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Geological information for the support of offshore wind farm development on the west Portuguese continental shelf

- Viana do Castelo -

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SUMMARY

This report compiles and interprets geophysical and geological information and data relevant for understanding the geological nature of the seafloor in the Viana do Castelo area for development of wind farms.

The information includes a summary of the regional geology, existent seismic reflection data, and seafloor sampling data in the area of interest.

Interpretation of high-resolution vintage seismic profiles that are property of IPMA is also included for the distribution of thickness of unconsolidated sediments for which maps are provided.

Annexes include data on sediment thickness interpretation along seismic lines, seafloor and base of sediments.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

1. INTRODUCTION

1.1. Preamble

The Portuguese government expressed the intention of developing until 2030 up to 10 GW of electrical production centers based on renewable energy sources of oceanic origin. Accordingly, a interministerial working group (Despacho n.º 11404/2022) was set up to produce a report with contributions and recommendations aiming to accomplish the goal set by the government. This working group released, in December 2022, a preliminary report with an initial spatialization plan for the preferred areas for the development of the ocean based renewable energy production areas. After this initial spatial plan proposal, followed a public hearing (Despacho nº 1396-C/2023), including meetings with the several stakeholders and the setup of a commission to put forward a proposal for the affectation plan (Proposta de Plano de Afetação para as Energias Renováveis Offshore – PAER). From a working group that included 21 public organizations and a roundabout at national level of meetings with stakeholders, resulted the revised version for the allocated areas for wind farms installation shown in Figure 1.1.

The allocated areas for offshore wind farms total an area of 3176 km2. The Viana do Castelo North is 312 km2 and Viana do Castelo Sul is 294 km2.

The present report aims at compiling, organizing, and describing the available geological and geophysical relevant information of the seafloor in the Viana do Castelo North and South areas. This information includes as agreed: i) a summary of the geological setting; ii) position maps of existent seismic reflection data, iii) Well data of the oil and Gas industry, iv) surface sediment samples, v) surface sediment maps, and vi) interpretation of vintage high resolution seismic profiles including the mapping of the thickness of the surficial sediments layer (probably unconsolidated sediments), correspondent to the time difference between the reflections of the sea bottom and sediment/bedrock interface, being the last intended as the uppermost geometrical unconformity between undeformed and tectonized strata.

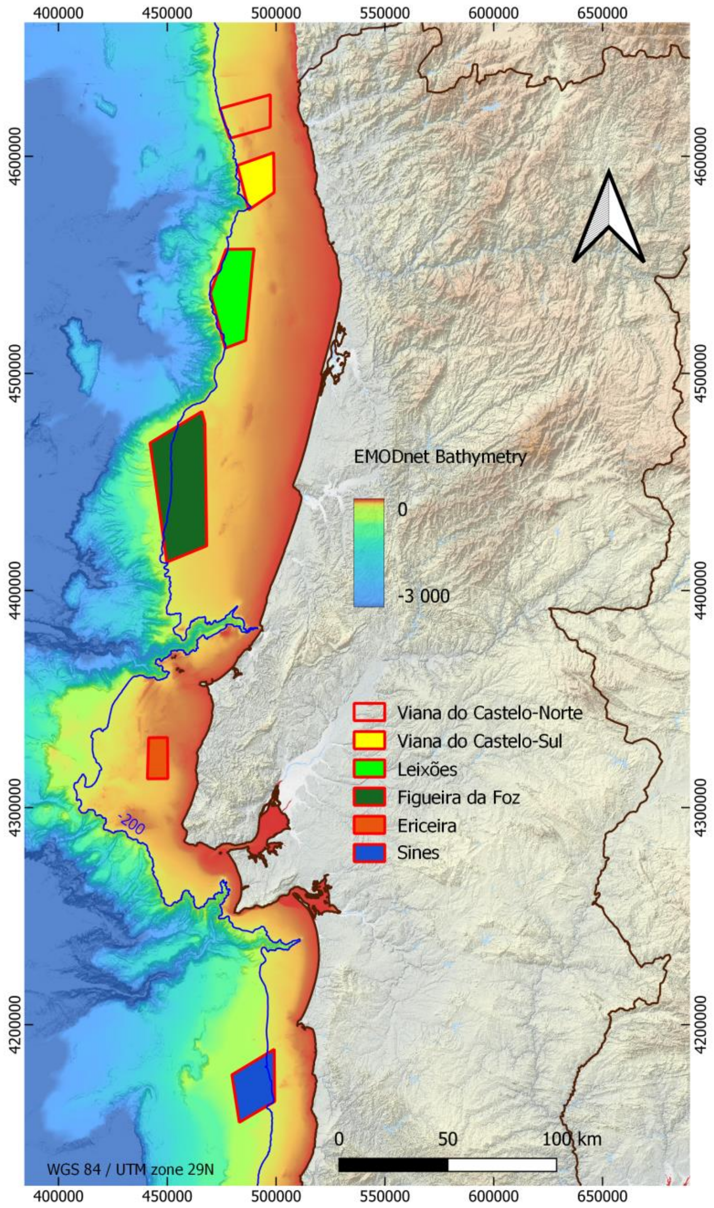


Figure 1.1 - Map showing the allocated areas for installation of offshore wind farms. (https://participa.pt/contents/consultationdocument/Plano%20de%20Afeta%C3%A7%C3%A3o_PAER_Versao_CP_outubro.pdf)

1.2. Geological setting

Viana do Castelo offshore wind farms areas are located in the Galicia-Minho Continental Shelf on the northwest of Portugal, between the Douro River at South and Minho River at North (Figure 1-2). In this area the width of the continental shelf is about 35 km in the north of Póvoa do Varzim, increasing to the south. The continental shelf edge lies around the 160 m depth. In the inner continental shelf, the Hercynian basement of Paleozoic age forms a relief along the shoreline with a maximum width of 10 km, corresponding mainly to granites and metamorphic rocks of Precambrian and Palaeozoic age.

Sedimentary rocks of Cenozoic age cover the middle continental shelf, ending against a NNW-SSE 50 km long relief named Beiral de Viana that consists of Cretaceous rocks forming the external continental shelf. Two main fault systems form a N-S trending graben (Pontal da Galega Graben), where the Porto-Tomar fault marks the contact between the sedimentary rocks and the Hercynian basement. The contact of the Cretaceous rocks with the Cenozoic sedimentary rocks is made by the Beiral de Viana fault.

Sediments are supplied to the shelf by five rivers (Minho, Lima, Cávado, Ave and Douro River). The Douro is the most important river, being responsible for ~80% of the sediments reaching the continental shelf. Several authors have focused on recent sediment distribution and characterization, having reported the presence of different classes of sediments, which ranges from mud to gravel (Dias et al. 1991 1984, 1992, 2001, 2002; Jouanneau et al. 2002; Magalhães et al. 1991, 1992; Fraga 1983; Vitorino et al. 2002a, b).

The Alpine orogeny major pulse of compression occurred during the Miocene. Folds and thrusts are widely recognized along the West Portuguese shelf and onshore. Accordingly, the main erosive unconformity is considered to be of late Miocene to Pliocene age and the sediment package on top of this unconformity is considerably less consolidated than the underlying rock formations.

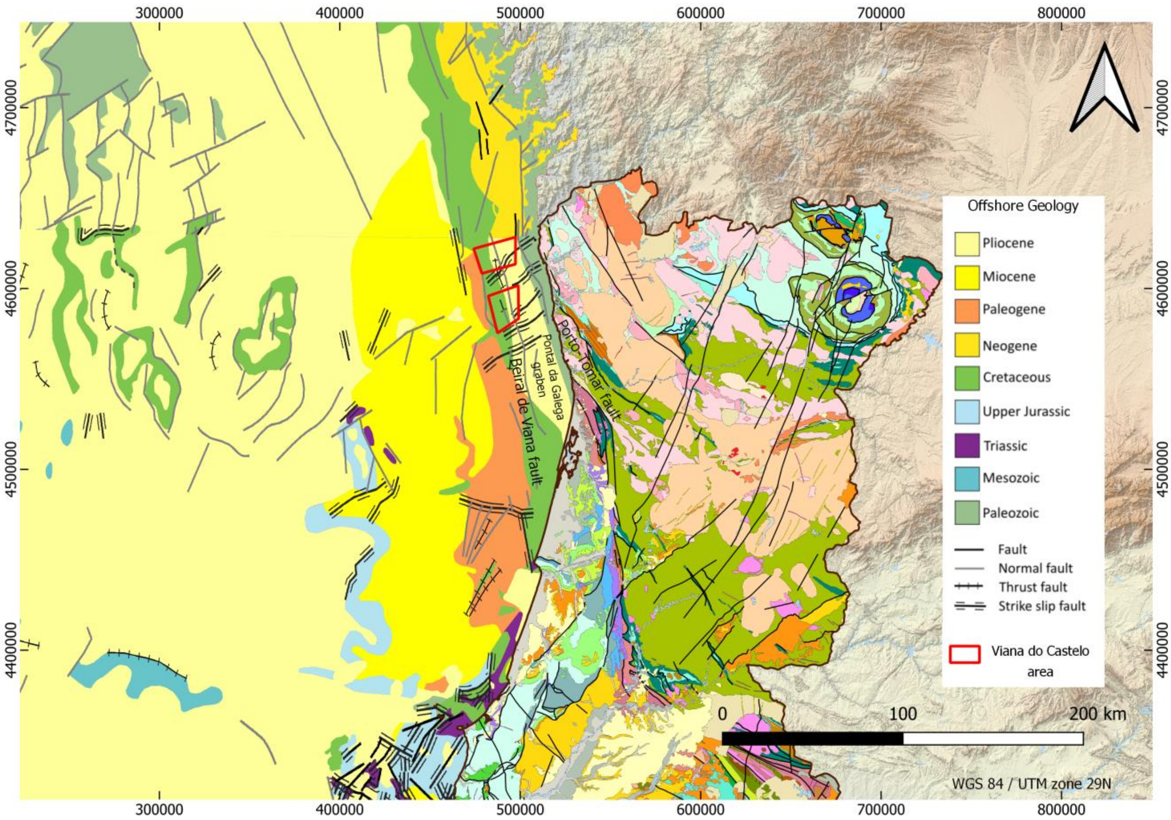


Figure 1.2 - Geological map of the North of Portugal.

2. AVAILABLE DATA

For this work previously acquired geophysical data (IPMA proprietary high-resolution seismic reflexion surveys; and DGEG proprietary medium to low resolution seismic reflexion surveys) were analysed as well as published material (e.g. oil and gas exploration reports; PhD thesis; scientific papers). Figure 2.1 presents all the available data (seismic reflexion surveys and oil and gas wells) for Viana do Castelo North and Viana do Castelo South.

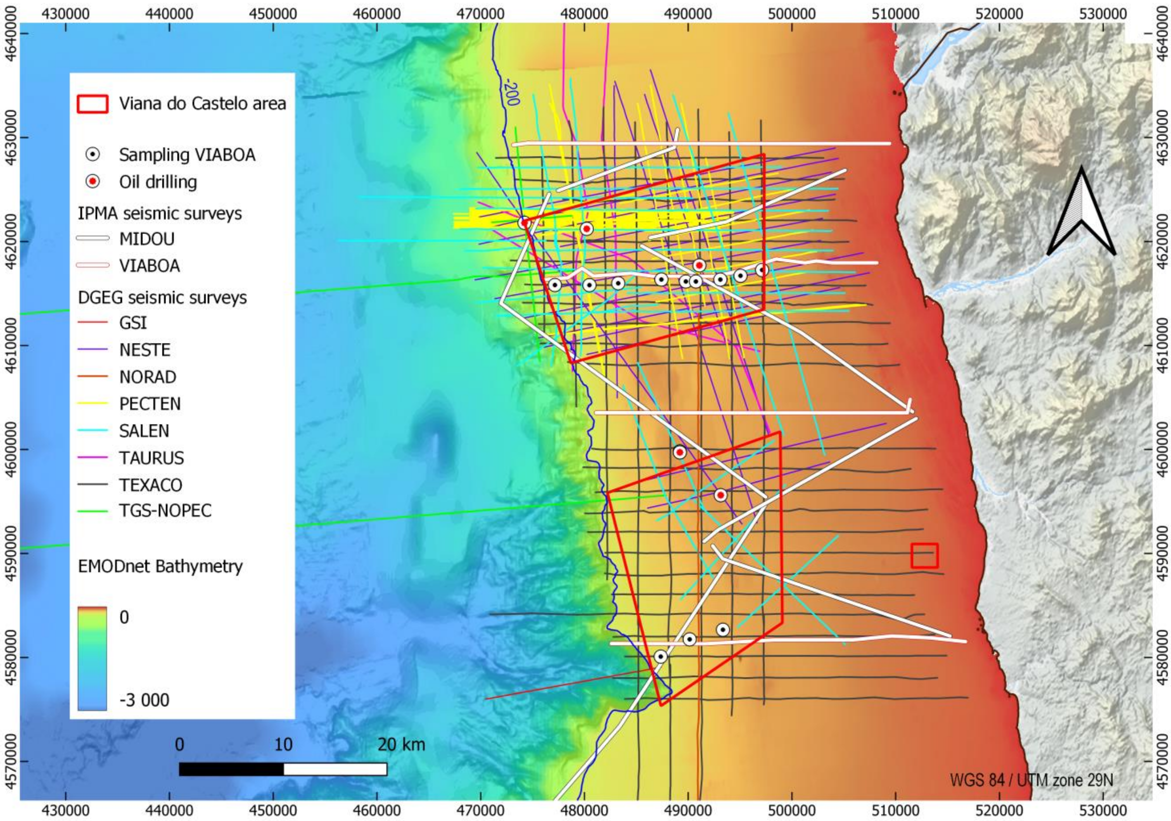


Figure 2.1 - Available data for the Viana do Castelo area.

2.1. Geophysical data

The datasets of seismic reflection profiles consist of lines acquired during 2 'vintage' surveys (VIABOA and MIDOU) and 11 seismic reflection surveys (Table 2.1) from oil & gas data inventory property from DGEG (Figure 2.1). The seismic lines from DGEG were not considered for cartographic purposes. A synthesis of the data characteristics from each survey is available in the forms of Annex 8.1.1. All the information was extracted from survey reports and from the seismic headers of the SGY's. The NORAD survey report was not available. The estimated vertical resolution of the seismic data from the oil & gas surveys varies from 20 to 30m.

Table 2.1 - Synthesis of the available Oil and Gas surveys and existent number of lines covering the area of Viana do Castelo

Survey	Operator	Year	Nº of lines
TEXACO 1975	TEXACO	1975	37
NORAD 1980	NORAD	1980	1
NESTE 1989	NESTE	1989	17
SALEN 1983	SALEN	1983	20
SALEN 1984	SALEN	1984	12
GSI 1984	GSI	1984	1
PECTEN 1985 SPRING	PECTEN	1985	29
PECTEN 1985 FALL	PECTEN	1985	32
TAURUS 1992	TAURUS	1992	4
TGS-NOPEC 2000	TGS-NOPEC	2000	3
TGS-NOPEC 2002	TGS-NOPEC	2002	1

2.2. Well data

Oil and Gas exploration companies drilled several wells in the Portuguese continental margins. Data from these drilling campaigns is available at Direção-Geral de Energia e Geologia; a synthesis of that data is present in this report.

Five wells were drilled in the Viana do Castelo area (Figure 2.2) by different companies, between the seventies and the nineties of the XX century. Table 2.2 presents relevant data on the drilling of the wells.

Table 2.2 - Oil and Gas exploration wells

Name	Abbreviation	Operator	Drilling Year	Total Depth (m)	Water Depth (m)
CAVALA-1	Cv-1	TEXACO PORT.	1976	1229,5	84
CAVALA-4	Cv-4	TEXACO PORT.	1979	2749,3	92
LIMA-1	Li-1	NESTE PETROL.	1990	2900	110
LULA-1	Lu-1	PECTEN PORT.	1985	4040	217.7
TOURO1/1Z	To-1/1Z	TAURUS PETROL.	1994	2853	131.5

Information collected from the exploration wells refers solely to Mesozoic formations of the basin (Table 2.3). With initial drilling without sample recovery, there is no information on the shallow formations or the unconsolidated sedimentary cover.

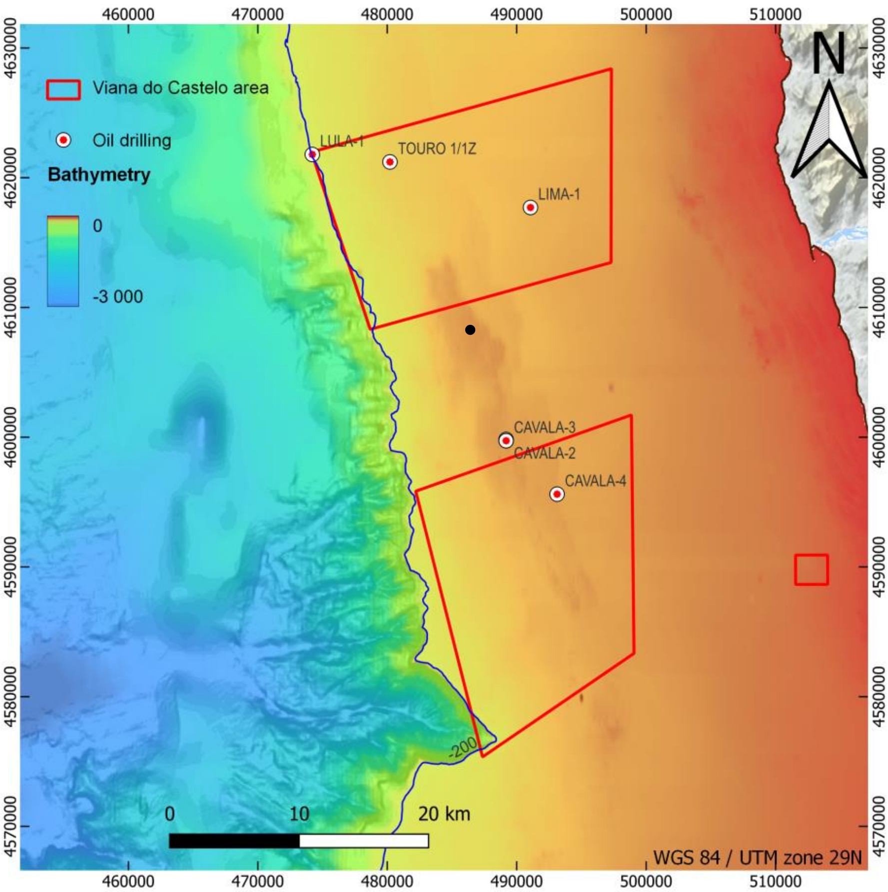


Figure 2.2: Location of wells drilled in the Viana do Castelo area for oil and gas exploration.

Table 2.3 - Synthesis of data from oil and gas exploration wells of Viana do Castelo

Well	Lithology	Stratigraphy (Thickness)
CAVALA-1 **Cv-1**	• No recovery	Up to 44 m
	• Limestone, moderately to very dolomitic; • Sandstone with calcareous cement interbedded with limestone, dolomite and siltstone; • Limestone, calcarenite, interbedded with glauconite rich fine to coarse grained sand; • Sand and limestones interlayered;	Late Cretaceous (615 m)
	• Sand with common lignite interbedded with limestone and minor clay; • Dark grey clays with coal, and interbeds of medium to coarse grained sand; • Limestone sometimes dolomitic and clays; • Medium to coarse- grained sand with red clays layers.	Early Cretaceous (452 m)

CAVALA-4 **Cv-4**	• No recovery	Up to 472 m
	• Oolitic limestone • Clastic unit including fine grained occasionally very coarse grained sands, interbedded non calcareous clays;	Upper Cretaceous (731 m)
	• Micritic limestone, occasional chert occurrences in the upper part and interlayered argillaceous bands in the lower part; • Argillaceous limestone and marls, slightly sandy at the top;	Lower Cretaceous (550 m)
	• Micritic limestone, occasionally sandy, argillaceous horizons near the base; • Limestone and grey micaceous mudstones; red to brown silty micaceous mudstones interlayered with medium to coarse grained sandstones, red marls and red-brown silty marls; dense pelletal wackestone and packstones, grey micritic limestone with plant remains, intergradational grey marls and dark grey argillaceous limestone;	Upper Jurassic (1468 m)
LIMA-1 **Li-1**	• No recovery	Up to 415 m
	• Fluvial to shallow marine sandstones with minor limestone with the presence of coal;	Upper Cretaceous: Carapau, Dourada and Gandara Fms (35 m)
	• Limestone with interbedded sandstone layers;	Upper Cretaceous: Cacém Fm (36 m)
	• Interbedded sandstone and claystone layers, evolving to siltstones, ocasionally marls. Claystone and marls at the lower levels;	Torres Vedras Fm (1812 m)
	• Limestone, sometimes dolomitic, with interbedded marls;	Linguado Fm (> 371 m)
	• Sandstone with interlayered marls; increasing clay component towards the bottom of the well with minor sandstone.	Grés Superiores + Alcobaça Fm (> 231 m)
LULA-1 **Lu-1**	• No recovery	Up to 600 m
	• Limestone (wakestone); sandstone with minor interlayered shales and siltstones;	Upper Cretaceous (~400 m)
	• Sandstones interlayered with siltstones and claystones. Calcareous layers and argillaceous layers; Thick siltstone beds (1100 m)towards the base with interbedded marls;	Lower Cretaceous (~1500 m)
	• Limestone; siltstone and sandstones interlayers;	Upper Jurassic

		(~200m)
	• Limestone, thick claystone and evaporitic sediments towards the base;	Lower Jurassic (~1000 m)
	• Evaporites, dolomites, sandstones.	Upper Triassic (+ 150 m)
TOURO1/1Z **To-1/1Z**	• No recovery	Up to 160 m
	• Limestone with layers of sandstone and dolomites; dolomites; •	Late Cretaceous (+ 625 m)
	• Sandstones with interlayered clays; dolomite beds; claystones; marls; claystones with interlayered sandstones; limestone beds towards the base.	Late Jurassic - Early Cretaceous (~2200 m)

2.3. Surface sediments

During the VIABOA campaign unconsolidated surface sediment sampling was done with Van Veen and Shipek grabs. In the area of Viana do Castelo 12 samples were collected, and the data on those samples, as well as a summary description of the sediment types is presented in Table 2.4. Location of the sampling sites is shown in Figure 2.3. The sampled sediments are sands, of variable grain size and generally with abundant bioclasts.

The “Carta de Sedimentos Superficiais da Plataforma Continental”, published by the Instituto Hidrográfico (2010) is the main document on the continental shelf surficial geology. At the area of Viana do Castelo (North and South) most of the loose sediments are Pleistocene or Holocene in age, mainly detrital of various grain size; some consolidated detrital Pliocene sediments and Cretaceous limestone are also present in the area.

The unconsolidated sediments of the area (Figure 2.4) are mainly detrital with various grain sizes and different bioclastic and lithoclastic components. The description of the sediments follows the Folk classification scheme, and the textural meaning is presented in Table 2.5.

Rocky outcrops of the continental shelf offshore Viana do Castelo occupy a considerable area and correspond to Pliocene sands, clays and silts at the eastern portion of the outcrop and Cretaceous limestone westward. These sediments constitute the substrate of the loose sediments of the area, that include muddy lithoclastic sands which are the most common sediments together with lithoclastic fine sands. Occurrences of other sediments include sandy lithoclastic mud, lithoclastic mud, lithobioclastic sandy mud, lithoclastic sand, lithobioclastic sand, bioclastic medium sand, biolithoclastic coarse sand, and biolithoclastic fine sand.

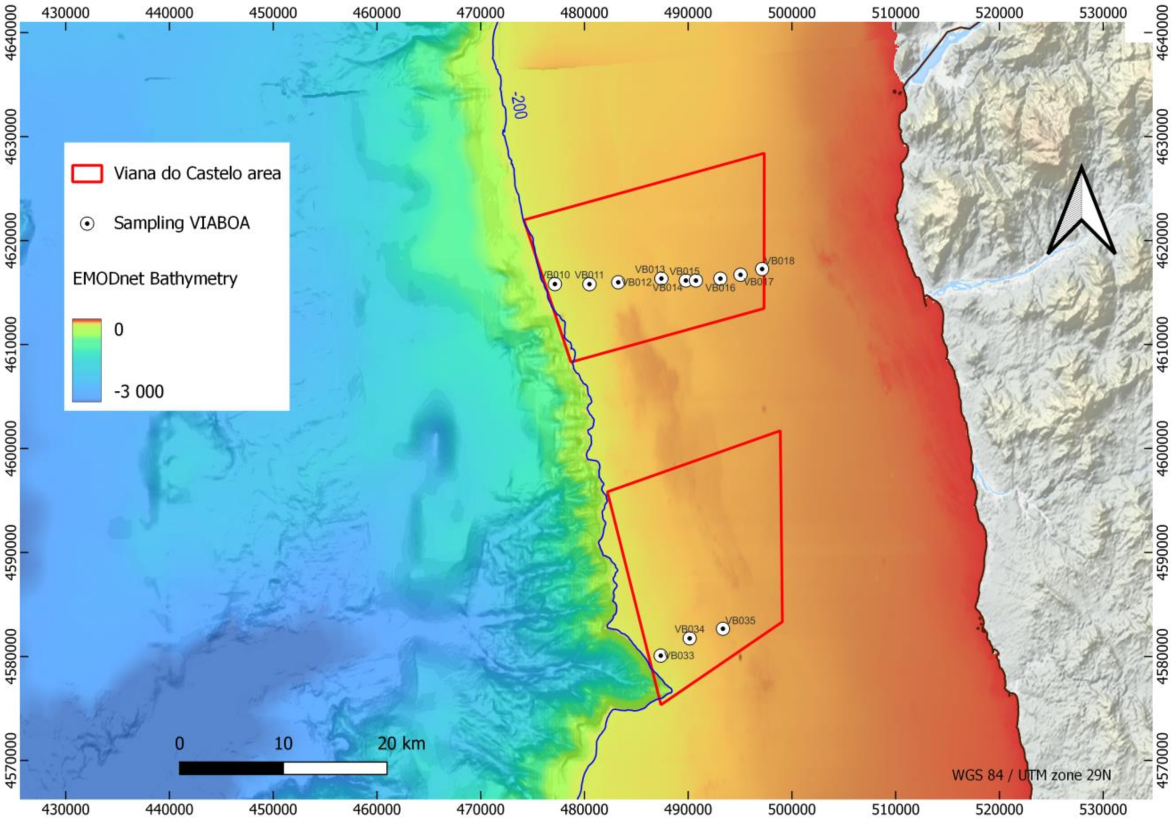


Figure 2.3: Location of VIABOA sampling sites.

Table 2.4 - Surface sediments collected during VIABOA campaign.

ID	Latitude	Longitude	Date	Depth (m)	Observations	Area
VB010	41.693789	-9.274663	1975/10/16	160	Fine grained grey sand, mica-rich with shells	VCN
VB011	41.693789	-9.234663	1975/10/16	135	Fine grained dark grey sand, with shells	VCN
VB012	41.695457	-9.201329	1975/10/16	125	Fine grained dark-green micaceous sand	VCN
VB013	41.698791	-9.151328	1975/10/16	110	Coarse grained sand with shells	VCN
VB014	41.697124	-9.122995	1975/10/16	105	Silty fine-grained sand with shells	VCN
VB015	41.697124	-9.111328	1975/10/16	100	Fine grained grey sand with shells	VCN
VB016	41.698791	-9.082994	1975/10/16	100	Coarse grained sand with shells	VCN
VB017	41.702125	-9.05966	1975/10/16	95	Silty fine-grained sand	VCN
VB018	41.707125	-9.03466	1975/10/16	90	Silty fine-grained sand	VCN
VB033	41.372118	-9.151322	1975/10/17	140	Medium-grined sand with shells	VCS
VB034	41.387118	-9.117989	1975/10/17	115	Fine grained grey sand with shells	VCS
VB035	41.395453	-9.079654	1975/10/17	100	Silty fine-grained grey sand	VCS

VCN – Viana do Castelo North; VCS – Viana do Castelo South

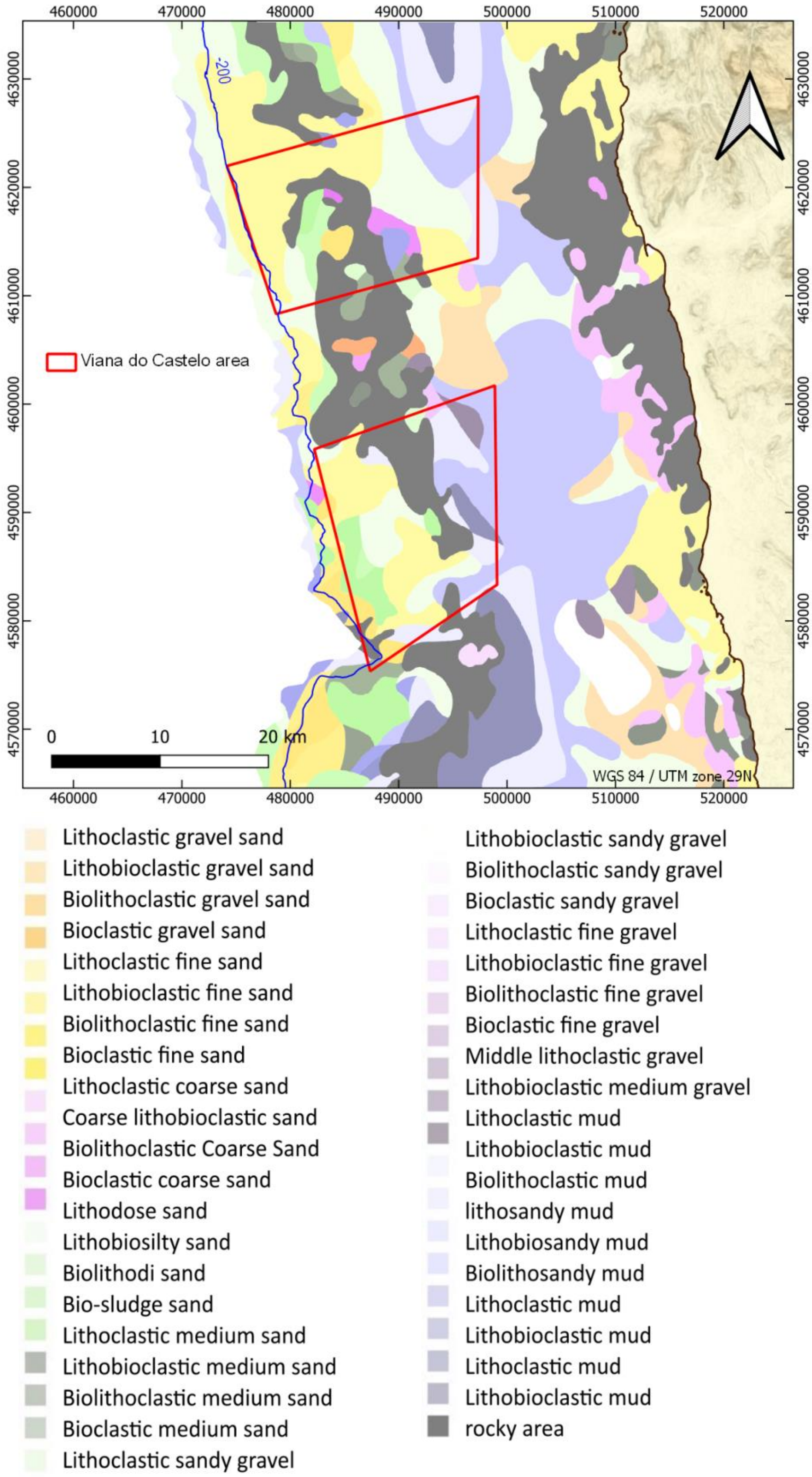


Figure 2.4 - Geological map of the surficial sediments of the Viana do Castelo are (IH, Carta de Sedimentos Superficiais da Plataforma Continental, 2010).

Table 2.5 - Reference values for the surficial sediments classification according to IH map

Gravel sediments	Sand sediments	Muddy Sediments
Mud < 10% Sand + Mud < 50% Gravel >50% Avg ≥ 2 mm	Mud < 10% Sand + Mud > 50% Avg ≤ 2 mm	Mud > 10%
Lithoclastic	carbonate < 30%	
Lithobioclastic	30% < carbonate < 50%	
Biolithoclastic	50% < carbonate < 70%	
Bioclastic	carbonate > 70%	

3. 'VINTAGE' HIGH RESOLUTION SEISMIC SURVEYS

3.1. Surveys' description

IPMA seismic data repository has a set of 2D high resolution seismic data from old seismic campaigns prior the 90s, herein named as 'vintage'. A selected set of these seismic lines (Figure 3.1) were interpreted with the purpose of assessing the thickness of the unconsolidated sedimentary cover of the Viana do Castelo area. Data was collected during two campaigns: the VIABOA (1975) and the MIDOU (1985). Table 3.1 contains the seismic acquisition characteristics of the campaigns that included sediment sampling (Van Veen, Shipek and Kastenlot grabs). MIDOU sampling was done outside the area of interest.

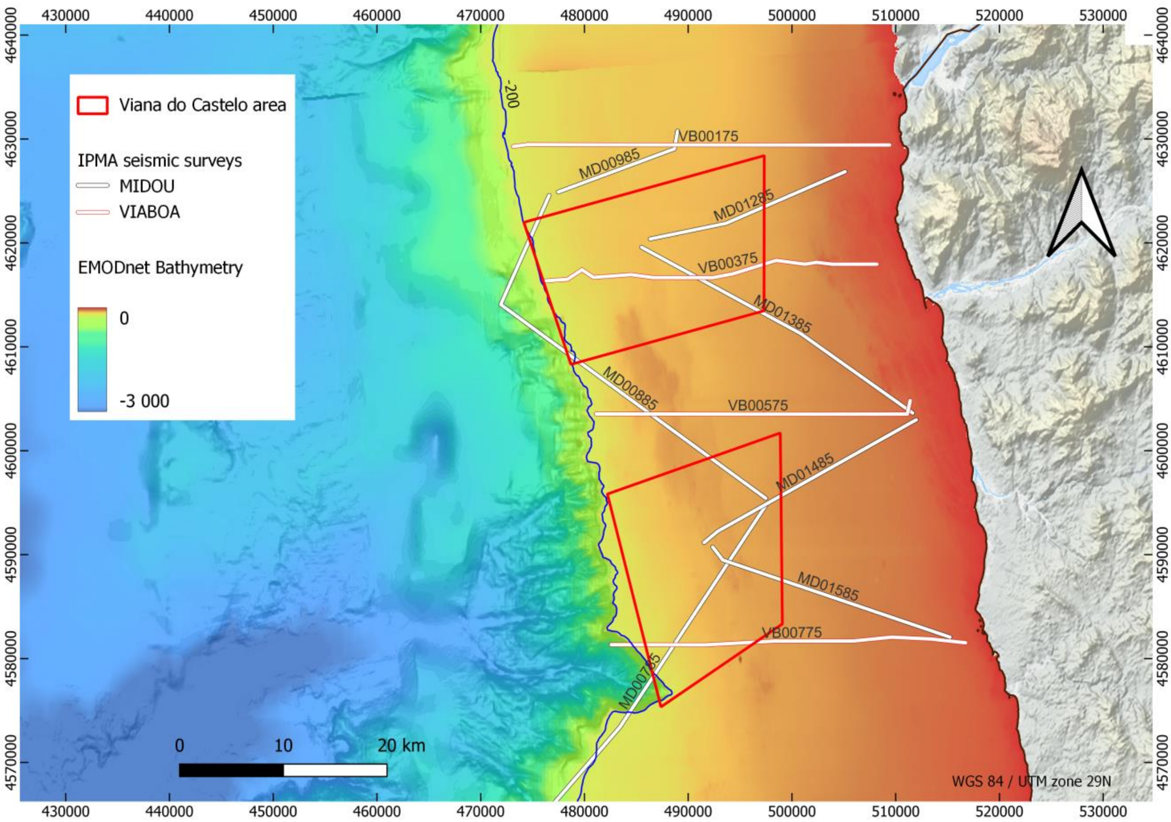


Figure 3.1 - 'Vintage' high-resolution seismic surveys location.

Table 3.1 Data of the ‘vintage’ seismic surveys

	VIABOA	MIDOU
Dates:	13 - 29 October 1975	27 - 29 August 1985
Promotor:	Serviços de Fomento Mineiro, SFM (Portuguese state)	Direção Geral de Geologia e Minas, DGGM (Portuguese state)
Contractor:	SFM and Hydrographic Institute (IH)	DGGM and Hydrographic Institute (IH)
Objective:	Acquisition of geologic data to access the shelf sedimentary cover	NA
Vessel:	NRP Almeida Carvalho	NRP Almeida Carvalho
Positioning:	Made by the crew officials by marked and estimated points, radar and DECA with an interval of 10 minutes	NA
Seismic Equipment	Sparker SIG 72J 6 KV with an energy source of 18-36-72 J; streamer of 100m with an active section of 2.1 m with 4 elements. Register Muirhead with amplifier and higg cut and low cuts hardware filters SIG. Shooting rates of 3 and 6 shots per second	Uniboom and Sparker EG&G
Sediment Sampling Equipment	Van Veen and Shipek grabs	Van Veen grab and Kastenlot corer

3.2. ‘Vintage’ seismic data

The ‘vintage’ seismic data originally in printed format were rasterized to digital format. These digital images are in grayscale .tiff format with 200 to 300 dpi resolution. The vertical registered window, in ms varies from 330 to 1000 ms. Furthermore, shot points location and navigation time are marked in images (Figure 3.2). These ‘vintage’ seismic data were converted to SEGY format, enabling the seismic interpretation with interpretation software. A description of these is presented as follows.

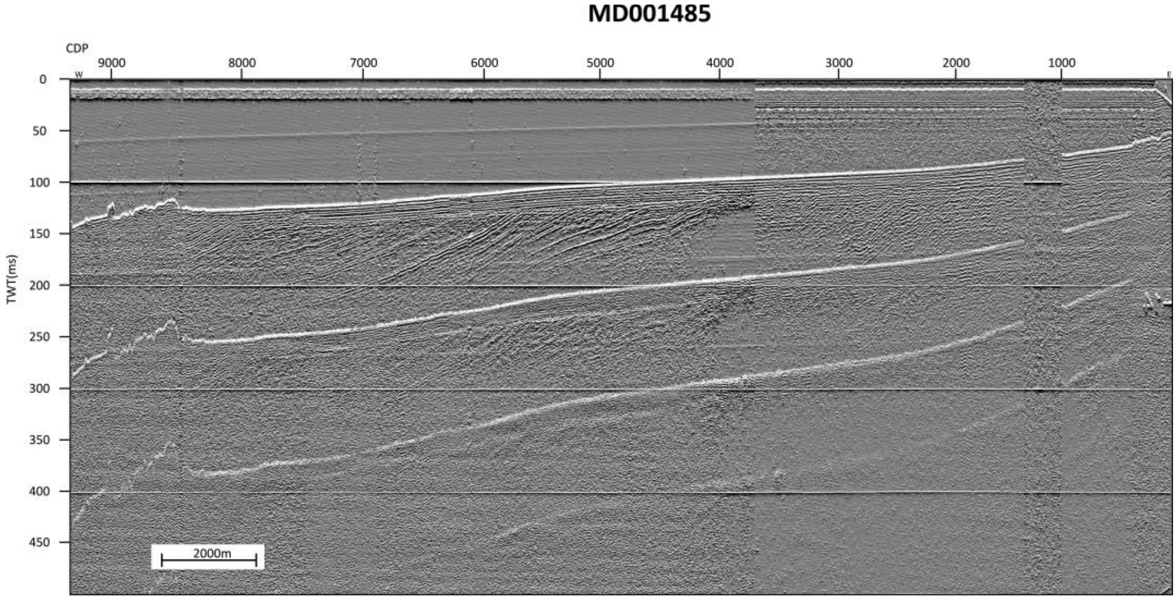


Figure 3.2 - Example of vintage seismic profile of MD001485 line from MIDOU campaign 1985 IPMA. Vertical marks refer to shotpoint locations and horizontal marks to time scale.

3.3. Methodology

The methodology used to transform the digital images of vintage seismic data into SEG-Y format and its interpretation is summarized in the following workflow (Figure 3.3).

Figure 3.3 - Representation of the workflow adopted for vintage seismic data interpretation.

3.3.1. Transformation of vintage seismic images into SEGY format

The transformation of digital images into SEGY format was performed with software scripts in open-source repositories, which were adapted and modified by the *Seislab* (Laboratório de Geologia e Geofísica Marinha - IPMA) team. The images were cropped to the usable area of seismic data. For each “Fora” (fix point) location was assigned the spatial information regarding UTM coordinates (WGS84_ UTM_Zone_29N), obtained from navigation and available in the campaign reports and the coordinates for the remaining shotpoints were interpolated or extrapolated. The SEGY Revison 1 was the format adopted for the SEGY files. Additionally, a Quality Control (QC) of the SEGY was carried out, to check the seismic image quality and checked the accuracy of the shot point’s location (Figure 3.4; Figure 3.5).

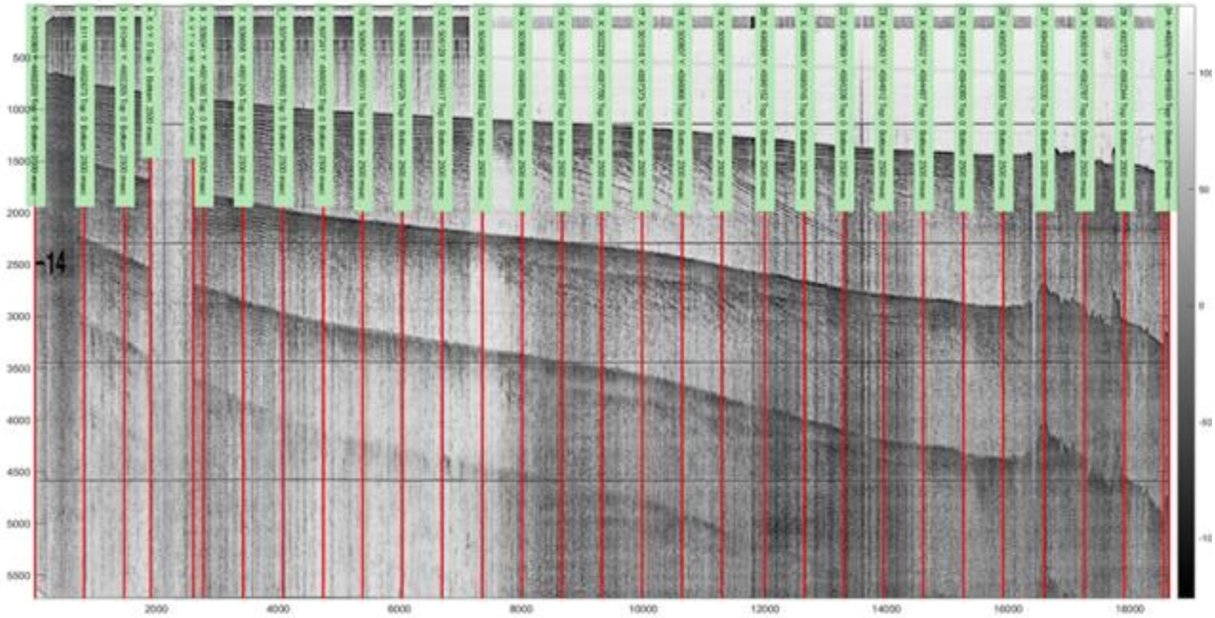


Figure 3.4 - Example of SEGY QC. Seismic profile with shot points location with UTM coordinates.

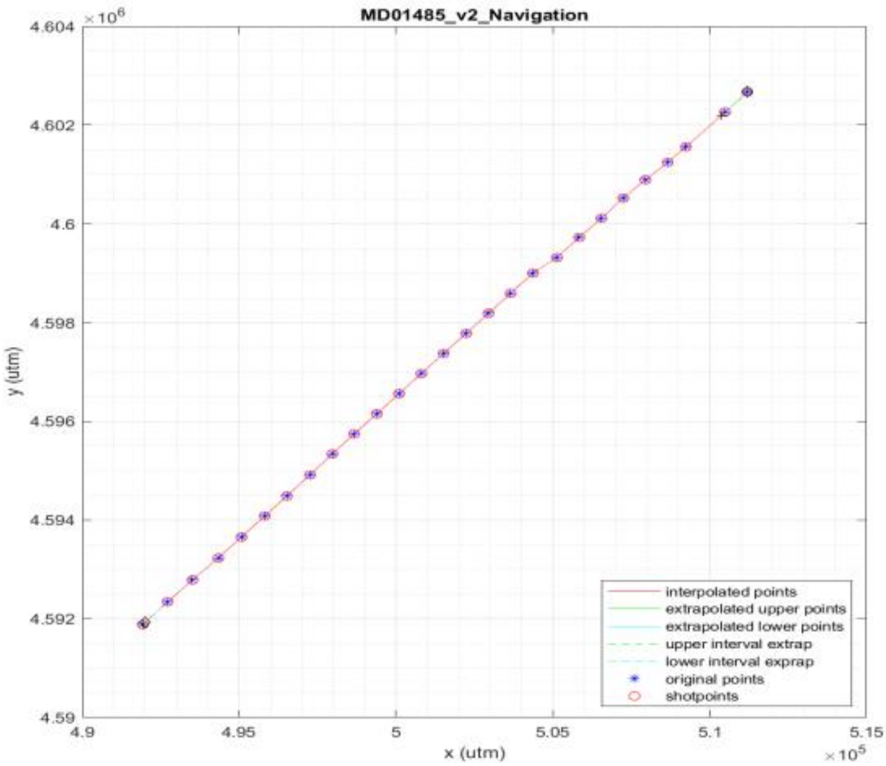


Figure 3.5 - Example of SEGY navigation QC.

3.3.2. Seismic processing

Two seismic processing flows, using simple techniques, were applied to the converted SEGYs. The objectives of the applied processing flows were, for the first one to apply geometrical corrections and homogenize sampling rates, and for the second one to remove noisy data and enhance seismic-to-noise ratio. The geometrical corrections were focused on the following main steps:

- Correction of navigation (elimination of duplicate coordinates due to the rounding and reinterpolation);
- Sample rate homogenization to a sample of 0.1 ms for all lines;
- Delays correction;
- Test of horizontalization correction;
- Sum of seismic traces and line length adjustments;
- Correction of vertical positioning by bulk line shift, to fit EMODnet bathymetry converted to time using a sound velocity of 1500 m/s;
- QC of navigation positioning;

After applying all the geometrical corrections (Figure 3.6) a new SEG-Y file was exported (res.seg). On the second processing flow, a Bandpass Filter and Spatial Filter were used to enhance reflection continuity, and a new SEG-Y was exported (proc.seg) (Figure 3.7).

Quality Control was also applied to seismic processing results (Figure 3.8).

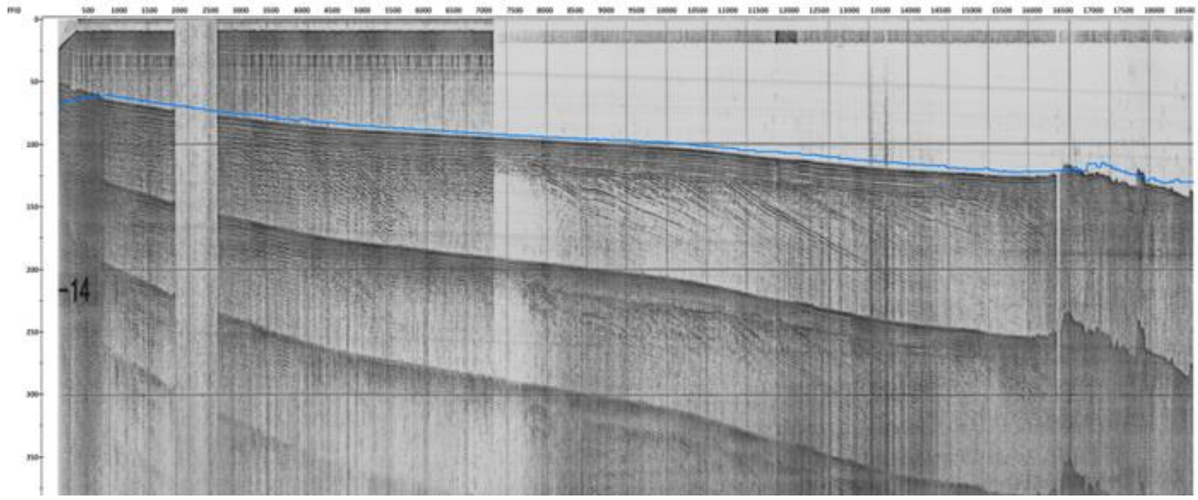


Figure 3.6 - SEG-Y (res.sgy) seismic profile after geometrical corrections. Blue line represents the seabed (data from IPMA database - EMODnet).

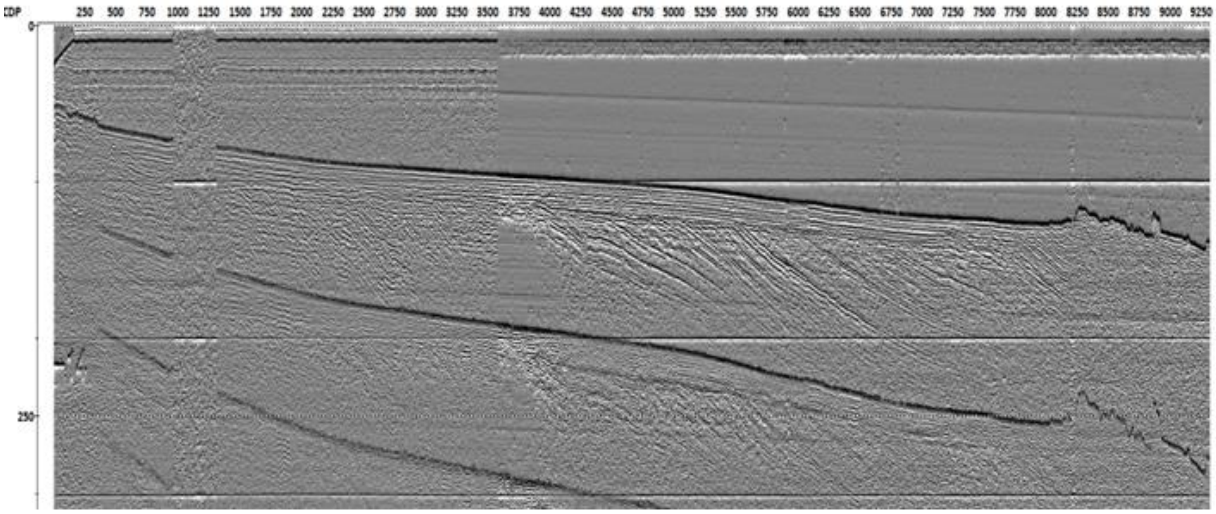


Figure 3.7 - SEG-Y (proc.sgy) processed seismic profile of the line presented in Figure 3.6.

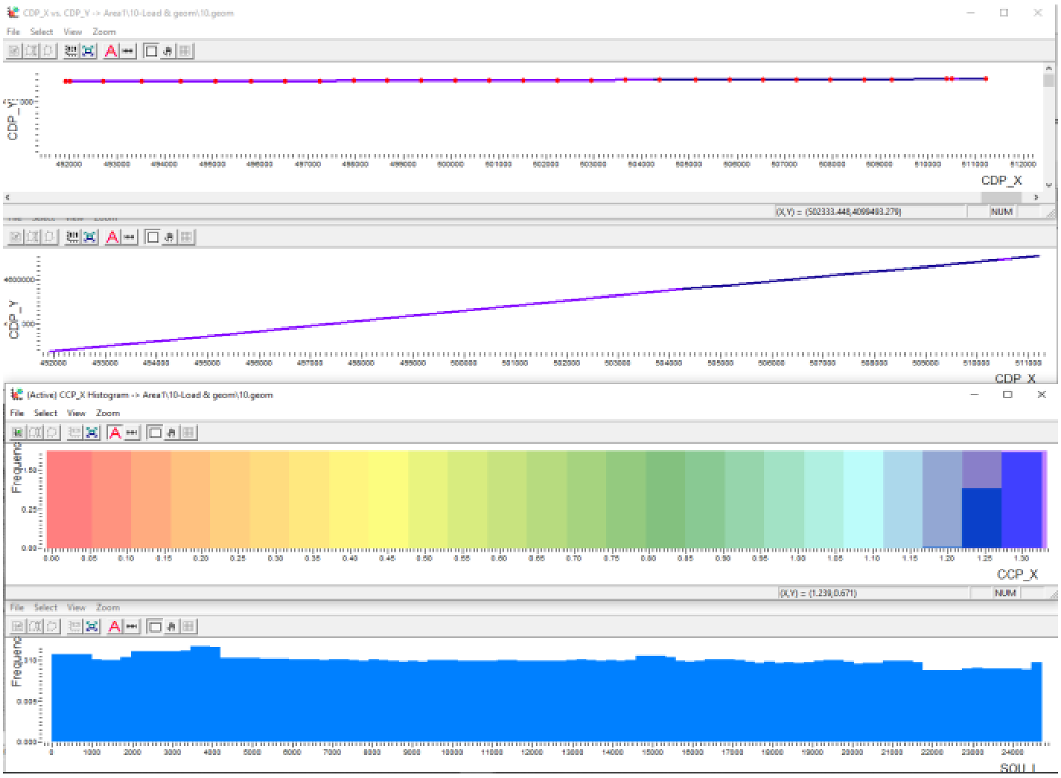


Figure 3.8 - Example of QC plot of navigation positioning for a 'vintage' IPMA seismic line. A- navigation plot of the seismic traces coordinates, "foras" (red dots) with original navigation coordinates and the interpolated coordinates colored according to trace spacing classes (panel C); B- Navigation plot with equal scale axis and dots colored according to trace spacing classes (panel C); C- Frequency of traces distribution by trace spacing classes; D- Frequency of traces distribution by cumulative trace spacing classes.

3.4. Interpretation of high-resolution seismic data

The interpretation of the vintage seismic datasets was based on the two (res.sgy and proc.sgy) output versions of SEG-Y files resultant from the processing stage. The original seismic data has different image quality (Figure 3.9, Figure 3.10), levels of noise (i.e. ringing, ghosts), and positioning accuracy. These differences have an impact on the seismic processing results and on the seismic interpretation potential of the datasets.

The positioning accuracy of the interpreted seismic lines was evaluated by comparison of the picked sea bottom reflection with the EMODnet bathymetry (grid with a 150 m cell size) converted to two-way time (TWT), using a sound velocity of 1500 m/s.

Both horizontal and vertical corrections were applied to the seismic data in order to minimize the observed discrepancies between the picked sea bottom from the seismic data and the Emodnet bathymetry used as reference. Firstly, horizontal corrections were applied by changing the seismic trace-shotpoint relation, to extend or compress the trace spacing along the seismic line in order to achieve a better fit with the bathymetry (Table 3.1). Secondly, a bulk vertical shift was applied to each seismic line in order to minimize the remaining misfit with the bathymetry and the mistiest with crossing seismic lines (Table 3.4 and Table 3.3). Finally, the resultant misfit between the picked seismic sea bottom and the Emodnet bathymetry was evaluated by generating a surface (grid) resultant from the computed difference between the interpolated picked sea bottom from the seismic lines and the Emodnet bathymetry (*Figure 3.11* and *Figure 3.12*).

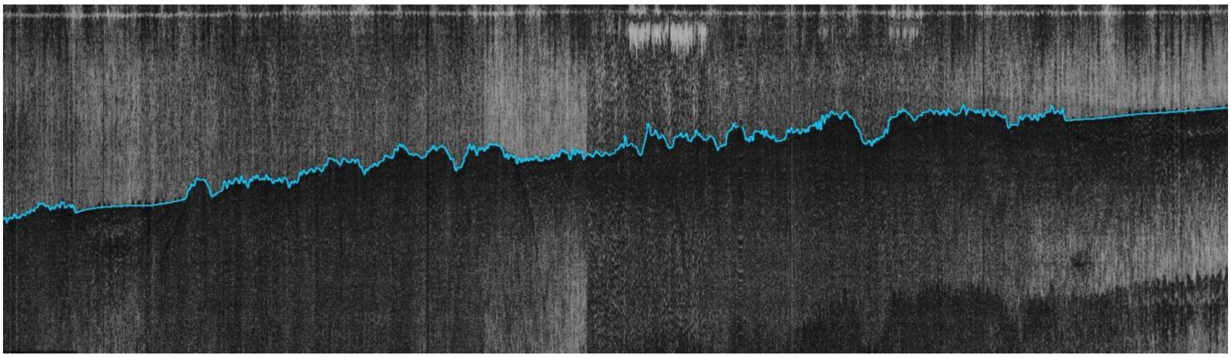


Figure 3.9 - Detail of VB00175 seismic line to highlight image quality. The blue line refers to the interpreted seabed.

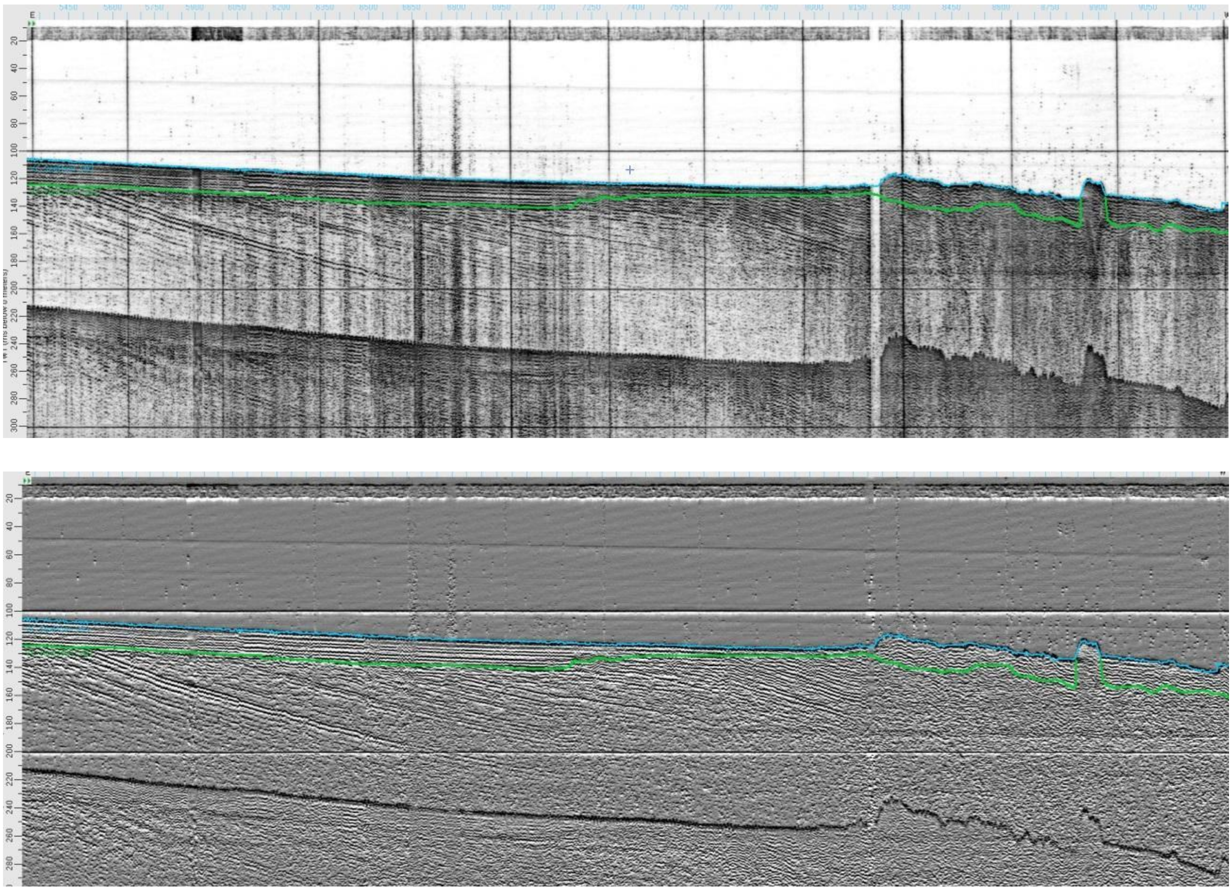


Figure 3.10 - Detail of MD01485 seismic line interpretation (top – res.sgy, bottom – proc.sgy seismic files). with the seabed in blue and base of sediments in green.

Table 3.2 - Modification of the seismic trace-shotpoints relation applied to the interpreted seismic lines to improve its adjustment to the reference Emodnet bathymetry – MIDOU survey.

Line Name	Shotpoint	Trace	Shot/Trace Ratio
MD00885	1	1	
	9555	8965	1.0658
	11944	12330	0.71
	12680	13605	0.5773
	14195	14905	1.1654
	17030	17030	1.3341
MD00785	1	1	
	740	855	0.8653
	915	1060	0.8537
	1960	2060	1.045
	2885	2930	1.0632
	3170	3275	0.8261
	3355	3600	0.5692
	6387	6387	1.0879
MD00985	1	1	
	970	1112	0.8722
	1803	1803	1.2055
MD01285	1	1	
	510	297	1.7196
	5537	5537	0.9594
MD01385	1	1	
	1050	1540	0.6816
	13938	13938	1.0395
MD01485	1	1	
	8570	8282	1.0348
	9323	9323	0.7233
MD01585	1	1	
	1374	1555	0.8835
	3945	3945	1.0757

Table 3.3 - Modification of the seismic trace-shotpoints relation applied to the interpreted seismic lines to improve its adjustment to the reference Emodnet bathymetry – VIABOA survey.

Line Name	Shotpoint	Trace	Shot/Trace Ratio
VB00375	1	1	
	2263	2604	0.869
	15630	16415	0.9679
	27515	28284	1.0013
	28824	28824	2.4241
VB00575	1	1	
	42717	42717	1
VB00175_1v2	1	1	
	27640	27640	1
VB00175_2v2	1	1	
	14780	15800	0.9354
	41799	41799	1.0392
VB00775	1	1	
	16003	17100	0.9358
	22466	24020	0.934
	24872	24872	2.8239

Table 3.4 - Vertical shifts applied to interpreted seismic lines to improve its adjustment to the reference EMODnet bathymetry and minimized the misties between crossing seismic lines.

Line Name	Survey	Original Shift	New Shift
MD00785	MIDOU	0	2
MD00885	MIDOU	0	-2
MD00985	MIDOU	0	-3
MD01285	MIDOU	0	-2
MD01385	MIDOU	0	-2
MD01485	MIDOU	0	-2
MD01585	MIDOU	0	-2
VB00375	VIABOA	0	-8
VB00575	VIABOA	0	-2
VB00175_1v2	VIABOA	0	0
VB00175_2v2	VIABOA	0	1
VB00775	VIABOA	0	-3

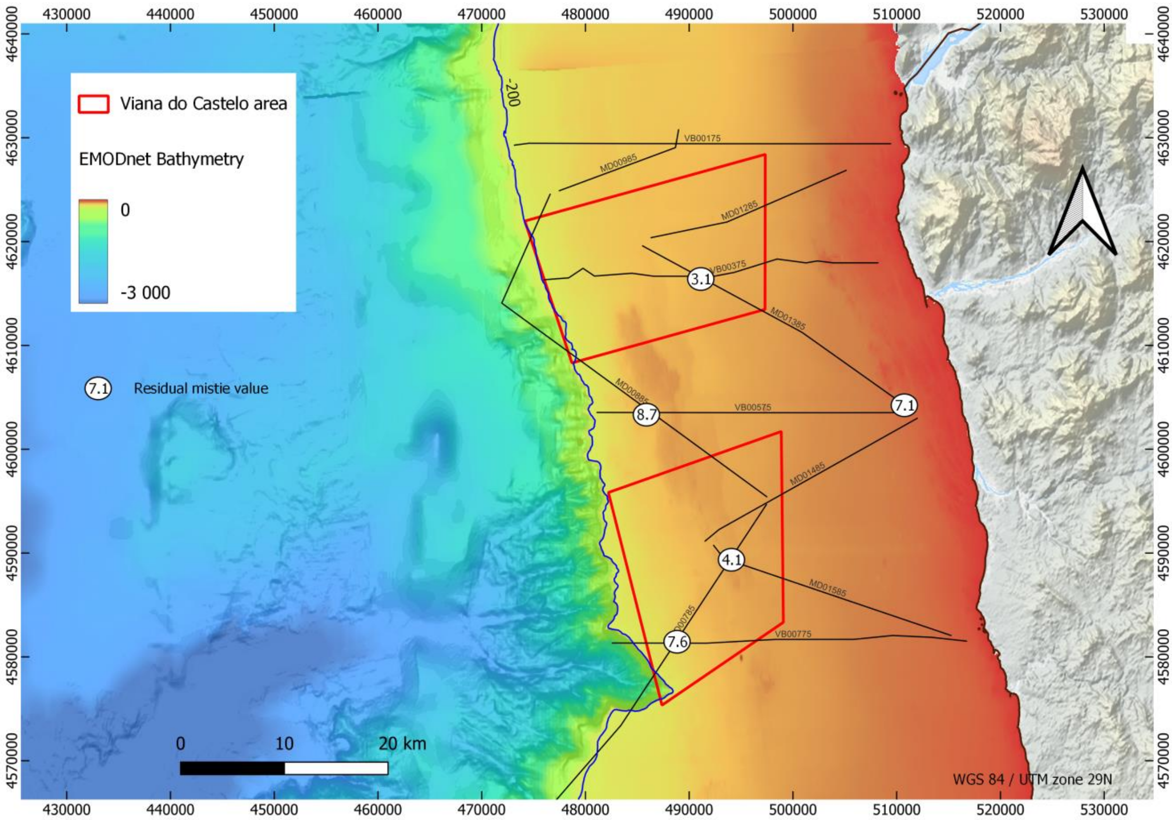


Figure 3.11 - Map of the remaining residual misties between crossing seismic lines after the horizontal and vertical adjustments applied.

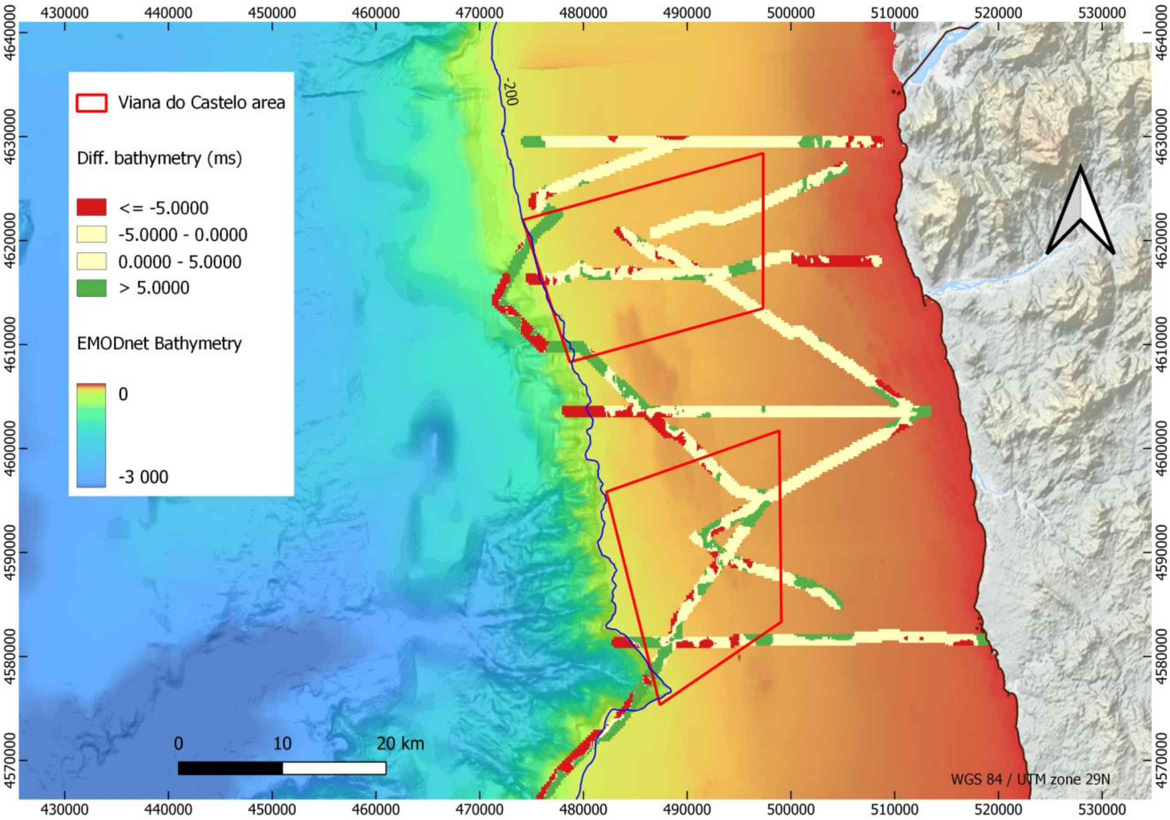


Figure 3.12 - Surface grid representing the residual vertical misfit (difference) between the interpolated surface from the picked seismic seabotom anf the reference Emodnet bathymetry.

The interpretation of the vintage seismic data aimed to infer the thickness of the recent sediments package. The seabed and the base of the recent sedimentary unit horizons were interpreted considering a best-case scenario, where the seabed corresponds to the first high amplitude reflector and the base of the recent sediments corresponds to the first unconformity identified in the seismic data. Considering the seismic data quality, it is not straightforward to distinguish significant reflections from spurious ones (e.g. noise and ghosts). This uncertainty in the seismic interpretation can lead to an overestimating of the thickness of the recent unconsolidated sedimentary package.

3.5. Estimation of unconsolidated sediments thickness

The base of the unconsolidated sediments seismic unit was picked in the vintage seismic lines, identified as the post Alpine orogeny unconformity. Onshore these sediments correspond to poorly consolidated sands with an argillaceous matrix of Pliocene to Quaternary age. The bedrock in the whole area of interest consists of Cretaceous through Eocene sedimentary rocks. According to the EMODnet-Geology map, these units are made up of limestones, dolomites and sandstones (https://emodnet.ec.europa.eu/en/geology).

An example of the interpretation is presented in Figure 3.10, and the map from the interpretation of all ‘vintage’ lines in Figure 3.13. The quality of the vintage seismic lines did not allow for an accurate determination of the base of sediments horizon in all the lines. In some instances, it was not possible to depict with a high degree of certainty the base of the loose sediments. Given these constraints the presented data should be considered a best-case scenario, possibly with some overestimated values, regarding the unconsolidated sediments thickness in the Viana do Castelo area.

The shallower seismic unit in the Viana do Castelo area, believed to correspond to unconsolidated sediments, observable outside the Mesozoic and Paleozoic formations outcrops, overlies a deformed (probably Miocene) unit resting on top of an erosional surface. Two different seismic facies characterize the unit: 1) transparent facies (Figure 3.14); 2) parallel (sub-horizontal) reflectors of low to medium amplitude (Figure 3.15).

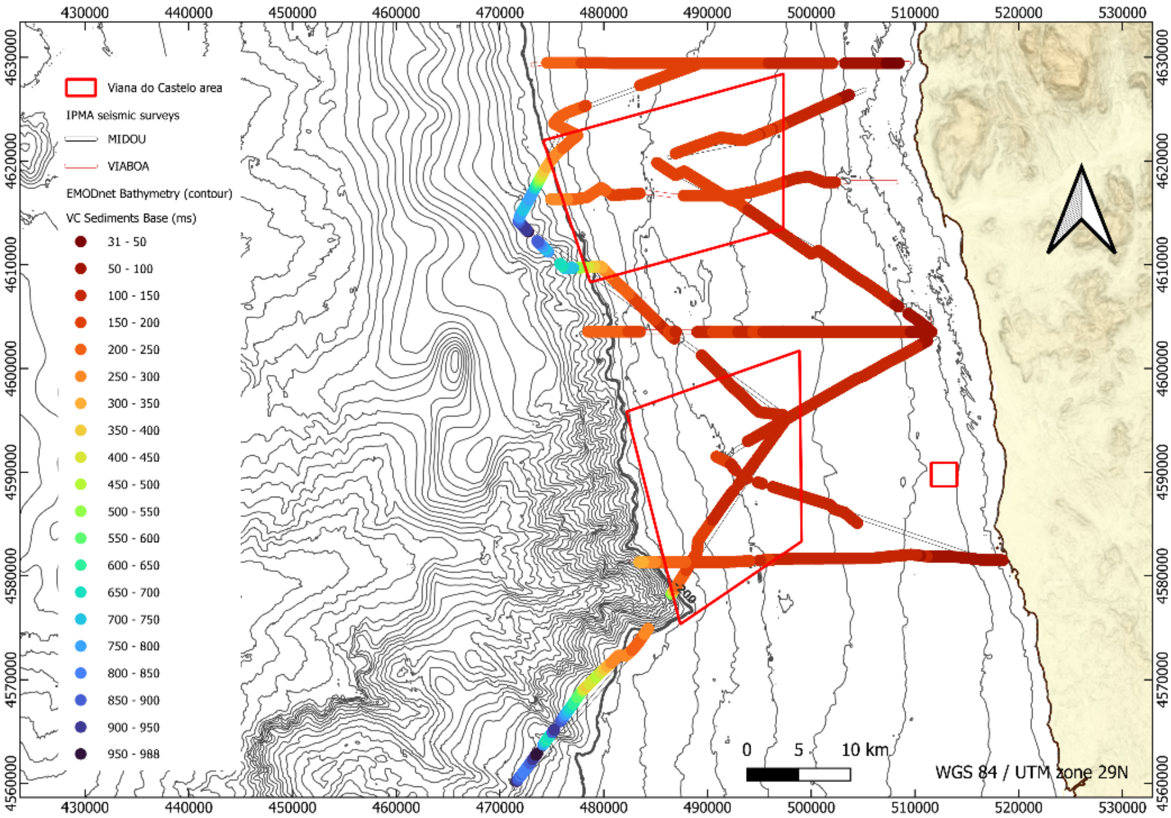


Figure 3.13 - Map of the base of unconsolidated sediments seismic unit (in ms - TWT).

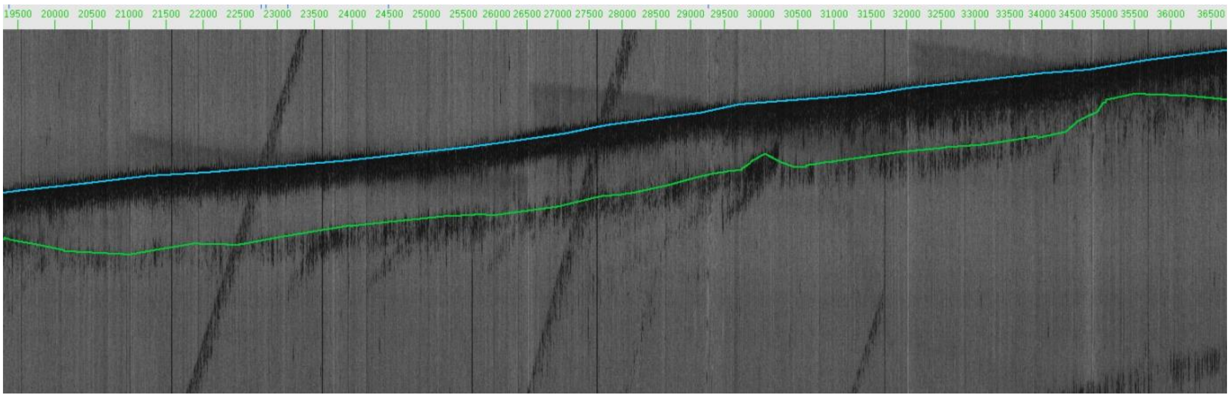


Figure 3.14 - Transparent seismic facies of the unconsolidated sediments unit.

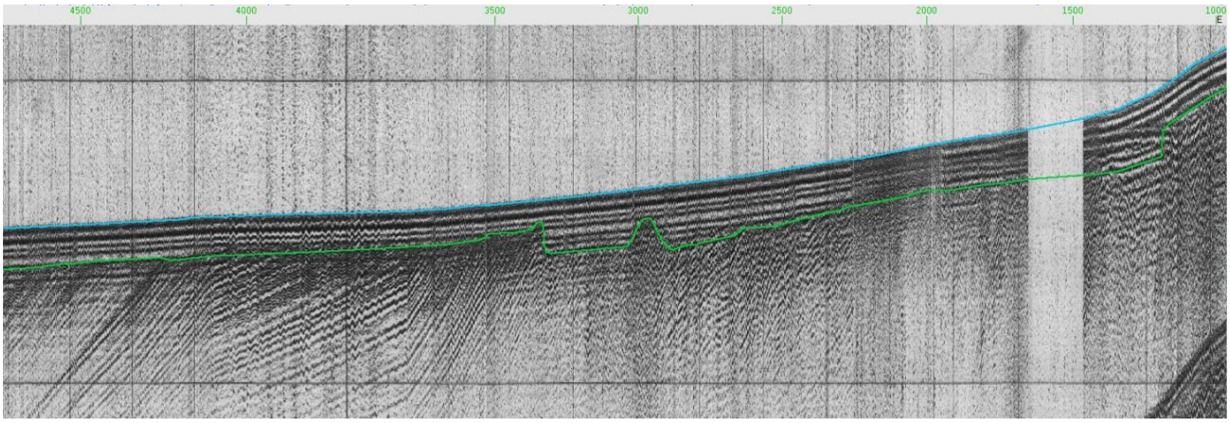


Figure 3.15 - Parallel seismic facies of the unconsolidated sediments unit.

The thickness of the recent sediments package was computed from the difference between the interpreted seafloor horizon and the base of the unconsolidated sediments horizon: Figure 3.16 presents the computed thickness of the unconsolidated sediments along the lines; and Figure 3.17 shows the same data plotted on top of the surficial sediments data from the IH map. Figure 3.18 shows a surface grid of the interpreted sediment thickness, resultant from a least square interpolation considering a buffer range of 1500 m around the seismic lines and Figure 3.19 shows the same surface grid plotted on top of the IH surficial sediments map.

Figure 3.20 A and B presents the surface grids of results of the kriging of the interpreted unconsolidated sediments unit thickness in ms- TWT (Figure 3.20A) and in m (Figure 3.20B), considering a sound velocity of 1700 m/s. This sound velocity value was considered in previous projects to be an acceptable approximation of the velocity for loose sediments in the area.

The estimated values for the thickness of the unconsolidated sediments range from 0 to 44 ms (TWT), with a median value around 14 ms (TWT). Considering a sound velocity of 1500 m/s or 2000 m/s the maximum and median sediment thickness can amount to 33-44 m and 10.5-14 m, respectively.

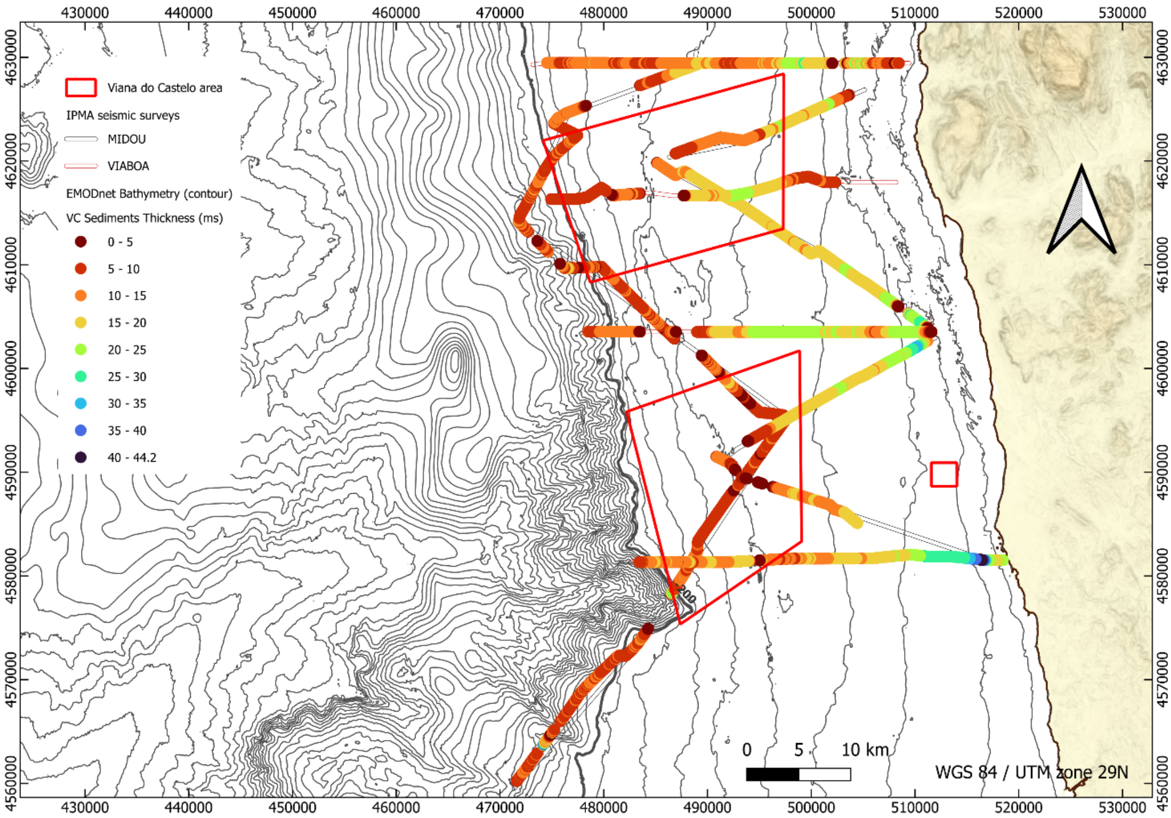


Figure 3.16 - Thickness of the shallower unit, probably of unconsolidated sediments, from the interpretation of the 'vintage' seismic sections (values in ms).

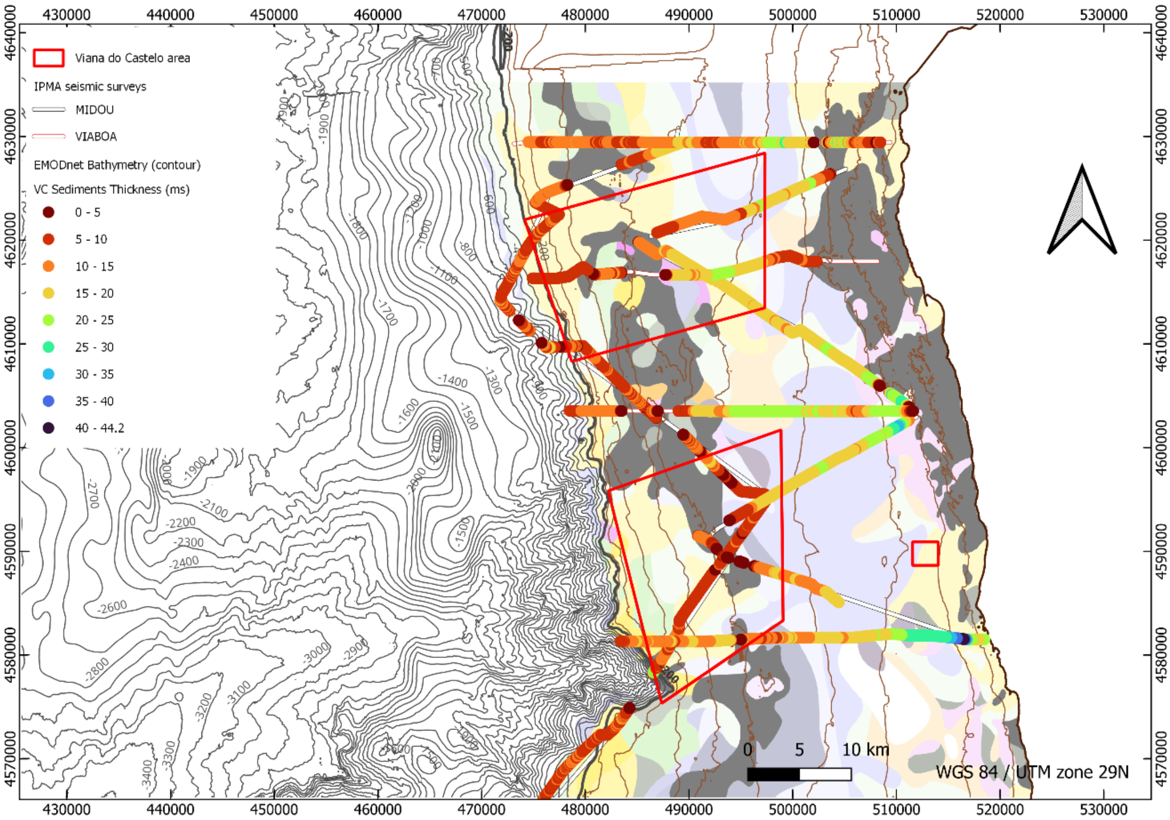


Figure 3.17 - Thickness of the shallower unit (in m), probably of unconsolidated sediments, from the interpretation of the 'vintage' seismic sections, converted to depth using an average sound propagation velocity of 1700 m/s. For color legend see Figure 2.4.

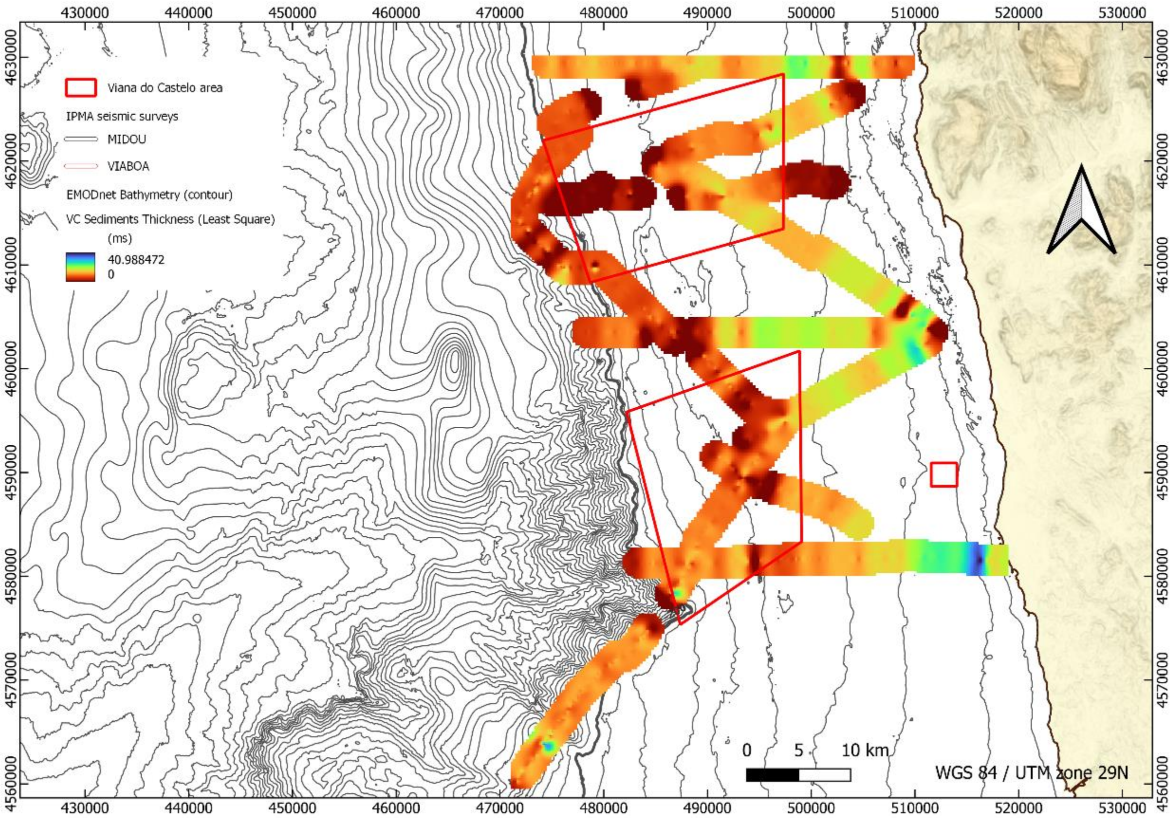


Figure 3.18 - Surface grid of the interpreted sediment thickness, resultant from a least square interpolation considering a buffer range of 1500 m around the seismic lines.

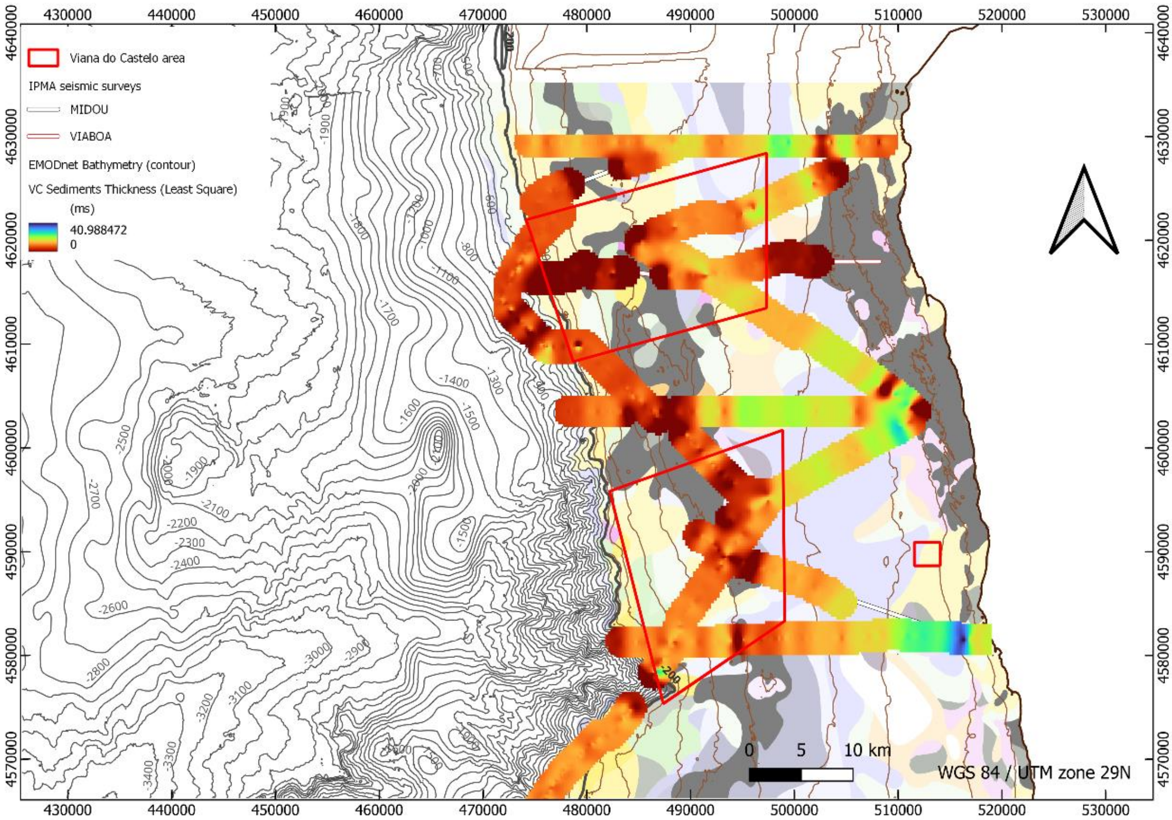
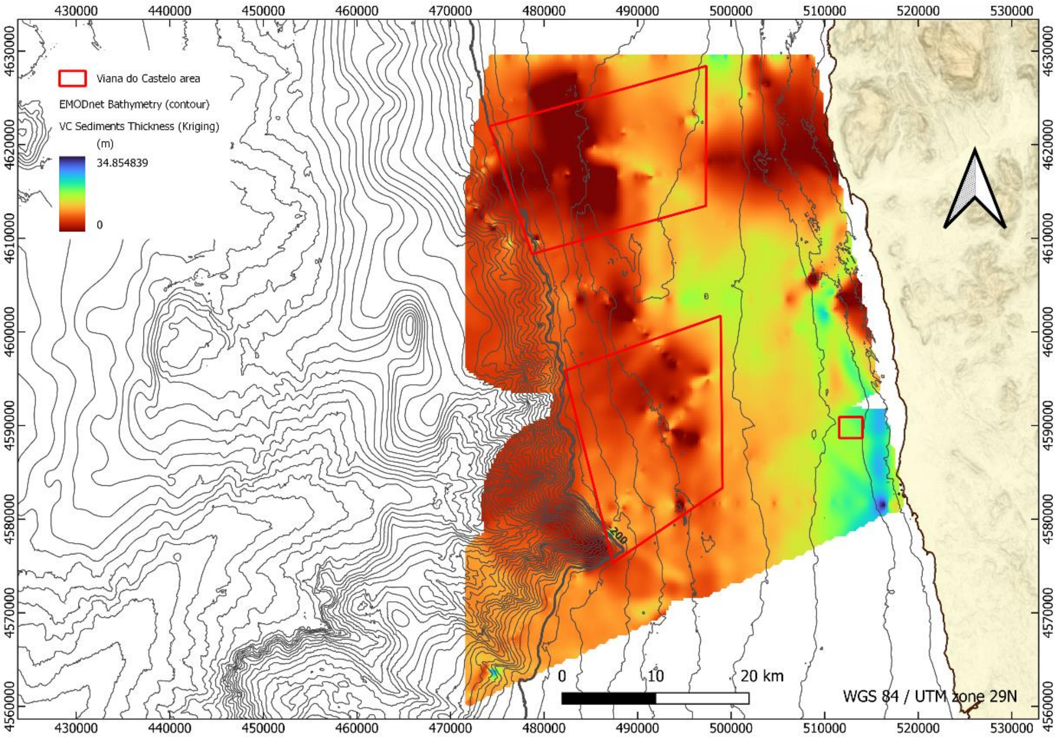


Figure 3.19 - Surface grid of the interpreted sediment thickness, resultant from a least square interpolation considering a buffer range of 1500 m around the seismic lines, plotted on the IH surficial sediments map. (for color legend see Figure 3-17). For color legend see Figure 2.4.



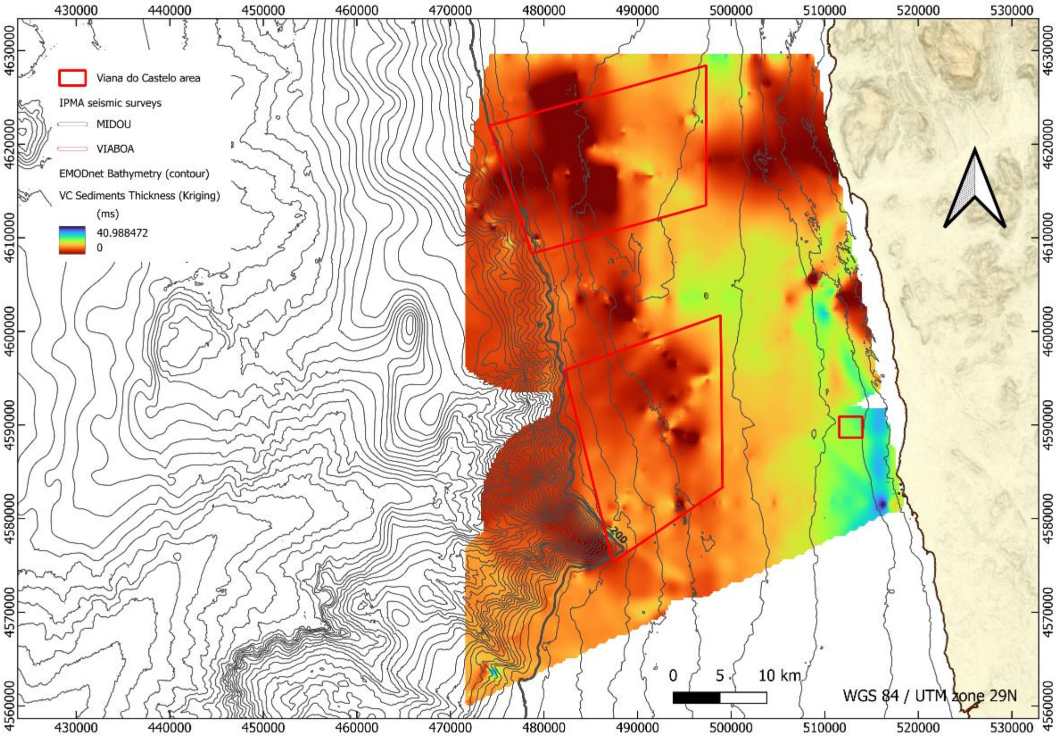


Figure 3.20 - Surface grid of results of the kriging of the interpreted unconsolidated sediments unit thickness; A - in ms (TWT); B – in m considering a sound velocity of 1700 m/s.

4. MEDIUM TO LOW RESOLUTION SEISMIC SURVEYS EVALUATION (OIL & GAS)

4.1. Surveys' Description

Oil and Gas exploration activities provide a vast set of information namely of medium- to low-resolution seismic surveys, represented in Figure 4.1. Surveys covering the area of Viana do Castelo were initially acquired during the 70's and the latest in 2002. They were acquired and processed by different companies (Table 4.1 and Annex 7.1). The surveys provide a varying quality image of the Mesozoic geology of the area.

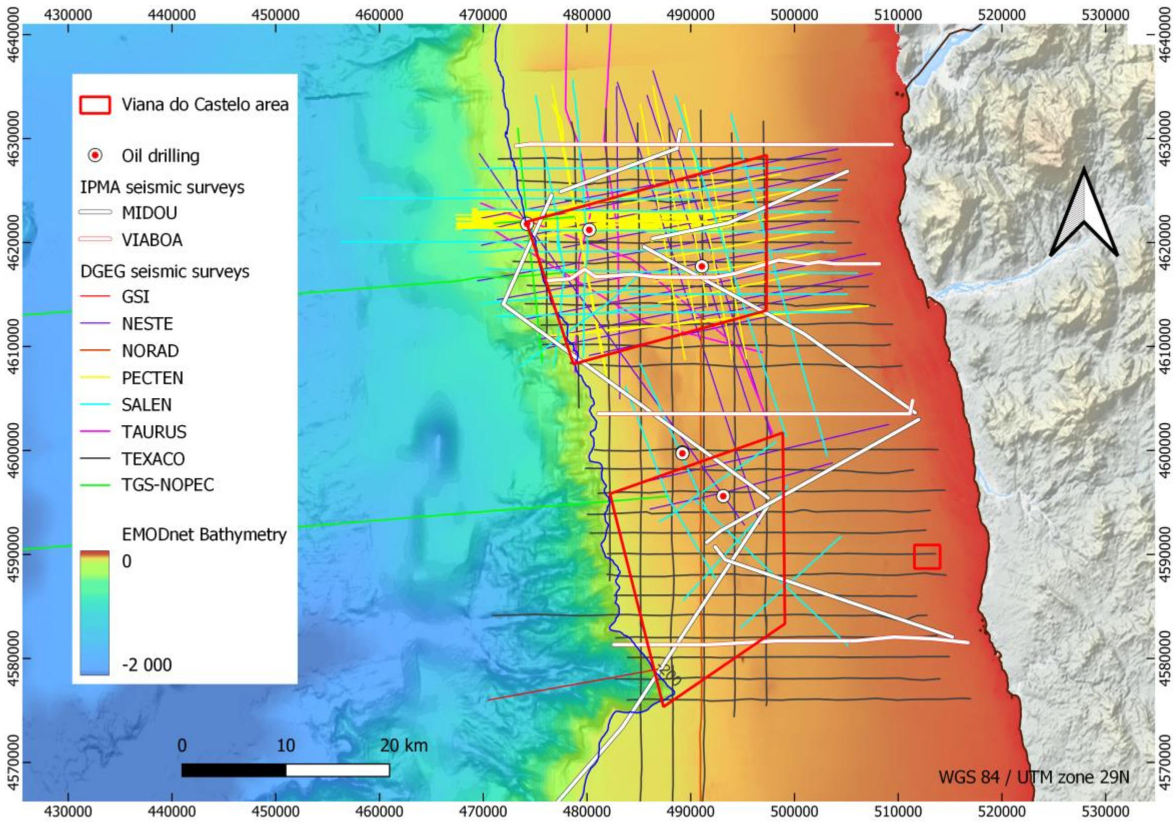


Figure 4.1 - Oil and Gas exploration seismic surveys location.

Table 4.1 - Oil and Gas exploration surveys

Survey	Operator	Year	Nº of lines
TEXACO 1975	TEXACO	1975	37
NORAD 1980	NORAD	1980	1
NESTE 1989	NESTE	1989	17
SALEN 1983	SALEN	1983	20
SALEN 1984	SALEN	1984	12
GSI 1984	GSI	1984	1
PECTEN 1985 SPRING	PECTEN	1985	29
PECTEN 1985 FALL	PECTEN	1985	32
TAURUS 1992	TAURUS	1992	4
TGS-NOPEC 2000	TGS-NOPEC	2000	3
TGS-NOPEC 2002	TGS-NOPEC	2002	1

4.2. Evaluation of quality and potential interest

Seismic surveys covering the area of interest were acquired in different years, using various acquisition systems, and processed by different companies with different workflows. Detailed data on the surveys is presented in Annex 7.1.

Evaluation of the quality and applicability of the surveys to the development of wind farms was done semi-quantitatively by applying two classification scales: i) the quality assessment was done using a five-element scale, focusing on the quality of the imaging; and ii) the applicability was also assessed using a five-element scale, focusing on the capacity of imaging the thin veneer of loose sediments in the area. The scales are presented in Table 4.2.

Table 4.2 Evaluation criteria applied to the Oil and Gas seismic surveys

Quality	Applicability
1 – Poor	1 – Inadequate Coverage
2 – Weak	2 – Low Resolution
3 – Medium	3 – Medium Resolution
4 – Good	4 – High Resolution
5 – Very Good	5 – Very High Resolution

Quality scale is self-explained, while Applicability needs some clarification: 1 - Inadequate Coverage refers to lines only covering small portions of the interest area; 2 – Low Resolution, refers to lines where the shallower package of sediments is invisible due to the resolution of the survey; 3 – Medium Resolution refers to lines where the thickest portions of the unconsolidated sediments package are resolvable; 4 – High Resolution refers to lines where the loose sediments package is clearly visible in most part of the line; 5 – Very High Resolution lines (absent in the set evaluated) refers to lines where the shallower package of sediments is visible and the seismic characteristics of the units are resolvable and characterizable.

The evaluated surveys of oil and gas exploration are of variable quality and in general with resolutions not suitable for the purpose of planning wind farm structures, with a classification of less than 2. Figure 4.2 presents a spider diagram synthesizing the results of the evaluation.

TGS-NOPEC lines, whit the highest quality, have a limited coverage of the Viana do Castelo area, resulting in their low values of applicability. For the other surveys the evaluation of the interest in re-processing the lines for improving the imaging of the first 10 m to 30 m, would imply a more detailed evaluation of the raw data, unavailable for IPMA.

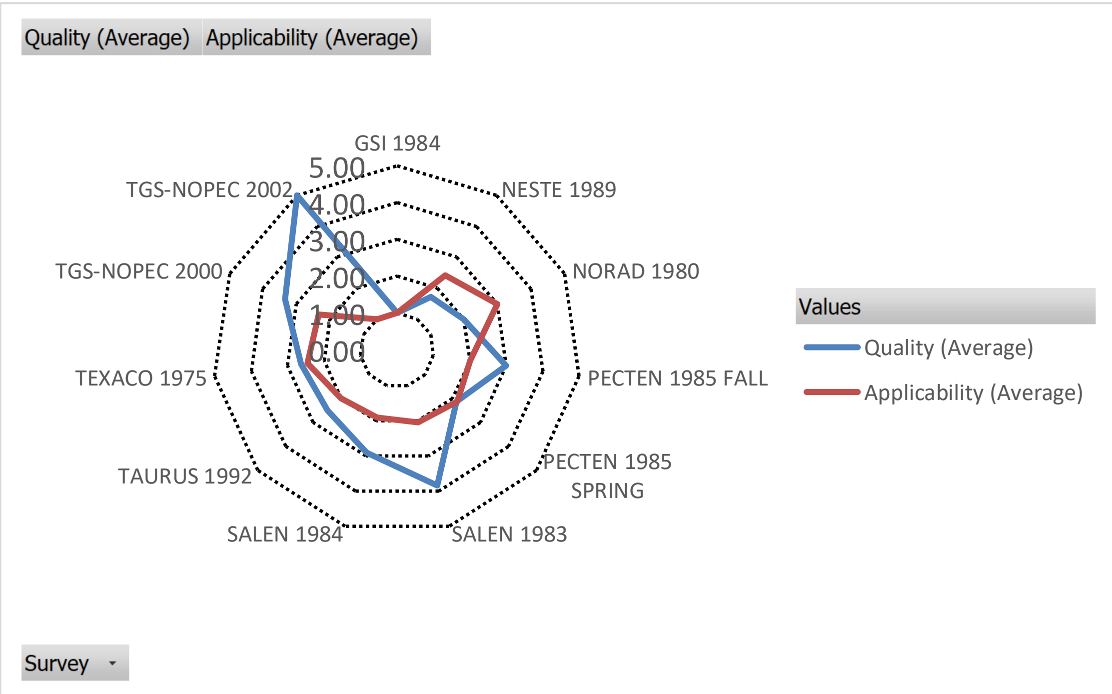


Figure 4.2 Results of the Oil and Gas seismic surveys evaluation.

5. CONCLUDING REMARKS

The continental shelf of the area of interest is a smooth surface dipping offshore covered by a package of unconsolidated sediments that can vary from 0 m to 44 m maximum thickness with a median value of 10 m to 14 m.

Sediment samples collected using grab collectors indicate grain sizes varying mainly from fine grained sand to gravel. Hard rock outcrops are indicated on the map of surficial sediments (Figure 2.4), which are consistent with seismic profiles.

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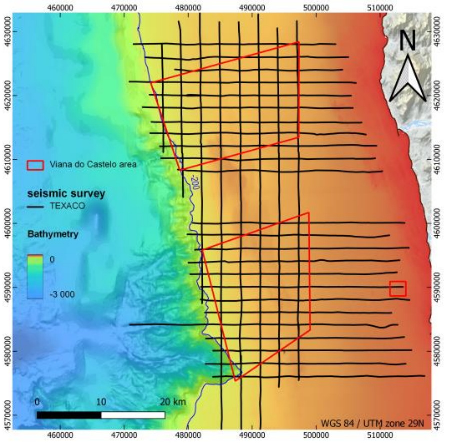
7. ANNEXES

7.1. Oil and gas surveys characterization files

<table>
<tr><td>Survey Name</td><td colspan="2">Seismic Survey Northern offshore Portugal</td><td colspan="2">Survey Dates</td><td colspan="2">15/07/1974 to 12/08/1974</td></tr>
<tr><td>Promotor</td><td colspan="2">Texaco Portugal Prospecção e Produção, SARL</td><td colspan="2">Contractor</td><td colspan="2">Seismic Explorations International.S.A.</td></tr>
<tr><td>Vessel</td><td colspan="2">M/V Seismic Surveyor</td><td colspan="2">Data Holder</td><td colspan="2">DGEG (Portugal)</td></tr>
<tr><td>Main Objectives</td><td colspan="6">Oil & Gas exploration</td></tr>
<tr><td>Positioning</td><td colspan="6">Shoran (Coastal Navigation)</td></tr>
<tr><td>Type of Data</td><td colspan="6">Processed seismic data in SEG-Y format</td></tr>
<tr><td colspan="7">Seismic data</td></tr>
<tr><td>Seismic Source</td><td colspan="6">Type: Airgun Array; Total Volume/Pressure/Energy: 1602cu.in./2000 psi.</td></tr>
<tr><td>Seismic Receiver</td><td colspan="6">Multidyne Digital Streamer, length: 2400m, groups spacing: 25m, number of channels: 96.</td></tr>
<tr><td>Sample Size (ms)</td><td>4</td><td>Trace Length (ms)</td><td>6000</td><td colspan="2">Shotpoint Interval (m)</td><td>200</td></tr>
<tr><td>Seismic Processing</td><td colspan="6">Deconvolution and gathered; Velocity determination; NMO correction; 48 CDP stack; Migration.</td></tr>
<tr><td>Observations</td><td colspan="6">Estimated line length in area of interest: 1200km</td></tr>
<tr><td colspan="7">Data Coverage in Area of Interest</td></tr>
<tr><td colspan="7">
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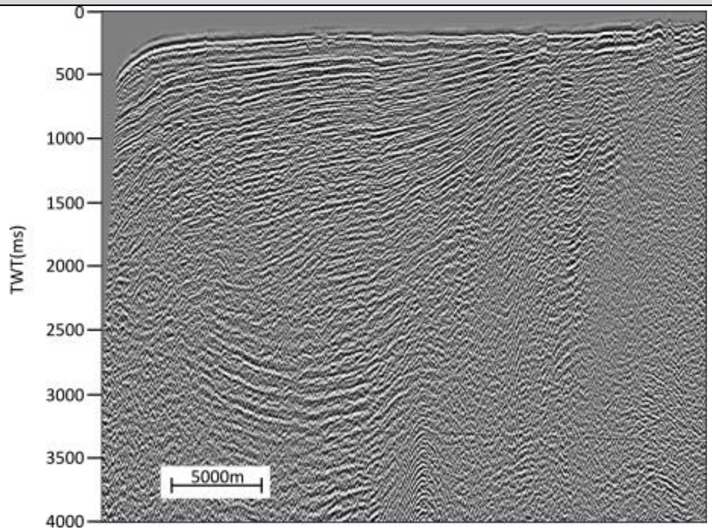
<tr><td colspan="7">
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<tr><td>Vessel</td><td colspan="2">NA</td><td colspan="2">Data Holder</td><td colspan="2">DGEG (Portugal)</td></tr>
<tr><td>Main Objectives</td><td colspan="6">Oil & Gas exploration</td></tr>
<tr><td>Positioning</td><td colspan="6">NA</td></tr>
<tr><td>Type of Data</td><td colspan="6">Processed seismic data in SEG-Y format</td></tr>
<tr><td colspan="7">Seismic data</td></tr>
<tr><td>Seismic Source</td><td colspan="6">Type: Airgun Array</td></tr>
<tr><td>Seismic Receiver</td><td colspan="6">PRAKLA HSSN; groups spacing: 50m, number of channels: 48.</td></tr>
<tr><td>Sample Size (ms)</td><td>4</td><td>Trace Length (ms)</td><td>6000</td><td colspan="2">Shotpoint Interval (m)</td><td>NA</td></tr>
<tr><td>Seismic Processing</td><td colspan="6">NMO correction; Deconvolution; Equalization; Migration.</td></tr>
<tr><td>Observations</td><td colspan="6">Estimated line length in area of interest: 20km</td></tr>
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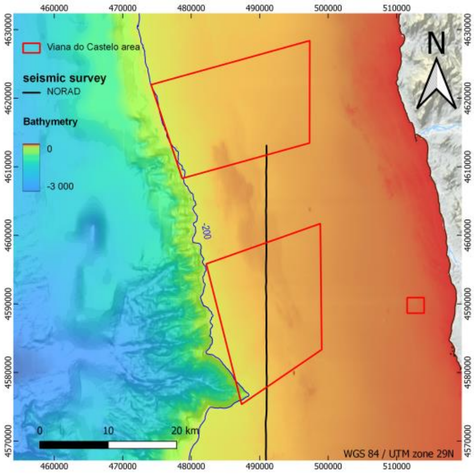
<tr><td colspan="7">
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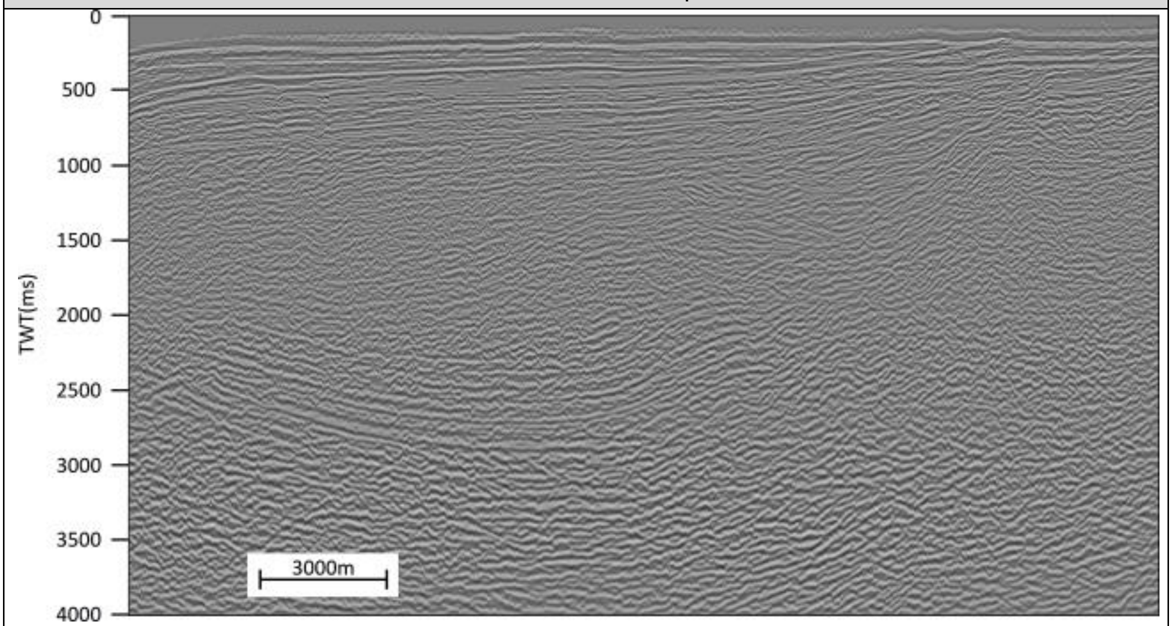
<tr><td colspan="7">
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<tr><td>Survey Name</td><td colspan="2">GSI Party No 293B</td><td colspan="2">Survey Dates</td><td colspan="2">11th November to 6th December 1984</td></tr>
<tr><td>Promotor</td><td colspan="2">Tullow/DPEP-DGGE</td><td colspan="2">Contractor</td><td colspan="2">Geophysical Services International</td></tr>
<tr><td>Vessel</td><td colspan="2">M/v P.E.Haggerty</td><td colspan="2">Data Holder</td><td colspan="2">DGEG (Portugal)</td></tr>
<tr><td>Main Objectives</td><td colspan="6">Oil & Gas exploration</td></tr>
<tr><td>Positioning</td><td colspan="6">SYLEDIS & GEONAV</td></tr>
<tr><td>Type of Data</td><td colspan="6">Processed seismic data in SEG-Y format</td></tr>
<tr><td colspan="7">Seismic data</td></tr>
<tr><td>Seismic Source</td><td colspan="6">Type; Airgun array, Total Volume/Pressure/Energy: 2775cu.in./1800-2000 psi.</td></tr>
<tr><td>Seismic Receiver</td><td colspan="6">Texas Instrument Neutral Buoyancy, length: 3039m, groups spacing: 25m, number of channels: 120.</td></tr>
<tr><td>Sample Size (ms)</td><td>2</td><td>Trace Length (ms)</td><td>6000</td><td colspan="2">Shotpoint Interval (m)</td><td>25</td></tr>
<tr><td>Seismic Processing</td><td colspan="6">Velocity analysis; NMO correction; CDP stack; Deconvolution; FK Migration.</td></tr>
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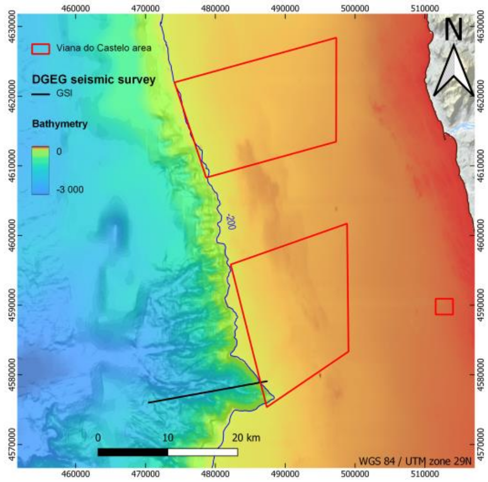
<tr><td colspan="7">
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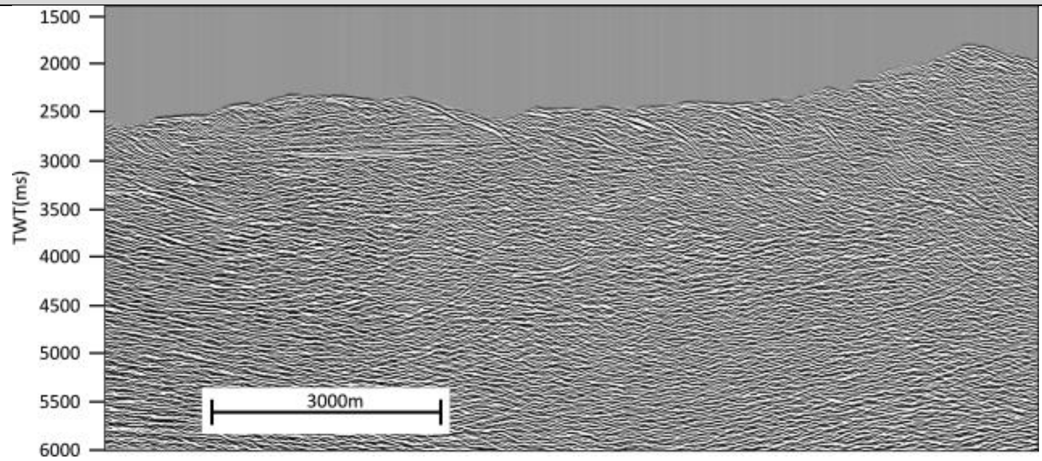
<tr><td colspan="7">
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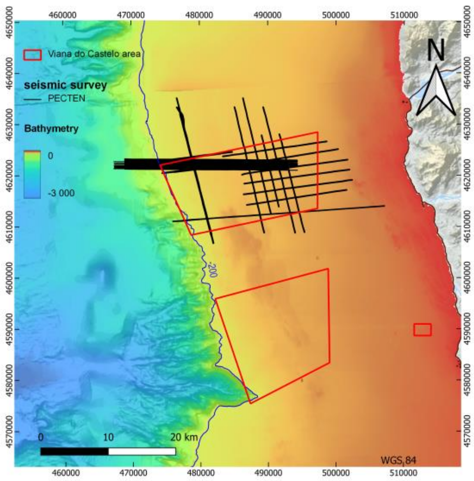
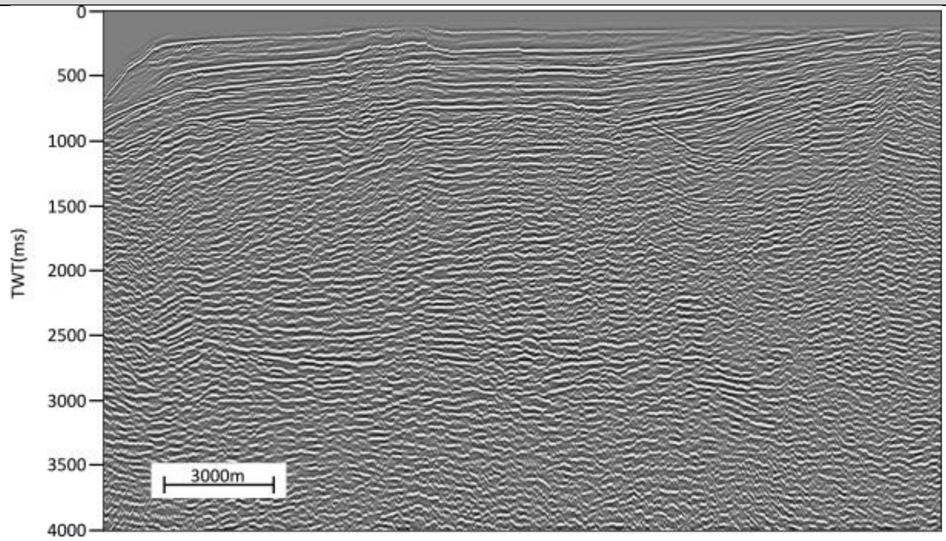
Survey Name	Offshore Portugal 1985		Survey Dates	24/04/1985 to 18/04/1985	
Promotor	Pecten Portugal Company.		Contractor	PRAKLA-SEISMOS	
Vessel	SV EXPLORA		Data Holder	DGEG (Portugal)	
Main Objectives	Oil & Gas exploration				
Positioning	Integrated navigation and data acquisition system: Syledis B				
Type of Data	Processed seismic data in SEG-Y format				
Seismic data					
Seismic Source	Type: B 071/75-array; Airgun, Model: Western Air Guns, Total Volume/Pressure/Energy: 1270cu.in./4500 psi.				
Seismic Receiver	SN 358 DMX Digital Streamer, length: 3000m, groups spacing: 25m, number of channels: 120.				
Sample Size (ms)	2	Trace Length (ms)	6000	Shotpoint Interval (m)	25
Seismic Processing	Spherical divergence correction; Deconvolution; velocity analysis; Migration.				
Observations	Estimated line length in area of interest: 1000km				
Data Coverage in Area of Interest					



Seismic Data Example



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<tr><td>Vessel</td><td colspan="2">M.V. Pacific Horizon</td><td colspan="2">Data Holder</td><td colspan="2">DGEG (Portugal)</td></tr>
<tr><td>Main Objectives</td><td colspan="6">Oil & Gas exploration</td></tr>
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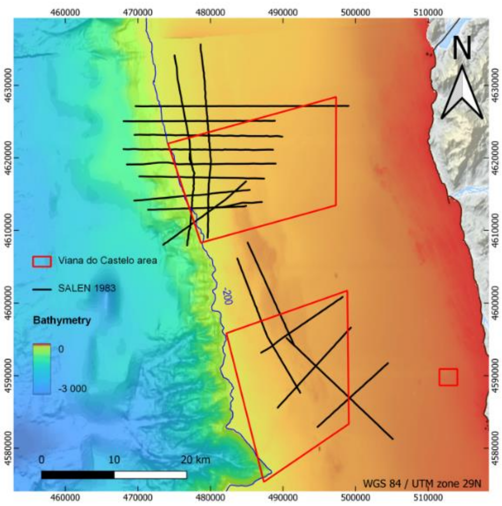
<tr><td>Seismic Receiver</td><td colspan="6">Liton Rawhide Streamer, length: 2400m, groups spacing: 25m, number of channels: 96.</td></tr>
<tr><td>Sample Size (ms)</td><td>2</td><td>Trace Length (ms)</td><td>6000</td><td colspan="2">Shotpoint Interval (m)</td><td>25</td></tr>
<tr><td>Seismic Processing</td><td colspan="6">Signature Deconvolution; NMO correction; 32 fold stack; Deconvolution; Migration.</td></tr>
<tr><td>Observations</td><td colspan="6">Estimated line length in area of interest:170km</td></tr>
<tr><td colspan="7">Data Coverage in Area of Interest</td></tr>
<tr><td colspan="7">
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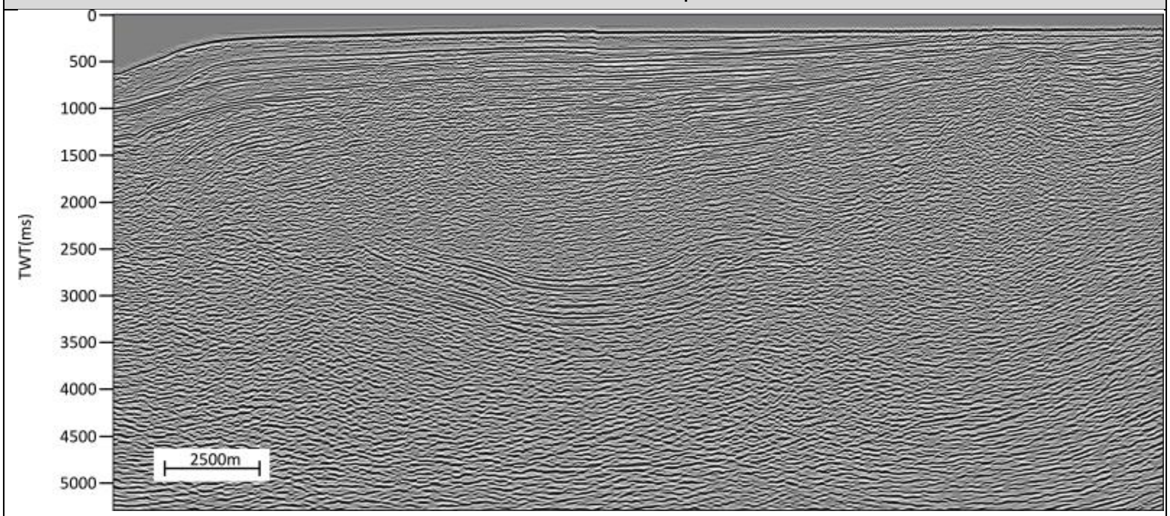
<tr><td colspan="7">Seismic Data Example</td></tr>
<tr><td colspan="7">
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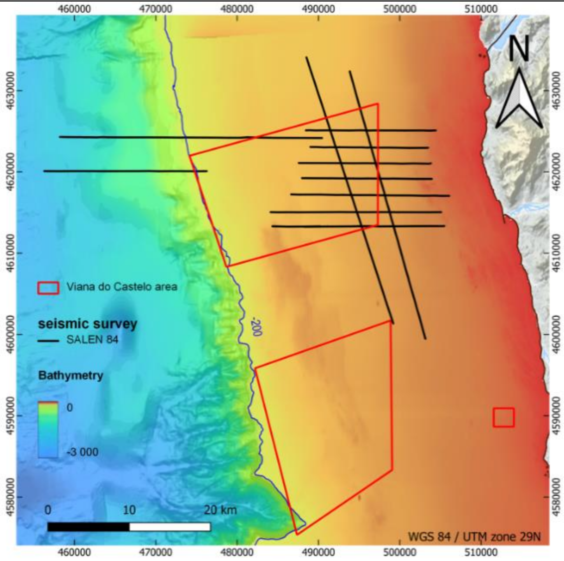
<tr><td>Survey Name</td><td colspan="2">SALEN 1984</td><td colspan="2">Survey Dates</td><td colspan="2">20/09/1984 to 02/10/1984</td></tr>
<tr><td>Promotor</td><td colspan="2">Salen Energy A/S</td><td colspan="2">Contractor</td><td colspan="2">C.G.G.</td></tr>
<tr><td>Vessel</td><td colspan="2">M.V. Lucien Beaufort</td><td colspan="2">Data Holder</td><td colspan="2">DGEG (Portugal)</td></tr>
<tr><td>Main Objectives</td><td colspan="6">Oil & Gas exploration</td></tr>
<tr><td>Positioning</td><td colspan="6">Syledis SR3</td></tr>
<tr><td>Type of Data</td><td colspan="6">Processed seismic data in SEG-Y format</td></tr>
<tr><td colspan="7">Seismic data</td></tr>
<tr><td>Seismic Source</td><td colspan="6">Type: 3 array configuration, Model: Starjet Vaporchoc 3, Total Volume/Pressure/Energy: 16500cu.in./60 bar.</td></tr>
<tr><td>Seismic Receiver</td><td colspan="6">AMS 45-51 Streamer, length: 3000m, groups spacing: 25m, number of channels: 120.</td></tr>
<tr><td>Sample Size (ms)</td><td>2</td><td>Trace Length (ms)</td><td>6000</td><td colspan="2">Shotpoint Interval (m)</td><td>25</td></tr>
<tr><td>Seismic Processing</td><td colspan="6">Designature; Velocity analysis; NMO correction; 6000% stack; Predictive Deconvolution; Wave Equation Migration.</td></tr>
<tr><td>Observations</td><td colspan="6">Estimated line length in area of interest:100km</td></tr>
<tr><td colspan="7">Data Coverage in Area of Interest</td></tr>
<tr><td colspan="7">
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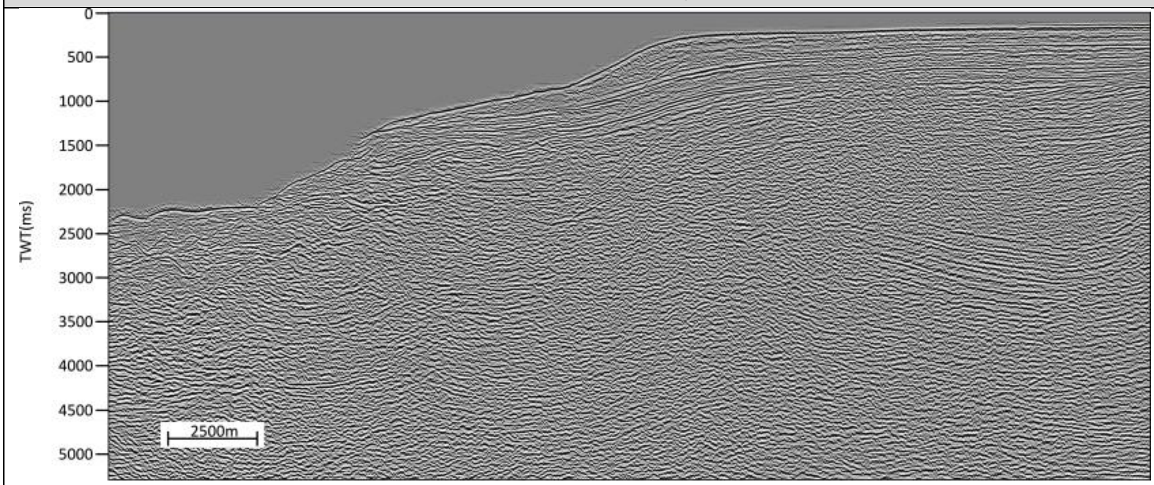
<tr><td colspan="7">Seismic Data Example</td></tr>
<tr><td colspan="7">
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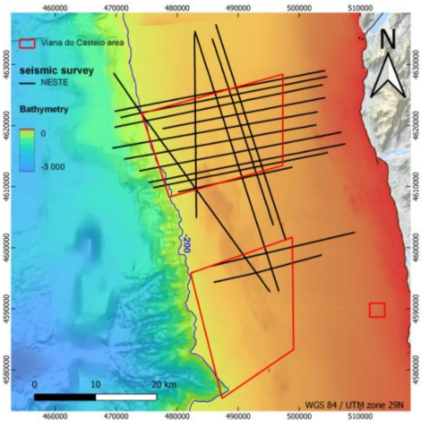
<tr><td>Promotor</td><td colspan="3">NESTE PETROLEO (PORTUGAL) SA</td><td colspan="2">Contractor</td><td colspan="2">DIGICON Geophysical corp.</td></tr>
<tr><td>Vessel</td><td colspan="3">M/V Arcadian Commaander</td><td colspan="2">Data Holder</td><td colspan="2">DGEG (Portugal)</td></tr>
<tr><td>Main Objectives</td><td colspan="7">Oil & Gas exploration</td></tr>
<tr><td>Positioning</td><td colspan="7">Primary System:Syledis; Secondary System: GPS Satellite</td></tr>
<tr><td>Type of Data</td><td colspan="7">Processed seismic data in SEG-Y format</td></tr>
<tr><td colspan="8">Seismic data</td></tr>
<tr><td>Seismic Source</td><td colspan="7">Type: Airgun, Model: Tuned Bolt array, Total Volume/Pressure/Energy: 3460cu.in./2000 psi.</td></tr>
<tr><td>Seismic Receiver</td><td colspan="7">Digicon DSS-240 Digital Streamer, length: 3000m, groups spacing: 12.5m, number of channels: 240.</td></tr>
<tr><td>Sample Size (ms)</td><td>2</td><td>Trace Length (ms)</td><td>6000</td><td colspan="3">Shotpoint Interval (m)</td><td>25</td></tr>
<tr><td>Seismic Processing</td><td colspan="7">Spherical divergence compensation; Deconvolution; Trace equalisation; NMO correction; Migration; Noise attenuation filter</td></tr>
<tr><td>Observations</td><td colspan="7">Estimated line length in area of interest: 280km</td></tr>
<tr><td colspan="8">Data Coverage in Area of Interest</td></tr>
<tr><td colspan="8">
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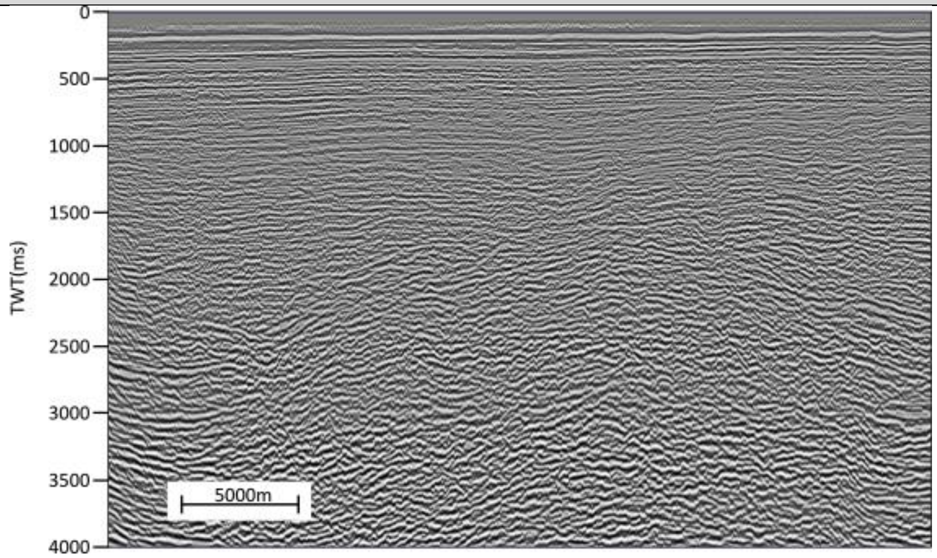
<tr><td colspan="8">Seismic Data Example</td></tr>
<tr><td colspan="8">
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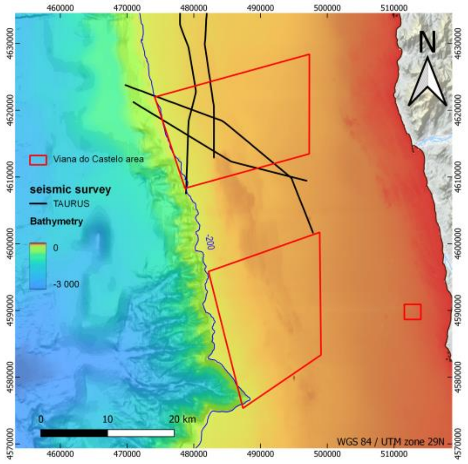
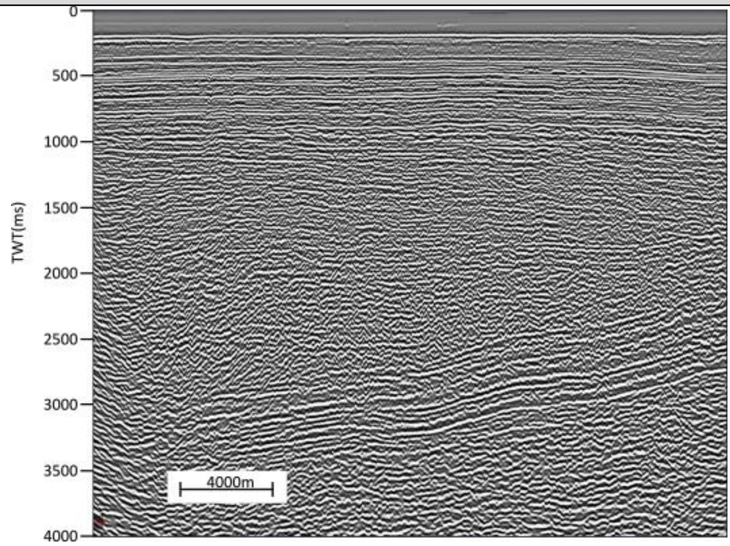
<tr><td>Survey Name</td><td colspan="2">Galicia Basin 92</td><td colspan="2">Survey Dates</td><td colspan="2">1st to 10th October 1992</td></tr>
<tr><td>Promotor</td><td colspan="2">Taurus Petroleum AB</td><td colspan="2">Contractor</td><td colspan="2">Digicon Geophysical</td></tr>
<tr><td>Vessel</td><td colspan="2">M/V Acadian Commander</td><td colspan="2">Data Holder</td><td colspan="2">DGEG (Portugal)</td></tr>
<tr><td>Main Objectives</td><td colspan="6">Oil & Gas exploration</td></tr>
<tr><td>Positioning</td><td colspan="6">Maxirand (429 MHz)</td></tr>
<tr><td>Type of Data</td><td colspan="6">Processed seismic data in SEG-Y format</td></tr>
<tr><td colspan="7">Seismic data</td></tr>
<tr><td>Seismic Source</td><td colspan="6">Type: Compact 1 Areal' Airgun Array; Airgun, Model: Bolt/Digicon, Total Volume/Pressure/Energy: 4640cu.in./2000 psi.</td></tr>
<tr><td>Seismic Receiver</td><td colspan="6">DIGICON DSS-240 Digital Streamer, length: 3000m, groups spacing: 12.5m, number of channels: 240.</td></tr>
<tr><td>Sample Size (ms)</td><td>2</td><td>Trace Length (ms)</td><td>6000</td><td colspan="2">Shotpoint Interval (m)</td><td>25</td></tr>
<tr><td>Seismic Processing</td><td colspan="6">Deconvolution before stack; Multiple attenuation; KIRCHOFF DMO; NMO correction; 30 fold stack; Deconvolution after stack; OMEGA-X Migration.</td></tr>
<tr><td>Observations</td><td colspan="6">Estimated line length in area of interest: 60km</td></tr>
<tr><td colspan="7">Data Coverage in Area of Interest</td></tr>
<tr><td colspan="7"></td></tr>
<tr><td colspan="7">Seismic Data Example</td></tr>
<tr><td colspan="7"></td></tr>
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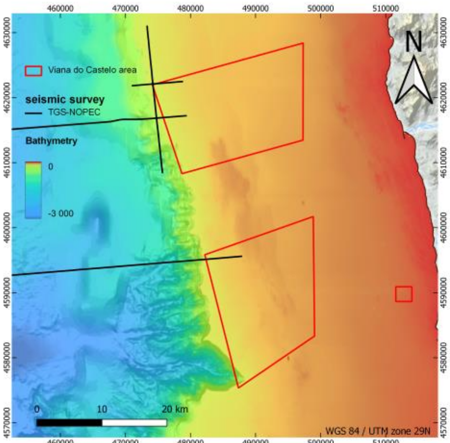
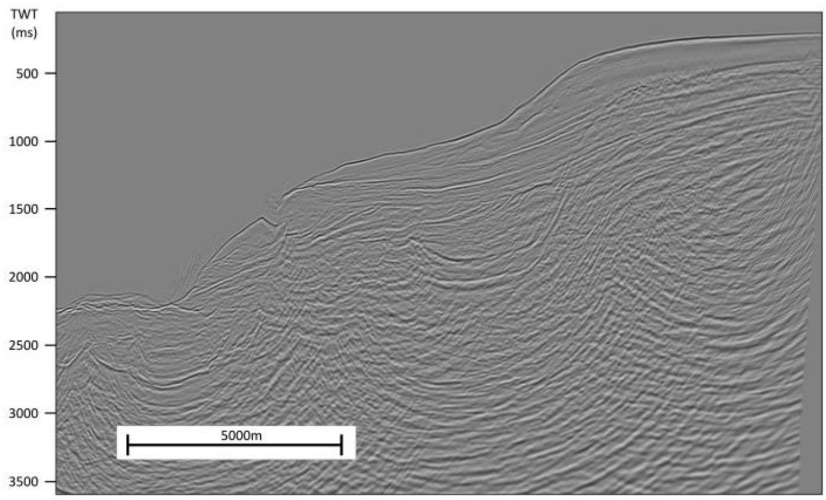
<tr><td>Survey Name</td><td colspan="2">Portugal Deep 2000</td><td colspan="2">Survey Dates</td><td colspan="2">Dec.1999 to Mar. 2002</td></tr>
<tr><td>Promotor</td><td colspan="2">TGS-NOPEC Geophysical Company</td><td colspan="2">Contractor</td><td colspan="2">Dalmorneftegophysica (DMNG)</td></tr>
<tr><td>Vessel</td><td colspan="2">M/V Zephyr</td><td colspan="2">Data Holder</td><td colspan="2">DGEG (Portugal)</td></tr>
<tr><td>Main Objectives</td><td colspan="6">Oil & Gas exploration</td></tr>
<tr><td>Positioning</td><td colspan="6">Starfix multi differential GPS operated by Fugro Survey</td></tr>
<tr><td>Type of Data</td><td colspan="6">Processed seismic data in SEG-Y format</td></tr>
<tr><td colspan="7">Seismic data</td></tr>
<tr><td>Seismic Source</td><td colspan="6">Type: Airgun, Model: Tuned Bolt array, Total Volume/Pressure/Energy: 2800cu.in./2000 psi.</td></tr>
<tr><td>Seismic Receiver</td><td colspan="6">Streamer type: SYNTRAK RDA, length: 6000m, groups spacing: 12.5m, number of channels: 480.</td></tr>
<tr><td>Sample Size (ms)</td><td>2</td><td>Trace Length (ms)</td><td>6000</td><td colspan="2">Shotpoint Interval (m)</td><td>37.5</td></tr>
<tr><td>Seismic Processing</td><td colspan="6">Minimum phase conversion; NMO correction; Velocity analysis; CMP stack; Deconvolution; Kirchhoff time migration.</td></tr>
<tr><td>Observations</td><td colspan="6">Estimated line length in area of interest: 12.5km</td></tr>
<tr><td colspan="7">Data Coverage in Area of Interest</td></tr>
</table>

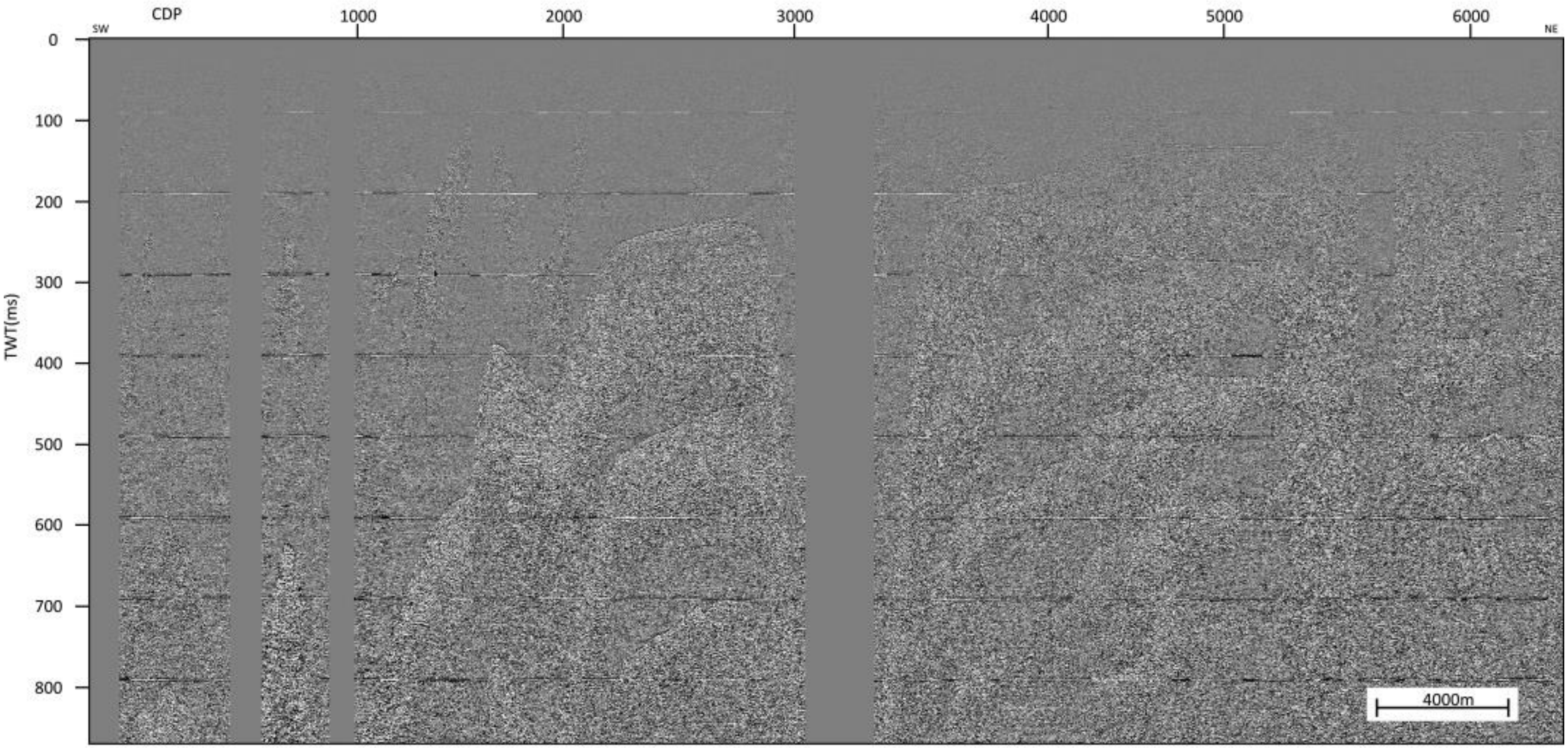


Seismic Data Example

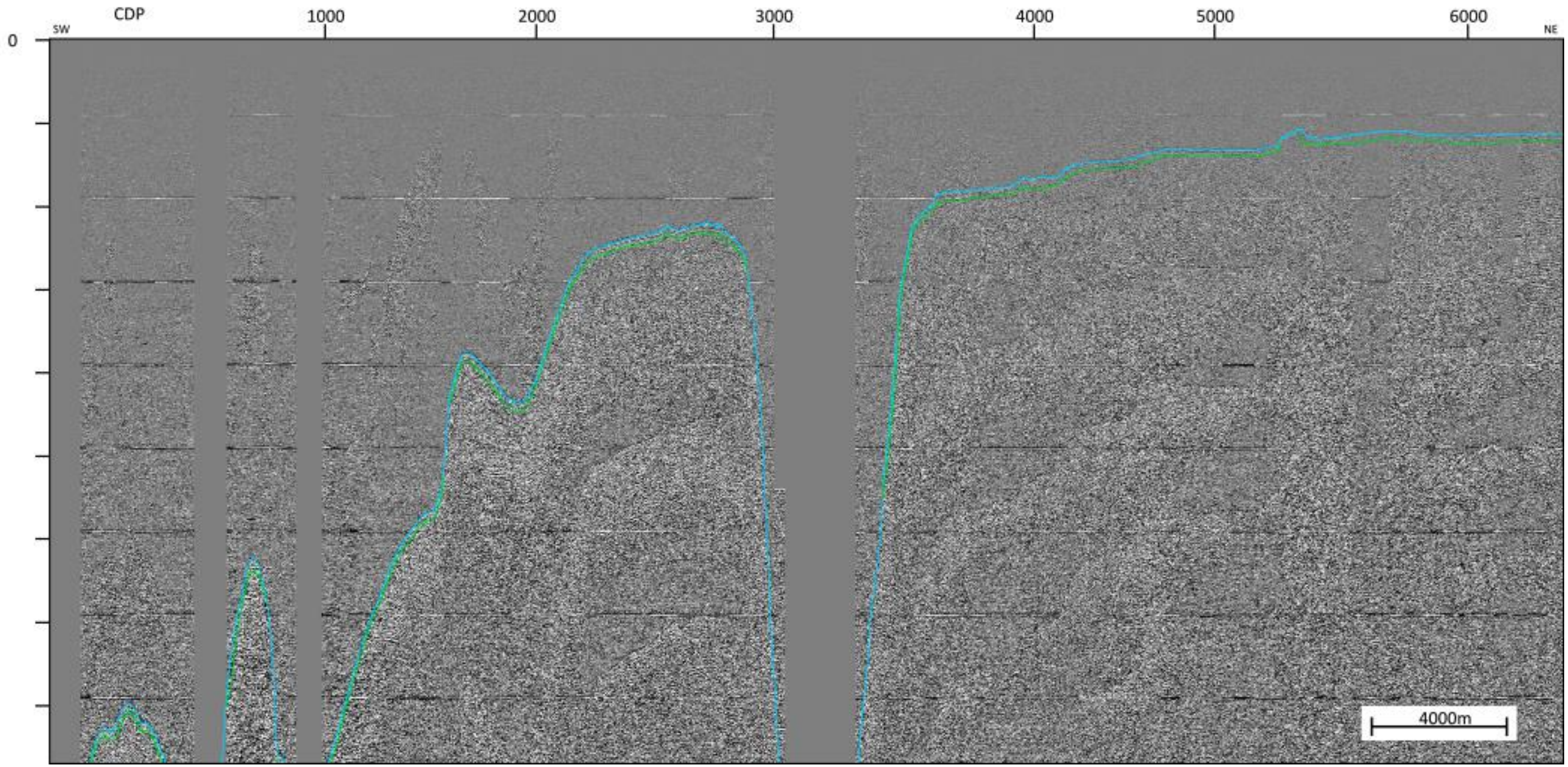


7.2. Examples of ‘vintage’ seismic sections

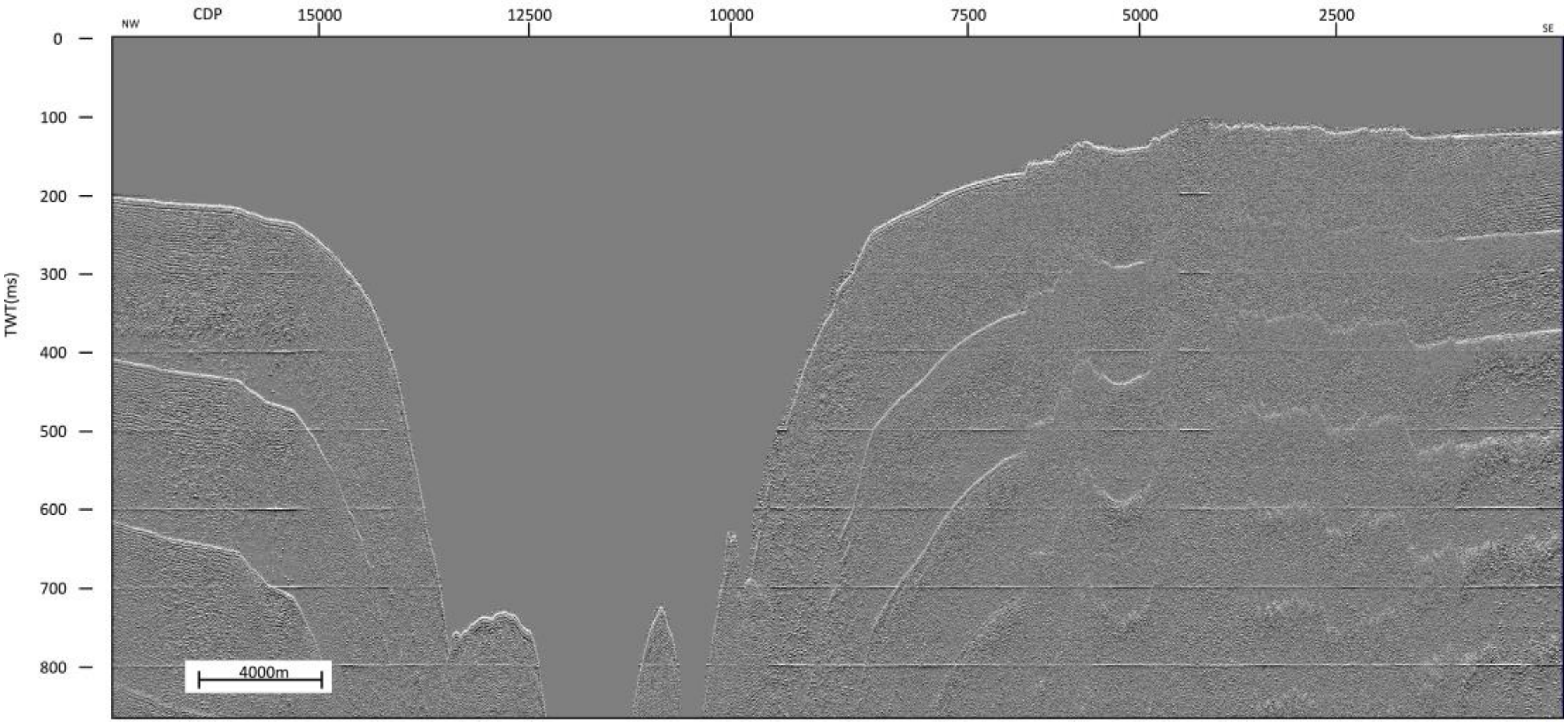
MD00785


CDP
SW
NE
1000
2000
3000
4000
5000
6000
TWT(ms)
0
100
200
300
400
500
600
700
800
4000m

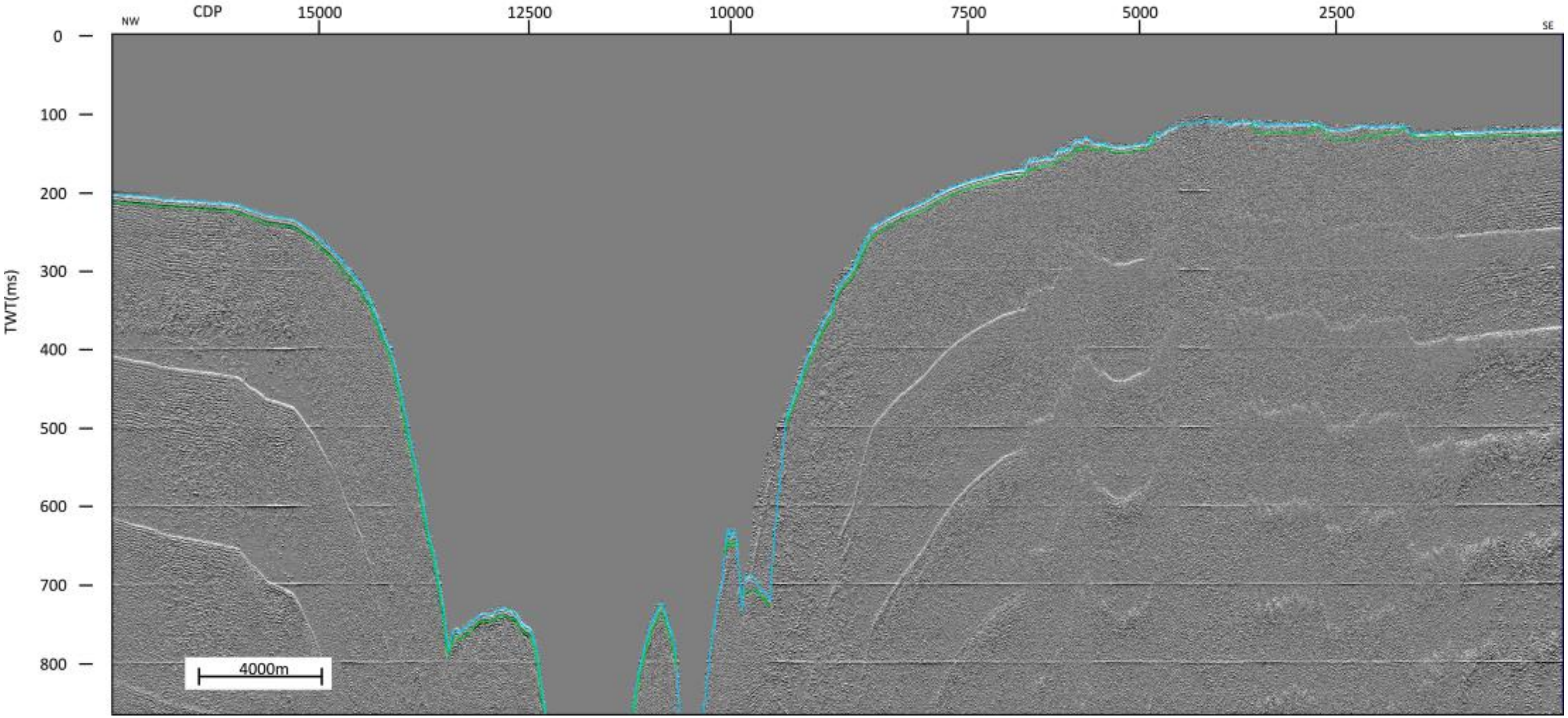
MD00785



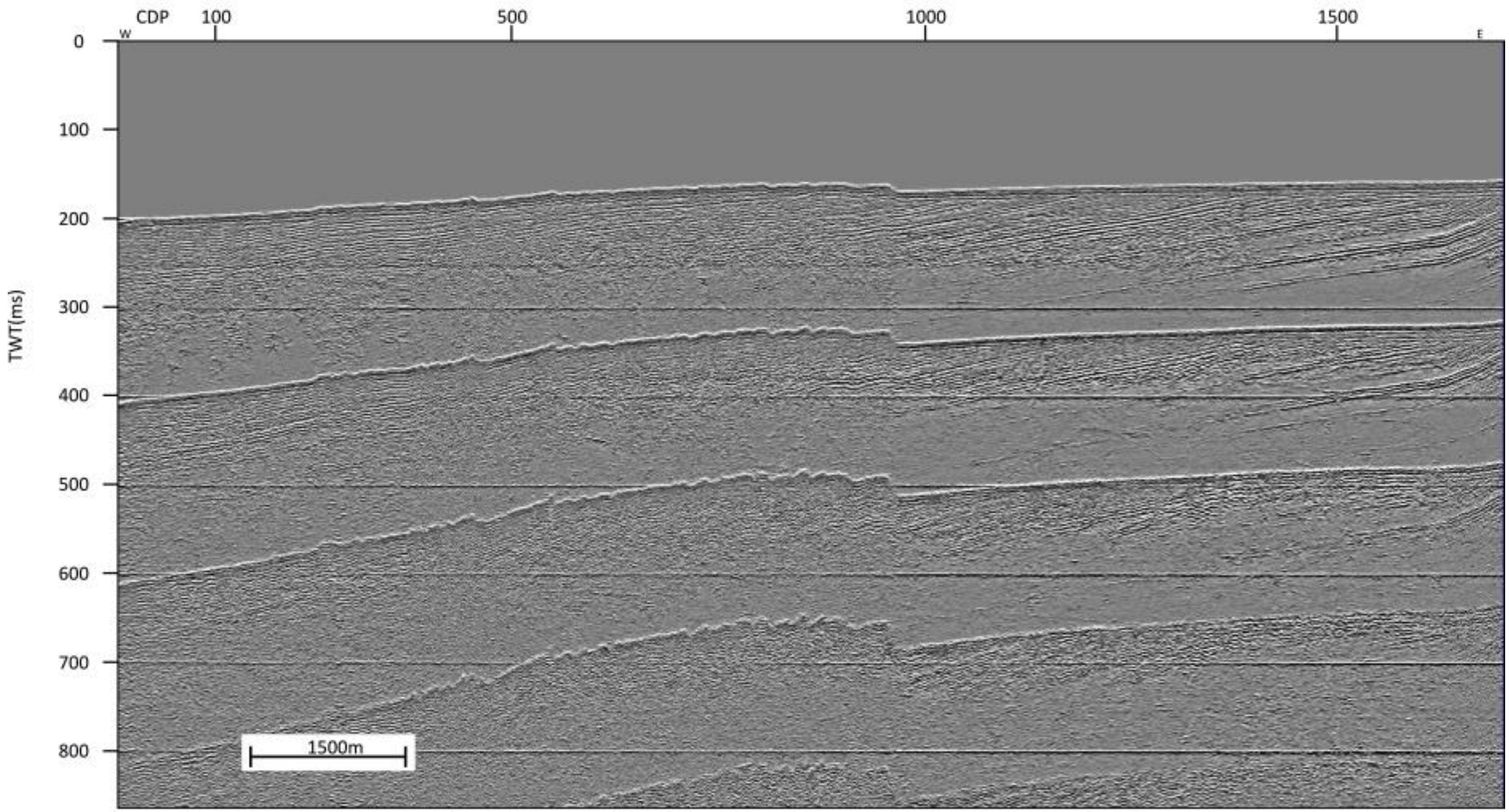
MD00885


CDP
15000
12500
10000
7500
5000
2500
NW
SE
0
100
200
300
400
500
600
700
800
TWT(ms)
4000m

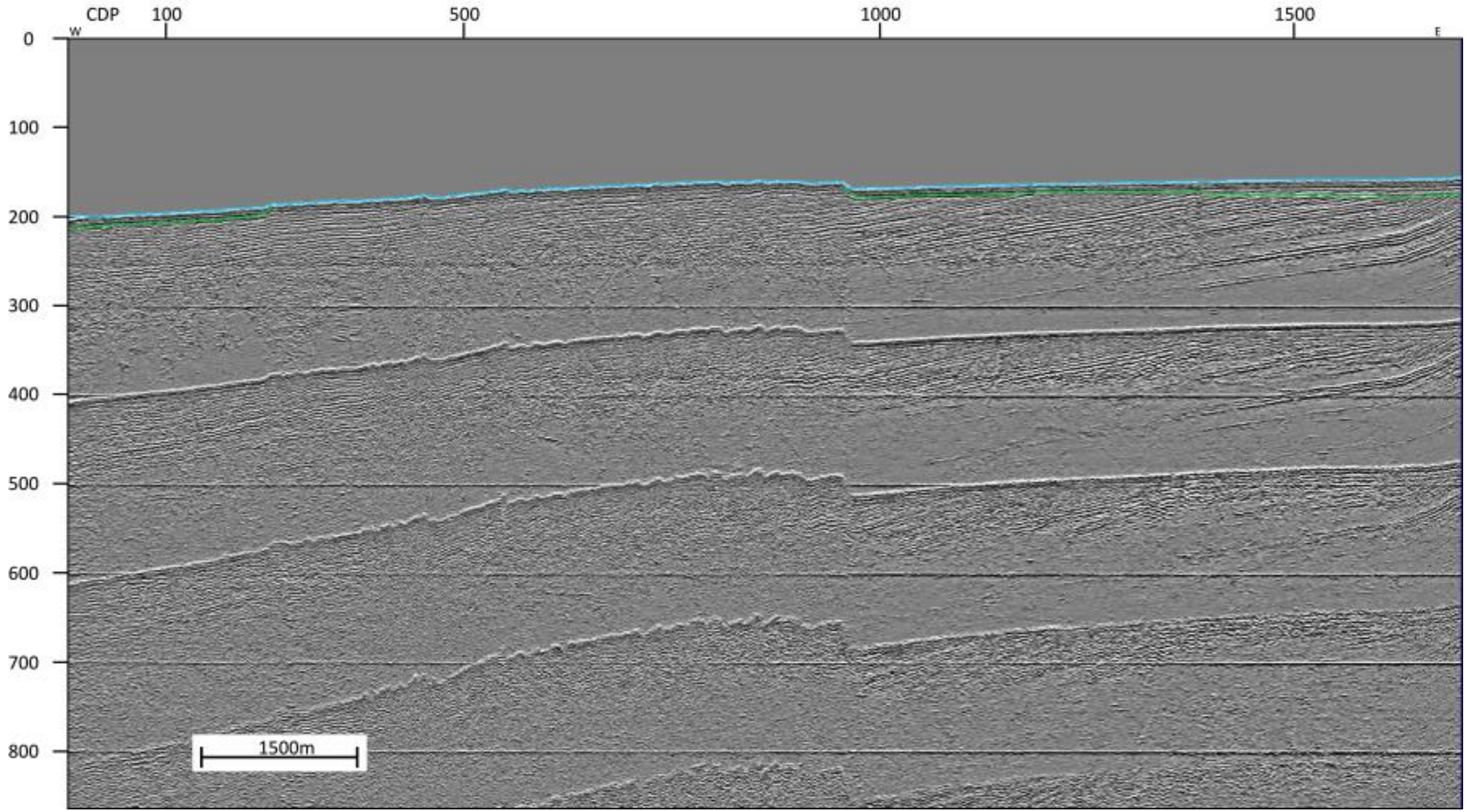
MD00885


NW
CDP
15000
12500
10000
7500
5000
2500
SE
0
100
200
300
400
500
600
700
800
TWT(ms)
4000m

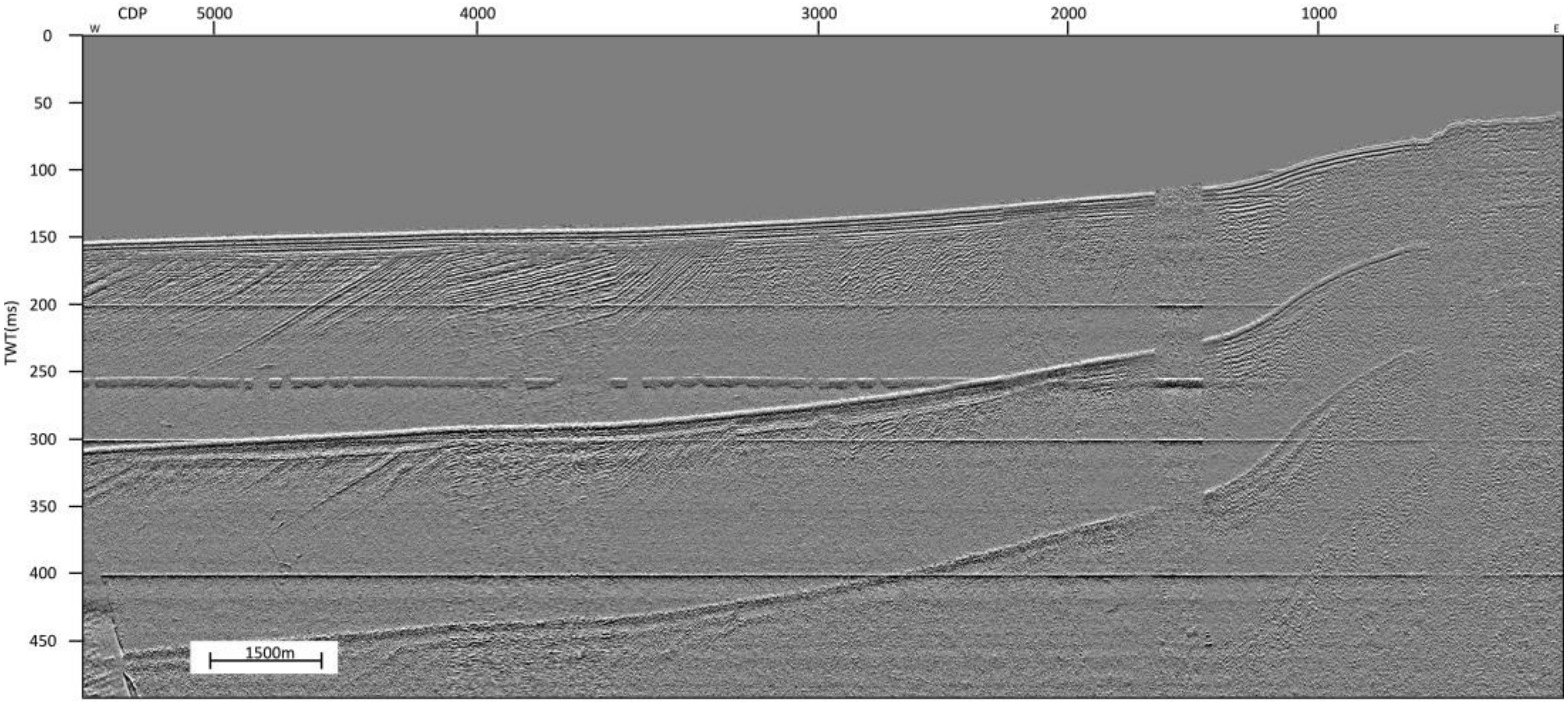
MD00985


CDP
100
500
1000
1500
W
E
0
100
200
300
400
500
600
700
800
TWT(ms)
1500m

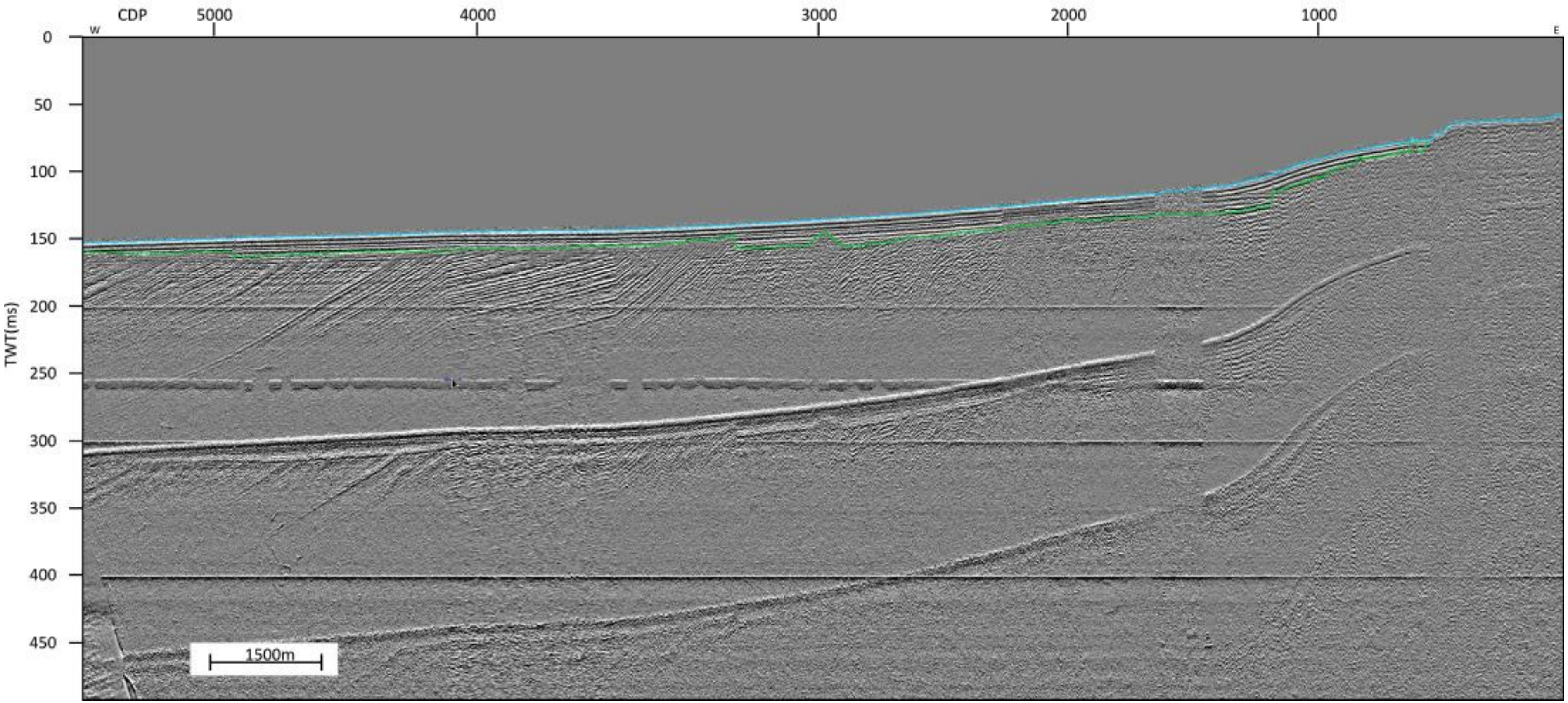
MD00985



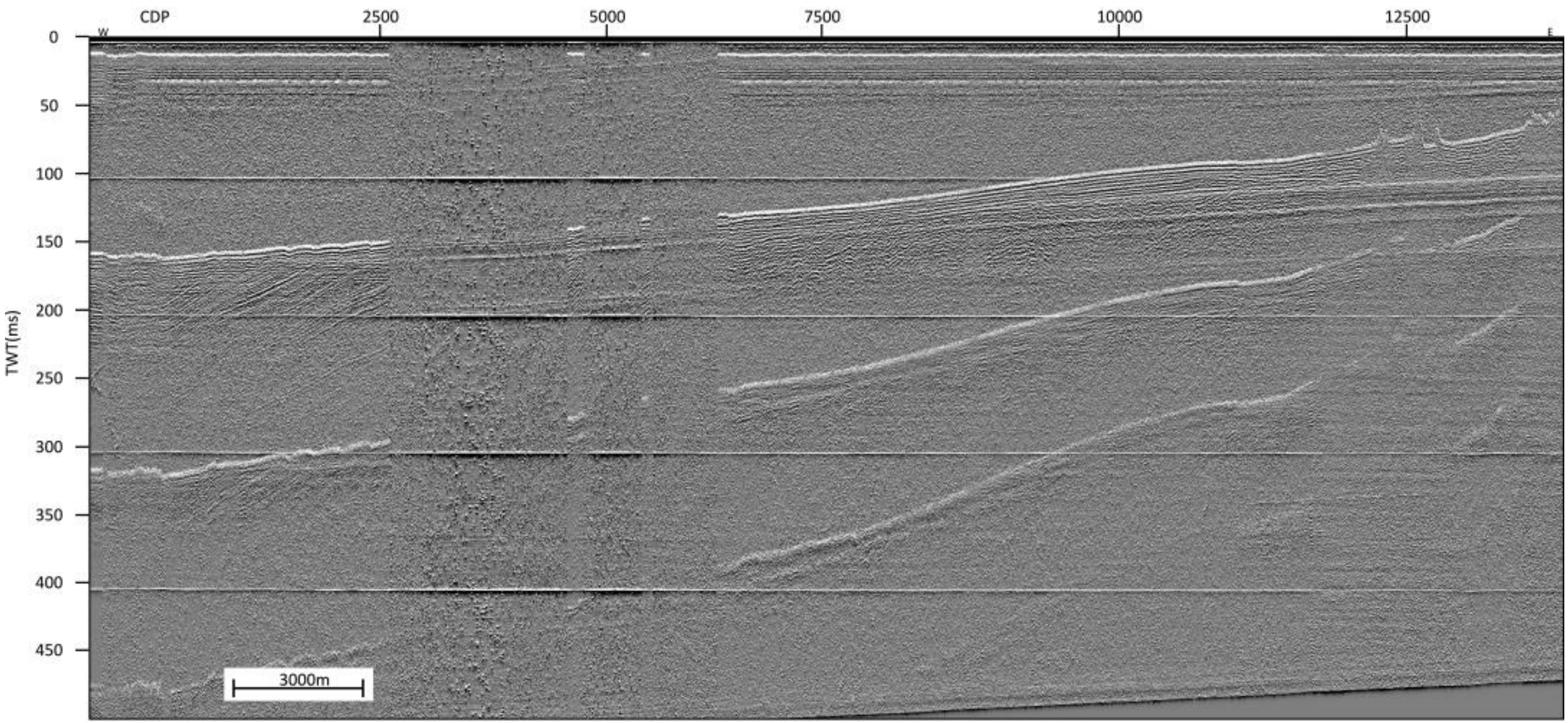
MD001285


CDP
5000
4000
3000
2000
1000
W
E
0
50
100
150
200
250
300
350
400
450
TWT(ms)
1500m

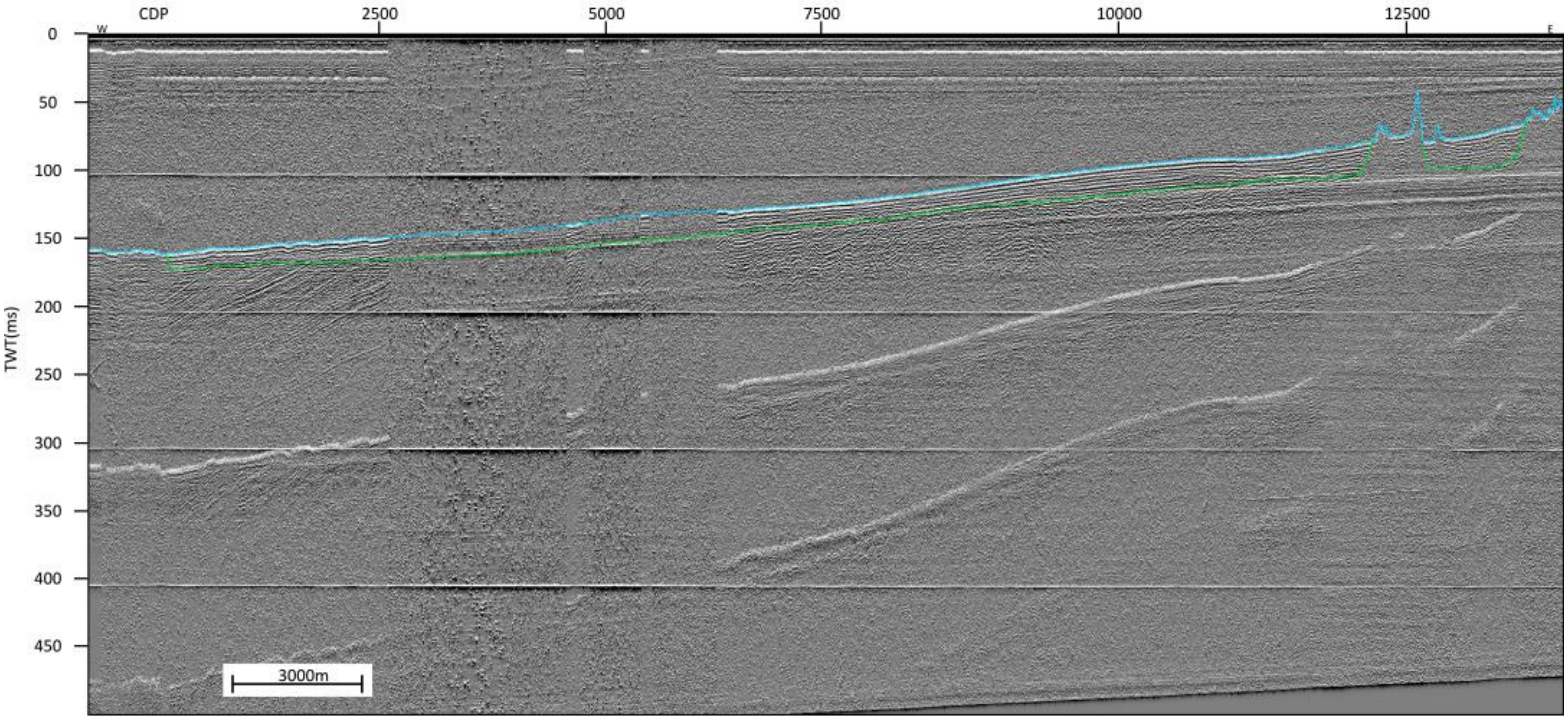
MD001285


CDP
5000
4000
3000
2000
1000
W
E
0
50
100
150
200
250
300
350
400
450
TWT(ms)
1500m

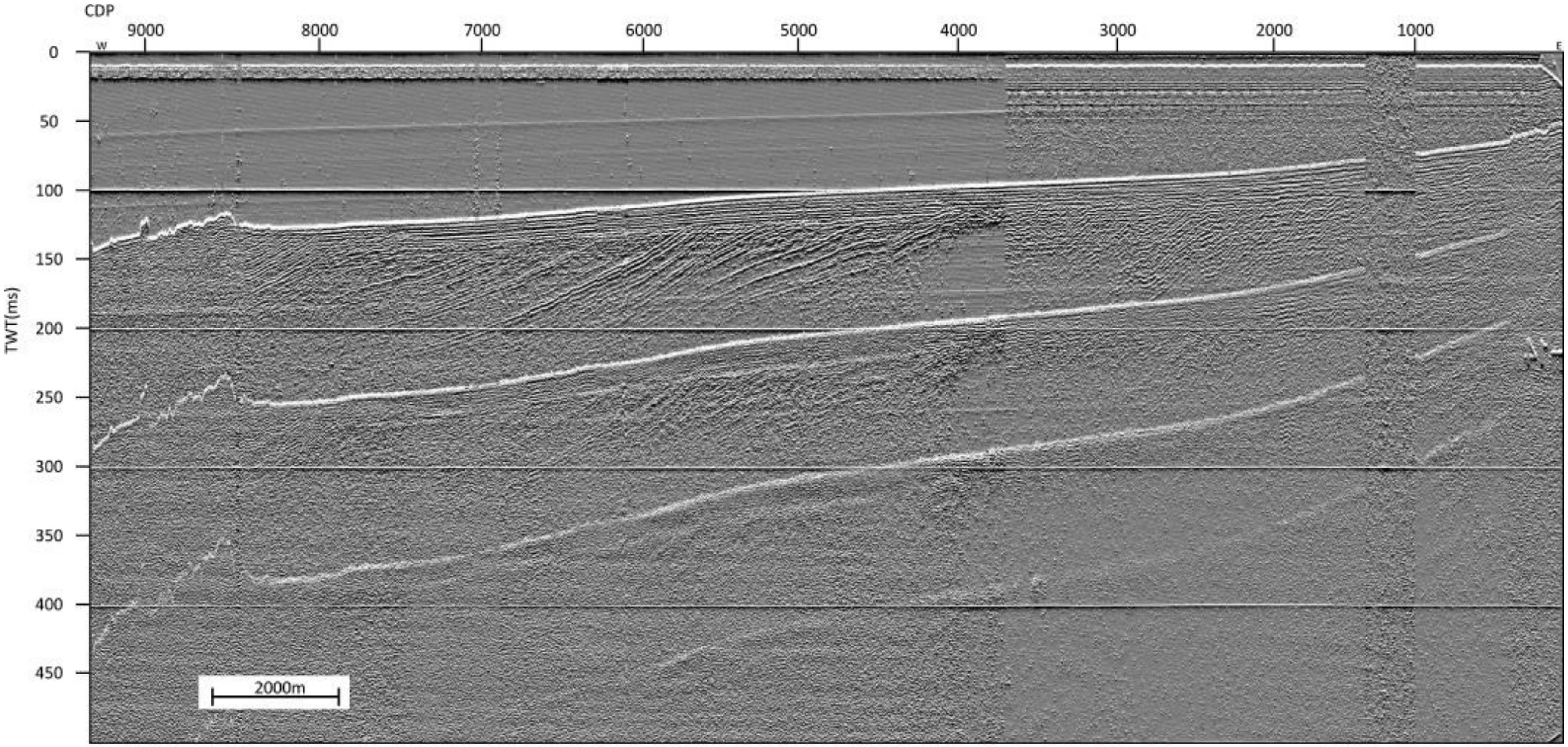
MD001385


CDP
2500
5000
7500
10000
12500
W
E
0
50
100
150
200
250
300
350
400
450
TWT(ms)
3000m

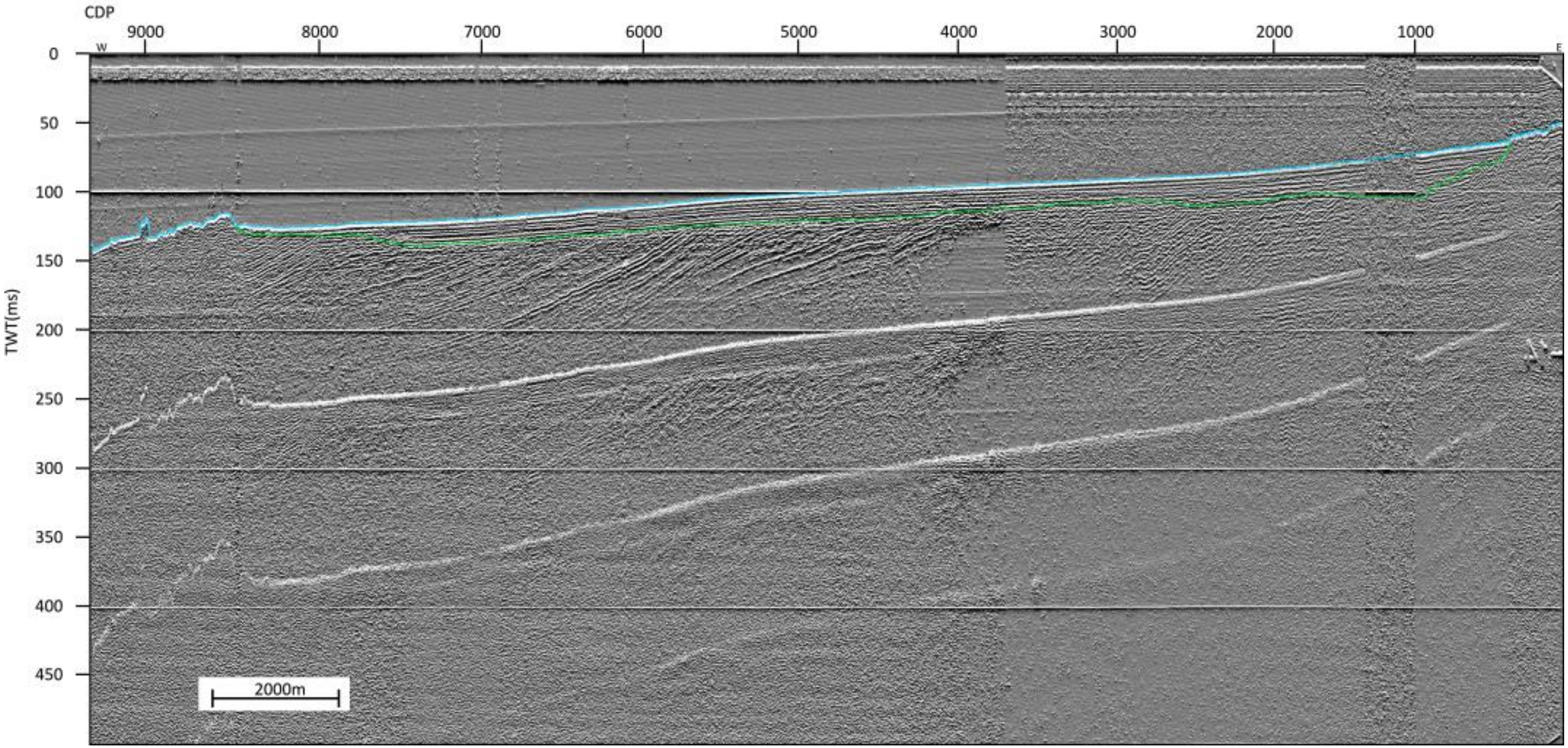
MD001385


CDP
2500
5000
7500
10000
12500
W
E
0
50
100
150
200
250
300
350
400
450
TWT(ms)
3000m

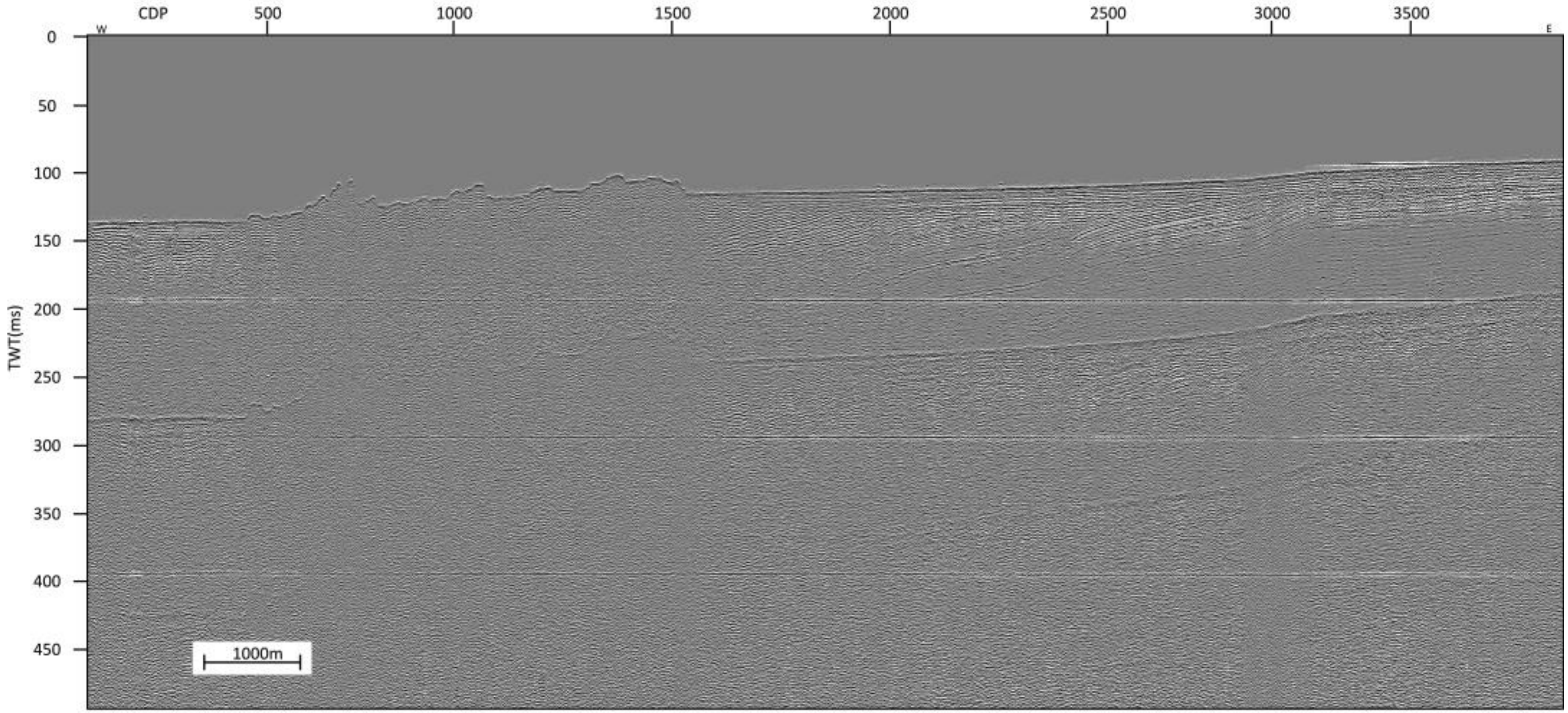
MD001485


CDP
9000
8000
7000
6000
5000
4000
3000
2000
1000
W
E
TWT(ms)
0
50
100
150
200
250
300
350
400
450
2000m

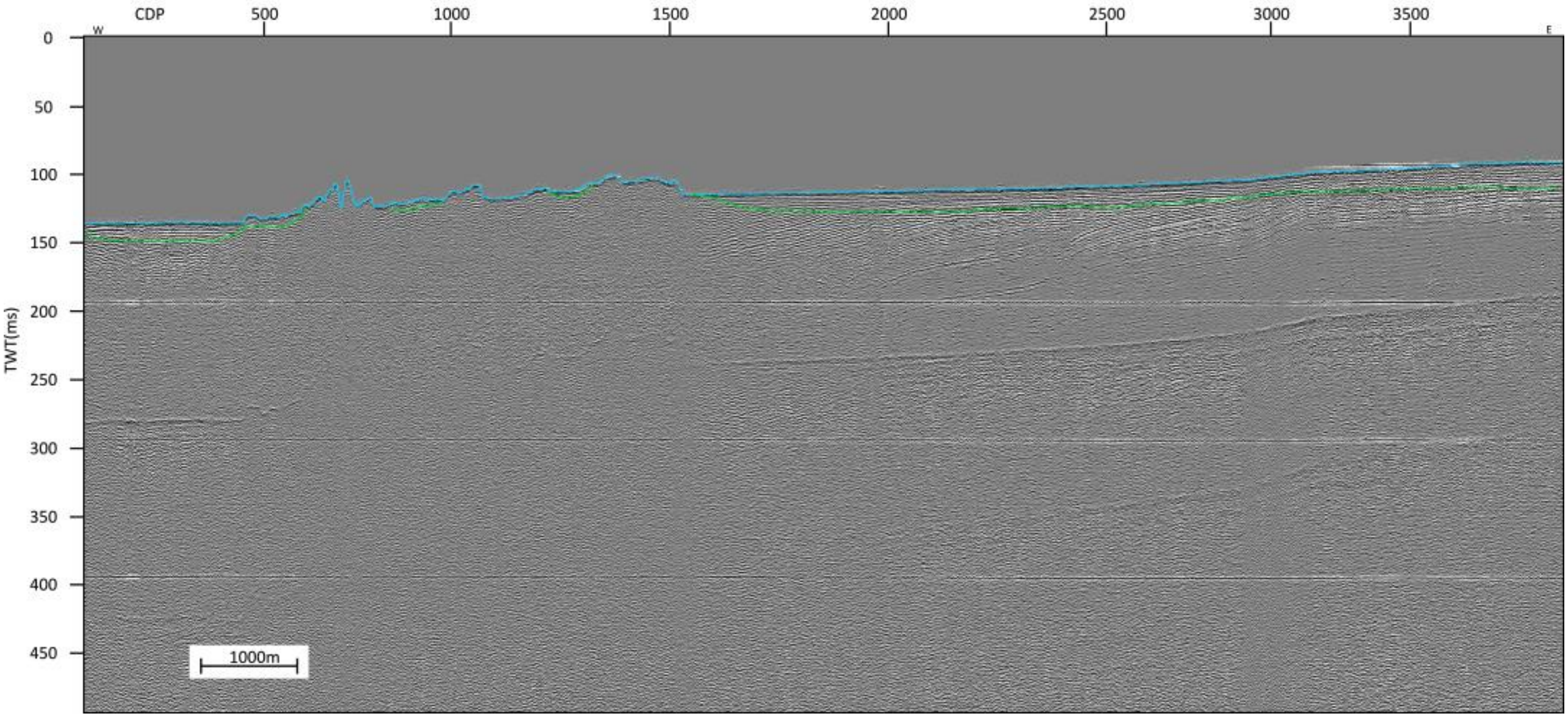
MD001485


CDP
9000
8000
7000
6000
5000
4000
3000
2000
1000
W
E
0
50
100
150
200
250
300
350
400
450
TWT(ms)
2000m

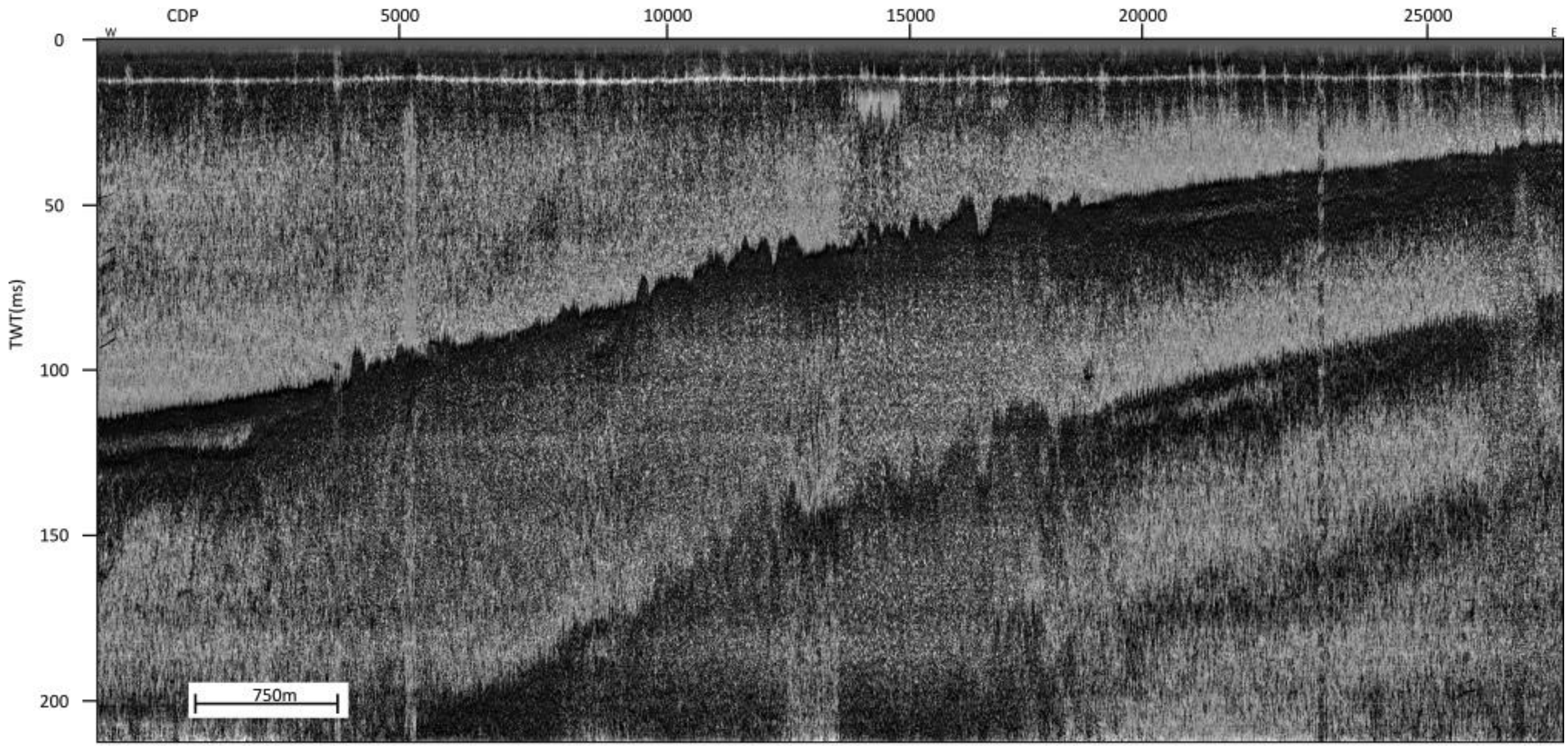
MD001585


CDP
500
1000
1500
2000
2500
3000
3500
W
E
0
50
100
150
200
250
300
350
400
450
TWT(ms)
1000m

MD001585


CDP
500
1000
1500
2000
2500
3000
3500
W
E
0
50
100
150
200
250
300
350
400
450
TWT(ms)
1000m

VB00175-1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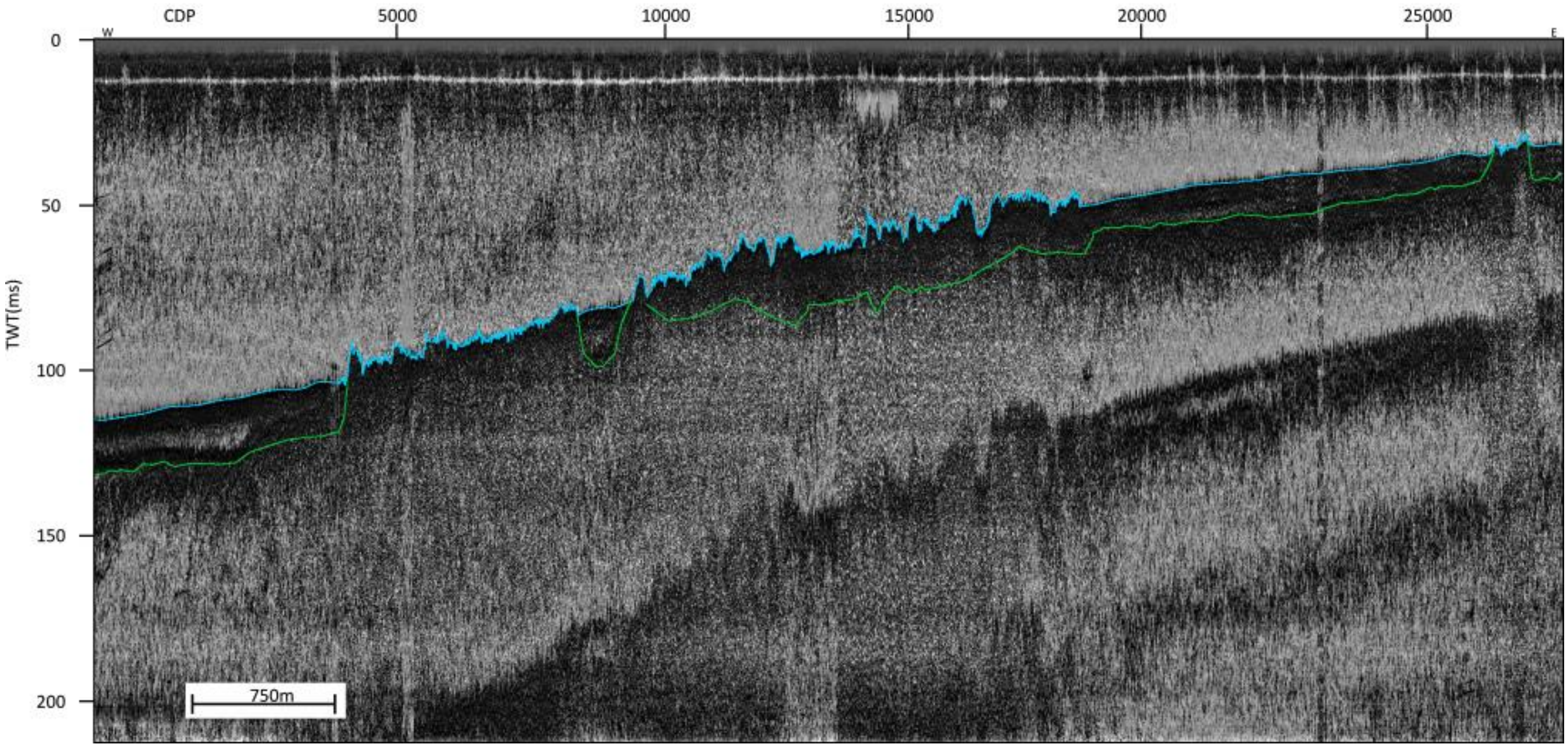
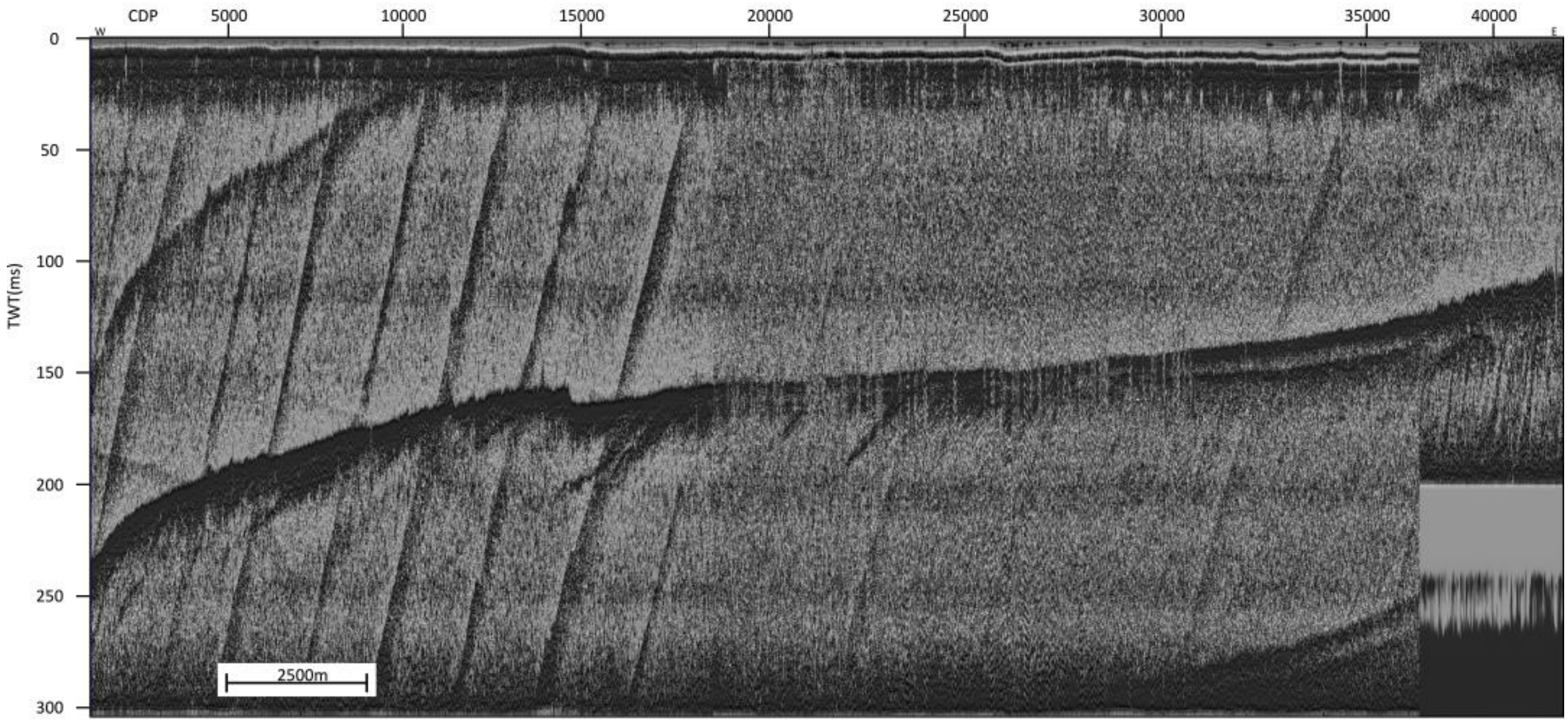
10000
15000
20000
25000
W
E
0
50
100
150
200
TWT(ms)
750m

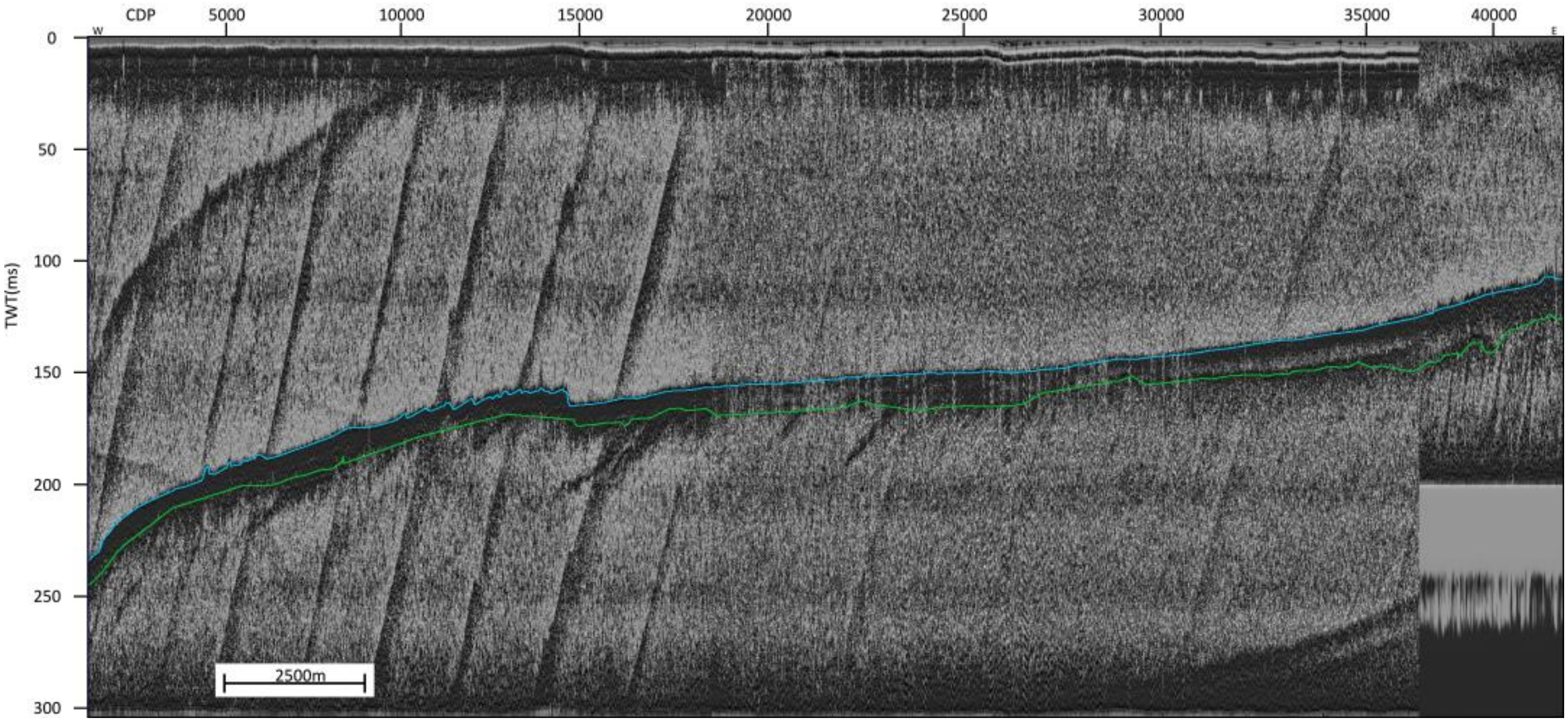
VB00175-1


CDP
5000
10000
15000
20000
25000
W
E
0
50
100
150
200
TWT(ms)
750m

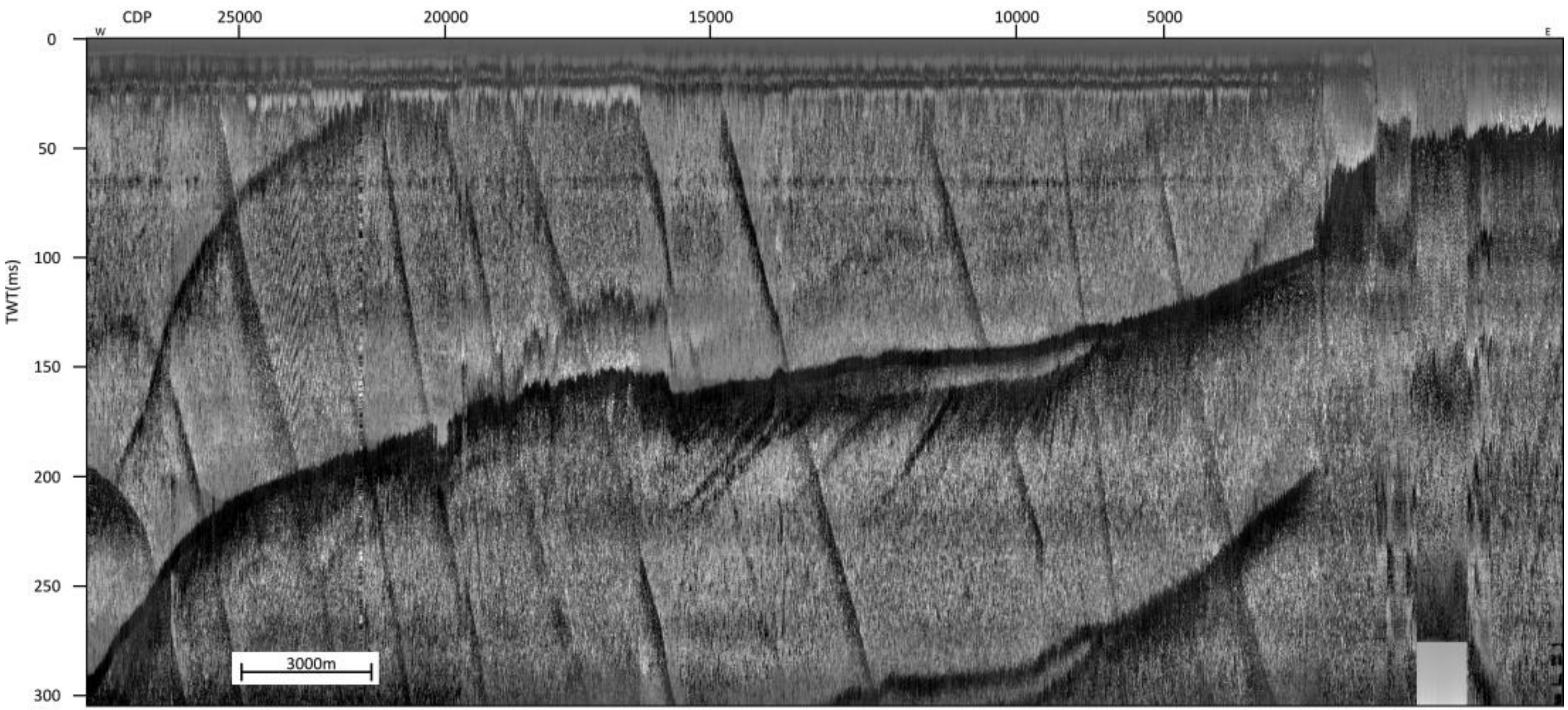
VB00175-2


CDP
5000
10000
15000
20000
25000
30000
35000
40000
W
E
0
50
100
150
200
250
300
TWT(ms)
2500m

VB00175-2


CDP
5000
10000
15000
20000
25000
30000
35000
40000
W
E
0
50
100
150
200
250
300
TWT(ms)
2500m

VB00375


CDP
25000
20000
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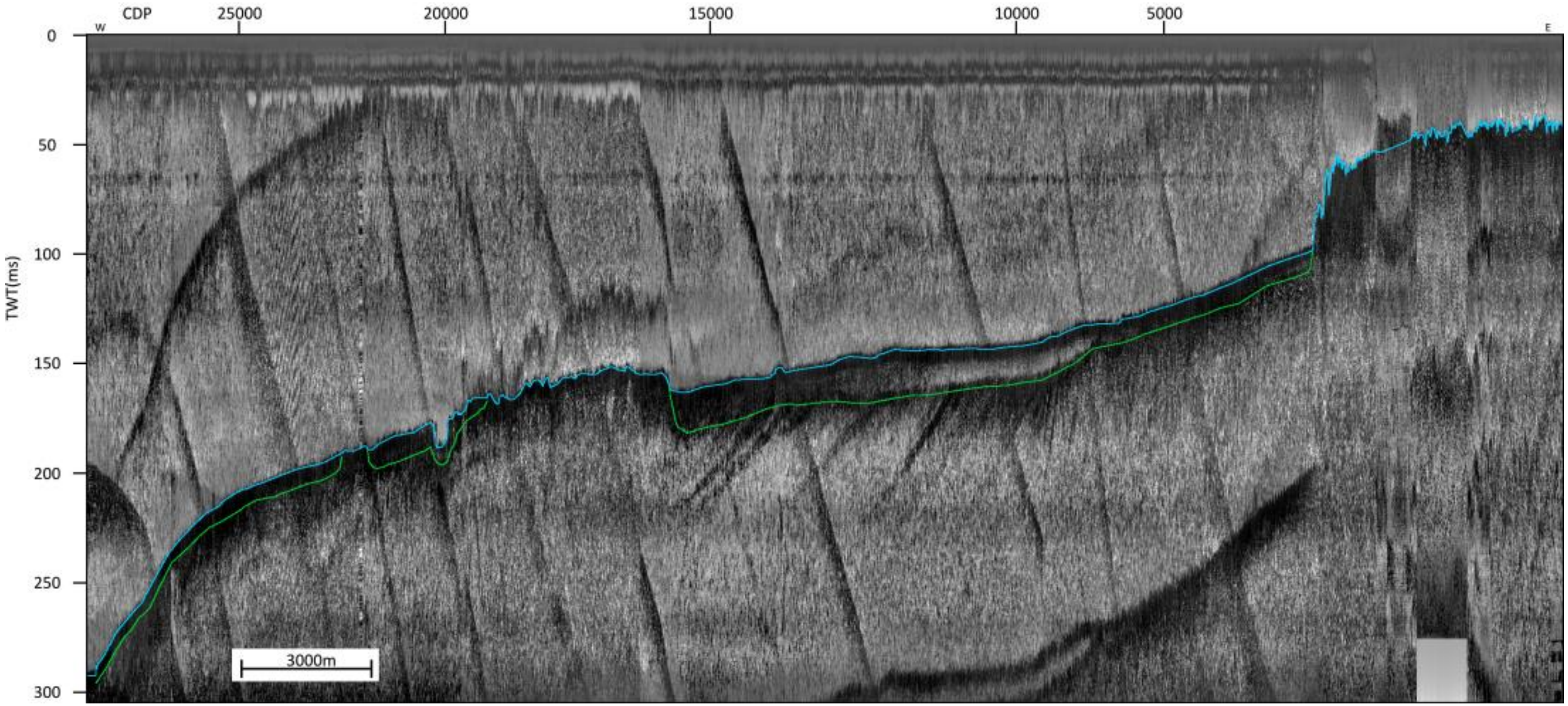
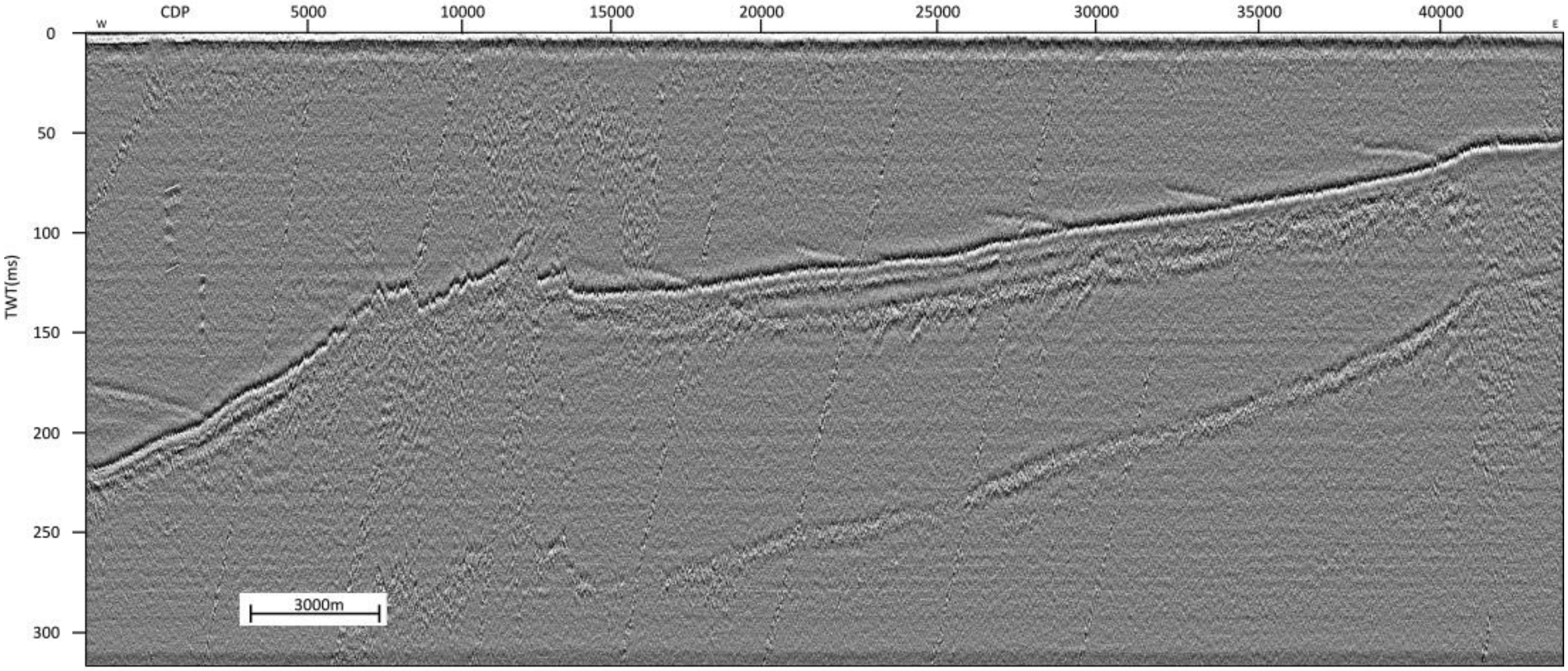
10000
5000
W
E
0
50
100
150
200
250
300
TWT(ms)
3000m

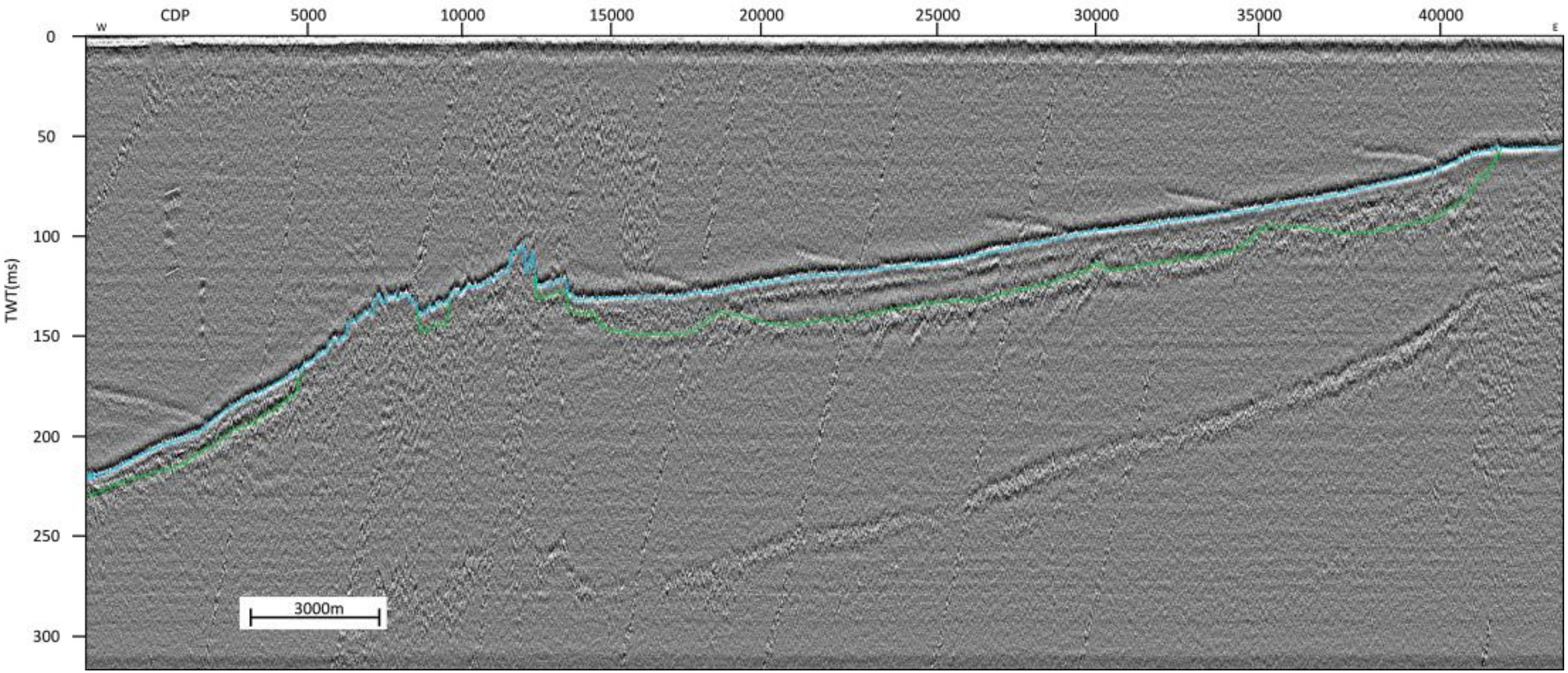
VB00375


CDP
25000
20000
15000
10000
5000
W
E
0
50
100
150
200
250
300
TWT(ms)
3000m

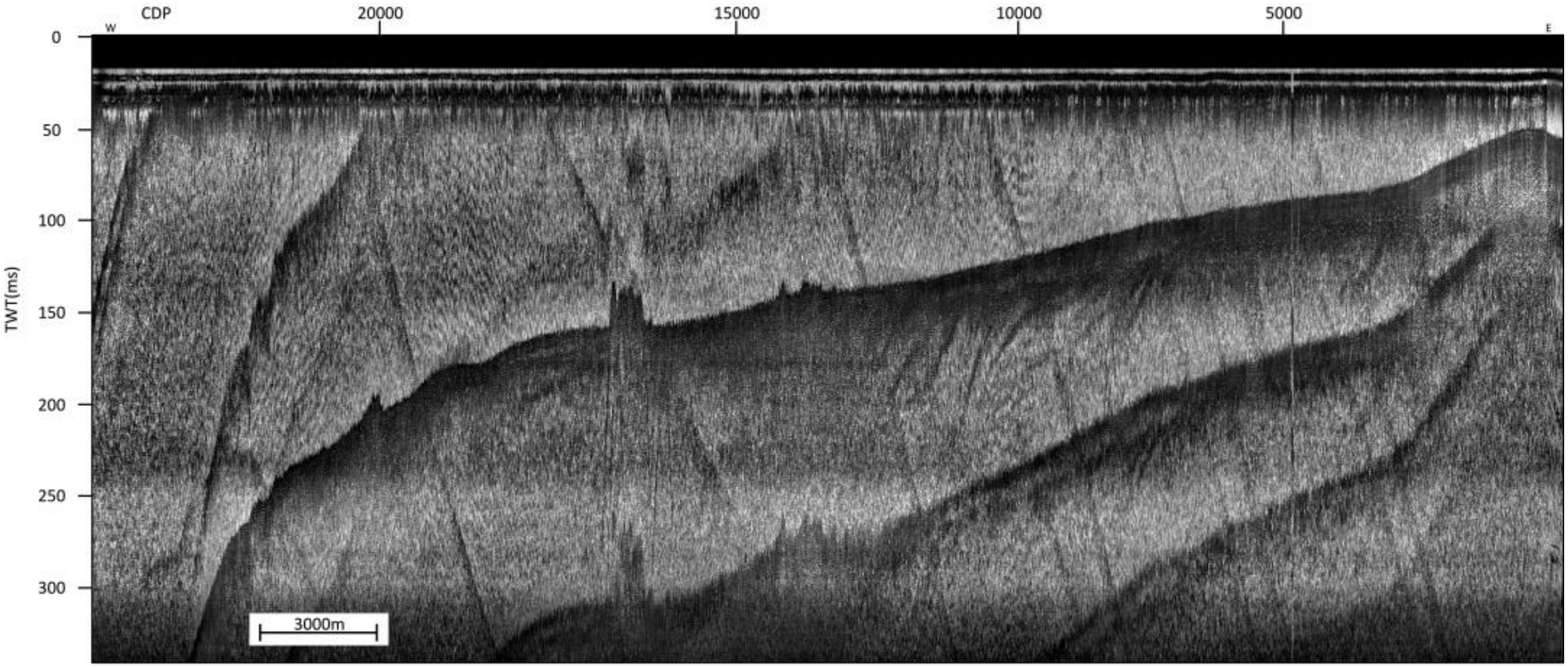
VB00575


W
CDP
5000
10000
15000
20000
25000
30000
35000
40000
E
0
50
100
150
200
250
300
TWT(ms)
3000m

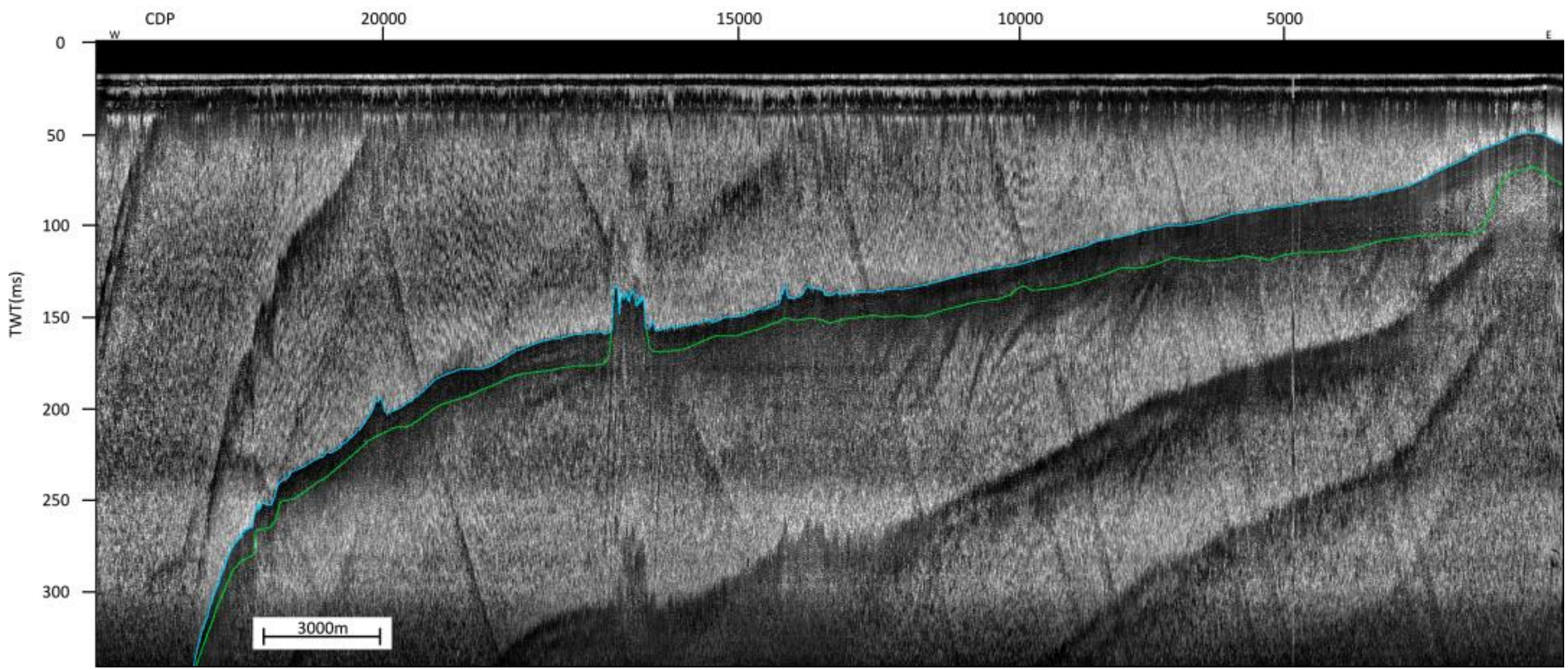
VB00575


W
CDP
5000
10000
15000
20000
25000
30000
35000
40000
E
0
50
100
150
200
250
300
TWT(ms)
3000m

VB00775


CDP
20000
15000
10000
5000
W
E
0
50
100
150
200
250
300
TWT(ms)
3000m

VB00575


CDP
20000
15000
10000
5000
W
E
0
50
100
150
200
250
300
TWT(ms)
3000m

IPMA Instituto Português do Mar e da Atmosfera

PRR Plano de Recuperação e Resiliência
REPÚBLICA PORTUGUESA
Financiado pela União Europeia
NextGenerationEU