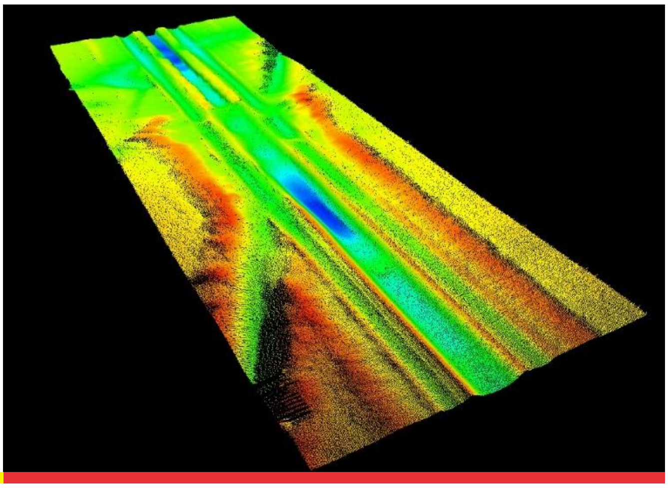
GEOPHYSICAL DEEP 2D SEISMIC SURVEY REPORT

104087-ENN-MMT-SUR-REP-WPC2D
REVISION A| FOR USE
JUNE 2023

ENERGINET



ENERGY ISLANDS - NORTH SEA

GEOPHYSICAL DEEP 2D & UHRS SURVEY FOR OFFSHORE WIND FARM AND ENERGY ISLAND

NORTH SEA
NOVEMBER 2022

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REVISION HISTORY

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ABBREVIATIONS AND DEFINITIONS

AOI	Area of Investigation
AVO	Amplitude Variation with Offset
BSB	Below Seabed
BSU	Base Seismic Unit
CDP	Common Depth Point
CM	Central Meridian
DTU21	Denmark Technical University 2021
DPR	Daily Progress Report
DTM	Digital Terrain Model
DVR90	Dansk Vertikal Reference 1990
EEZ	Exclusive Economic Zone
EI	Energy Island
EPSG	European Petroleum Survey Group
ETRS	European Terrestrial Reference System
GEUS	Geological Survey of Denmark and Greenland
GIS	Geographic Information System
GMSS	Geo Marine Survey Systems
GNSS	Global Navigation Satellite System
GRS80	Geodetic Reference System 1980
GS	Grab Sample / GeoSurveys
HD	High Definition
HF	High Frequency
HiPAP	High Precision Acoustic Positioning
HR	High Resolution
HRS	High Resolution Seismic
HV	High Voltage
INS	Inertial Navigation System
IHO	International Hydrographic Organisation
LF	Low Frequency
LGM	Late Glacial Maximum
m	Metres
ms	milliseconds
MAG	Magnetometer
MBES	Multibeam Echo Sounder
MIG	Migrated
MMO	Man Made Object
MSL	Mean Sea Level
MUL	Multiple Attenuated Stack
M/V	Motor Vessel
OWF	Offshore Wind Farm
POS MV	Position and Orientation System for Marine Vessels
POSPac	Position and Orientation System Package
PPS	Pulse Per Second

QC	Quality Control
SBET	Smoothed Best Estimated Trajectory
SBP	Sub-Bottom Profiler
SOG	Speed Over Ground
SOW	Scope of Work
STW	Speed Through Water
SVP	Sound Velocity Profile
SVS	Sound Velocity Sensor
TWT	Two Way Time
UHRS	Ultra High Resolution Seismic
USBL	Ultra Short Baseline
UTC	Coordinated Universal Time
UTM	Universal Transverse Mercator
UXO	Unexploded Ordnance
WP	Work Package

EXECUTIVE SUMMARY

AREA OF INVESTIGATION, MMT OWF SURVEY AREA	
INTRODUCTION	
Survey Dates	M/V Deep Helder: 07 to 16 November 2022
Equipment	Multibeam Echo Sounder (MBES), 2 Dimensional-Ultra High Resolution Seismic (2D-UHRS).
Coordinate System	Datum: European Terrestrial Reference System 1989 (ETRS89) Projection: Universal Transverse Mercator (UTM) Zone 32N, Central Meridian (CM) 9°E
GEOLOGY	
The MMT OWF survey area is located within a complex geologic setting. The interpreted Ground Model is based on 39 horizons that correspond to erosive surfaces and make up the base of the seismostratigraphic units.	
U05 (Holocene)	The uppermost unit (U05) is occasionally present on top of U10 and consists of fine-grained mobile sediments.
U10 (Holocene)	Unit (U10) is present at the seabed for the majority of the survey area and consists of marine Holocene sand deposits.
U20	Infills of small basins and channels, likely in a restricted marine-tidal setting, partially associated to a subaerial fluvial system.
U25	Fine sediments: fine sands-silts (?) deposited in a relatively low-energetic setting, possibly a glacial lake or a transgressive estuary. Subdivided into subunits U25-Te and U25.
U30	Fining-upward sequence, likely fluvial in nature.
U35	High energy fluvial bedforms (flash floods?), interpreted to consist of gravel and sands with enclaves of coarser-grained clasts, fining-upward (?)
U40	Drainage system of glaciar melt back from the north, and outwash plains, with variable sediment content. Glacial period (Weichselian?)
U60	High energy fluvial bedforms (flash floods?) comprising mainly sands with gravel and silt (?).
U70	Glaci-fluvial deposition, in a proglacial, sub-aerial environment (reoccupation of tunnel valley depressions by fluvial systems?), with variable sediment content. Glacial period (Weichselian?). Subdivided into subunits U61, U62, U69 and U70.
UKSA	Deformed deposits of variable sediment content. Glaciotectonism (Weichselian?). Subdivided into subunits U71, U72, and UKSA.
U85	High energy fluvial (possibly outwash plain?), composed of mainly sands with gravel and silt (?). Organic-rich muds at the base.
U90	Fan delta deposits comprising mainly sands and fine sediments.
UKSB	Deformed deposits of variable sediment content. Glaciotectonism (Saalian?):
Luna	Sandy-silty sediments deposited in a near-shore marine environment, during the Upper Miocene. Subdivided into subunits Intra Luna (PQ-01) and Luna.
Marbæk	Deposits of slope to shoreface sands, of Upper Miocene in age. Subdivided into subunits Intra Marbæk (PQ-02), Intra Marbæk (PQ-03), and Marbæk.
Gram	Muds and silt to fine-grained sands, deposited in a marine environment during the Lower Miocene. Subdivided into subunits Intra Gram (PQ-04) and Gram.
Lark	Thick succession of muds/clays intercalated with sand beds, generally prograding towards SW, deposited in a prodeltaic setting. Oligocene – Lower Miocene in age. Subdivided into subunits Intra Lark 05, Intra Lark 04, Intra Lark 03, Intra Lark 02, Intra Lark 01, and Lark.
Rogaland	Succession of muds, mudstones, and marlstones, deposited in a shallow open marine environment.

AREA OF INVESTIGATION, MMT OWF SURVEY AREA	
Ekofisk	Succession of marly limestones/chalk, deposited in a marine environment. Ekofisk is of Danian (Lower Paleocene) age, and it corresponds to the upper section of the Chalk Group.
Maastrichtian	Interval of chalk strata, deposited in a marine environment during the Upper Cretaceous. Lower section of the Chalk Group.
Cromer Knoll	Marine marls and clays, filling a post-rift basin of Lower Cretaceous age.
Kimmeridge	Rift basin fill consisting of clays. Deposited in the Upper Jurassic,
Base Seismic Unit	Jurassic and older (?) sedimentary sequence – variable sediment content.
SEABED AND SUB-SEABED HAZARDS	
Sediment deformation	Areas of tectonization/deformation have been observed predominately within UKSA and UKB. The origin of these deformed deposits is interpreted to be mainly glacial tectonics, but locally may be related to salt tectonics and gravitational deformation. Deformed deposits have geotechnical significance given their complex stress/load histories. Faults are present ubiquitous within the subsurface, and do not greatly affect sediments younger than U20.
Buried channels and tunnel valleys	Buried channels and tunnel valleys occur throughout the site. The more relevant erosive events that carved these channels correspond to the unit bases of U40, U70, UKSA, and UKSB. A potential geo-hazard related with the channels is the sharp contrasts in physical properties between the channel infill and surrounding units.
Tills	Tills likely comprising coarser material, such as boulder, cobbles, and gravel lags may be present in glacial deposits in the site. These are potential hazards and may constitute a constraint on offshore operations.
Fluid flow and gas features	Presence of gas was detected at the top of the seismic unit Lark, limited to an area where IDA-1 well is located. No other unambiguous seismic anomalies suggesting the presence of detectable gas in the subsurface were identified in the UHRS and SBP data.

1 | INTRODUCTION

1.1 | PROJECT INFORMATION

Energinet are developing the proposed Offshore Wind Farm (OWF) and Artificial Island in the Danish sector of the North Sea (Figure 1). MMT have been contracted to provide geophysical survey (including 2D UHRS) and grab sampling in the east part of the 3 GW OWF project site (the MMT OWF survey area).

The project includes various survey areas which are detailed in Table 1 and shown in Figure 1.

The scope of work was divided into separate Work Packages (WP), detailed in Table 2.

This report covers Work Package C – Deep 2D Seismic Survey, Artificial Island Area of Investigation.

Table 1 Survey area details.

Description	Comment
3 GW OWF Project Site	Complete project site area, including both the western and eastern zones.
3 GW OWF Area of Investigation	MMT OWF survey area (eastern part of the 3 GW OWF project site)
Artificial Island Area of Investigation	10 km x 10 km area around the Artificial Island Project Site
Artificial Island Project Site	2.5 km x 2.5 km focused area for detailed development of the Artificial Island.

Table 2 Work Package descriptions.

	Description	Survey Area
Work Package A – Offshore Windfarm	Geophysical site survey	MMT OWF survey area (zone east).
Work Package A – Energy Island	Geophysical site survey	Artificial Island Area of Investigation.
Work Package B	Magnetometry box surveys	Within the MMT OWF survey area.
Work Package C	Deep 2D seismic survey	Artificial Island Area of Investigation.
Work Package D	UXO survey and inspection	Artificial Island Project Site.

A summary of the project details is presented in Table 3.

Table 3 Project details.

CLIENT:	Energinet
PROJECT:	Energy Islands - North Sea
MMT SWEDEN AB (MMT) PROJECT NUMBER:	104087
SURVEY TYPE:	Geophysical Deep 2D Seismic
AREA:	Danish North Sea
SURVEY PERIOD:	November 2022
SURVEY VESSELS:	M/V Deep Helder
MMT PROJECT MANAGER:	Karin Gunnesson
CLIENT PROJECT MANAGER:	Martin Bak Hansen

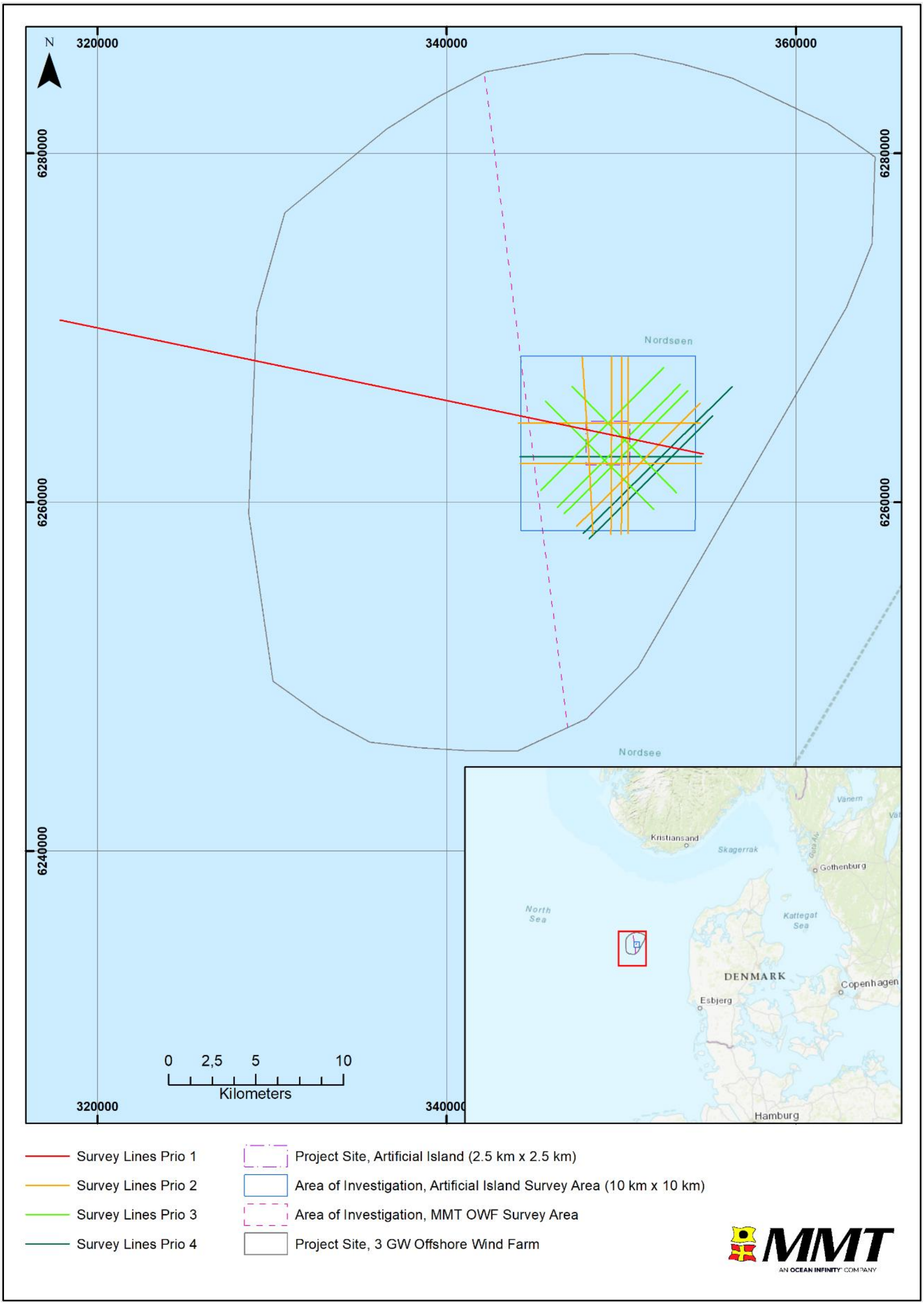


Figure 1 Overview of project survey areas and WPC survey lines to be performed.

1.2| SURVEY INFORMATION

The deep 2D seismic survey work scope at the Artificial Island Area of Investigation comprises of several tasks including:

- Project Management and Administration
- MBES Survey
- Deep 2D UHRS Survey

The MMT OWF survey area investigation covers an approximately 526 km2 area acquired by MMT and is located roughly 90 km offshore the coast of Jutland. Within the MMT area of investigation for the OWF, a 10 km x 10 km area of investigation is reported separately with particular relevance for the Artificial Island survey area and Artificial Island Project Site (2.5 km x 2.5 km).

This report covers the geophysical deep 2D seismic survey near the 10 km x 10 km Artificial Island Area of Investigation acquired by MMT and Geosurveys Ltd. The processing report is provided in Appendix B|.

1.3| SURVEY OBJECTIVES

The deep 2D seismic survey consist of a multi-channel / multi-source seismic system able to map the entire sub-surface succession, from the seabed down to the top chalk surface underneath the location for the future artificial energy island. The top chalk surface is located at a depth between 1200-1600 m in the area.

The acquired data will be the base for a seismic inversion analysis to determine the rock properties and elastic parameters of the sedimentary succession down to the top chalk surface.

Receiver arrays (both ends) and seismic sources must be positioned with GNSS antennas to determine their accurate location during acquisition.

1.4| SCOPE OF WORK

To mitigate the potential risk of settlements underneath the future location of the artificial energy island, a 2D seismic survey with a penetration depth down to the Top Chalk surface (1200-1600 m below the seafloor) is performed. The acquired seismic data will be used for a seismic inversion analysis to determine the elastic parameters of the sedimentary succession between the seabed and the Top Chalk surface.

1.4.1| DEVIATIONS TO SCOPE OF WORK

During the geophysical deep 2D seismic survey there was one deviation from the original SOW (Table 4).

Table 4 Deviations from the SOW.

Date	Description	Decision/Result/Conclusion
2022-11-15	Reduced Scope of work	Due to forecasted poor weather, Energinet decided to survey only 5 of the originally planned survey lines.

1.5| PURPOSE OF DOCUMENT

This report details the interpretation of the geophysical deep 2D seismic survey at the Artificial Island Area of Investigation.

The report summarises the conditions within the survey area with regards to subsurface geology. Geo-hazard identification and interpretation has also been considered.

All data obtained from the geophysical deep 2D seismic survey have been compared against existing geotechnical borehole information, in order to ground-truth the survey results.

Separate reports include the Artificial Island Area of Investigation Geophysical Survey Report and Operations Reports. A full list of reports is given in Table 5 (Reference Documents).

1.6| REPORT STRUCTURE

The results from the geophysical deep 2D seismic survey campaign are presented in two separate reports.

- Geophysical Survey Report (this report) – Includes a chart series of results. A full chart list is provided within Appendix A|.
- Operations Report – Covering the field operations conducted.

The Geophysical Survey Report chart series includes:

- Overview Chart
- Trackline Chart
- Sub-Seabed Geology Profile Charts (34 across the site)

1.6.1| GEOPHYSICAL SURVEY REPORT

Attached to the report are the following appendices:

- Appendix A| List of Produced Charts
- Appendix B| 2D UHRS Processing Report
- Appendix C| Inversion Interpretation Report

1.6.2| CHARTS

The MMT Charts describe and illustrate the results from the survey. The charts include an overview chart with a scale of 1:50 000, and Trackline chart with a scale of 1:50 000 and longitudinal profile charts with a horizontal scale of 1:15 000 and a vertical scale of 1:2 000.

A list of all produced charts is presented in Appendix A|.

OVERVIEW CHART

Shows coastlines, EEZ, large scale bathymetric features and area of investigations.

TRACKLINE CHARTS

The actual performed survey lines are presented.

SUB-SEABED GEOLOGY PROFILE CHARTS

A total of 5 profile charts shows the interpretation of the horizons and structures across the site.

1.7| REFERENCE DOCUMENTS

The documents used as references to this report are presented in Table 5.

Table 5 Reference documents.

Document Number	Title	Author
1100046209	Proposed Artificial Island Danish North Sea Geoarchaeology and geological desk study	From Client
104087-ENN-MMT-QAC-PRO-PROJMANU	Project Manual	MMT
104087-ENN-MMT-MAC-REP-DH	Mobilisation and Calibration Report – Deep Helder	MMT
104087-ENN-MMT-SUR-REP-OPREPWPC	Operations Report WP-C	MMT
103783-ENN-MMT-SUR-REP-SURVWPA	Geophysical Survey Report - WP-A	MMT
103783-ENN-MMT-SUR-REP-SURWPAEI	Geophysical Survey Report - Artificial Island Area of Investigation	MMT
103783-ENN-MMT-SUR-REP-SURWPB	Geophysical Survey Report – WP-B	MMT
103783-ENN-MMT-SUR-REP-SURWPD	Geophysical Survey Report – WP-B UXO Survey	MMT
104087-ENN-MMT-SUR-REP-WPDUXO	Geophysical Survey Report – WP-B UXO Inspection	MMT
REP22356-ENERGYISLAND_WPC_PROC_REPORT	UHRS 2D Geophysical Data Processing	GeoSurveys

1.8| AREA LINE PLAN

The survey line spacing and minimum parameters in the MMT OWF survey area are detailed in Table 6.

A breakdown of the survey lines is provided in Table 7.

The performed deep 2D seismic survey lines are shown in Figure 2.

Table 6 Survey line parameters.

GEOPHYSICAL SURVEY SETTINGS	SCOPE
Investigation area	Ca. 6.25 km^2 (plus tie line to existing well)
Line spacing 2D UHRS Main Lines	Various
Line spacing 2D UHRS Cross Lines	Various

Table 7 Survey line breakdown.

SURVEY LINE BREAKDOWN	SCOPE	ACTUAL SURVEYED
2D UHRS Survey Lines	188.6 km/ 16 Lines	90.4 km/ 5 Lines
2D UHRS Totals	**188.6 km/ 16 Lines**	90.4 km/5 Lines

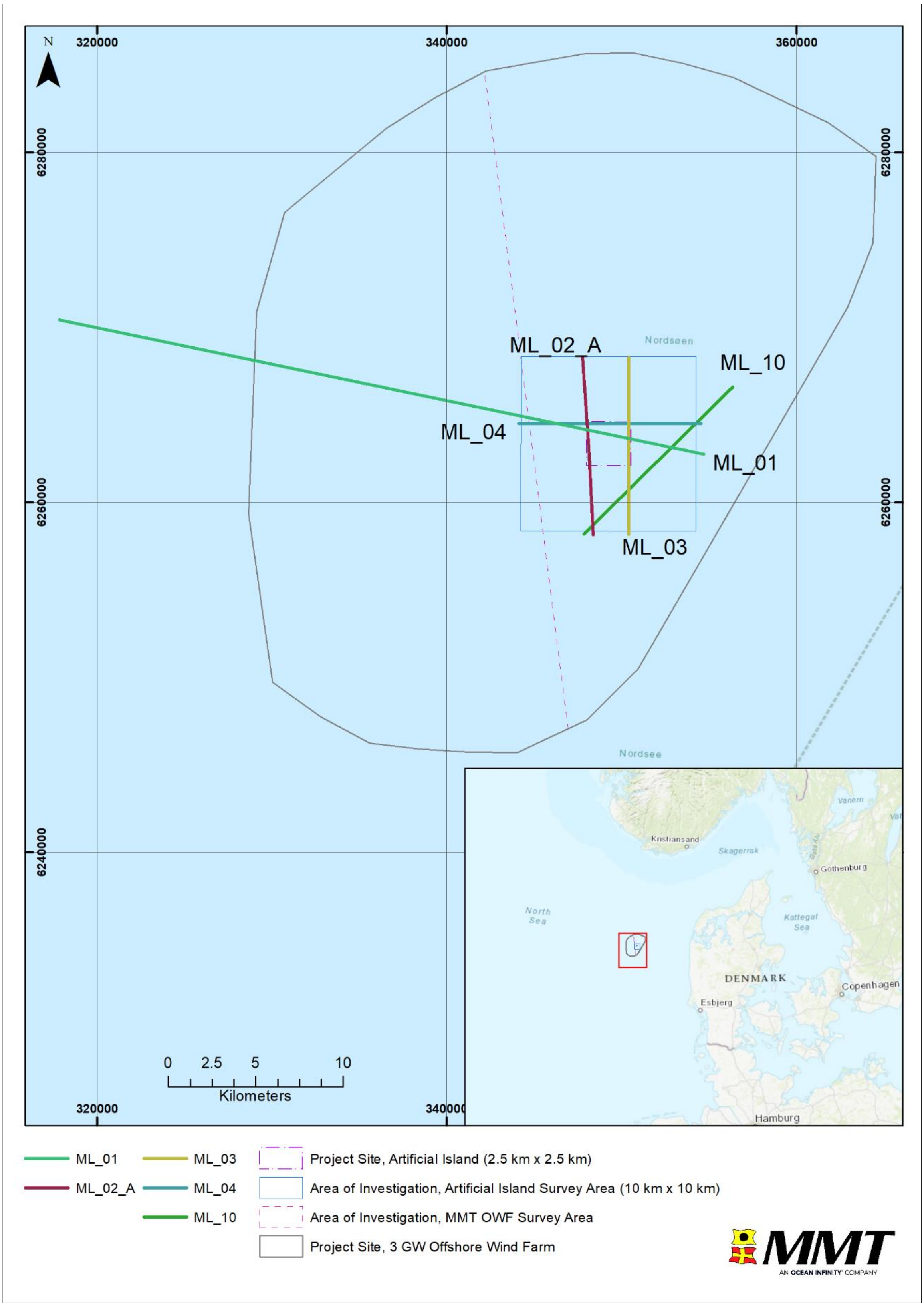


Figure 2 Performed survey lines – 2D UHRS.

2| SURVEY PARAMETERS

2.1| GEODETIC DATUM AND GRID COORDINATE SYSTEM

2.1.1| ACQUISITION

The geodetic datum used for raw MBES during acquisition are presented in Table 8. The geodetic datum used for 2D UHRS and Airgun equipment during acquisition are presented in Table 9.

Table 8 Geodetic parameters used during acquisition for MBES.

Horizontal datum: WGS 84	
Datum	World Geodetic System 1984
ESPG Datum code	6326
Spheroid	World Geodetic System 1984 (7030)
Semi-major axis	6 378 137.000m
Semi-minor axis	6 356 752.3142m
Inverse Flattening (1/f)	298.257223563

Table 9 Geodetic parameters used during acquisition for 2D UHRS and Airgun equipment.

Horizontal datum: ETRS89	
Datum	ETRS89
Ellipsoid	GRS80
Semi-major axis	6 378 137.000 m
Semi-minor axis	6 356 752.3142 m
Inverse Flattening (1/f)	298.257222101
Unit	International metre

2.1.2| PROCESSING

The geodetic datum used during processing and reporting are presented in Table 10.

Table 10 Geodetic parameters used during processing.

Horizontal datum: European Terrestrial Reference System 1989 (ETRS89)	
Datum	ETRS89
European Petroleum Survey group (EPSG) Datum Code	25832
Spheroid	GRS80
Semi-major axis	6 378 137.000 m
Semi-minor axis	6 356 752.3142 m
Inverse Flattening (1/f)	298.257222101

2.1.3 | TRANSFORMATION PARAMETERS

The transformation parameters used to covert from acquisition datum (WGS 84) to processing/reporting datum (ETRS89) are presented in Table 11.

Table 11 Transformation parameters.

DATUM SHIFT FROM WGS84 TO ETRS89 (RIGHT-HANDED CONVENTION FOR ROTATION - COORDINATE FRAME ROTATION)	
PARAMETERS	**EPOCH 2022.5**
Shift dX (m)	0.110250
Shift dY (m)	0.067110
Shift dZ (m)	-0.132890
Rotation rX (“)	-0.003543
Rotation rY (“)	-0.014426
Rotation rZ (“)	0.025962
Scale Factor (ppm)	0.003300

In order to verify that the transformation parameters have been correctly entered into the navigation system the following test coordinates were used (Table 12).

Table 12 Test coordinate for datum shift.

UTM Zone	Datum	Easting (m)	Northing (m)	Latitude	Longitude
32	WGS84	-	-	54°59'59.998N	13°29'59.989E
	ETRS 89	787756.3706	6104055.2342	54°59'59.979N	13°29'59.956E

2.1.4 | PROJECTION PARAMETERS

The projection parameters used for processing and reporting are presented in Table 13.

Table 13 Projection parameters.

Projection Parameters	
Projection	UTM
Zone	32 N
Central Meridian	09° 00' 00'' E
Latitude origin	0
False Northing	0 m
False Easting	500 000 m
Central Scale Factor	0.9996
Units	metres

2.1.5 | VERTICAL REFERENCE

The vertical reference parameters used for processing and reporting are presented in Table 14.

Table 14 Vertical reference parameters.

Vertical Reference Parameters	
Vertical reference	MSL
Height model	DTU21

The difference between the vertical height models (DTU21 and DVR90) are given below in Table 15. The average for each 5km MBES grid was compared.

Table 15 Average Height comparison between DTU21 and DVR90.

AVE HEIGHT DTU21 MSL (METRES)	AVE HEIGHT DVR90 MSL (METRES)	DIFFERENCE (METRES)
40.64	40.92	0.28

2.2| VERTICAL DATUM

Global navigation satellite system (GNSS) tide was used to reduce the bathymetry data to Mean Sea Level (MSL) the defined vertical reference level (Figure 3). The vertical datum for all depth measurements was MSL via DTU21 MSL Reduction from WGS84-based ellipsoid heights.

This tidal reduction methodology encompasses all vertical movement of the vessel, including tidal effect and vessel movement due to waves and currents. The short variations in height are identified as heave and the long variations as tide.

This methodology is very robust since it is not limited by the filter settings defined online and provides very good results in complicated mixed wave and swell patterns. The vessel navigation is exported into a post-processed format, Smoothed Best Estimated Trajectory (SBET) that is then applied onto the multibeam echo sounder (MBES) data.

The methodology has proven to be very accurate as it accounts for any changes in height caused by changes in atmospheric pressure, storm surge, squat, loading or any other effect not accounted for in a tidal prediction.

Within the OWF survey area, all positions below the sea surface are referred to as ***depths*** in the results section of this report.

The bathymetric processing software packages EIVA NaviModel and Caris HIPS inherently stores MBES DTMs and sounding data with a positive down depth convention. Report imagery obtained from these packages show the data in this convention.

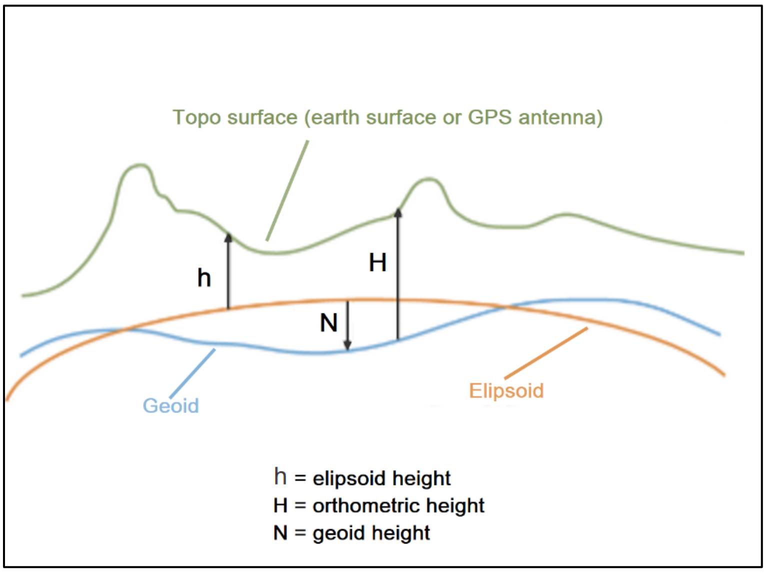


Figure 3 Overview of the relation between different vertical references.

2.3| TIME DATUM

Coordinated universal time (UTC) is used on all survey systems on board the vessel. The synchronisation of the vessels on board system is governed by the pulse per second (PPS) issued by the primary positioning system. All displays, overlays and logbooks are annotated in UTC as well as the daily progress report (DPR) that is referred to UTC.

3| SURVEY VESSEL AND EQUIPMENT

3.1| M/V DEEP HELDER

The survey was conducted by the DP2 vessel M/V Deep Helder (Figure 4). The vessel is fully equipped for survey activities in water depths between 15-250m. The vessel equipment is shown in Table 16.

Figure 4 M/V Deep Helder.

Table 16 M/V Deep Helder equipment.

Equipment	Type
Primary Positioning System	Applanix POS MV 320 with Fugro Starfix.G2 corrections (Horizontal Accuracy <0.10 m [2σ], Vertical Accuracy <0.15 m [2σ])
Secondary Positioning System	Fugro Seastar with XP2 corrections (Horizontal Accuracy 0.10 m [2σ], Vertical Accuracy 0.15 m [2σ])
Gyro and INS System	Applanix POS MV 320
Secondary Gyro	Fugro Starpack GNSS heading
Survey Navigation System	QPS QINSy
Multibeam Echo Sounder (Medium to Shallow Water)	Kongsberg EM2040D (200-400 kHz)
Surface Pressure Sensor	Vaisala Pressure Sensor
Sound Velocity Sensor	Valeport SVX2, deployed over the side Real-time SVS Valeport miniSVS, hull-mounted at the MBES transducers
Passive Acoustic Monitoring System	Seiche 4-channel PAMS

Equipment	Type
Air Gun spread	a) Airgun 120 Cui Mini G array 2 x 20 Cui + 2 x40 Cui Mini G array (120 Cui) b) 2 x 5437 Reavell Compressors + 1 spare (90 scfm) c) 192 channel x 6.25 m Group solid filled HV SEAL system with 4 spare sections, c/w Digicourse 5011 cable levellers plus spares, Partnerplast 800L tail buoy

Equipment	Type
Multi-Channel Ultra High Resolution Seismic (M-UHRS)	a) Triple Source 3 x 800 tips system plus back-up - Ultra hi-res Sparker System 3 x Geo-Spark 2000 XF Series (16 kJ Pulsed Power Supply) – Tuned Configuration – UP to 48KJ total 1 spare unit for redundancy 1 x Triple Geo-Source 800 tips surface towed sparker 3 x 75 m orange HV tow cable for max 40 m offset behind outrigger 1 spare for redundancy 3 x 25 m Deck lead to yellow HV tow cable 4 x 25 m Sea Ground cable 1 x Mini-Trace II as QC system 2 x Geo-Sense single Ch. 8 element Mini-streamer 1 x tool kit plus basic consumables b) 48 channel UHR streamer plus Multi-Trace recorder system plus 100 % back-up 2 x Geo-Sense 48 channel Gel Filled streamer with 3.125 m group interval, 40 m tow lead + lead-in buoy, 12.5 m stretch, 150m active, 12.5 m stretch, rope + tail buoy Multi-Trace 48 channel recording system 2 x Sea Ground cable 2 x source reference hydrophones c/w 100 m tow cable 1 x Multi-Trace for source reference hydrophones 1 x 19” industrial server 1 x Thinkpad back-up 1 x Data duplication/backup system plus specialized software (NAS) 1 X Electrical Winch c) Streamer and sparker positioning 50 % back-up 1` x Lead-in buoy with Dual DGPS c/w HD battery, (1 spare unit for 50 % redundancy) 1 x Tail buoy with dual DGPS c/w HD battery (1 spare unit for 50 % redundancy) 1 x Dual DGPS c/w HD battery pack for the GeoSource 400 Sparker 3 x spare battery packs heavy duty 2x battery chargers 2 x Long Range WIFI station, c/w LAN etc

4| DATA PROCESSING AND INTERPRETATION METHODS

4.1| SEISMIC - 2D UHRS AND HRS

The main goal of 2D ultra-high resolution (UHRS) and high resolution seismic (HRS) data was to provide pre-stack multi-channel seismic data capable to image beyond the pre-mapped Cretaceous chalk layer, down to 1 500 m bellow seabed, using the necessary seismic processing techniques to provide data suitable for amplitude variation with offset (AVO) inversion and seismic quantitative interpretation. In order to reach the main objective, a combined solution with air guns (HRS) and Sparker (UHRS) was used.

Air guns (120 Cui 4 x Mini G. cluster) were used in order to reach down to 1 500 m below seabed at 3 m vertical resolution; whilst a Triple 800 Sparker was used to allow higher resolution in the upper 200 m (vertical resolution between 0.5 and 1 m).

Several seismic data processing techniques were deployed and developed in the scope of this project in order to meet the goals and requirements:

- Pre-stack deconvolution;
- Pre-Stack Demultiple;
- Deghosting tools;
- Interactive Velocity Analysis;
- Pre-Stack Migration.

The subsurface geological interpretation and description is based on the assessment of the 2D UHRS and HRS data acquired within the Energy Island area. A total of 38 horizons were mapped in order to properly capture the subsurface complexity of the geological framework of this site. The Geological Ground Model was defined from the integration of geophysical data acquired for the North Sea East OWF and EI WPC project.

Seismostratigraphic interpretation of the 2D UHRS and HRS data was the basis for the geological ground model presented here. The interpretation approach employed included aspects of sequence stratigraphy, kinetostratigraphy, lithostratigraphy, and seismic facies analysis, in order to provide suitable horizons for AVO Inversion at a later stage (carried out by Solid Ground).

Table 17 summarises the gridding parameters applied for all interpreted horizons to produce surface grids (all grids delivered in the Kingdom Suite project). The selected settings were based on their ability to deliver optimal results (coverage between lines and minimising artefacts and edge effects).

Table 17 Gridding parameters.

Cell Size	5 m
Algorithm	Flex Gridding
Smoothness	6 (scale is 0 to 11)
Search radius	50 m

For full description of and details on the 2D UHRS and HRS processing see Appendix B|.

For full description of and details on the inversion interpretation see Appendix C|.

5| PROCESSED DATA QUALITY

5.1| SEISMIC 2D UHRS DATA QUALITY ANALYSIS

In order to assess the data quality of every acquired line, the following Offline QC processing flow was applied offshore to all lines, along with all external steps (Figure 5).

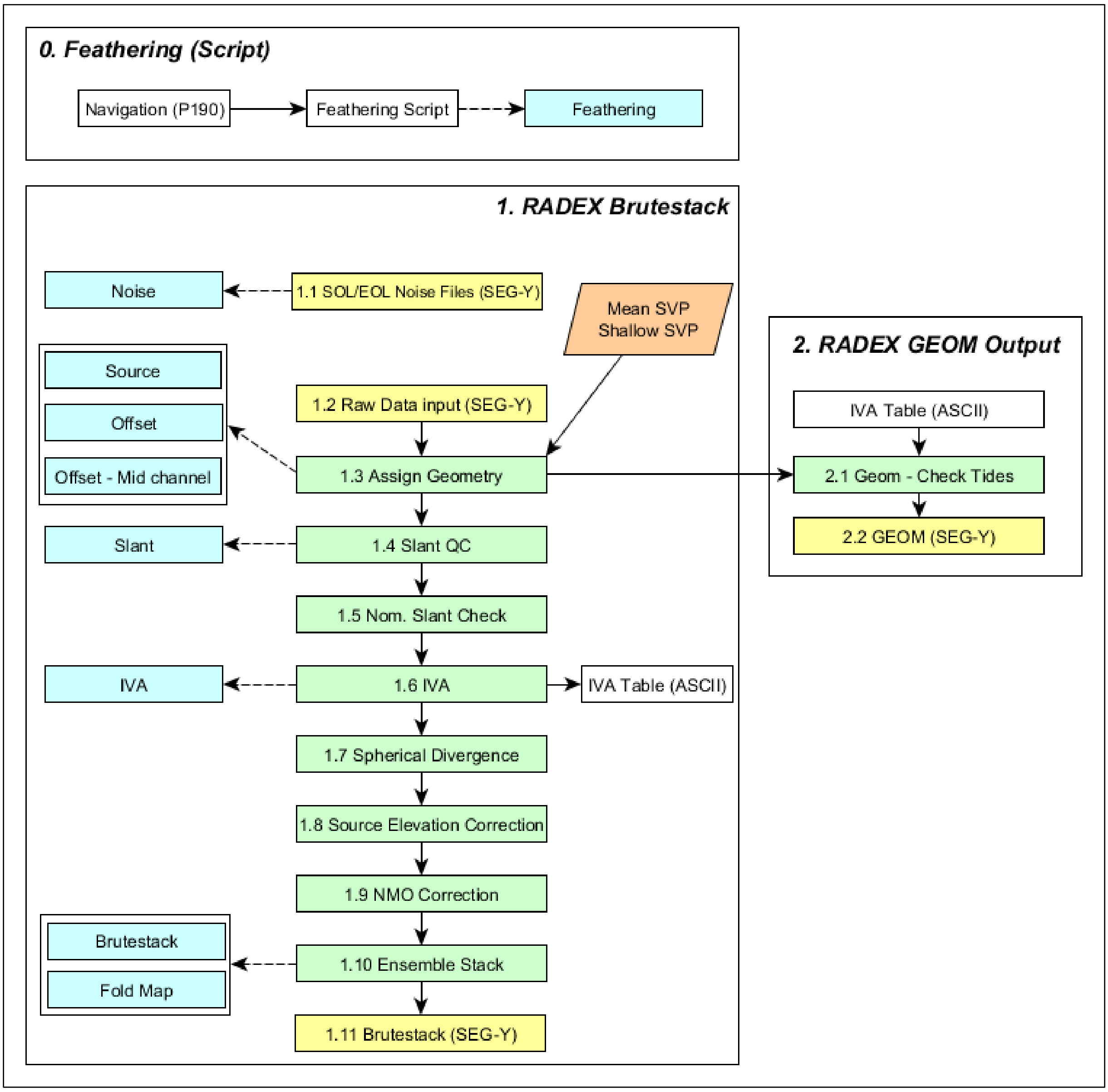


Figure 5 Processing workflow applied to the seismic lines offshore. Green boxes represent the processing steps, blues boxes represent the QC plots, yellow boxes represent the imported and exported SEG-Y data, white boxes represent the intermediate data and the orange box the Sound Velocity Profile (SVP) data.

The UHRS and HRS QC & QA is a seismic processing service that ensures that the acquired UHRS data meets the contracted technical requirements:

- Throughout the survey the data was QC'd and made available for review within 24 hours of completion of survey operations;
- The agreed quality criteria were ensured during the QC/QA of the 2D seismic data in regards to:
  - Coverage;
  - Line keeping;
  - Data resolution;
  - Signal penetration;
  - Signal quality;
  - Feathering;
  - Data fold.

For full description of and details on the 2D UHRS and HRS acquisition and offline QC see the Operations Report.

In addition to the offshore QC/QA, the seismic data underwent a second thorough assessment of the signal quality and geometry at GeoSurveys office in order to ensure data could be successfully processed. These procedures are typically necessary to keep precise control of the static reduction for each seismic profile and overall quality of the final results.

5.1.1| SIGNAL & NOISE ANALYSIS

The seismic data was inspected in shot and trace domain to assess noise types. The most significant types of noise recognized on the data were the following (see Figure 6):

- Vessel noise (blue in Figure 6) - this is a directional noise, that can be filtered using extended processing techniques without major negative impact on the signal.
- Front and tail cable tugging noise - represented in orange and red, respectively, in Figure 6. The front/tail tugging occurs when the front/tail frame is pulled by waves and currents and that creates a low frequency vibration along the streamer. This is a directional noise that can be removed using an F-K filter.
- Burst noise (green in Figure 6) – observed mainly in the UHRS data and in lines acquired in choppier sea due to the streamer surfacing.

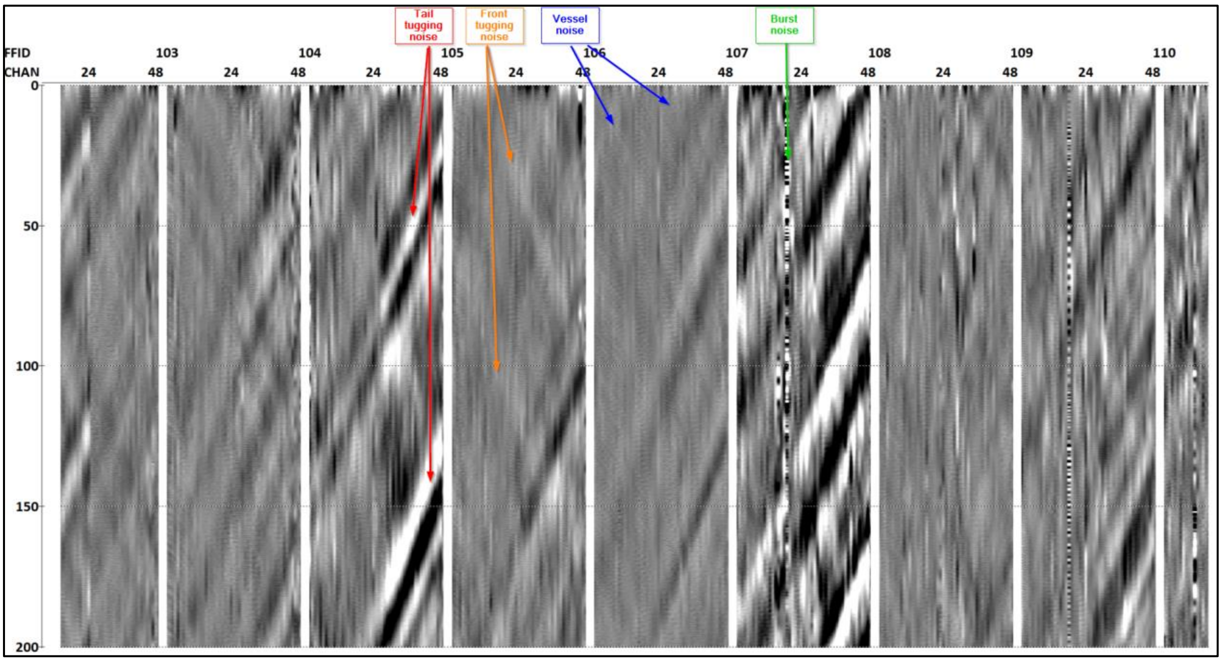


Figure 6 Main noise sources identified in a start of line noise file. Vertical scale in milliseconds. Vessel acoustic noise, bursts, and cable tugging at the front and tail recorded by the M-UHRS streamer.

5.1.2| SOURCE RECEIVER OFFSETS

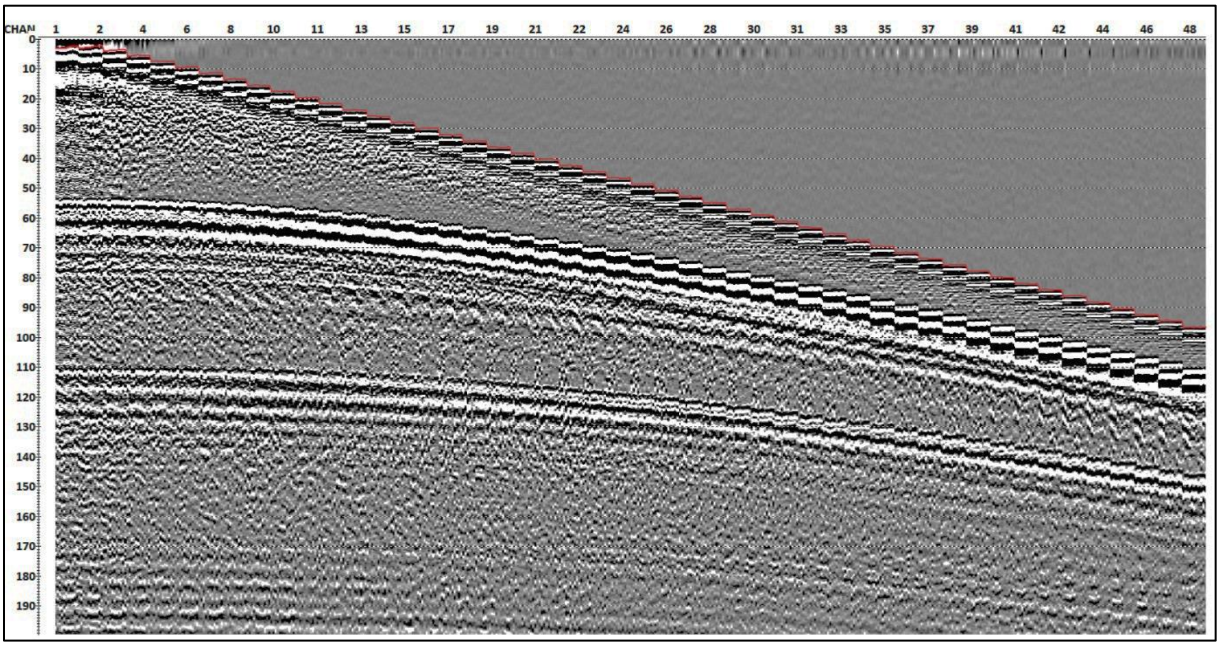
The UHRS source and receiver positions and the relative offsets were calculated using the DGPS antennas located on top of the sparker sources and on the UHRS streamer front and tail buoys. The HRS source and receiver positions were obtained through layback estimations using the vessel antenna coordinates as reference.

The accuracy of the source and receiver positioning was checked by comparing the offsets calculated from the source and receiver positions with direct arrival times (Equation 1). The offsets were estimated using the calculated distance between two points explained in Equation 1 and converted to time by dividing the obtained offset in metres by the measured water sound velocity (the sound velocity in the water was obtained from measured SVPs during the survey).

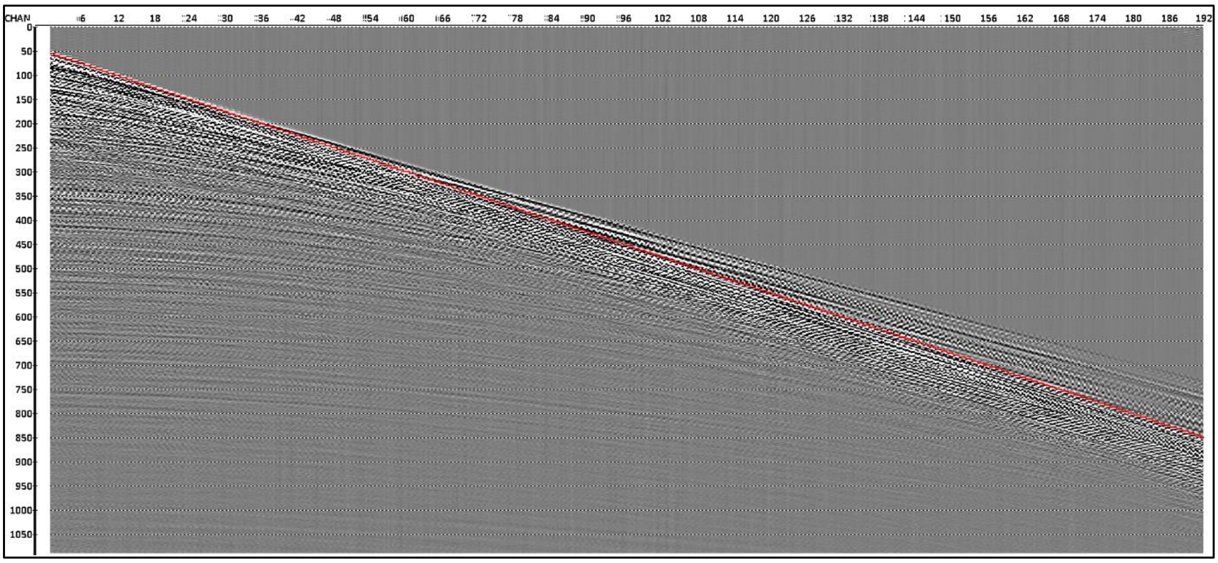
$$\boldsymbol{offset} = \sqrt{(\boldsymbol{Sou\_X} - \boldsymbol{Rec\_X})^2 + (\boldsymbol{Sou\_Y} - \boldsymbol{Rec\_Y})^2}$$

Equation 1 – Equation used for calculating the offsets based on the positioning.

In general, the offsets based on antenna position have a good match with the direct arrival (Figure 7). Occasional mismatch was observed, mainly due to the loss of differential correction on the DGPS antenna, nevertheless the difference between the direct arrival and calculated offsets was reasonable and most of the time below 1 ms.



(a)



(b)

Figure 7 Channel domain showing the calculated offsets for: (a) UHRS (sparker) and (b) HRS (air gun) data. Vertical scale in TWT (ms).

5.1.3| STREAMER GROUP BALANCING

Streamer balance integrity can vary depending on sea conditions, wave motion, vessel steering, surface currents, acquisition velocity, positioning precision and minor modifications of the system geometry during equipment recovery and deployment operations. All these factors may have negative impact on the final data as these effects may add up.

The streamers were balanced for a survey speed of approximately 4.0 knots speed over ground (SOG). Along the streamers, several weights were placed in order to achieve a slant shape for UHRS streamer and a flat configuration for HRS streamer.

The HRS streamer balancing was controlled offshore by the use of nine birds placed along the long streamer and logged every 100 shots.

The UHRS cable balancing was evaluated offshore by a direct observation of the receiver ghost along all channels in a line-by-line basis. At the GeoSurveys office, all the seismic profiles underwent to an onshore QC/QA in order to assess the source and streamer balancing and to ensure that the data could be successfully processed. The seismic profiles were analysed regarding the following motion components of the equipment: source heave, cable heave and cable relative depth.

The source and receiver motion were estimated and analysed for all the UHRS lines (Figure 8). The receiver motion component (green line in Figure 8) is usually smaller than the source motion due to the physical properties (weight and length) of the streamer.

The streamer depth along the line was assessed for all the UHRS lines. Figure 9 shows the streamer depth variation histogram (Figure 9 b) along an arbitrary seismic line (FFID) and for each channel the calculated relative cable depth (Figure 9 a). The streamer depth calculation uses the mean streamer depth as reference value and all the estimations for each channel are referenced to the streamer mean depth (zero value in the histogram). Hence, the histogram showing negative (shallower streamer section) and positive (deeper streamer section) values.

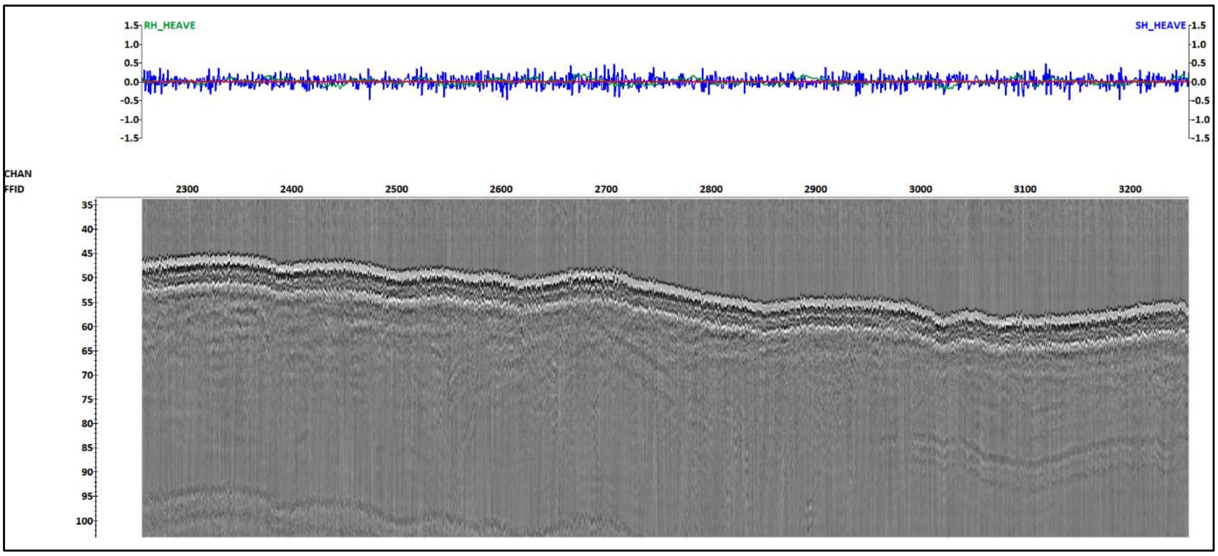
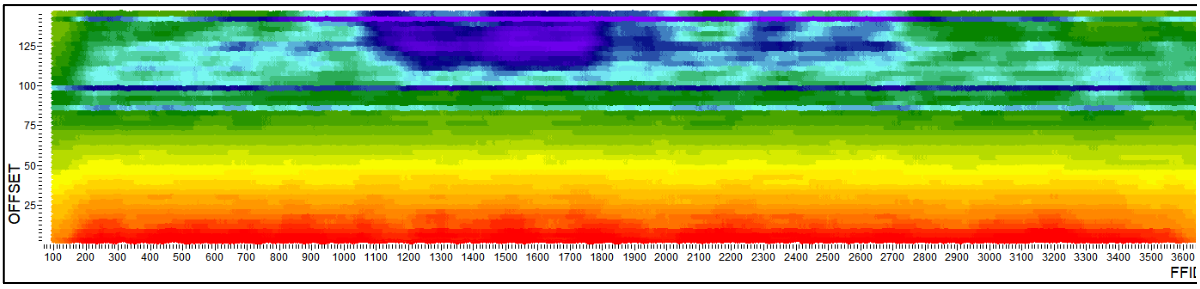
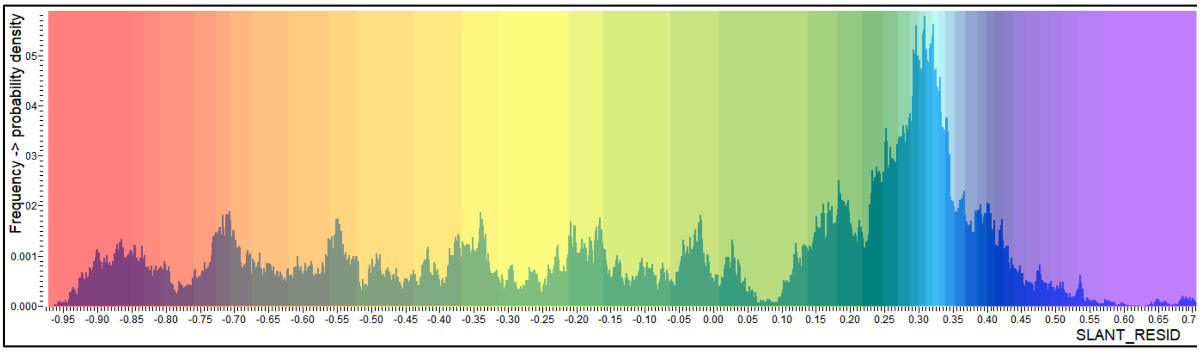


Figure 8 Source and receiver heave along the UHRS profile ML_01_Prio_1: source motion in blue and receiver motion in green. Vertical scales in TWT (ms).



(a)



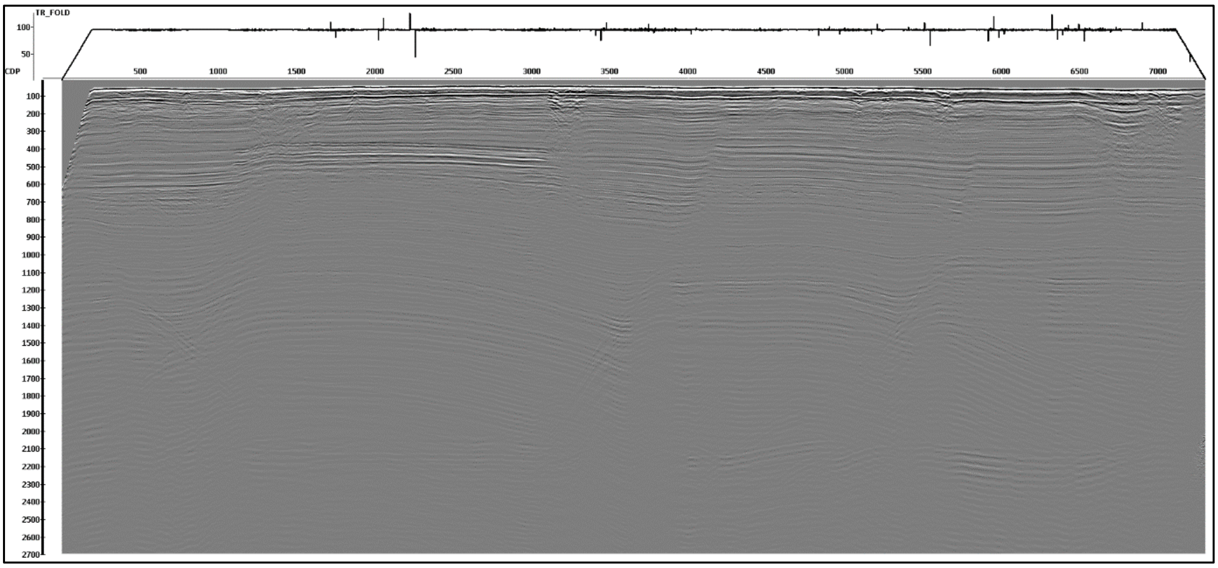
(b)

Figure 9 Streamer depth relative to the mean array depth along the UHRS profile ML_01_Prio_1: (a) streamer depth variation per offset along the seismic line and (b) histogram of the streamer depth relative to the mean array in milliseconds (TWT). The histogram values and colours correspond to a "colour bar" for streamer relative depths – negative values correspond to channels that are shallower than mean array depth (warm colours – reddish) and positive values represent deeper channels (colder colours – purple).

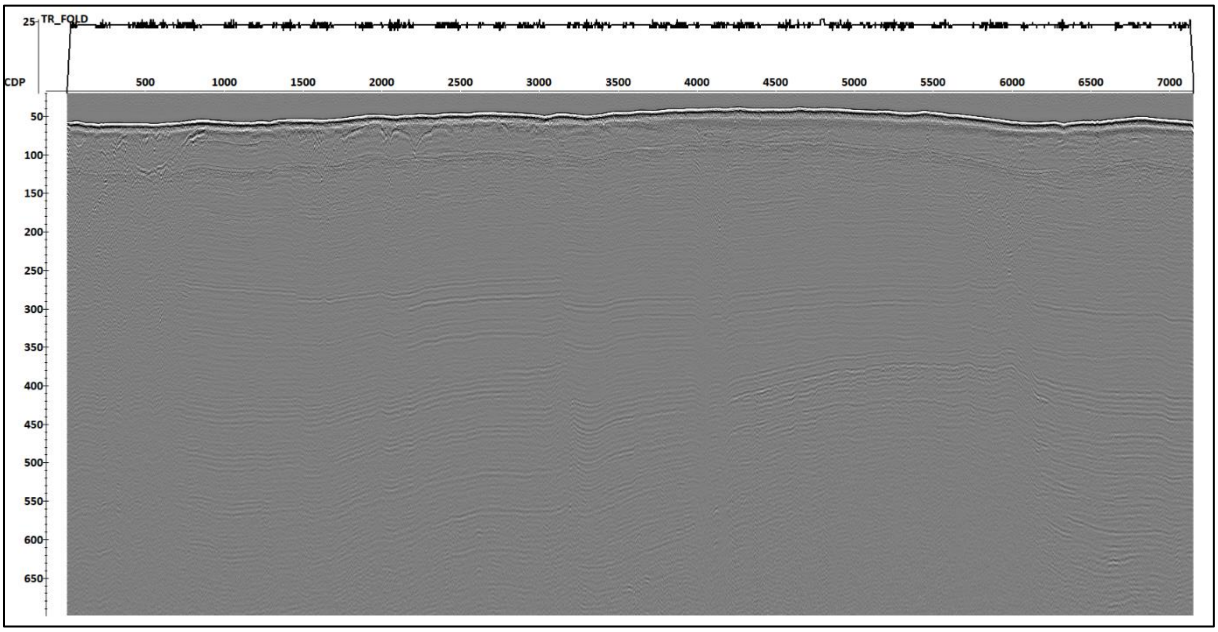
5.1.4| CDP FOLD & OFFICE BRUTESTACK

The impact of the positioning solution, triggering, steering, feathering, navigation, and the number of bad shots on the CDP bin fold regularity was assessed with CDP fold track plots (Figure 10). With minor deviations, all processed UHRS lines show a mean CDP fold around 24 and the HRS around 96. Trace fold header recorded values were used to assess the cumulative impact of steering & feathering and bad shots on the seismic data.

The office brutestack, generated during the TRIM track processing, provided a quick image of expected data quality, signal penetration and resolution (Figure 10). After conversion to depth using the SVP of the seismic line, the stacks are then used to calculate seismic misties (small shifts between lines that occurs due to swell, static corrections, feathering, among others) and estimate the corrections needed to reduce the seismic data to the vertical datum (MSL).



(a)



(b)

Figure 10 Trace fold values plotted on the top of stacked sections produced during TRIM track stage during the office works for line ML_01_Prio_1: (a) HRS (air gun) and (b) UHRS (sparker) data. The image is showing good penetration and acceptable signal to noise ratio. Vertical scale in TWT (ms).

5.2| SEISMIC 2D UHRS DATA PROCESSING OFFICE

Approximately 90.4 km of 2D Ultra-High-Resolution and High-Resolution Seismic data were acquired and processed in the scope of the present project.

Quality control procedures were carried out throughout the processing sequence. All processing steps were checked for the proper application of the seismic imaging enhancement. Several of these quality controls were delivered as part of this project submission, such as trace and offset QC; image of the TRIM stack (including CDP trace fold) and stack image of the final migrated dataset (FINAL track).

Furthermore, at some stages, quality control supervision was carried out by the project's Principal Reviewer to ensure that the seismic processing was being properly applied as well as for troubleshooting purposes. Finally, and after all intermediate quality controls, lines were inspected by both geophysicists and geologists for acceptance.

The processing flow was divided in three main stages, each of them with specific goals, as detailed below:

1. Sparker data was processed for TRIM track, where a trace-by-trace residual static correction was estimated in order to compensate for the vertical motions of the source and cable. TRIM track is an essential stage for the seismic datum corrections on UHRS. TRIM track for Airgun data was essentially used for QC, seismic misties corrections, and final vertical datum reduction.

2. Pre-stack FINAL track was carried out to produce a proper dataset for AVO inversion and quantitative interpretation. The main procedures of this processing stage included denoise, deconvolution, pre-stack multiple attenuation, pre-stack ghost attenuation and pre-stack Kirchhoff time migration to recover true geometry of primary reflections.

3. Post-stack FINAL track was carried out to generate stacked datasets for interpretation purposes: unmigrated, migrated, and depth converted migrated sections. The main procedures of this processing stage included ensemble stack, deconvolution (only for Sparker data), Time variant band-pass filtering and time-to-depth conversion.

A full processing report detailing all quality control steps, is available in Appendix B|.

6| BACKGROUND DATA AND CLASSIFICATIONS

Client provided background information and the GIS database were the main resources used during data interpretation. Additionally, academic literature resources were used to support interpretations and are listed within the references in Section 11|.

6.1| SUB-SEABED GEOLOGY CLASSIFICATION

The subsurface geological interpretation and description is based on the assessment of the 2D UHRS and HRS data acquired within the survey area. A total of 38 horizons were mapped in order to properly capture the subsurface complexity of the geological framework of the site.

The descriptions of the seismic units are provided according to their seismic facies and stratigraphic boundaries. The interpreted units are presented in Table 18. Further details on the seismostratigraphic interpretation and the proposed Geological Ground Model can be found in section 8.2| Seismostratigrapic Interpretation.

For further information on the processing steps and classification methods, see section 4.1|.

Table 18 Seismostratigraphic summary of the EI WPC Geological Ground Model.

<table>
<tr><th></th><th></th><th></th><th></th><th>HRZ ID #</th><th>SEISMIC UNIT</th><th>BASE HORIZON</th><th>BASE SURFACE</th><th>SEISMIC FACIES</th><th>DEPOSITIONAL ENVIRONMENT</th><th>EXPECTED SEDIMENT CONTENT</th></tr>
<tr><td rowspan="9">2D UHRS INTERPRETATION</td><td rowspan="9">UPPER ASSEMBLAGE</td><td rowspan="9">QUATERNARY</td><td rowspan="2">HOLOCENE</td><td>01</td><td>U05</td><td>H05</td><td>Irregular and discontinuous; low amplitude.</td><td>Transparent facies.</td><td>Marine mobile sediments.</td><td>Fine sands, mobile sediments.</td></tr>
<tr><td>02</td><td>U10</td><td>H10</td><td>Mostly flat, low to medium amplitude reflector. Erosive. Transgressive (wave cut) ravinement surface.</td><td>Low-medium amplitudes; transparent; faint parallel reflectors; prograding facies; internal erosion surfaces.</td><td>Marine sediments.</td><td>Sand, silty sands, and gravel.</td></tr>
<tr><td rowspan="7">PLEISTOCENE</td><td>03</td><td>U20</td><td>H20</td><td>Irregular; V-shaped incisions and wide shallow depressions. Erosive base.</td><td>Tabular (shallow and wide basin infill) or channel infill.
Lateral changes of reflector geometries, steep to low angle. Variable amplitude. Common high negative impedance contrasts. Infills of small basins and channels.</td><td>Infills of small basins and channels, likely in a restricted marine-tidal setting, partially associated to a subaerial fluvial system.</td><td>Fine sediments, clays, organic matter.</td></tr>
<tr><td>04</td><td rowspan="2">U25</td><td>H25 - Te</td><td>Irregular; mild undulations; non-continuous reflector. Erosive base.</td><td>Stacked channels and lenses. Transparent; or stratified (micro-parallel) with low amplitude reflectors. Common negative high amplitudes (soft-kicks).</td><td rowspan="2">Fine sediments (?) deposited in a relatively low-energetic setting, possibly glacial lake system or a transgressive estuary.</td><td>Silts and fine sands.</td></tr>
<tr><td>05</td><td>H25</td><td>Continuous and slightly undulating; variable amplitude (low-high).</td><td>Well-stratified facies; micro-parallel to parallel reflectors. Low to medium amplitudes. Common channel of transparent infill. Micro mounds and basins at the base.</td><td>Fine sediments: clays and fine sands-silts.</td></tr>
<tr><td>06</td><td>U30</td><td>H30</td><td>Sub-horizontal, uneven, undulating surface. Erosive base. Angular unconformity with underlying sediments.</td><td>Medium amplitudes; parallel reflectors; channel infills.</td><td>Fining-upward sequence, likely fluvial in nature.</td><td>Silts to fine sands.</td></tr>
<tr><td>07</td><td>U35</td><td>H35</td><td>Irregular base with localized incisions. Erosive base.</td><td>Complex; medium amplitudes; macro-parallel reflectors. Discontinuous dipping reflectors of variable amplitude; chaotic facies; stacked channel deposits and lenses. Parallel wavy internal erosive surfaces.</td><td>Possible outwash plain. High energy fluvial bedforms (flash floods?).</td><td>Mainly sands and gravel, with enclaves of coarser-grained clasts (?), fining-upward (?).</td></tr>
<tr><td>08</td><td>U40</td><td>H38</td><td>Undulating base, localized incisions.</td><td>Well stratified, micro-parallel, laminated; low to medium amplitudes.</td><td>Possible glacial lake infill; glacio-lacustrine.</td><td>Possible glacio-lacustrine; fine sediments, muds.</td></tr>
</table>

				HRZ ID #	SEISMIC UNIT	BASE HORIZON	BASE SURFACE	SEISMIC FACIES	DEPOSITIONAL ENVIRONMENT	EXPECTED SEDIMENT CONTENT
2D UHRS DATA	UPPER ASSEMBLAGE	QUATERNARY	PLEISTOCENE	09	U40	H40	Irregular; large U and V-shaped incisions; erosive base.	Reflector disruption; chaotic; folding and faulting; variable seismic facies and internal geometries: from parallel to chaotic facies. Heavily deformed.	Possible glacial thrust complexes and buried tunnel valleys; heavily deformed. Drainage system of glaciar melt back from the north, and outwash plains, with variable sediment content. Glacial period (Weichselian?)	Mixed sediments: possible glacial tills and glacio-fluvial deposits.
				10	U60	H60	Irregular, undulating surface. Erosive.	Complex facies of low to high amplitude reflectors; internal features of meso-scale proportions, such as mounds, channels, and lenses. Numerous oblique internal erosional surfaces. Large clinoform build-up facies. In general, the thickness of the internal packages decreases towards the top, becoming more sub-horizontal and sub-parallel.	High energy fluvial bedforms (flash floods?).	Mainly sands, with gravel and silt (?).
				11	U70	H61	Undulating base.	Low amplitudes, transparent, mounds-channels/small basins associations towards the base. Onlap.	Glaci-fluvial deposition, in a proglacial, sub-aerial environment (reoccupation of tunnel valley depressions by fluvial systems?), with variable sediment content. Glacial to inter-glacial period (?).	Fine sediments.
				12		H62	Undulating base; non-continuous reflector.	Low amplitudes; parallel layering and mounds-channels at the base, becoming chaotic towards the top.		Fine sediments.
				13		H69	Undulating and irregular base.	Low amplitude; transparent; faint parallel reflectors and mounds.		Sands.
				14		H70	Large buried U/V-shaped incisions.	Parallel reflectors of medium to high amplitude.		Clays with organic matter.
				15	UKSA	H71	Channel morphology, medium amplitude continuous reflector.	Chaotic facies of medium amplitude.	Deformed deposits of variable sediment content. Glaciotectonism.	Glacial till; diamicton.
				16		H72	Channel morphology, discontinuous reflector. Lenses.	Chaotic facies of medium amplitude.		Glacial till; diamicton.
				17		HKSA	Deformation front boundary. Truncating the parallel on the sides and beneath it.	Incoherent facies.		Deformed sediments.

				HRZ ID #	SEISMIC UNIT	BASE HORIZON	BASE SURFACE	SEISMIC FACIES	DEPOSITIONAL ENVIRONMENT	EXPECTED SEDIMENT CONTENT
2D UHRS DATA	UPPER ASSEMBLAGE	NEOGENE	PLIOCENE?	18	U85	H85	Irregular surface; undulating; erosive.	Low to medium amplitude. Internal parallel-oblique; hummocky; mounds-channels-lenses. Frequent internal erosive surfaces.	High energy fluvial (possibly outwash plain?).	Mainly sands with gravel and silt (?); organic-rich muds at the base.
				19	U90	H90	Planar, slightly undulating surface.	Parallel facies at the base and an association of parallel-mound-channel-shingled facies above, prograding.	Fan delta deposits.	Mainly sands and fine sediments.
				20	UKSB	HKSB	Deformation front boundary. Truncating the parallel on the sides and beneath it.	Incoherent facies.	Deformed deposits of variable sediment content. Glaciotectonism (Saalian?).	Deformed sediments.
	LOWER ASSEMBLAGE		MIOCENE	21	Luna	Intra Luna (PQ-01)	Moderate, continuous, undulating reflector.	Chaotic to transparent facies on top; parallel reflectors and channel-mound geometries at the base.	Near shore marine environment.	Sandy silts; shoreface sands.
				22		Luna	Moderate, continuous reflector.	Parallel to sub-parallel reflector pattern. Variable amplitude. Localised undulating reflector pattern.		
				23	Marbæk	Intra Marbæk (PQ-02)	Moderate, continuous reflector.	Parallel to sub-parallel facies of low amplitude, with a negative amplitude reflector on top.	Shoreface sand.	Slope to shoreface sands.
				24		Intra Marbæk (PQ-03)	Moderate, continuous reflector.	Parallel to sub-parallel facies of low amplitude, with a set of high amplitude reflectors on top.		
				25		Marbæk	Moderate, continuous reflector.	Parallel to sub-parallel facies of low amplitude.		
				26	Gram	Intra Gram (PQ-04)	High amplitude, continuous reflector.	Parallel to sub-parallel facies of low amplitude.	Marine muds.	Offshore muds; silt to fine-grained sands.
				27		Gram	High amplitude and continuous reflector. The reflector amplitude is locally extremely high possibly due to presence of gas.	Undulating parallel to sub-parallel facies of medium amplitude, with a set of high amplitude reflectors on top.		
2D HRS DATA		PALEOGENE	OLIGOCENE	28	Lark	Intra Lark 05	High amplitude and continuous reflector.	Parallel to sub-parallel reflectors; medium to high amplitude, increasing towards the top. Local very high amplitude reflectors on top, probably related to gas.	Prodeltaic mud and sand. Progradation toward south-west.	Offshore muds with sand intercalations.
				29		Intra Lark 04	High amplitude and continuous reflector.	Parallel to sub-parallel reflectors, medium amplitude. Common positive high amplitude reflectors.		

				HRZ ID #	SEISMIC UNIT	BASE HORIZON	BASE SURFACE	SEISMIC FACIES	DEPOSITIONAL ENVIRONMENT	EXPECTED SEDIMENT CONTENT
2D HRS DATA	LOWER ASSEMBLAGE	PALEOGENE	OLIGOCENE	30	Lark	Intra Lark 03	High amplitude and continuous reflector.	Parallel to sub-parallel; mottled facies with diffraction hyperbolas at the top; common prograding reflectors, pinch outs, mounds; medium to high amplitude.	Prodeltaic mud and sand. Progradation toward south-west.	Offshore muds with sand intercalations.
				31		Intra Lark 02	High amplitude and continuous reflector.	Downlapping, mounded, lenticular, hummocky, medium to high amplitude. Parallel to sub-parallel; medium to high amplitude;, mounded, lenticular, hummocky; downlaps.		
				32		Intra Lark 01	High amplitude and continuous reflector.	Parallel to sub-parallel facies; medium to high amplitude; common channels and mounds.		
				33		Lark	High amplitude and continuous reflector.	Parallel to sub-parallel facies; medium amplitude; occasionally chaotic; common mounds.		
			PALEOCENE	34	Rogaland	Rogaland	High negative to positive amplitude reflector; continuous.	Parallel to sub-parallel reflectors of medium to high amplitude reflectors; individual units not distinguishable.	Shallow to open marine.	Offshore muds; marlstone and mudstone succession.
				35	Ekofisk	Ekofisk	Low to medium amplitude and continuous reflector.	Parallel to sub-parallel reflectors of medium amplitude reflectors.	Marine.	Marly limestone.
		CRETACEOUS	UPPER	36	Maastrichtian	Maastrichtian	High positive to negative amplitude reflector; continuous.	Macro-parallel to sub-parallel reflectors.	Marine.	Chalk
			LOWER	37	Cromer Knoll	Cromer Knoll	High negative to positive amplitude reflector; continuous.	Macro-parallel, high amplitude reflectors.	Marine; post-rift basin fill.	Marls and clays.
		JURASSIC		38	Kimmeridge	Kimmeridge	Low amplitude reflector.	Macro-parallel reflectors.	Rift basin fill.	Clays.
		?		39	BSU	LK	-	Macro-parallel to sub-parallel reflectors; hummocky.	?	Variable sediment content

7| GEOLOGICAL FRAMEWORK

The Danish sector of the North Sea basin is connected to the east by the Scandinavian Shield and by the WNW-ESE striking Sorgenfrei-Tornquist fault zone (Figure 11). The Ringkøbing-Fyn High, located further south, emerged during the Late Permian (Pre-Zechstein) as a result of tectonic subsidence (Vejbæk, 1997; Vejbæk et al., 2007). This structural feature divides the Danish sector of the North Sea basin into the North German Basin, located south of the Ringkøbing-Fyn High, and the Danish-Norwegian Basin, north of Ringkøbing-Fyn High. During the Zechstein (Late Permian), four to five cycles of evaporites were deposited, infilling the structural lows (Sorgenfrei & Buch, 1964; Vejbæk et al., 2007). Further deepening of the North Sea basin resulted in thousands of metres of Mesozoic sediment deposition over the evaporites. The thick Mesozoic deposits activated diapirism of the underlying evaporites. Subsequently, several cycles of glaciations resulted in further loading, inducing reactivation and upward migration of the salt diapirs (Nielsen et al., 2008). This halokinesis is likely to be ongoing in modern times, also indicated by a high level of earthquakes in the Danish Basin, measured in the period 1920 to 1995 (Gregersen et al. 1998).

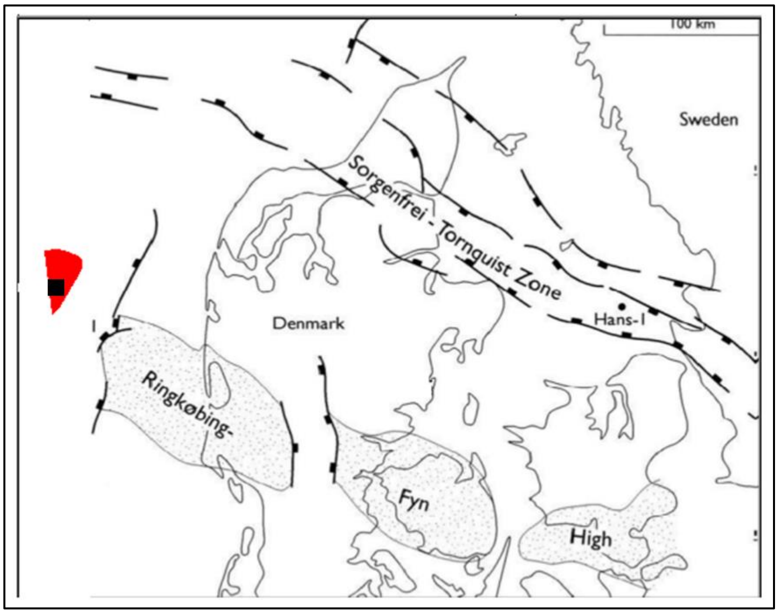


Figure 11 Major Danish structural elements (After Stemmerik et al., 2000); WPA location in red; Energy Island (WPC) location marked by black square.

During the Late Cretaceous, a major tectonic inversion episode affected the North Sea region, associated with initiation of the Alpine Orogeny, (Clausen & Huuse, 1999; Japsen, 2000). A warm epicontinental ocean covered the area, which led to the deposition of chalk formations (Knutz et al., 2022; Anderskouv & Surlyk, 2011). Cretaceous tectonism was followed by sequential episodes of uplift and major sea level fluctuations during the Paleogene to Neogene (Japsen et al. 2008), marked by a transition from chalk deposits to clastic sediments (Knutz et al., 2022). These events resulted in variable rates and types of sediment deposition. A major regional unconformity occurs between the Upper Eocene and lower Upper Oligocene, Brejning Fm. (Mica Clay) (Rasmussen et al., 2010). The Neogene deltaic deposits show a general shift moving from east to west. The Miocene succession is hundreds of metres thick in the Danish sector of the North Sea. From the rim of the North Sea basin at the Sorgenfrei-Tornquist Zone towards the central basin, the Pre-Quaternary deposits are successively younger below the base of the Quaternary.

The Top Chalk horizon has been mapped over several investigative stages using different generations of seismic data (Huuse, 1999; Vejbæk et al., 2007). The chalk surface is situated 1000-1200 m below the AOI (Fig. 2). North and east of the area the Chalk has been uplifted by diapirs of Permian salt. These vertical movements, caused by differential material densities, are associated with multiple tectonic phases movements during the Cenozoic and the effects of compaction-decompaction by continental ice sheets over the last 2.7 Ma (Rank-Friend & Elders, 2004; Knutz, 2010). The salt movements can influence the integrity of younger sedimentary packages, including faults, fluid escape and erosional features.

The Quaternary base represents an unconformity east of the so-called the transition zone in the North Sea (Nielsen et al., 2008) (Figure 12). West of the transition, the Quaternary sequences rest conformably on Pliocene deltaic sediments (Nielsen et al. 2008). Often, the unconformity shows a significant relief due to Quaternary glacial processes, and occurs at depths of a few hundred metres within valley structures to just below the seabed along the Danish west coast (Andersen, 2004; Huuse & Lykke-Andersen, 2000b; Leth et al., 2004, Novak & Duarte 2018). Across the wider region (e.g. central North Sea) this surface is characterized by strong undulation controlled by variable-scale structures in the Pre-Quaternary basement.

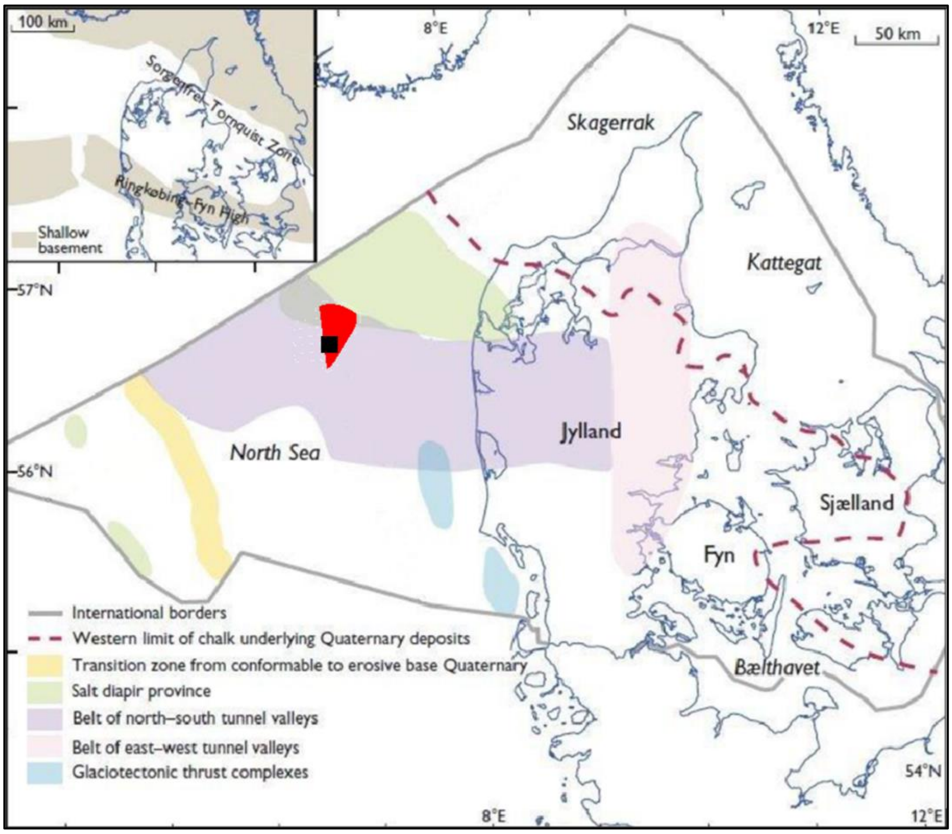


Figure 12 Regional geological map (After Nielsen et al., 2008); WPA location in red; Energy Island location marked by black square.

Only a few studies have been performed on the Quaternary deposits in the Danish North Sea. However, onshore studies provide a decent foundation for outlining the regional geology in the eastern North Sea (e.g. Sjørring & Frederiksen, 1980; Ehlers, 1990; Sandersen & Jørgensen, 2003; Pedersen, 2005; Jørgensen & Sandersen, 2006; Jacobsen, 2003; Høyer et al., 2013; Houmark-Nielsen, 2007).

In general, the Quaternary sequence thins from the central North Sea towards the Danish mainland. The Elster and Saale ice sheets extended across the entire North Sea (Figure 13). Glaciation came from the northwest over northeast and from the Baltic region (Sjørring & Frederiksen, 1980; Ehlers, 1990). The Weichselian ice sheet extended north and east of the main stationary line at the Late Glacial Maximum (LGM), which was located from inland Jutland towards the northwest into the North Sea (Figure 13). Morphological elements such as moraine ridges and elongated boulder reefs, occurring perpendicular to the main stationary line, indicate the location of the ice boundary on the seabed west of the Thyborøn at the Danish west coast (Nicolaisen, 2010). Onshore, southwest of the LGM, the so called "hill islands" (Dalgas, 1867), which outline the Saalian landscape, are found to extend into the North Sea (Larsen & Andersen, 2005, Larsen & Leth, 2001; Anthony & Leth, 2001). Morphological remnants are absent on the seabed due to marine erosion. However, seismic profiles reveal horizons that have been interpreted to represent this same landscape. The northern part of the actual survey area is expected to cross over the LGM stationary line; however, central and southern survey area has only been overridden by Saaleian or older glaciations.

Large-scale glaciotectonic thrust complexes have been identified in the Danish North Sea, as well as onshore the Danish main land (e.g., Huuse & Andersen 2000a, 2000b, Larsen & Andersen 2005, Vaughan-Hirsch & Phillips 2017, Novak & Duarte 2018, Høyer et al. 2013, Shack Pedersen 2005, Jacobsen 2003). In the eastern North Sea, the décollement surfaces are located in the Miocene or in the Quaternary level, and the thrust blocks comprise these sediments. The formation of glacial tectonic complexes found to the west and south of the Weichselian LGM boundary are attributable to the Saalian or older ice cover (Andersen, 2004; Huuse & Lykke-Andersen, 2000b; Vaughan-Hirsch & Phillips, 2017).

Systems of buried shelf valleys, 100-300m deep and several tens of kilometres long, are present (Figure 13) (Andersen, 2004; Huuse & Lykke-Andersen, 2000b; Novak & Duarte 2018). The submarine valleys can be correlated to onshore valleys and are considered to be of the Elster and Saale ages. Younger, reactivated Saale valleys have been found north and east of the Weichselian main stationary line (Smed 1979).

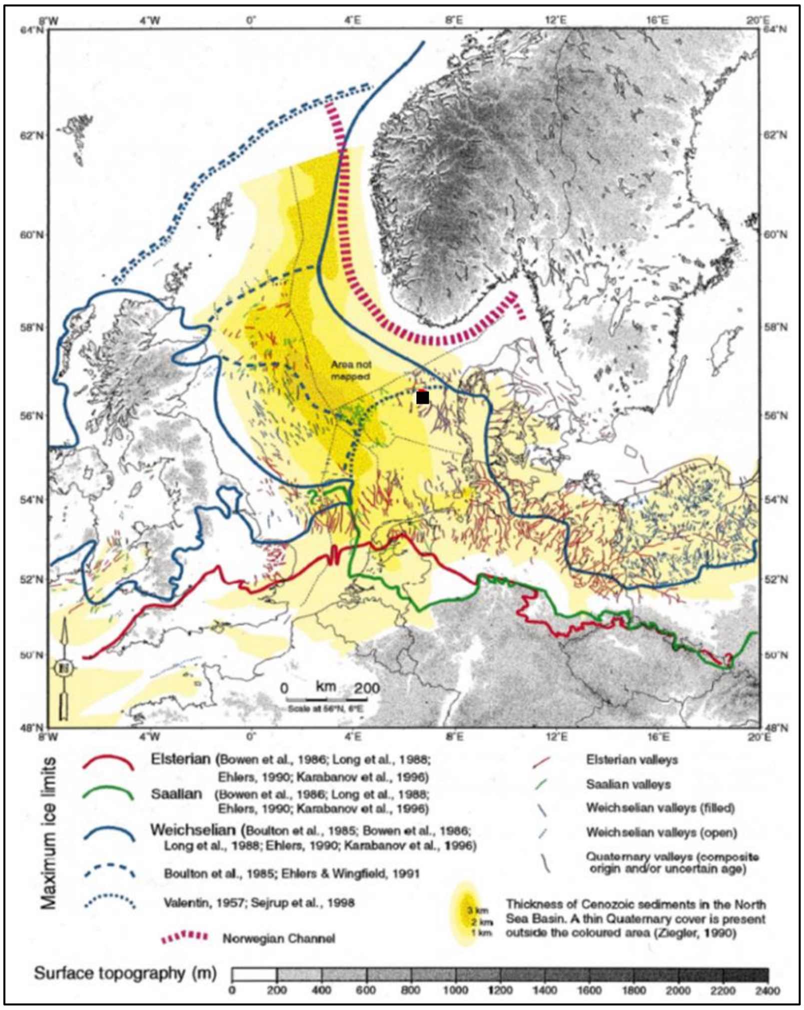


Figure 13 The Quaternary glaciations and an overview of Quaternary valleys in northwest Europe. (Huuse, M., and Lykke-Andersen, H. 2000); Energy Island location marked by black square.

The Paleo-North Sea extended across the region during the Eemian period. Eemian deposits are described both on and offshore in the south-westerly North Sea (Konradi et al., 2005), and Eem deposits representing valley infill were found in a borehole in the Vesterhav South OWF survey area (Fugro 2014).

Deposits from the Weichselian glaciations (Figure 14) comprise tills alternating with glaciofluvial sand and gravel, glaciolacustrine clay, silt, and sand, toward the north and east of the main stationary line. Towards the west and south of the LGM, glaciofluvial sand and gravel were deposited in morphological lows above the older Saale landscape (Houmark-Nielsen, 2007). The LGM occurred in the region around 22ka BP. The glaciers´ subsequent retreat generated accommodation space close to the ice front, where deposition of glaciolacustrine clay filled in, e.g Younger Yoldia Clay around 16-15ka BP. As Weichselian ice melted back, the subglacial-generated valleys emerged and laminated clay, silt, and fine sand deposited in the valleys (Figure 14).

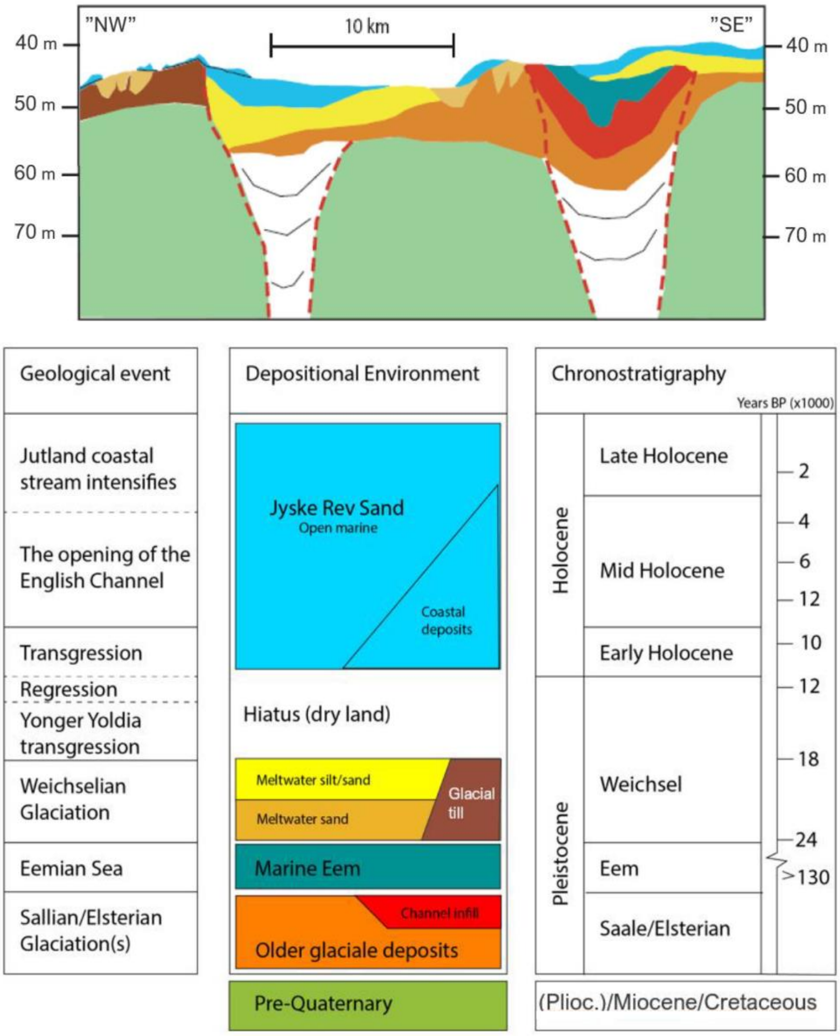


Figure 14 General stratigraphy model of the Quaternary geology in the eastern Danish North Sea. A composite profile from NW towards SE representing approximately 50 km from Jyske Rev and towards the shore. Below: Stratigraphic unit names and their relative age. Same colour code used above and below. (After Nicolaisen, 2010).

The removal of the glacial load triggered isostatic rebound and a regression that took place until 11ka BP. During this timeframe, relative sea level was, at a minimum, 55 to 45 metres lower than present, thus maintaining the eastern Danish shelf above sea level. Terrestrial conditions and rising temperatures increased organic material production, resulting in peat accumulations. This marker horizon has been found in many survey areas across Danish waters (Leth, 1996; Bennike et al., 1998, 2000; Novak & Björck, 2002; Novak & Pedersen, 2000). In the eastern Danish North Sea, fine-grained material was deposited in sheltered areas between till "islands", e.g, the Agger Clay unit (Leth, 1996). During the Holocene transgression, from 11ka BP to 6 ka BP, the Agger Clay depocenter shifted coastward and offshore low-lying islands were submerged. At the same time, coastal processes overtook the glaciogenic landscape where it was exposed to waves and currents. The result was the formation of spit/platform/lagoon deposits throughout the region (Johannesen et al., 2008; Novak & Pedersen, 2000).

In the eastern North Sea, metre-thick fossil sand waves were present at Jyske Rev (Leth 1996). These current- and wave-generated structures have often been formed around sandy-gravelly fossil beach ridges. Seismic data depict multiple generations of these events. After 6 ka BP, sea level was at its highest and the North Sea tidal system and coast-parallel Jylland current developed.

A recent mobile sediment unit is the latest deposit and is found to cover major areas of the eastern North Sea seabed. Coast-parallel strong currents and waves generate the active bedforms, i.e., mobile sandwaves and dunes. The Danish Coast Agency has documented bedform migrations of up to 20-50m per year; the dunes and waves are organized in kilometre-wide areas migrating across an apron of relict gravelly sand (Anthony & Møller, 2003; Anthony & Leth, 2001; Leth et al., 2004).

8| RESULTS

8.1| GENERAL

The results from the geophysical deep 2D seismic survey are presented in this report together with associated charts. The charts are presented in Appendix A|.

8.2| SEISMOSTRATIGRAPIC INTERPRETATION

The subsurface geological interpretation and description is based on the assessment of the 2D UHRS and HRS data acquired within the Energy Island area. A total of 38 horizons were mapped in order to properly capture the subsurface complexity of the geological framework of this site, for seismic inversion purposes.

The full seismic interpretation is available in the accompanying Kingdom Suite project. Its contents are presented below:

Kingdom Suite Project v2021 (SQL 2014) – **Energinet_EI_WPC**:

- HR Seismic datasets (air gun): DPT_S1R1, MIG_S1R1, MUL_S1R1, VINT_S1R1, and VRMS_S1R1; (6 X 5 = 30 SEG-Ys);
- UHR Seismic datasets (sparker): DPT_S2R2, MIG_S2R2, MUL_S2R2, VINT_S2R2 and VRMS_S2R2; (6 X 5 = 30 SEG-Ys);
- Interpretation Deliverables:
  - 40 Horizons in TWT, Depth & BSB;
  - 118 Horizons in total;
  - 121 Grids in meters;
  - 1 Hazard in TWT, depth, and meters BSB;
  - Unassigned Faults (TWT and depth).
- 1 Wells (IDA-1);

Nomenclature:

- ##_HXX or ##_FormationName – horizons;
- ##_Unit_Thick – thickness of unit ##;
- ##_Unit_Total_Thick – Total thickness of unit ##, considering the sum of its internal sub-units;
- ##_HXX_BSB – unit base (HXX) depth below seabed;
- Seabed horizon (H00_SB) was mapped in both datasets: S1R1 to designate HR seismic data (air gun), and S2R2 was used for UHR seismic data (sparker).

Table 19 List of horizons, grids present in the Kingdom Suite Project.

Kingdom Suite Colour Code	HORIZONS			GRIDS			
	Horizon Name	TWT and DPT	BSB	HORIZON	THICK	TOTAL THICK	BSB
DodgerBlue	00_H00_SB_S1R1	X		X			
DodgerBlue	00_H00_SB_S2R2	X		X			
Gold	01_H05	X	X	X	X		X
LightGreen	02_H10	X	X	X	X		X
SpringGreen	03_H20	X	X	X	X		X
Turquoise	04_H25_Te	X	X	X	X		X
RosyBrown	05_H25	X	X	X	X		X
Orange	06_H30	X	X	X	X		X
Yellow	07_H35	X	X	X	X		X
DarkCyan	08_H38	X	X	X	X		X
DarkMagenta	09_H40	X	X	X	X		X

Kingdom Suite Colour Code	HORIZONS			GRIDS			
	Horizon Name	TWT and DPT	BSB	HORIZON	THICK	TOTAL THICK	BSB
Red	10_H60	X	X	X	X		X
LavenderBlush	11_H61	X	X	X	X		X
LightPlum	12_H62	X	X	X	X		X
Magenta	13_H69	X	X	X	X		X
Blue	14_H70	X	X	X	X		X
DeepSkyBlue	15_H71	X	X	X	X		X
Cyan	16_H72	X	X	X	X		X
DarkRed	17_HKSA	X	X	X	X	X	X
MediumMagenta	18_H85	X	X	X	X		X
Cyan	19_H90	X	X	X	X		X
DarkRed	20_HKSB	X	X	X	X		X
DarkCyan	21_IntraLuna_PQ-01	X	X	X	X		X
LavenderBlush	22_Luna	X	X	X	X	X	X
Red	23_IntraMarbæk_PQ-02	X	X	X	X		X
Marron	24_IntraMarbæk_PQ-03	X	X	X	X		X
VioletRed	25_Marbæk	X	X	X	X	X	X
Tan	26_IntraGram_PQ-04	X	X	X	X		X
Gold	27_Gram	X	X	X	X	X	X
Violet	28_IntraLark05	X	X	X	X		X
Blue	29_IntraLark04	X	X	X	X		X
Sienna	30_IntraLark03	X	X	X	X		X
Orange	31_IntraLark02	X	X	X	X		X
Cyan	32_IntraLark01	X	X	X	X		X
LightRosyBrown	33_Lark	X	X	X	X	X	X
DarkRosyBrown	34_Rogaland	X	X	X	X		X
Orange	35_Ekofisk	X	X	X	X		X
LightGreen	36_Maastrichtian	X	X	X	X		X
LightSpringGreen	37_CromerKnoll	X	X	X	X		X
DeepSkyBlue	38_Kimmeridge	X	X	X	X		X

Table 20 List of geological features present in the Kingdom Suite Project.

Kingdom Suite Colour Code	GEOLOGICAL FEATURES		
	Horizon Name	TWT and DPT	BSB
OrangeRed	GHz Gas	X	X
Black	UHRS / HR Unassigned Faults	X	

8.2.1| SUB-SEABED GEOLOGY – GEOMODEL

The Geological Ground Model was defined from the integration of geophysical data acquired for the North Sea East OWF and EI WPC project. The main goal was to interpret 2D UHRS and HRS data in order to describe the subsurface geological conditions from the seabed to the Cretaceous Chalk Group. Geotechnical information was provided by Energinet in the form of borehole data to complement the seismic interpretation, providing information regarding sediment content. Well IDA-1 geophysical logs and lithostratigraphic formation tops (GEUS) were used for the analysis of Pre-Quaternary units, in deeper sections.

A thorough revision of previously acquired 2D UHRS data (OWF WPA, 2021) and available scientific literature was carried out to steer the seismic interpretation and ensure the formulation of a Geological

Ground Model that is consistent with the known geologic evolution of the region. Within these, the following studies were of relevance for the interpretation work presented here:

- Amoco Denmark. 1992. IDA-1, Final Well Report – Volume 2. 5606/13-1. GEUS Report file no. 5658;
- Amoco Denmark. 1994. IDA-1, Sonic Calibration Processing Report. 5606/13-1. GEUS Report file no. 5625;
- Amoco Denmark. 1992. IDA-1, Well Site Geologists' Final Well Report. 5606/13-1. GEUS Report file no. 5655;
- GeoSurveys. 2022. Energinet OWF – WP-A Geophysical 2D-UHRS Survey – Energy Island. UHRS 2D SEISMIC INTERPRETATION TO 200 m MSL. REP21317;
- MMT. 2021. North Sea OWF and Energy Islands – Geophysical Survey for Offshore Wind Farms and Energy Island Report. 103783-ENN-MMT-SUR-REP-SURVWPA-02;
- MMT. 2021. North Sea OWF and Energy Islands – Geophysical Survey for Offshore Wind Farms and Energy Island Report. 103783-ENN-MMT-SUR-REP-SURVWPAEI-02;
- Richardt et al., 2021. Energy Island Danish North Sea – Geoarchaeological and geological desk study. Rambøll Denmark Report for Energinet;
- Schiøler et al., 2007. Lithostratigraphy of the Palaeogene – Lower Neogene succession of the Danish North Sea. Geological Survey Of Denmark And Greenland Bulletin, 12. Geological Survey of Denmark and Greenland (GEUS).

Seismostratigraphic interpretation of the 2D UHRS and HRS data was the basis for the geological ground model presented here. The interpretation approach employed included aspects of sequence stratigraphy, kinetostratigraphy, lithostratigraphy, and seismic facies analysis, in order to provide suitable horizons for AVO Inversion at a later stage (carried out by Solid Ground).

The geological ground model comprises 38 horizons that correspond to seismic reflectors and/or boundaries deemed significant to build the main sub-surface geological framework, distinct depositional and erosion events, marking relevant environmental changes, and shifts in sediment types. The criteria for horizon selection were structure significance in the site's stratigraphic framework, spatial reflector continuity, and delimitation of seismic facies interfaces. The mapped horizons represent the bounding surfaces of the 38 seismic units described here. An additional seismic unit, referred to as the Base Seismic Unit (BSU), is also included in the model, the details of which are discussed later in this section. The lateral assemblage and vertical stacking of these units represent the structural aspect of the geological ground model. The associations and relationships amongst the structural elements represent the geologic evolution of the depositional environments at the site.

Seismic units' interpretation was carried out on both 2D UHRS and HRS data. Due to the limited seismic record of the UHRS data, horizon mapping and units' description were based on:

- 2D UHRS data (zero-phased): from seabed to seismic unit Gram; horizons picked at the wavelet's peak or trough;
- 2D HRS data (minimal phase): from Gram to BSU; horizons picked at wavelet's zero crossings.

Alongside the model, a careful and detailed analysis of direct seismic indicators (e.g., diffractions, amplitude anomalies, acoustic blanking, etc.) was carried out as part of the assessment of potential geohazards within the sub-surface.

An analytical interpretation of the Geological Ground Model is provided in section 8.2.26| Summary and Discussion. However, a short introduction to the site´s seismostratigraphic character is provided here to assist the descriptions of the individual seismic units comprising the model.

Figure 15 below shows a northwest-southeast profile with seismostratigraphic interpretation, displaying the mapped horizons and the interpreted seismic units. The horizons that bound the seismic units represent seismostratigraphic boundaries and mark the base of the deposits they define. As such, these boundaries have chronostratigraphic and kinetostratigraphic meaning, and should not be interpreted in lithostratigraphic terms. The bases and units are numbered sequentially based on their stratigraphic position, and have an alphanumeric naming convention (e.g., H10 corresponds to the base of seismic unit U10 (Figure 15). The deepest and oldest seismic unit is referred to Base Seismic Unit (BSU). The top of the Base Seismic Unit is defined by a composite surface produced from the amalgamation of the deepest mapped horizons. The bottom of the Base Seismic Unit corresponds to the processing "last knee" that is an artificial, linear boundary near the terminus of the seismic record.

The fundamental stratigraphic controls on the site´s geology, as inferred from the seismic data, are eustacy, isostasy, autogenic processes, and glaciogenic deposition and deformation. Despite the complex nature of the of site's stratal architecture, a reasonable approximation of the prevailing geologic conditions was captured in the 39 seismic units that were mapped. These units represent the structural elements of the Geological Ground Model. The principal characteristics of the model's individual seismic units are detailed below.

All figures and seismic interpretation work that are included in this report are part of the Kingdom Suite project associated to this report. All seismic profiles are FULL-processed, migrated and in depth (metres). Numbers on the horizontal and vertical axis refer to distance in metres. The colour bar for the seismic display is identical for all profiles ('Black to White 200' in Kingdom Suite). The colour bar used to show the lateral extension for each basemap is the 3D Effects: warm colours (red) indicate shallower depths, and cool colours (blue) indicate greater depths (unless stated otherwise). For every seismic unit, three basemaps are presented: (1) spatial extent of the mapped horizon, (2) grid of the depth below seabed of the base of the unit, (3) grid of the thickness of the unit. Vertical exaggeration on seismic section figures is variable: horizontal and vertical scales were adjusted to best illustrate the features of interest.

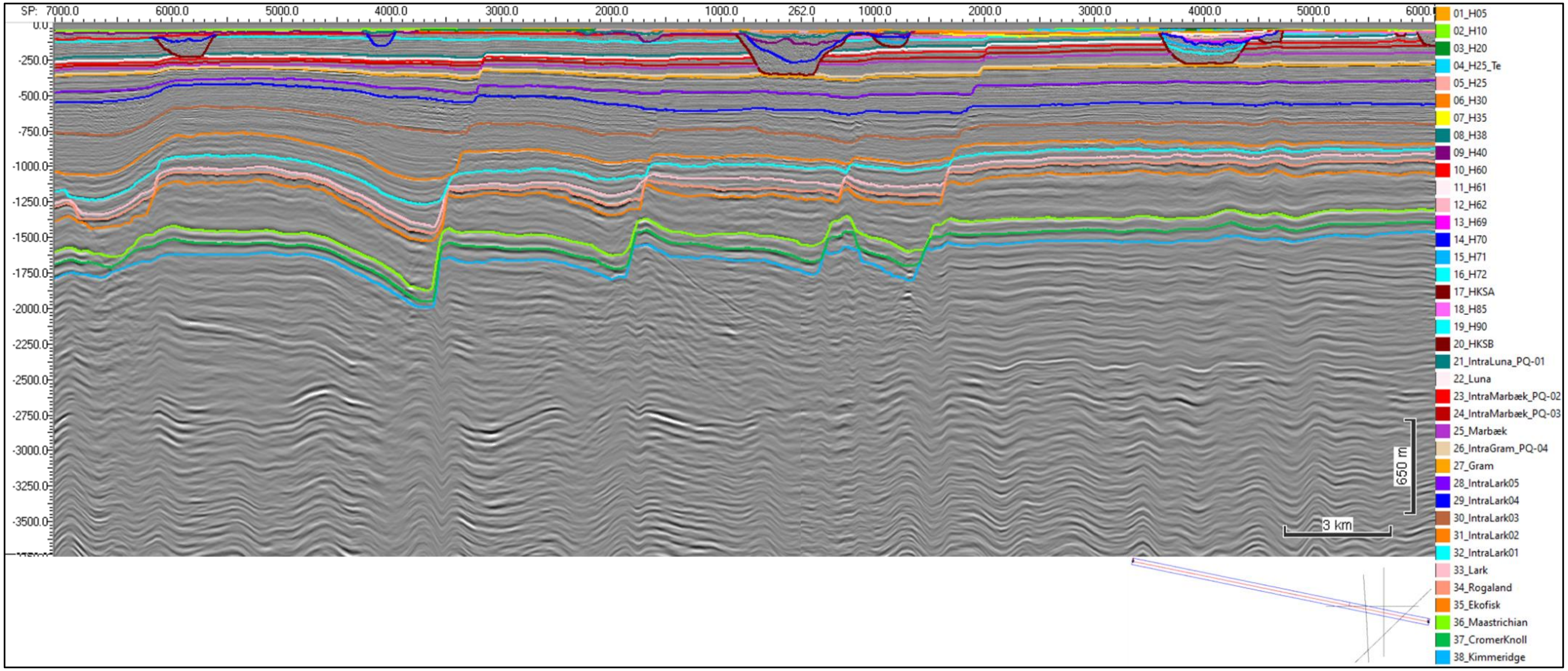


Figure 15 General sub-surface architecture of the survey area.
The image shows interpreted seismic units defined for the Geological Ground Model of the EI area. Arbitrary line with seismic profiles ML_01_Prio_1 and ML_01_Prio_1a.

8.2.1| SEISMIC UNIT U05

Base horizon: 01_H05

SEISMIC UNIT U05	**SEISMIC UNIT U05** **Base horizon: 01_H05** Depth: 27.6 - 47 Extent: Discontinuous across the site. Description: Irregular and discontinuous; low amplitude. **Unit seismic character:** Thickness: up to 2.6 Morphology: Mounded; tabular. Seismic facies: Transparent facies.
	Interpreted depositional environment: Marine mobile sediments. **Expected sediment content:** Fine sands to silty sands; mobile sediments.

Seismic unit U05 is a discontinuous package, mostly present in the northeast region of the survey area. The base of unit U05 is defined by horizon H05 (reference number 01). The spatial distribution, vertically referenced to MSL and depth below seabed are presented in Figure 16 and Figure 17, respectively.

Horizon H05 ranges in depths between 27.6 m and 47 m below MSL (Figure 16) and between 0 m and 2.6 m depth below seabed (Figure 17). It follows an irregular and discontinuous, low amplitude reflector. Unit U05 makes up shallow mounded structures and sand waves at the seabed, likely mobile in nature. Seismic unit U05 comprises recent marine sediments and is likely made up of silty-sands. U05 is interpreted to be of Holocene in age.

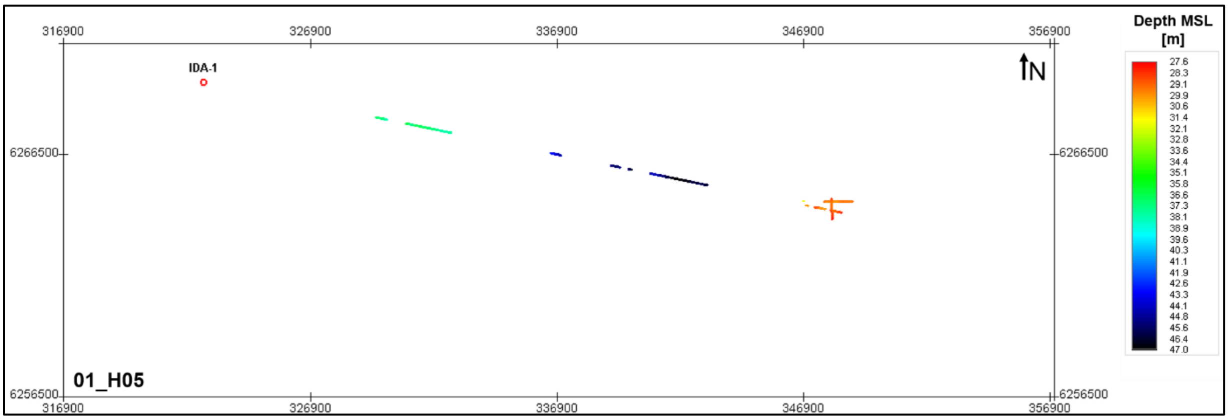


Figure 16 Map showing the lateral extent of U05.
Units in metres below MSL.

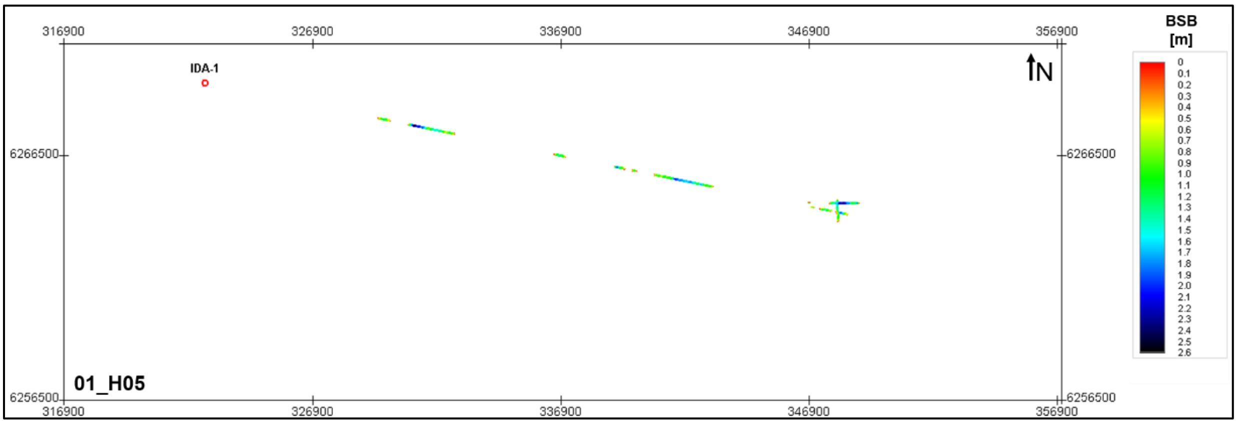


Figure 17 Depth below seabed of H05, which also represents the thickness of the unit.
Units in metres below seabed.

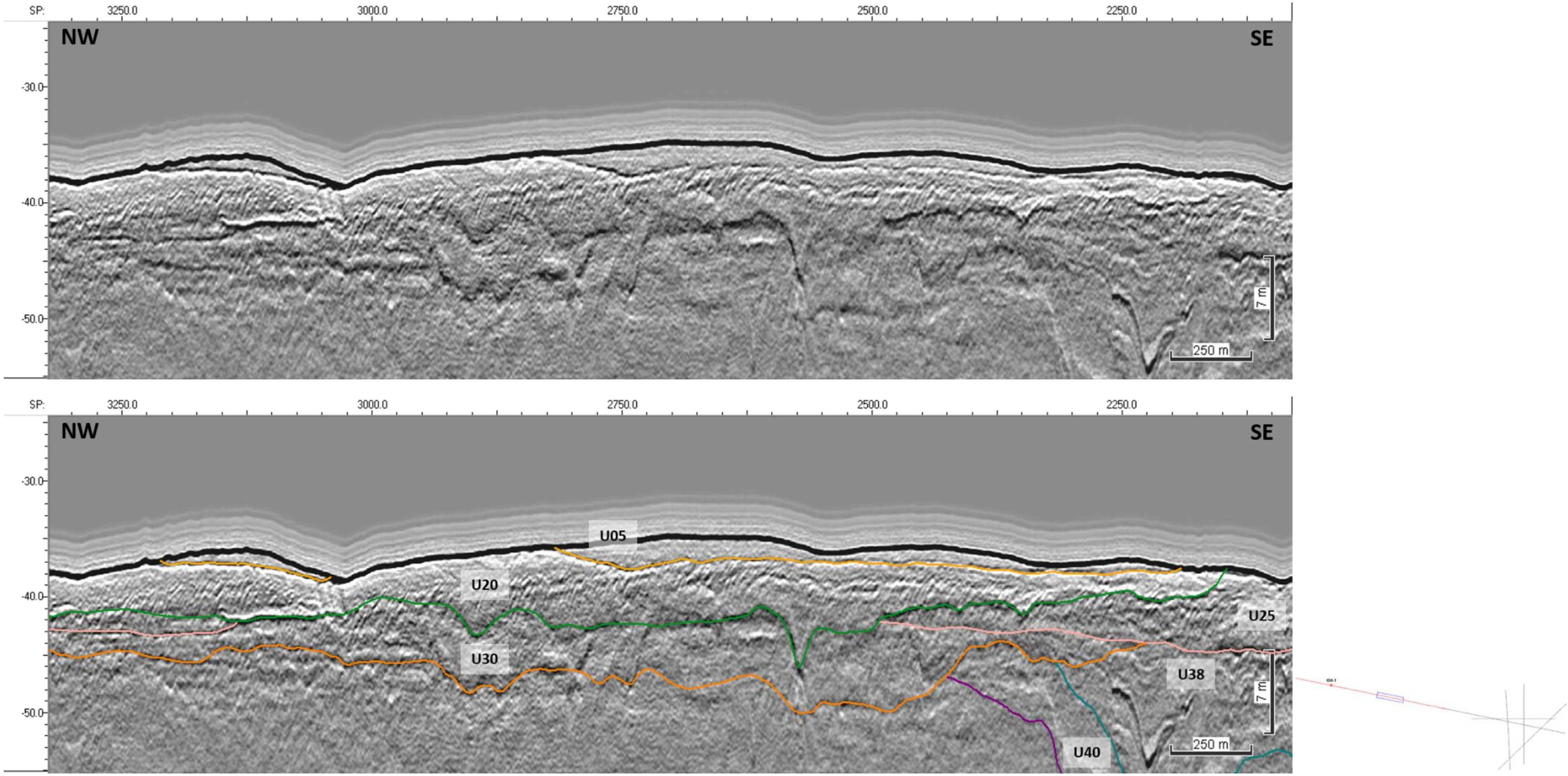


Figure 18 General facies of Seismic Unit U05, and the transparent character of horizon H05 (gold). Seismic profile ML_01_Prio_01.

8.2.2| SEISMIC UNIT U10

Base horizon: 02_H10

<table>
<tr><td rowspan="2">SEISMIC UNIT U10</td><td>SEISMIC UNIT U10
Base horizon: 02_H10
Depth: 34.6 - 49.6
Extent: Discontinuous across the site.
Description: Mostly flat, low to medium amplitude reflector. Erosive. Transgressive (wave cut) ravinement surface.
Seismic unit: U10
Thickness: up to 13.7
Morphology: Mounded; tabular.
Seismic facies: low-medium amplitudes; transparent; faint parallel reflectors; prograding facies; internal erosion surfaces.</td></tr>
<tr><td>Interpreted depositional environment: Marine sediments.

Expected sediment content: Sand, silty sands, and gravel.</td></tr>
</table>

Seismic unit U10 is a major element of the ground model, and extends across the EI and the NW corner of the survey area. The base of Seismic Unit U10 is defined by horizon H10 (reference number 02) and is present discontinuously within the survey area. Seismic unit U10 comprises the recent marine sediments that make up the seabed bedforms where present. The spatial distribution, vertical reference to MSL and the seabed, and thickness of the unit are presented in Figure 19, Figure 20, and Figure 21.

Horizon H10 ranges in depth between 34.6 m and 49.6 m below MSL (Figure 19), and between 0 m and 13.7 m depth below the seabed (Figure 20). It follows a flat and even reflector of medium amplitude (Figure 22). Occasionally, H10 follows a faint low amplitude reflector, and rarely displays reversed polarity.

Seismic unit U10 has a tabular external morphology in regions where it is thinner (from 0 m to 4 m thick); or it forms wide mounds of thicker sediment accumulation (up to 13.7 m thick).

The seismic facies of U10 have a generally low to transparent amplitude response (Figure 22). Where thicker, within the mounded structures, faint parallel reflectors, oblique downlap reflectors (prograding patterns) and small lenses are observed. Stippled high amplitude facies are locally observed at the base. Common discontinuous high amplitude reflectors and negative high impedance contrasts occur across the unit’s extent.

Horizon H10 is interpreted as a transgressive ravinement surface. The deposits of U10 are interpreted to be related to a marine transgressive setting (possibly high stand). Seismic unit U10 is likely made up of sands and silty-sands. Stippled high amplitude facies may indicate coarser-grained material, such as gravel. U10 is interpreted to be of Holocene in age.

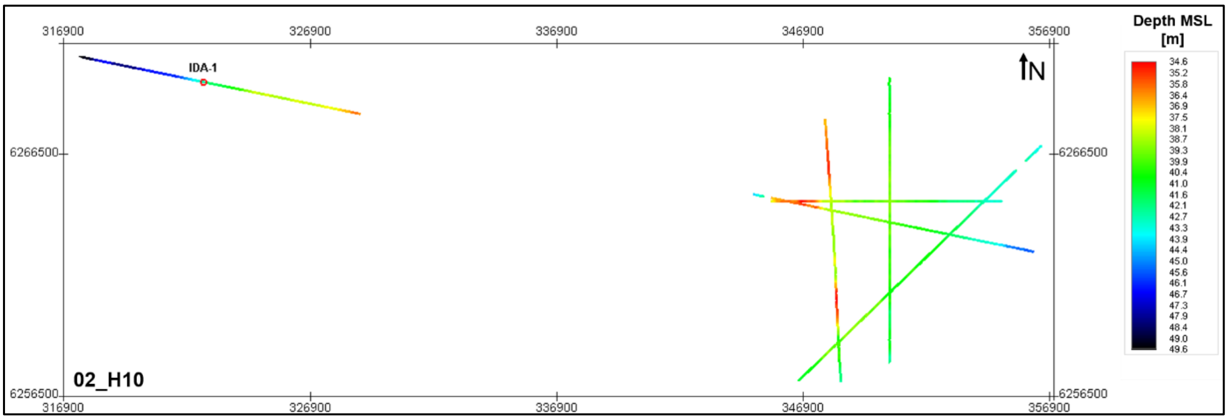


Figure 19 Map showing the lateral extent of U10.
Units in metres below MSL.

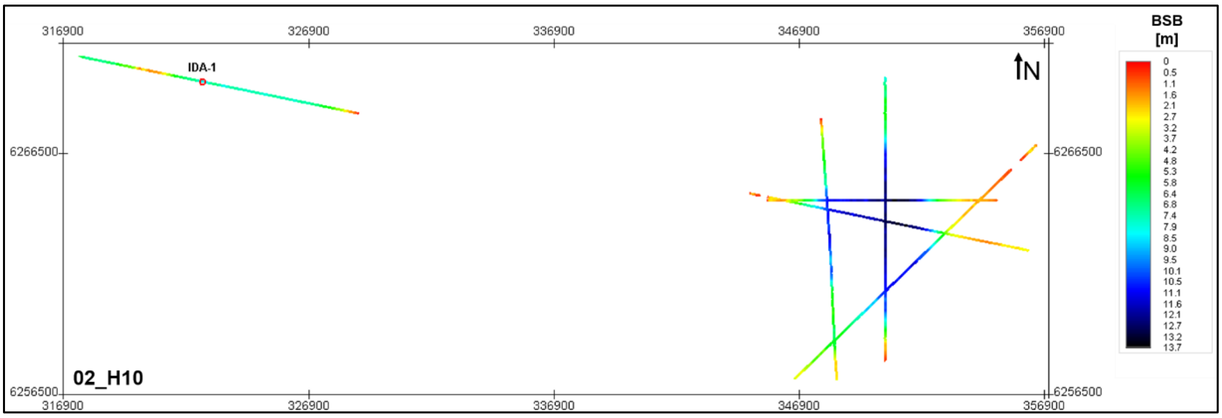


Figure 20 Depth below seabed of H10.
Units in metres below seabed.

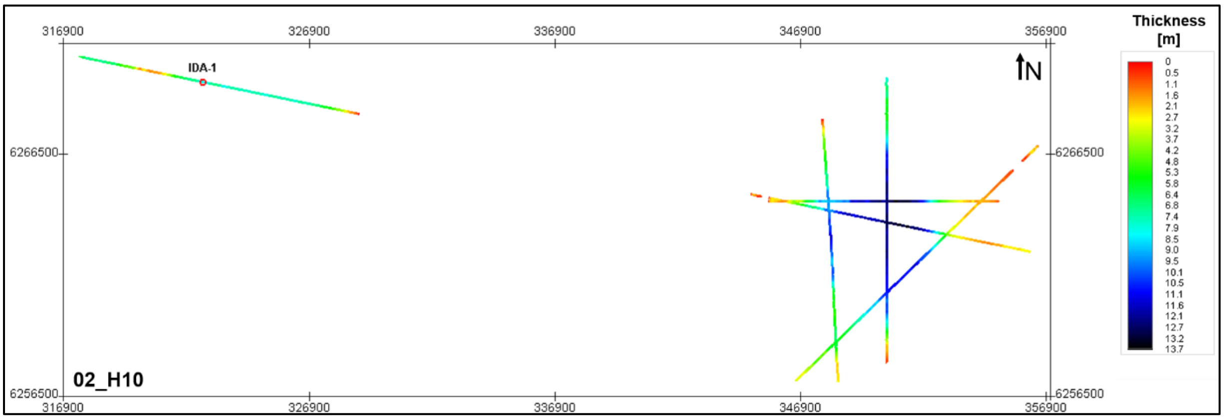


Figure 21 Thickness of unit U10.
Units in metres.

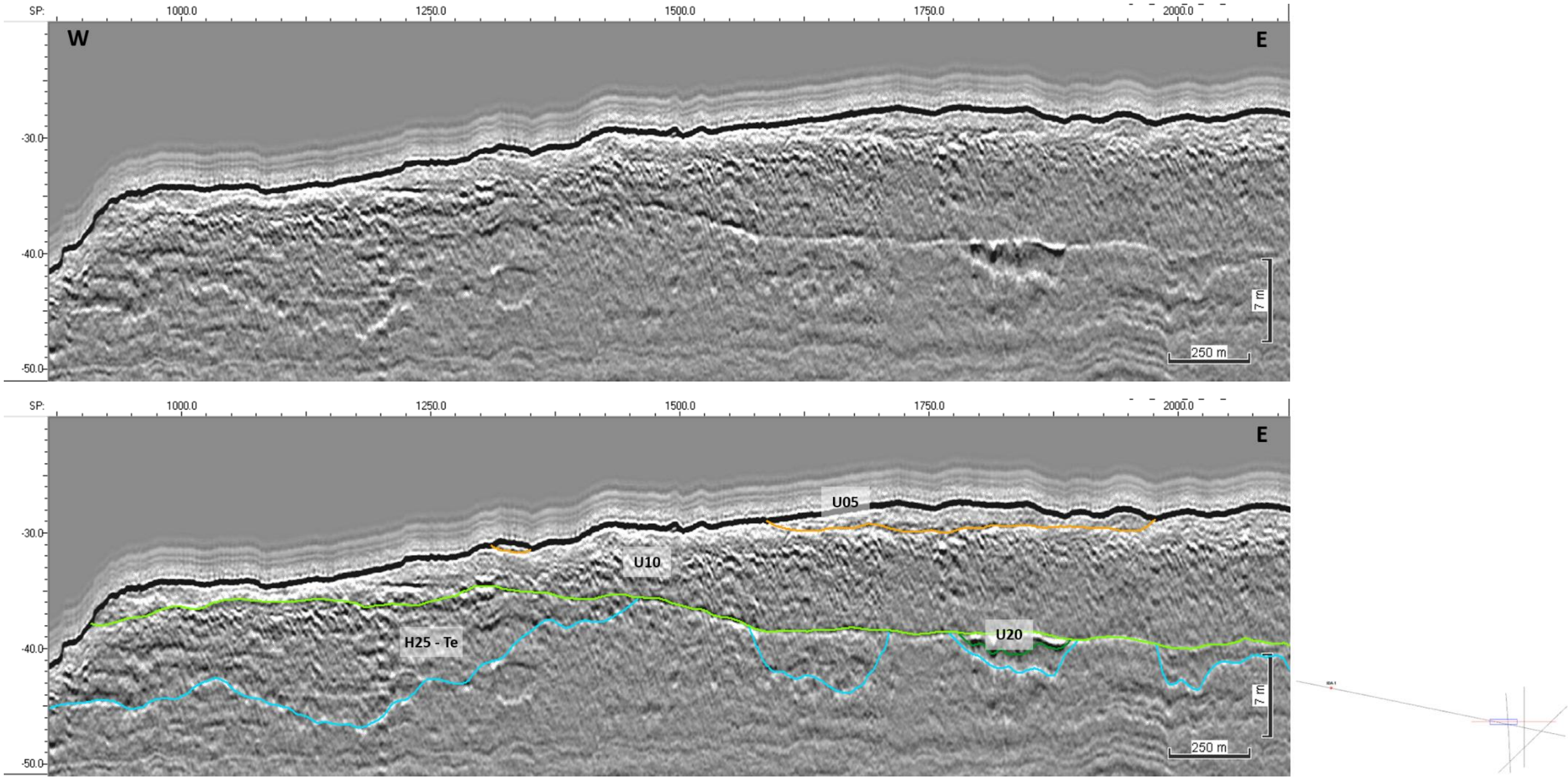


Figure 22 General facies of Seismic Unit U10, and the character of horizon H10 (light green). Seismic profile ML_04_Prio_2.

8.2.3| SEISMIC UNIT U20

Base horizon: 03_H20

SEISMIC UNIT U20	**SEISMIC UNIT U20** **Base horizon: 03_H20** Depth: 35.4 - 48.6 Extent: Sporadic and discontinuous across the site. Description: Irregular; V-shaped incisions and wide shallow depressions. Erosive base. **Seismic unit: U20** Thickness: up to 9.1 Morphology: Tabular (shallow and wide basin infill) or channel infill. Seismic facies: Lateral changes of reflector geometries, steep to low angle. Variable amplitude. Common high negative impedance contrasts. Infills of small basins and channels.
	Interpreted depositional environment: Infills of small basins and channels, likely in a restricted marine-tidal setting, partially associated to a subaerial fluvial system. **Expected sediment content:** Fine sediments, clays, organic matter.

The base of Seismic Unit U20 is delineated by H20 (reference number 03) and is found discontinuously across the site. The spatial distribution, vertical reference to MSL and the seabed, and thickness of the unit are presented in Figure 23, Figure 24, and Figure 25.

Horizon H20 ranges in depth between 35.4 m and 48.6 m below MSL (Figure 23), and between 0.0 m and 15 m depth below the seabed (Figure 24). It delineates the base of channelised incisions (Figure 26) and wide shallow basins (Figure 27), following a reflector of varying amplitude (from medium-high to low-medium), and often marking a significant facies shift. Below the basins, it is usually flat to slightly undulating.

Seismic unit U20 has tabular morphology in basin areas, or infills V-shaped channels. The thickness of U20 is up to 9.1 m (Figure 25).

Seismic unit U20 comprises two distinct facies:

1) **Channels:** channel incisions with chaotic to parallel infill (Figure 26);

2) **Wide shallow basins:** Low amplitude to transparent homogeneous, with faint micro-parallel reflectors and common negative high amplitude anomalies (Figure 27).

Horizon H20 is interpreted as a truncating erosional surface. As interpreted in previously acquired UHRS data, the general spatial arrangement of U20 is indicative of a drainage network. U20 is interpreted to have been deposited in restricted marine-tidal setting, partially associated to a subaerial fluvial system.

Within the wide basins, the deposits of U20 are expected to comprise fine sediments, from clays-silts-fine sands; whereas channel infills are likely to contain slightly coarser sediments such as fine sands-sands. The observed negative high amplitude reflectors may be related to the occurrence of organic matter within this unit.

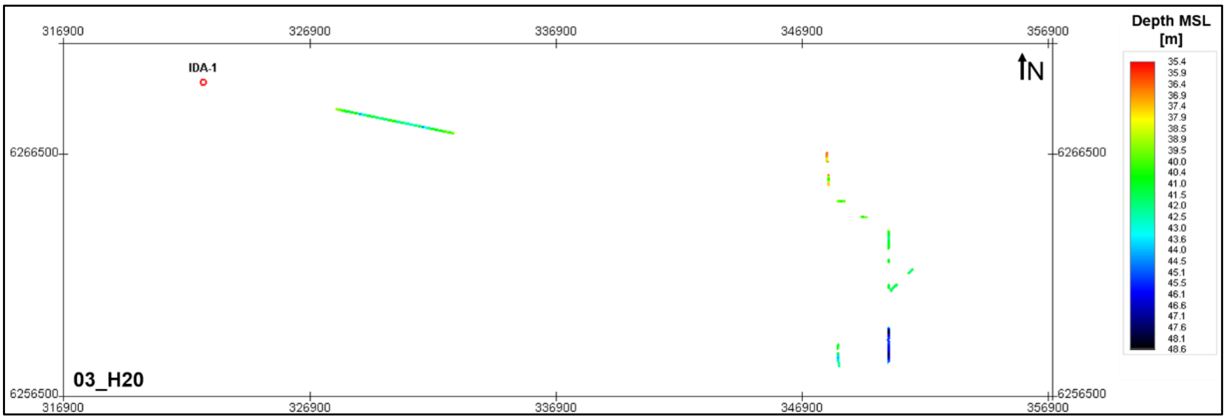


Figure 23 Map showing the lateral extent of H20.
Depth below MSL. Units in metres.

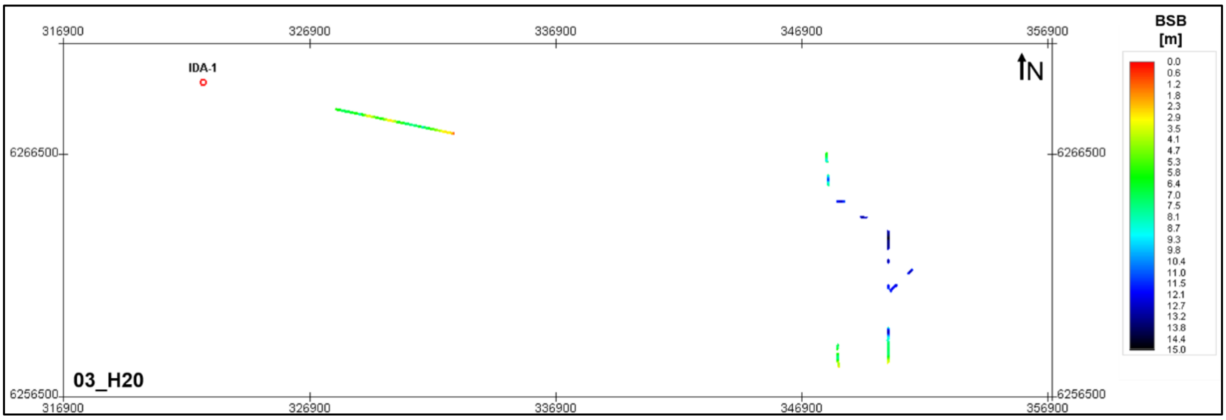


Figure 24 Depth below seabed of H20.
Units in metres below seabed.

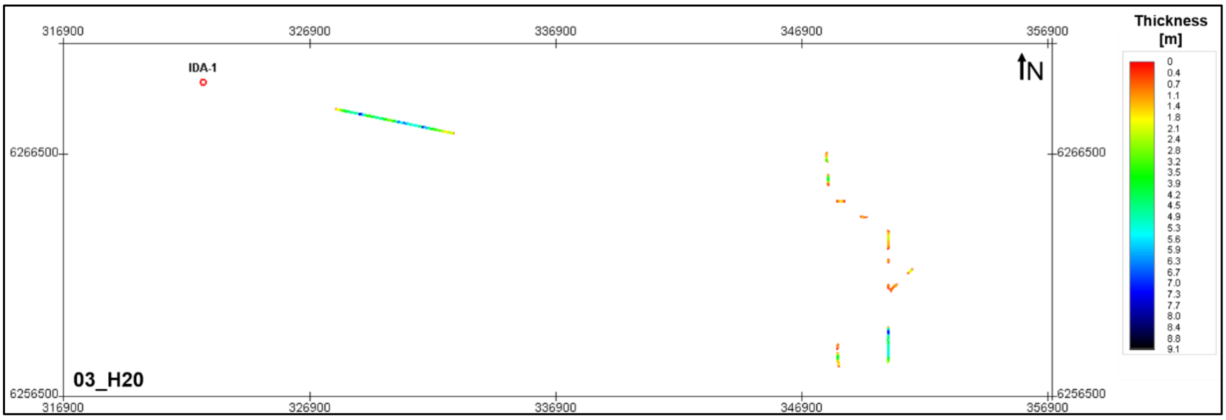


Figure 25 Thickness of unit U20.
Units in metres.

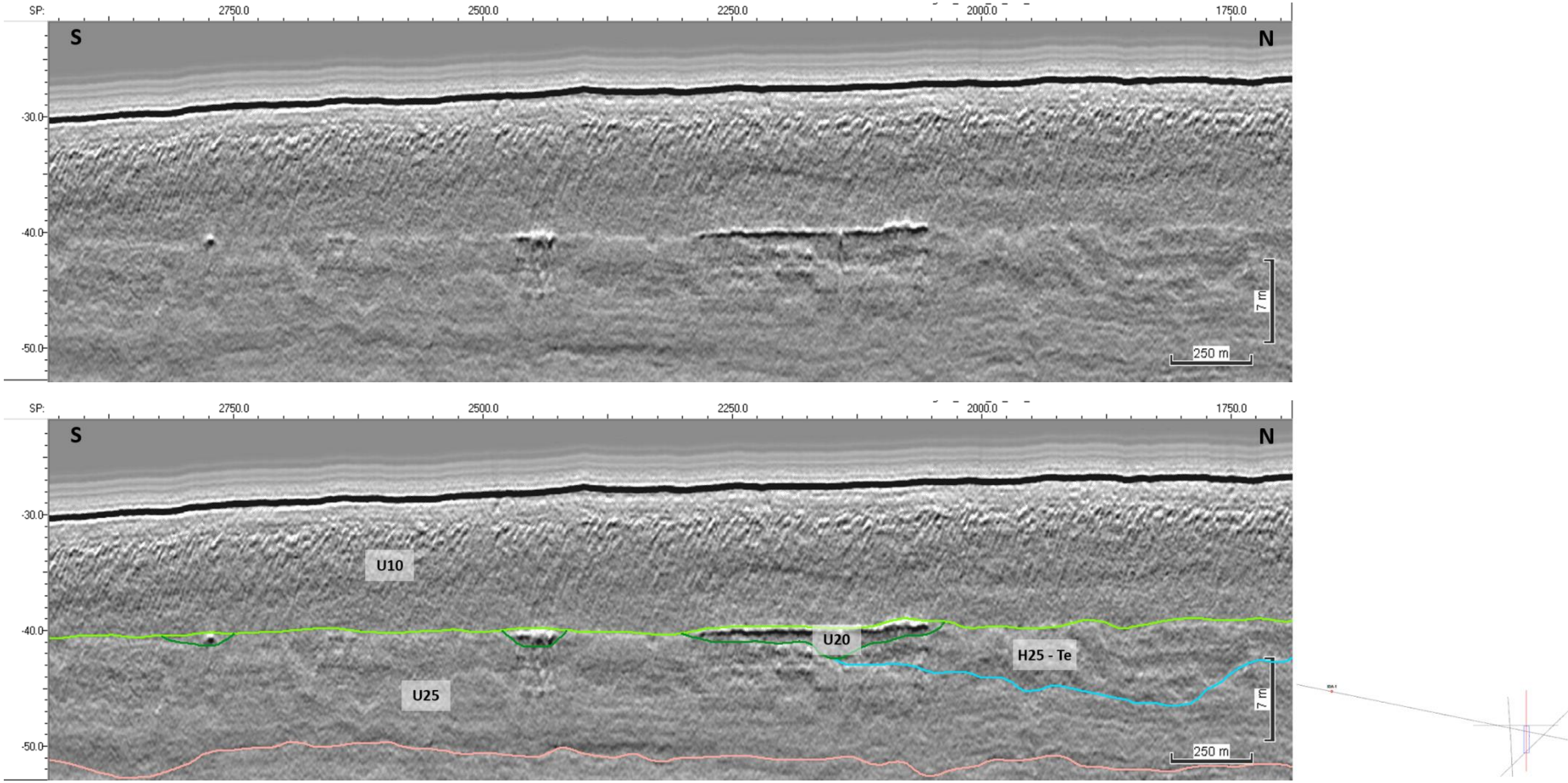


Figure 26 Infilled channel of Seismic Unit U20, and the character of horizon H20 (dark green). Negative high amplitude reflectors are observed at the top of U20.
Seismic profile ML_03_Prio_2.

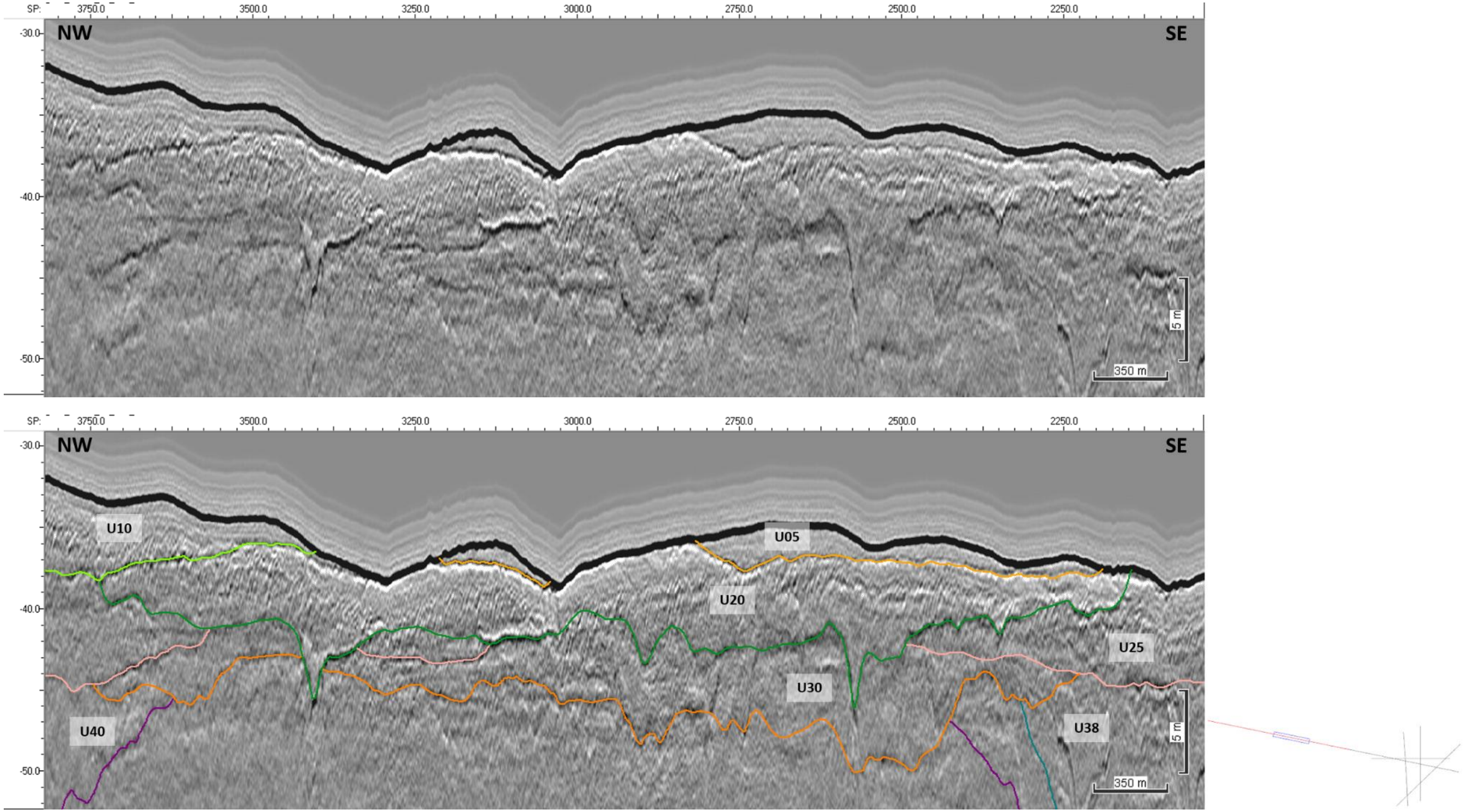


Figure 27 Infill facies of a wide shallow basin of Seismic Unit U20, and character of horizon H20. H20 is shown in dark green. Seismic profile ML_01_Prio_1.

8.2.4| SEISMIC UNIT U25

Internal horizon: 04_H25-Te

Base horizon: 05_H25

<table>
<tr><td rowspan="3">SEISMIC UNIT U25</td><td>SEISMIC SUBUNIT U25-Te
Base horizon: 04_H25-Te
Depth: 35.6 - 48.8
Extent: Present across EI area; absent towards NW.
Description: Irregular; mild undulations; non-continuous reflector. Erosive base.
Seismic subunit: U25-Te
Thickness: up to 11.2
Morphology: Wide and shallow channel infills; tabular.
Seismic facies: Stacked channels and lenses. Transparent; or stratified (micro-parallel) with low amplitude reflectors. Common negative high amplitudes (soft-kicks).</td></tr>
<tr><td>SEISMIC SUBUNIT U25
Base horizon: 05_H25
Depth: 40.8 - 56.7
Extent: Continuous across the site.
Description: Continuous and slightly undulating; variable amplitude (low-high).
Seismic subunit: U25
Thickness: up to 16
Morphology: Tabular (shallow and wide basin infill) or channel infill.
Seismic facies: Well-stratified facies; micro-parallel to parallel reflectors. Low to medium amplitudes. Common channel of transparent infill. Micro mounds and basins at the base.</td></tr>
<tr><td>Interpreted depositional environment: Fine sediments (?) deposited in a relatively low-energetic setting, possibly glacial lake system or a transgressive estuary.

Expected sediment content: Fine sediments: Silts and fine sands (U25 – Te); clays and fine sands-silts (U25).</td></tr>
</table>

Seismic unit U25 is a major component of the ground model, and extends spatially across the site, although being more prominent in the EI area. It is divided into two subunits of different seismic character: subunits U25-Te (above) and U25 (below). The spatial distribution, vertical reference to MSL and the seabed, and thickness of the seismic subunits are presented in Figure 28 to Figure 33.

SUBUNIT U25-TE

The base of seismic subunit U25-Te is defined by horizon H25-Te (reference number 04), between 35.6 m and 48.8 m depth below MSL (Figure 28), and between 0.0 m and 19.8 m depth below the seabed (Figure 29). H25-Te is a discontinuous and slightly undulating reflector of variable amplitude (low-high), delineating the base of wide and shallow channels.

Seismic subunit U25-Te only occurs within the EI area, being absent towards NW. U25-Te comprises the infill sediments of shallow and wide channels, up to 11.2 m thick (Figure 30). It marks a variation of acoustic impedance relative to the subunit U25 deposits below. It is often truncated by H20.

Subunit U25-Te comprises deposits infilling stacked channels and lenses (Figure 34 and Figure 35). The seismic facies of U25-Te are generally transparent; or stratified (micro-parallel) with low amplitude reflectors. The base of the channels is generally marked by a negative amplitude reflector.

SUBUNIT U25

The base of seismic subunit U25 is defined by horizon H25 (reference number 05), between 40.8 m and 56.7 m depth below MSL (Figure 31), and between 0.0 m and 27.4 m depth below the seabed (Figure 32). H25 is a continuous and slightly undulating reflector of variable amplitude (low-high). Locally this horizon defines a facies shift, onlapping onto the older U30 deposits.

Seismic subunit U25 has a general tabular morphology, infilling shallow and wide basins or channels. Its thickness is up to 16 m (Figure 33).

In general, U25 is characterised by well-stratified facies of low to medium amplitude. Internal reflectors are micro-parallel or laminated, gently undulating in places (Figure 34 and Figure 35). Their thickness and acoustic amplitude decrease towards the top. Small-scale, box-shaped channels with transparent infill are scattered at several levels within U25, truncating the thinly-layered sequence. The occurrence and size of these channels increase towards the top of the unit, with common vertical stacking. Micro mounds and small basins are observed at the base.

The sediments constituting seismic unit U25 are interpreted to have been deposited in a relatively low-energetic setting, possibly related to a glacial lake system or flood plain/transgressive estuary. However, the increase of small channel-incisions within the upper deposits of U25-Te suggests the onset of a regressive event/fluctuation. From the seismic character of U25 and its interpreted depositional system, it is estimated that the thinly-layered deposits comprise fine sediments, such as fine sands-silts (?), and that the transparent channel infill may correspond to unstructured fine sediments (?).

In previously acquired UHRS data, local areas of seismic unit U25 exhibit variable degrees of internal deformation.

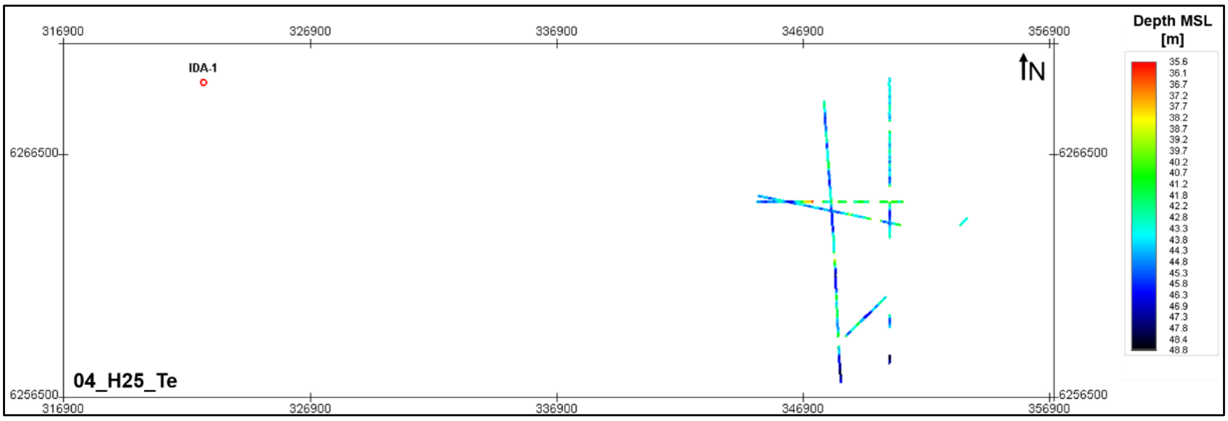


Figure 28 Map showing the lateral extent of subunit U25 - Te.
Units in metres below MSL.

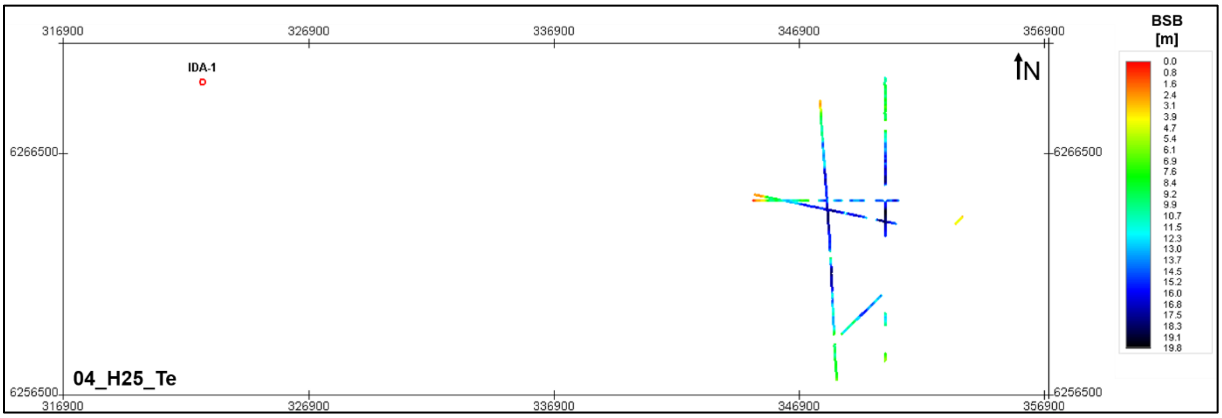


Figure 29 Depth below seabed of H25 - Te.
Units in metres below seabed.

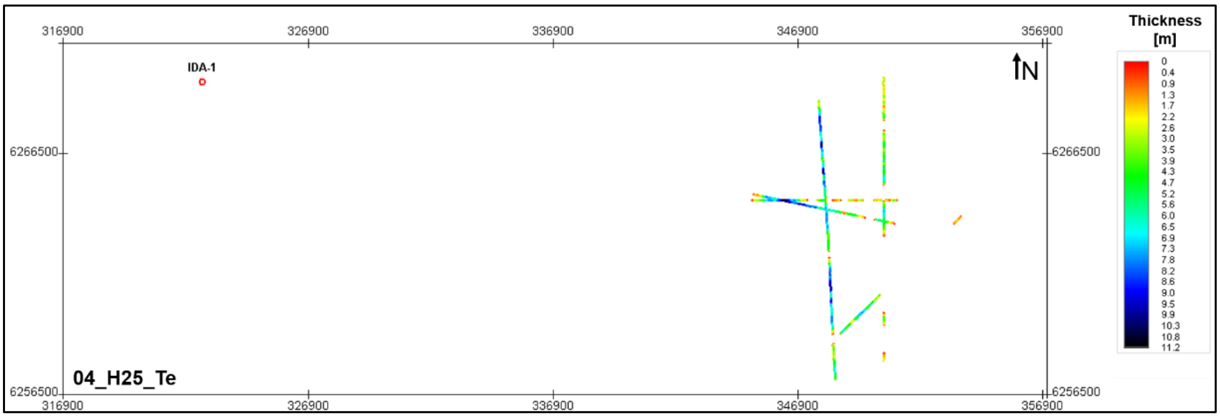


Figure 30 Thickness of subunit U25 - Te.
Units in metres.

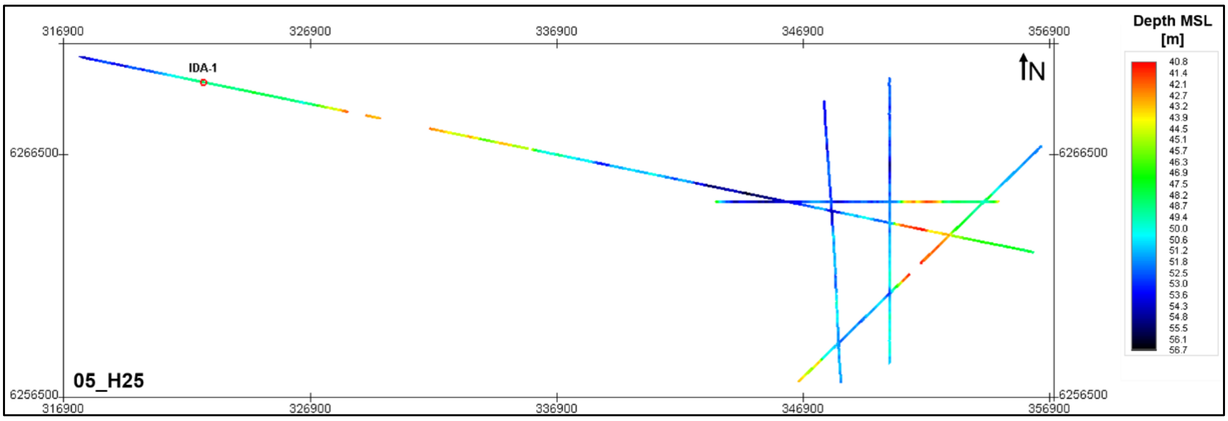


Figure 31 Map showing the lateral extent of U25.
Units in metres below MSL.

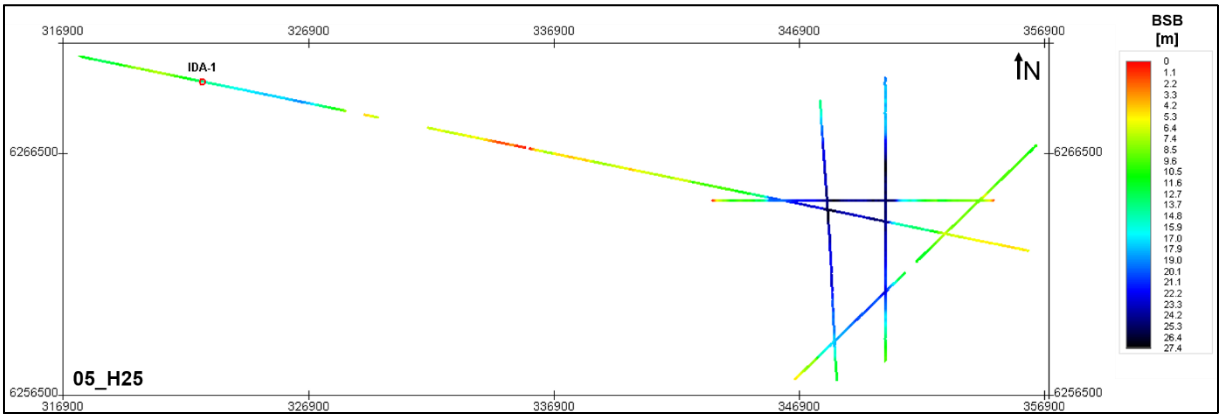


Figure 32 Depth below seabed of H25.
Units in metres below seabed.

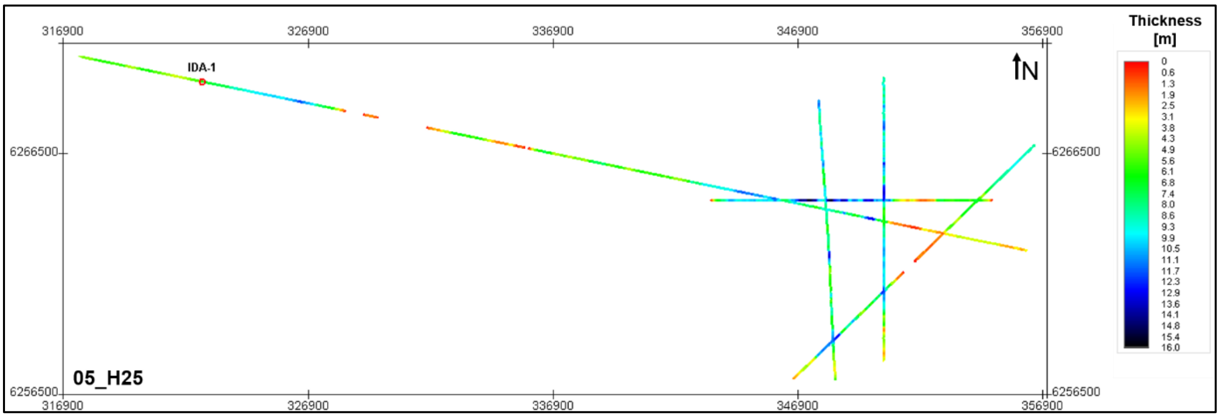


Figure 33 Thickness of unit U25.
Units in metres.

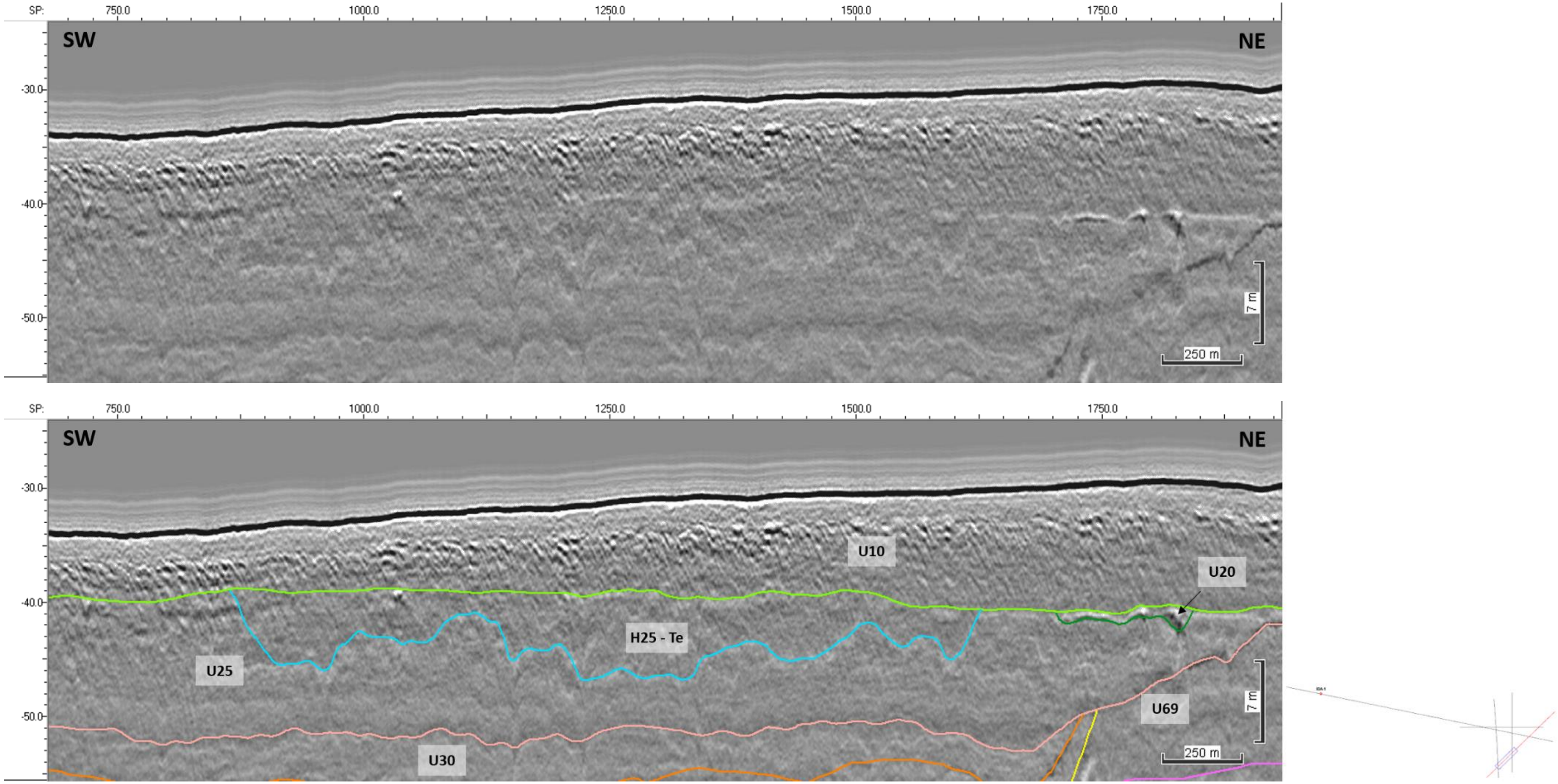


Figure 34 General facies of Seismic Subunit U25 - Te, and character of horizon H25 - Te. H25 - Te is shown in light blue. H25 is shown in rosy brown. Seismic profile ML_10_Prio_2.

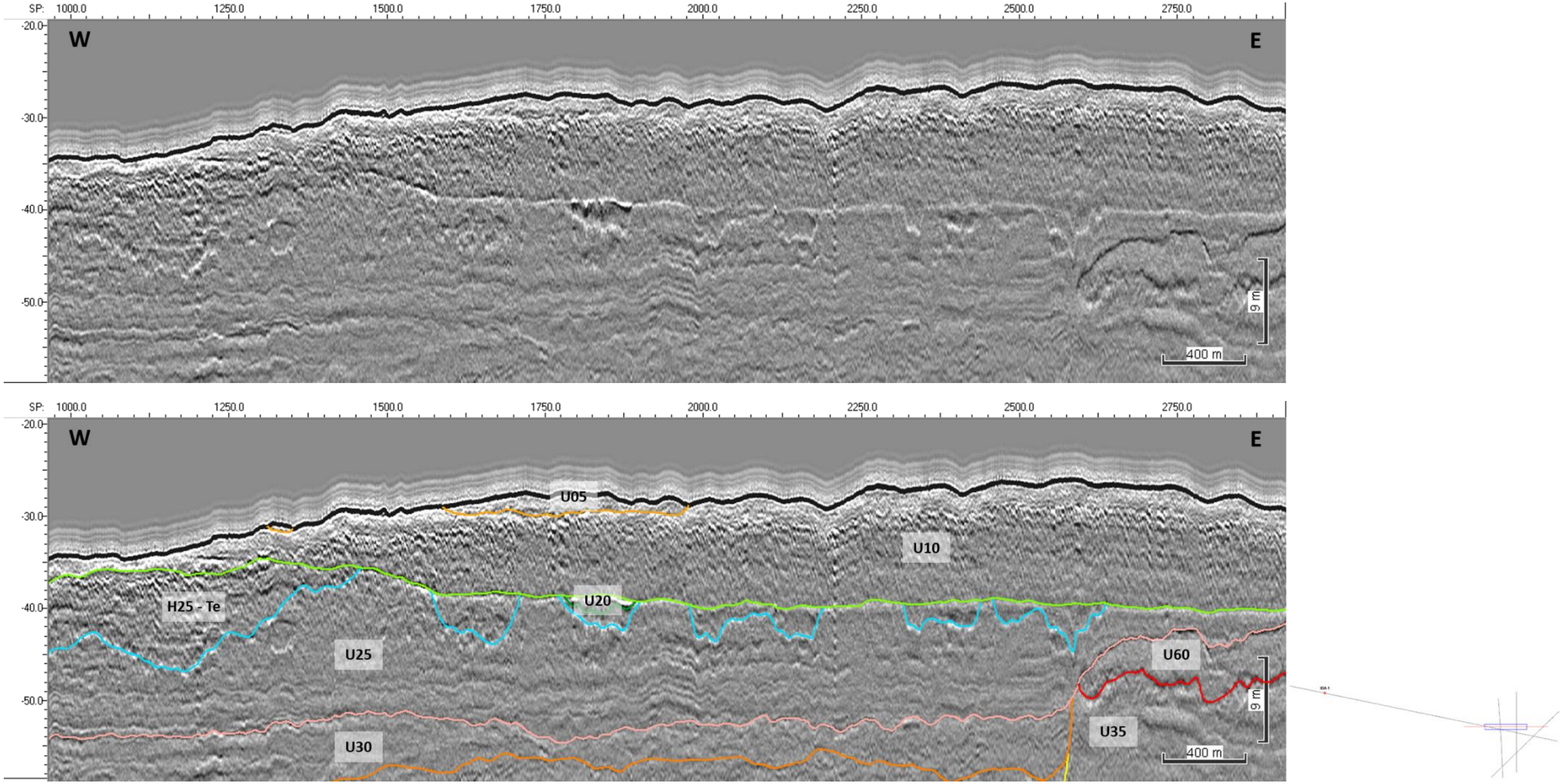


Figure 35 U25 facies within Energy Island area, where the unit is thicker. H25 is shown in rosy brown. Seismic profile ML_04_Prio_2.

8.2.5| SEISMIC UNIT U30

Base horizon: 06_H30

SEISMIC UNIT U30	
	SEISMIC UNIT U30 **Base horizon: 06_H30** Depth: 42.4 - 68.2 Extent: Discontinuous across the site. Description: Sub-horizontal, uneven, undulating surface. Erosive base. Angular unconformity with underlying sediments. **Seismic unit: U30** Thickness: up to 14 Morphology: Tabular (shallow and wide basin infill) or channel infill. Seismic facies: Medium amplitudes; parallel reflectors; channel infills.
	Interpreted depositional environment: Fining-upward sequence, likely fluvial in nature. **Expected sediment content:** Silts to fine sands.

Seismic unit U30 is defined by the base horizon H30 (reference number 06) and is present discontinuously within the survey area. The spatial distribution, vertical reference to MSL and the seabed, and thickness of the unit are presented in Figure 36, Figure 37, and Figure 38.

Horizon H30 ranges in depth between 42.4 m and 68.2 m below MSL (Figure 36), and between 2.8 m and 34.0 m depth below the seabed (Figure 37). Horizon H30 represents an uneven, undulating surface (Figure 39). This uneven base marks an erosional surface that truncates the deposits below it.

Seismic unit U30 has a tabular (shallow and wide basin infill) or channel morphology, up to 14 m thick. U30 is characterized by composite facies of medium to high amplitude (Figure 39). Towards the top, reflectors are sub-horizontal, parallel and wavy. Towards the base, the complexity of the seismic facies increases, with common mounds, lenses, channel infill, hummocky reflectors, and chaotic in parts.

The sediments constituting seismic unit U30 are interpreted to have been deposited in setting of slightly higher energy than the overlying U25, as evidenced by the occurrence of channel and chaotic deposits at the base. The sequence of seismic facies within U30 is indicative of decrease of energy from the base towards the top, possibly associated to a transgressive event. From the seismic character of U30 and its interpreted depositional system, it is estimated that, in general, there is a decrease in grain size towards the top, with probable sandier sediments at the base, getting progressively finer upwards (?).

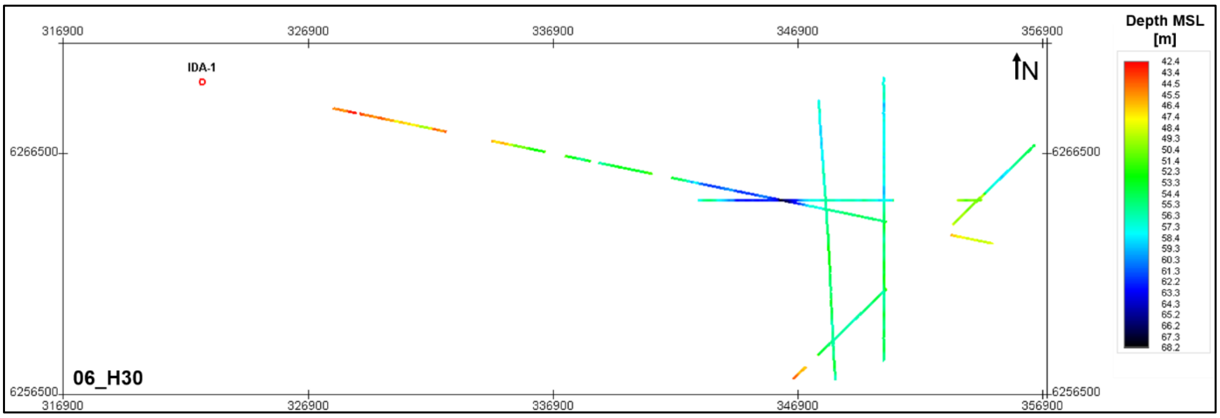


Figure 36 Map showing the lateral extent of U30.
Units in metres below MSL.

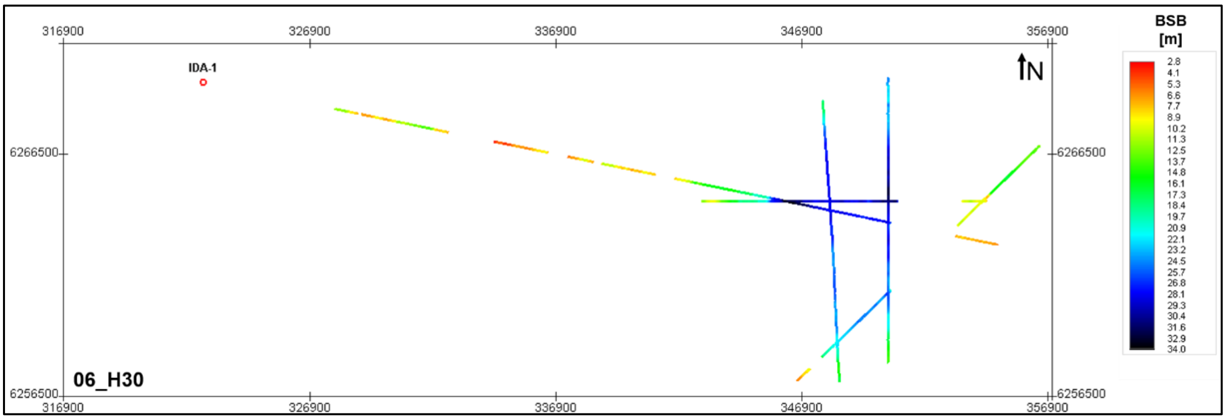


Figure 37 Depth below seabed of H30.
Units in metres below seabed.

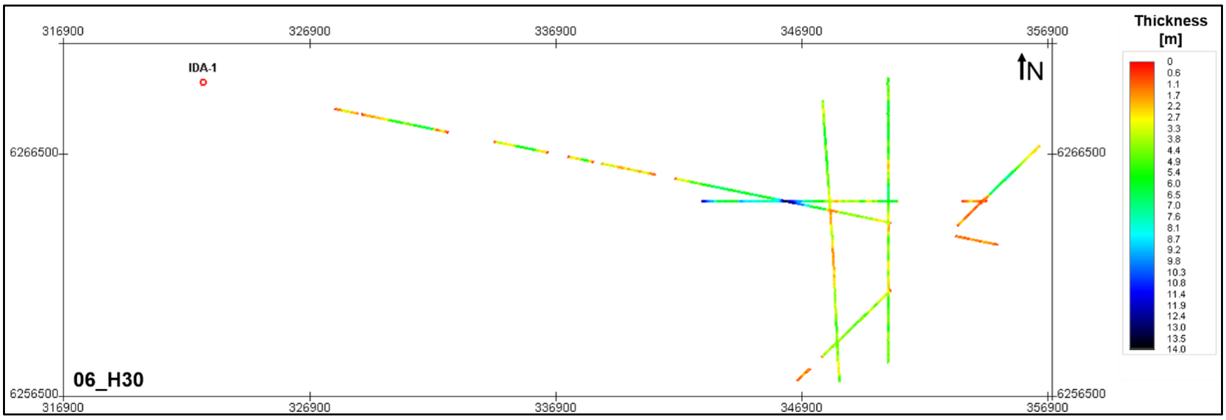
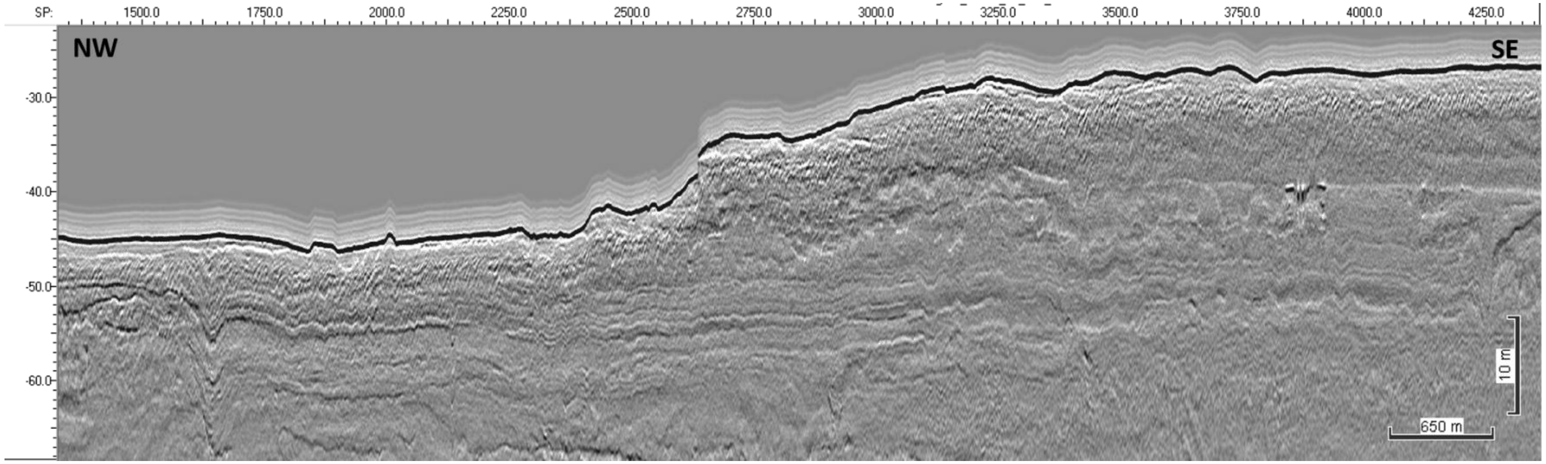
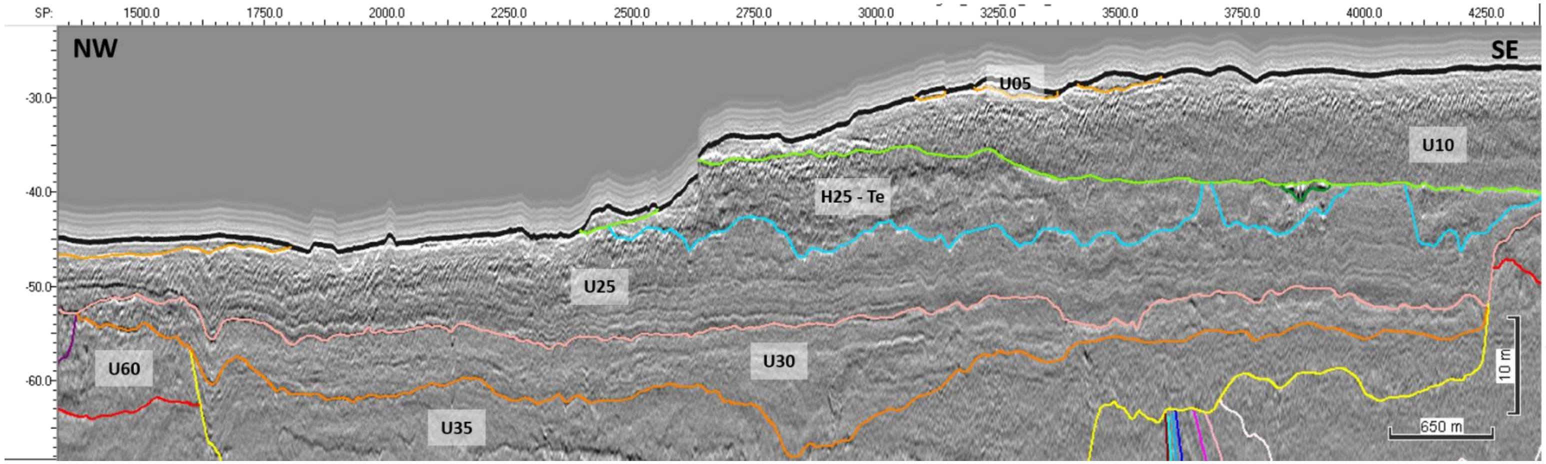


Figure 38 Thickness of unit U30.
Units in metres.





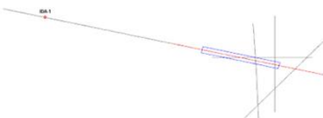


Figure 39 General facies of Seismic Unit U30, and the character of horizon H30 (orange). Seismic profile ML_01_Prio_1a.

8.2.6| SEISMIC UNIT U35

Base horizon: 07_H35

<table>
<tr><td rowspan="2">SEISMIC UNIT U35</td><td>SEISMIC UNIT U35
Base horizon: 07_H35
Depth: 43.2 - 87.3
Extent: Discontinuous; only present in EI area.
Description: Irregular base with localized incisions. Erosive base.
Seismic unit: U35
Thickness: up to 25.1
Morphology: Tabular to mega-lens shaped.
Seismic facies: Complex; medium amplitudes; macro-parallel reflectors. Discontinuous dipping reflectors of variable amplitude; chaotic facies; stacked channel deposits and lenses. Parallel wavy internal erosive surfaces.</td></tr>
<tr><td>Interpreted depositional environment: Possible outwash plain. High energy fluvial bedforms (flash floods?).

Expected sediment content: Mainly sands and gravel, with enclaves of coarser-grained clasts (?), fining-upward (?).</td></tr>
</table>

Seismic unit U35 is found exclusively within the EI area. The base of Seismic Unit U35 is defined by horizon H35 (reference number 07). The spatial distribution, vertical reference to MSL and the seabed, and thickness of the unit are presented in Figure 40, Figure 41, and Figure 42.

Horizon H35 ranges in depth between 43.2 m and 87.3 m below MSL (Figure 40), and between 7.1 m and 52.4 m depth below the seabed (Figure 41). Horizon H35 represents an uneven, rugose, undulating surface, with localized incisions (Figure 43). This uneven base marks an erosional surface, truncating the deposits below. When present and continuous, H35 was mapped along a reflector of variable amplitude (low to high).

Seismic unit U35 has a tabular to a mega lens-shaped morphology, up to 25.1 m thick (Figure 42). This unit is characterized by complex facies of low to high amplitude reflectors, discontinuous and dipping (Figure 43 and Figure 44). Compared to U30 above, U35 comprises larger proportioned and more complex seismic facies associations, such as meso-scale mounds, channels, and lenses. There are numerous internal erosional surfaces separating these features. In general, the thickness of the internal packages decreases towards the top, becoming more sub-horizontal and sub-parallel, grading up.

Seismic unit U35 sediments are interpreted to have been deposited in a high energy setting, as evidenced by the meso-scale facies association, the numerous internal erosional surfaces, and more complex geometries. Horizon H35 is an unconformity surface associated to a major erosional event, possibly related to ice-flow. The infill deposits constitute mega-bedforms, comprising high energy fluvial deposits (flash floods?), likely associated to a pro-glacial outwash plain. The combined sequence of seismic facies U35-U30-U25 is indicative of an overall decrease of energy from the base towards the top. From the seismic character of U35 and its interpreted depositional system, it is estimated that the sediments are likely gravel and sands with enclaves of coarser-grained clasts, possibly decreasing in grain size towards the top of the unit (fining-upward sequence?).

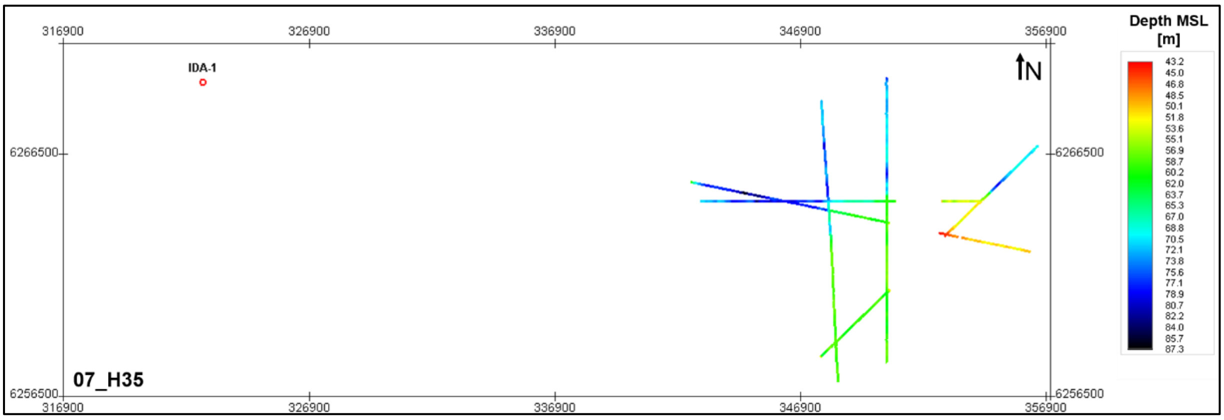


Figure 40 Map showing the lateral extent of U35.
Units in metres below MSL.

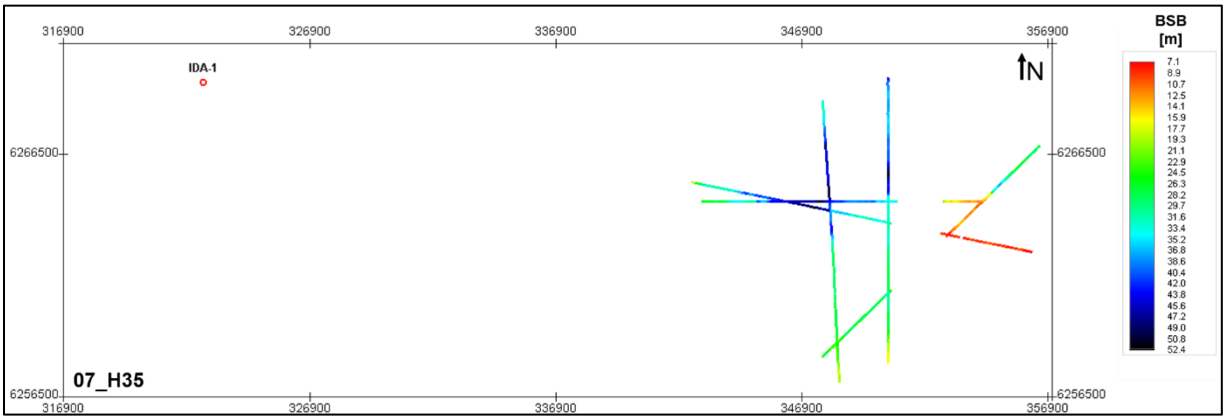


Figure 41 Depth below seabed of H35.
Units in metres below seabed.

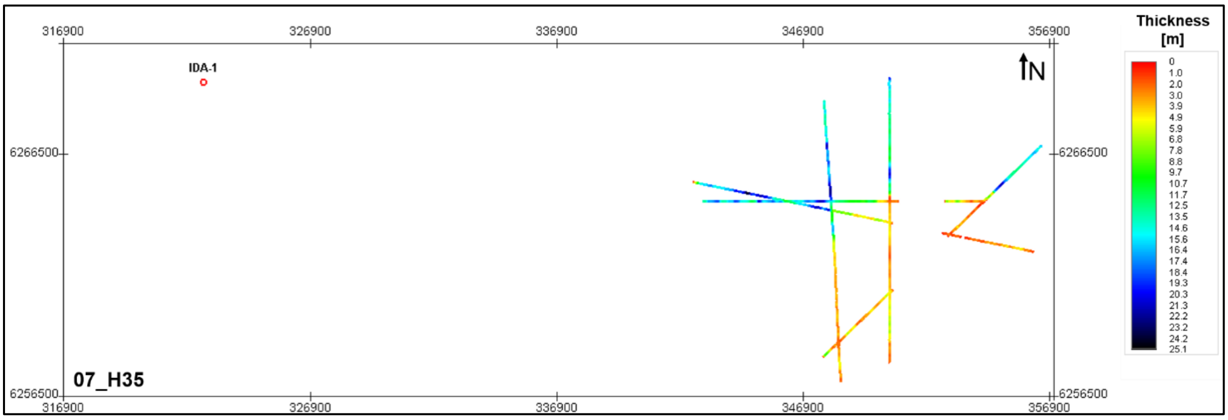


Figure 42 Thickness of unit U35.
Units in metres.

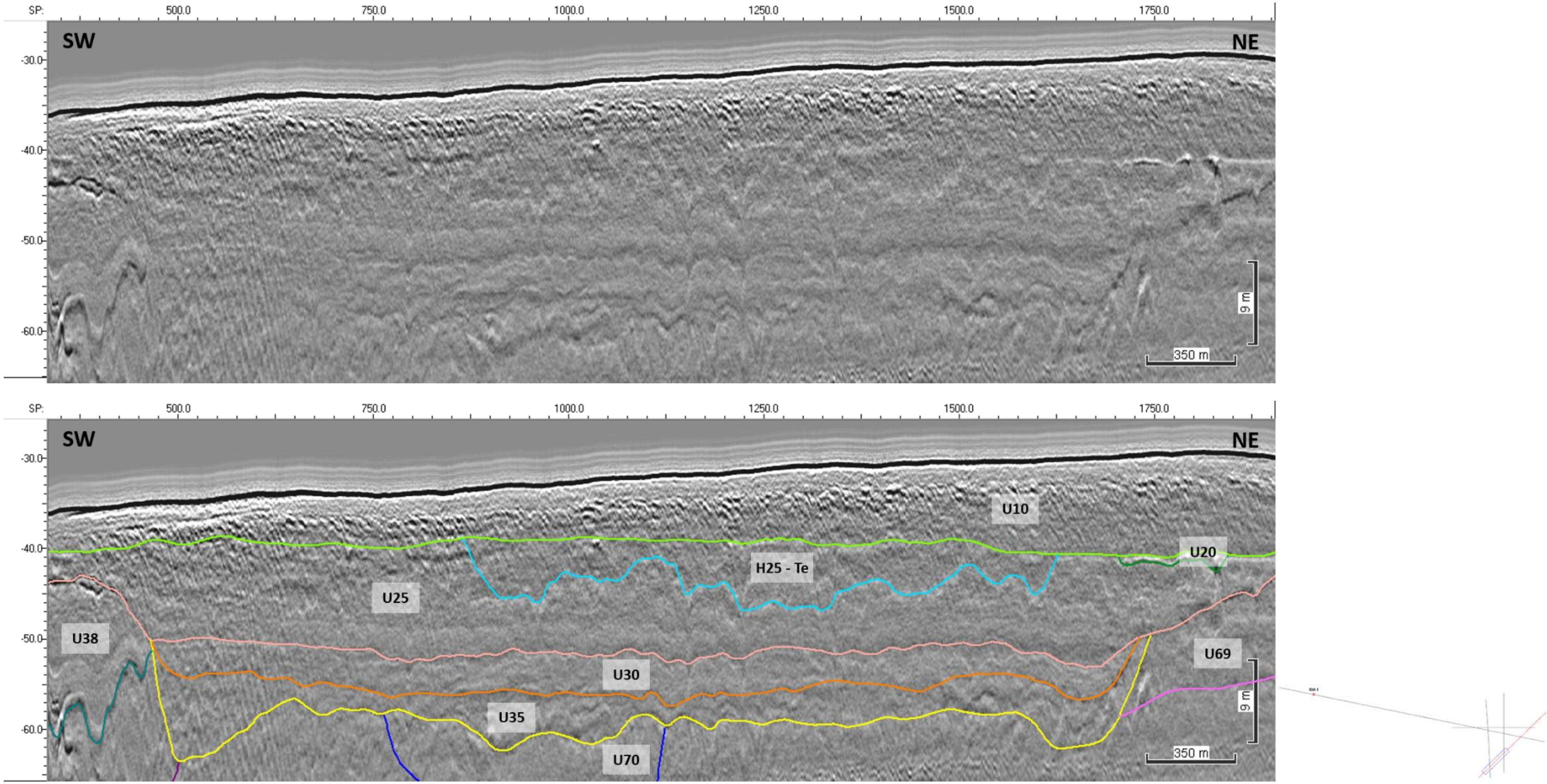


Figure 43 General facies of Seismic Unit U35, and the character of horizon H35. H35 is shown in yellow. Seismic profile ML_10_Prio_2.

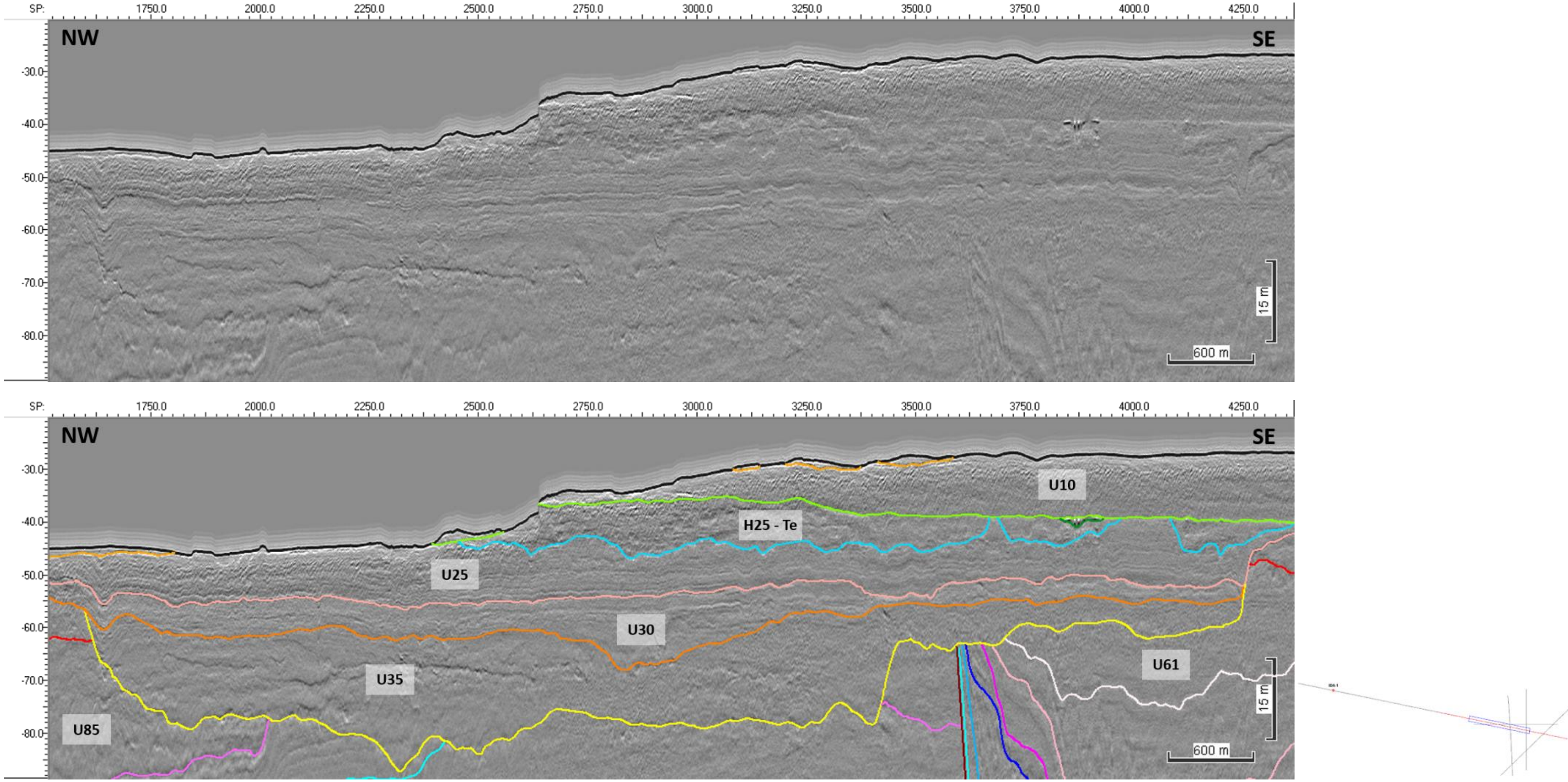


Figure 44 General facies of Seismic Unit U35, and the character of horizon H35. H35 is shown in yellow. Seismic profile ML_01_Prio_1a.

8.2.7| SEISMIC UNIT U40

Internal horizon: 08_H38

Base horizon: 09_H40

SEISMIC UNIT U40	**SEISMIC SUBUNIT U38** **Base horizon: 08_H38** Depth: 45.6 - 99.5 Extent: Discontinuous; mostly present towards NW. Description: Undulating base, localized incisions. **Unit seismic character:** Thickness: up to 46.5 Morphology: Channel infill. Seismic facies: Well stratified, micro-parallel, laminated; low to medium amplitudes.
	SEISMIC SUBUNIT U40 **Base horizon: 09_H40** Depth: 45.3 - 147.4 Extent: Discontinuous; mostly present towards NW. Description: Irregular; large U and V-shaped incisions; erosive base. **Unit seismic character:** Thickness: up to 59.5 Morphology: Channel infill; tabular. Seismic facies: Reflector disruption; chaotic; folding and faulting; variable seismic facies and internal geometries: from parallel to chaotic facies. Heavily deformed.
	Interpreted depositional environment: Possible glacial lake infill; glacio-lacustrine. Possible glacial thrust complexes and buried tunnel valleys; heavily deformed. Drainage system of glaciar melt back from the north, and outwash plains, with variable sediment content. Glacial period (Weichselian?) **Expected sediment content:** Possible glacio-lacustrine; fine sediments, muds. Mixed sediments: possible glacial tills and glacio-fluvial deposits.

Seismic unit U40 extends discontinuously across the site, being more prominent towards NW. It is divided into two subunits of different seismic character: subunits U38 (above) and U40 (below). The spatial distribution, vertical reference to MSL and the seabed, and thickness of the seismic subunits are presented in Figure 45 to Figure 50.

SUBUNIT U38

The base of seismic subunit U38 is defined by horizon H38 (reference number 08), between 45.6 m and 99.5 m depth below MSL (Figure 45), and between 5.4 m and 53.9 m depth below the seabed (Figure 46). H38 is a discontinuous, undulating reflector of variable amplitude (low-high), delineating the base of channel incisions.

Seismic subunit U38 comprises the infill sediments at the top of U40 incisions, up to 46.5 m thick (Figure 47).The seismic facies of subunit U38 are characterized by well stratified, micro-parallel, laminated reflectors, of low to medium amplitudes (Figure 51).

SUBUNIT U40

The base of seismic subunit U40 is defined by horizon H40 (reference number 09), between 45.3 m and 147.4 m depth below MSL (Figure 48), and between 7.8 m and 102 m depth below the seabed (Figure 49). H40 is an irregular erosive reflector of variable amplitude (low-high), delineating the base of large U and V-shaped incisions.

The infilled incisions of U40 exhibit a wide range of sizes and depositional characteristics, generally complex and heterogenous, up to 59.5 m thick (Figure 50). Internal seismic facies exhibit variable patterns, from parallel layering (generally undulating) to chaotic or transparent. Reflector disruption and internal folding and faulting are common. Some U40 channels are positioned (at least partially) directly above older incisions (commonly of U70), exploiting pre-existing incisions.

Seismic unit U40 is interpreted to be associated with glacier drainage and outwash plains. The seismic facies pattern in U40 is interpreted to represent channel deposition with variable infill history– i.e., periods with high energy and coarser material deposition, and periods of lower energy with deposits of fine sediments (subunit U38), which may be related to glaciolacustrine deposition (Figure 52). The deformation affecting U40 deposits is interpreted to be related to glacio-tectonics processes.

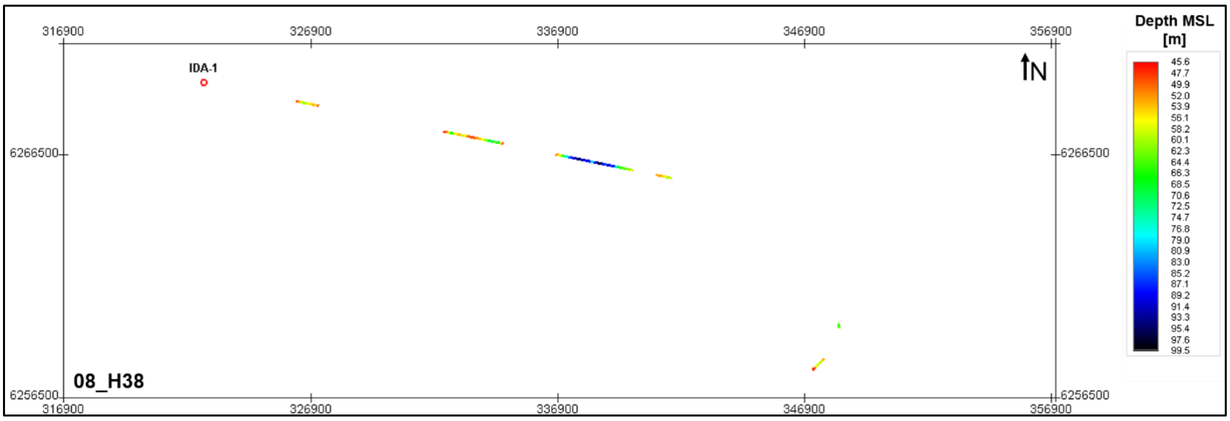


Figure 45 Map showing the lateral extent of U38.
Units in metres below MSL.

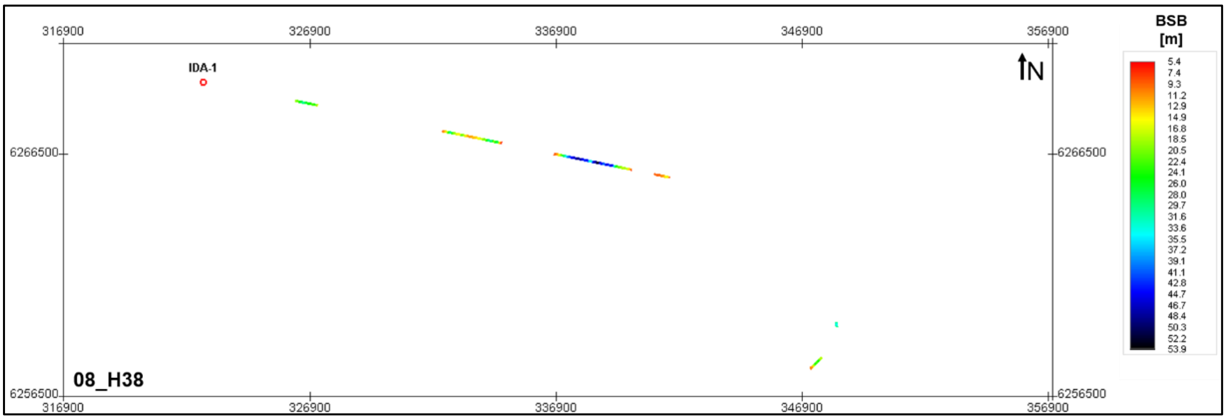


Figure 46 Depth below seabed of H38.
Units in metres below seabed.

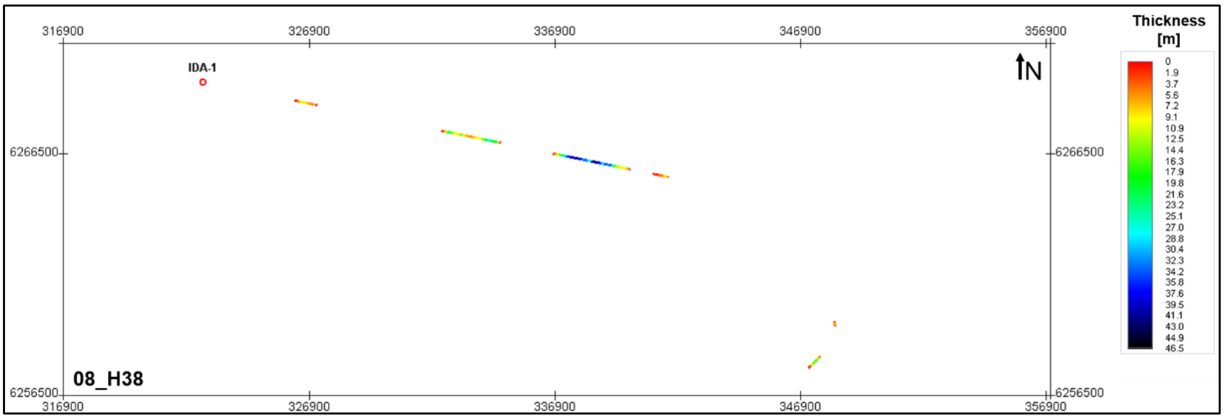


Figure 47 Thickness of unit U38.
Units in metres.

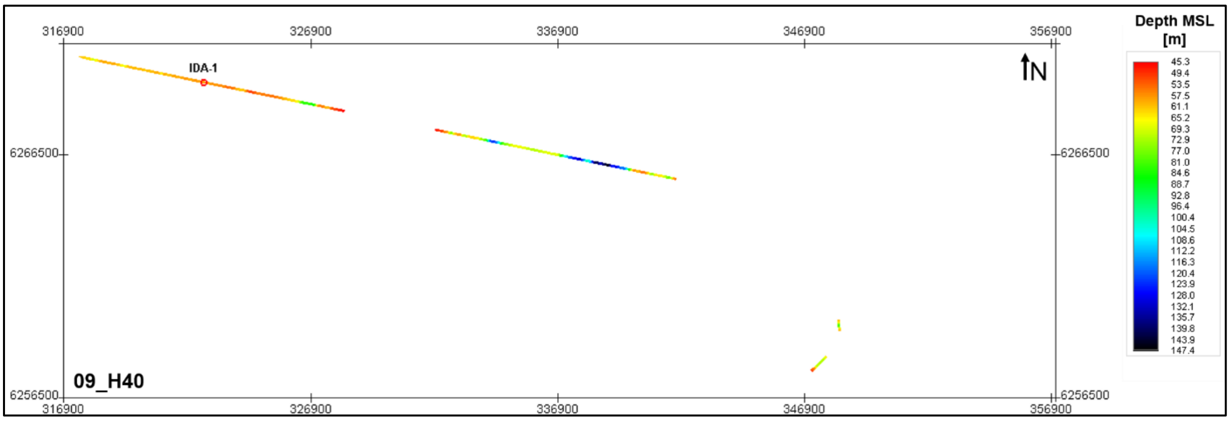


Figure 48 Map showing the lateral extent of U40.
Units in metres below MSL.

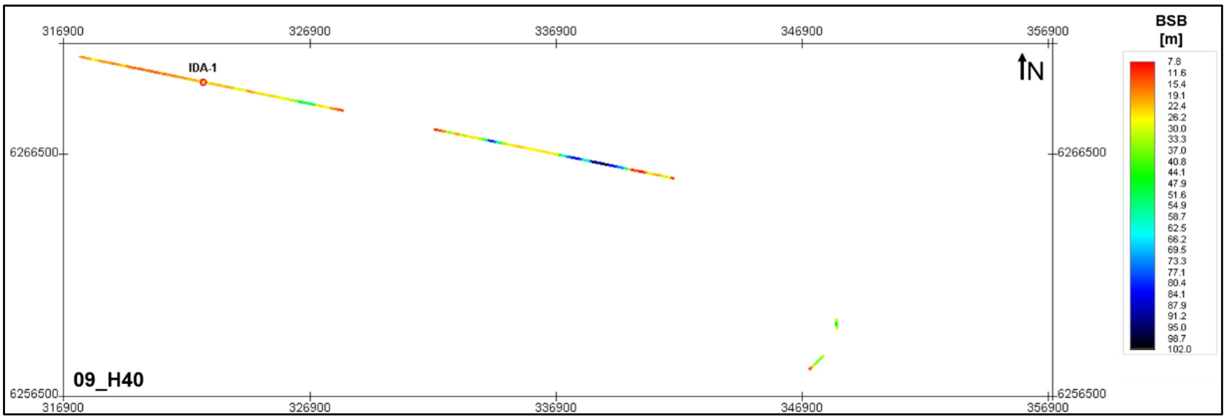


Figure 49 Depth below seabed of H40.
Units in metres below seabed.

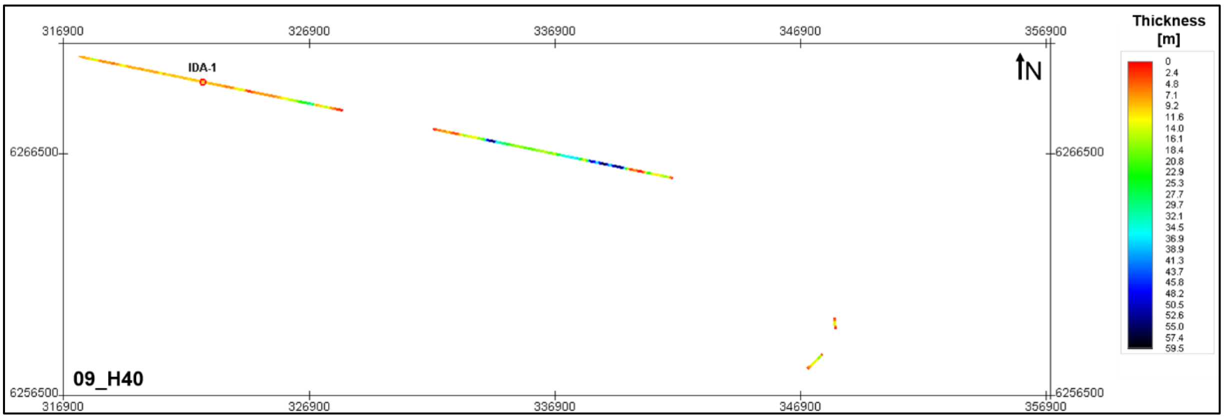


Figure 50 Thickness of unit U40.
Units in metres.

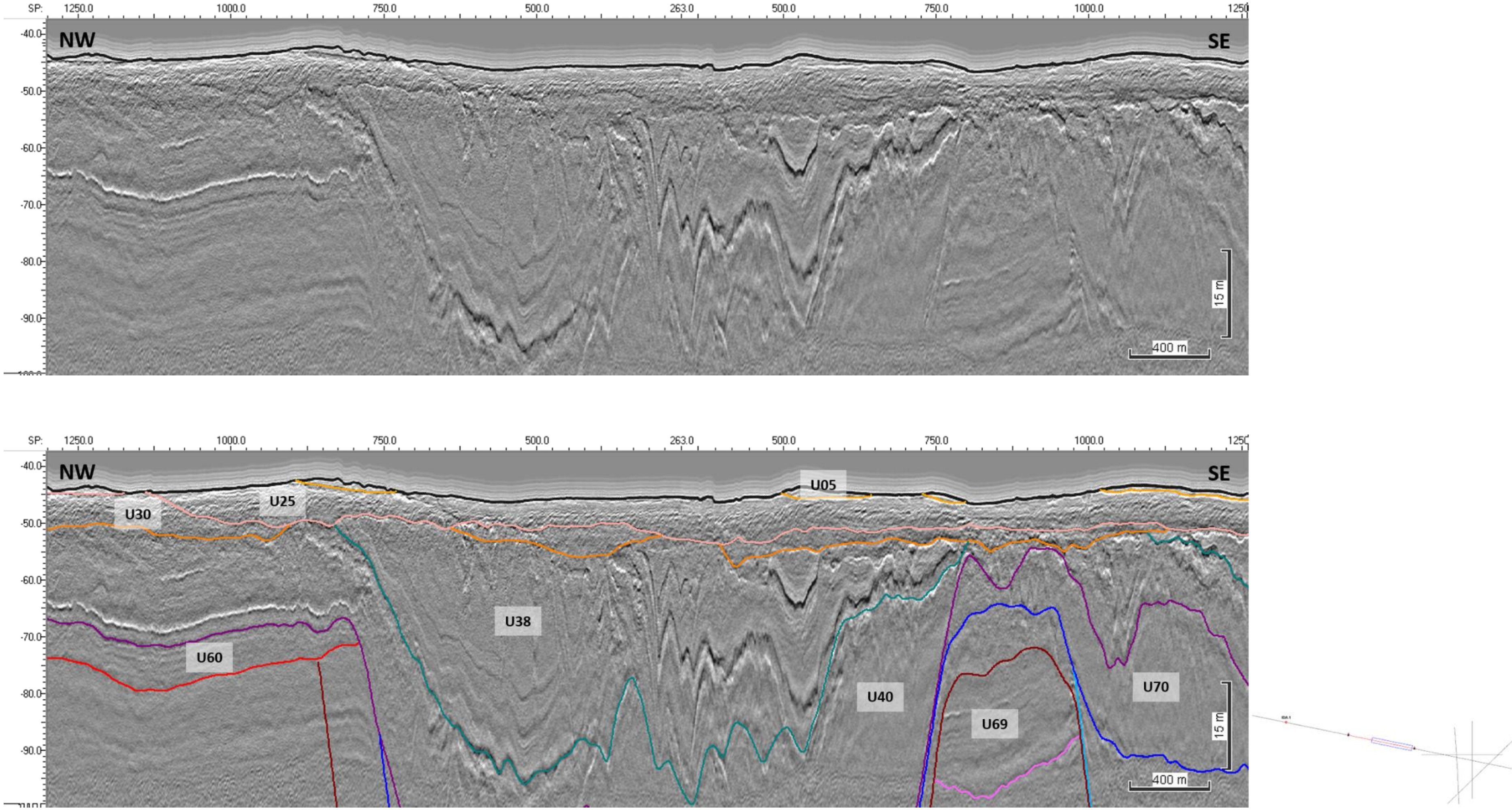


Figure 51 General facies of Seismic Unit U38, and the character of horizon H38. H38 is shown in dark cyan. Arbitrary line with seismic profiles ML_01_Prio_1 and ML_01_Prio_1a.

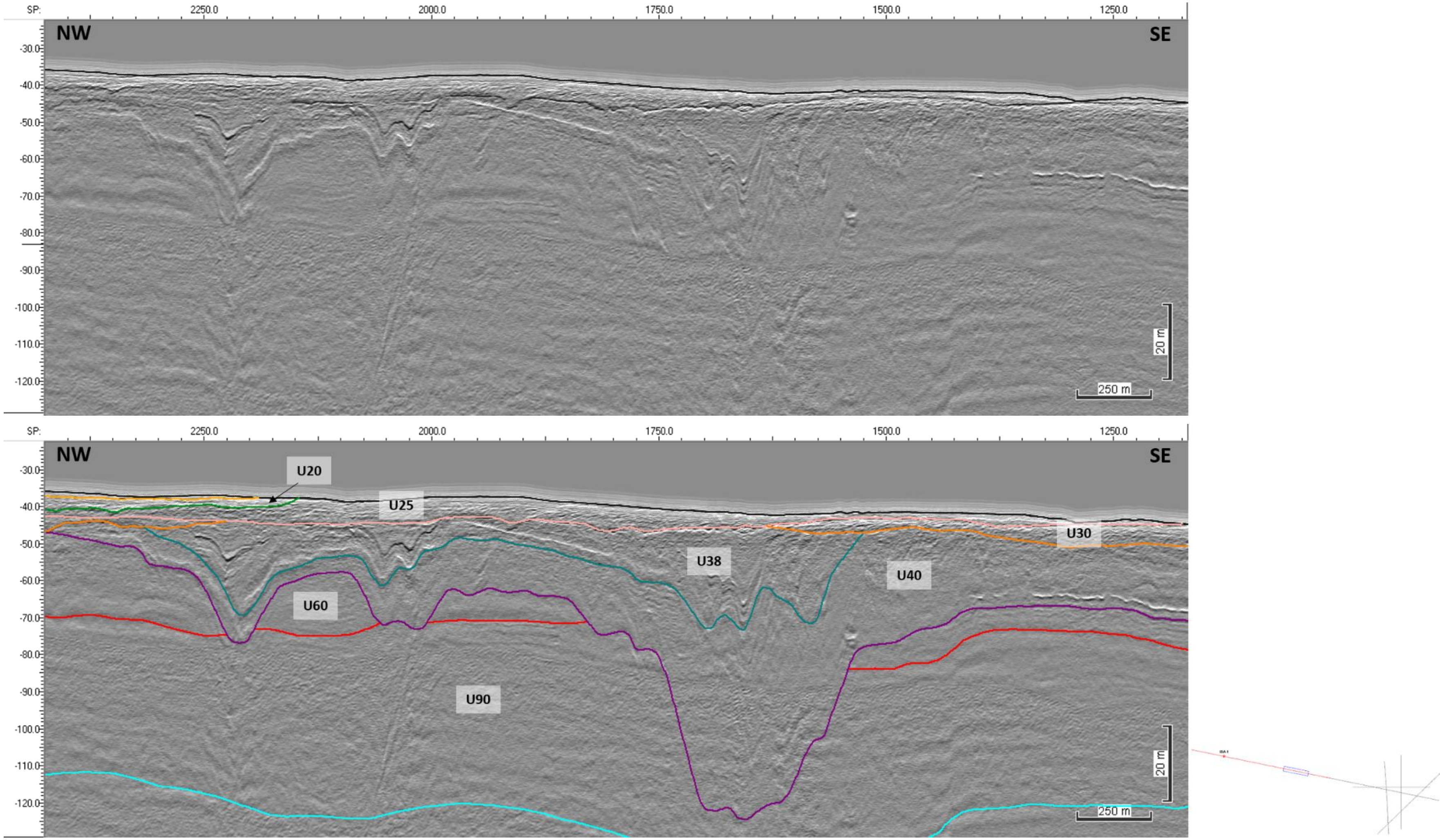


Figure 52 General facies of Seismic Unit U40, and the character of horizon H40. H40 is shown in dark magenta. Seismic profile ML_01_Prio_1.

8.2.8| SEISMIC UNIT U50

Seismic unit U50 was described in previously acquired UHRS data, and was not identified within the EI area. Seismic unit U50 deposits were interpreted to comprise fine sediments. Scattered point diffractors within U50 may be related to the presence of boulders. The origin of seismic unit U50 is uncertain, as it may correspond to a glacial drift deposit (aqua till?) or be associated to glaciolacustrine deposition (?).

8.2.9| SEISMIC UNIT U60

Base horizon: 10_H60

<table>
<tr><td rowspan="2">SEISMIC UNIT U60</td><td>SEISMIC UNIT U60
Base horizon: 10_H60
Depth: 42.1 - 110.9
Extent: Discontinuous across the survey area.
Description: Irregular, undulating surface. Erosive.
Seismic unit: U60
Thickness: up to 48.3
Morphology: Tabular to mega-lens shaped.
Seismic facies: Complex facies of low to high amplitude reflectors; internal features of meso-scale proportions, such as mounds, channels, and lenses. Numerous oblique internal erosional surfaces. Large clinoform build-up facies. In general, the thickness of the internal packages decreases towards the top, becoming more sub-horizontal and sub-parallel.</td></tr>
<tr><td>Interpreted depositional environment: High energy fluvial bedforms (flash floods?).

Expected sediment content: Mainly sands, with gravel and silt (?).</td></tr>
</table>

Seismic unit U60 is defined by horizon H60 (reference number 10) and is present discontinuously within the survey area. The spatial distribution, vertical reference to MSL and the seabed, and thickness of the unit are presented in Figure 53, Figure 54, and Figure 55.

Horizon H60 ranges in depth between 42.1 m and 110.9 m below MSL (Figure 53), and between 8.8 m and 68.9 m depth below the seabed (Figure 54). Horizon H60 traces an irregular, undulating surface of pronounced relief (up to 60 m vertical range), truncating the units below it (Figure 56). H60 follows a positive reflector of high amplitude.

Seismic unit U60 is generally a thick (up to 48.3 m) unit of sub-horizontal tabular to mega-lens shape, thickening at localized incisions of variable size (Figure 55).

Seismic unit U60 is recognizable in the UHRS dataset by its complex facies of low to high amplitude reflectors (Figure 56). U60 comprises internal features of meso-scale proportions, such as mounds, channels, and lenses. There are numerous oblique internal erosional surfaces separating these features, marked by high amplitude reflectors. In general, the thickness of the internal packages decreases towards the top, becoming more sub-horizontal and sub-parallel.

Seismic unit U60 sediments are interpreted to have been deposited in a high energy fluvial setting (flash floods?), evidenced by the meso-scale seismic facies association, the numerous internal erosional surfaces, and more complex geometries. Horizon H60 is an unconformity that shaped a pronounced paleo-relief. From the seismic character of U60 and its interpreted depositional system, it is estimated that the sediments are mainly sands with gravel and silt (?).

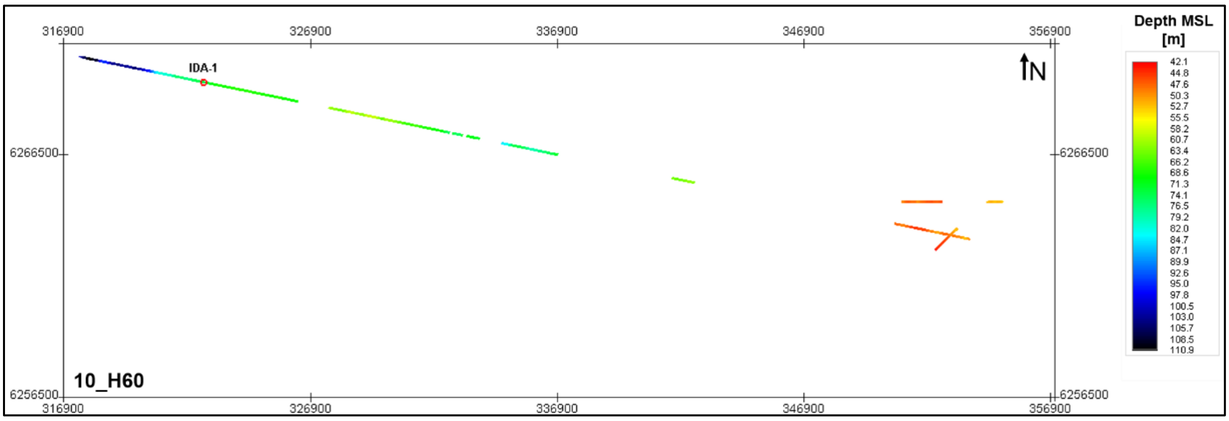


Figure 53 Map showing the lateral extent of U60.
Units in metres below MSL.

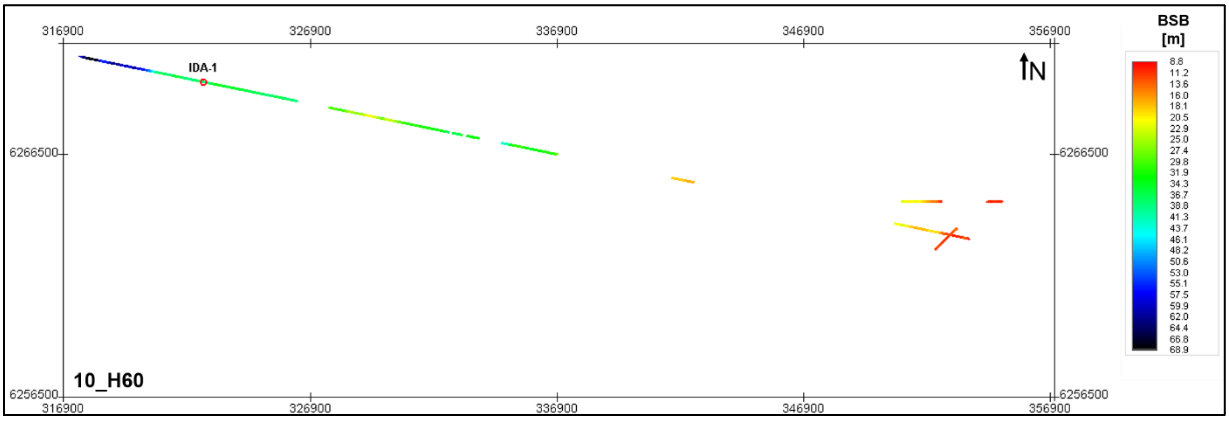


Figure 54 Depth below seabed of H60.
Units in metres below seabed.

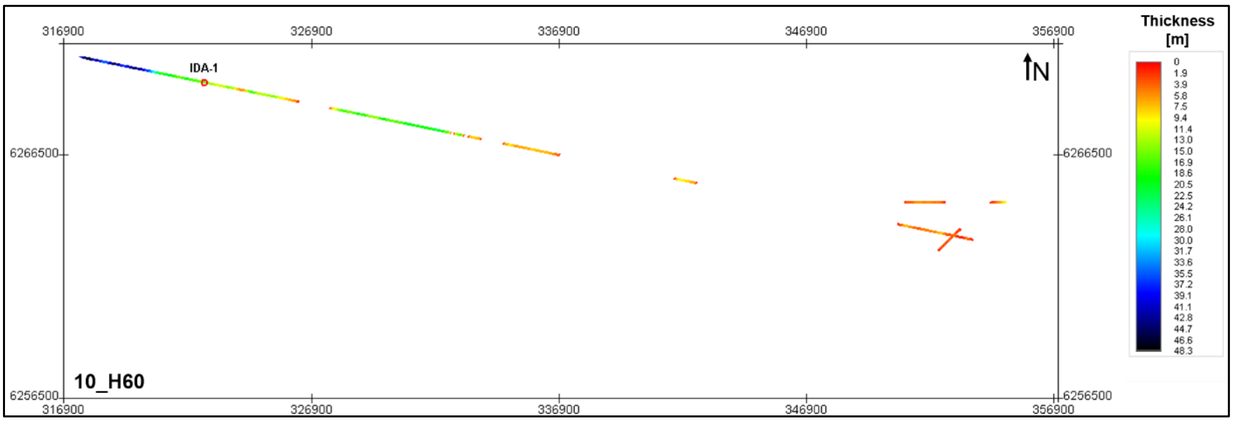


Figure 55 Thickness of unit U60.
Units in metres.

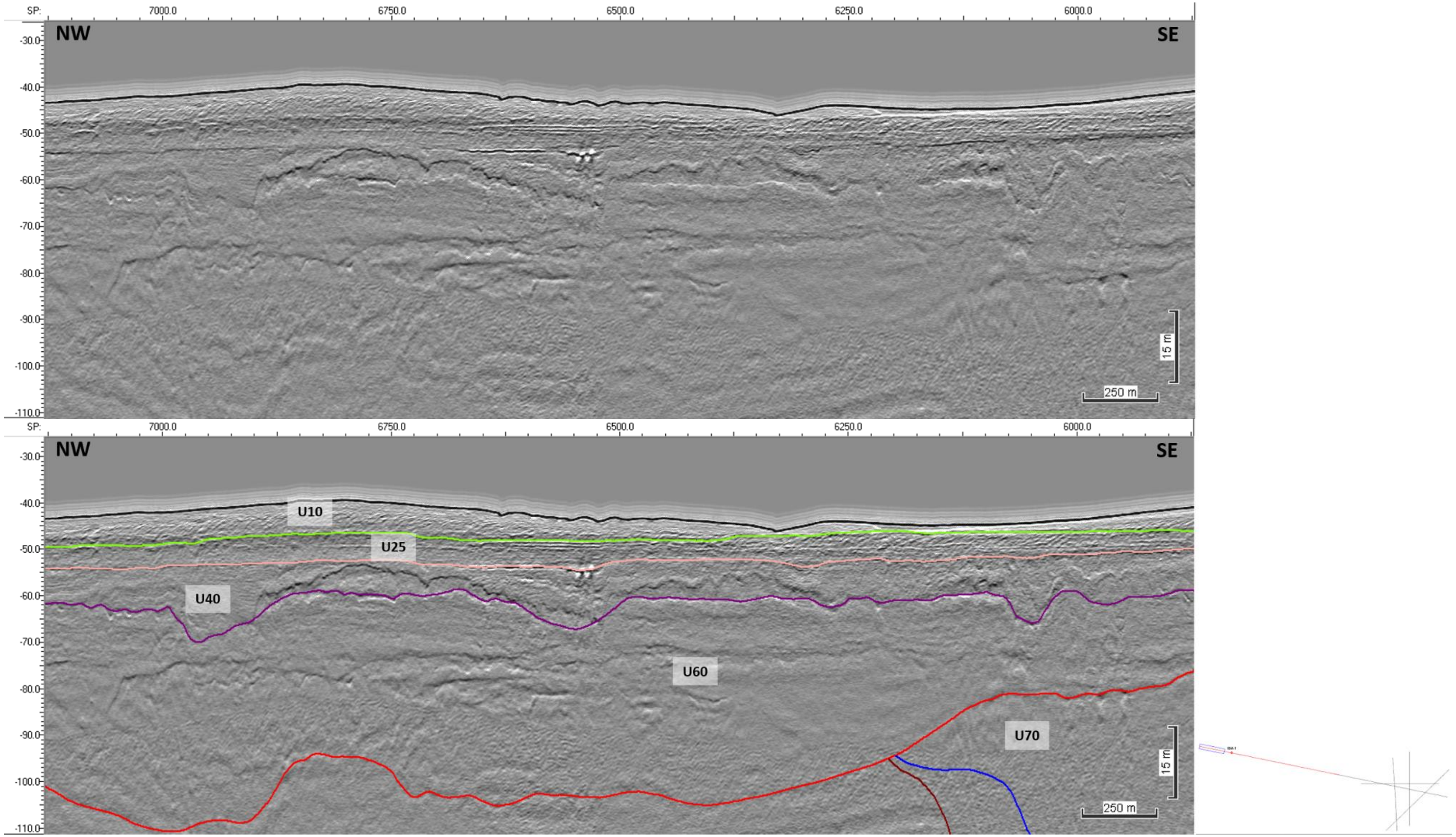


Figure 56 General facies of Seismic Unit U60, and the character of horizon H60. H60 is shown in red. Seismic profile ML_01_Prio_1.

8.2.10 | SEISMIC UNIT U70

Internal horizons: 11_H61; 12_H62; 13_H69

Base horizon: 14_H70

SEISMIC UNIT U70	**SEISMIC SUBUNIT U61** **Base horizon: 11_H61** Depth: 45.7 - 96 Extent: Limited within tunnel valley. Description: Undulating base. **Seismic subunit: U61** Thickness: up to 37.1 Morphology: Channel infill; tabular. Seismic facies: Low amplitudes, transparent, mounds-channels/small basins associations towards the base. Onlap.
	SEISMIC SUBUNIT U62 **Base horizon: 12_H62** Depth: 46.2 - 120.6 Extent: Limited within tunnel valley. Description: Undulating base; non-continuous reflector. **Seismic subunit: U62** Thickness: up to 37.4 Morphology: Channel infill; tabular. Seismic facies: Low amplitudes; parallel layering and mounds-channels at the base, becoming chaotic towards the top.
	SEISMIC SUBUNIT U69 **Base horizon: 13_H69** Depth: 62.6 - 156.2 Extent: Limited within tunnel valley. Description: Undulating and irregular base. **Seismic subunit: U69** Thickness: up to 45.1 Morphology: Channel infill; tabular. Seismic facies: Low amplitude; transparent; faint parallel reflectors and mounds.
	SEISMIC SUBUNIT U70 **Base horizon: 14_H70** Depth: 46.9 - 273.5 Extent: Tunnel valley infill. Description: Large buried U/V-shaped incisions. **Seismic subunit: U70** Thickness: up to 159.1 Morphology: Channel infill; tabular. Seismic facies: Parallel reflectors of medium to high amplitude.
	Interpreted depositional environment: Glaci-fluvial deposition, in a proglacial, sub-aerial environment (reoccupation of tunnel valley depressions by fluvial systems?), with variable sediment content. Glacial to inter-glacial period (?). **Expected sediment content:** Fine sediments; sands; clays with organic matter.

Seismic unit U70 extends discontinuously across the site. Seismic unit U70 comprises the infill deposits of large tunnel valley incisions, delineated at the base by horizon H70 (reference number 14). The largest tunnel valley occurring within the EI exhibits complex and variable internal facies. The infilling deposits were divided four subunits: subunits U61, U62, U69, and U70, from top to base. Subunits U61, U62, and U69 were not identified elsewhere in the survey area. The spatial distribution, vertical reference to MSL and the seabed, and thickness of the seismic subunits are presented in Figure 57 to Figure 68.

SUBUNIT U61

The base of seismic subunit U61 is defined by horizon H61 (reference number 11), between 45.7 m and 96 m depth below MSL (Figure 57), and between 12.3 m and 54.6 m depth below the seabed (Figure 58). H61 is an undulating surface truncating the underlying subunit U62 deposits.

Seismic subunit U61 comprises the infill sediments at the top of the large tunnel valley within the EI area. These deposits are up to 37.1 m thick (Figure 59), and are characterized by low amplitude parallel reflectors, and local mounds-channels/small basins associations towards the base (Figure 69). Chaotic-homogeneous transparent facies are also common in these upper sections.

SUBUNIT U62

Horizon H62 (reference number 12) delineates an erosive surface corresponding to the base of subunit U62. It follows an undulating reflector, limited within the tunnel valley. H62 occurs between 46.2 m and 120.6 m depth below MSL (Figure 60), and between 12.8 m and 78.8 m depth below the seabed (Figure 61).

The thickness of subunit U62 is up to 37.4 m (Figure 62). Its seismic facies comprise more complex patterns than U61 above, with parallel layering and mounds-channels at the base, becoming chaotic towards the top (Figure 70). Seismic amplitudes are generally low to nearly transparent.

SUBUNIT U69

Horizon H69 (reference number 13) defines an erosive surface corresponding to the base of subunit U69. It follows an undulating and irregular reflector, limited within the tunnel valley. H69 occurs between 62.6 m and 156.2 m depth below MSL (Figure 63), and between 34.7 m and 114.3 m depth below the seabed (Figure 64).

Subunit U69 comprises low amplitude to transparent deposits, with faint parallel reflectors and mounds. Its thickness reaches a maximum of 41.5 m (Figure 65).

SUBUNIT U70

The lower seismic subunit U70 is delineated by the base horizon H70 (reference number 14). H70 defines the base of valley incisions, of variable sizes, orientations, and shapes. H70 ranges in depth between 46.9 m and 273.5 m below MSL (Figure 66), and between 13.1 m and 227.9 m depth below the seabed (Figure 67). H70 is mapped either along medium-high amplitude reflector or tracing a vertical facies shift, truncating the units below it (Figure 70).

The facies of subunit U70 within the EI tunnel valley comprise well-organised parallel reflectors of medium to high amplitude, generally following the morphology of H70 (Figure 71). The thickness of subunit U70 reaches up to 159.1 m (Figure 68).

Outside the EI area, the deposits infilling other tunnel valleys are less organised, and facies associated to subunits U61, U62, and U69 were not identified. Seismic facies range from chaotic to transparent, with occasional parallel reflectors.

The subunits infilling the U70 tunnel valleys have composite facies that are generally organised and layered (albeit chaotic in places), which may be associated to glaci-fluvial deposition, in a proglacial, sub-aerial environment (e.g. reoccupation of tunnel valley depressions by fluvial systems). Most of these incisions rest above older deformed sediments which may be related to glaciotectonism and to the formation of the valley itself (evidenced by collapse structures directly below H70).

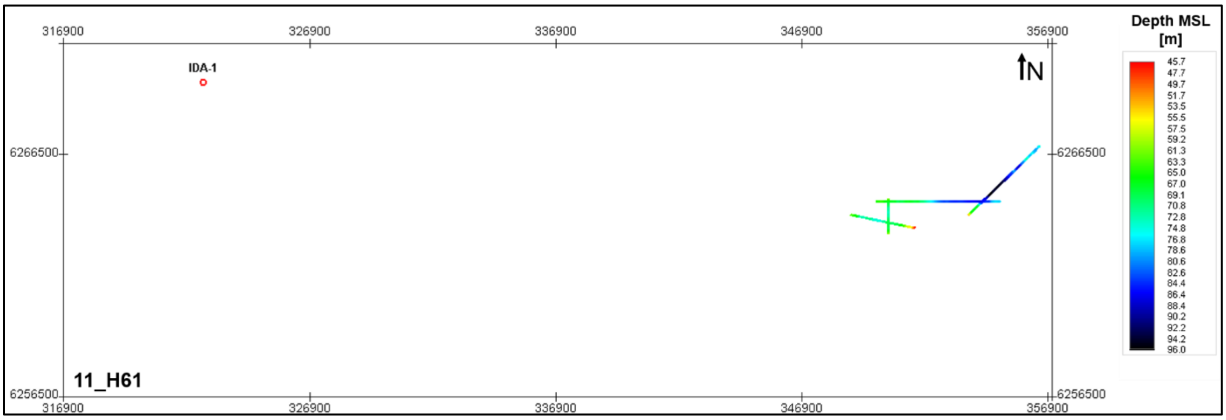


Figure 57 Map showing the lateral extent of U61.
Units in metres below MSL.

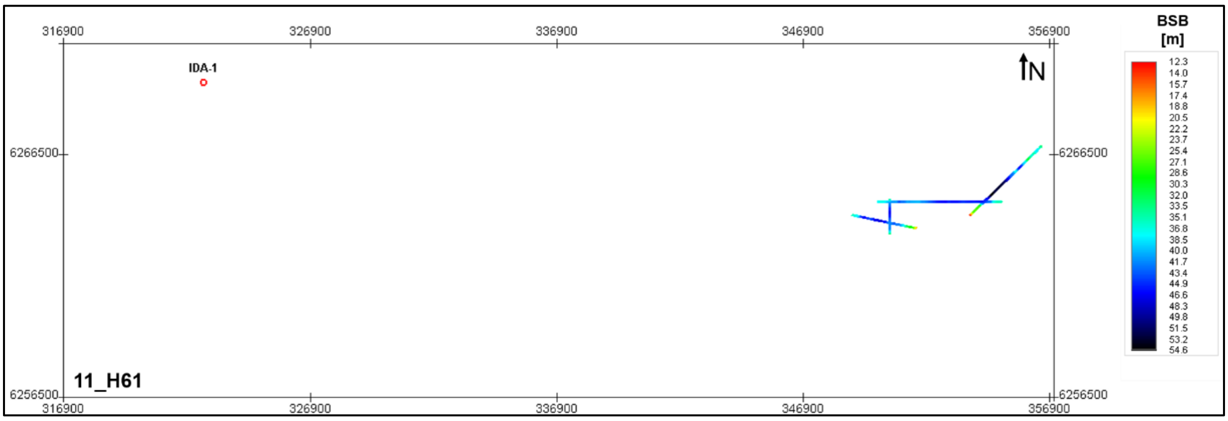


Figure 58 Depth below seabed of H61.
Units in metres below seabed.

Figure 59 Thickness of unit U61.
Units in metres.

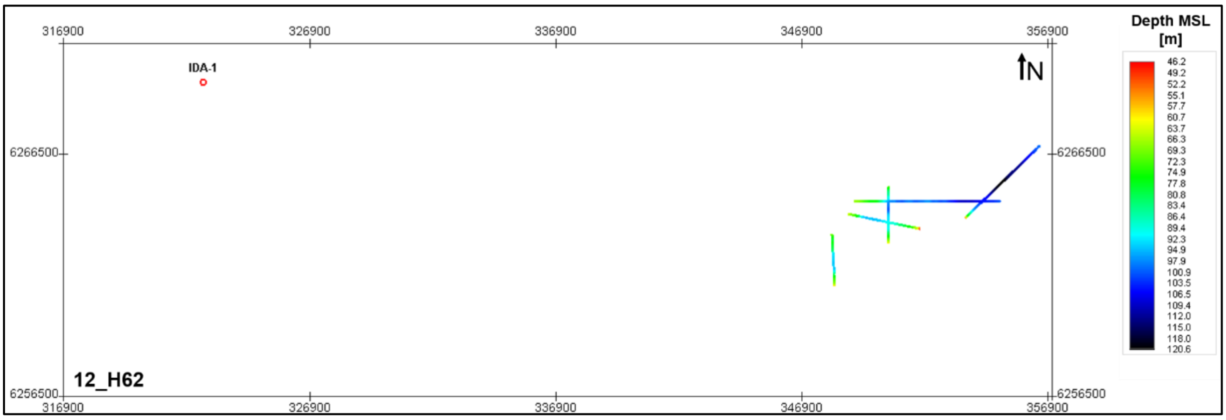


Figure 60 Map showing the lateral extent of U62.
Units in metres below MSL.

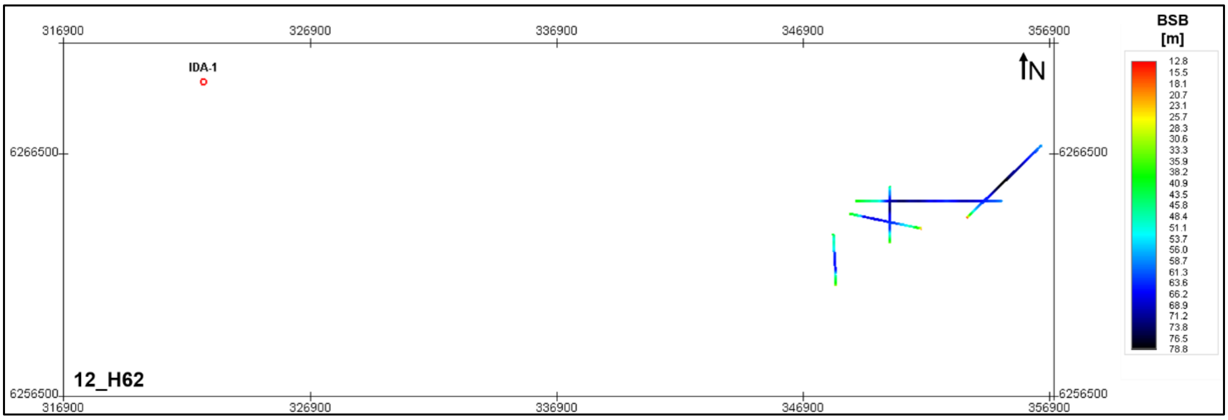


Figure 61 Depth below seabed of H62.
Units in metres below seabed.

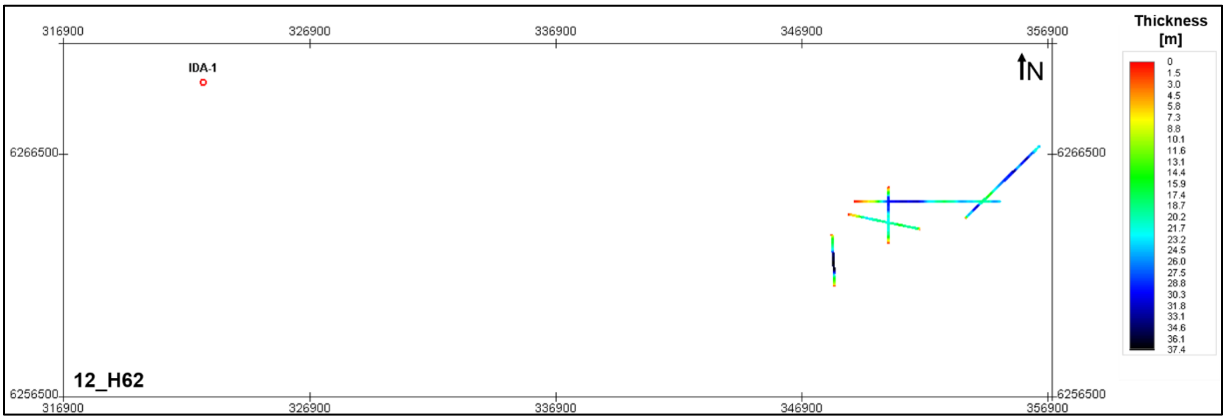


Figure 62 Thickness of unit U62.
Units in metres.

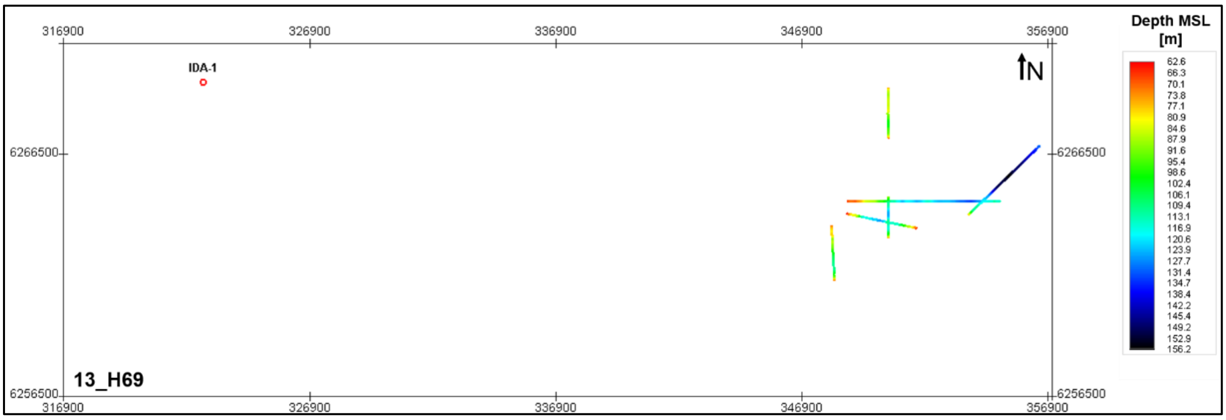


Figure 63 Map showing the lateral extent of U69.
Units in metres below MSL.

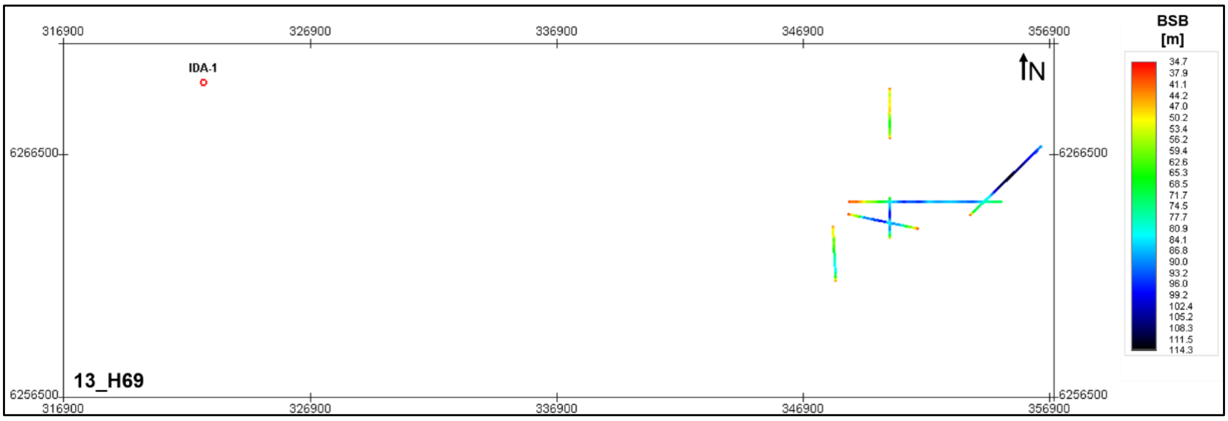


Figure 64 Depth below seabed of H69.
Units in metres below seabed.

Figure 65 Thickness of unit U69.
Units in metres.

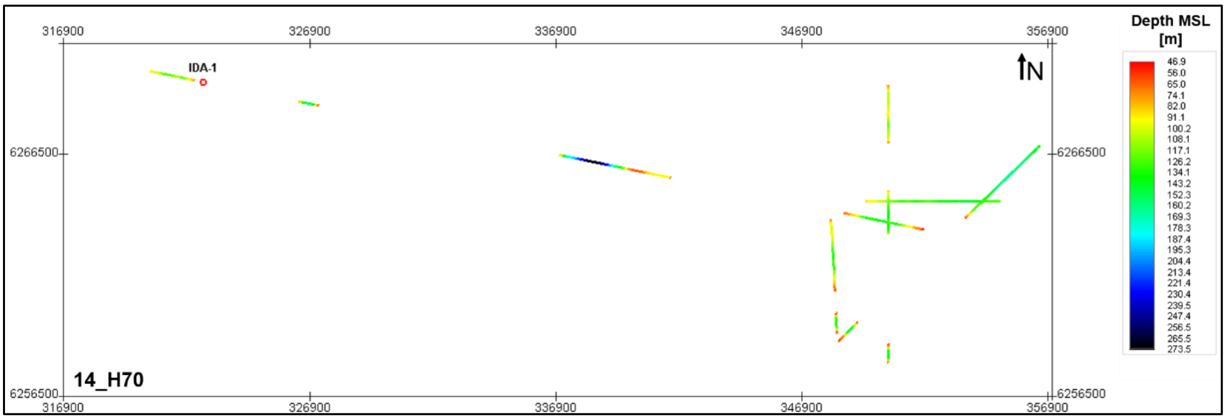


Figure 66 Map showing the lateral extent of U70.
Units in metres below MSL.

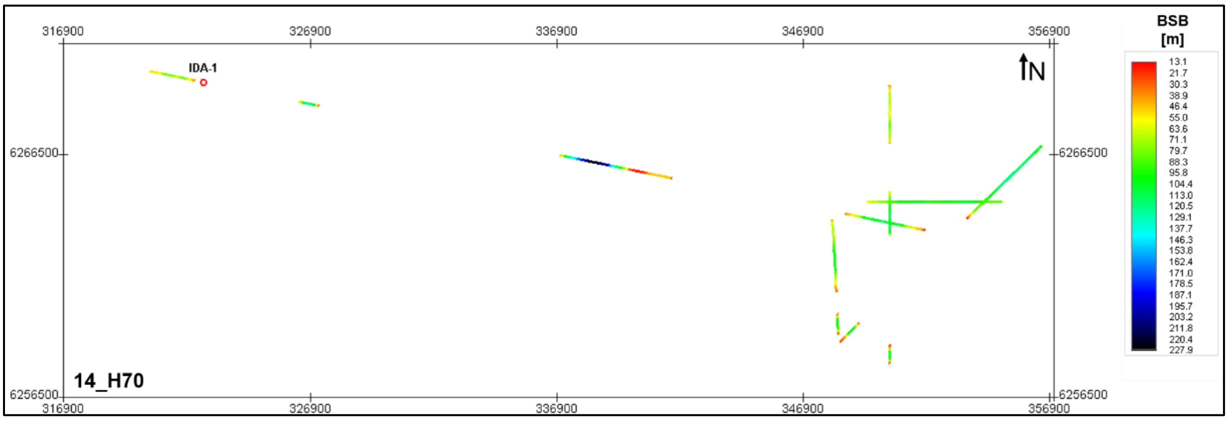


Figure 67 Depth below seabed of H70.
Units in metres below seabed.

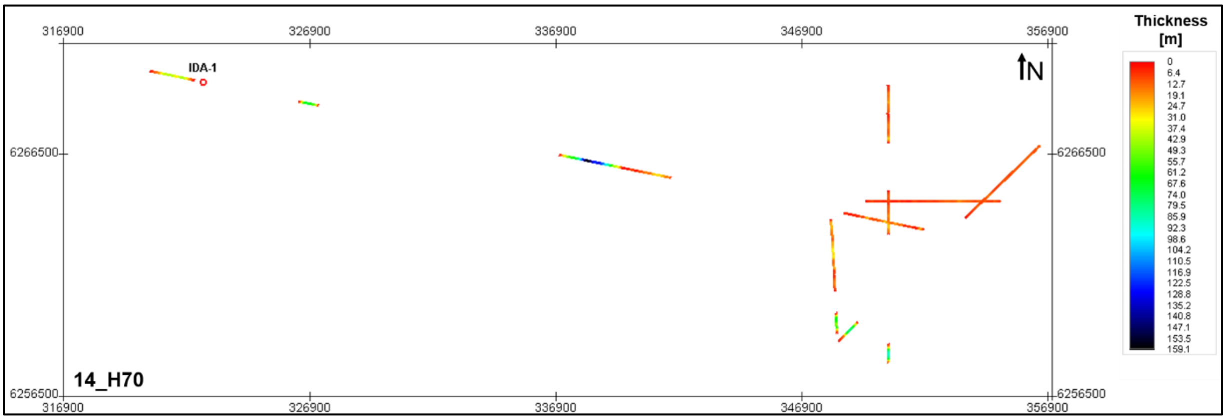


Figure 68 Thickness of unit U70.
Units in metres.

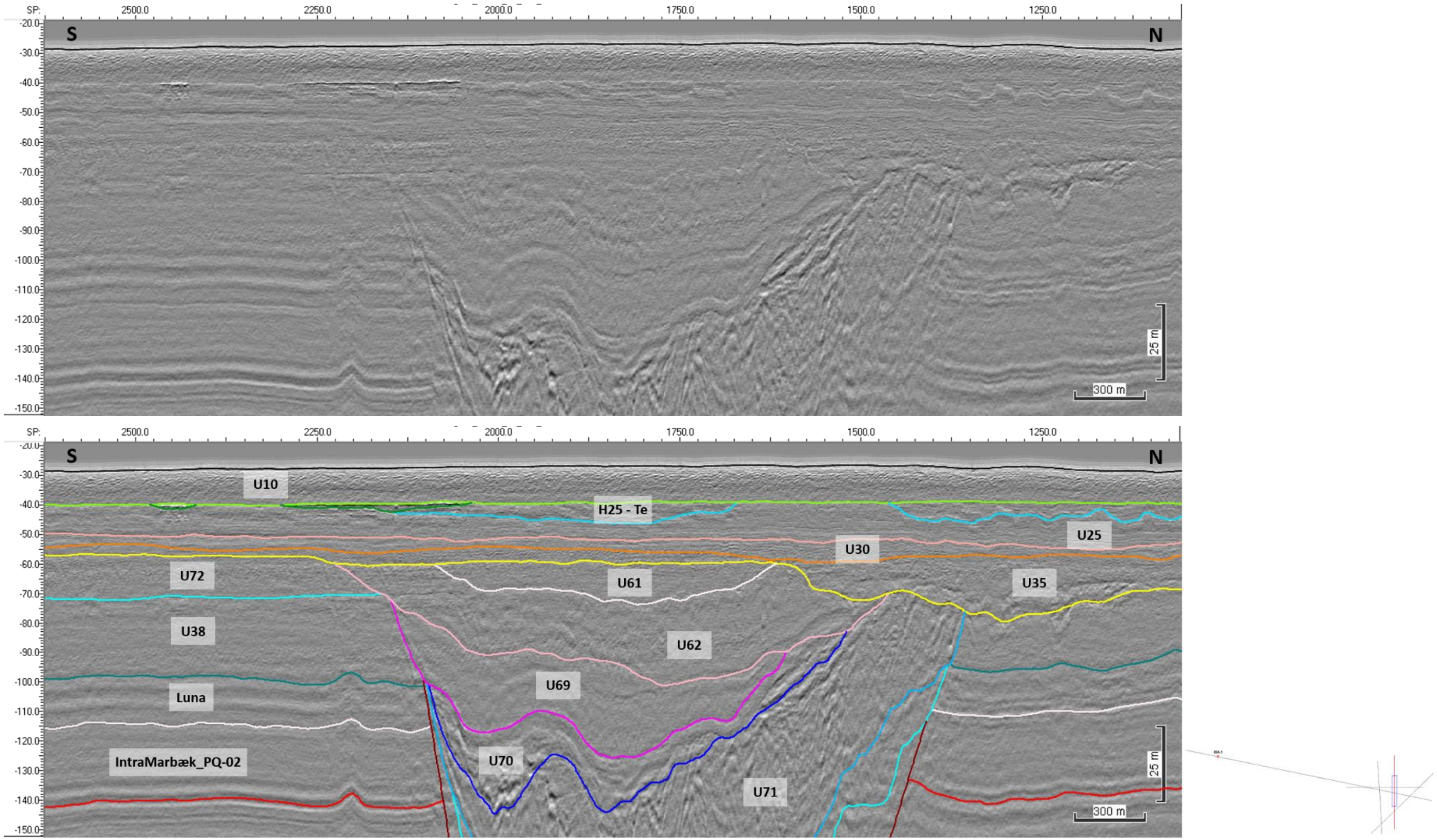


Figure 69 General facies of Seismic Unit U70 and the interpreted subunits (horizons H61, H62, H69 and H70). Seismic profile ML_03_Prio_2.

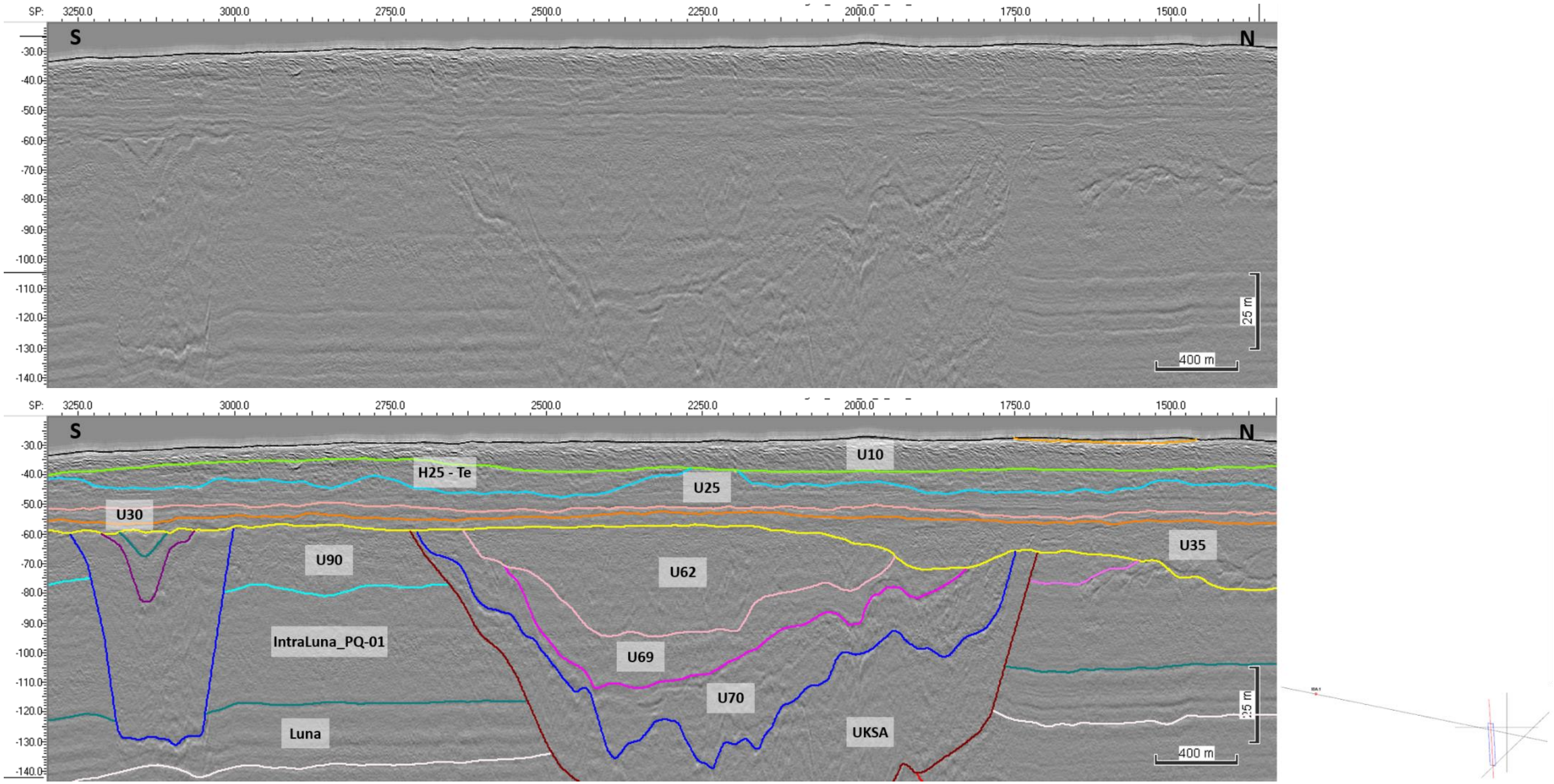


Figure 70 General facies of Seismic Unit U70 and the interpreted subunits (horizons H62, H69 and H70). Seismic profile ML_02_A_Prio_2.

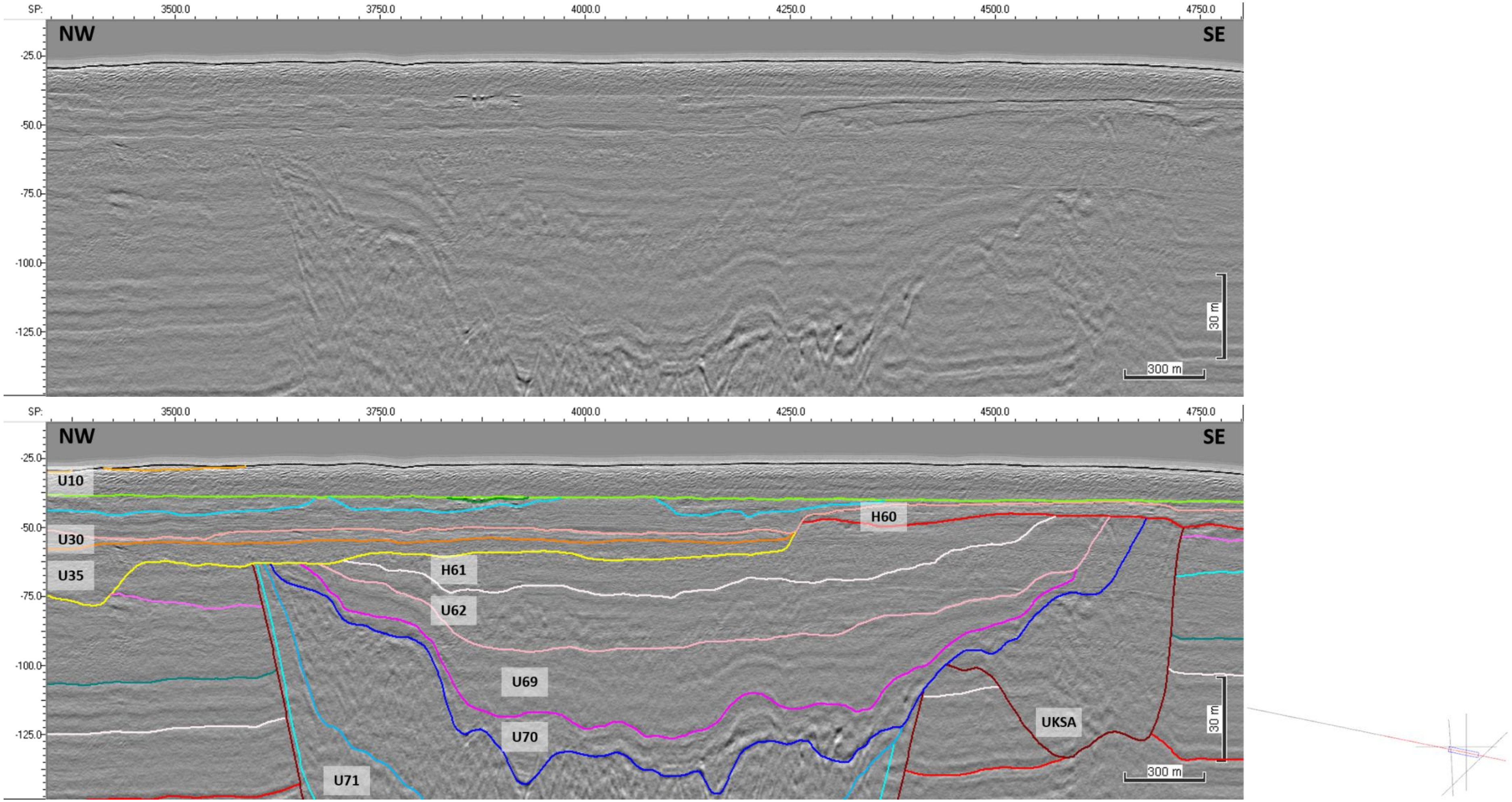


Figure 71 General facies of Seismic Unit U70 and the interpreted subunits (horizons H61, H62, H69 and H70). Seismic profile ML_01_Prio_1a.

8.2.11 | SEISMIC UNIT UKSA

Internal horizons: 15_H71; 16_H72

Base horizon: 17_HKSA

SEISMIC UNIT UKSA	**SEISMIC SUBUNIT U71** **Base horizon: 15_H71** Depth: 63.2 - 198.7 Extent: Limited within tunnel valley. Description: Channel morphology, medium amplitude continuous reflector. **Seismic subunit: U71** Thickness: up to 60 Morphology: Channel infill. Seismic facies: Chaotic facies of medium amplitude.
	SEISMIC SUBUNIT U72 **Base horizon: 16_H72** Depth: 63.3 - 250.1 Extent: Limited within tunnel valley. Description: Channel morphology, discontinuous reflector. Lenses. **Seismic subunit: U72** Thickness: up to 55.1 Morphology: Channel infill. Seismic facies: Chaotic facies of medium amplitude.
	SEISMIC SUBUNIT UKSA **Base horizon: 17_HKSA** Depth: 49.5 - 359.4 Extent: Limited within tunnel valley. Description: Deformation front boundary. Truncating the parallel on the sides and beneath it. **Seismic subunit: UKSA** Thickness: up to 162.4 Morphology: Channel infill. Seismic facies: Incoherent facies.
	Interpreted depositional environment: Deformed deposits of variable sediment content. Glaciotectonism. **Expected sediment content:** Glacial till; diamicton. Deformed sediments.

Horizon HKSA (reference number 17) defines the base of unit UKSA, which encompasses sediments belonging to seismic subunits U71, U72, and UKSA, found in the deepest sections of the tunnel valleys. The spatial distribution, vertical reference to MSL and the seabed, and thickness of the seismic subunits are presented in Figure 72 to Figure 80.

Strongly deformed or incoherent sediments occur at the base of tunnel valleys. Horizon HKSA delineates the boundary between these sediments and better-preserved strata adjacent to the tunnel valleys. Distinct facies separated by medium amplitude reflectors are observed inside seismic unit UKSA, corresponding to the subdivision of this seismic unit.

Horizon HKSA represents a deformation front boundary and, although part of the geological model, should not be interpreted with a chronostratigraphic meaning. It is an amalgamation of surfaces of glacial erosion, decollements, fault planes, and shear/fracture zone boundaries.

SUBUNIT U71

The base of seismic subunit U71 is defined by horizon H71 (reference number 15), between 63.2 m and 198.7 m depth below MSL (Figure 72), and between 23.6 m and 156.8 m depth below the seabed (Figure 73). H71 is medium amplitude continuous reflector with a wide-channel morphology (Figure 74).

Seismic subunit U71 comprises deformed sediments within tunnel valleys, generally with chaotic to incoherent facies of medium-high amplitude, with occasional parallel reflectors (Figure 81).

SUBUNIT U72

The base of seismic subunit U72 is defined by horizon H72 (reference number 16), between 63.3 m and 250.1 m depth below MSL (Figure 75), and between 35.8 m and 208.2 m depth below the seabed (Figure 76). H72 is an uneven medium amplitude reflector with a wide-channel morphology (Figure 81).

Seismic subunit U72 comprises deformed sediments along tunnel valleys, exhibiting chaotic facies of medium to high amplitude (Figure 81).

SUBUNIT UKSA

The base of seismic subunit UKSA is defined by horizon HKSA (reference number 17), between 49.5 m and 359.4 m depth below MSL (Figure 78), and between 14.1 m and 314 m depth below the seabed (Figure 79). HKSA corresponds to a deformation front boundary, truncating better-preserved strata adjacent to tunnel valleys.

Similar to the subunits above, seismic subunit UKSA comprises deformed sediments along tunnel valleys, exhibiting chaotic to incoherent facies of medium to high amplitude (Figure 81).

The deformed sediments of seismic unit UKSA are interpreted to be related to glaciotectonism and glacial deposition, associated to the formation of the valleys themselves. The subunits identified within UKSA may correspond to glacial tills/diamictons, which may incorporate reworked/deformed sediments of older deposits. As such, the expected sediment content may vary significantly.

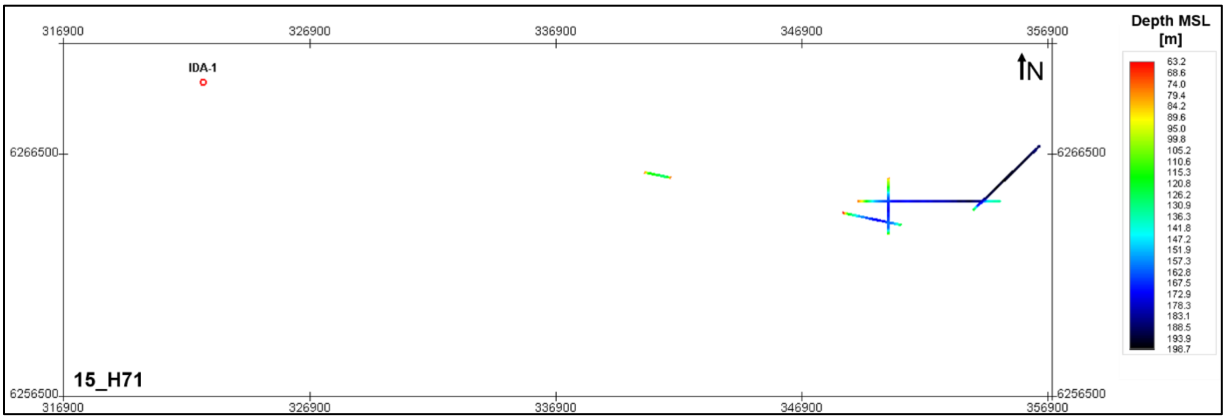


Figure 72 Map showing the lateral extent of U71.
Units in metres below MSL.

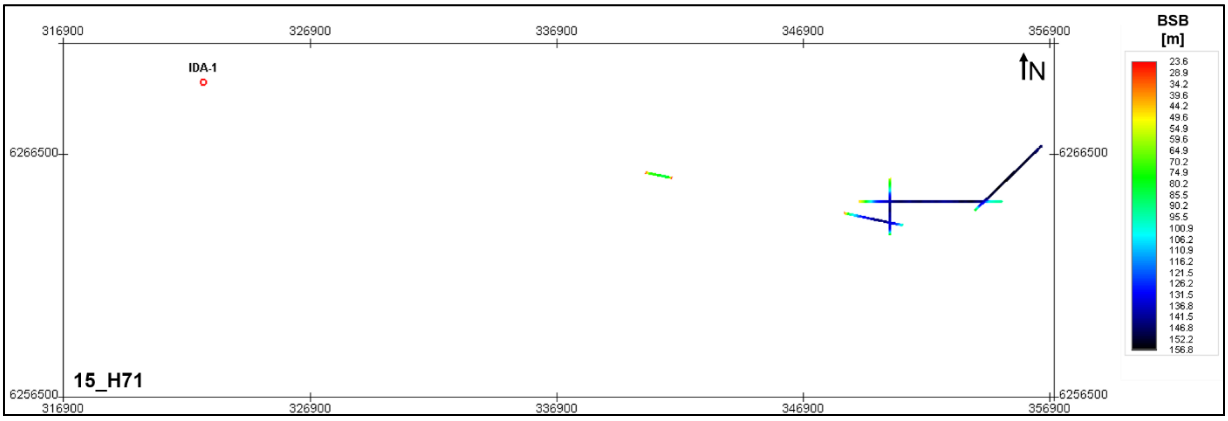


Figure 73 Depth below seabed of H71.
Units in metres below seabed.

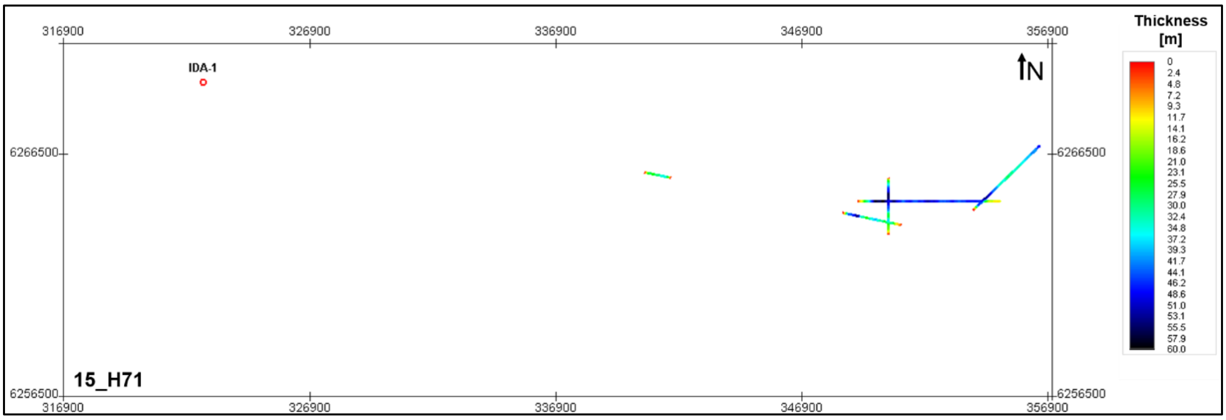


Figure 74 Thickness of unit U71.
Units in metres.

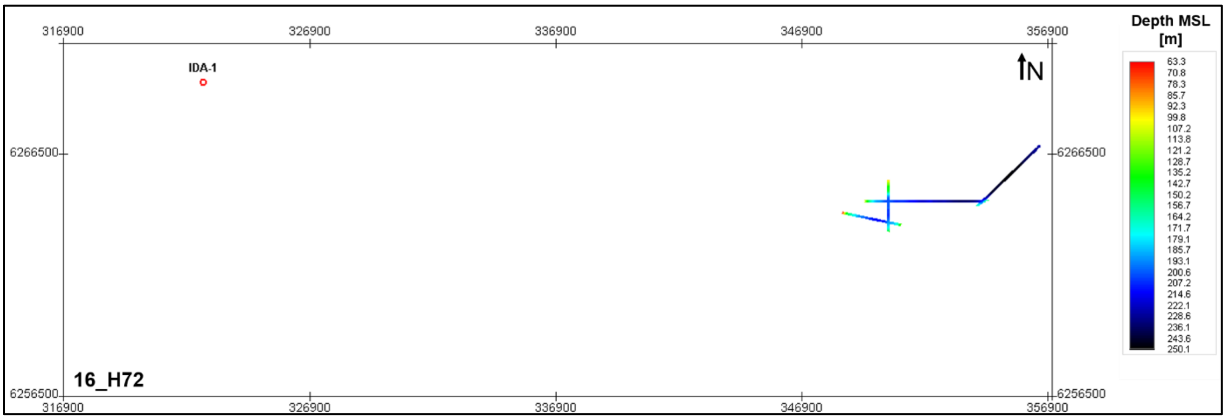


Figure 75 Map showing the lateral extent of U72.
Units in metres below MSL.

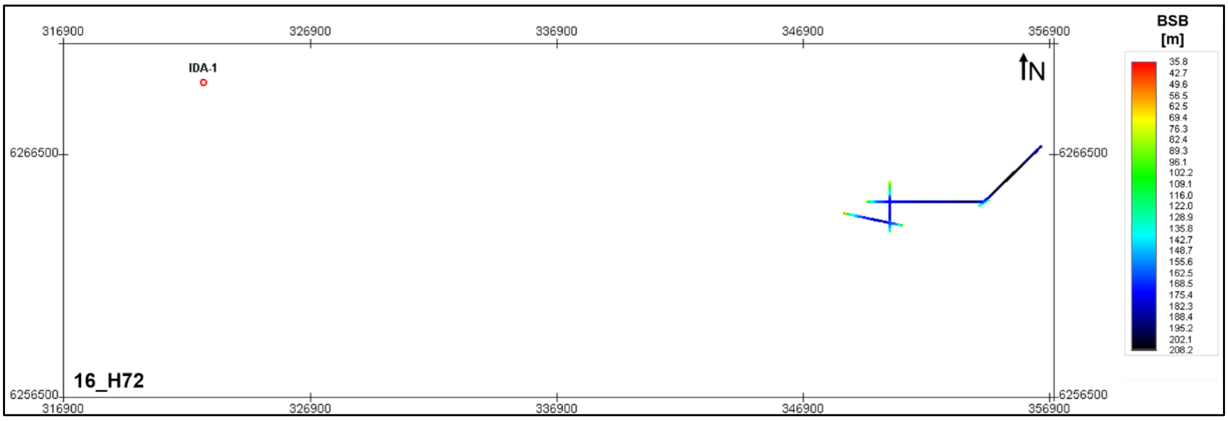


Figure 76 Depth below seabed of H72.
Units in metres below seabed.

Figure 77 Thickness of unit U72.
Units in metres.

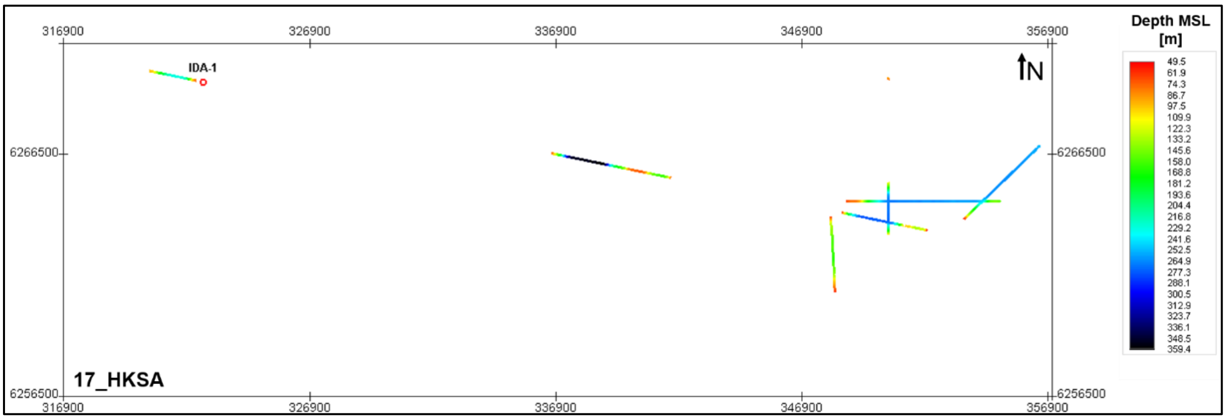


Figure 78 Map showing the lateral extent of UKSA.
Units in metres below MSL.

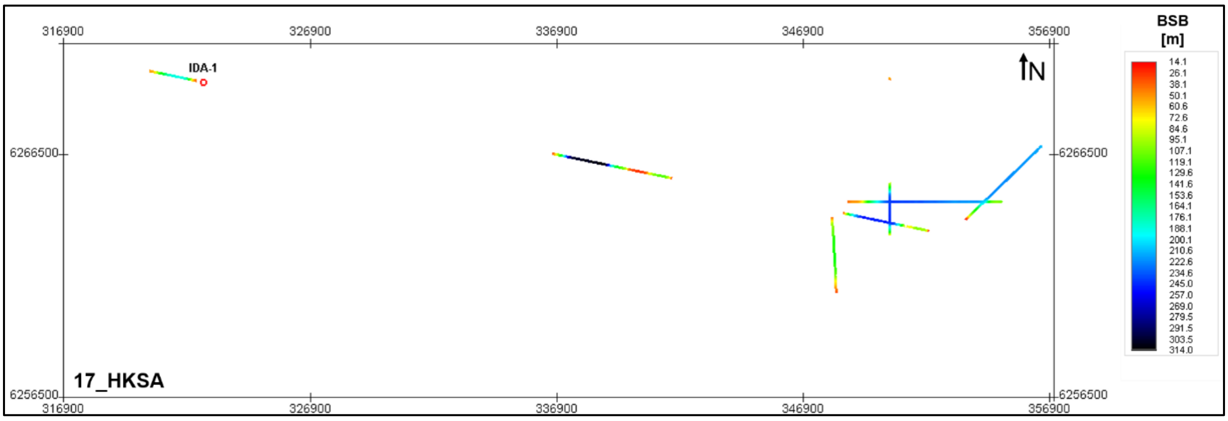


Figure 79 Depth below seabed of HKSA.
Units in metres below seabed.

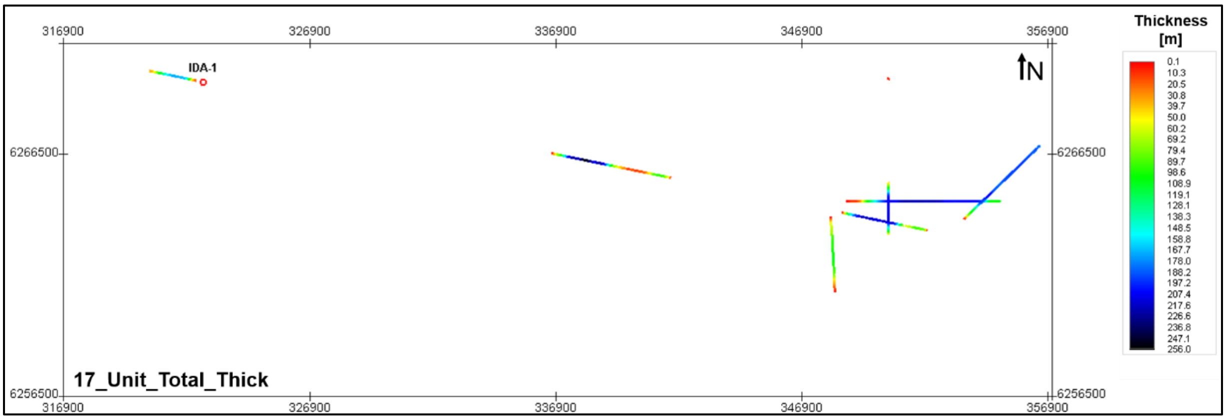


Figure 80 Thickness of unit UKSA.
Units in metres.

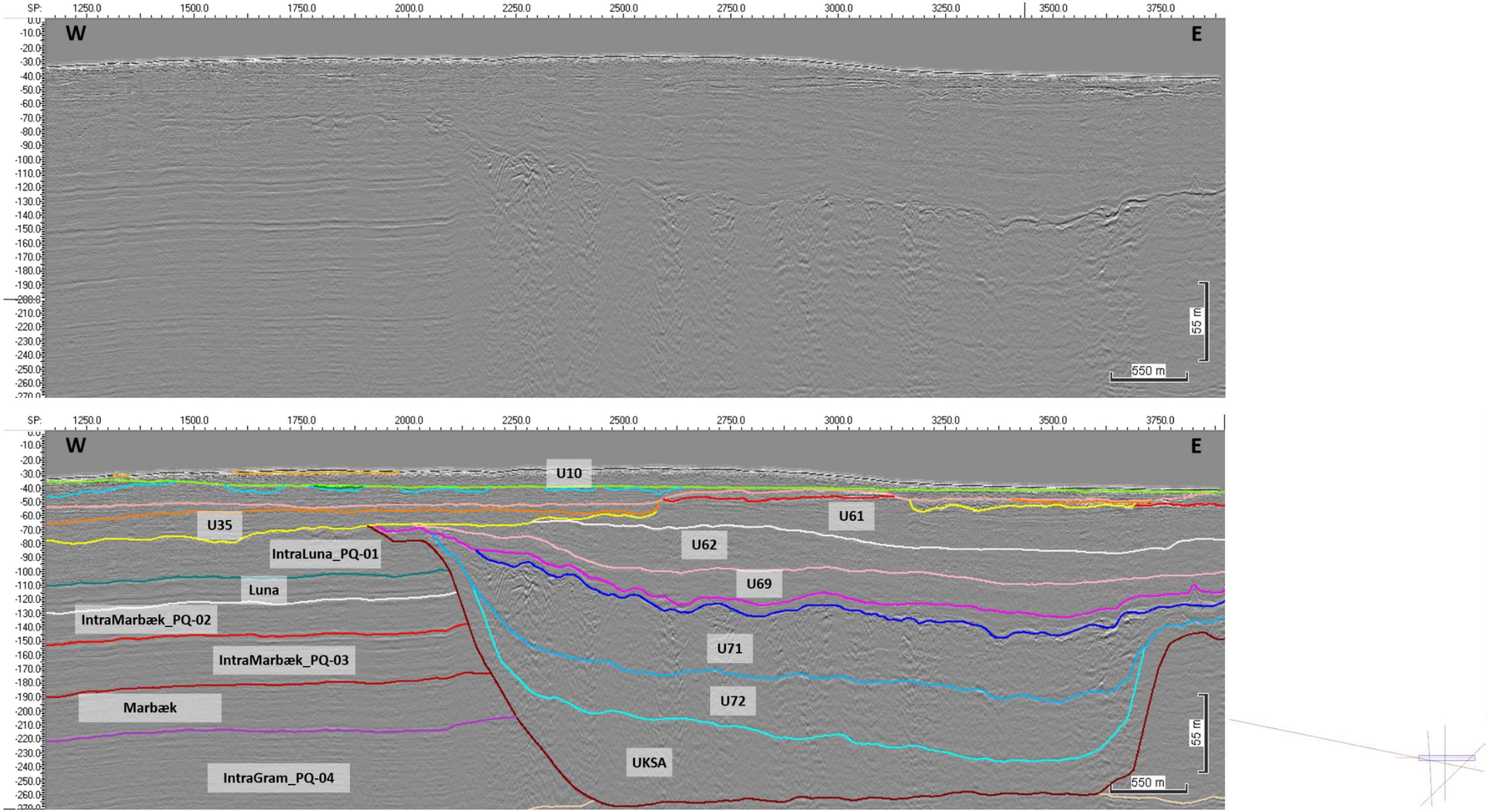


Figure 81 General facies of Seismic Unit UKSA and the interpreted subunits (horizons H71, H72 and HKSA). Seismic profile ML_04_Prio_2.

8.2.12| SEISMIC UNIT U85

Base horizon: 18_H85

<table>
<tr><td rowspan="2">SEISMIC UNIT U85</td><td>SEISMIC UNIT U85
Base horizon: 18_H85
Depth: 52.3 – 112.4
Extent: Limited and discontinuous.
Description: Irregular surface; undulating; erosive.
Seismic unit: U85
Thickness: up to 43
Morphology: Tabular.
Seismic facies: Low to medium amplitude. Internal parallel-oblique; hummocky; mounds-channels-lenses. Frequent internal erosive surfaces.</td></tr>
<tr><td>Interpreted depositional environment: High energy fluvial (possibly outwash plain?).

Expected sediment content: Mainly sands with gravel and silt (?); organic-rich muds at the base.</td></tr>
</table>

Seismic unit U85 has a limited and discontinuous extent in the survey area. The base of Seismic Unit U85 is defined by horizon H85 (reference number 18). The spatial distribution, vertical reference to MSL and the seabed, and thickness of the unit are presented in Figure 82, Figure 83 and Figure 84.

Horizon H85 ranges in depth between 52.3 m and 112.4 m below MSL (Figure 82), and between 10.2 m and 67.9 m depth below the seabed (Figure 83). Horizon H85 traces an uneven, rugose, undulating surface, truncating the units below it (Figure 85). Where present, H85 follows a positive reflector of high amplitude. However, H85 is mostly defined by a vertical facies shift.

Seismic unit U85 has generally sub-horizontal tabular morphology, with thicknesses ranging from 0 m to 43 m (Figure 84). Seismic unit U85 exhibits variable facies of low to medium amplitude reflectors, which may be parallel to oblique or hummocky (Figure 85). U85 comprises complex internal features of meso-scale proportions, such as mounds, channels, and lenses. Internal surfaces separate these features, marked by medium-high amplitude.

Seismic unit U85 sediments are interpreted to have been deposited in a high energy setting, likely of fluvial nature (possibly outwash plain?), as evidenced by the meso-scale seismic facies association, the numerous stacked subunits, internal surfaces, and channel incisions. From the seismic character of U85 and its interpreted depositional system, it is estimated that the sediments are mainly sands with gravel and silt (?). Soft sediment deposits (such as muds, possibly organic-rich) were previously interpreted near the base of U85, indicated by the presence high amplitude negative reflectors. U85 is possibly of Pliocene – Pleistocene (?) in age.

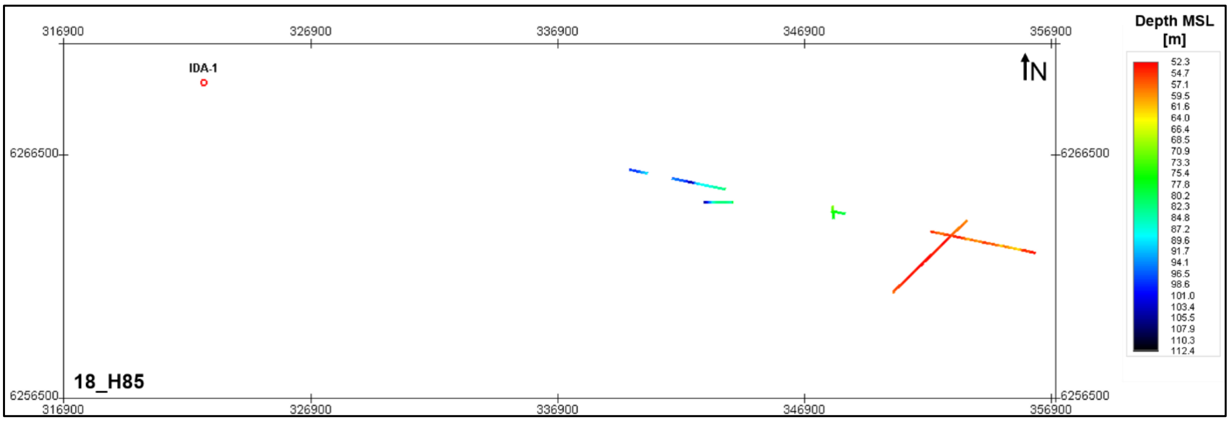


Figure 82 Map showing the lateral extent of U85.
Units in metres below MSL.

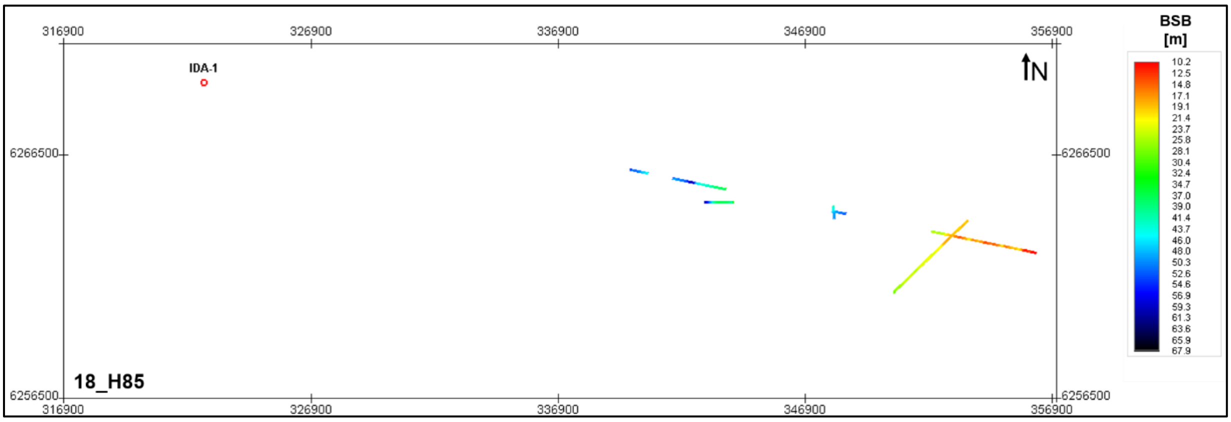


Figure 83 Depth below seabed of H85.
Units in metres below seabed.

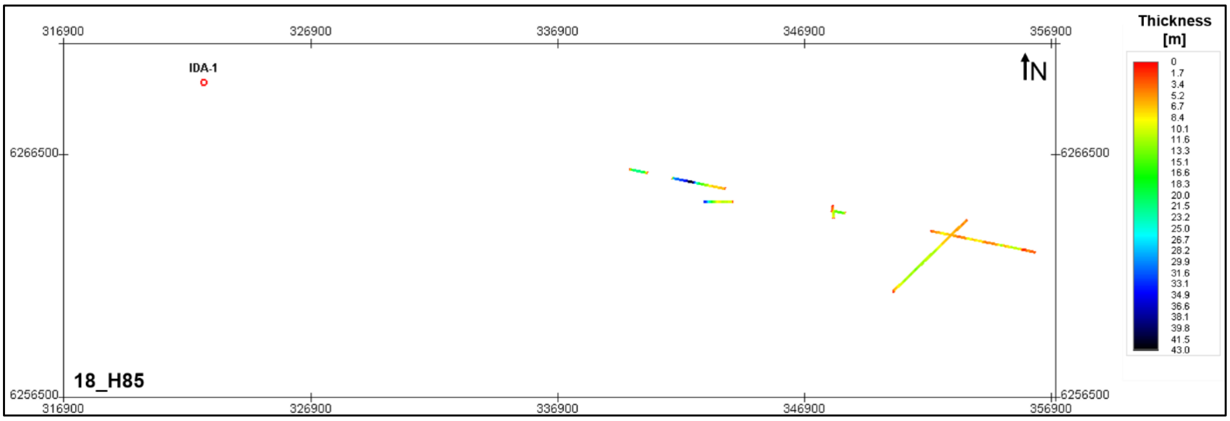


Figure 84 Thickness of unit U85.
Units in metres.

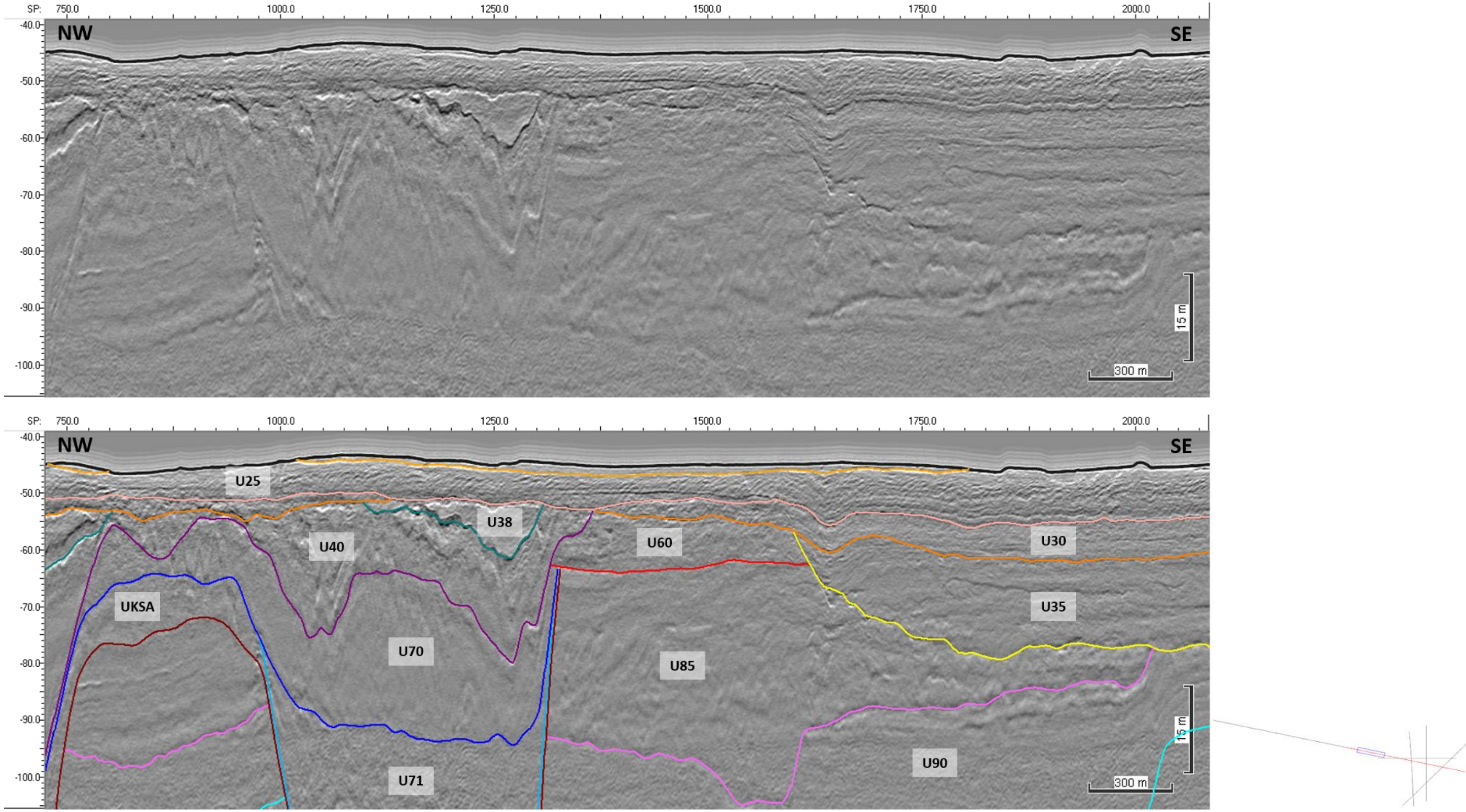


Figure 85 General facies of Seismic Unit U85, and the character of horizon H85. H85 is shown in magenta. Seismic profile ML_01_Prio_1a.

8.2.13 | SEISMIC UNIT U90

Base horizon: 19_H90

SEISMIC UNIT U90	**SEISMIC UNIT U90** **Base horizon: 19_H90** Depth: 61.6 - 133.6 Extent: Discontinuous across the survey. Description: Planar, slightly undulating surface. **Seismic unit: U90** Thickness: up to 55.2 Morphology: Tabular. Seismic facies: Parallel facies at the base and an association of parallel-mound-channel-shingled facies above, prograding.
	Interpreted depositional environment: Fan delta deposits. **Expected sediment content:** Mainly sands and fine sediments.

Seismic unit U90 is present discontinuously across the site. The base of Seismic Unit U90 is defined by horizon H90 (reference number 19). The spatial distribution, vertical reference to MSL and the seabed, and thickness of the unit are presented in Figure 86, Figure 87, and Figure 88.

Horizon H90 ranges in depth between 61.6 m and 133.6 m below MSL (Figure 86), and between 19.7 m and 91.9 m depth below the seabed (Figure 87). Horizon H90 defines a vertical facies shift, corresponding to a planar, slightly undulating surface, following a positive reflector of medium amplitude (Figure 89).

Seismic unit U90 has generally tabular shape, with thicknesses up to 55.2 m (Figure 88). Seismic unit U90 is characterized by its parallel-homogeneous facies at the base and an association of parallel-mound-channel-shingled facies above, all prograding (Figure 89).

Seismic unit U90 sediments are interpreted to have been deposited in a delta setting, as evidenced by its internal progradational nature. From the seismic character of U90 and its interpreted depositional system, it is estimated that the sediments are mainly sands-fine sediments (?). U90 is possibly of Pliocene – Pleistocene in age.

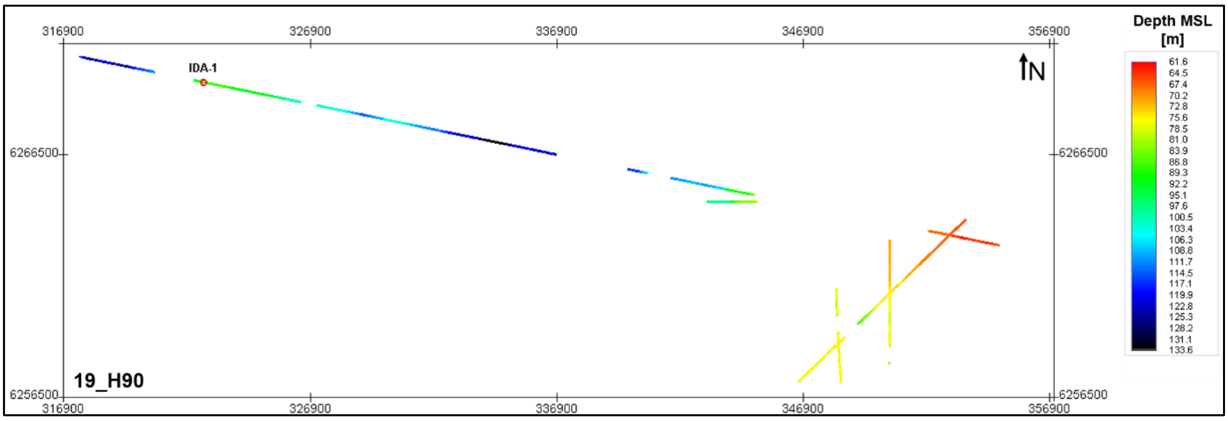


Figure 86 Map showing the lateral extent of U90.
Units in metres below MSL.

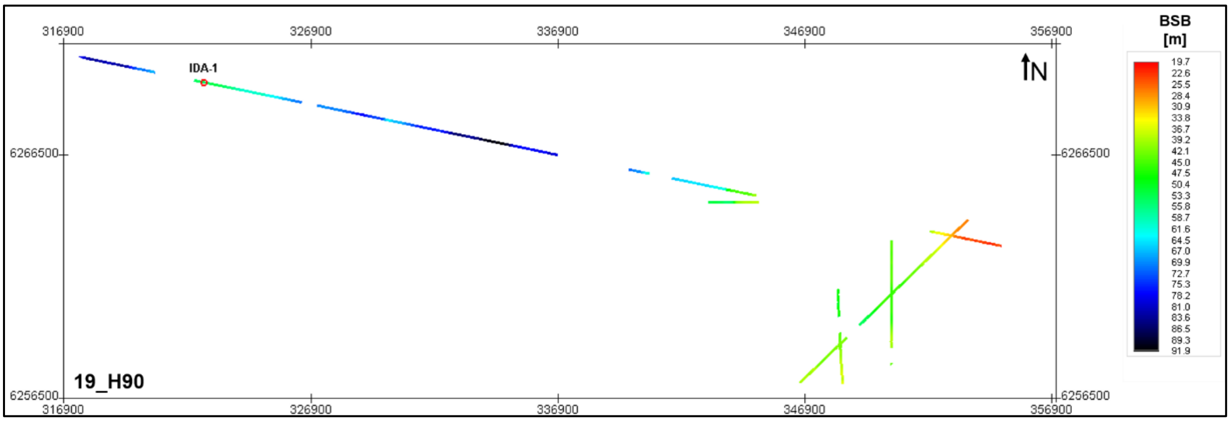


Figure 87 Depth below seabed of H90.
Units in metres below seabed.

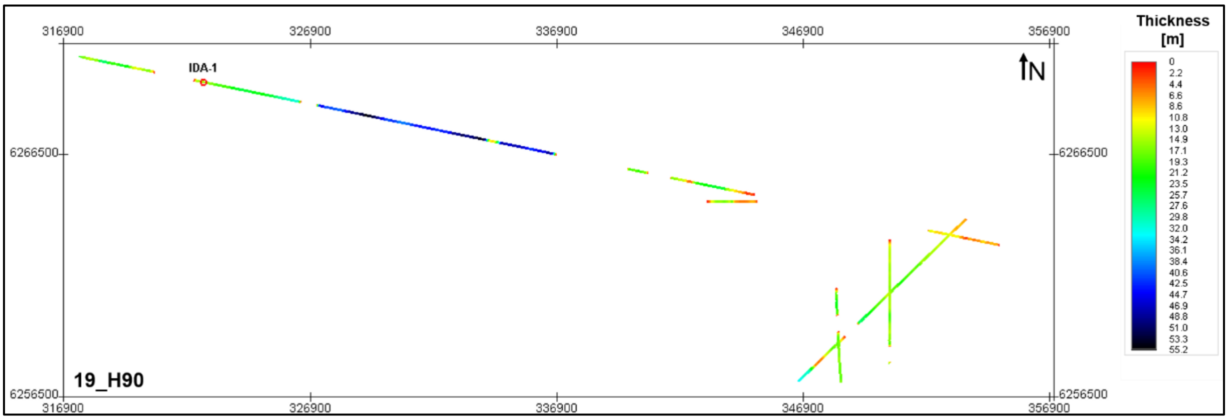


Figure 88 Thickness of unit U90.
Units in metres.

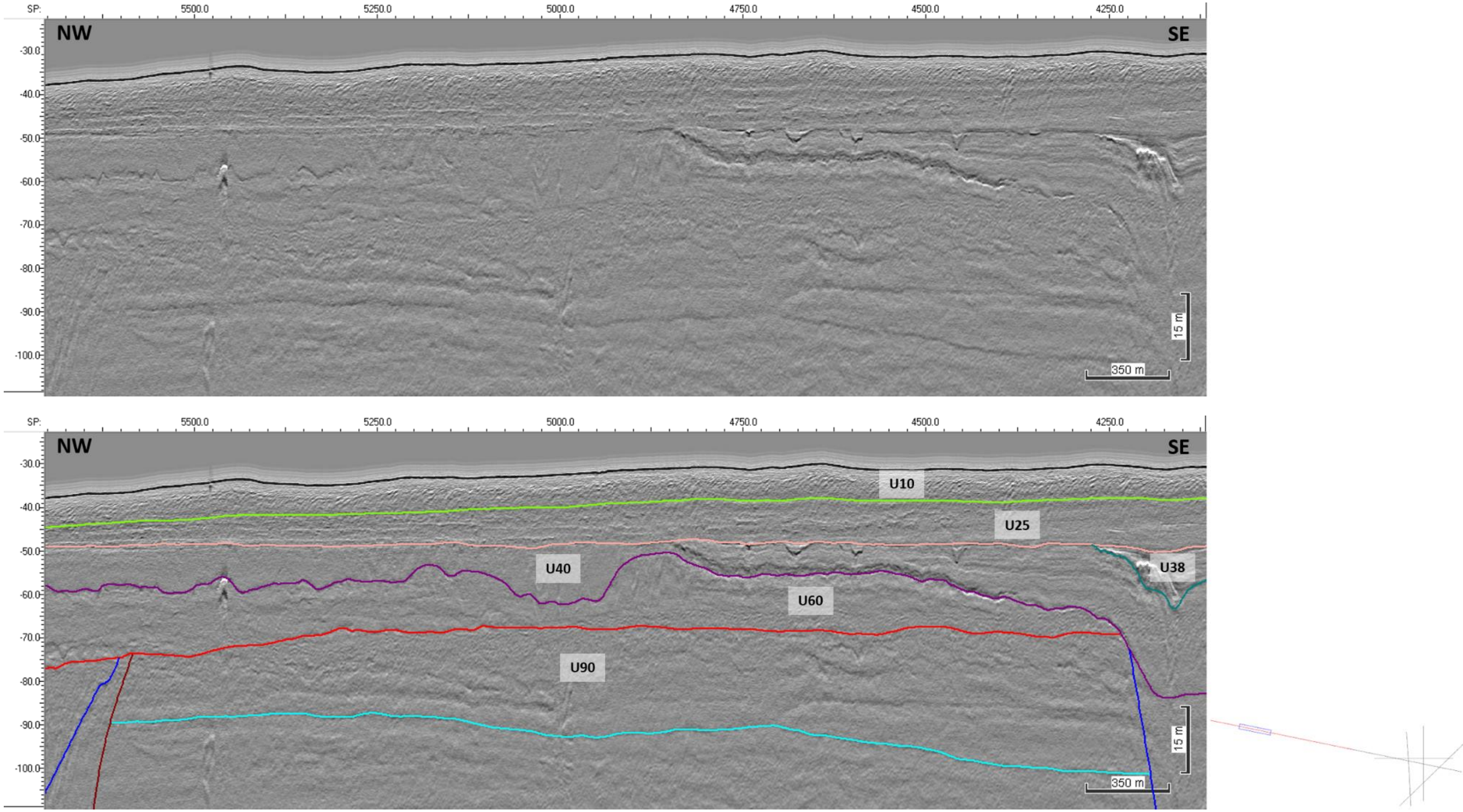


Figure 89 General facies of Seismic Unit U90, and the character of horizon H90. H90 is shown in cyan. Seismic profile ML_01_Prio_1.

8.2.14| SEISMIC UNIT UKSB

Base horizon: 20_HKSB

<table>
<tr><td rowspan="2">SEISMIC UNIT UKSB</td><td>SEISMIC UNIT UKSB
Base horizon: 20_HKSB
Depth: 56.5 - 151.9
Extent: Very limited; east limit of survey.
Description: Deformation front boundary. Truncating the parallel on the sides and beneath it.
Seismic unit: UKSB
Thickness: up to 98.4
Morphology: Channel shaped.
Seismic facies: Incoherent facies.</td></tr>
<tr><td>Interpreted depositional environment: Deformed deposits of variable sediment content. Glaciotectonism (Saalian?).

Expected sediment content: Deformed sediments.</td></tr>
</table>

Horizon HKSB (reference number 20) delineates the base of seismic unit UKSB. The spatial distribution, vertical reference to MSL and the seabed, and thickness of the seismic unit are presented in Figure 90 to Figure 92.

Horizon HKSB defines a significant vertical and lateral facies shift, separating deformed sediments from preserved deposits older than H90. Horizon HKSB ranges in depth between 56.5 m and 151.9 m below MSL (Figure 90), and between 13.7 m and 109.3 m depth below the seabed (Figure 91).

Seismic unit UKSB occurs in a very limited area in the eastern limit of the survey. It encompasses strongly deformed or incoherent sediments, up to 98.4 m thick (Figure 92). The seismic facies of this unit is complex and chaotic (Figure 93).

Similar to horizon HKSA, HKSB represents a deformation front boundary and, although part of the geological model, should not be interpreted with a chronostratigraphic meaning. Seismic unit UKSB encompasses strongly deformed sediments older than U90. The deformed sediments of seismic unit UKSA are interpreted to be related to glaciotectonism. The expected sediment content may vary significantly.

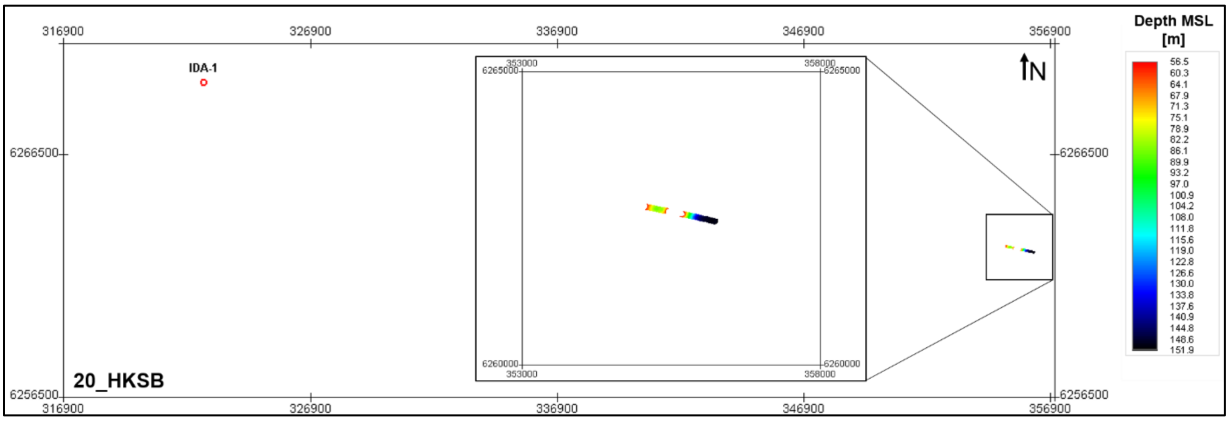


Figure 90 Map showing the lateral extent of horizon HKSB.
Units in metres below MSL.

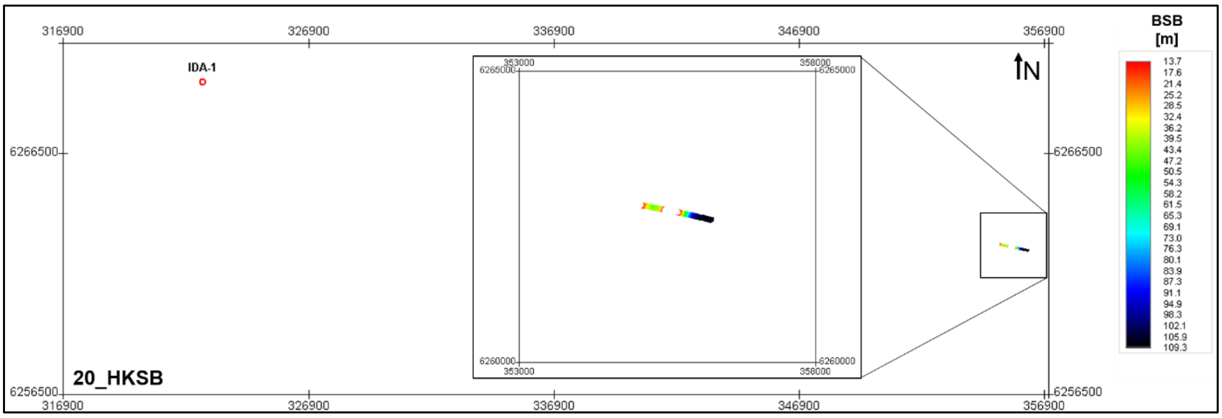


Figure 91 Depth below seabed of horizon HKSB.
Units in metres below seabed.

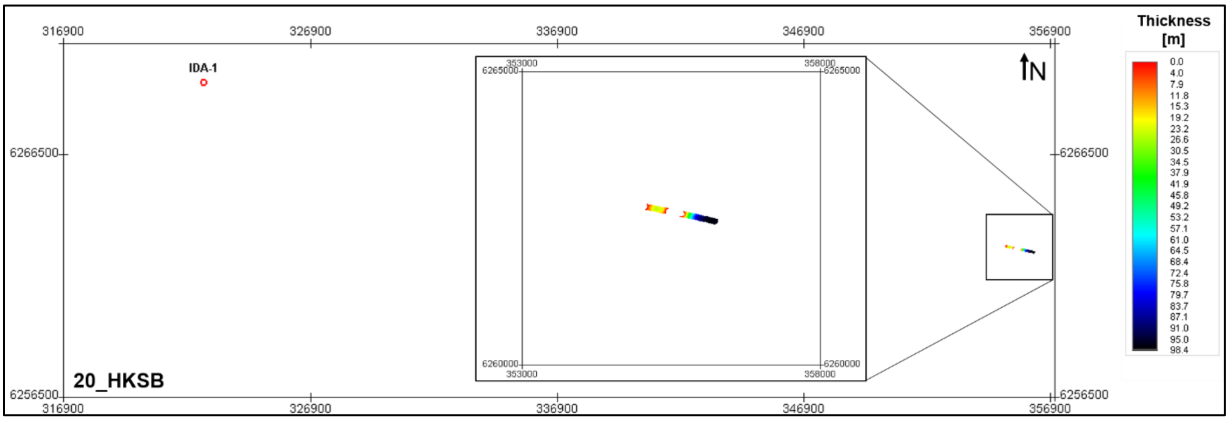


Figure 92 Thickness of unit UKSB.
Units in metres.

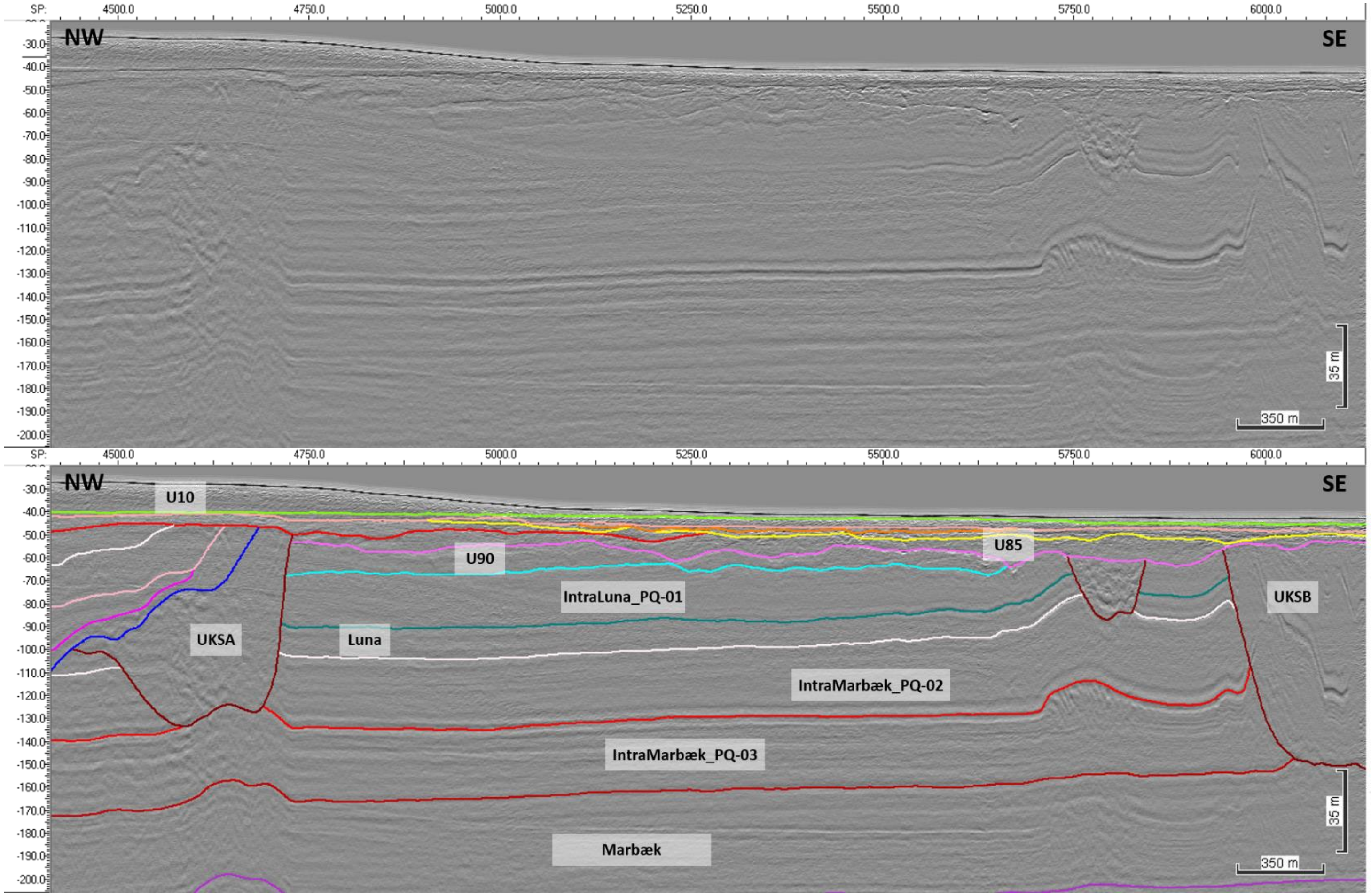


Figure 93 Thrust complex observed within Seismic Unit UKSB, which comprises deformed sediments older than U90. Horizon HKSB delineating a decollement surface, flats and ramps, and the deformation front plane. Thrust planes dip SE, indicating a compression advancing towards NW. Seismic profile ML_01_Prio_1a.

8.2.15| SEISMIC UNIT LUNA

Internal horizon: 21_Intra Luna (PQ-01)

Base horizon: 22_Luna

SEISMIC UNIT LUNA	**SEISMIC SUBUNIT INTRA LUNA (PQ-01)** **Base horizon: 21_Intra Luna (PQ-01)** Depth: 66.7 - 242.9 Extent: Continuous throughout the site. Description: Moderate, continuous, undulating reflector. **Seismic subunit: Intra Luna (PQ-01)** Thickness: up to 124.2 Morphology: Tabular; faulted. Seismic facies: Chaotic to transparent facies on top; parallel reflectors and channel-mound geometries at the base.
	SEISMIC SUBUNIT LUNA **Base horizon: 22_Luna** Depth: 76.1 - 268.1 Extent: Continuous throughout the site. Description: Moderate, continuous reflector. **Seismic subunit: Luna** Thickness: up to 28 Morphology: Tabular; faulted. Seismic facies: Parallel to sub-parallel reflector pattern. Variable amplitude. Localised undulating reflector pattern.
	Interpreted depositional environment: Near shore marine environment. **Expected sediment content:** Sandy silts; shoreface sands.

Seismic unit Luna is a major component of the ground model, and extends spatially across the site. It is only absent in tunnel valley areas, where it was eroded or incorporated into deformed sediment deposits. It is divided into two parallel subunits of different seismic character: subunits Intra Luna (PQ-01) (above) and Luna (below). The spatial distribution, vertical reference to MSL and the seabed, and thickness of the seismic subunits are presented in Figure 94 to Figure 99.

SUBUNIT INTRA LUNA (PQ-01)

The base of seismic subunit Intra Luna (PQ-01) is defined by horizon Intra Luna (PQ-01) (reference number 21), between 66.7 m and 242.9 m depth below MSL (Figure 94), and between 24.4 m and 199.9 m depth below the seabed (Figure 95). This horizon is a continuous reflector of moderate amplitude, slightly undulating (Figure 100).

Seismic subunit Intra Luna (PQ-01) has a flat, tabular morphology, generally dipping towards SW, up to 124.2 m thick (Figure 96). Intra Luna (PQ-01) comprises an upper section of chaotic to transparent facies, with parallel reflectors and channel-mound geometries at the base (Figure 100).

SUBUNIT LUNA

The base of seismic subunit Luna is defined by horizon Luna (reference number 22), between 76.1 m and 268.1 m depth below MSL (Figure 97), and between 33.8 m and 224.6 m depth below the seabed (Figure 98). This horizon is a continuous reflector of moderate amplitude (Figure 100).

Seismic subunit Luna has a flat, tabular morphology, generally dipping towards SW, up to 28 m thick (Figure 99). Luna is characterised by parallel to sub-parallel seismic facies of variable amplitude, with local undulating reflectors (Figure 100).

Complemented by geophysical data of well IDA-1 (namely, gamma ray) and previous seismic interpretations (Knutz et al., 2022), seismic unit Luna is interpreted to correspond to the Luna Formation. The Luna Formation comprises sandy-silty sediments deposited in a near-shore marine environment, during the Upper Miocene.

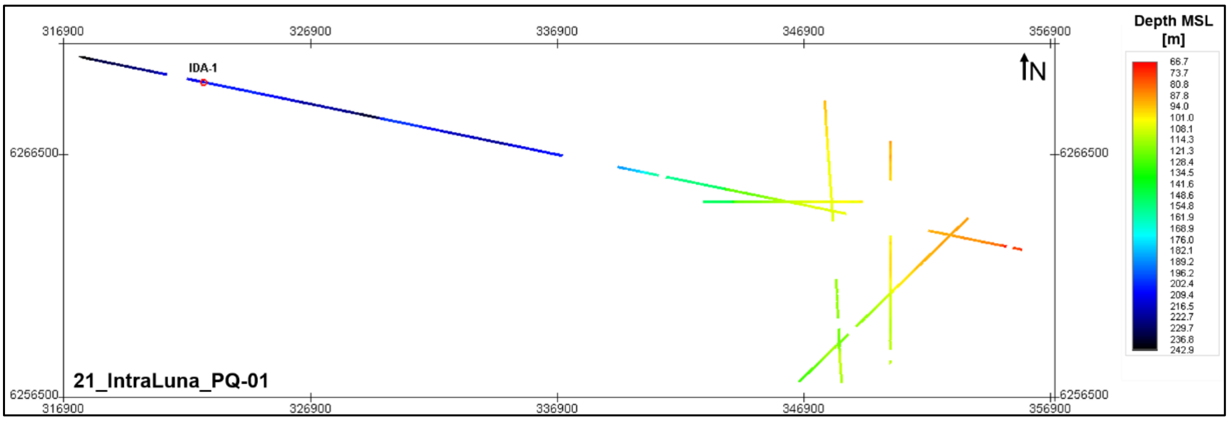


Figure 94 Map showing the lateral extent of horizon Intra Luna PQ-01.
Units in metres below MSL.

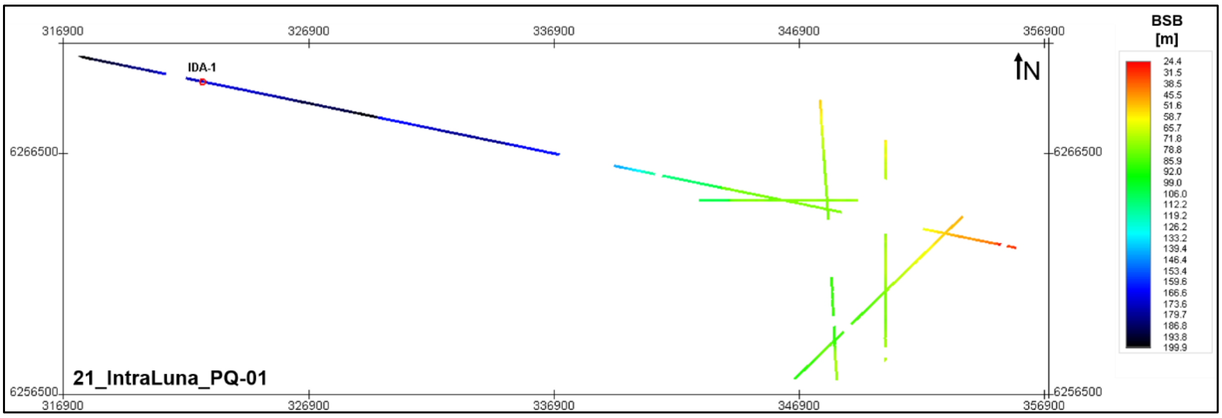


Figure 95 Depth below seabed of horizon Intra Luna PQ-01.
Units in metres below seabed.

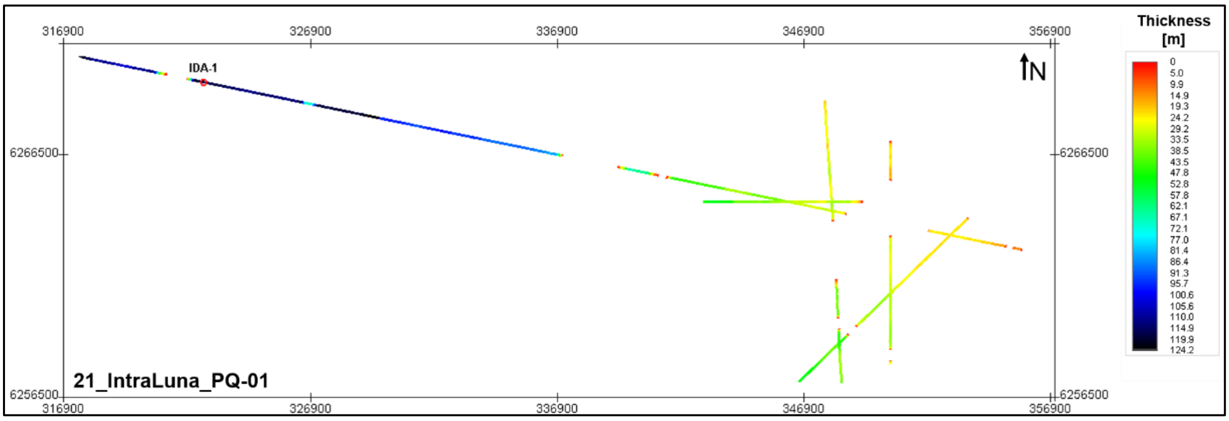


Figure 96 Thickness of unit Intra Luna PQ-01.
Units in metres.

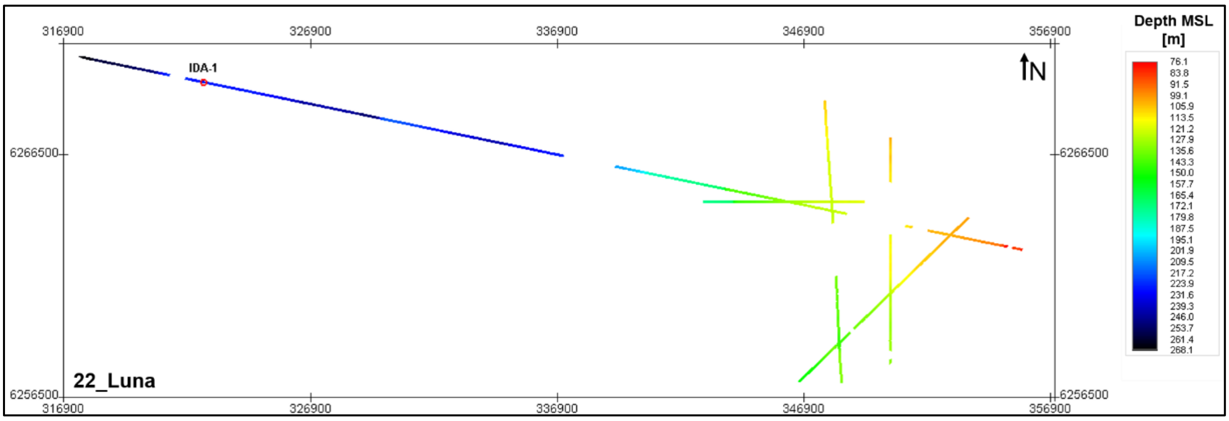


Figure 97 Map showing the lateral extent of horizon Luna.
Units in metres below MSL.

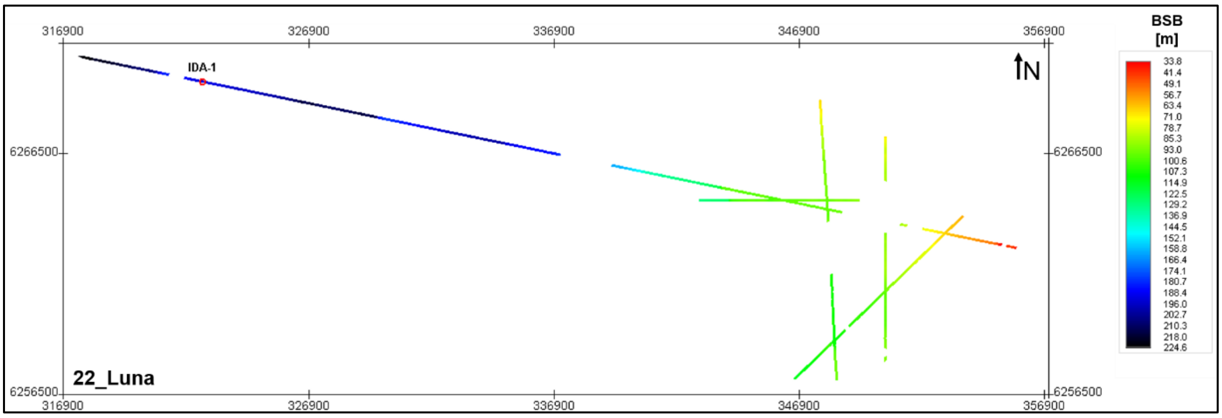


Figure 98 Depth below seabed of horizon Luna.
Units in metres below seabed.

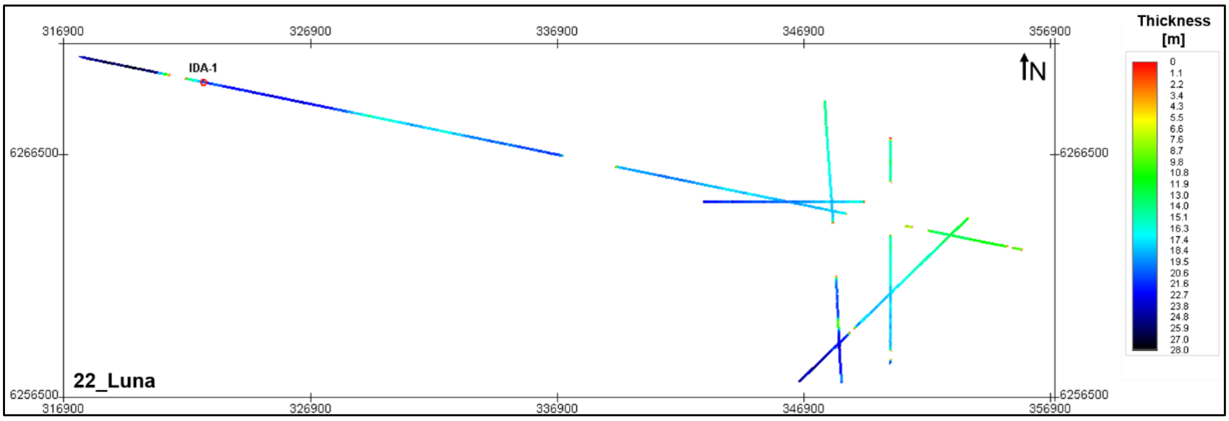


Figure 99 Thickness of unit Luna.
Units in metres.

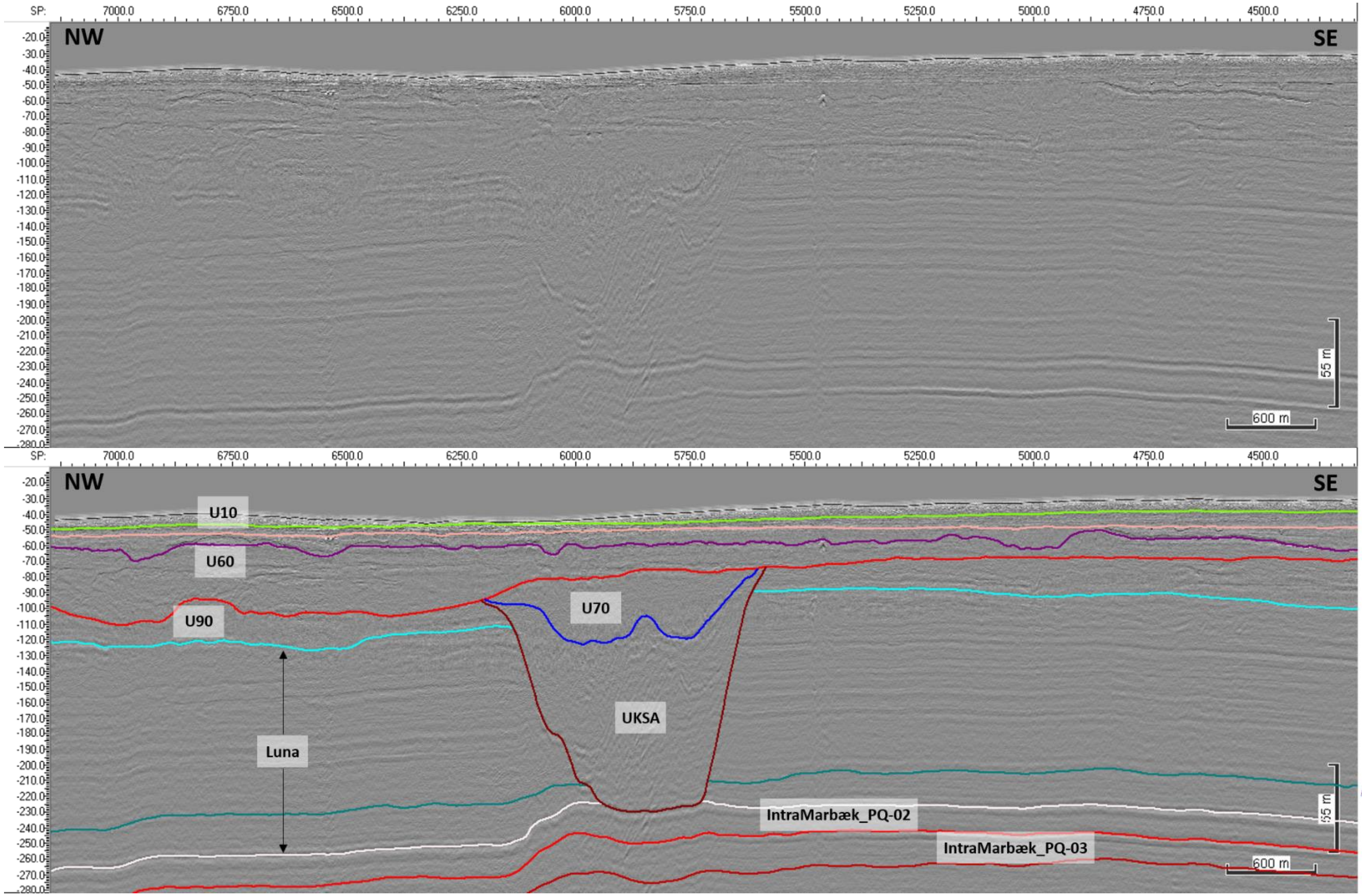


Figure 100 General facies of Seismic Unit Luna. Horizon Intra Luna (PQ-01) is shown in dark cyan and horizon Luna in white. Seismic profile ML_01_Prio_1.

8.2.16 | SEISMIC UNIT MARBÆK

Internal horizon: 23_Intra Marbæk (PQ-02); 24_Intra Marbæk (PQ-03)

Base horizon: 25_Marbæk

SEISMIC UNIT MARBÆK	**SEISMIC SUBUNIT INTRA MARBÆK (PQ-02)** **Base horizon: 23_Intra Marbæk (PQ-02)** Depth: 107.3 - 290.3 Extent: Continuous throughout the site. Description: Moderate, continuous reflector. **Seismic subunit: Intra Marbæk (PQ-02)** Thickness: up to 42 Morphology: Tabular; faulted. Seismic facies: Parallel to sub-parallel facies of low amplitude, with a negative amplitude reflector on top.
	SEISMIC SUBUNIT INTRA MARBÆK (PQ-03) **Base horizon: 24_Intra Marbæk (PQ-03)** Depth: 139 - 307.1 Extent: Continuous throughout the site. Description: Moderate, continuous reflector. **Seismic subunit: Intra Marbæk (PQ-03)** Thickness: up to 45.3 Morphology: Tabular; faulted. Seismic facies: Parallel to sub-parallel facies of low amplitude, with a set of high amplitude reflectors on top.
	SEISMIC SUBUNIT MARBÆK **Base horizon: 25_Marbæk** Depth: 176.5 - 324.6 Extent: Continuous throughout the site. Description: Moderate, continuous reflector. **Seismic unit: Marbæk** Thickness: up to 53.9 Morphology: T Tabular; faulted. Seismic facies: Parallel to sub-parallel facies of low amplitude.
	Interpreted depositional environment: Shoreface sand. **Expected sediment content:** Slope to shoreface sands.

Seismic unit Marbæk is a major component of the ground model, and extends spatially across the site. It is only absent in tunnel valley areas, where it was eroded or incorporated into deformed sediment deposits. It is divided into three parallel subunits: subunits Intra Marbæk (PQ-02) (above), Intra Marbæk (PQ-03) (centre), and Marbæk (below). The spatial distribution, vertical reference to MSL and the seabed, and thickness of the seismic subunits are presented in Figure 101 to Figure 109.

The overall seismic character of Marbæk is characterised by a succession of parallel to sub-parallel seismic reflectors, defining a layered interval with a flat, tabular morphology, generally dipping towards SW. The definition of subunits is based on the occurrence of seismic reflectors of higher amplitude that mark the transition between internal packages.

SUBUNIT INTRA MARBÆK (PQ-02)

The base of seismic subunit Intra Marbæk (PQ-02) is defined by horizon Intra Marbæk (PQ-02) (reference number 22), between 107.3 m and 290.3 m depth below MSL (Figure 101), and between

64.6 m and 246.8 m depth below the seabed (Figure 102). This horizon is a continuous reflector of moderate amplitude (Figure 110).

Seismic subunit Intra Marbæk (PQ-02) comprises parallel to sub-parallel facies of low amplitude, with a negative amplitude reflector on top (Figure 110). Its thickness reaches a maximum of 42 m (Figure 103).

SUBUNIT INTRA MARBÆK (PQ-03)

The base of seismic subunit Intra Marbæk (PQ-03) is defined by horizon Intra Marbæk (PQ-03) (reference number 23), between 139 m and 307.1 m depth below MSL (Figure 104), and between 104 m and 263.7 m depth below the seabed (Figure 105). This horizon is a continuous reflector of moderate amplitude (Figure 110).

Seismic subunit Intra Marbæk (PQ-03) comprises parallel to sub-parallel facies of low amplitude, with a set of high amplitude reflectors on top (Figure 110). Its thickness is up to 45.3 m (Figure 106).

SUBUNIT MARBÆK

The base of seismic subunit Marbæk is defined by horizon Marbæk (reference number 24), between 176.5 m and 324.6 m depth below MSL (Figure 107), and between 143.4 m and 284.1 m depth below the seabed (Figure 108). This horizon is a continuous reflector of moderate amplitude (Figure 100).

Seismic subunit Marbæk comprises parallel to sub-parallel facies of low amplitude (Figure 100). Its thickness reaches a maximum of 53.9 m (Figure 109).

Complemented by geophysical data of well IDA-1 (namely, gamma ray) and previous seismic interpretations (Knutz et al., 2022), seismic unit Marbæk is interpreted to correspond to the Marbæk Formation. The Marbæk Formation comprises deposits of slope to shoreface sands, of Upper Miocene in age.

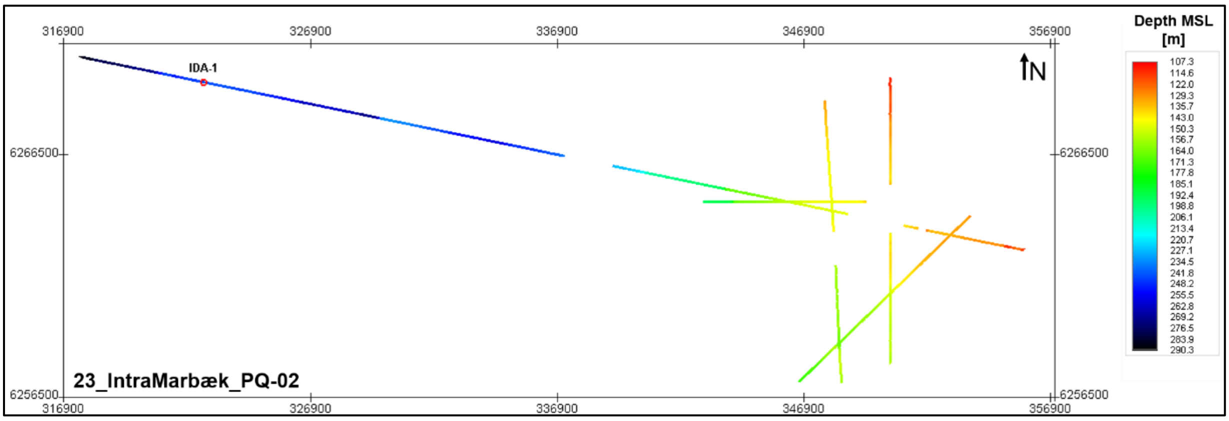


Figure 101 Map showing the lateral extent of horizon Intra Marbæk (PQ-02).
Units in metres below MSL.

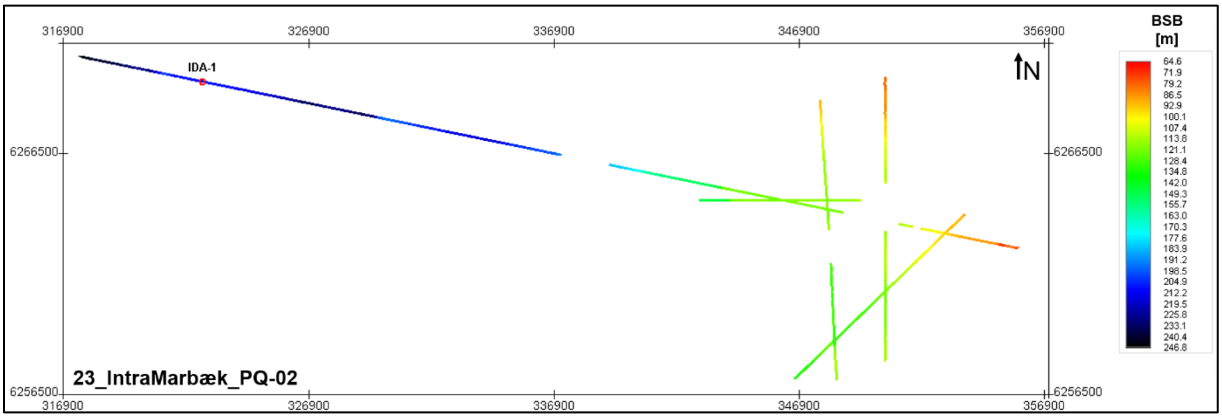


Figure 102 Depth below seabed of horizon Intra Marbæk (PQ-02).
Units in metres below seabed.

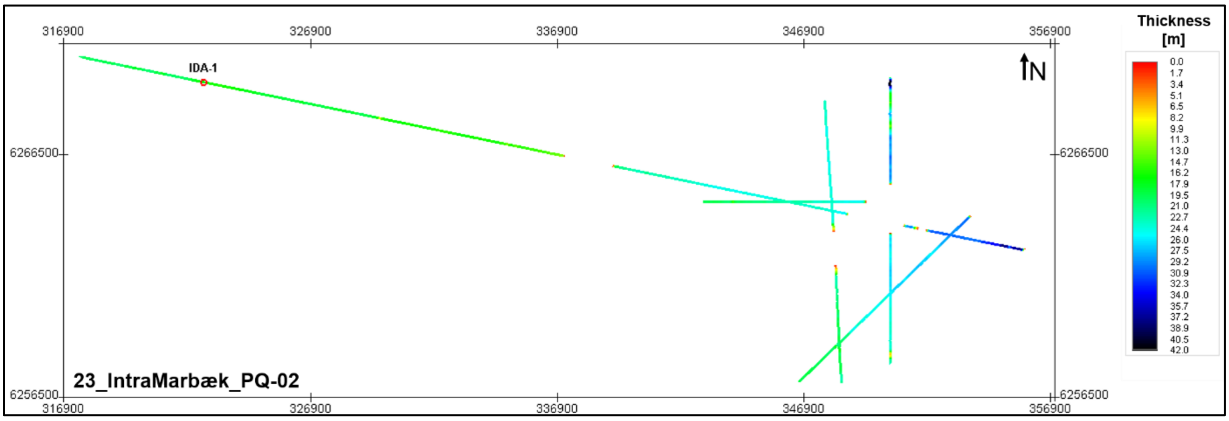


Figure 103 Thickness of unit Intra Marbæk (PQ-02).
Units in metres.

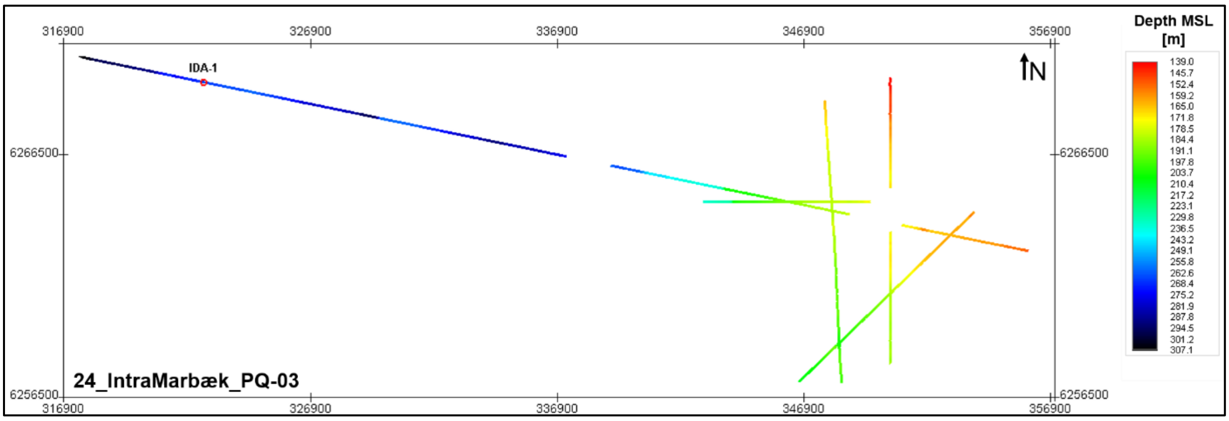


Figure 104 Map showing the lateral extent of horizon Intra Marbæk (PQ-03). Units in metres below MSL.

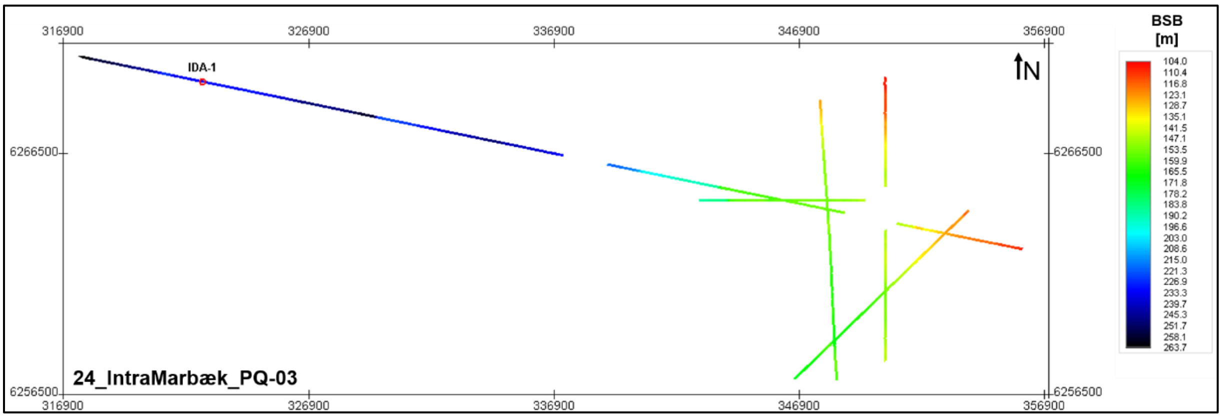


Figure 105 Depth below seabed of horizon Intra Marbæk (PQ-03). Units in metres below seabed.

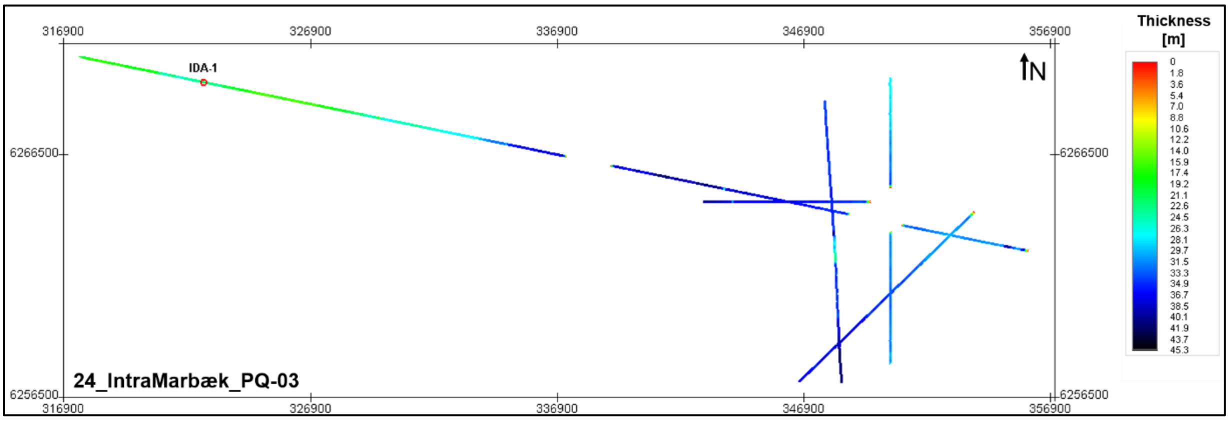


Figure 106 Thickness of unit Intra Marbæk (PQ-03). Units in metres.

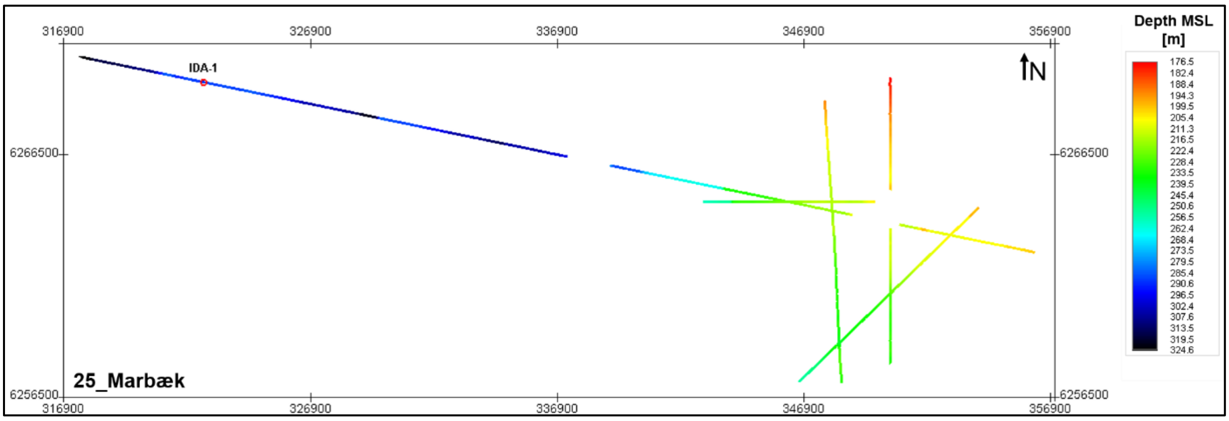


Figure 107 Map showing the lateral extent of horizon Marbæk.
Units in metres below MSL.

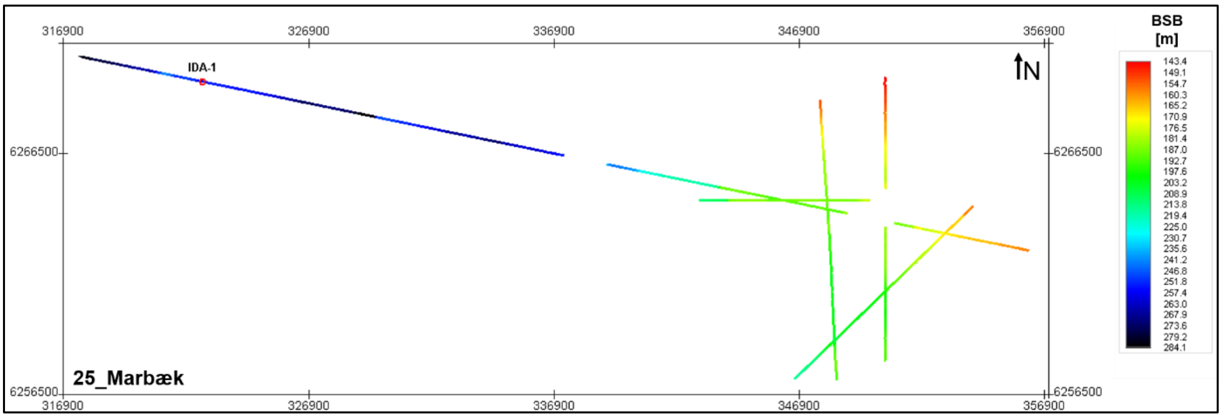


Figure 108 Depth below seabed of horizon Marbæk.
Units in metres below seabed.

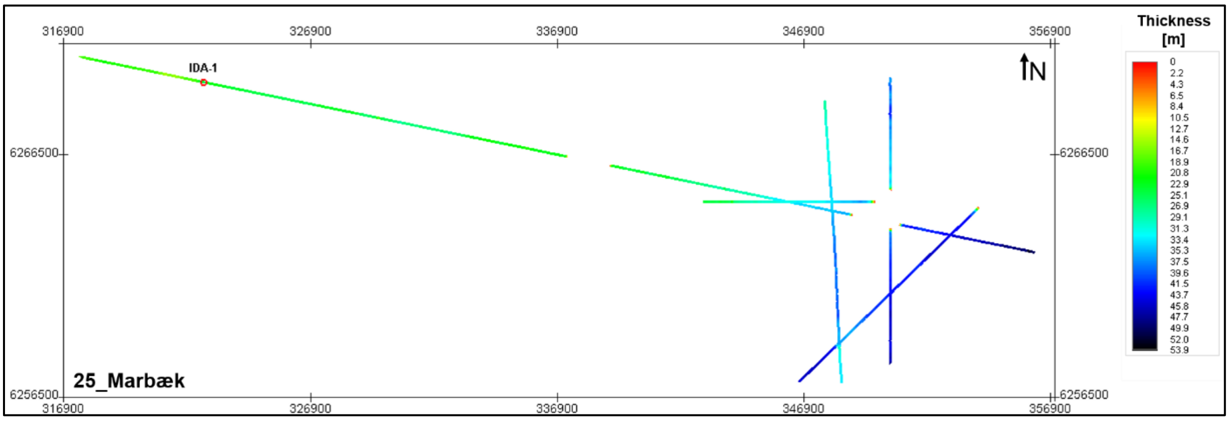


Figure 109 Thickness of unit Marbæk.
Units in metres.

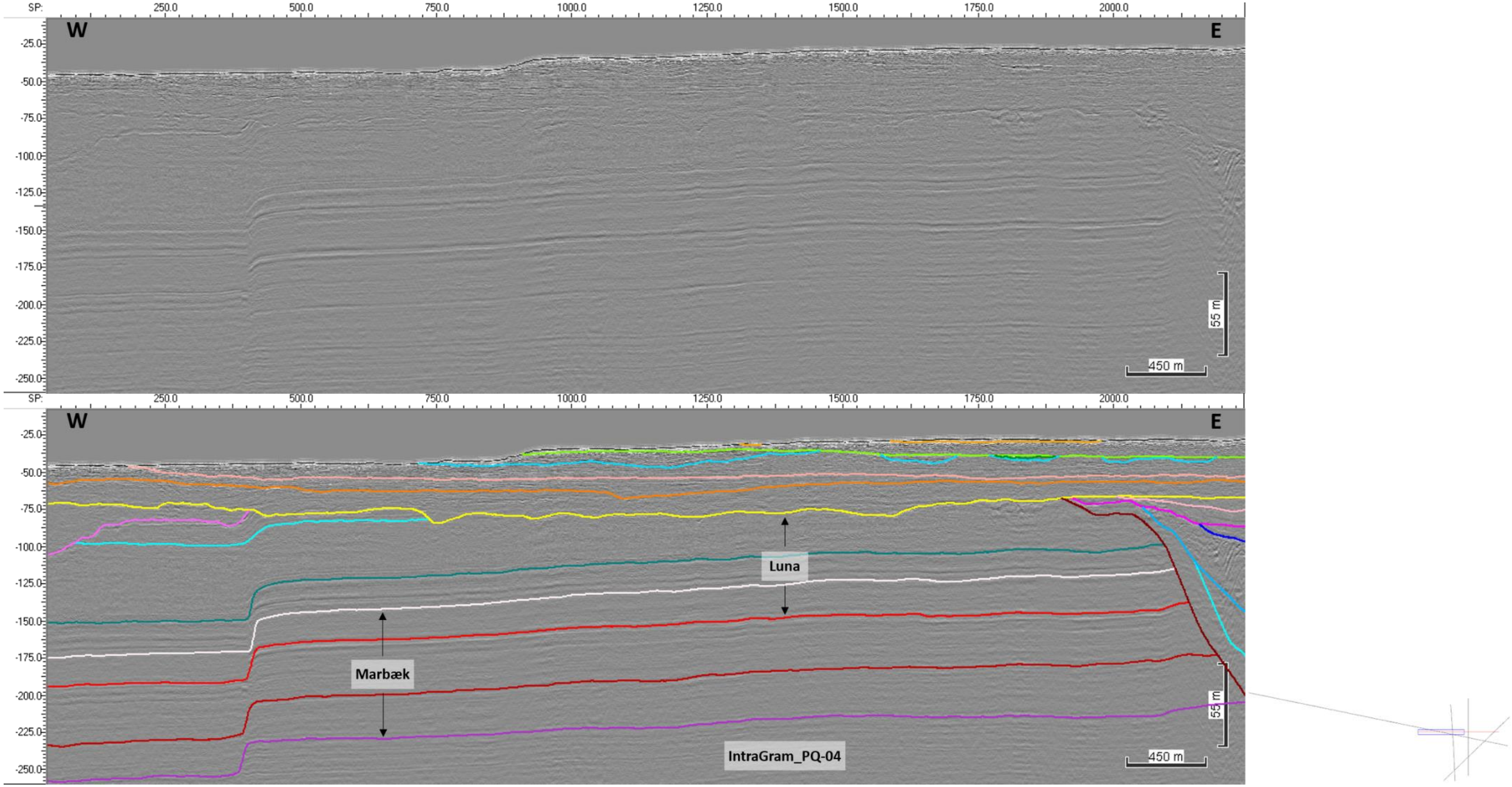


Figure 110 General facies of Seismic Unit Marbæk. Horizon Intra Marbæk (PQ-02) is shown in red, horizon Intra Marbæk (PQ-03) in marron and Marbæk in violet. Seismic profile ML_04_Prio_2.

8.2.17| SEISMIC UNIT GRAM

Internal horizon: 26_Intra Gram (PQ-04)

Base horizon: 27_Gram

<table>
<tr><td rowspan="3">SEISMIC UNIT GRAM</td><td>SEISMIC SUBUNIT INTRA GRAM (PQ-04)
Base horizon: 26_Intra Gram (PQ-04)
Depth: 221.5 - 372.3
Extent: Continuous throughout the site.
Description: High amplitude, continuous reflector.
Seismic subunit: Intra Gram (PQ-04)
Thickness: up to 121
Morphology: Tabular; faulted.
Seismic facies: Parallel to sub-parallel facies of low amplitude.</td></tr>
<tr><td>SEISMIC SUBUNIT GRAM
Base horizon: 27_Gram
Depth: 233.5 - 395.8
Extent: Continuous throughout the site.
Description: High amplitude and continuous reflector.
Seismic unit: Gram
Thickness: 5.4 - 28.5
Morphology: Tabular; faulted.
Seismic facies: Undulating parallel to sub-parallel facies of medium amplitude, with a set of high amplitude reflectors on top.</td></tr>
<tr><td>Interpreted depositional environment: Marine muds.

Expected sediment content: Offshore muds; silt to fine-grained sands.</td></tr>
</table>

Seismic unit Gram is a major component of the ground model, and extends spatially across the site. It is divided into two parallel subunits: subunits Intra Gram (PQ-04) (above), and Gram (below). The spatial distribution, vertical reference to MSL and the seabed, and thickness of the seismic subunits are presented in Figure 111 to Figure 116.

The overall seismic character of Gram is characterised by a succession of parallel to sub-parallel seismic reflectors, defining a layered interval with a flat, tabular morphology, generally dipping towards SW. The definition of subunits is based on the occurrence of seismic reflectors of higher amplitude that mark the transition between internal packages.

SUBUNIT INTRA GRAM (PQ-04)

The base of seismic subunit Intra Gram (PQ-04) is defined by horizon Intra Gram (PQ-04) (reference number 26), between 221.5 m and 372.3 m depth below MSL (Figure 111), and between 188.4 m and 326.5 m depth below the seabed (Figure 112). This horizon is a continuous reflector of high amplitude (Figure 117).

Seismic subunit Intra Gram (PQ-04) comprises a thick parallel to sub-parallel facies of low amplitude (Figure 117). Its thickness reaches a maximum of 121 m (Figure 113).

SUBUNIT GRAM

The base of seismic subunit Gram is defined by horizon Gram (reference number 27), between 233.5 m and 395.8 m depth below MSL (Figure 114), and between 200.4 m and 349.6 m depth below the seabed (Figure 115). This horizon is a continuous reflector of high amplitude (Figure 118).

Seismic subunit Gram comprises undulating parallel to sub-parallel facies of medium amplitude, with a set of high amplitude reflectors on top (Figure 118). Its thickness ranges from 5.4 m to 28.5 m (Figure 116).

Complemented by geophysical data of well IDA-1 (namely, gamma ray) and previous seismic interpretations (Knutz et al., 2022), seismic unit Gram is interpreted to correspond to the Gram Formation. The Gram Formation comprises muds, and silt to fine-grained sands, deposited in a marine environment during the Lower Miocene.

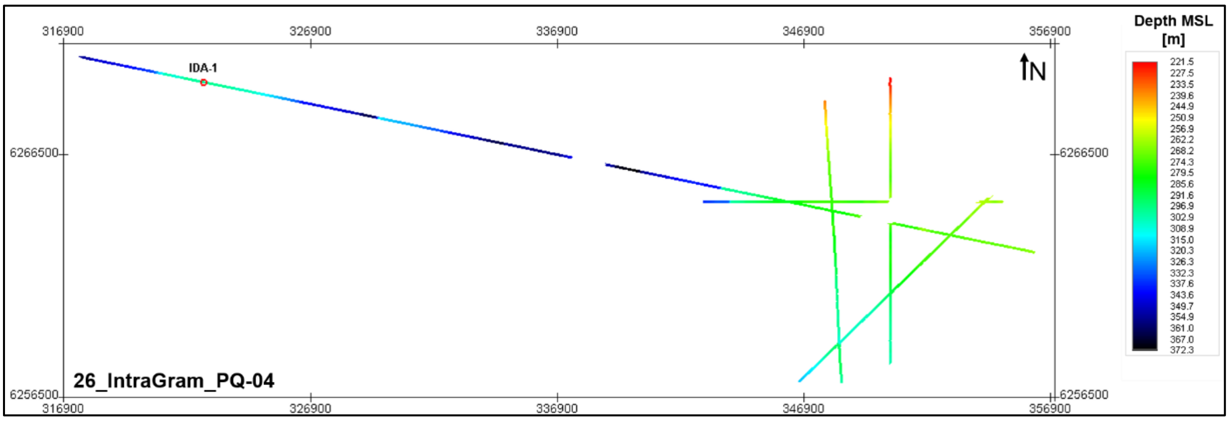


Figure 111 Map showing the lateral extent of horizon Intra Gram (PQ-04).
Units in metres below MSL.

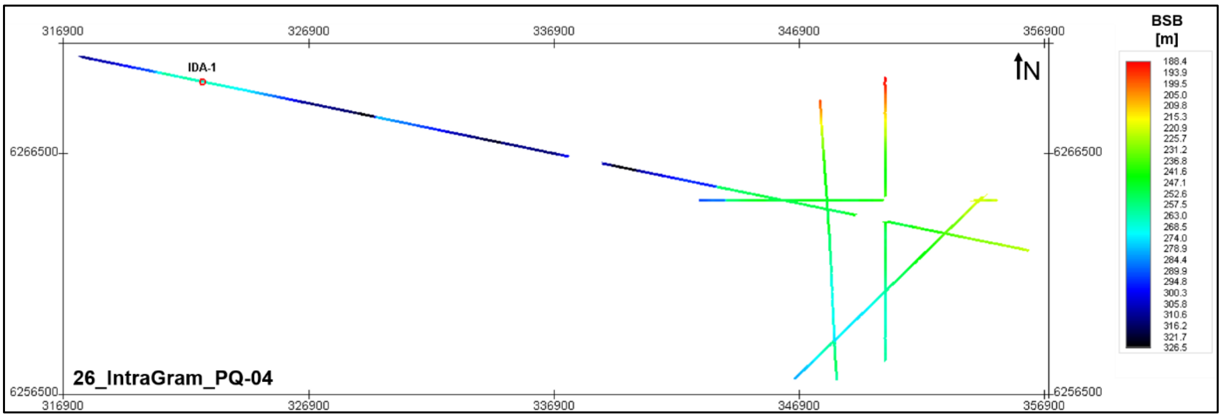


Figure 112 Depth below seabed of horizon Intra Gram (PQ-04).
Units in metres below seabed.

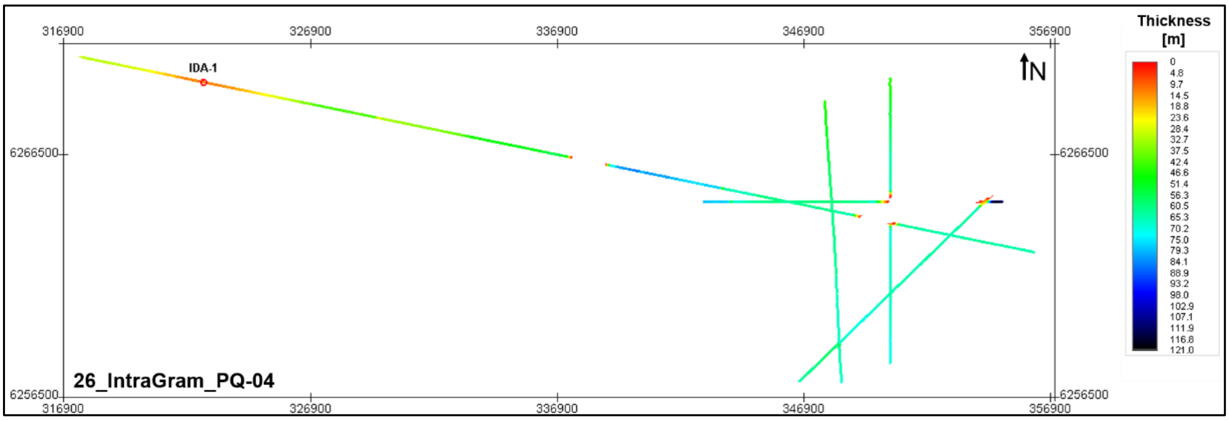


Figure 113 Thickness of unit Intra Gram (PQ-04).
Units in metres.

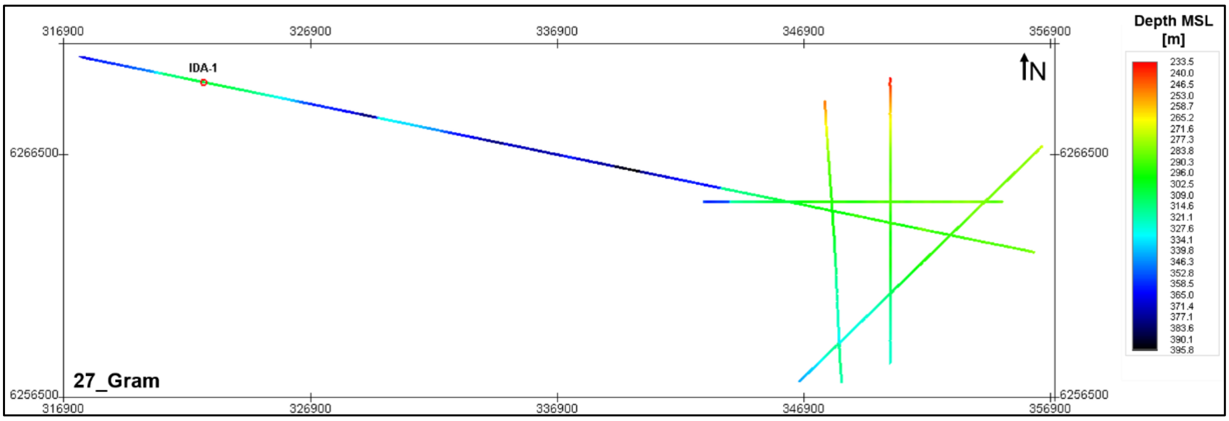


Figure 114 Map showing the lateral extent of horizon Gram.
Units in metres below MSL.

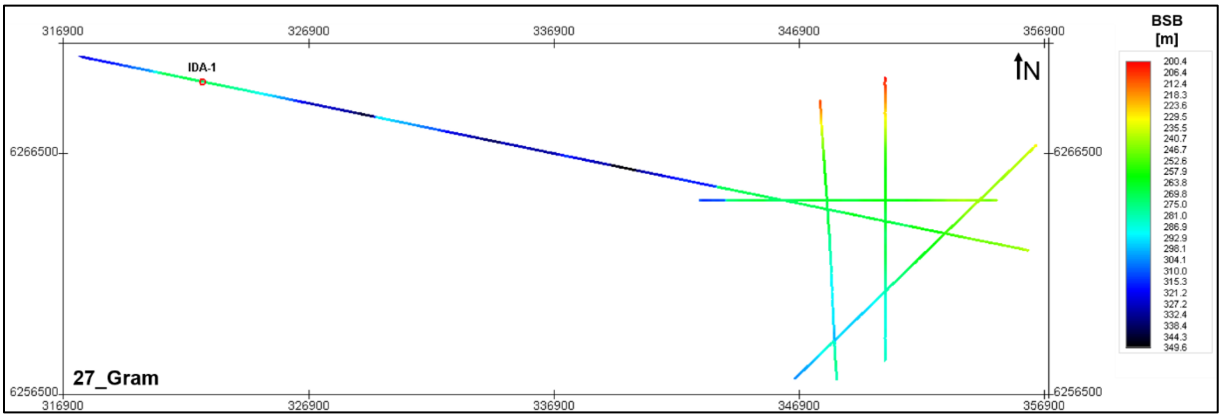


Figure 115 Depth below seabed of horizon Gram.
Units in metres below seabed.

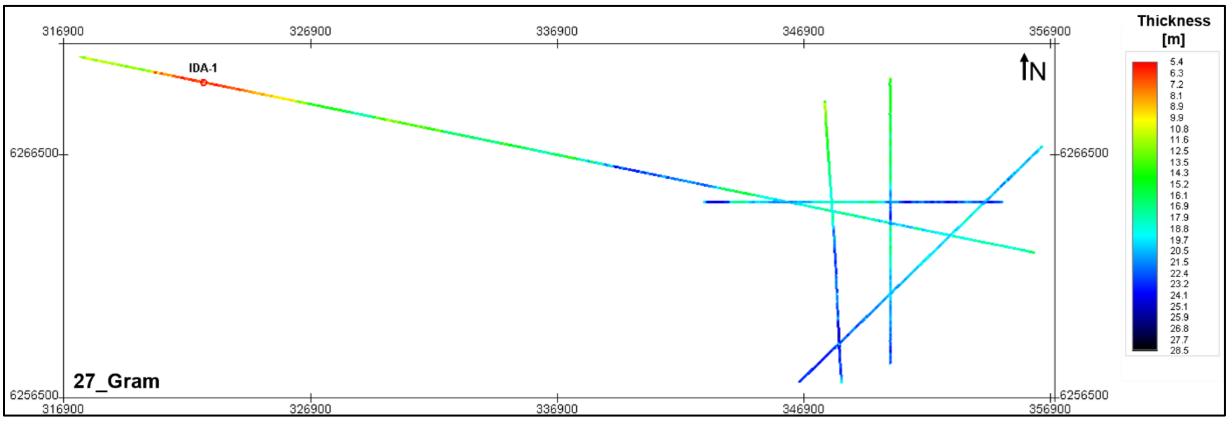


Figure 116 Thickness of unit Gram.
Units in metres.

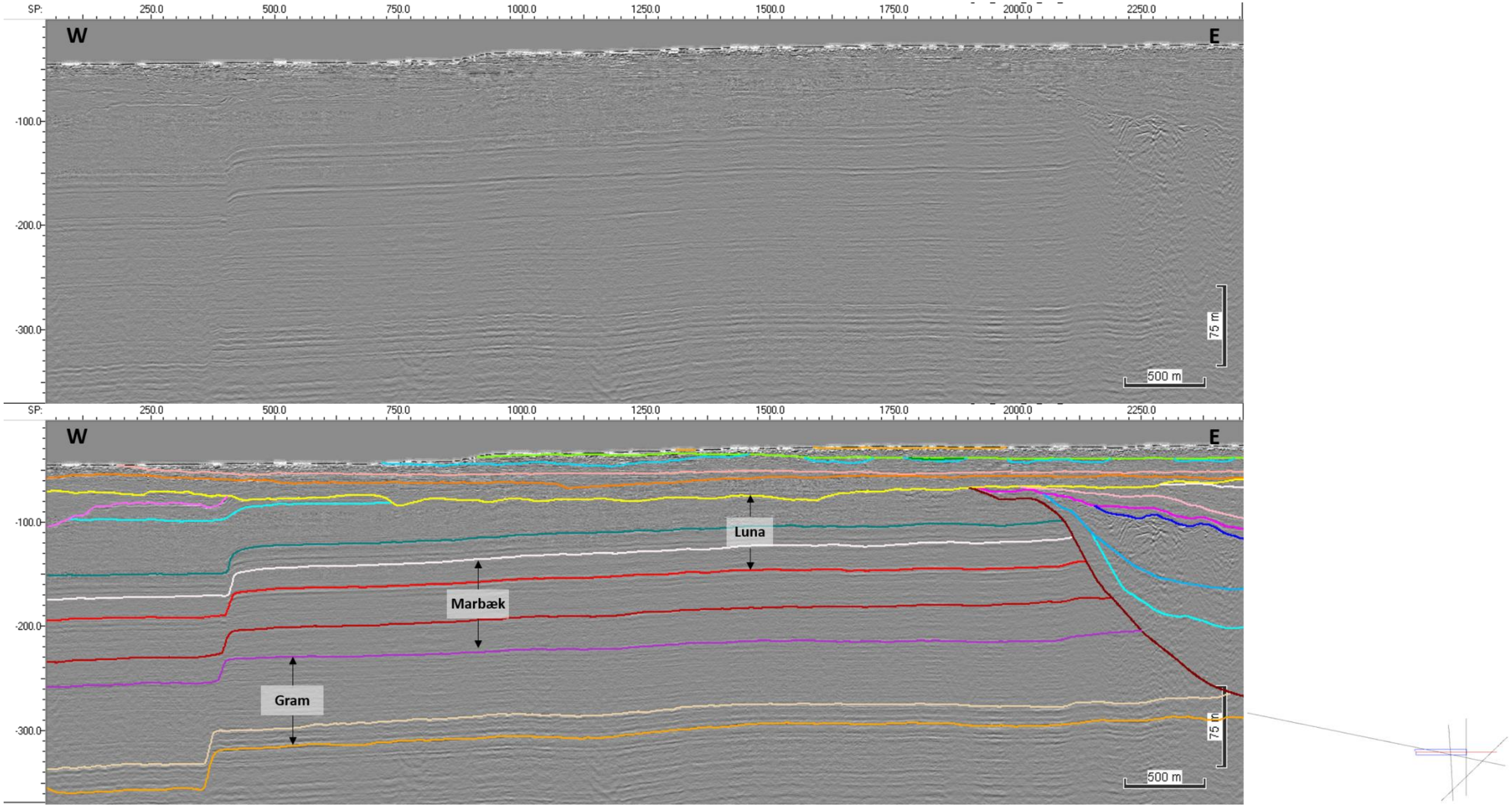


Figure 117 General facies of Seismic Unit Gram as observed in UHR seismic data. Horizon Intra Gram (PQ-04) is shown in beige and horizon Gram in gold. Seismic profile ML_04_Prio_2.

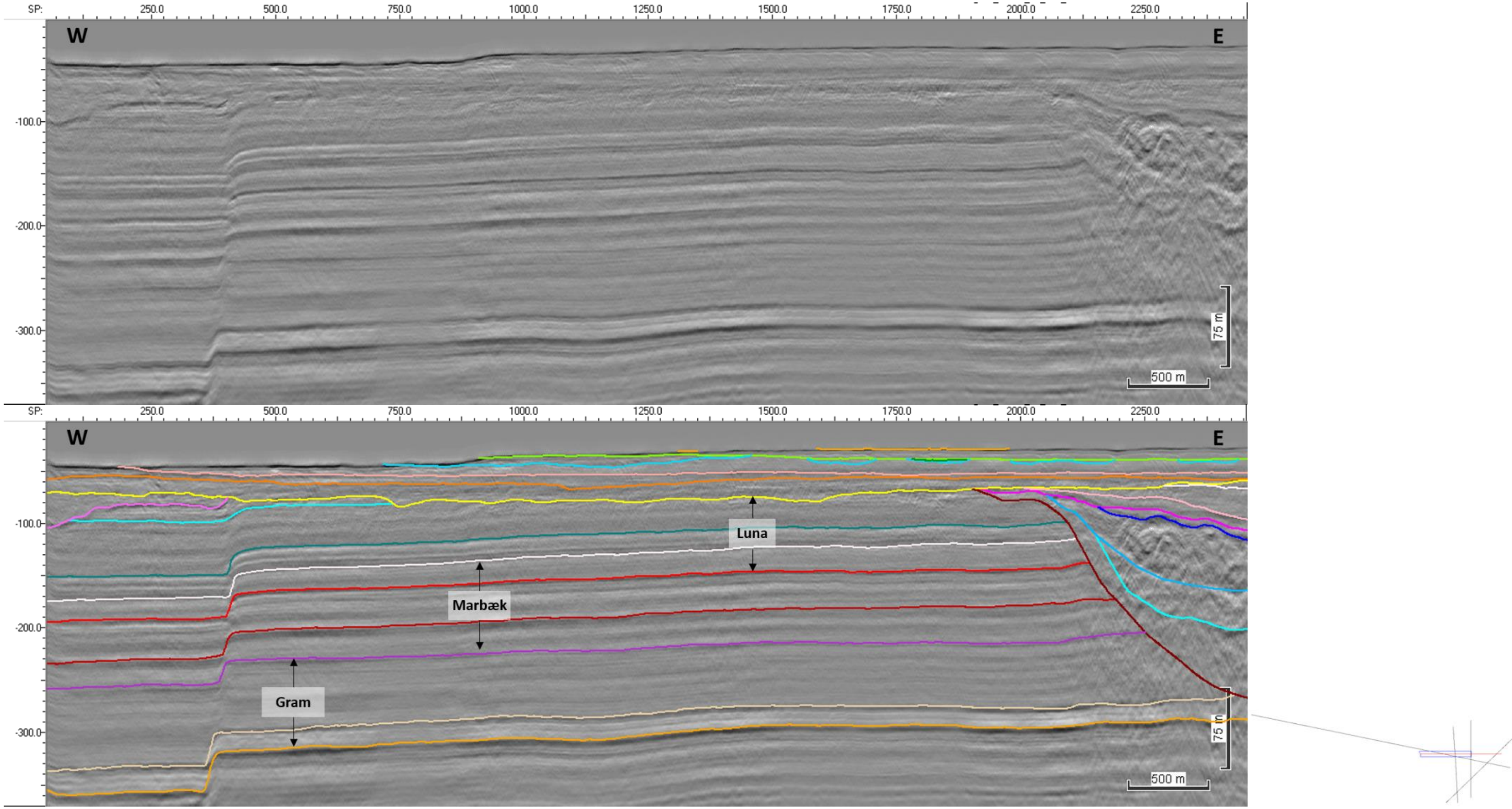


Figure 118 General facies of Seismic Unit Gram as observed in HR seismic data. Horizon Intra Gram (PQ-04) is shown in beige and horizon Gram in gold. Seismic profile ML_04_Prio_2.

8.2.18 | SEISMIC UNIT LARK

Internal horizons: 28_Intra Lark 05; 29_Intra Lark 04; 30_Intra Lark 03; 31_Intra Lark 02; 32_Intra Lark 01

Base horizon: 33_Lark

SEISMIC UNIT LARK	**SEISMIC SUBUNIT INTRA LARK 05** **Base horizon: 28_Intra Lark 05** Depth: 347.4 - 518.7 Extent: Continuous throughout the site. Description: High amplitude and continuous reflector. **Seismic subunit: Intra Lark 05** Thickness: 67.2 - 153.3 Morphology: Tabular; faulted. Seismic facies: Parallel to sub-parallel reflectors; medium to high amplitude, increasing towards the top. Local very high amplitude reflectors on top, probably related to gas.
	SEISMIC SUBUNIT INTRA LARK 04 **Base horizon: 29_Intra Lark 04** Depth: 418.3 - 672.7 Extent: Continuous throughout the site. Description: High amplitude and continuous reflector. **Seismic subunit: Intra Lark 04** Thickness: 30.5 - 184.6 Morphology: Tabular; faulted. Seismic facies: Parallel to sub-parallel reflectors, medium amplitude. Common positive high amplitude reflectors.
	SEISMIC SUBUNIT INTRA LARK 03 **Base horizon: 30_Intra Lark 03** Depth: 579.8 - 850.2 Extent: Continuous throughout the site. Description: High amplitude and continuous reflector. **Seismic subunit: Intra Lark 03** Thickness: 103.6 - 234.5 Morphology: Tabular; faulted. Seismic facies: Parallel to sub-parallel; mottled facies with diffraction hyperbolas at the top; common prograding reflectors, pinch outs, mounds; medium to high amplitude.
	SEISMIC SUBUNIT INTRA LARK 02 **Base horizon: 31_Intra Lark 02** Depth: 730.7 - 1096.2 Extent: Continuous throughout the site. Description: High amplitude and continuous reflector. **Seismic subunit: Intra Lark 02** Thickness: 79.8 - 349.5 Morphology: Tabular; faulted. Seismic facies: Downlapping, mounded, lenticular, hummocky, medium to high amplitude. Parallel to sub-parallel; medium to high amplitude; mounded, lenticular, hummocky; downlaps.
	SEISMIC SUBUNIT INTRA LARK 01 **Base horizon: 32_Intra Lark 01** Depth: 782 - 1269.1 Extent: Continuous throughout the site. Description: High amplitude and continuous reflector.

	Seismic subunit: Intra Lark 01 Thickness: 10.3 - 174.3 Morphology: Tabular; faulted. Seismic facies: Parallel to sub-parallel facies; medium to high amplitude; common channels and mounds.
	SEISMIC SUBUNIT LARK **Base horizon: 33_Lark** Depth: 848.6 - 1429.9 Extent: Continuous throughout the site. Description: High amplitude and continuous reflector. **Seismic unit: Lark** Thickness: 8.5 - 172.5 Morphology: Tabular; faulted. Seismic facies: Parallel to sub-parallel facies; medium amplitude; occasionally chaotic; common mounds.
	Interpreted depositional environment: Prodeltaic mud and sand. Progradation toward south-west. **Expected sediment content:** Offshore muds with sand intercalations.

Seismic unit Lark is a major component of the ground model, and extends spatially across the site. It is divided into six parallel subunits: subunits Intra Gram (PQ-04) (above), and Gram (below). The spatial distribution, vertical reference to MSL and the seabed, and thickness of the seismic subunits are presented in Figure 119 to Figure 136.

The overall seismic character of Lark is characterised by a succession of parallel to sub-parallel seismic reflectors, defining layered intervals with a flat, tabular morphology, generally dipping towards SW. The definition of subunits is based on the occurrence of seismic reflectors of higher amplitude that mark the transition between internal packages.

SUBUNIT INTRA LARK 05

The base of seismic subunit Intra Lark 05 is defined by horizon Intra Lark 05 (reference number 28), between 347.4 m and 518.7 m depth below MSL (Figure 119), and between 314.3 m and 473.5 m depth below the seabed (Figure 120). This horizon is a continuous reflector of high amplitude (Figure 137).

Seismic subunit Intra Lark 05 comprises a parallel to sub-parallel facies of medium to high amplitude, increasing towards the top (Figure 137). Reflectors are slightly undulating. Subunit thickness ranges from 67.2 m to 153.3 m (Figure 121).

At IDA-1 well location, reflector amplitude at the top of the subunit (top of Lark unit) are extremely high, possibly due to presence of gas. Seismic blanking is observed on UHRS data below these gas-related amplitude anomalies.

SUBUNIT INTRA LARK 04

The base of seismic subunit Intra Lark 04 is defined by horizon Intra Lark 04 (reference number 29), between 418.3 m and 672.7 m depth below MSL (Figure 122), and between 383.1 m and 634.8 m depth below the seabed (Figure 123). This horizon is a continuous reflector of high amplitude (Figure 137).

Seismic subunit Intra Lark 04 comprises a parallel to sub-parallel facies of medium amplitude (Figure 137). Localized reflectors of positive high amplitude are observed throughout. Subunit thickness ranges from 30.5 m to 184.6 m (Figure 124).

SUBUNIT INTRA LARK 03

The base of seismic subunit Intra Lark 03 is defined by horizon Intra Lark 03 (reference number 30), between 579.8 m and 850.2 m depth below MSL (Figure 125), and between 541.7 m and 812.2 m depth below the seabed (Figure 126). This horizon is a continuous reflector of high amplitude (Figure 137).

Seismic subunit Intra Lark 03 comprises a thick parallel to sub-parallel facies of medium to high amplitude (Figure 137). Towards the top, amplitudes increase, with very high amplitudes at the top. Common discontinuous areas of stippled/mottled, high amplitude reflectors are found throughout, occurring more frequently towards the top. These are associated to diffraction hyperbola on non-migrated seismic data. Localized oblique/prograding reflectors, mounds, internal pinch-outs. Subunit thickness ranges from 103.6 m to 234.5 m (Figure 127).

SUBUNIT INTRA LARK 02

The base of seismic subunit Intra Lark 02 is defined by horizon Intra Lark 02 (reference number 31), between 730.7 m and 1096.2 m depth below MSL (Figure 128), and between 697.6 m and 1062.8 m depth below the seabed (Figure 129). This horizon is a continuous reflector of high amplitude (Figure 137).

Seismic subunit Intra Lark 02 comprises a thick parallel to sub-parallel facies of medium to high amplitude (Figure 137). Common mounded and hummocky internal facies, and downlapping reflectors. Frequent discontinuous positive high amplitude reflectors. Subunit thickness ranges from 79.8 m to 349.5 m (Figure 130).

SUBUNIT INTRA LARK 01

The base of seismic subunit Intra Lark 01 is defined by horizon Intra Lark 01 (reference number 32), between 782 m and 1269.1 m depth below MSL (Figure 131), and between 748.9 m and 1235.7 m depth below the seabed (Figure 132). This horizon is a continuous reflector of high amplitude (Figure 137).

Seismic subunit Intra Lark 01 comprises a parallel to sub-parallel facies of medium to high amplitude (Figure 137). Common channels and mounds. Subunit thickness ranges from 10.3 m to 174.3 m (Figure 133).

SUBUNIT LARK

The base of seismic subunit Lark is defined by horizon Lark (reference number 33), between 848.6 m and 1429.9 m depth below MSL (Figure 134), and between 815.6 m and 1396.5 m depth below the seabed (Figure 135). This horizon is a continuous reflector of high amplitude (Figure 137).

Seismic subunit Lark comprises a parallel to sub-parallel facies of medium amplitude, occasionally with a more chaotic seismic character (Figure 137). Common mounds. Subunit thickness ranges from 8.5 m to 172.5 m (Figure 136).

Complemented by geophysical data of well IDA-1 (namely, gamma ray and velocity logs) and previous seismic interpretations (Knutz et al., 2022), seismic unit Lark is interpreted to correspond to the Lark Formation. The Lark Formation is a thick succession of muds/clays intercalated with sand beds, generally prograding towards SW, deposited in a prodeltaic setting. The Lark Formation is Oligocene – Lower Miocene in age.

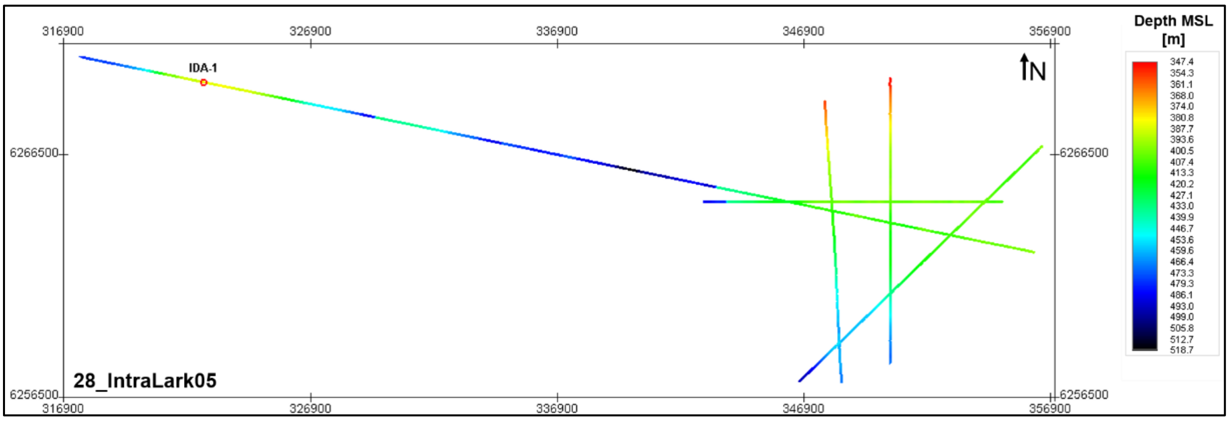


Figure 119 Map showing the lateral extent of horizon Intra Lark (05).
Units in metres below MSL.

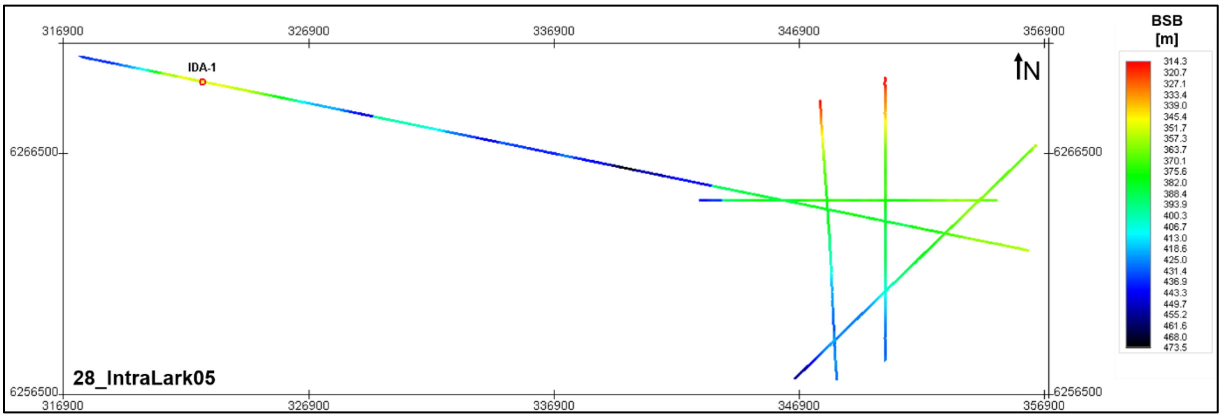


Figure 120 Depth below seabed of horizon Intra Lark (05).
Units in metres below seabed.

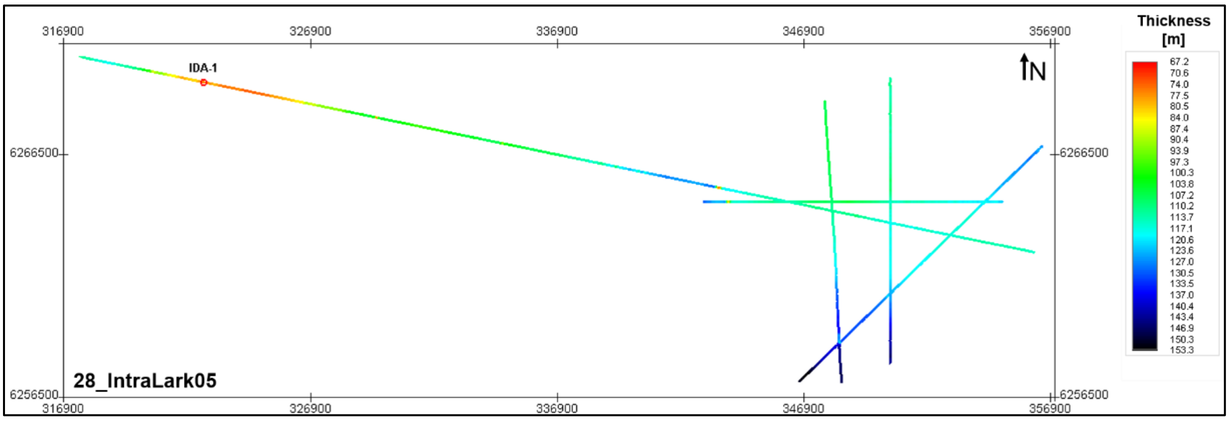


Figure 121 Thickness of unit Intra Lark (05).
Units in metres.

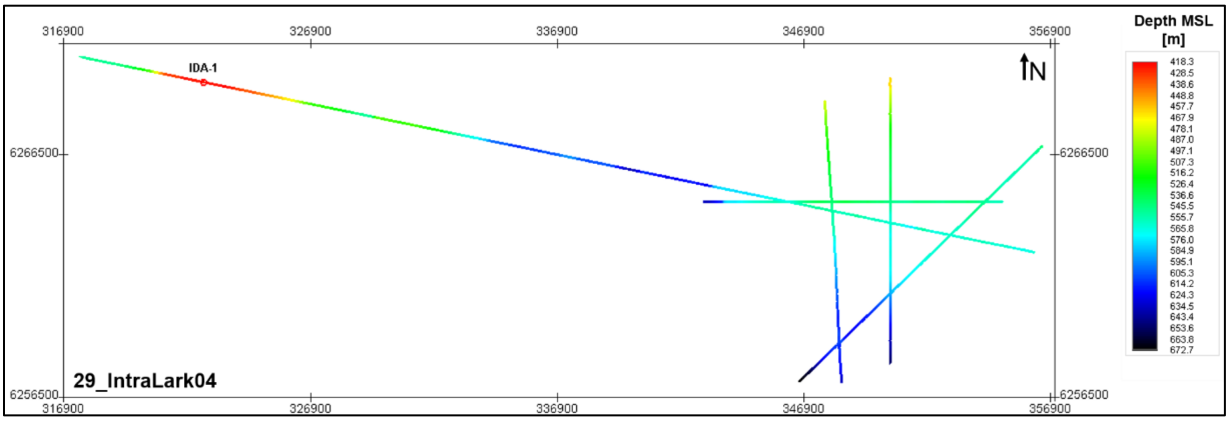


Figure 122 Map showing the lateral extent of horizon Intra Lark (04).
Units in metres below MSL.

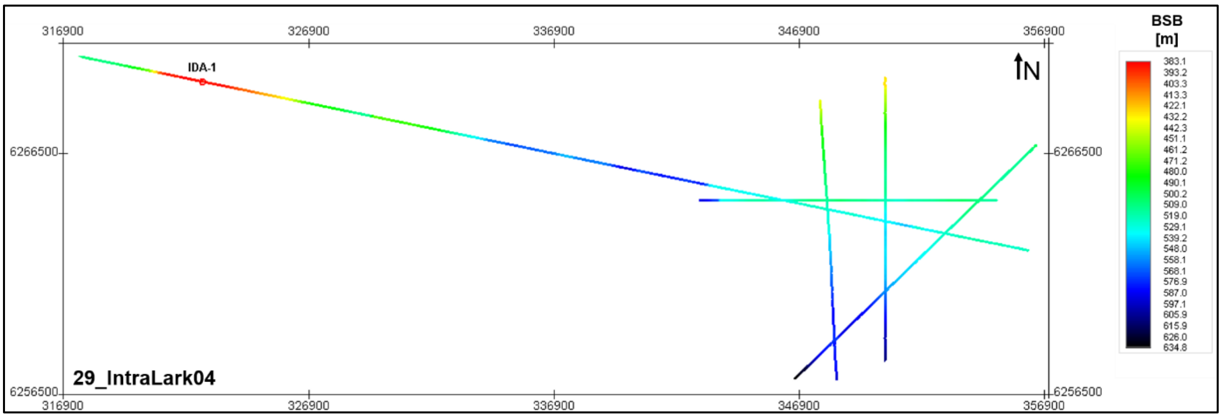


Figure 123 Depth below seabed of horizon Intra Lark (04).
Units in metres below seabed.

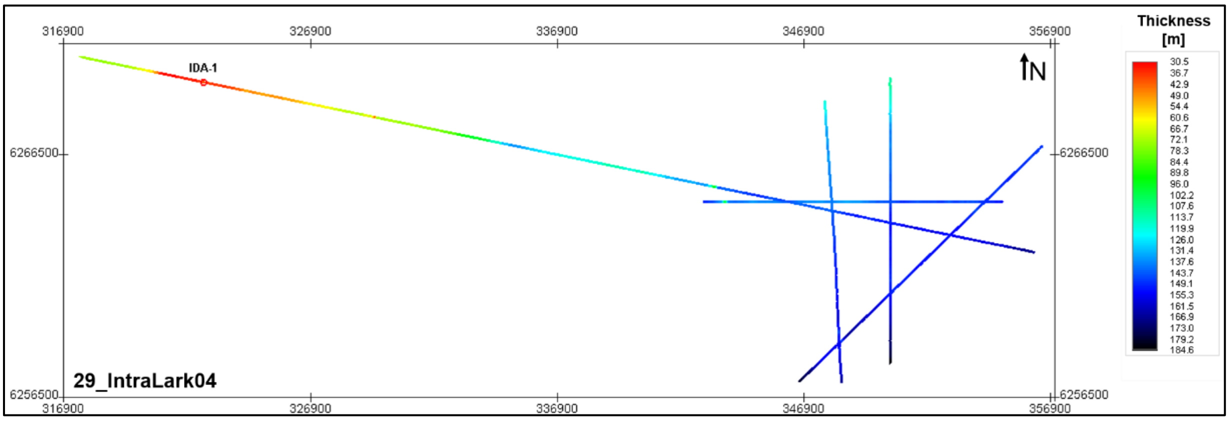


Figure 124 Thickness of unit Intra Lark (04).
Units in metres.

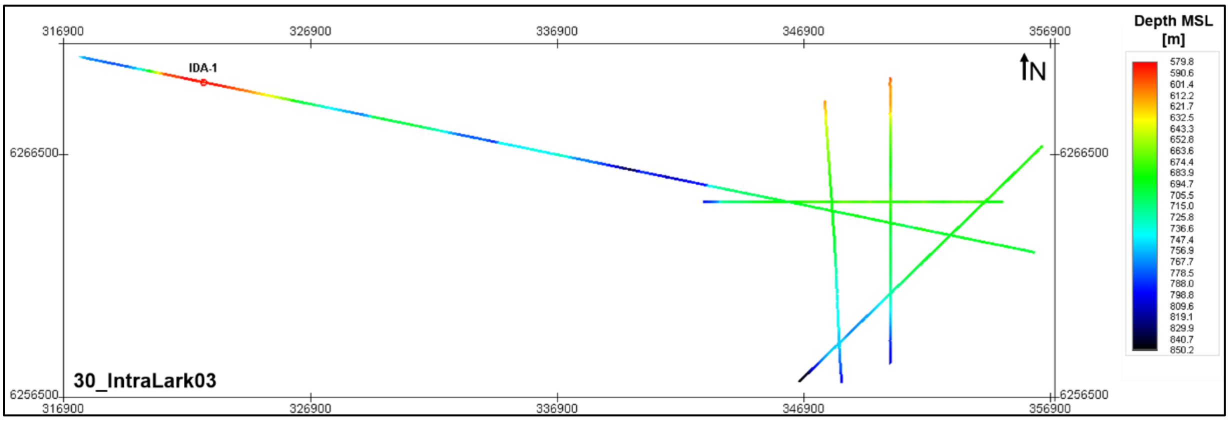


Figure 125 Map showing the lateral extent of horizon Intra Lark (03).
Units in metres below MSL.

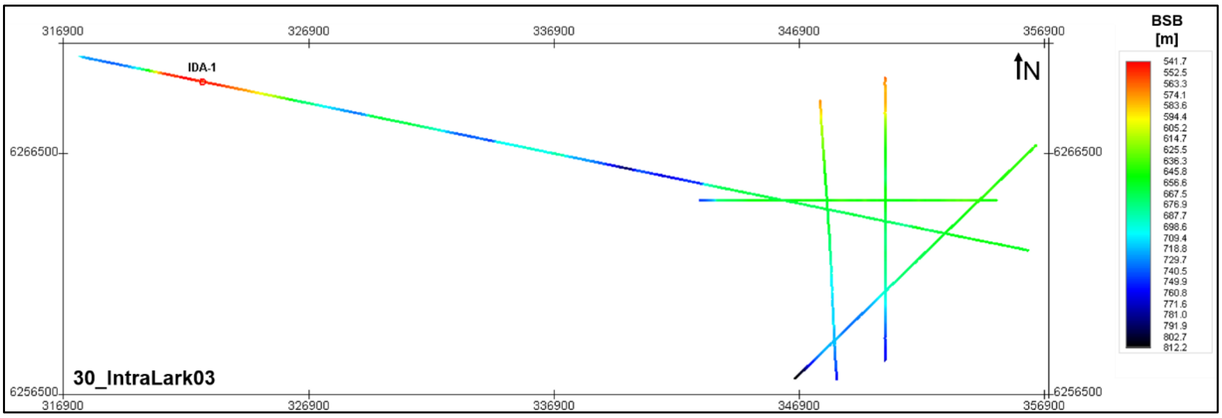


Figure 126 Depth below seabed of horizon Intra Lark (03).
Units in metres below seabed.

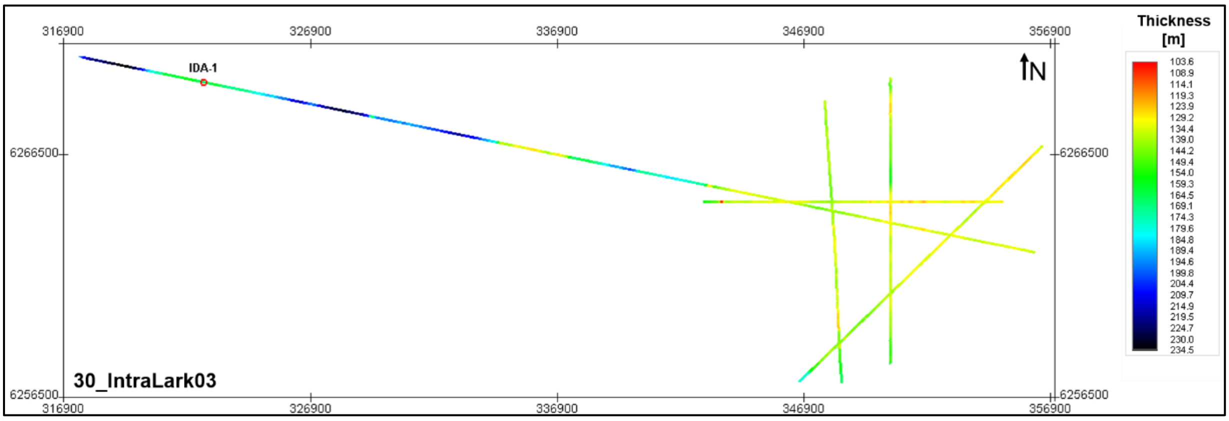


Figure 127 Thickness of unit Intra Lark (03).
Units in metres.

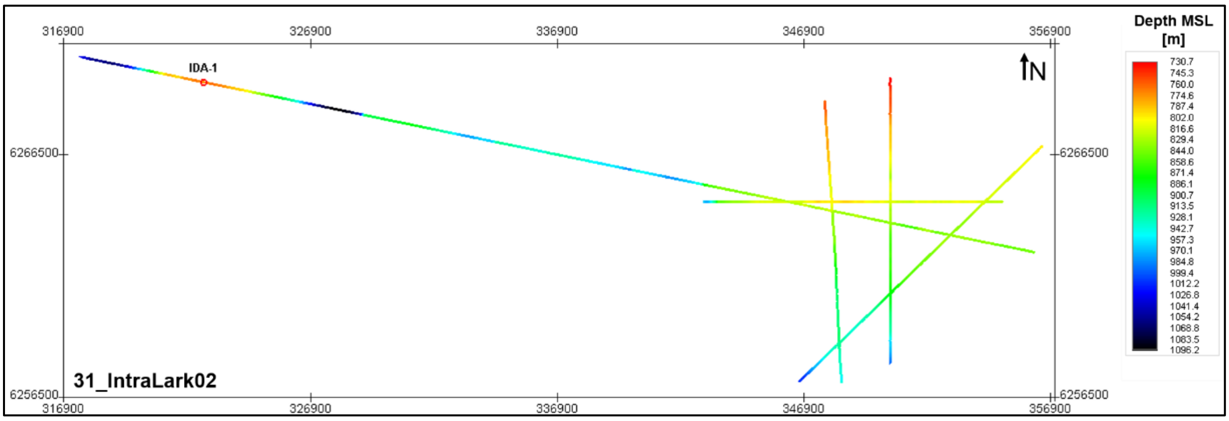


Figure 128 Map showing the lateral extent of horizon Intra Lark (02). Units in metres below MSL.

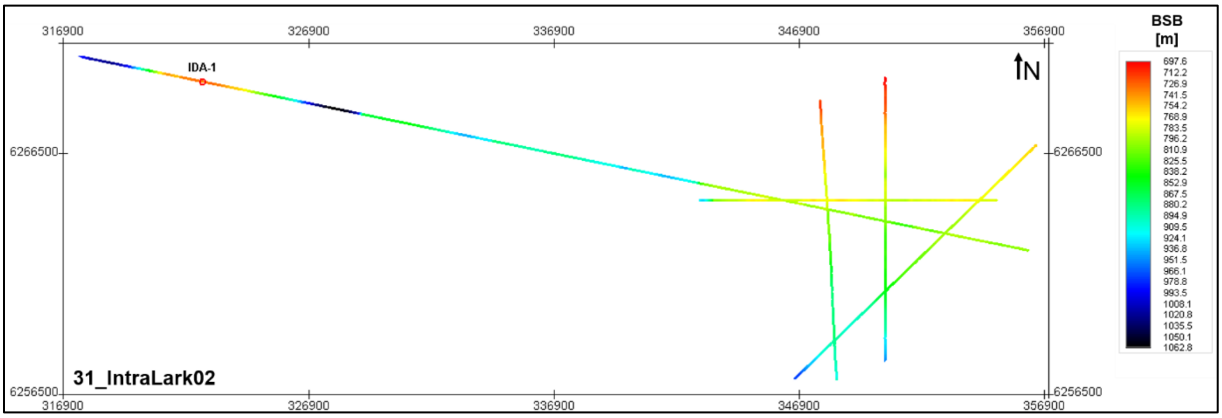


Figure 129 Depth below seabed of horizon Intra Lark (02). Units in metres below seabed.

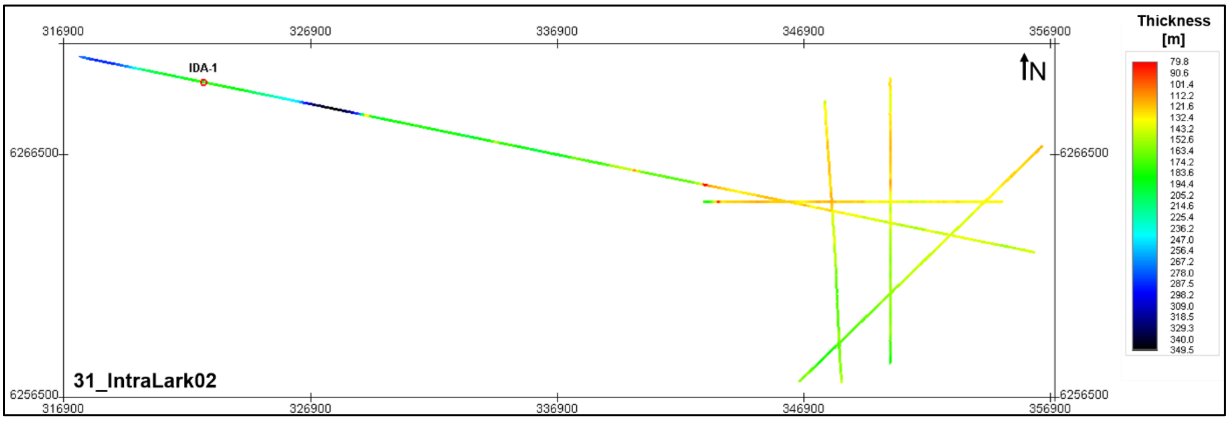


Figure 130 Thickness of unit Intra Lark (02). Units in metres.

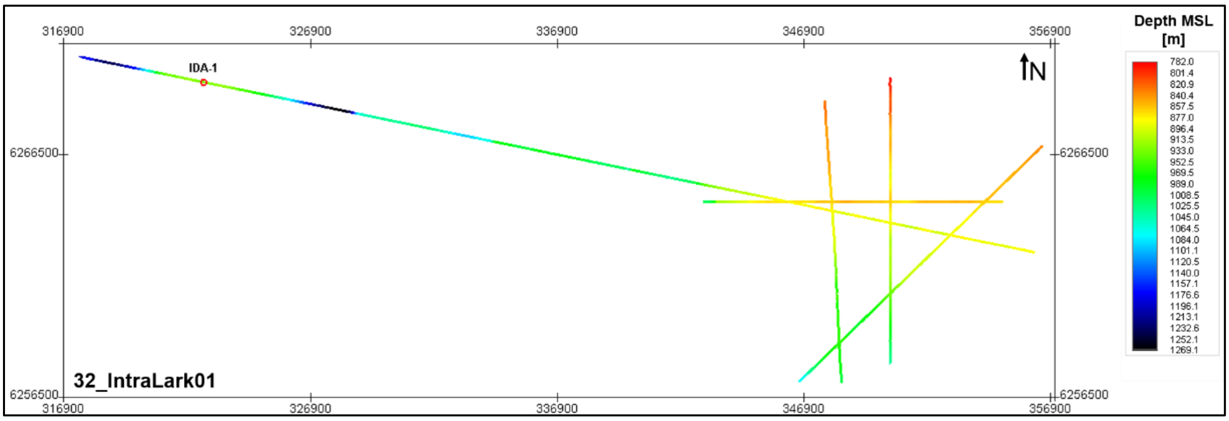


Figure 131 Map showing the lateral extent of horizon Intra Lark (01).
Units in metres below MSL.

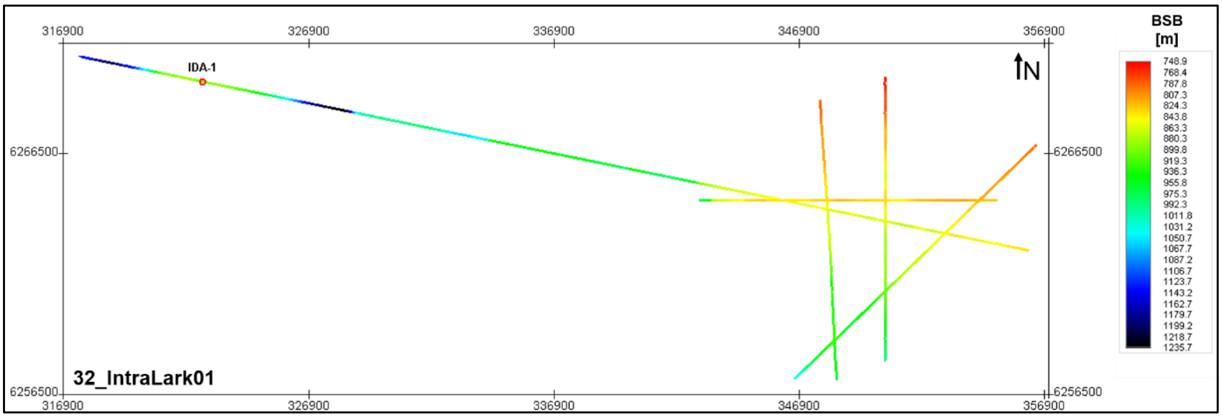


Figure 132 Depth below seabed of horizon Intra Lark (01).
Units in metres below seabed.

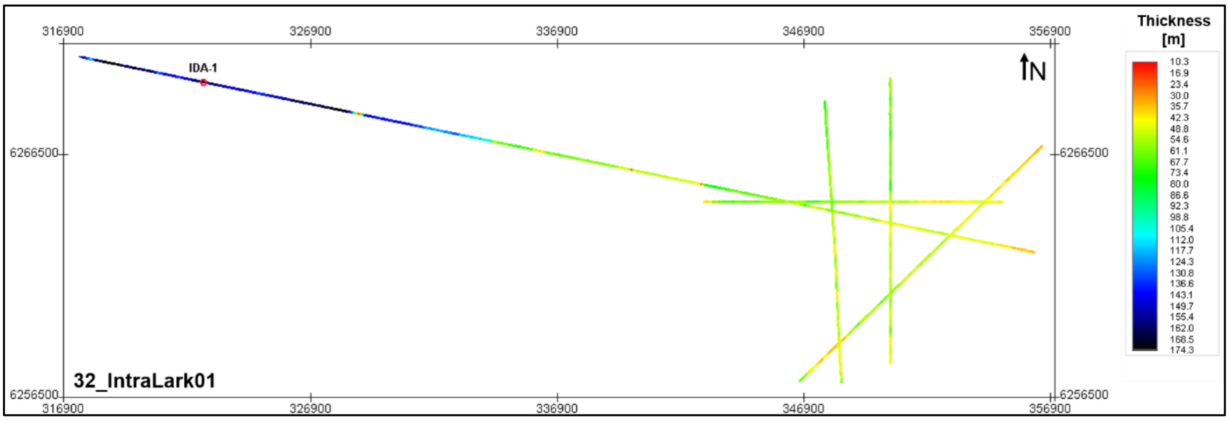


Figure 133 Thickness of unit Intra Lark (01).
Units in metres.

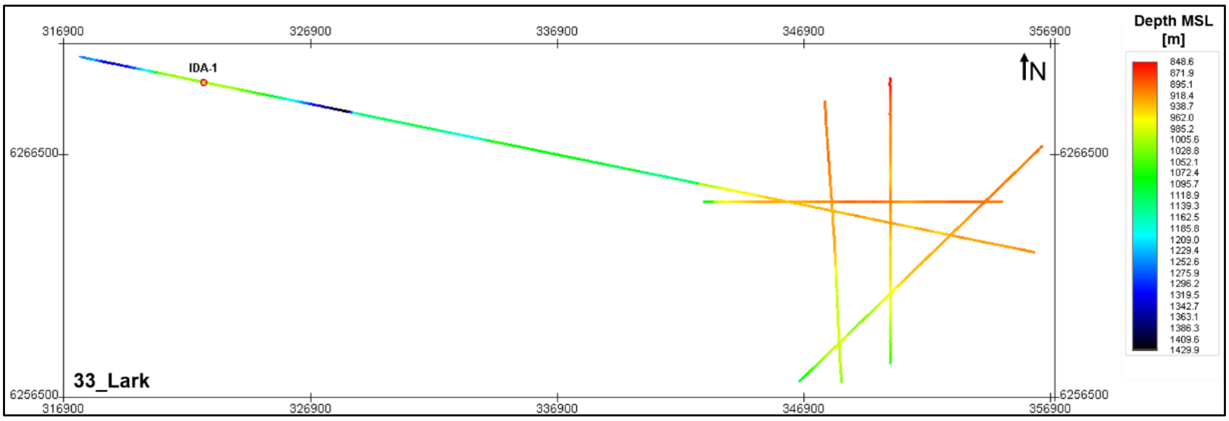


Figure 134 Map showing the lateral extent of horizon Lark.
Units in metres below MSL.

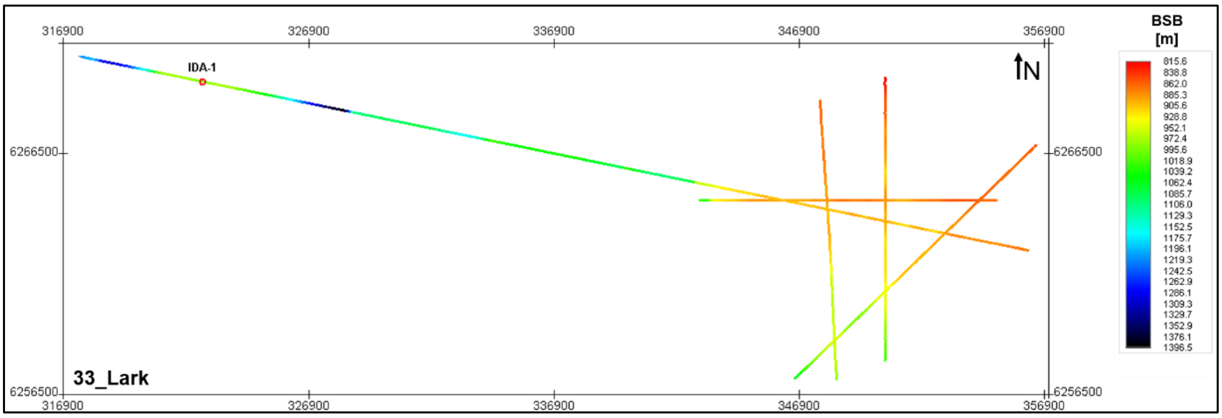


Figure 135 Depth below seabed of horizon Lark.
Units in metres below seabed.

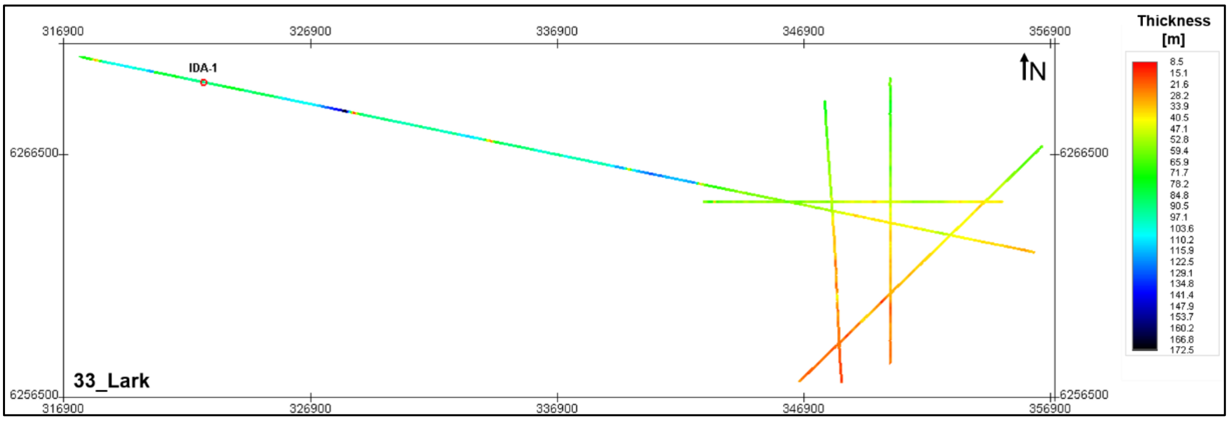


Figure 136 Thickness of unit Lark.
Units in metres.

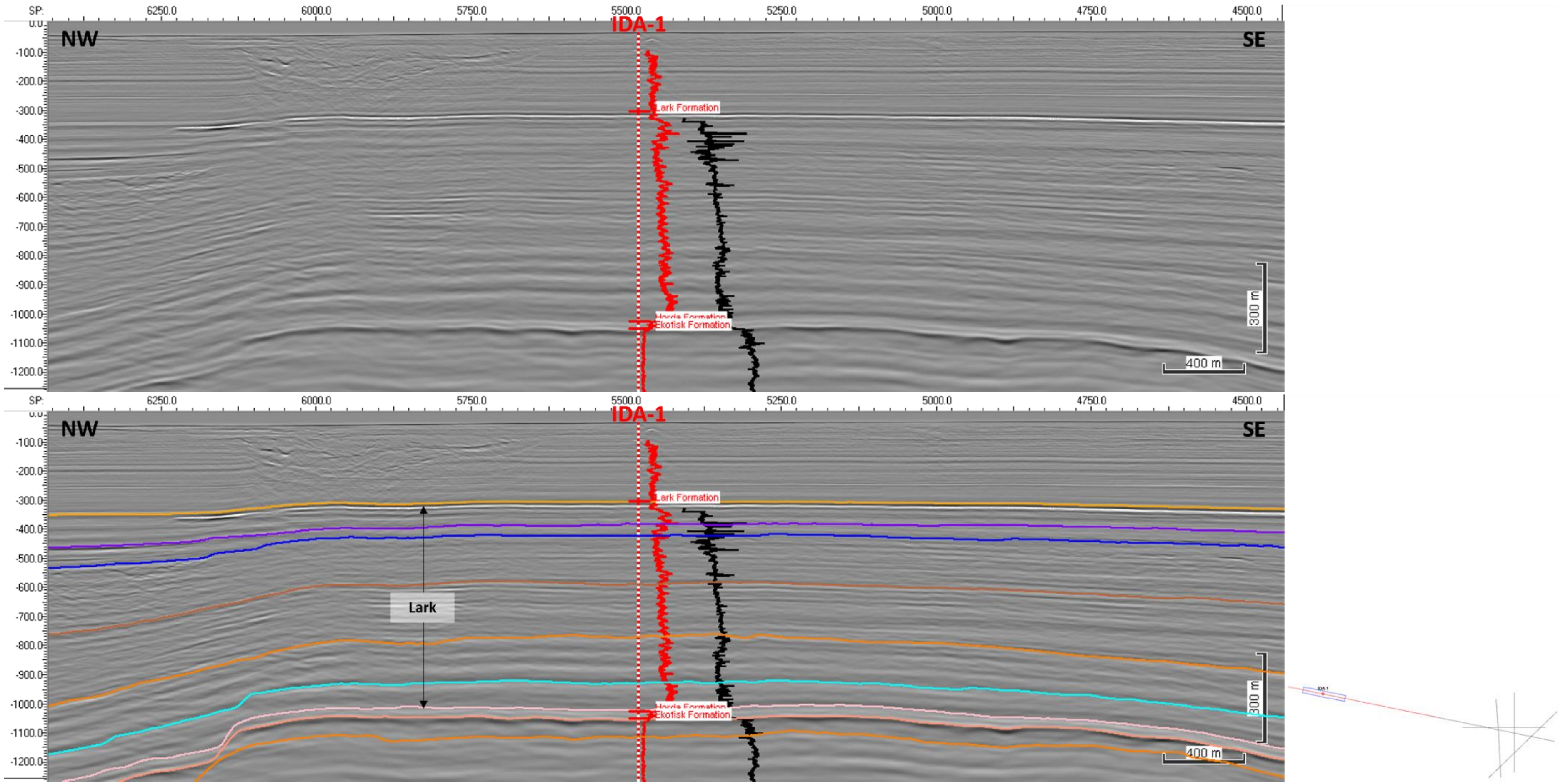


Figure 137 General facies of Seismic Unit Lark (HR seismic data). Horizon Intra Lark 05 is shown in violet, Intra Lark 04 in blue, Intra Lark 03 in brown, Intra Lark 02 in orange, Intra Lark 01 in cyan and Lark in light rosy brown. Amplitude anomaly associated to the presence of gas is observed at the top of Intra Lark 05. IDA-1 Well Log curves shown: gamma ray in red and sonic log in black (inverted slowness). Seismic profile ML_01_Prio_1.

8.2.19| SEISMIC UNIT HORDA

The occurrence of Horda Formation was previously identified in well data (IDA-1) within the survey area. In the acquired HRS data, the Horda Formation corresponds to a single reflector of low amplitude, almost unrecognizable (Figure 138. The minimal representation of Horda Fm is related to the reduced thickness of this interval, which is <10 m. The Horda Formation comprises the Røsnæs Clay and Lillebælt Clay formations in the onshore Danish sector (Knutz et al., 2022).

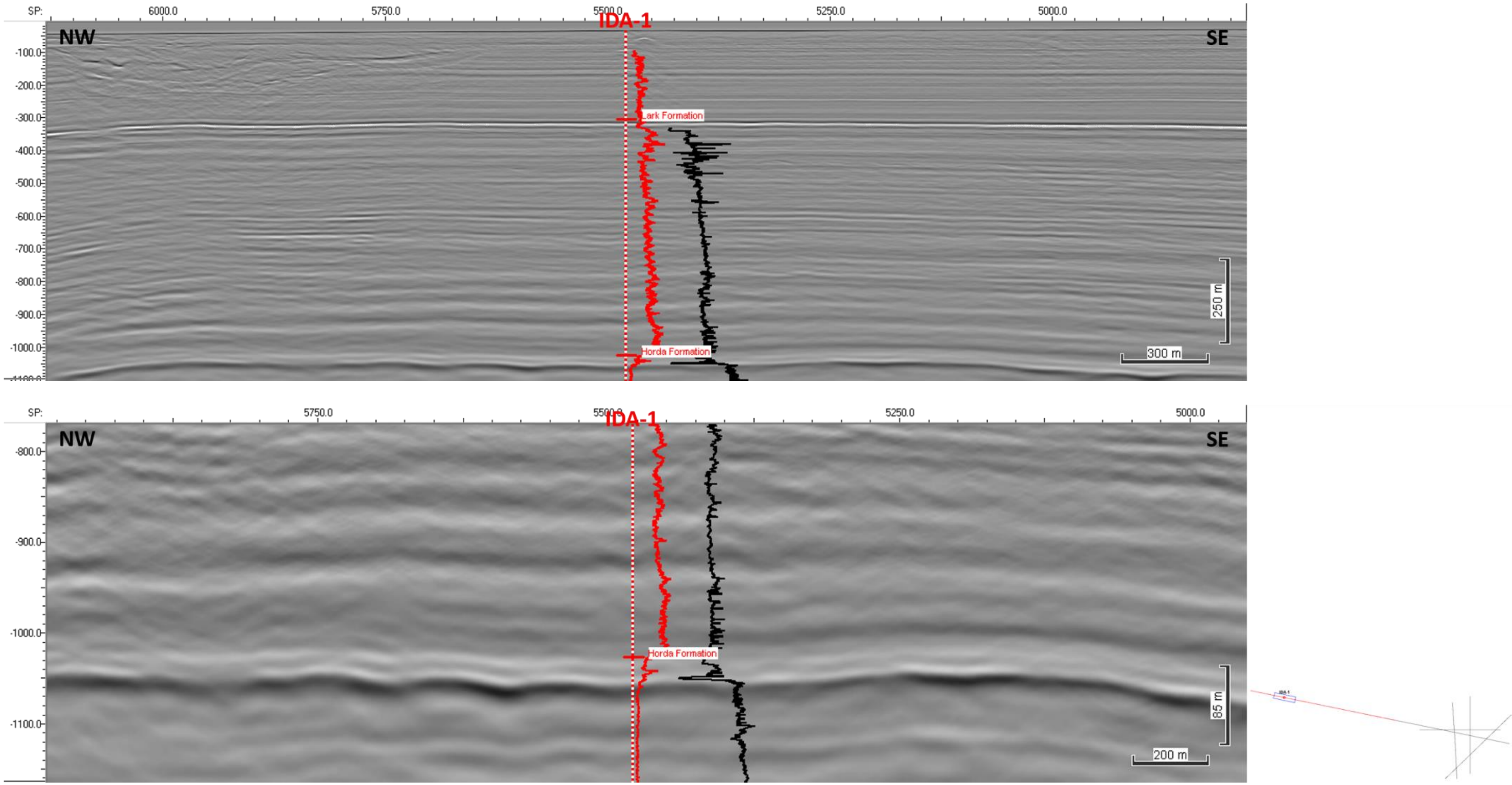


Figure 138 Formation top Horda at IDA-1 well location. Horda Formation is barely visible in HRS data due to the limited thickness of the unit. IDA-1 Well Log curves shown: gamma ray in red and sonic log in black (inverted slowness).

8.2.20| SEISMIC UNIT ROGALAND

Base horizon: 34 _Rogaland

<table>
<tr><td rowspan="2">SEISMIC UNIT ROGALAND</td><td>SEISMIC UNIT ROGALAND
Base horizon: 34_Rogaland
Depth: 880.7 - 1474.1
Extent: Continuous throughout the site.
Description: High negative to positive amplitude reflector; continuous.
Seismic unit: Rogaland
Thickness: 4.6 - 119.2
Morphology: Tabular; faulted.
Seismic facies: Parallel to sub-parallel reflectors of medium to high amplitude reflectors; individual units not distinguishable.</td></tr>
<tr><td>Interpreted depositional environment: Shallow to open marine.

Expected sediment content: Offshore muds; marlstone and mudstone succession.</td></tr>
</table>

Seismic unit Rogaland is delineated by horizon Rogaland (reference number 34), and extends spatially across the site. The spatial distribution, vertical reference to MSL and the seabed, and thickness of the seismic unit are presented in Figure 139 to Figure 141.

Horizon Rogaland ranges in depth between 880.7 m and 1474.1 m below MSL (Figure 139), and between 847.6 m and 1441.1 m depth below the seabed (Figure 140). It follows a continuous reflector marking the transition from a high negative to positive amplitude (Figure 142).

Seismic unit Rogaland corresponds to a set of parallel to sub-parallel of medium to high amplitude reflectors, defining a layered interval with a flat, tabular morphology, generally dipping towards SW. Its thickness ranges from 4.6 m to 119.2 m (Figure 141).

Complemented by geophysical data of well IDA-1 (namely, gamma ray and velocity logs) and previous seismic interpretations (Knutz et al., 2022), seismic unit Rogaland is interpreted to correspond to the Rogaland Group. The Rogaland Group comprises a succession of muds, mudstones, and marlstones, deposited in a shallow open marine environment.

The individual members of the Rogaland Group are not distinguishable due to their reduced thickness (lower than the vertical seismic resolution limit), albeit their identification on well data (IDA-1). The Rogaland Group comprises the Lista and Sele Formation (Knutz et al., 2022), ascribed to the Paleocene.

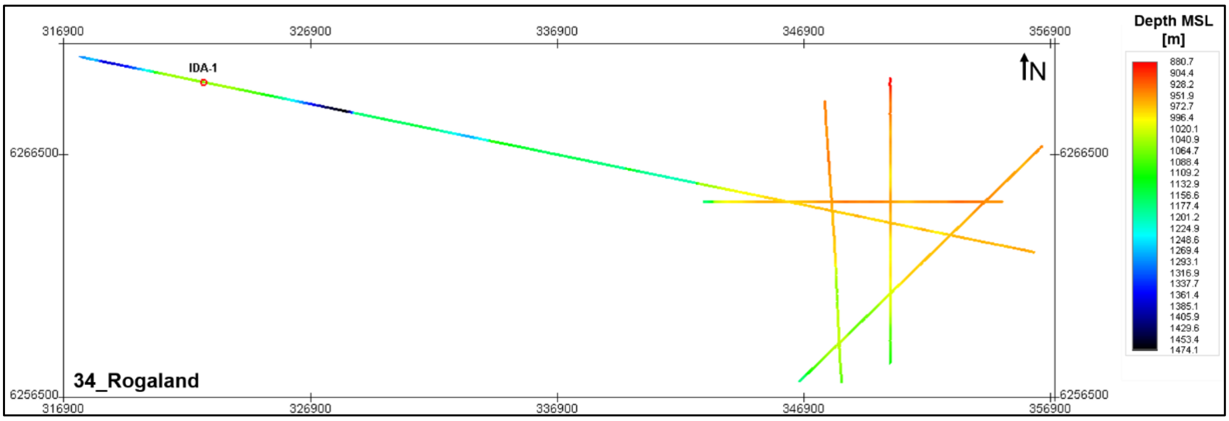


Figure 139 Map showing the lateral extent of horizon Rogaland.
Units in metres below MSL.

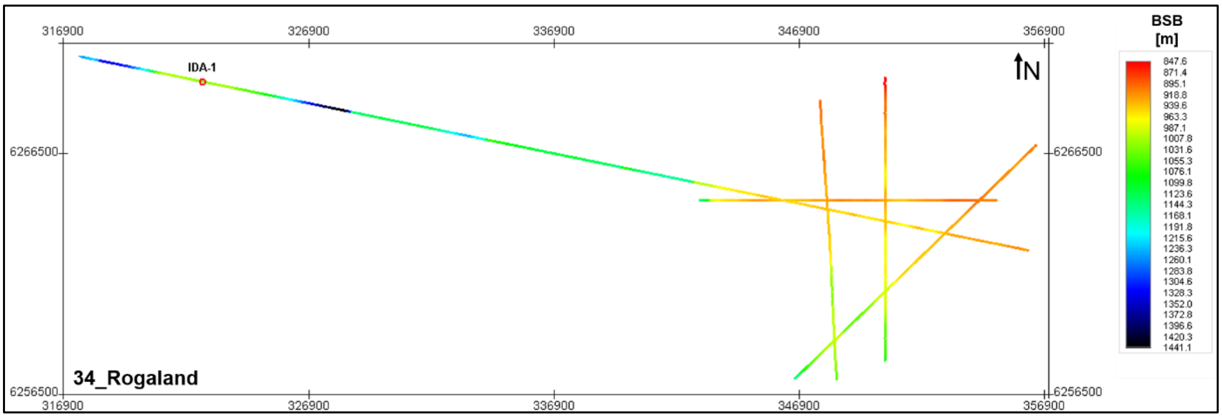


Figure 140 Depth below seabed of horizon Rogaland.
Units in metres below seabed.

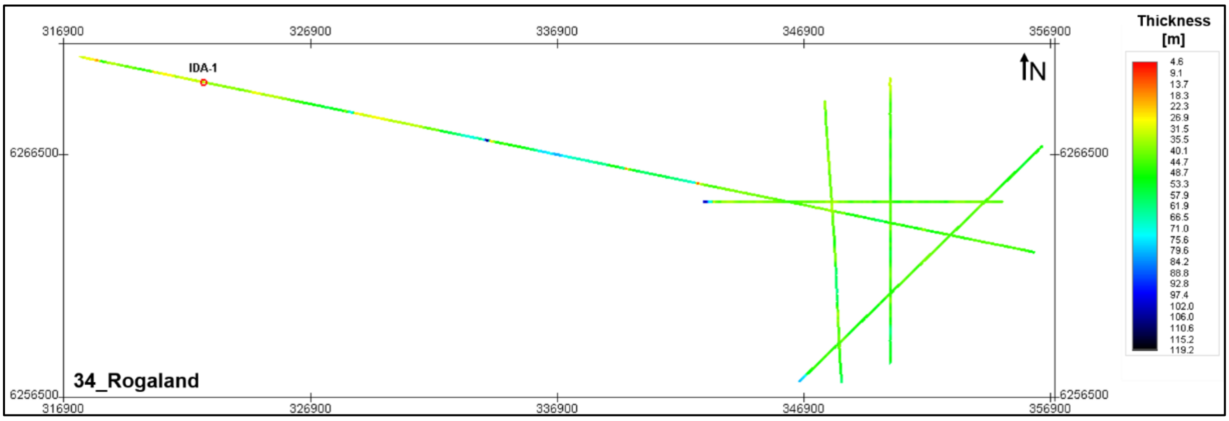


Figure 141 Thickness of unit Rogaland.
Units in metres.

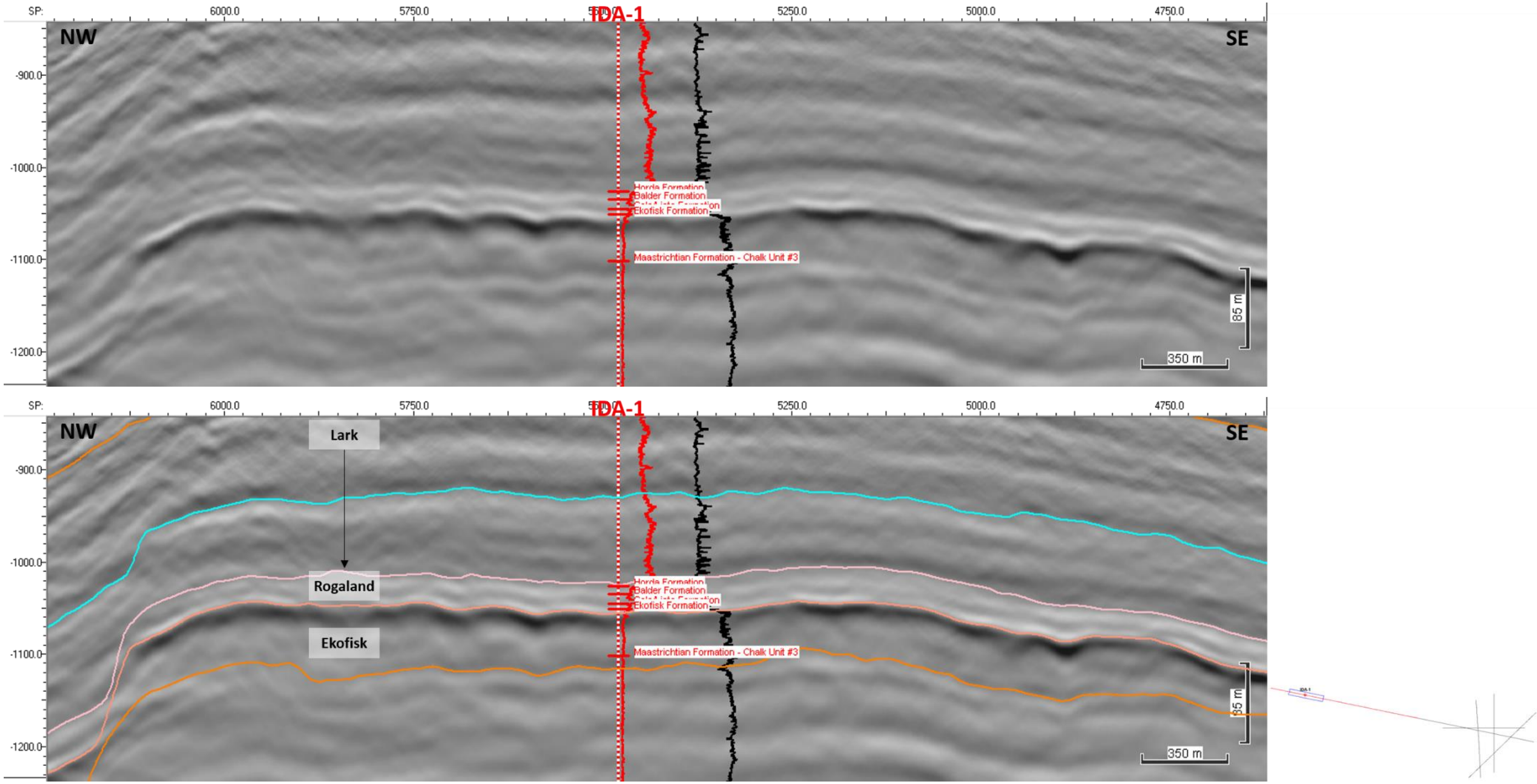


Figure 142 General facies of Seismic Unit Rogaland (HR seismic data). IDA-1 Well Log curves shown: gamma ray in red and sonic log in black (inverted slowness). Seismic profile ML_01_Prio_1.

8.2.21 | SEISMIC UNIT EKOFISK

Base horizon: 35 _Ekofisk

SEISMIC UNIT EKOFISK	**SEISMIC UNIT EKOFISK** **Base horizon: 35_Ekofisk** Depth: 951 - 1527.8 Extent: Continuous throughout the site. Description: Low to medium amplitude and continuous reflector. **Seismic unit: Ekofisk** Thickness: 7.8 - 123.4 Morphology: Tabular; faulted. Seismic facies: Parallel to sub-parallel reflectors of medium amplitude reflectors.
	Interpreted depositional environment: Marine. **Expected sediment content:** Marly limestone.

Seismic unit Ekofisk is delineated by horizon Ekofisk (reference number 35), and extends spatially across the site. The spatial distribution, vertical reference to MSL and the seabed, and thickness of the seismic unit are presented in Figure 143 to Figure 145.

Horizon Ekofisk ranges in depth between 951 m and 1527.8 m below MSL (Figure 143), and between 917.9 m and 1494.7 m depth below the seabed (Figure 144). It follows a continuous low to medium amplitude reflector (Figure 146).

Seismic unit Ekofisk corresponds to a set of parallel to sub-parallel of medium amplitude reflectors, defining a layered interval with a flat, tabular morphology, generally dipping towards SW. Its thickness ranges from 7.8 m to 123.4 m (Figure 145).

Complemented by geophysical data of well IDA-1, seismic unit Ekofisk is interpreted to correspond to the upper section of the Chalk Group, represented by the Ekofisk Formation. The Ekofisk Formation comprises a succession of marly limestones/chalk, deposited in a marine environment. Ekofisk is of Danian (Lower Paleocene) age, and it corresponds to the upper section of the Chalk Group.

The top of the Ekofisk corresponds to horizon Rogaland, that correlates to a significant and abrupt change on both gamma ray and velocity log data (Figure 146). Seismic velocities increase substantially, while gamma ray values decrease, being consistent with the transition from the muddy Rogaland succession above to the Chalk Group below.

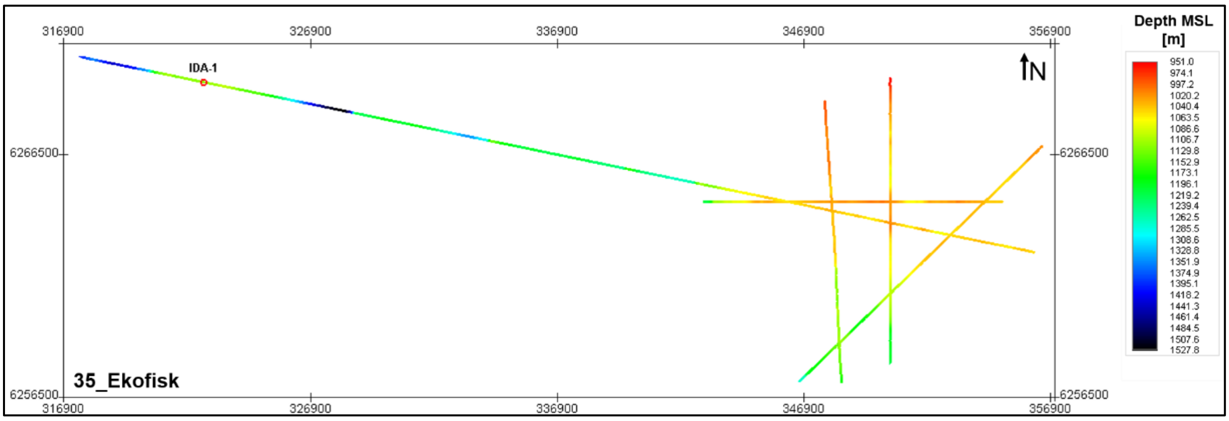


Figure 143 Map showing the lateral extent of horizon Ekofisk.
Units in metres below MSL.

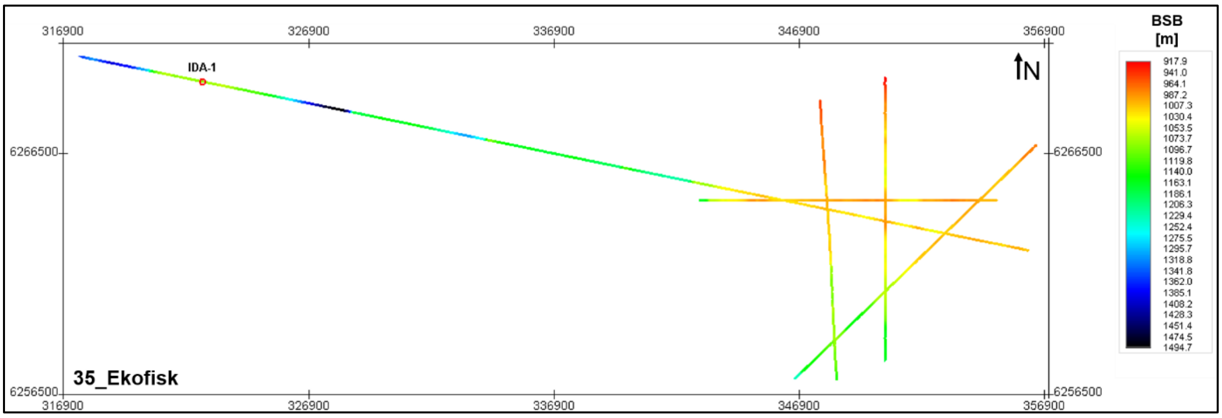


Figure 144 Depth below seabed of horizon Ekofisk.
Units in metres below seabed.

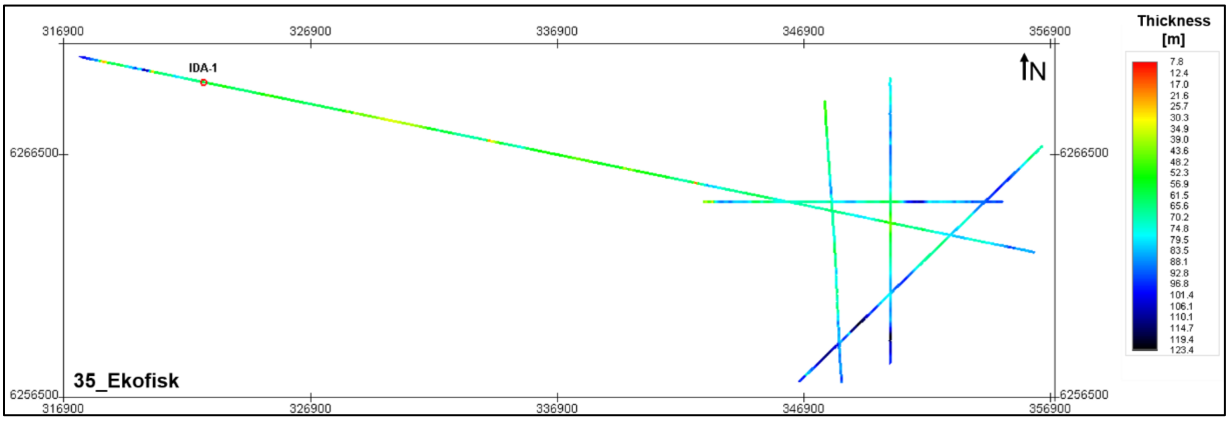


Figure 145 Thickness of unit Ekofisk.
Units in metres.

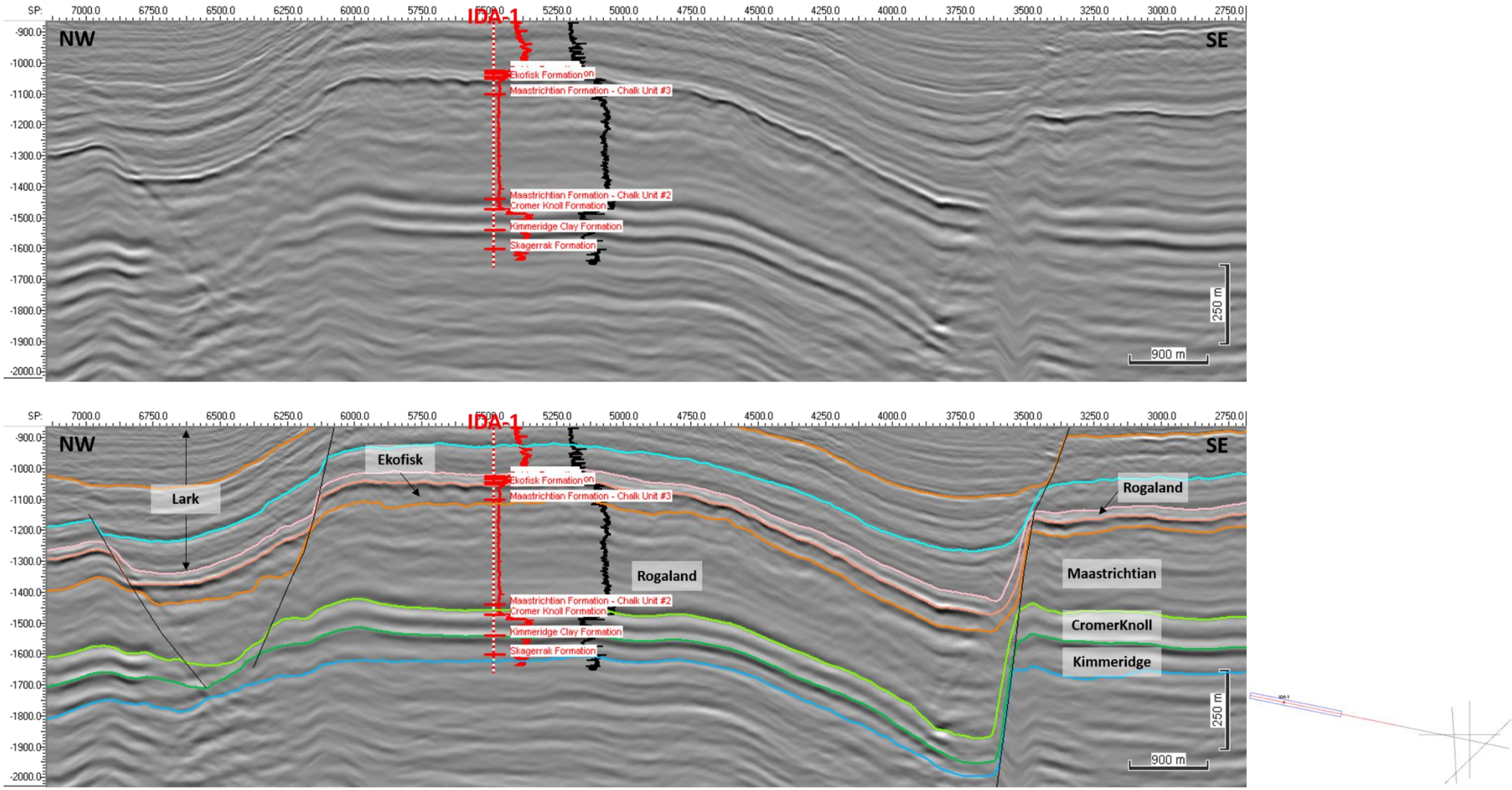


Figure 146 General facies of Seismic Unit Ekofisk (HR seismic data). IDA-1 Well Log curves shown: gamma ray in red and sonic log in black (inverted slowness). Seismic profile ML_01_Prio_1.

8.2.22| SEISMIC UNIT MAASTRICHTIAN

Base horizon: 36 _Maastrichtian

SEISMIC UNIT MAASTRICHTIAN	**SEISMIC UNIT MAASTRICHTIAN** **Base horizon: 36_Maastrichtian** Depth: 1224.8 - 1873.1 Extent: Continuous throughout the site. Description: High positive to negative amplitude reflector; continuous. **Seismic unit: Maastrichtian** Thickness: 44.1 - 362.2 Morphology: Tabular; faulted. Seismic facies: Macro-parallel to sub-parallel reflectors.
	Interpreted depositional environment: Marine. **Expected sediment content:** Chalk.

Seismic unit Maastrichtian is delineated by horizon Maastrichtian (reference number 36), and extends spatially across the site. The spatial distribution, vertical reference to MSL and the seabed, and thickness of the seismic unit are presented in Figure 147 to Figure 149.

Horizon Maastrichtian ranges in depth between 1224.8 m and 1873.1 m below MSL (Figure 147), and between 0.0 m and 18.1 m depth below the seabed (Figure 148). It follows a continuous high positive to negative amplitude reflector (Figure 150).

Seismic unit Maastrichtian corresponds to a set of macro-parallel to sub-parallel reflectors of medium amplitude, defining a layered interval with a flat, tabular morphology, generally dipping towards SW. Its thickness ranges from 44.1 m to 362.2 m (Figure 149).

Complemented by geophysical data of well IDA-1, seismic unit Maastrichtian is interpreted to correspond to the Maastrichtian Formation, which is part of the Chalk Group. The Maastrichtian Formation constitutes an interval of chalk strata, deposited in a marine environment during the Upper Cretaceous.

The base of the Maastrichtian correlates to a significant and abrupt change on both gamma ray and velocity log data (Figure 146). Seismic velocities decrease substantially, while gamma ray values increase, being consistent with the transition from the Chalk Group to the underlying muds of Cromer Knoll.

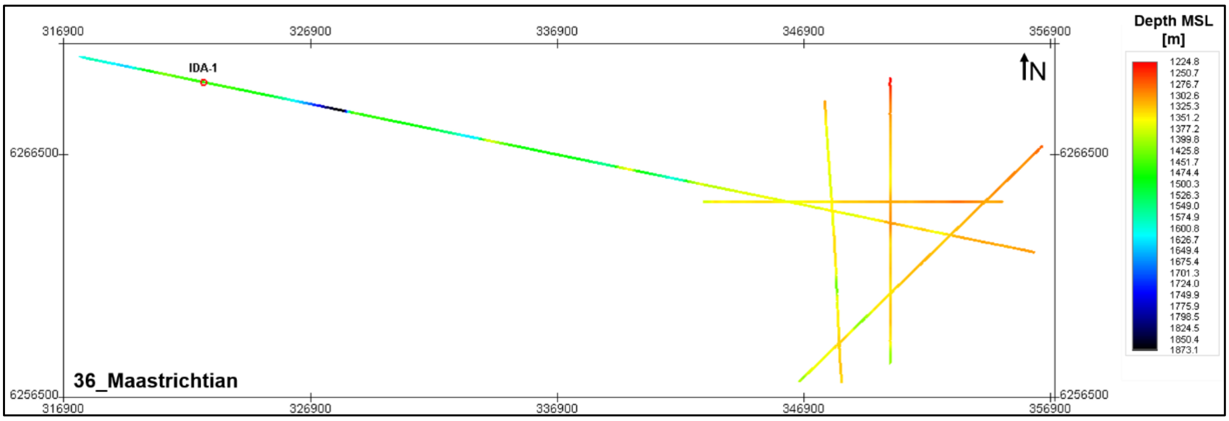


Figure 147 Map showing the lateral extent of horizon Maastrichtian.
Units in metres below MSL.

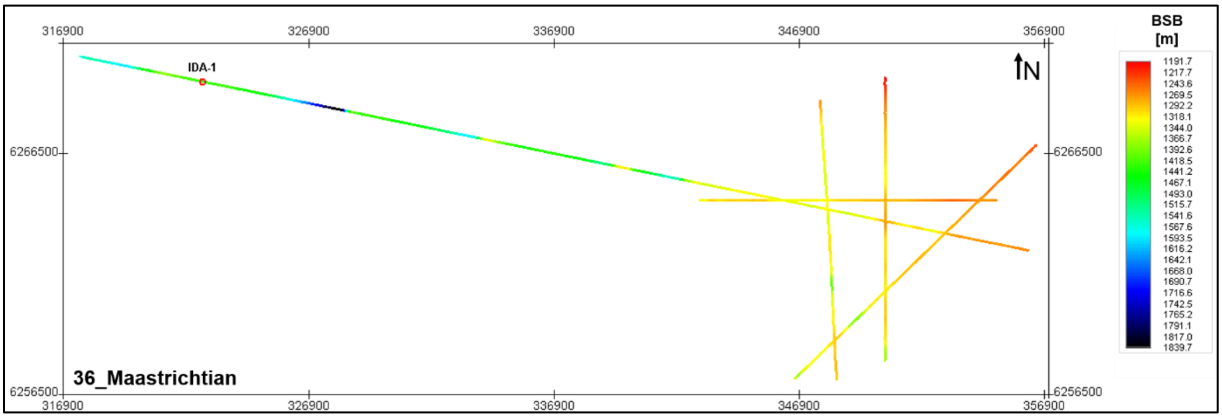


Figure 148 Depth below seabed of horizon Maastrichtian.
Units in metres below seabed.

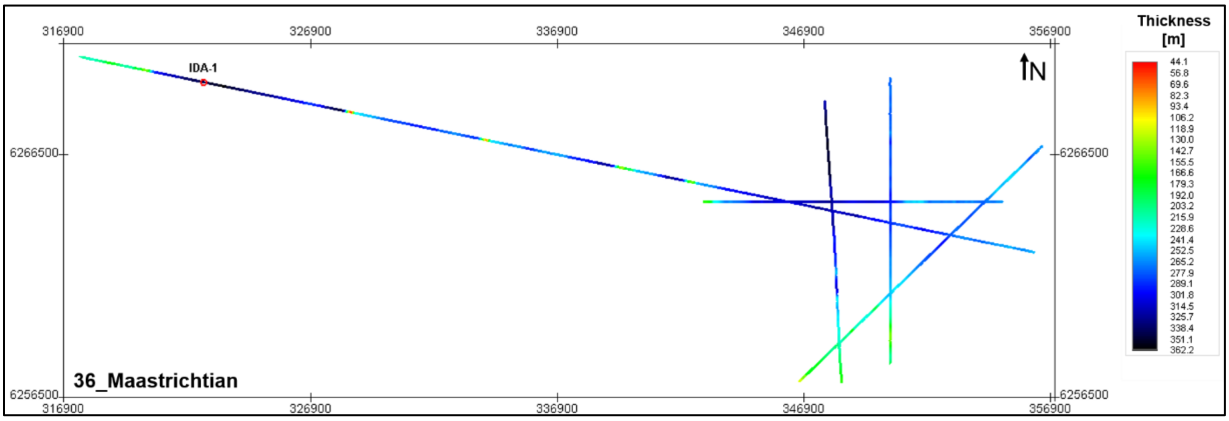


Figure 149 Thickness of unit Maastrichtian.
Units in metres.

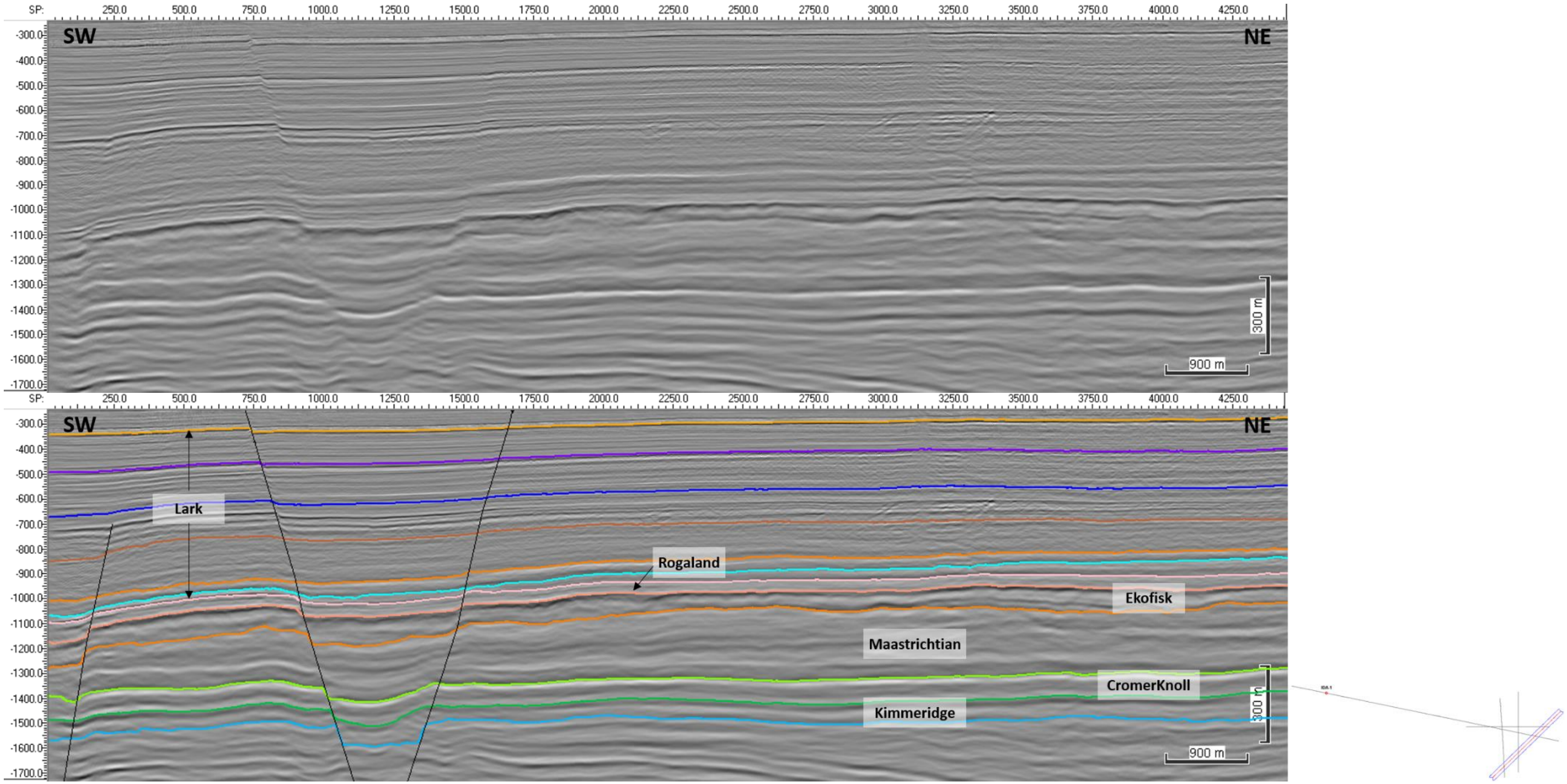


Figure 150 General facies of Seismic Unit Maastrichtian (HR seismic data).
Seismic profile ML_10_Prio_2.

8.2.23| SEISMIC UNIT CROMER KNOLL

Base horizon: 37 _Cromer Knoll

SEISMIC UNIT CROMER KNOLL	**SEISMIC UNIT CROMER KNOLL** **Base horizon: 37 _Cromer Knoll** Depth: 1327.1 - 1954.3 Extent: Continuous throughout the site. Description: High negative to positive amplitude reflector; continuous. **Seismic unit: Cromer Knoll** Thickness: 9.4 - 156.5 Morphology: Tabular; faulted. Seismic facies: Macro-parallel, high amplitude reflectors.
	Interpreted depositional environment: Marine; post-rift basin fill. **Expected sediment content:** Marls and clays.

Seismic unit Cromer Knoll is delineated by horizon Cromer Knoll (reference number 37), and extends spatially across the site. The spatial distribution, vertical reference to MSL and the seabed, and thickness of the seismic unit are presented in Figure 151 to Figure 153.

Horizon Cromer Knoll ranges in depth between 1327.1 m and 1954.3 m below MSL (Figure 151), and between 1294 m and 1920.9 m depth below the seabed (Figure 152). It follows a continuous negative to positive amplitude reflector (Figure 154).

Seismic unit Cromer Knoll corresponds to a set of macro-parallel to sub-parallel reflectors of high amplitude, defining a layered interval with a flat, tabular morphology, generally dipping towards SW. Its thickness ranges from 9.4 m to 156.5 m (Figure 153).

Complemented by geophysical data of well IDA-1, seismic unit Cromer Knoll is interpreted to correspond to the Cromer Knoll Formation. The Cromer Knoll Formation comprises an interval of marine marls and clays, filling a post-rift basin of Lower Cretaceous age.

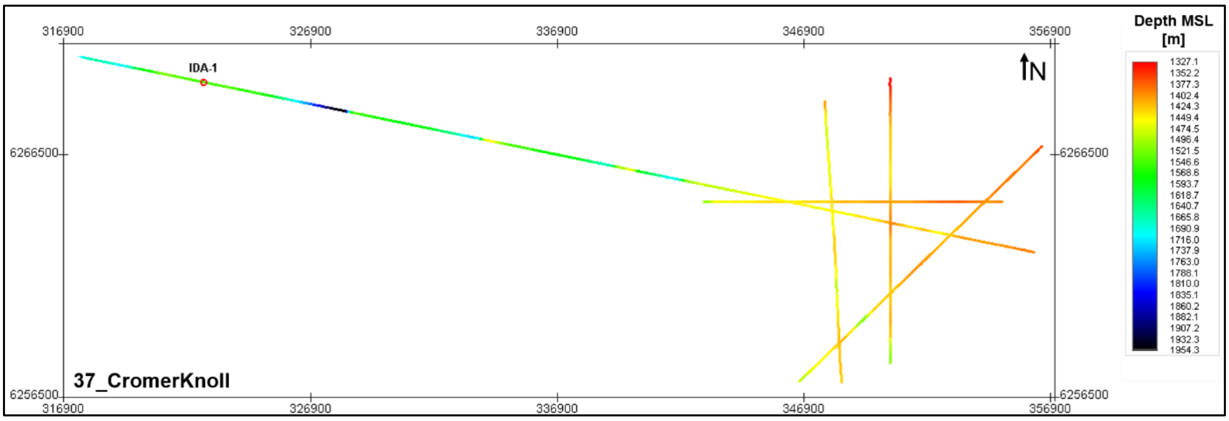


*Figure 151 Map showing the lateral extent of horizon Cromer Knoll.
Units in metres below MSL.*

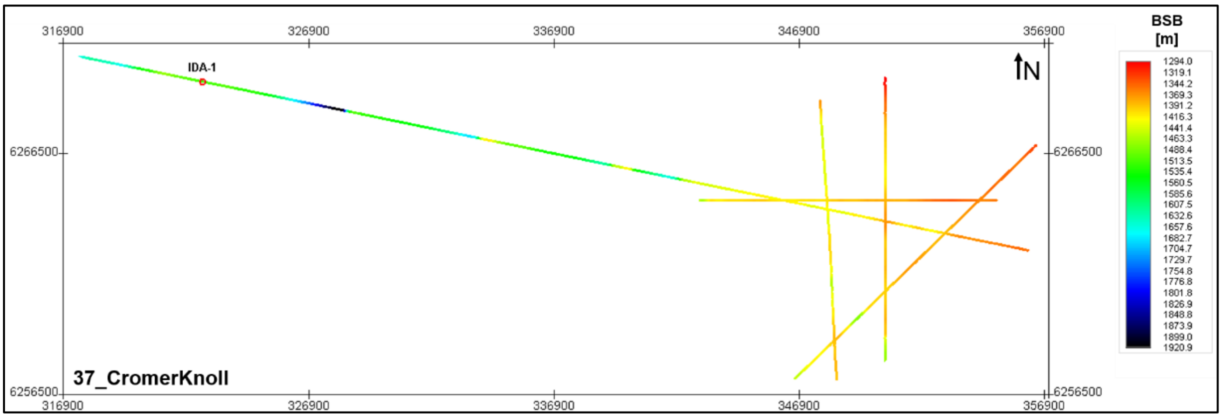


*Figure 152 Depth below seabed of horizon Cromer Knoll.
Units in metres below seabed.*

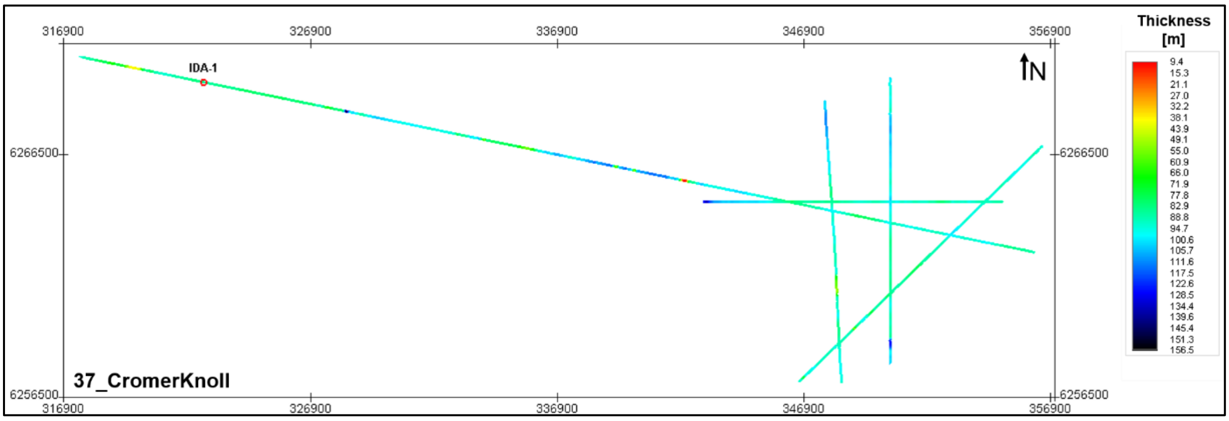


*Figure 153 Thickness of unit Cromer Knoll.
Units in metres.*

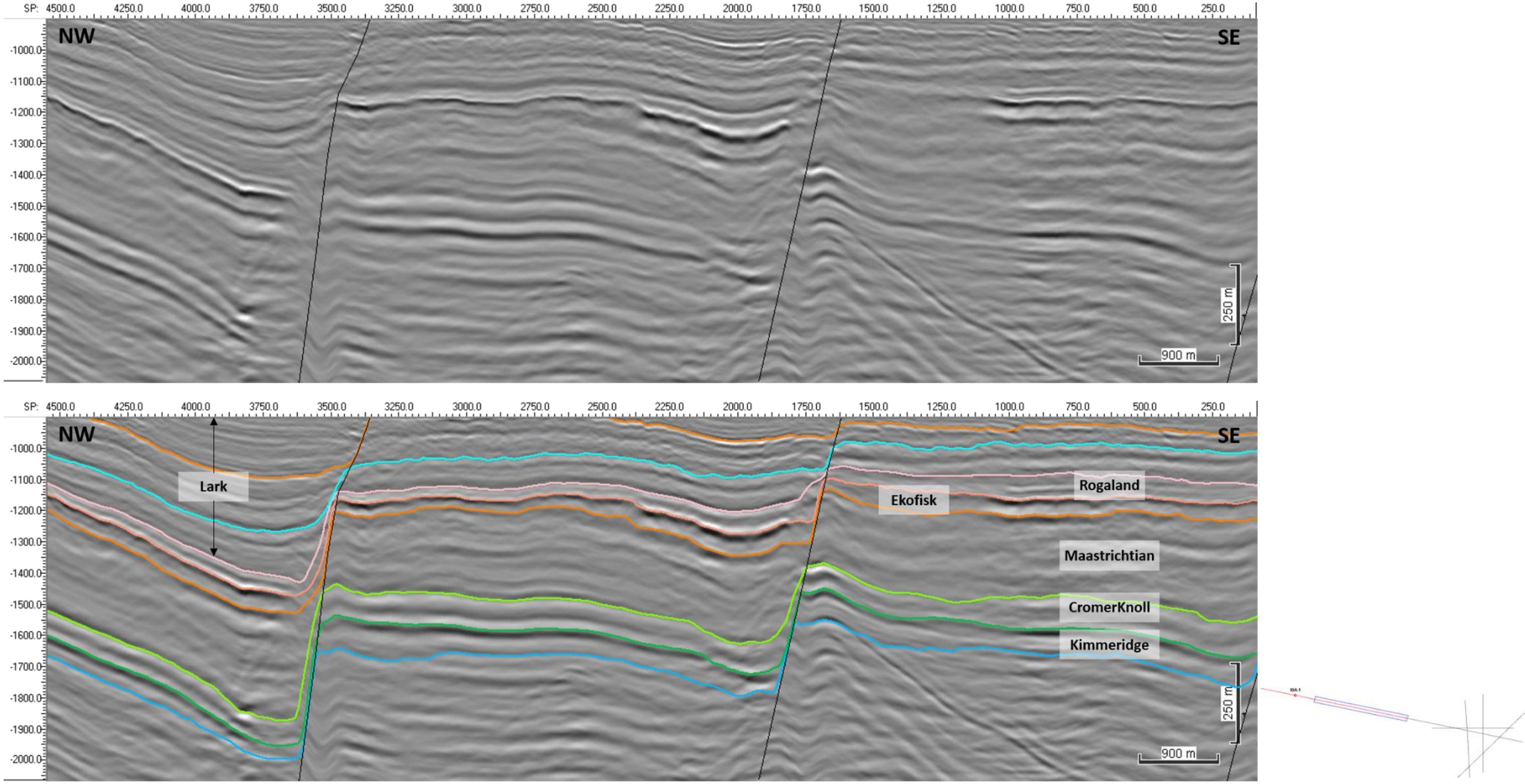


Figure 154 General facies of Seismic Unit Cromer Knoll (HR seismic data). Seismic profile ML_01_Prio_1.

8.2.24| SEISMIC UNIT KIMMERIDGE

Base horizon: 38 _Kimmeridge

SEISMIC UNIT KIMMERIDGE	**SEISMIC UNIT KIMMERIDGE** **Base horizon: 38 _Kimmeridge** Depth: 1399.9 - 1996.5 Extent: Continuous throughout the site. Description: Low amplitude reflector. **Seismic unit: Kimmeridge** Thickness: 8 - 134.8 Morphology: Tabular; faulted. Seismic facies: Macro-parallel reflectors.
	Interpreted depositional environment: Rift basin fill. **Expected sediment content:** Clays.

Seismic unit Kimmeridge is delineated by horizon Kimmeridge (reference number 38), and extends spatially across the site. The spatial distribution, vertical reference to MSL and the seabed, and thickness of the seismic unit are presented in Figure 155 to Figure 157.

Horizon Kimmeridge ranges in depth between 1399.9 m and 1996.5 m below MSL (Figure 155), and between 1366.8 m and 1963.2 m depth below the seabed (Figure 156). It follows a continuous low amplitude reflector (Figure 158).

Seismic unit Kimmeridge corresponds to a set of macro-parallel to sub-parallel reflectors of low to medium amplitude, defining a layered interval with a flat, tabular morphology, generally dipping towards SW. Its thickness ranges from 8 m to 134.8 m (Figure 157).

Complemented by geophysical data of well IDA-1, seismic unit Kimmeridge is interpreted to correspond to the Kimmeridge Clay Formation. The Kimmeridge Clay Formation comprises an interval of clays, filling a rift basin during the Upper Jurassic.

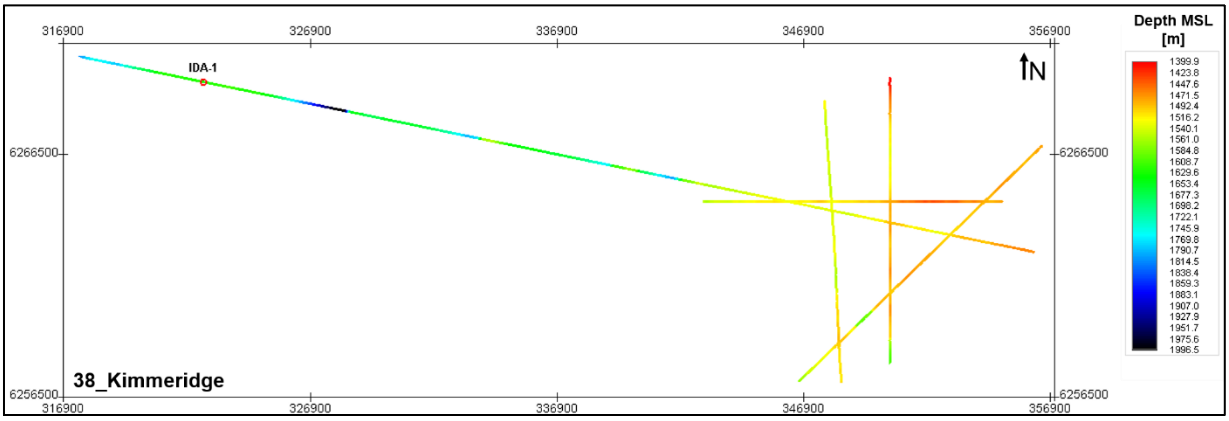


Figure 155 Map showing the lateral extent of horizon Kimmeridge.
Units in metres below MSL.

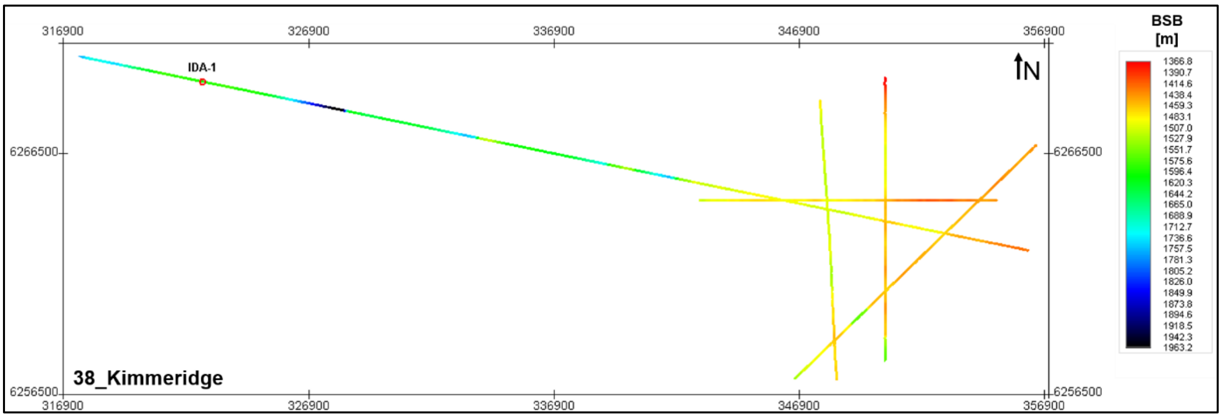


Figure 156 Depth below seabed of horizon Kimmeridge.
Units in metres below seabed.

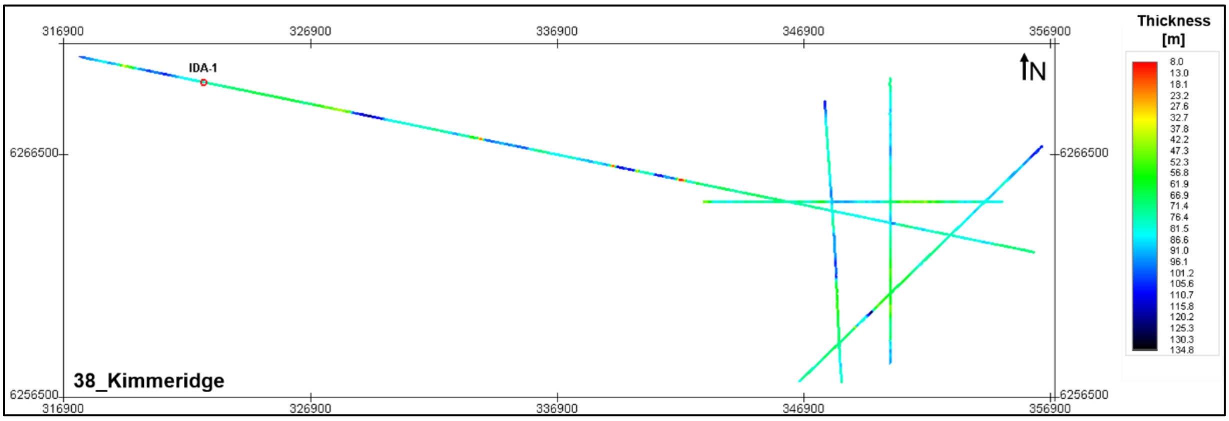


Figure 157 Thickness of unit Kimmeridge.
Units in metres.

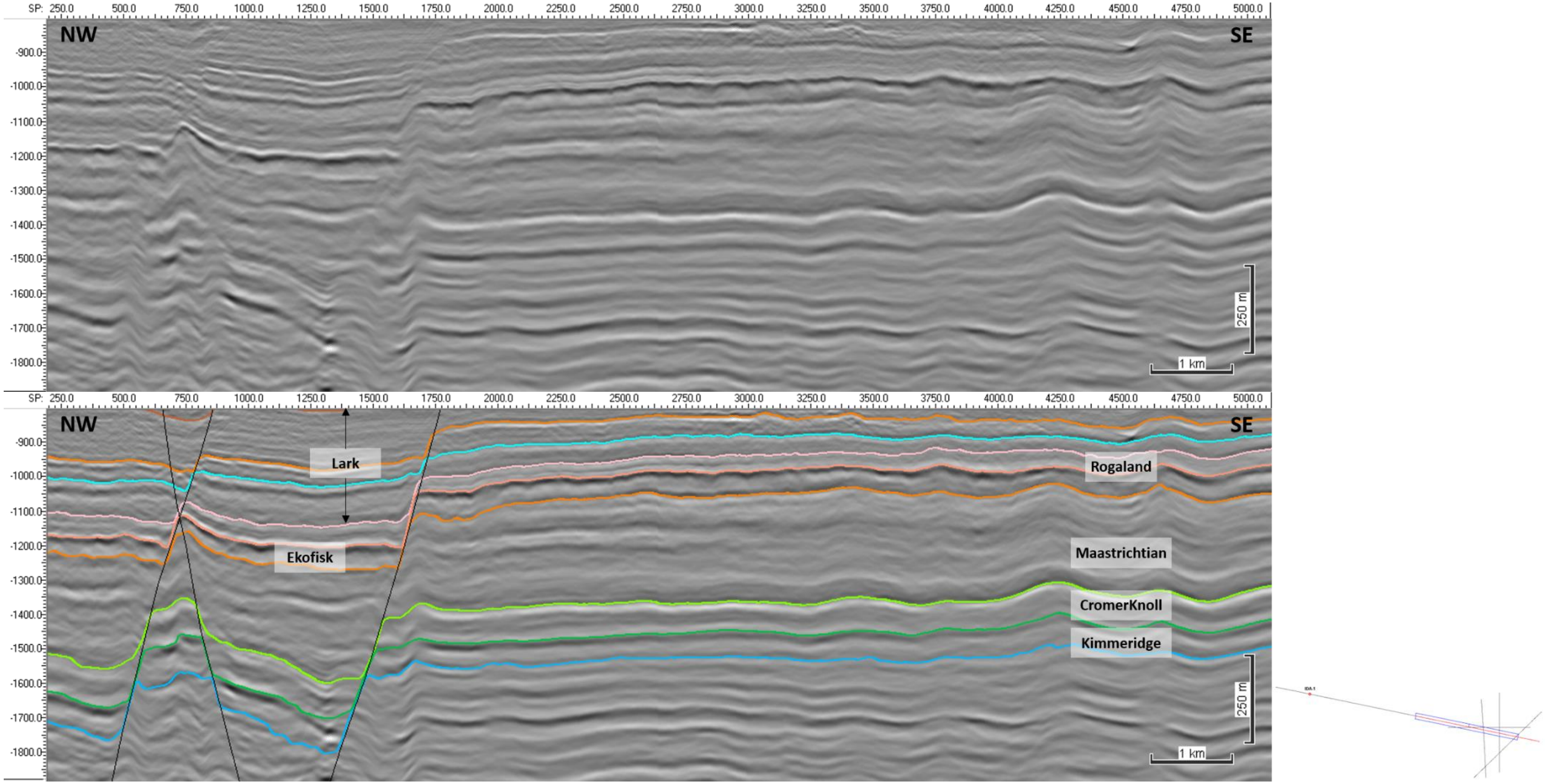


Figure 158 General facies of Seismic Unit Kimmeridge (HR seismic data). Seismic profile ML_01_Prio_1a.

8.2.25 | BASE SEISMIC UNIT BSU

Base horizon: 39_LK

SEISMIC UNIT BSU	
	SEISMIC UNIT BSU **Base horizon: 39_LK** Depth: 3750 Extent: Continuous throughout the site. Description: End of seismic record. **Seismic unit: BSU** Apparent thickness: 1753.5 - 2350.1 Morphology: Tabular; faulted. Seismic facies: Macro-parallel to sub-parallel reflectors; hummocky.
	Interpreted depositional environment: Variable depositional environments. **Expected sediment content:** Variable sediment content.

The Base Seismic Unit BSU is a major element of the ground model, and extends spatially across the full site. The base of the unit is at the processing “last knee" (reference number 39), near the terminus of the seismic record. The upper boundary is delineated by the deepest mapped horizon, the base of the Kimmeridge. The apparent thickness ranges from 1753.5 to 2350.1 m.

The seismic facies of BSU comprises a layered sequence of parallel to sub-parallel/hummocky reflectors of variable amplitude (Figure 159).

Complemented by geophysical data of well IDA-1, seismic unit Kimmeridge is interpreted to correspond to the Kimmeridge Clay Formation. The Kimmeridge Clay Formation comprises an interval of clays, filling a rift basin during the Upper Jurassic.

From the characteristics of the Base Seismic Unit and its stratigraphic position, it is interpreted that it corresponds to a sequence of deposits of Jurassic and older age, comprising variable sediment content.

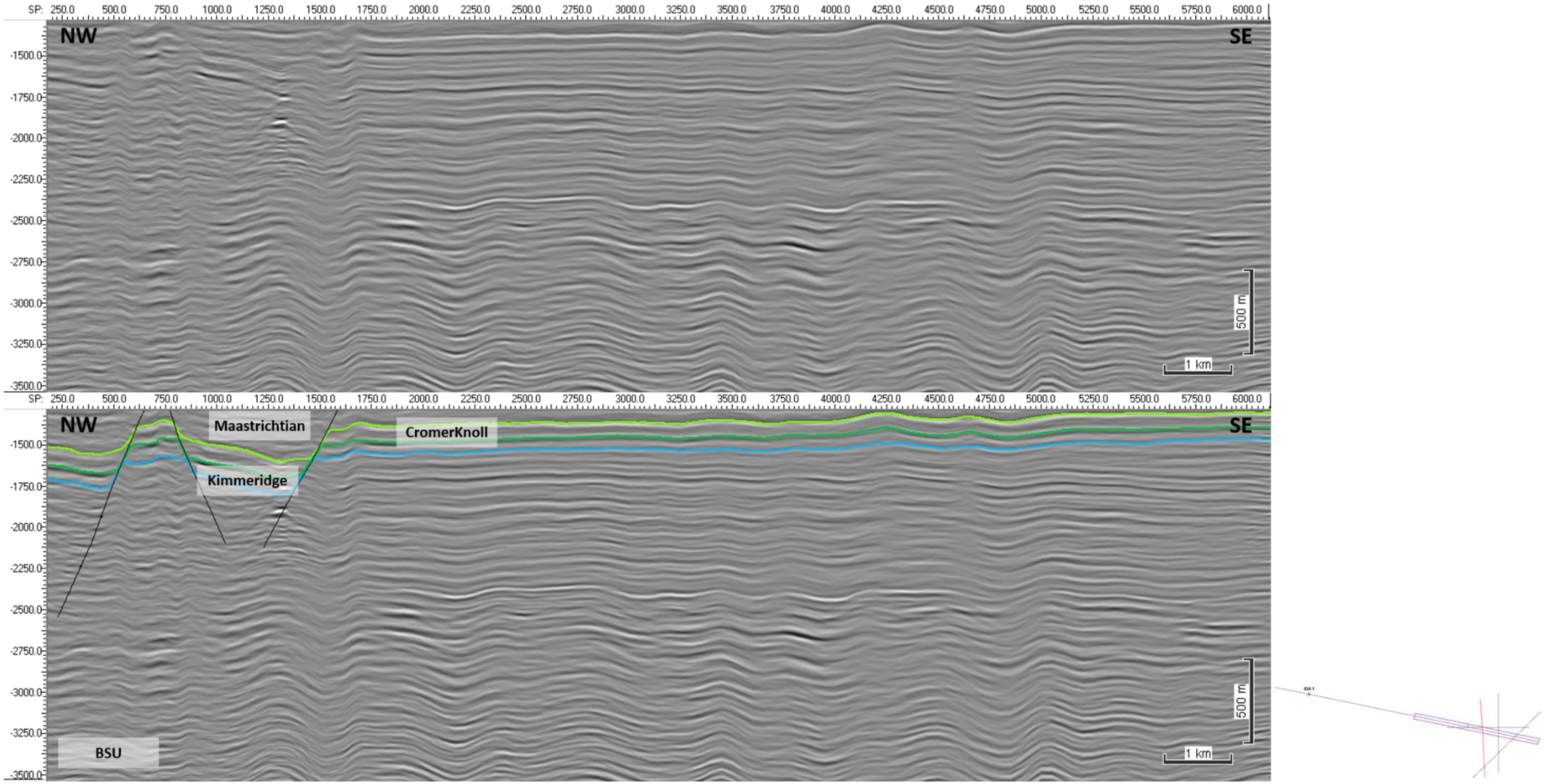


Figure 159 General facies of the Base Seismic Unit.
Seismic profile ML_01_Prio_1a.

8.2.26| SUMMARY AND DISCUSSION

The Ground Model presented in this report comprises 39 horizons, defining 39 seismic units that make up its geological framework, from the seabed to the Cretaceous Chalk Group. The available geotechnical information (borehole data) and previously geophysical campaigns' data complemented the seismic interpretation, providing valuable information regarding depositional environments, sediment content, and Pre-Quaternary formation tops. Seismic facies analysis, reflector terminations, and stratigraphic architecture provided the foundation for the 2D UHR and HR seismic interpretation. A review of the relevant scientific literature guided the interpretation process and placed the results within the known geologic context. It is important to understand that there are limitations associated to the interpretation provided. The complex geological architecture of the Quaternary deposits, and by extension, heterogeneity and spatial and vertical variations, posed challenges to the interpretation of the UHRS data.

The fundamental stratigraphic controls on the site´s geology, as inferred from the seismic data, are eustacy, isostasy, autogenic processes, and glaciogenic deposition and deformation. The deposits constituting seismic units UKSB to U35 exhibit a strong glacial signal, with direct and proximal influence of glacial processes. The remaining seismic units carry a eustatic-isostatic and autogenic signal, associated to high frequency, variable amplitude, sea-level fluctuations and related depositional environments and shoreline migration. These deposits are interpreted to represent cycles of deposition and erosion associated with sea-level transgressions and regressions. Superimposed on the eustatic-isostatic signal is the complex sedimentological arrangement produced by autogenic processes, including channel migration and avulsion, shallow basin, and coastal sediment dynamics.

Both systems of eustacy-isostacy and glacial dynamics taken in isolation are complex. The combination of the two, in conjunction with a strong overprinting of autogenic signal, has produced the complex geologic structure of the Quaternary sequence (upper section of UHRS data). Furthermore, salt tectonics have partially influenced the overall distribution of all the sedimentary sequences observed. Thus, the preservation of the geological sequences is limited due to the complex geological evolution of the area; variable sedimentary cycles; distinct erosional events; various stages of glaciers emplacement, erosion, and deformation.

Precise dating of seismic units to the Quaternary and its sea-level curve is not possible with the available data. One exception might be the last and most recent Holocene transgression. However, despite absolute chronological uncertainty, reasonable inferences can be made about the sea-level variations. Based on diagnostic characteristics of the seismic units' surfaces, stratal terminations and facies patterns, we have estimated sea-level behaviour for many of the seismic units.

Glaciotectonized sediments were individualised from the better-preserved sequences within seismic units (UKSA and UKSB). Horizons HKSA and HKSB represent deformation front boundaries and, although part of the geological model, should not be interpreted with a chronostratigraphic meaning.

The deposition of the deepest strata imaged in the HRS data – Base Seismic Unit BSU – marks the beginning of the geological evolution of the survey area as defined by the Ground Model. These deposits likely correspond to sediments of Jurassic or older age, which infilled Triassic and Jurassic rift basins. Above the BSU, the Kimmeridge unit, is also part of these deposits. All seismic units between the base of the Cromer Knoll to the base of unit U90 are generally characterized by a parallel to sub-parallel facies, defining a thick tabular sequence, generally dipping towards SW. Seismic unit boundaries and internal surfaces are generally marked by high amplitude reflectors. Within this sequence, the Upper Cretaceous Chalk Group is represented by seismic units Ekofisk and Maastrichtian, constituting an interval up to 422 m thick, and at 917.9 - 1839.7 m BSB. Paleogene and Neogene deposits correspond to seismic units Rogaland up to Luna (at least), that make-up the marine-deltaic Pre-Quaternary sequence.

Seismic sequence BSU-Luna was likely affected by salt-tectonics (associated to the Zechstein salt diapirism), as evidenced by the occurrence of extensional faulting and subsidence. The Pre-Quaternary sequence exhibits evidence for deformation near the east limit of the site (deformed seismic unit UKSB). There, previous fault pattern analysis suggested this deformation is related to Saalian glaciotectonism (maybe older) (see MMT Report 103783-ENN-MMT-SUR-REP-SURVWPA-02). Following, a large sub-aerial exposure and associated erosion event took place. This is captured by H90, displaying truncation the locally deformed Pre-Quaternary deposits. Above this surface, a delta system is present in unit U90, followed by the fluvial deposits of U85.

A more recent and newer episode of glaciotectonism ensued, forming large thrust complexes. These are evidenced by the deformation of units U90, U85 and UKSA. This deformation is likely related to the Weichselian glaciation, synchronous to the generation of the large tunnel valleys (or re-use of older) in which the U70 glacio-fluvial system is present. High energy fluvial bedforms corresponding to unit U60 were deposited, possibly also associated to outwash plains, and flash flood events. Glaciar meltdown and ice retreat may be associated with the establishment of the drainage network and subsequent sediment infilling of U40, alongside local glaciolacustrine deposition. This Weichselian (?) glaciogenic deposition and deformation is capped by the erosional event of H35.

Sediment deposition above H35 appears to be dominated by high frequency sea-level fluctuations, related to eustatic-isostatic and autogenic processes, away from any glacial influence. An overall transgressive sequence infilled the basins, starting with the deposition of U35 fluvial bedforms at the base, followed by the finer deposits of U30. Basin flooding led to the deposition of the lower section of unit U25, likely within a lacustrine or transgressive estuary setting. The increase of small channel-incisions within the upper deposits of U25 suggests the occurrence of a regressive event/fluctuation (at least in relative terms). The deposits of U20 consist of infills of small basins and/or channels, which could be related to a restricted marine-tidal deposition and partially to a subaerial fluvial infill. Above the ravinement surface of H10 (likely a wave cut) rests the last and most recent U10 deposits. This unit is made up of the recent transgressive deposits (possibly some high-stand) and includes the modern seabed marine sandy deposits.

8.3| SUB-SEABED HAZARDS

The 2D UHRS and HRS datasets were inspected in order to identify any potential constraints on future developments of the site; it does not directly correlate with a risk. This careful assessment revealed the presence of potential geohazards within the sub-surface of the survey area. The most relevant geohazards identified are:

- Sediment deformation (faulting);
- Buried channels and tunnel valleys;
- Fluid flow and gas features;
- Till deposits.

The interpretation and mapping of all geohazards described in this section were performed using manual picking as seismic data resolution and human precision allowed.

A more detailed description of the aforementioned geological hazards is presented within the sections below.

8.3.1 | SEDIMENT DEFORMATION

Areas of tectonization/deformation were identified throughout the survey area. Distinct patterns and degrees of deformation are observed, depending on which deformation process took place. In the survey area, the process in which the sediments became deformed are interpreted to have different origins: glacio-tectonics; salt tectonics; and gravitational deformation. These processes may work independently or simultaneously, increasing even further the complexity of the units' seismic facies. Regardless of the process, fault surfaces/zones are always observed. Fault mapping in the survey area is described below.

Evidence of faulting has been identified across the site. Faults were picked manually where relevant planar discontinuities, displacement of seismic reflectors, and major reflector-fault drags were recognised on the seismic data. Figure 160 displays the basemap of all mapped faults. Minor, isolated, and dubious features may have been left out due to the complexity of the subsurface framework and difficulty in recognizing all features and faults, as line spacing dictates the resolution in which subsurface features can be traced laterally (ex., tectonic structures). Lack of fault identification should not be taken as an assumption of total absence.

Faults are observed affecting all Quaternary units, but do not greatly affect sediments of U20 and younger (Figure 161 and Figure 162). Their type and size are highly variable. The majority of faulting is captured within UKSA and UKSB, as these units represent the extent of sediment deformation. Horizons HKSA and HKSB, the surface that delineates the deformation front, may itself be a fault plane (Figure 161). The majority of the faulting in the upper section is related to glaciotectonics. However, gravitational deformation was also previously identified. See Report 103783-ENN-MMT-SUR-REP-SURVWPA-02 for a more detailed analysis of fault networks affecting the Quaternary units.

Large faults with extensional displacement are clearly observed affecting the deeper Pre-quaternary deposits, up to seismic unit U90. These large-scale normal faults occur mostly towards NW, outside the limits of the EI area (Figure 160). All the normal faults observed in the survey area extend deeper than the HRS record. As such, and due to their extensional character, they are interpreted to be related to deep salt diapirism (ex., salt movement related to glacial load and melt back), associated to the Zechstein salt tectonics (Michelsen, 1993).

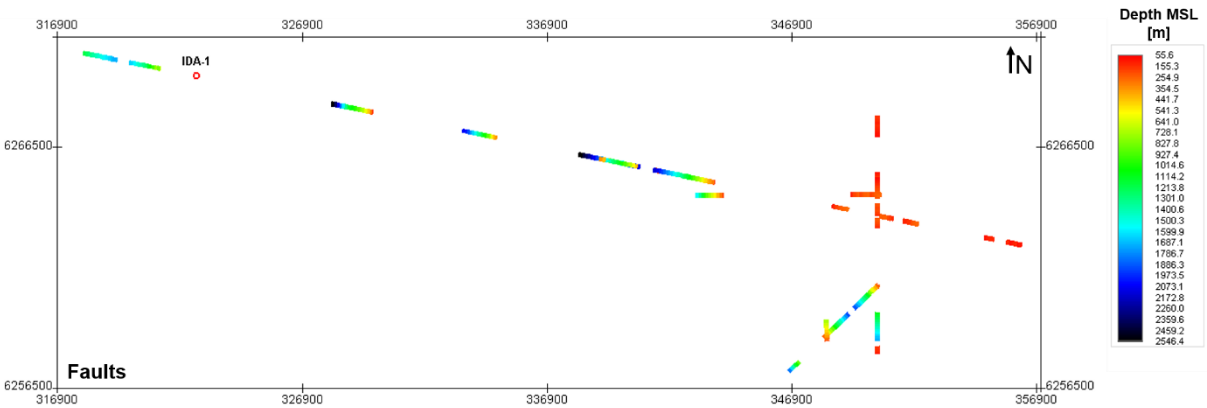


Figure 160 Map showing all mapped faults.
Units in metres below MSL.

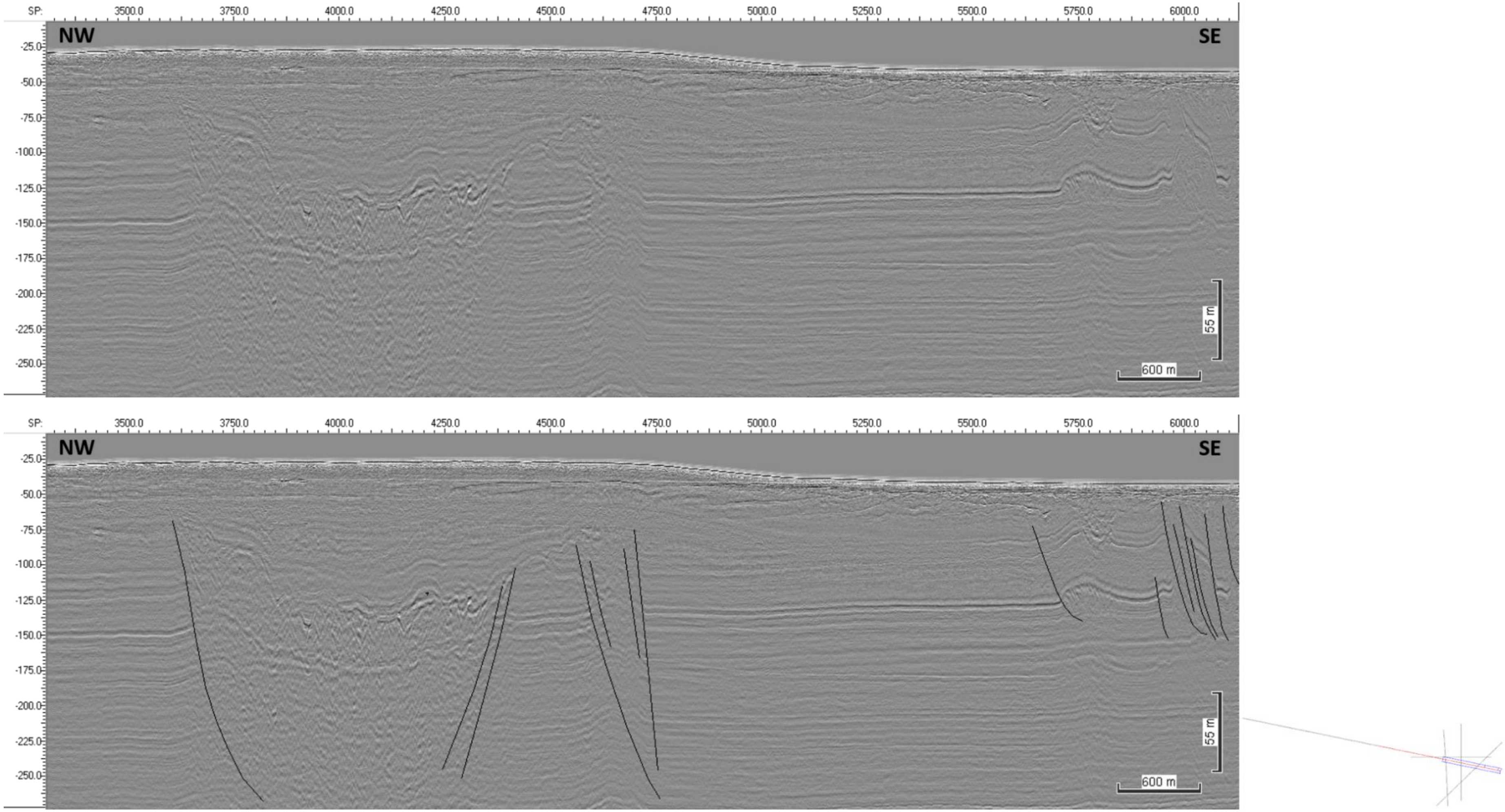


Figure 161 Example of faults mapped across the site. The faults shown are interpreted to be related to glaciotectonics, due to their compressional nature. Seismic profile ML_01_Prio_1a.

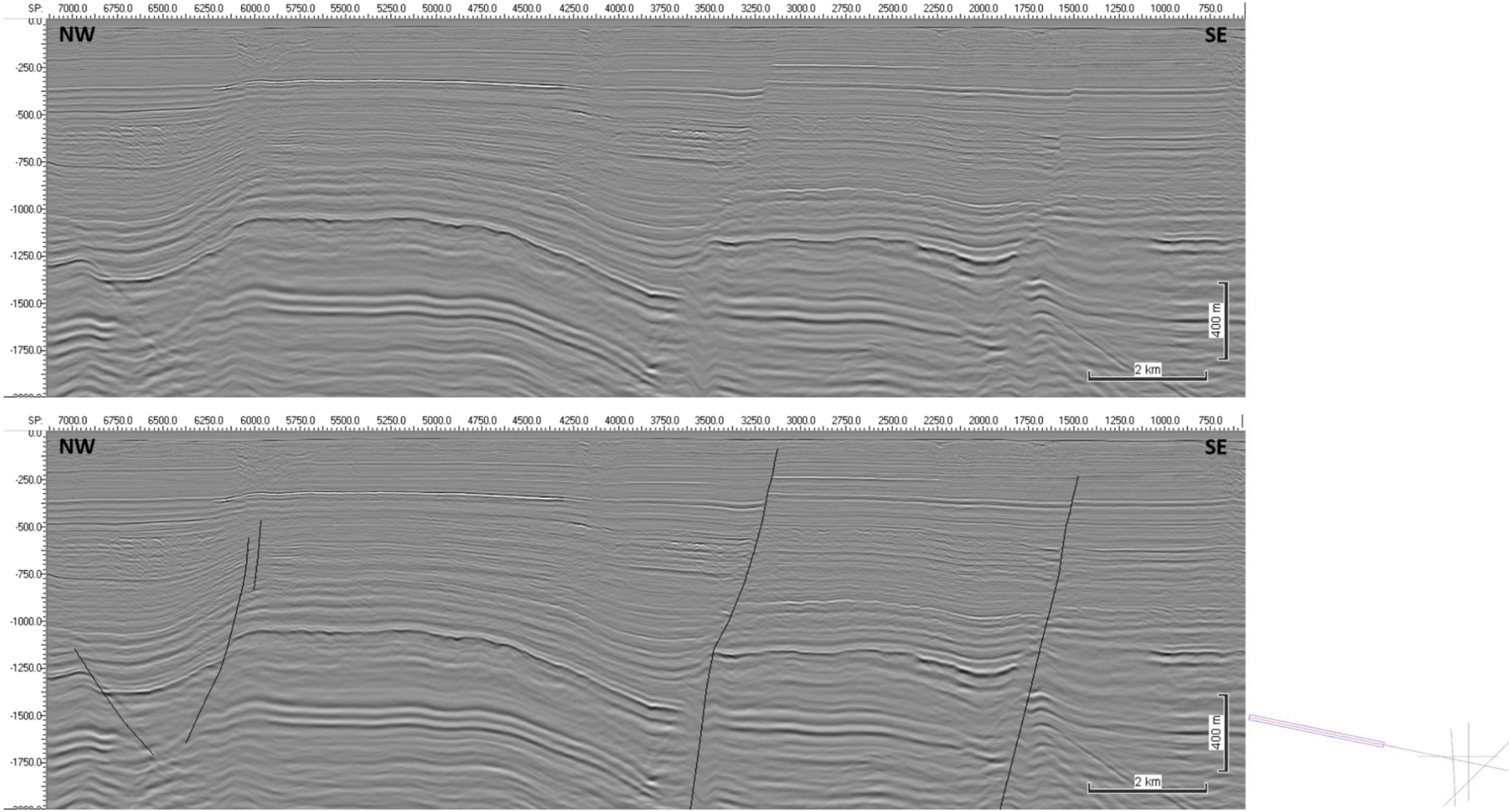


Figure 162 Example of faults mapped across the site. The faults shown are interpreted to be related to salt tectonics, due to their extensional nature. Seismic profile ML_01_Prio_1 (HR seismic data).

8.3.2| BURIED CHANNELS AND TUNNEL VALLEYS

Multiple paleo-valley, basins, and channel systems are widespread throughout the site, displaying a range of sizes and depositional characteristics. Often, the channels are interpreted as multi-generational, appearing as a vertical succession of channels/valleys nested one within another. The most significant erosional surfaces were identified and mapped. These major events correspond to the bases of the units described above, particularly seismic units U40, U70, UKSA, UKSB and their respective subunits. The channels and valleys can be easily identified in the various horizon basemaps (Figure 48, Figure 66, Figure 78 and Figure 90). Details on the seismic character of major incisions marked by unit bases can be found in the respective unit's description (see section 8.2.1|).

Channel morphology is diverse and ranges from V-shaped, U-shaped, to box-shaped. Similarly, there exists a broad distribution of channel widths and depths observable in the seismic data. The sediment infill of the channel features varies laterally and vertically. This degree of sediment heterogeneity may result in significant variability of geotechnical parameters within the channels.

From a hazard standpoint, the infill of tunnel valleys may be problematic for a variety of reasons. Tunnel valley infill is nearly always complex, with a heterogenous sediment composition, where lithological and mechanical properties may change rapidly over small spatial scales. Also, faulting and fracturing, from direct ice incision and pressurized hydraulic action, are common in tunnel valleys. Tills are commonly deposited near the base of tunnel valleys. Lastly, the complex load, and stress histories of tunnel valleys and their marginal deposits translates into abrupt differences in mechanical properties.

8.3.3| FLUID FLOW AND GAS FEATURES

Acoustic blanking, amplitude anomalies, phase reversals, and hyperbolas in the MUL (non-migrated) datasets may indicate the presence of gas in UHRS and HRS data. These indicators typically appear quite prominently when concentrations of free gas are present in sediments. However, the presence of a single marker of the above-mentioned items was never taken as evidence for the presence of shallow gas as there are a number of geological features that can be responsible for each of them individually. Instead, it was the combined presence of the mentioned evidences that was taken as indicator of the likely presence of shallow gas. Furthermore, signal masking, or acoustic turbidity, or decreased amplitudes were inspected either directly on the migrated and un-migrated seismic sections or on other amplitude-derived attributes, like envelope and reflectance datasets.

Seismic anomalies suggesting the presence of detectable gas in the subsurface were identified at the top of the Lark seismic unit. These are observed as a set of very high amplitude reflectors of limited extent, located at the IDA-1 well site (Figure 163 and Figure 164). The top of this anomaly features was mapped as "GF_Gas" (Figure 165). Acoustic attenuation of seismic reflectors is observed underneath the gas occurrence.

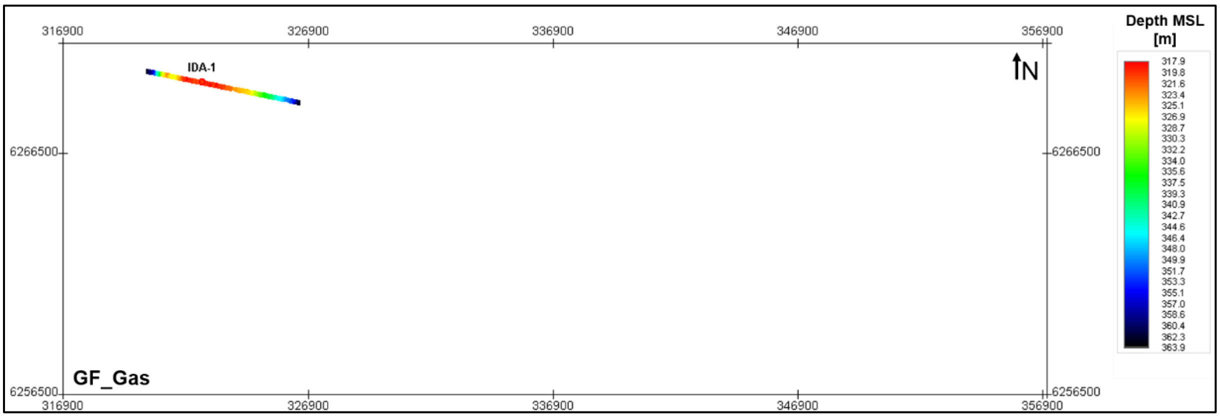


Figure 163 Map showing the lateral extent of horizon GF_Gas.
Units in metres below MSL.

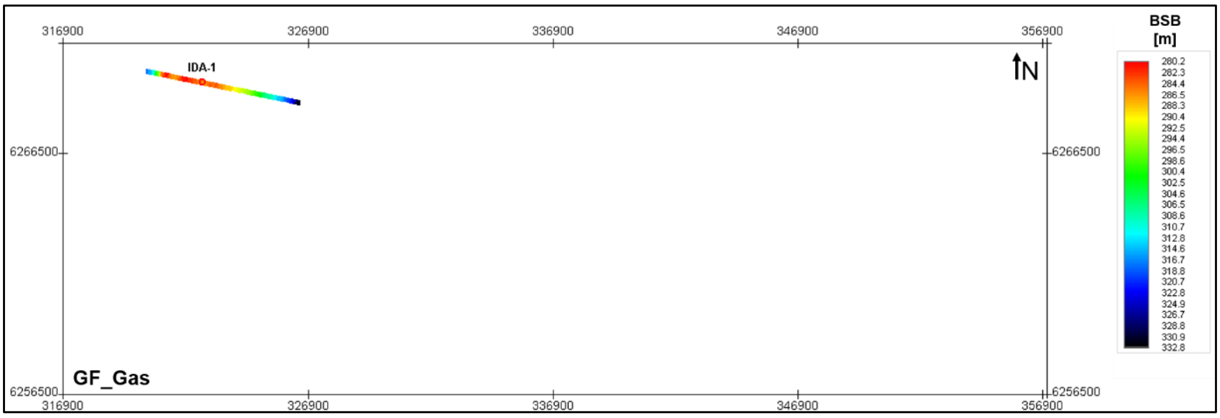


Figure 164 Depth below seabed of horizon GF_Gas.
Units in metres below seabed.

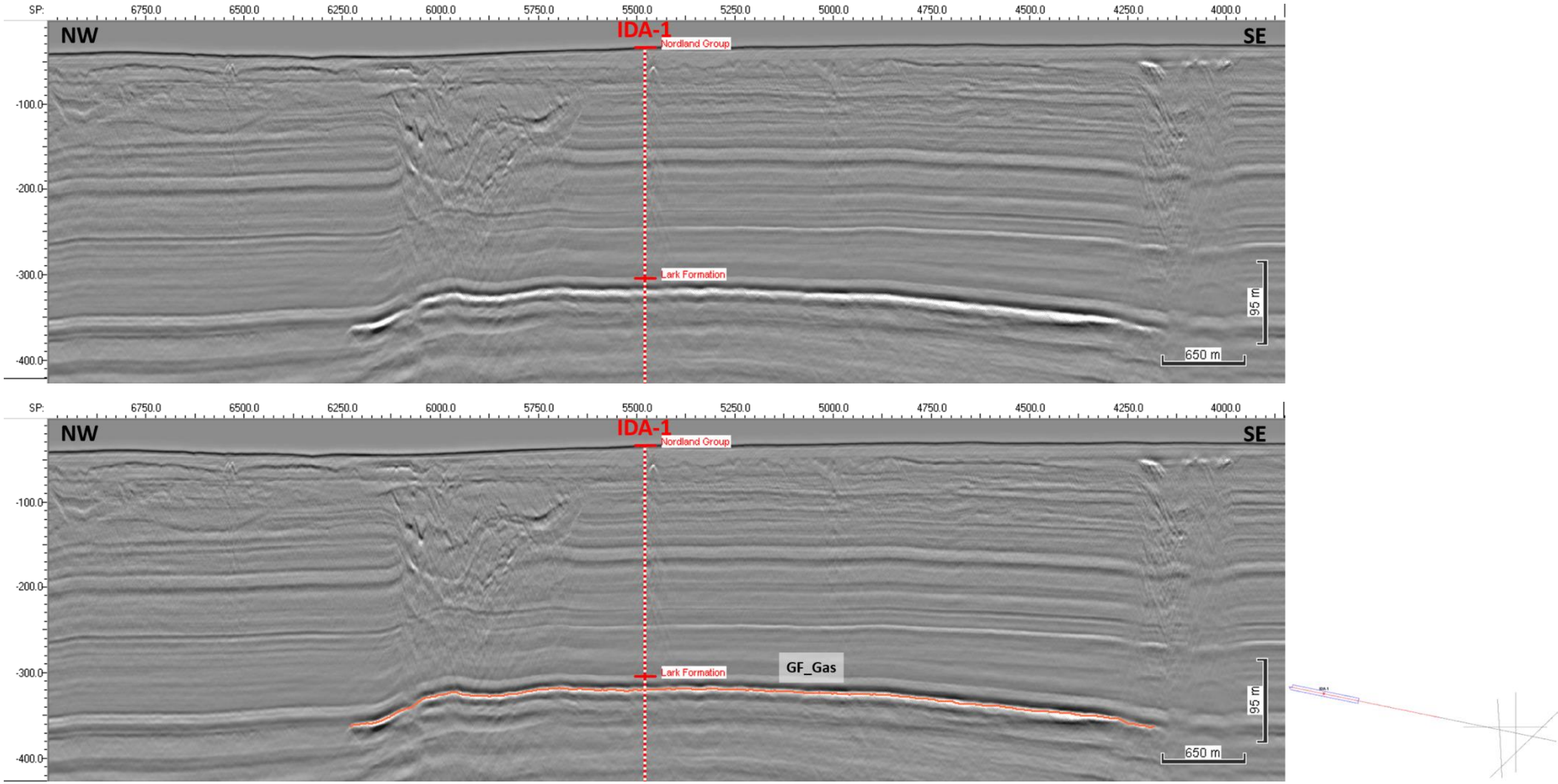


Figure 165 Geological feature GF_Gas identified at the top of the seismic unit Lark, interpreted to be associated to gas occurrence. Anomaly located at IDA-1 well location.
Seismic profile ML_01_Prio_1 (HR seismic data).

8.3.4| TILL DEPOSITS

Interpreting till deposits in UHRS data with high confidence can be difficult. Given its broad classification, and that it may contain sediment of any grain size, predicting its seismic characteristics is uncertain. However, considering the geological setting of the area, there should be a reasonable expectation of till in the units directly associated with glaciation. Possible tills were interpreted in seismic units UKSA. However, tills are commonly associated with and located in conjunction with glaciotectonism. Given this relationship, tills may also be present within U40, U70, and UKSB. Till may preferentially occur at the basal margins of the tectonized deposits, and associated to glacial surfaces of erosion or retreat.

9| CONCLUSIONS

Thirty-nine seismostratigraphic units were interpreted from the 2D UHRS and HRS datasets from the EI WPC survey area. Taken as a whole, these units represent the structural elements of the site's Geological Ground Model. The seismic units of the model were chosen primarily for their geotechnical significance, resulting from distinct depositional and erosion events, marking relevant environmental changes, and shifts in sediment types.

The seismostratigraphy of the site is complex. The stratal architecture is interpreted as being controlled by the interplay of eustacy-isostacy, autogenic processes, and direct glaciation.

The deposits constituting seismic units UKSB to U35 interpreted to be related to glacial processes, where glaciotectonics have the strongest influence of the seismostratigraphy. Deposits from this mode are interpreted as glacitectonites, glaciofluvial, glaciolacustrine, glacial drift, and outwash accumulations. The sedimentological composition of these deposits is a mixture of unconsolidated, siliciclastic, sediments, i.e., sands, silts, clay, and gravel. The seismic units that represent the glacial processes are positioned above the Pre-Quaternary sequences.

The Pre-Quaternary interval (from BSU to Luna) and the shallowest deposits comprise the sequences where eustatic-isostatic movements and tectonics have the strongest influence on the depositional environments. These deposits represent fluvial, tidal, estuarine, coastal marine, and open marine sediments. Of relevance is the Upper Cretaceous Chalk Group, represented by seismic units Ekofisk and Maastrichtian, constituting an interval up to 422 m thick, and at 917.9 - 1839.7 m BSB.

The variety of sub-surface geohazards identified from the UHRS data is typical for depositional settings at high latitudes. The main interpreted geohazards were: faults, both associated to glaciotectonics and salt tectonics; paleo channels and tunnel valleys; gas occurrence; and till.

10| RESERVATIONS AND RECOMMENDATIONS

The results in this report are based on interpretations of geophysical data obtained during the survey, complemented by previously acquired data. It should be considered that there is a natural limitation in the accuracy of interpretation. Results from borehole information have been used for verification of the geological interpretations and are considered as ground truthing at those locations where collected. Where considered applicable, the sampling results have been extrapolated to constitute a base for verifications also in the surroundings.

Seismic interpretation presented in this report is based solely on seismic interpretation techniques. Unit definition is based on the identification and mapping of the most prominent reflectors and seismic facies shift that correspond to significant changes on depositional environments and sediment type. Seismic facies identification, internal reflector termination and geometry of the erosive surfaces are the basis for the unit's description, inferred depositional environments and sediment type. All units display a certain degree of vertical and horizontal variability and heterogeneity. This is due to intrinsic nature of the geological processes that took place, the rapidly changing environment and the great extent of the site. The interpretation derived from the geophysical data should be validated by additional means of ground sampling (bore hole, cone penetrometer test and any soil inspection technique). Key aspects to be investigated are (1) seismic units inferred soil composition, (2) geotechnical relevance of facies shift (laterally and vertically), (3) geotechnical relevance of internal erosive surfaces, (4) importance of linear features (channels) in terms of mechanical/lithological properties and its variability, (5) mechanical relevance of the identified deformation evidences (glaciotectonics, faults, folds), (6) importance of intra-formational negative impedance contrasts, (7) presence and potential hazard of the identified gas, (8) presence of constrains in engineering and site development (boulders, coarse sediments), (9) accuracy of used depth-conversion velocity model.

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12 | DATA INDEX

The deliverables listed in Table 21 accompany this report.

Table 21 Deliverables.

Item	Group	Data Product	Comment
	SEISMIC 2D Airgun & UHRS DATA		
1.	Data	Processed UHRS recordings, SEGY format.	a. SEGY headers are configured with geometry
			b. Traces are corrected for motion
			c. Traces are aligned with datum
2.	Data	2D seismic instrument tracks, as TSG object TRACKS_LIN, indicate equipment carrier and equipment type in attributes.	
3.	Data	Seismic - Interpretation of the processed seismic data.	These data include interpretation points for digitized horizons identified in the seismic recordings. The data must be delivered as a point list file in CSV-format with the following data columns:
			a. PointID: Unique identification number
			b. Survey line ID: Unique survey line identification
			c. SEGY_Name: Filename of SEGY file
			d. KP: Km point or shotpoint ID
			e. Easting, Northing: Coordinates, meters
			f. TWT: Two-way-time, millisec
			g. Elevation: Elevation, LAT, meters
			h. Depth BSB: Depth Below Seabed, meters, based on constant velocity
4.	Data	Seismic - Generated elevation grids relative to vertical datum for each interpreted horizon in 5 m resolution as - GeoTiff grid	
5.	Data	Seismic - Generated elevation grids relative to vertical datum for each interpreted horizon in 5 m resolution as - (X,Y,Z) values in ASCII format	An (X,Y,Z) values in ASCII format (Z as the horizon elevation in meter)
6.	Data	Seismic - Generated depth below seabed (BSB) grids for each interpreted horizon in 5 m resolution as - Geotiff grid	
7.	Data	Seismic - Generated depth below seabed (BSB) grids for each interpreted horizon in 5 m resolution as - (X,Y,Z) values in ASCII format	An (X,Y,Z) values in ASCII format (Z as the horizon depth BSB in meter)
8.	Data	Seismic - Generated Isochore (layer thickness) grids for each interpreted soil unit in 5 m resolution as - Geotiff grid	
9.	Data	Seismic - Generated Isochore (layer thickness) grids for each interpreted soil unit in in 5 m resolution as - (X,Y,Z) values in ASCII format	An (X,Y,Z) values in ASCII format (Z as the layer thickness in meter)
10.	Data	Kingdom project including HR and UHR data, both as TWT and as DEPTH conversion. Updated Kingdom project with 2D seismic interpretation integrated with borehole data	

Item	Group	Data Product	Comment
		including 2D seismic data, both as TWT and as DEPTH converted version.	
		QUANTITATIVE INVERSION	
11.	SEG-Y	Angle stacks	
12.	ASCII & LAS	Borehole data conditioning	
13.	ASCII	Geotechnical and Seismic Interpretation	
14.	ASCII	Wavelet Estimation	
15.	SEG-Y	Geostatistical background model	
16.	SEG-Y	Simultaneous 3D relative and absolute AVO inversion results	
17.	Data	Spreadsheet containing deformation parameters	

APPENDIX A | LIST OF PRODUCED CHARTS

APPENDIX B | 2D UHRS PROCESSING REPORT

APPENDIX C | INVERSION INTERPRETATION REPORT