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Commands

File menu

The *File menu* offers these commands :

Open Profile...	**Opens** an existing database. Select SEIS32.DBD in profile directory.
New Profile...	**Creates** a new database. Set File name to new profile name and click Save.
Check Profile	Checks profile database for integrity
New Spread type...	Create new **receiver spread type**, browse existing types
Export Spread types...	Export all spread types to ASCII .SPR file
Import Spread types...	Import all spread types from ASCII .SPR file. Replace current types.
Import Data...	**Import** seismic trace data into profile database.
Import Data Settings	Settings to be used with above Import Data... command
SEG-2 import settings	Settings for SEG-2 file import with above Import Data... command
SEGY import settings	Settings for SEGY fie import with above Import Data... command
ASCII column format...	Specify **ASCII column format** for above Import Data... command
Update header data	Update profile database header data from various ASCII file types
Export header data	Export profile database header data to various ASCII file types
Export data Settings	Settings to be used with above Export header data commands
Shorten stored trace length...	Shorten stored trace length in database to conserve disk space. Available with Pro license only.
Print	Print currently selected section window
Print Setup...	Select and setup printer to be used for above Print command
External commands	Show database command feedback in DOS console etc.
Exit	Close profile database and shut down Rayfract(R) application

Import Data Settings

The *Import Data Settings submenu* is contained in **File menu** and offers these commands :

Allow missing traces for SeisImager, SeisOpt, Gremix and .3DD files Allow missing dead traces, for Geometrics SeisImager, Optim SeisOpt, Interpex Gremix and GeoTomCG .3DD files

Interpolate shot point elevation for SeisOpt and .3DD files Interpolate shot point elevation and hole depth, for Optim SeisOpt, GeoTomCG .3DD. These file formats do not specify the shot hole depth.

X coordinate is corrected for topography already Horizontal x coordinate is corrected for topography already, in input data files

Default distance unit is meter Default distance unit during import is meter or feet. Use for SeisOpt and SeisImager import.

Default time unit is seconds Default time unit during import is seconds or millisecs. Use for SeisOpt import.

Keep same Sample count for consecutive shot trace files Reuse sample count from previous shot trace file during import. Edit in Import shot dialog to override.

Profile start is default layout start Check to regard 'Default layout start is 1' setting, for first shot imported. Uncheck to get layout start and profile start from input file header of first shot imported.

Default layout start is 1 Spread layout starts at station no. 1 per default. Disable for default of 0. Not regarded if 'Profile start is default layout start' unchecked.

Swap borehole x with z Swap x with z borehole coordinates during import of .3DD and export of station and shotpoint coordinates. Y coordinate assumed all zero.

.3DD shot traces sorted by receiver offset Sort GeoTomCG .3DD shot traces by receiver elevation (vertical borehole) or by receiver x coordinate (horizontal borehole) or by inline offset (circular borehole).

Import horizontal borehole survey or .3DD refraction survey Import horizontal borehole survey, SEG-2 or .3DD shots. Support import of GeoTomCG .3DD refraction shots into refraction spread/line profile database.

Import circular borehole survey Import borehole line which loops back or is not straight in x or z plane. This option disables geometry checks and does not assume any particular line shape.

Adjust profile station spacing Determine averaged minimum receiver station spacing for current input file, and let you update profile station spacing.

Match .LST traces by station number Match .LST traces to database traces by station number or channel number

Round shot station to nearest whole station number Round shot station to nearest whole station number or half-station number

Unsafe import Use this option in case of low disk space or to speed up the import routine. Makes import unsafe.

Reset all Import Data settings to default value Reset all of above Import Data settings to their default values

SEG-2 import settings

The *SEG-2 import settings submenu* is contained in **File menu** and offers these commands :

Detect shifted trace data start with signal statistics Detect byte offset of shifted sample data start by minimum variance of signal samples. Fails with noisy traces.

First sample is at First non-zero byte Search for first non-zero byte in trace data and assume this is the first sample. Fails when first sample starts with zero byte. Test with 'Non-standard trace start' checked.

Determine SEG-2 trace data start by User logic Determine SEG-2 trace sample start by user logic, not by seismograph brand

Ignore SEG-2 trace descriptor block size Do not use SEG-2 trace descriptor block size specified by field X in trace descriptor, for determination of trace data start.

Non-standard SEG-2 trace data start Do not round up SEG-2 trace data start to next double-word (4-byte) boundary. Use for OYO and DMT SUMMIT files.

Skip 4 leading zero bytes at SEG-2 trace data start Skip 4 leading zero bytes at SEG-2 trace data start. Use for OYO and Geometrics files.

Standard SEG-2 string list Termination Per SEG-2 standard, end of string list is marked by two zero bytes. Uncheck to allow just one zero byte to mark end of string list. Uncheck for SARA s.r.l. DoReMi.

Get distance unit from user Check to override distance unit stored in SEG-2 file, with user setting in File|Import Data Settings

Reset SEG-2 import settings to default value Reset SEG-2 import settings to their default settings

SEGY import settings

The *SEGY import settings submenu* is contained in **File menu** and offer these commands :

Non-standard byte ordering : low byte stored first (NOT big-endian) Assume that .SGY was generated with little-endian format : low byte stored first, as customary on X86 processors

One shot per .SGY file : disregard original field record number in trace header Assume that all traces in one .SGY file belong to one shot. Disregard field record number in .SGY trace headers.

No receiver coordinates specified in .SGY file Assume that .SGY does not contain valid receiver coordinates. Determine receiver position from default spread type.

Force determine station numbers Force determine station numbers for layout start and shot position with inconsistent SEGY geometry. Use if unchecking 'No receiver coordinates specified in .SGY file' fails.

Set SEGY settings for Ambrogeo Echo non-standard .SGY files Set SEGY import settings for import of non-standard Ambrogeo Echo .SGY files

Reset SEGY import settings to defaults, for standard .SGY files Reset SEGY import settings to their default settings, for import of standard .SGY files

Update header data

Update header data submenu is contained in the **File menu** and offers these commands :

Update Geometry...   Update receiver and shotpoint coordinates from .PRN survey
                                    file. See \RAY32\DOC for sample .PRN .
Update Station Coordinates... Update inline receiver and shot station coordinates from
                                    .COR coordinate file
Update Shotpoint coordinates... Update shot positions (coordinates, inline, lateral offset)
                                    from .SHO shot point file, update shot time terms. Does NOT
                                    update shot station numbers. Reimport shots to update shot
                                    station numbers.
Update First Breaks...   Update header data with first breaks from .LST file
Update First Breaks from .CSV... Update header data with first breaks from .CSV file. See
                                    \RAY32\DOC for sample .CSV .
Import synthetic breaks from .LST... Import modeled first breaks from .LST listing file
Update from Gremix .GRM files... Update header data with first breaks, elevations and shot
                                    hole depths from Gremix .GRM files
Update from OYO .ODT files... Update header data with first breaks from OYO .ODT files

Export header data

The Export header data submenu is contained in the **File menu** and offers these commands :

Export Station Coordinates... Export inline receiver and shot station coordinates to .COR file

Export Shot Point Coordinates... Export shot positions and shot time terms to .SHO shot point file

Export First Breaks as ASCII... Export picked first breaks to .ASC ASCII file

Export Modeled First Breaks as ASCII... Export modeled first breaks to .ASC ASCII file

Export First Breaks... Export picked and modeled first breaks to .LST listing file

Export Traces to GeoTomCG .3DD... Export traces with geometry, to GeoTomCG .3DD file. Configure with File|Export Data Settings.

Export Modeled Times to GeoTomCG .3DD... Export modeled first breaks with geometry, to GeoTomCG .3DD file

Export Residuals to .TXT... Export residuals (difference between picked and modeled times) to .TXT file. Available with Pro license only.

Export depth section to .XYV... Export refractors to ASCII .XYV with station x/y coordinates, refractor elevations and velocities of current depth section

Export ASCII Model of depth section... Export ASCII model to .CSV with layer thicknesses and velocities of current depth section

Export data Settings

Export data Settings submenu is contained in the **File menu** and offers these commands :

Export coordinates in feet	Export coordinates in feet. Uncheck to export in meters.
Export horizontal inline offset to .COR	Export horizontal inline offset to .COR coordinate file. Also export weathering velocity v0 and DeltatV v0 if available.
Write empty line to .LST after each shot	Write empty line to .LST file after all traces for one shot have been written
Export dead traces to GeoTomCG .3DD	Export dead/unpicked traces to GeoTomCG .3DD, with first break pick -1. Uncheck to skip.
Gather traces by common receiver station	Sort traces by common receiver (primary key) and shot station (secondary key), for GeoTomCG.3DD export

Header menu

The *Header menu* offers these commands :

Profile   Lets you enter profile information such as name and **Station spacing**

Shot   Browse shot headers for shots imported into database. Edit shotpoint
                     offsets and Trigger delay.

Receiver   Browse receivers for shot selected with above command. Edit first break
                     time.

Station   Browse station info for all shotpoints and receivers. Edit station
                     coordinates and weathering velocity.

Trace menu

The *Trace menu* offers these commands :

Shot gather   Display all traces recorded for one shot. Browse shots. Pick
                             first breaks. Filter trace signal. Stack shot traces.

Midpoint gather   Display all traces recorded at one Common Mid-Point (CMP).
                             Pick first breaks. Filter trace signal.

Offset gather   Display all traces recorded for one Common Offset value.
                             Pick first breaks, filter trace signal.

Shot point gather   Display all traces recorded at one shotpoint. Pick first breaks
                             for shear waves, filter trace signal.

Receiver station gather Display all traces recorded at one receiver station. Pick first
                             breaks, filter trace signal.

Smooth invert menu

*Smooth invert men*u offers these commands :

WET with 1D-gradient initial model   Run Smooth inversion : determine
                                                         1D-gradient starting model and run
                                                         2D WET inversion with default
                                                         settings.

WET with constant-velocity initial borehole model   Determine constant-velocity starting
                                                         model for borehole survey. Run 2D
                                                         WET inversion.

Custom 1D-gradient velocity profile...   Use custom 1D velocity profile to
                                                         generate GRADIENT.GRD starting
                                                         model. Set limits of starting model.
                                                         Force velocity for constant-velocity

starting model.

Smooth inversion Settings   Settings to be used for above Smooth inversion.

DeltatV menu

The *DeltatV menu* offers these commands :

Automatic DeltatV and WET inversion   Determine 1.5D starting model with DeltatV & XTV inversion. Run 2D WET inversion with default parameters.

Interactive DeltatV (CMP Velocity vs. Depth)... Edit DeltatV parameters, determine 1.5D starting model

DeltatV Settings   Edit DeltatV settings for above DeltatV inversion

WET Tomo menu

The *WET Tomo menu* offers these commands :

Automatic WET tomography...   Select a starting model and run 2D WET inversion using default parameters.

Interactive WET tomography...   Select starting model, edit WET parameters and run 2D WET inversion.

WET Velocity constraints...   Keep tomogram velocity unchanged below/above velocity thresholds. Specify polygon blanking in tomograms.

WET Update weighting...   Edit parameters a&b for WET update weighting across wavepath with *Ricker differentiation* set to -2 [Cosine-Squared]

Coverage plot setup...   Thinning of wavepath coverage plot : plot wavepaths for every nth shot and receiver

WET tomography Settings|Blank   Specify blanking for above WET inversion

WET tomography Settings|Write   Write result files to disk during or at end of WET inversion

WET tomography Settings   Specify settings for above WET inversion

Grid menu

The *Grid menu* offers these commands :

Convert grid file between feet and meters...	Convert tomogram or starting model .GRD between feet and meters
Turn around grid file by 180 degrees...	Flip over .GRD
Convert .CSV layer model to Surfer .GRD...	Convert layer model .CSV to Surfer .GRD, matching existing .GRD dimensions
Export grid file to ASCII .TXT...	Export .GRD to ASCII x y z velocity .TXT file
Blank polygon area in grid...	Select VELOITXY.GRD and Surfer format .BLN blanking file to blank polygon
Convert elevation to Depth below topography...	Convert .GRD with absolute elevations to .GRD showing depth below topography
Image and contour velocity and coverage grids...	Image and contour VELOITXY.GRD & matching COVERGXY.GRD

Model menu

Model menu offers these commands :

Forward model traveltimes...	Forward model first break propagation through selected tomogram .GRD with Eikonal solver
Forward modeling Settings	Settings to be used with above Forward model command
Model synthetic shots...	Replace traveltimes for all imported shots or imported dummy shots (all picks are -1) with forward-modeled times for selected .GRD
Create Checkerboard grid...	Define checkerboard anomaly magnitude and size. Select input grid file and output grid file. Enabled for Rayfract® Pro license only.

Refractor menu

The *Refractor menu* offers these commands :

Shot breaks   Display shot-sorted traveltime curves. Select **branch points** delimiting refractors to map traces to refractors.

Midpoint breaks   Display CMP-sorted traveltime curves. Map traces to refractors using specified 1D velocity model.

Offset breaks   Display Common Offset-sorted traveltime curves. Shows geology even before running the inversion.

Depth menu

The *Depth menu* offers these commands once you have mapped trace to refractors in **Refractors/Shot breaks** or **Refractors/Midpoint breaks** :

Wavefront...   Layer-based refraction interpretation using Wavefront method for ray inversion

Plus-Minus...   Layer-based refraction interpretation using Hagedoorn's Plus-Minus method

CMP Intercept-Time Refraction...   Layer-based refraction interpretation with CMP Intercept-Time refraction method

Depth conversion Settings   Settings to be used for above layer-based interpretation methods

Velocity menu

The *velocity menu* offers these commands once time-to-depth conversion via **Depth menu** item has been done :

Wavefront   Display layer velocity plot for Wavefront method interpretation done in Depth menu

Plus-Minus   Plot layer velocity vs. profile station number for Plus-Minus interpretation done in Depth menu

CMP Refraction   Plot layer velocity vs. profile station number for CMP Intercept-Time refraction interpretation

Window menu

The *Window menu* offers these commands :

Cascade	Cascade all open section windows in Rayfract(R) main window
Tile	Vertical tile all open section windows
Tile horizontal	Horizontal tile all open section windows
Arrange Icons	Align minimized windows at bottom of main window just above status bar
Close All	Close all open section windows
Copy current Window to clipboard	Copy current window to Windows Clipboard. Select window with left mouse button click on window title bar.
Copy all Windows to clipboard	Copy all windows currently displayed to Windows clipboard. Next paste into third-party app document with CTRL+V.
Export depth section to .XYV...	Export refractors to ASCII .XYV with station x/y coordinates, refractor elevations and velocities of current depth section
Export ASCII model of depth section...	Export ASCII model to .CSV with layer thicknesses and velocities of current depth section
Display annotations in Arial	Display axis annotations and legends in Arial font or Ms Sans Serif font
Large annotations	Use large font size for display of axis annotations and legends
Print wide sections with large annotations	Print wide sections with large annotations and legends
Print with display colors	Use same colors for section printing as for display on screen
Show prompts on top of other applications	Force display of important prompts on top of other application's windows
No composite title bar in main window	Do not append title of currently active child window to title of main window

Help menu

The *Help menu* offers these commands :

Contents	Displays Table of Contents showing chapter topics. Click any chapter to show chapter text.
Keyboard	Function key combinations and keyboard shortcuts with assigned operations
Search for Help On...	Find help topic via keyword search
Using help	Explains how to use the help menu contents. Disabled in Windows 7 and later.
About...	Rayfract(R) software version description and licensing information plus Copyright notices

Processing menu

The *Processing menu* is shown when you display a Trace gather section by selecting a **Trace menu** item and offers these commands :

Scale trace to integer before processing	Scale trace samples to 16-bit integer before processing and filtering. Uncheck to process 32-bit floating point samples and scale after filtering only.
Trace processing...	Configure AGC, Trace signal smoothing, Remove dc offset from traces, Color nth trace
Process before filtering	Process trace as specified above before frequency filtering
Frequency filter...	Edit frequency filter (low-cut, high-cut) parameters
Bandpass filter...	Edit bandpass filter (band-reject) parameters
Trace display...	Edit station number range, time range to display. Specify printer scaling.
Edit offset range, disable offset zoom	Enable editing of station number/offset range with ALT+P. This will disable zooming offset with SHIFT+F1
Edit time window, disable time zoom	Enable editing of time window with ALT+P. This will disable zooming time with F1.
Trace annotation...	Configure Axis display and edit Axis titles. Press ENTER key to redisplay section.
Reverse trace polarity	Reverse polarity for current trace of shown gather. Select trace with keyboard left-arrow and right-arrow keys.

Reverse shot polarity	Reverse polarity for all traces of current gather. Browse gathers with F7/F8 keys.
Stack shots...	Stack two imported shots, in profile database. Show resulting shot in Trace|Shot gather.
Automatic picking of first breaks...	Automatic first break picking
Display raytraced traveltimes	Display raytraced traveltimes in section
Enable polyline picking	Show polyline segments, allow picking segments with right mouse key for semi-automatic first break picking. Disables solid pick display.
Delete picks for all traces of shot	Delete all first breaks for currently displayed shot and refresh display
Color traces	Color traces in Trace gather. Determine color from shot no. MOD 6, as in Shot breaks display.
Color traces by source type	Color traces in Trace gather. Determine color from source type specified in Header|Shot.
Color trace outline	Color trace outline. Color index is shot no. MOD 6.
Red trace outline	Color trace outline in red
Show picks on time axis	Show first break picks on time axis without amplitude offset
Use red cross for picked first breaks	Use red cross, file bigredcross.bmp for display of picked first breaks. Uncheck to use red circle, file redblack_circle.bmp.
Solid color pick display	Display first break pick bitmap with AND operator instead of XOR operator. Slows down trace display refresh when picking traces. Disables automatic picking.
Picks always cover traces	First break picks are displayed in separate loop, after all traces have been shown. Slows down trace gather display.
Check shot position when picking traces	Check shot position when picking traces in Trace|Shot gather display
Refresh shot breaks when picking traces	Refresh shot breaks display when picking traces in Trace|Shot gather display
Pick all shots, in shot point gather	Pick all shots with trace at current receiver station, not only current shot, in Trace|Shot point gather
Refresh breaks display...	Refresh breaks display opened with **Refractor menu** item

Mapping menu

The *Mapping menu* is shown when you display a Refractor section via **Refractor menu** and offers these commands :

Refractor mapping...	Shows **Refractor mapping parameters dialog** when selected in **Refractor/Midpoint breaks**. Configure CMP vs. offset regression and specify a 1D velocity model to which regressed velocities are matched.
Refractor display...	Specify station number range and time range or maximum offset (for Midpoint breaks) Press ENTER key to redisplay section.
Refractor annotation...	Configure Axis display and edit Axis titles
Automated updating of station V0	Automatically update station header velocity after mapping of first breaks to refractors
Update station V0 before depth conversion	Update weathering velocity in **Header/Station...** before time-to-depth conversion. Uncheck to update V0 after conversion when refreshing **Refractor/Midpoint breaks**.
Update station V0 for crossover smoothing only	Update weathering velocity in **Header/Station...** for Crossover distance smoothing only. If you skip Crossover smoothing V0 may be fine already, after mapping traces to refractors.
Undercorrect picks for shot point offset	Don't fully correct times for shot offset during layer refraction. Allows for diving waves, at near-shot point receivers.
Regard mapping for shot offset correction	Regard trace-to-refractor mapping and refractor velocities, for correction of first breaks for shot point offset
Check shot positions	Match shot positions against shot-sorted traveltime curves in **Refractor/Shot breaks**
Remap all traces	Test shot positions against traveltime curves and remap all traces to refractors
Crossover processing...	Shows **Crossover distance processing dialog** when selected in **Refractor/Midpoint breaks**. Smooth crossover distances and offset-limit basement coverage.
Undo trace mapping and corrections	Undo trace-to-refractor mapping and shot offset corrections, for all traces. Use before

	remapping traces to refractors in **Refractor/Shot breaks** and **Refractor/Midpoint breaks**.
Delete all branch points for current shot	Delete all **branch points** for currently selected shot and refresh display
Display raytraced traveltimes	Display raytraced traveltimes in section
Display synthesized traveltime curves	Display synthesized traveltime curves in **Shot breaks section**
Color picked traveltime curves	Color traveltime curves in **Shot breaks section** to ease recognition. Override refractor mapping.
Color picked curves by source type	Color shot-sorted traveltime curves in **Shot breaks section** by source type. Specify in *Header/Shot*. Override refractor mapping.
Gray picked traveltime curves	Display traveltime curves as gray in **Shot breaks section**. Override refractor mapping.
Dark gray traveltime curves	Use dark gray or light gray color, for traveltime curve display in *Shot breaks section*.
Blue direct wave first breaks	Color direct wave (weathering layer) first breaks in blue instead of orange in *breaks display.*
Refresh display	Refresh breaks display

Depth conversion menu

The *Depth conversion menu* is displayed when you open a depth section via **Depth menu** item and offers these commands :

Depth conversion...	Opens Model Parameters dialog for editing regression parameters and smoothing of overburden and basement refractors
Depth display...	Edit station number range and elevation range for depth section display. Press ENTER key to redisplay section.
Depth annotation...	Configure Axis display and edit Axis titles
Display Wavefront rays	Show wavefront method rays in layer above basement, emerging from common refractor point on basement top
Display Wavefront positions	Show wavefront method estimated basement locations on basement top
Blue weathering bottom	Color in blue bottom of weathering layer

	(refractor 1 elevation and velocity), for 3-layer case sections
Export depth section to .XYV...	Export refractors to ASCII .XYV with station x/y coordinates, refractor elevations and velocities of current depth section
Export ASCII Model of depth section...	Export ASCII model to .CSV with layer thicknesses and velocities of current depth section
Automatically Export depth section to .CSV and .GRD	Automatically export depth section to .CSV and layered .GRD starting model in LAYRTOMO subdirectory, image starting model in Surfer and run **WET inversion** after time-to-depth conversion

Velocity display menu

The *Velocity display menu* is shown once you open a velocity section with **Velocity menu** item and offers these commands :

Velocity display...	Edit station number range and velocity range. Configure scaling for printing of section.
Velocity annotation...	Configure Axis display and edit Axis titles
Refresh velocity display	Redisplay velocity section
Display raytraced velocities	Display velocities obtained by reducing normal and reverse shot traveltimes to basement
Show maximum velocity at bottom	Invert y axis of velocity plot : show maximum velocity at bottom, minimum at top

Depth conversion Settings

The *Depth conversion Settings submenu* is contained in **Depth menu** and offer these commands :

Link traveltime curves for Wavefront	Use algorithmically shifted and linked traveltime curves for Wavefront method instead of Brueckl regressed traveltimes
Link traveltime curves for Plus-Minus	Use algorithmically shifted and linked traveltime curves for Plus-Minus method instead of Brueckl regressed traveltimes

No Extrapolation of shots   Don't generate extrapolated shots when there are gaps in traveltime coverage along the profile. We recommend to leave this unchecked.

Skip reciprocal traveltime check   Don't reset regressed traveltimes if local reciprocal time estimate deviates from mean reciprocal time, for Wavefront and Plus-Minus

Reopen profile after mapping trace   Reopen profile database after mapping traces to refractors

Prefer geometric basement velocity for Wavefront   Determine basement refractor velocity from recording geometry (Jones and Jovanovich 1985). Uncheck with strong topography and recording geometry errors to average forward with reverse velocity obtained from traveltimes reduced to basement refractor (Brueckl 1987).

Introduction

RAYFRACT® is a Windows® 32-bit software package suited for processing of seismic profiles with low, medium or high coverage. We support the interpretation of both **P-wave and S-wave seismic refraction and borehole surveys**. First breaks are imported via ASCII or picked semi-automatically or interactively. Traveltimes may be mapped to refractors manually or semi-automatically based on apparent (instantaneous) CMP velocities measured and typical refractor velocity intervals specified by the interpreter. Traveltime data is processed on a per refractor basis with three different interpretation methods: **CMP intercept time refraction** (Gebrande and Miller 1985; Rühl 1995), **Plus-Minus** (Hagedoorn 1959) and **Wavefront** (Brückl 1987; Jones and Jovanovich 1985, Ali Ak 1990). Plus-Minus and Wavefront are based on **traveltime field regression** (Brückl 1987). Wavefront considers local emerging wavefront angles. A critically refracted ray is represented by first break and emergence angle at a receiver. Each reverse ray is combined with a matching forward ray such that both rays surface from an approximated common refractor location.

Version 3.32 released in December 2014 allows *automatic WET inversion with layered starting model* . The layered starting model is regenerated and you are prompted to start 2D WET inversion whenever you run *time-to-depth conversion* in *Depth menu* with Plus-Minus, Wavefront or CMP intercept-time refraction methods. See http://rayfract.com/tutorials/NORCAL14.pdf .

1.5D DeltatV inversion can work well in case of homogeneous overburden and for long profiles (longer than 500m) with dense shot and receiver spacing. This includes marine surveys. See tutorials

http://rayfract.com/tutorials/ot0608.pdf and http://rayfract.com/samples/GEOXMERC.pdf .

Obtain **smoother DeltatV starting models with less noise/artefacts** with non-default *DeltatV settings* as described in above tutorials ot0608 on page 3 and GEOXMERC on page 1. These non-default DeltatV settings work best for long refraction spreads/lines and dense shot spacing.

Our PowerPoint slide show http://rayfract.com/tutorials/Slope1.ppt shows how to interactively improve your first break picks. See http://rayfract.com/tutorials/Slope1.pdf for .pdf version.

The **resolution of finite-frequency traveltime tomography using Fresnel volumes is about one wavelength**. See https://dx.doi.org/10.1190/1.1820777 (Watanabe, 1999). If your average velocity is 2,000 m/s and your dominant first break frequency is 50Hz then

one wavelength = velocity/frequency = 2,000/50 = 40m.

So **the resolution of our WET tomograms is about 40m assuming above average velocity of 2,000 m/s and dominant first break frequency of 50Hz**. For high-quality picks with

◆ low reciprocal error showing in *Trace/Offset gather*

◆ high signal-to-noise ratio

◆ *WET inversion* with RMS error below 2 percent

you may reach a resolution of half a wavelength or a quarter wavelength : about 20m or 10m. See also peer-reviewed paper http://rayfract.com/SAGEEP2011_BlindRefraction.pdf & our tutorial http://rayfract.com/tutorials/sageep11_smooth50.pdf .

You can **consider our Wavefront method as an optimized version of the GRM**

(Generalized Reciprocal Method) algorithm described by Palmer (Palmer, 1980). Instead of assuming a user-specified constant receiver separation ("XY distance", "Optimum XY value") all along the profile, the Wavefront method automatically estimates the local receiver separation at each receiver station from local forward and reverse wavefront emergence angles. So the **receiver separation obtained may vary laterally along the profile** considerably. This means that the Wavefront method reliably images refractors with high relief (i.e. strongly undulating refractors, with pronounced troughs and humps). For a comparison of the Wavefront method with Plus-Minus and GRM methods using Dr. Palmer's synthetic models see (Ali Ak, 1990).

Release history

Since version 1.30 released in December 1998 our software offers the **DeltatV method** described by (Gebrande and Miller 1985). This pseudo-2D turning ray inversion method delivers continuous 1D depth vs. velocity profiles for all profile stations. The profiles are written to an ASCII file which may be processed with Golden Software's Surfer® etc. to produce **station no. vs. depth velocity maps / contour plots with velocity isolines**. The method **handles real-life geological settings** such as vertical velocity gradients inside layers / linear increasing of velocity with depth / velocity inversions / pinchouts and outcrops / faults and local velocity anomalies without requiring user-specified a priori model constraints. DeltatV **does not require the user to map traveltimes to refractors**. Importing seismic data and complementing it with geometry information / traveltime picks is all that is needed. DeltatV models show you the **relative velocity distribution in the subsurface**. Systematic velocity increases (at the top of the basement) and strong velocity anomalies such as low velocity zones, faults etc. will be visible in many situations. The absolute velocity values obtained may have an error of up to about 15 or 20 percent or more, however. Absolute velocity values, signatures and locations obtained for strong but narrow velocity anomalies may be distorted. **Pseudo-2D DeltatV generates systematic imaging artefacts in case of strong lateral velocity variation in the near-surface overburden. Apparent velocities below anticlines are too low, and apparent velocities below synclines are too high.** Use our **Smooth inversion method** to eliminate these artefacts in the 1D initial model and to obtain more reliable absolute velocity estimates.

Since version 2.01 released in October 2000 RAYFRACT® supports improved quality control of depth-velocity models obtained with our DeltatV method by forward modeling of wave propagation through these models. The **forward modeling algorithm** used for modeling of first breaks is the **first-order Eikonal solver as described by Podvin/Lecomte** (Lecomte 2000). It handles any geological setting such as vertical or lateral velocity gradients, sharp velocity changes (discontinuous velocity distribution, systematic changes at unit boundaries), strong velocity contrasts of local velocity anomalies and velocity inversions and runs fast, using multiple CPU cores. Thanks to this powerful quality control tool our **DeltatV method does not require core drilling data any longer. Just check and if necessary tune the DeltatV parameters by comparing synthetic i.e. modeled traveltimes with traveltimes measured and picked** as shown in the *Shot breaks display*. According to raytracing results from about 20 sample profiles **DeltatV does work for low-coverage surveys (just 5 or 7 shots per receiver spread).** Default values for the DeltatV parameters as proposed by the software will give good results in most cases.

Since version 2.11 released in February 2001 RAYFRACT® supports the iterative refining of DeltatV output or of Surfer® .GRD velocity models as obtained with third-party methods with our **WET Wavepath Eikonal Traveltime tomography** processing. See (Schuster 1993; Watanabe 1999). This sophisticated method supports extreme topography. **Wave propagation is modeled in a physically meaningful way with wavepaths i.e. Fresnel**

volumes (also known as "fat rays") based on our first-order Eikonal solver described above. WET allows for partial modeling of finite-frequency wave propagation such as diffraction and scattering. As a consequence **velocity anomalies such as low-velocity zones and faults may be imaged with higher contrast than with conventional ray tomography**.

Since version 2.34 released in March 2002 WET processing allows the **integration of uphole picks** for seismic traces recorded by surface receivers for shots positioned at the bottom of deep shot holes (e.g. recorded by same receiver spreads as used for surface based shots). Uphole shot positions need to tie in with the 2D surface-based refraction profile.

Since version 2.43 released in April 2003 RAYFRACT® supports the **automatic interpretation of 2D profiles with our DeltatV and WET inversion methods** including **automated gridding, imaging and contouring of resulting tomograms** with Golden Software Surfer®. We configure plots with BASIC language scripts run with Scripter utility coming with Surfer.

Since version 2.51 released in March 2004 RAYFRACT® per default uses a **fail-safe "Smooth inversion" option for automated determination of a 1D initial model and subsequent refinement with WET tomography processing**. A smooth initial 1D gradient model is determined directly from the traveltime data by horizontally averaging DeltatV method 1D velocity-depth profiles along the seismic line. This procedure delivers reliable smoothed and simple, artefact-free models even in case of velocity inversions. The 1D initial model guarantees that DeltatV artefacts (occurring e.g. in situations of strong refractor curvature / strong lateral velocity variation) are eliminated from the interpretation at an early stage.

For up-to-date information about features of version 2.61 and later versions of our software see

http://rayfract.com/help/release_notes.pdf

. Version 2.62 of our RAYFRACT® software released in August 2005 features **improved DeltatV internal static corrections**. During a second pass of statics computation **ray emergence angles are now regarded**. See the German language thesis of Roland A. Winkelmann available at amazon.de, ISBN 3932965043 , chapter 3.3. Also we offer an additional DeltatV setting *Suppress velocity artefacts* to **suppress the generation of processing artefacts** i.e. unrealistic velocity variation.

Version 2.71 of our RAYFRACT® software released in December 2006 **supports modeling of constant-velocity layers in addition to constant velocity-gradient layers with the XTV inversion method**. This method has been published by Roland A. Winkelmann in his 1998 Ph.D. thesis (Winkelmann 1998) with Professor Helmut Gebrande in Munich. Professor Gebrande has described the foundations of CMP refraction theory in (Gebrande and Miller, 1985) and (Gebrande 1986). See also

http://edoc.ub.uni-muenchen.de/archive/00000222/01/Gawlas_Peter.pdf . Describes XTV inversion in chapter 3.2.2.4, page 43 ff.

Version 2.73 of our RAYFRACT® software released in May 2007 has been adapted to work under **Microsoft Windows Vista, in addition to Windows XP. We now allow import of OPTIM LLC SeisOpt® data files** with first breaks and source/receiver geometry. When importing Interpex GREMIX or OPTIM LLC SeisOpt® files **dead traces missing from these files will be regenerated automatically** when located in the active part of the specified receiver spread type.

Version 3.01 of our RAYFRACT® software released in September 2007 supports **crosshole survey interpretation with our Smooth inversion method and a constant velocity initial model**. Data needs to be formatted as **GeoTomCG or SEG-2 or SEGY input files**. For instructions showing processing of a crosshole data set see

http://rayfract.com/tutorials/igta13.pdf

. We now support **import of Geometrics/OYO SeisImager PickWin and PlotRefa .VS** formatted files.

Version 3.05 released in January 2008 features an **optimized WET inversion** algorithm. The wavepath width is determined for each trace individually as a linear function of the picked traveltime. Uncheck *WET Tomo|WET tomography Settings|Scale wavepath width* to use the same wavepath width for all traces. We now use the undifferentiated Ricker wavelet for wavepath modeling and weighting per default instead of its derivative. You can edit WET parameters with *WET Tomo|Interactive WET tomography...* .

Version 3.06 released in February 2008 **scales WET smoothing filter height with depth below topography**. This ensures better vertical resolution of the weathering layer. The misfit between modeled and picked first breaks decreases faster during WET inversion needing fewer iterations. Disable this feature by unchecking *WET Tomo|WET tomography Settings|Scale WET filter height*.

Version 3.09 released in May 2008 supports traveltime tomography of first breaks recorded for **Walkaway VSP surveys with a constant-velocity initial model**. See http://rayfract.com/tutorials/walkaway.pdf . We offer improved support for **combination of uphole shots with surface refraction shots**, both recorded with surface refraction receiver spreads. See http://rayfract.com/tutorials/coffey04.pdf . You may generate uphole shots from multi-offset VSP downhole shot surveys with our GeoTomCG .3DD export and import routines implemented for version 3.12.

Version 3.10 released in June 2008 supports the interpretation of **horizontal borehole surveys**. Use *File|Import Data Settings|Import horizontal borehole survey or .3DD refraction survey* with *Header|Profile|Line type* Borehole spread/line .

Version 3.12 released in November 2008 allows export of first breaks and source/receiver geometry to GeoTomCG .3DD files. This lets you reverse Walkaway VSP surveys into uphole shot surveys. See our tutorial

http://rayfract.com/tutorials/coffey04.pdf

. We offer **new WET blanking options to suppress the generation of imaging artefacts** at the bottom of velocity tomograms.

Version 3.14 released in January 2009 allows **easy shear-wave picking of sign-inverted waveforms** generated at the same shot point in our new *Trace|Shot point gather display*. Color traces appropriately with new *Processing menu* items. We now support **import of SEG-2 trace data files into *Borehole spread/line profiles***.

Version 3.15 released in May 2009 fixes a few bugs with trace display and supports Golden Software Surfer version 9. We now display traces shifted by *delay time* and *trigger delay* specified in *Header|Shot* . This lets you **interactively correct shots for reciprocal errors caused by trigger delays** visible in our *Trace|Offset gather display* . See our tutorials http://rayfract.com/tutorials/riveral8.pdf and http://rayfract.com/samples/GEOXMERC.pdf .

For our expanded tutorial as presented at our SAGEEP 2009 short course see

http://rayfract.com/SAGEEP09.pdf .

Version 3.16 released in September 2009 **plots Line ID specified in Header|Profile, WET iteration number or description of initial model, RMS error (in percent) and software version** on Surfer-generated *velocity tomograms* and *wavepath coverage* plots. We have edited a new tutorial showing interpretation of 5 shots recorded with 12 channels. You may use our updated free trial to work through this. First break picking for these shots is tricky since no seismograph-supported stacking of hammer blows was done in the field. See

http://rayfract.com/tutorials/EJEMPL3.pdf .

We **do not support running our software on Windows® 98 and Windows® NT** any longer. When started up under Windows 98 or Windows NT, Rayfract® 3.16 will display an error message recommending using Windows® XP and will then shut down again. Version 3.16 has been tested to run on Windows® XP and Vista and also works fine under Windows® 7.

Version 3.16 released in February 2010 supports interpretation of **zero-offset downhole VSP Vertical Seismic Profiling** surveys. See

http://rayfract.com/tutorials/vsp.pdf

. Before running *Smooth inversion* and *WET tomography* we **check shot positions against traveltime curves**. If these do not match an error message prompts you to adjust first break picks or shot position. Also we caution against using **our deprecated *pseudo-2D DeltatV inversion* to avoid publication of artefacts**. See

http://rayfract.com/srt_evaluation.pdf , Fig. 1
http://rayfract.com/tutorials/depress.pdf
http://rayfract.com/tutorials/palmfig3.pdf
http://rayfract.com/tutorials/fig9inv.pdf
http://rayfract.com/tutorials/epikinv.pdf

Version 3.17 released in May 2010 **enables again our *DeltatV menu* and *pseudo-2D DeltatV inversion*** but only once you first run our *Smooth inversion* method and then check Smooth inversion setting *Allow unsafe pseudo-2D DeltatV inversion*. For profiles with 2,500 or more picked traces you don't need to run *Smooth inversion* first.

When creating a new profile database with version 3.17 import data setting *Round shot station to nearest whole station number* is unchecked per default. So shot stations are rounded to .5, e.g. to 0.5, 1.0, 1.5. This ensures a consistent traveltime curve display in *Refractor|Shot breaks* even once first break picks are corrected for inline and lateral offset of shot points. Reciprocal traveltime errors are now easier to recognize for small source-receiver offsets in *Trace|Offset gather display*. For our **SAGEEP10 short course manual** see

http://rayfract.com/SAGEEP10.pdf

. This includes introductory **slides describing Smooth inversion and relevant WET and DeltatV parameters**. We support installing and running version 3.17 under **Windows® 7 64-bit**. See our updated release notes at

http://rayfract.com/help/release_notes.pdf

Version 3.18 released in November 2010 uses multiple CPU cores during WET inversion (back-projection of traveltime misfits along wavepaths with a SIRT algorithm). Forward

modeling with our Eikonal solver still uses one core only. Generation of synthetic traveltimes for your custom Surfer .GRD model is now easier. See

http://rayfract.com/tutorials/palmfig9.pdf

. For a description of Smooth inversion and WET parameters and options see http://rayfract.com/SAGEEP10.pdf . For tutorials showing how to identify bad picks and correct reciprocal picking errors see http://rayfract.com/tutorials/riveral8.pdf and http://rayfract.com/samples/GEOXMERC.pdf . Aim for an RMS error (misfit between picked and modeled first break times) below 2% as shown on top of Surfer tomogram plots. For an evaluation of the sensitivity of our Smooth inversion and WET inversion with 1D initial model based on simple synthetic models for faults and small velocity anomalies see

http://rayfract.com/papers/Thesis_Report_Stefan_Jansen_20110105.pdf

, Appendix C (Jansen, 2010). Wavepath width used in Appendix E is too narrow for reliable interpretation with our software. Use the default WET wavepath width or even increase this for the WET inversion to robustly converge towards a meaningful interpretation especially in case of bad picks.

Version 3.19 released in May 2011 features easier keyboard shortcuts for deleting first breaks and branch points. Database utilities are now called directly instead of via Windows .BAT batch file. This should help with too stringent security checks for batch files. Back-projection of residuals along wavepaths in a SIRT-like algorithm now optimally uses multiple CPU cores. See our publication

http://rayfract.com/pub/SAGEEP11.pdf for our blind interpretation of the SAGEEP 2011 refraction data set.

Version 3.20 released in September 2011 allows frequency filtering of traces when displaying trace gathers in *Trace menu*. Filtering is done with recursive Chebyshev-Butterworth filter or single-pole filter. For more information on these digital filters see http://www.dspguide.com chapters 19 and 20. Chebyshev-Butterworth is theoretically more performant but often single-pole works better at **low rate of effective signal frequency to seismograph sample rate**. **Bidirectional filtering** preserves the original recorded waveform and first breaks.

3.20 **optionally allows using all installed RAM memory above 4GB and up to 64 GB** for caching of traveltime grids during WET inversion. This option is available with our Annual Pro Subscription license only. We now apply **more WET regularization** (wider wavepath width, increased WET smoothing filter size) in case of low-velocity sections (average velocity below 1,500 m/s at half-depth of initial velocity section). This makes our WET inversion more reliable for shear-wave surveys or areas with thick non-consolidated, loose overburden.
    The **four most recently opened profile databases** are listed at bottom of *File menu*. Select any of these to quickly reopen the profile. When you reopen any trace gather via *Trace menu* traces are displayed with same settings (coloring, zooming, filtering, processing) as the last time you worked in this display.

Tutorial http://rayfract.com/tutorials/mdw2011.pdf shows creation of a borehole spread/line profile database for crosshole survey. Next we show import of SEG-2 borehole receiver recorded traces and Smooth inversion.

Updated tutorial http://rayfract.com/tutorials/thrust.pdf shows building a thrust model with fault zone. Then we easily generate synthetic traveltimes for this model and invert these with our Smooth inversion and DeltatV methods. This tutorial shows that **our WET inversion is capable of imaging laterally varying velocity**.

Tutorial http://rayfract.com/tutorials/camp1.pdf shows how to build your own layered initial model for WET inversion. We recommend to use our default Smooth inversion method with automatically determined 1D initial model for reliable results.

http://rayfract.com/tutorials/riveral8.pdf shows interpretation of 6 shots into 12 channels, with Smooth inversion. We also show our new frequency filtering and how to recognize first break picking errors in Trace|Offset gather using the traveltime reciprocity principle.

http://rayfract.com/tutorials/ot0608.pdf compares default Smooth inversion with 1.5D DeltatV inversion for a long profile extending over more than 2 km. This is a high-coverage data set with 275 shots recorded by 200 or more channels each.

Version 3.21 released in April 2012 allows **import of SEGY formatted .SGY files** with one or multiple shots per .SGY file. We now support **batch import of shots via *.HDR batch file***.

See http://rayfract.com/help/2lamb15.hdr for a sample *.hdr batch import file* specifying import of shots from two .sgy files each containing multiple shots.

Updated http://rayfract.com/tutorials/mdw2011.zip with mdw2011.hdr batch file for batch import with tutorial http://rayfract.com/tutorials/mdw2011.pdf .

WET Tomo|Coverage plot setup… allows thinning of the *WET coverage plot*. Specify every nth shot and receiver for which wavepaths are plotted. Easier visualizing of wavepaths with dense plots.

Version 3.22 released in June 2012 allows using our **XTV inversion** method for determination of the 1D-gradient initial model during Smooth inversion. Check *Smooth invert|Smooth inversion Settings|Allow XTV inversion for 1D initial model* to enable this. XTV inversion allows modeling of a constant-velocity weathering overburden with the intercept-time method.

We have added fields to the WET inversion main dialog for more sophisticated termination of WET inversion : when RMS error goes below specified threshold in percent or when RMS error does not improve for n iterations, or after x minutes of running the inversion.

See our tutorial http://rayfract.com/tutorials/jenny10.pdf for instructions on using our XTV inversion method allowing imaging of constant-velocity weathering overburden. This tutorial also shows **imaging artefacts caused by Golden Software Surfer Kriging gridding method**. The Natural Neighbor gridding method works much better at least in this case, for imaging of pseudo-2D XTV inversion output. This may be the case for DeltatV output as well.

Version 3.23 released in December 2012 implements **fast parallel WET inversion** using up to 4 CPU cores both for forward modeling of traveltimes and back-projection of residuals over Fresnel volumes using SIRT algorithm.

Our Annual Pro Subscription license uses up to 16 CPU cores for even faster WET inversion. Tested under Windows 8 Pro 64-bit with Golden Software Surfer 11 free demo. Also tested under Windows 7 Pro 64-bit and Windows XP Pro SP3 32-bit.

Smooth invert|Smooth inversion Settings|Optimize XTV for layered starting model configures XTV for strong velocity contrast between overburden and basement in the starting model for Smooth inversion. This new option is enabled per default when creating a new or opening an

existing profile database.

DeltatV/XTV parameters for constant-velocity layers... has new *buttons Gradient model* and *Layer model*. Click these to reset XTV parameters for gradient model or layered model of subsurface velocity.

WET Tomo/WET Velocity constraints... lets you specify a velocity range with two edit fields. All velocities outside this range are kept unchanged during WET inversion. This may be used for marine refraction surveys, with water overburden set to constant 1,500 m/s in the starting model.

Version 3.24 released in April 2013 further increases **robustness and performance of our parallel WET inversion** using multiple CPU cores.

Web site page http://rayfract.com/modeling.htm lists links to tutorials and publications showing tomographic inversion of synthetic traveltime data generated for known models. Some of these tutorials and .zip archives come with ASCII formatted traveltime data. Objectively test accuracy of your own method with these data sets.

Our tutorial http://rayfract.com/tutorials/GEOEXP13.pdf shows reciprocity error check and how increasing *WET wavepath width* and *envelope width* results in deeper and more reliable imaging.

See also our tutorial http://rayfract.com/tutorials/bulgatrl.pdf showing systematic variation of *WET wavepath width* to explore non-uniqueness of the solution space.

Tutorial http://rayfract.com/tutorials/lnec17.pdf shows *Smooth inversion* of borehole survey with 3 adjacent holes. Our *Smooth inversion* method assumes that all receivers are positioned in central borehole and all sources located in external (left and right) boreholes. If not you need to sort traces by common receiver for such a pair of two adjacent holes. See http://rayfract.com/tutorials/a13r1dm.pdf .

Version 3.25 released in July 2013 allows plotting overburden and basement refractors from layer-based interpretation methods *Wavefront*, *Plus-Minus* and *CMP Intercept-Time Refraction* on 2D WET velocity tomograms. See http://rayfract.com/samples/jenny13.pdf .

You need to install Surfer 9 or later for above refractor plotting with polylines to work. Surfer 8 can only display one polyline or one refractor per Base map and .BLN file.

Updated tutorial http://rayfract.com/tutorials/palmfig9.pdf shows *Smooth inversion* and layer-based *Wavefront refraction* interpretation of 9 shots into 49 receivers.

Tutorial http://rayfract.com/tutorials/step.pdf shows how to build a synthetic "basement step" grid model with Surfer and how to forward-model synthetic shots over this step.grd grid. We show *Smooth inversion* and *Wavefront refraction layer-based interpretation*. We plot the 1.5 D Wavefront refractor on 2D WET tomograms.

Tutorial http://rayfract.com/tutorials/zivko13.pdf shows *2D WET inversion* of reverse VSP survey with 49 shots from two boreholes into 24 receivers.

Version 3.26 released in December 2013 allows stacking of shots in *Trace/Shot gather display*. Trace samples are now stored as 32-bit floating point samples in the profile database instead of being scaled to 16-bit integer samples. Before opening a profile database with

version 3.26 backup the 31 seis32.* profile database files named seis32.d01, seis32.d02, ..., seis32.dbd, seis32.k01, seis32.k02, ..., seis32.k14 to an external USB drive. Once you have opened a profile database with version 3.26 or later you cannot open it any longer with version 3.25 or earlier. For converted profile databases opened with earlier software versions *Trace gathers* are empty / do not show any seismograph traces.

Trace|Shot point gather now lets you simultaneously pick traces recorded for any shot at current receiver station if new option *Processing|Pick all shots* is checked in Shot point gather display. This lets you easily **pick shear-wave traces recorded for two shots with reversed polarity** at same receiver station.

Version 3.31 released in June 2014 allows **Gaussian weighting for WET smoothing instead of uniform weighting**. This can help to improve the resolution of your tomograms. We now support using the **Conjugate Gradient method for sharper imaging of strong velocity contrasts with WET inversion instead of the default Steepest Descent method**. See

http://www.cs.cmu.edu/~quake-papers/painless-conjugate-gradient.pdf .

http://rayfract.com/tutorials/ZONDDATA.pdf

shows Conjugate Gradient WET inversion using Gaussian weighting for smoothing.

Grid|Convert .CSV layer model to Surfer .GRD... lets you select a layer model .CSV exported from depth section and asks you to select a Surfer format .GRD tomogram created earlier. See

http://rayfract.com/tutorials/SAGEEP11_13.pdf Fig. 17 for instructions. The resulting layered .GRD can be used as starting model with ***WET Tomo menu*** commands.

Smooth invert|Smooth inversion Settings|Extra-large cell size further increases the cell size and speeds up WET inversion.

WET Tomo|Interactive WET tomography…|Edit velocity smoothing|Smooth nth iteration lets you specify how often WET smooths the tomogram during inversion. Increase for less smoothing.

Grid|Export grid file to ASCII .TXT... prompts to select a VELOITXY.GRD tomogram and converts this .GRD file to an ASCII .TXT file. Columns x/y/z/velocity are separated by a space ' ' character. This lets you easily **import 3D data into Golden Software Voxler**.

DeltatV|DeltatV Settings|Limit DeltatV velocity exported to maximum 1D-gradient velocity is enabled per default for version 3.31. This option helps to **suppress 1.5D DeltatV artefacts in the imaged basement**.

DeltatV|DeltatV Settings|Limit DeltatV velocity exported to maximum 1D-gradient velocity determines the 1D-gradient starting model in a separate DeltatV run, before doing the 1.5D DeltatV inversion. This 1D-gradient starting model is saved to disk as files ..\GRADTOMO\DLTAGRAD.GRD & .PAR .

DeltatV|Interactive DeltatV|Export Options|Max. velocity exported [m/s] shows the maximum velocity in the 1D-gradient starting model file DLTAGRAD.GRD with above option enabled.

File|Import Data…|Import data type shows new **GeoTomo TimePicker .3DTT** format option. Send us your **.3DTT** test files and we will make sure that we can import them.

Our expanded abstract

http://rayfract.com/pub/sageep14.pdf

presented at SAGEEP 2014 in Boston, MA compares weighting of the WET velocity update with Gaussian function vs. Ricker wavelet weighting using the SAGEEP11 blind refraction synthetic data with added noise. We show how to improve resolution of *WET inversion* by systematically decreasing the WET wavepath width. This corresponds to increasing the WET frequency.

We have updated the Windows help file chapter **WET tomography processing** with image of latest **Grid menu** version and explanation of all **Grid menu** commands and options. Use installer

http://rayfract.com/help/winhelp.exe

to update your Rayfract(R) installation.

Our latest tutorial

http://rayfract.com/tutorials/NORCAL14.pdf

compares using a 1D-gradient starting model vs. a layered CMP refraction starting model for WET inversion. We compare Gaussian vs. Uniform smoothing with vs. without adaptation of shape of rectangular smoothing filter. Define **realistic weathering velocity v0** in *Refractor|Shot breaks* by mapping traces to refractors with ALT+L. Or edit v0 in *Header|Station*. Now map traces to refractors in *Refractor|Midpoint breaks* with ALT+M and with *Direct wave first breaks recorded* unchecked as shown in above NORCAL14.pdf tutorial on bottom of page 3. Run time-to-depth conversion using this shot v0 by selecting *Depth|CMP Intercept-Time Refraction* or *Depth|Plus-Minus*.

Version 3.32 released in December 2014 allows *automatic WET inversion with layered starting model* . The layered starting model is regenerated and you are prompted to start WET inversion whenever you run *time-to-depth conversion* in *Depth menu* with Plus-Minus, Wavefront or CMP intercept-time refraction methods. See tutorial

http://rayfract.com/tutorials/NORCAL14.pdf

Depth|Plus-Minus, *Depth|Wavefront* and *Depth|CMP Intercept-Time Refraction* now automatically **export the layered depth section to .CSV, convert the .CSV to layered .GRD starting model, display this starting model in Surfer and prompt you to run WET inversion using this layered starting model**. Try this with our LINE14 sample profile : map traces to refractors interactively in *Refractor|Shot breaks*, select *Depth|Plus-Minus* refraction method and confirm prompt for subsequent automatic WET inversion using the PLUSMODL.GRD just determined as a starting model.

We now allow definition and use of **spread types with up to 999 channels** with our Pro license for import of shots with up to 999 channels. Our Standard license supports up to 360 channels per spread.

Far-offset shots are always used when determining the starting model. For 2D WET inversion far-offset shots are used if they are positioned inside overlapping spreads for which shots have been imported into the same profile database. See

http://rayfract.com/help/overlap.pdf

and chapter *Overlapping receiver spreads* for a good recording geometry.

New help chapter *Commands* lists top-level menu commands with short descriptions.

Our **improved SEG-2 import** now regards trace descriptor block size when determining trace data start. This makes our SEG-2 import more robust.

To import Geometrics .BPK first break picks use matching filenames for the SEG-2 .DAT or .SG2 and the .BPK files. For 2.DAT name the .BPK as 2.BPK in Windows Explorer. Then copy all .DAT or .SG2 and .BPK files into \RAY32\<your profile name>\INPUT and use our SEG-2 import routine via *File|Import Data…* .

Version 3.33 released in August 2015 supports **robust multiscale tomography** with our new multirun WET inversion. You can edit WET frequency and wavepath width for up to 10 consecutive WET runs. We show how multiscale tomography with iterative decreasing of wavepath width results in more robust imaging of velocity anomalies and less artefacts in our

http://rayfract.com/pub/sageep14.pdf

expanded abstract using the SAGEEP 2011 blind refraction session synthetic traveltime data (with added Gaussian noise) for which the true model is known. Our tutorial

http://rayfract.com/tutorials/CFE15.pdf

shows **tunnel overburden imaging with multirun WET**.

Also version 3.33 systematically blanks outside borehole tomogram. This assumes that all receivers are located in one hole and all sources are in the other hole. We determine the bounding polygon as in http://stackoverflow.com/questions/217578/point-in-polygon-aka-hit-test . *WET Tomo|WET tomography Settings|Blank outside borehole tomogram* enables/disables borehole tomogram blanking.

WET Tomo|WET Velocity constraints... now lets you select a *blanking file* and a *mask grid file* for **blanking of polygon specified in the blanking file with velocity copied from the mask grid file**.

Grid|Blank polygon area in grid... lets you **blank or reset to constant-velocity a polygon** specified in the selected *blanking file*.

Grid|Surfer plot Limits... lets you specify offset/elevation/velocity range for plotting of velocity tomograms.

Download and run updated help file installer

http://rayfract.com/help/winhelp.exe

on your PC. This also installs file windows.hlp into \Ray32\help directory to prevent Windows help from crashing our app when no help topic is available for the dialog control with current focus when pressing F1 help key. We have updated help file chapters Time-to-depth conversion showing layered WET and WET tomography processing showing our new multirun WET inversion. Also we added section *.CSV layered model file* to chapter File formats.

You now can toggle *distance unit* between feet and meters in *Header|Profile* with *Units combobox*. All distance parameters in all parameter dialogs can now be displayed and edited in feet.

SEGY import now starts a new shot in the profile database when SEGY trace header field EnergySourcePoint or FieldRecord changes. For previous software version a new shot is started when FieldRecord changes between traces only.

We show improved error message if invalid *Shot pos. [station number]* is specified during shot import into *borehole spread/line*. Set *Shot pos. [station number]* to nearest active receiver station. Set *Source x* and *Source z* to true shot coordinates. We set *Shot dx* and *Shot dz* in *Header|Shot* to offset of true shot coordinates from *Shot pos. [station number]* coordinates once you update trace headers with *File|Update header data|Update Station Coordinates...* and *File|Update header data|Update Shotpoint coordinates...* .

Version 3.33 supports calling into **Surfer 13** via our updated BASIC language scripts AUTOTOMO.BAS and DELTATV.BAS installed into C:\RAY32\DAT directory.

Also 3.33 allows import of ASCII.ASC formatted shots into *Header|Profile|Line type* Borehole spread/line. See tutorial http://rayfract.com/tutorials/CFE15.pdf .

Version 3.34 released in July 2016 allows forcing the *Grid Cell size[m]* used for Surfer X Spacing and Y spacing when creating a new starting model.

Also 3.34 offers improved support for calling into **Golden Software Surfer 13**. And 3.34 improves WET performance and robustness compared to the previous version 3.33. WET smoothing uses multiple CPU cores in parallel in version 3.34.

We now write the RMS error for each WET iteration to file ...\GRADTOMO\VEOITXY.STX after the last WET iteration for current WET run completes.

Our new tutorials http://rayfract.com/tutorials/sageep11_smooth50.pdf and http://rayfract.com/tutorials/multistep.pdf show multiscale tomography using our *multirun WET dialog*.

3.34 imports shots in one database transaction per import session. We write changes to the profile database once *File|Import Data… dialog* closes only. This makes the import more robust in case your PC should crash e.g. due to power failure.

Import of *Geometrics PlotRefa .VS files* and *Optim SeisOpt files* has been made more robust in case of missing traces in such input files.

Our *WET Tomo|Interactive WET tomography|Edit velocity smoothing dialog* now allows *Damping* of current iteration WET tomogram with previous iteration.

Version 3.35 released in November 2017 supports calling **Golden Software Surfer 14 and Surfer 15 beta version.**

Also version 3.35 offers another choice for ***weighting of WET velocity update across the wavepath with Cosine-Squared function*** (Chen and Zelt, 2012). Set parameter *Ricker differentiation* to -2 in *WET Tomo|Interactive WET tomography* and edit Cosine-Squared function parameter a&b in *WET Tomo|WET Update weighting dialog*. Cosine-Squared WET

update weighting can help to better image quasi-vertical fault zones in basement.

Version 3.35 offers *Custom 1D-gradient velocity profile dialog* allowing specifying your own 1D-gradient velocity-vs-depth profile. We also allow *forcing of grid limits* for starting model in same dialog. Also we offer more controls in *WET Velocity constraints dialog* for extrapolation of tomogram velocity to `.BLN` *blanking file* polygon boundary.

Version 3.35 allows joint *WET inversion* of first breaks picked for refraction shots and walkaway VSP shots. See tutorials

http://rayfract.com/tutorials/11REFR.pdf and http://rayfract.com/tutorials/1611HOLE.pdf .

Also version 3.35 allows *exporting a velocity range from .GRD file to ASCII .TXT file* . Paste together the resulting `.TXT` files from a few crossing 2D profiles and grid and contour in Golden Software Surfer to obtain a **basement map**.

File|Import Data... dialog offers new controls in version 3.35 to generate a *.HDR batch file* listing shots for all matching input files in selected *input directory*. Review and edit this `.HDR` batch file using your favorite text editor e.g. Microsoft WordPad and use for batch import of shots.

Our Eikonal solver used for forward modeling of traveltimes in our WET inversion now interpolates the modeled times grid more accurately at receivers. This helps especially with large cell size. Velocity at source/receiver is determined more reliably when forward modeling traveltimes.

We have added help file chapter **Calling Surfer** to trouble-shoot issues with calling Golden Software Surfer via their Scripter utility.

Version 3.35 allows importing and processing circular receiver spreads fore *Line type* `Borehole spread/line` using a constant-velocity starting model. Force starting model grid limits in *Custom 1D-gradient velocity profile dialog* . Specify the *blanking file* boundary polygon with our extended *WET Velocity constraints dialog* e.g. blanking WET velocity inside a tunnel or outside a column, pillar or tree. Our new tutorial http://rayfract.com/tutorials/tunnel16.pdf shows imaging of tunnel excavation disturbed zone (EDZ) using a **circular receiver spread** planted on the tunnel wall.

Our new tutorial http://rayfract.com/tutorials/KING17.pdf shows interpretation of first breaks recorded with receivers located in three boreholes. This tutorial requires our Pro license. You can add up to four (4) **Borehole spread/line** profiles to your main **Refraction spread/line** or **Borehole spread/line** profile using our Pro license.

Our new PowerPoint slide show http://rayfract.com/tutorials/Slope1.ppt shows how to interactively improve your first break picks. See http://rayfract.com/tutorials/Slope1.pdf for .pdf version.

Depth|Depth conversion Settings|Prefer geometric basement velocity for Wavefront is enabled per default. Uncheck for more robust basement velocity determination with our *Wavefront refraction* method in case of strong topography and recording geometry errors.

Our *WET Tomo|WET tomography Settings|Blank submenu* offers new options *Blank no coverage after each iteration* and *Blank no coverage after last iteration*.

We more reliably detect trace data start when importing Geometrics SeisModules SEG-2 files. Also we have improved our import of MoHo SoilSpy Rosina seismograph .SG2 trace files.

Georgios Tassis et al. 2017 show **detection of fracture zones in bedrock** inverting synthetic data forward modeled over known fault zone models at

http://www.ngu.no/upload/Publikasjoner/Rapporter/2017/2017_025.pdf

Our new tutorial http://rayfract.com/tutorials/NGUP1_1.pdf shows imaging of vertical fault zones using Plus-Minus starting model and WET inversion with Steepest Descent method and Cosine-Squared weighting of WET velocity update across wavepaths.

When our Pro version shows prompts "`OpenPolicy : Access is denied`" and "`Error : Cannot enable the SE_LOCK_MEMORY_NAME privilege. Failed with error 1300 : Not all privileges or groups referenced are assigned to the caller.`" under Windows 10 64-bit :

◆ click *Ok button* to confirm the prompts. WET inversion will continue without access to RAM memory above 4 GB limit.
◆ once WET inversion is complete select *File|Exit*
◆ right-click Rayfract® desktop icon and select *Properties*
◆ click *button Advanced* and check *box Run as administrator*
◆ click *buttons Ok* / *Apply* / *Continue* / *Ok*
◆ restart Windows 10
◆ startup our app via desktop icon as usual. Now WET inversion can use up to 64 GB of RAM with our Pro version.

Conventional *CMP intercept time refraction method* (Ruehl 1995) is not suited for obtaining reliable refractor velocities and depths with highly undulating refractors. The CMP sorted trace display (*Midpoint breaks display*) is suited for semi-automatically mapping first breaks to refractors even in case of strong refractor relief however. Advantages of carrying out this semi-automatic mapping over the conventional manual *branch points* picking in the *Shot breaks display* are repeatability, consistency, speed. Once this mapping has been carried out you may process the mapped first breaks with *Wavefront and Plus-Minus methods*. Especially the Wavefront method delivers reliable results even at the locations of steep refractor synclines and anticlines. For true 2D WET tomography processing of such profiles with strong basement undulations we recommend to use our *Smooth inversion* method, based on a 1D initial model.

If you prefer to carry out the mapping of first breaks to refractors in a more conventional and interactive way, you may do so in the *Shot breaks display*. This display supports the interactive positioning of *branch points* on shot-sorted traveltime curves. For low-coverage data, this is the only option available for mapping first breaks to refractors. Always **record your traces with overlapping receiver spreads optimally by as much as half the spread length**. If the basement coverage with first breaks is too discontinuous, traveltime field regression may not converge towards a stable solution.

The **Surfer® Kriging gridding method** sometimes generates artefacts such as false high velocity anomalies directly below the topography. If you want to experiment with different algorithms than the default Kriging method, select a different gridding method in *DeltatV|Interactive DeltatV|Export Options*. We offer gridding methods "Kriging", "Natural Neighbor", "Nearest Neighbor", "Delauney Triangulation" and "Minimum Curvature".

For resampling of shots, conversion between SEG-2 and SEGY etc. try the free Geogiga Front End, available at http://geogiga.com/en/frontend.php . Write the processed shots to SEG-2 files and import with our software.

Documentation conventions

The shorthand notation "Select *File|Open*" is used for the action of moving the cursor to the *File menu*, opening it by pressing your left mouse button on it and finally selecting menu item *Open* by dragging your mouse down until that item is highlighted and then releasing your left mouse key. *User interface items* such as menu items (including above shorthand notation), dialog box titles and dialog controls and section display window types are *italicized*. Seismic refraction methodology and practical recording / interpretation terms are underlined when referred to in **context sensitive help pop up dialogs** displayed when tabbing to a dialog control and pressing help key F1. You may search for definitions of these terms in the online help index. Select *Help|Search for Help On*. The RETURN key is used to signify both the ENTER key and the equivalent RETURN key. Hard-disk volume is used interchangeably with hard-disk partition. Expressions *receiver spread type*, spread type, receiver layout type and layout type are used interchangeably. **Important statements and terms** are printed in bold typeface.

System requirements

To run Rayfract® you will need the following :

◆ A 486 (or better) PC running Microsoft® Windows® XP, Windows Vista, Windows 7, Windows 8 or Windows 10, both 32-bit and 64-bit

◆ SVGA monitor or better, screen resolution of 1024 by 768 pixels or better

◆ At least 512 MBytes of RAM. For high coverage / long profiles and efficient WET tomography processing 1'024 MB or more are recommended.

◆ At least 100 MBytes of available hard-disk space for the program files including two sample profiles

◆ Enough hard disk space for your profiles. One profile typically consumes about 20 MBytes of space, depending on data density, profile length and the amount of data generated by our tomography processing and Surfer® gridding and imaging of results.

◆ Another 100 MBytes of free storage on your data disk containing Rayfract® profile databases to allow for storage of temporary traveltime grids for profile receiver stations. These are generated during WET tomography and will be deleted automatically once the tomography processing terminates. If you abort the processing with Windows® task manager, Rayfract® version 3.16 and later will delete these temporary grid files once you reopen the same profile. Earlier versions will not delete these grids if aborted. You may delete these S*.GRD and R*.GRD files manually in GRADTOMO, TOMO, LAYRTOMO and HOLETOMO subdirectories of your profile directory contained in \RAY32 root-level directory.

◆ Surfer® version 9, 10, 11, 12, 13, 14 or 15 for automatic plotting of tomograms. You may download a free demo from http://www.goldensoftware.com. This is print-disabled and edited tomogram plots can't be saved. But otherwise this works fine for on-the-fly creation of tomogram plots with our .BAS Scripter scripts from computed Surfer .GRD velocity grid files. The Surfer 11 demo has no time limit. Surfer 14 demo expires after two weeks.

◆ After installation of the free Surfer® demo start it up once interactively via the Start menu. Then click on the splash screen. If you omit this step Rayfract® is not able to automatically call Surfer® and will hang or crash in Scripter instead. After installing the full Surfer® version start it up and then register the software.

Support

If you have any questions regarding our Rayfract® software and processing of your data sets contact us via e-mail at **info@rayfract.com** . Also check our web site at **http://rayfract.com** for tutorials, course notes, application samples, links to theoretical papers, benchmark comparisons etc.

Tutorials available for download on our web site http://rayfract.com mostly cover our Smooth inversion method and our older "unsafe" DeltatV method and following WET tomographic inversion. While we offer conventional time-to-depth conversion methods including Hagedoorn's *Plus-Minus* method which require the user to assign refractors to segments of shot-sorted or CMP (Common MidPoint) sorted and stacked traveltime curves, we do not believe in the unqualified usefulness of the **theoretical concept of a "refractor" (i.e. a layer with no vertical velocity variation inside it)** any longer. **Once you assign first breaks to hypothetical refractors you just force a subjective and over-simplified model on the data at an early processing stage** and may get errors (regarding refractor depths

and velocities) later on, especially if subsurface seismic velocity increases gradually with depth. For conventional **layered refraction method interpretation samples** see http://rayfract.com/help/manual.pdf chapter 1.8 and following, http://rayfract.com/tutorials/line2.pdf, http://rayfract.com/pub/SAGEEP11.pdf, http://rayfract.com/tutorials/SAGEEP11_13.pdf and http://rayfract.com/pub/sageep14.pdf .

(Tassis et al. 2017) show modeling of basement fault zones using Plus-Minus method starting model at http://www.ngu.no/upload/Publikasjoner/Rapporter/2017/2017_025.pdf

Version 3.25 released in July 2013 allows **plotting overburden and basement refractors** obtained with layer-based interpretation methods *Wavefront*, *Plus-Minus* and *CMP Intercept-Time Refraction* on 2D WET velocity tomograms. See tutorial http://rayfract.com/samples/jenny13.pdf .

Version 3.32 released in Dec 2014 allows using layered refraction interpretation methods *Wavefront*, *Plus-Minus* and *CMP Intercept-Time Refraction* to automatically generate a **layered starting model** formatted as Surfer .GRD grid file. Next we prompt you to run 2D *WET inversion* using this 1.5D layered starting model. See tutorial http://rayfract.com/tutorials/NORCAL14.pdf .

The **identification of geological units / stratigraphic layers should be done once you have obtained the final tomogram only**. The interpreter needs to realize that the tomogram shows the **"in situ" subsurface seismic velocity**. I.e. not just the material velocity component but also the stress field induced component : increasing overburden pressure with burial depth results in smaller sediment pores and less fractured rock. Stress magnitude variation at folds and faults may have similar local effects i.e. cause a systematic variation of seismic velocity (R. J. Twiss and E. M. Moores 1992 : pp. 429-431).

Also, **mechanical and chemical weathering cause the rock quality and seismic velocity to decrease the closer the rock or sediment unit is to the surface**. In other words, rock quality and seismic velocity tend to increase with increasing burial depth. See B. Murck 2001 : chapter 6 Weathering and Erosion : joints, exfoliation and frost wedging etc.

For identification of stratigraphic units this stress and weathering induced velocity component needs to be "subtracted" from the subsurface velocity distribution as imaged. You then obtain the estimated material velocity component and may correlate that velocity with geological units as known to exist in the area i.e. from a geological map or core drilling. Of course it is very difficult to mathematically formalize this "subtraction" i.e. separation of the velocity components. It needs to be done mentally by the observer.

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Installation and licensing

To install the Rayfract® free trial :

For installation under Windows XP/VISTA/7/8/10 login as a user with "Administrator" rights. We support both Microsoft Windows 32-bit and 64-bit. Installation under 64-bit Windows has been tested for Rayfract® version 3.17 and later versions, on Windows 7, 8.1 and 10.

Under Windows 10 64-bit with Creators update tested Oct 15, 2017 first disable Real-time protection on both the download PC and target PC in Windows Defender, Virus and threat protection settings.

To open Windows Defender & disable protection under Windows 10 :
◆   left-click the Start button at bottom-left of your screen
◆   left-click the gear icon to open the Settings menu/panel
◆   left-click Update & Security
◆   left-click Windows Defender
◆   left-click Virus and threat protection settings
◆   disable Real-time protection by moving the switch to left with your mouse

. Download the installable archive file RAYTRIAL.EXE from our web site http://rayfract.com, link "Trial" or directly from the associated URL address http://rayfract.com/trial/RAYTRIAL.EXE. Start up your web browser such as Microsoft Edge or Mozilla Firefox or Google Chrome. Then specify one of these web addresses in the URL address field on top of the browser window and press ENTER/RETURN key.

Once you have downloaded RAYTRIAL.EXE copy it into a temporary directory on the target hardware e.g. C:\TEMP. Now run RAYTRIAL.EXE .

When the installation program displays the "Select Destination Directory" dialog, change the drive or partition part of the directory only and leave the rest as \RAY32 root level directory as per default (e.g. D:\RAY32).

Under Windows 10 64-bit with Creators update tested Oct 15, 2017
◆   add Exclusion in Windows Defender for file C:\RAY32\BIN\RAYFRACT32.EXE
◆   add Exclusion in Windows Defender for folder C:\RAY32
◆   reenable Real-time protection in Windows Defender
◆   now test starting our free trial via Windows desktop link
◆   if necessary repeat above installation, e.g. after restarting Windows 10

To verify the positive outcome of above installation test starting up the Rayfract® trial :

To start up Rayfract® under Windows XP/VISTA/7/8/10 double-click the desktop link with our icon.

To open Windows help files under Windows Vista and Windows 7/8/10 you need to download and install Microsoft WinHlp32.exe . This component is not included out-of-the-box any longer, with your Windows installation. For instructions and download links see

http://support.microsoft.com/kb/917607 .

Alternatively run our WINHELP.EXE installer (download link
http://rayfract.com/help/winhelp.exe) to install above WinHlp32.exe help viewer and the latest
help file RAYFRACT.HLP .

Your Rayfract® trial license will expire after 50 runs, or 30 days after having been run for the
first time. It will run without the need for any registration. When you start up the trial, a
licensing dialog may display. Just hit RETURN or click on the "Continue" button to continue.

Once the license has expired on a given hardware, the free trial will not run any longer run on
that hardware, even if you reinstall it as described above. You have the option to rent or
purchase a Standard functionality license : 4 month rental or unlimited license. For details see
our web site

http://rayfract.com,   link "Order".

You are welcome to pass on the trial installation file RAYTRIAL.EXE and this file TRIAL.TXT
to any interested third party by any means, as long as you do not charge them for the free
trial.

Here some more information concerning usage and functionality restrictions of your free trial
Rayfract® software :

Open Help menu &click on Contents for help topics. For a .pdf version of our Windows help
file see

http://rayfract.com/help/rayfract.pdf . This may be easier for viewing. However the .pdf
version is always lagging behind the help file so for latest help check our Help menu.

Now you are ready to work with your license. You may first want to open the existing sample
profiles LINE14 and PALMFIG4. Select the SEIS32.DBD in these subdirectories, to open the
profile database. See Starting up Rayfract® and profile management and later chapters in the
help menu for details. You may display help chapters by selecting menu items in the
rightmost Help menu. Be sure to read chapter System limitations as well. There you will find a
complete list of restrictions related to your trial license. Once you have opened profile LINE14,
select *Smooth invert*|*WET with 1D gradient initial model* to run our Smooth inversion.

We recommend to get acquainted with the processing capabilities of our Rayfract® software
by working through our SAPRI12.pdf tutorial available at
http://rayfract.com/tutorials/sapri12.pdf. Also review the introductory "Tutorial" chapter of our
manual at http://rayfract.com/help/manual.pdf . Or work through some tutorials at
http://rayfract.com/tutorials/TUTORIAL.ZIP, e.g. EJEMPL3, BULGATRL or THRUST12
tutorials.

The original data sets are available for download. Just click on the corresponding link in the
tutorial. For in-depth advice on how to adapt DeltatV and WET inversion parameters to your
situation see our help chapters WET tomography Processing and Pseudo-2D DeltatV
inversion. Also see our SAGEEP10 short course notes at http://rayfract.com/SAGEEP10.pdf
and NGU 2017 report http://www.ngu.no/upload/Publikasjoner/Rapporter/2017/2017_025.pdf
.

Your trial license will handle up to 30 shots per profile only ! Renumber shots to 0 to 29 during
import if necessary. Just edit the *Shot Number field* value in the *Import Shot dialog*. See help
topic System limitations for Rayfract® versions with extended capabilities. Also this free trial
license assumes flat topography and resets all topography to elevation zero during import of

shot files.

To obtain more information on an edit field in a dialog click on that field with your left mouse key or tab into it with TAB key and then press function key F1 to show a help popup window.

To automatically grid and plot/display WET tomography output you need to install **Golden Software's Surfer® version 9, 10, 11, 12, 13, 14 or 15**. You may download a free demo version at http://www.goldensoftware.com . The free demo version is print-disabled and edited tomogram plots can't be saved. But otherwise this works fine for on-the-fly automatic creation of tomogram plots with our software from computed Surfer .GRD velocity grid files. The Surfer 14 and later demo version has a time limit of 14 days. Surfer 11 demo version does not expire.

Start the free demo Surfer® interactively via Start menu after (re)installing it. Then click on the splash screen which covers the Surfer® window. If you skip this step Rayfract® is not able to call Surfer® automatically for tomogram plotting. For the full version startup Surfer® and enter your license number first.

Installation of CodeMeter runtime/driver software

If your Rayfract® license comes with a grey/metallic CodeMeter/CmStick USB dongle :

to update the CmStick CodeMeter driver open a browser window at wibu.com download page

http://www.wibu.com/en/downloads-user-software.html

. Download "CodeMeter Runtime for Windows" and backup the CodeMeterRuntime.EXE to USB flash drive or other permanent storage.

Next run CodeMeterRuntime.EXE on your Windows XP/Vista/7/8/10 PC for your grey/metallic CmStick USB dongle licenses to work.

To make sure the USB dongle is recognized by our software :

◆ unplug metallic CmStick USB dongle
◆ reboot your Windows PC
◆ install latest CodeMeter runtime software with CodeMeterRuntime.EX installer if not yet done so; see above
◆ click on Windows Start button
◆ select All Programs|CodeMeter|CodeMeter Control Center
◆ only now plug in your metallic CmStick USB dongle into this Windows PC
◆ wait until Serial number 2-… or 3-... is shown in CodeMeter Control Center dialog

This may take a few minutes. There may be balloon type messages in Windows status bar at right bottom of screen saying "Installing driver software…".

When you left-click this balloon message you may see another message window saying "***Searching Windows update for driver…***". Be patient and let this process complete which may take a few minutes. If you stop this process too early then the CodeMeter/CmStick dongle driver will not be installed correctly and our software cannot recognize the USB dongle.

Now startup our Rayfract® version 3.35 Standard software by double-clicking the desktop icon. See also

http://support.codemeter.com/en/faq/index.html

for instructions how to install the CodeMeter runtime software and how to check if the metallic USB CodeMeter/CmStick dongle is connected and recognized by the driver.

If Rayfract® shows a message "Out of certified time" with your **CmStick/CodeMeter dongle rental license**, update the certified time in your metallic CmStick USB dongle :

➢ click on Windows Start button
➢ select All Programs|CodeMeter|CodeMeter Control Center
➢ make sure your Windows XP/7/8.1 or Windows 10 PC is connected to the web with web browsing working
➢ make sure your metallic CodeMeter/CmStick USB dongle is plugged in with its serial number showing in CodeMeter Control Center main panel
➢ select Process|Update Time Certificates in CodeMeter Control Center

If your Rayfract® license comes with a green WibuKey license management device/dongle :

◆ Connect this device to your PC's parallel port (in between the port and the printer cable) or an USB port
◆ Try to start up your Rayfract® software (installed as described above). See topic Starting up Rayfract® and profile management. Open sample profile LINE14.
◆ If the Rayfract® main menu is displayed without any preceding message box skip the following instructions since your license has been activated already
◆ If the software displays a message box mentioning the WIBU key copy protection device complete the following instructions
◆ To activate/update/upgrade your license you need to generate a **context file** for your WIBU-KEY as lined out in the following steps :
◆ select menu item "Control Panel" in your Windows XP/Vista/7/8/10 Start menu
◆ double-click / open the WIBU-KEY icon
◆ left-click on small icon to left of dialog title bar and select "Advanced Mode" if available
◆ click on tab "WIBU-BOX Context" of the WIBU control applet now displayed
◆ click on text field "Remote Programming Context File"
◆ enter an output context file name e.g. "C:\TEMP\PROGRAM.RTC" into that field
◆ press the "apply" button

Once you have produced above context file e-mail it to us (as binary e-mail attachment) so that we can activate/update your Rayfract® license electronically. We will send you a **license update file** to do so along with instructions on how to process the update file. If your rental license has expired and you wish to purchase a refill or unlimited license please contact us for payment instructions.

System limitations

Your Standard functionality Rayfract® license is a **Windows 32-bit application** (compiled with Microsoft Visual C++ 2005 and OpenMP option) and has the following inherent limitations regarding size of data sets etc. :

◆ handles processing of seismic lines with up to **1'000 shots per profile**

◆ supports reading in of shots recorded with from **12 to 360 channels per shot** record. Pro license allows up to 999 channels per shot.

◆ supports processing of seismic lines with up to **360'000 traces per profile**. Pro license allows up to 999'000 traces per profile.

◆ minimum / maximum sample rate is one microsecond / one second

◆ maximum of 20'000 samples per trace

◆ supports raytracing through Surfer® grid files with up to **640'000 nodes per grid**. Pro license allows up to 1'280'000 nodes per grid.

◆ can use up to 3 GBytes of RAM memory. Pro license can use up to 64 GBytes.

◆ uses 4 CPU cores in parallel for WET inversion. Pro license uses up to 16 CPU cores.

◆ allows adding one `Borehole spread/line` profile to main profile in *Header|Profile*. Pro license allows adding up to 4 `Borehole spread/lines` to main profile.

◆ Pro license allows generating checkerboard grids based on obtained tomograms, for checkerboard resolution test

◆ assumes that trace data in .ASC ASCII files is sorted by increasing shot nr. and increasing receiver station (for same shot)

◆ all traces keyed to the same shot must be listed in the same .ASC ASCII file.

To **check whether you recorded enough shots for your profile**, review the *Midpoint breaks display*, by selecting *Refractor|Midpoint breaks*. Now map traces to refractors with ALT+M. If at a significant number of CMP's the traveltime curves start at an offset larger than 1 (i.e. are not connected to the top horizontal axis), subsequent inversion with DeltatV will become unstable because the weathering layer velocity is not constrained sufficiently with direct wave first breaks. You may improve the situation somewhat by increasing the *CMP stack width* (display and DeltatV) parameter. This amounts to widening the running average filter, for smoothing and interpolation of the weathering velocity. Velocities as determined below the shot points will be propagated to CMP's between the shot points, where no weathering velocity can be determined directly. But this may not help in all cases, especially if the weathering velocity varies laterally to a substantial degree (which may often be the case).

Our DeltatV and WET tomography inversion methods require a **shot spacing of 6 receiver stations or smaller**. Optimally shot points will be positioned at each 2nd or 3rd receiver station. Also, use a receiver spacing of 10 metres or less. We recommend using multiple overlapping receiver spreads with at least 24 channels per spread, per Rayfract® profile. **Please record 10 or more shots per receiver spread** to enable more reliable interpretation.

"Conventional" time-to-depth inversion methods (Wavefront, Plus-Minus, CMP Intercept-Time Refraction) will generally deliver more shallow refractor interpretations than the DeltatV method. This is because while **the DeltatV method models gradual velocity increase with depth inside one layer**, these conventional methods assume that velocity inside one layer remains constant with increasing depth (below top surface of layer). As a consequence, raypath segments within one layer will be modeled as straight lines. Corresponding raypath segments within layers as modeled with the DeltatV method are arcs of a circle, determined

by the vertical velocity gradient as modeled for each layer. These diving wave paths penetrate deeper into the subsurface than the conventional straight segment paths.

We strongly recommend to refine subsurface velocity models as obtained with our DeltatV method with our **Wavepath Eikonal Traveltime WET tomography** algorithm. This makes sense especially in situations of **extreme topography** (with absolute line elevation deviation from a horizontal or inclined flat plane along one receiver spread about equaling or exceeding the target depth being imaged). Check chapter **Pseudo-2D DeltatV Inversion** for more details on **data acquisition requirements**, such as coverage of profile receivers with first breaks etc.

The free **limited functionality Rayfract® trial license** is a **Windows® 32-bit application** as well (compiled with Microsoft Visual C++ 2005) and has these time and run limitations plus functional limitations :

◆ will expire after **30 days** or after **50 runs**, whichever happens first
◆ supports up to **30 shots per profile** only. You will need to renumber your shots as shot number 0 to shot number 29.
◆ **does not support topography specification**
◆ **does not support Crosshole survey Smooth inversion, with WET tomography**
◆ **does not support interactive Wavepath Eikonal Traveltime WET tomography processing**
◆ does not support interactive pseudo-2D DeltatV and XTV inversion
◆ does not offer time-to-depth inversion methods Wavefront and CMP intercept-time refraction
◆ does not offer *Midpoint breaks display* and *Offset breaks display*
◆ *Trace|Midpoint gather* and *Trace|Offset gather* displays are disabled
◆ does not support importing or specifying shot and receiver station coordinates. Assumes a **straight line recorded on a flat topography**.
◆ does not support importing or specifying lateral shot position offsets and shot hole depths
◆ does not offer semi-automatic first break picking for shot sorted trace gathers, in the *Shot breaks display*
◆ does not support printing of trace gathers/time sections/depth sections and velocity sections
◆ when importing or updating first breaks e.g. from Interpex Gremix .GRM files and OYO SEISREFA .ODT files, receiver elevations and shot hole depths will not be updated
◆ does not support exporting station and shot point coordinates to .COR and .SHO files

The trial license will expire whenever either it has been run 50 times, or after 30 days have passed. You may then purchase a 4 month rental or unlimited license. See our web site at http://rayfract.com/pricing.htm . Please contact us for further details, by e-mail to info@rayfract.com .

Strong refractor curvature

For true **2D WET tomography processing of profiles with strong basement undulations, we recommend to use our Smooth inversion method, based on a 1D initial model**. See e.g. our tutorials

http://rayfract.com/tutorials/broadepi.pdf ,
http://rayfract.com/tutorials/depress.pdf ,
http://rayfract.com/tutorials/palmfig3.pdf ,
http://rayfract.com/tutorials/fig9inv.pdf and
http://rayfract.com/tutorials/epikinv.pdf .

As shown in the last tutorial, to prevent velocity artefacts in the imaged basement, your **profile (overlapping receiver spreads) should extend over the edges of a basement depression** (e.g. a steep valley). You may need to limit the maximum imaged basement velocity during inversion to a value estimated e.g. with our Wavefront method; see http://rayfract.com/tutorials/palmfig3.pdf .

For conventional refraction interpretation of strong basement topography undulations, we recommend to prefer Wavefront and Plus-Minus interpretation results over CMP intercept time refraction interpretation. These interpretations may be based on semi-automatically mapping the first breaks to refractors in the *Midpoint breaks display*. Alternatively, you may want to manually map the first breaks to refractors for each shot sorted traveltime curve, in the *Shot breaks display*. For low coverage data, this is the only option available for mapping first breaks to refractors.

Conventional CMP intercept time refraction fails to deliver accurate refractor depths and velocities at locations of strong refractor curvature, such as at the top of steep/narrow anticlines and at the bottom of steep/narrow synclines. In case of constantly dipping refractors, sorting the traces by Common Mid Point (CMP) basically eliminates intercept time and slope errors caused by refractor dip. This automatic error correction does not work in situations of strong refractor curvature, however. The two delays (relative to the horizontal layering case) of raypath segments traveling down to the refractor and coming up from the refractor null out each other symmetrically to the CMP for each ray mapped to the same CMP in case of constantly dipping refractors. This is not true with strong refractor curvature. In such situations, delays along the down going and the emerging raypath segments of each ray add to each other, instead, with increasing offset from the CMP.

As a consequence, expect apparent CMP velocities at the vertex of steep/narrow anticlines (refractor humps) to be too low by about ten to twenty percent. In analogy, expect apparent CMP velocities at the bottom of steep/narrow synclines (refractor troughs) to be too high by about the same percentage. Semi-automatically mapping first breaks to refractors in the *Midpoint breaks display* will work even in such situations of strongly undulating refractors, however. I.e. laterally varying crossover distances can be determined reliably even in case of slightly wrong apparent CMP refractor velocities.

If CMP basement velocities and CMP basement depth show a strong correlation for certain station numbers, there is a high chance that refractor synclines/anticlines are located below these station numbers. This location information may be useful when interpreting Wavefront and Plus-Minus depth sections.

Optimize Windows

Here we first focus on **optimization of disk access** :

The **Windows Search Service** (Windows 7/8/10) or **Indexing Service** (Windows XP) indexes your files presumably to shorten the time needed to search your hard drive if you are looking for a specific file or part of a phrase inside a file. However the constant indexing of files actually slows down system performance considerably. Specifically the hard disk is accessed almost all the time. You may witness this by observing the constant flashing of the hard disk drive diode or similar.

To disable the Windows Search Service or Indexing Service permanently : click *Windows Start button (Windows 7/8/10) or Start and Run (Windows XP)*. In the *Search programs and files box (Windows 7/8/10)* or *Run dialog box (Windows XP)* type `services.msc` and press **ENTER** or click *OK button*. In the *Service window* scroll down and double-click the **Windows Search** or **Indexing Service** entry. Set *Startup Type to Disabled* and click *OK button*.

Furthermore we recommend to disable **file search indexing for Microsoft Office**. Under Windows 7 click on *Start button* and type in `indexing`. The first option should be `Indexing Options`. Here you will see a list of the currently indexed locations. You can click on the *Modify button* to change what locations you want indexed. By default, Windows 7 will index Outlook, IE history, any offline files, the Start Menu and your User directory, which contains Documents, My Pictures, etc. See also

https://www.online-tech-tips.com/computer-tips/simple-ways-to-increase-your-computers-performace-turn-off-indexing-on-your-local-drives/

. Under Windows XP click *Start and Control Panel*. Now double-click the *icon* with the binocular and yellow flash graphics. Then select *menu item "Stop indexing"* or similar in *menu Index*.

If you note that Windows is running slower and slower : shutdown Windows via the *Start button and Shutdown button (Windows 7/8/10) or Start menu "Turn Off Computer" item (Windows XP)*. Then start up Windows again. If program execution under Windows is still slow and you are using any **Internet Security, Firewall or Anti-Virus Suite** : test disabling such software if you feel safe doing this or after discussing this with your System Administrator. If program execution and disk access is still too slow you may want to stop a currently running virus scan. Or shut down and uninstall/reinstall your Anti-virus software.

We recommend to shut down all other non-essential applications before starting inversion with our WET method. Also you may want to **upgrade the amount of RAM installed** in your work station or notebook computer to the maximum amount allowed by your Windows version. See

https://msdn.microsoft.com/en-us/library/windows/desktop/aa366778(v=vs.85).aspx

Our Standard license can use up to 3 GBytes of RAM for caching traveltime grids during WET inversion. Our Pro license can use up to 64 GBytes of RAM during WET inversion.

For **safe Internet access** we recommend to stop using Microsoft Internet Explorer and use e.g. the free Mozilla Firefox browser instead. For details see

http://www.mozilla.org/products/firefox　　.

Also we recommend to stop using the Microsoft Outlook Express e-mail client and use a more secure alternative such as Thunderbird or Eudora, with automatic HTML display disabled. Always check your incoming e-mail in your webmail account and delete any spam. Only then download the relevant messages to your PC using your local e-mail client.

To **archive Rayfract® profile database files `seis32.*`** and WET tomography output files `*.GRD` and `*.PAR` etc. as written to profile subdirectories `GRADTOMO` (Smooth inversion), `LAYRTOMO` (Plus-Minus or Wavefront method starting model), `TOMO` (Automatic DeltatV and WET inversion) or `HOLETOMO` (for *Header|Profile|Line type* `Borehole spread/line`) we recommend the WinRAR utility. See

http://www.rarlab.com　　.

For more tips on administrating Microsoft Windows 10 see

https://support.microsoft.com/en-us/products/windows?os=windows-10 .

For more tips on securing your PC, we recommend the book "Computer Security for the Home and Small Office" Copyright © 2004 Thomas C. Greene, ISBN 1-59059-316-2.

Starting up Rayfract® and profile management

To **startup Rayfract®**, left-click the *Start button*. Select *menu item Rayfract®* and the *Rayfract® icon* contained in that folder. Or double-click the *Rayfract® desktop icon* with left mouse key.

When running our software under Windows 7/8/10 64-bit, it may be necessary to start it up with right-click of desktop icon, selecting "**Run as administrator**". Otherwise opening a profile database may fail with message "**Raima Object Manager Error:...**".

Opening a profile

To **open a profile**, select *File|Open Profile...* . Now this *Open Rayfract® Profile Folder dialog* appears, prompting you to **select a SEIS32.DBD database** schema :
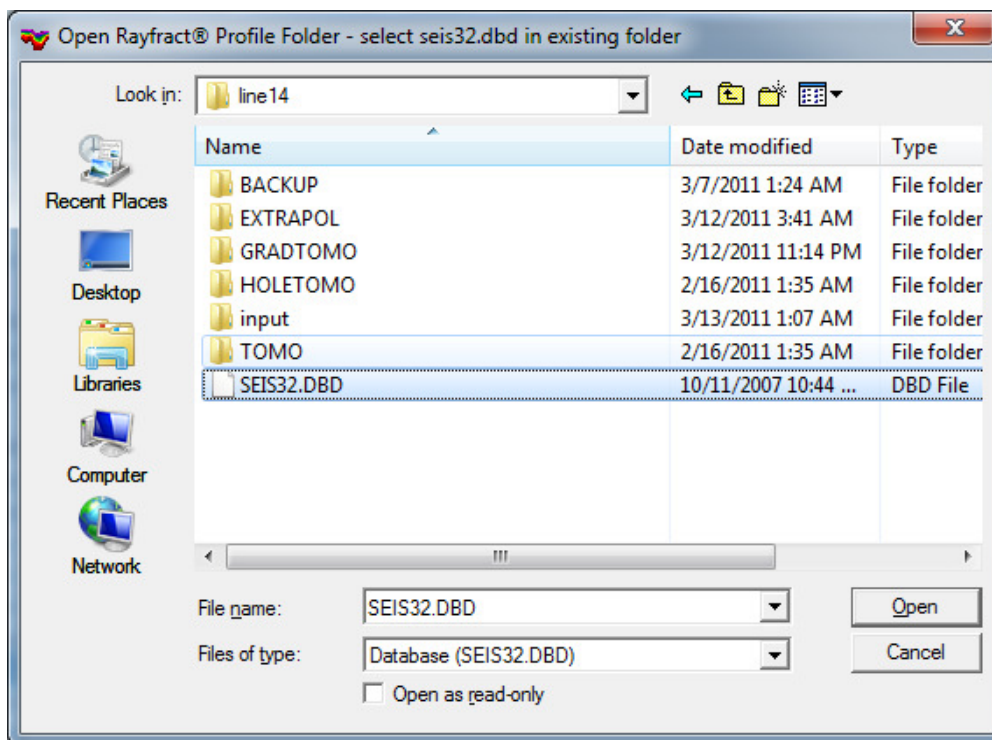
Select the drive by clicking the *Computer icon*. Next click on the root-level RAY32 directory in the central *directory list control*, and then the desired *profile directory,* e.g. line14*.* Now click the SEIS32.DBD file and click *Open button*.

All profile header, shot header, trace header, binary trace data and resulting model data related to one profile is stored in one **Rayfract® profile database**, defined by a seis32.dbd database schema. The 31 database component files are named **seis32.d01, seis32.d02, ..., seis32.d16, seis32.dbd, seis32.k01, seis32.k02, ..., seis32.k14**. Exactly one database is stored per *profile directory*.

Two sample profiles are located in *profile directories* **C:\RAY32\LINE14** and **C:\RAY32\PALMFIG4** . **LINE14** uses a custom spread type named "12: 24 refract" with non-

constant receiver spacing. The default spread type is named "10: 360 channels" and defines an equi-distant spread where all receivers are separated by the same distance : one *station spacing* defined in *Header|Profile* .

If you want to open a profile which you created earlier, select *File|Open Profile...* and navigate into the directory you specified when you created that profile with *File|New Profile...*. You can change the current profile database with *File|Open Profile* at any time. The current *profile directory* is displayed in the application's title bar.

Under rare circumstances our software may hang during *File|Open Profile…* . Open the *Windows Task Manager* with ALT+CTRL+DEL key combination. Now select *Image Name Rayfract32.exe* in *Processes tab* and click *End Process button*. Next restart Rayfract® via *desktop icon* and retry the open.

Defining a new profile

To initialize a new profile select *File|New Profile...* . Now *Create New Profile Folder dialog* is shown :
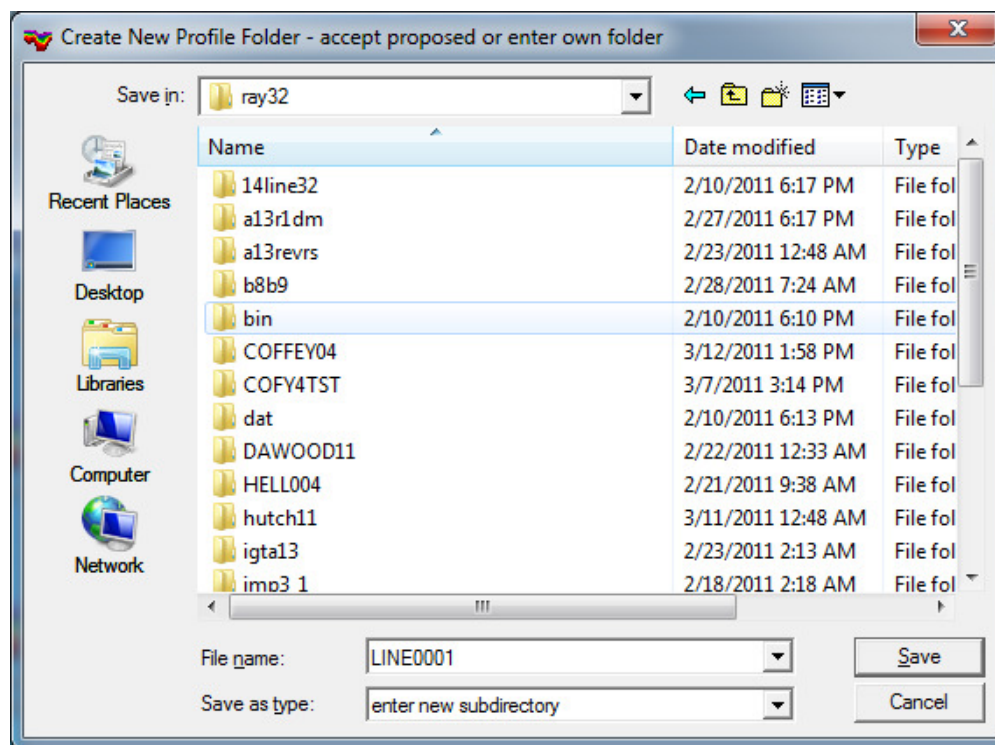
We recommend to have a directory named **RAY32** in the root directory of your hard-disk volume (does not have to be drive chosen at installation time) and then create subdirectories (*profile directories*) in that root-level directory, one for each profile to be processed.

◆   select the drive by clicking on the *Computer icon* at left of the dialog. Select the **RAY32** root-level directory to contain the new profile (i.e. its parent directory) via the *directory list control* in the center or on top of the dialog.

◆ either accept the default new profile subdirectory proposed e.g. `LINE0001` or enter a unique new profile name (up to 8 characters) in *edit field File name*. Long-format directory names (containing spaces or longer than 8 characters) are not allowed.

◆ click *Save button* to generate the new profile database and to open it as the current database.

◆ now a new empty Rayfract® profile database will be generated, in the *profile directory* as specified above. The 31 database component files are named `seis32.d01, seis32.d02, ..., seis32.d16, seis32.dbd, seis32.k01, seis32.k02, ..., seis32.k14`. The database will be filled in once you import seismic data files; see below.

◆ next select *Header/Profile* and fill out at least edit fields *Line ID*, *Job ID*, *Instrument*, and *Station spacing* (in meters). Then hit RETURN.

Creating a new profile may fail in certain rare circumstances. These typically are low disk-space situations. The software will display an error message indicating the problem and how to proceed. It will shut down once you accept the dialog (with RETURN or by clicking on the OK button). We recommend to reboot your PC in such a situation. Now make sure that there is ample disk space on both your C: drive, the drive/partition onto which you installed Rayfract®, and on the partition on which you tried to create the new profile database. 400 MBytes of free disk space on each of these drives/partitions should be safe. Then delete the invalid *profile subdirectory* within *Windows Explorer* (see below) and re-create it with Rayfract® *File/New Profile...* .

◆ if your PC crashes with a Rayfract® profile opened, Rayfract® under rare circumstances may not allow you to create a new or open any existing profile database, showing messages saying **Raima Object Manager Error** -905, -30 or similar. Please exit Rayfract® via *File/Exit* and

◆ open *Windows Explorer* window with *Windows key + E shortcut* or via *Windows menu Start/Run…* Explorer.exe

◆ navigate into directory `C:\RAY32\DAT`

◆ delete files `rdm.taf, vista.taf, and user1.log`

◆ restart Rayfract® with desktop icon, and retry *File/Open Profile*… or *File/New Profile…*

Validating a profile database

Check the consistency of the profile database currently opened with *File/Check Profile* at any time. The resulting message **"0 errors were encountered in 0 records/nodes"** signals that your profile database is in a consistent state.

Renaming and deleting Rayfract® profiles

To rename or delete a Rayfract® profile subdirectory :

◆ first quit our software via *File|Exit*

◆ start up **Windows Explorer. E.g. select *Start|Run...*, enter *command line "Explorer"* and hit ENTER**

◆ navigate to the drive containing your **\RAY32** data root-level directory

◆ click on the **\RAY32** directory with your *left mouse key* to expand it and show its subdirectories

◆ left-click on the targeted subdirectory/profile directory label

◆ right-click and select *menu item Rename or Delete*

◆ if your selected *Rename*, now enter the new *subdirectory name* (i.e. profile name) and then hit ENTER

◆ if you selected *Delete*, confirm the following prompt to delete the subdirectory and its content

Rename and backup tomogram subdirectories

To rename a tomogram subdirectory in your **C:\RAY32\<profile name>** profile directory :

◆ close the profile database with *File|Exit*

◆ open Windows Explorer and navigate into your profile directory **C:\RAY32\<profile name>**

◆ right-click subdirectory **GRADTOMO, TOMO, LAYRTOMO** or **HOLETOMO** and select *Rename*

◆ type in new subdirectory name e.g. **GRAD335** or **GRADNOV17** and press ENTER/RETURN key

◆ when you reopen profile **C:\RAY32\<profile name>** with *File|Open Profile…* we will recreate all of these subdirectories **GRADTOMO, TOMO, LAYRTOMO** and **HOLETOMO** if you renamed them as above

◆ now e.g. vary WET inversion parameters in *WET Tomo|Interactive WET tomography...* and rerun WET inversion with *Start tomography processing button*

◆ above procedure gives you tomogram subdirectories with multiple interpretations of the same data, obtained e.g. with different WET inversion settings

Backup of profile databases

To backup profile database files **seis32.d01, seis32.d02, ...,seis32.d16, seis32.dbd, seis32.k01, seis32.k02, ..., seis32.k14** we recommend the WinRar archiving utility. See http://rarlabs.com . You may optionally backup subdirectories **GRADTOMO, LAYRTOMO, HOLETOMO, TOMO, INPUT** and **BACKUP** of your *profile subdirectory* as well, e.g. into the same .RAR archive. These subdirectories contain tomographic interpretation output :

◆   **.TXT** Comma-Separated-Value files specifying the pseudo-2D or 1D initial model, generated by our DeltatV inversion
◆   Surfer® formatted **.GRD** grid files
◆   **.PAR** files (text file format) listing the inversion parameters used for generating the corresponding **.GRD** files
◆   **.FIT** files (text file format) detailing the traveltime misfit, between picked and modeled times for corresponding **.GRD** files
◆   Surfer **.SRF** plot files, for corresponding **.GRD** files

The **BACKUP** subdirectory contains files **COORDS.COR**, **SHOTPTS.SHO** and **BREAKS.LST** with recording geometry and first breaks picked. These backup files are written whenever you select *File|Import Data...* .

Dialog box control and function keys

Use the *TAB key* to cycle through the *control fields*, i.e. to change the *input focus*. Use the *RETURN key* to confirm the *dialog box* changes just made. Alternatively, click the *OK, Read, Accept or equivalent button* (if existing). Use the *ESC key* to cancel changes to the *dialog box* / not to carry out the transaction configured by the *dialog box*. Alternatively, click the *CANCEL or equivalent button* (if existing). Press F1 for popup dialog help on the *dialog control* currently holding the *input focus*.
   Displays opened by selecting menu items in *menu Trace* are called **Gather displays**. Displays opened by selecting menu items in *menu Refractor* are called **Breaks displays**.
   Here are the most important **function keys for working with Rayfract®** :

Function key combination	Meaning assigned to key combination
F1	Context sensitive online help in dialogs. Zoom time scale (*Gather displays*)
F2	Unzoom time scale (*Gather displays*)
CTRL+F1	Zoom traces, in amplitude coordinate (*Gather displays*). Pick *Branch point* 1, in *Shot breaks display*. Zoom *CMP curves* (reduced time axes) in *Midpoint breaks display* .
ALT+F1	Delete *Branch point* 1, in *Shot breaks display*
CTRL+F2	Unzoom traces, in amplitude coordinate (*Gather displays*). Pick *Branch point* 2, in *Shot breaks display*. Unzoom *CMP curves* (reduced time axes) in *Midpoint breaks display*.
ALT+F2	Delete *Branch point* 2, in *Shot breaks display*
CTRL+F3	Toggle trace display modes, in *Gather displays*
F7	Page backward (header data dialog boxes, gathers, *traveltime curves* in *Shot breaks display*)
F8	Page forward (header data dialog boxes, gathers, *traveltime curves* in *Shot breaks display*)
PAGE DOWN	Page downwards (increasing time) along zoomed time axis *(Gather displays)*
PAGE UP	Page upwards (decreasing time) along zoomed time axis *(Gather displays)*
CTRL+HOME	Page to up most time section (minimum recording time) *(Gather displays)*
CTRL+END	Page to bottom most time

	section(maximum recording time) *(Gather displays)*
ALT+PAGE DOWN	See F8 above
ALT+PAGE UP	See F7 above
ALT+HOME	Page to first record (dialog box / gather / *traveltime curve*)
ALT+END	Page to last record (dialog box / gather / *traveltime curve*)
SHIFT+F1	Zoom station number axis (horizontal axis), for *Gather displays*
SHIFT+F2	Unzoom station number axis (horizontal axis), for *Gather displays*
SHIFT+PAGE DOWN	Page to the right by one zoomed gather section / pan right, for *Gather displays*
SHIFT+PAGE UP	Page to the left by one zoomed gather section / pan left, for *Gather displays*
SHIFT+HOME	Page to leftmost section of zoomed gather, for *Gather displays*
SHIFT+END	Page to rightmost section of zoomed gather, for *Gather displays*
ALT+M	Display *Model parameter dialog*, for *Midpoint breaks* (Trace to refractor mapping parameters), CMP intercept time refraction, Plus-Minus and Wavefront menu items/displays. Display *Trace processing parameter dialog* for *Shot gather display*.
ALT+P	Display *Display parameter dialog*, for Gather and Breaks displays / Depth and Velocity sections
ALT+A	Display *Annotations parameter dialog*, for Gather and Breaks displays / Depth and Velocity sections
ALT+Y	Redisplay current *Gather display* and/or *Breaks display*, to ensure consistent display e.g. after repicking traces
SHIFT+O	Check shot positions vs. traveltime curves, in *Shot breaks display*
SHIFT+L	Reverse polarity of current trace, in *Shot Gather display*
ALT+L	Reverse polarity of all traces of current shot, in *Shot Gather*

	display. Remap traces to refractors based on current *Branch points*, in *Shot breaks display* .
ALT+G	Smooth crossover distance separating refractors, along profile, with running average filter. Use this after mapping traces to refractors in *Midpoint breaks display* with ALT-M .
ALT+U	Undo mapping of traces to refractors, in *Shot breaks display* and *Midpoint breaks display*. Also undo shot offset corrections, as applied to traveltime curves during earlier mapping.
Left button Mouse click	Select trace and sample and pick first break, in *Gather displays*
SHIFT+Left button Mouse click	Select trace and delete first break, in *Gather displays*
SPACE key	Pick first break at current trace and sample (at cursor location), in *Gather displays*
ALT+DEL and ALT+Z	Delete first break for current trace, in *Gather displays*
SHIFT+Z	Delete first breaks for all traces of shot, in *Trace|Shot gather display*. Delete all branch points for current shot, in *Refractor|Shot breaks display* .
ARROW DOWN	Move trace cursor down trace in *Gather displays*. Move CMP curve cursor to next larger offset in *Midpoint breaks display*
ARROW UP	Move trace cursor up trace in *Gather displays*. Move CMP curve cursor to next smaller offset in *Midpoint breaks display*.
ARROW LEFT	Move trace cursor one trace left in *Gather displays*. Move CMP curve cursor one CMP left in *Midpoint breaks display*. Move branch point pick cursor left in *Shot breaks display*.
ARROW RIGHT	Move trace cursor one trace right in *Gather displays*. Move CMP curve cursor one CMP right in *Midpoint breaks display*. Move branch point pick cursor right in *Shot breaks display*.

Data processing sequence overview

Select menus / menu items from left to right :

◆   create new profile with *File|New Profile...*
◆   initialize profile header with *Header|Profile...*
◆   import trace data and update header data (recording geometry and first break picks) with *File menu*
◆   review and if necessary edit header data with *Header menu*
◆   apply frequency filtering and trace processing as needed, in *Trace|Shot gather* or *Trace|Offset gather*
◆   review or pick first breaks, in *Trace|Shot gather* and *Trace|Offset gather*
◆   process your profile automatically with *Smooth invert|WET with 1D-gradient initial model*
◆   vary WET parameters interactively : increase *iteration count*, adapt *wavepath width* etc.

Next optionally do conventional layer-based refraction interpretation with Wavefront and Plus-Minus methods :

◆   assign traces to refractors (manually in *Shot breaks display*, semi-automatically in *Midpoint breaks display*)
◆   before mapping traces to refractors, decide if you want to **model your data as a 2-layer case (1 refractor) or as a 3-layer case (2 refractors)**
◆   when mapping traces to refractors in *Midpoint breaks display*, set *parameter Refractor count* in *Midpoint breaks display|Refractor Mapping dialog* (ALT+M) to 1 or 2
◆   map traces to refractors in *Shot breaks display* by segmenting traveltime curves with *branch points*
◆   convert time to depth with *Depth menu*, for conventional layer-based refraction interpretation
◆   display layer velocity sections with *Velocity menu*

Regularly export and backup to USB flash your station coordinates, shotpoint coordinates and first breaks picked, with

File|Export header data|Export Station Coordinates..
File|Export header data|Export Shotpoint Coordinates...
File|Export header data|Export First Breaks...

The resulting files COORDS.COR, SHOTPTS.SHO and BREAKS.LST are per default located in your \RAY32 profile subdirectory.

Whenever you repick first breaks, edit coordinates or delay times, or (re)import shots, first breaks or geometry, **previous results and trace-to-refractor mappings will be reset**.

Also, (re)importing one or more shots will automatically reset the profile geometry and first breaks picked, for the reimported shots. You will then need to update the geometry with *File|Update header data|Update Station Coordinates...* and *File|Update header data|Update Shotpoint Coordinates...,* and restore first breaks with *File|Update header data|Update First Breaks...* . Select the above backup files COORDS.COR, SHOTPTS.SHO and BREAKS.LST with these commands.

For an illustration of typical data processing sequences, see our manual and tutorial chapter, as available at

http://rayfract.com/help/manual.pdf   . Also review and work through some of our tutorials available at

http://rayfract.com/tutorials/TUTORIAL.ZIP .

Receiver spread types

If you are processing your seismic data both with reflection seismics methods and refraction seismics methods, you typically have no other choice than planting your receivers at constant intervals. Otherwise reflection seismics processing may not work. High coverage data typically is recorded for interpretation with reflection seismics methods, and possibly for parallel interpretation with refraction seismics methods. For reasons of simplicity, you may also want to employ spreads with receivers separated from each other by a constant distance interval for low and high coverage refraction surveys. We actually recommend to employ these already defined, regularly spaced layout types whenever possible.

For carrying out low coverage refraction seismics surveys, some parties prefer to define their own irregularly spaced layout types. You want to optimally map both the (typically thin) weathering layer (as indicated by direct wave arrivals, at near offset receivers) and refractors (as indicated by refracted wave first breaks, recorded at further offset receivers). To optimally map the direct wave velocity, you may want to place receivers close to each other and to the source at near offsets. To optimally map refracted wave velocities and intercept times, you need to record the refracted wavefronts over as long a distance as feasible with a limited number of channels. Resolution is not that important (and not easy to numerically achieve) for deeper refractors, so you will separate neighboring receivers by distances increasing with offset from source location. Note that we implicitly assume that velocity increases with depth, i.e. with refractor.

When importing seismic trace data recorded with one receiver spread, you need to specify the spread type used (relative distances between adjacent receivers), the *station spacing* (scale at which spread type is actually planted), and finally the *layout start*. The layout start is expressed in profile-relative, integer (whole) station numbers. The spread type is defined in spread-relative integer station numbers. These relative station numbers are relative to the first/leftmost receiver position of the spread, as planted. The spread-relative station number of the leftmost receiver position is always 0. The profile-relative station number of the first spread receiver position is defined by *layout start*. So the software will be able to convert between spread-relative and profile-relative station numbers by means of the *layout start*, as entered during data import. For more details, please see Station numbers and spread types.

The *station spacing* is defined once only for the whole profile, in the *Profile Header Editor* (*Header|Profile*).

Note that we assume that channel 1 of your seismograph always records trace data as registered by the receiver planted at the left limit of your spread (lowest station number, with station numbers increasing to the right). If you have the habit of turning this recording convention around by 180 degrees sometimes, please let us know.

Finally, we would like you to **lay out your spreads such that they overlap by a few receiver positions**, ideally by up to half the spread length. This makes data interpretation easier/safer, especially regarding absolute depth of refractors. See Overlapping receiver spreads.

To define your own receiver spread types, see Defining your own layout types.

We **recommend keeping 10:360 channels as default spread type** in import shot dialog. Our import routine will determine the number of active channels (360 channels or less) automatically, based on the input files selected. So when e.g. recording with a spread with 137 active and regularly spaced channels, spread type 10:360 channels still works fine, and you don't need to define a new spread type.

01:24 channels and 10:360 channels are spread types with constant receiver separation. All adjacent receivers are separated from each other by one station number interval, for these two spread types. Spread type 12:24 refraction is defined with variable receiver separation, in File|New Spread type... . Spread type 12:24 refract. is used for importing data into LINE14 profile, as described in LINE14.PDF available in archive

http://rayfract.com/tutorials/OLDTUTOR.ZIP

To **view the definition of all existing spread types** :

- select File|New Spread type...

- use F7/F8 keys to browse existing spread types

- use ESC key to leave this dialog

To **export your custom spread types to an ASCII text file**, and to reimport such a text file into your reference database, see Import/export of layout types.

Station numbers and spread types

The "station number" concept is widely used in Reflection Seismics processing, and is helpful for the reliable and correct interpretation of Refraction Seismics data as well.

The Interpex Gremix .GRM file format lists shot and receiver locations in metres, with the leftmost receiver conventionally positioned at an offset of one *station spacing*.

Let us assume that during import of one shot with *File|Import Data...* , *Layout start* is set to station nr. 1, *Station spacing* is set to 4 metres, and the first layout receiver is located at "position" 4m, as indicated in a related .GRM file. Also, let us assume that this is a profile with just one equidistant receiver spread. In this case, station nr. 0 corresponds to a .GRM position of 0m, and station nr. 1 corresponds to a .GRM position of 4m.

To convert a shot position in metres e.g. 12m to the left of the first profile receiver (corresponding to a .GRM location of -8m) to a station number :

1.   Determine the signed distance between the shot position and the first profile receiver, e.g. -12m.
2.   To obtain the relative position in station numbers (relative to the first profile receiver), divide this signed shot distance (from the first receiver) by the *station spacing*. E.g. -12m divided by 4m gives -3.
3.   Now add this relative position to the absolute station number of the first profile receiver, which is our *layout start* based on above assumptions. Add -3 to 1 and obtain -2, as the profile-relative shot position in station numbers.
4.   Finally enter this profile-relative shot position (in station nrs.) into field *Shot position*, of the *Import shot dialog*. Normally *Shot position* is determined automatically from your input data files.

To get a better understanding of the conversion from positions in metres to positions in station nos., also review topics *Receiver spread type* and Defining your own layout types.

To export your custom spread types to an ASCII text file, and to reimport such a text file into your reference database, see Import/export of layout types.

The station number concept and the related concept of Receiver spread types may be a bit difficult to understand at first sight. Especially to users who up to now have processed their data with other software such as Interpex Gremix, W_GeoSoft WinSism, Earth FX VIEWSEIS etc. These packages let the user specify shot locations and receiver positions in metres directly.

The advantages of our *station number* and related *Receiver spread type* concepts are :

◆   **much fewer recording geometry specification errors**, especially in situations where the receiver spacing varies along the spread. Correct geometry specification is paramount for obtaining meaningful tomographic and conventional layer-based refraction interpretations, of picked first breaks. We prefer to **catch geometry errors as early as possible with mandatory redundancy in the specification**, instead of giving your clients bad output based on an invalid geometry specification.
◆   let the user explicitly define and name his or her own receiver spread types.
◆   clear separation of the concepts "x coordinate" and "position in metres" vs. "station number".
◆   in situations of steep and strongly undulating topography, x and y coordinates can be

corrected for the topography in the *Station Editor (Header|Station)*, with buttons *Correct x* and *Correct y*.

◆   Station numbers always remain constant, independent of the topography.

◆   enable the easy and consistent **database-internal sorting of traces by CMP station number**. This is a prerequisite for subsequent interpretation of first breaks with our DeltatV method.

Overlapping receiver spreads

Far offset shots into one receiver spread per Rayfract® profile cannot be used for true 2D WET tomography because the all-important local weathering velocity cannot be determined at these far-offset shot points. Because there are no receivers there. Extrapolation of the weathering velocity determined at the first/last receiver to these far offset shot points is not feasible since the weathering velocity typically varies laterally to a large degree. To reach a deeper imaging you need to employ multiple *overlapping receiver spreads*.

These far-offset shots are regarded for layered refraction with Plus-Minus and Wavefront methods used to determine the layered starting model and for 1.5D DeltatV method used to determine the 1D-gradient starting model. So we still recommend to always record far-offset shots even for single-spread profiles. See our tutorial

http://rayfract.com/tutorials/NORCAL14.pdf

As specified in System limitations we require that multiple *receiver spreads* overlap each other if you want to process shots recorded by these spreads as one Rayfract® profile.

In the following we assume that you want to import shots recorded with six overlapping receiver spreads. Each such receiver spread has 24 active receivers.

If adjacent receiver spreads overlap at least at one receiver station then you can process the shots recorded by these receiver spreads as one Rayfract® profile. If there is no overlap between adjacent receiver spreads then you have to process each spread separately. The less far offset shots you record for each spread the more the spreads need to overlap to obtain a good coverage. If you don't record far offset shots at all spreads need to overlap 25% or even 50% of their length. Otherwise resulting tomograms will show coverage gaps. To check the coverage before inversion select *Refractor|Midpoint breaks*. **We recommend using an overlap of at 25% even with far-offset shots**. See http://rayfract.com/help/overlap.pdf as replicated below and made available by Donn Schwartzkopf at Terra Geosciences :
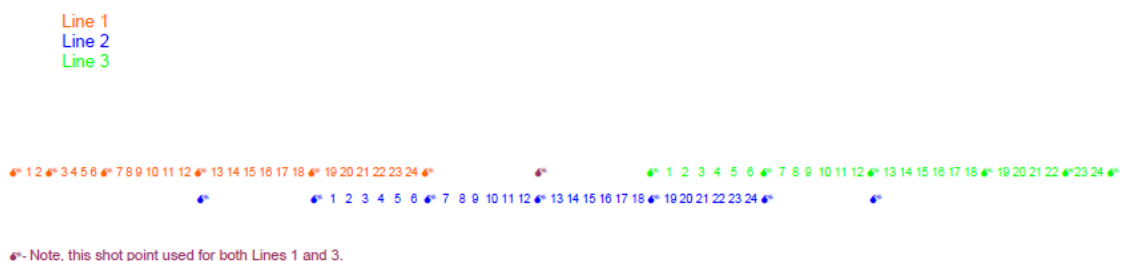
Geophones are spaced at 10-foot intervals and the shots are placed between the phones as indicated above. Each line will use 7 shot points at the same location as the overlapped spread. The overlapped geophones will occupy the same position for the next line. Length of line is 590 feet (59 spacings at 10' intervals) plus 20' for outside shots (each 10' off), for a total of 620'.

When importing a specific shot you need to review and if necessary edit *Layout start* and *Shot position* in the *Import shot* dialog. See Station numbers and spread types for more information.

We recommend to proceed as described below :

- create a new Rayfract® profile database named e.g. "NIRMTEST" as described in our manual http://rayfract.com/help/manual.pdf
- open command prompt e.g. via *Start|cmd.exe*
- change into \RAY32\NIRMTEST directory with cd command
- generate a separate subdirectory for each of your 6 spreads named e.g. \RAY32\NIRMTEST\SPREAD1 etc. with md command.
- copy the binary trace data and ASCII header data (Interpex Gremix .GRM etc.) files for each spread into the corresponding subdirectory with copy command or in *Windows Explorer*.
- make sure that shot numbers are unique over all spreads imported. E.g. rename shot nr. 1 of SPREAD1 to shot nr. 11, shot nr. 2 of SPREAD1 to shot nr. 12, ..., shot nr. 3 of SPREAD4 to shot 43, ..., etc.
- you can rename either the .DAT trace data files in subdirectories SPREAD1 ... SPREAD6 with rename command : rename 1.DAT to 21.DAT for SPREAD2, ..., rename 3.DAT to 43.DAT for SPREAD4, ..., etc. Or you can renumber the shots during import in the *Import shot* dialog.
- now import shots for SPREAD1 into profile NIRMTEST as described in http://rayfract.com/help/manual.pdf . Set *Input directory* to \RAY32\NIRMTEST\SPREAD1. Leave *Layout start* at its default value of 1.0.
- now import shots for SPREAD2. Set *Input directory* to \RAY32\NIRMTEST\SPREAD2. Edit *Layout start* to the profile relative station number of the first receiver of SPREAD2. E.g. if the first receiver of SPREAD2 is positioned at station no. / receiver no. 19 of SPREAD1 then set *Layout start* to 19.0. See Station numbers and spread types for more details.
- set *Shot position* for shots recorded with SPREAD2 to the spread relative shot pos. (starting at 1.0) PLUS the difference between *Layout start* for SPREAD2 and *Layout start* for SPREAD1. E.g. if a shot is positioned at station no. / receiver no. 3 of SPREAD2, specify its *shot position* as 3+ (19-1) = 3+18 = 21.0.
- proceed with importing shots from SPREAD3 etc. as described above for SPREAD2.
- instead of determining *layout start* and *shot position* manually as above, you may want to uncheck import option *File|Import Data Settings|Profile start is default layout start*. Then our import routine will determine *layout start* and *shot position* directly from the SEG-2 trace headers. Of course this will work reliably if SEG-2 trace headers contain valid recording geometry information only. This import option is unchecked per default.

To **fix geometry errors in SEG-2 trace data** files we recommend the free XVI32 hex. editor. See http://www.chmaas.handshake.de/delphi/freeware/xvi32/xvi32.htm :

- always edit SEG-2 files in overwrite mode and NOT insert mode. Otherwise you damage the file structure (pre-computed offsets to next field).
- to correct the *shot position* update SEG-2 field SOURCE_STATION_NUMBER or SOURCE_LOCATION for the first channel (CHANNEL_NUMBER 1) of the problem shot .
- to fix the *layout start* edit SEG-2 field RECEIVER_STATION_NUMBER or RECEIVER_LOCATION of the first channel.
- to correct the SEG-2 UNITS field from FEET to METER overwrite "FEET" with "METE" without the trailing 'R' using above XVI32 hex. editor. Otherwise you damage the SEG-2 file structure.

If your input data is formatted as ASCII .ASC/Interpex Gremix .GRM/OYO SEISREFA .ODT, W_GeoSoft WinSism .XYZ, Earth FX VIEWSEIS .PRN files, OPTIM LLC SeisOpt or Geometrics SeisImager PickWin/PlotRefa .VS, you may copy all files relevant for one profile (one file per *overlapping receiver spread* or "line") into the same subdirectory named e.g. INPUT. Then select one of these files in the **Import Shots dialog** with the *Select button*. Now

select the correct *receiver spread type* etc. and click on button *Import shots*. Now shots specified in all matching files (regarding file extension) stored in the same subdirectory will be displayed in the **Import Shot dialog** and may be imported with the *Read button*.

You may need to adjust *shot position* and *layout start* for these shots so that all station numbers are **relative to the layout start of the leftmost receiver spread** imported into the same profile database. See above. Also **shot number needs to be unique across all files (spreads)** to be imported into the same Rayfract® profile database.

You need a **maximum shot-geophone offset of 6 times the maximum target depth**. If you insist on a maximum target depth of 150 meters then the maximum shot-geophone offset required is at least 900 meters. We recommend to use a geophone spacing of 10 meters with your 48 channel spread. Some of our clients regularly use our software with such a receiver spacing. Use e.g. an overlap of 22 geophones between adjacent spread layouts. See below.

Then shoot into the first spread layout from maximum far reverse offset at 480 meters to right of last receiver. Shoot into the last spread layout from a maximum far forward offset at 480 meters to left of first receiver. For receiver spread layouts and shot positions refer to the following graphics :

```
 +--+--+--+--+--+--+--+--+ + + + + + + + +   : first spread

  + + + + +--+--+--+--+--+--+--+--+ + + + +   : second spread

   + + + + + + + + +--+--+--+--+--+--+--+--+  : third spread
```

The "+" symbol means a shot position. The "--------" line represents the 48 channel receiver spread. One character column corresponds to a distance of 20 meters. The shot spacing is 60 meters, receiver spacing is 10 meters.

The second spread is moved 260 meters to the right in relation to the first spread. Shot stations don't coincide between adjacent spreads but are "staggered" i.e. moved 20 meters to the right. Receiver stations do coincide in the overlapping section of two adjacent spread layouts.
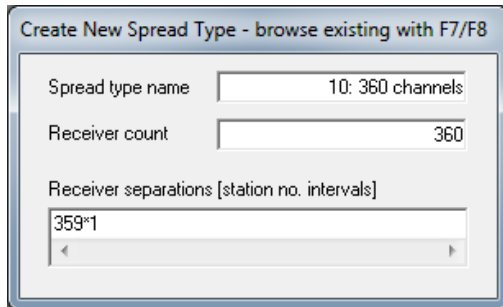
Since all shots "+" are positioned within or directly adjacent to at least one receiver spread layout, all shots can be used for WET true 2D tomography processing. In the context of SIRT-like WET tomographic processing, all spreads are "active" at the same time.

We recommend to **use a mobile weight drop as an energy source**. See e.g.

http://www.geoexpert.ch/equipment.html

Defining your own layout types

1.   Start up Rayfract® and open a profile if not yet done so, i.e. \RAY32\LINE14.

2.   Select *File|New Spread Type...* to bring up this dialog :

```
Create New Spread Type - browse existing with F7/F8

Spread type name          10: 360 channels

Receiver count                        360

Receiver separations [station no. intervals]
359*1
```

3.   Page through existing *receiver spread type* definitions with F7/F8. Position to a spread type resembling the new type you want to define.

4.   Enter a new unique *Spread type name* into the topmost edit field of the dialog. This name will be shown for selection of the spread type, in dialogs *Import Shots* and *Import Shot*.

5.   Enter the number of receiver positions you are going to define for the new spread type, into edit field *Receiver count*.

6.   Take a sheet of paper and write down relative receiver positions of your spread type, in meters or in feet. These positions are relative to the leftmost receiver position (layout start, which therefore is always 0). E.g. 0, 5, 15, 25, 45, 50, 60, ...

7.   Determine the greatest common divisor (GCD) of distances (in meters or in feet) separating adjacent receiver positions, of your spread type. E.g. if separations are 5 or 10 or 20 meters or feet, the GCD is 5 meters or feet. This GCD will be the *station spacing* of your spread type (as defined in your *Profile Editor, Header|Profile*). The GCD value corresponds to one station number interval, in meters or in feet.

8.   Divide all relative geophone positions (in meters or in feet) of your spread type by the GCD distance determined above, to obtain relative geophone positions in integer station numbers. E. g. for a spread type with receiver positions (in meters or in feet) 0, 5, 15, 25, 45, 50, 60, ..., the resulting receiver positions (in station numbers) are 0, 1, 3, 5, 9, 10, 12, ...

9.   Once you have rewritten your spread type with receiver positions expressed in relative integer station numbers (relative to layout start/leftmost position, equal to 0), translate this form of spread type definition into yet another, shorter form : the **receiver separations string**. This string is formed by counting the number of times the same receiver separation distance (in station numbers) is used between adjacent receiver positions, starting at the leftmost spread position equal to 0 and moving to the right / increasing receiver position station numbers. Once the receiver separation changes, append a term "x*y" to the receiver separations string. Replace the place holder x with the number of times the same receiver separation distance is used, and y with that receiver separation distance (in station numbers). If x is equal to 1, just append a term "y". Now count the number of times the new receiver separation is used, starting at the receiver position to the right of which this new

separation is used for the first time and proceeding to the right until the separation changes again. Then append the resulting new term to the end of above receiver separation string, separated from the previous term by a comma. E.g. for a spread type with receiver positions (in meters or in feet) 0, 5, 15, 25, 45, 50, 60, ..., and a station spacing of 5 meters the resulting receiver separation string is "1, 2*2, 4, 1, 2, ...".

10.   Now enter the receiver separation string as just computed into edit field *Receiver separations [station no. intervals]*, of your *Create New Spread Type dialog.* Then hit ENTER or click on *button Create* to generate the new receiver spread type.

11.   The new receiver spread type as just defined will now be available in all Rayfract® profiles you open or create, with this Rayfract® installation. Spread types are automatically exported to \RAY32\REF\MYSPREAD.SPR. Backup this file to USB flash.

12.   Create a new profile (via *File|New Profile*). Specify the correct *station spacing* in *Header|Profile*. If you just want to check if your new spread type definition was successful, you may just open an existing profile.

13.   Bring up the *Import shots dialog,* by selecting *File|Import Data*. Click on the combo box list control below label *Default spread type*. Scroll through spread type names available with up/down arrow keys. If your name appears, your spread type definition was successful.

14.   You may now want to actually import a shot. Be careful to correctly specify *layout start* and *shot position*. Then select the shot record in *Header|Shot* by browsing with F7/F8. Leave the editor with ESC.

15.   Now select *Header|Receiver*. Page through receiver records with F7/F8. Check if *Station positions* (i.e. station numbers) displayed are correct for all receiver *Channels nrs*. Note that station numbers displayed are absolute (profile-relative). You need to mentally subtract the station number of the first receiver channel (*layout start*), to obtain spread-relative station numbers.

Once you have become acquainted with this procedure, you may skip the formal steps 6 to 9 as described above and just perform these in your mind before proceeding to step 10, of course. Steps 12 to 15 are not a must as well.

Import and export of layout types

Version 2.72 and later versions of our Rayfract® software offer File menu functions for export/import of receiver spread types. Since version 2.73, you are not required to open a profile database first, to enable this import/export. Also, whenever you define a new spread type, all spread types are exported to file \RAY32\REF\MYSPREAD.SPR.
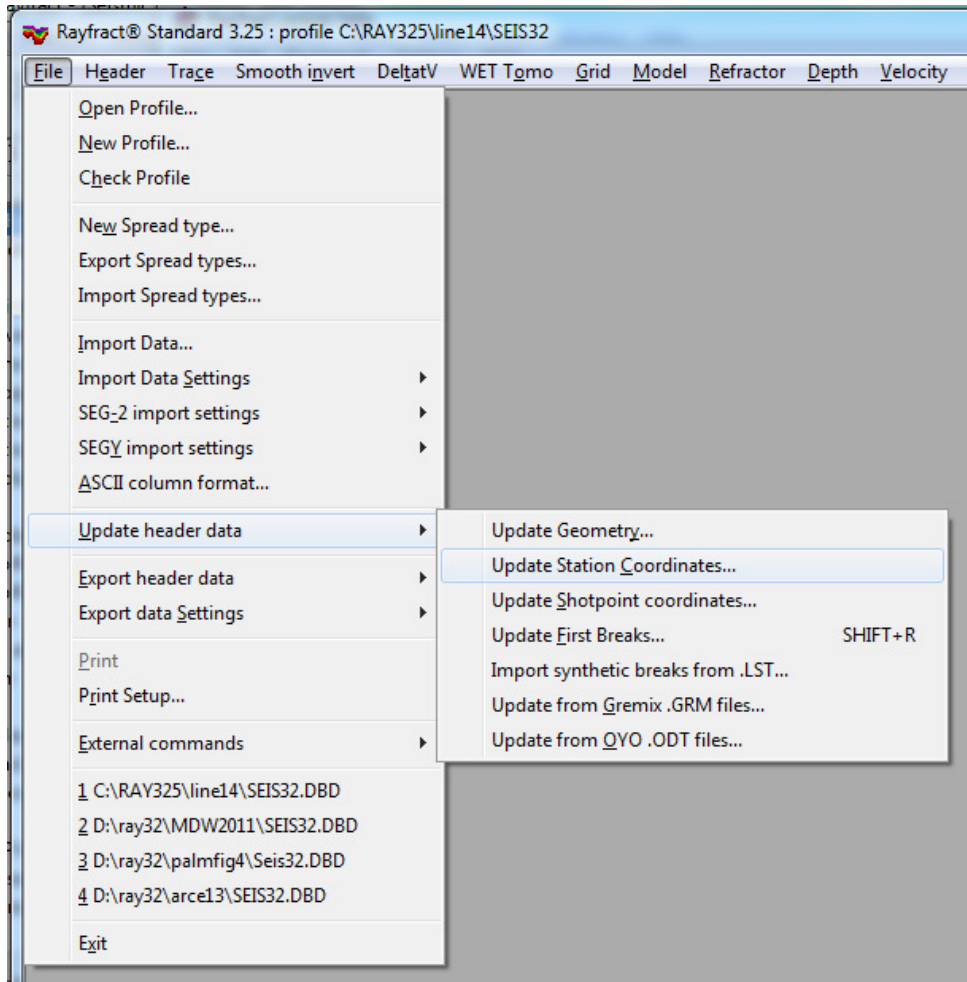
Spread types are stored in the reference database (directory \RAY32\REF, files SEISRF32.*), and not in the individual profile databases. So any custom spread type defined earlier is available for all profile databases. After installing an updated version of our software, you may want to reimport your custom spread types, as e.g. stored in \RAY32\REF\MYSPREAD.SPR . Version 2.73 and later of our installation routine will import your custom spread types automatically, into a reinstalled reference database.

ASCII format dialog

The **ASCII format dialog** contains drop down list boxes, one for each value column of the import file. The sequence of values in one ASCII import line (corresponding to one trace header) is *Shot number, Shot station, Receiver station* and *First break*. Optionally specify *Receiver elevation* and *Shot elevation* for following columns. With this you don't have to import/update recording geometry from COORDS.COR and SHOTPTS.SHO files.

Specify the value separator in edit field *Separator*. The default separator is a semicolon (;). Another frequently used separator is a comma (,), as used by Microsoft Excel® when generating .CSV comma-separated value files.

Specify the number of header lines in your ASCII file format at the bottom of the *ASCII format dialog*, in *edit field Header lines to skip*. This is set to 1 per default.

ASCII import files are supposed to have the **DOS file extension .ASC .** First break values in .ASC files are supposed to be specified in seconds. Please refer to sample file **ASCII.ASC** in your \RAY32\DOC directory for a typically formatted ASCII import file.

Rayfract® supports reading in multiple .ASC files from one directory, during one import session. Traces recorded for the same shot need all to be stored in the same .ASC file.

Seismic and header data import

DOS file names and extensions

Seismic data file format	DOS file name extension
SEGY	.SGY
SEG-2	.SG2 or .DAT (customary for Geometrics SEG-2 files)

Bison-2 9000 series	no extension
ASCII column format	.ASC
Geometrics SeisImager PickWin and PlotRefa modules	.VS
OPTIM LLC SeisOpt®	.TXT or no extension, files XYZ_SRC, XYZ_REC, XYZ_OBS

Interpex GREMIX / FIRSTPIX	.GRM
ABEM Terraloc Mark 3 OYO SEISREFA	.ABM .ODT
GeoTomCG .3DD	.3DD
GeoTomo TimePicker .3DTT	.3DTT
W_GeoSoft WinSism Earth FX VIEWSEIS	.XYZ .PRN

◆ for SEGY files the database shot number starts at 1 and is increased sequentially during each import session with *File|Import Data…* . SEGY header fields **Field Record No.** and **Energy Source Point No.** are shown in *Header|Shot*.

◆ for SEG-2, Bison-2 9000 and Terraloc Mark 3 files the **shot number** is determined by parsing the current shot input file's DOS filename. This filename is supposed to have the format "AAAXXXXX" plus the file extension, as specified above. "AAA" stands for an alphabetic label (must not contain digits) of the profile, i.e. "GLA". It may be empty. This label is discarded when the software reads in the file. "XXXXX" stands for a number string from which the shot number is determined, i.e. "00101".

◆ for ASCII column format files the shot number is from the corresponding column in the ASCII file.

◆ for Interpex GREMIX, OPTIM SeisOpt®, OYO SEISREFA, WinSism and VIEWSEIS files the shot number is read from the ASCII format shot headers as contained in these files.

◆ the shot number will be trimmed to a three digit number. I.e. shot number string "1001" will be truncated to Rayfract® shot number 1. You can renumber the shots during import e.g. to sequentially increasing numbers starting at 0 or 1. The original input file name remains visible in the read-only Shot header field **Original input disk filename** shown in the Shot editor *(Header|Shot)*.

◆ copy all shot files to be imported into one profile into the same subdirectory. This is typically the INPUT subdirectory of the directory holding the profile's database (e.g. \RAY32\LINE14\INPUT).

♦ for typical processing sequences including profile database creation and data import see http://rayfract.com/help/manual.pdf .

Conversion of unsupported data formats to SEG-2

We recommend to use the **Interpex IXSeg2SegY utility** (version 2.01 or higher) to convert binary trace data files from these formats to SEG-2 format : SEG-1, BISON Geopro-1 8000 series, BISON Geopro-2 5000 and 7000 series, EG&G Geometrics 1200 series (Seisview), EG&G Geometrics 2401, OYO McSeis, SCINTREX S-2 Echo, multiplexed .TF, Dolang. First breaks picked with IXSeg2SegY and exported to SEG-2 format will be imported by our Rayfract® software automatically (but .BPK and .FIR ASCII first break files in the input file directory have higher priority). Specify sample type 32-bit Integer or 16-bit Integer when exporting SEG-2 files from IXSeg2SegY. This utility also offers nice functionality for frequency filtering of seismic traces.

You may download a free trial version of IXSeg2Segy from http://www.interpex.com .

Alternatively try W_GeoSoft WinSism v. 10, for import of above data formats and first break picking. You may then generate either **ASCII.ASC** files or OPTIM SeisOpt® files for import into Rayfract®. See http://www.wgeosoft.ch .

For shot resampling, conversion between SEG-2 and SEGY etc. try the free Geogiga Front End, available at http://geogiga.com/en/frontend.php . This also lets you read problem SEG-2 files and save them to disk again in a cleaner format. Try this with SEG-2 files which our software cannot read.

Conversion between feet and meters

When importing SEG-2, Earth FX VIEWSEIS, Interpex Gremix .GRM files with header values specified in feet these are converted to meters during import automatically. To import OPTIM LLC SeisOpt files and Geometrics SeisImager PickWin/PlotRefa .VS files with locations specified in feet uncheck *File|Default distance unit is meter*. Our import routine currently (version 2.74) implicitly assumes that coordinates, elevations, shot offsets and shot depths in ASCII.ASC, W_GeoSoft WinSism and OYO SEISREFA files are specified in meters. We may regard the setting of *File|Default distance unit is meter* for these file types in a future version if wished. Source and receiver locations in ASCII.ASC are always specified in Station Numbers.

♦ if the **word feet or meter** is contained in a header line of a Survey Geometry .PRN, .SHO or .COR file, the shot and receiver positions and coordinates in that file are assumed to be specified in that **distance unit**. See http://rayfract.com/help/ln14feet.zip for sample files specified in feet.

♦ internally all computations are done in meters, to enable easier development and testing of the software. Specify the *station spacing* in meters in *Header|Profile* . Also specify *shot depth*, *shot position inline* and *lateral offsets* in meters in *Header|Shot*.

♦ to display and edit distance parameters in feet in all dialogs toggle *Header|Profile|Units*

between meters and feet.

◆ to generate Smooth inversion, DeltatV and WET output in feet please check *DeltatV|DeltatV Settings|Output DeltatV results in Feet* before running these inversion methods.

◆ to generate Smooth inversion, DeltatV and WET output in meters please uncheck *DeltatV|DeltatV Settings|Output DeltatV results in Feet* and check *DeltatV|DeltatV Settings|Output Horizontal offset of CMP pos. in meters* before running these inversion methods. For Smooth inversion you may alternatively use option *Smooth invert|Output inversion results in Feet.*

◆ once Smooth inversion or pseudo-2D DeltatV inversion possibly refined with WET tomography has completed you may convert Surfer .GRD grid files (velocity tomograms and coverage grids) with *Grid|Convert grid file between feet and meters.* Then plot these with *Grid|Image and contour velocity and coverage grids*.

Use of SEGY trace header fields during import

Byte	Field Description
9-12	Field record number (shown in Header|Shot)
17-20	Energy source point number (shown in Header|Shot)
41-44	Group elevation (Receiver elevation)
45-48	Source elevation (Shot elevation)
49-52	Source depth (Shot depth)
69-70	Scalar applied to above elevation and depth fields
71-72	Scalar applied to below Coordinate fields
73-76	Source X Coordinate (Shot X)
77-80	Source Y Coordinate (Shot Y)
81-84	Group X Coordinate (Receiver X)
85-88	Group Y Coordinate (Receiver Y)
109-110	Delay recording time (Shot delay)
115-116	Number of samples (Sample count)
117-118	Sample interval. Same as in Binary File Header : assume fixed-length traces.
157-158	Year data recorded (Date field in Header|Shot)
159-160	Day of year (appended to Date field)
215-216	Scalar applied to above Delay time

If you set **File|Import Data|Take shot record number from** to `Record number` then the shot number is determined from above Field record number. If you select `File number` then the shot number is determined from above Energy source point number.

Import data files into Rayfract®

Start with defining a new profile and Rayfract® database by selecting *File|New Profile*. See topic *Starting up Rayfract® and profile management*. For importing of ASCII file format review and if necessary edit the *ASCII format dialog* .

Next fill in *Header|Profile* fields *Line ID, Job ID, Instrument,* and *Station spacing* (in meters). Optionally adapt *Line type* in *Header|Shot*. *Line type* can only be edited as long as you have not yet imported any shots. Set *Units* to **meter** or **feet**.
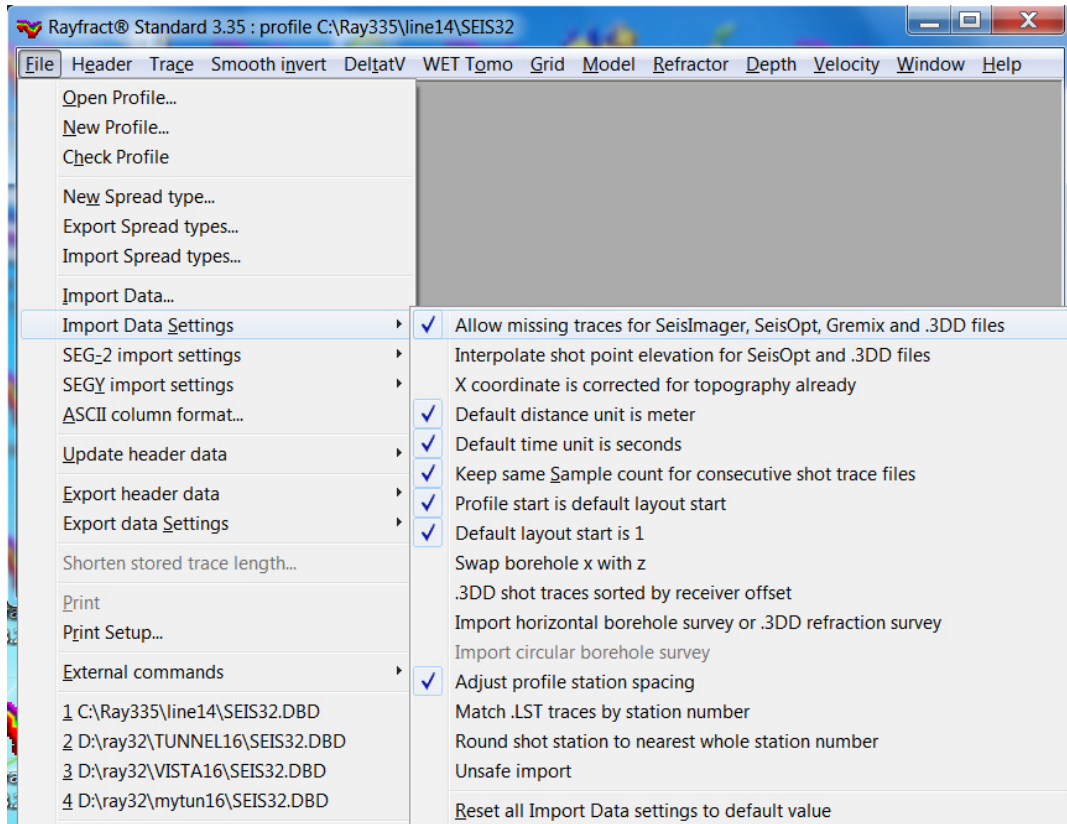
Next review and if necessary revise **File|Import Data Settings** options

◆   *Allow missing traces for SeisOpt and Gremix files*
◆   *X coordinate is corrected for topography already*
◆   *Default distance unit is meter*
◆   *Default time unit is seconds*
◆   *Keep same Sample count for consecutive shot trace files*
◆   *Profile start is default layout start*
◆   *Default layout start is 1*
◆   *Swap borehole x with z*
◆   *.3DD shot traces sorted by receiver offset*
◆   *Import horizontal borehole survey or .3DD refraction survey*
◆   *Import circular borehole survey*

◆ *Adjust profile station spacing*

◆ *Match .LST traces by station number*

◆ *Round shot station to nearest whole station number*

To import data into the profile database currently opened select *File/Import Data...* . Now the *Import shots dialog* is displayed :

You only need to fill out control fields *Import data type*, *Input directory* and *Default spread type*.

◆ specify the *Input directory* by clicking *button Select*. In the file selection dialog now appearing select an input file containing shot(s) to be imported in the appropriate input directory. All matching files in that directory will be imported.

◆ *Take shot record number from* is initialized acoording to the *Import data type* selected and should not be changed

◆ select a *.HDR batch file* with *.HDR batch button*. For .HDR batch format see chapter File formats.

◆ click *button Output .HDR* to specify .HDR filename to be written to listing all shots found in matching input files in *Input directory*

◆ check *Write .HDR only* to list shots in *Output .HDR* file and skip actually importing shots when you click *button Import shots*

◆ check *Import shots and write .HDR* to import shots into your current database and list imported shots in *Output .HDR* file with button *Import shots*

◆ check *Batch import* for batch import with *.HDR batch file* or for batch import of ASCII.ASC files

◆ check *Limit offset* and adjust *Maximum offset imported [station nos.]* if required

◆ specify the receiver spread type used during recording of the data with the *Default spread type drop down list box*. Spread types are named "X: YYY channels". If you need to define your own irregularly spaced/non-equidistant spread types see help topic Defining your own layout types. Also see topic Station numbers and spread types.

◆ *Target Sample Format* is currently not regarded. All sample formats are converted to 32-bit floating point format.

◆ check *Turn around spread by 180 degrees during import* if required. Be careful to correctly specify the *shot position* with this option.

◆ check *Correct picks for delay time* if required

◆ *Default sample interval [msec]* is used when importing shot files without seismograph traces e.g. for ASCII.ASC and Interpex Gremix .GRM to determine the time scale in *Trace/Shot gather* and *Refractor/Shot breaks*

◆ *Default sample count* is used when importing shot files without seismograph traces e.g. for ASCII.ASC and Interpex Gremix .GRM to determine the time scale in *Trace/Shot gather* and *Refractor/Shot breaks*

Specify the import file format by selecting the corresponding list entry in the *Import data type drop down list box*. Supported import file types are ABEM Terraloc Mark 3 / ASCII column format / Bison-2 9000 Series / Interpex GREMIX/OYO SEISREFA /SEG-2 / SEGY / W_GeoSoft WinSism / Earth FX VIEWSEIS / OPTIM LLC SeisOpt / Geometrics SeisImager Plotrefa / GeoTomCG .3DD / GeoTomo TimePicker .3DTT .

Refer to sample files in your \RAY32\DOC regarding the format of these input files :

◆ ASCII Survey geometry files SPRNG2XT.PRN, L5.PRN, LINEBC.PRN
◆ station coordinate files COORDS.COR, RECVRS.COR
◆ shotpoint coordinate file SHOTPTS.SHO
◆ first break pick files BREAKS.LST

- traveltimes and recording geometry ASCII.ASC
- Interpex Gremix LINE14.GRM
- OYO SEISREFA OYO.ODT
- W_GeoSoft WinSism TOMOEVAL.XYZ
- Earth FX VIEWSEIS VIEWSEIS.PRN
- OPTIM LLC SeisOpt SEISOPT_SRC & SEISOPT_REC & SEISOPT_OBS
- Geometrics SeisImager PLOTREFA.VS and PICKWIN.VS
- GeoTomCG .3DD IGTA13.3DD, IGTB13.3DD
- GeoTomo TimePicker .3DTT CON8FILES_090421.3DTT

Once you have specified above parameters click on *button Import shots* or hit RETURN. Now the **Import shot dialog** is displayed once for each shot contained in the input directory :

Import D:\RAY\LINE14\INPUT\L14-1.DAT...

Field Record No.		
Energy Source Point		
Shot Number	1	Read
Layout start [station no.]	1	Skip
Shot pos. [station no.]	-11.000	End
Shot inline offset [m]	0.000	
Shot lateral offset [m]	0.000	
Shot depth [m]	0.000	
Delay time [msec]	0.000000000	
Sample interval [msec]	0.125000000	
Sample count	1024	
Spread type	12: 24 refract.	
Active traces (from start)	24	

- edit the *Shot Number* if you need to renumber the shot.

- edit *Shot position [station numbers]* and *Layout start [station numbers]* if required for each shot being imported. See chapter Station numbers and spread types.

- adjust *Shot inline offset*, *Shot lateral offset* (offsets in meters or feet from *Shot position*) and *Shot depth* during import if required. Alternatively you can edit these later in *Header|Shot*.

- correct *Delay time* during import or edit *Trigger delay* later on in *Header|Shot*.

- best leave *Sample interval* and *Sample count* as initialized during import.

Confirm the dialog by hitting ENTER or by clicking on the *Read button* with your left mouse button. If you activated *check box Batch import* in *dialog Import shots* with *Import data type* ASCII the *Import shot dialog* is still displayed for each shot being imported, but you cannot edit its content. Instead the program simulates hitting the *Read button* and imports the shot at once.

When importing SEG-2, Geometrics or ABEM data files the import routine checks for the existence of **Rimrock Geophysics SIP .PIK, Geometrics .BPK or ABEM .FIR ASCII first breaks files in the input directory**. If these are present in the same directory as the data files to be imported and named the same way as the data files (not regarding the file extension) first breaks contained in these files are imported automatically. Check your \RAY32\DOC directory for sample files. .PIK files have precedence over .BPK or .FIR files if both versions are present in the current import directory.

SEG-2 import : shot position and layout start in station numbers

When importing SEG-2 formatted files the **shot position** is initialized according to SEG-2 trace header entries SOURCE_LOCATION and RECEIVER_LOCATION for the first channel read in. These locations may be specified either in meters or in feet according to the SEG-2 file header UNITS entry. It is assumed that the first channel stored in the SEG-2 file was recorded at the receiver location with the lowest station number of the spread employed for recording the data. Rayfract® parameters *Station spacing* and *Layout start* are used to determine the initial value for *shot position* (in station numbers), based on SOURCE_LOCATION and RECEIVER_LOCATION. See topic Station numbers and spread types for details.

If import option *File|Import data Settings|Profile start is default layout start* is disabled/unchecked then the *layout start* and *shot position* are determined from the SEG-2 trace header directly. SEG-2 trace header fields SOURCE_STATION_NUMBER and RECEIVER_STATION_NUMBER override fields SOURCE_LOCATION and RECEIVER_LOCATION :

◆ *Layout start* is set to RECEIVER_STATION_NUMBER of the first channel, or to RECEIVER_LOCATION divided by *station spacing* (*Header|Shot*)
◆ *Shot position* is set to SOURCE_STATION_NUMBER of the first channel, or SOURCE_LOCATION divided by *station spacing*.

If an ASCII .PIK / .FIR / .BPK first breaks file is present in the input directory and for the shot currently being imported, the shot position is determined from the source and first receiver location as specified in that file. This specification has precedence over the SEG-2 trace header entries SOURCE_LOCATION and RECEIVER_LOCATION. The distance unit is determined directly from the .PIK and .FIR files. For .BPK files the distance unit is determined from the corresponding SEG-2 file header UNITS entry.

If the shot position determined as just described and as displayed in the *Shot position edit field* of the current *Import shot dialog* is wrong, please **compute the correct shot position in station numbers manually**. Do this as explained in the following and in more detail in topic Station numbers and spread types :

◆ receiver no. 1 is typically located at station number 1, ..., receiver no. 24 at station

number 24, for an equidistant *receiver spread type* with 24 channels

◆ consider the station number coordinate system as being extended to include shot positions to the left of the first receiver / to the right of the last receiver

◆ as a consequence station numbers equal to or smaller than 0 and equal to or larger than 25 may be used to express shot positions

◆ determine the signed distance (in feet or meters) of the shot position from the position of the first layout receiver

◆ now divide this distance by the *station spacing* (see *Header|Profile)* e.g. 2.5m

◆ the result is the layout-relative shot position, in station numbers

◆ to obtain the profile-relative shot position in station numbers, add this spread-relative shot position to the station number assigned to the leftmost spread receiver (i.e. add it to *layout start*).

◆ enter this shot position into edit field labeled *Shot pos. [station nr.]* as displayed on the current *Import shot dialog* as shown above. Click on the *Read button* or hit ENTER to import the shots.

If you have ASCII .PIK / .FIR / .BPK first breaks files for the corresponding shots alternatively correct source and first receiver positions (in feet or meters) in these files with an ASCII editor and then reimport the corresponding shots and updated ASCII first breaks files.

When importing first breaks from ASCII.ASC files these files need to specify first break pick times for all receivers specified in the spread type used. If a trace cannot be picked (data is too noisy or the trace is dead) specify a time of -1, meaning "not picked".

Import of ASCII.ASC shots may show an error message **"Shot position of shot nr. … is not at traveltime curve minimum ".** The import routine detects for inline shots the two channels with the smallest first break picks. If the shot is not positioned between these two channels, above message is shown and the shot is not imported. You may want to repick traces or edit the .ASC such that the shot position is located between the two smallest first break times. You may need to introduce "artificial" picks for near-shot traces which you did not pick previously. The traveltime curve minimum position may deviate from the true shot position by an inline offset up to the shot depth as specified in the .ASC or in the *Import shot dialog* . As a last resort check *Smooth invert|Smooth inversion Settings|No shot position checking* and reimport the ASCII.ASC .

Update trace headers with coordinates and first breaks

After data import as described above you can export station coordinates, shotpoint coordinates at topography and first breaks via *File|Export header data submenu*. Now you can edit the resulting .COR, .SHO and .LST files with your favorite text editor e.g. Microsoft WordPad. Then update profile trace headers with *File|Update header data submenu*. **You cannot update source and receiver station numbers this way, just the coordinates. So if you need to changes source and receiver station numbers you need to reimport the shots.** Use our .HDR batch file format for easier editing of *shot position* and *layout start* in station numbers and to reimport all shots with edited station numbers.

You may update database records (trace header attributes) in an existing profile by **importing survey geometry**, **receiver and shot point coordinates, elevations, shot hole depths, first breaks and uphole times**. Do this via selecting the corresponding *File|Update header data command* :

Command   *File type imported*

File|Update header data|Update Station Coordinates...   COORDS.COR station coordinates*,* see below*. Generate with File|Export header data|Export Station Coordinates.*
File|Update header data|Update Shotpoint coordinates... SHOTPTS.SHO shotpoint coordinates*. Generate with File|Export header data|Export Shot Point Coordinates.*
File|Update header data|Update First Breaks...   BREAKS.LST first break picks*. Generate with File|Export header data|Export First Breaks.*
File|Update header data|Update from Gremix .GRM....   Interpex Gremix .GRM
File|Update header data|Update from OYO.ODT files...   OYO SEISREFA .ODT
File|Update header data|Update Geometry...   .PRN survey file geometry
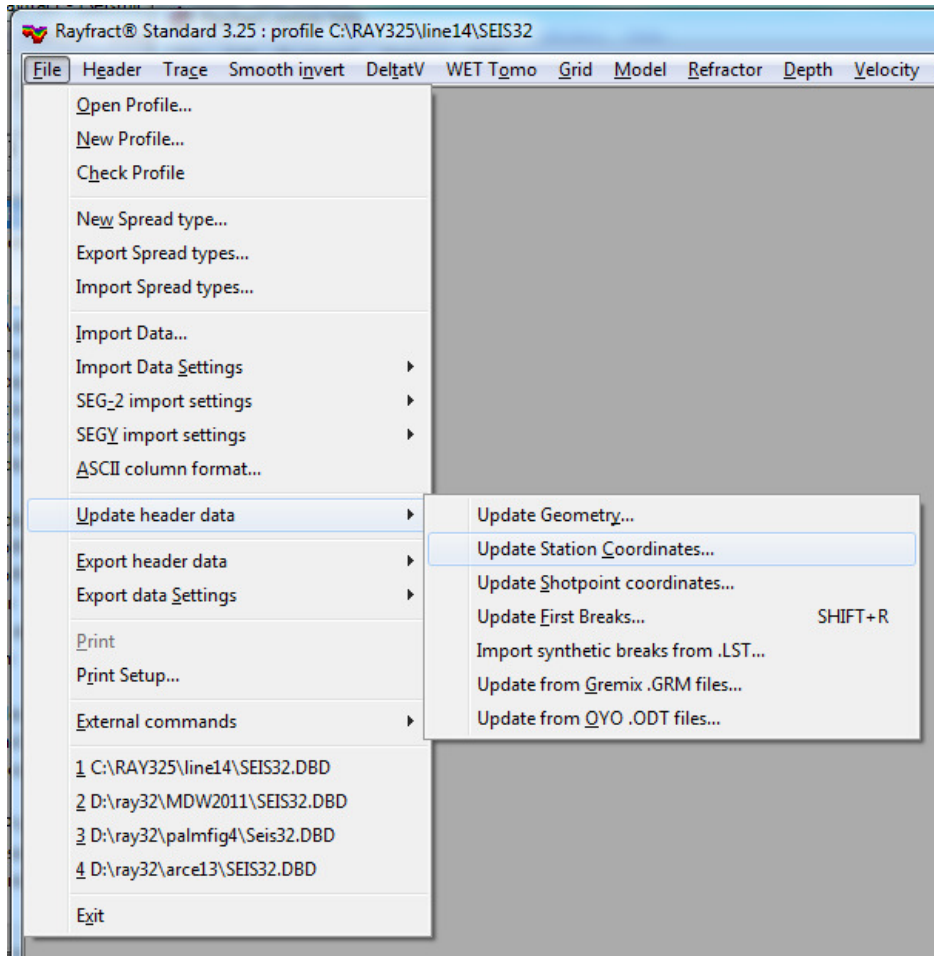
Before you can use these items you must have imported seismic data files as described above.

Select *File|Update header data|Update Station Coordinates...* to import COORDS.COR files :
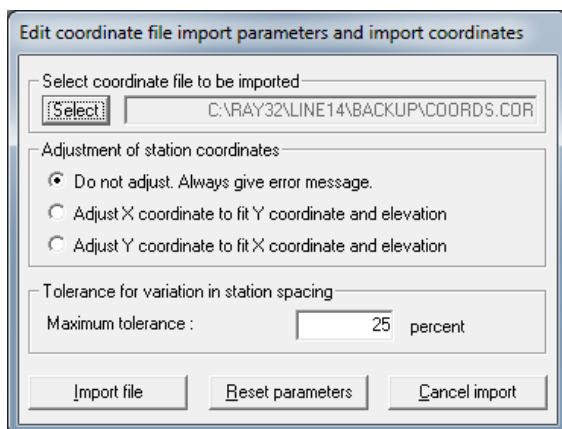
Select the COORDS.COR file to be imported with the *Select button*. Optionally edit parameters :

◆ *Do not adjust. Always give error message*

- *Adjust X coordinate to fit Y coordinate and elevation*
- *Adjust Y coordinate to fit X coordinate and elevation*
- *Maximum tolerance*

It is assumed that .COR files hold coordinates for inline (receiver) positions with whole station numbers only. The "seismic line" is assumed to be defined by all consecutive receiver positions. Since shot points are often located at inline and lateral offsets from the next receiver position (whole station number) it does not make sense to specify shot point coordinates for shot stations in .COR inline coordinate files. You may specify coordinates for far-offset shot points in .COR files, however. See your \RAY32\DOC\COORDS.COR file for coordinates for \RAY32\LINE14 sample profile. See chapter File formats for more details on COORDS.COR file format.

Inline shot position coordinates at shot stations are obtained by interpolating at the shot station between the two nearest receiver station positions. You may specify *inline and lateral shot point offsets from shot station* and *shot hole depths* in *Header|Shot*.
      Alternatively specify **absolute shot point coordinates at topography** (x, y and elevation of shot point at line topography), shot hole depths and uphole times in a .SHO or .PRN file as shown in \RAY32\DOC sample files. Then import this .PRN or .SHO file by selecting *File|Update header data|Update Geometry...* or *File|Update header data|Update Shotpoint coordinates...* . These offsets will be regarded when estimating weathering velocities and correcting traveltimes for shot position offsets.

If the y coordinate column (and shot hole depth column and uphole time column) of a .PRN file is empty Rayfract® will set the y coordinate of all station positions to 0.0 when such a .PRN file is imported with *File|Update Geometry...* . See sample file LINEBC.PRN in \RAY32\DOC .

Sample file BREAKS.LST contains first breaks for the profile TRA9002 as illustrated in our manual and tutorial chapter. See http://rayfract.com/help/manual.pdf .Values in one line of a first breaks .LST file are supposed to be separated from each other by either one or more TAB characters or by one or more spaces. First breaks in .LST files are supposed to be specified in milliseconds.

If the first (few) line(s) in .PRN, .SHO , .COR and .LST do(es) not contain number formatted data these header lines will be skipped by the corresponding Rayfract® import routines automatically. These header lines may contain column headers/titles etc. If the **word feet or meter** is contained in such a header line of a .PRN, .SHO or .COR file, the shot and receiver positions and coordinates in that file are assumed to be specified in that **distance unit**. See http://rayfract.com/help/ln14feet.zip for sample files specified in feet.
      You may process the binary trace data and pick first breaks with your FIRSTPIX software as published by Interpex. Then import the resulting first breaks with *File|Import Data...* or *File|Update header data|Update from Gremix .GRM files...* . Receiver elevations and shot hole depths are imported from .GRM files automatically as well. If your Rayfract® profile contains shot trace records as recorded with multiple receiver spreads along the same 2D line, just copy all corresponding .GRM files into the same subdirectory and select one of these in the file selection dialog.
      If you have processed your trace data and picked first breaks with SEISREFA as published by OYO you may import the resulting first breaks with *File|Import Data...* . Receiver elevations and shot hole depths are imported from .ODT files automatically as well. *File|Update header data|Update from OYO .ODT files...* lets you update an existing Rayfract® profile with first break data. If your Rayfract® profile contains shot trace records as recorded with multiple receiver spreads along the same 2D line just copy all corresponding .ODT files into the same subdirectory and select one of these in the file selection dialog. It is assumed that one .ODT file lists first breaks recorded with exactly one receiver spread only.

Editing header data

Before importing your data, make sure that you correctly specify the profile's header data in *Header|Profile :*

- ◆ fill in at least *edit fields Line ID, Job ID, Instrument,* and *Station spacing* (in meters).

- ◆ set *Line type* to **Refraction spread/line** for surface refraction profiles or **Borehole spread/line** if receivers are placed in vertical or horizontal borehole. Use arrow up/down keys on your keyboard to toggle this setting. You cannot change *Line type* any longer once you have imported shots into this profile database with *File|Import Data...* .

- ◆ parameter *Station spacing* is of utmost importance because estimated *DeltatV* velocities and layered refraction velocities are based on this distance unit. *WET* velocities depend on source and receiver coordinates only.

- ◆ parameter *Left handed coordinates* lets you specify the orientation of your coordinate system depending on your hemisphere.

- ◆ *Cell size[m]* lets you edit the cell size (Surfer *X spacing* and *Y spacing*) used when generating the starting model with *Smooth invert menu* commands. Check box *Force grid*

cell size to use this *Cell size* next time a starting model is generated.

◆ with *Force grid cell size* not checked we update *Cell size[m]* to the default cell size determined next time a starting model is generated. You can increase or decrease the default cell size with options in menu *Smooth invert|Smooth inversion Settings*.

◆ the uppermost *Select button* lets you specify a profile database with *Line type* **Borehole spread/line** by selecting its **SEIS32.DBD** database schema in its profile subdirectory. First breaks picked for this *Borehole line* are used together with first breaks picked for the *main profile* for joint *WET inversion*.

◆ the three (3) lower *Select buttons* are enabled for our Pro license only. These allow specifying 3 more *Borehole line profiles* for joint *WET inversion*.

◆ close this dialog with ENTER key or click *OK button* to accept the edited settings. Use **ESC** key or *Cancel button* to cancel editing of parameters. Clear out all *Borehole lines* selected with *Reset button*.

◆ now import your data.

◆ see http://rayfract.com/help/manual.pdf for creation of a new profile, data import and typical processing sequences.

Once you have imported your data, inspect shot headers with *Header|Shot* :

Page through shots with *function keys F7/F8*. Adjust fields if required :

◆   *Shot type*   set to *Refraction shot* or *Uphole shot* for *Line type* `Refraction spread/line` & *Downhole shot* or *Crosshole shot* for *Line type* `Borehole spread/line`

◆   *Shot inline offset*   inline offset of the shot point at and along line topography, in meters, from the *shot position* shown in read-only field *Pos.* (in whole station numbers or ending with .5)

◆   *Shot lateral offset*   horizontal offset of the shot point position from the seismic line (i.e. from the spread), in meters

◆   *Shot depth*   shot hole depth, in meters*.* Vertical offset of source from shot point elevation (shotZ at line topography).

◆   *Source Type*   regarded only for traveltime curve coloring in *Refractor|Shot breaks*, with option *Mapping|Color picked curves by source type*.

◆   *Trigger delay*   use this field to interactively shift the shot specific traveltime curve in the *Shot breaks display*. The total time shift is the sum of BOTH *delay time* and trigger delay

Browse the trace headers of the current shot (as selected in *Header|Shot)* with `F7/F8` in *Header|Receiver* :

Edit the first breaks in *edit field First break time*. A first break value of 0 or -1 means no first break picked for this trace. *Receiver offset* values are not regarded during processing at this time.

Elevation specification

To specify elevations for all profile shot and receiver stations, select *Header|Station* :

♦ browse station records with **F7/F8** . If x/y/z are correct already exit with **ESC** key.
♦ otherwise click on button *Reset coordinates and v0*
♦ leave x/y coordinates empty for all stations
♦ enter elevation z for a few non-adjacent stations
♦ you do not need to enter z elevation for all stations
♦ now click on button *Interpolate coordinates and v0*

Reopen the station editor with *Header|Station*. Browse station records with **F7/F8** to check the interpolated elevations. Also, x/y coordinates have been generated automatically.

To specify a known/fixed elevation at more stations before interpolation, you need to first click on *Reset coordinates and v0*. Then reenter the elevation at all relevant stations, and click again on *Interpolate coordinates and v0*.

Alternatively, you can create a **COORDS.COR** coordinate file with *File|Export header data|Export Station Coordinates...* . Edit this **COORDS.COR** file with your favorite text editor e.g. Windows Wordpad or Notepad. See **\RAY32\DOC\COORDS.COR** for a sample file. Next, select *File|Update header data|Update Station Coordinates...*, and select this edited **COORDS.COR** file. Finally, open the station editor with *Header|Station* and browse station records with **F7/F8** to check the updated station coordinates. For description of **COORDS.COR** file format see topic File formats.

When saving the file in Notepad with *File|Save As* in your current directory, specify file name "**COORDS.COR**" including the enclosing "" . This prevents Notepad from appending the **.txt**

extension resulting in file name **COORDS.COR.txt** .
Or select Notepad command *File|Save As*. Now click on field right of label *Save as type* and select option **All files (*.*)** instead of default setting **Text Documents (*.txt)**.
Now set field *File name* to **COORDS.COR** with or without enclosing "" and click *Save button*.

To reopen our **COORDS.COR** file with Notepad select *File|Open*, click on **Text Documents (*.txt)** field at bottom-right of dialog and select **All Files (*.*)**.

You may want to use a better ASCII editor than Notepad. We like Zeus for Windows editor, see http://www.zeusedit.com .

To force ***use of the correct shot point elevation for offset shots*** positioned outside your profile's receiver range :

◆ *File|Export header data|Export Station Coordinates…* and save to **COORDS.COR**

◆ *File|Export header data|Export Shot Point Coordinates…* and save to **SHOTPTS.SHO**

◆ edit **elevation[m]** column of **COORDS.COR** for offset shot station(s) outside profile's receiver range

◆ *File|Update header data|Update Station Coordinates…* with your edited **COORDS.COR**

◆ edit **shotZ[m]** and **holeDepth[m]** columns in **SHOTPTS.SHO** for offset shot station(s)

◆ *File|Update header data|Update Shot Point Coordinates…* with above edited **SHOTPTS.SHO**

Above procedure prevents extrapolation of receiver station coordinates to offset shot points. For more information on **COORDS.COR** and **SHOTPTS.SHO** file formats see chapter File formats. You can also force the elevation of in-spread shot points (preventing elevation interpolation between adjacent receivers) exactly as described above.

Weathering velocity specification

Skip this step for Smooth inversion, and DeltatV and subsequent WET tomography processing. For conventional time-to-depth conversion methods you are required to specify a weathering velocity (e.g. 500 to 800 meters/second) for at least one station, in the *Station & Shot point Editor (Header|Station)*. **Version 2.66 and later versions of our software will copy weathering velocities to station records and correct first breaks for Shot position offset automatically, once you (re)map traces to refractors or smooth crossover distances (*Mapping|Crossover processing)* in *Midpoint breaks display*. So you can skip the following paragraphs.**

Specification of laterally varying weathering velocity is supported. Manually pick *branch points* in the *Shot breaks display*. Interactively map first breaks of the currently selected traveltime curve to refractors, on a segment-wise/branch-wise basis, see Mapping traces to refractors. Once you have picked branch points for all relevant traveltime curves, copy the resulting weathering velocities to all profile stations and shot points, in *Header|Station with button v0 from Shots*

If the traveltime coverage is high enough (if receivers and shot points are spaced close enough to each other), you may alternatively obtain a laterally varying weathering velocity function in the *Midpoint breaks display*. See Mapping traces to refractors. Once you have mapped first breaks to refractors in the *Midpoint breaks display*, select *Header|Station* and click button *v0 from CMP*.

Before you pick first breaks and map traces to refractors in Mapping traces to refractors, check if you specified the correct *shot hole depth and inline / lateral offsets* (in meters) for all shot records. Open your *Shot Editor* with *Header|Shot*, and browse records with **F7/F8**. Next specify appropriate (laterally varying) weathering velocities in your *Station & Shot Point Editor (Header|Station)* as just described. Now compute and apply to first breaks corrections for *Shot position offset* (for inline and lateral offsets / shot hole depth) with button *Correct breaks*, in *Station & Shot Point Editor*. These corrections are computed and applied to first breaks automatically when clicking buttons *v0 from Shots* or *v0 from CMP*.

Once shot position offset corrections have been applied to all traces, redisplay your *Shot breaks display (Refractor|Shot breaks)* or *Midpoint breaks display (Refractor|Midpoint breaks)*. Reopen the display or click on its title bar with your left mouse key and press keys **ALT+Y**. Traveltime curves are now reduced to shapes which you would have recorded with your source located at the same elevation as and aligned with the (adjacent) receivers. First breaks mapped to the weathering layer are corrected according to a different formula than first breaks mapped to refractors. This may lead to the necessity to repick *branch points*, in your *Shot breaks display* or *Midpoint breaks display*. Pick branch point positions such that traveltime curves do not show artefacts of the picking process (irregularities near branch points picked). These artefacts may become visible when first breaks are corrected for shot position offsets and you redisplay the *Shot breaks display* or *Midpoint breaks display*. Once you have repicked branch points, go back into the *Station and Shot Point editor* via *Header|Station*. Click on button *v0 from Shots* or *v0 from CMP*, to recompute and copy velocity values into all station and shot point positions.

When you have carried out time-to-depth conversions and resulting refractor velocities are known, you may remap traces to refractors (*Mapping|Remap all traces*) and redo the time-to-depth conversions. This may result in slightly improved results, especially in situations where velocity contrasts are low.

To undo shot position offset corrections as applied to all traces, select *Mapping|Undo trace mapping and corrections* in the *Shot breaks display* or *Midpoint breaks display*. Or use keyboard shortcut **ALT+U**.

Filtering traces

Since version 3.20 released in September 2011 we allow frequency filtering of traces when displaying *trace gathers* in *Trace menu*. Filtering is done with recursive Chebyshev-Butterworth filter or single-pole filter. For more information on these digital filters see **Steven W. Smith 1997 Digital Signal Processing** and http://www.dspguide.com , chapters 19 and 20. Chebyshev-Butterworth is theoretically more performant but often single-pole works better (less overshoot and ringing of filtered trace), at **low rate of effective signal frequency to seismograph sample rate**. Also, **bidirectional filtering** often gets the first breaks above the noise level, by preserving the original waveform.

For display, traces are first processed with high-pass/low-pass filter, and then with bandpass/band-reject filter, as specified below. Finally other trace processing including AGC is applied, to the filtered traces.

Apply a high-pass or low-pass frequency filter to displayed traces with *Processing|Frequency filter* (ALT+Q) :
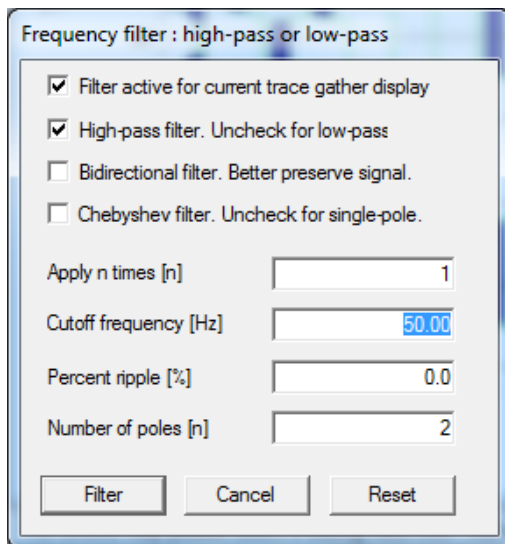
Interactively specify the following parameters :

- *Filter active for current trace gather display*
- *High-pass filter. Uncheck for low-pass*
- *Bidirectional filter. Better preserve signal*
- *Chebyshev filter. Uncheck for single-pole.*
- *Apply n times [n]*
- *Cutoff frequency [Hz]*
- *Percent ripple [%]*
- *Number of poles [n]*

Apply a bandpass or band-reject filter to displayed traces with *Processing|Bandpass filter* (SHIFT+Q) :
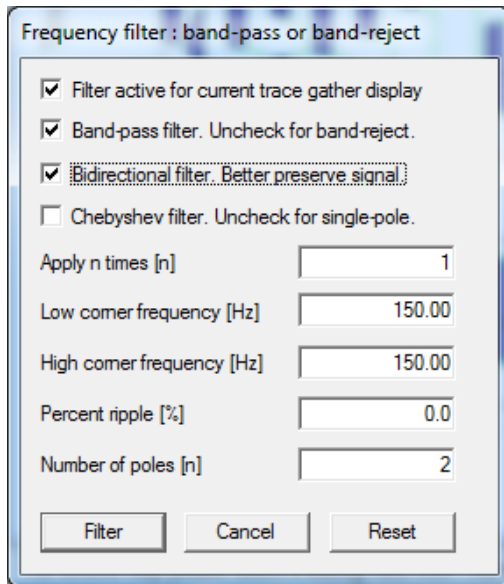
- *Filter active for current trace gather display*
- *Band-pass filter. Uncheck for band-reject*
- *Bidirectional filter. Better preserve signal*
- *Chebyshev filter. Uncheck for single-pole.*
- *Apply n times [n]*
- *Low corner frequency [Hz]*
- *High corner frequency [Hz]*
- *Percent ripple [%]*
- *Number of poles [n]*

Traces are filtered for display only. Traces stored in the profile database remain the original raw, unfiltered traces.

You may **process traces for enhanced visibility of first breaks** with *Processing|Trace processing* (ALT+M) :
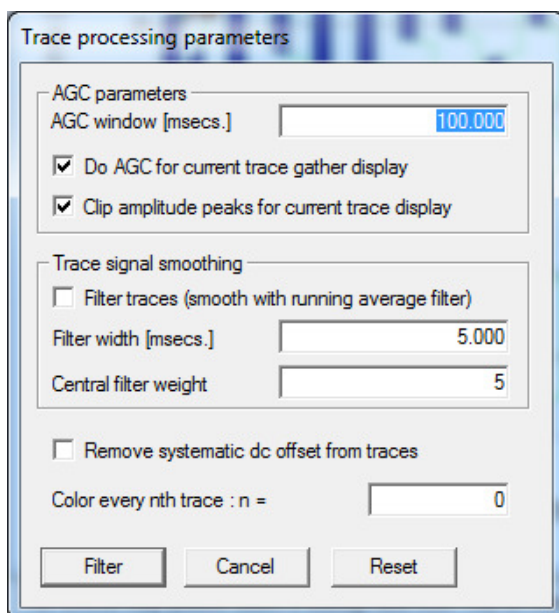
Interactively specify the following parameters :

- *AGC window*   AGC window length in ms
- *Do AGC for current trace display*   Check this to enable AGC
- *Clip amplitude peaks for current trace display*   trace signals are displayed with peaks and troughs clipped.
- *Filter traces*   running average smoothing filter, with filter width and central sample weight as specified with the following two parameters
- *Filter width*   filter width of the running average smoothing filter to be applied to trace signals, in milliseconds
- *Central filter weight*   weight applied to central sample of current trace sample time window
- *Remove systematic dc offset from traces*   remove systematic dc offset signals from traces

Again, traces are processed for display only. Traces stored in the database remain the original, unprocessed/raw traces, as imported from your seismograph.

Stack imported shots in profile database

Stack two imported shots with *Processing|Stack shots...* (SHIFT+A) in *Trace|Shot gather display* :
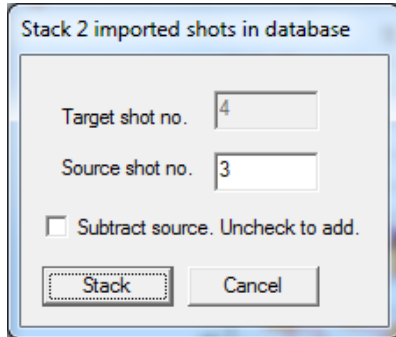
Specify these parameters :

- *Target shot no.*   shot number which is updated in profile database. Select with F7/F8 in *Trace|Shot gather*.
- *Source shot no.*   shot number which is added to or subtracted from *Target shot no.* Enter source shot number in this field.
- *Subtract source. Uncheck to add.*   leave unchecked to add *Source shot no.* to *Target shot no.* when stacking the two shots. Check to subtract source from target.

When stacking these two shots we regard the *Trigger delay* specified in *Header|Shot*.

For resampling of shots and conversion between SEG-2 and SEGY etc. try the free Geogiga Front End, available at http://geogiga.com/en/frontend.php . Write the processed shots to SEG-2 files and import with our software.

Picking first breaks

Select *Trace|Shot gather* :
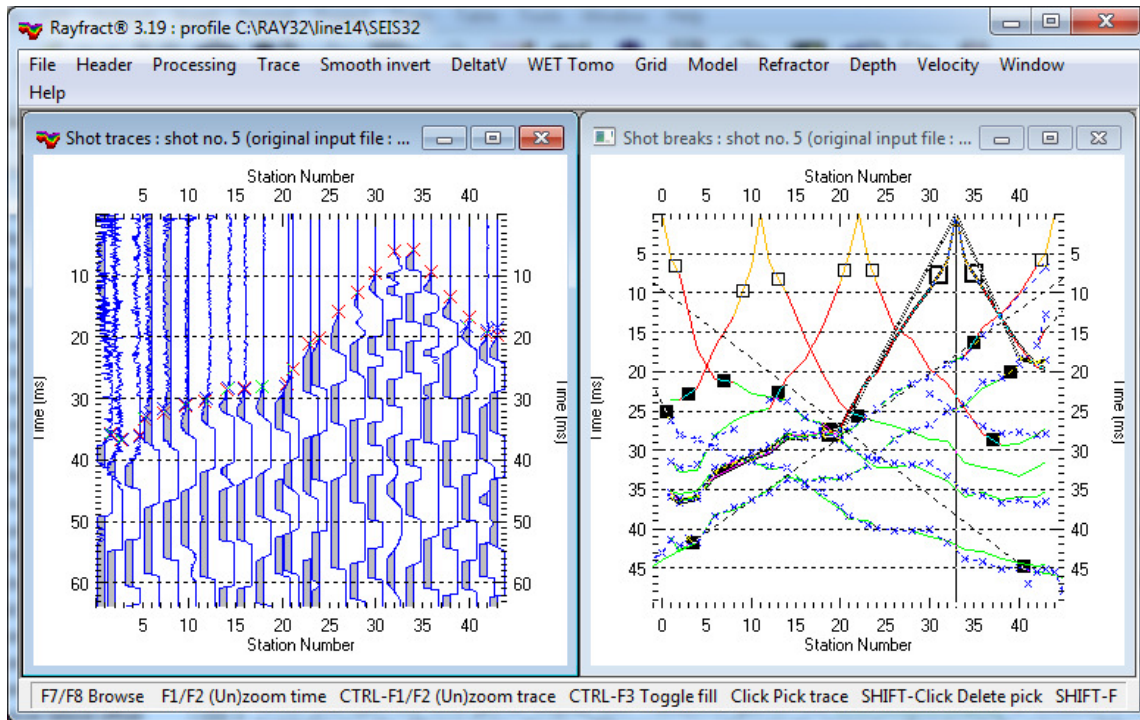
- ◆ browse shot records with function keys F8 (forward) and F7 (reverse)
- ◆ zoom/unzoom traces in the amplitude coordinate with function keys CTRL+F1/CTRL+F2
- ◆ toggle trace display modes with CTRL+F3
- ◆ zoom/unzoom the vertical time scale with F1/F2
- ◆ page down the zoomed time axis by one section with PgDn
- ◆ page up the zoomed time axis by one section with PgUp
- ◆ zoom/unzoom the horizontal station number axis with SHIFT+F1 and SHIFT+F2
- ◆ page left one zoomed gather section with SHIFT+PgUp
- ◆ page right one zoomed gather section with SHIFT+PgDn

See Dialog box control and function keys, for a complete listing of function keys and their functionality.

Color traces

Color traces in *Trace menu gather displays*, with options in menu *Processing* :

Standard 3.31 : profile C:\Ray331\line14\SEIS32

| | Processing | Trace | Smooth invert | DeltatV | WET Tomo | Grid |

	Scale trace to integer before processing	
	Trace processing...	ALT+M
	Process before filtering	
	Frequency filter...	ALT+Q
	Bandpass filter...	SHIFT+Q
	Trace display...	ALT+P
	Edit offset range, disable offset zoom	ALT+N
✓	Edit time window, disable time zoom	ALT+I
	Trace annotation...	ALT+A
	Reverse trace polarity	SHIFT+L
	Reverse shot polarity	ALT+L
	Stack shots...	SHIFT+A
	Automatic picking of first breaks...	ALT+B
✓	Display raytraced traveltimes	ALT+T
	Enable polyline picking	ALT+E
	Delete picks for all traces of shot	SHIFT+Z
✓	Color traces	ALT+C
	Color traces by source type	ALT+S
✓	Color trace outline	ALT+O
	Red trace outline	ALT+R
	Show picks on time axis	ALT+X
	Use red cross for picked first breaks	ALT+U
✓	Solid color pick display	ALT+D
	Picks always cover traces	ALT+V
✓	Check shot position when picking traces	ALT+K
	Refresh shot breaks when picking traces	
	Pick all shots, in shot point gather	
	Refresh breaks display...	ALT+Y

◆ Color the variable trace area filling with *Processing|Color traces*
◆ Color the trace outline with *Processing|Color trace outline*.
◆ *Processing|Color traces by source type* colors shot traces by *source type*, as selected in *Header|Shot*.

Since version 3.20, above *trace display* settings and following *trace filtering* and *trace processing* settings are stored separately in your profile database, for each gather type (shot-sorted, midpoint-sorted, offset-sorted, shotpoint-sorted, receiver-sorted). Also, these settings

are restored whenever you reopen this profile database via *File menu*, and when you reopen these gather type displays with *Trace menu*.

Pick and delete first breaks & navigate traces and samples with keyboard or mouse

◆ move the *picking cursor* ("plus" symbol) along the currently selected trace outline with up-arrow and down-arrow keys. Move the cursor to next left/right trace with left-arrow and right-arrow keys.

◆ hit the *space bar key* to pick the first break for the current trace, at the current sample (as indicated at bottom of display)

◆ pick with the *left mouse key* to first select current trace and sample and then pick the first break at that position, in one operation

◆ delete the first break pick for the current trace, with ALT+DEL or ALT+Z. Use *SHIFT+left mouse key* to first select the trace and then delete the pick for that trace, in one operation

◆ use SHIFT+Z keyboard shortcut, to delete first break picks for all traces of the current shot

Trace cursor attributes are shown at bottom of trace gather display, when moving the pick cursor with left/right/up/down arrow keys. We show station number, gather specific trace number, shot number, channel number, sample number, time and amplitude attributes .

SHIFT+L keyboard shortcut lets you *reverse polarity of current trace* in *Trace menu gather displays*. Select the current trace with arrow-left and arrow-right keys.

When you open the *Shot gather display* with *Trace|Shot gather*, the *Shot breaks display* is rendered in the lower half of your display. Select *Window|Tile* for above side-by-side window display. The traveltime curve corresponding to the currently selected shot gather is highlighted in the *Shot breaks display*. Whenever you interactively (re)pick a first break for a trace of the current shot gather, that traveltime curve is redisplayed automatically. If you selected branch points for that traveltime curve before repicking first breaks, automatic branch point validation is carried out while redisplaying the traveltime curve. To redisplay the whole *Shot breaks display*, press keys ALT+Y (*Processing|Refresh breaks display*). You may zoom up the *Shot gather display* to fill the whole screen by double-clicking on its title bar with your left mouse key. Double-click on the main Rayfract® title bar as well to maximize its size.

Make sure that **picked traveltime curves for adjacent shots are at least somewhat similar to each other**, when reviewing them in our *Refractor|Shot breaks display*. See our tutorials at http://rayfract.com/tutorials/TUTORIAL.ZIP and http://rayfract.com/SAGEEP10.pdf for typical traveltime curve sections. Refraction tomography is based on the assumption that subsurface physical properties (related to propagation speed of seismic waves) have a quasi-continuous nature and do not vary randomly on a small scale. Since first break energy incited at adjacent shot points propagates through the subsurface along similar wave paths and rays, the measured and picked traveltime curves for these shots should be similar.

Traces in *Trace menu displays* are shifted by *delay time* and *trigger delay*, as specified in *Header|Shot* . This lets you interactively correct shots for reciprocal errors caused by trigger delays, visible in our *Trace|Offset gather display*. For tutorials showing how to identify reciprocal picking errors see

http://rayfract.com/tutorials/riveral8.pdf and http://rayfract.com/samples/GEOXMERC.pdf.

Automatic picking

Do semi-automatic first break picking with *Processing|Automatic picking* (ALT+B) :

Edit these parameters :

- *Search window width*
- *Minimum propagation velocity*
- *Maximum propagation velocity*
- *First break envelope length*
- *First break stabilization factor.*

For context-sensitive help on these parameters, tab to the dialog control of interest and then press F1.

Once you have specified appropriate parameter values, hit enter key to carry out the semi-automatic picking. In situations of strong pre-first break noise or weak first break signals, adjust parameters *First break envelope length* and *First break stabilization factor.*

Polyline-guided picking

With noisy traces you can force first breaks picked automatically to be located in the vicinity of a polyline consisting of multiple straight line segments connected to each other, picked interactively with the right mouse button. Move the mouse cursor to the trace located closest to the shot point position, positioning it at a vertical time offset approximating the visually estimated first break time. Then click the right mouse button once. Now move the mouse away from the shot point, i.e. to the left for reverse shots and to the right for normal (forward) shots. Try to follow the visually estimated positions of first breaks, for the traces being crossed with the mouse. Once you detect a systematic change of slope of that direction, click the right mouse button a second time, to define the first line segment of the polyline. Once you have done so, automatic picking will be carried out for all traces located in the offset range covered by that line segment. For each such trace, the pick search window will be centered at the linearized time just picked. The window's width will be limited to parameter

Search window width, as specified above.

Once these traces have been picked for the first line segment, you may define further line segments of the same polyline by moving the mouse still further away from the shot position, and clicking the right mouse button at appropriate offsets. Whenever a new line segment has been picked by you in such a way, the traces recorded at offsets covered by that segment will be picked automatically, as just described for the first segment. Terminate the polyline picking process by clicking the left mouse button. Please note that parameters *First break envelope length* and *First break stabilization factor* are regarded during this picking process, while parameters *Minimum propagation velocity* and *Maximum propagation velocity* have a meaning if no linearized time has been defined for a trace by picking such a polyline only. In case of low signal to noise ratio or bad traces, we advise to set parameter *Search window width* to its minimum value of 0.1 msec.

Recompute depth and velocity sections after repicking traces or remapping refractors

Whenever you repick a first break or remap traces to refractors, all depth and velocity sections computed previously are invalidated. If such sections are currently displayed, these windows are shut down automatically. To recompute and redisplay these depth and velocity sections, remap all traces to refractors by selecting Mapping|Remap all traces in your Shot breaks display or Midpoint breaks display. Then optionally update the weathering velocity specification in Header|Station. Now reselect the appropriate items in the Depth menu and Velocity menu.

Select Mapping|Undo trace mapping and corrections in your *Shot breaks display* or *Midpoint breaks display* to internally reset the trace to refractor mapping for all traces and to reset first break corrections for shot position offsets and shot hole depths as computed and applied previously. This gives you the option to restart the weathering velocity estimation and subsequent correction of traveltimes for shot position offsets and hole depths from a clean slate.

Select Mapping|Display regressed traveltimes in your *Shot breaks display* to show synthetic traveltimes for the basement (deepest refractor) as computed from the traveltime field characteristic functions resulting from the traveltime field regression (as described by Brueckl, E. 1987). This regression is carried out automatically whenever you redo the Wavefront or Plus-Minus time-to-depth conversion after selecting Mapping|Remap all traces as described above.

Instead of picking first breaks in the *Trace|Shot gather display*, you may pick in *Trace|Offset gather display*. Use arrow keys as described above, for trace and sample navigation. Color traces with menu items in *Processing menu*. Do frequency filtering, bandpass filtering and trace processing as in *Trace|Shot gather display*. For identification and correction of reciprocal traveltime errors, see http://rayfract.com/tutorials/riveral8.pdf and http://rayfract.com/samples/GEOXMERC.pdf . You may repick individual traces, or correct the *trigger delay* for whole shots, in **Header|Shot** .

Picking of shear-wave records, with sign-inverted traces recorded for the same shot point, is easy with our *Trace|Shot point gather display* and appropriate trace coloring with our *Processing menu*.

Use SHIFT+S keyboard shortcut to export first breaks to .LST, in *Trace menu* and *Refractor menu displays*. The current trace gather display or refractor display will stay open. This allows you to quickly save different picking versions to .LST .

Smooth inversion

Version 2.51 and later versions of our software implement a fail-safe "Smooth inversion" option, for fully automated determination of a 1D initial model and subsequent refinement with WET tomography processing.

Start this inversion with *Smooth inversion|WET with 1D-gradient initial model* :
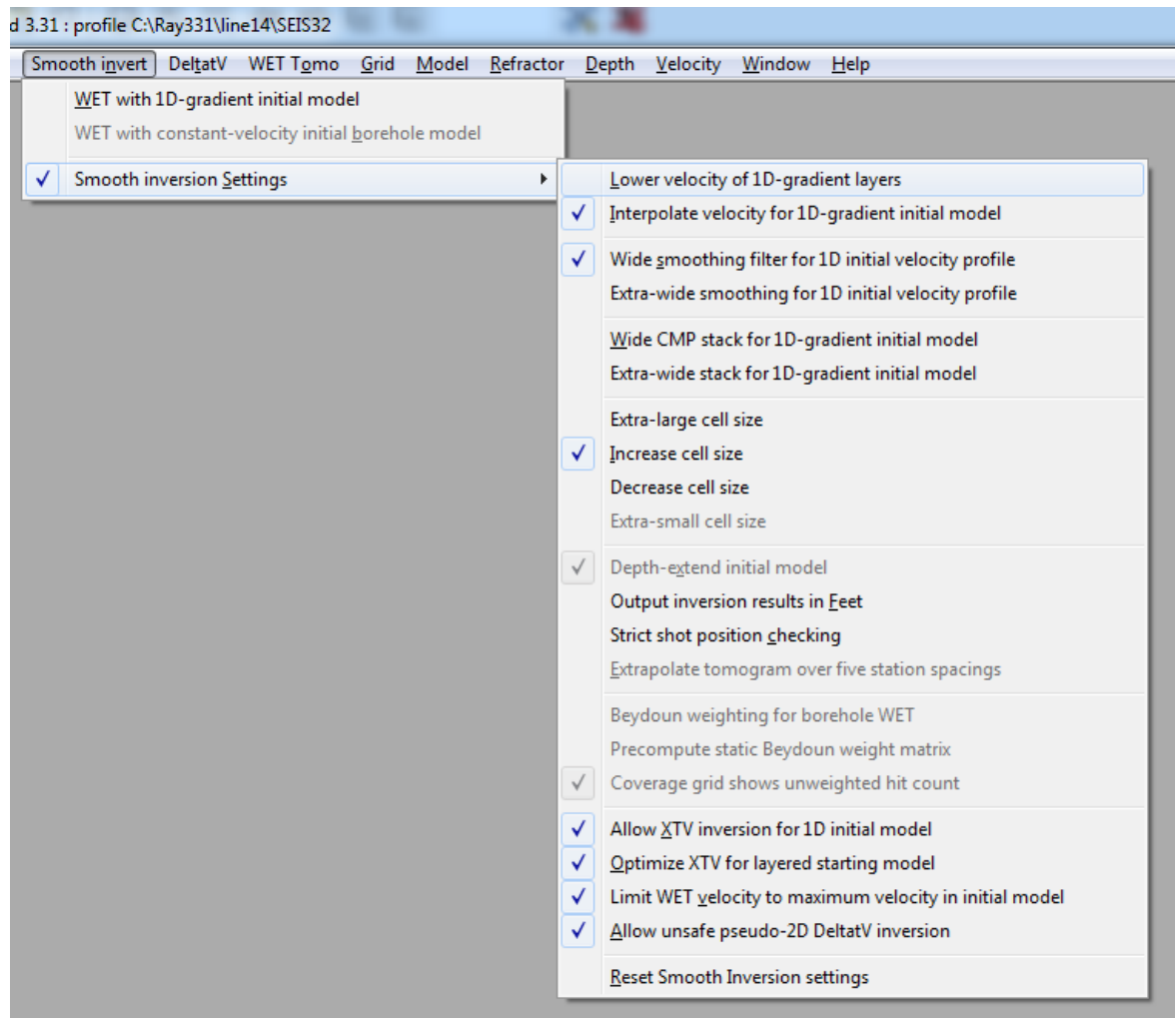
Wait for scripting to plot the **initial 1D model** in Golden Software Surfer®. Click on Surfer icon at bottom of screen to display this :
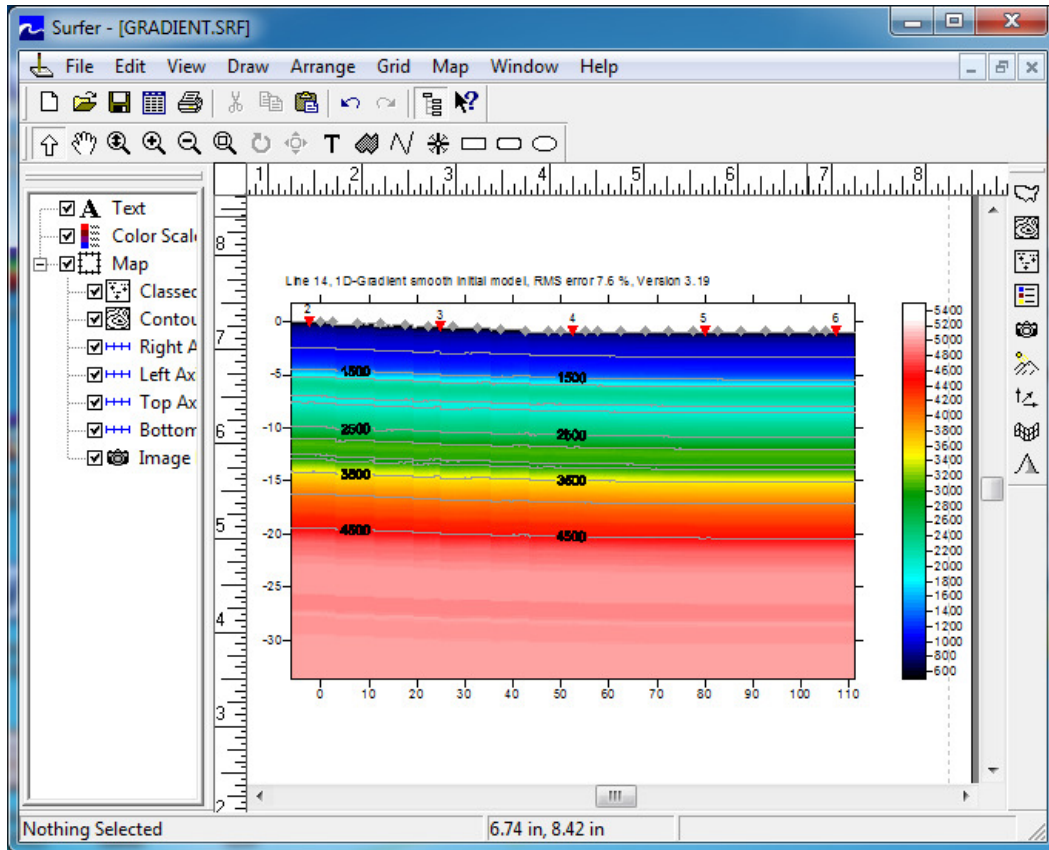
Next click on Rayfract® icon at bottom of screen, and confirm this prompt :
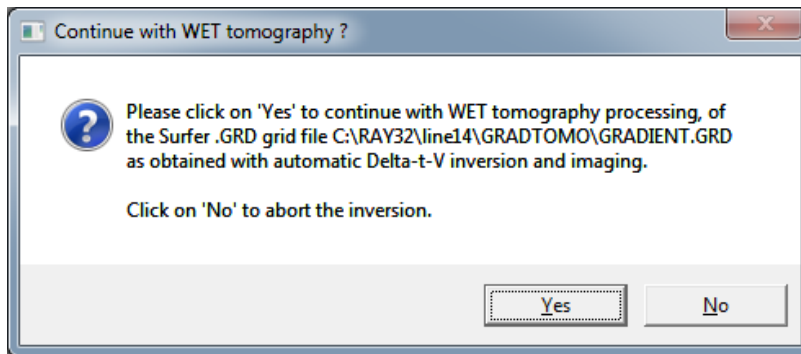
Once WET finishes, confirm the two prompts to automatically display the resulting **WET tomogram** in Golden Software Surfer® :
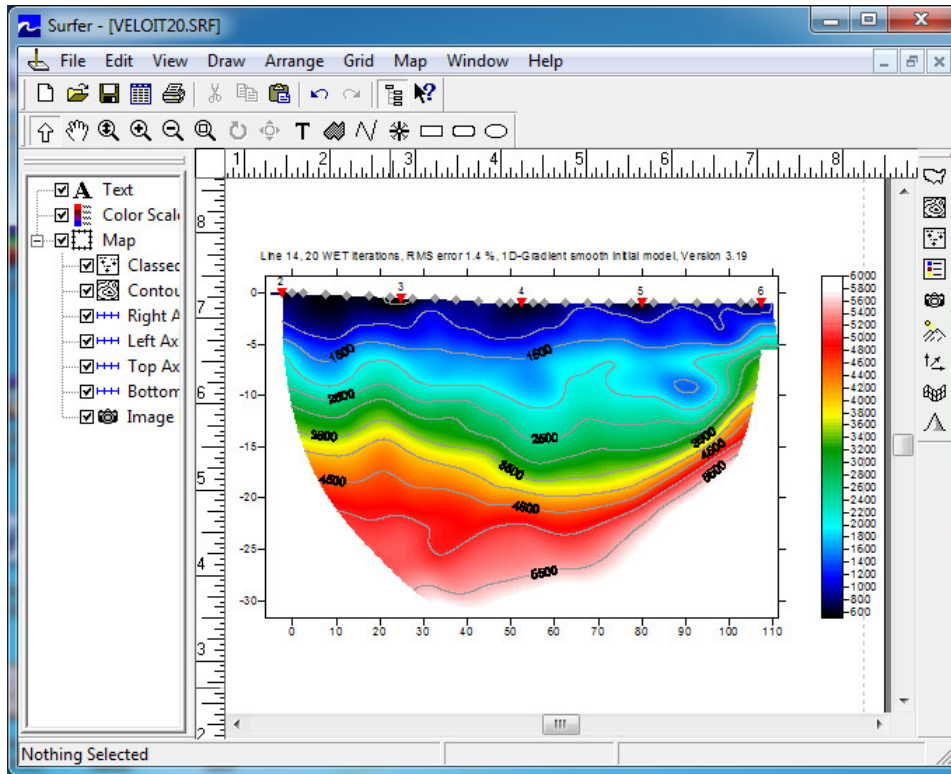
Use CTRL+TAB key combination in Surfer®, to view **WET wavepath coverage plot** :
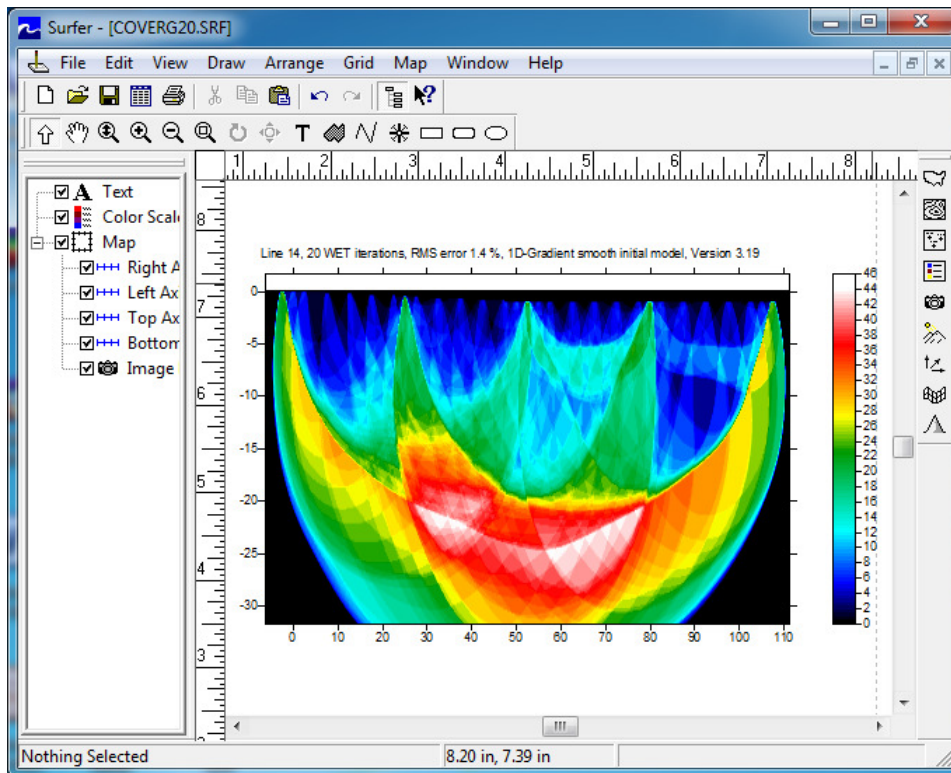
Select *Refractor|Shot breaks* in Rayfract® software, to check match between modeled (dashed blue) and picked (solid grey or colored) traveltime curves :
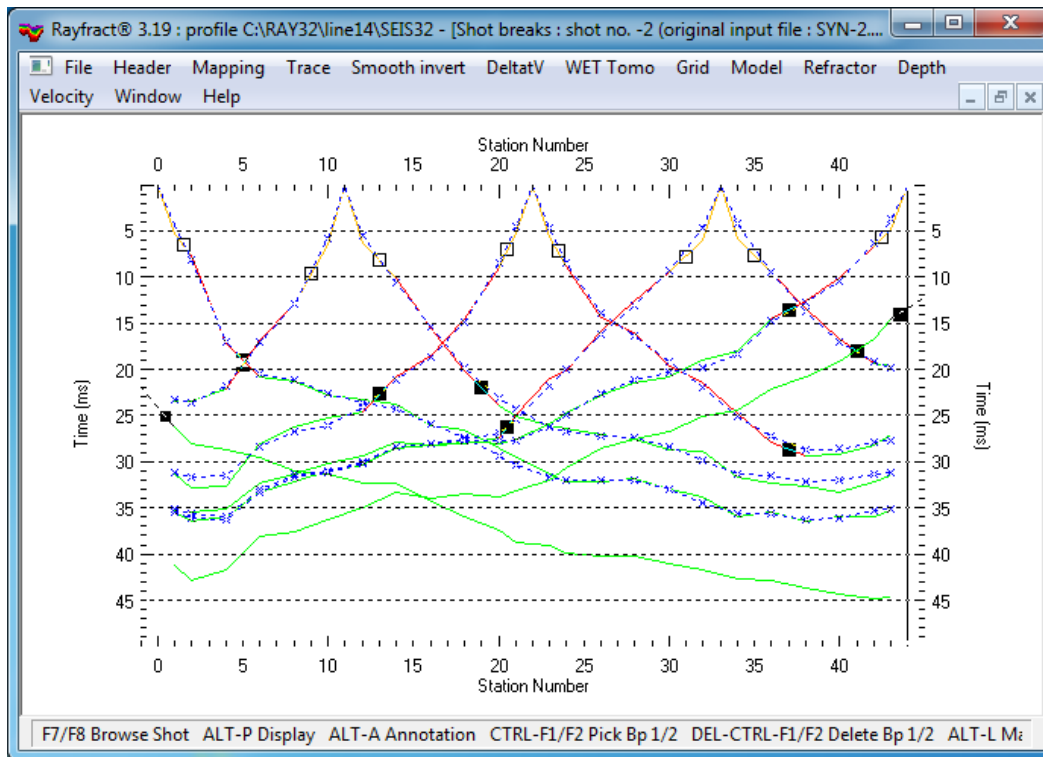
1D initial model

The 1D initial model guarantees that pseudo-2D DeltatV velocity artefacts (occurring e.g. in situations of strong refractor curvature / strong lateral velocity variation) are virtually eliminated from the interpretation at an early stage. The **pseudo-2D DeltatV initial model as determined with our DeltatV inversion will show systematic velocity artefacts : too low velocity below anticlines and too high velocity below synclines**. The 1D initial model still shows a good initial traveltime fit, between measured and picked times. This artefact-free simple initial model and good initial fit is required for WET true 2D tomography processing to have a chance to converge towards a meaningful final model. The simple smooth starting model ensures that WET inversion can find the global traveltime misfit minimum and does not get stuck in a local minimum of the misfit function.

The 1D initial model is determined automatically as follows :

◆   first the pseudo-2D DeltatV initial model is determined. This will give individual velocity vs. depth profiles below each profile station

◆   then the average velocity vs. depth profile is determined by horizontally averaging velocities of the pseudo-2D DeltatV initial model over all profile stations, at common depths

◆   finally this averaged velocity vs. depth profile is extended laterally along the whole profile. A 1D velocity grid is generated based on these average velocities.

◆   XTV inversion is disabled automatically during this procedure if *Smooth invert|Smooth inversion Settings|Allow XTV inversion for 1D initial model* is unchecked

See our short manual and tutorial at http://rayfract.com/help/manual.pdf for more processing sequences.

   For an alternative **description of Smooth inversion and WET parameters and options** see our SAGEEP 20110 short course notes http://rayfract.com/SAGEEP10.pdf .

Smooth inversion Settings

Here we list options offered in *Smooth invert|Smooth inversion Settings menu* :
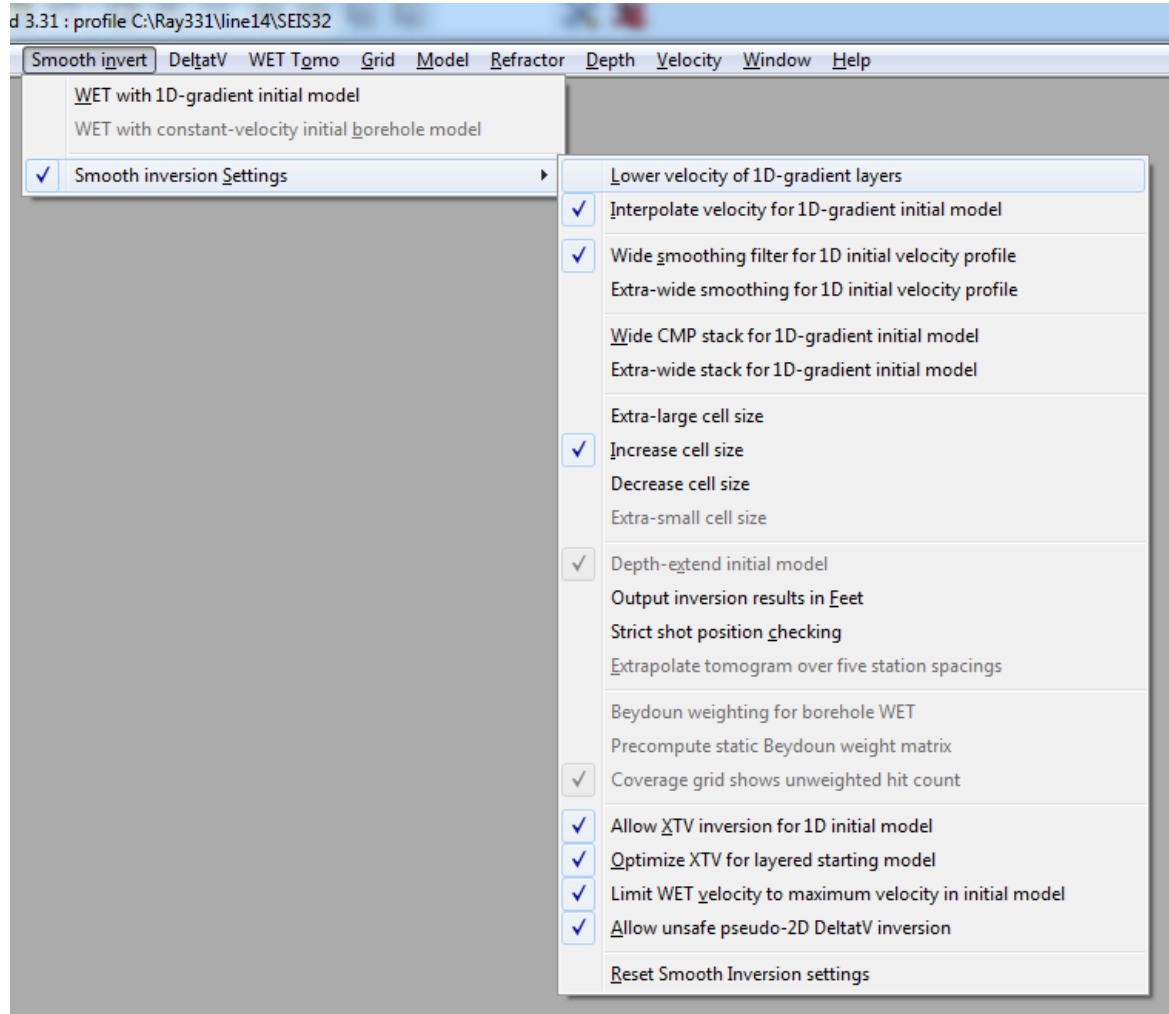
- ◆ *Lower velocity of 1D-gradient layers*
- ◆ *Interpolate velocity for 1D-gradient initial model*
- ◆ *Wide smoothing filter for 1D initial velocity profile*
- ◆ *Wide CMP stack for 1D-gradient initial model*
- ◆ *Extra-wide stack for 1D-gradient initial model*
- ◆ *Extra-large cell size*
- ◆ *Increase cell size*

- *Decrease cell size*
- *Extra-small cell size*
- *Edit cell size*
- *Depth-extend initial model*
- *Output inversion results in Feet*
- *Strict shot position checking*
- *No shot position checking*
- *Beydoun weighting for borehole WET*
- *Precompute static Beydoun weight matrix*
- *Coverage grid shows unweighted hit count*
- *Allow XTV inversion for 1D initial model*
- *Optimize XTV for layered starting model*
- *Limit WET velocity to maximum velocity in initial model*
- *Allow unsafe pseudo-2D DeltatV inversion*

Vary WET inversion parameters

Once you have completed the first run of our Smooth inversion with default parameters you may want to run our WET true 2D tomography processing a second time. Specify the same GRADIENT.GRD 1D initial model but increase the *WET iteration count* to e.g. 50 or 100 iterations. See our tutorial http://rayfract.com/SAGEEP10.pdf and (Tassis et al. 2017). Increasing the WET iteration count and decreasing WET smoothing typically helps **to increase the vertical and lateral velocity resolution** e.g. to obtain a sharper velocity contrast between imaged overburden and basement. Velocity inversions and horizontal velocity variation may be easier to recognize with an increased WET iteration count and optimized WET smoothing.

Increase the *WET wavepath width* for more smoothing in case of uncertain first break picks and noisy traces to avoid over-interpretation of the data and artefacts due to bad picks. Bad first break picks may lead to wavepaths becoming engraved in the WET velocity tomogram for the source-receiver pairs corresponding to these bad traces. Also increase the *wavepath width* if the wavepath coverage plot shows black regions without wavepaths. Increasing the *wavepath width* has the same result as decreasing the *WET frequency* i.e. the *Central Ricker wavelet frequency.*

Velocity artefacts are unrealistic imaged velocity variations caused by the imaging algorithm and not by the input traveltime data. These variations are not necessary to explain the measured and picked input data. The goal is to explain traveltimes with minimum-structure models without artefacts.

For a peer-reviewed third-party evaluation of our Smooth inversion method, see

http://rayfract.com/pub/srt_evaluation.pdf   .

This benchmark study by Jacob Sheehan et al. entitled "An Evaluation of Methods and Available Software for Seismic Refraction Tomography Analysis" has been published in the March 2005 issue of EEGS Journal of Environmental & Engineering Geophysics, ISSN-1083-1363. The paper compares our Rayfract® software and Smooth inversion method with Geometrics/OYO SeisImager and GeoTomo LLC GeoCT-II.

http://rayfract.com/papers/Thesis_Report_Stefan_Jansen_20110105.pdf (Jansen, 2010) evaluates our Smooth inversion method with synthetic data for models of faults and small velocity anomalies in Appendix C. Wavepath width used in Appendix E is too narrow for reliable interpretation with our software. Please use the default WET wavepath width or even increase this for the WET inversion to have a chance to robustly converge towards a meaningful interpretation, especially in case of bad picks.

If initial processing with our Smooth inversion method indicates a sub-horizontally layered subsurface geology without strong refractor relief try our DeltatV based WET inversion and compare the resulting interpretations. Be aware that DeltatV usually generates more artefacts and is less reliable than Smooth inversion.

Check option *WET Tomo/WET tomography Settings/Scale WET filter height* for better overburden resolution and less artefacts at bottom of tomogram.
Check option *WET Tomo/WET tomography Settings/Scale wavepath width* for better overburden resolution for long profiles. Uncheck this option for short profiles with 48 or less receivers, in case of strong topography and for wide shot spacing.

For comparison of 1D initial model based WET inversion with pseudo-2D DeltatV based WET inversion see our tutorials

http://rayfract.com/tutorials/broadepi.pdf
http://rayfract.com/tutorials/depress.pdf
http://rayfract.com/tutorials/palmfig3.pdf
http://rayfract.com/tutorials/fig9inv.pdf
http://rayfract.com/tutorials/epikinv.pdf

Since our Smooth inversion is based on our pseudo-2D inversion, both methods share some parameters. E.g. to limit the maximum velocity exported by DeltatV :

◆ select *DeltatV/Interactive DeltatV/Export Options* and adjust edit field *Max. velocity exported*.
◆ change this field e.g. to 3,000 m/s from default 5,000 m/s. Confirm with *Accept button*.
◆ you don't need to complete the pseudo-2D inversion; click on *Cancel button* to skip the inversion.
◆ now run our Smooth inversion with *Smooth invert/WET with 1D-gradient initial model*

This low-pass velocity filter helps to **eliminate horizontal layering artefacts in the 1D initial model**, mainly in the basement.

To generate tomograms in feet, select *Smooth invert/Output inversion results in Feet*. For borehole WET options see topic Crosshole survey interpretation.

Review DeltatV and WET settings in .PAR file

To **check the DeltatV and WET settings used for your Smooth inversion** review ASCII text file \RAY32\<your profile name>\GRADTOMO\VELOIT20.PAR generated for the last WET iteration number 20 :

◆ select *Start|Run...,* enter command line "Notepad" (without the enclosing "") and hit ENTER

◆ select *File of type* option *All Files* in the Notepad Open dialog

◆ open this file VELOIT20.PAR in your \RAY32\<your profile name>\GRADTOMO subdirectory

◆ close Notepad before running WET again to avoid deadlocks when WET or forward modeling or grid imaging routines try to access this .PAR file

Identify and fix bad shot positions

Smooth inversion and forward modeling check if shots are positioned at traveltime curve minima. If not so processing stops with this error message :
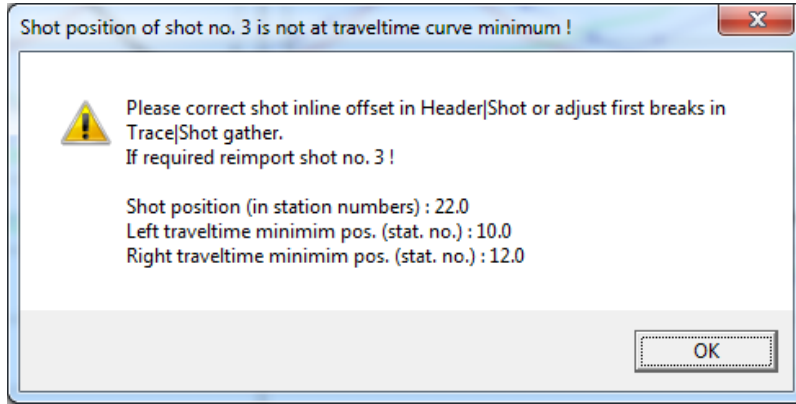
To identify and fix bad shot positions :
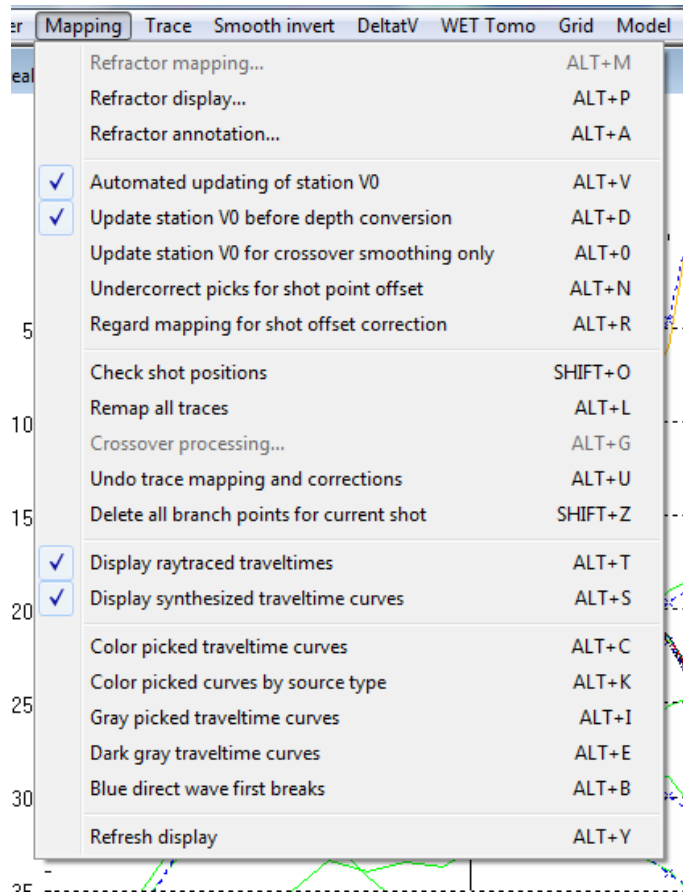
◆ first backup your first break picks to an .LST file with *File|Export header data|Export First Breaks…*

- select *Refractor|Shot breaks*
- uncheck *Mapping|Display raytraced traveltimes*
- uncheck *Mapping|Display synthesized traveltime curves*
- optionally check *Mapping|Gray picked traveltime curves*
- use F7/F8 to browse picked traveltime curves
- the vertical pick bar indicates the *shot position* you specified during import
- so a bad *shot position* shows as a horizontal offset between traveltime curve minimum and pick bar
- use SHIFT+O keyboard shortcut for *Mapping|Check shot positions* for automatic checking
- use *Smooth invert|Smooth inversion Settings|Strict shot position checking* for more accurate checking with above SHIFT+O command in *Refractor|Shot breaks display*
- reimport identified bad shot(s) with correct *shot position* or repick traces for bad shot(s) in *Trace|Shot gather display*
- *Header|Shot|Shot inline offset* (relative to *shot station*) may be set to maximally plus/minus one *station spacing* as defined in *Header|Profile*. If you need to change the *inline offset* to a larger amount, reimport the shot with corrected *shot position* (in station numbers).
- to reimport shots with changed *shot position* or *layout start* and **keep current first break picks**, first store picks to .LST with *File|Export header data|Export First Breaks…* . Now reimport the shots. Next select *File|Update header data|Update First Breaks…* and specify the .LST just generated.
- as a last resort check *Smooth invert|Smooth inversion Settings|No shot position checking*

Custom 1D-gradient velocity profile & starting model limits

Since version 3.35 command *Smooth invert|WET with 1D-gradient initial model* generates a file C:\RAY32\<your profile name>\GRADTOMO\1DVELO.TXT . 1DVELO.TXT contains the averaged 1D velocity profile (velocity vs. depth below topography) obtained by horizontally averaging velocities of the pseudo-2D DeltatV initial model over all profile stations, at common depths.

To replace above computed 1D velocity profile with your custom profile select *Smooth invert|Custom 1D-gradient velocity profile* :

Edit these parameters :

- ◆ *Force grid limits* : check to regard the following limits when generating the GRADIENT.GRD or CONSTVEL.GRD starting model for *Smooth inversion*
- ◆ *Reset limits to grid* : click to select a .GRD velocity tomogram created earlier in ...\GRADTOMO or ...\TOMO or ...\HOLETOMO subdirectories
- ◆ *Grid bottom elevation* : edit bottom elevation[m] for GRADIENT.GRD or CONSTVEL.GRD starting model for *Smooth inversion*
- ◆ *Grid top elevation* : edit top elevation[m] for starting model .GRD
- ◆ *Left limit of grid* : edit left limit of grid[m] for starting model .GRD
- ◆ *Right limit of grid* : edit right limit of grid[m] for starting model .GRD
- ◆ *Replace velocity active* : use velocity profile selected with button *Select velocity profile* to generate GRADIENT.GRD starting model
- ◆ *Select velocity profile* : click to select a .TXT velocity profile with columns depth below topography and velocity
- ◆ *Velocity profile* : enter .TXT filename containing velocity profile including disk drive and whole path
- ◆ *Force constant velocity* : check to use value entered for following field *Forced velocity* when generating the CONSTVEL.GRD starting model

◆   *Forced velocity*   : edit velocity to be used when generating the
    CONSTVEL.GRD starting model

Check box *Replace velocity active*, click *button OK* and select *Smooth invert|WET with 1D-gradient initial model* to

◆   write the averaged DeltatV velocity vs. depth profile to file …\GRADTOMO\1DVELO.TXT
◆   read in your custom .TXT velocity profile specified in above dialog shown with *Smooth invert|Custom 1D-gradient velocity profile*
◆   interpolate your velocity profile to all depths in 1DVELO.TXT & use this to compute the GRADIENT.GRD with topography varying along your line
◆   write the interpolated custom velocity vs. depth profile to file …\GRADTOMO\1DUSER.TXT
◆   plot the generated GRADIENT.GRD in Surfer as usual

Dynamic Poisson's ratio imaging

We show imaging of dynamic Poisson's ratio based on Smooth inversion of P-wave and S-wave data recorded along the same profile in

http://rayfract.com/tutorials/poisson.pdf   .

This tutorial shows how to image a function based on two variables (i.e. the P-wave velocity grid and the S-wave velocity grid) using Surfer® Grid Math. See your Surfer® 8 manual chapter 18 for more details on grid operations such as Grid Math.

To determine the elastic constants (R.E. Sheriff "Encyclopedic Dictionary of Exploration Geophysics") you need an estimate of the density. This can be obtained with empirical formulas e.g. Gardner's Equation estimating density rho from P-wave velocity Vp :

rho = 0.31 * pow(Vp, 0.25)

with Vp in m/s and rho in g/cm3 . See https://en.wikipedia.org/wiki/Gardner%27s_relation

and http://www.crewes.org/ForOurSponsors/ResearchReports/1991/1991-17.pdf .

Next you can obtain Shear Modulus G from shear wave velocity Vs and density rho according to Sheriff :

Vs = pow(G/rho, 0.5) gives
G = pow(Vs, 2.0) * rho

Now you can obtain other elastic constants (Young's modulus E, Bulk modulus k, Lame's Landa constant) from Poisson's Ratio and Shear Modulus. See formulas in

R.E. Sheriff "Encyclopedic Dictionary of Exploration Geophysics", SEG Tulsa OK ISBN 0-931830-31-3 under entry Elastic Constants and

http://li.mit.edu/Archive/Links/iso_elast_const/index.html and
http://www.efunda.com/formulae/solid_mechanics/mat_mechanics/calc_elastic_constants.cfm

. You can use Surfer Grid Math to transform P-wave velocity 2D grid to density grid, S-wave velocity grid to Shear Modulus grid etc. as in above Poisson.pdf tutorial.

Finally you can image obtained 2D .GRD grids for above elastic constants with Surfer Map|Image Map command.

Crosshole survey interpretation

Since version 3.01 we support crosshole traveltime tomography based on a constant-velocity initial model which is iteratively refined with WET Wavepath Eikonal Traveltime tomography processing.

After creating the profile database with *File|New Profile…* set *Line type* to **`Borehole spread/line`** in *Header|Profile* before importing any shots. For this line type **all source and receiver coordinates must be strictly 2D** with y coordinate reset to 0.0 and assumed equal 0.0 at all times.

We support importing SEG-2, SEGY, GeoTomCG .3DD and ASCII.ASC formatted shot files into *Line type* **`Borehole spread/line`** .

Tutorial http://rayfract.com/tutorials/mdw2011.pdf shows creation of a profile database for crosshole survey. Next mdw2011.pdf shows import of SEG-2 borehole receiver traces. You need to specify *Default spread type*, *Layout start* and *Shot pos.* as usual.

For crosshole interpretation of GeoTomCG .3DD formatted data see tutorial
http://rayfract.com/tutorials/igta13.pdf

Our tutorial http://rayfract.com/tutorials/KING17.pdf shows interpretation of first breaks recorded with receivers located in three boreholes. This tutorial requires our Pro license.

In dialog *Header|Profile* you can add up to four (4) **`Borehole spread/line`** profiles to your main profile using our Pro license. With our Standard license you can add one **`Borehole spread/line`** only.

Before importing a GeoTomCG .3DD survey file listing receivers in multiple boreholes (with all y coordinates equal 0.0) you need to split the .3DD into multiple .3DD files such that all traces contained in one .3DD are recorded with receivers located in the same **`Borehole spread/line`** or along the same **`Refraction spread/line`**.

Set shot station to active receiver station for Line type Borehole spread/line
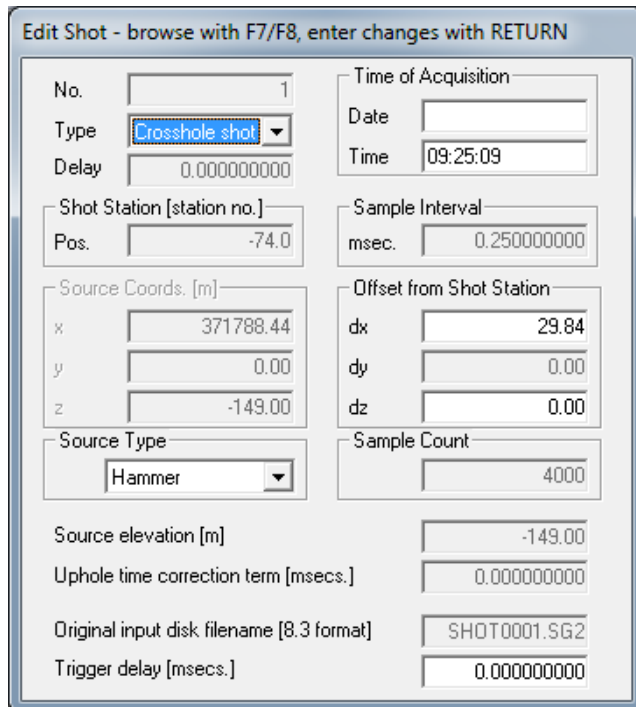
In the following we use data shown in our tutorial http://rayfract.com/tutorials/mdw2011.pdf .

During **import of borehole shots** into profile with *Header|Profile|Line type* `Borehole spread/line`, set *Shot pos. [station no.]* to **active receiver station no. nearest to the shot point**. If your shot point is outside active receiver spread just specify active receiver station no. closest to shot point.

Contrary to *Line type* `Refraction spread/line`, *Shot pos. [station no.]* for *Line type* `Borehole spread/line` must be set to **station no. of a receiver inside active** *receiver spread* used to record and import this shot. So *Shot pos. [station no.]* must be in range *Layout start [station no.]* .. *Layout start [station no.]* + *Active traces (from start)* - 1

Once you update header data with *File|Update header data|Update Station Coordinates...* and *File|Update header data|Update Shotpoint coordinates...* we set *Shot dx* and *Shot dz* shown in *Header|Shot* to offset of shot point from *Shot Station* coordinates.

Review and optionally correct shot point coordinates shown in *Source Coords. frame* in *Header|Shot* by editing *dx* and *dz* fields in frame *Offset from Shot Station* :

In the screen shot of *Header|Shot* shown above, *Shot station* -74 specifies the active receiver station number which is at same elevation or closest to elevation of the *shot point*. *Offset from shot station* frame specifies the relative offset (both horizontal and vertical) of the actual shot point from this borehole receiver station number which has the following coordinates as shown in *Header|Station* :

By convention elevation of *borehole receiver stations* is negative, relative to elevation 0 at topography. As a consequence *station numbers* are negative too. **Station numbers are computed by dividing the station elevation with *Station spacing*** specified in *Header/Profile*.

Borehole-recorded shots can be positioned outside the receiver spread. But the ***Shot pos.[station no.]*** specified during import into profile with *Line type* `Borehole spread/line` has to match an active receiver station no. used to record this shot. Once all shots have been imported go into *Header/Shot* and review&optionally edit fields ***dx*** and ***dz*** in frame `Offset from Shot Station`. Tab through dialog controls until absolute coordinate fields ***x*** and ***z*** in frame `Source Coords.` are updated. See e.g. our new http://rayfract.com/tutorials/1611HOLE.pdf tutorial. Walkaway VSP shots are recorded with 3 spreads in one borehole.

Pick first breaks for borehole receivers

Pick first breaks for borehole receivers in *Trace/Shot gather* :
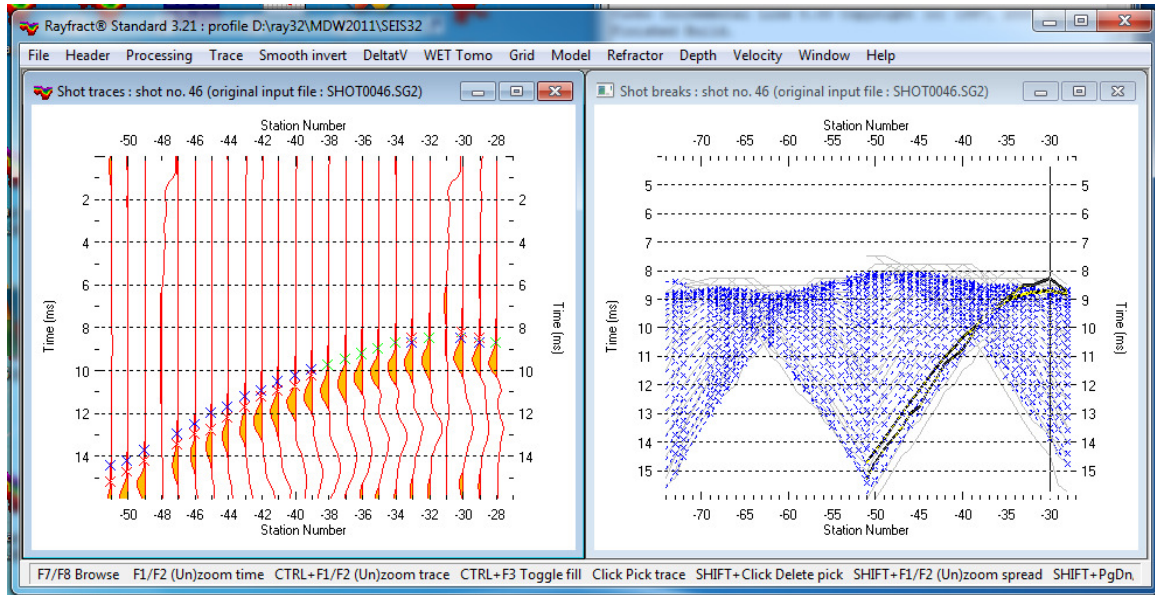
For **polarized shear waves** pick first breaks in our *Trace/Shotpoint gather* display for **pairs of shots with reversed trace polarity recorded at common shot points**.

Update shot point and receiver station coordinates from COORDS.COR and SHOTPTS.SHO and first breaks from BREAKS.LST. These files are available in archive

http://rayfract.com/tutorials/mdw2011.zip

together with the SEG-2 formatted trace files. For a description of these file formats see topic File formats.

Next run our Smooth inversion method as usual and shown in tutorial
http://rayfract.com/tutorials/mdw2011.pdf .

Crosshole survey velocity update weighting

Our Smooth inversion algorithm implements improved weighting/preconditioning for inversion of crosshole surveys. Velocity artefacts/anomalies at grid corners and at grid edges/directly adjacent to boreholes are suppressed. See Beydoun and Mendes 1989 "Elastic Ray-Born L2-Migration/Inversion" with abstract at https://dx.doi.org/10.1111/j.1365-246X.1989.tb00490.x. See also Luo and Schuster 1991 "Wave-equation Traveltime Inversion" Appendix B, with abstract at https://dx.doi.org/10.1190/1.1443081 . Luo and Schuster describe this weighting as "… Another modification is to use a preconditioned gradient (search) direction (formula). This preconditioning compensates for geometrical expansion (Beydoun and Mendes, 1989)".

The high sensitivity of WET to velocity variations directly at source/receiver is welcome for surface refraction surveys since receivers are located close to the shot point in this case. For borehole surveys the closest receiver is in the other hole. So velocity variation at source/receiver cannot be measured reliably in this case and needs to be suppressed during tomography processing. More weight is given to the central portion of the subsurface section located between the two boreholes. The fundamental assumption is that for borehole surveys there are no "large" velocity variations i.e. minimum velocity smaller than e.g. 50% of maximum velocity. For surface refraction surveys minimum velocity (directly below topography) may be as small as 10% or less of maximum subsurface section velocity (in basement).

To disable dynamic Beydoun weighting during WET inversion of borehole surveys check *Smooth invert|Precompute static Beydoun weight matrix*. Static weighting assumes that each pixel is affected by all wave paths. Dynamic weighting does not make this assumption. Static weighting is more conservative and a compromise between dynamic weighting and no weighting at all.

Use option *Smooth invert|Beydoun weighting for borehole WET* to enable or disable Beydoun weighting.

Use option *Coverage grid shows unweighted hit count*. If unchecked the coverage grid shows the hit count of each grid cell, scaled by Beydoun weighting (if enabled).

Posting and labeling of shot points and receivers on WET tomograms

To enable or disable posting and labeling of shot points and/or receivers on WET tomograms check or uncheck the corresponding menu item in *menu Grid* before starting our Smooth inversion. You don't have to redo Smooth inversion to redisplay WET tomograms :

➢   check or uncheck corresponding items at bottom of *menu Grid*
➢   select *Grid|Image and contour velocity and coverage grids...*
➢   select desired WET tomogram grid file e.g. VELOIT20.GRD (output after 20 WET iterations), stored
➢   in profile subdirectories GRADTOMO (Smooth inversion),
➢   LAYRTOMO (layered refraction starting model)
➢   HOLETOMO (crosshole survey) or
➢   TOMO (pseudo-2D DeltatV inversion).

Our tutorial http://rayfract.com/tutorials/CFE15.pdf shows **tunnel overburden imaging with multirun WET**.

http://rayfract.com/tutorials/tunnel16.pdf shows **imaging of tunnel excavation disturbed zone** (EDZ) with version 3.35 of our software.

http://rayfract.com/tutorials/lnec17.pdf hows how to image two adjacent cross-hole surveys (3 boreholes) in one tomogram.

Doug Crice describes how to record and process borehole shear-wave surveys including VSP in

http://www.geostuff.com/Shearwaves2.pdf

We also tested our new crosshole tomography routine with sample survey files made available by our Spanish client I.G.T. International Geophysical Technology. These files are formatted as GeoTomCG .3DD files. See

http://rayfract.com/samples/borehole.zip

To generate GeoTomCG .3DD input files for our crosshole tomography routine we recommend using TomTime picking software available from GeoTom LLC. Contact Daryl Tweeton at tweetond@tc.umn.edu or at dtweeton@giscogeo.com . TomTime reads all common seismograph formats, and offers versatile frequency filtering and display options. See http://giscogeo.com for more information.

For instructions on crosshole data interpretation of GeoTomCG .3DD formatted data see our tutorial

http://rayfract.com/tutorials/igta13.pdf

We currently regard X and Z coordinates only for crosshole surveys. Y coordinates as specified e.g. in GeoTomCG input files are not regarded and are assumed to be all zero.If you want us to support your crosshole data format and samples you are welcome to send us these files, as long as you have a current support contract.

For above IGTA13 tutorial a synthetic model is available at

http://rayfract.com/samples/swiss.zip

This allows determination of vertical and lateral velocity resolution in WET output.

To display GeoTomCG .3DD files in a readable way with line breaks :

➢ select *Start|Run*
➢ enter "Wordpad.exe" without the enclosing "" and click OK
➢ select *File|Open* in Wordpad program
➢ select *File type* All Documents *.*
➢ navigate to your \RAY32\DOC directory and select e.g. IGTA13.3DD

Downhole VSP interpretation

Import your SEG-2 or GeoTomCG .3DD files as for crosshole surveys, into a *borehole spread/line* database. See our tutorial

http://rayfract.com/tutorials/vsp.pdf

. Next review or pick first breaks in *Trace/Shot gather*, and invert the picks with *Smooth invert/WET with constant-velocity initial borehole model*.

You can import multiple VSP shots positioned at different offsets from top-of-borehole, if these are recorded with borehole receivers located in one and the same borehole. See

http://rayfract.com/tutorials/walkaway.pdf

. Vertical resolution is best along the borehole receiver spread. Resolution decreases with increasing lateral offset from borehole.

Since version 3.35 we support **joint inversion of surface refraction shots with VSP shots or other borehole shots**. See our new tutorials http://rayfract.com/tutorials/11REFR.pdf and http://rayfract.com/tutorials/1611HOLE.pdf .

Interpret reverse VSP shots into a common surface-based receiver/hydrophone spread as in http://rayfract.com/tutorials/zivko13.pdf . Shoot from two or more boreholes into the same receiver spread, to maximize angular coverage of 2D subsurface with rays and wave paths.

Doug Crice describes how to record and process borehole shear-wave surveys including VSP in

http://www.geostuff.com/Shearwaves2.pdf

. Pick S-wave first breaks in our *Trace/Shotpoint gather display* for pairs of shots with reversed trace polarity recorded at common shot points. Then record a P-wave survey for the same borehole and image Poisson's ratio.

Uphole shots and uphole picks

Our tutorial http://rayfract.com/tutorials/11REFR.pdf show how to **constrain WET inversion of surface-refraction shots with walkaway-VSP shots** with Rayfract(R) version 3.35.

Our tutorial http://rayfract.com/tutorials/KING17.pdf shows interpretation of first breaks recorded with receivers located in three boreholes. This tutorial requires our Pro license. You can add up to four (4) **Borehole spread/line** profiles to your main **Refraction spread/line** or **Borehole spread/line** profile using our Pro license.

Interpret reverse VSP shots into a common surface-based receiver/hydrophone spread as in http://rayfract.com/tutorials/zivko13.pdf . Shoot from two or more boreholes into the same receiver spread, to maximize angular coverage of 2D subsurface with rays and wave paths.

You can do walkaway surveys with multiple-offset downhole shots, recorded with a borehole hydrophone string. Import these downhole shots into a profile database with *Line type* **Borehole spread/line** . See

http://rayfract.com/tutorials/walkaway.pdf

. To constrain your refraction shots with these walkaway VSP shots using Rayfract(R) version 3.35 or later follow our tutorial http://rayfract.com/tutorials/11REFR.pdf

Rayfract(R) versions older than version 3.35 don't allow adding one ore more **Borehole refraction spread/line(s)** to your main profile. So convert these walkaway VSP shots to uphole shots by gathering traces by common borehole receiver, while exporting to .3DD format. See

http://rayfract.com/tutorials/a13r1dm.pdf

. Now import these uphole shots into a surface-based 2D refraction profile. See

http://rayfract.com/tutorials/coffey04.pdf

. You can do this for multiple boreholes spaced along the same 2D refraction profile.

Integration of such uphole picks with surface picks should increase the resolution of and confidence in the lower half of the WET tomograms. Positioning two deep shot holes at the profile start and at the profile end (just inside the receiver spread) helps to make sure that the depth coverage as obtained with our DeltatV method (by recording and picking/processing far offset shots) is not lost again during WET processing.

Uphole picks for seismic traces recorded with surface based receivers for deep uphole shots are very useful during tomography processing to **increase the degree of angular coverage with wavepaths, the resolution in the lower half of the depth section and the depth coverage.** Since the tomography processing can use shots situated between profile receivers (or maximally offset from the first / last profile receiver by two station number intervals) only, deep **uphole shots positioned at profile start and profile end can increase the depth coverage in tomograms obtained considerably**.

The **deep shot hole locations need to tie in with the 2D surface based seismic line**, i.e.

be situated between receiver stations or offset from the first or last profile receiver by an inline distance of maximally two station numbers. It is assumed that **uphole picks** for each uphole shot have been recorded with a surface-based 2D receiver spread which is part of (i.e. runs in the same line direction and overlaps with) the 2D surface-based seismic refraction line. The surface-based 2D refraction line consists of the (overlapping) receiver spreads used to record surface-based shots (or shot from shallow shot holes).

You are not required to pick *branch points* i.e. map first breaks to refractors for uphole shots. We do not support interpretation of uphole shots with our Wavefront and Plus-Minus conventional layer-based refraction methods. Instead use our fail-safe **Smooth inversion** . See http://rayfract.com/tutorials/coffey04.pdf .

Be sure to correctly specify the depth of the shot below surface with *Header|Shot shot depth*. This value is crucial for correct forward modelling of wave propagation, during tomography processing.

Identify uphole shots in *Header|Shot*, by setting *Type* to `Uphole shot`. Or update shot point coordinates with *File|Update header data|Update Shotpoint coordinates...* , with column *correction* in the SHOTPTS.SHO file containing a value different from zero, e.g. 0.01. A value of zero for *correction* in the SHOTPTS.SHO identifies a refraction shot. This *uphole time correction term* is also shown in *Header|Shot* as a read-only field, and is updated whenever you change *Type* from `Refraction shot` to `Uphole shot` or vice-versa.

Build your own model

WET cannot increase the depth range (row count) of the initial model grid. WET can only decrease the imaged depth range of the model grid. So if the a priori initial model depth range is too small, WET will get stuck in a local traveltime misfit function minimum by definition. In our experience, WET can only reliably find the global traveltime misfit function minimum if the depth range of the initial model grid is equal to or larger than the depth range and row count as specified by the simple 1D-gradient initial model.

You can build your own model grid file with Surfer® 8, as described in our tutorials

http://rayfract.com/tutorials/palmfig9.pdf
http://rayfract.com/tutorials/thrust.pdf
http://rayfract.com/tutorials/camp1.pdf

. For **synthetic traveltime data generation**, you need to import a dummy shot multiple times. Edit e.g. the ONESHOT.ASC linked to in above tutorial palmfig9.pdf, to change the number of 48 channels imported per shot. Use 98CHANEL.ASC for 98 channels per shot. You can use the SEIS32.BLN Surfer® blanking file generated during Smooth inversion, for blanking out model grid cells above the profile topography. Or edit your own .BLN blanking file. See your Surfer® 8 manual Appendix C for the required file format. **Generate a synthetic model and traveltime data set** according to above tutorials palmfig9.pdf and thrust.pdf :

1.   create a new Rayfract® profile database e.g. \RAY32\MYLINE. See Profile managment and http://rayfract.com/help/manual.pdf , chapter 1.1 .
2.   import above ONESHOT.ASC file for each dummy shot position into this new profile, with *File|Import Data...* . Edit *shot position* and *layout start* as required.
3.   build your own model as a Surfer MODEL.GRD file for this profile and store it into directory \RAY32\MYLINE\MODEL. Make sure **grid cells are small and quadratic**, by specifying the same value e.g. 0.2m for X increment and Y increment, in the Surfer *Grid Function dialog*. Also, make sure your grid has a height of 200 or more rows.
4.   select *Model|Model synthetic shots...* and specify your model grid file MODEL.GRD
5.   invert your synthetic shots via *Smooth invert|WET with 1D-gradient initial model* .

To **invert an existing field recorded data set with your own initial model**, please import the data into a profile database as usual. See our manual.pdf . Now invert your data with *Smooth invert|WET with 1D-gradient initial model*, as usual. Next build your Surfer MODEL.GRD model file, as described in tutorial http://rayfract.com/tutorials/camp1.pdf . Make sure your grid column and row counts and grid cell size are identical to dimensions of the GRADIENT.GRD generated during Smooth inversion. Use Surfer command *Options|Grid Info...* to show these dimensions.

Or use Surfer Kriging to generate the MODEL.GRD from a MODEL.CSV Comma Separated Value file. One line should contain x (distance), y (elevation) and z (velocity at x/y), in meters. Make sure your x/y/z triples cover the whole x/y range of the GRADIENT.GRD and GRADIENT.TXT as generated during Smooth inversion. If you have a **borehole with 1D velocity/depth profile**, just replicate this profile at sufficient x positions, and extrapolate y to sufficient depth.

Next invert your existing field data profile with *WET Tomo|Automatic WET tomography..* or *WET Tomo|Interactive WET tomography...* and select your custom MODEL.GRD initial model. Specify GRADIENT.PAR as parameter file. Or copy GRADIENT.PAR to MODEL.PAR.

Above procedure will help you to explore the ambiguity inherent in seismic first break interpretation, due to non-uniqueness of the data. Also, you will get a feeling for how much

the final tomography output depends on the initial model. Increasing the WET iteration count renders WET output less dependant on the initial model, and lets WET remove artefacts of the initial model. Use at least 50 or 100 WET iterations. Also, the closer the shot and receiver spacing, the more reliable our WET inversion will work. See http://rayfract.com/tutorials/epikinv.pdf and http://rayfract.com/tutorials/fig9inv.pdf .

We recommend to base your WET tomography inversions on Smooth inversion 1D gradient initial models. If you base your WET inversions on your own or third-party initial models as described above, we cannot give any guarantee regarding the reliability of WET output.

If you still decide to build your own initial model, and use this model with our interactive WET tomography processing, first leave *wavepath width* and *grid smoothing* at their default settings. You may need to increase the *WET iteration count* to 100 or more iterations and optimize/decrease WET smoothing to make sure that WET output converges towards a realistic model.

Our WET tomography processing has been designed and tested to work with smooth 1D initial models such as obtained with our Smooth inversion. This method gives a good initial fit between modeled and picked first breaks, even in case of velocity inversions. To check the goodness of fit for your own initial model, select *Model|Forward model traveltimes...* and specify your MODEL.GRD initial model. Use *Grid|Image and contour velocity and coverage grids* command to plot your initial model with RMS error shown in plot title.

The better the initial fit between modeled and picked first breaks and the simpler the initial model, the higher the chance that WET inversion converges towards a realistic model. See tutorial http://rayfract.com/tutorials/camp1.pdf .

Forward model traveltimes

Starting with version 2.01, RAYFRACT® now supports **forward modeling of first breaks**. The algorithm implemented is the first-order eikonal solver as described by Podvin and Lecomte (1991, 2000). Thanks to this new tool it is no longer necessary to calibrate DeltatV parameters against a priori depth velocity information obtained from third party sources such as coring. Just select *Model|Forward model travel times...* and then specify the Surfer® .GRD grid file to run our new eikonal solver over :
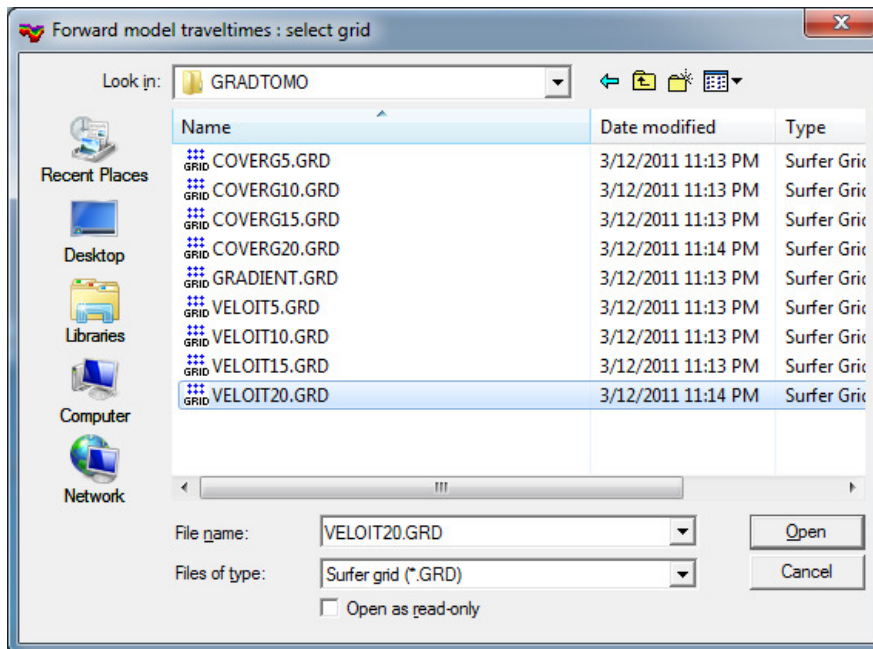
Display modeled traveltimes on top of measured and picked times in the *Shot breaks display*. Modeled traveltime picks and curves are colored blue. A close match between picked and synthesized times means that parameters used previously to obtain the DeltatV based model are reasonable. Default values for these parameters will lead to a good agreement of these two traveltime sets for most profiles, recording geometries and geological settings.

You will note that the forward modeling algorithm rejects Surfer® .GRD grid files with non-quadratic cells. Just regrid the .TXT file with the **X/Y Dir. # of Lines as proposed in the message displayed in the status bar** at the bottom of the RAYFRACT® window.
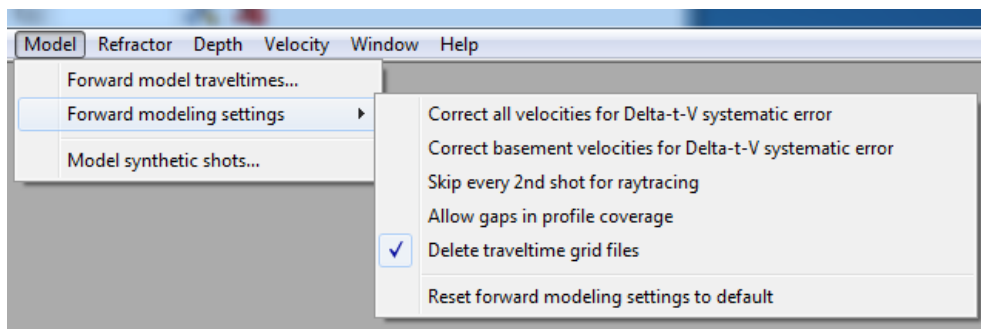
Select option *Model|Forward modeling settings|Correct all velocities for DeltatV systematic error* to reduce all grid node velocities as indicated in the Surfer® .GRD grid file by 10 percent

before running the model through the raytracing algorithm.

Select option *Model|Forward modeling settings|Correct basement velocities for DeltatV systematic error* to reduce basement grid node velocities as indicated in the Surfer® .GRD grid file by 15 percent before running the model through the raytracing algorithm. "Basement" just means high velocity regions, as indicated by values in the grid file.

Select option *Model|Forward modeling settings|Skip every 2nd shot for raytracing* to speed up the forward modeling process and optimize the amount of information displayed in the *Shot breaks display* for high coverage surveys.

For the forward modeling algorithm to work reliably, the Surfer® grid should not be too coarse. Increase Surfer® gridding parameters **X/Y Dir. # of Lines** as necessary, until there is a reasonably close match between picked and modeled traveltime curve features. Regard the limit of 640'000 nodes : this is the maximum number of nodes our eikonal solver will accept, to reasonably conserve RAM memory and hard disk space available. 600 columns versus 200 rows or similar may be a reasonable setting. For the free limited trial, try e.g. 300 columns vs. 100 rows (regarding the limit of 100'000 nodes).

WET Wavepath Eikonal Traveltime tomography

Since version 2.11 released in February 2001 Rayfract® supports refining DeltatV output with our new WET Wavepath Eikonal Traveltime tomography processing (Schuster 1993; Watanabe 1999). For a complete description of WET parameters and options see below. Also see our SAGEEP 2010 short course notes at http://rayfract.com/SAGEEP10.pdf .

Since version 3.32 released in December 2014 we allow easy **automatic WET inversion with layered starting model**. The layered starting model is regenerated and you are prompted to start WET inversion whenever you run time-to-depth conversion in Depth menu with Plus-Minus, Wavefront or CMP intercept-time refraction methods. See our tutorial http://rayfract.com/tutorials/NORCAL14.pdf

Increase maximum imaged depth for single-spread profiles

◆   uncheck *WET Tomo|WET tomography Settings|Blank below envelope* after last iteration
◆   increase *WET Tomo|Interactive WET tomography…|Wavepath width* to 20%, 30% or even 50%
◆   click button *Start tomography processing* and confirm prompts as usual
◆   or use overlapping receiver spreads so profile-internal far-offset shots are used for WET inversion

Increasing the WET *wavepath width* as described above corresponds to lowering the modeled signal frequency. So resolution decreases but maximum imaged depth increases. See also our SAGEEP14 expanded abstract http://rayfract.com/pub/sageep14.pdf and our new tutorial http://rayfract.com/tutorials/CFE15.pdf which shows how to activate multiscale tomography with *Iterate button* in *WET Tomo|Interactive WET tomography…* .

Far-offset shots located more than one *Station spacing* outside first/last profile receiver are not used for 2D WET inversion. These shots are regarded for layered refraction with Plus-Minus and Wavefront methods used to determine the layered starting model and for 1.5D DeltatV method used to determine the 1D-gradient starting model. So we still recommend to **always record far-offset shots even for single-spread profiles**.

Far-offset shots into one receiver spread per Rayfract® profile cannot be used for true 2D WET tomography because the all-important local weathering velocity cannot be determined at these far-offset shot points. Because there are no receivers there. Extrapolation of the weathering velocity determined at the first/last receiver to these far offset shot points is not feasible since the weathering velocity typically varies laterally to a large degree. To reach a deeper imaging you need to employ multiple *overlapping receiver spreads.* See chapter Overlapping receiver spreads.

We strongly recommend to first run our Smooth inversion method with default DeltatV and WET settings to avoid pseudo-2D DeltatV artefacts. Then optionally change WET parameters and redo WET :

◆   increase **WET iteration count** to 50 or 100 iterations
◆   change **WET Tomo|Interactive WET tomography|Ricker differentiation** from default -1 (Gaussian update weighting) to -2 (Cosine-Squared update weighting) to better image fault zones. See http://www.ngu.no/upload/Publikasjoner/Rapporter/2017/2017_025.pdf .

- ◆ to explore non-uniqueness of the solution space, vary the **WET wavepath width** in *WET Tomo|Interactive WET tomography...* . See http://rayfract.com/tutorials/bulgatrl.pdf .
- ◆ set options *WET Tomo|WET tomography Settings|Scale wavepath width* and
- ◆ *WET Tomo|WET tomography Settings|Scale WET filter height* as needed
- ◆ for short profiles with less than 50 receiver stations uncheck *WET Tomo|WET tomography Settings|Disable wavepath scaling for short profile* to enable above two scaling options

Decrease WET velocity smoothing

You can try to increase the resolution of WET tomograms by **decreasing WET velocity smoothing** : change one or more **WET Tomo|Interactive WET tomography|Edit velocity smoothing controls** :

- ◆ set **Smooth nth iteration : n =** to e.g. 10 instead of default 1 to smooth each 10th iteration only
- ◆ uncheck **Smooth velocity update** to smooth after the update is applied to current velocity grid only
- ◆ check **Minimal smoothing** instead of default **Full smoothing**
- ◆ check **Gaussian** radio button instead of default **Uniform** radio button
- ◆ click buttons *Accept parameters* and *Start tomography processing*

Conjugate Gradient method

Since version 3.31 we support the *Conjugate Gradient* method in addition to default *Steepest Descent* search method in our *WET Tomo|Interactive WET tomography... dialog*. See our tutorial http://rayfract.com/tutorials/sageep11_16.pdf showing *Conjugate Gradient* method. Our companion tutorial http://rayfract.com/tutorials/sageep11_smooth50.pdf shows processing of the same data set using *Steepest Descent* method. Our *Steepest Descent* method is more reliable and more reproducible than *Conjugate Gradient* method. Before version 3.31 *Steepest Descent* was the only method available and always implicitly selected. *Conjugate Gradient* can sometimes reach a lower RMS error with good data.

Our *WET inversion* control *CG iterations* is the number of outer loop iterations *imax* and our *Line Search iters.* is the number of inner loop iterations *jmax* in the **Conjugate Gradient algorithm shown on page 53 of (Shewchuk, 1994)**. One inner loop iteration is done with one *WET iteration*. Our *Tolerance* parameter corresponds to Shewchuk epsilon ε for outer loop termination. Our *Line Search tol.* parameter corresponds to Shewchuk epsilon ° used for inner loop termination. Our *Initial step* parameter corresponds to Shewchuk sigma σ used during first *Secant method* iteration in Equation (58) on page 46 of (Shewchuk, 1994).

Georgios Tassis et al. 2017 show **detection of fracture zones in bedrock** inverting synthetic data forward modeled over known fault zone models at

http://www.ngu.no/upload/Publikasjoner/Rapporter/2017/2017_025.pdf

Our new tutorial http://rayfract.com/tutorials/NGUP1_1.pdf shows imaging of vertical fault zones using Plus-Minus starting model and WET inversion with Steepest Descent method

and Cosine-Squared weighting of WET velocity update across wavepaths.

Since version 3.35 we allow **joint inversion of refraction shots and borehole-recorded shots** including VSP shots. See our new tutorials

http://rayfract.com/tutorials/11REFR.pdf and http://rayfract.com/tutorials/1611HOLE.pdf .

Alternatively we allow **importing uphole shots into refraction profiles**. Convert walkaway VSP surveys into uphole shots. See chapter Uphole shots and uphole picks.

WET tomography Settings
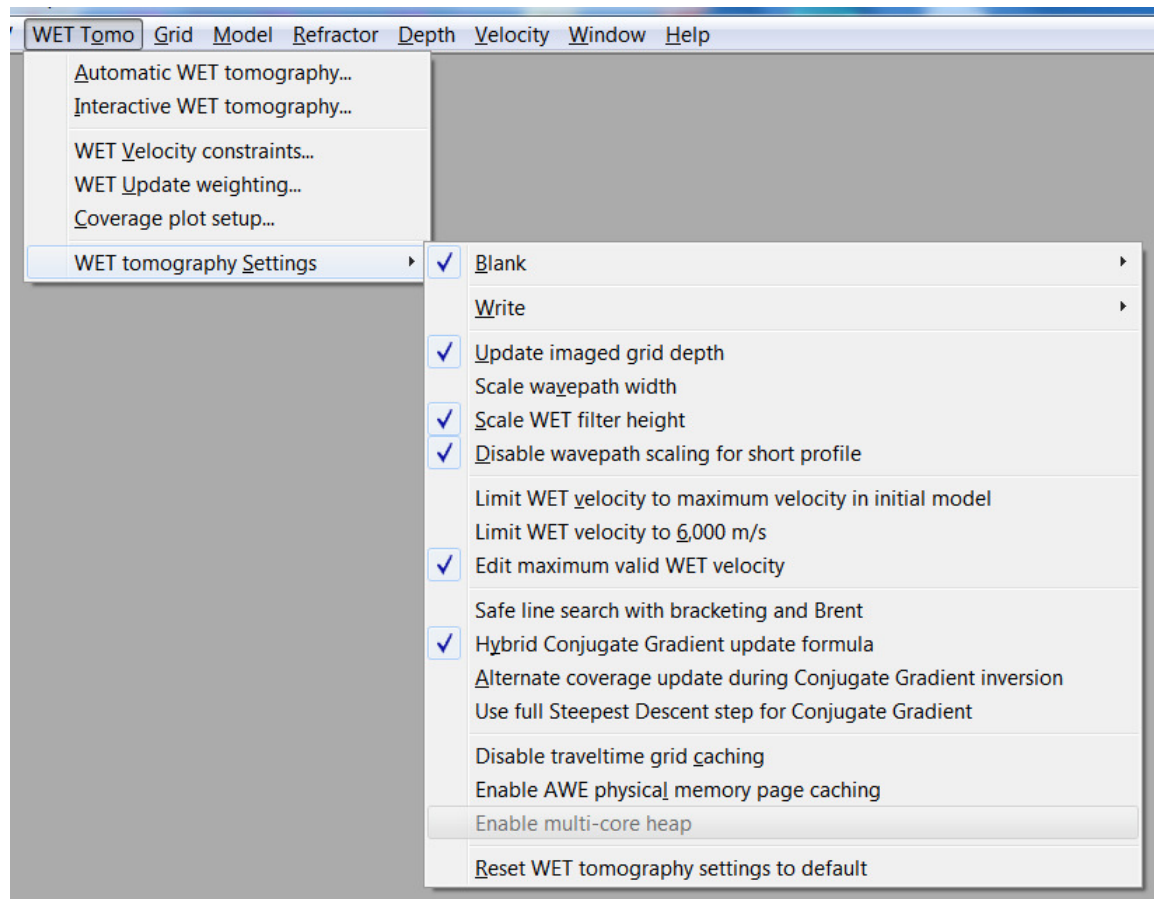
Edit these settings in *menu WET Tomo|WET tomography Settings* :

- ◆   *Update imaged grid depth*
- ◆   *Scale wavepath width*
- ◆   *Scale WET filter height*
- ◆   *Disable wavepath scaling for short profile*
- ◆   *Limit WET velocity to maximum velocity in initial model*
- ◆   *Limit WET velocity to 6,000 m/s*
- ◆   *Edit maximum valid WET velocity*

- *Safe line search with bracketing and Brent*
- *Hybrid Conjugate Gradient update formula*
- *Alternate coverage update during Conjugate Gradient inversion*
- *Use full Steepest Descent step for Conjugate Gradient*
- *Disable traveltime grid caching*
- *Enable AWE physical memory page caching*
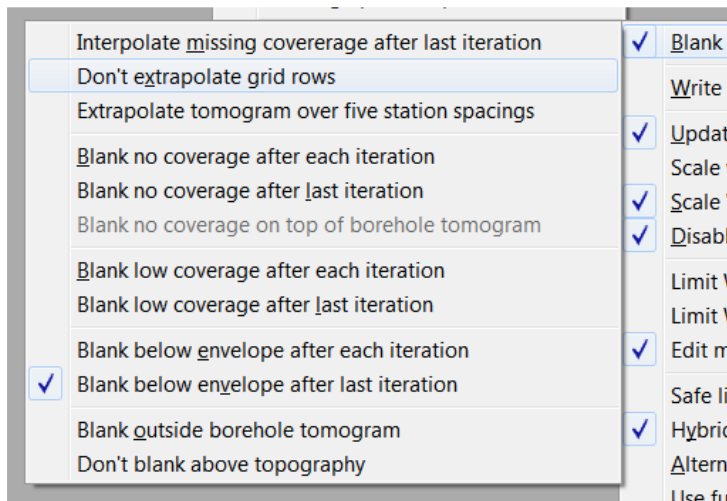
Edit these settings in *menu WET Tomo|WET tomography Settings|Blank* :

- *Interpolate missing coverage after last iteration*
- *Don't extrapolate grid rows*
- *Extrapolate tomogram over five station spacings*
- *Blank no coverage after each iteration*
- *Blank no coverage after last iteration*
- *Blank no coverage on top of borehole tomogram*
- *Bank low coverage after each iteration*
- *Blank low coverage after last iteration*
- *Blank below envelope after each iteration*
- *Blank below envelope after last iteration*
- *Blank outside borehole tomogram*
- *Don't blank above topography*

Interactive WET tomography main dialog

Now select *WET Tomo|Interactive WET tomography...* to display the WET parameters dialog :

Edit WET Wavepath Eikonal Traveltime Tomography Parameters

Specify initial velocity model

| Select | D:\RAY32\TRA9002\GRADTOMO\GRADIENT.GRD |

Stop WET inversion after

Number of WET tomography iterations :	20	iterations
☐ or RMS error gets below	2.0	percent
☐ or RMS error does not improve for n =	20	iterations
☐ or WET inversion runs longer than	100	minutes

WET regularization settings

Wavepath frequency :	50	Hz	[Iterate]
Ricker differentiation [-1=Gaussian, -2=Cosine] :	-2	times	
Wavepath width [percent of one period] :	6.0	percent	[Iterate]
Wavepath envelope width [% of period] :	0.0	percent	
Min. velocity : 10 Max. velocity : 5000		m/sec.	
Width of Gaussian for one period [sigma] :	3.0	sigma	

Gradient search method

● Steepest Descent   ○ Conjugate Gradient

Conjugate Gradient Parameters

CG iterations	10	Line Search iters.	2
Tolerance	0.001	Line Search tol.	0.0010
Initial step	0.10	☐ Steepest Descent step	

| Edit velocity smoothing | Edit grid file generation |
| Start tomography processing | Reset | Cancel |

Edit these parameters :

- ◆ *Number of WET tomography iterations*   : increase to 50 or 100 to remove artefacts/layering of the initial model. Disabled for Conjugate Gradient method.
- ◆ *or RMS error gets below*   : check for WET stop when RMS error gets below threshold, in percent
- ◆ *RMS error threshold*   : default is RMS error threshold of 2 percent
- ◆ *or RMS error does not improve for n =*   : check for WET to stop when RMS error does not improve for n WET iterations
- ◆ *RMS error constant for n iterations*   : edit this to specify the number of WET iterations to check for not-decreasing RMS error

◆ *or WET inversion runs longer than* : check this to stop WET inversion after max. runtime of ... minutes. Default is 100 minutes.

◆ *max. WET runtime minutes* : specify max. runtime of WET inversion, in minutes. Default is 100 minutes.

◆ *Wavepath frequency* : leave this at default value of 50 Hz. One period is 1/50Hz = 20ms.

◆ *Ricker differentiation* : default -1. Try 0 or 1 for sharper layer boundaries, possibly artefacts. Set to -1 for Gaussian. Set to -2 for Cosine-Squared.

◆ *Wavepath width [percent of one period]* : increase for more smoothing and deeper imaging, decrease for more resolution or more artefacts

◆ *Envelope wavepath width [% of period]* : increase for deeper but more uncertain imaging, at bottom of tomogram

◆ *Min. velocity [m/sec]* : limit minimum velocity in tomogram to this threshold value

◆ *Max. velocity [m/sec.]* : limit maximum velocity in tomogram to this threshold value

◆ *Width of Gaussian for one period [sigma]* : cutoff for Gaussian function in sigma, for weighing of velocity update across wavepath

◆ *Steepest Descent* : use Steepest Descent method for WET inversion

◆ *Conjugate Gradient* : use Conjugate Gradient method for WET inversion

◆ *CG iterations* : how many Line Searches (outer loop iterations) are started by Conjugate Gradient method

◆ *Line Search iterations* : how many WET iterations per each Line Search (inner loop iterations) are started by Conjugate Gradient method

◆ *Tolerance* : error tolerance Epsilon for Conjugate Gradient method (outer loop)

◆ *Line Search tolerance* : tolerance for Secant method or Brent's method (Line Search during Conjugate Gradient method, inner loop)

◆ *Initial Step* : initial guess for bracketing during Line Search minimization with Secant or Brent's method

◆ *Steepest Descent step* : update the tomogram with a Steepest Descent step after each WET iteration done by Conjugate Gradient method

WET update weighting

Edit parameters for WET update weighting in *WET Tomo|WET Update weighting dialog* :
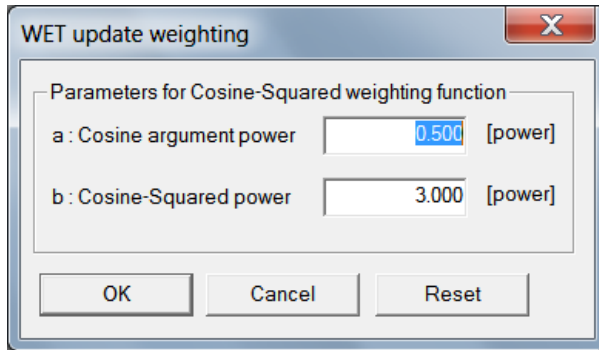
- *a : Cosine argument power*   : pow(Cos(Pi/2 * pow(d,a)), 2b) with d=delay
  from wavepath center [ms] divided by one period [ms]
- *b : Cosine-Squared power*   : pow(Cos(Pi/2 * pow(d,a)), 2b). See (Chen
  and Zelt, 2012) Fig. 5(a) .

Select starting model for WET inversion

Click on button *Select* in *WET Tomo|Interactive WET tomography* to specify the starting
model :
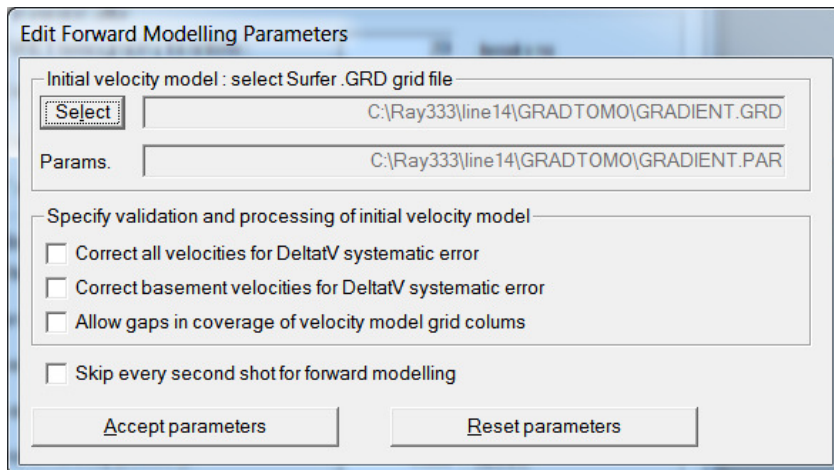
Edit these parameters :

- *Correct all velocities for DeltatV systematic error*
- *Correct basement velocities for DeltatV systematic error*
- *Allow gaps in coverage of velocity model grid columns*
- *Skip every second shot for forward modeling*

Edit WET velocity smoothing

In WET main dialog click on button *Edit velocity smoothing* to specify parameters for smoothing of the updated velocity grid as obtained after each tomography iteration :

Edit WET Tomography Velocity Smoothing Parameters

Determination of smoothing filter dimensions
- ⦿ Full smoothing after each tomography iteration
- ○ Minimal smoothing after each tomography iteration
- ○ Manual specification of smoothing filter, see below

Smoothing filter dimensions
Half smoothing filter width :   10   columns
Half smoothing filter height :   2   grid rows

Filter shallow dipping wavepath artefacts from model
☑ Automatically adapt shape of rectangular filter matrix

Maximum relative velocity update after each iteration
Maximum velocity update :   25   percent

Smooth after each nth iteration only
Smooth nth iteration : n =   1   iterations

Smoothing filter weighting
- ○ Gaussian   ⦿ Uniform
Used width of Gaussian   1.0   sigma
Uniform central row weight   1.0   [1..100]

Smooth velocity update before updating tomogram
☑ Smooth velocity update   ☑ Smooth last iteration

Damping of tomogram with previous iteration tomogram
Damping [0..1]   0.000   ☐ Damp before smoothing

[Accept parameters]   [Reset parameters]

Adjust these parameters :

- ◆ *Full smoothing after each tomography iteration*
- ◆ *Minimal smoothing after each tomography iteration*
- ◆ *Manual specification of smoothing filter, see below*
- ◆ *Half smoothing filter width*

- *Half smoothing filter height*
- *Automatically adapt shape of rectangular filter matrix*
- *Maximum velocity update*
- *Smooth nth iteration*
- *Gaussian weighting*
- *Uniform weighting*
- *Used width of Gaussian*
- *Uniform central row weight*
- *Smooth velocity update*
- *Smooth last iteration*
- *Damping [0..1]*

Multiscale tomography : multirun WET inversion

Click on button *Iterate* in *WET Tomo|Interactive WET tomography* main dialog to specify parameters for multirun WET inversion allowing multiscale tomography :

Run No.	Freq. [Hz]	Width [%]	Width [ms]	Iterations		
Run 1	50.0	30.0	6.0	20	☐ Blank	
Run 2	50.0	22.0	4.4	20	☐ Blank	
Run 3	50.0	16.0	3.2	20	☐ Blank	
Run 4	50.0	10.0	2.0	20	☐ Blank	
Run 5	50.0	7.0	1.4	20	☐ Blank	
Run 6	50.0	5.0	1.0	20	☐ Blank	
Run 7	50.0	4.0	0.8	20	☐ Blank	
Run 8	50.0	3.0	0.6	20	☑ Blank	
Run 9	50.0	2.0	0.4	0	☑ Blank	
Run 10	50.0	1.0	0.2	0	☑ Blank	

Edit WET runs - wavepath width

OK | Cancel | Reset

☑ WET runs active
☐ Scale default widths
☑ Plot runs in Surfer
☐ Prompt run misfit
Runs completed   8
☑ All runs completed
Current run no.   -1
☑ Resume current run

Blank below wavepath envelope
☐ Blank after each run   ☑ Blank after last run

Edit these parameters :

- *Freq. [Hz]*
- *Width [%]*
- *Width [ms]*

- *Iterations*
- *Blank*
- *Blank after each run*
- *Blank after last run*
- *WET runs active*
- *Plot runs in Surfer*
- *Prompt run misfit*
- *Resume current run*
- *Reset*

Edit grid file generation

In *WET Tomo|Interactive WET tomography...* main dialog click on button *Edit grid file generation* to specify what kind of intermediate Surfer® formatted disk grid files should be generated and kept by the tomography processing :

Edit these parameters :

- *Delete traveltime grid files for last WET iteration*
- *Write wavepaths to disk for shot no.*
- *Write misfit gradients to disk for shot no.*
- *Write section velocity update grids after each iteration*
- *Write section coverage grids after each iteration*
- *Store each nth iteration only*
- *Write grids for Line Search during Conjugate Gradient*

Once you have reviewed and optionally edited above parameters, click *buttons Accept parameters* and *button Start tomography processing* .

Once the tomography processing has terminated, a message is shown in the status bar at the bottom of the Rayfract® window. The updated velocity model grid as obtained after each or each nth iteration is stored as disk file **VELOIT1.GRD** for iteration 1 etc. . These Rayfract® generated and Surfer® **.GRD** formatted files are in the same directory as the one holding the starting model, as specified above. To obtain a velocity tomogram, contour and plot the corresponding **VELOITXX.GRD** file with Surfer® version 9 or higher, via Rayfract® command *Grid|Image and contour velocity and coverage grids.*

Grid menu options and commands

Use these ***Grid menu*** options and commands :

Grid Model Refractor Depth Velocity Window Help
Convert grid file between feet and meters...
Turn around grid file by 180 degrees...
Convert .CSV layer model to Surfer .GRD...
Export grid file to ASCII .TXT...
Blank polygon area in grid...
Convert elevation to Depth below topography...
Image and contour velocity and coverage grids...
Select ASCII .CSV layer model for refractor plotting...
Plot topography on tomogram
✓ Plot refractors on tomogram
Plot refractors only without tomogram
Plot layer velocity without tomogram
Grid and image DeltatV .TXT file...
Velocity vs. Two-way time...
✓ Post shot points on tomogram
✓ Label shot points on tomogram
✓ Stack shot labels at same offset
✓ Post receiver stations on tomogram
Label receiver stations on tomogram
GS CENTERED font for receivers
Reset DeltatV and WET settings to .PAR file...
Surfer plot Limits...
Surfer invocation...

◆   *Convert grid file between feet and meters...*   Lets you select a
     VELOITXY.GRD tomogram and converts this to feet/meters

◆   *Turn around grid file by 180 degrees...*   Flip over **VELOITXY.GRD**
     tomogram. then image with *Image and contour velocity and coverage grids...*

- *Convert .CSV layer model to Surfer .GRD...*   Replace velocities in
  GRADIENT.GRD or **VELOITXY.GRD** with layer model **.CSV** velocities

- *Export grid file to ASCII .TXT...*   Write velocity nodes in
  VELOITXY.GRD to ASCII **.TXT** with 3D x/y/z/velocity coordinates. Use with Voxler.

- *Blank polygon area in grid...*   Blank or reset to constant
  grid velocity in **VELOITXY.GRD** in polygon area specified in Surfer **.BLN** *blanking file*

- *Convert elevation to Depth below topography...*   Flatten out/remove
  topography from **VELOITXY.GRD** tomogram. Please first make a backup copy of
  VELOITXY.GRD.

- *Image and contour velocity and coverage grids...*   Call Golden Software Surfer
  to generate plot with contour and image maps, of **VELOITXY.GRD** and
  COVERGXY.GRD.

- *Select ASCII .CSV layer model for refractor plotting...*   Select layer model **.CSV**
  with refractors. Also check *Plot refractors on tomogram*. Then select *Image and
  contour...*

- *Plot topography on tomogram*   Check this option to plot
  topography in selected layer model **.CSV** on tomogram with *Image and contour
  velocity...*

- *Plot refractors on tomogram*   Check this option to plot
  refractors in selected layer model **.CSV** on tomogram with *Image and contour velocity...*

- *Plot refractors only without tomogram*   Check to plot refractors only
  from selected layer model **.CSV** without tomogram, with *Image and contour velocity...*

- *Plot layer velocity without tomogram*   Check to plot refractor
  velocities only from selected layer **.CSV** without tomogram, with *Image and contour
  velocity...*

- *Grid and image DeltatV .TXT file...*   Call Golden Software Surfer
  to grid and image DeltatV velocities in **.TXT** file written by DeltatV inversion

- *Velocity vs. Two-way-time...*   Select a **VELOITXY.GRD**,
  write 3-column ASCII file **TWTIME.TWT** with CMP station no., two-way time (s) and
  velocity (m/s)

- *Post shot points on tomogram*   Check this option to plot
  shot point symbol (inverted red triangle) on Surfer plot with *Image and contour
  velocity...*

- *Label shot points on tomogram*   Check this to plot shot
  number above each shot point (inverted red triangle) on Surfer plot with *Image and
  contour velocity...*

- *Stack shot labels at same offset*   Check to vertically stack
  shot labels in tomogram plot for shots positioned at same location of 2D profile

- *Post receiver stations on tomogram*   Check this to plot receiver
  symbol (grey filled circle with overlaid cross) on Surfer plot with *Image and contour
  velocity...*

- *Label receiver stations on tomogram*   Check this option to plot the
  receiver station number above each receiver station symbol with *Image and contour
  velocity...*

- *GS CENTERED font for receivers*   Plot receivers with **GS
  CENTERED** font symbol no. 48. Uncheck for font **GSI Default Symbols**, symbol no.
  102.

- *Reset DeltatV and WET settings to .PAR file...*   Select a **VELOITXY.GRD**

and reset DeltatV and WET settings to settings read from matching `VELOITXY.PAR` file

◆ *Surfer plot Limits...*   Lets you edit min./max.
offset, elevation and velocity for plotting of WET velocity tomogram with *Image and contour velocity...*

◆ *Surfer invocation...*   Select `Scripter.EXE` for
calling into Surfer, in `C:\PROGRAM FILES\GOLDEN SOFTWARE\SURFER XY\SCRIPTER\`

Improve WET tomogram

If WET tomography processing terminates with a message "Updated velocity model has gaps" or you are not satisfied with the tomogram obtained :

◆ **make sure that you are running the latest version of our software**. Our WET inversion method has been made more robust by setting WET parameter *Ricker differentiation* to -1 per default and with new options *Scale WET filter height* and *Scale wavepath width*. See http://rayfract.com/help/release_notes.pdf

◆ change ***WET Tomo|Interactive WET tomography|Ricker differentiation*** from default -1 (Gaussian update weighting) to -2 (Cosine-Squared update weighting) to **better image quasi-vertical fault zones in basement**. Edit Cosine-Squared parameters a&b in *WET Tomo|WET Update weighting dialog* to e.g. a=0.5&b=10.0. To improve imaging of fault zones in basement test disabling option *WET Tomo|WET tomography Settings|Limit WET velocity to maximum velocity in initial model* or check *Edit maximum valid WET velocity* and edit *WET Tomo|Interactive WET tomography|Max. velocity*.

◆ **check if the first breaks have been picked correctly** at the corresponding profile positions. Use our *Trace|Offset Gather display* to check your first breaks for consistency regarding reciprocal traveltimes. For the same offset and midpoint (station number), first breaks picked (red crosses) should collapse onto a single pick. If these are displayed on the same trace but vertically offset from each other, such picks violate the **traveltime reciprocity principle** which states that traveltime is invariant to exchanging source and receiver between two constant measuring stations (Ackermann et al. 1986 : reciprocity). See our tutorials http://rayfract.com/tutorials/Slope1.pdf, http://rayfract.com/tutorials/riveral8.pdf and http://rayfract.com/samples/GEOXMERC.pdf . **Aim for an RMS error (misfit between picked and modeled first break times) below 2%** as shown on top of all Surfer tomogram plots.

◆ make sure that picked **traveltime curves for adjacent shots are at least somewhat similar to each other** when reviewing them in our *Refractor|Shot breaks display*. See our tutorials at http://rayfract.com/tutorials/TUTORIAL.ZIP and http://rayfract.com/SAGEEP10.pdf for typical traveltime curve sections. Refraction tomography is based on the assumption that subsurface physical properties (related to propagation speed of seismic waves) have a quasi-continuous nature and do not vary randomly on a small scale. Since first break energy incited at adjacent shot points propagates through the subsurface along similar wave paths and rays, the measured and picked traveltime curves for these shots should be similar (Ackermann et al. 1986 : parallel construction).

◆ our PowerPoint slides http://rayfract.com/tutorials/Slope1.ppt show **how to interactively improve your first break picks**. See http://rayfract.com/tutorials/Slope1.pdf for .pdf version.

◆ traces in *Trace menu displays* are shifted by *delay time* and *trigger delay*, as specified in *Header|Shot* . This lets you **interactively correct shots for reciprocal errors caused by trigger delays**, visible in our *Trace|Offset gather display*

◆ **make sure that the profile topography *(Header|Station*) and recording geometry (shot point coordinates : specify inline and lateral offsets from shot station in *Header|Shot*) has been specified correctly**. Missing or incorrectly specified topography and recording geometry may cause the imaging of non-existent velocity anomalies. If you need to change the shot station for one or more shots you need to re-import these shots. See chapter File formats for our .HDR batch file format which allows easy re-import of shots.

◆ if your seismic refraction line has one or more gap(s) without coverage, activate option *Allow gaps in coverage of velocity model grid columns* in dialog *Edit Forward Modeling Parameters* which appears when you click on button *Select* of the main WET tomography parameters dialog.

◆ use our **Smooth inversion** to obtain a 1D starting model devoid of lateral velocity artefacts. For our pseudo-2D DeltatV inversion use a different Surfer® gridding method than the default Kriging method. Specify your preferred gridding method via *DeltatV|Interactive DeltatV|Export Options|Gridding method*. Confirm with *Accept button*. Abort the interactive DeltatV inversion with *Cancel button*. Now regrid the DELTATV.TXT generated during an earlier inversion with *Grid|Grid and image DeltatV .TXT file...* .

◆ for **more layered 1D-gradient starting model** check *Smooth invert|Smooth inversion Settings|Allow XTV inversion for 1D initial model* and *Optimize XTV for layered starting model*. Now reselect *Smooth invert|WET with 1D-gradient initial model*.

◆ since version 3.32 we support **automatic WET inversion with layered refraction starting model**. The layered starting model is regenerated and you are prompted to start WET inversion whenever you run time-to-depth conversion in Depth menu with Plus-Minus, Wavefront or CMP intercept-time refraction methods. See http://rayfract.com/tutorials/NORCAL14.pdf . To enable menu items in *Depth menu* you first need to map traces to refractors.

◆ **if the vertical velocity variation is still too smooth** and does not indicate any sharp velocity increase at the top of the basement : redo the WET inversion with *WET Tomo|Interactive WET Tomography...* and decreased **WET velocity smoothing** : e.g. increase **Smooth nth iteration : n =** from 1 to 10. Also increase the *WET iteration count* to e.g. 50 or 100 iterations. And/or enable *WET Tomo|WET tomography Settings|Scale wavepath width* for narrow shot spacing.

◆ to explore non-uniqueness of the solution space systematically vary the *WET wavepath width* in *WET Tomo|Interactive WET tomography...* . See http://rayfract.com/tutorials/bulgatrl.pdf .

◆ enable multirun WET inversion for **multiscale tomography** as shown in http://rayfract.com/pub/sageep14.pdf for more reliable imaging of velocity anomalies with less artefacts especially with noisy first break picks. Our tutorial http://rayfract.com/tutorials/sageep11_16.pdf shows our *Conjugate Gradient* method using multirun WET option. Our companion tutorial http://rayfract.com/tutorials/sageep11_smooth50.pdf shows processing of the same data set using *Steepest Descent* method with multirun WET option.

◆ increase *WET Tomo|Interactive WET tomography|Wavepath frequency* for more narrow wavepaths in single-run or multirun WET inversion. E.g. for crosshole survey increase WET frequency from default 50 Hz to 100 Hz or 200 Hz. Visually determine dominant period [in seconds] of your trace signal in *Trace|Shot gather*. Next determine dominant frequency = 1/period and edit *WET wavepath frequency*. *WET wavepath width* [in seconds] is specified in percent of one period with period = 1/*WET wavepath frequency*.

◆ for **noisy traces, uncertain first break picks and Smooth inversion RMS error above 2%, increase the *WET wavepath width***, e.g. multiply by two. This gives smoother WET output and avoids WET inversion artefacts.

◆ also increase *WET wavepath width* **if subsurface velocity is slower than normal**, e.g. in case of S-wave surveys and low-velocity, unconsolidated overburden sediments. Otherwise the too thin wavepaths may cause **black uncovered regions in the wavepath coverage plot** with too wide shot spacing. This may prevent robust convergence towards meaningful interpretation with increasing WET iteration count. Since version 3.20 we automatically increase default WET wavepath width and smoothing filter size for low-velocity sections.

◆ **overemphasized near-surface anomalies** possibly due to inaccurate first break picks may refract the modeled wavepaths for larger offsets at a too shallow depth. **Decrease *WET Tomo|Interactive WET tomography|Wavepath width*** interactively by 35%, but only in case of accurate first break picks. For long profiles, dense enough shot spacing and accurate first break picks, enable *WET Tomo|WET tomography Settings|Scale wavepath width* instead to avoid these artefacts. Also reset WET parameter *Ricker differentiation* to 0 or -1 for Gaussian Bell weighting or -2 for Cosine-Squared WET update weighting. Our PowerPoint slides http://rayfract.com/tutorials/Slope1.ppt show **how to interactively improve your first break picks**.

◆ to suppress horizontal layering artefacts in the 1D starting model limit the *maximum exported DeltaV velocity* to e.g. 3,000 m/s instead of default 5,000 m/s. Increase *WET iteration count* to 50 or 100 iterations and decrease WET smoothing : increase *Smooth nth iteration : n =* from default 1 to 5 or 10. See our tutorials http://rayfract.com/tutorials/palmfig3.pdf and http://rayfract.com/SAGEEP10.pdf page 25 of 44. To improve imaging of fault zones in basement test disabling option *WET Tomo|WET tomography Settings|Limit WET velocity to maximum velocity in initial model* or check *Edit maximum valid WET velocity* and edit *WET Tomo|Interactive WET tomography|Max. velocity*.

◆ to obtain **high-quality seismograph traces with good signal-to-noise ratio** we recommend to stack 5 to 10 shots at the same shot point. This enables accurate first-break picking, a prerequisite for SRT .

◆ for exact shot timing try GISCO piezoelectric trigger switches . Correct timing is essential for shot stacking.

◆ try **disabling AGC Automatic Gain Control on your seismograph when stacking shots**. Otherwise pre-first break noise may not cancel out while adding shots to the stack. Verify this on your seismograph trace display.

◆ SRT Seismic Refraction Tomography and seismic refraction methods in general will not work reliably or at all in **strong velocity-inversion situations with a continuous high-velocity layer (paved road) above a lower-velocity sediment layer**. You may have a chance to image this by orientating the line perpendicular to the road and planting shots

and receivers both on and besides the road, at sufficient offsets to reach the higher-velocity basement. See http://rayfract.com/samples/street_crossing.pdf . In other words SRT usually can cope with **non-continuous lense-type velocity inversions and high-velocity zones** given enough maximum offset between source and receiver. To determine the required maximum offset multiply the maximum desired imaged depth by 6.

Increase maximum imaged depth

If you are not satisfied with the **depth penetration i.e. the maximum depth imaged with the resulting WET tomogram** please note the following :

Far offset shots into one receiver spread per Rayfract® profile cannot be used for WET tomography because the all-important local weathering velocity cannot be determined, at these far-offset shot points. Because there are no receivers there. Extrapolation of the weathering velocity determined at the first/last receiver to these far offset shot points is not feasible since the weathering velocity typically varies laterally to a large degree. To reach a deeper penetration you need to employ multiple, *overlapping receiver spreads*. See topic Overlapping receiver spreads. Also see our tutorial

http://rayfract.com/tutorials/tra9002.pdf   and our client recording geometry sample

http://rayfract.com/help/overlap.pdf

. Basically you need to make sure that the "far offset" shot locations for one receiver spread layout are "inside" another receiver spread layout along the same line. And receiver spread layouts employed along the same "line" need to overlap with both their preceding and their following spread layout at a few common "active" receiver stations.
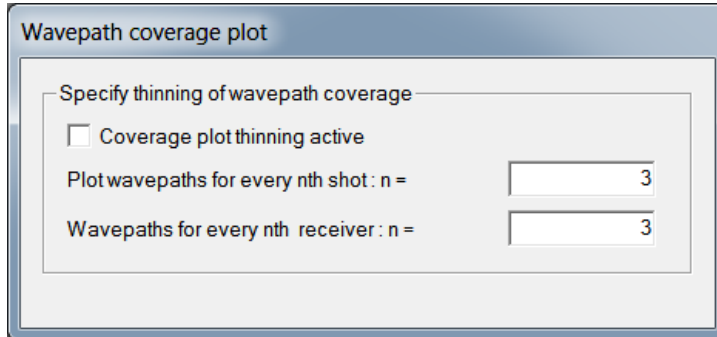
We always use far-offset shots for determination of the starting model with DeltatV or Plus-Minus or Wavefront methods. So we still recommend to **record these far-offset shots in the field even when not using overlapping receiver spreads**.

WET can't open or write disk file

If WET aborts with a status bar message "**Error encountered while opening/writing disk file** ..." : select *Start*/*Run* and enter **CHKDSK /F** command . Then make sure that the hard disk drive / partition holding your **\RAY32** profile subdirectory has property ***Compress drive to save disk space* disabled**. Right-click on the drive symbol in an Explorer window and select menu item *Properties* to display the *Properties dialog*. If drive compression is enabled uncheck the box and click on *button Apply* to uncompress existing files. If this does not help make sure to disable any backup utility or virus scanner which might access directories with Surfer **.GRD** files and **.PAR** files generated by our WET inversion. And avoid browsing profile subdirectories **GRADTOMO**, **LAYRTOMO**, **HOLETOMO** and **TOMO** in Windows Explorer or a similar utility while our WET inversion is running.

Configure WET coverage plot

Select *WET Tomo|Coverage plot setup...* to **thin the WET wavepath coverage plot**, for easier visualizing of wavepaths in dense plots :

Edit these parameters :

◆ *Coverage plot thinning active*
◆ *Plot wavepaths for every nth shot*
◆ *Wavepaths for every nth receiver*

WET Velocity constraints

Select *WET Tomo/WET Velocity constraints...* to specify a velocity range, with two edit fields. All velocities outside this range are kept unchanged during WET inversion. Use e.g. for marine refraction surveys with water overburden set to constant 1,500 m/s in the starting model. Also you can specify **polygon blanking** or reset blanked pixels to mask grid :

Edit these parameters :

- *Keep velocity unchanged below*
- *Low velocity limit*
- *Keep velocity unchanged above*
- *High velocity limit*
- *Polygon blanking active*
- *Blank outside polygon*
- *Smooth polygon border*
- *Pad polygon border*
- *Select blanking file*
- *Blanking file*
- *Mask grid file active*
- *Select mask grid file*
- *Mask grid file*

- *Extrapolate to top*
- *Extrapolate to bottom*
- *Extrapolate to left*
- *Extrapolate to right*

Edit Surfer plot limits

Select *Grid|Surfer plot Limits...* to **edit offset range, elevation range and velocity range** used for plotting of **VELOITXY.GRD** velocity tomograms and **COVERGXY.GRD** coverage plots :

Click button *Reset to grid* to reset offset/elevation/velocity range to selected **VELOITXY.GRD** tomogram in profile subdirectories **...\GRADTOMO**, **...\LAYRTOMO**, **...\TOMO** or **...\HOLETOMO**.

Check box *Proportional XY Scaling* to use the same distance scale along X and Y axis.

Once you have reconfigured above parameters redo WET tomography e.g. with *WET Tomo|Interactive WET tomography...* or redisplay your tomogram with *Grid|Image and contour velocity and coverage grids...*

Configure RAM memory for WET with Pro version

When our Pro version shows prompts "`OpenPolicy : Access is denied`" and "`Error : Cannot enable the SE_LOCK_MEMORY_NAME privilege. Failed with error 1300 : Not all privileges or groups referenced are assigned to the caller.`" under Windows 10 64-bit :

◆ click *Ok button* to confirm the prompts. WET inversion will continue without access to RAM memory above 4 GB limit.
◆ once WET inversion is complete select *File/Exit*
◆ right-click Rayfract® desktop icon and select *Properties*
◆ click *button Advanced* and check *box Run as administrator*
◆ click *buttons Ok / Apply / Continue / Ok*
◆ restart Windows 10
◆ startup our app via desktop icon as usual. Now WET inversion can use up to 64 GB of RAM with our Pro version.

Pseudo-2D DeltatV inversion

Please always first invert your refraction data with our fail-safe Smooth inversion method. Smooth inversion guarantees a realistic interpretation even in case of **strong lateral velocity variation in the overburden**. The 1D initial model computed by our Smooth inversion method guarantees that DeltatV artefacts (occurring in situations of strong refractor curvature / strong lateral velocity variation) are virtually eliminated from the interpretation at an early stage. The pseudo-2D DeltatV initial model will show systematic velocity artefacts in such situations : too low velocity below anticlines and too high velocity below synclines.

DeltatV can work well in case of homogeneous overburden and for long profiles (longer than 500m) with dense shot and receiver spacing. This includes marine surveys. See tutorials

http://rayfract.com/tutorials/ot0608.pdf and http://rayfract.com/samples/GEOXMERC.pdf .

Obtain **smoother DeltatV starting models with less noise/artefacts** with non-default *DeltatV settings* as described in above tutorials ot0608 on page 3 and GEOXMERC on page 1. These non-default DeltatV settings work best for long refraction spreads/lines and dense shot spacing.

See our tutorial http://rayfract.com/tutorials/jenny10.pdf for illustrated instructions on using our XTV inversion method allowing imaging of constant-velocity weathering overburden. This tutorial also shows **imaging artefacts caused solely by Golden Software Surfer version 8 Kriging gridding method**. Natural Neighbor gridding method works much better at least in this case, for imaging of pseudo-2D XTV inversion output. This may be the case for DeltatV output as well.

If the Smooth inversion interpretation shows at least some degree of quasi-horizontal subsurface layering you may optionally run pseudo-2D DeltatV based WET inversion . **To start the automated version of our pseudo-2D DeltatV inversion select** *DeltatV|Automatic DeltatV and WET inversion* :
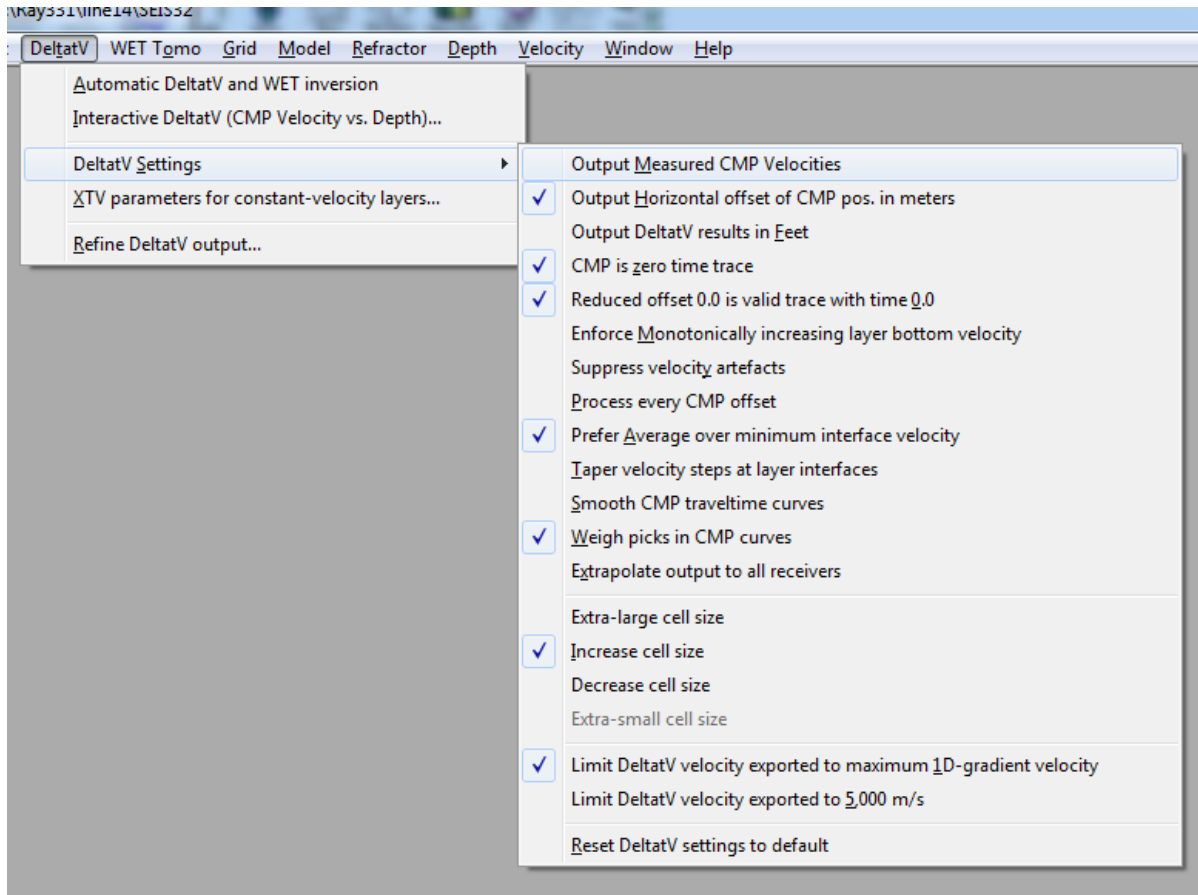
To use pseudo-2D DeltatV method output as a starting model for WET tomography inversion, you need to configure the DeltatV method as follows (as per default) :

♦ select *DeltatV|DeltatV Settings|Output Horizontal offset of CMP pos. in meters*
♦ optionally select *DeltatV|DeltatV Settings|Output DeltatV results in Feet*
♦ *DeltatV|Interactive DeltatV|Export options* : if you select option *depth below topo* or do not specify any topography i.e. set the topography to 0.0, you need to select *negative depths* in the same dialog.

Introduction to DeltatV inversion

Since version 1.30, released in December 1998, our Rayfract® software implements the **DeltatV method** as described by (Gebrande and Miller 1985). This turning-ray inversion method delivers continuous depth vs. velocity profiles for all profile stations. These profiles consist of (horizontal inline offset, depth, velocity) triples. The profiles are written to an ASCII file which may be processed conveniently with Golden Software's Surfer® etc., to produce **color-coded inline offset vs. depth velocity-contour maps** / **velocity isolines**. The method **handles real-life geological situations such as velocity gradients** / linear increasing of velocity with depth / velocity inversions / pinching out layers and outcrops / faults and local velocity anomalies gracefully. Furthermore, it **does not require the user to map traveltimes to refractors at all**. Importing seismic data and complementing it with geometry information / traveltime picks is all that is needed. Be sure to do **quality control of models**

obtained by comparing synthetic traveltimes as obtained with our integrated raytracing algorithm against times as measured and picked (as shown in the *Shot breaks display*). Default values for the DeltatV parameters as proposed by the software automatically will work in most cases and no tuning of the parameter values is necessary (but is possible; see below for a description of all parameters).

Alternatively, you may want to have **one core drilling site along the profile**, to check depths delivered by the DeltatV method with velocity-depths as reconstructed from the core. Our **DeltatV method requires 10 or more shots per profile for reliable inversion results**. The more shots the better, as long as first breaks are picked carefully. You may want to record uphole picks from such a deep hole bottom, e.g. with the same receiver spread(s) used to record surface shot picks. These uphole picks can then be integrated with surface picks during the **WET tomography inversion**. Typically, **shot point distances** should not exceed 6 times the receiver distance. A ratio of 1:3 would be ideal. You may want to employ an accelerated weight drop of high mobility to reach a high enough number of shots recorded per hour. Be sure to record enough far **offset shots** (inline offset from the receiver spread by one half to one spread length) to reach your targeted depth / increase the maximum depth imaged. **Receiver spreads should overlap** by a few positions, ideally by up to one half spread length.

For each CMP station nr., a smoothed *CMP traveltime curve* is computed and automatically partitioned into short segments. Each such segment contains first breaks critically refracted (i.e. with the corresponding rays turning back to the surface) inside one hypothetical layer. An individual velocity gradient function is determined for each such layer, based on first breaks measured. The ASCII (inline offset, depth, velocity) triples will be written to a file named DELTATV.TXT in the current profile database directory, e.g. \RAY32\LINE14 when processing the sample profile. One triple will be written for each hypothetical layer interface. The velocity value of that triple is the minimum or average of the bottom velocity of the upper layer and the top velocity of the lower layer. Another file named SEIS32.BLN will be generated in the same directory (not for free trial). It contains a Surfer® boundary format definition of the topography which may be used to blank out gridded values situated above the topography elevation, with *Surfer® menu item Grid|Blank*.

The DeltatV method may deliver **too deep or too shallow interpretations if the receiver or source spacing is too wide to enable proper identification and imaging of the topmost weathering layers**. These depth errors will be revealed when carrying out quality control of these interpretations with our integrated forward modeling algorithm. Just run the Eikonal solver over the depth-velocity model obtained to get a set of synthetic traveltimes for all profile shots. Then compare the modeled times with times as measured and picked, in the *Shot breaks display*. The closer the agreement, the better the model.

To automatically adjust the subsurface velocity model until the synthetic times optimally match the first break times as measured and picked, please employ our new **WET Wavepath Eikonal Traveltime tomography processing.Subsequent WET tomography processing makes it less important to tune the DeltatV parameters**. Default values for DeltatV parameters should give acceptable initial subsurface velocity models for WET processing in most geological settings.

Parameters for Delta-t-V method

CMP curve stack width [CMPs]   25

Regression over offset stations   5

Linear regression method
● least squares   ○ least deviations

Weathering sub-layer count   3

Maximum valid velocity [m/sec.]   6000

Process all CMP curves
● process all CMP   ○ skip every 2nd

Shot & Recvr spacing [Stations], CMPs/Recvr
    11.0   1.8   3.3

Static Corrections   Export Options

Delta-t-V Inversion   Reset   Cancel

When looking at DeltatV output, please be aware that you should give most weight to near-surface imaging. **The deeper the structure imaged, the more uncertainty is involved in determining depth and velocity**. This is caused by **accumulation of modeling errors in the overburden, during reduction of deeper traveltimes to the next lower level** ("overburden layer stripping"). These modeling errors may occur if you specify uncalibrated values for parameter *Regression over offset stations* and other DeltatV parameters. As a consequence of these modeling errors in the overburden, deeper traveltimes will be reduced with unrealistic delay times and may be under- /over corrected. This error accumulation may result in unrealistically high/low velocities as imaged beyond a certain depth (e.g. below the bottom of the overburden) or too shallow/deep interpretations. You may want to adjust (increase from default value of 5) the value for parameter *Regression over offset stations*. and vary parameter *CMP curves stack width*. Alternatively, make use as appropriate, of parameters *Maximum valid velocity* and *Maximum velocity exported* (see below) to suppress the consideration during processing and the later output of unrealistically high velocities. The value specified for the former parameter should exceed the value for the latter and maximum velocity estimates obtained as outlined in the following paragraph by e.g. about 500 to 1000 meters per second.

You may obtain a first guess at maximum real velocities present in the subsurface by measuring traveltime curve dips as displayed in your *Shot breaks display*, using a ruler. Alternatively, you may numerically display these velocities at the bottom of your screen during the *semi-automatic picking of first breaks* in your *Shot gather display*. Also, you may carry out a conventional traveltime curve processing as described in topics Mapping traces to refractors and Time-to-Depth Conversion, to obtain basement velocity estimates. But note that these velocity estimates will be too low in most cases, since there almost always exists a positive vertical velocity gradient inside the basement itself as well. I.e. seismic velocity increases with depth of penetration into the basement, at the turning points of the seismic rays sampling the subsurface.

With option *Output Measured CMP Velocities*. activated, our DeltatV method will combine inverted velocities and depths as obtained during inversion of the CMP sorted and stacked traveltime curves with instantaneous velocities as measured directly on the CMP sorted curves as input to the inversion, at corresponding source-receiver offsets. While disabling this option should deliver more realistic results from a strictly wave propagation physics point of

view (as verifiable with raytracing), enabling it may help to enhance the imaging of near surface velocity anomalies. Please be aware that enabling this option means that basement velocities are not corrected for anomalies in the overburden. So if your primary objective is to image anomalies in the near surface / overburden, you may want to enable this option. If your main goal is to make an educated guess at the basement structure and depth, we recommend to disable this option. Note that <u>unchecking this option may deliver better results</u> in case of undulating topography along the line (with static corrections applied, as per default). Also, unchecking may help with inaccurately picked first breaks (i.e. in low signal-to-noise ratio situations), with low velocity contrasts between overburden and basement geological units and if shot positions are not specified exactly. For the sample profile TRA9002 (tra9002.pdf tutorial on our web site), we recommend to disable this option because of the deep valley the profile crosses. **This option will be <u>unchecked by default</u> when you create a new profile**.

There will always be a significant mismatch between synthetic and picked traveltimes for some traces when checking DeltatV output with subsequent forward modeling i.e. ray tracing though the model obtained, regardless of DeltatV parameters chosen. So you may just as well generate pseudo-2D DeltatV output with default parameters and then carry out subsequent WET tomography processing to automatically adjust the subsurface velocity model. Even better, use our Smooth inversion method, which builds a 1D initial model virtually free of artefacts. With such a 1D gradient initial model, true 2D WET tomography runs a much lower risk to get stuck in a local minimum of the traveltime misfit function (Schuster 1993, equation 1).

DeltatV Settings

Before inverting the traveltime data with our DeltatV method, you may toggle options in
DeltatV|DeltatV Settings :
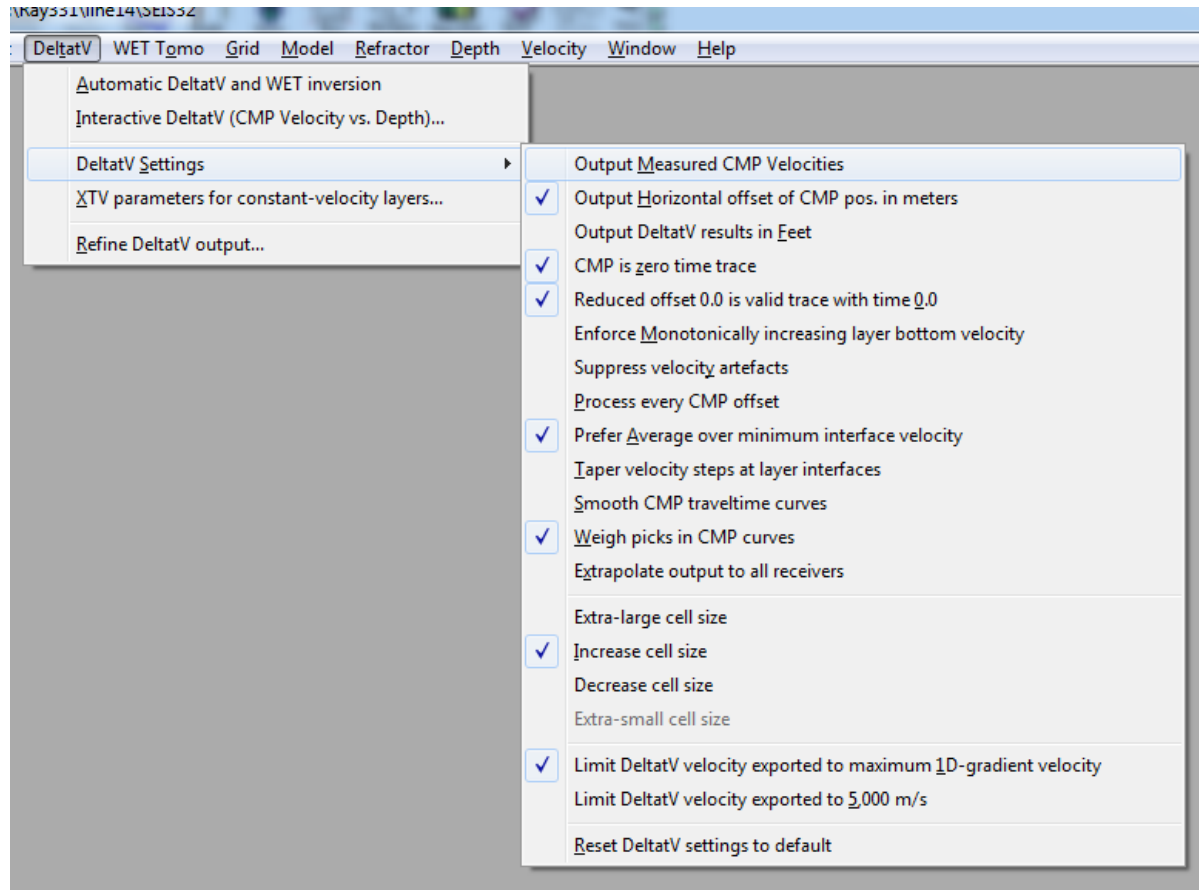
- *Output Measured CMP Velocities* (see above)
- *Output Horizontal offset of CMP pos. in meters*
- *Output DeltatV Results in feet*
- *CMP is zero time trace*
- *Reduced offset 0.0 is valid trace with time 0.0*
- *Enforce Monotonically increasing layer bottom velocity*
- *Suppress velocity artefacts*
- *Process every CMP offset*
- *Prefer Average over minimum interface velocity*
- *Taper velocity steps at layer interfaces*
- *Smooth CMP traveltime curves*
- *Weigh picks in CMP curves*
- *Extrapolate output to all receivers*
- *Extra-large cell size*

- *Increase cell size*
- *Decrease cell size*
- *Extra-small cell size*
- *Edit cell size*
- *Limit DeltatV velocity exported to maximum 1D-gradient velocity*
- *Limit DeltatV velocity exported to 5,000 m/s*

Options *Output DeltatV Results in feet* and *Output Horizontal offset of CMP pos. in meters* may not be activated both at the same time.

Interactive DeltatV

To interactively invert your traveltime data with the DeltatV method, select *DeltatV|Interactive DeltatV*. Read and confirm the warning prompt(s). Review this *Parameters for DeltatV method dialog* :

Adjust these parameters :

◆ *CMP curve stack width [CMPs]*
◆ *Regression over offset stations*
◆ *Least squares regression method*
◆ *Least deviations regression method*
◆ *Weathering sub-layer count*
◆ *Maximum valid velocity [m/s]*
◆ *Process all CMPs*
◆ *Skip every 2nd CMP*

If you invert the traveltime data for the first time, just accept the default parameter values with button *DeltatV Inversion.* If you are not happy with the output or raytracing shows a significant mismatch between picked and synthesized first breaks, change DeltatV options (see above) or default parameter values as following :

Parameters *CMP curves stack width* and *Regression over offset stations* let you specify to what degree the traveltime data should be smoothed horizontally and vertically. We advise you to **vary parameter *Regression over offset stations* between values of 5 to 20 offset stations**. Generally, smaller values for this parameter will deliver more shallow velocity-depths. For **low coverage surveys** or situations of high velocity contrasts between clearly recognizable layers, we recommend to set this parameter to a value near the minimum value of 5. Also, **vary parameter *CMP curves stack width* between values of 10 to 50**

(neighboring Common MidPoints). One station number interval corresponds to two CMP positions (at positions .0 and at .5).

Group box *Linear regression method* lets you select between the two methods *least squares* and *least deviations*. The method specified will be used to carry out a piecewise linearization of *CMP traveltime curves*, to determine smoothed local apparent CMP velocities. With option *least deviations*, the inversion will take about ten times as long as with option *least squares*. See (Press et al. 1986) chapter 14 for details. *Least deviations* will recognize outliers / less relevant data points and give them less weight when modeling / linearizing the trend inherent in the data. *Least squares* treats all data points with the same priority. **Compare *least squares* output with *least deviations* output, in situations of high coverage and noisy picks/automatic picking**. Save the resulting DELTATV.TXT files to differently named files and then image both with Golden Software Surfer®, see below. Set limits and scale of both resulting contour plots to the same values, optimally fit the contour plots to the screen size and page through the plots with CTRL-TAB in Surfer, to compare them visually.

Increase the value of *Weathering sub-layer count* to **obtain slightly slower and more detailed topmost / weathering velocity imaging**. As a consequence, synthetic traveltimes obtained by raytracing through the resulting DeltatV model will be slightly slower.

Parameter *Maximum valid velocity* lets you specify the maximum velocity value accepted as valid when processing CMP curves. Apparent CMP velocities higher than this value will be skipped. See above.

Group box *Process all CMP curves* lets you specify the lateral data density of the ASCII file generated. Option *process all CMP* will process CMP sorted traveltime curves at every CMP location. Option *skip every 2nd* will process every second CMP only. Use this option to reduce computation time for the inversion and the following gridding with Surfer®. This may help to **achieve a fast turnaround time while iteratively calibrating DeltatV parameters against raytracing results or a-priori information** such as core drilling data, data from nearby construction sites such as tunnels or data from geological maps.

DeltatV Static Corrections

In *DeltatV|Interactive DeltatV* main dialog click *button Static Corrections* to display this dialog :
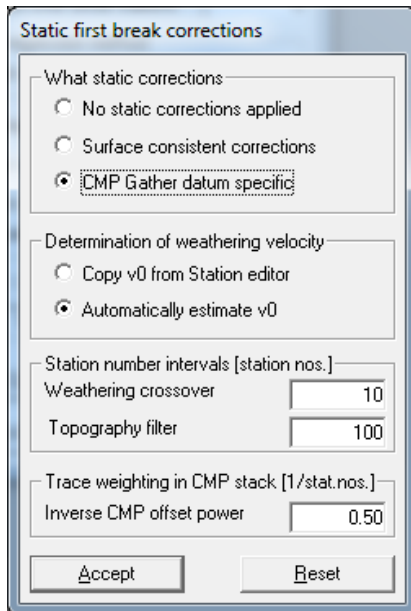
Edit these parameters, for correction of first breaks for undulating topography :

♦   *No static corrections applied*
♦   *Surface-consistent static corrections*
♦   *CMP Gather datum-specific*
♦   *Copy v0 from Station editor*
♦   *Automatically estimate v0*
♦   *Weathering crossover*
♦   *Topography filter*
♦   *Inverse CMP offset power*

The DeltatV method works best if all sources and receivers belonging to the CMP gather currently evaluated are located on a dipping plane. So in case of rough topography, you may want to compute and apply refracted wave first break corrections for each source and receiver, hypothetically moving these vertically up or down until they are located on that dipping datum plane. Refracted wave first breaks will be corrected for shot hole depth and topography, while direct wave first breaks will be corrected for shot position offsets including shot hole depth (assuming a straight ray path between source and receiver). The algorithm makes the simplifying assumption that the turning rays as corresponding to refracted wave first breaks reach the receiver vertically from below / dip down vertically from the source. For source and receiver elevations above the datum elevation determined as below, a negative first break correction is computed and applied (hypothetically moving the source/receiver vertically down, onto the datum plane). For source and receiver elevations below the datum elevation determined as below, a positive first break correction is computed and applied (hypothetically moving the source/receiver vertically up, onto the datum plane).

Group box *Static first break corrections* lets you select between option *No static corrections applied* and the two computation methods *Surface consistent* and *CMP gather datum specific*. See (Frei, 1995) for details. Our CMP gather datum plane is not constricted to a horizontal plane, but will have a constant dip fitting the relevant CMP gather trace specific source and receiver elevations. This is based on the assumption that subsurface geology roughly follows the topography. Also, first break corrections will be as small in value as possible as a consequence. This reduces the danger of over-correcting first breaks for topography features, e.g. if employing a too low weathering velocity for the computation of the datum corrections as described above. We recommend to process each RAYFRACT®profile with two DeltatV parameter values sets : the first set consists of the default values as displayed in these dialogs when processing that profile the first time. The second parameter values set consists of the same values as in the first set, except for *Static first break corrections* : change that parameter to *No static corrections applied*.

Group box *Determination of weathering velocity* lets you choose between the two options *Copy v0 from Station editor* and *Automatically estimate v0*.

Parameter *Weathering crossover* specifies the estimated average crossover distance separating direct wave arrivals from refracted arrivals. You may make an educated guess at this mean crossover distance by looking at the *Midpoint breaks display* (available for full functionality licenses only) or the *Shot breaks display*. This parameter will be used for *Static first break corrections* options *No static corrections applied* and *CMP gather datum specific* to estimate the near-surface weathering velocity. This laterally varying velocity estimate is required for the computation of shot position offset corrections and static corrections, for direct wave and refracted first breaks; see above.
Parameter *Topography filter* specifies the filter width used to obtain a smoothed topography in the context of first break correction method *Surface consistent*, see above.

DeltatV Export Options

In *DeltatV|Interactive DeltatV* main dialog click *button Export Options* to show the *DeltatV method export options dialog* :
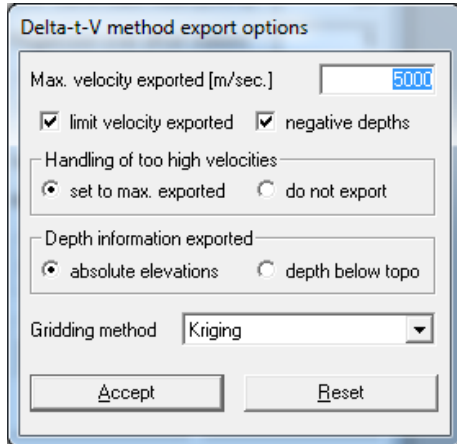
Edit parameters determining the format of the ASCII output file DELTATV.TXT, generated at the end of the DeltatV inversion :

◆   *Maximum velocity exported* lets you specify the maximum value of velocities written to the DELTATV.TXT. See above.

◆   Check box *limit velocity exported* to apply a low-pass filter to velocities written to DELTATV.TXT. This helps to prevent horizontal layering artefacts in the 1D initial model, see http://rayfract.com/tutorials/palmfig3.pdf .

◆   Check box *negative depths* to write depth with a leading minus "-" sign to DELTATV.TXT, in connection with *radio button depth below topography*.

◆   Group box **Handling of too high velocities** lets you specify what should be done with velocities exceeding *Maximum velocity exported* if check box *limit velocity exported* is checked. Select *radio button set to max. exported* to replace the velocity with *Maximum velocity exported*. Select *radio button do not export* if velocities exceeding *Maximum velocity exported* should be skipped during creation of DELTATV.TXT.

◆   Group box **Depth information exported** lets you define if either *absolute elevations* or *depth below topography* should be exported. Select the appropriate radio button.

Once you have edited all parameter values you want to change or to accept the default parameter values, click button *DeltatV Inversion* to start the inversion or abort the inversion with the ESC key.

Observe messages displayed in the status bar at the bottom of your Rayfract® main window. You may switch to other Windows applications while the inversion proceeds. The size of the resulting DELTATV.TXT ASCII file will give you a hint at how many velocity-depth points have been obtained. Inspect the file with a plain ASCII text editor to check if results have been obtained for most CMP stations.

Imaging of DeltatV output

The inversion routine generates files **DELTATV.TXT, MINVELO.TXT** etc. You may want to grid both of these, as described below. The DELTATV.TXT file contains *average interface velocities*, for all CMP's and infinitesimal layers. The MINVELO.TXT contains *minimum interface velocities*. See entry *Z data unit description* of the corresponding .PAR file. Both of these .TXT files normally represent good solutions; the DELTATV.TXT velocities are just a bit faster than the MINVELO.TXT velocities

For automatic gridding and plotting with Golden Software Surfer®, select *Grid|Grid and image DeltatV .TXT file...* :
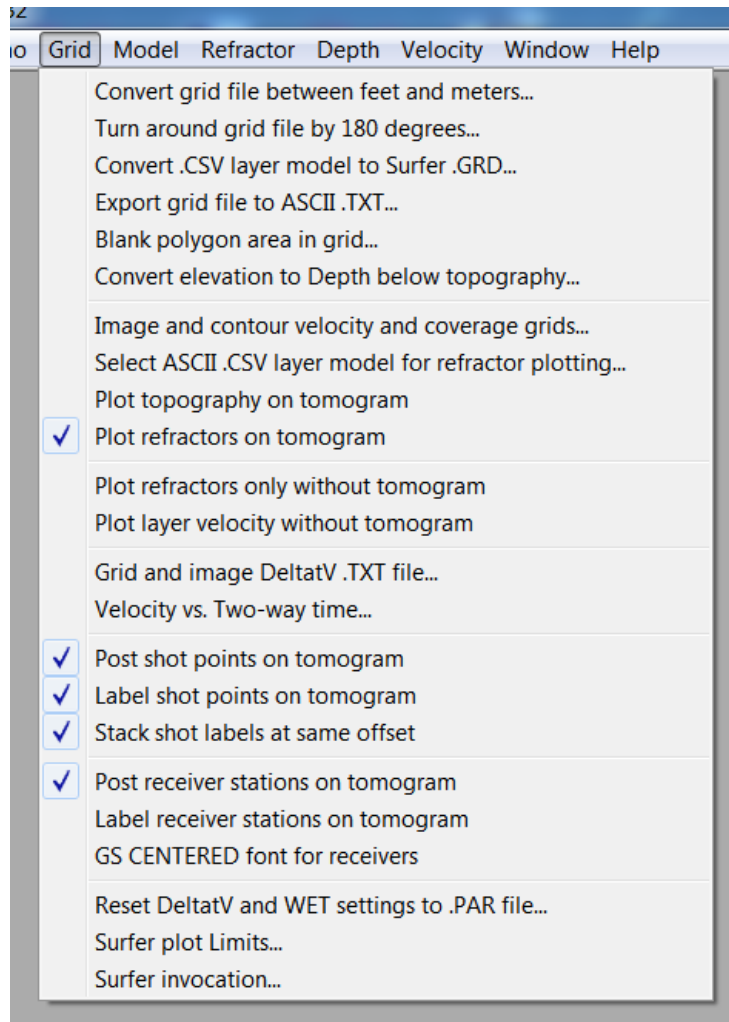
Then select the DELTATV.TXT or MINVELO.TXT as generated by our software. These .TXT files are located in your \RAY32 profile subdirectory. Configure display and labeling of shot points and receivers on Surfer® tomogram plots, with above *Grid menu* options.

For interactive gridding and plotting with Golden Software Surfer®, see our tutorial LINE14.PDF at http://rayfract.com/tutorials/line14.pdf   .

Use our **Smooth inversion**, to obtain a 1D starting model virtually devoid of velocity artefacts. For our pseudo-2D DeltatV inversion, you may want to use a different Surfer®

gridding method than the default kriging method. Specify your preferred gridding method via *DeltatV|Interactive DeltatV|Export Options|Gridding method*. Confirm with *Accept button*. You can then abort the interactive DeltatV inversion with *Cancel button*. Now regrid the DELTATV.TXT generated during an earlier inversion, with *Grid|Grid and image DeltatV .TXT file...* . See our tutorial http://rayfract.com/tutorials/jenny10.pdf for an extreme case of data extrapolation by Surfer kriging method, generating a strong artefact / low-velocity layer in y region -5m to -10m. Natural Neighbor gridding method works much better in this case.

Processing of DeltatV output

When specifying Surfer® section limits in Surfer® menu Map (*Map/Limits*), suppress the display of the first five and last five or so CMP stations of the profile, if these are positioned outside the first/last receiver station. Blanking out these margins at the profile start and end will guarantee that the depth-velocity information displayed in the Surfer® section is based on sufficient coverage of CMP's with first breaks (especially direct wave arrivals). Also, be sure to limit the vertical elevation range / maximum depth shown on the section. The bottom part of the section as displayed with Surfer® default section limits will not convey much useful information, and gridding/contouring of the scarce data with Surfer® becomes instable. This is because ray density in that area is very low in most cases. Only the first breaks recorded for the largest source-receiver offsets will penetrate the subsurface to that depth.

We recommend to use the **Surfer® Matrix Smoothing** (Grid filtering) feature, to obtain a more regular subsurface image. This will help especially in case of irregular topography and noisy DeltatV output (with static corrections applied). E.g. enter values 1 and 15 for edit fields "Rows on Either Side of Center" and "Columns on Either Side of Center". Our Rayfract® DeltatV method (with default parameter values) implicitly applies a higher degree of vertical smoothing than horizontal (lateral) smoothing, to CMP-binned and stacked traveltime curves. If using Surfer® 7, when you smooth over too many rows (e.g. more than 3), low weathering velocities at the topmost grid pixels will be lost and are not recovered during raytracing by extrapolating velocities from lower rows. As a consequence, raytracing will give back too fast synthetic traveltimes. We **recommend to use Surfer® 8 version Matrix Smoothing** (Grid filtering) instead. It preserves data at the topography and at the edges of the grid region covered with velocity data.

Use horizontal smoothing aggressively. For a grid of e.g. 800 horizontal by 200 vertical pixels, use a user-defined running average filter of 3 rows vs. 41 columns. This ensures that local DeltatV artifacts are filtered out while the general velocity trend with depth is preserved. Keeping the original velocity is important directly below the topography. The weathering velocity typically increases quite suddenly with depth over just a few rows. So we recommend to smooth just over 3 rows.

For short profiles with e.g. 24 or less receiver stations, try activating DeltatV option *DeltatV/DeltatV Settings/Output DeltatV Results in feet* to obtain a more regular model when kriging/gridding and smoothing DeltatV output with Surfer®. Then convert the Surfer® .GRD file obtained back to meters with *Grid/Convert Grid file between feet and meters... .*

In situations of undulating line topography, refine DeltatV output with *DeltatV/Refine DeltatV output... .* This menu item asks you to specify a Surfer® .GRD file obtained from previous DeltatV or WET output for the same line and with identical processing options and parameters. DeltatV internal static corrections will then be computed by integrating the delay time over .GRD velocity cells at corresponding source and receiver locations, instead of applying the smoothed weathering velocity as done during standard DeltatV processing (see above). You may specify a Surfer® .GRD file as generated by WET tomography processing, e.g. C:\RAY32\GRADTOMO\VELOIT10.GRD.

For reflection seismic processing, you may obtain a rough estimate of zero offset near-surface vertical velocity vs. two-way time with *Grid/Velocity vs. Two-way time... .*

To refine the DeltatV output with true 2D WET, see topic **WET tomography processing**.

XTV inversion

Delta-t-V and XTV inversion assume that traces are gathered by Common Mid-Point CMP (Diebold and Stoffa 1981). Also, these inversion methods rely on the suppression of layer dip effects on apparent velocity, when sorting traces in a CMP gather by unsigned offset (Diebold and Stoffa 1981). This suppression fails at locations of strong refractor curvature. Barton and Baker (2003) try to obtain improved apparent velocities by regarding the shot direction.

To enable the realistic interpretation of sudden apparent velocity increase in CMP sorted traveltime curves, (Winkelmann 1998) proposes to extend the Delta-t-V gradient layer inversion (Gebrande 1986), with Dix inversion and Intercept Time inversion. These two additional inversion methods allow the **modeling of constant-velocity layers**.

As described by (Winkelmann 1998) and (Gawlas 2001), the XTV inversion reconstructs the 1D velocity vs. depth function v(z) below a CMP based on XTV data triples, with values X = (reduced) unsigned offset, T = (reduced) time and V = apparent velocity. These data triples sample a (reduced) CMP sorted traveltime curve. The inversion is based on the layer stripping principle. With "offset" we always mean "unsigned offset" in the following.

XTV inversion uses three separate methods, for inversion of a data triple into a model layer :

➢   Modified Dix inversion
➢   Intercept Time inversion
➢   Gradient layer inversion (original Delta-t-V method)

The inversion starts with the first XTV triple at the smallest offset X, as determined from the original CMP curve. Once the first layer has been determined by one of above methods, offset and time for all other triples are reduced to the bottom of this first layer. Then the XTV triple at the next smallest offset X is inverted into a second layer, and remaining triples are reduced to the bottom of this second layer. This triple inversion process is continued iteratively, until all XTV triples have been processed.

We first describe each of these three inversion methods in detail. We then describe the overall XTV algorithm, which decides what inversion method should be applied to the current XTV triple. All inversion methods are described for the two-layer case only. Since the XTV inversion is based on layer stripping, we only need to deal with two layers (current overburden, current refractor) during each iteration and triple-to-layer inversion step.

The modified **Dix inversion assumes reflection of a ray**. The layer thickness h is determined as follows :

$$ h \; = \; \frac{\Delta}{2} \sqrt{\frac{Vt}{\Delta} - 1} $$

(1)

Δ is the unsigned offset X between shot point and receiver.
t is the traveltime T between shot point and receiver, separated by offset Δ.
V is the measured apparent velocity, at the bottom of the layer i.e. at offset Δ.

The average layer velocity $\bar{v}$ is obtained with

$$\bar{v} = \sqrt{\frac{V\Delta}{t}}$$

(2)

Velocities at the top and at the bottom of the modeled layer are both set to this average velocity $\bar{v}$.

The **Intercept Time inversion assumes critical refraction of a ray**, with both overburden and basement layer having a constant velocity. Using intercept time τ as determined from the XTV triple with

$$\tau = t - \frac{\Delta}{V}$$

(3)

the layer thickness h is determined with

$$h = \frac{\tau}{2\sqrt{(1/v_1)^2 - (1/V)^2}}$$

(4)

v_1 is the direct wave velocity (for first XTV triple) or the velocity as modeled for the bottom of the previously determined layer (for reduced XTV triples).

Velocities at the top and at the bottom of the modeled layer are both set to v_1 .

The **Gradient layer inversion method or Delta-t-V method assumes a diving wave ray and a constant velocity-gradient** equal to a. So the layer's velocity-depth function is

$$v(z) = a \cdot z + v_0$$

(5)

Since the velocity gradient a is assumed constant, the diving first-break ray follows a circular arc, between shot point and receiver. Based on the two equations

$$\Delta(V) = \frac{2}{a}\sqrt{V^2 - v_0^{\,2}}$$

(6)

and

$$t(V) = \frac{2}{a} arch(\frac{V}{v_0})$$

(7)

the velocity v_0 at the top of the modeled layer is determined numerically. Then the layer thickness h is

$$h = \frac{\Delta}{2}\sqrt{\frac{V - v_0}{V + v_0}}$$

(8)

and the velocity at the bottom of the modeled layer is set to the measured velocity V. v_0 can be smaller than the velocity measured at the bottom of the overlying layer. So the gradient layer inversion can recognize velocity inversions, at least in some situations. Also, the gradient layer inversion does not use the intercept time τ. Layer stripping is done using equations as described by Gibson et al. (1979).

XTV parameter dialog

Display the *XTV parameter dialog* with *DeltatV|XTV parameters for constant-velocity layers* :
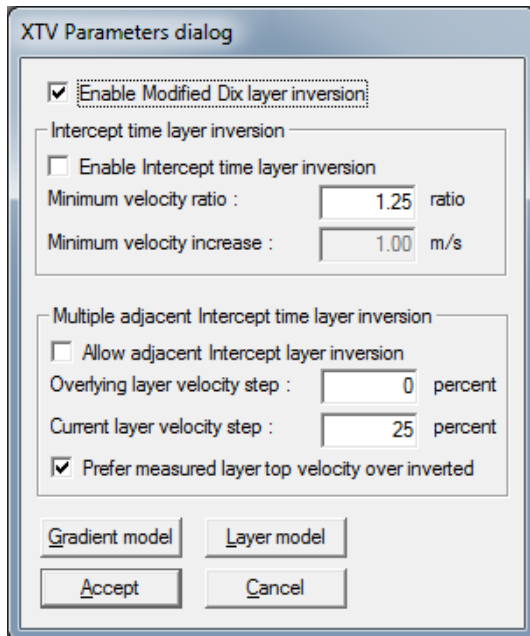
Our **XTV inversion implementation** assumes that apparent velocity increases with offset. So XTV triples are sorted by offset, for layer inversion as described here. (Winkelmann 1998) proposes the following XTV inversion algorithm :

♦ Use Intercept Time inversion if the apparent velocity V increases suddenly, between adjacent XTV triples. The *Minimum velocity ratio* required for application of the Intercept Time layer inversion can be adjusted by the user. Set this to 1.01 to force application of Intercept Time method whenever possible. Intercept Time inversion can be disabled with XTV parameter box *Enable Intercept Time layer inversion*.

♦ Otherwise use Dix inversion if both the average velocity $\bar{v}$ (determined with Dix inversion) and the velocity v_0 at the top of the modeled layer (determined with Gradient layer inversion) are smaller than the velocity modeled for the bottom of the previously determined layer. You may disable Dix inversion with XTV parameter box *Enable Modified Dix layer inversion*.

♦ Otherwise use Gradient layer inversion.

Check which layer inversion method has been used for each XTV triple, in last column of file GRADIENT.TXT for Smooth inversion, or DELTATV.TXT for pseudo-2D DeltatV inversion :
1=DeltatV Gradient, 2=Modified Dix reflection, 3=Intercept-time method.

A candidate XTV triple is optionally rejected if its apparent velocity V or intercept time τ are larger than average values for the next three XTV triples. This triple filtering has the aim of

suppressing reflections erroneously picked as first breaks.

Intercept Time layer inversion for multiple adjacent XTV triples

v_1 as required for Intercept Time layer inversion is not clearly defined, especially if the previous layer has been obtained with Intercept Time inversion as well. You may suppress application of our Intercept Time inversion to multiple adjacent XTV triples, with XTV parameter *Allow adjacent Intercept time layer inversion*.

If the previous XTV triple was inverted with Intercept Time layer inversion as well, then the velocity v_1 for the bottom of the previous layer may be assumed to be the previous v_1, or the apparent velocity V of the previous XTV triple, or any value between these two velocities. Alternatively, v_1 can be determined by interpolating between the previous v_1 and the apparent velocity V of the current XTV triple.

You may specify how v_1 should be determined with XTV parameters *Overlying layer velocity step* and *Current layer velocity step*.

If the resulting v_1 exceeds the previous apparent velocity V, v_1 used for inversion of the current XTV triple is reset to V of the previous triple.

The XTV inversion ensures that the sum of *Overlying layer velocity step* and *Current layer velocity step* does not exceed 100%.

If you want to use apparent velocities V (from previous and current XTV triples) exclusively and disregard previous v_1, for determination of the current v_1 based on step parameters *Overlying layer velocity step* and *Current layer velocity step*, just enable XTV option *Prefer measured layer top velocity over inverted*. If this option is enabled, the apparent velocity V as obtained for the previous XTV triple and layer is taken as an estimate for the velocity at the top of the current layer. In analogy, the velocity at the top of the previous layer is estimated with the apparent velocity V of the previous-previous XTV triple.

Parameters for XTV inversion

Minimum velocity ratio

The minimum velocity ratio (between apparent velocity V of the current XTV triple and the previous triple) required for application of the Intercept time layer inversion. If the actual ratio is smaller, the Intercept Time layer inversion method will not be applied. Instead, Dix inversion or Gradient layer inversion will be applied to the current XTV triple. Valid ratio values range from 1.01 to 2.5 . This ratio is regarded if XTV parameter _Enable XTV Intercept Time layer inversion_ is checked only.

Enable Intercept Time layer inversion

Check this XTV option if you want to enable XTV Intercept Time layer inversion

Enable Modified Dix layer inversion

Check this XTV option if you want to enable Dix layer inversion

Allow adjacent Intercept time layer inversion

Check this XTV option to enable application of our Intercept Time inversion method, for multiple adjacent XTV triples.

Overlying layer velocity step

This XTV parameter is used if _Allow adjacent Intercept time layer inversion_ is enabled only. This step parameter may vary between values 0% and 100%. The velocity step determines how v_1 needed for Intercept Time inversion of the current XTV triple is obtained, from the previous XTV triple and by interpolation between the previous v_1 (step 0%) and the previous apparent velocity V (step 100%).

Current layer velocity step

This XTV parameter is used if _Allow adjacent Intercept time layer inversion_ is enabled only. This step parameter may vary between values 0% and 99%. The velocity step determines how v_1 needed for Intercept Time inversion of the current XTV triple is obtained, by interpolation between v_1 as obtained with step parameter _Overlying layer velocity step_ (current step 0%) and the current apparent velocity V (current step 100%).

Prefer measured layer top velocity over inverted

Check this XTV option to use apparent velocities V (belonging to previous and current XTV triples) exclusively and disregard the previous v_1 , for determination of the current v_1 , based on step parameters _Overlying layer velocity step_ and _Current layer velocity step_ .

Overburden velocity v_1 is needed for our Intercept Time two-layer case inversion method. If this option is enabled, the apparent velocity V as obtained for the previous XTV triple and layer is taken as an estimate for the velocity at the top of the current layer.

Suppress velocity artefacts

Enable this *DeltatV|DeltatV Settings* option to suppress the generation of processing artefacts, i.e. unrealistic velocity variations. Use best for medium and high coverage profiles. See (Winkelmann 1998), top of page 36. If enabled, a candidate ray will be used for modeling of an incremental layer if the ray specific apparent velocity and intercept time (as modeled by local regression on CMP curve, at ray specific offset) both are lower than the mean of apparent velocity and intercept time, as estimated for the next three higher CMP offsets. This triple filtering has the aim of suppressing reflections erroneously picked as first breaks. If this setting is disabled, no candidate ray selection, i.e. filtering / enforcing of *CMP traveltime curve* continuity, based on apparent velocity and intercept time will occur.

Model sharp velocity contrast between overburden and basement with Smooth XTV inversion

To **image a sudden velocity increase at bottom of weathering overburden in your 1D initial model for Smooth inversion :**

◆   check *Smooth invert|Smooth inversion Settings|Allow XTV inversion for 1D initial model*
◆   uncheck *Smooth invert|Smooth inversion Settings|Interpolate velocity for 1D-gradient initial model*
◆   uncheck *DeltatV|DeltatV Settings|Reduced offset 0.0 is valid trace with time 0.0*
◆   select *DeltatV|XTV parameters for constant-velocity layers...* to display XTV parameters dialog
◆   check box *Enable Modified Dix layer inversion*
◆   check box *Enable Intercept time layer inversion*
◆   check box *Allow adjacent Intercept time layer inversion* to realistically image this velocity jump
◆   set *Minimum velocity ratio* to 1.01 to use intercept-time method whenever possible
◆   click *Accept button*
◆   now run *Smooth invert|WET with 1D-gradient initial model* and confirm prompts as usual

Alternatively click *button Layer model* in *DeltatV|XTV parameters for constant-velocity layers...* to configure XTV inversion for assumed layered subsurface.

Click *button Gradient model* in *DeltatV|XTV parameters for constant-velocity layers...* to configure XTV inversion for assumed gradual increase of velocity with depth.

See our tutorial http://rayfract.com/tutorials/jenny10.pdf for detailed and illustrated instructions. This also shows **imaging artefacts caused solely by Golden Software Surfer version 8 Kriging gridding method**. Natural Neighbor gridding method works much better, at least in this case, for imaging of pseudo-2D XTV inversion output.

DeltatV and XTV method references

J. B. Diebold and P. L. Stoffa 1981. The traveltime equation, tau-p mapping, and inversion of common midpoint data. SEG Geophysics, volume 46, pp. 238-254.

Roland A. Winkelmann 1998   Ph. D. Thesis. Entwicklung und Anwendung eines Wellenfeldverfahrens zur Auswertung von CMP-sortierten Refraktionseinsaetzen. Akademischer Verlag Muenchen, Munich. ISBN 3-932965-04-3.

Gawlas, Peter Florian 2001 Ph. D. Thesis. Möglichkeiten eines DMO-Prozesses in der CMP-Refraktionsseismik. LMU Munich: Faculty of Geosciences. See http://edoc.ub.uni-muenchen.de/222/1/Gawlas_Peter.pdf

H. Gebrande 1986. CMP-Refraktionsseismik. Paper presented (in German) at Mintrop Seminar / Uni-Kontakt Ruhr-Universitaet Bochum, Expanded abstract "Seismik auf neuen Wegen", pp. 191-205.

H. Gebrande and H. Miller 1985. Refraktionsseismik (in German). In: F. Bender (Editor), Angewandte Geowissenschaften II. Ferdinand Enke, Stuttgart; pp. 226-260. ISBN 3-432-91021-5.

Bruce S. Gibson, Mark E. Odegard and George H. Sutton 1979. Nonlinear least-squares inversion of traveltime data for a linear velocity-depth relationship. Geophysics, volume 44, pp. 185-194.

Barton P. and Barker N. 2003. Velocity imaging by tau-p transformation of refracted seismic traveltimes. Geophysical Prospecting, volume 51, pp. 195-203.

Midpoint breaks display

Displays first breaks in a Common Mid Point (CMP) versus offset coordinate system. Open this display with *Refractor|Midpoint breaks* :
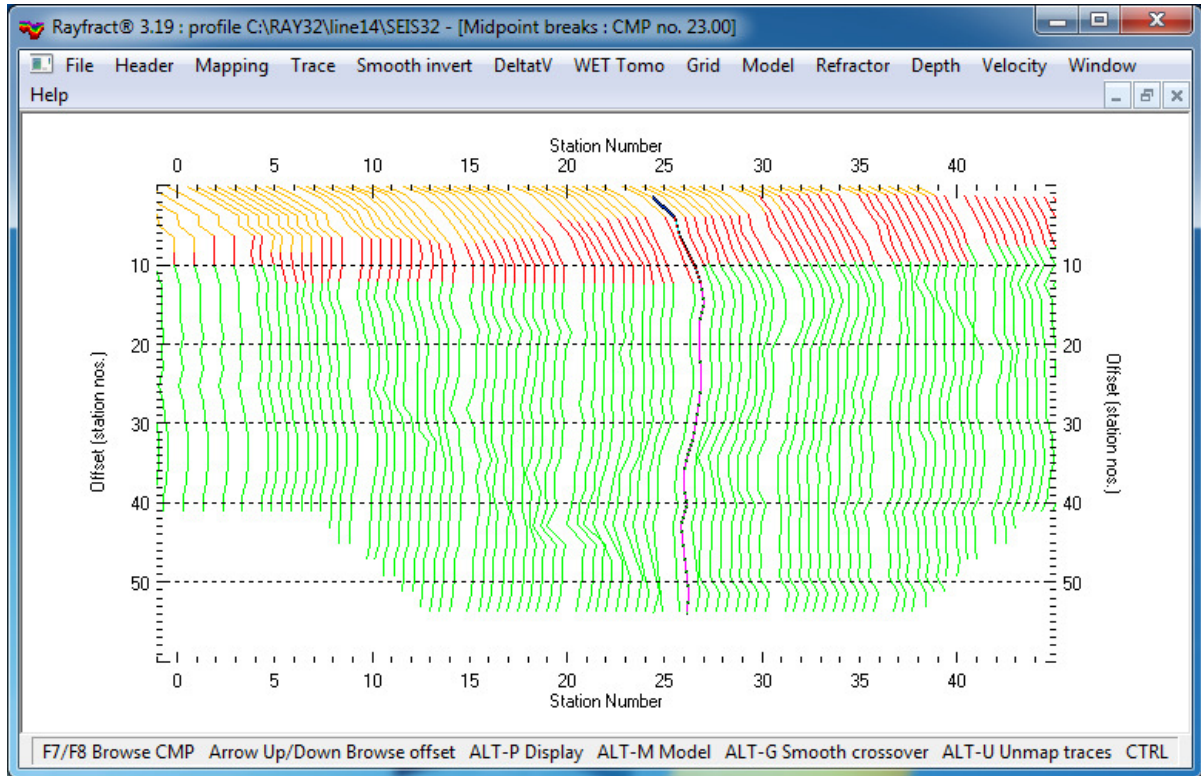
At each CMP (horizontal axis, in station numbers), a local coordinate system is appended, with its origin at that CMP. It has recording time as horizontal axis (not displayed; overlaps CMP station number axis) and unsigned shot point to receiver offset as vertical axis.

In each local coordinate system, one CMP traveltime curve is displayed. The curve is constructed by connecting first breaks picked for traces mapped to that CMP and with adjacent unsigned offsets by straight line segments. Traveltime curves for adjacent CMP positions are binned and stacked according to parameter value *CMP Stack Width*.

The **instantaneous velocity** as directly available from the local traveltime curve dip (at specific offset and CMP) is less dependent on the refractor dip than velocities as inferred from shot sorted traveltime curves. Also, the vertical plotting of traveltime curves makes it easier for the eye to recognize gradual velocity variations.

Trace to refractor mapping parameters

You may **semi-automatically assign first breaks to refractors** (based on instantaneous velocity) with ALT+M :

Trace to refractor mapping parameters

Processing Options	
☑ Direct wave first breaks recorded	

Velocity Determination Parameters

Refractor Count [1 or 2]	2
CMP Stack Width [CMPs]	25
Regression Receiver Count	3
Direct Wave Delta [station	3
Refracted Wave Offset Delta	5

Specify Upper Layer Velocity Limits [m/sec.]

Weathering	Refractor 1	Refractor 2
930	1550	7000

Median Layer Velocities Detected [m/sec.]

Weathering	Refractor 1	Refractor 2
819	1372	1719

Shot & Recvr spacing [Stations], CMPs/Recvr

11.0	1.8	3.3

Map traces	Reset	Cancel

Edit these parameters :

◆ *Direct wave first breaks recorded*
◆ *Refractor Count*
◆ *CMP Stack Width*
◆ *Regression Receiver Count*
◆ *Direct Wave Delta*
◆ *Refracted Wave Offset Delta*
◆ *Weathering velocity limit*
◆ *Refractor 1 velocity limit*

To display the context-sensitive help popup, tab to the parameter field of interest and press function key F1 . See also topic Mapping traces to refractors.

Once you have edited these parameters, click button *Map traces*.

Crossover distance processing

Next select *Mapping/Crossover processing* or press keyboard shortcut ALT+G :
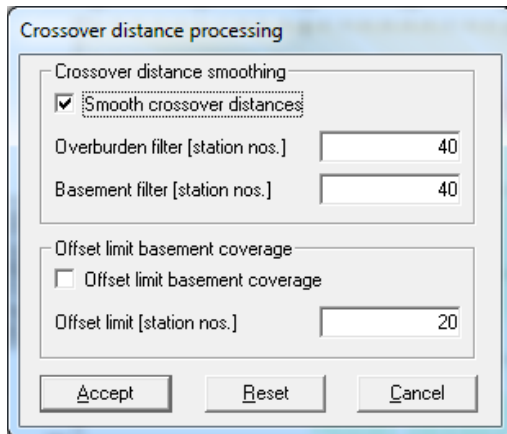
The *Crossover distance processing dialog* lets you edit these parameters :

- *Smooth crossover distances*
- *Overburden filter [station nos.]*
- *Basement filter [station nos.]*
- *Offset limit basement coverage*
- *Offset limit [station nos.]*

To display the context-sensitive help popup, tab to the parameter field of interest and press function key F1 .

Once you have edited these parameters, click button *Accept* to smooth the crossover distances and redisplay the *Midpoint breaks display.*

Mapping traces to refractors

Manually assign traces to refractors by interactively picking branch points for single shot-sorted traveltime curves in Shot breaks display

When interpreting a low-coverage refraction profile (e.g. less than 20 shots), or you want to have complete control over the process of assigning traces to refractors, select *Refractor|Shot breaks* :
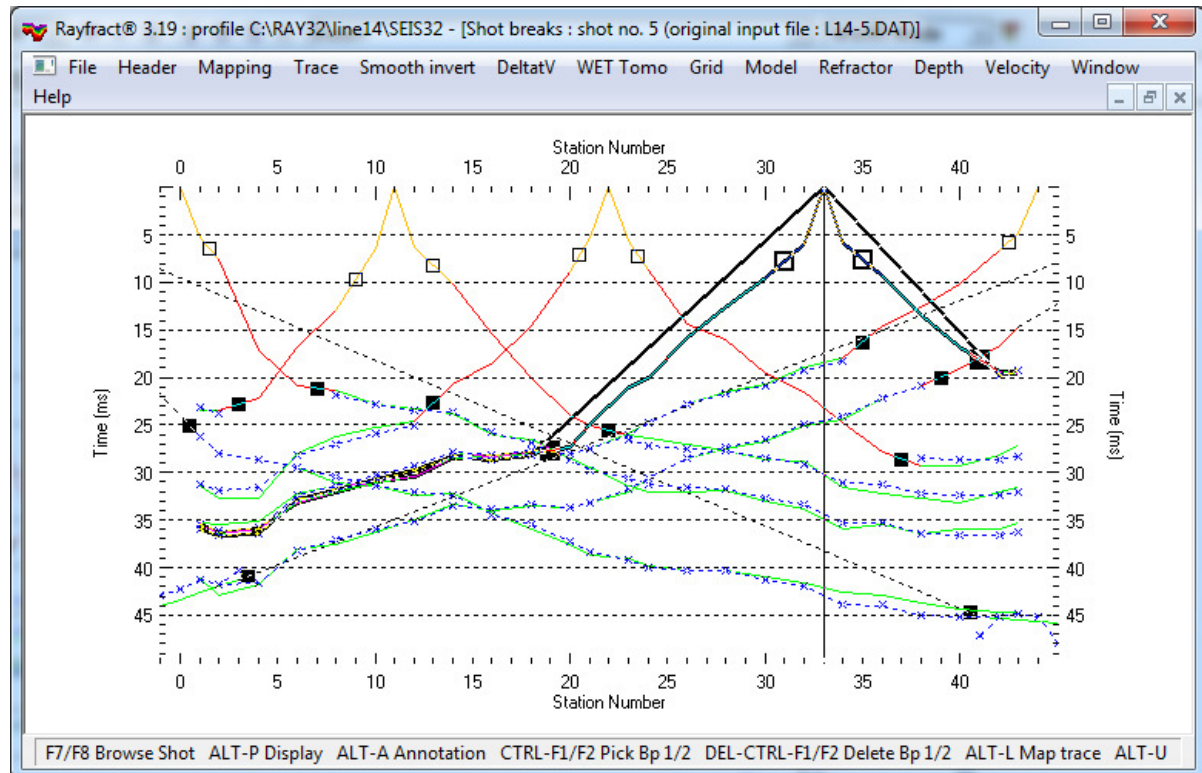
We split one travel time curve (forward or reverse shooting direction) into two or three segments or branches with *branch points* based on apparent velocity or dip of curve segment in *Refractor|Shot breaks display*.

In this display a steep dip of the curve (at shot point/at time 0) means low velocity and the more shallow the dip gets along the curve (moving away from shotpoint and down in time) the higher the apparent velocity. Assuming a layered subsurface we can observe sudden changes in dip or slope of traveltime curves at offsets where the first breaks critically refracted by a deeper refractor overtake first breaks from the overlying refractor or direct wave (**crossover distance**). *Branch points* should be picked at the crossover distance along the traveltime curve.

The hollow/outlined *first branch point 1* (empty box) separates the direct wave (yellow) from first refractor (red) branch.

The black square *second branch point 2* separates the first refractor (red) from 2nd refractor (green).

Our *Refractor|Shot breaks display* visualizes first breaks picked for all profile traces in a conventional *Shot breaks display*. **To pick a branch point** :

◆   select desired shot sorted traveltime curve with **F7/F8** function keys

◆   move the vertical ***pick bar*** horizontally with your cursor left/cursor right keys (left arrow key/right arrow key)

◆   move the pick par until it is located at an assumed *branch point* for the currently selected (highlighted) traveltime curve

◆   pick the branch point at that location with **CTRL-F1** (first branch point) or **CTRL-F2** (second branch point)

Once you have picked *branch points* for both forward and reverse shot directions of the currently selected traveltime curve, select the previous/next traveltime curve with **F7/F8**. Now first breaks of the formerly selected curve are mapped to refractors according to the *branch points* picked as above. Any errors with your *branch point* selection will be indicated in an error prompt.

Handling of **pinching out weathering layer/first refractor** (3-layer case) : if the weathering layer pinches out pick the second *branch point* only or pick both first and second branch point at same location directly besides shotpoint (in between shotpoint and closest receiver). If the first refractor pinches out pick both *branch points* at the same profile position (for same shot direction).

To delete one branch point picked :

◆   select traveltime curve with **F7/F8**

◆   move the pick bar to the left/right of the shot point depending on whether you want to delete a *branch point* in the reverse/forward shot direction

◆   press **ALT+F1** to delete *branch point* 1 or **ALT+F2** to delete *branch point* 2

To delete all branch points for the currently selected shot use **SHIFT+Z** keyboard shortcut.

	Mapping	Trace	Smooth invert	DeltatV	WET Tomo	Grid	Model

	Refractor mapping...	ALT+M
	Refractor display...	ALT+P
	Refractor annotation...	ALT+A
✓	Automated updating of station V0	ALT+V
✓	Update station V0 before depth conversion	ALT+D
	Update station V0 for crossover smoothing only	ALT+0
	Undercorrect picks for shot point offset	ALT+N
	Regard mapping for shot offset correction	ALT+R
	Check shot positions	SHIFT+O
	Remap all traces	ALT+L
	Crossover processing...	ALT+G
	Undo trace mapping and corrections	ALT+U
	Delete all branch points for current shot	SHIFT+Z
✓	Display raytraced traveltimes	ALT+T
✓	Display synthesized traveltime curves	ALT+S
	Color picked traveltime curves	ALT+C
	Color picked curves by source type	ALT+K
	Gray picked traveltime curves	ALT+I
	Dark gray traveltime curves	ALT+E
	Blue direct wave first breaks	ALT+B
	Refresh display	ALT+Y

To **remap all traces to refractors based on branch points picked** interactively as described above select *Mapping|Remap all traces* or press `ALT+L` in the *Shot breaks display*. If you select this menu item with the *Midpoint breaks display* currently activated the *Trace to refractors mapping parameters dialog* will be shown instead (see below). Whenever you repick a first break or remap traces to refractors by repicking *branch points* as described above **all depth and velocity sections computed previously are invalidated**. Section windows are closed automatically. To recompute and redisplay these depth and velocity sections remap all traces to refractors as just described. Then optionally update the weathering velocity in *Header|Station*. Now reselect the appropriate items in the *Depth menu* and *Velocity menu* to redo the time-to-depth conversion and redisplay the resulting sections.

Branch points separate segments of the shot-sorted traveltime curve connecting your first break picks at spread receivers. Therefore **branch points are positioned between receivers**. The shot point is considered as a receiver with fixed traveltime 0.0.

Near the *shot point* we move the pick bar in 0.25 *station spacing* increments with `arrow-left` or `arrow-right keys` instead of one *station spacing* to slow down movement of the pick bar when you keep pressing `arrow-left` or `arrow-right keys` to move the pick bar along the traveltime curve.

At the shot point the *branch point* picking is more critical for correct determination of *weathering velocity*. This has a large effect on the imaging of deeper layers. If you pick the branch point directly besides the shot point (between shot point and adjacent receiver) then you define an outcrop of the 1st refractor at the shot point, with weathering layer thickness equal to zero (0.0).

When browsing shot-sorted traveltime curves with **F7/F8 keys** in *Refractor|Shot breaks* : at the left end of the *receiver spread* we position the pick bar 0.25 or 0.5 *station spacings* to left of first spread receiver if there are no receivers to left of current shot point.

If the *shot point* is located to the right of the leftmost spread receiver then we position the pick bar 0.25 or 0.5 station spacings left of the shot point i.e. between shot point and next-lower receiver position .

Semi-automatically / iteratively assign traces to refractors by specifying a typical 1D-velocity model and fitting mapping parameters in Midpoint breaks display

Your Rayfract® software is optimally suited to process first breaks gathered from high-coverage seismic surveys e.g. from seismic reflection surveys. With the term "high coverage" we mean lines with more than 20 shots recorded per profile and **with a shot fired at every fourth receiver position or with an even closer spacing of shot points e.g. at every second receiver position**. To view the first breaks for all traces of such a survey in a CMP sorted display select *Refractor|Midpoint breaks.* You will see your first breaks displayed in a *Midpoint breaks display*. This display has been described by Gebrande and Miller (Gebrande and Miller, 1985). Its advantage when compared to the traditional shot traveltime curve display is based on the fact that **the influence of the dip of layers on the traveltime curves is reduced in the CMP gather** display (Rühl, 1995).

Apparent CMP velocities will be incorrect by about ten to twenty percent at locations of strong refractor curvature however. This typically occurs at the bottom of narrow/steep synclines and at the top of narrow/steep anticlines. Also this display offers the possibility to **uniquely map profile position (i.e. station number) to crossover distance** for each refractor. As a consequence *crossover distances* (offsets where head wave first breaks from a deeper refractor overtake head wave first breaks from a shallower refractor or direct arrivals) may be identified more easily as systematic discontinuities in slope of *CMP traveltime curves* (abrupt changes of slope). We will from now on call the location of such a discontinuity a *branch point*. A traveltime curve mapped to refractors is separated by *branch points* into segments. First breaks (receivers) contained in one segment are all mapped to the same refractor. Such a segment is commonly called a *refractor branch* (located on a traveltime curve).

Open the *Refractor|Midpoint breaks display* :
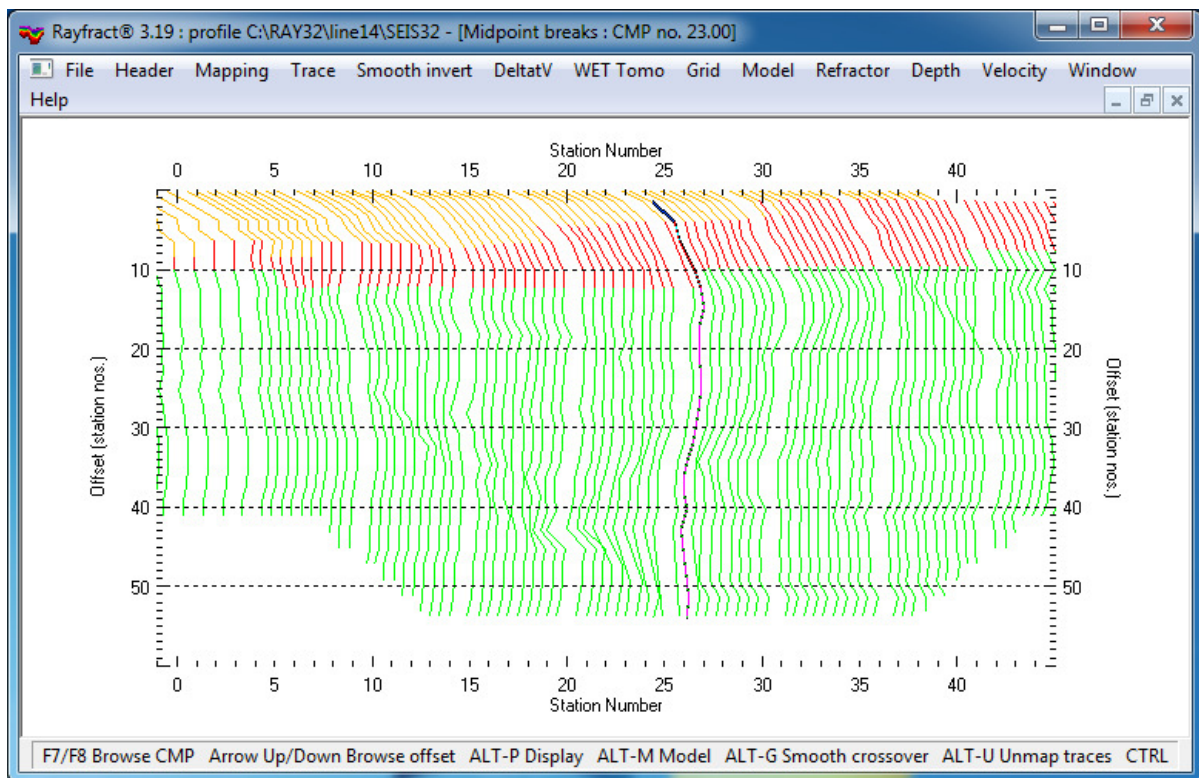
Browse CMP sorted traveltime curves with `F7/F8` function keys. Browse offset along one curve with `Arrow Up/Arrow down` keys. The status bar will show local apparent velocity etc.

Trace to refractor mapping parameters

Press `ALT+M` to display the **Trace to refractor mapping parameters dialog** :

This lets you set the following parameters :

◆ *Direct wave first breaks recorded*

◆ *Refractor Count,*

◆ *CMP Stack Width,*

◆ *Regression Receiver Count,*

◆ *Direct Wave Offset Delta,*

◆ *Refracted Wave Offset Delta*

◆ *Weathering layer velocity limit*

◆ *Refractor 1 velocity limit*

Check **Direct wave first breaks recorded** if receivers and shot points are spaced closely enough to each other so that the first few receivers next to a shot point record the direct wave as a first break. Or pick first *branch points* for all shots in *Refractor|Shot breaks* and press `ALT+L` to copy realistic *weathering velocity* into *Header|Station*. Now uncheck **Direct wave first breaks recorded** in *Refractor|Midpoint breaks*`|ALT+M`, edit other mapping parameters

as described above and press button *Map traces*. Subsequent time-to-depth conversion via *Depth menu* is based on the weathering velocity specified in *Header|Station.* This prevents over-estimation of *weathering velocity* in *Midpoint breaks display* resulting in a too deep basement refractor. See our tutorial http://rayfract.com/tutorials/NORCAL14.pdf .

CMP Stack Width (valid values : 1 to 25) defines how many adjacent CMP positions (centered at the CMP position currently being evaluated) are regarded when constructing a *CMP traveltime curve* This stacking is done when mapping traces to refractors in the *Midpoint Breaks display* and when determining CMP intercept times and apparent velocities from first breaks assigned to the same *refractor branch* during CMP Intercept Time Refraction time-to-depth conversion.

Regression Receiver Count (valid values : 3, 4 or 5) specifies how many adjacent receiver positions with first breaks recorded (on the same *CMP traveltime curve*) are minimally considered when determining a local apparent CMP velocity (for a given CMP point and a given offset). Velocity estimation is done by carrying out a least-squares linear regression through these first breaks. For medium-coverage data (e.g. less than 10 first breaks per CMP curve) a value of 3 is recommended. For high-coverage data a value of 4 may be more appropriate (if offset differences between adjacent first breaks on the same CMP curve are small enough). The actual number of receiver positions used for local traveltime curve linearization may be higher than the minimum value specified here depending on the values specified for *parameters Direct Wave Offset Delta* and *Refracted Wave Offset Delta*, see below.

Direct Wave Offset Delta (valid values : 3 to 10) and **Refracted Wave Offset Delta** (valid values : 3 to 20) specify the offset range (in unsigned shotpoint-to-receiver offset station numbers) considered when determining a local apparent CMP velocity, for a given CMP position and offset. *Direct Wave Offset Delta* is relevant for small shotpoint-to-receiver offsets, when mapping the weathering layer. *Refracted Wave Offset Delta* applies to all other, larger offsets. Since velocity contrast between weathering layer velocities and refractor velocities is usually quite high, but coverage of the weathering layer *refractor branch* is short, a value of 3 to 5 may be most appropriate for *parameter Direct Wave Offset Delta*. If velocity contrast between refractor 1 and refractor 2 velocities is small, or if refractor 1 contains local velocity inversion zones, a value of 5 to 10 may be appropriate, for parameter *Refracted Wave Offset Delta*. This high value / long offset range may be necessary to cleanly detect *branch points* (systematic apparent velocity changes identifying *crossover distances* separating refractor 1 branches from refractor 2 branches).

The next two editable *control fields* **Weathering** and **Refractor 1** contained in *group box Specify Upper Layer Velocity Limits*, specify a 1D velocity model. For a 2-layer case, just the first value is needed. The corresponding refractor velocity intervals as defined by these limits are used to map an apparent CMP velocity, estimated as described above, to a refractor. **Velocity inversions are not supported** and it is assumed that the speed of refractor 2 is strictly higher than the speed of refractor 1 and that the speed of refractor 1 is strictly higher than the weathering velocity (speed of direct wave) at one CMP position. When regarding one *CMP traveltime curve* it is assumed that apparent CMP velocity strictly increases with offset (between shot point and receiver for all traces mapped to that CMP).

The bottom-most three *static (read only) text fields* contained in *group box **Median Layer Velocities Detected*** display the median refractor velocities detected by local velocity estimation as described above, over the whole profile. These are output-only fields. They may serve to iteratively improve your 1D velocity model as specified above. Once you have (re)assigned traces to refractors redisplay the dialog with **ALT+M** and inspect these median values.

Once you have entered correct values for all input fields of *dialog Trace to refractor mapping*

parameters, click **button Map traces** or press **ENTER/RETURN** to accept these values and to carry out the automatic assignment of traces/first breaks to refractors based on parameter settings entered. Traveltime curve segments assigned to the weathering layer are displayed in yellow (orange if your graphics card is configured to display more than 256 colors). Segments assigned to refractor 1 are displayed in red. Segments assigned to refractor 2 are displayed in green.

Smooth crossover distances

Once you have mapped first breaks to refractors as above, **laterally smooth the crossover distances** (color boundaries) obtained for each refractor. Press **ALT+G** or select *Mapping|Crossover processing* :

The *Crossover distance processing dialog* offers these parameters :

◆ *Smooth crossover distances*,
◆ *Overburden filter*
◆ *Basement filter*
◆ *Offset limit basement coverage*
◆ *Offset limit*.

Scale/zoom the display via the *Display parameter dialog* shown with **ALT+P** :

Edit field *Reduction velocity* lets you zoom the slope of CMP traveltime curves.

Zoom the reduced time axis of local CMP coordinate systems by pressing **CTRL+F1** once or twice until *branch points* (discontinuities in slope, per *CMP traveltime curve*) are clearly visible. Unzoom CMP traveltime curve dip with **CTRL+F2**. See Dialog box control and function keys .

An **optimum mapping of first breaks to refractors** has occurred when refractor limits detected (changes of colors) closely agree with the location of *branch points* (identified by systematic changes in slope along traveltime curves) for as many *CMP traveltime curves* as possible along the whole profile. If refractor limits are systematically located above *branch points*, increase the refractor's velocity limit in the corresponding edit field in *dialog Trace to refractor mapping parameters.* If refractor limits are below *branch points* decrease the corresponding velocity limit.

Select *Refractor|Shot breaks* to display your traveltime field in a more conventional way. Page through shot-sorted traveltime curves with function keys **F8/F7**.

Common Offset time section

Display your traveltime field in a coordinate system with CMP station number as horizontal axis and recording time as vertical axis with *Refractor|Offset breaks* :
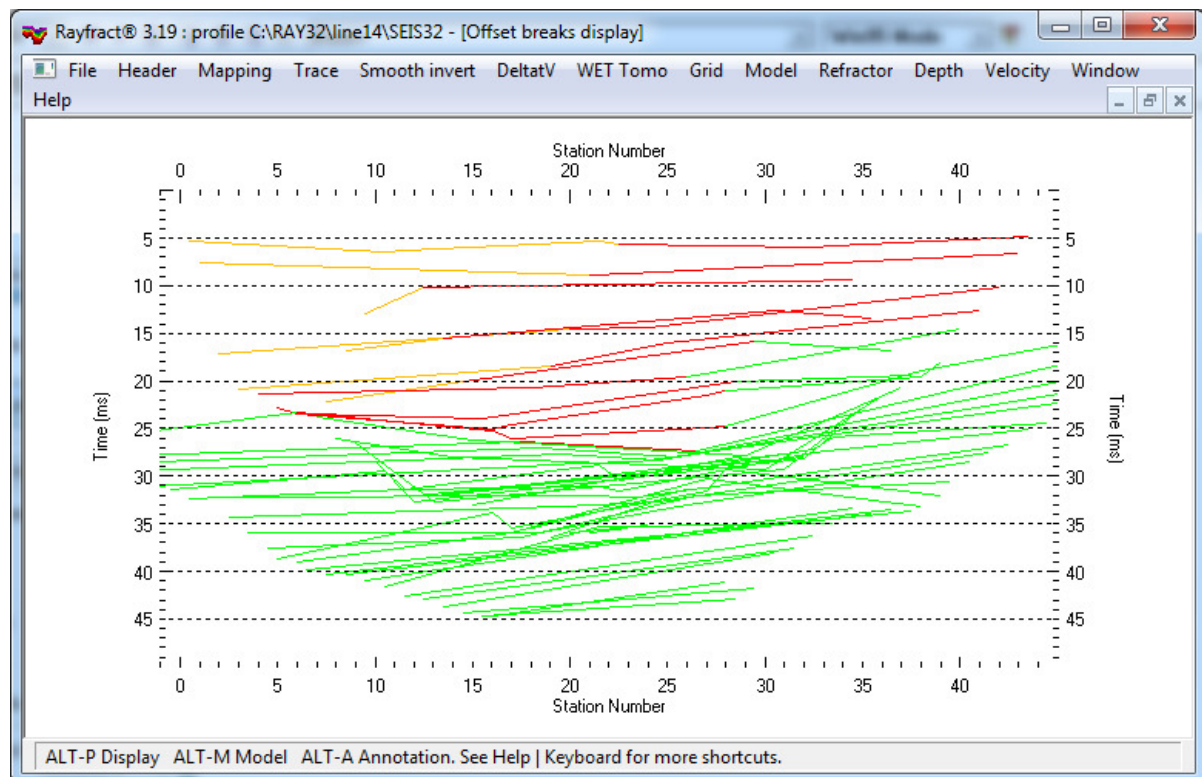
Common-offset traveltime curves displayed connect first breaks belonging to shot receiver pairs with constant unsigned offset along the profile. This kind of display lets you guess at refractor dip and shape even before doing time-to-depth conversion.

Time-to-depth conversion

Once you have iteratively reached a satisfying mapping of first breaks to refractors, do the time-to-depth conversion. *Depth menu items* are **enabled only if you either (re)mapped all traces in the *Shot breaks display* or in the *Midpoint breaks display*** with *Mapping|Remap all traces*. If you did the mapping in your *Midpoint breaks display*, continue with *Depth|CMP Intercept-Time Refraction..., Depth|Wavefront... or Depth|Plus-Minus...,* see below. If you manually selected the *branch points* in your *Shot breaks display*, continue with *Depth menu items Plus Minus...* or *Wavefront...* .

Before choosing a depth conversion method you may want to review your *Depth|Depth conversion Settings* .

When you are prompted during depth conversion to generate extrapolated refractor branches, click *Cancel button* and retry the depth conversion, with *Depth|Wavefront…* or *Depth|Plus-Minus…* . This may work on 2nd try without needing to extrapolate refractor branches.
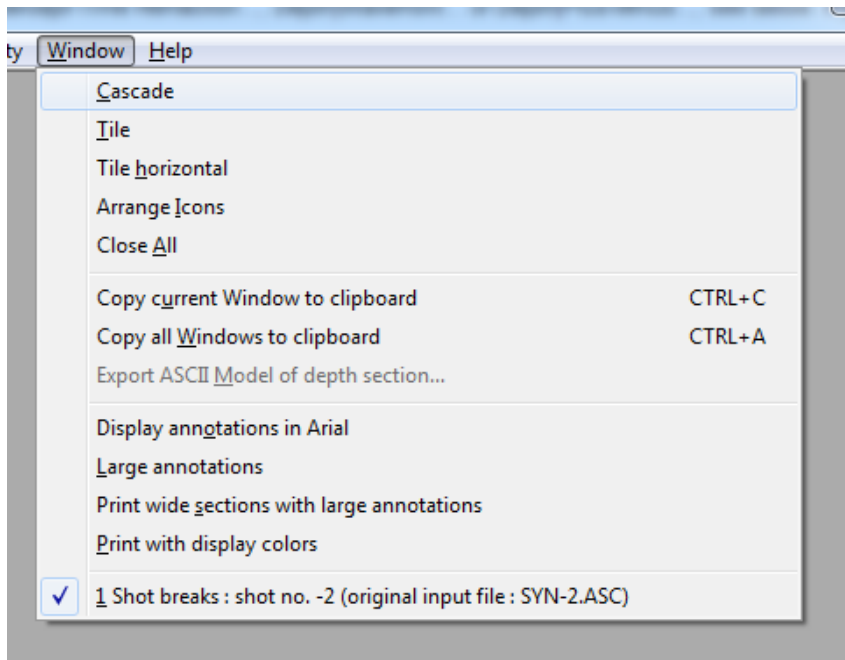
When displaying sections on screen, you may **lay out up to three sections adjusted vertically and displayed below each** other by selecting *Windows|Tile horizontally*. Be careful to specify the same profile section limits for all three sections. These limits may be specified in the *Display parameters dialog* for each section (ALT+P).

If you lay out more than three sections with option *Windows|Tile horizontally,* these will be displayed the same way as with option *Windows|Tile*. So close the less significant sections, regarding your current interpretation needs, and retile.

CMP Intercept Time Refraction processing

Select *Depth/CMP Intercept Time Refraction*, to do time-to-depth conversion, as described by (Rühl, 1995) :
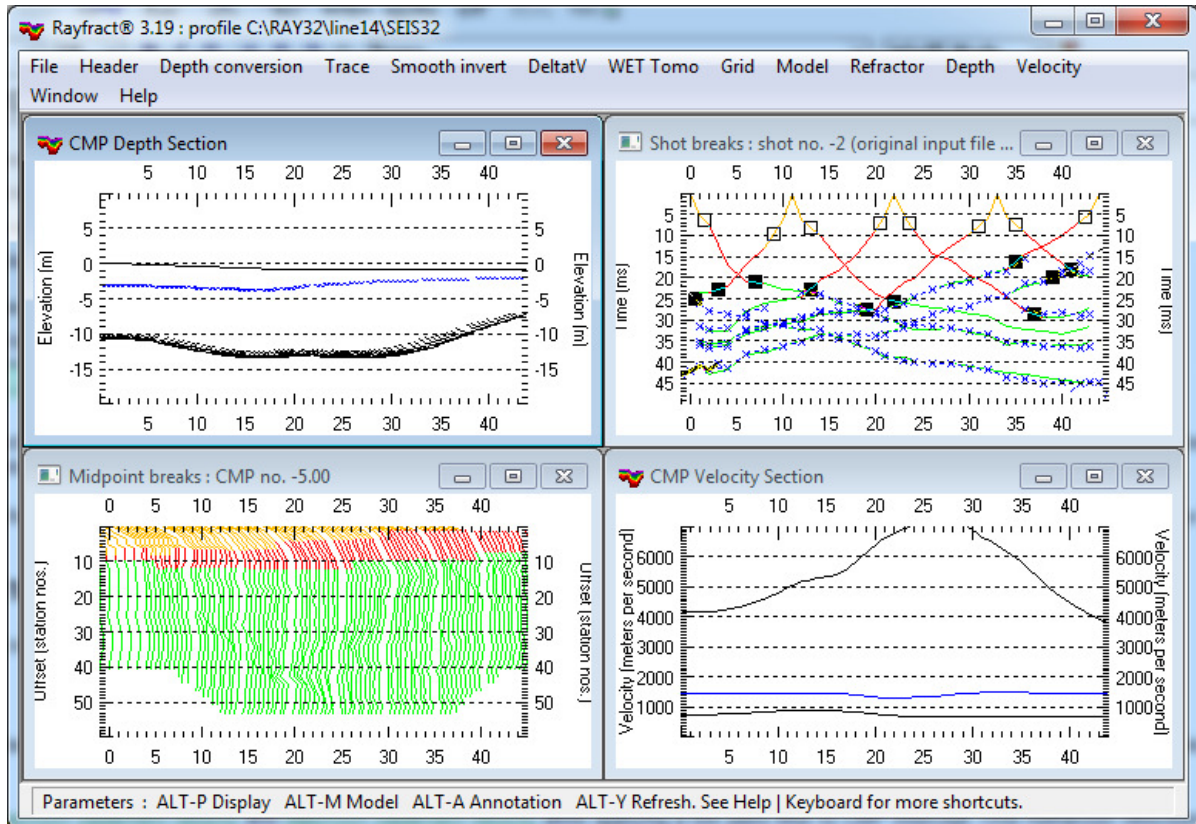
The accuracy of refractor depths and velocities obtained is limited in case of strong refractor curvature. Select *Velocity/CMP Refraction* to display corresponding velocities.

Click on the *CMP Depth section* and press ALT+M to display the *CMP **Model Parameters dialog*** :
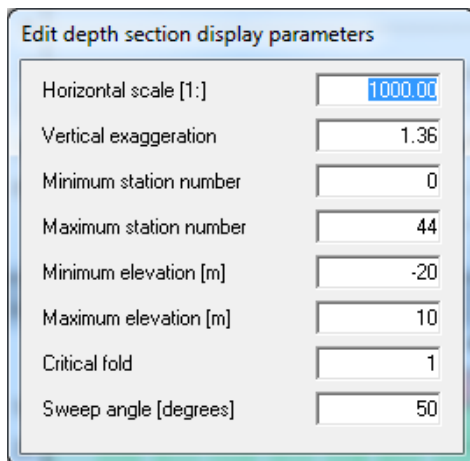
Parameters *limit maximum basement velocity* and *Maximum basement velocity* allow applying a low-pass filter to CMP Intercept Time Refraction velocities estimated for the basement. When the estimated velocity at a station number exceeds the maximum velocity specified, no velocity and depth estimations are output for that station. Velocity and depth are interpolated/extrapolated from neighboring stations with valid results, instead. This may help in case of strong refractor curvature, to suppress too high apparent velocities at bottom of synclines. This will not help to avoid too low apparent velocities at the top of anticlines.

Parameters **Overburden filter** and **Base filter width** specify widths of smoothing filters (in station numbers; running average), for smoothing elevation and velocity of refractor 1 or 2, respectively. You may want to increase the default values (5, 10) to higher values, for difficult data and strongly undulating apparent refractor topography (e.g. 7, 12 or even 10, 15). Parameter *Degree of Surface Consistency* specifies to what degree the smoothed surface of refractor 1 should follow the line's topography. If the basement refractor is just below the topography and there is a high velocity contrast between weathering layer and basement then you can decrease lateral refractor smoothing, to obtain higher lateral resolution of basement.

Click on the *CMP Depth section* and press ALT+P to show the **Display parameters dialog** :

Edit depth section display parameters

Horizontal scale [1:]	1000.00
Vertical exaggeration	1.36
Minimum station number	0
Maximum station number	44
Minimum elevation [m]	-20
Maximum elevation [m]	10
Critical fold	1
Sweep angle [degrees]	50

Use controls *Minimum station number* and *Maximum station number* to specify the station number interval displayed. For depth sections, use controls *Minimum elevation* and *Maximum elevation*, to specify the elevation interval displayed. For time and velocity sections, use parameters *Minimum velocity or time* and *Maximum velocity or time* to define the vertical data value range displayed. Scale your section plot with parameters *scale, vertical exaggeration.*

Click on the *CMP Depth section* and press ALT+A to display the **Annotation parameters dialog** :

This lets you specify *horizontal axis title* and *vertical axis title* texts. Also, this dialog lets you specify if axes should be drawn with a solid pen via option *Outline axes*. Use options *Annotate axes*, *Show axis titles*, and *Axis big tick size* to further customize your section display.

Plus-Minus and Wavefront processing

Close all section windows with *Window|Close All*.

Select *Depth menu items Depth|Plus-Minus*, *Velocity|Plus-Minus*, *Depth|Wavefront* and *Velocity|Wavefront* :
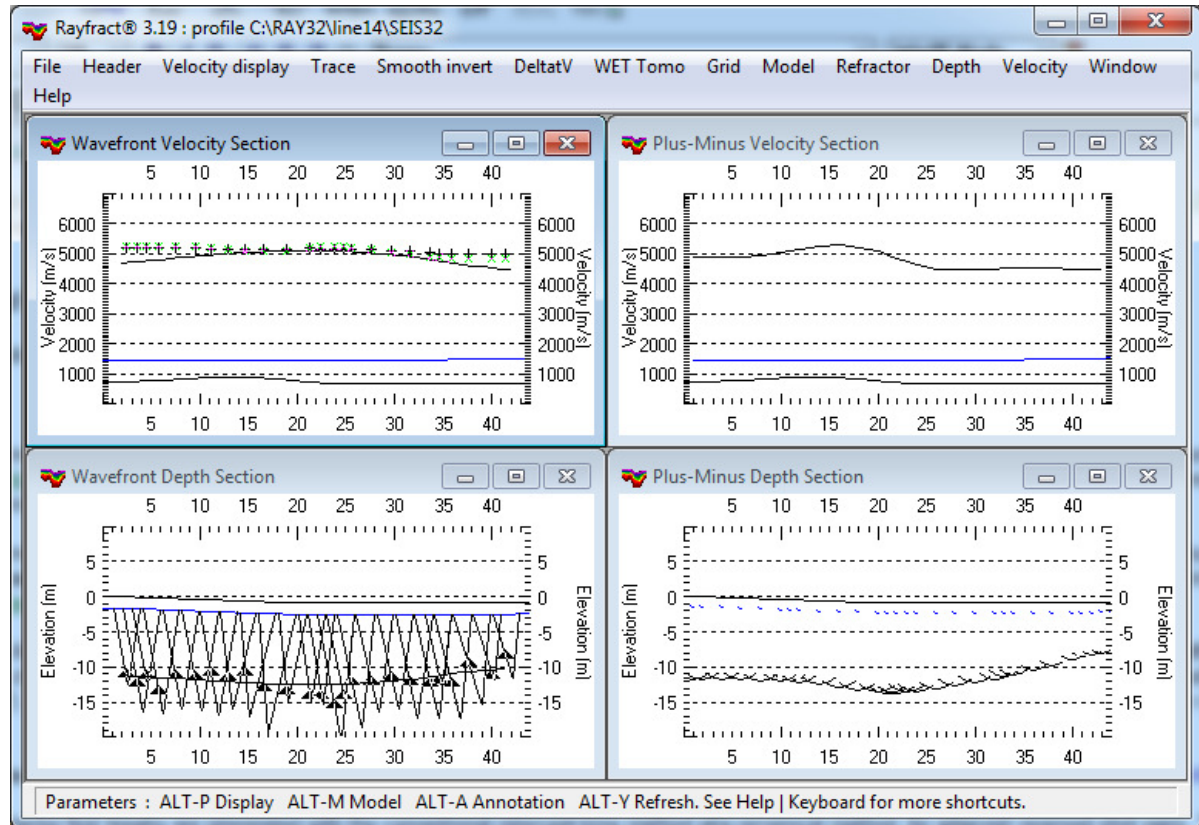
Commands Depth|Plus-Minus and *Depth|Wavefront* do time-to-depth conversion as described by (Hagedoorn, 1959) and (Brückl, 1987). Both algorithms are based on traveltime field regression (Brückl 1987). The **trace-to-refractor mapping** last done (either in the *Shot breaks display*, or in the *Midpoint breaks display*, with *Mapping|Remapping all traces*) is regarded for this traveltime field regression and the subsequent time-to-depth conversion. You may edit parameters for these two algorithms as described above, for *CMP intercept time refraction*. You may activate *check box Recompute traveltime characteristics* to redo the traveltime field regression.

When you are prompted during depth conversion to generate extrapolated refractor branches, click *Cancel button* and retry the depth conversion, with *Depth|Wavefront…* or *Depth|Plus-Minus…* . This may work on 2nd try without needing to extrapolate refractor branches. This applies for sample profile GEOXMERC, see

http://rayfract.com/samples/GEOXMERC.pdf . In this case, coverage of the dipping basement refractor is insufficient at right end of the (long) section. This renders the traveltime field regression unstable.
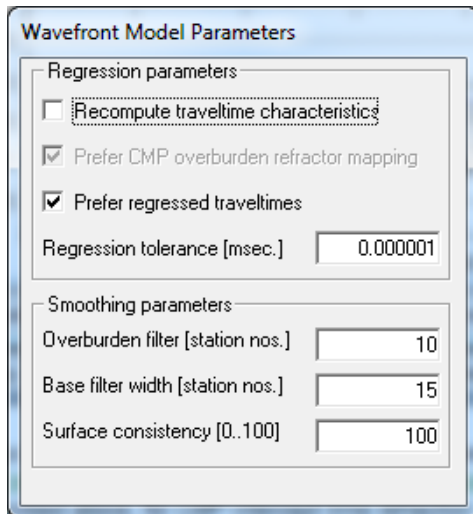
Two additional parameters for these methods are *check box Prefer regressed traveltimes*, and *edit field Relative regression tolerance*. In low-coverage situations, always toggle *Prefer regressed traveltimes*, and compare the two resulting depth sections. A **significant difference in refractor depth** estimates may mean that the basement coverage with first breaks is too discontinuous for traveltime field regression to converge towards a robust solution. Always **record your traces with overlapping receiver spreads** to avoid such situations.

Configure depth section display with *menu Depth Conversion* :
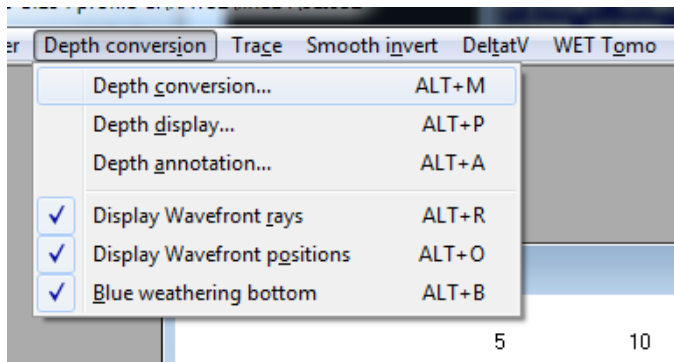
Wavefront and Plus-Minus inversion may abort with a **message saying "Refractor coverage may be too low or too short"**. Record more (far offset) shots for this profile, and use a shorter receiver spacing. Also, use longer receiver spreads, with more channels. Our Plus-Minus and Wavefront inversions include a preliminary processing step called "traveltime field regression" which reduces basement refractor first breaks to a single pair of forward and reverse traveltime curves (Brückl 1987). This data reduction step requires a certain data density. If too few shots were recorded or the receiver spacing was too wide and/or receiver spreads were too short to cover the basement, this reduction algorithm may not be able to reduce the data set.

For conventional **Wavefront method interpretation tutorials**, see http://rayfract.com/help/manual.pdf chapter 1.8 and following, and http://rayfract.com/tutorials/line2.pdf .

Also, overburden refractor first breaks are interpreted with the conventional intercept-time

method aka reciprocal method, for adjacent reversed shot pairs. This step requires a certain data density as well. Such low-coverage problems do not arise with our Smooth inversion and DeltatV and WET inversion, since these methods do not require you to map traces to refractors at all.

Always be sure to process your data with all three of the above methods (CMP Intercept Time Refraction, Plus-Minus and Wavefront). Then compare the resulting depth and velocity sections, at the same scale. Plus-Minus has a theoretically lower lateral resolution when compared to the Wavefront method, because it basically assumes that critically refracted rays emerge vertically from the refractor. The error caused by this assumption increases with increasing overburden thickness or decreasing velocity contrast, between the layer above the refractor being mapped and the refractor itself. CMP Intercept Time Refraction has systematic problems in case of strong refractor curvature. Also, CMP Intercept Time Refraction will give you fast results, but may not be as reliable as Wavefront or Plus-Minus for data sets with bad first breaks, since these two methods iteratively minimize first break picking errors by first carrying out a regression over the whole traveltime field, for each refractor.

In case of strongly undulating refractor topography, refractor elevations in CMP depth sections will systematically differ from elevations in resulting Wavefront and Plus-Minus depth sections. Furthermore, low-velocity contrast/diving wave situations and complex geologic target situations in general may lead to these variations in results. You may want to remap traces to refractors to minimize variations between different methods. Also, you may want to reduce the number of refractors being mapped from the default value 2 to the new value 1. See parameter *Refractor Count* in Mapping traces to refractors above. We advise you to apply our **Smooth inversion method** (*Smooth inversion|WET with 1D-gradient initial model*) if coverage is high enough (at least about 5 to 10 shots per receiver spread, one shot at every 3rd receiver) in such difficult situations.

WET inversion with layered refraction starting model

Window|Export ASCII Model of depth section lets you **write topography, refractor elevations and velocities to a comma-separated value .CSV file**. You may import this into Microsoft Excel etc. .CSV column 1 lists receiver station number, column 2 shows horizontal inline offset in meters.
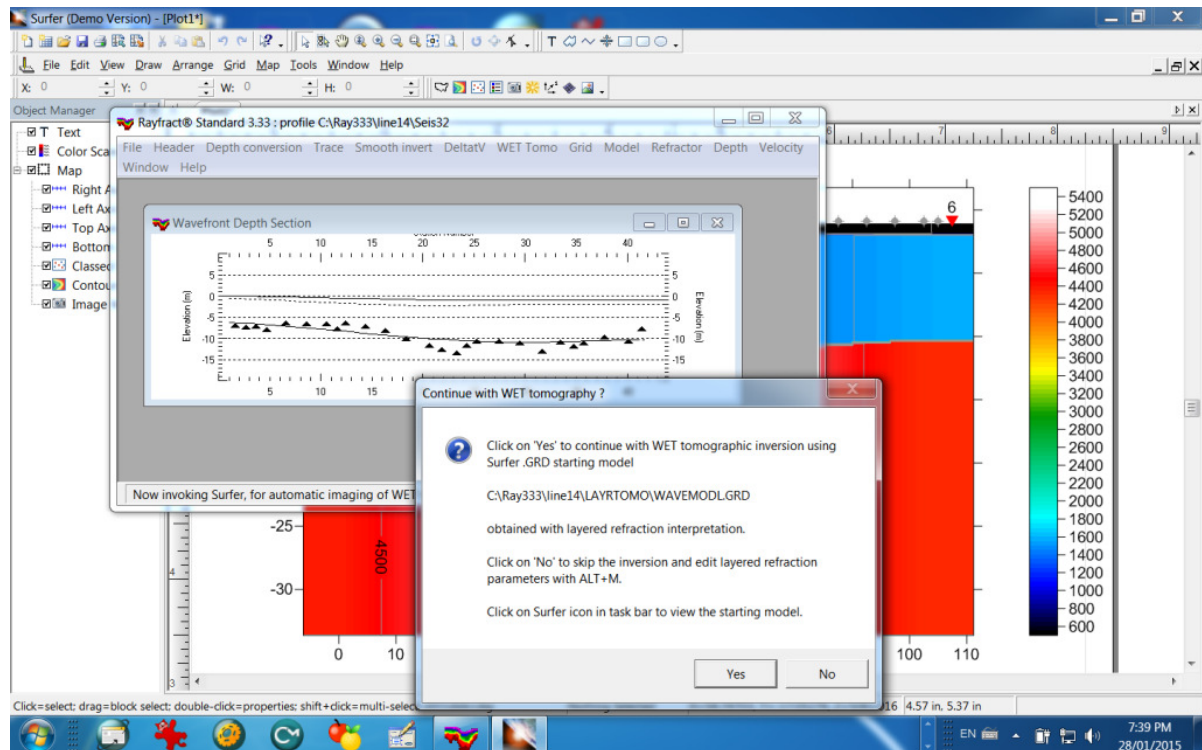
Since version 3.32 we allow **WET inversion with layered starting model**. The layered starting model is regenerated and you are prompted to start WET inversion whenever you run time-to-depth conversion in *Depth menu* with Plus-Minus, Wavefront or CMP intercept-time refraction methods. The starting model is named PLUSMODL.GRD / WAVEMODL.GRD / CMPMODL.GRD and is stored into subdirectory `C:\RAY32\<your profile name>\LAYRTOMO` . When prompted to continue with automatic WET inversion using this starting model you may click *No button* and edit layered refraction parameters with ALT+M, see above. We also write .CSV files PLUSMODL.CSV / WAVEMODL.CSV / CMPMODL.CSV into the same subdirectory. For the format of these .CSV layered model files see chapter File formats. See also our tutorial http://rayfract.com/tutorials/NORCAL14.pdf .
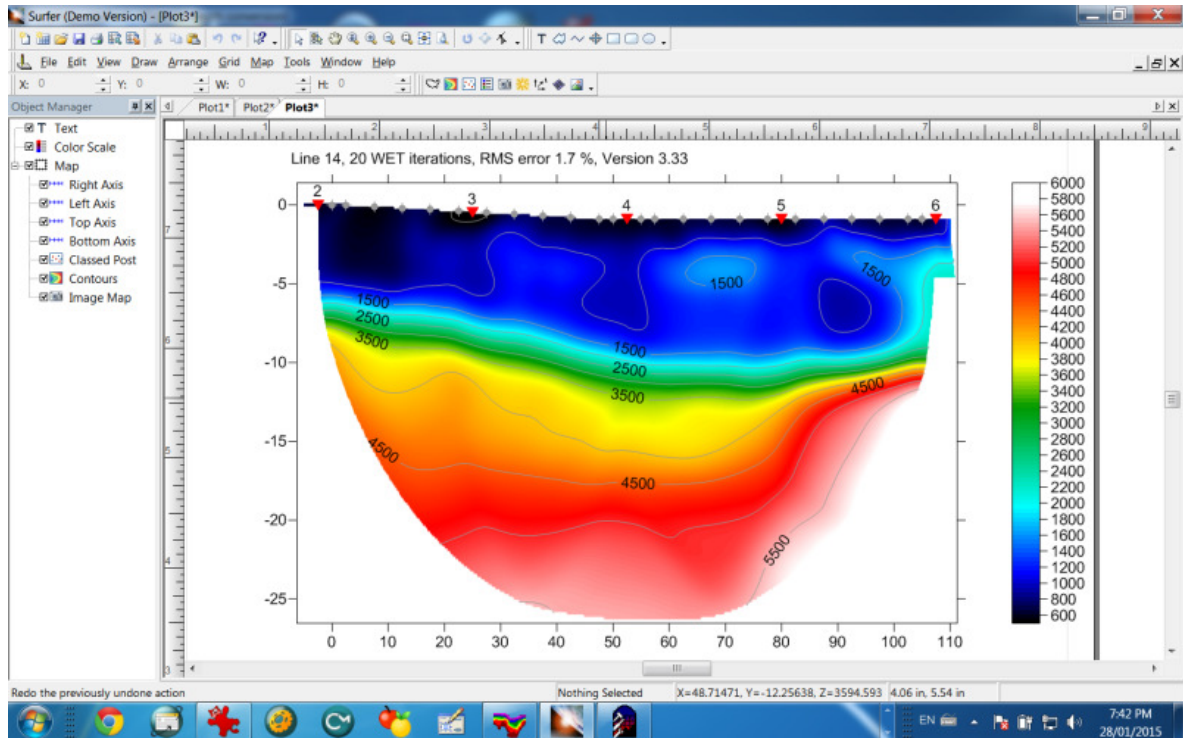
Layered WET tomography using above WAVEMODL.GRD starting model obtained with *Depth*/*Wavefront* method

File formats

After data import you can export station coordinates, shotpoint coordinates and first breaks via *File|Export header data submenu*. Now you can edit the resulting .COR, .SHO and .LST files with your favorite text editor e.g. Microsoft WordPad. Then update profile trace headers with *File|Update header data submenu*. You cannot update source and receiver station numbers this way, just the coordinates. So if you need to changes source and receiver station numbers you need to reimport the shots.

Station coordinate files

Station coordinate files have file extension .COR and are per default named COORDS.COR . They contain four columns of data :

Column 1   Column 2   Column 3   Column 4
Station number   x coordinate[m]   y coordinate[m]   z coordinate[m]

Column values are separated by semicolons ";". Here we show the first few lines of the sample COORDS.COR file in your \RAY32\DOC directory, as generated from sample profile \RAY32\LINE14 :

```
station number;x coordinate[m];y coordinate[m];elevation[m];
-11;-29.9955;0.0000;0.5000
-10;-27.4959;0.0000;0.4545
-9;-24.9963;0.0000;0.4091
-8;-22.4967;0.0000;0.3636
-7;-19.9971;0.0000;0.3182
-6;-17.4975;0.0000;0.2727
-5;-14.9979;0.0000;0.2273
-4;-12.4983;0.0000;0.1818
-3;-9.9988;0.0000;0.1364
-2;-7.4992;0.0000;0.0909
-1;-4.9996;0.0000;0.0455
0;-2.5000;0.0000;0.0000
1;0.0000;0.0000;0.0000
2;2.5000;0.0000;0.0000
3;4.9995;0.0000;-0.0500
4;7.4990;0.0000;-0.1000
6;12.4980;0.0000;-0.2000
...
```

Station number -11 is the *shot station* for shot number 1. Station number 0 is the shot station for shot number 2. Station number 1 is the first receiver station. Coordinates for station numbers -10 to -1 are interpolated, between these two first shot stations. You can delete these interpolated stations from the COORDS.COR file. Also, you do not have to specify coordinates for all receiver stations. Missing station coordinates will be interpolated automatically, during import with *File|Update header data|Update Station Coordinates*... .
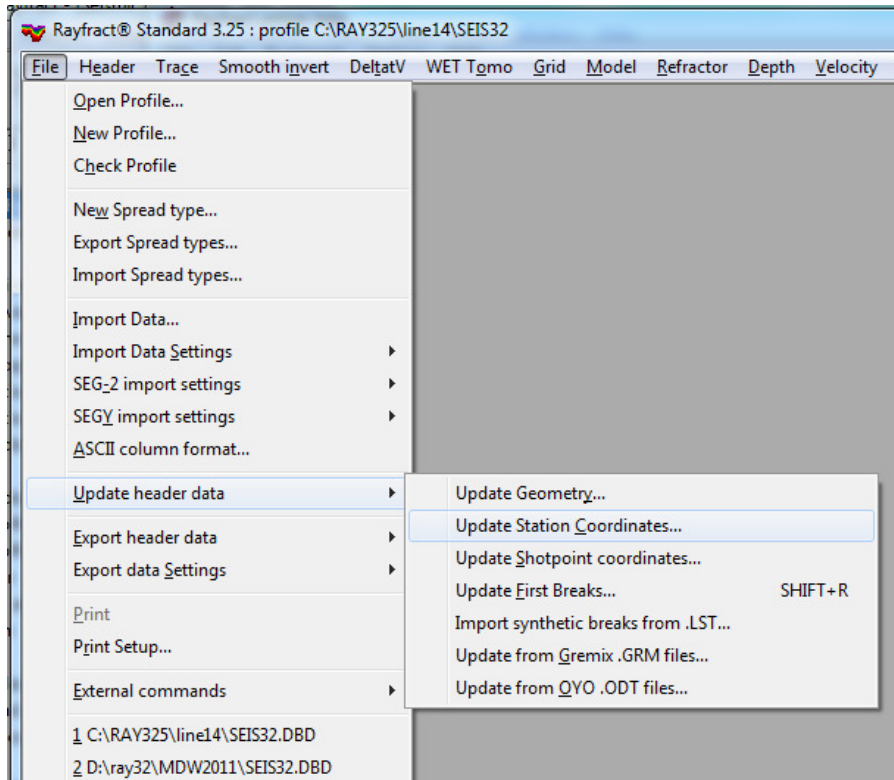
Generate a COORDS.COR coordinate file with coordinates for all stations of your currently opened profile with *File|Export header data|Export Station Coordinates...* :
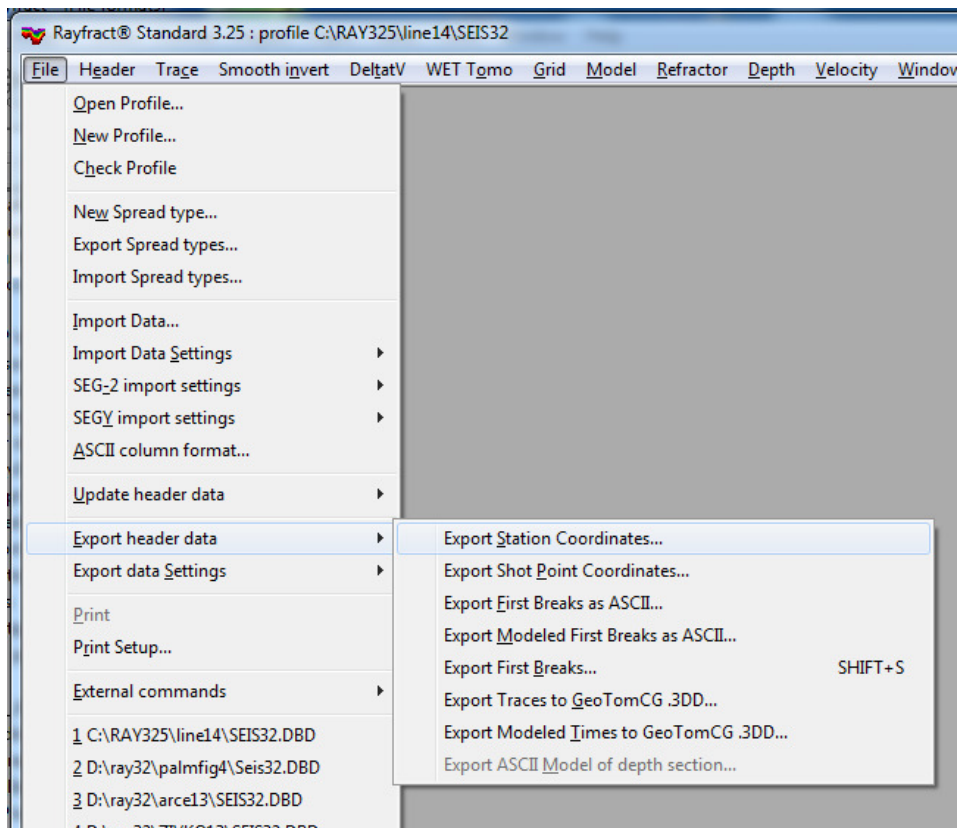
Shotpoint coordinate files

Shotpoint coordinate files have extension .SHO and are named SHOTPTS.SHO per default. To generate a SHOTPTS.SHO file listing shot points for your currently opened profile, select *File|Export header data|Export Shot Point Coordinates...*, as shown in above *File menu* screen shot.

SHOTPTS.SHO files contain 12 columns of data :

Col. 1   Col. 2   Col. 3   Col. 4   Col. 5   Col. 6
Col. 7   Col. 8   Col. 9   Col. 10   Col. 11
Col. 12
shotNr shotX[m]   shotY[m]   shotZ[m]   holeDepth[m]   upholeTime[ms]
Correction[ms]   shotDelay[ms] triggerDelay[ms] shotStation   shot inline offs.[m]
lateral offset[m]

Column values are separated by space or tab characters. Here we show the first few lines of the SHOTPTS.SHO file generated for your \RAY32\LINE14 sample profile :

```
    shotNr   shotX[m]    shotY[m]    shotZ[m]   holeDepth[m]   upholeTime
Correction   shotDelay   triggerDelay   shotStation   shot inline,
lateral offset[m]
      -2     137.50        0.00        -0.90         0.00         0.00
0.00         0.00        0.00       55.00         0.00         0.00
      -1     -27.50        0.00         0.50         0.00         0.00
0.00         0.00        0.00      -11.00         0.00         0.00
       1     -27.50        0.00         0.50         0.00         0.00
0.00         0.00        0.00      -11.00         0.00         0.00
       2       0.00        0.00         0.00         0.00         0.00
0.00         0.00        0.00        0.00         0.00         0.00
       3      27.50        0.00        -0.50         0.00         0.00
0.00         0.00        0.00       11.00         0.00         0.00
       4      55.00        0.00        -0.90         0.00         0.00
0.00         0.00        0.00       22.00         0.00         0.00
       5      82.50        0.00        -0.90         0.00         0.00
0.00         0.00        0.00       33.00         0.00         0.00
       6     110.00        0.00        -0.90         0.00         0.00
0.00         0.00        0.00       44.00         0.00         0.00
       7     137.50        0.00        -0.90         0.00         0.00
0.00         0.00        0.00       55.00         0.00         0.00
```

Column 1 in the .SHO file lists the *shot number* specified during data import and shown in *Header|Shot* dialog.

Shot numbers -2 and -1 are synthetic shots, automatically generated during conventional Wavefront and Plus-Minus interpretation. These extrapolated far-shot-point traveltime curve segments are needed for interpretation, since shot no. 1 does not cover the shot point of shot number 7 and vice-versa, for our \RAY32\LINE14 sample profile.

For *Line type* `Refraction spread/line` by convention columns 2/3/4 specify the **shot point coordinates vertically projected to line topography** i.e. at top-of-hole if the source is placed in a (drilled) hole. Specify vertical offset of source from line topography as hole depth in column 5. *Shot offset coordinates dx/dy/dz* shown in *Header|Shot* are determined during *File|Update header data|Update Shot Point Coordinates…* as difference between columns 2/3/4 in the .SHO file and the shot station coordinates.

Column 7 of the SHOTPTS.SHO lists the *uphole time correction term* in ms. This correction term is used to identify uphole shots, with a value different from 0 e.g. 0.01 ms. The *Shot type* shown in *Header|Shot* is updated accordingly, during *File|Update header data|Update Shot Point Coordinates...* . Specify the absolute *uphole time* in ms in column 6. However this absolute uphole time is currently not used during first-break traveltime interpretation.

Column 8 lists the *shot delay time* in ms. Column 9 lists the *trigger delay* in ms. Column 10 shows the *shot station* specified when importing this shot earlier.

The last two columns 11 and 12 of the SHOTPTS.SHO file list *shotpoint inline and lateral offset*, from the shot station listed in column 10. These two columns 11 and 12 are not regarded, during *File|Update header data|Update Shot Point Coordinates...*. Instead *shot inline and lateral offset* are recomputed, based on coordinates specified in *Header|Station* for the *shot station*, and absolute shot point x/y/z coordinates (z assumed at line topography) specified in columns 2/3/4 of the SHOTPTS.SHO file. Review these updated *inline and lateral shotpoint offsets* in *Header|Shot*. Also check read-only field **Source elevation** shown in *Header|Shot* : this shows the sum of *shot station elevation* (*Header|Station*) plus *shot dz* minus *shot depth* (*Header|Shot*).

For *Line type* `Borehole spread/line` we enforce that all y coordinates for any shot point and receiver are 0.0 (zero). Set shot point x & z (column 2&4 in .SHO file) coordinates to horizontal distance along section and absolute elevation. By convention topography has elevation of 0.0 (zero) so the z coordinate (elevation) becomes more negative going down the borehole. Column 5 (shot depth for *Line type* `Refraction spread/line`) is ignored for *Line type* `Borehole spread/line` when updating your profile database with the .SHO file.

For *Line type* `Refraction spread/line` the **conversion of shot point coordinates x/y/z to shot station number plus inline and lateral shotpoint offsets, and back to absolute coordinates** is not trivial, especially in case of strong topography and varying receiver separation. The *shot station number* shown in *Header|Shot* (and specified when importing the shot) is either an integer value, or ends in .5 e.g. 0.5. To ensure shot point x/y/z coordinates (z assumed at line topography) and shot hole depth are specified correctly in the profile database, import shots and update station and shotpoint coordinates as usual. Next select *File|Export header data|Export Shot Point Coordinates…* :
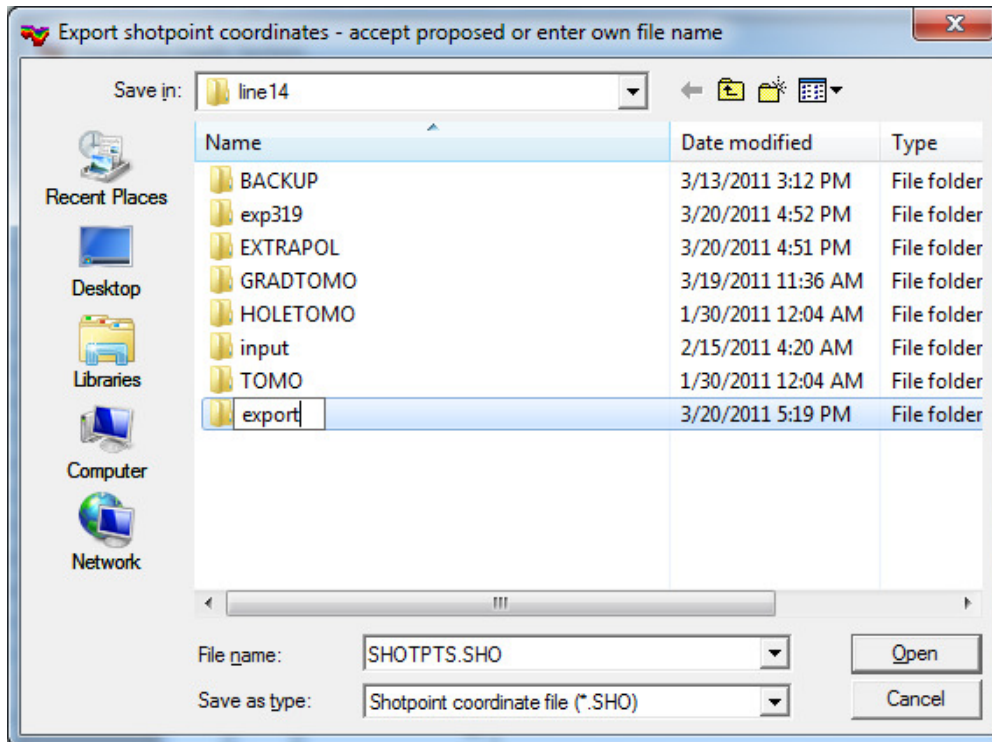
- ◆ left-click *Create New Folder icon* on top right of above *Export shotpoint coordinates dialog*
- ◆ name this new folder e.g. export
- ◆ navigate into this new export folder, and store SHOTPTS.SHO into this folder with *Open button*
- ◆ open SHOTPTS.SHO e.g. with Windows WordPad text editor
- ◆ ensure for all shotNr values (column 1) that shotX, shotY and shotZ (columns 2/3/4) specify shot point coordinates vertically projected to line topography
- ◆ fix shotZ to shot point elevation at line topography in this editor session if required (in overwrite mode)
- ◆ update shot hole depth to vertical offset of source from shotZ (line topography) in column 5 if required. Negative depth means source is located above line topography. This can happen if the source is laterally offset from the receiver line.
- ◆ save the fixed SHOTPTS.SHO to disk from within your editor, e.g. with *File|Save command*
- ◆ update Rayfract® profile with *File|Update header data|Update Shotpoint coordinates…*and your fixed SHOTPTS.SHO file
- ◆ uncheck *File|Import Data Settings|Round shot station to nearest whole station number* before importing your data files, to minimize above conversion error between *shot station number* plus inline and lateral shotpoint offset, and absolute shot point coordinates. With this unchecked, *shot stations* are rounded to .5, e.g. to values 0.5, 1.0 or 1.5 . Version 3.17 and later versions of our software will uncheck this option automatically during *File|New Profile…* .

First break files

First break files have extension .LST, and are named BREAKS.LST per default. To generate a BREAKS.LST file listing picked first breaks for your currently opened profile, select *File|Export header data|Export First Breaks...*, as shown in above *File menu* screen shot.

Or use SHIFT+S keyboard shortcut, in *Trace menu gather displays* or *Refractor menu traveltime curve displays* e.g. *Refractor|Shot breaks display*.

BREAKS.LST files contain 5 columns of data :

Column 1	Column 2	Column 3	Column 4	Column 5
shot no.	trace no.	Station no.	time [ms]	synthetic pick [ms]

Column values are separated by space or tab characters. Here we show the first few lines of the BREAKS.LST file generated for your \RAY32\LINE14 sample profile :

```
First breaks stored in profile database C:\RAY32\line14\Seis32

 shot no. trace     pos.      time   synthetic (millisecs.)
      1        0   -11.00     0.000      0.000
      1        1     1.00    26.250     -1.000
      1        2     2.00    28.000     -1.000
      1        3     4.00    28.625     -1.000
      1        4     6.00    29.500     -1.000
      1        5     8.00    31.000     -1.000
      1        6    10.00    31.375     -1.000
      1        7    12.00    32.375     -1.000
      1        8    14.00    32.250     -1.000
      1        9    16.00    34.250     -1.000
      1       10    18.00    35.875     -1.000
      1       11    20.00    37.500     -1.000
      1       12    21.00    38.750     -1.000
      1       13    23.00    39.000     -1.000
      1       14    24.00    39.875     -1.000
      1       15    26.00    40.250     -1.000
      1       16    28.00    40.250     -1.000
      1       17    30.00    41.000     -1.000
      1       18    32.00    41.625     -1.000
      1       19    34.00    42.625     -1.000
      1       20    36.00    42.875     -1.000
      1       21    38.00    43.750     -1.000
      1       22    40.00    44.375     -1.000
      1       23    42.00    44.750     -1.000
      1       24    43.00    44.625     -1.000
      2        0     0.00     0.000      0.000
      2        1     1.00     5.375      4.328
      2        2     2.00     7.625      8.190
      2        3     4.00    17.125     17.005
      2        4     6.00    20.875     20.490
      2        5     8.00    21.375     21.166
      2        6    10.00    22.750     22.643
      2        7    12.00    23.250     23.650
      2        8    14.00    23.750     24.193
      2        9    16.00    26.000     25.873
```

```
2       10      18.00     26.500     27.408
2       11      20.00     28.500     29.324
2       12      21.00     29.500     30.290
2       13      23.00     31.375     31.594
2       14      24.00     32.125     31.923
2       15      26.00     32.125     31.982
2       16      28.00     31.875     32.033
2       17      30.00     33.000     33.006
2       18      32.00     33.875     34.436
2       19      34.00     35.875     35.602
2       20      36.00     35.375     35.653
2       21      38.00     36.375     36.256
2       22      40.00     36.000     36.143
2       23      42.00     36.000     35.351
2       24      43.00     35.250     35.199
3        1       1.00     23.500     23.294
3        2       2.00     23.500     23.534
3        3       4.00     22.125     21.831
3        4       6.00     16.875     17.107
3        5       8.00     12.875     12.844
```

◆   *Shot no.* in column 1 lists the shot number for which this trace was recorded

◆   *Trace no.* in column 2 identifies the seismograph channel number used to record this trace, and starts at 1

◆   *Pos.* in column 3 shows the station number at which the receiver used to record this trace was located

◆   *Time* in column 4 lists the first break picked for this trace, in ms. A value of 0 or -1 means "not picked".

◆   synthetic traveltimes generated during forward modeling are listed in column 5, again in ms

Trace no. 0 identifies the shot position, with pos. (column 3) showing the *shot position in station numbers*, and time (column 4) set to 0.0 ms.

To update the currently opened profile database with first breaks stored in an .LST file generated earlier, select *File|Update header data|Update First Breaks...* . Per default, traces listed in the .LST are matched to traces stored in your profile database by common channel number. See option *File|Import data Settings|Match .LST traces by station number*. When matching traces by channel number, you can to reimport shots with changed *shot position* or *layout start* and keep current first break picks :

◆   backup picks to .LST with *File|Export header data|Export First Breaks…*

◆   reimport the relevant shots, with corrected *shot position* in *Import shot dialog*, using the *Read button*. Skip all other shots, with *Skip button*.

◆   select *File|Update header data|Update First Breaks…* and specify the .LST just generated.

ASCII.ASC files

ASCII.ASC files have extension .ASC and are named ASCII.ASC per default. To generate an ASCII.ASC file listing picked first breaks and recording geometry for your currently opened profile, select *File|Export header data|Export First Breaks as ASCII...*, as shown in above *File menu* screen shot.

ASCII.ASC files contain at least 4 columns of data :

Column 1	Column 2	Column 3	Column 4	Column 5	Column 6
shot no.	shot station	recvr. station	first break[s]	receiver elev.[m]	shot elev.[m]

Column values are separated by semicolon ';' characters. Above columns 5 and 6 are optional. Specify these additional columns 5 and 6 in ASCII.ASC with *File|ASCII column format... dialog*. But don't change order of first 4 columns.

Here are the first few lines of the ASCII.ASC file generated for your \RAY32\LINE14 sample profile :

```
Shot No.;Shot Station;Receiver Station;First Break (seconds)
…
1;-11.00;28.00;0.040250
1;-11.00;30.00;0.041000
1;-11.00;32.00;0.041625
1;-11.00;34.00;0.042625
1;-11.00;36.00;0.042875
1;-11.00;38.00;0.043750
1;-11.00;40.00;0.044375
1;-11.00;42.00;0.044750
1;-11.00;43.00;0.044625
2;0.00;1.00;0.005375
2;0.00;2.00;0.007625
2;0.00;4.00;0.017125
2;0.00;6.00;0.020875
2;0.00;8.00;0.021375
2;0.00;10.00;0.022750
2;0.00;12.00;0.023250
2;0.00;14.00;0.023750
2;0.00;16.00;0.026000
2;0.00;18.00;0.026500
2;0.00;20.00;0.028500
2;0.00;21.00;0.029500
2;0.00;23.00;0.031375
2;0.00;24.00;0.032125
2;0.00;26.00;0.032125
2;0.00;28.00;0.031875
2;0.00;30.00;0.033000
2;0.00;32.00;0.033875
2;0.00;34.00;0.035875
2;0.00;36.00;0.035375
2;0.00;38.00;0.036375
2;0.00;40.00;0.036000
2;0.00;42.00;0.036000
2;0.00;43.00;0.035250
3;11.00;1.00;-1.000000
```

```
3;11.00;2.00;-1.000000
3;11.00;4.00;0.022125
3;11.00;6.00;-1.000000
3;11.00;8.00;0.012875
3;11.00;10.00;0.006500
3;11.00;12.00;0.006250
3;11.00;14.00;0.010125
3;11.00;16.00;0.015500
3;11.00;18.00;0.020125
3;11.00;20.00;0.023875
3;11.00;21.00;0.025125
3;11.00;23.00;0.026000
3;11.00;24.00;0.026375
```

You can interactively specify the column order and contents of ASCII.ASC with *File/ASCII column format... dialog* :

Once you have done this, generate ASCII.ASC files with third-party software e.g. Microsoft Excel or W_GeoSoft WinSism. Then import these ASCII.ASC files with *File/Import Data...* and *Import data type ASCII column format.*

Receiver station numbers must be whole integer numbers. *Shot station numbers* can have a fractional part, e.g. 0.5, 1.5 2.0, 2.5 etc.

Uncheck *File/Import data Settings/Round shot station to nearest whole station number*, to round to 0.5 accuracy during import. This improves the accuracy of coordinate interpolation and static corrections.

.CSV layered model file

Once you map traces to refractor in *Refractors menu* and run Time-to-depth conversion in *Depth menu* we automatically export the layered depth section to .CSV and convert this to a layered Surfer format .GRD starting model. The .CSV is named after the depth conversion method : PLUSMODL.CSV for Plus-Minus method, WAVEMODL.CSV for Wavefront method and CMPMODL.CSV for CMP Intercept-time refraction method. These .CSV & .GRD files are written to directory `C:\RAY32\<your profile name>\LAYRTOMO`.

Here we show file PLUSMODL.CSV obtained for sample profile LINE14 :

```
Plus-Minus Depth Section in meters for profile Line 14
Stat.No.,offset,topo,fold0,v0,topo1,fold1,v1,topo2,fold2,v2
1.000,0.000,0.000,1,456.825,-0.563,1,901.845,-7.538,7,4726.979
2.000,2.500,0.000,1,451.614,-0.614,1,913.058,-7.570,7,4726.979
4.000,7.499,-0.100,1,438.586,-0.840,1,941.089,7.614,5,4726.979
6.000,12.498,-0.200,1,425.320,-1.068,1,969.629,-7.617,5,4737.529
8.000,17.497,-0.300,1,412.055,-1.297,1,998.170,-7.662,6,4823.548
10.000,22.496,-0.400,1,401.984,-1.517,1,1032.141,-7.802,6,4972.525
11.000,24.994,-0.500,1,400.524,-1.667,1,1055.202,-7.921,14,5041.297
12.000,27.494,-0.500,1,401.498,-1.712,1,1082.401,-8.088,6,5102.488
14.000,32.493,-0.600,1,410.597,-1.882,1,1148.950,-8.614,5,5195.857
16.000,37.492,-0.700,1,422.890,-2.043,1,1220.930,-9.396,5,5226.187
18.000,42.491,-0.800,1,435.183,-2.205,1,1292.909,-10.253,5,5143.703
20.000,47.490,-0.900,1,447.146,-2.364,1,1363.642,-11.023,4,4966.542
21.000,49.990,-0.900,1,451.309,-2.376,1,1392.156,-11.335,4,4862.687
22.000,52.490,-0.900,1,453.708,-2.372,1,1414.026,-11.579,11,4765.358
23.000,54.990,-0.900,1,454.343,-2.351,1,1429.250,-11.739,5,4682.311
24.000,57.490,-0.900,1,453.214,-2.314,1,1437.829,-11.829,5,4615.547
26.000,62.490,-0.900,1,447.320,-2.205,1,1441.282,-11.831,5,4539.454
28.000,67.490,-0.900,1,441.095,-2.094,1,1443.489,-11.680,5,4521.940
30.000,72.490,-0.900,1,434.870,-1.982,1,1445.696,-11.463,5,4528.231
32.000,77.490,-0.900,1,431.406,-1.889,1,1450.698,-11.207,5,4543.151
33.000,79.990,-0.900,1,432.766,-1.862,1,1456.327,-11.058,12,4545.341
34.000,82.490,-0.900,1,436.229,-1.849,1,1464.086,-10.874,5,4541.864
36.000,87.490,-0.900,1,449.338,-1.864,1,1485.859,-10.346,4,4522.719
38.000,92.490,-0.900,1,465.209,-1.896,1,1510.427,-9.655,5,4491.613
40.000,97.490,-0.900,1,481.079,-1.928,1,1534.996,-8.909,5,4454.246
41.000,99.990,-0.900,1,489.015,-1.944,1,1547.280,-8.558,0,4448.534
42.000,102.490,-0.900,1,496.666,-1.960,1,1559.125,-8.232,7,4448.534
43.000,104.990,-0.900,1,502.901,-1.972,1,1568.777,-7.945,7,4448.534
```

`Stat.No` in column 1 is the station number for which model results are listed in the following columns.

`offset` is the horizontal inline offset from first profile receiver which is at station no. 1.0 for above PLUSMODL.CSV. `topo` is the topography (z coordinate) at respective station no. `topo1` is the elevation of refractor 1 (first refractor), `topo2` is elevation of refractor 2 (second refractor).

Convert .CSV layer model to Surfer .GRD layered starting model

When a depth section window is opened via *Depth menu items* you can also export the layered model to .CSV with command *Window|Export ASCII Model of depth section...*

You can also edit above .CSV with your own refractor elevations and velocities using your favorite text editor e.g. Microsoft WordPad. Then select *Grid|Convert .CSV layer model to Surfer .GRD...* to **generate a Surfer format .GRD layered starting model based on your edited .CSV layered model**. We prompt you to select the .CSV file and next we prompt you to select a .GRD grid file to match. This can be e.g. `C:\RAY32\<your profile name>\GRADTOMO\GRADIENT.GRD` or `DLTAGRAD.GRD` or `VELOIT20.GRD` in same directory. These .GRD files are generated during Smooth inversion of your first break picks.

.HDR Batch file

.HDR batch files have extension .HDR and are named e.g. after the database profile, e.g. LINE14.HDR. Create a .HDR file e.g. with your favorite text editor or Microsoft Windows Notepad or Wordpad.

.HDR files contain 11 columns of data. See e.g. http://rayfract.com/help/2lamb15.hdr, as shown below :

```
File Name           ;Shot No.;Shot No.;Layout Start;Shot Pos.;Inline
Offset;Lateral Offset;Depth;Delay Time;Sample Interval;Sample Count
containing shots   ;in file ;in db  ;Station No. ;Stat. No.;m from
Stat. ;m from line   ;m    ;msecs.    ;msecs.        ;Number
FOPL15V.sgy        ;1       ;1       ;1           ;-2      ;0.0
;0.0          ;0.0  ;0.1       ;0.125        ;301
FOPL15V.sgy        ;2       ;2       ;1           ;2       ;0.0
;0.0          ;0.0  ;0.0       ;0.125        ;301
FOPL15V.sgy        ;3       ;3       ;1           ;4       ;0.0
;0.0          ;0.0  ;0.1       ;0.125        ;301
FOPL15V.sgy        ;4       ;4       ;1           ;6       ;0.0
;0.0          ;0.0  ;0.0       ;0.125        ;301
FOPL15V.sgy        ;5       ;5       ;1           ;8       ;0.0
;0.0          ;0.0  ;0.0       ;0.125        ;301
FOPL15V.sgy        ;6       ;6       ;1           ;10      ;0.0
;0.0          ;0.0  ;0.0       ;0.125        ;301
FOPL15V.sgy        ;7       ;7       ;1           ;12      ;0.0
;0.0          ;0.0  ;0.0       ;0.125        ;301
FOPL15V.sgy        ;8       ;8       ;1           ;14      ;0.0
;0.0          ;0.0  ;0.0       ;0.125        ;301
FOPL15V.sgy        ;9       ;9       ;1           ;16      ;0.0
;0.0          ;0.0  ;0.0       ;0.125        ;301
FOPL15V.sgy        ;10      ;10      ;1           ;18      ;0.0
;0.0          ;0.0  ;0.1       ;0.125        ;301
FOPL15V.sgy        ;11      ;11      ;1           ;20      ;0.0
;0.0          ;0.0  ;0.0       ;0.125        ;301
2FOPL15V.sgy       ;3       ;12      ;1           ;4       ;0.0
;0.0          ;0.0  ;0.1       ;0.125        ;301
2FOPL15V.sgy       ;4       ;13      ;1           ;6       ;0.0
;0.0          ;0.0  ;0.0       ;0.125        ;301
2FOPL15V.sgy       ;5       ;14      ;1           ;8       ;0.0
;0.0          ;0.0  ;0.0       ;0.125        ;301
2FOPL15V.sgy       ;6       ;15      ;1           ;10      ;0.2
;2.5          ;0.0  ;0.0       ;0.125        ;301
```

- ◆ `File Name`   lists the name of the input file, without the directory
- ◆ `Shot No. in file`   specifies the sequential shot number in the input file, starting at 1
- ◆ `Shot No. in db`   specifies the shot number to be used in the profile database
- ◆ `Layout Start`   lists the station number of the first/leftmost receiver position for this shot
- ◆ `Shot Pos.`   lists the *shot position* for this shot, in station numbers

- ◆ `Inline Offset [m]`   specifies the offset in meters, of the actual shot
  position from `Shot Pos.`
- ◆ `Lateral Offset [m]`   specifies the lateral offset of the shot position, from
  the line as defined by the receiver spread layout
- ◆ `Depth [m]`   lists the depth of the shot point below topography, at
  `Shot Pos.`
- ◆ `Delay Time [ms]`   specifies the *Delay time* for this shot
- ◆ `Sample Interval [ms]`   specifies the *Sample interval* for this shot
- ◆ `Sample Count`   specifies the *Sample count* for this shot

Specify the .HDR batch file to be used during import of shots in the *Import Shots dialog* displayed with *File|Import Data...* command :

You need to check *Batch import* to enable batch import with .HDR file selected above.

All shots listed in the .HDR file are imported with the same *Default spread type* specified in *Import shots dialog*. If you want to batch-import shots recorded with multiple *spread types* into the same profile database, you thus need to edit one .HDR batch file for each spread type.

Since version 3.35 we offer new controls *Output .HDR*, *Write .HDR only* and *Import shots and write .HDR* in our *Import shots dialog* shown with *File|Import Data... command*. See above screen shot. These controls let you generate a *.HDR batch file* listing all matching shots in input files contained in selected *Input directory* :

◆   click button *Output .HDR* and specify filename e.g.
      C:\RAY32\LINE14\INPUT\BATCH.HDR

◆   check box *Write .HDR only*

◆   click button *Import shots* to generate the *.HDR batch file*

◆   open this **.HDR** file in your favorite text editor e.g. Microsoft WordPad

◆   review and optionally edit columns in the **.HDR**

◆   save the edited **.HDR** file to disk with different filename e.g. **LINE14.HDR** instead of default **BATCH.HDR** filename

◆   save your edited **.HDR** file into your profile's input directory e.g.
      C:\RAY32\LINE14\INPUT\LINE14.HDR where you copied all your input data files

◆   now select this updated **LINE14.HDR** with button *.HDR batch*

◆   check *Batch import* and optionally check *Overwrite all*

◆   click button *Import shots* to automatically import all shots listed in your **LINE14.HDR** file

Convert Surfer .GRD file to ASCII .TXT with x/y/z/velocity for each grid cell

Once you have run **Smooth inversion** or **interactive WET inversion** you may want to post-process the obtained `VELOITXY.GRD` velocity tomograms. To convert the binary `.GRD` file format to ASCII .TXT use our ***Grid|Export grid file to ASCII .TXT...*** command available in our version 3.35 software since Nov 2016 :
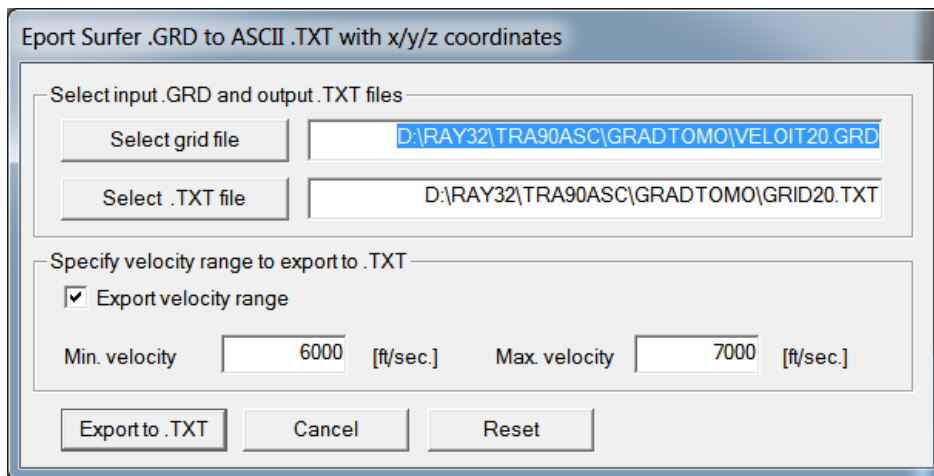
Use these controls and edit fields to setup the export :

- *Select grid file*   click to select *Input .GRD filename* to be exported to ASCII `.TXT` format
- *Input .GRD filename*   edit with keyboard or select with button *Select grid file*
- *Select .TXT file*   click to select *Output .TXT filename*
- *Output .TXT filename*   edit with keyboard or select with button *Select .TXT file*
- *Export velocity range*   check to export grid cells with velocity in range *Min. velocity* to *Max. velocity* to ASCII `.TXT`
- *Min. velocity*   set to minimum velocity to be exported to `.TXT` file or leave empty
- *Max. velocity*   set to maximum velocity to be exported to `.TXT` file or leave empty
- *Export to .TXT*   click to export x/y/z/velocity for each grid cell in `.GRD` to ASCII `.TXT` format (4 columns)

Once you have exported a "basement velocity" range from 2D velocity tomograms obtained for a few crossing 2D profiles to `.TXT` you can

- ➢ paste all `.TXT` files into one `.TXT` file e.g. with Microsoft Excel or in Golden Software Surfer worksheet
- ➢ grid the resulting `.TXT` file in Surfer to obtain `.GRD` file with ***basement map***
- ➢ contour the resulting `.GRD` in Surfer

To keep the size of the resulting `.TXT` small you can **down-sample the Surfer .GRD before exporting to ASCII** as above :

◆ in Surfer select *Grid|Mosaic* and your `...\GRADTOMO\VELOIT20.GRD`
◆ adapt/increase *Output grid geometry* fields *X spacing* and *Y spacing*. You need to keep the cell size quadratic i.e. set *X spacing* and *Y spacing* to same/as close as possible value
◆ click *OK* to export to `OUT.GRD`
◆ in Windows Explorer copy `...\GRADTOMO\VELOIT20.PAR` to `OUT.PAR`
◆ select our *Grid|Export grid file to ASCII.TXT* and above `...\GRADTOMO\OUT.GRD`

Calling Surfer

We support calling Golden Software Surfer versions 9, 10, 11, 12, 13, 14 and 15 Beta through their Scripter utility. Here are a few steps to try if Scripter can't find Surfer when running our `DELTATV.BAS` or `AUTOTOMO.BAS` scripts e.g. showing error message **"(10094) ActiveX Automation: Object var is 'Nothing' " :**

- ◆ **in Windows Control Panel | Programs and Features double-click Surfer, check "Repair" option and click "Next".**
- ◆ **try to run our scripts again e.g. via our** *Smooth invert/WET with 1D-gradient initial model*
- ◆ **if required select the correct Scripter version in** *Grid/Surfer invocation dialog*

If repairing Surfer does not help continue with following steps :

- ◆ **uninstall all installed Surfer versions in Windows Control Panel | Programs and Features : double-click Surfer version, check "Remove" option and click "Next"**
- ◆ **reinstall Surfer e.g. by running S11DEMO.EXE installer as Admin : right-click S11DEMO.EXE in Windows Explorer and select "Run as administrator"**
- ◆ **reboot your PC**
- ◆ **first open Surfer(R) by right-clicking desktop icon and selecting "Run as administrator"**
- ◆ **now open Rayfract(R) by right-clicking desktop icon and selecting "Run as administrator"**
- ◆ **try to run our scripts again e.g. via our** *Smooth invert/WET with 1D-gradient initial model*

If uninstalling and reinstalling Surfer does not help try these steps :

◆ **uninstall Surfer in Windows Control Panel | Programs and Features as above**

◆ **click Windows menu icon, enter program name REGEDIT.EXE and hit ENTER/RETURN**

◆ **delete Windows Registry key** HKEY_CURRENT_USER | SOFTWARE | Golden Software | Surfer (Demo) | 10 (or 9, 11, 12, 13, 14, 15)

◆ **delete Windows Registry key** HKEY_LOCAL_MACHINE | SOFTWARE | Golden Software | Surfer (Demo) | 10 (if there is one)

◆ **reinstall Surfer as Admin as above and open Surfer & Rayfract as Admin as above**

◆ **try to run our scripts again e.g. via our *Smooth invert|WET with 1D-gradient initial model***

If all of the above does not help also try **adding Surfer directly as a reference in Scripter** :
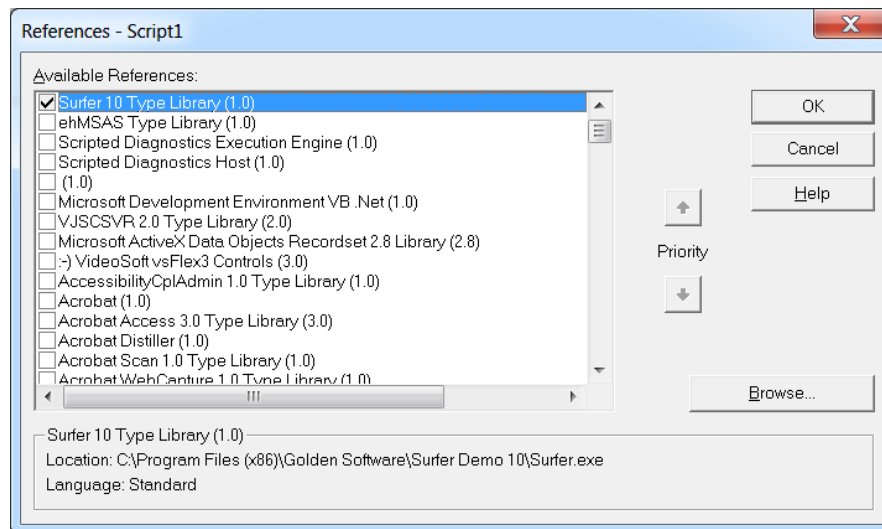
◆ open **Scripter** e.g. by clicking `C:\Program Files (x86)\Golden Software\Surfer Demo 11\Scripter\Scripter.EXE` in Windows Explorer

◆ in Scripter click **Edit** | **References**

◆ in the `Available References` section find and check **Surfer 11 Type Library**

◆ click *OK button*

◆ try to run our scripts again e.g. via our *Smooth invert|WET with 1D-gradient initial model*

If you are running an older version of our software and are installing&using a later released Golden Software Surfer version :

◆ Scripter Basic language and object type system has been changed by Golden Software over the years

◆ because of these language and object type changes later Scripter versions can't run earlier versions of our `DELTATV.BAS` and `AUTOTOMO.BAS` scripts

◆ so either continue using your old Surfer&Scripter version with your old Rayfract® software
   version or upgrade to our latest software version supporting the latest Surfer version

If all of the above does not help contact us at info@rayfract.com .

Multi-user access to LAN profile databases

Starting with our Rayfract® 32-bit version 2.34 as released in March 2002, we now support installation and access by multiple users, of profile databases on networked LAN (Local Area Network) hard disk drives/partitions.

You may purchase more than one end user license to our Rayfract® software. Each purchase of an additional license will give you an additional WIBU-KEY dongle. Exactly one end user may start up Rayfract® 32-bit from each PC / workstation with a WIBU-KEY connected locally. Profile databases may be created on networked LAN drives. **The software ensures that at most one user works with a specific LAN profile database at all times**. If a second user (from another workstation) tries to open the same LAN profile database, he will receive a notification that the database is currently being worked on by another user. He may then either choose to wait until that other user is done, or cancel the request to work with that database.

This **multi-user collision prevention mechanism** has been implemented with a file lock mechanism. The first user who opens a particular database causes the Rayfract® software to create a lock file named SEIS32.LCK in the corresponding profile database directory. For all other users who try later on to open the same LAN profile database, the software will discover that this SEIS32.LCK file exists already. Access to the database will be allowed for one of these other users once the first user closes that LAN profile database only. At that time, the software will delete the SEIS32.LCK file automatically.

The software will **automatically detect if the user i.e. workstation who first opened a LAN profile database has crashed**. That workstation normally will rewrite the SEIS32.LCK LAN file once every five seconds. As a consequence, the "last modification" timestamp will reflect the time of that rewrite and will be updated all five seconds. Whenever another user tries to open the same LAN database, and the software finds that the SEIS32.LCK file exists already, it will wait for ten seconds and verify that the timestamp of SEIS32.LCK has been updated. If this update is not detected i.e. if the "last modification" timestamp remains unchanged, the software assumes that the user who first opened the LAN database has crashed. Rayfract® 32-bit will then display a corresponding message and prompt the user if he wishes to delete (and then recreate) the SEIS32.LCK file and then open the LAN database as the new "first user".

This lock file mechanism will work with an unlimited number of users / workstations i.e. is not limited to just two users.

WIBU dongle setup and printing sections

A few notes concerning printing of *Gather displays / Refractor displays / Depth* and *Velocity sections* :

When issuing a print command from Rayfract® (selecting a window as current display, selecting *File/Print*), please wait until the printing process has finished, before you proceed with interacting with Rayfract®. Otherwise you may witness messages indicating failure of communication, between Rayfract® and your LPT parallel port WIBU key.

When your current printer driver drives a plotter, i.e. does not support bitmap display, **Rayfract® needs specific plotter drivers to render axis titles**. When running under Windows 95/98, Rayfract® assumes that the **HP 7550A** printer driver is installed, set up in landscape mode and with page size A3 selected. When run under Windows NT 4.0 Workstation, Rayfract® assumes that the **HP-GL/2 Plotter** driver is installed, set up in landscape mode and with page size A3 selected. These drivers are accessed by Rayfract® to render and rotate axis title text, for output on plotters. If they are not installed or not configured correctly, the printing process will abort and a corresponding message will be displayed on screen.

You may **generate HPGL / HP-GL/2 or PostScript files** by selecting the appropriate Windows printer driver (e.g. HP 7470A or HP7475A for HPGL; HP-GL/2 Plotter for HP-GL/2; HP LaserJet IIISi PostScript for PostScript) and then setting up these drivers for output to file. See your Windows operating system documentation. Make sure that the page size selected provides enough space for the section size, as determined by your horizontal and vertical scaling of the plot. Under Windows NT 4.0 Workstation only, you may select e.g. the HP-GL/2 Plotter driver, to generate HP-GL/2 format plot files.

Alternatively, and to document error messages, **generate screen dumps** as follows :

➢ click on the "Maximize" rectangle at the right upper corner of Rayfract® window
➢ maximize the targeted display (shot gather, depth section etc.) as well
➢ press ALT-PRTSC (PrintScreen) key combination
➢ select Start menu item Run... and enter command "MSPAINT.EXE"
➢ paste screen dump into MSPAINT document with CTRL-V
➢ now save the Paint "Untitled" document as .JPG file

Alternatively to MSPAINT.EXE, paste the screen dump e.g. into an Adobe Photoshop document, Microsoft Word or Golden Software Surfer® plot document. Since Rayfract® version 3.17, you can **copy window content into the Windows® Clipboard, with CTRL-C or CTRL-A** :

➢ copy any trace gather/refractor display/depth or velocity section to Microsoft Windows® clipboard as follows
➢ select the section window with mouse left-click on its title bar, or via Windows menu
➢ press CTRL-C shortcut, to copy window content as bitmap to clipboard
➢ open a document in Golden Software Surfer®, Microsoft Word®, Microsoft Paint (MSPAINT.EXE) etc.
➢ use CTRL-V shortcut, to paste clipboard content into current document
➢ copy bitmap of all opened section windows to clipboard with CTRL-A shortcut

If after (re)installing our Rayfract® software on your PC, the software displays an error message **"Program needs WIBU-BOX with ...", and you are using a green USB port WIBU key** on this PC, please proceed as follows :

➢   remove all WIBU-KEY dongles from your PC
➢   select Start|Control Panel
➢   double-click on the WIBU-KEY applet icon
➢   left-click on small icon to left of dialog title bar, select "Advanced Mode" if available
➢   click on the "Install" tab
➢   click on button "Plug & Play..."
➢   confirm the prompt with "Yes" button
➢   click on "OK" buttons to leave WIBU-KEY applet
➢   uninstall WIBU-KEY driver with Control Panel/Add/Remove Software/WIBU-KEY Setup Remove
➢   now reboot your PC
➢   reinstall the WIBU-KEY driver with \RAY32\WIBUKEY\SETUP.EXE
➢   reinsert the USB key
➢   note bubble "Found New Hardware" at bottom of screen
➢   after a few seconds, note display of **"Found New Hardware Wizard"** window
➢   select radio button "No, not this time" to prevent connecting to Windows Update
➢   click on "Next" button twice, and on following "Finish" button

If above procedure does not work, make sure to uninstall the WIBU-KEY driver with Control Panel/Add/Remove Software/WIBU-KEY Setup Remove (Control Panel/Programs and Features under Windows Vista), directly before rebooting your PC. Then reboot, and now reinstall the WIBU-KEY driver with \RAY32\WIBUKEY\SETUP.EXE . Then reinsert the USB key.

Please install the green LPT parallel port WIBU key coming with your Rayfract® license on your parallel printer port LPT1. Replug your printer cable into the WIBU-KEY dongle, instead of directly plugging it into the parallel printer port LPT1. This dongle is highly compatible with most printers and printer drivers. One known problem case is the HP LaserJet 5L printer : it needs to be installed as PCL printer driver (custom installation) and WITHOUT the PCL status window, so that the WIBU dongle can communicate with the Rayfract® package correctly. If printing does not work in that configuration, try to reconfigure the printer driver driver by deactivating both the spooler and bidirectional communication with the printer.

If you need to reinstall the WIBU key driver software for any reason, please run the command line \RAY32\WIBUKEY\SETUP and follow instructions.

If the dongle is still not recognized by the WIBU-KEY driver software (e.g. on Toshiba Satellite or Dell Notebook computers), please check and **update the LPT: port address** as follows :

➢   start up Windows Explorer, and search for the MSINFO32.EXE utility on your C: drive
➢   run MSINFO32.EXE and click on Components/Ports/Parallel
➢   write down the (hexadecimal) IO Range Base parameter (left of hyphen), e.g. 0378 or BDA8
➢   start up the WIBU-KEY Control Panel applet with Start/Control Panel/WIBU-KEY
➢   left-click on the small icon to the left of the dialog title bar, select "Advanced Mode" if available
➢   click on the "Setup" tab
➢   uncheck "System default"
➢   make sure the "Port address" is the same as noted above e.g. 0378 or BDA8
➢   if not, enter the address as shown by MSINFO32.EXE manually, into field "Port address"
➢   now click on button "Apply"
➢   then try to start up Rayfract® again

If the above does not help with your LPT port WIBU-KEY communication, please try connecting a printer with a parallel port printer cable plugged into the LPT WIBU-KEY or unplug such a cable.

Some PC's have a non-standard LPT port hardware and/or do not supply enough power to the dongle. If the LPT port dongle is still not recognized by the WIBU-KEY driver, you may introduce a delay factor to prevent a timeout, in case of too low power supply to the dongle. See also http://support.wibu.com/en/faq/faq.html#Delay . Please

➢ download the .ZIP archive http://rayfract.com/dongle/diaglpt.zip from our web site
➢ *Start*/*Run* "explorer.exe" (without enclosing ""), to open Windows Explorer
➢ create a directory \ray32\wibukey\diaglpt on your PC's hard disk with Windows Explorer
➢ copy diaglpt.zip file into this directory, and unzip it e.g. with WINRAR utility.

Now slow down the communication speed between the LPT port and the WIBU-KEY dongle :

➢ open a DOS command prompt via *Start*/*Run* "cmd.exe" (without the enclosing "").
➢ change the current directory of that prompt with command line "cd \RAY32\WIBUKEY\DIAGLPT".
➢ navigate with Windows Explorer to your \ray32\wibukey\diaglpt directory, as created above.
➢ click on w2k_delay4.reg, and confirm the two prompts.
➢ switch to the DOS prompt as opened above
➢ enter command line "WKU32 RESET ALL"
➢ try to start up Rayfract® again.

If this does not help, please repeat the above last four steps for all other .reg files in your DIAGLPT directory. ...delay12.reg will slow down the communication speed the most. If your LPT WIBU-KEY dongle is still not recognized by the WIBU-KEY driver, please contact us for an USB key license upgrade offer.

Should you unexpectedly have serious trouble with printing (presumably caused by your WIBU dongle), or witness communication failure between WIBU-KEY dongle and Rayfract® (in connection with a certain printer / printer driver), you may contact the WIBU-SYSTEMS hotline, located in Germany. Their number is :

+49-721-93172-14

or email support@wibu.de or support@wibu.com .

You may also direct your Web browser at http://www.wibu.com for drivers, answers to FAQ's (frequently asked questions) etc. Current drivers are contained in various installable archives which you may download from that site.

Processing and interpretation controls

.3DD shot traces sorted by receiver offset

Check this option to improve detection of shots when importing `GeoTomCG` `.3DD` with multiple shots recorded at same shot point but with shifted receiver spread. Otherwise such shots are merged into one shot during `.3DD` import.

a : Cosine argument power

See (Chen and Zelt, 2012) Fig. 5(a) for Cosine-Squared weighting function pow(Cos(Pi/2 * pow(d,a)), 2b) with d=delay from wavepath center [ms] divided by one period [ms]. Try a=0.5 and b=10.0 for optimal imaging of basement fault zones.

Absolute elevations

Select this radio button to export absolute elevations to file DELTATV.TXT, in (station nr., depth, velocity) triples.

Acquisition date

Date of recording of seismic data. It is recommended that the date be specified in dd/mm/yyyy format. Alternatively, to avoid any possible confusion in the ordering of the day and month, use format dd/mmm/yyyy, with mmm being a three-letter abbreviation of the month.

Acquisition time

Time of recording of seismic data. The contents of this field is not used during processing. As a consequence, its format is not fixed. It is recommended that the time be stored in the 24-hour hh:mm:ss format.

Active traces

This read-only field in *Import shot dialog* shows the number of traces recorded for the current shot, to be imported by clicking *Read button*.

Adjust profile station spacing

Determine averaged minimum receiver station spacing for current input file during data import, and let you optionally update the *profile station spacing*.

Adjust X coordinate to fit Y and elevation

Select this radio button to automatically adjust x coordinates imported to fit y coordinates and elevations imported, such that the resulting station spacing corresponds to the Station

spacing as specified in *Header|Profile*.

Adjust Y coordinate to fit X and elevation

Select this radio button to automatically adjust y coordinates imported to fit x coordinates and elevations imported, such that the resulting station spacing corresponds to the Station spacing as specified in *Header|Profile*.

AGC window length

Length of time window (in milliseconds) enclosing samples which are regarded when carrying out automatic gain control (AGC) on sample central to that window.

Allow adjacent Intercept time layer inversion

Check this XTV option to enable application of our Intercept Time inversion method, for multiple adjacent XTV triples. See topic XTV inversion for details.

Allow gaps in coverage of velocity model grid columns

Select this option to allow grid columns with no velocity values between the first and last grid columns with velocity values. This may be necessary if there was a gap in coverage along the original 2D field seismic line, i.e. when crossing a river. We recommend to leave this option at its default value i.e. disabled.

Allow missing traces for SeisOpt and Gremix files

Check this option to enable import of SeisOpt and Gremix files with missing unpicked or dead traces. If there are traces missing from SeisOpt or Interpex Gremix input data files, these missing traces are regenerated during import automatically for the active part of the *receiver spread type* specified. This option is checked/enabled per default, when creating a new profile database.

Allow unsafe pseudo-2D DeltatV inversion

If you want to invert   first breaks with our pseudo-2D *DeltatV method*, first run *Smooth inversion*. Then check this Smooth inversion setting, to enable our DeltatV menu.

Allow XTV inversion for 1D initial model

Check this option in *Smooth invert|Smooth inversion Settings*, to enable using our XTV inversion method for determination of the 1D initial model used for Smooth inversion. XTV inversion allows modeling of a constant-velocity weathering overburden with the intercept-time method, in addition to modeling of gradient layers with DeltatV inversion.

Annotate axes

Deactivate this option to display axes without annotations, i.e. without labeling of big ticks.

Annotation parameters dialog

This dialog lets you customize the labeling and coordinate system display of your sections.

Annotations inside view port

Check this option to display annotations such as axis calibration and axis title inside the coordinate system.

Apply bandpass n times

Cascade this bandpass frequency filter n times in sequence, for stronger effect.

Apply n times

Cascade this frequency filter n times in sequence, for stronger effect.

Automatically adapt shape of rectangular filter matrix

Check this item to automatically adapt the shape of the rectangular filter matrix to suppress processing artefacts. Check to avoid horizontal streaking artefacts just below steep topography. Uncheck for sharper imaging of sudden increase of velocity with depth for quasi-horizontal topography.

Automatically estimate v0

Activate this option to force estimation of a laterally varying near-surface velocity based on the laterally constant crossover distance **Weathering crossover**. Use this option e.g. in situations of locally outcropping geologic formations. Also, with this option there is no need to map first breaks to refractors explicitly, in your **Shot breaks** or **Midpoint breaks** display.

Axis big tick size

Size of big axis ticks, in millimeter.

b : Cosine-Squared power

See (Chen and Zelt, 2012) Fig. 5(a) for Cosine-Squared weighting function pow(Cos(Pi/2 * pow(d,a)), 2b) with d=delay from wavepath center [ms] divided by one period [ms]. Try a=0.5 and b=10.0 for optimal imaging of basement fault zones.

Band-pass filter

Check this box to apply a band-pass frequency filter to traces before displaying them. Uncheck for band-reject filter. See Steven W. Smith, Digital Signal Processing.

Bandpass filter active for current trace gather display

Check this box to activate bandpass frequency filter. Hit Enter or Return key to redisplay traces in current gather window, with this filter applied to traces shown.

Base filter width

This parameter lets you specify over how many adjacent stations the running average smoothing filter will be applied, for the deepest refractor being mapped.

Basement crossover filter

Filter width (in station numbers) used for smoothing the laterally varying crossover distance separating first breaks mapped to the wave critically refracted by the first refractor from first breaks mapped to the wave critically refracted by the second refractor. If you specified a *Refractor Count* of 1, substitute weathering layer and first refractor for first refractor and second refractor, in the preceding sentence.

Batch import

Check this option to import all shots listed in *.HDR batch file* or all shots contained in ASCII.ASC files in input directory specified. Shots are imported in batch mode, without need of confirmation of shot data in the *Import shot dialog*.

Beydoun weighting for borehole WET

Check this option to enable Beydoun weighting, uncheck to disable Beydoun weighting. Use option *Precompute static Beydoun weight matrix* to specify static or dynamic Beydoun weighting.

Bidirectional bandpass filter

Check this box for bidirectional filtering. This better preserves the original waveform. See Steven W. Smith, Digital Signal Processing, chapter 19. Recursive method used to produce a zero phase filter. The signal is first filtered from left-to-right, then the intermediate signal is filtered from right-to-left.

Bidirectional filter

Check this box for bidirectional filtering. This better preserves the original waveform. See Steven W. Smith, Digital Signal Processing, chapter 19. Recursive method used to produce a zero phase filter. The signal is first filtered from left-to-right, then the intermediate signal is filtered from right-to-left.

Blank after each run

Click this button in multirun WET dialog to check/uncheck all *Blank* boxes for all runs except

for the last run. The last run is the one before first run with 0 iterations.

Blank after last run

Click this button in multirun WET dialog to check/uncheck *Blank* box for last run. The last run is the one before first run with 0 iterations.

Blank after WET run

This column in multirun WET dialog lets you enable/disable the *blanking below wavepath envelope* after the last iteration of each WET run no. 1 to 10. Regards WET parameter *Envelope wavepath width* .

Blank below envelope after each iteration

Check this WET blanking setting to blank the WET tomogram below envelope of all wavepaths, after each iteration except the last. Regards WET parameter *Envelope wavepath width.* This option is disabled per default when creating a new profile or opening an existing profile database. We recommend to leave this blanking option disabled since it blanks excessively and may suppress meaningful output in lower half/at bottom of tomogram.

Blank below envelope after last iteration

Check this WET blanking setting to blank the WET tomogram below envelope of all wavepaths after the last WET iteration. Regards WET parameter *Envelope wavepath width* . This option is enabled per default.

Polygon blanking active

Check this box to enable blanking during WET inversion in polygon specified in *blanking file* selected with button *Select blanking file.* If the *blanking flag* in the selected *blanking file* is 0 then the tomogram is blanked outside the polygon. *Blanking flag* value 1 means blank inside polygon. Option *Blank outside polygon* lets you override the *blanking flag* specified in the selected *blanking file*.

Blank low coverage after each iteration

Check this WET blanking setting to blank low coverage areas at tomogram bottom after each iteration except the last one. Low coverage means less than 10 percent of maximum grid coverage. This blanking option is disabled per default.

Blank low coverage after last iteration

Check this WET blanking setting to blank low coverage areas at tomogram bottom after the last WET iteration. This option is disabled per default. Low coverage means less than 10 percent of maximum coverage in WET tomogram.

Blank no coverage after each iteration

Check this option in *WET Tomo|WET tomography Settings|Blank submenu* to blank the updated WET velocity tomogram outside the area covered with wavepaths after each WET iteration.

Blank no coverage after last iteration

Check this option in *WET Tomo|WET tomography Settings|Blank submenu* to blank the updated WET velocity tomogram outside the area covered with wavepaths after the last WET iteration.

Blank no coverage on top of borehole tomogram

check *WET Tomo|WET tomography Settings|Blank|Blank no coverage on top of borehole tomogram* in addition to blanking options *Blank no coverage after each iteration* or *Blank no coverage after last iteration* to blank on top of borehole tomogram. With this option unchecked we only blank no coverage area at the bottom of the borehole tomogram obtained for *Header|Profile|Line type* `Borehole spread/line` .

Blank outside borehole tomogram

Since version 3.33 WET inversion blanks outside borehole tomogram with this option enabled. This assumes that all receivers are located in one hole and all sources are in the other hole. We determine the bounding polygon as in
http://stackoverflow.com/questions/217578/point-in-polygon-aka-hit-test

Blank polygon area in grid

Blank velocity or reset to constant grid velocity in VELOITXY.GRD in polygon area specified in Surfer .BLN *blanking file*.

Blanking file

Surfer format .BLN blanking file selected with button *Select blanking file* in *WET Tomo|WET velocity constraints*. This file should specify a polygon which is blanked during WET inversion or with command *Grid|Blank polygon area in grid...* . See your Golden Software Surfer manual for format of blanking file. You can create the `.BLN` blanking file with **Map|Digitize** in Surfer on a tomogram plot. Once done optionally open the `.BLN` file in Microsoft WordPad and specify **blanking velocity** in third column of the polygon header line. E.g. 31,1,1500 means polygon with 31 points, blank inside, reset to 1500 m/s or feet. Optionally specify **blanking percentage** in fourth column of polygon header line. E.g. 31,1,1500,20 means allow maximum deviation of 20% between WET velocity and blanking velocity of 1500 m/s or feet.
    Create the Surfer `.BLN` blanking file as described in
https://support.goldensoftware.com/hc/en-us/articles/226661208-How-can-I-create-a-BLN-file-in-Surfer : digitize the boundary with **Map|Digitize** and save to a `.BLN` file. Optionally first

draw the polygon on the velocity tomogram in an empty base layer with Surfer ***Draw/Polygon command***. Change the *blanking flag* (2nd column in header line) from 1 to 0 with e.g. Microsoft WordPad to blank outside the polygon.

Blanking flag

The *blanking flag* is specified in 2nd column of the `.BLN` *blanking file* header. E.g. header line 31,1 means polygon with 31 points, blank inside. 31,0 means blank outside. When creating the *blanking file* with *Map/Digitize* command in Golden Software Surfer the *blanking flag* is set to 1 per default. Once you have saved the *blanking file* in Surfer you can change this flag to 0 with e.g. Microsoft WordPad editor.

Blank outside polygon

Check this box to force blanking outside the polygon specified in the selected *blanking file* regardless of the value of the *blanking flag* in the *blanking file* header. If this box is not checked then the *blanking flag* is regarded.

Borehole 1 line select button

Click to navigate into profile subdirectory with *Line type* `Borehole spread/line` and select its SEIS32.DBD database schema to add this *Borehole line profile* to your *main profile* selected with *File/Open Profile... .* First breaks picked for both profiles are used for joint *WET inversion*.

Branch point

The location on a traveltime curve offset from the CMP location or from the shot point by a crossover distance is called a **branch poin**t. A traveltime curve mapped to refractors is separated by *branch points* into segments, also called *refractor branches*.

Cancel import

Use this button to abort the import of shots into your Rayfract® profile database.

Central filter weight

Weight applied to central sample of current trace sample time window, when filtering trace signals with the running average smoothing algorithm. All other samples are assigned a weight of 1.

CG iterations

Specify how many line searches are started by the Conjugate Gradient method. See

http://www.cs.cmu.edu/~quake-papers/painless-conjugate-gradient.pdf

on page 53 for an outline of the algorithm. *CG iterations* is the number of outer loop iterations

imax.

Chebyshev bandpass filter

Check this box to apply Chebyshev-Butterworth filter to traces. Uncheck for single-pole filter. Chebyshev achieves a faster roll-off than Butterworth by allowing ripple in the passband. Single-pole works well for low-frequency signals, and causes less ringing and overshoot. See Steven W. Smith, Digital Signal Processing, chapter 20, sections **Step Response Overshoot** and **Stability**.

Chebyshev filter

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Client

Free format text field naming the company or organization sponsoring data acquisition and processing.

Clip amplitude peaks for current trace display

When this option is activated, trace signals are displayed with peaks and troughs clipped. This guarantees that trace signals of adjacent traces do not overlap.

CMP curve stack width

This field in *DeltatV/Interactive DeltatV* main dialog lets you specify how many adjacent CMP positions, in a CMP station number interval centered at the current CMP position, are considered when constructing the averaged CMP traveltime curve for the current CMP position. The number of CMP's in a given station number interval may be computed with the formula **CMP count = (station nr. difference covered) * 4 + 1**.

CMP gather datum

Select this option to compute first break static corrections relative to a dipping datum plane specific to the CMP gather currently being processed. This datum plane is obtained by linear regression through elevations of all sources and receivers employed for recording traces mapped to that Common Mid-Point.

CMP Stack Width

This field in *CMP refractor mapping dialog* lets you specify how many adjacent CMP positions, in a CMP station number interval centered at the current CMP position, are considered when constructing the averaged CMP traveltime curve for the current CMP position.

CMP traveltime curve

The midpoint breaks display is constructed by displaying all CMP traveltime curves for the current profile. One CMP traveltime curve is constructed by stacking the first breaks picked for CMP Stack Width adjacent CMP positions (centered at the CMP position currently being evaluated) and connecting first breaks located at adjacent unsigned offsets with straight line segments. If more than one first break are being mapped to the same unsigned trace offset during construction of the stack/traveltime curve, these breaks are averaged out numerically.
Cell size

Check box *Force grid cell size* and edit cell size in meters or feet to desired value to be used for Surfer grid X Spacing (column spacing) and Y spacing (row spacing) next time a starting model is computed.

Column 1

Specify the content of your ASCII format, column 1, by selecting the corresponding entry from the drop down list box.

Column 10

Specify the content of your ASCII format, column 10, by selecting the corresponding entry from the drop down list box. If your format does not specify this column, specify content type No value.

Column 2

Specify the content of your ASCII format, column 2, by selecting the corresponding entry from the drop down list box.

Column 3

Specify the content of your ASCII format, column 3, by selecting the corresponding entry from the drop down list box.

Column 4

Specify the content of your ASCII format, column 4, by selecting the corresponding entry from the drop down list box.

Column 5

Specify the content of your ASCII format, column 5, by selecting the corresponding entry from the drop down list box. If your format does not specify this column, specify content type No value.

Column 6

Specify the content of your ASCII format, column 6, by selecting the corresponding entry from the drop down list box. If your format does not specify this column, specify content type No value.

Column 7

Specify the content of your ASCII format, column 7, by selecting the corresponding entry from the drop down list box. If your format does not specify this column, specify content type No value.

Column 8

Specify the content of your ASCII format, column 8, by selecting the corresponding entry from the drop down list box. If your format does not specify this column, specify content type No value.

Column 9

Specify the content of your ASCII format, column 9, by selecting the corresponding entry from the drop down list box. If your format does not specify this column, specify content type No value.

Common Mid Point (CMP)

A profile position, expressed in station numbers, which represents the midpoint between shot and receiver position for one or more traces recorded for that profile.

Company

Free format text field. Name of company responsible for acquiring and/or processing the data.

Conjugate Gradient

Check this radio button in WET Tomo|Interactive WET tomography dialog to use Conjugate Gradient method for WET inversion. See

http://www.cs.cmu.edu/~quake-papers/painless-conjugate-gradient.pdf

. Default is *Steepest Descent* method. Conjugate Gradient method can give sharper image and lower RMS error with fewer WET iterations. But Steepest Descent is more robust in case of noisy first break picks with reciprocal traveltime errors and recording geometry errors.

Conjugate Gradient tolerance

This parameter is the error tolerance Epsilon described by (Shewchuk, 1994) for Conjugate Gradient method. See

http://www.cs.cmu.edu/~quake-papers/painless-conjugate-gradient.pdf

on page 53 for an outline of the algorithm. Our *Tolerance* parameter corresponds to (Shewchuk, 1994) epsilon ε for outer loop termination.

Context sensitive online help

Whenever you are displaying a dialog box, you may cycle through its controls by pressing the TAB key repeatedly. The control with the focus is visually highlighted. To get online help on that control, press F1. Now a pop up window containing a short description of the control's usage and meaning is displayed. To dismiss that pop up online help window under Windows 95, press any key, such as ESC.

When running Rayfract® under NT 4.0 Workstation or Windows 3.1, press ALT-TAB instead, to return the focus to your dialog box and currently selected control. Or shut down the help window, with ALT-F4 or by clicking on its close icon in its upper right corner.

Convert .CSV layer model to Surfer .GRD...

Replace velocities in GRADIENT.GRD or VELOITXY.GRD with layer model .CSV velocities. Store resulting layered .GRD with same filename as selected .CSV file. Asks you to first select the .CSV layer model and then a matching tomogram .GRD file. Next select *Image and contour velocity and coverage grids..* and the just created layered model .GRD named PLUSMODL.GRD for Plus-Minus refraction, WAVEMODL.GRD for Wavefront refraction or CMPMODL.GRD for CMP intercept-time refraction method.

Convert elevation to Depth below topography...

Flatten out/remove topography from VELOITXY.GRD tomogram. Please first make a backup copy of VELOITXY.GRD, because we do not support adding back the topography to a flattened tomogram. You can image the flattened tomogram with *Image and contour velocity and coverage grids...* . We do not flatten COVERGXY.GRD wavepath coverage grids.

Convert grid file between feet and meters

Use this *Grid menu* command to convert previously generated velocity tomograms VELOITXX.GRD (and matching coverage grids COVERGXX.GRD, if existing) between feet and meters. Then image the converted tomogram with *Grid|Image and contour velocity and coverage grids...* .
    Surfer .GRD files are stored in profile subdirectories GRADTOMO (1D gradient based Smooth inversion), LAYRTOMO (layered refraction starting model), TOMO (pseudo-2D DeltatV inversion) and HOLETOMO (Crosshole survey interpretation).

Copy v0 from Station editor

Use this option to reuse weathering velocities as specified in the Station editor (*Header|Station*) for the computation of static corrections. This option will preserve existing mappings of first breaks to refractors and resulting weathering velocities and corrections of first breaks for shot position offsets.

Correct all velocities for DeltatV systematic error

Select this option to reduce all grid node velocities as indicated in the Surfer® .GRD grid file by 10 percent before running the model through the raytracing algorithm during the first WET tomography iteration.

Correct basement velocities for DeltatV systematic errors

Select this option to reduce basement grid node velocities as indicated in the Surfer® .GRD grid file by 15 percent before running the model through the raytracing algorithm during the first WET tomography iteration. "Basement" just means high velocity regions, as indicated by values in the grid file.

Correct breaks

Once you have specified correct *shot hole depths and inline/lateral shot position offsets* for all shots and correct weathering velocities for all stations, click this button to correct first breaks for shot position offsets. It is assumed that the bottom of the shot hole is located in the uppermost, weathering layer.

Correct picks for delay time

This flag is disabled per default. Experience has shown that sometimes ASCII files with first breaks are encountered where first breaks have not yet been corrected for the delay time. One specific case are Rimrock Geophysics .PIK files. This problem may be caused by the Seismograph software not storing the delay time into the SEG-2 trace headers.

Correct x

If x coordinate values are specified and have been interpolated for all profile station nrs. previously, you may correct x coordinates for topography change along the line. To automatically generate x and y coordinate values for all stations, just export coordinates via the File menu and then reimport the generated .COR file.

Correct y

If y coordinate values are specified and have been interpolated for all profile station nrs. previously, you may correct y coordinates for topography change along the line. To automatically generate x and y coordinate values for all stations, just export coordinates via the File menu and then reimport the generated .COR file.

Coverage grid shows unweighted hit count

If this option is unchecked, the coverage grid generated by borehole WET shows the hit count of each grid cell, scaled by Beydoun weighting (if enabled, with option *Beydoun weighting for borehole WET*). With this option checked, the coverage grid shows the unweighted hit count.

Coverage plot thinning active

Check this box to activate thinning of the WET wavepath coverage plot, with parameters Plot wavepaths for every nth shot and Wavepaths for every nth receiver.

Critical fold

Relevant for Plus-Minus and CMP intercept time refraction depth sections only. If the fold (i.e. the number of first breaks stacked at the current position, for the current refractor) is smaller than the value specified for this parameter, the corresponding depth location arc is not outlined, but drawn with a dashed pen instead.

Crossover distance, crossover offset

Crossover distance means the in line offset in station numbers (from shot location or CMP location) where head wave first breaks from a deeper refractor overtake head wave first breaks from a shallower refractor. They are identified by visually or algorithmically locating systematic discontinuities in slope of traveltime curves (abrupt changes of slope). In situations of highly sloping / undulating refractor surfaces, crossover distances may be more easily identified on a CMP sorted traveltime curve display than on a shot sorted traveltime curve display. The reason for this better visibility of crossover offsets is that the influence of the dip of layers on traveltime curves is filtered out to a higher degree in the CMP sorted traveltime curve display (Rühl, T. 1995).

Current layer velocity step

This XTV parameter is used if Allow adjacent Intercept time layer inversion is enabled only. This step parameter may vary between values 0% and 99%. The velocity step determines how v_1 needed for Intercept Time inversion of the current XTV triple is obtained, from the current XTV triple and by interpolation between v_1 as obtained with step parameter Overlying layer velocity step (current step 0%) and the current apparent velocity V (current step 100%). The default value for this parameter is 25%. See topic XTV inversion for details.

Cutoff frequency

This specifies the frequency separating the bassband from the stopband, of this filter.

Damping

This field lets you specify the damping factor a. The velocity tomogram for the current WET iteration is damped with previous iteration tomogram : V(i+1)=a*V(i)+b*V(i+1); a+b=1; b=1-a . This makes WET inversion more robust especially with our *Conjugate Gradient* option and bad picks and when using our new *multirun WET* / multiscale tomography option.

Default distance unit is meter

Check to specify distance unit meter, for OPTIM LLC SeisOpt and Geometrics SeisImager

PickWin/PlotRefa .VS file import. Uncheck to specify distance feet.

Default layout start is 1

Check this option to make our import routine use the default value 1.0 for the layout start of the first shot shown in the *Import shot dialog*. With this option unchecked, the layout start defaults to 0.0. This option is checked per default. If you uncheck import option *Profile start is default layout start,* layout start and shot position will be determined directly from the SEG-2 trace headers instead. *Profile start is default layout start* is unchecked per default.

Default sample count

This value specified in dialog *File/Import Data…* is used when importing shot files without seismograph traces e.g. for ASCII.ASC and Interpex Gremix .GRM to determine the time scale in *Trace/Shot gather* and *Refractor/Shot breaks*

Default sample interval

This value specified in dialog *File/Import Data…* is used when importing shot files without seismograph traces e.g. for ASCII.ASC and Interpex Gremix .GRM to determine the time scale in *Trace/Shot gather* and *Refractor/Shot breaks*

Default shot hole depth

Specify the default shot hole depth, in meters, for all shots to be imported into the currently opened profile database.

Default spread type

Spread types are named "X: YYY channels". X enumerates the spread types. YYY stands for the number of receivers in spread type X. We support 12 to 360 receivers per spread. Select the type matching the number of receivers you used to record your data. If no exact match is available, select the *spread type* with the next higher number of receivers. For irregular receiver layout and seismograph data types SEG-2, Bison-2 9000 Series, ABEM Terraloc Mk III or ASCII.ASC format, you may need to define your own *spread type*. See help topic
Defining your own layout types **.**

Default time unit is seconds

Check this option, to specify time unit seconds for first breaks specified in OPTIM LLC SeisOpt input files. Uncheck to specify time unit milliseconds.

Degree of Surface Consistency

This parameter specifies to what degree the smoothed surface of refractor 1 should follow the line's topography. You will want to set this value according to the weatherability of refractor 1 : if the refractor consists of a formation with relatively high propagation of speed of sound, it will

resist to weathering to a higher degree than the weathering layer itself. Therefore, refractor 1 will more likely keep its shape over time, with a higher degree of independence from the shape of the topography above it. The more refractor 1 resists to weathering or the weaker the weathering layer itself in relation to refractor 1, the smaller the degree of surface consistency specified should be.

Delay time

This value will normally be 0. If you start recording trace data after a certain delay after generating the sound waves (i.e. by firing a shot or dropping a weight), specify that delay with this parameter, in milliseconds. If the recording of samples starts BEFORE the shot is fired, the time difference needs to be specified as a NEGATIVE delay time. When importing SEG-2 binary trace data files, this field will be initialized from the SEG-2 trace headers automatically.

Delete traveltime grid files for last WET iteration

Uncheck this option if you want to keep Surfer® .GRD formatted disk files holding the traveltime fields as computed with the Eikonal Solver for each shot, during the last WET iteration. These grid files will be named S1.GRD for shot number 1 etc.

Depth below topography

Select this radio button to export depths below topography in (station nr., depth, velocity) triples to file DELTATV.TXT. If depths should be preceded with a minus "-" sign, check box *negative depths*.

Depth-extend initial model

Smooth inversion per default depth-extends the 1D initial model (generated by horizontally averaging DeltatV output, and based on surface-based refraction shots only) to elevation level of deepest uphole shot.

DeltatV Inversion

Click on this button once you have specified all parameters for the DeltatV inversion, or to accept the default parameter values as proposed by the software.

Detect shifted 32-bit floating point sample data start

This option was implicitly enabled before version 2.64. But the import routine cannot detect the true trace start in every case (by determining the correct byte shift with the minimum trace signal variance), so we decided to disable this option per default. If your imported binary shots don't show any coherent signal in *Trace/Shot*, reimport with this option enabled.

Direct wave first breaks recorded

Deselect this option if the shot-receiver spacing employed during data registration was too coarse to register direct wave first break arrivals. This occurs if all first breaks picked belong

to refracted waves and with thin weathering layers.

Direct Wave Offset Delta

Valid values : 3 to 10. Offset range considered when carrying out piecewise linearization of first breaks mapped to the same CMP traveltime curve and assigned to the weathering layer.

Disable traveltime grid caching

Check this WET setting to write all traveltime grids to disk during WET inversion instead of caching grids in RAM. Checking this option may help to reduce disk swapping in case of low free RAM memory availability.

Disable wavepath scaling for short profile

For profiles with less than 72 receiver stations, *WET wavepath width scaling* and *filter height scaling* are disabled per default, to prevent artefacts in the resulting tomograms. If you are confident in your first break picks (default Smooth inversion RMS error less than 2%), and your shots are spaced closely enough, you may uncheck this *WET Tomo|WET tomography Settings* setting, to enable these two options.

Display parameters dialog

This dialog lets you specify the station number and data range displayed. Furthermore, it lets you scale the plot generated when printing the current section.

Do AGC for current trace gather display

Enable AGC for the shot gather display currently being displayed.

Do not adjust coordinates

Select this radio button to display error messages for all coordinate values which do not fit the line geometry (station spacing) within the tolerance as specified with *Maximum tolerance*.

Do not export

Select this radio button in connection with options *Maximum velocity exported* and *limit velocity exported*, to skip velocity values exceeding *Maximum velocity exported* during generation of file DELTATV.TXT.

Don't blank above topography

Check this WET blanking setting *WET Tomo|WET tomography Settings|Blank|Don't blank above topography* to not blank above topography during WET inversion for

Header|Profile|Line type **Refraction spread/line** *.*

Don't extrapolate grid rows

check *WET Tomo|WET tomography Settings|Blank|Don't extrapolate grid rows* to not
extrapolate grid rows at left and right margins during WET inversion. May prevent high-
velocity artefacts below topography and at tomogram edges. May cause WET to fail
especially in *Conjugate Gradient* mode.

Edit cell size

Check this option in *Smooth invert|Smooth inversion Settings* to regard the user-specified *Cell
size* in *Header|Profile* when determining the starting model. Alternatively check box
Header|Profile|Force grid cell size.

Edit grid file generation

This button brings up a dialog for specifying what kind of intermediate grid files should be
generated and kept by the WET tomography processing. These intermediate Surfer®
formatted grid disk files may be contoured and plotted with Surfer® and will let you follow the
intermediate stages of the tomography processing. You may activate the generation of
wavepath / gradient misfit / velocity update and composite subsurface wavepath coverage
grid files.

Edit maximum valid WET velocity

Check this WET setting to allow editing of interactive WET parameter *Maximum valid velocity.*
When you check this option, options *Limit WET velocity to maximum velocity in initial model*
and *Limit WET velocity to 6,000 m/s* will be unchecked.

Edit velocity smoothing

Click on this button in *WET Tomo|Interactive WET tomography* main dialog to determine the
dimensions of the smoothing filter to be applied to the updated velocity model grid after each
tomography processing iteration. Also specify the maximum allowed relative change after one
iteration, for velocity values of grid cells. Also you can decrease WET smoothing by setting
control *Smooth nth iteration : n =* to 5 or 10 instead of default setting 1. Use *Gaussian
weighting* instead of *Uniform weighting* for sharper features in resulting WET tomogram.
Increase *Used width of Gaussian* from default 1.0 to 3.0 or 5.0 for even sharper tomogram
with *Gaussian weighting* selected.

Enable AWE physical memory page caching

Check this WET setting to use RAM memory above 4GB up to 64 GB for traveltime grid
caching during WET inversion, using Microsoft® Address Windowing Extension. See

http://msdn.microsoft.com/en-us/library/aa366527%28v=vs.85%29.aspx

. Also see Mark Russinovich's description of AWE at

http://windowsitpro.com/systems-management/inside-win2k-scalability-enhancements-part-1

. This setting is enabled with our Rayfract® Pro annual subscription license or Permanent Pro license only. Normally 32-bit Windows® applications can only use maximally 2 or 3 GB of RAM. This option speeds up WET inversion.

Enable Intercept Time layer inversion

Check this XTV option if you want to enable XTV Intercept Time layer inversion. See topic XTV inversion.

Enable Modified Dix layer inversion

Check this XTV option if you want to enable Dix layer inversion. See topic XTV inversion.

End shot import

Click this button to end the import of shots into your currently opened Rayfract® profile database.

Enforce Monotonically increasing layer bottom velocity

Select this option to enforce a strictly physical modeling of 1D seismic refraction per CMP. Disable this option to prevent giving too much weight to apparent high velocity anomalies in the shallow i.e. overburden subsurface region. Reasons for unrealistically high apparent shallow subsurface velocity anomalies can be : strongly undulating topography, geometry specification errors, bad i.e. too early traveltime picks etc. You may want to disable this setting to enhance the low velocity imaging capability of the DeltatV inversion.

Envelope wavepath width

Use this parameter to specify the width (in percent of one period) of the wavepaths used to construct the envelope at the bottom of the tomogram. We recommend to leave this parameter at its default value of 0.0. To obtain somewhat deeper but more uncertain imaging, you may increase this parameter up to a maximum value about 0.1% smaller than the wavepath width.

Export grid file to ASCII .TXT...

Write velocity node values in **VELOITXY.GRD** to ASCII **.TXT** with 3D x/y/z coordinates. Import into Golden Software Voxler for 3D imaging. Optionally *export velocities in specified velocity range* only. Paste together the **.TXT** obtained from a few crossing 2D profiles. Grid and contour the resulting **.TXT** to obtain a pseudo-3D *basement map*.

Export modeled WET times to .LST

Check this WET setting to write an ASCII format disk file named VELOITXY.LST after each

WET iteration XY. The .LST file lists picked and synthetic modeled times in ms, for all shots and traces modeled during WET inversion.

Export Options

Click on this button to specify parameters describing the format of the ASCII file generated and containing the velocity-depth results as output by the DeltatV inversion.

Export to .TXT

Click this button in dialog *Grid|Export grid file to ASCII.TXT…* to export x/y/z/velocity for each grid cell in .GRD to ASCII .TXT format (4 columns)

Export velocity range

Check this box in dialog *Grid|Export grid file to ASCII.TXT…* to export grid cells with velocity in range *Min. velocity* to *Max. velocity* to ASCII .TXT format with x/y/z/velocity (4 columns)

DeltatV|DeltatV Settings|Extrapolate output to all receivers

This option horizontally extrapolates DeltatV inversion output to all receivers, beyond first/last CMP stations. This option is disabled per default. We recommend to place far-offset shot points to left of first profile receiver and to right of last profile receiver, to ensure sufficient depth coverage of the DeltatV inversion output.

Extrapolate to bottom

Check this box to vertically extrapolate tomogram velocity downwards to .BLN *blanking file* boundary when blanking outside polygon. Extrapolate velocity vertically upwards to .BLN blanking file polygon boundary when blanking inside polygon. See e.g. tutorial http://rayfract.com/tutorials/tunnel16.pdf .

Extrapolate to left

Check this box to horizontally extrapolate tomogram velocity to left towards .BLN *blanking file* boundary when blanking outside polygon. Extrapolate velocity horizontally to right from outside left blanking polygon boundary when blanking inside polygon.

Extrapolate to right

Check this box to horizontally extrapolate tomogram velocity to right towards .BLN *blanking file* boundary when blanking outside polygon. Extrapolate velocity horizontally to left from outside right blanking polygon boundary when blanking inside polygon.

Extrapolate to top

Check this box in dialog *WET Tomo|WET Velocity constraints* to vertically extrapolate

tomogram velocity upwards to .BLN *blanking file* boundary when blanking outside polygon. Extrapolate velocity vertically downwards to .BLN blanking file polygon boundary when blanking inside polygon.

Extrapolate tomogram over five station spacings

check *WET Tomo|WET tomography Settings|Blank|Extrapolate tomogram over five station spacings* to use shotpoints offset maximally 5 station intervals from first/last profile receiver, for DeltatV and WET inversion. May cause velocity artefacts in tomogram due to missing receivers. Use if absolutely necessary only. Available with Pro license only.

Far offset shot points

Shot points positioned before the first receiver station or behind the last receiver station of a profile (or receiver spread) are called far offset shot points. It is important to record shots fired from such far offsets (e.g. 5 or 10 station intervals away from the first/last receiver station) to ensure sufficient depth penetration of the seismic waves / first breaks recorded.

Filter active for current trace gather display

Check this box to activate frequency filter. Hit Enter or Return key to redisplay traces in current gather window, with this filter applied to traces shown.

Filter traces

Enable this option to apply a high frequency filter to the traces currently displayed. The filter is implemented by a running average smoothing algorithm, with filter width and central sample weight as specified with the following parameters *Filter width* and *Central filter weigh*t.

Filter width

Filter width of the running average smoothing filter to be applied to trace signals, in milliseconds. The bigger the filter width, the lower the cutoff frequency of the filter.

First break envelope length

This parameter (in milliseconds) determines the trace signal time window regarded when automatically picking the first break for that trace. Increase this parameter in case of weak first break amplitudes and if the automatically picked first breaks are too late. Once all first breaks are picked about correctly or too early, increase parameter *First break stabilization factor* to prevent too early picks due to pre-first break noise.

First break stabilization factor

This parameter helps in situations of strong pre-first break noise, caused by surface sources, such as circulation / trees moved by wind / footsteps. Increase its value to filter out increasingly larger amplitude noise / if first breaks picked automatically are too early.

First break time

Specifies time (in milliseconds, relative to time when shot was fired) at which the first break energy arrives at the corresponding receiver. It may be picked interactively in *menu Trace.* Alternatively, it may be edited numerically in this field.

First refractor velocity limit

Specifies the maximum expected velocity of the first refractor. Apparent CMP velocities higher than this limit are interpreted as belonging to the head wave critically refracted by the second refractor.

Force constant velocity

In dialog *Smooth invert|Custom 1D-gradient velocity profile…* check this box to use value entered for following field *Forced velocity* when generating the CONSTVEL.GRD starting model with *Smooth invert|WET with constant-velocity initial borehole model.*

Forced velocity

In dialog *Smooth invert|Custom 1D-gradient velocity profile…*edit velocity to be used when generating the CONSTVEL.GRD starting model with *Smooth invert|WET with constant-velocity initial borehole model* with above box *Force constant velocity* checked

Force grid cell size

Check this box and edit *Cell size [m]* to desired value to force the Surfer grid X Spacing (column spacing) and Y Spacing (row spacing) to this cell size next time a starting model is computed.

Force grid cell size setting is synchronized with *Smooth invert|Smooth inversion Settings|Edit cell size* setting.

Force grid limit

Check this box to regard the limits specified in *Smooth invert|Custom 1D-gradient velocity profile dialog* when generating the GRADIENT.GRD starting model with *Smooth invert|WET with 1D-gradient initial model* .

Freq. [Hz]

This column in multirun WET dialog lets you edit the WET *wavepath frequency* [Hz] for WET runs 1 to 10. One period = 1*/Freq. [Hz]* .

Full smoothing after each tomography iteration

Select this radio button for full smoothing (i.e. a wide averaging filter) to be applied after each tomography iteration. The resulting velocity model i.e. tomogram will be relatively smoother

accordingly. We recommend to select this option during the first few (e.g. first ten) WET tomography iterations.

Gaussian smoothing filter weighting

Check this radio button for Gaussian weighting of smoothing filter nodes, when smoothing the tomogram after each (nth) WET iteration.

General constant

This value must be a positive decimal number of 12 or fewer digits.

Grid and image DeltatV .TXT file

For our pseudo-2D DeltatV inversion, you may want to use a different Surfer® gridding method than the default kriging method. Specify your preferred gridding method via *DeltatV|Interactive DeltatV|Export Options|Gridding method*. Confirm with *Accept button*. You can then abort the interactive DeltatV inversion with *Cancel button*. Now regrid the DELTATV.TXT generated during an earlier inversion, with *Grid|Grid and image DeltatV .TXT file... .*

Grid bottom elevation

In dialog *Smooth invert|Custom 1D-gradient velocity profile…* specify bottom elevation[m] of GRADIENT.GRD or CONSTVEL.GRD starting model to be generated with *Smooth invert|WET with 1D-gradient initial model or Smooth invert|WET with constant-velocity initial borehole model.* Or use button *Reset limits to grid* to update *Grid bottom elevation.*

Grid top elevation

In dialog *Smooth invert|Custom 1D-gradient velocity profile…* specify top elevation[m] of GRADIENT.GRD or CONSTVEL.GRD starting model to be generated with *Smooth invert|WET with 1D-gradient initial model or Smooth invert|WET with constant-velocity initial borehole model.* Or use button *Reset limits to grid* to update *Grid top elevation.*

Gridding method

Specify the Surfer® gridding method used for gridding of pseudo-2D DeltatV inversion results, with this DeltatV export option. You may select methods *Delauney Triangulation*, *Kriging*, *Minimum Curvature*, *Natural Neighbor* and *Nearest Neighbor*. Per default this option is set to method *Kriging*.

GS CENTERED font for receivers

Checking this option forces use of font `GS CENTERED` symbol no. 48 for plotting of receivers. Uncheck to use font `GSI Default Symbols` symbol no. 102.

Half smoothing filter height

This edit field will be enabled if you choose manual smoothing. It shows the number of grid rows scanned above and below the current pixel / grid cell to obtain a smoothed average value for the velocity of that cell.

Half smoothing filter width

This edit field will be enabled if you choose manual smoothing only. It shows the number of columns scanned on each side of the current pixel / grid cell, for smoothing the value of that cell.

.HDR batch file

A .HDR batch file lists shots to be imported with *File/Import Data...* For a sample .HDR file see http://rayfract.com/help/2lamb15.hdr . For each shot, you can specify column fields

File Name [input file]; Shot No in input file.; Shot No. in database; Layout Start [station number]; Shot Pos. [station number]; Inline Offset [m from Shot Pos.]; Lateral Offset [m from line] ;Depth [m]; Delay Time [ms]; Sample Interval [ms]; Sample Count

For detailed description of .HDR batch file format see chapter File formats.

Header lines to skip

Use this edit field to specify the number of header lines in your ASCII import file format. These lines will be skipped during import before starting mapping line content to trace header parameters, as specified above.

High corner frequency

Defines high frequency limit of the passband for this bandpass filter, in Hz. See Steven W. Smith, Digital Signal Processing.

High velocity limit

Upper bound of velocity range updated during WET inversion with *Keep velocity unchanged above* checked.

High-pass filter

Check this box to apply a high-pass frequency filter to traces before displaying them. Uncheck for low-pass frequency filter.

Horizontal axis ticks

Use this Annotations parameters dialog setting to specify the type of axis ticks shown on the horizontal X axis. Select type Major&Minor, Major ticks or No ticks.

Horizontal axis title

Specify the axis title for the horizontal axis. It may not exceed 32 characters.

Horizontal grid lines

Use this setting in the Annotations parameters dialog, to specify the type of auxiliary horizontal grid line shown in parallel to the X axis, at Y axis ticks. Select setting Dashed line, Dotted line or No line.

Horizontal scale [1:]

Specify the ratio between the horizontal profile distances as printed or plotted and as measured (in meters). When displaying sections on screen, the section is scaled to the window's width regardless of the value of this parameter.

Hybrid Conjugate Gradient update formula

This WET option combines the Polak-Ribiere update formula with Fletcher-Reeeves to prevent *Conjugate Gradient* "jamming". See section 6 in

http://www.caam.rice.edu/~zhang/caam554/pdf/cgsurvey.pdf

Image and contour velocity and coverage grids

Use this *Grid menu* command to plot previously generated Surfer® `.GRD` grid files (velocity tomograms and coverage grids) with Surfer. Just select the desired `VELOITXX.GRD` (e.g. `VELOIT10.GRD` for WET iteration 10). Our software will then automatically image both the `VELOITXX.GRD` and the corresponding `COVERGXX.GRD` (if existing). You may flip over velocity tomograms with *Grid|Turn around grid file by 180 degrees...* , and convert tomograms between feet and meter with *Grid|Convert grid file between feet and meters...* .
    Surfer `.GRD` files are stored in profile subdirectories `GRADTOMO` (1D gradient based Smooth inversion), `LAYRTOMO` (layered refraction starting model), `TOMO` (pseudo-2D DeltatV inversion) and `HOLETOMO` (Crosshole survey interpretation).

Import circular borehole survey

Checking this option to disable receiver spread geometry checks and to not make any assumption regarding shape of borehole spread. Use when *Line type* `Borehole spread/line` loops back on itself. Check source&receiver positions on tomogram plot. Export coordinates via *File|Export header data* and update source&receiver coordinates via *File|Update header data|Update Station coordinates* and *Update Shotpoint coordinates*. See chapter File formats and tutorial http://rayfract.com/tutorials/tunnel16.pdf .

Import data type

Select the appropriate entry from this drop down list box in *File|Import Data...* to specify the data file format of your seismic trace data files. Currently import file types ABEM Terraloc

Mark 3 / ASCII column format / Bison-2 9000 Series / Interpex GREMIX / OYO SEISREFA / SEG-2 / SEGY / W_GeoSoft WinSism / Earth FX VIEWSEIS / OPTIM LLC SeisOpt / Geometrics SeisImager Plotrefa / GeoTomCG .3DD / GeoTomo TimePicker .3DTT are supported.

Import horizontal borehole survey or .3DD refraction survey

Check this option before importing .3DD GeoTomCG files into a profile with *Line type Borehole spread/line*, with receivers in a horizontal borehole. Or check before importing .3DD refraction survey into profile with *Line type Refraction spread/line*.

Import shot dialog

This dialog lets you edit the shot and trace header data during import of each shot stored in *Input directory* once you click *Import Shots button* in *File|Import Data...* . The current shot trace file is shown in title of this dialog and is written to the profile database once you click the *Read button*.

Import shots

Click this buttons once you have specified values for all parameter fields in your *Import shots dialog*.

Import shots and write .HDR

Check this box in dialog File|Import Data… to import shots into your current database and list imported shots in *Output .HDR* file with button *Import shots*

Import shots dialog

This dialog is displayed when selecting *Files|Import Data*. It lets you define the input file format, the directory containing files to be imported and further parameters valid during this import session.

Increase cell size

Check this option in Smooth invert|Smooth inversion Settings or DeltatV|DeltatV inversion settings, to increase the grid cell size used for generating Surfer .GRD files. Increasing the cell size will speed up the WET inversion, but may render the inversion less robust, especially in case of velocity inversions.

Initial step

This parameter is the initial guess for bracketing during line search minimization before using Secant method or Brent's method for sectioning of the minimum. Our *Initial step* parameter corresponds to (Shewchuk, 1994) sigma σ used during first *Secant method* iteration in Equation (58) on page 46 of (Shewchuk, 1994). See

http://www.cs.cmu.edu/~quake-papers/painless-conjugate-gradient.pdf

Input directory Select button

Use this button in *File|Import Data...* to select one shot trace file located in the subdirectory from which you want to import shot files. Note that only shot files with a file extension matching the data type format selected with *Import data type* will be listed.

Input .GRD filename

Edit with keyboard or select with button *Select grid file* the binary Surfer format .GRD filename to be exported to ASCII .TXT format

Instrument

<manufacturer name> <model number/name> <serial number>. This identifies the instrument used to acquire the data stored in the file.

Interpolate coordinates

Click on this button once you have specified x/y/z coordinates and weathering velocities for all station positions deemed necessary. Browse through station positions with F7/F8 function keys. Once you click this button and coordinates have been interpolated for all station positions, the dialog will be shut down.

Interpolate missing coverage after last iteration

Check this WET blanking setting in case of coverage gaps in your recording geometry. WET inversion will interpolate over blank tomogram areas where WET tomogram velocities are available to left and right of this blank area.

Interpolate velocity for 1D-gradient initial model

Enable to linearly interpolate the averaged 1D-velocity profile (in vertical direction) when computing the 1D initial model, based on DeltatV output. Disable for constant-velocity initial overburden layers, with the layer-top velocity assumed for the whole layer except the bottom-most 0.1m. This option is enabled per default, since WET tomography works most reliably with a smooth minimum-structure initial model.

Inverse CMP offset power

This parameter lets you weight first break picks when stacking *CMP curves*. Allowed values are in range 0 to 1. Default value is 0.5. The lower this parameter, the more weight is given to picks recorded for CMP stations horizontally offset from the CMP station which is central to the CMP curve stack currently being constructed.

Inverted polarity

Check this option if the trace was recorded with inverted polarity. The setting of this option is not regarded during processing.

Iterate

Click this button to bring up dialog which lets you edit wavepath width and number of iterations for WET runs 1 to 10. This dialog allows specification of your schedule for multiscale tomography as shown in our SAGEEP14 expanded abstract http://rayfract.com/pub/sageep14.pdf . To activate these runs click check box WET runs active.

Iterations

This column in multirun WET dialog lets you edit number of WET iterations for WET runs 1 to 10.

Job ID

Free format text field. Names the job during which the seismic data was recorded, in the context of Line ID.

Profile start is default layout start

This import option is unchecked per default. With this option disabled/unchecked, our import routine determines layout start and shot position directly from the SEG-2 trace headers. SEG-2 trace header fields SOURCE_STATION_NUMBER and RECEIVER_STATION_NUMBER override fields SOURCE_LOCATION and RECEIVER_LOCATION. SOURCE_LOCATION and RECEIVER_LOCATION of the first trace are divided by the *profile station spacing (Header|Profile)* to obtain *shot position* and *layout start* in station numbers.

With this option checked our import routine sets layout start to 1.0 if option *Default layout start is 1* is checked and to 0.0 otherwise.

Keep same sample count for consecutive shot trace files

Check this option to have our import routine reuse the sample count specified for the previously import shot, as specified in the *Import shot dialog*. With this option unchecked, our import routine will determine the sample count directly from the SEG-2 shot file header. This option is checked/enabled per default.

Keep velocity unchanged above

Check this box to keep velocities with starting value larger than *High velocity limit* unchanged during WET inversion.

Keep velocity unchanged below

Check this box to keep velocities with starting value smaller than *Lower velocity limit*

unchanged during WET inversion.

Layout start

Profile relative position of first / leftmost receiver spread position used for recording of current shot, in whole station numbers. See online help topic Station numbers and spread types.

Least deviations

Select this radio button to specify linear regression method **Least absolute deviations**. This method will be used to determine local apparent CMP velocities. Velocity estimates may be more realistic than with method *least squares*. Processing time for the whole DeltatV inversion will amount to about ten times the time spent when selecting the alternative option *least squares*, however. **See (Press et al. 1986) chapter 14** for details. *Least deviations* will automatically recognize outliers / less relevant data points and give them less weight when modeling / linearizing the trend inherent in the data. *Least squares* treats all data points with the same priority. In **low coverage situations**, *least squares* may be more appropriate, giving equal weight to all first breaks available.

Least squares

When you select this radio button, local apparent CMP traveltime curve velocities are determined by carrying out a least squares linear regression over traveltimes located in an offset interval having length *Regression over offset stations* and centered at the offset currently being evaluated.

Left limit of grid

In dialog *Smooth invert|Custom 1D-gradient velocity profile…* specify left limit of grid[m] of GRADIENT.GRD or CONSTVEL.GRD starting model to be generated with *Smooth invert|WET with 1D-gradient initial model or Smooth invert|WET with constant-velocity initial borehole model.* Or use button *Reset limits to grid* to update *Left limit of grid*.

Left handed coordinates

If this option is deactivated (by default), a right handed coordinate system is assumed. This means that X-Axis, Y-Axis and Z-Axis are orientated to each other as thumb, index finger and middle finger of the right hand. Orientate thumb and index finger horizontally and your middle finger vertically pointing to the ceiling. Longitude, latitude and elevation in the northern hemisphere are a right handed coordinate system. In a right -handed coordinate system, lateral shot point offsets have a positive sign when offset to the left from the profile (when looking along the profile in direction of increasing station numbers).

Limit DeltatV velocity exported to maximum 1D-gradient velocity

This DeltatV setting is enabled per default for version 3.31. This option helps to suppress 1.5D DeltatV artefacts in the imaged basement. With this option checked, we determine the 1D-gradient starting model in a separate DeltatV run, before doing the 1.5D DeltatV inversion. This 1D-gradient starting model is saved to disk as files ..\GRADTOMO\DLTAGRAD.GRD &

.PAR .

Uncheck this option when you just want to edit or review current interactive DeltatV settings including static correction settings and export options. Otherwise you may have to wait a long time until the interactive DeltatV parameter dialog shows up, for a large dataset with many traces.

Limit maximum basement velocity

Activate this option if you want to filter the estimated CMP basement velocity against the value as specified with the next parameter. This filtering will occur during CMP intercept time refraction time-to-depth conversion. It may be appropriate in case of steep / narrow synclinal refractor topography.

Limit offset

Import traces which have been recorded at receiver positions offset from the shot position not farther than the value specified in the following edit field Maximum offset imported (in station numbers).

Limit velocity exported

Check this box to apply a low pass filter to velocities written to file DELTATV.TXT. Specify the corresponding velocity threshold value with parameter *Maximum velocity exported*. Select radio button *set to max. exported* or *do not export* in group box *Handling of too high velocities* as appropriate.

Limit WET velocity to maximum velocity in initial model

Checking this option can help to better resolve a sudden increase of velocity with depth at top-of-basement. Maximum depth imaged with WET inversion may decrease, with this option checked.

Line ID

Free format text field. Names the seismic profile along which the data was recorded.

Line search iterations

Specify how many WET iterations should be done for each line search started by the Conjugate Gradient algorithm. *Line search iterations* is the number of inner loop iterations *jmax* in the algorithm described on page 53 of (Shewchuk, 1994). See

http://www.cs.cmu.edu/~quake-papers/painless-conjugate-gradient.pdf

. One inner loop iteration is done with one *WET iteration* .

Line search tolerance

The meaning of this parameter depends on the line search method used. Per default we use the Secant method described by (Shewchuk, 1994). See

http://www.cs.cmu.edu/~quake-papers/painless-conjugate-gradient.pdf

on page 53 for algorithm using Secant method error tolerance epsilon °. Our *Line Search tol.* parameter corresponds to Shewchuk epsilon ° used for inner loop termination.

When you change the line search method to bracketing and sectioning with Brent's method as described by Press et al. in chapter 10 of Numerical Recipes, this parameter is the tolerance for Brent's method. Check *WET Tomo|WET tomography Settings|Safe line search with bracketing and Brent* to use Brent's method for line search.

Line type

Select **Refraction spread/line** for surface refraction profiles. Select **Borehole spread/line** if receivers are placed in vertical or horizontal borehole. *Line type* can only be edited as long as you have not yet imported any shots into the current profile database.

Low corner frequency

Defines low frequency limit of the passband for this bandpass filter, in Hz. See Steven W. Smith, Digital Signal Processing.

Low velocity limit

Lower bound of velocity range updated during WET inversion with *Keep velocity unchanged below* checked.

Lower velocity of 1D-gradient layers

Use this to set the gradient-layer bottom velocity to (top velocity + bottom velocity)/2, for each layer in the initial model. This option is disabled per default. Enable to lower the velocity of the overburden layers.

Manual specification of smoothing filter

Select this radio button if you prefer to manually specify the dimensions (half width and half height) of the smoothing filter to be applied after each iteration. We recommend to prefer full smoothing or minimal smoothing.

Mask grid file

Surfer format velocity .GRD file with same dimensions (column count & row count & cell size) as *WET initial model .GRD* selected in *WET Tomo|Interactive WET tomography...* Select the *mask grid file* with button *Select mask grid file* in dialog *WET Tomo|WET velocity constraints*.

Mask grid file active

Check this box to enable resetting of WET velocity during polygon blanking to velocity in *Mask grid file* selected with button *Select mask grid file*.

Match .LST traces by station number

Match .LST traces to database traces by station number or channel number. This option is unchecked per default. When matching traces by channel number, you can reimport shots with changed *shot position* or *layout start* and **keep current first break picks** :

◆   backup picks to .LST with *File|Export header data|Export First Breaks…*
◆   reimport the relevant shots, with corrected *shot position* in *Import shot dialog*, using the *Read button*. Skip all other shots, with *Skip button*.
◆   select *File|Update header data|Update First Breaks…* and specify the .LST just generated.

max. WET runtime minutes

specify max. WET runtime, in minutes. Default is 100 minutes. Check box <u>or WET inversion runs longer than</u>, to activate this stop criterion.

Maximum basement velocity

This parameter (in meters per second) specifies the highest CMP basement velocity recognized as valid when carrying out CMP intercept time refraction time-to-depth conversion.

Maximum elevation

Elevation isoline value for upper station number axis, in depth section display.

Maximum offset imported

If the preceding check box <u>Limit offset</u> has been checked, traces recorded at receivers offset from the shot position farther than the value specified in this edit field (in station numbers) are not imported. If all traces of the shot currently being imported are offset farther than that value, the entire shot is not imported.

Maximum propagation velocity

Maximum velocity (in meters per second) regarded when carrying out automatic first break picking. Trace signal peaks/troughs detected earlier than the time window resulting from mapping this velocity gradient to the current shot gather are not regarded during the picking process. If you carry out <u>Semi-automatic first break picking</u> by interactively picking a polyline with the right mouse button, this parameter has no meaning.

Maximum station number

Constant station number location for displaying right vertical axis.

Maximum tolerance

Use this field to specify the maximum relative difference allowed between effective station spacing (as computed from the coordinates of neighboring stations) and station spacing as specified in Header|Profile.

Maximum valid velocity

Specify the maximum velocity regarded as valid when processing CMP curves with this option. Apparent CMP velocities exceeding this value will be skipped during processing.

Max. velocity

Use this field to limit the maximum WET velocity modeled. This value overrides the Maximum valid velocity field as specified for the DeltatV inversion.

Maximum velocity exported

Use this parameter to apply a low pass filter to velocities exported into file DELTATV.TXT in connection with check box *limit velocity exported* and group box *Handling of too high velocities* controls.

Maximum velocity or time displayed

Maximum velocity isoline value at which the top horizontal station number axis is displayed, in *velocity sections*. In *time sections*, this field specifies the maximum time isoline value at which the bottom horizontal station number axis is displayed.

Maximum velocity update

This parameter lets you specify the maximum allowed relative update of each velocity model cell, after one iteration. If computed relative updates exceed this threshold value the applied update will be limited by this threshold. Valid range is 0.01% to 35%.

Min. horizontal separation

Header|Profile field "Min. horizontal separation [%]" defines the minimum horizontal station offset applied during coordinate interpolation, in percent of the inline station offset, if no x/y coordinates have been specified. You may want to leave this field at its default value of 25%, for most recording geometry situations.

If you import .ASC files with shot and receiver elevations, and then don't specify x/y coordinates for shot and receiver stations (e.g. with COORDS.COR import), x/y coordinates are determined automatically based on the *station spacing* and elevations specified. If the elevation change between adjacent stations equals or exceeds the *station spacing*, the horizontal offset between these stations should be zero, according to Pythagoras.

However, we recognize that in practice, the inline receiver separation may vary along the line. In above situation, we therefore set the horizontal offset between these stations to "Min. horizontal separation" / 100 * "Station spacing".

Min. velocity

Use this field to limit the minimum WET velocity modeled. We recommend to leave this field at its default value of 10 m/s.

Minimal smoothing after each tomography iteration

Select this radio button for minimal smoothing (i.e. a narrow averaging filter) to be applied to the updated velocity grid after each tomography iteration. The resulting velocity model i.e. tomogram will show more details than with full smoothing, but also more artefacts. You can try this option during the last few WET tomography iterations. Since version 3.06, we recommend to *scale WET filter height* instead.

Minimum elevation

Elevation isoline value for displaying bottom station number axis, in depth section display.

Minimum propagation velocity

Minimum velocity (in meters per second) regarded when carrying out automatic first break picking. Trace signal peaks/troughs detected later than the time window resulting from mapping this minimum velocity gradient to the current shot gather are excluded from the picking process. If you carry out Semi-automatic first break picking by interactively picking a polyline with the right mouse button, this parameter has no meaning.

Minimum station number

Constant station number position for displaying left vertical axis.

Minimum velocity or time displayed

Minimum velocity isoline value at which the bottom horizontal station number axis is displayed, in *velocity sections*. In *time sections*, this field specifies the minimum time isoline value at which the top horizontal station number axis is displayed.

Minimum velocity ratio

The minimum velocity ratio (between apparent velocity V of the current XTV triple and the previous triple) required for application of the Intercept time layer inversion. If the actual ratio is smaller, the Intercept Time layer inversion method will not be applied. Instead, Dix inversion or Gradient layer inversion will be applied to the current XTV triple. Valid ratio values range from 1.01 to 2.5 . Set to 1.01 to apply Intercept Time method for as many XTV triples as

possible. This ratio is regarded if XTV parameter Enable XTV Intercept Time layer inversion is checked only. See topic XTV inversion for more details.

Model Parameters dialog

This dialog lets you parameterize the time-to-depth conversion. You may specify to what degree the data should be smoothed etc.

Alternate coverage update during Conjugate Gradient inversion

Check this WET setting for alternate blanking at tomogram bottom during *Conjugate Gradient* WET inversion.

Negative depths

Check this box to write depths with a preceding minus "-" to DELTATV.TXT, in connection with radio button depth below topo.

No static corrections

Click this radio button to disable the computation and application to first breaks, of static corrections. This option makes sense in situations of *flat topography or topography approximating a dipping plane*. Note that first breaks will still be corrected for shot position offsets and shot hole depth. The near-surface weathering velocity required for computation of these corrections is determined with parameter Weathering crossover.

Note

A paragraph consisting of multiple lines, describing further recording parameters and background information deemed important for processing. Up to 512 characters.

Number of bandpass poles

See Steven W.Smith, Digital Signal Processing, chapter 20. The more poles are used, the more performant the resulting filter will be, with faster rolloff in frequency domain. But more poles make recursive filtering unstable at low frequencies,with increasing overshoot and ringing of step response.

Number of poles

See **Steven W.Smith 1997 Digital Signal Processing**, chapter 20. The more poles are used, the more performant the resulting filter will be, with faster rolloff in frequency domain. But more poles make recursive filtering unstable at low frequencies,with increasing overshoot and ringing of step response. Used for Chebyshev-Butterworth filter only. Not used for single-pole filter.

Number of WET tomography iterations

This parameter lets you specify the number of WET tomography iterations to be carried out with the parameters specified, once you click on button *Start tomography processing*. Increase to 50 or 100 iterations to better remove artefacts/horizontal layering of the initial model. Enabled for Steepest Descent method only. Disabled for Conjugate Gradient method. Use parameters **CG iterations** and **Line Search iters.** to control number of WET iterations for Conjugate Gradient method.

Observer

The name of the individual responsible for data acquisition. Free format text field.

Offset breaks display

Displays your traveltime field in a coordinate system with CMP station numbers as horizontal axis and recording time as vertical axis. Common offset traveltime curves are constructed by connecting first breaks belonging to shot receiver pairs with constant unsigned offset and neighboring CMP position.

Offset limit

Use this parameter (station numbers) to limit the basement penetration depth of ray paths regarded during time-to-depth conversion. First breaks mapped to the basement and recorded at an offset exceeding the local basement crossover distance plus this offset limit are not regarded.

Offset limit basement coverage

Check this option in diving wave situations, with relatively flat refractor topography. First breaks mapped to the basement and recorded at offsets exceeding the local crossover distance for the basement plus the value of the following parameter *Offset limit* are not regarded during time-to-depth conversion.

Optimize XTV for layered starting model

Configures XTV for strong velocity contrast between overburden and basement, in starting model for Smooth inversion. This new option is enabled per default, when creating a new or opening an existing profile database. Uncheck this option and option *Allow XTV inversion for 1D initial model* for gradual increase of velocity with depth, in 1D starting model for Smooth inversion. Unchecking these options can make the inversion more reliable/give deeper output, in case of bad/too early first break picks.

or RMS error does not improve for n =

check this box to stop WET inversion when the relative RMS error does not improve during <u>RMS error constant for n iterations</u> consecutive WET iterations. Default is 10 iterations.

or RMS error gets below

check this box to stop WET inversion when the relative RMS errors gets below the specified RMS error threshold, in percent.

or WET inversion runs longer than

check this box to stop WET inversion after running for max. WET runtime minutes of ... minutes. Default is 100 minutes.

Outline axes

Check this option to outline axes.

Output .HDR

Click this button in dialog *File|Import Data…* to specify directory and filename of *.HDR file* to be written to listing all shots found in matching input files in *Input directory*

Output DeltatV Results in feet

Activate this option if you want CMP positions, elevations or depths below topography and velocities in the resulting DELTATV.TXT file to be specified in feet and feet per second. If this option is not active, values will be output in station numbers, meters and meters per second.

Output inline CMP pos. in meters

Select this option if you want CMP positions in resulting DELTATV.TXT files to be specified in meters. Otherwise CMP positions will be listed by their station number positions.

Output inversion results in Feet

Check this option to generate tomograms in feet. Uncheck to generate velocity tomograms in meters.

Output Measured CMP Velocities

With this option activated, the DeltatV method will combine inverted velocities and depths as obtained during inversion of the CMP sorted and stacked traveltime curves with **instantaneous velocities as measured directly on the CMP sorted curves as input to the inversion**, at corresponding source-receiver offsets. If the option is not active, velocities as written into the resulting DELTATV.TXT are based on inverted velocities only.

Output .TXT filename

Edit this field in dialog *Grid|Export grid file to ASCII.TXT…* with keyboard or select with button

Select .TXT file the .TXT filename to be written when clicking button *Export to .TXT*

Overburden crossover filter

Filter width (in station numbers) for smoothing the laterally varying crossover distance separating first breaks mapping the direct wave from first breaks mapped to the first refractor.

Overburden filter

Specify width of overburden filter, for carrying out running average smoothing of overburden refractor data, i.e. elevation and velocity of first refractor. Also used for smoothing of *crossover distances*, in *Midpoint breaks display*.

Overlying layer velocity step

This XTV parameter is used if <u>Allow adjacent Intercept time layer inversion</u> is enabled only. This step parameter may vary between values 0% and 100%. The velocity step determines how v_1 needed for Intercept Time inversion of the current XTV triple is obtained, from the previous XTV triple and by interpolation between the previous v_1 (step 0%) and the previous apparent velocity V (step 100%). The default value for this parameter is 0%. See topic <u>XTV inversion</u> for details.

Overwrite all

Select this radio button to automatically overwrite all shots already imported, with same shot number as currently imported. If you select the opposite button *Prompt overwriting*, you will be prompted for confirmation before each existing shot is overwritten.

Pad polygon border

Check this option in *WET Tomo|WET Velocity constraints* to extend blanking polygon border by one pixel (one grid cell) in all directions when blanking the current iteration tomogram. This option is enabled per default.

Percent bandpass ripple

The more ripple you allow in the passband, the faster the rolloff of the filter, separating passband from reject band. Set to 0 for Butterworth filter. See Steven W. Smith, Digital Signal Processing, chapter 20. Used for Chebyshev filter only. Not used for single-pole filter.

Percent ripple

The more ripple you allow in the passband, the faster the rolloff of the filter, separating passband from reject band. Set to 0 for Butterworth filter. See **Steven W. Smith 1997 Digital Signal Processing**, chapter 20. Used for Chebyshev filter only. Not used for single-pole filter.

Plot runs in Surfer

Check this box to plot the last iteration of each run (WET tomogram and WET coverage plot) in Surfer before continuing with next WET run during multirun WET tomography.

Plot wavepaths for every nth shot

Set this parameter to 1 to plot wavepaths for every shot. Set to 2 to show wavepaths for every 2nd shot etc.

Precompute static Beydoun weight matrix

Static weighting assumes that each pixel is affected by all wave paths. Dynamic weighting does not make this assumption. Static weighting is more conservative, and a compromise between dynamic weighting and no weighting at all. Disable/uncheck this option to specify dynamic weighting.

Prefer Average over minimum interface velocity

You may want to disable this setting to enhance the low velocity imaging capability of the DeltatV inversion. To enhance the high velocity anomaly imaging capability in the near surface region, you may want to enable this option. Since WET tomography processing has more difficulties when needing to deepen a too shallow (fast) interpretation than when rendering a too deep (slow) interpretation more shallow, you may want to disable this setting for surveys where the imaging targets are low velocity anomalies. Leave this setting enabled in case of strong lateral velocity variation.

Prefer CMP overburden mapping

Check this option for Plus-Minus and Wavefront time-to-depth conversion if you want to prioritize the trace-to-refractor mapping as carried out in the Midpoint breaks display over another mapping as specified interactively by picking *branch points* in the Shot breaks display.

Prefer measured layer top velocity over inverted

Check this XTV option to use apparent velocities V (belonging to previous and current XTV triples) exclusively and disregard the previous v_1, for determination of the current v_1, based on step parameters Overlying layer velocity step and Current layer velocity step .
Overburden velocity v_1 is needed for our Intercept Time two-layer case inversion method. If this option is enabled, the apparent velocity V as obtained for the previous XTV triple and layer is taken as an estimate for the velocity at the top of the current layer. See topic XTV inversion for details.

Prefer regressed traveltimes

Prefer regressed traveltimes is activated by default. Deactivate it to base your refractor elevations and velocities on algorithmically linked traveltime curves, instead of on regressed traveltime curves. In low coverage situations, a significant difference between resulting depth sections may mean that the basement coverage is too low for traveltime field regression to

work reliably.

Process all CMP

Activate this option to process CMP sorted traveltime curves at all profile CMPs. This will ensure maximum lateral resolution of the subsurface as imaged.

Process every CMP offset

Use this option to obtain better vertical velocity resolution, by inverting for an incremental gradient layer at every CMP offset . This new option may increase the amount of artefacts in the output, especially for low coverage data sets and noisy first break picks.

Processing date

The date a processed file was created. It is recommended that the date be specified in dd/mm/yyyy format. Alternatively, to avoid any possible confusion in the ordering of the day and month, use format dd/mmm/yyyy, with mmm being a three-letter abbreviation of the month.

Processing time

The time a processed file was created..

Profile start offset

Use this field to specify a horizontal inline offset different from 0.0, for the first profile receiver. This start offset value will be used by subsequent DeltatV and WET imaging. On resulting Surfer® plots, the first profile receiver will be positioned at an x coordinate amounting to this start offset value.

Prompt overwriting

Select this radio button if you want to be prompted before a shot imported earlier and with the same shot number as the one currently being imported is overwritten in the profile database.

Prompt run misfit

Check this box to show prompt with WET run misfit after completion of each run. Uncheck to suppress display of these prompts.

Proportional XY Scaling

Check to use same distance scale along horizontal X and vertical Y axis. As stated in Golden Software Surfer manual : "When the box is checked, any changes made to the scale for the X or Y dimensions is automatically reflected in the other dimension". With this option checked change X Scale and Y Scale in Surfer Object manager : click Map node and Scale tab.

Read shot

Click on this button to import the current shot, once you have specified all shot related header values, as displayed in the *Import shot dialog*.

Receiver count

Specify the number of receiver positions to be defined for the new spread type, by the Receiver separations string as displayed below. Once you hit RETURN to create the new spread type, the software will verify that the Receiver separations string defines intervals between exactly Receiver Count positions. If not so, a corresponding error message will be shown.

Receiver depth

If the receiver was buried below topography, use this field to specify its depth below surface. Normally this field will be 0. Note that its value is not regarded during processing, contrary to shot hole depth.

Receiver in line offset

Specify the in line offset of the receiver, in meters, from the receiver position, as specified in station numbers. This offset will normally be 0. If you need to move the actual receiver for some small in line distance due to unexpected problems at the exact position planned, make use of this parameter.

Receiver lateral offset

Specify the offset of the actual receiver position from the seismic line (i.e. from the spread), in meters. Normally this offset is 0. If you need to offset the receiver position from the spread due to some unexpected problem at the in line position planned, please use this value to do so.

Receiver separations

See online help topic Defining your own layout types. The receiver separations string is formed by counting the number of times the same receiver separation distance (in station numbers) is used between adjacent receiver positions, starting at the leftmost spread position equal to 0 and moving to the right / increasing receiver position station numbers.

Receiver type

Use this drop down list box to specify the type of receiver used for registering seismic data. The value of this field is not regarded during processing.

Recompute traveltime characteristics

You may activate *check box Recompute traveltime characteristics* to redo the (time intensive)

traveltime field regression. This should not be necessary under normal circumstances, though. If you remap traces to refractors, the traveltime field regression is redone automatically, at the next time you go into the Wavefront model display with *Depth|Wavefront* (and bring up the *Wavefront Model Parameters dialog* and confirm it). The same holds true for Plus-Minus interpretation.

Reduced offset 0.0 is valid trace with time 0.0

Enabling this option (as per default) ensures that the information contained in the near-offset part of CMP sorted and stacked traveltime curves is used to the fullest, during DeltatV inversion. Disable this option if the output obtained (as gridded and contoured with Surfer®) is e.g. too noisy.

Reduction velocity

First breaks are reduced according to the *Reduction velocity* specified before display in the *Midpoint breaks display*. As a consequence, a refractor segment with apparent velocity of first breaks equal to *Reduction velocity* is displayed as a vertical <u>CMP traveltime curve</u> segment.

Reference topography smoothing filter width

Use this parameter to specify the number of stations over which a running average filter will be applied to compute the smoothed elevation at each receiver station. XY coordinates or elevations will be automatically adjusted during import of the coordinate file specified if the smoothed elevation difference between neighboring stations has the same sign as the unsmoothed difference in elevation. We recommend to leave this parameter at its default i.e. 5.

Refracted Wave Offset Delta

Valid values : 1 to 20. Specifies the offset range being considered when determining a local apparent CMP refractor velocity from a CMP traveltime curve, for a given CMP position and unsigned trace offset.

Refractor 1 velocity detected

Median refractor 1 velocity detected, when carrying out piecewise linearization of all CMP traveltime curve segments mapped to refractor 1.

Refractor 2 velocity detected

Median refractor 2 velocity detected, when carrying out piecewise linear regression over all traveltime curve segments assigned to refractor 2.

Refractor branch

A traveltime curve mapped to refractors is separated by *branch points* into segments. First breaks contained in one segment are all mapped to the same refractor. Such a segment is

commonly called a **refractor branch** (of a traveltime curve).

Refractor Count

(valid values : 1 or 2) specifies how many refractors are being modeled. Enter a value of 1 if you want to model your data as a 2-layer case (weathering layer, and 1 refractor). Enter a value of 2 for a 3-layer case (weathering layer, and 2 refractors).

Regard uphole picks for DeltatV inversion

This option is not offered by our software any longer. Check this option only if you are sure that plausible *uphole time correction terms* have been specified for all uphole shots of the profile, and that you have or are going to specify a reasonable value for *weathering crossover*. Since obtaining good values for these two parameters at the same time is a bit of a guessing game, this option is disabled per default. You may want to enable it if you need the uphole picks to extend the coverage of the basement, at profile start and end, and are ready to sacrifice some accuracy for this extended coverage.

Regression over offset stations

Lets you specify the length of the offset station interval used to carry out local piecewise linearization of **CMP traveltime curves**. This linearization is required to obtain a smoothed local apparent CMP velocity value. You may select the *linear regression method* used for piecewise linearization in the group box positioned below this edit field.

Regression Receiver Count

Lets you specify how many adjacent receiver positions should minimally be considered when carrying out piecewise linearization of a CMP traveltime curve, for a given CMP position and offset.

Relative regression tolerance

The default value of this parameter is 0.000001 msec. It specifies a termination criterion used during carrying out traveltime field regression. The smaller the value, the more iteration steps will be carried out until that criterion (relative improvement of average traveltime modeling error, from one iteration step to next iteration step) is reached. You are advised not to change this value at will. The iteration will stop after maximally 10,000 steps.

Remap

Check this option to reassign traces to refractors, based on parameters specified in dialog *Trace to refractors mapping parameters*. The traces will be semi-automatically reassigned once you confirm the parameters displayed in the dialog by pressing the RETURN key.

Remove systematic dc offset

Check this option to remove systematic dc offset signals from traces. These offsets are

presumably caused by systematic errors of the seismic trace recording system.

Replace velocity active

Check this box to activate replacement of the computed average 1D velocity vs. depth profile with your custom profile specified in field *Velocity profile* or selected with button *Select velocity profile*. Your custom .TXT velocity profile is used next time you select *Smooth invert|WET with 1D-gradient initial model* to generate the GRADIENT.GRD starting model.

Reset coordinates and v0

Click on this button to reset both coordinates and v0, for all stations. This should help in situations where invalid coordinates have been entered and are being rejected by the software.

Reset DeltatV and WET settings to .PAR file...

Select a VELOITXY.GRD and reset DeltatV and WET inversion settings in profile database to settings read from matching VELOITXY.PAR file.

Reset limits to grid

Click to select a .GRD velocity tomogram created earlier in ...\GRADTOMO or ...\TOMO subdirectories. *Custom 1D-Gradient velocity profile dialog* fields *Grid bottom elevation*, *Grid top elevation*, *Left limit of grid*, *Right limit of grid* are updated to the limits of the .GRD tomogram you selected.

Reset multirun WET dialog

Click this button to reset all parameters and controls in multirun WET dialog to their default values. *Freq. [Hz]* will be reset to the current value of *Wavepath frequency* in main WET dialog. *Width [%]* is reset to sequence 30, 22, 16, 10, 7, 5, 4, 3, 2, 1 for WET runs no. 1 to 10. *Blank* is unchecked for WET runs no. 1 to 7 and checked for runs no. 8 to 10. *Iterations* is reset to 20 for runs no. 1 to 8 and to 0 for runs 9 and 10.

Reset to grid

Click this button to reset offset/elevation/velocity range to selected VELOITXY.GRD tomogram.

Reset v0

Click this button to reset weathering velocities v0 for all station and shot point records to 0.

Resume current run

Check this box to resume multirun WET tomography at last run completed next time you click

button *Start tomography processing* after early termination of multirun WET tomography. Early termination may occur e.g. due to power supply issues or accidentally switching off your PC.

Ricker differentiation

This parameter lets you specify how many times in time the Ricker wavelet used to modulate the amplitude of the wavepath misfit gradient should be differentiated. Set this parameter to -1 for Gaussian weighting of velocity update across WET wavepath during WET inversion. Set to -2 for Cosine-Squared weighting (Chen and Zelt 2012). Edit Cosine-Squared parameters a&b in *WET Tomo|WET Update weighting dialog*.

Since version 3.31 we recommend to leave this parameter at the new default value of -1 instead of old default value of 0. See (Schuster 1993) for details. Before version 3.05, the default value was 1. Using the undifferentiated Ricker wavelet (instead of its derivative) or a Gaussian function for weighting of velocity updates across WET wavepaths renders the tomographic inversion more robust, and results in less artefacts (Schuster, personal communication; Colin Zelt, personal communication). Setting this parameter to 0 or 1 can help to obtain sharper layer boundaries with WET inversion. See http://rayfract.com/help/release_notes.pdf . Set to -2 to avoid artefacts when increasing *Wavepath width* to 10.0 percent or higher and when using *Conjugate Gradient* method for `Borehole spread/line` lines. Also set to -2 for deeper imaging of quasi-vertical basement fault zones.

Right limit of grid

in dialog *Smooth invert|Custom 1D-gradient velocity profile…* specify right limit of grid[m] of GRADIENT.GRD or CONSTVEL.GRD starting model to be generated with *Smooth invert|WET with 1D-gradient initial model or Smooth invert|WET with constant-velocity initial borehole model.* Or use button *Reset limits to grid* to update *Right limit of grid*.

RMS error constant for n iterations

specify the number of WET iterations to check for non-decreasing RMS error, with box <u>or RMS error does not improve for n =</u> checked.

RMS error threshold

edit this field to the desired relative RMS error threshold, for stopping the WET inversion with check box <u>or RMS error gets below</u>.

Round shot station to nearest whole station number

Uncheck this import data setting to round shot stations to nearest .5 during import, e.g. to station number 0.5, 1.0 or 1.5. This ensures a consistent traveltime curve display in *Refractor|Shot breaks* even once first break picks are corrected for inline and lateral offset of shot points. Also reciprocal traveltime errors are now easier to recognize for small source-receiver offsets, in *Trace|Offset gather display*. And conversion of absolute shotpoint coordinates x/z/y to/from *shot station number* plus *shotpoint inline and lateral offset* becomes more consistent.

Safe line search with bracketing and Brent

Check this option to use bracketing and Brent's method as in http://www.nr.com, Numerical Recipes, Press et al. chapter 10 instead of Secant method for *Conjugate Gradient* WET inversion.

The Secant method lets WET inversion converge faster to an optimal interpretation, but can sometimes result in irregular WET interpretations with noisy artefacts. Bracketing and Brent's method forces WET inversion to converge slower toward optimal interpretation but WET inversion converges more reliably, with less risk of noisy WET artefacts.

Checking this option should also diminish the chance of early stopping of WET inversion, due to *increasing traveltime misfit* between picked and modeled times.

Sample count

Use this parameter to specify how many samples to import from seismic data file traces. If your import data type is ASCII, all sample values displayed will be 0.

Sample interval

Length of time step, in milliseconds, between the measurement of two consecutive samples on the same seismic data trace.

Scale wavepath width

Check this option to make WET determine the wavepath width for each trace individually, as a linear function of the picked time. Earlier picks will result in smaller wavepath width. This ensures improved overburden resolution, and more smoothing/less artefacts in the basement (at the bottom of the velocity tomogram). Uncheck this option to make WET use the constant wavepath width as specified in *WET Tomo|Interactive WET tomography* or as determined automatically, for our Smooth inversion method. This option is enabled per default, for profiles with 72 or more receiver stations.

Scale WET filter height

Check this *WET Tomo|WET tomography Settings* option to scale WET tomography processing smoothing filter height, with depth below topography. This ensures better vertical resolution of the weathering layer, and fewer artefacts at the bottom of WET tomograms. Also, the misfit between modeled and picked first breaks may decreases faster during WET inversion, with fewer iterations. This option is checked per default, for profiles with 72 or more receiver stations.

Search window width

This parameter is used in connection with Semi-automatic first break picking. You may pick first breaks for a shot gather semi-automatically by interactively defining a polyline (consisting of multiple straight line segments connected to each other) with the right mouse button. If such a line segment crosses the offset at which the trace currently being picked automatically

has been recorded, the search window width is applied to the linearized time at that offset. The automatic picking algorithm carried out subsequently for that trace limits the search for an optimum pick to the resulting time window. <u>Decrease the value of this parameter in situations of a high degree of pre-first break noise, or weak first break signals.</u> The smaller the parameter value, the closer the automatic pick will be located to the linearized time defined by the polyline as picked by you.

SEG-2

The SEG-2 file format is a trace data file format recommended by the SEG Society of Exploration Geophysicists for raw or processed shallow seismic or digital radar data in the small computer environment. It is described exhaustively in the article

S. E. Pullan, 1990. Recommended standard for seismic (/radar) data files in the personal computer environment. Geophysics, volume 55, no. 9, pp. 1260-1284.

Select .TXT file

Click this button in dialog *Grid|Export grid file to ASCII.TXT* to select *Output .TXT filename* to be created with ASCII format x/y/z/velocity rows (4 columns) for each .GRD cell

Select ASCII .CSV layer model for refractor plotting...

Select layer model .CSV with refractors exported from depth section. Also check *Plot refractors on tomogram*. Then select *Image and contour velocity and coverage grids...* and a VELOITXY.GRD tomogram. See tutorial

http://rayfract.com/samples/jenny13.pdf

Select blanking file

Click this button in dialog *WET Tomo|WET Velocity constraints* to select a Surfer format .BLN *blanking file* which contains the polygon to be blanked during WET inversion.

Select coordinate file

Click on this *Select button* in dialog *File|Update Station Coordinates…* to show a file selection dialog, for specifying the coordinate file to be imported.

Select grid file

Click this button in dialog *Grid|Export grid file to ASCII.TXT* to select *Input .GRD filename* to be exported to ASCII .TXT format

Select initial velocity model

Clicking on this button will bring up a file selection dialog, for selecting the initial / starting velocity model (formatted as a Surfer® .GRD file). If there does not exist a .PAR parameter file (as generated by the DeltatV method) with the same name and in the same directory, you

will be asked to specify the .PAR file explicitly as well. You may specify .GRD files / velocity models as obtained by previous WET tomography runs, i.e. refine the output of earlier WET processing.

Select mask grid file

Click this button to select the Surfer format velocity .GRD *Mask grid file* containing velocity to be copied into the WET tomogram in the blanking polygon specified in .BLN *blanking file*.

Select velocity profile

Click this button to display a dialog which lets you select a .TXT *Velocity profile* with two columns : depth below topography and velocity.

Separator (one character)

Specify the column separator character in this field. The default separator is a semicolon (;). Another frequently used separator is a comma (,).

Set to max. exported

Select this radio button in connection with parameters *Maximum velocity exported* and *limit velocity exported* to reset velocity values exceeding the threshold value *Maximum velocity exported* to that value.

Shot acquisition date

Date of recording of seismic data in *Header|Shot*. It is recommended that the date be specified in dd/mm/yyyy format. Alternatively, to avoid any possible confusion in the ordering of the day and month, use format dd/mmm/yyyy, with mmm being a three-letter abbreviation of the month.

Shot acquisition time

Time of recording of seismic data in *Header|Shot*. The contents of this field is not used during processing. As a consequence, its format is not fixed. It is recommended that the time be stored in the 24-hour hh:mm:ss format.

Shot breaks display

Displays first breaks sorted by common shot. Open this display by selecting *Refractor|Shot breaks*. Traveltime curves are constructed by connecting first breaks recorded and picked for the same shot and at adjacent receiver positions by straight line segments. You may interactively map first breaks of each shot sorted traveltime curve to refractors by positioning *branch points* accordingly. Synthetic traveltimes obtained by *Depth|Forward model traveltimes...* or *Depth|Wavefront...* are displayed in blue. Toggle display options *Mapping|Display raytraced traveltimes* and *Mapping|Display synthesized traveltime curves* as necessary.

Shot depth

In *Header|Shot* field *Depth* specify the *shot hole depth* in meters. You do not need to modify the value displayed if it is correct already, i.e. if the current shot's hole depth is equal to the default shot depth specified earlier, during import. You may specify a negative depth if the source elevation is higher than the elevation as shown in read-only field *Source elevation* (in *Header|Shot*). This may occur if the shot point has been offset laterally from the line, as specified in field *Shot lateral offset*. *Source elevation* is updated automatically whenever you edit *Depth* or *inline offset* and move to the next field or confirm the dialog (*Header|Shot*) with ENTER/RETURN key or browse with F7/F8. Source elevation is the sum of shot station elevation plus shot dz minus shot depth.

Shot dx

This field in *Header|Shot frame Offset from Shot Station* can be edited once you have imported shots into *Line type* **Borehole spread/line** and updated station coordinates with *File|Update header data|Update Station Coordinates...* from COORDS.COR file and updated shotpoint coordinates with *File|Update header data|Update Shotpoint coordinates...* from SHOTPTS.SHO file. See chapter File formats for description of COORDS.COR and SHOTPTS.SHO format.

Shot dx is the horizontal offset of actual shotpoint from *Shot station x coordinate*. The **Shot station** is specified during import in **Import shot dialog** field **Shot pos. [station no.]** and is shown in *Header|Shot frame Shot Station [station no.]* . The *Shot station x coordinate* can be looked up in *Header|Station*.

Once you edit *Shot dx* and press F7/F8 we will show the updated shotpoint x coordinate in *Header|Shot frame Source Coords* for *Line type* **Borehole spread/line**.

Shot dz

This field in *Header|Shot frame Offset from Shot Station* can be edited once you have imported shots into *Line type* **Borehole spread/line** and updated station coordinates with *File|Update header data|Update Station Coordinates...* from COORDS.COR file and updated shotpoint coordinates with *File|Update header data|Update Shotpoint coordinates...* from SHOTPTS.SHO file. See chapter File formats for description of COORDS.COR and SHOTPTS.SHO format.

Shot dz is the vertical offset of actual shotpoint from *Shot station elevation*. The **Shot station** is specified during import in **Import shot dialog** field **Shot pos. [station no.]** and is shown in *Header|Shot frame Shot Station [station no.]* . The *Shot station elevation* can be looked up in *Header|Station*.

Once you edit *Shot dz* and press F7/F8 we will show the updated shotpoint z coordinate in *Header|Shot frame Source Coords* for *Line type* **Borehole spread/line**.

Shot gather display

Displays traces sorted by common shot. Open this display by selecting *Trace|Shot gather*. You may interactively and *semi-automatically pick first breaks* by picking a polyline with your right mouse button.

Shot inline offset

Specify the *inline offset* of the shot point at and along line topography from the *shot position* (in whole station numbers or ending in .5 e.g. 0.5) in *Header|Shot*. If you need to move the shot position for some small inline distance due to unexpected problems at the exact position planned, make use of this parameter. For example to avoid damage to the geophones. Also update *Depth* field with shot hole depth. Once you enter the correct inline offset and depth and move to next field with TAB key or confirm the dialog with ENTER key or use F8/F7 function keys the read-only field *Source elevation* (*Header|Shot*) is updated automatically. The source elevation is determined from interpolation between adjacent receiver stations at *shot station* and this *shot inline offset* and then subtracting the *shot hole depth* specified in *Depth* field. Specify the *inline offset* of the shot point in meters or feet depending on *Header|Profile|Units*.

Shot lateral offset

Specify the offset of the shot point position from the seismic line (i.e. from the spread), in meters. Normally this offset is 0. If you need to offset the shot position from the spread due to some unexpected problem at the in line shot position (e.g. a rock or pipe), please use this value to do so.

Shot Number

If the automatically determined *shot number* is incorrect, use this parameter to specify the correct value, in *Import Shot dialog*. This should be necessary in rare cases only, however.

Shot point is zero time trace

Enable this menu item to ensure that a hypothetical first break time of 0.0 is assumed for offset 0.0, at each Common MidPoint (CMP) during our DeltatV inversion. This will normally help to give more realistic weathering velocities directly below the line topography. As a consequence, deeper structures will be imaged more reliably as well. Disable this option e.g. if near offset first breaks are difficult to pick or you don't like the output as obtained with this option enabled (as gridded and contoured with Surfer®).

Shot position

Use this parameter in *Import shot dialog* to specify the inline and profile relative shot position in station numbers. This value must be either an integer value or end in .5 e.g. 0.5. See online help topic Station numbers and spread types.

Shot type

Set *Type* field in *Header|Shot* to value **Refraction shot** or **Uphole shot** *for Line type* **Refraction spread/line**, and value **Downhole shot** or **Crosshole shot** *for Line*

type **Borehole spread/line**. When combining refraction shots with uphole shots in a profile with *Line type* **Refraction spread/line** as in http://rayfract.com/tutorials/coffey04.pdf , this *Type* field is used to discriminate between uphole and refraction shots. First break picks for uphole shots are not corrected for *shot inline offset* (*Header*/*Shot*) since uphole shots are not regarded during conventional layer-based interpretation. Also, when sorting traces by common receiver before export to `.3DD` with *File*/*Export header data*/*Export Traces to GeoTomCG .3DD*, the negative *shot hole depth* (*Header*/*Shot*) is used as secondary sort key for uphole shots. For refraction shots the *shot position* in station numbers (*Header*/*Shot*) is used as secondary sort key.

Show axis titles

Deselect this option to display axes without axis title, e.g. to save screen space.

Skip every 2nd

Activate this option to process CMP sorted traveltime curves for every second CMP only. This will reduce the computation time for the inversion and the following gridding of the data with Surfer®.

Skip every second shot for forward modeling

Select this option to speed up tomography processing by skipping every second shot. This will of course result in a coarser / more uncertain velocity model.

Skip shot

Click on this button to skip the currently displayed shot record, i.e. in order NOT to import it into your Rayfract® profile database.

Smooth CMP traveltime curves

Use this option for high coverage profiles only. For such profiles, this option may help to filter out bad picks from CMP sorted and stacked traveltime curves. For low coverage profiles, enabling this option may result in the destruction of valuable vertical gradient information, describing subsurface acoustic wave velocity distribution. Enabling this option will result in smaller .TXT output files as generated during the DeltatV inversion.

Smooth crossover distances

Check this option in case of irregular traveltime field region boundaries, separating traces mapped to different refractors or the weathering layer from each other. First breaks mapped to one region, i.e. one refractor, are all displayed in the same color. These boundaries are defined by the laterally varying vertical position of the color change, for all Common Mid Points (CMP)'s of a profile. E.g. the change from red to green identifies the boundary separating first breaks of the wave critically refracted by the first refractor from first breaks of the wave critically refracted by the second refractor. The estimated crossover distance for a particular CMP corresponds to the vertical offset of the color change on that CMP's midpoint sorted CMP traveltime curve, from the upper horizontal station number axis. This axis is located at offset 0.

Smooth last iteration

Check this box to smooth the tomogram obtained with the last WET iteration, regardless of setting of parameter *Smooth nth iteration*.

Smooth nth iteration

Smooth tomogram after each nth WET iteration only. Increase for less smoothing. E.g. increase from default 1 to 10 or 15.

Smooth polygon border

Check this option in *WET Tomo|WET velocity constraints* to smooth velocity over the blanking polygon border specified in .BLN *blanking file* selected with *Select blanking file* during WET inversion. Uncheck to strictly enforce the blanking polygon border.

Smooth velocity update

Check this box to smooth the velocity update separately before applying it to the tomogram during WET inversion. The velocity update and tomogram with update applied are smoothed after each nth WET iteration as specified with parameter *Smooth nth iteration*.

Source shot no.

Shot number which is added to or subtracted from Target shot no. Enter *source shot number* in this field.

Source type

Specify the source type used to excite the ground, by selecting the corresponding entry from this drop down list box. The value of this field is regarded for traveltime curve coloring in *Refractor|Shot breaks*, with option *Mapping|Color picked curves by source type*.

Specify starting velocity model

Click on this button in *WET Tomo|Interactive WET tomography* main dialog to bring up the *Forward modeling parameters* dialog. This dialog lets you specify the initial / starting velocity model .GRD used as a basis for the WET tomography processing. Also, you may specify if velocities should be corrected for systematic DeltatV errors. Finally, you may specify if every second shot should be skipped during the tomography processing to reduce the processing time.

Spread type

Use this drop down list box to specify a spread type different from the *Default spread type*, as

specified earlier.

Spread type name

Enter a unique name (up to 31 characters long) identifying the new spread type to be created. Once you have filled in all edit fields of the *Create New Spread Type* dialog and hit RETURN, the software will verify that this name has not yet been used. If it is not unique, a corresponding error message will be displayed and the focus will be returned to this edit field.

Stack shot labels at same offset

Check this *Grid menu* option to vertically stack shot labels in tomogram plot for shots positioned at same location of 2D profile

Start tomography processing

Click on this button once you have reviewed and optionally adjusted the WET tomography processing parameters.

Static Corrections

Use this button to bring up a dialog which lets you specify parameters used during the process of *correcting first breaks for topography features such as local humps (anticlines) or troughs (synclines) and for shot position offsets (hole depth / inline offset / lateral offset)*. This correction is necessary to obtain realistic CMP velocity estimates for the maximum depth reached by refracted / turning rays.

Station elevation

In *Header|Station* edit the z coordinate i.e. elevation of the station located at station no. *Station position*, in meters or feet depending on *Header|Profile|Units* setting.

Station spacing

Specifies how many meters correspond to one station number interval. Normally (i.e. in an equidistant spread type, where all adjacent receiver positions are separated from each other by one station number interval), the station spacing is equivalent to the receiver spacing.

Station x coordinate

In *Header|Station* edit the x coordinate of the station located at station no. *Station position*, in meters or feet depending on *Header|Profile|Units* setting.

Station y coordinate

Specify the y coordinate of the station located at position *Station position*, in meters. Use an

appropriate coordinate system.

Steepest Descent

Check this radio button in WET Tomo|Interactive WET tomography dialog to use default Steepest Descent method for WET inversion. See

http://www.cs.cmu.edu/~quake-papers/painless-conjugate-gradient.pdf

. Alternatively select *Conjugate Gradient* method.

Steepest Descent step

check to update the tomogram with a *Steepest Descent* step after each WET iteration (inner loop iteration) during *Conjugate Gradient* inversion using algorithm described by (Shewchuk, 1994) on page 53 of his paper

http://www.cs.cmu.edu/~quake-papers/painless-conjugate-gradient.pdf

. This *Steepest Descent step* is not mentioned by (Shewchuk, 1994) but can make the WET inversion more robust with noisy first break picks.

Store nth iteration only

You may edit this value n such that Surfer® grid files are stored for each nth iteration only. This will help to preserve free disk space. The default value is 5. For Smooth inversion, Surfer® .GRD grid files are written to profile subdirectory GRADTOMO. For Automatic DeltatV and WET inversion, grid files are stored in profile subdirectory TOMO.

Strict shot position checking

Check this *Smooth invert|Smooth inversion Settings* option for more accurate checking of *shot position*, against minimum of picked traveltime curve. Interactively check with SHIFT+O command, in *Refractor|Shot breaks display*. This checking is done automatically before forward modeling and inversion of the traveltime data.

Subtract source. Uncheck to add.

Leave unchecked to add Source shot no. to Target shot no. when stacking the two shots. Check to subtract source from target.

Suppress velocity artefacts

Enable this option to suppress the generation of processing artefacts, i.e. unrealistic velocity variations. Use best for medium and high coverage profiles. See (Winkelmann 1998), top of page 36. If enabled, a candidate ray will be used for modeling of an incremental layer if the ray specific apparent velocity and intercept time (as modeled by local regression on CMP curve, at ray specific offset) both are lower than the mean of apparent velocity and intercept

time, as estimated for the next three higher CMP offsets. If this setting is disabled, no candidate ray selection, i.e. filtering / enforcing of <u>CMP traveltime curve</u> continuity, based on apparent velocity and intercept time will occur.

Surface consistent

Activate this option to compute static first break corrections relative to a floating datum obtained by applying a running average smoothing filter to the topography specified or imported earlier. The filter width may be specified within edit field **Topography filter**.

Surfer invocation

Select `SRIPTER.EXE` for calling into Surfer, in directory `C:\PROGRAM FILES\GOLDEN SOFTWARE\SURFER XY\SCRIPTER\` . Explicitly selecting the `Scripter.EXE` may be required when you have installed multiple Surfer versions on the same PC. Normally our software can lookup the `Scripter.EXE` path in the Windows registry. But sometimes the registry becomes corrupted and the Surfer invocation fails, with command *Grid and image velocity and coverage grids...* . For related error prompts and remedies see our chapter Calling Surfer.

Surfer plot Limits

Shows dialog for editing min./max. offset, elevation and velocity for plotting of WET velocity tomogram with *Image and contour velocity...* Reset offset/elevation/velocity range to selected Surfer `.GRD` format `...\GRADTOMO\VELOITXY.GRD` or `...\LAYRTOMO\VELOITXY.GRD` or `...\HOLETOMO\VELOITXY.GRD` velocity tomogram with *button Reset to grid*. Check box *Plot limits active* to enforce limits next time you select *Grid|Image and contour velocity...* For more details see edit Surfer plot limits.

Swap borehole x with z

Swap x with z borehole coordinates during import of .3DD and export of station and shotpoint coordinates. Y coordinate is reset to all zero, during data import.

Sweep angle [degrees]

Use this parameter to specify the width of arcs symbolizing estimated refractor location, in degrees. Note that intercept time methods such as CMP intercept time refraction and Plus-Minus do not deliver the exact lateral location of refractor features. They deliver the layer thickness above refractor only, as measured vertically upwards from the layer's bottom / the refractor's top. The refractor shape may be derived visually from the display by following the outlined curve defined by overlapping segments of adjacent depth arcs, however. Mathematically, this curve is called an envelope.

Take shot record number from

This parameter indicates how the shot number of the shot currently being imported is determined. It is set automatically, according to the Import data type specified above. You are advised not to change this parameter at will.

Taper velocity steps at layer interfaces

Enabling this option may result in an enhanced vertical resolution of subsurface layer interfaces, in case of subhorizontal layering and for high coverage surveys (e.g. 15 or more shots per profile). Leave this option disabled in case of strong lateral velocity variation. If this option is enabled, the two velocity values as obtained for each hypothetical incremental layer interface during DeltatV inversion are not merged into one value. Instead the estimated velocity at the upper layer's bottom and the inverted velocity as obtained for the lower layer's top are both written as separate triples (inline offset, depth, velocity) to the .TXT file. The second triple (for the lower incremental layer's top velocity) will specify a depth which is computed from the layer interface depth plus half of the thickness of the hypothetical lower layer, as determined during inversion. The resulting model will be slightly too deep i.e. too slow, in most situations and by construction. But this minor deficiency is easily and automatically compensated for during subsequent WET Tomography processing.

Target Sample Format

Specify the sample format for writing samples imported into the currently opened Rayfract® profile database. Since version 3.26 samples are written as 32-bit floating point values regardless of the setting of this parameter. Previous to version 3.26 we stored samples as 16-bit integers.

Target shot no.

Shot number which is updated in profile database. Select with F7/F8 in *Trace|Shot gather* display. Once this shot number has been stacked the original shot is overwritten and not available any longer.

Topography filter

Use this edit field to specify the filter width for the running average filter applied to topography specified or imported earlier, to obtain a smoothed floating datum. See option *Static first break corrections* method **Surface consistent**.

Trace sort

This drop down list box lets you specify the sort method of trace data files recorded for this profile. The value specified is not regarded during processing.

Trace to refractor mapping parameters dialog

This dialog is displayed when using ALT-M in your *Midpoint breaks display*. It lets you parameterize the semi-automatic mapping of first breaks to refractors. This mapping is carried out based on apparent CMP velocity of the local CMP traveltime curve segment, at the first break to be mapped.

Trigger delay

Use this field to interactively shift the shot specific traveltime curve in the <u>Shot breaks display</u>. The total time shift is the sum of BOTH <u>delay time</u> and trigger delay. The delay time may be changed during (re)import of the shot only.

Turn around grid file by 180 degrees

Use this *Grid menu* command to flip over previously generated velocity tomograms VELOITXX.GRD (and matching coverage grids COVERGXX.GRD, if existing). Then image the flipped tomogram with *Grid|Image and contour velocity and coverage grids...* .
     Surfer .GRD files are stored in profile subdirectories GRADTOMO (1D gradient based Smooth inversion), LAYRTOMO (layered refraction starting model) TOMO (pseudo-2D DeltatV inversion) and HOLETOMO (Crosshole survey interpretation).

Turn around spread 180 degrees during import

Use this option to store the first recorded sample trace at the last (right-most) receiver position of the receiver spread type selected. Specify the *shot position* correctly when importing shots, with this option. You may want to check the imported shot in *Trace|Shot gather*, and reimport with adjusted shot position if required. You may skip all other shots, in *Import shot dialog*.

Uniform

Check this radio button for uniform weighting of smoothing filter nodes when smoothing the tomogram after each (nth) WET iteration.

Uniform central row weight

Check radio button *Uniform* in *WET smoothing dialog* and edit the weight to be given to the central row of the smoothing filter kernel (matrix) during WET smoothing. Valid values are 1..100. Default value is 1. Increase for sharper vertical contrast between quasi-horizontal layers in WET tomogram.

Units

This drop down list box lets you specify the linear distance measuring unit used throughout this profile. The value of this field is forced to `meters` or `feet`. When you select inches we select feet and when you select centimeters we select meters. The *Station spacing* and all other distance parameters displayed in all dialogs are in meters or in feet according to your selection.

Update imaged grid depth

This option is enabled by default. If enabled, the grid depth will be updated after each WET tomography iteration. Otherwise, the imaged grid depth will stay the same as for the initial model. Please note that the grid depth can only decrease compared to the initial model.

Uphole time as measured

This field is not shown in *Header|Shot* any longer, and never was used by our software. The uphole time correction term in *Header|Shot* is used to discriminate between shot type *Refraction shot* (value 0.00) and *Uphole shot* (value 0.01).

Uphole time correction term

This parameter is not used during inversion and cannot be edited in *Header|Shot* any longer. Uphole shots are not used for conventional layer-based interpretation with Wavefront and Plus-Minus methods any longer. Uphole shots are not used to determine the 1D-gradient initial model for Smooth inversion, see http://rayfract.com/tutorials/coffey04.pdf . *When you change shot type in Header|Shot from Refraction shot to Uphole shot, Uphole time correction term* is changed from 0.00 to 0.01 and vice-versa. And *Uphole time correction term* shown in *Header|Shot* is updated during *File|Update header data|Update Shotpoint coordinates...* , according to value of column no. 7 *correction* in the selected SHOTPTS.SHO file. Also, the shot type in *Header|Shot* is updated automatically during the SHOTPTS.SHO import. *Correction* value 0 means *Refraction shot*, and a value different from zero means *Uphole shot*.

Use full Steepest Descent step for Conjugate Gradient

check *WET Tomo|WET tomography Settings|Use full Steepest Descent step for Conjugate Gradient* with *Edit velocity smoothing|Maximum velocity update* below 15% so *Conjugate Gradient* WET inversion stays focused

Used width of Gaussian [sigma]

Specify cutoff in sigma's for Gaussian bell function used for weighting of smoothing filter nodes. The lower this value, the flatter the smoothing filter will be.

v0 from CMP

Click this button to copy estimated weathering velocities from your *Midpoint breaks display* (*Refractor|Midpoint breaks*) into all station and shot point records. Shot position offset corrections will be computed and applied to first breaks automatically.

v0 from Shots

Click on this button to copy estimated weathering velocities from your *Shot breaks display* (*Refractor|Shot breaks*) into all station and shot point records. Shot position offset corrections will be computed and applied to first breaks automatically.

Velocity vs. Two-way-time...

Select a VELOITXY.GRD and write 3-column ASCII file TWTIME.TWT with columns CMP station no., two-way time (s) and velocity (m/s). Use this for static correction step during reflection seismic processing.

Velocity profile

Edit filename including disk drive and directory of a .TXT velocity file with two columns : depth below topography and velocity. Or click button *Select velocity profile* to interactively navigate your directory structure and select such a .TXT file. You can copy file C:\RAY32\<your profile name>\GRADTOMO\1DVELO.TXT to e.g. MYVELO.TXT. Now edit MYVELO.TXT with Microsoft WordPad or any other text editor. Next select your edited .TXT file with button *Select velocity profile*.

Vertical axis ticks

Use this Annotations parameters dialog setting to specify the type of axis ticks shown on the vertical Y axis. Select type Major&Minor, Major ticks or No ticks.

Vertical axis title

Specify the vertical axis title in this field. Note that it will be clipped to a length of 32 characters.

Vertical exaggeration

Specify the ratio of horizontal distances printed or plotted to vertical distances printed or plotted with this parameter. E.g. specify a value of 10, for a ratio of 1:10. Note that the vertical axis of depth sections displayed on screen is scaled to the height of the window containing the display, regardless of the setting of this parameter.

Vertical grid lines

Use this setting in the Annotations parameters dialog, to specify the type of auxiliary vertical grid line shown in parallel to the Y axis, at X axis ticks. Select setting Dashed line, Dotted line or No line.

Vertical scale

This edit field lets you specify to how many centimeters a velocity interval of 1000 m/sec. should be scaled when printing or plotting a v*elocity section*. When printing or plotting a *time section*, this field specifies to how many centimeters a time interval of 100 msecs. should be scaled. Note that the vertical axis is scaled to the height of the display window containing the section on screen, regardless of the value of this parameter.

Wavepath frequency

This edit field in *WET Tomo|Interactive WET tomography* main dialog lets you specify the central frequency of the Ricker wavelet used to modulate the wavepath misfit gradient amplitude. We usually leave it at the default value i.e. at 50 Hz. One period is 1/50Hz = 20ms*.* See (Schuster 1993) for details.

Wavepath width

This edit field in *WET Tomo|Interactive WET tomography...* lets you specify the wavepath width, in percent of one period of the *Wavepath frequency* as specified in the same dialog. See (Schuster 1993) for details. You may vary this parameter between 0.1 and 100 percent. An increased width will result in wider wavepaths and smoother velocity models as obtained with our WET tomography processing. You can also specify a schedule for systematically decreasing the wavepath width between consecutive WET runs with our multirun WET option.

Decreasing the wavepath width can increase the resolution, in high-velocity basement. But decreasing the wavepath width can also result in **artefacts in the final velocity tomogram, with wavepaths "engraving" themselves into the tomogram**. This "engraving" goes hand-in-hand with a strong correlation between velocity tomogram and wavepath coverage plot, with high-velocity zones mapping to high-coverage regions (focused wavepath refraction) in the coverage plot.

Wavepaths for every nth receiver

Set this parameter to 1 to plot wavepaths for every receiver, of shot being plotted. Set to 2 to show wavepaths for every 2nd receiver etc.

Weathering crossover

Use this edit field in the DeltatV *Static Corrections dialog* to specify the laterally constant estimated average **crossover distance** (in station numbers) separating direct wave arrivals from refracted arrivals. This parameter is relevant during **first break corrections** : traces with an absolute source-receiver offset equal to or exceeding the value of *Weathering crossover* will be corrected for shot hole depth and topography elevation, if CMP gather datum specific static corrections option is selected. Direct wave arrivals will be corrected for shot hole depth and *shot position offsets*, if either static corrections option No static corrections applied or CMP gather datum specific is selected.

Weathering layer velocity limit

This parameter lets you specify the maximum expected velocity of the direct wave. Apparent CMP velocities above this limit are interpreted as belonging to critically refracted head waves, either mapping the first or the second refractor.

Weathering sub-layer count

Use this parameter to control weathering velocity estimation in situations of strong possibly nonlinear vertical velocity gradients right below the topography. Uncompacted soil or sand at the topography are typical examples of such situations. Valid values for this parameter are 0 to 1000. The default value is 3. The higher the value, the lower and the more accurate and detailed the resulting weathering velocity imaging will be in general. As a consequence, synthetic traveltimes obtained by raytracing through the model obtained will be slightly slower. So increase this parameter if synthetic traveltimes are too fast (systematic offset between picked and synthesized traveltime curves, in *Shot breaks* display), compared to times as measured and picked.

Weathering velocity

Specify the weathering velocity in meters per second estimated for current *Station position* in *Header/Station*. Or click *v0 from Shots* or *v0 from CMP* to copy estimated shot or CMP intercept time refraction weathering velocities into all station positions.

Weathering velocity detected

Median weathering velocity detected, when carrying out piecewise linear regression over all CMP traveltime curve segments assigned to the weathering layer.

Weigh picks in CMP curves

We recommend to always enable this option, as per default. With this option enabled, each individual traveltime pick is weighted with the reciprocal of the square root of the distance (in station nrs.) between the trace CMP and the central stack CMP, when constructing CMP stacked traveltime curves. This weighing is essential to ensure that a systematically dipping basement is imaged without artefacts. The individual picks and weights are displayed in the status bar at the bottom of the Midpoint breaks display. Just browse CMPs with F7/F8 and trace a chosen CMP curve with vertical cursor keys.

WET runs active

Check this box for multirun WET tomography next time you click button *Start tomography processing* in main WET dialog. Uncheck this box for single-run WET tomography, ignoring multirun parameters specified in this dialog next time you click *Start tomography processing*.

Wide CMP stack for 1D-gradient initial model

This option lets you toggle DeltatV parameter *CMP curve stack width* between default value 120 and wide setting 240, for Smooth inversion.

Wide smoothing filter for 1D initial velocity profile

Vertical smoothing filter width is 20% of depth range of 1D-gradient initial model, instead of 10%. Disable for low-coverage and short profiles.

Width [ms]

Width [ms] column in multirun WET dialog is read-only and cannot be edited by user. It is computed as (1.0/Freq. [Hz]) * Width [%]/100.0 * 1000.0 . This value is used to compute wavepaths for WET inversion.

Width of Gaussian for one period [sigma]

Specify cutoff for Gaussian Bell function, in sigma. This width of Gaussian is regarded when weighing the WET velocity update across the wavepath. Default value is 3 sigma. Minimum value is 0.1 sigma. A smaller width results in a flatter weighting of velocity update across WET wavepath. Increase *Width of Gaussian for one period [sigma]* to 10.0 or 50.0 from default 3.0 for wide shot spacing and low-coverage lines e.g. tutorial

http://rayfract.com/tutorials/jenny13.pdf to avoid artefacts at low frequency/for first few runs of *multiscale tomography* (at wide wavepath width). Or change *Ricker differentiation* from -1 [Gaussian bell] to 0 [Ricker wavelet].

Width%

This column in multirun WET dialog lets you edit the wavepath width [in percent of one period] for WET runs 1 to 10. One period = 1/*Freq. [Hz]* specified in first column.

Write .HDR only

Check this box in dialog *File|Import Data…* to list shots in *Output .HDR* file and skip actually importing shots when you click button *Import shots*

Write grids for every iteration

Enable this setting to force the generation of Surfer® .GRD grid files for velocity and coverage, for every WET iteration. If enabled, this setting will override the current setting of Interactive WET tomography grid file generation setting *Store each nth iteration only*.

Write grids for Line Search during Conjugate Gradient

Check this box to store WET tomograms obtained after each Line Search started by Conjugate Gradient method.

Write misfit gradients to disk for shot nr.

Enter a valid shot number into this edit field to generate disk files of the misfit gradients for the wavepaths of all receivers i.e. traces recorded for this shot. The resulting Surfer® formatted .GRD files will be named G001:001.GRD for trace number 1 of shot number 1 etc. See (Schuster 1993) for details.

Write section coverage grids after each iteration

Enable this option to generate Surfer® .GRD formatted disk files showing the coverage of each velocity model grid cell with wavepaths, after each WET iteration. Disk files will be named COVERG01.GRD for the first WET tomography processing iteration etc.

Write section velocity update grids after each iteration

Enable this option to generate Surfer® .GRD formatted disk files holding the velocity change / update to be applied to the output of the previous WET iteration. Disk files will be named VELUPD01.GRD for the first WET tomography processing iteration etc.

Write wavepaths to disk for shot nr.

Enter a valid shot number into this edit field to generate disk files of the wavepaths for all receivers i.e. traces recorded for this shot. The resulting Surfer® formatted .GRD files will be

named W001:001.GRD for trace number 1 of shot number 1 etc. See (Schuster 1993) for details.

X coordinate is corrected for topography already

With this box in dialog *File|Update header data|Update Station Coordinates…* checked, our import routine will determine the inline offset between adjacent receivers with Pythagoras of (corrected for elevation change) true x and z coordinate offsets. If this option is unchecked, the inline offset is assumed to be the (uncorrected for elevation change) inline x coordinate offset. This inline offset is then used to match planted receivers to *spread type* receiver positions.