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Geological, archaeological and metocean information for the support of offshore wind farm development on the west Portuguese continental shelf

- Leixões -

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SUMMARY

This report compiles and interprets geophysical, geological, archaeological and metocean information and data relevant for understanding the geological nature of the seafloor in the Leixões area for development of wind farms.

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

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

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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, an 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, a public hearing (Despacho nº 1396-C/2023) followed, 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 km^2. The Leixões area corresponds to 644 km^2.

The present report aims at compiling, organizing, and describing the available geological and geophysical relevant information of the seafloor in the Leixões area. This information includes: i) a summary of the geological setting; ii) position maps of existent seismic reflection data, iii) surface sediment samples, iv) surface sediment maps, and v) 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. Information on the OIL & Gas available data will be included in the extended version of this report.

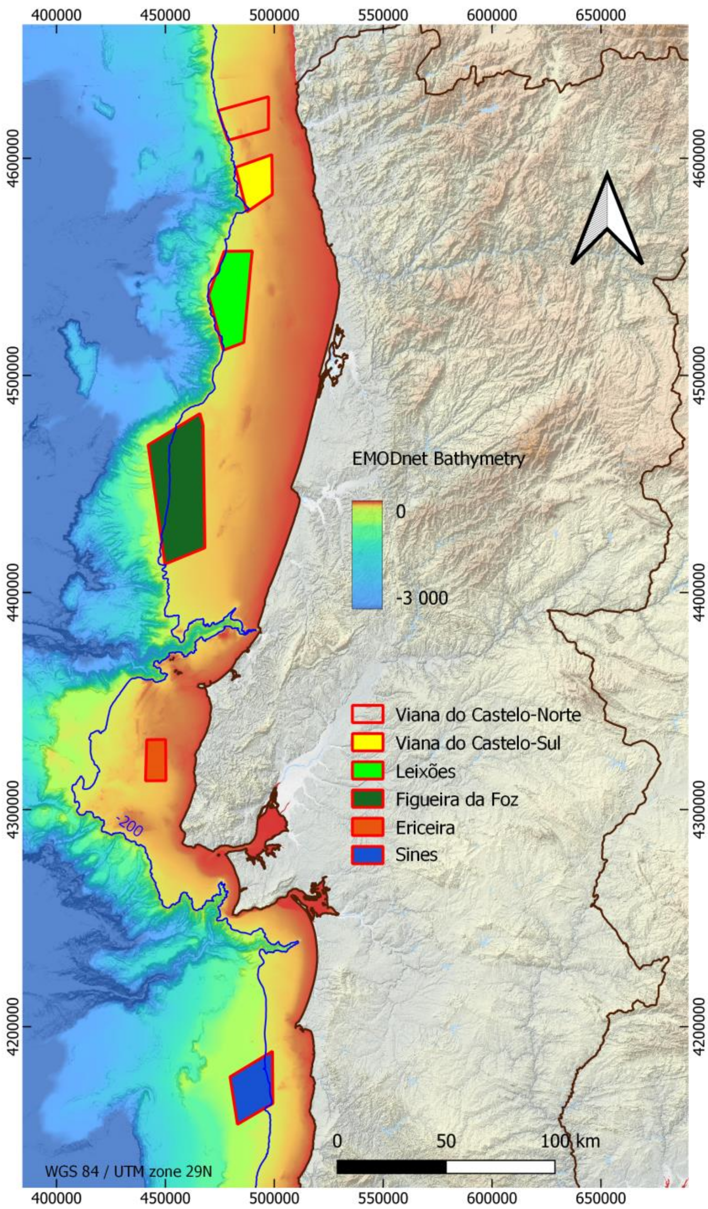


Figure 1.1 - Map showing the allocated areas for installation of offshore wind farms. (https://participa.pt/contents/consultationdocument/Plano%20de%20Afeta%C3%A7%C3%A3o_PAER_Versao_CP_outubro.pdf)

1.2. Geological Setting

Leixões offshore wind farms areas is located in the continental shelf on the northwest of Portugal (Western Iberian Margin – WIM), south of Beiral de Viana, between Vouga River at the south and Douro River at the north (Figure 1.2). In this area the width of the continental shelf ranges between 65 and 80 km approximately. The continental shelf edge lies around the 150 m depth.

The WIM developed in strict relation with the opening of the Atlantic Ocean. The Lusitanian Basin (LB), which constitutes a significant portion of the WIM, is a Meso-Cenozoic basin developed as a multiphase rift throughout much of the Mesozoic, overlying a Paleozoic basement made of metamorphic and magmatic rocks. The LB evolution started during the Late Triassic-Early Jurassic, with the onset of the first rifting event, after which two other rifting episodes – Late Jurassic and Early Cretaceous – affect the area. The continental break-up occurred close to the Early and Late Cretaceous transition. During the Mesozoic the sedimentation occurred in alternating continental, transitional and marine environments, with siliciclastic (of varying grain size and cements) and carbonate (mainly limestone, sporadically dolomites) lithologies being the more common.

During the Cenozoic the basin was affected by two tectonic inversion episodes of Eocene and Miocene ages associated with the Alpine orogeny that reactivated the Pre-Mesozoic faults (mostly Late Hercynian faults) and folded the sedimentary packages. The sedimentation is mainly detrital with carbonate formations included. The thickness of the Mesozoic is highly variable, mainly controlled by the development of syn-rifting faults and/or salt basins. The thickness of the Cenozoic is controlled by tectonic inversion structures. A main erosive unconformity (late Miocene to Pliocene age) separates the underlying sedimentary packages from the sediment package on top considerably less consolidated.

Sedimentary rocks of Cenozoic age cover the continental shelf at the Leixões area (Figure 1.2): Paleogene limestones, dolomites and sandstones at the eastern portion of the area; and Miocene sandstones, limestones, siltstones and claystones at the western part of the interest area.

Sediments are mainly supplied to the shelf by six rivers (Minho, Lima, Cávado, Ave, Douro and Cávado 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. 1981, 1984, 1992, 2001a, b, 2002; Jouanneau et al. 2002; Magalhães et al. 1991, 1992, 1999; Fiuza 1983; Vitorino et al. 2002a,b).

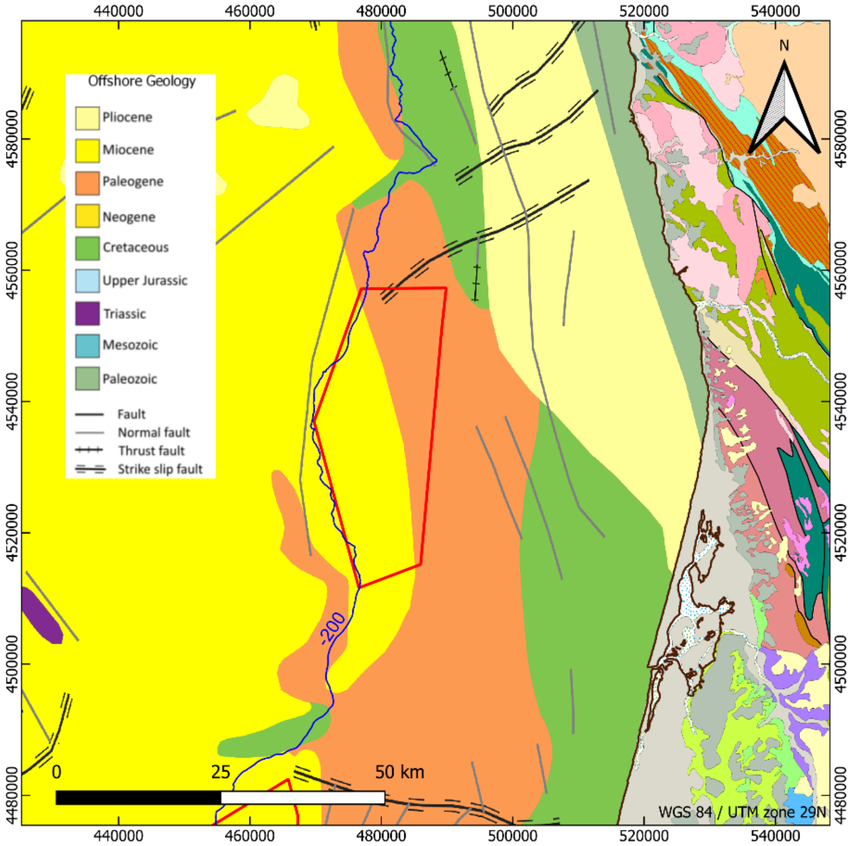


Figure 1.2 - Geological map of Leixões area, Portugal.

2. AVAILABLE DATA

For this work previously acquired geophysical data (IPMA proprietary high-resolution seismic reflection surveys; and Direção-Geral de Energia e Geologia (DGEG) proprietary medium to low resolution seismic reflection surveys) were analyzed as well as published material (e.g. oil and gas exploration reports; PhD thesis; scientific papers). Figure 2.1 presents all the data used in this report for the Leixões area, namely, seismic reflection surveys and surface sediments samples. To overcome the small amount of data, the seismic lines covering the continental shelf between the area and the shore were also analyzed (Figure 2.1).

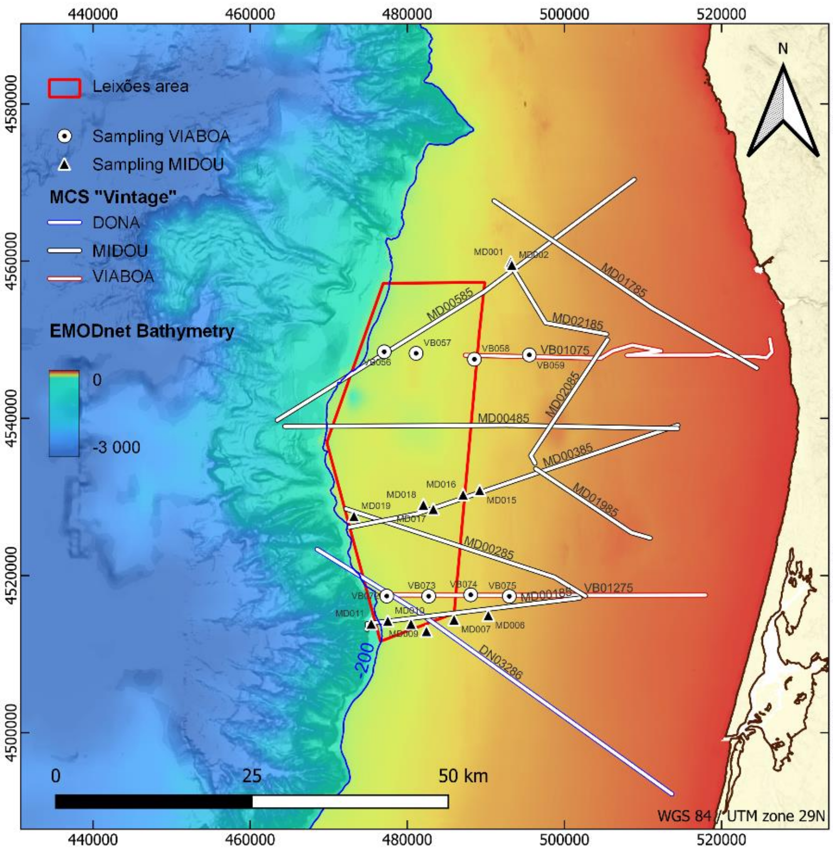


Figure 2.1 - Available data for the Leixões area used in the current report

2.1. Geophysical data

The datasets of seismic reflection profiles consist of lines acquired during 3 ‘vintage’ surveys (VIABOA – 1975; MIDOU – 1985; and DONA - 1986) covering the continental shelf near the Leixões area, and 54 seismic lines (Table 2.1) from the oil & gas data inventory from DGEG

(Figure 2.1). The acquired seismic reflection profiles are approximately 450 km long, with 100 km of them acquired over the studied area.

The **VIABOA** survey was done between the 13th and the 29th October 1975, aiming to acquire geological data to access the continental shelf sedimentary cover. The promotor was the Serviço de Fomento Mineiro (SFM) and the contractors were the SFM and the Instituto Hidrográfico (IH). The survey was conducted on the Almeida Carvalho vessel; the positioning was made by the crew officials by marked and estimated points, radar and DECA with an interval of 10 minutes. The seismic equipment used was 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.

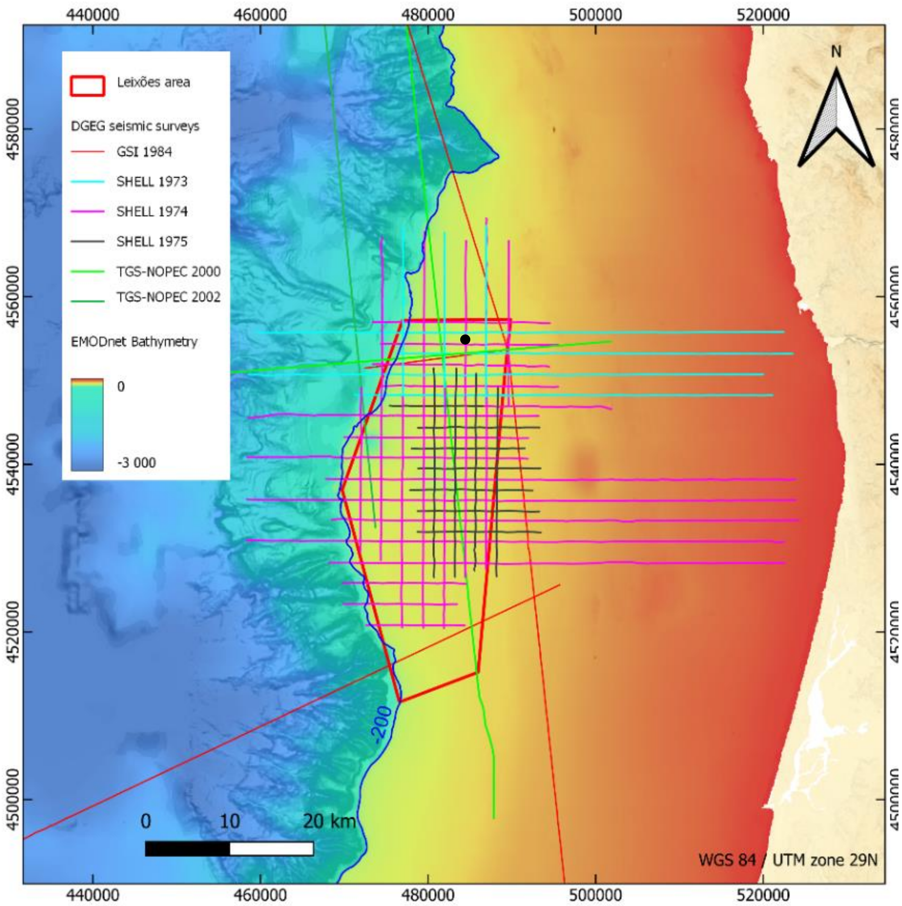


Figure 2.2: Oil and Gas Exploration Seismic Surveys. Oil drilling represented by the black dot.

Table 2.1 - Synthesis of the available Oil & Gas surveys and existent number of lines covering the area of Leixões

Survey	Operator	Year	Nº of lines
GSI 1984	GSI	1984	4
SHELL 1973	Shell	1973	8
SHELL 1974	Shell	1974	28
SHELL 1975	Shell	1975	11
TGS-NOPEC 2000	TGS-NOPEC	2000	3

The **MIDOU** survey took place between 27th and the 29th August 1985. The promotor was the Direção Geral de Geologia e Minas (DGGM) and the contractors were DGGM and IH. The objectives were not specified in the report of the campaign. The survey was done on the Almeida Carvalho vessel. The seismic equipment was Uniboom and Sparker EG&G.

The **DONA** survey took place between the 5th and the 12th December 1986, aiming to acquire geological data to access the continental shelf sedimentary cover. The promotor was the Serviço de Fomento Mineiro (SFM) and the contractors were the SFM and the Instituto Hidrográfico (IH). The survey was done on the Almeida Carvalho vessel; the positioning was done from satellite with an interval of 10 minutes. The seismic equipment used was Uniboom and Sparker.

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 DGEG; a synthesis of that data focused on the implementation area is present in this report.

One well was drilled in the Leixões area (Figure 2.2), 5A-1, by Shell, in the year of 1975. Table 2.2presents relevant data on the drilling of the well.

Table 2.2 - Oil and Gas exploration wells

Name	Abbreviation	Operator	Drilling Year	Total Depth (m)	Water Depth (m)
5A-1	5A-1	SHELL P. PORTUGAL	1975	2626	125

Information collected from the exploration well refers to Mesozoic and Paleogene 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.

Table 2.3 - Synthesis of data from oil and gas exploration well 14C-1A

Depth (m)	Formation	Lithology	Stratigraphy
Seabed – 287	Espadarte	Argillaceous limestone gradding to dolomite	Paleogene
287-401	Dourada	Dolomitic limestone, sandy dolomites and marls	Maastritchian – Upper Campanian
401-633	Carapau	Marls, limestones	Upper Campanian – Coniacian Upper Turonian
633-680	Gandara	Medium to coarse grained sandstones with interbedded clay and dolomite stringers	
680-738	Cacém	Dolomite, argillaceous dolomite	Upper Cenomanian
738-1182	Torres Vedras	Medium to very coarse (sometimes gravel) sandstone interbedded with subordinate clay; sporadic dolomite and limestones	Middle Cenomanian – Lower Cretaceous
1182-1454	Linguado	Limestone, argillaceous occasionally sandy, interbedded with marls and minor sandstones	Portlandian
1454-1731	Esturjão	Limestone, argillaceous, interbedded with marl; stringers of anhydrite, claystone, siltstone and minor sandstone	Middle-Lower Jurassic
1731-2558	Dagorda	Rock salt interbedded with shale, anhydrite, marl and minor dolomite and limestone	Early Lower Jurassic – Upper Triassic
2558-2588	Silves	Shale/siltstone	Triassic
2588–2626	Basement	Low grade metamorphic rocks	Pre-Mesozoic

2.3. Surface Sediments

During the oceanographic campaigns VIABOA (1975) and MIDOU (1985) unconsolidated surface sediments were sampled with Van Veen and Shipek grabs (VIABOA), and Van Veen grab and Kastelnot sediment corer (MIDOU). In the area of Leixões a total of 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 2.1. The sampled sediments are mostly sands, of variable grain size and generally with abundant bioclasts; some of the samples are clay-rich or silt-rich facies.

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 Leixões 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 2.3) are mainly detrital with various grain sizes (ranging between mud and coarse sand) and different bioclastic and lithoclastic components. The description of the sediments follows the Folk classification scheme, and the textural meaning is presented in Table 2.4.

Table 2.4 - Surficial sediments samples from VIABOA (VB) and MIDOU (MD) campaigns

ID	Latitude	Longitude	Date	Depth (m)	Observations
VB056	41.087111	-9.272985	1975-10-20	170	Fine grained sand with bioclasts and micas
VB057	41.085446	-9.224650	1975-10-20	160	Fine grained sand with bioclasts and micas
VB058	41.078780	-9.136316	1975-10-21	130	Dark green mud
VB059	41.083781	-9.052982	1975-10-21	100	Sandy mud with glauconite
VB072	40.807107	-9.267979	1975-10-21	160	Fine grained sand with heavy minerals
VB073	40.807107	-9.204644	1975-10-21	140	Fine grained sand with heavy minerals
MD009	40.775441	-9.231311	1985-08-30	146	Bioclastic clayed sand with glauconite
MD010	40.778773	-9.266312	1985-08-30	170	Glauconitic clayed sand
MD016	40.923777	-9.152980	1985-08-30	126	Fine grained sand
MD017	40.907109	-9.197980	1985-08-30	135	Medium to coarse grained bioclastic sand
MD018	40.912109	-9.212981	1985-08-30	137	Bioclastic coarse sand with glauconite
MD019	40.898775	-9.317982	1985-08-30	160	Clayed bioclastic coarse sand

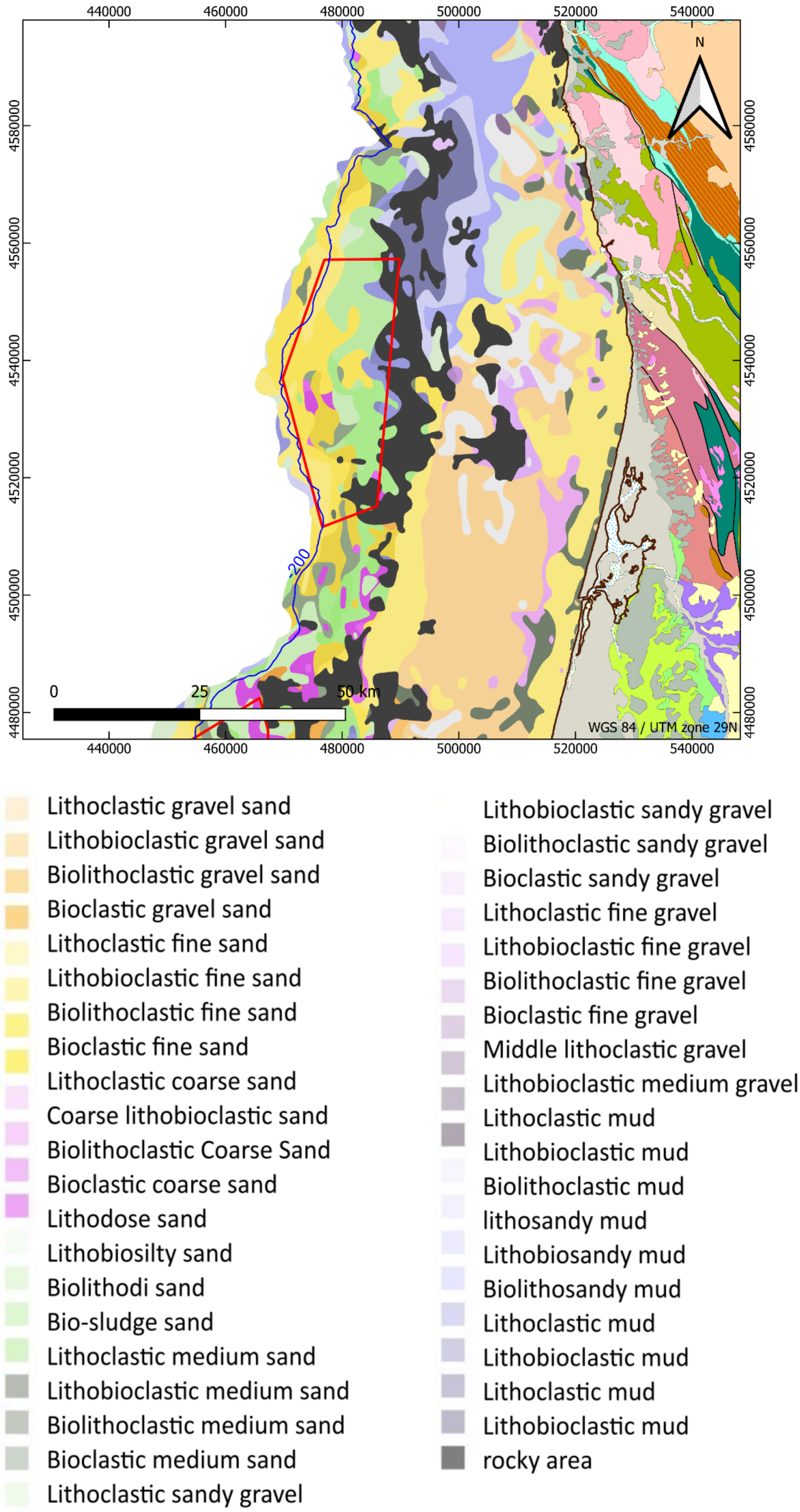


Figure 2.3 - Surficial sediments map (IH, 2010).

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%
[redacted]		
Lithoclastic	carbonate < 30%	
Lithobioclastic	30% < carbonate < 50%	
Biolithoclastic	50% < carbonate < 70%	
Bioclastic	carbonate > 70%	

Rocky outcrops of the continental shelf offshore Leixões occupy a small area in the eastern side and correspond to Paleogene limestone, dolomites and sandstones. Besides the Paleogene, pre-Quaternary formations in this area are the Miocene sandstones, limestones, siltstones and claystones, occurring in the western portion of the Leixões sector (Figure 1.2). These sediments constitute the substrate of the loose sediments of the area.

2.4. Metocean Data

Information on wave and wind conditions are fundamental for the planning of the geophysical surveys. Data from a 45 years’ time series was used to assess the number of days available with optimal conditions for the surveys as well as the more favorable months.

Offshore hindcast data was obtained running a 3rd generation wave prediction model on a global grid and on several regional grids (EU-shelf, Mediterranean, Black Sea, Red Sea, Persian gulf) when appropriate. The used global grid has a resolution of 50 km; the models provide 3-hourly time series of wave spectra and parameters covering a period of approximately 45 years (1979 – near present day). Hindcast data was extracted for the years 1980-2023; satellite measurements (1992-2022), collected within a radius of 20 to 40 km around the central location of the area were used to calibrate model hindcast significant wave height.

The data (Annexes 9.2, 9.3) is presented in a graphical format and includes: (i) the fraction of workable days and the number of workable days per month against the years analyzed, including all-year averages, for all 12 hours windows length (wave height and wind speed limits); and (ii) the mean delay time spent waiting for weather windows per month against the years analyzed, including all-year averages.

2.5. Archeological Heritage

The study of the underwater cultural heritage factor (PCS) aimed to characterize the maritime use of the area where the project is located and the occurrence of maritime accidents, allowing to define its archaeological potential. Compilation of the data from different data bases allowed the mapping of the occurrences of higher potential, and differentiate between the involved remains defining their historical importance and their dangerousness.

The data was collected from the files stored at the Centro Nacional de Arqueologia, the United Kingdom Admiralty (“Wrecks and Obstructions Shapefiles”) accessible at the Marine Data Portal, the wrecksite.eu the biggest database devoted to ship wrecks, and from the Base de Dados de Arqueologia Nacional Endovélico.

The collected data is described in Table 2.6.

Table 2.6 - List of information collected from the archeological databases

Typology	Type of occurrence (Ship wreck, Finding, Aircraft crash)
Chronology	Period from which the detected traces come/year of occurrence
Latitude	Geographical coordinate
Longitude	Geographical coordinate
Designation	Name given to an archaeological site or name given by sources for known shipwrecks
Origin	Ship flag for shipwrecks and aircraft crashes
Hull Material	Wood; Iron/Steel
Cargo	Material that was on board at the time of the sinking
Dimensions max. (m)	Largest known size of the wreck
Asset Value	High; Medium; Low
Explosives	Probable presence of explosives – Yes or No

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 Leixões area. Data was collected during three campaigns: VIABOA (1975), MIDOU (1985) and DONA (1986). 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.

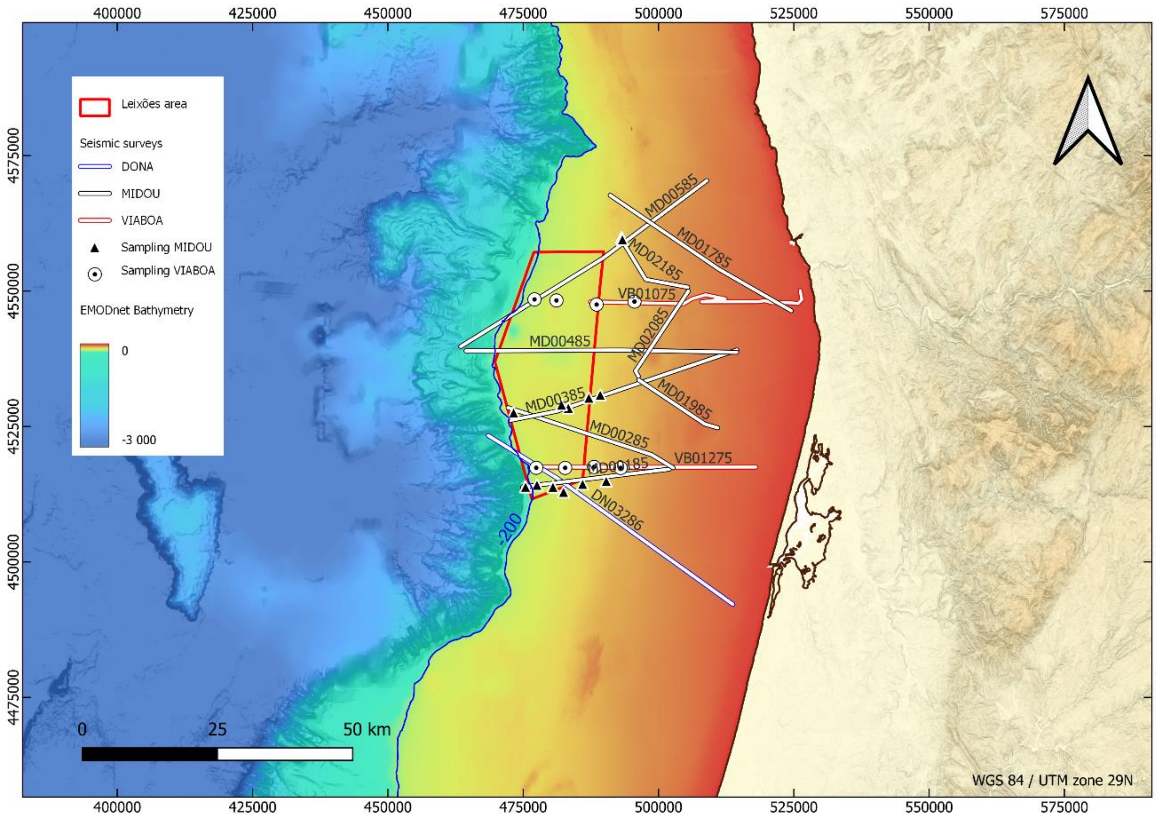


Figure 3.1 - 'Vintage' high-resolution seismic surveys location.

Table 3.1 Data of the 'vintage' seismic surveys

	VIABOA	MIDOU	DONA
Dates:	13 - 29 October 1975	27 - 29 August 1985	5 – 12 December 1986
Promotor:	Serviços de Fomento Mineiro, SFM (Portuguese state)	Direção Geral de Geologia e Minas, DGGM (portuguese state)	Serviços de Fomento Mineiro, SFM (Portuguese state)
Contractor:	SFM and Hydrographic Institute (IH)	DGGM and Hydrographic Institute (IH)	SFM and Hydrographic Institute (IH)
Objective:	Acquisition of geologic data to access the shelf sedimentary cover	NA	Acquisition of geological data on the continental shelf between Douro River's mouth and the Nazaré Canyon
Vessel:	NRP Almeida Carvalho	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	From satellite with an interval of 10 minutes
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	Uniboom and Sparker
Sediment Sampling Equipment	Van Veen and Shipek grabs	Van Veen grab and Kastenlot corer	Van Veen grad and gravity corer

3.2. 'Vintage' Seismic Data

The 'vintage' seismic data originally in printed format was 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 this procedure is presented as follows.

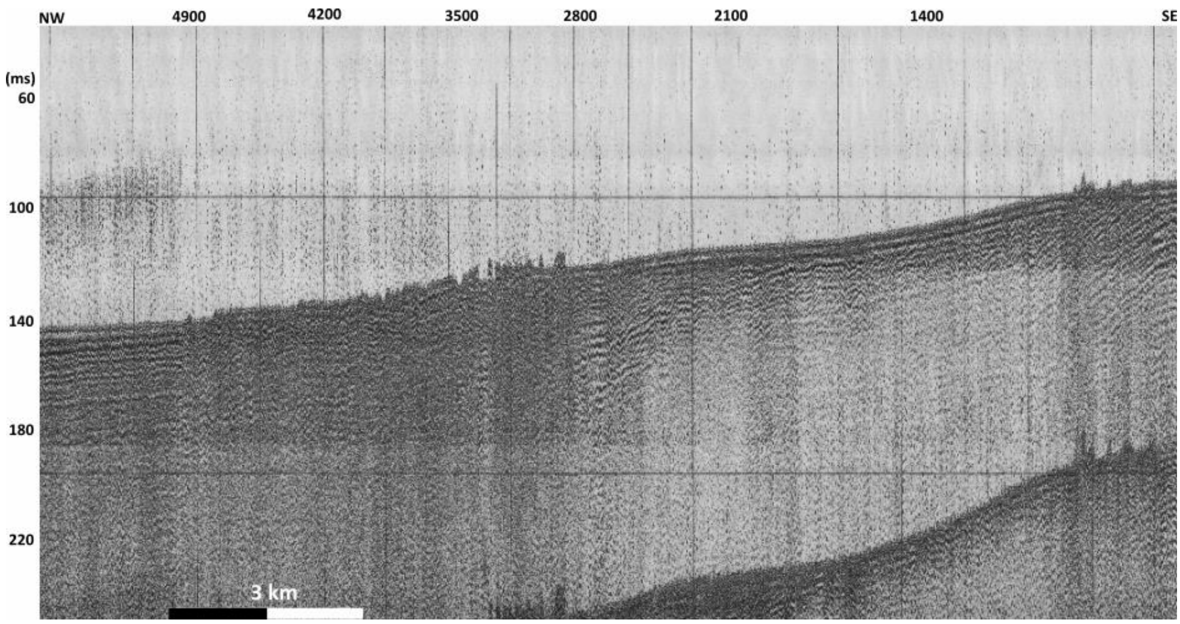


Figure 3.2 - Example of ‘vintage’ seismic profile of MD02185 line from MIDOU campaign 1985 IPMA. Vertical marks refer to shotpoint locations and horizontal marks to time scale.

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).

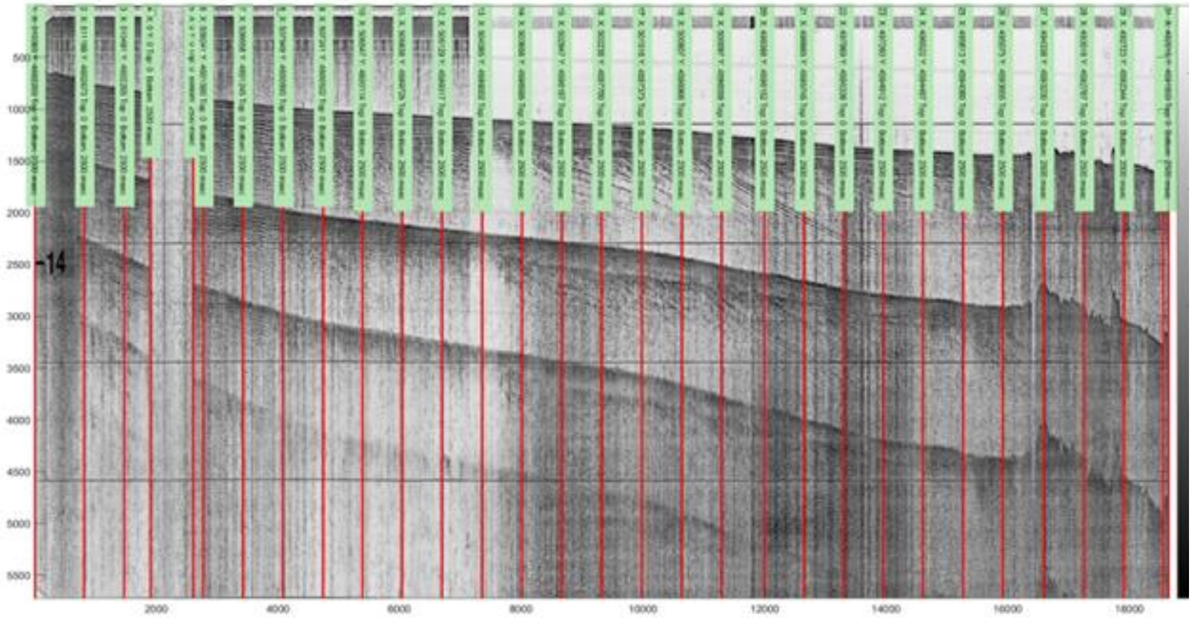


Figure 3.4 - Example of SEGY QC. Seismic profile with shot points location with UTM coordinates.

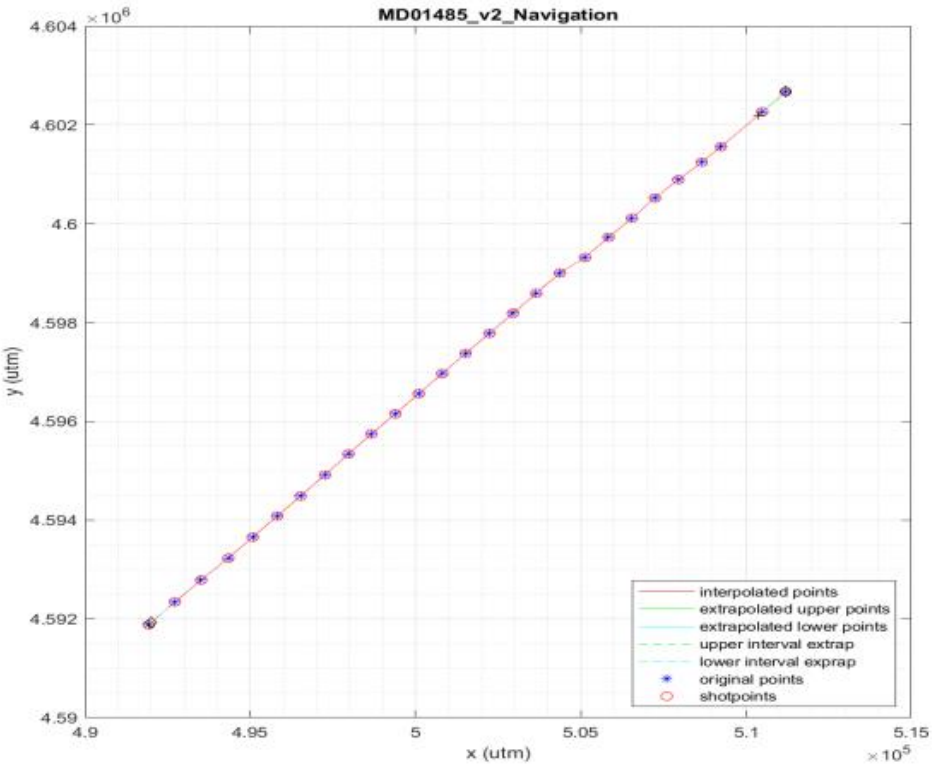


Figure 3.5 - Example of SEGY navigation QC.

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).

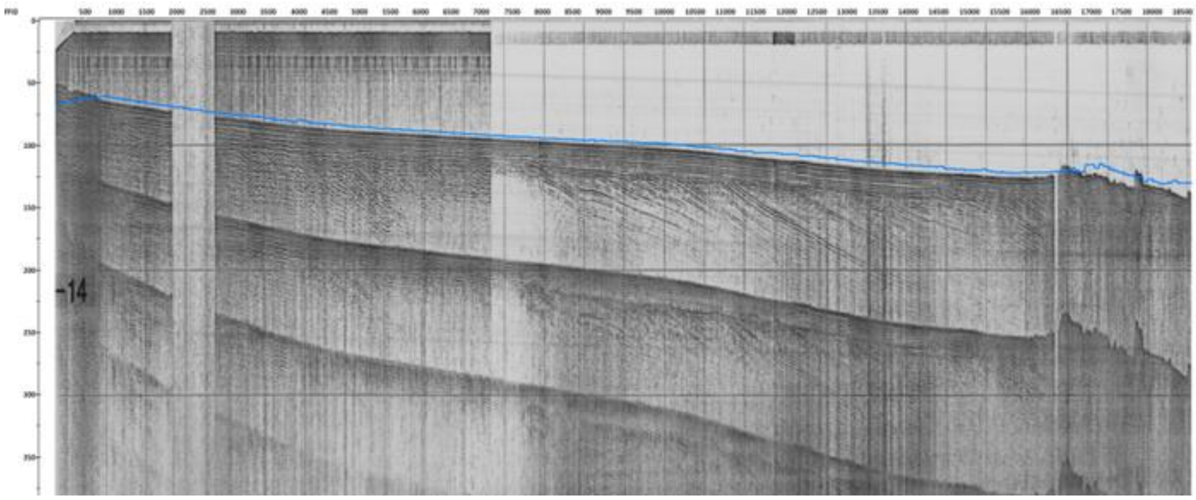


Figure 3.6 - SEG-Y (res.sgy) seismic profile after geometrical corrections. Blue line represents the seabed (data from IPMA database - EMODnet).

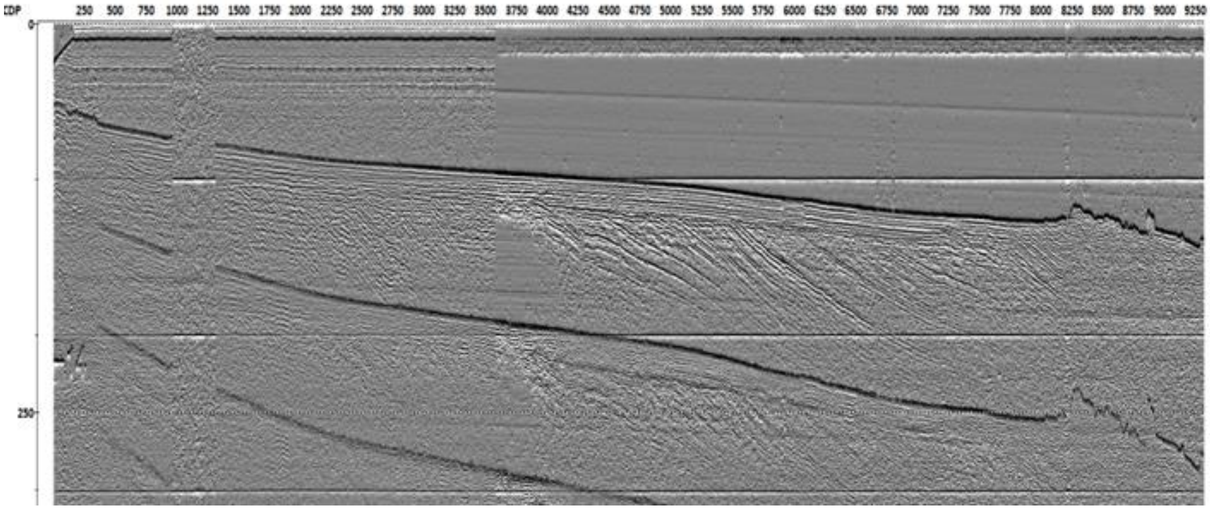


Figure 3.7 - SEG-Y (proc.sgy) processed seismic profile of the line presented in Figure 3.6.

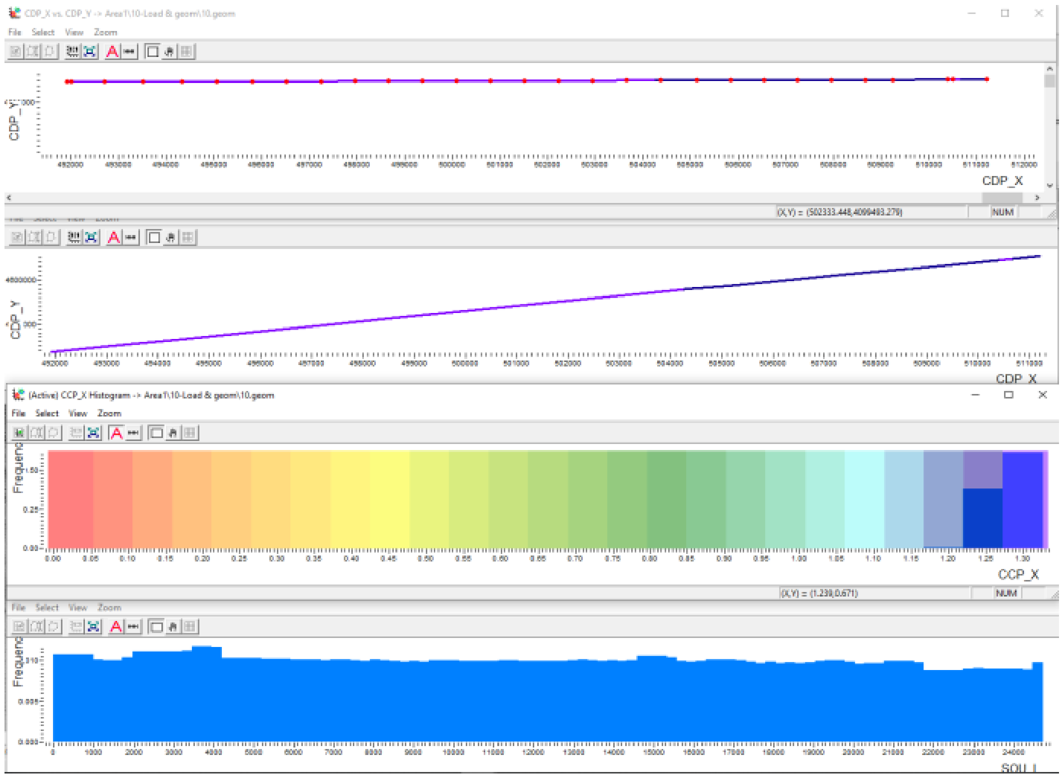


Figure 3.8 - Example of QC plot of navigation positioning for a 'vintage' IPMA seismic line. A- navigation plot of the seismic traces coordinates, "foras" (red dots) with original navigation coordinates and the interpolated coordinates colored according to trace spacing classes (panel C); B- Navigation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

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. A bulk vertical shift was applied to each seismic line in order to minimize the misfit with the bathymetry and the mistiest with crossing seismic lines (Table 3.2). 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.

In Annex 9.4 are shown the cross sections of the 'vintage' seismic lines for the Leixões area. For each seismic line the resulting processed seismic (proc.sgy) and the seismic interpretation of the seabed (blue line) and the base of the unconsolidated sediments (red line) are presented.

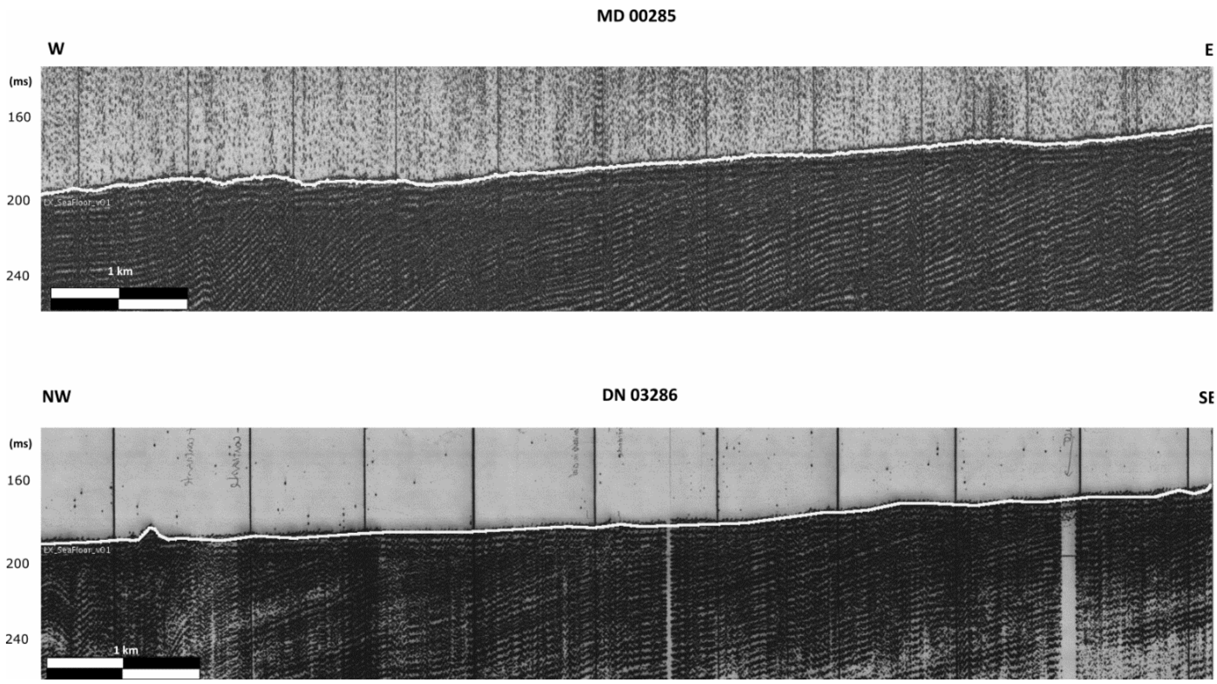


Figure 3.9 - Details of seismic lines MD00285 and DN03286 highlighting the image quality. The white line indicates the interpreted seabed.

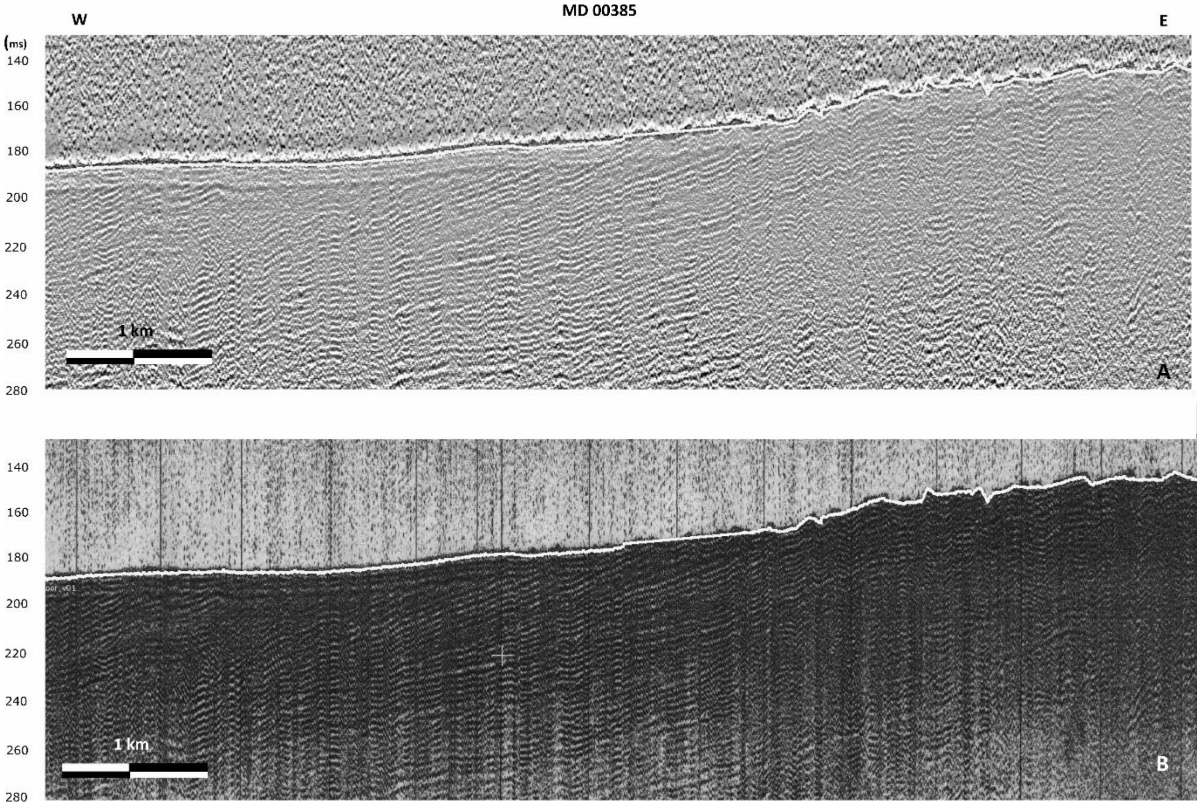


Figure 3.10 - Detail of MD00385 seismic line interpretation (A – res.sgy, B – proc.sgy seismic files), with the seabed in white.

Table 3.2 - Vertical shifts applied to the 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
MD00185	MIDOU	0	-3
MD00285	MIDOU	0	8
MD00385	MIDOU	0	3
MD0485	MIDOU	0	-4
MD0585	MIDOU	0	-1
MD1785_1	MIDOU	0	-1
MD1785_2	MIDOU	0	0
MD1785_3	MIDOU	0	0
MD01985	MIDOU	0	-6
MD02085	MIDOU	0	0
MD02185	MIDOU	0	2
VB001075_1	VIABOA	0	0
VB001075_2	VIABOA	0	0
VB001275	VIABOA	0	7
DN03286_1	DONA	0	0
DN03286_2	DONA	0	-4

The seismic 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 overestimation 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 EMODnet-Geology (https://emodnet.ec.europa.eu/en/geology) map these units are made up of limestones, dolomites and sandstones.

A map with the interpretation of the base of the unconsolidated sediments in all ‘vintage’ lines is presented in Figure 3.11 and in Figure 3.12 overlying the map of sediments from IH (2010). 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, even with the use of seismic attributes. 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 Leixões area.

The shallower seismic unit in the Leixões area, believed to correspond to the unconsolidated sediments, observable outside the Mesozoic and Cenozoic formations outcrops, overlies a deformed (probably Miocene) unit resting on top of an erosional surface. The seismic facies characterizing the unit are: 1) transparent; 2) parallel (sub-horizontal) reflectors of low to medium amplitude; 3) low amplitude contorted; 4) low to medium amplitude chaotic; and 5) mound-shaped.

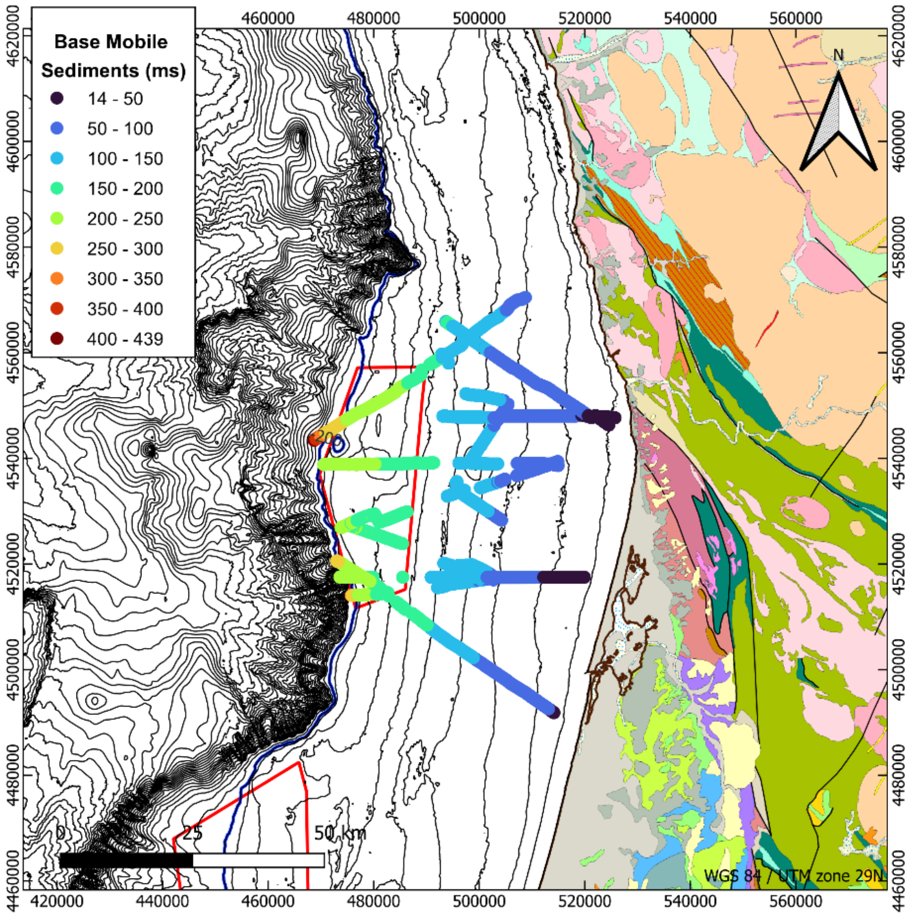


Figure 3.11 - Map of the base of unconsolidated sediments seismic unit (in ms - TWT).

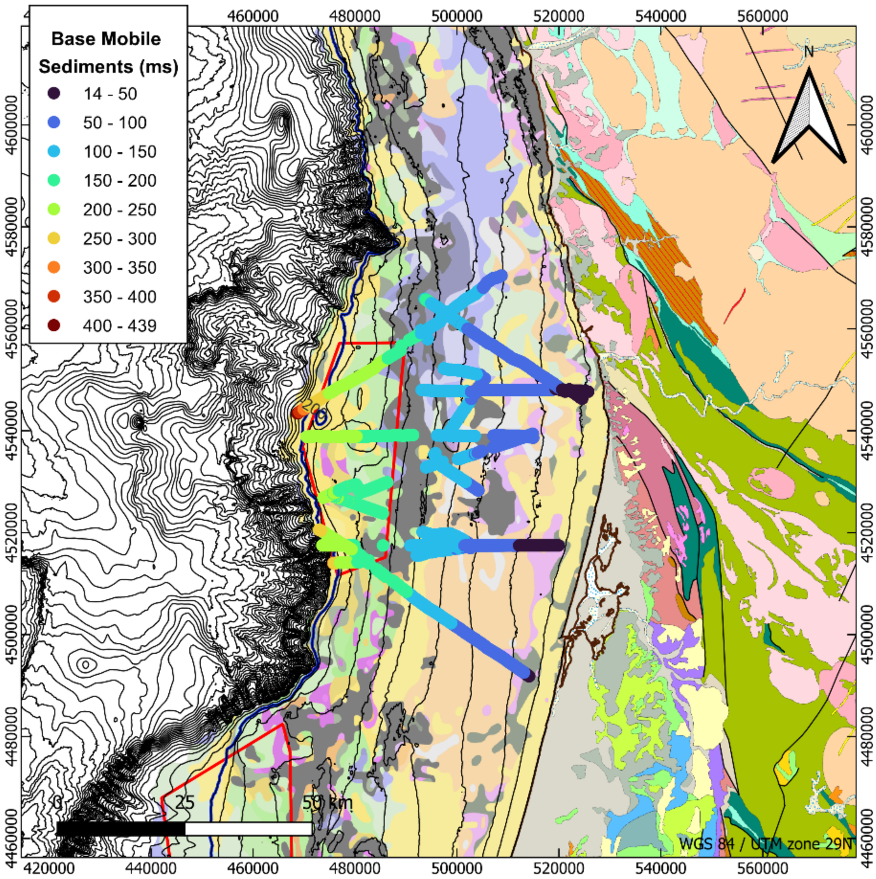


Figure 3.12 - Map of the base of the unconsolidated sediments seismic unit overlying IH (2010) continental shelf sediments map (values in ms - TWT; legend for the IH map presented in Figure 2.3)

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 3.13 presents the computed thickness of the unconsolidated sediments along the lines in TWT; and Figure 3.14 shows the same data plotted on top of the surficial sediments map from the IH (2010).

The conversion to depth was done using a sound velocity value considered to be an acceptable approximation of the velocity for loose sediments in the area and used in previous projects: 1700 m/s. The maps of the calculated values are presented in Figure 3.15, and in Figure 3.16 overlaying the surficial sediments map of the IH (2010). Figure 3.17 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 3.18 shows the same surface grid plotted on top of the IH surficial sediments map.

Since the seismic reflection coverage extends further away the projected area towards shore, two calculations of the unconsolidated thickness were done: using all the data set for the area

(Figure 3.1) and restricting the information to the limiting polygon. For the entire data set the unconsolidated sediment thickness ranges between nil and a maximum value of 19 ms (TWT), with a median value of 8 ms. Considering the a value of 1700 m/s for the velocity of the sound the thickness of the unit varies between 0 and approximately 16 meters, with a median value of 12 meters. Considering only the data inside the Leixões polygon, the thickness of the unconsolidated sediments varies between 0 and 15 ms (TWT) with a median of 7 ms, which represents 0 to 13 meters with a median of 6 meters, considering the 1700 m/s as the value of sound propagation velocity in the unconsolidated sediments.

Taking into consideration the crude estimation of the sound velocity for the unit, the range limits of 1500 m/s and 2000 m/s were used to establish a worst-case scenario and a best-case scenario for the thickness of the formation. Considering those values, the thickness of the unconsolidated sediments maximum values, range between 12 m and 15 m in the limited area and 14m and 19 m for the all data set.

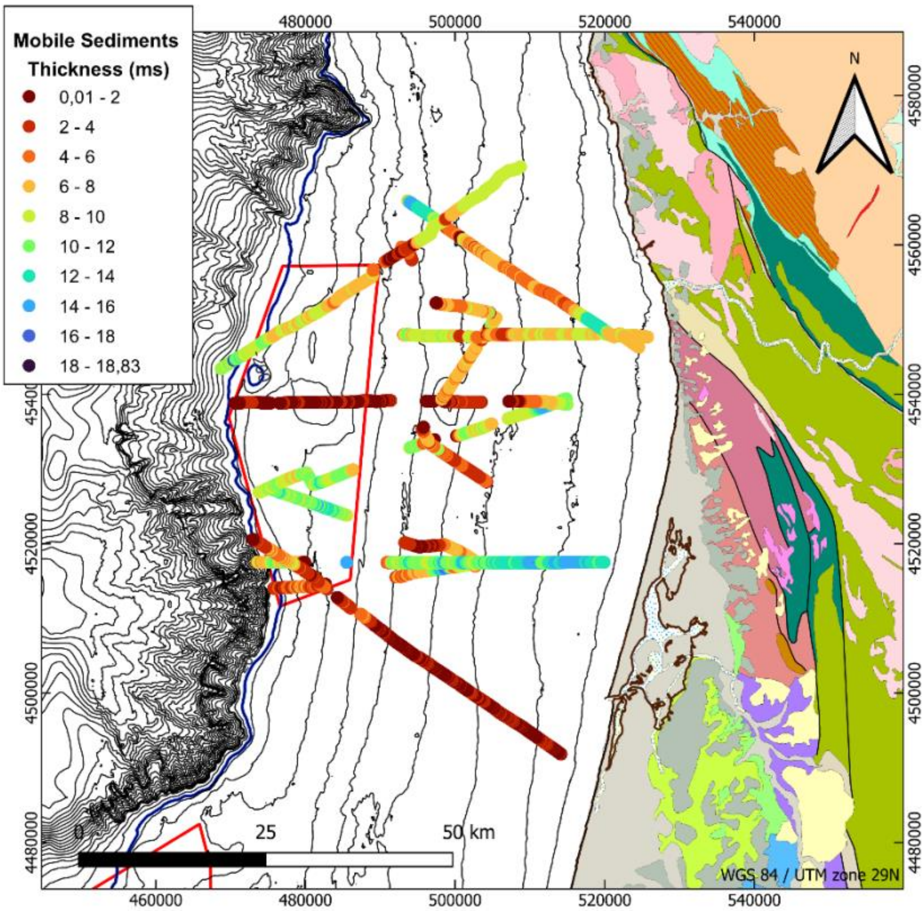


Figure 3.13 - Thickness of the shallower unit, probably of unconsolidated sediments, from the interpretation of the 'vintage' seismic sections (values in ms).

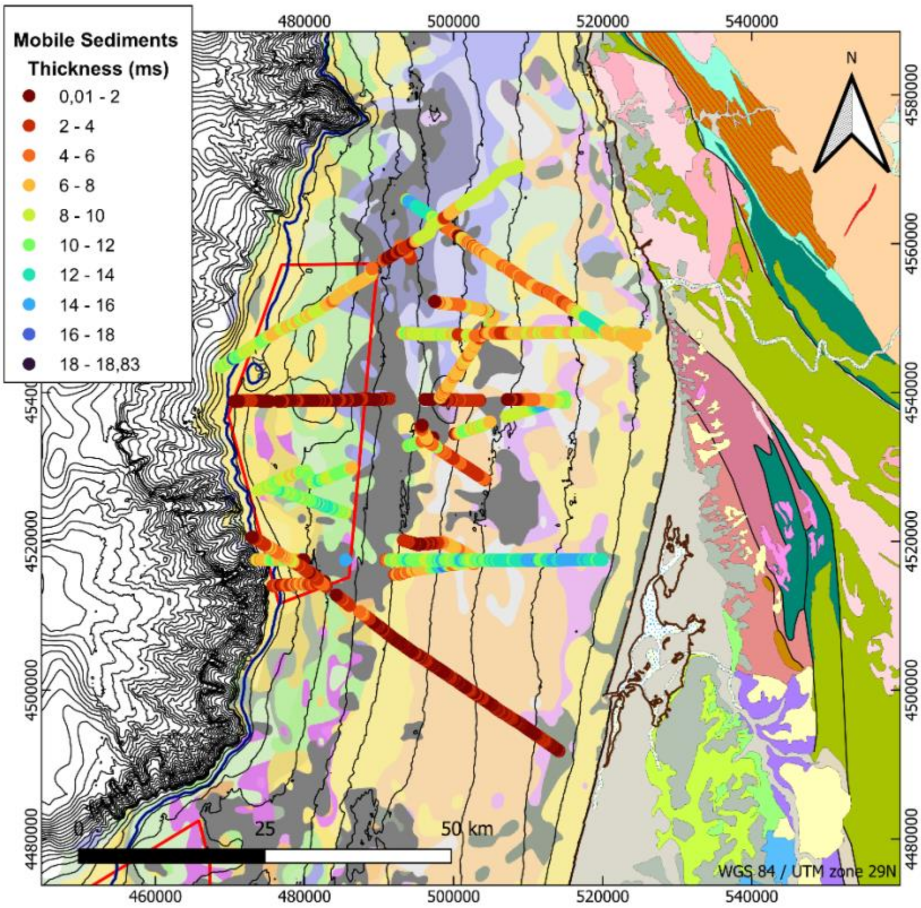


Figure 3.14 - Thickness of the shallower unit (in ms), probably of unconsolidated sediments, from the interpretation of the 'vintage' seismic sections plotted over the Surficial Sediments Map (legend for the IH map presented in Figure 2.3).

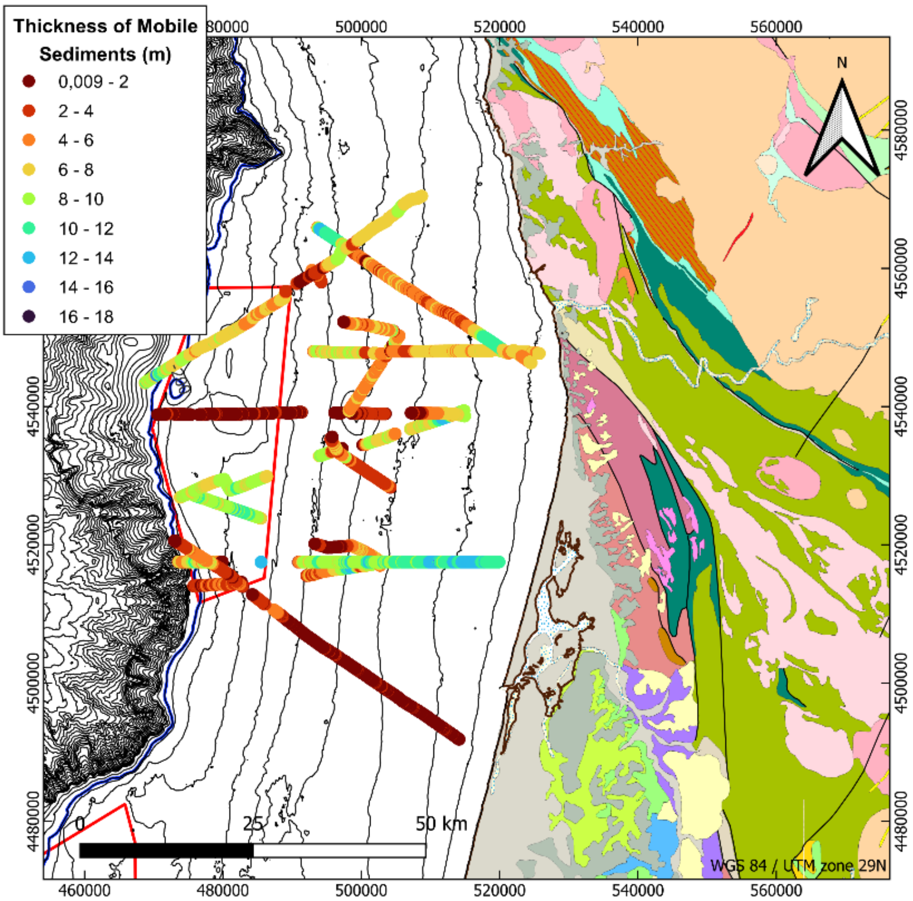


Figure 3.15 - Thickness of the shallower unit (in m), probably of unconsolidated sediments, from the interpretation of the 'vintage' seismic sections, converted to depth using an average sound propagation velocity of 1700 m/s

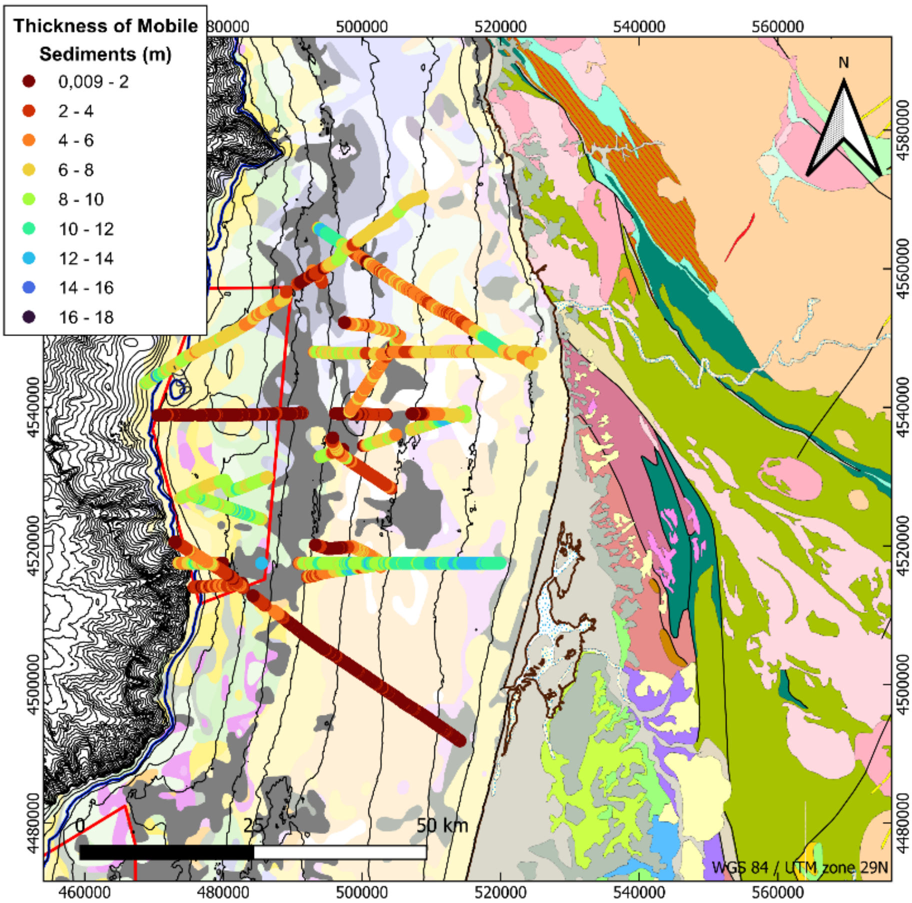


Figure 3.16 - Thickness of the shallower unit (in m), probably of unconsolidated sediments, from the interpretation of the 'vintage' seismic sections, converted to depth using an average sound propagation velocity of 1700 m/s (legend for the IH map presented in Figure 2.3).

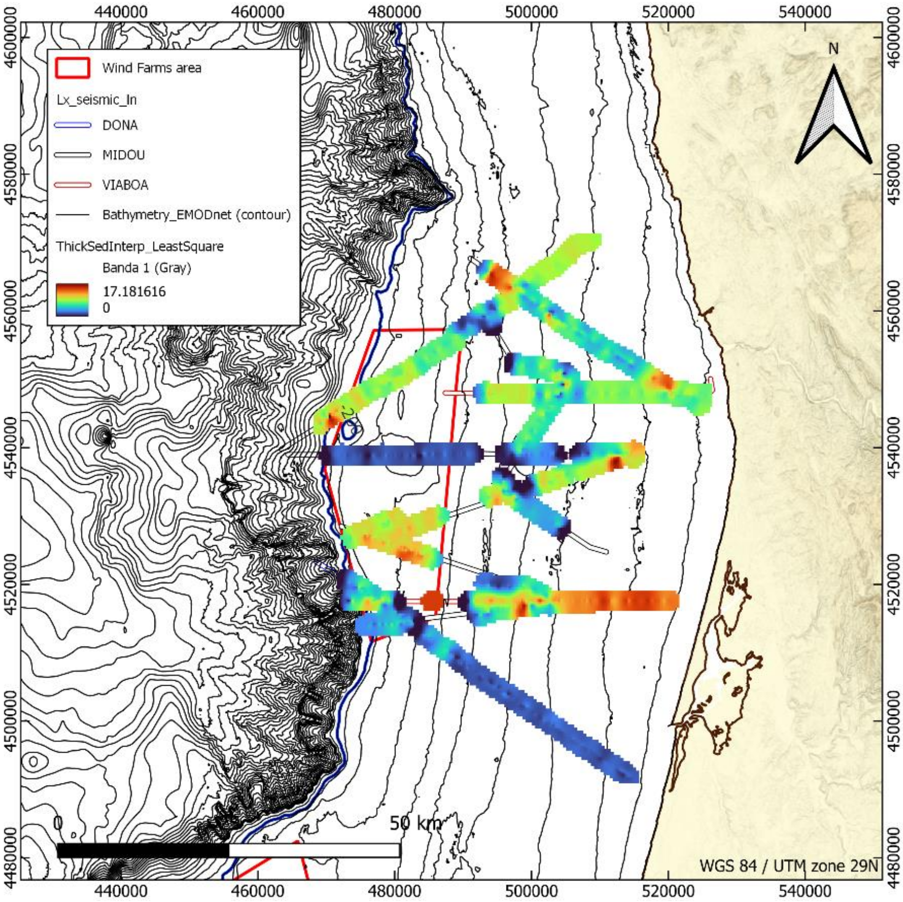


Figure 3.17 - Surface grid of the interpreted sediment thickness, resultant from a least square interpolation considering a buffer range of 1500 m around the seismic lines.

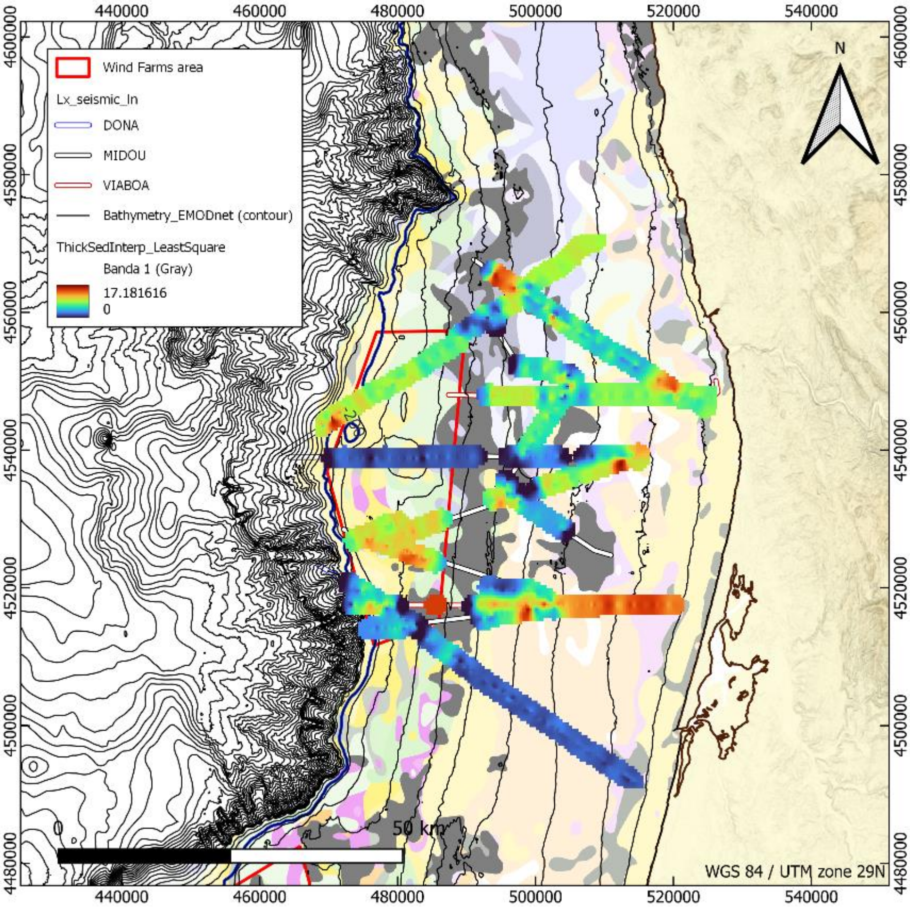


Figure 3.18 - Surface grid of the interpreted sediment thickness, resultant from a least square interpolation considering a buffer range of 1500 m around the seismic lines, plotted on the IH surficial sediments map. (for color legend see Figure 2.3).

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 Leixões were initially conducted during the 1970's and the latest in 2002. They were acquired and processed by different companies (Table 4.1 and Annex 9.1). The surveys provide a varying quality image of the Mesozoic geology of the area.

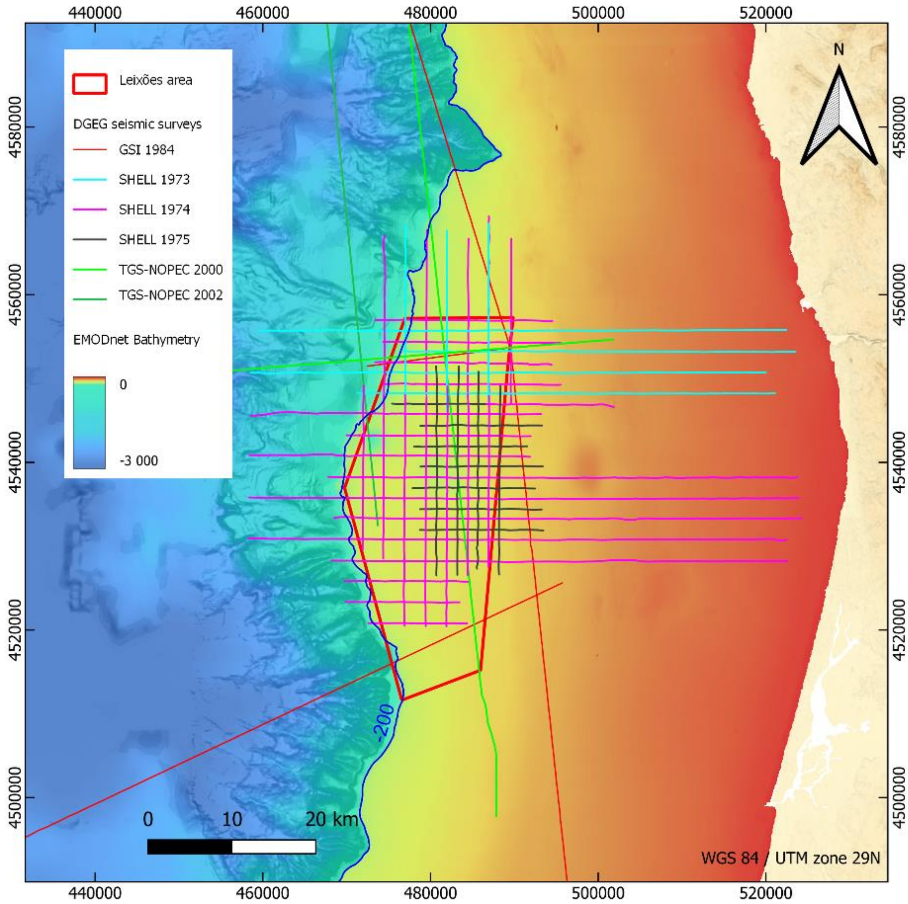


Figure 4.1 - Oil and Gas exploration seismic surveys location.

Table 4.1 - Oil and Gas exploration surveys

Survey	Operator	Year	Nº of lines
GSI 1984	GSI	1984	4
SHELL 1973	Shell	1973	8
SHELL 1974	Shell	1974	28
SHELL 1975	Shell	1975	11
TGS-NOPEC 2000	TGS-NOPEC	2000	3

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 9.1.

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 applicability less than 2. Figure 4.2 presents a spider diagram synthesizing the results of the evaluation.

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.

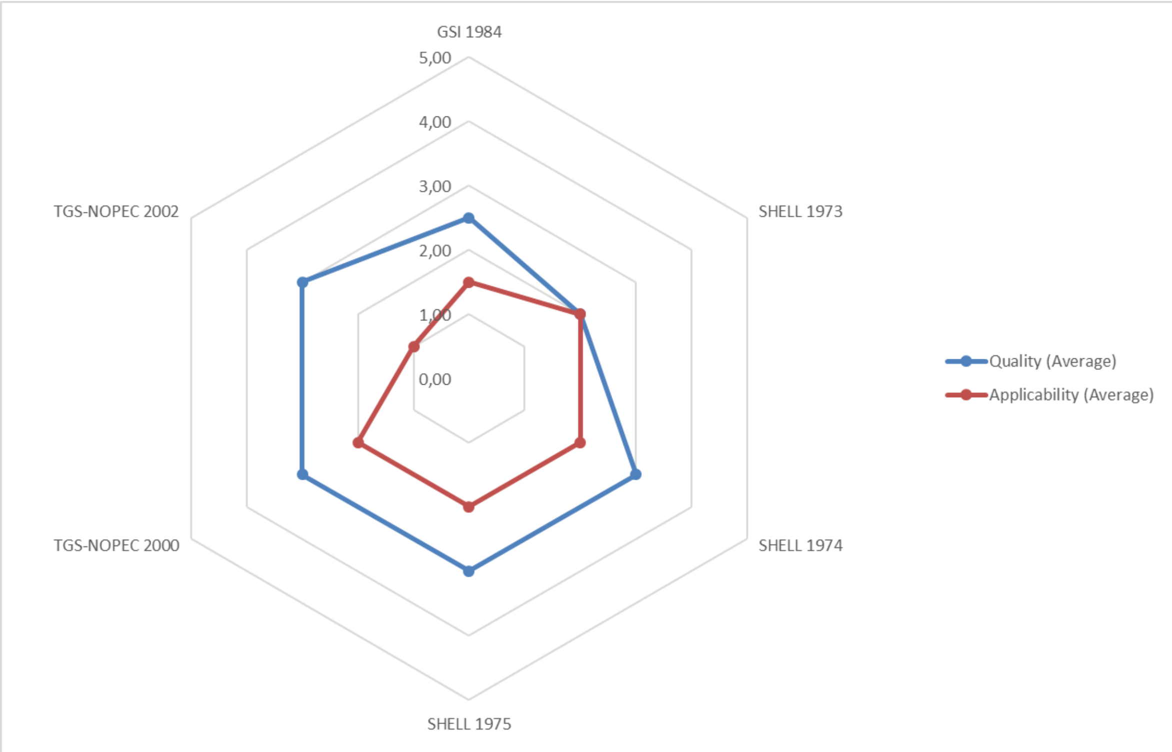


Figure 4.2 Results of the Oil and Gas seismic surveys evaluation.

5. METOCEAN DATA

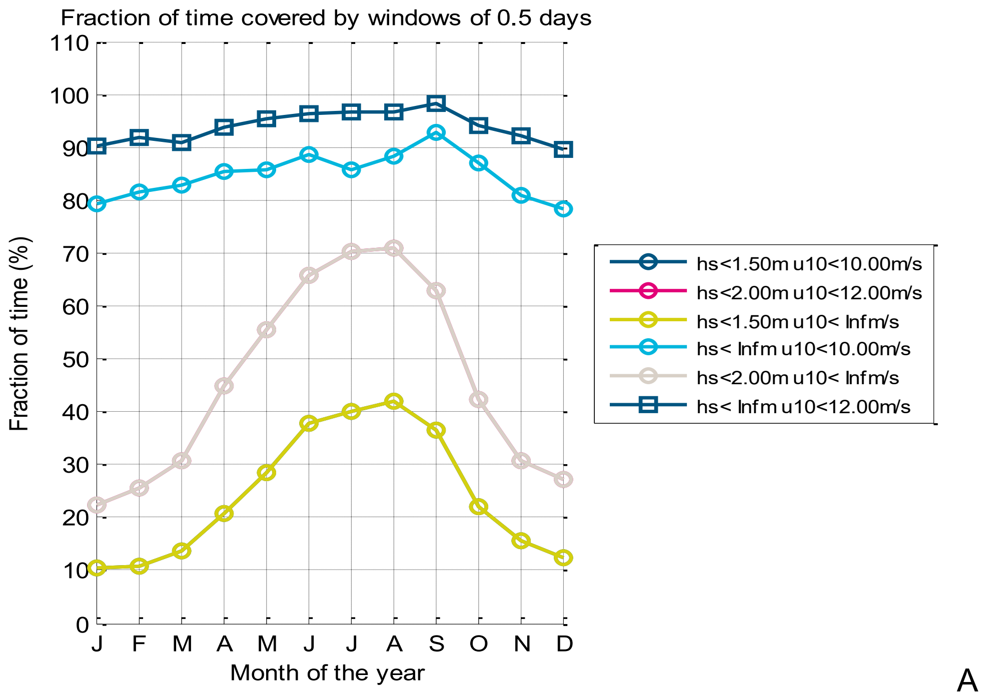
Analysis of the significant wave height and wind speed at 10 m above the sea surface time-series was done considering 12-hour periods for the conditions described in Table 5.1.

Table 5.1 Scenarios for metocean persistency analysis

Scenario	Wave Significant Height (m)	Wind Speed (m/s)
C1	< 1.50	< 10.00
C2	< 2.00	< 12.00
C3	< 1.50	no limit
C4	no limit	<10.00
C5	< 2.00	no limit
C6	no limit	< 12.00

Figure 5.1A and Figure 5.1B present the results of the analysis for the central point of the Leixões deployment area regarding the fraction of time covered by 12 hours windows per month (minimum, maximum and mean values for the 12 months are presented in Annex 9.2, 9.3). Results show that regardless of scenario, months with better joint conditions of significant wave height and 10 m high wind speed are the months of the May-October period (Figure 5.1A). For the number of 12 hour windows, results are similar (Figure 5.1B). The estimated delay time (Figure 5.2) is significantly different between the scenarios: for scenarios C3 and C5, the period of May to September, is the more favorable for the work at the sea.

Detailed plots are presented in Annex 9.3.



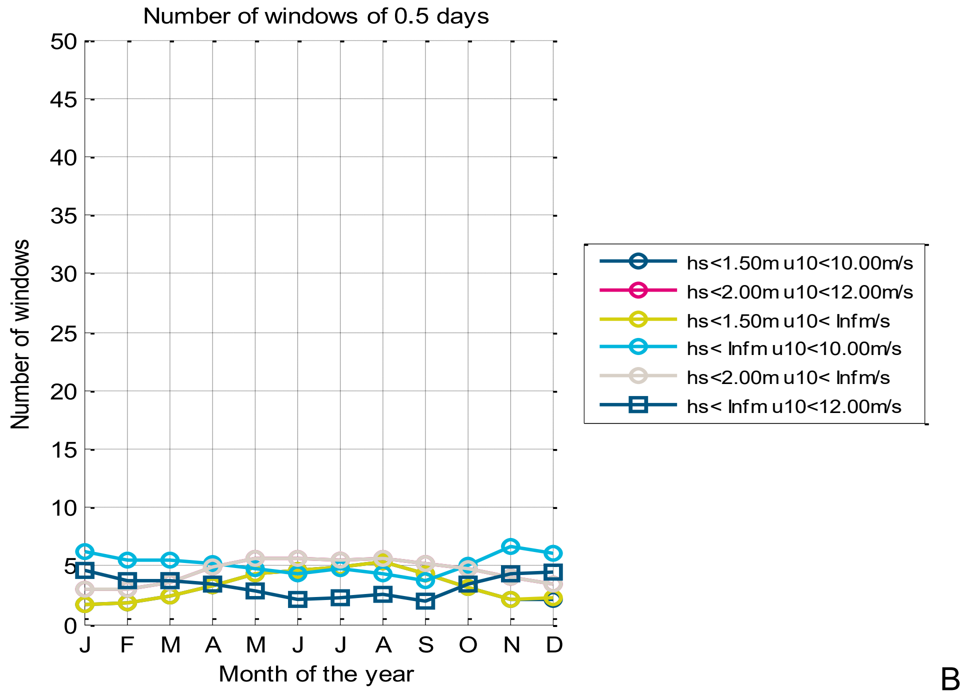


Figure 5.1 Variation over the years of the extent (A) and the number of weather windows (B) per month

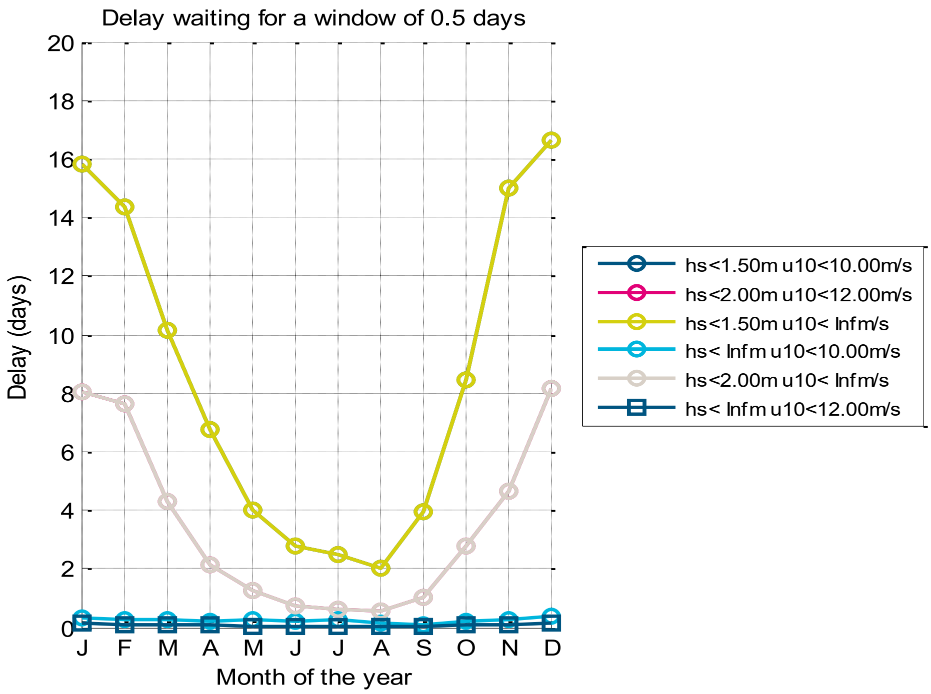


Figure 5.2 Variation of mean delay waiting for weather windows over the years

6. ARCHAEOLOGICAL HERITAGE

In the area of Leixões, 60 potential occurrences are referred in the databases: 5 correspond to aircraft crashes, 17 are shipwrecks and the remaining 38 are of an undetermined nature (Figure 6.1). The oldest bibliographical reference of a shipwreck on this coast dates back to 1691, corresponding to the loss of a ship coming from Brazil loaded "with a thousand chests of sugar". During the centuries that followed, there were fewer references to accidents along this coast than in the area further north, with emphasis on the loss of the ships São José and Nossa Senhora das Mercês in 1793, with almost all of his crew and cargo, on his way back from Spain, where he had been on a military mission.

For more recent periods, we highlight the activity of German submarines during the first and second world wars. At least, two of these submarines rest in these waters, U-566 and U-1277, both sunk by crews in 1943 and 1945 respectively. At the time of the sinking, it is unknown what weapons were on board, but a VIIC class submarine, such as the U-566, would have a maximum capacity of 14 torpedoes, complemented by an 8.8 cm artillery piece and the corresponding ammunition and 1 or 2, 20 mm anti-aircraft machine guns.

War activity in recent times has led to a considerable loss of vessels in these waters, especially during the First World War. In the project's affected area, off Leixões, we found records of two cargo ships that would have sunk as a result of the German submarine war, the SS Britannic and the Giralda. The SS Britannic, was loaded with iron ore for Barrow, from Almeria, when it was sunk in 1917 by the German submarine UC-37. The SS Giralda on her way to Pasajes with iron pyrites, from Huelva, when she was sunk by U-152.

The SS River Tyne sank in October 1916 with a load of iron ore that moved in the basement.

During the Second World War, several aircraft were lost. All 5 occurrences for this area are British bombers crashed in 1943. Two bombers crashed off Porto after breaking down. These correspond to a Short Sutherland and a Bristol Blenheim respectively. The first corresponds to a seaplane known mainly for its capabilities against submarines, although we cannot say with certainty what its configuration or armament would have been at the time of the accident.

Two other bombers docked off Vila do Conde, and Póvoa de Varzim, a Vickers Wellington and a Bristol Blenheim, the latter possibly washing ashore later. These aircraft have the particularity of being light bombers with a crew of just two and a smaller bomb load capacity, around 500kg, although the configuration and armament of this specific aircraft are not known.

A last Vickers Wellington crashes off Cortegaça after reports of combat with a German Junkers JU88 aircraft. Once again, the weapons that were on board the aircraft at the time of the loss are unknown.

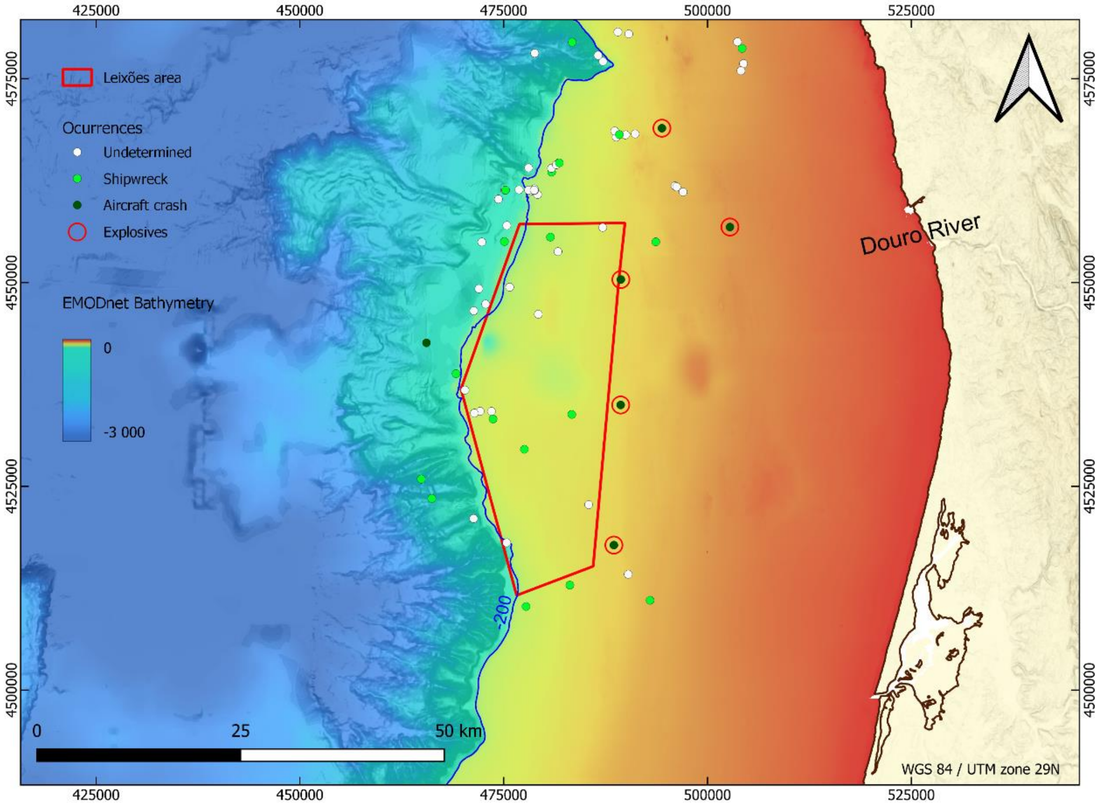


Figure 6.1 Location of potential archeological occurrences

7. 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 19 m maximum thickness.

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 2.3), which are consistent with seismic profiles.

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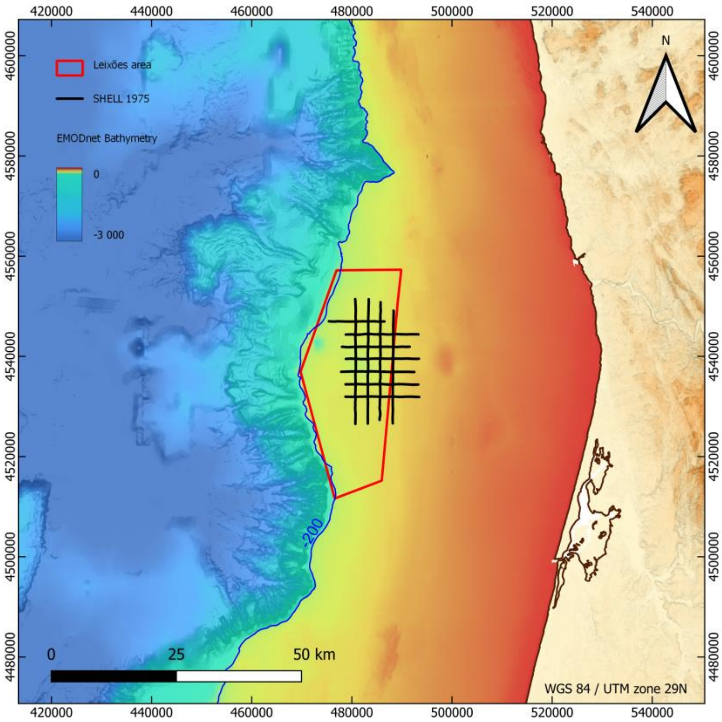
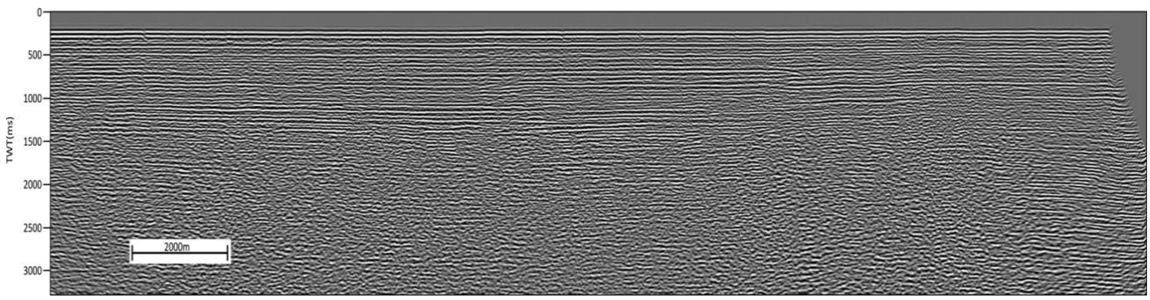
9. ANNEXES

9.1. Oil and Gas Surveys Characterization Files

Survey Name	SHELL75		Survey Dates	14/09/1975 to 05/10/1975	
Promotor	Shell Prospex Poruguesa S.A.R.L.		Contractor	Seismograph Service LTD	
Vessel	M.V. Seis Mariner		Data Holder	DGEG (Portugal)	
Main Objectives	Oil & Gas exploration				
Positioning	Primary: Extended Range Shoran; Secondary: Doppler Sonar Nav. Syst.				
Type of Data	Processed seismic data in SEG-Y format				
Seismic data					
Seismic Source	Bolt Associates Incorporated; Airgun array, Total Volume/Pressure/Energy: 2100cu.in./2000psi				
Seismic Receiver	Seismic Engineering Company, length: 1500m, groups spacing: 25m, number of channels: 60.				
Sample Size (ms)	4	Trace Length (ms)	6000	Shotpoint Interval (m)	25
Seismic Processing	Velocity analysis; Predictive Deconvolution; Horizontal Stacking				
Observations	Estimated line length in area of interest: 150km				
Data Coverage in Area of Interest					



Seismic Data Example



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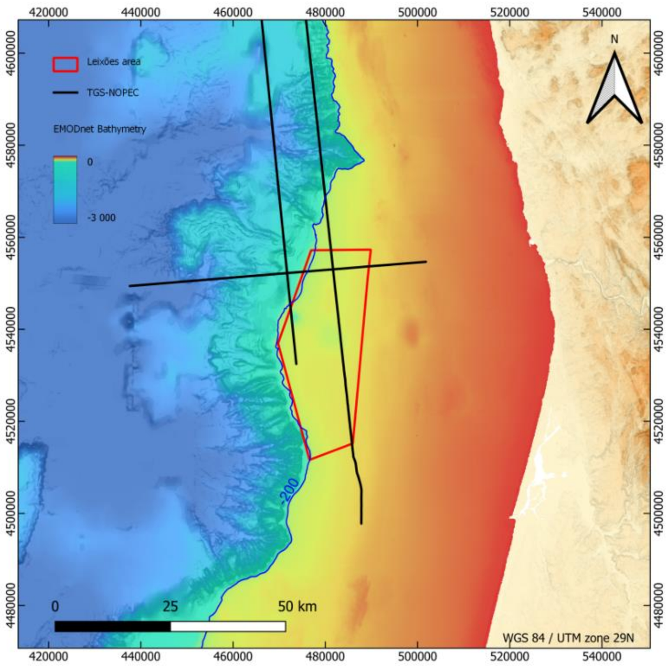
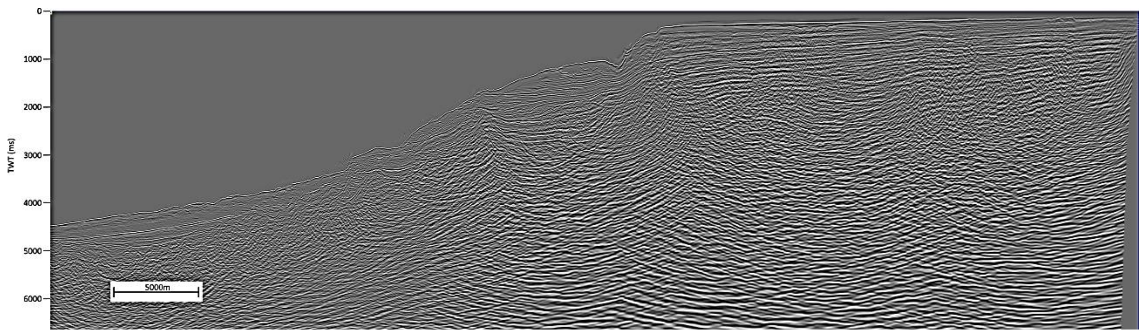
<tr><td>Promotor</td><td colspan="2">TGS-NOPEC Geophysical Company</td><td colspan="2">Contractor</td><td colspan="2">Dalmorneftegophysica (DMNG)</td></tr>
<tr><td>Vessel</td><td colspan="2">M/V Zephyr</td><td colspan="2">Data Holder</td><td colspan="2">DGEG (Portugal)</td></tr>
<tr><td>Main Objectives</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: 65km</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>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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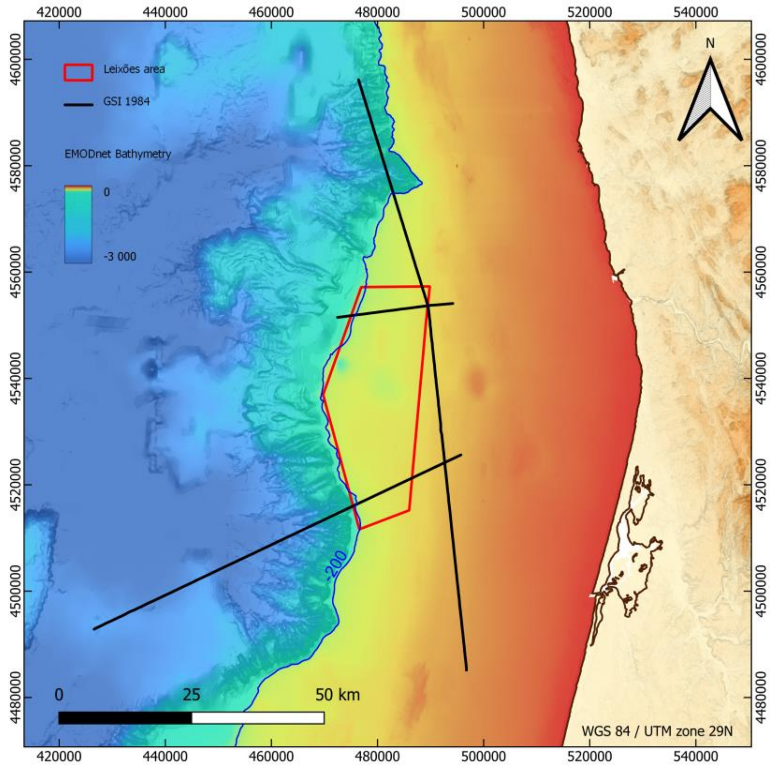
<tr><td colspan="7">
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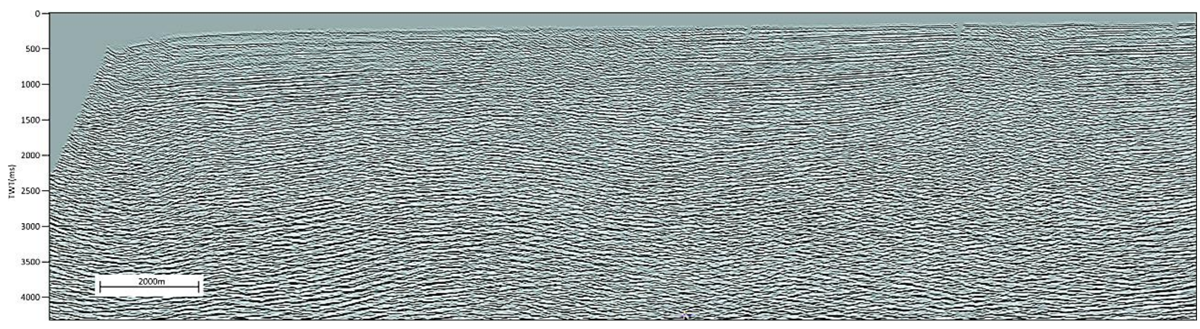
<tr><td colspan="7">
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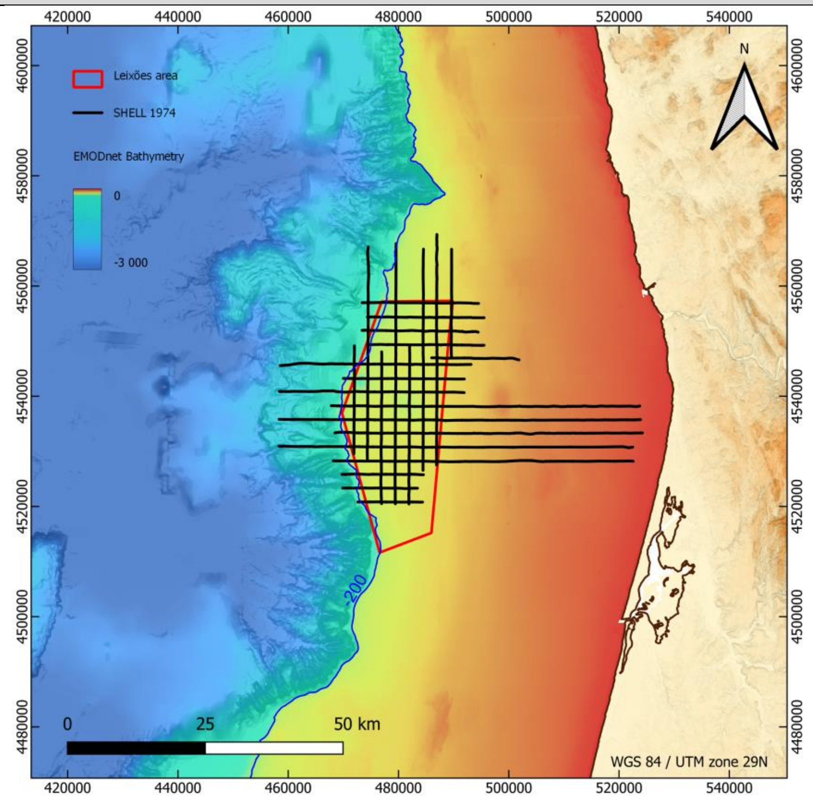
<tr><td>Survey Name</td><td colspan="2">SHELL74</td><td colspan="2">Survey Dates</td><td>April 11 to July11 of 1974</td></tr>
<tr><td>Promotor</td><td colspan="2">Shell Prospex Poruguesa S.A.R.L.</td><td colspan="2">Contractor</td><td>Seismic Explorations International</td></tr>
<tr><td>Vessel</td><td colspan="2">M/V Seismic Surveyor</td><td colspan="2">Data Holder</td><td>DGEG (Portugal)</td></tr>
<tr><td>Main Objectives</td><td colspan="5">Oil & Gas exploration</td></tr>
<tr><td>Positioning</td><td colspan="5">Complete X-R Shoran system.</td></tr>
<tr><td>Type of Data</td><td colspan="5">Processed seismic data in SEG-Y format</td></tr>
<tr><td colspan="6">Seismic data</td></tr>
<tr><td>Seismic Source</td><td colspan="5">Airgun array, Total Volume/Pressure/Energy: 1602cu.in./2000psi</td></tr>
<tr><td>Seismic Receiver</td><td colspan="5">Seismic Engineering Company, 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>Shotpoint Interval (m)</td><td>25</td></tr>
<tr><td>Seismic Processing</td><td colspan="5">Velocity analysis; Predictive Deconvolution; Horizontal Stacking</td></tr>
<tr><td>Observations</td><td colspan="5">Estimated line length in area of interest: 400km</td></tr>
<tr><td colspan="6">Data Coverage in Area of Interest</td></tr>
<tr><td colspan="6">
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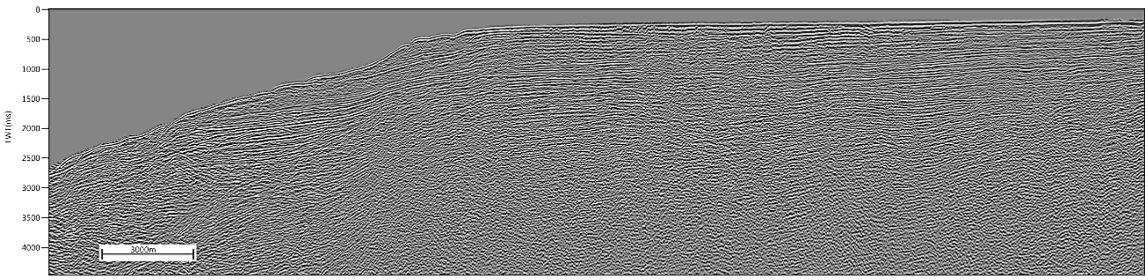
<tr><td colspan="6">Seismic Data Example</td></tr>
<tr><td colspan="6">
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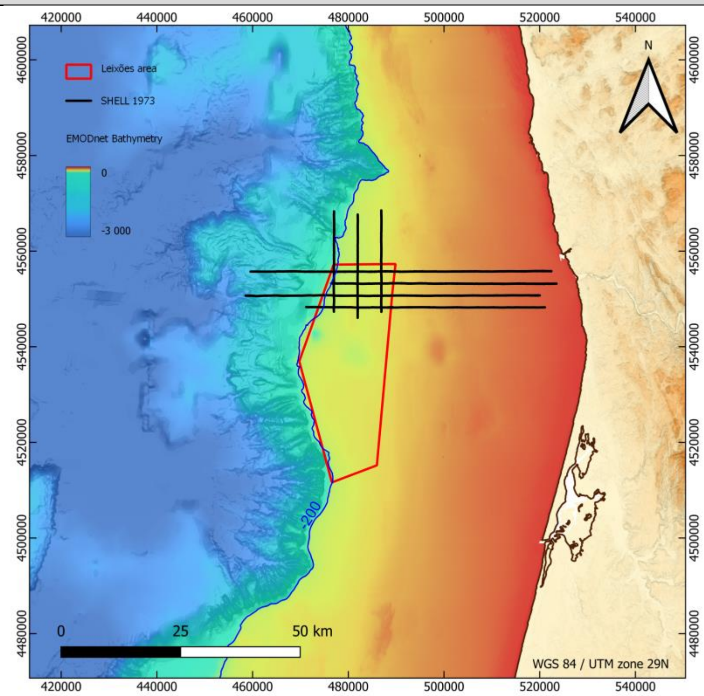
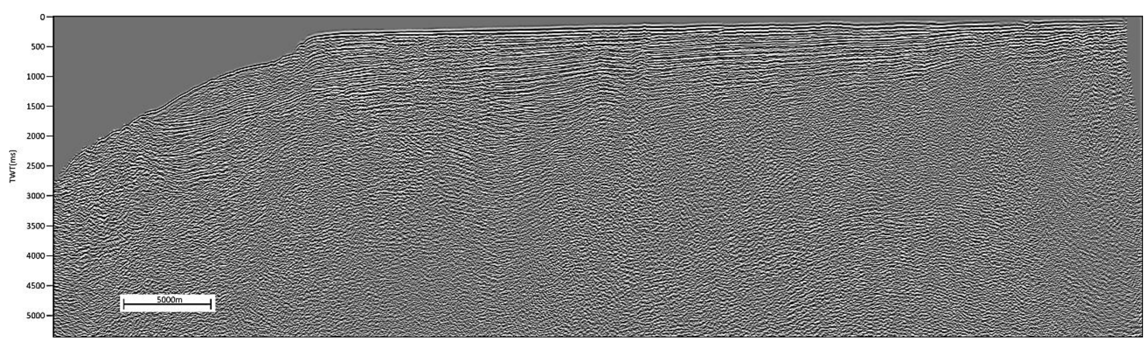
<table>
<tr><td>Survey Name</td><td colspan="2">SHELL73</td><td colspan="2">Survey Dates</td><td colspan="2">01/10/1973 to 02/12/1973</td></tr>
<tr><td>Promotor</td><td colspan="2">Shell Prospex Portuguesa S.A.R.L.</td><td colspan="2">Contractor</td><td colspan="2">Seismograph Service LTD</td></tr>
<tr><td>Vessel</td><td colspan="2">M.V. Seis Mariner</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">Primary: Extended Range Shoran; Secondary: Doppler Sonar Nav. Syst.</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">Bolt Associates Incorporated; Airgun array, Total Volume/Pressure/Energy: 1200cu.in./150atm</td></tr>
<tr><td>Seismic Receiver</td><td colspan="6">Seismic Engineering, length: 2400m, 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>Shotpoint Interval (m)</td><td colspan="2">25</td></tr>
<tr><td>Seismic Processing</td><td colspan="6">Velocity analysis; Predictive Deconvolution; Horizontal Stacking</td></tr>
<tr><td>Observations</td><td colspan="6">Estimated line length in area of interest: 86km</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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9.2. Metocean Synthetic Data

Parameters for persistency analysis:

Location: 40°59'N, 009°15'W

Data Period: 1980-2023

Window: 0.5 days

Scenario	Wave Significant Height (m)	Wind Speed (m/s)
C1	< 1.50	< 10.00
C2	< 2.00	< 12.00
C3	< 1.50	no limit
C4	no limit	<10.00
C5	< 2.00	no limit
C6	no limit	< 12.00

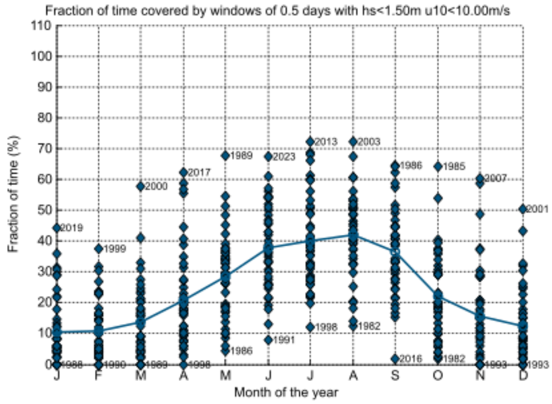
Fraction of time covered by 12 hours windows per month																		
(% time)																		
Limit	**C1**	**C1**	**C1**	**C2**	**C2**	**C2**	**C3**	**C3**	**C3**	**C4**	**C4**	**C4**	**C5**	**C5**	**C5**	**C6**	**C6**	**C6**
Month	**min**	**mean**	**max**	**min**	**mean**	**max**	**min**	**mean**	**max**	**min**	**mean**	**max**	**min**	**mean**	**max**	**min**	**mean**	**max**
Jan	0	10	44	0	22	62	0	10	44	55	79	99	0	22	62	72	90	100
Feb	0	11	38	0	26	71	0	11	38	60	82	99	0	26	71	77	92	100
Mar	0	14	58	2	31	78	0	14	58	54	83	100	2	31	78	23	91	100
Apr	0	21	62	9	45	84	0	21	62	59	85	100	9	45	84	80	94	100
May	4	29	68	25	55	90	4	29	68	59	86	100	25	55	90	85	95	100
Jun	8	38	68	39	66	86	8	38	68	66	89	100	39	66	86	78	96	100
Jul	12	40	72	40	70	90	12	40	72	58	86	98	40	70	90	83	97	100
Aug	13	42	72	50	71	92	13	42	72	71	88	100	50	71	92	86	97	100
Sep	2	37	65	42	63	89	2	37	65	74	93	100	42	63	89	92	98	100
Oct	2	22	64	17	42	81	2	22	64	73	87	100	17	42	81	81	94	100
Nov	0	16	60	2	31	90	0	16	60	56	81	98	2	31	90	82	92	100
Dec	0	12	50	0	27	67	0	12	50	48	78	100	0	27	67	67	90	100

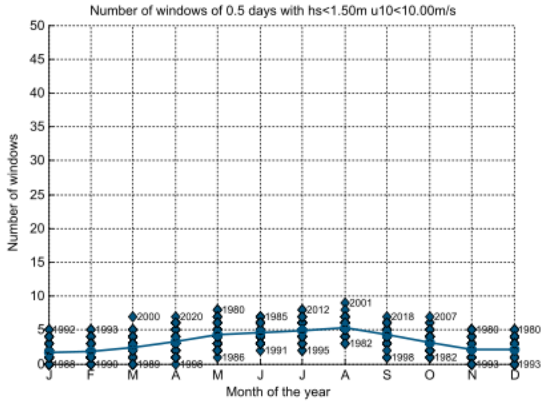
Fraction of time covered by 12 hours windows per month																		
(number of windows)																		
Limit	**C1**	**C1**	**C1**	**C2**	**C2**	**C2**	**C3**	**C3**	**C3**	**C4**	**C4**	**C4**	**C5**	**C5**	**C5**	**C6**	**C6**	**C6**
Month	**min**	**mean**	**max**	**min**	**mean**	**max**	**min**	**mean**	**max**	**min**	**mean**	**max**	**min**	**mean**	**max**	**min**	**mean**	**max**
Jan	0,00	1,73	5,00	0,00	3,07	7,00	0,00	1,70	5,00	2,00	6,25	12,00	0,00	3,07	7,00	1,00	4,66	11,00
Feb	0,00	1,89	5,00	0,00	2,98	7,00	0,00	1,89	5,00	2,00	5,50	10,00	0,00	2,98	7,00	1,00	3,80	10,00
Mar	0,00	2,36	7,00	1,00	3,61	7,00	0,00	2,36	7,00	1,00	5,48	11,00	1,00	3,61	7,00	1,00	3,80	8,00
Apr	0,00	3,32	7,00	2,00	4,86	8,00	0,00	3,32	7,00	1,00	5,14	9,00	2,00	4,86	8,00	1,00	3,36	9,00
May	1,00	4,30	8,00	3,00	5,64	8,00	1,00	4,30	8,00	1,00	4,73	10,00	3,00	5,64	8,00	1,00	2,91	7,00
Jun	2,00	4,59	7,00	2,00	5,59	10,00	2,00	4,59	7,00	1,00	4,25	7,00	2,00	5,59	10,00	1,00	2,07	4,00
Jul	2,00	4,89	8,00	2,00	5,52	10,00	2,00	4,89	8,00	2,00	4,77	8,00	2,00	5,52	10,00	1,00	2,25	7,00
Aug	3,00	5,39	9,00	2,00	5,64	10,00	3,00	5,39	9,00	1,00	4,34	8,00	2,00	5,64	10,00	1,00	2,55	8,00
Sep	1,00	4,34	7,00	1,00	5,20	9,00	1,00	4,34	7,00	1,00	3,70	7,00	1,00	5,20	9,00	1,00	2,05	4,00
Oct	1,00	3,20	7,00	1,00	4,77	8,00	1,00	3,20	7,00	1,00	4,98	10,00	1,00	4,77	8,00	1,00	3,36	8,00
Nov	0,00	2,11	5,00	1,00	3,95	7,00	0,00	2,11	5,00	2,00	6,61	13,00	1,00	3,95	7,00	1,00	4,27	12,00
Dec	0,00	2,18	5,00	0,00	3,45	6,00	0,00	2,20	5,00	1,00	6,00	11,00	0,00	3,45	6,00	1,00	4,48	12,00

Variation of mean delay waiting for weather windows over the years																		
(days)																		
Limit	**C1**	**C1**	**C1**	**C2**	**C2**	**C2**	**C3**	**C3**	**C3**	**C4**	**C4**	**C4**	**C5**	**C5**	**C5**	**C6**	**C6**	**C6**
Month	**min**	**mean**	**max**	**min**	**mean**	**max**	**min**	**mean**	**max**	**min**	**mean**	**max**	**min**	**mean**	**max**	**min**	**mean**	**max**
Jan	2,91	15,82	43,56	0,97	8,02	31,56	2,91	15,82	43,56	0,01	0,30	0,72	0,97	8,02	31,56	0,00	0,12	0,35
Feb	1,85	14,38	37,98	0,55	7,64	24,24	1,85	14,38	37,98	0,01	0,28	0,83	0,55	7,64	24,24	0,00	0,10	0,36
Mar	1,07	10,17	36,31	0,54	4,27	14,50	1,07	10,17	36,31	0,00	0,24	0,79	0,54	4,27	14,50	0,00	0,09	0,52
Apr	0,82	6,73	23,06	0,22	2,13	7,53	0,82	6,73	23,06	0,00	0,21	0,93	0,22	2,13	7,53	0,00	0,07	0,30
May	0,56	4,02	15,12	0,10	1,28	3,61	0,56	4,02	15,12	0,00	0,24	1,34	0,10	1,28	3,61	0,00	0,05	0,22
Jun	0,98	2,77	7,04	0,18	0,73	3,19	0,98	2,77	7,04	0,00	0,18	1,00	0,18	0,73	3,19	0,00	0,05	0,35
Jul	0,60	2,49	7,56	0,13	0,64	2,50	0,60	2,49	7,56	0,02	0,23	1,19	0,13	0,64	2,50	0,00	0,03	0,16
Aug	0,43	2,02	7,76	0,15	0,54	1,23	0,43	2,02	7,76	0,00	0,17	0,57	0,15	0,54	1,23	0,00	0,04	0,17
Sep	0,75	3,97	21,65	0,13	1,02	2,69	0,75	3,97	21,65	0,00	0,08	0,42	0,13	1,02	2,69	0,00	0,02	0,09
Oct	1,78	8,43	22,51	0,27	2,79	12,60	1,78	8,43	22,51	0,00	0,19	0,66	0,27	2,79	12,60	0,00	0,07	0,29
Nov	0,87	15,01	46,06	0,13	4,64	15,33	0,87	15,01	46,06	0,02	0,26	0,58	0,13	4,64	15,33	0,00	0,10	0,33
Dec	2,19	16,64	46,56	0,59	8,15	28,28	2,19	16,63	46,56	0,00	0,37	2,14	0,59	8,15	28,28	0,00	0,13	0,55

9.3. MetOcean Graphic Data

C1





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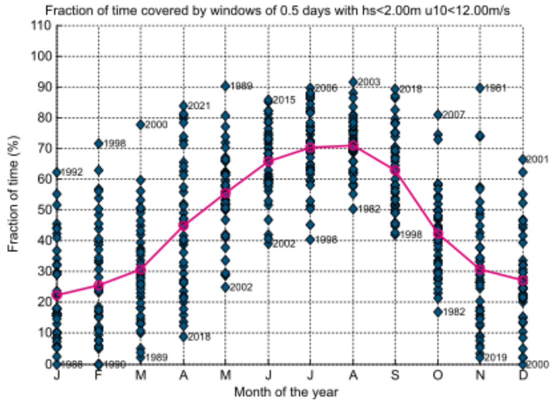

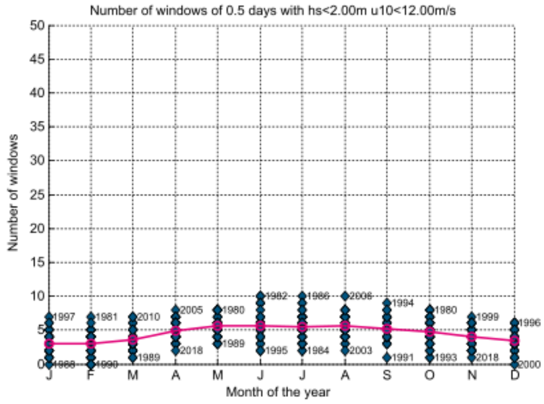

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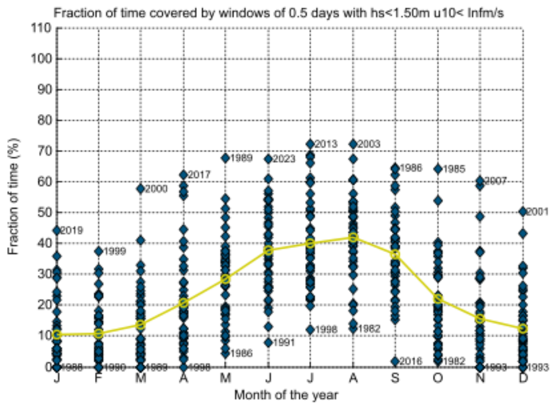

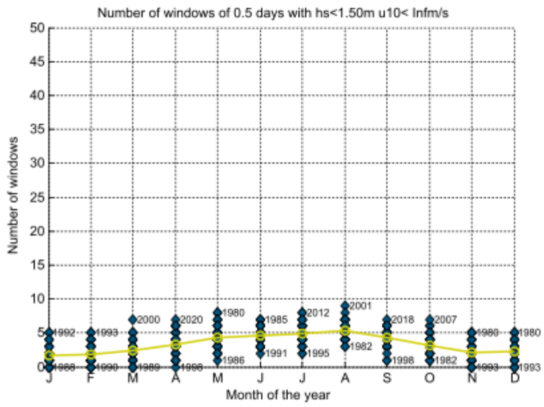

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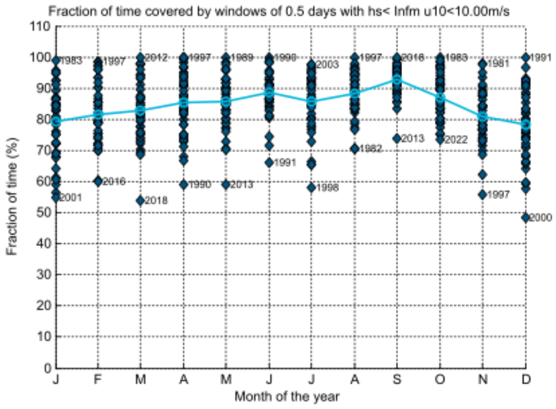
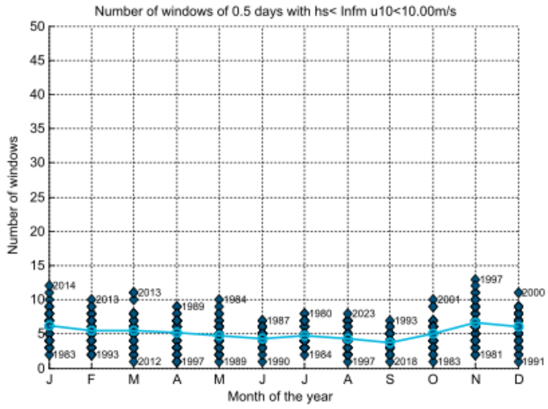
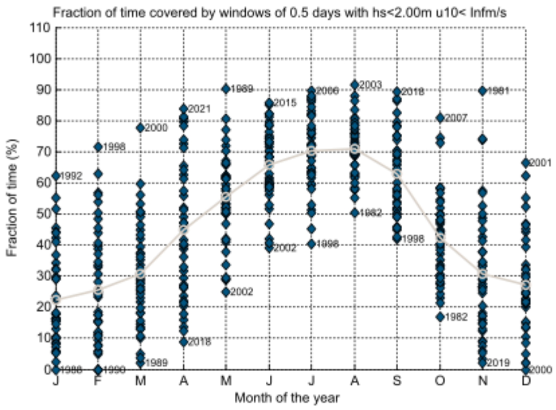
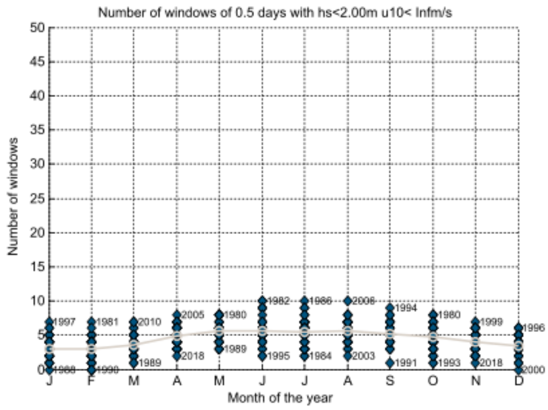

Fraction of time covered by windows of 0.5 days with hs< Infm u10<10.00m/s
Fraction of time (%)
Month of the year
J F M A M J J A S O N D

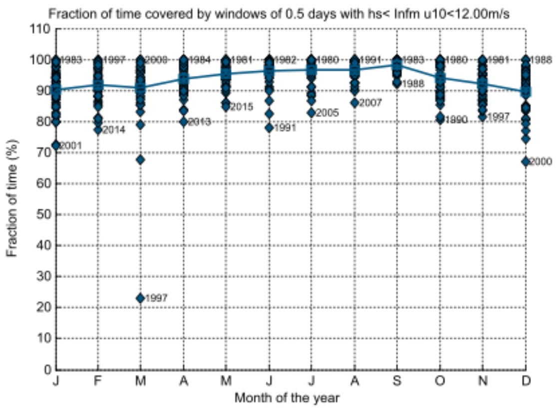

Number of windows of 0.5 days with hs< Infm u10<10.00m/s
Number of windows
Month of the year
J F M A M J J A S O N D

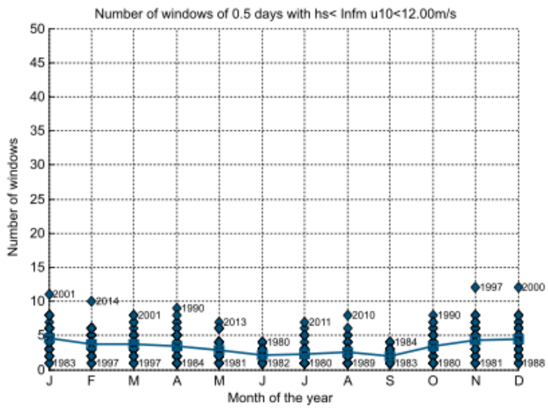
C5

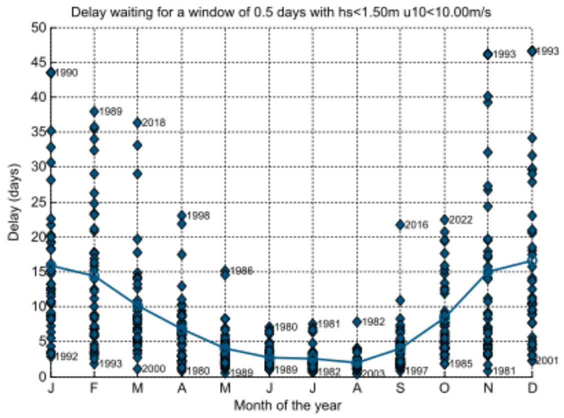

Fraction of time covered by windows of 0.5 days with hs<2.00m u10< Infm/s
Fraction of time (%)
Month of the year
J F M A M J J A S O N D


Number of windows of 0.5 days with hs<2.00m u10< Infm/s
Number of windows
Month of the year
J F M A M J J A S O N D

C6


Fraction of time covered by windows of 0.5 days with hs< Infm u10<12.00m/s
Fraction of time (%)
Month of the year
J F M A M J J A S O N D


Number of windows of 0.5 days with hs< Infm u10<12.00m/s
Number of windows
Month of the year
J F M A M J J A S O N D



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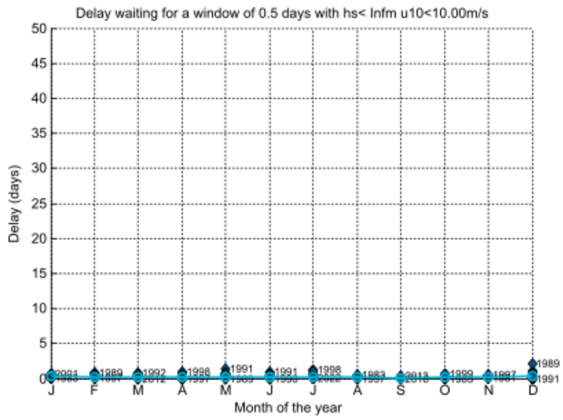

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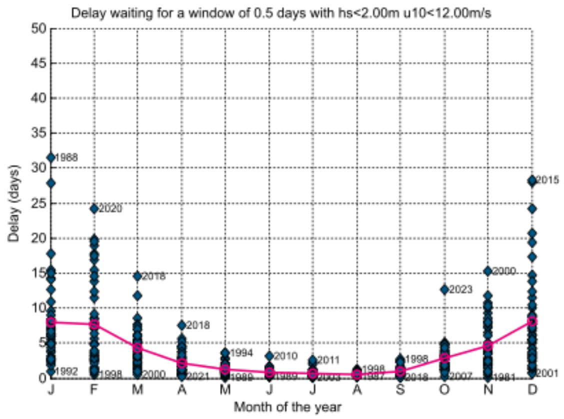

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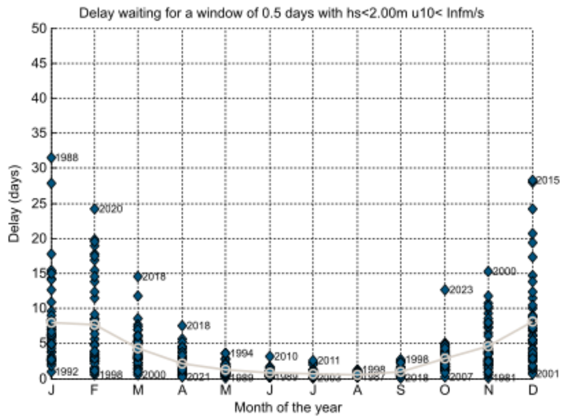

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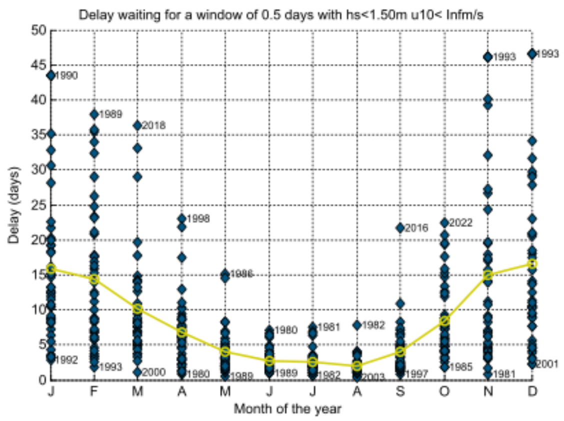

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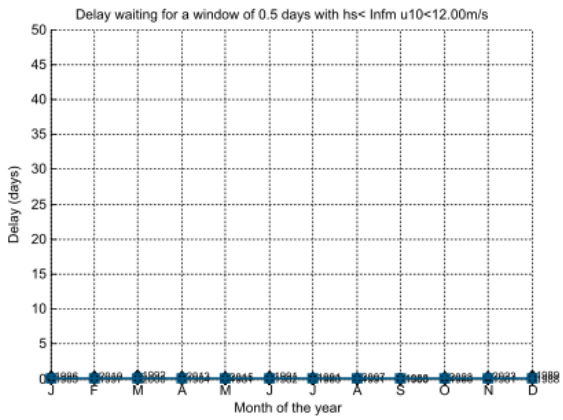
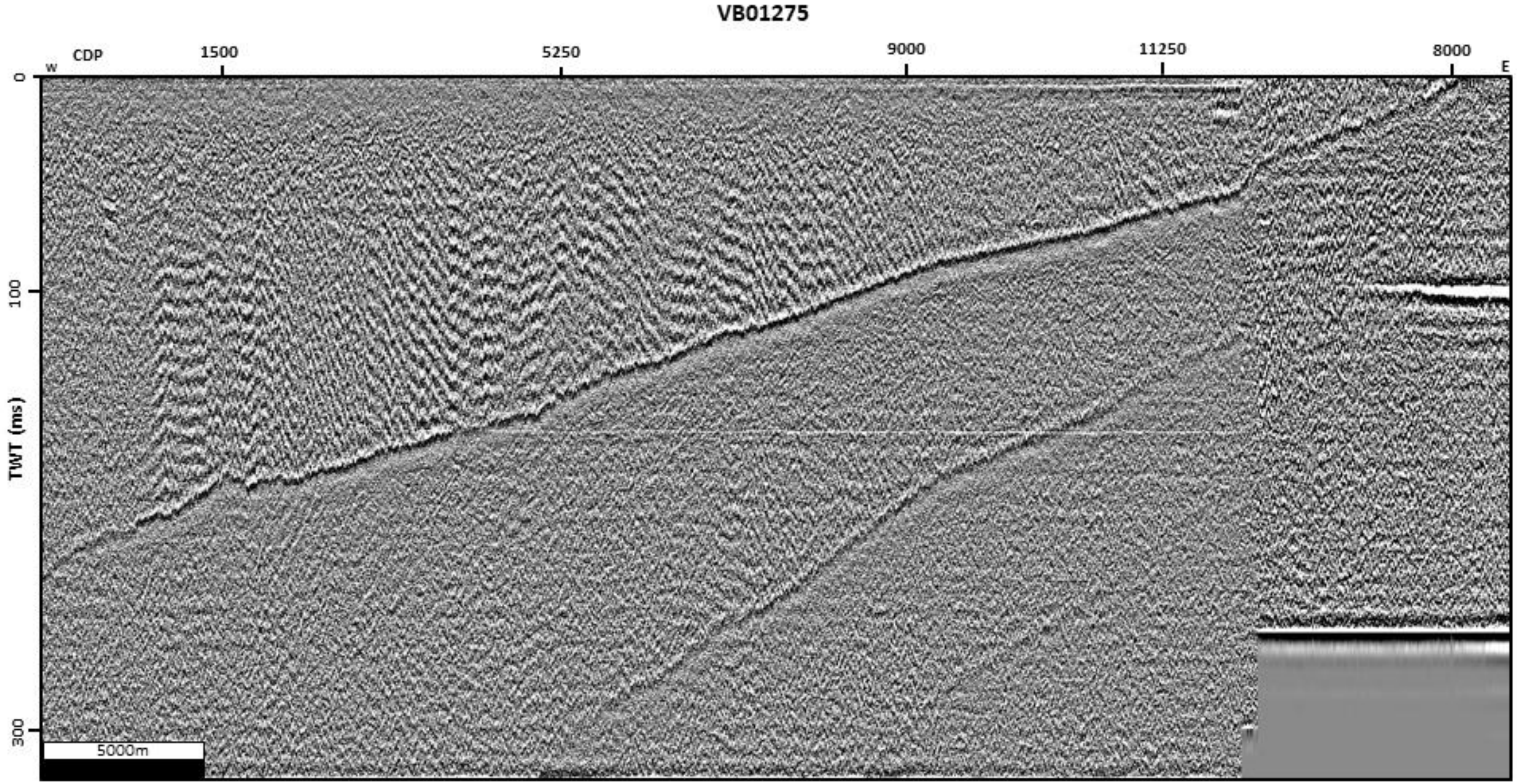
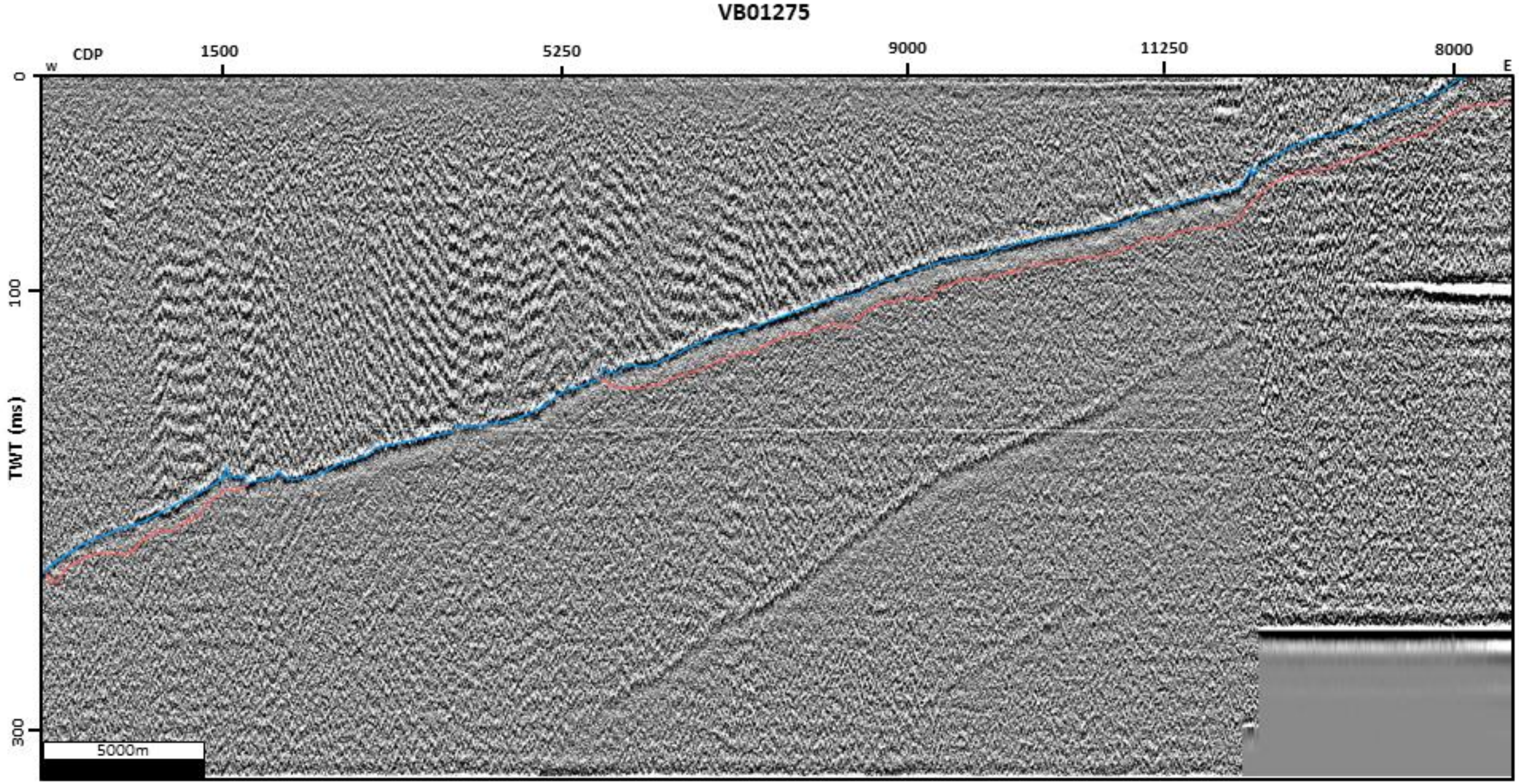
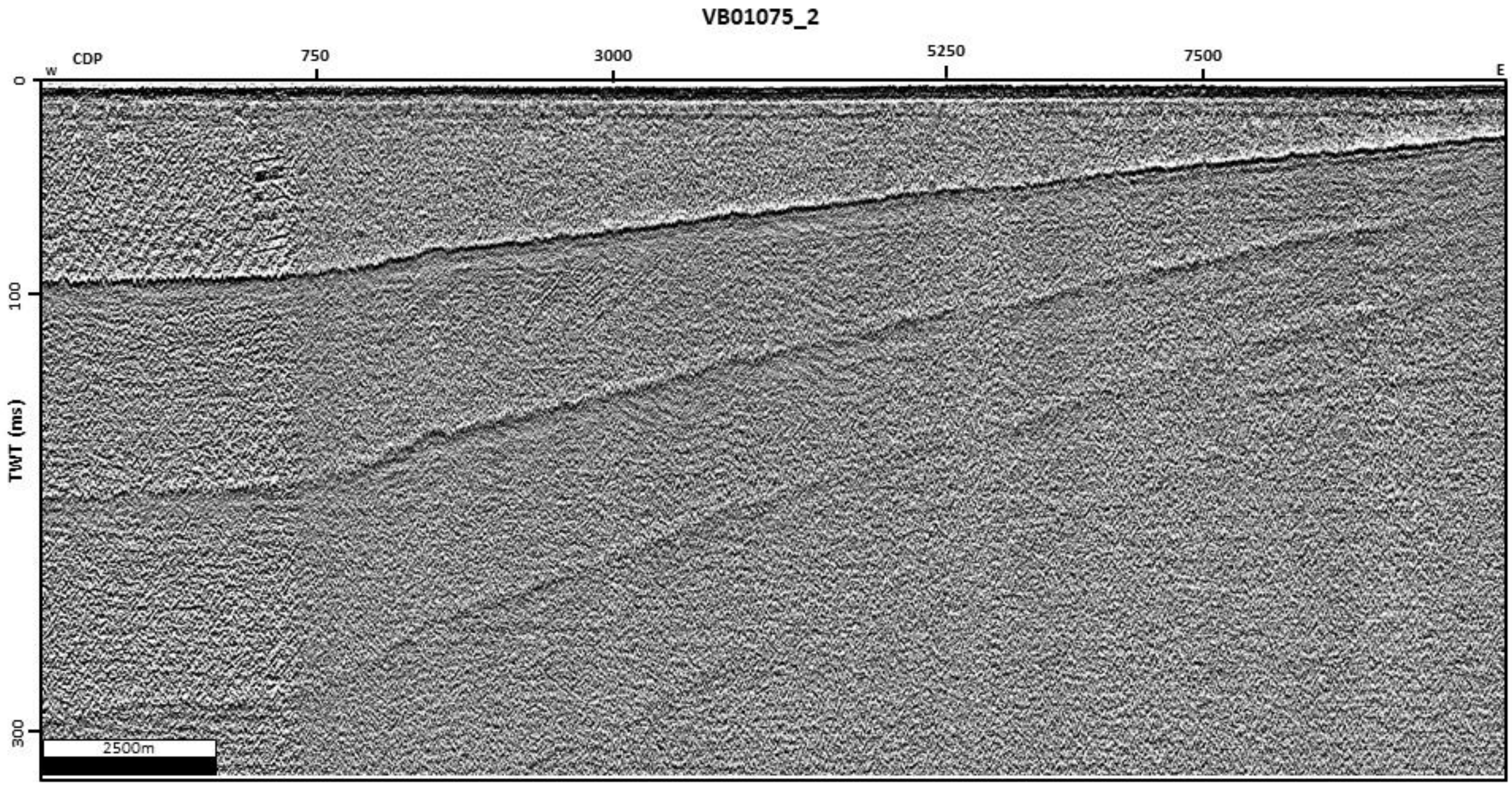


C6

9.4. Examples of ‘Vintage’ Seismic Sections


VB01275
CDP
W
E
1500
5250
9000
11250
8000
0
100
300
TWT (ms)
5000m


VB01275
CDP
1500
5250
9000
11250
8000
W
E
0
100
300
TWT (ms)
5000m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CDP
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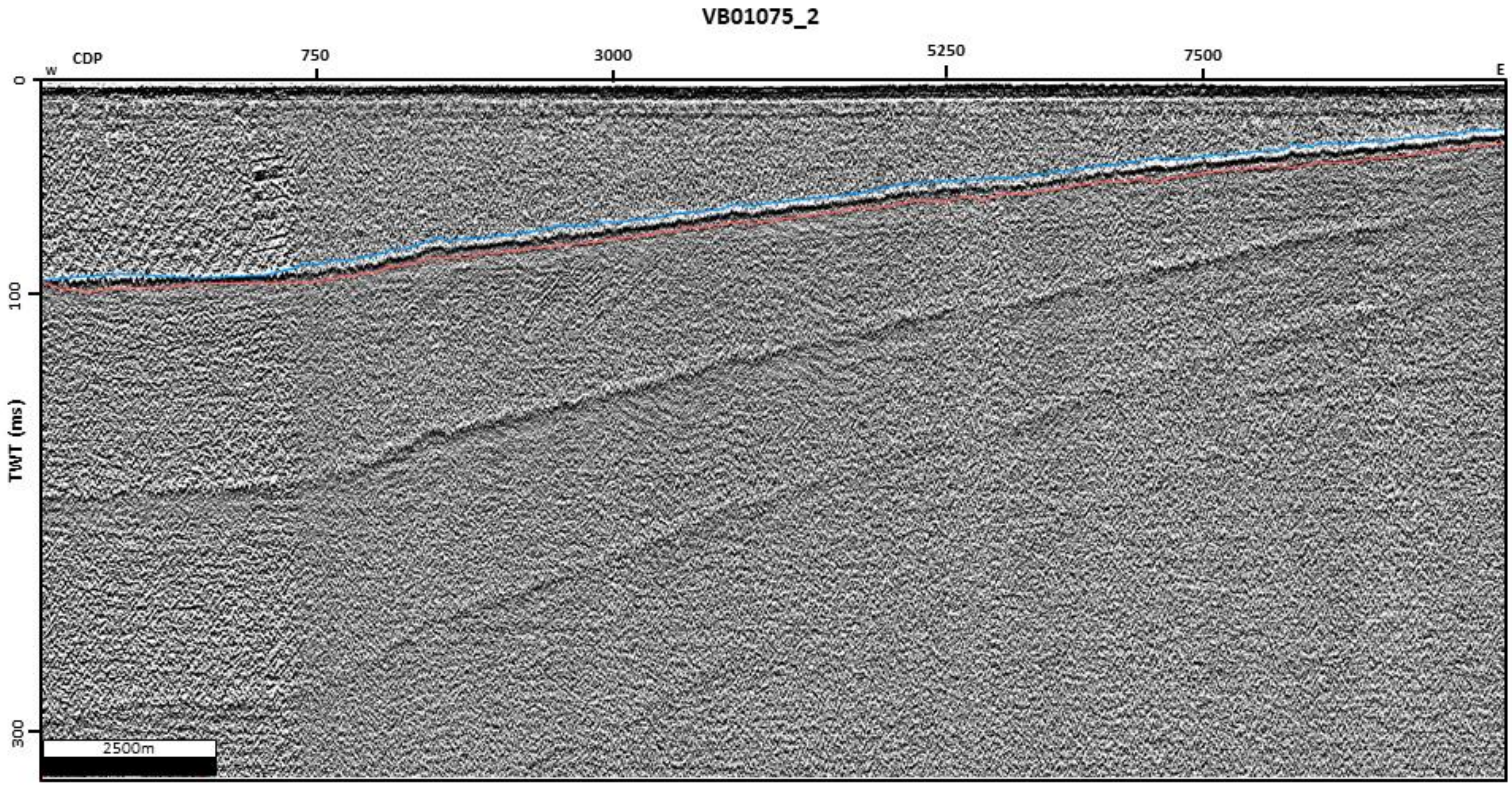
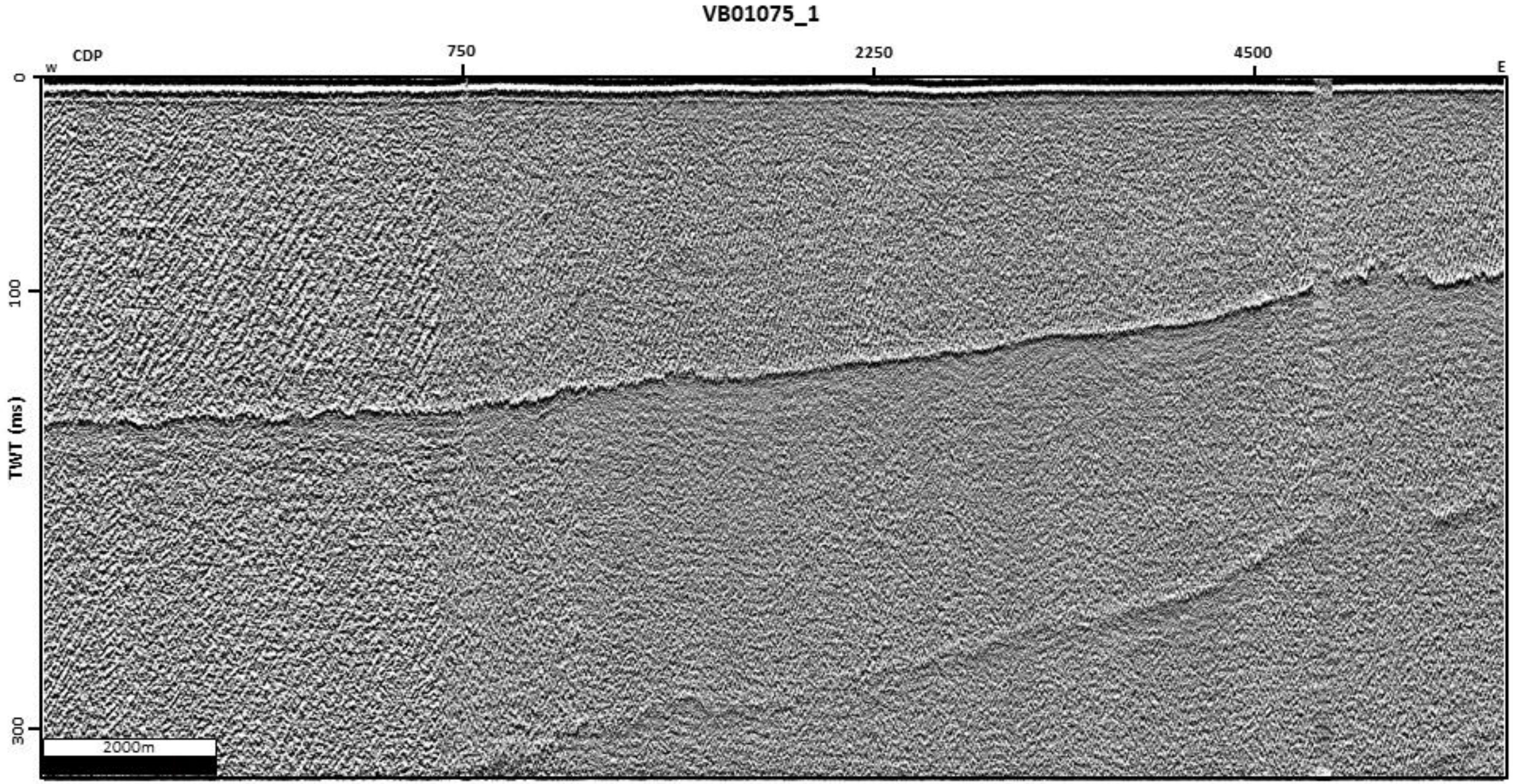
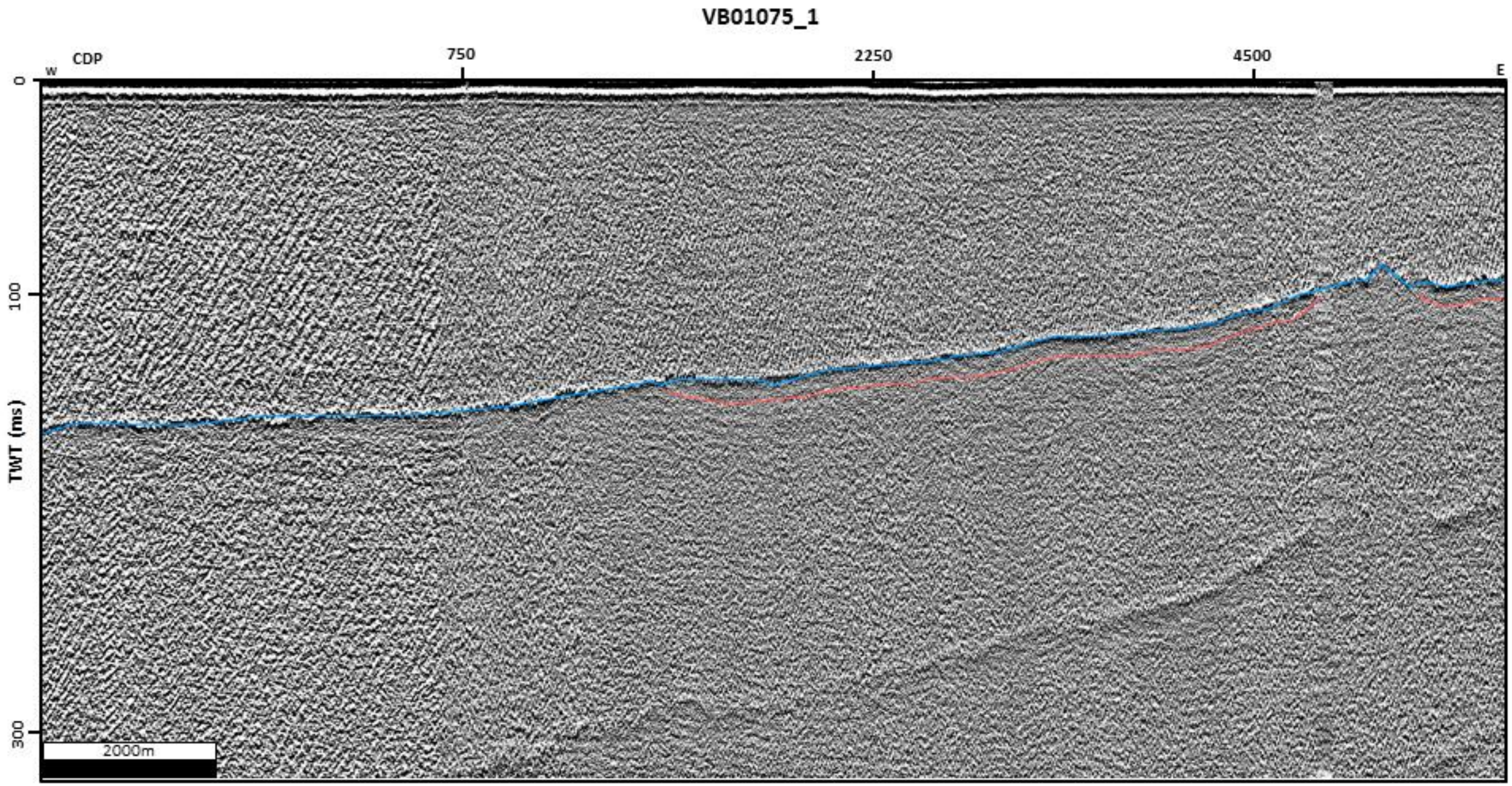
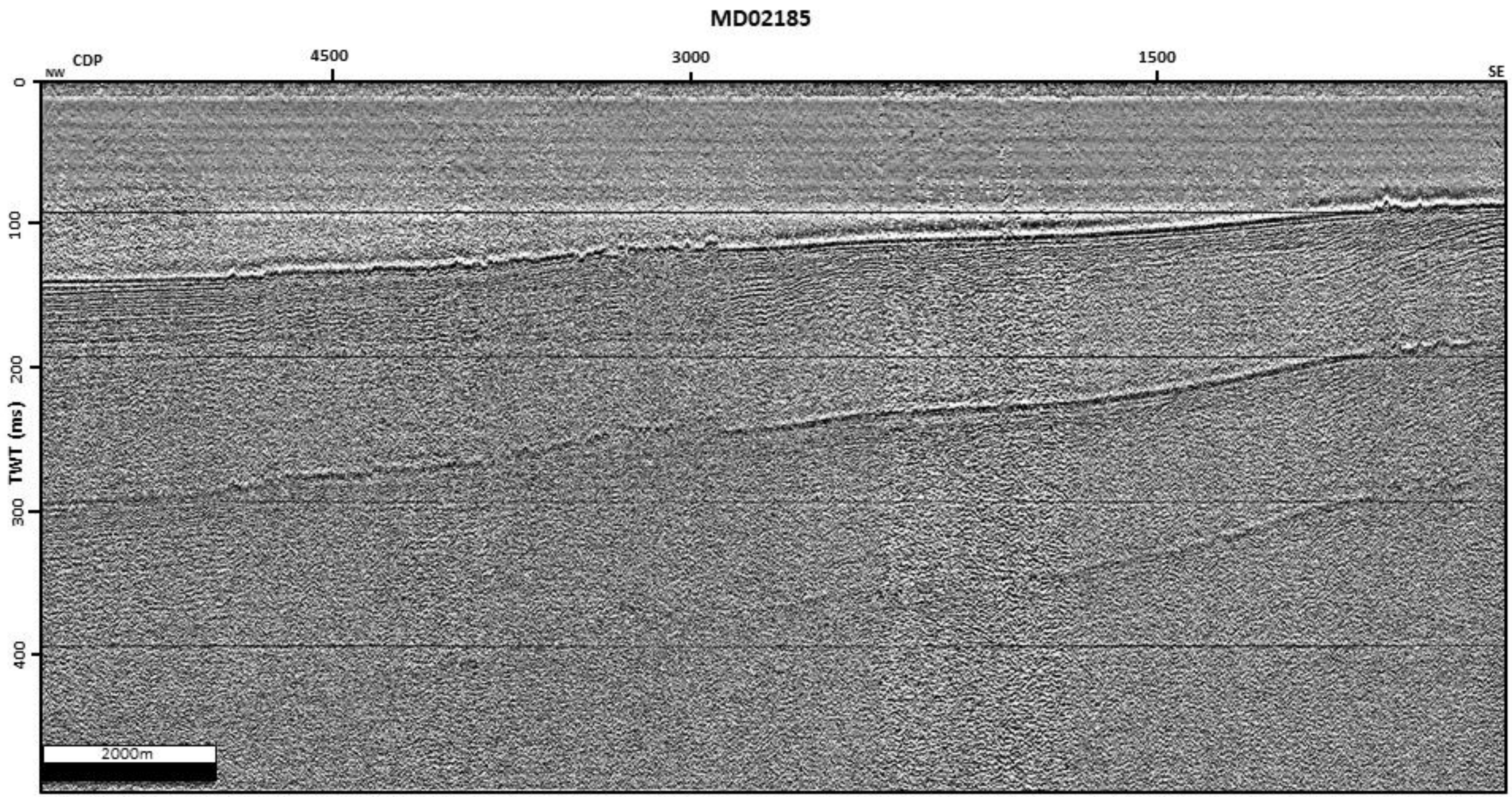
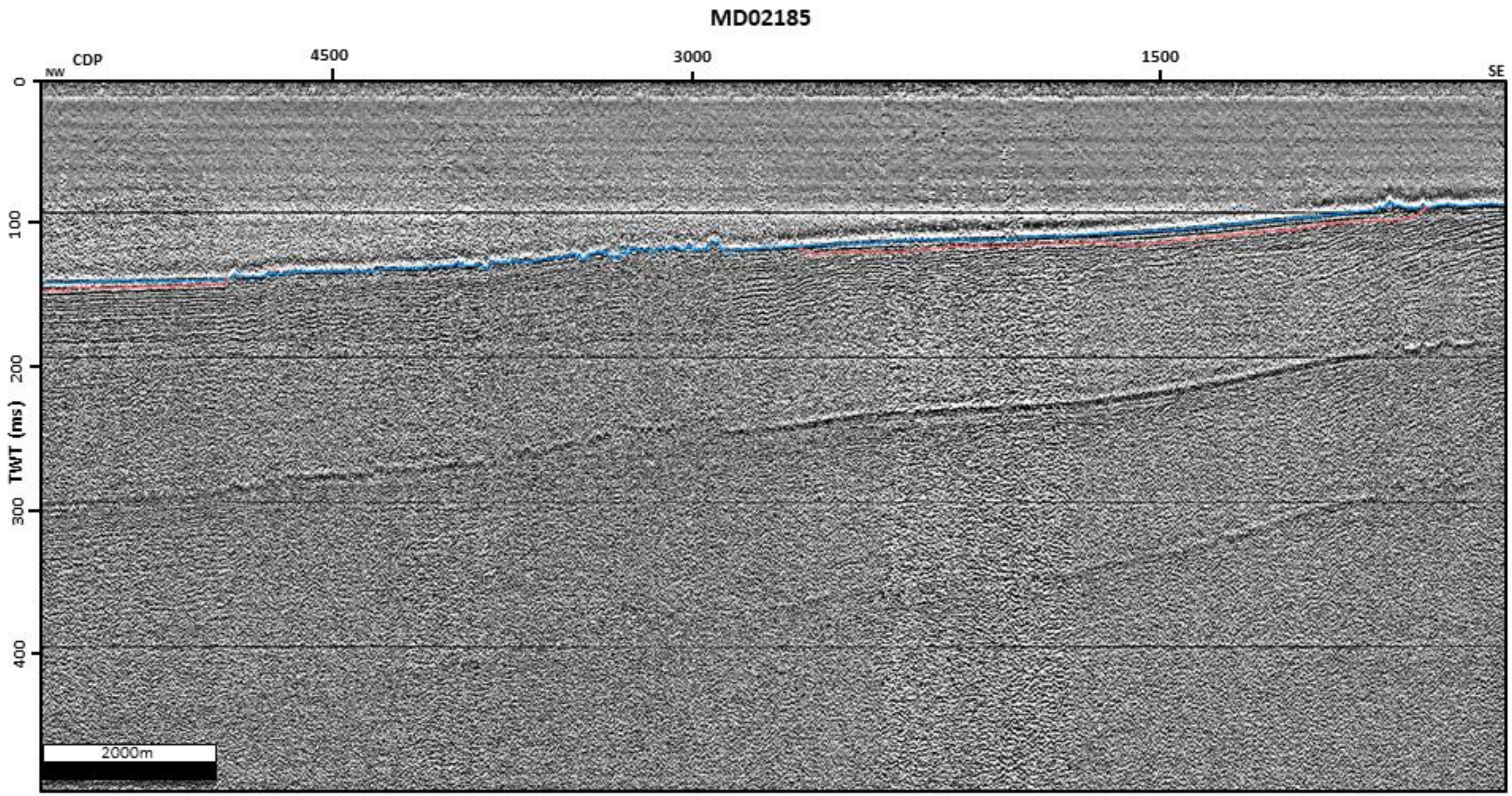
3000
5250
7500
W
E
0
100
300
TWT (ms)
2500m

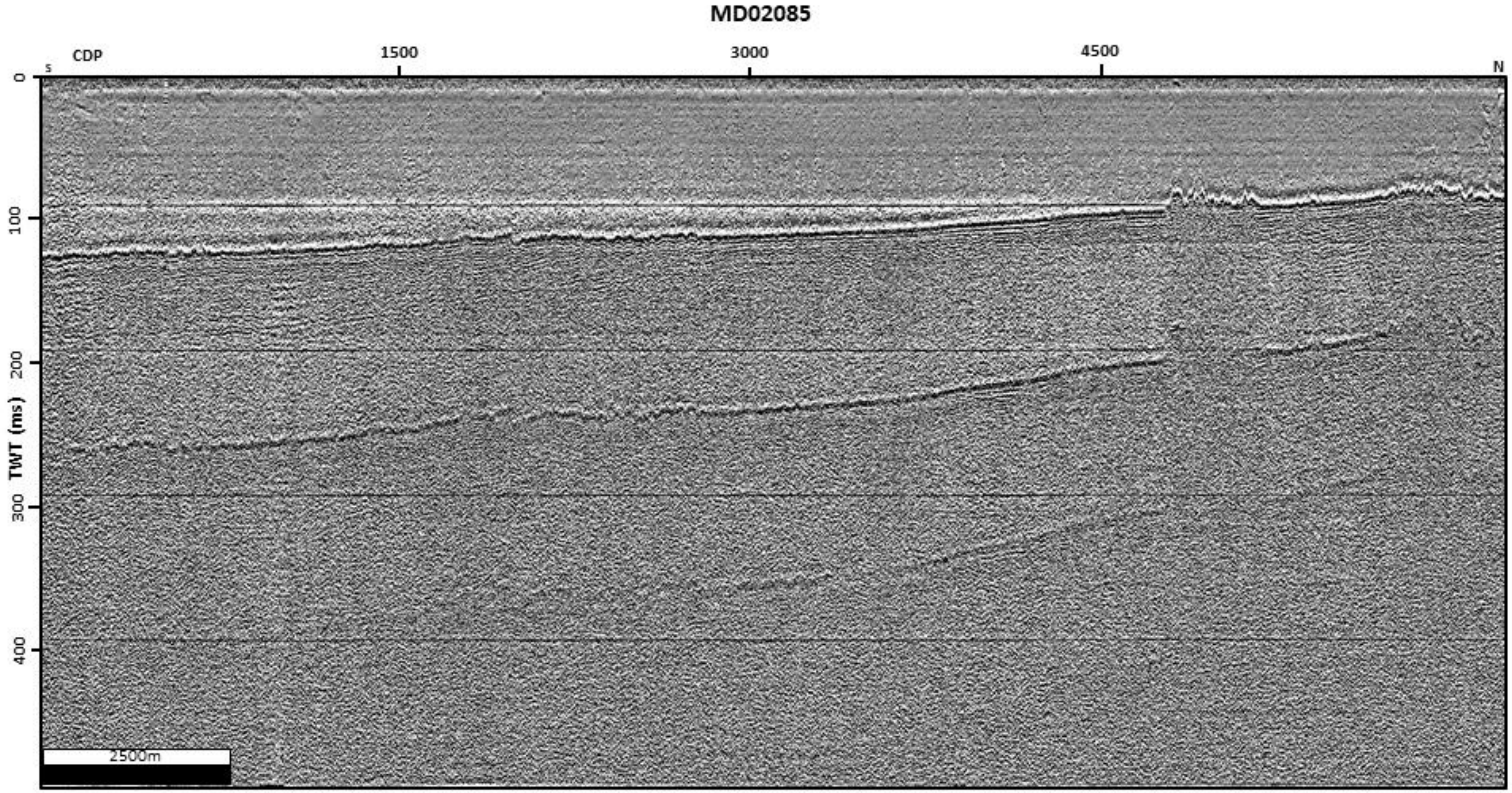

VB01075_2
CDP
750
3000
5250
7500
W
E
0
100
300
TWT (ms)
2500m


VB01075_1
CDP
750
2250
4500
W
E
0
100
300
TWT (ms)
2000m


VB01075_1
CDP
W
750
2250
4500
E
0
100
300
TWT (ms)
2000m


MD02185
CDP
NW
4500
3000
1500
SE
0
100
200
300
400
TWT (ms)
2000m


MD02185
CDP
4500
3000
1500
NW
SE
0
100
200
300
400
TWT (ms)
2000m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CDP
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3000
4500
S
N
0
100
200
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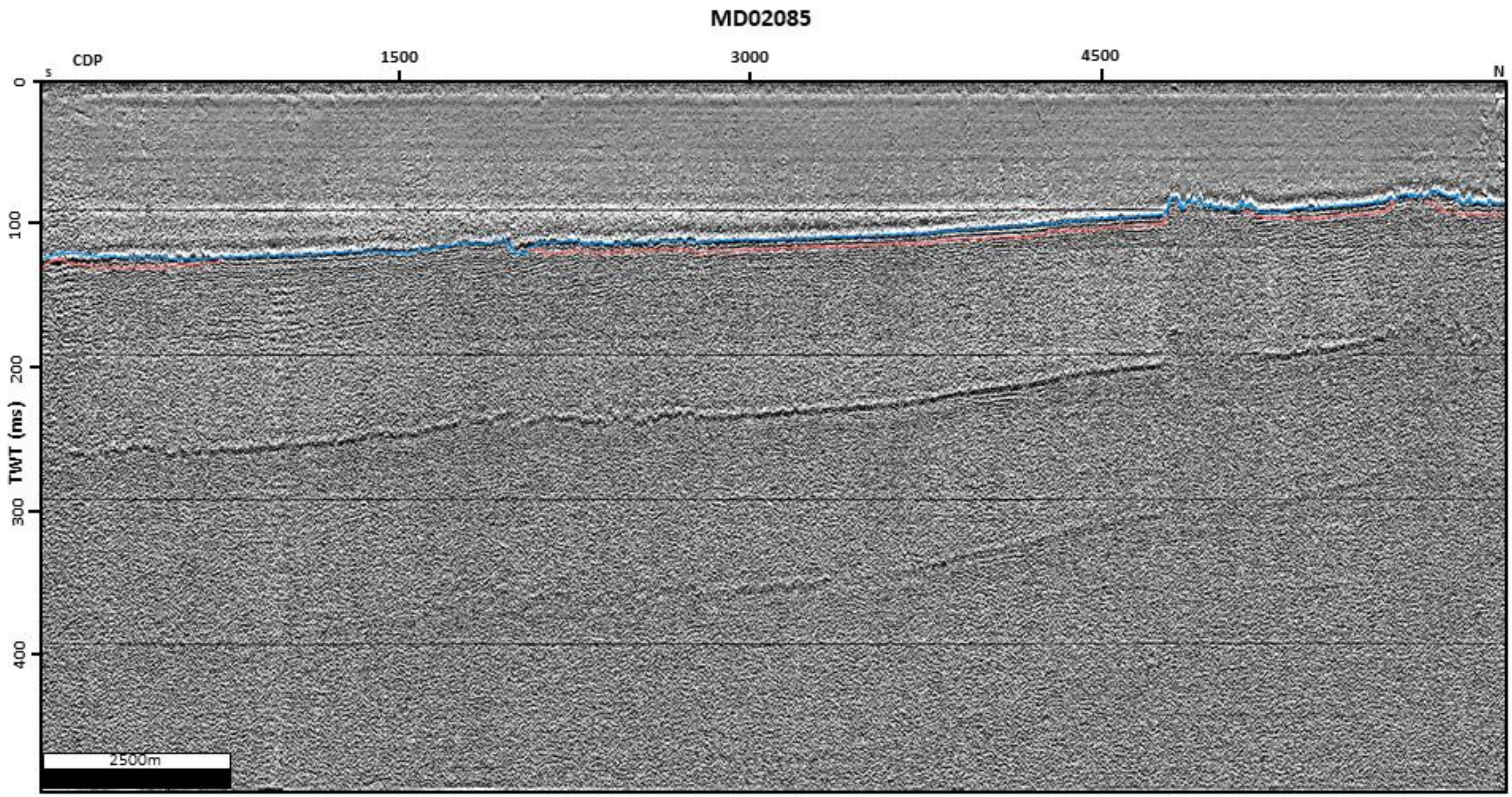
TWT (ms)
2500m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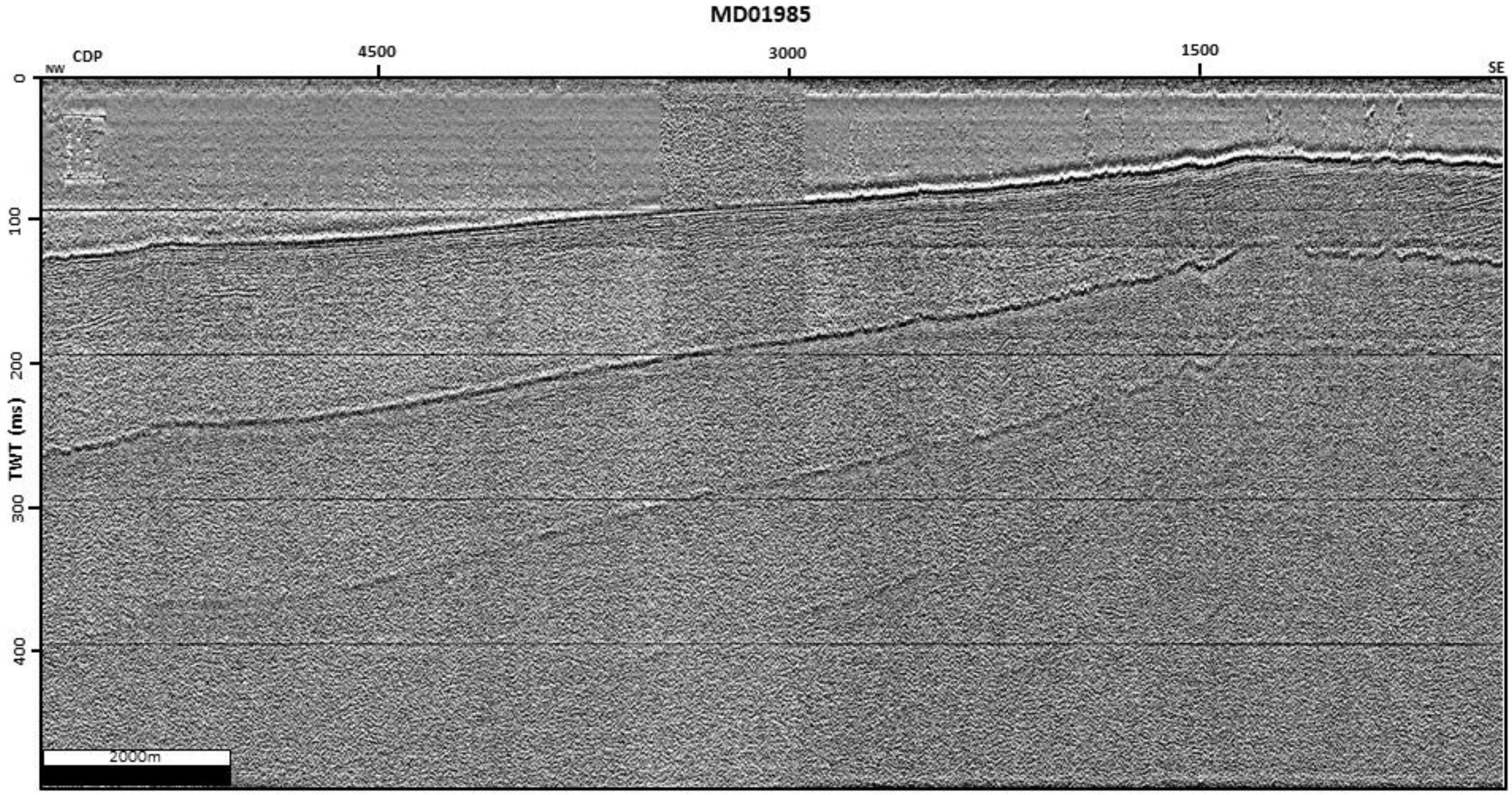
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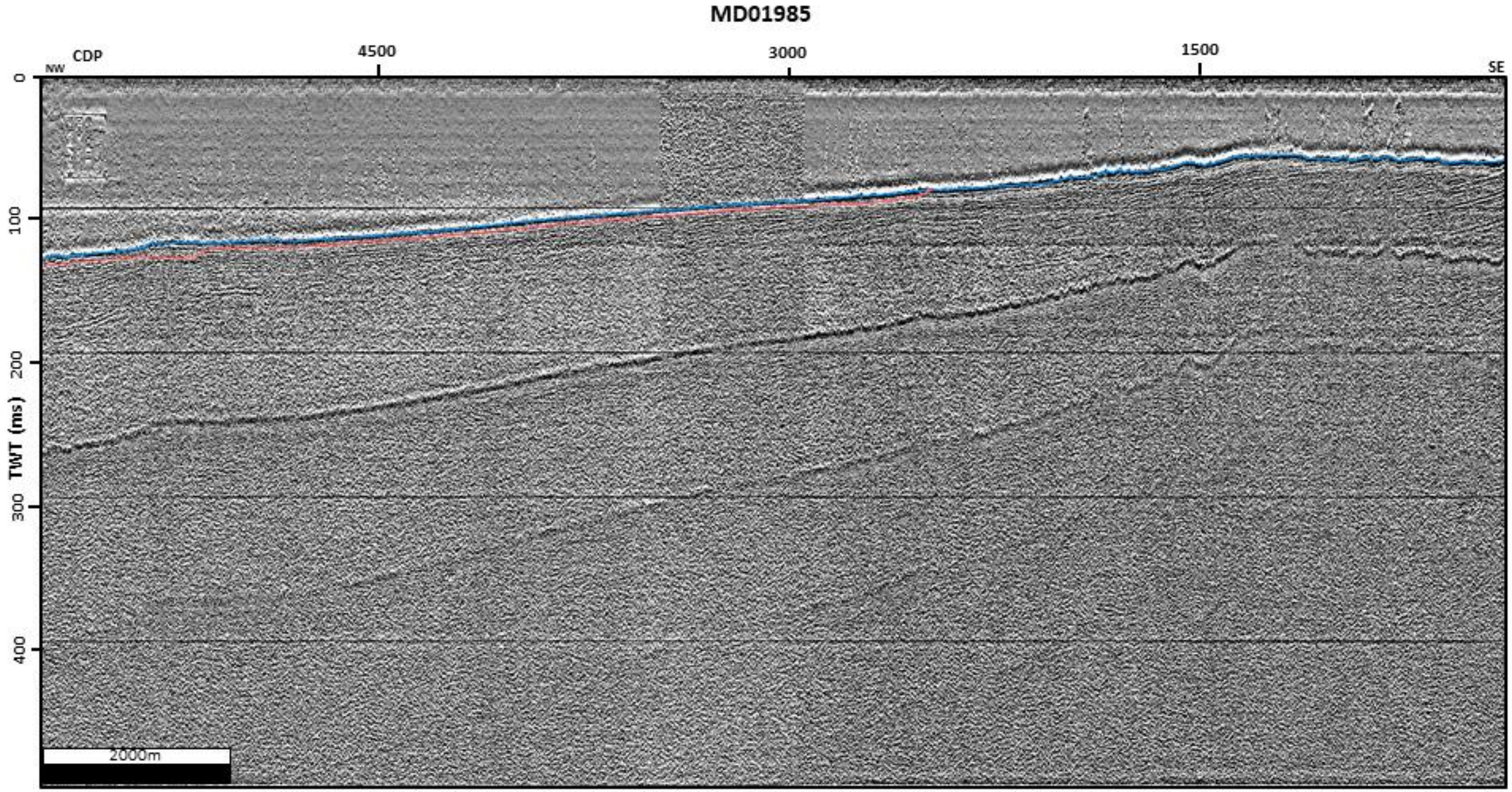
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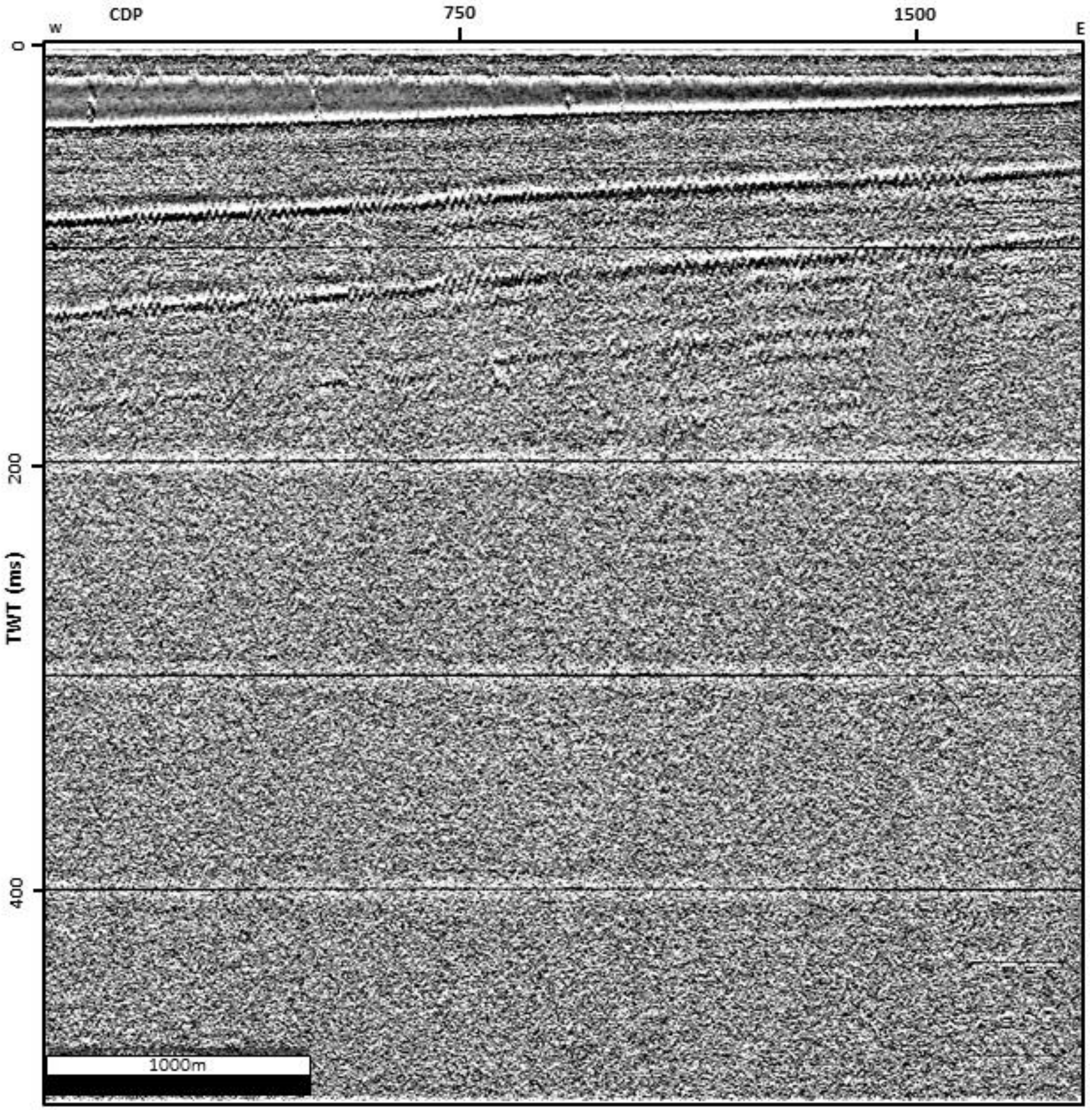

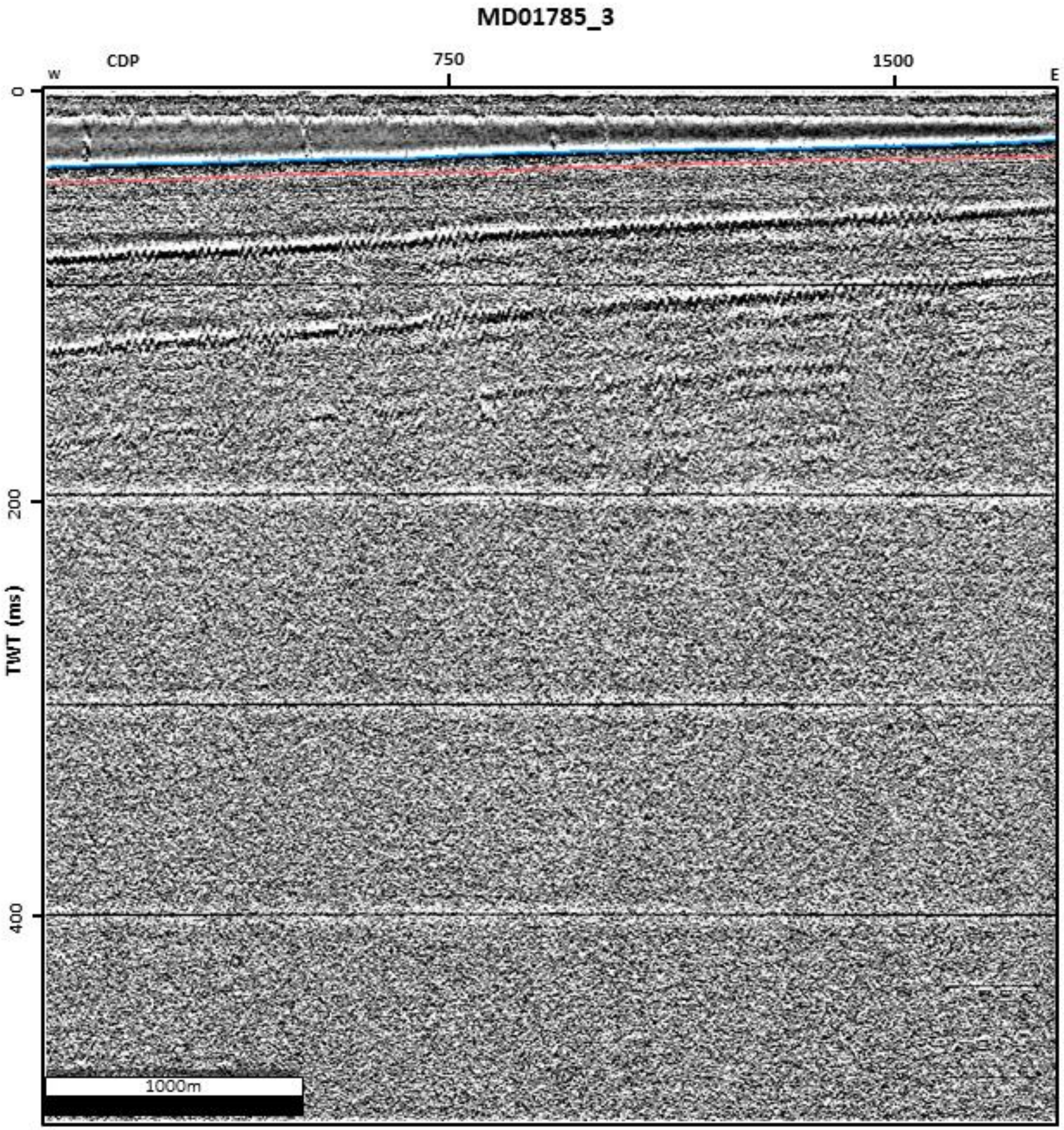
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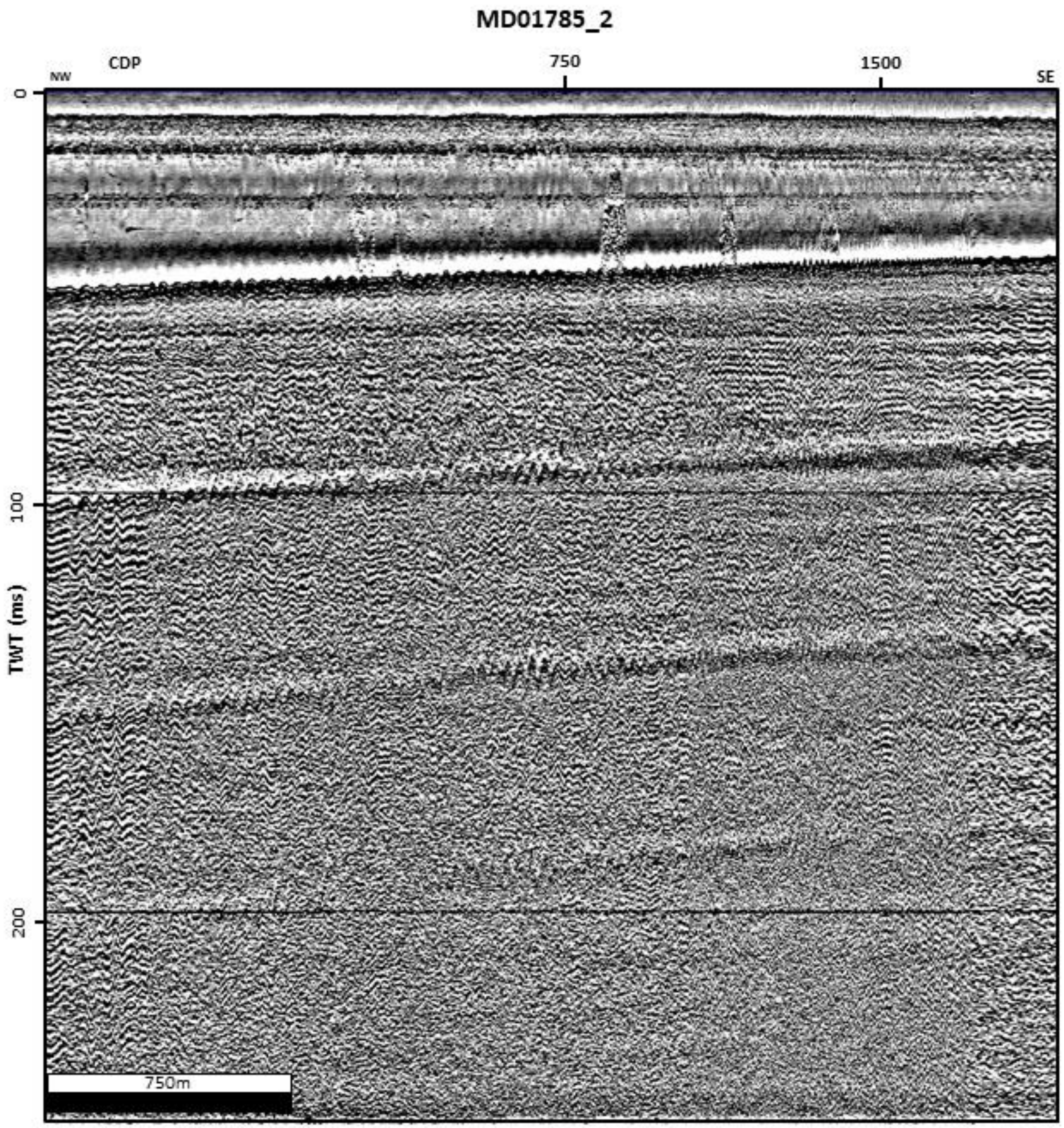
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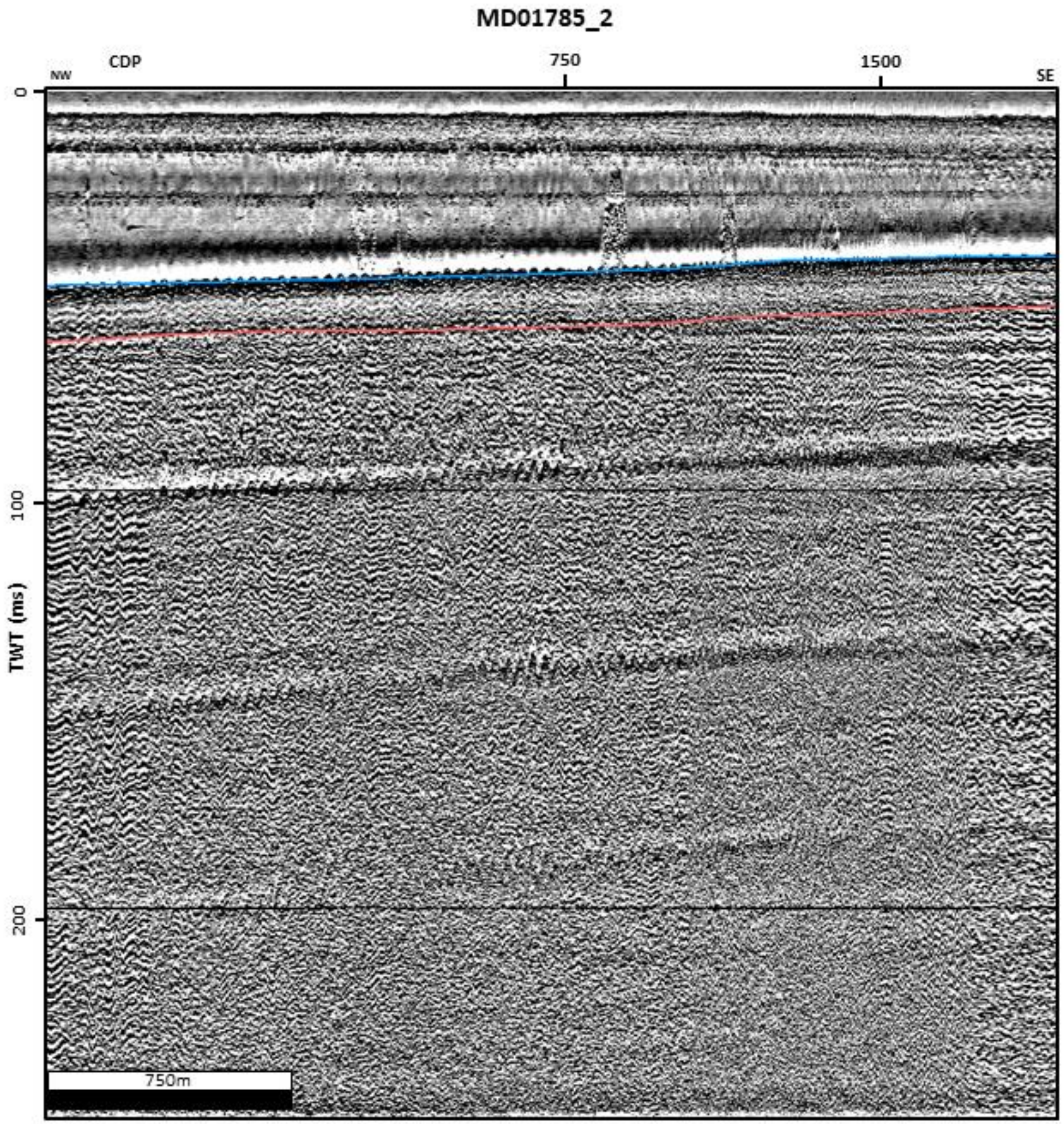
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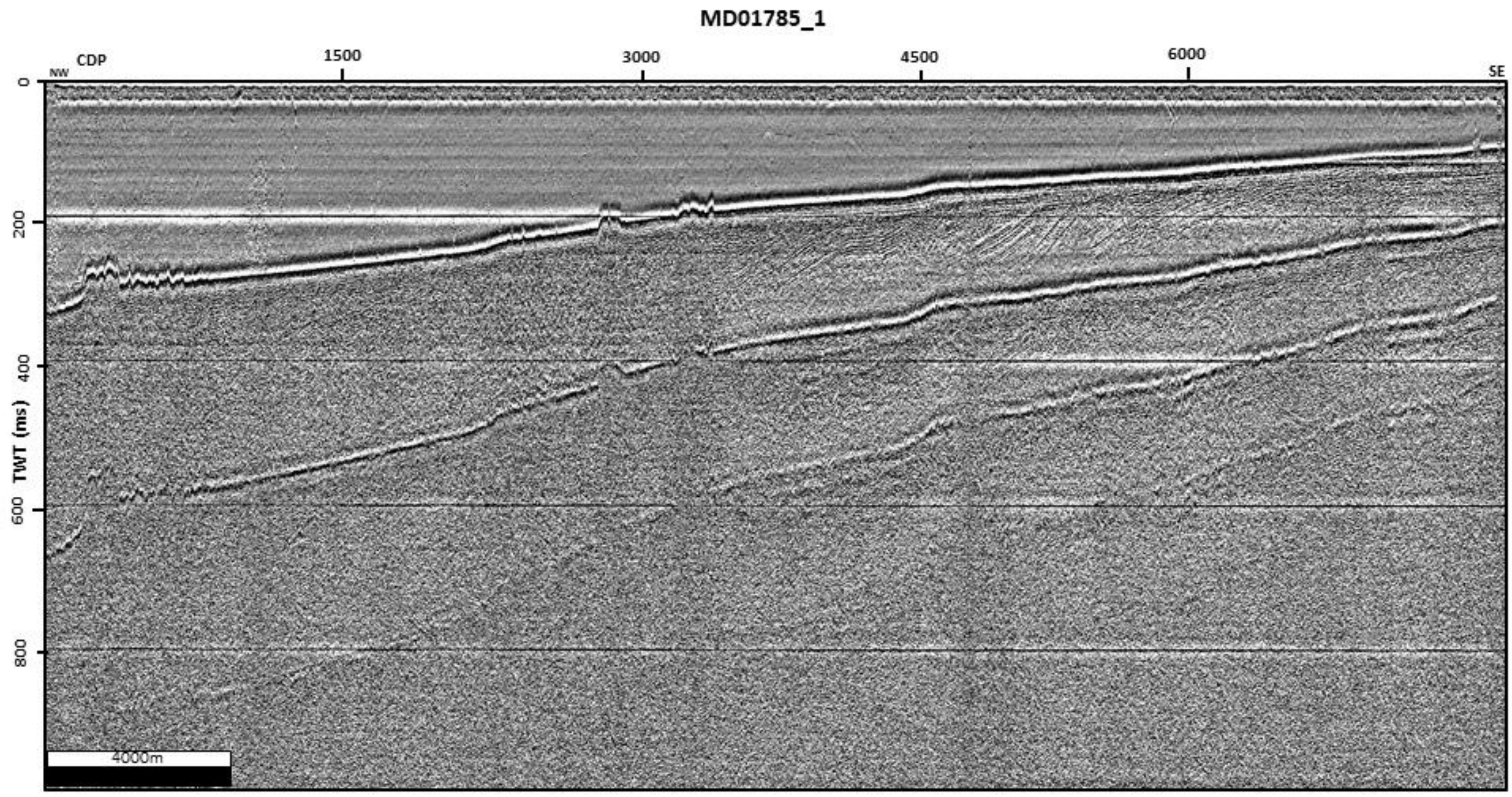
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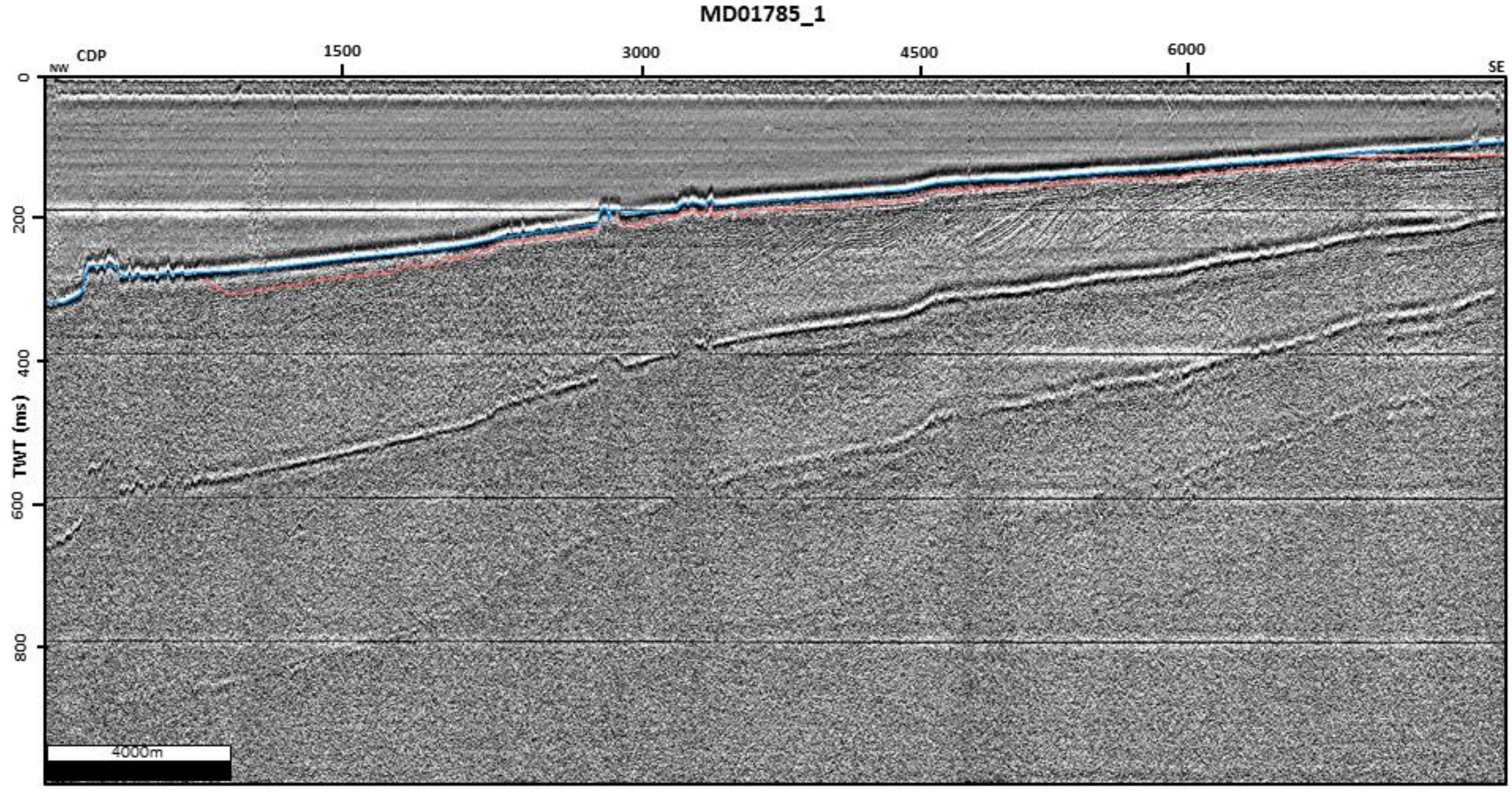
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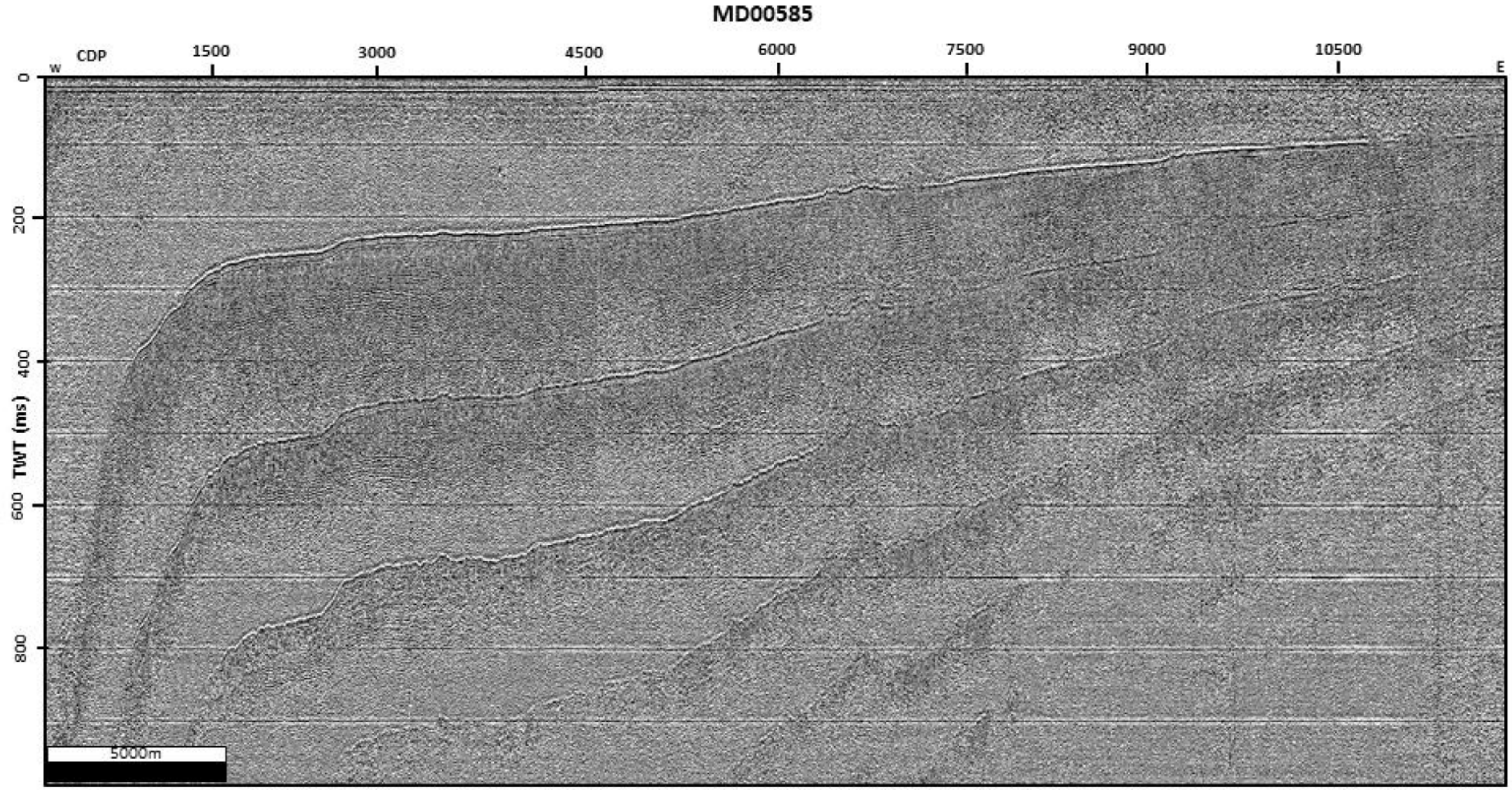
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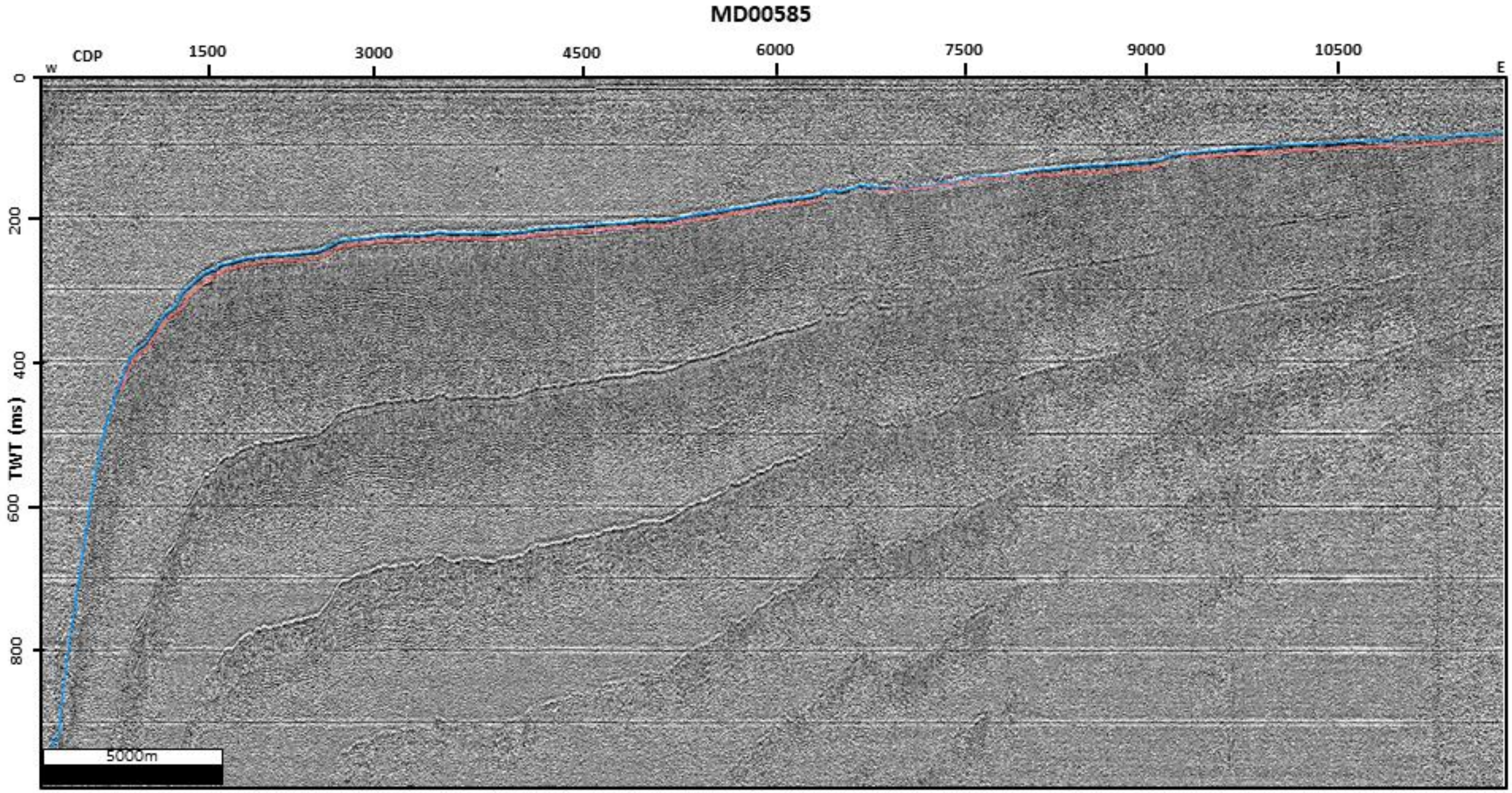
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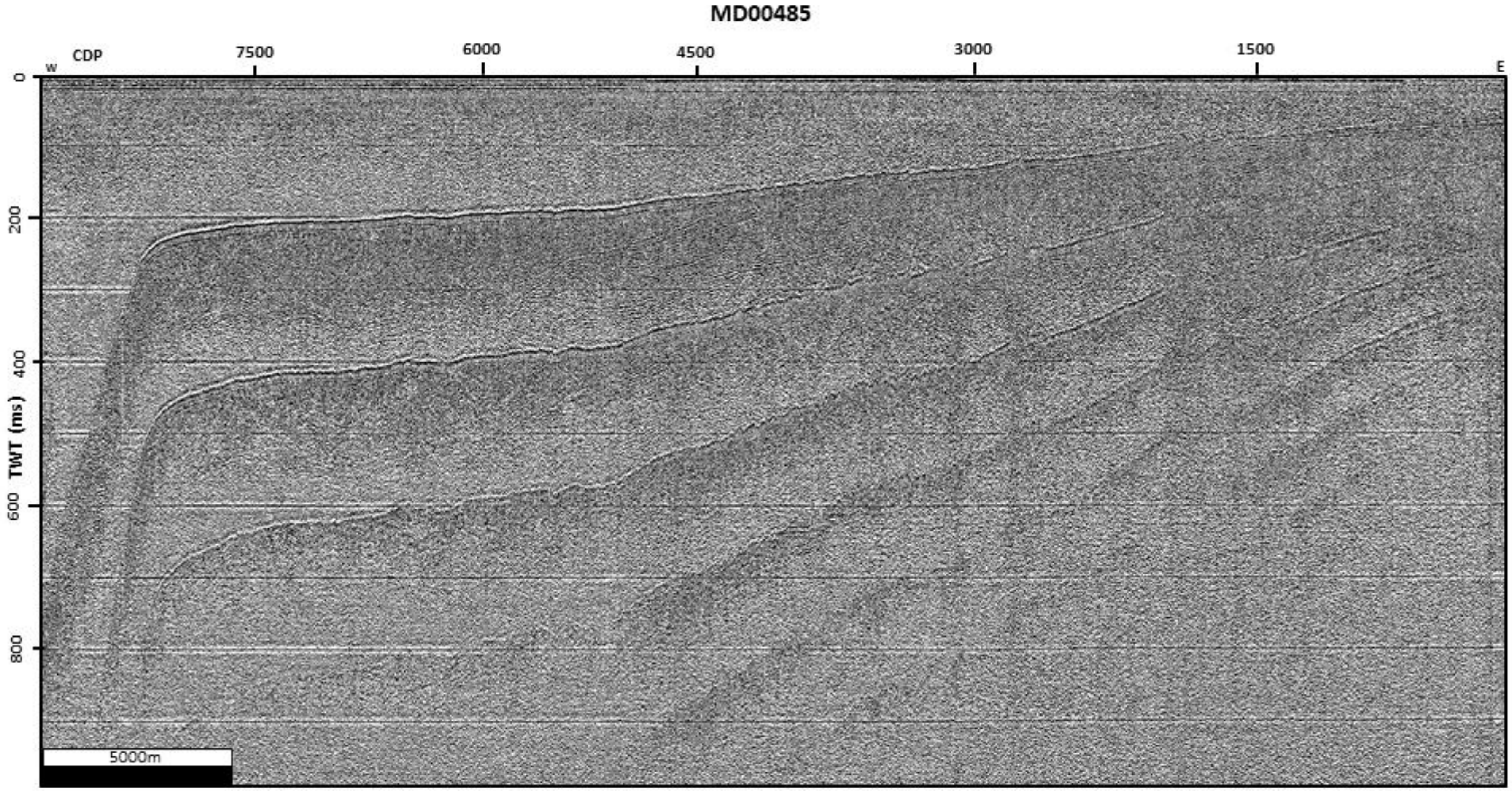
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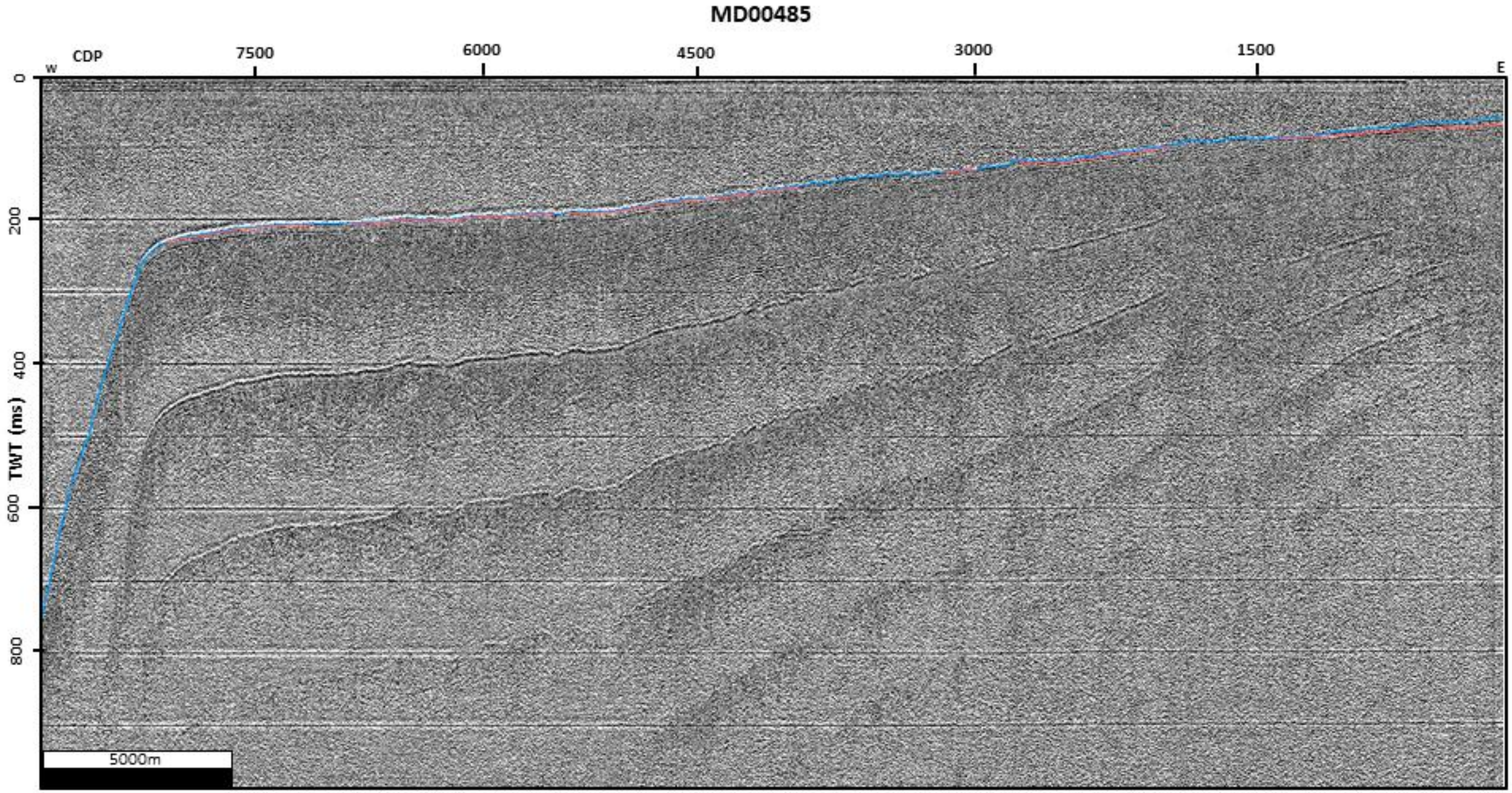
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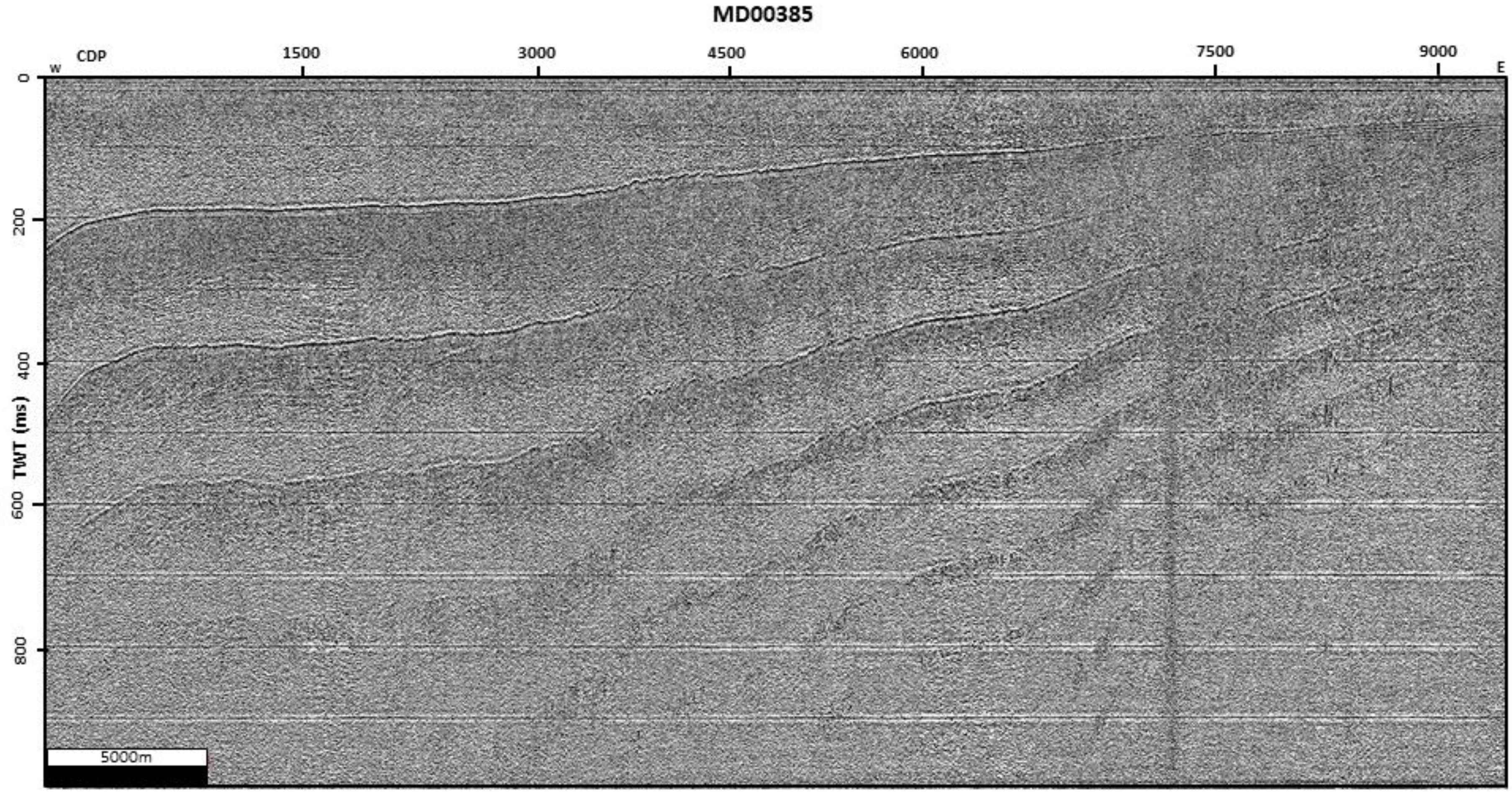
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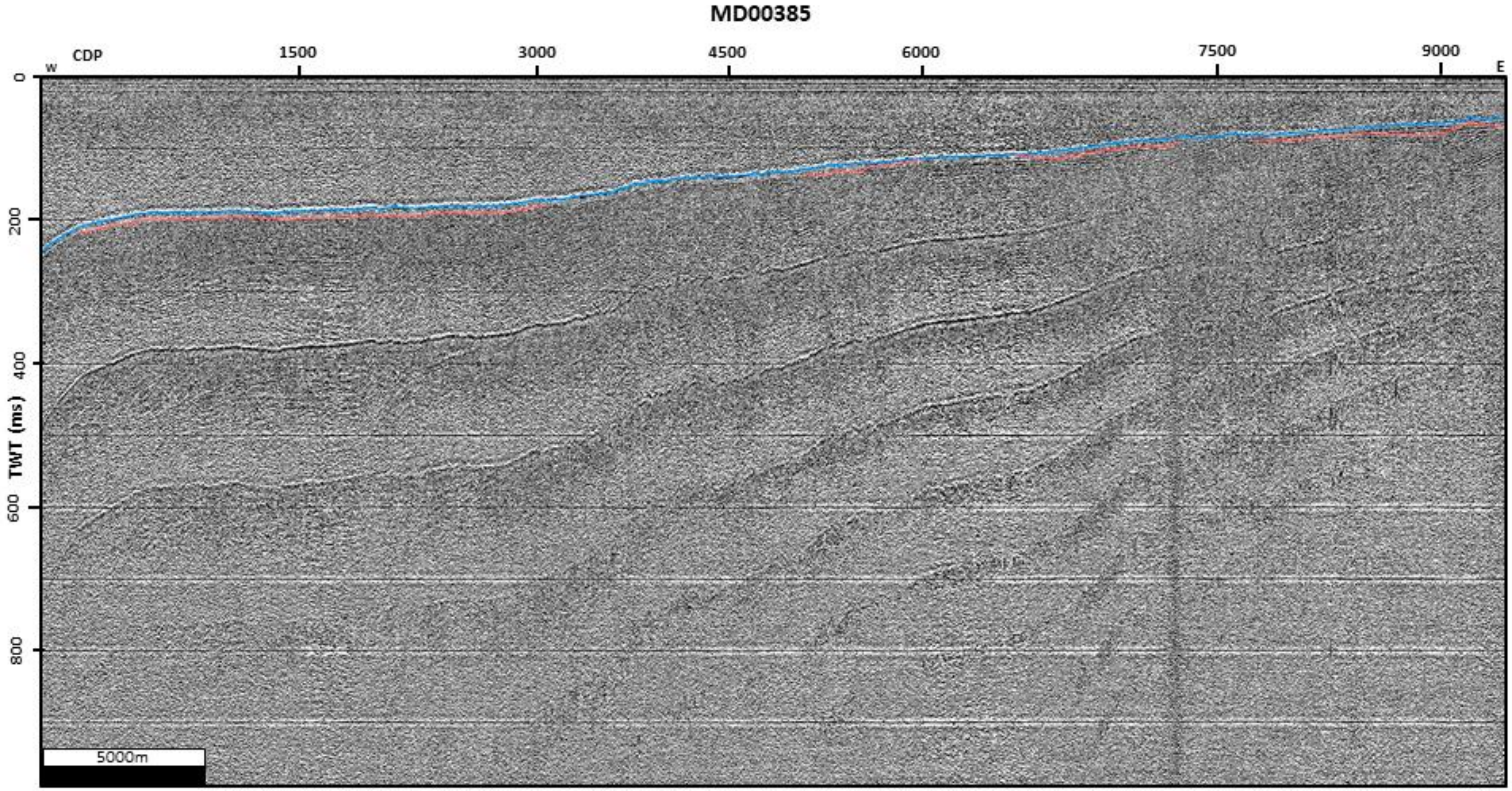
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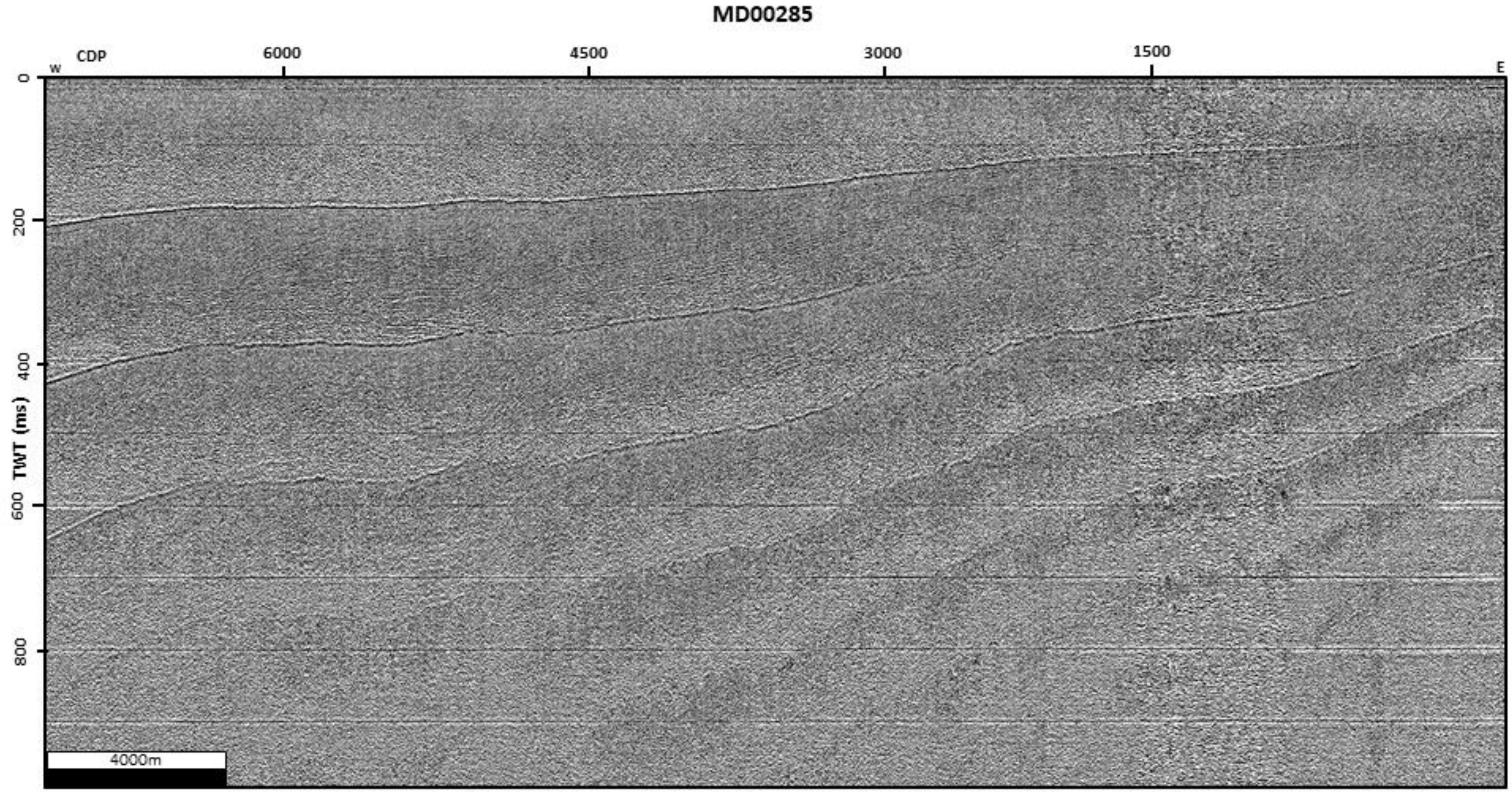
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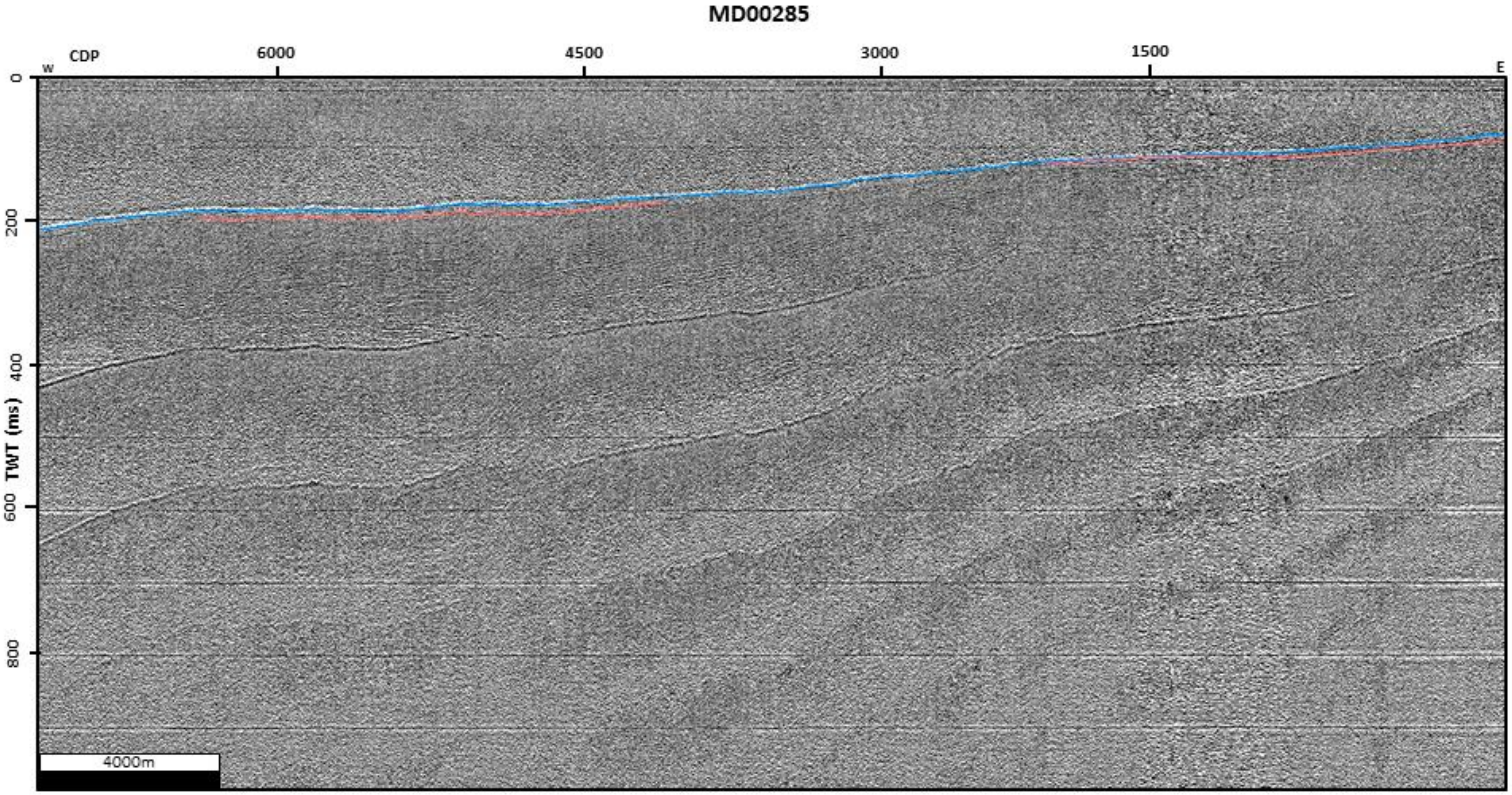
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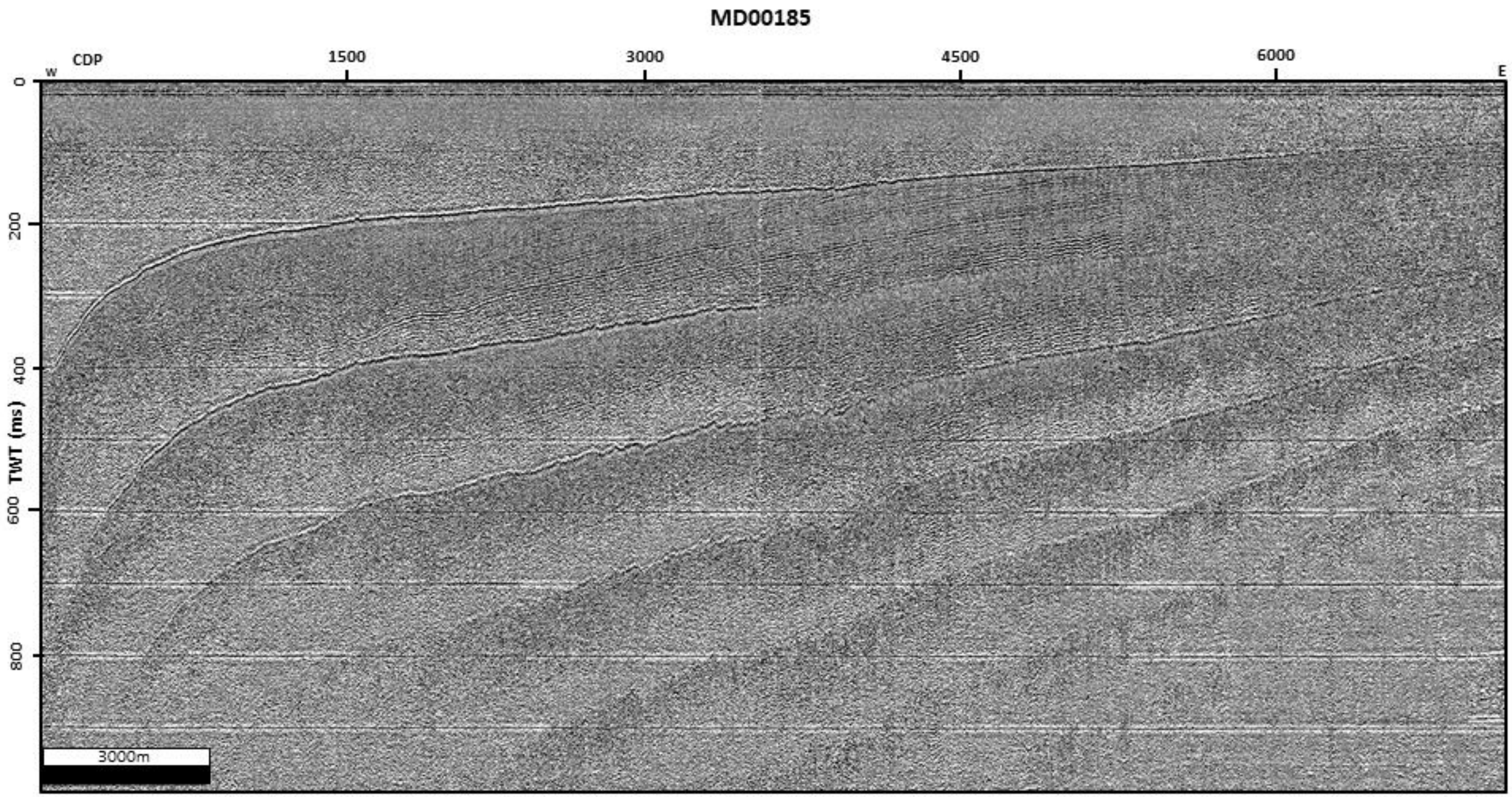
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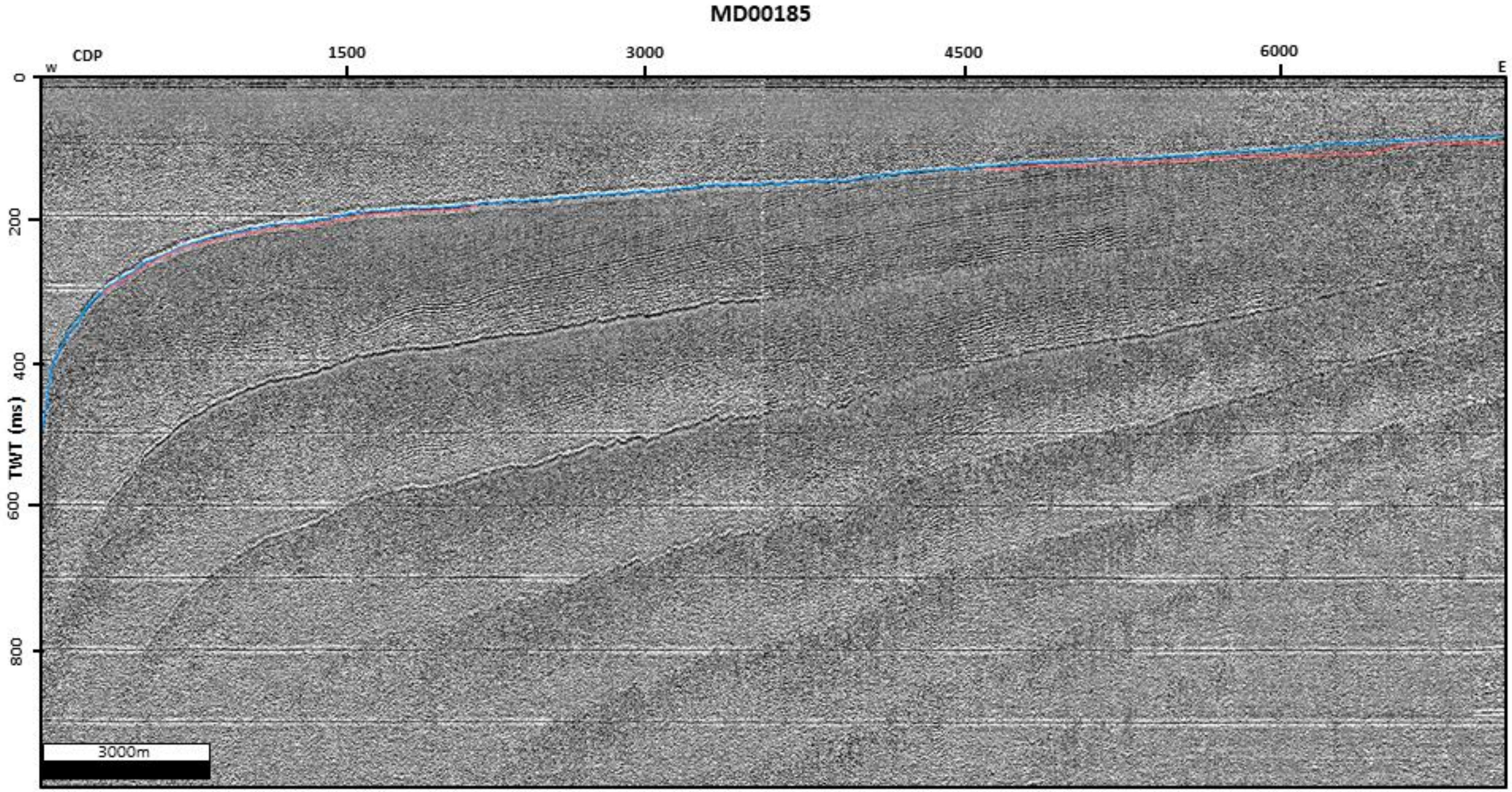
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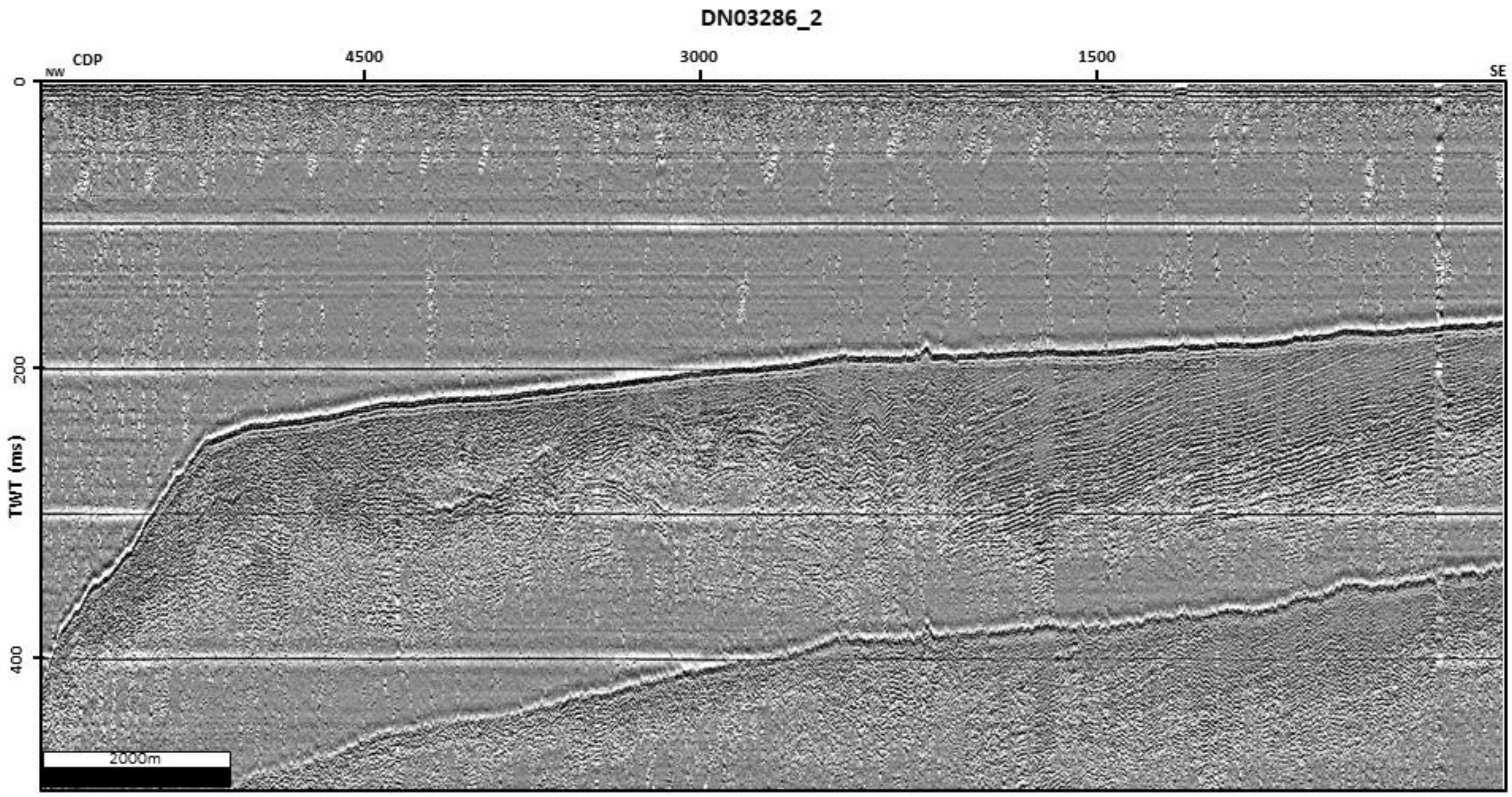
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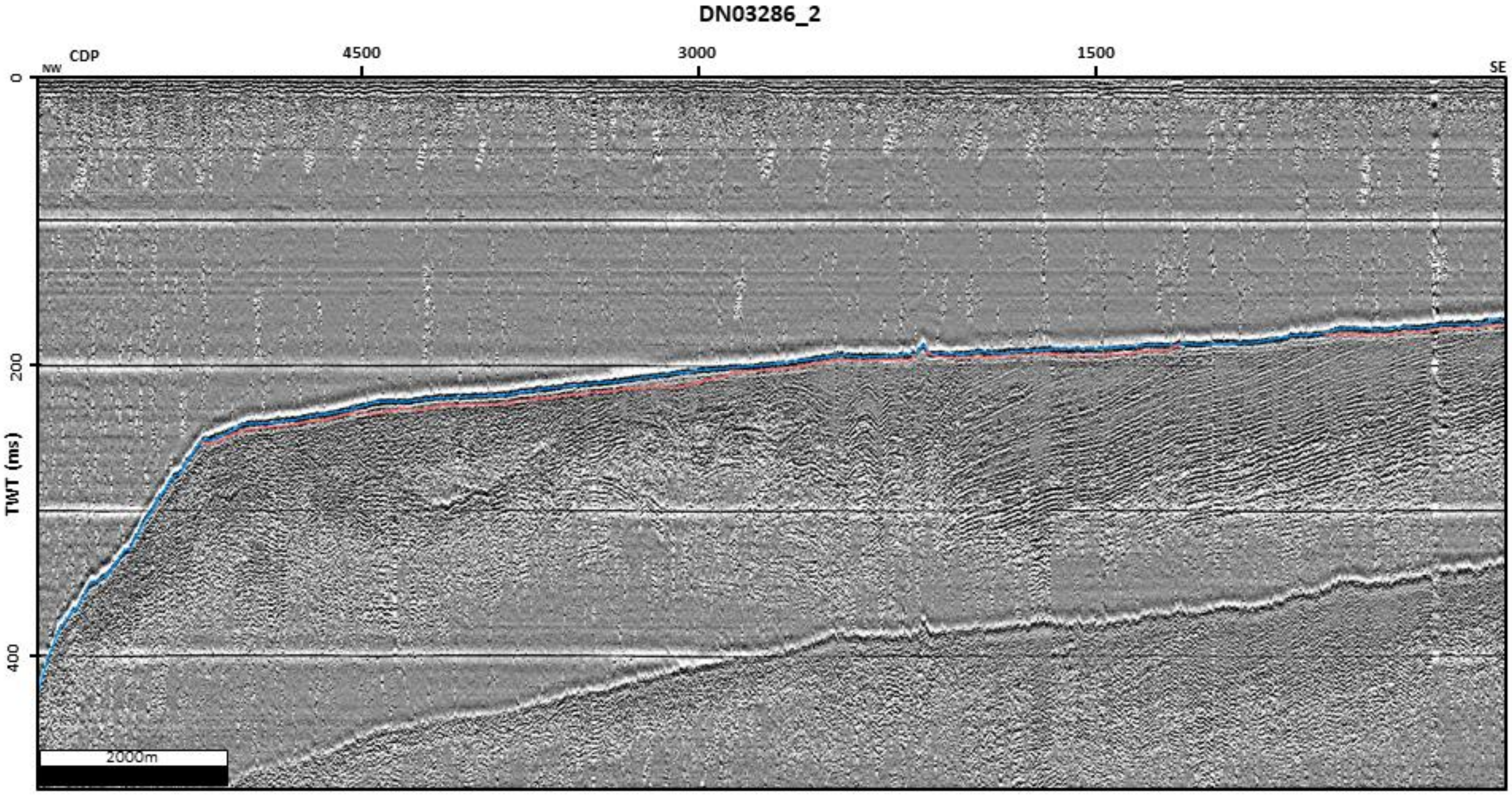
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TWT (ms)
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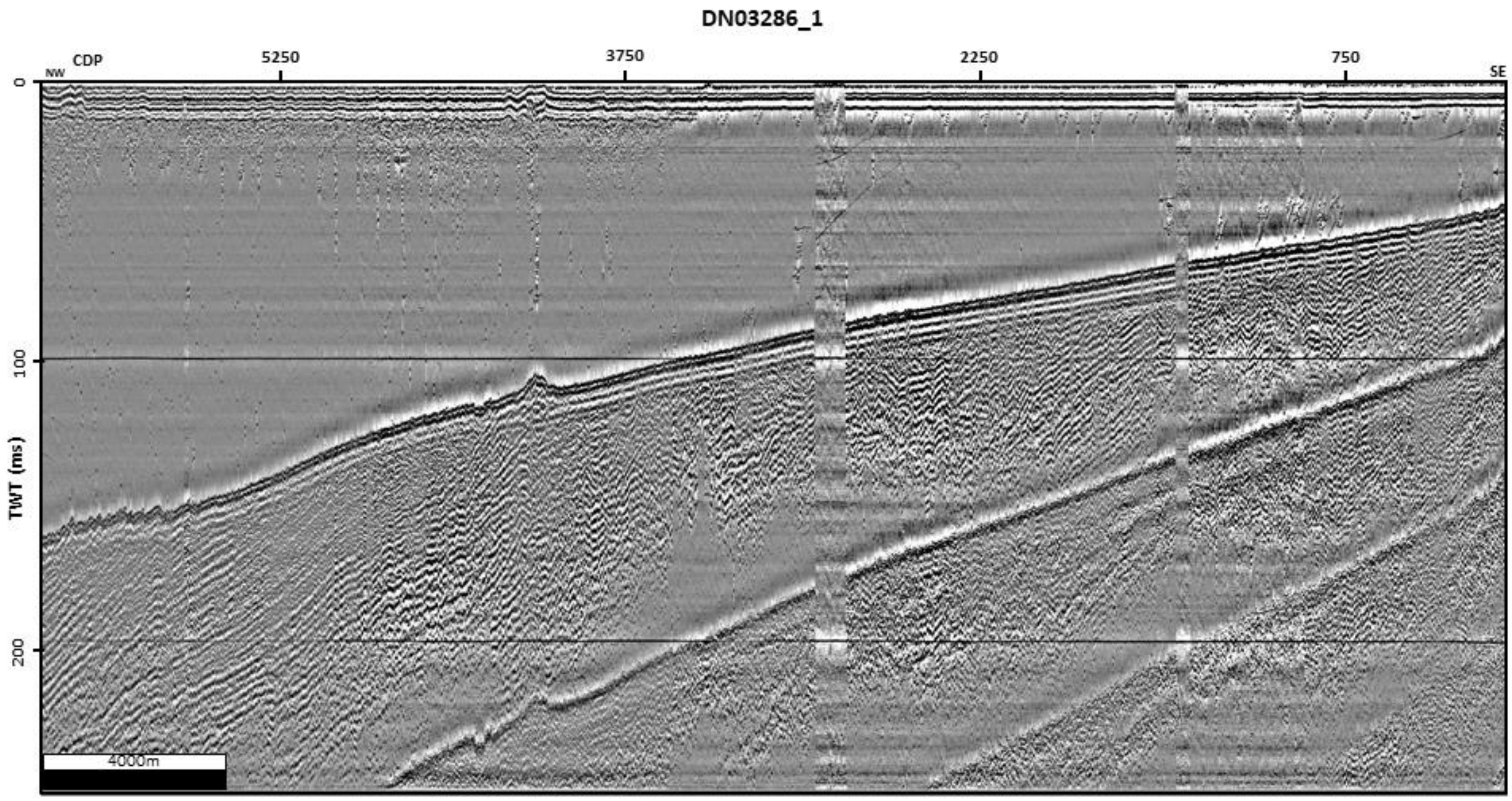
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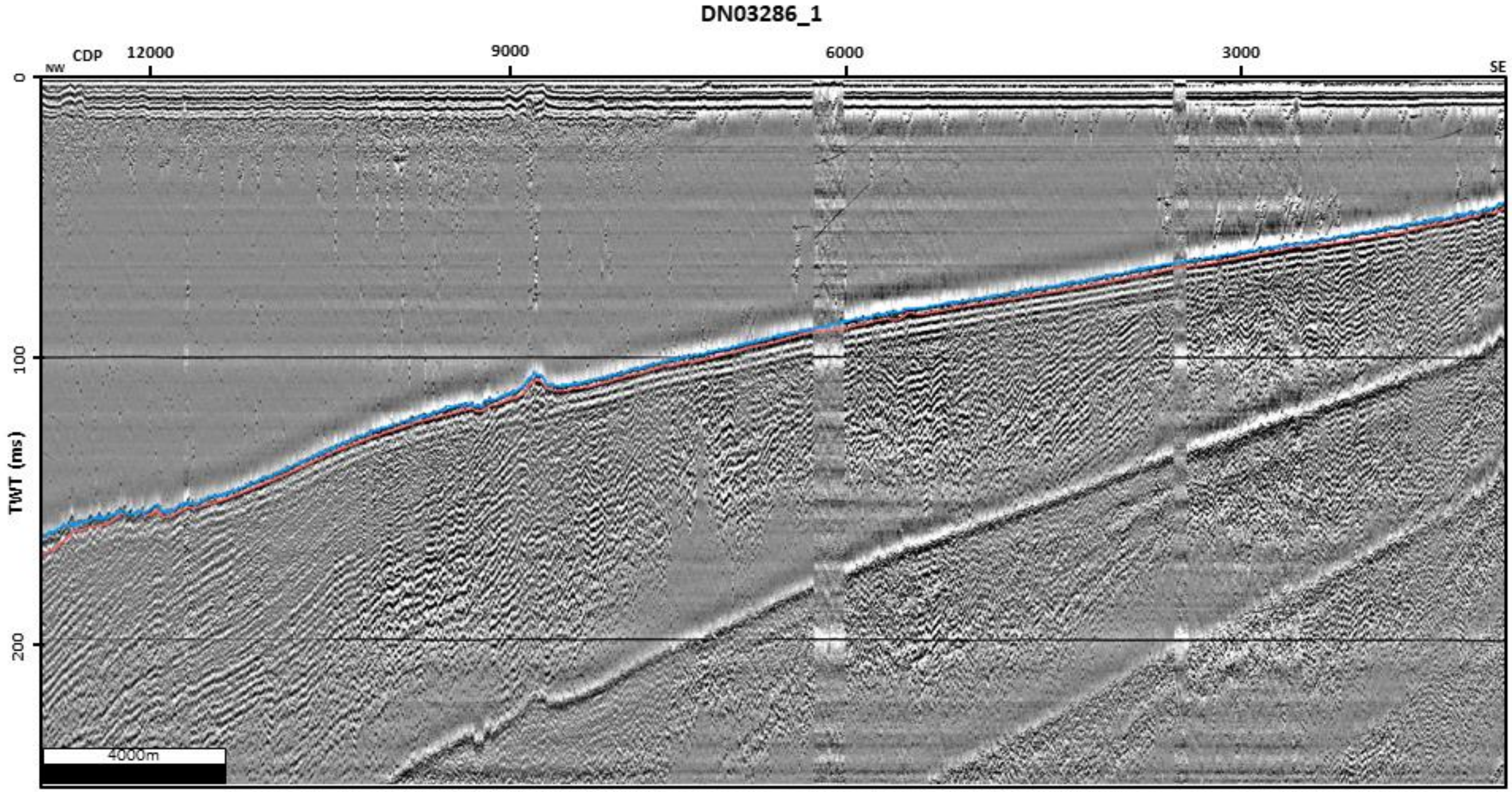
TWT (ms)
4000m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200
TWT (ms)
4000m

IPMA Instituto Português do Mar e da Atmosfera

PRR Plano de Recuperação e Resiliência
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