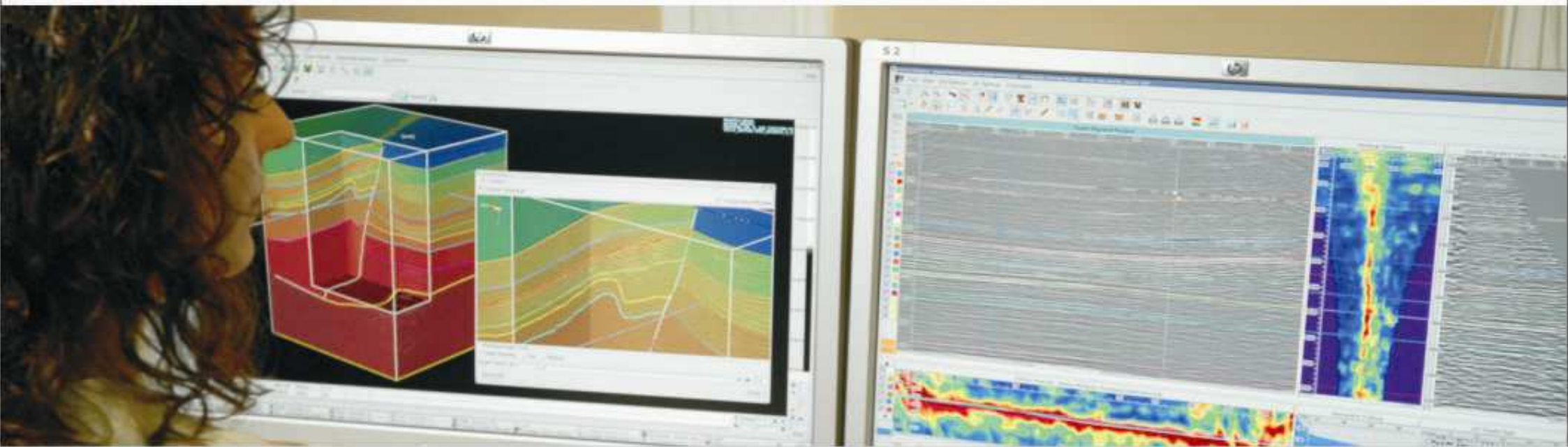


New generation of Seismic Data Processing



INTEGRATED GEOPHYSICAL SERVICES
Seismic Data Processing

Utrecht Feb. 2014

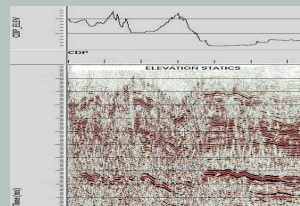
- **introduction**
- **processing innovations: ES360, 5D modules, ECP, RTM/CRAM, IWS ...**
- **GT specialty: land seismic across the world**
- **processing marine seismic data**
- **C-wave seismic**

Seismic data processing services from GT (Geofizyka Torun)

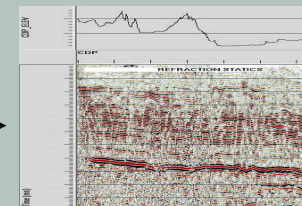


Digital processing services since 1973 - over 40 years of experience worldwide

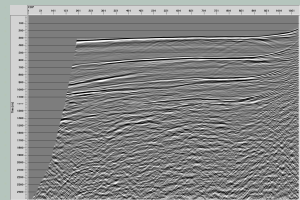
Specialty: land seismic data 2D /3D / VSP / 3C



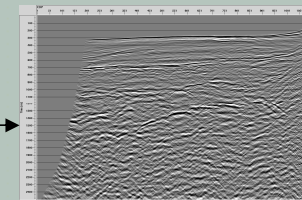
GT statics



Experience in marine data processing



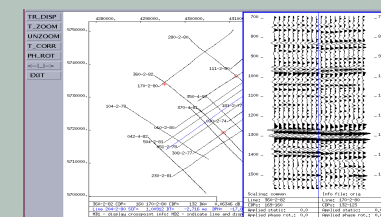
demult



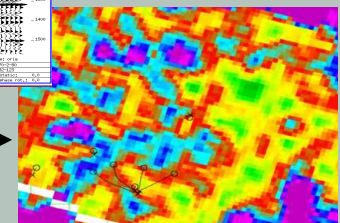
Experience from various geologies: S. America, Europe, Africa, Middle East, India, Far East



Proprietary GT modules complement and enhance commercial processing packages



Currently: focus on shale gas and other unconventional hydrocarbon resources



Processing experience from various geologic settings

Hardware: 700 TB disc, 3000 cores, 33 Tflops, 40 processing seats

People: 70 employees - about 60 geophysicists - 2-shift work - dedicated centres



Main clients

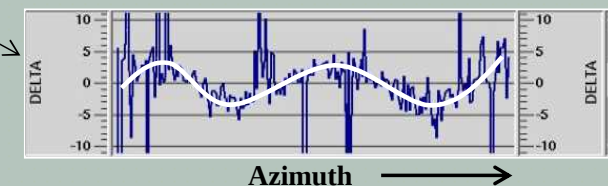
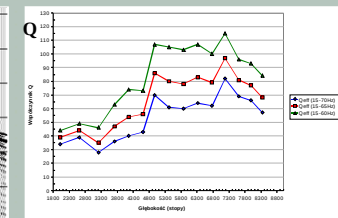
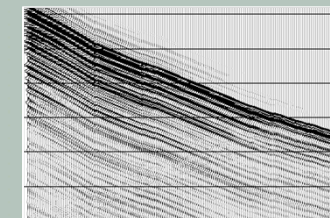
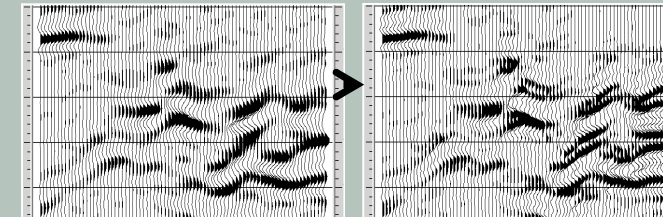
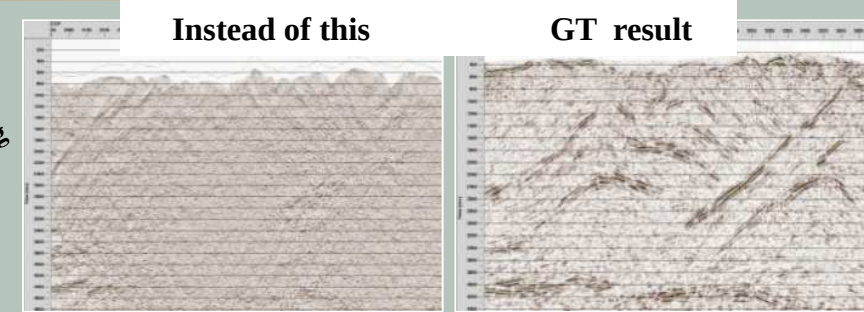
- PGNiG
- ADDAX
- Amerada Hess
- Amoco
- British Gas E&P
- Cairn Energy
- CEPSA
- Conoco
- ENI
- InterOceanMetal
- Oil India
- ONGC
- Petrobaltic
- Repsol
- Robertson
- RWE
- Shell
- Sherritt Intl Corp.
- Sonatrach
- TOTAL
- ExxonMobil

Processing innovations from GT

Some processing innovations

1. IRSC – Interactive Residual Static Correction
2. NOCOR – Near Offset for 5D interpolation and regularization
3. ECP – Enhanced Coherency Processing (generalized stacking)
4. IWS – Interactive Wavelet Shaping, with GT method for Low Frequency range
5. SpecDiQ – estimation of Q, and HTI anisotropy from VSP data
6. AZEC – Azimuthal Estimation and Correction for RMO
7. Shale gas package:
 - preprocessing with 5D modules; azimuth preserved in s-c processes.
 - ES360 - WAZ, depth, double-angle imaging

Multifactor
Interactive Processing

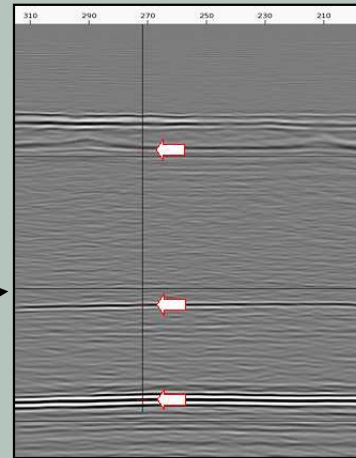


Let's begin review of GT innovations
with ES360 package

Wide-azimuth seismic solves unconventional and conventional puzzles ...

- demand for seismic dedicated to shale/tight gas and hydrothermal

Structurally smooth geology,
similar to case of NP-01



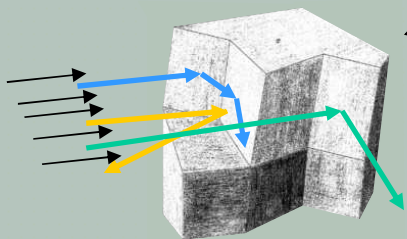
Complex anhydrite-salt structure of Zechstein

Silurian

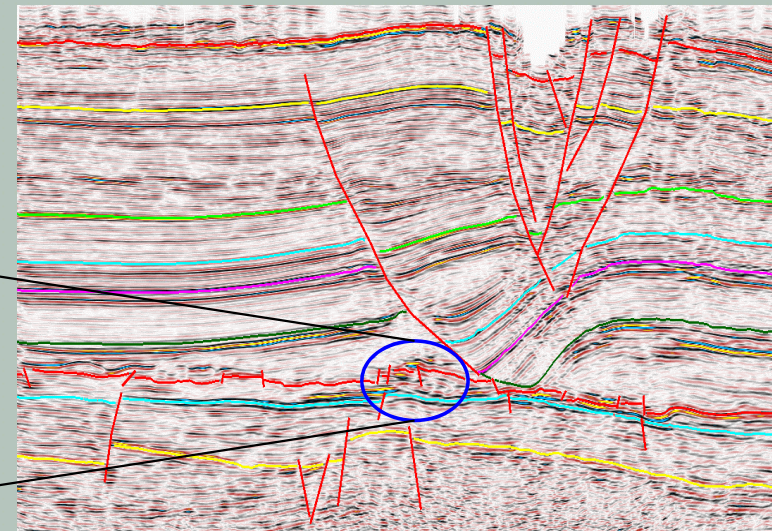
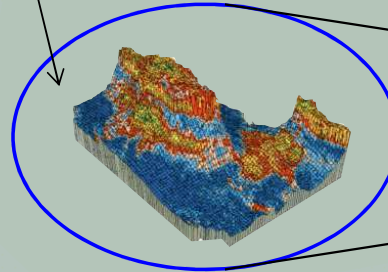
Ordovician

HTI anisotropy

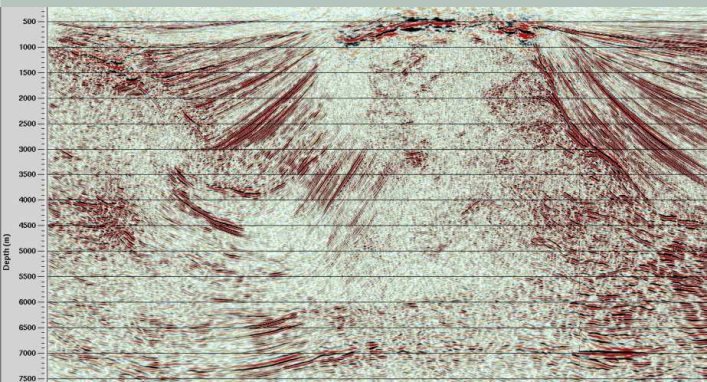
- expectation to provide new solutions for conventional seismic



Body of irregular shape
needs full azimuth
illumination



Detection of unconventional resources begins with precise 3D A PreSDM ...



Earth Study 360 (ES 360) package has proven its value for GT on a couple of land full-azimuth 3D projects

It replaces former, sector-oriented, time-domain technique which has been applied since 10 years

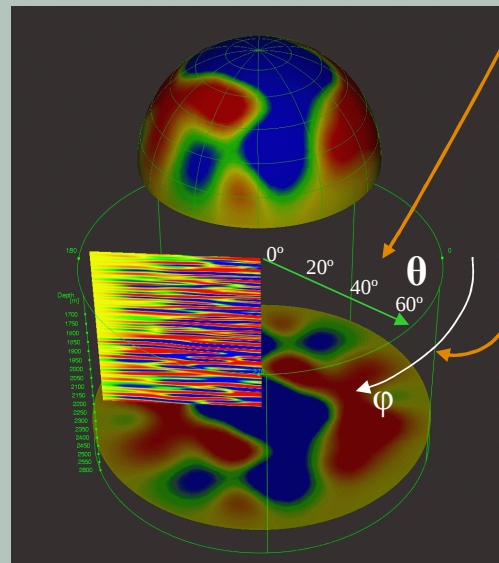
ES360 works on wide azimuth 3D seismic

On the right: azimuth – offset distribution spider for individual CDP bin and horizontal cutting of traces from single CDP bin after interpolation

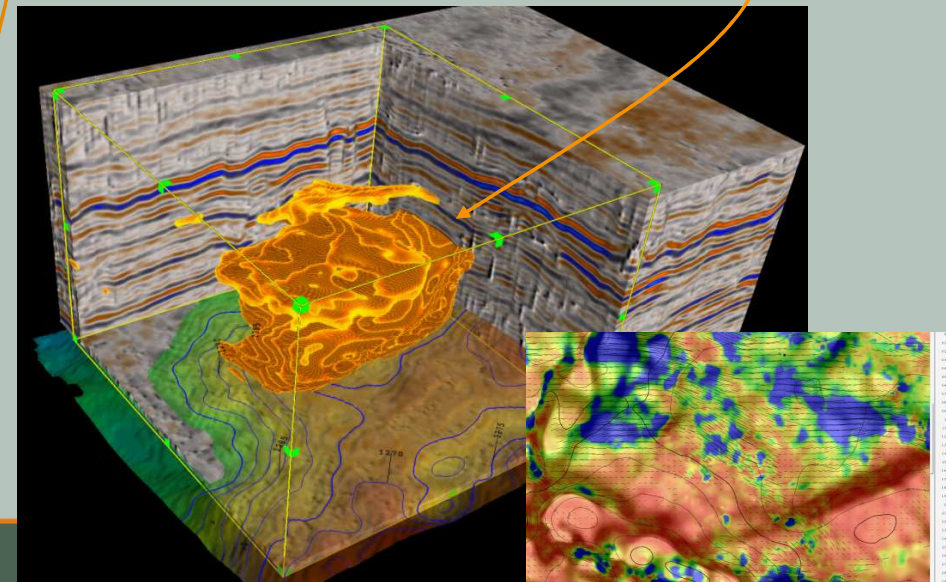
... consists of interactive 3D analyses:

AVA – Amplitude Versus Angle θ

AVAZ – Amplitude Versus Azimuth ϕ ...

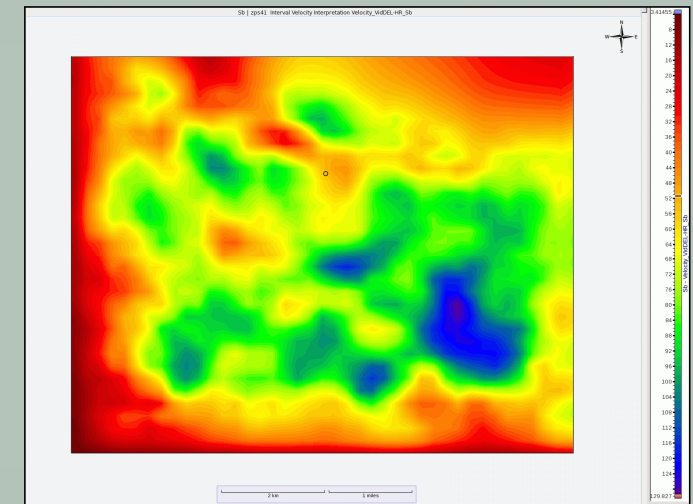
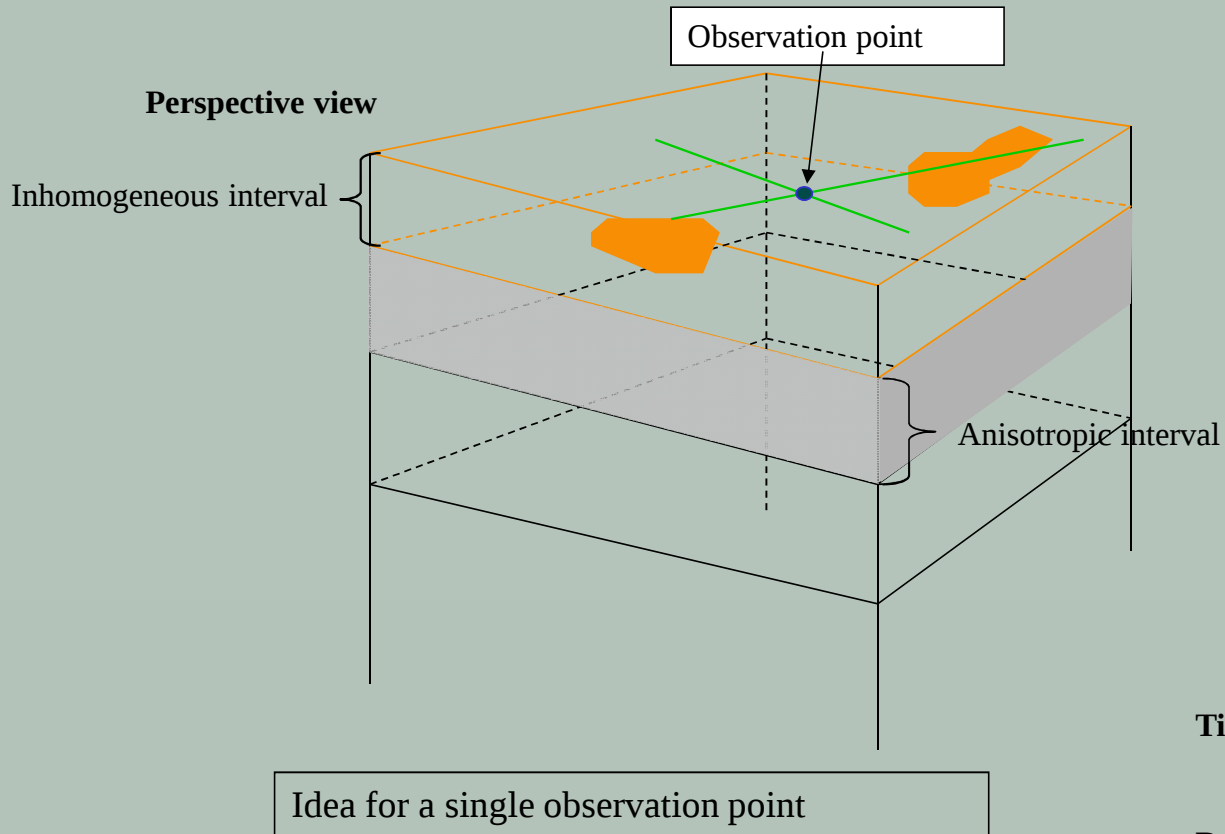


... and goes to estimation of interval attributes which provide physical parameters of geobodies and their combinations, e.g. „sweet spot” attribute



Correction for overburden inhomogeneity

Inaccessible in standard 3D depth imaging:
inhomogeneities of overburden separated from
HTI anisotropy



Time domain:

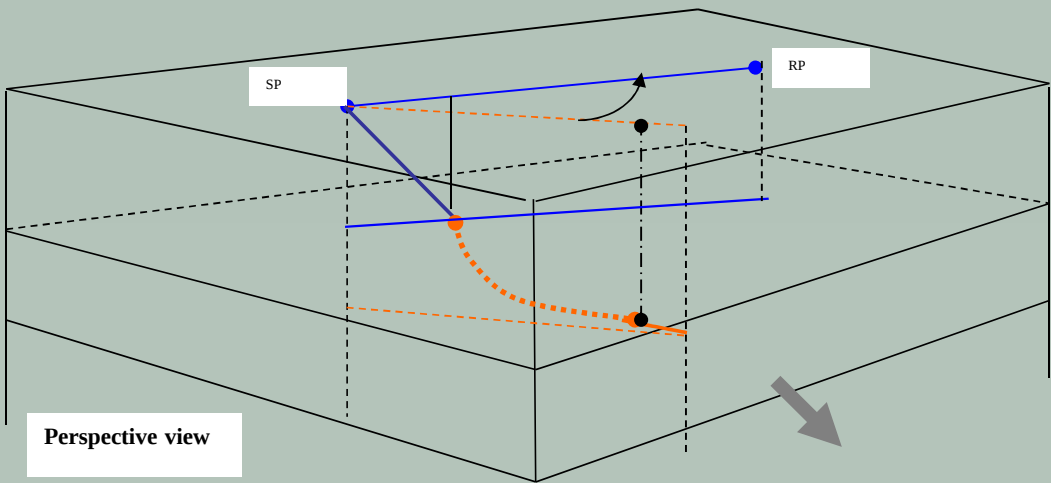
$V_{eff\ a} > V_{eff\ b}$ - then: HTI ? - **ambiguous**

~~≠~~

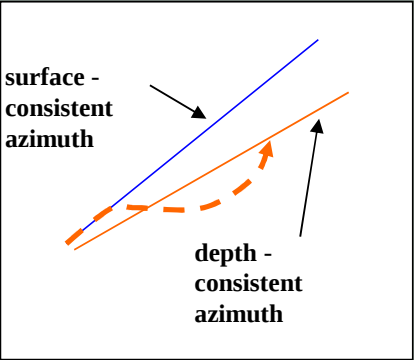
Depth domain:

$V_z\ a = V_z\ b$ - then: no anisotropy

Interval attributes from effective ones – through system of equations



Perspective view

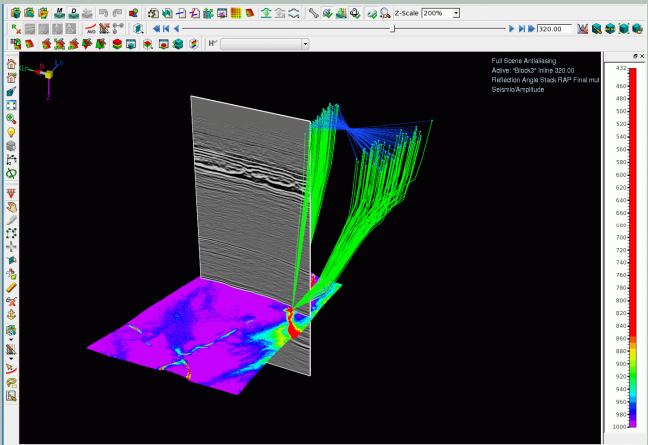


Top view

Depth-consistent azimuth is different from surface-consistent azimuth

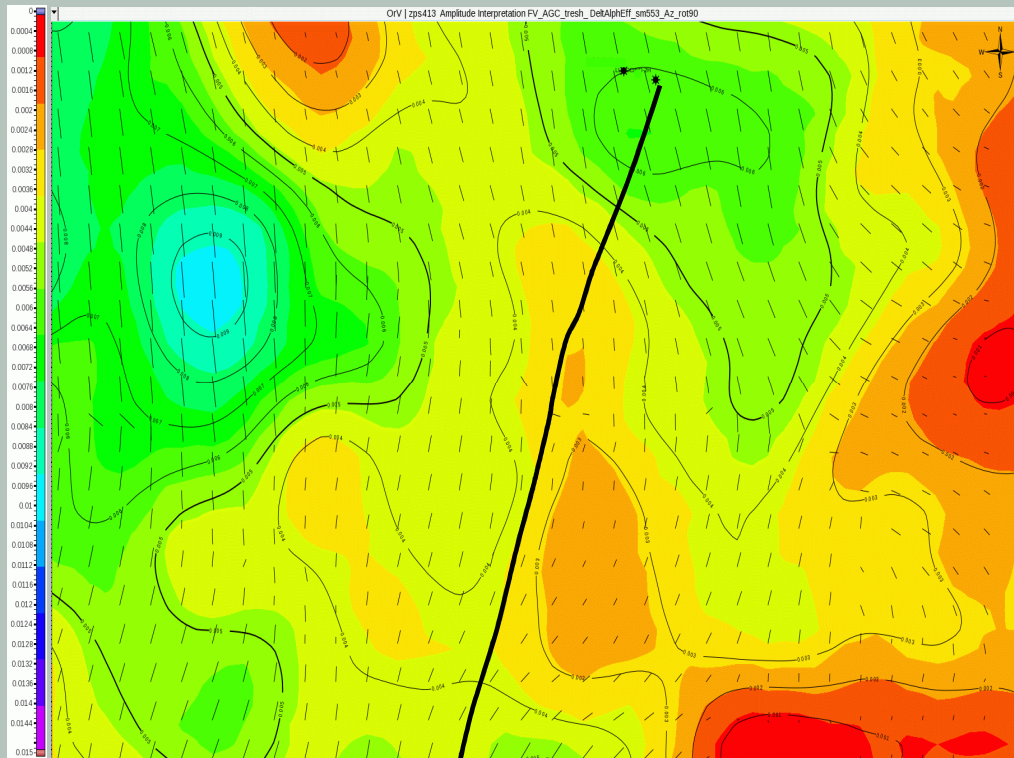
Inaccessible in standard 3D depth imaging: accounting for depth-variant azimuth

- Interval attributes** are key diagnostics in shale gas prospection. Reliably estimated due to:
- migration-based (tomographic) **removal of heterogeneities**
 - account for **HTI** in raytracing-based Generalized **Dix Equations**
 - **exact, in-depth azimuths** without smoothing action of sectors

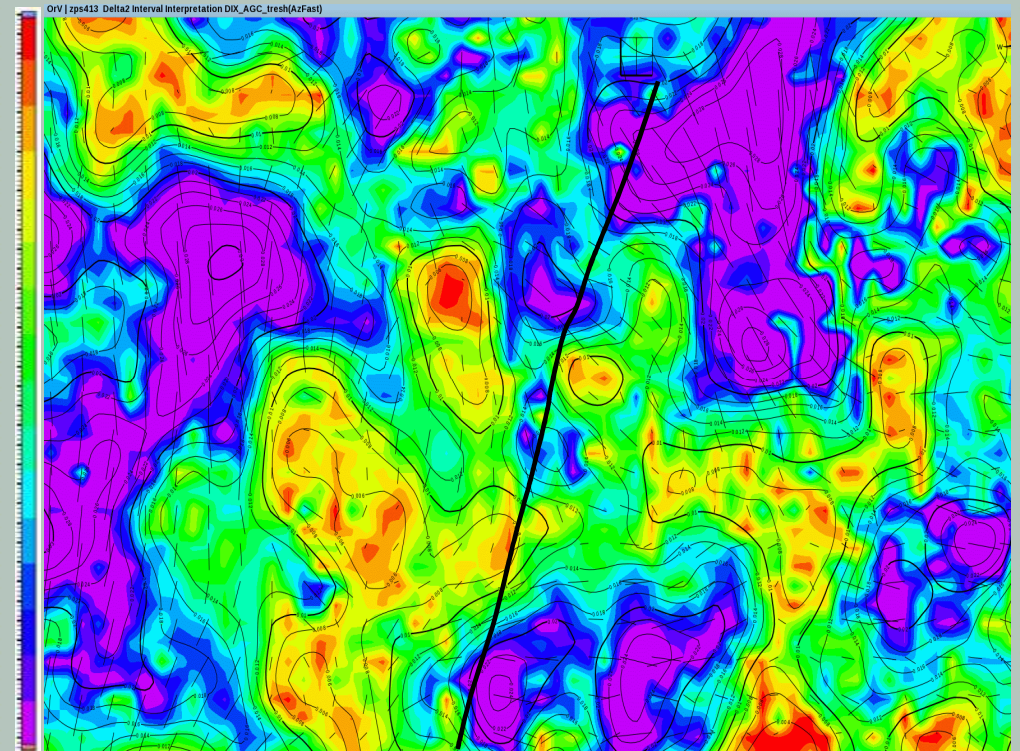


Amplitudes corrected for illumination:
attributes estimated from geometry of reflector, model of medium, filtered through geometry of a real spread.

Removal of overburden impact: conversion of effective into interval attributes

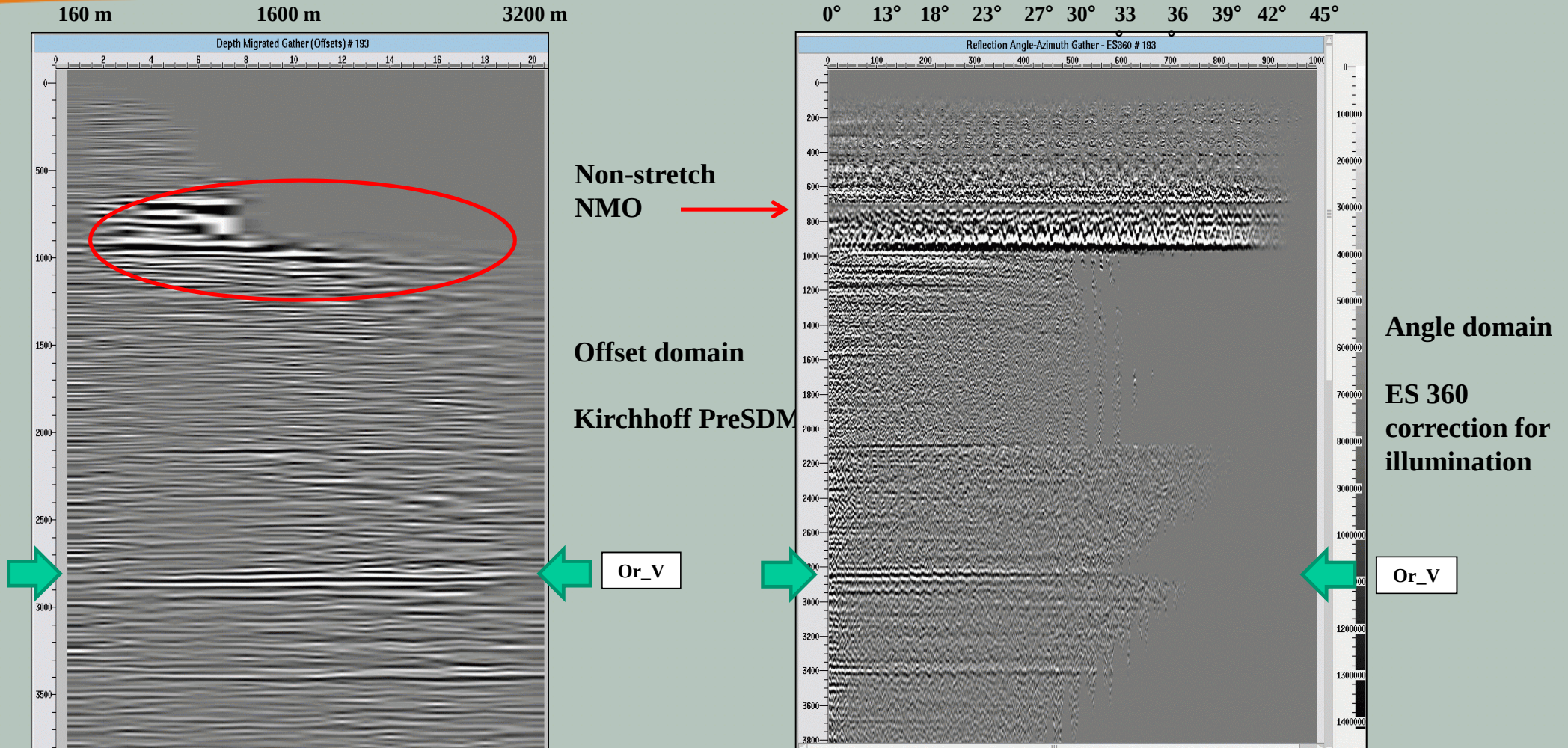


Map of **effective δ_2**
for the top horizon

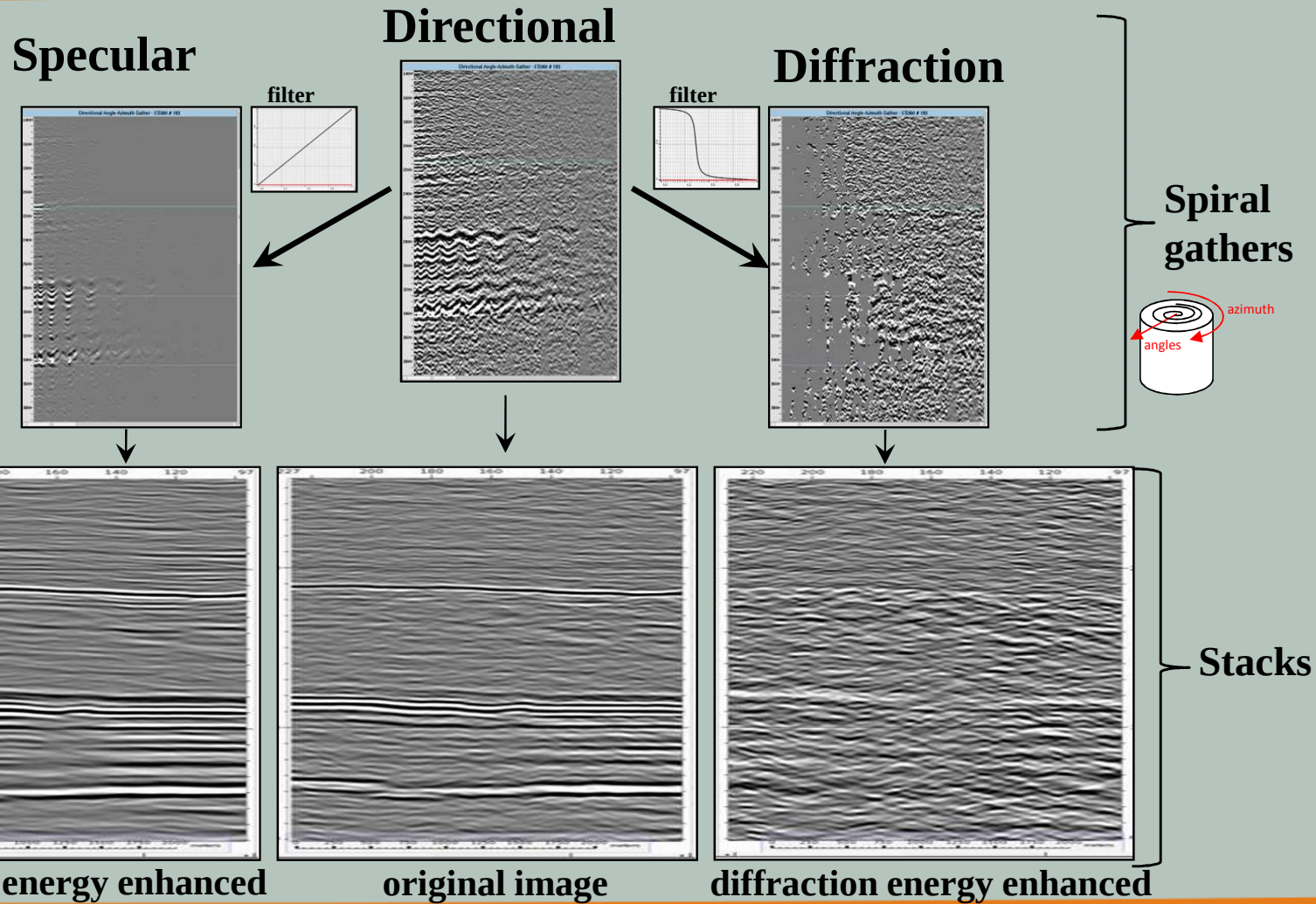


Map of **interval δ_2**
converted with azimuth-dependent generalized Dix equations
- attributes directly related to elastic rock parameters

High Resolution seismic: - work in angle domain allows to remove NMO-stretch

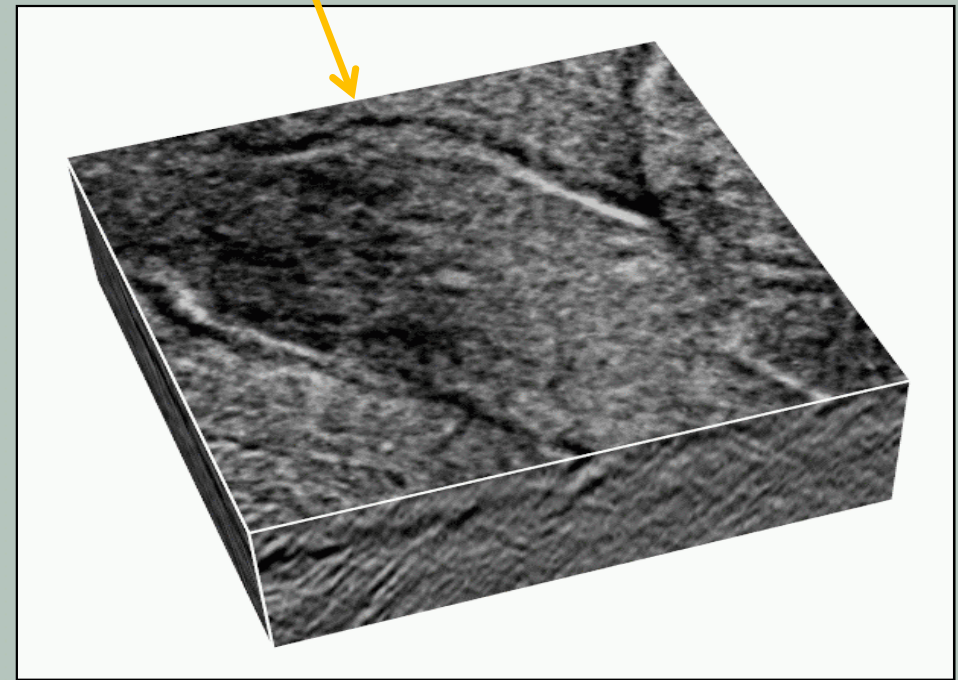
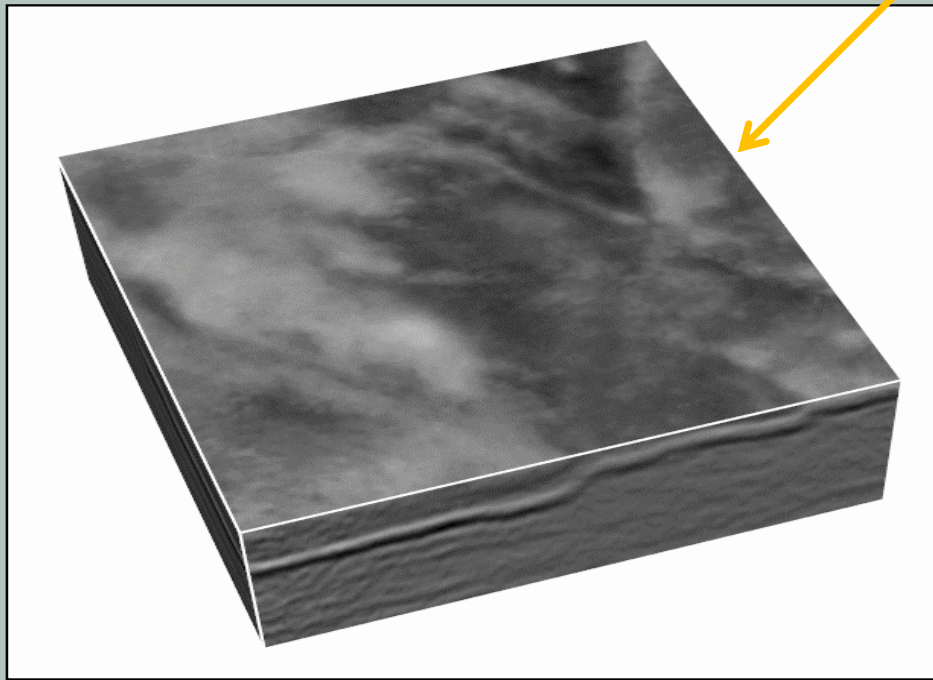


Novelty attribute: diffractive images - result of wavefield splitting into reflective and diffractive components



Conventional 3D prestack data can be split into two components of the same wavefield

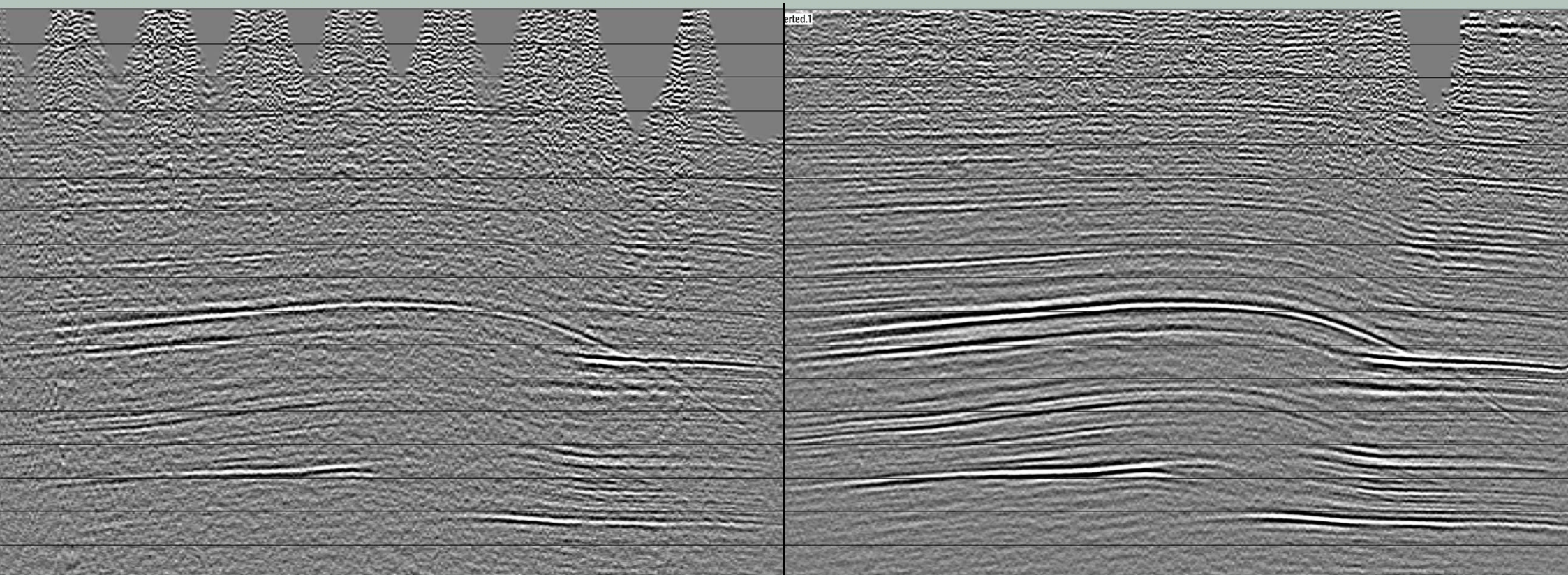
Novelty attribute: diffractive images - result of wavefield splitting into reflective and diffractive components



Conventional 3D poststack image from the land WAZ seismic, and diffractive stack - new geologic information from seismic. ES 360, in a sense, can be regarded as top-advanced general stacking system, working in depth, double-angle domain (α , θ). „Plane wave destruction” (S. Fomel) is a key technique to get diffractive stack.

3D prestack trace interpolation: 5D + GT solution

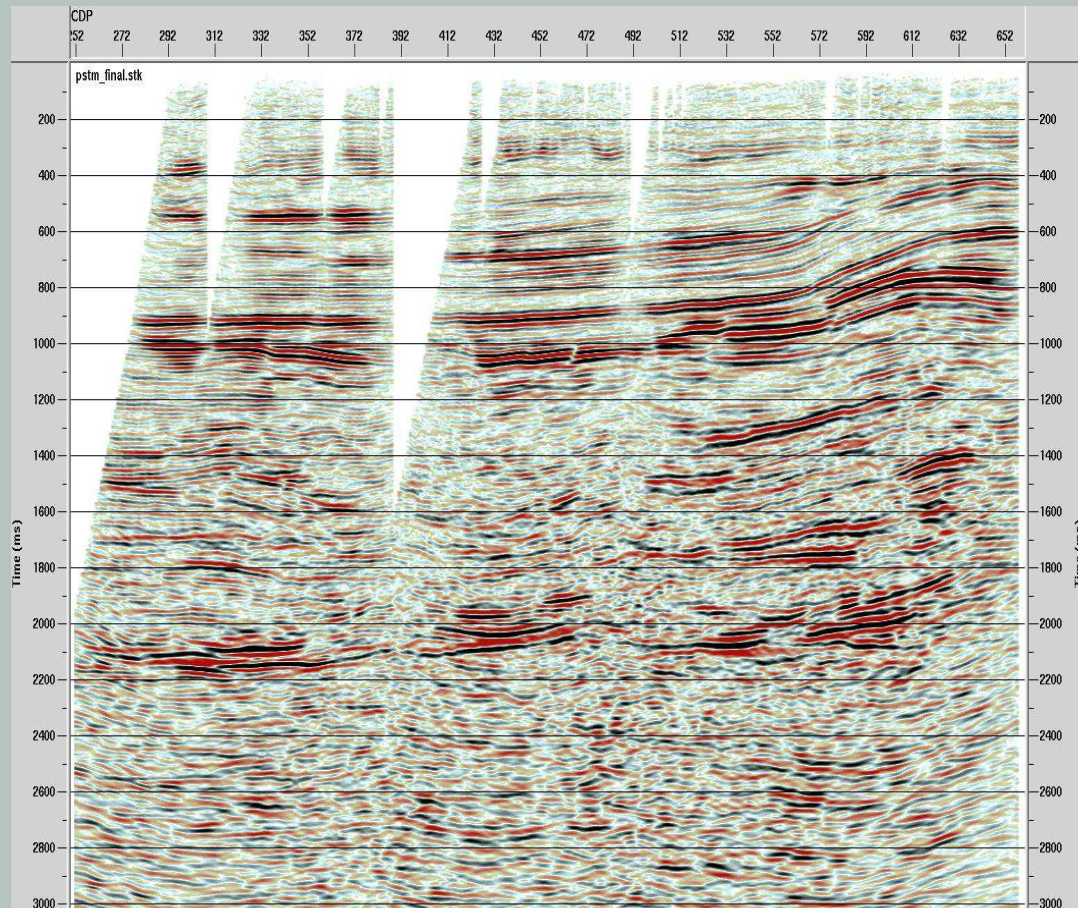
5D prestack interpolation makes interpretation of seismic data more reliable than before



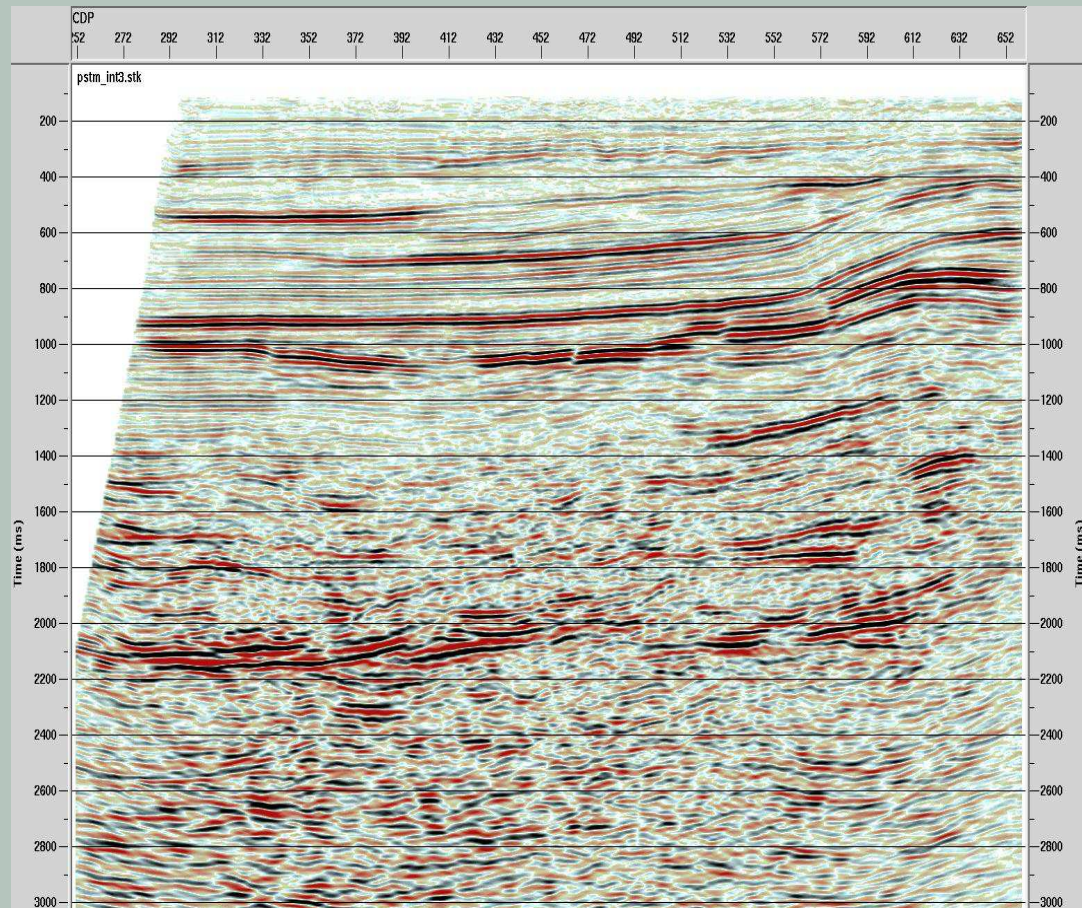
3D section before

after 5D prestack interpolation

2D prestack trace interpolation

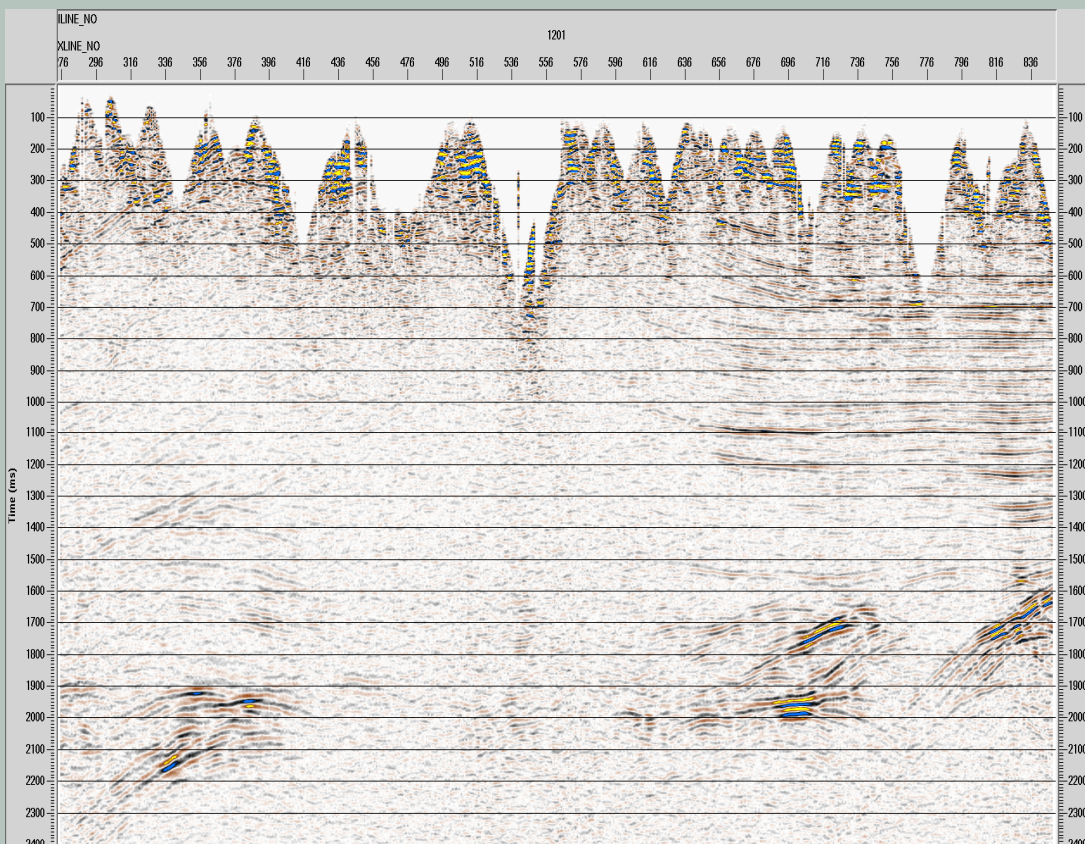


Original data

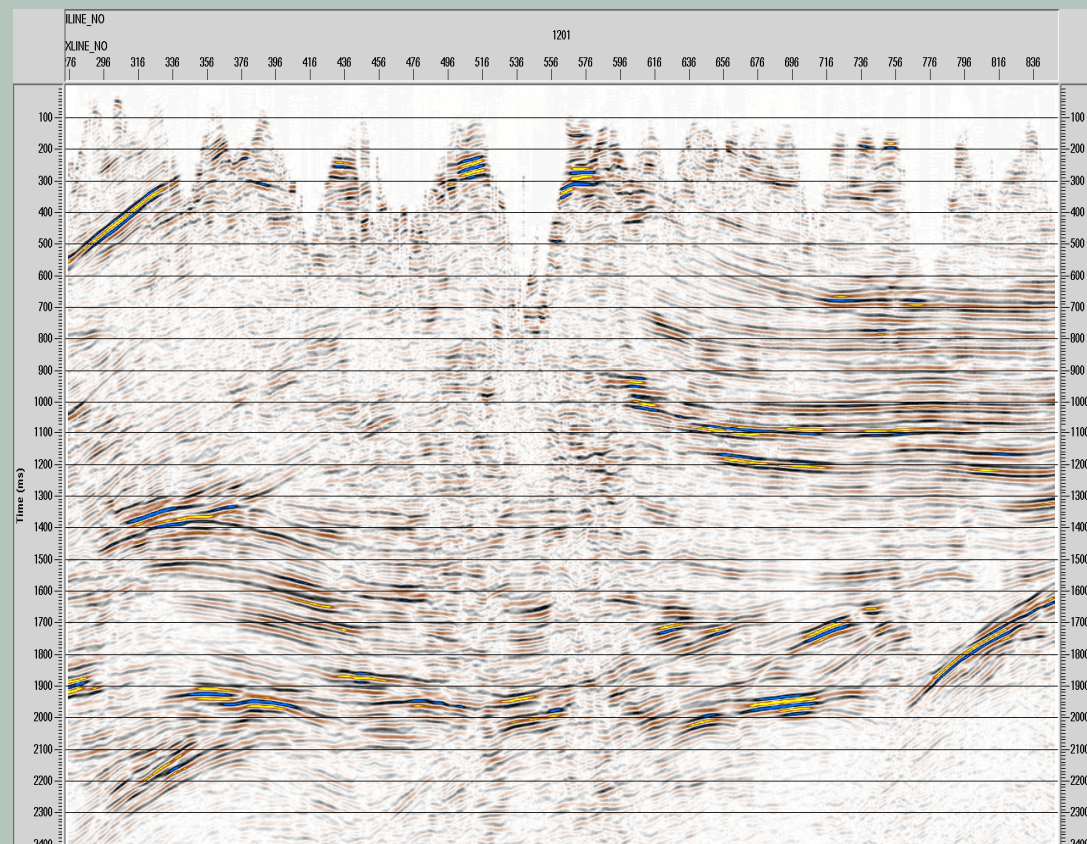


2D section after prestack interpolation

ECP - generalized stacking

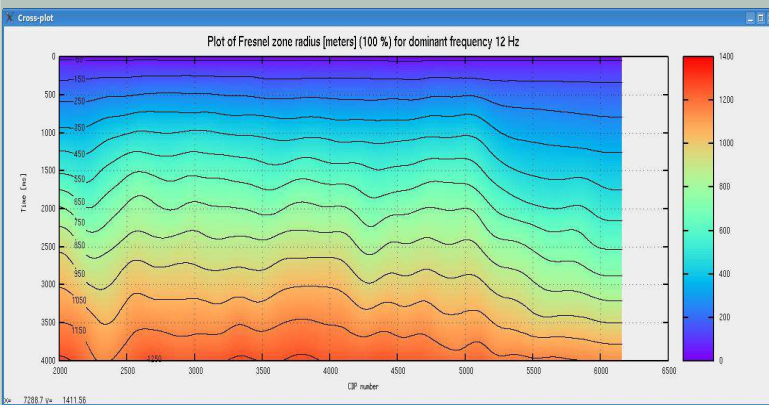


3D survey, Poland. Conventional processing

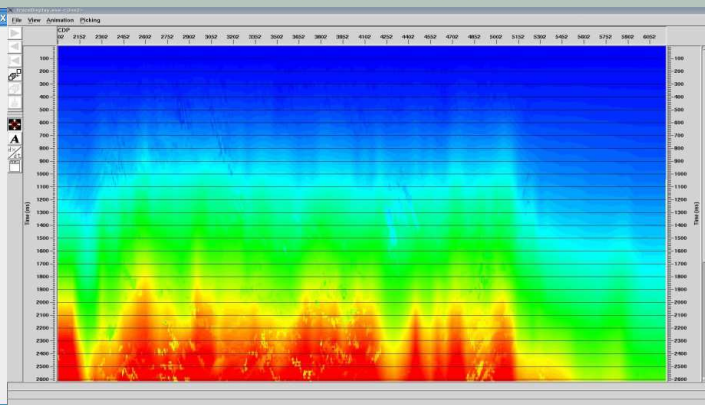


3D ECP

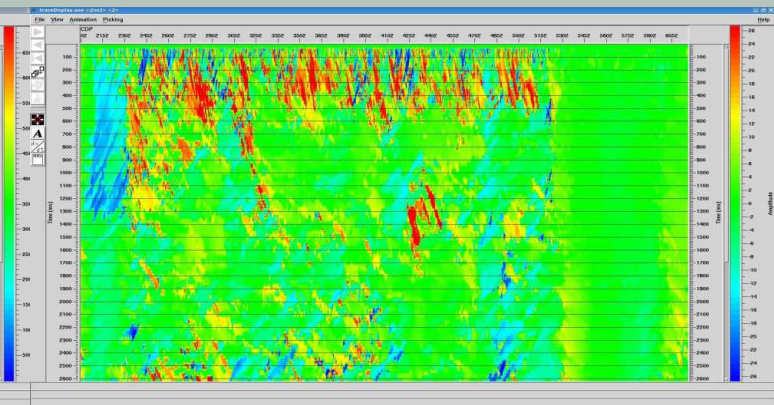
3D/2D ECP - „generalized stacking” family: multiattribute estimation



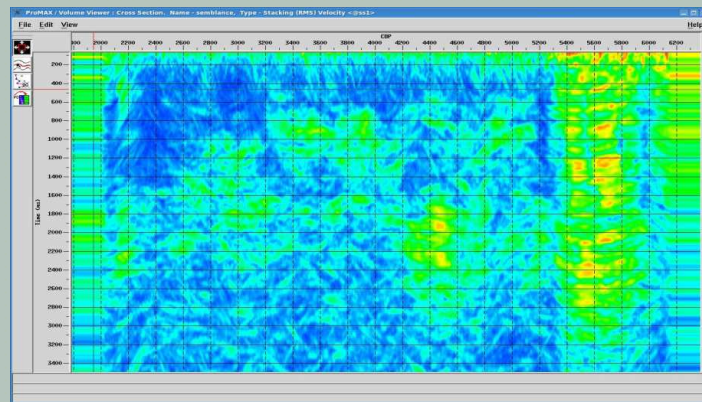
Radius of the Fresnel zone



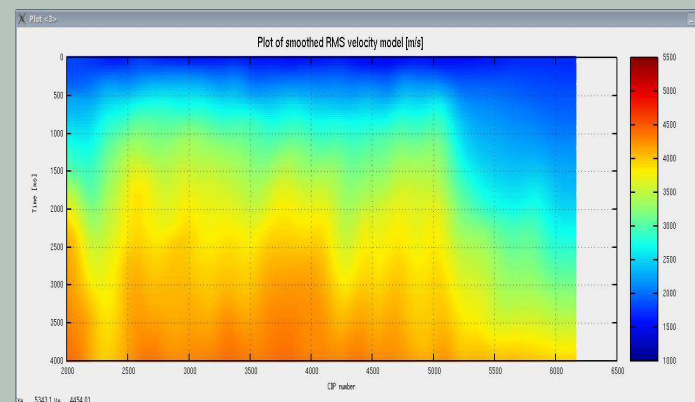
Rnnp



Dip



Semblance



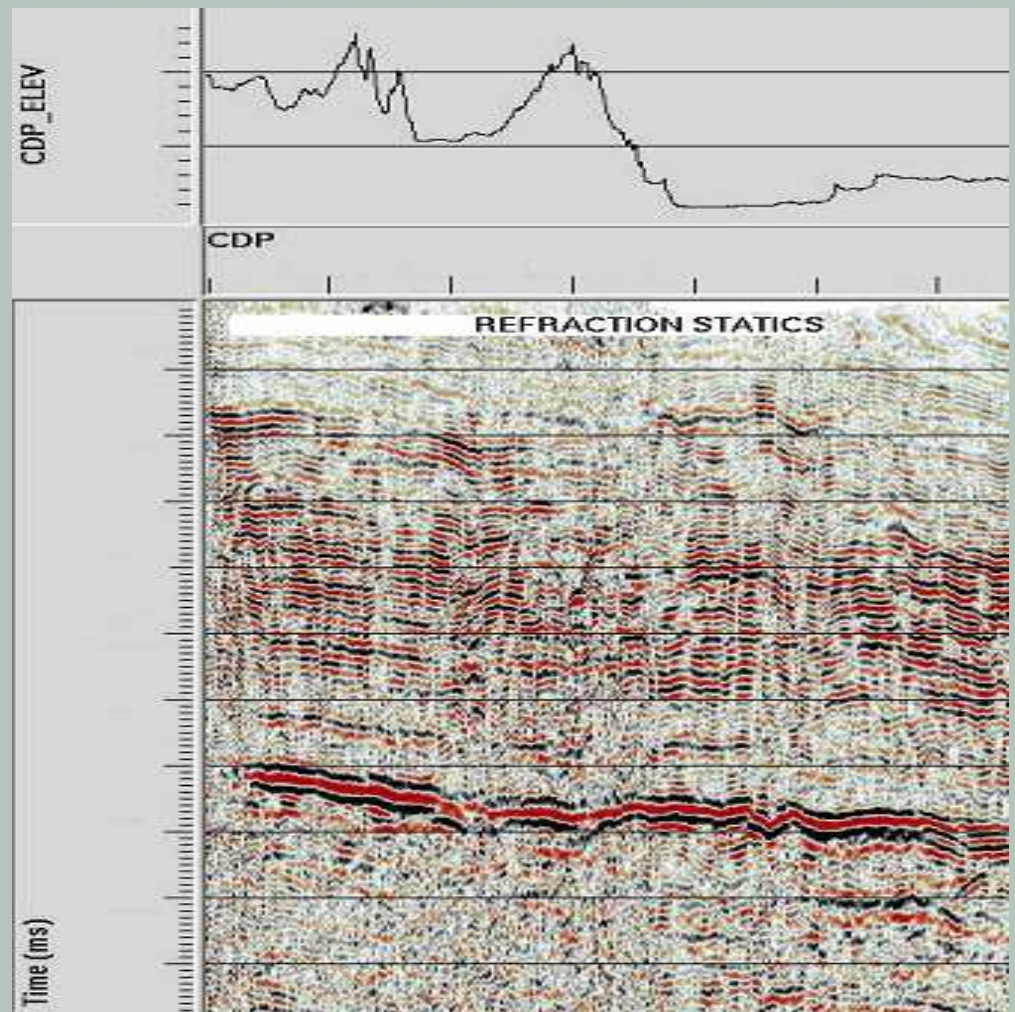
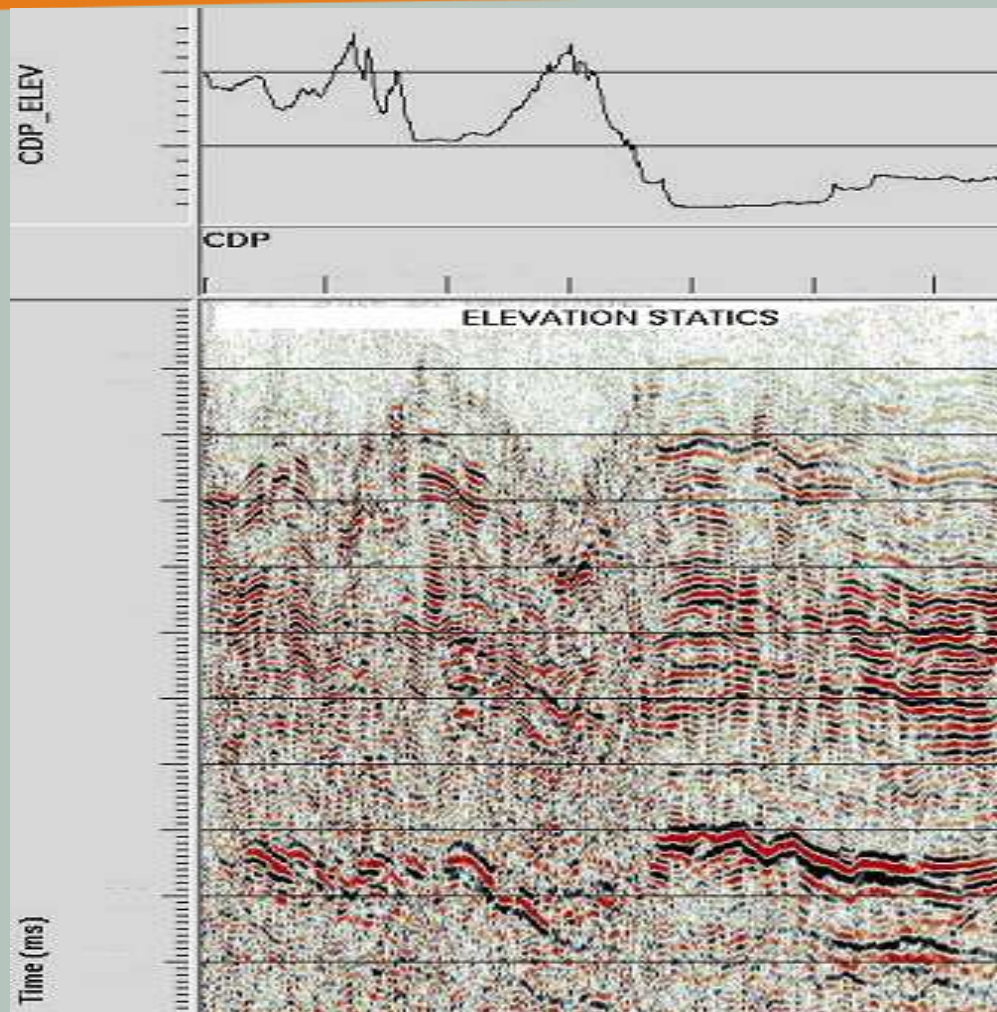
RMS velocity model

**Multiattribute set
of seismic properties
includes azimuthal
attributes in case of
HTI geology**

GT specialty: land seismic across the world

Static corrections	- refraction (GLI / tomo), modeling, interactive, comprehensive QC - software: Hampson-Russell GLI 2D/3D, FUSION Seismic Studio, GT software - uphole calibration for long-wavelength component
Noise removal	- linear coherent waves (e.g. ground roll), multiples, various industrial noise, random noise - tools: Radon transform, modeling + adaptive subtraction
Multi-line 2D	- GT-designed, dedicated software package
Converted waves	- Commercial modules + GT software package

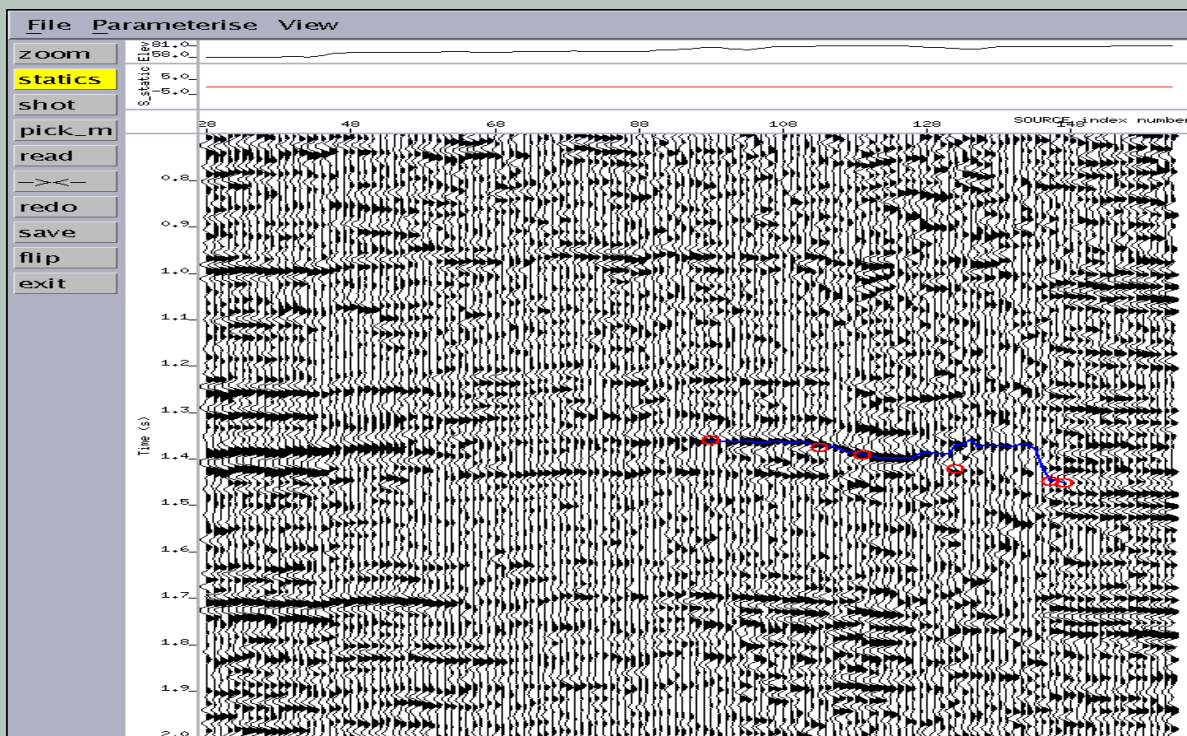
Refraction-based GT statics for difficult near-surface



Interactive Residual Static Correction (IRSC) - GT proprietary tool

IRSC is employed when automatic residual statics are ineffective because of high magnitude of residuals.

IRSC provides interactive environment where, in single session, several iterations of common shot, common receiver, or CMP offset-limited stacks are interpreted to estimate the best statics



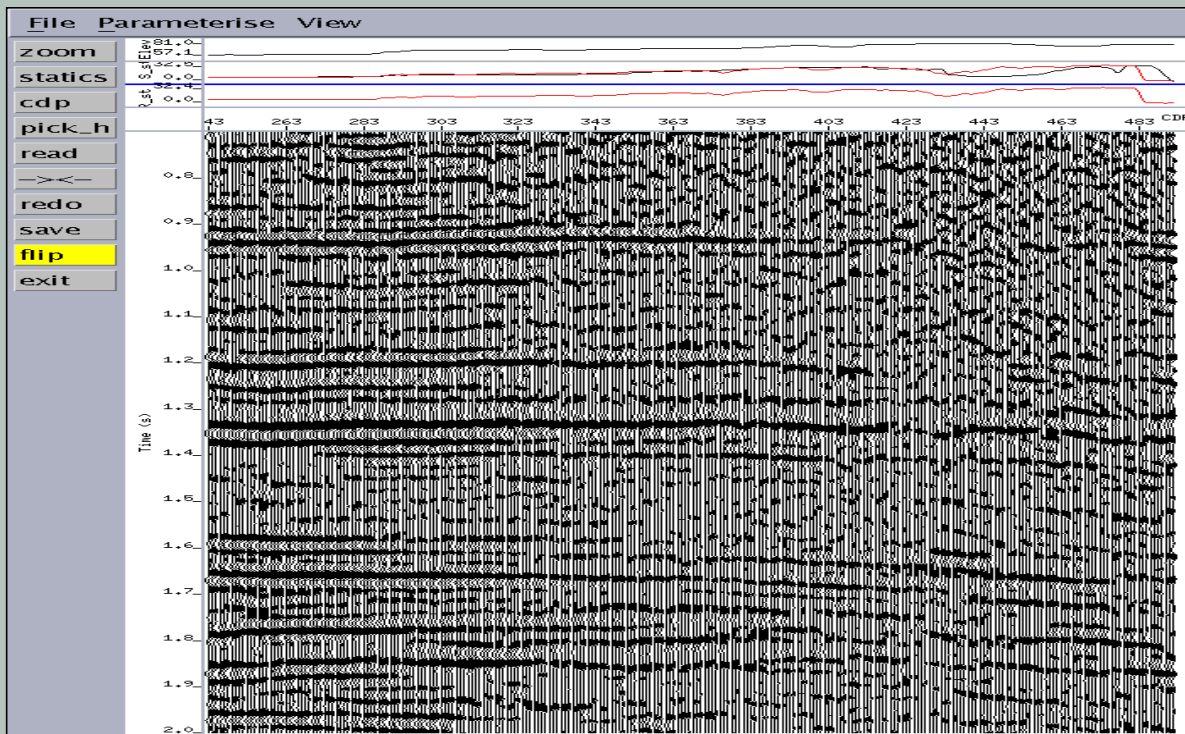
Horizon picking on Common Shot Stack and/or Common Receiver Stack.

Two interpretations of reference horizon: input and interpreter's guess are picked, and make input to estimation of correction.

Interactive Residual Static Correction (IRSC) - GT proprietary tool

IRSC is employed when automatic residual statics are ineffective because of high magnitude of residuals.

IRSC provides interactive environment where, in single session, several iterations of common shot, common receiver, or CMP offset-limited stacks are interpreted to estimate the best statics

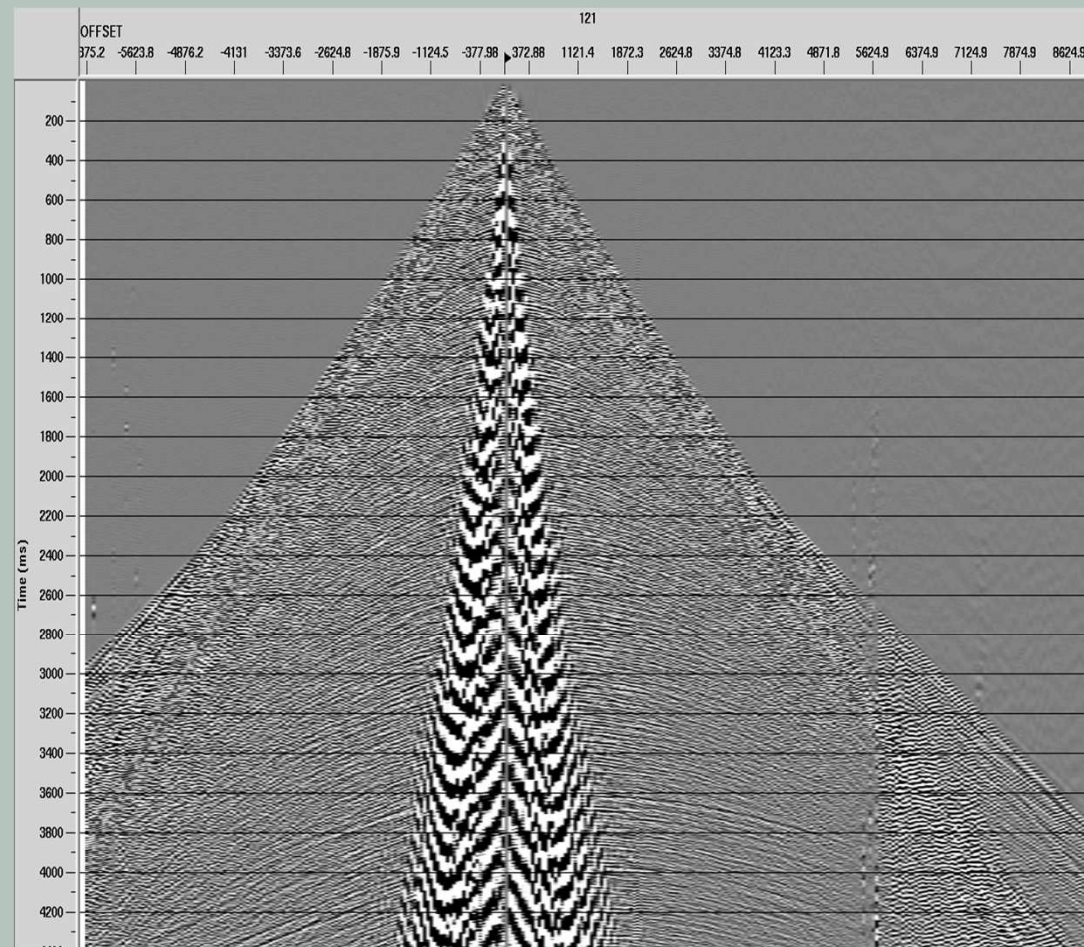


QC: CMP Stack after IRSC corrections.

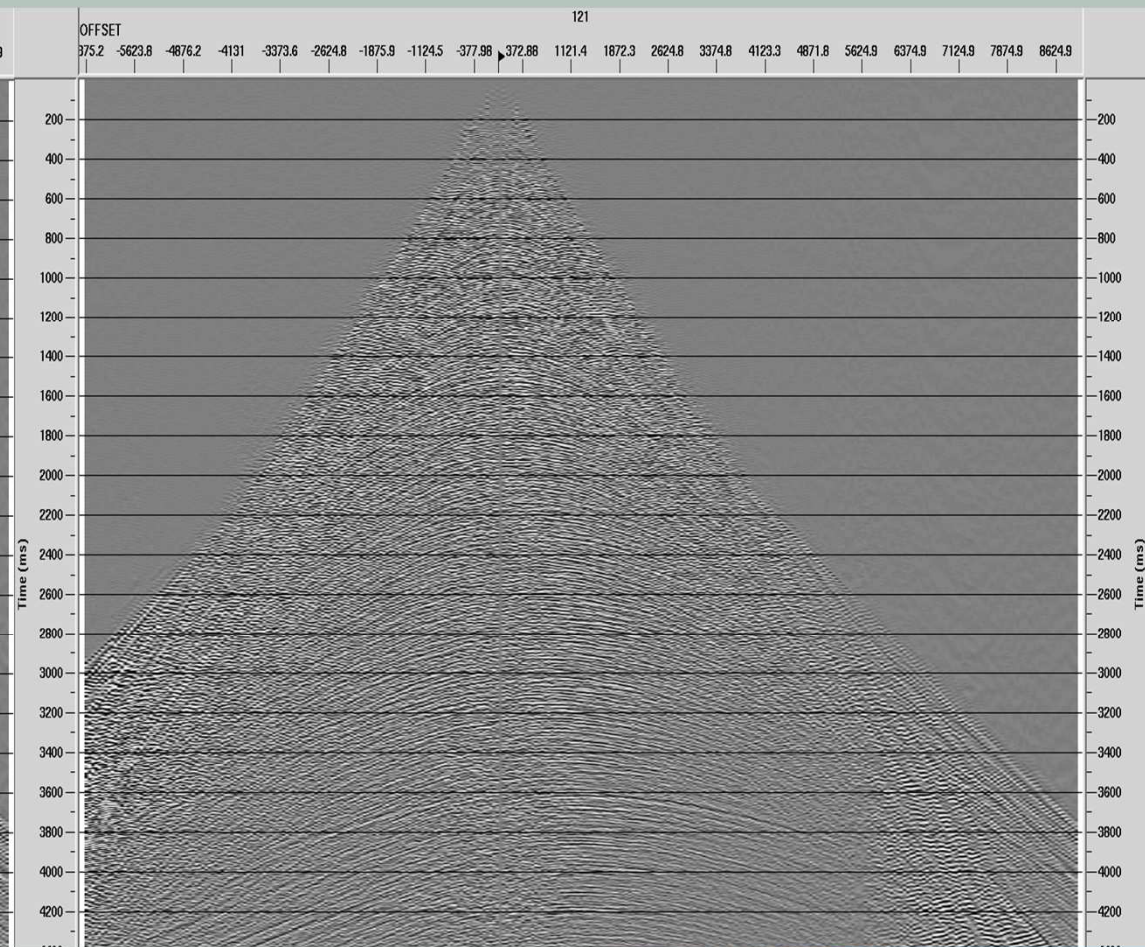
Static corrections are based on interactive examination of data in three domains: common source, common receiver, and common depth point.

Surface noise attenuation

Original shot record



After adaptive subtraction of modeled noise



Noise elimination

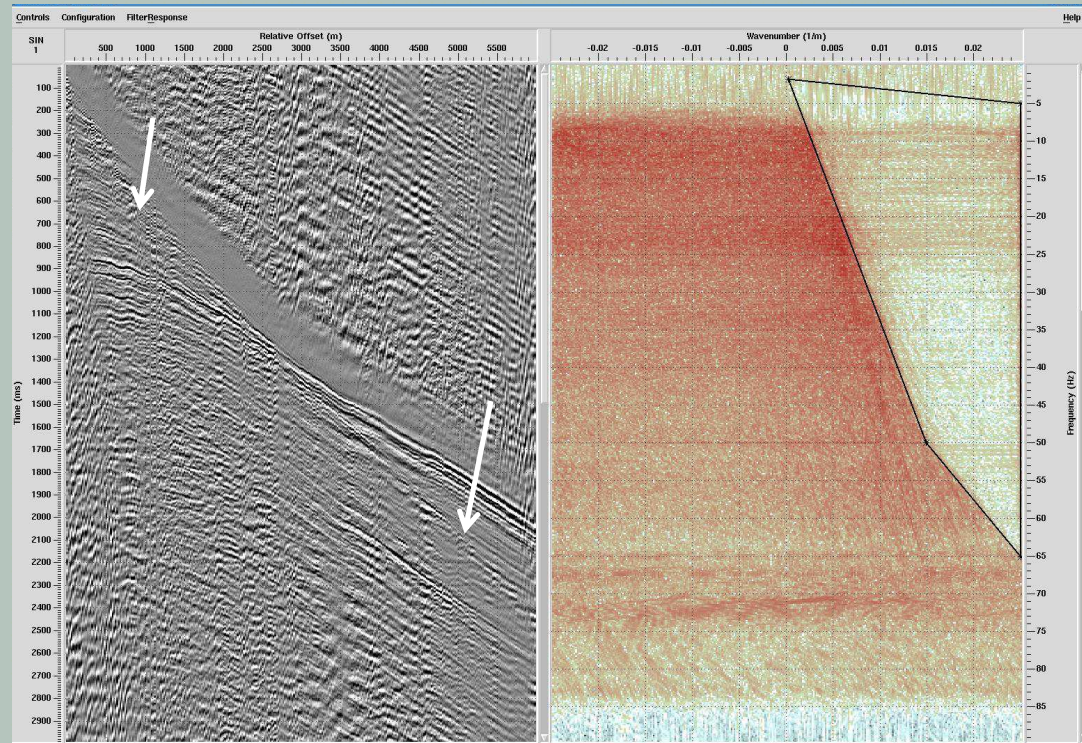
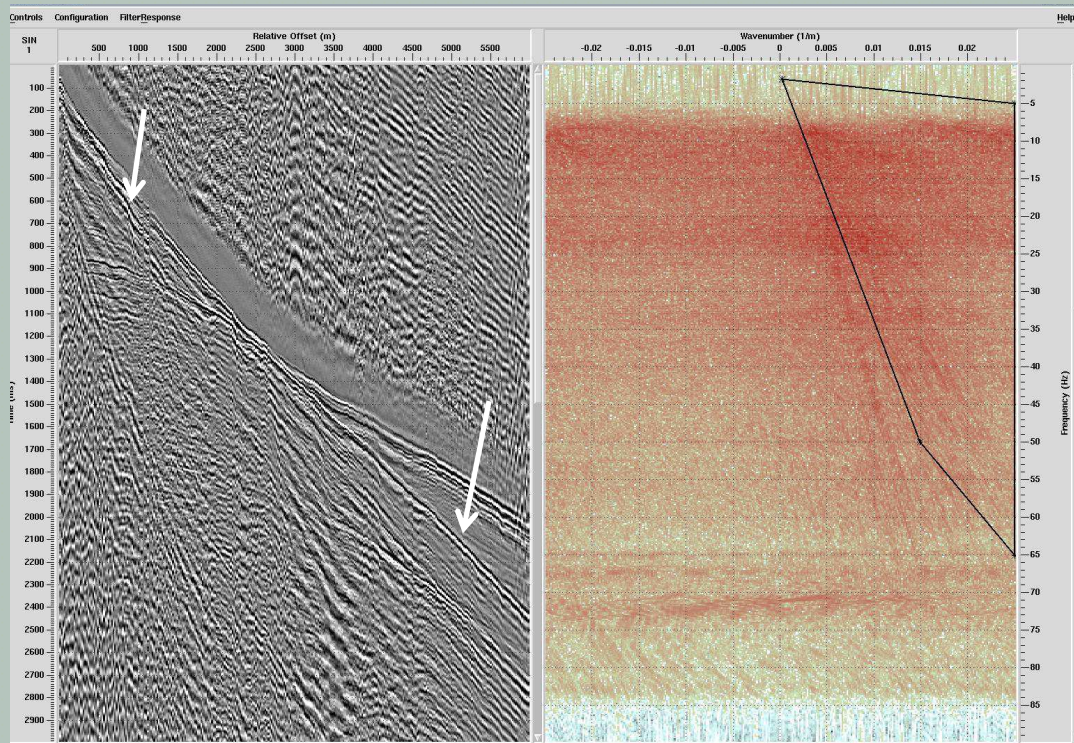
f-k

input data in x-t

input data in f-k

result in x-t

result in f-k

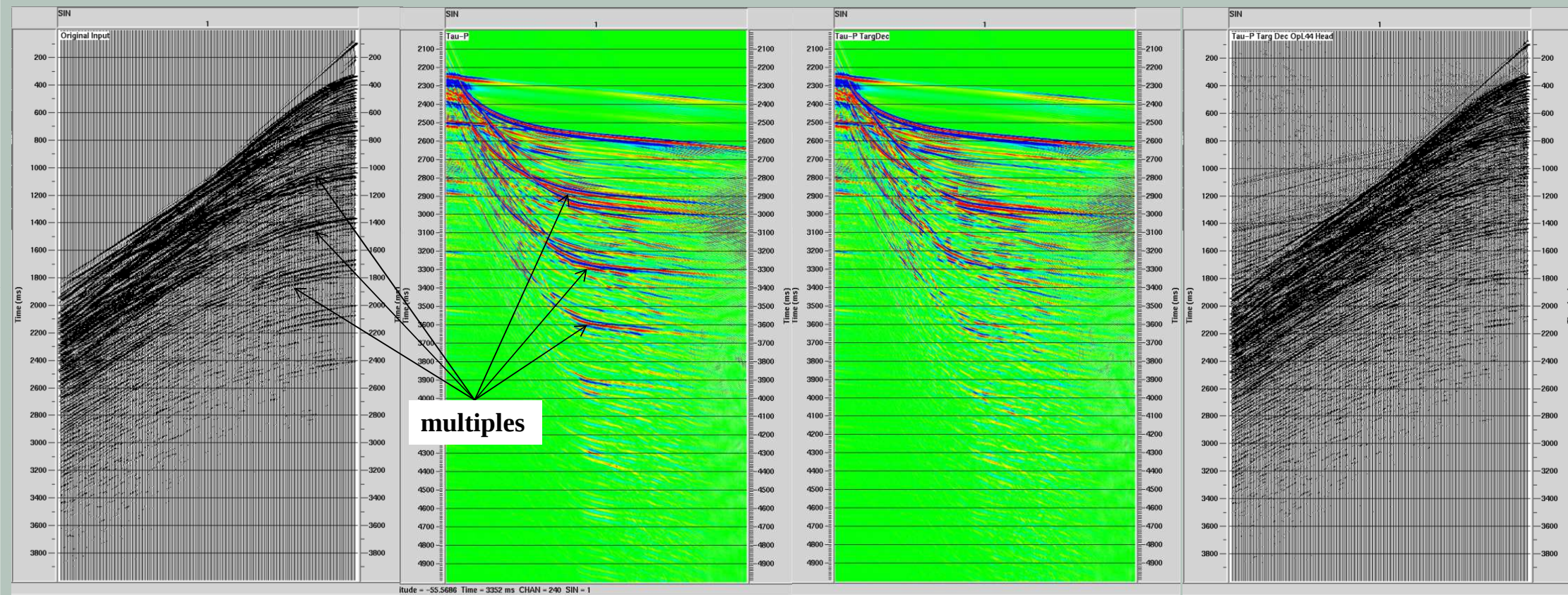


f-k filter is one of tools applied to remove unwanted noise. Spatial-variant application follows interactive design of f-k filter.

Noise elimination

$\tau - p$ or Radon

Application of the targeted predictive decon in τ -p domain

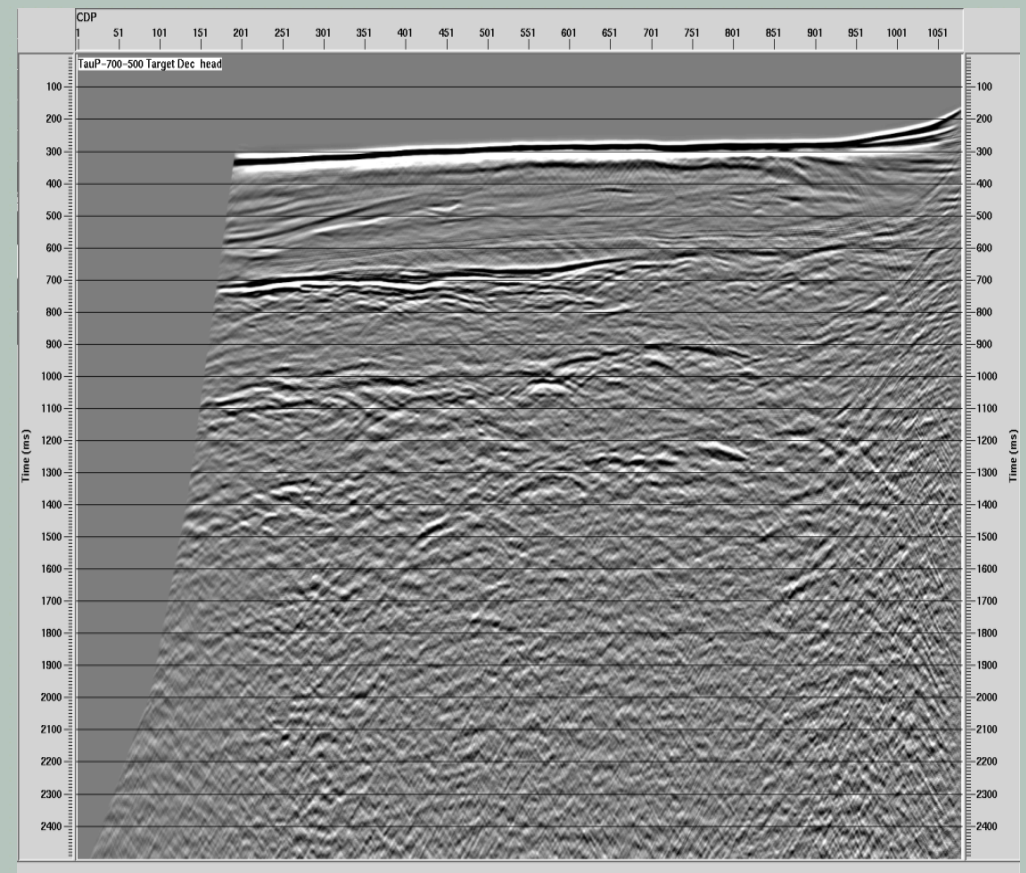
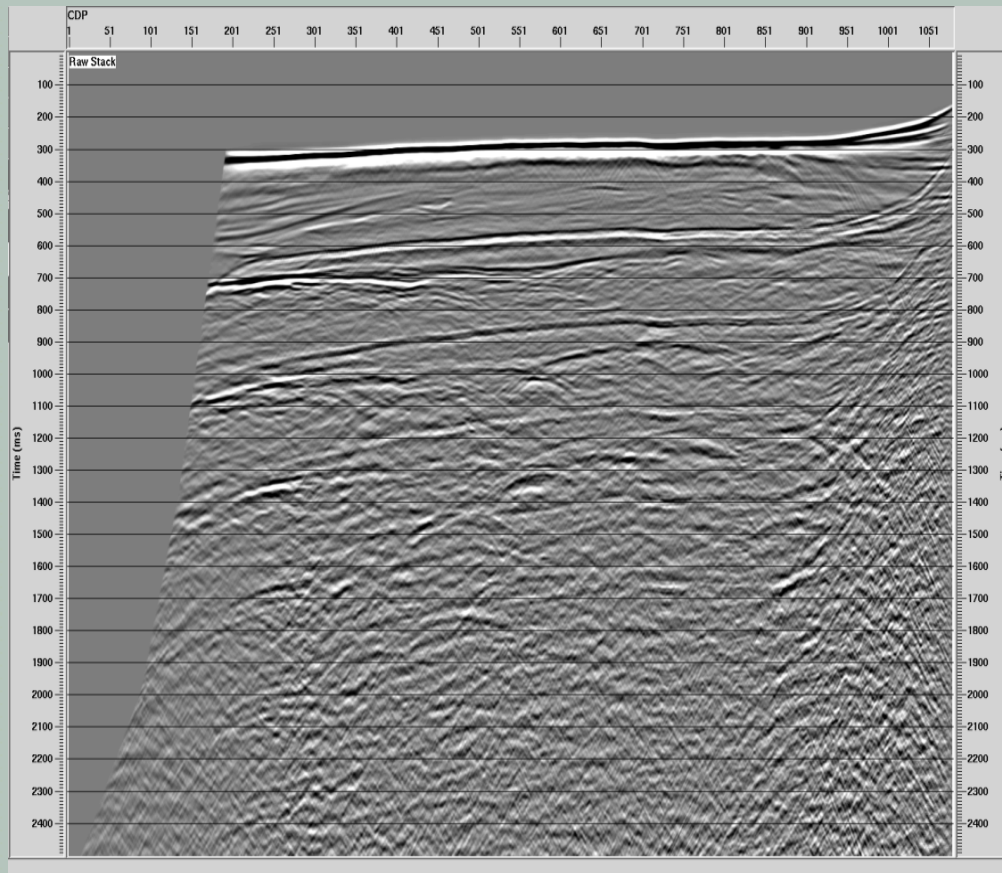


More transforms and noise elimination techniques are available: eigenvalue filtering (K-L), wavelet transform, frequency – domain filters. The Radon itself can be linear, parabolic, hyperbolic combined with HR.

Noise elimination

$\tau - p$ or Radon

Application of the targeted predictive decon in τ -p domain



Seismic Mistie Analysis for 2D Surveys

Multi-Line 2D

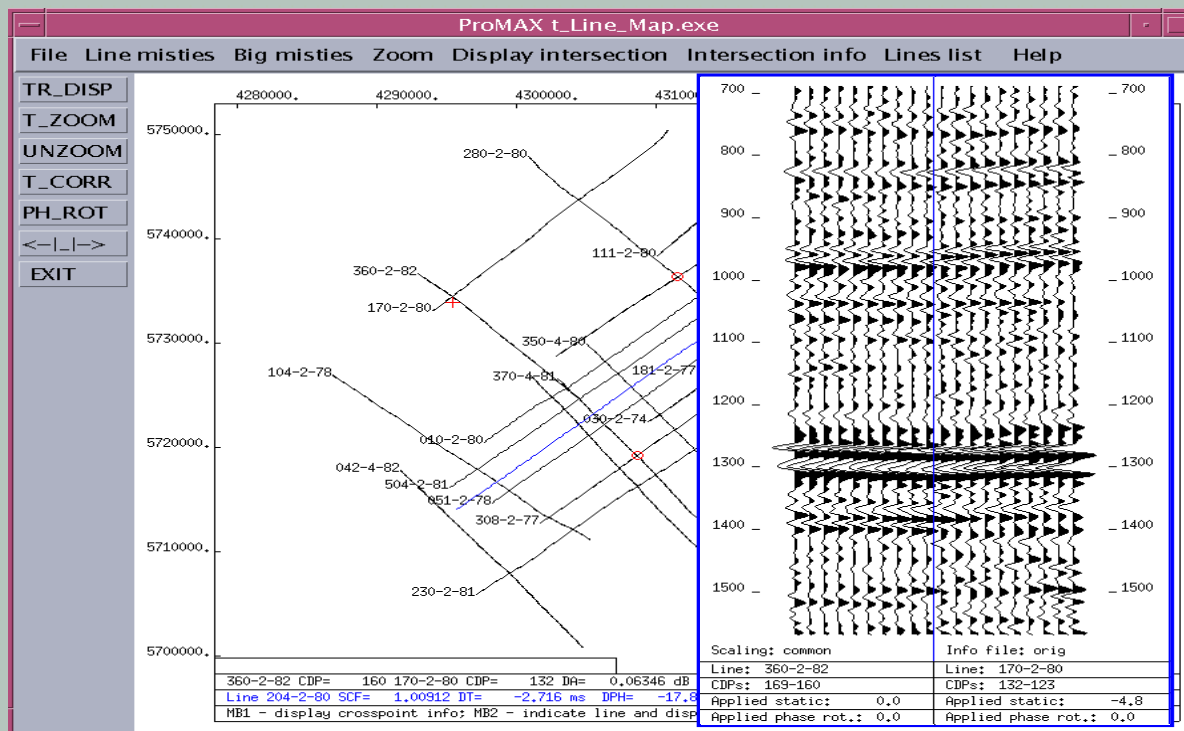
Phase/Time Mistie Modules:

- **Mistie Analysis**

- interactive stack extracted at a line intersection (time and phase manipulation)
- computes amplitude, time and phase mistie
- creates mistie file

- **Lines Map**

- basemap with intersections highlighted where mistie values exceed a specified limit
- misties for highlighted line

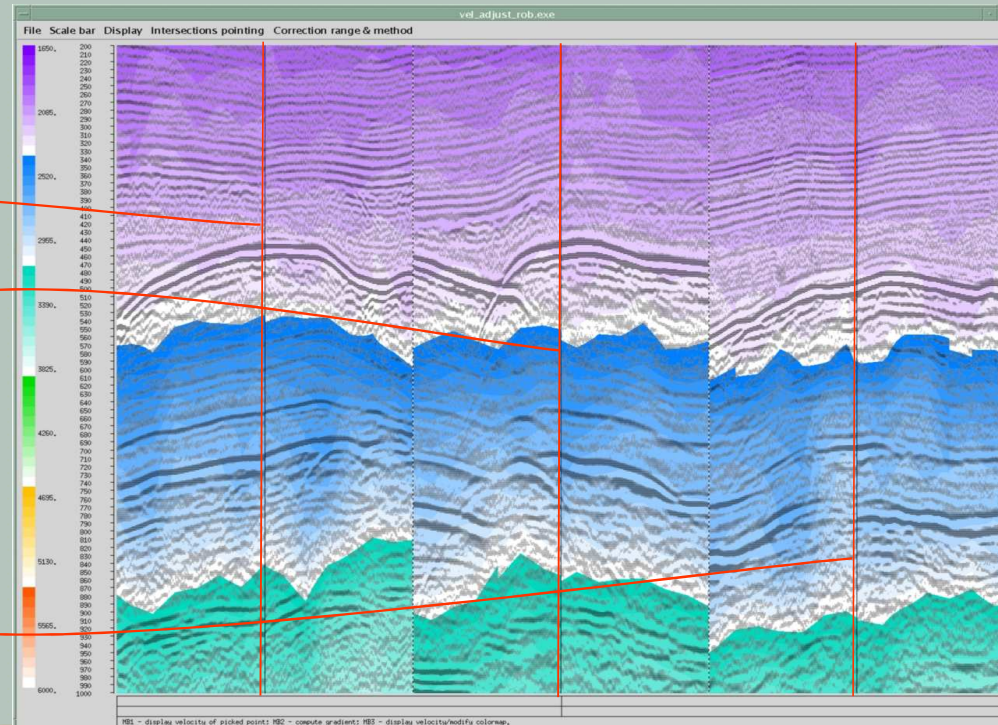
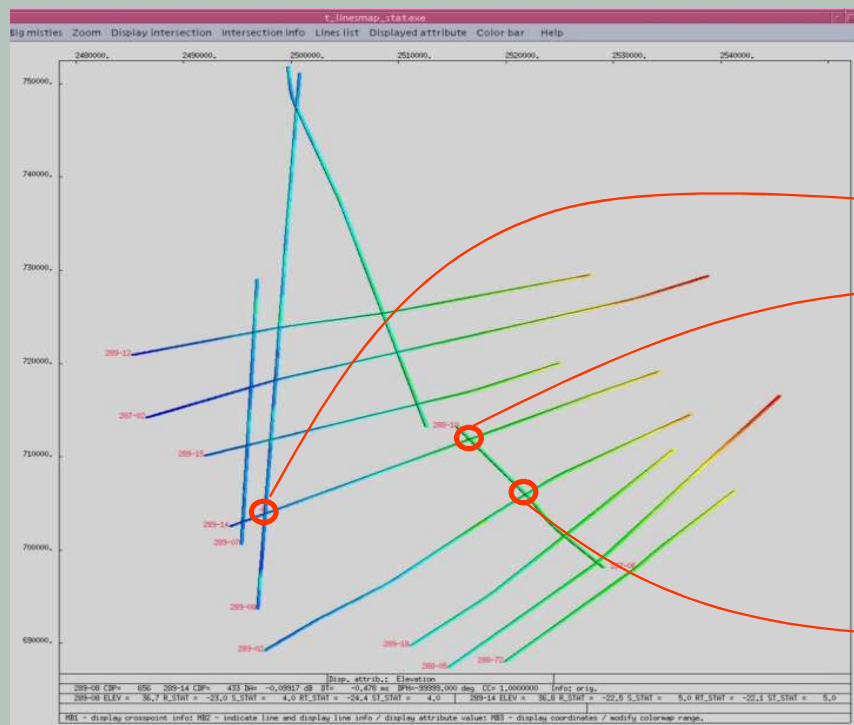


Velocity Mistie Analysis for 2D Surveys

Multi-Line 2D Interactive Velocity Editor :

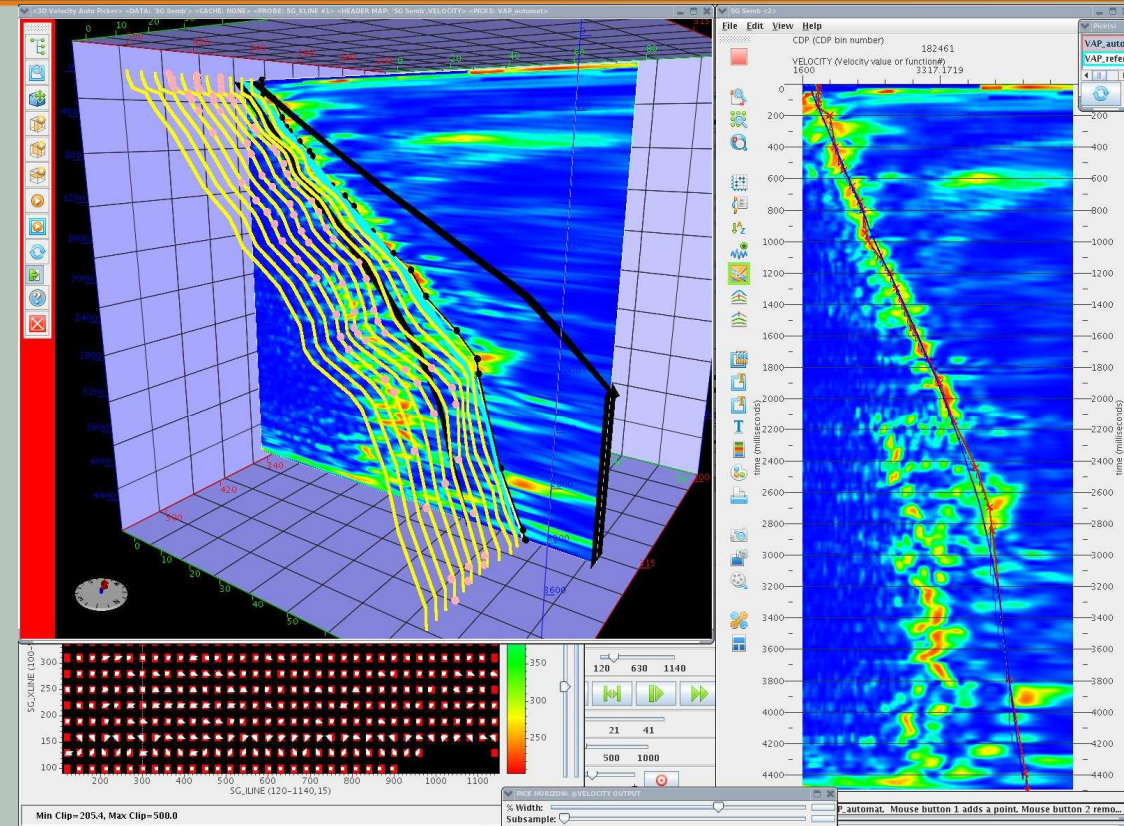
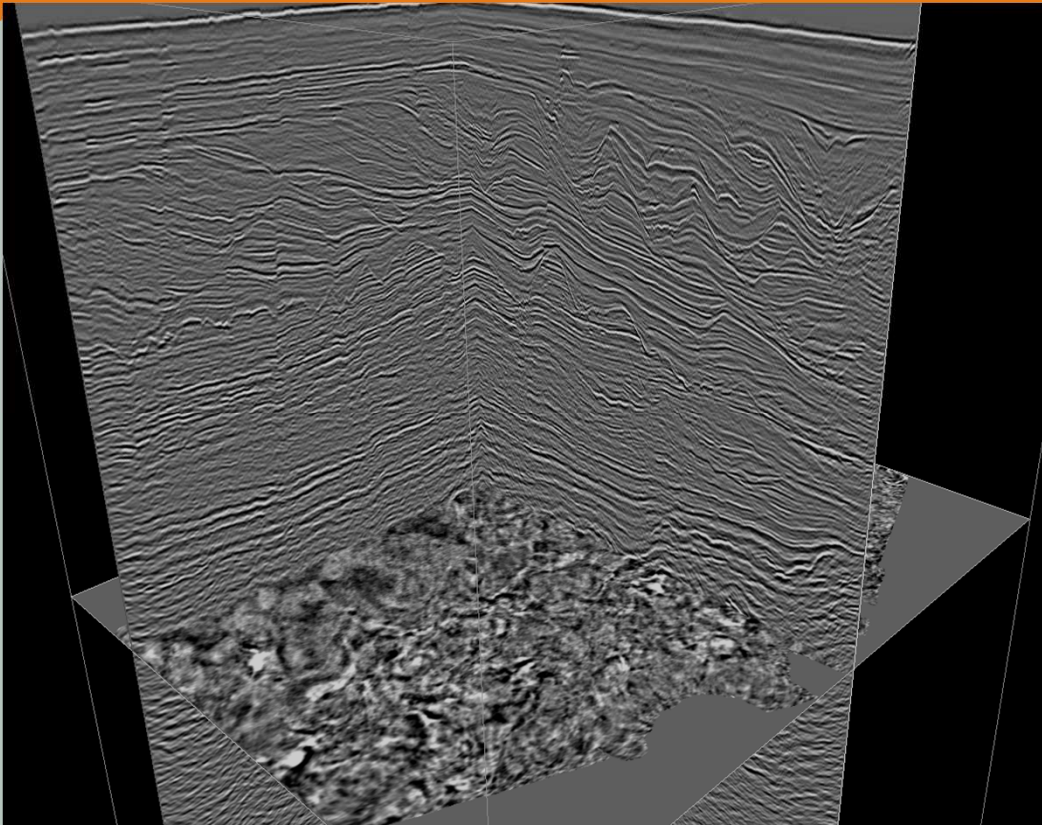
- QC and correction of misties,
- RMS or interval velocity handling,
- Complements GT 2D multi-line package.

GT ML software converts 2D sections into sparse 3D cube



seismic
with model

Short turnaround time for 3D / 2D surveys

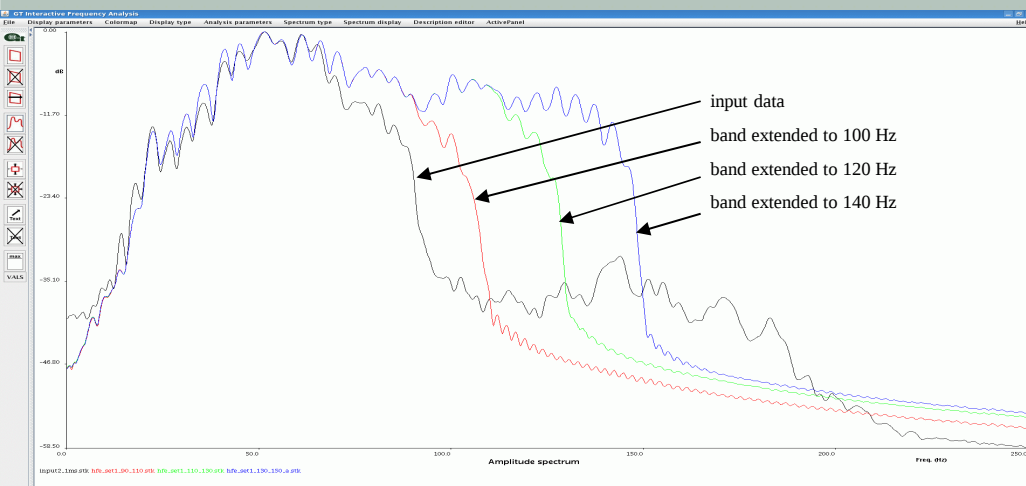


Short turnaround time for land 3D surveys is possible with a suite of dedicated solutions:

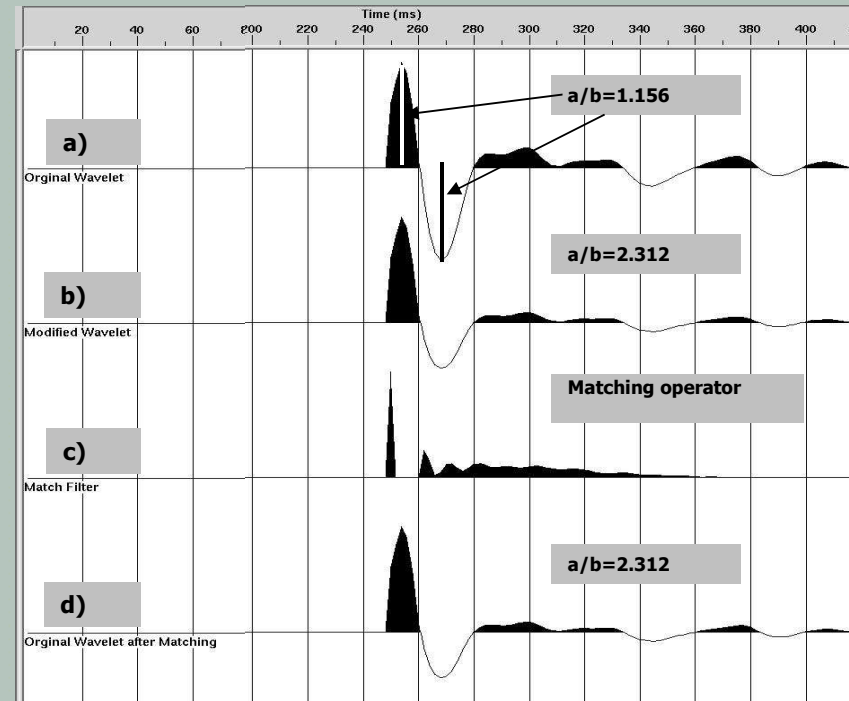
- multi-CPU software
- semi-automatic trace edit and FB picking
- latest-generation model builders in time or depth
- large disc space for disc-to-disc processing
- automatic-plus-correction velocity picking
- efficient 3D interactive QC

Increasing vertical resolution of seismic – IWS solution - GT

IWS – GT solution, where two key methods are combined to improve quality of stack



Extension of HF (high frequency) side – with harmonics



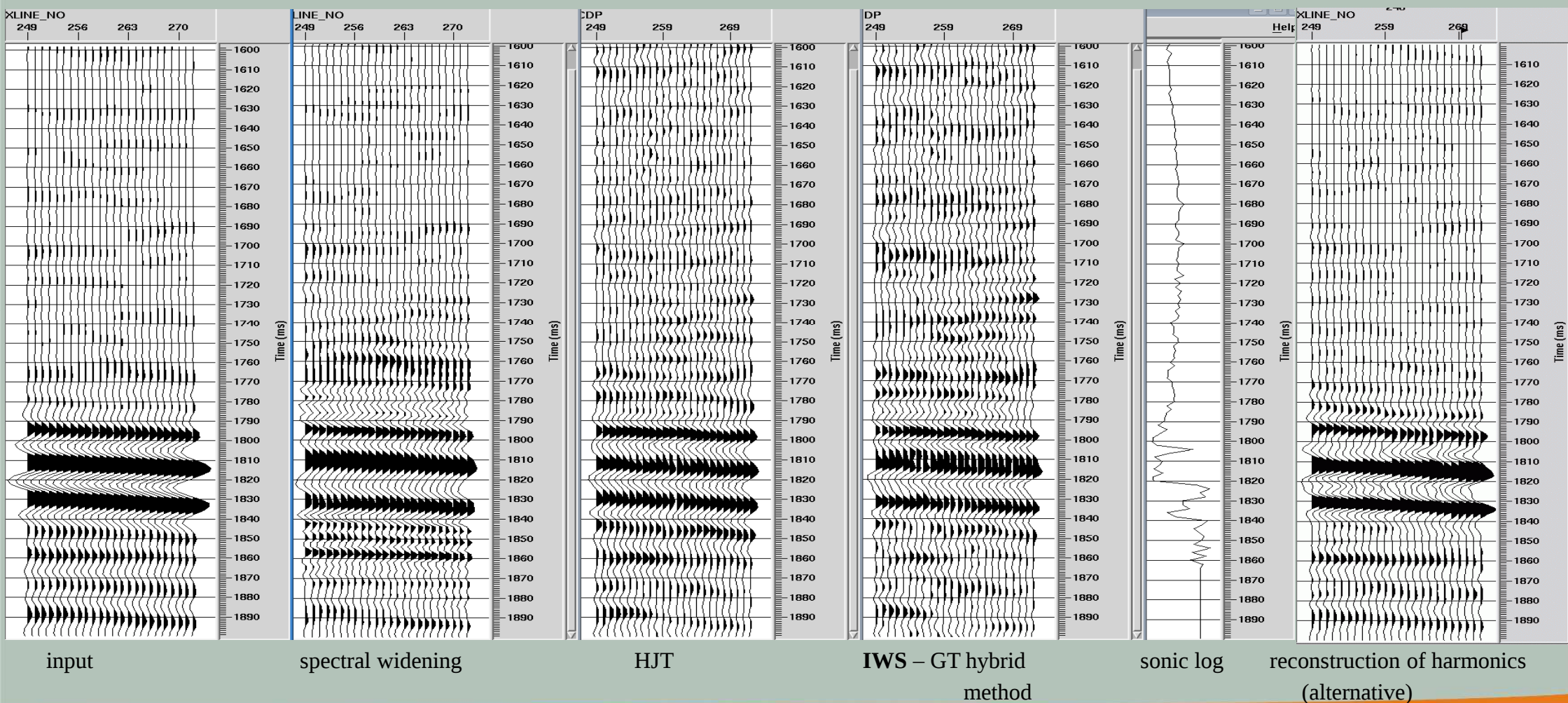
Shaping wavelet:

- a) initial;
- b) modeling;
- c) matching operator;
- d) Shaped wavelet

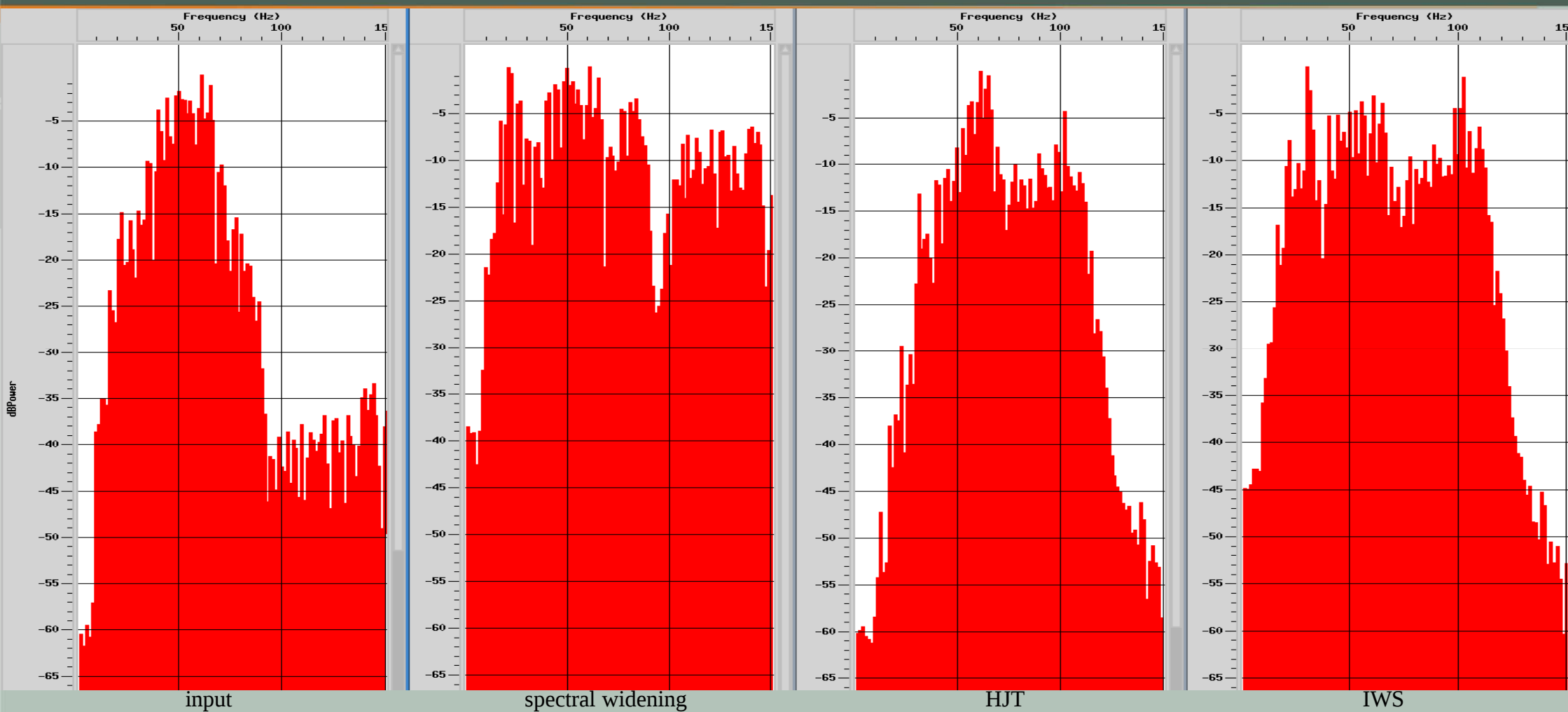
Extension of LF (Low Frequency) side – GT solution

Parameters of IWS procedure, and limits of band extension, are estimated from tests

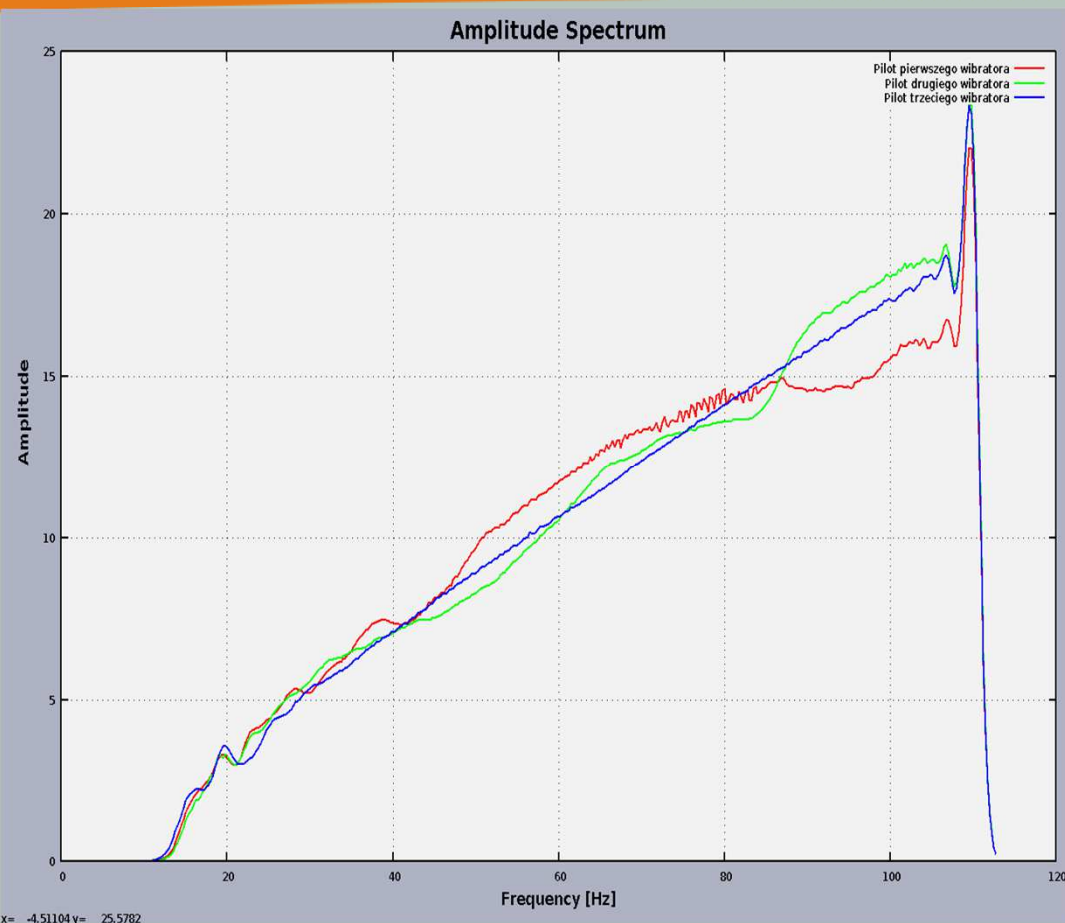
IWS – Interactive Wavelet Shaping – GT hybrid method



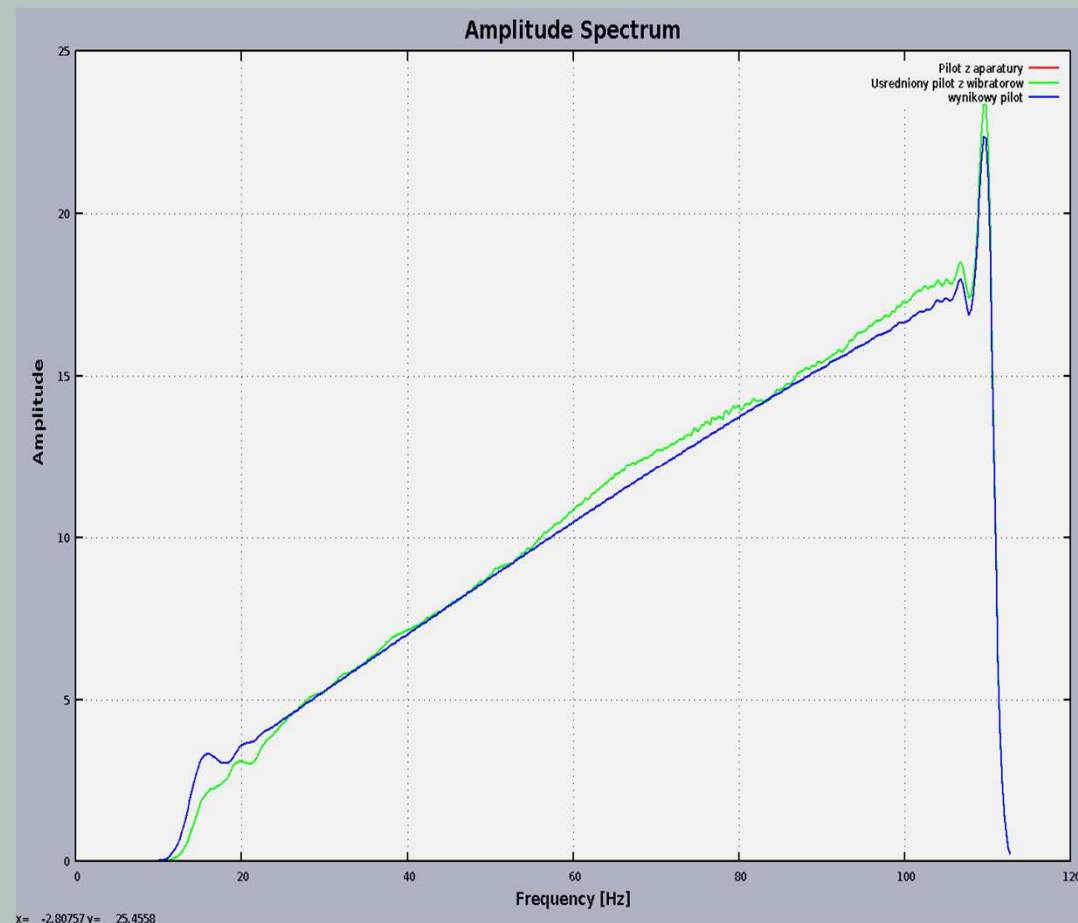
IWS method compared to alternatives



Harmonizing field vib data



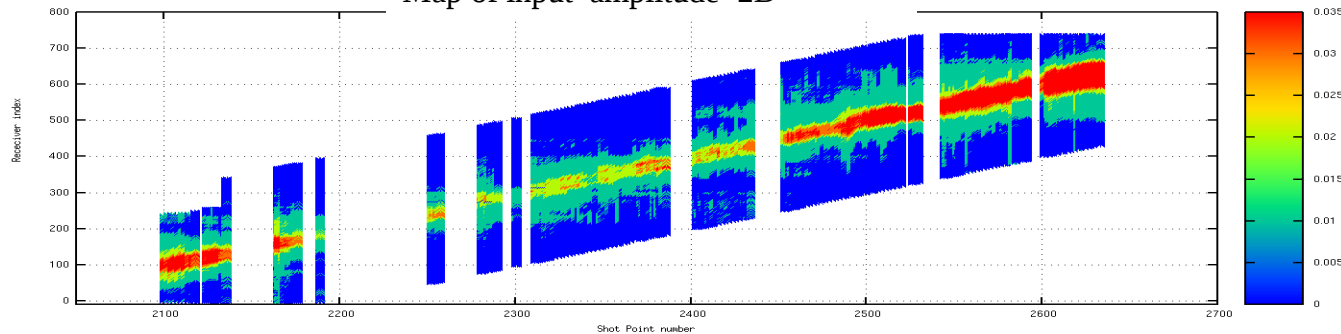
Signals of individual vibs of a group



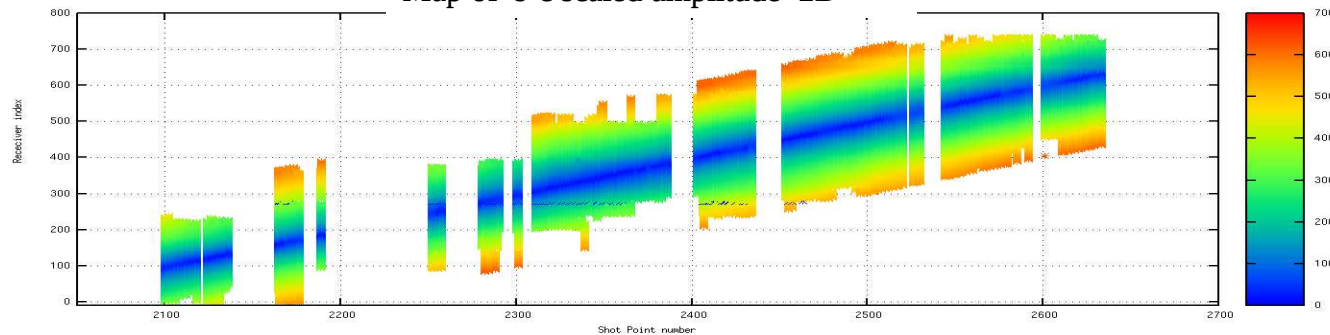
Pilot, average of three vibs, and corrected signal

Reconstruction of amplitude relations

Map of input amplitude 2D



Map of s-c scaled amplitude 2D

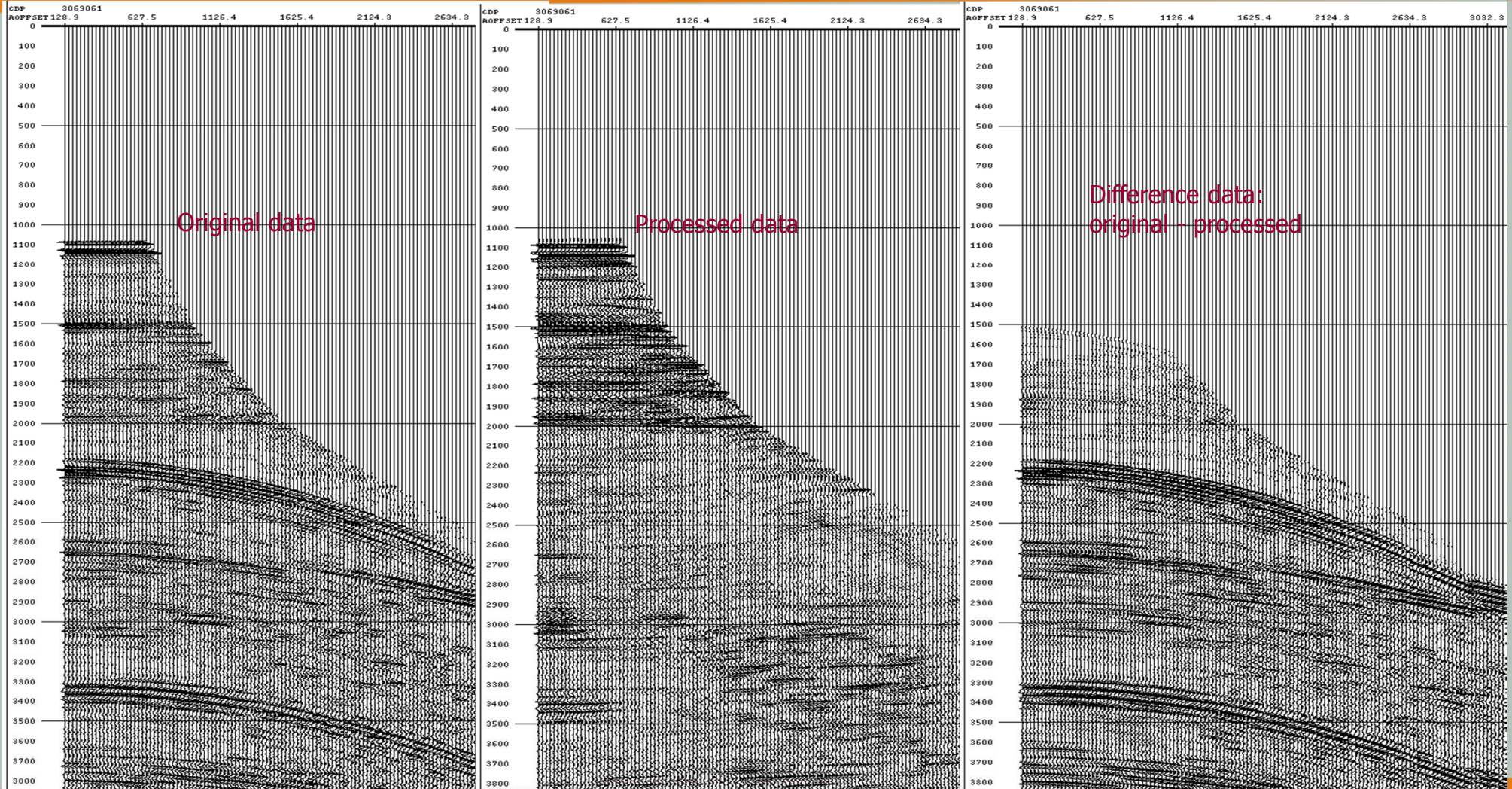


- spherical divergence correction
- anelastic attenuation correction
- emission angle correction for source
- s-c scaling at selected stages
- reference wavelet in some cases
- generating synthetics to identify tuning
- synthetic AVO gathers as reference
- CMP-consistent shadows correction

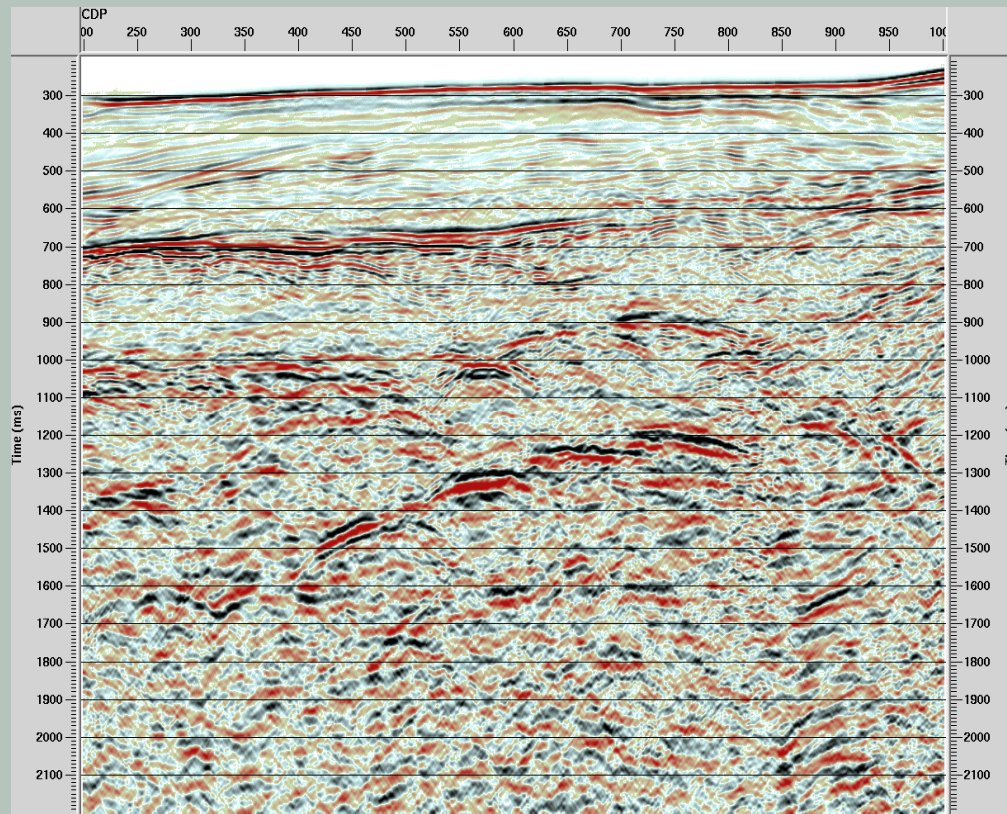
Processing marine seismic data

- | | |
|------------------------------------|---|
| Source signature | - set of tools dedicated to wavelet processing. Source signature is preferred in deterministic option with provided impulse response, but other options are also possible |
| Noise removal | <div>{</div> <div><ul style="list-style-type: none">- any type of noise, coherent or random, can be removed with minimum harm to primaries- up to 10 types of noise, if identified and modeled can be adaptatively subtracted in one pass</div> |
| Attenuation of multiples | - Several state-of-the-art techniques, or their hybrides, are available, including 3D prestack |
| Data regularization | - 5D prestack tool for 3D data, as well as GT solutions for 2D data |
| Automatic velocity analyses | - efficient, fast 3D / 2D technique plus QC and editing with interactive 3D composite display |

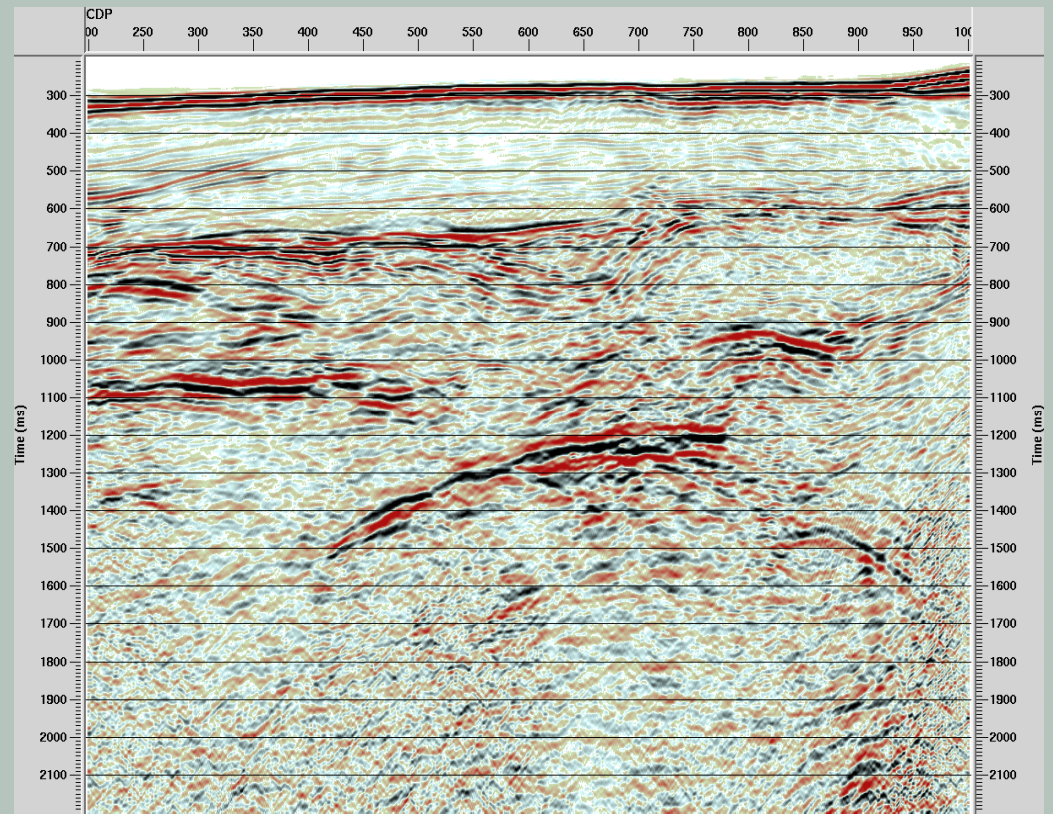
Multiple attenuation – decon in τ -p



Multiples attenuation - waterbottom



Waterbottom multiples



attenuated with Radon velocity filter

Comprehensive QC throughout processing



ToolBoxP v. 2013

Wavelet processing QC

S/N Ratio, coh.,
Phase rotation

Matching to well data

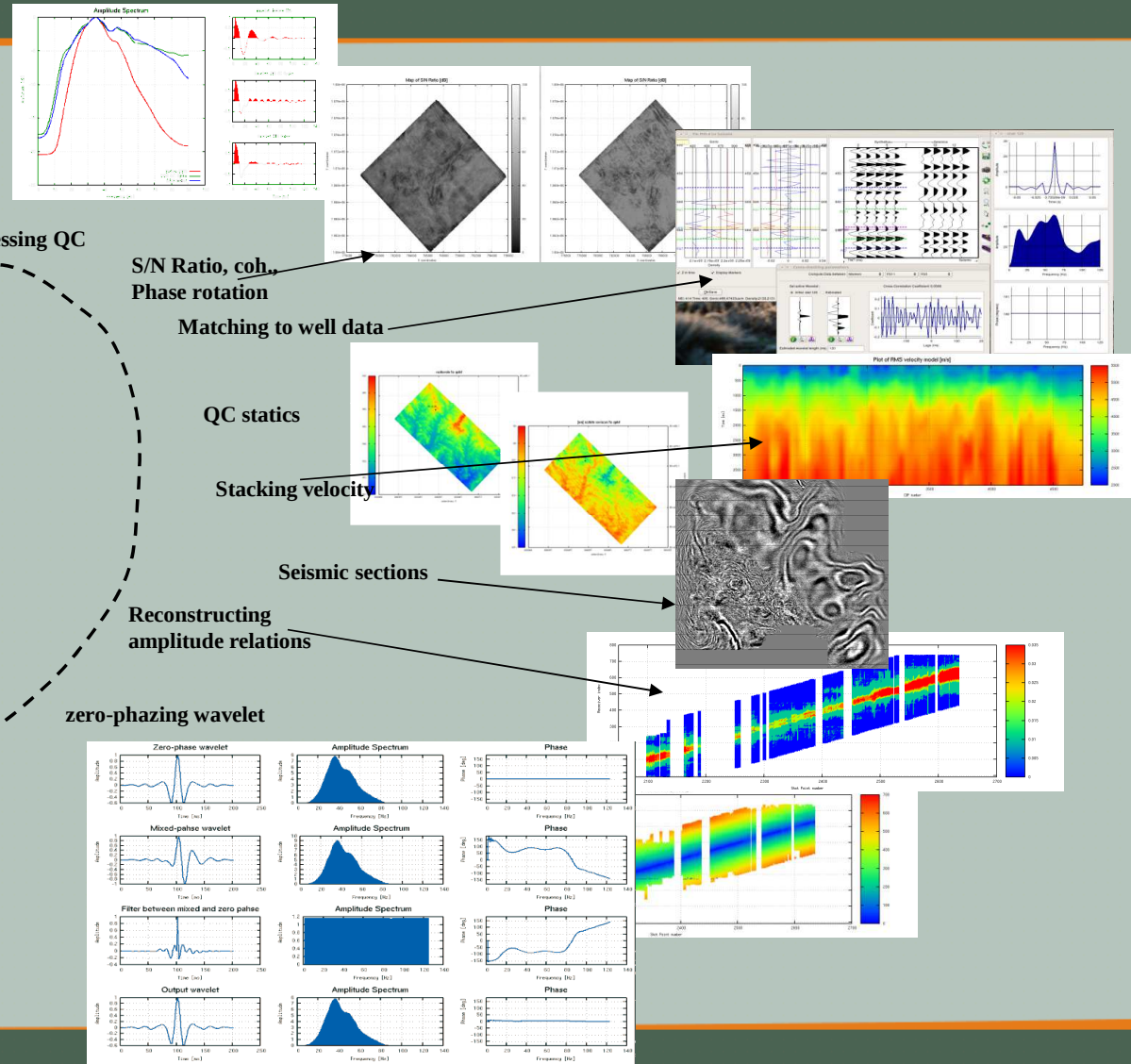
QC statics

Stacking velocity

Seismic sections

Reconstructing
amplitude relations

zero-phasing wavelet



Processing issues specific to 3C

1. **Correct for irregular orientation of receivers, both vertical and horizontal,**
2. **First process P-wave component, and identify events,**
3. **Estimate and correct for horizontal anisotropy if present,**
4. **Use modeling to guide processing (synthetic CCP gathers),**
5. **Guide receiver statics with smooth uphole Vp/Vs and P-wave statics,**
6. **Early ACP binning. Surface-consistency is valid till CCP binning,**
7. **Pre-process near offsets of horizontal components:**
two-component decon, two-component amplitude s-c scaling,
8. **Estimate initial Vp/Vs,**
9. **Run near offset full processing,**
10. **Run η analysis for full offset range,**
11. **Run C-wave DMO or C-wave PreSTM,**
12. **Final Vp/Vs analysis,**
13. **CCP stack,**
14. **Post-stack processing. C-wave PoSTM if DMO was applied.**

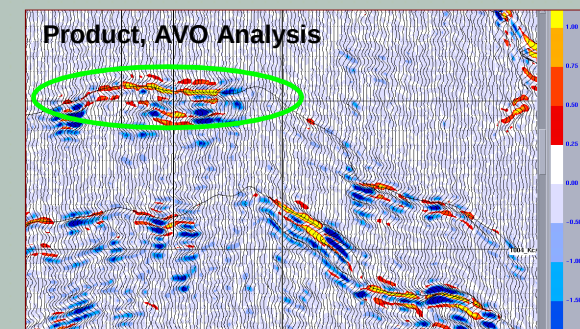
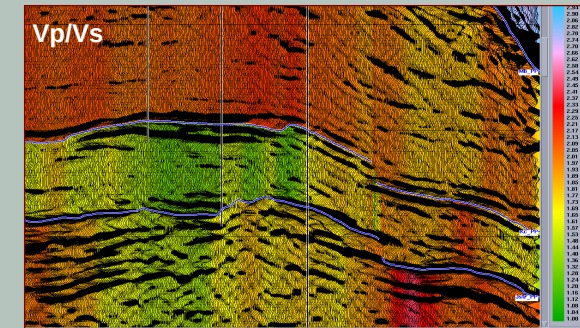
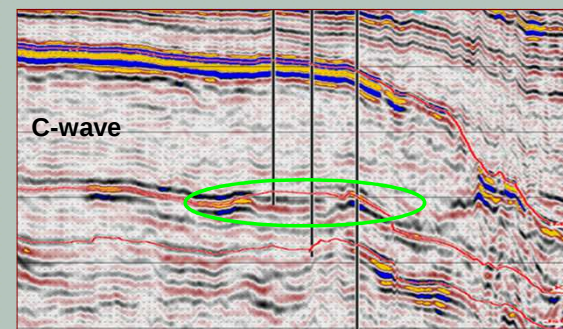
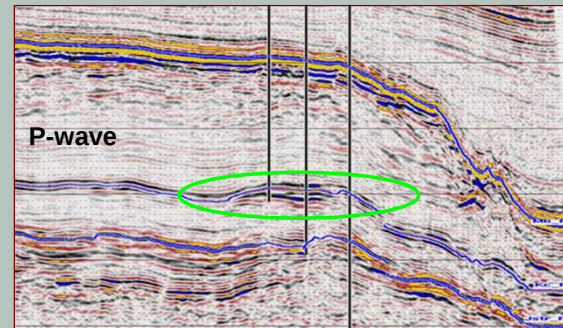
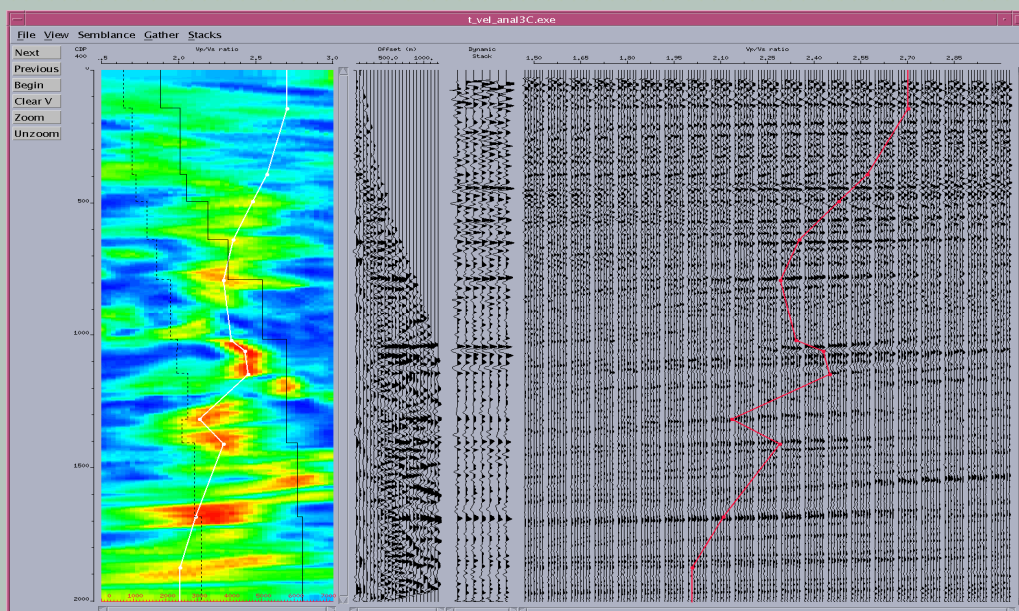
C-wave seismic data processing

GT proprietary:

- Interactive Vp/Vs analysis
- C-wave Velocity Manipulation

C-wave workflow based on ProMAX + GT modules

Some 14 processes specific to C-waves



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experience

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