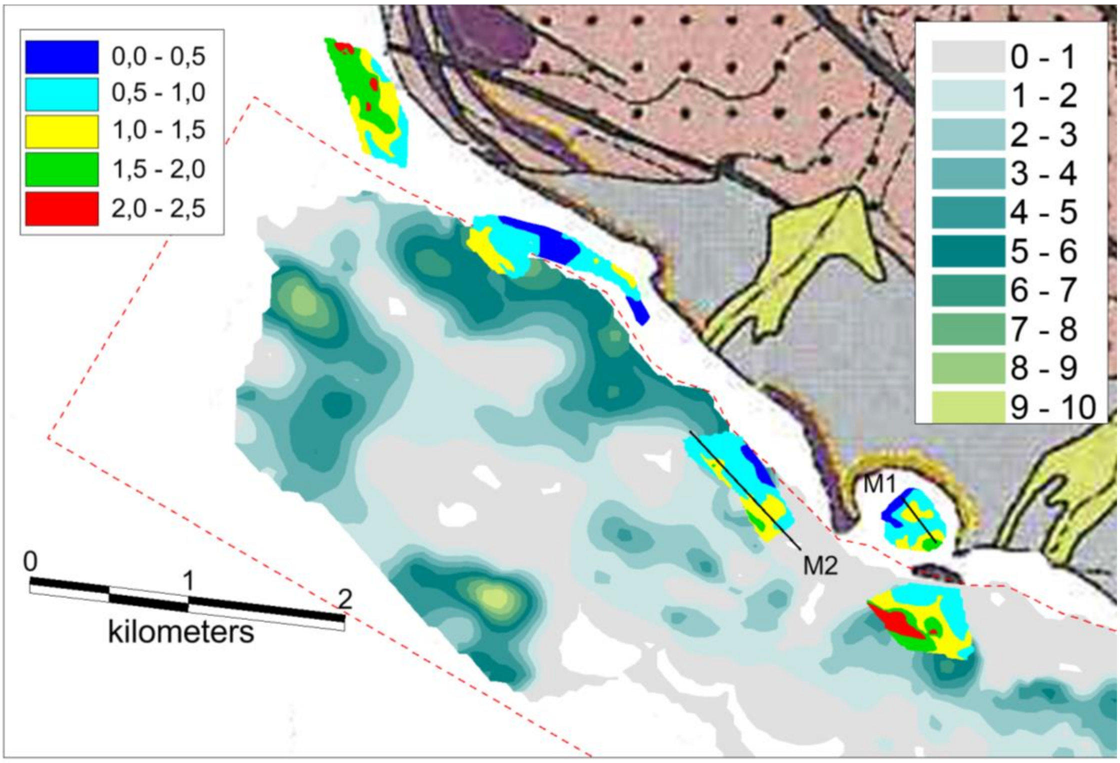

Figure 11. Potential resource thickness in area 1a in the SES 2000 mapped areas on top of the 2015 thickness map on basis of interpretation of Boomer seismic data.

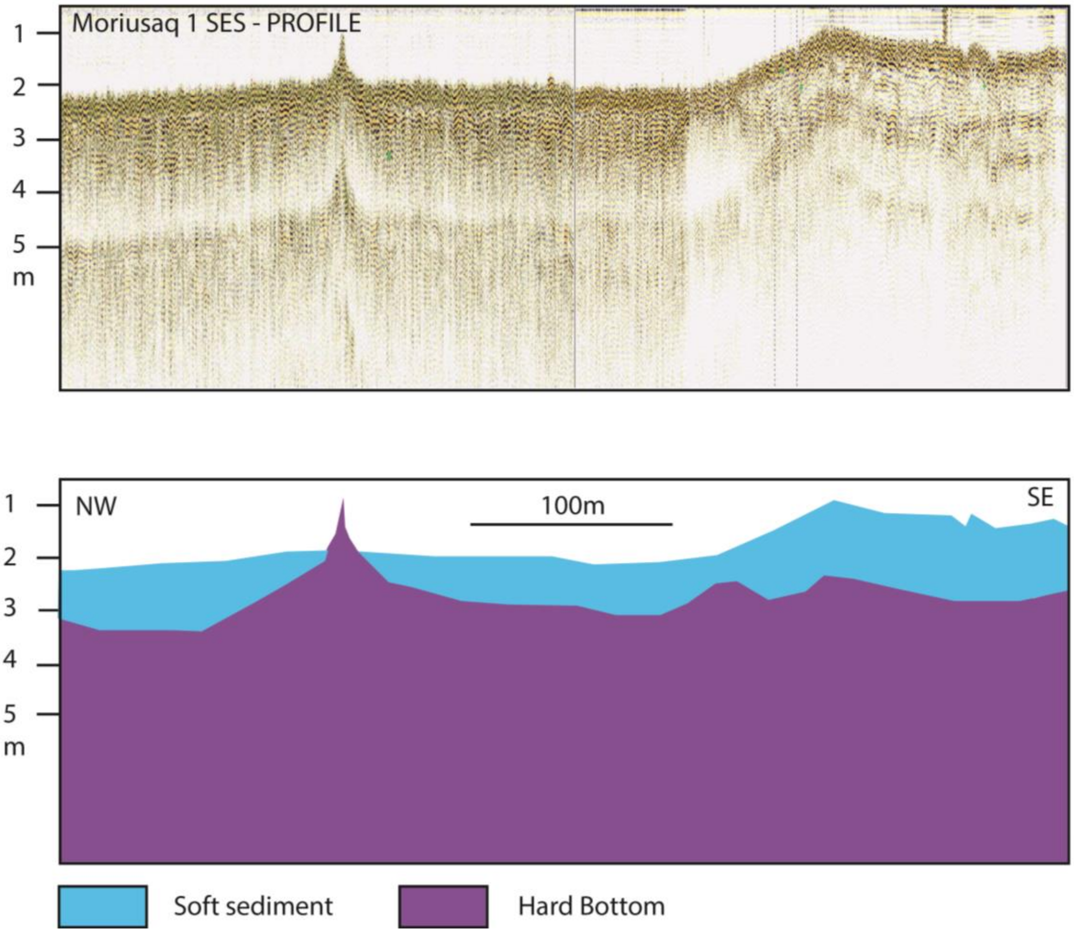

Figure 12. SES2000 profile Moriusaq 1 and interpretation of seismic units.

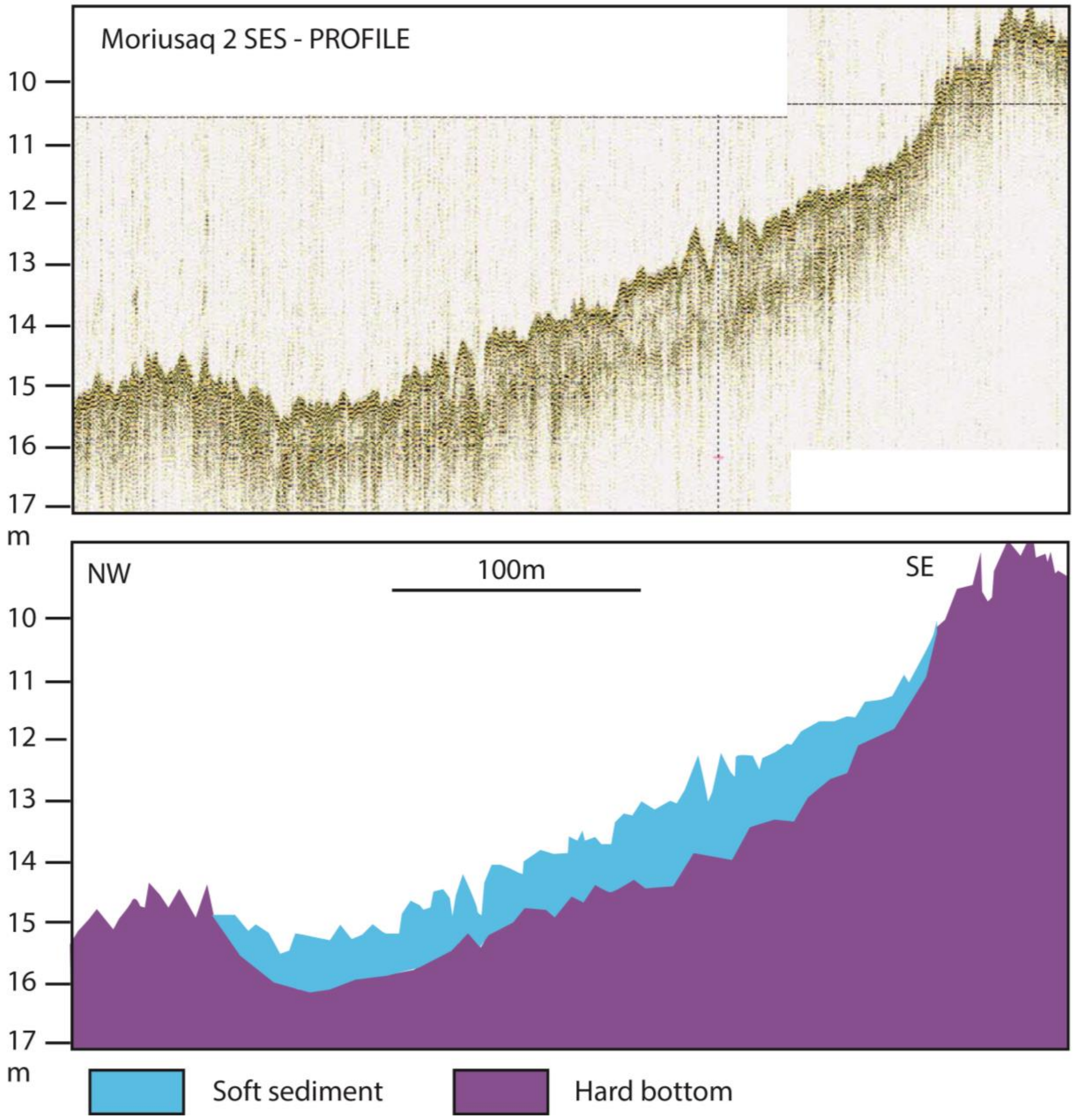

Figure 13. SES2000 profile Moriusaq 2 and interpretation of seismic units.

5.2 Potential black sand resources in area 2a based on the SES2000 data

In the shallow marine part of Iterlak Delta, the SES2000 sediment echosounder was not able to penetrate the soft sediments to depths of more than a few metres (Figures 14 and 15). As a consequence, the thickness map based on the 2015 boomer data, has not been updated.

The SES 2000 data gives however more detailed information of the uppermost few meters as illustrated in Figure 15, where the shallow part of the delta front (0 – 5m below sea level) shows internal stratified reflectors that can be correlated to vibrocore information.

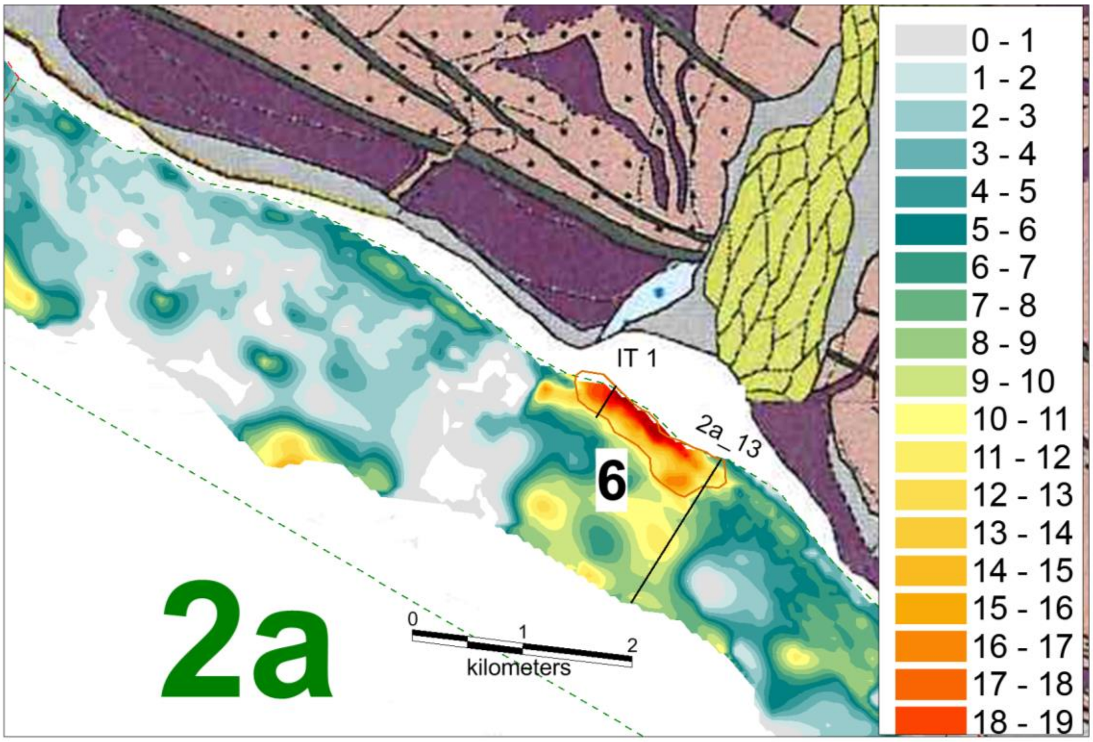

Figure 14. Location of SES2000 mapped area (Orange polygon) and 2015 Boomer mapped potential resource thickness in area 2a.

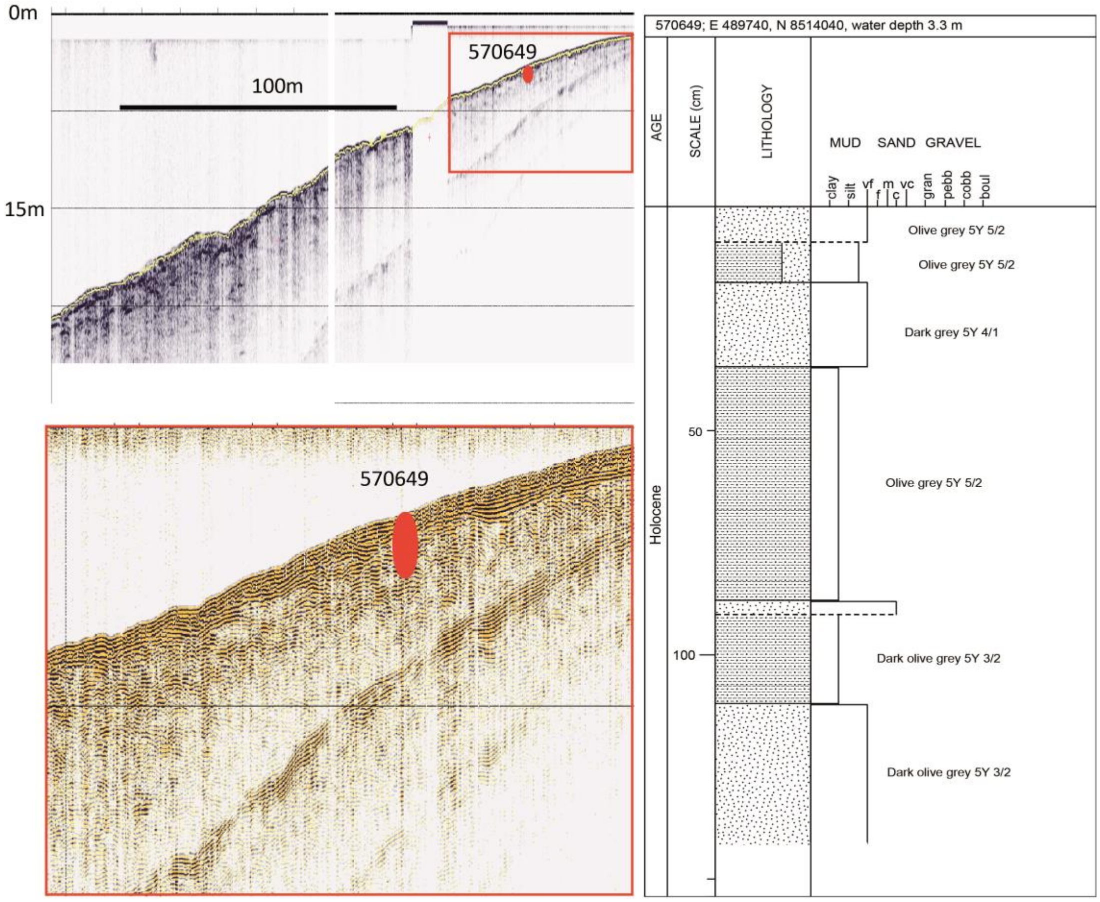

Figure 15. C-boom profile 2a_07 and interpretation of seismic units. For details see appendix B3 and location Figure 19.

Another example of the additional information that can be extracted from the SES2000 profiles, compared to the boomer data from 2015, is illustrated in figures 16 and 17.

Boomer profile 2a_13 (Figure 16) is located in the eastern part of Iterlak Delta front and shows a rather uniform 3 – 5m thick sediment unit on top of the Sedimentary Bedrock. The internal reflection pattern of the sediment unit shows only faint stratification.

However, the high resolution SES2000 profile example in Figure 17 shows that at water depths of more than 14m a very hummocky internal reflector pattern characterises the data. This is believed to be related to repetitive stranding of icebergs and ploughing of the seabed.

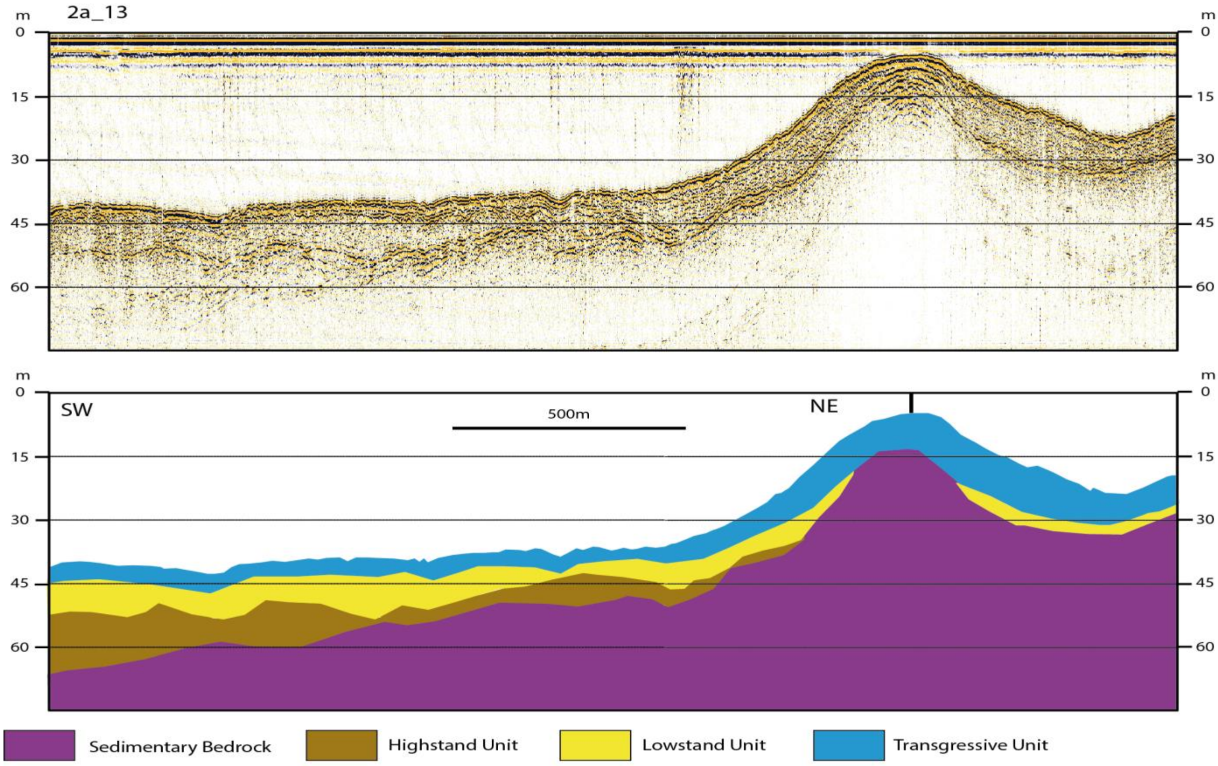

Figure 16. C-boom profile 2a_13 and interpretation of seismic units.

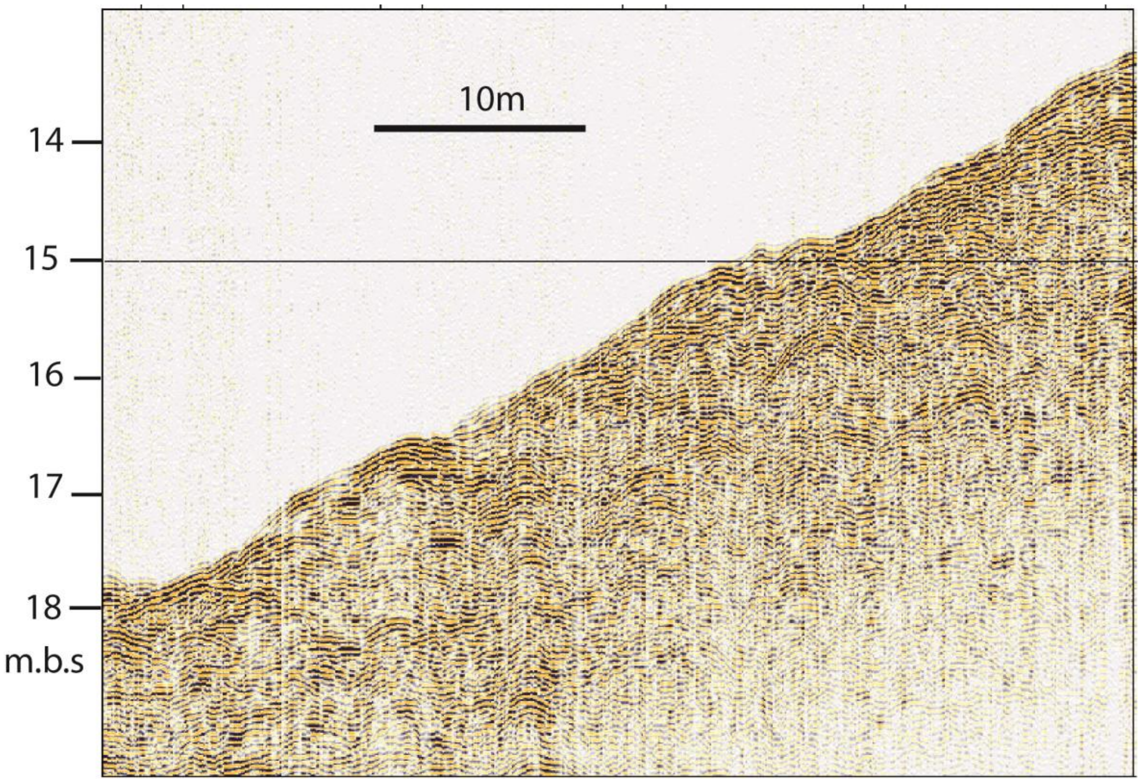

Figure 17. Example of SES2000 sediment echo sounder data at water depths greater than 14 m.

6. Conclusions

The overall conclusions of SES 2000 survey conducted in 2016 are:

- Detailed near coastal shallow bathymetric data has been collected with an overlap on 2015 data
- 5 areas of soft sediment with minor volumetric potential were identified close to Morisuaq. An additional area of soft sediment was identified in Iterlak delta.

- A shallow sill (>1m) is observed at the entrance to Mourisaq Bay, while the shallow zone of >5m water depth in general only represents few hundred meters along the coastline.

- At Iterlak a very steep delta front was mapped. Here, the bathymetry increased from 0.5 – 10 m within a distance of about 200m.

- Mourisaq Bay acts as a small sediment trap. Four additional pocket shaped basins were observed at water depths of more than 10 m. The very uneven surface of the soft sediment surface at water depths of more than 10m suggests that icebergs have ploughed the sediment.

- In Iterlak Delta the SES2000 sediment echo sounder was not able to penetrate the soft sediments to a hard bottom.

- The SES 2000 data gives however more detailed information of the uppermost few meters as example internal stratified reflectors that can be correlated to vibrocore information.

- At water depths of more than 14m a very hummocky internal reflector pattern is characteristic. This is believed to be related to repetitive stranding of icebergs and ploughing of the seabed.

7. References

Flemming, K. & Lambeck, K. 2004, Constraints on the Greenland ice sheet since the Last Glacial Maximum from sea-level observations and glacial-rebound models. Quaternary Science Reviews, **23**,1053-1077.

Jensen, J.B. and Rödel L. G. 2015: Thule Black Sand offshore mapping. Sea-floor bathymetry, boomer profiling and grab sampling. GEUS Report 2015/74.

8. Digital data delivery

In addition to the report the following will be delivered:

- Survey lines in MapInfo GIS format utm zone 19 wgs84
- Bathymetric X,Y Z data in meters below corrected for tidal effects in ASC format.
- Bathymetric Grid in Vertical mapper GRD file format utm zone 19 wgs 84.
- Thickness X,Y, Z data in meters ASC format
- Soft sediment thickness Grid in Vertical mapper GRD file format utm zone 19 wgs 84.