GEOLOGICAL SURVEY OF ESTONIA

Geophysical studies of seabed on cable route from Finland to Estonia (in Estonian waters)

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Cover photo: View from Kakumäe harbour.

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Geophysical studies of seabed along cable route from Finland to Estonia (in Estonian waters)

Sten Suuroja PhD
Anu Veski MSc
Kalle Suuroja PhD

Lead of workgroup Sten Suuroja
Director of Geological Survey of Estonia Alvar Soesoo

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Abstract

Sten Suuroja, Anu Veski, Kalle Suuroja. **Geophysical studies of seabed along cable route from Finland to Estonia (in Estonian waters). Geological Survey of Estonia, Rakvere, 2018.**

The geophysical studies of seabed were made on the planned cable route from Kakumäe Peninsula to the border of the Estonian Exclusive Economic Zone (EEZ). Survey was carried out using two different system of sub-bottom profiles (20–50 kHz UHF Chirp and 2–9 kHz LF Chirp). Totally 32 (4x8) survey profiles were performed within the studies, *ca* 51 km in the Estonian waters and Exclusive Economic Zone. Meridata MDCS (MDCS data acquisition systems) and MDPS (MDPS data processing and interpretation software) software was used for the data collection and interpretation.

Contents

Introduction

The current study is compiled on the order of the Lilaco Offshore Ltd (001 SURVEY E-FINEST; 2.07.2018). The seabed construction conditions were studied geophysically along the planned cable route between Kakumäe Peninsula and the border of the Estonian Exclusive Economic Zone (EEZ). The investigation area was determined by Lilaco Offshore Ltd. Data was collected from pre-determined area on Estonian waters – Estonian territorial and Exclusive Economic Zone (EEZ) in July 2018. The survey was made using Lilaco Offshore's survey boat in July 2018.

The aim of investigations was to determine the distributions of different sediment layers and bedrock morphology along the pre-determined cable route vertically and laterally. Two different sub-bottom profiler systems were used for acoustic-seismic studies. The low-frequency Chirp with frequency 2–9 kHz was used for 'deeper penetration' and ultra-high frequency 20–50 kHz was used for higher resolution of layer of soft sediments. The lateral distribution of the sediments was determined basing on multi-beam back-scatter data. Meridata MDCS (Data Acquisition Systems) software was used for data collection and Meridata MDPS (Data Processing and Interpretation Software) software was used for data interpretation. The Quaternary deposits (till, sand and gravel, clay, mud) cover most of the seabed area across the Gulf of Finland. The thickness of soft deposits varies from a thin to up to 50 m in thickness. On the northern part of study area the bedrock (crystalline basement) outcrops are prevailing on the shallow areas.

The Finnish Coordinate Reference System (ETRS98-TM35FIN) and the Mean Water Level (MWL) were used for data projections.

1. Methods

1.1. Geophysical profiling

The geophysical profiling was carried out using two types of acoustic-seismic sub-bottom profiles (*Chirps*). For the deeper penetration was used 'low-frequency' Chirp with range 2 to 9 kHz and for better resolution was used ultra-high frequency Chirp with range 20 to 50 kHz. According to common principle that the higher frequencies of operation provide the highest resolution but are limited in amount of penetration in sediments. The lower frequencies provide more penetration, but less resolution respectively.

The acoustic energy transmitters and receivers were mounted to the vessel hull on stern outside of the vessel propeller water.

The data of both instruments were recorded using Meridata MDCS (Data Acquisition Systems) Sofware in specific file format (*HFC and *LHC accordingly to UHF Sub-bottom profiler and LF Sub-bottom profiler datasets).

UHF Sub-bottom profiler 20–50 kHz

According to specification of the Meridata company description this equipment gives the ultimate layer resolution ca 3 cm indensely varved fine sediments can be obtained using the 20–50 kHz UHF Chirp transducer. The current system is able to penetrate soft sediment (mud, clay, ultra fine sand).

LF Sub-bottom profiler 2–8 kHz

By the Meridata company description this equipment gives the layer resolution better than 20 cm. The method gives penetration through the soft and sandy sediment layers. In current study the method gives penatration up to surface of the till and bedrock.

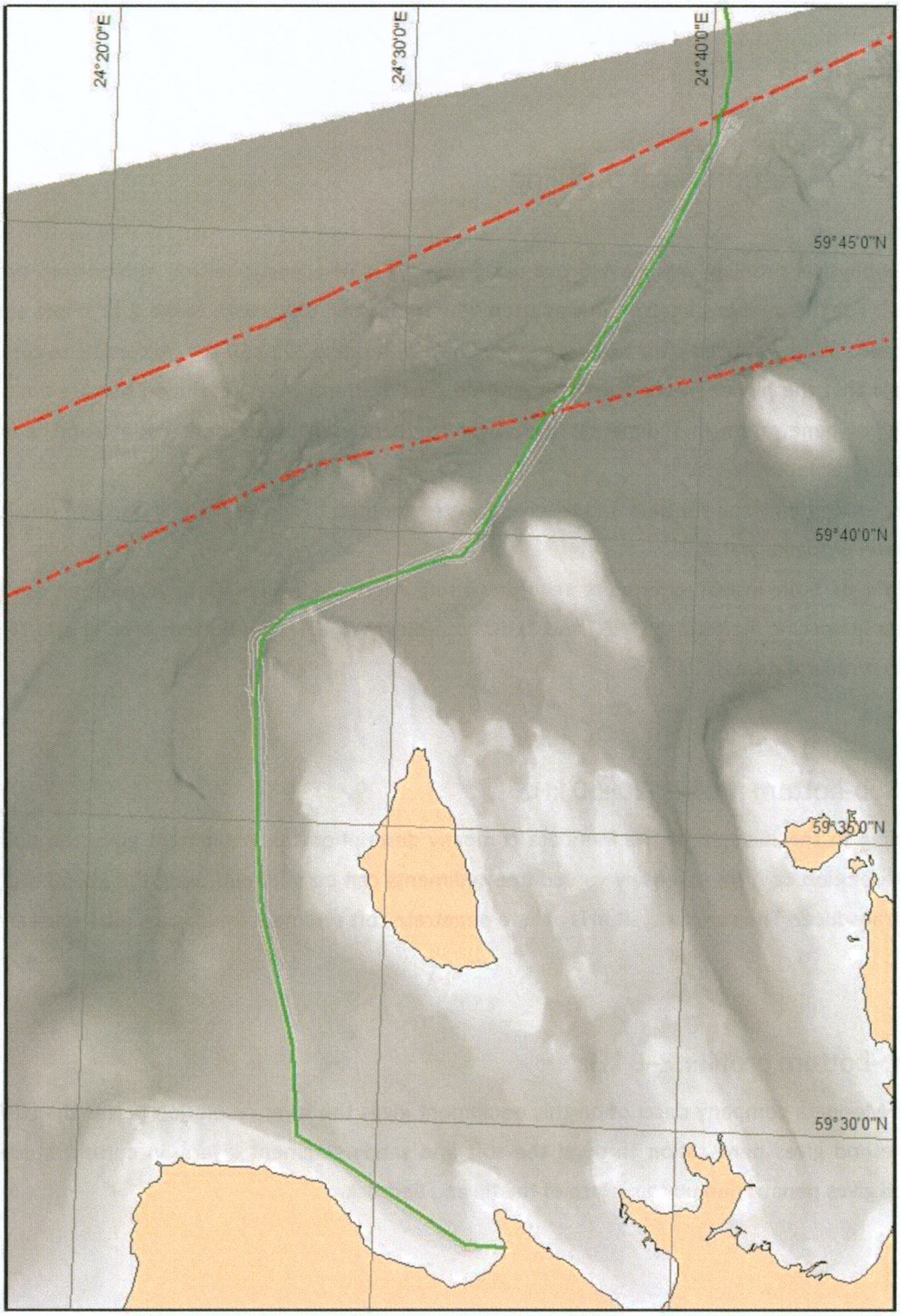


Figure 1.1.1. Cable route area in Estonian waters between Kakumäe peninsula and Estonian Economic Zone. Location of profiles.

1.2. Data processing

Meridata MDCS (Data Acquisition Systems) was used for the data collecting. The data from both instruments were recorded using Meridata MDCS (Data Acquisition Systems) Sofware in specific file format (*.HFC and *LHC accordingly to UHF Sub-bottom profiler and LF Sub-bottom profiler datasets).

Meridata MDPS (Data Processing and Interpretation Software) was used for the sub-bottom profile data interpretations. The recorded survey raw data was transferred into the sounding database with the Finnish Coordinate Reference System (ETRS98-TM35FIN) projection. For sensor configures were used same inputs as determined in MDCS datasets.

Seven acoustic complexes were determined according to acoustical properties of rocks and deposits. These complexes mostly coincide with the litostratigraphical units. Interpreted acoustical complexes (layers) are:

- Crystalline bedrock;
- Sedimentary bedrock (Lower-Cambrian (Tiskre formation) and Blue clays (Lükati and upper part of Lontova formations); Ediacaran silt- and sandstones (Kroodi formation);
- Diamicton (till);
- Firm (varved) clay (Baltic Ice Lake sediments);
- Soft clay (Yoldia, Ancylus Lake, Lithorina sea sediments);
- Mud (Limnea sea sediments);
- Sand and silt (recent sedimentation)

The following speed values for units were considered in calculations:

- ✓ Water column: 1450 m/s
- ✓ Crystalline bedrock: ca 5000 m/s
- ✓ Diamicton (till): 1700 m/s
- ✓ Firm clay (Baltic Ice Lake sediments): 1600 m/s
- ✓ Soft clays (Yoldia, Ancylus, Lithorina): 1500 m/s
- ✓ Mud (recent sedimentation, Limnea sea sediments): 1500 m/s
- ✓ Sand, silt (recent sedimentation): 1550 m/s

The multibeam echosounder backscatter data mosaic image was used for determining lateral boundaries of sub-bottom profiles interpretation data.

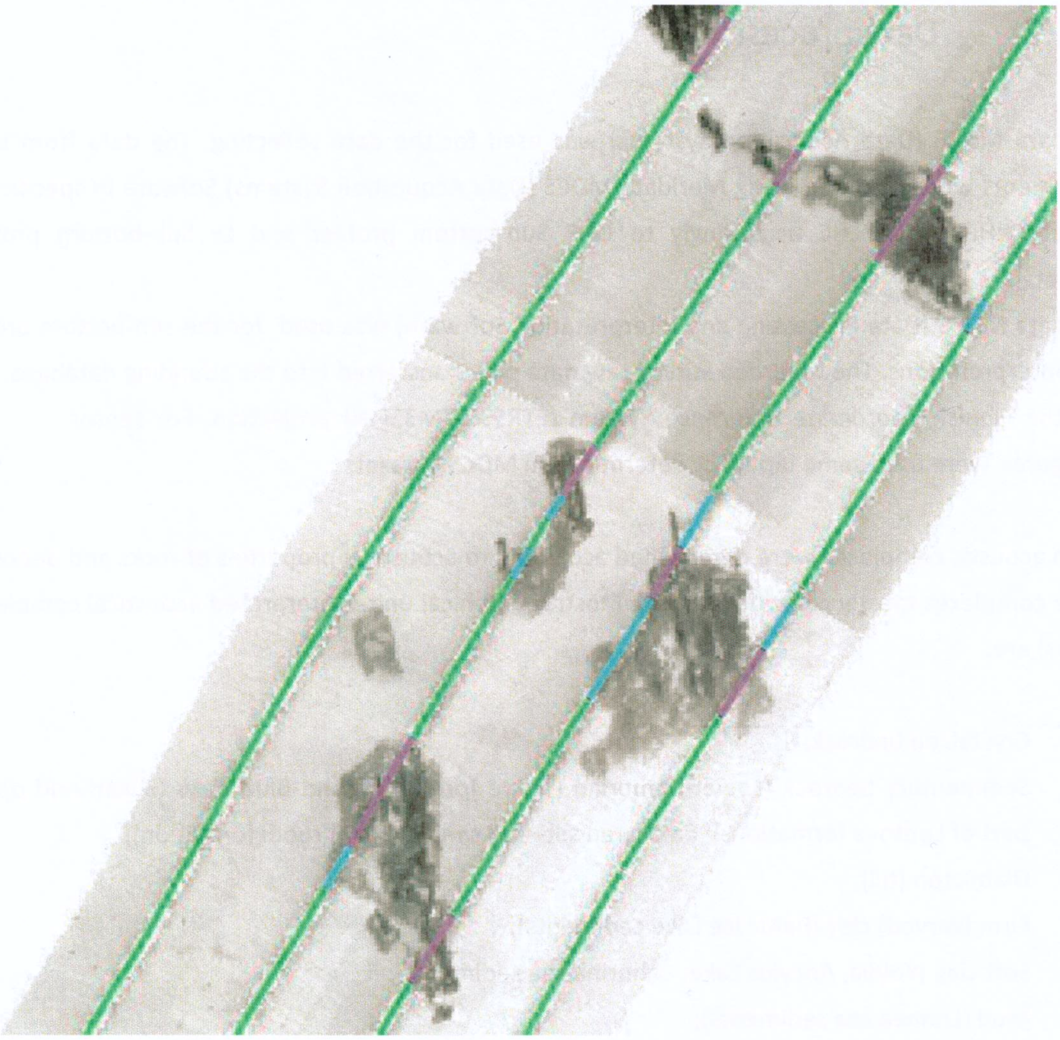


Figure 1.2.1. The multibeam echosounder backscatter data mosaic image of the seabottom (northward of Uusmadal) with interpreted Chirp lines. Purple – crystalline basement, blue – firm clay, green – mud.

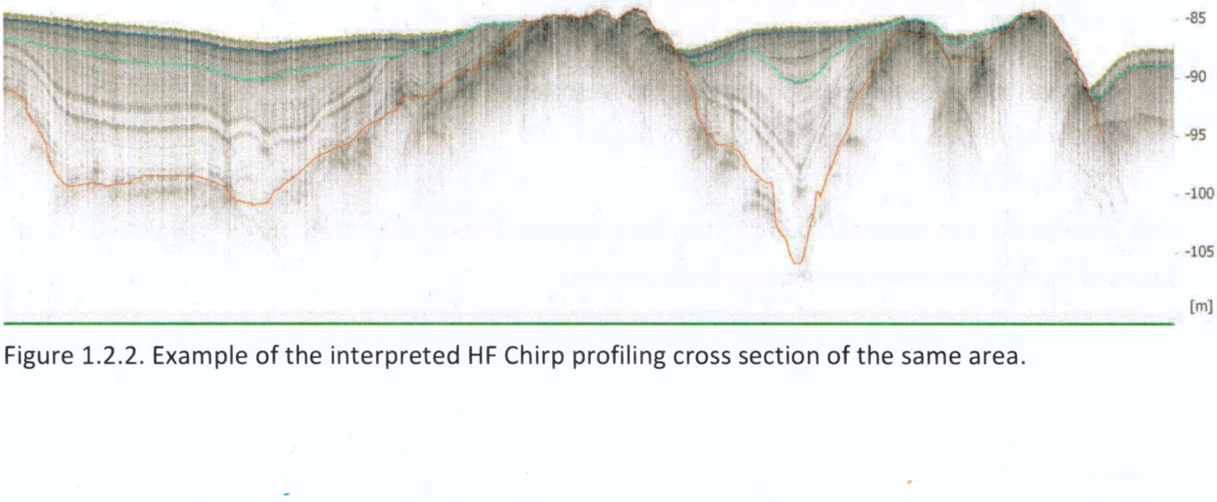


Figure 1.2.2. Example of the interpreted HF Chirp profiling cross section of the same area.

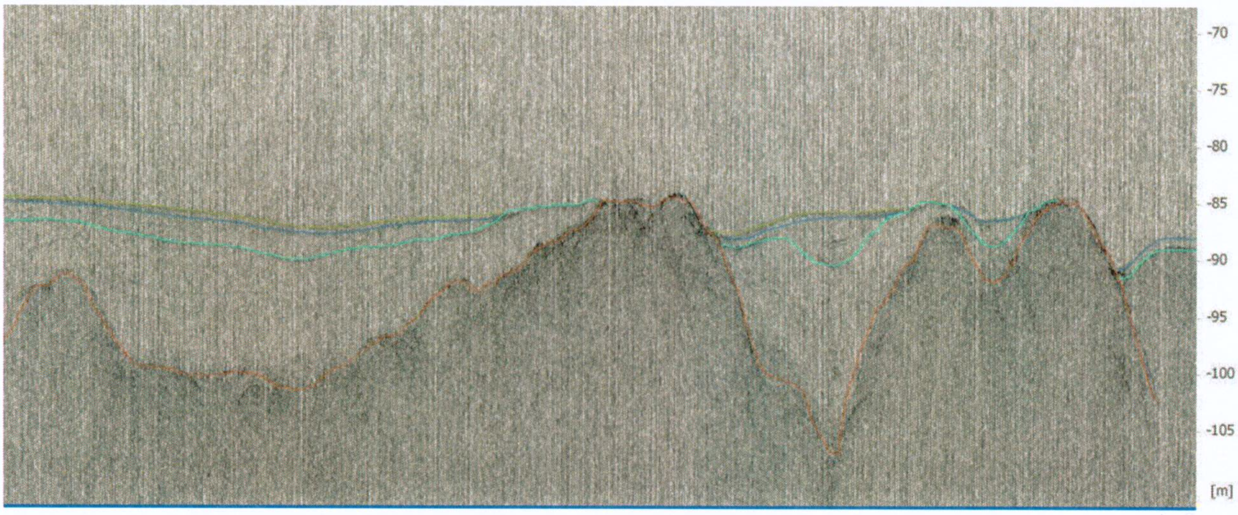


Figure 1.2.3. Example of the interpreted LF Chirp profiling cross section of the same area.

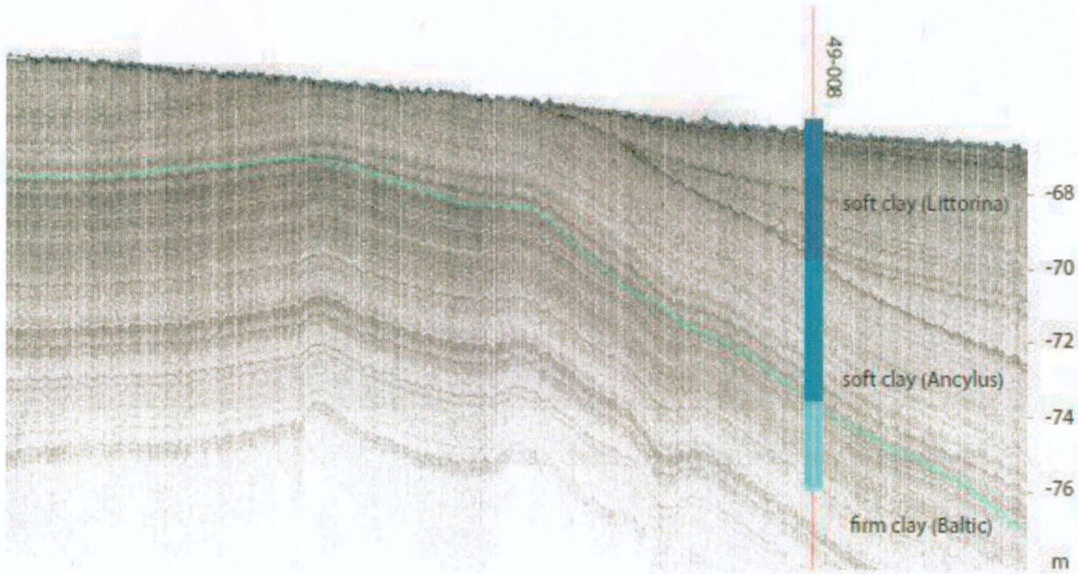


Figure 1.2.4. Example of the HF Chirp profile image comparing with gravity coring data of previous investigations of Finnish Gulf (Talpas *et al* 1994). Sampling point 49-008.

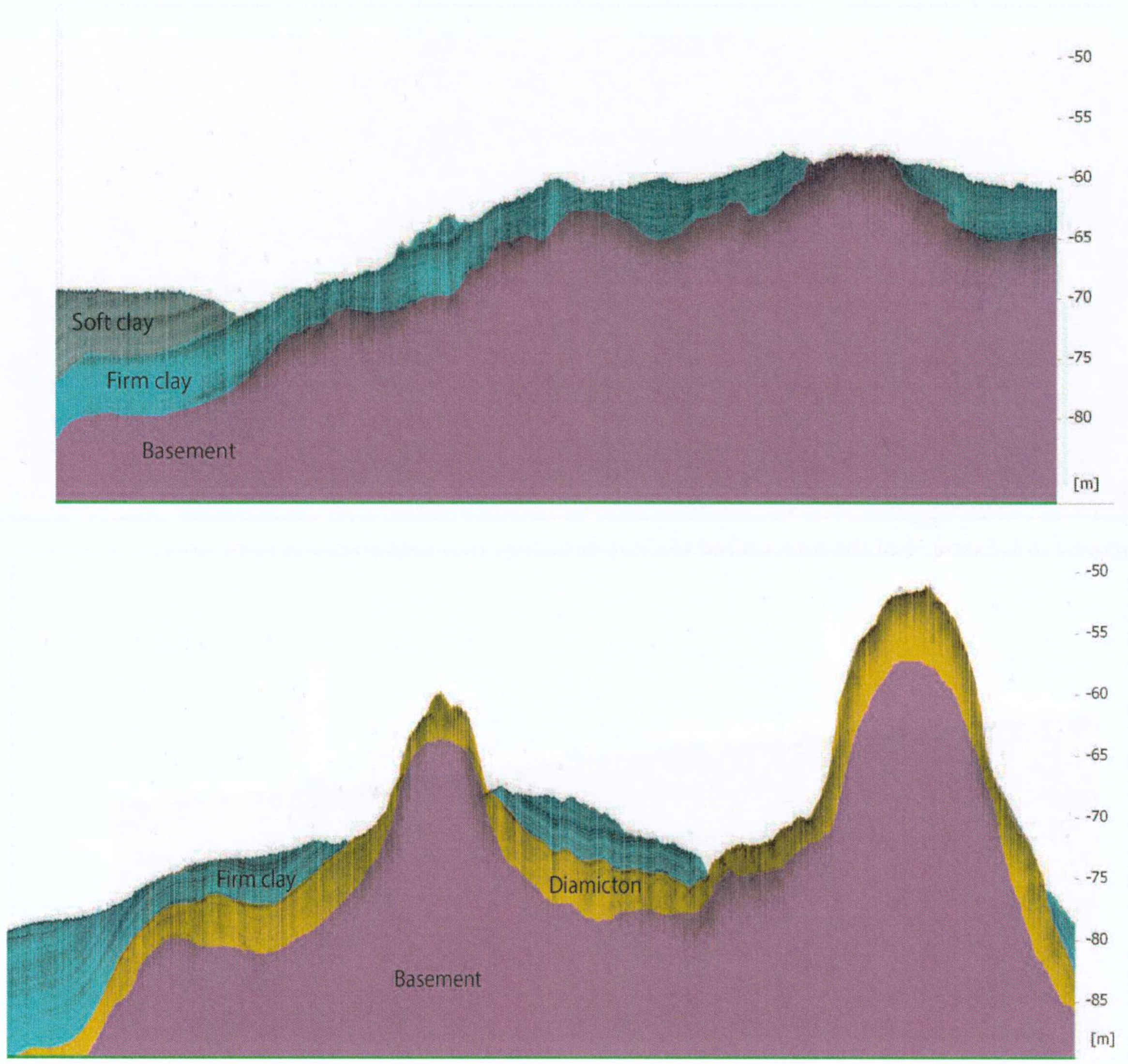


Figure 1.2.5. Examples of the interpreted HF Chirp data images.

1.3. Digital Output

All Chirp lines were interpreted with surface material. Chirp line that was closest to the planned cable route was chosen to interprete the whole profile.

All interpreted data layers were exported as single profile into ASCII file as X, Z coordinate file with multiple Z level values (for each interpreted material layers). For the data density was used interval 1 m.

Interpreted Chirp data with surface material for all Chirp lines was exported as Meridata .cb4 files.

Interpretation layers and boundaries of the materials (based on back-scatter data) were exported as MD .cb4 files.

Sea charts were exported into Autocad DXF file format.

2. Geological setting of the cable route zone in its Estonian segment

The study area is located at the border of the East European Platform and the Fennoscandian Shield. Geological section consists of two principal elements in the platform area (i.e. Estonian coast): the Precambrian crystalline basement and sedimentary cover. The sedimentary cover comprises rocks belonging to the Ediacaran (Vendian) and Cambrian systems (bedrock), and loose Quaternary deposits. The sedimentary cover in the Kakumäe area reaches up to 140 metres in thickness. Bedding in the sedimentary cover is close to horizontal (in average, dipping southwards 2–3 m/km), where some linear dislocations may occur.

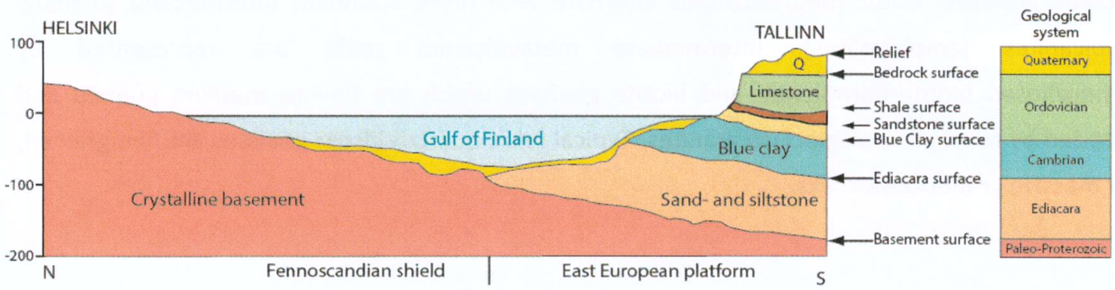


Figure 2.1. A simplified geological north-south cross-section through the Gulf of Finland.

The Quaternary deposits cover practically the whole area. Their thickness varies between some tens of centimetres up to 150 meters in buried valleys (154 m in well no. F167 on Mähe). Kakumäe–Kopli buried valleys are up to 150 m deep and can be observed from northwest to southeast. Similar buried valley is stretched between Naissaar Island and Uusmadal shallow. Buried valleys are filled with up to 150 m thick layer of Quaternary deposits (till, silt, sand and gravel).

The thickness of Quaternary deposits outside the buried valleys varies from 1 to 60 m on the sea bottom (56 m in well no. 120 on Naissaar). They consist of up to five strata (from top to bottom): recent deposits (mud) – up to 5 m; post-glacial deposits (Yoldia, Ancylus, Lithorina soft clays) – up to 20 m; late-glacial (Baltic Ice Lake) deposits (firm/varved clays) – more than 20 m; glacial deposits (diamicton) – up to 10 m.

The Cambrian system is represented mainly by its lower series – Lykati and Lontova formation (thickness *ca* 90 m), which consists mainly of blue clays. The complex is covered by quaternary deposits and is not exposed in the seabed.

The Ediacaran system is represented mainly by weakly cemented sand- and siltstones (*ca* 60 m in thickness). The complex is covered by quaternary deposits and is not exposed in the seabed.

The Precambrian crystalline basement is represented by different complexes of Palaeoproterozoic (Orosirian 1.88–1.98 Ga) metamorphic rocks. The crystalline basement has been subjected to intense denudation during pre-Ediacaran time. Therefore, the crystalline basement is covered by a 2–20 m thick weathering crust under the sedimentary rock cover. The weathering crust is absent in the sea bottom areas. There are only postglacial deposits cover the crystalline basement, and the surface of the crystalline basement is uneven (such as *roche moutonnée* features). The crystalline basement is exposed in the limited areas – ca 1,5 km westward of Uusmadal. From 5 km northward of Uusmadal until the border of Estonian Economic Zone there are various smaller outcrops of crystalline basement.

The crystalline basement is characterized by the stratified Jägala complex of intercalacting sillimanite-cordierite and biotite gneisses, felsic, intermediate and mafic metavolcanites, and leucocratic gneisses. Acidic metavolcanites alternate with more abundant intermediate to mafic metavolcanites (amphibolites). Intermediate metavolcanics rocks are represented by metamorphosed biotite-hornblende and biotite gneisses which are fine to medium grained and migmatized by microgline-plagioclase granites. Typical felsic quartzfeldspar gneisses are fine grained, rather massive granoblastic rocks.

Conclusion

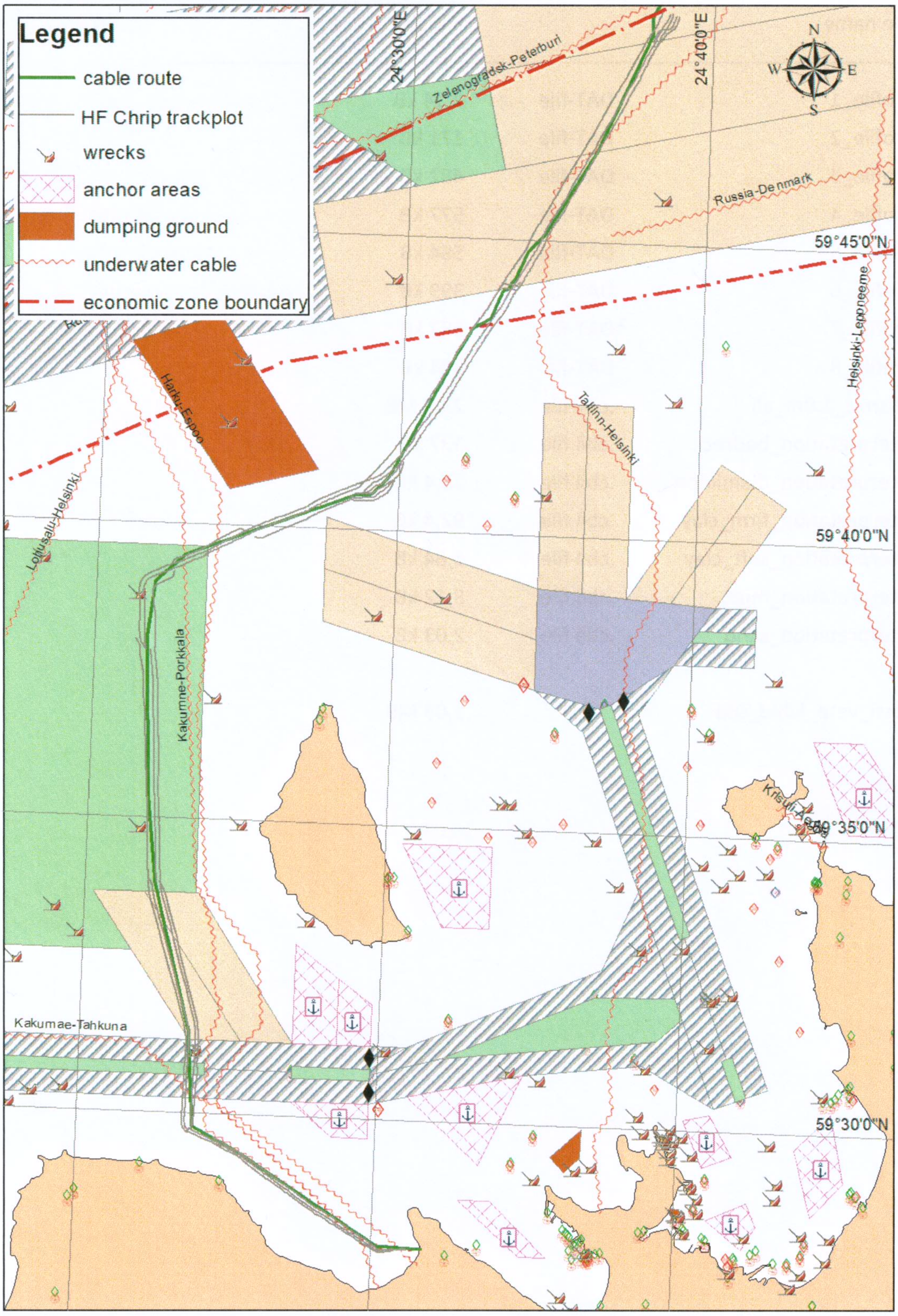
The possible cable route is located mostly on post-glacial soft and firm clays. The total thickness of post-glacial soft and firm clays is 10–20 m and up to 25 m in the buried valleys. The hard crystalline basement metamorphic rocks are outcropping on limited areas on the top of *roche moutonnée* (sheepback) features from 5 km northward of Uusmadal until the border of Estonian Economic Zone. The slopes of the features are sporadically covered by moraine layer.

Northwest of Naissaar (on the turning point) the cable route is crossing several till ridges laying on the crystalline basement.

References

A. Talpas, J. Kask jt. 1994. Balti mere šelfiala geoloogiline kaardistamine lehtedel O-34-VI,O-34-XII,O-35-I,II. EGF 4860.

Appendix 1. Sea chart data



Appendix 2. Data files

File name		File size
Profile_1	DAT-file	2,14 kB
Profile_2	DAT-file	171 kB
Profile_3	DAT-file	482 kB
Profile_4	DAT-file	577 kB
Profile_5	DAT-file	584 kB
Profile_6	DAT-file	399 kB
Profile_7	DAT-file	587 kB
Profile_8	DAT-file	384 kB
Seismic_1.0m_all	.cb4 file	23,8 MB
Interpretation_bedrock	.cb4 file	137 kB
Interpretation_diamicton	.cb4 file	18,4 kB
Interpretation_firm_clay	.cb4 file	92,4 kB
Interpretation_soft_clay	.cb4 file	1,64 kB
Interpretation_mud	.cb4 file	8,12 kB
Interpretation_sand	.cb4 file	2,03 kB
Eesti_vete_kihid_DXF		1,03 MB