



Arklow Bank Wind Park (ABWP) 2D & 3D UHRs Geophysical Survey

2D & 3D UHRs INTERPRETATION REPORT

Document No.: REP2433023-INT

16th July 2025

	Processing Report - Green Rebel 2024 survey of Arklow Bank	Doc No: AW-GRR-000- GEP-REP-0007
Classification: Internal		
Status: IFU		Rev: U01

Project / Scope:			
Project Name	ARKLOW BANK WIND PARK PHASE 2		
Project I.D. No.	LF1000034	Scope:	Green Rebel 2024 Geophysical Surveys

Contractor Document Information			
Contractor Name	Green Rebel Marine Limited		
Sub Contractor Name	GeoSurveys, Geophysical Consultants Lda.		
Contractor Doc No	REP2433023-INT-	Rev	V2
Document Title	2D & 3D UHRS INTERPRETATION REPORT - Arklow Bank Wind Park (ABWP) 2D & 3D UHRS Geophysical Survey		

SSER Document Number	No of pages
AW-GRR-000-GEP-REP-0007	1 of 181

Revision Information					
Rev	Document Issue Status	Date	Originator	Checker	Approver
V2	Issue for use				

	Processing Report - Green Rebel 2024 survey of Arklow Bank	Doc No: AW-GRR-000- GEP-REP-0005
Classification: Internal		
Status: IFU		Rev: U01

Acceptance Status of Contractor Document			
Code	Description of Code	SSE Designated Signatory	Date
1	Accepted		
2	Further Information Required		
3	Rejected		
4	No comments		

Document Change Summary

Rev	Date	Details of Change	Changed by
02	18-09-2025	Revision based on SSE comments	JM

Tag Details

Tag Number	Description
n/a	n/a

GEOSURVEYS DOCUMENT CONTROL

Project Title:	Arklow Bank Wind Park – ABWP
Document Title:	2D & 3D UHRS INTERPRETATION REPORT
Document Type:	Technical Report
Contractor:	Green Rebel
Client:	Green Rebel and SSE

Client Ref.:	2433023
Document Ref.:	REP2433023-INT
Draft:	V2
Date:	18 July 2025
Draft Status:	V2

Revision History		Date	Author	Reviewed	Approved
01	V1	16/07/2025	SD / AV	AM	JM
02	V2	18/09/2025		AM	JM

Project team		
Abv.	Team	Position
JM	Jhonny Miranda	Project Manager
HD	Henrique Duarte	Processing Reviewer
FC	Fábio Correia	Processing Reviewer
AM	Ana Maia	Interpretation Manager / Interpretation Reviewer
VV	Vasco Valadares	Lead Geologist / Interpretation Reviewer
NA	Nélia Alves	Team Coordinator / Principal Interpreter
MSM	Mónica Melo	Principal Interpreter
CP	Cíntia Pereira	Principal Processor
SD	Shane Dunn	Interpretation Consultant
AV	A. Velhote	Interpreter

SUMMARY

Green Rebel contracted GeoSurveys (GS) to provide offline quality-control (QC), processing and interpretation of 3D UHRS sparker multi-channel data, acquired by Geomarine Survey Systems, within the scope of the Arklow Bank Wind Park (ABWP) survey area.

Data were acquired from 4th June to 2nd August, 2024, in the southeast coast of Arklow, 8 to 12 km off the coast of County Wicklow, Ireland. The area is approximately 67 km², with water depth in the range of -0.9 to -51m to m LAT.

This document reports the 3D seismic data interpretation of seventy-one 3D UHRS Volumes (corresponding to 822 swaths, including re-runs and infills from both vessels, making up a total line length of 600 km) in the survey area, from multi-channel seismic reflection data acquired with a sparker system; and 2D UHRS data interpretation of ~145 km seismic lines (represented by 34 individual seismic sections).

The survey site is located offshore the southeast coast of Ireland (Figure 1), 8 to 12 km off the coast of County Wicklow. The area is approximately 67 km² with water depth in the range -0.9 to -51m LAT.

The interpretation presented here was carried out by GeoSurveys, using Kingdom Suite software from S&P Global.

The procedures described in the present document are confidential and intellectual property of GeoSurveys.

TABLE OF CONTENTS

1. INTRODUCTION	16
1.1. SURVEY AREA	17
2. REGIONAL GEOLOGICAL SETTING	19
3. SEISMIC INTERPRETATION.....	21
3.1. DELIVERABLES	22
4. UHRS SEISMOSTRATIGRAPHIC INTERPRETATION	24
4.1. SEISMIC INTERPRETATION STRATEGIES AND METHODOLOGIES	25
4.2. SEISMOSTRATIGRAPHIC FRAMEWORK	28
4.3. SEISMIC UNIT DESCRIPTIONS.....	31
4.3.1. <i>Seismic Unit U0</i>	31
4.3.2. <i>Seismic Unit U0A</i>	36
4.3.3. <i>Seismic Unit U0B</i>	42
4.3.4. <i>Seismic Unit U1A</i>	46
4.3.5. <i>Seismic Unit U1</i>	51
4.3.6. <i>Seismic Unit U2</i>	59
4.3.7. <i>Bedrock</i>	64
4.4. 3D UHR SEISMIC VOLUME INTERPRETATION.....	68
4.5. POTENTIAL HAZARDS	69
4.5.1. <i>Gravel</i>	70
4.5.2. <i>Soft Sediments</i>	71
4.5.3. <i>Over-consolidated Sediments</i>	75
4.5.4. <i>Heterogeneous Deposits</i>	75
4.5.5. <i>Glaciotectonized Deposits</i>	77
4.5.6. <i>Sediment Transport</i>	78
4.5.7. <i>Paleochannels</i>	80
4.5.8. <i>Boulders</i>	81
4.5.9. <i>Other Features</i>	82
5. POINT DIFFRACTORS / POTENTIAL BOULDERS.....	85
5.1. SUBSURFACE OBJECT DETECTION USING UHRS DATA – 3D SEISMIC MIGRATION OF POINT DIFFRACTORS	85
5.2. LIMITATIONS AND UNCERTAINTIES IN SUBSURFACE OBJECT DETECTION AND INTERPRETATION USING UHRS DATA	87
5.3. PD ASSESSMENT STRATEGY	95

5.3.1. Methodology and Classifications	95
5.3.2. Position and Dimensions	97
5.3.3. Single or Clustered PD	98
5.3.4. PD Facies	98
5.3.5. Confidence Assignment	98
5.3.6. Geological Unit	99
5.3.7. QC of PD interpretations	99
5.4. PD ASSESSMENT RESULTS	100
5.4.1. Point Diffractors / Potential Boulders	100
5.4.2. Potential Isolated Boulders	100
5.4.3. Potential Boulder Clusters	108
5.4.4. Potential PD facies.....	108
5.4.5. PD assessment results summary	111
6. CONCLUSION	121
6.1. 2D SEISMIC INTERPRETATION.....	121
6.2. 3D MICROSITING ASSESSMENT.....	122
6.3. POINT DIFFRACTORS / POTENTIAL BOULDERS	123
7. RESERVATIONS AND RECOMMENDATIONS	124
8. REFERENCES	125

INDEX OF FIGURES

FIGURE 1 - LOCATION OF THE ARKLOW, SOUTHEAST COAST OF IRELAND IN THE SEA. SURVEY AREA OUTLINED IN WHITE.	17
FIGURE 2 - ARKLOW ACQUIRED 2D AND 3D UHRS SURVEY LINES.	18
FIGURE 3 - THE MAXIMUM EXTENT OF THE DEVENSIAN BRITISH-IRISH ICE SHEET (COMPILED FROM SEJRUP ET AL., 2005, BRADWELL ET AL., 2008 AND SEJRUP ET AL., 2016).	20
FIGURE 4 - A. STYLIZED SEA-LEVEL CURVE SHOWING THE TIMING OF TRADITIONAL SEQUENCE STRATIGRAPHIC SYSTEMS TRACTS (LEFT). B. CURVE REPRESENTING THE TIMING OF GLACIATION AND SEDIMENT ACCUMULATION THAT UNDERPINS GLACIODYNAMIC SEQUENCE STRATIGRAPHY (RIGHT). THE SIDE-BY-SIDE COMPARISON OF THE TWO SYSTEMS POINTS TO THE LACK OF CONGRUENCE BETWEEN DEPOSITION AND PRESERVATION POTENTIAL ON NON-GLACIATED AND GLACIATED CLASTIC SHELVES. THE THEORETICAL ASSEMBLAGE OF SYSTEMS TRACTS AND THEIR ASSOCIATED BOUNDARY SURFACES ARE UNLIKELY TO BE PRESENT OR INTERPRETABLE ON GLACIATED SHELVES. ADAPTED FROM FIGURE 8 IN HUUSE ET AL. (2012).	25
FIGURE 5 - SEISMIC PROFILE DEPICTING THE BASIC STRATIGRAPHIC FRAMEWORK INTERPRETED ACROSS THE SURVEY AREA, IN THE 2D SEISMIC DATA, THAT FORMED THE BASIS FOR THE DETAILED MAPPING OF THE 3D VOLUMES. 2D SEISMIC LINE 24G02_RR_007.	27
FIGURE 6 - SEISMIC PROFILE DEPICTING THE THREE FUNDAMENTAL COMPONENTS OF THE GEOLOGIC FRAMEWORK FOR THE SURVEY AREA, I.E., BEDROCK, PLEISTOCENE GLACIOGENIC SEQUENCE, AND HOLOCENE SURFICIAL SANDS. 2D SEISMIC LINE 24G02_RR_119_P1.	28
FIGURE 7 - FUNDAMENTAL GLACIOGENIC DEPOSITIONAL ZONES THAT REPRESENT FIRST-ORDER CONTROLS ON THE TYPE AND DEGREE OF EROSION AND SEDIMENTATION IN GLACIATED ENVIRONMENTS (LEFT). A CONCEPTUAL REPRESENTATION OF GLACIOGENIC DEPOSITS ASSOCIATED WITH A GLACIER TERMINATING IN A MARINE ENVIRONMENT, AS IS THE SUSPECTED CASE FOR THE IRISH SEA, SOUTH OF THE ISLE OF MAN. ADAPTED FROM FIGURES 3 AND 6 IN KURJANSKI ET AL. (2019).	29
FIGURE 8 - SPATIAL EXTENT OF MAPPED HORIZON B0, REFERENCED TO LAT (IN METRES).	32
FIGURE 9 - SEISMIC PROFILE DEPICTING AN EXAMPLE OF U0 THAT CORRESPONDS TO THE SURFACE SANDS FORMATION. THE SEDIMENTS OF U0 ARE MOSTLY SAND, BUT MAY ALSO CONTAIN GRAVEL DEPOSITS. 2D SEISMIC LINE 24G02_RR_119_P1.	33
FIGURE 10 - SEISMIC PROFILE DEPICTING THE SURFICIAL SANDS AND GRAVEL THAT COMPRISE THE DEPOSITS OF U0. ACCORDING TO THE FORMATION TOPS AND CPT DATA, SURFICIAL SANDS GRADE INTO GRAVELS BELOW THE SEABED. 2D SEISMIC LINE 24G02_RR_119_P2, CPT008.	34
FIGURE 11 - SEISMIC PROFILE DEPICTING LARGE SUBAQUEOUS DUNES WITH SMALLER, SUPERIMPOSED, SAND RIPPLES THAT ARE COMMON AT THE SURFACE OF U0. THESE TYPES OF SEDIMENT BEDFORMS ARE THE RESULT OF ENERGETIC SEDIMENT TRANSPORT. 2D SEISMIC LINE 24G02_RR_203.	35
FIGURE 12 - SPATIAL EXTENT OF MAPPED HORIZON B0A, REFERENCED TO LAT (IN METRES).	37

FIGURE 13 - SEISMIC PROFILE DEPICTING THE MANIFOLD EROSIONAL SURFACES AND GENERAL COMPLEXITY OF THE U0A SEISMIC FACIES. 2D SEISMIC LINE 24G02_RR_119_P1.	38
FIGURE 14 - SEISMIC PROFILE DEPICTING THE INTRICATE SEISMIC FACIES THAT IS LOCALLY PRESENT WITHIN U0A. MULTIPLE INTERPRETATIONS MAY BE ASCRIBED TO THIS COMPLICATED INTERNAL GEOMETRY, E.G. CHANNELIZATION, INTERNAL SUBAQUEOUS DUNE STRUCTURE, AND GLACIOTECTONISM. 2D SEISMIC LINE 24G02_RR_200.	39
FIGURE 15 - SEISMIC PROFILE WITH CPT DATA DEPICTING THE SANDY DEPOSITS THAT REPRESENT THE MAJORITY OF SEDIMENTS WITHIN U0A. 2D SEISMIC LINE 24G02_RR_007, CPT029.	40
FIGURE 16 - SEISMIC PROFILE DEPICTING APPARENT DEFORMATION RELATED TO GLACIOTECTONISM THAT IS OCCASIONALLY PRESENT WITHIN U0A. 2D SEISMIC LINE 24G02_RR_007.	41
FIGURE 17 - SPATIAL EXTENT OF MAPPED HORIZON B0B, REFERENCED TO LAT (IN METRES).	43
FIGURE 18 - SEISMIC PROFILE DEPICTING THE TRANSPARENT FACIES THAT IS COMMON TO U0B, POTENTIALLY REPRESENTING GLACIOLACUSTRINE DEPOSITS. 2D SEISMIC LINE 24G02_RR_007.	44
FIGURE 19 - SEISMIC PROFILE DEPICTING THE CLAYEY SEDIMENTS THAT ARE PREVALENT WITHIN U0B. OFTEN, THE SOFT CLAYS OF U0B ARE OVERLAIN BY STIFFER, SANDY SEDIMENTS. 2D SEISMIC LINE 24G02_RR_200_A, CPT091.	45
FIGURE 20 - SPATIAL EXTENT OF MAPPED HORIZON B1A, REFERENCED TO LAT (IN METRES).	47
FIGURE 21 - SEISMIC PROFILE DEPICTING FORESET BEDDING SUGGESTIVE OF DELTAIC DEPOSITION. THESE DEPOSITS MAY REPRESENT DELTAIC INPUT TO EITHER A GLACIOMARINE OR GLACIOLACUSTRINE ENVIRONMENT. 2D SEISMIC LINE 24G02_LK_XL_09.	48
FIGURE 22 - SEISMIC PROFILE DEPICTING THE TYPICAL FACIES OF U1A THAT IS MOSTLY INCOHERENT AND POSSIBLY INDICATIVE OF GLACIOMARINE DEPOSITION. 2D SEISMIC LINE 24G02_RR_059_R1.	49
FIGURE 23 - SEISMIC PROFILE AND CPT DATA DEPICTING SANDS OVERLYING CLAYEY SEDIMENTS THAT IS A COMMON SEQUENCE WITHIN U1A. 2D SEISMIC LINE 24G02_RR_059_R1, CPT048B-C.	50
FIGURE 24 - SPATIAL EXTENT OF MAPPED HORIZON B1, REFERENCED TO LAT (IN METRES).	52
FIGURE 25 - SPATIAL EXTENT OF MAPPED HORIZON BUTU1, REFERENCED TO LAT (IN METRES).	53
FIGURE 26 - SEISMIC PROFILE DEPICTING THE CONTRASTING SEISMIC FACIES OF THE UPPER AND LOWER MEMBERS OF U1. THE BASAL DEPOSITS, I.E., THE BEDDED MEMBER DISPLAY BEDDING WITH LATERAL CONTINUITY. THE OVERLYING DEPOSITS, I.E., THE UPPER TILLS, DISPLAY A SEMITRANSSPARENT TO CHAOTIC FACIES. 2D SEISMIC LINE 24G02_RR_XL_245.	54
FIGURE 27 - SEISMIC PROFILE DEPICTING AN EXAMPLE OF THE LAYERED FACIES THAT IS PRESENT, PERIODICALLY, IN THE BASAL DEPOSITS OF U1. THESE DEPOSITS MAY CORRESPOND TO THE BEDDED MEMBER OF THE CBF. 2D SEISMIC LINE 24G02_RR_210.	55
FIGURE 28 - SEISMIC PROFILE DEPICTING THE LAYERED SEDIMENTS AT THE BASE OF U1, THAT ACCORDING TO CPT DATA, ARE INTERBEDDED SAND AND CLAY. 2D SEISMIC LINE 24G02_RR_007, CPT032.	56

- FIGURE 29 - SEISMIC PROFILE DEPICTING THE GENERALLY, NON-COHERENT SEISMIC FACIES THAT PREVAILS WITHIN THE UPPER DEPOSITS OF U1. THESE DEPOSITS HAVE BEEN INTERPRETED AS THE UPPER TILLS OF THE CBF. 2D SEISMIC LINE 24G02_RR_XL_246. 57
- FIGURE 30 - SEISMIC PROFILE AND CPT DATA DEPICTING THE SEDIMENTOLOGICAL HETEROGENEITY COMMON WITHIN U1. 2D SEISMIC LINE 24G02_RR_XL_245_A, CPT021. 58
- FIGURE 31 - SPATIAL EXTENT OF MAPPED HORIZON B2, REFERENCED TO LAT (IN METRES). 60
- FIGURE 32 - SEISMIC PROFILE DEPICTING AN EXAMPLE OF B2, THAT SIMULTANEOUSLY REPRESENTS THE TOP OF BEDROCK AND THE BASE OF U2. 2D SEISMIC LINE 24G02_RR_007. 61
- FIGURE 33 - SEISMIC PROFILE DEPICTING THE MOSTLY INCOHERENT AND CHAOTIC SEISMIC FACIES OF U2 THAT SUGGESTS DIAMICTS, MOSTLY TILLS. 2D SEISMIC LINE 24G02_RR_007. 62
- FIGURE 34 - SEISMIC PROFILE AND CPT DATA DEPICTING THE HETEROGENEOUS SEDIMENTS PRESENT WITHIN U2. U2 IS UNDER SAMPLED IN THE CPT DATA DUE TO ITS DEPTH BELOW THE SEABED, I.E., LACK OF PENETRATION OF THE CPT PROBE. 2D SEISMIC LINE 24G02_RR_007, CPT035A. 63
- FIGURE 35 - SEISMIC PROFILE DEPICTING AN EXAMPLE OF WHERE TOP OF WEATHERED BEDROCK (RED) AND TOP OF INTACT BEDROCK (YELLOW) WAS INTERPRETED IN THE DETAILED MAPPING OF THE WT 3D VOLUMES. LINE 145 FROM WT48 3D VOLUME. 65
- FIGURE 36 - SEISMIC PROFILE DEPICTING AN EXAMPLE OF WHERE THE BEDROCK SURFACE IS EASILY DELINEATED GIVEN ITS CORRESPONDENCE TO AN ANGULAR UNCONFORMITY, 2D SEISMIC LINE 24G02_LK_XL_07. 66
- FIGURE 37 - SEISMIC PROFILE DEPICTING >10M OF PENETRATION INTO THE BEDROCK. THIS DEGREE OF PENETRATION BY A RELATIVELY HIGH-FREQUENCY, LOW POWER, SEISMIC SYSTEM POINTS TO A LACK OF COMPETENCY IN THE BEDROCK. 2D SEISMIC LINE 24G02_RR_007. 67
- FIGURE 38 - SEISMIC PROFILE DEPICTING THE GRAVELLY SEDIMENTS THAT EXIST IN THE UPPER DEPOSITS OF U0A AND AT THE BASE OF U0. 2D SEISMIC LINE 24G02_RR_076, CPT017. 70
- FIGURE 39 - SEISMIC PROFILE AND CPT DATA DEPICTING THE PREVALENCE OF SOFT SEDIMENTS WITHIN THE UPPER TILLS OF U1. AS PER THE CPT MEASUREMENTS, THE SOFT SEDIMENTS WITHIN THE SURVEY AREA ARE CLASSIFIED AS CLAY. 2D SEISMIC PROFILE 24G02_RR_007, CPT035A. 72
- FIGURE 40 - SEISMIC PROFILE AND CPT DATA DEPICTING HARD-OVER-SOFT CONDITIONS WITHIN THE GLACIOLACUSTRINE DEPOSITS INTERPRETED WITHIN U0B. 2D SEISMIC LINE 24G02_RR_119_P2, CPT019. 73
- FIGURE 41 - SEISMIC PROFILE AND CPT DATA DEPICTING HARD-OVER-SOFT CONDITIONS WITHIN THE UPPER TILLS OF U1, WHERE STIFF SANDS RAPIDLY GIVE WAY TO SOFT CLAYS. 2D SEISMIC LINE 24G02_RR_119_P1, SCPT006A. 74
- FIGURE 42 - SEISMIC PROFILE DEPICTING THE HETEROGENEITY OF SEDIMENTS WITHIN THE GLACIOGENIC DEPOSITS THAT REPRESENT THE BULK OF THE NEAR-SURFACE GEOLOGY OF THE SURVEY AREA. 2D SEISMIC LINE 24G02_RR_007, CPT 021. 76
- FIGURE 43 - SEISMIC PROFILE DEPICTING THE CONTORTED, CHAOTIC, SEISMIC FACIES OF THE UPPER TILLS OF U1, THAT STRONGLY SUGGEST GLACIOTECTONISM. 2D SEISMIC LINE 24G02_RR_076. 77

- FIGURE 44 - SEISMIC PROFILE DEPICTING COMPOSITE SUBAQUEOUS DUNES INDICATIVE OF SEDIMENT TRANSPORT. 2D SEISMIC LINE 24G02_RR_203. 78
- FIGURE 45 - SEISMIC PROFILE DEPICTING AN EXAMPLE OF POTENTIAL SCOURING, WHERE THE SURFICIAL SANDS HAVE BEEN WINNOWED AWAY LEAVING GLACIOGENIC SEDIMENTS EXPOSED AT THE SEABED. 2D SEISMIC LINE 24G02_RR_031. 79
- FIGURE 46 - SEISMIC PROFILE DEPICTING THE RARE OCCURRENCE OF A WELL-DEFINED CHANNEL FEATURE IN THESE DATA. 2D SEISMIC LINE 24G02_LK_XL_08. 80
- FIGURE 47 - SEISMIC PROFILE DEPICTING THE COMPLICATED GEOMETRIES OF THE INTERNAL EROSIONAL SURFACES THAT OCCUR LOCALLY WITHIN UOA. 2D SEISMIC LINE 24G02_RR_200. 81
- FIGURE 48 - STRONG NEGATIVE IMPEDANCE ANOMALY (SOFT-KICK) WITHIN THE RECENT SEDIMENTS AT WT33, APPROXIMATELY 14.5M LENGTH, 3M WIDTH AND AT 2.5 M BSB. 83
- FIGURE 49 - STRONG NEGATIVE IMPEDANCE ANOMALY (SOFT-KICK) WITHIN THE RECENT SEDIMENTS AT WT41, APPROXIMATELY 3M LENGTH, 1.5M WIDTH AND AT 2.5 M BSB 83
- FIGURE 50 - GREEN REBEL'S 2024 MBES DATA AT WTG LOCATIONS WT41 (TOP LEFT) AND WT33 (BOTTOM LEFT), AND RESPECTIVE SLOPE PROFILES A-A' AND B-B' AT THE RIGHT. TOP: LOW-RELIEF SEABED DEPRESSION ABOVE THE 3D UHRS ANOMALY OF WT41; BOTTOM: LOW-RELIEF BEDFORM ABOVE THE 3D UHRS ANOMALY OF WT33. 84
- FIGURE 51- THE PRINCIPLES OF 3D MIGRATION. GREEN SECTIONS SHOW 2D CUTS ON A 3D HYPERBOLOID DIFFRACTION VOLUME. 86
- FIGURE 52 - DATA EXAMPLES DEPICTING OF THE DIAGRAM OF FIGURE 1, SHOWING NON-MIGRATED 3D UHRS DATA. A NON-MIGRATED SEISMIC INLINE (MUL) CORRESPONDS TO THE DIRECTION NUMBER 2 OF FIGURE 1 INTERSECTING THE BLUE (REAL HYPERBOLOID APEX) AND GREEN DOTS (APPARENT APEX) AT DIFFERENT DEPTHS. A PERPENDICULAR CROSSLINE MUL CORRESPONDS TO THE DIRECTION NUMBER 1 SHOWING THE GREEN DOT AS AN APPARENT HYPERBOLOID APEX. EXAMPLE SHOWN NOT FROM 3D UHRS ABWP SURVEY. 86
- FIGURE 53 - TIME SLICES OF NON-MIGRATED, MIGRATED, AND ENVELOPE DATA INTERSECTING THE PD SHOWN IN FIGURE 2. THE DIFFRACTION HYPERBOLOID OBSERVED IN THE MUL DATA (LEFT) COLLAPSES INTO A HIGH AMPLITUDE (CENTRE)/ENVELOPE (RIGHT) OBJECT IN MIG DATA. EXAMPLE SHOWN NOT FROM 3D UHRS ABWP SURVEY. 87
- FIGURE 54 - SCHEMATIC REPRESENTATION OF HOW POINT OBJECTS OR PDS OF VARIABLE SIZES MAY BE OBSERVED IN SEISMIC SLICES, ACCORDING TO THEIR ACOUSTIC RESPONSE AND POSITION RELATIVE TO THE SEISMIC BINNING GRID. BLACK CIRCLES REPRESENT OBJECTS OF DIFFERENT SIZES, WHEREAS GREY SQUARES SHOW THE BIN AREAS IN WHICH THEIR RESPECTIVE ACOUSTIC RESPONSE WOULD BE DETECTED IN SEISMIC SLICES, DEPENDING ON THEIR CENTER LOCATION RELATIVE TO THE BIN GRID. DIMENSIONS OF SMALL TARGETS MAY BE OVERESTIMATED WHEN THEIR RESPONSE IS DETECTED IN SEVERAL BINS. 89
- FIGURE 55 - WORKFLOW FOR THE MANUAL MAPPING OF POINT DIFFRACTIONS. 96

- FIGURE 56 - BURIED ANOMALY CONFIDENCE ASSIGNMENT: PD3 = HIGH CONFIDENCE; PD2 = MEDIUM CONFIDENCE; PD1 = LOW CONFIDENCE; PD0 = CONFIDENCE ZERO (POINT ANOMALIES DETECTED WITHIN THE MULTIPLE INTERVAL). 99
- FIGURE 57 - EXAMPLES OF INTERPRETED PD3 TARGETS - PDs WITH HIGH CONFIDENCE OF BEING RELATED WITH POTENTIAL SUBSURFACE BOULDERS. IMAGES SHOW INLINE, CROSSLINE AND DEPTH SLICE DISPLAYS (LEFT, CENTRE, AND RIGHT, RESPECTIVELY), INTERSECTING EACH PD AT ITS CENTRE POSITION. 101
- FIGURE 58 - EXAMPLES OF INTERPRETED PD3 TARGETS - PDs WITH HIGH CONFIDENCE OF BEING RELATED WITH POTENTIAL SUBSURFACE BOULDERS. IMAGES SHOW INLINE, CROSSLINE AND DEPTH SLICE DISPLAYS (LEFT, CENTRE, AND RIGHT, RESPECTIVELY), INTERSECTING EACH PD AT ITS CENTRE POSITION. 102
- FIGURE 59 - EXAMPLES OF INTERPRETED PD2 TARGETS - PDs WITH MEDIUM CONFIDENCE OF BEING RELATED WITH POTENTIAL SUBSURFACE BOULDERS. IMAGES SHOW INLINE, CROSSLINE AND DEPTH SLICE DISPLAYS (LEFT, CENTRE, AND RIGHT, RESPECTIVELY), INTERSECTING EACH PD AT ITS CENTRE POSITION. 103
- FIGURE 60 - EXAMPLES OF INTERPRETED PD2 TARGETS - PDs WITH MEDIUM CONFIDENCE OF BEING RELATED WITH POTENTIAL SUBSURFACE BOULDERS. IMAGES SHOW INLINE, CROSSLINE AND DEPTH SLICE DISPLAYS (LEFT, CENTRE, AND RIGHT, RESPECTIVELY), INTERSECTING EACH PD AT ITS CENTRE POSITION. 104
- FIGURE 61 - EXAMPLES OF INTERPRETED PD1 TARGETS - PDs WITH LOW CONFIDENCE OF BEING RELATED WITH POTENTIAL SUBSURFACE BOULDERS. IMAGES SHOW INLINE, CROSSLINE AND DEPTH SLICE DISPLAYS (LEFT, CENTRE, AND RIGHT, RESPECTIVELY), INTERSECTING EACH PD AT ITS CENTRE POSITION. 105
- FIGURE 62 - EXAMPLES OF INTERPRETED PD1 TARGETS - PDs WITH LOW CONFIDENCE OF BEING RELATED WITH POTENTIAL SUBSURFACE BOULDERS. IMAGES SHOW INLINE, CROSSLINE AND DEPTH SLICE DISPLAYS (LEFT, CENTRE, AND RIGHT, RESPECTIVELY), INTERSECTING EACH PD AT ITS CENTRE POSITION. 106
- FIGURE 63 - EXAMPLES OF INTERPRETED PD0 TARGETS - PDs WITH ZERO CONFIDENCE – POINT ANOMALIES DETECTED WITHIN MULTIPLE INTERVAL. IMAGES SHOW INLINE, CROSSLINE AND DEPTH SLICE DISPLAYS (LEFT, CENTRE, AND RIGHT, RESPECTIVELY), INTERSECTING EACH PD AT ITS CENTRE POSITION. 107
- FIGURE 64 - EXAMPLES OF INTERPRETED C2 CLUSTERS - GROUPING OF PDs WITH MEDIUM CONFIDENCE OF BEING RELATED WITH POTENTIAL SUBSURFACE BOULDERS. IMAGES SHOW INLINE, CROSSLINE AND DEPTH SLICE DISPLAYS (LEFT, CENTRE, AND RIGHT, RESPECTIVELY), INTERSECTING EACH CLUSTER AT ITS CENTRE POSITION. 109
- FIGURE 65 - EXAMPLES OF INTERPRETED C1 CLUSTERS - GROUPING OF PDs WITH LOW CONFIDENCE OF BEING RELATED WITH POTENTIAL SUBSURFACE BOULDERS. IMAGES SHOW INLINE, CROSSLINE AND DEPTH SLICE DISPLAYS (LEFT, CENTRE, AND RIGHT, RESPECTIVELY), INTERSECTING EACH CLUSTER AT ITS CENTRE POSITION. 110
- FIGURE 66 - EXAMPLE OF INTERPRETED PD FACIES (PDF) – POSSIBLE COARSE-GRAINED DEPOSITS WITH POTENTIAL HIGH DENSITY OF SMALL OBJECTS (GRAVELS, PEBBLES, COBBLES, AND SMALL BOULDER “CLOUDS”), WITHIN WHICH IT IS NOT POSSIBLE TO DISCERN INDIVIDUAL. IMAGES SHOW INLINE, CROSSLINE AND DEPTH SLICE DISPLAYS (LEFT, CENTRE, AND RIGHT, RESPECTIVELY). 111

INDEX OF TABLES

TABLE 1 - ARKLOW PROJECTION SYSTEM AND VERTICAL DATUM.	18
TABLE 2 - PARAMETERS USED FOR GRIDDING HORIZONS.	21
TABLE 3 - KS PROJECT DETAILS.	22
TABLE 4 - GROUND MODEL HORIZONS INCLUDED IN THE KS PROJECT – 2D AND 3D HORIZONS.	22
TABLE 5 - GROUND MODEL GRIDS INCLUDED IN THE KS PROJECT – 2D AND 3D HORIZONS.	23
TABLE 6 – NOMENCLATURE FOR INTERPRETATION ITEMS FEATURED IN THE KS PROJECT FOR ASSESSMENT OF GEOHAZARDS AND PDS.	23
TABLE 7 - TABLE 4-1 FROM THE ARKLOW OFFSHORE WIND FARM INTERIM GROUND MODEL REPORT REV 1, THAT SHOWS THE STRATIGRAPHIC FRAMEWORK FOR THE INTERIM GROUND MODEL.	26
TABLE 8 - THE QUATERNARY GEOLOGIC FRAMEWORK FOR THE RELEVANT AREA OF THE IRISH SEA, TABLE 2-1 FROM ARKLOW OFFSHORE WIND FARM INTERIM GROUND MODEL REPORT REV 1, ADAPTED FROM MELLETT ET AL. (2015).	30
TABLE 9 - LIST OF WTGS WHERE SEISMIC UNIT U0 IS PRESENT.	32
TABLE 10 - LIST OF WTGS WHERE SEISMIC UNIT U0A IS PRESENT.	37
TABLE 11 - LIST OF WTGS WHERE SEISMIC UNIT U0B IS PRESENT.	43
TABLE 12 - LIST OF WTGS WHERE SEISMIC UNIT U1A IS PRESENT.	47
TABLE 13 - LIST OF WTGS WHERE SEISMIC UNIT U1 IS PRESENT.	52
TABLE 14 - LIST OF WTGS WHERE SEISMIC UNIT U2 IS PRESENT.	60
TABLE 15 - TABLE 6 FROM MELLETT ET AL. (2015) THAT LISTS FEATURES OF IRISH SEA GEOLOGY THAT MAY REPRESENT ENGINEERING HAZARDS AND RELATED CONSTRAINTS.	69
TABLE 16 - TABLE 7 FROM MELLETT ET AL. (2015) PROVIDES A LIST OF THE RANGES OF UNDRAINED SHEAR STRENGTH (S_u) VALUES FOR THE RELEVANT FORMATIONS WITHIN THE SURVEY AREA, I.E., WEST IRISH SEA FORMATION AND CARDIGAN BAY FORMATION. S_u METRICS CAN BE USED TO APPROXIMATE THE LEVEL OF OVER-CONSOLIDATION IN SEDIMENT DEPOSITS.	75
TABLE 17 - POSITION AND SIZE OF BURIED NEGATIVE AMPLITUDE ANOMALIES DETECTED IN WT33 AND WT41.	82
TABLE 18 - OBJECT REAL SIZE VERSUS ITS PERCEIVED HORIZONTAL SIZE IN 0.5 M BIN SEISMIC DATA.	90
TABLE 19 – SUBSURFACE PDS – CONTACT LIST ATTRIBUTES (IN SHAPEFILE).	97
TABLE 20 - SUMMARY OF FINDINGS OF THE PD/ POTENTIAL BOULDERS ASSESSMENT FOR THE ABWP SURVEY.	112

ABBREVIATIONS

ABWP	Arklow Bank Wind Park
BSB	Below Seabed
BSU	Base Seismic Unit
C	Cluster
CBF	Cardigan Bay Formation
CPT	Cone Penetration Test
DPT	Depth migrated stack
E	East
ESE	East-southeast
GH	Geohazard
BSB	Below Seabed
BSU	Base Seismic Unit
GS	Geosurveys
GM	Geological ground model
GR	Green Rebel
km	Kilometres
KS	Kingdom Suite
m	Metres
MBES	Multi Beam Eco Sounder
MIG	Migrated stack
LAT	Lowest Astronomical Tide
UHRs	Multichannel Ultra-High Resolution Seismic
MUL	Multiple attenuated (non-migrated) stack
N	North
NE	Northeast
NNE	North-Northeast

OS	Offshore Site
OSI	Offshore Site Investigation
PD	Point-diffraction (<i>plural</i> PDs)
PDF	PD facies
PQ	Pre-Quaternary
Q	Quaternary
QC	Quality control
S	South
SE	Southeast
SNR	Signal-to-Noise Ratio
SSE	Scottish and Southern Energy
SSE	South-southeast
SNR	Signal-to-noise ratios
TWT	Two-way travel time
UHRs	Ultra-High Resolution Seismic
VEL_INT	Interval velocities used for depth conversion
VEL_RMS	Root Mean Square velocities used for depth conversion
W	West
WISF	Western Irish Sea Formation
WGS	World Geodetic System
WGS84	World Geodetic System 84
WNW	West-Northwest
WTG	Wind Turbine Generator

1. INTRODUCTION

The 3D multichannel Ultra High Resolution Seismic (UHRS) data processing reported herein was performed within the scope of the Arklow Bank Wind Park (ABWP) survey area. The survey was carried out by Green Rebel, on board of the Roman Rebel vessel (from 4th June to 2nd August 2024) and MV Lady Kathleen vessel (from 13th of July to 3rd of August, 2024).

The general scope of the ABWP project was to execute a reconnaissance survey to support the planning and de-hazard for the installation of offshore windfarm infrastructures, providing an understanding of the expected shallow subsurface ground conditions across the site. As a complement to the interpretation of the geological ground model, the 2D and 3D UHRS data were inspected in order to identify any potential constraints on future developments of the site.

The main objectives of the 2D and 3D UHRS survey and works are:

- Geological ground modeling down to 100 m below seabed (considering that the achieved penetration will be dependent on the sediment properties at the site);
- Detailed and clear delineation of the subsurface geological layers and structural elements;
- Resolve and determine bedrock depth across the site as far as possible and, wherever possible, to identify weathered rockhead;
- Provide accurate information on changes in subsurface unit stratigraphy, including lateral variability, thickness of units, and changes in material properties;
- Identify subsurface relevant features and geohazards that may impact site design and development (e.g. very soft or very hard geological surfaces and seismic units, faults or fault zones, shallow gas, etc.).

Seismic data interpretation was carried out at GeoSurveys (GS) office, using Kingdom Suite software from S&P Global.

The survey site is located offshore the southeast coast of Ireland (Figure 1), 8 to 12 km off the coast of County Wicklow. The area is approximately 67 km² with water depth in the range of -0.9 to -51 m LAT.

The UHRS data acquisition and processing was not the same for the two vessels. The UHRS data acquisition carried out by Roman Rebel used an UHRS system that included: three Geo-Source 200 tips LW, three Geo-Spark 2000XF0 power supplies, five Geo-Sense Ultra-Light Weight 48 channels streamer (group interval of 1m), ten multi-trace units, thirteen dual-DGNSS antennas MK3 located on each sparker sources and at the front and tail buoy of each streamer and a Geo-Sense reference hydrophone

(single element). The acquisition carried out by M/V Lady Kathleen used an UHRS system that included: two Geo-Source 200 tips LW, two Geo-Spark 1000X power supplies, five Geo-Sense Ultra-Light Weight 24 channels streamer (group interval of 0.5m), five multi-trace units, one dual-DGNSS antenna MK4 located on each sparker source and a Geo-Sense reference hydrophone (single element). Further details on the UHRS data acquisition and processing can be found in the 3D UHRS Processing Report – Arklow_3D_UHRS_PROCESSING_REPORT.



Figure 1 - Location of the Arklow, southeast coast of Ireland in the Sea. Survey area outlined in white.

1.1. SURVEY AREA

The Arklow survey comprises a total of 71 3D UHRS volumes acquired along 822 swaths (717 swaths by the Roman Rebel vessel and 105 swaths by the Lady Kathleen vessel), making up a total line length of approximately 600 km (Figure 2). Of these, approximately 145 km lines (represented by 34 individual seismic sections) constitute the 2D UHRS survey that interlinks the 3D UHRS volumes at WTG locations. The projection system used is the WGS84 / UTM Zone 30N (EPSG 32630) and the vertical datum is Lowest Astronomical Tide (LAT) (Table 1).

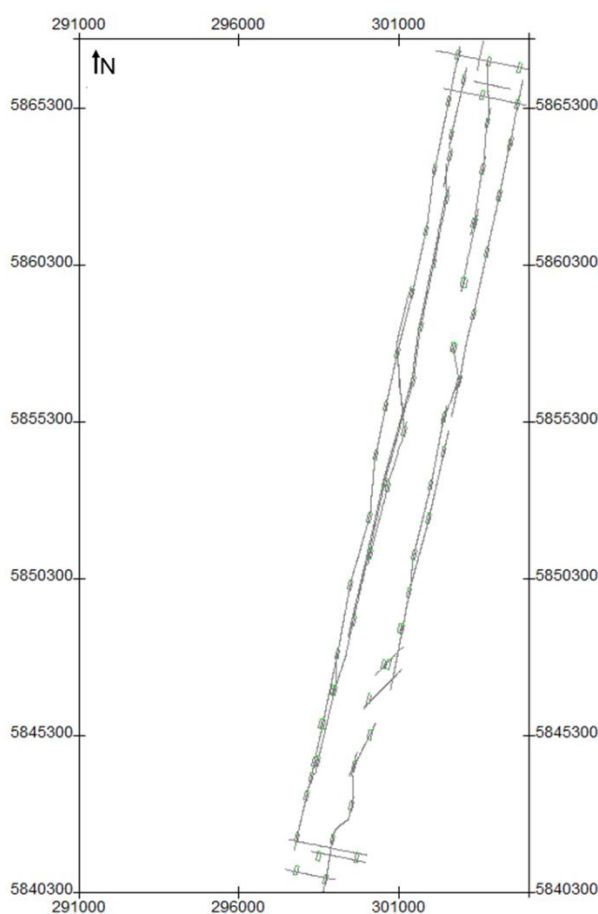


Figure 2 - Arklow acquired 2D and 3D UHRS survey lines.

Table 1 - Arklow projection system and vertical datum.

Location	Offshore Arklow, SE coast of Ireland
Coordinate system	WGS 84 UTM zone 30N
Vertical datum	LAT
Water depth	-0.9 to -51 m

2. REGIONAL GEOLOGICAL SETTING

The Arklow region is situated on Ireland's eastern seaboard within Wicklow County. The geologic history of the area is complex having been shaped by numerous processes, e.g., tectonics, volcanism, sea-level fluctuations, and glaciations, which began in the Proterozoic and extend to the Quaternary. This synthesis outlines the region's tectonic underpinnings and stratigraphic framework, with an emphasis on stratigraphy, glacial geomorphology, offshore sedimentary architecture, and post-glacial processes.

The Arklow coastal region is underlain by metasedimentary and volcanic rocks deposited in oceanic basins that formed prior to, and contemporaneously with, the closure of the Iapetus Ocean. It was the closure of this ancient ocean that brought about the union of two disparate terranes, forming what is now referred to as the British Isles. Bedrock types include slates, sandstones, greywackes, conglomerates, and volcanoclastic units of Ordovician age. Cambrian sandstones have also been recorded offshore. Younger Mesozoic and Cenozoic strata, predominantly of Triassic, Jurassic, and Paleogene age, occur to the south and west of the region and represent extensional basin infill associated with the initial rifting of Pangaea.

The marine shelf offshore Arklow represents an extension of onshore bedrock lithologies, now covered by variable Quaternary deposits. The Quaternary unit is periodically disrupted by faulting and glacial erosion. Subsurface mapping of the region points to Paleozoic strata being overlain unconformably by glaciogenic units. The Quaternary deposits represent a discontinuous sediment cover that overlies the basement rocks across onshore and offshore environments. The glaciogenic component of these deposits are the result of repeated glaciation events, predominantly from the Middle and Late Pleistocene. They exhibit a wide range of sediment types and sedimentary structures reflecting subglacial, proglacial, and paraglacial processes.

Glacial deposits predating Late Pleistocene glaciations exist within the Irish Sea. However, there is a strong preservation bias towards sediment deposits associated with the Weichselian glaciation, $\approx$ 115,000 to 11,700 years ago. During the Last Glacial Maximum $\approx$ 26,500 years ago, ice from Scotland, Ireland and western Britain coalesced into the British-Irish Ice Sheet that covered the Irish Sea. The convergence of the aforementioned glaciers within the topographic confines of the Irish Sea basin gave rise to the formation of the Irish Sea Ice Stream (ISIS). The ISIS under pressure from massive ice accumulation in the Scottish Highlands became a fast-moving glacier that progressed southward within the confines of the Irish Sea's trough-like basin. Currently, it is assumed that the ISIS terminated and retreated within a marine environment, south of the Isle of Man.

The advancement and subsequent retreat of the ISIS produced the complex glaciogenic sequence that exists largely in the subsurface of the modern continental shelf. The sediment types and morphologies

of the glaciogenic deposits are diverse, including subglacial tills, ice-marginal moraines, tunnel valleys, glaciolacustrine and glaciomarine sediments.

Following rapid sea-level rise during the Holocene and the coincident transgression of the continental shelf, 10,000-6000 years ago, intertidal and marine conditions prevailed in the Irish Sea. The shelf's glacial deposits were reworked in the marine environment under the combined energy of currents, tides, and waves. The Irish Sea is known for its energetic tidal currents that are the predominate force shaping the modern seabed. The Holocene deposits are mostly sands, winnowed from glaciogenic deposits, that now comprise sediment bedforms that range in size from massive sandbanks and sandwaves to minor ripples. In some cases, currents have removed the Holocene sediments exposing Pleistocene glaciogenic deposits at the seabed. Gravel lags may also be present at the modern seabed or near the base of the Holocene sands.

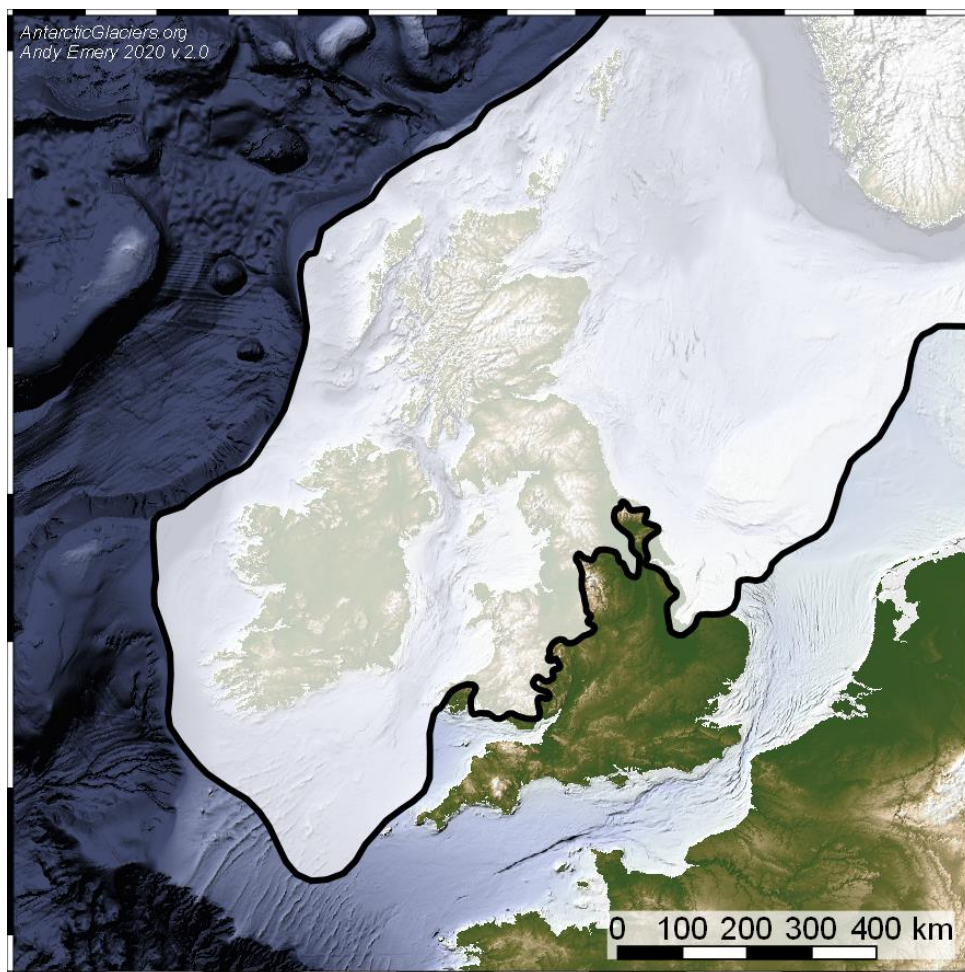


Figure 3 - The maximum extent of the Devensian British-Irish Ice Sheet (compiled from Sejrup et al., 2005, Bradwell et al., 2008 and Sejrup et al., 2016).

3. SEISMIC INTERPRETATION

The seismic interpretation and descriptions included in this report are based on the assessment of the UHRS data acquired within the survey area, processed according with the procedures described in the accompanying Arklow Bank Wind Park (ABWP) 3D UHRS Geophysical Survey Processing Report (Document No. REP2433023).

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), unless stated otherwise. Numbers on the horizontal and vertical axis refer to distance in metres. The colourbar for the seismic display is identical for all profiles ('Black to White 200' in Kingdom Suite). The colourbar used 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, two basemaps are presented: (1) mapped surface of the base horizon, referenced to LAT, showing its spatial extent; (2) grid of the depth below seabed of the base of the unit; Vertical exaggeration on seismic section figures is variable: horizontal and vertical scales were adjusted to best illustrate the features of interest. Each seismic section is displayed with and without interpretation.

Table 2 summarizes the gridding parameters, used for all grids in the Kingdom Suite project and displayed in this report. These settings are based on their ability to deliver the best results (coverage between lines whilst minimizing artefacts and edge effects). At a second stage, grids were clipped so that undesired extrapolation onto other units is minimized.

Table 2 - Parameters used for gridding horizons.

Cell size	5 m
Algorithm	Flex Gridding
Fit to data	0.5
Smoothness	6
Search radius	50 m

3.1. DELIVERABLES

The final 2D and 3D UHRS interpretation is included in the accompanying Kingdom Suite project which contents are presented in the tables below (Table 3 to Table 6).

All seismic interpretation data were exported from KS project and delivered as ASCII files:

- Horizons (TWT & depth) - exported as "GeoQuest-CARD IMAGE 7" format;
- Grids (TWT & depth) - exported as "XYZ" format;
- Faults (depth) - exported as "GeoQuest-CARD IMAGE 7" format.

Table 3 - KS project details.

KS project name	Arklow
SQL version	Auto SQL Server Express 2014
Seismic datasets	2D UHRS: FAST_MIG, FAST_MUL, FAST_DPT, FAST_VEL_INT, FAST_VEL_RMS 3D UHRS: MIG, MUL, DPT, VEL_INT, VEL_RMS
Culture	ARK_60x60m3DUHRsSurveyOption2_SSE_24052024 SSE Arklow Bank 100mx100m_Box
2D Ground model horizons	7 horizons in TWT and depth (LAT) (Table 4)
2D Ground model grids	14 grids in TWT and depth (LAT) (Table 5)
3D Micrositing horizons (Ground model & Geohazards)	611 horizons in TWT and depth (LAT)
3D Micrositing grids (Ground model & Geohazards)	1238 grids in TWT and depth (LAT, BSB, Thickness)

Table 4 - Ground model horizons included in the KS project – 2D and 3D horizons.

KS HORIZONS				UHRS INTERPRETATION
Name	KS colour code	TWT	Depth LAT	Description
00	Dodger Blue	✓	✓	Seabed
B0	Salmon	✓	✓	Ravinement surface; base of surficial sediments; Surface Sands Fm.
B0A	Hot Pink	✓	✓	Erosional surfaces of different origins (marine and glaciogenic? processes); part of Western Irish Sea Fm (?)
B0B	Spring Green	✓	✓	Base glaciolacustrine deposits (?); part of Western Irish Sea Fm (?).
B1A	Green	✓	✓	Base of Western Irish Sea Fm.
B1	Blue	✓	✓	Base of Upper Till Member of Cardigan Bay Fm (?).
B2	Yellow	✓	✓	Base of Bedded and/or Infill Members of Cardigan Bay Fm (?).
BUTU1	Orange	✓	✓	Base of Cardigan Bay Fm; top of bedrock.

Table 5 - Ground model grids included in the KS project – 2D and 3D horizons.

KS GRIDS					
Name	KS colour code	2D Depth LAT	3D Depth LAT	3D Depth BSB	3D Thickness
O0	Dodger Blue	✓	✓	✓	✓
B0	Salmon	✓	✓	✓	✓
B0A	Hot Pink	✓	✓	✓	✓
B0B	Spring Green	✓	✓	✓	✓
B1A	Green	✓	✓	✓	✓
B1	Blue	✓	✓	✓	✓
B2	Yellow	✓	✓	✓	✓
BUTU1	Orange	✓	✓	✓	✓

Table 6 – Nomenclature for interpretation items featured in the KS Project for assessment of geohazards and PDs.

Geohazards	3D Horizons	WTGname_Unit-XX (TWT and Depth LAT)
	3D Grids	WTGname_Unit-XX (Depth LAT)
PD Assessment	Culture	WTGname_Delivery1 (1 st assessment) WTGname_Delivery2 (2 nd assessment)
	3D Horizons	WTGname_C2_X (Cluster confidence 2) WTGname_C1_X (Cluster confidence 1) WTGname_HZ_X (Geological Feature) WTGname_PDF_X (Geological Feature) WTGname_HZ_AA_X (Geological Feature, negative amplitude)
	Faults	WTGname_PD3 TWT (Isolated PD confidence 3) WTGname_PD2 (TWT) (Isolated PD confidence 2) WTGname_PD1 (TWT) (Isolated PD confidence 1) WTGname_PD0 (TWT) (Isolated PD confidence 0)

4. UHRS SEISMOSTRATIGRAPHIC INTERPRETATION

Initial seismic interpretation was performed on a set of regional 2D lines that were produced from the 3D field acquisition program. The interpretation of the 2D lines was performed with input from an already established interim ground model and formation tops derived from geotechnical data (Arklow Offshore Wind Farm Interim Ground Model – Report 20240193-02-R by NGI (2024)). As is typically the case when new data is assimilated into vintage interpretations, perfect alignment was not achieved between the existing unit horizons and formation tops and the new seismostratigraphic interpretation developed using the most recent dataset. However, the fundamental stratigraphic framework and unit structure are conserved in GeoSurveys' interpretations. The aforementioned 2D lines, that intersect and link the 3D seismic volumes positioned at the WTG locations, formed the basis for their interpretation. Detailed mapping and interpretation were performed on the 3D seismic volume for each WTG location. The results of this analysis are provided on a block-by-block basis in the WTG reports.

Interpretation of the seismic data points to the survey area as being comprised of three basic geologic units. The basal unit is a meta-sedimentary bedrock, the surface of which has been sheared and weathered by multiple Pleistocene glaciations. A relatively thick, glaciogenic sequence unconformably overlies the bedrock surface. The glacial deposits are predominantly diamictic, largely tills. Glaciolacustrine and glaciomarine sediments are also interpreted within the survey area. Glaciogenic deposits are comprised of a mixture of clay, silt, sand, and gravel. The Pleistocene glaciogenic deposits are overlain by a Holocene sand unit. The surface of the Holocene sands, that represent the seabed sediments, are interpreted as highly mobile owing to the prevalence of sandwaves and ripples. Holocene sediments are mostly sand with localized deposits of gravel.

Geohazard analysis of the combined seismic, geotechnical, and MBES data resulted in the potential hazards listed below:

- Boulders and cobbles;
- Gravel;
- Sediment transport;
- Heterogeneous sediments;
- Soft sediments;
- Hard-over-soft conditions;
- Glaciotectonized deposits;
- Over-consolidated sediments;

- Paleochannels.

4.1. SEISMIC INTERPRETATION STRATEGIES AND METHODOLOGIES

The interpretation of these data was performed using a hybridized methodology, implementing elements of classical seismic stratigraphy, sequence stratigraphy, and lithostratigraphy. The application of sequence stratigraphic principles, that often provide a framework for seismic interpretation, were limited in these data, given that many of the bounding surfaces are directly related to glacial processes that are not in-phase with sea-level coupled systems tracts (Figure 4). Seismic facies analysis was an essential component of the interpretation process. Additionally, the geotechnical data with their derivative formation tops were also key to the process of choosing the most relevant seismostratigraphic surfaces to map (NGI, 2024). A base-centric approach was employed when digitizing the seismic horizons that delineate the bounds of the seismic units. For example, B0 is the seismic horizon that delineates the base of Seismic Unit 0 (U0) and so on. One caveat to this rule is B2, as it represents simultaneously the base of Seismic Unit 2 (U2) and the top of bedrock.

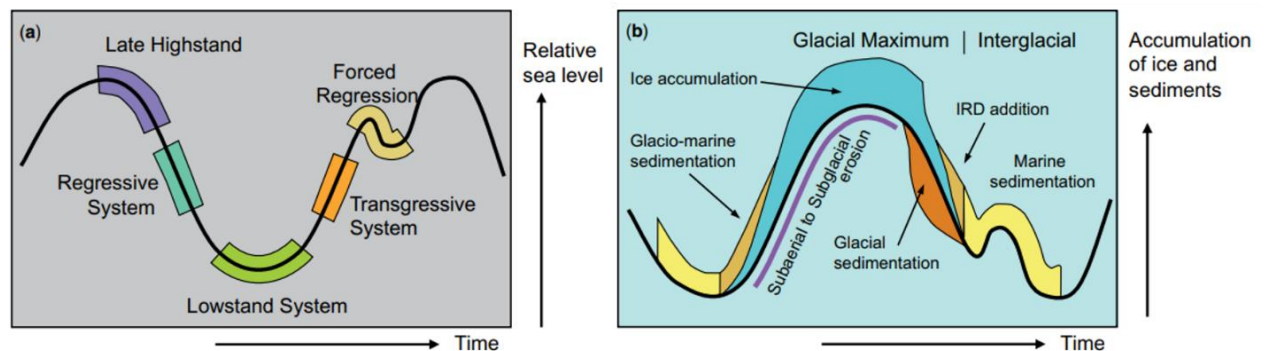


Figure 4 - A. Stylized sea-level curve showing the timing of traditional sequence stratigraphic systems tracts (left). B. Curve representing the timing of glaciation and sediment accumulation that underpins glaciodynamic sequence stratigraphy (right). The side-by-side comparison of the two systems points to the lack of congruence between deposition and preservation potential on non-glaciated and glaciated clastic shelves. The theoretical assemblage of systems tracts and their associated boundary surfaces are unlikely to be present or interpretable on glaciated shelves. Adapted from figure 8 in Huuse et al. (2012).

It is important to note that the interpretation of these data represent only the most recent iteration of an earlier, established ground model (see Table 7 for details). Previously acquired datasets, interpretations, and ground model formulations, established outside of the purview of GeoSurveys, served as the starting point for interpreting these data. When possible, the interpretation of the seismic data was performed in a manner that facilitated alignment with the constituent horizons of the existing ground model and the formation tops provided by the client. However, as is typically the case in GeoSurveys' experience, the incorporation of new, more illuminating datasets forces modifications to existing conceptions of a site's geology. For example, unit U0B and all or part of unit

U0A are interpreted as potentially glaciogenic and not Holocene marine deposits, as per the interim ground model table.

The most recent 2D seismic lines, derived from the 3D acquisition program, that provide site-scale coverage, were used to establish the stratigraphic framework (Figure 5) for 3D block interpretations. Initial interpretations of the 2D lines were guided by a series of gridded horizons derived from the previously established ground model. Additionally, the 2D horizons that comprise the updated ground model framework were interpreted so as to facilitate a “best fit” to the provided formation tops. Despite this effort, non-congruence frequently exists among formation tops and the interpretation of corresponding units. The foundational horizons (2D) that delineate the established Units, e.g., U0, U0A, U0B, U1A, U1, U2, etc., were interpreted whenever possible on each of the 3D volumes. In addition to the interpretation of the unit base horizons, detailed mapping was performed on all 3D volumes. This exercise generated additional “internal” horizons that subdivide the ground model units.

Table 7 - Table 4-1 from the Arklow Offshore Wind Farm INTERIM GROUND MODEL Report Rev 1, that shows the stratigraphic framework for the interim ground model.

Geological Age	Depositional environment	Geological Formation	Unit	Subunits	Main soil/rock type
Holocene	Marine	Surface Sands	U0	U0_S	SAND
				U0_G	GRAVEL
			U0A	U0A_S	SAND
Holocene / Late Pleistocene	Intertidal to Marine		U0B	U0B_S	SAND
				U0B_C	CLAY
Late Pleistocene	Deltaic to glaciomarine / Glaciolacustrine	Western Irish Sea Formation	U1A	U1A_S	SAND
				U1A_C	CLAY
			U1	U1_S	SAND
				U1_C	CLAY
				U1_HF	HIGH FINES
Pleistocene	Primarily subglacial	Cardigan Bay Formation	U2	U2_S	SAND
				U2_C	CLAY
				U2_G	GRAVEL
Palaeozoic (Cambrian)	Various	Lower Paleozoic bedrock	U 3	U3_W	Weathered Bedrock (Sandstone, Mudstone)
				U3	Bedrock (Sandstone, Mudstone)

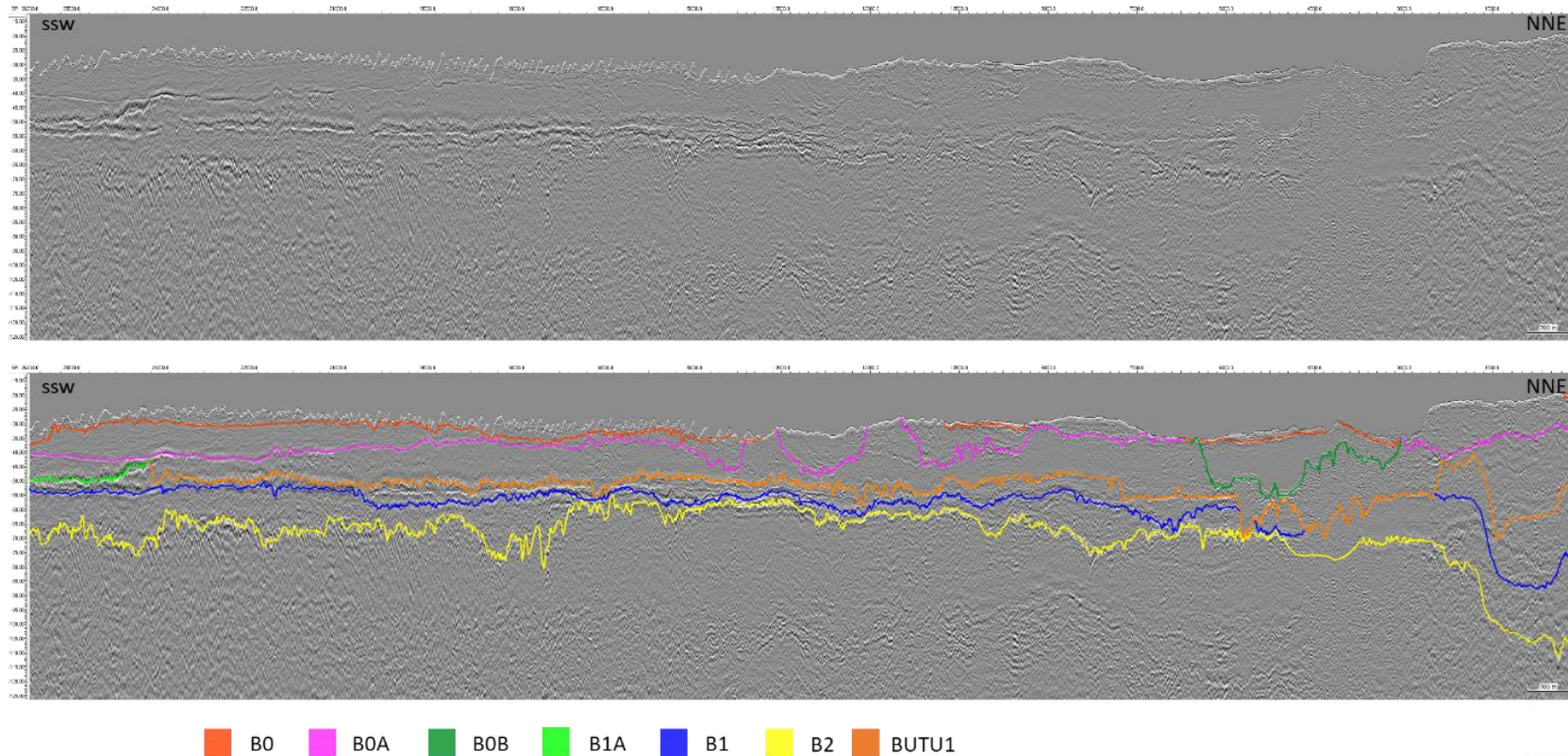


Figure 5 - Seismic profile depicting the basic stratigraphic framework interpreted across the survey area, in the 2D seismic data, that formed the basis for the detailed mapping of the 3D volumes. 2D seismic line 24G02_RR_007.

4.2. SEISMOSTRATIGRAPHIC FRAMEWORK

The seismostratigraphic architecture of the site, expressed in fundamental terms, is a tripartite, where bedrock is overlain by a Pleistocene glaciogenic sequence, that is then overlain by a Holocene intertidal to marine deposit (Figure 6). The top of bedrock, also the base of the glaciogenic sequences, undulates across the survey area and displays considerable variance in physical character and acoustic response in the seismic data. The wide variance in seismic character of the bedrock has been attributed to the degree of weathering at the rockface. In some instances, two bedrock surfaces were mapped, one corresponding to the start of weathered bedrock material, and a second delineating the top of “intact bedrock”.

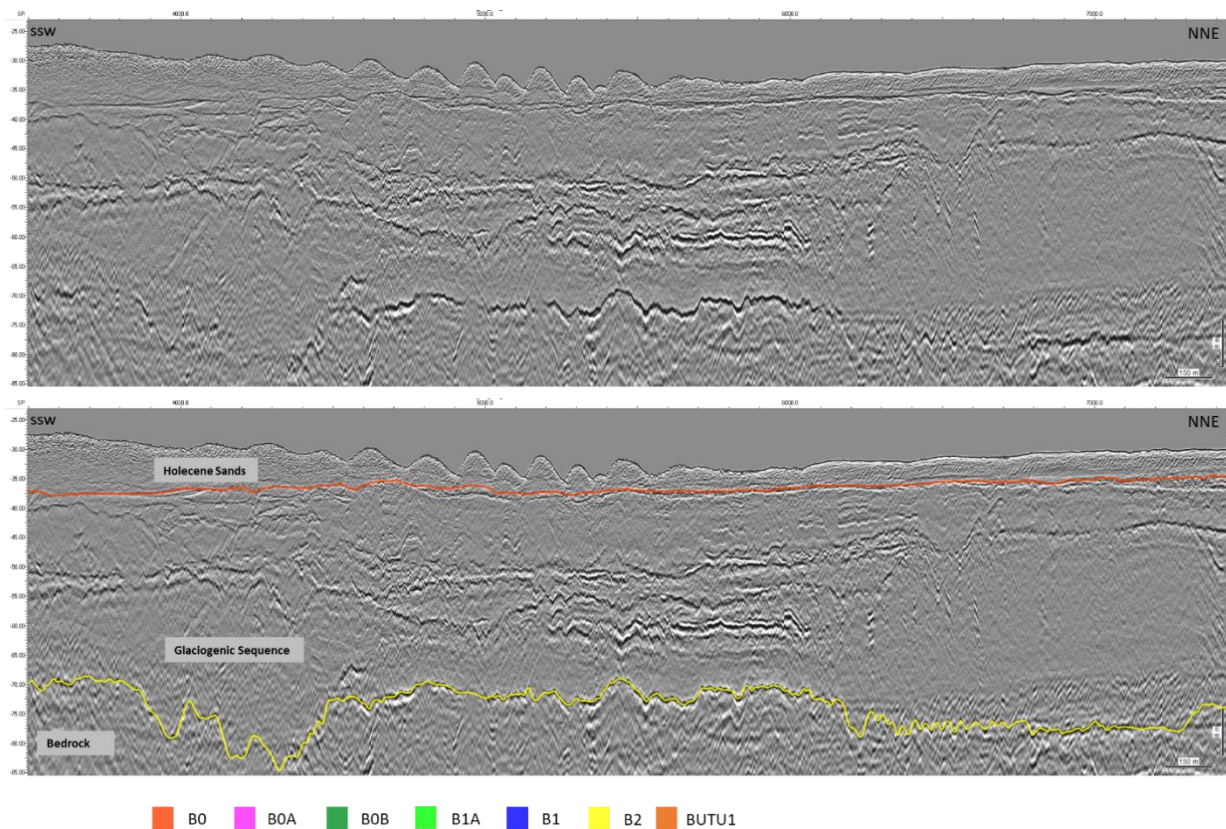


Figure 6 - Seismic profile depicting the three fundamental components of the geologic framework for the survey area, i.e., bedrock, Pleistocene glaciogenic sequence, and Holocene surficial sands. 2D Seismic line 24G02_RR_119_P1.

The Pleistocene glaciogenic sequence represents the bulk of sediments mapped across the site, in terms of total volume. All basic manners of glacial depositional environments are assumed to be present in the seismic data, i.e., subglacial, ice marginal, and proglacial settings (Figure 7). Most of the glaciogenic sediments are interpreted, generally, as diamict, largely till. However, glaciolacustrine and glaciomarine deposits are also present within the site, the former occupying basins incised into the underlying till. Many of the glaciogenic deposits exhibit seismic characteristics indicative of tectonism,

where internal stratigraphy is deformed, chaotic, or absent. The Quaternary deposits of previously glaciated continental shelves are the product of complex paleoenvironments. As such, the site's glaciogenic sediments are diverse and include clays, silts, sands, gravel and boulders.

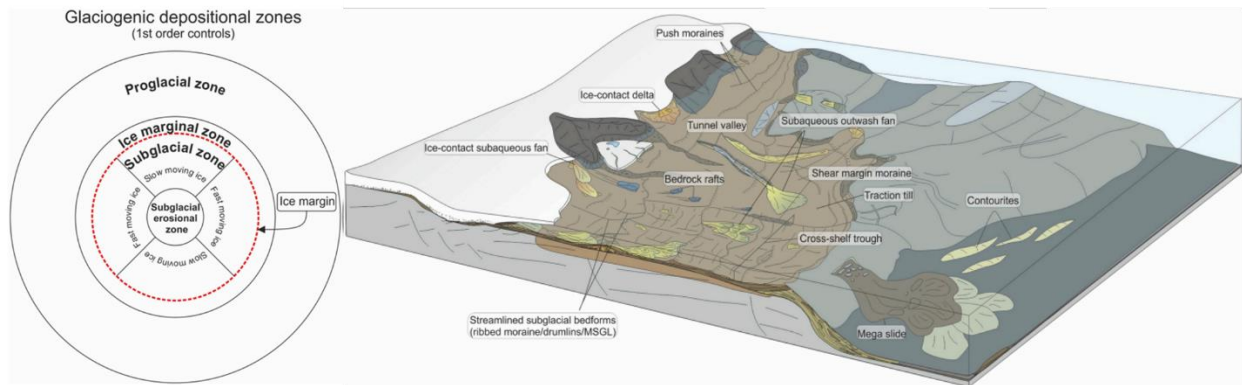


Figure 7 - Fundamental glaciogenic depositional zones that represent first-order controls on the type and degree of erosion and sedimentation in glaciated environments (left). A conceptual representation of glaciogenic deposits associated with a glacier terminating in a marine environment, as is the suspected case for the Irish Sea, south of the Isle of Man. Adapted from figures 3 and 6 in Kurjanski et al. (2019).

The Holocene deposits should be contained within the surficial unit, that is mostly sand and occasionally gravel. These sediments were deposited within an intertidal to marine environment beginning during the onset of the Holocene transgression and extend into modern highstand conditions. A considerable portion of the Holocene sediments are assumed to be mobile given the degree to which the surface of this deposit is occupied by sandwaves and ripples. Holocene deposits typically represent the seabed sediments. However, in some instances, glaciogenic deposits outcrop at the seafloor.

The formation names, geologic ages, and assumed depositional environments from the *Arklow Offshore Wind Farm INTERIM GROUND MODEL Report Rev 1*, derived from Mellett et al. (2015) were implemented in Geosurveys' interpretation and representation of the seismic units (Table 8). Notable deviations from said ground model are the classification of UOB as glaciogenic, potentially glaciolacustrine, and UOA as also being, at least partially, glaciogenic in nature.

Table 8 - The Quaternary geologic framework for the relevant area of the Irish Sea, Table 2-1 from Arklow Offshore Wind Farm INTERIM GROUND MODEL Report Rev 1, adapted from Mellett et al. (2015).

Geological Age	Geological Formation	Member / Facies	Depositional Environment	Soil Type
Holocene	Surface Sands Formation	Seabed depression member	Marine	Sand and clay
		Sediment Layer 1	Active Marine	Sand
		Sediment Layer 2	Intertidal to marine	Sand, silts and clay
Late Pleistocene (Weichselian)	Western Irish Sea Formation A	Codling Bank*	Proglacial	Cobbles and boulders
		Mud	Glaciomarine to marine	Silt with sand, patches of cobbles and boulders
		Prograded	Deltaic to glaciomarine	Sand
	Western Irish Sea Formation B	Mud	Glaciomarine to marine	Silt with sand, patches of cobbles and boulders
		Prograded	Deltaic to glaciomarine	Sand
		Chaotic	Glaciomarine to glaciolacustrine	Gravels with clay, sand, cobbles and boulders
	Cardigan Bay Formation	Upper Till	Glacial to subglacial	Diamict (clay to boulders)
		Bedded member	Proglacial	Silt overlying gravelly sand
		Infill member	Glacial channels infilled during deglaciation	Unknown
		Lower Till	Glacial to subglacial	Diamict (clay to boulders)
Mid-Late Pleistocene (Saalian to Eemian)	Cardigan Bay Formation	Bedded member	Proglacial	Silt overlying gravelly sand
		Infill member	Glacial channels infilled during deglaciation	Unknown
Mid Pleistocene (Saalian)	Cardigan Bay Formation	Lower Till	Glacial to subglacial	Diamict (clay to boulders)

4.3. SEISMIC UNIT DESCRIPTIONS

4.3.1. SEISMIC UNIT U0

Seismic unit U0, the base of which is delineated by B0, is interpreted as broadly corresponding to the *Surface Sands Formation* described within Mellett et al. (2015). The spatial distribution and depth LAT of unit's base are presented in Figure 8. U0 is present across the majority of the survey area and ranges in thickness from 0.18 m to 18.67 m a thin sediment veneer that may exceed the lower limit of seismic resolution. U0 is locally absent in the northern extent of the survey area and along the western margin of the site. The absence of U0 may be attributable to sediment transport, namely scour, that has removed the Holocene surficial sands, possibly exposing Pleistocene glaciogenic sediments at the seabed. These areas, i.e., Pleistocene outcrops, may be more prone to the occurrence of gravel, cobbles and boulders at the seabed.

The base of U0, represented by the seismic horizon B0, is an erosional surface that is interpreted as being, at least in part, a ravinement surface (Figure 9). However, the mechanism by which this ravinement surface was cut, e.g., waves or tides, is not clear. Additionally, it is reasonable to assume that the surface represented by B0 is the product of an amalgamation of erosional processes, transgressive ravinement being only one.

Geotechnical data, i.e., cone penetrometer testing, indicates that U0 is comprised mostly of sandy sediments. However, in some instances, U0 may contain a substantial fraction of finer sediments, e.g., silts. Gravelly sediments may also be present within U0, particularly near its base (Figure 10).

The top surface of U0, that corresponds to seabed, is replete with evidence for vigorous sediment transport (Figure 11). Large sandwaves and other subaqueous dune features are common to the survey area, that grow in size and prevalence in the southerly direction. Even at the resolution of the seismic data, the superimposition of smaller sediment ripples on more massive sandwaves is clearly evident. These compound dune structures suggest a seabed dynamism where current vectors vary through time and space.

Based on the seismic interpretation, seismic unit U0 is present in the WTG 3D volumes listed in Table 9.

2D & 3D UHRS INTERPRETATION REPORT

Table 9 - List of WTGs where seismic unit U0 is present.

Seismic Unit U0							
OSPN	WT07	WT17	WT26	WT35	WT45	WT108	WT146
OSPS	WT08	WT18	WT27	WT36	WT46	WT113	GERE
WT01	WT09	WT19	WT28	WT37	WT47	WT117	
WT02	WT10	WT20	WT30	WT38	WT50	WT122	
WT03	WT12	WT21	WT31	WT39	WT51	WT130	
WT04	WT13	WT22	WT32	WT40	WT52	WT134	
WT05	WT14	WT23	WT33	WT41	WT54	WT139	
WT06	WT16	WT24	WT34	WT43	WT55	WT141	

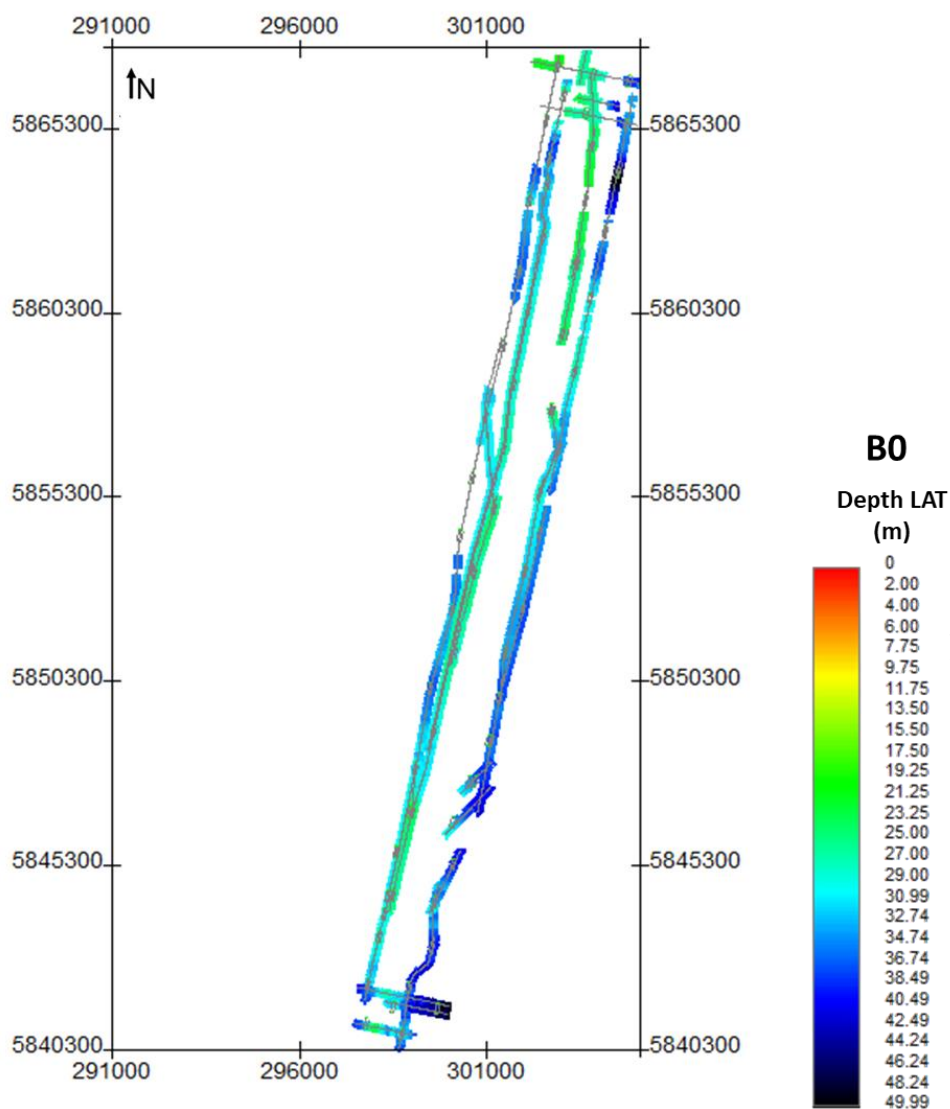


Figure 8 - Spatial extent of mapped horizon B0, referenced to LAT (in metres).

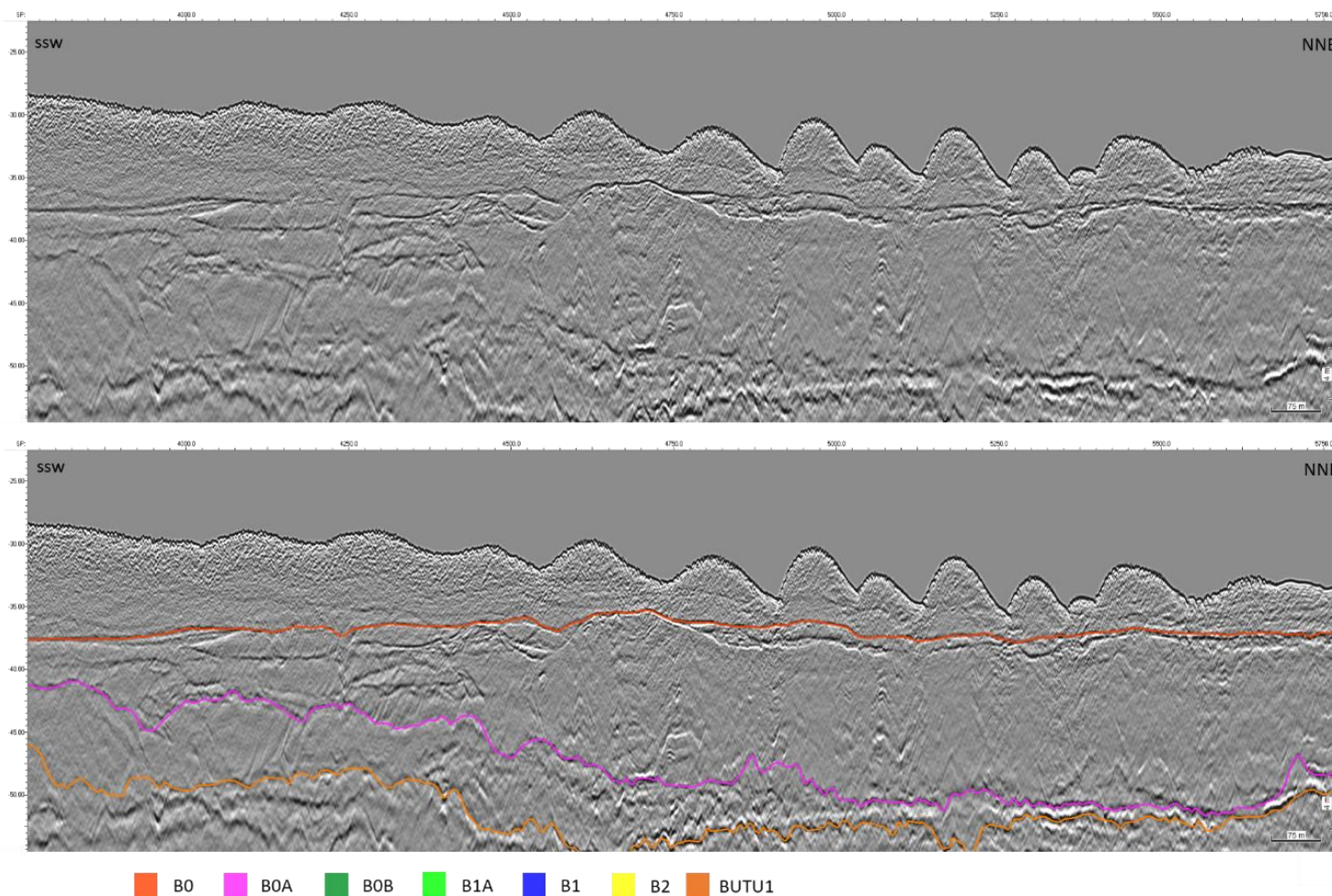


Figure 9 - Seismic profile depicting an example of U0 that corresponds to the Surface Sands Formation. The sediments of U0 are mostly sand, but may also contain gravel deposits. 2D Seismic line 24G02_RR_119_P1.

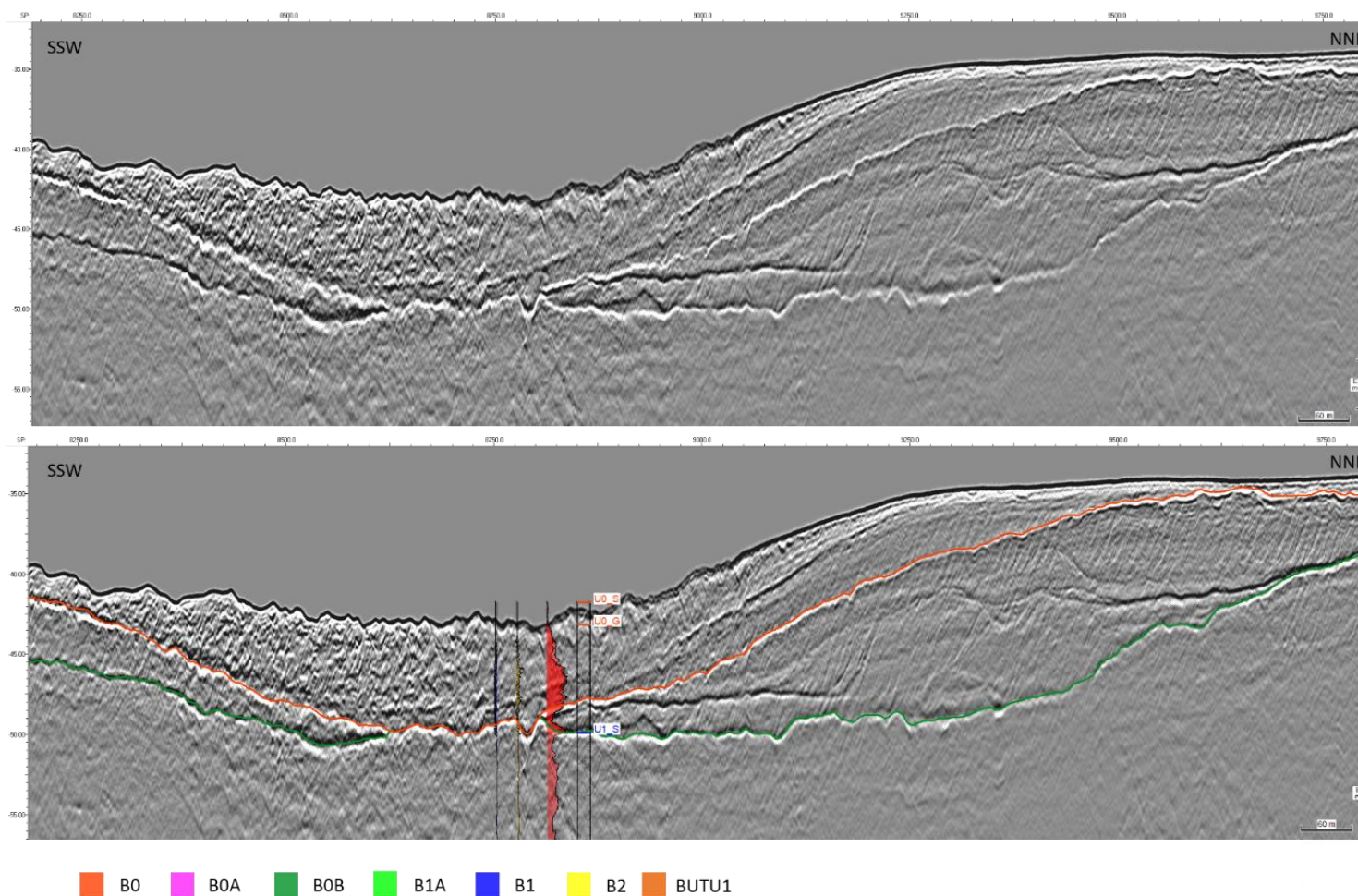


Figure 10 - Seismic profile depicting the surficial sands and gravel that comprise the deposits of U0. According to the formation tops and CPT data, surficial sands grade into gravels below the seabed. 2D Seismic line 24G02_RR_119_P2, CPT008.

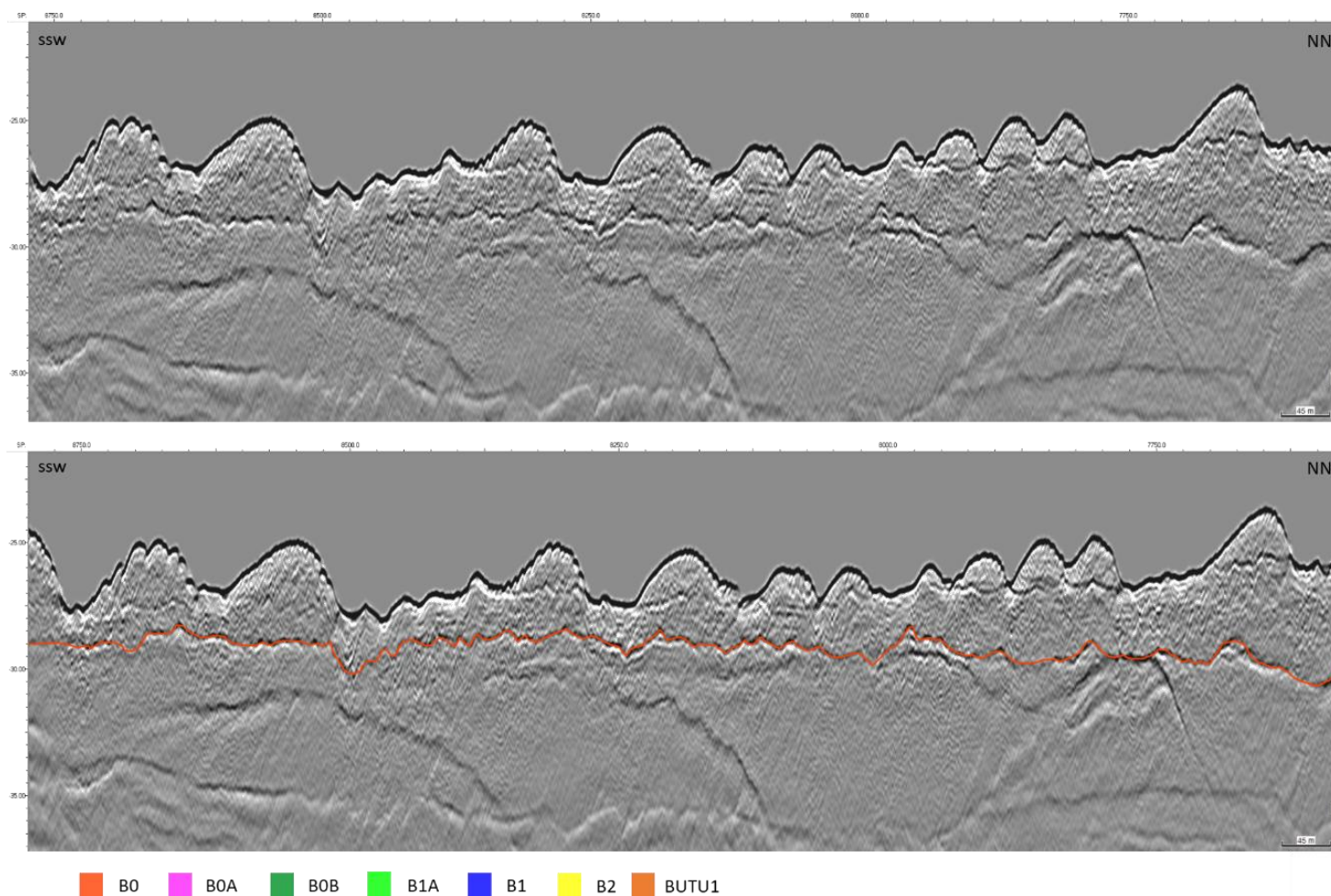


Figure 11 - Seismic profile depicting large subaqueous dunes with smaller, superimposed, sand ripples that are common at the surface of U0. These types of sediment bedforms are the result of energetic sediment transport. 2D Seismic line 24G02_RR_203.

4.3.2. SEISMIC UNIT U0A

Seismic unit U0A, the base of which is delineated by B0A, is interpreted as broadly corresponding to constituents of the *Western Irish Sea Formations* (WISF) as described within Mellett et al. (2015). The spatial distribution and depth LAT of unit's base are presented in Figure 12. Generally speaking, the WISF are comprised of glaciogenic sediments, to include glaciolacustrine, glaciomarine, and otherwise proglacial deposits. U0A is present across the majority of the site and ranges in thickness from 1.06 m to 26.62 m. U0A is typically overlain by U0, i.e., the *Surface Sands Formation*, but may also outcrop at the seabed where scour is most intense.

The seismic facies of U0A is complex, pointing to a diverse and dynamical depositional environment that is consistent with a proglacial setting (Figure 13). U0A contains manifold erosional surfaces that may be attributable to several mechanisms belonging to both glacial and marine processes. According to Mellett et al. (2015) and references therein, the Irish Sea Ice Stream terminated in a marine environment, south of the Isle of Man. If true, differing opinions are presented in McCarroll (2001) and Scourie and Furze (2001), then U0A may be comprised of sediments from meltwater deltas, ice-contact fans, subaqueous fans, outwash deposits, sediment plumes, and ice-rafted debris (Kurjanski et al. 2019 and Huuse et al. 2015).

If a glaciomarine environment were to have been predominate, then a channelized outwash plain should be lacking in these data. This is, for the most part, consistent with the seismostratigraphy of B0A, with some notable exceptions. The type of pattern in the seismic data shown in Figure 14, could be interpreted as a stacked channel sequence, the kind that typify subaerial, glaciofluvial outwash plains. However, multiple other interpretations might be valid. Such as, subglacial channelization, i.e., drainage networks, or intricate deformation resulting from glaciotectonism. Alternatively, and an important possibility, is that U0A may contain Holocene sediments, reworked in a hyper-energetic marine environment. This complicated stratigraphy may be the record of migration and intermingling of subaqueous dunes.

According to the geotechnical data U0A is mostly comprised of sandy deposits that correspond to a (semi)transparent or hummocky seismic facies within the unit (Figure 15). Locally, gravel deposits occur within U0A, typically in its uppermost sediments. U0A, occasionally, exhibits organized stratigraphy represented by a layered facies. Where thin layering is present in U0A, silts and clays are inferred from the CPT data, potentially representing varved deposits. Glaciotectonism is also interpreted within U0A, having been induced within the proglacial environment by periodic readvancements of the glacial margin (Figure 16).

Based on the seismic interpretation, seismic unit U0A is present in the WTG 3D volumes listed in Table 10.

2D & 3D UHRs INTERPRETATION REPORT

Table 10 - List of WTGs where seismic unit U0A is present.

Seismic Unit U0A						
OSPN	WT17	WT28	WT37	WT46	WT113	WT146
OSPS	WT18	WT29	WT38	WT47	WT117	GERE
WT01	WT20	WT30	WT39	WT48	WT122	
WT03	WT21	WT31	WT40	WT49	WT130	
WT04	WT22	WT32	WT41	WT50	WT134	
WT06	WT23	WT33	WT42	WT51	WT139	
WT09	WT24	WT34	WT43	WT53	WT141	
WT13	WT26	WT35	WT44	WT54	WT142	
WT16	WT27	WT36	WT45	WT55	WT144	

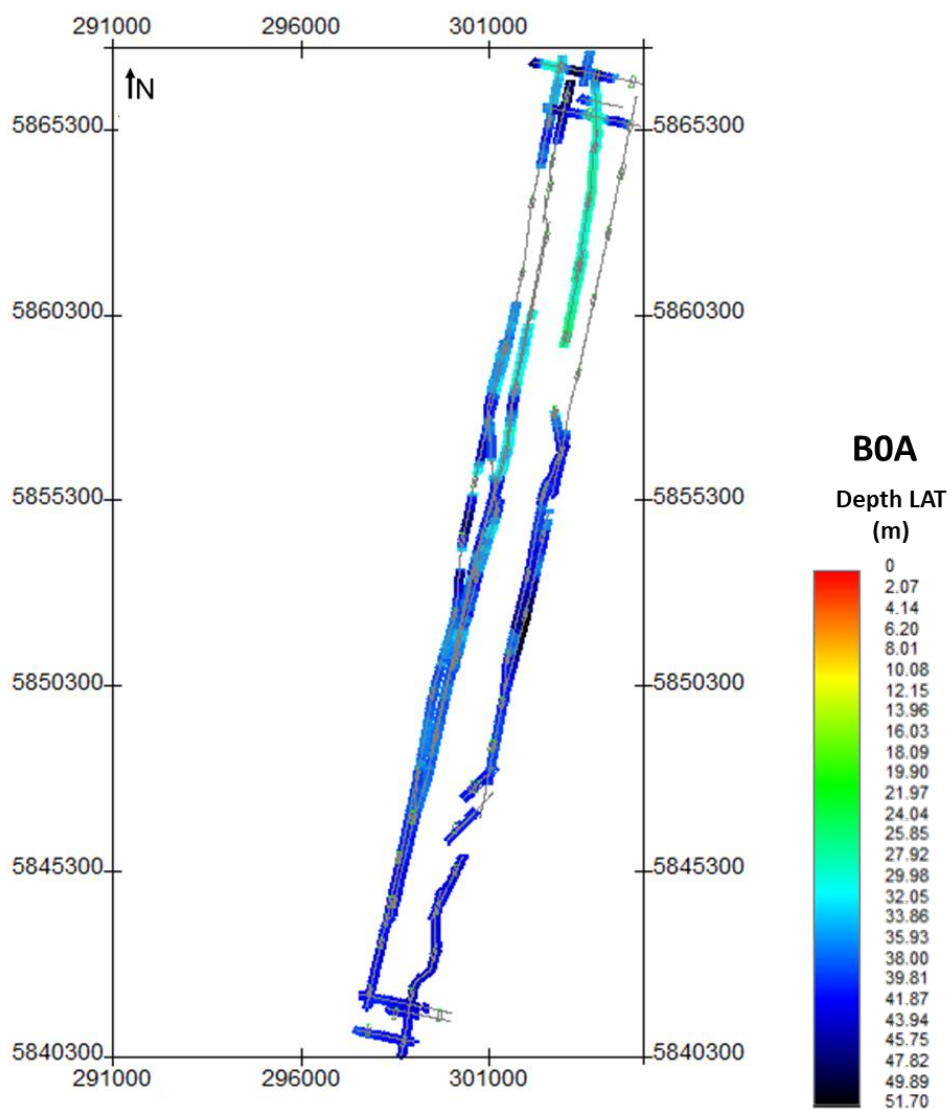


Figure 12 - Spatial extent of mapped horizon B0A, referenced to LAT (in metres).

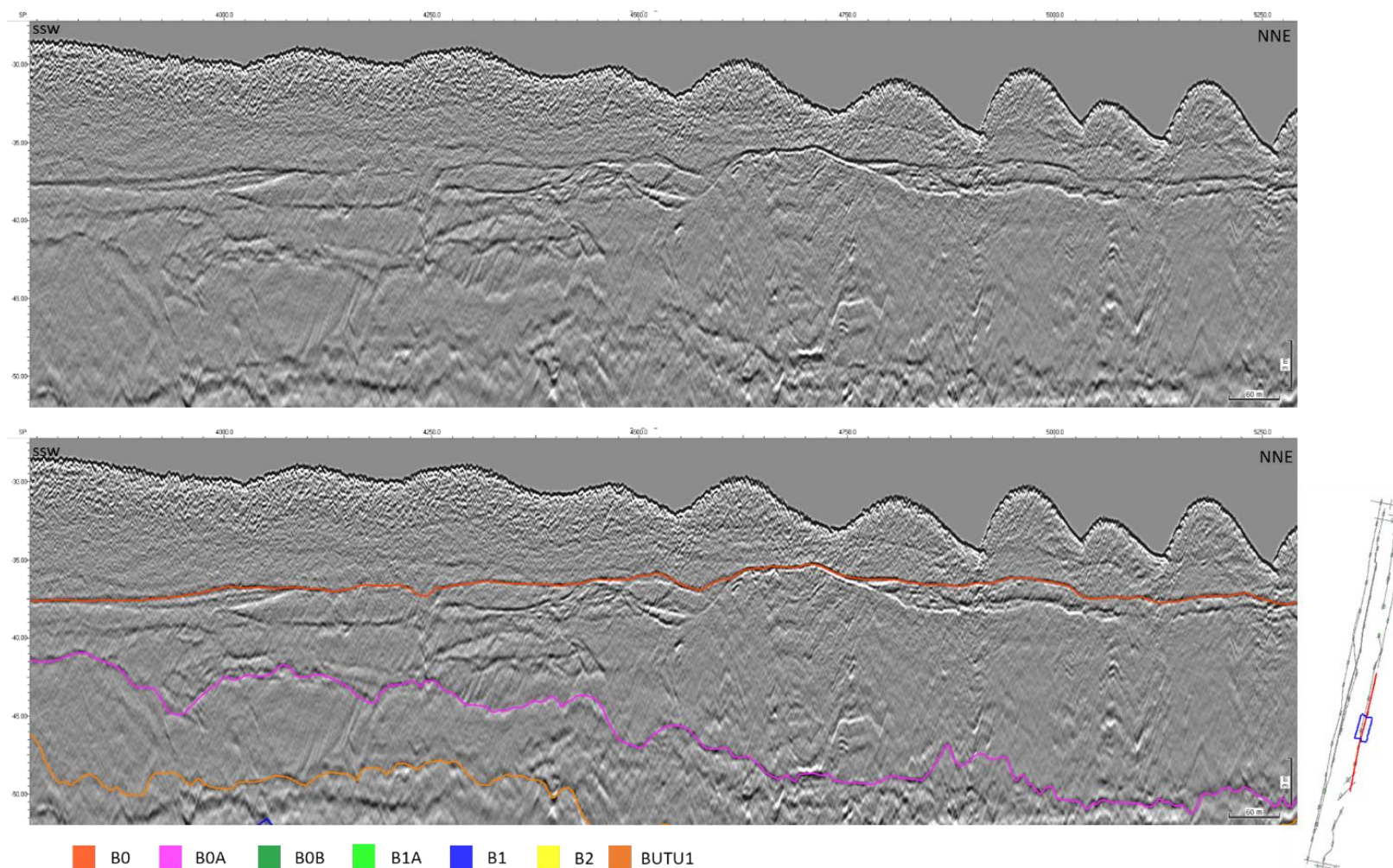


Figure 13 - Seismic profile depicting the manifold erosional surfaces and general complexity of the U0A seismic facies. 2D Seismic line 24G02_RR_119_P1.

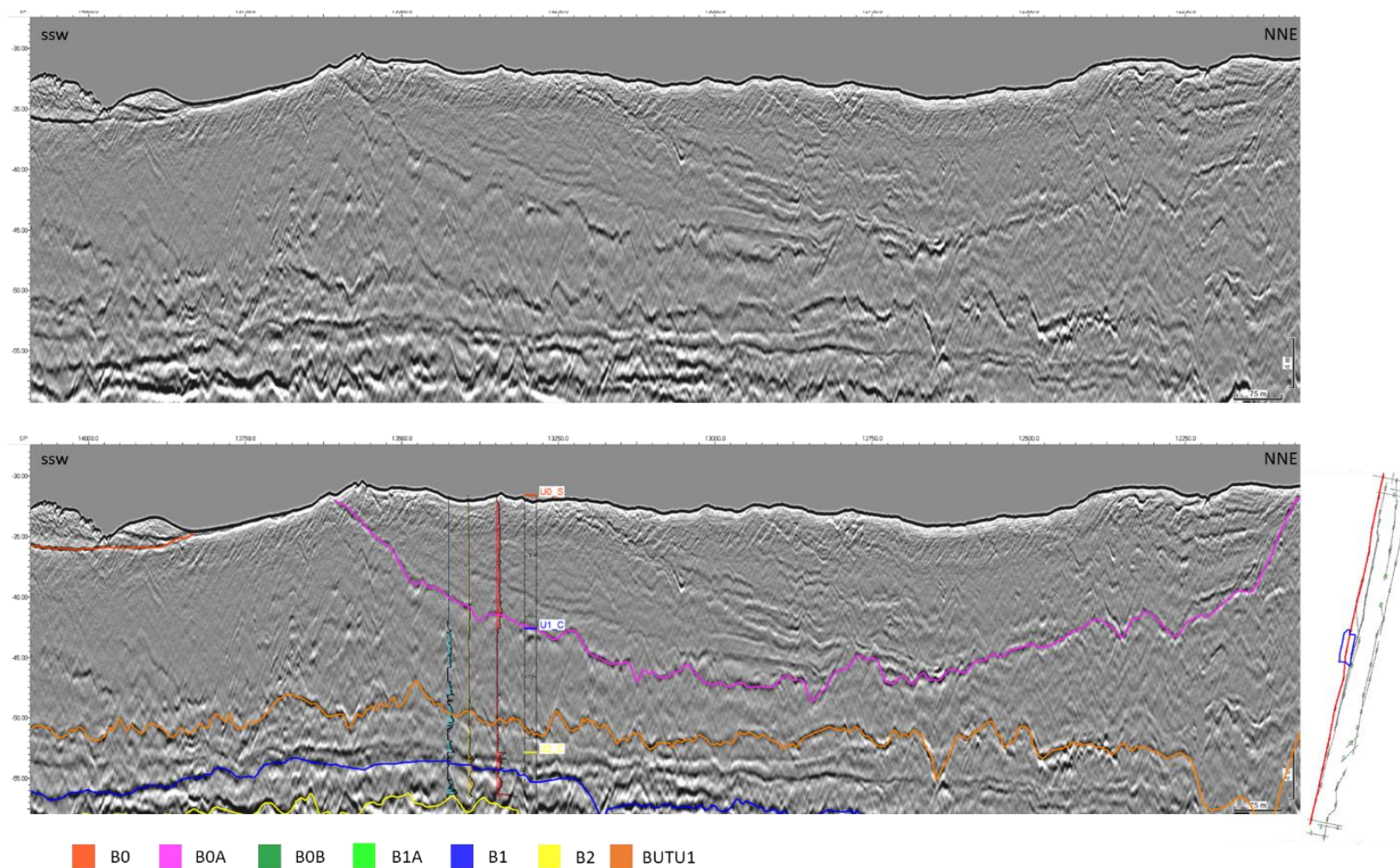


Figure 14 - Seismic profile depicting the intricate seismic facies that is locally present within U0A. Multiple interpretations may be ascribed to this complicated internal geometry, e.g. channelization, internal subaqueous dune structure, and glaciotectonism. 2D Seismic line 24G02_RR_200.

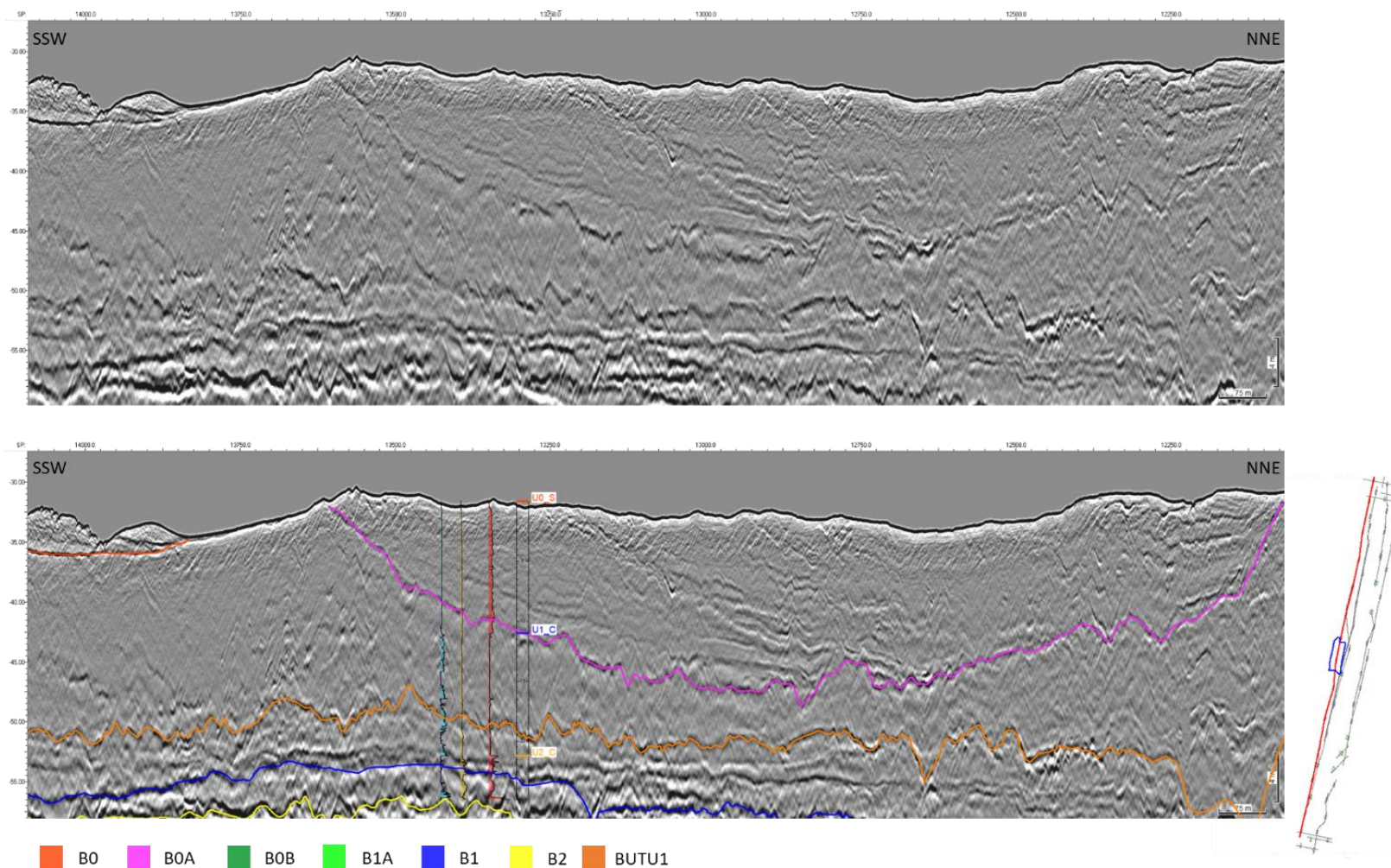


Figure 15 - Seismic profile with CPT data depicting the sandy deposits that represent the majority of sediments within U0A. 2D Seismic line 24G02_RR_007, CPT029.

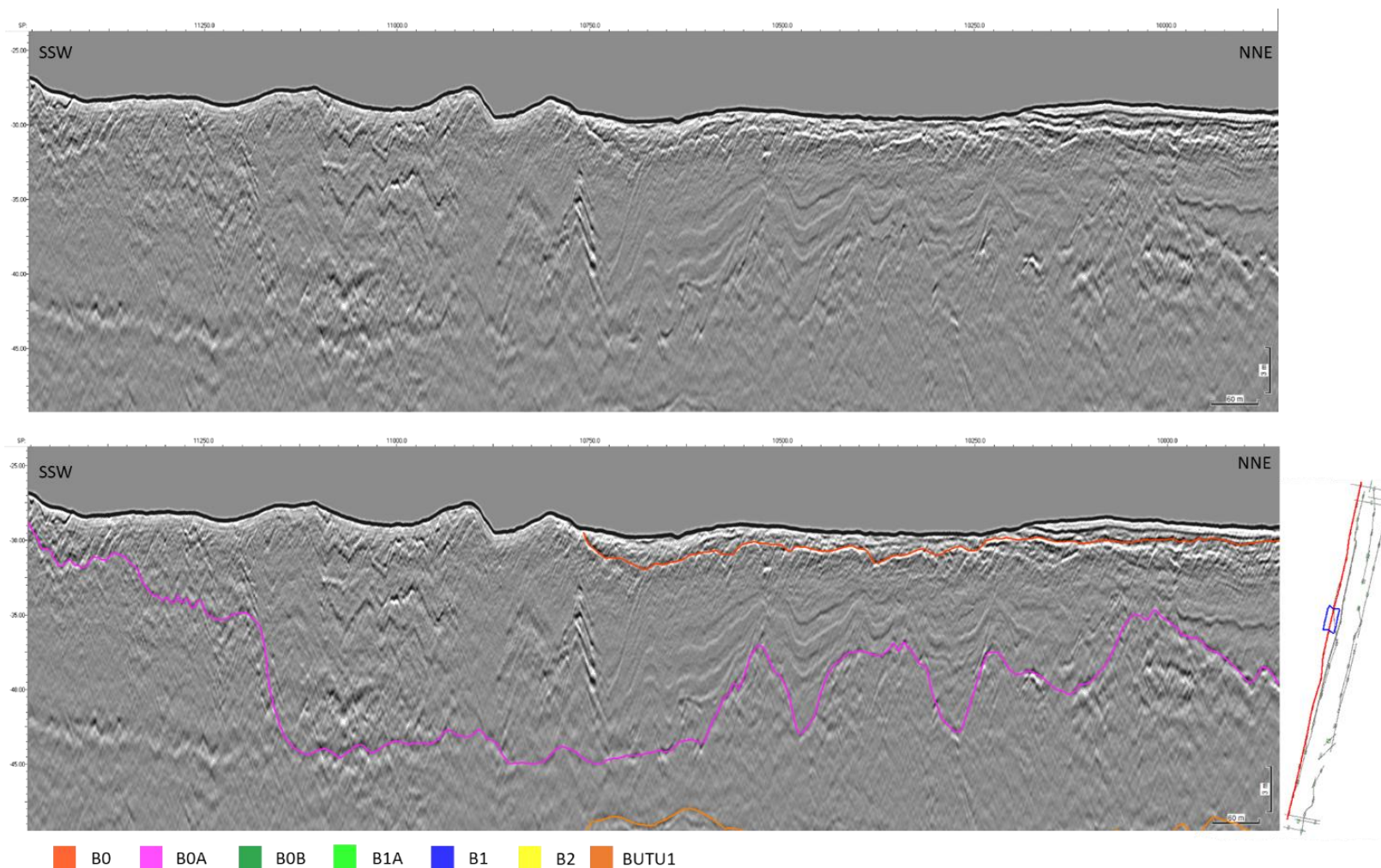


Figure 16 - Seismic profile depicting apparent deformation related to glaciotectionism that is occasionally present within U0A. 2D Seismic line 24G02_RR_007.

4.3.3. SEISMIC UNIT U0B

Seismic unit U0B, the base of which is delineated by B0B, is interpreted as corresponding to specific elements of the *Western Irish Sea Formations* (WISF) as described within Mellett et al. (2015), namely glaciolacustrine deposits. The spatial distribution and depth LAT of unit's base are presented in Figure 17. U0B is constrained to the northern extent of the site where it appears within a basin feature, with thickness varying from 27.44 m to 63.86 m.

The base U0B is a prominent erosional surface in the data that marks an abrupt transition in seismic facies (Figure 18). The U0B facies, fine layering and acoustic transparency, suggest deposition in a quiet, low energy environment, consistent with distal regions of a proglacial lake. Underlying U0B is U1 that displays contorted and chaotic facies, indicating a tectonized diamict, likely till. We speculate that the advancement of ice incised existing till deposits, that upon glacial retreat formed basins, providing the accommodation space for proglacial lakes. Laterally continuous, thin bedding is common within U0B, consistent with varved clays.

According to the geotechnical data U0B is comprised of clays and sand (Figure 19). Clayey sediments are predominant where U0B is thickest, and may represent varved deposits. Sands become more prevalent at the margins of U0B where it is thinner. In some instances, sandier sediments overlie the deeper clay deposits, possibly the result of high-energy glacial outwash processes.

Based on the seismic interpretation, Seismic unit U0B is present in the WTG 3D volumes listed in Table 11.

2D & 3D UHR5 INTERPRETATION REPORT

Table 11 - List of WTGs where seismic unit U0B is present.

Seismic Unit U0B					
VOSP	WT05	WT07	WT08	WT10	WT12
WT14	WT16	WT17	WT19	WT108	WT117

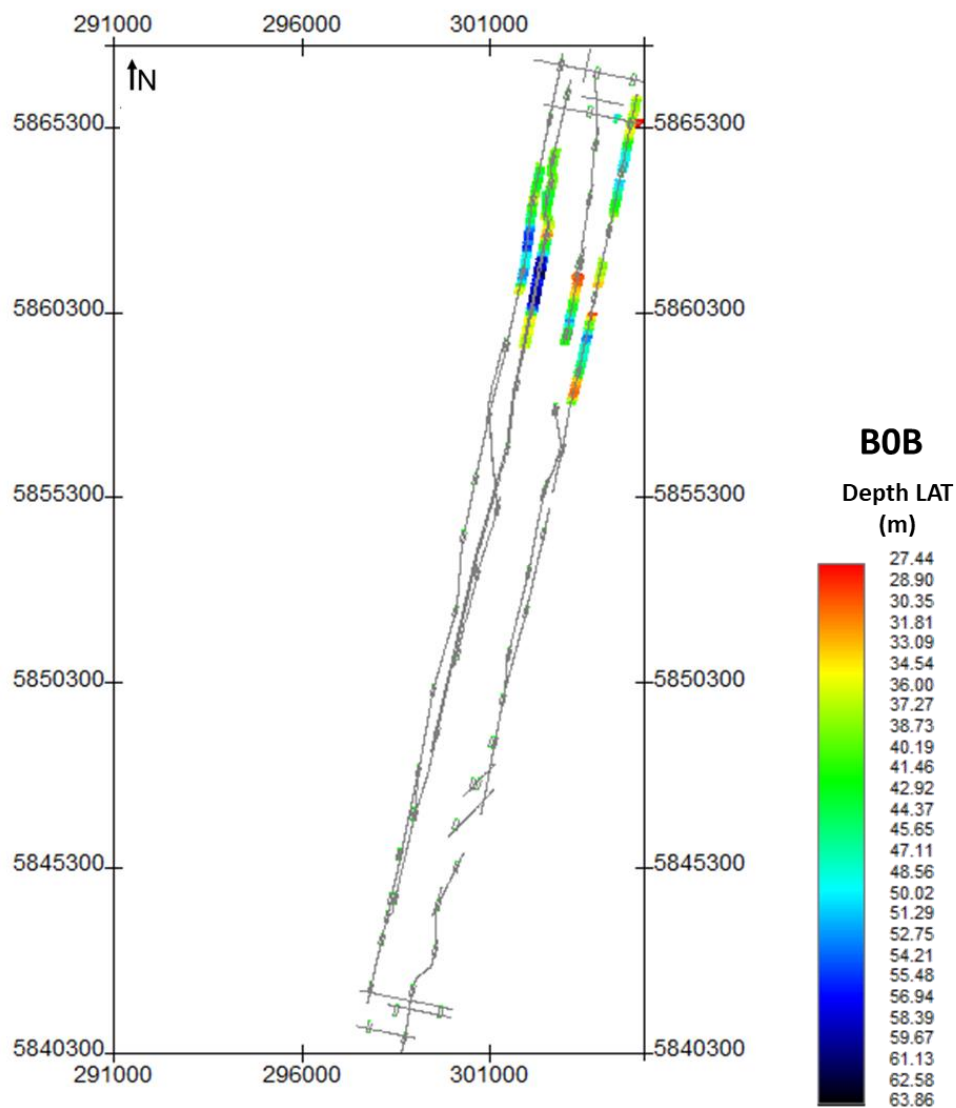


Figure 17 - Spatial extent of mapped horizon B0B, referenced to LAT (in metres).

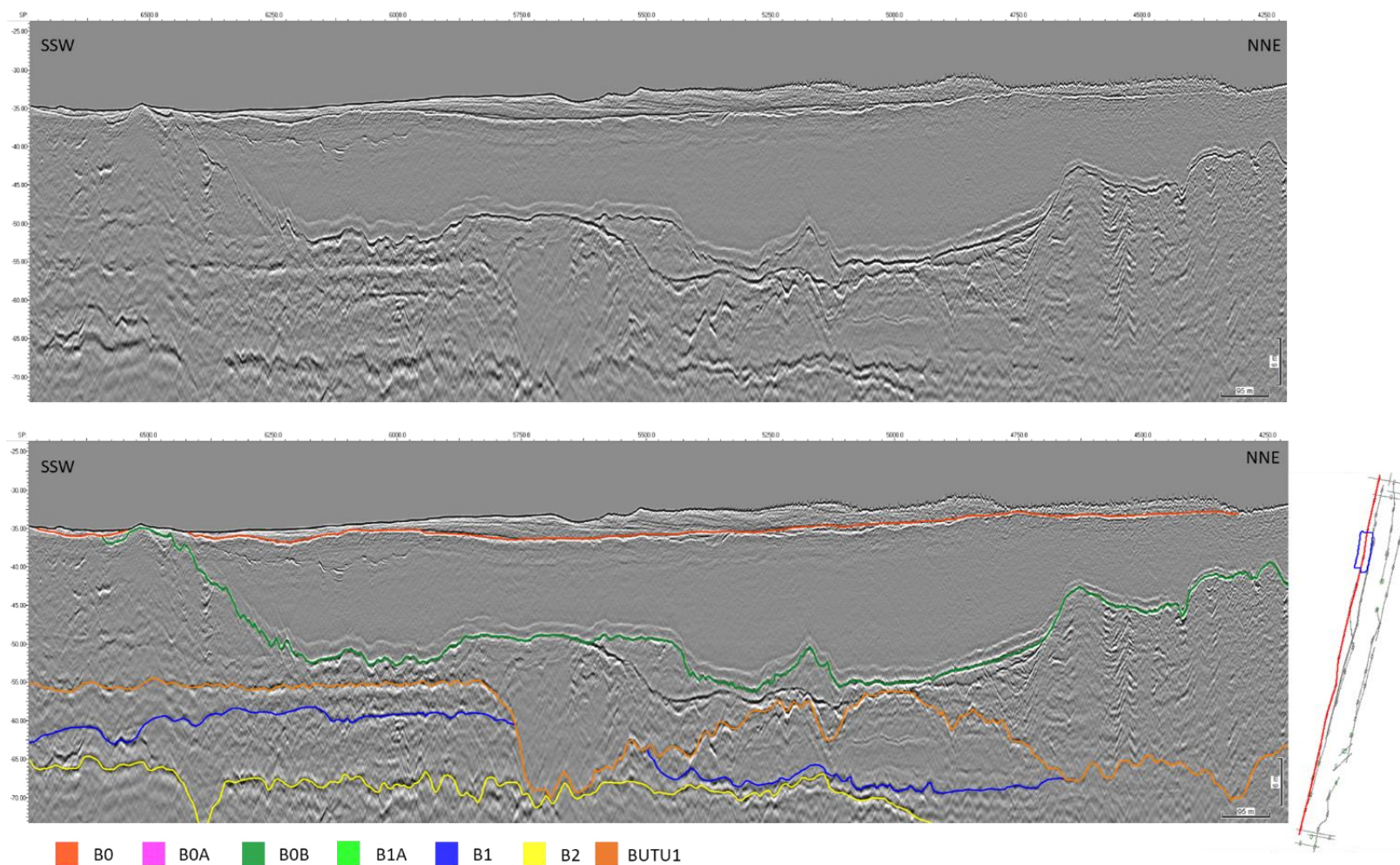


Figure 18 - Seismic profile depicting the transparent facies that is common to UOB, potentially representing glaciolacustrine deposits. 2D seismic line 24G02_RR_007.

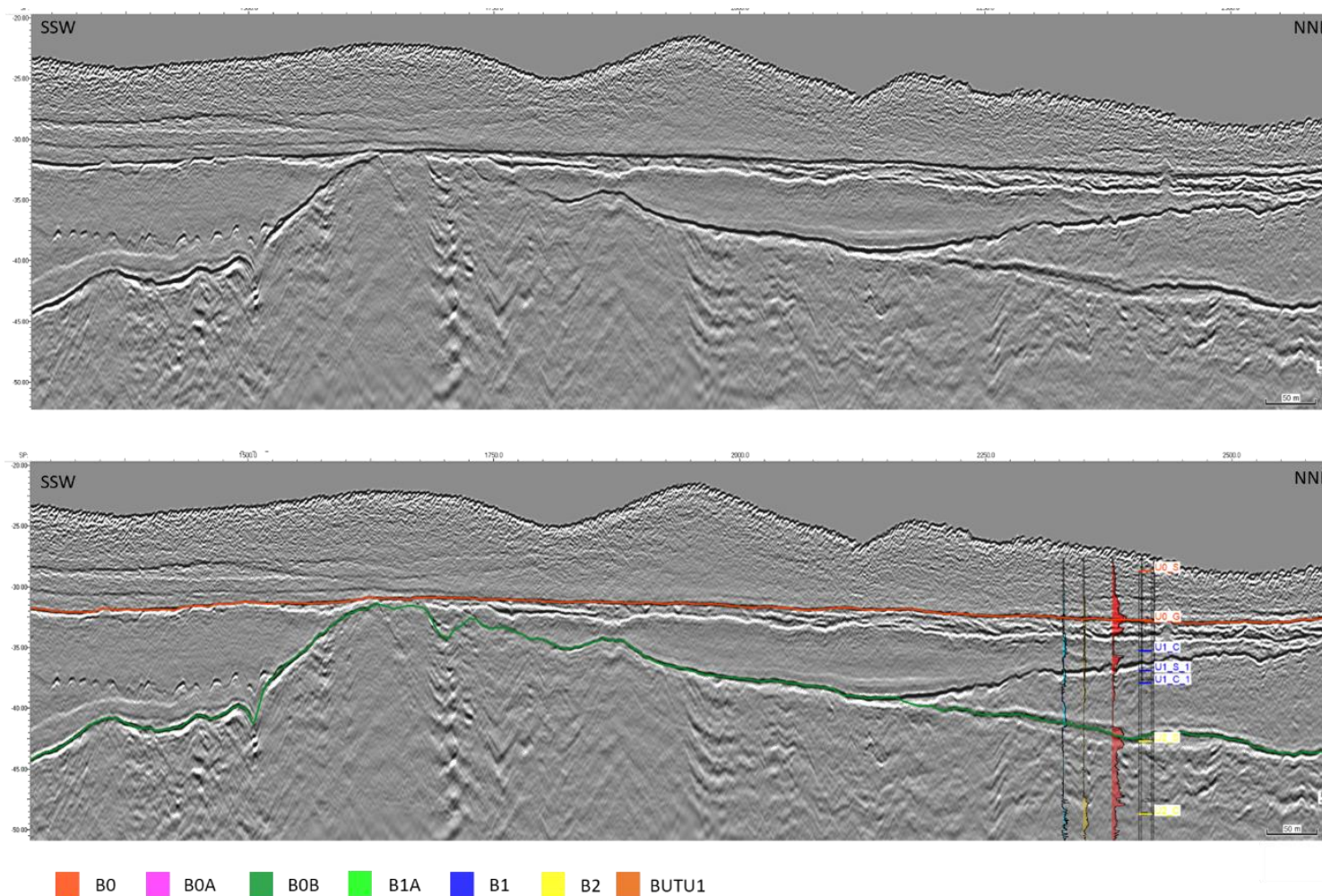


Figure 19 - Seismic profile depicting the clayey sediments that are prevalent within U0B. Often, the soft clays of U0B are overlain by stiffer, sandy sediments. 2D Seismic line 24G02_RR_200_A, CPT091.

4.3.4. SEISMIC UNIT U1A

Seismic unit U1A, the base of which is delineated by B1A, is interpreted as corresponding to specific elements of the *Western Irish Sea Formations* (WISF) as described within Mellett et al. (2015). The spatial distribution and depth LAT of unit's base are presented in Figure 20. U1A is constrained to the southern extent of the site, where it varies in thickness from 0.10 m to 18.02 m. U1A is proposed to be a glaciolacustrine or glaciomarine deposit.

Foreset bedding is interpreted within U1A that is indicative of deltaic deposition (Figure 21). Deltaic deposits of this sort commonly occur within the confines of proglacial lakes. However, it is also possible that such deposits (delta foresets) might occur within a glaciomarine environment. Additionally, much of the seismic facies of U1A is disorganized or incoherent, e.g., semi-transparency, hummocky, and chaotic, that is more in line with a glaciomarine interpretation rather than glaciolacustrine (Figure 22).

According to the geotechnical data U1A is comprised of sands and clays. The sandier sediments of U1A appear to be finer, and less resistant in CPT terms, than the overlying surficial sands. When clay is present within U1A it tends to occur near the base of the unit and is overlain by the sandy deposits (Figure 23).

Based on the seismic interpretation, Seismic unit U1A is present in the WTG 3D volumes listed in Table 12.

Table 12 - List of WTGs where seismic unit U1A is present.

Seismic Unit U1A									
OSPS	WT45	WT47	WT48	WT49	WT50	WT51	WT52	WT53	WT54

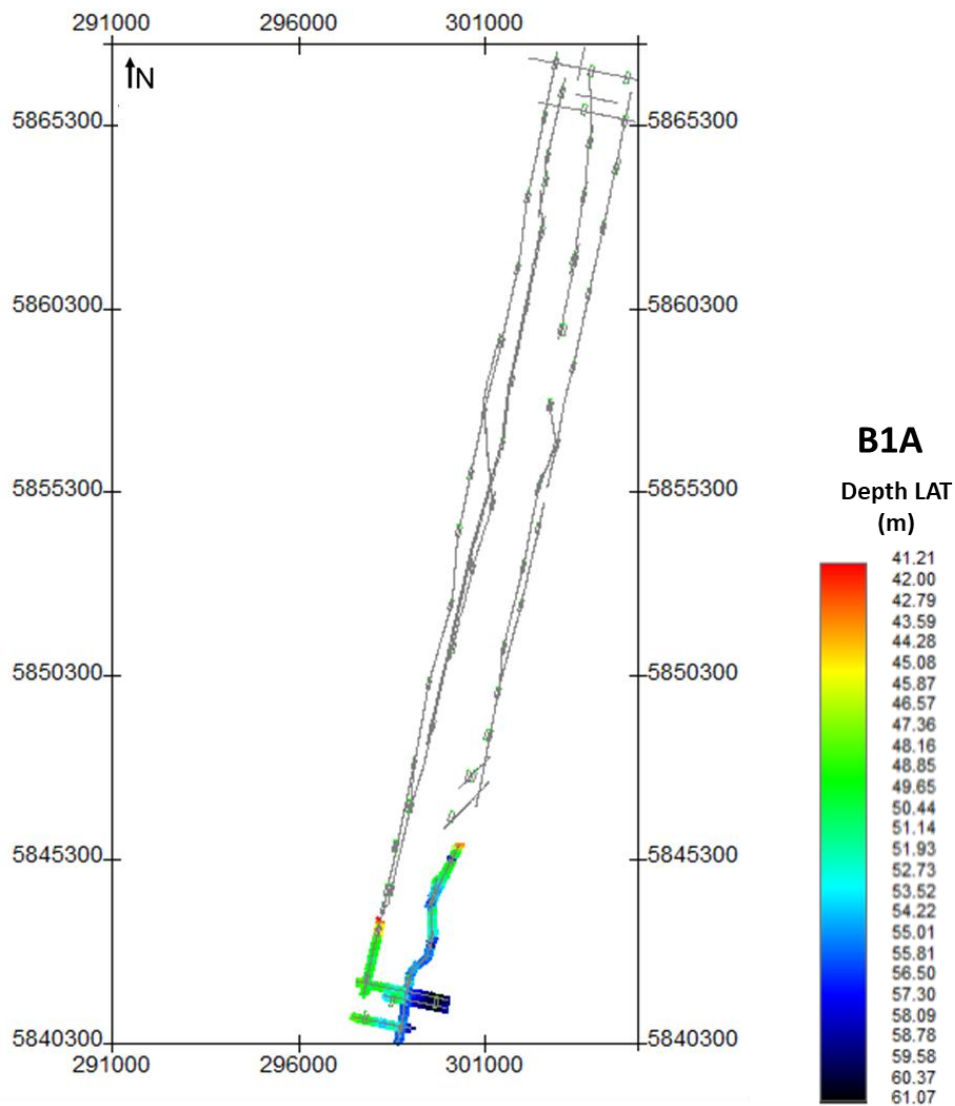


Figure 20 - Spatial extent of mapped horizon B1A, referenced to LAT (in metres).

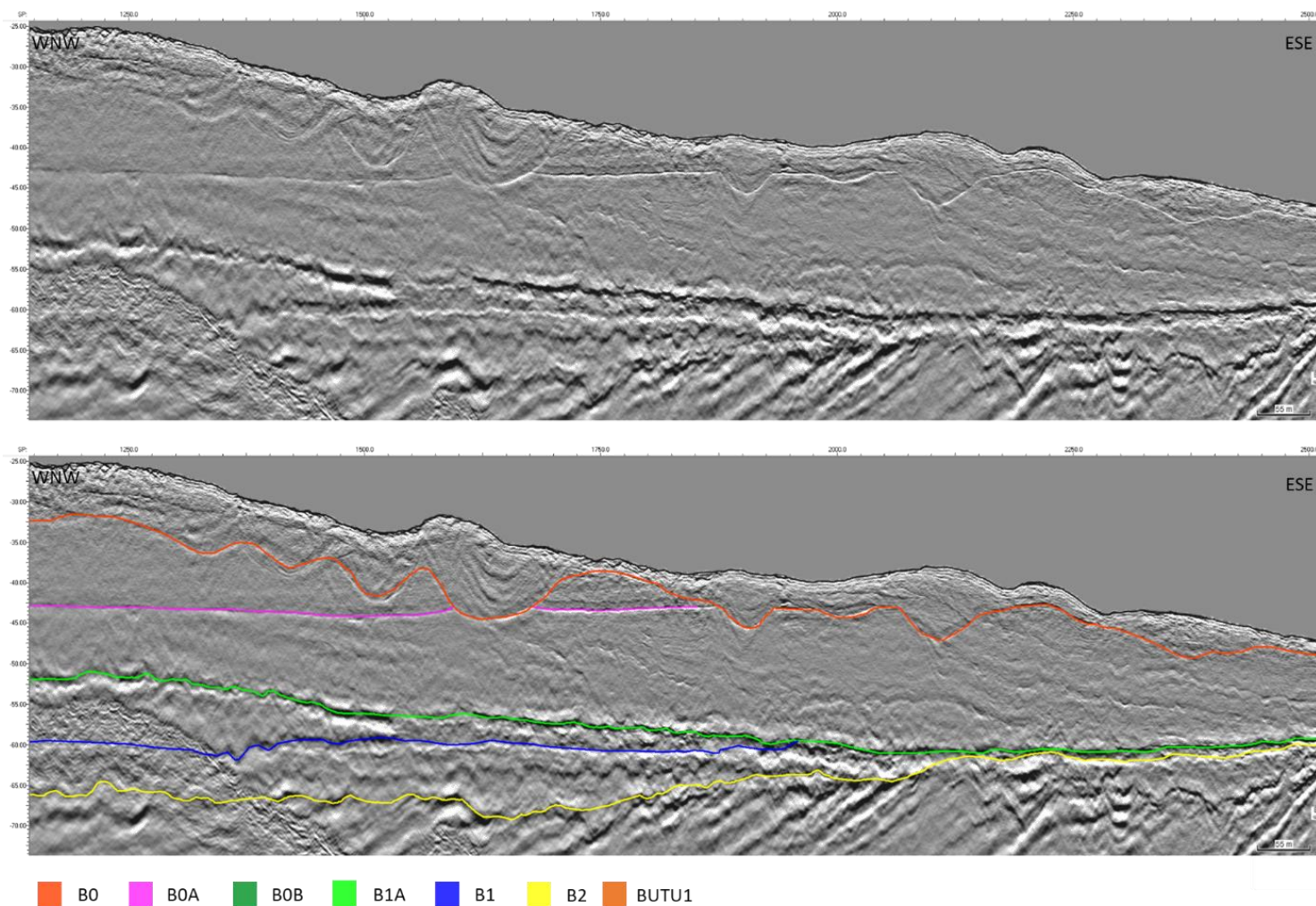


Figure 21 - Seismic profile depicting foreset bedding suggestive of deltaic deposition. These deposits may represent deltaic input to either a glaciomarine or glaciolacustrine environment. 2D Seismic Line 24G02_LK_XL_09.

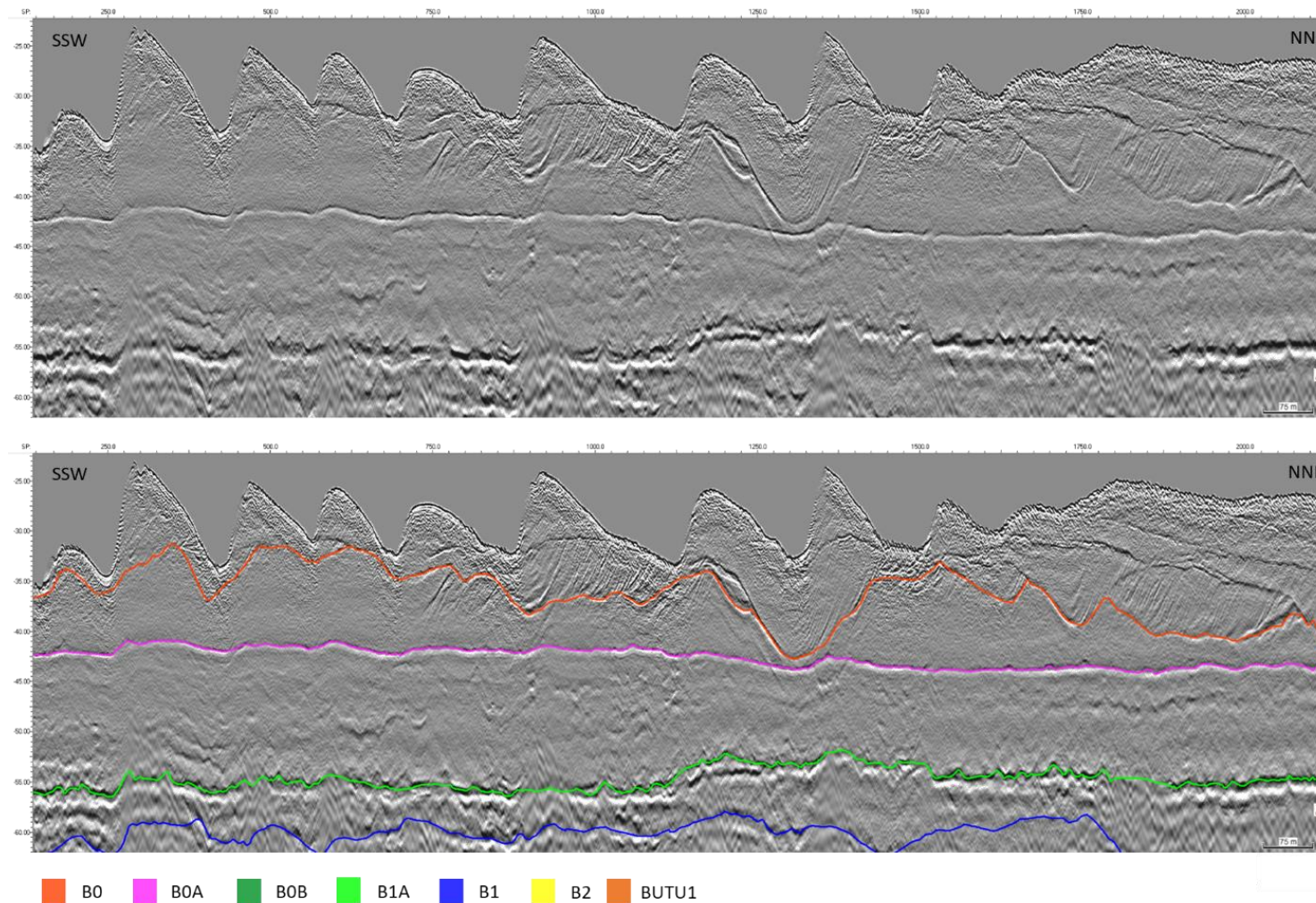


Figure 22 - Seismic profile depicting the typical facies of U1A that is mostly incoherent and possibly indicative of glaciomarine deposition. 2D Seismic line 24G02_RR_059_R1.

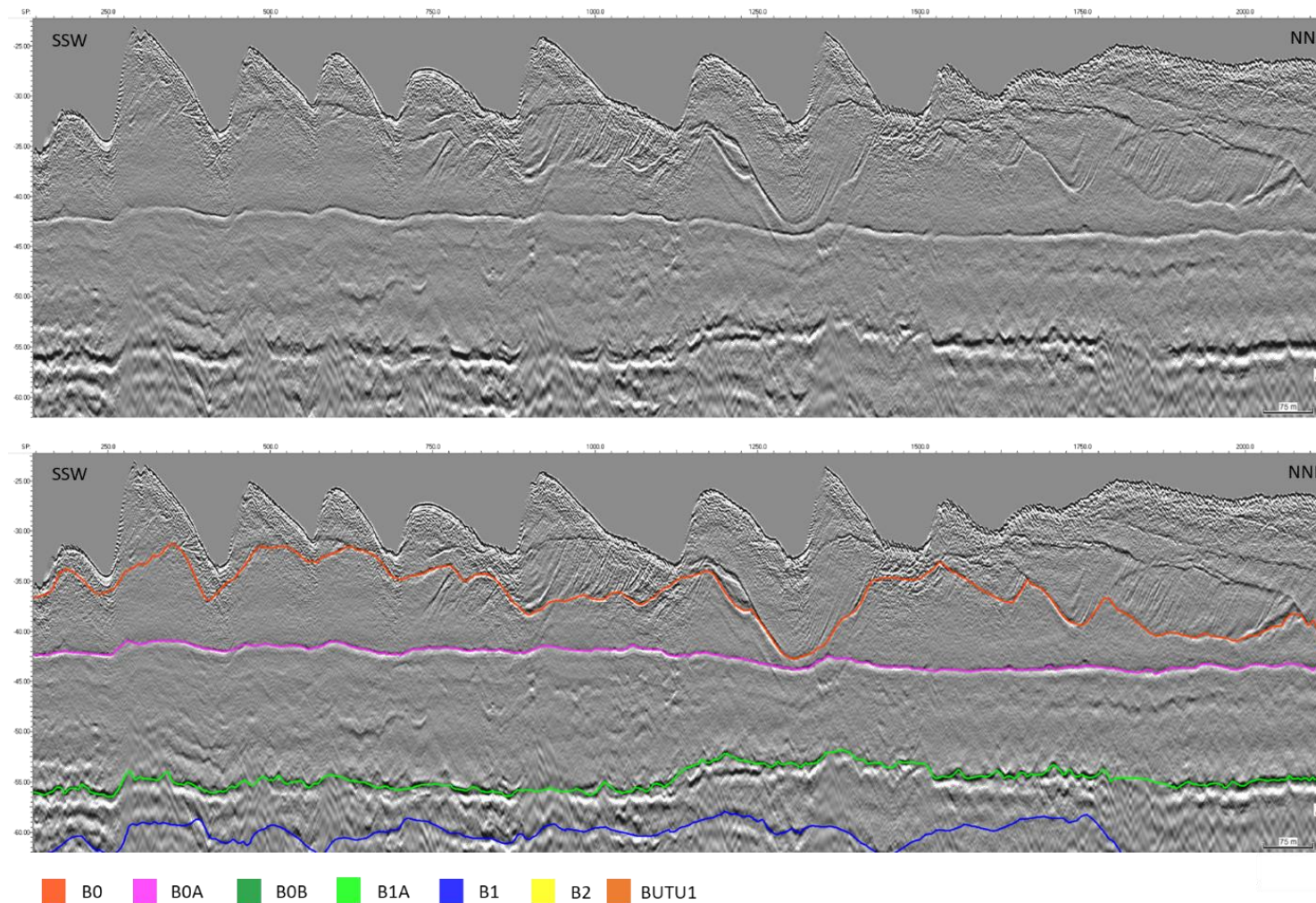


Figure 23 - Seismic profile and CPT data depicting sands overlying clayey sediments that is a common sequence within U1A. 2D Seismic line 24G02_RR_059_R1, CPT048b-c.

4.3.5. SEISMIC UNIT U1

Seismic unit U1, the base of which is delineated by B1, is interpreted as possibly corresponding to constituents of the *Cardigan Bay Formation* (CBF) as described within Mellett et al. (2015). U1 is a composite unit in that it contains two distinguishable sediment deposits or formation members. The two members are separated by Horizon BUTU1 in the 2D ground model seismostratigraphic framework, and by U1-internal horizons in the 3D volumes. The spatial distribution and depth LAT of horizons B1 and BUTU1 are presented in Figure 24 and Figure 25, respectively. The lower member of U1, that which typically occurs directly above B1 (Figure 26), is interpreted as potentially representing the Bedded and/or Infill members of the CBF. However, there does appear to be some ambiguity as to whether these deposits are confirmed in the western Irish Sea.

The basal deposits of U1, i.e., the Bedded Member, varies widely in thickness and periodically exhibits (semi)coherent acoustic stratigraphy, such as layered facies, and horizontal reflections with extended lateral continuity (Figure 27). As such, these deposits are unlikely to be strictly diamictic, but should still be glaciogenic, and according to Mellett et al. (2015), the Bedded Member is comprised of silts and gravelly sands. CPT data from the basal deposits of U1 also reflect a bedded structure with sand and clay components (Figure 28).

The upper deposits of U1 are interpreted as potentially representing the Upper Till Member of the CBF. Even if the assignment of these deposits to the CBF is incorrect, their interpretation as diamicts, namely tills, remains likely. The seismic character and facies of the upper section of U1 is consistent with that of tills and glacioteconites. The seismic facies range from chaotic to (semi)transparent, indicating a lack of coherent stratification that is diagnostic of tills and diamicts more generally (Figure 29). Additionally, the seismic data displays potential thrusts and acute deformation suggesting widespread glacioteconism throughout this part of the unit.

The sedimentological composition of this deposit shows spatial heterogeneity and is comprised of sediments ranging from clays to sands, according to the CPT data (Figure 30). This type of sediment structure, or lack thereof, is also suggestive of glacial tills. It is worth noting that the upper tills of B1, where measured as clay in the CPT data, may be quite soft relative to its upper and lower bounding units.

Based on the seismic interpretation, Seismic unit U1 is present in the WTG 3D volumes listed in Table 13.

2D & 3D UHRS INTERPRETATION REPORT

Table 13 - List of WTGs where seismic unit U1 is present.

Seismic Unit U1							
OSPN	WT07	WT19	WT30	WT39	WT47	WT108	WT144
OSPS	WT08	WT20	WT32	WT40	WT48	WT111	WT146
WT01	WT09	WT21	WT33	WT41	WT49	WT113	GERE
WT02	WT11	WT23	WT34	WT42	WT50	WT130	
WT03	WT13	WT24	WT35	WT43	WT51	WT134	
WT04	WT14	WT25	WT36	WT44	WT53	WT139	
WT05	WT15	WT27	WT37	WT45	WT54	WT141	
WT06	WT18	WT28	WT38	WT46	WT55	WT142	

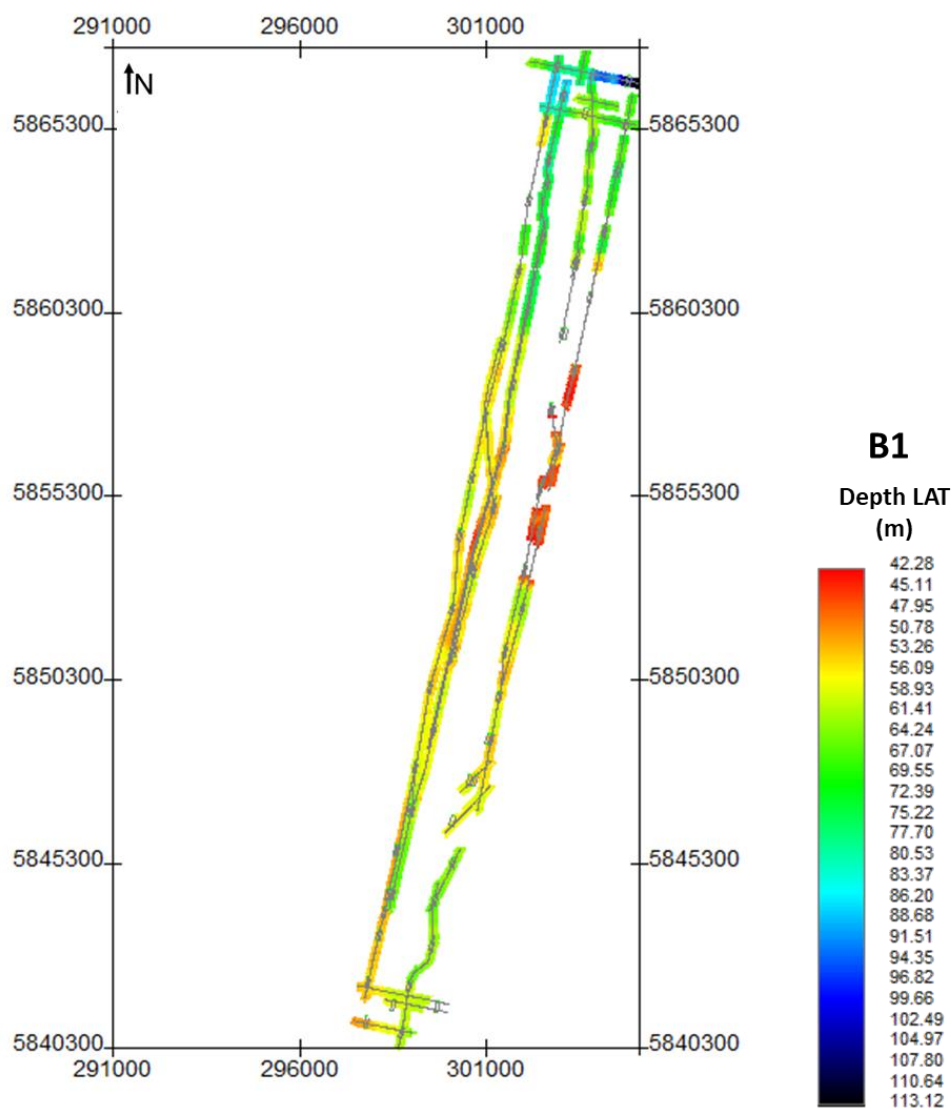


Figure 24 - Spatial extent of mapped horizon B1, referenced to LAT (in metres).

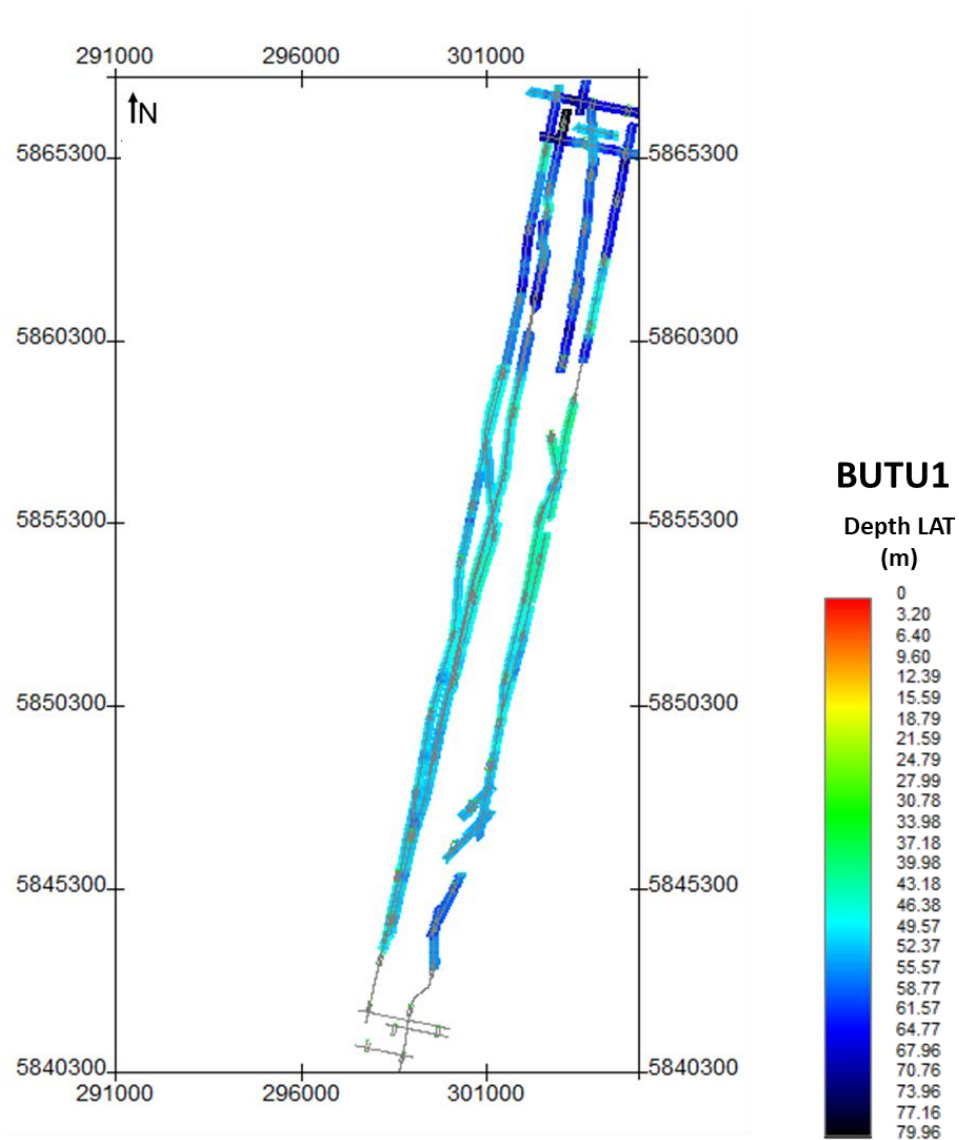


Figure 25 - Spatial extent of mapped horizon BUTU1, referenced to LAT (in metres).

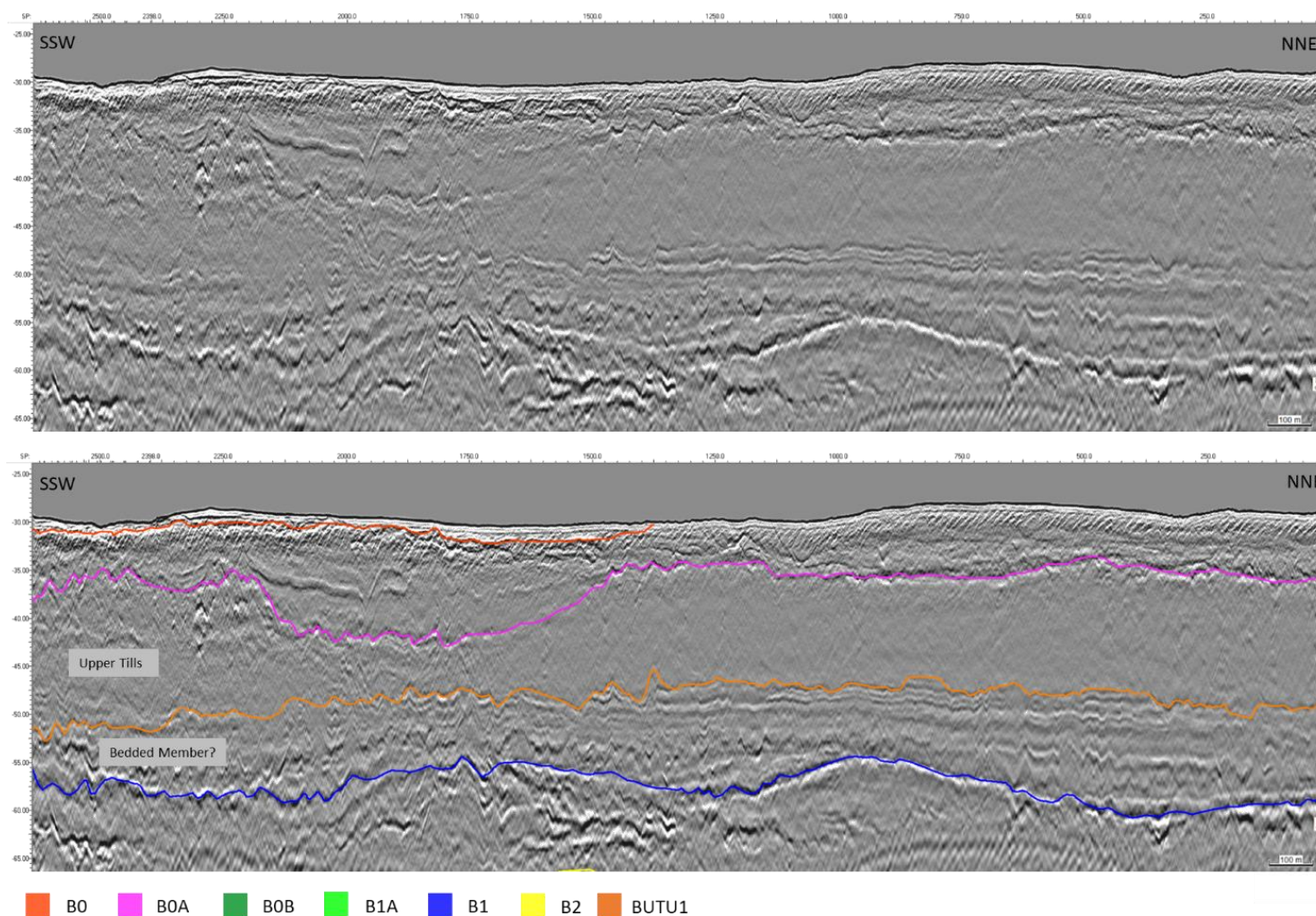


Figure 26 - Seismic profile depicting the contrasting seismic facies of the upper and lower members of U1. The basal deposits, i.e., the Bedded Member display bedding with lateral continuity. The overlying deposits, i.e., the Upper Tills, display a semitransparent to chaotic facies. 2D Seismic Line 24G02_RR_XL_245.

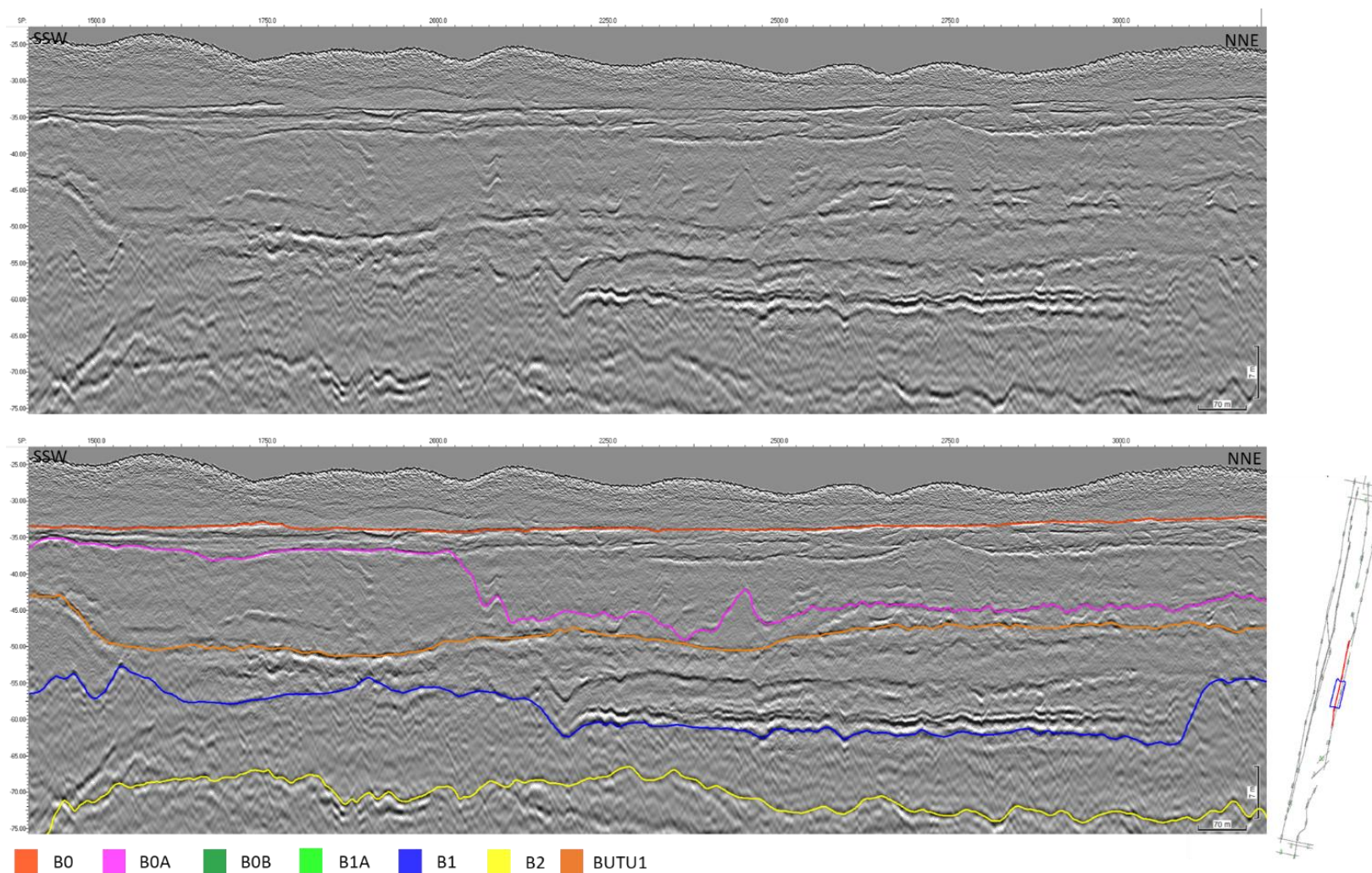


Figure 27 - Seismic profile depicting an example of the layered facies that is present, periodically, in the basal deposits of U1. These deposits may correspond to the Bedded Member of the CBF. 2D Seismic line 24G02_RR_210.

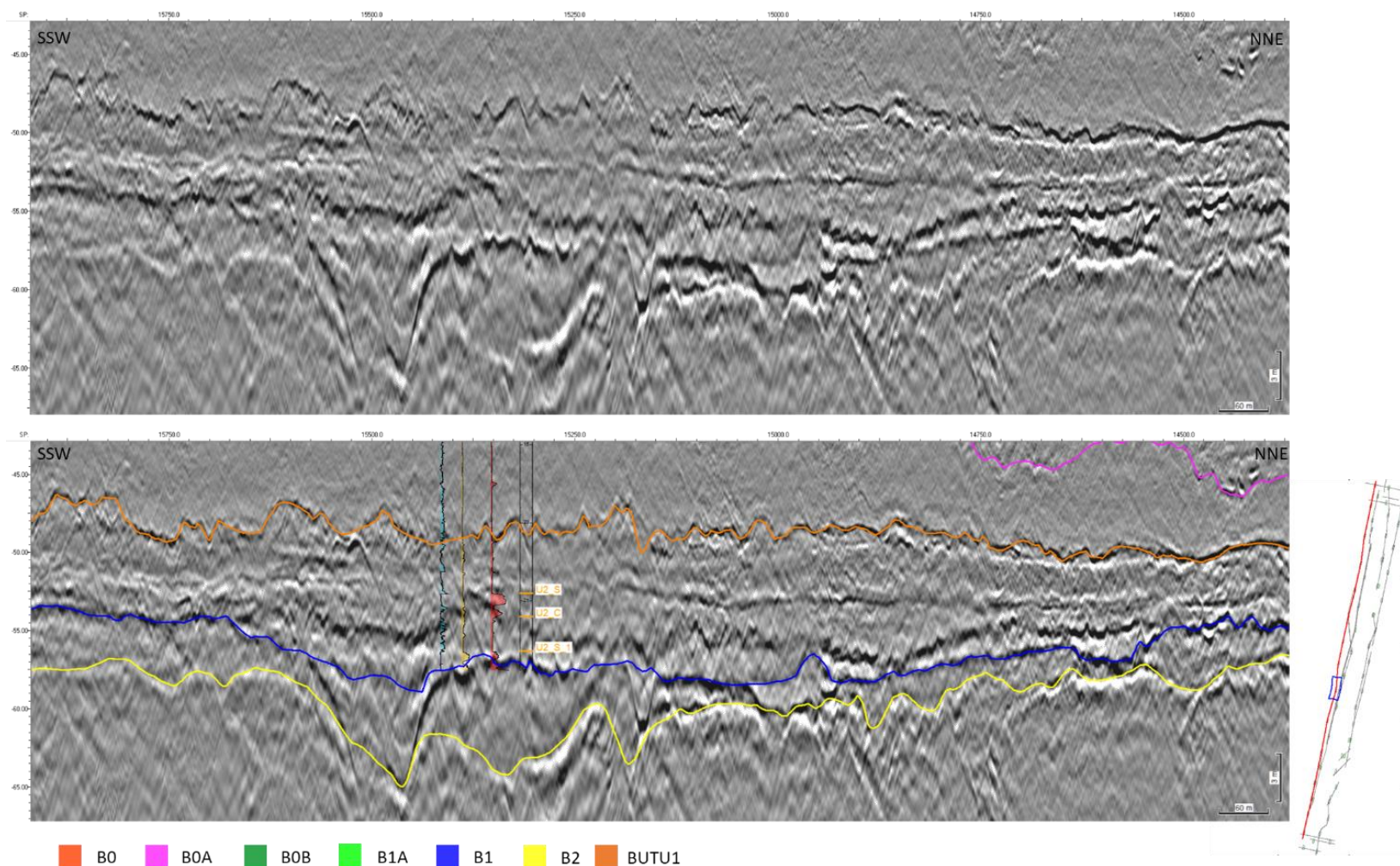


Figure 28 - Seismic profile depicting the layered sediments at the base of U1, that according to CPT data, are interbedded sand and clay. 2D Seismic Line 24G02_RR_007, CPT032.

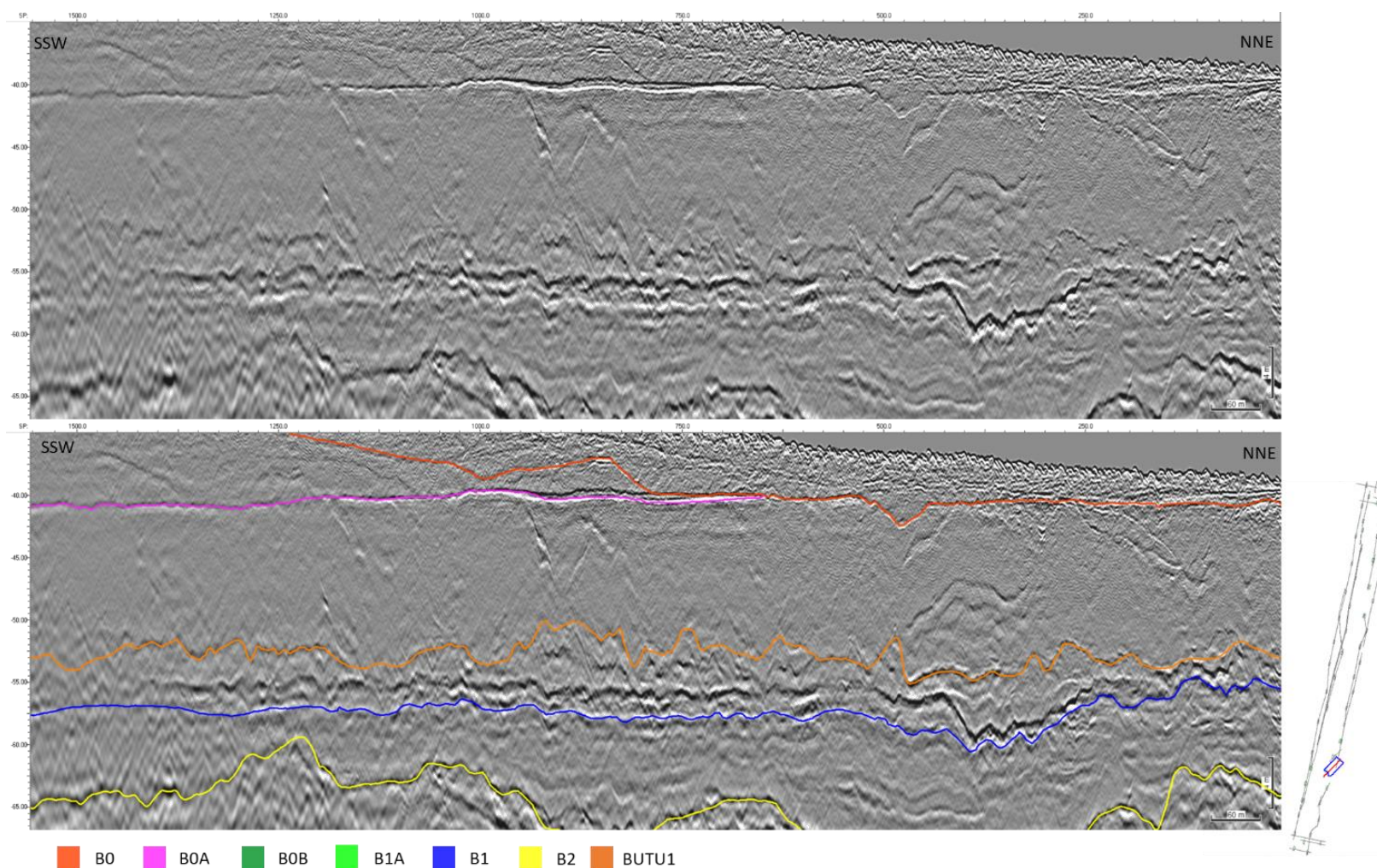
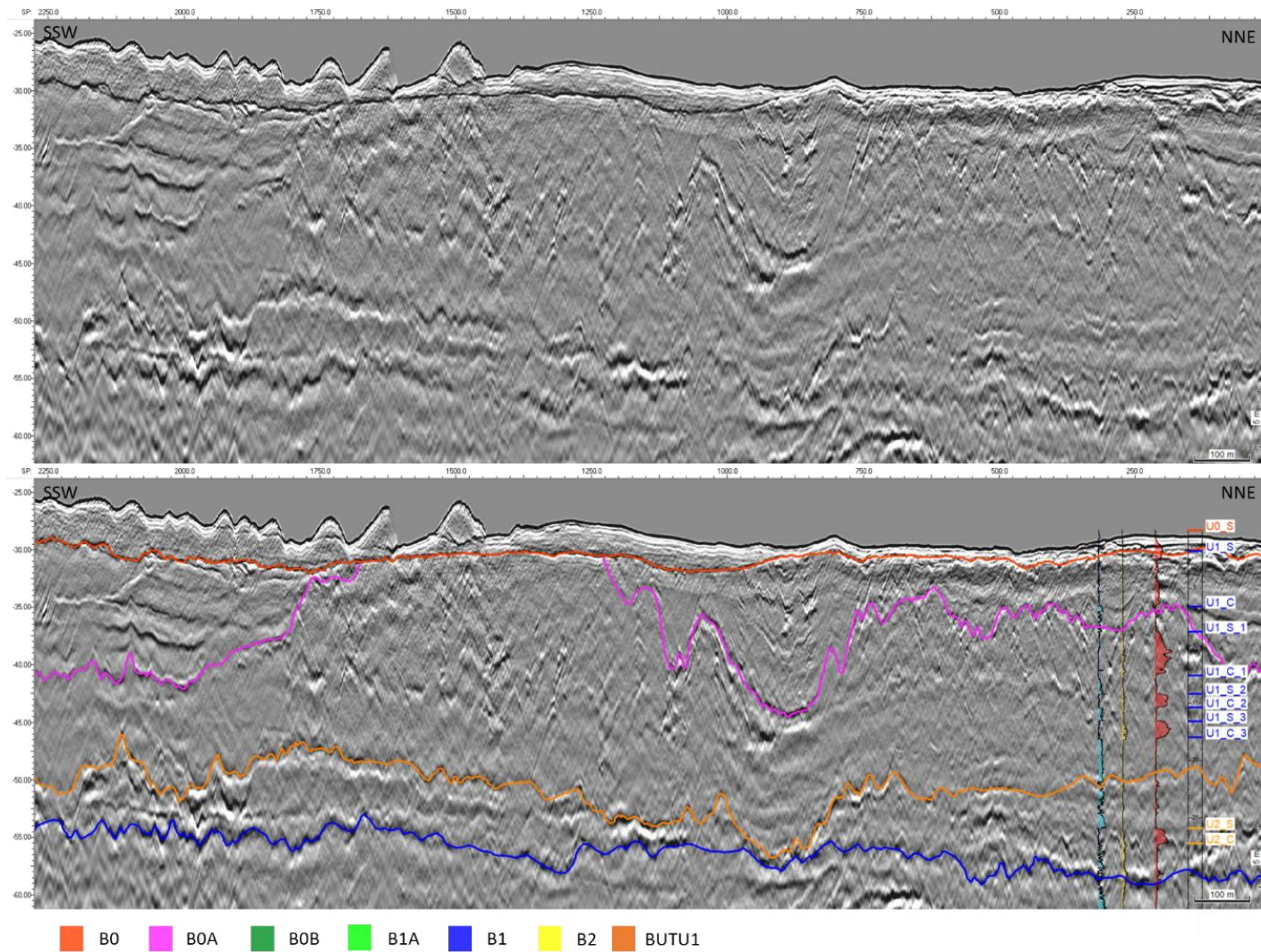


Figure 29 - Seismic profile depicting the generally, non-coherent seismic facies that prevails within the upper deposits of U1. These deposits have been interpreted as the Upper Tills of the CBF. 2D Seismic line 24G02_RR_XL_246.



4.3.6. SEISMIC UNIT U2

Seismic unit U2, the base of which is delineated by B2, is interpreted as possibly corresponding to constituents of the *Cardigan Bay Formation* (CBF) as described within Mellett et al. (2015). It is important to note that B2 often simultaneously represents the base of U2 and the top of bedrock (Figure 32). Interpretation of the top of bedrock was not always straightforward owing to what is assumed to be a substantial differential in the degree of weathering at the rockface. When possible and/or necessary, the “top of weathered bedrock” and “top of intact bedrock” were both mapped in the 3D data, the latter corresponding to B2. The occurrence of weathered bedrock was inferred from observations on both 2D and 3D UHRS (considering impedance contrast variations and reflector geometries), supported by geotechnical data when available.

U2 is interpreted to be comprised of glaciogenic sediments, some of which were deposited in a subglacial environment. U2 deposits should be diamicts, possibly traction tills. U2 is thickest in the northeastern region of the survey area and thins in a southerly direction. U2 should be, at least partially, comprised of the Lower Till member of the CBF. The seismic facies of U2 is typically chaotic, or otherwise incoherent, that is indicative of tills or other diamicts (Figure 33). Additionally, the seismic data displays potential thrusts and acute deformation suggesting glaciotectonism within the unit.

CPT data coverage is sparse within U2, as compared to the other seismic units, owing to its depth below the seabed. Where CPT data extends into U2, sediments are variable, ranging from soft clays to stiffer sands (Figure 34). The basal deposits of U2 may contain elements of weathered bedrock to include gravel and larger rock fragments.

Based on the seismic interpretation, Seismic unit U2 is present in the WTG 3D volumes listed in Table 14.

2D & 3D UHRS INTERPRETATION REPORT

Table 14 - List of WTGs where seismic unit U2 is present.

Seismic Unit U2								
OSPN	WT06	WT14	WT23	WT31	WT39	WT48	WT108	WT141
OSPS	WT07	WT16	WT24	WT32	WT40	WT49	WT111	WT142
VOSP	WT08	WT17	WT25	WT33	WT41	WT50	WT113	WT144
WT01	WT09	WT18	WT26	WT34	WT42	WT51	WT117	WT146
WT02	WT10	WT19	WT27	WT35	WT43	WT52	WT122	GERE
WT03	WT11	WT20	WT28	WT36	WT44	WT53	WT130	
WT04	WT12	WT21	WT29	WT37	WT45	WT54	WT134	
WT05	WT13	WT22	WT30	WT38	WT46	WT55	WT139	

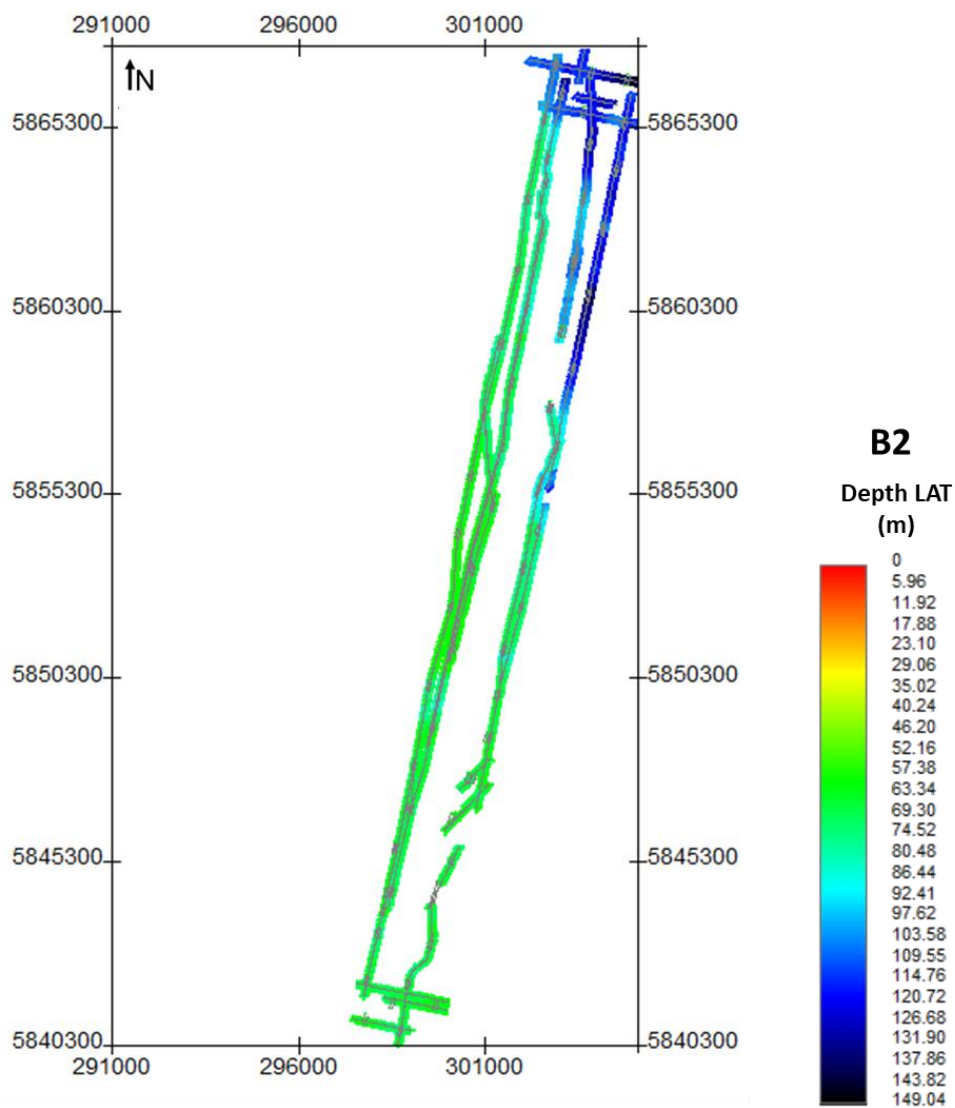


Figure 31 - Spatial extent of mapped horizon B2, referenced to LAT (in metres).

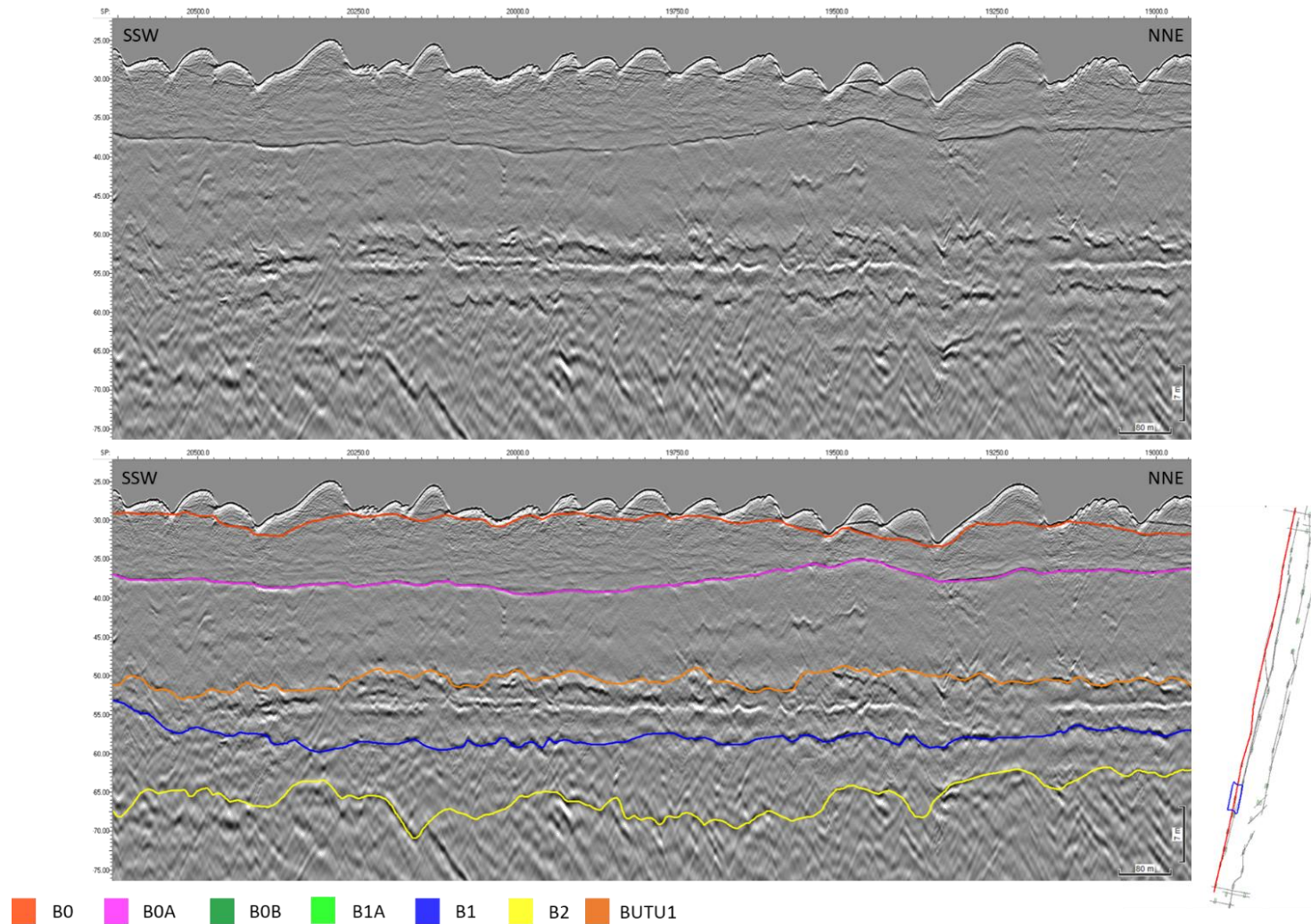


Figure 32 - Seismic profile depicting an example of B2, that simultaneously represents the top of bedrock and the base of U2. 2D Seismic line 24G02_RR_007.

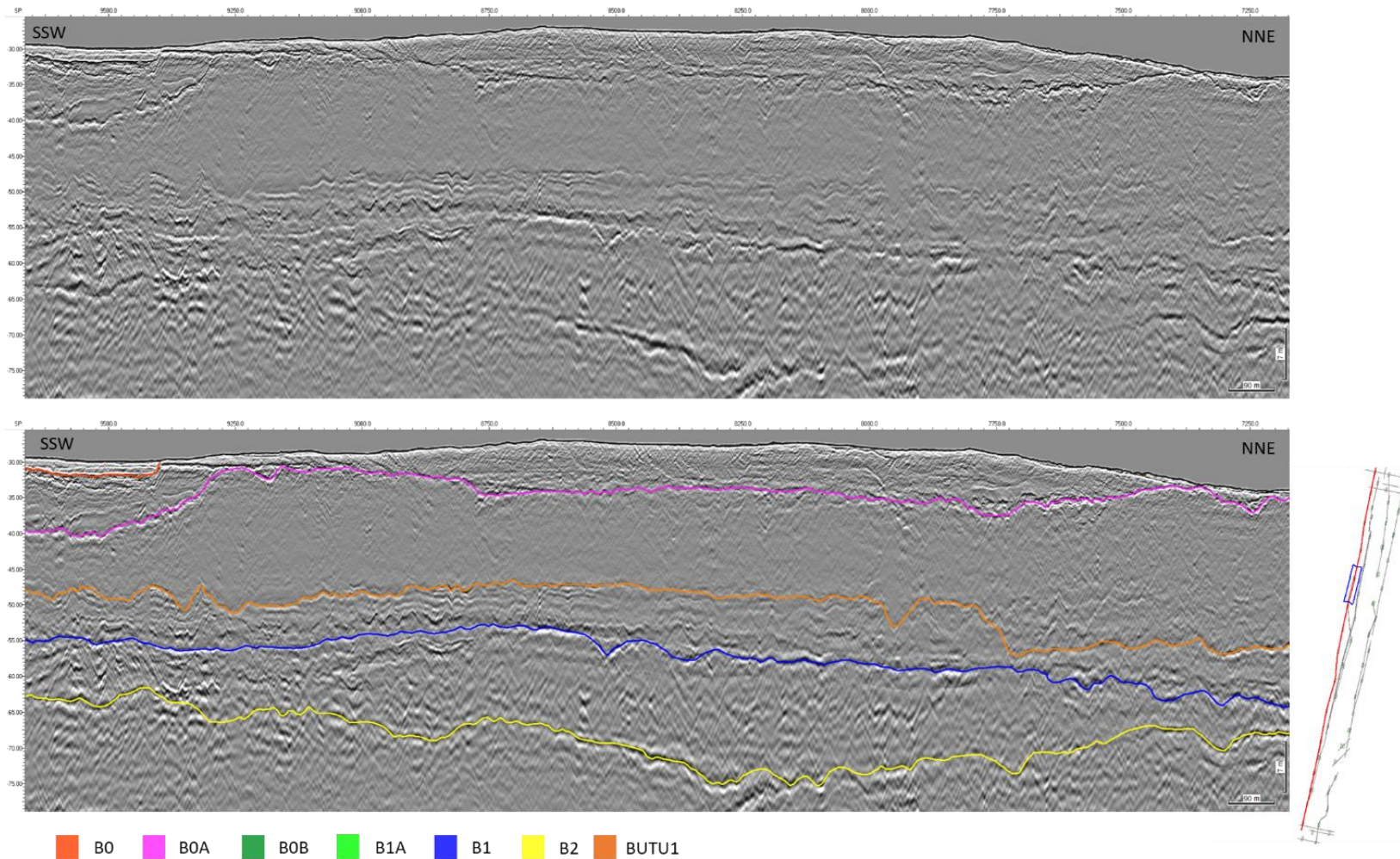


Figure 33 - Seismic profile depicting the mostly incoherent and chaotic seismic facies of U2 that suggests diamicts, mostly tills. 2D Seismic line 24G02_RR_007.

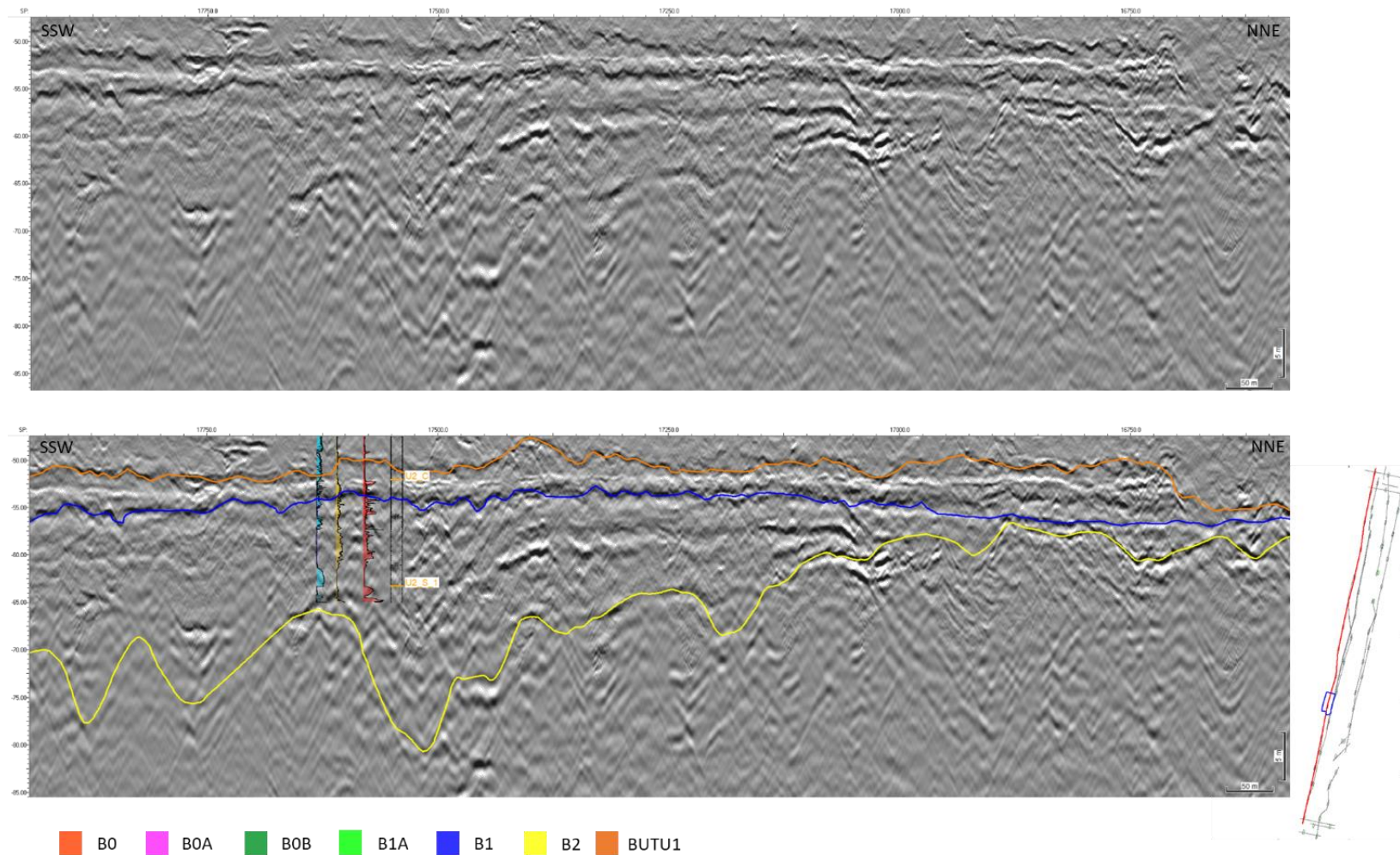


Figure 34 - Seismic profile and CPT data depicting the heterogeneous sediments present within U2. U2 is under sampled in the CPT data due to its depth below the seabed, i.e., lack of penetration of the CPT probe. 2D Seismic line24G02_RR_007, CPT035a.

4.3.7. BEDROCK

The bedrock surface was mapped across the full survey area, traced mostly by horizon B2. Confidence in the interpretation of bedrock varied based on several factors, including, its depth below seabed, its position relative to the multiple, and the degree to which it is weathered. Exposure of the bedrock's internal dipping strata, at the sheared rockface, has contributed to differential weathering. Differences in the competency of the internal layering promote non-uniform erosion at the bedrock surface. When it was apparent from the 3D seismic data that the top of bedrock was highly weathered, two surfaces were mapped, one corresponding to the weathered surface (horizon U2-01 in Figure 35) and a second, deeper, surface representing "intact" bedrock (horizon B2).

The top of bedrock undulates in the subsurface across the survey area, and no outcrops were mapped in any of the blocks. The seismic expression of the bedrock was highly variable across the site. At times, particularly when the bedrock surface was represented by an angular unconformity, mapping the top-of-rock was straightforward (Figure 36). Conversely, when the bedrock occurs deep in the section or is substantially weathered, mapping the rockface was more problematic. 2D line orientation, i.e., strike or dip alignment with the internal bedrock strata also affected bedrock interpretation. On rare occasions, faulting was interpreted on the 3D seismic volumes.

The representation of the bedrock in the seismic data suggests that it may be relatively "soft". This assertion is based partially on what appears to be the rock's susceptibility to weathering. However, the degree to which the seismic signal, that is high-frequency and low power in comparison to exploration systems, penetrates into the rock, points to a relatively soft composition (Figure 37). Further, in some instances, the seismic reflector interpreted as the top of bedrock exhibits negative impedance, suggesting a decrease in rigidity (shear modulus) compared to the overlying sediments. Based on the seismic data, the physical/mechanical conditions of the upper bedrock vary widely. Although, taken as a whole, the upper several metres of the bedrock do not show signs of high competency.

Bedrock was mapped in all 3D WTG Blocks.

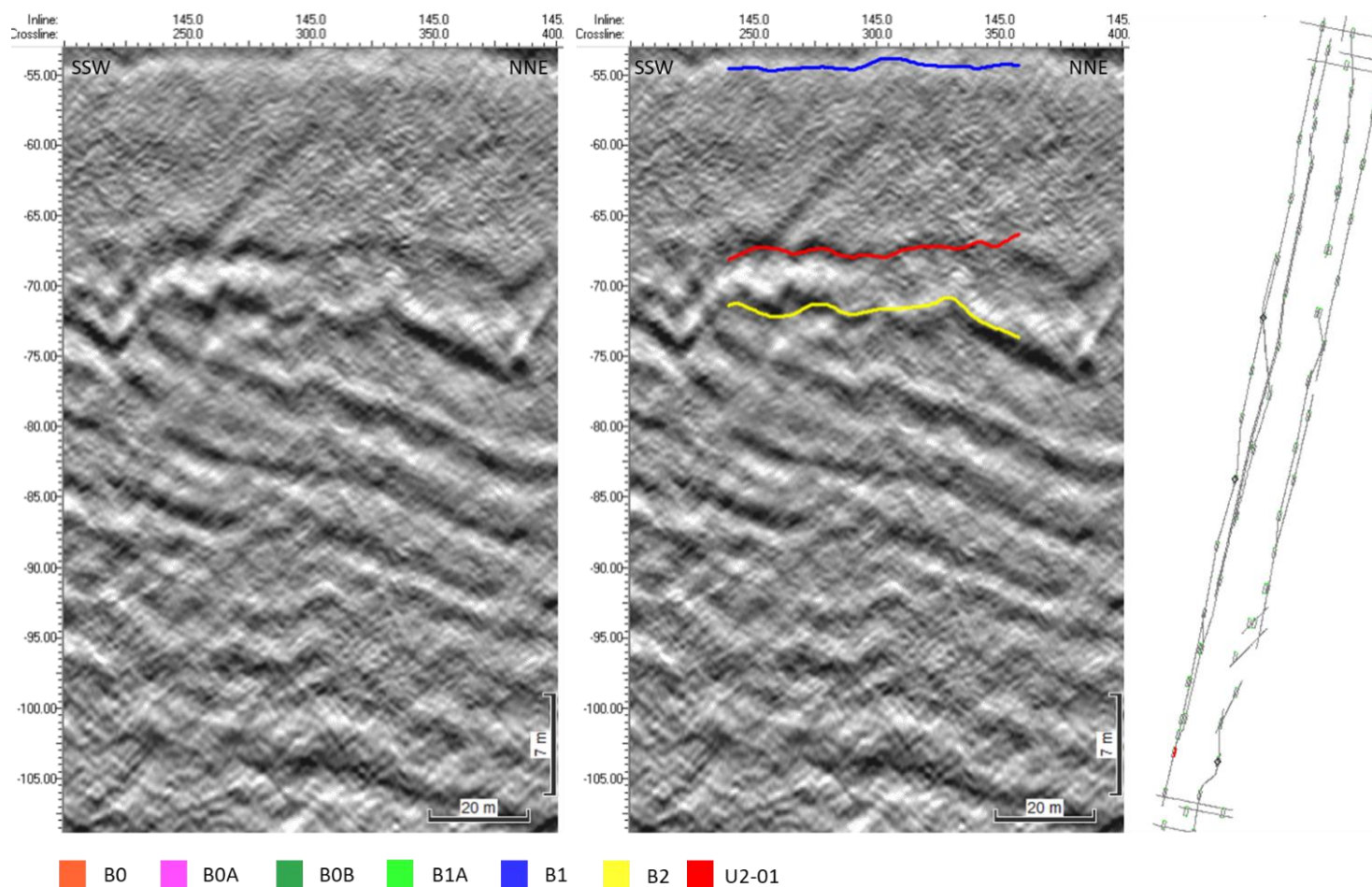


Figure 35 - Seismic profile depicting an example of where top of weathered bedrock (red) and top of intact bedrock (yellow) was interpreted in the detailed mapping of the WT 3D volumes. Line 145 from WT48 3D volume.

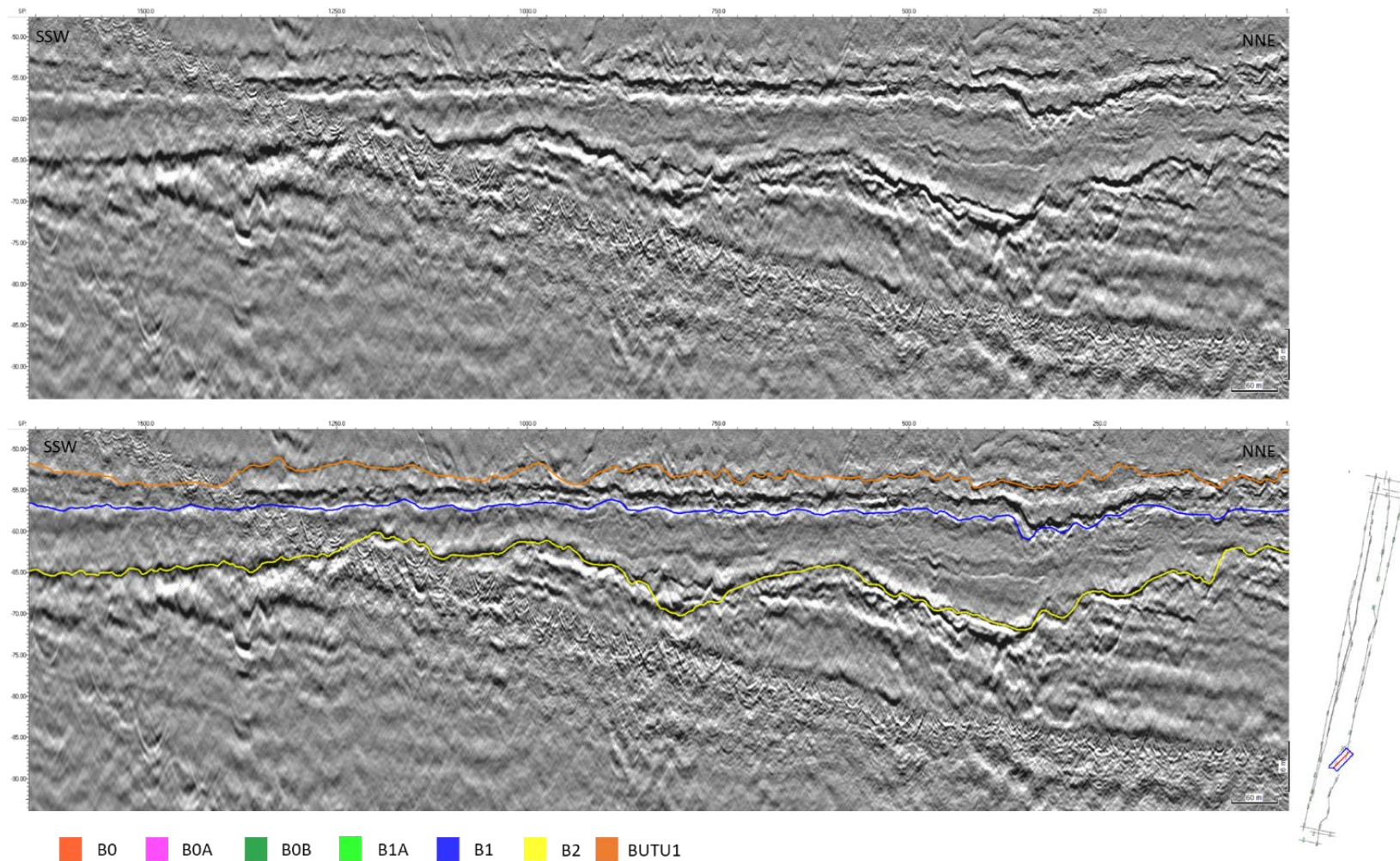
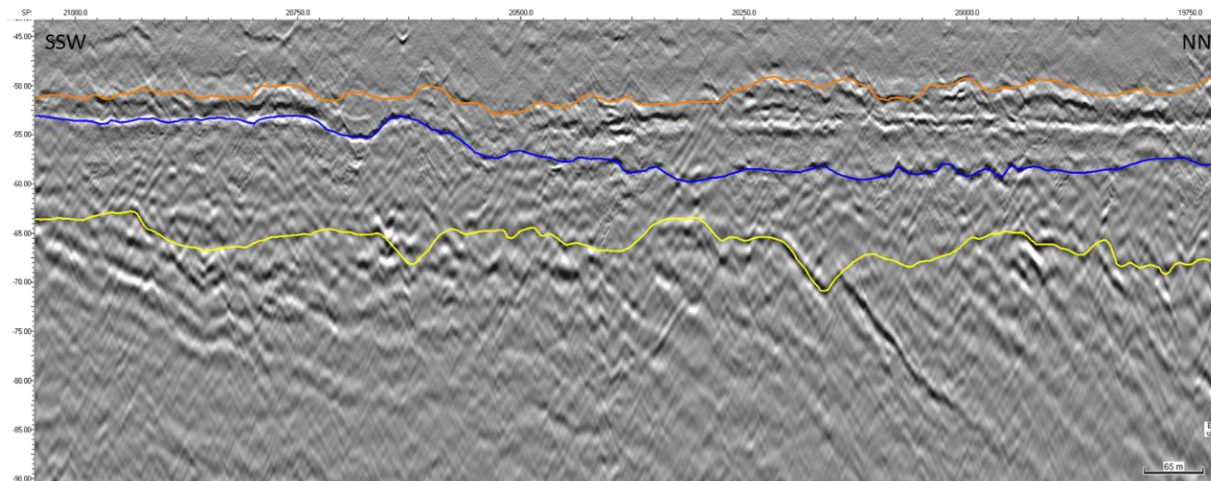
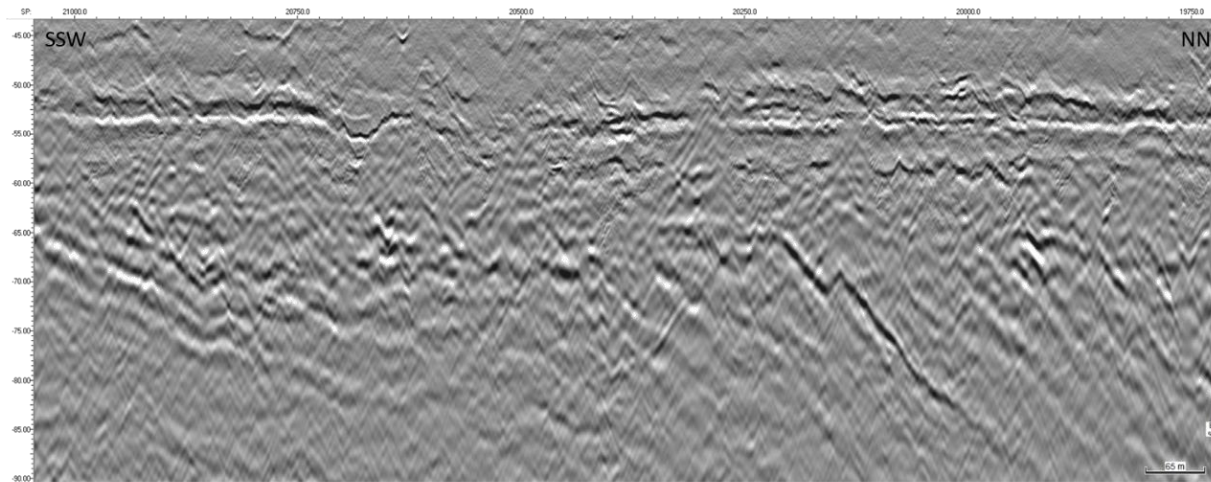


Figure 36 - Seismic profile depicting an example of where the bedrock surface is easily delineated given its correspondence to an angular unconformity, 2D Seismic line 24G02_LK_XL_07.



■ B0
 ■ B0A
 ■ B0B
 ■ B1A
 ■ B1
 ■ B2
 ■ BUTU1

Figure 37 - Seismic profile depicting >10m of penetration into the bedrock. This degree of penetration by a relatively high-frequency, low power, seismic system points to a lack of competency in the bedrock. 2D seismic line 24G02_RR_007.

4.4. 3D UHR SEISMIC VOLUME INTERPRETATION

The formation boundaries and unit boundaries, i.e., base horizons, established in the 2D data were interpreted across the 71 individual 3D seismic volumes. Detailed mapping of the 3D volumes involved further interpretation and subdivision of the ground model units. The decision to interpret additional, internal subunits was made on a block-by-block basis based on the contents of the seismic data and corresponding lithology inferred from the geotechnical data. For example, if a prominent reflector was present in the 3D seismic that did not correspond to an established unit base horizon, it was mapped. Additionally, if a significant change in lithology was present in the geotechnical data but its correspondent seismic reflection appeared insignificant or lacked continuity, it became a candidate for mapping.

The results of the detailed mapping on the 3D volumes are provided in the accompanying WTG Reports, included in Appendix A. A WTG Report was prepared for each 3D volume that are centered on a proposed WTG location. The WTG Reports contain fully interpreted seismic examples and descriptions of the constituent units. Observations specific to the data and geology of the WTG locations are provided in the reports, as well as details on reflector characteristics, depths below LAT/seabed, unit thickness and horizon/CPT alignment.

4.5. POTENTIAL HAZARDS

A geohazard analysis was performed using the seismic data and supporting datasets, e.g., multibeam bathymetric surfaces and geotechnical data. Additionally, information about the general types and prevalence of geohazards in the Irish Sea was obtained from the scientific literature. A summary of known Irish Sea geohazards and their potential consequences, from Mellett et al. (2015), is shown in Table 15 below.

Table 15 - Table 6 from Mellett et al. (2015) that lists features of Irish Sea geology that may represent engineering hazards and related constraints.

Geological characteristic/process	Potential Constraint
Seabed sediments	
Soft muds in Western and Eastern Irish Sea Mudbelts	Low strength means they will not bear large loads.
Coarse lag (gravel to boulders) deposits	May be present below mobile sediment and provides a hard substrate that is difficult to penetrate.
Mobile sediment	
Migrating bedforms change topography (can create seabed features up to 36 m in height)	Can bury or expose structures or present a barrier to activities.
Mobile sediment can change sediment characteristics at seabed	The mobile sediment layer is constantly changing. Therefore, expect variation between samples taken from the same site at different times.
Bedforms can migrate in the opposite direction to predicted from morphology and tidal residual	Do not assume sediment migration pathways from morphology. Repeat bathymetric surveys should be carried out.
Relict glacial landscapes can be interpreted as bedforms indicative of mobile sediment	Misinterpretation will indicate mobile sediment is a constraint in an area where it is not present.
Bedform topography (that is constantly changing) modifies currents and can lead to scour	Emplacing infrastructure on the seabed can also modify currents and may lead to scour.
Gas/fluid escape and MDAC	
Gas or fluid present in shallow subsurface	Can lead to blow outs when drilling
MDAC	Creates a hard substrate that is recognised as a special habitat that must be preserved
Quaternary	
Variable sediment thickness	Locally sediment thickness can change from thin (<5 m) to thick (>100 m) over a short distance.
Variable lithology (vertical and spatial)	Glacial processes rework and deposit sediments that are highly variable over large areas. This is problematic if using a single foundation design. Landforms and onshore analogues can be used to try to predict variability.
Heterogeneous sediment composition	Sediments are typically diamict which are poorly sorted mixtures of silt, sand, gravel and CLAY. Diamicts can be interbedded with sands.
Overconsolidated sediments	Repeated loading by ice has overconsolidated sediment and shear strength values can exceed 900 kPa.
Bedrock	
Bedrock outcrop at seabed	Provides a hard substrate for emplacement of seabed infrastructure.
Permo-Triassic sandstone and mudstone	Shows uniform properties. May be weathered and display lower strengths at the interface with Quaternary sediments.
Carboniferous sandstone, mudstone and limestone	Interbedding of different rock types means the properties of the Formation can change rapidly. May be weathered and display lower strengths at the interface with Quaternary sediments.
Igneous intrusions	Rocks around the igneous intrusions may have been altered as the magma was intruded and may have different properties
Mining	May have weakened the overlying rocks with potential for tremors if mines collapse.

The general geohazard assessment arising from seismic analysis revealed the hazards discussed in the forthcoming text. Additionally, a comprehensive boulder hazard analysis, based on point-source diffraction (PD) interpretation, is contained in Section 4.5.9. Any hazard analysis based wholly or largely on indirect geophysical methods is subject to multiple constraints related to the underlying physical principles, measurement error and uncertainty, positional accuracies, data coverage, etc. As such, the end users of these results should bear in mind the epistemic principle that, absence of evidence does not directly infer evidence of absence.

4.5.1. GRAVEL

Gravel deposits have been confirmed within the site by way of the geotechnical data. Integration of the CPT and seismic data points to gravel being most prevalent at the base of U0 and within the top of the underlying unit, e.g., U0A (Figure 38). However, the apparent trend of gravel being constrained to units near the seabed is likely spurious owing to constraints in seismic resolution and CPT penetration. The presence of gravel may be possible in any of the glaciogenic units and may be especially high near the bedrock surface, being the product of mechanical weathering of the rockface.

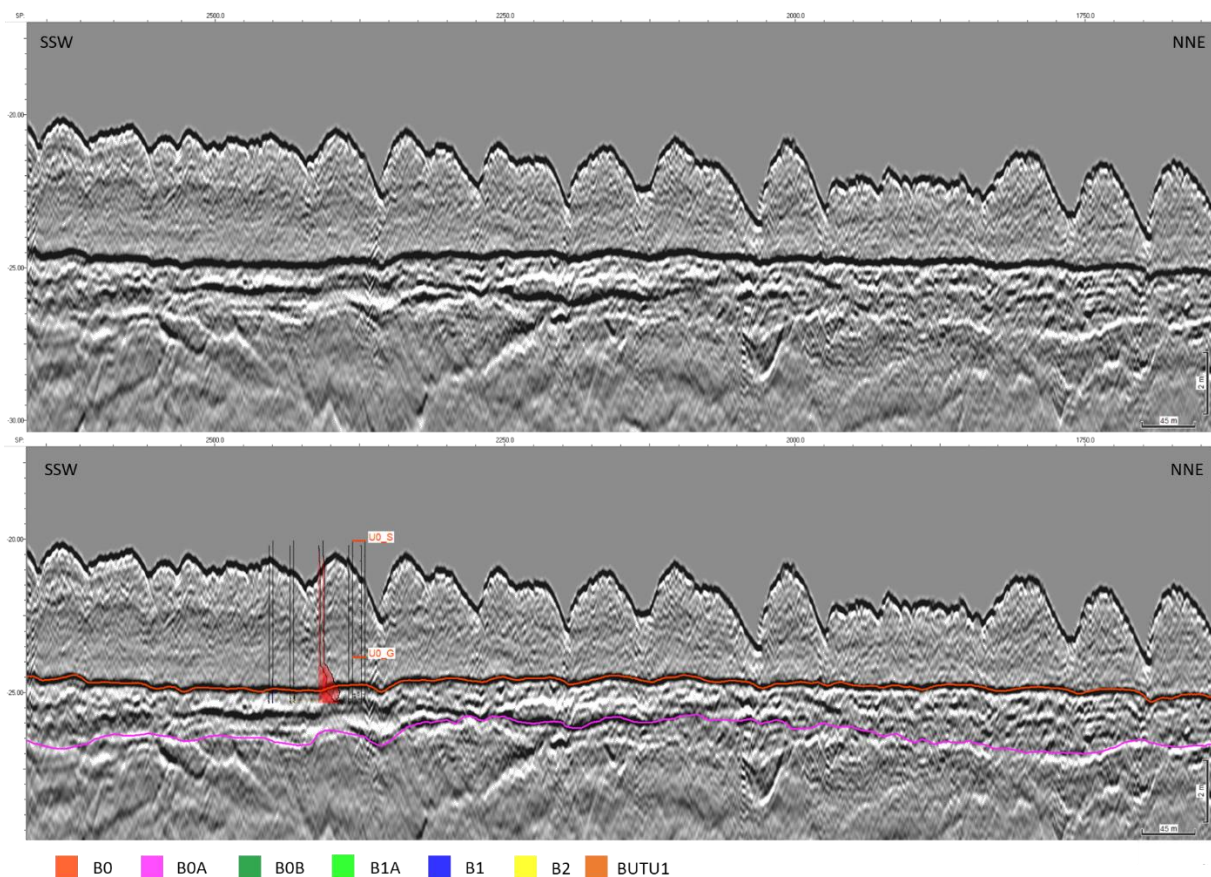


Figure 38 - Seismic profile depicting the gravelly sediments that exist in the upper deposits of U0A and at the base of U0. 2D Seismic line 24G02_RR_076, CPT017.

4.5.2. SOFT SEDIMENTS

Soft sediments have been confirmed within the site by way of the geotechnical data. The softest or least resistive of these sediments, as per the CPT measurements, are inferred to be clays. Soft sediments are most prevalent in the upper till deposits of U1 and regions of the glaciolacustrine/marine deposits of U0B and U1A (Figure 39). However, given the nature of diamicts and the general tendency towards heterogeneity in glaciated terranes, localized occurrences of soft sediments is likely.

Hard-over-soft conditions are common across the site. As the term suggests, hard-over-soft conditions refer to situations where assumptions of increasing density with depth are invalid. In many instances, stiffer, more resistant, sand and gravel deposits overlie the deformable, compressive glacial clays (Figure 40). Often, this transition, i.e., hard to soft, is abrupt, occurring over vertical distances of much less than a metre (Figure 41).

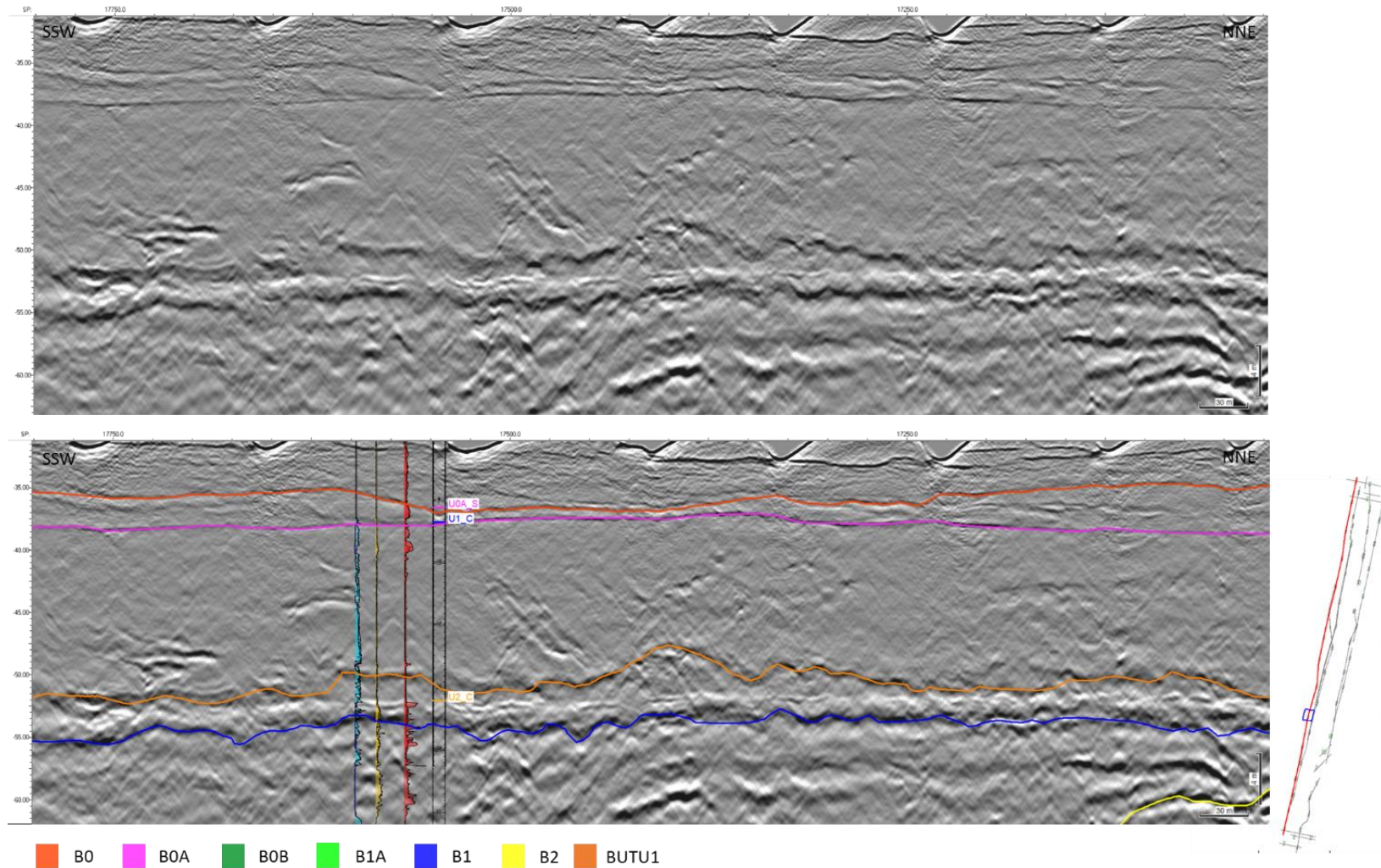


Figure 39 - Seismic profile and CPT data depicting the prevalence of soft sediments within the upper tills of U1. As per the CPT measurements, the soft sediments within the survey area are classified as clay. 2D Seismic profile 24G02_RR_007, CPT035a.

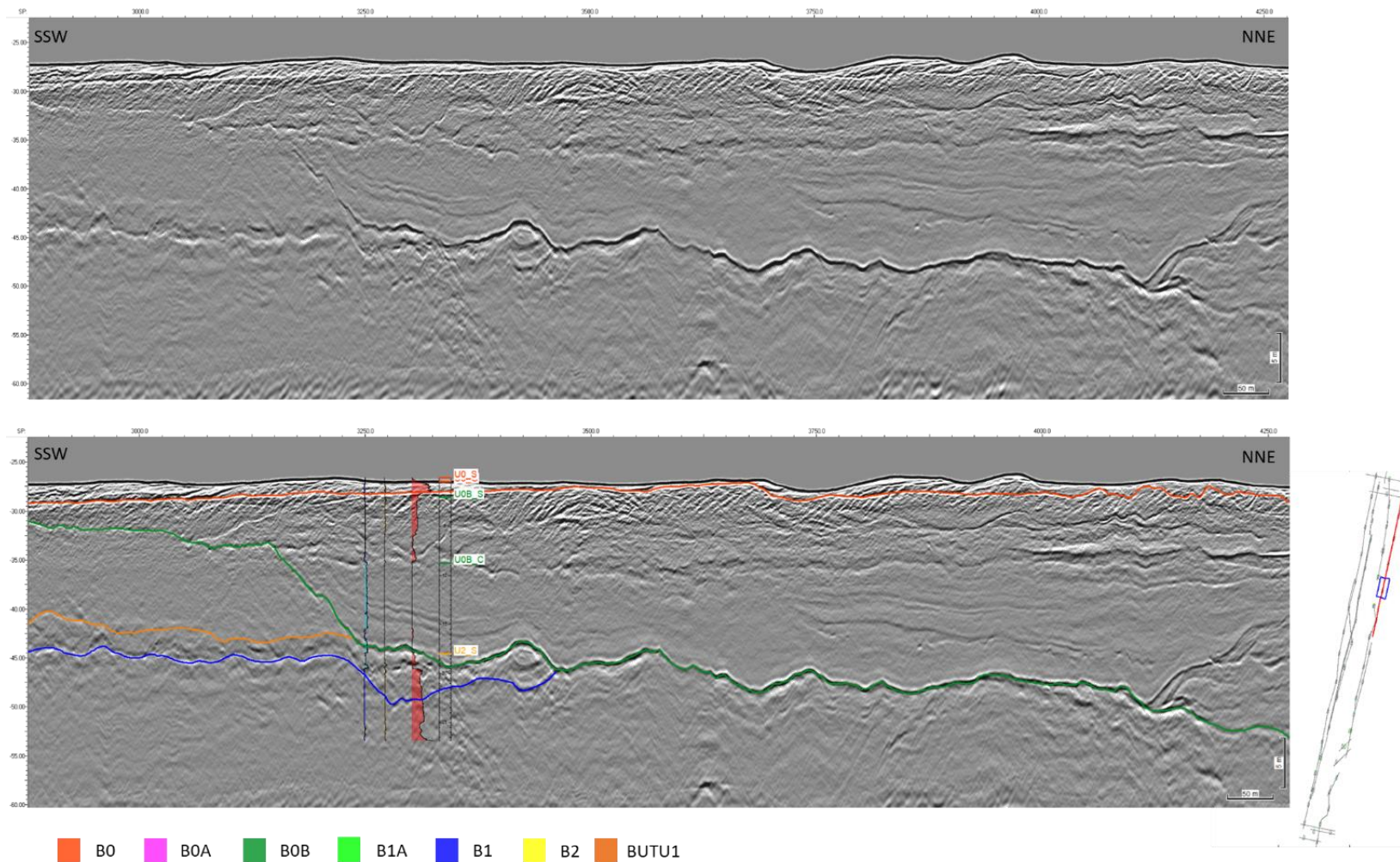


Figure 40 - Seismic profile and CPT data depicting hard-over-soft conditions within the glaciolacustrine deposits interpreted within UOB. 2D Seismic line 24G02_RR_119_P2, CPT019.

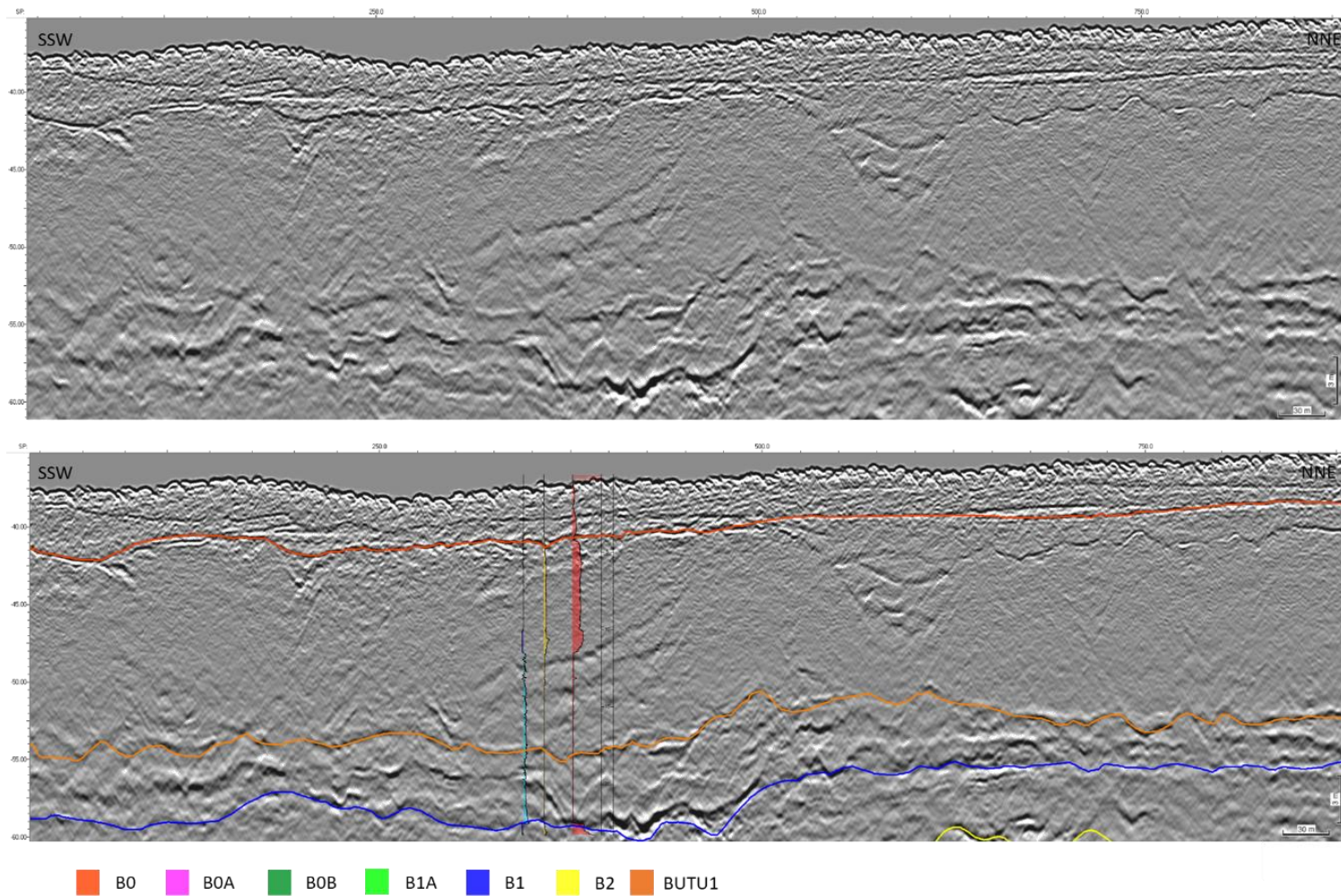


Figure 41 - Seismic profile and CPT data depicting hard-over-soft conditions within the upper tills of U1, where stiff sands rapidly give way to soft clays. 2D Seismic line 24G02_RR_119_P1, SCPT006a.

4.5.3. OVER-CONSOLIDATED SEDIMENTS

The probability of over-consolidated sediments being present in the site should be assumed as high. Over-consolidated sediments are those which have been exposed to greater amounts of stress than they are currently under. The over-consolidation ratio, shown below, is a concise representation of this relationship. The site's glacial deposits, particularly those deeper in the subsurface, near the bedrock, would have been overridden and compressed by multiple ice sheets enhancing compaction to a point of over-consolidation.

Mellet et al. (2015) reports on the geotechnical properties of sediments within the Irish Sea, to include metrics indicative of over-consolidation (Table 16). According to the data provided in the table, undrained shear strength values may exceed 900 kPa in the lower tills of the CBF.

Table 16 - Table 7 from Mellett et al. (2015) provides a list of the ranges of undrained shear strength (S_u) values for the relevant formations within the survey area, i.e., West Irish Sea Formation and Cardigan Bay Formation. S_u metrics can be used to approximate the level of over-consolidation in sediment deposits.

Group / Formation / Member	S_u (kPa)	UCS (MPa)	$I_s(50)$ (MPa)
Western Irish Sea Formation A (WIS-A)	20 - 63	-	-
Cardigan Bay Formation - Upper Till Member	25 - 630	-	-
Cardigan Bay Formation - Bedded Member	80 - 525	-	-
Cardigan Bay Formation - Lower Till Member	50 - >900	-	-
Mercia Mudstone Group	150 - 1091	0.25 - 4.6	0.02 - 2.2
Sherwood Sandstone Group	-	9 - 45	0.1 - 2.75
Carboniferous (Undifferentiated)	-	0.2 - 98	0.02 - 7.7

4.5.4. HETEROGENEOUS DEPOSITS

Most of the sediment deposits interpreted across the site have glaciogenic origins. Glacial deposition and erosion are tightly coupled to the interplay of ice sheet dynamics and physical changes in the peripheral environment. The tempo of change in a glacial environment may be exceedingly slow or near instantaneous. Similarly, the level and availability of energy can change dramatically, spatially and temporally, throughout the evolution of glaciated landscapes and continental shelves. Additionally, the nonlinear advancements and retreats of ice sheets further complicates the geologic composition of deglaciated environments. All of the aforementioned aspects of glacial processes are the drivers of geologic complexity and sedimentological heterogeneity within the survey area. Sediment type and mechanical properties of deposits are susceptible to omnidirectional change over sub-metre distances (Figure 42). Assumptions of lateral and/or vertical continuity of mechanical properties should be conservative and calibrated with careful data analysis.

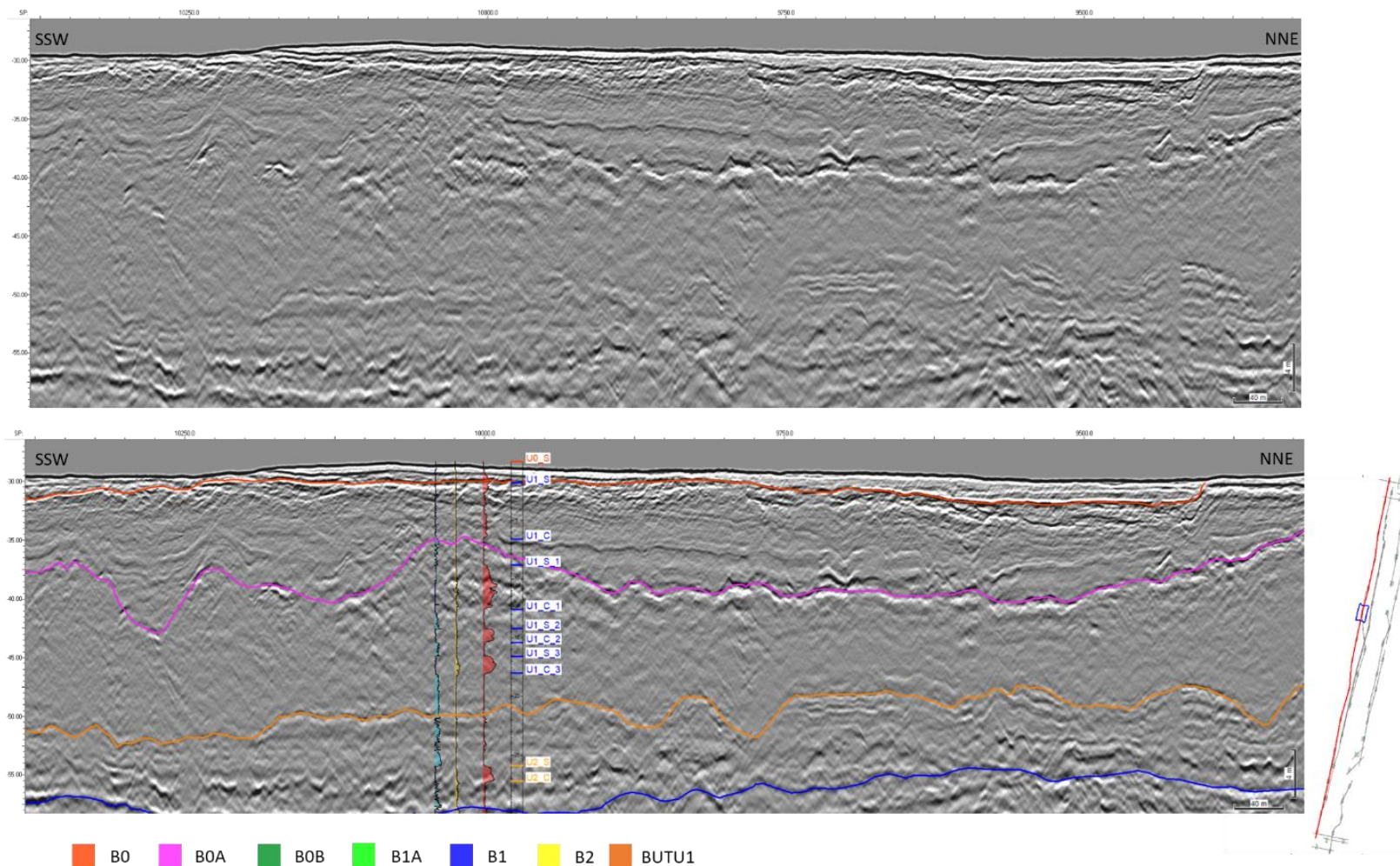


Figure 42 - Seismic profile depicting the heterogeneity of sediments within the glaciogenic deposits that represent the bulk of the near-surface geology of the survey area. 2D Seismic line 24G02_RR_007, CPT 021.

4.5.5. GLACIOTECTONIZED DEPOSITS

Based on the seismic data and established geologic history of the site, glaciotectonized deposits are assumed to present, even widespread, across the survey area. Glaciotectonism, that is deformative by definition, is expressed in seismic data via wavy, chaotic, and transparent facies or otherwise distortions to the antecedent stratigraphy (Figure 43). Glaciogenic sediment deposits may trend towards heterogeneity absent tectonism. However, the imposition of tectonism further complicates the physical composition, structure, and engineering properties of sediment deposits. Glaciotectonized deposits may also be prone to weak zones and slippage planes, e.g., decollement surfaces.

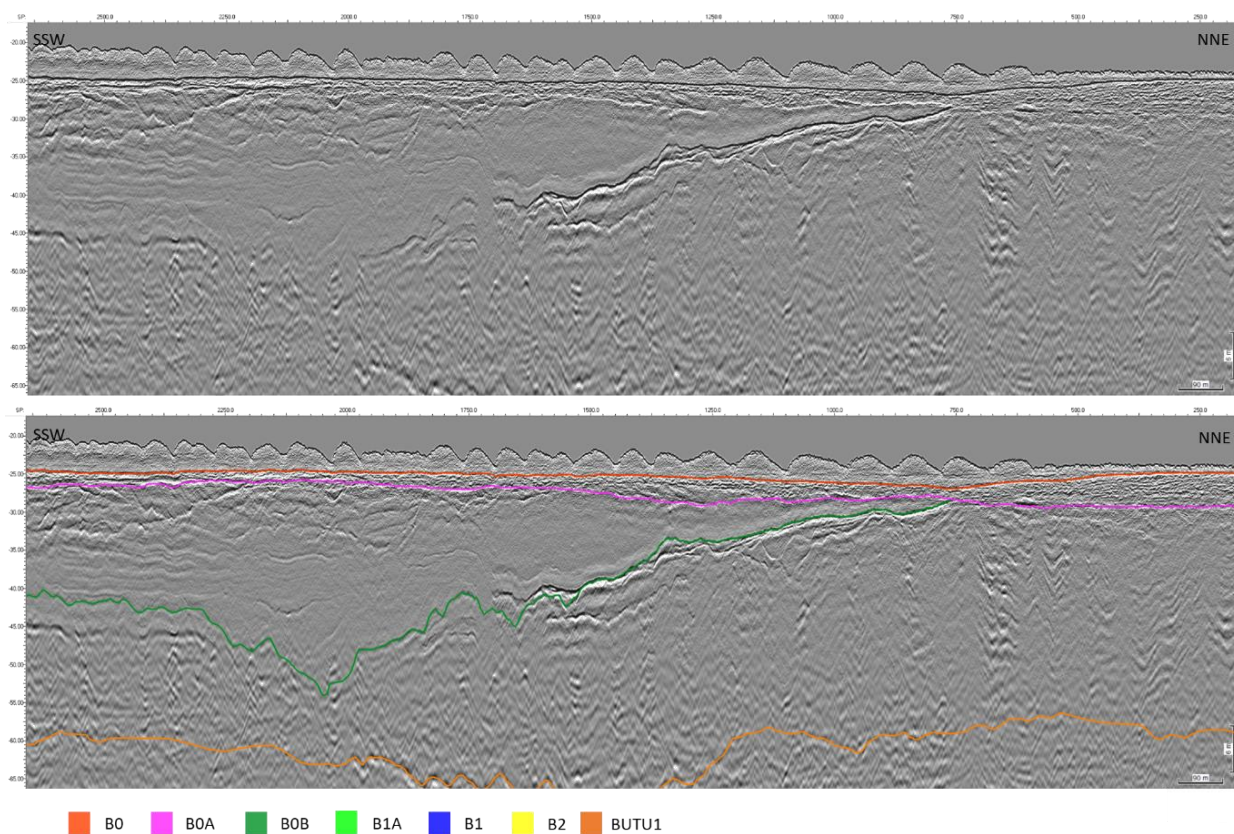


Figure 43 - Seismic profile depicting the contorted, chaotic, seismic facies of the upper tills of U1, that strongly suggest glaciotectonism. 2D Seismic Line 24G02_RR_076.

4.5.6. SEDIMENT TRANSPORT

Active sediment transport is occurring within the site. The most conspicuous signs of vigorous sediment transport are the large sand waves and ridges that cover the seabed across much of the survey area (Figure 44). Smaller sand ripples are also ubiquitous at the seabed and are frequently seen traversing the surfaces of the larger bedforms.

Additionally, swaths of the seabed show signs of scour. In areas of intense scour, the *Surface Sands Formation* or U0, may be entirely removed, diminished to a veneer, or reduced to small sand ripples (Figure 45). The removal of the surficial sands via scour produces exposures of glaciogenic sediments at the seabed that have distinct mechanical properties as compared to the flanking Holocene sediments.

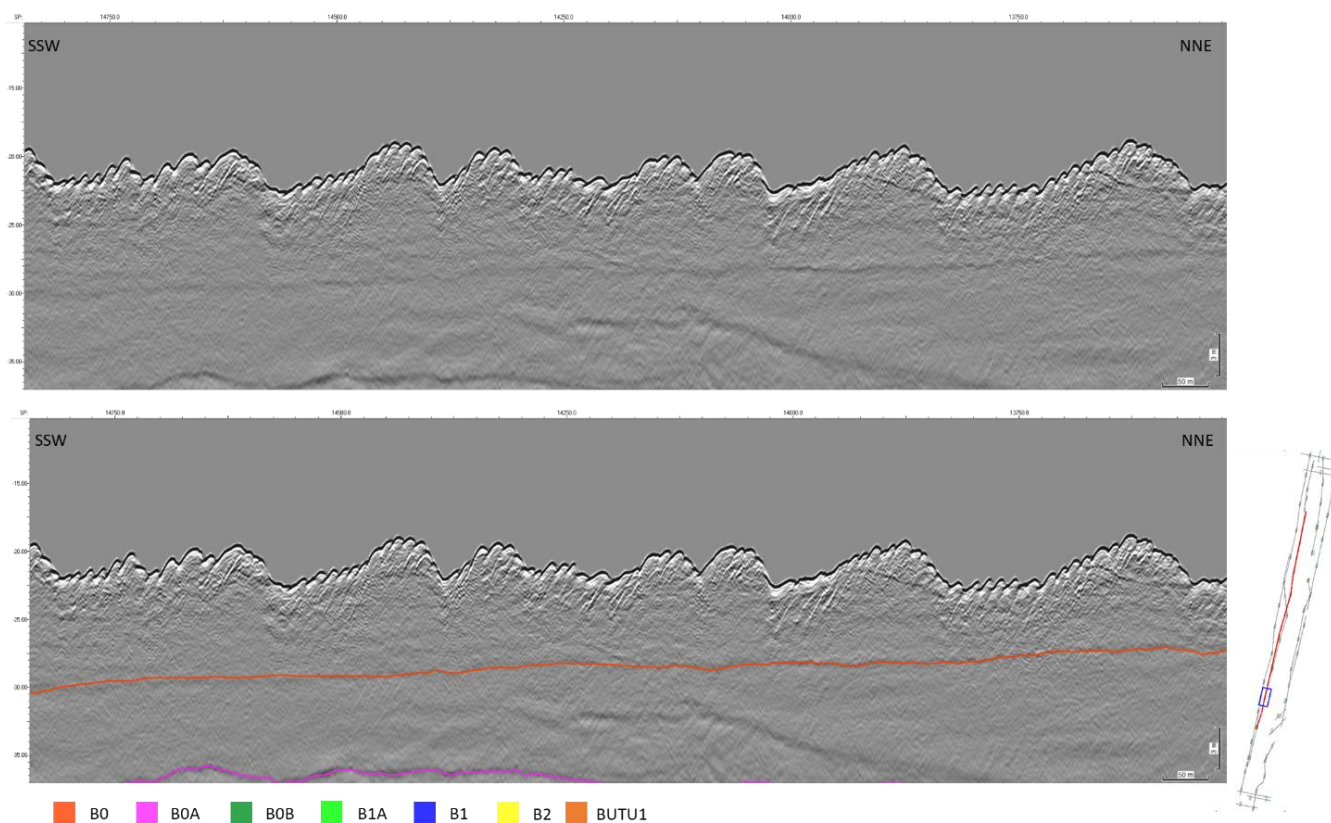


Figure 44 - Seismic profile depicting composite subaqueous dunes indicative of sediment transport. 2D seismic line 24G02_RR_203.

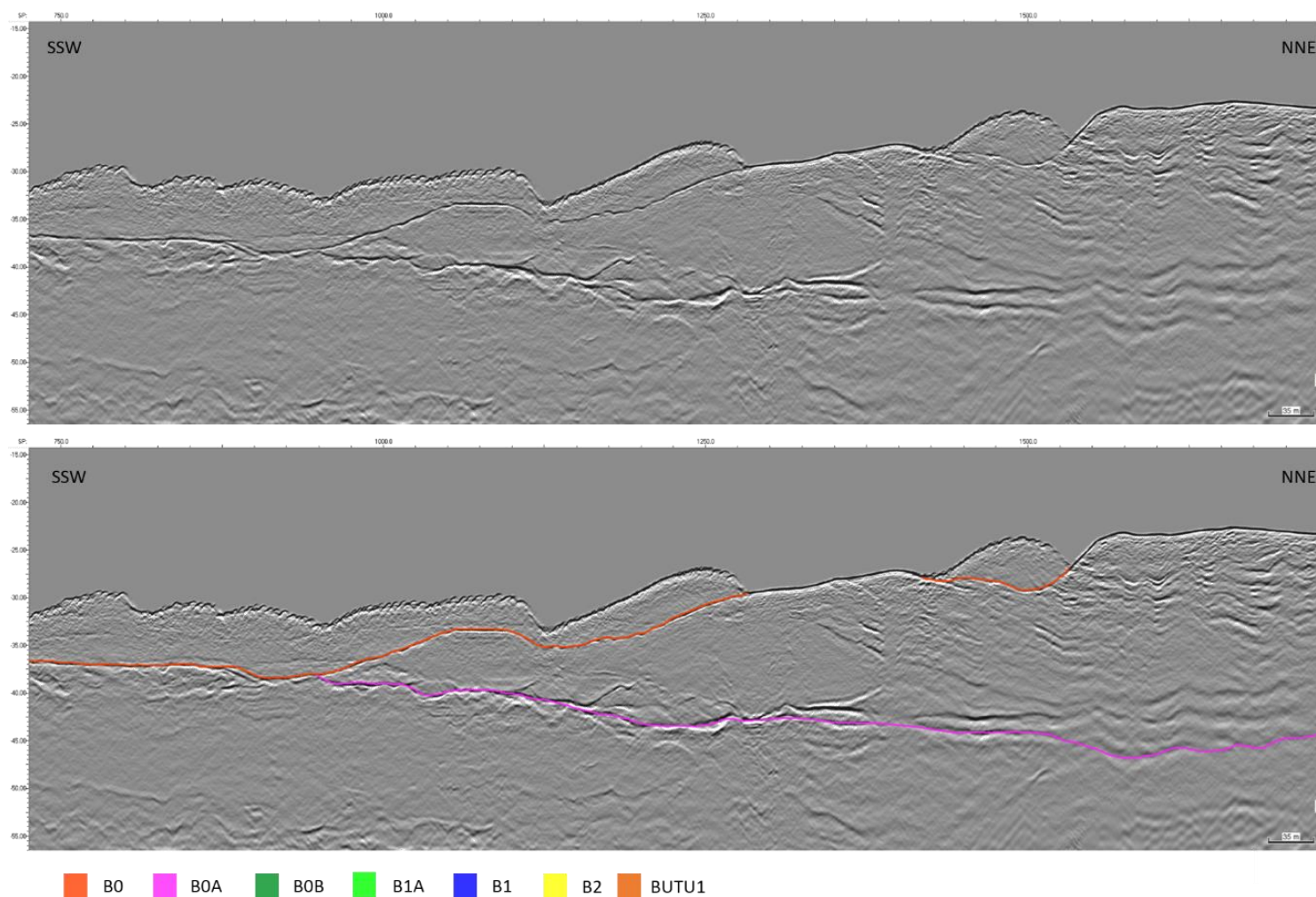


Figure 45 - Seismic profile depicting an example of potential scouring, where the surficial sands have been winnowed away leaving glaciogenic sediments exposed at the seabed. 2D Seismic line 24G02_RR_031.

4.5.7. PALEOCHANNELS

Paleochannels are occasionally present within the survey area (Figure 46). However, paleochannel features are much less numerous in these data, as compared to what is often the case for UHRS surveys acquired on continental shelves. If the Irish Sea Ice Stream terminated in a marine environment, as is postulated in the literature, this may explain the lack of channel incision. Glacial margins submerged in marine waters preclude the development of extensive outwash plains that traverse terrestrial environments. Outwash plains and subaerial shelf exposure more generally, give rise to the manifold channel complexes often imaged in UHRS data. A notable exception to the apparent scarcity of paleochannels may occur in UOA, where an array of erosional surfaces form complicated geometric patterns (Figure 47). It is at least possible that these deposits may be related to an ancient channel system.

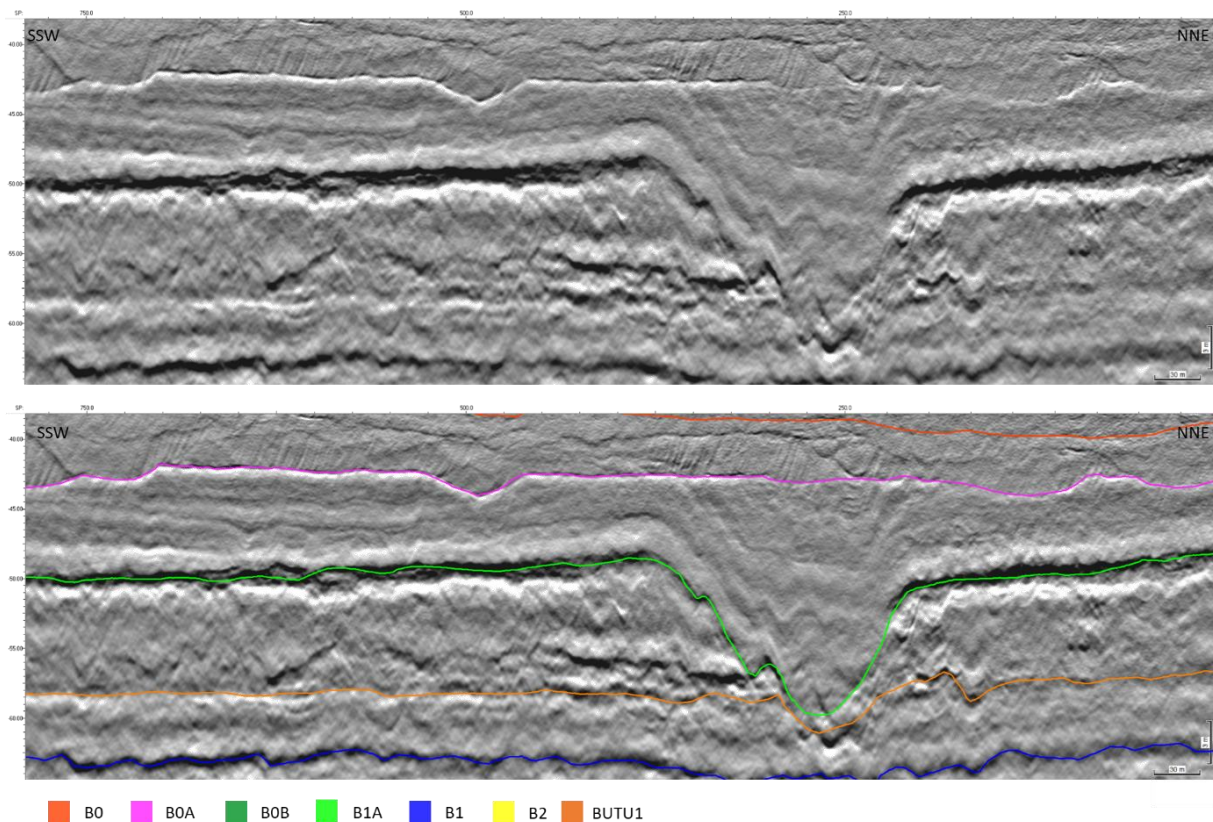


Figure 46 - Seismic profile depicting the rare occurrence of a well-defined channel feature in these data. 2D Seismic line 24G02_LK_XL_08.

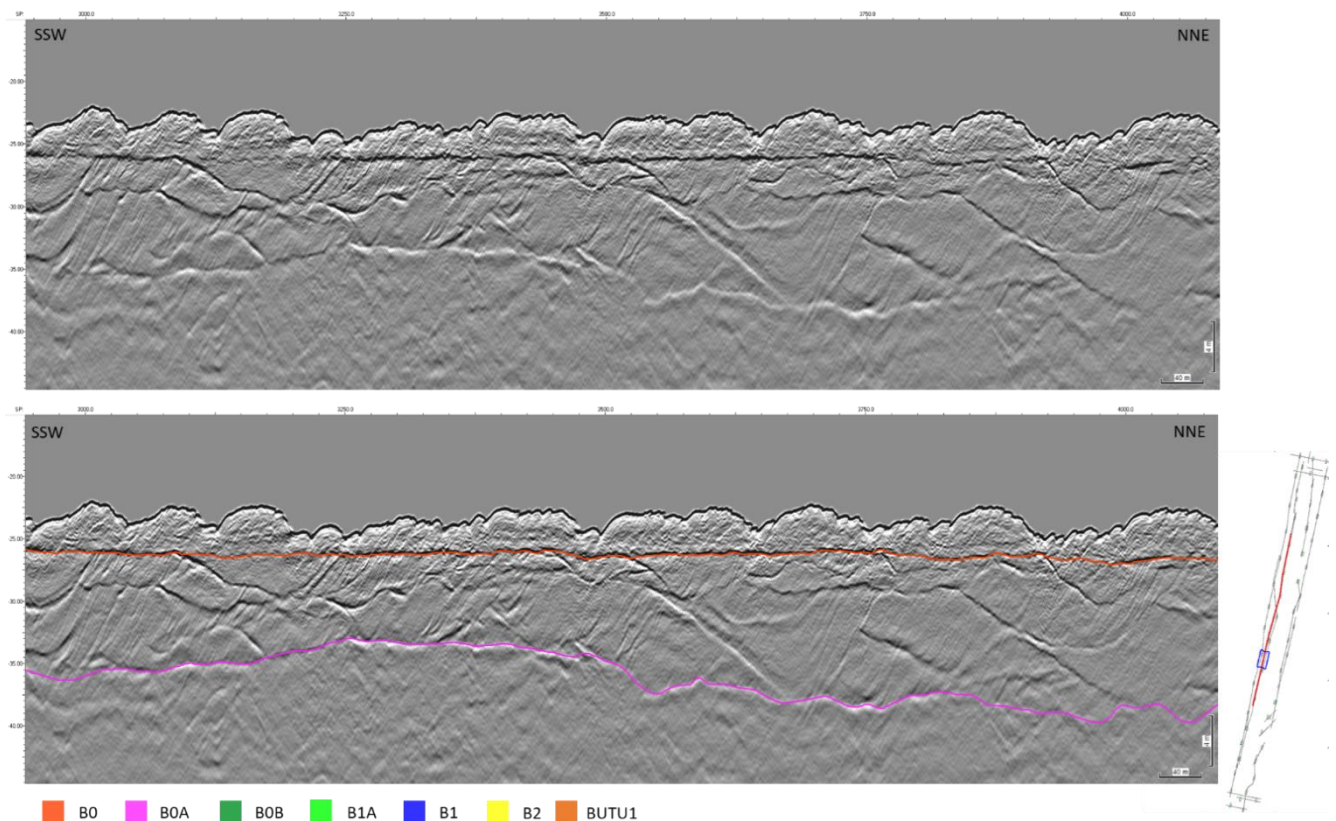


Figure 47 - Seismic profile depicting the complicated geometries of the internal erosional surfaces that occur locally within U0A. 2D Seismic Line 24G02_RR_200.

4.5.8. BOULDERS

Boulders have been confirmed within the survey area, confidently at the seabed based on multibeam bathymetry and side-scan sonar data, and should be assumed present, at some frequency, in the subsurface based on the region's geologic history. The probability of boulder occurrence should be greater in the glaciogenic seismic units, i.e., U0A, U0B, U1A, U1, and U2 relative to the Holocene *Surface Sands Formation* or U0. A comprehensive boulder analysis based on PD interpretation is contained in Section 4.5.9.

4.5.9. OTHER FEATURES

The 3D UHRS datasets were inspected in order to identify any subsurface feature that can pose a potential constraint on future developments of the site; this does not directly correlate with a risk. The mapping of these features was limited to the most significant and potentially hazardous features for pile foundation installation.

From this assessment, two significant buried anomalies were identified in two separate WTG localisations: WT33 (located northwards of WTG box; Figure 49) and WT41 (within the SW quadrant of the WTG area; Figure 49). These anomalies are observed as strong negative impedance contrasts (soft-kicks reflections) in the shallow subsurface (approximately 2.5 m deep) within the recent sediments (Holocene *Surface Sands Formation* or unit U0). Their shape is elongated and approximate dimensions taken from the 3D UHRS data are:

- WT33: ~14.5m length x 3m width;
- WT41: ~3m length x 1.5m width.

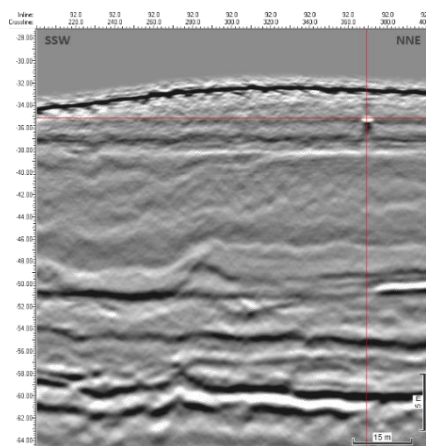
Details on their positioning and dimensions are provided in Table 17, and their description is featured in Table 20 in section 5.4.5.

The character of these anomalies (soft-kicks) suggest they may be related with features that are less dense than the materials they are embedded with, representing softer materials. Alongside their shape, shallow burial depth, depositional context in which they are emplaced, and their isolated occurrence, these are interpreted to be unlikely related with geological features. Green Rebel's analysis of the 2024 MBES data shows a low-relief seabed depression that corresponds to the anomaly at WT41; another low-relief bedform can be seen at WT33 (Figure 50). The morphology of these seabed features is ambiguous, but their scale is consistent with potential mounding and scouring at wreck sites. No magnetometer information is available to ascertain the occurrence of magnetic anomalies at these locations. The origin of these anomalies is uncertain, and further investigation on their origin is advised.

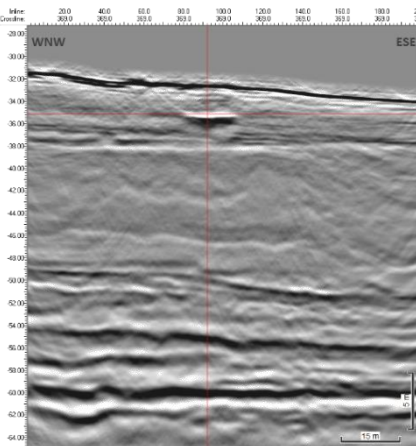
Table 17 - Position and size of buried negative amplitude anomalies detected in WT33 and WT41.

WTG	Position	X	Y	IL	XL	Depth m	Depth m BSB	Length m	Width m
WT33	Centre	301949.55	5852263.68	92	369	35.1	2.5	14.5	3
	E	301956.68	5852261.94						
	W	301943.08	5852264.21						
WT41	Centre	300511.03	5847565.59	77	270	17.7	2.5	3	1.5
	E	300512.69	5847565.20						
	W	300509.84	5847565.84						

WT33 | MIG_DPT | Inline 92



WT33 | MIG_DPT | Xline 309



WT33 | MIG_DPT | Depth Slice 31.50m

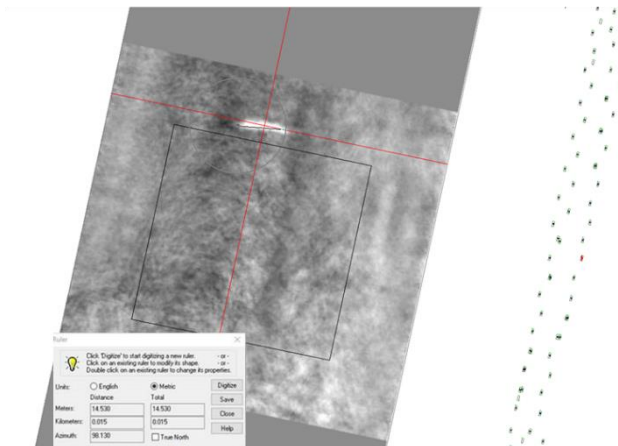
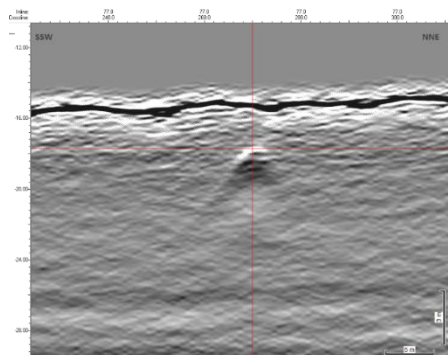
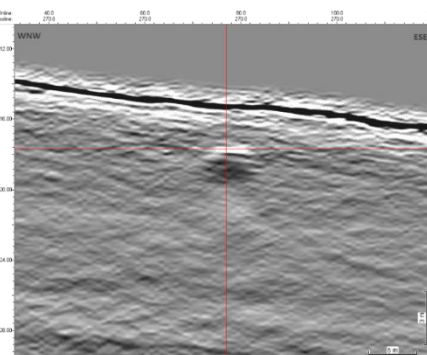


Figure 48 - Strong negative impedance anomaly (soft-kick) within the recent sediments at WT33, approximately 14.5m length, 3m width and at 2.5 m BSB.

WT41 | MIG_DPT | Inline 77



WT41 | MIG_DPT | Xline 270



WT41 | MIG_DPT | Depth Slice 17.70m

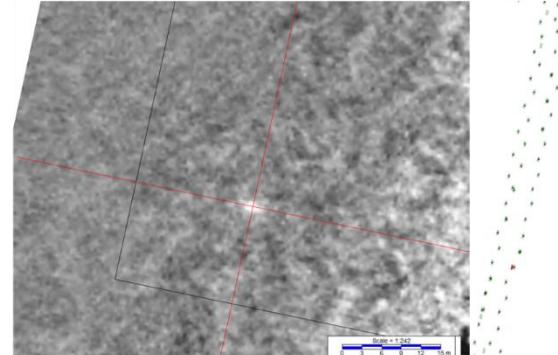


Figure 49 - Strong negative impedance anomaly (soft-kick) within the recent sediments at WT41, approximately 3m length, 1.5m width and at 2.5 m BSB

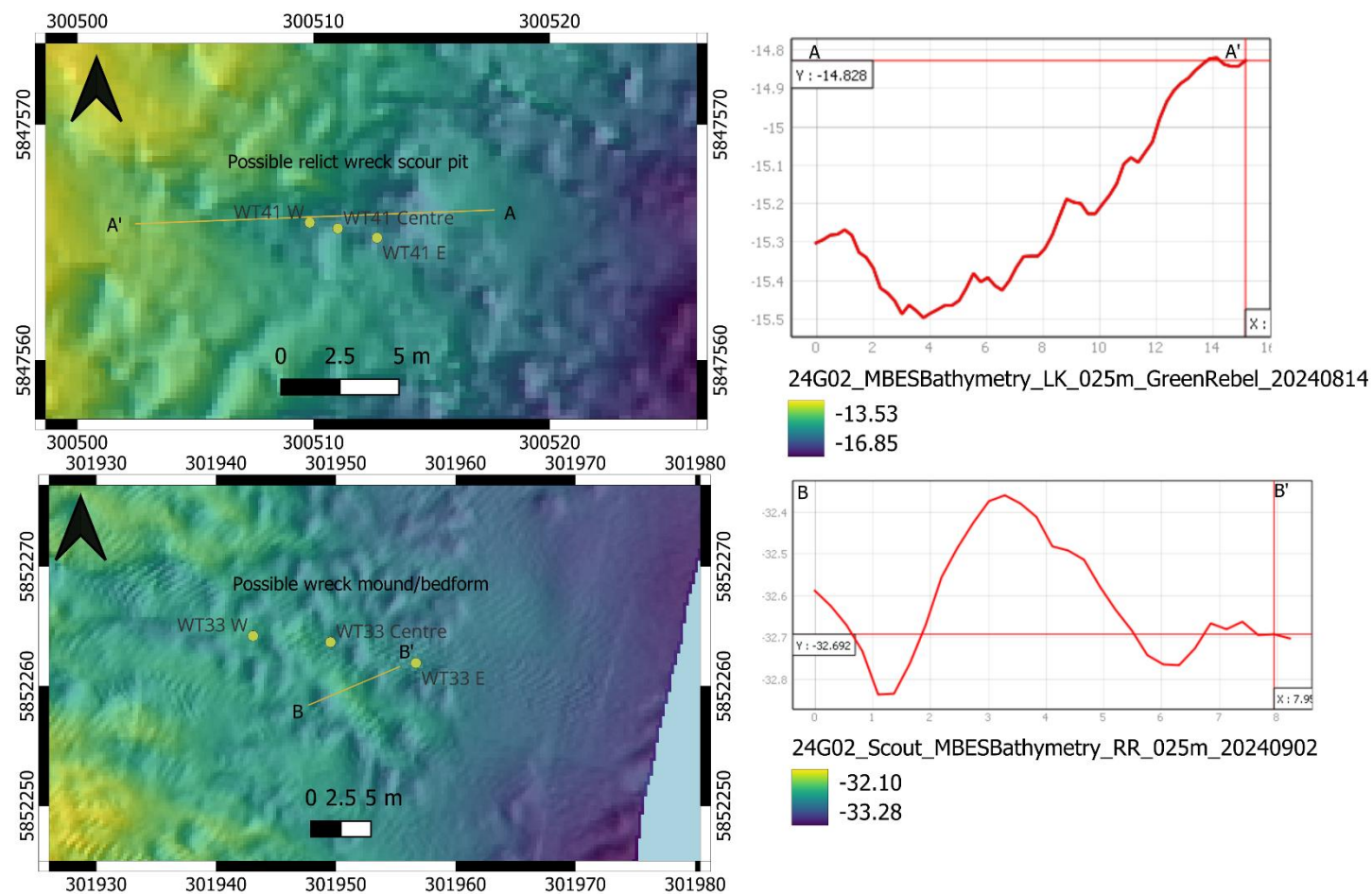


Figure 50 - Green Rebel's 2024 MBES data at WTG locations WT41 (top left) and WT33 (bottom left), and respective slope profiles A-A' and B-B' at the right. Top: low-relief seabed depression above the 3D UHRS anomaly of WT41; bottom: low-relief bedform above the 3D UHRS anomaly of WT33.

5. POINT DIFFRACTORS / POTENTIAL BOULDERS

Coarse sediments, such as boulders, cobbles, and gravels are expected to be prevalent in glacial environments, given the highly energetic processes of bedrock erosion and sediment remobilization typically associated with these settings. These materials, particularly boulders, may constitute geohazards for offshore site development. For better understanding of the boulders assessment results, this section provides background information regarding geophysical and geological processes that may impact the imaging and mapping of these features.

5.1. SUBSURFACE OBJECT DETECTION USING UHRs DATA – 3D SEISMIC MIGRATION OF POINT DIFFRACTORS

For better understanding of the Point Diffractors (PD) assessment results, this Section provides background information regarding 3D seismic migration.

Potential boulders may be identified within the 3D UHRs data as PD, typically marked by diffraction hyperboloids on non-migrated 3D seismic data. Diffraction hyperboloids result from scattering of energy from a subsurface feature associated with abrupt changes in physical properties. Generally, diffraction hyperboloids may arise on 3D seismic data depending on a specific set of conditions, such as: density of contrasting media, size of the bodies associated with those contrasts, and frequency content of the signal.

When migrating a diffraction hyperboloid, the scattered energy is focused (collapses) into a seismic reflection. There will always be a mistie between the migrated 2D and 3D structures, even if a 2D survey is acquired in a perfectly dip and strike direction for a 3D structure. For a moderately complex geological structure, much of the energy on a 2D section will be recorded out of the plane (sideswipe). Appropriate migration of a 3D survey will cancel any sideswipe events and provide a clean image of geological structure to be interpreted. Generally, most of the 2D migration methods can also be used in 3D. For a constant velocity in 2D, a point reflector will produce a hyperbolic diffractor. In a constant velocity 3D medium, a point reflector (blue dot on Figure 52) produces a hyperboloid diffraction volume which yields a hyperbola when vertically cut in a 2D direction (green sections on Figure 51). Migration of the diffraction hyperboloid weights and sums all the amplitude and places them at the apex. For 3D data, focuses the energy of the diffraction hyperboloid into the real spatial location of the object (blue dot). However, migration on 2D data collapses the energy away from the object, if not directly above it, as shown by the green dot on Figure 51.

Though the diffractor model is over simplified, it is of vital significance in migration and velocity analysis theory, as any complex structures can be considered as a continuum of diffractors. Choice of migration algorithm is data dependent and usually is extensively tested to obtain optimum results.

One extensively used migration algorithm is the Kirchhoff Migration. The 3D Kirchhoff migration can simply weight and sum all the amplitudes and place them at the apex (blue dot) (Figure 51).

Data examples depicting Figure 51 are provided in Figure 52 showing non-migrated 3D UHRS data and respective migrated envelope attribute. A non-migrated seismic inline (MUL) corresponds to the direction number 2 of Figure 51, and a perpendicular crossline MUL corresponds to the direction number 1. Figure 53 displays depth slices of non-migrated, migrated, and envelope data intersecting the PD shown in Figure 52. The diffraction hyperboloid observed in the MUL data collapses into a high amplitude/envelope object in migrated data (MIG).

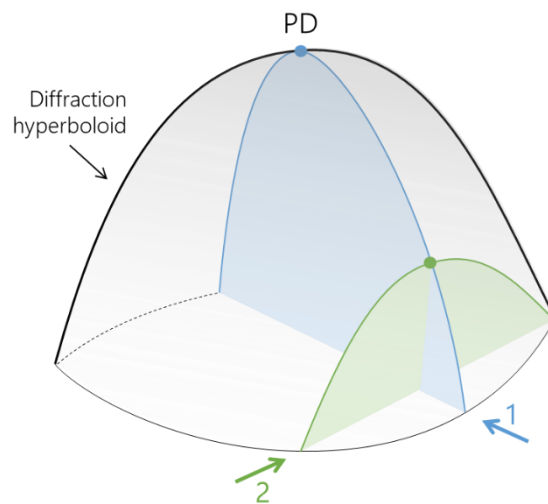


Figure 51- The principles of 3D Migration. Green sections show 2D cuts on a 3D hyperboloid diffraction volume.

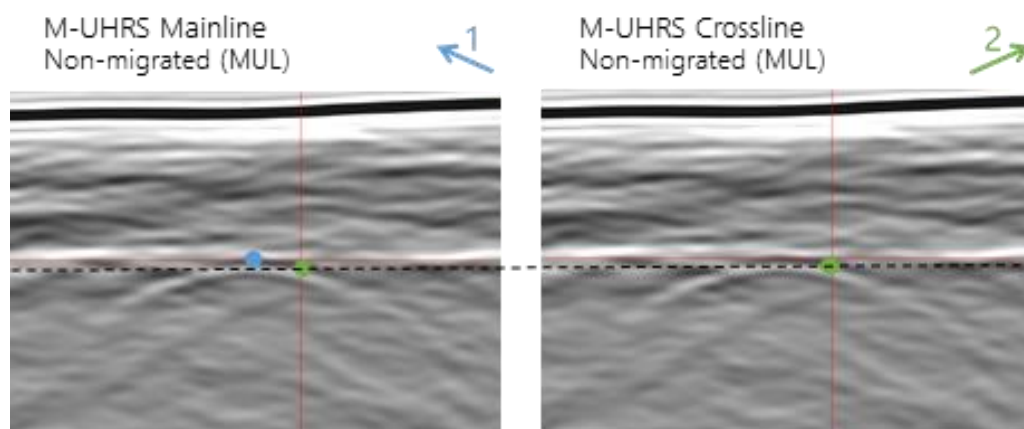


Figure 52 - Data examples depicting of the diagram of Figure 1, showing non-migrated 3D UHRS data. A non-migrated seismic inline (MUL) corresponds to the direction number 2 of Figure 1 intersecting the blue (real hyperboloid apex) and green dots (apparent apex) at different depths. A perpendicular crossline MUL corresponds to the direction number 1 showing the green dot as an apparent hyperboloid apex. Example shown not from 3D UHRS ABWP Survey.

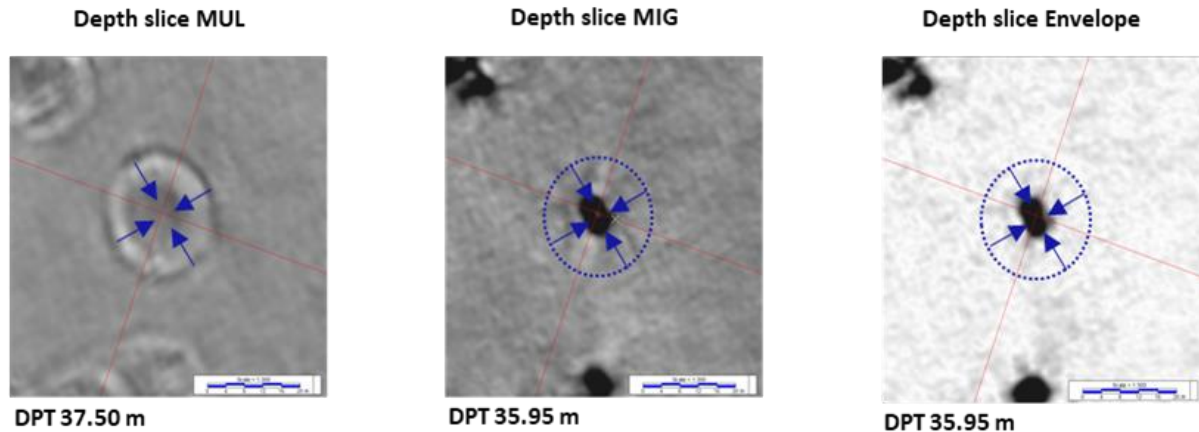


Figure 53 - Time slices of non-migrated, migrated, and envelope data intersecting the PD shown in Figure 2. The diffraction hyperboloid observed in the MUL data (left) collapses into a high amplitude (centre)/envelope (right) object in MIG data. Example shown not from 3D UHRS ABWP Survey.

5.2. LIMITATIONS AND UNCERTAINTIES IN SUBSURFACE OBJECT DETECTION AND INTERPRETATION USING UHRS DATA

3D UHRS data allows detailed imaging of geological structures and subsurface objects, including possible boulders. However, its application is not without limitations and uncertainties. These challenges arise from the interplay of seismic wave propagation physics, acquisition and processing constraints, and the inherent complexity of geological systems, particularly when applied to detecting possible boulders in heterogeneous geological settings.

This section explores key factors limiting the precision and reliability of subsurface object detection and interpretation in 3D UHRS surveys.

The identification of potential boulders in 3D UHRS is dependent on:

- Seabed and subsurface geology complexity
- Acquisition conditions (noise and towed array stability);
- Data frequency content;
- Signal-to-noise ratio (SNR);
- Seismic penetration and resolution variation with depth (earth's filtering effect);
- Bin size;
- Impedance contrasts;
- Seismic velocities impact on migration;
- Target sizes;
- Fold coverage;

- Aliasing effects;
- Tuning effects;
- Migration aperture.

Depending on these factors (some of which described below and in the 3D UHRS Processing Report), not all existing subsurface boulder-related PDs can be imaged on the seismic record.

Uncertainties in their interpretation also arise from ambiguity in diffraction sources and geological context in which they occur.

Frequency content and signal-to-noise ratio

The frequency content of seismic data plays a critical role in the detection of subsurface possible boulders. High frequencies enhance vertical and horizontal resolution, allowing for more precise imaging of subsurface structures. However, these frequencies are subject to rapid attenuation with depth due to absorption and scattering, leading to signal loss and reduced resolution in deeper sections. Additionally, the higher sensitivity to noise at elevated frequencies may have an impact on their detection, particularly in areas with low signal-to-noise ratios (SNR). Environmental and acquisition-related noise, and the complex scattering caused by heterogeneous materials often obscure or distort true seismic signal and boulder-related diffractions. This limits the detection range of small possible boulders and reduces the likelihood of identifying them in deeper subsurface layers.

Advanced filtering and noise suppression techniques are applied during data processing to improve SNR and final imaging. These techniques need to be fine-tuned and adequately applied to avoid inadvertently removing subtle but critical features.

Resolution Constraints and signal loss with depth

Vertical and horizontal resolutions are fundamental to accurately imaging possible boulders, yet they are inherently limited by seismic acquisition and processing constraints. Vertical resolution, governed by the dominant frequency, often deteriorates with depth as attenuation reduces the effective bandwidth of the signal. Horizontal resolution, on the other hand, depends on bin size, UHRS frequency content, the seismic wave's Fresnel zone, seismic contrast, and the efficiency of the data migration algorithm. The expansion of the Fresnel zone with depth may cause diffraction signals from closely spaced possible boulders to overlap. In these situations, the collapse of the hyperboloids becomes increasingly sensitive to the quality of the migration velocities and yields ambiguous imaging results. Signal loss with depth exacerbates these issues, as the amplitude of boulder-related diffractions decreases with increasing depth, making them harder to distinguish from subtle

impedance contrasts, leading to incomplete imaging of small or low-reflectivity targets. These resolution constraints have an impact on the ability to differentiate thin or overlapping geological features.

Furthermore, depending on the object position relative to the bin grid, its signal may be detected by several surrounding voxels, which increases its “footprint” and thus its apparent horizontal size (Figure 54 and Table 18). This effect is more significant in small targets (<2 m), and one must keep in mind that this is the expected impact of bin sizes in the measurement of potential targets. The minimum horizontal dimensions of a detected point diffraction are within the order of the bin size. For safety/risk purposes, consider that horizontal measurements provided may be overestimated, particularly for smaller targets.

Another consequence of this effect (alongside imaging aliasing) is that the perceived contrast of a potential target may be attenuated, since its acoustic response is distributed by the number of bins in which it is detected. For example: an object with 0.5 m diameter and positioned at the bin centre would be perceived to have a significantly higher contrast since its acoustic response would be entirely captured within a single 0.5 m bin; however, the same object positioned off the bin centre would be represented in more bins but its contrast would appear dimmer (since its response is distributed by the number of bins it occupies).

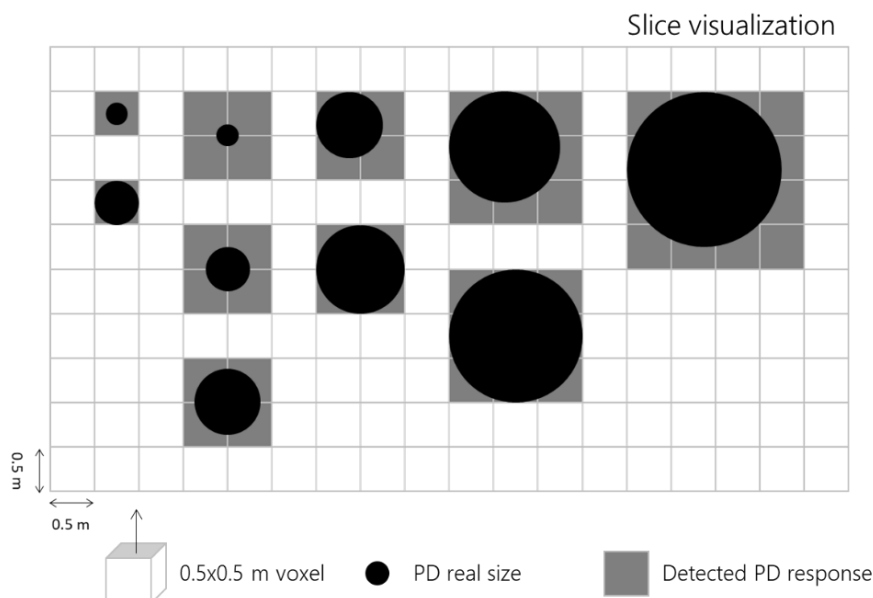


Figure 54 - Schematic representation of how point objects or PDs of variable sizes may be observed in seismic slices, according to their acoustic response and position relative to the seismic binning grid. Black circles represent objects of different sizes, whereas grey squares show the bin areas in which their respective acoustic response would be detected in seismic slices, depending on their center location relative to the bin grid. Dimensions of small targets may be overestimated when their response is detected in several bins.

Table 18 - Object real size versus its perceived horizontal size in 0.5 m bin seismic data.

Boulder diameter (m)	PD size imaged in 0.5m bin UHRS (m)
0.25	0.5 x 0.5, 1 x 1
0.5	0.5 x 0.5, 1 x 1
1	1 x 1
1.5	1.5 x 1.5
2	2 x 2
2.5	2.5 x 2.5
3	3 x 3

Impedance contrasts and object visibility

Detection of subsurface Point Diffractors depends heavily on the contrast in acoustic impedance between the possible boulders and their surrounding materials. High impedance contrasts, such as those between dense rock boulders and soft sediments, generate strong diffraction patterns that are easier to identify. Conversely, boulders composed of materials with impedance values similar to the surrounding matrix produce weak or indistinct diffractions, reducing their visibility in seismic data. This is particularly problematic in materials with minimal density or velocity variations. For instance, a boulder made of limestone embedded in calcareous sediments may produce minimal impedance contrast, resulting in subtle signals that can be overlooked during interpretation.

Seismic velocities and the impact on diffraction migration

Accurate velocity models are critical for proper migration and imaging of boulder-related diffractions. Variations in seismic velocities within the subsurface, caused by lateral heterogeneities or anisotropic materials, can distort the apparent position and shape of possible boulders in the migrated seismic image. Errors in velocity modeling can also amplify uncertainties in estimating the size, shape, and location of subsurface objects, particularly in complex geological environments. These may lead to target mispositioning and potentially causing interpreters to misidentify boulder locations or fail to detect them entirely.

Fold Coverage

When fold coverage is low, the ability to accurately detect and image subsurface objects diminishes. Low fold leads to a reduced SNR (in which noise may not be sufficiently suppressed, hindering data quality), sparse data sampling (affecting the continuity of seismic reflections), decreased resolution, and possible introduction of artefacts. The overall SNR impact of low fold is further compounded by the importance of having sufficient fold per offset on any given bin. The gaps caused by low fold per

offset introduce aliasing artifacts in the regularized offset slices. This type of regularization aliasing can seriously compromise the recovery of the hyperboloids.

Aliasing Effects

Aliasing in 3D seismic data occurs when seismic waves are under sampled in space or time, causing higher-frequency signals to be misrepresented as lower frequencies in the recorded data. This misrepresentation leads to distortions in the seismic image and can severely impact the detection and interpretation of subsurface objects. Aliased frequencies can appear as spurious reflections or noise and distort the geometry of subsurface structures, resulting in obscured or misplaced features. For the Arklow 3D UHRS survey, acquisition design and processing techniques (anti-aliasing filtering and regularization) were designed to minimize aliasing effects and ensure reliable subsurface imaging.

Tuning Effects

Tuning in 3D seismic data refers to the constructive or destructive interference of seismic reflections from closely spaced subsurface interfaces. This phenomenon occurs when the thickness of a layer or the separation between two reflecting interfaces approaches or is smaller than the vertical resolution of the seismic data. When this separation is less than a quarter of the dominant wavelength of the seismic wave, reflections from the top and bottom interfaces overlap and interfere, altering the seismic response. This can lead to amplitude distortion where:

- Constructive interference can enhance the amplitude of the seismic response, making thin layers appear thicker or more prominent than they are;
- Destructive interference can reduce or even cancel out the reflection amplitude, causing thin beds or interfaces to be missed entirely.

At the limit of the 3D UHRS resolution, tuning effects may have a significant impact in the detection of subsurface possible boulders. These are observed in cases of close proximity of potential targets or when these occur resting along geological interfaces: constructive interference may enhance amplitudes, potentially leading to false positives targets; whereas destructive interference may mask their response, particularly when it obscures the negative base reflection (i.e., only a positive point anomaly is visible, representing the top of a boulder; base reflection of the “hard-kick” response is not present). The latter may lead to failure in the identification of potential targets (false negatives), and underestimations of their occurrence in the subsurface. Tuning effects also significantly impact size estimations of potential targets.

Ambiguity in diffraction sources and geological context

One of the most significant uncertainties in boulder detection arises from the ambiguity in the sources of diffractions. Diffractions can be produced by a range of subsurface features, including faults and fractures, voids, irregular interfaces, and small-scale heterogeneities, in addition to possible boulders. Distinguishing between these sources is often challenging and requires detailed knowledge of the geological context and careful interpretation, as different geological features can produce similar diffraction patterns.

Ambiguities may arise when multiple sources overlap spatially or temporally, creating composite signals that are difficult to decompose and further complicating the detection of individual objects. For instance, in heterogeneous environments with intricate layering, diffractions can interact with reflections, producing artifacts or masking true subsurface objects. Potential boulder-rich deposits (ex., tills, outburst flood deposits, gravel lags, etc.) in particular may be associated with areas of increased interpretation uncertainty, as the acoustic response of individual Point Diffractors may be masked due to the amount and close proximity of these features and/or other coarse materials. Diffractions overlap and disrupt individual responses (scattering), producing speckled/granular facies patterns. Furthermore, these effects may mask larger targets if embedded in coarse or “stiff” sediments, which are impossible to distinguish individual objects due to low impedance contrasts. Aggregates of gravels, pebbles, cobbles, and small boulders (<50cm) can cause effects similar to those of bubble clouds/curtains on acoustic propagation, causing scattering, frequency attenuation and characteristic speckled seismic facies (Koller & Shankar, 1994; Raveau, 2019) that can be hard to distinguish from high frequency noise.

Understanding the geological setting is therefore essential, but it remains a subjective process that depends heavily on the interpreter’s expertise and assumptions. Misinterpreting the source of a diffraction can lead to incorrect conclusions about the size, shape, or distribution of boulders in the subsurface.

Some of the most common geological features found in glacial environments that can generate similar diffraction patterns to subsurface boulders, or create seismic artefacts that mask their response are:

- Deformation: folding (fold apex/hinges, particularly at small scale), fractures and fault discontinuities;
- Irregular/rugose geological surfaces, micro-morphologies;
- Coarse-grained deposits;
- Ice scraping features;
- Buried channel margins and thalwegs;

- Possible shallow gas.

Manual Interpretation and Subjectivity

Considering all limitations and uncertainties described above related to imaging and the geological context, manual interpretation remains the best approach to the detection and interpretation of possible boulders in seismic data. PDs potentially related to subsurface boulders were mapped manually and, although conducted in a precise manner, uncertainties associated with the seismic data and human perception should be considered.

Interpreters must identify and prioritize features of interest while navigating uncertainties and ambiguities in the data. This process is inherently subjective and influenced by the experience and biases of the interpreter. Small or weak diffractions that might indicate possible boulders can be overlooked or dismissed as noise, while stronger but ambiguous signals may be misclassified as boulders when they originate from other features.

Given the geological complexity of the environments in which boulders occur and imaging limitations, combined with the need for interpreters to simplify or generalize their findings, the manual detection and characterization of possible boulders is susceptible to imprecisions and inconsistencies. For safety/risk purposes, an error of $\pm 1.5\text{m}$ for each PD centre coordinate should be considered. This uncertainty increases with depth (lower frequency content and changes on signal to noise ratio).

Project-specific considerations

While UHRS data provides powerful tools for detecting and interpreting possible subsurface boulders, the process is subject to numerous limitations and uncertainties, and these must be carefully considered. Frequency content, signal-to-noise ratio, resolution constraints, impedance contrasts, fold coverage, and velocity modeling all play critical roles in the quality and reliability of boulder imaging. Ambiguities in diffraction sources and the subjective nature of manual interpretation further complicate the process, highlighting the need for robust validation and multidisciplinary approaches. Understanding and addressing these challenges is essential for maximizing the utility of seismic data in boulder detection and ensuring successful outcomes in subsurface investigations.

For the ABWP project, the most significant factors impacting the identification of potential boulder-related PDs were associated with:

- Seabed morphology:
 - Seabed irregularities related to recent sediment bedforms produced a significant number of diffractions. Pre-stack migration effectively migrated energy to their true

geometry, though there may be inherent energy loss as the sound travels through this dispersive and scattering medium;

- Subsurface geology complexity:
 - Complex geology and the occurrence of uneven reflections with anomalous amplitudes that may constructively/destructively interfere with possible seismic artefacts (such as migration artefacts, remnant noise, and multiples) producing ambiguous responses and patterns;
- Acquisition conditions affecting towed array stability:
 - Strong currents, likely amplified by the seabed morphology, affected the streamers arrangement during acquisition onboard the Roman Rebel vessel, leading to seismic data re-positioning at the office to ensure the recovery of high frequency signals;
- Footprint:
 - Some geological features were occasionally aligned with the acquisition footprint. Although filters are applied to minimize the footprint effect, the filter had to be adapted accordingly to allow for a balanced approach, to avoid over-attenuation of the primary wavefield; as such, some remnant footprint acquisition artifacts may persist which may introduce uncertainty for PD detection;
- Multiple attenuation:
 - Dipping areas posed significant difficulties in pre/post-stack multiple attenuations. Similar to the footprint attenuation, a softer filtering approach was needed in some cases to preserve primary reflections, despite keeping some of the multiple wavefield. Any form of attenuation may affect the primary, particularly for small targets. As a result, evaluating PDs at or below the multiple surfaces proved to be more challenging. Nevertheless, data were carefully processed to achieve the best SNR in order to allow for hazards identification;
- Migration:
 - Pre-stack migration was fine-tuned in order not to over nor under-migrate the data. To minimize artifacts from pre-stack migration within WTG boundaries (60 m wide), blocks were set with 100 m widths, incorporating 20 m buffer on each side. Despite this, some edge artifacts persisted in some cases, especially in areas with very high acoustic impedance;
- Natural frequency attenuation with depth, exacerbated by strong acoustic impedance events, may impact PD identification certainty.

Despite these challenges, the ABWP 3D UHRS survey successfully achieved its objectives. As described above, each obstacle was addressed with tailored solutions, ensuring the integrity and accuracy of the data. Adaptive processing strategies were important in overcoming complex geological and environmental conditions.

5.3. PD ASSESSMENT STRATEGY

The Arklow project's scope comprised the assessment and mapping of subsurface PDs that may be related with potential boulder occurrences, within 71 boxes centered on targeted Wind Turbine Generators (WTG) and Offshore Substations (OSS) planned locations across the Arklow site. The strategy for PD mapping in 3D UHRS data was carried out manually down to 50m below seabed or to the top of the bedrock if it is above 50m below the seabed, and conducted in a staged process that involved two assessment phases:

- The 1st assessment included the identification and mapping of all PDs (sized $\geq 1\text{m}$) within a 60 x 60m box centred at each WTG/OSS location, according to their interpretation confidence rating as representing potential boulders (PD3 – high confidence; PD2 – medium confidence; PD1 – low confidence; PD0 – confidence zero, related with point anomalies detected within the multiple interval).
- The 2nd assessment stage included PD assessment and dimensioning of single PDs selected and validated by the SSE for each WTG/OSS.

3D UHRS datasets and interpretation results were delivered in batches of nr min 6 -nr max 11 WTG/OSS, making up a total of 8 batches delivered.

5.3.1. METHODOLOGY AND CLASSIFICATIONS

The methodology for mapping of PD was manual and conducted in a staged process outlined in Figure 55.

The detection and assessment of PD were carried out by the detailed analysis of both non-migrated (MUL) and migrated (MIG) 3D UHRS data. Amplitude and envelope responses were examined for the MIG data. The process involved the identification of PD, and the derivation of PD attributes required for the final contact listing. The required attributes are outlined within Table 19. The table includes information on what attributes are provided for PD identified through assessment of standard processed.

Details of the methodology and how various attributes were derived is explained within the subsections below.

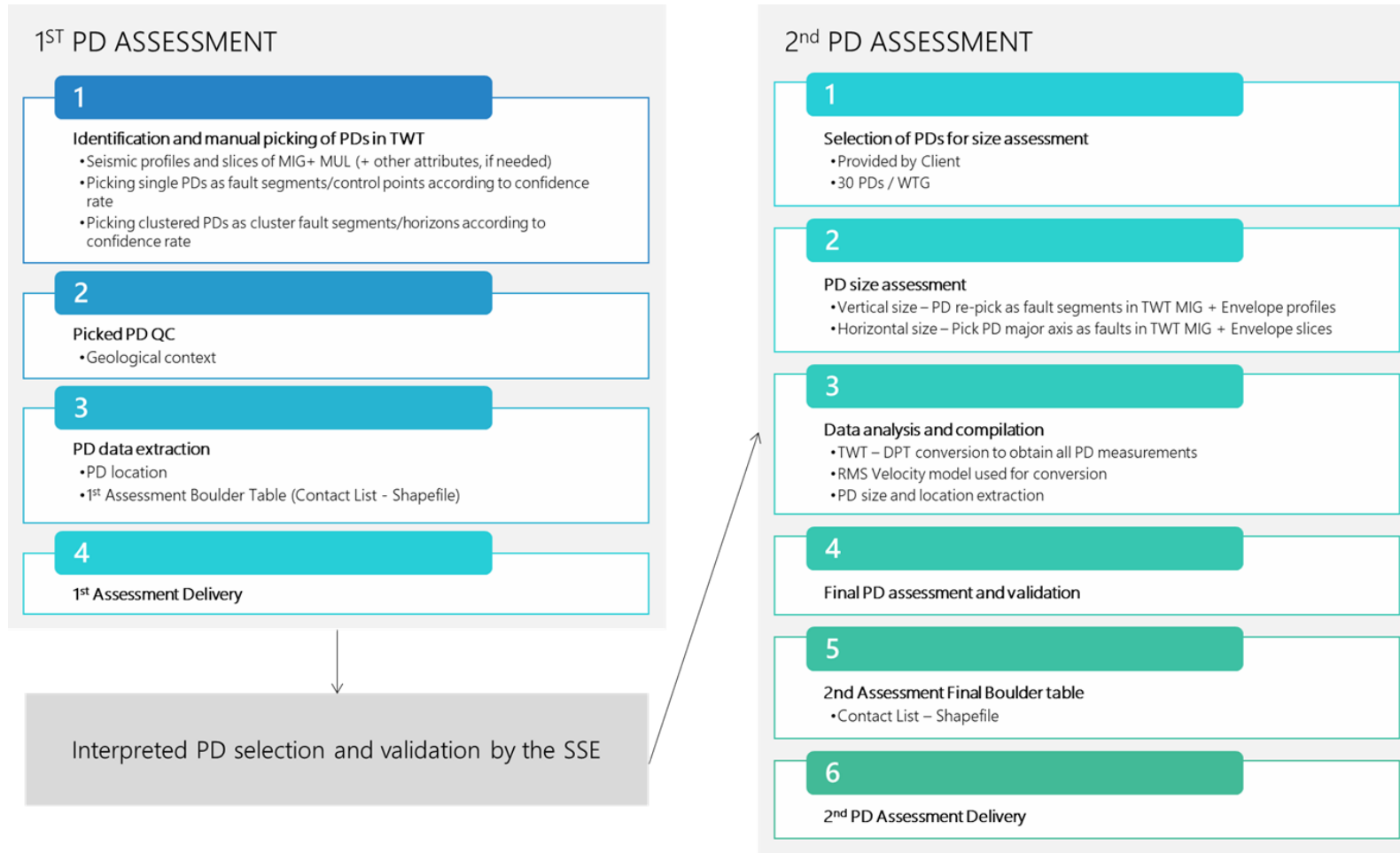


Figure 55 - Workflow for the manual mapping of point diffractions.

Table 19 – Subsurface PDs – contact list attributes (in shapefile).

Attribute	Abbreviation	1 ST Assessment	2 ND Assessment
ID	ID	✓	✓
Easting (m)	Easting	✓	✓
Northing (m)	Northing	✓	✓
Water Depth (m)	Wdepth (m)	-	✓
Time of Burial	DoB (ms)	✓	-
Anomaly TWT (ms)	ArrivalTWT	✓	✓
Depth LAT (m)	Depth LAT(m)	-	✓
Depth of Burial	DoB (m)	-	✓
Root Mean Square Velocities	VRMS (m/s)	-	✓
Horizontal Size (m)	Hor Diam	-	✓
Vertical Size (m)	Vert Size	-	✓
Confidence	Confidence	✓	✓
Associated Geological Unit	Geo Unit	-	✓

5.3.2. POSITION AND DIMENSIONS

PD estimated dimensions were derived from their response on standard processed MIG data and respective envelope.

Horizontal measurements were taken on a maximum decay gradient with the minimum necessary gain to prevent overprinting as to not mask the PD seismic signature. The procedure was carried out assessing both amplitude and envelope (unmigrated and migrated) data to reduce measurement uncertainty, by mapping a horizontal fault segment across the length of a target's major axis. Vertical measurements were made across a target's vertical axis on the migrated data, thus being possible to determine the top (depth of burial) and center coordinates of the PD body.

After a careful and extensive QC, from the spatial correspondence and manipulation of these elements (fault segments), the position, and (approximate) horizontal dimensions of PD were obtained. Measurements were carried out in the TWT domain in Kingdom Suite and later converted to depth using the RMS velocity model.

5.3.3. SINGLE OR CLUSTERED PD

PD/Potential boulders may be found as single isolated targets or grouped in a cluster. A cluster is a delineation of areas with abundant subspherical features that do not meet all the criteria to be interpreted as a potential isolated boulder.

The assessment of the PD is associated with a single of targets is included within the contact listing. Clusters were exported as horizons in an ASCII file format.

5.3.4. PD FACIES

Some coarse-grained deposits, where small-sized objects (at the limit of seismic resolution) occur in close proximity, may produce a particular seismic facies in fully processed datasets. The seismic facies has a characteristic mottled or granular/speckled texture that is interpreted to be associated with numerous small PDs related with gravels, pebbles, cobbles, and small boulder “clouds”. Although it is not possible to discern individual targets nor estimate the size of these objects, it is assumed that most of these objects are <1 m, and seismic facies interpreted to be potentially associated with high density of small targets. However, it is possible that larger-sized boulders may occur embedded within these deposits and their individual response may be masked due to a low impedance contrast compared with a stiff surrounding matrix, or may be attenuated by the occurrence of numerous overlapping diffractions. Considering that these deposits may pose a potential hazard/constraint to planned installation operations, the mapping of these facies – PD facies (PDF) – was included in this assessment, provided as horizons in ASCII file format.

5.3.5. CONFIDENCE ASSIGNMENT

Confidence assignment was applied to the mapped PD during assessment and included within the contact listing. Confidence assignment is based on the interpretation of isolated PD responses and their likelihood of corresponding to potential boulders, by analysing their seismic response in both vertical profiles and TWT slices. Classification of high (PD3) to low (PD1) confidence PDs is based on their contrast, character, and shape, and follows the guide matrix Stronger point anomalies detected within multiple interval marked as PD0 (confidence zero) (Figure 56).

CONFIDENCE	AMPLITUDE	CHARACTER	SHAPE	GEOLOGICAL CONTEXT	BOULDER LIKELIHOOD
PD3	High	Positive over negative	Circular	Likelihood of boulder occurrence:	High
PD2	↑	↑	↑	- Deposition setting - Sediment types	↑
PD1	Low	Positive (no negative below)	Irregular	Surrounding seismic facies: - Background matrix amplitude - Internal complexity	Low
PD0	Point contrasts detected within the multiple interval				

Figure 56 - Buried Anomaly Confidence Assignment: PD3 = High confidence; PD2 = Medium confidence; PD1 = Low confidence; PD0 = confidence zero (point anomalies detected within the multiple interval).

In addition to the criteria described above, geological context is also considered when estimating the likelihood of a PD to correspond to a potential boulder, based on observations of surrounding seismic facies (background amplitudes and internal complexity) and interpretations of possible depositional setting and expected sediment content. Furthermore, all the factors described in sections 5.1 and 5.2 related with the limitations and uncertainties of subsurface object detection in 3D UHRS data were considered, particularly those that introduce potential interpretation ambiguity and/or affecting seismic imaging. These factors were most relevant on the interpretation of low confidence targets.

PD clusters were also classified according to the likelihood of being related with the occurrence of potential boulders in close proximity within a limited area, according to the confidence of PDs within it (from high to low confidence – C3, C2 and C1).

Examples of each PD type are provided in the results section 5.4

5.3.6. GEOLOGICAL UNIT

During the mapping of PDs, the geological context was considered in order to verify the possible origin of the PD and discard any that may not be related to the occurrence of boulders, since other geological features can generate similar diffraction patterns (e.g., irregular geological surfaces, ice scraping features, buried channel margins, gravel lags, as discussed in Section 5.2).

Following assessment of the PD and determination that the PD is a potential boulder, the geological unit in which it is mapped, was assigned. The assigned unit is based on the existing ground model for the site and unit IDs refer to Table 7. In case of future adjustments to the ground model (considering new insights provided by 3D UHRS data), the unit assignment to each interpreted PD may need to be updated.

5.3.7. QC OF PD INTERPRETATIONS

Two phases of QC were applied. The first QC was performed after manual mapping, to check if all point diffractions mapped are potential boulders. After the first QC, faults segments were exported to

extract the information necessary to fill the final Contact list. To finalize the interpretation of potential boulders, a final QC was carried out.

5.4. PD ASSESSMENT RESULTS

5.4.1. POINT DIFFRACTORS / POTENTIAL BOULDERS

Results from the PD assessment for the Arklow area are summarized within Sections 5.4.1 to 5.4.5 below, featuring examples of interpreted PDs, according to their confidence in corresponding to potential boulders.

Two types of PD features may be identified on 3D UHRS data, with different significance of potential risk:

- Potential Isolated Boulders, picked as vertical fault segments;
- Potential Clustered Boulders, mapped as horizons delineating the top and the lateral extent of PD clusters.

Table 20 (section 5.4.5) summarizes all the interpretation results for each WTG in the Arklow site. The assessment of isolated targets and PD clusters followed the procedures described within Section 5.3.

5.4.2. POTENTIAL ISOLATED BOULDERS

Potential isolated boulders were identified and mapped in the fully processed 3D UHRS datasets (MIG and MUL). These objects are interpreted to have sizes equal to or larger than 1m (horizontal measurement), and their occurrence may be associated with a potential higher risk.

A total of 1710 potential isolated boulders were identified across the full Arklow survey. The search areas for potential isolated boulders were variable, following the phased strategy sequence described in Section 5.3.

Examples of interpreted PDs are displayed in the following figures, according to their confidence:

- PD3 (high confidence): Figure 57 and Figure 58;
- PD2 (medium confidence): Figure 59 and Figure 60;
- PD1 (low confidence): Figure 61 and Figure 62;
- PD0 (confidence zero; point anomalies detected within the multiple interval): Figure 63.

A summary of the PDs / potential boulder interpretation is provided within Table 20 (Section 5.4.5) divided by WTG/OSS site.

PD3 examples

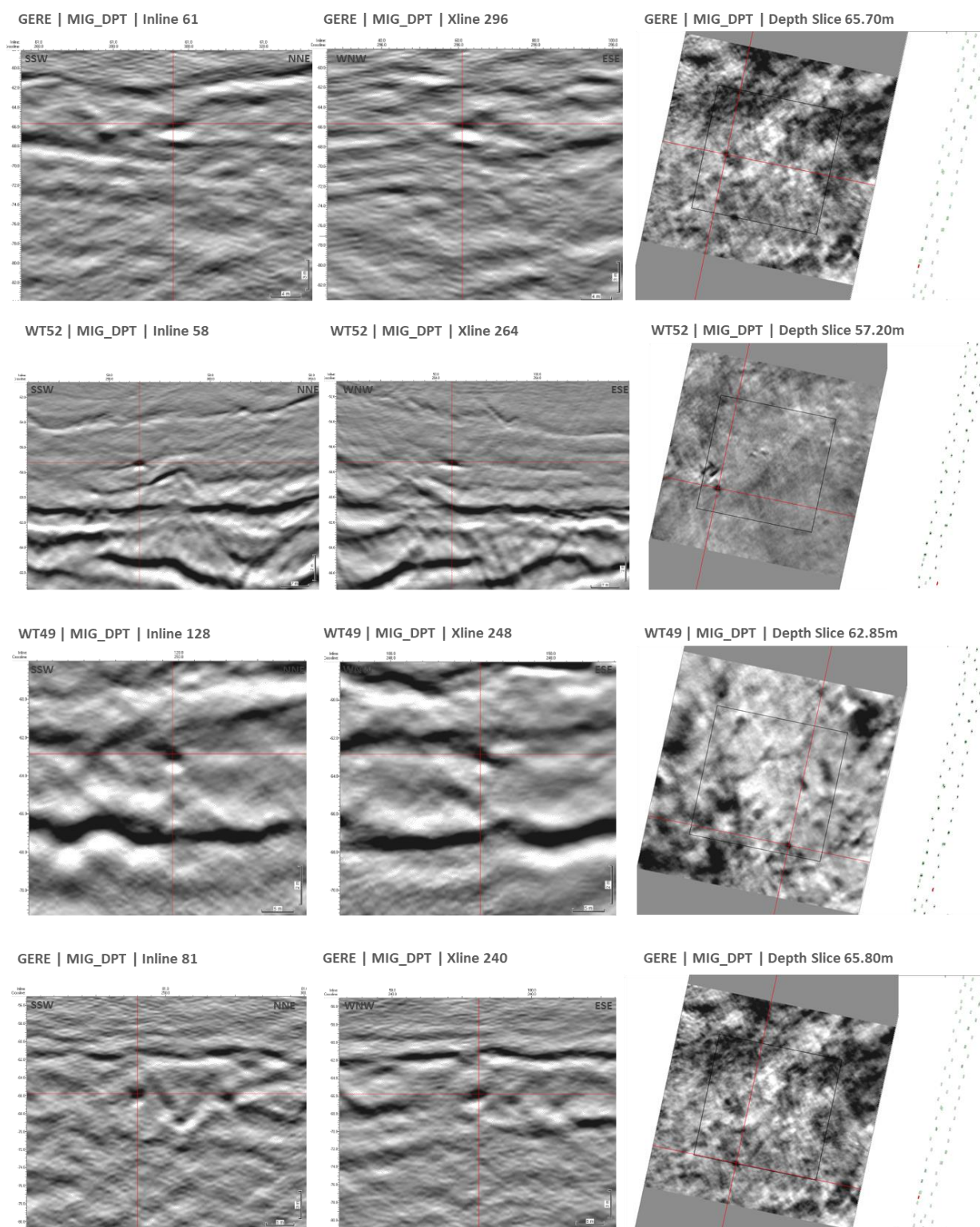
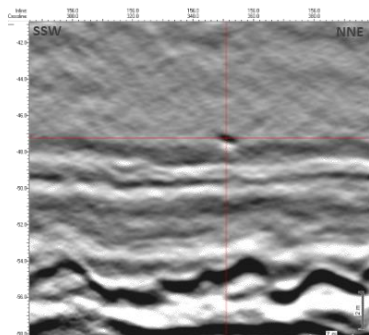


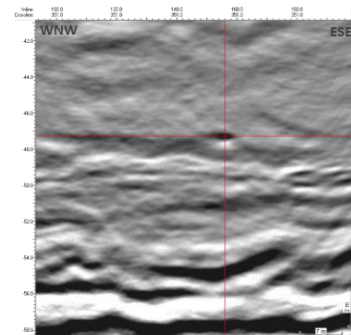
Figure 57 - Examples of interpreted PD3 targets - PDs with high confidence of being related with potential subsurface boulders. Images show inline, crossline and depth slice displays (left, centre, and right, respectively), intersecting each PD at its centre position.

PD3 examples

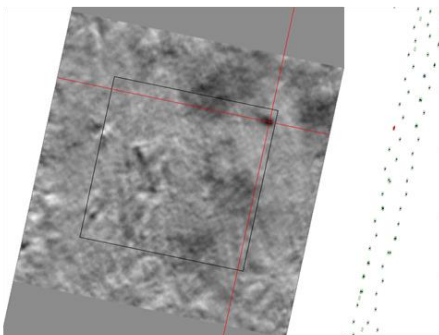
WT21 | MIG_DPT | Inline 156



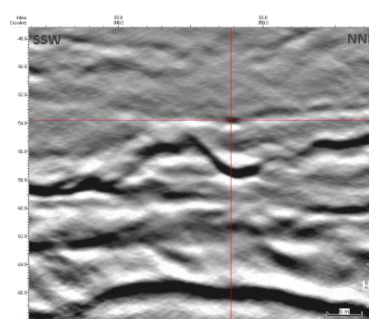
WT21 | MIG_DPT | Xline 351



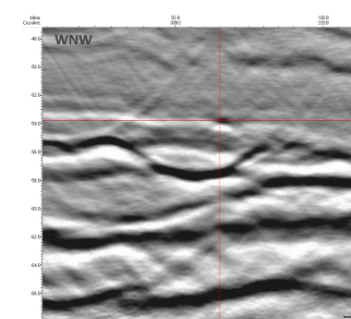
WT21 | MIG_DPT | Depth Slice 47.25m



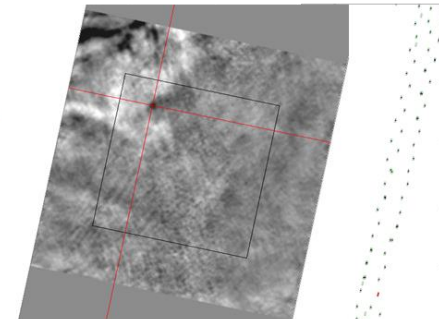
WT49 | MIG_DPT | Inline 65



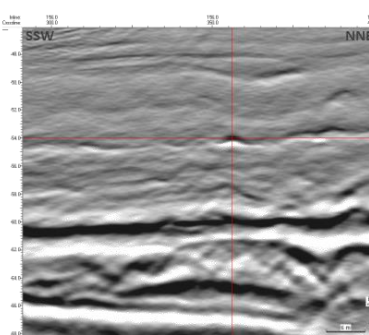
WT49 | MIG_DPT | Xline 339



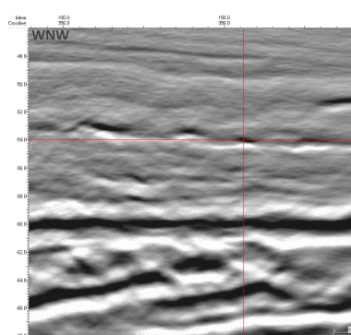
WT49 | MIG_DPT | Depth Slice 53.75m



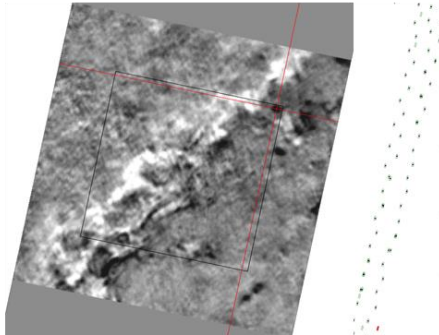
WT52 | MIG_DPT | Inline 156



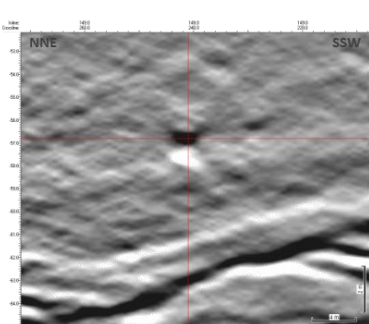
WT52 | MIG_DPT | Xline 356



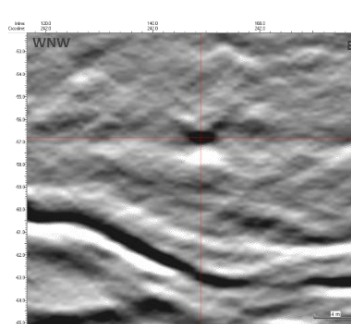
WT52 | MIG_DPT | Depth Slice 54.00m



WT02 | MIG_DPT | Inline 149



WT02 | MIG_DPT | Xline 242



WT02 | MIG_DPT | Depth Slice 56.80m

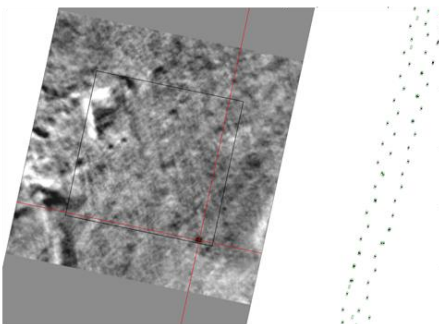
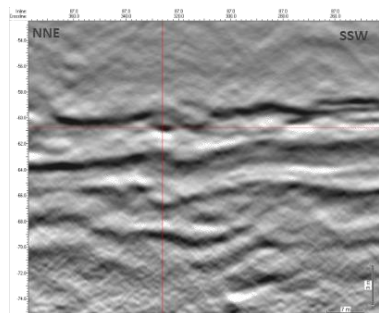


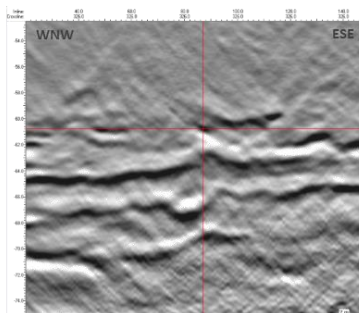
Figure 58 - Examples of interpreted PD3 targets - PDs with high confidence of being related with potential subsurface boulders. Images show inline, crossline and depth slice displays (left, centre, and right, respectively), intersecting each PD at its centre position.

PD2 examples

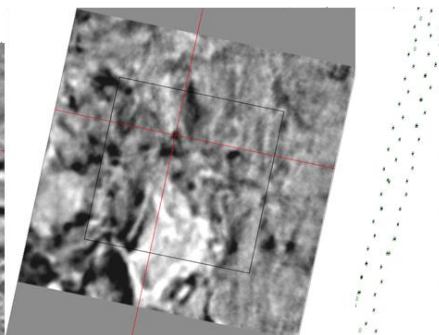
WT05 | MIG_DPT | Inline 87



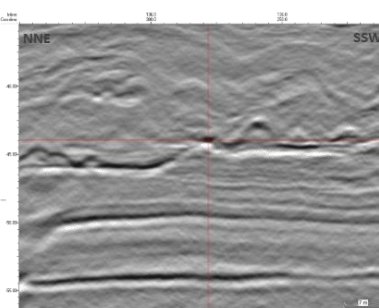
WT05 | MIG_DPT | Xline 326



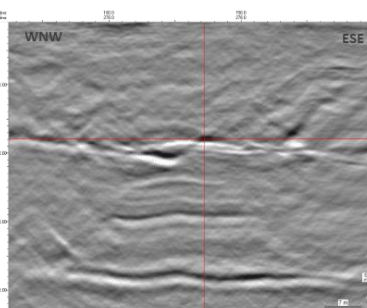
WT05 | MIG_DPT | Depth Slice 60.75m



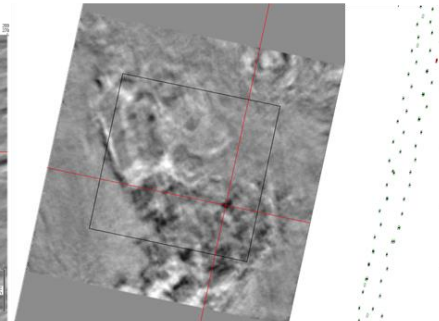
WT111 | MIG_DPT | Inline 136



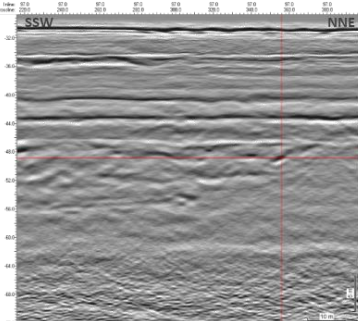
WT111 | MIG_DPT | Xline 279



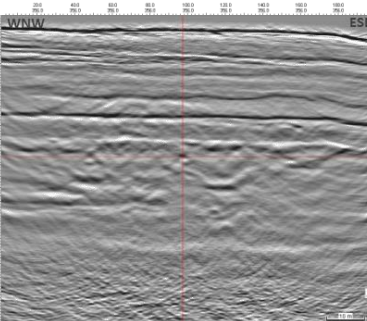
WT111 | MIG_DPT | Depth Slice 43.95m



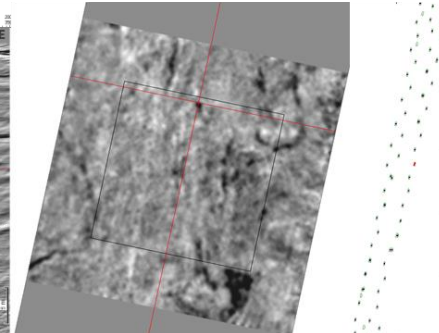
WT28 | MIG_DPT | Inline 95



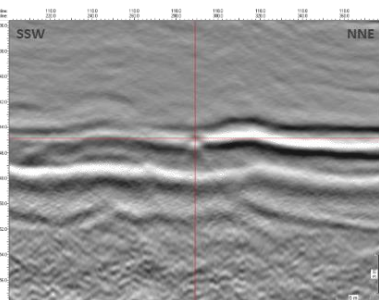
WT28 | MIG_DPT | Xline 356



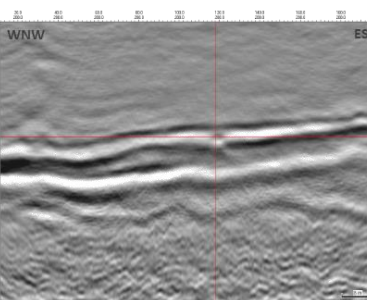
WT28 | MIG_DPT | Depth Slice 48.85m



OSPn | MIG_DPT | Inline 118



WT02 | MIG_DPT | Xline 288



WT02 | MIG_DPT | Depth Slice 44.85m

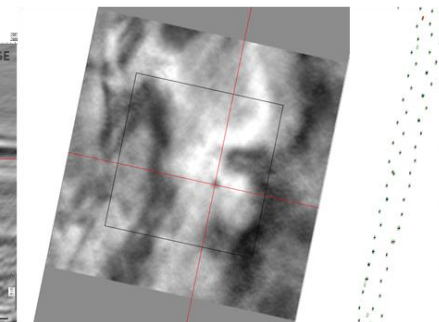
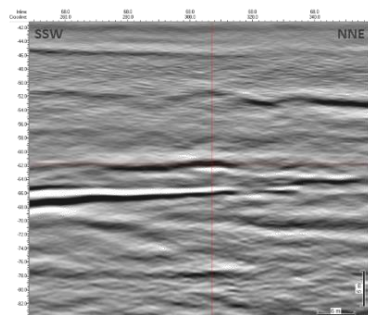


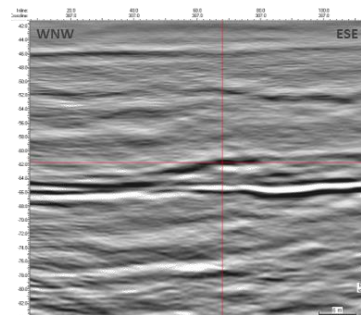
Figure 59 - Examples of interpreted PD2 targets - PDs with medium confidence of being related with potential subsurface boulders. Images show inline, crossline and depth slice displays (left, centre, and right, respectively), intersecting each PD at its centre position.

PD2 examples

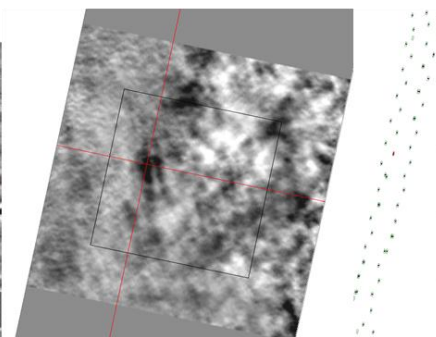
WT27 | MIG_DPT | Inline 68



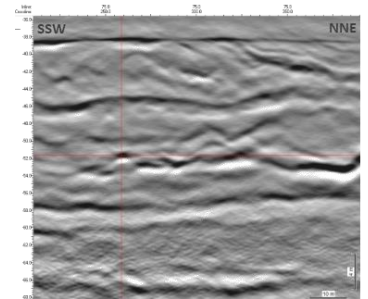
WT27 | MIG_DPT | Xline 307



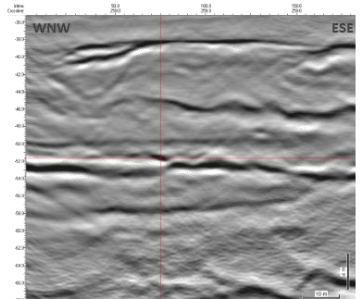
WT27 | MIG_DPT | Depth Slice 61.75m



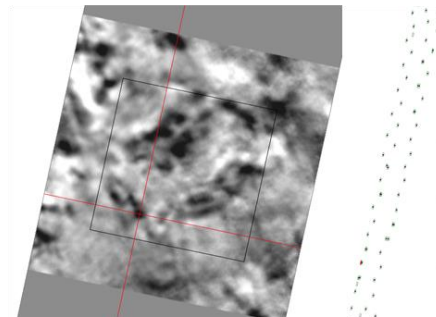
WT144 | MIG_DPT | Inline 57



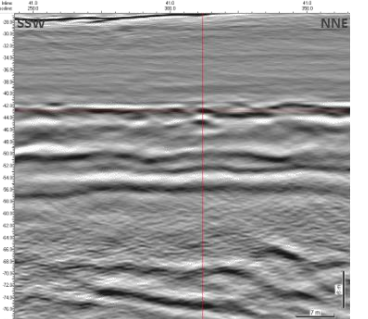
WT144 | MIG_DPT | Xline 259



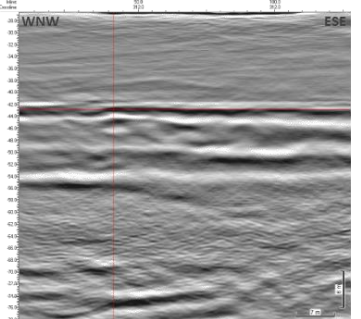
WT144 | MIG_DPT | Depth Slice 51.65m



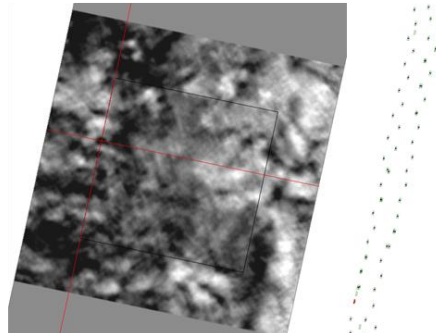
WT48 | MIG_DPT | Inline 41



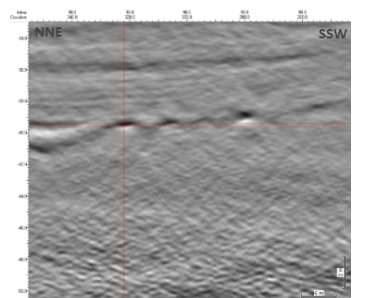
WT48 | MIG_DPT | Xline 312



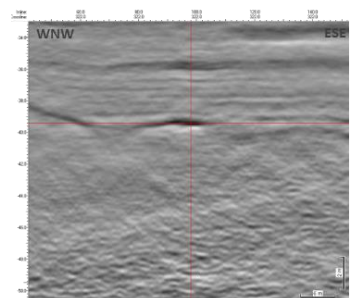
WT48 | MIG_DPT | Depth Slice 42.80m



WT16 | MIG_DPT | Inline 98



WT16 | MIG_DPT | Xline 322



WT16 | MIG_DPT | Depth Slice 39.40m

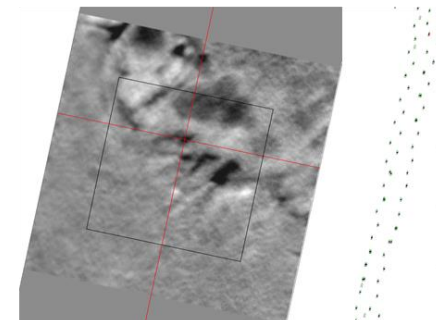
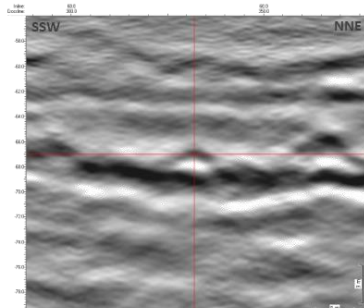


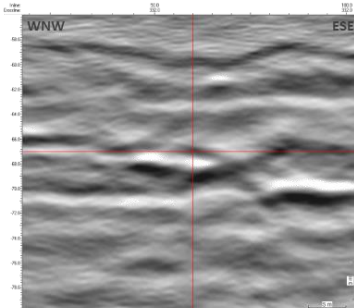
Figure 60 - Examples of interpreted PD2 targets - PDs with medium confidence of being related with potential subsurface boulders. Images show inline, crossline and depth slice displays (left, centre, and right, respectively), intersecting each PD at its centre position.

PD1 examples

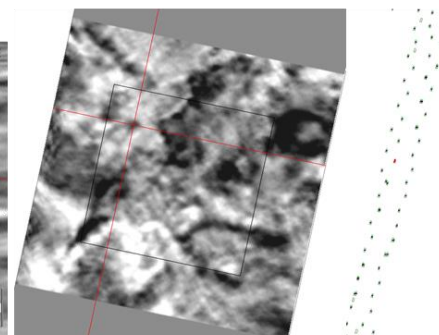
WT27 | MIG_DPT | Inline 68



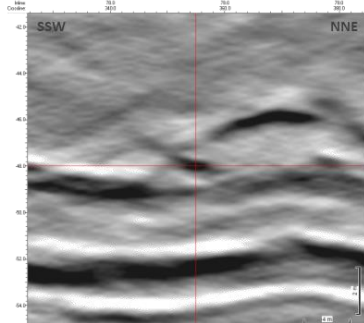
WT27 | MIG_DPT | Xline 307



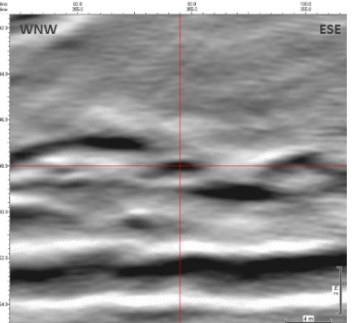
WT27 | MIG_DPT | Depth Slice 61.75m



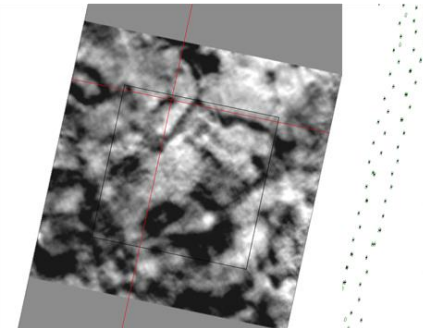
WT50 | MIG_DPT | Inline 78



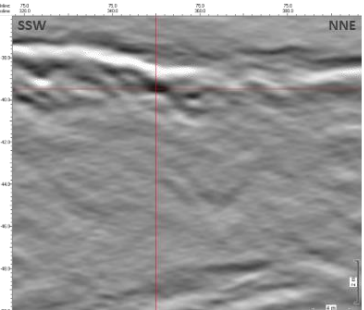
WT50 | MIG_DPT | Xline 355



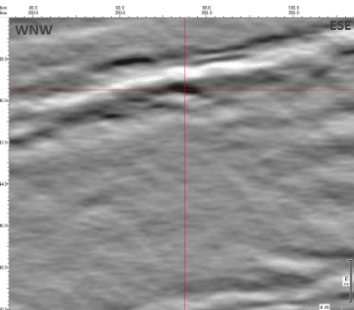
WT50 | MIG_DPT | Depth Slice 48.00m



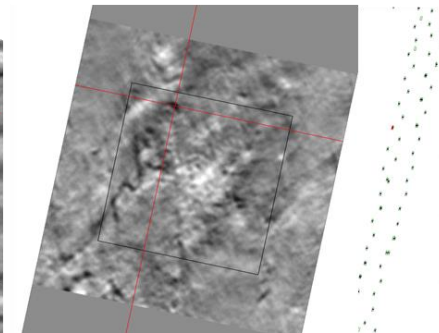
WT21 | MIG_DPT | Inline 75



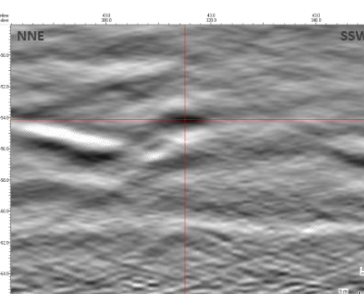
WT21 | MIG_DPT | Xline 350



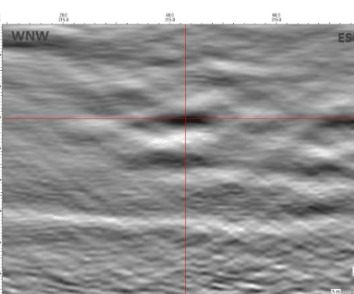
WT21 | MIG_DPT | Depth Slice 39.50m



VOSP | MIG_DPT | Inline 98



VOSP | MIG_DPT | Xline 322



VOSP | MIG_DPT | Depth Slice 39.40m

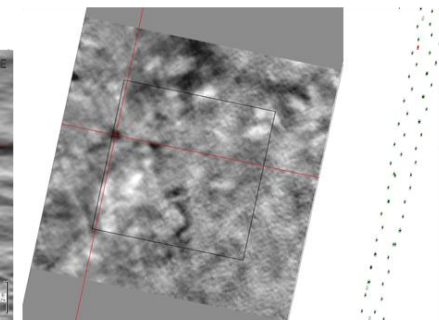
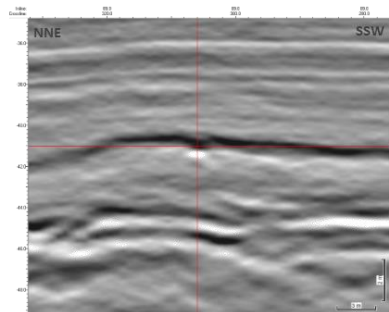


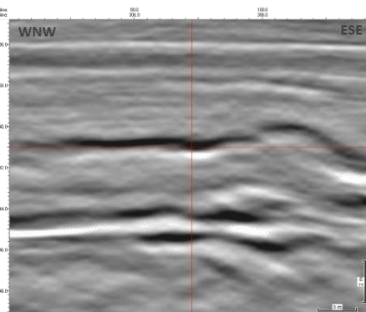
Figure 61 - Examples of interpreted PD1 targets - PDs with low confidence of being related with potential subsurface boulders. Images show inline, crossline and depth slice displays (left, centre, and right, respectively), intersecting each PD at its centre position.

PD1 examples

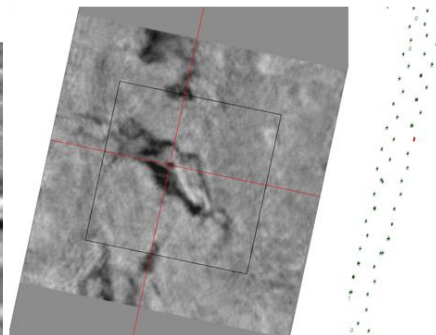
WT24 | MIG_DPT | Inline 89



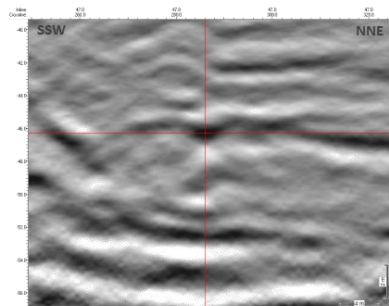
WT24 | MIG_DPT | Xline 306



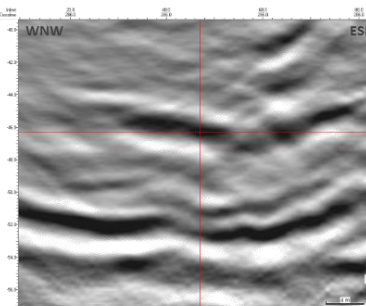
WT24 | MIG_DPT | Depth Slice 41.00m



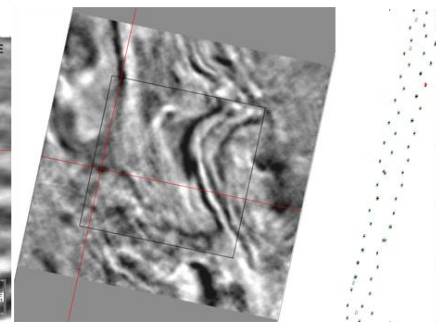
WT15 | MIG_DPT | Inline 47



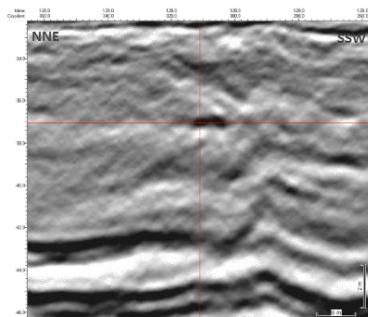
WT15 | MIG_DPT | Xline 286



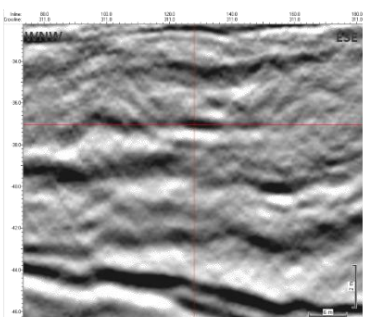
WT15 | MIG_DPT | Depth Slice 46.30m



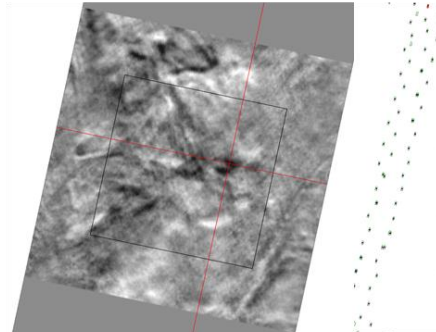
WT03 | MIG_DPT | Inline 128



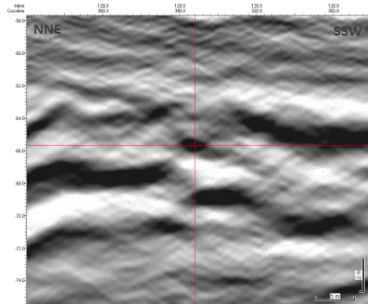
WT03 | MIG_DPT | Xline 311



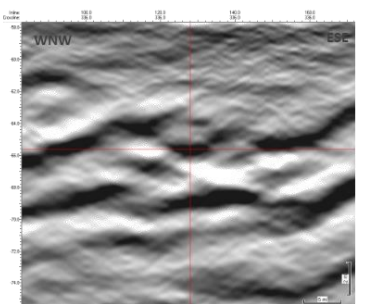
WT03 | MIG_DPT | Depth Slice 37.05m



WT43 | MIG_DPT | Inline 128



WT43 | MIG_DPT | Xline 336



WT43 | MIG_DPT | Depth Slice 65.65m

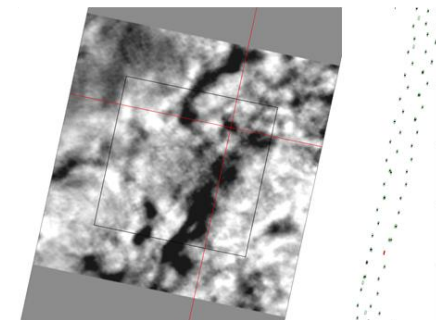
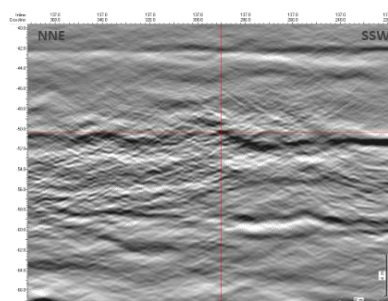


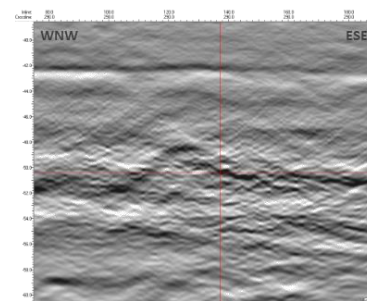
Figure 62 - Examples of interpreted PD1 targets - PDs with low confidence of being related with potential subsurface boulders. Images show inline, crossline and depth slice displays (left, centre, and right, respectively), intersecting each PD at its centre position.

PD0 examples

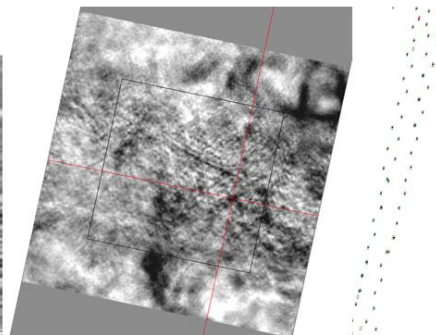
OSPS | MIG_DPT | Inline 137



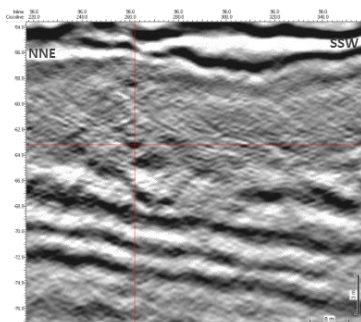
OSPS | MIG_DPT | Xline 290



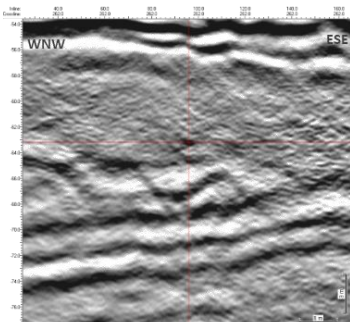
OSPS | MIG_DPT | Depth Slice 50.40m



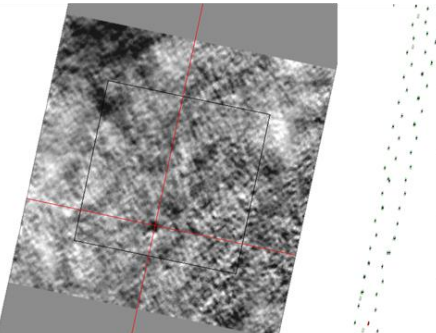
WT51 | MIG_DPT | Inline 96



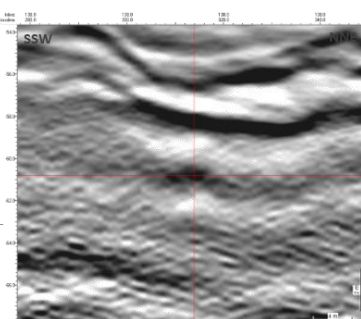
WT51 | MIG_DPT | Xline 262



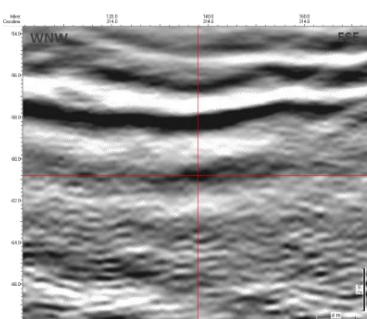
WT51 | MIG_DPT | Depth Slice 63.20m



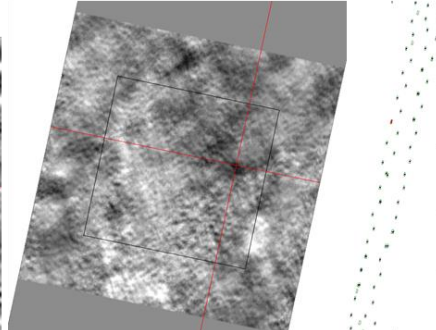
WT21 | MIG_DPT | Inline 138



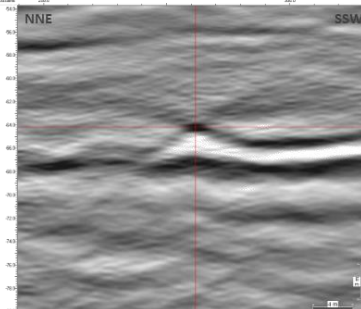
WT21 | MIG_DPT | Xline 314



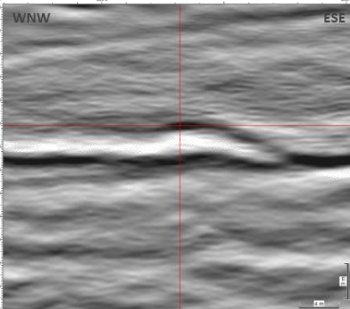
WT21 | MIG_DPT | Depth Slice 60.80m



WT144 | MIG_DPT | Inline 116



WT144 | MIG_DPT | Xline 280



WT144 | MIG_DPT | Depth Slice 64.20m

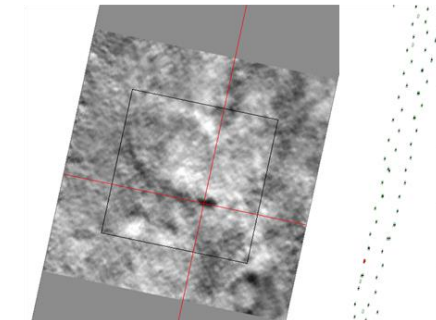


Figure 63 - Examples of interpreted PD0 targets - PDs with zero confidence – point anomalies detected within multiple interval. Images show inline, crossline and depth slice displays (left, centre, and right, respectively), intersecting each PD at its centre position.

5.4.3. POTENTIAL BOULDER CLUSTERS

Potential clustered boulders are interpreted to have a higher significance in terms of risk compared to the isolated PD contacts. A cluster is defined as two or more boulders where discrete objects are separated by a short distance and/or occur within the same deposit.

Potential clusters were mapped as horizons delineating the top and the lateral extent of the clusters, within the 60 x 60 m WTG areas, in the time domain. A total of 54 potential boulder clusters were identified and mapped in the fully processed 3D UHRS datasets (MIG and MUL).

Examples of interpreted clustered PDs are displayed in the following figures, according to their confidence:

- Clusters C2 (medium confidence): Figure 64;
- Clusters C1 (low confidence): Figure 65.

No high confidence clusters (C3) were identified.

Potential boulder-rich surfaces and deposits associated with PD interpretation ambiguity and increased uncertainty were also traced by horizons and described in the summary Table 20 (section 5.4.5).

5.4.4. POTENTIAL PD FACIES

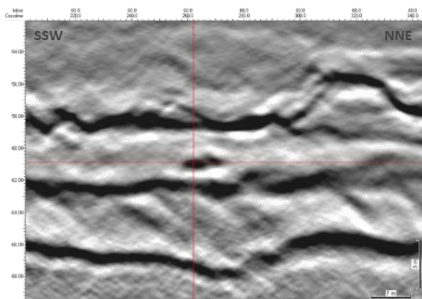
Potential PD facies (PDF) are interpreted to be related with coarse-grained deposits with potential high density of small objects (gravels, pebbles, cobbles, and small boulder “clouds”), within which it is not possible to discern individual targets.

PDF areas were mapped as horizons that delimit the top and the lateral extent of packages with the characteristic PD facies (described in Section 5.3.4). The PDF horizons were mapped within the 60 x 60 m WTG areas in the time domain. A total of 11 potential PDF areas were identified and mapped in the fully processed 3D UHRS datasets (MIG and MUL).

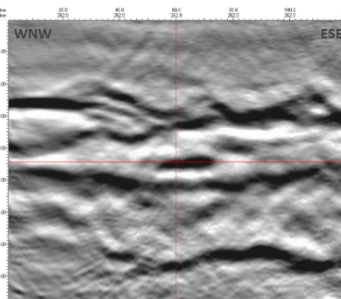
Interpreted PDF areas are summarized in Table 20 (section 5.4.5), and examples are displayed in Figure 66.

C2 examples

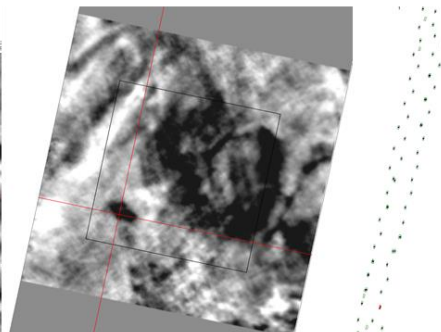
WT49 | MIG_DPT | Inline 60



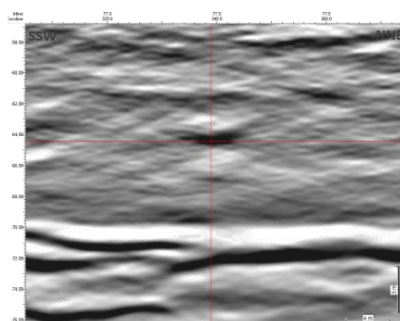
WT49 | MIG_DPT | Xline 262



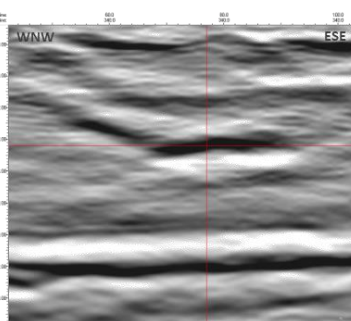
WT49 | MIG_DPT | Depth Slice 60.90m



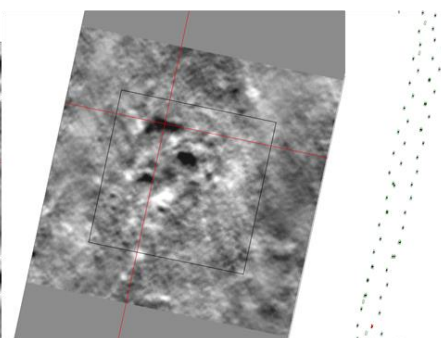
WT51 | MIG_DPT | Inline 77



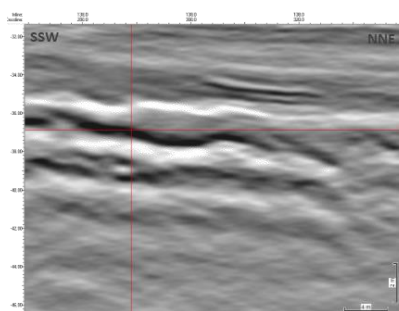
WT51 | MIG_DPT | Xline 340



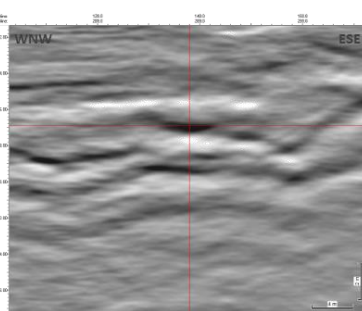
WT51 | MIG_DPT | Depth Slice 64.40m



WT21 | MIG_DPT | Inline 138



WT21 | MIG_DPT | Xline 289



WT21 | MIG_DPT | Depth Slice 37.05m

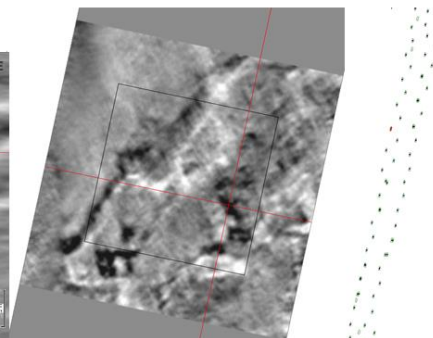
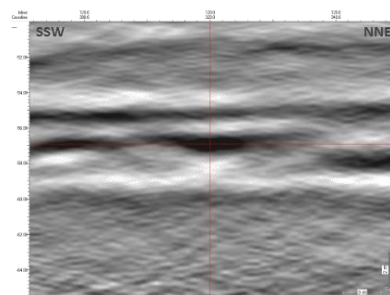


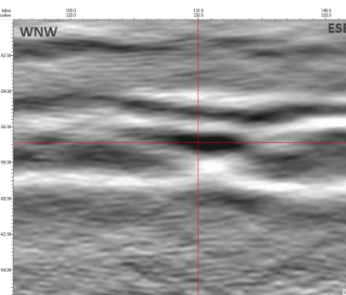
Figure 64 - Examples of interpreted C2 clusters - grouping of PDs with medium confidence of being related with potential subsurface boulders. Images show inline, crossline and depth slice displays (left, centre, and right, respectively), intersecting each cluster at its centre position.

C1 examples

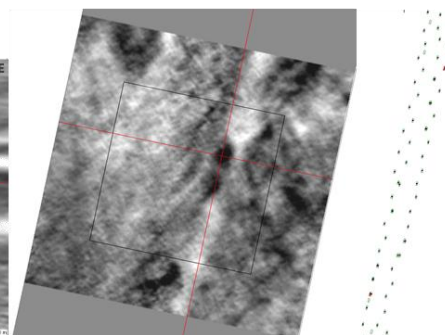
WT146 | MIG_DPT | Inline 120



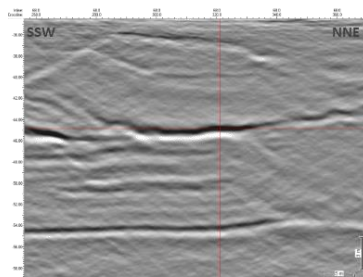
WT146 | MIG_DPT | Xline 320



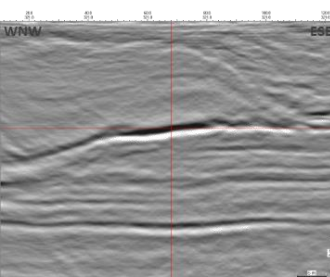
WT146 | MIG_DPT | Depth Slice 56.90m



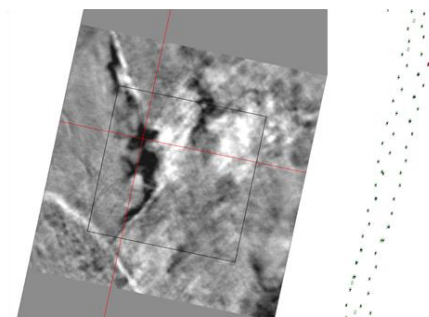
WT11 | MIG_DPT | Inline 68



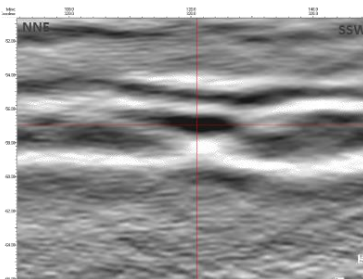
WT11 | MIG_DPT | Xline 321



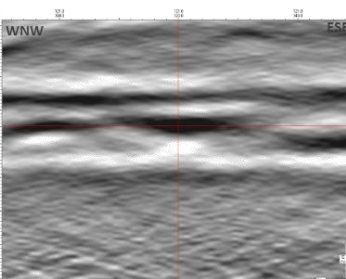
WT11 | MIG_DPT | Depth Slice 44.85m



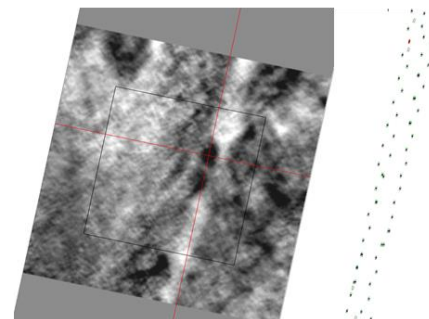
WT07 | MIG_DPT | Inline 121



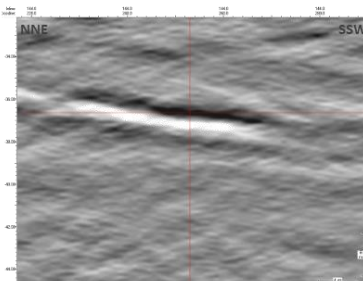
WT07 | MIG_DPT | Xline 320



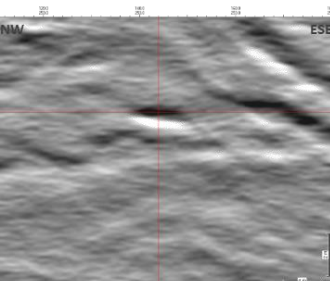
WT21 | MIG_DPT | Depth Slice 56.95m



WT25 | MIG_DPT | Inline 143



WT25 | MIG_DPT | Xline 253



WT25 | MIG_DPT | Depth Slice 36.65m

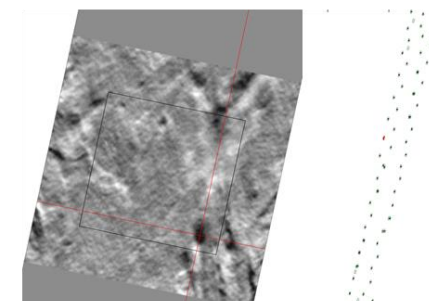


Figure 65 - Examples of interpreted C1 clusters - grouping of PDs with low confidence of being related with potential subsurface boulders. Images show inline, crossline and depth slice displays (left, centre, and right, respectively), intersecting each cluster at its centre position.

PDF example

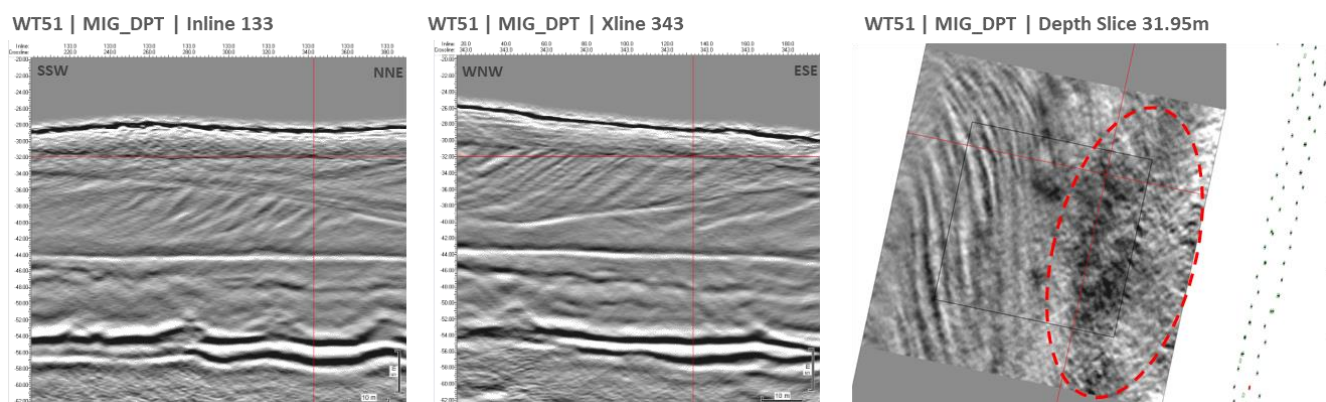


Figure 66 - Example of interpreted PD facies (PDF) – possible coarse-grained deposits with potential high density of small objects (gravels, pebbles, cobbles, and small boulder “clouds”), within which it is not possible to discern individual. Images show inline, crossline and depth slice displays (left, centre, and right, respectively).

5.4.5. PD ASSESSMENT RESULTS SUMMARY

A summary of the PD/ Potential Boulder results is provided within Table 20 divided by WTG/OSS site.

Table 20 - Summary of findings of the PD/ Potential boulders assessment for the ABWP survey.

PD / POTENTIAL BOULDER ASSESSMENT RESULTS																		
WTG/OS S	WTG/OSS Centre coordinates	Interpretation Depth (m BSB)	PD / POTENTIAL BOULDERS					CLUSTERS				HORIZONS				POTENTIAL HAZARDS	BATCH	VESSE L
			PD 0	PD 1	PD 2	PD 3	TOTAL	C1	C2	C3	TOTAL	PDF s	AA	H Z	TOTAL			
46	X 298486.586 Y 5844474.415	Top of bedrock	11	31	-	-	42	1	-	-	1	-	-	-	-	Unit WT46_U1 affected by multiple artefacts, producing numerous PD-like responses; difficult to assess potential boulder occurrence; stronger point anomalies marked as low confidence. WT46_B1 - Irregular and undulating, high contrast surface; ambiguous PD patterns possibly related with irregularities and/or artefacts	1	RR
48	X 298101.090 Y 5843390.372	Top of bedrock	9	24	1	-	34	-	-	-	-	2	-	-	2	WT48_PDF_B0A - Hard-kick reflection associated with horizon WT48_B0A. WT48_PDF_U1A - Top of interval with ambiguous patterns, possibly related with internal irregularities, however boulder occurrence cannot be excluded; stronger amplitude contrasts provided by horizon WT48_AA_U1A; base of interval marked by horizon WT48_B1A.	1	RR
49	X 299523.000 Y 5843065.000	Top of bedrock	-	27	2	2	31	-	1	-	1	2	-	-	2	WT49_PDF_U1A-01 and 02 - Areas with speckled facies (PD facies); possibly related with coarser materials. WT49_B1A, B1, and U2-01 - Irregular and undulating, high contrast surfaces; ambiguous PD patterns (PD facies) possibly related with irregularities, occurrence of coarser materials, and/or artefacts. Hummocky facies between U2-01 and B2, producing ambiguous PD-like responses.	1	RR
50	X 297804.740 Y 5842066.430	Top of bedrock	8	17	-	-	25	-	-	-	-	-	-	-	-	WT50_B0 - Surface with speckled facies (PD facies); possibly related with coarse materials, but boulder occurrence is unlikely given the depositional setting. Occasional point anomalies within upper sediments (between SB and WT50_B0A) unlikely related with >1m boulder occurrence. WT50_B1 - Undulating, high contrast surface, partially affected by SB multiple; ambiguous PD patterns possibly related with irregularities, occurrence of coarser materials, and/or artefacts.	1	RR
51	X 298917.214 Y 5841998.142	Top of bedrock	16	7	-	-	23	2	-	-	2	1	-	-	1	WT51_PDF_U0-01 - Surface with speckled facies (PD facies); WT51_C1_B0_01 and WT51_C1_B0A_02 - Clusters of point anomalies. These horizons are possibly related with coarse materials, but boulder occurrence is unlikely given the depositional setting.	1	RR
52	X 299680.481 Y 5841410.130	Top of bedrock	-	30	4	2	36	-	-	-	-	-	-	-	-	WT52_B0A - Irregular surface with ambiguous localised amplitude contrasts. WT52_B1 - Undulating, high contrast surface; ambiguous patterns (PD facies) possibly related with irregularities and/or occurrence of coarser materials.	1	RR
53	X 297786.174 Y 5841008.164	Top of bedrock	7	12	-	-	19	-	-	-	-	-	-	-	-	WT53_B1A - Irregular, high contrast reflection; no potential targets detected confidently along this surface, but their occurrence cannot be excluded with certainty given its irregular morphology.	1	RR
54	X 298731.824 Y 5840721.978	Top of bedrock	4	20	41	3	27	-	-	-	-	2	-	-	2	WT54_PDF_U0-01 - Surface with speckled facies (PD facies); possibly related with coarse materials, but boulder occurrence is unlikely given the depositional setting. Ambiguous isolated amplitude contrasts between ~0.0605s TWT and horizon WT54_B1A; high uncertainty if related with potential targets.	1	RR
146	X 298363.114 Y 5844464.485	Top of bedrock	5	29	5	-	39	1	-	-	1	-	1	-	1	Ambiguous patterns observed within unit WT46_U1 and along its base (WT146_B1), possibly related with internal facies geometries. WT146_U1-01 - Irregular, high contrast surface, with ambiguous PD patterns, possibly related with morphology and occurrence of coarse materials (boulder presence cannot be excluded); stronger amplitude contrasts traced by horizon WT146_AA_U1-01, relevant isolated anomalies picked.	1	RR

PD / POTENTIAL BOULDER ASSESSMENT RESULTS																		
WTG/OS S	WTG/OSS Centre coordinates	Interpretation Depth (m BSB)	PD / POTENTIAL BOULDERS					CLUSTERS				HORIZONS				POTENTIAL HAZARDS	BATCH	VESSE L
			PD 0	PD 1	PD 2	PD 3	TOTAL	C1	C2	C3	TOTAL	PDF s	AA	H Z	TOTAL			
OSP South Gere	X 298263.830 Y 5843969.300	Top of bedrock	4	20	1	5	30	-	-	-	-	1	-	-	1	PD at IL81-XL296-TWT0.0381s, within recent sediments and thus unlikely to be boulder-related. Ambiguous patterns observed within unit GERE_U1 and along its base (GERE_B1), possibly related with internal facies geometries and artefacts. Units U1 and U2 affected by multiple artefacts, producing numerous PD-like responses; difficult to assess potential boulder occurrence; stronger point anomalies marked.	1	RR
29	X 300284.421 Y 5854249.340	50	-	24	1	-	25	-	-	-	-	-	-	-	-	PD interpretation stopped at top of multiple interval, since top of intact bedrock not visible. Between WT29_B1 and WT29_U2-01 - Weathered bedrock interval with complex facies; discontinuous and wavy internal reflections of high contrast; ambiguous PD patterns possibly related with irregularities, but boulder occurrence cannot be excluded.	2	RR
32	X 300073.012 Y 5852249.197	50	2	20	2	-	24	3	-	-	3	1	-	-	1	Strong point anomalies (hard-kicks) at IL118-XL295-TWT0.0436s and IL135-XL314-TWT0.0436s, within recent sediments and thus unlikely to be boulder-related (picked as PD1). WT32_PDF_U1_01 - Top of interval with speckled texture observed in slices, with dispersed ambiguous responses; base traced by WT32_U1-02. WT32_U1-02 and 03 - Irregular and undulating, high contrast surfaces, with ambiguous PD patterns, possibly related with morphology; interval between these surfaces with speckled texture and dispersed ambiguous PDs (boulder presence cannot be excluded).	2	RR
34	X 300134.985 Y 5851083.334	Top of bedrock	2	9	2	-	13	-	-	-	-	-	-	-	-	WT34_U0-01 - Surface with speckled facies (PD facies), higher contrasts at NE corner of WTG box; possibly related with coarser materials; boulder occurrence is unlikely given the depositional setting. Unit U1 affected by multiple artefacts; difficult to assess potential boulder occurrence; stronger point anomalies marked. WT34_B1 - Irregular surface with ambiguous patterns, masked by multiple artefacts; no potential targets detected confidently along this surface, but their occurrence cannot be excluded.	2	RR
36	X 299486.866 Y 5850094.829	Top of bedrock	3	19	1	-	23	-	-	-	-	-	2	-	2	WT36_AA_U1_01 - Local hard kick reflection. WT36_U1-01 and WT36_U2-01 - Undulating and discontinuous high contrast surfaces, with ambiguous PD patterns, possibly related with irregularities (boulder presence cannot be excluded). Between horizons WT36_B1 and WT36_U2-01: Poorly organised to chaotic character; several localised hard-kick anomalies and ambiguous PD responses; uncertainty if related with boulder occurrence due to their extent; stronger anomalies extracted and traced by horizon WT36_AA_U2_01.	2	RR
38	X 299599.460 Y 5848962.694	Top of bedrock	4	15	-	-	19	-	-	-	-	1	-	-	1	WT38_B1 and WT38_U2-01 - Irregular and undulating, high contrast surfaces, with ambiguous PD patterns, possibly related with morphology.	2	RR
40	X 299083.560 Y 5847914.765	Top of bedrock	8	17	2	-	27	-	-	-	-	-	-	1	1	Between horizons WT40_HZ_01 and WT40_U1-01 - Seismic artefacts and possible discontinuities producing ambiguous PD-like responses. Between WT40_U1-01 and WT40_B1 - Deposit with poorly organised to chaotic character; several discontinuous hard-kick anomalies and ambiguous PD responses; uncertainty regarding their origin (possible internal discontinuities and/or seismic artefacts), but boulder occurrence is highly likely (particularly in northern-most quadrant; potential boulder-rich). WT40_U2-01 - Irregular and undulating, high contrast surface, with ambiguous PD patterns, possibly related with morphology.	2	RR

PD / POTENTIAL BOULDER ASSESSMENT RESULTS																		
WTG/OS S	WTG/OSS Centre coordinates	Interpretation Depth (m BSB)	PD / POTENTIAL BOULDERS					CLUSTERS				HORIZONS				POTENTIAL HAZARDS	BATCH	VESSE L
			PD 0	PD 1	PD 2	PD 3	TOTAL	C1	C2	C3	TOTAL	PDF s	AA	H Z	TOTAL			
42	X 298998.056 Y 5846729.215	Top of bedrock	7	26	1	-	34	4	-	-	4	1	-	-	1	Some ambiguous responses between horizons WT42_B0A and WT42_B1, possibly related with internal geometries. Units U1 and U2 affected by potential sediment deformation and multiple artefacts, producing numerous PD-like responses; challenging to assess potential boulder occurrence. Potential PD facies (possibly containing boulders) between horizons WT42_U2-02 and WT42_B2.	2	RR
44	X 298622.920 Y 5845676.008	Top of bedrock	6	24	3	-	33	1	-	-	1	-	-	-	-	WT44_B0A - Seismic artefacts and possible discontinuities producing ambiguous PD-like responses. WT44_U1-01 and 02 - Undulating and discontinuous surfaces, with ambiguous PD patterns, possibly related with morphology (boulder presence cannot be excluded). WT44_B1 - Irregular and undulating, high contrast surface, with several potential targets; other ambiguous PD patterns possibly related with irregularities, but boulder occurrence cannot be excluded. WT44_B2 - Irregular and undulating, high contrast surface, with several potential targets.	2	RR
134	X 300086.755 Y 5851119.832	Top of bedrock	3	11	1	-	15	-	-	-	-	-	-	-	-	Ambiguous patterns observed at the base of unit U1, likely related with multiple artefacts; difficult to assess potential boulder occurrence; stronger point anomalies marked.	2	RR
142	X 298935.882 Y 5846761.449	Top of bedrock	2	23	-	-	25	-	-	-	-	-	-	-	-	Some ambiguous responses between horizons WT142_B0A and WT142_U1-01, possibly related with internal geometries. Units U1 and U2 affected by potential sediment deformation and multiple artefacts, producing numerous PD-like responses; challenging to assess potential boulder occurrence. Potential PD facies (possibly containing boulders) between horizons WT142_U2-03 and WT142_B2.	2	RR
144	X 298559.486 Y 5845670.473	Top of bedrock	5	25	2	-	32	1	-	-	1	-	-	-	-	WT144_B0A - Seismic artefacts and possible discontinuities producing ambiguous PD-like responses. WT144_U1-02 - Undulating surface, with ambiguous PD patterns, possibly related with morphology (boulder presence cannot be excluded). WT144_B1 - Irregular and undulating, high contrast surface, with several potential targets; other ambiguous PD patterns possibly related with irregularities, but boulder occurrence cannot be excluded. Potential PD facies (possibly containing boulders) between horizons WT144_U2-02 and WT144_B2.	2	RR
16	X 302122.841 Y 5860372.279	50	-	8	8	-	16	4	4	-	8	-	-	-	-	WT16_B1: Irregular and undulating, high contrast surface; ambiguous PD patterns possibly related with irregularities and/or artefacts. From horizon WT16_B0B to horizon WT16_U2-01: Seismic artefacts and possible discontinuities producing ambiguous PD-like responses.	3	RR
18	X 301442.640 Y 5859392.731	Top of bedrock	1	13	1	-	15	-	-	-	-	-	1	-	1	From WT18_U0A-01 to WT18_B0A: interval with hummocky to granular facies, which may be related with presence of coarser sands; likelihood of >1m boulder occurrence is low in post-glaciogenic sands. From horizon WT18_B0A to horizon WT18_U1-01: Seismic artefacts and ambiguous isolated amplitude contrasts WT18_AA_U1-01, relevant isolated anomalies picked.	3	RR
20	X 301711.392 Y 5858339.530	Top of bedrock	2	13	-	-	15	-	-	-	-	-	-	-	-	From the horizon WT20_B1 to horizon WT20_B2: interval with complex facies, producing numerous PD-like responses; difficult to assess potential boulder occurrence; relevant contrasts picked.	3	RR

PD / POTENTIAL BOULDER ASSESSMENT RESULTS																		
WTG/OS S	WTG/OSS Centre coordinates	Interpretation Depth (m BSB)	PD / POTENTIAL BOULDERS					CLUSTERS				HORIZONS				POTENTIAL HAZARDS	BATCH	VESSE L
			PD 0	PD 1	PD 2	PD 3	TOTAL	C1	C2	C3	TOTAL	PDF s	AA	H Z	TOTAL			
21	X 300961.636 Y 5857499.678	Top of bedrock	1	37	6	1	45	-	6	-	6	-	1	3	4	From WT21_HZ_01 to WT21_HZ_02: highly hyperbolic interval (MUL data) with complex, wavy and discontinuous reflections, possibly related with occurrence of coarse sediments (sands, gravels, pebbles, cobbles...); challenging to distinguish potential boulder-related PDs from surface irregularities. Stronger amplitude contrasts found along WT21_U1-04, and most relevant individual and clustered PDs picked. Potential boulders response may be masked. Maximum amplitudes extracted for this interval provided by horizon WT21_AA_01. WT21_HZ_03: Undulating, strong positive amplitude reflection; top of interval with complex internal geometries producing ambiguous PD patterns, possibly related with morphology (boulder occurrence may be masked).	3	RR
23	X 301458.788 Y 5856597.525	Top of bedrock /50	2	11	-	-	13	-	-	-	-	-	-	1	1	WT23_HZ_01: Undulating, strong positive amplitude reflection, ridged morphology; top of interval with complex internal geometries producing ambiguous PD patterns, possibly related with morphology (boulder occurrence may be masked).	3	RR
25	X 300603.307 Y 5855806.352	Top of bedrock	-	21	3	-	24	2	-	-	2	-	-	1	1	From seabed to WT25_U1-02: complex facies with undulating geometries, speckled texture, and internal surfaces with variable contrast, with ambiguous responses (possibly related with irregularities or seismic artefacts); stronger point anomalies marked. WT25_HZ_01: Irregular and discontinuous surface of variable amplitude; top of interval with complex internal geometries producing ambiguous responses (boulder occurrence may be masked).	3	RR
27	X 301192.843 Y 5854994.474	Top of bedrock	1	17	1	-	19	-	-	-	-	-	-	1	1	Some ambiguous point contrasts between ~0.0391 and 0.0470 possibly related with internal geometries and/or occurrence of coarse materials (>1m boulder occurrence is unlikely given the depositional setting - U0A). WT27_B1 - Irregular and undulating, high contrast surface; ambiguous PD patterns (PD facies) possibly related with irregularities, occurrence of coarser materials, and/or artefacts. Some ambiguous responses between horizons WT27_B1 and WT27_U2-01, possibly related with internal geometries. WT27_HZ_01: Irregular and discontinuous surface of variable amplitude; producing ambiguous responses (boulder occurrence may be masked).	3	RR
30	X 300675.983 Y 5853230.170	Top of bedrock	4	11	4	-	19	-	-	-	-	-	-	-	-	Few ambiguous point contrasts between horizons WT30_U2_01 and WT30_B2 possibly related with irregularities and/or occurrence of coarse materials (>1m boulder occurrence is unlikely given the depositional setting - U0A).	3	RR
39	X 301025.740 Y 5848703.845	Top of bedrock	1	14	-	-	15	-	-	-	-	-	-	-	-	WT39_B1 - Undulating and discontinuous high contrast surface, with ambiguous PD patterns, possibly related with irregularities (boulder presence may be masked). WT39_U2-01 - Seismic artefacts and possible discontinuities producing ambiguous PD-like responses.	3	RR
130	X 300582.850 Y 5853377.775	Top of bedrock	1	12	1	-	14	-	-	-	-	-	-	-	-	Occasional point anomalies within upper sediments (between SB and WT130_U1-01); >1m boulder occurrence is unlikely given the depositional setting. Some ambiguous responses along and between horizons WT130_B1 and WT130_U2-02 possibly related with surface morphology and occurrence of coarse materials (boulder presence may be masked).	3	RR
139	X 301129.558 Y 5848696.724	Top of bedrock	-	20	1	-	21	-	-	-	-	-	-	-	-	Some ambiguous responses between horizons WT139_B1 and WT139_U2-01 possibly related with irregularities, coarser sediments, and/or artefacts (boulder presence may be masked). WT139_U2-01 - Undulating and discontinuous high contrast surfaces, with ambiguous PD patterns, possibly related with irregularities (boulder presence cannot be excluded).	3	RR
01	X 302867.034 Y 5866991.400	50	-	18	-	-	18	-	-	-	-	-	-	-	-	Some ambiguous responses between horizons WT01_U1-02 and WT01_U1-01 possibly related with internal geometries. WT01_U2-02: Irregular and undulating, high contrast surface; ambiguous PD patterns possibly related with irregularities and/or artefacts.	4	RR

PD / POTENTIAL BOULDER ASSESSMENT RESULTS																		
WTG/OS S	WTG/OSS Centre coordinates	Interpretation Depth (m BSB)	PD / POTENTIAL BOULDERS					CLUSTERS				HORIZONS				POTENTIAL HAZARDS	BATCH	VESSE L
			PD 0	PD 1	PD 2	PD 3	TOTAL	C1	C2	C3	TOTAL	PDF s	AA	H Z	TOTAL			
04	X 302572.428 Y 5865529.597	Top of bedrock/50	1	10	-	-	11	-	-	-	-	-	-	-	-	Some ambiguous responses between SB and horizon WT04_U1-03, related with internal geometries and discontinuities. WT04_B1: Irregular and undulating, high contrast surface; ambiguous PD patterns possibly related with irregularities and/or artefacts.	4	RR
07	X 302660.641 Y 5864451.051	Top of bedrock	-	6	-	-	6	-	-	-	-	-	-	-	-	Horizon WT07_U1-01 and horizon WT07_B1: Irregular and undulating, high contrast surface; ambiguous PD patterns possibly related with irregularities and/or artefacts.	4	RR
10	X 302127.576 Y 5863341.208	Top of bedrock	1	4	-	-	16	2	-	-	2	-	-	-	-	Ambiguous point contrasts throughout the volume, likely related with seismic artefacts. Uncertainty regarding PD assessment.	4	RR
12	X 302517.074 Y 5862396.759	Top of bedrock/50	3	6	-	-	9	-	-	-	-	-	-	-	-	Some ambiguous point contrasts between horizon WT12_B0B and ~0.0520s TWT, most likely related with internal geometries. From WT12_MLTP_Top to WT12_B2: seismic artefacts (multiple masking) and possible discontinuities producing ambiguous responses; challenging to interpreted.	4	RR
14	X 301872.970 Y 5861395.618	Top of bedrock	-	28	-	-	28	-	-	-	-	-	1	-	-	WT14_U0B-01: Surface with discontinuous high amplitude reflections, within recent sediments (unlikely to be related with potential boulders). Stronger amplitudes extracted and traced by horizon WT14_U0B-01_AA. Strong point anomaly (hard-kick) at IL105-XL319-TWT 0.0535s, within recent sediments and thus unlikely to be boulder-related (picked as PD1). Some ambiguous responses between horizons WT14_B0B and WT14_B2 possibly related with internal geometries.	4	RR
45	X 300084.120 Y 5845327.874	Top of bedrock	-	3	-	-	3	-	-	-	-	-	-	-	-	From the horizon WT45_U1A-01 to horizon WT45_B1: internal geometries and possible discontinuities producing ambiguous PD-like responses.	4	RR
47	X 299582.041 Y 5844302.315	Top of bedrock	-	6	-	-	6	-	-	-	-	-	-	-	-	WT47_B1: Irregular and undulating, high contrast surface; ambiguous PD patterns possibly related with irregularities and/or artefacts.	4	RR
OSP North	X 303043.300 Y 5866201.700	50	1	10	1	-	12	1	1	-	1	-	-	-	-	From the horizon OSP_N_B0 to horizon OSP_N_U1-02: wavy and discontinuous reflections, possibly related with occurrence of coarse sediments (sands, gravels, pebbles, cobbles...); challenging to distinguish potential boulder-related PDs from surface irregularities. Some ambiguous responses along and between horizons OSP_N_U1-03 and OSP_N_U1-02 possibly related with surface morphology and occurrence of coarse materials (boulder presence may be masked); relevant isolated anomalies picked From horizon OSP_N_U1-01 to horizon OSP_N_U2-02 speckled texture observed in slices, strong and wide multiple masking which makes PD ID and picking almost impossible.	4	RR
Vestas OSP	X 302612.950 Y 5863789.600	50	-	15	1	-	16	2	-	-	-	-	-	-	-	Stronger amplitude contrast found between horizon VOSP_B0A and horizon VOSP_U0B-01, most relevant clustered PDs picked; Horizon VOSP_B0B: Irregular and undulating, high contrast surface; ambiguous PD patterns possibly related with surface irregularities. Some ambiguous responses between horizons VOSP_B0B and VOSP_B1 possibly related with morphology.	4	RR

PD / POTENTIAL BOULDER ASSESSMENT RESULTS																		
WTG/OS S	WTG/OSS Centre coordinates	Interpretation Depth (m BSB)	PD / POTENTIAL BOULDERS					CLUSTERS				HORIZONS				POTENTIAL HAZARDS	BATCH	VESSE L
			PD 0	PD 1	PD 2	PD 3	TOTAL	C1	C2	C3	TOTAL	PDF s	AA	H Z	TOTAL			
24	X 302895.256 Y 5856594.032	Top of bedrock	3	25	-	-	28	1	-	-	1	-	-	-	-	Horizon WT24_U1-02: ambiguous PD patterns possibly related with irregularities and/or artefacts. May contain boulders; stronger point anomalies marked; From horizon WT24_U1-02 to horizon WT24_B1: interval with complex facies, producing numerous PD-like responses; challenging to assess potential boulder occurrence; relevant contrasts picked. From horizon WT24_B1 to horizon WT24_U2-01: Some ambiguous responses along and between horizons; possibly related with surface morphology and occurrence of coarse materials (boulder presence may be masked). From horizon WT24_U2-03 to horizon WT24_B2: speckled texture observed in slices; multiple masking.	5	RR
26	X 302411.783 Y 5855468.760	50	-	8	-	-	8	-	-	-	-	-	1	-	1	From horizon WT26_U2-01 down to ~60m BSB: Interval with complex internal geometries (micromorphologies, discontinuous reflections), producing numerous ambiguous responses. WT26_U2-01_AA: Localised strong positive amplitude anomaly.	5	RR
28	X 302417.825 Y 5854335.007	Top of bedrock/50	-	30	2	-	32	-	-	-	-	-	1	-	1	From horizon WT28_B0 to horizon WT28_B0A: interval with granular facies, which may be related with presence of coarser sands. From horizon WT28_U2-01 to WT28_U2-02: Interval with complex internal geometries (channel features, micromorphologies, discontinuous reflections), producing numerous ambiguous responses. Relevant point anomalies marked. WT28_B2_AA: Localised strong positive amplitude anomaly.	5	RR
31	X 301987.837 Y 5853294.310	Top of bedrock	4	16	-	-	20	-	-	-	-	-	3	-	3	From horizon WT31_B1 down to ~0.065s TWT: Interval with complex internal geometries (channel features, hummocky facies, micromorphologies, discontinuous reflections), producing numerous ambiguous responses. From horizon WT31_U1-01 to MLTP_base: Some ambiguous responses along and between horizons, possibly related with surface morphology and occurrence of coarse materials (boulder presence may be masked). Maximum amplitudes extracted for this interval provided by horizon WT31_B2_AA.	5	RR
33	X 301945.770 Y 5852228.481	Top of bedrock	-	11	-	-	11	-	-	-	-	-	1	-	1	Ambiguous point contrasts from horizon WT33_B1 down to ~0.077s TWT, most likely related with internal geometries, surface irregularities, high contrast discontinuous surfaces, and artefacts. WT33_U2-02 - ambiguous PD patterns possibly related with irregularities and/or artefacts. May contain boulders; stronger point anomalies marked. Strong negative amplitude anomaly within recent sediments (top at ~35.1 m depth, 2.5m BSB), northwards of WTG box: elongated along XL 368 (between ILs 79-106), ~13.5m x 3m in size).	5	RR
35	X 301465.307 Y 5851076.273	Top of bedrock	3	7	-	-	10	-	-	-	-	-	-	-	-	N/A	5	RR
37	X 301327.561 Y 5849857.687	Top of bedrock	1	9	-	-	10	-	-	-	-	-	-	-	-	Some ambiguous point contrasts between horizon WT37_B0A and WT37_B1, most likely related with internal geometries.	5	RR
09	X 303627.111 Y 5863351.677	50	-	17	-	-	17	-	-	-	-	-	-	-	-	Ambiguous point contrasts throughout the volume, likely related with seismic artefacts. Uncertainty regarding PD assessment. Some ambiguous point contrasts between horizons WT09_B0 and WT09_B0A. Occasional point anomalies within upper sediments (between SB and WT130_U1-01); >1m boulder occurrence is unlikely given the depositional setting. Horizon WT09_B1: Irregular and undulating, high contrast surface; ambiguous PD patterns possibly related with irregularities and/or artefacts.	6	RR

PD / POTENTIAL BOULDER ASSESSMENT RESULTS																		
WTG/OS S	WTG/OSS Centre coordinates	Interpretation Depth (m BSB)	PD / POTENTIAL BOULDERS					CLUSTERS				HORIZONS				POTENTIAL HAZARDS	BATCH	VESSE L
			PD 0	PD 1	PD 2	PD 3	TOTAL	C1	C2	C3	TOTAL	PDF s	AA	H Z	TOTAL			
11	X 304137.580 Y 5862492.724	50	2	40	1	-	43	2	-	-	2	-	-	-	-	From SB to horizon WT11_U1-02: Irregular and undulating, high contrast surface; ambiguous PD patterns possibly related with irregularities and/or artefacts; stronger isolated and clustered point anomalies picked as low confidence.	6	RR
13	X 303329.681 Y 5861650.413	50	-	13	-	-	13	-	-	-	-	-	-	-	-	From ~ 0.0400 to~ 0.0501: Irregular and undulating, high contrast surface; ambiguous PD patterns possibly related with irregularities and/or artefacts.	6	RR
15	X 303761.894 Y 5860708.171	50	2	19	-	-	21	1	-	-	1	-	-	-	-	From SB to horizon WT15_B1: Irregular and undulating; ambiguous PD patterns possibly related with irregularities, morphology and/or artefacts. Maximum amplitudes extracted for the interval (0.0410-0.0480) provided by horizon WT15_C1_B1_01. From horizon WT15_B1 to horizon 50m_BSB: strong and wide multiple masking.	6	RR
17	X 303009.341 Y 5859736.395	50	-	18	-	-	18	-	-	-	-	-	1	1	2	From horizon WT17_B0A to horizon WT17_U0B-01: slices with a significant striping pattern; Some ambiguous responses between horizons possibly related with irregularities, morphology, and/or artefacts (boulder presence may be masked). Horizon WT17_HZ_01 - Surface with numerous discontinuous (slightly arcuate) linear features of high positive amplitude, striking NE-SW and up to >50m length; features produce hyperbolic responses and may be related with localised occurrence of coarser clastics (possible sand lenses/bedforms interbedded in soft sediments); stronger amplitudes extracted and traced by horizon WT17_AA_01; concentric point anomalies within these picked as isolated targets of low confidence.	6	RR
19	X 303343.517 Y 5858721.603	50	2	39	-	-	41	-	-	-	-	-	-	-	-	From horizon WT19_BOB to ~0.0689: Irregular and undulating, high contrast surface; ambiguous PD patterns possibly related with irregularities and/or artefacts. interval with complex facies, producing numerous PD-like responses; difficult to assess potential boulder occurrence; relevant contrasts picked.	6	RR
111	X 304166.498 Y 5862526.781	50	2	48	3	-	53	5	-	-	5	-	-	-	-	From ~0.0551 to horizon WT111_U1-02: Some ambiguous responses between horizons possibly related with irregularities, morphology, and/or artefacts (boulder presence may be masked). Horizon WT111_U1-02: Irregular and undulating, high contrast surface; ambiguous PD patterns possibly related with irregularities and/or artefacts; may contain boulders; stronger isolated and clustered point anomalies picked as low to medium confidence.	6	RR
113	X 303413.951 Y 5861634.403	50	-	36	-	-	36	-	-	-	-	-	-	-	-	Between horizon WT113_B0 and horizon WT113_B0A: interval with complex facies, producing numerous PD-like responses; difficult to assess potential boulder occurrence; possibly related with internal geometries and/or occurrence of coarse materials (>1m boulder occurrence is unlikely given the depositional setting). From horizon WT113_U1-01 to horizon WT113_U1-02: irregular and undulating; ambiguous PD patterns possibly related with irregularities, morphology and/or artefacts Horizon WT113_U1-02 Irregular and undulating, high contrast surface; ambiguous PD patterns possibly related with irregularities and/or artefacts.	6	RR
117	X 303095.390 Y 5859724.563	50	3	23	1	-	27	-	-	-	5	-	1	1	2	From horizon WT117_B0B to horizon 50m_BSB: Irregular and undulating, high contrast surface; ambiguous PD patterns possibly related with irregularities and/or artefacts; stronger point anomalies marked. Horizon WT117_HZ_01 - Surface with numerous discontinuous (slightly arcuate) linear features of high positive amplitude, striking NE-SW and up to >50m length; features produce hyperbolic responses and may be related with localised occurrence of coarser clastics (possible sand lenses/bedforms interbedded in soft sediments); stronger amplitudes extracted and traced by horizon WT117_AA_01; concentric point anomalies within these picked as isolated targets of low confidence.	6	RR

PD / POTENTIAL BOULDER ASSESSMENT RESULTS																		
WTG/OS S	WTG/OSS Centre coordinates	Interpretation Depth (m BSB)	PD / POTENTIAL BOULDERS					CLUSTERS				HORIZONS				POTENTIAL HAZARDS	BATCH	VESSE L
			PD 0	PD 1	PD 2	PD 3	TOTAL	C1	C2	C3	TOTAL	PDF s	AA	H Z	TOTAL			
02	X 304791.828 Y 5866585.960	50	5	67	4	1	77	-	-	-	-	-	-	1	1	Occasional point anomalies within upper sediments (between SB and WT02_B0); >1m boulder occurrence is unlikely given the depositional setting. From horizon WT02_B0 to horizon WT02_U1-01_HZ: Thick interval with pervasive granular/speckled texture, with numerous point contrasts throughout; stronger point anomalies towards the base of the interval; some uncertainty related with seismic artefacts that may be masking responses.	7	RR
03	X 303830.509 Y 5866789.167	50	1	25	-	-	26	4	-	-	4	-	1	-	1	Horizon WT03_U1-01: Irregular and undulating, high contrast surface, with several potential targets; other ambiguous PD patterns possibly related with irregularities, but boulders cannot be excluded; stronger amplitude contrasts extracted and traced by horizon WT03_U1-01_AA, possibly related with boulder occurrence. Ambiguous point contrasts throughout the volume, possibly related with internal geometries and/or seismic artefacts.	7	RR
05	X 304744.814 Y 5865407.115	50	2	22	5	-	29	-	-	-	-	-	2	-	2	Horizon WT05_B0B_AA_01: Localised high amplitude contrasts along horizon WT05_B0B, at the base of a V-shaped incision (brightening may be related with structure geometry or occurrence of coarser materials). Horizon WT05_U1-01: Irregular, undulating, high contrast surface, with several potential targets; top of hummocky package comprising discontinuous high amplitude reflections; ambiguous PD patterns may be related with internal geometries, but boulders cannot be excluded; stronger amplitude contrasts extracted and traced by horizon WT05_U1-01_AA_01, possibly related with boulder occurrence.	7	RR
06	X 303787.549 Y 5864829.407	50	3	34	3	-	40	-	-	-	-	-	2	-	2	Horizon WT06_U1-01: Irregular and undulating, high contrast surface, with several potential targets; other ambiguous PD patterns possibly related with irregularities, but boulders cannot be excluded; stronger amplitude contrasts extracted and traced by horizons WT06_U1-01_AA_01 and 02, possibly related with boulder occurrence.	7	RR
08	X 304481.660 Y 5864117.600	50	1	24	-	-	25	-	-	-	-	-	1	-	1	From approx. 5m (0.007s TWT) above horizon WT08_U1-01: Interval with complex facies, with wavy and discontinuous reflections, likely deformed (faulting and folding); internal geometries produce ambiguous point contrasts. From horizon WT08_U1-01 to horizon WT08_B1- Complex, wavy, high contrast interval, comprising discontinuous high amplitude reflections, with several potential targets; other ambiguous PD patterns possibly related with irregularities, but boulder occurrence cannot be excluded; stronger amplitude contrasts extracted and traced by horizon WT08_B1_AA_01. Horizon WT08_B1: Irregular and undulating, high contrast surface; ambiguous PD patterns possibly related with irregularities and/or artefacts. From horizon WT08_MLTP_Top to horizon 50m_BSB: speckled texture observed in slices; multiple masking.	7	RR
108	X 304481.660 Y 5864117.600	50	2	19	1	-	22	-	-	-	-	-	-	-	-	Ambiguous point contrasts from ~58.5m depth (~0.073s TWT) down to horizon WT108_U1-01, most likely related with internal geometries, surface irregulates, and discontinuous reflections, and/or artefacts; stronger point anomalies marked. From horizon WT108_U1-01 to horizon WT108_B1 - Complex, wavy, high contrast interval, comprising discontinuous high amplitude reflections; ambiguous PD patterns possibly related with irregularities, but boulder occurrence cannot be excluded. Horizon WT108_B1: Irregular and undulating, high contrast surface; ambiguous PD patterns possibly related with irregularities and/or artefacts.	7	RR

PD / POTENTIAL BOULDER ASSESSMENT RESULTS																		
WTG/OS S	WTG/OSS Centre coordinates	Interpretation Depth (m BSB)	PD / POTENTIAL BOULDERS					CLUSTERS				HORIZONS				POTENTIAL HAZARDS	BATCH	VESSE L
			PD 0	PD 1	PD 2	PD 3	TOTAL	C1	C2	C3	TOTAL	PDF s	AA	H Z	TOTAL			
22	X 302716.262 Y 5857675.394	50	1	15	-	-	16	1	-	-	1	-	-	-	-	Between seabed and horizon WT22_B0: Faint positive point contrast at IL92-XL311-TWT0.0247s; not possible to ascertain its origin, although it is highly unlikely to be related with a >1m boulder. Several dispersed strong points anomalies (soft-kicks) within recent sediments (deepest at ~2.9m BSB): IL 129 -XL265; IL139-XL251; IL141-XL258; IL145-XL287; IL150-XL250. From horizon WT22_B0A: Irregular and undulating, ambiguous PD patterns possibly related with irregularities and/or artefacts; stronger point anomalies marked; Some ambiguous point contrasts between ~0.0595s TWT and 50m BSB , seismic artefacts and possible discontinuities producing ambiguous responses; challenging to interpret.	8	LK
41	X 300510.538 Y 5847579.082	Top of bedrock/50	1	24	-	-	25	1	-	-	1	-	-	-	-	Strong negative amplitude anomaly (soft-kick) at IL77-XL270-TWT0.0236s (~17.7m depth); stronger amplitude contrasts extracted and traced by horizon WT41_C1_U1-01-01, possibly related with boulder occurrence. From horizon WT41_U1-01 to horizon WT41_B1: ambiguous PD patterns possibly related with irregularities and/or artefacts.	8	LK
43	X 300059.800 Y 5846486.827	Top of bedrock		31	18	-	49	2	-	-	2	-	-	-	-	Strong point anomaly (hard-kick) at IL139-XL329-TWT 0.0419s, within recent sediments and thus unlikely to be boulder-related (picked as PD1). Horizon WT141_B0A: ambiguous PD patterns possibly related with irregularities and/or artefacts.	8	LK
55	X 303639.800 Y 5865723.000	50	8	31	-	-	39	1	-	-	1	-	-	-	-	Strong point anomaly (hard-kick) at IL64-XL244-TWT 0.0316s, within recent sediments and thus unlikely to be boulder-related (picked as PD1); Horizon WT55_B0A: ambiguous PD patterns possibly related with irregularities and/or artefacts; From horizon WT55_MLTP_Top to horizon WT55_U1-01: Thick interval with pervasive granular/speckled texture, with numerous point contrasts throughout; some uncertainty related with seismic artefacts that may be masking responses; Horizon WT55_U1-01: ambiguous PD patterns possibly related with irregularities and/or artefacts; may contain boulders; From horizon WT55_B1 to horizon 50m BSB: seismic artefacts and possible discontinuities producing ambiguous responses; challenging to interpret.	8	LK
122	X 302775.872 Y 5857665.489	50	3	31	-	-	34	1	-	-	1	-	-	-	-	From horizon WT122_B0 to horizon WT122_U2-01: frequent point contrasts possibly related with occurrence of coarse sediments (sands, gravels, pebbles, cobbles...), particularly between WT122_B0 and WT122_B0A (hummocky facies also introduce some ambiguity); challenging to distinguish potential boulder-related PDs from surface irregularities. Some ambiguous point contrasts between horizon WT122_U2-01 to 50m BSB, seismic artefacts and possible discontinuities producing ambiguous responses; challenging to interpret.	8	LK
141	X 300696.556 Y 5847563.715	Top of bedrock	4	21	-	-	25	-	-	-	-	-	-	-	-	Horizon WT141_B0A: ambiguous PD patterns possibly related with irregularities and/or artefacts. From horizon WT141_B0A to horizon WT141_U1-01: Some ambiguous responses along and between horizons, possibly related with surface morphology and occurrence of coarse materials (boulder presence may be masked). From horizon WT141_U1-01 to horizon WT141_B2: multiple masking.	8	LK
OSP South	X 298495.093 Y 5841460.387	Top of bedrock	6	21	-	-	27	-	-	-	-	-	-	-	-	From the OSPS_B0A horizon to the OSPS_B1 horizon: strong seabed multiple, masking possible PD responses. Based on observations in neighbouring WTGs (RR acquisition), PDs were detected within this range; thus, possible point anomalies were picked with very low confidence in this interval.	8	LK

6. CONCLUSION

This document reports on the seismostratigraphic framework from regional 2D UHRS lines and the 3D UHRS microsite assessment carried out within the scope of the Arklow Bank Wind Park (ABWP) survey area. 3D UHRS seismic interpretation included the identification and mapping of potential subsurface boulders.

2D and 3D UHRS data of the Arklow site was assessed, analysed and interpreted, successfully achieving the main objectives of this project:

- Geological ground modeling down to 100 m below seabed;
- Fully 3D UHRS imaging covering 60 x 60 m areas centred over proposed WTG/OSS locations;
- Provide accurate information on changes in subsurface unit stratigraphy, including lateral variability, thickness of units, and changes in material properties;
- Determination of bedrock depth across the site as far as possible and, wherever possible, to identification of weathered rockhead;
- Assessment of PD occurrences and distributions that may be related with potential boulders in the subsurface (with size ≥ 1 m);
- Identification of relevant subsurface features that may pose potential constraints to installation activities.

A total of 71 WTG/OSS sites were assessed and interpreted.

6.1. 2D SEISMIC INTERPRETATION

A seismostratigraphic framework was developed from regional 2D lines, with input from an established ground model and relevant geotechnical data. The 2D horizons, comprising the seismostratigraphic framework, represent the formation boundaries and their constituent units as reported in *Arklow Offshore Wind Farm INTERIM GROUND MODEL Report Rev 1*, with minor alterations. Unit U0A is listed as belonging to the Holocene *Surface Sands Formation*. However, based on the interpretation of these data, U0A appears to have glaciogenic features. Unit U0B is also listed as belonging to the *Holocene Surface Sands Formation*. Although, again, based on the interpretation of these data, U0B appears more likely to be glaciolacustrine in nature.

The site's stratigraphic architecture, based on the interpretation of the seismic data, is comprised of three principle geologic units. The basal unit is bedrock, that is reported as being Paleozoic mudstones and sandstones. The bedrock surface has been heavily weathered and sheared, presumably by

numerous ice sheets during the Pleistocene. A relatively thick Pleistocene glaciogenic sequence unconformably overlies the bedrock surface. The glacial sequence is comprised of subglacial and proglacial deposits, to include glaciomarine and glaciolacustrine sediments. Based on the unit geometries and seismic facies, most of the glaciogenic sediments are interpreted as diamicts, namely till. Localized occurrences of thin layering and transparent seismic facies within basin or basin-like features are interpreted as glaciolacustrine deposits. Deposits with internal foreset bedding and hummocky seismic facies are interpreted as glaciomarine. A Holocene sand unit overlies the Pleistocene glaciogenic deposits across most of the site. The surficial sand unit may be a veneer or several metres thick. Occasionally, the Holocene sands are absent, likely due to sediment transport, i.e., scour, and glaciogenic deposits may be present at the seabed. The surface of the Holocene sands is frequently covered by large sandwaves and smaller ripples.

The site's geohazard profile is mostly consistent with expectations for formerly glaciated continental shelves. One exception may be the degree to which the seabed sediments are mobile. Based on the size and frequency of large subaqueous dunes, e.g., sandwaves, issues related to sediment transport, e.g., scour or sediment loading, should be considered likely. The types of geohazards deemed as present or likely within the site are listed below.

- Sediment transport;
- Boulders and cobbles;
- Gravel deposits;
- Soft sediments and hard-over-soft conditions;
- Heterogeneous deposits;
- Over-consolidated sediments;
- Glaciotectonized deposits;
- Paleochannels.

6.2. 3D MICROSITING ASSESSMENT

The main unit boundaries established in the 2D data were interpreted across the 71 individual 3D seismic volumes. Detailed mapping of the 3D volumes involved further interpretation and subdivision of the ground model units, correlated with lithological information inferred from the available geotechnical data. The results of the detailed mapping on the 3D volumes were documented in individual WTG Reports (included in Appendix A).

6.3. POINT DIFFRACTORS / POTENTIAL BOULDERS

The 3D UHRS data assessment and interpretation of potential subsurface boulders was divided into two stages:

- 1st Assessment: Detection and positioning of PDs interpreted to be related with potential subsurface boulders larger than 1 m in diameter, down to 50 m BSB, or to the top of the interpreted bedrock if above 50m below the seabed;
- 2nd Assessment: Dimensioning of PDs (micro-siting analysis) selected from the results of the 1st Assessment.

PDs with potential to be related with subsurface boulders were identified and mapped within 60 x 60 m areas. Both isolated and clustered PDs were identified on 3D UHRS MIG data; picked, respectively, as vertical fault segments and horizons.

Potential subsurface boulders were interpreted from the identification of spherical to ellipsoid PD features of high positive amplitude response observed in migrated (MIG) datasets (cross-checked with unmigrated data and complementary seismic attributes), in the time domain. PDs display variable seismic response depending mostly on their nature and contrasting properties relative to surrounding materials, and size of the object. Depending on their seismic response, an interpretation confidence rating was attributed to each feature (see section 5.3.5). PDs were mapped separately, according to the likelihood of being related with potential subsurface boulders:

- High interpretation confidence – isolated PD3;
- Medium interpretation confidence – isolated PD2 and clustered C2;
- Low interpretation confidence – isolated PD1 and clustered C1;
- Zero interpretation confidence – isolated PD0, related with point anomalies found within the multiple interval.

A total of 1710 PDs interpreted to be related with potential isolated boulders were identified across the full Arklow survey. The results from the 1st Assessment were provided to SSE for their analysis and validation of isolated PDs per WTG/OSS for micro-siting purposes (2nd Assessment stage, including targets dimensioning). The PDs detected were found within the glaciogenic seismic units, i.e., U0A, U0B, U1A, U1, and U2 – consistent with the geological context of the area. Minor PDs observed within the Holocene Surface Sands Formation or unit U0 are most likely related with occurrence of coarse-materials (such as gravels); or could be related with the presence of buried objects of different origin.

7. RESERVATIONS AND RECOMMENDATIONS

The geological descriptions and PD mapping results presented in this report are based on interpretations of the 2D and 3D UHRS data acquired for the Arklow survey. It should be considered that there is a natural limitation in the accuracy of interpretation. 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 seismic units display a certain degree of vertical and horizontal variability and heterogeneity. This is due to the complex nature of the geological processes that took place in the area.

The procedure carried out for the identification of potential boulders within the subsurface, although carefully executed, has some limitations and uncertainties associated. As such, the identification of PD is dependent on data frequency content; signal quality and signal/noise ratio; impedance contrasts; and target sizes. Uncertainty also increases with depth, due to frequency content shift towards lower frequencies and changes to signal/noise ratio.

Higher resolution is achieved vertically on 3D UHRS data when compared to traditional 2D data. Horizontal resolution is dependent on bin size, frequency content, impedance contrasts, and other factors related with the processing sequence, particularly with the migration algorithm efficiency. Vertical resolution depends on seismic wavelength and bed thickness. The horizontal measurements uncertainty of the collapsed PD is significantly higher when compared to vertical measurements (not obtained during the project). Furthermore, PD manual mapping procedures are ultimately interpreter dependent. Therefore, there is always a certain amount of imprecision associated with manual mapping and dimension estimation. Hence, for safety/risk purposes, it should be considered $\pm 0.5\text{m}$ uncertainty for each given PD center coordinate and horizontal measurement. Within the UHRS resolution, a vertical uncertainty of $\pm 0.3\text{ m}$ should also be considered.

Limitations and uncertainties of object detection in 3D UHRS data are described in detail in section 5.2.

8. REFERENCES

Arklow Offshore Wind Farm INTERIM GROUND MODEL Report Rev 1 (2024).

Clark, C. D., Hughes, A. L. C., Greenwood, S. L., Jordan, C., & Sejrup, H. P. (2012). Pattern and timing of retreat of the last British–Irish Ice Sheet. *Quaternary Science Reviews*, 44, 112–146.

Geological Survey Ireland (GSI). (2021). The Standard Stratigraphic Nomenclature of Offshore Ireland: An Integrated Lithostratigraphic, Biostratigraphic, and Sequence Stratigraphic Framework. Department of the Environment, Climate and Communications.

Huuse, M., Le Heron, D. P., Dixon, R., Redfern, J., Moscariello, A., & Craig, J. (2012). Glaciogenic reservoirs and hydrocarbon systems: an introduction.

Koller, D. P. & Shankar, P. M. (1994). Acoustical emissions from bubble clouds. *Ultrasonics*, Vol. 32, Issue 3, pp. 229-233

Kurjanski, B., Rea, B. R., Spagnolo, M., Cornwell, D. G., Howell, J., & Archer, S. (2020). A conceptual model for glaciogenic reservoirs: from landsystems to reservoir architecture. *Marine and Petroleum Geology*, 115, 104205.

Maynooth University. (2023). The First Quaternary Map of an Irish Offshore Region: The Porcupine Bank, West of Ireland. Retrieved from: <https://www.maynoothuniversity.ie>

McCarroll, D. (2001). Deglaciation of the Irish Sea Basin: a critique of the glaciomarine hypothesis. *Journal of Quaternary Science: Published for the Quaternary Research Association*, 16(5), 393-404.

Mellet, C., Long, D., Carter, G., Chiverrell, G., & Van Landeghem, K. (2015). Geology of the seabed and shallow subsurface: the Irish Sea. British Geological Survey Commissioned Report. CR/15/057.

NGI (2024). Arklow Offshore Wind Farm – Interim Ground Model. Norwegian Geotechnical Institute. Report 2020193-02-R.

O'Cofaigh, C., Evans, D. J. A., & England, J. (2007). Quaternary glaciations in Ireland. In: Elias, S.A. (Ed.), *Encyclopedia of Quaternary Science*. Elsevier, Amsterdam.

Raveau, M. P. (2019) Attenuation of low-frequency sound in water containing dense bubble clouds. *The Journal of the Acoustical Society of America*, Vol. 145 (2), pp. 892-902.

Scourse, J. D., & Furze, M. F. (2001). A critical review of the glaciomarine model for Irish Sea deglaciation: evidence from southern Britain, the Celtic shelf and adjacent continental slope. *Journal of Quaternary Science: Published for the Quaternary Research Association*, 16(5), 419-434.

Scourse, J. D., Haapaniemi, A. I., Colmenero-Hidalgo, E., Hall, I. R., & Peck, V. L. (2009). Growth, dynamics and deglaciation of the last British–Irish Ice Sheet: The deep-sea ice-rafted detritus record. *Quaternary Science Reviews*, 28(27-28), 3066–3084.

Sustainable Energy Authority of Ireland (SEAI). (2018). Arklow Bank Wind Park Phase 1 – Offshore Wind Overview. Retrieved from: <https://www.seai.ie/publications/Arklow-Bank-Wind-Park-Overview.pdf>