MINISTÈRE
DE LA TRANSITION
ÉNERGÉTIQUE
Liberté
Égalité
Fraternité

TECNOAMBIENTE
A TRADEBE COMPANY

Document reference				Issue information	
Project	**Package**	**Issuer**	**Chrono**	**Revision**	**Status**
MED_AO6	*GPY*	*TEC*	*51*	*0*	*IFR*

Title	***MED_TEC_51_Factual report - Seismic survey - OWF Zone 4 AO6 area_0***			
Additional Metadata	**Discipline**	**Document Type**	**System**	**Activity**
	GPY	*Factual report*	-	*Seismic survey*
	Contract	**Acceptance Class**	**Dossier**	**Alternative ref.**
	AO6-AO7	-	-	-
	Confidentiality	**Print format**	**Subcontractor**	**Contractor ref.**
	Restricted	*A4*	-	-

Date	Rev	Status	Reason for revision	Issued by	Checked by	Approved by
28/06/2023	*0*	*IFR*	*Issued*	*BMC*	*PW*	*FLO*

Change Log

Document uncontrolled when printed/downloaded.

Always check with document control for the latest revision.

MINISTÈRE
DE LA TRANSITION
ÉNERGÉTIQUE
Liberté
Égalité
Fraternité

MED_AO6 AREA – OWF ZONE 4 **UHR SEISMIC SURVEY**	MED_TEC_51_FACTUAL REPORT - SEISMIC SURVEY - OWF ZONE 4 AO6 AREA_0
	PROJECT No. 113401341
FACTUAL REPORT	No. OF PAGES 103

0	*28/06/2023*	*Issued*	*BMC*	*PW*	*FLO*	*CPC*	*BCO*
REV	***DATE***	***DESCRIPTION***	***BY***	***CHK***	***ENG***	***PM***	***CLIENT***

CONTENTS

LIST OF FIGURES

LIST OF TABLES

ABBREVIATIONS

ADCP	Acoustic Doppler Current Profiler
ASV	Assumed Sound Velocity
Ch	Channel
cm	Centimetre
CMP	Common Mid-Point
C-O	Computed Minus Observed
CoG	Centre of Gravity
CRP	Central Reference Point

ABBREVIATIONS

CSP	Central Shot Point
DEMOB	Demobilisation
DGEC	Direction générale de l'énergie et du climat
DP	Dynamic Positioning
DPO	Dynamic Positioning Officer
DPR	Daily production report
EP	Environmental Protection
FLO	Fisheries Liaison Officer
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
GRS	Geodetic Reference System
GSO	Geophysical Services Offshore
h	Hour
IMO	International Maritime Organization
J	Joule
JNCC	Joint Nature Conservation Committee
kHz	Kilohertz
LAT	Low Astronomical Tide
m	Meters
min	Minutes
MBES	Multibeam echosounder
mm	Millimetre
MOB	Mobilisation
MRU	Motion Reference Unit
POB	Personnel On Board
PAM	Passive Acoustic Monitoring
PPP	Precise Point Positioning
PPSU	Pulse Power Supply Unit
QA-QC	Quality Assurance – Quality Control

ABBREVIATIONS

RTE	Réseau de Transport d'Électricité
RTK	Real Time Kinematics
s	Second
SHOM	Service Hydrographique et Océanographique de la Marine
SN	Serial Number
SRF	Ship's Reference Frame
SVP	Sound Velocity Profiler
SVS	Sound Velocity Sensor
TBC	To be confirmed
TTS	TTSurvey Ltd (Seismic equipment hire company)
UHR	Ultra-High Resolution
UTC	Coordinated Universal Time
UTM	Universal Transverse Mercator
VSAT	Very-Small-Aperture Terminal
WB	Water Bottom
WD	Water Depth
WGS84	World Geodetic System 1984
WT	Work time
ZH	Hydrographic Zero or Hydrographic Datum

EXECUTIVE SUMMARY

According to the detected bathymetric results in the acquired lines of the offshore windfarm survey area, the depth range correspond between -86.78 meters in the shallowest part at the north-eastern region, to -112.85 meters in the deepest part at the southern region.

The seabed slopes are gentle, with average seabed gradients of 1.07°, maximum values of 28.17º and minimum values of 0º. The seabed gradient was computed at 22 planned borehole locations distributed over the range of water depths across the site.

Late Pleistocene sediments, comprising interbeds of soft silty clay and coarser reworked sands occur throughout the OWF area. Unconsolidated sediments extend to deeper than the depth of interest within the OWF survey area (60m+) in thickness, and the units all dip gently towards the southeast.

No shallow gas, or other geohazards are expected within the OWF area.

1. INTRODUCTION

1.1. PROJECT OVERVIEW

Tecnoambiente carried out four geophysical surveys within the proposed MED_AO6 lot located along the southeast coast of the French Mediterranean shore in the Gulf of Lion. The areas of interest are located in the Gulf of Lion off the French Mediterranean coast. These areas are 4 offshore windfarm (Zone 1 OWF, Zone 2 OWF, Zone 3 OWF and Zone 4 OWF) and 3 offshore substations (Zone 1 OSS, Zone 2 OSS and Zone 3 OSS) which are under investigation in this project (Figure 1-1). Each site is under consideration for a windfarm and offshore substation.

The area of relevance in this report is Zone 4, located off the coast of Marseille (Figure 1-2):

- **Area: 267.35 km^2**
- ***Dimensions:* 21.40 km x 20.39 km.**
- ***Bathymetric range:* -87 m to -113 m *(Vertical reference Bathyelli v2 ZH)***

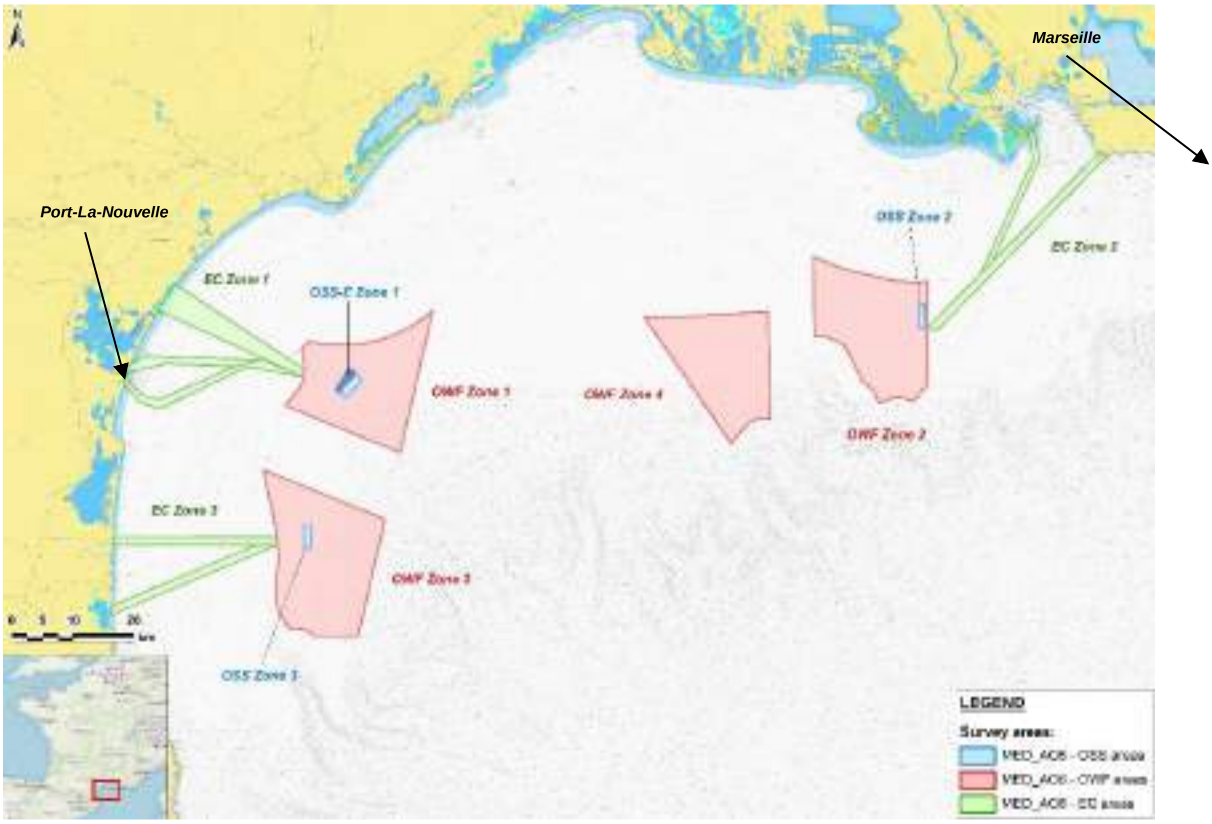


Figure 1-1: MED_AO6 survey area.

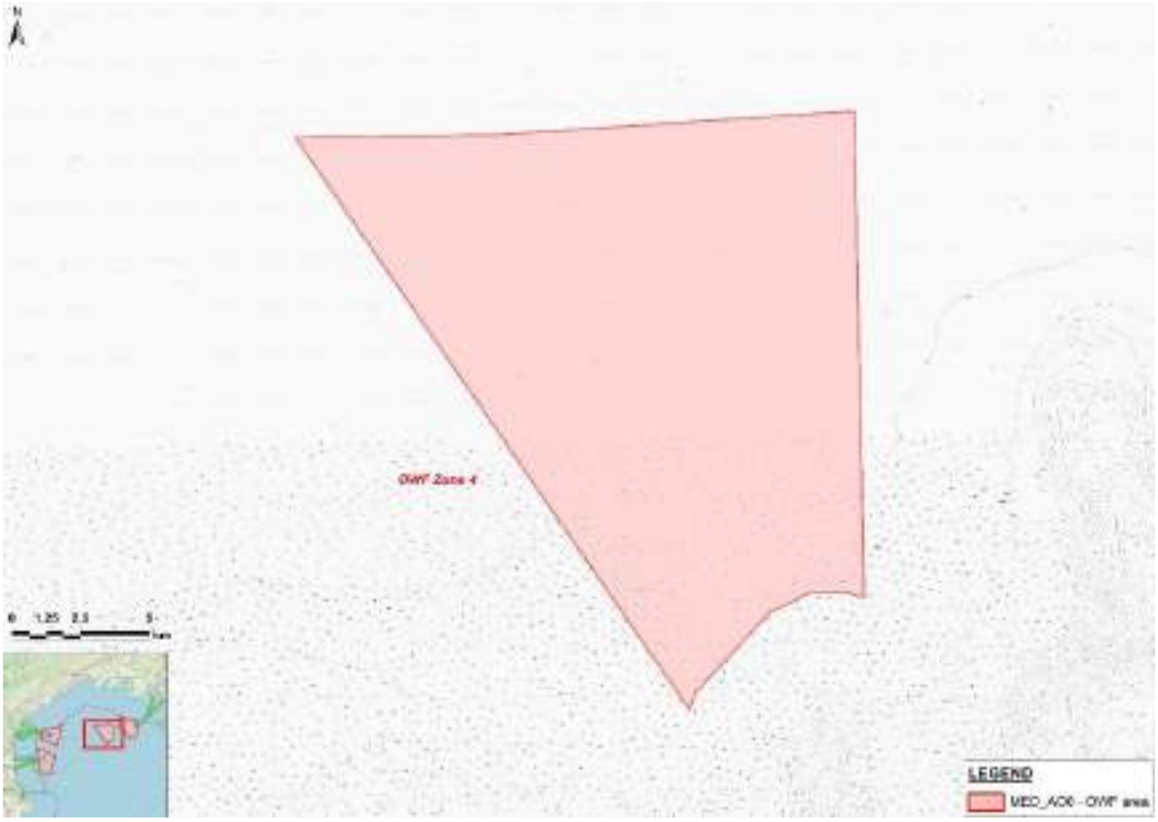


Figure 1-2: Windfarm area (OWF) in the MED_AO6 Zone 4 Survey area.

The following data were used in the study:

- 392.40 km of MBES and UHRS data

The goals of this first phase of the geophysical surveys are to perform

1. 2D UHR surveys in the wind farm areas in zones 1 to zone 4,
2. 2D UHR survey on offshore substations in zones 1 to zone 3.

Figure 1-3 shows the survey line plan.

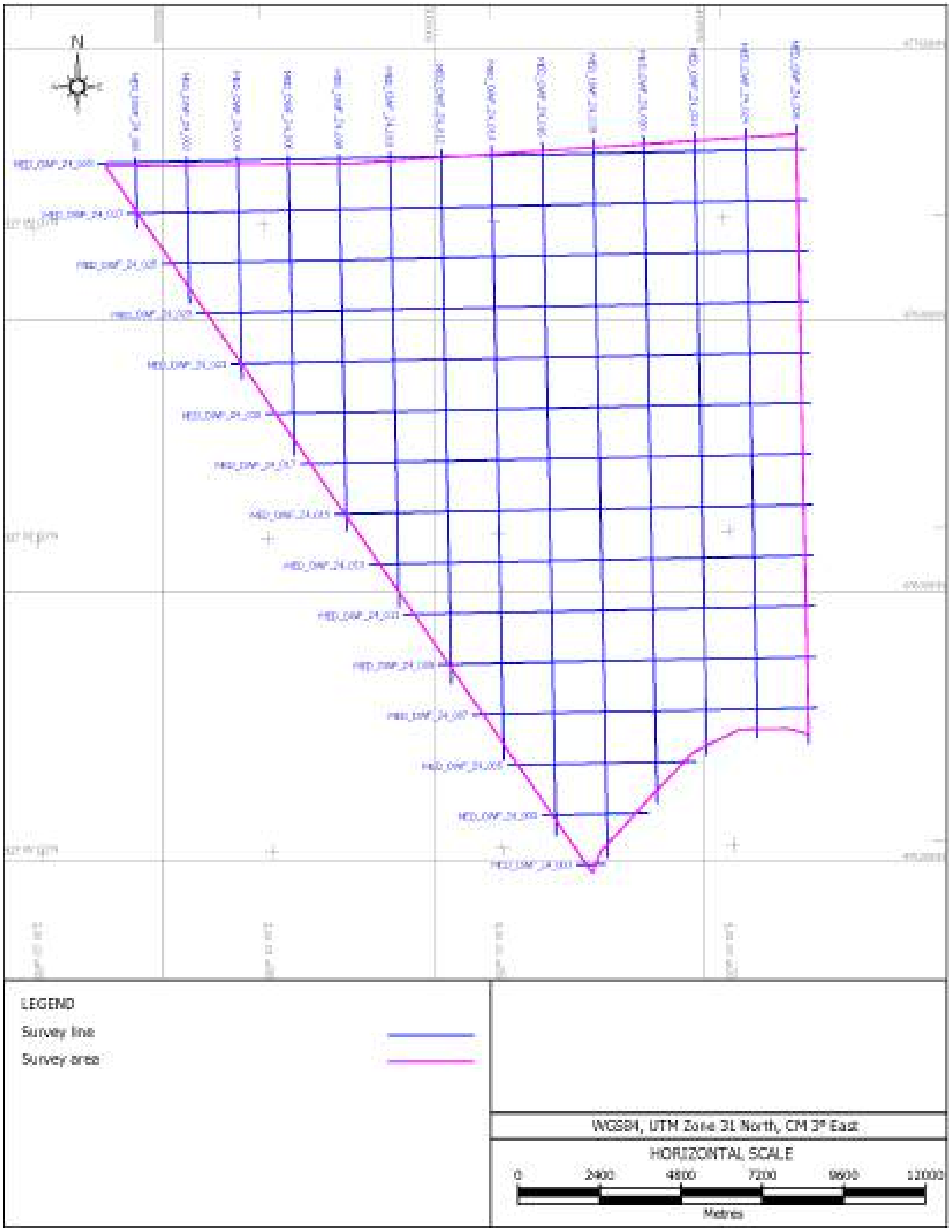


Figure 1-3: Line plan for MED_AO6 Zone 4 Windfarm area (OWF).

1.2. SCOPE OF WORK

The objective of the site survey was to perform a geophysical survey over the proposed OWF and OSS sites comprising MBES, SBP and UHRS datasets. The purpose of this was to:

- To define the water depths and seabed topography.
- To define the shallow (nominally 30 m BSB) subsurface geology.
- Review proposed borehole locations for geohazards.

The main purpose of the study is to provide an interpretation of the geophysical data to better understand the main characteristics of the seabed and geology at the project location and to undertake a derisking study over the MED_AO6 Zone 4 OWF site.

1.3. GEODETIC PARAMETERS

1.3.1. Survey datum

These parameters are detailed below.

Table 1: Datum parameters table

DATUM	
Survey Datum:	WGS 84
Spheroid	GRS 1980
Semi-Major Axis (a)	6378137.000000000
Semi-Minor Axis (b)	6356752.314245179
Inverse Flattening (1/f)	1/298.257223563

Table 2: Projection parameters table.

PROJECTION	
Projection	UTM
False Easting	500000
False Northing	0
Latitude of Origin	0º00'00.000000''
Central Meridian	3º00'00.000000''
UTM Zone	31 N
Scale Factor on CM	0.9996
Units:	Meters

1.3.2. Vertical datum

The vertical datum used in the QINSy software is Bathyelli v2.0 ZH geoid published by the SHOM in December 2013. The Bathyelli v2.0 ZH (SHOM 2013) is a surface based on the GRS 1980 spheroid, and it is a set of surfaces each of which defines the separation of one vertical datum from the WGS84 ellipsoid to the vertical maritime reference Hydrographic Datum or Hydrographic Zero. These ellipsoidal heights are given in meters.

This geoid covers the intersection between the SHOM tidal model and the different tidal zones of France.

For the survey area MED_AO6 Z4, the corrections to hydrographic zero are made by tidal observations of the port of Marseille (Corniche) (43º16' N – 05º 21' E). The difference between the hydrographic zero and the LAT reference level for this port is 0.27 m, according to the study by SHOM "*Références Altimétriques Maritimes. Ports de France métropolitaine et d'outre-mer*" of 2019.

1.3.3. Tidal reduction

In order to carry out the survey as accurately as possible, Tecnoambiente was receiving MarineStar PPP corrections by satellite signal. When using an accurate GNSS system the tidal corrections were carried out in real-time through QINSy computations, as it is shown in the next figure.

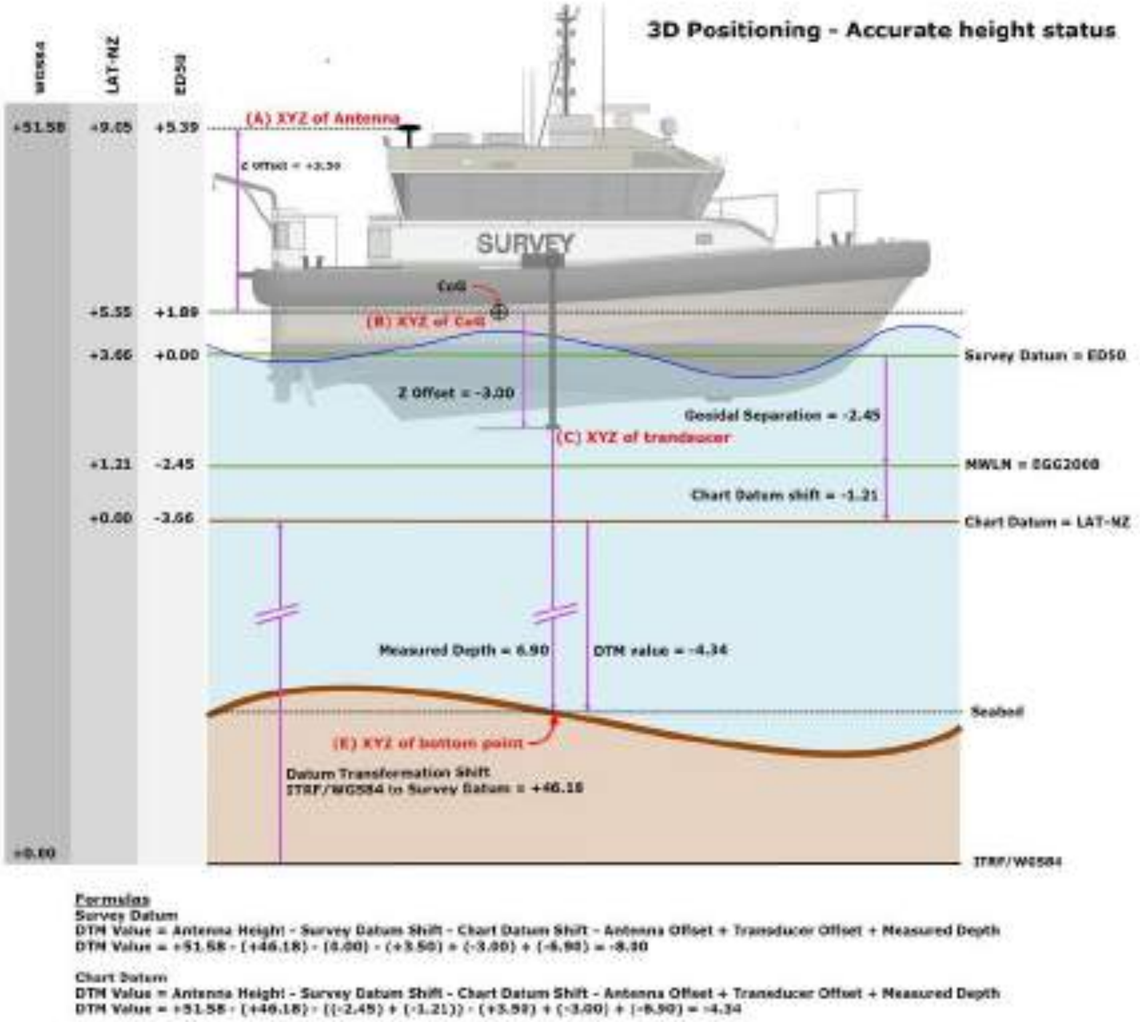


Figure 1-4: QINSy's method for accurate tide calculation.

In the event that corrections drop out they can be applied in post processing.

2. METHODOLOGY

2.1. MBES BATHYMETRY

2.1.1. Data acquisition

The objective during the data acquisition is the referencing of the acquired seismic data, therefore, the total coverage of the study area was not necessary. Due to this the project lines have been designed with a spacing of 1500 meters.

During the data acquisition, the vessel's master must follow the previously programmed routes of the project lines, governed by the indications of the computer screen (Helmsmann indicator), which is shown, by means of visual and audible alarms, when it separates from its course more than a specified amount (variable according to weather conditions in the area, but never more than 2.5 metres from the theoretical line), and also when there is a problem in a peripheral, such as the loss of GPS corrections.

While the master follows the navigation lines, the acquisition module of the hydrography program captures all the position data sent by the GPS, as well as the soundings sent by the multibeam sounder for each transmission pulse, as well as the values of the heading, wave height, roll and head angles sent by the MRU.

Parallel to the data entry, the data acquired by the equipment and peripherals is synchronized. This process is carried out by QINSy itself, complemented by the input of the time and the pulse per second (PPS) provided by the MRU, so that all the data is time synchronised.

The guidelines followed by Tecnoambiente during the survey for MBES data acquisition were the following ones:

- IT-CM-01. Guidelines for Hydrography Project management, 5
- IT-CM-04. Bathymetric survey, 1
- IT-CM-14 Survey Basics Guidance, 1
- IT-CM-15 Online Surveying procedure, 3

These guidelines can be found in the quality plan document MED_TEC_04_Quality Plan.

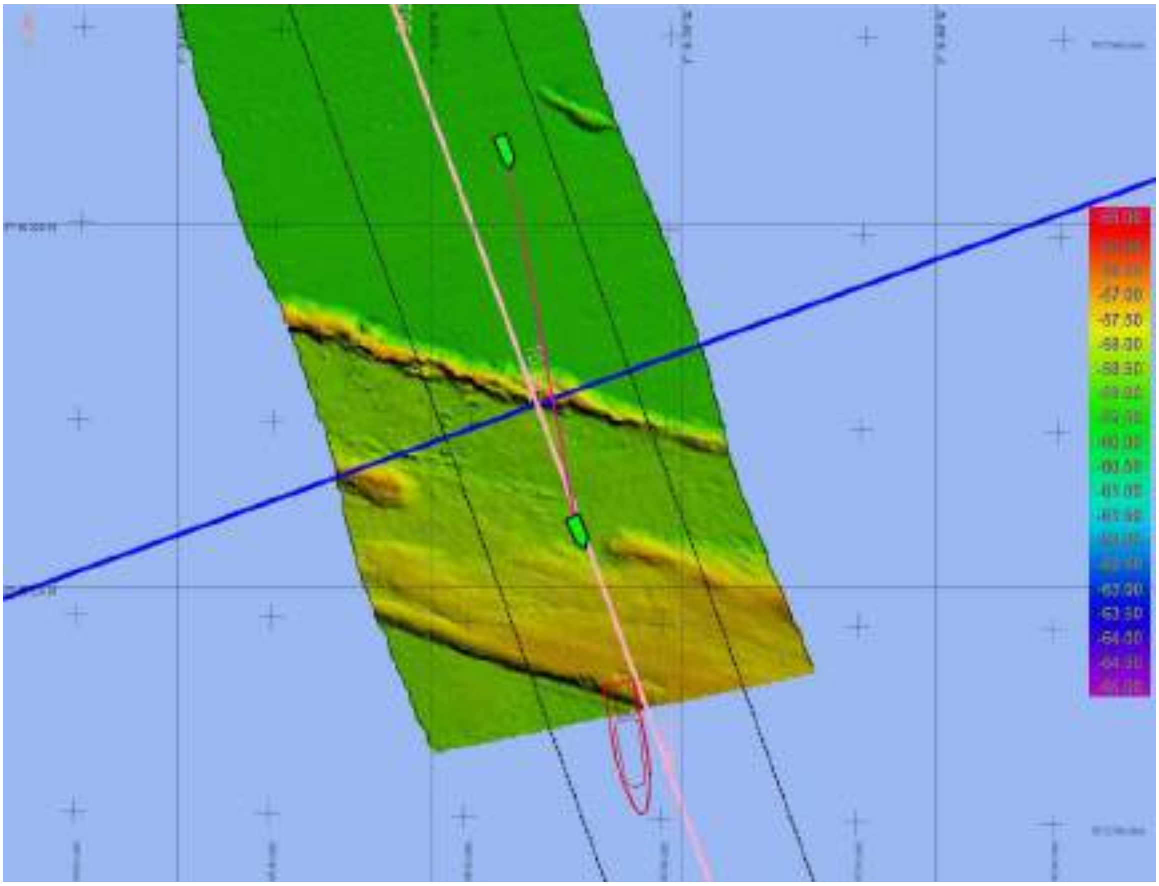


Figure 2-1: MBES bathymetry data acquisition with the QINSy software.

2.1.2. Data processing

A single head Kongsberg EM 2040 high resolution MBES system that is permanently installed on the Geo Focus vessel was used to produce digital terrain models (DTMs).

Along the processing phase of the acquired data, the lines on the screen are processed in order to manually match the height of the bathymetric lines and also correct the noise that appears in the records, noise produced by multiple factors such as, multipath in position, air bubbles, motor interference of the vessel etc. in the digital register of soundings.

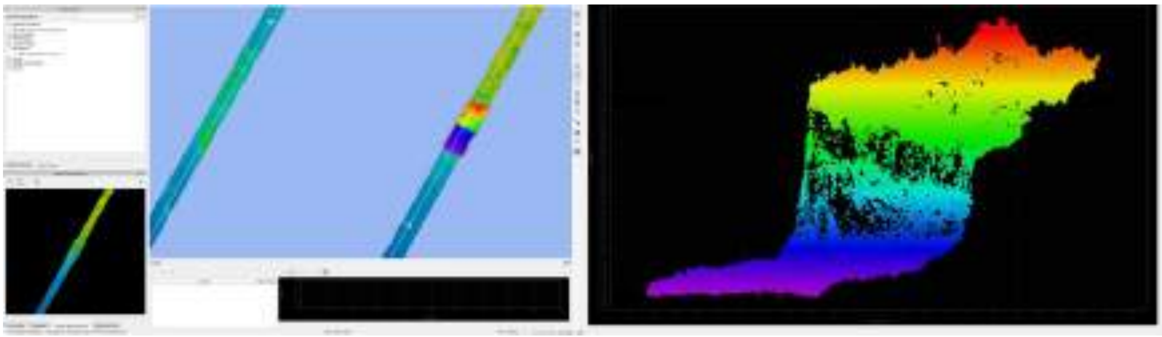


Figure 2-2: Processing screen of MBES bathymetry data with the Qimera software.

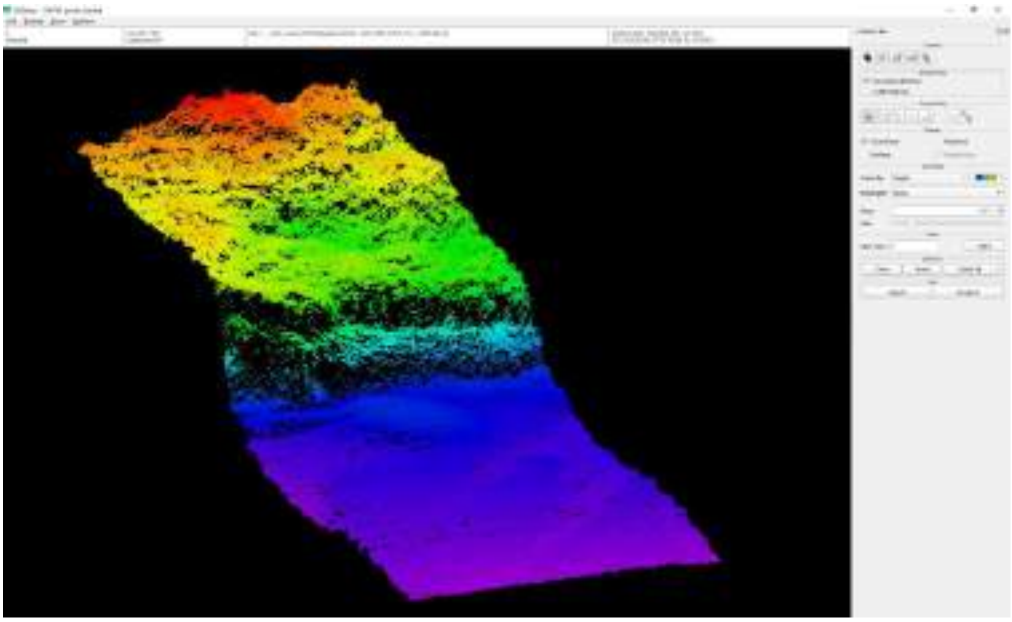


Figure 2-3: 3D image of the MBES bathymetry processing.

Once the possible existing errors in the records have been deleted, a digital model of the terrain with 1 x 1 m grid size has been made with a minimum cell size to obtain the maximum resolution of the seabed.

The general MBES processing workflow is presented in the following figure.

Figure 2-4: MBES bathymetry processing overview.

2.1. UHR SEISMIC

2.1.1. Data acquisition

UHR Seismic data was acquired using GSO 400-tip Sparker sled and Applied Acoustics CSP-N pulsed power supply unit were mobilised as the acquisition source, interfaced with a Geometrics GEOEEL LH16 recording system and 48 channel UHR streamer. The first 24 channels of the streamer at 1m group interval and the remaining 24 channels at 2m. The streamer was kept at a depth of 1m by a head and tail buoy as well as 2 Digicourse 5011 levellers (Birds).

Accurate positioning was collected using Modulus 101G GPS pods mounted on each towed system, Sparker sled as well as head & tail buoys for streamer positioning.

The shot point interval for the survey was 1 m, giving a nominal fold of 36 when binning with a CDP spacing of 1m to keep the bins consistent with the variable channel spacing. True fold will vary around this value when real source and receiver positions are used rather than nominal geometry, according to variations in ship speed and feather angle changes between shots.

Table 3: UHRS operational parameters.

Parameter	Value
Active Streamer Length	75m
Number of channels	48
Group Length	Channels 1-24: 1 m
	Channels 25-48: 2 m
Target Tow Depth	1m +/-0.5m
Near Offset	~5-6m
Sample Rate	0.0625ms
Record Length	0.250ms
Shot Point Interval	1m
Source	Sparker – GSO – 400 tips
Target Source Tow Depth	0.3 m

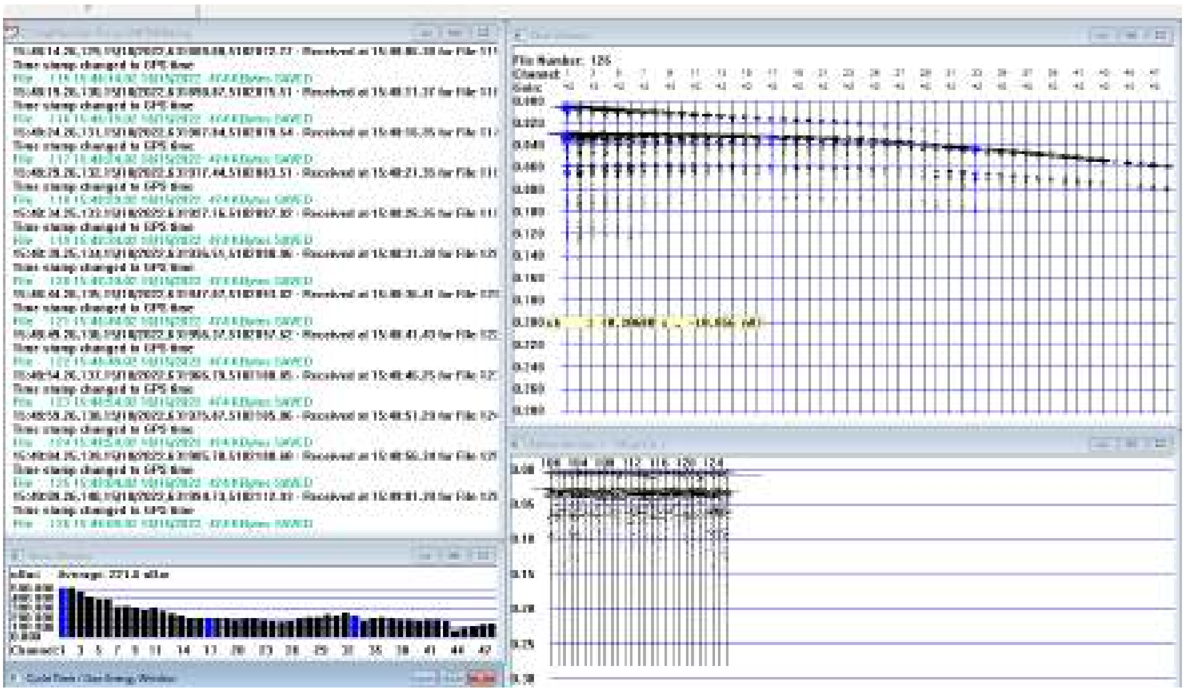


Figure 2-5: Screenshot from Geometrics LH16 software during UHR Seismic acquisition.

The guidelines followed by Tecnoambiente during the surveying for UHR Seismic data acquisition were the ones provided from TTS, which are:

- IT-CM-17 Sparker Deployment Recovery, 1
- IT-TTS- 01_Geoeel Instrument Verification Procedure
- IT-TTS-02_Multichannel Seismic Streamer Procedure
- IT-TTS-03_Sparker Pulse Test Procedures
- IT-TTS-04_Streamer Recovery

These guidelines can be found in the quality plan document MED_TEC_04_Quality Plan.

2.1.2. Data processing

Data processing and interpretation was performed within the MED_AO6 area to a recorded length of 100 m sub-seabed for both OWFs and OSSs. This interpretation was done for evaluation of seabed and sub-seabed conditions.

The dataset was quality controlled offshore on board the vessel Geo Focus by Peak Processing using a Linux based system with Landmark's ProMAX/SeisSpace processing software.

The dataset was then made available to Peak Processing upon completion of the fieldwork with the processing of the raw UHR seismic data performed and finalised using Shearwater Reveal version 5.1 on a small cluster.

Stacking velocities generated during the processing of the UHR data were used to help choose velocities in the time-depth calculation. Standardised velocities were chosen based on the sediment characteristics expected. For the interbedded sands and clays, as interpreted in AO6, an assumed seismic velocity of 1700m/s has been used.

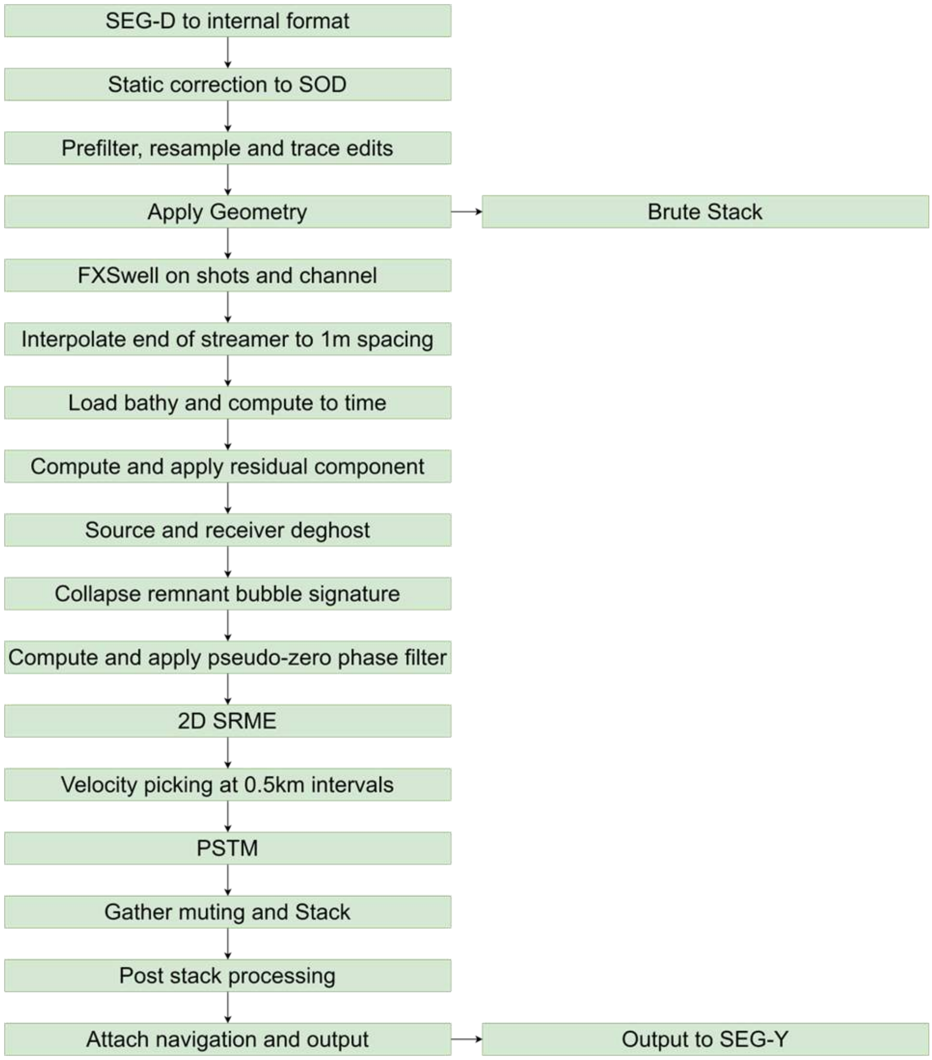


Figure 2-6: UHR Seismic processing overview.

For quality assurance, displays of the following were produced for each line with a copy provided to the client representative offshore, in addition to the Brute Stack SGY exported:

- Near trace
- Shot record examples (displayed every 100 shots)
- RMS Noise Display (calculated every 100 shots)
- Spectral Analysis

- Offset QC checks, showing computed arrival time from offsets derived from GPS navigation data overlaid on top of the direct arrival in the data itself
- Velocity Semblance/Gather Example
- Brute Stack, annotated with trace fold header plot

Processing of the dataset took place ashore, and full details of the processing can be found in a dedicated seismic processing report. As a summary, the evolution of the dataset can be seen in the following examples shown at three different stages of the processing:

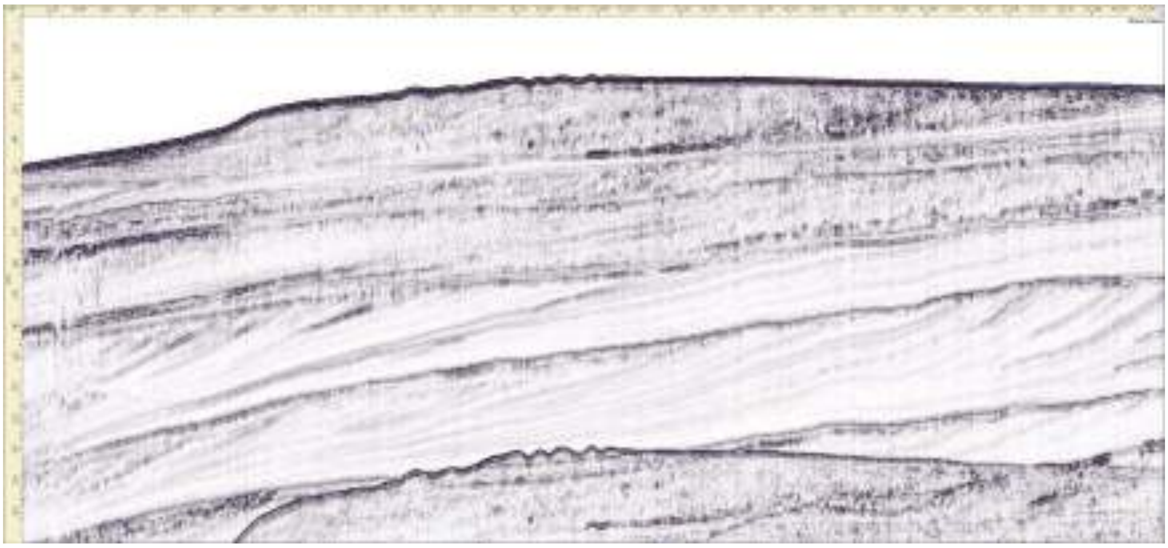


Figure 2-7: Minimum phase brute stack.

Figure 2-8: Zero-phase corrected control stack (Demultiple, Noise filtering, Deghost, Static Correction, Far Trace Mute & Pre-Stack Migration).

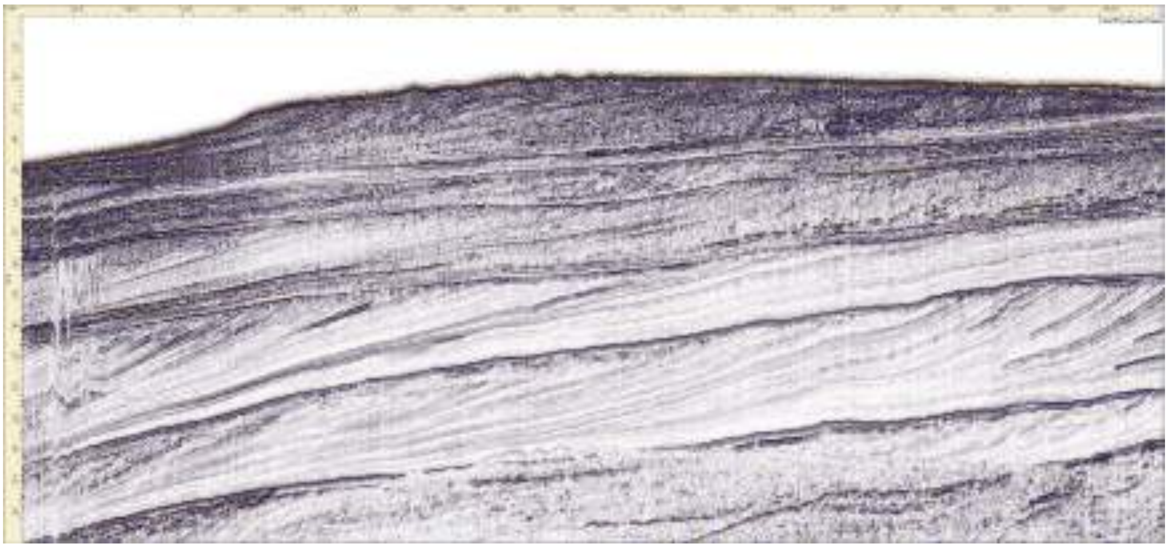


Figure 2-9: Zero-phase corrected final processed stack (Time-Variant Bandpass filter, FK filter, Gain balancing).

Interpretation was cross-checked for consistency at all crossline locations. Additionally, geo-hazards assessment was carried out focusing on the areas for planned shallow geotechnical operations. Heave corrections are applied after datum alignment with the MBES data.

3. RESULTS

3.1. BATHYMETRY

The detailed resolution of the bathymetry grid (Digital Elevation Model for seabed data following QUA-01-B GIS specifications) allows for enhanced visualization of depth and interesting seafloor features. The main use of the multibeam data is to reference the seismic profiles to the real seafloor (ZH Bathyelli v2 geoid).

In the acquired lines of the MED_AO6 Zone 4 offshore windfarm survey area, the depth range correspond between -86.78 meters in the shallowest part at the north-eastern region, to -112.85 meters in the deepest part at the southern region.

A colour table for the representation of the three-dimensional terrain model was created, from red -86.78 meters depth and magenta for the maximum depth -112.85 meters.

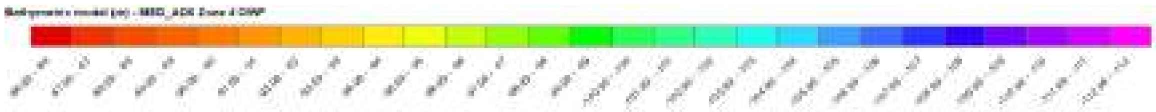


Figure 3-1: Colour table for the representation of the MBES terrain model.

Bathymetric data from the vessel multibeam sensor has been processed into a 1 meters grid size bathymetry for all the acquired lines.

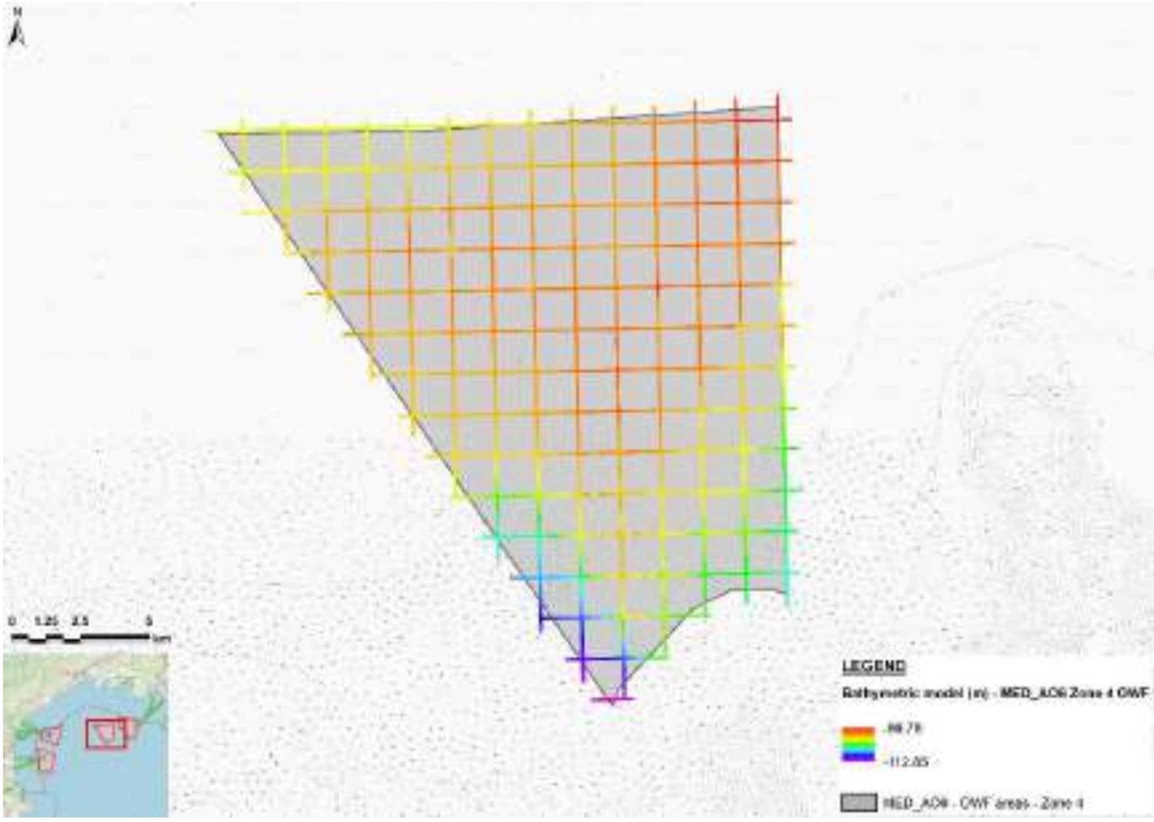


Figure 3-2: Whole bathymetric data grid model (1 x 1 m) for the MED_AO6 Zone 4 OWF.

Several examples of the results of the MBES processed data are shown below:

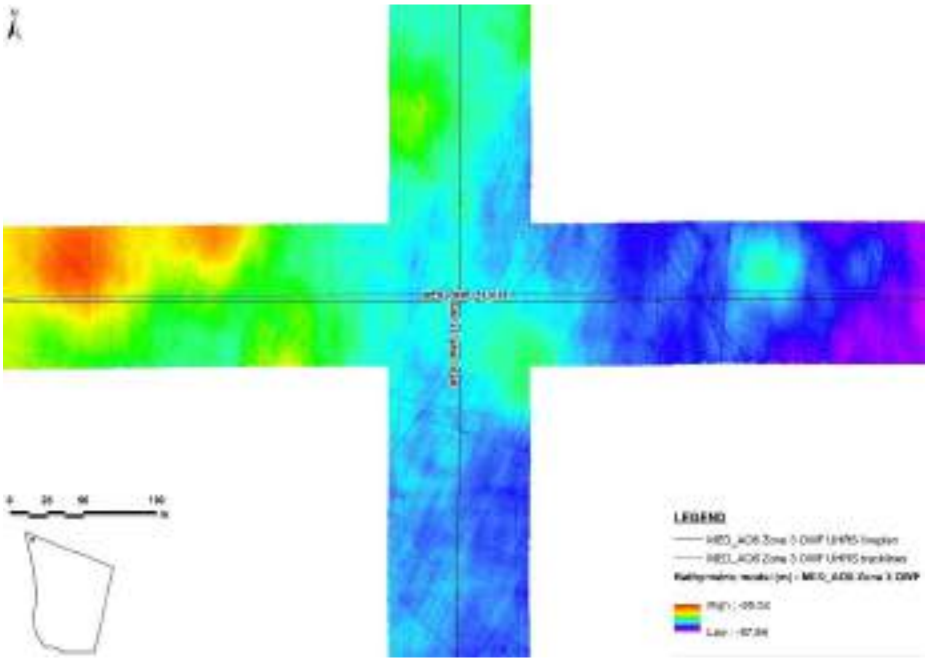


Figure 3-3: Detail of the bathymetric data grid model (1 x 1 m) for the offshore windfarm of the MED_AO6 Z3 area – Survey lines and tracklines MED_OWF_Z3_002-035.

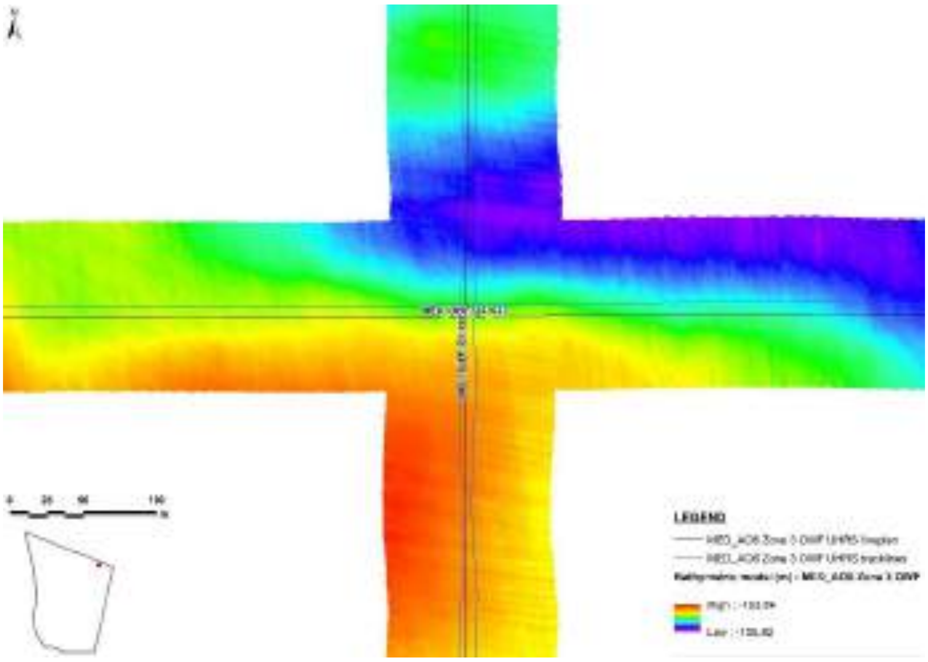


Figure 3-4: Detail of the bathymetric data grid model (1 x 1 m) for the offshore windfarm of the MED_AO6 Z3 area – Survey lines and tracklines MED_OWF_Z3_022-027.

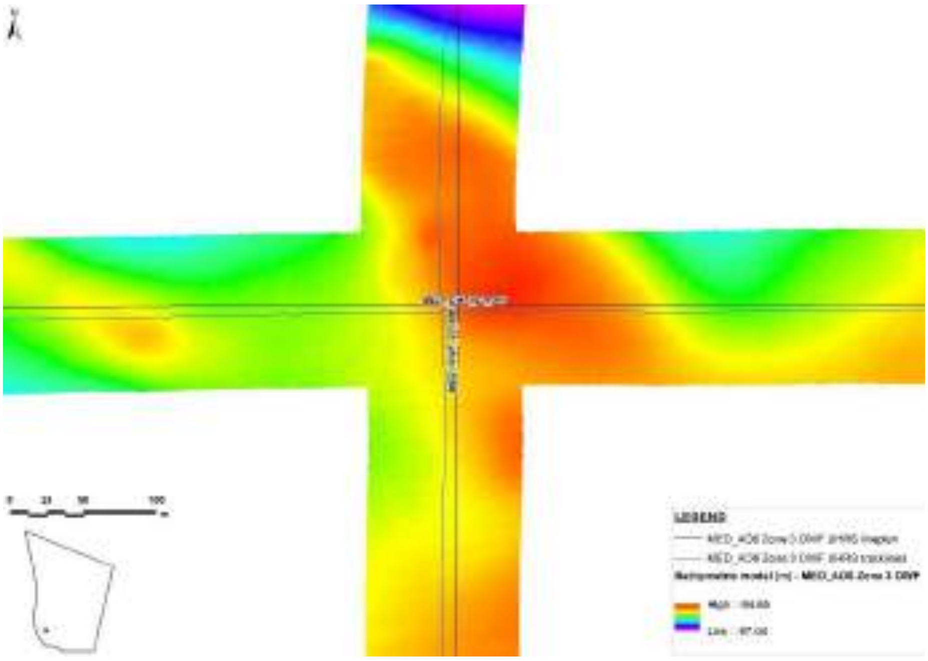


Figure 3-5: Detail of the bathymetric data grid model (1 x 1 m) for the offshore windfarm of the MED_AO6 Z3 area – Survey lines and tracklines MED_OWF_Z3_006-007.

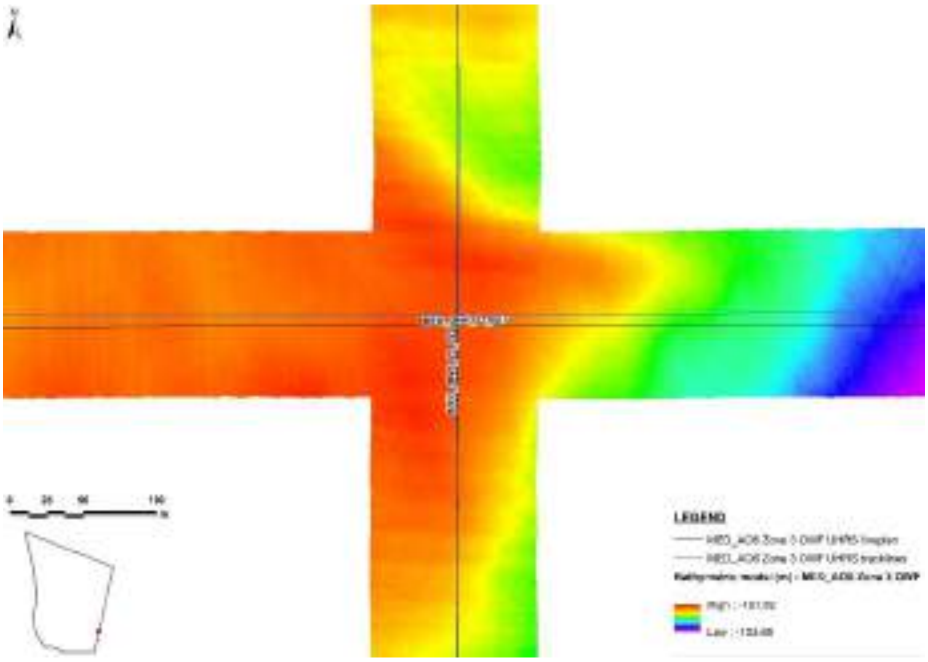


Figure 3-6: Detail of the bathymetric data grid model (1 x 1 m) for the offshore windfarm of the MED_AO6 Z3 area – Survey lines and tracklines MED_OWF_Z3_022-007.

3.2. GEOLOGY

3.2.1. Geological setting from background data

The Gulf of Lions is located in the northwestern sector of the Mediterranean Sea bounded by the Pyrenees and the alps. It comprises a wide shelf and continental slope, before descending to the abyssal area of the Algero-Balearic Basin. The basin formed as a result of tectonic rifting during the Oligocene – Miocene period (Gorni, et al. 1994), leading to the accumulation of a large amount of clastic sediments forming a thick wedge on the inner shelf, and more than 2km on the outer shelf (Lofi, 2002). The continental shelf edge leads to the prograding margin observed in the Gulf of Lions during the end of the last glacial cycle. The geology within the Golf of Lion is described as a relatively low energy passive prograding margin, dominated by a rapid period of sedimentation during the Late Pleistocene, with layers of reworked sediments at a time when sea-levels were about 100m lower. At the end of the Last Glacial Maximum, sea levels were cyclically higher and lower as ice masses in the two hemispheres contracted and advanced. The deglacial succession overlies the major erosional discontinuity related sea level rises since the Last Glacial Maximum. It consists of basal transgressive deposits, subsequently reworked into dunes and sand ridges, interbedded with regressive prograding, marine derived sediments. The shelf 'relict' sands, pass rapidly into marine muds. The transition between sand and muds is outlined by a distinct regional step in sea-floor morphology.

3.2.2. Geological sequence

Within the depth of interest (up to 30m), the MED_AO6 OWF zone 4 area comprises a sedimentary succession of Late Pleistocene sediments, predominantly marine derived during periods of deposition. The shallow geology (30 m below seabed) within the MED_AO6 Zone 4 OWF site has been divided into units based on the sequence boundaries of major erosional surfaces. Five coherent stratigraphic packages, over the first 30 m subsea are distinguished, with the base of the units marked by sequence boundaries where there are clear unconformable, erosional events and a strong change in the dip angle of the sediments. The angle of dip may have been defined by the onlapping of sediments at the shelf edge, the change in a river pathway or other similar process. The presence of the strong change in dip suggests an erosional surface between that. These events mark clear sequence boundaries where there has been a change in conditions and hence separated into varying sedimentary units. The units are all interpreted to be similar in composition, and without geotechnical data to aid interpretation within zone 4 a succession of marine derived silty clay with some sand is interpreted.

Four horizons have been mapped within the Zone 4 AO6 OWF area which have been interpreted to represent, as already mentioned sequence variations. Some changes in the seismic acoustic character also suggests variations in the sediments within the units. The units are, the base of the uppermost marine drape (Base of Unit 1 – H05), a unit more chaotic in nature (base of Unit 2 – H15); the base of an acoustically quieter unit (Unit 3 – H20); and the base of a strongly dipping surface, with some evidence of channelling and coarser sediments within the channels.

Within the OWF, Unit 1, a blanket drape of acoustically quiet sediments, interpreted as a silty clay of Holocene age, and deposited since sea levels were at current levels which ranges in thickness from about 0.5 to 9 m (BSB). The base of unit 1 (H05) is interpreted as an erosional surface, with evidence across some areas of the OWF of channelling at the base, as well as a strong normal phase unconformity with parallel bedded reflectors above, interpreted as the drape of Unit 1, and a more chaotic acoustic character below (Unit 2). H05 has been mapped across the whole of the OWF, and converted into depths using an ASV of 1600m/s. An isopach to the depth to the base of Unit 1 is illustrated in Figure 3-9**¡Error! No se encuentra el origen de la referencia.** below as a thickness below seabed.

Below unit 1, a sand unit (Unit 2), is interpreted across much of the site. From the acoustic nature of the data, this unit appears to be more chaotic, and there is evidence of small channels, and much more variation in the amplitude response than found in Units 1 and 3. This suggests a variability in sediments found within the unit, with coarser lag deposits also interpreted as present within the data. Unit 2 pinches out in the northwest of the area. In this area, the base of unit 1 H05 is interpreted to have eroded into the underlying Unit 3 sediments. Unit 2, where present, occurs between 0.8m below seabed and 21.5m below seabed, with the deepest section occurring in the centre of the survey area, below a sand bank. Unit 2 is illustrated in Figure 3-7, with the isopach to the depth to the base of Unit 2 illustrated on Figure 3-10.

Below Unit 2, there is a thin, acoustically quieter unit of sediments interpreted as marine derived silty clays (Unit 3). The base of this unit (H20) is gently dipping to the northwest. The base of this unit is present across most of the site, apart from where there are large channels incising into the base of it, as illustrated on Figure 3-8. The depth to the base of unit 3 varies between 6.1m below seabed in the north of the survey area, to 26m below seabed in the centre and southwest of the survey area. The acoustic character of the sediments infilling the channels suggest a different composition to the sediments found within Unit 3. An isopach to the base of Unit 3 is illustrated on Figure 3-11.

Unit 4 is interpreted as similar in nature to Unit 2. The base of Unit 4 (H30) is marked by a strong variation in the angle of dip and the acoustic character of the sediments. Within Unit 4, there are predominantly parallel bedded reflectors with these in the north becoming acoustically more chaotic and less coherent. This suggests a degree of weathering or erosion within this unit, interpreted to have occurred during a period of reduced sea levels when the sediments were aerially exposed. The depth to the base of Unit 4 is illustrated on Figure 3-12 as an isopach, and occurs between 11.4m below seabed in the northwest of the OWF, and at 37m below seabed in the southeast, or is absent where the large channels are observed in the seismic data in the south

Below Unit 4, Unit 5 is interpreted to be similar in acoustic character to Unit 4, the primary difference between the two units is the angle of the dip, and hence the sequence boundary between the two units representing a change in environmental conditions during their deposition.

Channels are interpreted in the south of the survey area. The location of these are shown on Figure 3-8, and Figure 3-13 displays their extents. These are predominantly beyond the depth of interest for anchor emplacement but have been included for completeness due to their size.

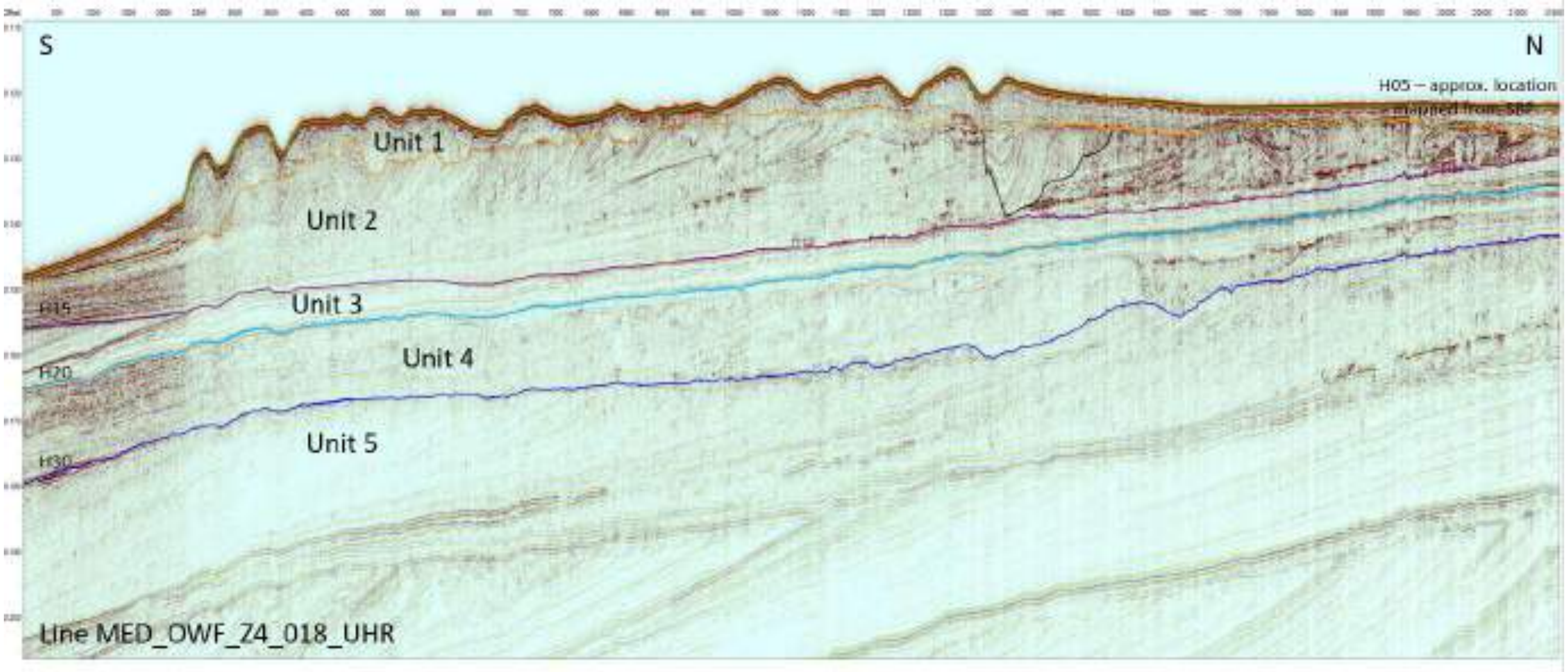


Figure 3-7: Line AO6_OWF_Z4_018.

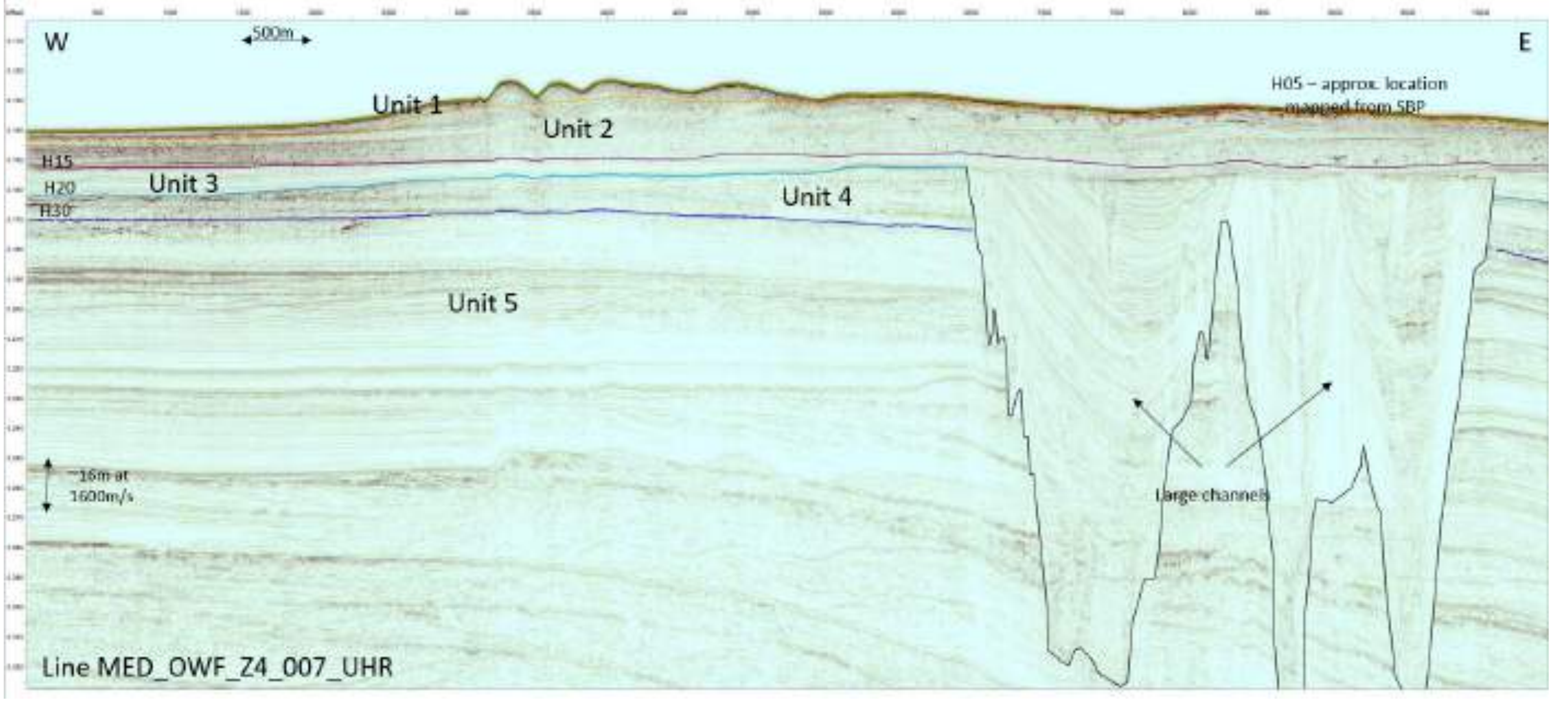


Figure 3-8: Line AO6_OWF_Z4_007.

Table 4: Shallow geological units.

Unit	Upper surface	Lower surface	Description	Depositional Environment
1	**Seabed**	**H05**	Uppermost unit mapped off the Innomar data, with an erosional surface at the base marked by small channels. Thins to 0.9m in the northwest and is up to 9m thick in the center of the survey area. The erosional base suggests there may be some coarser or lag deposits present	Shallow marine, a drape of sediment deposited since sea level rise and the area was exposed.
2	**H05**	**H15**	Discontinuous reflectors, a package of sediment marking multiple events of depositional reworking and erosion. Exposed above sea level. Acoustically of higher amplitude. Evidence of unconformities, channelling within. Strong normal phase unconformable reflector at the top and base of the unit, interpreted as predominantly sandy in nature, some coarser material, and occasional small clay beds may be present within.	Estuarine/lacustrine depositional and some terrestrially reworked
3	**H15**	**H20**	Acoustically quiet unit with little to no structure within it. Interpreted as marine clays rapidly deposited during a period of higher sea levels.	Marine deposited parallel bedded acoustically quieter unit.
4	**H20**	**H30**	Discontinuous reflectors, a package of sediment marking multiple events of depositional reworking and erosion. Exposed above sea level. Acoustically of higher amplitude. Evidence of unconformities, channelling within. Strong normal phase reflector at the top and base of the unit, interpreted as predominantly sandy in nature, some coarser material, and occasional small clay beds may be present within.	Estuarine/lacustrine depositional and some terrestrially reworked
5	**H30**		Discontinuous reflectors, a package of sediment marking multiple events of depositional reworking and erosion. Exposed above sea level. Acoustically of higher amplitude. Evidence of unconformities, channelling within. Strong normal phase unconformable reflector at the top of the unit. Interpreted as predominantly sandy in nature, some coarser material, and occasional small clay beds may be present within.	Marine deposited parallel bedded acoustically quieter unit.

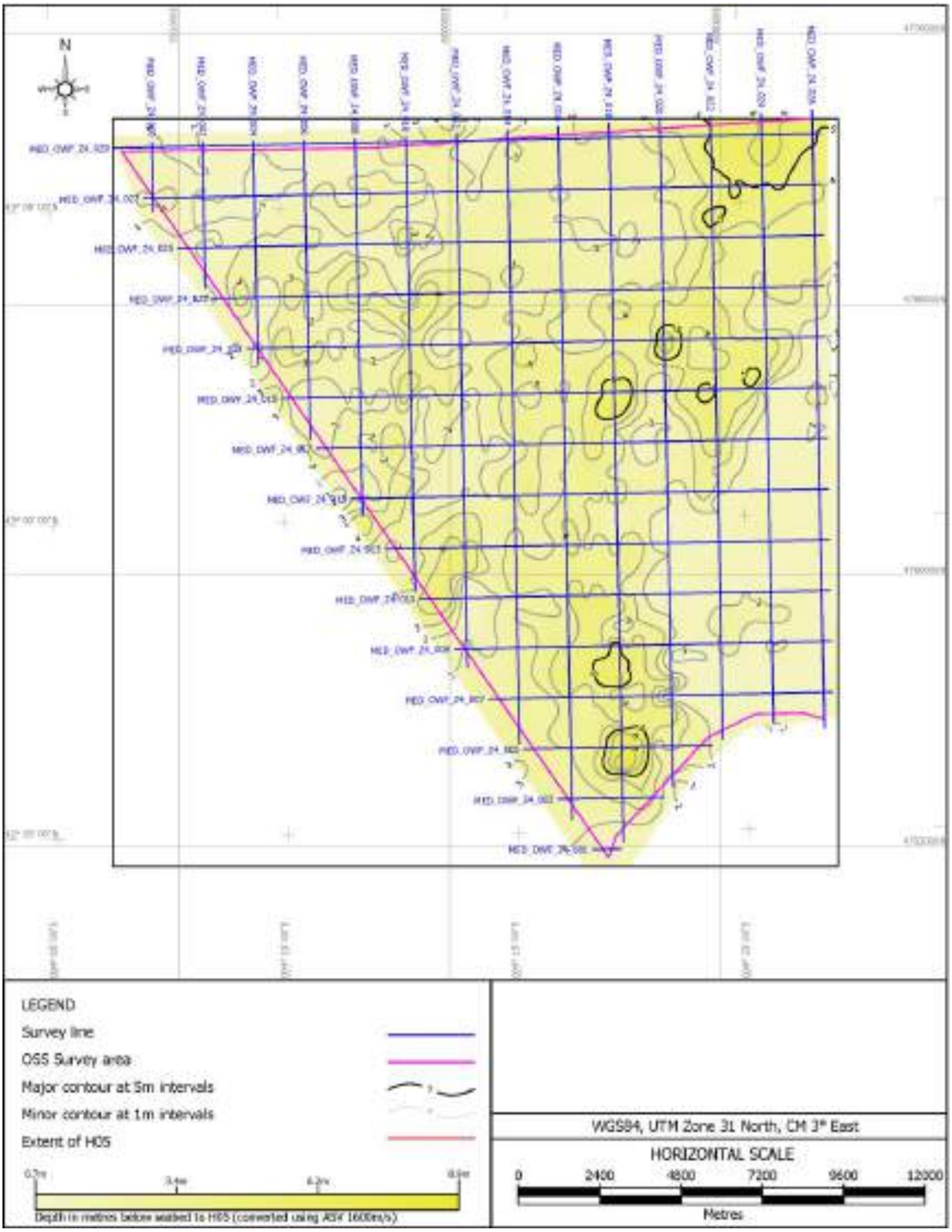


Figure 3-9: Isopach of depth to Base Unit 1 (H05)

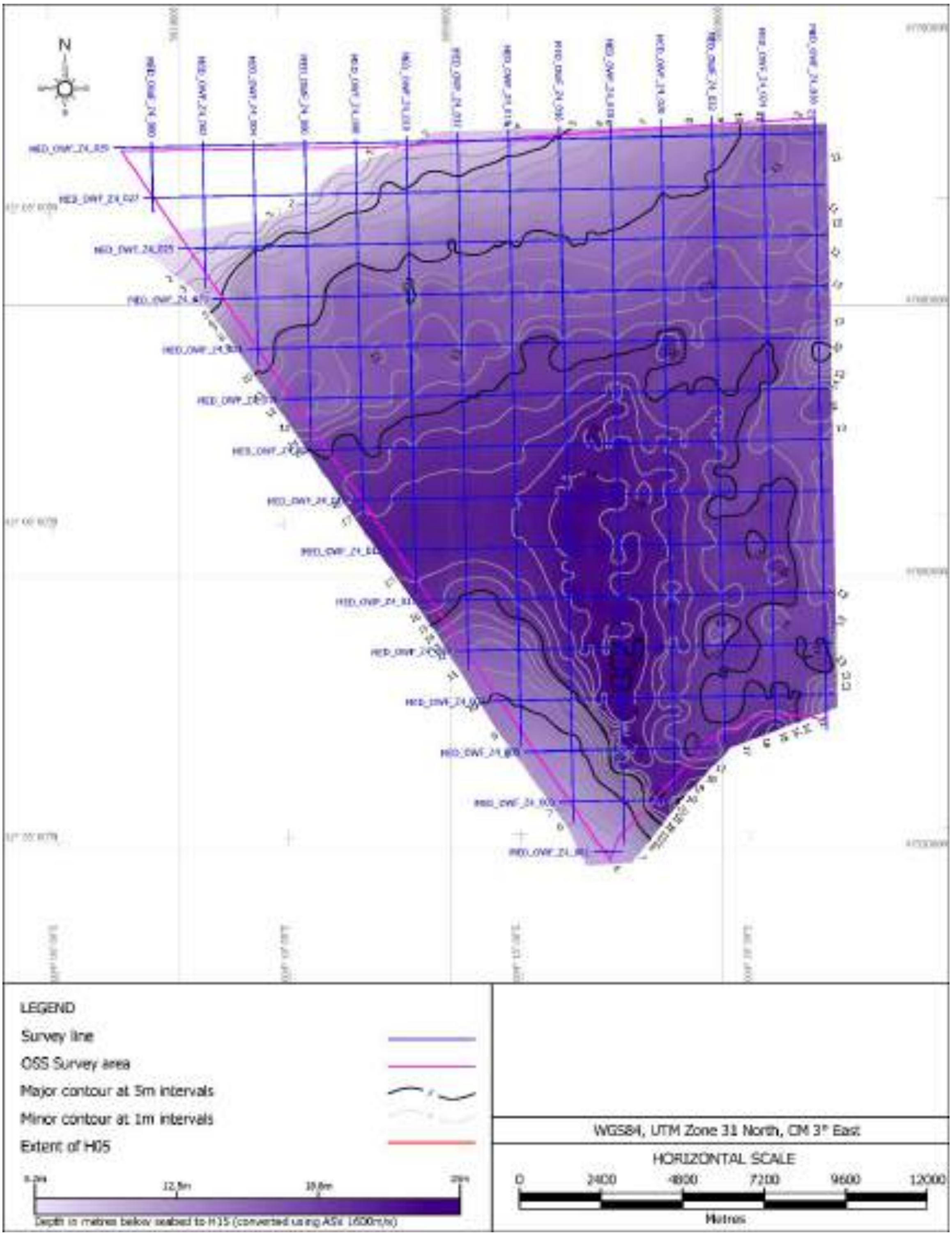


Figure 3-10: Isopach of depth to Base Unit 2 (H10).

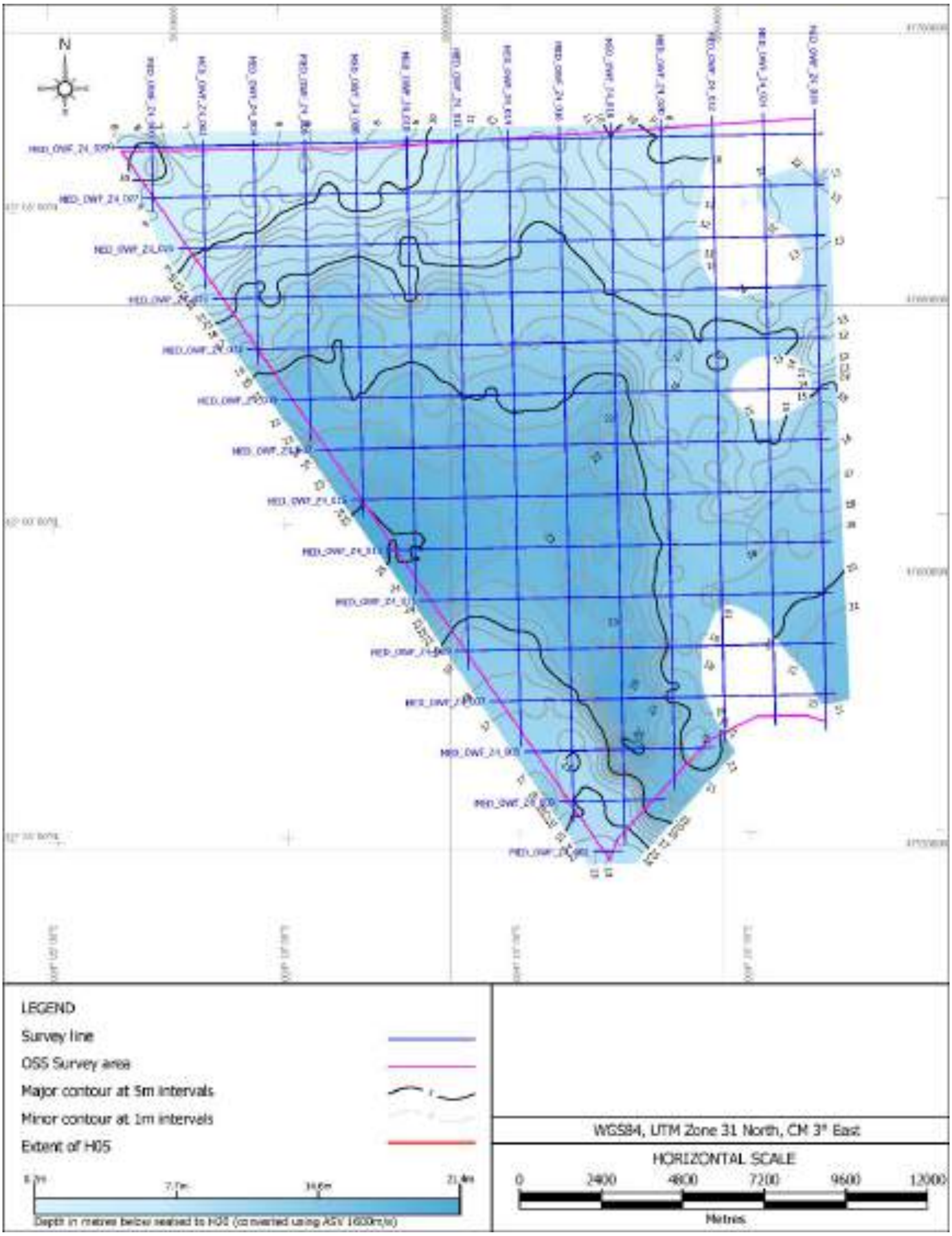


Figure 3-11: Isopach of depth to Base Unit 3 (H20).

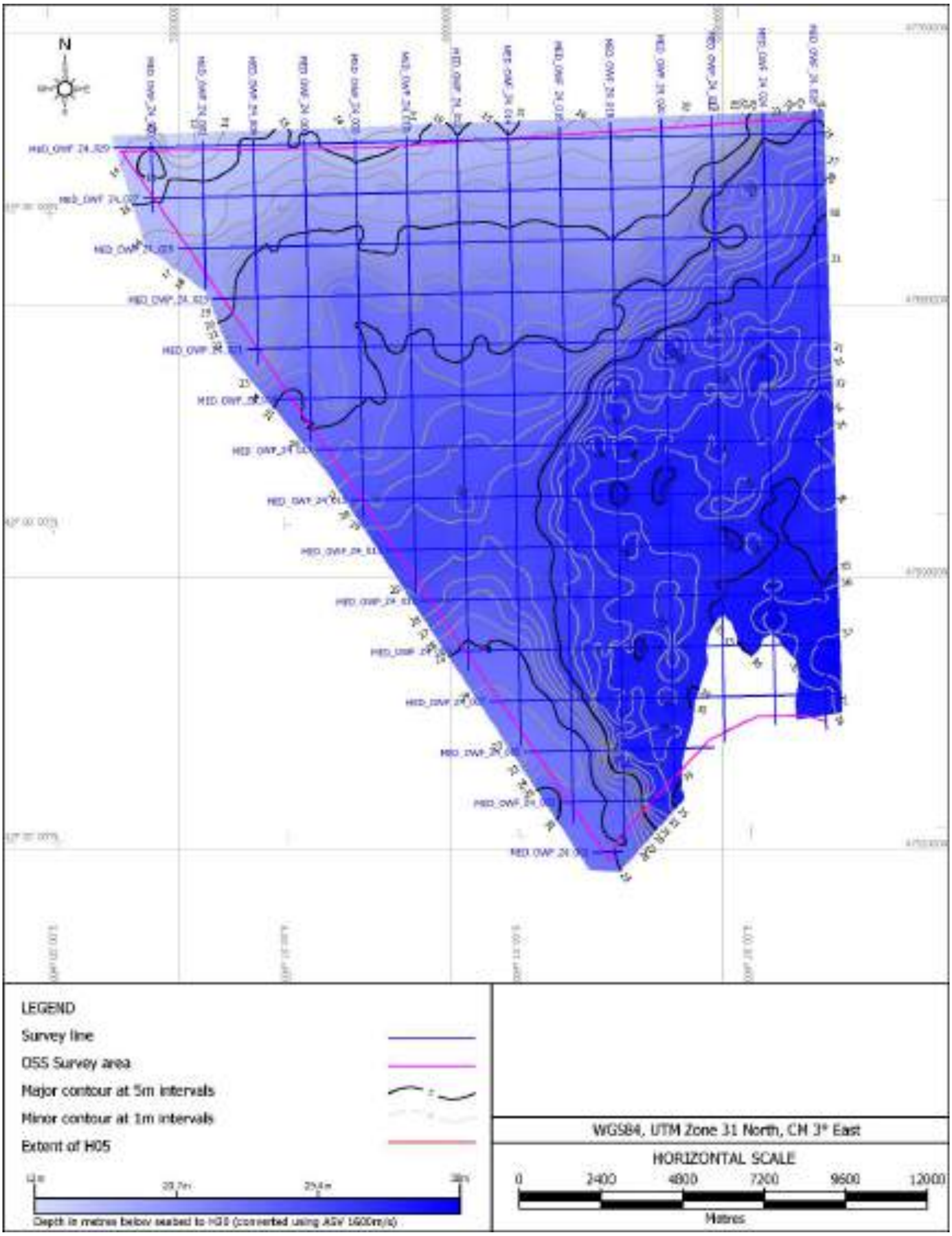


Figure 3-12: Isopach of depth to Base Unit 4 (H30).

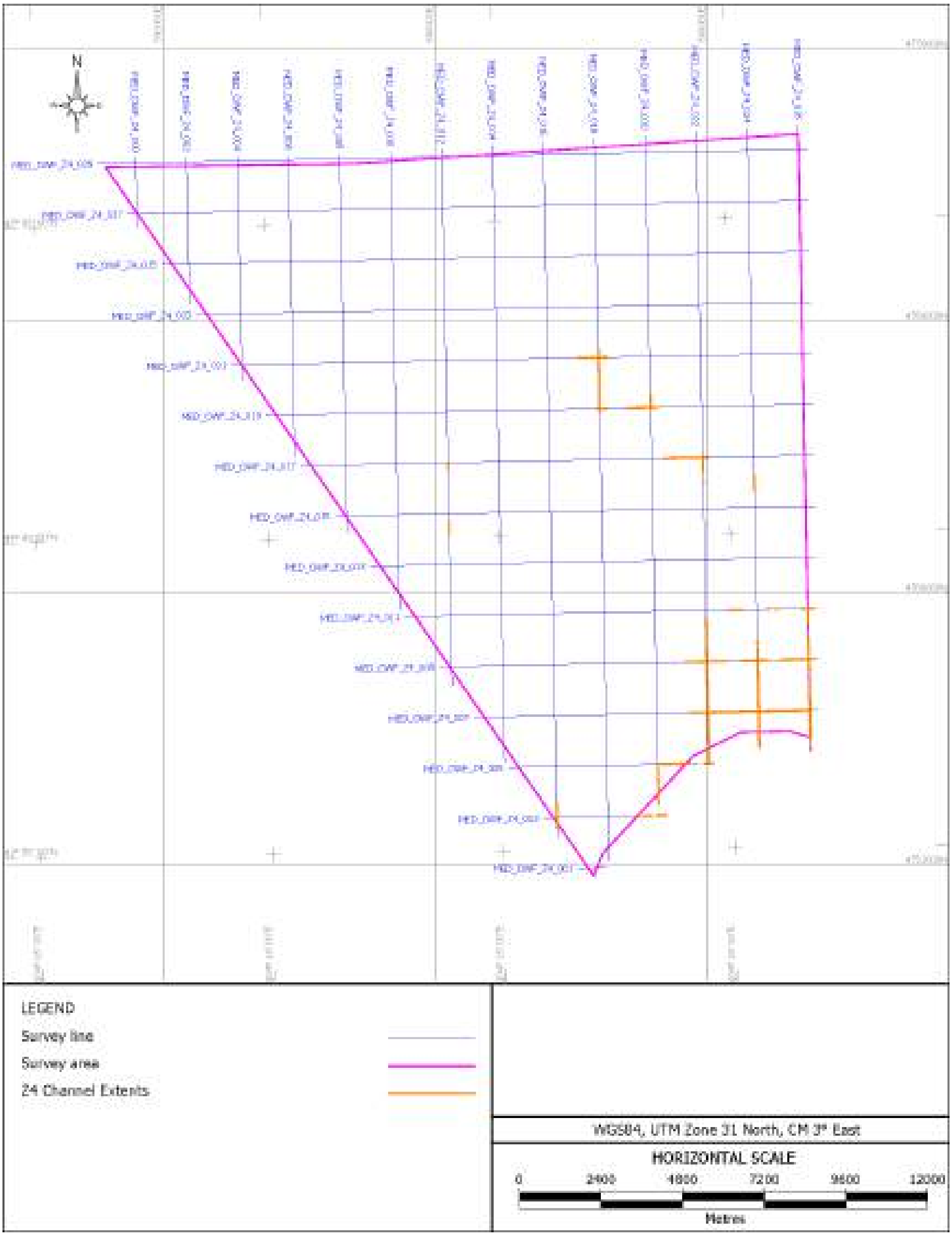


Figure 3-13: Large channel extents within Zone 4 OWF area.

3.2.3. Geohazards

The shallow geology has been checked for any evidence of any shallow geohazards that may affect the installation or operation of a floating wind farm. Constraints may relate to composition and distribution variability of sediments (at the seabed and in the subsurface) within the first 30 m below the seafloor. Other constraints may relate to past or presently active geological processes, such as gas seepage and faulting.

A summary of geological conditions and potential constraints on infrastructure and engineering activities, applied to the Zone 4 MED_AO6 site, is provided in (Table 5) modified after (Mellet, Long, Carter, Chiverell, & Van Landeghem, 2015).

Within the upper 30m of the Zone 4 OWF, there are various conditions, that may or may not be considered a hazard based on the installation design.

- Large channels observed in the south of the survey area within the upper 30m will mean there are sediment variations which would need investigating before anchor emplacement is planned.
- Coarse or lag deposits interpreted to be present in the base of Unit 1 and throughout Unit 2 may need to be considered for anchoring purposes.

There is no evidence of gas, or slope failure or other similar geohazards within the Zone 4 OWF, with a full list of all geohazards and the potential constraint listed in Table 5 below.

Table 5: Geological characteristics / processes and potential constraints.

Geological characteristic / process	Potential constraint	MED_AO6 OWF site
Seabed sediments		
Soft muds	Low strength means they will not bear large loads	Probable
Coarse lag (gravel to boulders) deposits	May be present below mobile sediment	Probable
Mobile sediment		
Migrating bedforms change topography (can create seabed features several metres height)	Can bury or expose structures or create a barrier to activities	Not evident
Mobile sediment can change sediment characteristics at seabed	Mobile sediment is constantly changing. Therefore, expect variation between samples taken from the same site at different times.	Not evident
Bedforms can migrate in the opposite direction to that predicted from morphology and tidal residual	Do not assume sediment migration pathways from morphology. Repeat bathymetric surveys should be carried out.	Not evident
Gas/fluid escape and MDAC		
Gas or fluid present in shallow subsurface	Can lead to blowouts when drilling	Not evident
MDAC	Creates a hard substrate that is recognized as a special habitat that must be preserved	Not evident
Quaternary		
Variable sediment thickness	Locally, sediment thickness can change from thin (<5 m) to thick (> 50 m) over a short distance	Expected
Variable lithology (vertically and spatially)	Glacial processes rework and deposit sediments that are highly variable over large areas. Smaller and isolated features such as channels are not always mapped across the site. With the large line spacing some of the variations may not be incorporated into the interpretation.	Expected
Heterogeneous sediment composition	Sediments are typically glacially diamict which are poorly sorted mixtures of silt, sand, gravel, and clay. Diamicts can be interbedded with sands.	Probable
Bedrock		
Bedrock outcrop at seabed	Provides a hard substrate for emplacement of seabed infrastructure.	Not evident
Faulting	Active faults are susceptible to ground surface ruptures that can compromise infrastructure; seabed forms that indicate pre-existing seabed instability, surface displacements, or fluid escapes are conditions that pose risk to infrastructure; Sub-surface fault zones may provide preferential conduits for gas migration, or may be hydraulically active during (or shortly after) earthquakes	Not evident

The depth values were converted from time (TWT) using sound velocity of 1,600 m/s in sediments and 1,510 m/s in the water column.

3.2.4. Background data summary and regional geology

To provide background context for regional stratigraphy and structural geology relevant portions of text from (Bassetti, 2006) are reproduced here:

In the Gulf of Lions, which is considered as a relatively low energy continental shelf, most of the authors still consider that the offshore sands are relict features, only the transgressive processes, at a time when sea-level was lower by about 100 m, being able to rework sediments (Aloïsi, 1986; Berné et al., 1998; Monaco, 1971). However, ultra-high resolution seismic data, coring and 14C dating, as well as numerical modelling of wind stress on oceanic circulation, allow us to demonstrate that a mobile carpet of sand is periodically active at the shelf edge, feeding slope and rise deposits and contributing to the episodic reworking of shelf morphology.

Morphology and seismic facies of post-glacial deposits

(a) Sand ridges- In the studied area, the major morphological feature is represented by the sand ridges, localized between 95 and 110 m water depth. They have limited areal (Bassetti et al. (Marine Geology)) distribution, variable heights (up to 9 m) a mainly WNW-ESE orientation, as recognized on the bathymetric maps. They have an irregular topography and mainly show a linear, elongated shape. On the chirp profiles their surface is smooth, they form bodies of maximum length of 5 km and they rest on a major erosional surface (ravinement surface) that is possibly exposed beyond the ridge field. The ridges have an asymmetric transverse profile (with the steepest slope facing the SW). At times, they show a nearly symmetric profile, but it concerns only the smaller bodies. They show distinct clinoforms, dipping in the SW direction and some chaotic internal reflections probably in relation with coarse-grained material diffracting seismic waves. However, some major erosional surfaces (discontinuities) can be recognized within the ridge, that may be related

to storm events affecting the ridge growth, although they cannot be correlated from one ridge to another.

(b) the dunes were only detected when we used high-resolution swath bathymetric systems, such as the EM 1000 and EM1002S. They have an average spacing of 130 m and maximum height of 2 m. Their great axis has a NNW-SSE orientation in the NE part of the surveyed area, turning progressively to NW-SE in the SW corner. Their internal structure was not detectable considering their small size. They are classified as transverse dunes in the sense of Ashley (1990) and they clearly rework the shape of the sand ridges. On top of the sand ridges, chirp and sub-bottom seismic profiles display a thick pattern of parallel reflections, that was first considered as the result of some ringing effect representing the pulse length of the seismic sources, instead of a real sedimentary layer. However, extensive coring and bathymetric data demonstrated that a distinct layer actually exists at the sea-floor interface.

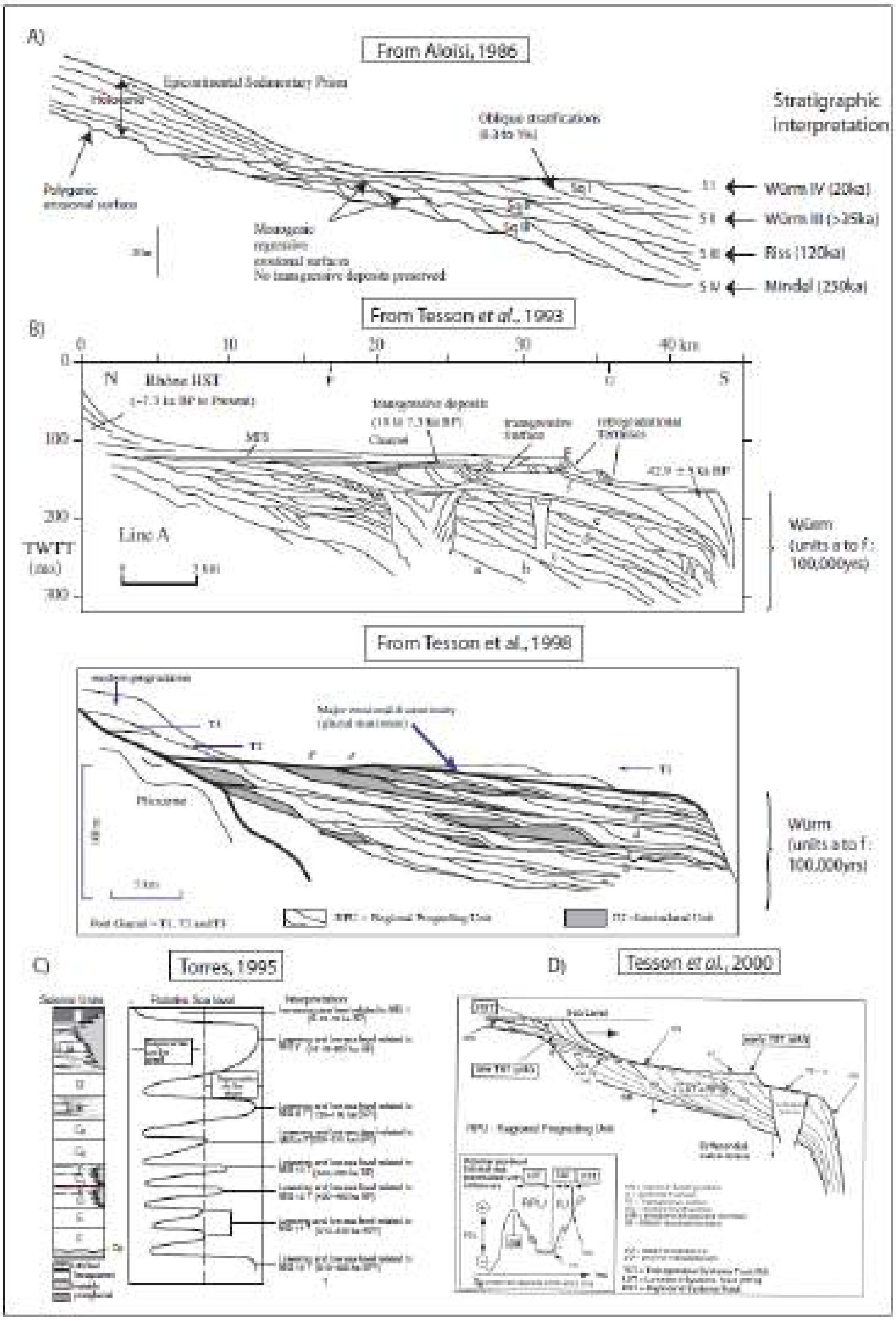


Figure 3-14: Figure showing the geology (Figure 3 from Rabineau et al., 2003; Benabdellouahed, 2011; Paquet et al. - b, in preparation).

3.2.5. Conclusions and recommendations/comments

Horizons were mapped to define units of similar sedimentary facies based on acoustic nature and known geology and environmental conditions during the time of deposition from background material. These have been illustrated as isopachs to show rough sedimentary thicknesses and assist with a ground model. The sediment types and any hazards present were mapped.

No evidence of shallow gas or faulting is observed.

To improve knowledge of potential geological constraints the following data acquisition could prove beneficial.

1. Acquire additional high-resolution seismic data at a closer line spacing to improve spatial mapping of stratigraphic units.

2. Acquire sidescan sonar imagery data to coincide with the multibeam bathymetry and backscatter data.
   a. A detailed seafloor mapping with sidescan sonar data will identify potential natural and anthropogenic seafloor geohazards.

3. Acquire repeat multibeam bathymetry and backscatter data during sidescan sonar data acquisition
   a. Use this comparative multibeam bathymetry data to assess potential for sediment mobility.
   b. Although a recent study concluded that sediment mobility is not apparent at the NOR_AO4 OSS site, monitoring for its potential could be beneficial for long-term development planning.

4. Acquire seabed ground-truthing “light” geotechnical data (e.g., grab samples) to confirm the variable seafloor composition illuminated with the sidescan sonar data.

4. REFERENCES

Actimar. (2021). *Offshore wind farm and its connection to the Bay of Seine, Hydro-sedimentary and morphodynamic analysis.*

Barrie, J. V., & Conway, K. (2014). Seabed characterization for the development of marine renewable energy on the Pacifi c margin of Canada. *Continental Shelf Research*, 45-52. doi:http://dx.doi.org/10.1016/j.csr.2013.10.016

Benabdellouahed, M., Dugue, O., Tessien, B., Thinon, I., Guennoc, P., & Bourdillon, C. (2014). New mapping of the bedrock of the Bay of Seine and landsea. *Geology of France*, 26.

Mellet, C., Long, D., Carter, G., Chiverell, R., & Van Landeghem, K. (2015). Geology of the seabed and shallow subsurface: The Irish Sea. *British Geological Survey Commissioned Report*, 52.

Paquet, F., Benabdellouahed, M., Dugue, O., Tessier, B., Briais, J., Lasseur, E., . . . Bernachot, I. (2021). Extract from the Geological Map of France at 1:250,000. *Bay de Seine Sheet (unpublished)*.

Thinon, I., & Serrano, O. (2021). *Geological overview of the EMR-AO4 area of interest in the Bay of Seine.* Bureau de Recherches Géologiques et Minières (BRGM).

Ziegler, P. (1990). *Geological atlas of Western and Central Europe.*

APPENDIX I – CHARTING

CHART NUMBER	CHART TITLE
1	Z4_OWF_BATHYMETRY
2	Z4_OWF_GRADIENT
3	Z4_OWF_PROFILE_018
4	Z4_OWF_PROFILE_023
5	Z4_OWF_PROFILE_023
7	Z4_OWF_ISOPACH_H05
8	Z4_OWF_ISOPACH_H15
9	Z4_OWF_ISOPACH_H20
10	Z4_OWF_ISOPACH_H30

MINISTÈRE DE LA TRANSITION ÉCOLOGIQUE

TECNOAMBIENTE

CARTOGRAPHIC INFORMATION	GRAPHIC SCALE		DATE:	LEGEND:	PROJECT TITLE:	AREA:	CHART:
ELEVATION REFERRED TO BATHYELLI v2 GEOID	0 700 1400 2100 2800 3500 Metres		June 2023	OSS Survey area Major contour at 5m intervals Minor contour at 1m intervals	Geophysical Survey - A06 OWF Area	A06 Zone 4	1 of 1
	DATUM:	PROJECTION:	COMMENTS:	Depth in metres Data gridded at 1m cell size 68m 80m 92m 104m	CHART TITLE:	REFERENCE:	SCALE:
	WGS84	UTM 31N	- - -		A06 Zone 4 OWF Area Bathymetry Chart	A06 Zone 4	1:35000

MINISTÈRE DE LA TRANSITION ÉCOLOGIQUE

TECNOAMBIENTE

CARTOGRAPHIC INFORMATION

ELEVATION REFERRED TO BATHYELLI v2 GEOID

GRAPHIC SCALE

0 700 1400 2100 2800 3500

Metres

DATE: June 2023

DATUM: WGS84

PROJECTION: UTM 31N

COMMENTS: - - -

LEGEND:

OSS Survey area

Slope in degrees
Data gridded at 1m cell size

0° 3.5° 7°

PROJECT TITLE: Geophysical Survey - A06 OWF Area

AREA: A06 Zone 4

CHART: x of x

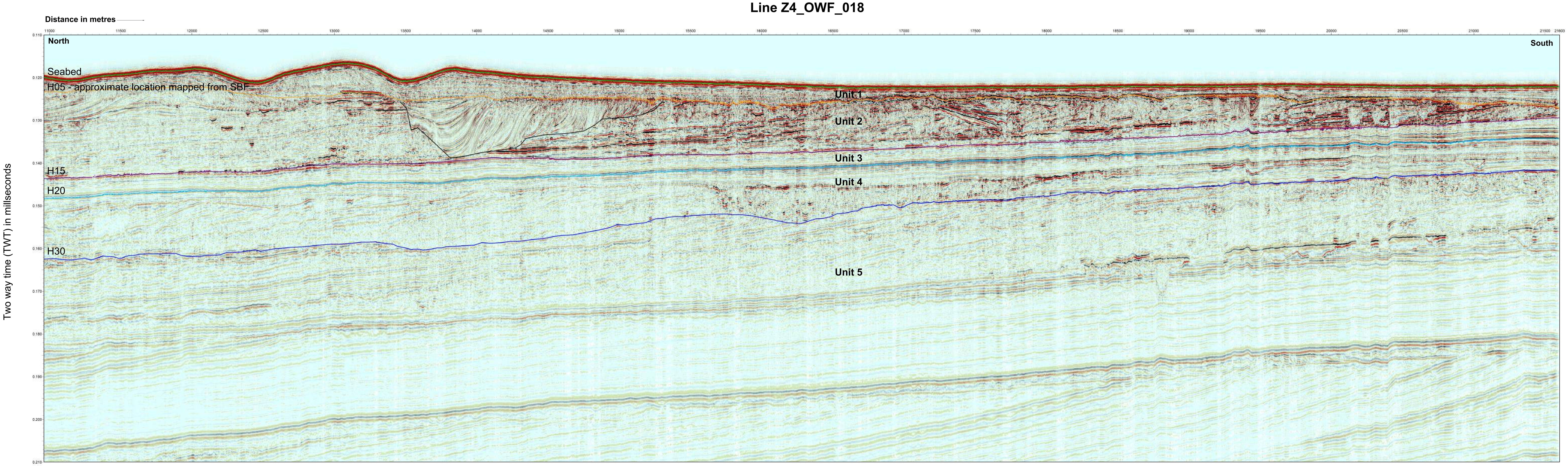
CHART TITLE: A06 Zone 4 OWF Area Gradient Chart

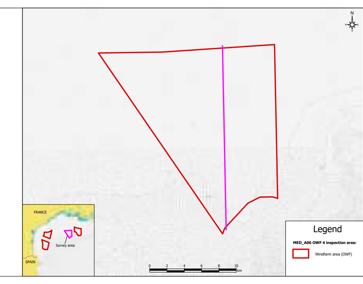
REFERENCE: A06 Zone 4

SCALE: 1:35000

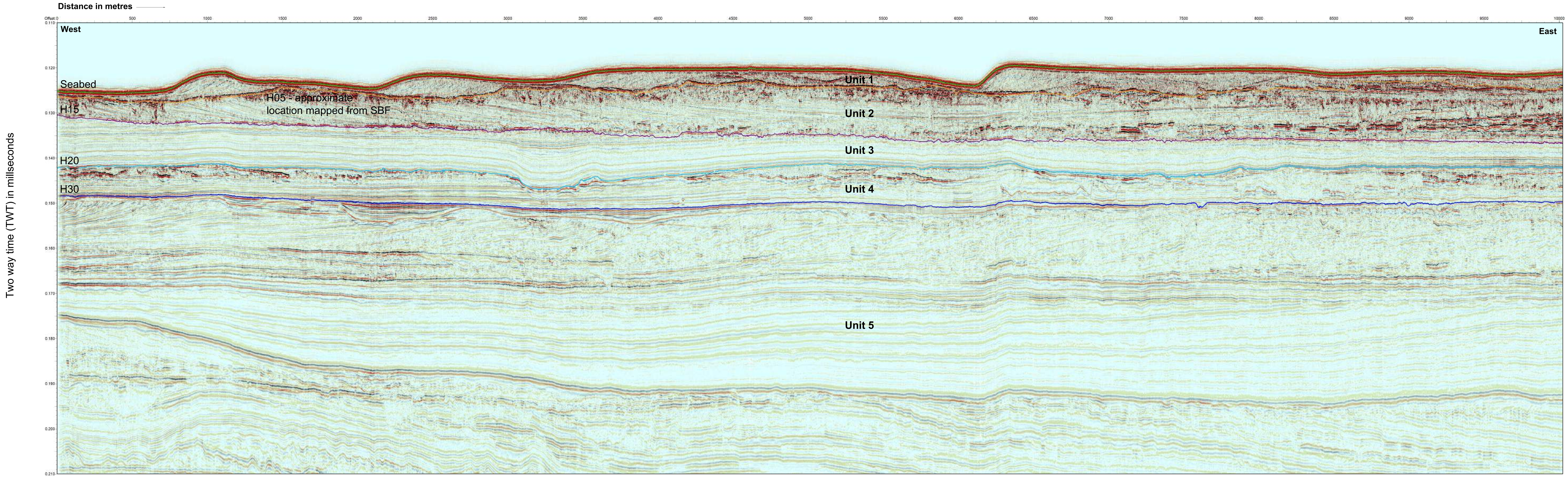
Line Z4_OWF_018

Line Z4_OWF_018

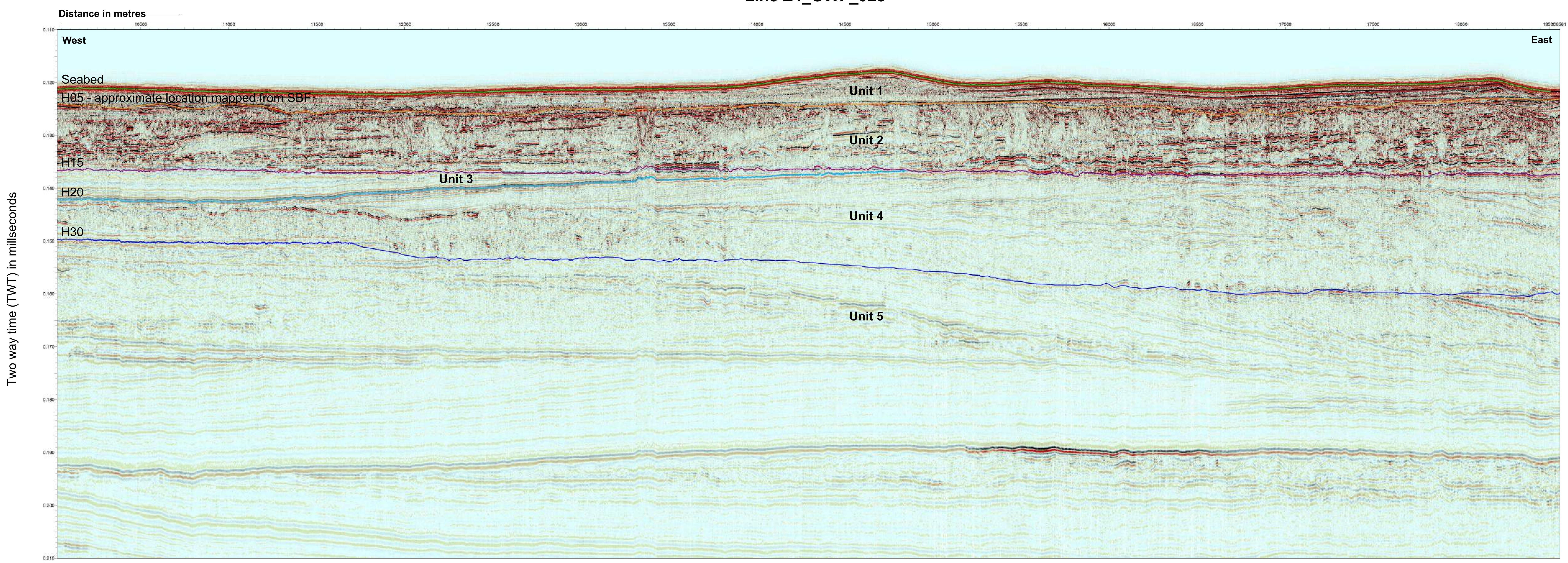


MINISTÈRE DE LA TRANSITION ÉCOLOGIQUE	TECNOAMBIENTE	CARTOGRAPHIC INFORMATION *ELEVATION REFERRED TO BATHYELLI v2 GEOID*	GRAPHIC SCALE 0 100 200 300 400 500 Metres	DATE: June 2023	LEGEND:		PROJECT TITLE: Geophysical Survey - A06 OWF Area	AREA: MED	CHART: x of x
			DATUM: WGS84 / PROJECTION: UTM 31N	COMMENTS: ---			CHART TITLE: A06 Zone 4 OWF Profiles	REFERENCE: ---	SCALE: 1:10000

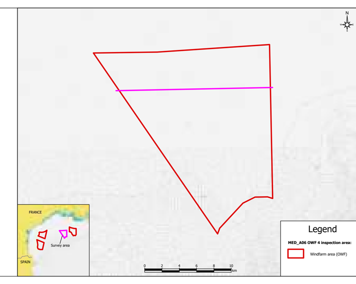
Line Z4_OWF_023



Line Z4_OWF_023



MINISTÈRE DE LA TRANSITION ÉCOLOGIQUE	TECNOAMBIENTE A TRADEBE COMPANY	CARTOGRAPHIC INFORMATION	GRAPHIC SCALE 0 100 200 300 400 500 Metres		DATE: June 2023	LEGEND:		PROJECT TITLE: Geophysical Survey - A06 OWF Area	AREA: MED	CHART: x of x
		ELEVATION REFERRED TO BATHYELLI v2 GEOID	DATUM: WGS84	PROJECTION: UTM 31N	COMMENTS: ---			CHART TITLE: A06 Zone 4 OWF Profiles	REFERENCE: ---	SCALE: 1:10000



MINISTÈRE DE LA TRANSITION ÉCOLOGIQUE

TECNOAMBIENTE
A TRADEBE COMPANY

CARTOGRAPHIC INFORMATION

ELEVATION REFERRED TO BATHYELLI v2 GEOID

GRAPHIC SCALE

0 700 1400 2100 2800 3500
Metres

DATE: June 2023

DATUM: WGS84

PROJECTION: UTM 31N

COMMENTS: - - -

LEGEND:
OWF Survey area
Major contour at 5m intervals
Minor contour at 1m intervals

Depth in metres
Data gridded at 1m cell size
0.7m 2.75m 4.8m 8.9m

PROJECT TITLE: Geophysical Survey - A06 OWF Area

AREA: A06 Zone 1

CHART: x of x

CHART TITLE: A06 Zone 1 OWF Area Isopach H05 Chart

REFERENCE: A06 Zone 1

SCALE: 1:35000

MINISTÈRE DE LA TRANSITION ÉCOLOGIQUE	TECNOAMBIENTE A TRADEBE COMPANY	CARTOGRAPHIC INFORMATION *ELEVATION REFERRED TO BATHYELLI v2 GEOID*	GRAPHIC SCALE: 0 700 1400 2100 2800 3500 Metres DATUM: WGS84 PROJECTION: UTM 31N	DATE: June 2023 COMMENTS: - - -	LEGEND: OSS Survey area Major contour at 5m intervals Minor contour at 1m intervals Depth in metres Data gridded at 1m cell size 0.5m 7.5m 15.0m 21.4m	PROJECT TITLE: Geophysical Survey - A06 OWF Area CHART TITLE: A06 Zone 4 OWF Area Isopach H15 Chart	AREA: A06 Zone 4 CHART: 1x of 1 REFERENCE: A06 Zone 4 SCALE: 1:35000

MINISTÈRE DE LA TRANSITION ÉCOLOGIQUE	TECNOAMBIENTE A TRADEBE COMPANY	CARTOGRAPHIC INFORMATION *ELEVATION REFERRED TO BATHYELLI v2 GEOID*	GRAPHIC SCALE 0 700 1400 2100 2800 3500 Metres	DATE: June 2023	LEGEND: OSS Survey area Major contour at 5m intervals Minor contour at 1m intervals	Depth in metres Data gridded at 1m cell size 6.2m 10.9m 15.6m 25m	PROJECT TITLE: Geophysical Survey - A06 OWF Area	AREA: A06 Zone 4	CHART: 1x of 1
			DATUM: WGS84 / PROJECTION: UTM 31N	COMMENTS: - - -			CHART TITLE: A06 Zone 4 OWF Area Isopach H20 Chart	REFERENCE: A06 Zone 4	SCALE: 1:35000

MINISTÈRE DE LA TRANSITION ÉCOLOGIQUE

TECNOAMBIENTE

CARTOGRAPHIC INFORMATION	GRAPHIC SCALE		DATE:	LEGEND:	PROJECT TITLE:	AREA:	CHART:
ELEVATION REFERRED TO BATHYELLI v2 GEOID	0 700 1400 2100 2800 3500 Metres		June 2023	OSS Survey area	Geophysical Survey - A06 OWF Area	A06 Zone 4	1x of 1
	DATUM:	PROJECTION:	COMMENTS:	Major contour at 5m intervals	CHART TITLE:	REFERENCE:	SCALE:
	WGS84	UTM 31N	- - -	Minor contour at 1m intervals	A06 Zone 4 OWF Area Isopach H30 Chart	A06 Zone 4	1:35000

Depth in metres
Data gridded at 1m cell size
12m 20.6 29.2 38m

APPENDIX II – SEISMIC PROCESSING OVERVIEW

MED_AO6 SEISMIC PROCESSING OVERVIEW

UHR SURVEY PARAMETERS

PARAMETER	VALUE
Sample Rate	0.0625ms
Record Length	0.250ms
Shot Point Interval	1m
Source	Sparker – GSO – 400 tips
Target Source Tow Depth	0.4m

PARAMETER	VALUE
Active Streamer Length	75m
Number of channels	48
Group Length	Channels 1-24 :1m Channels 25-48 : 2m
Target Tow Depth	1m +/-0.5m
Near Offset	~5-6m

PEAKPROCESSING

SEISMIC PROCESSING OVERVIEW

Pre-Processing

↓

Noise Attenuation

↓

Static Correction

↓

Deghost / Pseudo zero phase conversion

↓

Demultiple

↓

Velocities and PSTM

↓

Stack and Post-Stack Processing

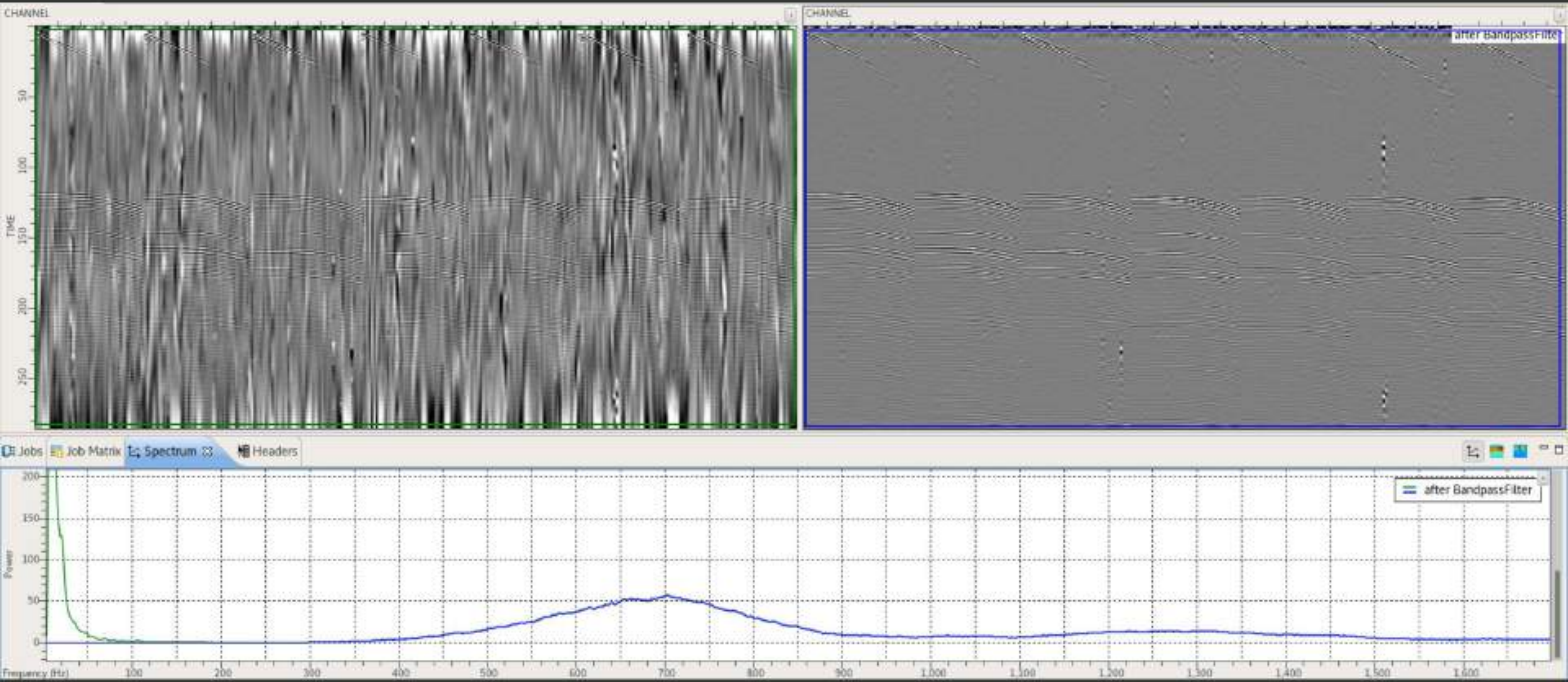
PEAKPROCESSING

PREPROCESSING

Pre-Processing

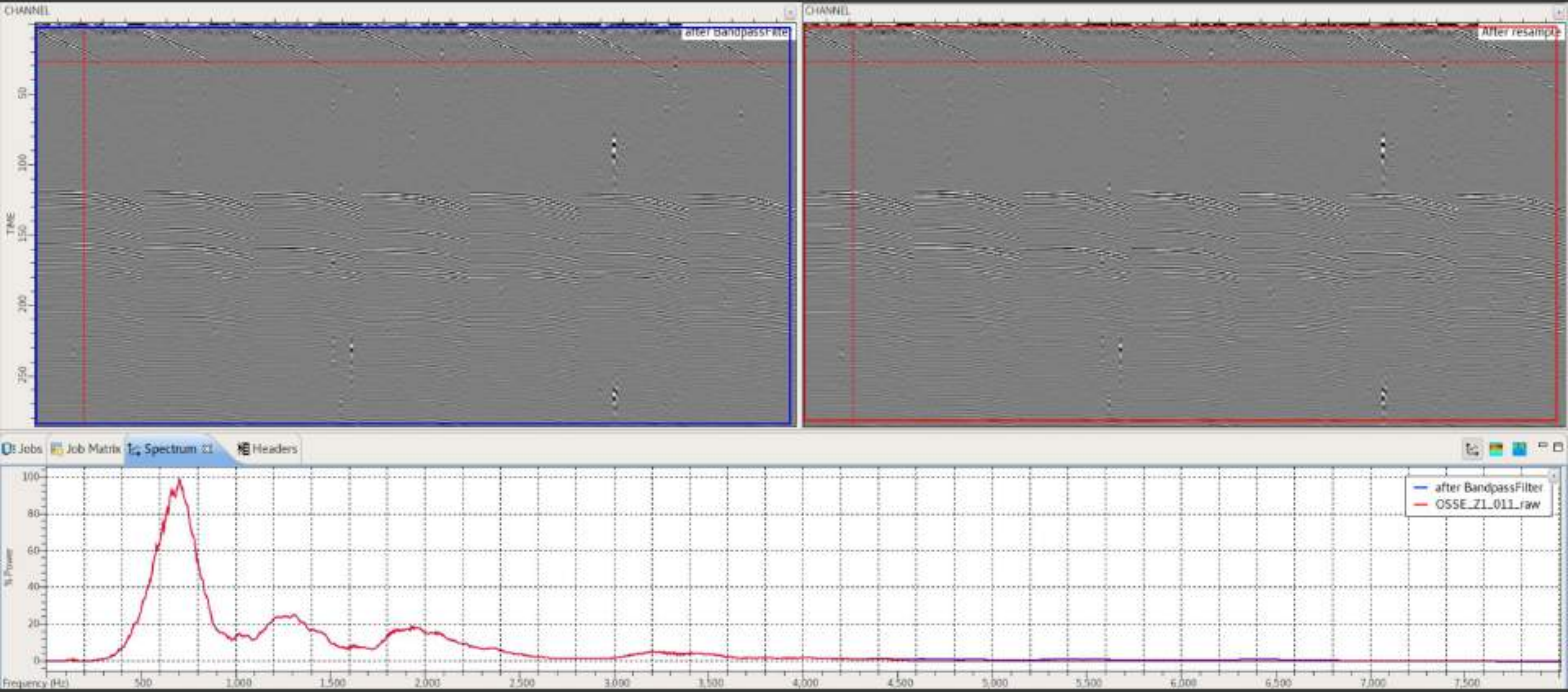
- Static correction to SOD
- Prefilter → Bandpass - 120hz 36dB slope
- Resample → Resample to 0.1ms - 5khz
- Apply Geometry → Assign offset
- Brute Stack → Stack with single velocity function

PRE-FILTER



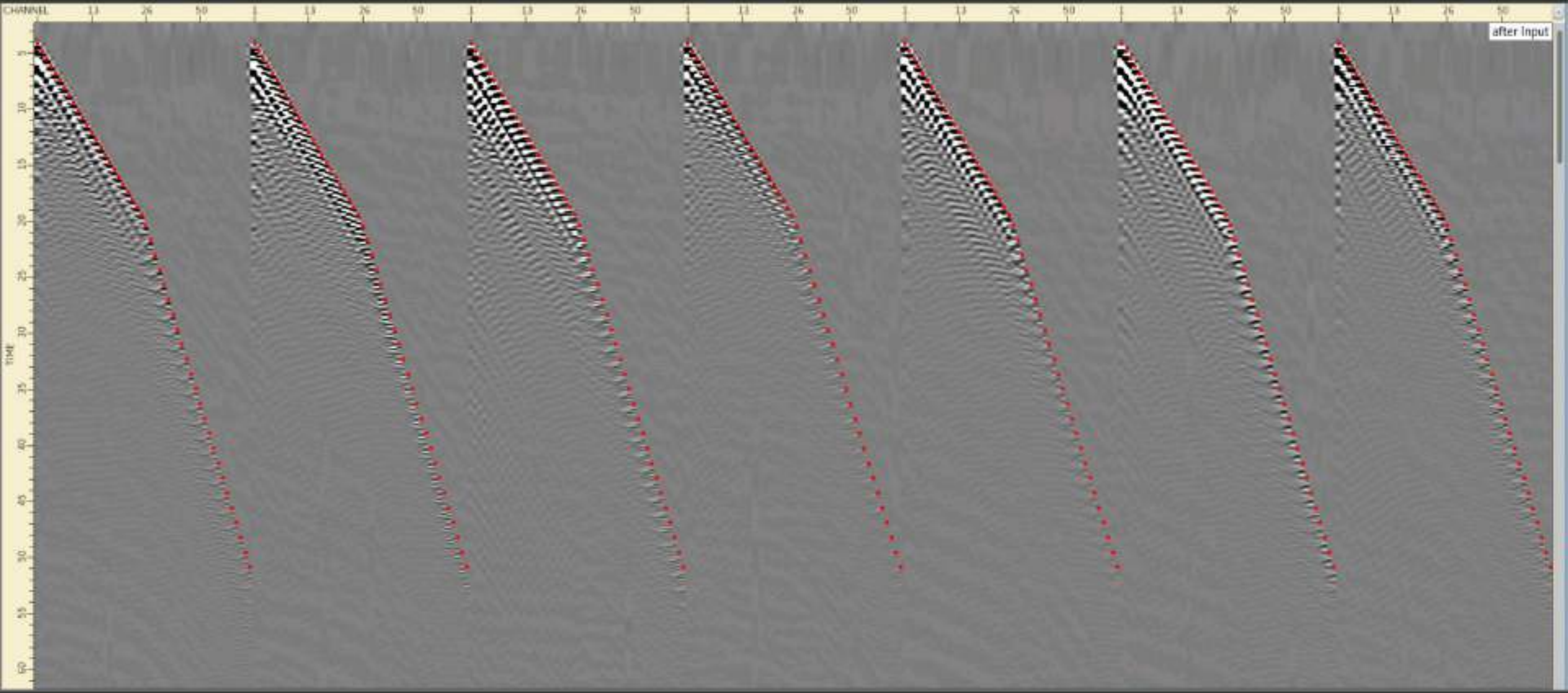
PEAKPROCESSING

INCREASE SAMPLE RATE TO 0.1MS



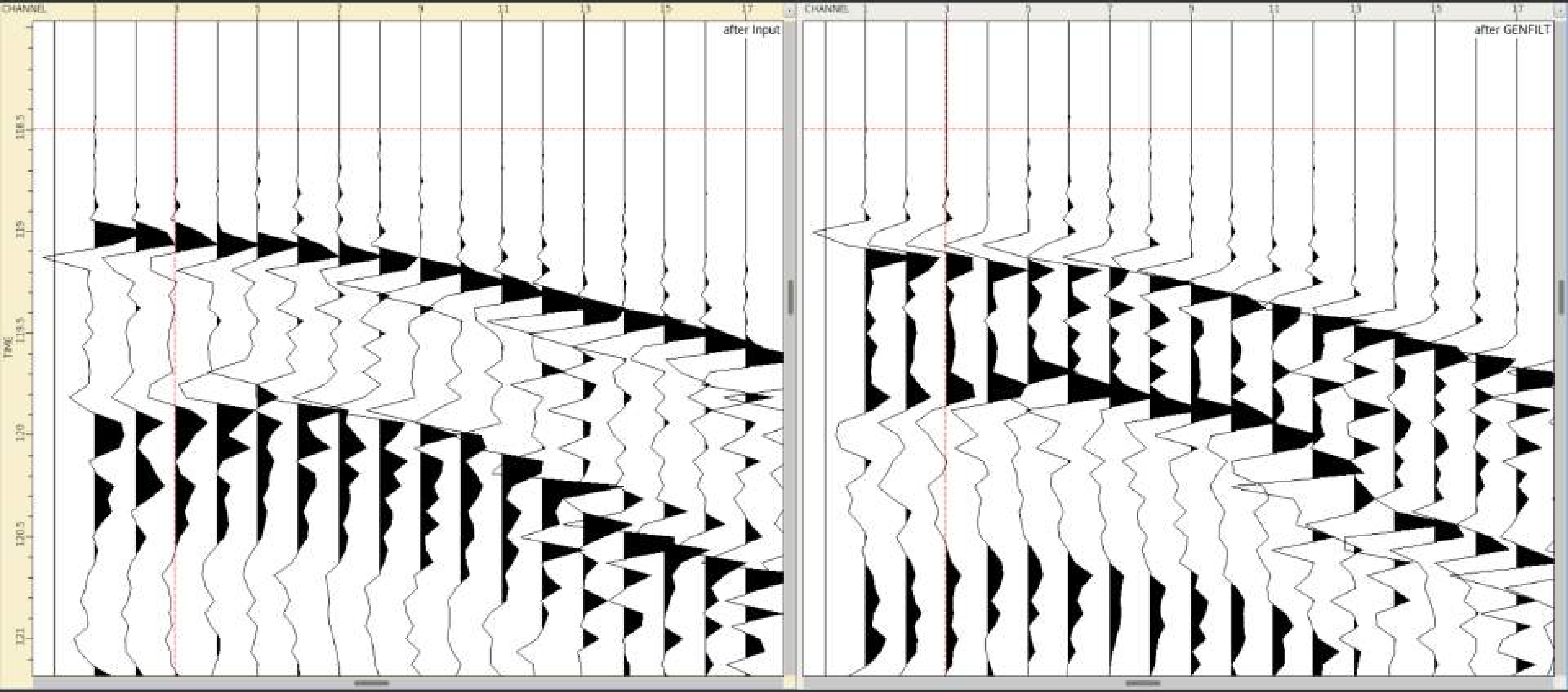
PEAKPROCESSING

DIRECT ARRIVAL GEOMETRY QC



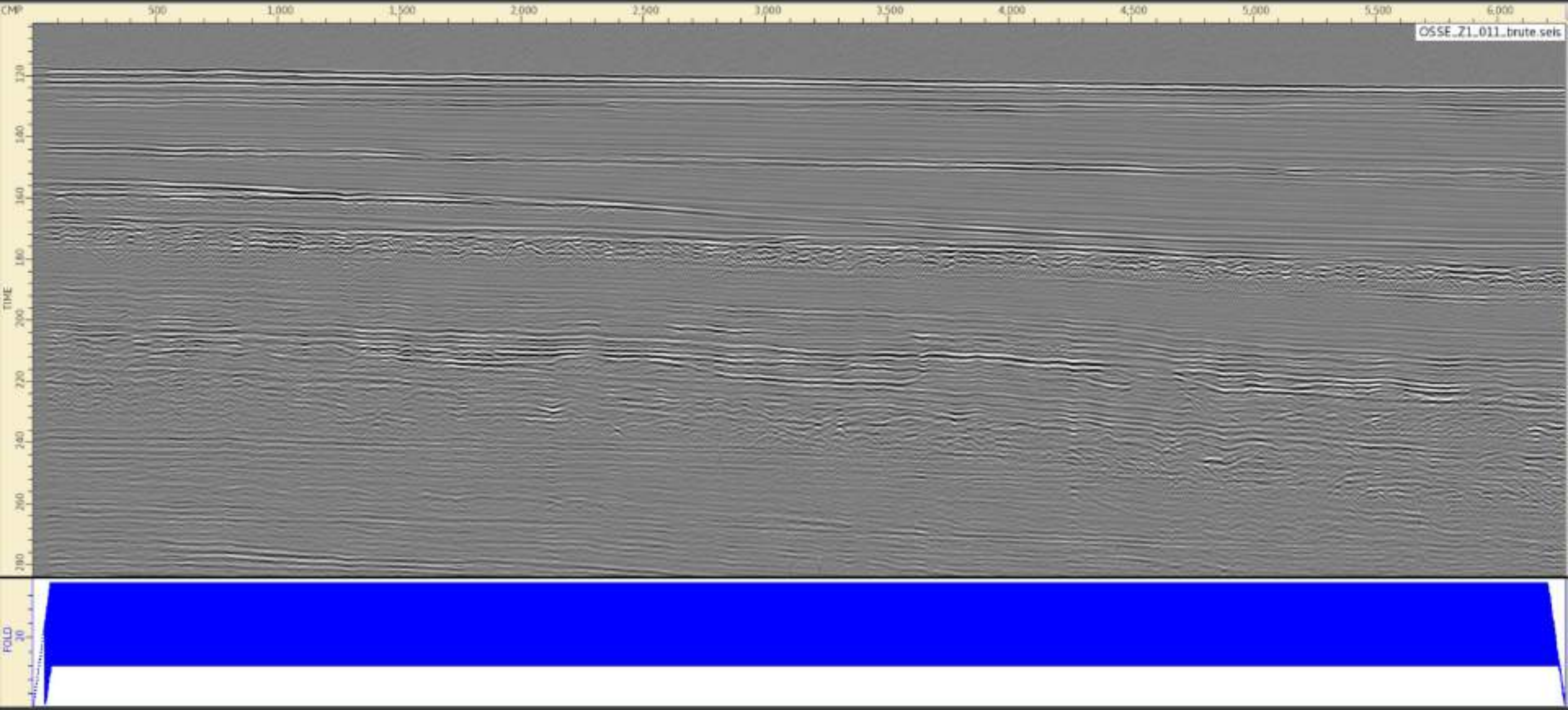
PEAKPROCESSING

FLIP POLARITY



PEAKPROCESSING

BRUTE STACK

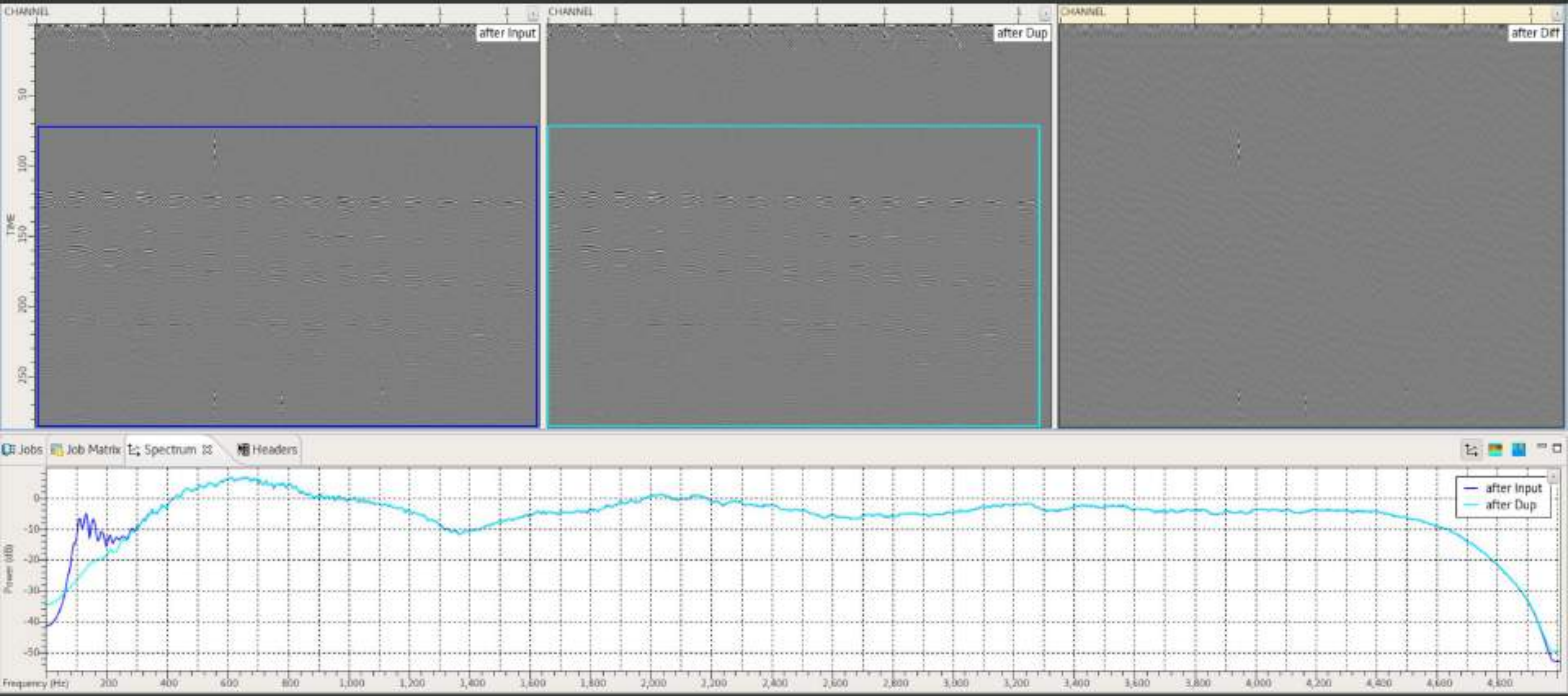


PEAKPROCESSING

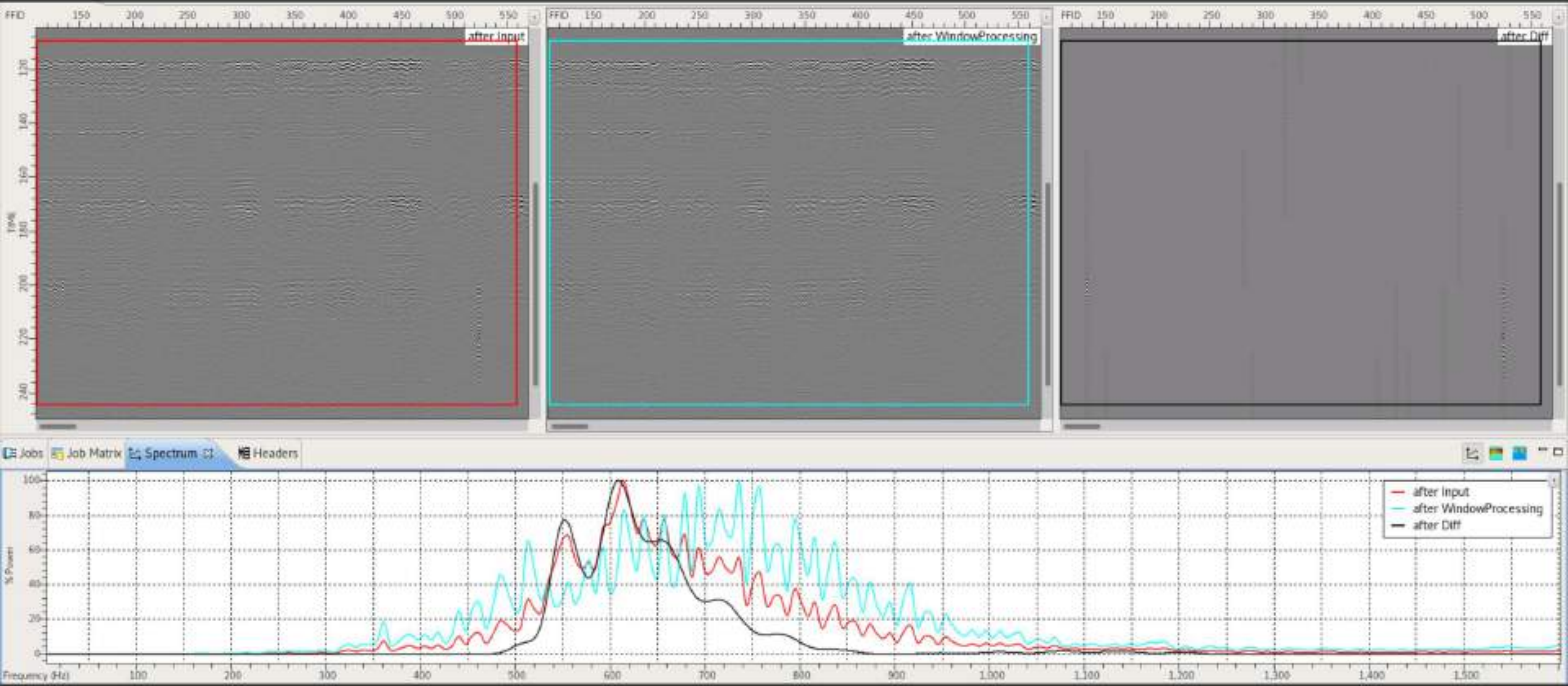
NOISE ATTENUATION

Noise Attenuation	
FXSwell on shots	2 passes - Cascaded approach 1st pass: 7tr x 21ms, 0-500hz 2nd pass: 11tr x 100ms, 50-250hz
FXSwell on common channel	11tr x 50ms, 200-1500hz
Interpolate end of streamer to 1m spacing	Fourier based interpolation Water velocity wrapped

1ST PASS NOISE ATTENUATION – FXSWELL ON SHOTS

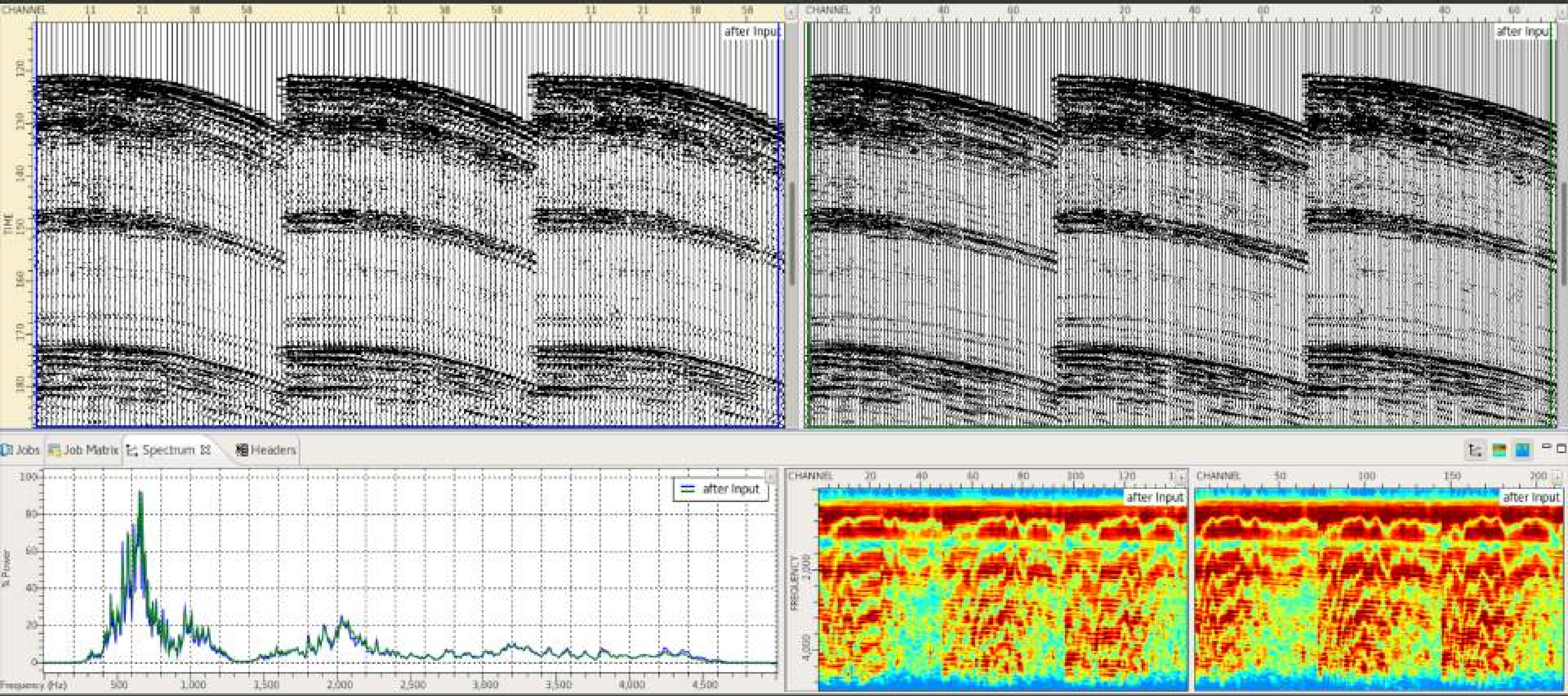


2^{ND} PASS NOISE ATTENUATION – FXSWELL ON CHANNELS



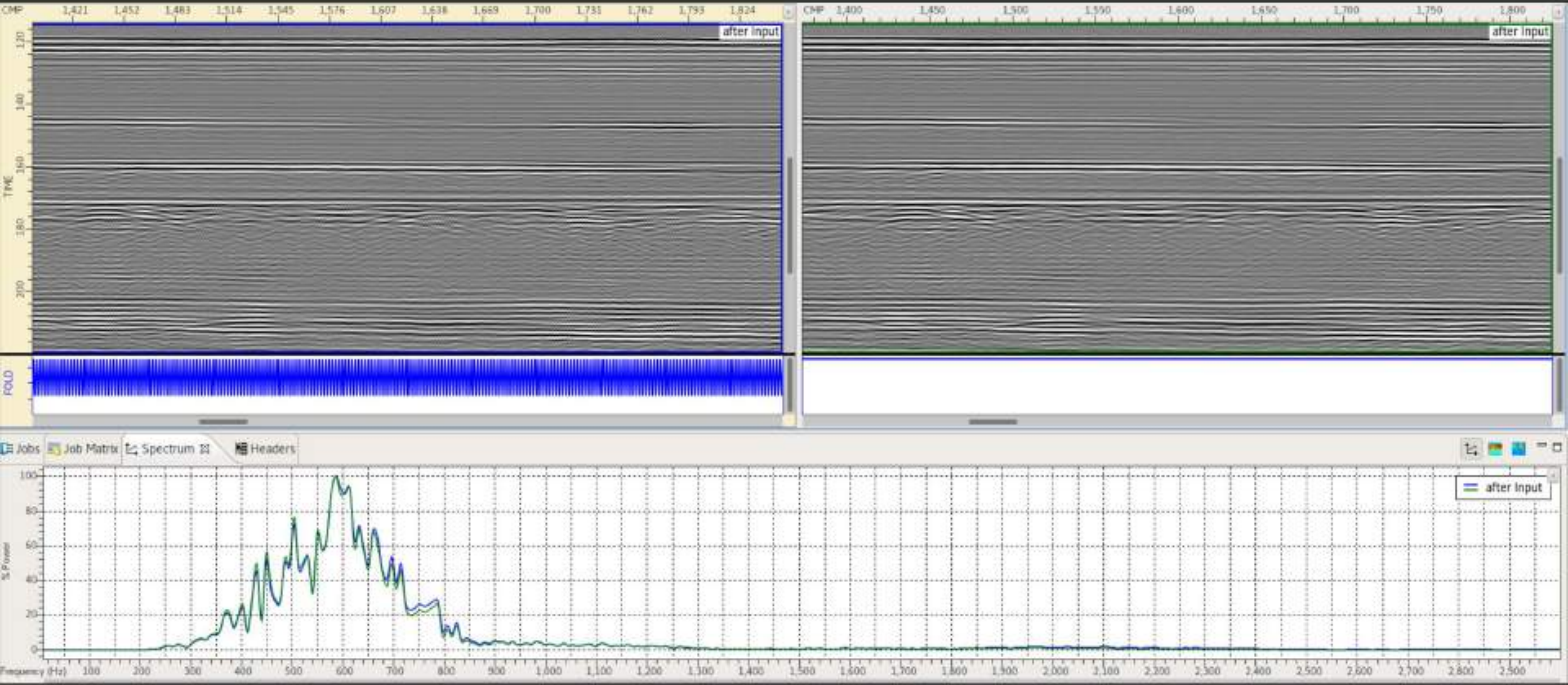
PEAKPROCESSING

INTERPOLATE SHOTS TO 1M RECEIVER SPACING



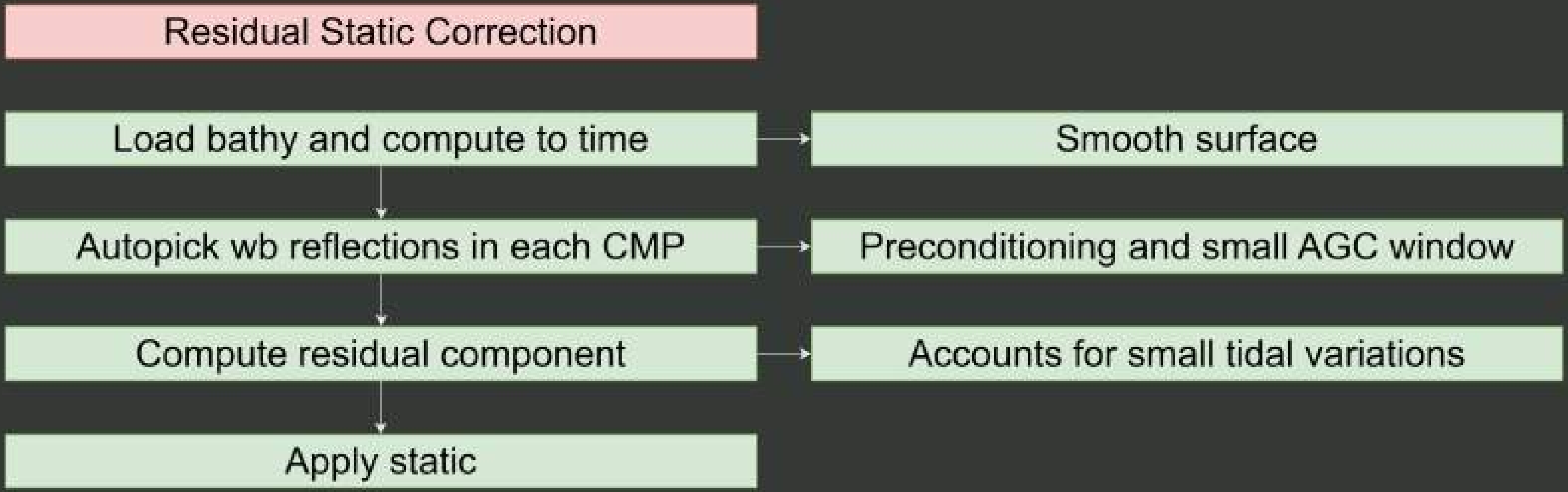
PEAKPROCESSING

DENOISE STACK VS. INTERPOLATED STACK

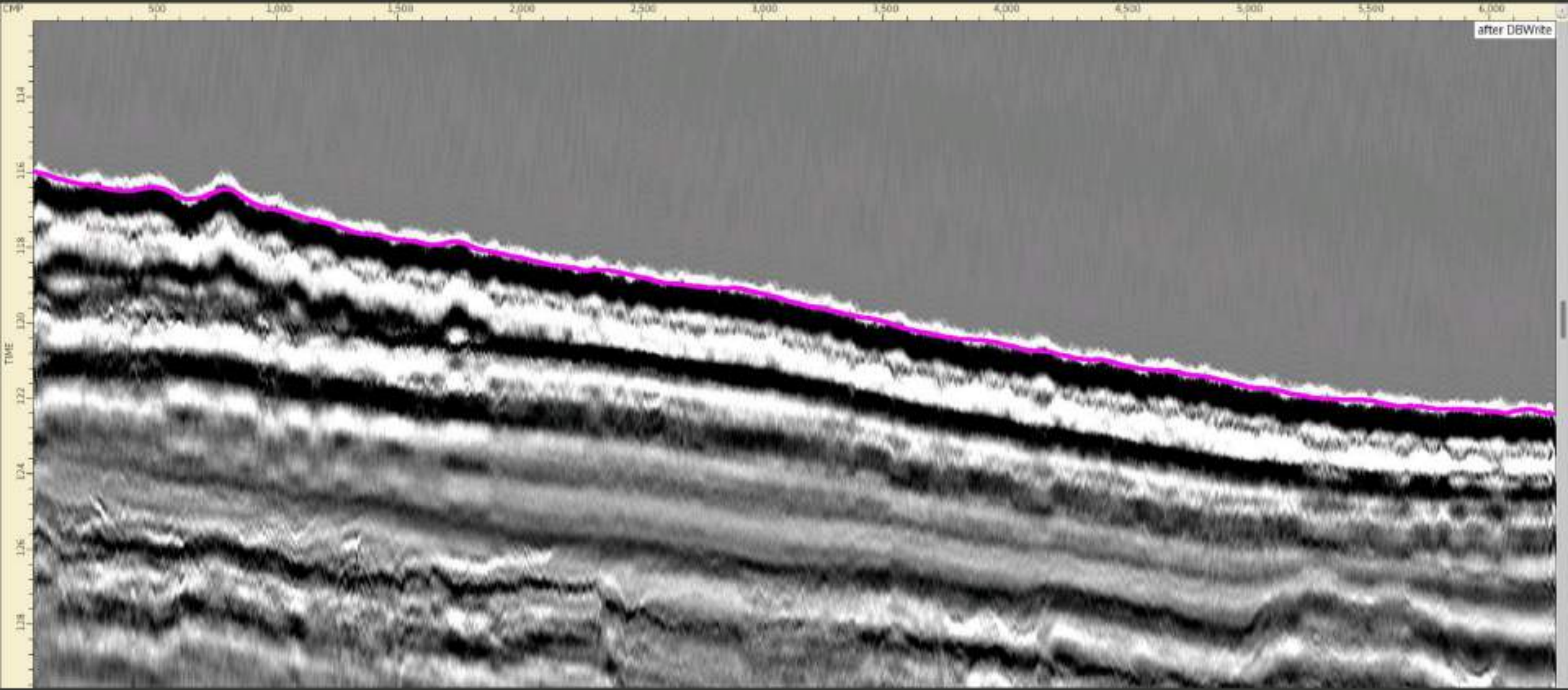


PEAKPROCESSING

RESIDUAL STATIC CORRECTION

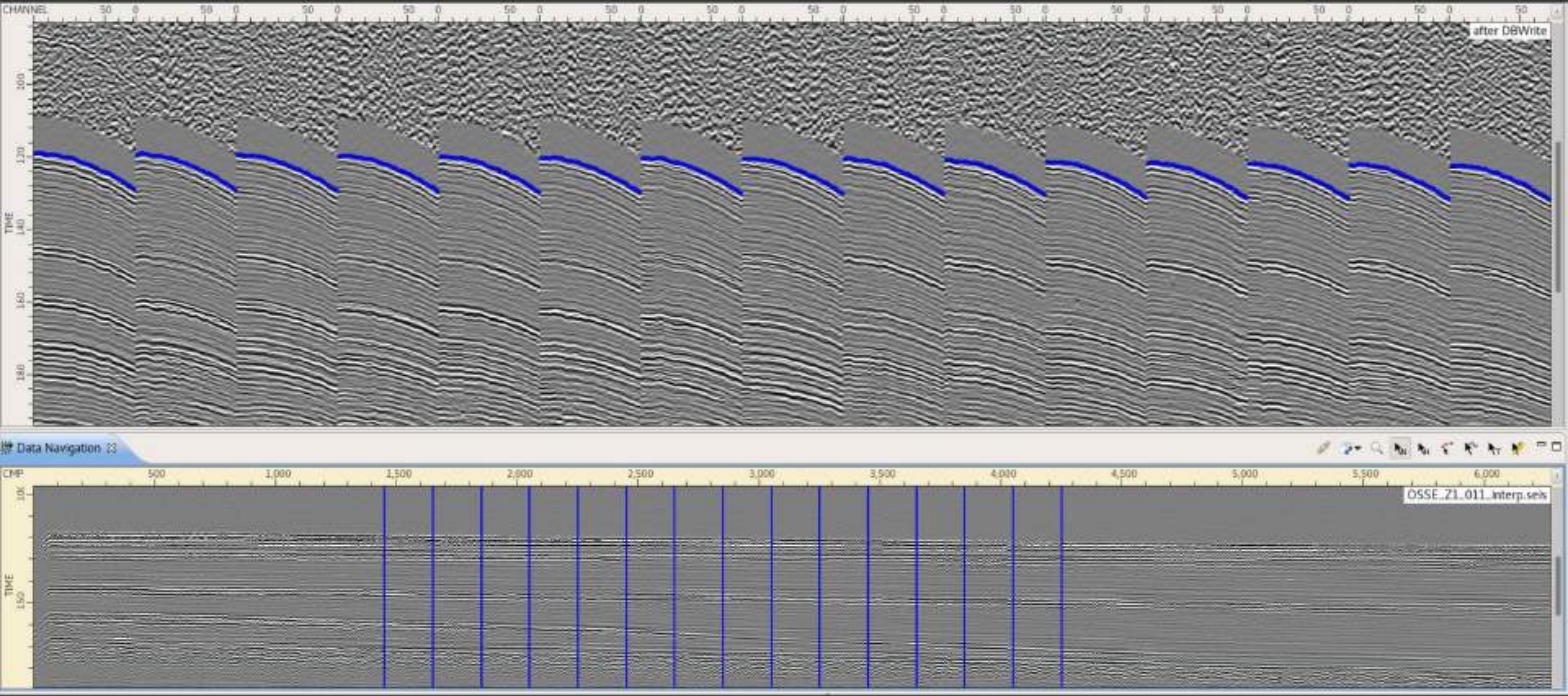


MULTIBEAM OVERLAY ON STACK



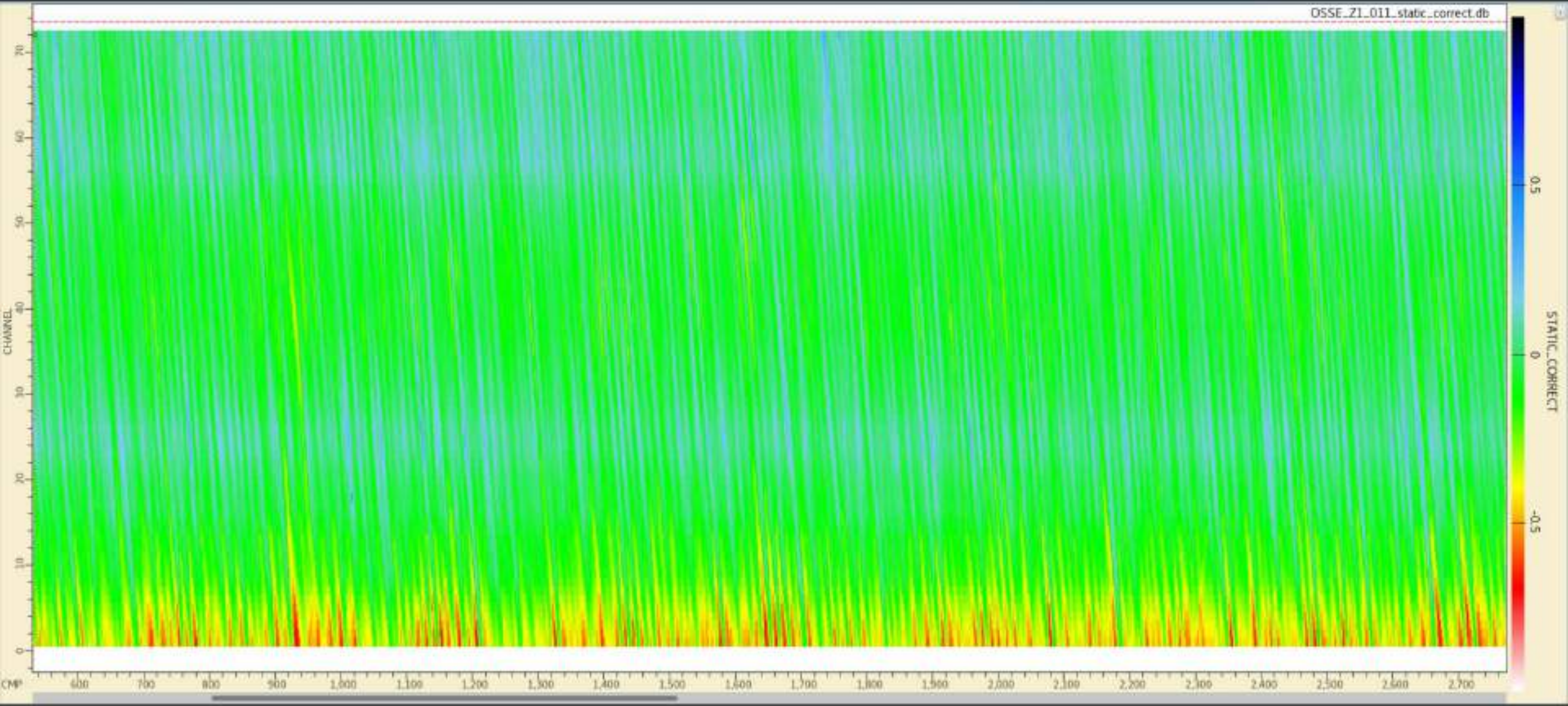
PEAKPROCESSING

AUTOPICKED WB REFLECTION TIMES



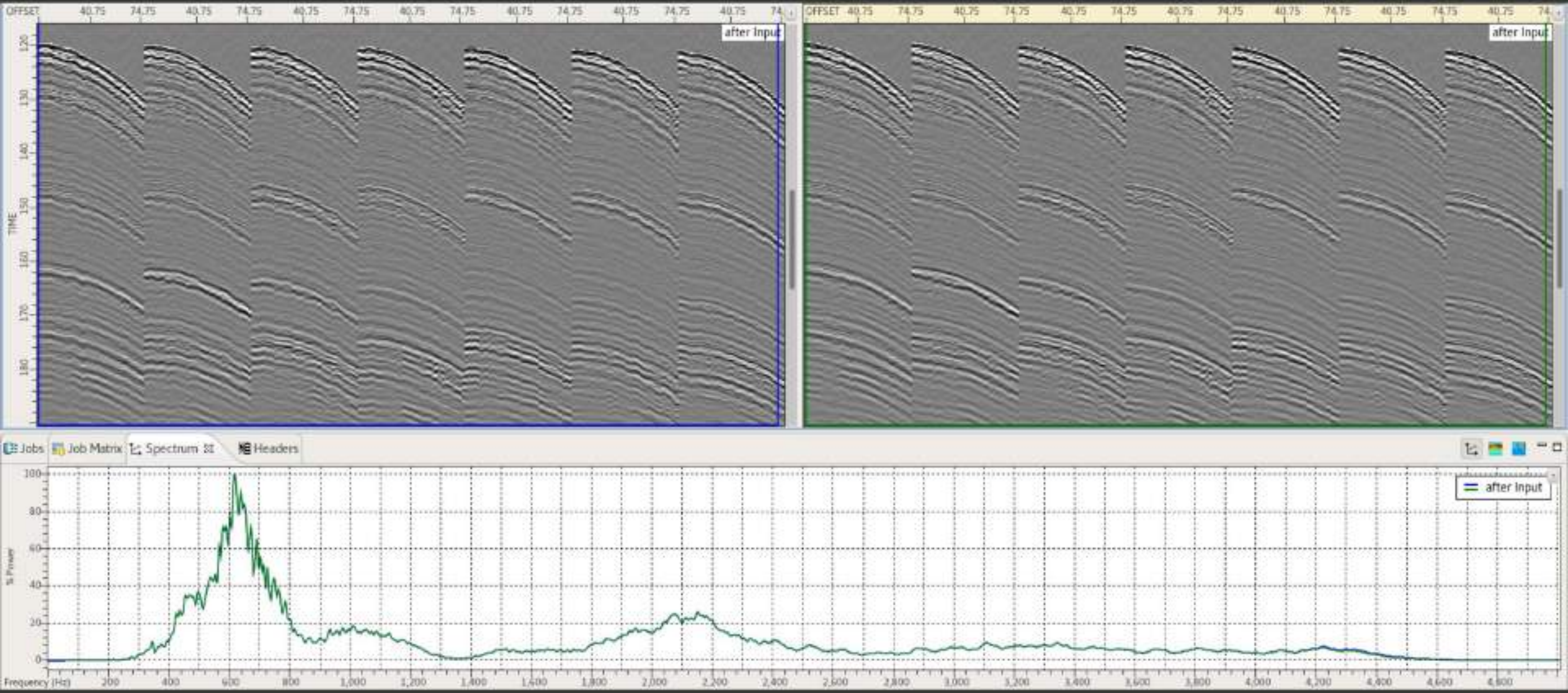
PEAKPROCESSING

STATIC MAP



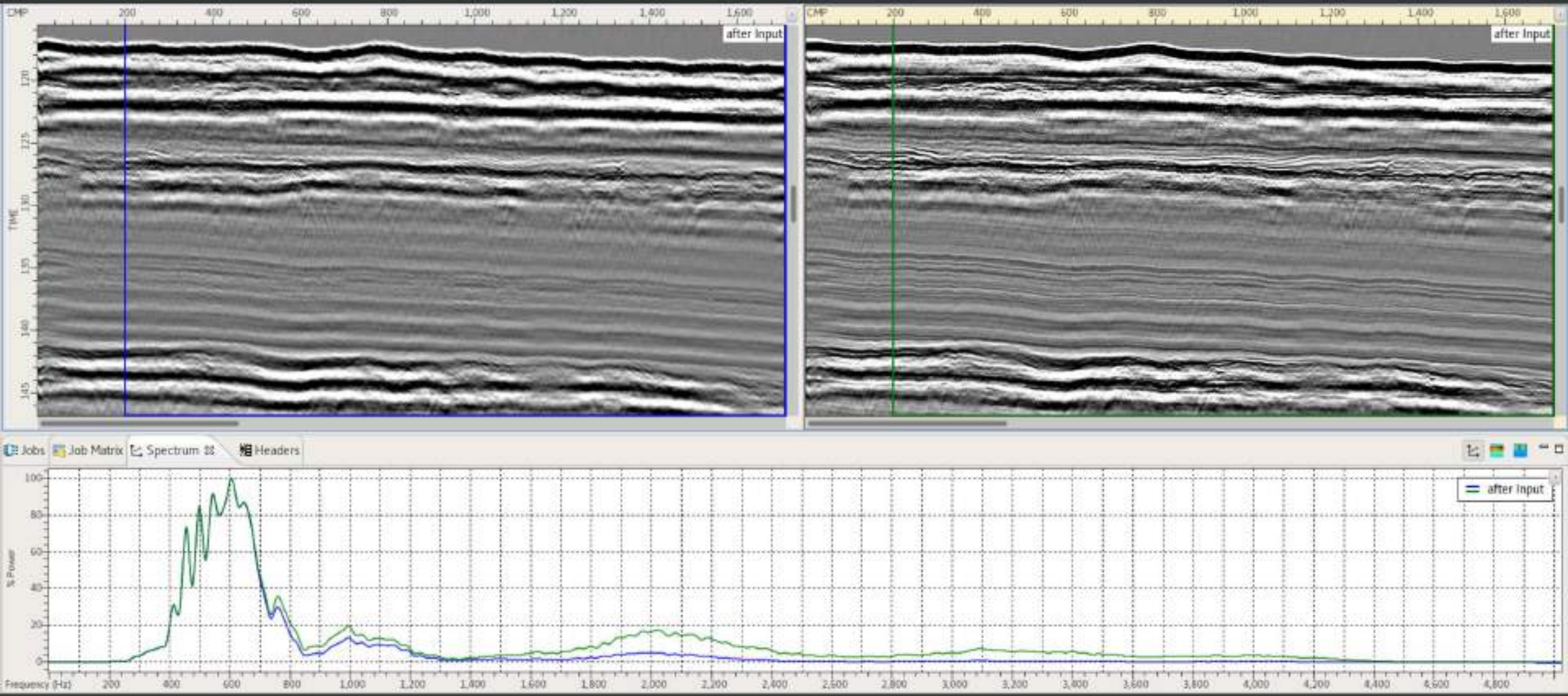
PEAKPROCESSING

CMPS BEFORE AND AFTER CORRECTION



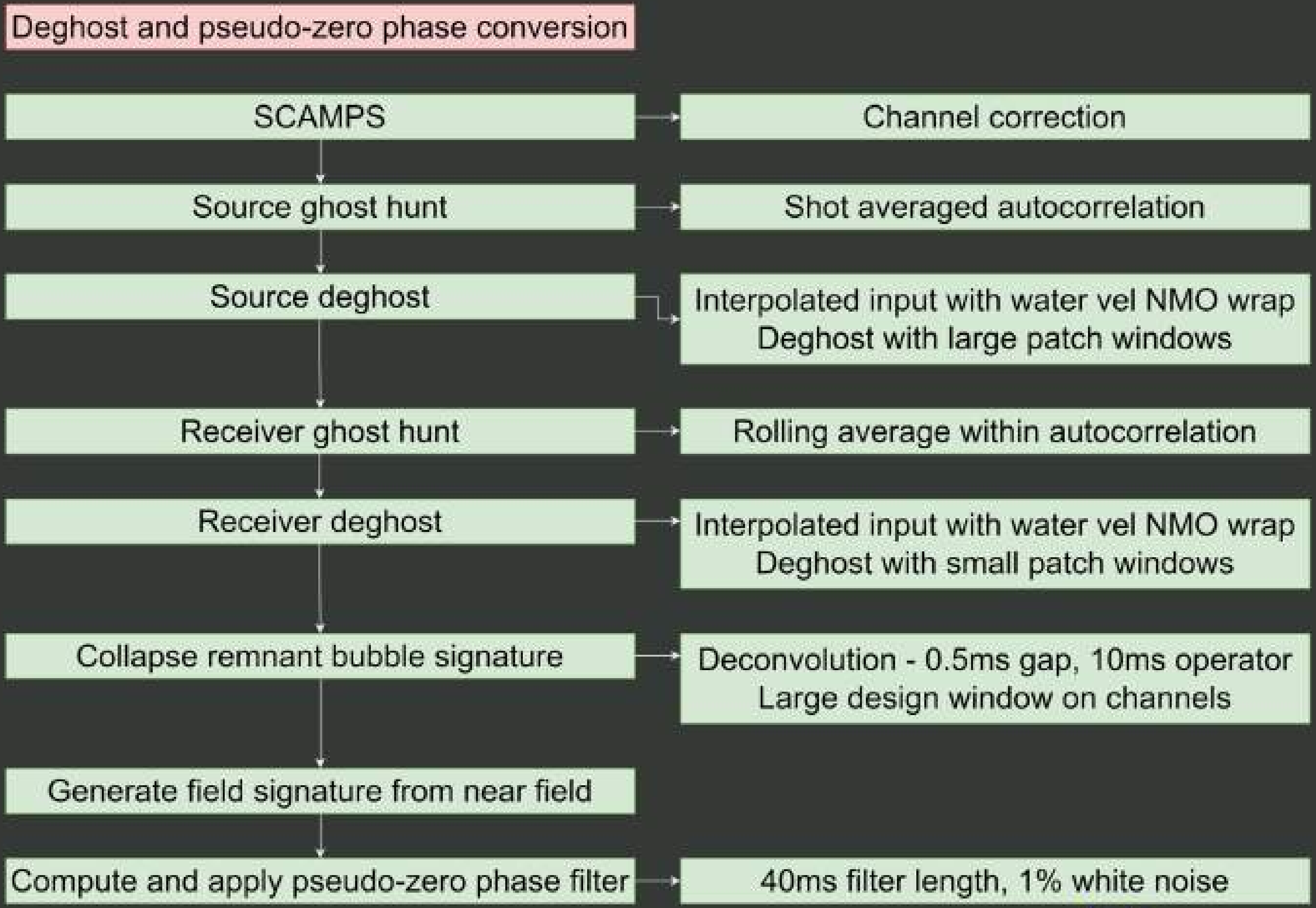
PEAKPROCESSING

INTERPOLATED STACK VS. CORRECTED STACK



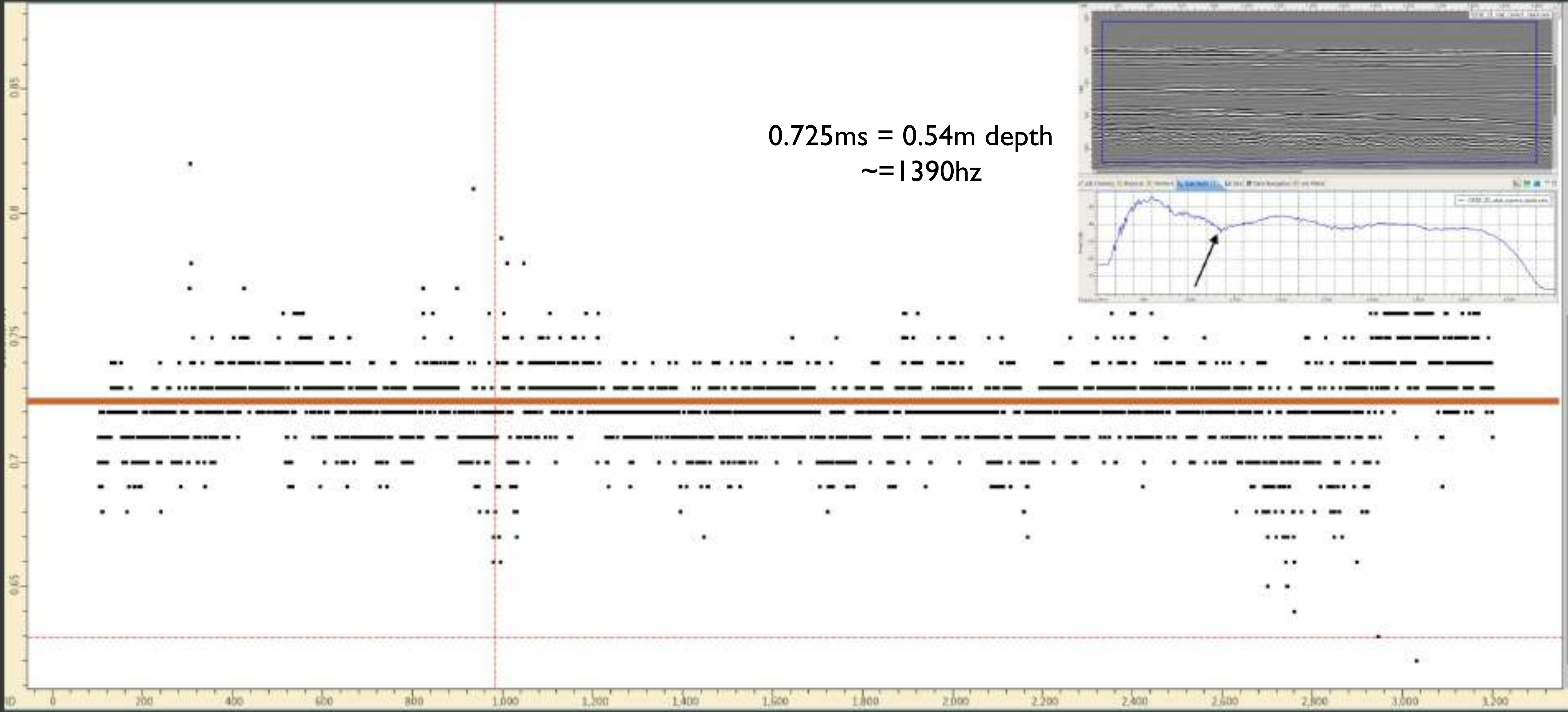
PEAKPROCESSING

DEGHOST AND PSEUDO-ZERO PHASE CONVERSION

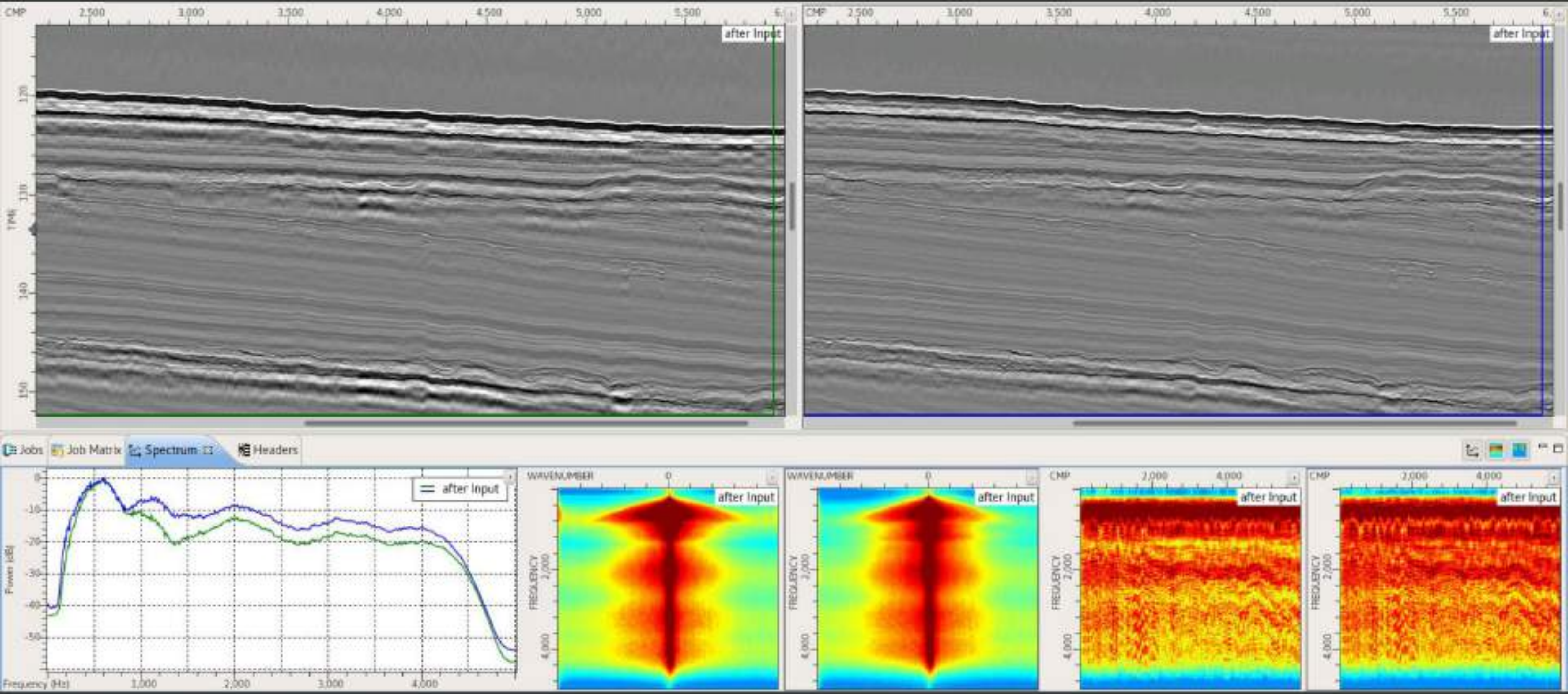


PEAKPROCESSING

SOURCE DEPTH CALCULATION

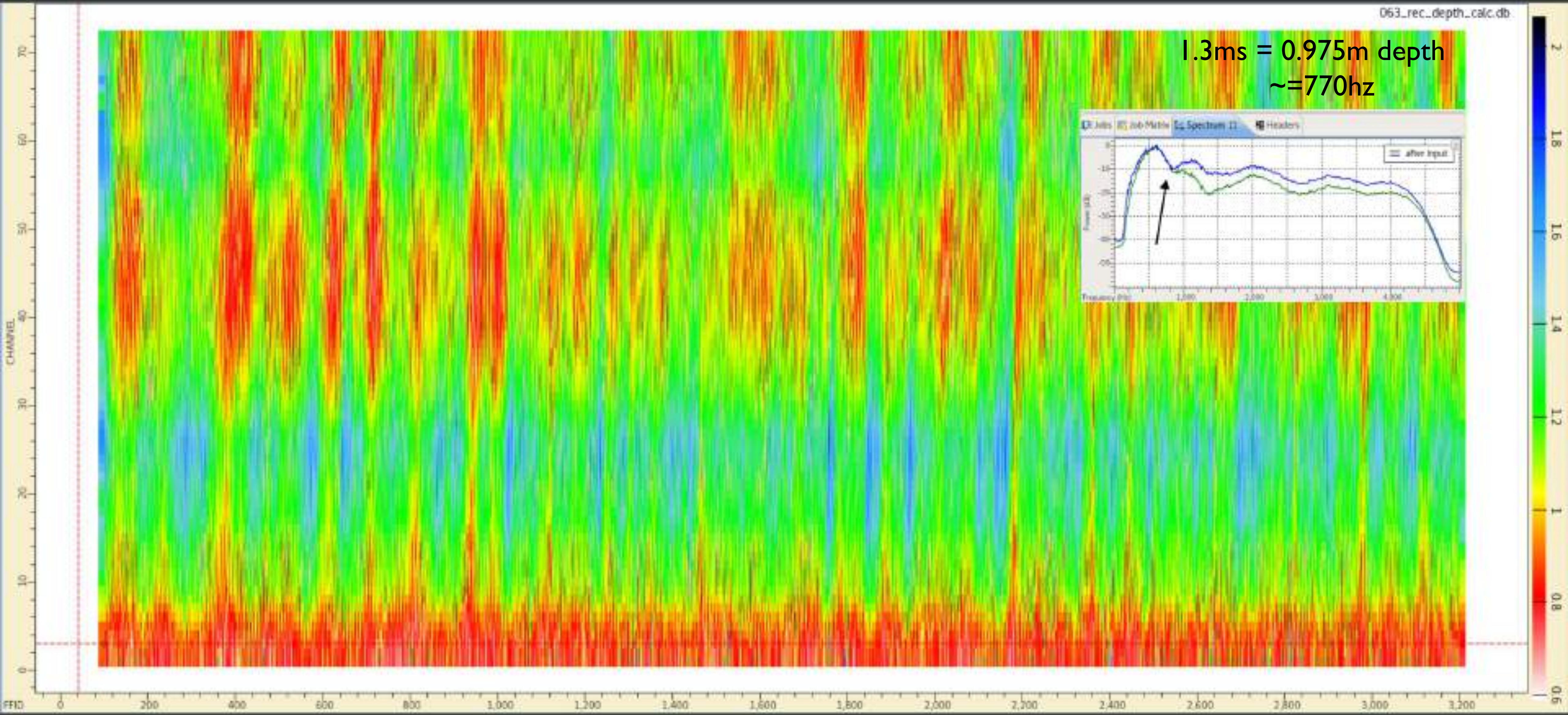


BEFORE AND AFTER SOURCE DEGHOSTING



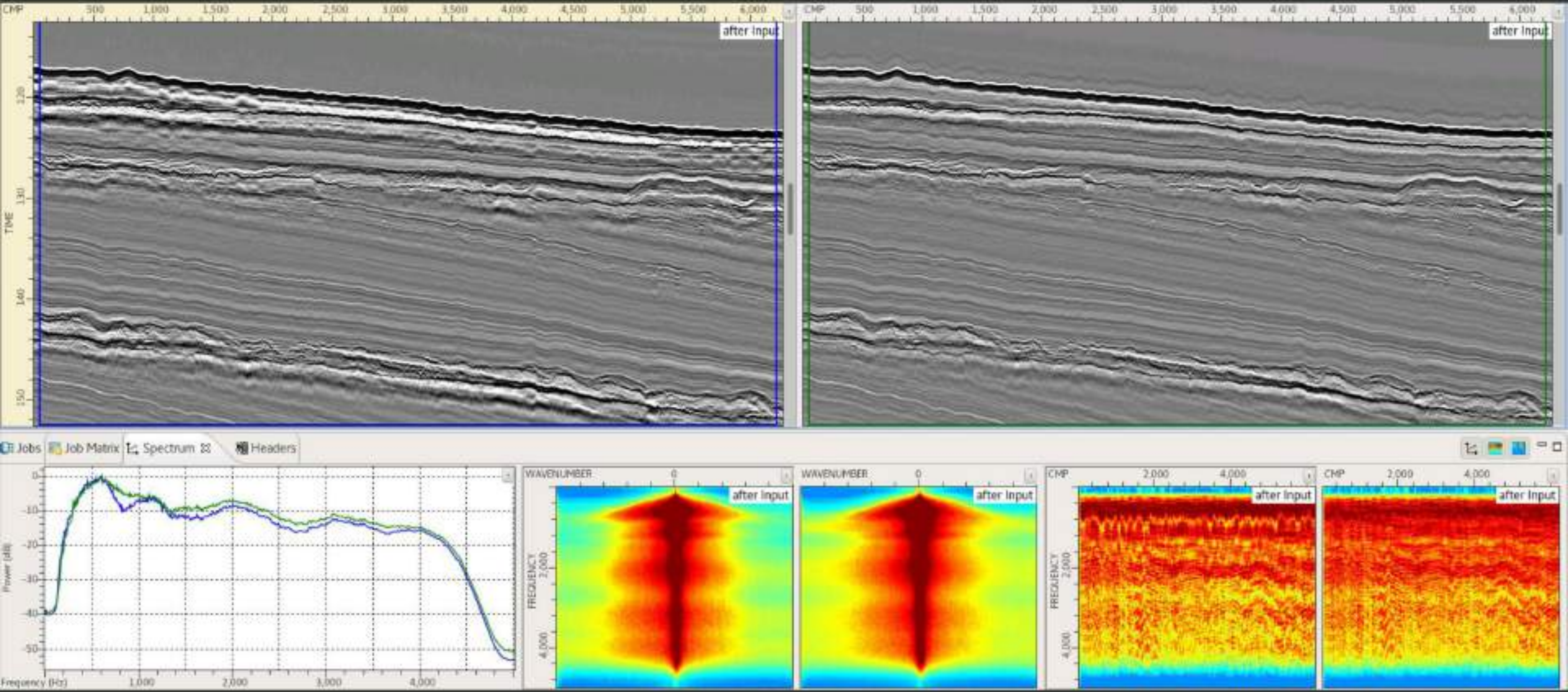
PEAKPROCESSING

RECEIVER DEPTHS – FFID VS. CHANNEL



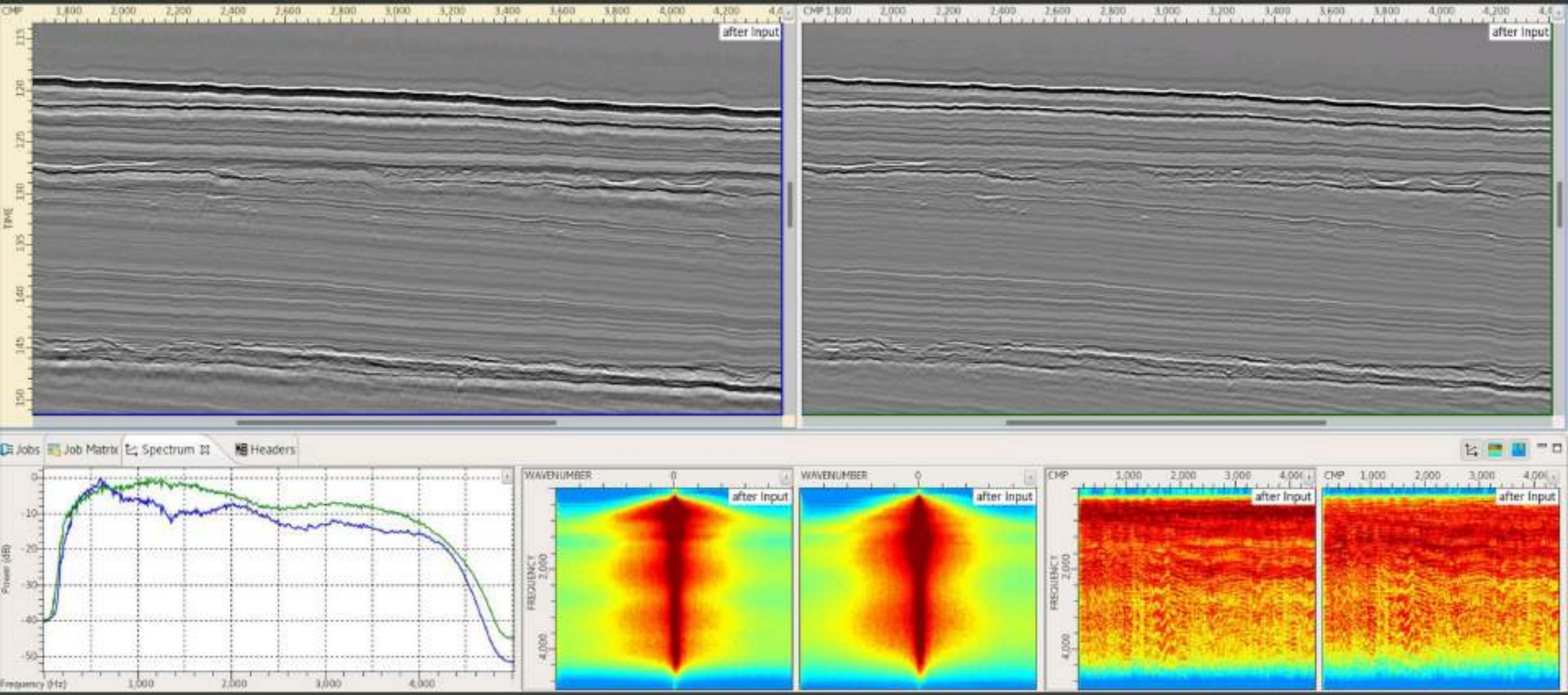
PEAKPROCESSING

BEFORE AND AFTER RECEIVER DEGHOSTING



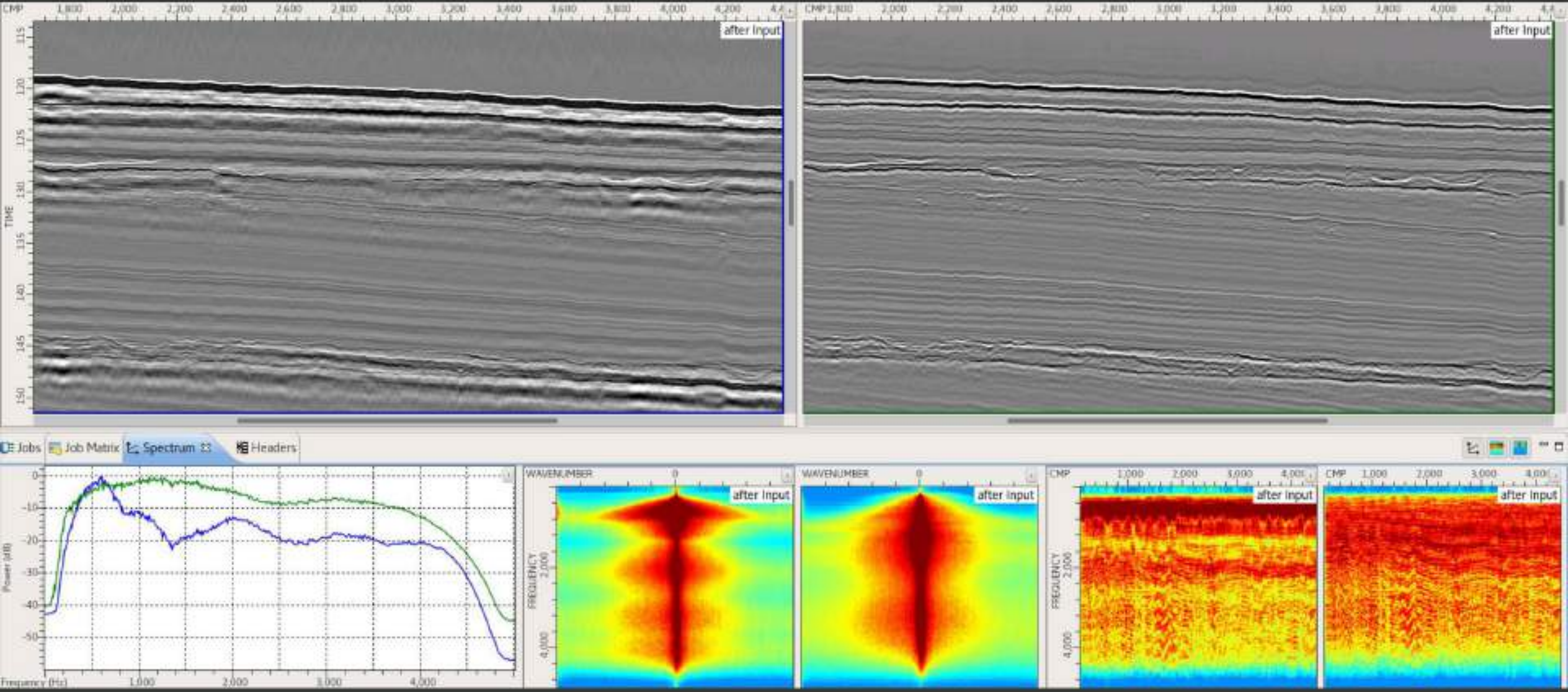
PEAKPROCESSING

BEFORE AND AFTER WAVELET COMPRESSION



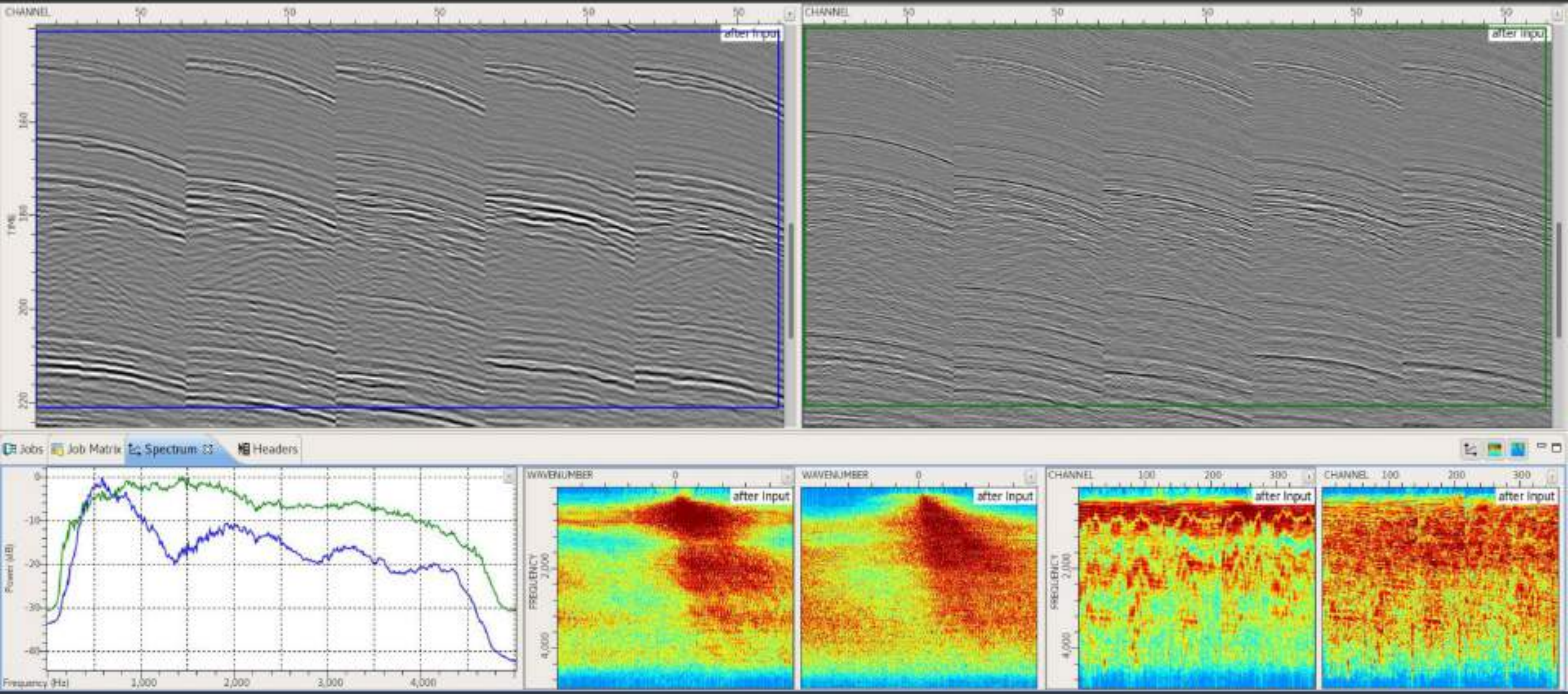
PEAKPROCESSING

BEFORE AND AFTER DEGHOSTING



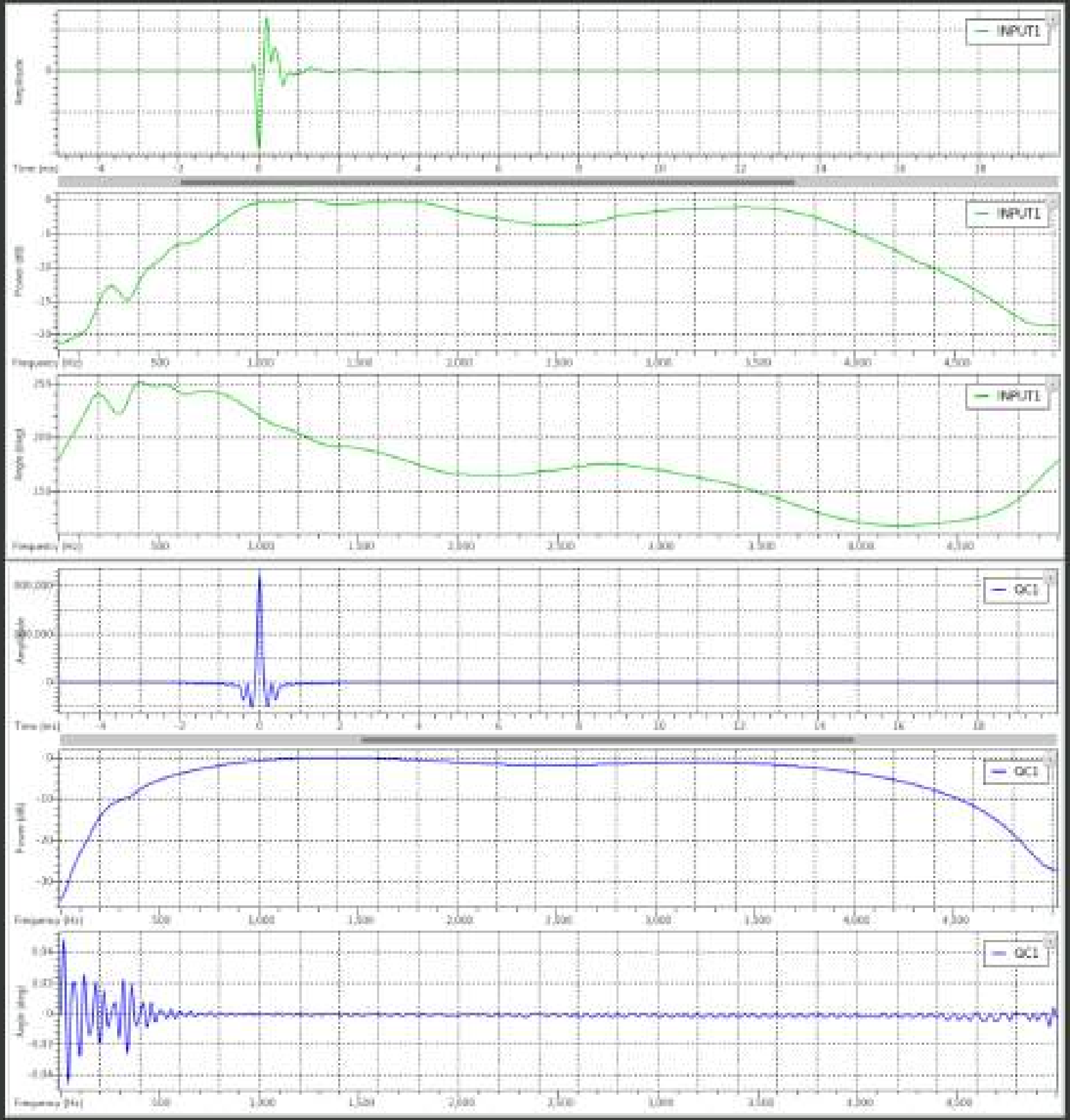
PEAKPROCESSING

SHOTS BEFORE AND AFTER DEGHOSTING



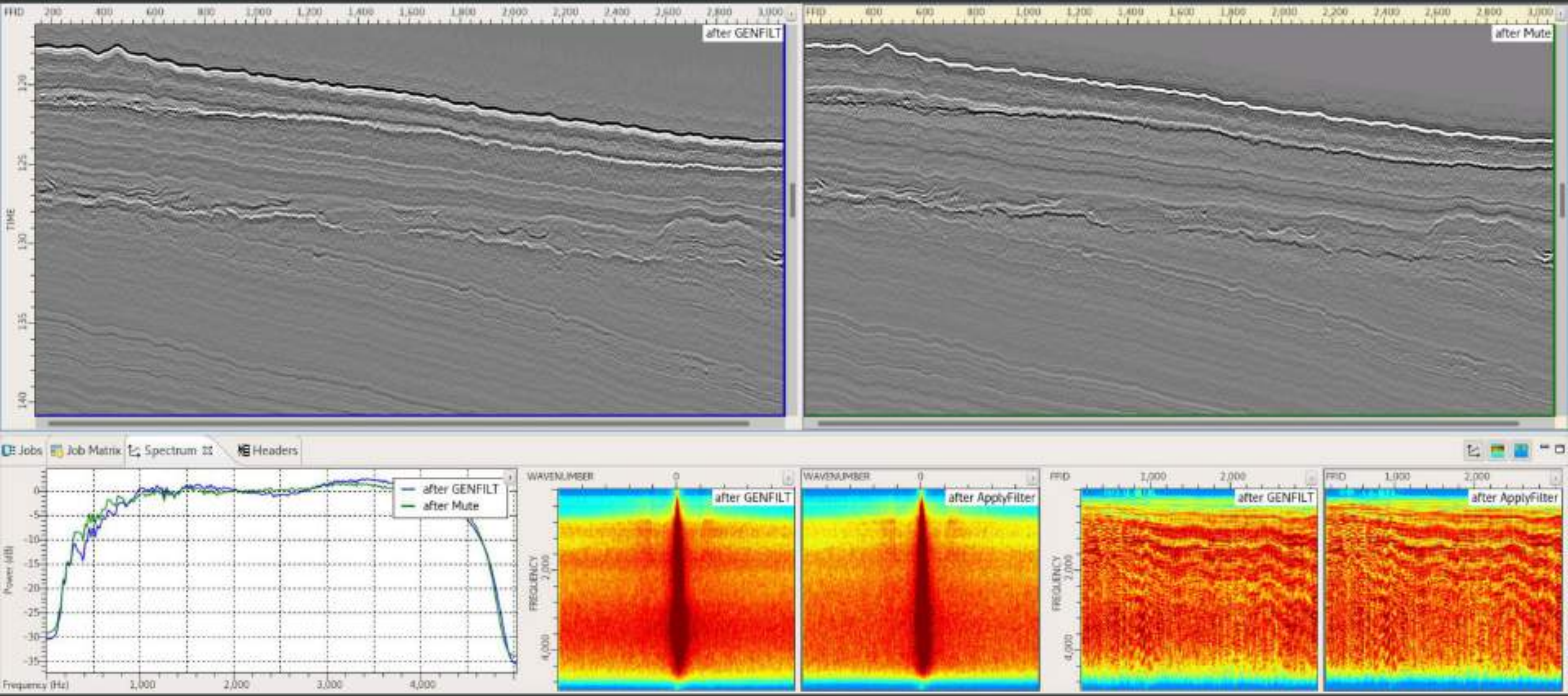
PEAKPROCESSING

WAVELET DESIGN



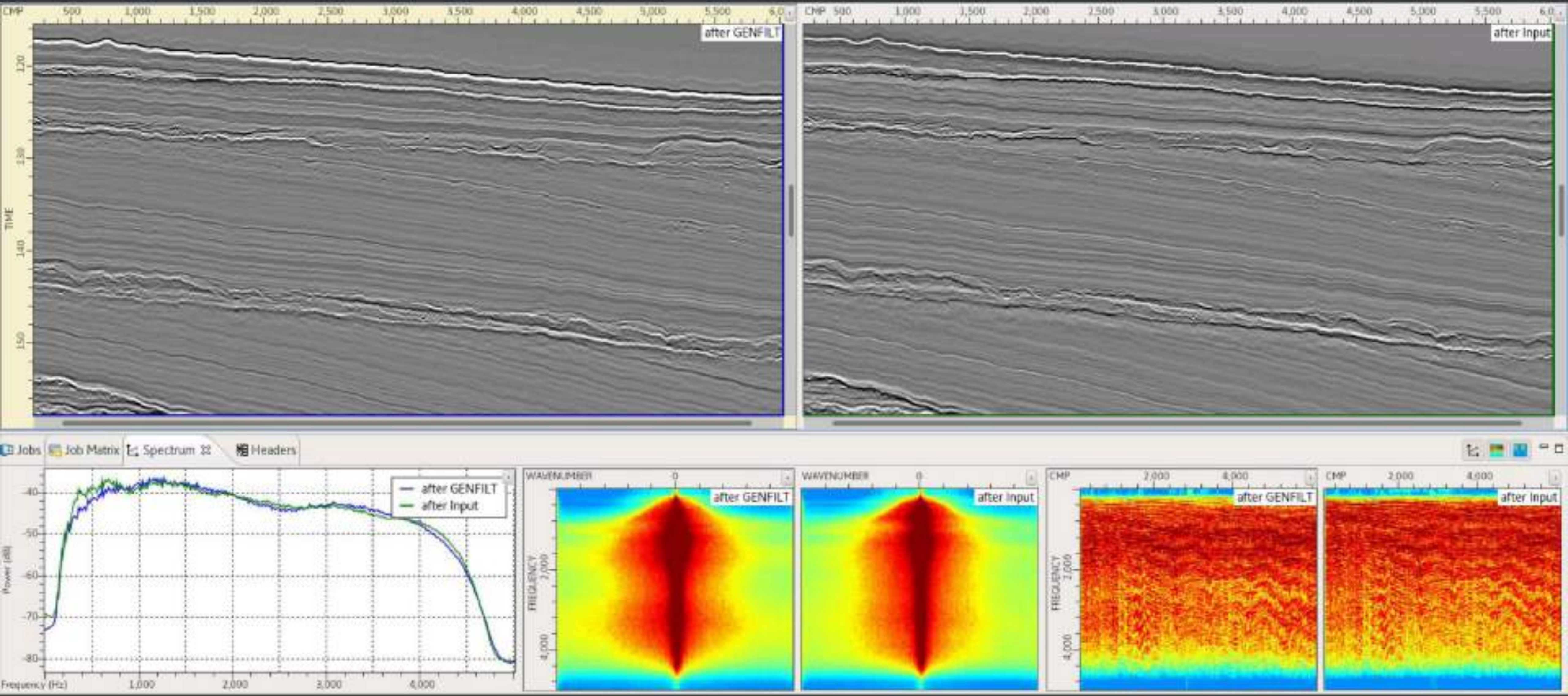
PEAKPROCESSING

CHANNEL 10 – BEFORE AND AFTER PSEUDO-ZERO PHASE



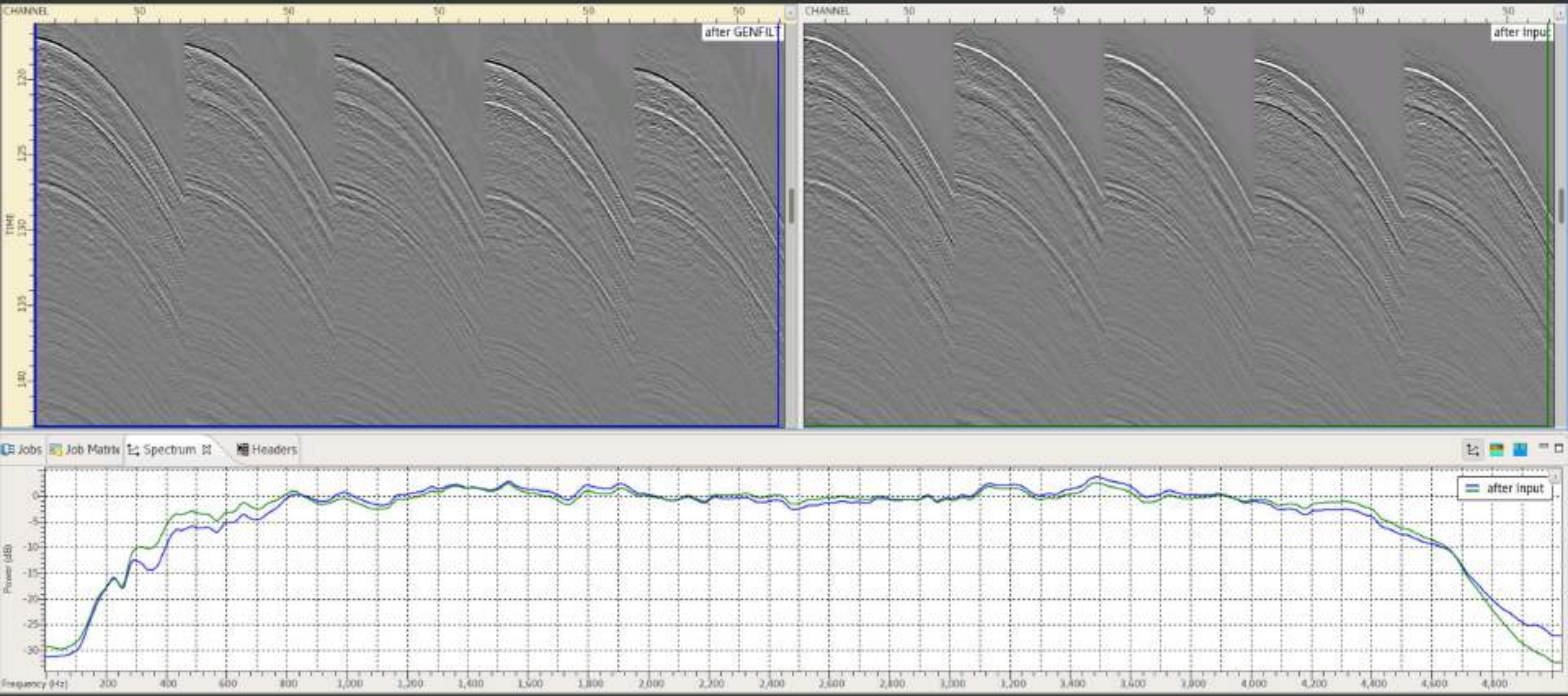
PEAKPROCESSING

STACKS BEFORE AND AFTER PSEUDO-ZERO PHASING



PEAKPROCESSING

SHOTS BEFORE AND AFTER PSEUDO-ZERO PHASING



PEAKPROCESSING

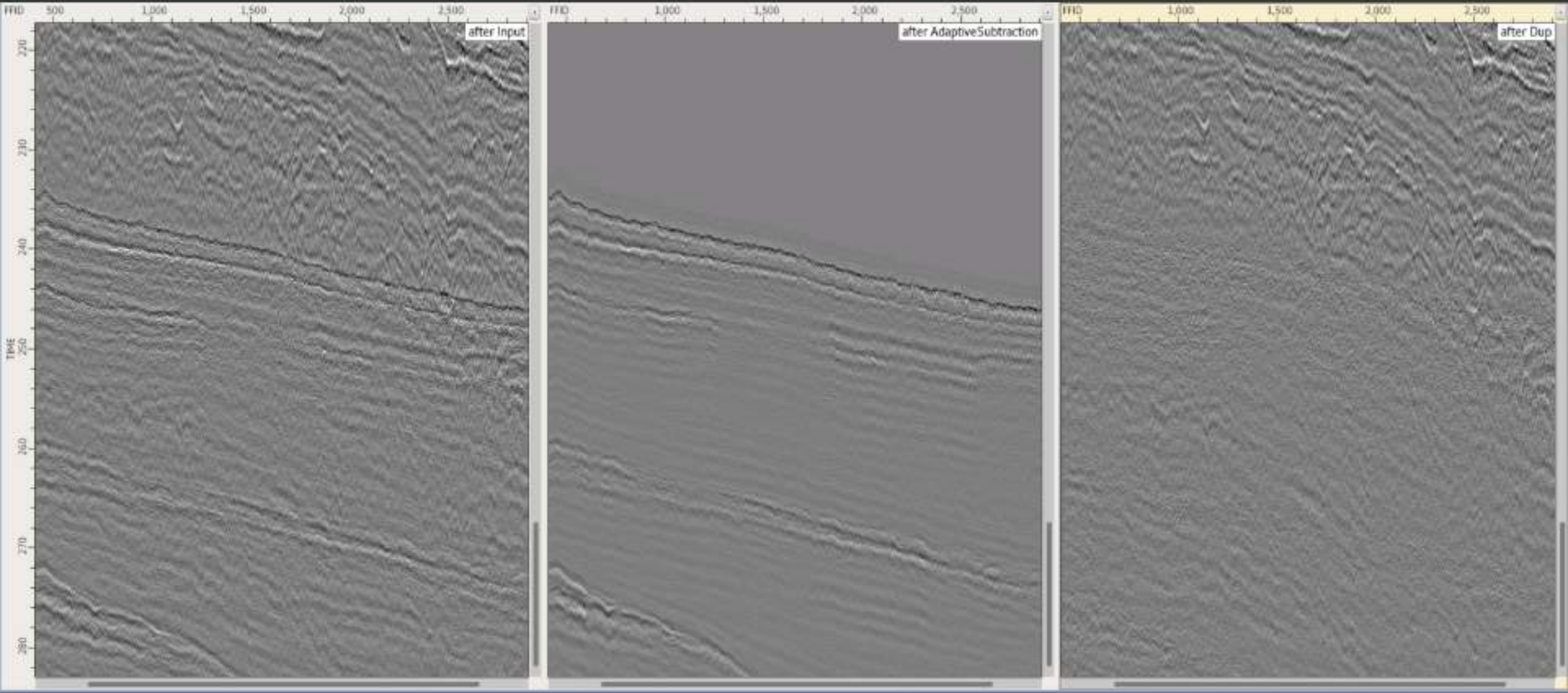
DEMULTIPLE

Demultiple

Generate multiple model	Shallow water multiple estimation
Match multiple to input	Match on shots - small matching window
Subtract matched multiple from input	Subtract on channels - wide matching window

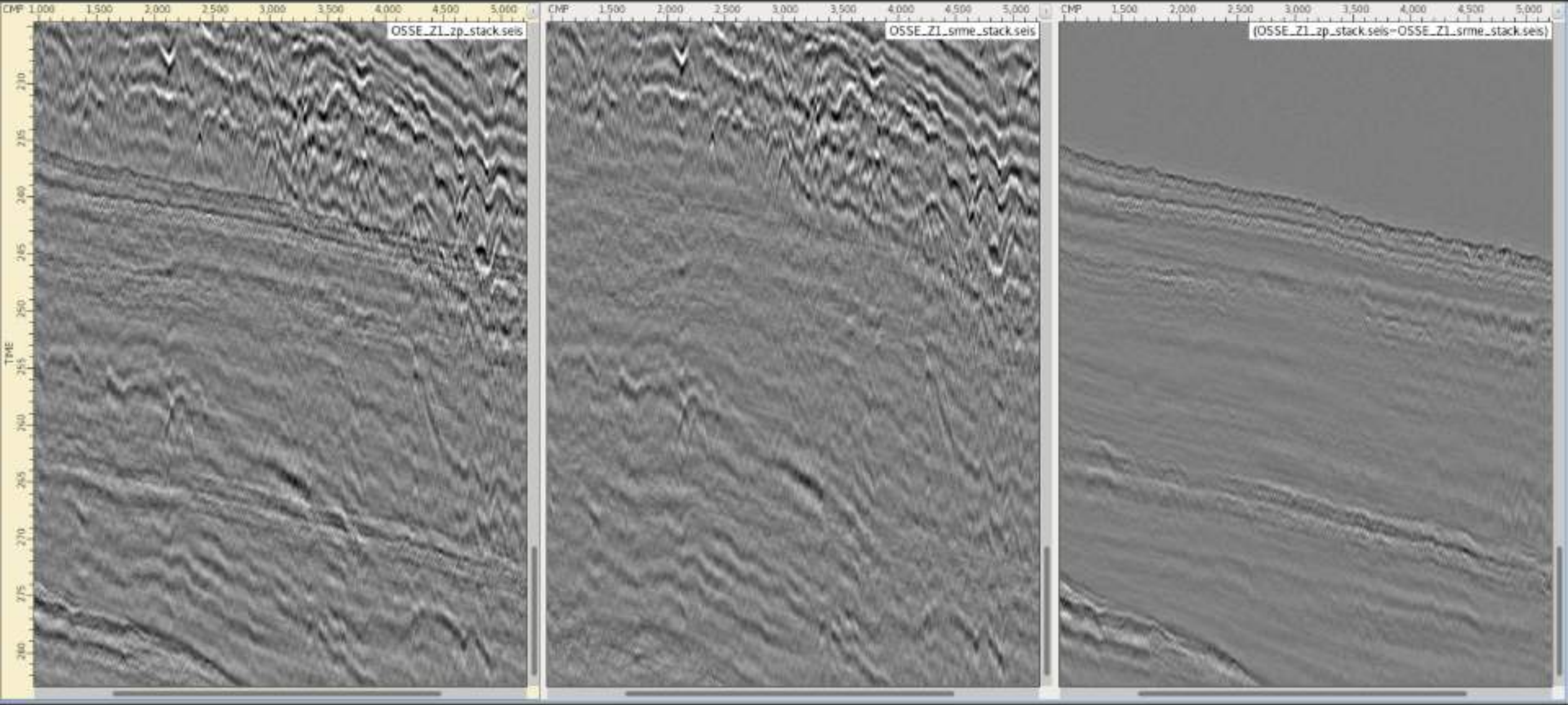
PEAKPROCESSING

CHANNEL 1 – BEFORE, MODEL AND AFTER SUBTRACTION



PEAKPROCESSING

STACKS – BEFORE, AFTER AND DIFFERENCE



PEAKPROCESSING

VELOCITY PICKING, PSTM AND STACK

Velocity picking, PSTM and Stack

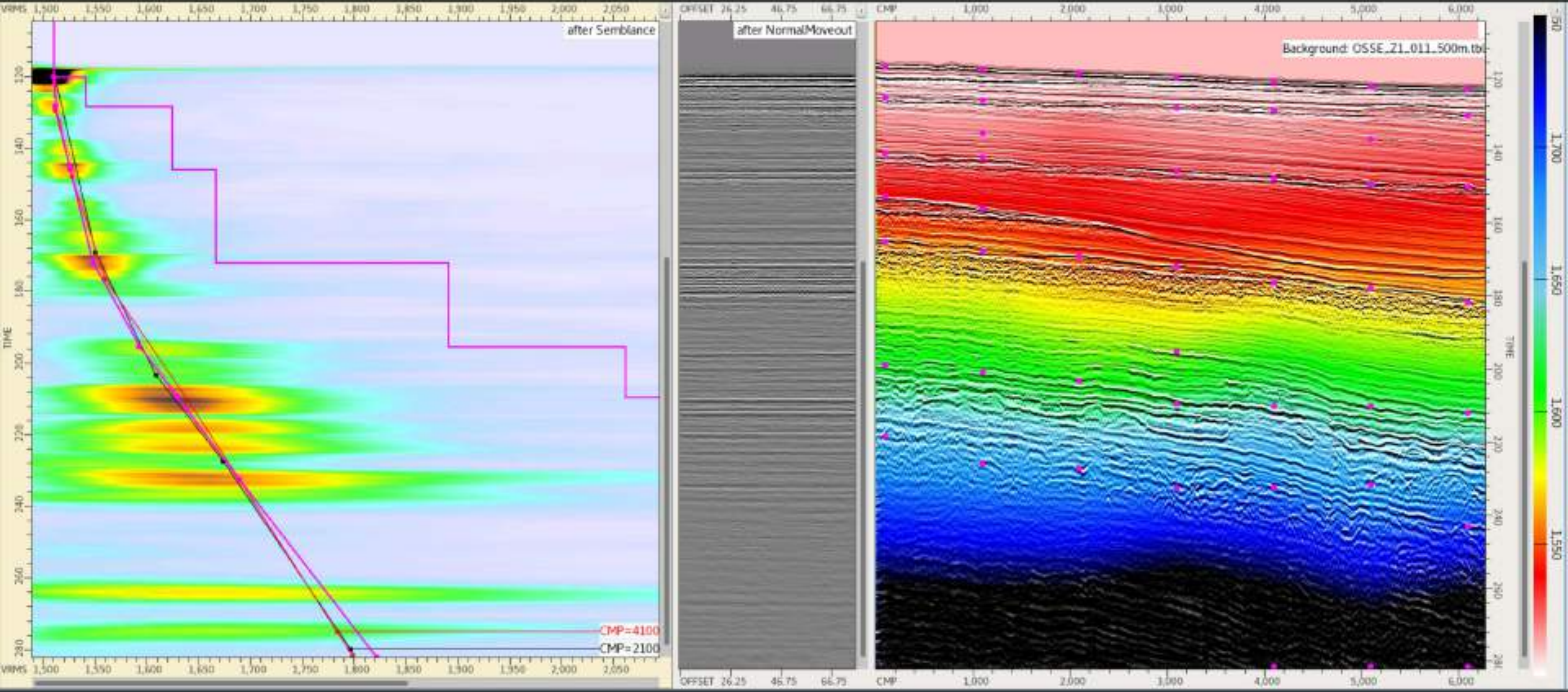
Stacking velocity picking at 0.5km intervals

PSTM → 250m aperture (radius)

Gather muting → 20 degree angle mute

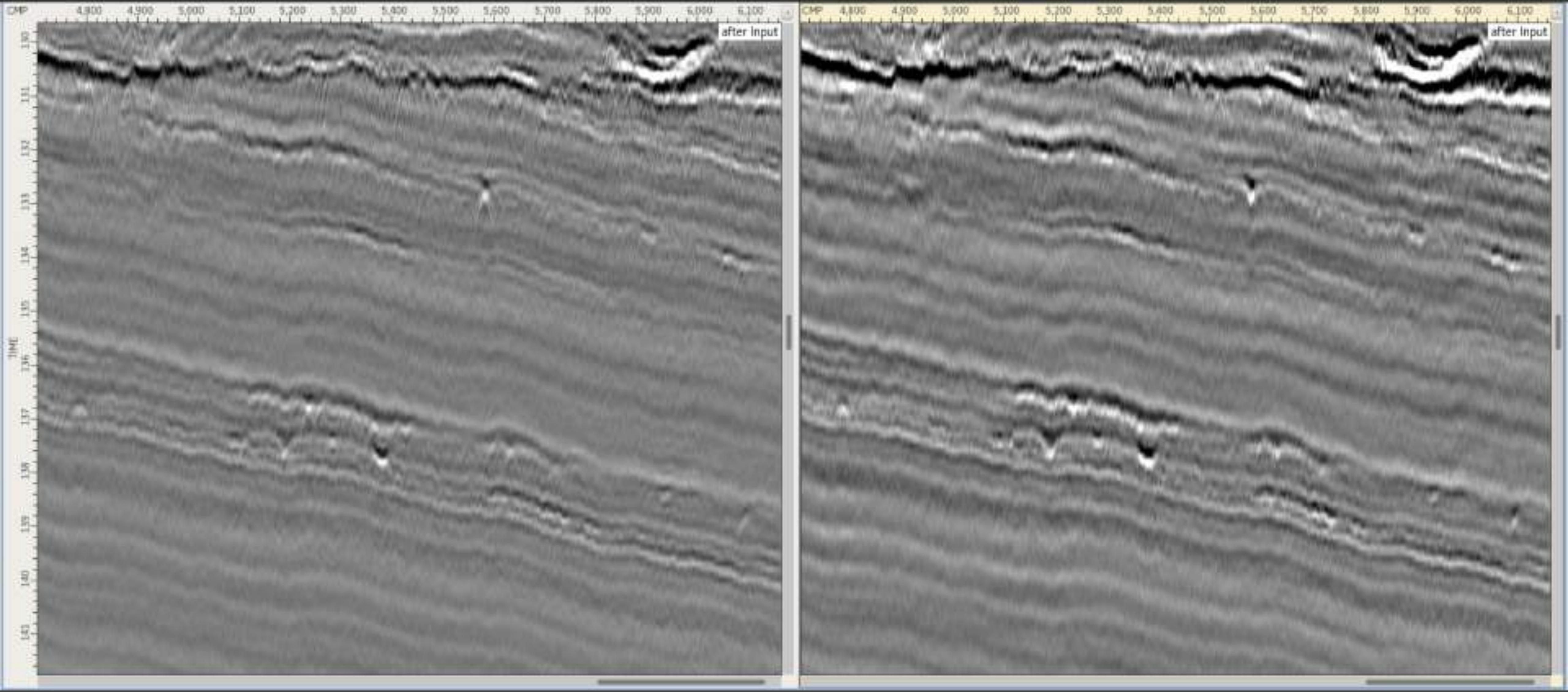
Stack → Mean stack

VELOCITY PICK EXAMPLE AT 0.5KM INTERVAL



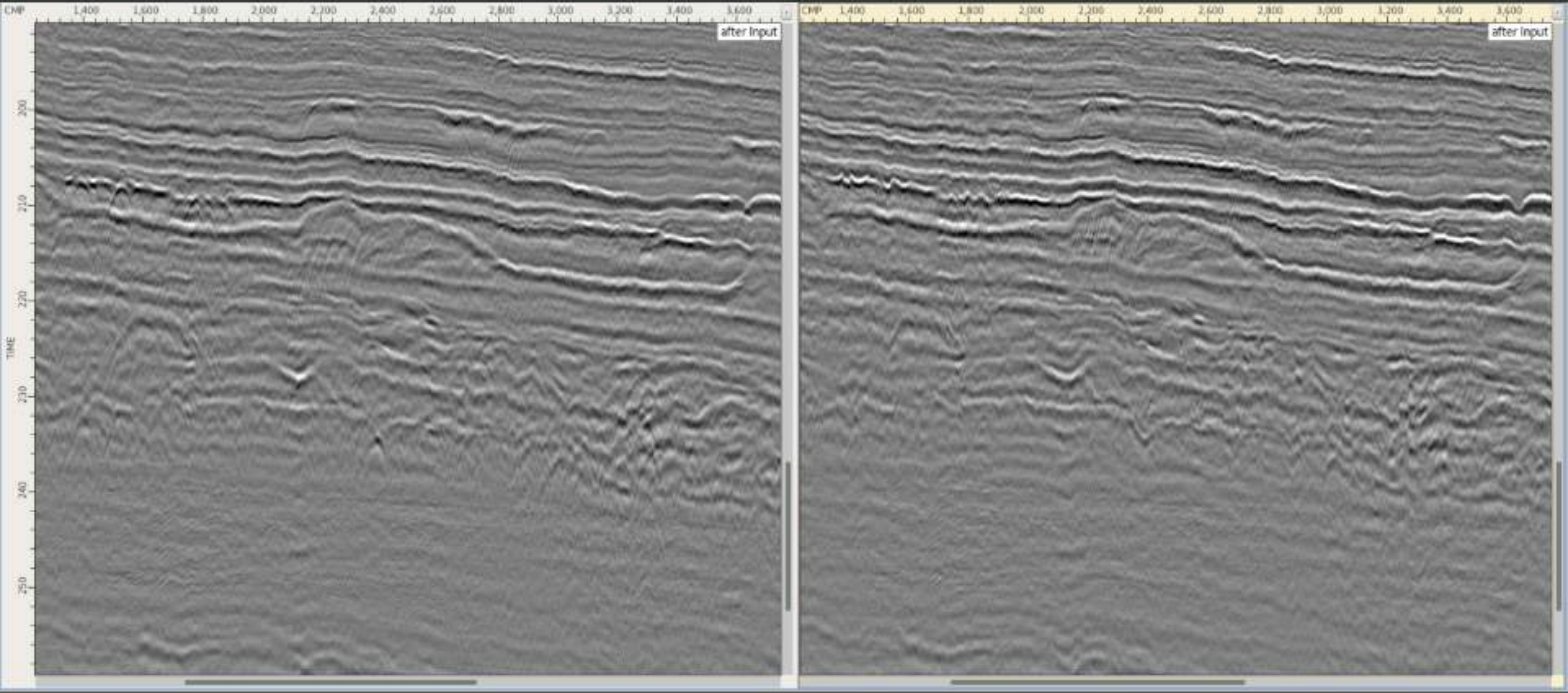
PEAKPROCESSING

STACKS BEFORE, AFTER MIGRATION – SHALLOW SECTION

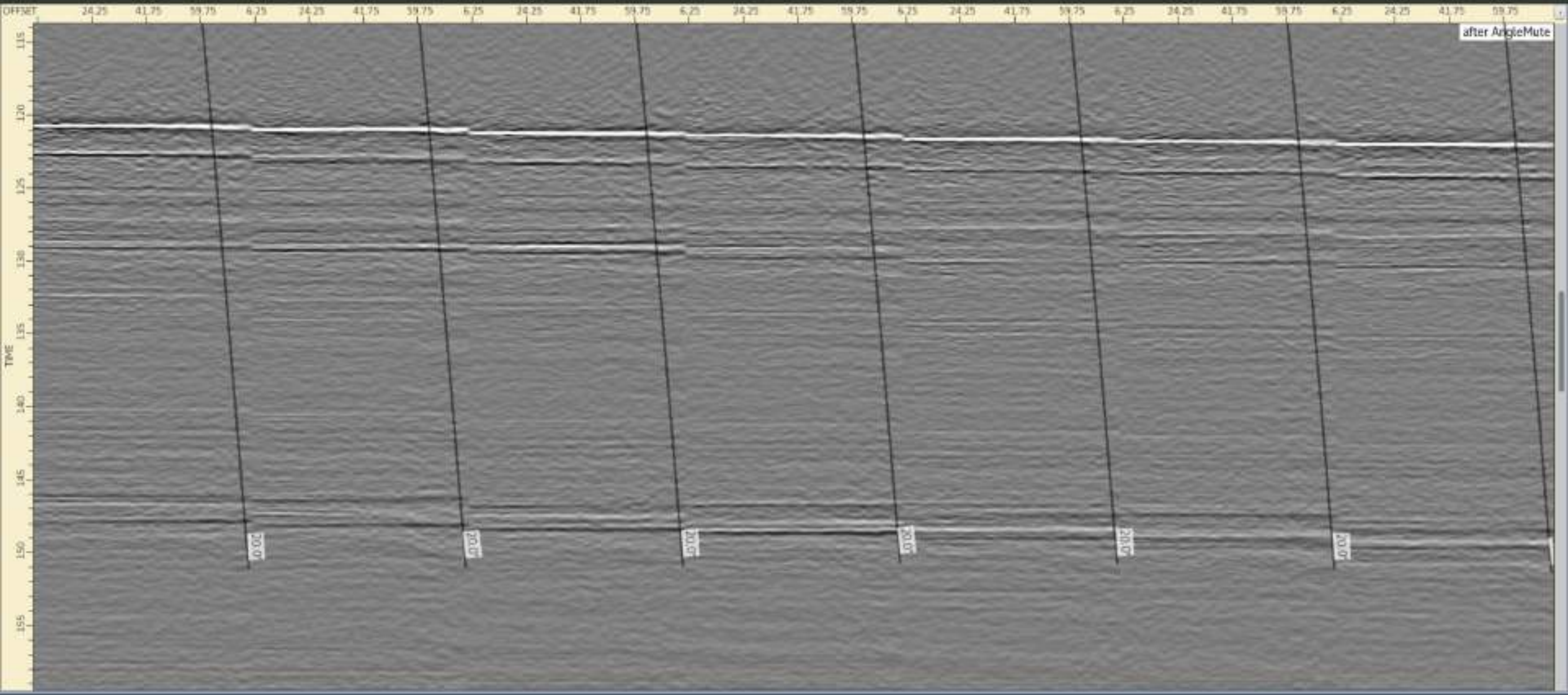


PEAKPROCESSING

STACKS BEFORE, AFTER MIGRATION – DEEPER SECTION

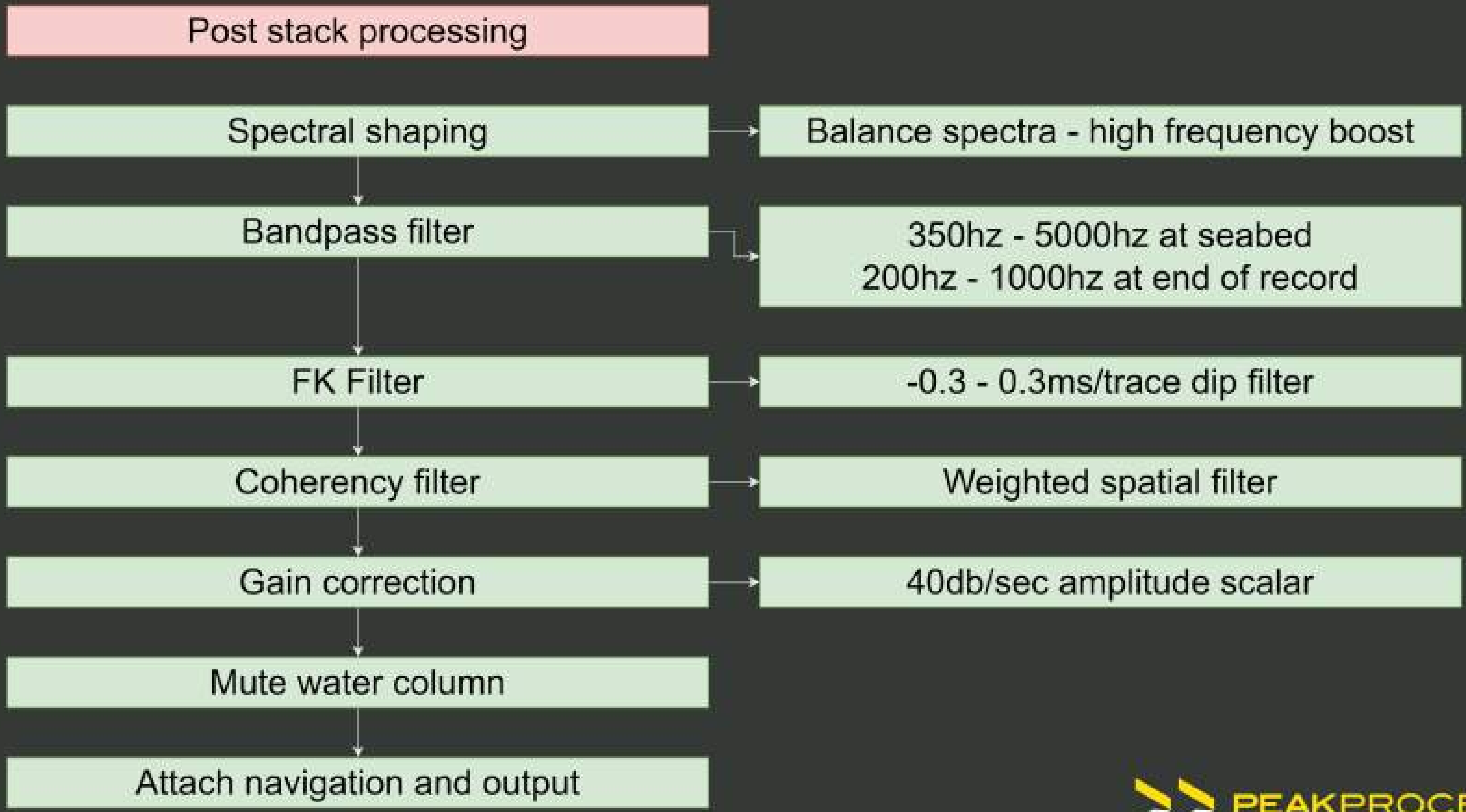


GATHERS – PROPOSED ANGLE MUTE

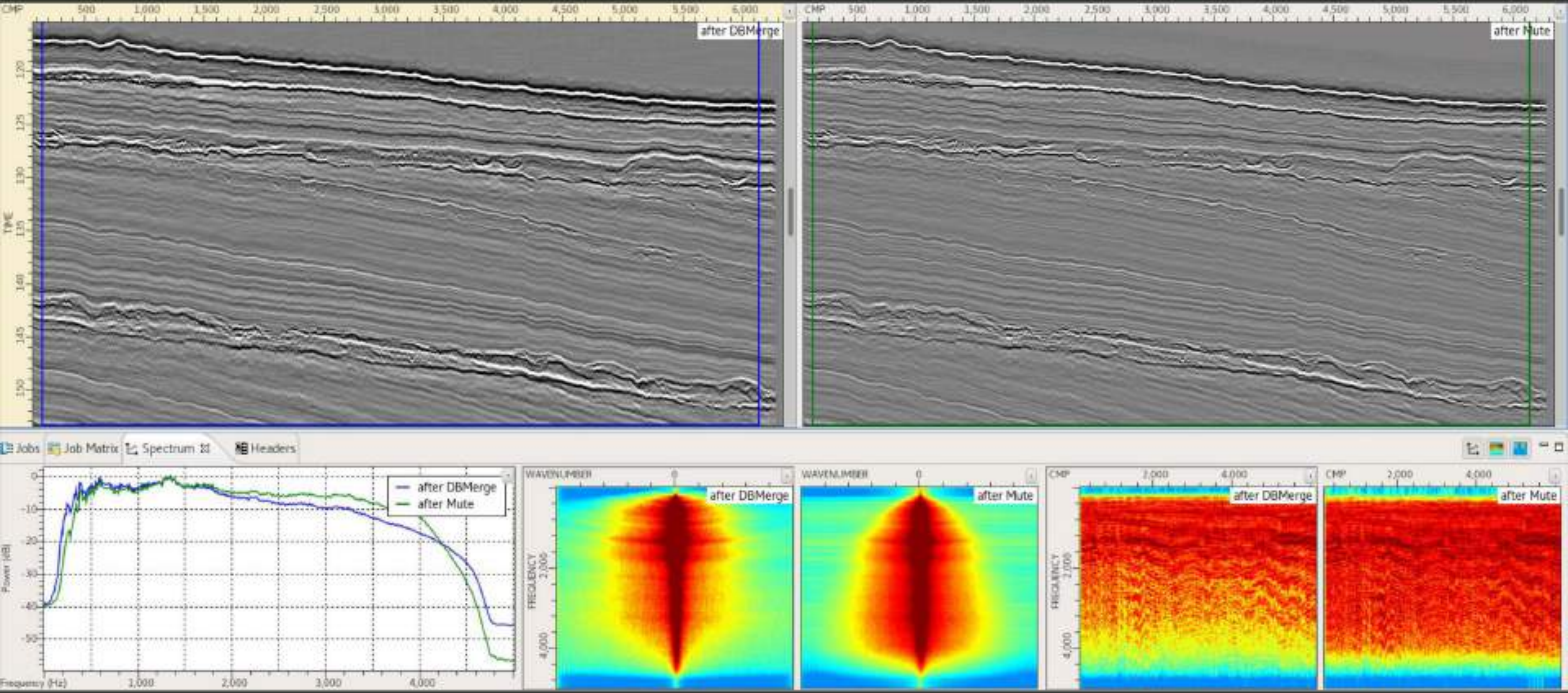


PEAKPROCESSING

POST STACK PROCESSING

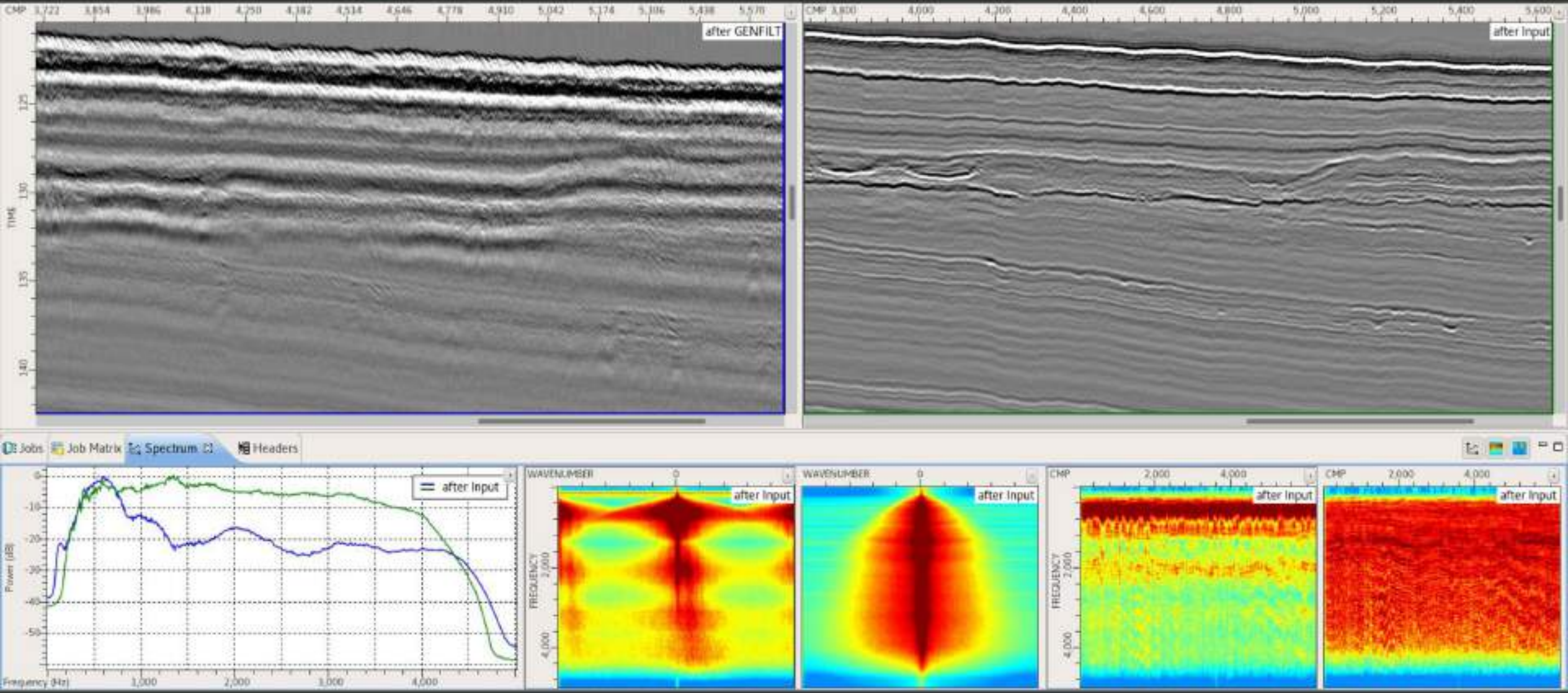


BEFORE AND AFTER POST STACK PROCESSING



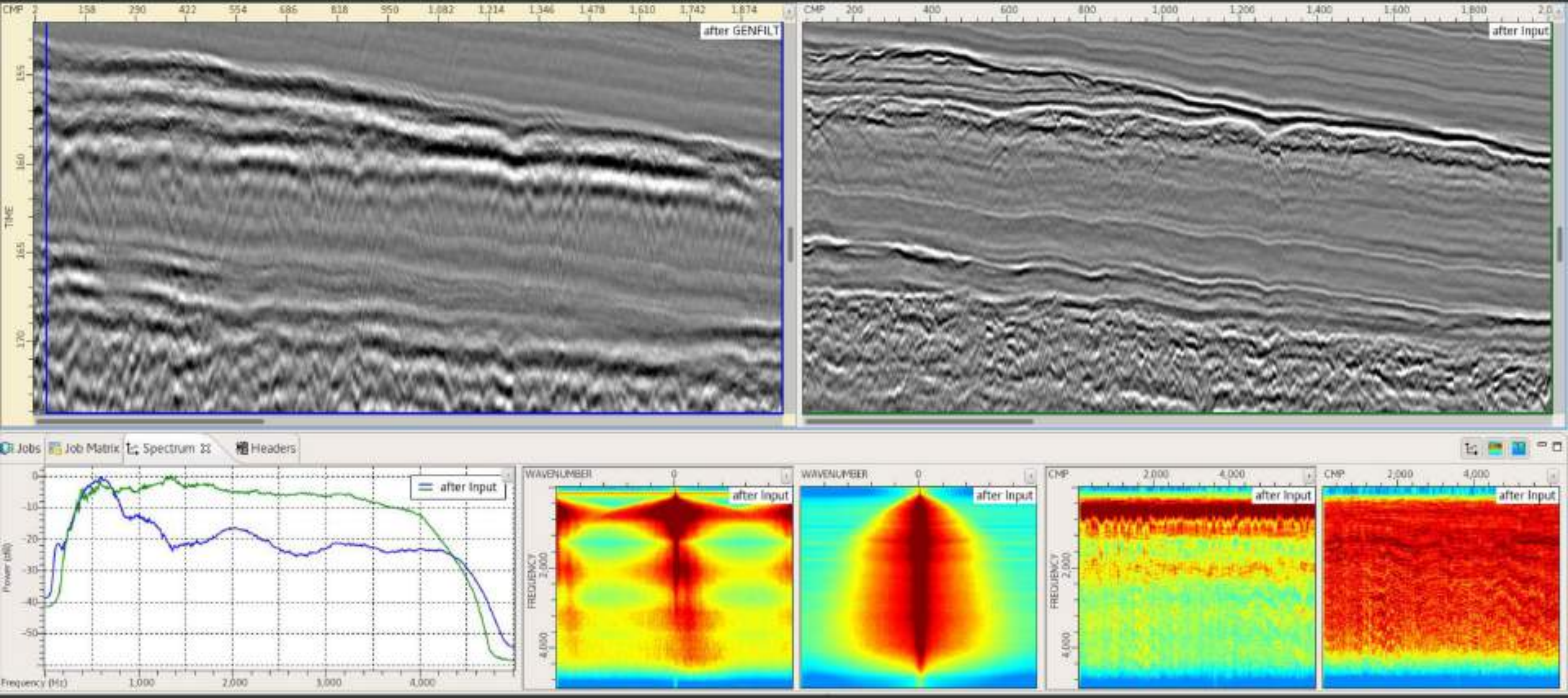
PEAKPROCESSING

BRUTE VS. FINAL COMPARISON



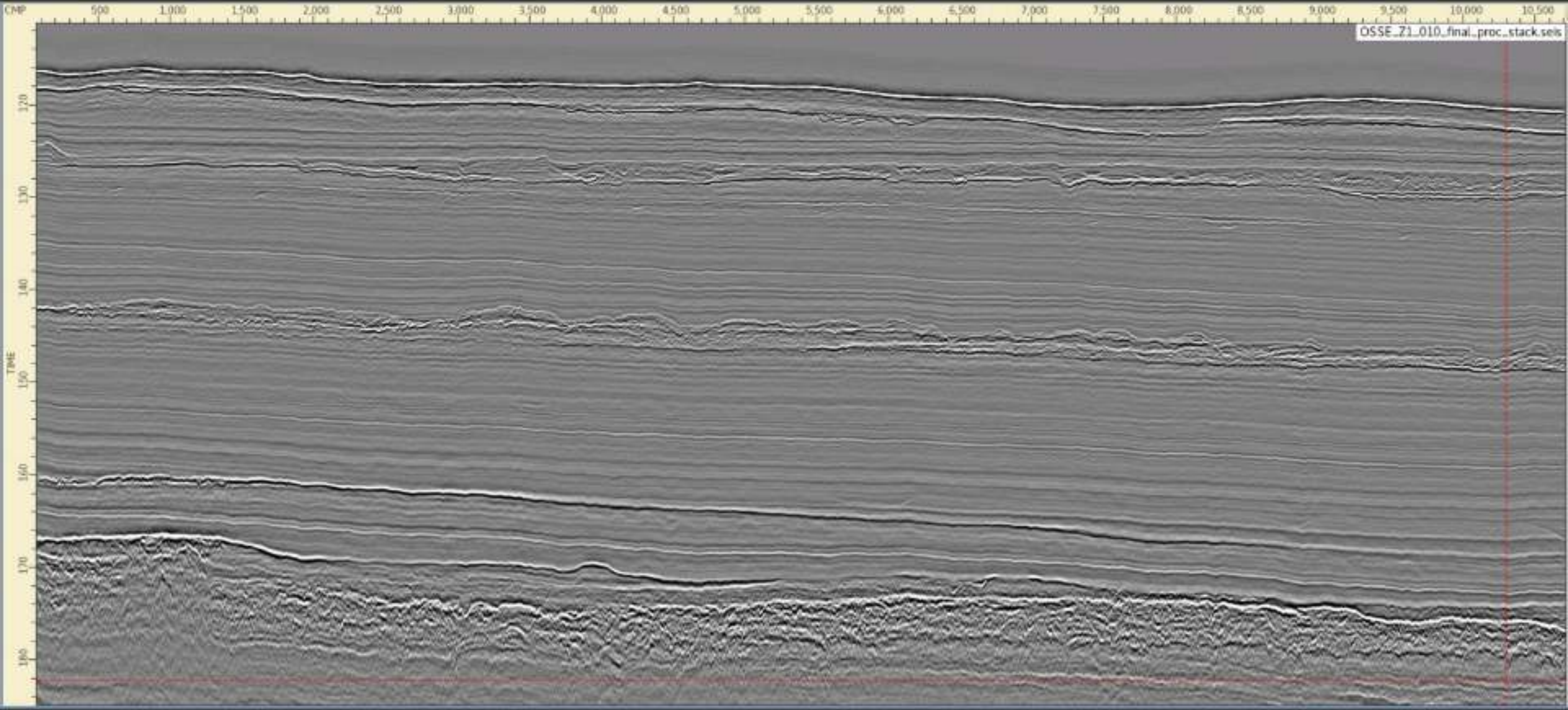
PEAKPROCESSING

BRUTE VS. FINAL COMPARISON

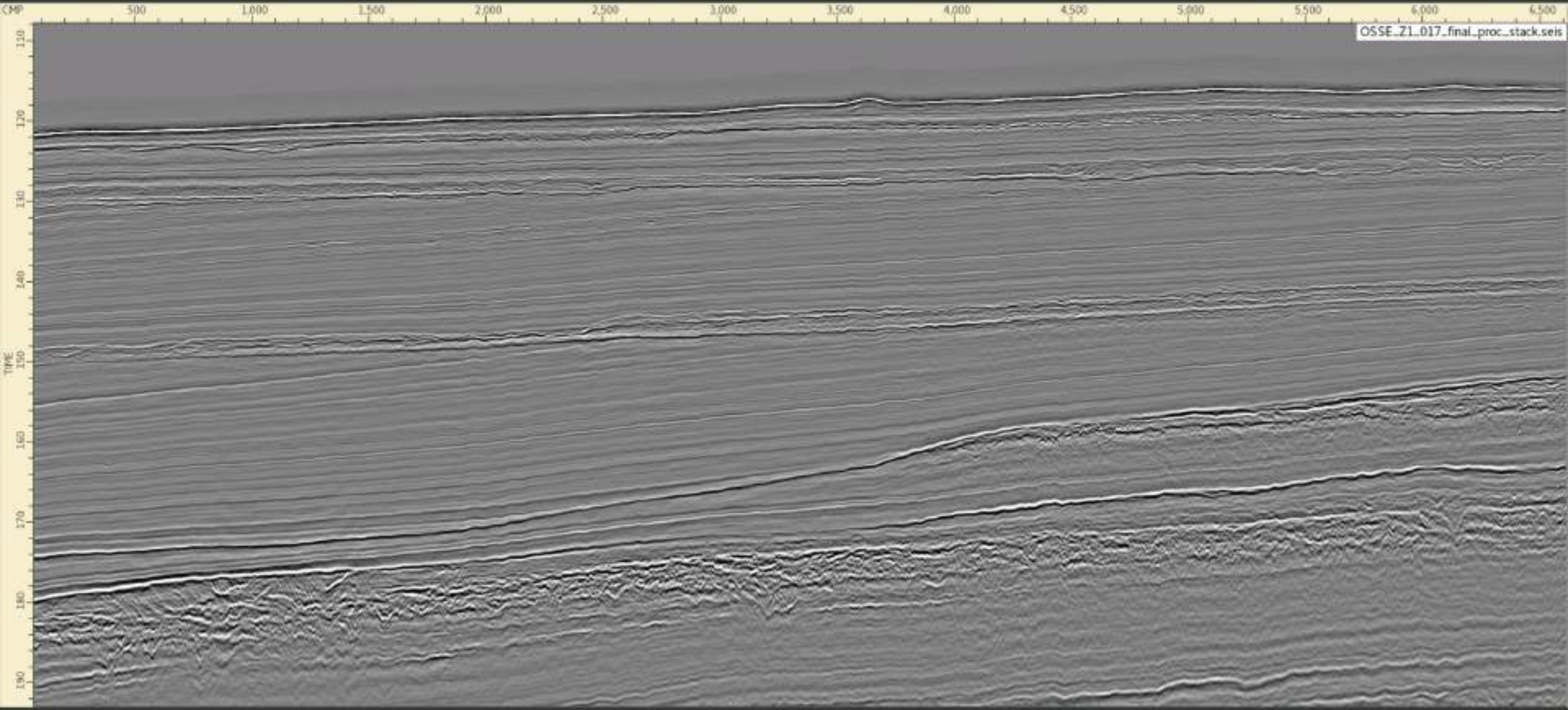


PEAKPROCESSING

OSSE_Z1_010 FINAL EXAMPLE



OSSE_Z1_017 FINAL EXAMPLE



PEAKPROCESSING