Brief information about the company

- **Tesseral Technologies Inc.** founded in Canada (Calgary) in 1997 and since 2009 it is part of the TETRALE Group, a holding company of Tesseral Technologies and TetraSeis.
- The main office is located in Calgary, Canada - where software development, maintenance and support, consulting and services are carried out.
- Tesseral Technologies Inc. is a leader in full-wave modeling.
- For 20 years already hundreds of geophysicists in more than thirty countries of the world have been using Tesseral software products (www.tesseral-geo.com)

The Company Products

- Full 2D-2.5D-3D modeling of surface and borehole seismograms
- Ray 2D and 3D modeling
- Survey systems design
- Modeling of passive sources and seismic responses during hydraulic fracturing

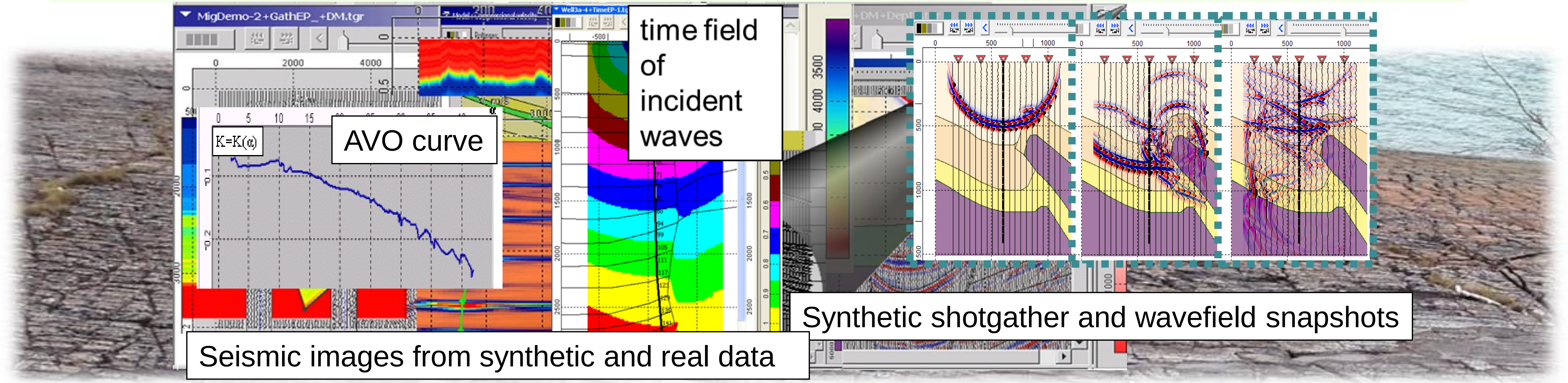
What you can do with the Seismic Modeling

With *Full-wave modeling* you can produce synthetic gathers, snapshots and time sections for different kinds of wave equation approximations, sources, wavelets, etc taking into account :

- ➢ Rough topography, various near-surface conditions, surface waves, refractions, etc
- ➢ Thin-layered models that are build on the basis of well-log data
- ➢ Complex anisotropy : transversally isotropic media and fracturing systems
- ➢ Porous fluid-saturated media (Gasman approximation)
- ➢ Q-factor modeling (viscoelastic) in Frequency band Insencitive approximation

Also, basing on *Full-wave and Ray-tracing modeling* may be done:

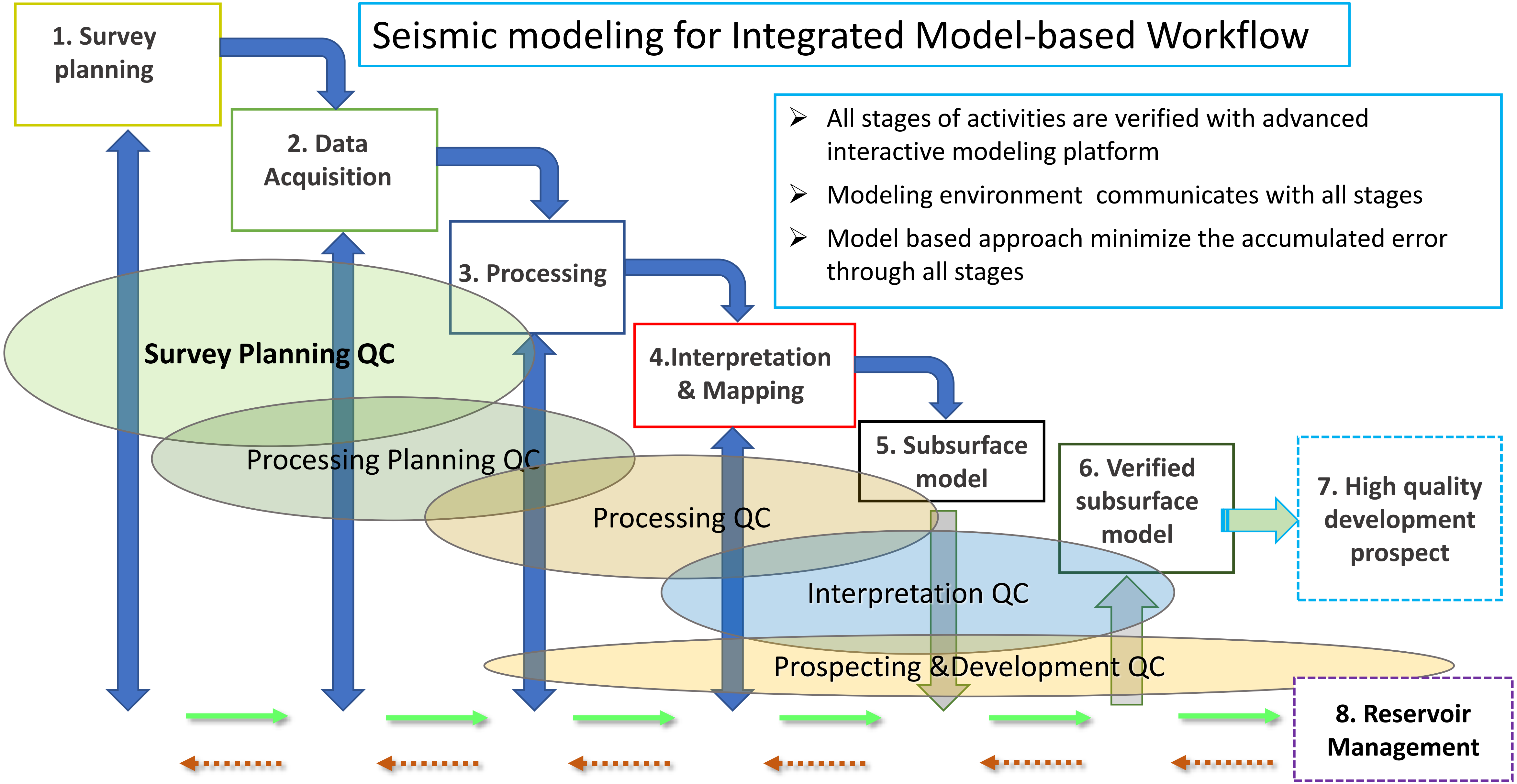
- ✓ Building of velocity model by seismic data
- ✓ Seismic Imaging : post-stack, pre-stack depth and time migrations for surface and VSP.
- ✓ AVO-modeling (Tesseral 2D) for anisotropic, porous, fluid-saturated, viscoelastic, thin-layered media.



Our Technologies: Tesseral Modeling

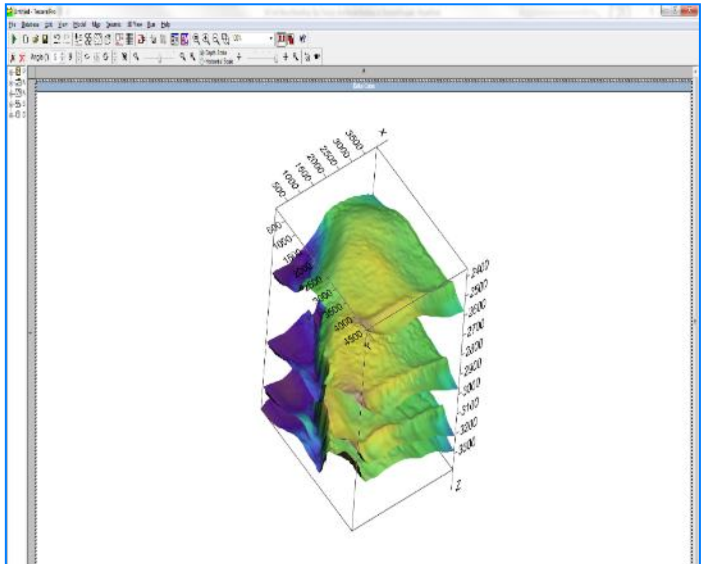
Seismic modeling for Integrated Model-based Workflow

- All stages of activities are verified with advanced interactive modeling platform
- Modeling environment communicates with all stages
- Model based approach minimize the accumulated error through all stages

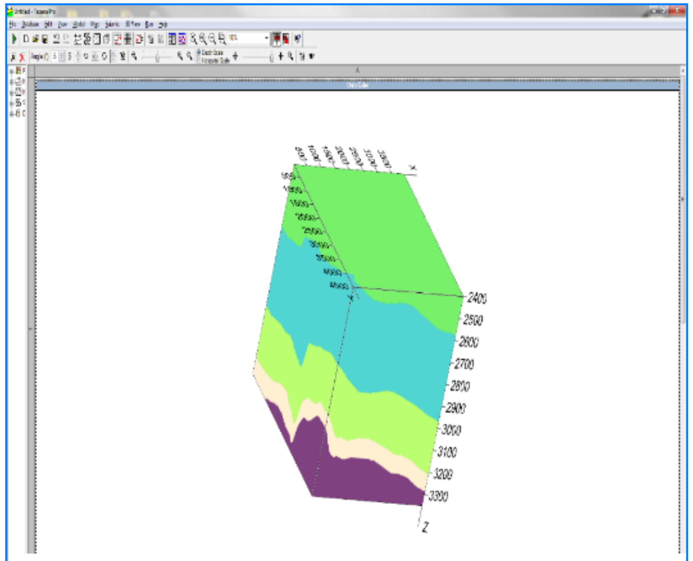


Building of depth-velocity model

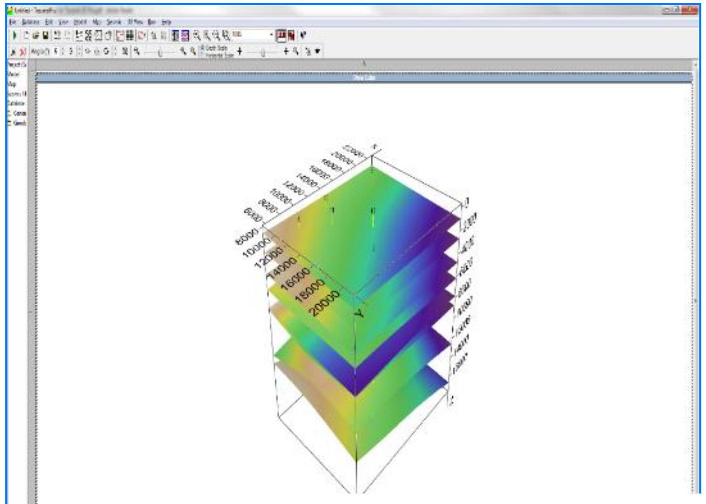
- The model can be created manually (SIMPLE model)
- From seismic files (cubes of velocities, anisotropy, quality parameters);
- By the aggregate of depth maps and isochron maps;
- Based on stratigraphic ties input into the project database; From LAS files;
- From SPS files;
- From the drawings of the models;
- Text files, etc.



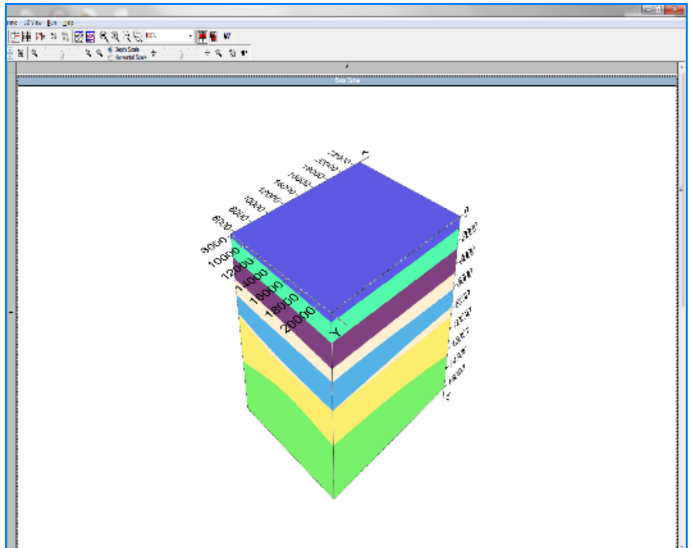
Structural surfaces in 3D imaging



Generated 3D Depth velocity model

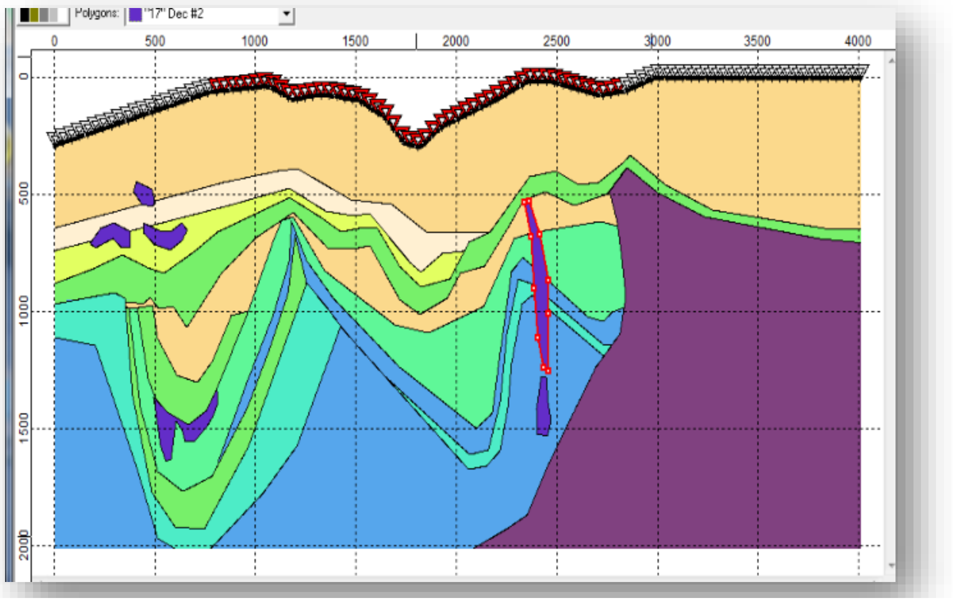


Creating a surface by spline approximation

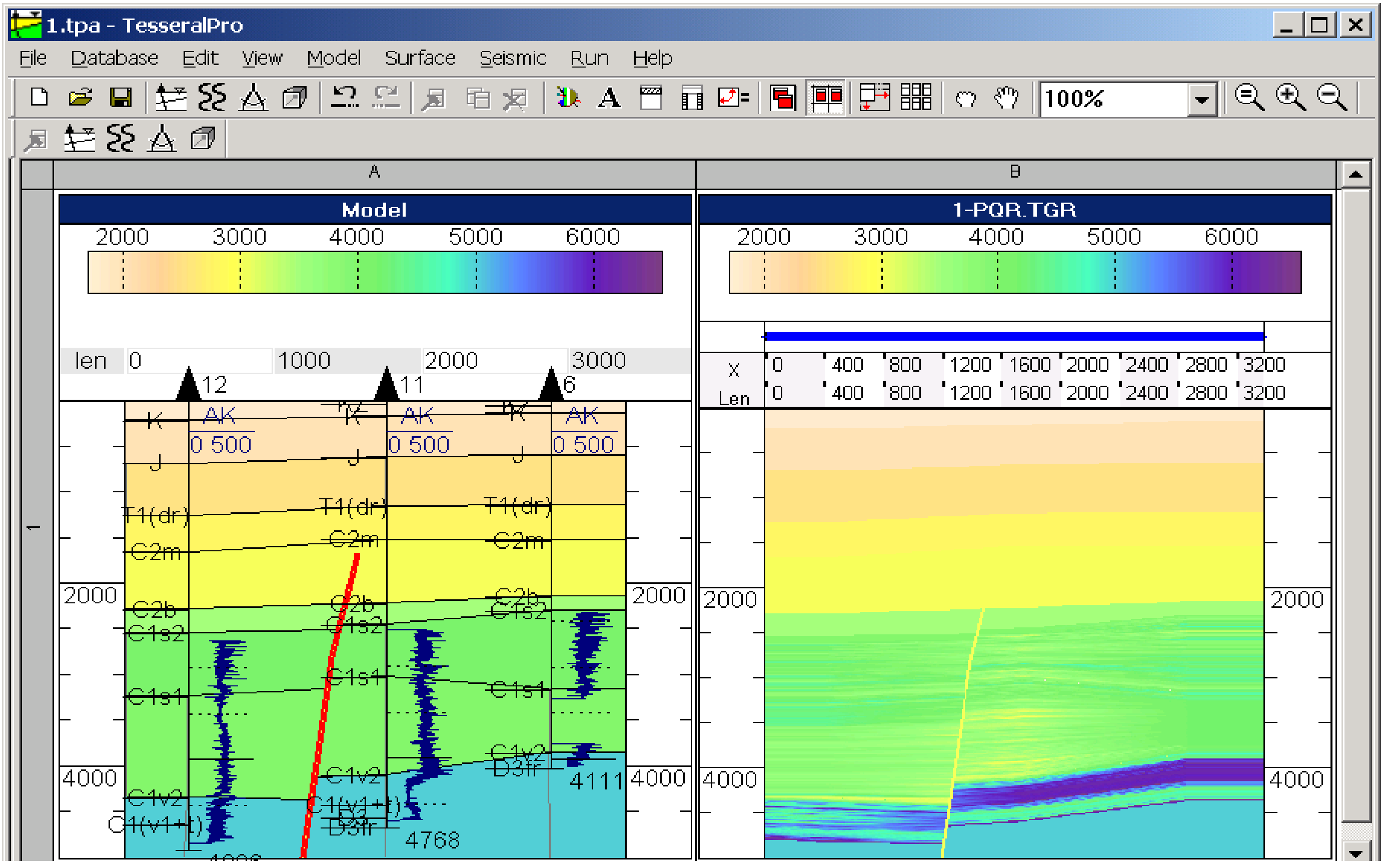


Generated velocities cube

Building the model manually



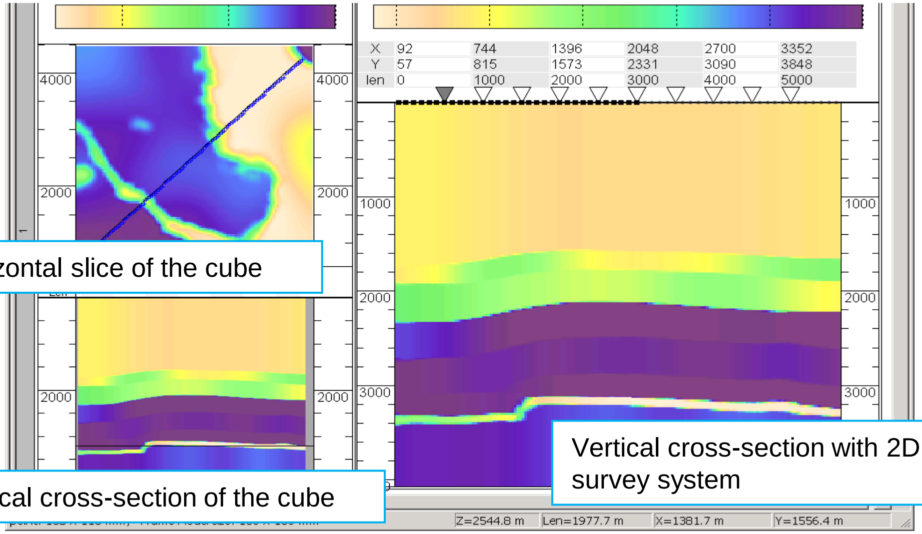
Thin-layered model with a fault, built according to the stratigraphic ties and well data



Cross-well correlation

Thin-layered model

The velocity cube in SEGY format can be used as a model

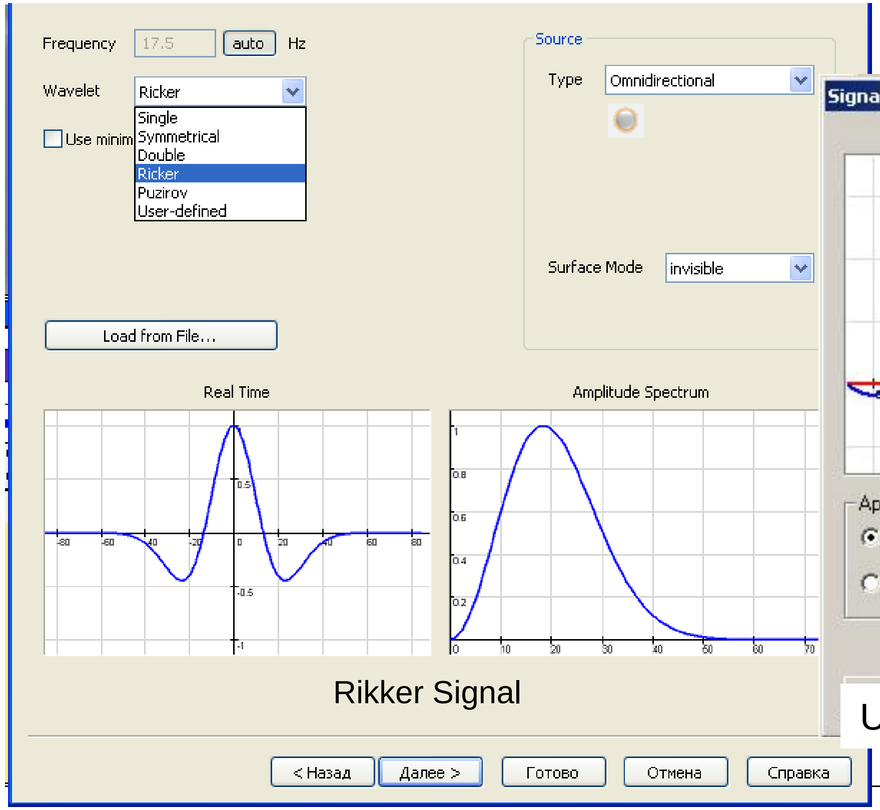


Horizontal slice of the cube

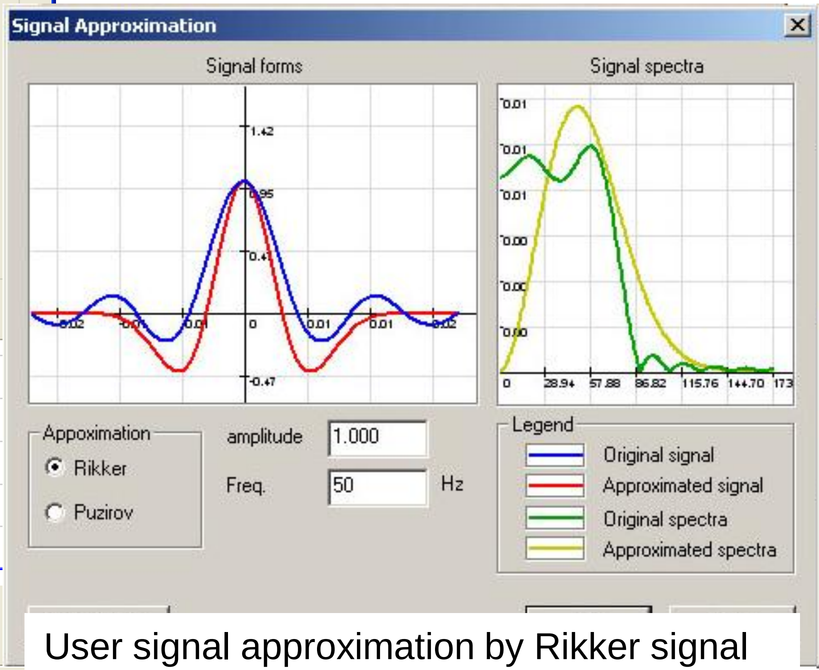
Vertical cross-section of the cube

Vertical cross-section with 2D survey system

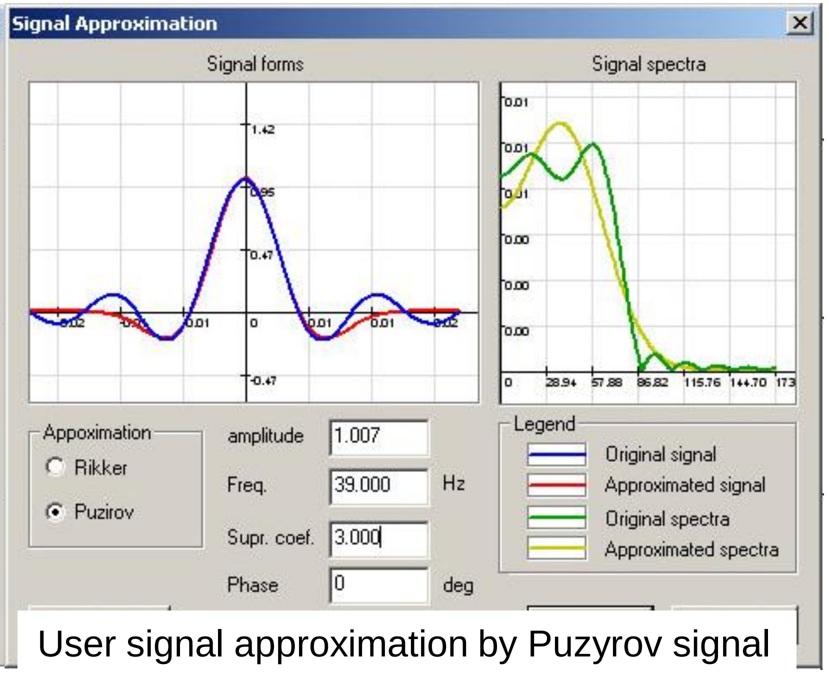
Signal for modeling



Rikker Signal



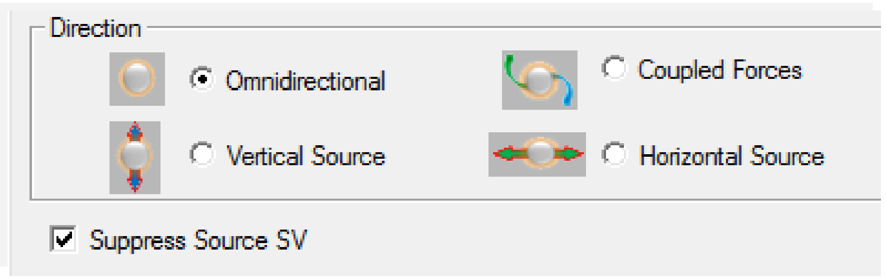
User signal approximation by Rikker signal



User signal approximation by Puzyrov signal

Various signals can be used for simulation. The main are the signals of Puzyrov, Rikker, the original signal of the user, which also can be approximated by the Rikker or Puzyrov signal

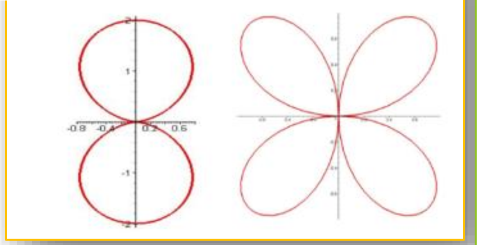
Some special source types

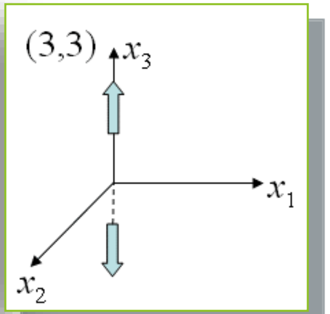


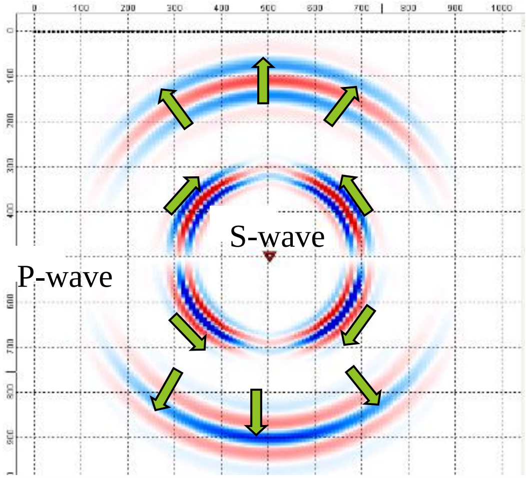
Vertical component of displacement vector

Vertical Source

(3,3) $a_P = 2\cos^2\theta, \quad a_S = -\sin 2\theta$



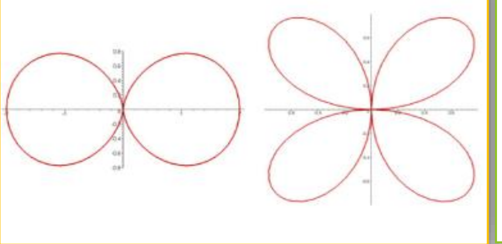


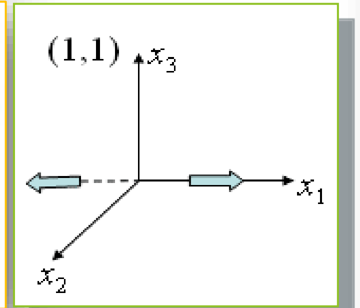


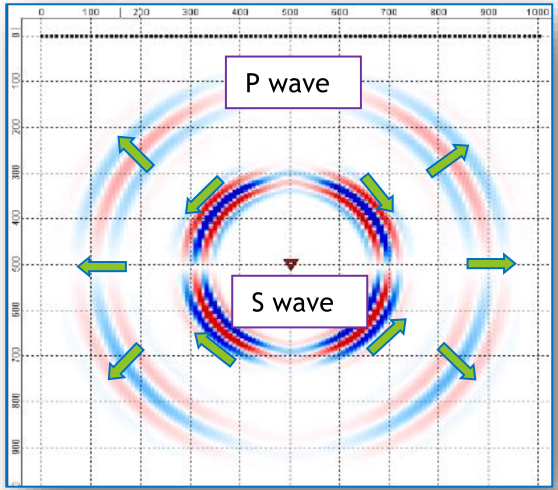
Dipole source of type (3, 3)

Horizontal Source

(1,1) $a_P = 2\sin^2\theta, \quad a_S = \sin 2\theta$



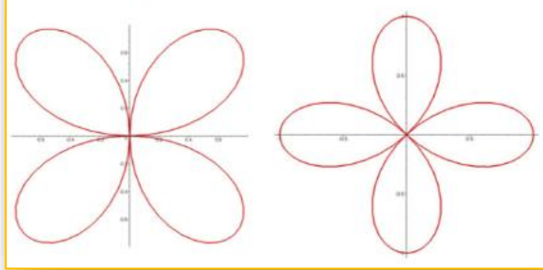


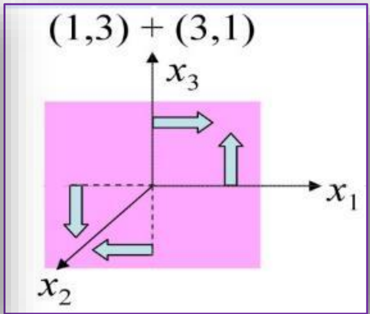


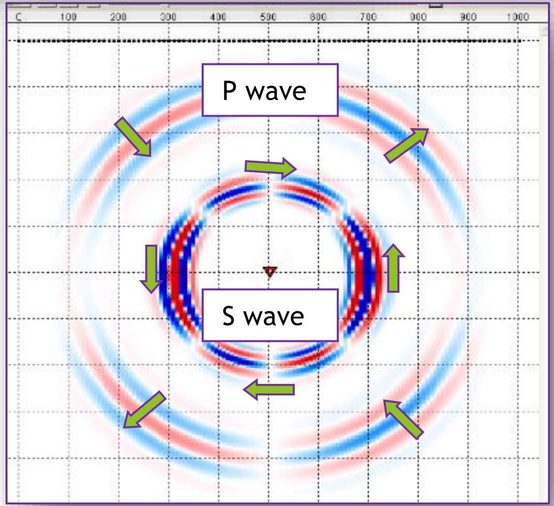
Dipole source of type (1, 1)

Coupled forces

(1, 3) $a_P = \sin 2\theta, \quad a_S = \cos 2\theta$







Dipole source of type (1, 3)+ (3, 1)

Built-in processing programs for modeling data control the results of the field data processing

In finite-difference modeling, practically no restrictions are imposed on the complexity of the model in terms of geometric structural shapes, the presence of anisotropy, thin layering, absorption, complexity of the observation surface, etc.

To control the results of processing field data, the package contains built-in migration programs, in which the Green's function is calculated:

- Various attributes of the synthetic wavefield are applied to improve the migration result and, in particular, to get rid of the shadow zone or focus the target object.

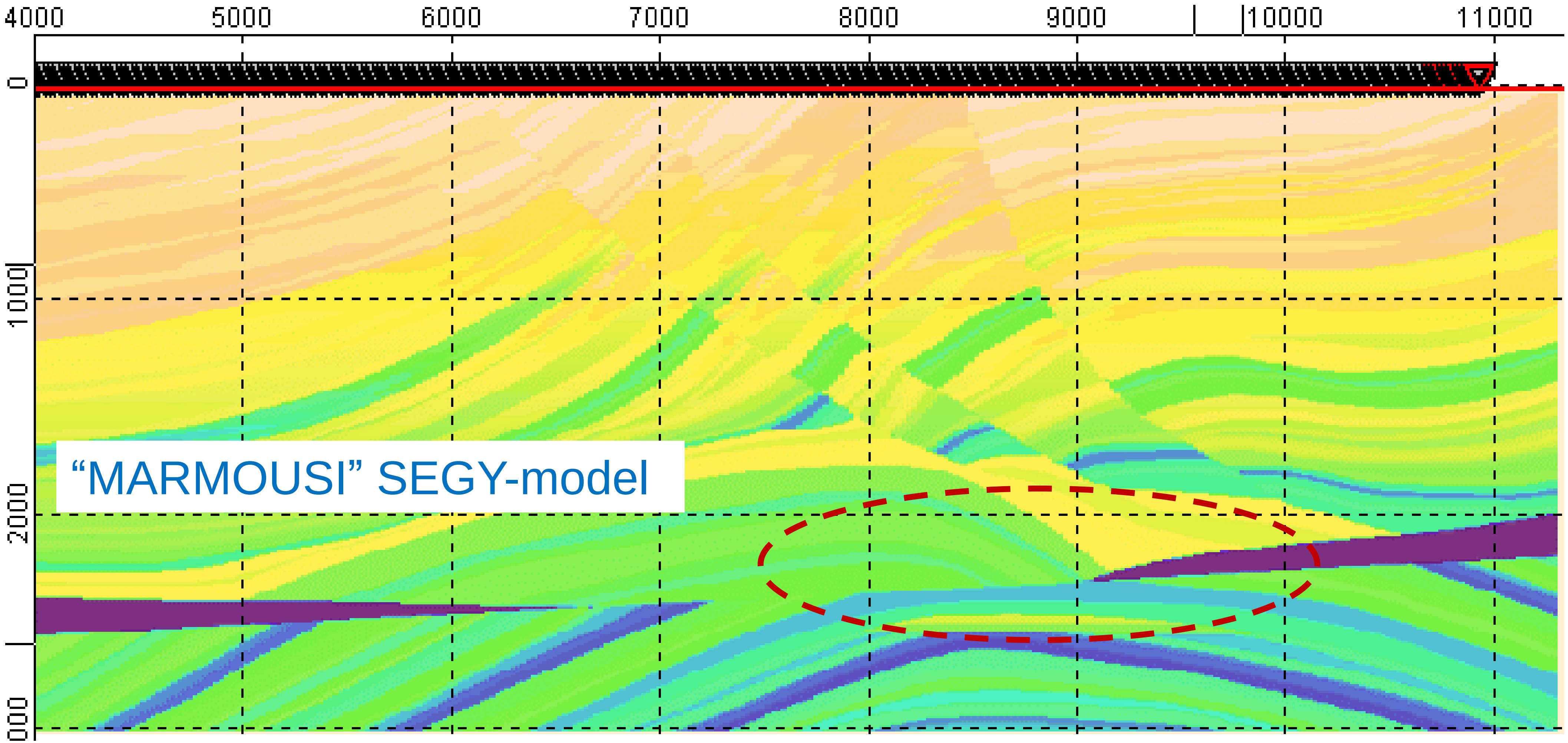
The following attributes are applied to configure the appropriate wave migration operator:

    - First arrival, Maximum energy, Maximum divergence, Maximum rotor, Maximum vertical component

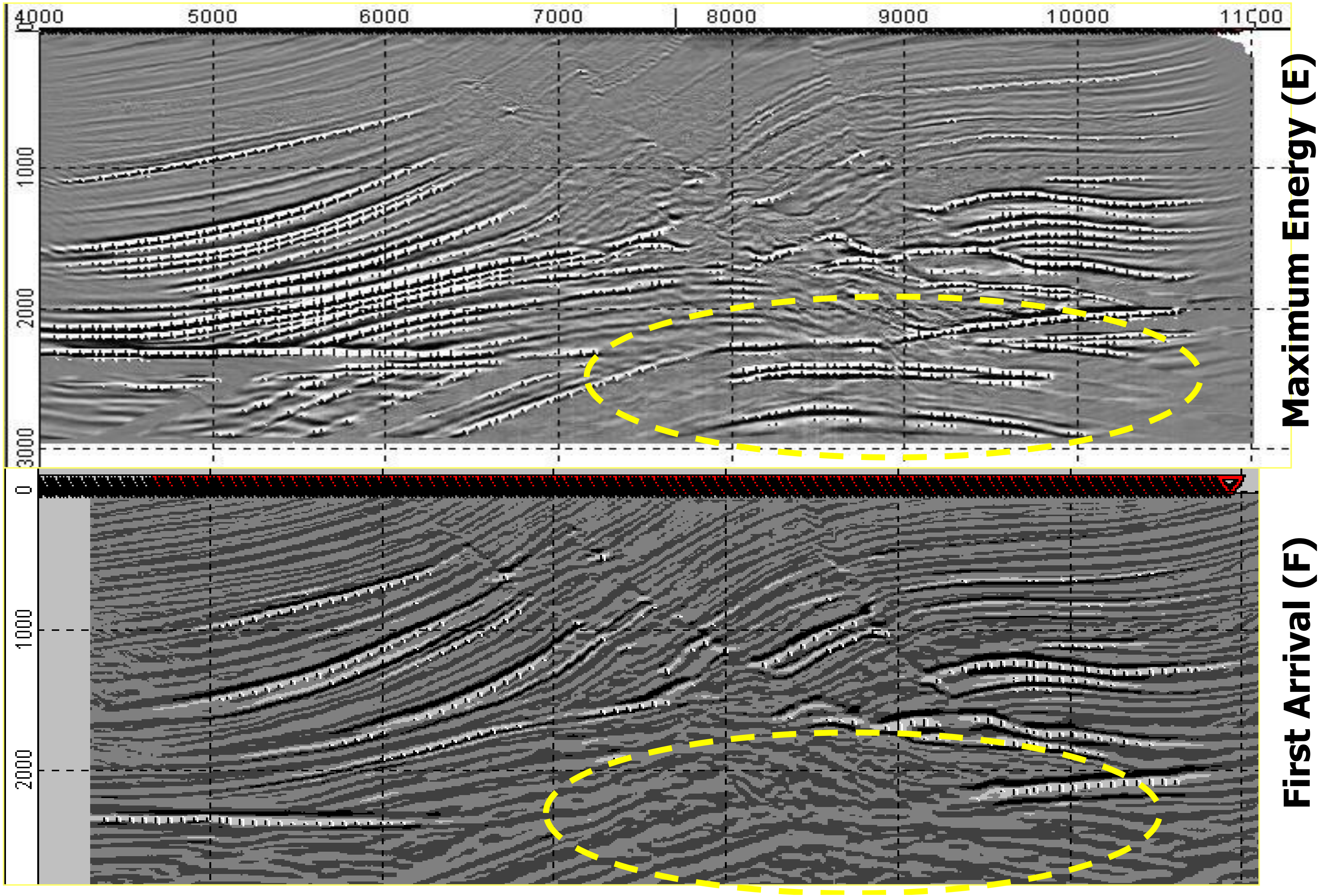
- Using the eikonal equation
- By the kinematics of a duplex wave in the mode of reflected and transmitted compression and converted waves
- In accordance with the kinematics of reflected and converted waves at VSP

However, the main methodological technique is the use by the user of his software and the original graph of data processing.

Synthetic seismograms generation in complex seismic geological conditions and analysis of their images

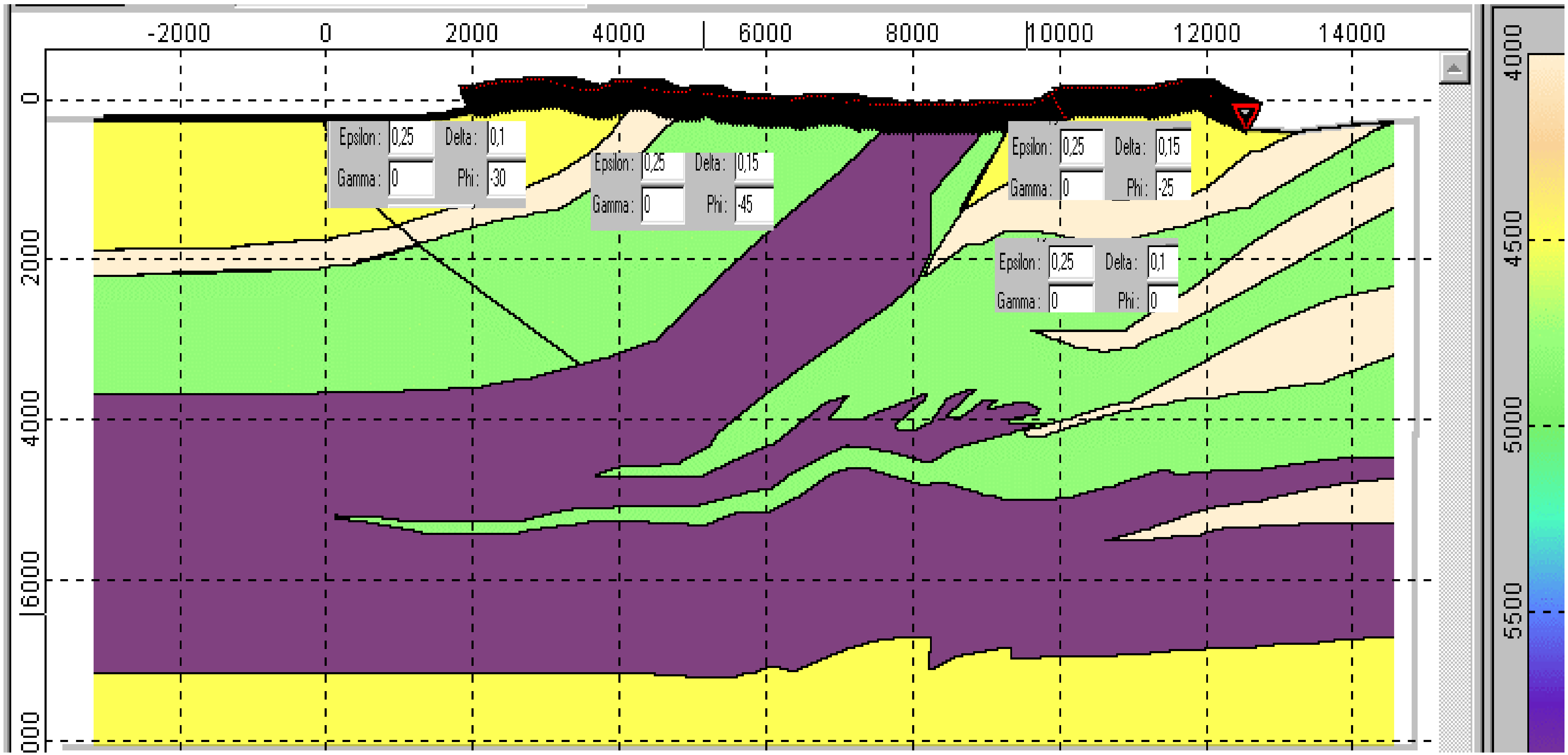


The elliptical contour shows the target gas reservoir



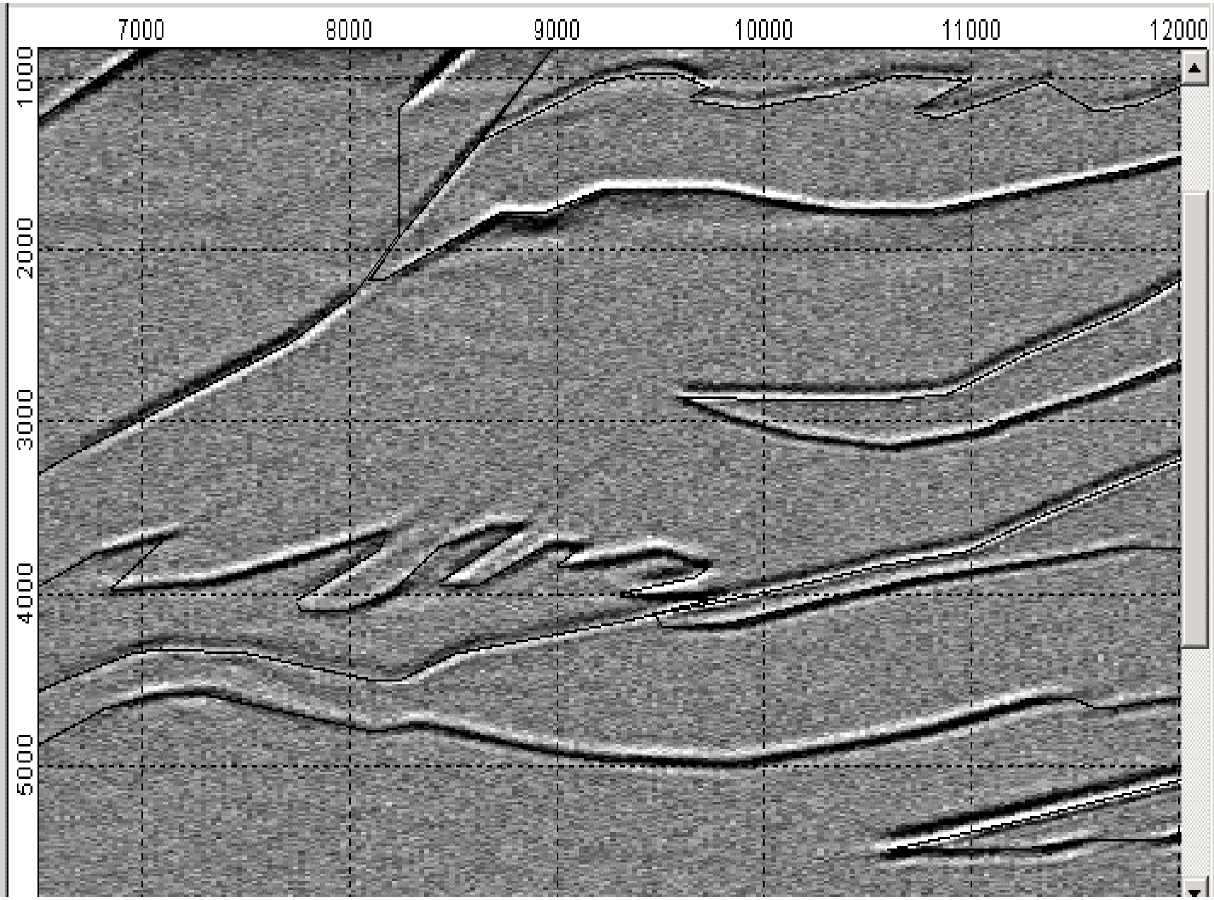
Pre-stack migration of simulated data using the elastic wave equation. The upper image, obtained with the **maximum energy operator**, fully corresponds to the model.

Anisotropic model (Rocky Mountains, Canada)

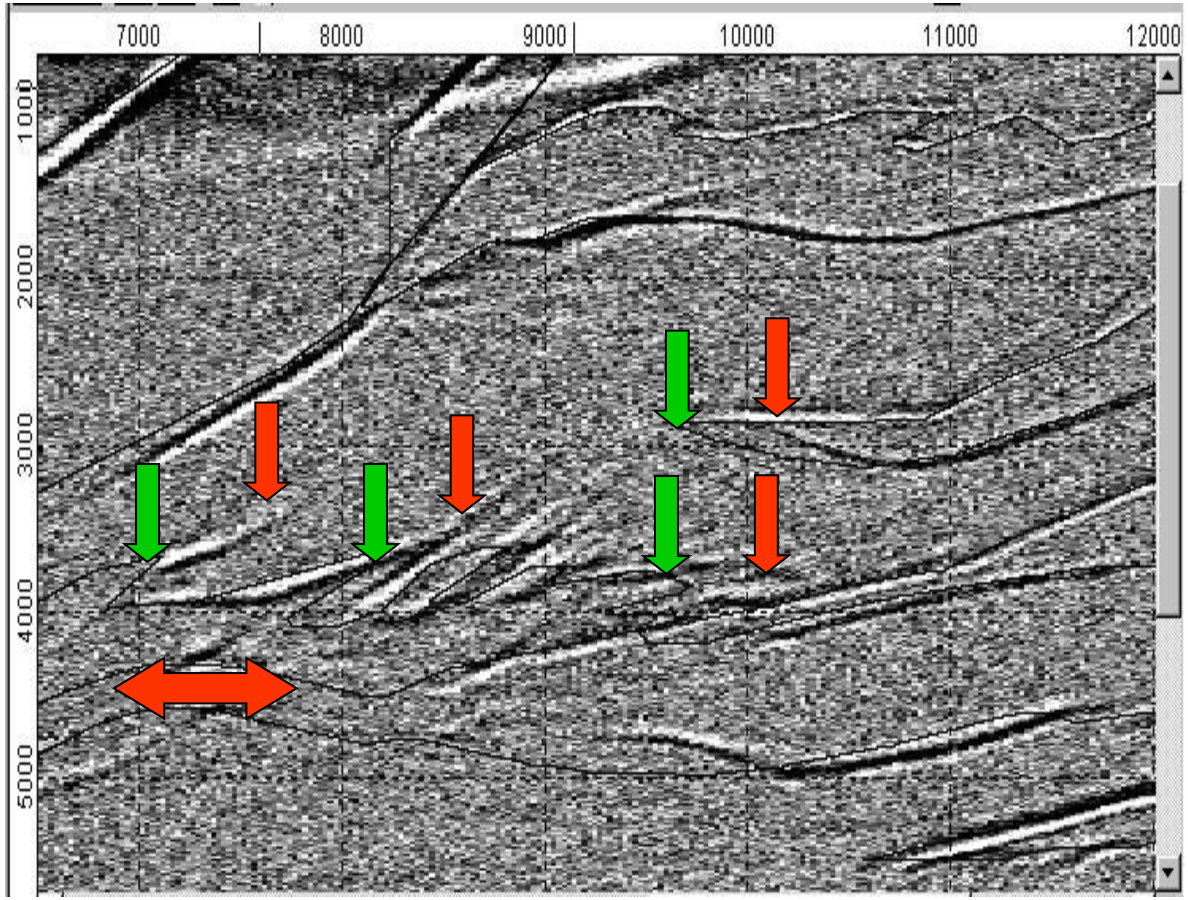


The boxes show the parameters of anisotropic shale deposits

Anisotropic and Isotropic PSDM results (Tesseral Pro)

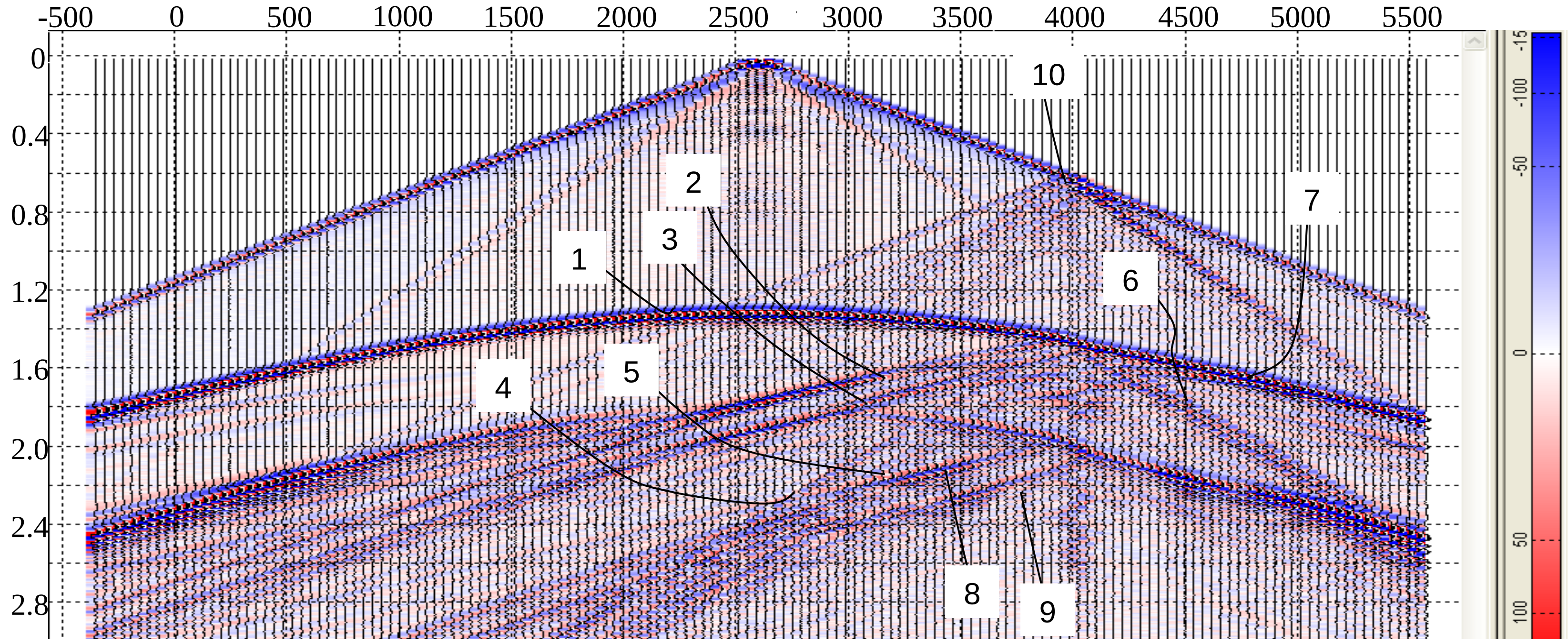


Depth migration considering anisotropy fully corresponds to the model



Depth migration without regard to anisotropy leads to significant distortion of the image. Red arrow - model position of the object, green - distorted

Modeling of reflections from vertical boundaries for advanced processing



Synthetic shotgather, which demonstrates duplex waves originated on vertical layer 80 m thickness (previous slide), at coordinate X=4000m.

Legend:

1 – reflections from base boundary

2 – compressional duplex wave, reflected from nearest to the source side of a vertical layer

3 – compressional duplex wave, reflected from a far side of a vertical layer

4 – converted duplex wave, reflected from nearest to the source side of a vertical layer

5 – converted duplex wave, reflected from a far side of a vertical layer

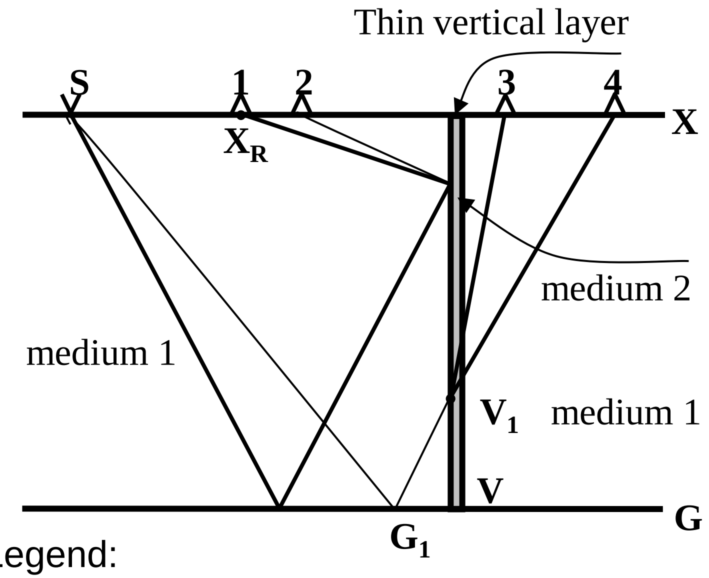
6 – converted duplex wave, transmitted through the vertical layer

7 – compressional duplex wave, transmitted through the vertical layer

8 and 9 - reflected duplex waves, originated from PS-wave, which changed mode on a base boundary

10 – transmitted duplex wave, originated on top of a vertical layer as result of incidence on it of direct compression wave

Scheme of origin of reflected and transmitted waves on thin vertical layer



Legend:

1-duplex reflected PPS converted wave

2- duplex reflected monotype PPP-wave

3-duplex passing monotype PPP-wave

4-duplex pass-through PPS converted wave

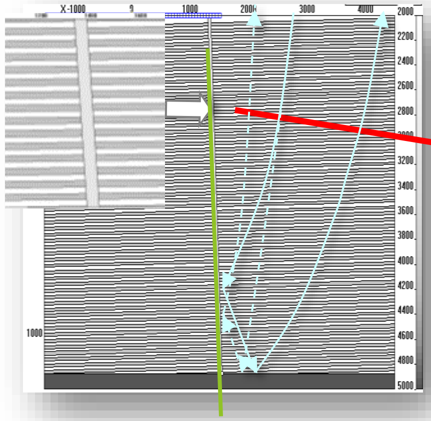
Modeling for studying of Duplex Wave Migration (DWM) properties

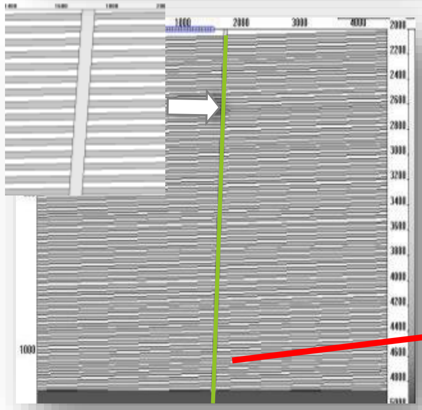
Differently oriented low-amplitude disjunctives in a thin-layered medium

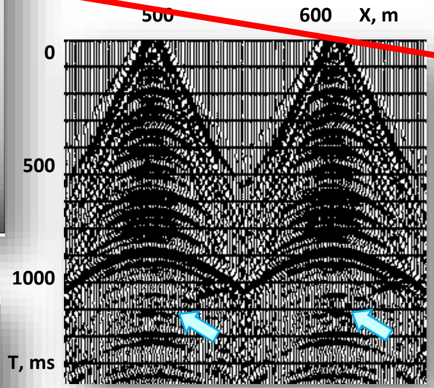
Model

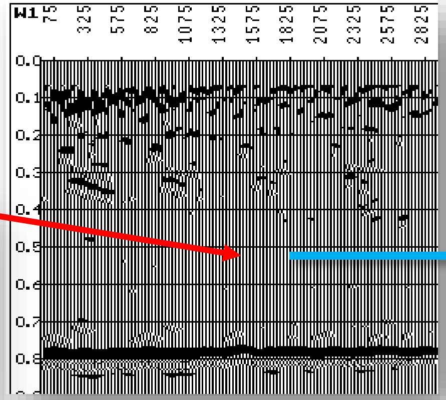
Conventional processing

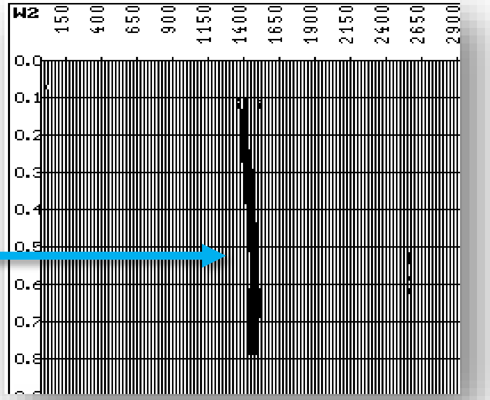
DWM

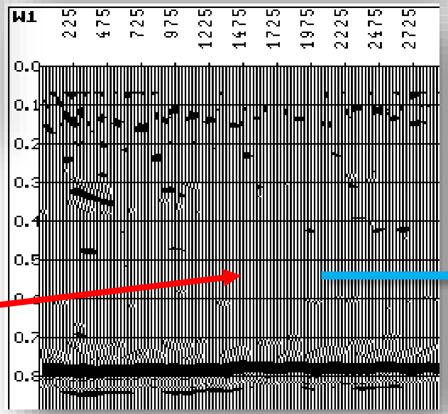


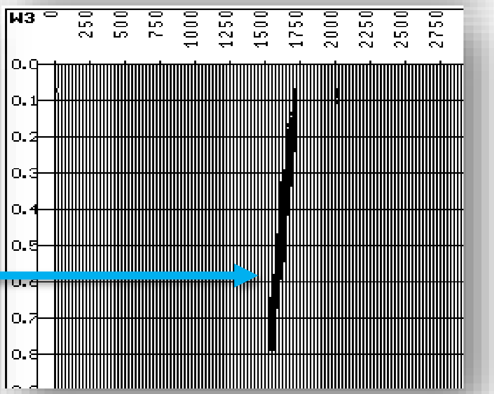












Synthetic gathers (the duplex waves are shown with arrows)

Duplex waves ray-scheme is shown with blue colors

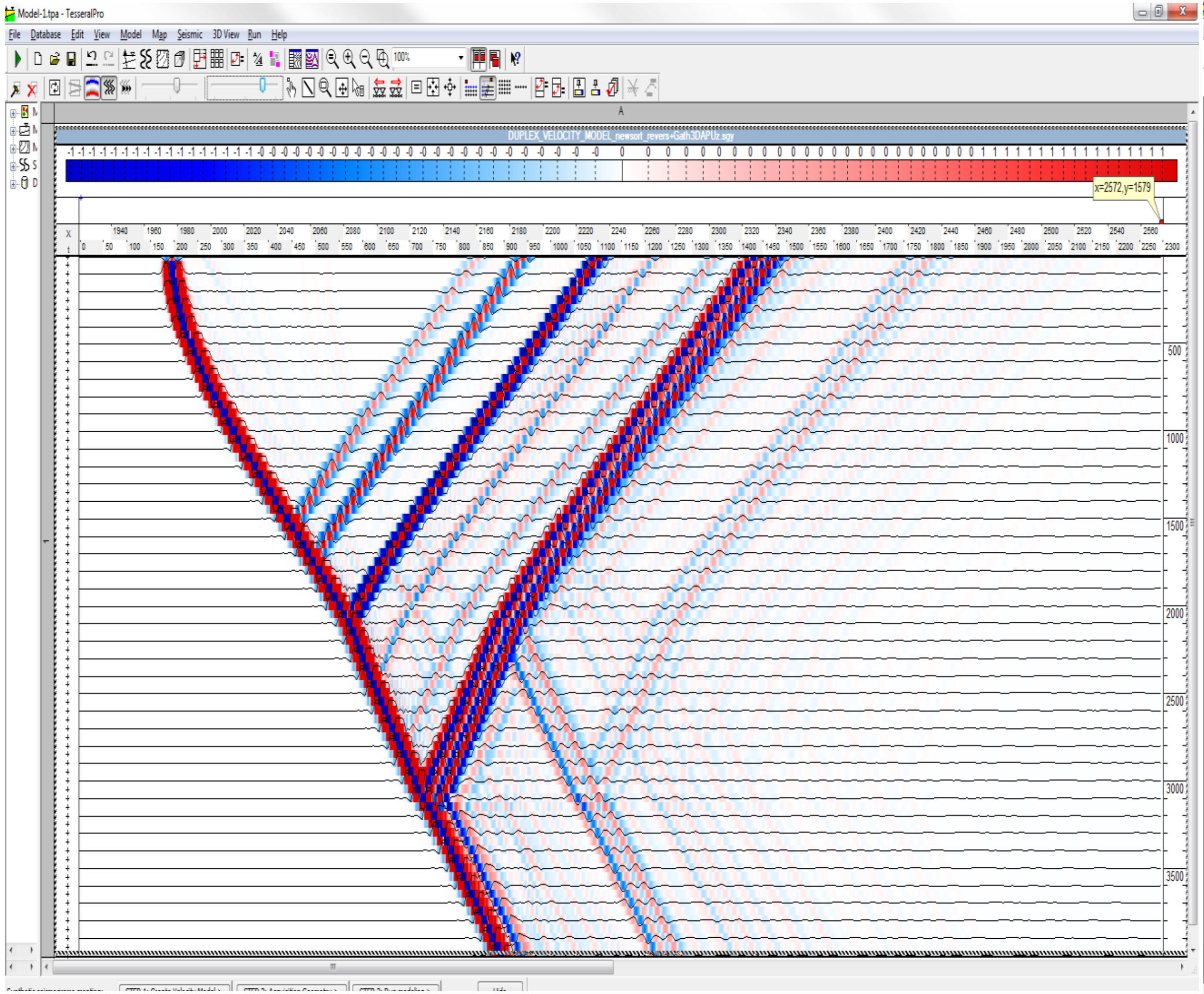
Result of a standard depth migration

Image of the disjunctive obtained by DWM

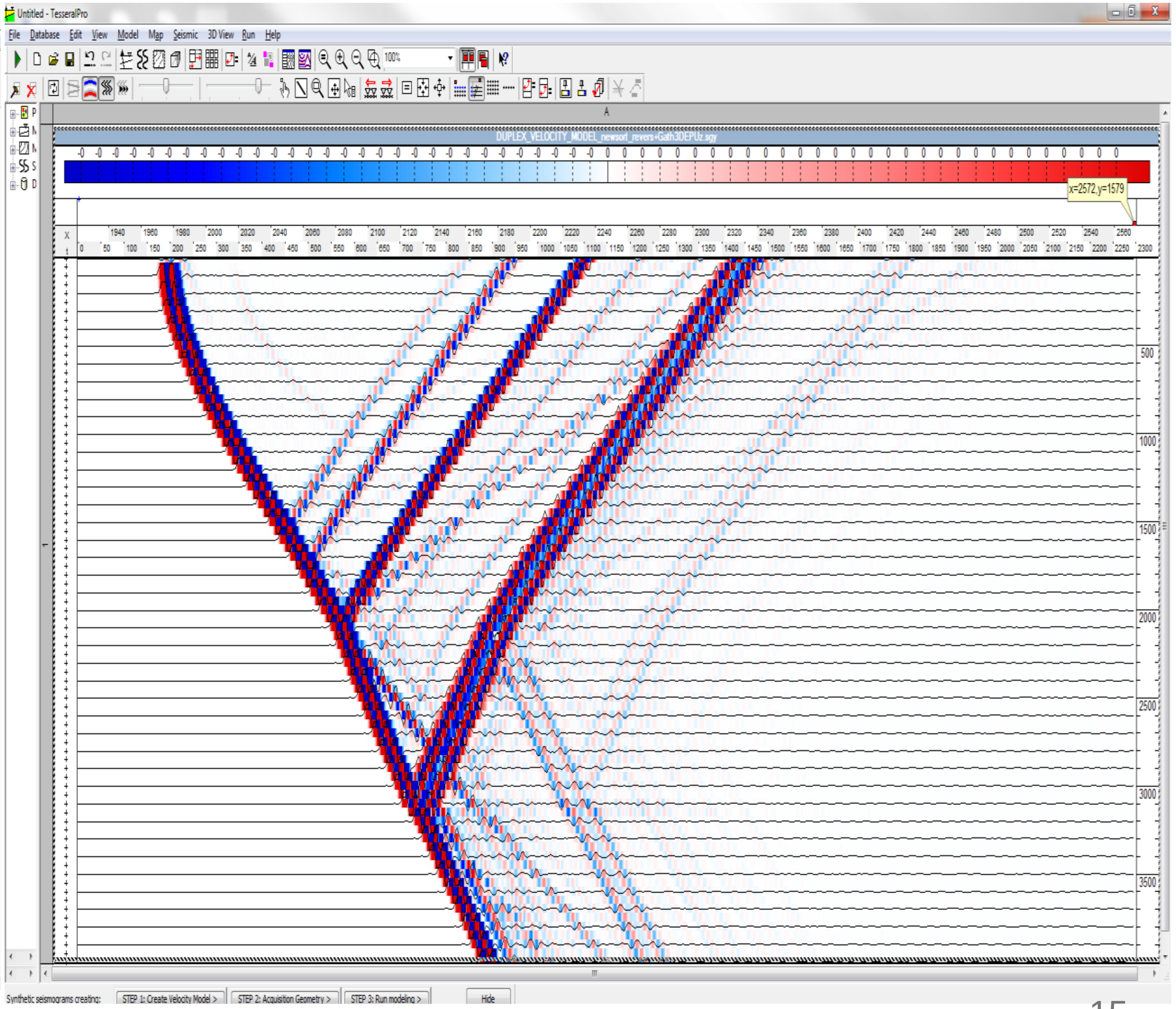
The example shows that in some cases we do not see disjunctives in case of the standard seismic data processing, but they may be revealed by DWM

Synthetic VSP shot gathers generated by 3D modeling

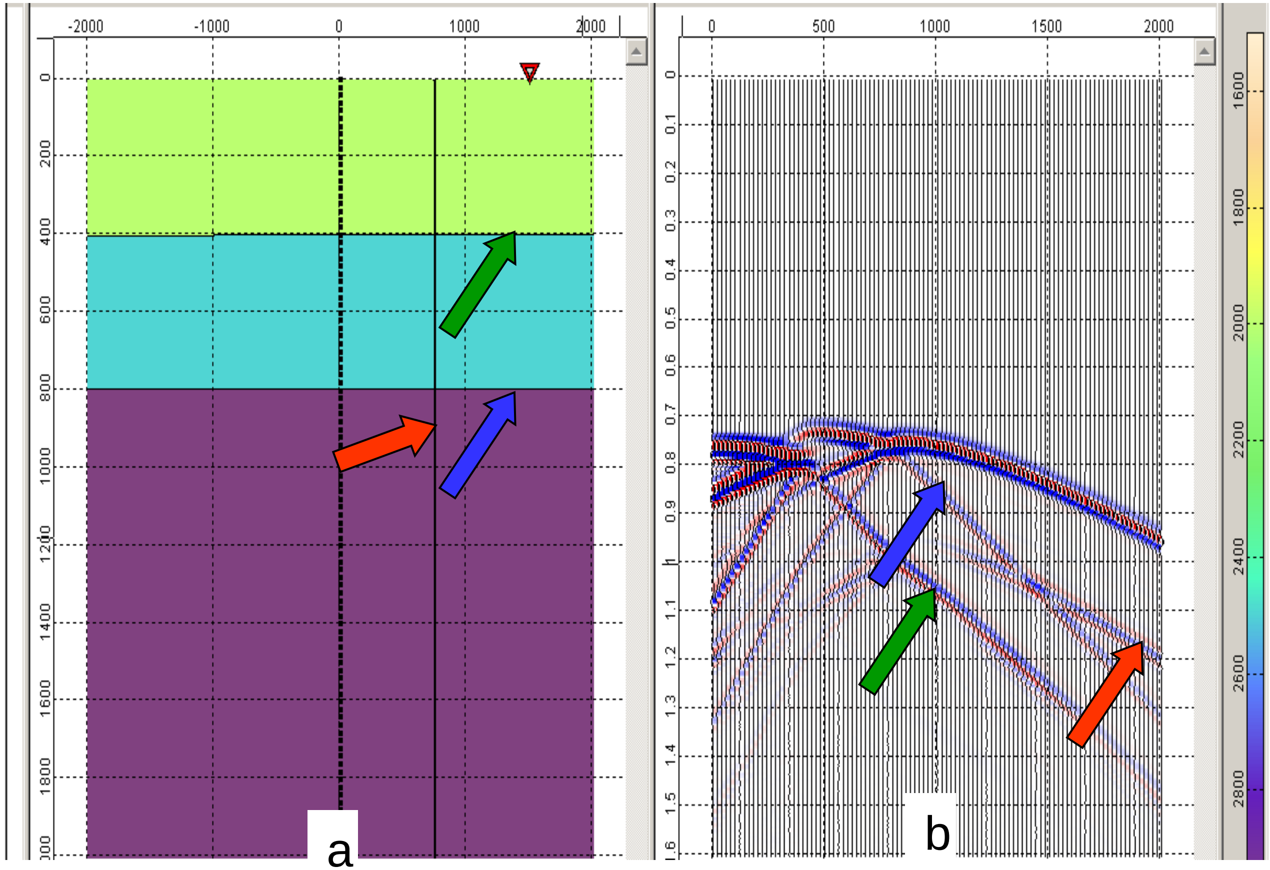
3D acoustic modeling
(Signal: Ricker at 35 Hz, Z-Component)



3D elastic modeling
(Signal: Ricker at 35 Hz, Z-Component)

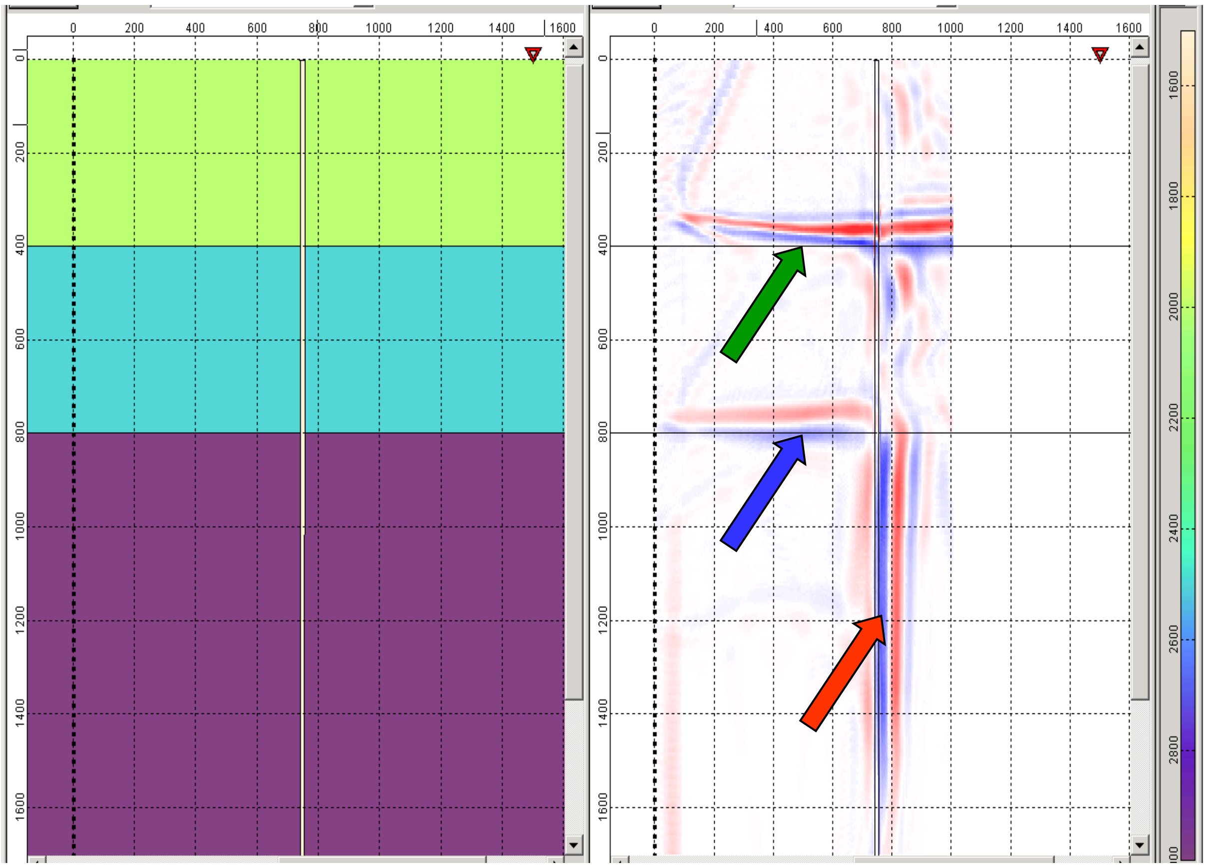


Modeling of reflections from vertical and horizontal boundaries at VSP



a - Model, **b** - VSP seismogram: the green arrow shows the transmitted converted wave, which is exchanged at the first horizontal boundary; the blue arrow shows the transmitted converted wave, which is exchanged at the second horizontal boundary, the red arrow shows the transmitted converted wave, which is exchanged at the vertical boundary

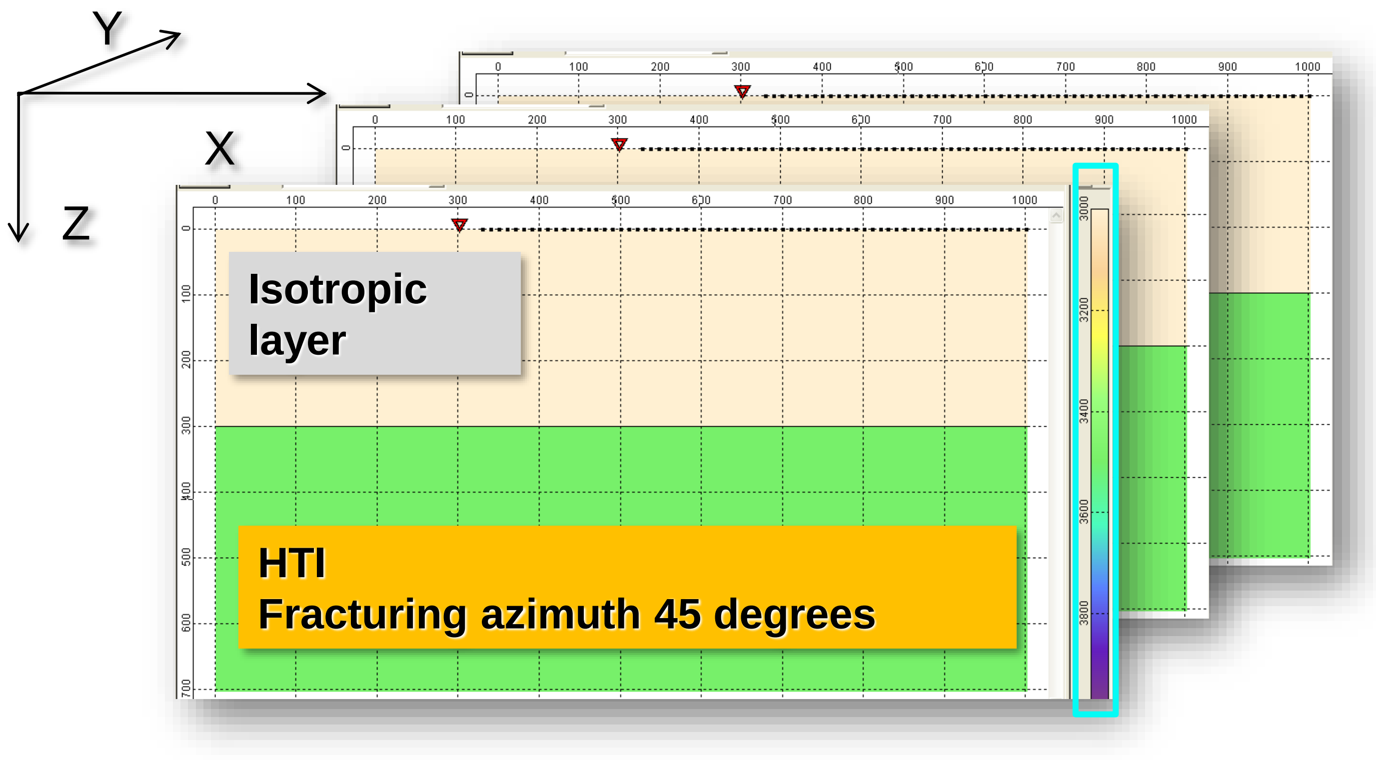
Migration of transmitted converted waves for VSP



During the migration of transmitted converted waves images of horizontal and vertical boundaries are formed

2.5D-3C Modeling

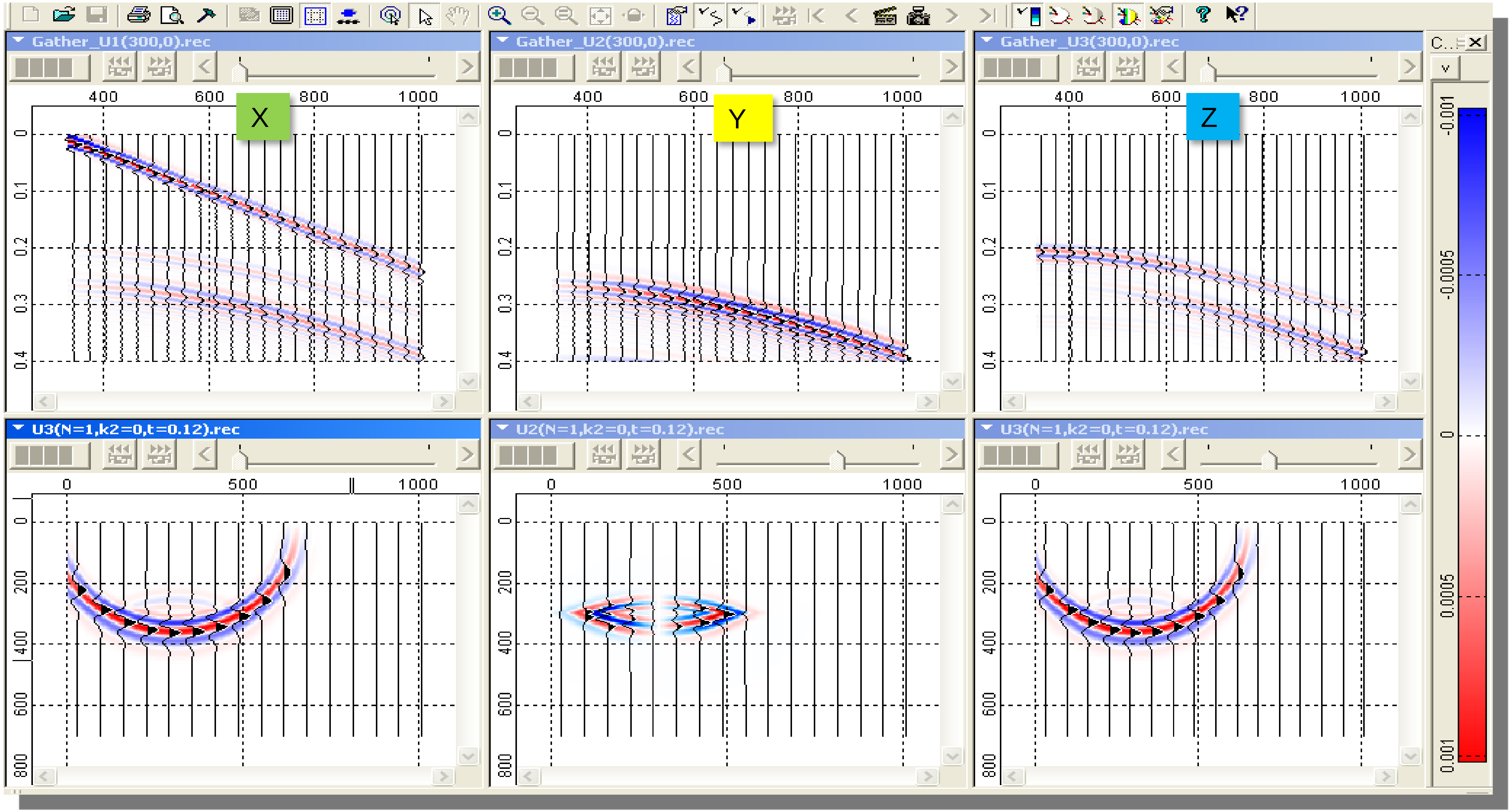
- **2.5D-3C modeling** (as opposed to full 3D modeling) simplifies the environment model. **It is assumed that the elastic parameters are constant along the OY axis**. However, the symmetry of all anisotropic parameters (including fracture-induced anisotropy) can be of any spatial orientation, as in 3D
- **2.5D-3C modeling** offers significant technological advantages in calculations using GPU cards and GPU clusters



Result of 2.5D-3C modeling

The incident P-wave reached the boundary with the anisotropic layer

On Y-component appeared fast S_1- wave polarized along the fracturing



A

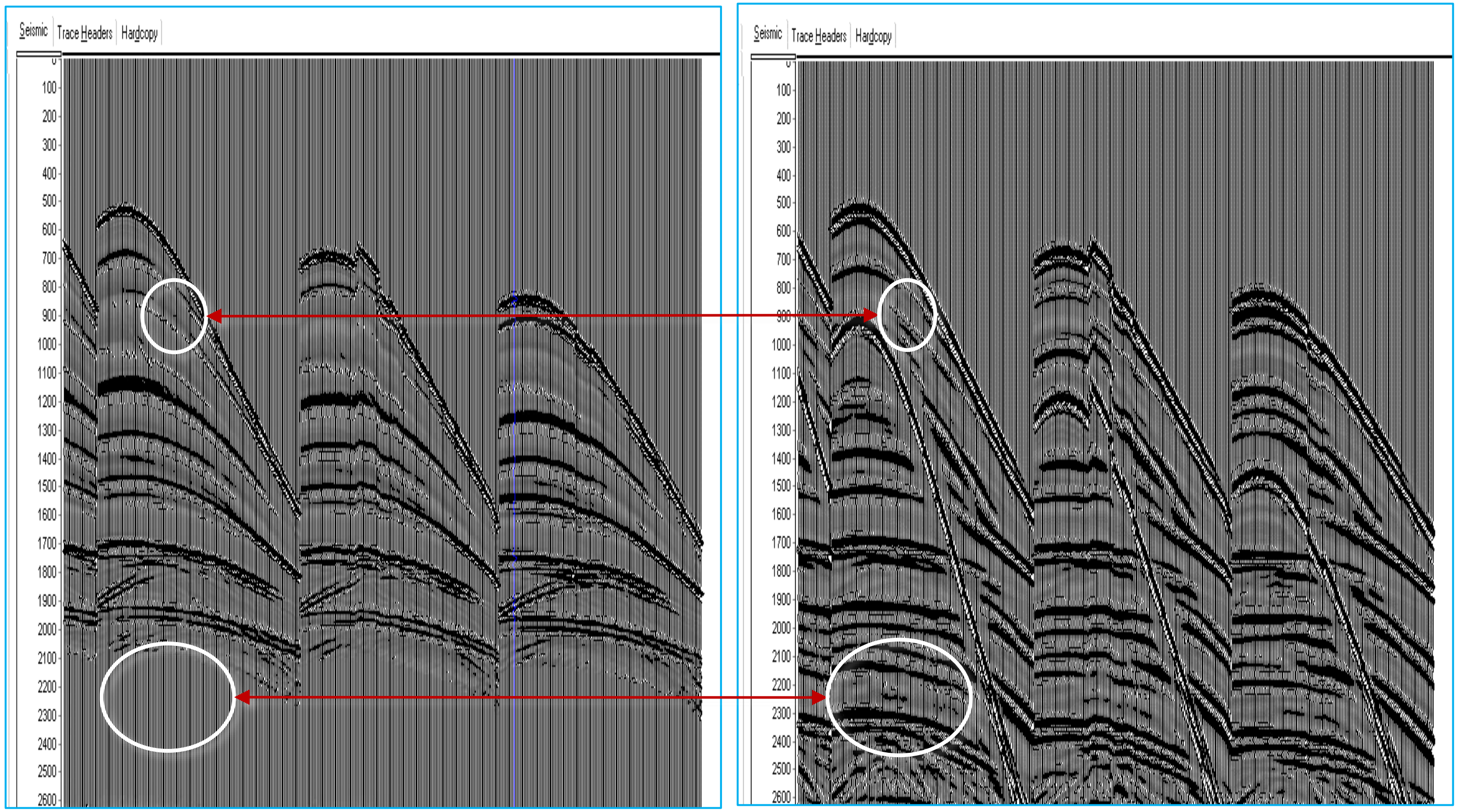
B

A-Shotgathers, B-Snapshots (t=0.12 s)

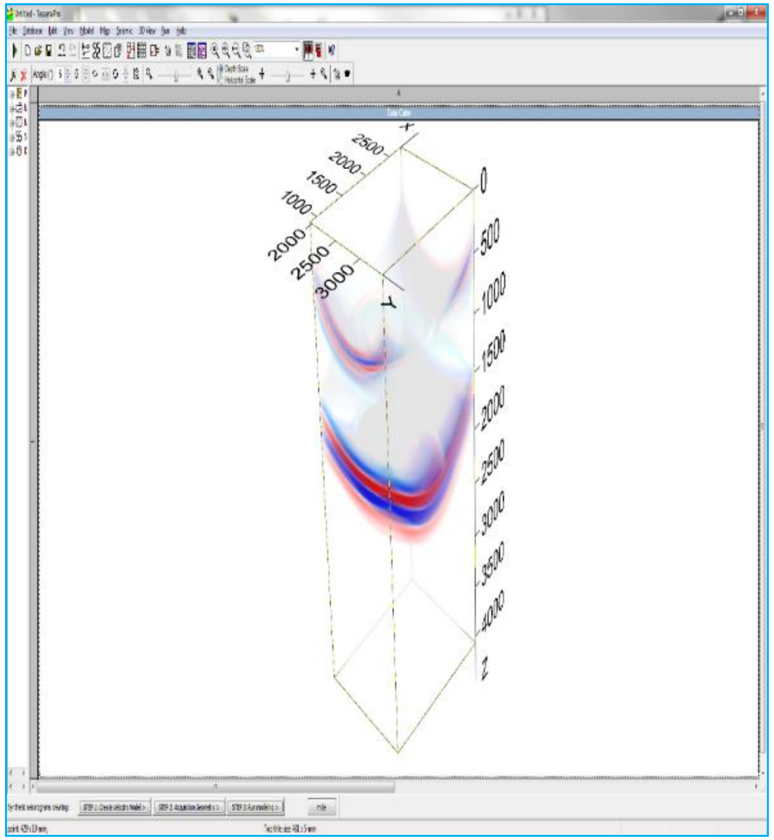
3D modeling

3D acoustic modeling

3D elastic modeling



Comparison of gathers produced with acoustic and elastic 3D modeling



Example of the 3D snapshot in the velocities cube

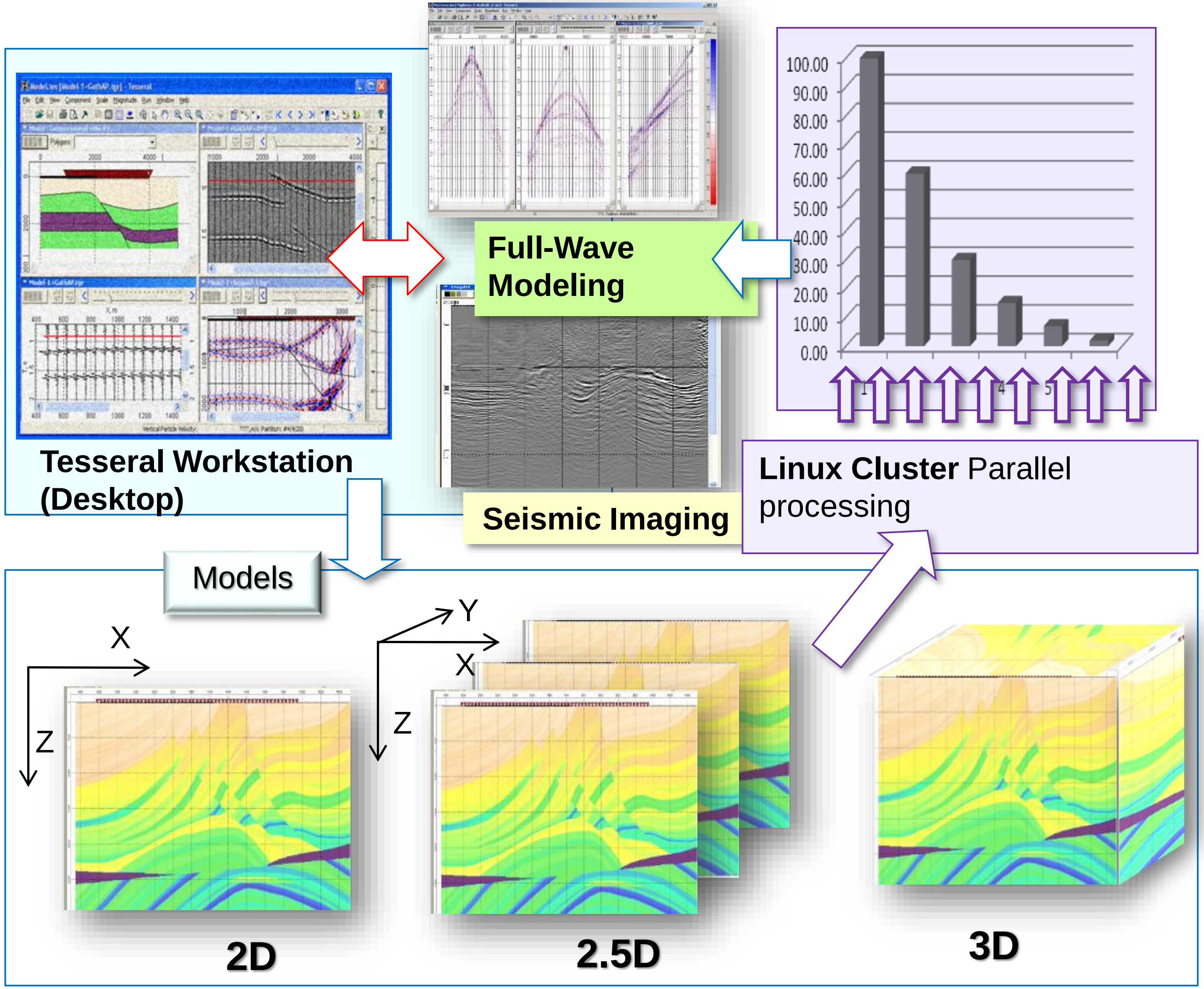
Performance and parallel computing

Computations are optimized for the use of different high-performance computing architectures:

- Multi-core and multi-processor servers
- Personal computers and workstations with graphics accelerators (GPUs) based on CUDA (all) and OpenCL (2D only)
- Multi-machine clusters (based on MPI: OpenMPI, LAM MPI, etc.)
- Multi-machine hybrid clusters (MPI + GPU)
- Computer classes of Windows-machines

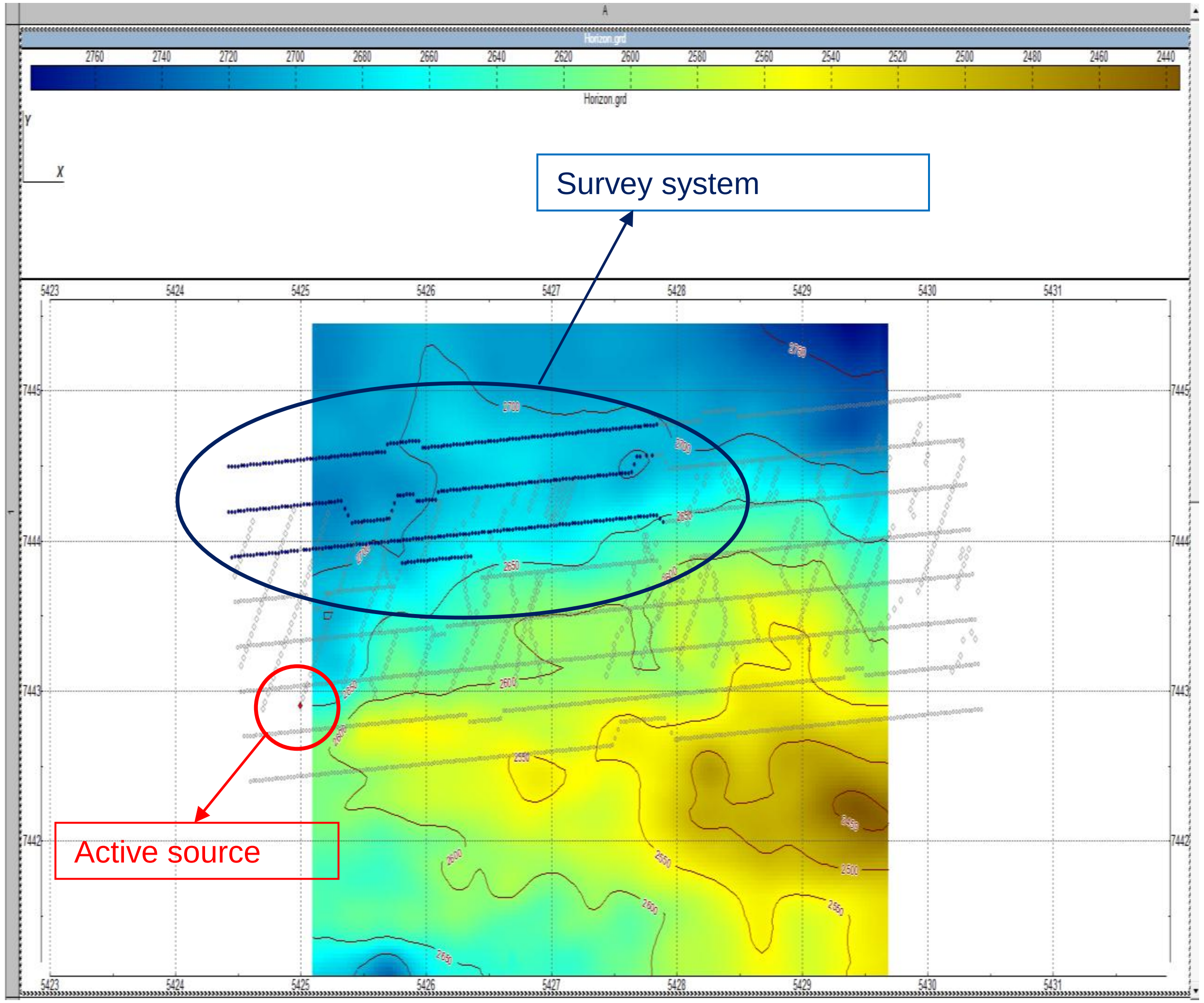
Operating Systems:

- Windows
- UNIX (Linux, Ubuntu, macOS, etc.)

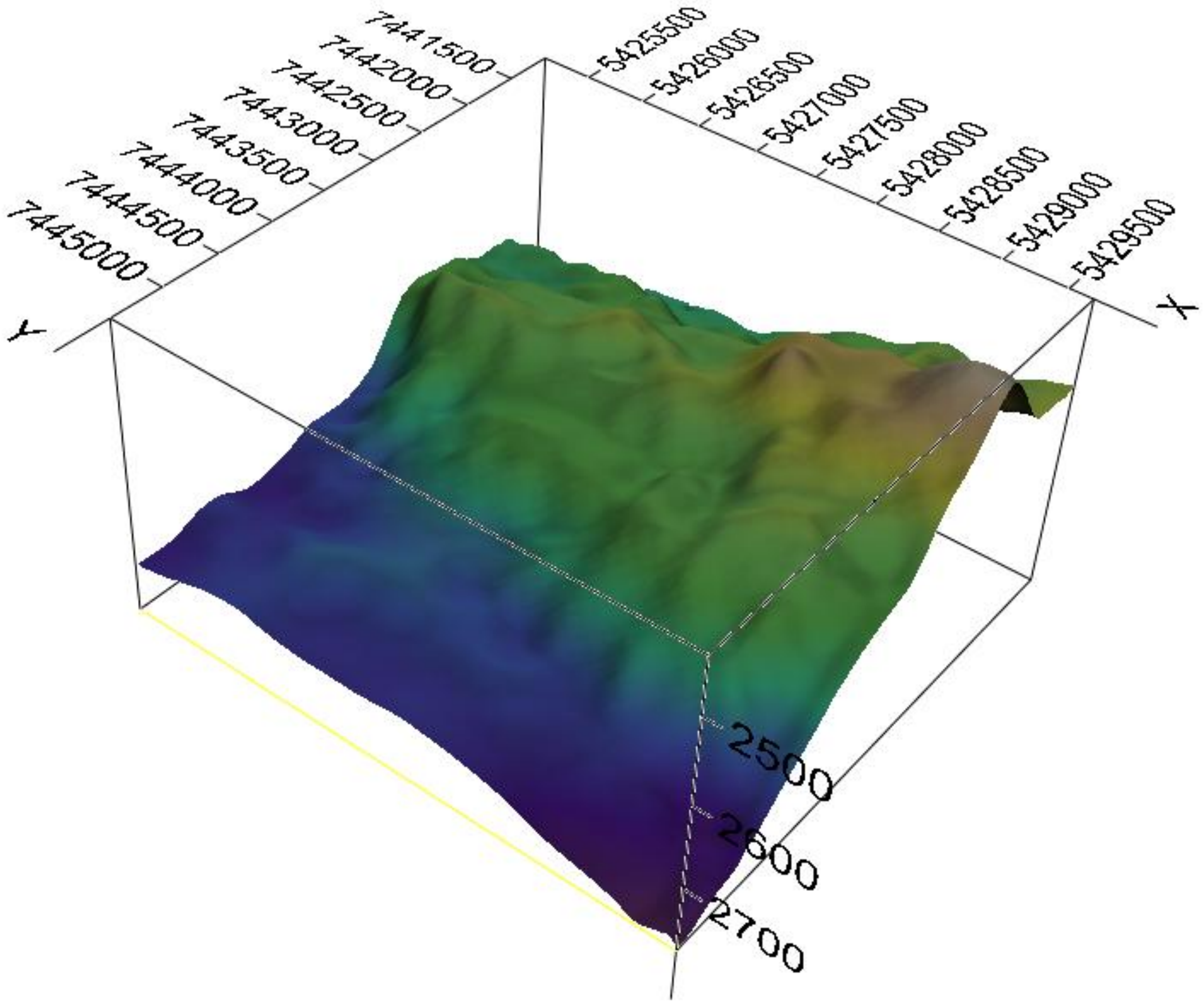


Building of the 3D survey system

Structural map with the survey system loaded from the field SEGY file



Structural surface in 3D imaging



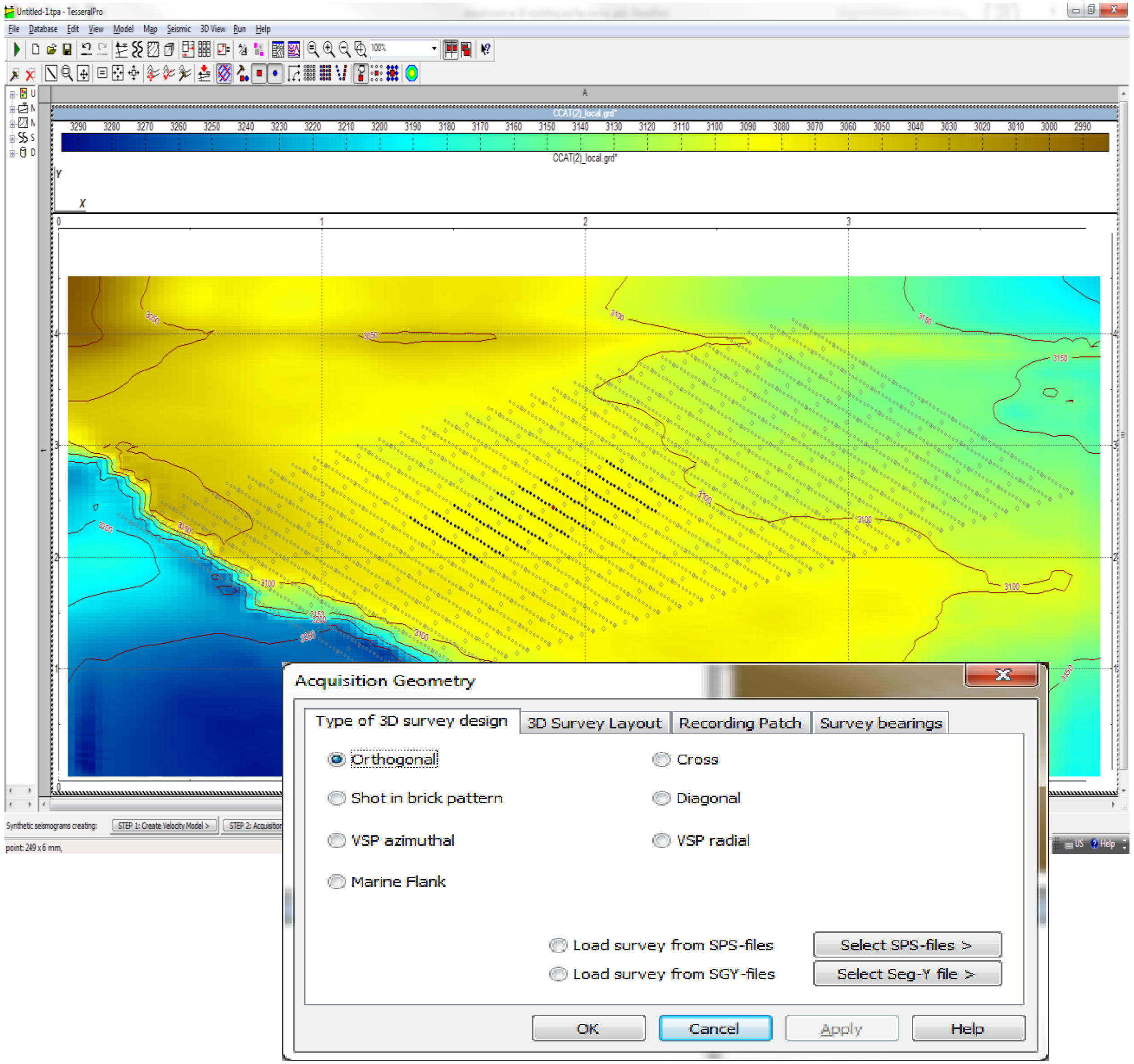
<u>Legend</u>:

The selected vibration source is shown in the red outline

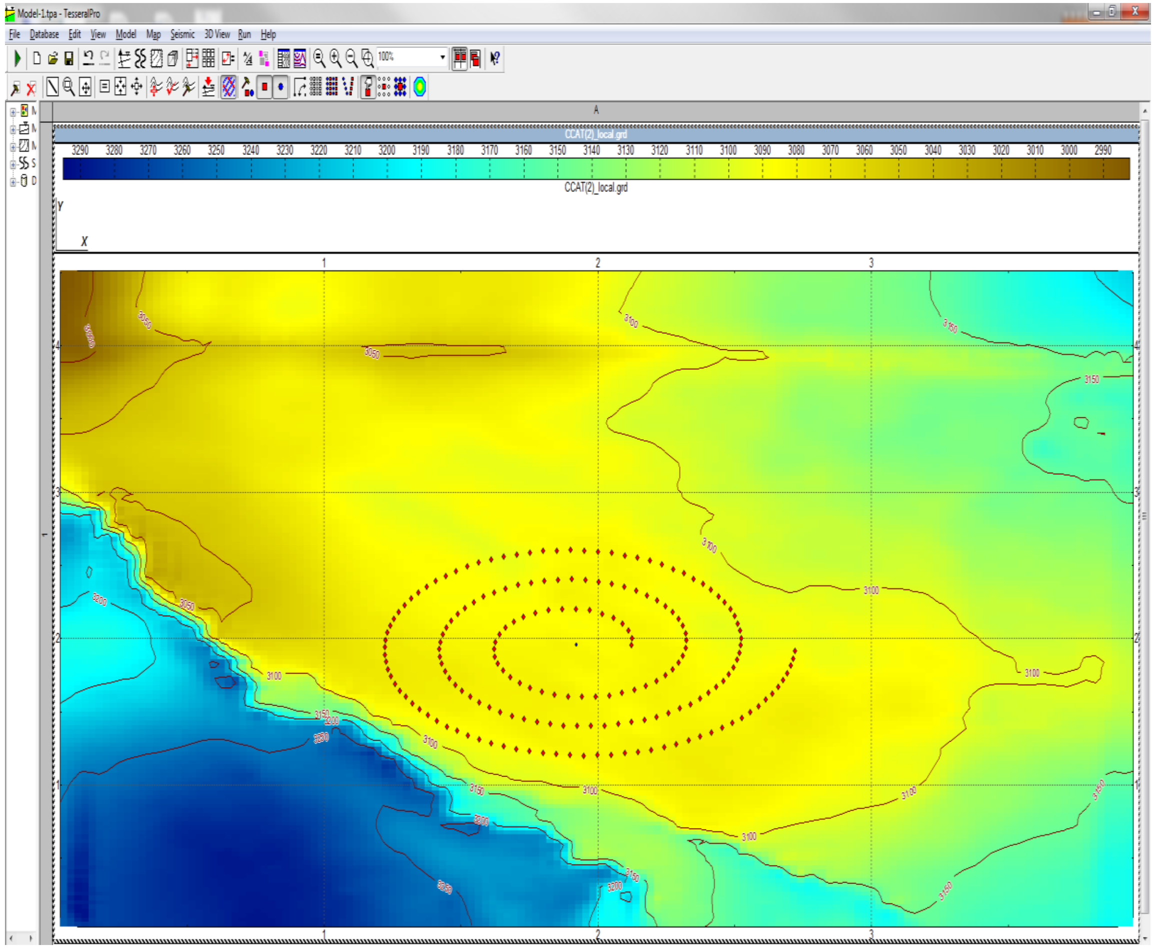
In the blue outline are shown the receives, corresponding to the selected source

Structural map and survey system

3D Surface survey. System of sources, plotted over the structural map (active shotgather)

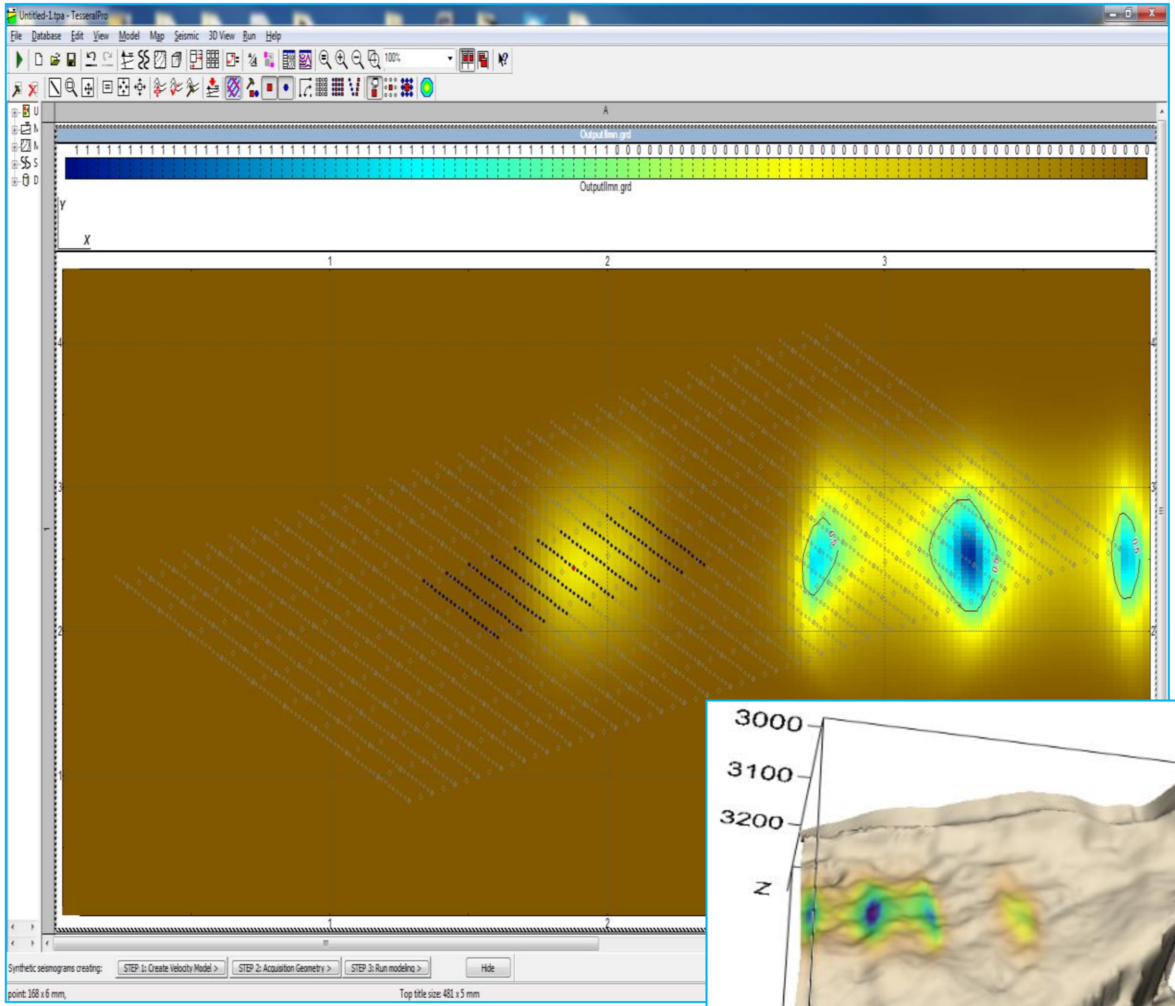


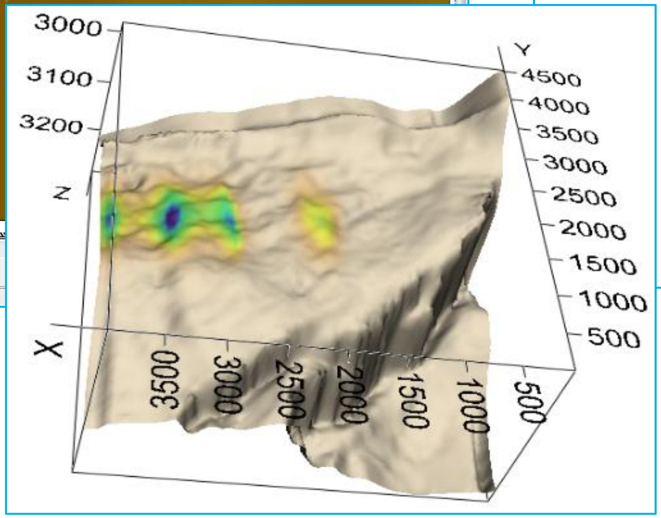
- 3D-VSP radial survey system



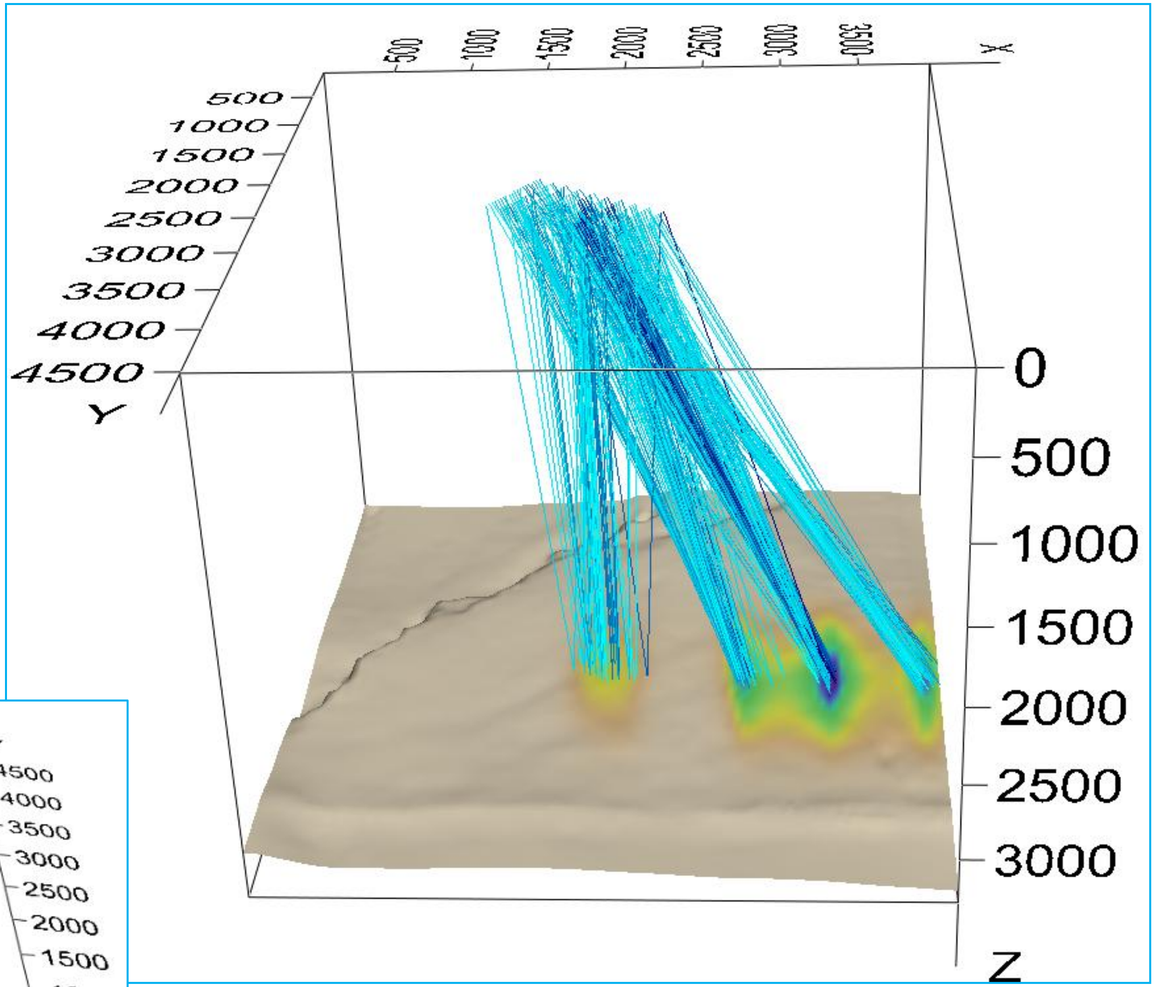
3D folds map and ray-tracing

Folds map on the structural surface

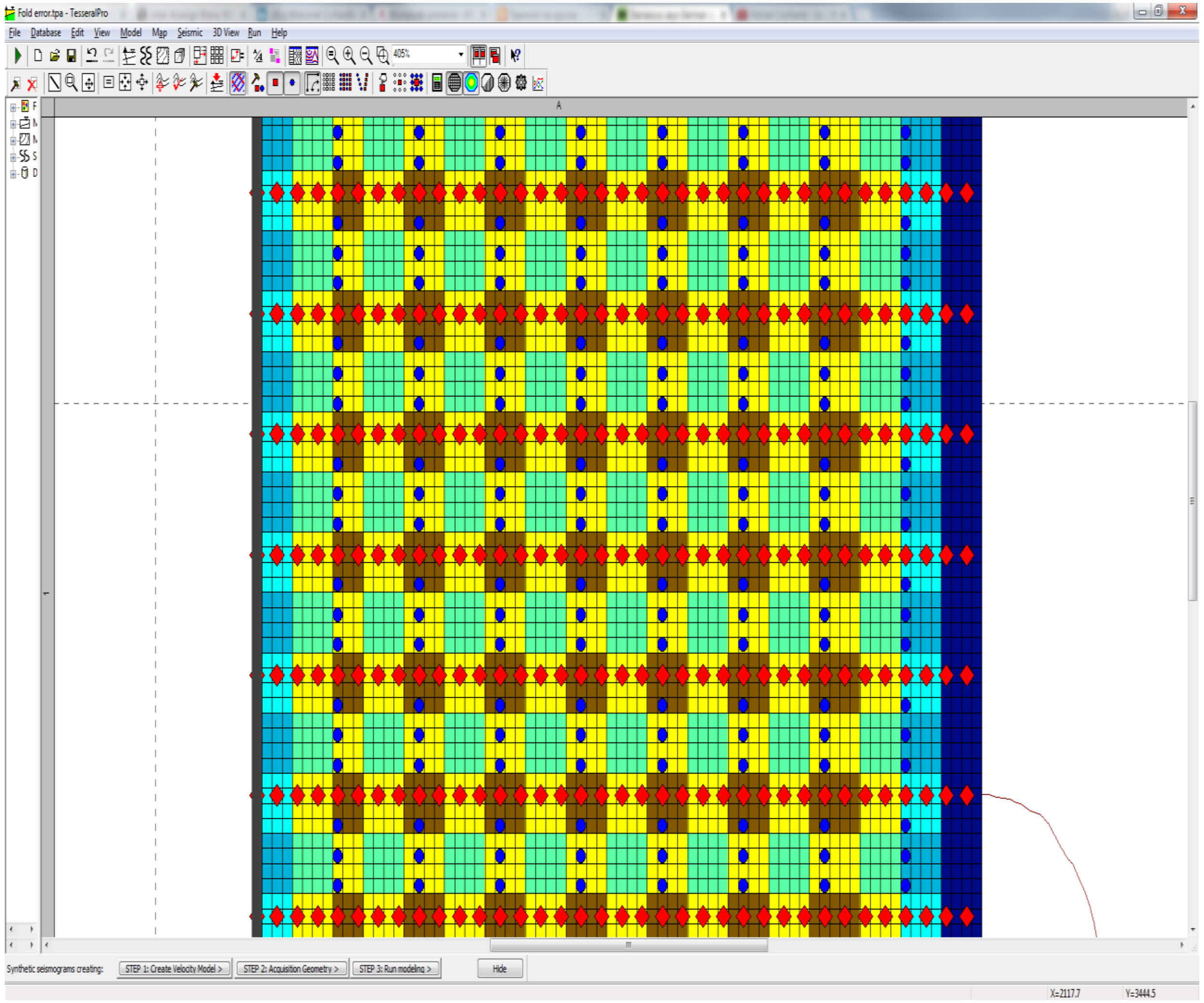


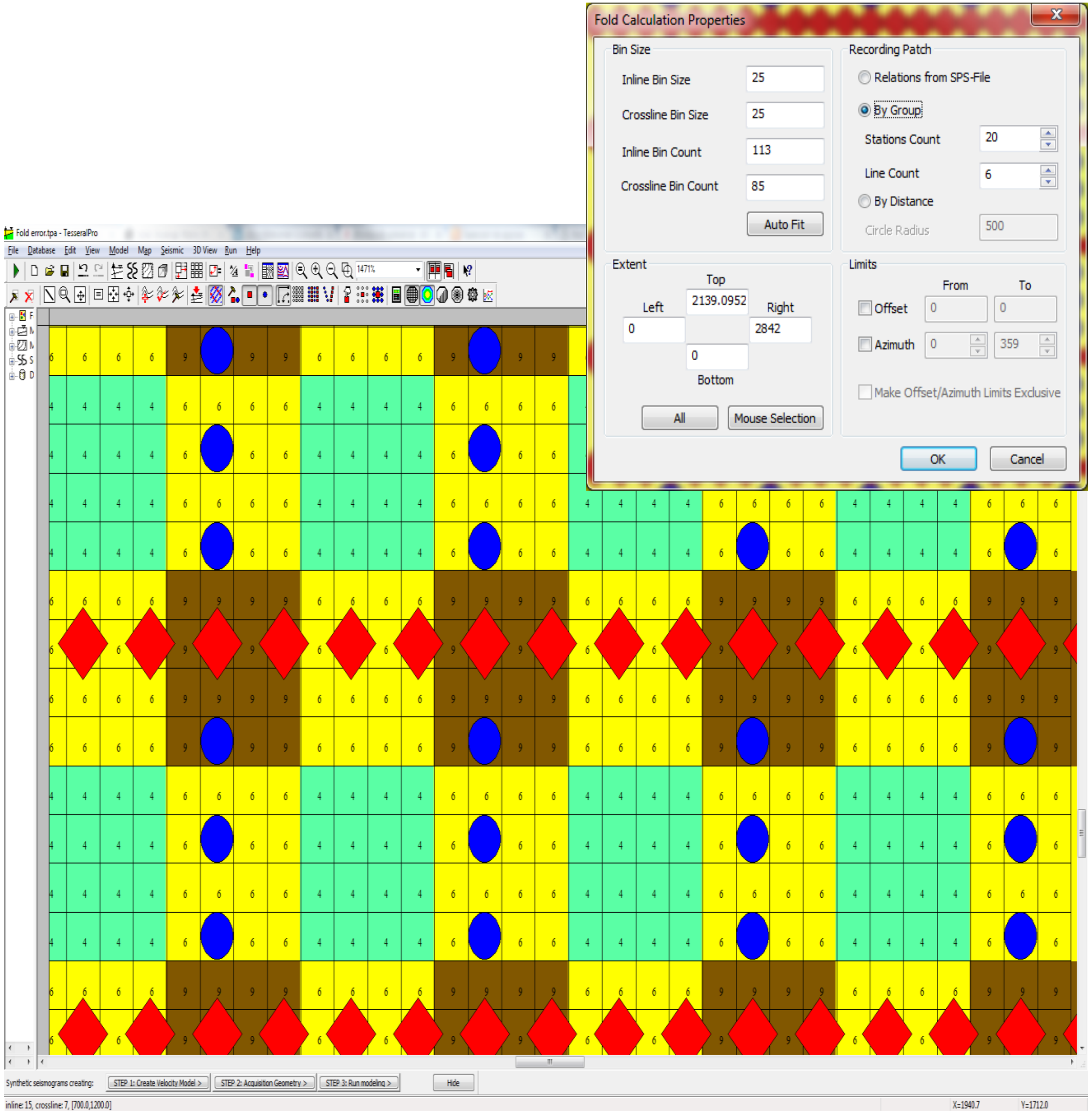


3D image of rays



Folds map for 3D survey system





Summary

Modeling allows to see the consequences of your proposed decisions before they are implemented (and paid for)

- ✓ Full-wave modeling is a QC tool for improving the quality and reliability of the interpretation of seismic surveys. It is particularly helpful for planning acquisition parameters, fine-tuning of the processing sequence...
- ✓ Full-wave modeling allows consistently analyze characteristics of seismic records for complexly structured geological media including: thin- and sub-vertical layering, abrupt velocity changes in all directions, anisotropy and fracturing systems… It may be especially helpful for interpreters working with seismic record dynamics, i.e. AVO analysis, multi-component acquisition ...
- ✓ *Tesseral Pro* is easy to use visual learning tool. It can help geoscientists in developing and testing seismic processing procedures and sequences for different geology and survey scenarios, investigating particular wave phenomena in relation with specific seismic exploration method, and to present results in visual and consistent form
- ✓ *Tesseral Pro* provides a whole range of seismic modeling and model building solutions from simplest to the most complete allowing sustainably guide and QC field works and mitigate economic risks and environmental impact at all stages of the geological prospect
- ✓ *Predictive (Proxy) Modeling* may be used at stage of Artificial Neural Networks (ANN) image recognition learning process aiming to improve all stages of the site development activities
- ✓ By creating series of close to real world geological and survey system scenarios models *Predictive (Proxy) Modeling QC* may be used as risks mitigation and therefore money saving tool in one or another way for different kinds of seismic methods used for oil/gas and mining industries, especially at proof of concept and development stages

Questions?

Thank you for your attention!

Comments?