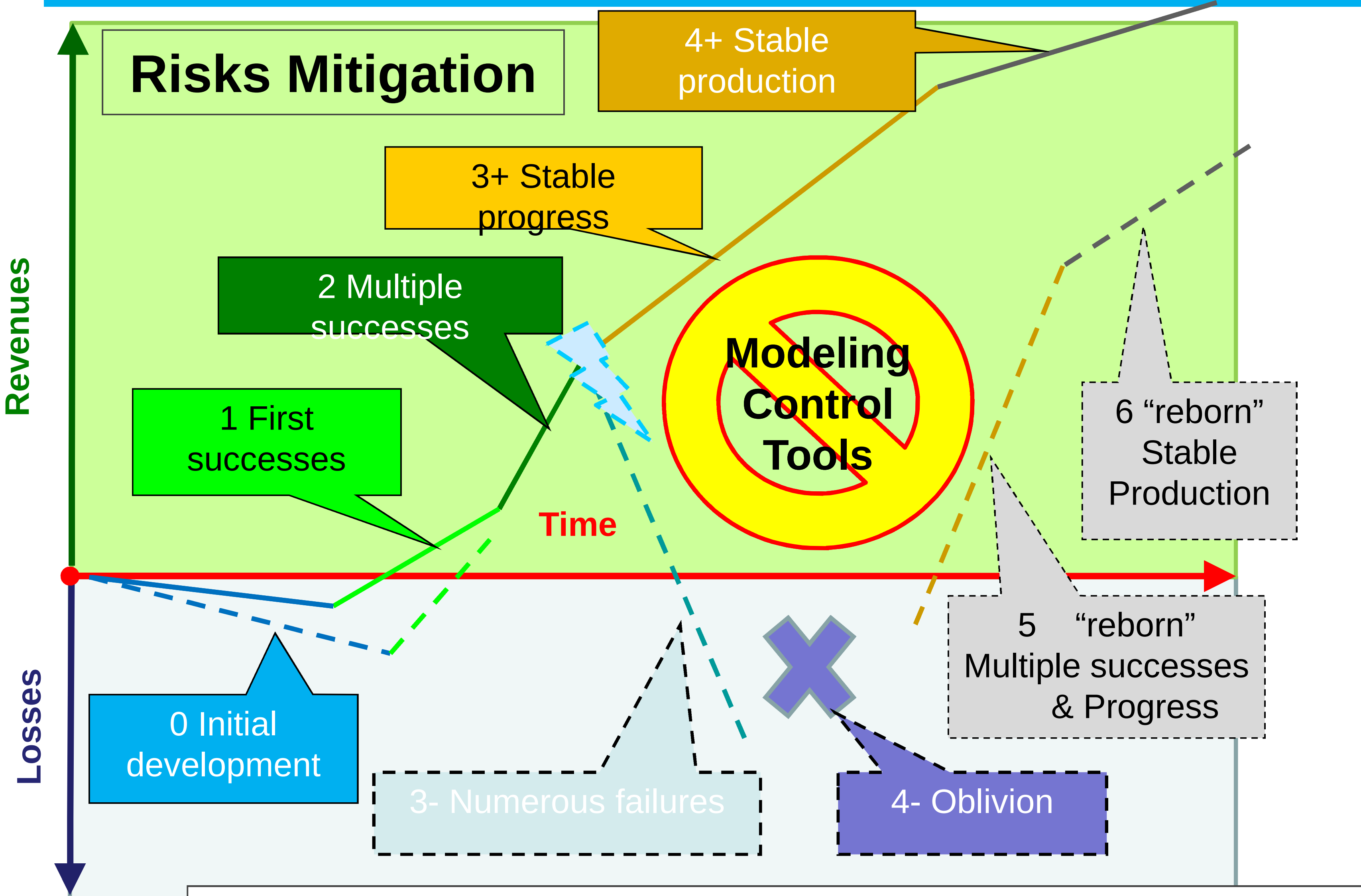
Introduction

to Tesseral Geo Modeling
Solutions for Seismic Survey Planning
and Processing & Interpretation QC

2D & 2.5D-3C & Pro

www.tesseral-geo.com

Why you need Modeling in Seismic? …



Typical Development & Revenues curve
+ *via modeling and testing (cautious)*;
- via trial-and-error method (optimistic)

Tesseral Technologies - is an international company recognized for **developing commercial software packages for accurate wave field modeling based on a digital model of a complex solid body**, the supplementing functionalities allow to carry out **various kinds of pre-stack and post-stack interpretation**. This modeling software uses unique algorithms and intuitive interface. Tesseral Technologies is also engaged in marketing, sales and support of its products. Presently it is a part of ***TETRALE Technologies Inc.*** – a Holding Co for Tesseral Technologies and TetraSeis Inc.

Company's Orientation

The company works on developing of an advanced and convenient tool intended to provide the user with **software suitable for various kinds of geological-geophysical works, ranging from academic researches up to exploration geophysics**. It also can be used as **a learning tool** as well as for **presentation and estimation for geophysical projects**.

General

The main office is located in Calgary, Canada - where we provide software development, support, consultation and distribution.

Company branches:

-***In Ukraine*** (Kiev) - we provide software development, support, consulting, processing and distribution.
- ***In Russia*** (Moscow) - we provide software support and distribution.
- ***In China*** (Beijing) - we provide software support and distribution.

From 1997 to 2000: Tesseral Technologies Inc. concentrated on: *marketing, research and development* of the pilot and Beta-versions of the software package *Tesseral 2-D v.2.5*. The majority of the work was conducted in Calgary Canada and in Kiev Ukraine, under the guidance of the intergovernmental organization - Scientific and Technical Center of Ukraine. Tesseral Technologies Inc. was allocated some governmental grants by the National Research Advice of Canada and the Canadian Agency of the International Development for its engagement in the development of leading edge technology.
From 2001 to this date the third to the fifth versions of the software package were developed. Now the company is actively marketing, selling and supporting the software package *Tesseral-2D* v.6.0, and also is releasing of the fully redeveloped *Tesseral-Pro* – Enterprise variant of the package. *Training and consultations* for software's users is provided. Important feedback from current and potential users was instructed in the development of our software.

Company logotype
TESSERAL means isometric, regular, related to - or similar to, tessera - four, to have four corners, to consist of four parts, a part of mosaic or puzzle.

Presently Tesseral Technologies Inc. employs more than 15 highly qualified geophysicists, programmers and marketing professionals

Our clients

North America - 20

South America - 5

Other - 5

Euro-Asia - 25

Europe - 10

Asia - 25

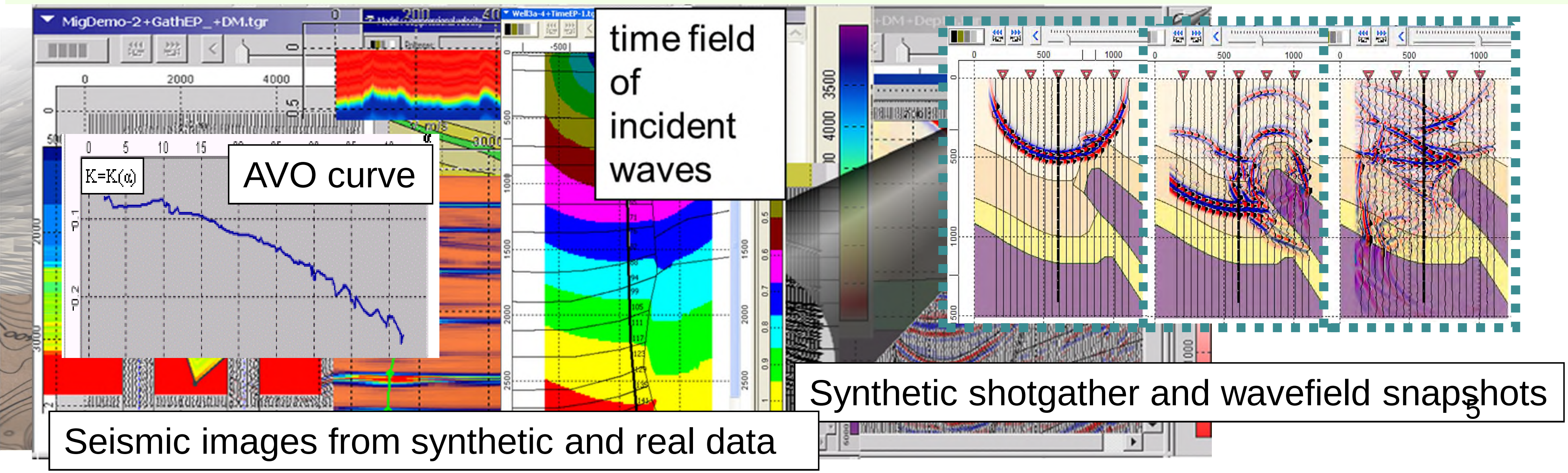
What you can do with the Seismic Modeling

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 :

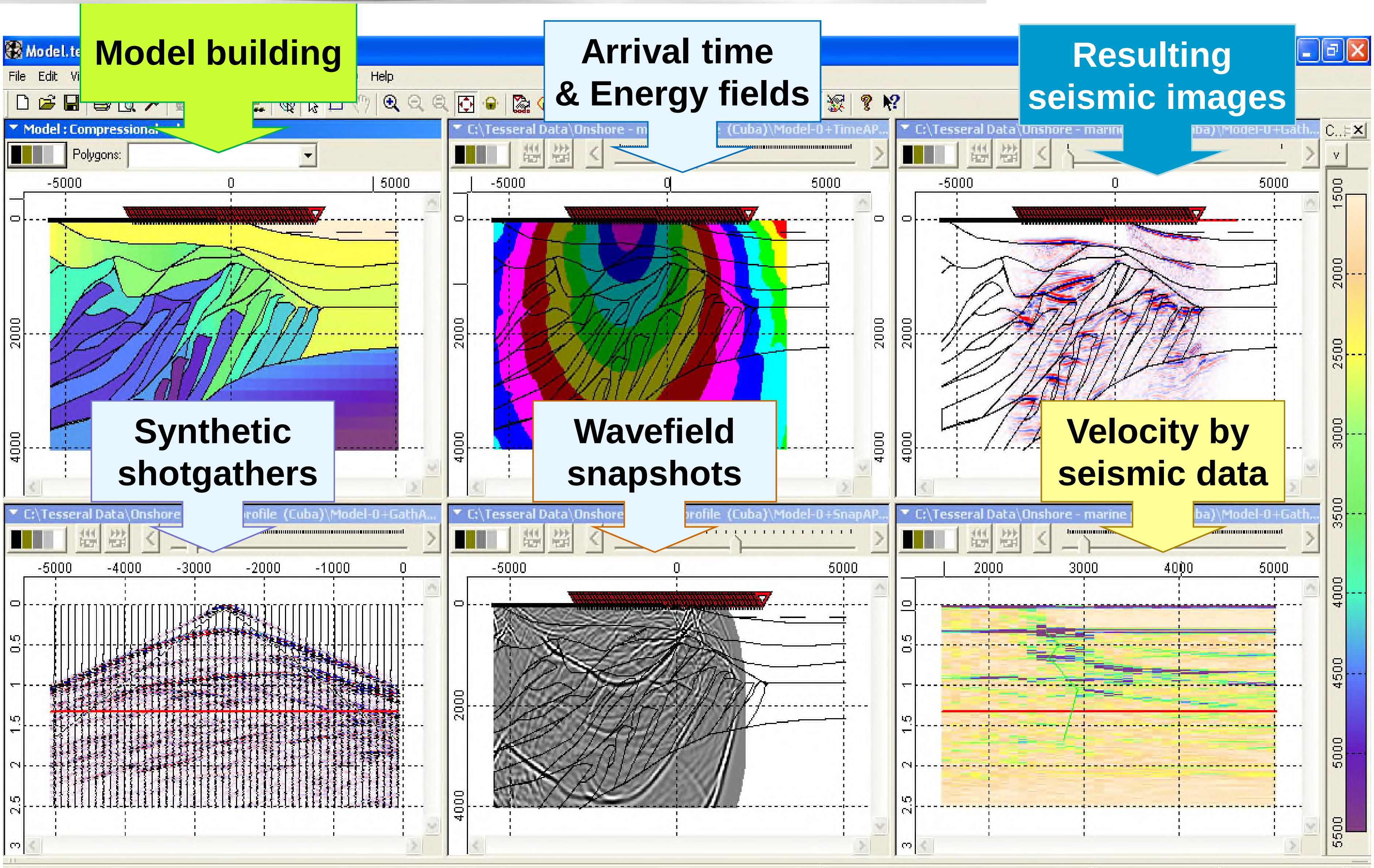
- Rough topography, various near-surface conditions, surface waves, refractions, etc
- Thin-layered models that are build on the basis of well-log data
- Complex anisotropy : transversally isotropic media and fracturing systems
- Porous fluid-saturated media (Gasman approximation)
- Q-factor modeling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

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

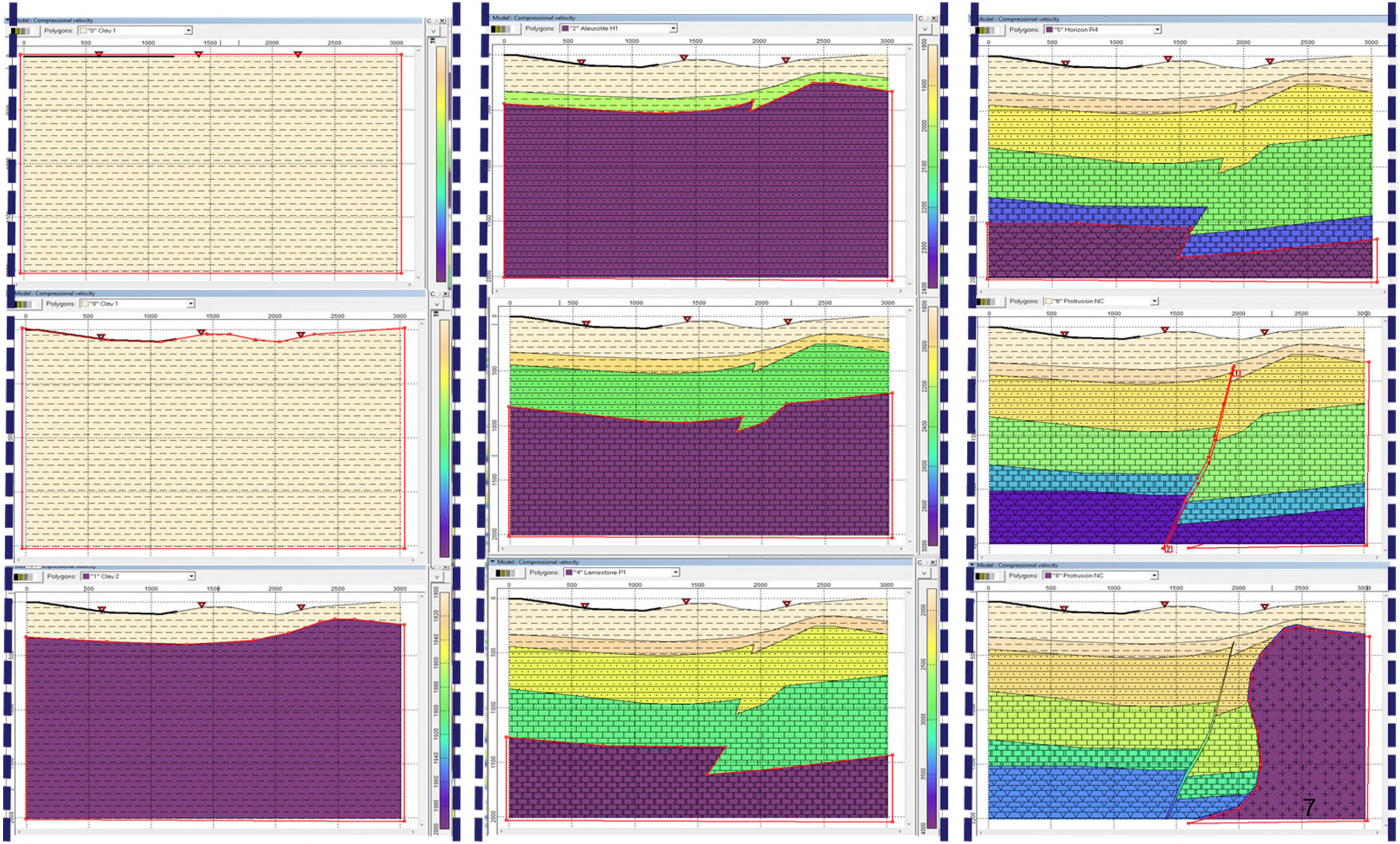
- ✓ Building of velocity model by seismic data
- ✓ Seismic Imaging : post-stack, pre-stack depth and time migrations for surface and VSP.
- ✓ AVO-modeling for anisotropic, porous, fluid-saturated, viscoelastic, thin-layered media.



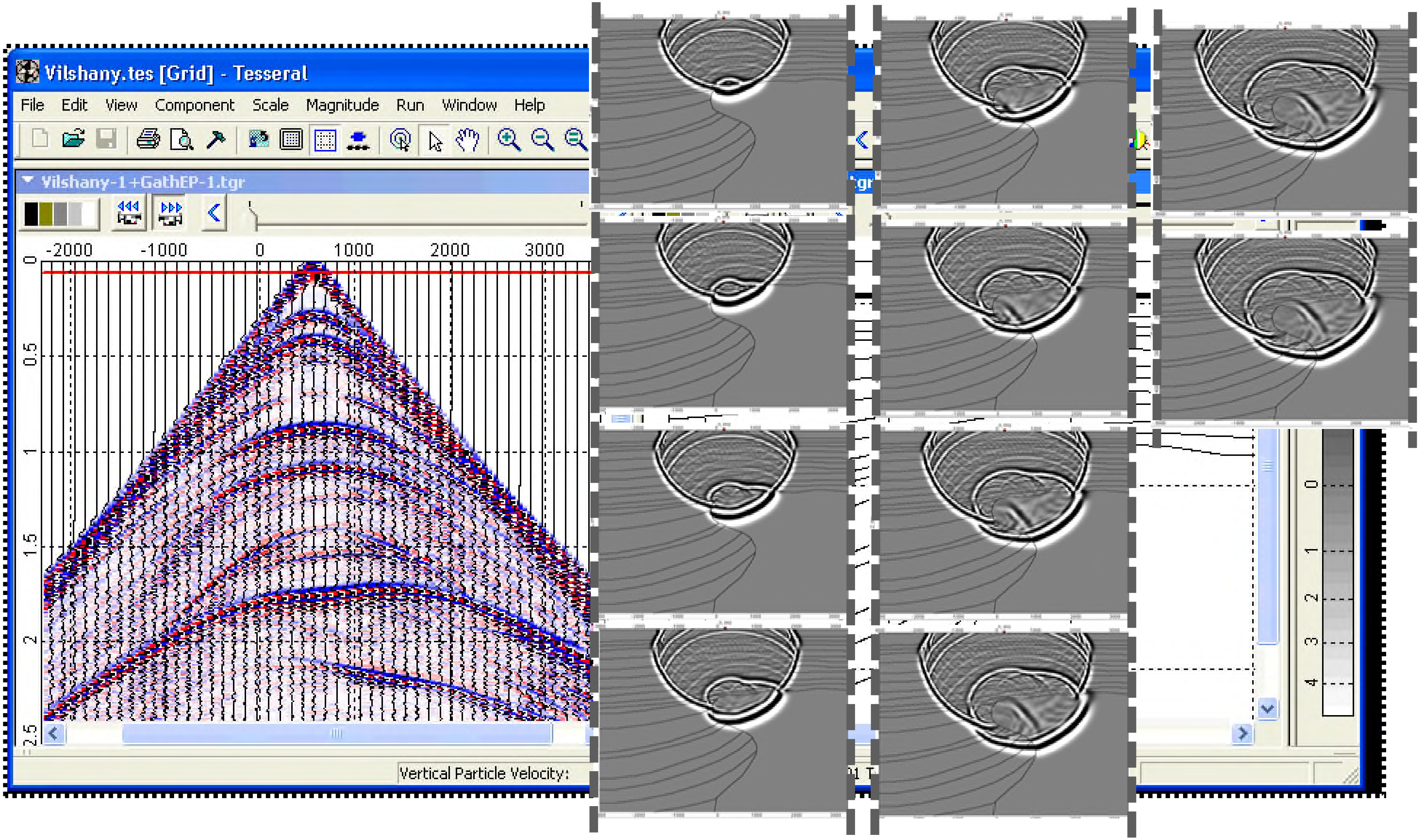
Interactions with the package

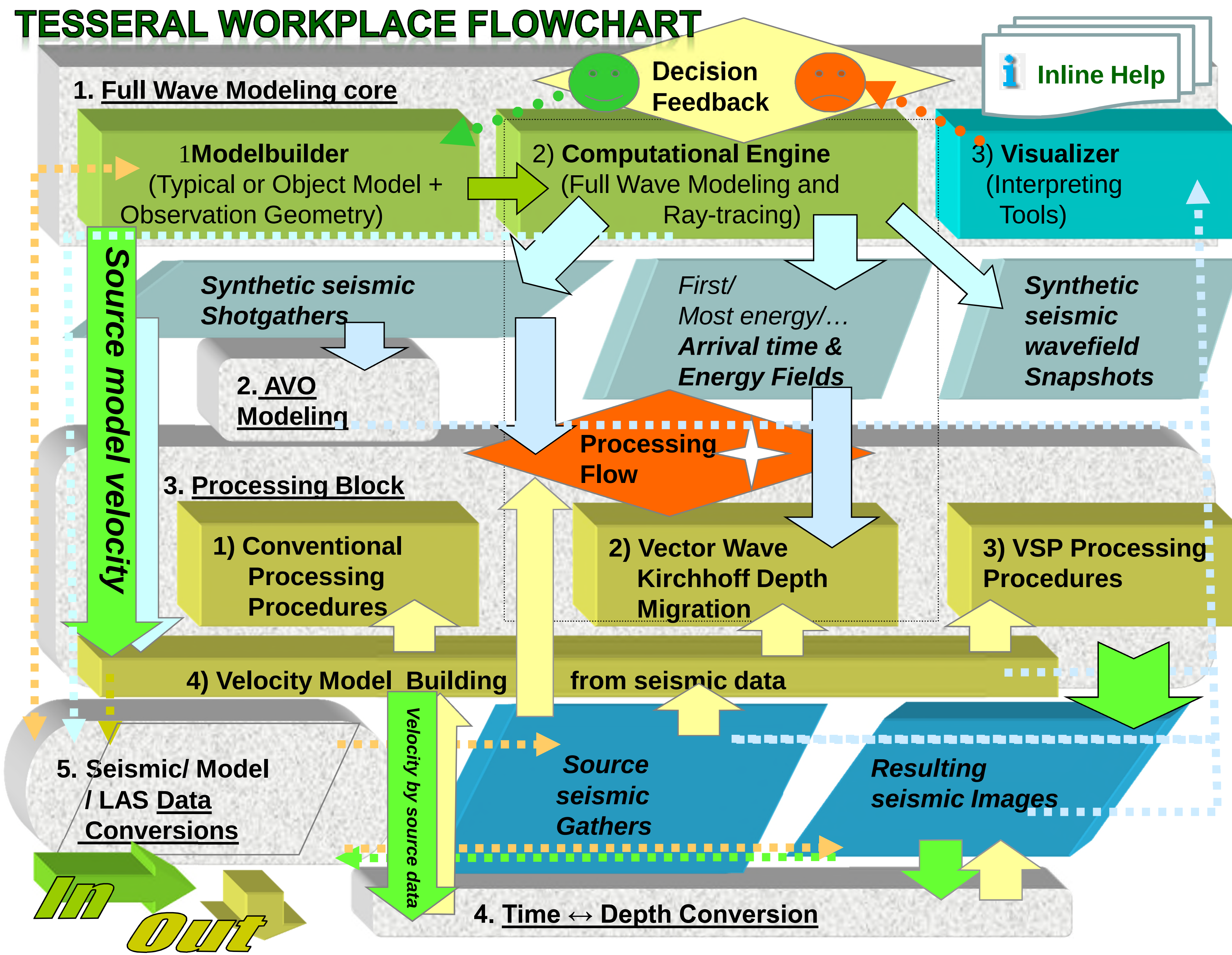


Modelbuilding as a set of overlapping polygons



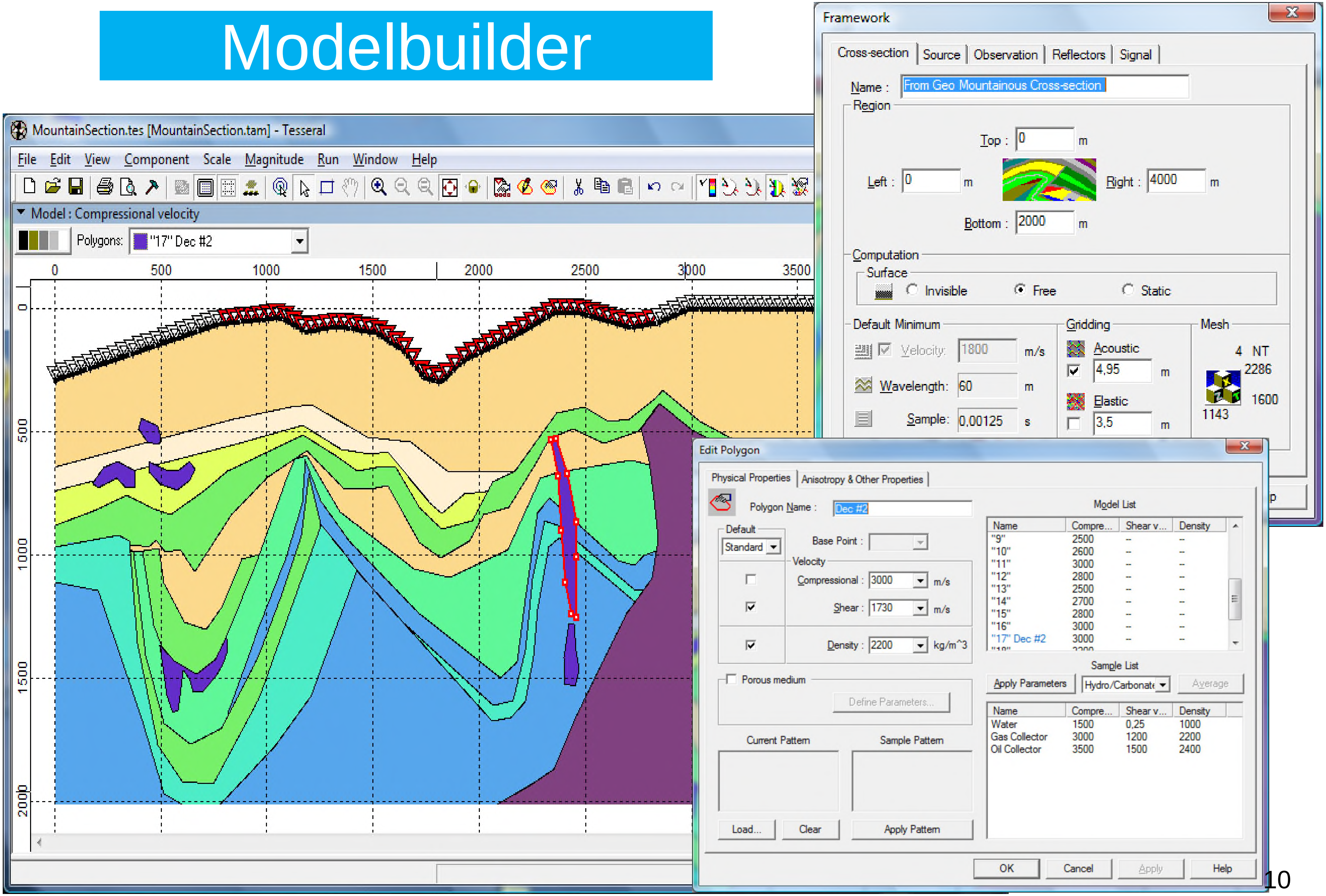
Tracing waves: “Salt dome cornice model”





TESSERAL WORKPLACE FLOWCHART
Decision Feedback
Inline Help
1. Full Wave Modeling core
1Modelbuilder (Typical or Object Model + Observation Geometry)
2) Computational Engine (Full Wave Modeling and Ray-tracing)
3) Visualizer (Interpreting Tools)
Source model velocity
Synthetic seismic Shotgathers
First/ Most energy/… Arrival time & Energy Fields
Synthetic seismic wavefield Snapshots
2. AVO Modeling
Processing Flow
3. Processing Block
1) Conventional Processing Procedures
2) Vector Wave Kirchhoff Depth Migration
3) VSP Processing Procedures
4) Velocity Model Building from seismic data
5. Seismic/ Model / LAS Data Conversions
Velocity by source data
Source seismic Gathers
Resulting seismic Images
In
Out
4. Time ↔ Depth Conversion

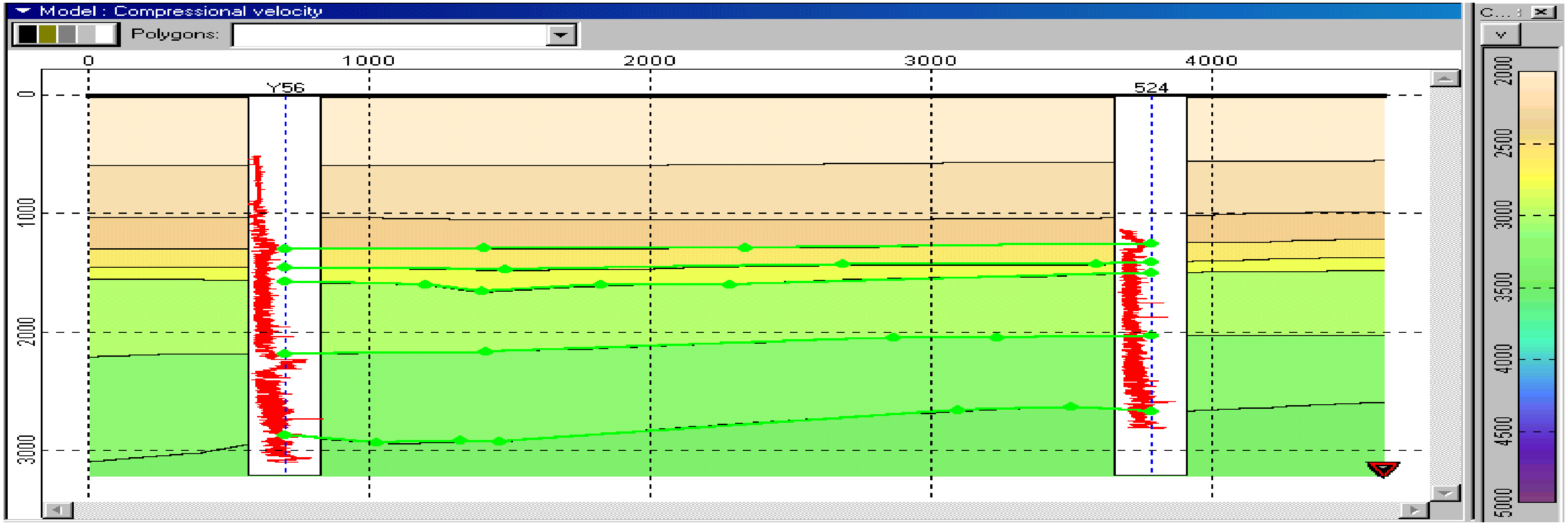
Modelbuilder

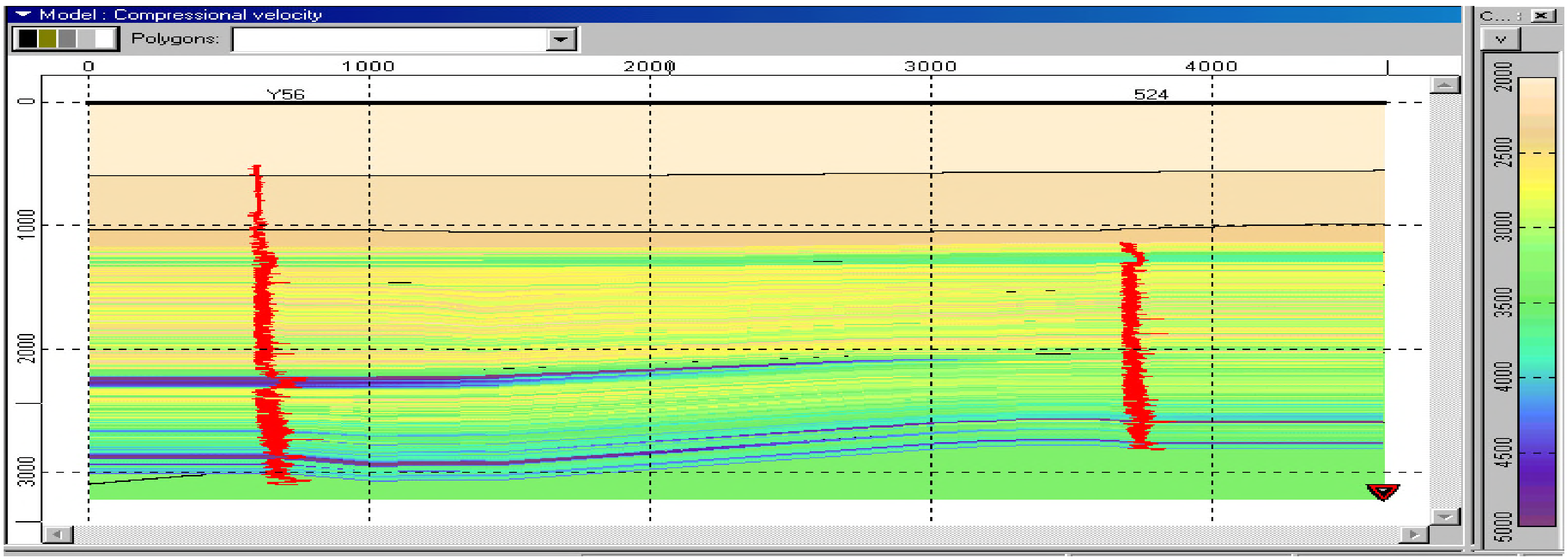


Name	Compre...	Shear v...	Density
"9"	2500	-	-
"10"	2600	-	-
"11"	3000	-	-
"12"	2800	-	-
"13"	2500	-	-
"14"	2700	-	-
"15"	2800	-	-
"16"	3000	-	-
"17" Dec #2	3000	-	-

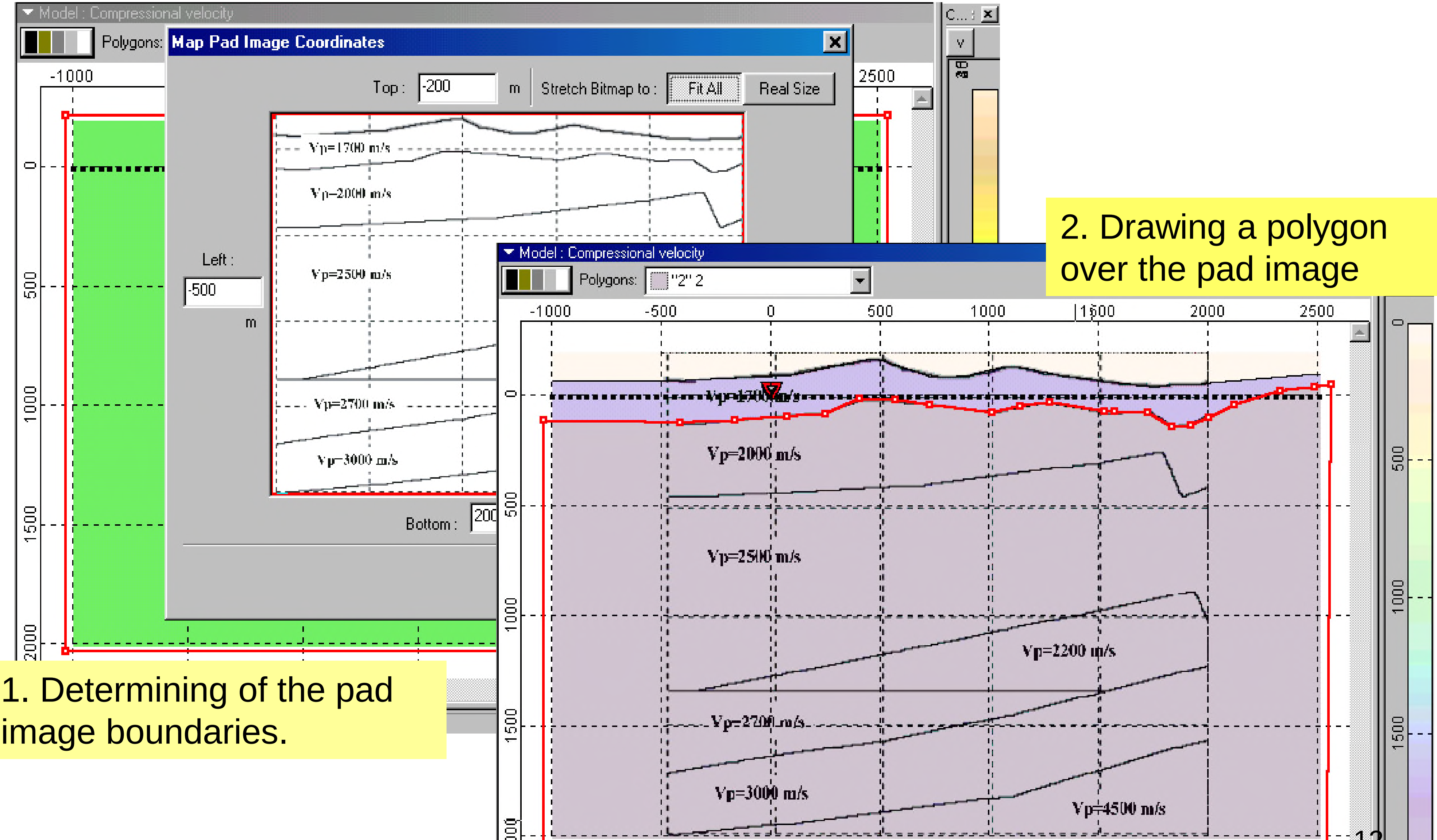
Name	Compre...	Shear v...	Density
Water	1500	0,25	1000
Gas Collector	3000	1200	2200
Oil Collector	3500	1500	2400

✓ Creation of thin-layered model by well-logs (LAS files





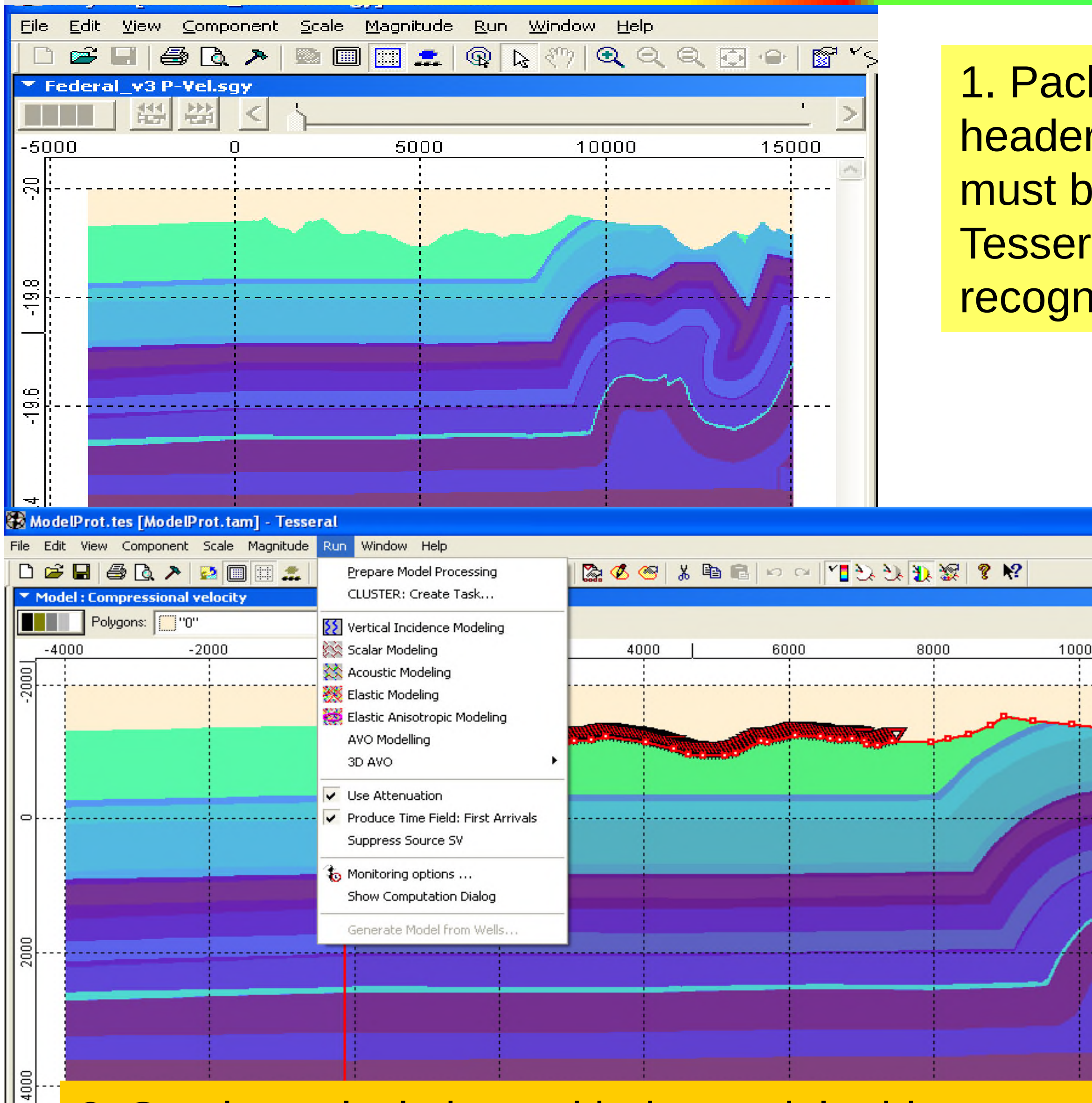
✓ Modelbuilding using raster image



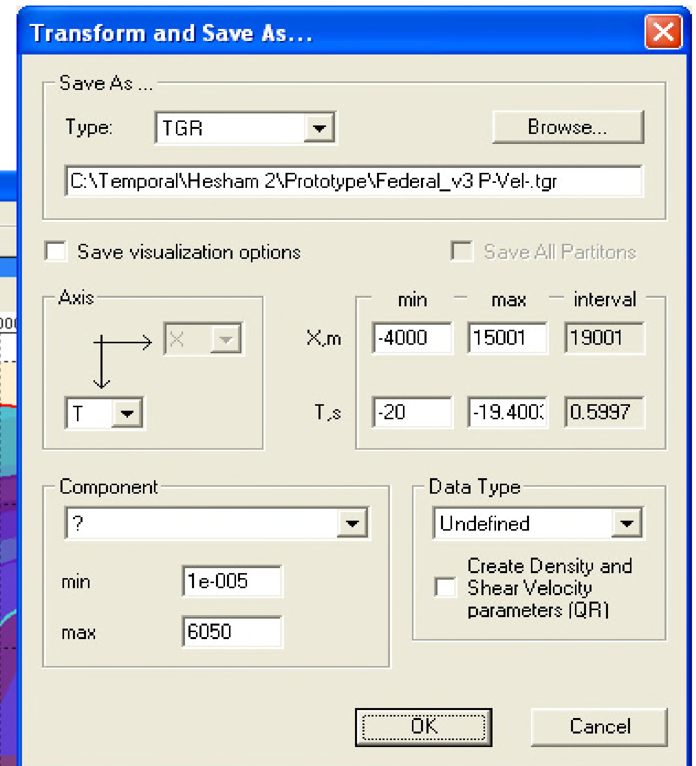
1. Determining of the pad image boundaries.

2. Drawing a polygon over the pad image

✓ Modelbuilding using data in grid formats

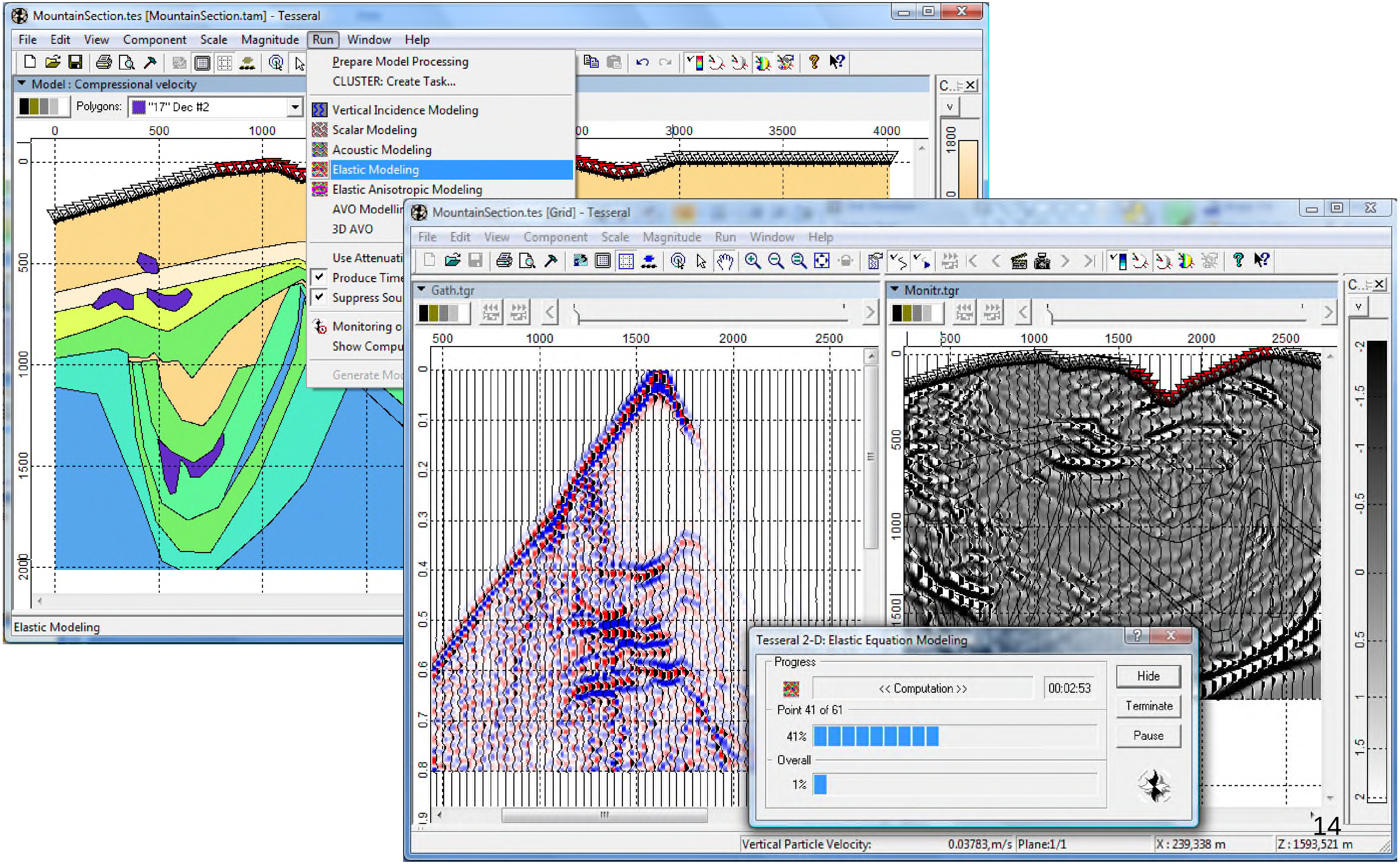


1. Package interpret SEGY file headers and data as it is. This file must be converted into internal Tesseral grid format and be recognized as a model grid file.



2. Starting calculations with the model grid

Modeling Engine…



(1) $$\frac{\partial^2 U(x,t)}{\partial t^2} = b(x)\frac{\partial}{\partial x}\left(\frac{\partial \tau(x,t)}{\partial t}\right)$$

…speed & precision of calculations

Formulation

1.Immediate central difference (2st order) : the *calculated value* depends only on **a difference between the variables in adjacent points**;

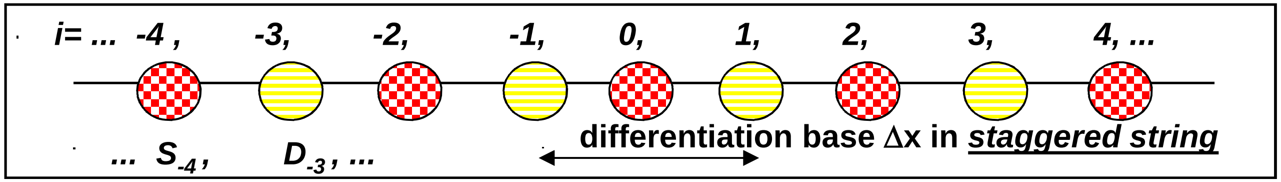
2.Staggered string: *the dynamic values* **are defined in each direction** of the Cartesian co-ordinate system **at every point but one (*staggered grid(s)*)**.

identical

Scheme

Let consider two functions ***S*** and ***D*** ***(stress - displacement notation)*** on a line with discrete points ***i*** = ..., -2, -1, 0, 1, 2, ... ***S*** and ***D*** – are defined in ***even*** and ***odd*** positions correspondingly.

(1.1)



identical

Discrete form

There are defined **immediate central difference operations**:

Δt is a value ascribed to one step **k**=0,1,2,...of computations: **t=k* Δt**

(2) $$k = 0,1,2,\ldots \frac{[0]}{[1]}\begin{cases} i = \ldots,-2,0,2,\ldots \\ i = \ldots,-1,1,\ldots \end{cases} \quad \begin{cases}\tau_i \leftarrow \tau_i + a_i\frac{\Delta t}{\Delta x}(U_{i+1}+U_{i-1})\end{cases} \quad \begin{cases}U_i \leftarrow U_i + b_i\frac{\Delta t}{\Delta x}(\tau_{i+1}+\tau_{i-1})\end{cases}$$

identical

– In the integral form (1) is written as:

(2.1) $$\tau(x,t) = a(x)\int_0^t \frac{\partial U(x,t)}{\partial x}dt$$
$$U(x,t) = b(x)\int_0^t \frac{\partial \tau(x,t)}{\partial x}dt$$
$$where \quad \Delta x, \Delta t \to 0$$

Integral form

identical

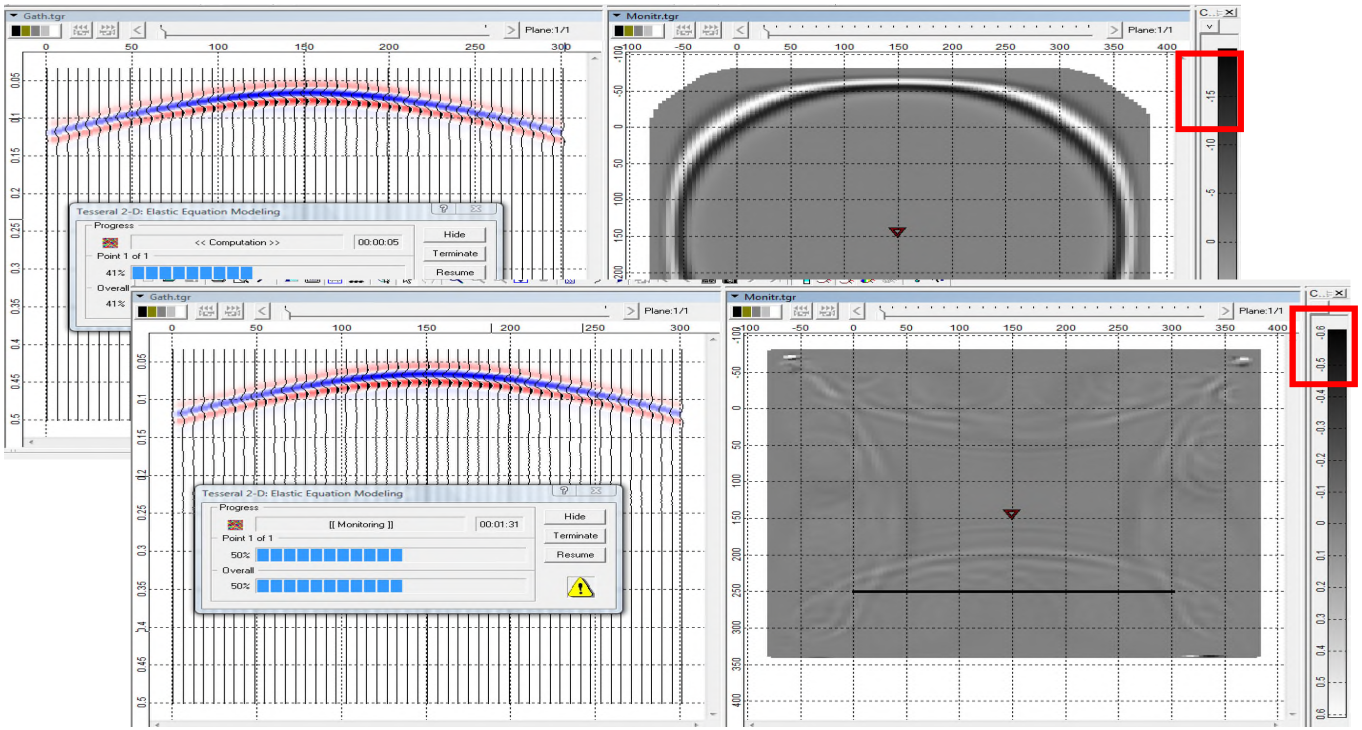
Or when twice differentiated by *t*:

(2.2) $$\frac{\partial^2 \tau(x,t)}{\partial t^2} = a(x)\frac{\partial}{\partial x}\left(\frac{\partial U(x,t)}{\partial t}\right)$$
$$\frac{\partial^2 U(x,t)}{\partial t^2} = b(x)\frac{\partial}{\partial x}\left(\frac{\partial \tau(x,t)}{\partial t}\right)$$

identical

Differential form

…enhancements

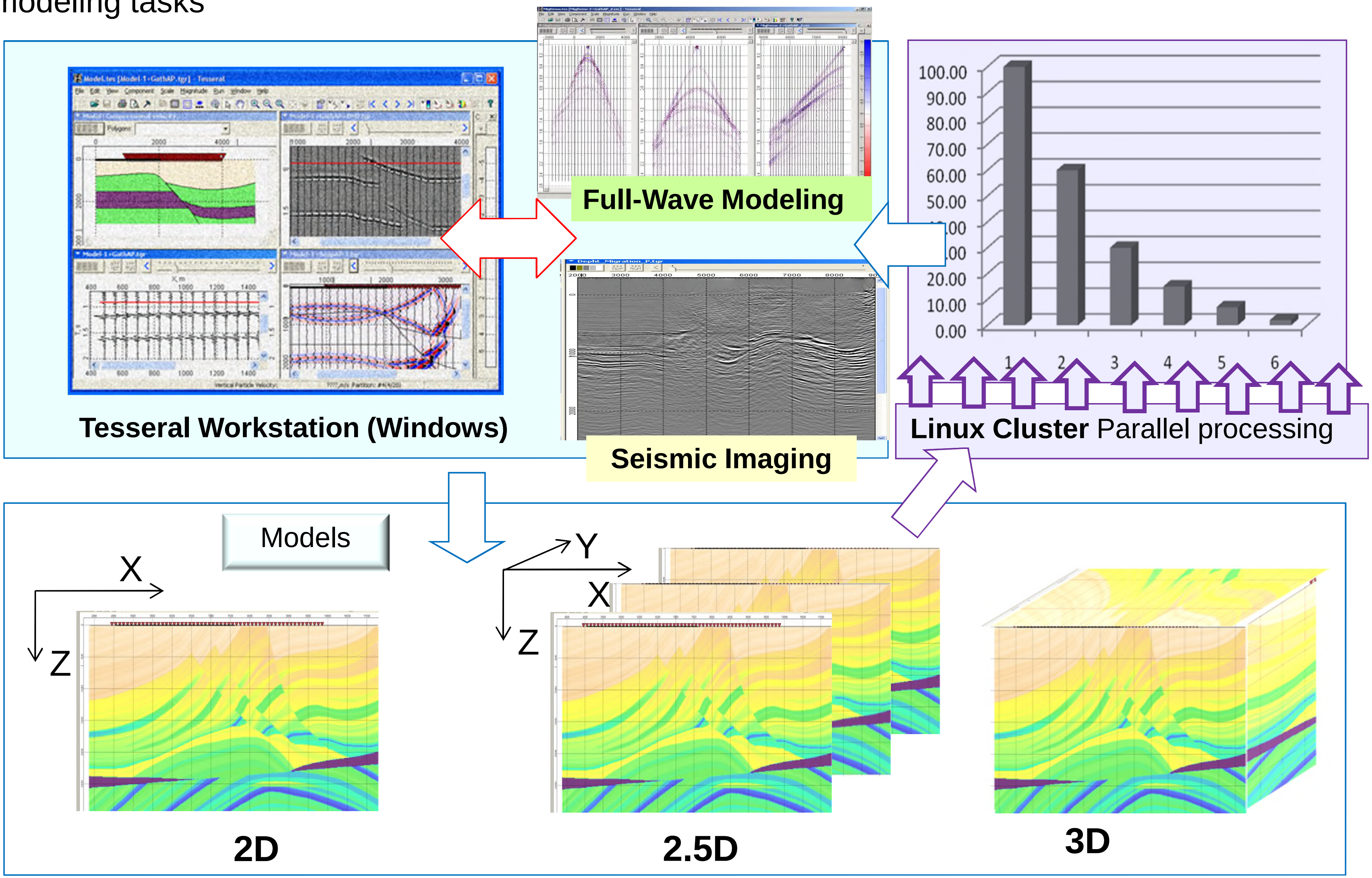


✓ **Absorption scheme** of the **artificial reflections (less than 1%** of incoming to the border signal) from the grid borders allows to have **narrow absorbing margins** and use **much less computation resources** for this purpose.

✓ and many more …

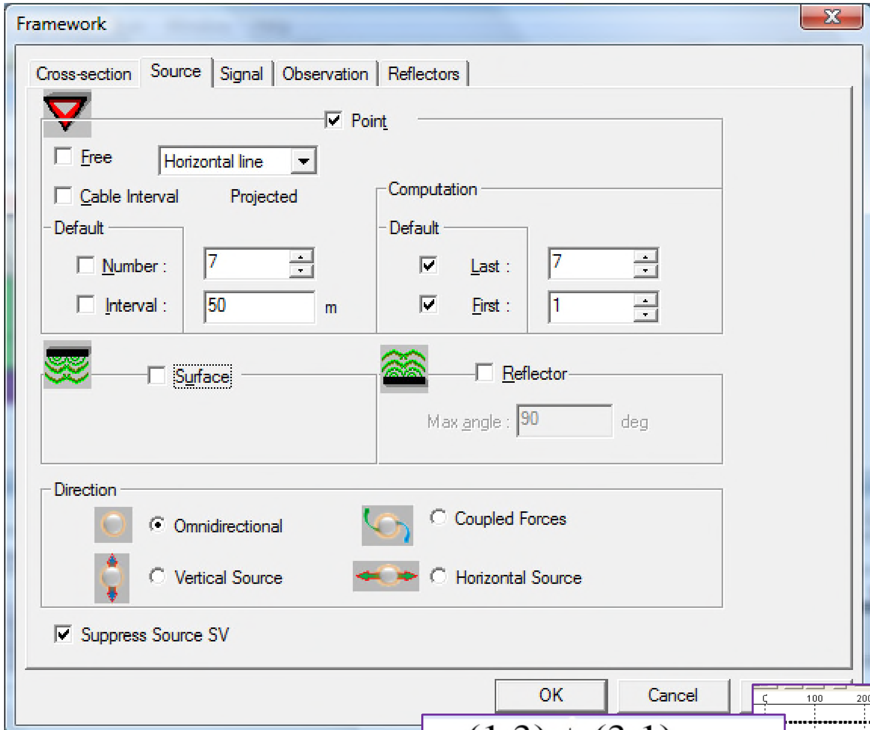
Cluster and Network ***Tesseral Parallel Computational Engines***

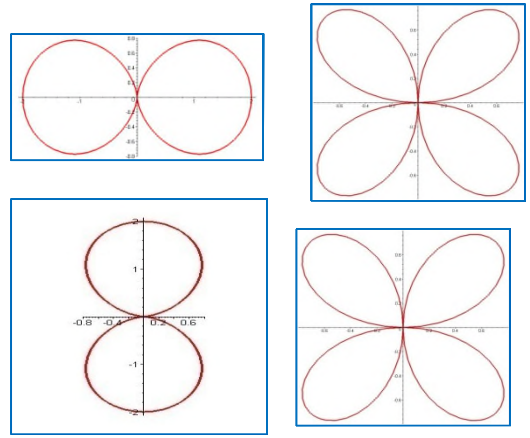
… under LINUX cluster or Windows network/cluster multi-core and multi-GPU systems may be used to multiple times accelerate huge calculation volumes needed for production-scale full-wave modeling tasks

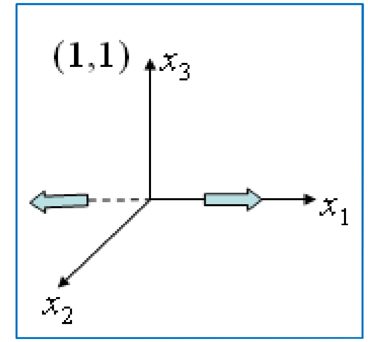


What sources are used?

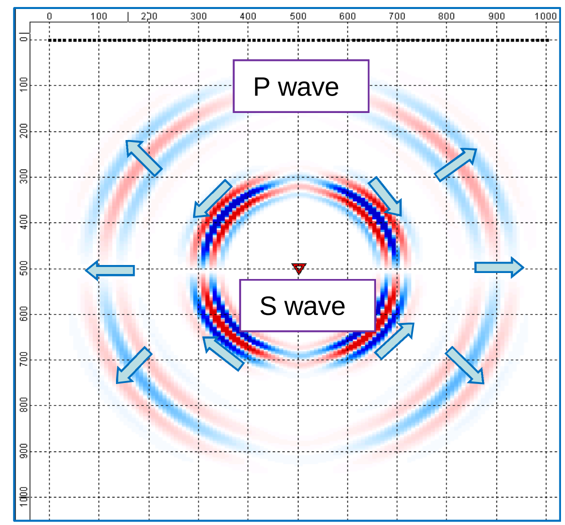
Some special source types



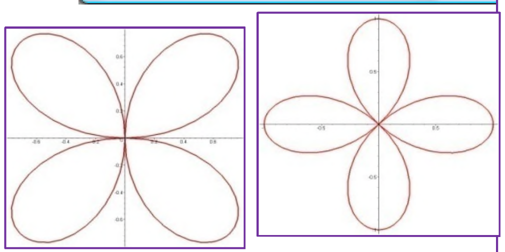


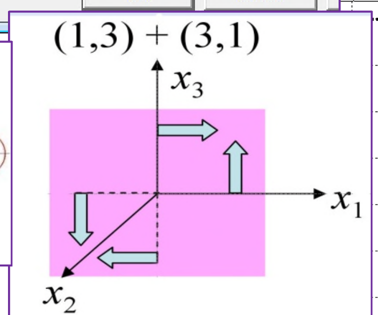


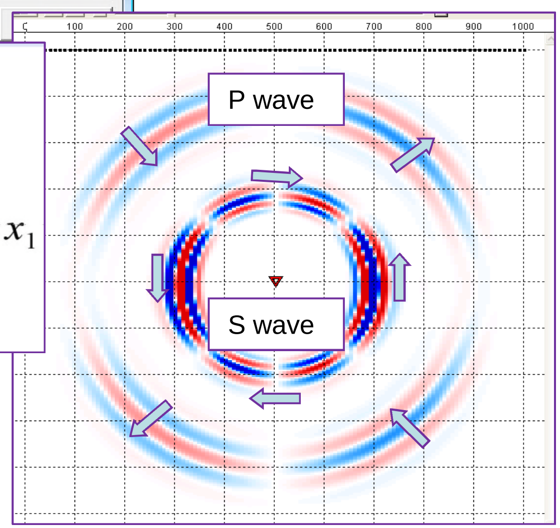
Compensated linear vector dipole



Vertical component of displacement vector

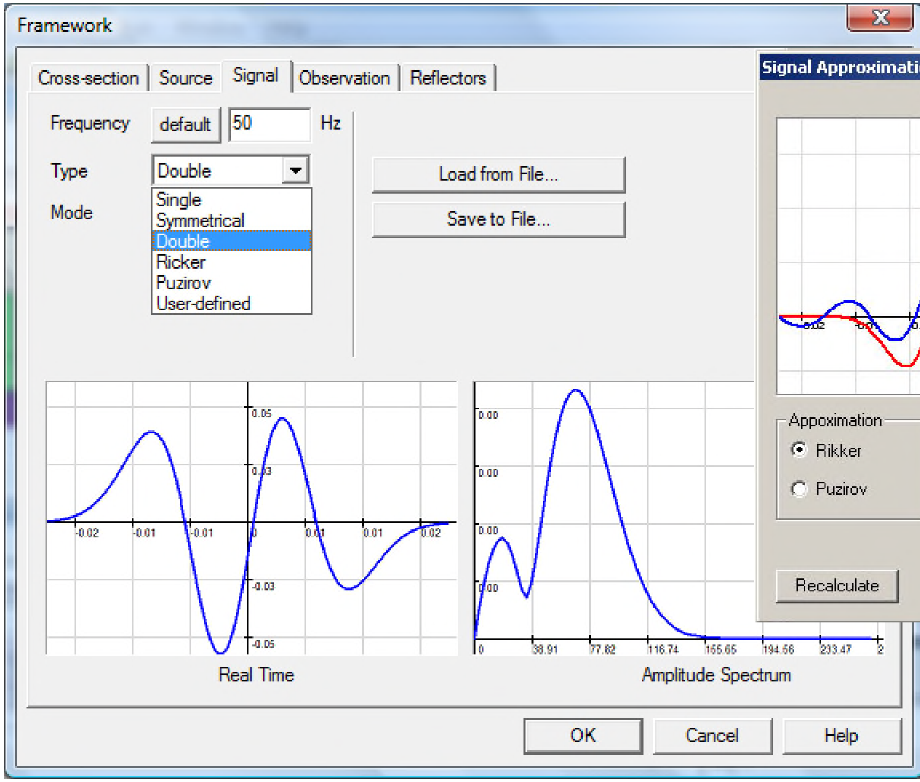




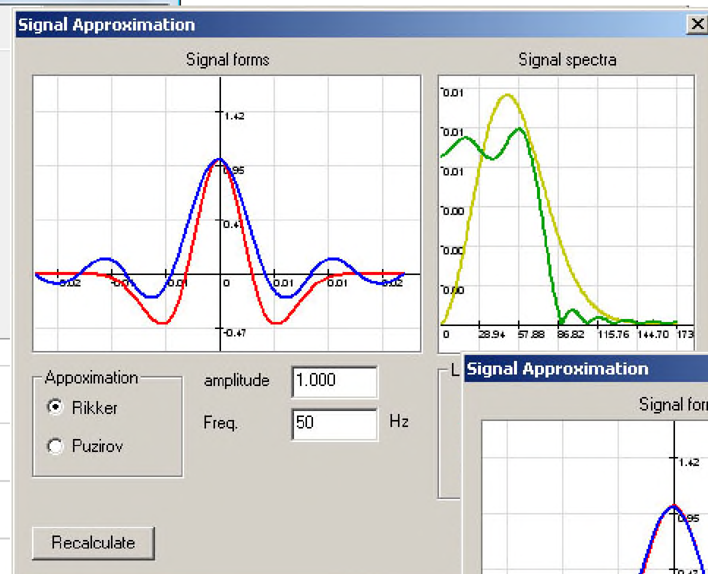


Double couple

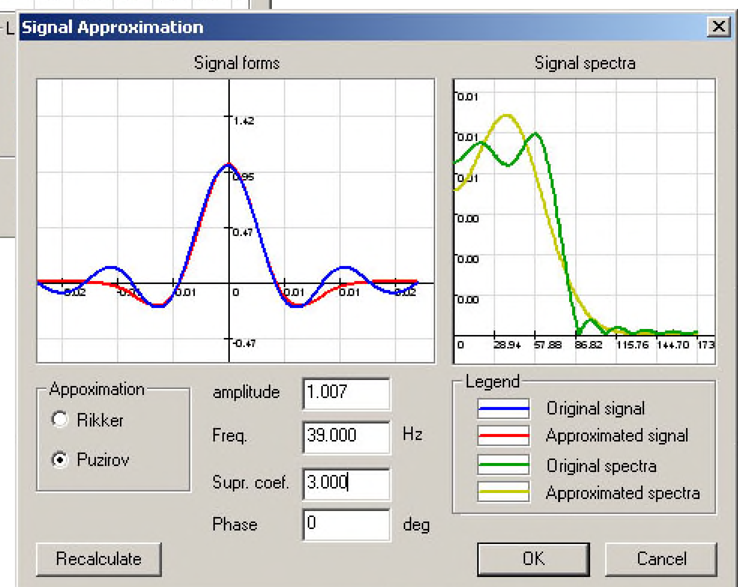
What wavelets are used?



User custom wavelet in tabular form



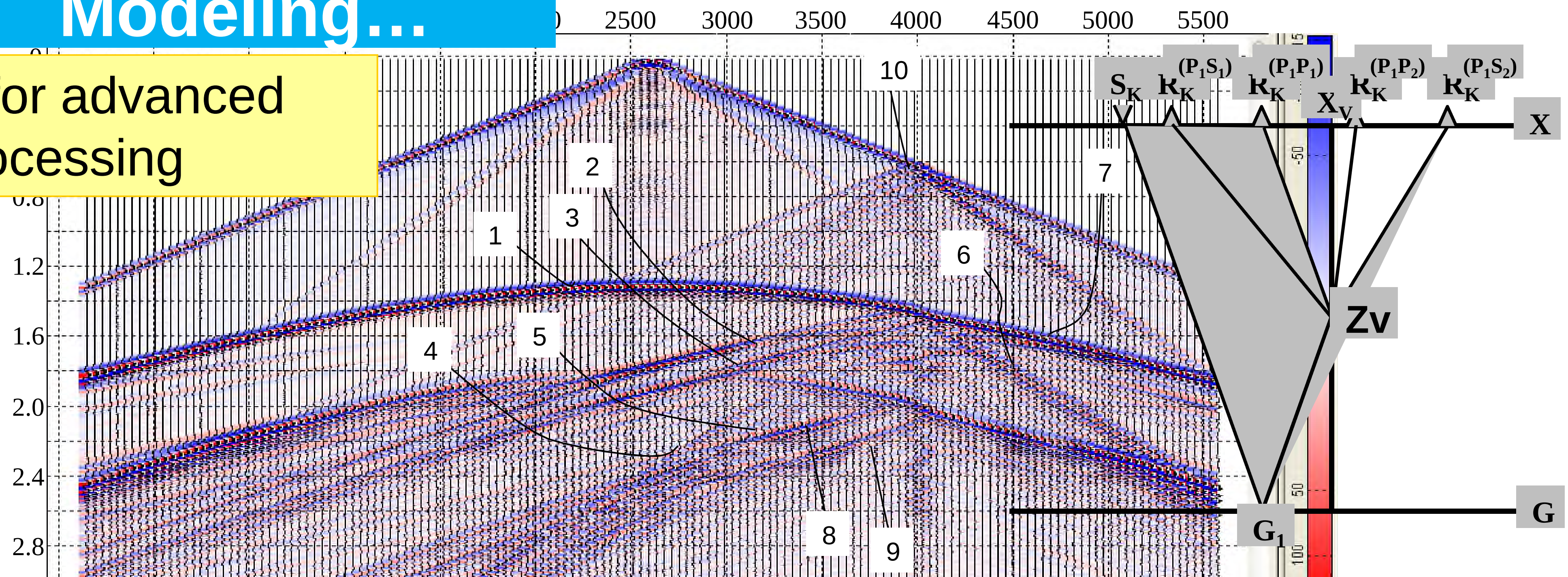
Approximation of user custom wavelet with Rikker wavelet



Approximation of user custom wavelet with Puzirov wavelet

Modeling…

…for advanced processing

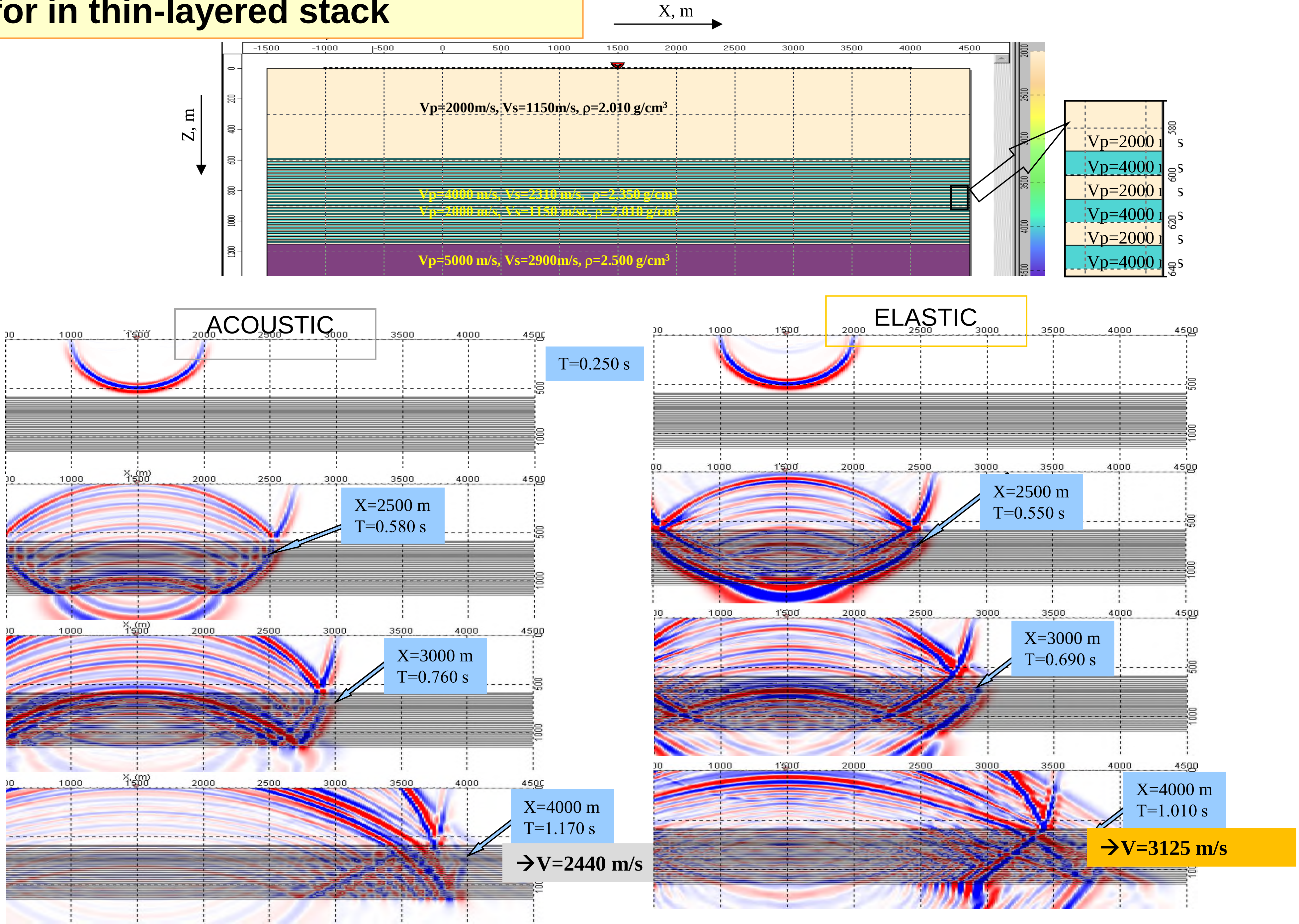


Synthetic shotgather, which demonstrates duplex waves originated on vertical layer 80 m thickness (previous slide), at coordinate X=4000m. **Legend:**

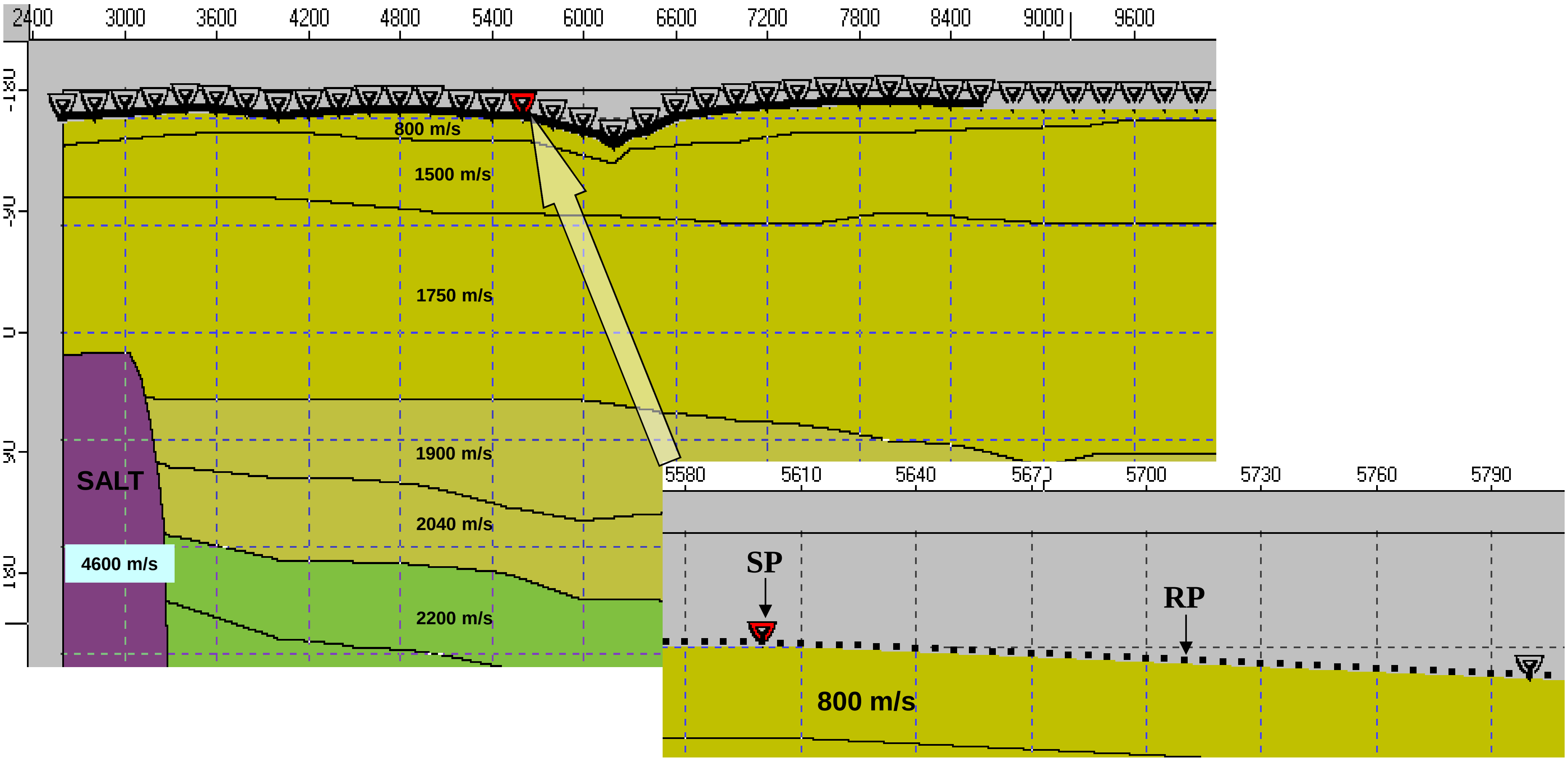
Scheme of origin of reflected and transmitted waves on thin vertical layer

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 compressional wave.

…for in thin-layered stack

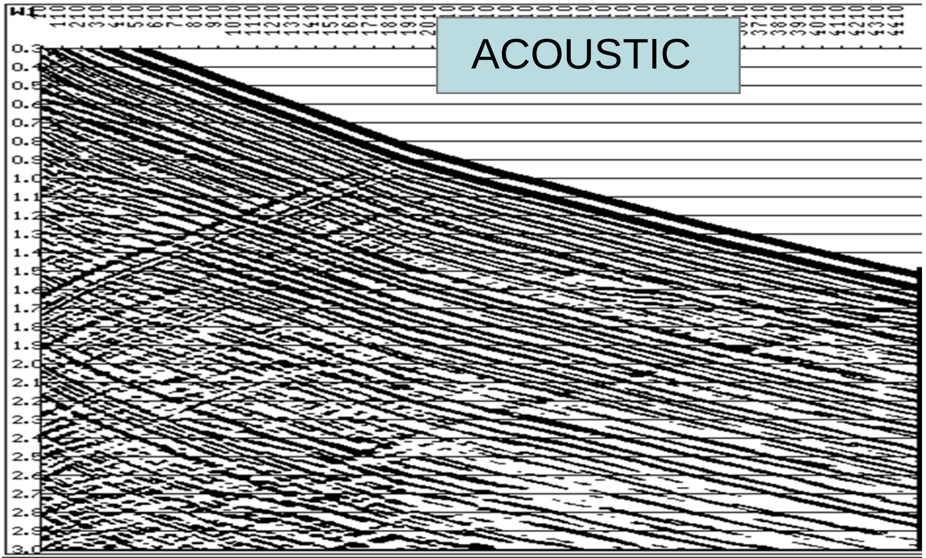


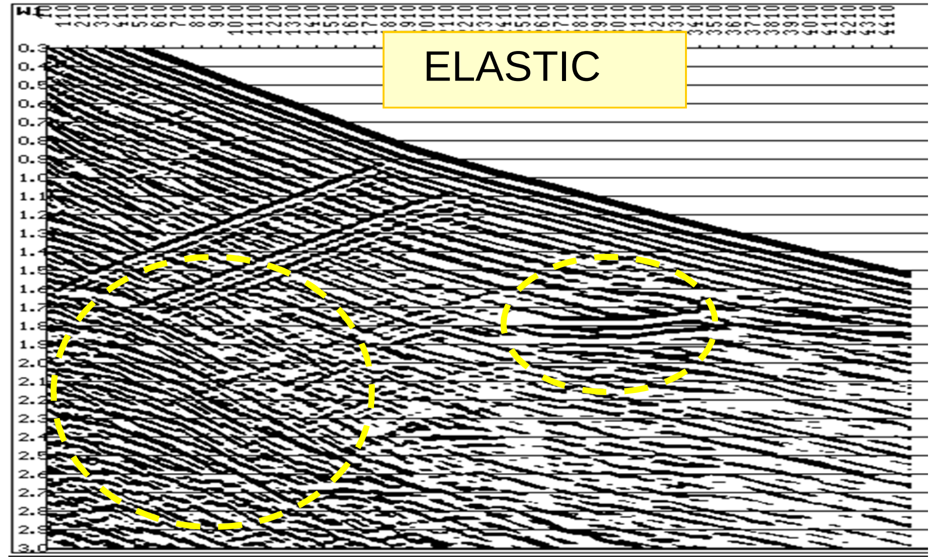
…effect of LVZ surface waves and uneven surface



Detailed model of low velocity zone (LVZ)

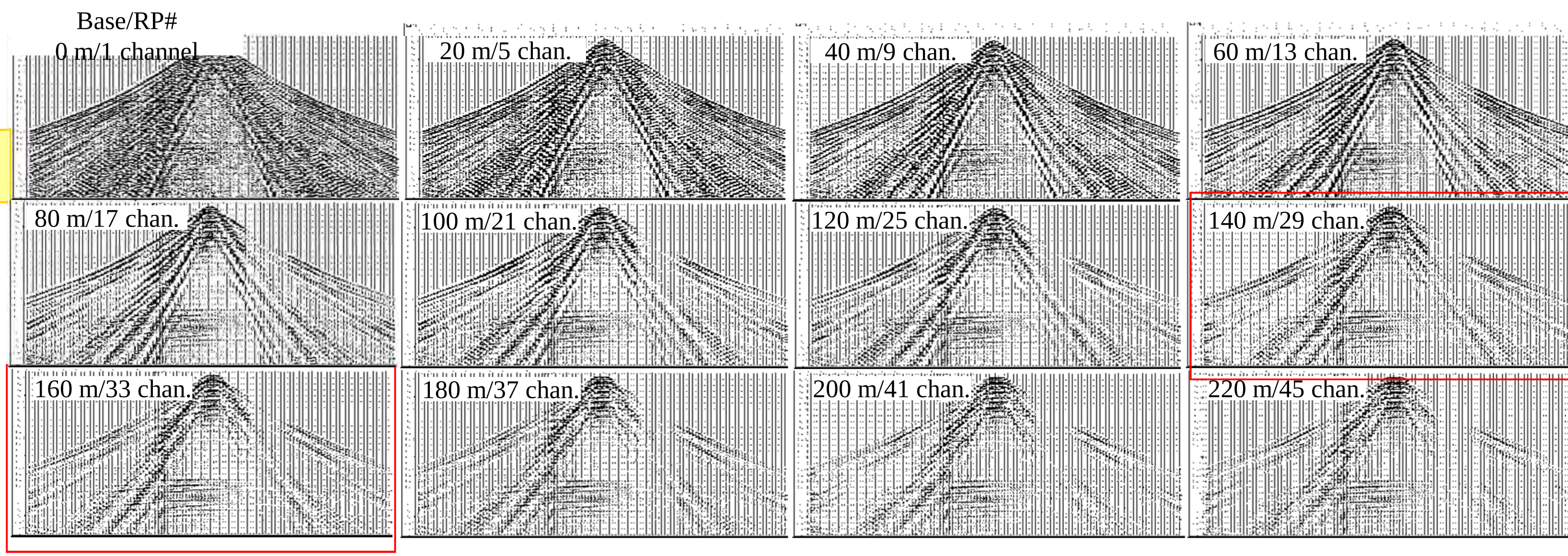
…effect of surface wave Z-component in VSP data



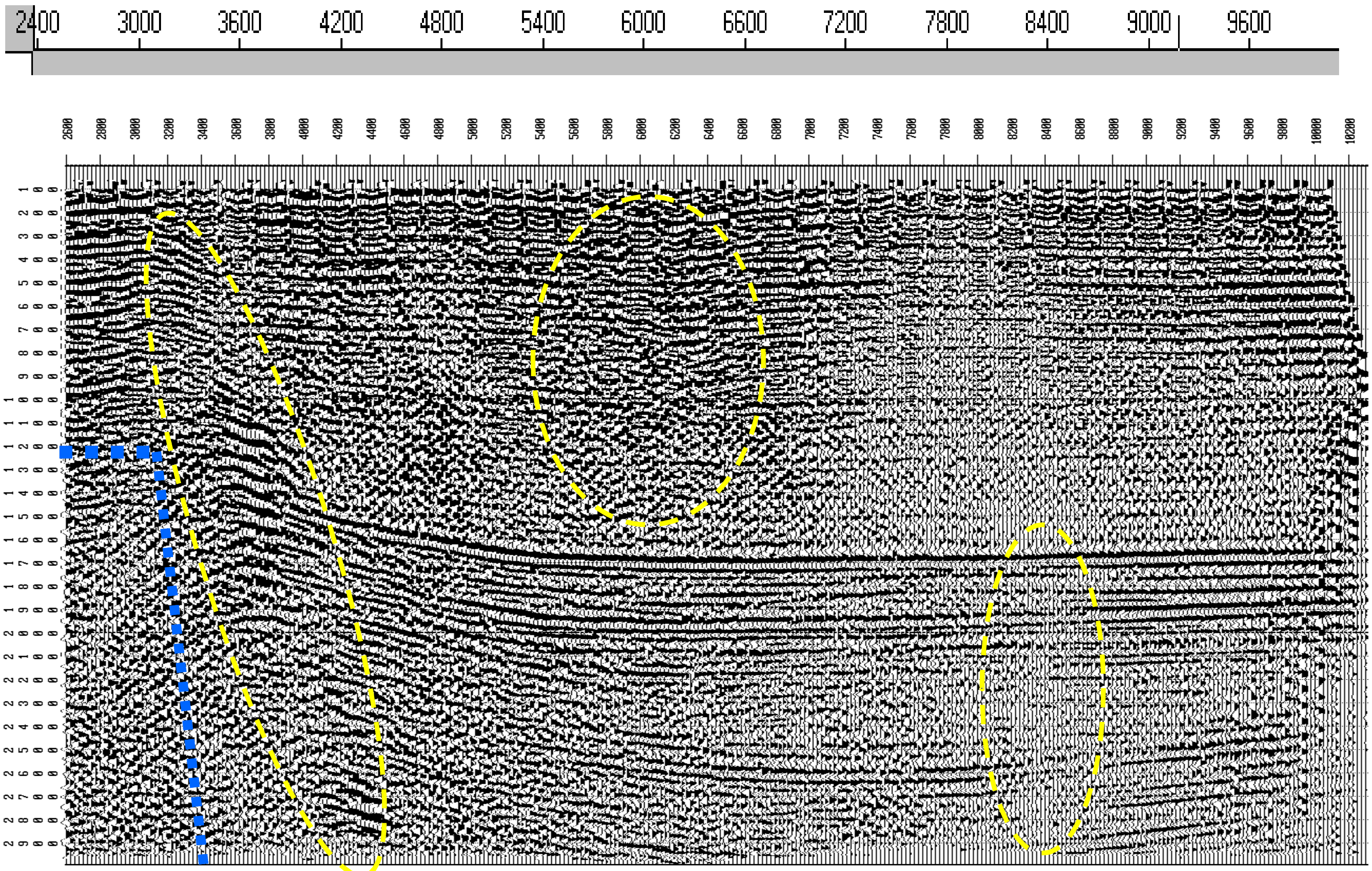


…effect of surface wave Z-component in Surface seismic data

ELASTIC



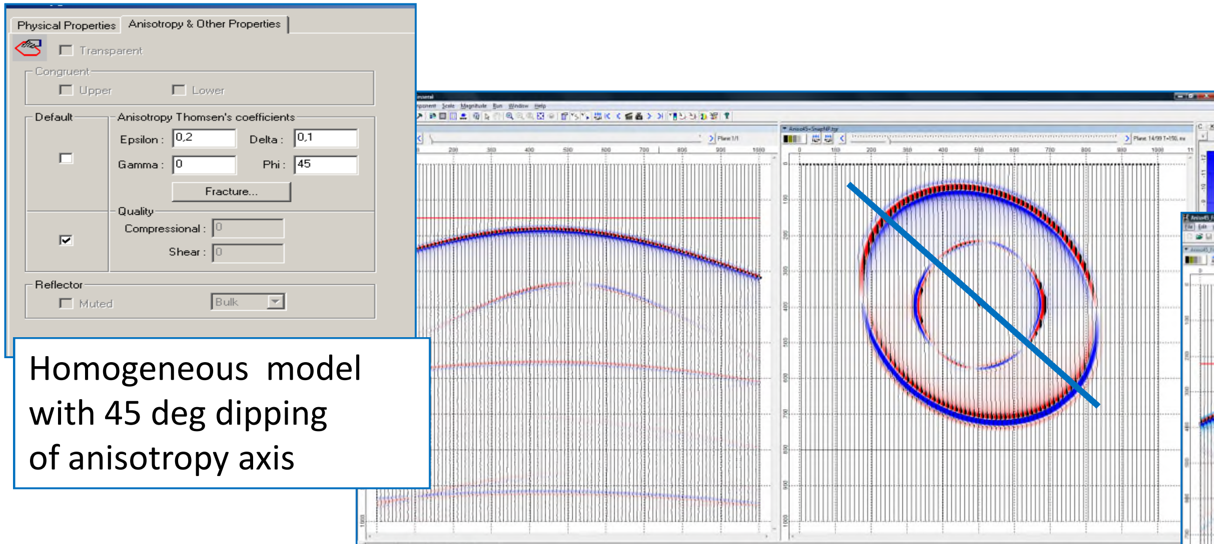
…effect of LVZ surface waves and uneven surface on CDP data imaging



Synthetic time cross-section. The receiver grouping base 150 m
With ellipse are shown zones of seismic image distortions caused by LVZ conditions, which erroneously could be interpreted on real data.

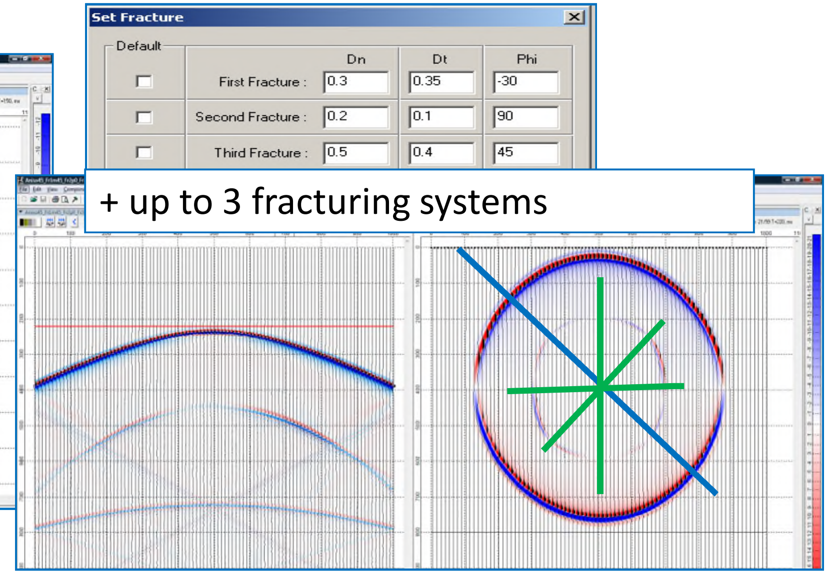
…TTI-anisotropy and fracturing

Entering of TTI-anisotropy parameters



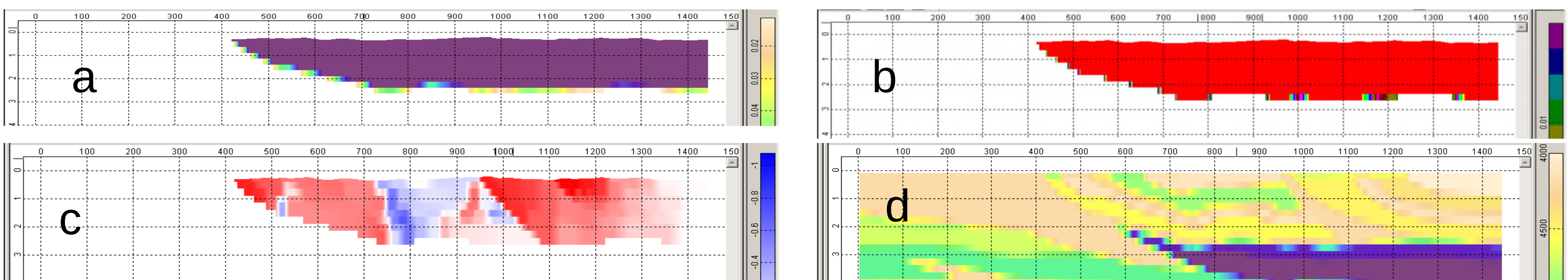
Homogeneous model with 45 deg dipping of anisotropy axis

Entering of fracturing parameters



\+ up to 3 fracturing systems

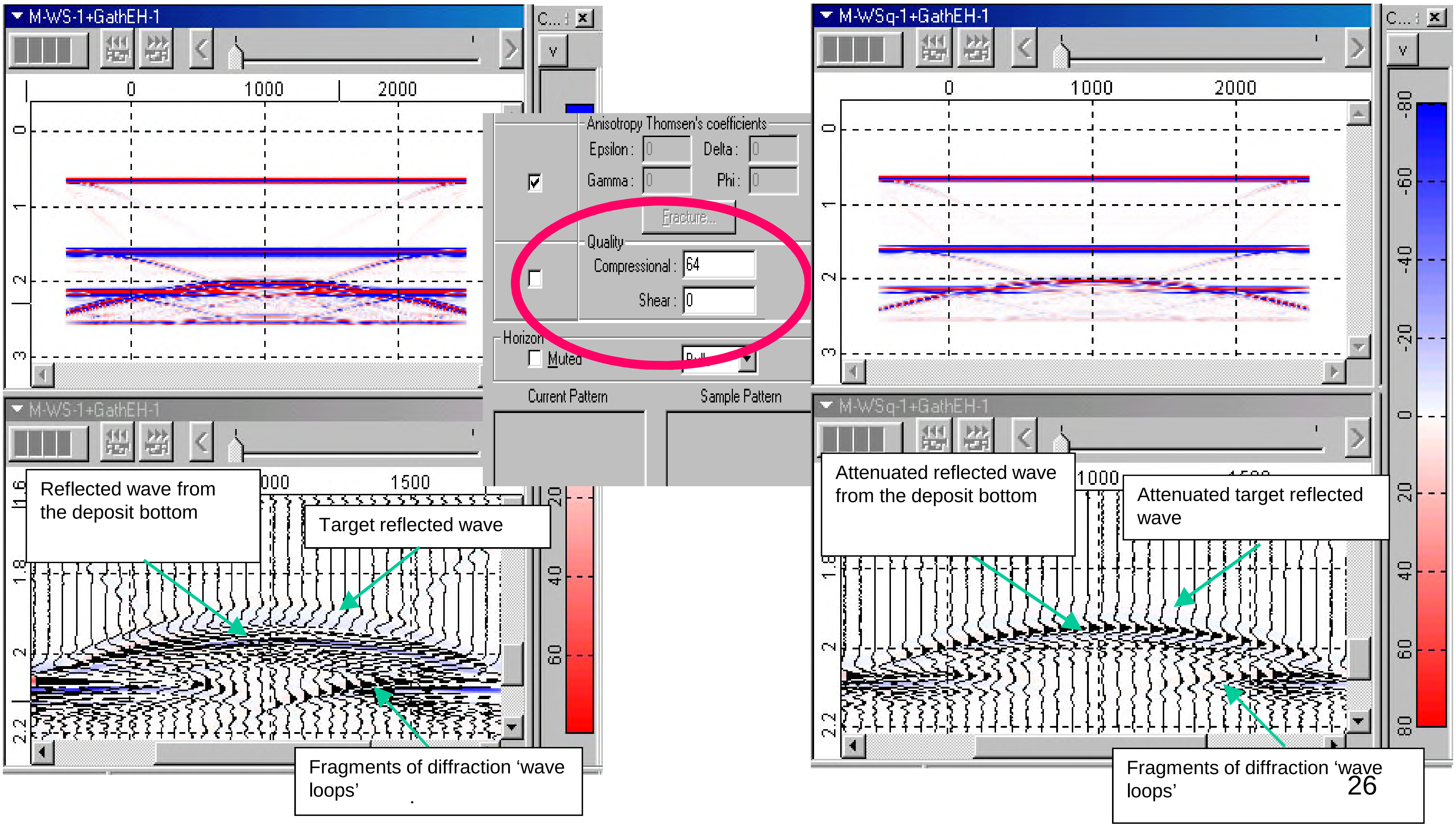
Entering anisotropy parameters in grid format from SEGY-files



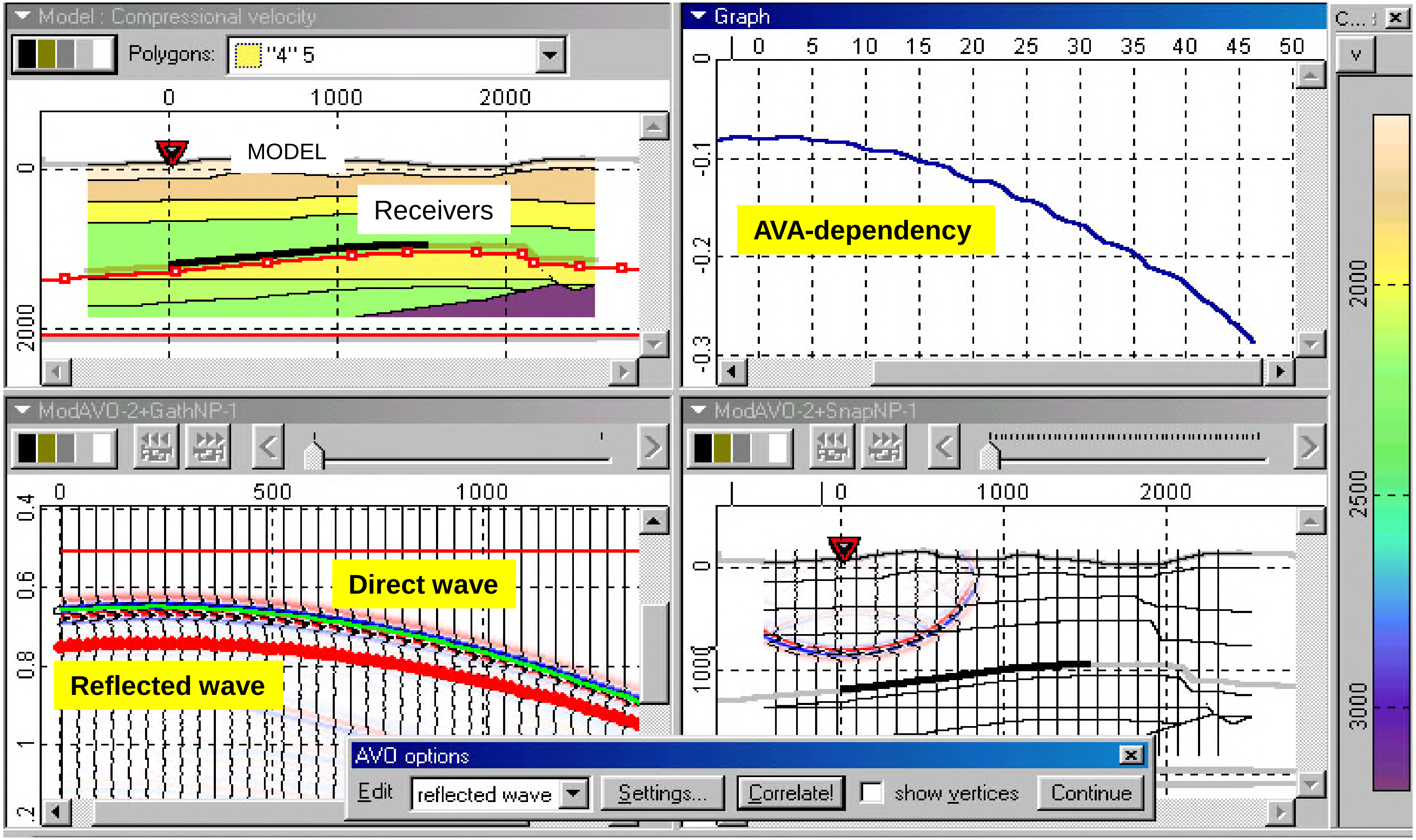
(a) – Thompsen's parameter ε; (b) – Thompsen's parameter δ;
(c) – dipping angle of TTI anisotropy axis; (d) – velocity model

...attenuation (Q-factor)

Visco-elastic wave equation



…AVO in conditions of thin-layered, anisotropic, fractured, viscous-elastic media



…conditions of uneven relief and complex geology

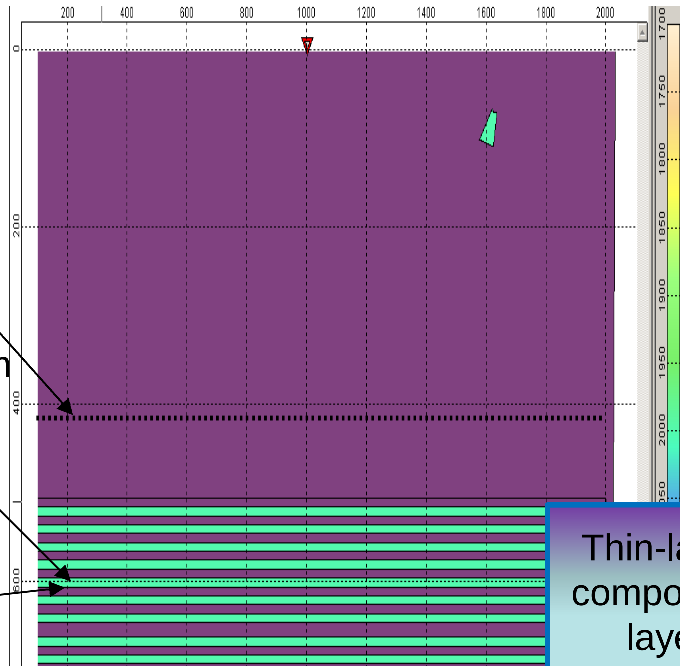
…AVO for thin-layered stack

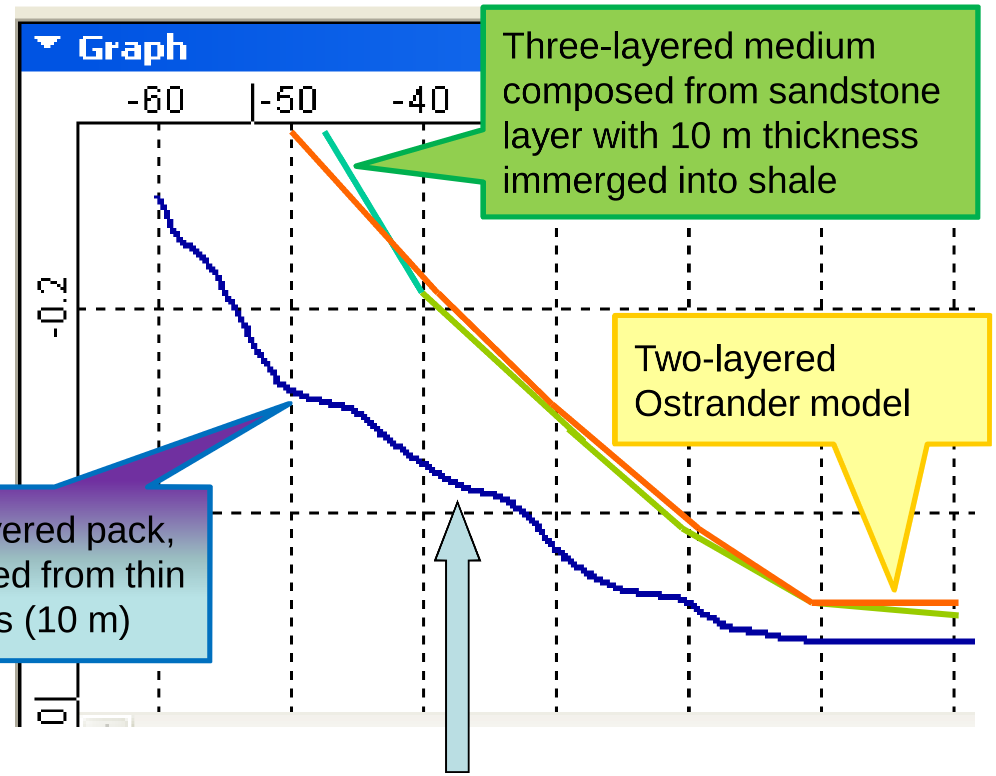
Comparison of AVO graphs for two-layered, three-layered and multilayered, models with a 20 Hz Ricker wavelet .

Shale (top)
Vp=2200 m/s
Vs=800 m/s
ρ =2086 kg/m³

Gas-saturated sandstone h=10m
Vp=2000 m/s
Vs=1300 m/s
ρ =2010 kg/m³

Shale thin layers h=10м
Vp=2200 m/s
Vs=800 m/s
ρ =2086 kg/m³



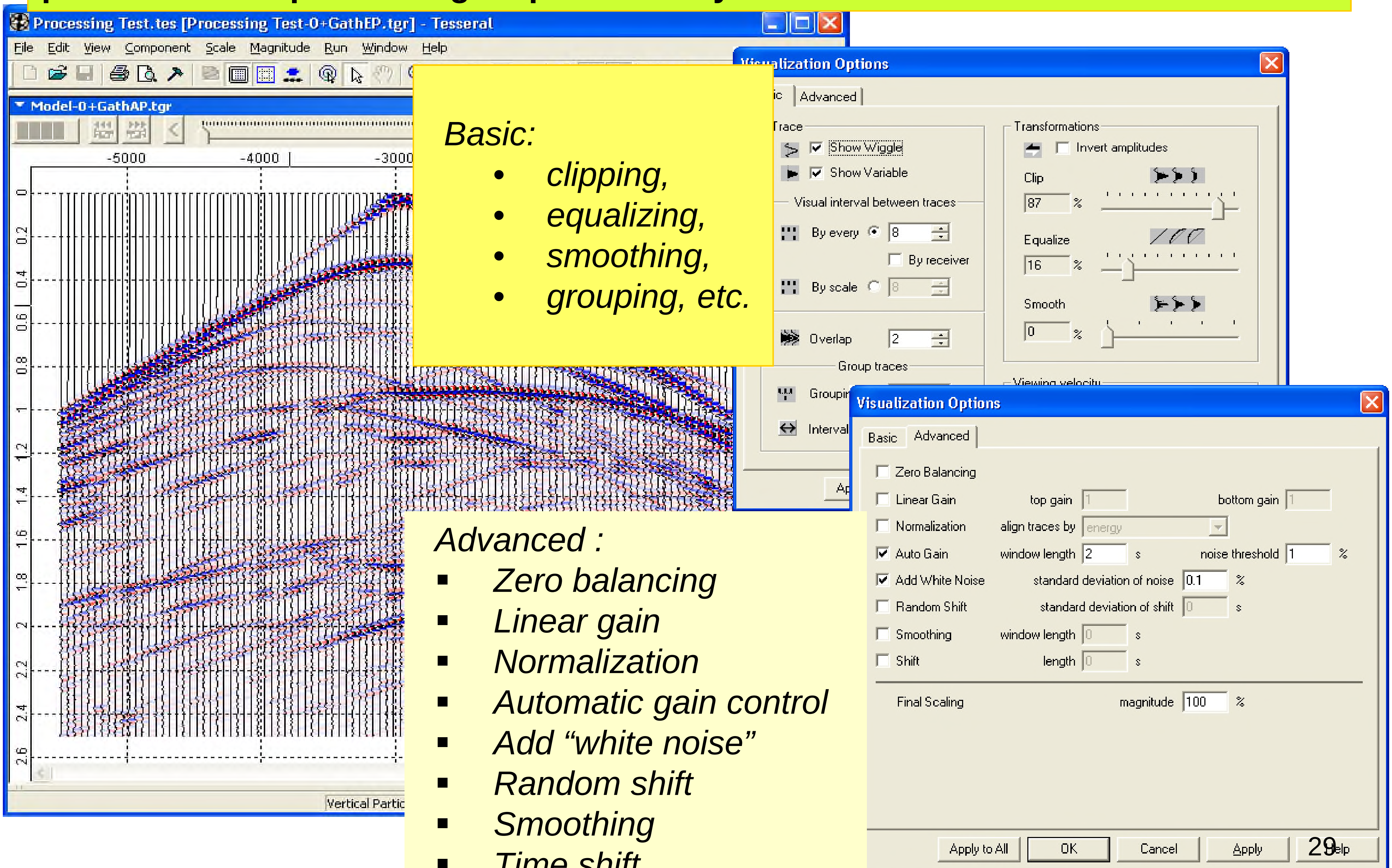


Stack effective parameters:

Vp=2090 m/s, Vs=967 m/s, ρ =2050 kg/m³
σ =0,36; ε =-0,052; δ =-0,118

Due to frequency-dependent response of thin-layered stack AVO-curve for multilayered model is considerably lower than for two-layered and three-layered ones.

There are the following visualization and single-trace procedures, useful for post-stack and processing sequence analysis



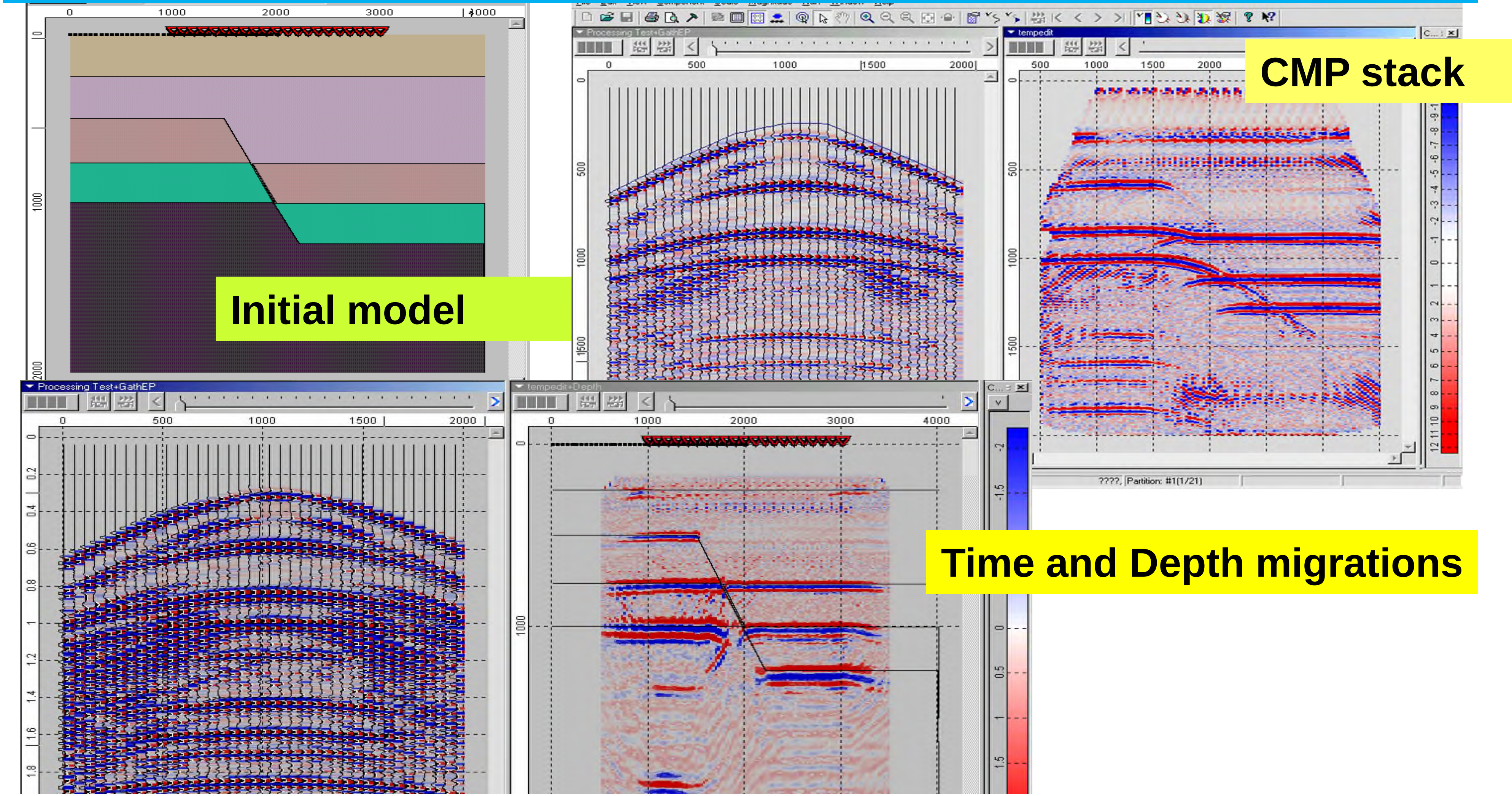
Basic:

- *clipping,*
- *equalizing,*
- *smoothing,*
- *grouping, etc.*

Advanced :

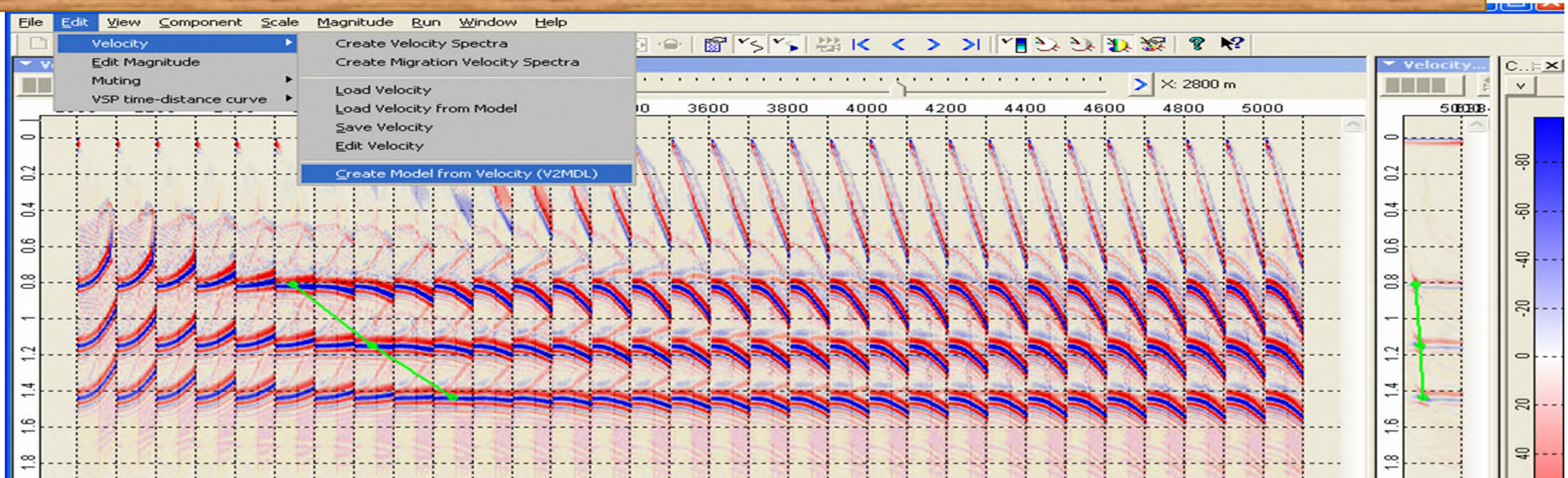
- *Zero balancing*
- *Linear gain*
- *Normalization*
- *Automatic gain control*
- *Add "white noise"*
- *Random shift*
- *Smoothing*
- *Time shift*

Seismic Imaging for post-stack interpretation



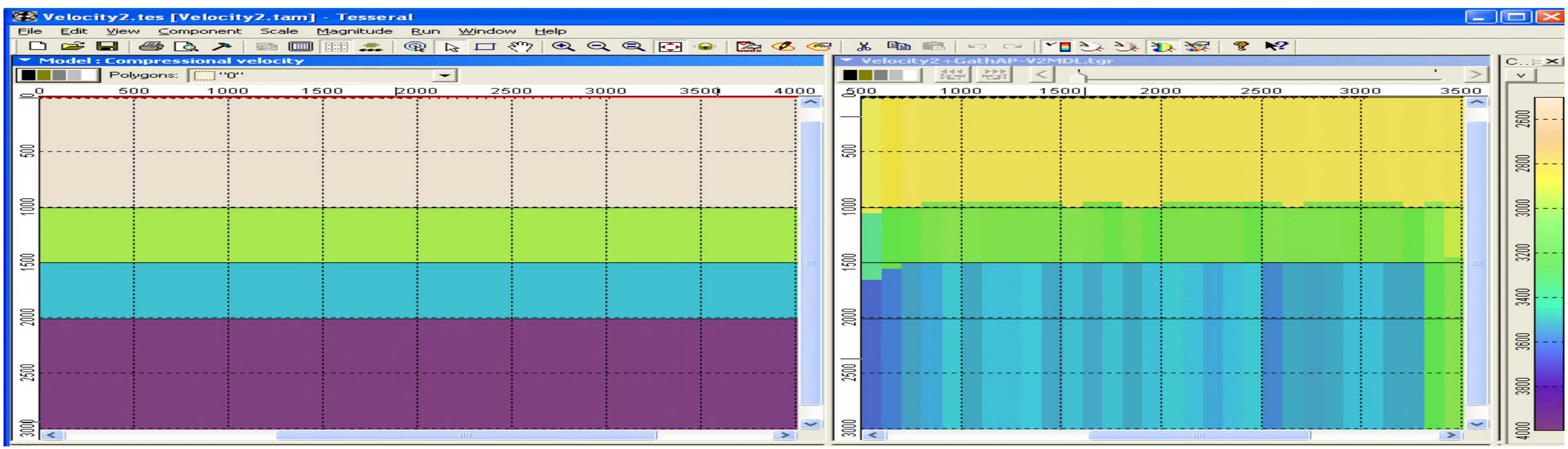
Tesseral package has processing block, oriented on processing of synthetic gathers produced by the package. You can also process real seismic profile records in *SEGY* format.

Velocity model building from seismic data

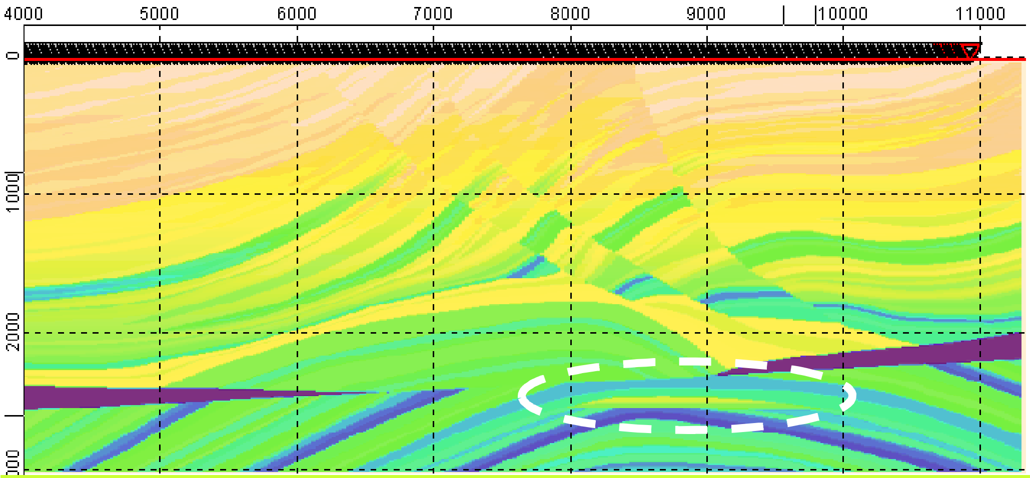


Realization of Sattlegger's method for determining of migration velocities

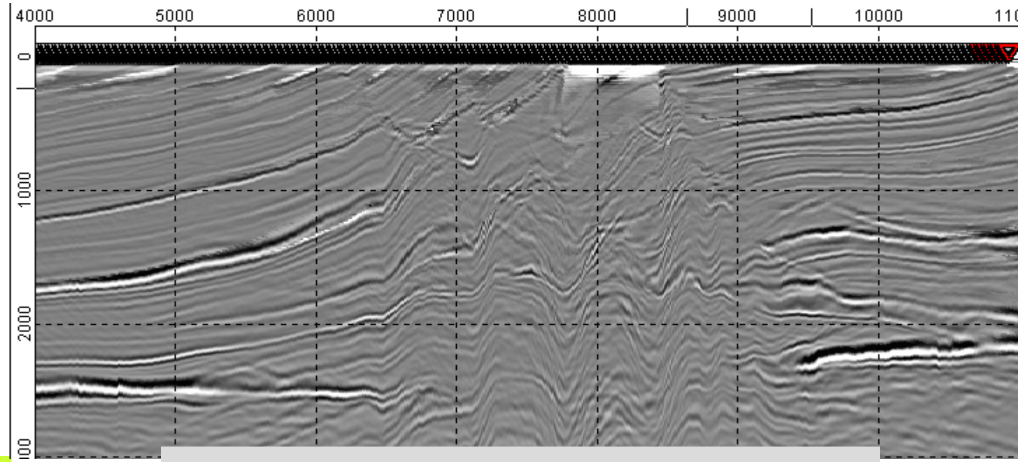
Recalculation of effective velocities into the interval velocities



...post-stack interpretation for complexly built medium

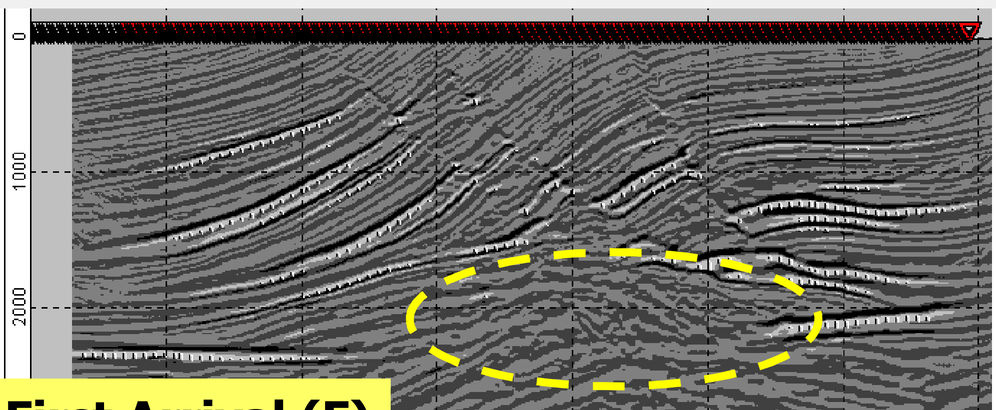


“MARMOUSI” SEGY-Model
with ellipse is shown target “gas deposit”

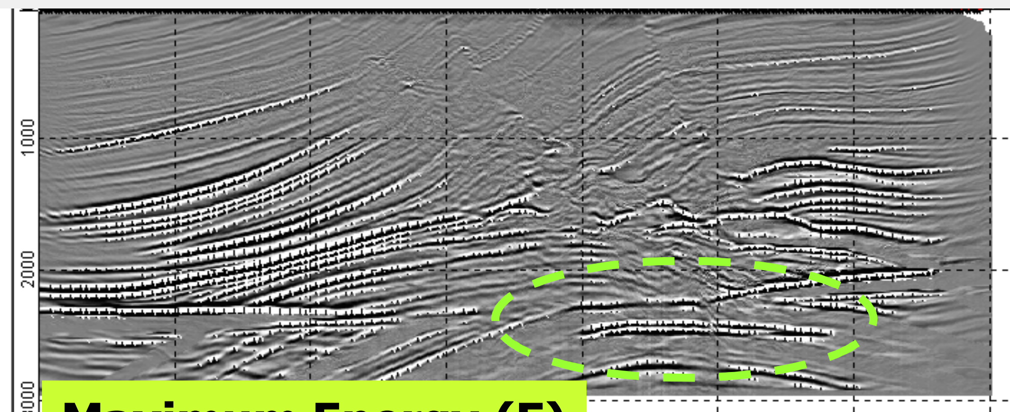


Time Pre-stack migration

Migration procedures included in the package allow to check different processing sequence scenarios

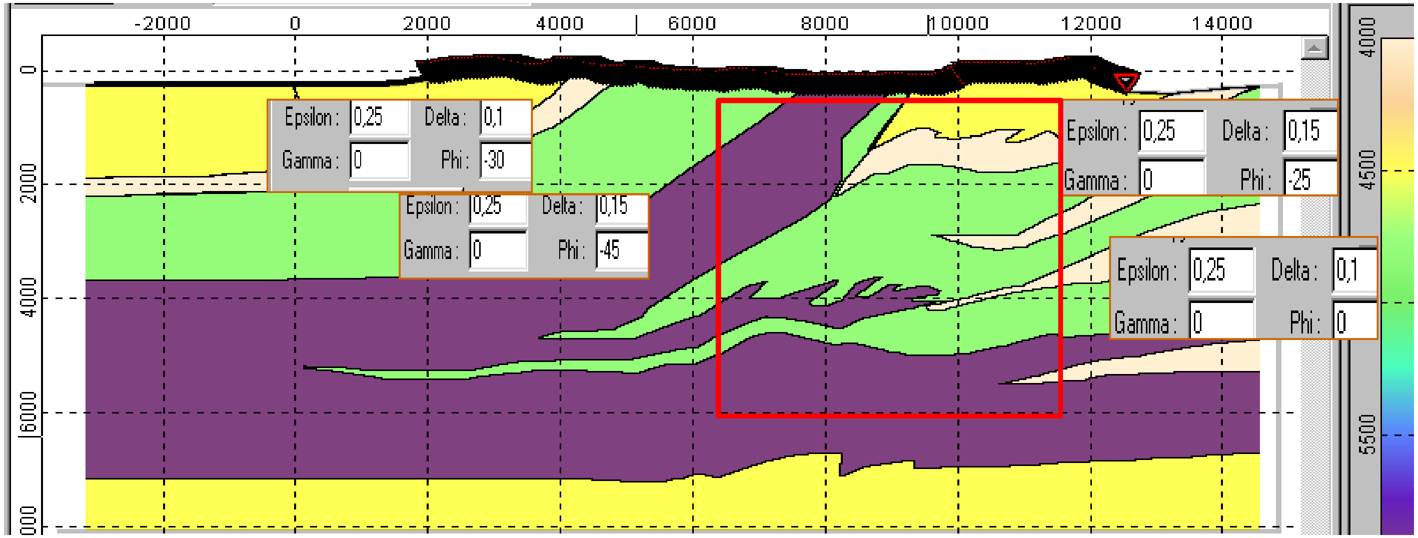


First Arrival (F)

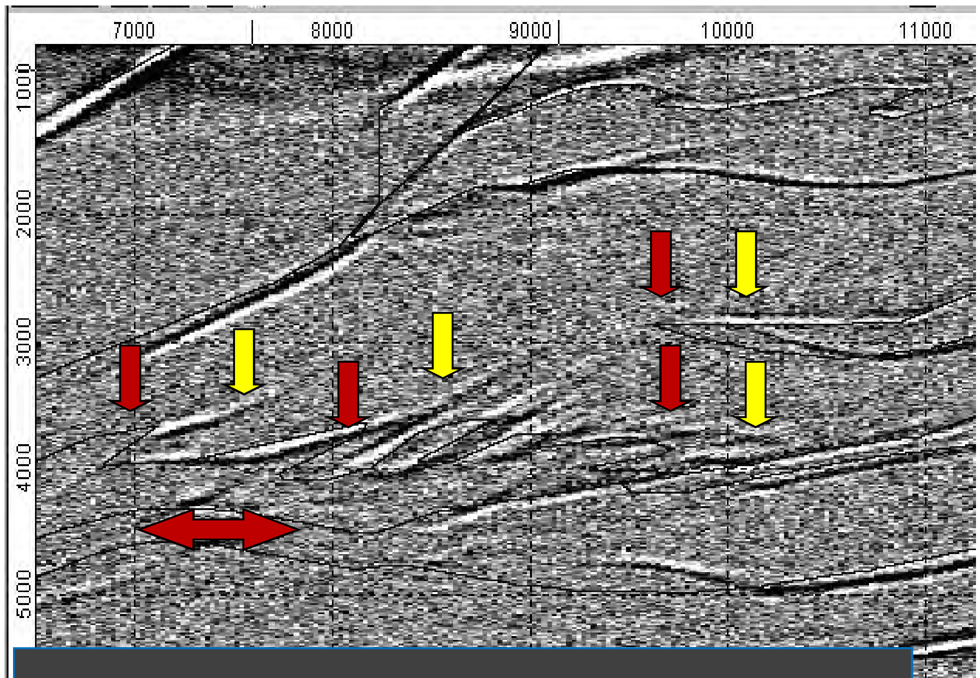


Maximum Energy (E)

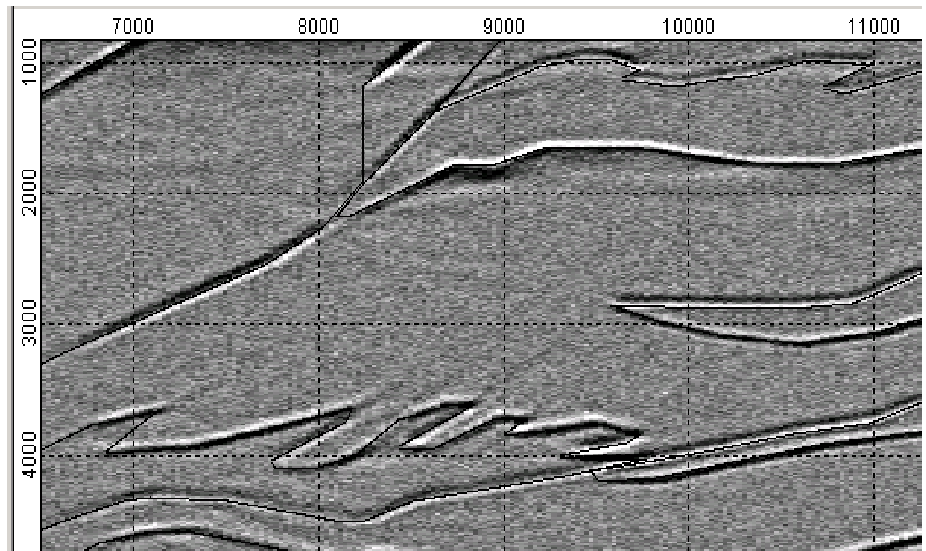
… for estimation of anisotropy influence in pre-stack Depth Migrations



Anisotropic "Big Horn" Foothills Model



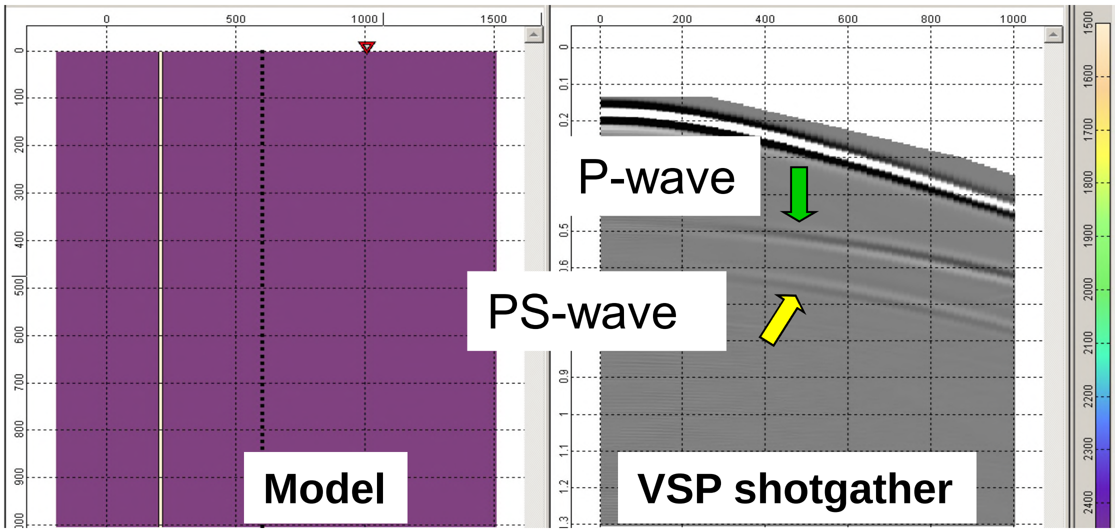
Imaging without anisotropy



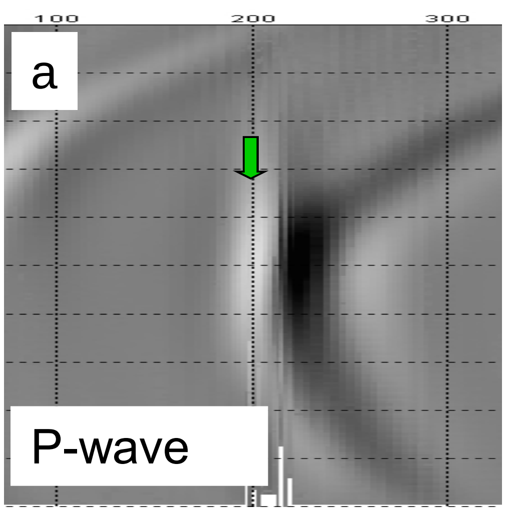
Taking anisotropy into account
for the best possible case scenario – exact velocity model and data.

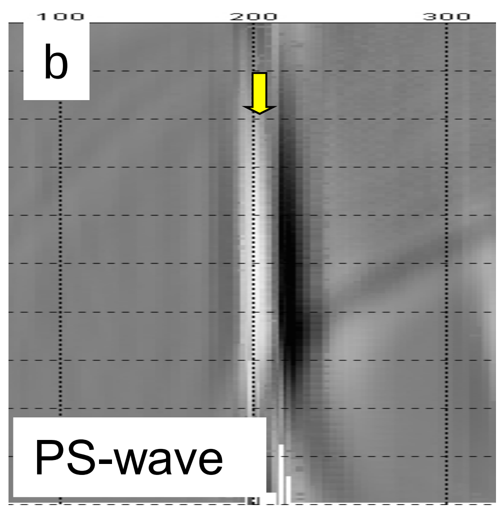
...for VSP data

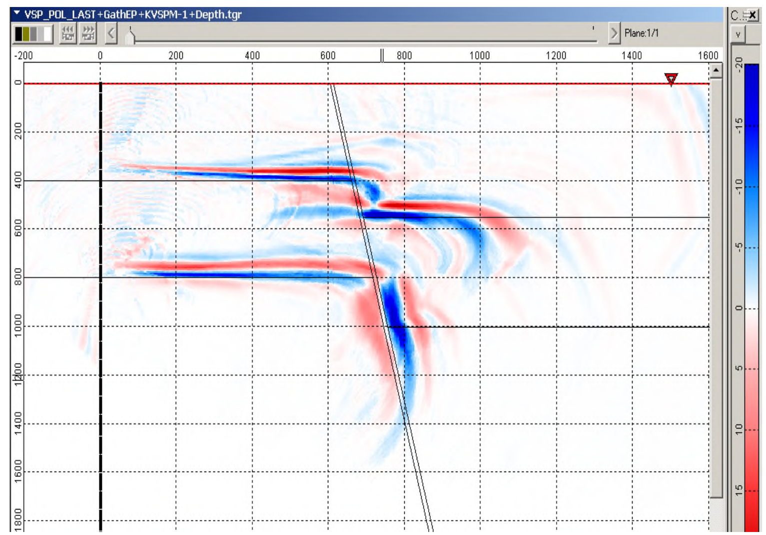
Formation of image of sub-vertical boundary



VSP Depth Migration on transmitted converted waves
Polarization criteria
For 2C - 3C observations





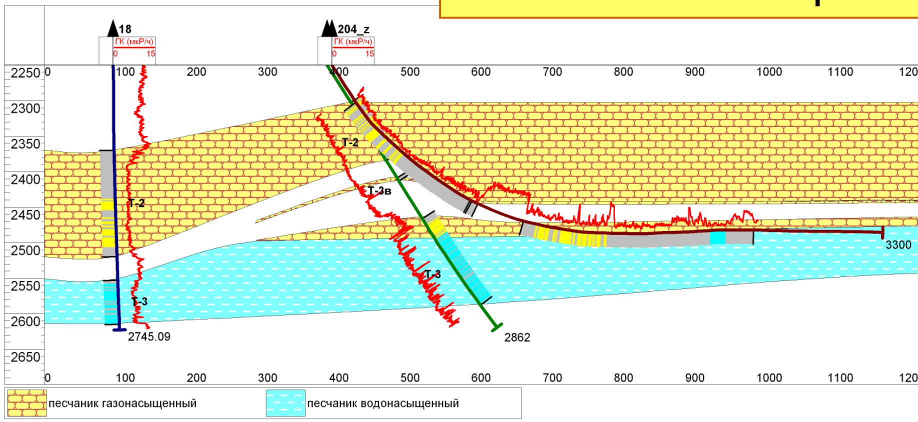


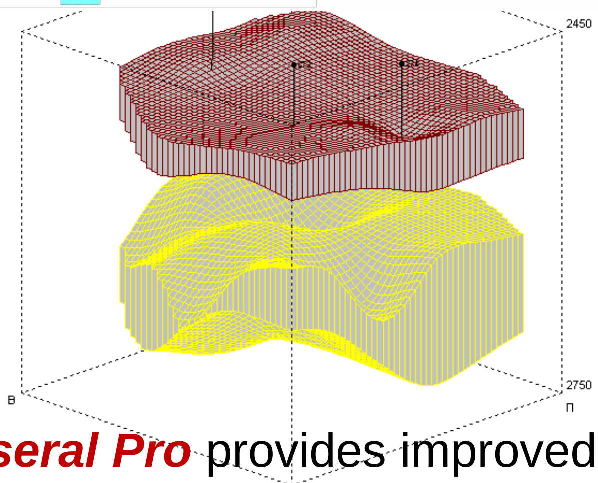
By 2C on transmitted converted waves (30^0 threshold)

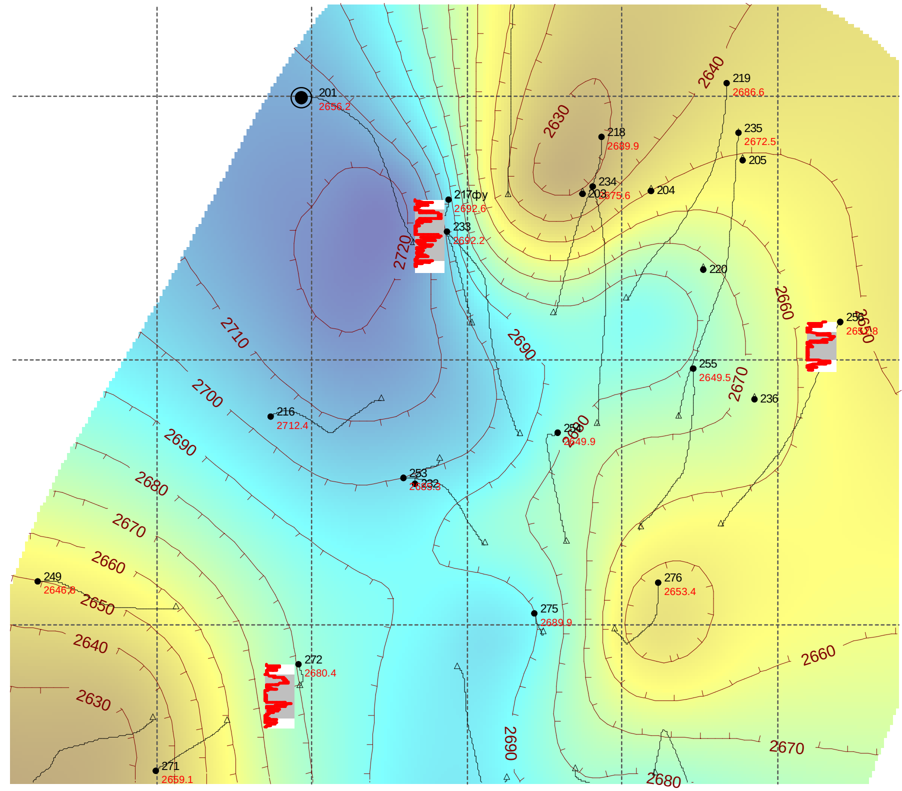
Vertical image: a –reflected compressional waves, b –converted reflected waves.

Object-oriented Model for areas with Complex geology

Tesseral Pro Improved thin-layer 3D model building …

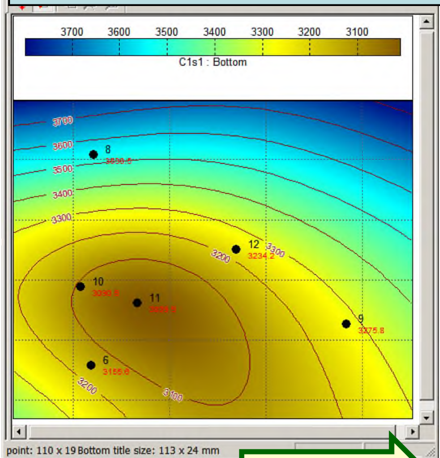




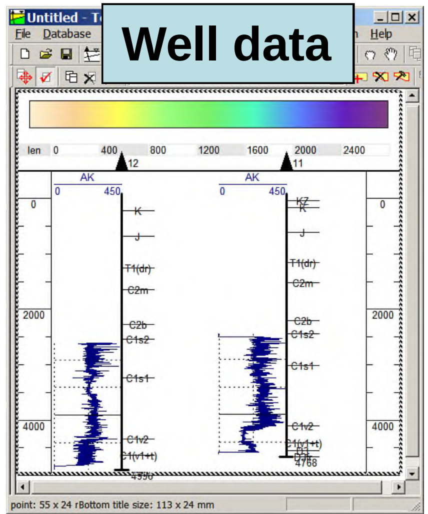


- ✓ ***Tesseral Pro*** provides improved thin-layer model building on the base of collected well log information, utilizes complex well information including well logs, their interpretation, strata boundaries, well coordinates and inclinometer data about the well geometry.
- ✓ ***Tesseral Pro*** can be used for graphical document design compound from sections, surfaces, 3D plots, seismograms and seismic sections, text fields, pictures, etc.

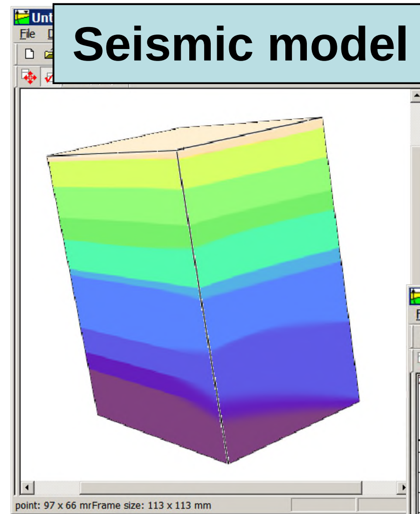
Strata surface maps



Well data

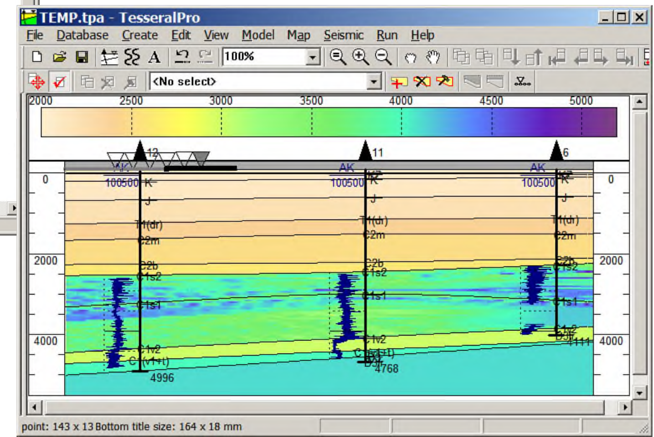


Seismic model



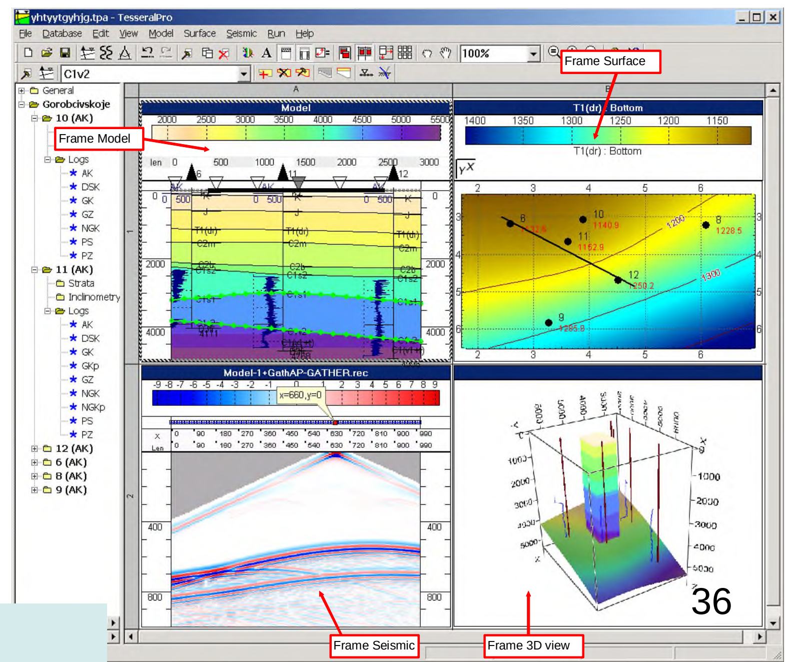
Goal

Detailed model for simulation



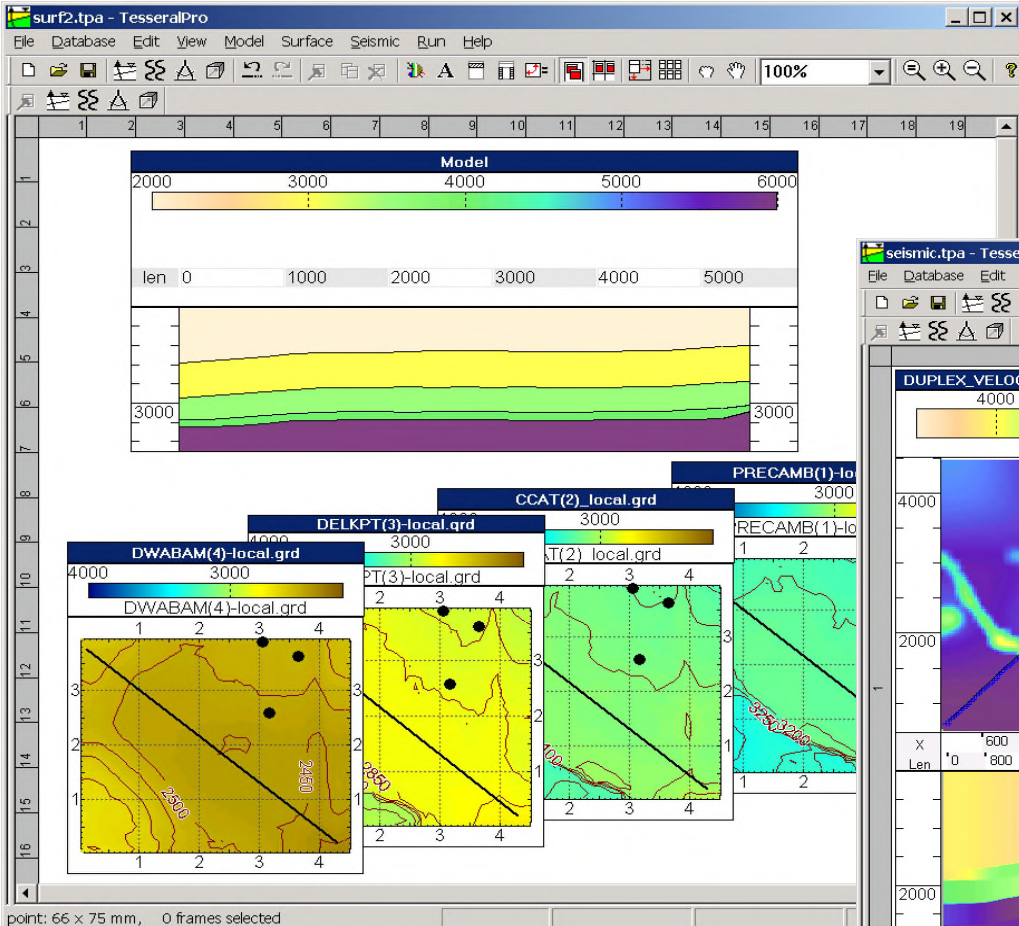
Workflow

1. Import available well information (well coordinates and trajectories, well-logs, strata tops in the wells) into the database
2. Calculate and/or import the strata horizon maps
3. Build a section frame as a base for further simulation model design. Well and strata information is automatically transmitted to the section frame
4. Edit the section polygons to enrich the section model by extra details and more seismic parameters (migration model can be used too)
5. Design or import an appropriate observation layout
6. Submit medium model for simulation using the 2D/2.5D computation engine
7. View and analyze results

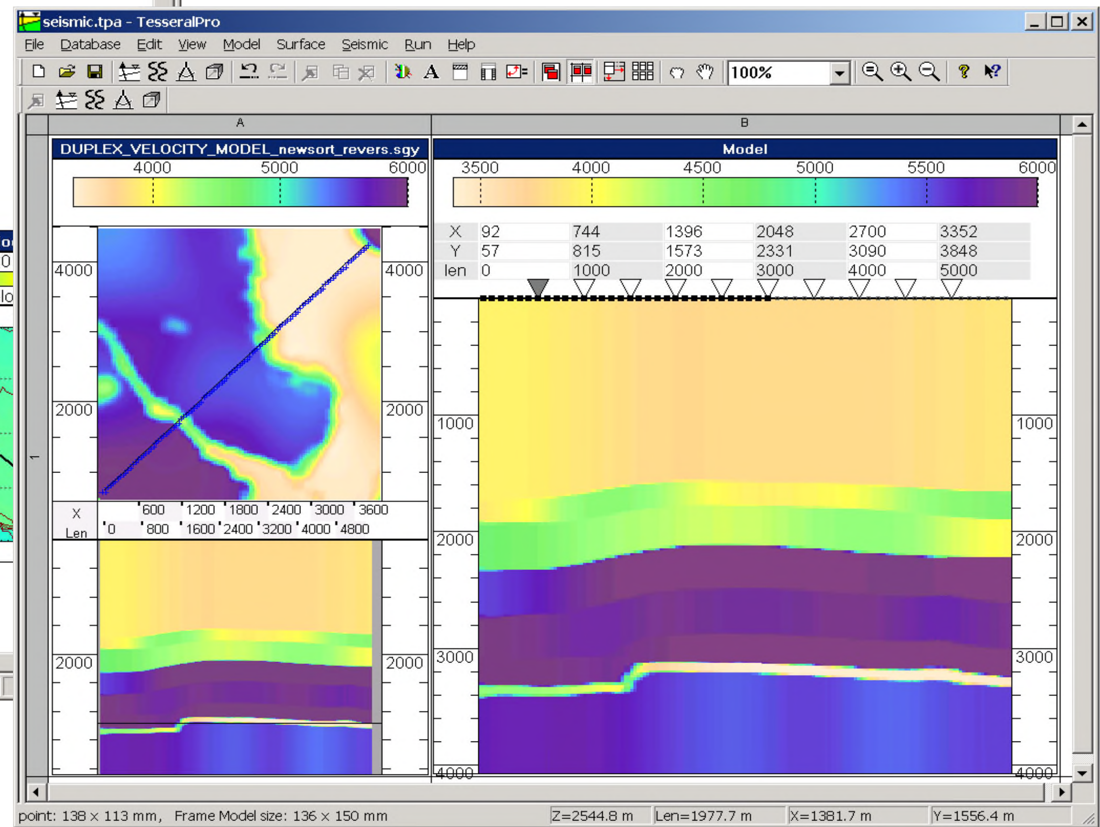


Tesseral Pro Concept of Object-oriented Modeling

Model building by horizon surface maps



& Model building by Velocity Cube

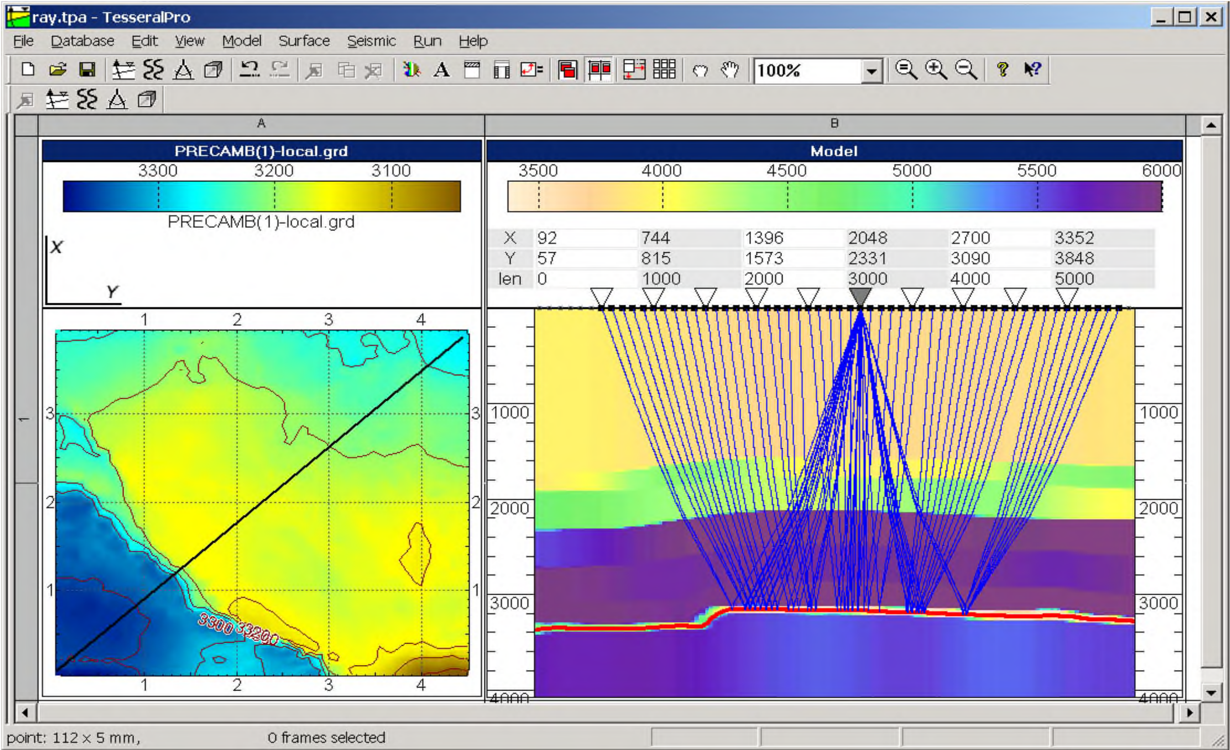


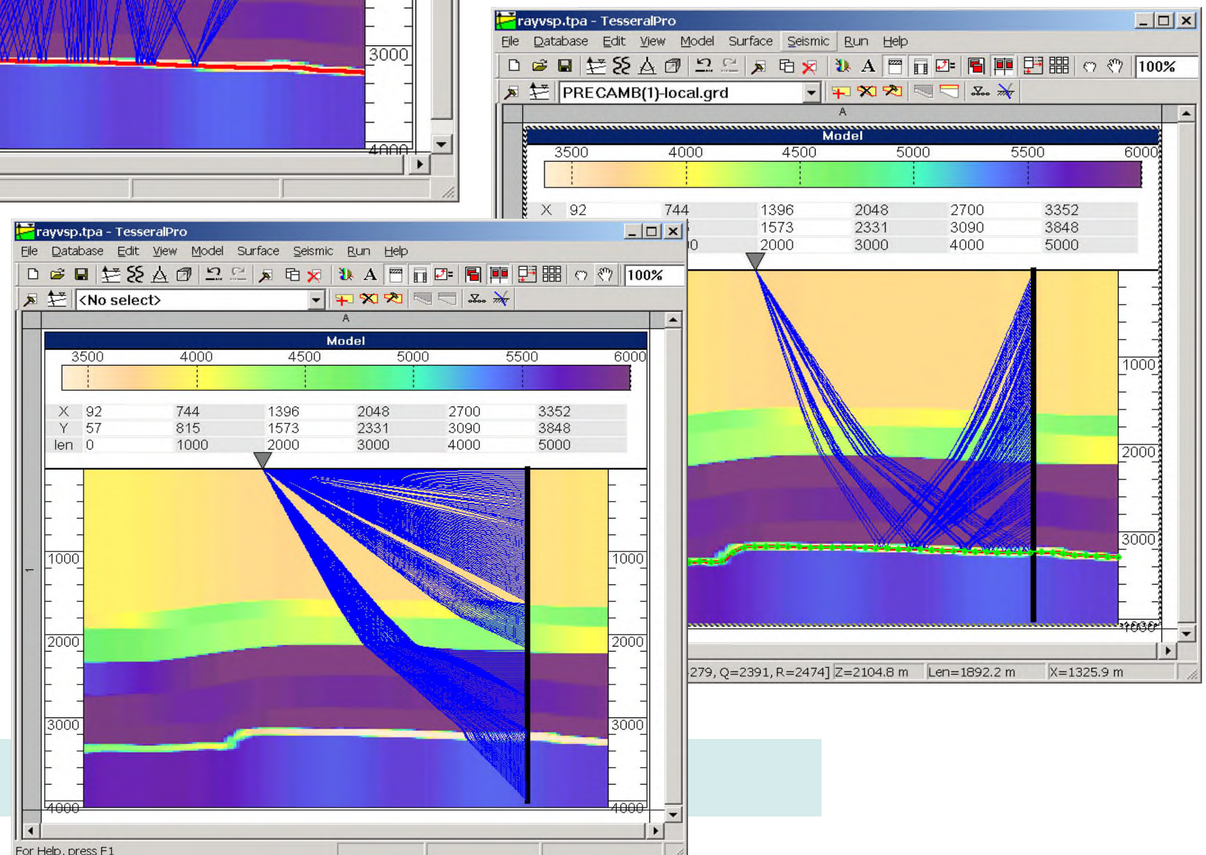
Model example. Surface maps

Model example. Velocity Cube

Tesseral Pro Concept of Object-oriented Modeling

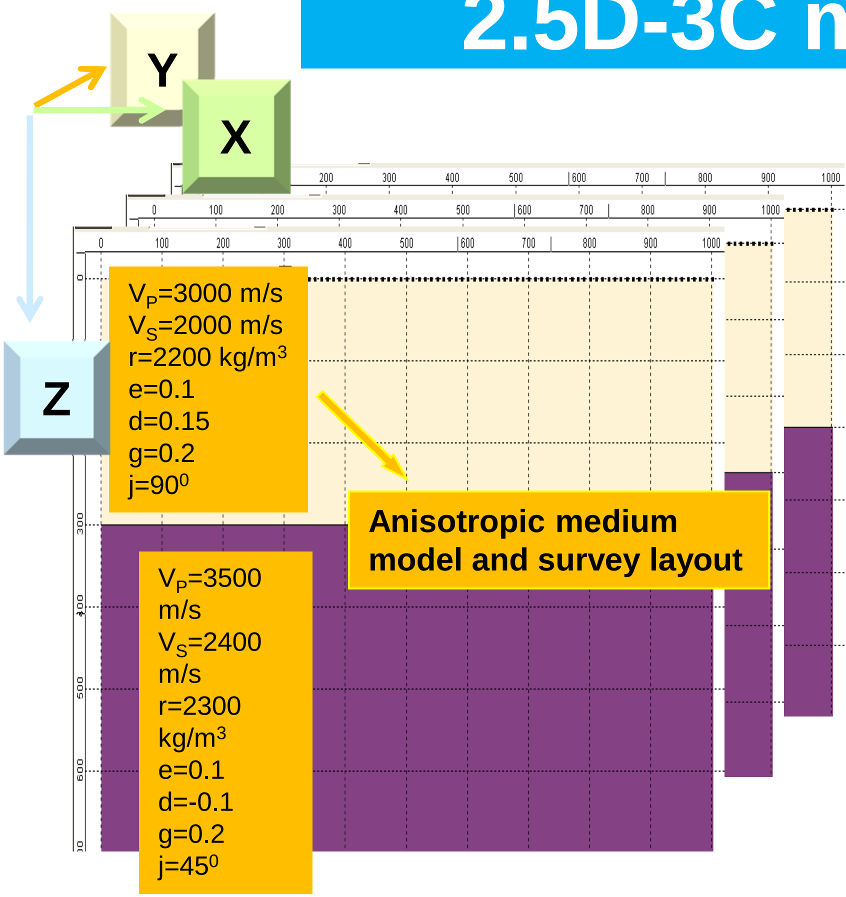
Ray-tracing by velocity grid

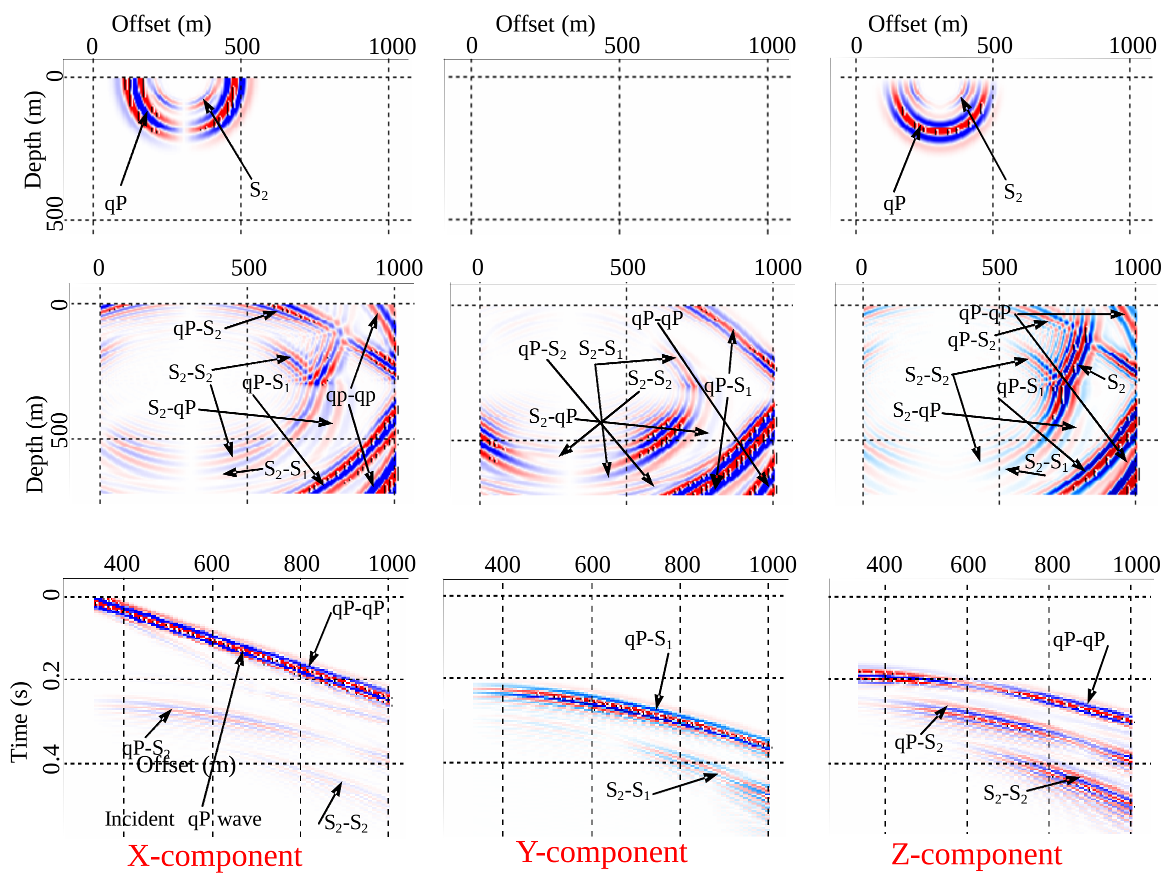




Ray-tracing

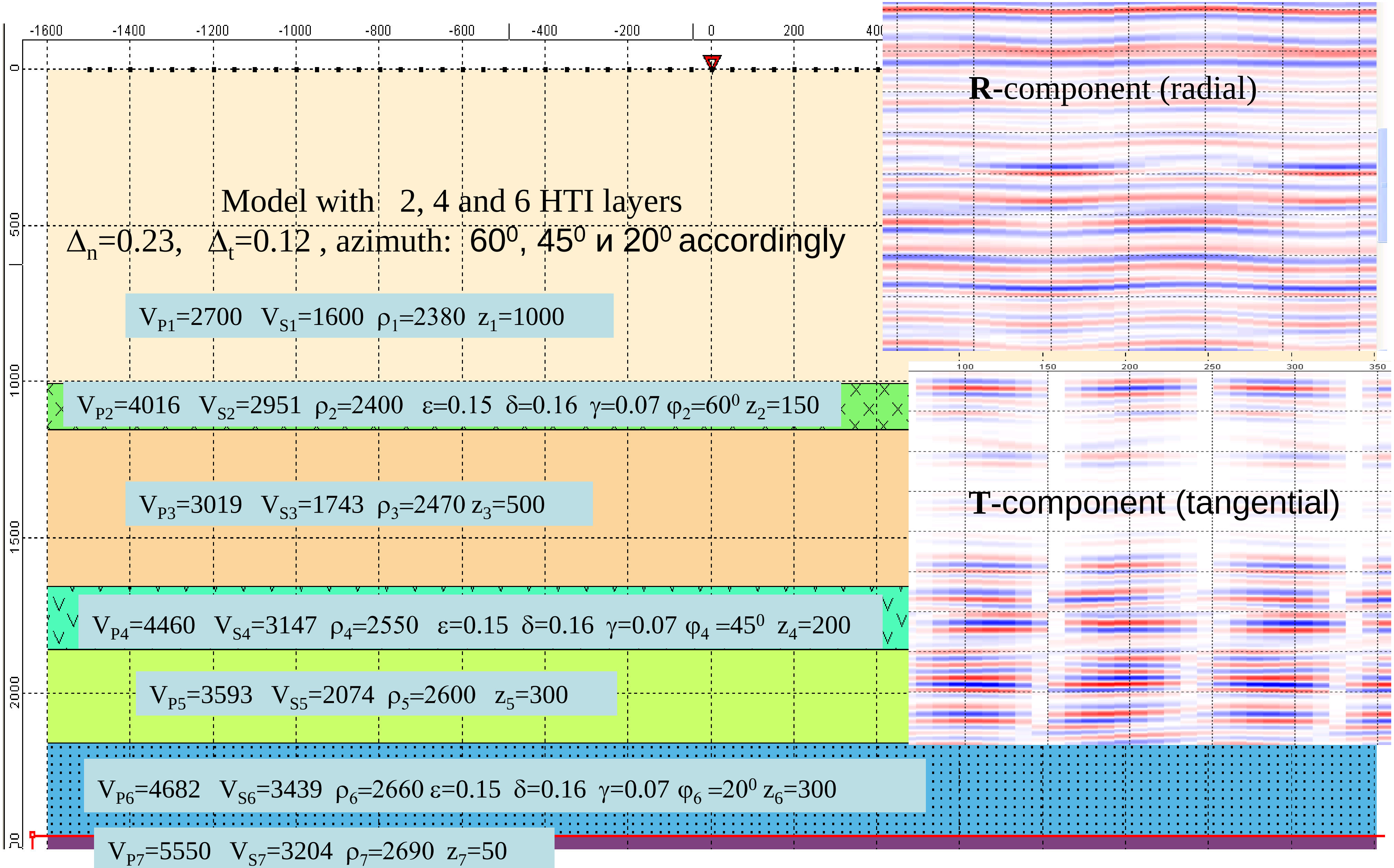
2.5D-3C modeling





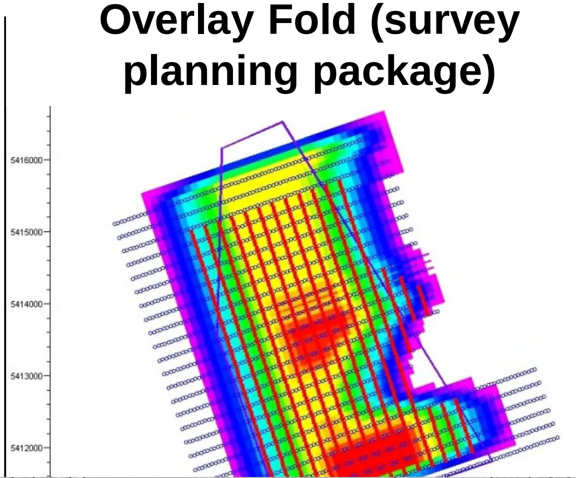
Example of 2D-3C modeling (**2.5D**) for HTI anisotropic medium of quasi-compressional qP, and also fast qS_1 and slow qS_2 quasi-shear waves is shown. Time of calculations for 2.5D modeling is much less than for 3D modeling of analogous medium.

Modeling for different Fracturing Azimuths

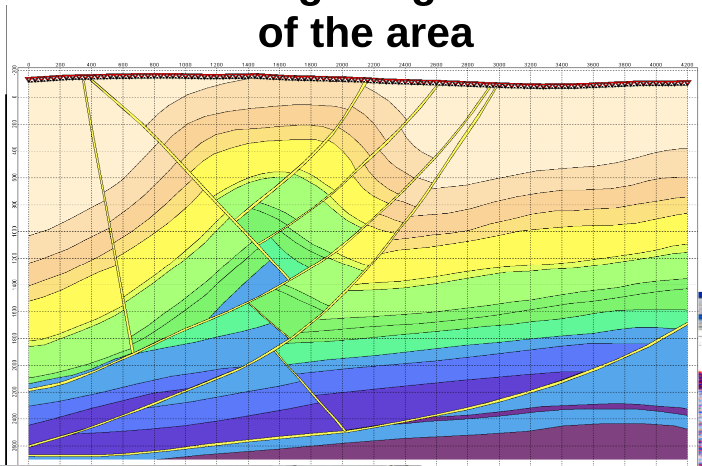


… for Survey Planning

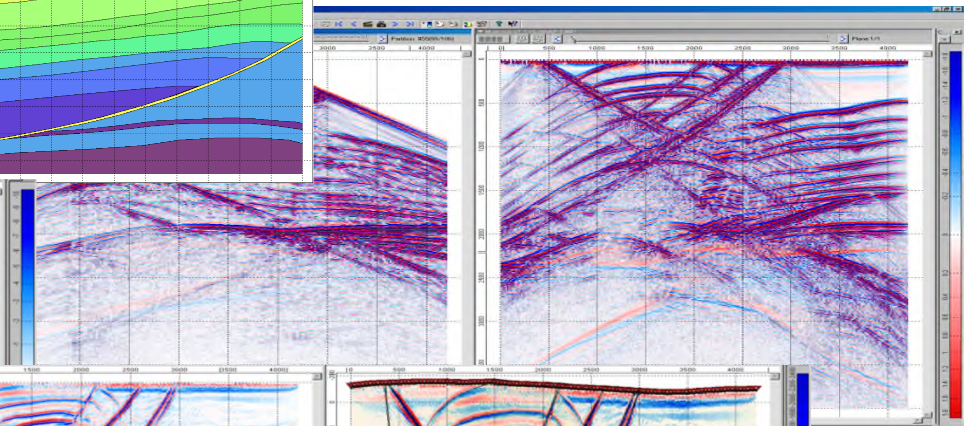
Scheme of the Survey Overlay Fold (survey planning package)

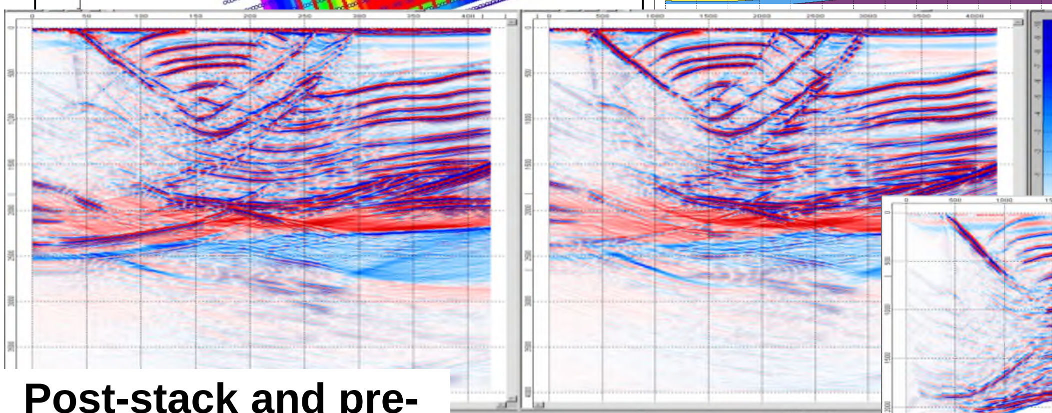


Seismic-geologic Model of the area

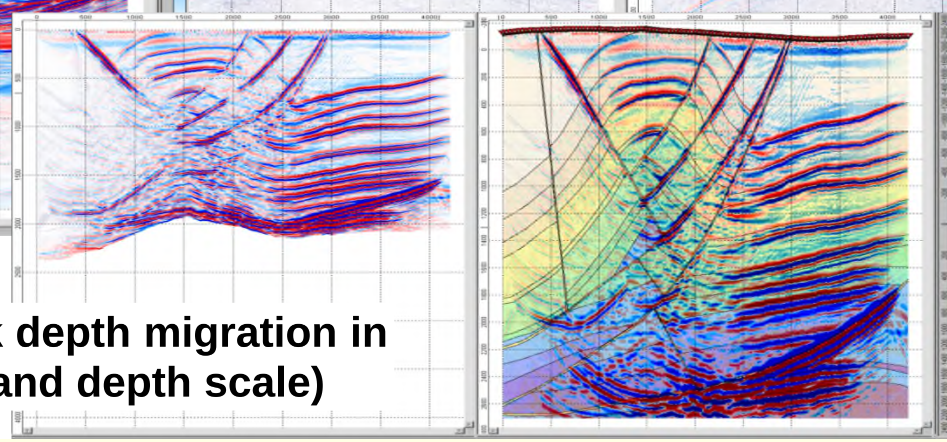


Example of a synthetic gather and CDP time cross-section





Post-stack and pre-stack time migration (in time scale)

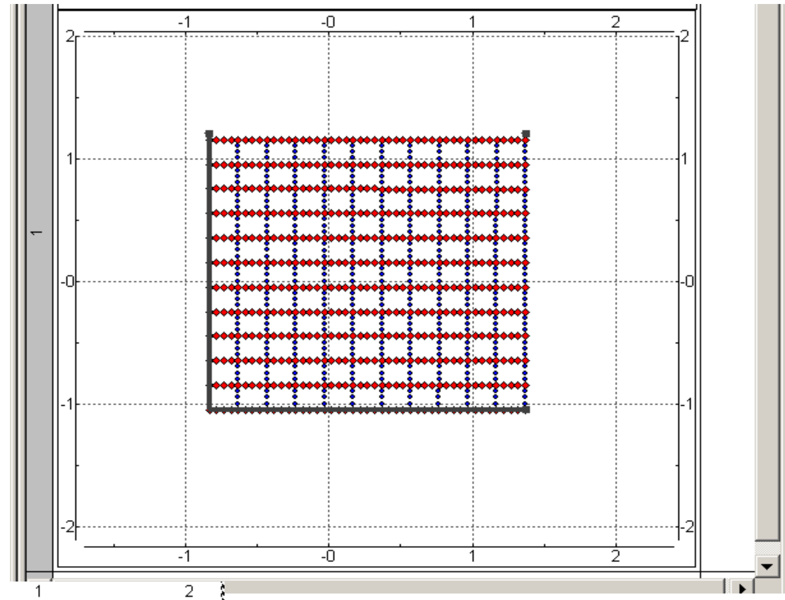


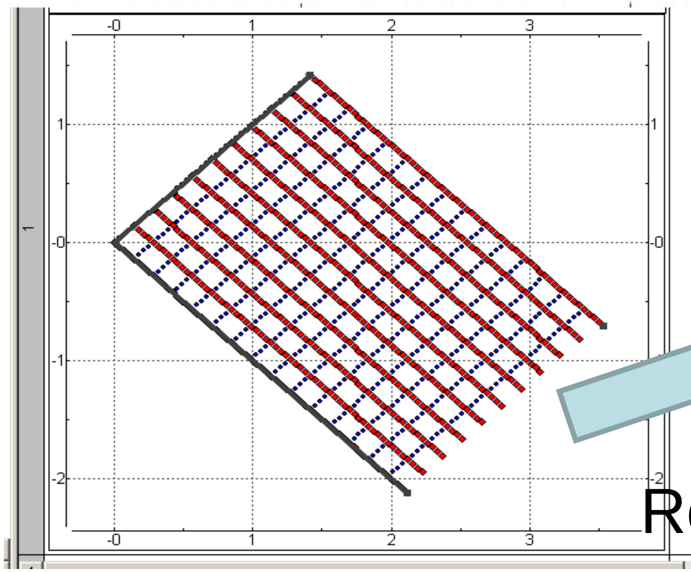
Pre-stack depth migration in (time and depth scale)

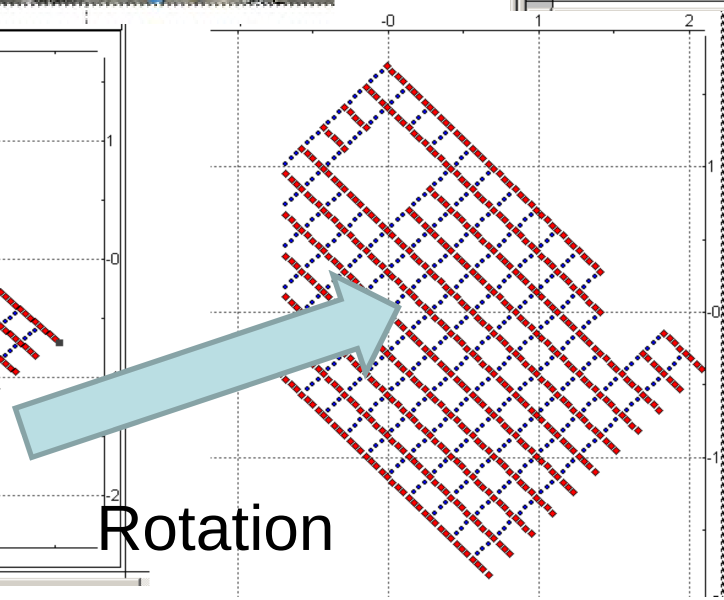
- **Configuration and parameters of the seismic acquisition geometry, location of receiving and shooting lines within the area under study play the crucial role for exploration of hydrocarbon deposits and new territories for oil & gas prospects.**

2013 release: 3D survey design, ray-tracing and Illumination studies

Load survey from SPS files



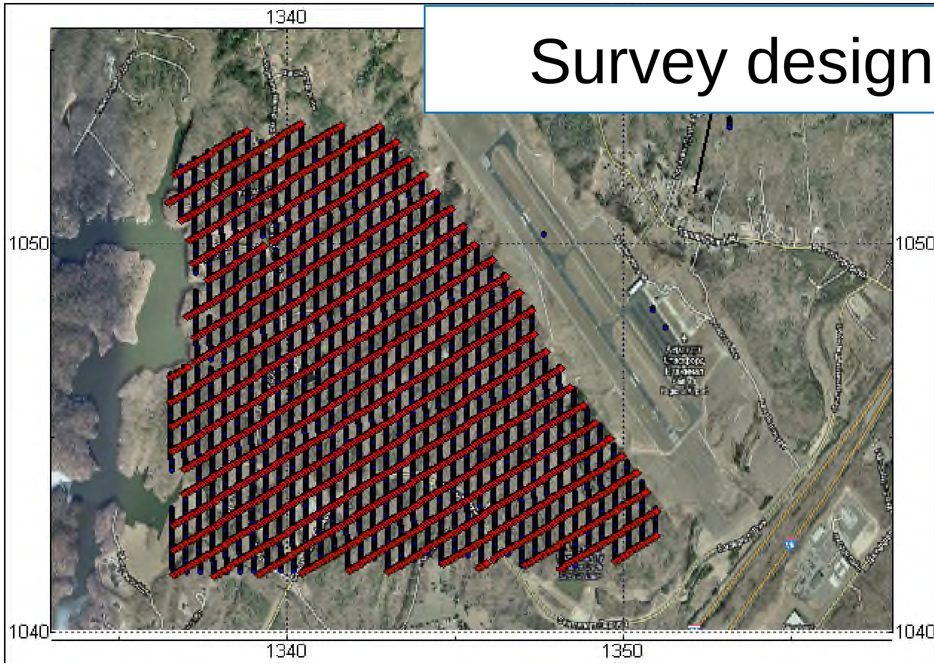


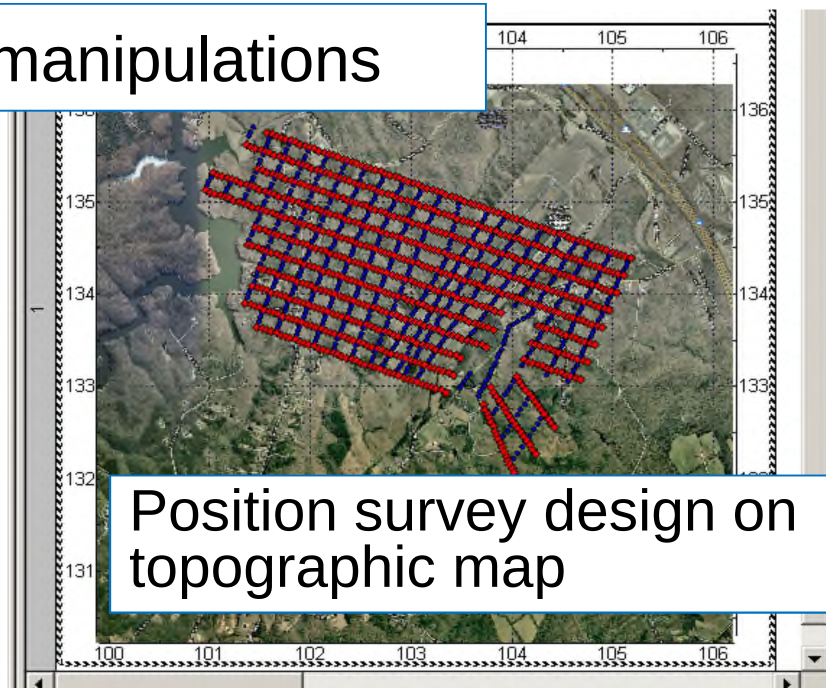


Rotation

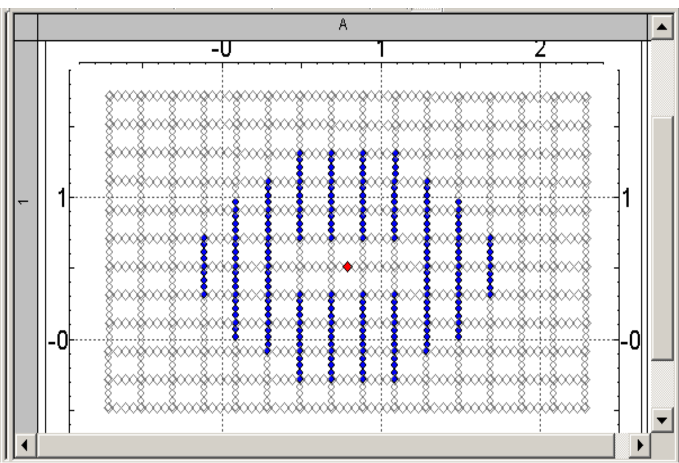
- Orthogonal
- Shot in crankshaft pattern
- Diagonal

Survey design manipulations

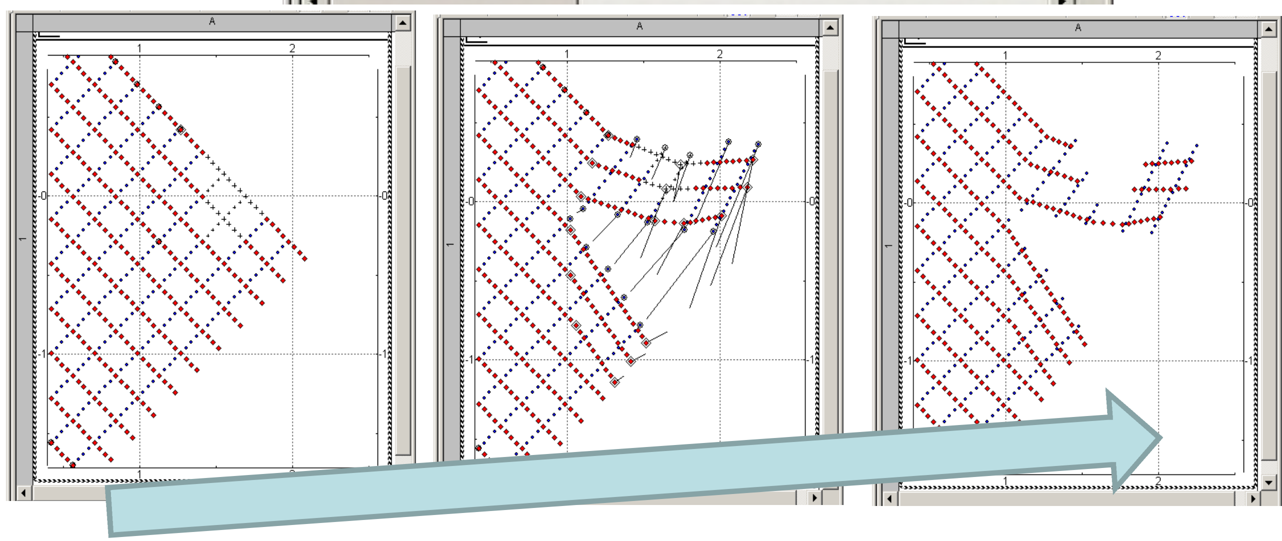




Position survey design on topographic map

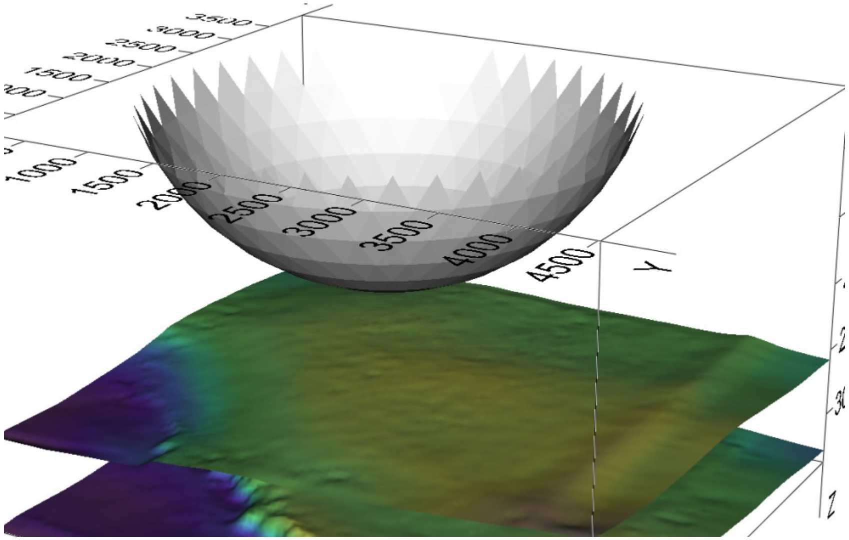


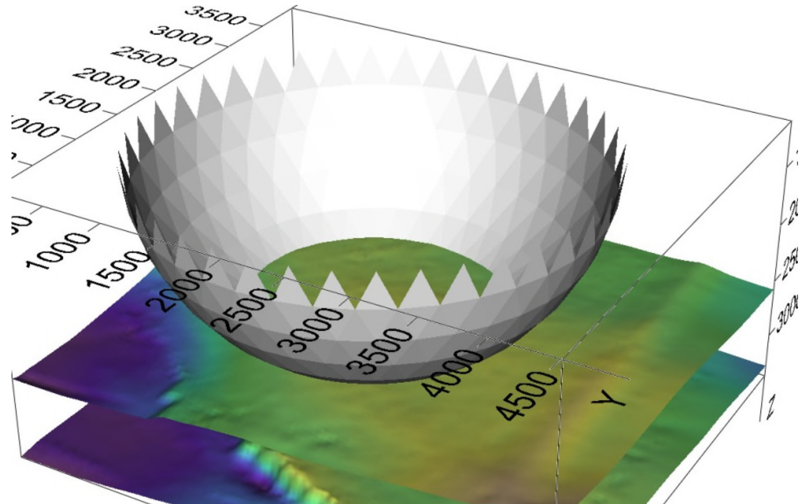
Recording patch design

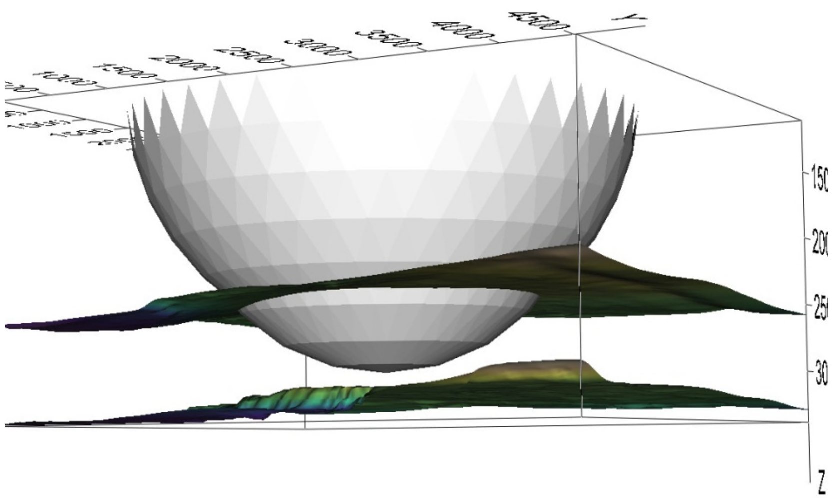


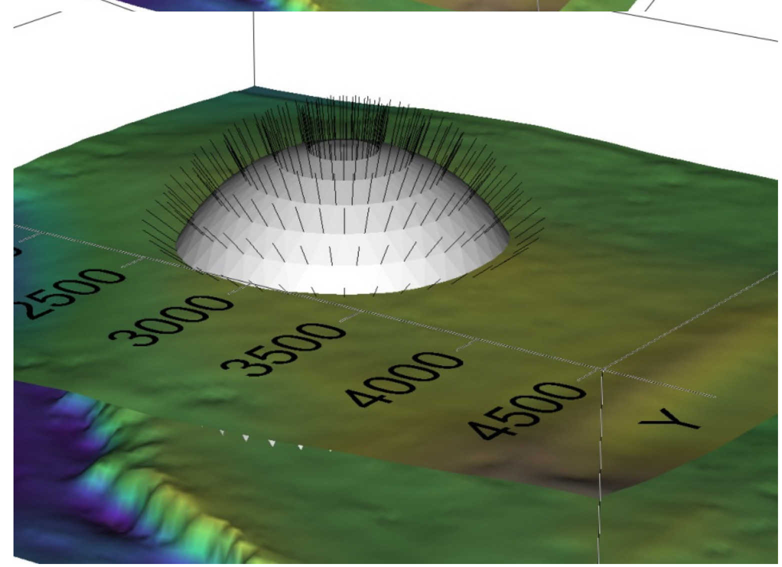
Moving Source and receiver lines in desired direction

3D ray-tracing

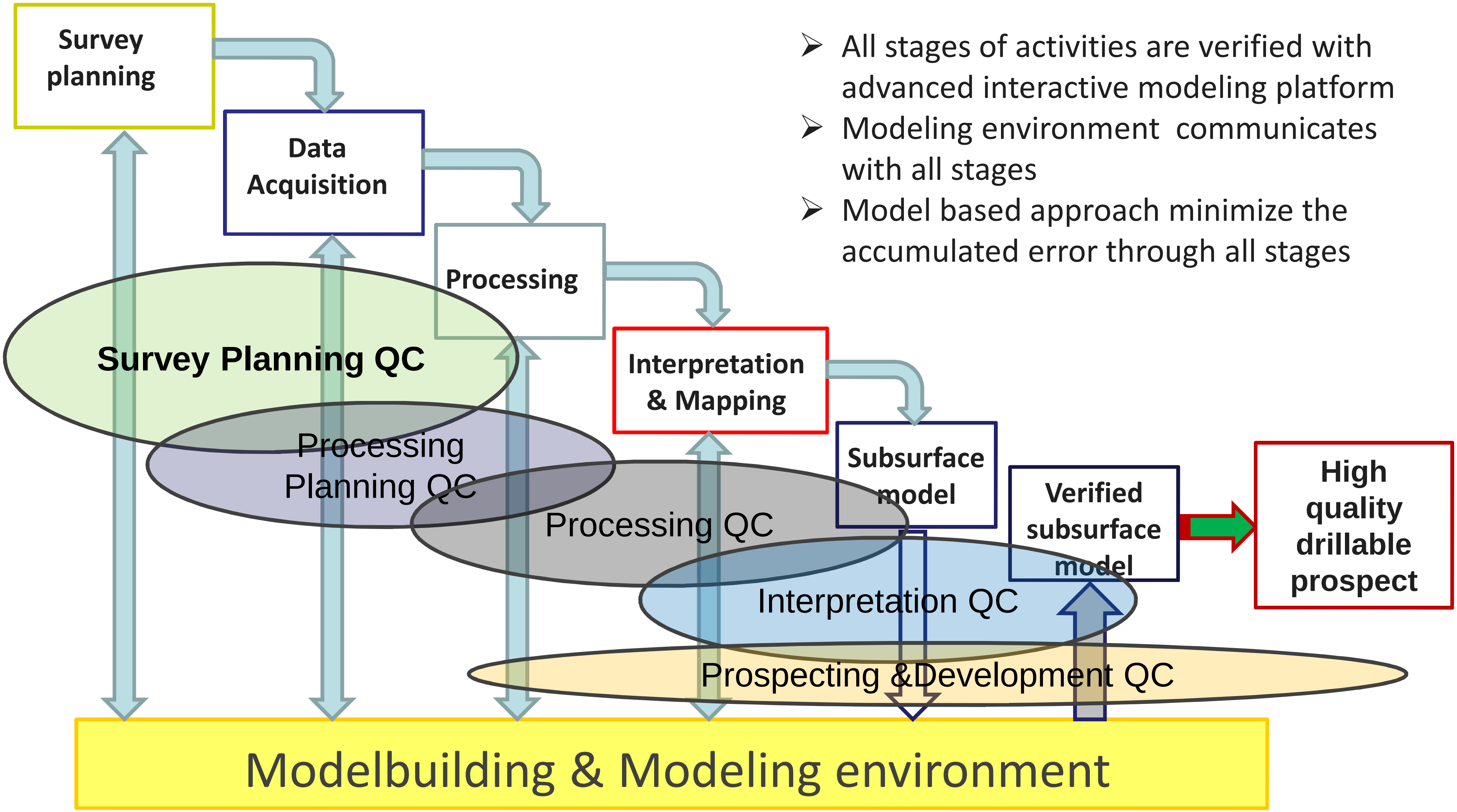








… for Integrated Model-based Workflow



- 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

Summary

- **Full-wave modeling** is a 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 (polarized seismic prospecting) ...

- ***Tesseral 2D - 2.5D – 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**.