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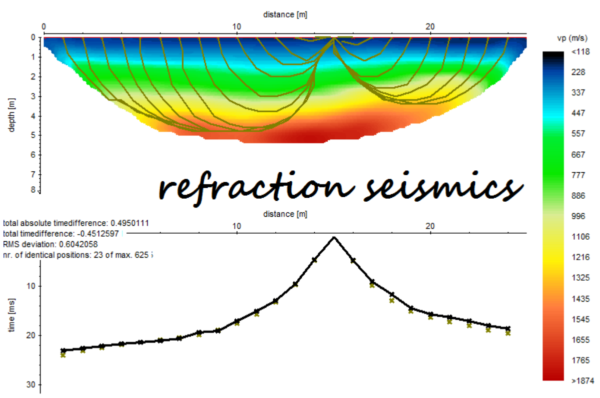
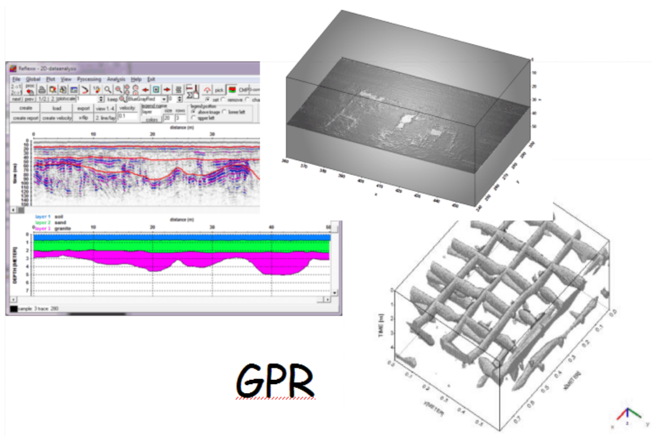
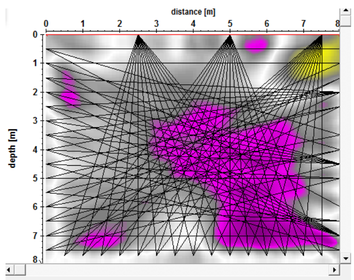
Software catalogue 2020

REFLEXW

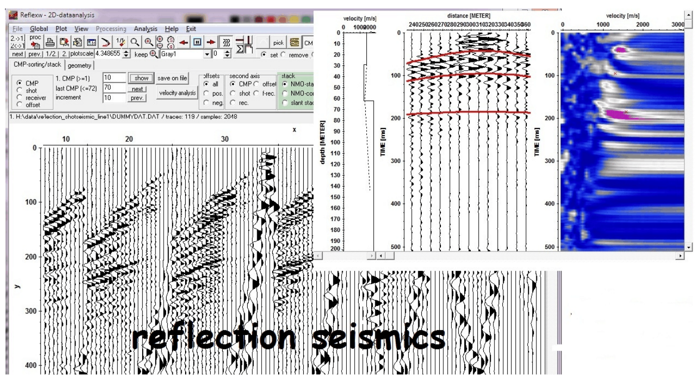
the 2D- and 3D-processing and interpretation package for







crosshole, single hole, VSP



Reflex2DQuick

The easy handling of 2D ZO lines or seismic shots

Reflex3DScan

The fast access to a 3D-view of the underground

ReflexVibro

Our tool for the interpretation of seismic vibration data

Table of Contents

One software package for nearly all wave data like GPR, reflection seismics, refraction seismics

REFLEXW - the complete 2D processing and 2D/3D interpretation software of reflection, refraction and transmission data with a wide range of applications:

➡ GPR (Ground penetrating radar)
➡ reflection seismics
➡ refraction seismics
➡ borehole-borehole wave data

	GPR	reflection seismics	refractions seismics	crosshole, VSP	ultrasound
2D-data-analysis	x	x	x	x	x
3D-data-interpretation	x	x			x
modelling (simulation/inversion)	x	x	x	x	x

Apart from the complete range of the standard filter- and CMP-processing steps many elements especially designed for various applications are incorporated:

➟ 3D-datainterpretation incl. calculation of timeslices
➟ picking of first arrivals or horizons
➟ wavefront-inversion of first arrival traveltimes
➟ raytracing using a Finite Difference approximation of the eikonal equation
➟ tomographic interpretation using SIRT
➟ Simulation of the wave propagation using a Finite Difference (FD) approximation of the elastic or electromagnetic wave equation

The following modules of **REFLEXW** are available:

* module **<u>2D data-analysis</u>** for GPR, reflection seismics, refraction seismics, borehole-borehole data
Many different **processing** possibilities - interactive processing of single files or by generating a batch-file, one- and multi-channel filters, editing, static correction, deconvolution, migration and much more. All processing steps are documented.
Easy **import** of data of many different formats (e.g. SEGY, SEG2, most of the GPR- and seismic systems (for example: GSSI, Sensors&Software, MALA, IDS, UTSI, 3D-Radar, ABEM, SEGY,SEG2, Summit and so on)), integration of other non-standard formats.
conversion of single sections and of a profile sequence (automatic assembling and storing of the sections under one single datafile or automatic generation of datafiles for parallel and inline-sections).
Velocity analysis of zero offset or shot data using an interactive hyperbola or line adaptation or an intercepttime method
Picking of arrivals - manual, automatic or semi-automatic, ASCII- and DXF conversion of the picks
CMP-processing for GPR, reflection seismics and refraction seismics
single-shot data processing (sorting, display, processing, NMO-analysis, stacking)
interactive analysis of CMP- or shot-data using a **semblance analysis** or an interactive adaptation method calculating either the reflection hyperbolas (reflection seismics) or the complete traveltime branch including diving waves (refraction seismics).

* module **<u>3D data-interpretation</u>** for GPR and reflection seismics
Display of x-,y- or z-slices. The **slices** are either displayed in manually scalable windows or by moving through the 3D-dataset using a track bar.
3D-cube display of the individual slices or of the full 3D-data using shading algorithms
3D-Picking of arrivals.
3D-fixed array tool for a fast interpretation of multichannel data with fixed lateral offset between the channels which allows to easily interactively reach each point within the dataset.

* module **<u>modelling</u> with wavefield simulation and traveltime inversion** for refraction seismics, borehole-borehole data, GPR and reflection seismics data including
- **refraction traveltime analysis** for refraction seismics.
Interpretation of refraction seismic first arrivals. The module includes various sorting and combining possibilities for the picked traveltimes. These combined traveltimes are the bases for a FD based wavefront-inversion. Different raytracing methods are available for the evaluation of synthetic traveltimes. An interactive 1D-velocity analysis tool allows the adaptation of the complete traveltime branch including diving waves.
- **forward modelling** for simulating the electromagnetic and seismic wave propagation in a 2-dimensional medium using a Finite Difference scheme.
- A **tomographic** approach based on SIRT is incorporated for the inversion of the picked traveltimes (refraction and transmission). Straight and curved rays are supported.

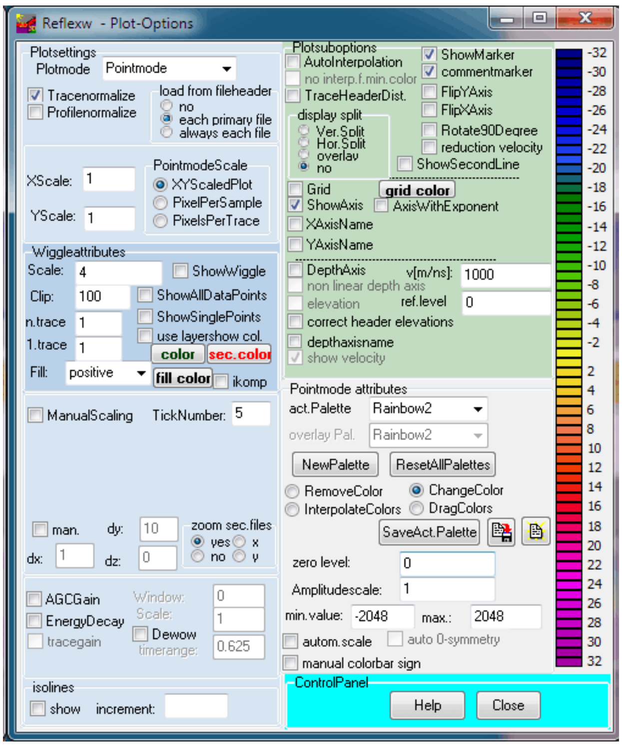
The module **2D data-analysis** allows the complete 2-dimensional processing of single shots, zero offset lines or multi-shot gathers. The module is useful for the following applications:

- GPR (Ground penetrating radar)
- reflection seismics (single and multi channel)
- refraction seismics
- borehole wave data
- ultrasound data

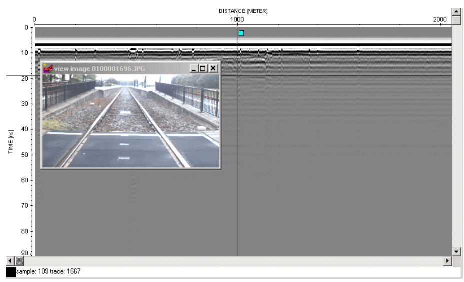
Import data

An **import** option allows the loading of the data for almost all existing GPR and seismic data formats (e.g. GSSI, Sensors&Software, MALA, IDS, UTSI, 3D-Radar, ABEM, SEGY,SEG2). Single sections as well as a profile sequence (automatic assembling and storing of the sections under one single datafile or automatic generation of datafiles for parallel and inline-sections) may be imported.

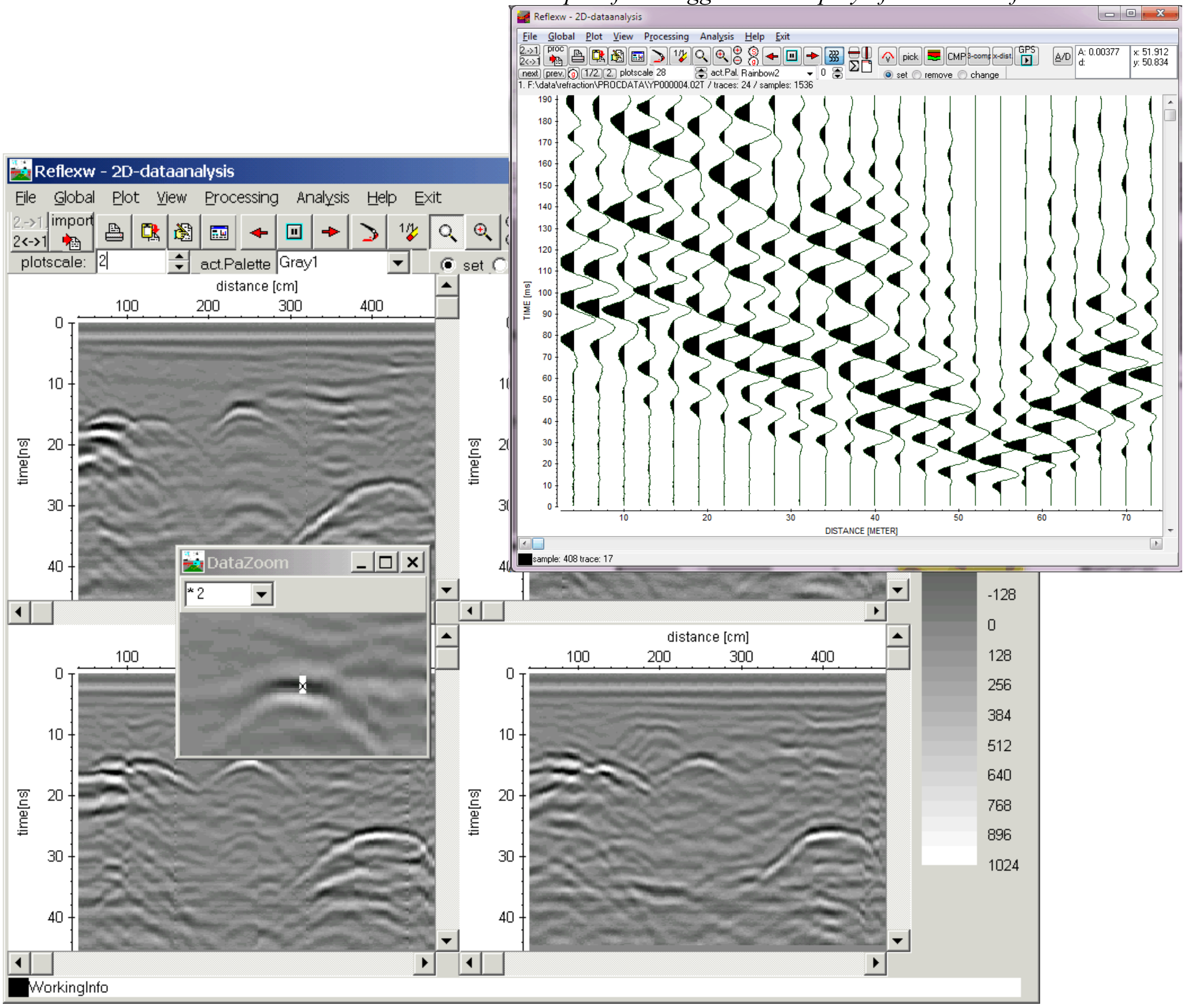
The data **display** and **printing** possibilities



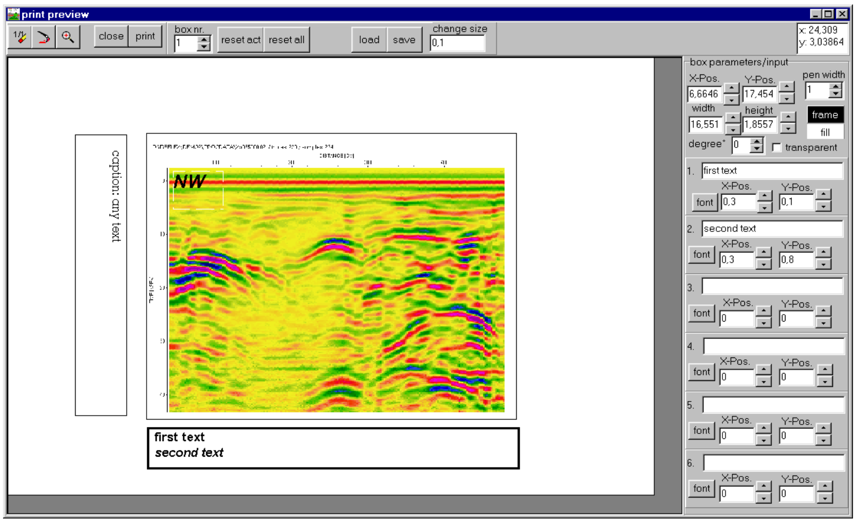
- display of the data either in **wiggle** or filled area **point mode**
- "normal" reflection (time axis from top to bottom) or refraction (time axis from bottom to top) display
- 90 degree rotated display for e.g. borehole data
- continuous display of the current mouse position parameters including time, distance, amplitude and depth
- the user may switch between two different scale modes:
  1. the data are completely plotted into the actual window with subsequent free zooming and moving possibilities
  2. trace based scale: the user chooses the pixel size for each trace. If the line is not completely plotted into the window moving possibilities are available.
- **zoom**- and **autoscroll** possibilities
- loading of a secondary profile, horizontal or vertical split-mode or overlapping of the profiles
- loading of up to 4 different files with single or multi axisscaling, horizontal and/or vertical split-mode
- interactive **magnifying glass** option (see figure on the next page) with choosable zoom factor - a freely choosable data part is continuously magnified when moving the mouse
- interactive **color amplitude assignment** for point mode
- many different **plot options**, e.g. rotated display, combination of wiggle and point mode, free choosable axis and so on
- easy transfer of the data to the **clipboard**
- **printing** out the data with freely choosable scale either in cm or scale like 1:1000; support of banner output (continuous printing on printers which support banner output, e.g. HP Deskjet 1120 C), possibility of freely placed **annotations** (see print preview).
- **stack printing** of a complete set of 2D-lines using the same printing parameters
- **Print preview** menu - allows to preview the size and shape of the print output and to define a print header consisting of up to 30 different header comment boxes containing up to 6 different comments.
- **oscilloscope-function** - wiggle plot of the actual trace with the indication of the actual amplitude, time and frequency
- **view camera images** - camera images are shown based on the actual cursor positions within a freely moveable and scalable window.
- comprehensive context sensitive **online help**



Example of the wigglemode display of a seismic refraction section



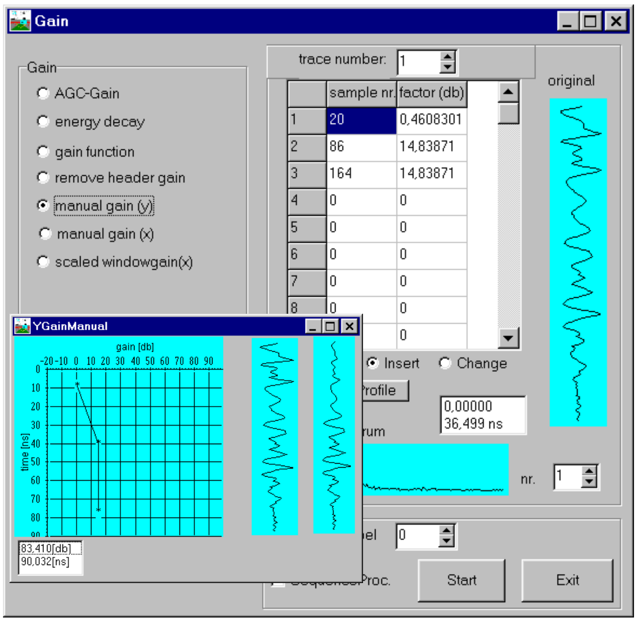
Example of the pointmode display of 4 different GPR-lines with activated magnifying glass



Print preview window with the possibility of defining freely placed boxes each containing up to 6 different comments

The **dataprocessing** possibilities

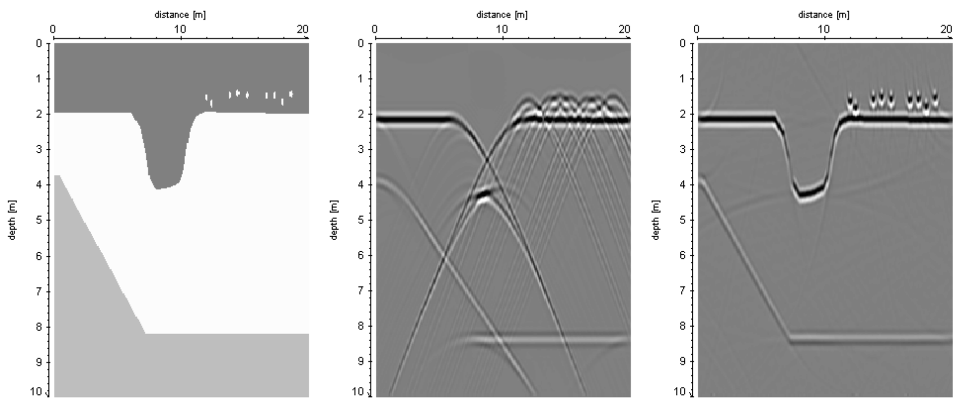
A single radargram or seismogram section can be **interactively processed**. Primary and secondary profile are displayed simultaneously.
The **batch mode** allows the automatic processing for a choosable number of lines. A sequence of processing steps will be applied on an arbitrary number of profiles. The batch mode runs totally automatically. Primary and secondary profile will be displayed, whereby a direct control of the result is given.
All processing steps are stored for each profile and can be edited at any time.



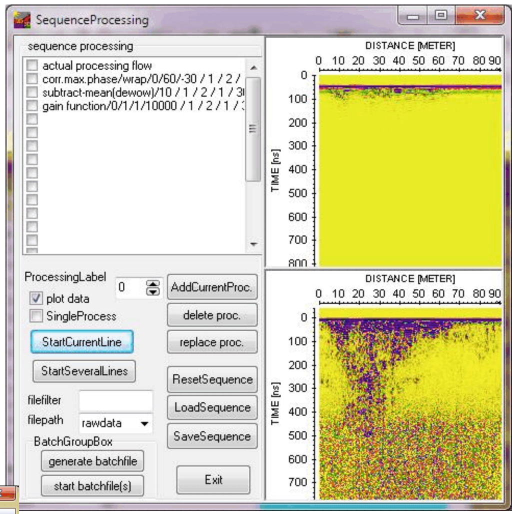
- The dataprocessing is completely interactive. The effect of the filter is online controlled when changing the filter parameters by showing both the original and filtered trace. All edit inputs may be entered either interactively in the original profile or using the table input.

  An overview of the different **processing functions**:

- editing functions (like removing, extracting of single traces/trace ranges, muting, stacking, subtracting or adding of profiles and much more)
- Horizontal rescaling of the data based on markers (manual or automatic) or on GPS coordinates
- flipping the profile in x-direction or y-direction
- static correction -interactive input of the correction values, read from an ASCII-file with support of GPS coordinates, automatic correction of the first arrivals, swell removal, slant stack correction and so on
- gain-functions in horizontal und vertical direction, AGC (AutomaticGainControl), automatic trace balancing, linear and exponential gain function, automatic gain based on mean amplitude decay curve
- a great variety of 1D-filters like bandpass working in time- and frequency range, notch-filter, timedependent bandpass, arithmetic function, averaging, median-filter, mean-filter, deconvolution (spiking, predictive, min.phase, ...), shaping filter, declipping, complex trace analysis (instantaneous frequency, phase, envelope), time-depth conversion, background removal, cross- and autocorrelation, ...
- Spectral analysis - single spectra, moving-window-analysis, dispersion curve analysis
- migration - 2D Kirchhoff, 2D fk-migration, 2D Finite Difference migration with lateral varying velocities, 3D Kirchhoff, topography migration, prestack migration
- 2D-filters like subtracting average, running average, stack, compress and expand, ... Special 2D-filters for timeslices.
- fk-filter with the possibility of manually input the filter range within the fk-spectrum or by defining a velocity fan. Different tapers and taper width are available.
- and much more possibilities
- All processing steps are stored in the header of each profile and can be asked for at any time.

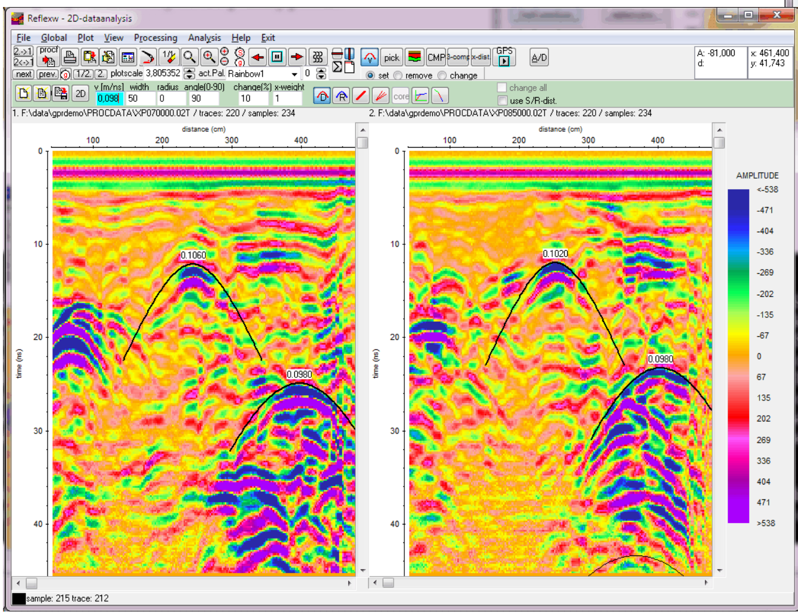


Example for the application of the migration: On the left the model including some diffrations and a synclinar structure is shown. The original ZO data are shown in the middle. The right panel shows the migrated result.



batch-processing

The batch-processing facilitates a completely automatic sequence of processing steps for a choosable number of profiles. Primary and secondary section are displayed simultaneously, whereby a direct control of the result is given. You may choose between the so called sequence mode and the single processing mode with the possibility of applying the processing steps individually on the primary profile.



velocity analysis

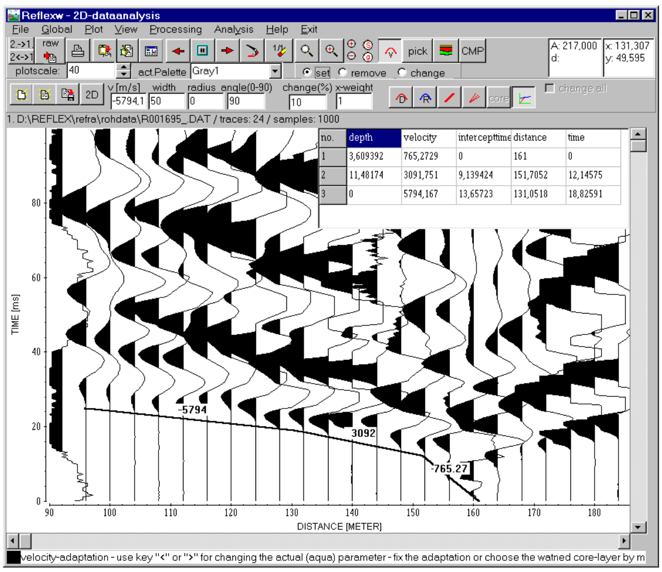
An interactive hyperbola-adaption for a simple determination of the average velocity from a zero-offset or CMP profile (see figure on the left) is integrated. It is possible to adapt **diffractions, reflections and straight lines**. You may change the velocity, the radius of the target, the angle between the line and the target and the width of the calculated diffraction or reflection hyperbola.

There is also the possibility of fitting **linear features** either by changing interactively a line or by setting two points.

The option **core** allows to vary interactively the velocities of the single layers of the individual cores stored within an ASCII-file.

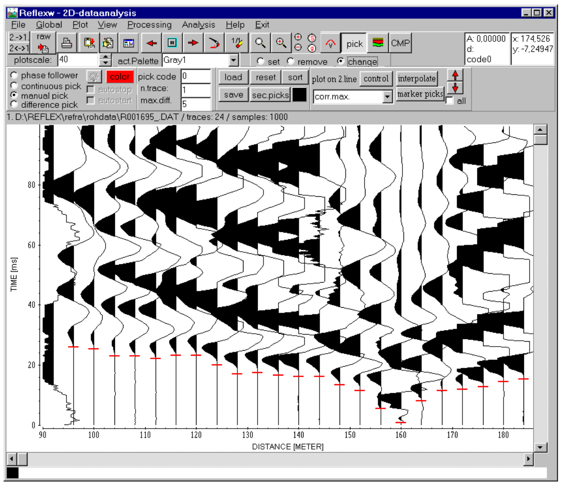
In addition an interactive use of the **intercept time method** for seismic refraction data is included. The option enables to get a first 1D-model very quickly.

The velocities may be stored on file and may be reloaded at any time. The velocities are combined into a **2D-model** by using a special interpolation. Such a 2D-velocity distribution may be used in a subsequent step for the migration or the time-depth conversion.



Use of the intercepttime method for refraction data

Picking the onsets/first arrivals



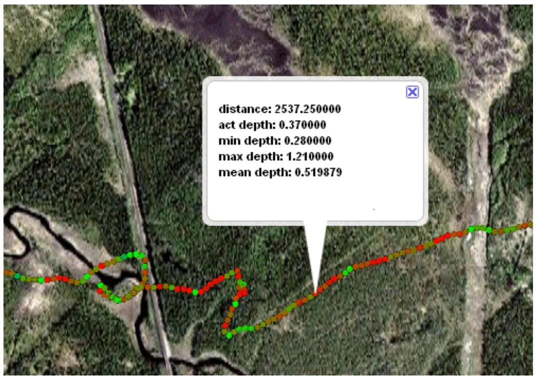
The picking option allows to pick the traveltime and the amplitude of different onsets like reflectors or hyperbola or the first arrivals.

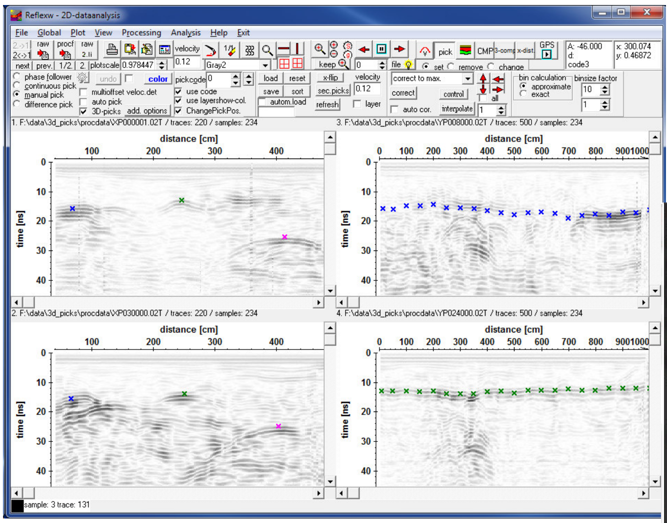
You have the choice between **manual** picking, **continuous** picking, a **semi-automatic** picking using a phase follower (manual editing is always possible) and a **full automatic** picker.

The picked values may be **corrected** to the extrema or the zero-crossing. In addition a time/distance correction to the maximum value within a given window is available. This allows you for example to pick the hyperbola cusps very quickly.

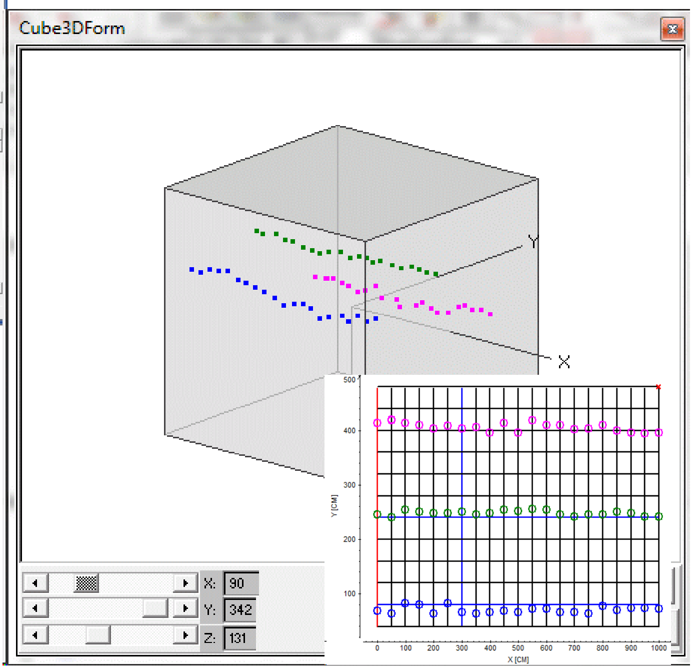
For GPS based data the picks may be interactively controlled within a profile or Google map.

It is possible to export the picks into different **ASCII-formats** together with the 3 space co-ordinates for a subsequent interpretation. The **Google KML-format** is supported which allows a direct link to Google-Earth. Each datapoint within the KML-file contains an information box about the distance, actual, min., mean and max. depth. A red-green-blue color scheme for the icons will be used with red corresponding to the smallest values and blue to the largest depth values.
In addition a **DXF** export is integrated.





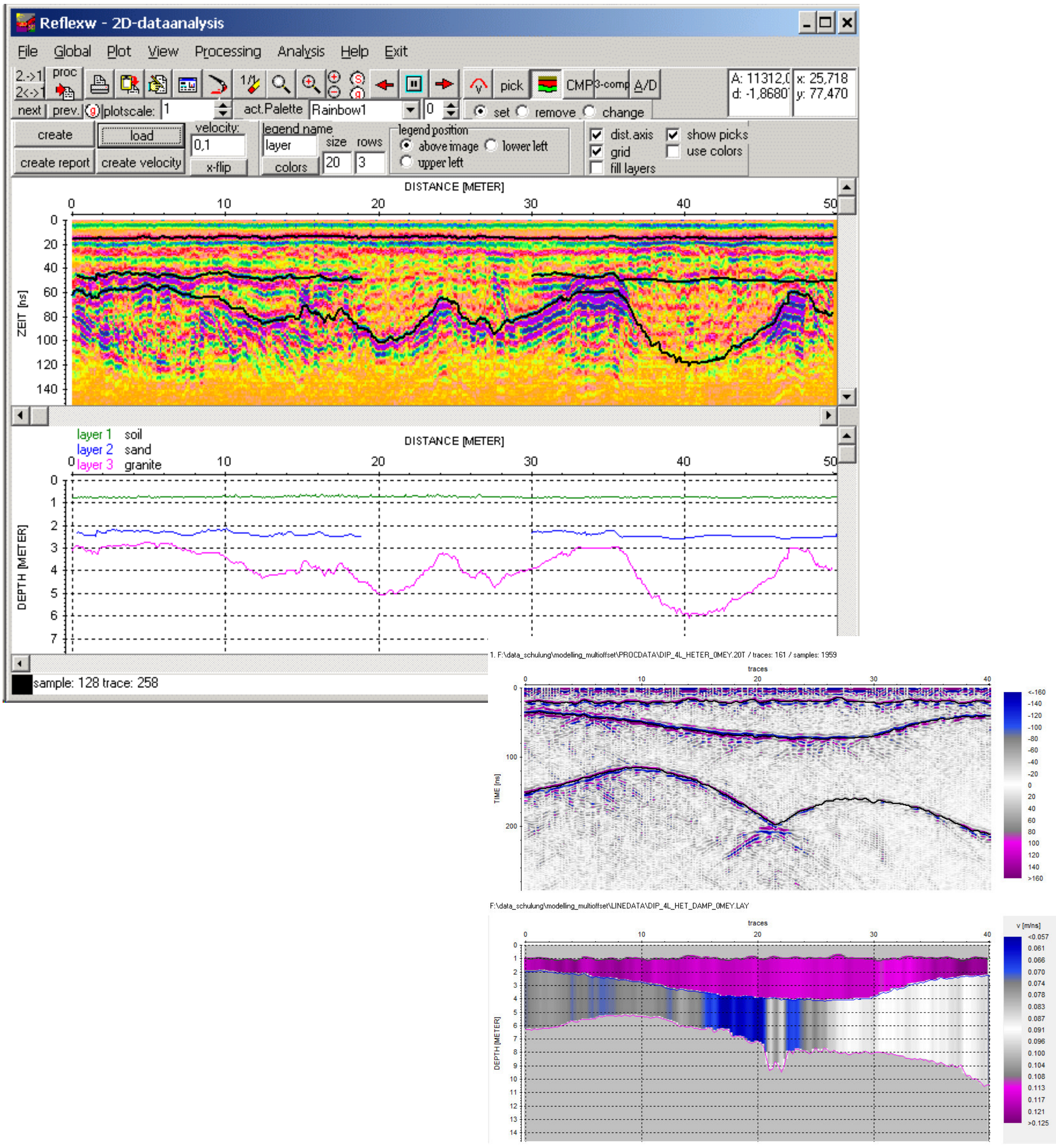
A **3D-picking** is included. Picking may be done within all visible windows and the picks will only be displayed on the corresponding 2D-line including the crossing points.

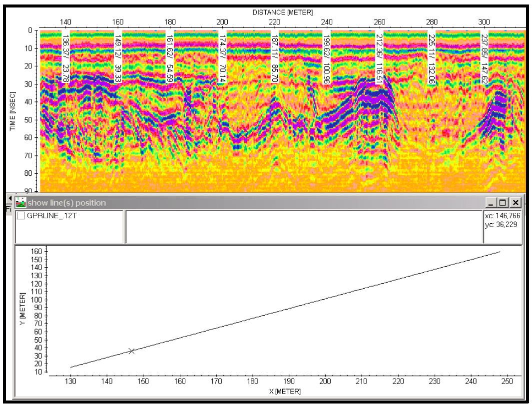


The picks may also be displayed within the profile or Google map.A 3D-view is possible if the option 3D-pick cube is activated in addition.
The option may be used for parallel and crossing lines as well as for GPS based crooked lines.

REFLEXW 2D-data analysis picking

The so called **layer-show** offers the possibility to combine individual pick files, to plot them together with the wiggle-files and to output them in report form on printer or file containing the depths, velocities and amplitudes of the individual layers. The time-depth conversion of the picks is either based on a constant velocity for each layer or on a 2-dimensional velocity distribution allowing to take into account vertical and lateral velocity changes. The 2D-velocity structure may be overlaid and also stored as a separated Reflexw formatted file.





Handle the traceheader(GPS)-coordinates

REFLEXW allows to handle so called traceheader coordinates which are stored within the header of each trace. Several ASCII-formats for the GPS-data are supported in order combine the traceheaders with the GPS-coordinates. Therefore it is possible to use GPS-coordinates for special analysis.

The GPS coordinates can be used for **exporting picked data** to an ASCII-file.

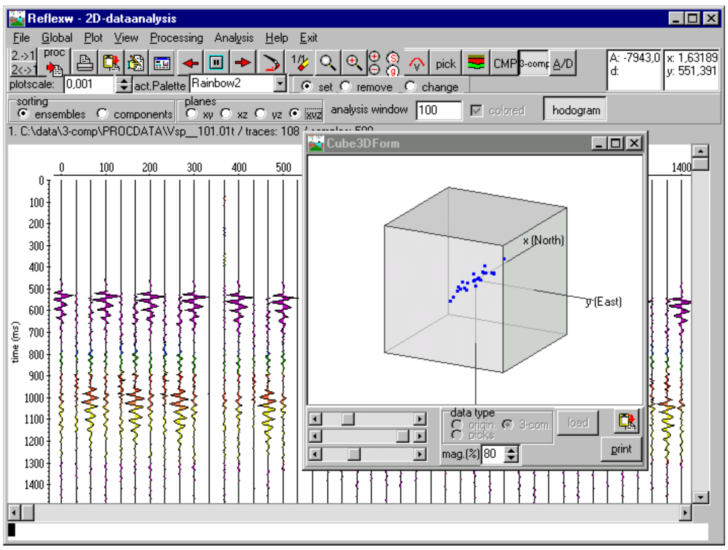
In addition there exist two different **viewing options** of the GPS coordinates (see figure on the right).
First the profile location based on the traceheader coordinates can be shown in an additional window (any curvature of the line coordinates is displayed). When moving the mouse cursor within the data window the actual xy-position of the mouse cursor is also shown. The secondary window may contain a blank map or a Google map.
Second the xy-receiver traceheader-coordinates may be displayed along the distance axis.

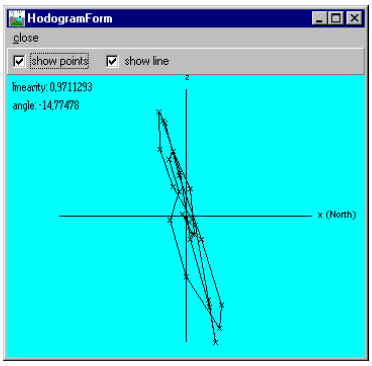
The GPS z-coordinates can be used for a static correction either as a plotoption or as a processing step.

3-component analysis

The option allows the interpretation of 3 component data. The final REFLEXW 3-component datafile will be constructed from several original datafiles containing multicomponent data. Each original datafile must contain one single multicomponent dataset.

The data may be sorted after ensembles with each ensemble containing the 3 component traces (see figure on the right). It is also possible to display the into 3 different windows with each window containing all traces of one single component.
The **particle motion** and the **actual polarization** angle can be displayed.
The option **colored** allows to color the wiggles based on the actual polarization angle. The analysis window determines the length of the traveltime window for the polarization analysis. The option **hodogram** allows you to continuously display the particle motion within the chosen plane when moving the mouse cursor in the data. The linearity factor (1 - completely linear, 0 - circular) and the dominant angle are also determined and displayed when you have chosen one of the 2-dimensional planes (see figure on the left). If the plane xyz has been chosen, a 3D-cube display of the particle motion is shown.

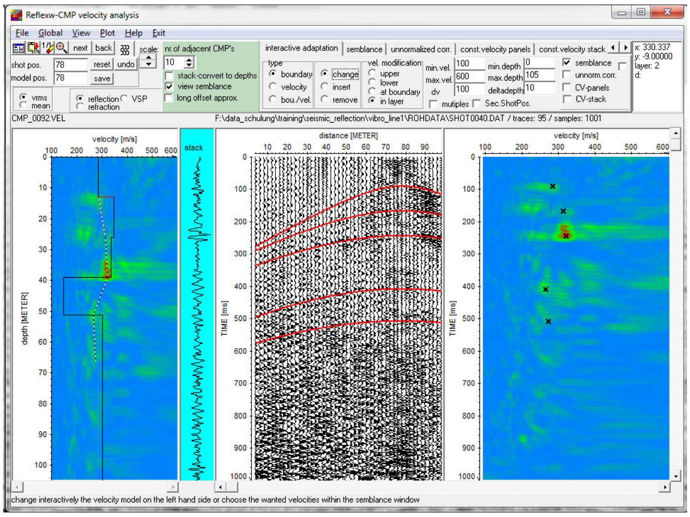




The **CMP-analysis** module consists of two parts (the CMP velocity analysis and the CMP-processing):
The module is useful for the following applications:

- reflection seismics
- GPR (Ground penetrating radar)

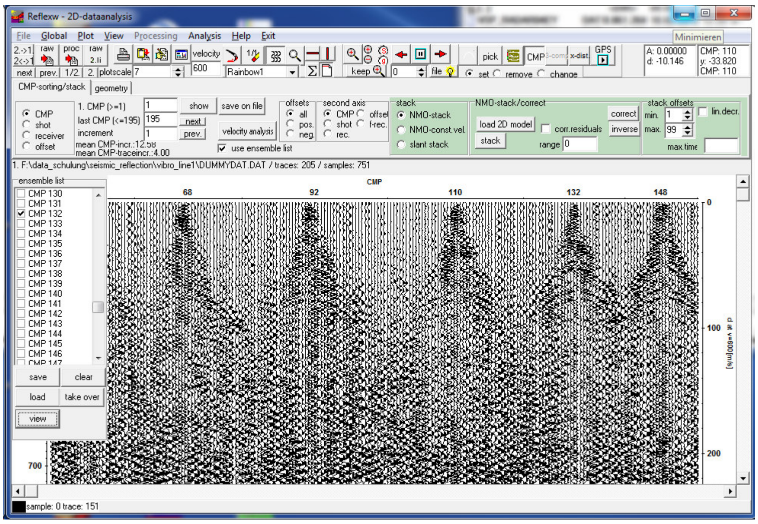
CMP-velocity-analysis



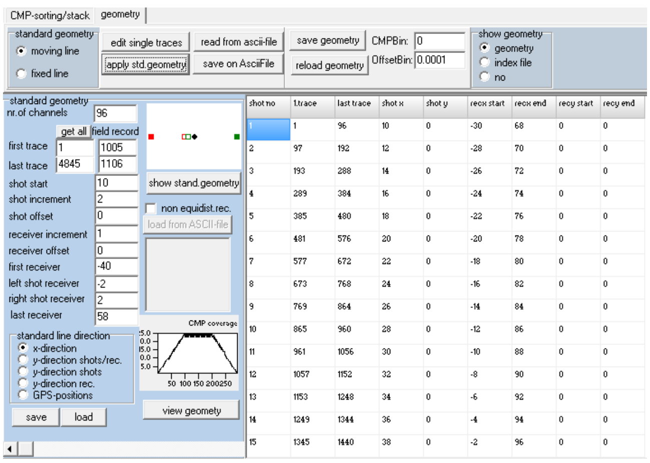
The **CMP-velocity-analysis** allows the calculation of a one-dimensional velocity-depth-distribution from CMP- or moveout-data based on different analysis techniques. The module offers the following possibilities:

- interactive generation and change of a velocity-model for a CMP- or a moveout-section with continuous indication of the actual reflections
- **semblance analysis** or **constant velocity analysis** for a given velocity-interval, interactive choice of a vrms-depth-distribution from the semblance analysis or from the interactive adaptation panel
- loading of a second CMP-section for a parallel adaptation of the reflections
- loading of a zero-offset section with true distance information for a calibration of the corresponding reflections
- generation of a 2-dimensional velocity-model based on the resulting 1D-velocity-depth distributions. This 2D-model represents the base for the stacking.

CMP-processing



The **CMP-processing** allows the sorting of raw data to CMP, Common Shot, Common Receiver and Common Offset. It is very easy to change interactively between the given sorting possibilities.
Stacking or simple **NMO-correctio**n of CMP-Gather, Common Shot-Gather or Common Receiver-Gather is possible based on a 2-dimensional velocity-distribution (see velocity analysis) or using a slant stack algorithm (only stacking).
Optionally an automatic correction of the **residual statics** is applied.
There are different possibilities of entering or changing the **geometry**:
Two different standard geometries are implemented: moving line and fixed line.
Activating **moving line** allows you to define the geometry for a geophone line moving with the shots.



Activating fixed line allows you to define the geometry for a fixed geophone line for different shot points.
The original shot geometry may contain **GPS** coordinates. In this case the receiver geometry will be calculated from a moving line relative to these GPS-coordinates
In addition the geometry of each trace may be edited individually and the geometry may also be loaded from an ASCII-file.

The module **3D data-interpretation** allows the interpretation of 3-dimensional data by displaying x-, y- or z-slices. The module is useful for the following applications:

- GPR (Ground penetrating radar)
- reflection seismics

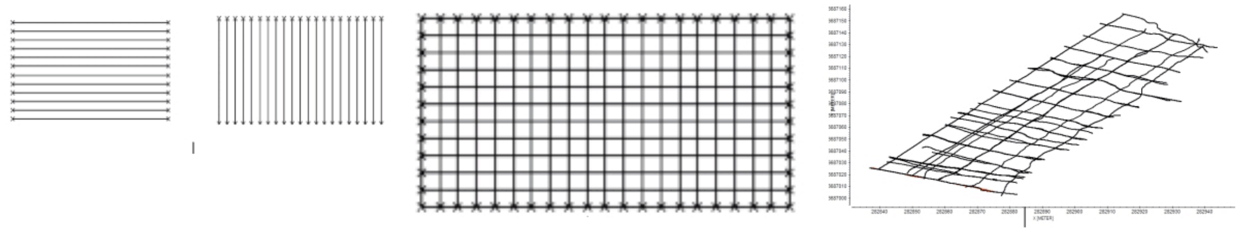
The 3D-datainterpretation includes different possibilities of handling 3D-data:

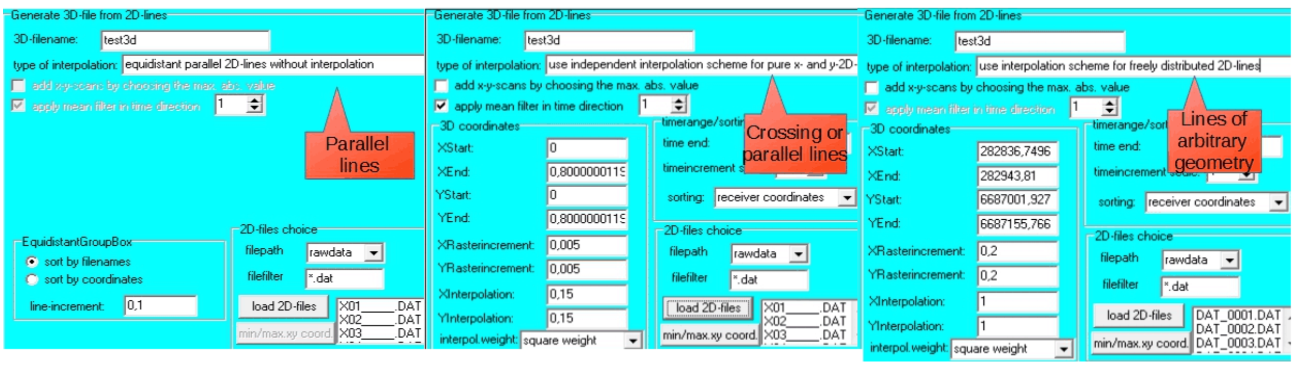
- load up to 25 different 2D parallel or non parallel lines in order to display them within the different modes scroll and window (see below). The scale of the different 2D-files can vary.
- create and interpret a complete 3D-datablock
- create single timeslices

create a complete 3D-datablock:

The **3D-data** may be easily constructed from equidistant or non-equidistant 2D-lines either during the import or in a later stage. The generation of 3D-files may be done for parallel or crossing lines as well as for freely distributed lines. In all cases a spacial interpolation may be done (necessary for crossing and freely distributed lines). The max. number of 3D-datapoints in all directions (x, y and time) is 2048.

2D parallel lines with equidistant but not necessarily equal increments within and between the lines	2D crossing lines with equidistant but not necessarily equal increments within and between the lines	2D lines with arbitrary geometry or single traces with GPS coordinates





Depending on the original data there are several ways to generate a 3D-file in ReflexW format:

generate 3D-file without an interpolation:

Precondition is that the original data have been acquired along **parallel equidistant 2D-lines**. If this is true the 3D-file may be generated
- from original 2D- or 3D-data during the import. In this case the complete dataprocessing is done for the 3D-datafile.
- from REFLEXW formatted 2D-lines. The 2D-lines may be raw data (then the processing is done for the 3D-datafile) or already processed data. There are no general rules whether the processing shall be done for the 3D-datafile or for the individual 2D-lines.
The rasterincrements of the resulting 3D-datafile will not be changed.

generate a 3D-file with interpolation:

The 3D-datafile may be constructed from Reflexw formatted **parallel 2D lines**, **crossing 2D lines** or from **freely distributed lines** using e.g. GPS based coordinates.
The rasterincrements of the resulting 3D-datafile may be freely entered.

In both cases, the data points of the resulting 3D-file have fixed increments in x-, y- and time-direction, respectively. The resulting 3D-datafile has the same REFLEXW format like a 2D-datafile (the ensemble number within the traceheader controls the sequential storing) and it therefore may be processed within the 2D-dataanalysis module whereby the interpretation must be done within the 3D-datainterpretation.

The data are completely loaded into the RAM of the computer whereby a fast visualization of the data is possible.
Rescaling or **subdivision** for 3D-dataset:
The max. number of points in each direction is restricted to 2048. If the points exceed this boundary Reflexw offers two possibilities rescale and subdivide: The option **rescale** automatically calculates rescaling factors in all directions where the number of points exceed the 2048 boundary. The option **subdivide** will only be enabled if only the number of points in line direction exceeds the 2048 boundary. Activating this option generates a number of subdatasets of the complete 3D-dataset in this direction.

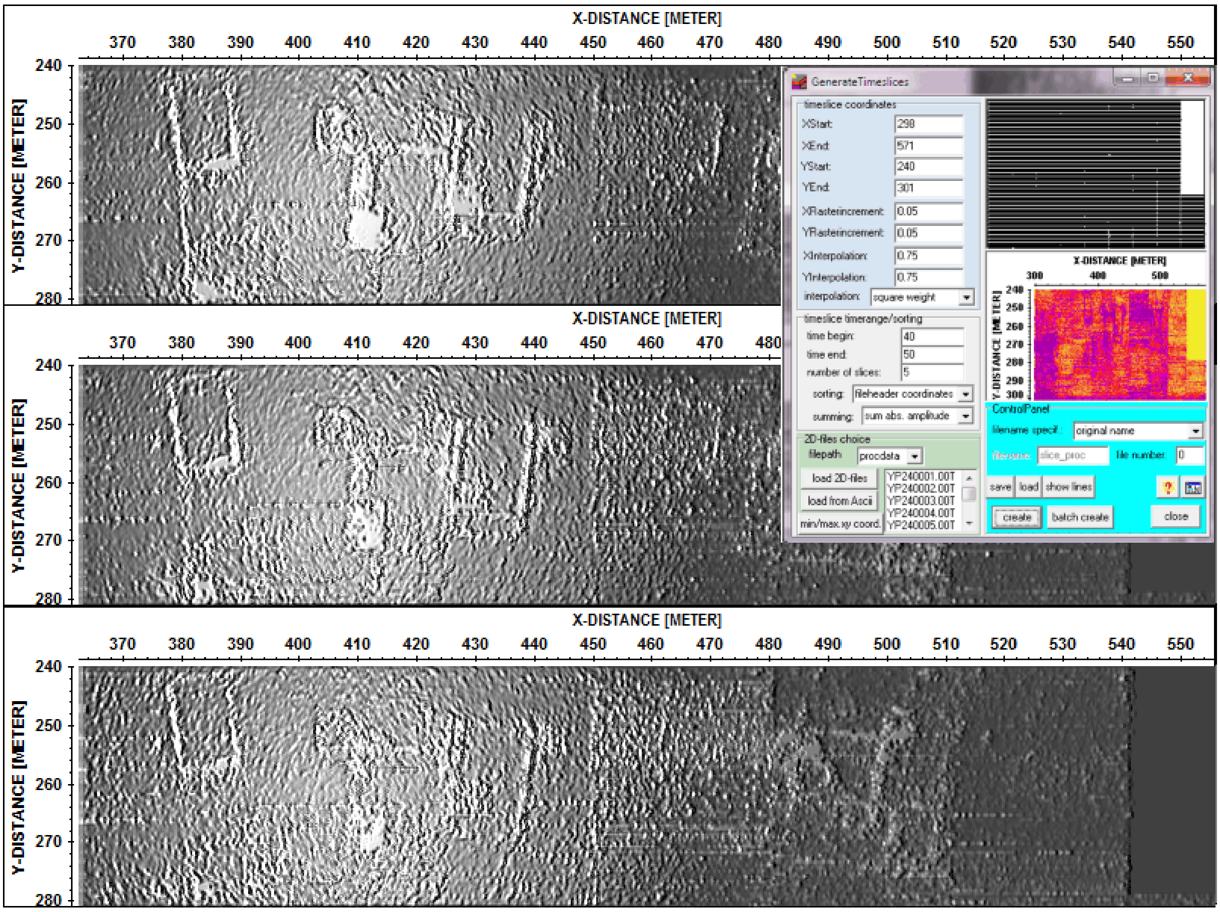
Apart from the **3D-cube display** (see the next but one page) two different display options ‚mode‘ and ‚windows‘ (see next page) are available.

A **second 3D-data** file can be viewed in addition for a direct comparison.

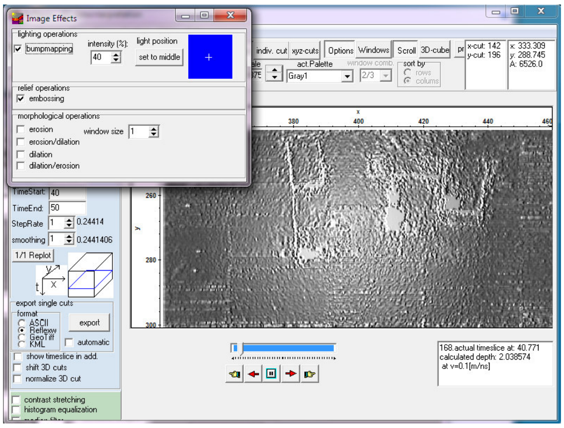
create single timeslices:

In addition you may construct **single timeslices (C-scans)** from different 2D-lines originating all from one acquisition plane without any (significant) restriction in size.The profiles may be arbitrarily orientated and GPS coordinates are suported. The spatial interpolation ranges can be freely determined. The timeslice is considered as a simple Reflexw section - all processing and display possibilities within the 2D-dataanalysis module can be applied on.

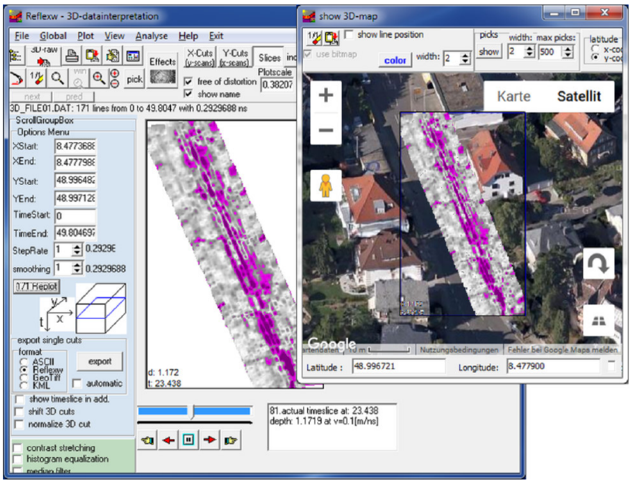
Within the lower picture timeslices with a size of 5500*1250 points have been created from more than 1000 original 2D-files.

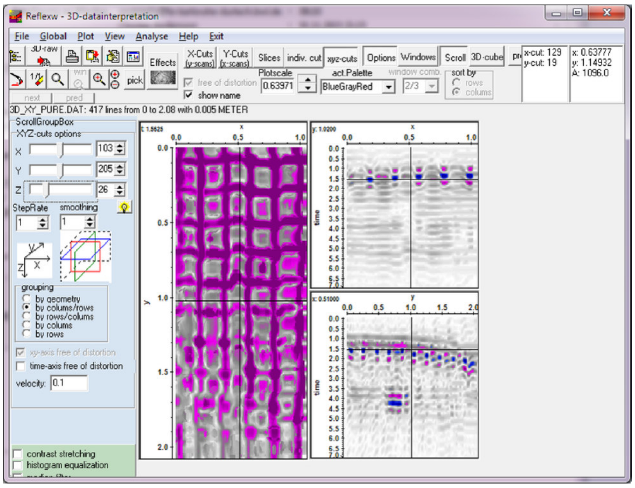


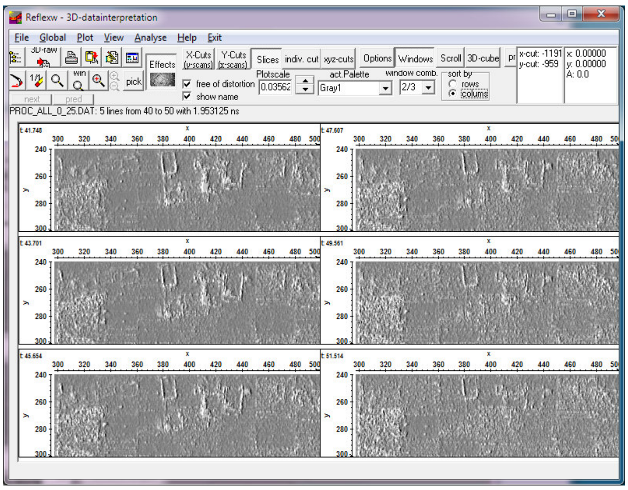
Scrolling the 3D-datablock



Using the option **"scroll"** (see figure on the right) you may continuously move through the 3D-cube either in x-, y- or z-direction using the track bar. The step and smoothing rates are freely choosable.
An optional **image processing** (e.g. median filter, edge sharpening, contrast stretching, normalization, shift compensation, bumpmapping, embossing ...) is supported.
The slices may also be simultaneously displayed using Google maps if the 3D-data has been created using GPS-coordinates..Different possibilities for an **export** are given.The timeslice may be exported to a KML file for a later use within Google Earth or to a georeferenced tiff-file. Different overlay techniques are supported.
The different cuts may be viewed at the same time and may be changed interactively using the mouse wheel and the mouse position.

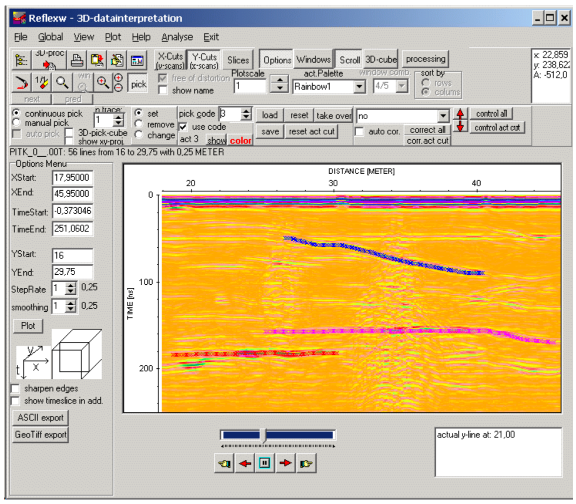






Windowing the 3D-datablock

Using the option **"windows"** (see figure on the left) the slices are displayed in manually scalable windows (up to 25 different windows naturally independent from the original 3D-datasize). Again the step and smoothing rate may be freely chosen.



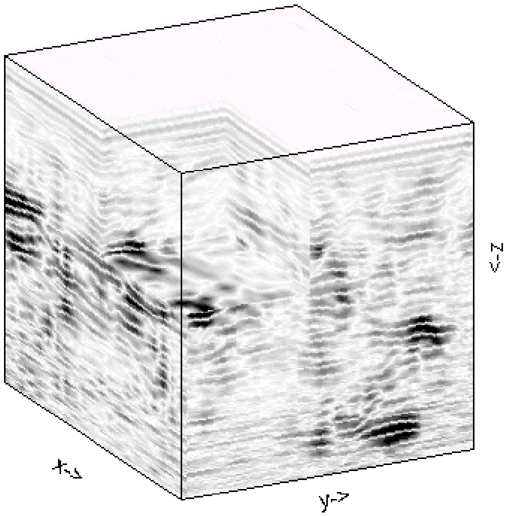
A **MPEG moviefile** for the later use with a MPEG-player may be easily constructed for the scroll and the 3DCube (see next page) mode.

3D-picking

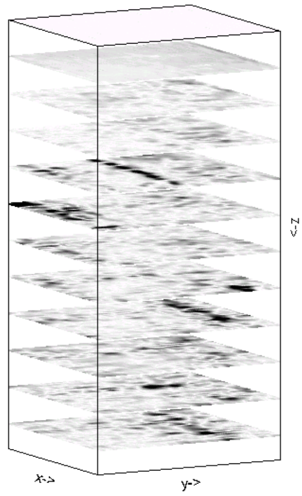
3D-Picking may be done within the individual 2D-cuts (scroll or windows mode) or within the 3D-datacube display. You have the choice between manual picking and continuous pick. The 3D-pick surfaces may also be included within the 3D-cube (see next page).

3D cube-display

The 3D-data can also be displayed within a 3D-cube. The program supports an interactive rotation of the 3D cube. The data can be viewed from any direction and can be zoomed. The 3 axis may be freely labelled.
You may select if only the front or back planes of the datacube are displayed or the full 3D-data volume. In addition you only may select single cuts and scroll through the cube in one distinct direction.

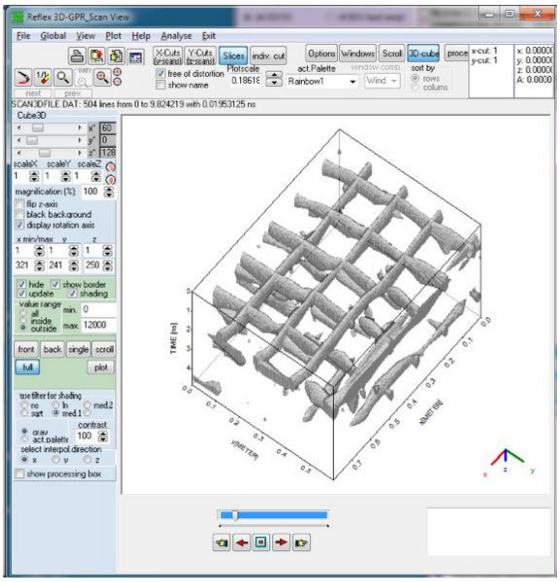


With the options **<u>front</u>** or **<u>back</u>** activated only the front or back planes of the datacube are displayed. In addition you may select a distinct **cornerpoint** which serves as the starting point for a cutting out of the cube (see picture on the left).



With the option **<u>single</u>** activated you may select any combination of x-, y- and z-cuts (see picture on the right).

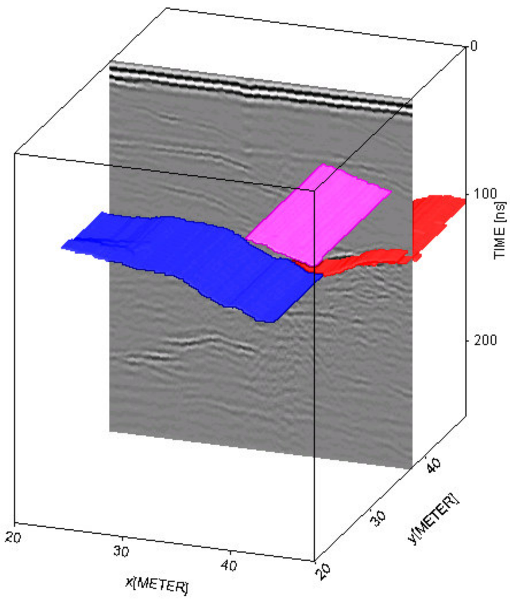
With the option **<u>scroll</u>** activated it is possible to continuously move through the 3D-cube either in x-, y- or z-direction using the track bar. The **step** rate is freely choosable. It is possible to plot a “background” consisting of any combination of x-, y- and z-cuts in addition.

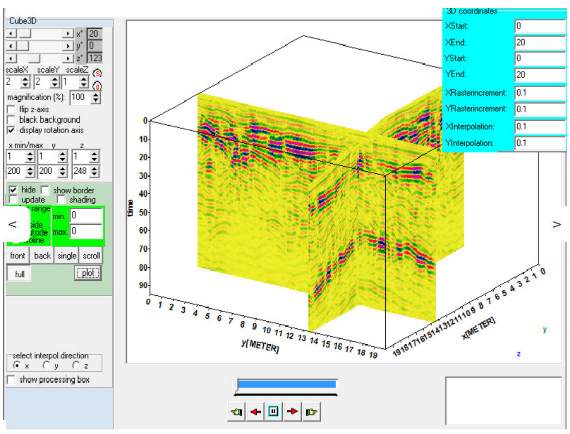


With the option **<u>full</u>** activated all data of the 3D-cube are displayed. Shading and hiding are supported. Not visible parts of profiles are covered. However there is the possibility to "look through” certain parts of the 3D-data volume, whose amplitude values are smaller than the given **threshold** value.

With the option **shading** activated a special shading algorithm is used in addition (see picture on the left).

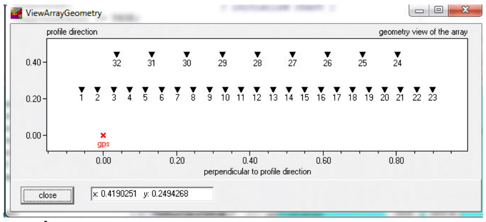
The **picked** surfaces may also be included within the 3D-datacube (see figure on the right).

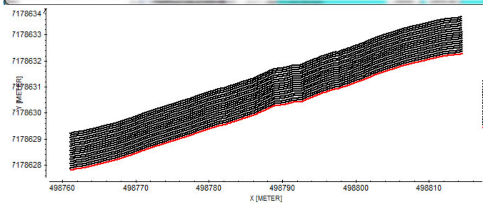




It is also possible to display single 2D-lines with different (arbitrary) orientations within the 3D-cube.

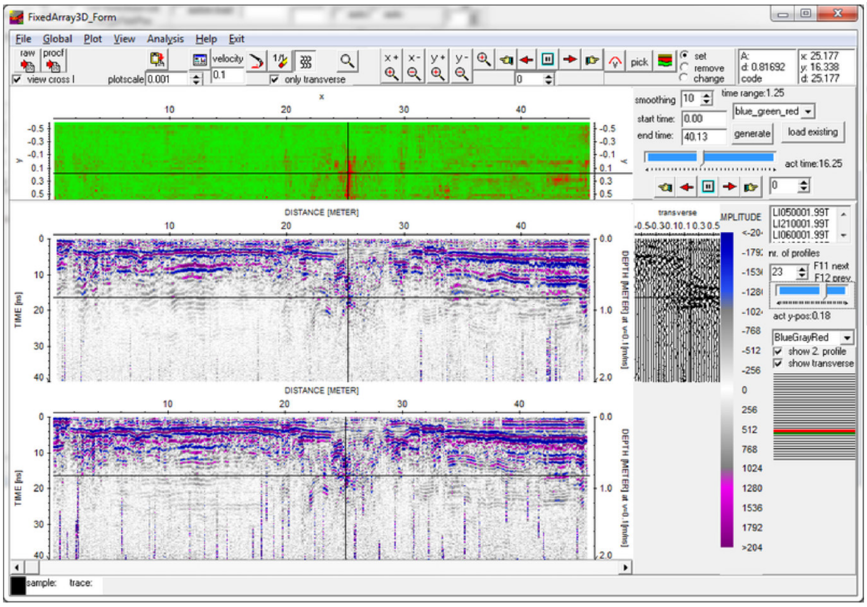
3D fixed array

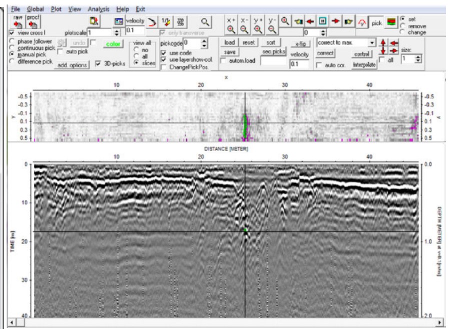




The **3D fixed array** module allows the interactive interpretation of multichannel data with a fixed lateral offset of the individual channels based on relative coordinates. The target of this module is the interpretation of data consisting of many traces into one direction, e.g. along a road and a relatively small number of datapoints perpendicular to it (number of parallel lines).
Reflexw supports the automatic import of the geometry of many different multichannel array devices. The GPS data will be automatically updated for the different channels.

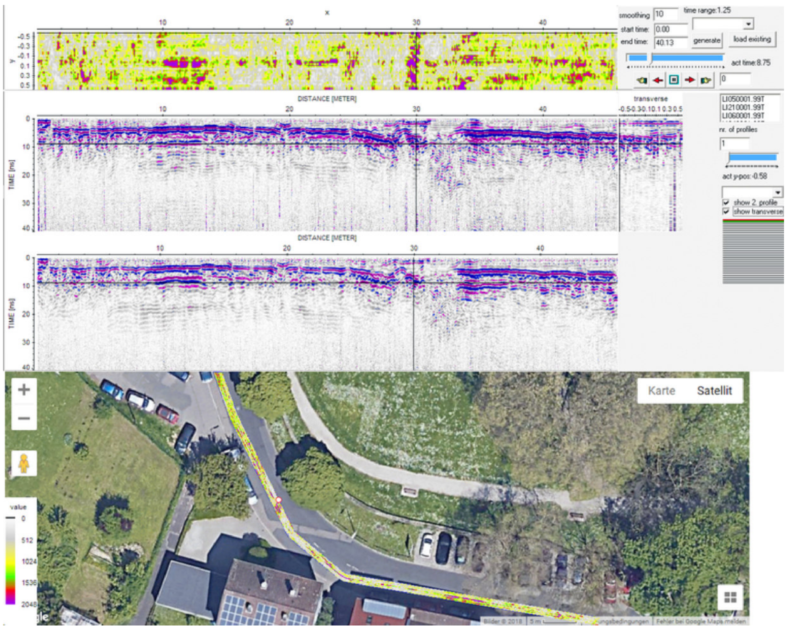
An easy and fast calculation of **timeslice**s without interpolation but including smoothing in time direction is incorporated. A fast interactive switch between the different lines and timeslices is possible either using the mouse (pressed right mouse key or using the scroll wheel) or using the trackbars.





A **2D** and **3D-picking** is incorporated.

The traceheaders may contain the gps coordinates whereby an additional view of the timeslices withiin a **gps map** is given.



The **refraction traveltime analysis** module allows to analyse and interpret picked first arrivals. The module is useful for the following applications:

- refraction seismics

The module consists of two different parts:

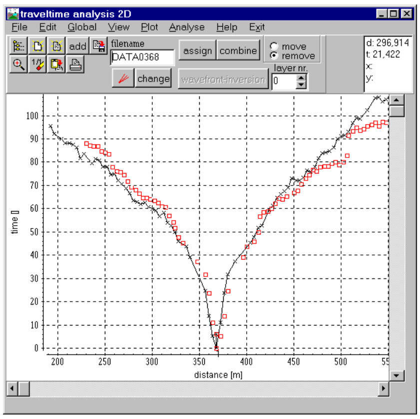
The first part (**traveltime processing**) contains the possibility to put together the picked traveltimes from several shots and to assign the picks to special layers.
The second part (**traveltime interpretation**) contains the interpretation tools like wavefront-inversion, forward raytracing, interactive 1-dimensional adaptation and refraction tomography.

Traveltime processing

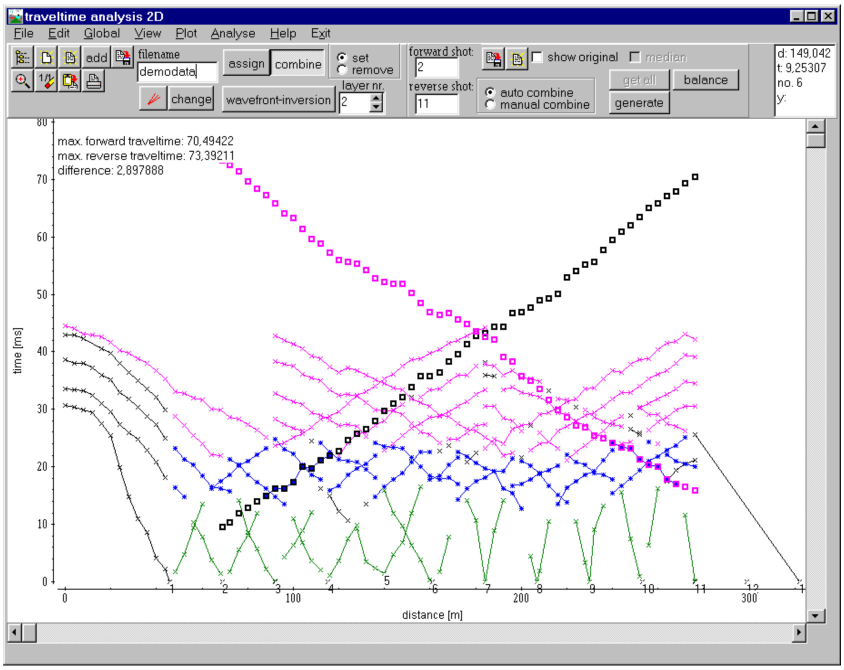
Within this menu it is possible to analyse and interpret picked first arrivals (refraction seismics). Precondition is that all chosen data are located along one line within one acquisition plane. You may put together the traveltimes from several shots and assign the traveltimes to special layers. Those traveltimes stemming from several shots and belonging to one layer may be combined together to one forward and reverse traveltime curve. These combined traveltimes are the basis for a subsequent 2D wavefront-inversion which allows to invert both the structure of the layer and the smoothed refractor velocity.

The traveltime processing part offers comprehensive tools for

* sorting of the traveltime data
* interactive editing (moving a set of traveltimes, cancelling of single traveltimes, combining different branches, ...)
* comparison of traveltime data (e.g. real and synthetic data); calculation of the discrepancies
* CMP-sorting (e.g. for 1-D-modelling)
* interactive assignment of arrival times to layers
* manual or automatic phantoming
* reverse traveltime control - output on screen or file



Comparison of a single shot traveltimecurve and the corresponding CMP-sorted traveltime branch

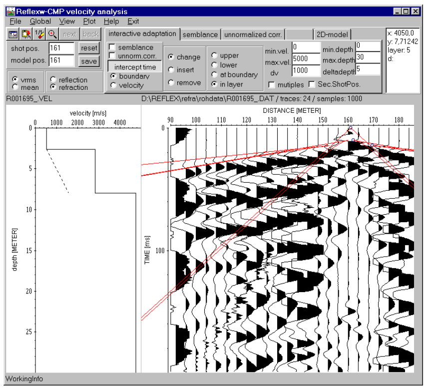


Traveltime data put together and assigned to 3 different layers - for layer 2 one complete forward and reverse traveltime curve has been automatically generated which is the basis for a subsequent wavefront inversion

Traveltime interpretation

The first arrivals may be interpreted in the following different ways:

- ➟ interactive 1-dimensional traveltime adaptation
- ➟ 2-dimensional wavefront inversion of the complete forward and reverse traveltime curves
- ➟ timeterm analysis
- ➟ 2-dimensional forward raytracing and comparison of the real and the calculated traveltime data
- ➟ refraction tomography



1-dimensional traveltime adaptation

The 1-dimension traveltime adaptation allows the interactive calculation of a one-dimensional velocity-depth-distribution from refraction shot or CMP-data. The intercepttime option allows to calculate a first starting model which may be refined interactively (depth and velocities). The resultant diving waves, reflections (incl. overcritical) and surface multiples are displayed in real time. A comparison can be done with either real traveltime data or the complete data set (in this case picking is not necessary).

wavefront inversion:

The wavefront inversion allows to migrate the combined forward and reverse traveltimes into depth using a Finite Difference approximation of the eikonal equation. The following traveltime processing steps must have been performed before:

- ✗ put the different traveltime curves together
- ✗ assignment to the actual layer
- ✗ combination to one single forward and reverse traveltime curve (see figure on the previous page).

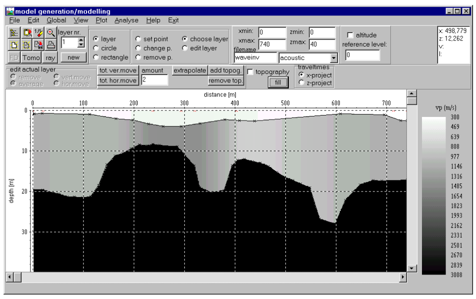
The method allows:

- interactive back propagation of the wavefronts using finite differences approximation of the eikonal equation; the backpropagation is exact, even for very complicated overburdens.
- no parameter adjustments are necessary
- inversion of layer interfaces and layer velocities
- the topography can directly be included in the inversion process (no static correction is necessary)

The complete forward and reverse wavefronts are continued downward based on the given overburden model. The new refractor is automatically constructed at those points where the sum of the downward traveltimes is equal to the reciprocal traveltime. The refractor velocity is determined from the mean of the slopes of the forward and reverse wavefronts at the new calculated refractor points.

The method is iterative. This means that each layer must be inverted separately and that the overburden must be existent. It may contain any 2-dimensional structure.

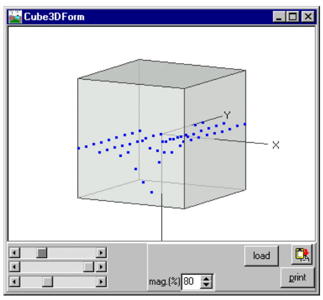
The results (interfaces of the layers and layer velocities) can easily be manipulated (e.g. smoothed). A priori information can easily be incorporated to the overburden prior to the inversion of the next interface. This guarantees that all available information contributes to the inversion result.



timeterm analysis

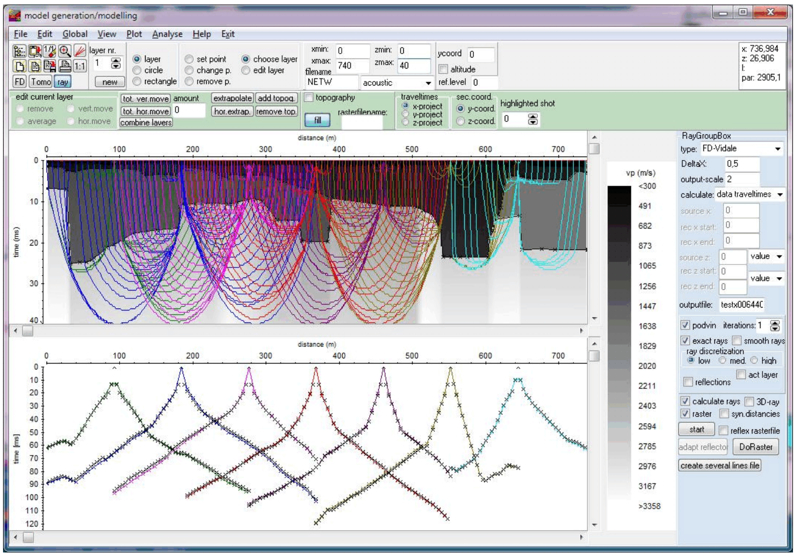
The timeterm analysis allows the reconstruction of a 3D-refractor from xy-traveltimedata. The essential feature of the method is, that each traveltime t_{ij} may be written in the form $t_{ij} = a_i + b_j + \Delta_{ij}/v$, where a_i and b_j are timeterms which are characteristic of the shot- and receiver point respectively, Δ_{ij} is the distance between shot and receiver and v is the refractor velocity. Under special conditions it is possible to derive a_i, b_j and v which give the best fit to the observed traveltimes t_{ij}. The preconditions are :

– the velocity of the overburden varies only with depth within the critical refracted ray cone under the shot or receiver
– the refractor velocity is assumed to be constant
– slope and curvature of the refractor is small
– the model consists of one layer and a half space



forward raytracing:

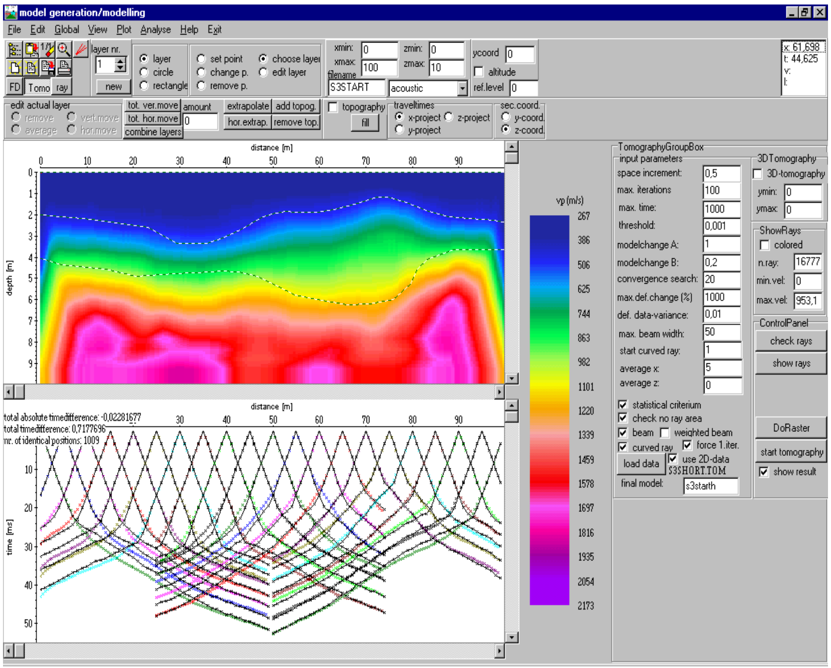
The **forward raytracing** method can be used either for a validation of the models derived from the wavefront inversion or from the refraction tomography or it can be used as a trial and error method in order to improve the model or even to construct a model of the underground. The main goal is to calculate the traveltimes of the first arrivals but also reflections from layer boundaries can be built.
The method is based on a **finite difference** approximation of the **eikonal equation** for calculating first arrivals. It takes into the account the existence of different propagation waves like transmitted, diffracted or head waves. Therefore no practical limitation concerning the 2D complexity of the medium is given. The method is very suitable for near surface investigations, because there is no need for approximations concerning the complexity of the models. The wavefronts and therefore the raypaths can be stored and displayed.



The information about the geometry (shot and receiver positions) can automatically be adopted from the shot records or from the traveltime files. Editing, if necessary, is easily possible. The number of shots (e.g. a complete refraction seismic line) is not limited.

refraction tomography:

The **refraction tomography** allows an automatic inversion of the combined traveltimes. The data coverage must be high enough but no assignment to layers is necessary. The inversion is based on a two-dimensional **tomographic approach** based on **SIRT** (simultaneous iterative reconstruction technique). The **curved rays** are calculated using a finite difference approximation of the eikonal equation (see forward raytracing). A start model must be defined. The start model may be a simple constant velocity velocity without any pre-informations but may also consists of a complex layered model, e.g. resulting from a previous wavefront inversion. The resulting velocity model is a rasterfile stored in REFLEX-format whereby all possibilities of Reflexw are available for a further interpretation.

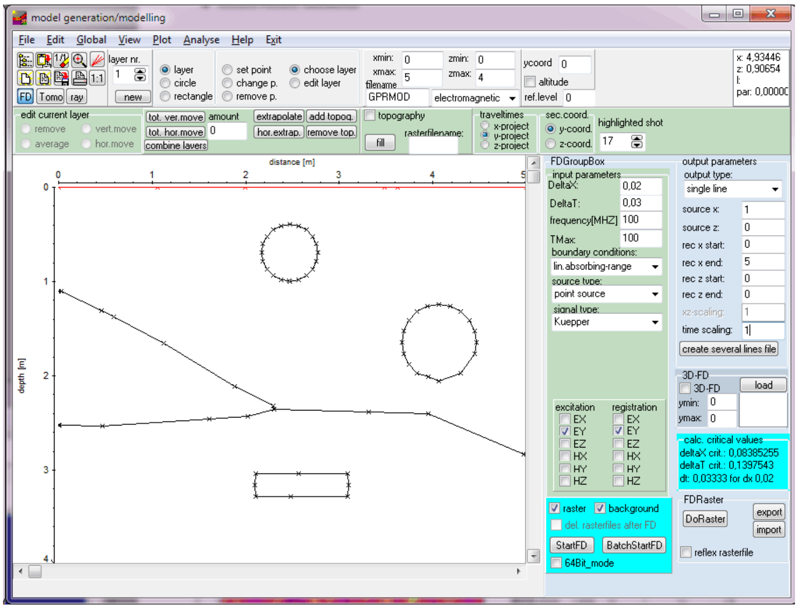


Example of a refraction tomographic inversion - the original data are calculated from a 3-layer model with v1=300 m/s, v2=800 m/s and v3=1500 m/s. The result of the tomography is shown in the upper panel - the original layerboundaries are overlaid. The lower panel shows the original traveltimes in comparison to the calculated traveltimes based on the tomograhic result.

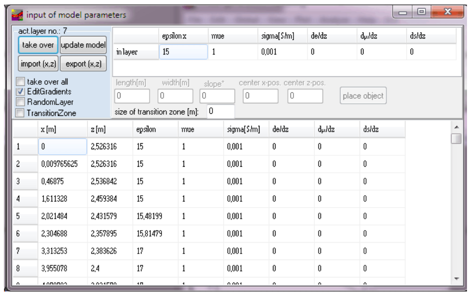
forward modelling

The module **forward modelling** allows the simulation of the electromagnetic or seismic wave propagation in a 2-dimensional subsurface medium using a **Finite Difference scheme** enabling you for example to optimize your survey design in front of a measurement. The module is useful for the following applications:

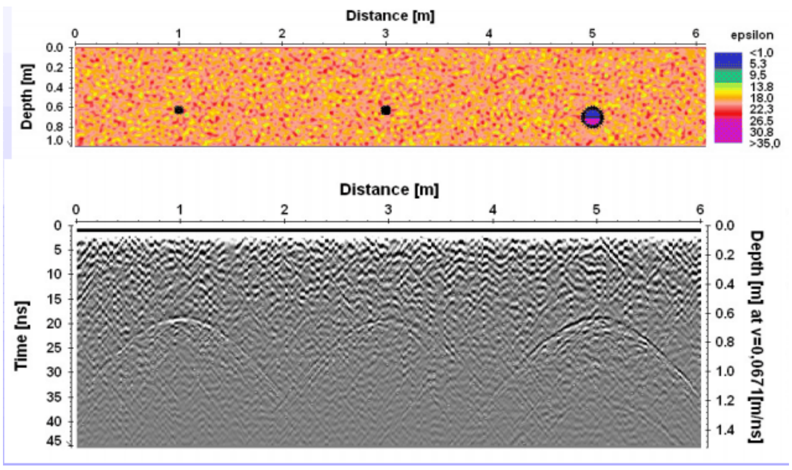
- GPR (Ground penetrating radar)
- reflection seismics
- refraction seismics
- borehole/borehole transmission

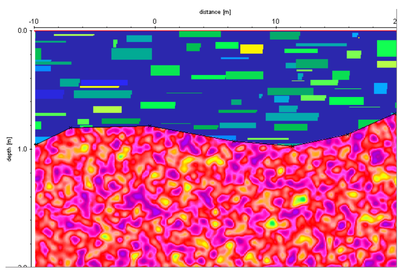


The module **forward modelling** allows the calculation of the complete electromagnetic or seismic wavefield for a 2-dimensional subsurface model. You may interactively edit any layer boundary and some predefined elements (e.g. circle or rectangle). The physical parameters may vary along the boundary whereby lateral changes are easily defined. The parameters are entered within a table which also may be used for entering the boundary values (see right figure below).

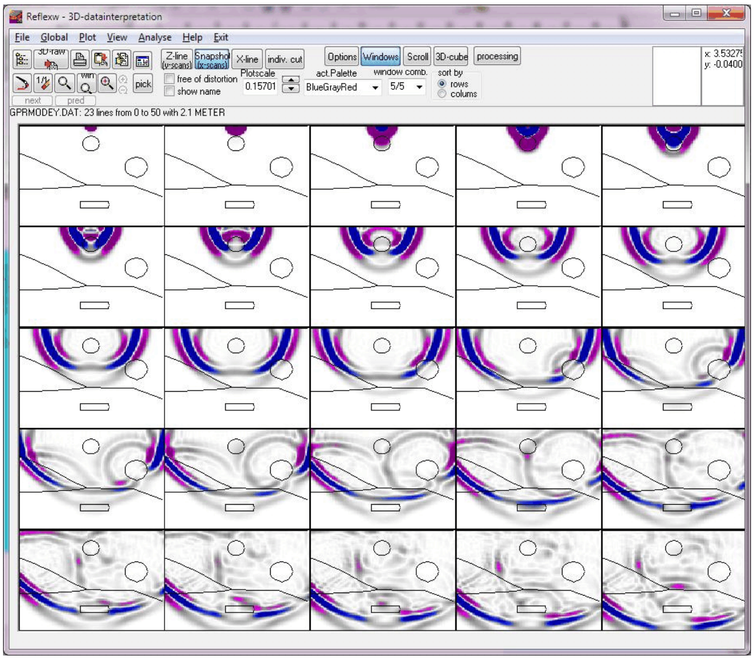


The option **RandomLayer** allows to specify statistic parameters for a random perturbation of the physical parameters of the individual layer. It is possible to choose between <u>fluctuations</u> (see left figure below - 2. layer) and <u>discontinuous</u> perturbations (see left figure below - 1.layer). Different <u>spatial distributions</u> as well as different statistic <u>distributions</u> for the <u>physical parameters</u> are available.

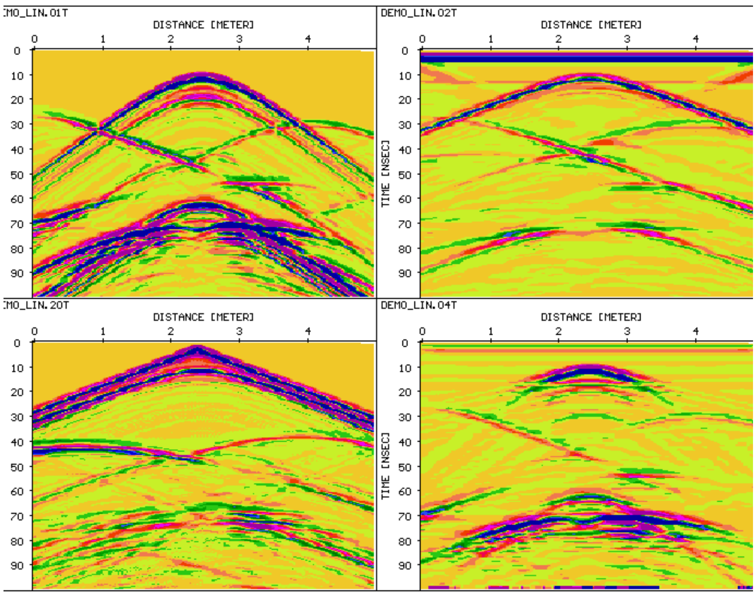




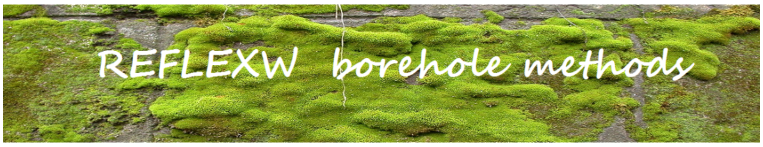
The forward modelling is done using a **Finite Difference** scheme solving the Maxwell equations (elastic wave equation, respectively). 3 different sources are implemented: **point-source, plane wave** and **exploding reflector model**. Using the point source you may model the wave propagation from any point in the model (e.g. a transmitter at the surface). The exploding reflector model allows the modelling of a complete zero offset section in only one step. The complete wave-field or a single line is stored. The complete wavefield may be interpreted within the 3D-datainterpretation, the single line may be processed and interpreted like any 2D-data line.
In the case of the seismic wave propagation **absorbing boundaries conditions** are used in order to reduce the reflections at the model borders. In the case of the electromagnetic wave propagation an **absorbing boundary range** is used for this pupose.



Snapshot sequence for a point source - 25 snapshots bewtween 0 and 50 ns are shown

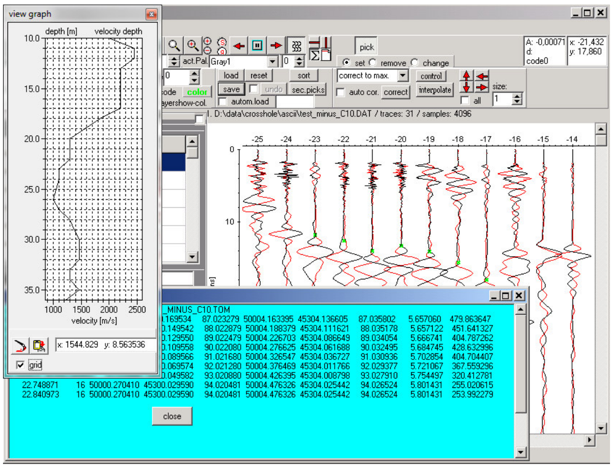


Synthetic radargrams for different source types. Upper panel left: Exploding Reflector Model, upper panel right: plane wave, lower panel left: point-source (gain-function in time-direction applied), lower panel right: Exploding Reflector Model with transmitter and receiver in the air

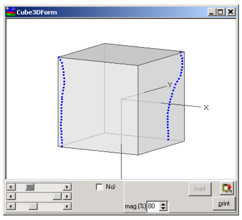


REFLEXW allows to analyse different kinds of GPR-or seismic **borehole** data:

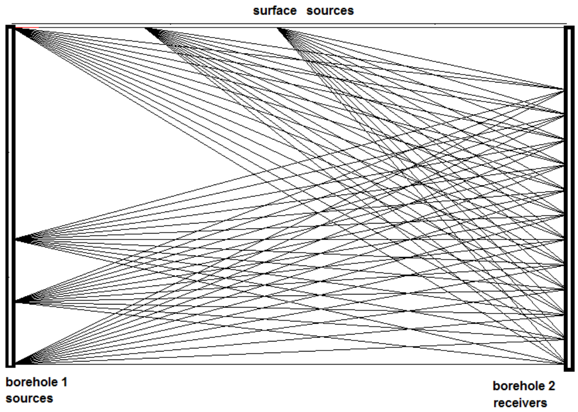
Crosshole Seismic Testing



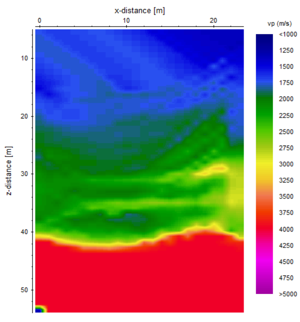
In this method, also known as Crosshole Sonic Logging (CSL), the source (p- or s-wave source) and the receiver are located at the same depth within two separate boreholes. The traveltimes of the first arrivals are transformed into p- and or s-velocities which represent average values between the boreholes. A multi-directional receiver array is supported. The deviation of the boreholes (true xyz-coordinates) can be taken into account. The picking of the first arrivals can be done by different automatic methods or manually or by a combination of both. If a shear wave source with 2 different orientations has been used the raw data can be overlaid for a more accurate picking. The result of the interpretation is a 1-dimensional velocity distribution.



Crosshole transmission tomography

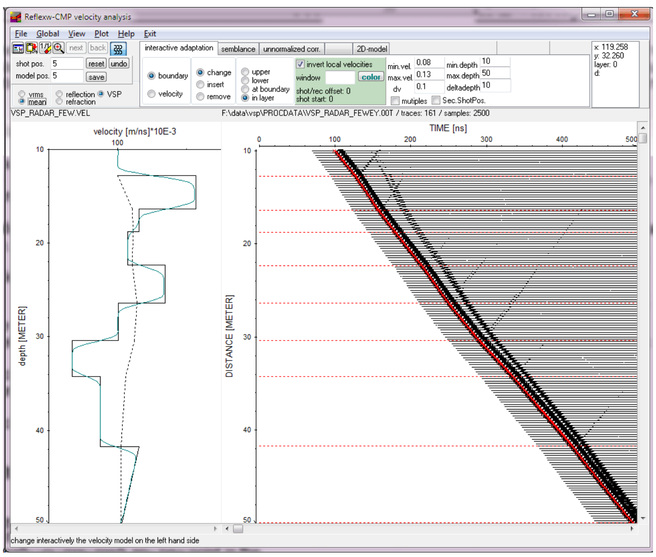


In this method the sources (p- or s-wave source) and the receivers may be freely placed within 2 boreholes or at the surface (see picture on the right). Again the first arrivals must be picked and these traveltimes form the base for a subsequent tomographic 2D or 3D-inversion (see picture on the left) based on **SIRT** (simultaneous iterative reconstruction technique- see also forward modelling/tomography). . The **picking** of the first arrivals can be done by different automatic methods or manually or by a combination of both. The **deviation of the boreholes** (true xyz-coordinates) can be taken into account. Besides this crosshole geometry the tomographic inversion can also handle data of any complex 2D-geometry.



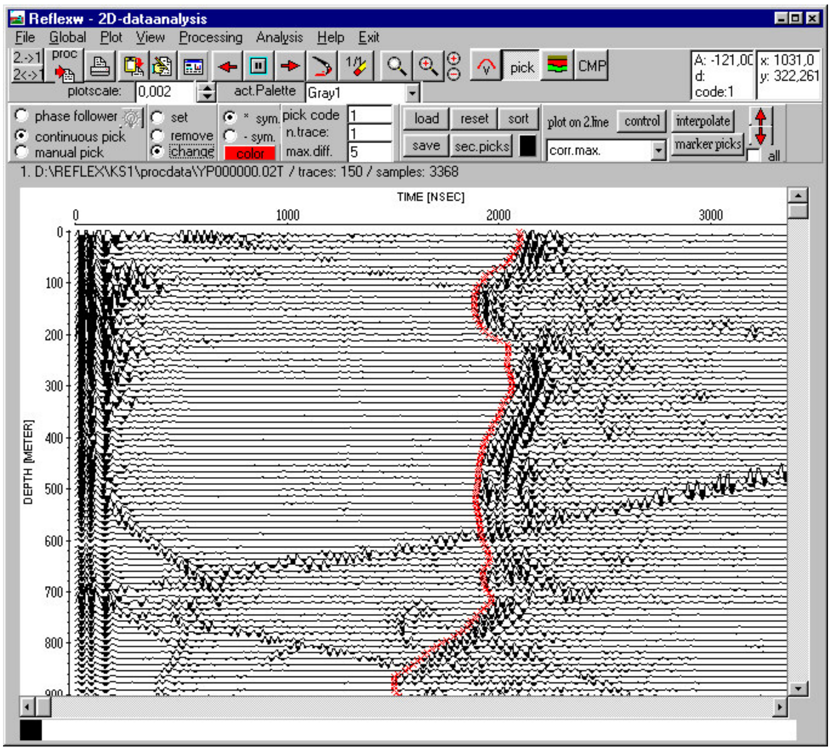
Vertical Seismic Profiling

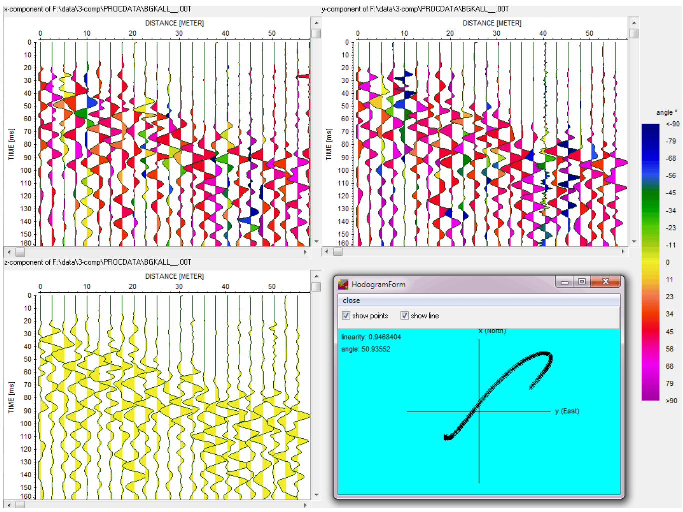
In this method the source is located at the surface and the receivers are placed within the borehole or vice versa. The picked first arrival traveltimes or the raw data can be manually adapted by a 1D-depth velocity distribution. In addition to the interactive model adaptation the local velocities can also be directly inverted. The velocities are smoothed over a given depth window.



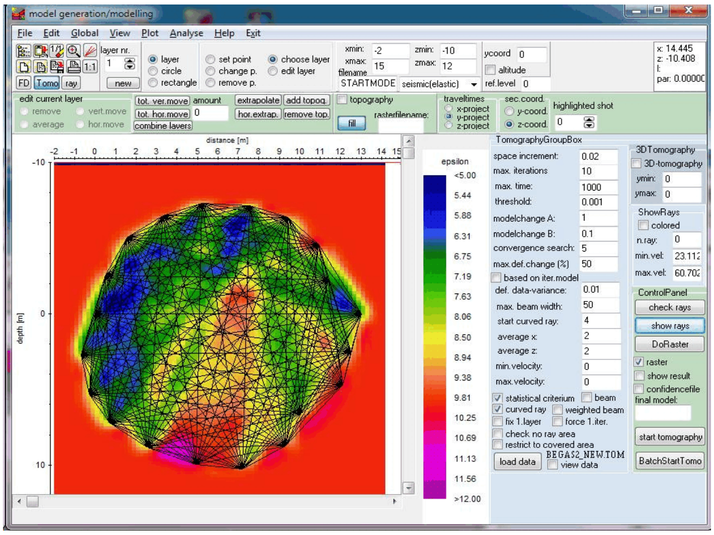
Single borehole reflection data (also multicomponent)

The figure at the right shows an example of a borehole GPR-reflection measurement (data from Kali+Salz, Kassel, Germany). There are many different kinds of displaying the equidistant or non equidistant profiles in the point and wiggle mode with zoom- and moving possibilities, manual and automatic scaling. All the features available in the modules data-analysis and data-interpretation may be used for the processing and the interpretation of the borehole data. Distinct elements may be picked, processed and compared to other borehole data. It is possible to extract all available signal informations like traveltime, amplitude, energy or nominal frequency.
In addition a 3-component analysis of single borehole data is possible (see picture below - see also 2D-dataanalysis - 3-component).





transmission tomography

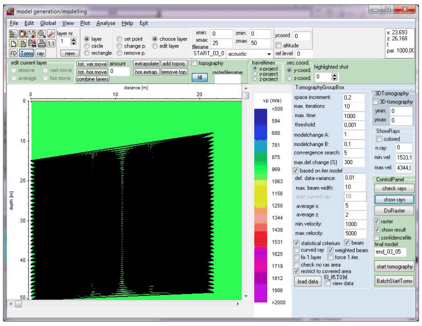


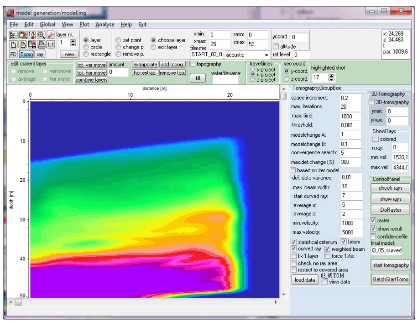
example of a tomographic inversion for a cylindrical object

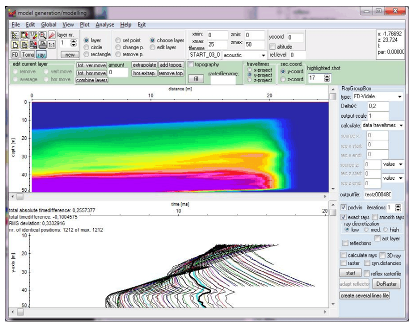
A 2- and 3-dimensional **tomographic approach** based on **SIRT** (simultaneous iterative reconstruction technique) may be used for the inversion of transmission traveltime data. The geometries of the individual sources and receivers are arbitrarily.

sequence for a tomographic inversion

The **starting model** is interactively constructed and may contain any kind of inhomogeneities. The geometry of the rays may be loaded into the starting model (see figure on the left, homogeneous starting model).
Either **straight rays or curved rays** are used for the ray-tracing contained in the **SIRT-algorithm**. For the curved rays a finite difference approximation of the eikonal equation is used (see also refraction traveltime inversion). The middle figure shows the result of the **tomographic inversion**.
The **forward raytracing** included within the modelling tool can be used for a **validation** of the tomographic result (see figure on the right). The rays can also be calculated and included within the model - here they have been omitted for easons of clarity.

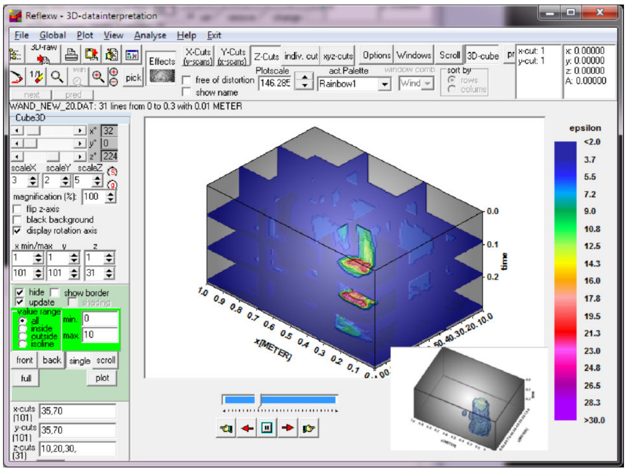


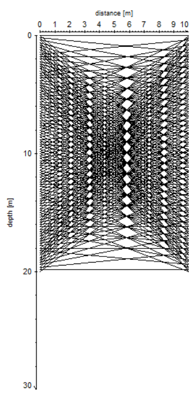


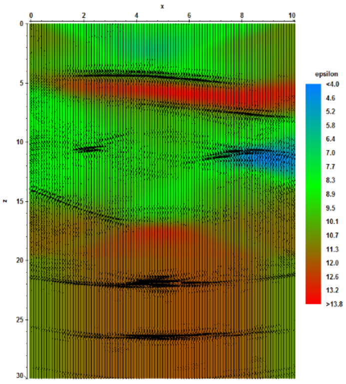


The **3D-tomography** is restricted to straight rays. The result of the 3D-tomography can be viewed within the 3D-datainterpretation menu (see picture on the right).

The **prestack migration** is also available for crosshole data. It may be used in combination with a traveltime tomography in order to improve the inversion taking into account the wave propagation.







Reflex2DQuick

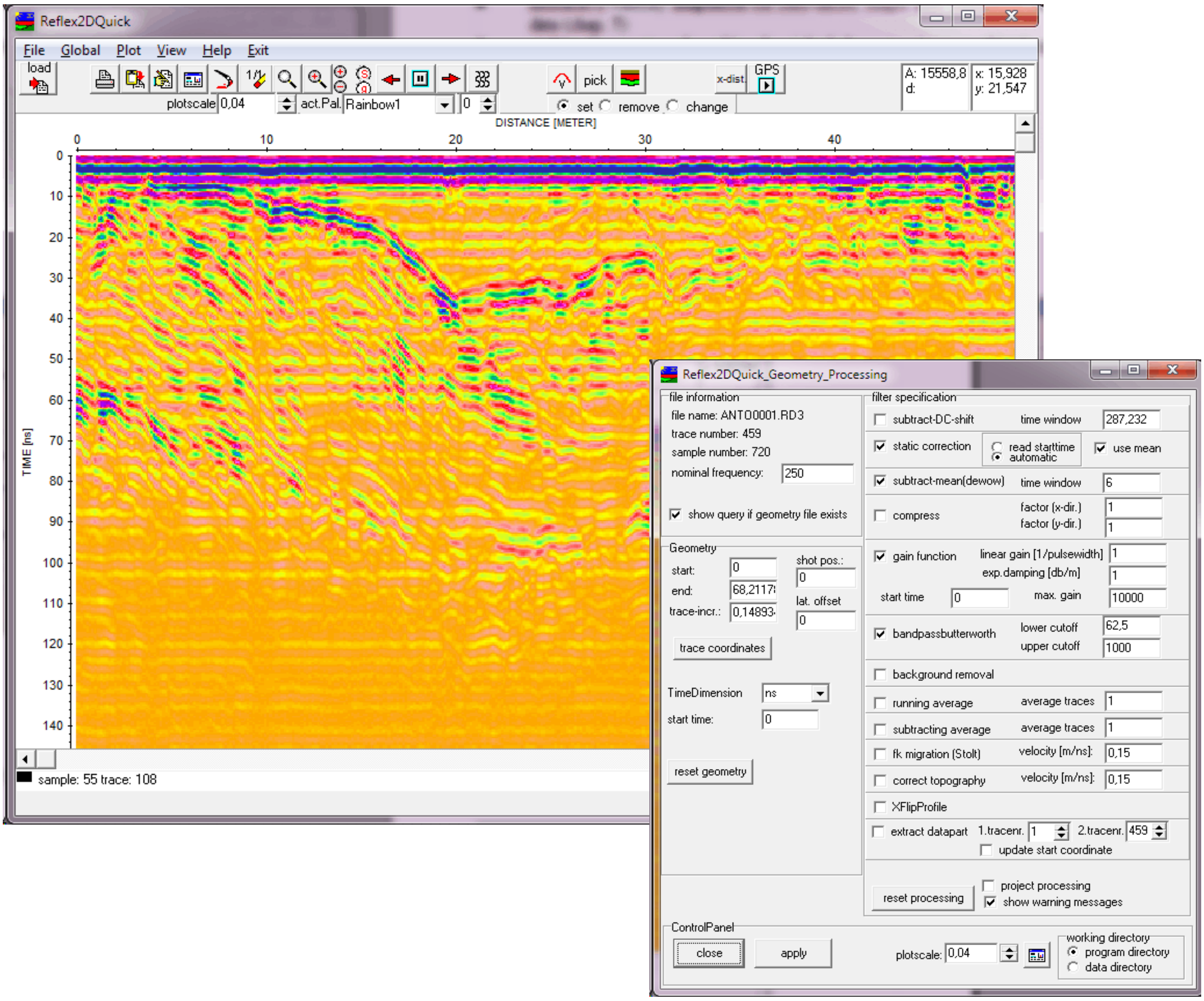
the easy handling of 2D GPR lines or seismic shots

The program **Reflex 2D-Quick** allows an easy import, display, processing and interpretation of 2-dimensional **G**round**P**enetrating**R**adar and **seismic** data. The program offers the following possibilities:

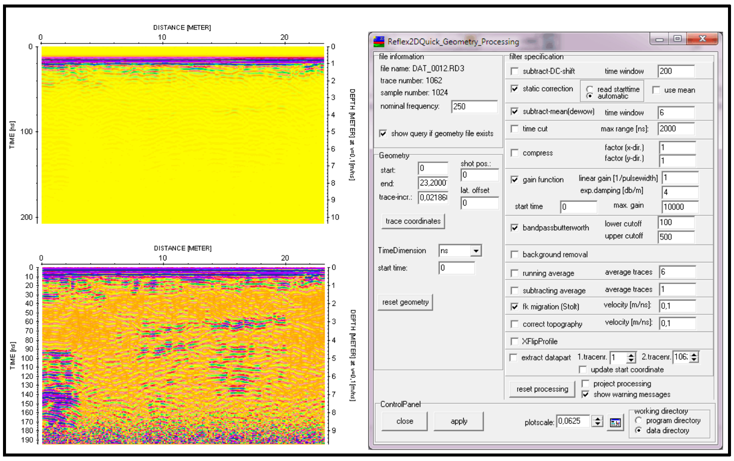
- direct import from different formats (SEGY, SEG2, Mala (RD3), Gssi (DZT), PulseEkko (DT1), Utsi, IDS)
- easy change of the distance scaling
- standard processing with predefined default parameters which can be manually changed
- different display possibilities like point or wiggle mode, scaling and zooming functions
- printing the profiles with free scaling
- interactive velocity adaptation for zero-offset, single shot (reflection and refraction) or VSP data
- picking the onsets
- export the data to other formats like SEGY, SEG2
- It is possible to start the program twice for a comparison of two different datasets. Consequently, you are also able to compare a processed dataset with the original dataset.

The program is useful for the following applications:

- GPR or seismic reflection constant (zero) offset data
- GPR or seismic single shot data (e.g. refraction seismics or single CMP's)



processing and display

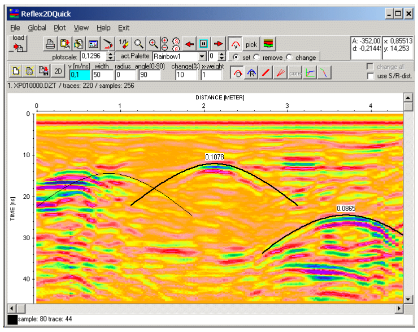


Comparison of the original raw data (upper panel) with the processed data (lower panel) based on the settings given in the right geometry_processing menu.

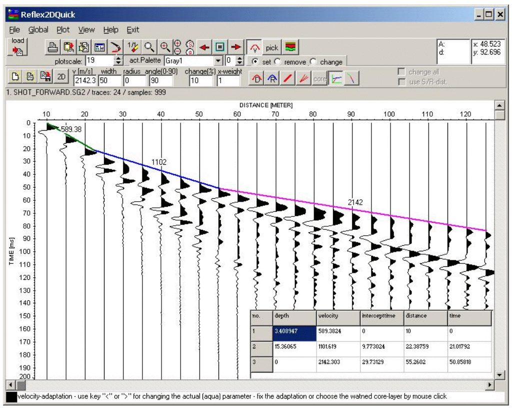
The following **processing** options are available:

- subtract DC-shift
- static correction
- subtract mean (dewow)
- compress
- gain function
- bandpass butterworth
- background removal
- running average
- subtracting average
- fk migration
- correct topography
- XflipProfile
- extract datapart

The picture on the right shows a GPR example There are many different **display** possibilities like point or wiggle mode, scaling and zooming functions available. The data may be **exported** to the clipboard or saved as ASCII- or bitmap-data. **Printing** is possible with freely choosable scale either in cm or scale like 1:1000 with a print preview menu which allows to preview the size and shape of the print output and to define an individual print header.

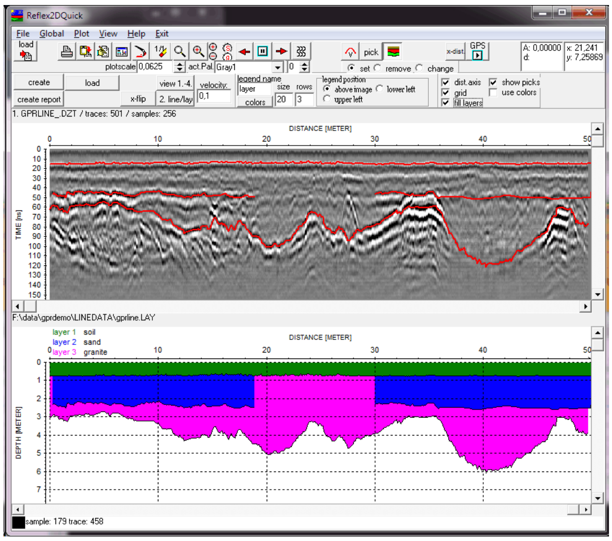


velocity analysis



An interactive hyperbola-adaption for a simple determination of the average velocity from a zero-offset or CMP profile (see figure on the left) is integrated (see picture on the left). It is possible to adapt **diffractions, reflections and straight lines**. You may change the velocity, the radius of the target, the angle between the line and the target and the width of the calculated diffraction or reflection hyperbola. There is also the possibility of fitting **linear features** either by changing interactively a line or by setting two points. The option **core** allows to vary interactively the velocities of the single layers of the individual cores stored within an ASCII-file. In addition an interactive use of the **intercept time method** for seismic refraction data is included (see picture on the right). The option enables to get a first 1D-model very quickly.

Picking the onsets/first arrivals

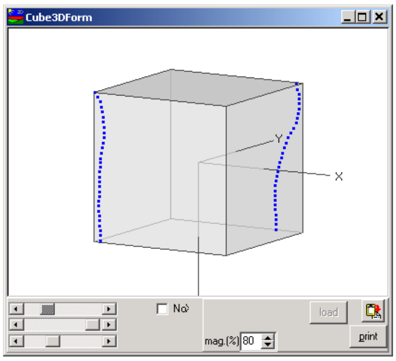


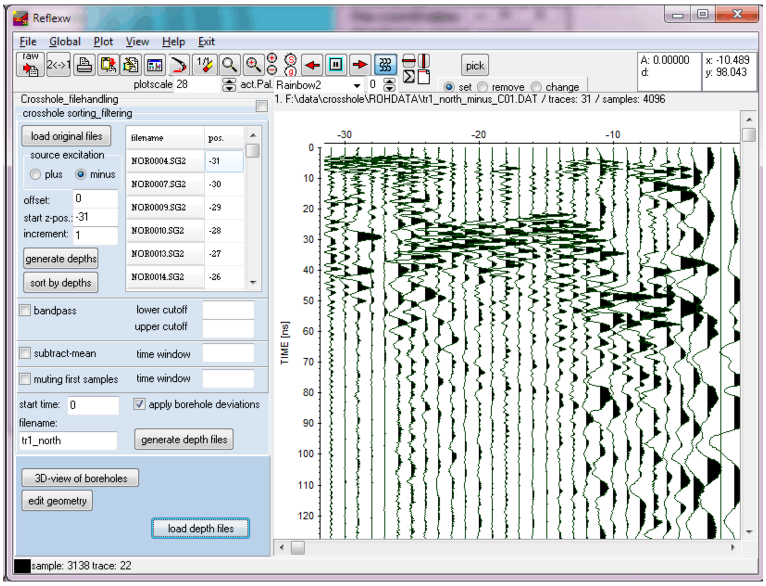
The picking option allows to pick the traveltime and the amplitude of different onsets like **reflectors** or **hyperbola** or the **first arrivals**. You have the choice between manual picking, continuous picking and a semi-automatic picking using a phase follower (manual editing is always possible).
It is possible to export the picks into an ASCII-format together with the 3 space coordinates for a subsequent interpretation.

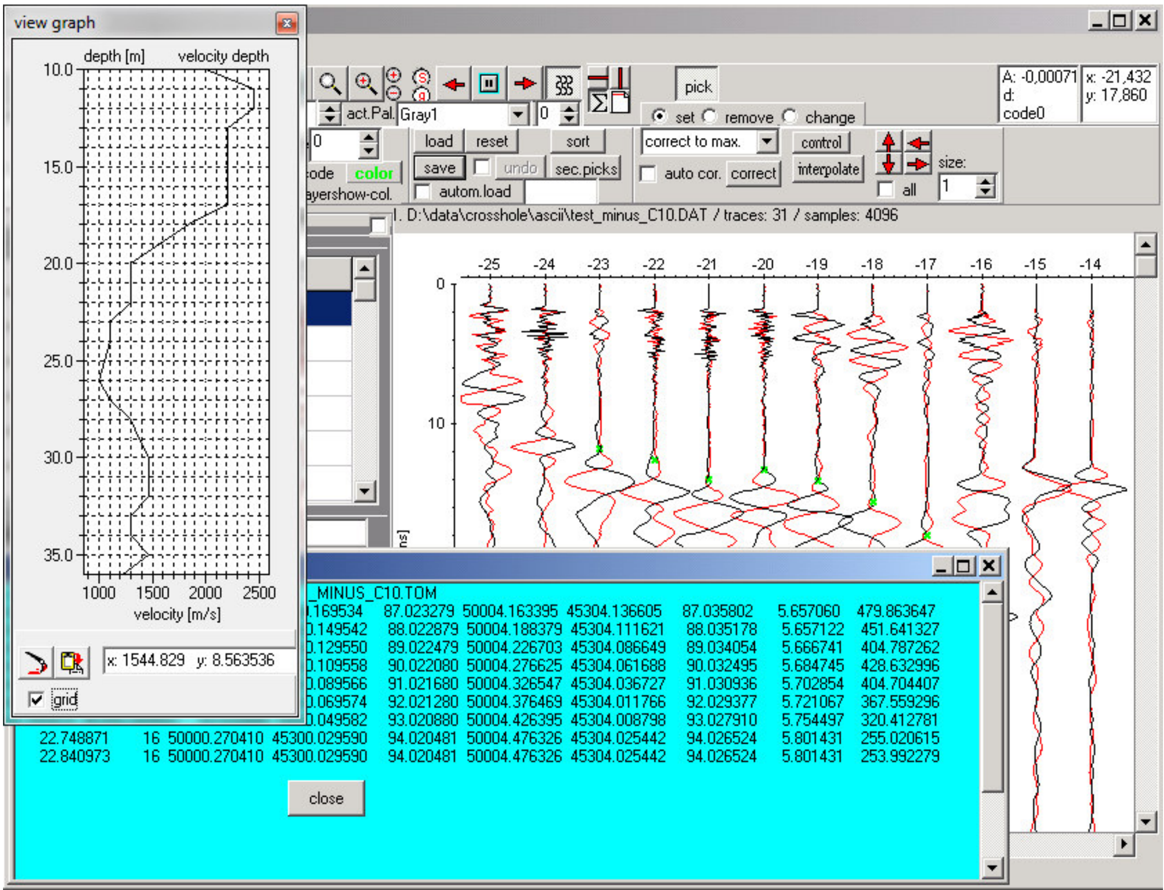
The so called **layer-show** (see picture on the right) offers the possibility to combine individual pick files, to plot them together with the wiggle-files and to output them in report form on printer or file containing the depths, velocities and amplitudes of the individual layers. The time-depth conversion of the picks is either based on mean or layer velocities.

Crosshole Seismic Testing

In this method, also known as Crosshole Sonic Logging (CSL), the source (p- or s-wave source) and the receiver are located at the same depth within two separate boreholes. The traveltimes of the first arrivals are transformed into p- and or s-velocities which represent average values between the boreholes. A multi-directional receiver array is supported. The deviation of the boreholes (true xyz-coordinates) can be taken into account. The picking of the first arrivals can be done by different automatic methods or manually or by a combination of both. If a shear wave source with 2 different orientations has been used the raw data can be overlaid for a more accurate picking. The result of the interpretation is a 1-dimensional velocity distribution.



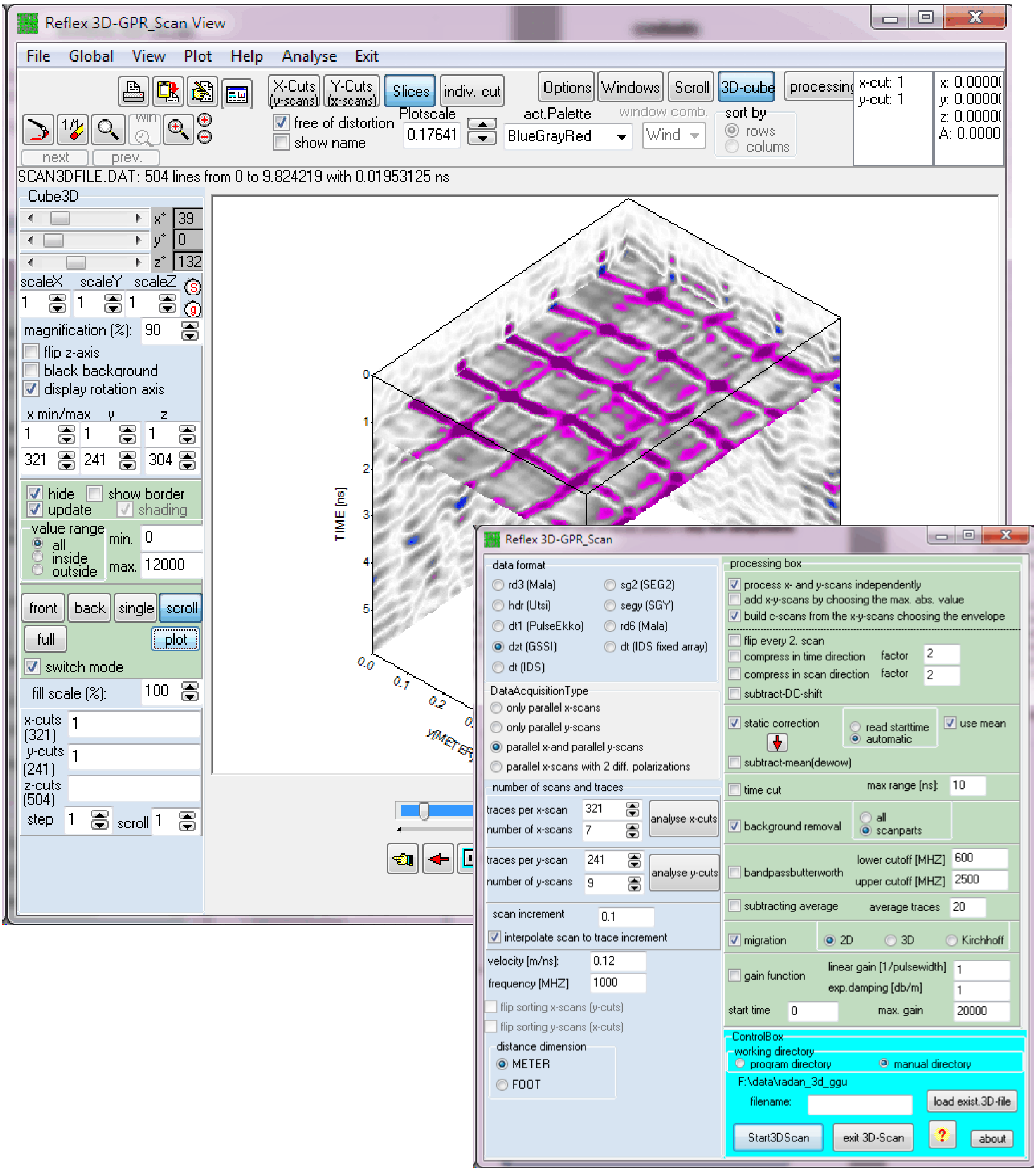


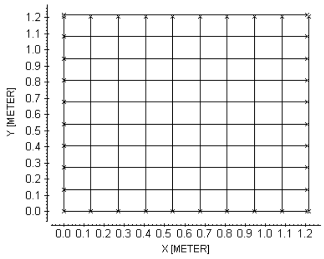


Reflex3DScan

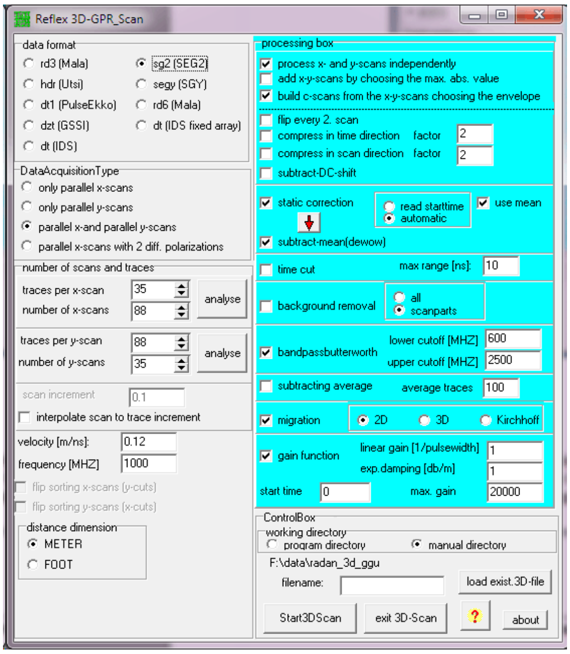
the fast access to a 3D-view of the underground

The program **Reflex 3D-Scan** allows to import and to analyse automatically rectangular 3-dimensional GPR- or seismic data which have been acquired along 2D-parallel lines in one or two perpendicular directions.





Precondition is that the data have been acquired along equidistant parallel 2D-lines on a regular rectangular grid. This means that the traceincrement in one direction (x or y), the startposition of the 2D-lines and the scan increment between the 2D-lines must be equal. The data may have been stored on individual 2D-files or within a 3D-file. If stored within a 3D-file the end-positions of the internal 2D-lines must be identical in addition as well as the number of traces into profile direction.



The **traceincrement** must be given within the original data. In addition if the data have been acquired in two perpendicular directions (**crossing lines**) the trace increment must be equal for all 2D-lines but the scan increment between the parallel lines does not need to equal the traceincrement if the option interpolate scan to trace increment is active. In this case an **automatic interpolation** will be done.

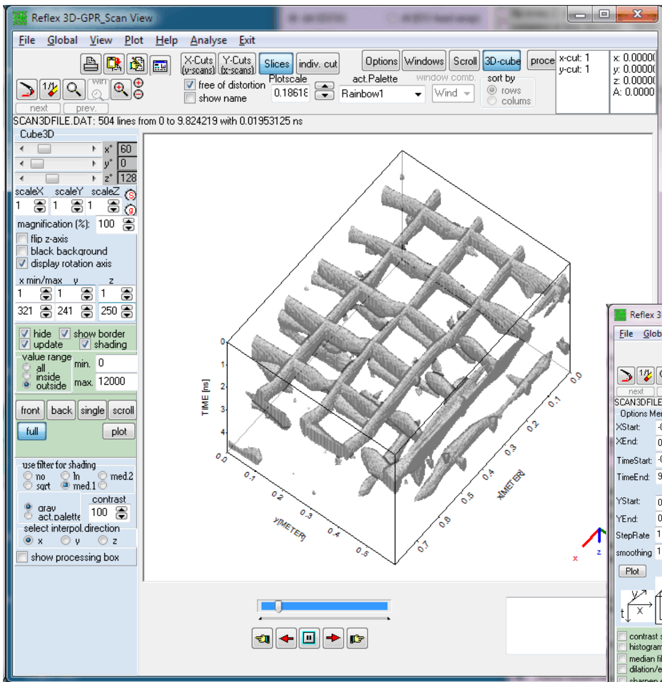
If these preconditions are satisfied the 3D-scan program allows a very fast interpretation of your 3D-data.

Different **dataformats** are supported (see picture left). The original data may be stored on individual 2D-files or on one 3D-file with the 2D-lines sequentially stored. With 2D-files acquired an automatic interpolation filter allows a resampling of the data in the direction of each line if the number of traces slightly differ in each 2D-line. A **meandering** data acquisition of the 2D-lines is supported.

Optionally some **filter** steps are automatically performed. They are: flip every 2. scan, compress, subtract DC-shift, dewow, static correction, time cut, background removal, bandpassbutterworth, subtracting average, migration (2D and 3D) and gain in timedirection.

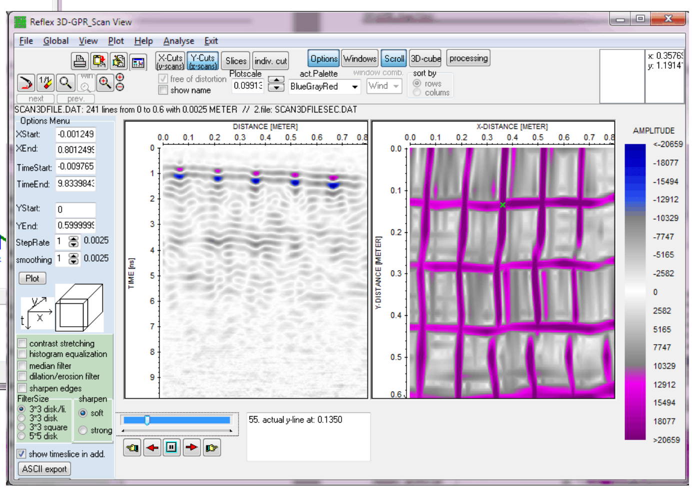
The processing of the x- and y-scans may be done independently and the c-scans also may be built independently chosing the envelope of the original data.

Within the **3D-GPR ScanView** menu which opens after all sorting and processing steps have been finished all display options of the 3D-datainterpretation are available (option **windows**, option **scroll** and option **3D-cube -** see also Reflexw 3D-datainterpretation).



A **MPEG moviefile** for the later use with a MPEG-player may be easily constructed for the scroll and the 3DCube mode.

Optionally the actual timeslice depending on the mouse position is shown in a second window. The actual cursor position is marked by a cross within the timeslice.

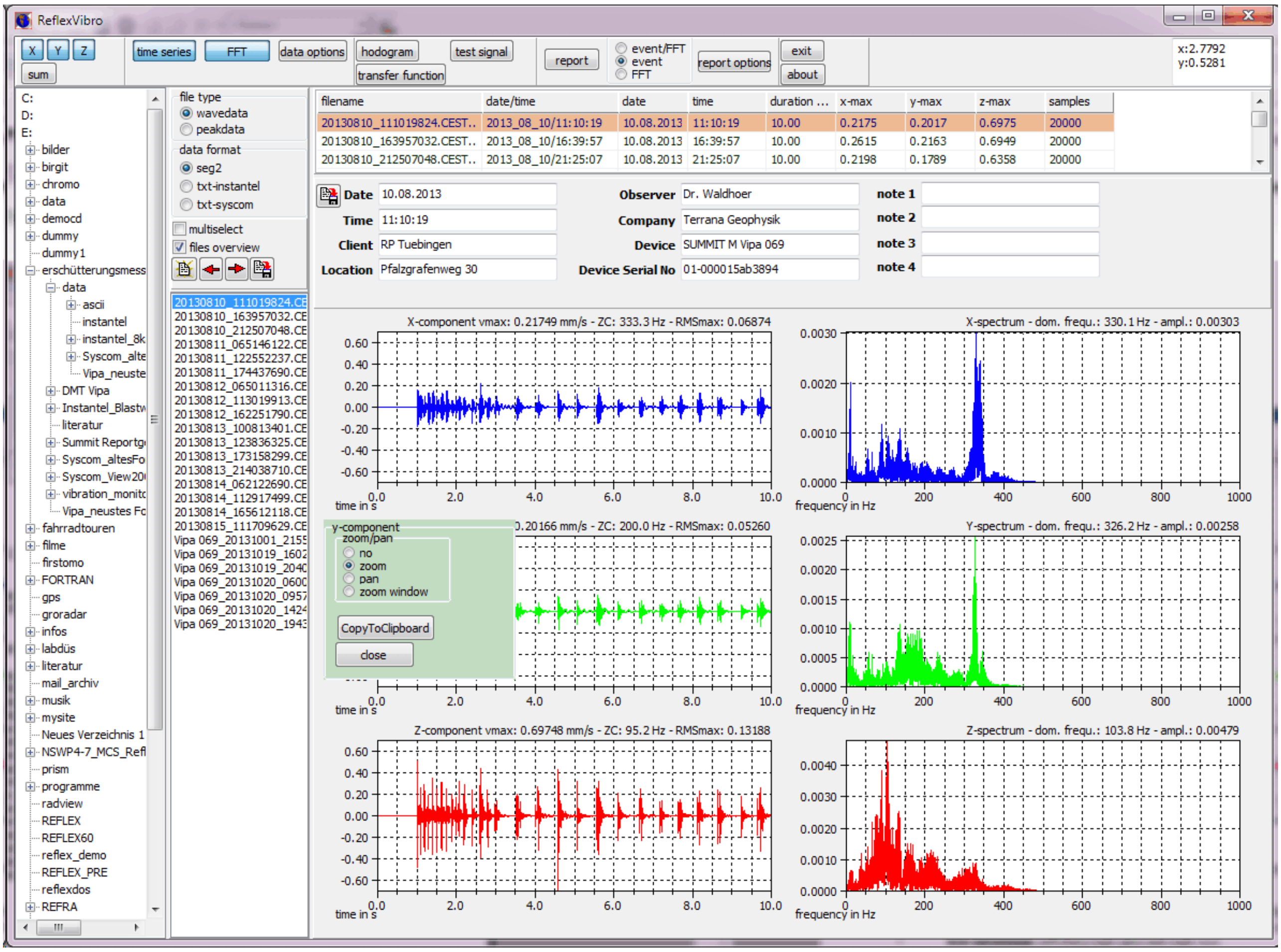


ReflexVibro

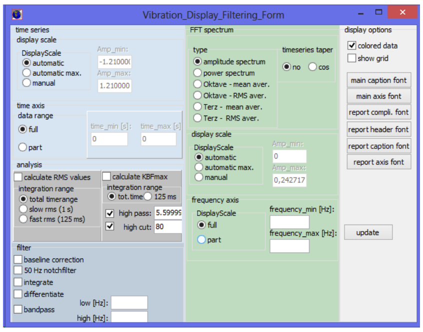
Our software for the interpretation of seismic vibration data

The program **ReflexVibro** has been designed for the interpretation of seismic vibration data. The program offers the following possibilities:

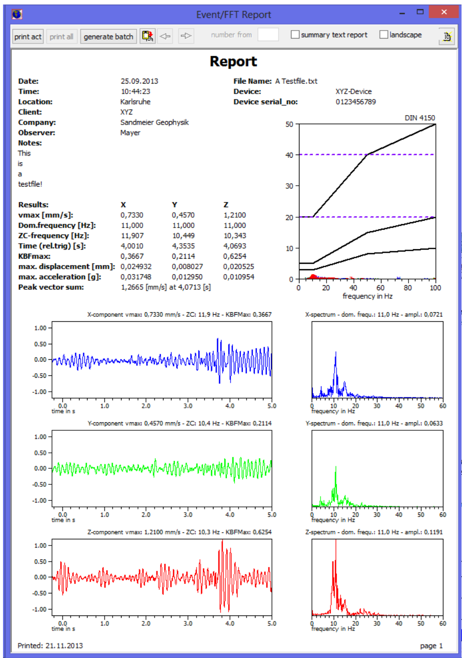
- easy import of **wave** and **peak** data in different formats of up to 8 channels (seg2, csv-DMT, Instantel and Ssyscom).
- amplitude **spectrum**, power and octave spectrum
- **filtering** (DC-correction, 50 Hz Notchfilter, integration, differentiation and bandpass).
- many different display possibilities (discretely adjustable axis-lengths for time-series and spectra, ...).
- **KB-calculation** (arbitrary high pass and high cut).
- generation of event and FFT **reports**, including compliance graphs (DIN 4150 and other).
- printing of reports in different languages.
- generation of synthetic **test signals**
- **hodogram** calculation for an interactive display of the movement direction.
- generation of a **transfer function**



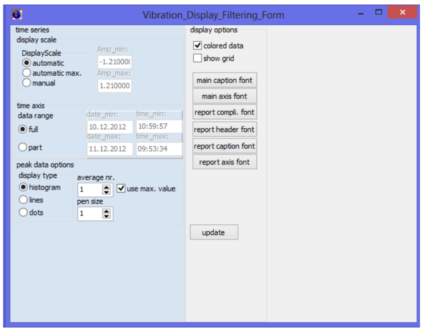
Wave and **peak** data can be displayed and processed in different ways and a standard report can be output for a single datafile or for a set of datafiles within one step.



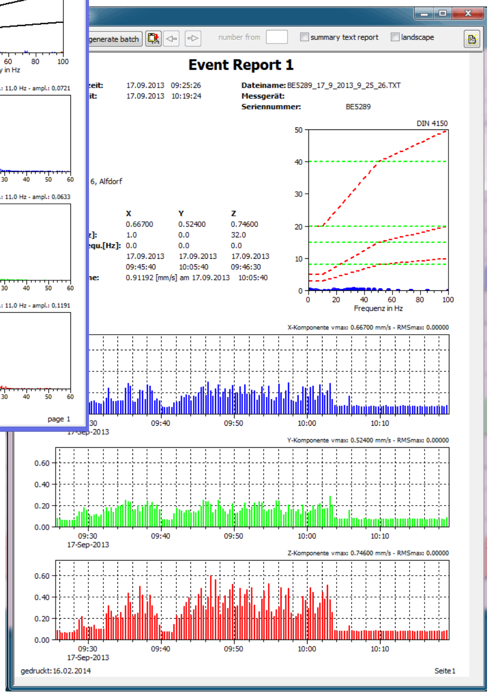
Wave data options



Wave data report

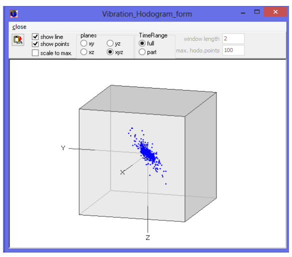


Peak data options

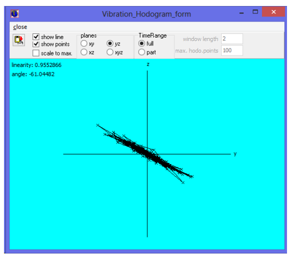


Peak data report

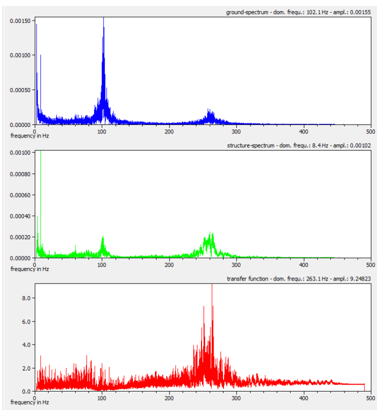
Hodogram option which allows to display the spatial distribution of the movement in 2 or 3 dimensions.
The linearity and the angle of the main vibration direction are calculated and displayed.



Hodogram: Data shown as cube.



Hodogram: Same Data shown in y-z-plane



The **transfer function** can be calculated based on the spectra of the ground and structure data.