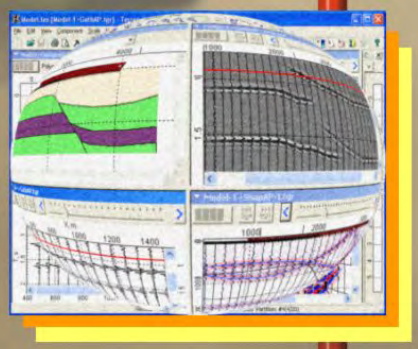
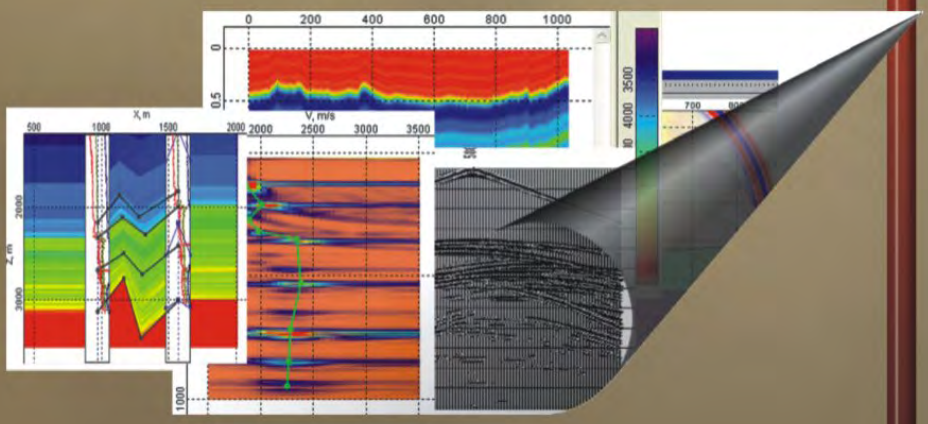
Tesseral

Technologies Inc.

Multiparameter Medium Model for Processing and Interpretation



Modeling of seismic and acoustic fields
on personal computer,
Windows network and LINUX cluster



Tesseral - your reach just got longer!

In the past, full-wavefield seismic modeling was not widely utilized in geophysical studies due to the lack of PC computational power. Less computationally intensive and simplified methods of seismic modeling such as ray tracing or scalar wave equation based on finite-difference techniques were used.

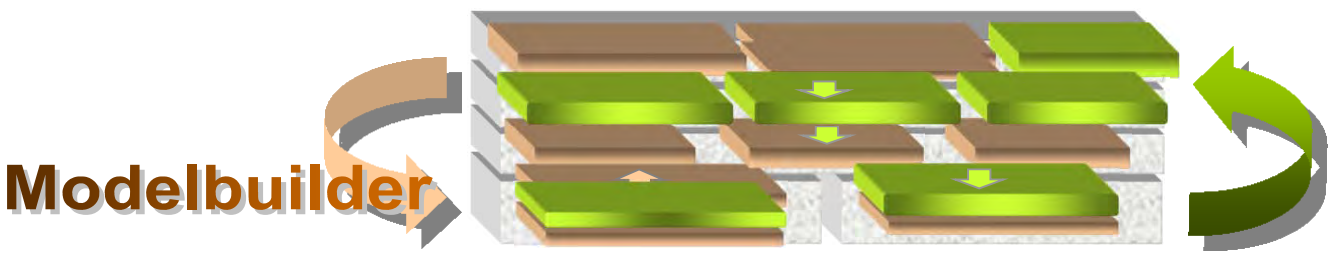
Tesseral 2-D is the first commercially available PC-based full wavefield modeling software package. You can now easily simulate various seismic recording systems and build digital model cross-sections containing complex geology. The Tesseral package calculates P-, S- and SV-wavesurface waves propagation in heterogeneous media faster and more precisely than ever before. Windows network and Linux cluster versions of the package for parallel computations are now available.

Tesseral 2-D uses an economical and reliable computation method based on the finite-difference calculations. This makes it possible to model very complex geological media - including a combination of solids and liquids - quickly. In addition, during the development of the Tesseral algorithms, many of the computational problems inherent in wave equation numerical solutions were eliminated and calculation flaws were fixed.

Tesseral 2-D was designed for interactive analysis and verification of depth-velocity models. Integration with conventional seismic data processing and interpretation is straightforward. Model construction can be facilitated using input of physical rock properties that include correlations, lithology patterns, and a library of typical geological situations. Models in different grid and ASCII formats can be imported and used in the calculations.

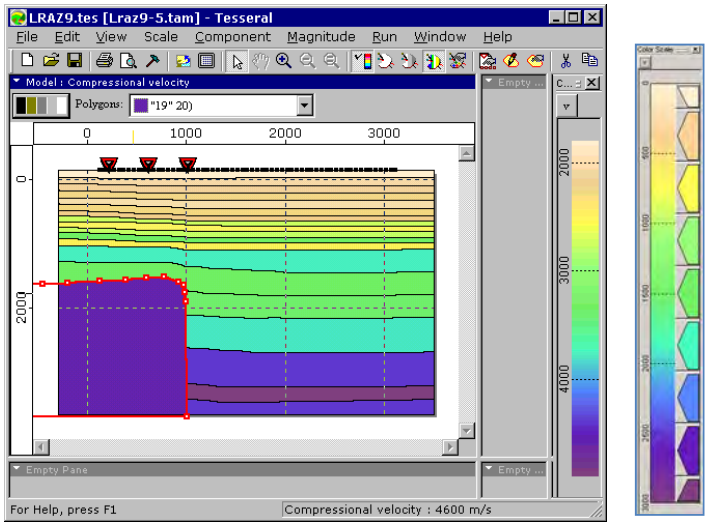
Tesseral 2-D now consists of four major modules: ***Modelbuilder, Computation Engine, Viewer*** and the ***Processing Block.***

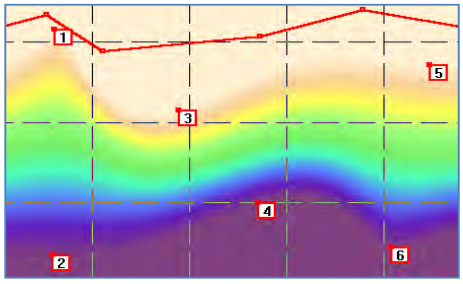
- ***Modelbuilder*** is used to design 2-D density-velocity models of pre-defined geological cross-sections of any complexity. Sonic log data in LAS format can be used to input P- and S- velocity and density values and easily build thin-layered medium model.
- ***Computation Engine*** calculates synthetic seismograms and a series of wavefield snapshots for acoustic, elastic wavefield propagation through heterogeneous media. Media types include thin-layering, vertically and laterally gradational velocities, anisotropic and absorbing.
- ***Viewer*** interactively produces results of the calculations in a visual format and exports the data results for further processing within or outside of the Tesseral package. It allows one to conveniently compare different components of the seismic wavefield, extract values of the signal amplitudes, correlate coherent axes etc. User can easily produce a number of pictures in different movie and separate raster images formats to use them in reports and presentations.
- ***Processing Block*** allows processing of synthetic shotgathers inside the Tesseral package including velocity analysis, CMP sorting and stacking, migrating in time and depth using pre-stack and post-stack time and depth processing. It is possible to conveniently measure AVO effects for complex models. There is convenient possibility of AVO effect measuring for models of arbitrary complexity.

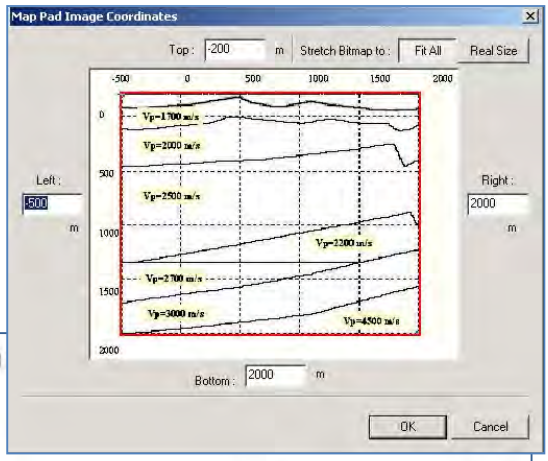


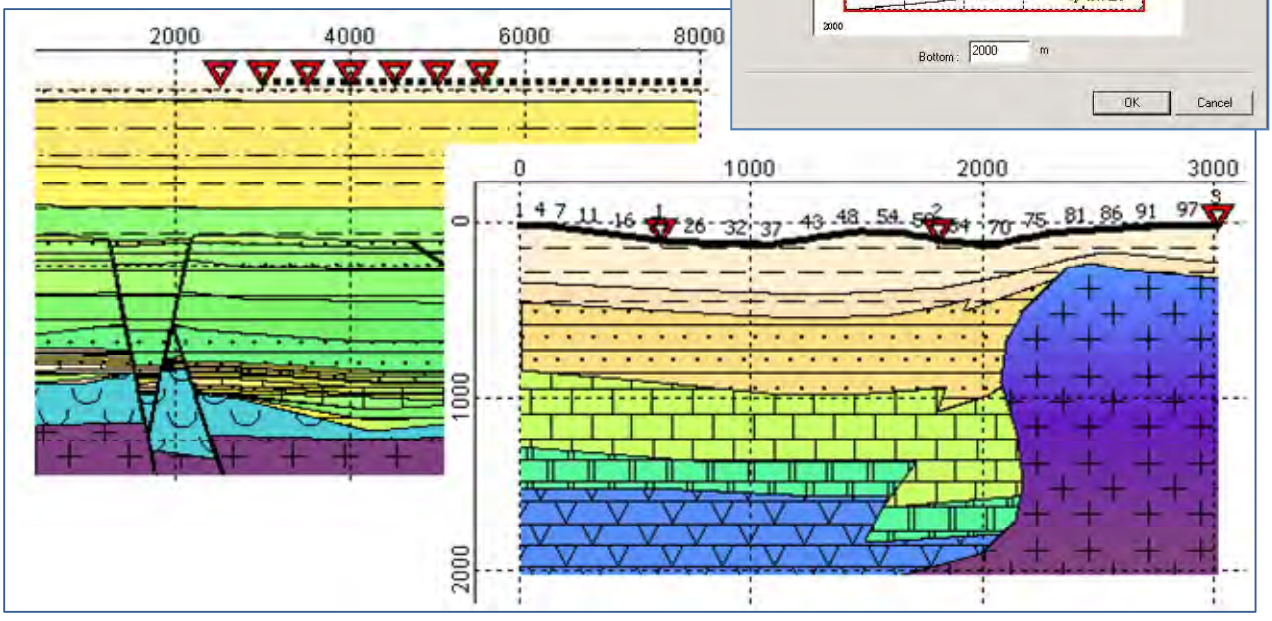
allows you to interactively draw models of geological cross-sections and to input the physical parameters. Practically, any kind of geological structure can be simulated and complex patterns of P- and S-wave velocities and densities can be used. Capabilities include:

- Creating a model as a set of overlapping polygons.
- Simulating complex distributions of physical parameters - including gradients.
- Presenting information in different units of measurement and with predefined precision.
- Adjusting a set of color palettes representing parameter distribution.
- Using raster images as aid to build a new model.
- Inputting a variety of seismic observation acquisition setups.
- Using models in a grid format created from other packages including anisotropy parameters, such as Thompsen's, fracturing and Q.
- Creating thin-layered cross-sections using sonic log data in LAS format.
- Producing Rikker and Puzirov signals with specified parameters.



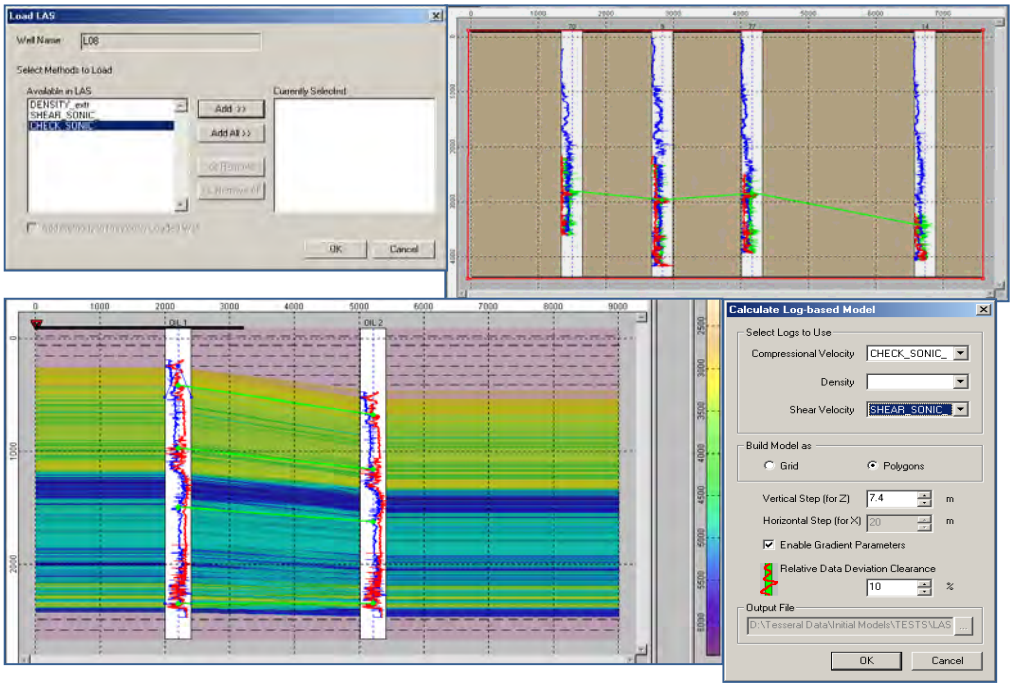






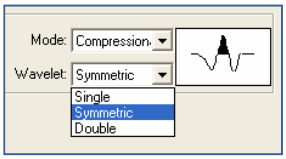
Work with LAS (well-log) files

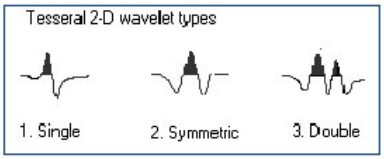
The package allows the user to import well-log LAS files (P and S velocities and density) and convert them into a Modelbuilder polygon model or into a Viewer grid. Using LAS-files makes it possible to easily create a real thin-layered model consisting of a large number of layers.



Ways to specify signal

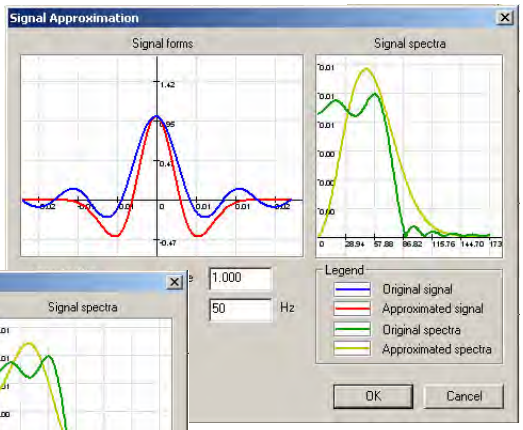
Tesseral 2-D allows choosing one of three wavelet types in combo-box: **Single, Symmetric, Double**

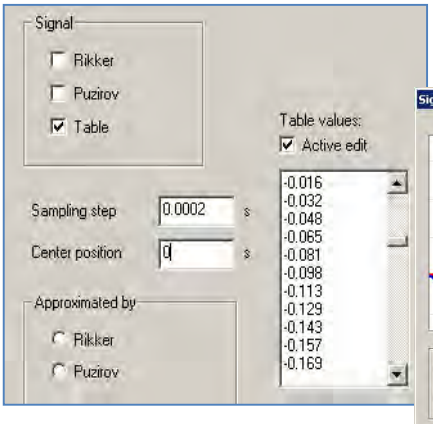


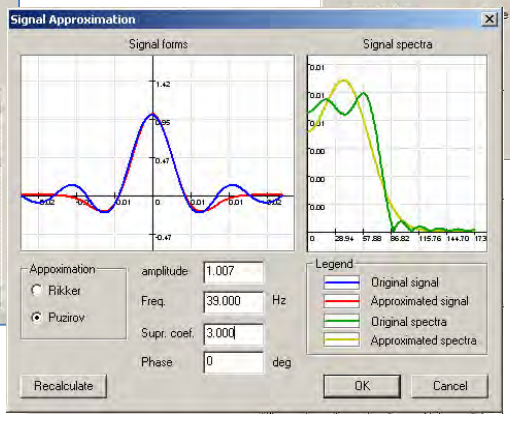


The package allows users to work with the signal form in advanced mode:

Users have a **possibility to form Rikker and Puzirov signals with specified parameters.** Also it's possible to automatically adjust signal parameters which approximate tabulated signal with maximum precision.



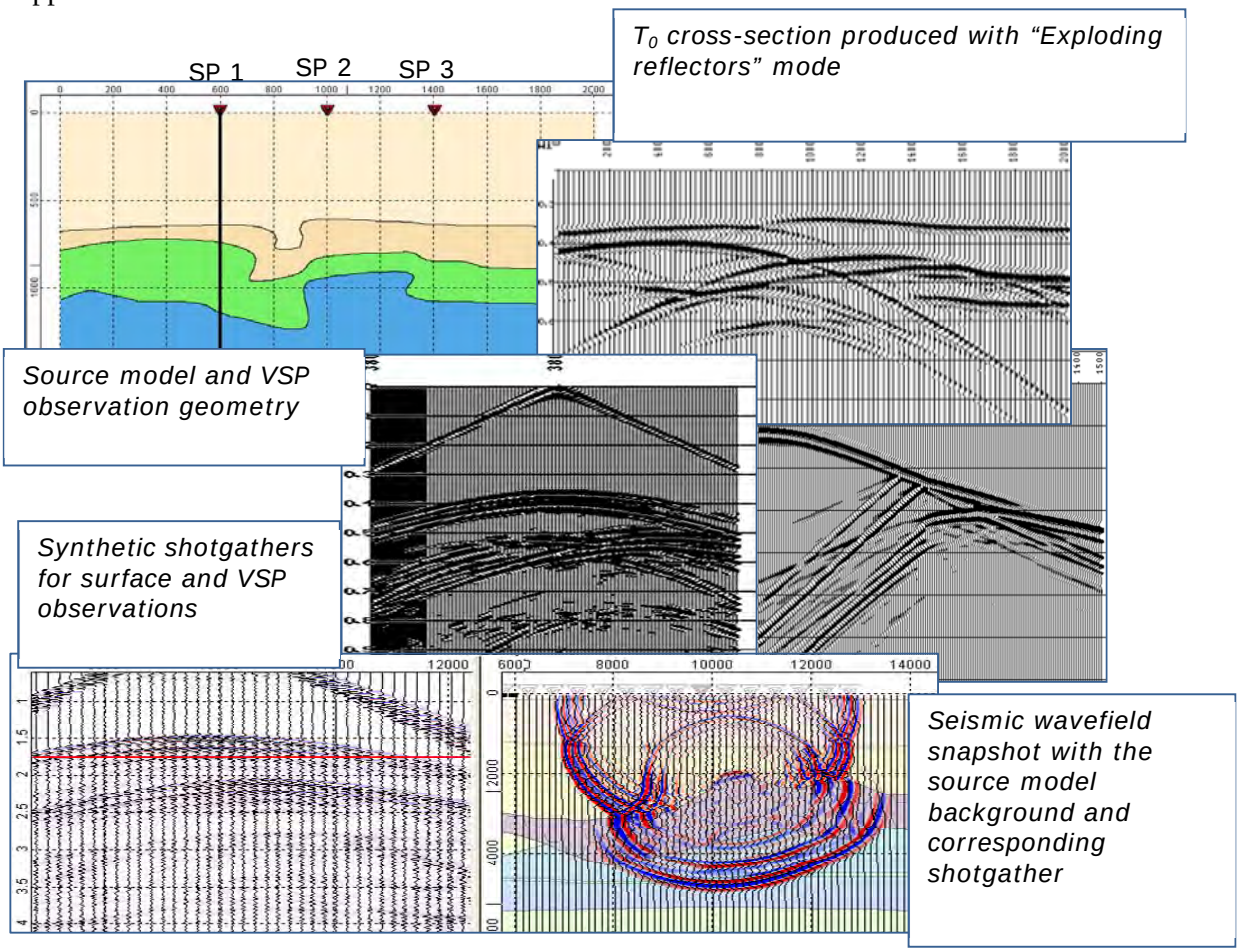




Computation Engine

provides five numerical methods for wave equation finite-difference solutions:

- ***Vertical wave propagation*** - quickly computes reflection traveltimes and seismic amplitudes for vertical 1-D seismic propagation.
- ***Scalar medium model*** – uses the P-wave velocities only and this is the fastest way to model 2-D wave propagation.
- ***Acoustic medium model*** – effectively approximates 2-D wave effects of seismic energy propagation in a real geological situation.
- ***Elastic medium model*** – permits the user to precisely and consistently model 2-D seismic energy propagation in the solid medium, including all wave effects appropriate to geological media, such as wave P-S and S-P conversions. In case of marine observations user can model true effects of water-bottom discontinuity.
- ***Elastic anisotropic medium model*** - is an extension of the elastic wave equation. The difference between physical properties in vertical and horizontal directions (where it is defined) is taken into account. Anisotropy properties are defined using Thompsen's parameters, ε,δ and φ in addition three systems of fracturing can be determined.
- Each computational formula may include ***three*** additional ***modes***: 1) producing ***first arrivals time field*** that provides additional information about the seismic wave field, 2) ***suppressing SV-waves from source*** allows switching on/off surface waves produced by the source, 3) ***wave energy attenuation*** allowing the estimation of absorption of the seismic energy by the medium with temporal approximation.
- ***Exploding surface*** and ***Exploding reflectors*** source modes allow the user quickly obtain approximations to the seismic time cross-section.



AVO Modeling
Visualization / Export of Results

enables the user to view synthetic gathers and wavefield propagation snapshots calculated by the Computation Engine, real seismic data and images, customize displays, and convert data. Files in other standard formats can also be viewed and customized.

An interpreter can:

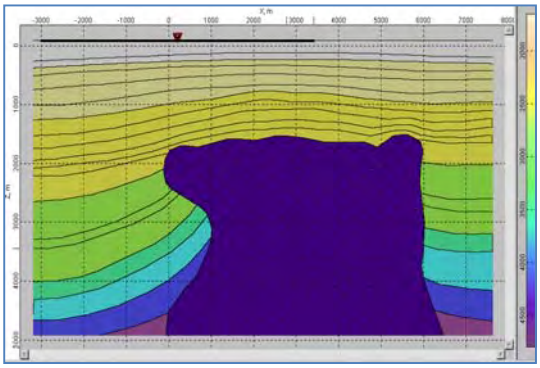
- Easily regulate parameters of amplitudes, amplify small signals and smooth portions of data.
- View snapshots individually or in animated succession in order to understand the propagation of the wavefield resulting in a particular seismic event.
- Analyze different pressure and particle motion components of the seismic wave field.
- Use gray scale and color palettes, show seismic trace profiles in variable area and wiggle trace forms, invert signal etc.

Viewer allows the application of some additional transformations to the resulting data, such as: *DC Balancing*, *Linear Gaining*, various kinds of *Normalization*, *Auto Gaining*, *Addition of "White Noise"*, and *Random shifting*, *Smoothing etc.*

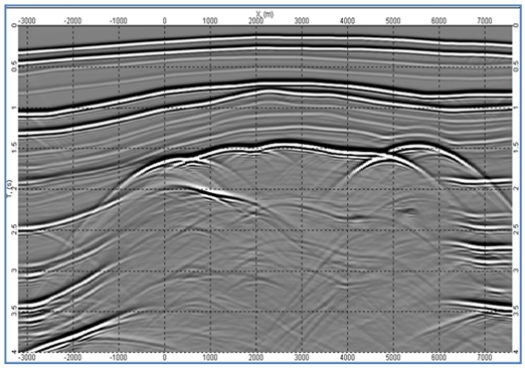
Application of digital processing to modeled results

There is a toolbox of seismic data processing within the Tesseral 2-D package:

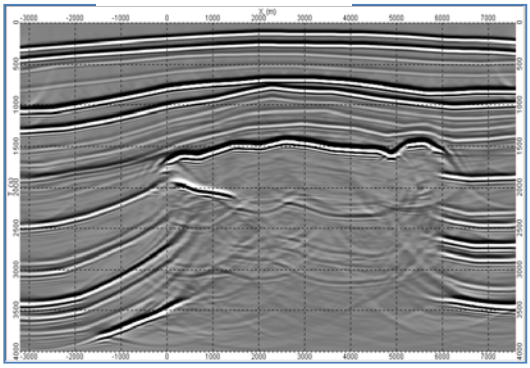
1. Analysis of CMP velocities using velocity spectra;
2. Obtaining of CMP time cross-section;
3. Post-stack Kirchhoff migration;
4. Weighted post-stack Kirchhoff migration;
5. Post-stack FK migration;
6. Pre-stack Kirchhoff migration;
7. Weighted pre-stack Kirchhoff migration;
8. Pre-stack converted wave Kirchhoff migration;
9. Pre-stack depth migration;
10. Time-depth conversion, etc.



Source model



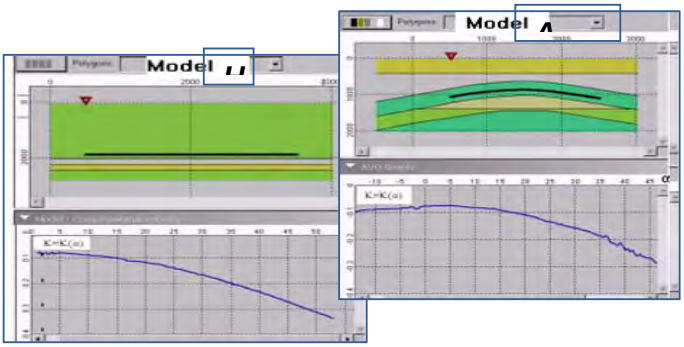
Model time cross-section



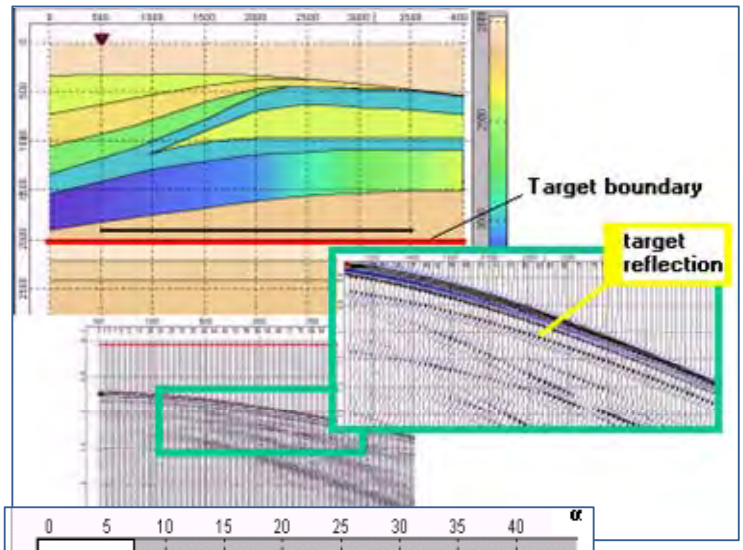
Migrated time cross-section

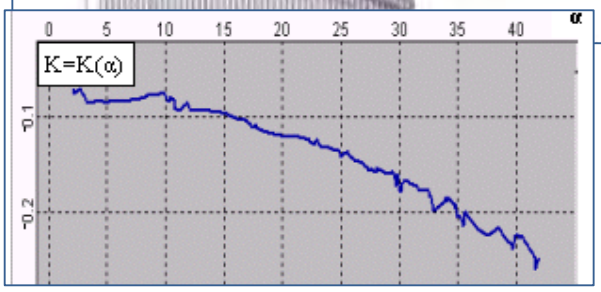
Data processing can be performed on models with complex geology such as salt dome tectonics. This processing can be done within the Tesseral package allowing to quickly estimate modeling results.

can be performed for complex media: isotropic, anisotropic, absorbing, gradient, thin-layered, for plain and curved reflecting boundaries.

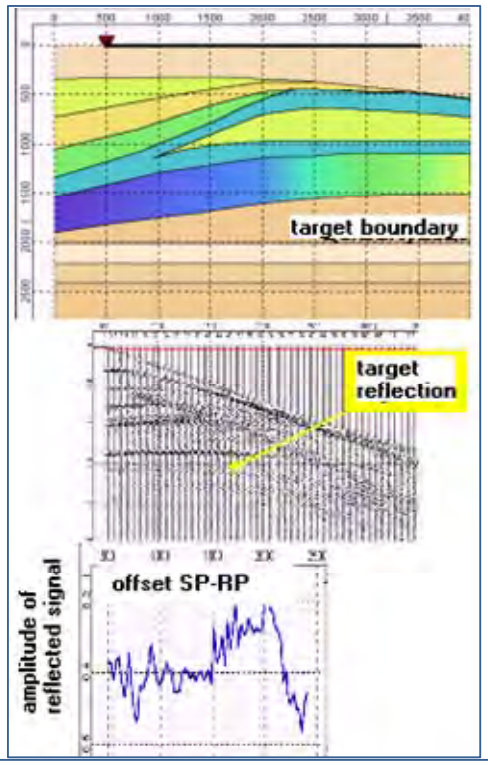


estimating influence of complex geological structure on the measured AVO attributes:





Dependency of reflection coefficients from wave incidence angle.

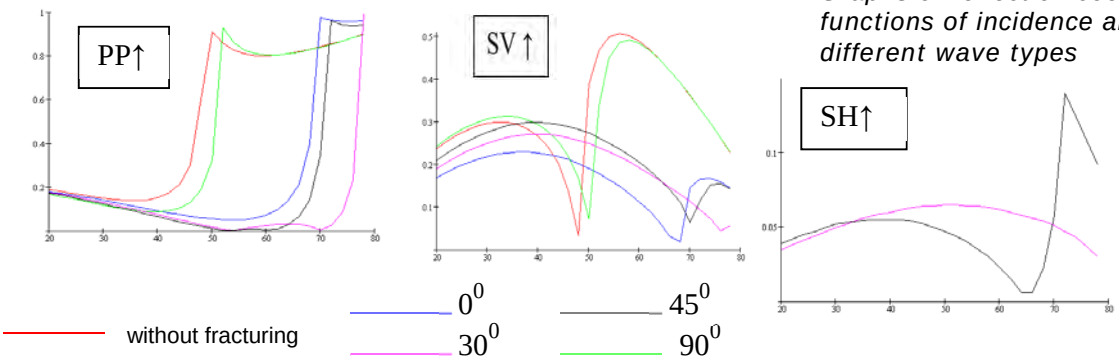


Dependency of the reflected signal amplitude on the observation surface from offset.

3-D AVO modeling

Azimuth 3-D AVO modeling of matching anisotropic absorbing fractured thin-layered stack with arbitrarily oriented symmetry axes of anisotropy and fracture direction.

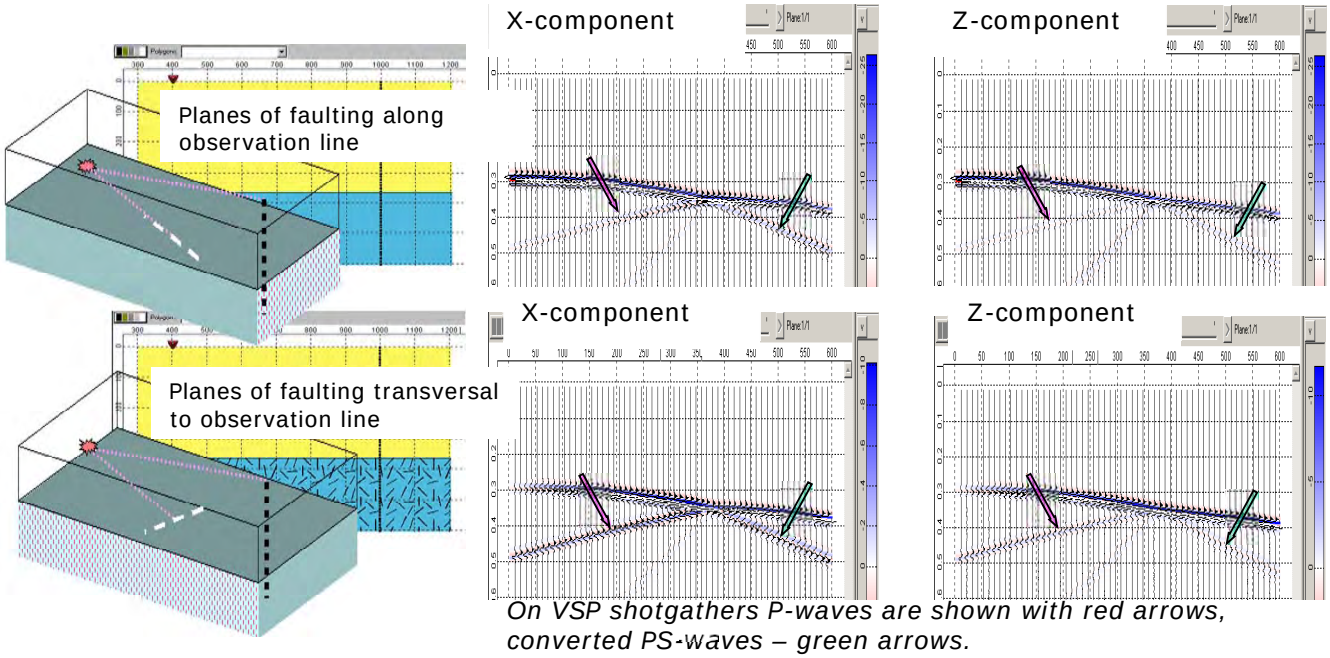
Graphs of reflection coefficients as functions of incidence angles for different wave types



Anisotropy Modeling

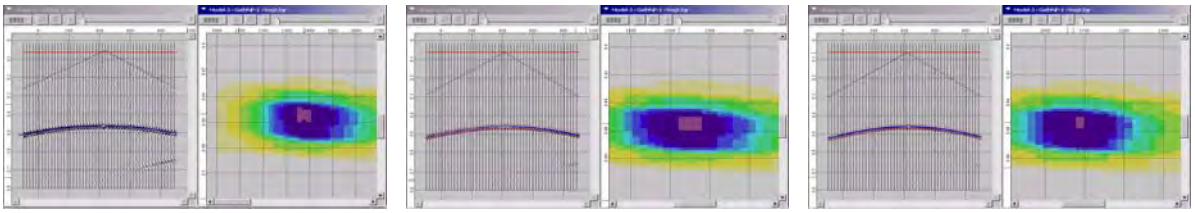
for transversally isotropic and ortho-rhombically symmetrical media along any anisotropy axes.

Estimation of wave effects, caused by longitudinal and transversal faulting for modeling of azimuthal VSP.



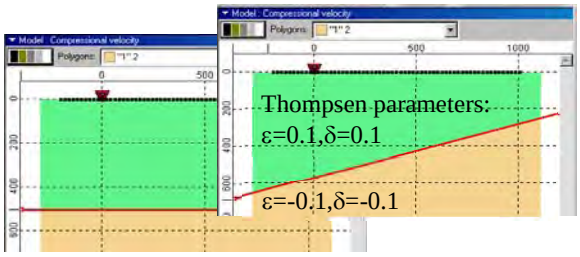
On VSP shotgathers P-waves are shown with red arrows, converted PS-waves – green arrows.

AVO analysis application to determining the influence of anisotropy on effective velocities.

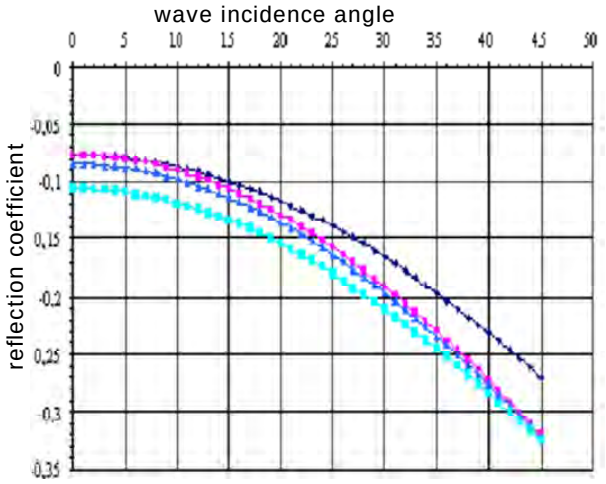


δ=0.1 ε=0 V=2373m/s δ=0 ε=0 V=2220m/s δ=-0.1 ε=0 V=2070m/s

AVO modeling in anisotropic medium for different angles of reflecting boundary and anisotropy axes.



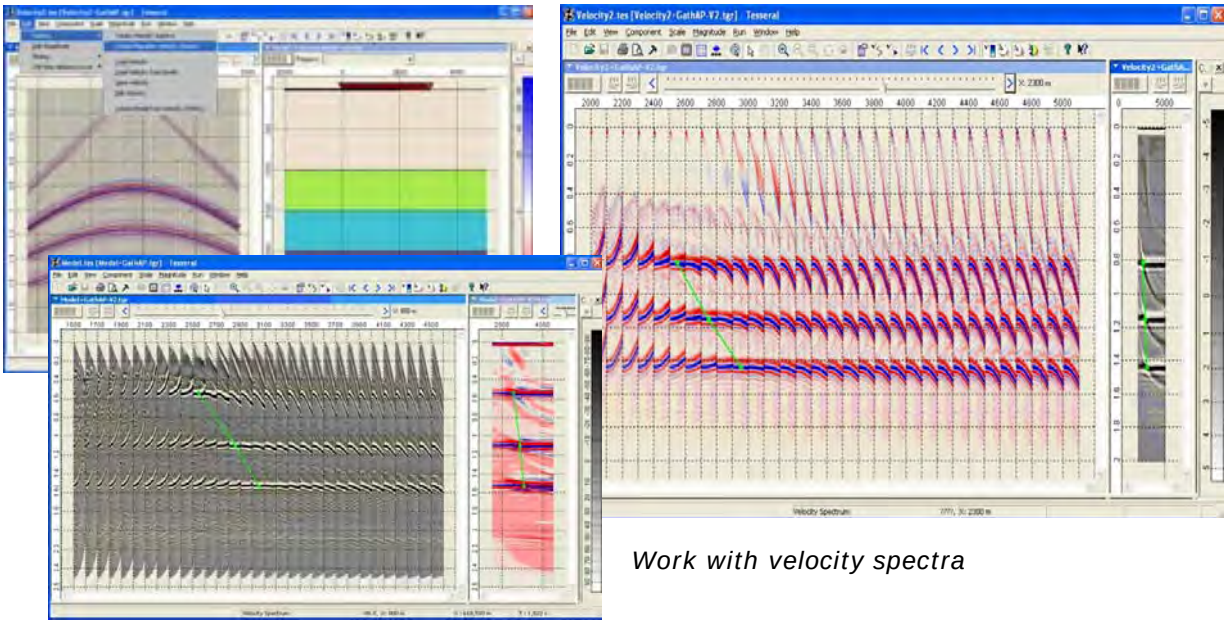
- Isotropic medium, boundary inclination - 0
- Anisotropic medium, inclination - 0
- Anisotropic medium, inclination - 15
- Anisotropic medium, inclination - 30



Migration Velocity Analysis

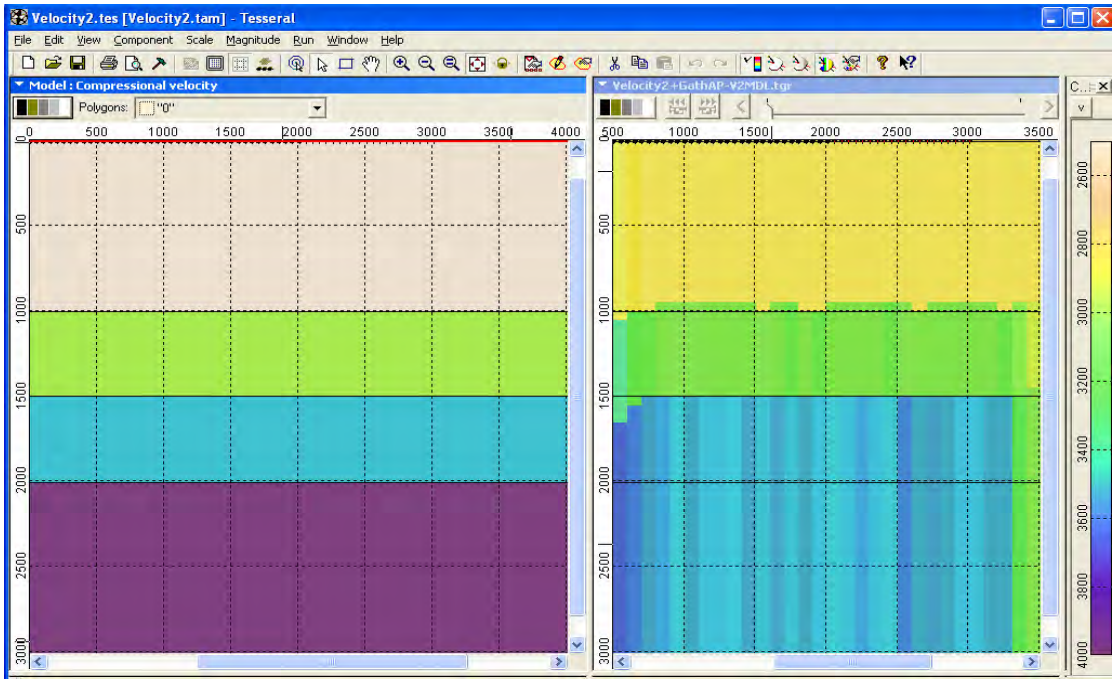
The package allows determining migration velocities close to average ones. Kirchhoff Migration for separate equidistance systems, extracted from CSP seismograms (J.Sattlegger principle) is used.

Migration velocities are determined by the presence of horizontal correlated axes on the sets of migrated traces for given constant velocity values, or as usually on velocity spectra.



Work with velocity spectra

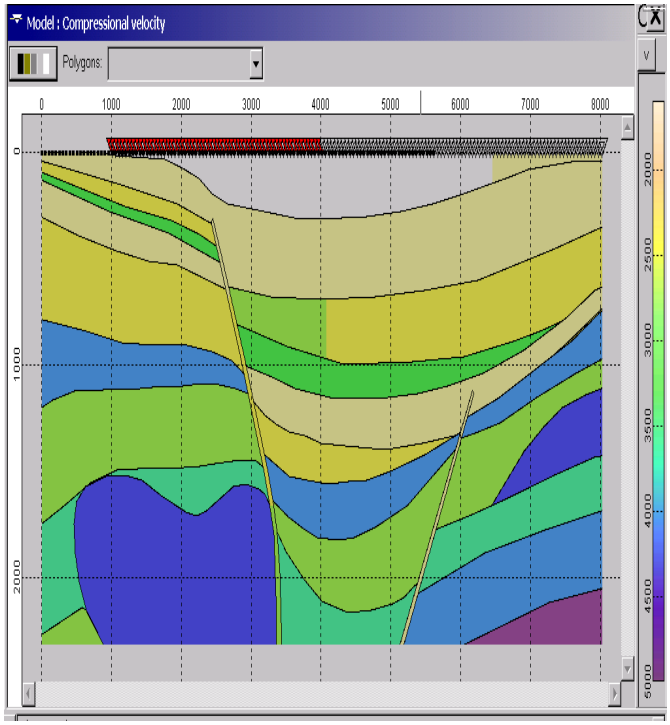
The program allows user to save and optionally correct the obtained average velocity graphs. Subsequently, these average velocities can be used for pre-stack or post-stack migration in time domain.



Source velocity model

Migration velocities as layer velocities

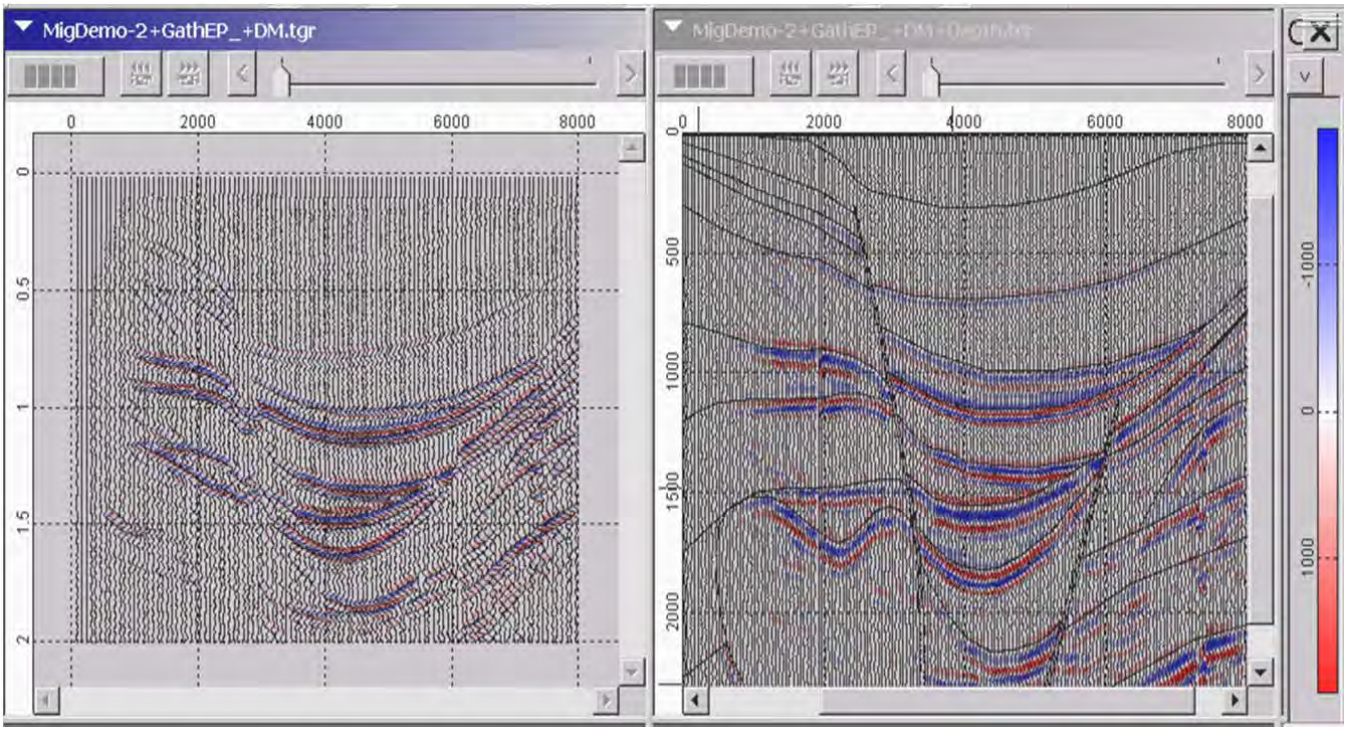
Depth migration conversions



Depth migration in the Tesseral package produces time fields allowing to calculate **times of incident wave arrival and corresponding Green function scalar** as a step that immediately follows the synthetic shotgathers computation. It allows to correctly perform Kirchhoff depth migration taking into account surface relief, velocity anisotropy with practically arbitrary symmetry, thin-layering nature of the medium, and refraction. In the latter case, migration may be used to form images of sub-vertical boundaries.

The flexibility of velocity model input and a convenient interface for data manipulation allows to migrate not only synthetic gathers, but also real data. Time fields can be fine-tuned to different migration operator criteria, such as First Arrivals, Maximum Energy, Maximum Rotor, Maximum Divergence etc.

Results of depth migration



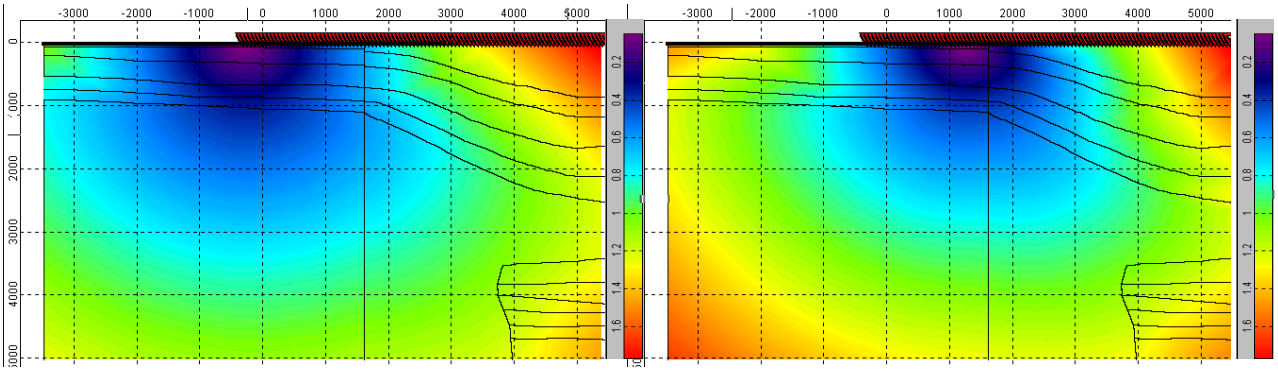
Seismic image (migrated cross-section) in time scale;

Seismic image in depth scale (initial model is shown in background).

DEPTH MIGRATION UNDER CONDITIONS OF TTI-VELOCITY ANISOTROPY

Thinly-layered, fractured, unevenly loaded, and other types of media with dipping boundaries give rise to a phenomenon known as TTI-anisotropy, which has a significant effect upon the lateral positioning of geological objects on migrated sections. The possibility of modeling seismic wavefields in anisotropic media with practically arbitrary direction of symmetry, along with pre-stack depth migration of these data, allow **estimating the effect of TTI-anisotropy upon the results of depth migration**.

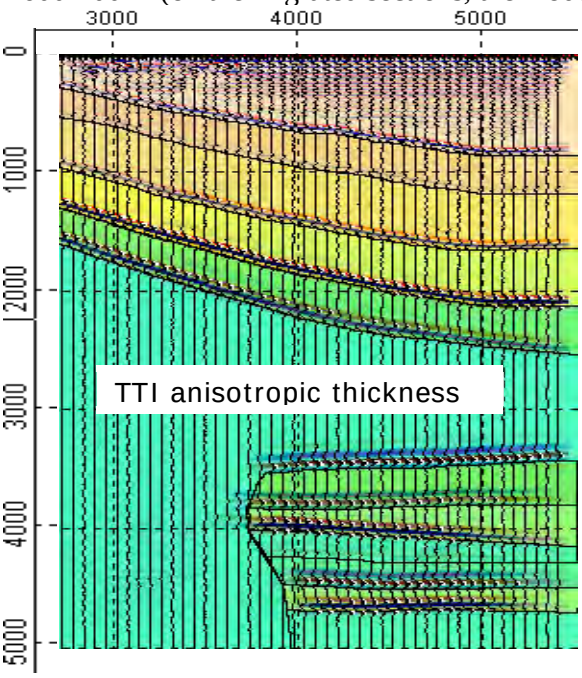
For Kirchhoff migration, time fields are computed while generating synthetic gathers, which allows taking into account all wave effects which are characteristic for wave propagation in an elastic medium. The influence of TTI-anisotropy upon time field character for a model with TTI-velocity anisotropy manifests itself as the inclination of the isochrone axis in accordance with the position of indicatrix of anisotropy.



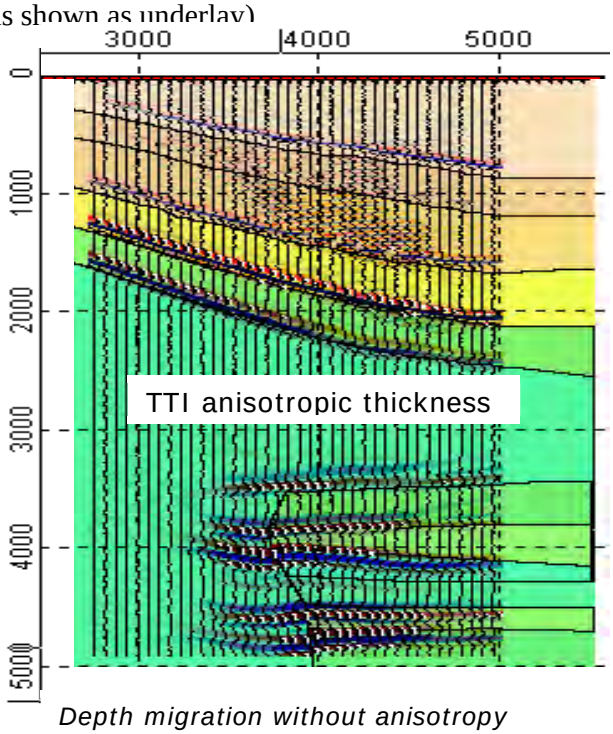
Time field for SP-1 (X=-320 m)

Time field for SP-29 (X=1360 m)

Modeling of the gathers and their subsequent depth migration helped to evaluate the effect of not taking anisotropy into account upon determination of the position of the target block. When anisotropy is not taken into account, the position of the block is displaced relative to the model by 600-700 m (on the migrated sections, the model is shown as underlay).



Depth migration with anisotropy



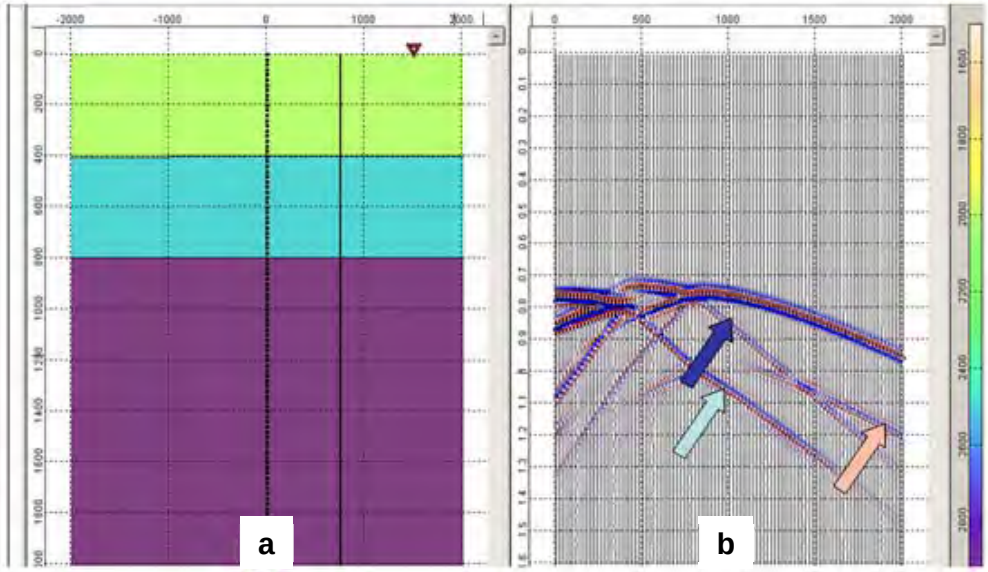
Depth migration without anisotropy

Depth Migration of VSP Data

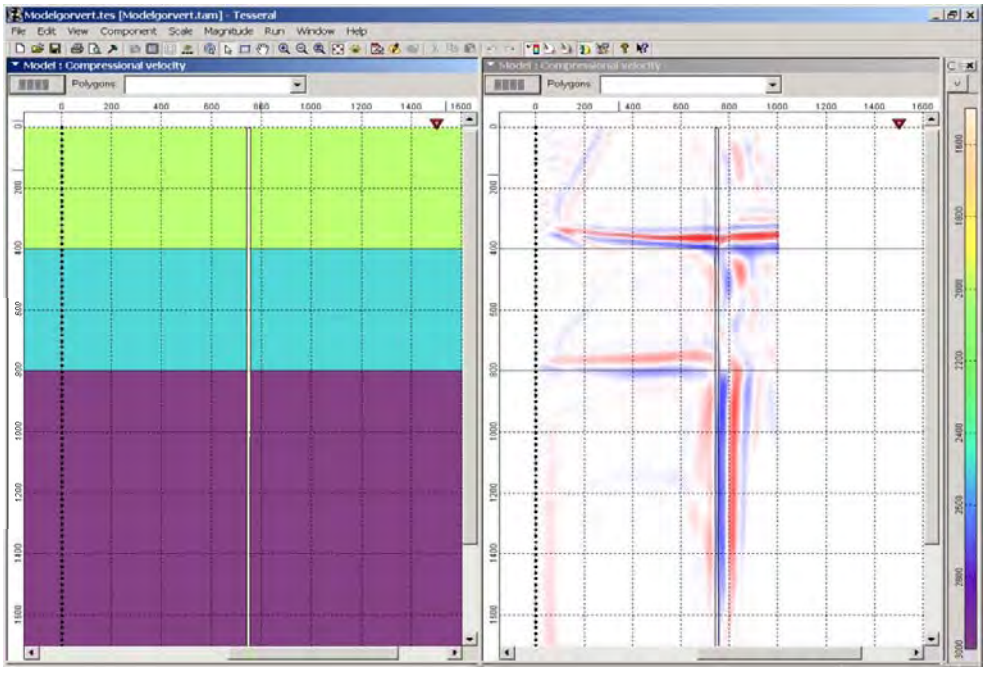
The Tesseral package includes the following VSP data depth migration procedures:

1. Eikonal-Kirchhoff migration, including:
   - Migration for sub-horizontal boundaries on monotypic and converted reflected waves;
   - Migration for seismic imaging without constrains of boundary's inclination angles using transmitted converted waves;
   - Migration for imaging of sub-vertical boundaries on monotypic and converted reflected waves.

2. Migration of monotypic and converted waves with computation of migration operator into account anisotropy on compressional and shear waves, refraction with incidence wave changing direction from descending to ascending, thin-layering, seismic record's frequency dependency on boundary's roughness, changing wave type during wave propagation, etc.

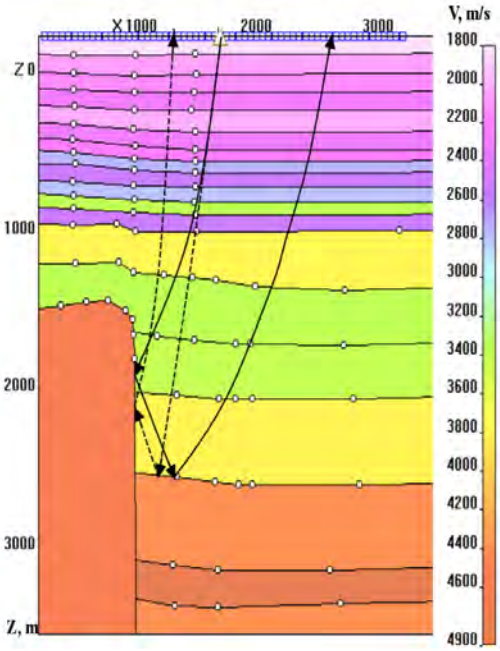


a – MODEL, b – VSP shotgather: with green arrow the transmitted converted wave from the first boundary is shown; blue arrow – transmitted converted wave of the second boundary, red arrow - a transversal converted wave from vertical boundary



Migration on transmitted converted waves. Simultaneous formation of sub-horizontal and sub-vertical boundaries

TIME SLICE ANALYSIS OF MODELED WAVEFIELD

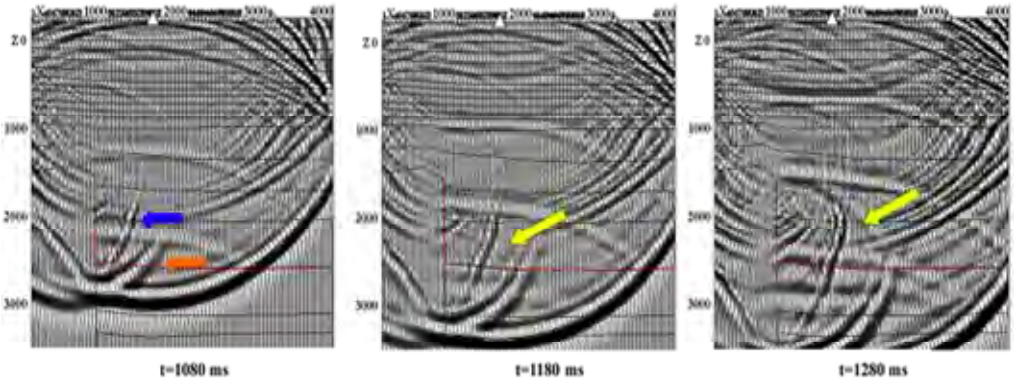


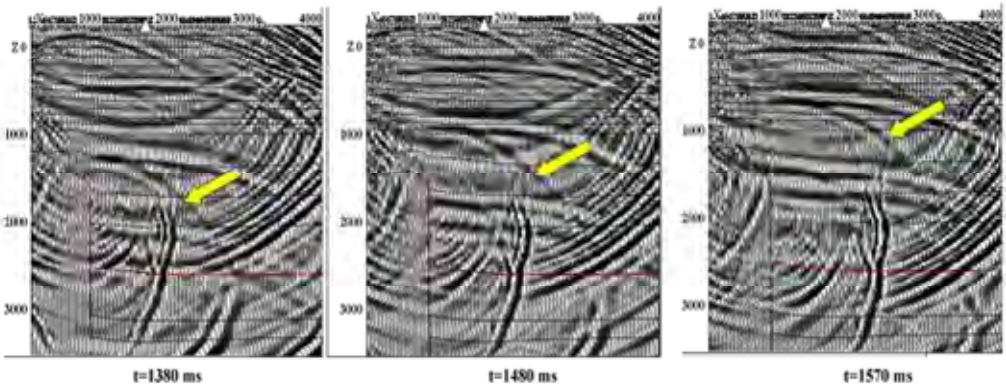
Salt dome model

Under complex media conditions, it is very important being able to distinguish various wave types on the modeled gather. In the Tesseral package, this problem is solved with the help of the **wavefield time slice (snapshot) analysis**. Such snapshots may be visualized in both the wavefield of the Z-component of the medium particle displacement velocity, as well as the X-component, which allows to easily distinguish the downgoing and the reflected waves of various types. Pressure component, usually registered by hydrophones is also modeled.

The salt intrusion example shows the identification of the waves, reflected from the walls of the salt plug, and the doubly reflected waves, which have undergone a double (duplex) reflection from first the salt plug wall, and then from an adjacent horizontal boundary.

Snapshots, obtained by generating waves from the same source. Red arrow shows the longitudinal wave, and the blue arrow – the converted wave, both reflected from the salt dome wall. The yellow arrow shows the duplex P-wave, which can be traced from its inception to the moment of its registration at surface. The model boundaries are shown on the migrated section as an underlay.





What you can do with the package

With *Tesseral 2-D* you can model the seismograms and time sections for:

The models of virtually arbitrary complexity including the ones with strong lateral velocity contrast, steep boundaries, compartmentalization, and caustic zones, producing the waves of complex ray-path including those reflected from the vertical boundaries etc.

- The models with complex topography and various near-surface conditions, including the situation when source/receivers are on different elevations, traps, permafrost, low-velocity zone of variable thickness (by correctly taking into account kinematics and dynamics of surface waves, satellite waves, refractions, etc.).
- Thin-layered models that are build on the basis of the acoustic and density well-logs.
- Transversally isotropic media models with the tilted symmetry axis, that may be complicated by tilted fracturing systems that produce the most complex anisotropy in the conditions of the 2-D media – the monocline one.
- Models for porous fluid-saturated media (Gasman approximation).

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Also, using Tesseral 2-D Full Wave modeling package, one can obtain:

- AVO-dependencies for anisotropic, porous, fluid-saturated, viscoelastic, thin-layered media, for curved boundaries complicated by changing physical properties both vertically and laterally, and to evaluate the extend of the distortions of the AVO curve that can be caused by heterogeneities in the overlaying thickness.
- Evaluation of the Q-factor for thin-layered media by comparing the synthetic VSP gathers (using the acoustic well-logging results) and field VSP results.

The package also has a number of auxiliary modules, including:

- Depth migration module that has the following procedures:
  - Post-stack and pre-stack Kirchhoff depth migration (Eikonal);
  - "Universal" Kirchhoff depth migration with the calculation of the Green function using the vector wave equation that allows:
    - tuning the migration operator for the qualities of the specific cross-section using maximum energy, maximum divergence, maximum rotor, etc time fields;
    - taking into account the thin-layering of the model (so called velocity micro-model);
    - take into account the anisotropy and topography;
    - image the vertical (up to 90 degrees) boundaries using refracted waves;
- A tool kit of time post-stack and pre-stack migration in both space-time and f-k domains,
- DMO, velocity analysis for CDP's, etc,
- Velocity analysis for anisotropy,
- Time and depth VSP migrations.

The package also allows producing and studying:

- the "snapshots" of the wave field and
- the time field of incident waves that can be used for interpretation of complex wave field and for educational purposes.

What the package can do for you

1) Seismic data interpretation verification, including the quality control of:
   a) proper handling of discontinuities and structural elements;
   b) dynamic characteristics of the seismic records within complex geological models;
   c) presence and influence of seismic artifacts – phenomena in the interpreted wave field, not caused by the predefined geological model or resulting from conventional data processing;
   d) resolution capability of the acquisition system.
2) Provide insights useful in planning of seismic acquisition, monitoring a specific site, seismic data acquisition and subsequent processing.
3) Creation of sample data sets for geophysical software development.
4) Visual illustration of subsurface coverage of the intended Zone of Interest.
5) Seismic data processing.
6) Use as an educational and research tool.

Summary

- ***Tesseral 2-D*** is a powerful tool for improving the quality and reliability of the interpretation of seismic surveys. The package is useful in all stages of data processing and decision-making. It is particularly helpful for planning acquisition parameters, verification and in the fine-tuning of the processing sequence.
- ***Tesseral 2-D*** may be especially helpful for interpreters working with seismic record dynamics, i.e. AVO analysis, multi-component acquisition (polarized seismic prospecting) ... It is also useful for identifying and interpreting characteristics of seismic records produced by a thin-layered non-monotonous quasi-anisotropic media. It may be applied to the modeling of complex structured geological media, including sub-vertical layering. The program also provides a means to thoroughly research complex geological situations.
- ***Tesseral 2-D*** is a highly interactive and easy to use visual learning tool for students and professional geophysicists alike. It can help geoscientists to better understand wave processes in geological media and the specifics of the seismic exploration methods.

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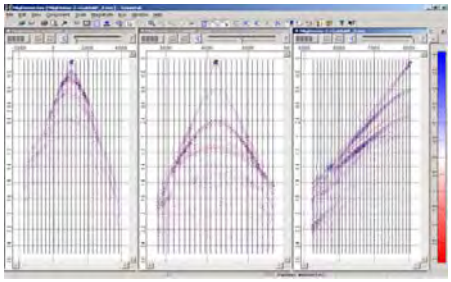
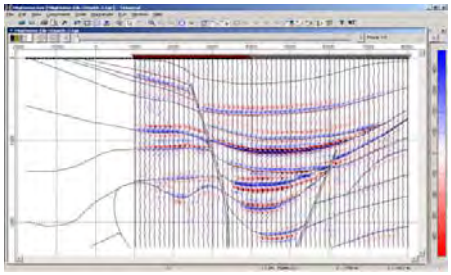
Tesseral Technologies Inc's goal is to provide our clients with a user-friendly software package and with a high quality product and service.

1. The basic package ***Tesseral –PC- variant***, independently of the version, runs under Windows operation system. This allows creating and editing models, computing synthetic shotgathers and processing seismic data.
2. **Variant for Windows network: Tesseral –WN- (Windows Network)** enables to use a local windows network for parallel calculations. The network version of the software package allows to carry out calculations on a local PC network, in this way accelerating (in proportion to number of simultaneously used PC) the full-wave modeling and data processing for real models of geological medium. The price for the network version depends on a number of PC bundled in the calculations – the license key is encoding number of remote PCs used as a calculation unit. The network could have more nodes than those ones licensed, however user have to determine the PCs to be used before launching the calculations. The network version works under any Windows series NT (NT, 2000, XP) even with heterogeneous networks (full instruction regarding this matter is provided).
3. ***Variant for Linux-cluster:*** **Tesseral –LC- (Linux Cluster),** allowing to carry out parallel calculations on Linux-cluster.
4. ***Variant for Windows-cluster:*** **Tesseral –WC- (Windows Cluster),** allowing to carry out parallel calculations on Windows-cluster.

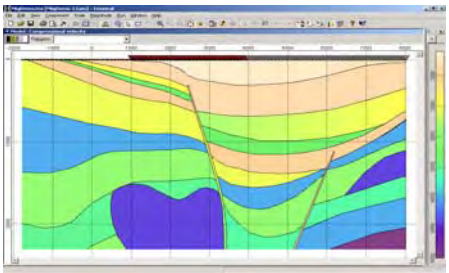
LINUX MULTIPROCESSOR SYSTEMS BASED ON STANDARD PROCESSORS MAY BE USED TO ACCELERATE HUGE CALCULATION VOLUMES NEEDED FOR FULL-WAVE MODELING AND DATA PROCESSING.



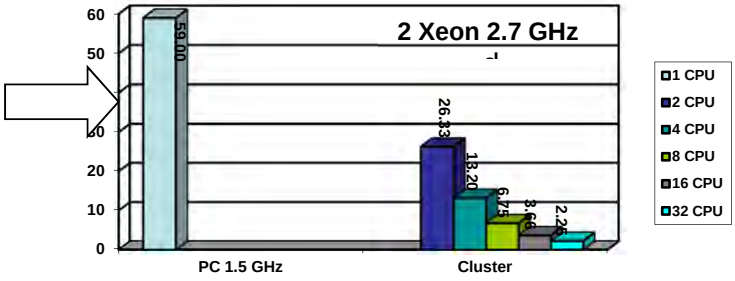
Full-Wave Modeling



Vector Wave Kirchhoff Migration



Tesseral –PC- (Windows)



Tesseral –LC-/-WC- (cluster) processing time (min)