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Commands

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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

Reinitialize profile Reset database to initial state. All imported data and model results are permanently deleted from the profile. Use before toggling option(s) in ***Import data Settings***.

Import Data... **Import** seismic trace data into profile database.

Import Data Settings Settings to be used with above Import Data... command

More import Settings More settings for trace file import with Import Data... command

SEG-2 import settings Settings for SEG-2 file import with above Import Data... command

SEGY import settings Settings for SEGY file 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

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.

Customize spread types Check option ***Customize Default spread type*** to automatically customize selected *Default spread type* to match irregular receiver layout with missing traces. Minimizes geometry modeling errors by storing a separate receiver spread for each variation of missing traces in the profile database. Enabling this option will cause database revision to fail when opening this profile with early 3.36 or earlier version of our software. Check option *One spread per shot* if receiver coordinates vary for same spread layout between shots.

Print Print currently selected section window

Print Setup... Select and setup printer to be used for above Print command

Shorten stored trace length... Shorten stored trace length in database to conserve disk space. Available with Pro license only.

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 SEG-2, SEGY, SeisImager, SeisOpt, Gremix and .3DD Allow missing dead traces, for Geometrics SeisImager, Optim SeisOpt, Interpex Gremix, GeoTomCG .3DD and Geogiga .TTX files

Assume regular/equidistant receiver spacing Assume receivers are spaced at multiples of *Header|Station spacing*. Uncheck to better support import of irregularly spaced receivers e.g. with .3DD import into borehole spread/line.

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..

Import horizontal borehole survey Import horizontal borehole survey, SEG-2 or .3DD shots.

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.

Check all shots for station spacing Check all shot files in input directory for station spacing and propose adjustment of profile's station spacing if required. Uncheck to propose adjustment for first shot file only.

Adjust Receiver station coordinates Re-center each receiver station at end of import to average of coordinates for all receivers linked to this station. Helps with importing of irregularly spaced streamer data in formats SEG-2, SEGY, Geogiga DWTOMO .TTX, PlotRefa .VS and GeoTomCG .3DD. This linking of receivers to receiver stations is done during shot import with *File|Import Data…* . See ***Header|Receiver*** dialog in chapter Editing header data and our marine streamer tutorial https://rayfract.com/tutorials/SR6.pdf .

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

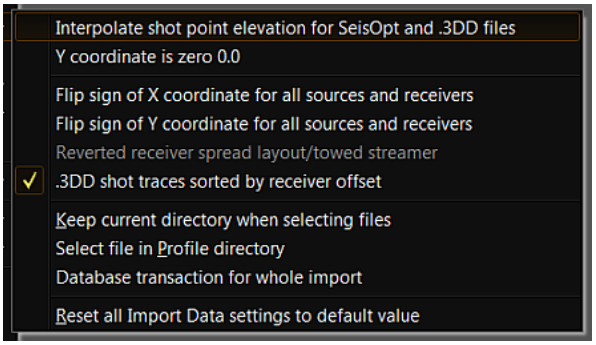
Allow shot inline offset from shot station larger than two spacings Allow inline offset of shot point from shot station exceeding two station spacings. This invalidates DeltatV method interpretation.

Extrapolate receiver line coordinates Extrapolate receiver line coordinates beyond first/last receiver station. Disable to set offend shot stations to absolute shot point coordinates.

Use bent line inline offset for shot pos. and layout start Regard receiver x/y/z when accumulating inline offset along bent line for determination of *Layout start* and Shot pos. in station numbers, for SEG-2 and SEGY import

More import Settings

The ***More import Settings submenu*** is also in ***File menu*** and offers these commands :



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.

Y coordinate is zero 0.0 Reset y coordinate to zero 0.0 during import for all shots and receivers. Use with GeoTomCG .3DD import into *Header|Profile|Line type* **Refraction spread/line**. For *Line type* **Borehole spread/line** all y coordinates for all sources and receivers are reset to zero 0.0 during import independent of this option.

Flip sign of X coordinate for all sources and receivers Flip sign of x coordinate for all sources and receivers specified in trace input files. Use for SEGY, SEG-2 and GeoTomCG .3DD formats.

Flip sign of Y coordinate for all sources and receivers Flip sign of y coordinate for all sources and receivers specified in shot trace input files. Use for SEGY, SEG-2 and GeoTomCG .3DD formats.

Reverted receiver spread layout/towed streamer Spread channel no. decreases with inline offset. Read-only. Toggle in File|Import Data dialog when importing your shot files.

.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*).Our .3DD import assumes that traces in .3DD input files are sorted by common shot number since the .3DD format does not contain a column with the shot number. Shots are numbered sequentially starting at one during .3DD import. With this option checked our .3DD import assumes ***additionally*** that all traces for same shot (listed sequentially in the .3DD) are sorted by receiver offset along line : x coordinate for *horizontal receiver spreads* or z coordinate for vertical receiver spreads.

Keep current directory when selecting files Start file selection in current directory. Uncheck to start in input directory.

Select file in Profile directory Start file selection in current profile's main directory. Uncheck to start in input directory.

Database transaction for whole import Changes database

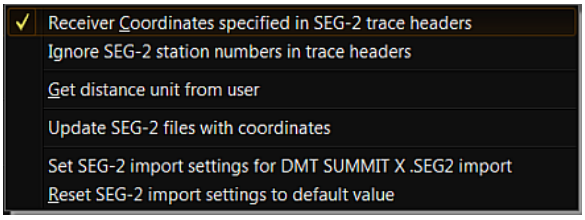
transaction management during import. Check for one global transaction.

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 in ***File menu*** and offers these options :



Receiver Coordinates specified in .DAT or .SG2 file SEG-2 .DAT or .SG2 files have trace header fields RECEIVER_STATION_NUMBER or RECEIVER_LOCATION. Check to enable import setting *Allow missing traces for SEG-2*.

Ignore SEG-2 station numbers in trace headers use with DMT SUMMIT X ONE .SEG2 files to disregard station numbers in SOURCE_STATION _NUMBER and RECEIVER_STATION_NUMBER header entries.

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

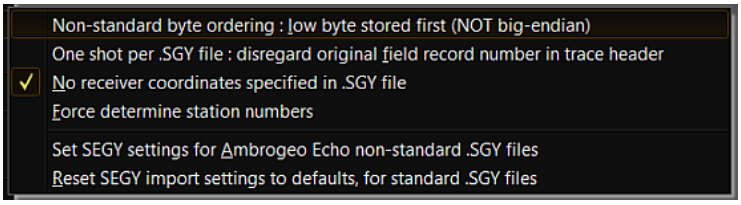
Update SEG-2 files with coordinates update SEG-2 trace header fields SOURCE_LOCATION and RECEIVER_LOCATION with true x/y/z coordinates using SEG2_EDIT utility and 3D.TXT response files

Set SEG-2 import settings for DMT SUMMIT X .SEG2 select to check option *Receiver Coordinates specified* and to check option ***Ignore SEG-2 station numbers in trace headers***

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 options :



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*.

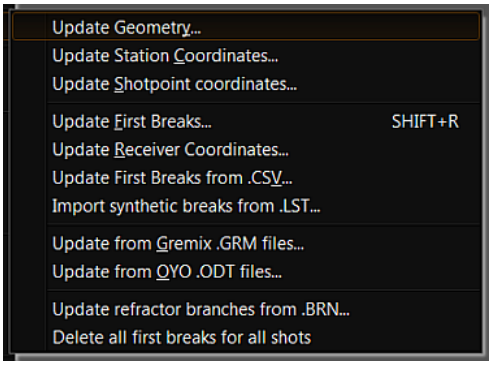
Force determine station numbers Force determine station numbers for layout start and shot position with inconsistent SEGY geometry. Use if unchecking 'No receiver coordinates specified in .SGY file' fails.

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

The Update header data submenu is 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. See chapter File formats.

Update Shotpoint coordinates... Update shot positions (coordinates, inline, lateral offset) from .SHO shot point file, update shot time terms. See chapter File formats. 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. See chapter File formats.

Update Receiver Coordinates... Update header data with receiver coordinates from .LST file. Receiver station coordinates are re-centered to average of coordinates for all receivers linked to that station. This linking of receivers to receiver stations is done during import of shots with File|Import Data... . See Header|Receiver dialog in chapter Editing header data and our marine streamer tutorial https://rayfract.com/tutorials/SR6.pdf .

Update First Breaks from .CSV... Update header data with first breaks from .CSV file. See \RAY32\DOC for sample .CSV . Each line starts with shot no. and then lists first breaks for all channels.

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

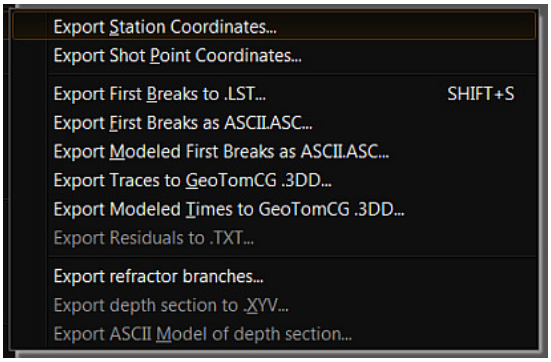
Update from OYO .ODT files... Update header data with first breaks from OYO .ODT files

Update refractor branches from .BRN… Update branch points for all shots in Refractor|Shot breaks display from .BRN file

Delete all first breaks for all shots Delete all first break picks for all shots in profile database

Export header data

The *Export header data submenu* is 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. Configure with File|Export Data Settings.

Export Traces to GeoTomCG .3DD... Export traces with geometry, to GeoTomCG .3DD file. Configure with File|Export Data Settings. Traces in the .3DD are sorted by common shot.

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. Enabled for Pro License only.

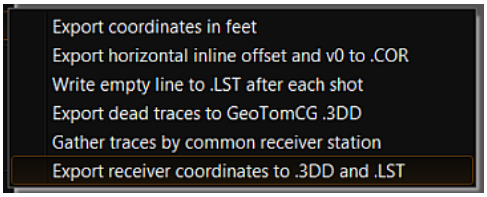
Export refractor branches to BRN... Export picked branch points for all shots from *Refractor|Shot breaks* display to .BRN file

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 layered model file with layer thicknesses and velocities of current depth section

Export data Settings

The *Export data Settings submenu* is 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

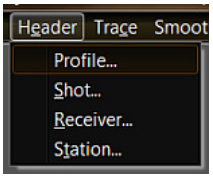
Export dead traces to GeoTomCG .3DD Export dead/unpicked traces to GeoTomCG .3DD, with first break pick -1. Uncheck to skip.

Gather traces by common receiver station Sort traces by common receiver (primary key) and shot station (secondary key), for GeoTomCG.3DD export

Export receiver coordinates to .3DD and .LST Export receiver coordinates shown in *Header|Receiver* to .3DD and .LST. Uncheck to export receiver station coordinates.

Header menu

The *Header menu* offers these commands :



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

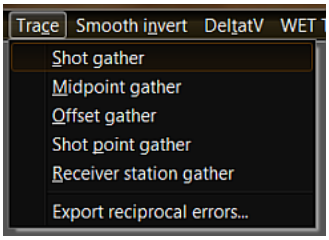
Shot Browse shot headers for shots imported into database. Edit shotpoint offsets and *Trigger delay*.

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. Remove trigger jitter.

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.

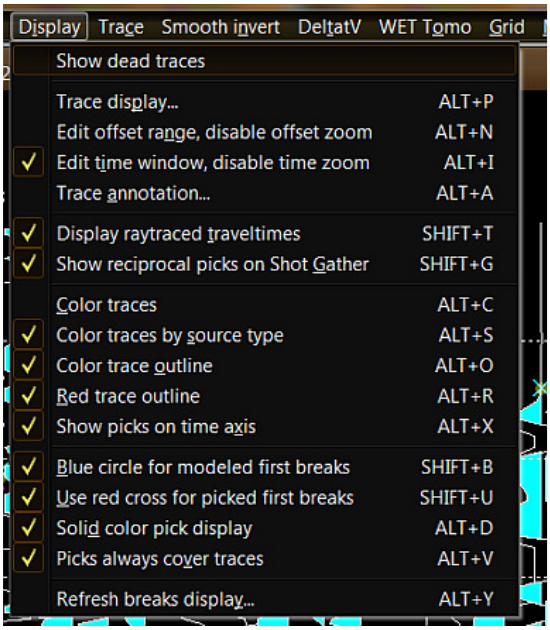
Shot point gather Display all traces recorded at one shotpoint. Pick first breaks for shear waves, filter trace signal.

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

Export reciprocal errors... Compute and export reciprocal traveltime picking errors to ASCII .ERR file. Import the .ERR file into Microsoft Excel and sort by any column.

Display menu

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



Show dead traces Show dead traces without recorded seismograph data. Uncheck to skip dead traces when displaying and picking traces

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 trace gather section.

Display raytraced traveltimes Display raytraced traveltimes in trace gather display

Show reciprocal picks on Shot Gather Show your reciprocal picks on Trace|Shot gather display. Lets you quality-control your picks. First export reciprocal picking errors to .ERR file via Trace|Export reciprocal errors and update database.

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

Blue circle for modeled first breaks Use blue circle for display of modeled first breaks. Uncheck to use blue cross instead.

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.

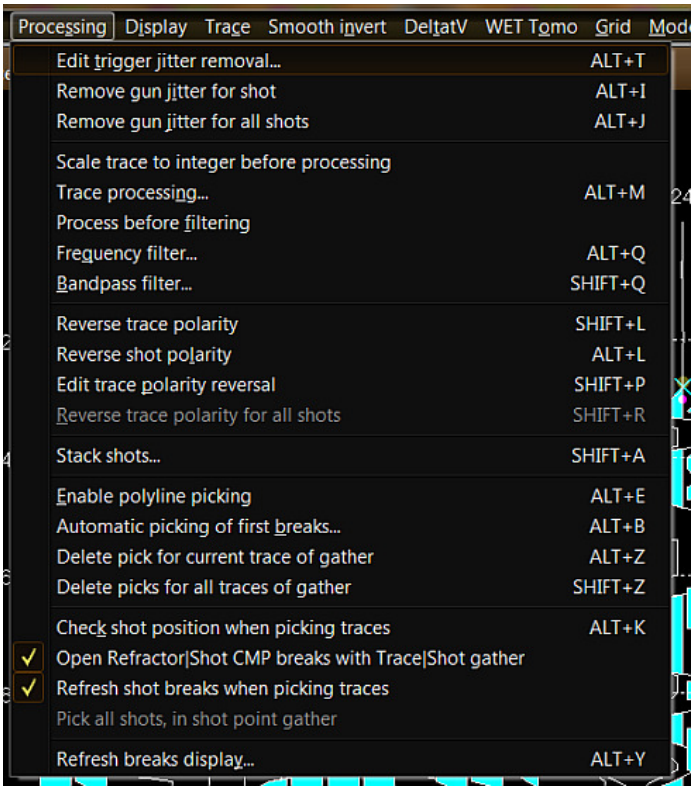
Solid color pick display Display first break pick bitmap with AND operator instead of XOR operator. Slows down trace display refresh when picking traces. Disables automatic picking.

Picks always cover traces First break picks are displayed in separate loop, after all traces have been shown. Slows down trace gather display.

Refresh breaks display Refresh the *Refractor|Shot breaks* or *Refractor|Shot CMP breaks* window if this is currently opened, using your latest first break picks.

Processing menu

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



Edit trigger jitter removal Edit Trigger Jitter removal settings

Remove gun jitter for shot Remove trigger jitter for currently displayed shot in *Trace|Shot gather* using Trigger jitter removal settings

Remove gun jitter for all shots Remove trigger jitter for all shots in *Trace|Shot gather* using current Trigger jitter removal settings

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 in Trace processing dialog

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

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.

Edit trace polarity reversal Edit parameters for shot trace polarity reversal. Specify range of traces/channels to be reversed.

Reverse trace polarity for all shots Reverse trace polarity for all imported shots. Use settings from *Edit trace polarity reversal* dialog. Available with Pro version only.

Stack shots... Stack two imported shots, in profile database. Show resulting stacked shot in *Trace*|*Shot gather*.

Enable polyline picking Show polyline segments, allow picking segments with right mouse key for semi-automatic first break picking. Disables solid pick display.

Automatic picking of first breaks... Automatic first break picking

Delete pick for current trace of gather Delete first break pick for current trace of trace gather displayed. Navigate traces with left/right arrow keys. Use SHIFT+Click shortcut to select a trace and delete its pick in one operation.

Delete picks for all traces of gather Delete all first breaks for currently displayed shot and refresh display. Use SHIFT+Z shortcut.

Check shot position when picking traces Check shot position when picking traces in *Trace*|*Shot gather* display

Open Refractor*|*Shot CMP breaks with Trace*|*Shot gather Open Refractor menu *Shot CMP breaks* instead of *Shot breaks* display when user selects *Trace*|*Shot gather* command.

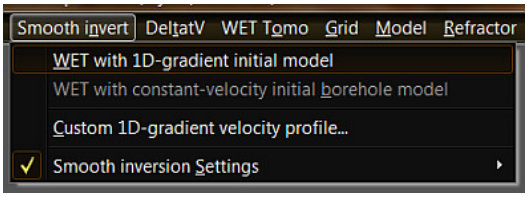
Refresh shot breaks when picking traces Refresh shot breaks display when picking traces in *Trace*|*Shot gather* display

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 previously with *Refractor* menu item

Smooth invert menu

The *Smooth invert menu* 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.

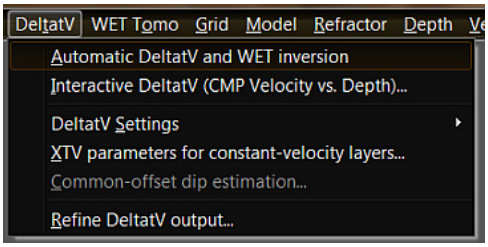
WET with constant-velocity initial borehole model Determine constant-velocity starting model for borehole survey. Run 2D WET inversion.

Custom 1D-gradient velocity profile... Use custom 1D gradient velocity profile to generate GRADIENT.GRD starting model. Set limits of starting model. Force velocity for constant-velocity starting model for *Line type* **`Borehole spread/line`**.

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 using default settings. Run 2D WET inversion with default parameters.

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

DeltatV Settings Edit DeltatV settings for above DeltatV inversion

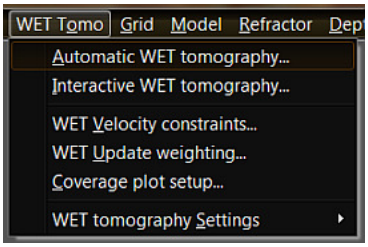
XTV parameters for constant-velocity layers... Edit XTV parameters for DeltatV & XTV inversion

Common-offset dip estimation... Edit parameters for estimation of dip of common-offset sorted traveltime curves and for improved DeltatV velocity estimation with Pro license

Refine DeltatV output Select a Surfer® .GRD file obtained from previous DeltatV or WET inversion for the same line. 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.

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. Plot wavepath weights summed over all wavepaths instead of number of wavepaths per pixel.

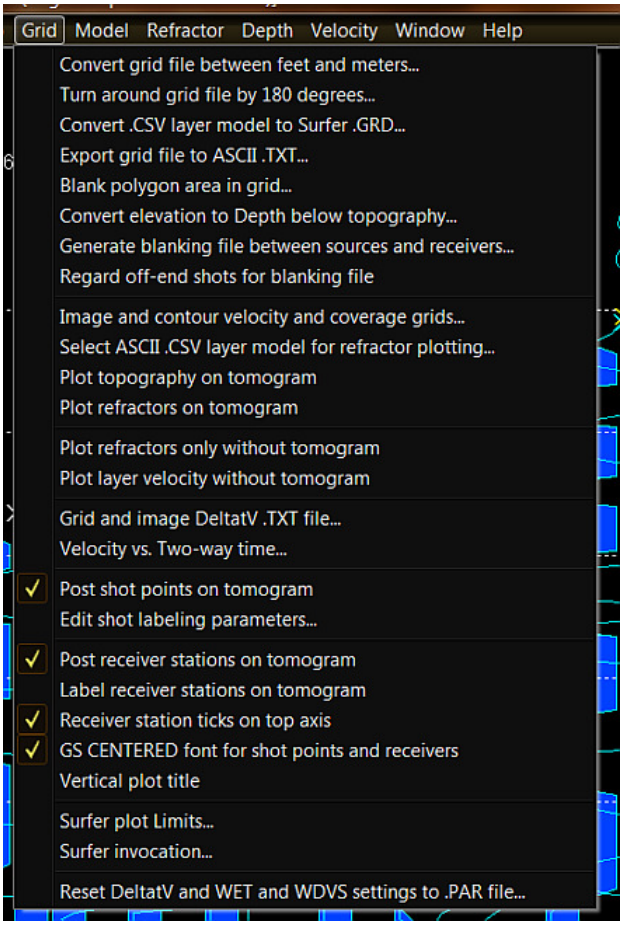
WET tomography Settings|Blank Specify blanking for above WET inversion

WET tomography Settings|Write Write result files to disk during or at end of WET inversion. *Keep WET smoothing record in database* lets you keep the WET smoothing record in database when changing grid cell size. Uncheck to delete smoothing record at this time.

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

Generate blanking file between sources and receivers Write *blanking file* for area between sources and receivers. Use for marine surveys with sources above receiver spread.

Regard off-end shots for blanking file Regard off-end shots when generating *blanking file*. May not work with strong topography.

Image and contour velocity and coverage grids... Image and contour VELOITXY.GRD & matching COVERGXY.GRD

Select ASCII .CSV layer model for refractor plotting... Select layer model .CSV with refractors

Plot topography on tomogram Plot topography from above .CSV on .GRD selected with *Image and contour...*

Plot refractors on tomogram Plot refractors from above .CSV on .GRD selected with Image and contour...

Plot refractors only without tomogram Plot refractors from .CSV only without tomogram, with Image and contour...

Plot layer velocity without tomogram Plot layer velocity only from .CSV without tomogram, with Image and contour...

Grid and image DeltatV .TXT file... Call Surfer to grid and image .TXT file with pseudo-2D DeltatV inversion results

Velocity vs. Two-way time... Write ASCII .TWT file listing velocity vs. two-way time for selected .GRD tomogram

Post shot points on tomogram Post shot point symbols on tomogram for .GRD selected with *Image and contour...*

Edit shot labeling parameters… Edit shot labeling parameters : label shots, stack shot labels at same inline offset, determine vertical shot label offset.

Post receiver stations on tomogram Post receiver symbols on tomogram for .GRD selected with Image and contour...

Label receiver stations on tomogram Label receiver stations on tomogram for .GRD selected with Image and contour...

Receiver station ticks on top axis Check to show station numbers on Surfer tomogram plots. Edit in *Grid|Surfer plot Limits*. Uncheck to show horizontal inline offset from first profile receiver.

GS CENTERED font for receiver Plot receivers using Surfer font GS CENTERED or GSI Default Symbols font

Vertical plot title Plot plot title vertical on left side of tomogram. Uncheck to plot title horizontally on top of tomogram.

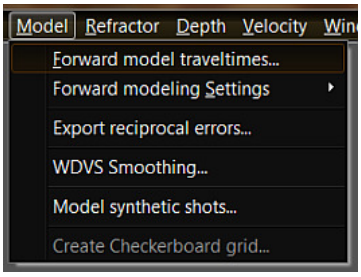
Surfer plot Limits... Edit Surfer plot limits: offset, elevation and velocity limits for velocity and coverage plots. Also edit size of plot plus size and labeling of color scale bar.

Surfer invocation... Select Scripter .EXE for calling into Golden Software Surfer via .BAS scripts

Reset DeltatV and WET settings to .PAR file... Reset DeltatV, Smooth invert & WET settings to values in .PAR file matching name of selected .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

Normalize RMS error with maximum picked time Normalize absolute RMS error with maximum picked time. Uncheck to normalize with averaged picked time.

Model each receiver not receiver stations Check to forward-model traveltimes at receiver coordinates as shown in Header|Receiver. Uncheck to forward-model at receiver station coordinates shown in Header|Receiver.

Export reciprocal errors… Export of reciprocal traveltime picking errors to ASCII .ERR file with columns listing absolute reciprocal error in ms and relative error in percent. Sort this .ERR file in Microsoft Excel by any column to identify bad shots or receivers.

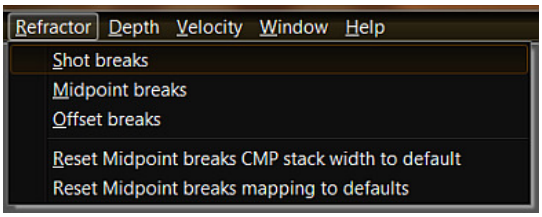
WDVS Smoothing… Edit WDVS : Wavelength-Dependent Velocity Smoothing. See Zelt, C. A. and J. Chen, Frequency-dependent traveltime tomography for near-surface seismic refraction data, Geophys. J. Int., 207, 72-88, 2016.

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 :



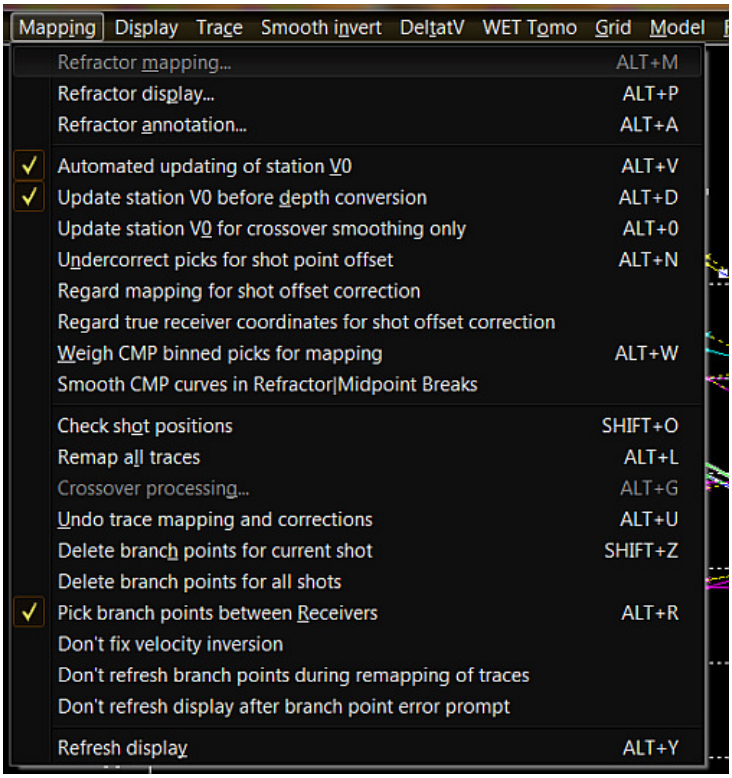
Shot breaks Display shot-sorted traveltime curves. Select ***branch points*** delimiting refractors to map traces to refractors.

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.

Mapping menu

The *Mapping menu* is shown when you display a Refractor time 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 from inline shot station.

Regard true receiver coordinates for shot offset correction Regard individual receiver coordinates shown in *Header|Receiver* dialog when correcting first breaks for offset of shot point from receiver line. Uncheck to use averaged receiver station coordinates instead.

Weigh CMP binned picks for mapping Weigh CMP binned picks for mapping of traces to refractors, in *Refractor|Midpoint breaks display*. Uncheck if noisy picks or inhomogeneous subsurface.

Smooth CMP curves in Refractor|Midpoint breaks Smooth CMP-sorted and stacked traveltime curves in *Refractor|Midpoint breaks display*. Use for high-coverage, dense and long lines.

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. Use ALT+G shortcut directly after mapping traces to refractors.

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. Use SHIFT+Z shortcut.

Delete branch points for all shots Delete branch points for all shots in profile and refresh display. First backup your branch points with *File|Export header data|Export refractor branches to .BRN* .

Pick branch points between receivers Toggle this option to pick and display branch points between receivers or on receivers as appropriate.

Don't fix velocity inversions Skip automatic fixing of velocity inversions between overburden and basement refractors for 3-layer case when mapping first breaks to refractors in *Refractor|Shot breaks* .

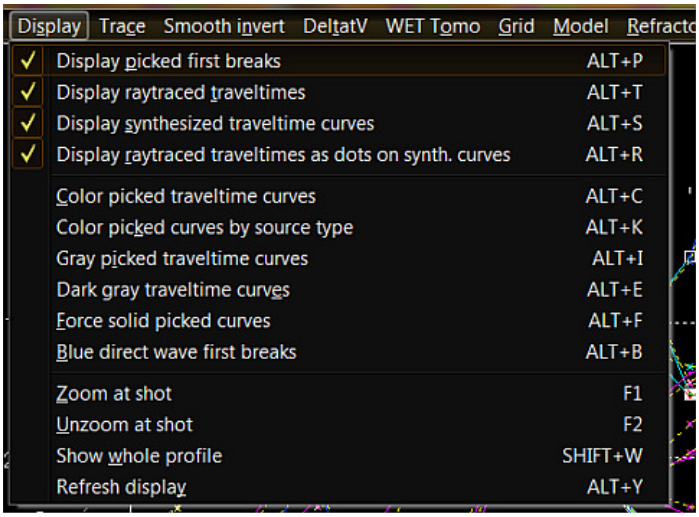
Don't refresh branch points during remapping of traces Skip redisplay of branch points when remapping traces to refractors for all shots with ALT+L in *Refractor|Shot breaks* display.

Don't refresh display after branch point error prompt Skip redisplay of *Refractor|Shot breaks* after branch point error prompt when remapping traces to refractors for all shots with ALT+L.

Refresh display Refresh breaks display

Refractor display menu

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



Display picked first breaks Display user-picked first breaks in *Shot breaks* section

Display raytraced traveltimes Display forward-modeled traveltimes in *Shot breaks* section.

Display synthesized traveltime curves Display synthesized traveltime curves in *Shot breaks section*

Display raytraced traveltimes as dots on synth. curves Display forward-modeled picks as small dots on synthesized traveltime curves if shown 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*.

Force solid picked curves Force drawing of picked traveltime curves with solid pen. Uncheck to use dotted pen at gaps (unpicked or missing traces) in curve.

Blue direct wave first breaks Color direct wave (weathering layer) first breaks in blue instead of orange in *breaks display*.

Zoom at shot Zoom *Shot breaks* display at currently selected shot.

Unzoom at shot Unzoom *Shot breaks* display at

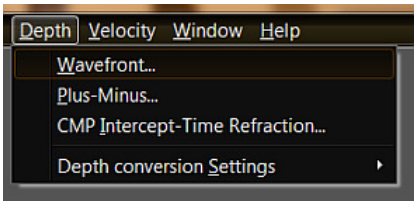
currently selected shot.

Show whole profile Redisplay *Shot breaks* section showing all profile receiver stations.

Refresh display Refresh breaks display.

Depth menu

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



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

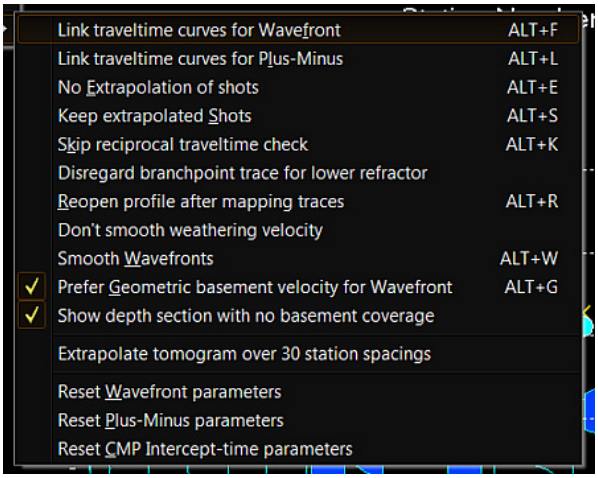
Plus-Minus... Layer-based refraction interpretation using Hagedoorn's Plus-Minus method

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

Depth conversion Settings

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



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.

Keep extrapolated Shots Don't delete extrapolated .ASC shot files in ...\EXTRAPOL subdirectory. Leave unchecked to avoid importing stale extrapolated shots.

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

Don't smooth weathering velocity Don't laterally smooth weathering velocity v0 for layered refraction interpretation

Smooth Wavefronts Smooth wavefronts for Wavefront method interpretation. Helps with noisy first break picks. Use *Base filter width [station nos.]* setting specified in *Depth|Wavefront* display with ALT+P.

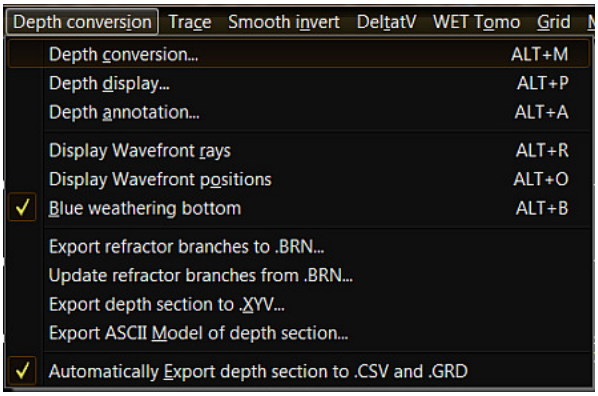
Prefer geometric basement velocity for Wavefront Determine basement refractor velocity from recording geometry (Jones and Jovanovich 1985). Uncheck with strong topography and recording geometry errors to average forward with reverse velocity obtained from traveltimes reduced to basement refractor (Brueckl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

Show depth section with no basement coverage Show depth section even with no basement coverage. Press ALT+M and decrease *Base filter width* and press ENTER to see if this helps to determine the basement refractor.

Extrapolate tomogram over 30 station spacings Extrapolate starting models and WET tomograms over 30 station spacings instead of two. Shots offset up to 30 stations from first/last profile receiver are used for WET inversion. Alternatively extrapolate tomograms in *Header|Profile*.

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 refractor branches to .BRN… Export branch points and refractor branches (refractor start+end in channel nos.) for all shots to .BRN ASCII file

Update refractor branches from .BRN... Update branch points and refractor branches from .BRN file

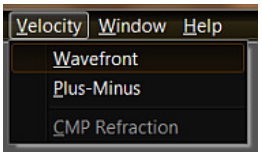
Export depth section to .XYV... Export refractors to ASCII .XYV with station x/y coordinates, refractor elevations and velocities of current depth section

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 just computed depth section to .CSV and layered .GRD starting model in LAYRTOMO subdirectory, image starting model in Surfer and prompt to run ***WET inversion*** after time-to-depth conversion. Click *No* button in WET continuation prompt and press ALT+M in depth section window to edit ***model parameters*** : refractor smoothing etc.

Velocity menu

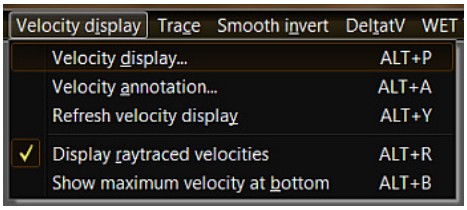
The *velocity menu* offers these commands once time-to-depth conversion via ***Depth menu*** item has been done :



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

Velocity display menu

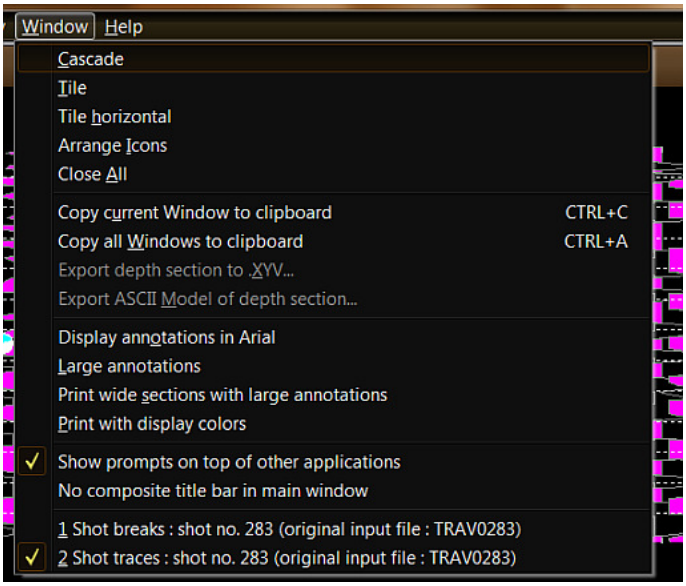
The *Velocity display menu* is shown once you open a velocity section with ***Velocity menu*** item and offers these commands :



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

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

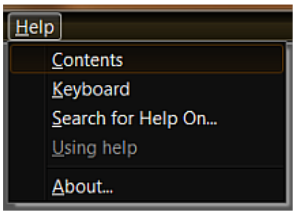
on screen

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

About... Rayfract(R) software version description and licensing information plus Copyright notices

Introduction

RAYFRACT® is a Windows® 32-bit refraction tomography software that works just fine under Windows 7/8/10/11 64-bit Pro and is suited for processing and interpretation 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.

Since Version 2.51 released in 2004 we offer our fail-safe Smooth inversion option (Sheehan et al. 2005) for fully automated determination of a 1D-gradient initial model and subsequent refinement with WET tomography processing.

Always first run our Smooth inversion once you have imported your shots and picked or imported first break picks. See chapter Smooth inversion.

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 https://rayfract.com/tutorials/NORCAL14.pdf and https://rayfract.com/tutorials/P6.pdf .

1.5D DeltatV inversion (Gebrande and Miller 1985; Gebrande 1986) models diving waves and 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

https://rayfract.com/tutorials/ot0608.pdf and https://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.

XTV inversion (Winkelmann 1998) allows modeling of sudden apparent velocity increase in CMP sorted traveltime curves and extends the DeltatV gradient layer inversion (Gebrande 1986) with Dix inversion and Intercept Time inversion. These additional inversion methods allow the **modeling of constant-velocity layers without internal vertical gradient.**

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

The **resolution of finite-frequency traveltime tomography using Fresnel volumes is about one wavelength**. See https://library.seg.org/doi/abs/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 https://rayfract.com/SAGEEP2011_BlindRefraction.pdf & our tutorial https://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.** 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) as well.** 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

https://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

https://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

https://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 https://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 https://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

https://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 https://rayfract.com/tutorials/riveral8.pdf and https://rayfract.com/samples/GEOXMERC.pdf . **Use Trace menu item Export reciprocal errors...** to compute and export reciprocal traveltime picking errors to ASCII .ERR file. Import the .ERR file into Microsoft Excel and sort by any column.

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

https://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

https://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

https://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

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

https://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

https://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

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

. For a description of Smooth inversion and WET parameters and options see https://rayfract.com/SAGEEP10.pdf . For tutorials showing how to identify bad picks and correct reciprocal picking errors see https://rayfract.com/tutorials/riveral8.pdf and https://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. **Use Trace menu item Export reciprocal errors...** to compute and export reciprocal traveltime picking errors to ASCII .ERR file. Import the .ERR file into Microsoft Excel and sort by any column.

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

https://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

https://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 https://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 allow 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 https://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 https://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 https://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.

https://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.

https://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 https://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 https://rayfract.com/tutorials/mdw2011.zip with mdw2011.hdr batch file for batch import with tutorial https://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 https://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 32 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 https://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 https://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 https://rayfract.com/tutorials/bulgatrl.pdf showing systematic variation of *WET wavepath width* to explore non-uniqueness of the solution space.

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

Tutorial https://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 https://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

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

https://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

https://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

https://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

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

to update your Rayfract(R) installation.

Our latest tutorial

https://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

https://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

https://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

https://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

https://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 https://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

https://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 9 to 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 https://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 9 to 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 https://rayfract.com/tutorials/sageep11_smooth50.pdf and https://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 August 2018 supports calling **Golden Software Surfer 9 to 14 and Surfer 15.** See updated chapter Calling Surfer.

We now regard ***File|Import Data Settings|Allow missing traces for SEG-2, SeisImager, SeisOpt, Gremix and .3DD files*** when importing SEG-2 files. Tested with our sample LINE14 profile with *Default spread type* 10: 360 channels and *Header|Profile|Station spacing* of 2.5m. You need to check SEG-2 import setting *Receiver Coordinates specified in .DAT or .SG2 file* so our import routine regards *File|Import Data Settings|Allow missing traces for SEG-2, SeisImager, SeisOpt, Gremix and .3DD files* when importing SEG-2 files with *File|Import Data...* .

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

https://rayfract.com/tutorials/11REFR.pdf and https://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. See our new tutorial

https://rayfract.com/tutorials/tunnel16.pdf

showing imaging of tunnel excavation disturbed zone (EDZ) using a **circular receiver spread** planted on the tunnel wall.

Our new tutorial https://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 https://rayfract.com/tutorials/Slope1.ppt shows how to interactively improve your first break picks. See https://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. And our SEG-2 import features more robust scanning of string format subblocks when importing SEG-2 files. Helps with non-standard **`OYO CORPORATION INSTRUMENT PICKWIN95 .DAT`** files.

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

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

Our new tutorial https://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.

Version 3.36 released in June 2020 supports calling **Golden Software Surfer 9 to 16 & 17 &18**. See updated chapter Calling Surfer.

We ported our software from Visual C++ 2005 to **Visual C++ 2017 compiler** for improved conformance with Microsoft Windows 10/11 and increased performance.

Version 3.36 offers better support for marine streamer refraction surveys. Check *File|Import data Settings|Allow missing traces* and check *File|SEG-2 Settings|Receiver Coordinates specified in .DAT or .SG2 file* or uncheck *File|SEGY import settings|No receiver coordinates specified in .SGY file*.

Now check *File|Import data Settings|Adjust Receiver station coordinates* to **re-center each receiver station at end of import to average of coordinates for all receivers linked to this station**. Use *File|Import Data|Default spread type* **`10: 360 channels`** with these import settings to import irregularly spaced streamer data in formats SEG-2, SEGY, Geogiga DWTOMO .TTX, PlotRefa .VS, Optim SeisOpt and GeoTomCG .3DD . Set *Header|Profile|Station spacing* to smallest distance between two adjacent receivers. We assume that adjacent receivers are approximately separated by an integer multiple of this spacing.

Shot pos. [station no.] & *Layout start [station no.]* are determined automatically based on source and receiver x/y/z specified in the SEG-2 traces headers with SOURCE_LOCATION & RECEIVER_LOCATION. Check *File|Import Data Settings|Use bent line inline offset for shot pos. and layout start* to use cumulative inline offset along bent line (regarding receiver x/y/z coordinates) to determine *Shot pos.* and *Layout start* in station numbers, for SEG-2 and SEGY import.

Use *Grid|Generate blanking file between sources and receivers* to generate a Surfer format *.BLN blanking file* with blanking polygon of the area between all sources and receivers. Use e.g. with marine refraction surveys for water-layer blanking with sources positioned above receivers.

Specify negative shot hole depth in *Header|Shot|Depth* control or in **`SHOTPTS.SHO`** to move up the sources above the receiver spread. The *blanking velocity* in header column no. 3 of the .BLN file is set to 1,500 m/s per default. Select this .BLN blanking file with button *Select blanking file* in WET Tomo|WET velocity constraints dialog. Check boxes *Blank initial model* & *Polygon blanking active*.

Also check *WET Tomo|WET tomography Settings|Blank|Regard negative shot depth* to disable default WET blanking above topography during DeltatV & WET inversion & forward modelling.

We have improved DeltatV static corrections. We now use *Surface-consistent corrections* per default instead of CMP gather datum corrections. We decreased the default width of *Topography filter* used for surface-consistent corrections, from previous 100 to new 15 stations. This prevents over-correction of traveltimes in case of strongly undulating topography. Try disabling static corrections completely with option *No static corrections* in DeltatV|Interactive DeltatV|Static Corrections dialog.

We now allow optional display of station numbers on top axis of Surfer tomogram plots. Check *Grid|Receiver station ticks on top axis*. On bottom axis we still always show horizontal inline offset from first profile receiver.

Our Pro version now allows writing & reading Surfer .GRD files with up to 100,000,000 grid cells. Force the *grid cell size* in Header|Profile dialog. Our Standard license allows up to 640,000 grid cells.

Our new tutorial https://rayfract.com/tutorials/SR6.pdf shows WET inversion of shallow marine refraction data using multiple starting models. We show water layer blanking with sources above the refraction spread. Also we show SEG-2 import of Geometrics .DAT files. We describe how to add source and receiver x/y/z coordinates to SEG-2 trace headers using the SEG2_EDIT utility, and how to generate and edit the *.BLN blanking file*.

Our tutorial https://rayfract.com/tutorials/P6.pdf shows fracture zone detection in bedrock in Norway. Compares multiple starting models for WET inversion. Shows .HDR batch import of

ABEM SEG-2 .SG2 files and how to specify *Layout start* and *Shot pos.* in station numbers in the .HDR batch file.

Our new tutorial https://rayfract.com/tutorials/TYLERLN1_2019.pdf shows reprocessing of Tyler sinkhole data. Our interpretation matches GeoTomo LLC interpretation available at https://www.slideshare.net/oncel/sinkhole-geophysics.

Updated Walkaway VSP tutorial available at https://rayfract.com/tutorials/Walkaway19.pdf .

Ostrowski & Lasocki show impressive landslide imaging at https://www.researchgate.net/publication/330207269_Massive_Landslide_Characterization_Using_Refraction_Seismic_and_Electric_Tomography (EAGE NSG Porto 2018).

Ostrowski et al. show fault zone imaging at https://www.researchgate.net/publication/307594394_Fault_Zone_Imaging_with_Seismic_Refraction_Tomography (EAGE NSG 2016).

Capizzi et al. show Statistical approach for cavity detection using seismic refraction and electrical resistivity data (Capizzi et al. Univ. Palermo 2017) at https://www3.ogs.trieste.it/gngts/files/2017/S32/Presentazioni/1430-capizzi.pdf .

Jacob et al. show Mapping sand and clay-filled depressions on a coastal chalk clifftop using gravity, SRT and borehole data for landslide hazard assessment in Normandy, France (Engineering Geology 2018). See

https://hal-brgm.archives-ouvertes.fr/hal-01898945/file/Mapping%20sand%20ad%20clay-filled%20depressions.pdf .

Liu et al. show Constraints on the shallow deformation around the Main Frontal Thrust in central Nepal from refraction velocities (Tectonophysics Feb 2020) . See https://doi.org/10.1016/j.tecto.2020.228366 .

Version 4.01 released in May 2021 supports calling **Golden Software Surfer 9 up to 21**. See updated chapter Calling Surfer.

We now support export of reciprocal traveltime picking errors to ASCII .ERR file with space character separated columns listing absolute reciprocal error in ms and relative reciprocal error in percent. See **Whiteley J. et al. 2020**. Landslide monitoring using seismic refraction tomography - The importance of incorporating topographic variations. Engineering Geology 2020. https://www.researchgate.net/publication/339280163

Also we now support WDVS Wavelength-Dependent Velocity Smoothing. See **Zelt, C. A. and J. Chen, Frequency-dependent traveltime tomography for near-surface seismic refraction data, Geophys. J. Int., 207, 72-88, 2016**. See https://dx.doi.org/10.1093/gji/ggw269 and https://www.researchgate.net/publication/305487180_Frequency-dependent_traveltime_tomography_for_near-surface_seismic_refraction_data .

We use multiple CPU cores in parallel for fast WDVS velocity smoothing. We demonstrate WDVS smoothing in our updated tutorial https://rayfract.com/tutorials/epikinv.pdf showing interpretation of Broad Epikarst synthetic data (Sheehan et al. 2005) and in our VSP constrained refraction tutorial https://rayfract.com/tutorials/11REFR.pdf . See more updated tutorials showing WET inversion using WDVS :

https://rayfract.com/tutorials/epikinv.pdf
https://rayfract.com/tutorials/camp1.pdf
https://rayfract.com/tutorials/11REFR.pdf
https://rayfract.com/tutorials/jenny13.pdf
https://rayfract.com/tutorials/NORCAL14.pdf
https://rayfract.com/tutorials/Aaknes-1.pdf
https://rayfract.com/tutorials/sageep11_16.pdf
https://rayfract.com/tutorials/rjj9to10.pdf
https://rayfract.com/tutorials/ot0608.pdf
https://rayfract.com/tutorials/SR6.pdf
https://rayfract.com/tutorials/Palmfig4.pdf
https://rayfract.com/pub/final.pdf

WDVS can improve the resolution and give a sharper image of layer boundaries in WET tomograms if WDVS parameters are tuned correctly. You need to limit the *max. WET velocity* in WET Tomo|Interactive WET tomography main dialog to suppress a bias towards too high basement velocities with WDVS enabled and with too low *WDVS frequency*.

Dr. Parsa Bakhtiari Rad working at University of Mississippi, The National Center for Physical Acoustics (NCPA) shows Tunnel detection using Frequency-Dependent Traveltime Tomography in his slides available at https://rayfract.com/pub/final.pdf .

We have added a new dialog **DeltatV|Common-offset dip estimation** which is enabled for our Pro license version only. This dialog lets you specify parameters for estimation of dip of common-offset sorted traveltime curves and for better estimation of true refractor velocity based on *apparent CMP velocity* and this offset dip during pseudo-2D DeltatV inversion. With steeply dipping refractors the true refractor velocity deviates significantly from the apparent CMP velocity measured on CMP sorted traveltime curves. Using the dip of common-offset sorted traveltime curves we compute improved estimates for the true refractor velocity (**Gebrande and Miller 1985; Gebrande 1986**).

We ported our software from Visual C++ 2017 to **Visual C++ 2019 compiler** for further improved conformance with Microsoft Windows 10 and increased performance.

Version 4.01 comes with improved routine for importing SEGY .SGY files. We now allow importing .SGY files with missing traces, with *File|Import data Settings|Allow missing traces* checked and with *File|SEGY import settings|No receiver coordinates specified in .SGY file* unchecked. Also we now regard shot x/y/z and receiver x/y/z specified in SEGY .SGY traces headers when importing .SGY.

We have added ***File|Import Data|Reverted spread layout*** checkbox in updated Import Data dialog. Use for SEG-2 and SEGY import with channel number decreasing with increasing inline offset along profile.

Check ***Header|Profile|Force first receiver*** and edit ***First receiver [station number]*** in our updated Profile dialog.

File|Import data Settings|Extrapolate receiver line coordinates is now unchecked per default when creating a new profile database with File|New Profile or when resetting import settings to their default values with *File|Import data Settings|Reset all Import Data settings to default value* .

We describe our updated Model|Create Checkerboard grid dialog in chapter Forward model traveltimes. This dialog is available with our Pro software version only.

Copying minimized WET smoothing settings optimized for one profile to another profile is not recommended and not supported. Default full WET smoothing filter size and default wavepath width are determined automatically based on grid dimensions (grid cell size, number of columns & rows), velocity distribution in the starting model and maximum picked time. Since these parameters are specific to each profile and starting model you need to always start with our Smooth inversion. Next you can optionally try step-wise decreasing of WET smoothing, for consistently picked traveltimes and correctly specified recording geometry.

We now regard ***Grid|GS CENTERED font for shot points and receivers*** option when plotting source symbols (as red circles instead of red triangles). To install updated **.BAS** Surfer scripts download & run updated installer https://rayfract.com/common/Ray336_Scripts.exe on PC where you installed our version 3.36 or 4.01 software.

Version 4.01 completes 10 WET runs for our https://rayfract.com/tutorials/1_1D.pdf in about two minutes on 2020 macMini with 3.0 GHz 6-Core Intel Core i5 processor, using 4 cores in Parallels Desktop 16. This takes about 3 minutes on 2017 iMac with 2.3 GHz Intel Core i5 processor using 4 cores, in Windows 7 64-bit Pro virtual machine running under Parallels Desktop 16.

Uncheck ***File|Import Data Settings|Assume regular/equidistant receiver spacing*** to better support import of irregularly spaced receivers e.g. with GeoTomCG .3DD import into Borehole spread/line. Uncheck to minimize the offset between receiver coordinates and receiver stations as shown in *Header|Receiver*. Check if all receiver spacings are multiples of *Header|Profile|Station spacing*. This option is unchecked per default. Check to restore import behavior as with older builds.

Before importing SEG-2/SEGY/GeoTomCG .3DD trace files with irregular receiver spacing check *File|Customize spread types* items *Customize Default spread type* and *One spread per shot*. This allows more accurate modeling of recording geometry and receiver positions as shown in *Header|Receiver*. Please note that you cannot open such a profile database with older version 3.36 or 3.35 builds of our software, once you import shots with these *Customize spread types* items checked.

Our https://rayfract.com/tutorials/Aaknes-1.pdf tutorial shows Smooth inversion of dense refraction survey with uncertain picks due to low signal-to-noise ratio and with highly uncertain recording geometry. We show WET inversion using both the default 1D-gradient starting model and Plus-Minus method layered refraction starting model. We increase the default WET wavepath width from 6 to 12 percent for more robust inversion with this noisy data set. Also we show improvement of resolution using Wavelength-Dependent Velocity Smoothing (WDVS; Zelt and Chen 2016).

Our updated https://rayfract.com/tutorials/SR6.pdf tutorial shows trigger jitter removal for shallow marine refraction surveys. This dialog is available with our Pro version only. Also we show improvement of resolution using WDVS.

View our **SAGEEP 2021 slides** on **Improving the resolution of Fresnel volume tomography with Wavelength-Dependent Velocity Smoothing** at https://rayfract.com/pub/SAGEEP%202021%20slides.pdf .

Carollo et al. https://doi.org/10.1016/j.jappgeo.2020.104069 describe Joint interpretation of seismic refraction tomography and electrical resistivity tomography by cluster analysis to detect buried cavities (JAG July 2020). See also Capizzi et al.

https://www3.ogs.trieste.it/gngts/files/2017/S32/Presentazioni/1430-capizzi.pdf (Univ. Palermo 2017).

Colombo et al. https://doi.org/10.1190/geo2016-0018.1 nicely explain the 3D CMP refraction recording geometry and apparent velocity processing using CMP bins (SEG Geophysics 2016). This has been described earlier e.g. by Thomas Ruehl 1995 https://doi.org/10.3997/1365-2397.1995005 : Determination of shallow refractor properties by 3D-CMP refraction seismic techniques. EAGE First Break 1995, volume 13, pp. 69-77.

Hutchinson et al. https://www.thggeophysics.com/wp-content/uploads/2019/11/69-Refraction-Paper-in-the-Journal.pdf show Stratigraphic Analysis with Refraction Tomography (GSA 2019).

Ortega Perez et al. https://dial.uclouvain.be/pr/boreal/object/boreal:182845 use SRT and OSL (Optically Stimulated Luminescence) to determine evolution of water storage capacity for the four Melque reservoirs in central Spain during the period A.D. 600–1900 (Geoarcheology 2017). Refraction profile sediment depths were cross-checked by manual augering.

Review Geophysical investigations of pyroclastic density current processes and deposit properties at Mount St. Helens, Washington (Cleveland Gase Thesis https://scholarworks.boisestate.edu/td/1297/ Boise State Univ. 2016).

Nielson https://scholarworks.boisestate.edu/td/1354/ shows hydrogeophysical imaging of critical zone with ERT and SRT (Master Thesis, Boise State Univ. 2017).

Review Mebrahtu et al. https://doi.org/10.1016/j.geomorph.2020.107382 Tectonic conditioning revealed by seismic refraction facilitates deep-seated landslides in the western escarpment of the Main Ethiopian Rift (Geomorphology 2020).

Alvaro Polin Tornero shows synthetic modeling of cavity in dam in his thesis (Univ. Uppsala 2018). See https://www.diva-portal.org/smash/record.jsf?pid=diva2:1259425 .

Andrea Gomez Casalta compares separate ERT & SRT interpretation with RES2DINV® and Rayfract® with joint inversion using Zond Software ERT & SRT and correlates results with borehole data (Thesis Andrea Gomez Casalta, Institut Cartografic i Geologic de Catalunya 2019). See https://upcommons.upc.edu/handle/2117/345009 .

Barbero and Naldi (2018) show good match between MASW and SRT in landslide area. See https://www.researchgate.net/publication/329126057 .

Version 4.02 released in August 2021 supports calling **Golden Software Surfer 9 up to 22**. See updated chapter Calling Surfer.

We now support exporting reciprocal picking errors to .ERR file with space character separated columns listing absolute reciprocal error in ms and relative reciprocal error in percent. See (Whiteley 2020). Sort this .ERR file in Microsoft Excel by any column to identify bad shots or receivers.

Also we support importing **Geogiga DWTomo .TTX** files with first breaks and recording geometry.

Check *File|SEG-2 import settings|Ignore SEG-2 station numbers in trace headers* to determine source and receiver locations from SEG-2 trace header entries SOURCE_LOCATION and RECEIVER_LOCATION. Use for import of DMT SUMMIT X .SEG2 files. We use this option in our tutorial https://rayfract.com/tutorials/Test21.pdf .

We now offer our trigger jitter removal dialog and menu items also for our Standard license and free trial, not just with our Pro license.

We added button ***Backup times*** to trigger jitter removal dialog. Click to backup station coordinates, shot point coordinates including trigger delay and delay time and first breaks to **COORDS.COR**, **SHOTPTS.SHO** and **BREAKS.LST** in **Backup** subdirectory of currently opened profile.

Also we added button ***Reset receiver coordinates*** in *Header|Receiver* dialog to reset coordinates for all receivers to their linked receiver stations.

We tested version 4.02 of our software with Microsoft **Windows 10 21H1**. We rebuilt version 4.02 with Microsoft **Visual Studio 2019 Version 16.10.4** for improved conformance with **Windows 10 Pro 64-bit**.

We have updated many chapters in this help file including Commands chapter and added more and updated menu screen shots.

Updated https://rayfract.com/tutorials/mdw2011.pdf crosshole survey tutorial describes

- how to determine station numbers for ***Shot pos.*** and ***Layout start*** for import of borehole shots into *Header|Profile|Line type* **`Borehole spread/line`**
- how to generate, edit and apply COORDS.COR and SHOTPTS.SHO files once you imported your SEG-2 shots into the profile
- see also chapter Crosshole survey interpretation

Review our new documentation showing common procedures required for licensing our software with CodeMeter CmStick USB dongles :

- **installation of CodeMeter runtime** at https://rayfract.com/help/CodeMeter_Runtime_Install.pdf
- **generation of license request file** at https://rayfract.com/help/Generate_Rayfract_LicenseRequest.pdf
- **import of license update file** at https://rayfract.com/help/Import_Rayfract_LicenseUpdate.pdf

Our tutorial https://rayfract.com/tutorials/Test21.pdf shows optimal imaging of strongly weathered granitic basement in NSW Australia and import of DMT SUMMIT X ONE .SEG2 files.

Our latest tutorial https://rayfract.com/tutorials/D1P2NO24.pdf shows improved imaging of constructed low-velocity zones in Stillwater model dam (Thesis Leti Wodajo Univ. of Mississippi 2018; Wodajo 2018). We lower the *WET frequency* from default 50Hz to 30Hz and increase the *WET wavepath width* to 30 percent. Also we set WET parameter *Ricker differentiation* to 0 to weight WET velocity update across the wavepath with Ricker wavelet during back-projection of traveltime residuals (Schuster 1993).

We updated instructions in https://rayfract.com/tutorials/sapri12.pdf tutorial showing SeisImager PlotRefa .VS import .

We edited a new .pdf explaining how to download seismic data files and header files needed for our tutorials at https://rayfract.com/help/Download_tutorialData.pdf . Also we give recommendations on how to learn about Rayfract® functionality.

Dr. Parsa Bakhtiari Rad compares near-surface reflection with SRT for imaging of soft soil subsurface (SAGEEP 2021, Univ. of Mississippi). https://www.researchgate.net/publication/352332628_Imaging_of_near-surface_seismic_reflections_using_kinematic_wavefront_attributes

Ross et al. show Seismic refraction investigation of the Strengbach watershed (Vosges Mountains, France) using P and S-wave first-arrival tomography (EOST at Univ. Strasbourg 2017). https://www.researchgate.net/publication/351268607

Fabien-Ouellet shows an integrated approach to shallow seismic interpretation in his paper Using all seismic arrivals in shallow seismic investigations, Journal of Applied Geophysics 2014. https://gfabieno.github.io/bib/Fabien-Ouellet-2014.pdf

Jaramillo Lopez shows correlation between geomechanical properties, number of blows and geophysical data (Thesis Jaramillo Lopez, Universidad Politécnica Salesiana Sede Quito, 2021). https://dspace.ups.edu.ec/handle/123456789/20383

Raul et al. show multi-method geophysical investigation on a very large, slow-moving landslide (EAGE First Break, Aug 2021 issue).https://doi.org/10.3997/1365-2397.fb2021063

Dr. Hector Hinojosa shows using body wave SRT for geotechnical engineering in Karst terrains (Linkedin Nov 2020) at https://www.linkedin.com/pulse/usefulness-body-waves-refraction-tomography-karst-hinojosa-p-g- . He also shows usage of Poisson's Ratio plots to detect water-saturated zones at top-of-bedrock.

Yang et al. (2021) describe First-arrival traveltime inversion of seismic diving waves observed on undulant surface at https://www.researchgate.net/publication/348727672 (Geophysical Journal International 2021) . They apply gradient layer stripping equations described by Gibson et al (1979) and used with our DeltatV method (Rohdewald 2011a. https://rayfract.com/pub/deltatv.pdf; Rohdewald 2011b. XTV inversion. https://rayfract.com/xtv_inversion.pdf) and estimate source and receiver specific velocity gradients to account for strongly undulating topography. Shi et al. (2015) describe the same layer stripping method for 3D refraction interpretation (Journal of Earth Science 2015) at https://www.researchgate.net/publication/282546603 .

Review The Effect of Aspect and Elevation on Critical Zone Architecture in the Reynolds Creek Critical Zone Observatory: A Seismic Refraction Study (Travis Nielson et al. Front. Water, 19 July 2021). https://doi.org/10.3389/frwa.2021.670524

Hartl et al. show tunnel based SRT (University of Leoben, Austria 2019). https://doi.org/10.1007/s00501-019-00912-y

Version 4.03 released in June 2022 supports calling Golden Software ***Surfer 10 up to 25***. See updated chapter Calling Surfer.

Also version 4.03 allows export of refractor branches and branch points to .BRN file and restoring refractor branches and branch points from .BRN file. Also we have added an option ***Update branch points with Plus-Minus*** in Midpoint breaks mapping dialog to automatically update branch points in Refractor|Shot breaks display. With this option checked we update branch points in Refractor|Shot breaks display once you click button Map Traces and next select Depth|Plus-Minus or Depth|Wavefront layered refraction method in Depth menu.

This option ***Update branch points with Plus-Minus*** is reset/unchecked once it has been applied during Time-to-Depth conversion. Next you can optionally edit your branch points in our Refractor|Shot breaks display, remap traces to refractors with ALT+L and redo the Time-to-Depth conversion. Try toggling option Mapping|Pick branch points between Receivers. Backup your branch points with File|Export header data|Export refractor branches to .BRN.

We automatically fix velocity inversions between refractor 1 and refractor 2 for 3-layer case when mapping first breaks to refractors in *Refractor|Shot breaks* with ALT+L with option ***Mapping|Don't fix velocity inversion*** unchecked.

Also we added controls ***limit maximum basement velocity*** and ***Max. basement velocity [m/sec]*** in *Depth|Plus-Minus* and *Depth|Wavefront* sections. Press ALT+M to bring up the *model parameters* dialog.

Also we added an option ***Use above XTV settings for Automatic DeltatV*** in *DeltatV|XTV parameters* dialog. Leave unchecked to force *Gradient model* XTV settings for *Automatic DeltatV inversion*. See Fig. 27 in tutorial https://rayfract.com/tutorials/NGU_G1.pdf .

Review our updated help chapter *Picking first breaks*. We describe how to pick shear-waves on the last two pages, using our *Trace|Shotpoint gather* display.

We renamed DeltatV parameter *DeltatV|Interactive DeltatV|Static Corrections|Weathering crossover* to ***Basement crossover***. This emphasizes that this parameter must not be decreased (from default 10 stations) to avoid over-correction of basement-refracted arrivals to floating datum using too low *overburden velocity* obtained from this crossover value especially with strongly undulating topography and with too wide ***Topography filter*** parameter. See our tutorial https://rayfract.com/tutorials/NGU_G1.pdf Fig. 30.

Our new dialog ***Grid|Edit shot labeling parameters*** allows forcing of the vertical offset between shot labels for shots positioned at same offset.

We now show progress of WET inversion in ***new WET progress dialog*** . Allows early termination of WET with *Cancel* button. The last WET iteration completed is plotted in Surfer.

Our SEG-2 import now supports 64-bit floating point sample format. Tested with ABEM Terraloc Pro 2 .SG2 files. All sample formats are converted to 32-bit floating point format when storing imported traces in the profile database.

Version 4.03 regards Golden Software Surfer limit of max. 32,767 grid columns and max. 32,767 grid rows when generating **.GRD** grid file for initial/starting model for Pro license and with long lines e.g. with marine refraction lines.

Review our new tutorial https://rayfract.com/tutorials/TRA9002_resolution_test.pdf showing ***checkerboard resolution test*** for our sample profile TRA9002 using multiscale Conjugate-Gradient WET inversion with WDVS@250Hz (Wavelength-Dependent Velocity Smoothing, Zelt and Chen 2016).

Version 4.03 prompts to automatically correct any shot station outside the active receiver spread to the nearest active receiver station used to record the shot, during import into *Header|Profile|Line type* `Borehole spread/line`.

Check new version 4.03 option *Model|Model each receiver not receiver stations* to forward-model traveltimes at receiver coordinates as shown in Header|Receiver. Uncheck this option to forward-model traveltime grids at averaged receiver station coordinates shown in Header|Receiver.

Check new version 4.03 option *DeltatV|DeltatV Settings|Regard 3D source-receiver offset for all traces* to use 3D Cartesian distance between source and receiver as offset for DeltatV inversion for all traces. Uncheck to regard 3D distance within 5 station spacings from shot point only and to use station number difference for all other traces. This option may help with bent 2D lines.

We tested version 4.03 of our software with **Microsoft Windows 10 Pro 64-bit 22H2** and Windows 10 Pro 32-bit 21H2 and **Windows 11 Pro 64-bit 22H2**. We rebuilt version 4.03 with Microsoft Visual Studio 2022 Version 17.4.4 for improved conformance with Windows 10 Pro and Windows 11 Pro.

Version 4.04 released in June 2023 offers more options in menu *Refractor|Shot breaks|Display* for display of picked and modeled first breaks. We split *Refractor|Shot breaks|Mapping* menu into *Mapping* and *Display* menus.

Our updated tutorial https://rayfract.com/tutorials/poisson_Surfer23.pdf showing dynamic Poisson's ratio imaging with Surfer 23 now also shows how to ***plot your reciprocal traveltime picks on shot trace gathers***. This lets you quality-control your first break picks and validates your specified recording geometry. We show reciprocal Shot/Channel and reciprocal Offset[m]/CMP station in status bar if the current trace has a reciprocal trace in *Trace|Shot gather* window. Navigate traces with arrow-left and arrow-right keys as usual.

We added new display type ***Refractor|Shot CMP breaks***. First breaks for shot-sorted traces are displayed at their CMP position = (shot pos. + trace pos.)/2 (Brueckl 1987). This makes it easier to recognize reciprocal traveltime picking errors. Also the subsurface geology can be recognized more easily on the traveltime curves than in *Refractor|Shot breaks* display.

We added an option ***Pick all shots*** (Pro license only) to *automatic picking parameters* dialog shown with **ALT+B** in *Trace|Shot gather* display.

Our new dialog *Trace|Shot gather|Processing|**Edit trace polarity reversal*** allows editing the channel range for which the trace polarity is reversed. Reverse all shots imported into your current profile using this channel range setting with command *Trace|Shot gather|Processing|Reverse trace polarity for all shots* available with our Pro version.

We added edit fields *Blanking velocity* and *Blanking percentage* to *WET Tomo|**WET velocity constraints*** dialog plus check boxes to force using these edited values instead of values specified in the selected **.BLN** blanking file during WET inversion.

Duffek et al. describe Origin of block accumulations based on the near-surface geophysics (Open Geosciences, De Gruyter Apr 2023) correlating ERT with our SRT. https://doi.org/10.1515/geo-2022-0468 .

Heng et al. describe Reservoir Dam Safety Study – A Multidisciplinary Approach using ERT, SRT, GPR and FEM correlated with geotechnical borehole cores (EAGE 5th Asia Pacific meeting Taiwan March 2023). https://doi.org/10.3997/2214-4609.202378013 .

Nelliat et al. describe Rock mass characterization and delineation of weak zones in a foundation regime using integrated geophysical methods: a case study from Mangalore, India (Indian Geotechnical Conference 2022, Kochi). https://igc2022kochi.org/Img/FINAL_PAPER/TH-05/TH-05-052.pdf .

Paul et al. describe Subsurface Soil Characterization by Correlating P–wave velocity with engineering properties of soil (16th Symposium on Earthquake Engineering, IIT Roorkee, 2018) correlating SRT P-wave velocity with SPTN-Value. https://www.researchgate.net/publication/346777193 .

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 10/11 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 10/11
- startup our app via desktop icon as usual. Now WET inversion can use up to 1TB 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 https://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.

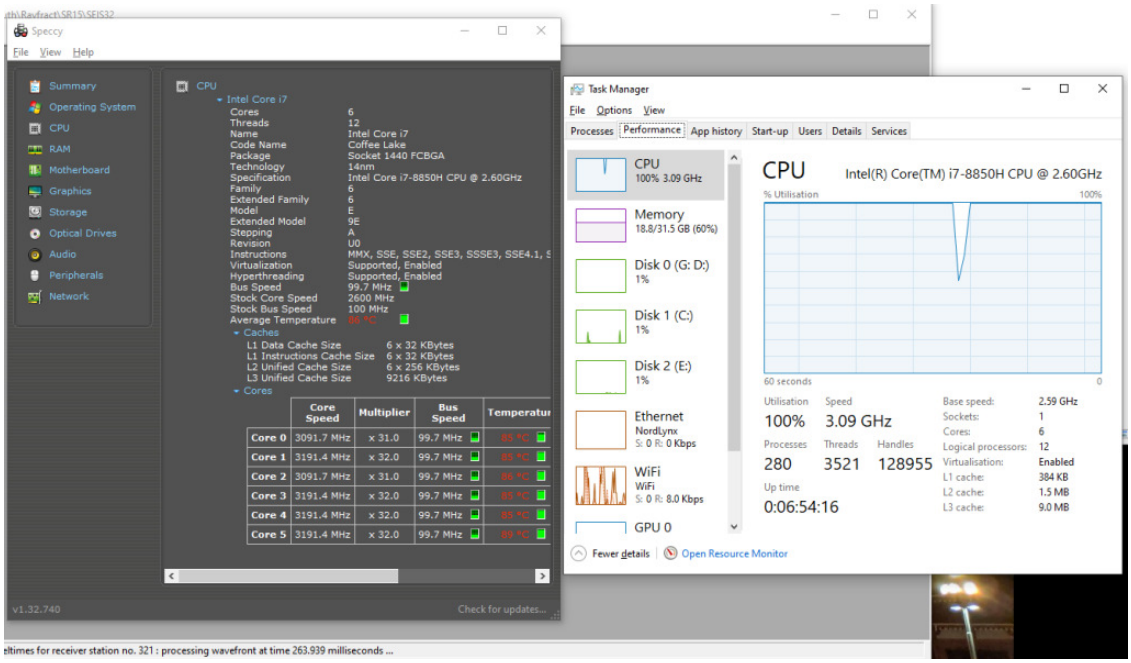
System requirements

To use Rayfract®, you will need the following :

- A 486 (or better) PC running Microsoft® Windows 7, Windows 8 or Windows 10/11, 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 50 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 500 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 to 26 for automatic plotting of tomograms. You may download a free demo from https://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.
- 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.
- Our Standard license can use up to 4GB of RAM under Windows 10/11 64-bit Pro
- Our Pro license can use up to 1TB of RAM under Windows 10/11 64-bit Pro for fast WET

inversion of long/dense lines, caching all traveltime grids instead of needing to swap them to disk .GRD files

- Our Standard license can use up to 4 logical CPU cores in parallel for WET inversion
- Our Pro license can use up to 32 logical CPU cores in parallel for fast WET inversion, using OpenMP multithreading



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 **https://rayfract.com** for tutorials, course notes, application samples, links to theoretical papers, benchmark comparisons etc.

Tutorials available for download on our web site https://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) in many situations later on, especially if subsurface seismic velocity increases gradually with depth. For conventional **layered refraction method interpretation samples** see https://rayfract.com/help/manual.pdf chapter 1.8 and following, https://rayfract.com/tutorials/line2.pdf, https://rayfract.com/pub/SAGEEP11.pdf, https://rayfract.com/tutorials/SAGEEP11_13.pdf, https://rayfract.com/pub/sageep14.pdf ,

https://rayfract.com/tutorials/SR6.pdf, https://rayfract.com/tutorials/NGU_G1.pdf, https://rayfract.com/tutorials/NGU_G4.pdf, https://rayfract.com/tutorials/Line3.pdf, https://rayfract.com/tutorials/3016.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 https://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 tutorials https://rayfract.com/tutorials/NORCAL14.pdf and https://rayfract.com/tutorials/Line3.pdf and https://rayfract.com/tutorials/jenny13_24.pdf and https://rayfract.com/tutorials/3016.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.

Version 4.03 released in June 2022 allows ***export of refractor branches and branch points*** to .BRN file and ***restoring refractor branches and branch points*** from .BRN file. Also we have added an option ***Update branch points with Plus-Minus*** in *Refractor|Midpoint breaks mapping dialog* to automatically update branch points in *Refractor|Shot breaks* display. With this option checked we update branch points in *Refractor|Shot breaks* display once you click button *Map Traces* and next select *Depth|Plus-Minus* or *Depth|Wavefront* layered refraction method in our ***Depth menu***.

This option ***Update branch points with Plus-Minus*** is reset/unchecked once it has been applied during Time-to-Depth conversion. Next you can optionally edit your branch points in our *Refractor|Shot breaks* display, remap traces to refractors with ALT+L and redo the Time-to-Depth conversion. Try toggling option *Mapping|Pick branch points between Receivers*. Backup your branch points with *File|Export header data|Export refractor branches to .BRN*.

We automatically fix velocity inversions between refractor 1 and refractor 2 for 3-layer case when mapping first breaks to refractors in *Refractor|Shot breaks* with ALT+L with option ***Mapping|Don't fix velocity inversion*** unchecked.

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Installation and licensing

To install the Rayfract® trial :

For installation under Windows 7/8/10/11 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, 10 and 11.

Under Windows 10 64-bit with 21H1 update tested Aug/Sep 2021 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 https://rayfract.com, link "Trial" or directly from the associated URL address https://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 Pro 64-bit update 21H1 tested Aug/Sep 2021 :

- 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 7/8/10/11 double-click the desktop link with our icon.

To open Windows help files under Windows 7/8/10/11 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

https://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

https://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

https://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 https://rayfract.com/tutorials/sapri12.pdf. Also review the introductory "Tutorial" chapter of our manual at https://rayfract.com/help/manual.pdf . Or work through some tutorials at https://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 https://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 Surfer® versions 10 to 25**. You may download a free demo version at https://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 :

first review our new documentation https://rayfract.com/help/CodeMeter_Runtime_Install.pdf .

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

https://www.wibu.com/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 installer on your Windows 10/11 PC for your grey/metallic CmStick USB dongle licenses to work.

For Windows 7 64-bit Pro use CodeMeter runtime version 6.90b instead with installer available at

https://rayfract.com/common/CodeMeterRuntime.exe

CodeMeter runtime version 7.01 and later crashes after installation in Windows 7 64-bit Pro virtual machine running under Parallels Desktop Pro on Apple macOSX and iMac. This forces you to restore a previous version of this virtual machine.

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.EXE 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 4.03 Standard software by double-clicking the desktop icon. See also

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

for instructions on 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 7/8.1 or Windows 10/11 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 CodeMeter service fails to start in **CodeMeter Control Center** with command *Process|Start CodeMeter service* :

- try repairing CodeMeter Runtime Kit in Windows *Control Panel|Programs and Features*
- if this does not help : run regedit.exe via *Windows Start menu*. Delete registry key **`HKEY_LOCAL_MACHINE\SOFTWARE\WIBU-SYSTEMS\CodeMeter`**. Leave Registry Editor via *File|Exit*.

Generate license request file and apply license update file

Review our new .pdf https://rayfract.com/help/Generate_Rayfract_LicenseRequest.pdf showing how to generate a CodeMeter license request file for your CmStick USB dongle.

Once we sent you the matching license update file review our new .pdf https://rayfract.com/help/Import_Rayfract_LicenseUpdate.pdf .

System limitations

Your Standard Rayfract® license is a **Windows 32-bit application** (compiled with Microsoft Visual Studio 2022 C++ compiler and OpenMP option) that works just fine under Windows 7/8/10/11 64-bit Pro 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 100'000'000 nodes per grid**.
- can use up to 4 GB of RAM memory for WET inversion. Pro license can use up to 1TB of RAM for fast WET inversion, caching all traveltime grids instead of swapping them to .GRD disk files.
- uses 4 CPU cores in parallel for WET inversion. Pro license uses up to 32 CPU cores for fast WET inversion using **OpenMP for multithreading**.
- allows adding one **`Borehole spread/line`** profile to main profile in *Header|Profile*. Pro license allows adding up to 4 **`Borehole spread/lines`**. First breaks picked for the main profile and for all added borehole profiles are used for joint WET inversion.
- 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 and diving waves, 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, recommended minimum profile length 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 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

The trial license will expire when 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 https://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-gradient initial model**. See e.g. our tutorials

https://rayfract.com/tutorials/broadepi.pdf ,
https://rayfract.com/tutorials/depress.pdf ,
https://rayfract.com/tutorials/palmfig3.pdf ,
https://rayfract.com/tutorials/fig9inv.pdf and
https://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 https://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 can 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) reduces 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 at least 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 7/8/10/11) 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 7/8/10/11)*. In the *Search programs and files box (Windows 7/8/10/11)* 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, the Start Menu and your User directory, which contains Documents, My Pictures, etc. See also

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

If you note that Windows is running slower and slower : shutdown Windows via the *Start button and Shutdown button.* 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 4 GBytes of RAM for caching of traveltime grids during WET inversion. Our Pro license can use up to 1 TBytes 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

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

Also we recommend stop using the Microsoft Outlook Express e-mail client and use a more secure alternative such as Thunderbird, 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

https://www.rarlab.com .

Be sure to shutdown our app via *File*|*Exit* before archiving the profile. Otherwise the archived profile database files may be corrupted. Open a Windows Explorer window and navigate into directory **`C:\RAY32`** . Now right-click your current profile directory e.g. **`LINE14`** in **`C:\RAY32`** and create a .RAR or .ZIP archive. Next backup this archive to permanent storage.

For more tips on administrating Microsoft Windows 10/11 see

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

We recommend **disabling Windows 11 automatic updates completely** to prevent having to reinstall a corrupted Windows 11. See

https://www.windowscentral.com/how-stop-automatic-updates-windows-11

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.

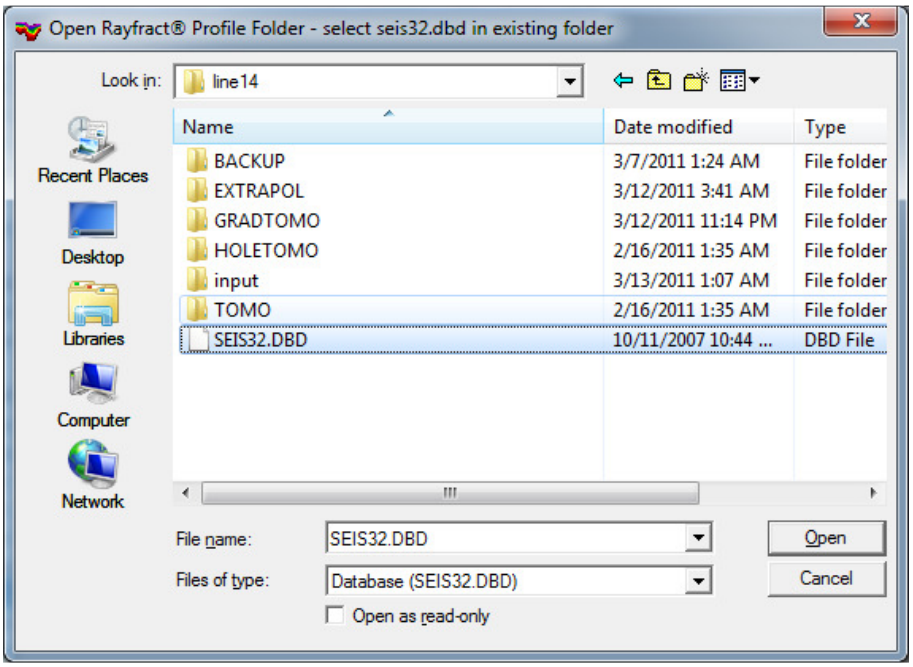
Starting up Rayfract® and profile management

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 7/8/10/11 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 the *Open Rayfract® Profile Folder dialog* prompts 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*. Then click on 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, processing and interpretation parameters 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 equidistant spread where all receivers are separated by the same distance : one *station*

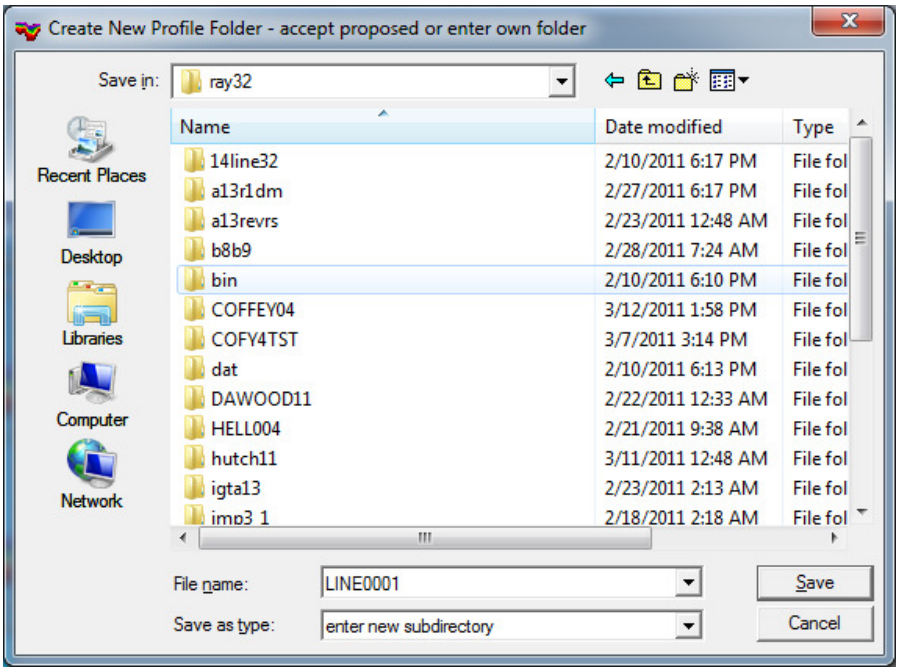
spacing defined in *Header|Profile* .

To open a profile which you created earlier select *File|Open Profile...* and navigate into the directory where 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

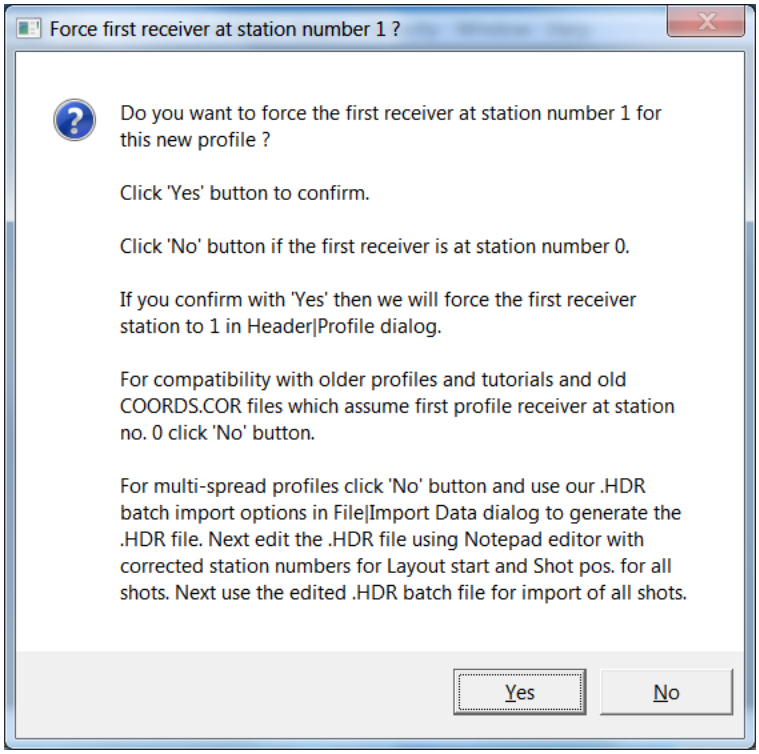
To initialize a new profile select *File|New Profile...* . Now the *Create New Profile Folder dialog* is shown :



We recommend having a directory named **RAY32** in the root directory of your hard-disk volume (does not have to be drive chosen at installation time). 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*** in *edit field File name*. Long-format directory names with space chars. or longer than 8 characters ARE allowed since version 3.36 released in Nov 2018.
- click *Save button* to generate the new profile database and to open it as the current database.

- now a new empty Rayfract® profile database is 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 is populated with traces when you import seismic data files; see below.
- also the following subdirectories are created in the new *profile directory* : **`INPUT`**, **`GRADTOMO`**, **`TOMO`**, **`LAYRTOMO`**, **`HOLETOMO`**, **`BACKUP`**.
- next we show a prompt **Force first receiver at station number 1 ?** / see below :



- if you confirm with ***Yes button*** then we will *force the first receiver station* (used for *Layout start* of first shot imported via File|Import Data) to 1 in *Header|Profile* dialog. We recommend clicking ***Yes button*** for ***single-spread profiles*** mainly.
- for compatibility with older profiles and tutorials and old COORDS.COR station coordinate files which assume the first profile receiver at station no. 0 click ***No button***
- for ***multi-spread profiles*** also click ***No button*** and use our .HDR batch import options in File|Import Data dialog / see below
- next select *Header|Profile* and fill out at least edit fields *Line ID* and *Station spacing* (in meters). Then press RETURN.
- for ***multi-spread profiles*** next use our .HDR batch import options in *File|Import Data* dialog to generate the .HDR file
- next edit the .HDR file using MS Notepad editor with corrected station numbers for *Layout start* and *Shot pos.* for all shots listed in the .HDR file
- next use the edited .HDR batch file for import of all shots via *File|Import Data* dialog
- for ***single-spread profiles*** with all shots recorded by the same receiver spread you can directly import the shots via *File|Import Data* and skip generating and editing and using the .HDR batch file as described in previous steps

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 prompt with RETURN key 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 currently opened profile database 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 press 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 vary WET inversion parameters and starting model 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 . 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 matching **.GRD** files
- **.FIT** files (text file format) detailing the traveltime misfit, between picked and modeled times for matching **.GRD** files
- Surfer **.SRF** plot files for matching **.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...* .

Be sure to shutdown our app via *File|Exit* before archiving the profile. Otherwise the archived profile database files may be corrupted if not all database updates have yet been written to disk. Open a Windows Explorer window and navigate into directory **C:\RAY32** . Now right-click your current profile directory e.g. **LINE14** in **C:\RAY32** and create a .RAR or .ZIP archive.

Reset inversion parameters from .PAR file for matching .GRD file

To reset inversion settings to previous settings

- select ***Grid menu*** item ***Reset DeltatV and WET and WDVS settings to .PAR file***
- navigate into profile subdirectory **…\GRADTOMO** or **…\TOMO** or **…\LAYRTOMO** or **…\HOLETOMO**
- select Surfer **.GRD** file **VELOITXY.GRD** or **DELTATV.GRD** and click *Open button*
- now we reset inversion parameters to values stored in the matching **.PAR** file with same filename as the selected **.GRD** file
- check if the Status bar at bottom of main window shows text “Resetting inversion parameters completed”

Dialog box control and function keys

Use the *TAB key* to cycle through the dialog's *control fields*, i.e. to change the *input focus*. Use the *RETURN key* to confirm the changes just made in the dialog. Alternatively, click the *OK, Read, Accept or equivalent button* (if existing). Use the *ESC key* to cancel changes to the *dialog box* / to skip 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 generated by selecting menu items in *menu Trace* are called ***Gather displays***. Displays generated 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*). Zoom shot (*Shot breaks display*).
F2	Unzoom time scale (*Gather displays*). Unzoom shot (*Shot breaks display*).
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*
SHIFT+W	Unzoom *Shot breaks display* to show whole profile length.
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 in *WET Tomo menu* : increase *iteration count*, adapt *wavepath width*, change *wavepath frequency*, edit *WET velocity smoothing* etc.
- activate *Model|WDVS Smoothing* (Wavelength-Dependent Velocity Smoothing, Zelt and Chen 2016) and vary WDVS frequency for improved WET inversion results.

Next optionally do conventional layer-based refraction interpretation with Wavefront, Plus-Minus and CMP intercept-time refraction 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* into refractor branches.
- convert time to depth with *Depth menu*, for conventional layer-based refraction interpretation. We show the layered refraction model in Surfer.
- confirm WET continuation prompt to run Automatic WET inversion using your layered refraction starting model
- cancel WET continuation prompt and display layer velocity sections with Velocity menu
- also cancel WET continuation prompt and press ALT+M in depth section window to edit parameters such as lateral smoothing of refractors etc.

Regularly export and backup to USB flash drive or permanent storage your station coordinates, shotpoint coordinates, first breaks and refractor branches picked, with

File|Export header data|Export Station Coordinates..
File|Export header data|Export Shotpoint Coordinates...
File|Export header data|Export First Breaks...
File|Export header data|Export refractor branches to .BRN...

The resulting files COORDS.COR, SHOTPTS.SHO, BREAKS.LST and BRANCHES.BRN 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. 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.

Restore previous refractor branch points with *File|Update header data|Update refractor branches from .BRN* using above BRANCHES.BRN file.

Review and work through some of our step-by-step tutorials available at

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

Also work through our SAGEEP 2010 short course manual available at

https://rayfract.com/SAGEEP10.pdf .

Also view our new .pdf

https://rayfract.com/help/Download_tutorialData.pdf showing how to get started with our tutorials and describing how to download the sample data used with our tutorials.

https://rayfract.com/tutorials/P6.pdf shows how to automatically convert mapped refractors to a layered starting model and refine this with WET inversion.

https://rayfract.com/tutorials/SR6.pdf shows how to use a layered refraction starting model for WET inversion of marine refraction data.

https://rayfract.com/tutorials/Line3.pdf shows data import, Smooth inversion and layered WET using Plus-Minus refraction starting model. Also we show how to activate WDVS (Wavelength-Dependent Velocity Smoothing; Zelt and Chen 2016) to improve the WET resolution. Also we show plotting of reciprocal traveltime picks on shot gather traces for easy quality control.

https://rayfract.com/tutorials/Gasch23.pdf shows multiscale WET inversion of P-wave refraction data recorded crossing a landslide.We use our default fail-safe 1D-gradient starting model and CMP Intercept-Time layered refraction starting model. Also we show how to activate WDVS (Wavelength-Dependent Velocity Smoothing; Zelt and Chen 2016) to improve the WET resolution. Also we show plotting of reciprocal traveltime picks on shot gather traces for easy quality control.

https://rayfract.com/tutorials/MDW2011_23.pdf shows import of SEG-2 crosshole shots into profile with *Line type* Borehole spread/line and Smooth inversion using constant-velocity starting model. Also we show how to activate WDVS (Wavelength-Dependent Velocity Smoothing; Zelt and Chen 2016) to improve the WET resolution. Also we show plotting of reciprocal traveltime picks on shot gather traces for easy quality control.

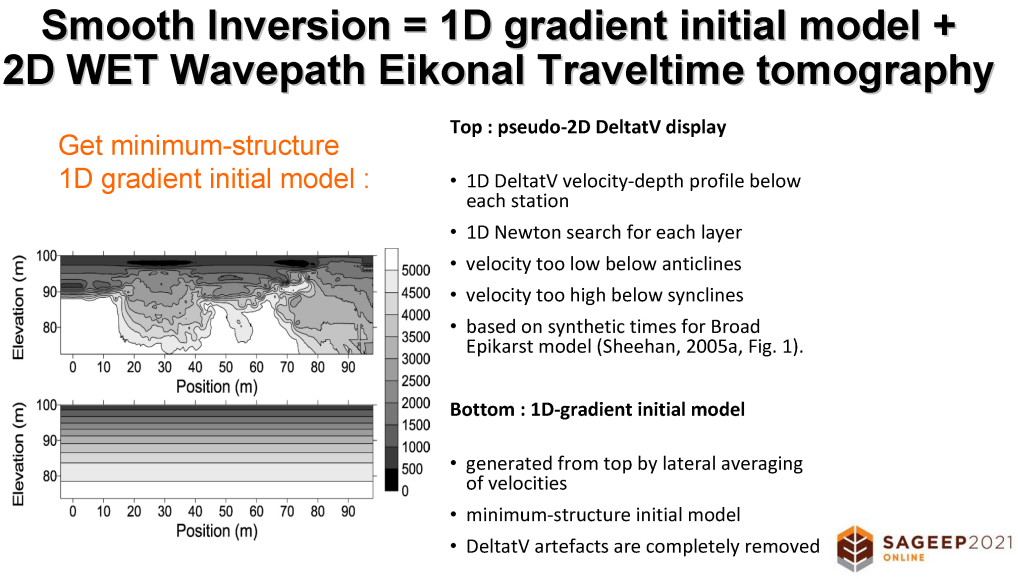
https://rayfract.com/tutorials/1_1D.pdf shows Conjugate-Gradient multiscale WET inversion of synthetic fault zone data using our DeltatV+XTV starting model vs. using our default fail-safe 1D-gradient starting model. We use Cosine-Squared WET update weighting for improved WET imaging of vertical fault zones.

https://rayfract.com/tutorials/jenny13_24.pdf shows Smooth inversion using 1D-gradient starting model and layered WET inversion using Plus-Minus starting model. Also we use WDVS (Wavelength-Dependent Velocity Smoothing; Zelt and Chen 2016) to improve the WET resolution.

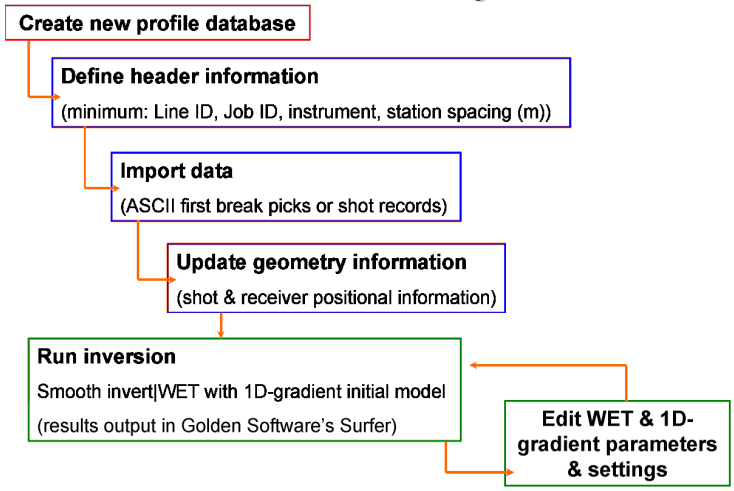
Also see our 2006 tutorial chapter, as available at

https://rayfract.com/help/manual.pdf .

Below we show slides from our SAGEEP 2021 publication (Rohdewald S.R.C. 2021a) with slides available at https://rayfract.com/pub/SAGEEP%202021%20slides.pdf :



Generalized Rayfract® Flow Chart



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Smooth Inversion, DeltatV and WET Parameters

- ❑always start with default parameters: run Smooth inversion without changing any setting or parameter
- ❑next adapt parameters and option settings if required, e.g. to remove artefacts or increase resolution
- ❑more smoothing and wider WET wavepath width in general results in less artefacts
- ❑increasing the WET iteration count generally improves resolution
- ❑don't over-interpret data if uncertain picks : use more smoothing and/or wider wavepaths.
- ❑explain traveltimes with minimum-structure model
- ❑tuning of parameters and settings may introduce or remove artefacts. Be ready to go one step backwards.
- ❑use Plus-Minus layered refraction method (Hagedoorn, 1959) as alternate starting model

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WET tomography main dialog: see help menu

Number of WET tomography iterations	Default value is 20 iterations. Increase to 50 or 100 for better resolution and usually less artefacts. WET can improve with increasing iterations, even if RMS error does not decrease.
Wavepath frequency	Ricker wavelet used to modulate/weight the wavepath misfit gradient, during model update. Leave at default of 50Hz. One period is 1/50Hz = 20ms. See (Schuster, 1993).
Degree of differentiation of Ricker wavelet	0 for original Ricker wavelet, 1 for once derived wavelet. Value 1 may give artefacts: wavepaths may become "engraved" in the tomogram. New default is -1: Gaussian weighting. Set to -2 for Cosine-Squared weighting, for better imaging of vertical fault zones.
Wavepath width	In percent of one period of Ricker wavelet. Increase width for smoother tomograms. Decreasing width too much generates artefacts and decreases robustness of WET inversion. Click Iterate button to specify multirun WET schedule for decreasing wavepath width between consecutive WET runs.
Envelope wavepath width	Width of wavepaths used to construct envelope at bottom of tomogram. Default is 0.0. Increase for deeper imaging.
Maximum valid velocity	Limit the maximum WET velocity modeled. Default is 6,000 m/s. Decrease to prevent high-velocity artefacts in tomogram.
Full smoothing	Default smoothing filter size, applied after each WET iteration
Minimal smoothing	Select for more details, but also more artefacts. May decrease robustness and reliability of WET inversion.
Manual smoothing	Specify half-width and half-height of smoothing filter in grid columns and grid rows. Gaussian or Uniform weighting. Smooth nth iteration. Smooth velocity update. Maximum velocity update. Check No smoothing to disable WET smoothing. Specify Damping for Conjugate-Gradient WET inversion.

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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 employing these already defined, regularly spaced layout types whenever possible.

For 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 increasing refractor number. The weathering layer corresponds to refractor number 0.

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 our software can convert between spread-relative and profile-relative station numbers using the *layout start*, as entered during data import. For more details see chapter Station numbers and spread types.

The ***station spacing*** is defined once only for the whole profile in the ***Profile Header Editor*** (*Header*|*Profile*). See chapter Editing header data.

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 your spread layout is turned around by 180 degrees use controls *Turn around spread during import* and *Reverted spread layout* in ***File|Import Data...*** dialog. See chapter ***Seismic and header data import|Import Shots dialog***.

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 chapter Overlapping receiver spreads.

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

We **recommend keeping *10:360 channels* as default spread type** in *File*|*Import Data…* dialog. Our import routine will determine the number of active channels (360 channels or less) based on the input files selected. Also leave option ***File|Import Data Settings|Allow missing traces*** checked. So when e.g. recording with a spread with 137 active channels and regularly or irregularly spaced receivers spread type ***10:360 channels*** should work just 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

https://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 chapter Import/export of layout types.

Actual receiver locations and coordinates may slightly deviate from station number coordinates. See option ***File|Import Data Settings|Adjust Receiver station coordinates***. With this option checked as per default we re-center each receiver station at end of import to average of coordinates for all receivers linked to this station. This helps with importing of irregularly spaced streamer data in formats SEG-2, SEGY, Geogiga DWTOMO .TTX, PlotRefa .VS and GeoTomCG .3DD. This linking of receivers to receiver stations is done during import of shots with *File|Import Data…* . See ***Header|Receiver*** dialog in chapter Editing header data and our marine streamer tutorial https://rayfract.com/tutorials/SR6.pdf .

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 layout-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

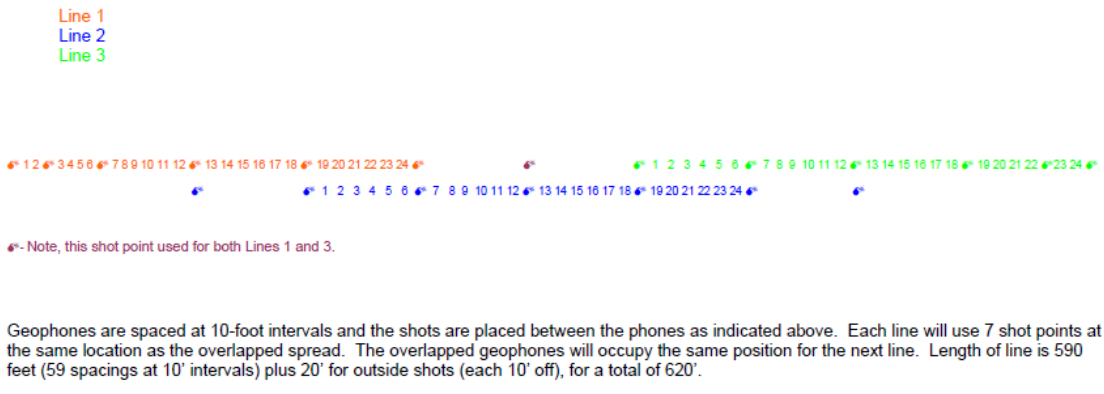
https://rayfract.com/tutorials/NORCAL14.pdf

Since version 4.03 we allow **forcing extrapolation of the starting model and subsequent WET tomograms** via Header|Profile controls *Extrapolate tomograms* and *Extrapolate [stations spacings]*. With *Extrapolate tomograms* checked our WET inversion will regard far-offset / off-end shot points with the *shot station* at a distance of up to *Extrapolate [station spacings]* stations from first/last profile receiver station. See e.g. our tutorial https://rayfract.com/tutorials/NGU_G4.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 recorded**. See https://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 https://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 https://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 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.

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, Geogiga DWTomo .TTX, 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 ***File|Import Data Import Shots dialog*** with the *Select button*. Now leave the ***Default spread type*** at default **`10: 360 channels`** and click 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)** 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.

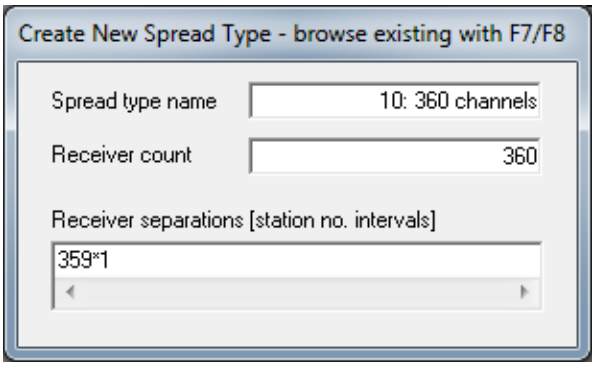
We recommend to **use a mobile weight drop as an energy source**. See e.g.

https://geoexpert.ch/about-us/equipment/

Defining your own layout types

1. Start up Rayfract® and open a profile with ***File|Open Profile…*** i.e. \RAY32\LINE14.

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



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 is listed for selection of the ***Default spread type*** in dialog ***File|Import Data|Import Shots*** .

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 drive and permanent storage.

12. Create a new profile with ***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 with ***File***|***Open Profile***.

13. Bring up the *Import shots dialog* with ***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 new spread name appears, your spread type definition was successful.

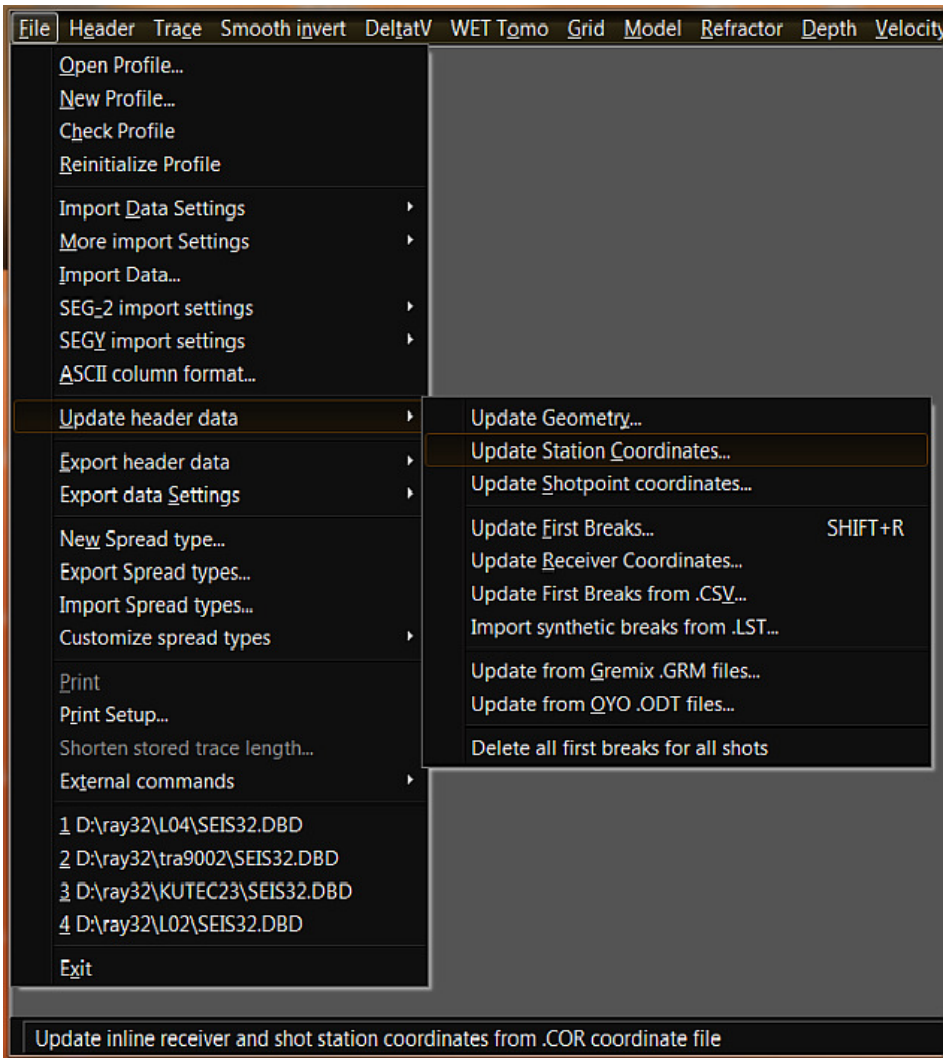
14. You may now want to actually import a shot. Be careful to correctly specify ***Layout start*** and ***Shot position*** in station numbers. Then select the shot record in ***Header***|***Shot*** by browsing with F7/F8. Leave the dialog with ESC key.

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 *Channel nrs*. Note that station numbers displayed are absolute (profile-relative). You need to 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 steps 6 to 9 described above and just perform these in your mind before proceeding to step 10. Steps 12 to 15 are not strictly required either.

Import and export of layout types

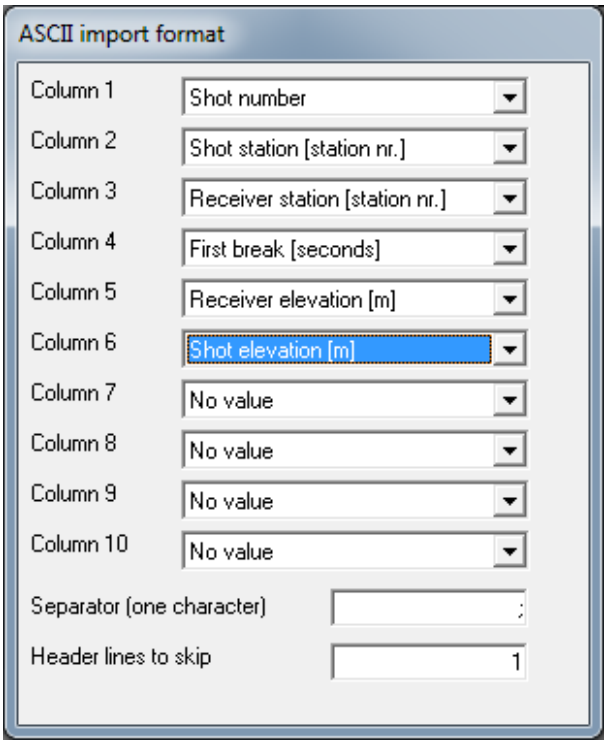
Version 2.72 and later versions of our Rayfract® software offer File menu functions for export/import of receiver spread types. Since version 2.73, you are not required to open a profile database first, to enable this import/export. Whenever you open a different profile with ***File|Open Profile…*** we export all spread types to file \RAY32\<your profile directory>\MYSPREAD.SPR. 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 stored in **`\RAY32\REF\MYSPREAD.SPR`** or **`\RAY32\<your profile name>\MYSPREAD.SPR`** . Version 2.73 and later of our base installer routine imports your custom spread types automatically from file **`\RAY32\REF\MYSPREAD.SPR`** 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 default 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. Refer to sample file **ASCII.ASC** in your \RAY32\DOC directory, for a typically formatted ASCII import file. Also see chapter File Formats.

Rayfract® supports reading in multiple .ASC files from one directory during one import session started with ***File|Import Data|Import Shots dialog***. Traces recorded for the same shot need 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 or .SEG2
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	.ABM
Geogiga DWTomo .TTX	.TTX
Geogiga Refractor .TX	.TX
GeoTomCG .3DD	.3DD
GeoTomo TimePicker .3DTT	.3DTT
W_GeoSoft WinSism	.XYZ
Earth FX VIEWSEIS	.PRN
OYO SEISREFA	.ODT

- 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" The last 3 digits of this number string are regarded only.

- for SEG-2 you can alternatively change *File*|*Import Data*|*Take shot record number from* to **File number** from its default setting **DOS file name**. With choice **File number** selected the database shot number starts at 1 and is increased sequentially during each import session with *File*|*Import Data…* . If you specify SEG-2 trace header key SHOT_SEQUENCE_NUMBER with a value equal to or higher than 0 then we number imported shots using this SHOT_SEQUENCE_NUMBER value instead.

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

- for Interpex GREMIX, OPTIM SeisOpt®, Geogiga DWTomo, OYO SEISREFA, WinSism and VIEWSEIS files the shot number is read from the ASCII format shot headers as contained in these files. Shot numbers higher than 999 are truncated to last 3 digits.

- the shot number is trimmed to a three digit number. I.e. shot number string "1001" is truncated to Rayfract® shot number 1. You can renumber the shots during import e.g. to sequentially increasing numbers starting at 0 or 1. Use our .HDR batch import. The original input file name is shown in the read-only field **Original input disk filename** 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 profile directory e.g. \RAY32\LINE14\INPUT. This INPUT directory is created automatically when you create a new profile with *File*|*New Profile...* command.

- for typical processing sequences including profile database creation and data import see https://rayfract.com/help/manual.pdf . For many tutorials see https://rayfract.com/tutorials/TUTORIAL.ZIP . See also our SAGEEP 2010 short course manual at https://rayfract.com/SAGEEP10.pdf .

Conversion of unsupported data formats to SEG-2

We recommend using the **Interpex IXSeg2SegY utility** (version 2.01 or higher) to convert binary trace data files from these formats to SEG-2 : 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 are imported by our Rayfract® software but .PIK, .BPK or .FIR ASCII first break files in the input directory have higher priority. Specify sample type 32-bit Integer when exporting SEG-2 files from IXSeg2SegY. This utility also offers nice functionality for frequency filtering of seismic traces.

Download a free trial version of IXSeg2Segy from http://www.interpex.com .

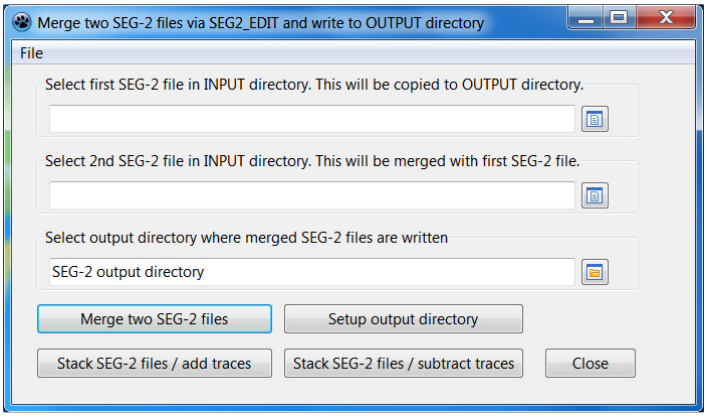
Alternatively try W_GeoSoft WinSism v. 10 or higher for import of above data formats and first break picking. Next generate ASCII.ASC files or OPTIM SeisOpt® files for import into Rayfract®. See http://www.wgeosoft.ch .

For shot resampling, shot stacking, conversion between SEG-2 and SEGY etc. try the free Geogiga Front End, available at https://geogiga.com/en/frontend.php .

Merge or stack two SEG-2 files into one file

To merge or stack two SEG-2 trace files into one SEG-2 file

- select ***File/SEG-2 import settings and commands/Merge or stack two SEG-2 files into one file*** to display the following dialog :



- select first SEG-2 file in input directory e.g. 1270.DAT
- select 2nd SEG-2 file in input directory e.g. 1271.DAT
- select an output directory where the updated SEG-2 files are written. This is ...\INPUT2 per default.
- once you click button ***Merge two SEG-2 files*** we append all traces from 2nd file to first SEG-2 file selected and write the resulting SEG-2 file into selected output directory
- once you click button ***Stack SEG-2 files / add traces*** we vertically stack all traces of first SEG-2 file with traces from 2nd SEG-2 file selected and write the resulting SEG-2 file into selected output directory

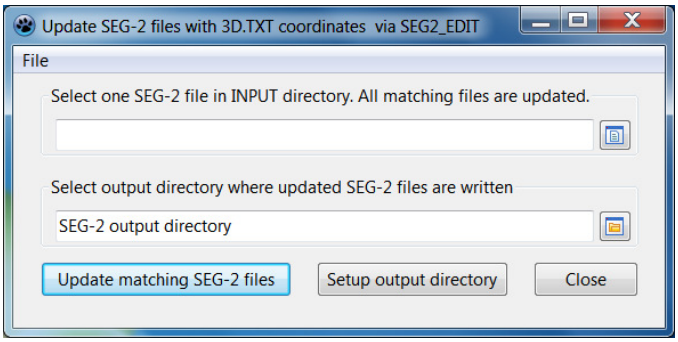
Update SEG-2 source and receiver coordinates

To update SEG-2 trace header fields SOURCE_LOCATION and RECEIVER_LOCATION with true x/y/z coordinates :

- interactively edit (or generate with another program) .TXT files formatted as https://rayfract.com/tutorials/1270_3D.TXT
- use SEG2_EDIT utility available at https://pubs.usgs.gov/of/2003/ofr-03-141/ to update the SEG-2 file https://rayfract.com/tutorials/1270.DAT with source/receiver coordinates specified in the 1270_3D.TXT response file :
- open a Windows command prompt and enter command line
- SEG2_EDIT –set_keywords –infile 1270.DAT –outfile 1270_OUT.DAT <1270_3D.TXT

- we also include a utility program in our Standard and Pro license installation which matches 3D.TXT files to SEG-2 files by filename and then updates all matching file pairs in one batch invocation of SEG2_EDIT :

- select ***File|SEG-2 import settings|Update SEG-2 files with coordinates*** to display the following dialog :



- select one SEG-2 file in input directory e.g. 1270.DAT

- select an output directory where the updated SEG-2 files are written

- once you click button "Update matching SEG-2 files" we match the 3D.TXT response files to SEG-2 files by filename. E.g. 1270_3D.TXT is matched to 1270.DAT SEG-2 file.

- we then generate and run a Windows .BAT batch file which invokes the SEG2_EDIT utility for all matching file pairs found in previous step

- see also our tutorial for shallow marine refraction at https://rayfract.com/tutorials/SR6.pdf

- for refraction lines we assume that SOURCE_LOCATION specifies the shot location vertically projected to elevation of receiver line at source location x/y. So the SOURCE_LOCATION z coordinate should be obtained by interpolating receiver station coordinates at source x/y.

- specify the vertical offset of the true shot location from the receiver line after SEG-2 import by editing *Header|Shot|Shot depth* parameter. Or export shot point coordinates to SHOTPTS.SHO file format via *File|Export header data|Export Shot Point Coordinates*. Then edit the *shot depth* in SHOTPTS.SHO using MS NotePad text editor. Then update shotpoint coordinates with *File|Update header data|Update Shotpoint coordinates*. A negative shot depth means that the true shot location is above the receiver line e.g. for marine refraction surveys.

- for off-end shots recorded for land seismic refraction lines set SHOTPTS.SHO columns 2/3/4 to true source coordinates shotX/shotY/shotZ and set column 5 to hole depth 0.0

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 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 https://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 check *DeltatV|DeltatV Settings|Output DeltatV results in Feet* before running these inversion methods.
- to generate Smooth inversion, DeltatV and WET output in meters 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 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

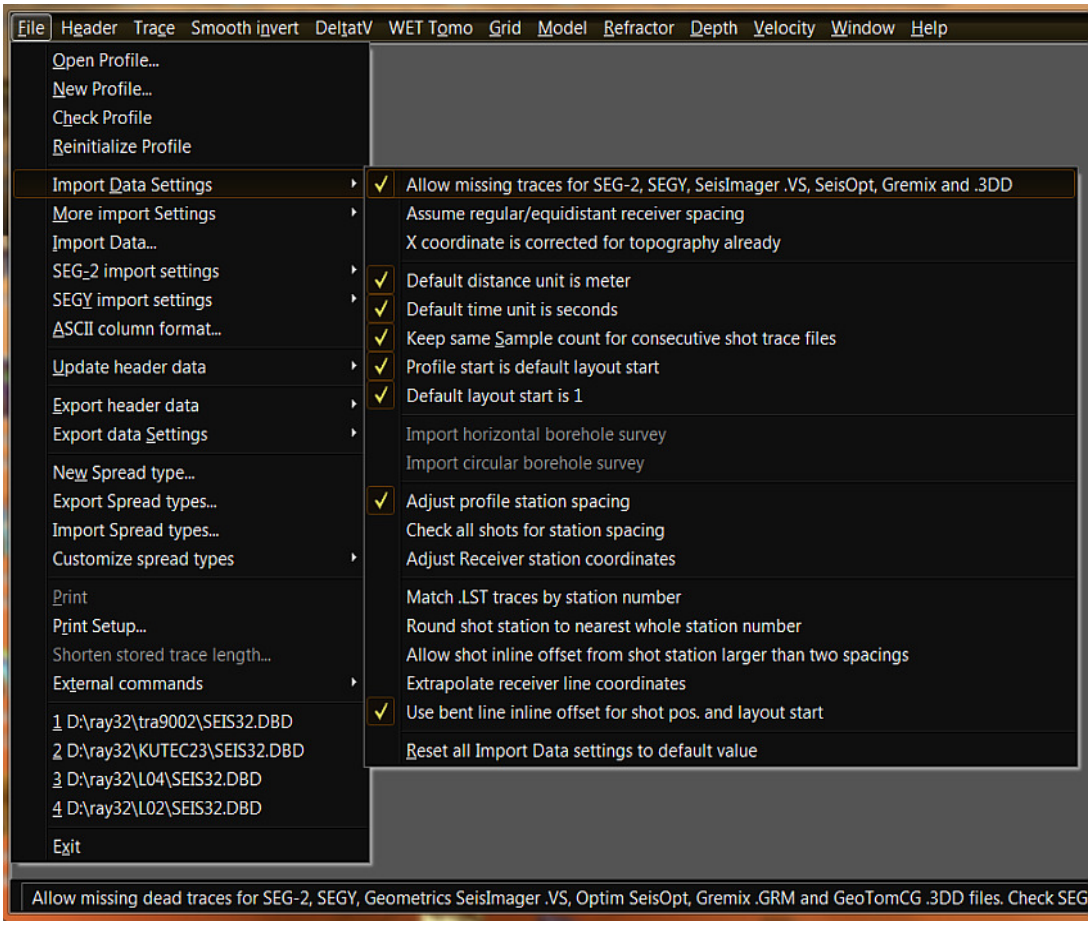
Byte	Field Description
9-12	Field record number (shown in Header|Shot)
17-20	Energy source point number (shown in Header|Shot)
41-44	Group elevation (Receiver elevation)
45-48	Source elevation (Shot elevation)
49-52	Source depth (Shot depth)
69-70	Scalar applied to above elevation and depth fields
71-72	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 chapter Starting up Rayfract® and profile management. For import of ASCII.ASC 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|Profile*. *Line type* can be edited only 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 as described in chapter **Commands** :

- ***Allow missing traces for SEG-2, SEGY, SeisImager, SeisOpt, Gremix and .3DD*** Allow missing dead traces, for Geometrics SeisImager, Optim SeisOpt, Interpex Gremix, GeoTomCG .3DD and Geogiga .TTX files

- ***Assume regular/equidistant receiver spacing*** Assume receivers are spaced at multiples of *Header|Station spacing*. Uncheck to better support import of irregularly spaced receivers e.g. with .3DD import into borehole spread/line.
- ***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. Uncheck for feet. Use for SeisOpt and SeisImager import.
- ***Default time unit is seconds*** Default time unit during import is seconds. Uncheck for 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..
- ***Import horizontal borehole survey*** Import horizontal borehole survey, SEG-2 or .3DD shots.
- ***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. Lets you update profile *station spacing*.
- ***Check all shots for station spacing*** Check all shot files in input directory for station spacing and propose adjustment of profile's *station spacing* if required. Uncheck to propose adjustment based on first shot file only.
- ***Adjust Receiver station coordinates*** Re-center each receiver station at end of import to average of coordinates for all receivers linked to this station. Helps with importing of irregularly spaced streamer data in formats SEG-2, SEGY, PlotRefa .VS, GeoTomCG .3DD and Geogiga DWTomo .TTX. This linking of receivers to receiver stations is done during import of shots with File|Import Data... .
- ***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
- ***Allow shot inline offset from shot station larger than two spacings*** Allow inline offset of shot point from shot station exceeding two station spacings. This invalidates DeltatV method interpretation.
- ***Extrapolate receiver line coordinates*** Extrapolate receiver line coordinates beyond first/last receiver station. Disable to set offend shot stations to absolute shot point coordinates. Disabled per default.
- ***Use bent line inline offset for shot pos. and layout start*** Regard receiver x/y/z when accumulating inline offset along bent line for determination of *Layout start* and *Shot pos.* in station numbers, for SEG-2 and SEGY import

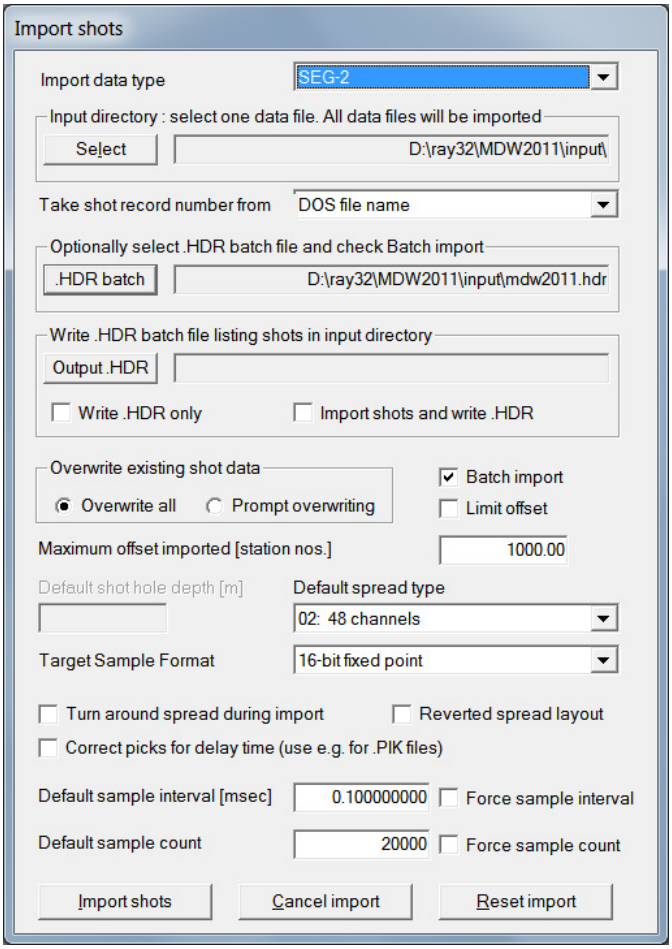
The ***More import Settings submenu*** is also contained in ***File menu*** and offers options :

- ***Interpolate shot point elevation for SeisOpt and .3DD files*** Interpolate shot point elevation and hole depth for Optim SeisOpt and GeoTomCG .3DD. These file formats do not specify the shot hole depth.
- ***Y coordinate is zero 0.0*** Reset y coordinate to zero 0.0 during import for all shots and receivers. Use with GeoTomCG .3DD import into *Header|Profile|Line type* **`Refraction spread/line`**. For *Line type* **`Borehole spread/line`** all y coordinates for all sources and receivers are reset to zero 0.0 during import independent of this option.
- ***Flip sign of X coordinate for all sources and receivers*** Flip sign of x coordinate for all sources and receivers specified in trace input files. Use for SEGY, SEG-2 and GeoTomCG .3DD formats.

- ***Flip sign of Y coordinate for all sources and receivers*** Flip sign of y coordinate for all sources and receivers specified in shot trace input files. Use for SEGY, SEG-2 and GeoTomCG .3DD formats.
- ***Reverted receiver spread layout/towed streamer*** Spread channel no. decreases with inline offset. Read-only. Toggle in File|Import Data dialog when importing your shot files.
- ***.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*).Our .3DD import assumes that traces in .3DD input files are sorted by common shot number since the .3DD format does not contain a column with the shot number. Shots are numbered sequentially starting at one during .3DD import. With this option checked our .3DD import assumes ***additionally*** that all traces for same shot (listed sequentially in the .3DD) are sorted by receiver offset along line : x coordinate for *horizontal receiver spreads* or z coordinate for vertical receiver spreads.
- ***Keep current directory when selecting files*** Start file selection in current directory. Uncheck to start in input directory.
- ***Select file in Profile directory*** Start file selection in current profile's main directory. Uncheck to start in input directory.
- ***Database transaction for whole import*** Changes database transaction management during import. Check for one global transaction.
- ***Reset all Import Data settings to default value*** Reset all of above Import Data settings to their default values.

Import Shots dialog

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



Always edit control fields ***Import data type*** and ***Input directory*** and optionally edit other fields :

- choose the ***Input directory*** by clicking *button* ***Select***. In the file selection dialog navigate into your input directory and select one shot file. All matching shot files in that directory (with same file name extension) will be imported once you click button *Import shots*.
- ***Take shot record number*** *from* is initialized acoording to the *Import data type* selected
- optionally select a ***.HDR batch file*** with ***.HDR batch*** *button*. For .HDR batch format see chapter File formats. See also our tutorial https://rayfract.com/tutorials/P6.pdf .
- optionally click ***button Output .HDR*** to specify .HDR filename to be written listing all shots found in matching input files in *Input directory*
- check ***Write .HDR only*** to list shots in *Output .HDR* file only and skip actually importing

shots when you click *button Import shots*

- check ***Import shots and write .HDR*** to both import shots into your current database and list shots imported 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. For ASCII.ASC and .HDR batch formats see chapter File formats.

- check ***Limit offset*** and adjust ***Maximum offset imported*** *[station nos.]* if required. Import traces with receiver offset from the shot position not farther than *Maximum offset imported [station nos.]* only.

- optionally use the ***Default spread type*** *drop down list box* to specify the receiver spread type used for import of the shot data. Spread types are named "X: YYY channels". Normally we recommend leaving *Default spread type* at default setting **`10: 360 channels`** and leaving option ***File|Import data Settings|Allow missing traces*** checked. If you prefer defining your own irregularly spaced/non-equidistant spread types see chapter Defining your own layout types. Also see chapter Station numbers and spread types.

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

- check ***Turn around spread during import*** if required. Also check ***Reverted spread layout*** if your receiver spread's channel number decreases with increasing inline offset along profile / with towed streamer. Correctly specify the *shot position* and *layout start* with these options.

- optionally 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, Interpex Gremix .GRM, DWTomo .TTX and SeisImager .VS to determine the time scale in *Trace|Shot gather* and *Refractor|Shot breaks*

- check ***Force sample interval*** to use your edited *Default sample interval* when importing shots with seismograph traces in formats SEGY, SEG-2, ABEM Terraloc Mark 3

- ***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*

- check ***Force sample count*** to use your edited *Default sample count* when importing shots with seismograph traces in formats SEGY, SEG-2, ABEM Terraloc Mark 3

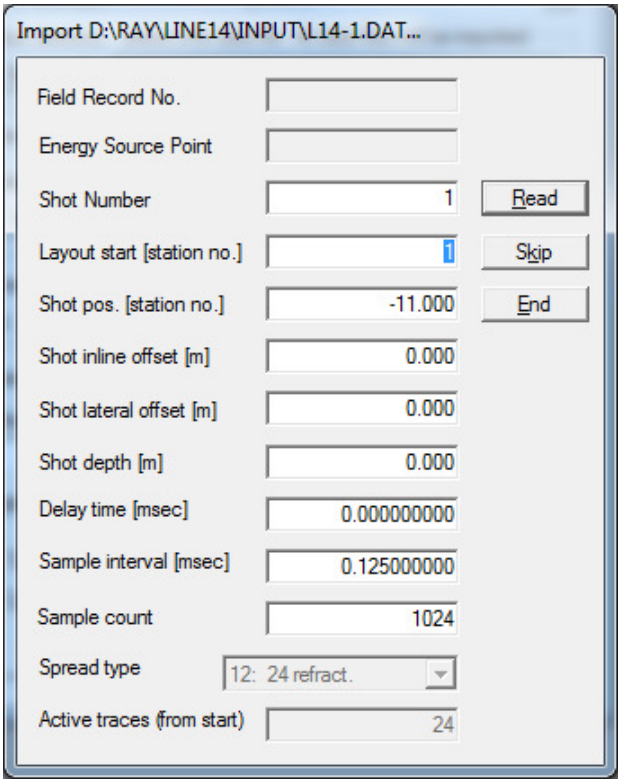
Always first specify the import file format with the *Import data type drop down list box*. Supported import file types are ABEM Terraloc Mark 3 / ASCII column format / Bison-2 9000 Series / Interpex GREMIX/OYO SEISREFA / SEG-2 / SEGY / W_GeoSoft WinSism / Earth FX VIEWSEIS / OPTIM LLC SeisOpt / Geogiga DWTomo .TTX / Geometrics SeisImager Plotrefa / GeoTomCG .3DD / GeoTomo TimePicker .3DTT .

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

- ASCII Survey geometry files SPRNG2XT.PRN, L5.PRN, LINEBC.PRN
- station coordinate files COORDS.COR, RECVRS.COR, TRA9002.COR, TRA9002_Recvrs.COR . See chapter File formats.
- shotpoint coordinate file SHOTPTS.SHO . See chapter File formats.
- first break pick files BREAKS.LST . See chapter File formats.
- traveltimes and recording geometry ASCII.ASC, SSA17FT.ASC (elevations in feet). See File formats and https://rayfract.com/help/manual.pdf .
- Interpex Gremix LINE14.GRM
- OYO SEISREFA OYO.ODT
- W_GeoSoft WinSism TOMOEVAL.XYZ . See https://rayfract.com/help/manual.pdf .
- Earth FX VIEWSEIS VIEWSEIS.PRN
- OPTIM LLC SeisOpt SEISOPT_SRC & SEISOPT_REC & SEISOPT_OBS . See tutorial https://rayfract.com/tutorials/clud1.pdf .
- Geogiga DWTomo MA01-01_2_TRIGCORR.TTX
- Geogiga Refractor SRT23-03_FB.TX
- Geometrics SeisImager PLOTREFA.VS and PICKWIN.VS. See tutorial https://rayfract.com/tutorials/sapri12.pdf .
- GeoTomCG .3DD IGTA13.3DD, IGTB13.3DD. See tutorial https://rayfract.com/tutorials/igta13.pdf .
- GeoTomo TimePicker .3DTT CON8FILES_090421.3DTT

Import one shot dialog

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



- 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*** . See chapter Editing header data.
- correct ***Delay time*** during import or edit ***Trigger delay*** later in ***Header***|***Shot***
- best leave ***Sample interval*** and ***Sample count*** as initialized during import

Confirm the dialog with ENTER key or click the *Read button* with left mouse button. If you checked *Batch import* in *File*|*Import Data dialog* 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 clicking the *Read button* and imports the shot at once.

When importing SEG-2, Geometrics or ABEM data files we check for **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 and named the same way as the shot trace files (not regarding the file extension) first breaks contained in these first breaks 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 selected 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 in meters or in feet according to the SEG-2 file header UNITS entry. We assume 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. We use parameters *Station spacing* and *Layout start* to determine the *shot position* (in station numbers) based on SOURCE_LOCATION and RECEIVER_LOCATION. See topic Station numbers and spread types .

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 if *File|SEG-2 import settings|Ignore SEG-2 station numbers* is not checked :

- *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 in the input directory matches the shot filename, the shot position is determined from the source and first receiver location as specified in that first breaks 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 matching SEG-2 file's UNITS entry.

If you check option *Header|Profile|Force first receiver* and edit *Header|Profile|First receiver [station number]* then we update station numbers obtained for *Layout start* and *Shot position* from SOURCE_LOCATION and RECEIVER_LOCATION as described above :

- for the first shot imported via *File|Import Data* we force *Layout start* to your *First receiver [station number]* and shift *Shot position* by (*First receiver – original Layout start*) in station numbers
- for all subsequent shots imported via the same *File|Import Data* session we shift both *Layout start* and *Shot position* by the same shift amount as determined for the first shot imported

If the shot position shown in the *Shot position edit field* of the *Import shot dialog* is wrong **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

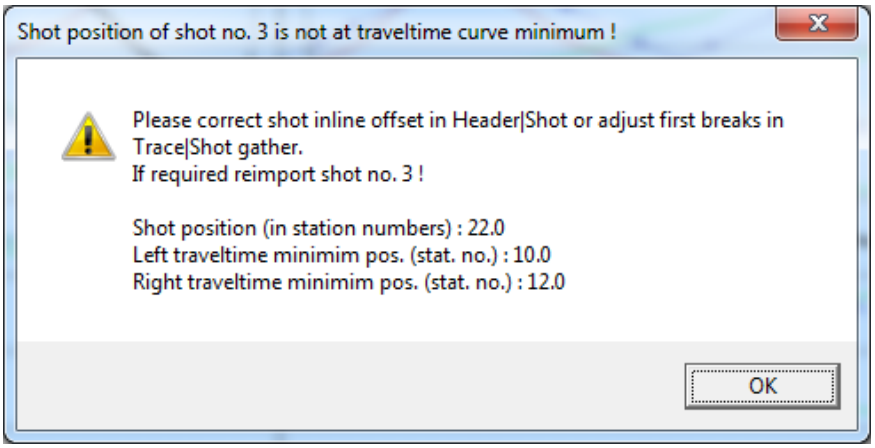
positions to the left of the first receiver / to the right of the last receiver

- station numbers equal to or smaller than 0 and equal to or larger than 25 may be used to specify shot positions offset from first/last receiver
- 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 spread-relative shot position in station numbers
- to obtain the profile-relative shot position in station numbers add this spread-relative shot position to the spread's *layout start* also specified in station numbers
- enter this shot position into edit field *Shot pos. [station nr.]* displayed in *Import shot dialog* as shown above. Click on the *Read button* or press ENTER to import the shot.
- use our .HDR batch import : edit layout start and shot pos. columns in the .HDR batch file and then use this .HDR file with File|Import Data... See also our tutorials https://rayfract.com/tutorials/P6.pdf and https://rayfract.com/tutorials/Line3.pdf showing creation and usage of BATCH.HDR batch files.
- we recommend using our .HDR batch import especially when importing shots recorded with multiple overlapping receiver spreads into the same profile.

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 shot files and matching updated ASCII first breaks files.

ASCII.ASC import : fix bad shot position

ASCII.ASC files need to specify first break pick times for all receivers in the *Default 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 above error message **“Shot position of shot nr. … is not at traveltime curve minimum "**. For inline shots we detect 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. 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 / with first break pick time -1. 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 .

Import GeoTomCG .3DD trace files

Since the **.3DD format does not include a column listing the shot number** our .3DD import assumes that .3DD traces are sorted by increasing shot number. During .3DD import shots are numbered sequentially starting at one. With option ***File|More import Settings|.3DD shot traces sorted by receiver offset*** checked our .3DD import ***additionally*** assumes that all traces for same shot (listed sequentially in the .3DD) are sorted by receiver offset along line : x coordinate for ***Line type*** `Refraction spread/line` and horizontal borehole surveys or z coordinate for vertical borehole receiver spreads or receiver inline offset for circular borehole survey. Option ***File|Import Data Settings|Allow missing traces*** is checked per default for ***File|Import Data|Import Data Type*** GeoTomCG .3DD. Review our tutorial https://rayfract.com/tutorials/igta13.pdf showing import from .3DD and Smooth inversion of a crosshole survey. When importing traces into ***Line type*** **`Borehole spread/line`** we reset y coordinates for all sources and for all receivers to zero 0.0.

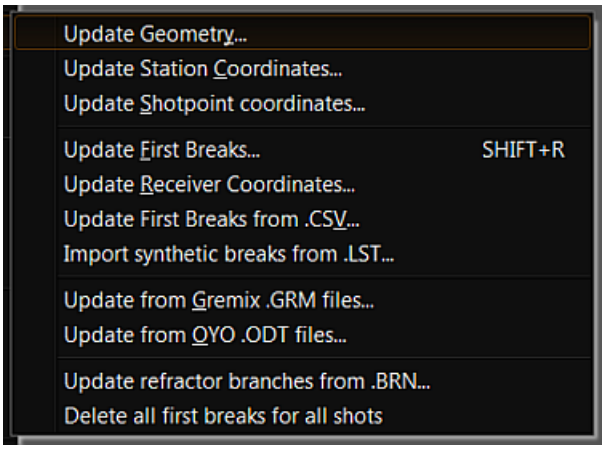
Before importing a GeoTomCG .3DD survey file listing receivers in multiple boreholes (with all y coordinates equal 0.0) you need to split the .3DD into multiple .3DD files such that all traces contained in one .3DD are recorded with receivers located in the same **`Borehole spread/line`** or along the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

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 Notepad. 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 change 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. See our tutorial https://rayfract.com/tutorials/P6.pdf and chapter *File formats*.

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

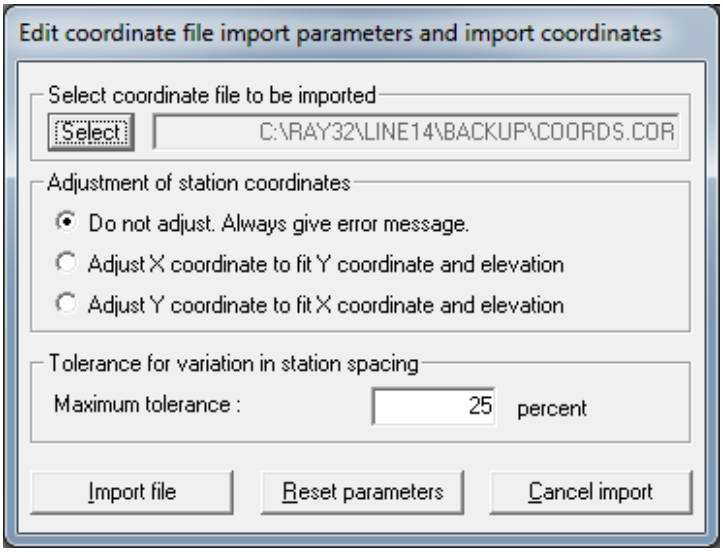
Command	*File type imported*
File|Update header data|Update Station Coordinates...	COORDS.COR station coordinates, see below. *Generate with File|Export header data|Export Station Coordinates.*
File|Update header data|Update Shotpoint coordinates...	SHOTPTS.SHO shotpoint coordinates. *Generate with File|Export 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 refractor branches from .BRN	Branch point .BRN . Generate with *File|Export header data|Export refractor branches to .BRN*
File|Update header data|Update Geometry...	.PRN survey file geometry



These commands are enabled once you have imported seismic data files as described above.

Update station coordinates with COORDS.COR

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*** : Display error messages for all coordinate values which do not fit the line geometry (*station spacing*) within the tolerance as specified with *Maximum tolerance*
- ***Adjust X coordinate to fit Y coordinate and elevation*** : Adjust x coordinates imported to fit y coordinates and elevations imported, such that the resulting station spacing corresponds to the *Station spacing* specified in *Header|Profile*
- ***Adjust Y coordinate to fit X coordinate and elevation*** : Adjust y coordinates imported to fit x coordinates and elevations imported, such that the resulting station spacing corresponds to the *Station spacing* specified in *Header|Profile*
- ***Maximum tolerance*** : Maximum relative difference allowed between effective station spacing (computed from the coordinates of neighboring stations) and *Station spacing* specified in *Header|Profile*

We assume that .COR files hold coordinates for inline receiver station positions at whole station numbers. You additionally can list coordinates for off-end shot points and inline shot stations at whole or non-integer station numbers in .COR files. The "seismic line" is assumed to be defined by all consecutive receiver station positions.

See chapter File formats for more details on COORDS.COR file format. Inline shot position coordinates at shot stations are normally obtained by interpolating x/y/z coordinates at the shot station between the two closest receiver stations. Specify *inline and lateral shot point offsets from shot station* and *shot hole depths* in *Header|Shot* .

See \RAY32\DOC\TRA9002.COR sample file for all receiver station coordinates and shot station coordinates for TRA9002 sample profile shown in https://rayfract.com/help/manual.pdf and https://rayfract.com/tutorials/tra9002.pdf. See \RAY32\DOC\TRA9002_Recvrs.COR for same TRA9002 profile but listing receiver stations only, with missing receiver stations. Coordinates at missing receiver stations and at missing shot stations are interpolated and

extrapolated with *File|Update header data|Update Station Coordinates...* .

Update shot point coordinates with SHOTPTS.SHO

We recommend using our .SHO file format instead of the older .PRN file format. See chapter File formats.

Inline shot position coordinates at shot stations are normally obtained by interpolating x/y/z coordinates at the shot station between the two nearest receiver stations. 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 are regarded when estimating weathering velocities and when correcting traveltimes for shot position offsets from shot station.

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 .

Update first break picks with BREAKS.LST

Column values in lines of a first breaks .LST file are separated by either one or more TAB characters or by one or more spaces. First breaks in .LST files are specified in milliseconds. Use *File|Update header data|Update First Breaks* to update first breaks from BREAKS.LST file. Sample file \RAY32\DOC\BREAKS.LST contains first breaks for the profile TRA9002 . See our short manual https://rayfract.com/help/manual.pdf

Skip header lines in header data input files

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 https://rayfract.com/help/ln14feet.zip for sample files specified in feet.

Import or update from Interpex Gremix and SEISREFA OYO

Process the binary trace data and pick first breaks with your FIRSTPIX software as published by Interpex. Then import the resulting first breaks with our *File*|*Import Data...* or *File*|*Update header data*|*Update from Gremix .GRM files...* . Receiver elevations and shot hole depths are imported from .GRM files also.

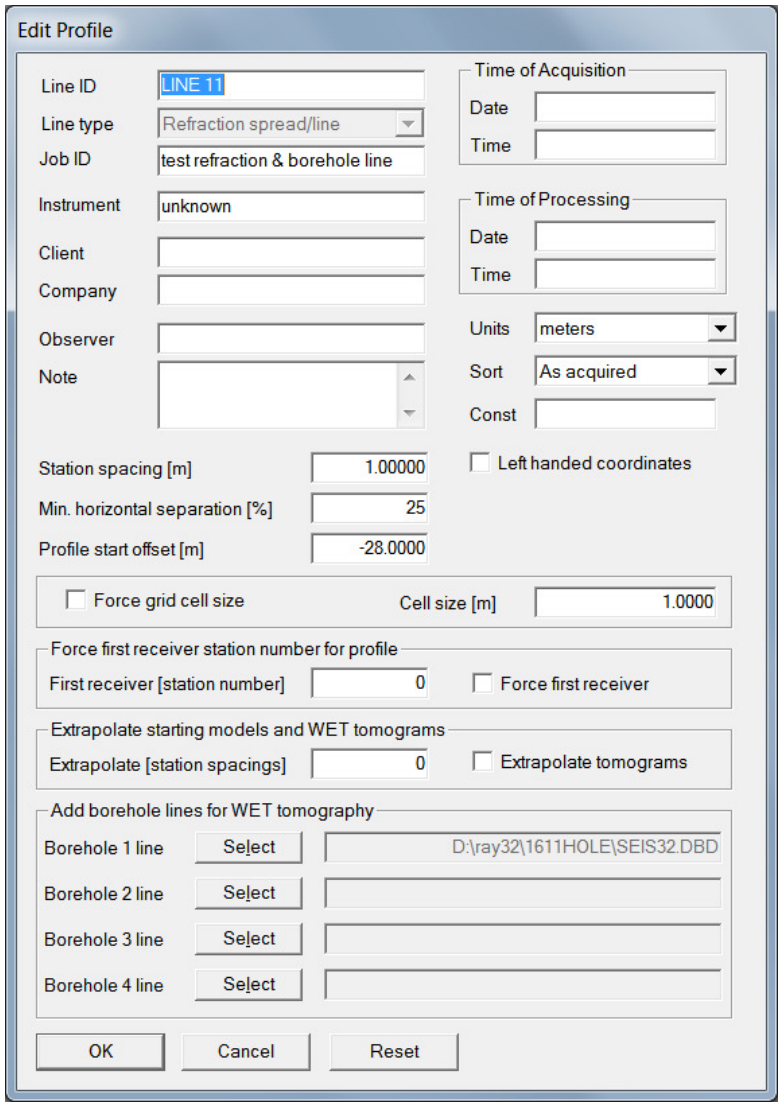
If you processed your trace data and picked first breaks with SEISREFA as published by OYO also import the resulting first breaks with *File*|*Import Data...* . Receiver elevations and shot hole depths are imported from .ODT files also. *File*|*Update header data*|*Update from OYO .ODT files...* lets you update an existing Rayfract® profile with first break data.

If your Rayfract® profile contains shot traces recorded with multiple receiver spreads along the same 2D line just copy all corresponding Gremix .GRM or SEISREFA .ODT files into the same subdirectory and select one of these in the file selection dialog. We iterate over all .GRM or .ODT files in this subdirectory. We assume that one .ODT file lists shots and first breaks recorded with exactly one receiver spread only. One .GRM file may list shots and first breaks recorded with multiple receiver spreads.

Editing header data

Profile dialog

Before importing your data 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 as shown in ***Header*|*Receiver*** dialog.
- if you recorded a profile with varying receiver spacing : set ***Station spacing*** to Greatest

Common Divisor GCD of your spacings used. E.g. if you planted some spreads with spacing of 5m and other spreads with 3m : set *Station spacing* to 1m. Now check ***File|Import Data Settings|Allow missing traces*** and import your SEG-2 **`.DAT`** or **`.SG2`**, SEGY **`.SGY`**, Geometrics Plotrefa **`.VS`**, OPTIM LLC SeisOpt, Interpex GREMIX **`.GRM`**, GeoTomCG **`.3DD`** or Geogiga DWTomo **`.TTX`** with ***File|Import Data...*** and ***Default spread type*** **`10: 360 channels`** or **`999: 999 channels`** (available with Pro license only) as usual.

- 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*.
- to determine the grid cell size of your generated ..\GRADTOMO\GRADIENT.GRD or VELOIT20.GRD or ..\HOLETOMO\CONSTVEL.GRD open the .GRD file with Surfer and select ***Grid Info*** command
- to force the first receiver station number (*Layout start*) for the first shot imported during import of shots : check box ***Force first receiver*** and edit ***First receiver [station number]***. Then reimport your shot files with *File|Import Data* dialog.
- to extrapolate starting model grids and WET velocity grids check box ***Extrapolate tomograms*** and edit parameter ***Extrapolate [station spacings]***. This lets you force WET inversion to regard off-end shot points.
- 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*.
- when adding **`Borehole spread/line`** profiles to main **`Refraction spread/line`** profile in *Header|Profile* : adjust ***Profile start offset [m]*** of main profile until the x axis coordinates shown on resulting starting model and tomogram Surfer plots match the x coordinates used for added **`Borehole spread/line`** profiles. Keep adjusting until shot point elevation for downhole shots or receiver elevation for uphole shots matches topography of main Refraction spread/line profile as shown in plots. See tutorial https://rayfract.com/tutorials/11REFR.pdf .

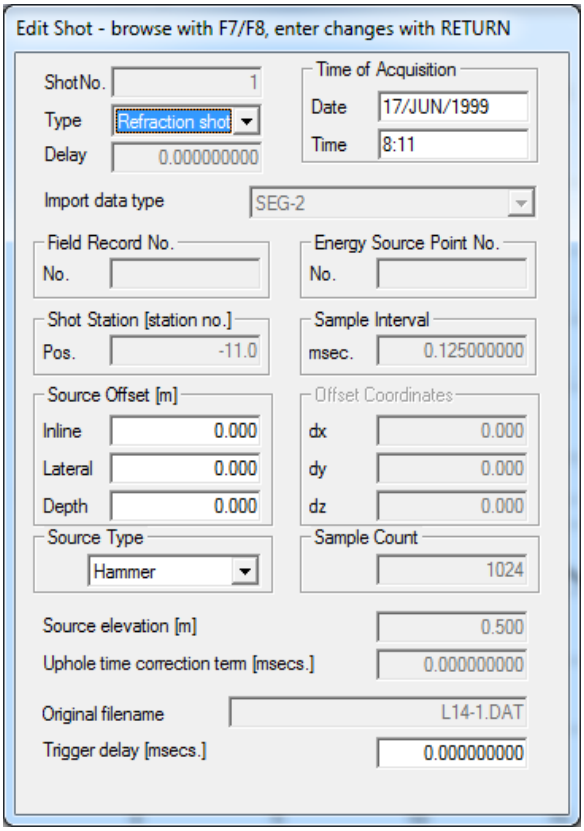
- close this dialog with **`ENTER`** key or click ***OK button*** to accept the edited settings. Use **`ESC`** key or ***Cancel button*** to cancel editing of parameters. Clear out all *Borehole lines* selected with ***Reset button***.

- now import your data with ***File|Import Data...*** dialog.

- see https://rayfract.com/help/manual.pdf for creation of a new profile, data import and typical processing sequences. Also see our SAGEEP 2010 short course manual at https://rayfract.com/ SAGEEP10.pdf for background information and two illustrated step-by-step tutorials.

Shot dialog

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

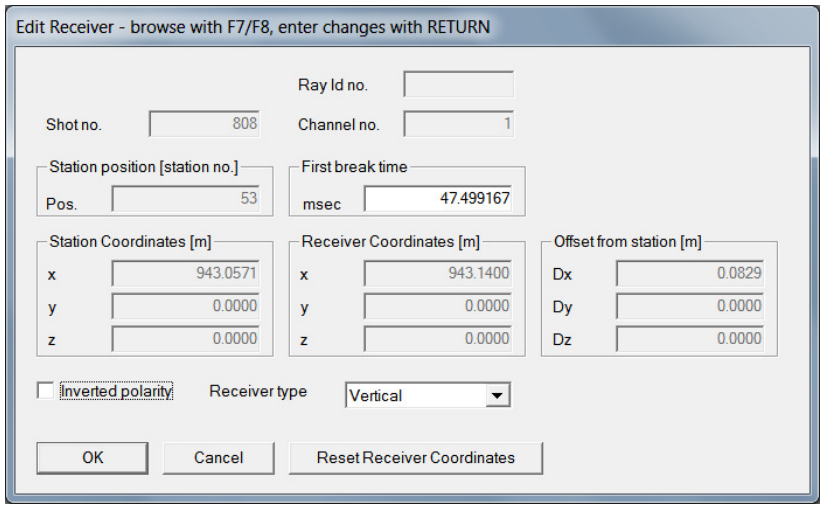


Page through shots with *function keys F7/F8*. Adjust fields if required :

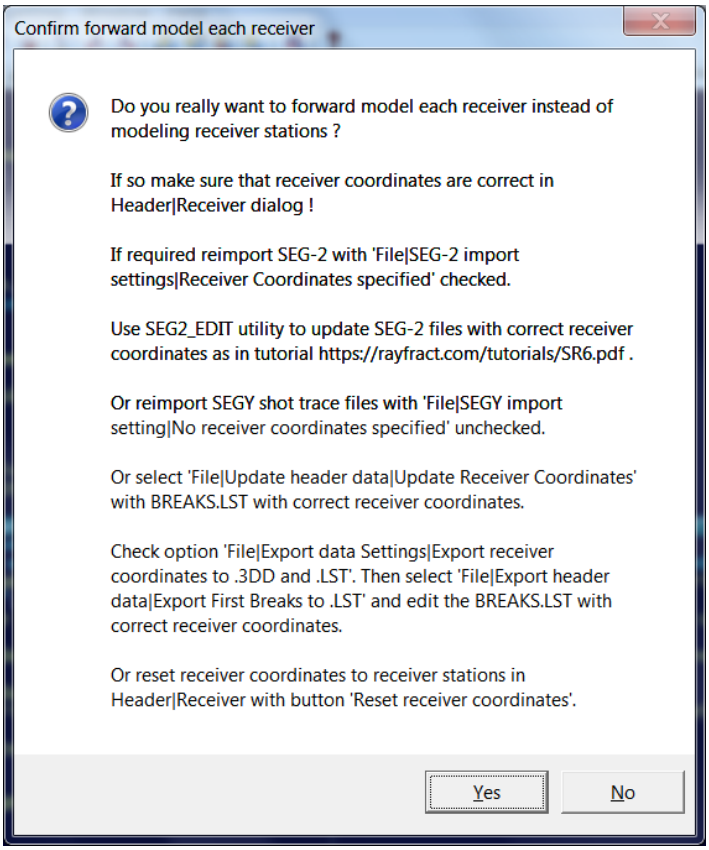
- ***Shot type*** : set to *Refraction shot* or *Uphole shot* for ***Line type*** **`Refraction spread/line`** & *Downhole shot* or *Crosshole shot* for ***Line type*** **`Borehole spread/line`**
- ***Shot inline offset*** : inline offset of the shot point along line topography, in meters, from the *shot position* shown in read-only field *Pos.* (in whole station numbers or ending with .5)
- ***Shot lateral offset*** : horizontal offset of the shot point 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* checked.
- ***Trigger delay*** : interactively shift shot-specific traveltime curve in the *Shot breaks display*. The total time shift is the sum of BOTH *delay time* and trigger delay. Use our ***Trigger jitter removal*** dialog in ***Trace|Shot gather|Processing menu*** to automatically correct shot traces and *Trigger delay* for trigger variation between shots, assuming constant overburden velocity.

Receiver dialog

Browse trace headers of shot selected in ***Header*|*Shot*** with **`F7/F8`** in ***Header*|*Receiver*** :



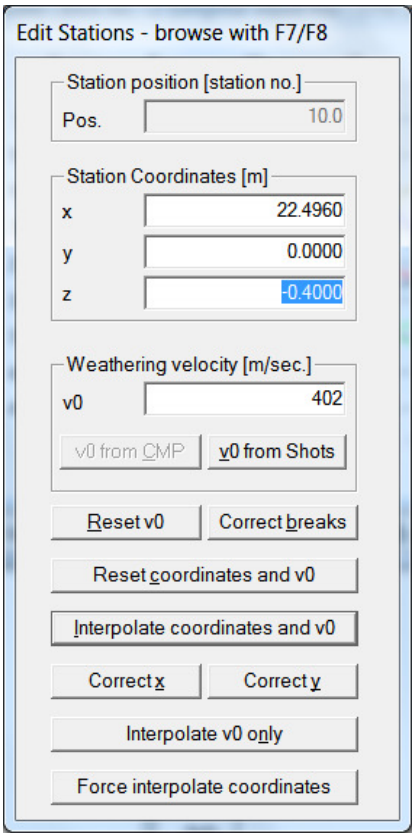
Edit the first breaks in field *First break time*. A first break value of 0 or -1 means no first break picked for this trace. Click button ***Reset Receiver Coordinates*** to reset all receiver coordinates to coordinates at their linked receiver stations. Check option ***Model*|*Model each receiver not receiver stations*** to forward-model traveltimes at shown Receiver Coordinates. Uncheck this option to forward-model at shown Station coordinates. When you check option *Model*|*Model each receiver not receiver stations* we prompt you to confirm :



At the end of our import routine we update coordinates at each receiver station by averaging the coordinates of all receivers linked to that station. This helps for streamer-recorded lines with irregular receiver spacing. See our tutorial https://rayfract.com/tutorials/SR6.pdf . We recommend customizing spread types with options in our File menu so the used receiver geometry is modelled more accurately in the profile database.

Elevation specification in Station dialog

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*
- click button *Interpolate v0 only* to not reset *shot dx/dy/dz* in *Header*|*Shot* to Cartesian offset from *shot station* based on *shot inline offset* and *lateral offset*
- click button *Force interpolate coordinates* to re-interpolate coordinates and v0 for all stations and reset shot dx/dy/dz for all shots even without having edited anything
- click button *Correct x* to correct x coordinates for topography change along the line : convert x coordinate from inline offset along the receiver line (along slope) to horizontal inline offset
- click button *Correct y* to correct y coordinates for topography change along the line : convert y coordinate from inline offset along the receiver line (along slope) to horizontal inline offset

Reopen the station editor with *Header*|*Station*. Browse station records with **F7/F8** to check the interpolated elevations. Also, missing 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 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 https://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]** (shot point elevation at topography) 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. To enable extrapolation of receiver station coordinates to off-end shot points during import check option *File|Import data Settings|Extrapolate receiver line coordinates*. This import option is unchecked per default.

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 chapter 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 chapter 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 or feet) from *shot station* for all shot records. Select *Header|Shot* and browse shots with **F7/F8**. Next specify appropriate (laterally varying) weathering velocities in *Header|Station* as just described. Now compute and apply to first breaks corrections for *Shot position offset* (for *inline shot offset* and *lateral shot offsets* / *shot hole depth*) with button *Correct breaks*, in *Header|Station*. 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 *Header|Station*. Click on button *v0 from Shots* or *v0 from CMP*, to recompute and copy weathering velocity values into all receiver stations and *shot stations*.

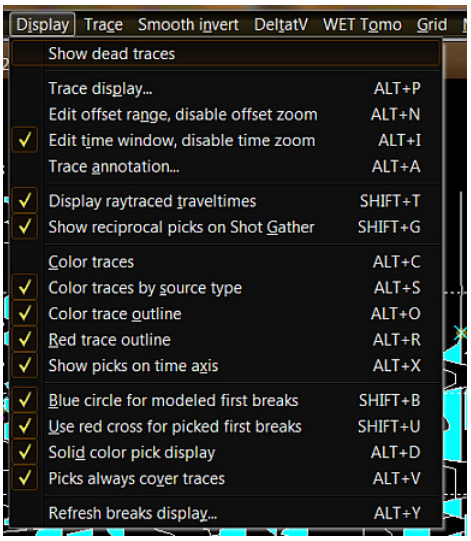
Once you have done time-to-depth conversion and resulting refractor velocities are known, you may remap traces to refractors (*Mapping|Remap all traces* or **ALT+L**) and redo the time-to-depth conversion. This may result in slightly improved results, especially in situations where velocity contrasts 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

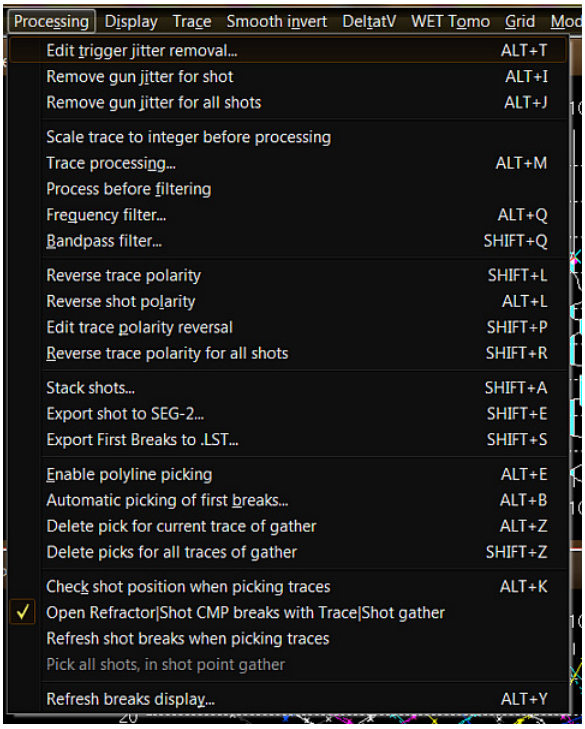
We frequency filter traces for display with *Trace menu*. Filtering is done with recursive Chebyshev-Butterworth filter or single-pole filter. See **Steven W. Smith 1997** with options as described on following pages. Chebyshev-Butterworth is theoretically more performant but often single-pole works 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.

Color traces in *Trace menu gather displays* with options in menu *Display* :



- Color the variable trace area filling with *Display|Color traces*
- Color the trace outline with *Display|Color trace outline*.
- *Display|Color traces by source type* colors shot traces by *source type*, see ***Header|Shot***.

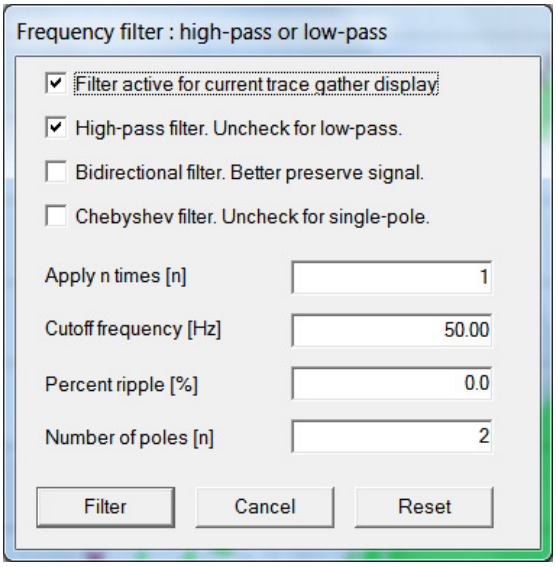
For display traces are first processed with high-pass/low-pass filter and then with bandpass/band-reject filter as specified below. Finally other trace processing including AGC is applied to the filtered traces. Select trace processing options in menu *Processing* :



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*.

High-Pass or Low-Pass frequency filter

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



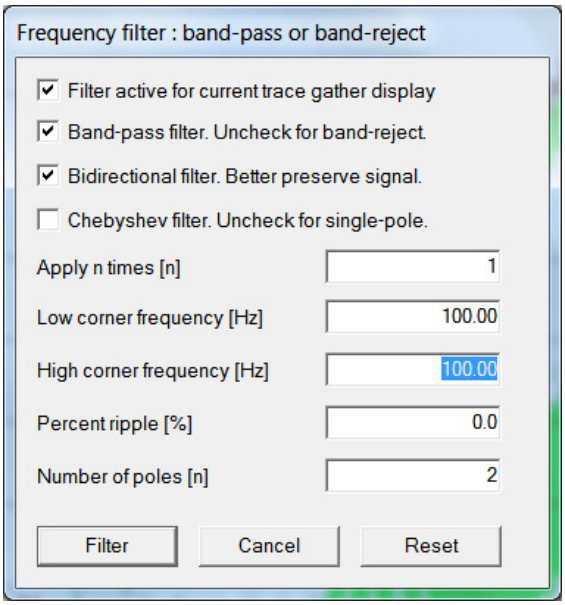
Interactively specify the following parameters :

- ***Filter active for current trace gather display*** Activate frequency filter. Hit Enter or Return key to redisplay traces in current gather window, with this filter applied to traces shown.
- ***High-pass filter. Uncheck for low-pass*** Apply a high-pass frequency filter to traces before displaying them. Uncheck for low-pass frequency filter.
- ***Bidirectional filter. Better preserve signal*** 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.
- ***Chebyshev filter. Uncheck for single-pole.*** 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 1997, Digital Signal Processing, chapter 20, sections Step Response Overshoot and Stability.
- ***Apply n times [n]*** Cascade this frequency filter n times in sequence, for stronger effect.
- ***Cutoff frequency [Hz]*** Specify the frequency separating the bassband from the stopband, of this 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.
- ***Number of poles [n]*** 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.

Bandpass or band-reject filter

Apply a **bandpass or band-reject filter** to displayed traces with *Processing|Bandpass filter* (SHIFT+Q) :

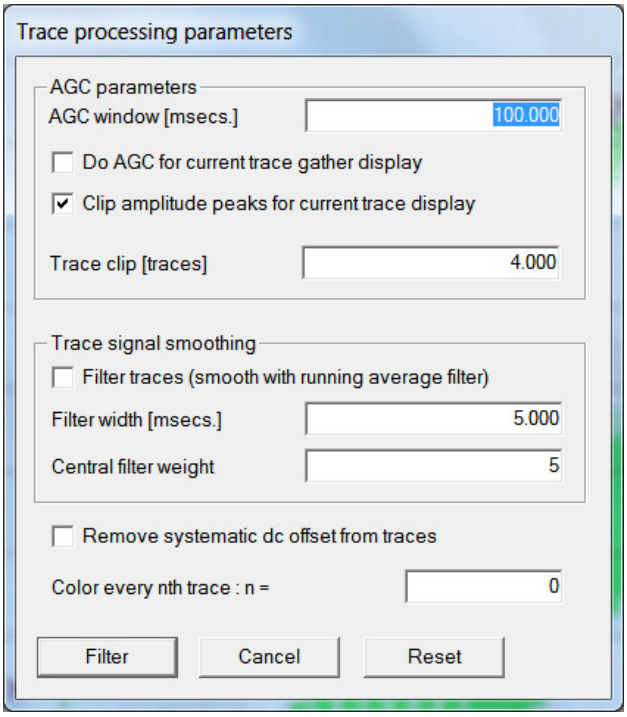


- *Filter active for current trace gather display*
- *Band-pass filter. Uncheck for band-reject*
- *Bidirectional filter. Better preserve signal*
- *Chebyshev filter. Uncheck for single-pole.*
- *Apply n times [n]*
- *Low corner frequency [Hz]*
- *High corner frequency [Hz]*
- *Percent ripple [%]*
-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

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

Trace Processing dialog

You may **process traces for enhanced visibility of first breaks** with *Processing*/*Trace processing* (ALT+M) :



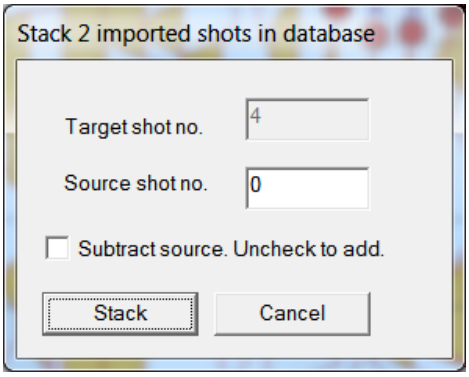
Interactively specify the following parameters :

- ***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

Traces are processed for display only. Traces stored in the database remain the original, unprocessed/raw traces as imported from your seismograph with ***File*/*Import Data…*** .

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.

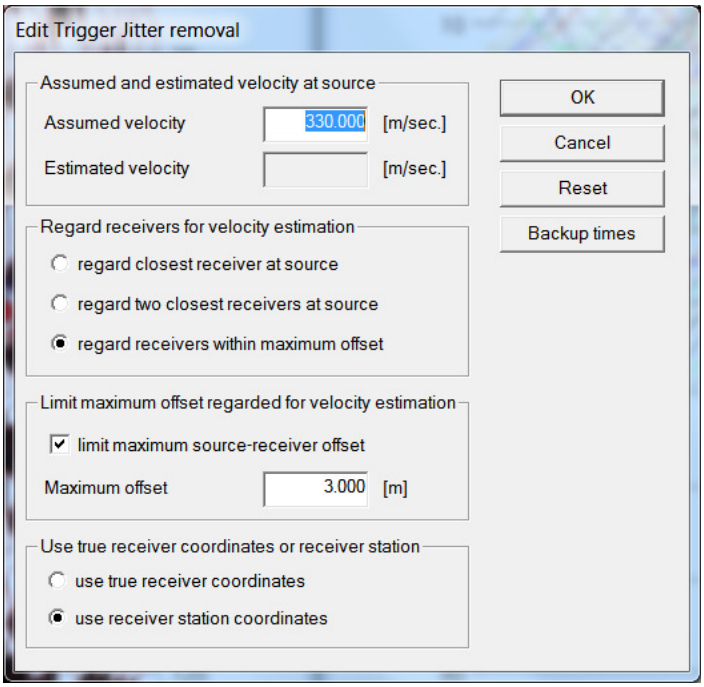
When stacking these two shots we regard the ***Trigger delay*** specified in ***Header*|*Shot***.

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

Remove trigger jitter

This dialog allows removing trigger jitter (delay time variation) from shallow marine refraction surveys or from land-based profiles with a constant overburden (weathering) velocity at all shot points. See our tutorial https://rayfract.com/tutorials/SR6.pdf .

Select *Trace*|*Shot gather*|*Processing*|*Edit trigger jitter removal* to display this dialog :



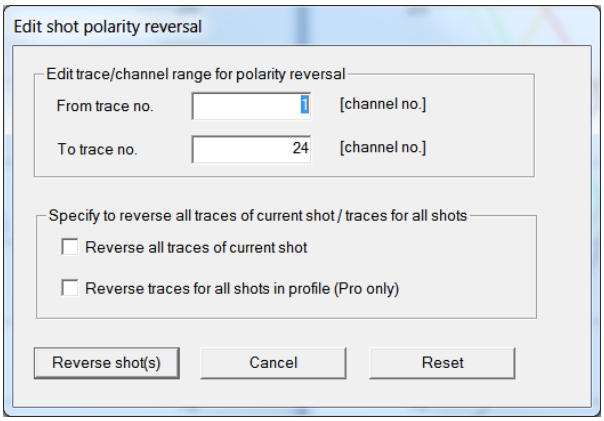
Edit these parameters :

- ***Assumed velocity*** Specify the assumed weathering or overburden velocity directly below shot points. This velocity is used to compute the hypothetical delay of the direct wave between shot point and adjacent trace in ms, regarding the actual source-receiver offset. Next the trigger jitter is determined by subtracting the actual delay (first break pick time) at the same trace from this hypothetical delay. Finally the shot's current *trigger delay* is increased by this trigger jitter.
- ***regard closest receiver at source*** Determine the trigger jitter from *Assumed velocity* and offset and first break at closest trace to shot point.
- ***regard two closest receivers at source*** Average the trigger jitter determined from *Assumed velocity* over two closest traces to shot point.
- ***regard receivers within maximum offset*** Average the trigger jitter determined from *Assumed velocity* over all traces within *Maximum offset* from shot point.
- ***Limit maximum source-receiver offset*** Limit the maximum source-receiver offset for traces regarded for trigger jitter estimation via *Assumed velocity*. If no trace is within this offset limit for a particular shot then that shot's *trigger delay* remains unchanged.
- ***Maximum offset*** Specify the maximum source-receiver offset regarded for traces adjacent to shotpoint when determining the trigger jitter via *Assumed velocity*.
- ***use true receiver coordinates*** Use receiver coordinates as shown in Header|Receiver to determine the source-receiver offset and trigger jitter from *Assumed velocity* and first breaks at traces adjacent to shot point.
- ***use receiver station coordinates*** Use receiver station coordinates as shown in Header|Receiver to determine the source-receiver offset and trigger jitter from *Assumed velocity* and first breaks at traces adjacent to shot point.
- ***Backup times*** Backup station coordinates, shot point coordinates including time terms delay time and trigger delay, and first breaks to files COORDS.COR, SHOTPTS.SHO and BREAKS.LST in Backup subdirectory of currently opened profile.

To undo your trigger jitter correction(s) : first select *File|Update header data|Update Shotpoint coordinates* and file SHOTPTS.SHO in Backup directory. Next select *File|Update header data|Update First Breaks* and file BREAKS.LST in Backup directory.

Trace polarity reversal

Select *Trace|Shot gather|Processing|Edit trace polarity reversal* to display this dialog :

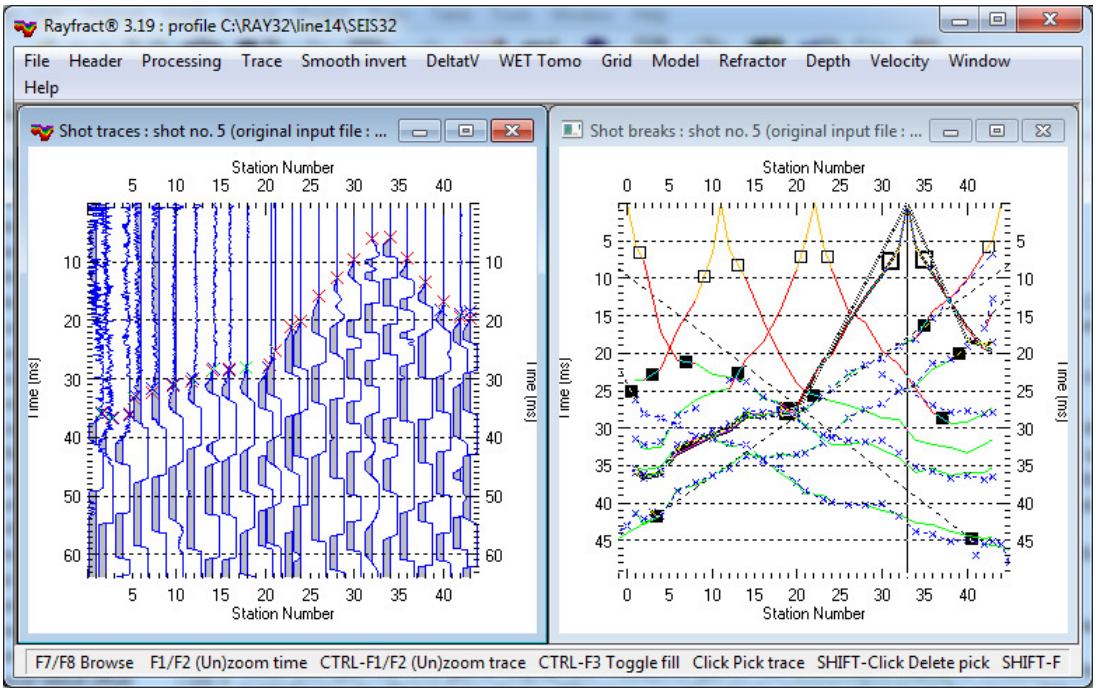


Edit these controls :

- ***From trace no.*** Specify the first channel no. of the channel range for which the trace polarity should be reversed.
- ***To trace no.*** Specify the last channel no. of the channel range for which the trace polarity should be reversed.
- ***Reverse all traces of current shot*** Check to reverse polarity of all traces for current shot displayed in *Trace|Shot gather*.
- ***Reverse traces for all shots in profile (Pro only)*** Check to reverse polarity of traces for all shots imported into your current profile database. This option is enabled for our Pro license only.
- ***Reverse shot(s)*** Click to reverse trace polarity for current shot or for all shots.

Picking first breaks

To pick or review first breaks select *Trace*|*Shot gather* :

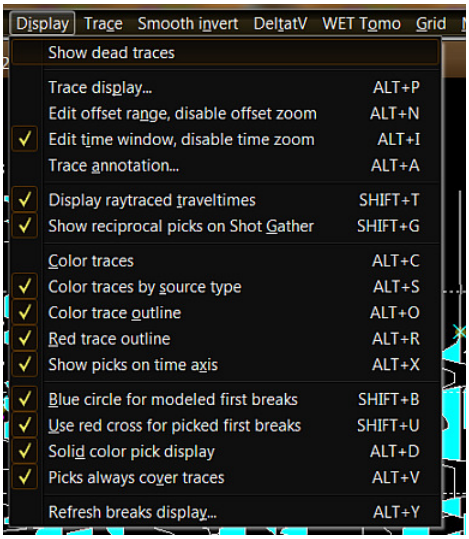


- browse shot records with function keys F8 (forward) and F7 (reverse)
- zoom/unzoom traces in the amplitude coordinate with function keys CTRL+F1/CTRL+F2
- toggle trace display modes with CTRL+F3
- zoom/unzoom the vertical time scale with F1/F2
- page down the zoomed time axis by one section with PgDn
- 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 chapter Dialog box control and function keys for all function keys and their functionality.

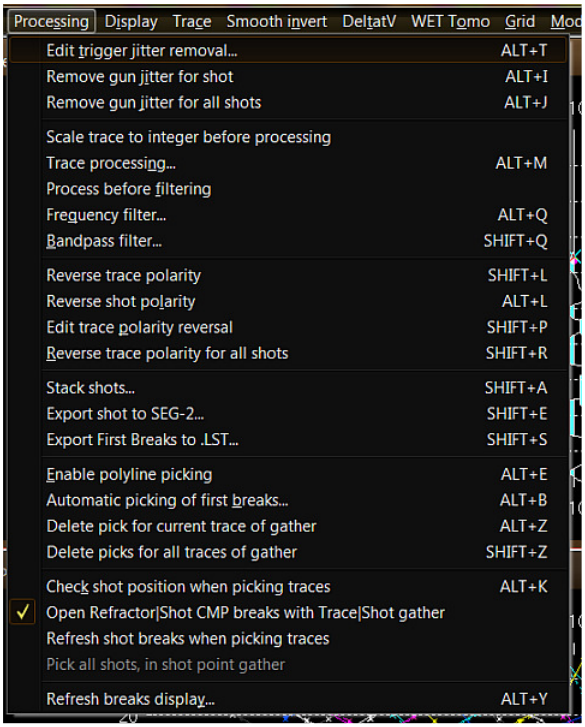
Trace display and processing

Color traces in *Trace menu gather displays* with options in menu *Display* shown below :



- Color the variable trace area filling with *Display|Color traces*
- Color the trace outline with *Display|Color trace outline*.
- *Display|Color traces by source type* colors shot traces by *Source type*. See *Header|Shot*.

Edit trace processing options and select processing commands in menu *Processing* :



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.

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.

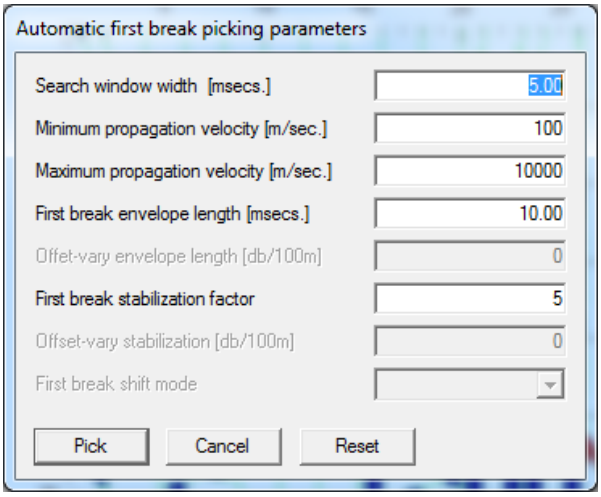
Make sure that **picked traveltime curves for adjacent shots are at least somewhat similar to each other**, when reviewing them in our *Refractor*|*Shot breaks display*. See our tutorials at https://rayfract.com/tutorials/TUTORIAL.ZIP and https://rayfract.com/SAGEEP10.pdf for typical traveltime curve 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* plus *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 https://rayfract.com/tutorials/riveral8.pdf and https://rayfract.com/samples/GEOXMERC.pdf. **Use Trace menu item Export reciprocal errors...** to compute and export reciprocal traveltime picking errors to ASCII .ERR file. Next select ***Trace*|*Shot gather*|*Display*|*Show reciprocal picks on Shot Gather*** to plot your reciprocal picks as green dots on shot traces. See our tutorials https://rayfract.com/tutorials/Gasch23.pdf and https://rayfract.com/tutorials/Line3.pdf and crosshole tutorial https://rayfract.com/tutorials/MDW2011_23.pdf .

Use our Trigger jitter removal dialog to automatically update the *trigger delay* assuming a constant-velocity overburden.

Automatic picking

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



Edit these parameters :

- ***Search window width*** : This parameter is used for Semi-automatic first break picking. Decrease this parameter in situations of a high degree of pre-first break noise, or with weak first break signals. The smaller the parameter value, the closer the automatic pick will be to the linearized time defined by your picked polyline.

- ***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.

- ***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.

- ***First break envelope length*** : Determine the trace signal time window regarded when automatically picking the first break. 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*** : Helps in situations of strong pre-first break noise, caused by surface sources, such as circulation / trees moved by wind / footsteps. Increase parameter value to filter out increasingly larger amplitude noise / if first breaks picked automatically are too early.

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 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.

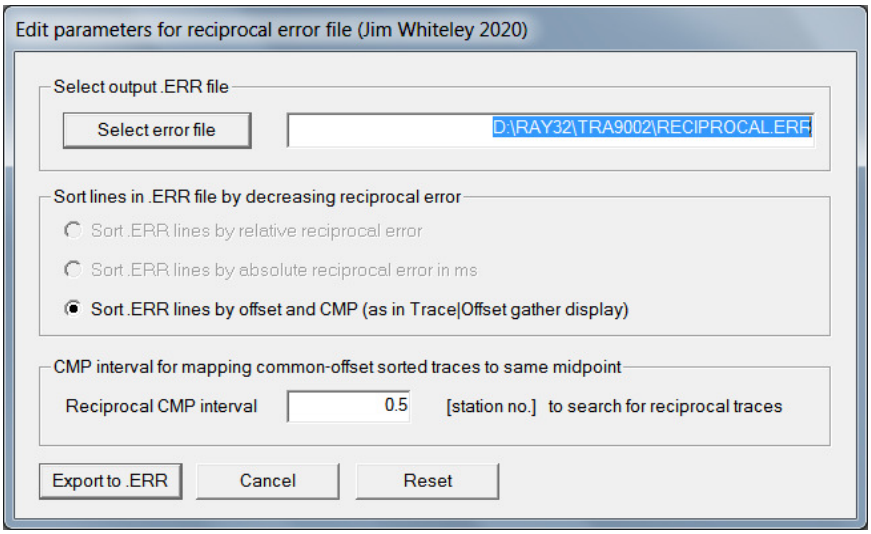
Instead of picking first breaks in the *Trace*|*Shot gather display*, you may pick in *Trace*|*Offset gather display*. Use arrow keys as described above, for trace and sample navigation. Color traces with menu items in ***Display menu***. Do frequency filtering, bandpass filtering and trace processing as in *Trace*|*Shot gather display* using our ***Processing menu***. For identification and correction of reciprocal traveltime errors, see https://rayfract.com/tutorials/riveral8.pdf and https://rayfract.com/samples/GEOXMERC.pdf . You may repick individual traces, or correct the *trigger delay* for whole shots in ***Header*|*Shot*** . **Use *Trace menu*** item ***Export reciprocal errors...*** to compute and export reciprocal traveltime picking errors to ASCII .ERR file. Import the .ERR file into Microsoft Excel and sort by any column. Next select ***Trace*|*Shot gather*|*Display*|*Show reciprocal picks on Shot Gather*** to plot your reciprocal picks as green dots on shot traces. See our tutorials https://rayfract.com/tutorials/Gasch23.pdf and https://rayfract.com/tutorials/Line3.pdf . Also works for cross-hole surveys as shown in tutorial https://rayfract.com/tutorials/MDW2011_23.pdf .

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

Reciprocal traveltime picking error export

Since version 4.01 released in May 2021 we support export of reciprocal traveltime picking errors to ASCII .ERR file with space character separated columns listing absolute reciprocal error in ms and relative reciprocal error in percent. See **Whiteley J. et al. 2020**. Landslide monitoring using seismic refraction tomography - The importance of incorporating topographic variations. Engineering Geology 2020. https://www.researchgate.net/publication/339280163

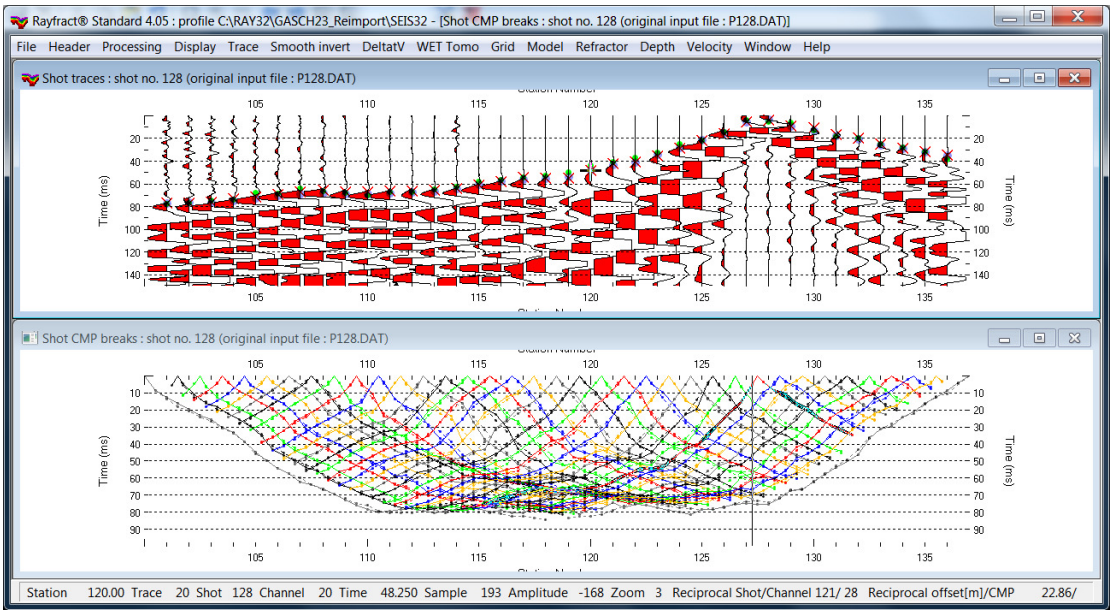


Edit these parameters in ***Trace|Export reciprocal errors*** dialog :

- ***Error file name*** : Specify the filename of the ASCII formatted .ERR file written to
- ***Select error file*** : Click to select folder and to specify filename for .ERR file written to
- ***Sort .ERR lines by offset and CMP*** : Sort ASCII text lines in the .ERR file by offset in meters (first column) and CMP station (second column).
- ***Reciprocal CMP interval*** : Specify the CMP interval [in station numbers] to search for pairs of reciprocal traces mapping to the same CMP

- we list in the .ERR file absolute reciprocal error in ms and relative reciprocal error in percent
- we also list in the .ERR file the forward shot&channel and reverse shot&channel plus shot station and receiver station of trace pairs used to computer these reciprocal errors. Sort this .ERR file in Microsoft Excel by any column to identify bad shots or receivers
- .ERR lines are sorted by offset (m) and CMP station as in our ***Trace|Offset gather*** display. Any trace pair with relative reciprocal picking error above 5 percent or absolute error exceeding 5ms or 10ms needs to be repicked.
- next select ***Trace|Shot gather|Display|Show reciprocal picks on Shot Gather*** to plot your reciprocal picks as green dots on shot traces. See our tutorial https://rayfract.com/tutorials/Gasch23.pdf . Also works for cross-hole surveys with *Line type* Borehole spread/line. See tutorial https://rayfract.com/tutorials/MDW2011_23.pdf .

Plot your reciprocal traveltime picks on shot-sorted trace gathers

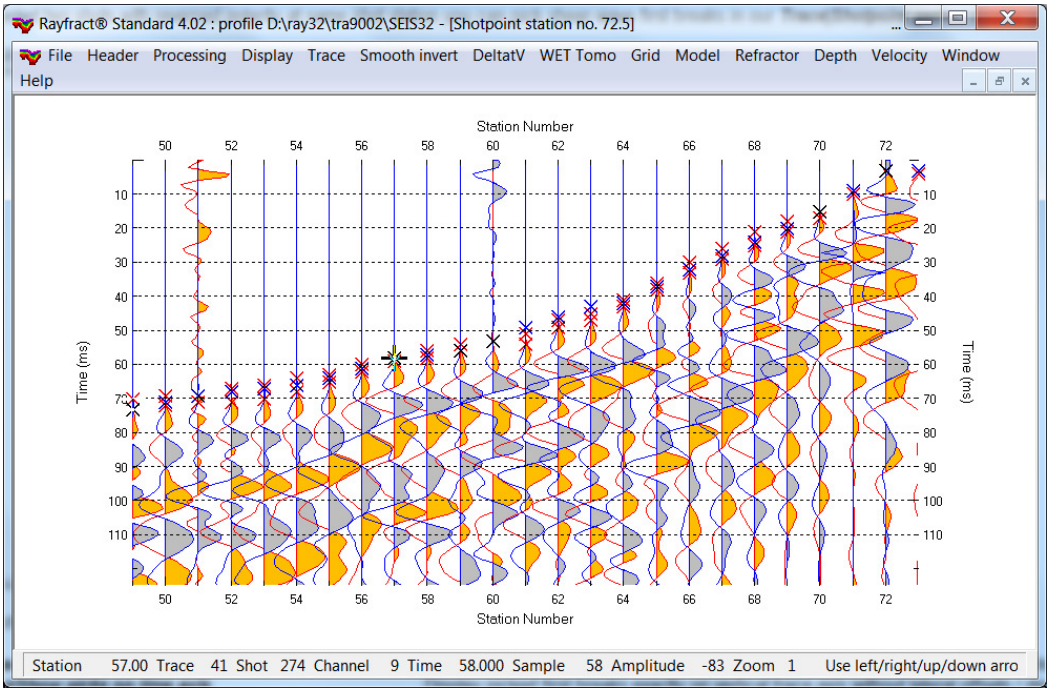


We strongly recommend plotting your reciprocal traveltime picks on shot-sorted trace gathers. This lets you quality-control your first break picks and check the validity of your recording geometry specification (shot station numbers and receiver station numbers specified during shot import). See **Whiteley J. et al. 2020**. Landslide monitoring using seismic refraction tomography - The importance of incorporating topographic variations. Engineering Geology 2020. https://www.researchgate.net/publication/339280163 .

- select ***Trace|Export reciprocal traveltime picks and update database*** to display above dialog shown on preceding page
- click button *Select error file* and click *Save* button
- click button *Export to .ERR*
- optionally check new option ***Trace|Open Refractor|Shot CMP breaks with Shot gather***
- select ***Trace|Shot gather***
- check new version 4.06 option ***Display|Show reciprocal picks on Shot Gather***
- browse and zoom trace gathers with function keys F7/F8, F1/F2 etc. as usual
- navigate traces with arrow-left and arrow-right keys
- if a reciprocal pick was determined/matched to the current trace then this is plotted as a green dot on the trace. See above figure.
- also we show ***Reciprocal Shot/Channel*** and ***Reciprocal offset[m]/CMP*** in status bar at bottom of ***Trace|Shot gather*** window if a reciprocal pick is available in the .ERR file
- see our tutorials https://rayfract.com/tutorials/Line3.pdf, https://rayfract.com/tutorials/Gasch23.pdf and crosshole tutorial https://rayfract.com/tutorials/MDW2011_23.pdf
- when you repick first breaks in *Trace|Shot gather* you invalidate the reciprocal trace error .ERR file and need to regenerate this as per above steps
- also when you update header data with ***File|Update header data*** menu commands you invalidate the reciprocal trace error .ERR file and need to regenerate this as per above steps. We will prompt you to regenerate the .ERR file.

Shear wave picking

If you recorded two shots with reversed polarity at same shot station you can pick shear-wave first breaks in our ***Trace*|*Shotpoint gather*** display :



Optionally check these options :

- ***Processing*|*Pick all shots, in shotpoint gather*** Pick traces from all shots at same station number and in same shotpoint gather display with one mouse click
- ***Display*|*Show picks on time axis*** Display picked first breaks exactly on vertical trace axis without lateral offsets / disregarding the trace signal amplitude at the picked sample

Browse between shotpoint gathers with F7/8 function keys as described for ***Trace*|*Shot gather*** display; see top of this chapter.

Doug Crice describes cross-hole and down-hole shear wave recording geometry in his paper http://geostuff.com/Downhole_Shearwaves.pdf .

For Smooth inversion and WET inversion we assume that you record shots with a hydrophone streamer in one borehole as shown at https://geotomographie.de/equipment/borehole-receivers/

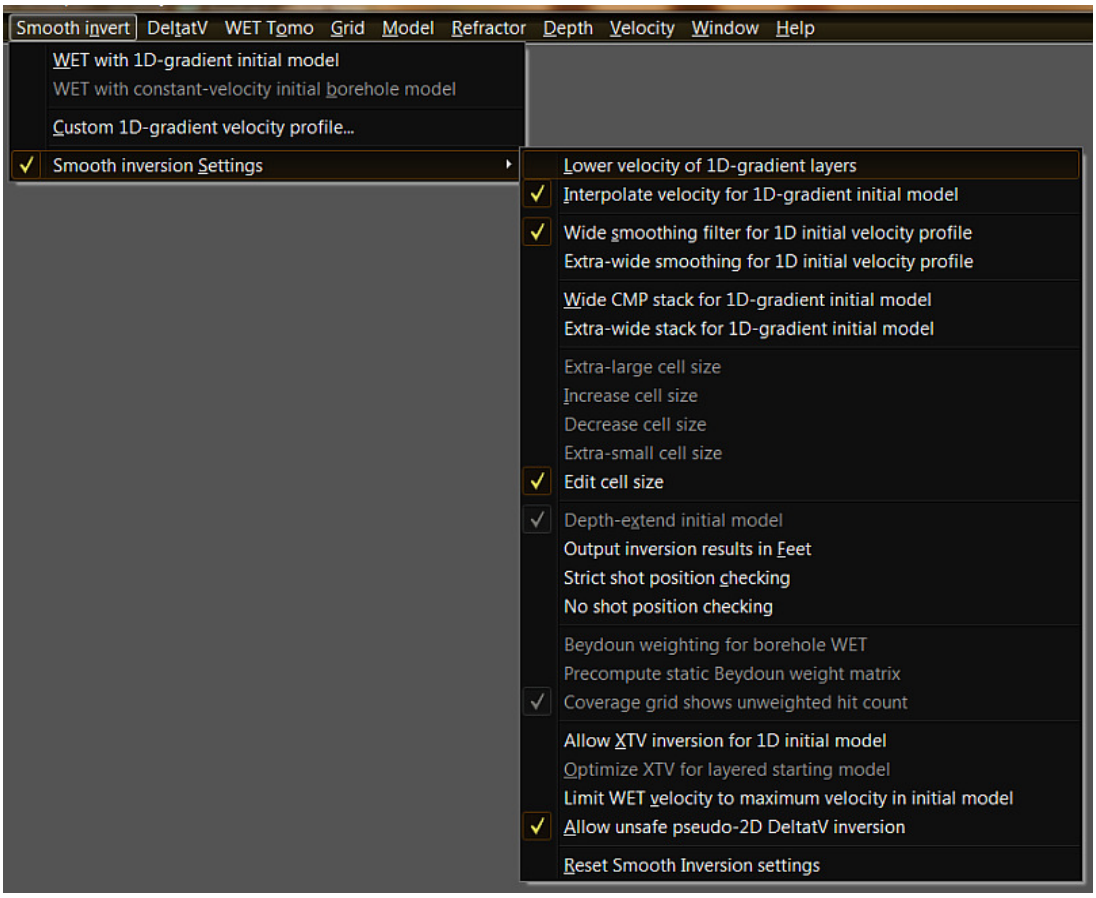
e.g. hydrophone string BHC5 with e.g. 24 channels.

Next import the SEG-2 shots, pick first breaks and run our Smooth inversion and WET inversion with constant-velocity CONSTVEL.GRD starting model as in chapter Crosshole survey interpretation and as in our tutorial https://rayfract.com/tutorials/mdw2011.pdf .

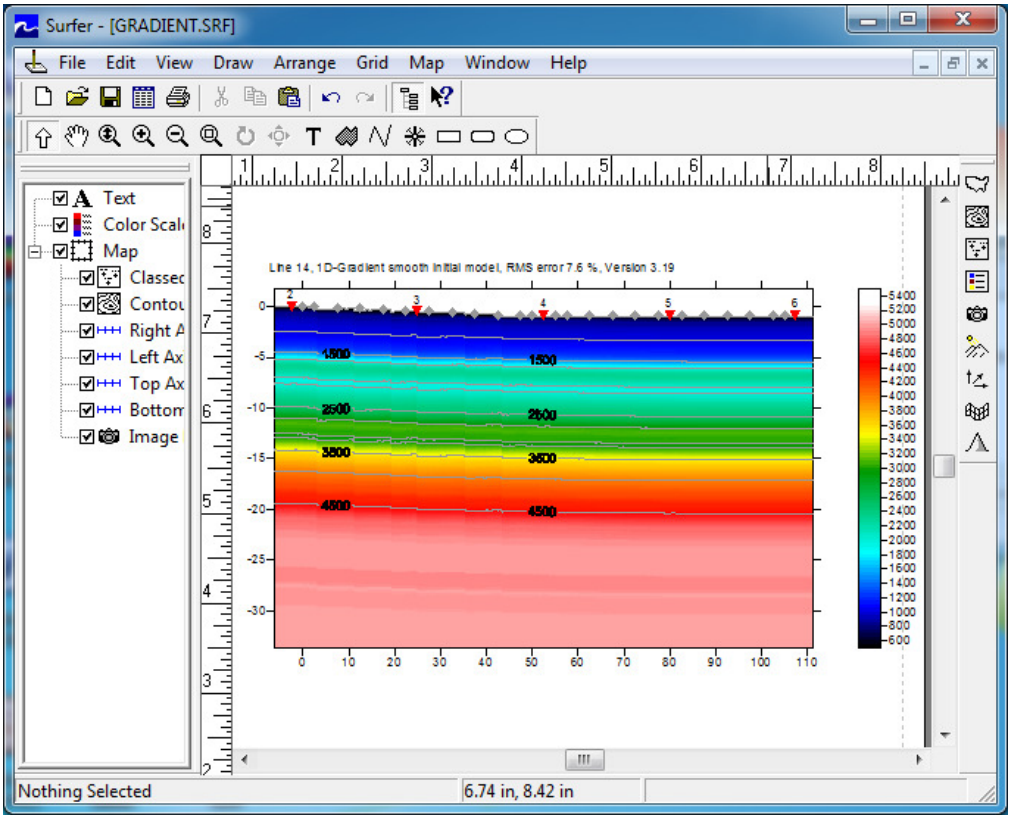
Smooth inversion

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

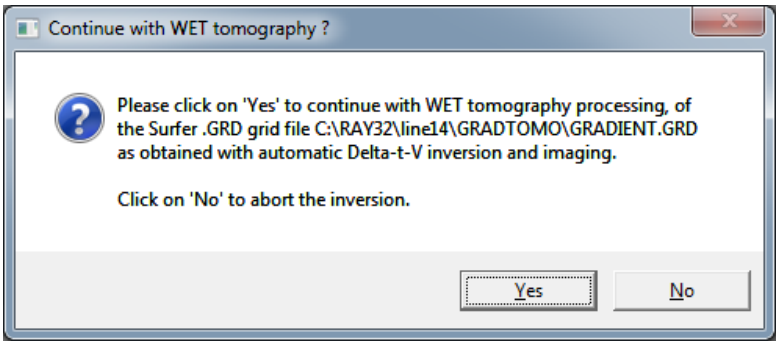
Start this inversion with ***Smooth inversion*/*WET with 1D-gradient initial model*** :



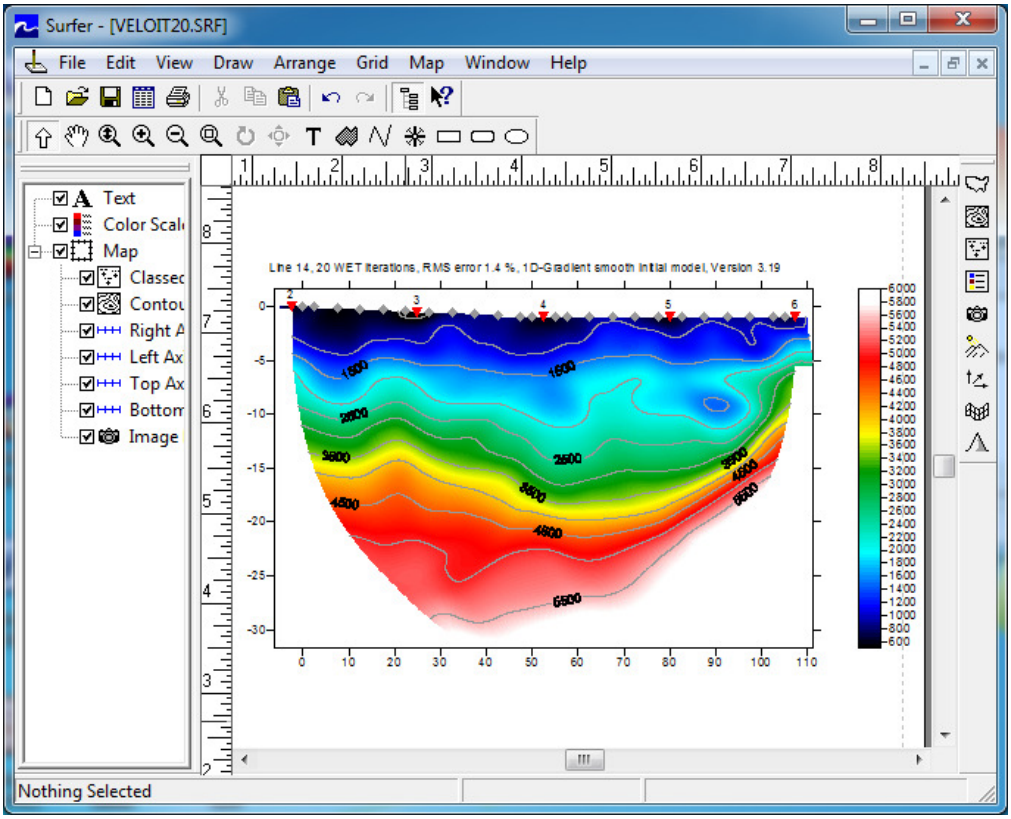
Wait for scripting to plot the **initial 1D-gradient model** in Golden Software Surfer®. Click on Surfer icon at bottom of screen to display this :



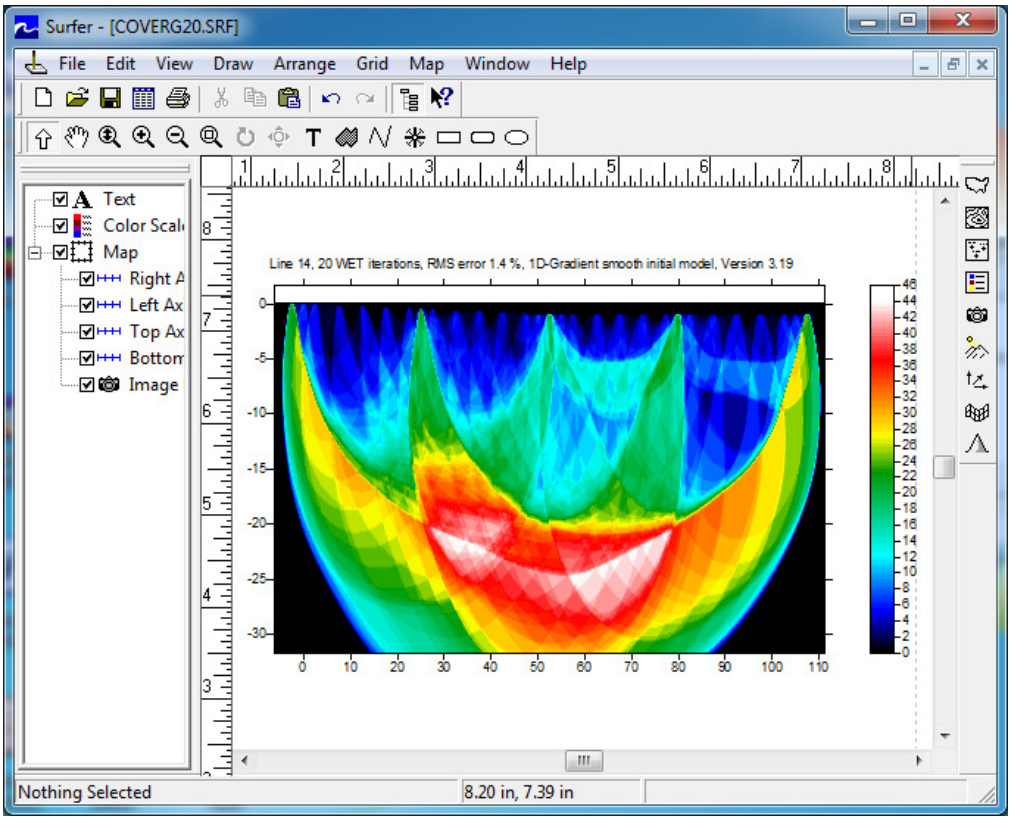
Next click on Rayfract® icon at bottom of screen, and confirm this prompt :



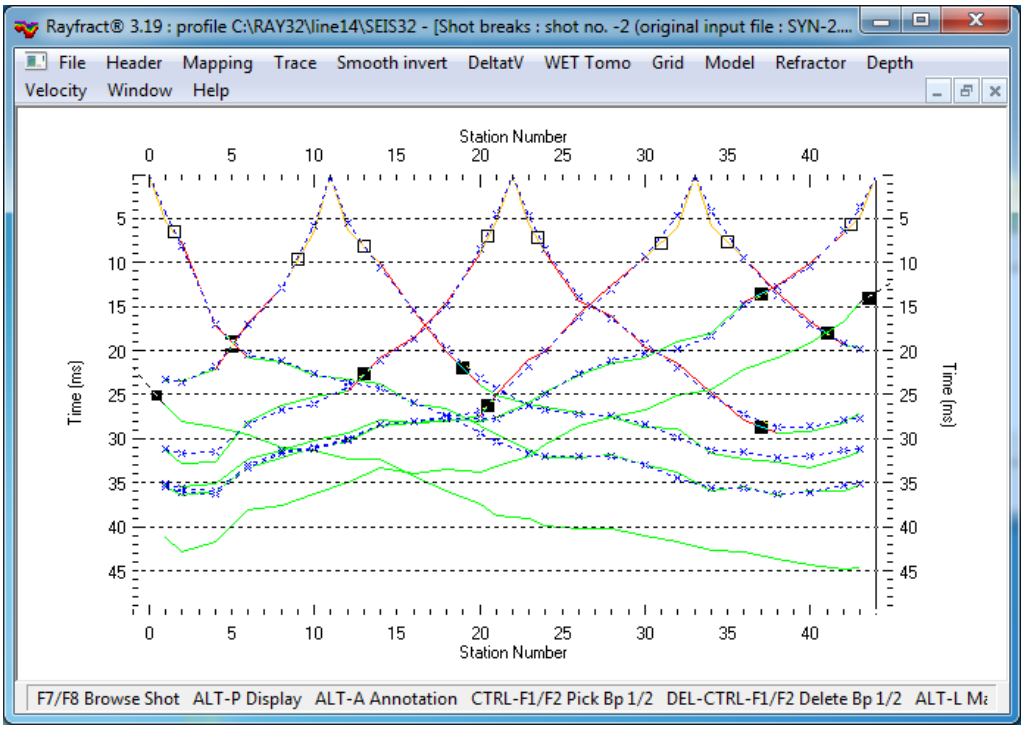
Once WET finishes confirm the two prompts to display the resulting **WET tomogram** in Golden Software Surfer® :



Use CTRL+TAB key combination in Surfer®, to view **WET wavepath coverage plot** :



Select ***Refractor|Shot breaks*** to check match between modeled (dashed blue) and picked (solid grey or colored) traveltime curves :



1D-gradient initial model

The 1D-gradient initial model determined with command ***Smooth invert|WET with 1D-gradient 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-gradient initial model still shows a good initial traveltime fit, between measured and picked times. This artefact-free simple initial model and good initial fit are required for WET true 2D tomography processing to have a chance to converge towards a meaningful final model. The simple and smooth starting model ensures that WET inversion can find the global traveltime misfit minimum and is not getting stuck in a local minimum of the misfit function.

The 1D-gradient initial model is determined automatically as follows :

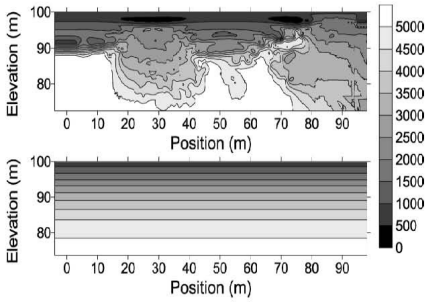
- first the pseudo-2D DeltatV initial model is determined. This will give individual velocity vs. depth profiles below each profile station
- then the average velocity vs. depth profile is determined by horizontally averaging velocities of the pseudo-2D DeltatV initial model over all profile stations, at common depths
- finally this averaged velocity vs. depth profile is extended laterally along the whole profile. A 1D-gradient velocity grid is generated based on these average velocities.
- XTV inversion is disabled during this procedure if *Smooth invert|Smooth inversion Settings|Allow XTV inversion for 1D initial model* is unchecked

Also see (Sheehan 2005). For a summary **description of Smooth inversion and WET parameters and options** see our SAGEEP 2010 short course manual at https://rayfract.com/SAGEEP10.pdf .

Below we show slides from our SAGEEP 2021 publication (Rohdewald S.R.C. 2021a) with slides available at https://rayfract.com/pub/SAGEEP%202021%20slides.pdf :

Smooth Inversion = 1D gradient initial model + 2D WET Wavepath Eikonal Traveltime tomography

Get minimum-structure
1D gradient initial model :



Top : pseudo-2D DeltatV display

- 1D DeltatV velocity-depth profile below each station
- 1D Newton search for each layer
- velocity too low below anticlines
- velocity too high below synclines
- based on synthetic times for Broad Epikarst model (Sheehan, 2005a, Fig. 1).

Bottom : 1D-gradient initial model

- generated from top by lateral averaging of velocities
- minimum-structure initial model
- DeltatV artefacts are completely removed

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Generalized Rayfract® Flow Chart

Create new profile database

Define header information
(minimum: Line ID, Job ID, instrument, station spacing (m))

Import data
(ASCII first break picks or shot records)

Update geometry information
(shot & receiver positional information)

Run inversion
Smooth invert|WET with 1D-gradient initial model
(results output in Golden Software's Surfer)

Edit WET & 1D-gradient parameters & settings

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Smooth Inversion, DeltatV and WET Parameters

❑always start with default parameters: run Smooth inversion without changing any setting or parameter

❑next adapt parameters and option settings if required, e.g. to remove artefacts or increase resolution

❑more smoothing and wider WET wavepath width in general results in less artefacts

❑increasing the WET iteration count generally improves resolution

❑don't over-interpret data if uncertain picks : use more smoothing and/or wider wavepaths.

❑explain traveltimes with minimum-structure model

❑tuning of parameters and settings may introduce or remove artefacts. Be ready to go one step backwards.

❑use Plus-Minus layered refraction method (Hagedoorn, 1959) as alternate starting model

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WET tomography main dialog: see help menu

Number of WET tomography iterations	Default value is 20 iterations. Increase to 50 or 100 for better resolution and usually less artefacts. WET can improve with increasing iterations, even if RMS error does not decrease.
Wavepath frequency	Ricker wavelet used to modulate/weight the wavepath misfit gradient, during model update. Leave at default of 50Hz. One period is 1/50Hz = 20ms. See (Schuster, 1993).
Degree of differentiation of Ricker wavelet	0 for original Ricker wavelet, 1 for once derived wavelet. Value 1 may give artefacts: wavepaths may become "engraved" in the tomogram. New default is -1: Gaussian weighting. Set to -2 for Cosine-Squared weighting, for better imaging of vertical fault zones.
Wavepath width	In percent of one period of Ricker wavelet. Increase width for smoother tomograms. Decreasing width too much generates artefacts and decreases robustness of WET inversion. Click Iterate button to specify multirun WET schedule for decreasing wavepath width between consecutive WET runs.
Envelope wavepath width	Width of wavepaths used to construct envelope at bottom of tomogram. Default is 0.0. Increase for deeper imaging.
Maximum valid velocity	Limit the maximum WET velocity modeled. Default is 6,000 m/s. Decrease to prevent high-velocity artefacts in tomogram.
Full smoothing	Default smoothing filter size, applied after each WET iteration
Minimal smoothing	Select for more details, but also more artefacts. May decrease robustness and reliability of WET inversion.
Manual smoothing	Specify half-width and half-height of smoothing filter in grid columns and grid rows. Gaussian or Uniform weighting. Smooth nth iteration. Smooth velocity update. Maximum velocity update. Check No smoothing to disable WET smoothing. Specify Damping for Conjugate-Gradient WET inversion.

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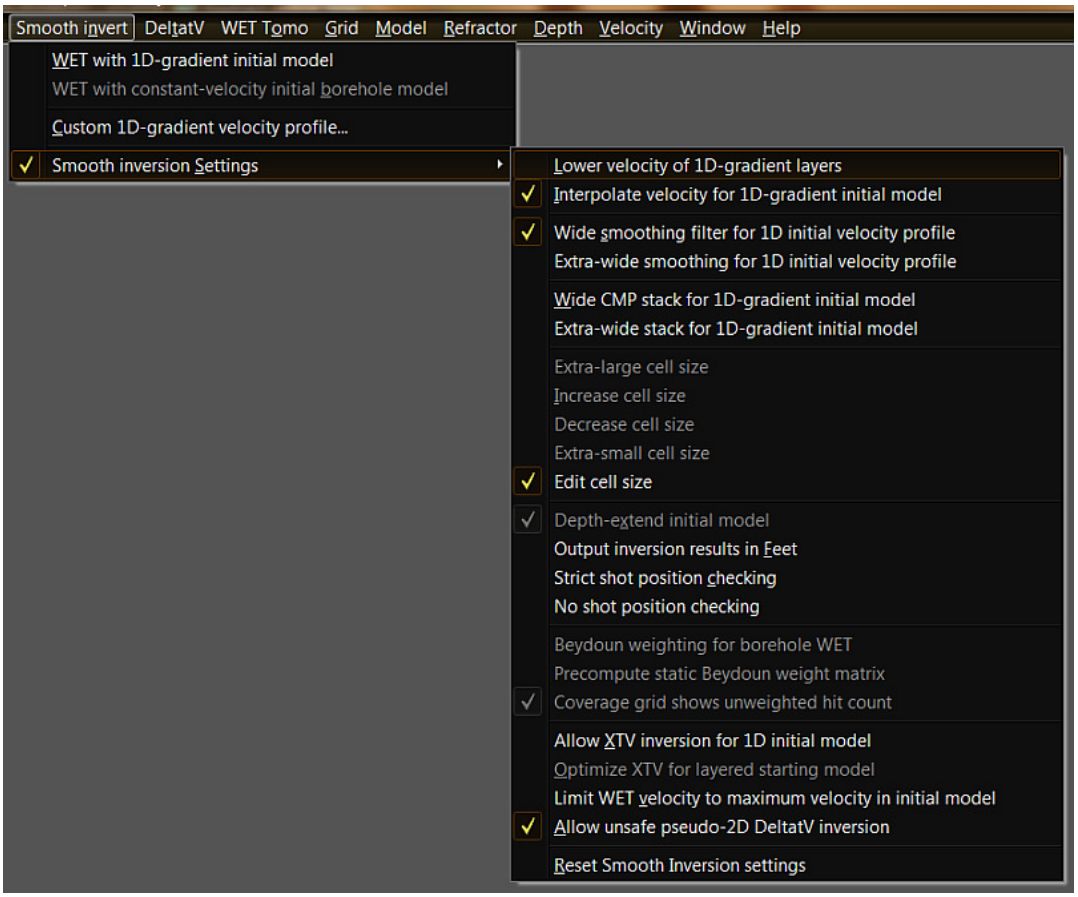
Smooth inversion Settings

Here we list options offered in ***Smooth invert*|*Smooth inversion Settings*** *menu* :



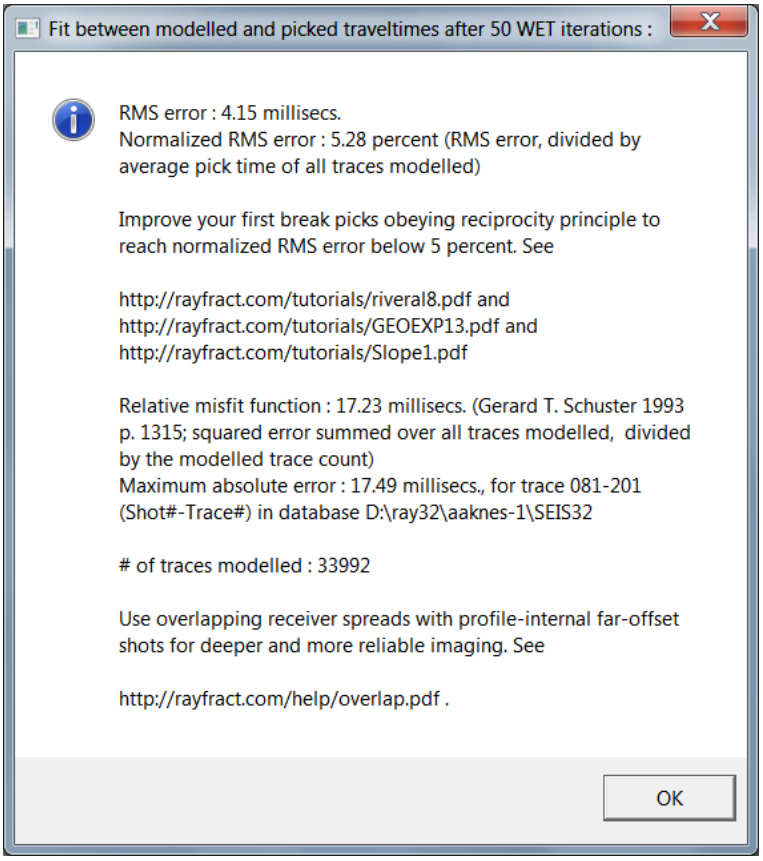
- ***Lower velocity of 1D-gradient layers*** Set the gradient-layer bottom velocity to (top velocity + bottom velocity)/2, for each layer in the initial model. Disabled per default. Enable to lower the velocity of the overburden layers.
- ***Interpolate velocity for 1D-gradient initial model*** Linearly interpolate the laterally averaged 1D-velocity profile (in vertical direction) when computing the 1D-gradient 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.
- ***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.
- ***Wide CMP stack for 1D-gradient initial model*** Toggle DeltatV parameter *CMP curve stack width* between default value 120 and wide setting 240 for Smooth inversion.
- ***Extra-wide stack for 1D-gradient initial model*** Use *CMP stack* with max. 1,200 CMP curves, for construction of averaged CMP curve for Smooth inversion. Stack width is limited to number of CMP's in profile.
- ***Extra-large cell size*** Extra large cell size of grid. Speeds up WET inversion. Use with long and shallow initial model, for fewer grid rows. WET inversion may become unstable in case of velocity inversions.
- ***Increase cell size*** 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.

- ***Decrease cell size*** Decrease *grid cell size*. Slows down WET inversion. Use for more detailed imaging, and better imaging of sharp velocity contrast at top-of-basement.
- ***Extra-small cell size*** Extra small *grid cell size*. Use for even better imaging of sharp velocity contrasts. Available with Pro license only.
- ***Edit cell size*** Regard the user-specified *grid cell size* in *Header|Profile* when determining the 1D-gradient starting model. Alternatively check *Header|Profile|Force grid cell size*. When you check this option all other cell size options in Smooth invert|Smooth inversion Settings and in DeltatV|DeltatV Settings will be unchecked and *Header|Profile|Force grid cell size* will be checked.
- ***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.
- ***Output inversion results in Feet*** Generate tomograms in feet. Uncheck to generate velocity tomograms in meters.
- ***Strict shot position checking*** 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.
- ***No shot position checking*** Disable shot position checking with missing/unpicked traces adjacent to shot point to suppress false positives.
- ***Beydoun weighting for borehole WET*** Enable Beydoun weighting. Velocity artefacts/anomalies at grid corners and at grid edges/directly adjacent to boreholes are suppressed and more weight is given to central area of tomogram during WET inversion. Use option *Precompute static Beydoun weight matrix* to specify static or dynamic Beydoun weighting.
- ***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.
- ***Coverage grid shows unweighted hit count*** Show the hit count of each grid cell, scaled by *Beydoun weighting for borehole WET* . With this option checked, the coverage grid shows the unweighted hit count.
- ***Allow XTV inversion for 1D initial model*** Use XTV inversion for determination of the 1D-gradient initial model used for Smooth inversion. XTV inversion better models a constant-velocity weathering overburden with the intercept-time method, in addition to modeling of gradient layers with DeltatV inversion.
- ***Optimize XTV for layered starting model*** Configures XTV for strong velocity contrast between overburden and basement in starting model for Smooth inversion. Uncheck this option and uncheck option *Allow XTV inversion for 1D initial model* for gradual increase of velocity with depth in 1D-gradient starting model for Smooth inversion. Unchecking these options can make the inversion more reliable/give deeper output with bad/too early first break picks.
- ***Limit WET velocity to maximum velocity in initial model*** 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. We recommend checking this option when engaging WDVS for WET inversion to suppress a WDVS bias towards too high basement velocities and to avoid imaging high-velocity anomalies in overburden with too much contrast.

- ***Allow unsafe pseudo-2D DeltatV inversion*** If you want to invert first breaks with pseudo-2D DeltatV method first run Smooth inversion. Then check this option to enable the DeltatV menu.

Improve your first break picks

If the normalized RMS error exceeds 5 percent we prompt after WET inversion to improve your traveltime picks regarding the traveltime reciprocity principle :



Use our *Trace*/*Offset Gather* display to check your first break picks 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 https://rayfract.com/tutorials/Slope1.pdf, https://rayfract.com/tutorials/riveral8.pdf and https://rayfract.com/samples/GEOXMERC.pdf . **Aim for an RMS error (misfit between picked and modeled first break times) below 3%** as shown on top of all Surfer tomogram plots. **Use Trace menu item Export reciprocal errors...** to compute and export reciprocal traveltime picking errors to ASCII .ERR file. Import the .ERR file into Microsoft Excel and sort by any column.

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 https://rayfract.com/SAGEEP10.pdf and (Tassis et al. 2017). Increase the *WET iteration count* and at the same time decrease WET smoothing **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

https://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.

https://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

https://rayfract.com/tutorials/broadepi.pdf
https://rayfract.com/tutorials/depress.pdf
https://rayfract.com/tutorials/palmfig3.pdf
https://rayfract.com/tutorials/fig9inv.pdf
https://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.

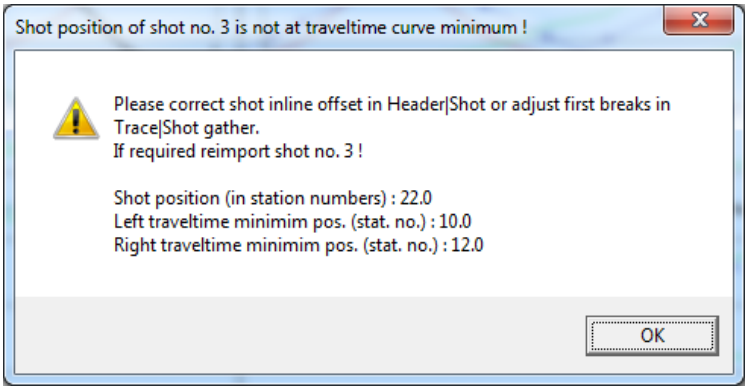
Review DeltatV and WET settings in .PAR file

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 :

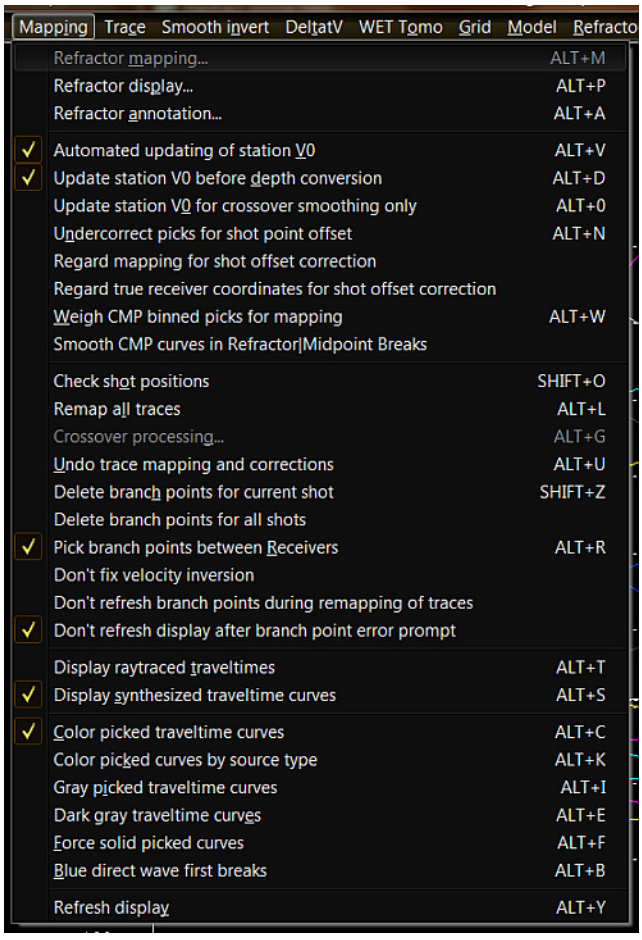
- select *Start|Run...,* enter command line "Notepad" (without the enclosing "") and hit ENTER
- select *File of type* option *All Files* in the Notepad Open dialog
- open this file VELOIT20.PAR in your \RAY32\<your profile name>\GRADTOMO subdirectory
- close Notepad before running WET again to avoid 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 automatically 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 configure your *Refractor|Shot breaks* display with Mapping menu items :



- first backup your first break picks to an .LST file with *File|Export header data|Export First*

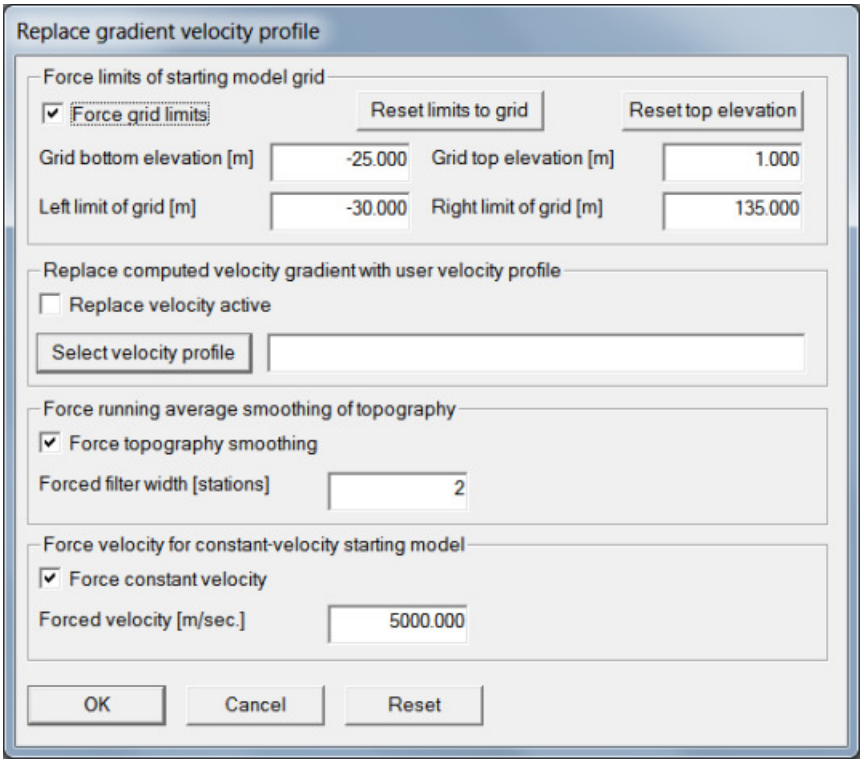
Breaks…

- 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 two *station spacings* 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). Use our .HDR batch import for consistent reimport of all shots. Or check option *File*|*Import data Settings*|*Allow shot inline offset from shot station larger than two spacings*. Enabling this option gives less accurate DeltatV inversion results.
- 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 **...\LAYRTOMO** 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 topography smoothing*** Check to smooth the topography using a running-average smoothing filter with filter width of *Forced filter width* stations when determining the laterally averaged 1D-gradient starting model
- ***Forced filter width*** Edit this field to specify the width of the running-average smoothing filter [in stations] used for smoothing of topography with option *Force topography smoothing* checked
- ***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

https://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.

In our new tutorial https://rayfract.com/tutorials/poisson_Surfer23.pdf we show using Golden Software Surfer version 23 to generate the POISSON.GRD grid file. Use our new version 4.04 command ***Grid|Image Surfer .GRD without .PAR file*** to image the resulting POISSON.GRD. First check new version 4.04 option ***Use data limits*** in ***Grid|Surfer plot Limits*** dialog.

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 coordinate 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 https://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 data interpretation of GeoTomCG .3DD formatted data see our tutorial https://rayfract.com/tutorials/igta13.pdf .

Our tutorial https://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

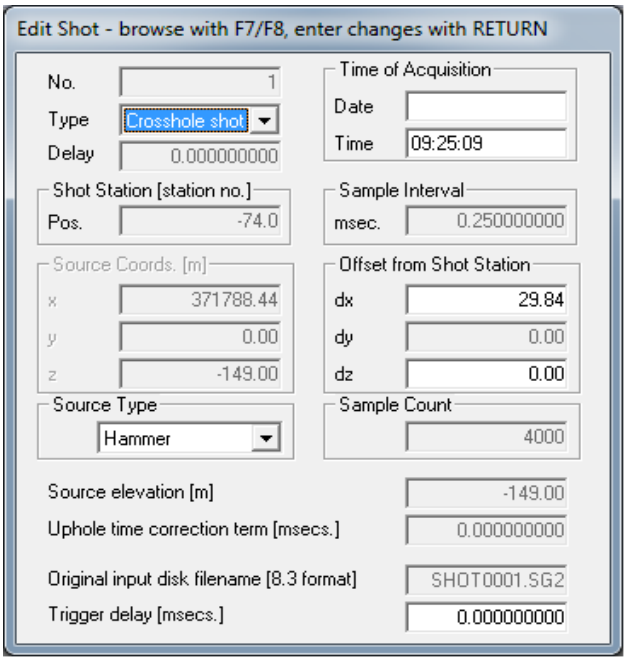
In the following we use data shown in our tutorial https://rayfract.com/tutorials/mdw2011.pdf .

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. Since version 4.03 we prompt you to correct the borehole shot station to the automatically determined closest receiver station, with shot point outside active receiver spread.

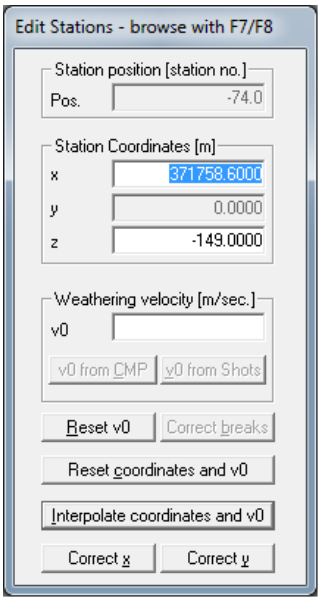
Contrary to *Line type* **`Refraction spread/line`**, ***Shot pos. [station no.]*** for *Line type* **`Borehole spread/line`** must be set to station no. of a receiver inside active *receiver spread* used to record and import this shot. So for equidistant receiver spacing ***Shot pos. [station no.]***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

When 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.

Since version 4.03 we prompt you to correct the borehole shot station to the automatically determined closest receiver station, with shot point outside active receiver spread.

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 https://rayfract.com/tutorials/1611HOLE.pdf tutorial. Walkaway VSP shots are recorded with 3 spreads in one borehole.

Edit and update station coordinates and shotpoint coordinates after shot import

For description of our COORDS.COR and SHOTPTS.SHO file formats see chapter File formats.

Once you have imported your SEG-2 shots with correct ***Shot pos.*** and ***Layout start*** in station numbers please

- select ***File*|*Export header data*|*Export Station coordinates*** to COORDS.COR
- edit x/y/z coordinates for receiver station numbers in COORDS.COR using Microsoft Notepad
- select ***File*|*Update header data*|*Update Station coordinates*** with your edited COORDS.COR file
- select ***File*|*Export header data*|*Export Shot Point coordinates*** to SHOTPTS.SHO
- edit shot point x/y/z coordinates in SHOTPTS.SHO using Microsoft Notepad
- select ***File*|*Update header data*|*Update Shotpoint coordinates*** with your edited SHOTPTS.SHO file

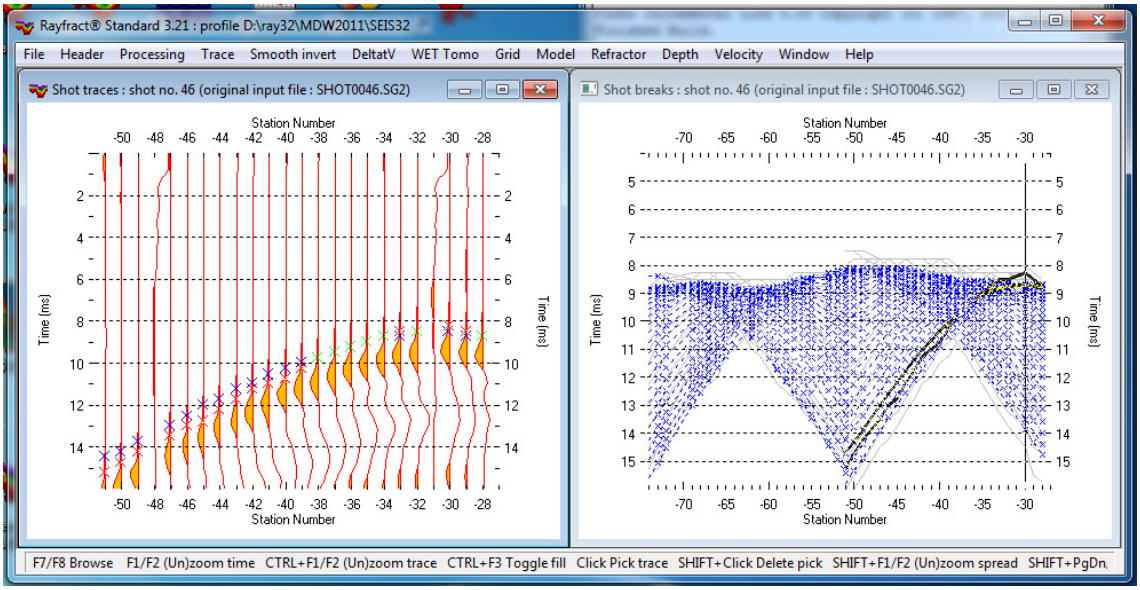
Remember that for *Line type* **`Borehole spread/line`** all y coordinates need to remain at zero. So edit x and z only in COORDS.COR and SHOTPTS.SHO files. As shown in tutorial https://rayfract.com/tutorials/mdw2011.pdf Fig. 1 and Fig. 2 boreholes can deviate from the vertical.

For horizontal boreholes check option ***File*|*Import Data Settings*|*Import horizontal borehole survey*** before importing your SEG-2 shot files.

For import into circular receiver spread planted on tunnel wall see our tutorial https://rayfract.com/tutorials/tunnel16.pdf using option ***File*|*Import Data Settings*|*Import circular borehole survey*** .

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

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

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

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

Borehole survey velocity update weighting : Beydoun weighting

Our WET inversion algorithm implements improved weighting/preconditioning for inversion of crosshole surveys. We call this **Beydoun weighting**. Velocity artefacts/anomalies at grid corners and at grid edges/directly adjacent to boreholes are suppressed. See (Luo and Schuster 1991) Wave-equation traveltime inversion, Appendix B on page 653, 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)". During velocity update more weight is given to the misfit gradient in central area of tomogram. The gradient weighting factor is "**square root of ((pixel distance from source) times (pixel distance from receiver))**". See (Luo and Schuster 1991) on page 653.

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. With Beydoun weighting **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 as described above.

Use option ***Smooth invert|Coverage grid shows unweighted hit count***. If unchecked the coverage grid shows the hit count for each grid cell (wavepaths per pixel), scaled by Beydoun weighting with this option checked.

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 the Smooth inversion to redisplay WET tomograms :

- check or uncheck corresponding items at bottom of *menu Grid*
- edit parameters in dialog Grid|***Edit shot labeling parameters***
- 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 https://rayfract.com/tutorials/CFE15.pdf shows **tunnel overburden imaging with multirun WET**.

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

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

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

https://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

https://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

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

This allows estimation 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

https://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

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

Interpret reverse VSP shots into a common surface-based receiver/hydrophone spread as in https://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 https://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 https://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 https://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

https://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 https://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

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

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

https://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 https://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

https://rayfract.com/tutorials/palmfig9.pdf
https://rayfract.com/tutorials/thrust.pdf
https://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 https://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 https://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 ...\GRADTOMO\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. Increase the *WET iteration count* and optionally decrease WET smoothing to render WET output less dependant on the initial model and to 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 https://rayfract.com/tutorials/epikinv.pdf and https://rayfract.com/tutorials/fig9inv.pdf .

We strongly recommend to always 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.

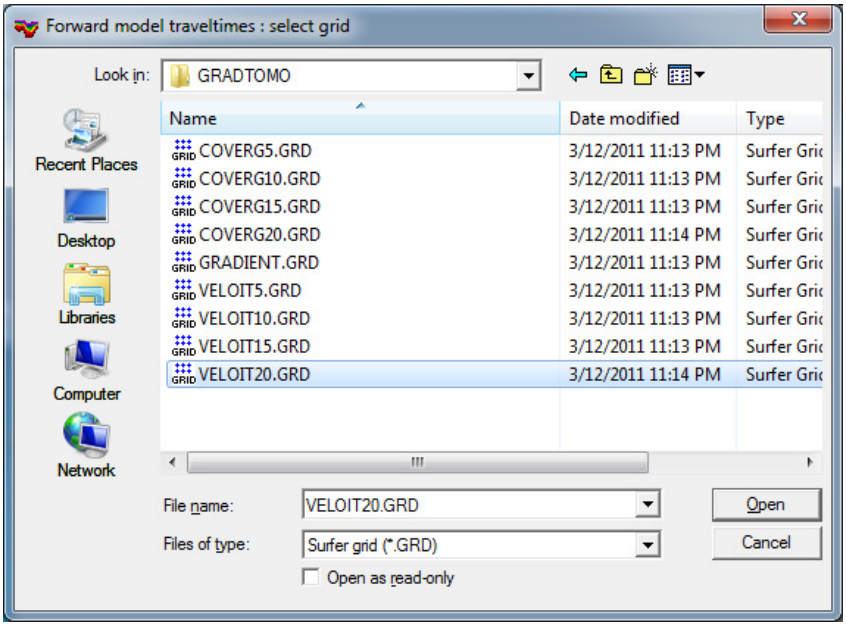
If you still decide to build your own initial model and use this model with our interactive WET tomography processing, first leave *wavepath width* and *grid smoothing* at their default settings. You may need to increase the *WET iteration count* to 100 or more iterations and optimize/decrease WET smoothing to make WET output converge 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, please 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 updated 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 https://rayfract.com/tutorials/camp1.pdf .

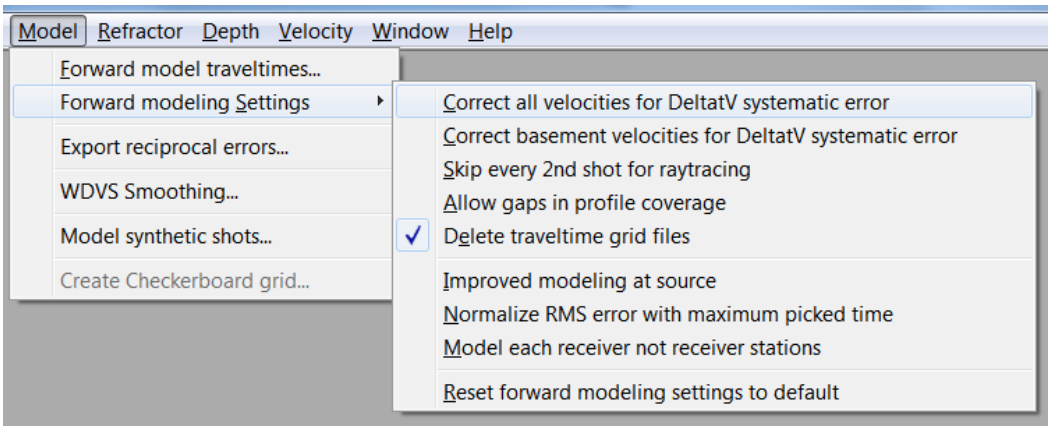
Forward model traveltimes

Starting with version 2.01, RAYFRACT® 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 strictly 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 times on top of measured and picked times in the ***Refractor*|*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 reasonable agreement of these two traveltime sets for most profiles, recording geometries and geological settings. But there will always be profile regions with larger misfit due to DeltatV artefacts caused by strong refractor curvature or topography curvature. To avoid these artefacts in the starting model we recommend using our laterally averaged 1D-gradient starting model obtained with our Smooth inversion (Sheehan, 2005). Or use layered refraction starting models obtained with Plus-Minus method, Wavefront method or CMP Intercept-time refraction method. See our Depth menu.

Our forward modeling 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.

Select option *Model|Delete traveltime grid files* to delete traveltime grid files after forward modelling to conserve free disk space.

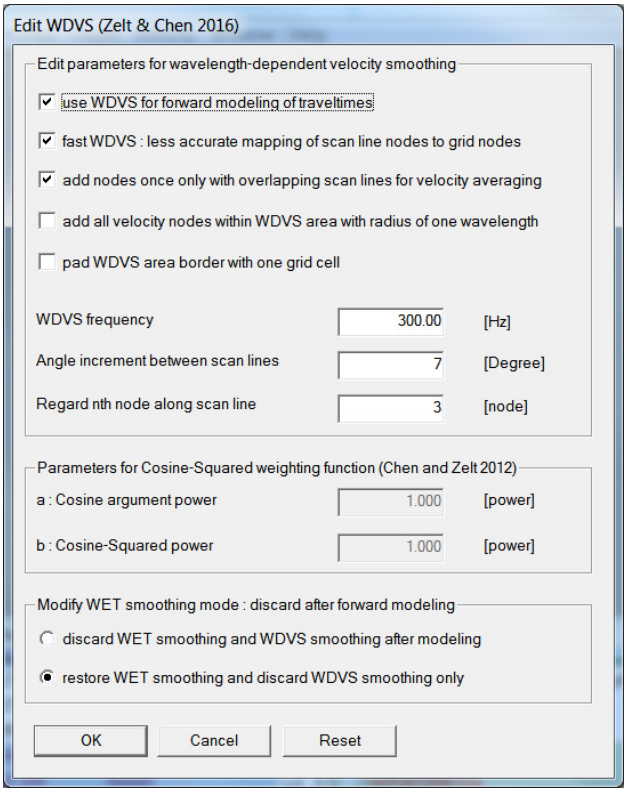
Select option *Model|Forward modeling settings|Normalize RMS error with maximum picked time* to normalize the absolute RMS error between modelled and picked times with maximum picked time instead of average picked time, over all traces modeled. This results in smaller normalized RMS errors. Before March 2019 this option was implicitly enabled.

Select option *Model|Model each receiver not receiver stations* to forward-model traveltime grids at each receiver location instead of at averaged receiver stations during WET inversion. Requires correct receiver coordinates in Header|Receiver dialog.

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 for Standard version : this is the maximum number of nodes our eikonal solver will accept, to reasonably conserve RAM memory and hard disk space available. About 600 columns versus 200 rows or 300 columns versus 100 rows may be a reasonable setting. For the free limited trial, try e.g. 300 columns vs. 100 rows.

WDVS velocity smoothing

Since version 4.01 released in Oct 2020 we support WDVS Wavelengh-Dependent Velocity Smoothing. See **Zelt, C. A. and J. Chen, Frequency-dependent traveltime tomography for near-surface seismic refraction data, Geophys. J. Int., 207, 72-88, 2016**. See https://dx.doi.org/10.1093/gji/ggw269 and https://www.researchgate.net/publication/305487180_Frequency-dependent_traveltime_tomography_for_near-surface_seismic_refraction_data .



Edit these WDVS parameters in ***Model*|*WDVS Smoothing*** dialog :

- ***use WDVS for forward modeling of traveltimes*** do WDVS velocity smoothing (Zelt and Chen 2016) before running Eikonal solver during WET inversion or with *Model*|*Forward model traveltimes* to forward-model traveltimes over current velocity grid.
- ***fast WDVS : less accurate mapping of scan line nodes*** faster but less accurate mapping of scan line nodes to velocity grid nodes when averaging velocity grid nodes over area with radius of one wavelength centered at current grid node along scan lines.
- ***add nodes once only with overlapping scan lines for velocity averaging*** : add velocity grid nodes once only if scan lines overlap. See (Zelt and Chen 2016) Fig. 4 and equation (1).
- ***add all velocity nodes within WDVS area with radius of one wavelength*** : add all velocity grid nodes within WDVS area of one wavelength, for determination of weighted averaged velocity. See (Zelt and Chen 2016) Fig. 4 and equation (1).

- ***pad WDVS area border with one grid cell*** pad WDVS area with one grid cell. This should not make any difference since the weight at radius of one wavelength is 0.0 as per (Zelt and Chen 2016) equation (1).
- ***WDVS frequency*** specify in Hz : 0.01 Hz to 10'000 Hz. Used to determine the duration of one wavelength i.e. one period in time. Is set to 200Hz per default. Should be two to four or eight times the ***Wavepath frequency*** specified in ***WET Tomo|Interactive WET tomography*** main dialog. See (Zelt and Chen 2016). Increase to decrease WDVS smoothing and to speed up WDVS.
- ***Angle increment between scan lines*** specify in degrees : 1 to 10 degrees. This determines the angular separation between straight scan lines radiating outwards from the current grid node when determining the WDVS averaged velocity at that node. Increase this parameter to speed up WDVS. Default is 7 degrees.
- ***Regard nth node along scan line*** specify values 1 to 5. Regard each nth node along current angle and scan line when determining WDVS velocity at current grid node via weighted average (Zelt and Chen 2016). Increase to speed up WDVS. Default is 3. All nodes are regarded to determine time delay along scan line. Scan line nodes are separated by the *grid cell size* in m, as forced in Header|Profile.
- ***discard WET smoothing and WDVS smoothing after modeling*** restore the unsmoothed WET velocity grid after forward modeling during WET inversion, discarding both the WDVS smoothing and WET smoothing at this time.
- ***discard WDVS smoothing only and restore WET smoothing*** restore the smoothed WET velocity grid after forward modeling during WET inversion, discarding the WDVS smoothing only at this time. This option is checked per default.

See our published papers Rohdewald S.R.C. 2021a and Rohdewald S.R.C. 2021b for application of WDVS smoothing to synthetic model data and field recorded data.

We use WDVS smoothing in our updated tutorial https://rayfract.com/tutorials/epikinv.pdf showing interpretation of Broad Epikarst synthetic data (Sheehan et al. 2005) and in our VSP constrained refraction tutorial https://rayfract.com/tutorials/11REFR.pdf . See more updated tutorials showing WET inversion using WDVS :

https://rayfract.com/tutorials/camp1.pdf
https://rayfract.com/tutorials/Line3.pdf
https://rayfract.com/tutorials/jenny13.pdf
https://rayfract.com/tutorials/NORCAL14.pdf
https://rayfract.com/tutorials/Aaknes-1.pdf
https://rayfract.com/tutorials/sageep11_16.pdf
https://rayfract.com/tutorials/rjj9to10.pdf
https://rayfract.com/tutorials/ot0608.pdf
https://rayfract.com/tutorials/SR6.pdf
https://rayfract.com/tutorials/Palmfig4.pdf
https://rayfract.com/pub/final.pdf
https://rayfract.com/tutorials/Test21.pdf
https://rayfract.com/tutorials/D1P2NO24.pdf
https://rayfract.com/tutorials/Line14_WDVS.pdf
https://rayfract.com/tutorials/3016.pdf
https://rayfract.com/tutorials/TRA9002_resolution_test.pdf
https://rayfract.com/tutorials/NGU_G1.pdf
https://rayfract.com/tutorials/NGU_G4.pdf

Dr. Parsa Bakhtiari Rad working at University of Mississippi, The National Center for Physical Acoustics (NCPA) shows Cavity detection using Frequency-Dependent Dependent Traveltime Tomography in his slides available at https://rayfract.com/pub/final.pdf .

WDVS can improve the resolution in overburden and give a sharper image of top-of-basement in WET tomograms if WDVS parameters are tuned correctly. You need to limit the *max. WET velocity* in *WET Tomo|Interactive WET tomography* main dialog to suppress a bias towards too high basement velocities with WDVS enabled and with too low *WDVS frequency*.

Find the optimum *WDVS frequency* by iteratively decreasing from 400Hz/200Hz/100Hz/75Hz/50Hz (Zelt and Chen 2016) to obtain sharper imaging of velocity contrast and more shallow basement top. Optionally also decrease WDVS parameters *Regard nth node* and *Angle increment* or *WDVS frequency* to obtain sharper imaging of velocity contrast and more shallow basement top. One robust strategy is to **leave Regard nth node and Angle increment at their default settings and vary WDVS frequency only**.

You need to tune the *WDVS frequency* for each individual line. If you decrease the *WDVS frequency* too much then high-velocity anomalies in overburden may show too much contrast and top-of-basement will be imaged too shallow and too fast. Also the RMS error will increase too much with too low *WDVS frequency*.

Check option *WET Tomo|WET tomography Settings|Limit WET velocity to maximum velocity in initial model* to counter a bias towards too high velocities in basement when enabling WDVS. This bias gets stronger when you decrease the *WDVS frequency* or the two other WDVS parameters : *Angle increment* and *Regard nth node*. Or limit *max. WET velocity* in ***WET Tomo|Interactive WET*** main dialog with option *WET Tomo|WET tomography Settings|Edit maximum valid WET velocity* checked.

(Zelt and Chen 2016) show the effect of varying the WDVS frequency.

The optimum choice of the ***WDVS frequency*** is subjective. The lower the WDVS frequency the stronger the contrast of imaged velocity anomalies in overburden and the more shallow the top-of-basement is imaged. Same applies when optionally decreasing WDVS parameters *Regard nth node* and *Angle increment*.

To speed up WDVS try increasing the *grid cell size* in ***Header|Profile***. Or increase WDVS parameters *WDVS frequency* or *Regard nth node* or *Angle increment*.

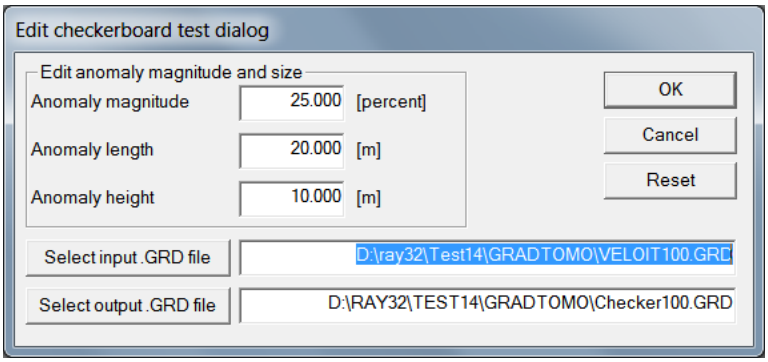
We recommend using WDVS with *Steepest-Descent WET inversion* and *minimal WET smoothing* for better convergence towards a well-resolved tomogram and minimized RMS error. See our tutorial https://rayfract.com/tutorials/ot0608.pdf .

Conjugate-Gradient WET inversion may not converge towards a realistic tomogram when enabling WDVS, especially when *discarding WET smoothing*. As shown in tutorial https://rayfract.com/tutorials/Test21.pdf we recommend enabling option ***discard WET smoothing and WDVS smoothing*** for our Smooth inversion or for *WET Tomo|Automatic WET* inversion only. When using our ***WET Tomo|Interactive WET*** inversion and minimizing the WET smoothing we strongly recommend checking default option ***restore WET smoothing and discard WDVS smoothing only*** instead to prevent high-velocity artefacts below the shot points in the resulting WET tomogram.

To **find the optimum WDVS frequency** for your profile follow these heuristics :

- start with WDVS frequency at default setting of 300Hz
- for a short line (100m or 200m long) with shallow high-velocity basement increase WDVS frequency to 400Hz or higher. See our Broad Epikarst tutorial https://rayfract.com/tutorials/epikinv.pdf .
- for a short line with thick and low-velocity overburden as in https://rayfract.com/tutorials/Test21.pdf decrease WDVS frequency to 100Hz or 150Hz
- for a longer line up to 1km or 2km long : decrease WDVS frequency to 50Hz or 60Hz. See our tutorial https://rayfract.com/tutorials/Aaknes-1.pdf .
- if you lower the WDVS frequency too much then the top-of-basement is imaged too shallow and overburden velocity anomalies show too strong magnitude
- also the RMS error shown on top of WET tomograms increases too much with too low WDVS frequency

Create Checkerboard grid



Edit these fields in Model|Create Checkerboard grid available with our Pro software version :

- ***Anomaly magnitude*** magnitude of checker anomaly in percent of background velocity
- ***Anomaly length*** length of checker anomaly
- ***Anomaly height*** height of checker anomaly
- ***Select input .GRD file*** click to select input WET tomogram .GRD to which the checker pattern is applied
- ***Input grid .GRD*** filename including drive and directory of the input .GRD file
- ***Select output .GRD file*** click to select output grid .GRD file to which the generated checkerboard grid .GRD is written
- ***Output grid .GRD*** filename including drive and directory of the output .GRD file

Each anomaly (checker) in *Output grid .GRD* is determined by multiplying the *Anomaly magnitude* percentage with the local grid velocity determined from *Input grid .GRD* and weighting with sin(x offset)sin(y offset) functional and then adding this velocity delta to or subtracting from local grid velocity in a checker pattern (Zelt 1998).

See our tutorial https://rayfract.com/tutorials/TRA9002_resolution_test.pdf .

WET Wavepath Eikonal Traveltime tomography

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 or strongly undulating topography**. 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.

Once you have run our Smooth inversion method you can optionally try to tune/optimize **WET settings** and **DeltatV settings**. DeltatV settings are also regarded when determining the laterally smoothed 1D-gradient starting model.

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 https://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 tutorials https://rayfract.com/tutorials/P6.pdf and https://rayfract.com/tutorials/NORCAL14.pdf and https://rayfract.com/tutorials/Line3.pdf .

Overview of WET inversion

Rayfract uses the Wavepath Eikonal Traveltime (WET) method (Schuster and Quintus-Bosz, 1993; Woodward, 1992).

The WET inversion algorithm uses the Fresnel volume approach (Watanabe et al., 1999 which is an alternative to the raypath approach used by most inversion schemes. A Fresnel volume is defined by a set of waveforms that arrive within a half period of the fastest waveform.

The inversion methods that use ray paths make the assumption that the frequency of the source is infinite, and hence the wavelength is zero. This means that only the properties of the portions of the model through which the rays pass directly affect the results. This assumption is not accurate in reality because real waves have a finite wavelength and will be affected by adjacent parts of the model in the vicinity of the ray path. The Fresnel volume approach addresses this issue by taking into account ray paths with slightly longer travel times.

WET inversion allows partial modeling of finite frequency wave propagation :

- partial modeling of diffraction around low-velocity areas
- WET parameters sometimes need to be adjusted, to avoid artefacts

The ***WET frequency*** specifies the frequency of the Ricker wavelet used to weight the WET model update across the wavepaths during one WET iteration. Leave WET frequency at default of 50Hz.

The WET frequency defines the width of the Fresnel volume. The lower the frequency the wider the Fresnel volume. A wider Fresnel volume results in smoother WET tomograms. We recommend leaving the WET frequency at its default setting of 50Hz.

The ***WET wavepath width*** specifies how wide the wavepaths used for WET inversion are. The wavepath width is expressed in percent of one period of the Ricker wavelet. Increase the width for smoother tomograms. Decreasing the width too much generates artefacts and decreases robustness of WET inversion.

Valid range of WET wavepath width is 1 percent to 50 percent of one period. We determine a reasonable default WET wavepath width based on the velocities in the selected starting model grid .GRD file. 50 percent wavepath width means that modeled traveltimes arriving up to half a period later than the fastest time are regarded during WET inversion and for back-projection of the traveltime residual (misfit between modeled and picked time) along the wavepath. We use the Eikonal Solver described by (Lecomte 2000) for forward modeling of wave propagation.

You can interactively vary the WET wavepath width in WET Tomo|Interactive WET dialog. Use the WET wavepath coverage plot as a guide. If the WET wavepaths shown in the coverage plot are too narrow with black/uncovered areas between the wavepaths then increase the WET wavepath width e.g. by factor 2.

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.

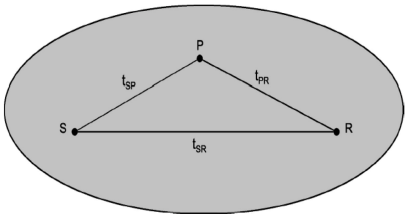
Also increase the WET wavepath width for deeper imaging if your tomograms are too shallow. Or disable WET blanking options in WET Tomo|WET tomography Settings|Blank menu.

As an alternative to increasing the WET wavepath width you can also decrease the WET frequency. E.g. decrease the WET frequency from default 50Hz to 20Hz or even just 10Hz for long profiles or profiles with a thick and low-velocity overburden.

Below we show slides from our SAGEEP 2021 publication (Rohdewald S.R.C. 2021a) with slides available at https://rayfract.com/pub/SAGEEP%202021%20slides.pdf :

2D WET Wavepath Eikonal Traveltime inversion

Fresnel volume or
wave path approach :

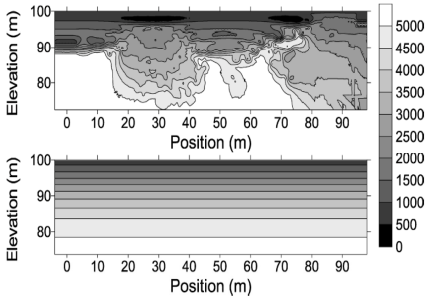


- rays that arrive within half period of fastest ray : $t_{SP} + t_{PR} - t_{SR} <= 1 / 2f$ (Sheehan, 2005a, Fig. 2)
- nonlinear 2D optimization with steepest descent, to determine model update for one wavepath
- SIRT-like back-projection step, along wave paths instead of rays
- natural WET smoothing with wave paths (Schuster 1993, Watanabe 1999)
- partial modeling of finite frequency wave propagation
- partial modeling of diffraction, around low-velocity areas
- WET parameters sometimes need to be adjusted, to avoid artefacts
- see RAYFRACT.HLP help file

SAGEEP2021 ONLINE

Smooth Inversion = 1D gradient initial model + 2D WET Wavepath Eikonal Traveltime tomography

Get minimum-structure
1D gradient initial model :



Top : pseudo-2D DeltatV display

- 1D DeltatV velocity-depth profile below each station
- 1D Newton search for each layer
- velocity too low below anticlines
- velocity too high below synclines
- based on synthetic times for Broad Epikarst model (Sheehan, 2005a, Fig. 1).

Bottom : 1D-gradient initial model

- generated from top by lateral averaging of velocities
- minimum-structure initial model
- DeltatV artefacts are completely removed

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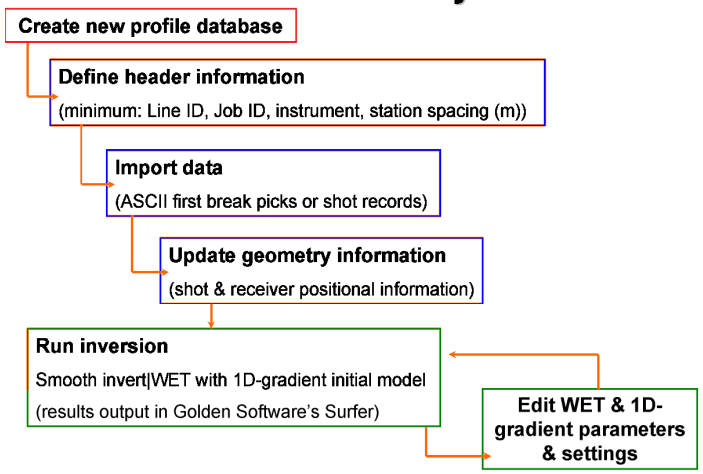
Generalized Rayfract® Flow Chart



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Smooth Inversion, DeltatV and WET Parameters

- ❑always start with default parameters: run Smooth inversion without changing any setting or parameter
- ❑next adapt parameters and option settings if required, e.g. to remove artefacts or increase resolution
- ❑more smoothing and wider WET wavepath width in general results in less artefacts
- ❑increasing the WET iteration count generally improves resolution
- ❑don't over-interpret data if uncertain picks : use more smoothing and/or wider wavepaths.
- ❑explain traveltimes with minimum-structure model
- ❑tuning of parameters and settings may introduce or remove artefacts. Be ready to go one step backwards.
- ❑use Plus-Minus layered refraction method (Hagedoorn, 1959) as alternate starting model

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WET tomography main dialog: see help menu

Number of WET tomography iterations	Default value is 20 iterations. Increase to 50 or 100 for better resolution and usually less artefacts. WET can improve with increasing iterations, even if RMS error does not decrease.
Wavepath frequency	Ricker wavelet used to modulate/weight the wavepath misfit gradient, during model update. Leave at default of 50Hz. One period is 1/50Hz = 20ms. See (Schuster, 1993).
Degree of differentiation of Ricker wavelet	0 for original Ricker wavelet, 1 for once derived wavelet. Value 1 may give artefacts: wavepaths may become "engraved" in the tomogram. New default is -1: Gaussian weighting. Set to -2 for Cosine-Squared weighting, for better imaging of vertical fault zones.
Wavepath width	In percent of one period of Ricker wavelet. Increase width for smoother tomograms. Decreasing width too much generates artefacts and decreases robustness of WET inversion. Click Iterate button to specify multirun WET schedule for decreasing wavepath width between consecutive WET runs.
Envelope wavepath width	Width of wavepaths used to construct envelope at bottom of tomogram. Default is 0.0. Increase for deeper imaging.
Maximum valid velocity	Limit the maximum WET velocity modeled. Default is 6,000 m/s. Decrease to prevent high-velocity artefacts in tomogram.
Full smoothing	Default smoothing filter size, applied after each WET iteration
Minimal smoothing	Select for more details, but also more artefacts. May decrease robustness and reliability of WET inversion.
Manual smoothing	Specify half-width and half-height of smoothing filter in grid columns and grid rows. Gaussian or Uniform weighting. Smooth nth iteration. Smooth velocity update. Maximum velocity update. Check No smoothing to disable WET smoothing. Specify Damping for Conjugate-Gradient WET inversion.

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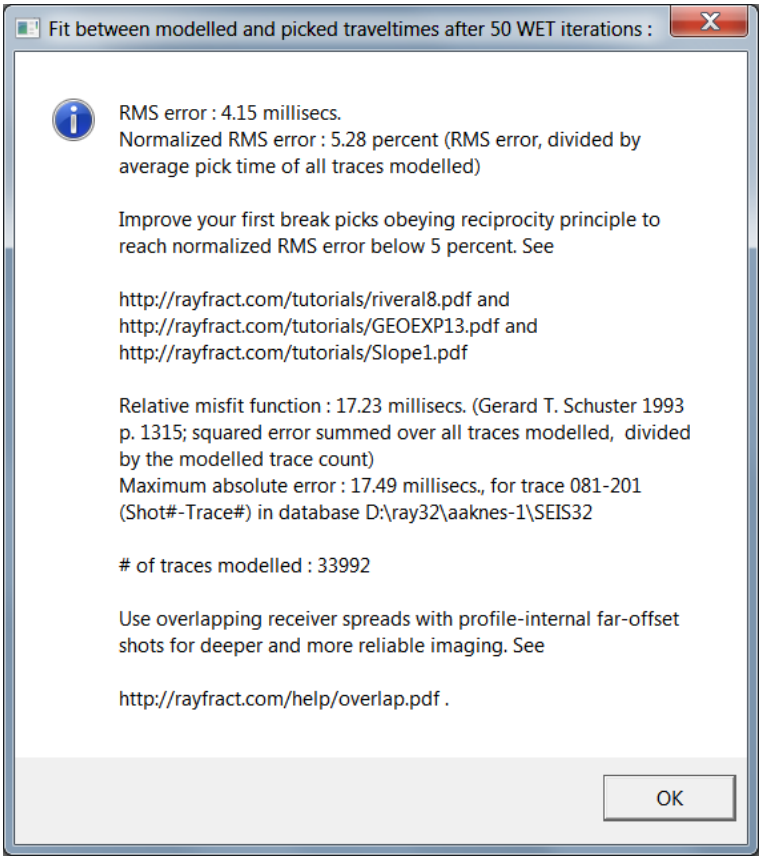
Improve your first break picks

If the normalized RMS error exceeds 5 percent we prompt after WET inversion to improve your traveltime picks regarding the traveltime reciprocity principle :



Use our *Trace*|*Offset Gather* display to check your first break picks 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 https://rayfract.com/tutorials/Slope1.pdf, https://rayfract.com/tutorials/riveral8.pdf and https://rayfract.com/samples/GEOXMERC.pdf . **Aim for an RMS error (misfit between picked and modeled first break times) below 5%** as shown on top of all Surfer tomogram plots. **Use *Trace menu*|*Export reciprocal errors...*** to compute and export reciprocal traveltime picking errors to ASCII .ERR file. Import the .ERR file into Microsoft Excel and sort by any column.

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
- as a last resort check option ***Extrapolate tomograms*** in Header|Profile dialog and edit parameter ***Extrapolate [station spacings]***. This lets you force WET inversion to regard off-end shot points. You need to re-generate the initial/starting model for this to work.

Increasing the WET *wavepath width* as described above corresponds to lowering the *Wavepath frequency*. So resolution decreases but maximum imaged depth increases. See also our SAGEEP14 expanded abstract https://rayfract.com/pub/sageep14.pdf and our tutorials https://rayfract.com/tutorials/sageep11_16.pdf and https://rayfract.com/tutorials/CFE15.pdf which show 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.

As a last resort check option ***Extrapolate tomograms*** in Header|Profile dialog and edit parameter ***Extrapolate [station spacings]***. This lets you force WET inversion to regard off-end shot points. You need to re-generate the initial/starting model for this to work.

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. Change to 0 (Ricker wavelet weighting) to better image velocity inversions.
- to explore non-uniqueness of the solution space, vary the ***WET wavepath width*** in *WET Tomo|Interactive WET tomography...* . See https://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

For **multirun WET inversion** 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*

For **single-run WET inversion** we strongly recommend to always first run our **Smooth inversion** to obtain the 1D-gradient starting model and confirm to continue with default WET inversion using *Full smoothing* and 20 Steepest-Descent WET iterations. Next you **optionally try to decrease the WET smoothing but not too much so WET is not prevented from improving on the starting model** and does not get stuck in a local minimum of the traveltime misfit function.

Copying minimized WET smoothing settings optimized for one profile to another profile is not recommended and not supported. Default full WET smoothing is determined automatically based on grid dimensions, recording geometry and velocity distribution in the starting model. Since these parameters are specific to each profile and starting model you need to always start with our Smooth inversion. Then you can try step-wise decreasing of WET smoothing.

If you decrease WET smoothing too much then you effectively prevent WET inversion from improving on the starting model. This is true for any starting model : Plus-Minus, pseudo-2D DeltatV or 1D-gradient obtained with our *Smooth invert|WET with 1D-gradient initial model*.

You need to interactively adapt WET smoothing to your profile data (first breaks and recording geometry). Don't force some arbitrary smoothing copied from another profile and assume that this should just work with your current data. This is not supported.

For multi-run WET inversion of synthetic data as shown in https://rayfract.com/tutorials/sageep11_16.pdf tutorial you can decrease WET smoothing more than for single-run WET inversion of field surveys as shown in https://rayfract.com/tutorials/P6.pdf tutorial. For P6 we leave WET smoothing at default *Full smoothing* and increase the *WET iteration count* only, from default 20 to 100. But we keep using default *Ricker differentiation* -1 [Gaussian], default *Steepest Descent* search method and default *Full smoothing*.

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 https://rayfract.com/tutorials/sageep11_16.pdf showing *Conjugate Gradient* method. Our companion tutorial https://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.

Be sure to leave ***Damping*** at its default setting of 0.9 when activating the *Conjugate Gradient* option. Damping is reset to 0.0 when you activate Steepest Descent search method instead in our WET Tomo|Interactive WET tomography dialog.

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 º 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

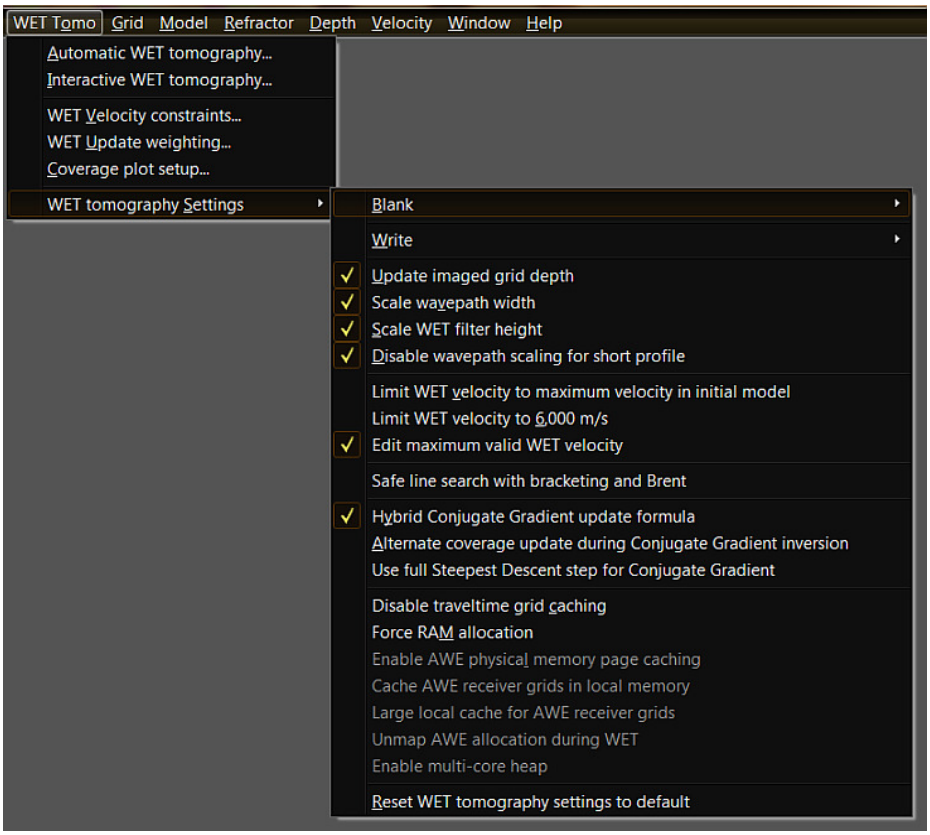
Our new tutorial https://rayfract.com/tutorials/NGUP1_1.pdf shows imaging of vertical fault zones using Plus-Minus starting model and WET inversion with Steepest Descent method and Cosine-Squared weighting of WET velocity update across wavepaths.

Since version 3.35 we allow **joint inversion of refraction shots and borehole-recorded shots** including VSP shots. See our new tutorials

https://rayfract.com/tutorials/11REFR.pdf and https://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

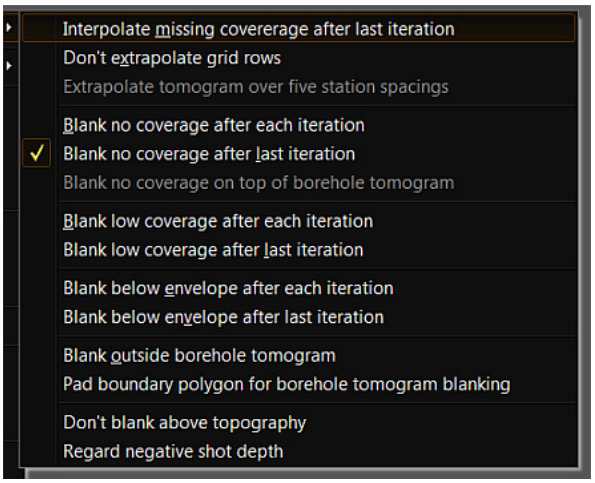


Edit these settings in *menu WET Tomo|WET tomography Settings* :

- ***Update imaged grid depth*** This option is enabled by default. If enabled, the grid depth will be updated after each WET tomography iteration.
- ***Scale wavepath width*** Determine the wavepath width for each trace individually, as a linear function of the picked time. Earlier picks result in smaller wavepath width.
- ***Scale WET filter height*** 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.
- ***Disable wavepath scaling for short profile*** For profiles with less than 72 receiver stations, *WET wavepath width scaling* and *filter height scaling* are disabled with this option checked, to prevent artefacts in the resulting tomograms.
- ***Limit WET velocity to maximum velocity in initial model*** 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.
- ***Limit WET velocity to 6,000 m/s***
- ***Edit maximum valid WET velocity*** Allow editing of interactive WET parameter *Maximum valid velocity.*
- ***Safe line search with bracketing and Brent*** Use bracketing and Brent's method as in http://www.numerical.recipes, Numerical Recipes, Press et al. chapter 10 instead of Secant method for *Conjugate Gradient* WET inversion.
- ***Hybrid Conjugate Gradient update formula*** Combine 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 .

- ***Alternate coverage update during Conjugate Gradient inversion*** Alternate blanking at tomogram bottom during *Conjugate Gradient* WET inversion.
- ***Use full Steepest Descent step for Conjugate Gradient*** Check with *Edit velocity smoothing|Maximum velocity update* below 15% so *Conjugate Gradient* WET inversion stays focused
- ***Disable traveltime grid caching*** Write all traveltime grids to disk during WET inversion instead of caching grids in RAM.
- ***Enable AWE physical memory page caching*** Pro version option to use RAM memory above 4GB up to 256 GB for traveltime grid caching during WET inversion.



Edit these settings in *menu WET Tomo|WET tomography Settings|Blank* :

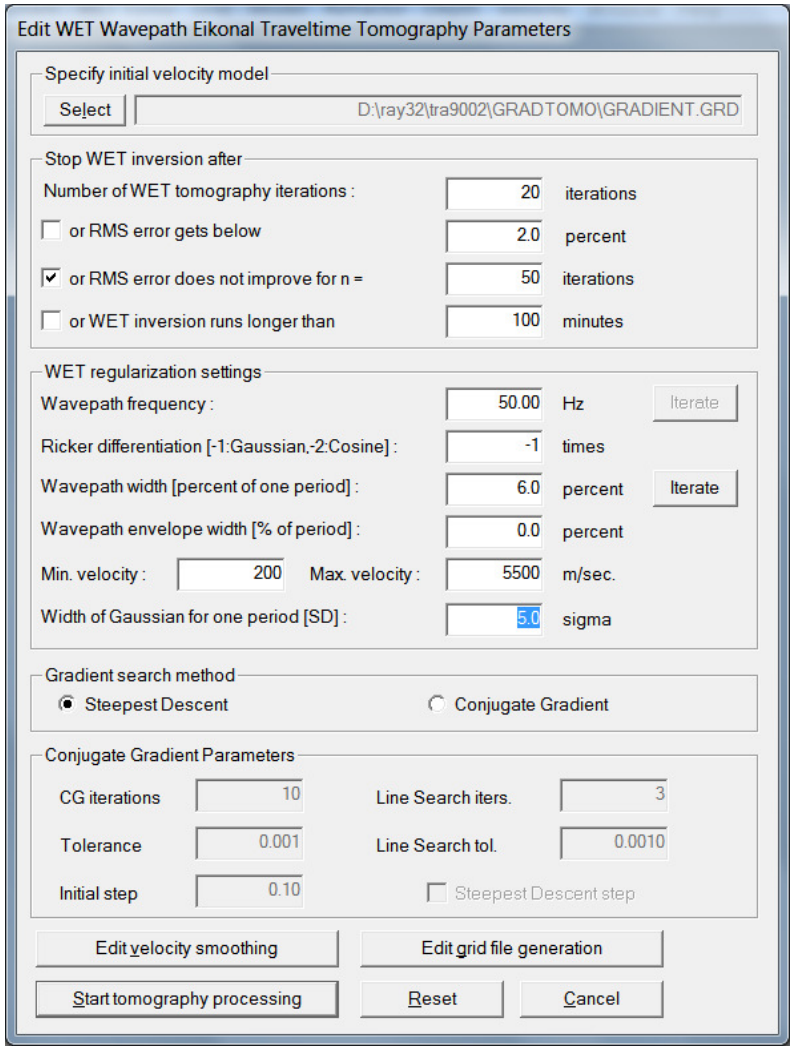
- ***Interpolate missing coverage after last iteration*** Interpolate coverage at tomogram bottom with coverage gaps in your recording geometry.
- ***Don't extrapolate grid rows*** Don't extrapolate grid rows at left and right margins during WET inversion.
- ***Extrapolate tomogram over five station spacings*** Pro option to use shotpoints offset maximally 5 station intervals from first/last profile receiver, for DeltatV and WET inversion.
- ***Blank no coverage after each iteration*** Blank the updated WET velocity tomogram outside the area covered with wavepaths after each WET iteration.
- ***Blank no coverage after last iteration*** 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 with *Blank no coverage after each iteration* or *Blank no coverage after last iteration* to blank on top of borehole tomogram.
- ***Bank low coverage after each iteration*** 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.
- ***Blank low coverage after last iteration*** Blank low coverage areas at tomogram bottom after the last WET iteration.
- ***Blank below envelope after each iteration*** Blank tomogram below envelope of all wavepaths, after each iteration except the last. Regards WET parameter *Envelope wavepath width.*
- ***Blank below envelope after last iteration*** Blank tomogram below envelope of all wavepaths after the last WET iteration. Regards WET parameter *Envelope*

wavepath width .

- ***Blank outside borehole tomogram*** Blanks outside borehole tomogram. This assumes that all receivers are located in one hole and all sources are in the other hole.
- ***Pad boundary polygon for borehole tomogram blanking*** Pad boundary polygon for borehole tomogram blanking by one grid cell.
- ***Don't blank above topography*** Don't blank above topography during WET inversion for *Header|Profile|Line type* **`Refraction spread/line`** .
- ***Regard negative shot depth*** Regard negative shot depth for DeltatV and WET inversion and forward modeling.

Interactive WET tomography main dialog

Now select ***WET Tomo/Interactive WET tomography...*** to display the WET main parameters dialog :



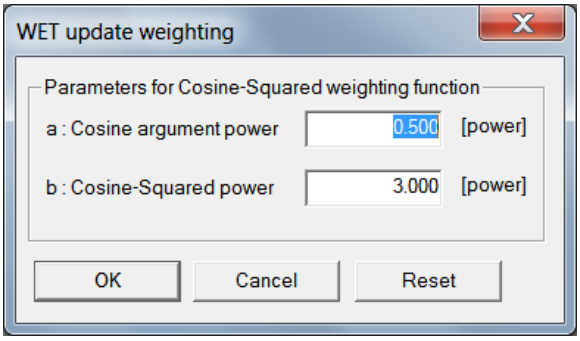
Edit these WET main parameters :

- ***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*** Stop WET 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 =*** Stop WET when RMS error does not improve for n WET iterations
- ***RMS error constant for n iterations*** Specify the number of WET iterations to check for not-decreasing RMS error
- ***or WET inversion runs longer than*** 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 or decrease to 30Hz or 10Hz for deeper imaging. One period is 1/50Hz = 20ms.
- ***Ricker differentiation*** Default -1. Try 0 or 1 for sharper layer boundaries and cavities (Schuster, 1993). 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 [SD]*** Cutoff for Gaussian function in Standard deviations (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; Shewchuk 1994) 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; Shewchuk 1994)
- ***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

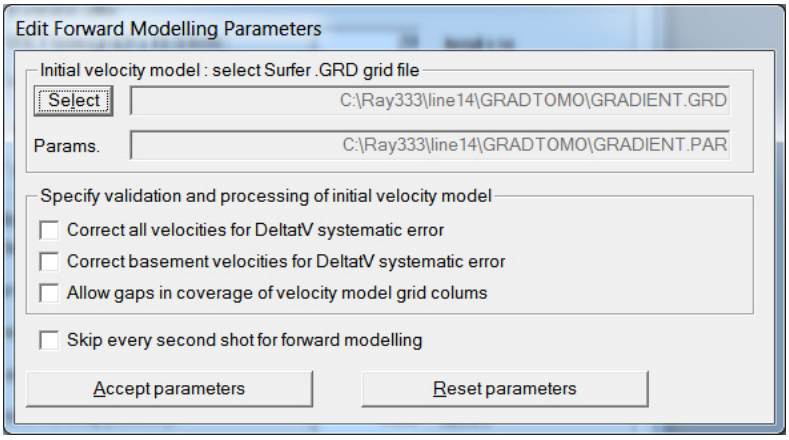
Edit parameters for WET update weighting with *Ricker differentiation* set to -2 in *WET Tomo|WET Update weighting dialog* :



- ***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* in WET main dialog to specify the starting model :



Edit these parameters :

- ***Correct all velocities for DeltatV systematic error*** Reduce all grid node velocities in the Surfer® .GRD grid file by 10 percent before forward modeling during the first WET iteration
- ***Correct basement velocities for DeltatV systematic error*** Reduce basement grid node velocities in the Surfer® .GRD grid file by 15 percent before forward modeling during the first WET iteration. "Basement" just means high velocity regions as indicated by velocity values in the grid file.

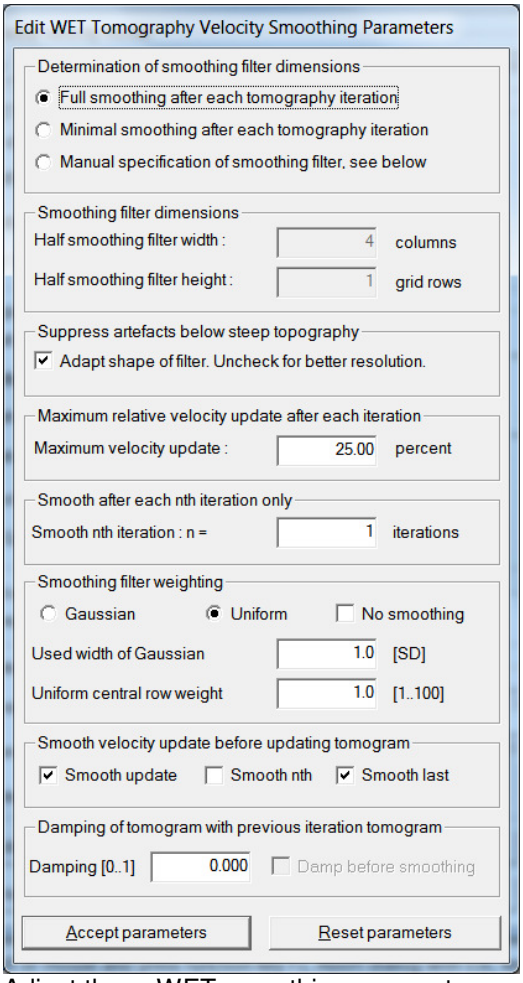
- ***Allow gaps in coverage of velocity model grid columns*** Allow grid columns with no velocity values between the first and last grid columns with velocity values. This may be necessary e.g. when your refraction profile crosses a river or a road.
- ***Skip every second shot for forward modeling*** Speed up WET inversion by skipping every second shot. This may result in a coarser / more uncertain WET tomogram.

Click ***Select button*** to select the initial velocity model .GRD file :

- **C:\RAY32\<your profile>\GRADTOMO\GRADIENT.GRD** created with *Smooth invert* menu for *Line type* **Refraction spread/line**
- **C:\RAY32\<your profile>\HOLETOMO\CONSTVEL.GRD** created with *Smooth invert* menu for *Line type* **Borehole spread/line**
- **C:\RAY32\<your profile>\TOMO\DELTATV.GRD** created with *DeltatV menu*
- **C:\RAY32\<your profile>\LAYRTOMO\PLUSMODL.GRD** created with *Depth menu command Plus-Minus*
- **C:\RAY32\<your profile>\LAYRTOMO\WAVEMODL.GRD** created with *Depth menu command Wavefront*
- **C:\RAY32\<your profile>\LAYRTOMO\CMPMODL.GRD** created with *Depth menu command CMP Intercept-Time Refraction*

Edit WET velocity smoothing

In WET main dialog shown with *WET Tomo*|*Interactive WET tomography* click button *Edit velocity smoothing* to specify smoothing of the updated velocity grid after each WET iteration :



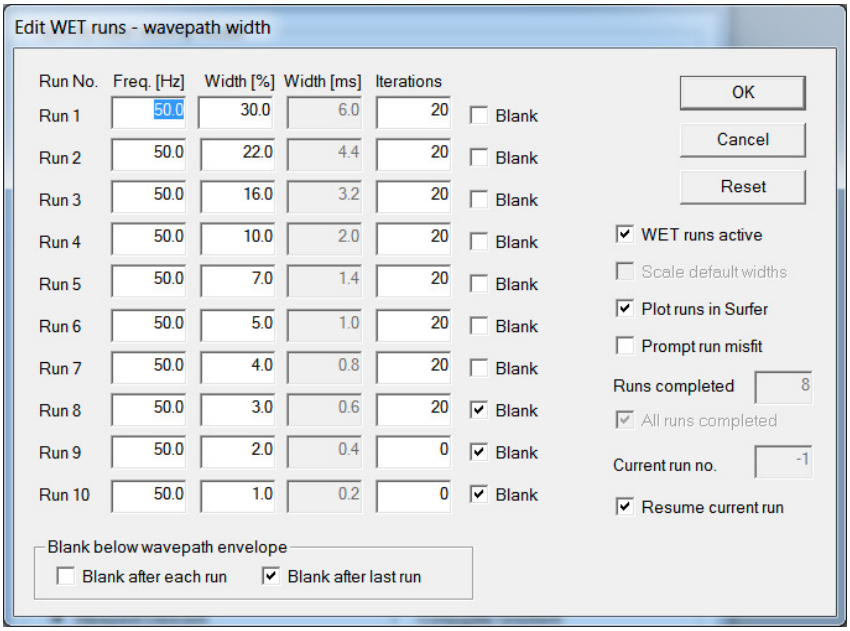
Adjust these WET smoothing parameters :

- ***Full smoothing after each tomography iteration*** Full smoothing (using a wide smoothing filter) to be applied after each tomography iteration
- ***Minimal smoothing after each tomography iteration*** Minimal smoothing (using a narrow smoothing filter) to be applied after each tomography iteration
- ***Manual specification of smoothing filter, see below*** Explicitly specify the dimensions (half width and half height) of the smoothing filter
- ***Half smoothing filter width*** Number of columns scanned on each side of the current grid cell, for smoothing the value of that cell.
- ***Half smoothing filter height*** Number of grid rows scanned above and below the current grid cell to obtain a smoothed value for the velocity of that cell
- ***Automatically adapt shape of rectangular filter matrix*** Automatically adapt the shape of the rectangular filter matrix to suppress processing artefacts
- ***Maximum velocity update*** Maximum allowed relative update of each velocity model cell, after one WET iteration
- ***Smooth nth iteration*** Smooth the tomogram after each nth WET iteration only. Increase for less smoothing. Default setting is 1.
- ***Gaussian weighting*** 2D Gaussian weighting of smoothing filter nodes centered at current pixel
- ***Uniform weighting*** Uniform weighting of smoothing filter nodes

- ***No smoothing*** Completely disable WET smoothing. Does not disable WET damping.
- ***Used width of Gaussian*** Cutoff in Standard deviations or sigma for Gaussian bell function used for weighting of smoothing filter nodes
- ***Uniform central row weight*** Check *Uniform* and edit in this field the weight given to the central row of the smoothing filter kernel
- ***Smooth update*** Smooth the velocity update separately before applying it to the tomogram during WET inversion
- ***Smooth nth*** Smooth the velocity update for each nth iteration only as specified with control *Smooth nth iteration : n =*
- ***Smooth last*** Smooth the tomogram obtained with the last WET iteration
- ***Damping [0..1]*** 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 .

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 :

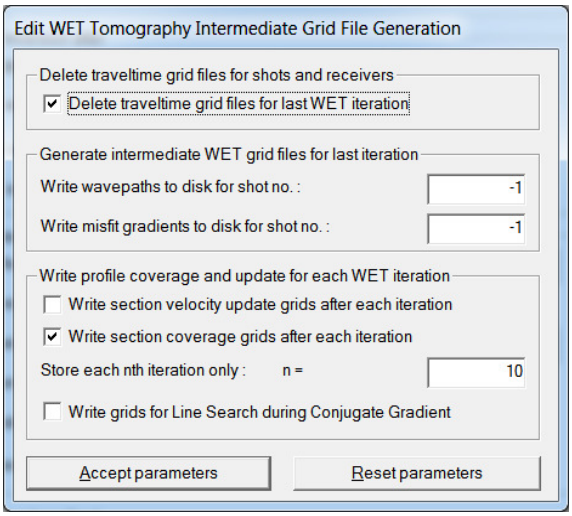


Edit these parameters :

- ***Freq. [Hz]*** *WET wavepath frequency* [Hz] for WET runs 1 to 10. One period = 1/*Freq. [Hz]* .
- ***Width [%]*** *WET wavepath width* [in percent of one period] for WET runs 1 to 10. One period = 1/*Freq. [Hz]* specified in first column.
- ***Width [ms]*** Read-only field computed as (1.0/*Freq. [Hz]*) * *Width [%]*/100.0 * 1000.0 . Used to compute wavepaths for WET inversion.
- ***Iterations*** Edit number of WET iterations for WET runs 1 to 10.
- ***Blank*** Enable/disable the *blanking below wavepath envelope* after the last iteration of each WET run no. 1 to 10.
- ***Blank after each run*** 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*** Check/uncheck *Blank* box for last run. The last run is the one before first run with 0 iterations.
- ***WET runs active*** Do multirun WET tomography next time you click button *Start tomography processing* in main WET dialog.
- ***Plot runs in Surfer*** Plot the last iteration of each run (WET tomogram and WET coverage plot) in Surfer before continuing with next WET run.
- ***Prompt run misfit*** Show prompt with WET run misfit after completion of each run. Uncheck to suppress display of these prompts.
- ***Resume current run*** Resume WET at last run completed next time you click button *Start tomography processing* after early termination of multirun WET tomography.
- ***Reset*** Reset all parameters and controls in multirun WET dialog to their default values.

Edit grid file generation

In *WET Tomo|Interactive WET tomography...* main dialog click on button ***Edit grid file generation*** to specify which Surfer® grid files should be generated and kept :



Edit these parameters :

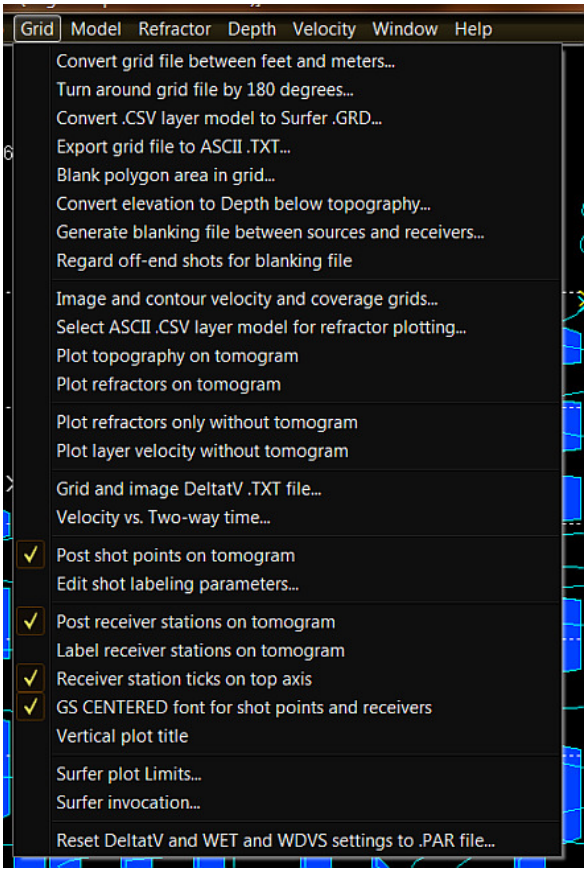
- ***Delete traveltime grid files for last WET iteration*** Keep Surfer® .GRD files with traveltime fields computed by Eikonal Solver for each shot during last WET iteration. These grid are files are named S1.GRD for shot number 1 etc.
- ***Write wavepaths to disk for shot no.*** Shot number for which to generate Surfer .GRD files with the wavepaths for all receivers i.e. traces recorded for this shot. .GRD files are named W001:001.GRD for trace number 1 of shot number 1 etc.
- ***Write misfit gradients to disk for shot no.*** Shot number for which to generate Surfer .GRD files with misfit gradients for the wavepaths of all receivers i.e. traces recorded for this shot. .GRD files are named G001:001.GRD for trace number 1 of shot number 1 etc.
- ***Write section velocity update grids after each iteration*** Write Surfer® .GRD files with the velocity update to be applied to the output of the previous WET iteration. .GRD files are named VELUPD01.GRD for the first WET iteration etc.
- ***Write section coverage grids after each iteration*** Write Surfer® .GRD files with the coverage of each WET velocity grid cell with wavepaths, after each WET iteration..GRD files are named COVERG01.GRD for the first WET iteration etc. Unit is wavepaths per pixel.
- ***Store each nth iteration only*** Surfer® grid files are stored for each nth iteration only. Preserve free disk space. Default value is 10.
- ***Write grids for Line Search during Conjugate Gradient*** Store WET tomograms obtained after each Line Search started by Conjugate Gradient method.

Once you have reviewed and optionally edited above parameters, click *button* ***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 grid as obtained after each nth iteration is stored as disk file **`VELOIT10.GRD`** for iteration 10 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 .SRF plot : contour and plot the **`VELOITXX.GRD`** file with Surfer® version 9 or higher via command ***Grid|Image and contour velocity and coverage grids***.

Grid menu options and commands

Use these ***Grid menu*** options and commands :



- ***Convert grid file between feet and meters...*** 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**.
- ***Generate blanking file between sources and receivers...*** Write **.BLN** *blanking file* with polygon area between all sources and receivers. Use with marine survey and negative *shot depth* for water-layer blanking.
- ***Regard off-end shots for blanking file*** Regard off-end shots when generating blanking file. May not work with strong topography.
- ***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*** Plot topography in selected layer model **.CSV** on tomogram with *Image and contour velocity...*
- ***Plot refractors on tomogram*** Plot refractors in selected layer model **.CSV** on tomogram with *Image and contour velocity...*
- ***Plot refractors only without tomogram*** Plot refractors only from selected layer model **.CSV** without tomogram, with *Image and contour velocity...*
- ***Plot layer velocity without tomogram*** 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*** Plot shot point symbol (inverted red triangle) on Surfer plot with *Image and contour velocity...*
- ***Edit shot labeling parameters*** Edit parameters for labeling of shot points with shot number. Edit vertical stacking of shot number labels.
- ***Post receiver stations on tomogram*** Plot receiver symbol (grey filled circle with overlaid cross) on Surfer plot with *Image and contour velocity...*
- ***Label receiver stations on tomogram*** 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.
- ***Vertical plot title*** Plot plot title vertical on side of tomogram. Uncheck to plot title horizontally on top of tomogram.
- ***Surfer plot Limits...*** Edit Surfer plot limits: 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**
- ***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

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 https://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. See (Tassis et al. 2017). 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 https://rayfract.com/tutorials/Slope1.pdf, https://rayfract.com/tutorials/riveral8.pdf and https://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. **Use Trace menu item Export reciprocal errors...** to compute and export reciprocal traveltime picking errors to ASCII .ERR file. Import the .ERR file into Microsoft Excel and sort by any column.

- 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 https://rayfract.com/tutorials/TUTORIAL.ZIP and https://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 https://rayfract.com/tutorials/Slope1.ppt show **how to interactively improve your first break picks**. See https://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.* Use our Trigger jitter

removal dialog to automatically adjust *trigger delay* assuming a constant-velocity overburden.

- **make sure that the profile topography *(Header*|*Station*) and recording geometry (shot point coordinates : specify inline and lateral offsets from shot station plus shot hole depth 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. See also our tutorial https://rayfract.com/tutorials/P6.pdf .

- 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 https://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 https://rayfract.com/tutorials/bulgatrl.pdf .

- enable multirun WET inversion for **multiscale tomography** as shown in https://rayfract.com/pub/sageep14.pdf for more reliable imaging of velocity anomalies with less artefacts especially with noisy first break picks. Our tutorial https://rayfract.com/tutorials/sageep11_16.pdf shows our *Conjugate Gradient* method using multirun WET option. Our companion tutorial https://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 https://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 https://rayfract.com/tutorials/palmfig3.pdf and https://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 https://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

https://rayfract.com/tutorials/tra9002.pdf and our client recording geometry sample

https://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**.

Since version 4.03 we allow **forcing extrapolation of the starting model and subsequent WET tomograms** via Header|Profile controls *Extrapolate tomograms* and *Extrapolate [stations spacings]*. With *Extrapolate tomograms* checked our WET inversion will regard far-offset / off-end shot points with the *shot station* at a distance of up to *Extrapolate [station spacings]* stations from first/last profile receiver station. See e.g. our tutorial https://rayfract.com/tutorials/NGU_G4.pdf .

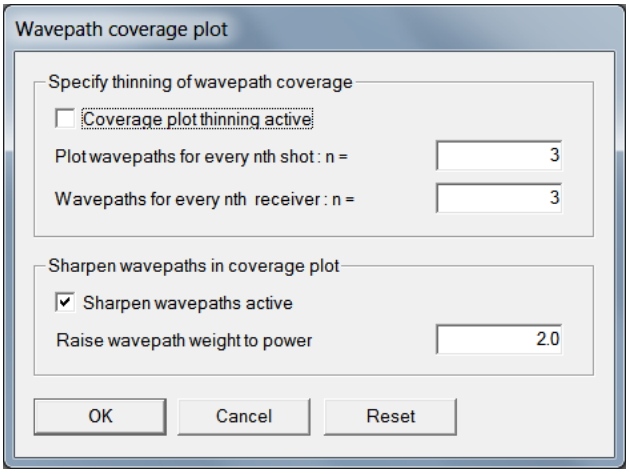
WET can’t open or write disk file

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 :

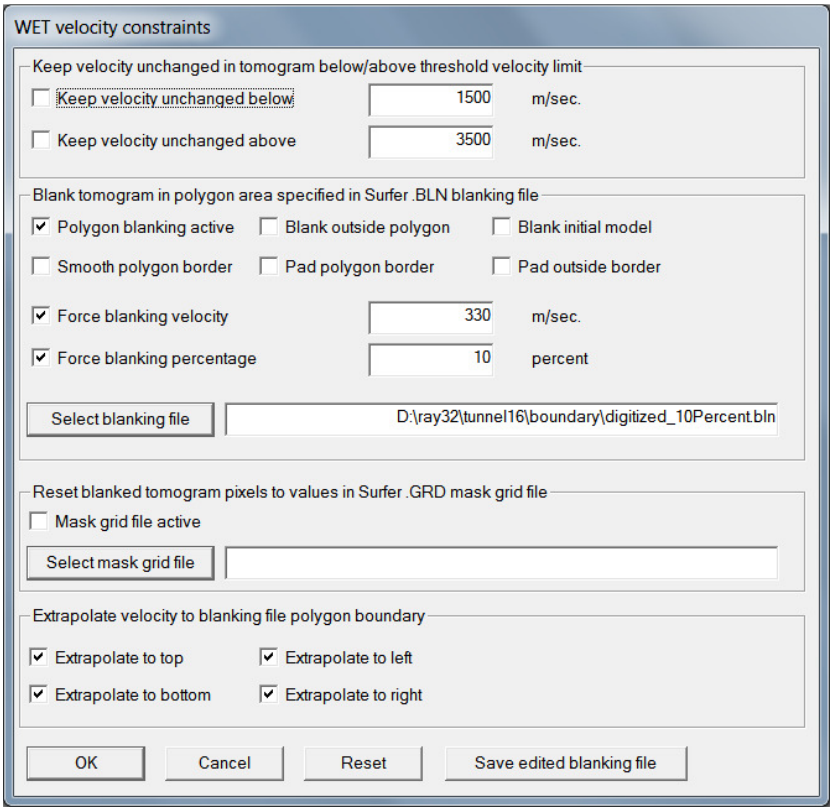


Edit these parameters :

- ***Coverage plot thinning active*** Activate thinning of the WET wavepath coverage plot, with parameters *Plot wavepaths for every nth shot* and *Wavepaths for every nth receiver*.
- ***Plot wavepaths for every nth shot*** Set to 1 to plot wavepaths for every shot. Set to 2 to show wavepaths for every 2nd shot etc.
- ***Wavepaths for every nth receiver*** Set to 1 to plot wavepaths for every receiver, of shot being plotted. Set to 2 to show wavepaths for every 2nd receiver etc.
- ***Sharpen wavepaths active*** Plot wavepath weights summed over all wavepaths instead of number of wavepaths per pixel, in WET coverage plots.
- ***Raise wavepath weight to power*** Power to which the wavepath weight is raised before summing weights over all wavepaths. Increase from 1.0 (use original weights) to 2.0 (squared weights) etc.

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 :



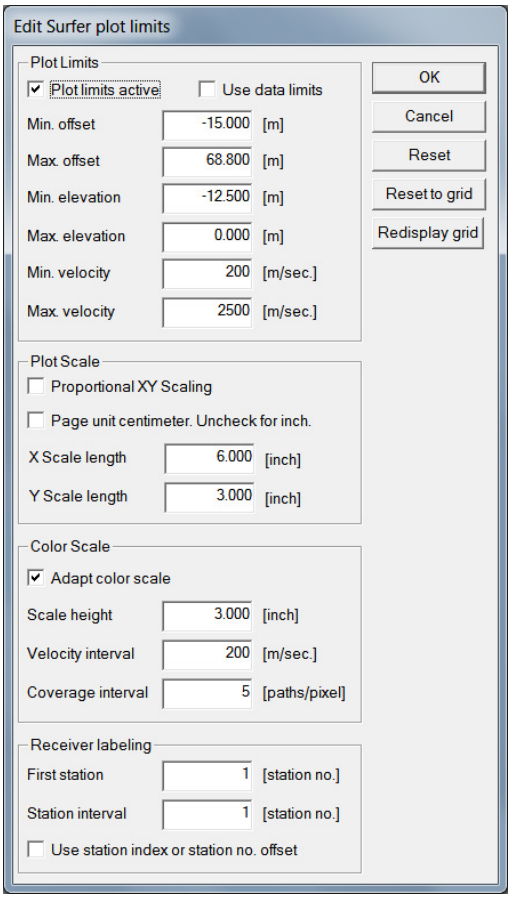
Edit these parameters :

- ***Keep velocity unchanged below*** Keep velocities with starting value smaller than *Lower velocity limit* unchanged during WET inversion.
- ***Low velocity limit*** Lower bound of velocity range updated during WET inversion with *Keep velocity unchanged below* checked.
- ***Keep velocity unchanged above*** Keep velocities with starting value larger than *High velocity limit* unchanged during WET inversion.
- ***High velocity limit*** Upper bound of velocity range updated during WET inversion with *Keep velocity unchanged above* checked.
- ***Polygon blanking active*** Enable blanking during WET inversion in the polygon specified in *blanking file* selected with button *Select blanking file*.
- ***Blank outside polygon*** Force blanking outside the polygon specified in the selected *blanking file* regardless of the value of the *blanking flag* in the *blanking file* header.
- ***Blank initial model*** Blank the initial model selected in WET Tomo|Interactive WET tomography during WET inversion with the .BLN *blanking file* selected.
- ***Smooth polygon border*** Smooth velocity over the blanking polygon border specified in .BLN *blanking file* selected with *Select blanking file* during WET inversion.

- ***Pad polygon border*** Extend blanking polygon border by one pixel (one grid cell) in all directions when blanking the current iteration tomogram.
- ***Pad outside border*** Pad polygon border outside the blanking polygon. Uncheck to pad inside the blanking polygon.
- ***Force blanking velocity*** Check to override blanking velocity specified in the selected *blanking file* with blanking velocity edited in field *Edit blanking velocity*.
- ***Edit blanking velocity*** Edit the blanking velocity and check box *Force blanking velocity* to override the blanking velocity specified in the selected *blanking file*.
- ***Force blanking percentage*** Check to override blanking percentage in the selected *blanking file* with blanking percentage edited in field *Edit blanking percentage*.
- ***Edit blanking percentage*** Edit the blanking percentage and check box *Force blanking percentage* to override blanking percentage specified in the selected *blanking file*.
- ***Select blanking file*** Select a Surfer format .BLN *blanking file* which contains the polygon to be blanked during WET inversion.
- ***Save edited blanking file*** To enable this button you first must select an existing .BLN disk file with button *Select blanking file*. Click to save the edited blanking velocity and blanking percentage to .BLN disk file.
- ***Blanking file*** Surfer format .BLN blanking file selected with button *Select blanking file*. This file should specify a polygon which is blanked during WET inversion or with command *Grid|Blank polygon area in grid...* . Also the .BLN optionally can specify the *blanking velocity* and the *blanking percentage* in columns 3 and 4 of the first/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.
- ***Mask grid file active*** Enable resetting of WET velocity during polygon blanking to velocity in *Mask grid file* selected with button *Select mask grid file*.
- ***Select mask grid file*** 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*.
- ***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...*
- ***Extrapolate to top*** Vertically extrapolate tomogram velocity upwards to `.BLN` *blanking file* boundary when blanking outside polygon.
- ***Extrapolate to bottom*** Vertically extrapolate tomogram velocity downwards to `.BLN` *blanking file* boundary when blanking outside polygon.
- ***Extrapolate to left*** Horizontally extrapolate tomogram velocity to left towards `.BLN` *blanking file* boundary when blanking outside polygon.
- ***Extrapolate to right*** Horizontally extrapolate tomogram velocity to right towards `.BLN` *blanking file* boundary when blanking outside polygon.

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 ***Plot limits active*** to force Surfer plot limits to edited offset range, elevation range and velocity range when imaging .GRD with button ***Redisplay grid*** or with ***Grid|Image and contour velocity and coverage grids***.

Check box ***Use data limits*** to disregard the edited velocity range and to use data limits in the selected .GRD instead with button ***Redisplay grid*** or with ***Grid|Image and contour velocity and coverage grids*** or ***Grid|Image Surfer .GRD without .PAR file***.

Check box ***Proportional XY Scaling*** to use the same distance scale along X and Y axis.

If you check ***Grid|Receiver station ticks on top axis*** then we regard settings of ***First station*** and ***Station interval*** when plotting and labelling station number ticks on top axis of tomogram in Surfer. Check box ***Use station index*** in case of irregular receiver station spacing.

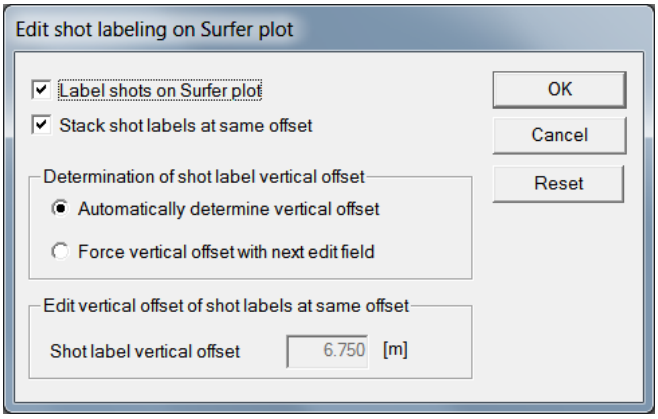
Once you have reconfigured above parameters redo WET tomography e.g. with ***WET Tomo|Interactive WET tomography...*** or redisplay your tomogram with ***Grid|Image and contour velocity and coverage grids...*** . Since version 3.36 we also offer button ***Redisplay Grid*** in above Surfer plot Limits dialog as a shortcut.

Use our new version 4.04 command ***Grid|Image Surfer .GRD without .PAR file*** to image WDVSTIME.GRD and WDVSVELO.GRD in DEBUG folder of your profile directory and to image POISSON.GRD obtained as in our new poisson_Surfer23.pdf tutorial. First check new version 4.04 option ***Use data limits*** in above dialog.

Check option ***WET Tomo|WET tomography Settings|Write|Write blanked and mask grids and WDVS debug grids*** to generate WDVSTIME.GRD and WDVSVELO.GRD in your profile's DEBUG folder during WET inversion with WDVS activated. See our marine refraction tutorial SR6.pdf .

Edit shot labeling parameters

Select *Grid|Edit shot labeling parameters...* to label shots on Surfer plots and stack shot labels at same offset :



Use these controls :

Label shots on Surfer plot Label shot points with shot number on Surfer plot

Stack shot labels at same offset Vertically stack shot numbers for shot points located at same inline offset

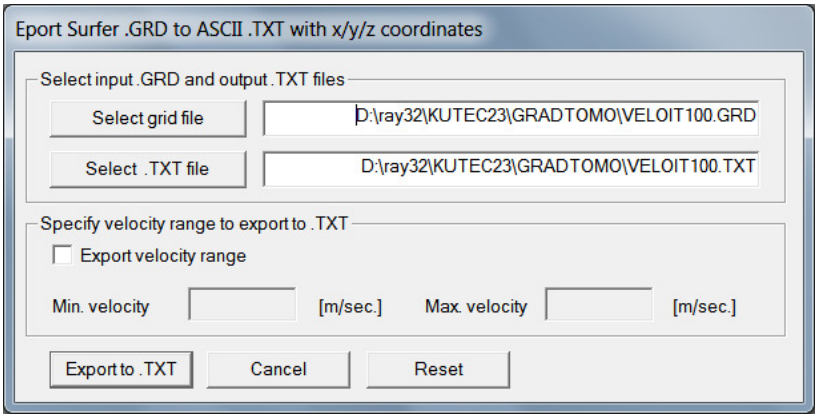
Automatically determine vertical offset Automatically determine vertical offset between shot number labels when *stacking shot labels*

Force vertical offset with next edit field Force vertical offset between shot number labels by editing field Shot label vertical offset

Shot label vertical offset Edit vertical offset between shot number labels

Export Surfer grid to ASCII

Select *Grid|Export grid file to ASCII.TXT* to show the following dialog :



Use these controls :

Select grid file Click to navigate into ...\GRADTOMO or ...\TOMO or ...\LAYRTOMO or ...\HOLETOMO directory and select VELOITXX.GRD where XX is the iteration number

Input .GRD filename Edit filename including path with keyboard or select with button *Select grid file*

Select .TXT file *Output .TXT filename* is updated to ...\VELOITXX.TXT when you select the grid file with *Select grid file*

Output .TXT filename Edit with keyboard or select with button *Select .TXT file*

Export velocity range Check to export VELOITXX.GRD grid cells with velocity in range *Min. velocity* to *Max. velocity* to ASCII .TXT format

Min. velocity VELOITXX.GRD pixels with velocity lower than *Min. velocity* are not exported to .TXT file

Max. velocity VELOITXX.GRD pixels with velocity higher than *Max. velocity* are not exported to .TXT file

Export to .TXT Click to export columns x/y/z/velocity for each grid cell in .GRD to ASCII .TXT format (4 columns)

See (Oyan 2019) Use of seismic refraction in determining rock mass anisotropy. https://egrove.olemiss.edu/cgi/viewcontent.cgi?article=2775&context=etd on page 78 for detailed instructions on how to import Surfer .GRD tomogram files into Golden Software Voxler.

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 *Grid|Export grid file to ASCII.TXT* and above **`...\GRADTOMO\OUT.GRD`**

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 10/11 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 10/11
- startup our app via desktop icon as usual. Now WET inversion can use up to 1'024 GB of RAM with our Pro version.

Pseudo-2D DeltatV inversion

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 (Sheehan 2005)**. The 1D gradient 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 (Sheehan 2005). 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 ***apparent velocity*** pseudo-sections can be compared to ER ***apparent resistivity*** pseudo-sections. See e.g. https://pages.mtu.edu/~ctyoung/LOKENOTE.PDF chapter 2.3 on page 8. Quote :

"The pseudosection is useful as a means to present the measured apparent resistivity values in a pictorial form, and as an initial guide for further quantitative interpretation. One common mistake made is to try to use the pseudosection as a final picture of the true subsurface resistivity." quoted from page 8 of above LOKENOTE.pdf .

Overview of DeltatV inversion

The DeltatV turning-ray gradient-layer inversion method (Gebrande and Miller 1985; Gebrande 1986) delivers continuous 1D velocity vs. depth profiles for all profile stations. CMP (Common MidPoint) sorted traveltime curves are horizontally/laterally stacked to make the inversion more robust. Inverted 1D velocity profiles are imaged in one pseudo-2D apparent velocity section using Surfer gridding and kriging.

DeltatV can work well for long profiles and laterally homogeneous overburden with flat topography and without strong lateral velocity variation in the overburden. DeltatV has been shown to work well for imaging of deep sedimentary basins (Caielli et al. Tectonophysics 2023) or for broad river valleys with velocity inversions in the overburden (GEOXMERC.pdf tutorial).

In case of strong topography or strong lateral velocity variation in the overburden we recommend using our one-dimensional 1D-gradient starting model obtained with our fail-safe Smooth inversion instead (Sheehan 2005). The 1D DeltatV velocity vs. depth profiles are laterally averaged over the whole profile at common depths to get a smooth 1D-gradient starting model. This step eliminates apparent DeltatV velocity artefacts from the starting model. Because WET inversion begins with a simple smooth model there are no artefacts of concern in the final WET tomogram.

As stated by (Sheehan 2005) using the DeltatV method helps to identify small features and velocity inversions. The disadvantage of directly using the raw DeltatV output for the initial model is that there may be artefacts in the DeltatV output that are not removed completely by the subsequent tomography algorithm.

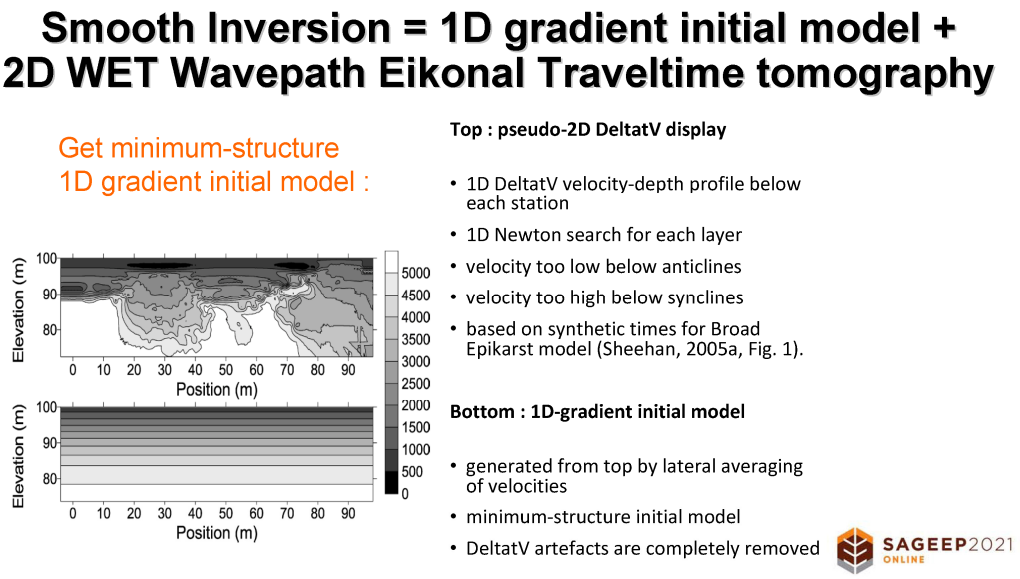
The default settings for WET tomography using either starting model usually work well, although a second run with less smoothing may help bring out details missed with the default smoothing (Sheehan 2005).

To enable the realistic interpretation of sudden apparent velocity increase in CMP sorted traveltime curves, (Winkelmann 1998) proposes to extend the DeltatV gradient layer inversion (Gebrande 1986) with Dix inversion and Intercept Time inversion. These two additional inversion methods allow the modeling of constant-velocity layers. See our OT0608.pdf tutorial.

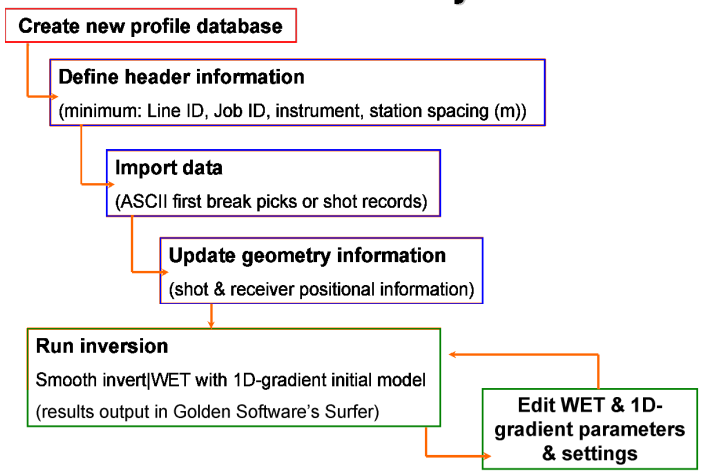
The XTV method parameter dialog allows toggling between two modes :

- click button *Gradient model* to reset XTV inversion parameters to settings optimized for gradient layer inversion, assuming diving waves and using DeltatV Gradient layer inversion
- click button *Layer model* to reset XTV inversion parameters to settings optimized for constant-velocity layer inversion, using Intercept-Time inversion whenever possible
- check box *Use above XTV settings for Automatic DeltatV* to regard your edited XTV inversion parameters for Automatic DeltatV inversion

Below we show slides from our SAGEEP 2021 publication (Rohdewald S.R.C. 2021a) with slides available at https://rayfract.com/pub/SAGEEP%202021%20slides.pdf :



Generalized Rayfract® Flow Chart



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Smooth Inversion, DeltatV and WET Parameters

- ❑always start with default parameters: run Smooth inversion without changing any setting or parameter
- ❑next adapt parameters and option settings if required, e.g. to remove artefacts or increase resolution
- ❑more smoothing and wider WET wavepath width in general results in less artefacts
- ❑increasing the WET iteration count generally improves resolution
- ❑don't over-interpret data if uncertain picks : use more smoothing and/or wider wavepaths.
- ❑explain traveltimes with minimum-structure model
- ❑tuning of parameters and settings may introduce or remove artefacts. Be ready to go one step backwards.
- ❑use Plus-Minus layered refraction method (Hagedoorn, 1959) as alternate starting model

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WET tomography main dialog: see help menu

Number of WET tomography iterations	Default value is 20 iterations. Increase to 50 or 100 for better resolution and usually less artefacts. WET can improve with increasing iterations, even if RMS error does not decrease.
Wavepath frequency	Ricker wavelet used to modulate/weight the wavepath misfit gradient, during model update. Leave at default of 50Hz. One period is 1/50Hz = 20ms. See (Schuster, 1993).
Degree of differentiation of Ricker wavelet	0 for original Ricker wavelet, 1 for once derived wavelet. Value 1 may give artefacts: wavepaths may become "engraved" in the tomogram. New default is -1: Gaussian weighting. Set to -2 for Cosine-Squared weighting, for better imaging of vertical fault zones.
Wavepath width	In percent of one period of Ricker wavelet. Increase width for smoother tomograms. Decreasing width too much generates artefacts and decreases robustness of WET inversion. Click Iterate button to specify multirun WET schedule for decreasing wavepath width between consecutive WET runs.
Envelope wavepath width	Width of wavepaths used to construct envelope at bottom of tomogram. Default is 0.0. Increase for deeper imaging.
Maximum valid velocity	Limit the maximum WET velocity modeled. Default is 6,000 m/s. Decrease to prevent high-velocity artefacts in tomogram.
Full smoothing	Default smoothing filter size, applied after each WET iteration
Minimal smoothing	Select for more details, but also more artefacts. May decrease robustness and reliability of WET inversion.
Manual smoothing	Specify half-width and half-height of smoothing filter in grid columns and grid rows. Gaussian or Uniform weighting. Smooth nth iteration. Smooth velocity update. Maximum velocity update. Check No smoothing to disable WET smoothing. Specify Damping for Conjugate-Gradient WET inversion.

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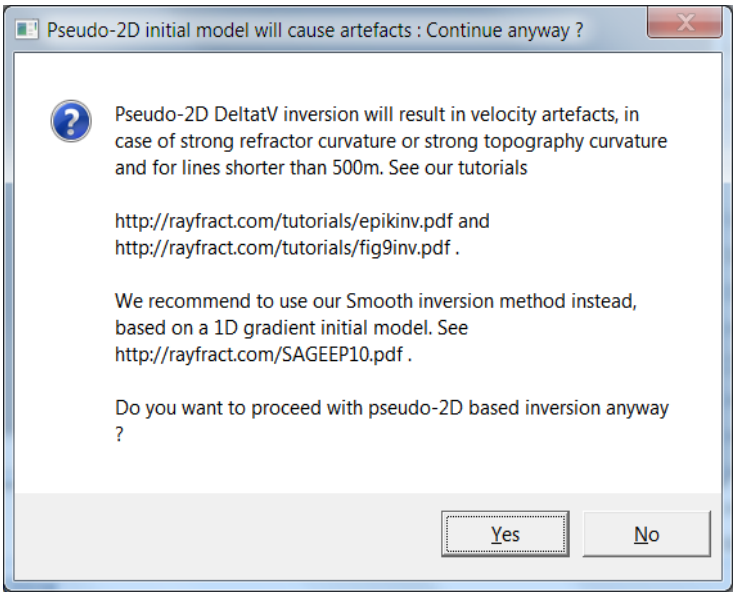
When you start DeltatV inversion with DeltatV menu commands *Automatic DeltatV and WET inversion* or *Interactive DeltatV* we show the following prompt :



You need to click Yes button to continue with DeltatV inversions of your first breaks.

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

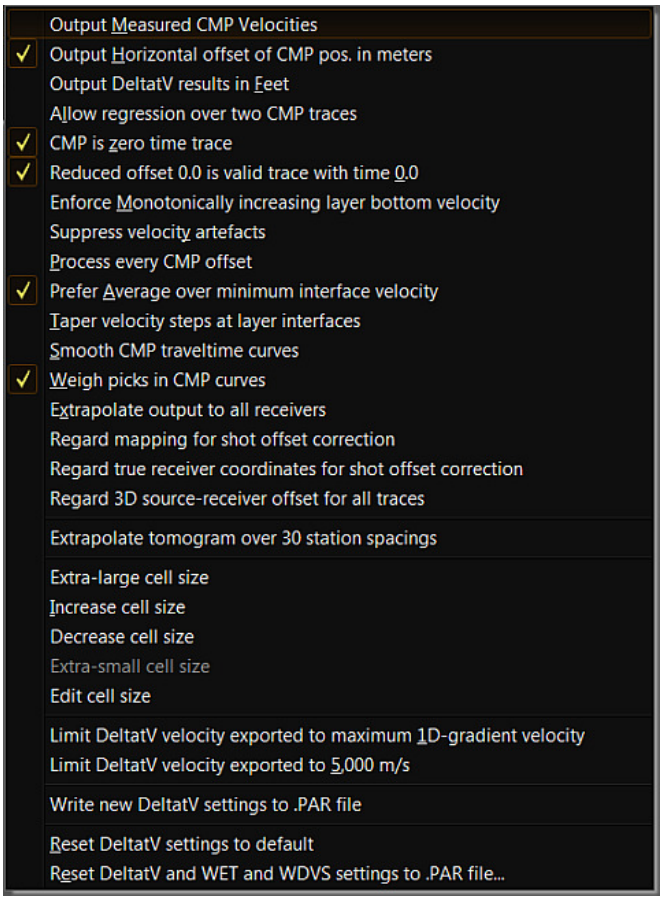
https://rayfract.com/tutorials/ot0608.pdf and https://rayfract.com/samples/GEOXMERC.pdf and https://rayfract.com/tutorials/3016.pdf and https://rayfract.com/tutorials/SR6.pdf and https://rayfract.com/tutorials/NGU_G4.pdf .

Enable options *Supress velocity artefacts* and *Smooth CMP traveltime curves* in *DeltatV|DeltatV Settings submenu* for long and dense lines, for **more regular DeltatV output with less artefacts and less noise**. See also above tutorials ot0608 on page 3 and GEOXMERC on page 1. For short and low-coverage lines leave these two options disabled for better resolution if appropriate.

See our tutorial https://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.

Our tutorial https://rayfract.com/tutorials/thrust.pdf shows construction of a synthetic fault zone model using Surfer and forward modeling of synthetic traveltimes. DeltatV inversion shown in this thrust.pdf tutorial shows quite a realistic image of the fault zone. So pseudo-2D DeltatV can sometimes image fault zones given a favorable geological setting with homogeneous overburden beneath flat topography and close enough spacing of receivers and shots . E.g. use receiver station spacing of 2m with 48 or more channels and a shot at every 2nd receiver as shown in thrust.pdf tutorial. Always also run our Smooth inversion and compare with DeltatV-based WET inversion to identify areas where the two inversions differ. Prefer the Smooth inversion output for such areas especially for too short profiles/profiles shorter than the recommended 500m or for profiles with strong topography or with strong refractor curvature or for profiles with too wide receiver and shot spacing.

Review our https://rayfract.com/tutorials/sageep11_16.pdf tutorial where DeltatV inversion fails in Fig. 16. due to too strong refractor curvature in the original synthetic "basement step with fault zone" model shown in Fig. 17 (Zelt et al. 2013).



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 output as a starting model for WET tomography inversion configure DeltatV in DeltatV|DeltatV Settings menu 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

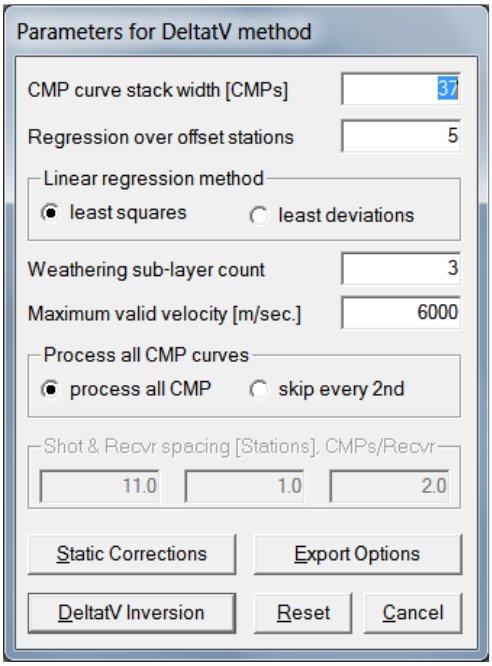
Since version 1.30 released in December 1998 our Rayfract® software implements the **DeltatV method** as described by (Gebrande and Miller 1985). This turning-ray inversion method delivers continuous depth vs. velocity profiles for all profile stations. These profiles consist of (horizontal inline offset, 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 subdirectory 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 profile directory e.g C:\RAY32\LINE14 (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 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 adjust the subsurface velocity model until the synthetic times optimally match the first break times as measured and picked use **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.



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

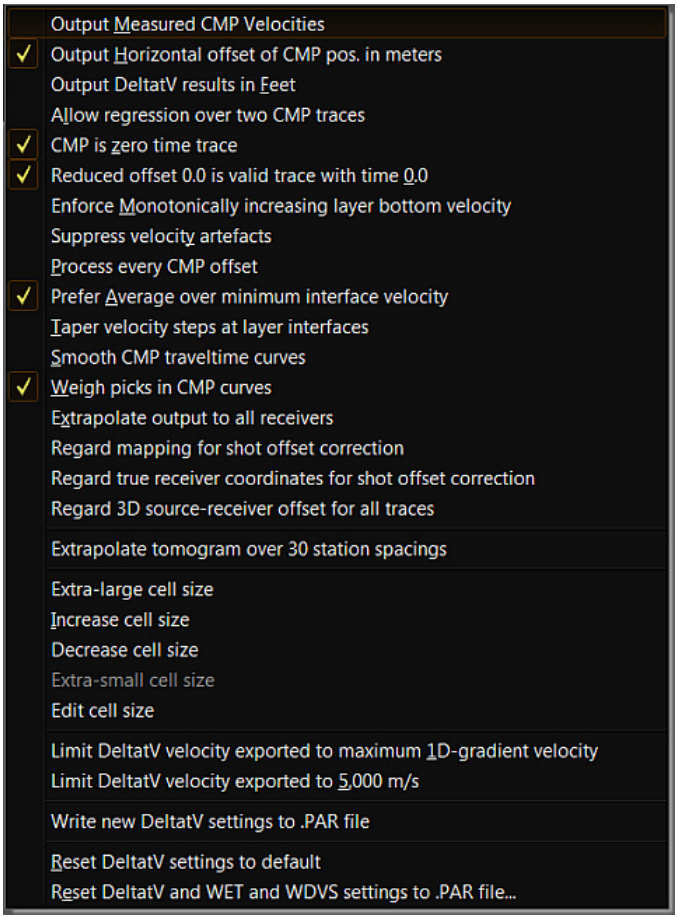
subsurface.

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 unchecking this option may deliver better results 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 unchecked by default 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 DeltatV inversion method toggle options in menu *DeltatV|DeltatV Settings :*



- ***Output Measured CMP Velocities*** (see above) Combine inverted velocities and depths with instantaneous velocities as measured directly on the CMP sorted curves.
- ***Output Horizontal offset of CMP pos. in meters*** CMP positions in DELTATV.TXT files are in meters. Uncheck to list CMP positions in station numbers.
- ***Output DeltatV Results in feet*** CMP positions in DELTATV.TXT files are in feet.
- ***Allow regression over two CMP traces*** Allow linear regression over just two CMP-stacked first breaks for velocity determination. Uncheck for regression over at least 3 CMP traces giving less detailed overburden imaging and less artefacts.
- ***CMP is zero time trace*** First break time of 0.0 is assumed for offset 0.0, at each Common MidPoint (CMP) during DeltatV inversion.
- ***Reduced offset 0.0 is valid trace with time 0.0*** Near-offset part of CMP sorted and stacked traveltime curves is inverted with more details. Disable if the output obtained (as gridded and contoured with Surfer®) is too noisy.
- ***Enforce Monotonically increasing layer bottom velocity*** 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.

- ***Suppress velocity artefacts*** 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.
- ***Process every CMP offset*** Obtain better vertical velocity resolution, by inverting for an incremental gradient layer at every CMP offset . This option may increase the amount of artefacts in the output, especially for low coverage data sets and noisy first break picks.
- ***Prefer Average over minimum interface velocity*** Disable this setting to enhance the low-velocity imaging capability of the DeltatV inversion. Enable to enhance the high-velocity anomaly imaging capability in the near-surface region.
- ***Taper velocity steps at layer interfaces*** 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 disabled in case of strong lateral velocity variation.
- ***Smooth CMP traveltime curves*** For high-coverage profiles this option may help to filter out bad picks from CMP sorted and stacked traveltime curves.
- ***Weigh picks in CMP curves*** Check to weigh traveltime picks 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.
- ***Extrapolate output to all receivers*** Horizontally extrapolate DeltatV inversion output to all receivers, beyond first/last CMP stations. Disabled per default.
- ***Regard mapping for shot offset correction*** Regard trace-to-refractor mapping and refractor velocities, for correction of first breaks for shot point offset from inline shot station.
- ***Regard true receiver coordinates for shot offset correction*** Regard true receiver coordinates for correction of first breaks for shot point offsets instead of regarding averaged receiver station coordinates. Requires correct receiver coordinates in Header|Receiver dialog.
- ***Regard 3D source-receiver offset for all traces*** Use 3D Cartesian distance between source and receiver as offset for DeltatV inversion for all traces. Uncheck to regard 3D distance within 5 *station spacings* from shot point only and to use station number difference for all other traces. This option is regarded if *DeltatV|Interactive DeltatV|Static Corrections|No Statics/Regard shot offset and 3D offsets for all traces* is checked only.
- ***Extrapolate tomogram over 30 station spacings*** Extrapolate starting models and WET tomograms over 30 station spacings instead of two station spacings. Shots offset up to 30 stations from first/last profile receiver are used for WET inversion. Alternatively use option *Extrapolate tomograms* and edit control *Extrapolate [station spacings]* in Header|Profile dialog.
- ***Extra-large cell size***
- ***Increase cell size*** 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.
- ***Decrease cell size***
- ***Extra-small cell size***
- ***Edit cell size*** Regard the user-specified *Cell size* in *Header|Profile* when determining the 1D-gradient starting model. Alternatively check *Header|Profile|Force grid cell size*.
- ***Limit DeltatV velocity exported to maximum 1D-gradient velocity*** 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 .
- ***Limit DeltatV velocity exported to 5,000 m/s***
- ***Write new DeltatV settings to .PAR file*** Write new setting *Regard mapping for shot offset correction* to .PAR file. Uncheck so older version 3.36 builds of our software can still read .PAR files written with 3.36 build May 2020 and higher versions. .PAR files are generated during DeltatV inversion & Smooth inversion and are updated with WET settings during following WET inversion.

- ***Reset DeltatV settings to default*** Reset DeltatV inversion settings to their defaults.
- ***Reset DeltatV and WET and WDVS settings to .PAR file*** Select a VELOITXY.GRD and reset DeltatV and WET inversion and WDVS settings in profile database to settings read from matching VELOITXY.PAR file located in same profile subdirectory.

Options *Output DeltatV Results in feet* and *Output Horizontal offset of CMP pos. in meters* may not be activated both at the same time.

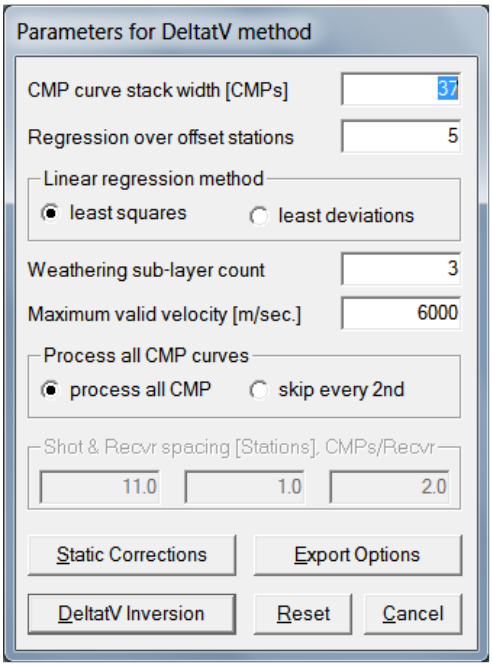
Suppress velocity artefacts

Enable this option in *DeltatV|DeltatV Settings* menu 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.

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]*** lateral/horizontal smoothing in velocity plot. 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.
- ***Regression over offset stations*** vertical smoothing in velocity plot. Specify the length of the offset station interval used to carry out local piecewise linearization of CMP traveltime curves.
- ***Least squares regression method*** default regression method. Local apparent velocities on CMP traveltime curves are determined by a least squares linear regression over traveltimes inside an offset interval with width *Regression over offset stations* and centered at the offset currently being evaluated.
- ***Least deviations regression method*** alternative regression method for estimating apparent velocity along segments of CMP sorted and stacked traveltime curve.
- ***Weathering sub-layer count*** increase this parameter to obtain more detailed velocity imaging in weathering layer
- ***Maximum valid velocity [m/s]*** specify the maximum velocity accepted as valid when processing CMP curves. Apparent CMP velocities higher than this value will be skipped.
- ***Process all CMPs*** process CMP sorted traveltime curves at every CMP location
- ***Skip every 2nd CMP*** process every second CMP only. Use this option to reduce computation time for DeltatV/XTV inversion and for gridding with Surfer®.

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 curve 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 curve stack width* between values of 20 to 50** (neighboring Common MidPoints) for lines up to 500m long. For lines exceeding 1 or 2 km in length increase stack width to 100 or 200. One station number interval corresponds to two CMP positions (at station positions .25 and at .75, with all shot stations at .5). As a rule of thumb set this stack width to (line length in station numbers)/5. E.g. with line length of 500m assuming a *Station spacing* of 2m set *CMP curve stack width* to 50. For line length of 2km set to 200. With a station spacing of 4m set to (line length in meters)/20. But set to at least 20, especially for short receiver spreads.

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.

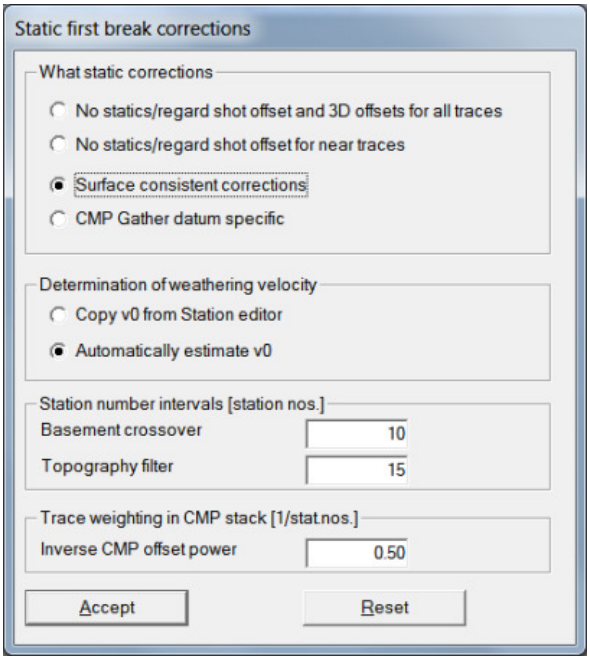
Increase the value of ***Weathering sub-layer count*** to obtain slightly slower and more detailed topmost / weathering velocity imaging. As a consequence, synthetic traveltimes obtained by raytracing through the resulting DeltatV model will be slightly slower.

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 statics/regard shot offset and 3D offsets for all traces*** 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. Regard offset of shot point from *shot station* for all traces. Regard 3D source-receiver offset for all traces when determining apparent CMP velocities. Also check *DeltatV|DeltatV Settings|Regard 3D source-receiver offset for all traces*. With these two options checked our pseudo-2D DeltatV method works better for crooked lines. Our 2D WET inversion assumes a straight 2D line when projected onto horizontal x/y plane.
- ***No statics/regard shot offset for near traces*** 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. Regard offset of shot point from *shot station* for traces near shot point only.

- ***Surface-consistent static corrections*** Compute first break static corrections relative to a floating datum obtained by applying a running-average smoothing filter to the topography. Specify the filter width with ***Topography filter***. **This is the default static correction method**. Works for both undulating topography and flat/constantly dipping topography. Basement-refracted first breaks are corrected for vertical offset of source and receiver from datum plane or floating datum. For this correction we use the laterally varying weathering velocity determined using ***Basement crossover*** *(formerly Weathering crossover).*
- ***CMP Gather datum-specific*** 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.
- ***Copy v0 from Station editor*** 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. **DeltatV weathering velocity needs to represent the whole overburden and not just the topmost "weathering layer" used in layered refraction interpretation with Plus-Minus method**.

- ***Automatically estimate v0*** Estimate laterally varying near-surface velocity based on the laterally constant crossover distance ***Weathering crossover***. Use this option e.g. in situations of locally outcropping bedrock. **This is the default setting for Group box *Determination of weathering velocity***.
- ***Basement crossover*** Specify the laterally constant estimated average crossover distance (in station numbers) separating direct wave arrivals and overburden-refracted arrivals from basement-refracted arrivals. Formerly named *Weathering crossover*. **Leave at default 10 station numbers**.
- ***Topography filter*** Specify the filter width for the running-average filter applied to the line topography to obtain a smoothed floating datum. **Leave at default 15 station numbers**.
- ***Inverse CMP offset power*** Weight first break picks when stacking *CMP curves*. Allowed values are in range 0 to 1. Default value is 0.5. Decreasing this parameter to 0.1 or 0.2 means increasing the lateral smoothing in the DeltatV velocity plot. Increasing to 0.9 means decreasing the lateral smoothing in DeltatV plot.

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*** (Frei, 1995). 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*.

Please note that the **DeltatV weathering velocity needs to represent the whole weathered overburden and not just the topmost "weathering layer" used in layered refraction interpretation with Plus-Minus method**. So the DeltatV weathering velocity typically needs to be much higher than the layered refraction "weathering velocity". Otherwise DeltatV static

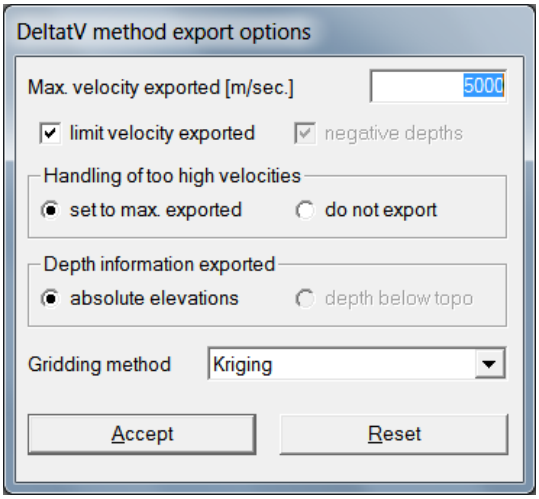
correction will over-correct first breaks to floating datum especially with strongly undulating topography and strong topography curvature and with too wide *Topography filter* used for *Surface consistent* static corrections or with too low weathering velocity obtained with too low *Basement crossover.*

Parameter ***Basement crossover*** specifies the estimated average crossover distance (in station numbers) separating direct wave arrivals and overburden-refracted arrivals from basement-refracted arrivals. Guess at this mean crossover distance by looking at the *Midpoint breaks display* or the *Shot breaks display*. Decrease by a few station numbers from average basement crossover so first breaks refracted at weathered basement top are also corrected to datum plane. This parameter is used to estimate the near-surface weathering/overburden velocity needed for static correction of first breaks. This laterally varying velocity estimate is required for the computation of corrections for shot position offset from shot station for direct wave and overburden-refracted arrivals and for static corrections for basement-refracted first breaks. **Leave at default setting of 10 station number**s. If you decrease this too much to e.g. 3 or 4 stations then the estimated overburden velocity obtained with this parameter will be too low and basement-refracted first breaks will be over-corrected for vertical offset of source and receiver from datum plane or floating datum especially in case of strong topography curvature.

Parameter ***Topography filter*** specifies the running average filter width in station numbers, used to obtain a smoothed topography and floating datum for first break correction method *Surface consistent*. **Leave at default of 15 station numbers**. Do NOT increase for strongly undulating topography with strong curvature. If you increase this filter width too much with strong topography then first breaks will be over-corrected since the smoothed floating datum will cut into the subsurface and even into top-of-basement too much at anticlines. Or the smoothed floating datum will be positioned above topography too much at synclines. See tutorial https://rayfract.com/tutorials/NGU_G1.pdf for default static correction settings (Fig. 25) and for pessimized settings (Fig. 30). Also see tutorial https://rayfract.com/tutorials/Aaknes-1.pdf for default static correction settings (Fig. 29) and for pessimized settings (Fig. 28).

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 https://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.
- *Gridding method* let you specify the Surfer® gridding method used for gridding of pseudo-2D DeltatV inversion results. Select methods *Delauney Triangulation*, *Kriging*, *Minimum Curvature*, *Natural Neighbor* and *Nearest Neighbor*. Per default this option is set to method *Kriging*.

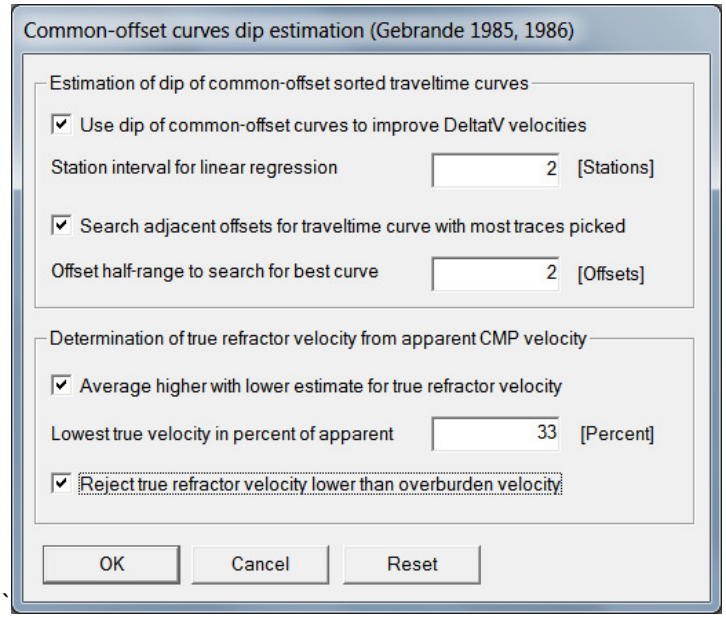
Once you have edited all parameter values you want to change or to accept the default parameter values, click button *DeltatV Inversion* to start the inversion or abort the inversion with the ESC key.

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.

Common-Offset Dip estimation

In DeltatV menu select command ***Common-offset dip estimation...*** available with our Pro license and Pro software version to show the *Common-offset curves dip estimation dialog* :



Edit these parameters for estimation of dip of common-offset sorted traveltime curves and for improved DeltatV velocity estimation :

- ***Use dip of common-offset curves to improve DeltatV velocities*** Check to improve DeltatV velocity estimation using common-offset dip (Gebrande and Miller, 1985; Gebrande 1986).
- ***Station interval for linear regression*** Specify the CMP station interval used for linear regression over common-offset sorted picked traces to determine the dip of common-offset sorted traveltime curves
- ***Search adjacent offsets for traveltime curve with most traces picked*** Check to activate search of common-offset curve with most traces picked, over offset interval specified with *Offset half-range to search for best curve*
- ***Offset half-range to search for best curve*** Specify the number of adjacent offset gathers to search in both directions, for given offset and CMP station during pseudo-2D DeltatV inversion
- ***Average higher with lower estimate for true refractor velocity*** Check to average higher with lower estimate for true refractor velocity based on apparent CMP velocity and offset dip during pseudo-2D DeltatV inversion (Gebrande and Miller 1985; Gebrande 1986).
- ***Lowest true velocity in percent of apparent*** Specify the smallest accepted estimate for true refractor velocity, in percent of apparent CMP velocity during pseudo-2D DeltatV inversion
- ***Reject true refractor velocity lower than overburden velocity*** Reject estimated true refractor velocity if lower than overburden velocity during pseudo-2D DeltatV inversion. Regard apparent refractor velocity as true velocity instead.

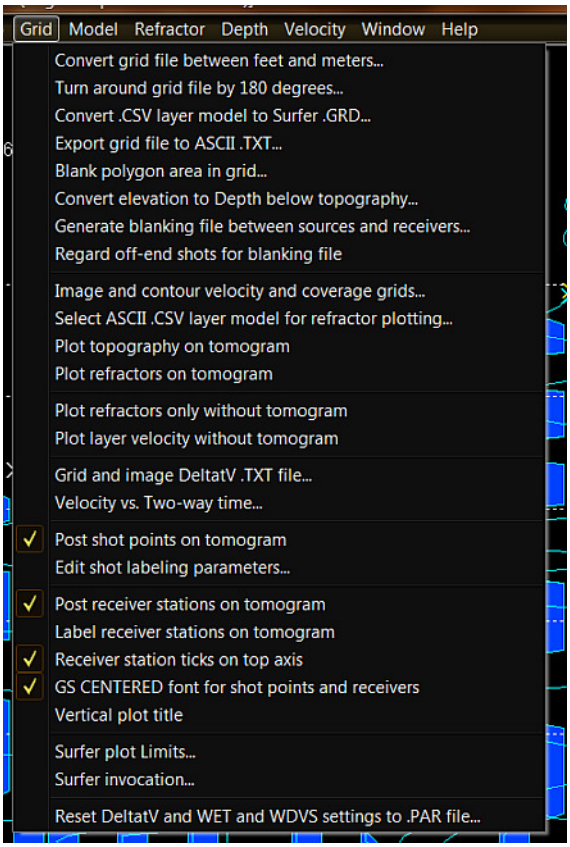
With steeply dipping refractors the true refractor velocity deviates significantly from the apparent CMP velocity measured on CMP sorted traveltime curves (Gebrande and Miller 1985; Gebrande 1986). Above dialog lets you estimate the true refractor velocity based on

local dip of common-offset sorted traveltime curves, apparent CMP velocity and overburden velocity as described by (Gebrande 1986) in equations (13) and (14).

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 gridding and plotting with Golden Software Surfer® select ***Grid|Grid and image DeltatV .TXT file...*** in our Grid menu :



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 https://rayfract.com/tutorials/line14.pdf .

Use our **Smooth inversion** to obtain a laterally smoothed 1D-gradient starting model 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 in subdirectory C:\RAY32\<your profile name> generated during an

earlier inversion with ***Grid|Grid and image DeltatV .TXT file...*** . See our tutorial https://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. First breaks recorded for the largest source-receiver offsets will penetrate the subsurface to that depth only.

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.

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 location 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**.Our version 4.02 released in May 2022 allows Wavelength-Dependent Velocity Smoothing (WDVS; Zelt and Chen 2016) during WET inversion. WDVS helps to suppress DeltatV noise and artefacts. See our tutorial https://rayfract.com/tutorials/TRA9002_resolution_test.pdf .

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 :

$$h = \frac{\Delta}{2}\sqrt{\frac{Vt}{\Delta} - 1} \qquad (1)$$

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

$$\bar{v} = \sqrt{\frac{V\Delta}{t}} \tag{2}$$

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

$$\tau = t - \frac{\Delta}{V} \tag{3}$$

the layer thickness h is determined with

$$h = \frac{\tau}{2\sqrt{(1/v_1)^2 - (1/V)^2}} \tag{4}$$

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

$$v(z) = a \cdot z + v_0 \tag{5}$$

Since the velocity gradient is assumed constant, the diving first-break ray follows a circular arc, between shot point and receiver. Based on the two equations

$$\Delta(V) = \frac{2}{a}\sqrt{V^2 - v_0^{\,2}} \tag{6}$$

and

$$t(V) = \frac{2}{a} arch(\frac{V}{v_0}) \tag{7}$$

the velocity v_0 at the top of the modeled layer is determined numerically. Then the layer thickness h is

$$h = \frac{\Delta}{2}\sqrt{\frac{V - v_0}{V + v_0}} \tag{8}$$

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).

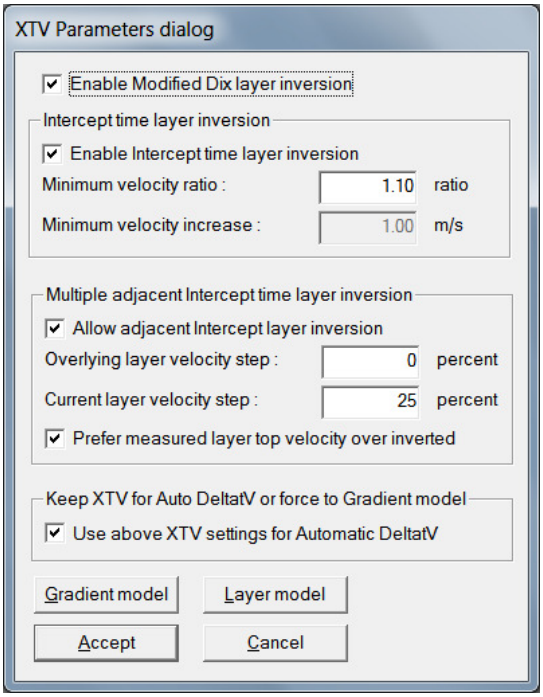
XTV triples are sorted by unsigned offset X, for layer inversion as described here. Winkelmann (1998) proposes the following **XTV inversion algorithm** :

- 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. Intercept Time inversion can be disabled with XTV parameter *Enable Intercept Time layer inversion*.
- Otherwise use Dix inversion if both the average velocity $\overline{v}$ (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 *Enable Modified Dix layer inversion*.
- Otherwise use Gradient layer inversion.

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.

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 layer 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 by unchecking XTV parameter ***Enable Intercept Time layer inversion***.
- 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 by unchecking XTV parameter ***Enable Modified Dix layer inversion***.
- Otherwise use DeltatV 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.

Use above XTV settings for Automatic DeltatV

To force ***DeltatV|Automatic DeltatV and WET inversion*** to regard your edited XTV inversion parameters as shown above, you need to check XTV option *Use above XTV settings for Automatic DeltatV*. This option is available since our version 4.03 software released in July 2022 only.

Suppress velocity artefacts

Enable this option in *DeltatV|DeltatV Settings* menu 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.

XTV 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.

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
click button *Layer model* to reset XTV inversion parameters to settings optimized for constant-velocity layer inversion, using Intercept-Time inversion whenever possible
click *Accept* button

Alternatively edit XTV parameters controls as follows :

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

Instead of editing XTV parameters as described above you can also

check Smooth invert|Smooth inversion Settings|Allow XTV inversion for 1D initial model
check Smooth invert|Smooth inversion Settings|Optimize XTV for layered starting model
select Smooth invert|WET with 1D-gradient initial model and confirm prompts as usual

See our tutorial https://rayfract.com/tutorials/jenny10.pdf for detailed and illustrated instructions. This also shows imaging artefacts caused solely by Golden Software Surfer Kriging gridding method. Natural Neighbor gridding method works much better, at least in this case, for imaging of pseudo-2D XTV inversion output.

Use edited XTV settings for Automatic DeltatV inversion

XTV parameters are always used for inversion with ***DeltatV|Interactive DeltatV***.

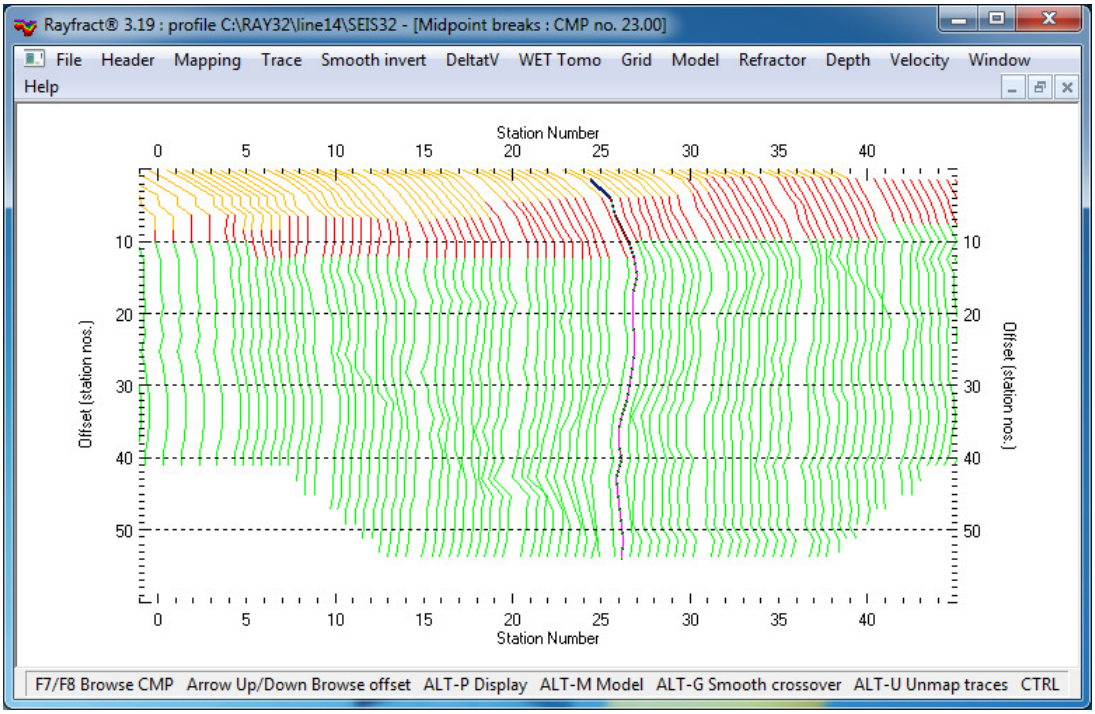
To force ***DeltatV|Automatic DeltatV and WET inversion*** to regard your edited XTV inversion parameters as shown above, you need to check XTV option *Use above XTV settings for Automatic DeltatV*. This option is available since our version 4.03 software released in July 2022 only.

If you leave this option unchecked or in earlier versions of our software not offering this option, menu item *DeltatV|Automatic DeltatV and WET inversion* will internally reset XTV inversion options to settings obtained by clicking button *Gradient model* in above XTV parameters dialog.

See our 2022 tutorial https://rayfract.com/tutorials/NGU_G1.pdf for DeltatV+XTV inversion assuming constant-velocity layers (Fig. 23 and Fig. 25 in NGU_G1.pdf), of synthetic first break picks forward-modeled over NGU G1_SYNTHETHIC.GRD. We set XTV parameter Minimum velocity ratio to 1.05 and 1.10 respectively, for Fig. 23 and Fig. 25. See Fig. 27 in NGU_G1.pdf tutorial. Also see our 2023 tutorial https://rayfract.com/tutorials/NGU_G4.pdf .

Midpoint breaks display

Displays first breaks in a Common Mid Point (CMP) versus offset coordinate system. Open this display with ***Refractor*/*Midpoint breaks*** :



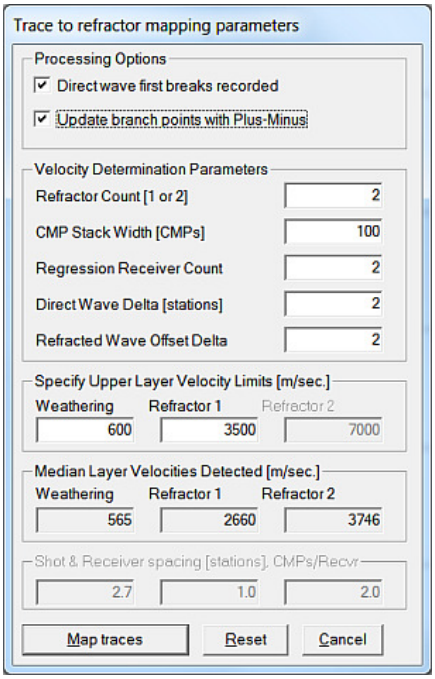
At each CMP (horizontal axis, in station numbers), a local coordinate system is appended, with its origin at that CMP. It has recording time as horizontal axis (not displayed; overlaps CMP station number axis) and unsigned shot point to receiver offset as vertical axis.

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 :



Edit these parameters :

- *Direct wave first breaks recorded*
- *Update branch points with Plus-Minus*
- *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.

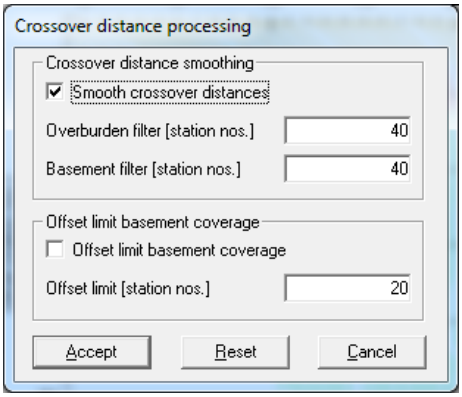
Once you have edited these parameters, click button *Map traces*.

Check box ***Update branch points with Plus-Minus*** to automatically update branch points in *Refractor|Shot breaks* display. With this option checked we update branch points in *Refractor|Shot breaks* display once you click button *Map Traces* and next select *Depth|Plus-Minus* or *Depth|Wavefront* layered refraction method in our ***Depth menu***.

Next you can interactively improve these updated branch points in our *Refractor|Shot breaks* display. See our new 2023 tutorial https://rayfract.com/tutorials/Line3.pdf .

Crossover distance processing

After mapping traces to refracors with ALT+M dialog 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.*

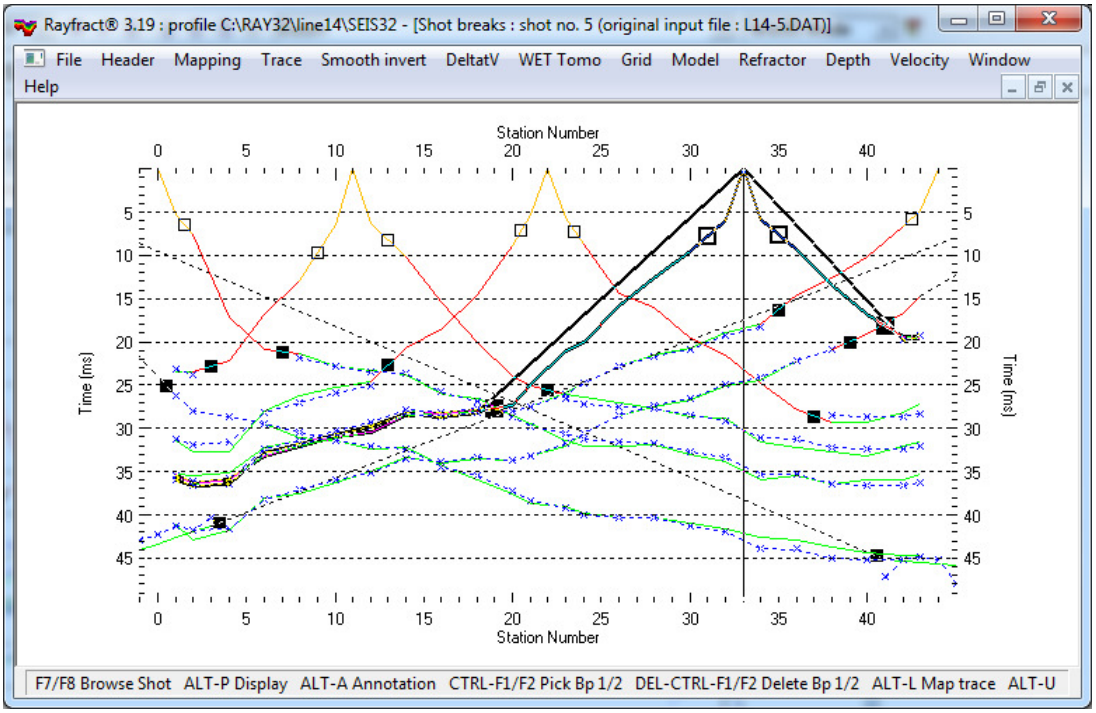
Check ALT+M mapping option ***Update branch points with Plus-Minus*** to automatically update branch points in *Refractor*|*Shot breaks* display. With this option checked we update branch points in *Refractor*|*Shot breaks* display once you click button *Map Traces* and next optionally smooth crossover distances and then select *Depth*|*Plus-Minus* or *Depth*|*Wavefront* layered refraction method in our ***Depth menu***.

Next you can interactively improve these updated branch points in our *Refractor*|*Shot breaks* display. See our new 2023 tutorial https://rayfract.com/tutorials/Line3.pdf .

Mapping traces to refractors

Manually assign traces to refractors by picking branch points for 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 picked *branch points* in 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* just picked. Any errors with your *branch point* selection are shown 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 (at closest receiver). If the first refractor pinches out pick both *branch points* at the same profile position (for same shot direction).

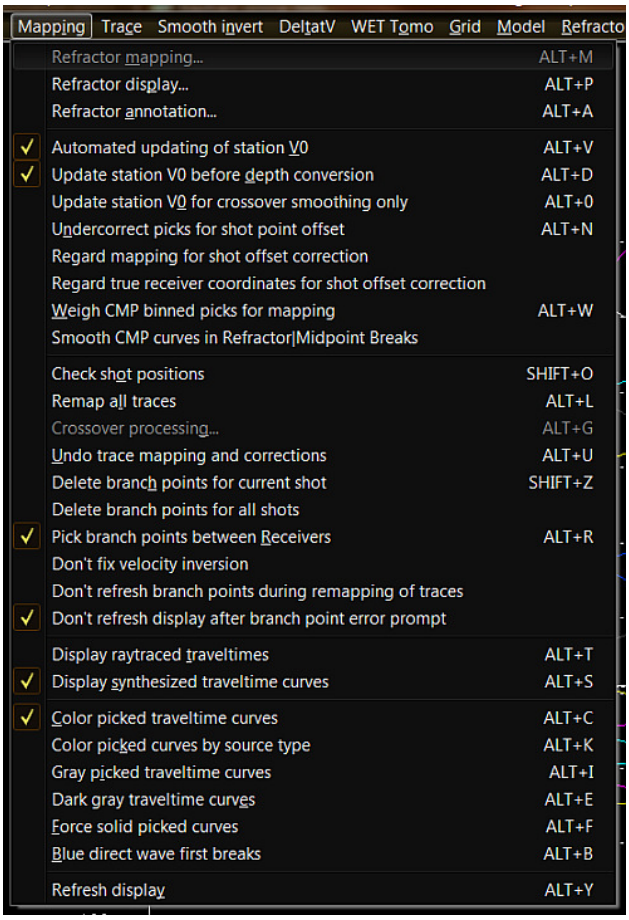
To delete one branch point picked :

- 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.

To delete all branch points for all shots select *Mapping*|*Delete branch points for all shots* .

See our *Mapping menu* shown below :



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. The shot point is considered as a receiver with fixed traveltime 0.0.

We automatically fix velocity inversions between refractor 1 and refractor 2 for 3-layer case when mapping first breaks to refractors in *Refractor|Shot breaks* with ALT+L with option ***Mapping|Don't fix velocity inversion*** unchecked. For other branch point errors we show a dialog prompt describing the error and how to resolve it by repicking branch points. Also we automatically zoom in on the current shot for which these branch point errors were detected. Use function keys F1/F2 to zoom/unzoom the current shot horizontally. Use keyboard shortcut SHIFT+W to unzoom the *Shot breaks* display to show traveltime curves for the whole profile length. Use SHIFT+Z to delete all branch points for current shot.

Option *Mapping|Pick branch points between Receivers* is unchecked per default. Backup your

branch points with *File|Export header data|Export refractor branches to .BRN* and restore branch points with *File|Update header data|Update refractor branches from .BRN… .* This works best with option *Mapping|Pick branch points between Receivers* unchecked.

Near the *shot point* we move the ***branch point pick bar*** (vertical black line) 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 (at adjacent receiver) then you define an outcrop of the 1st refractor at the shot point, with weathering layer thickness close to zero.

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.

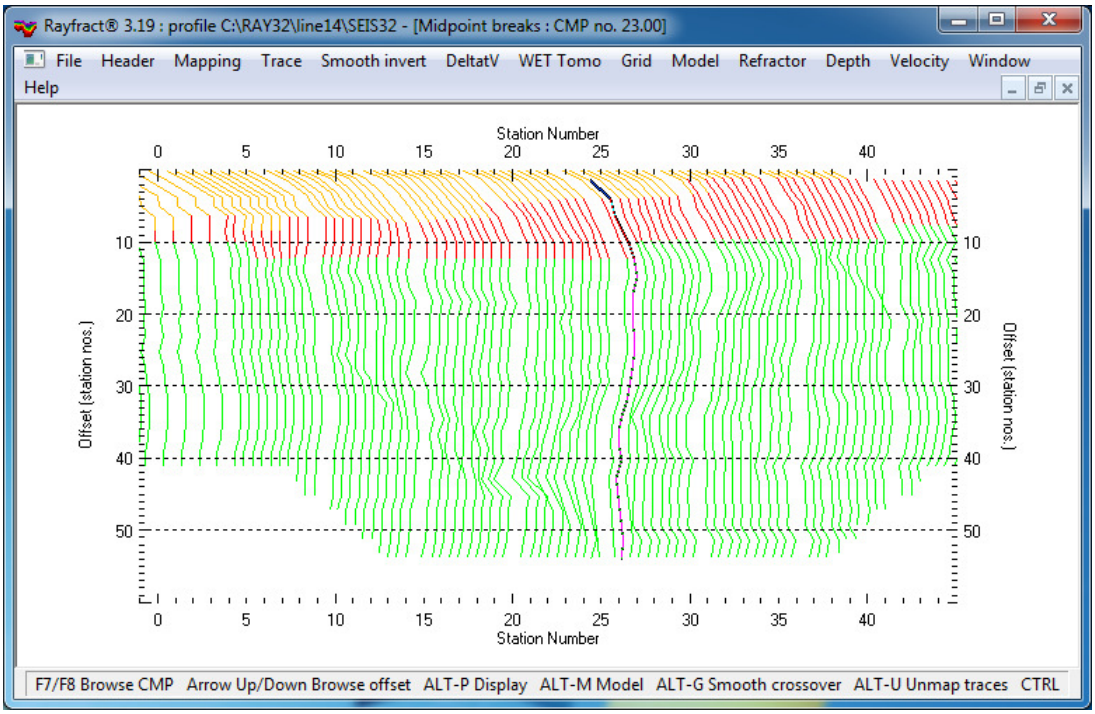
If the *shot point* is located to the right of the leftmost spread receiver then we position the pick bar 0.25 or 0.5 station spacings left of the shot point i.e. between shot point and next-lower receiver position .

Semi-automatically / iteratively assign traces to refractors with a 1D velocity model and fit 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).

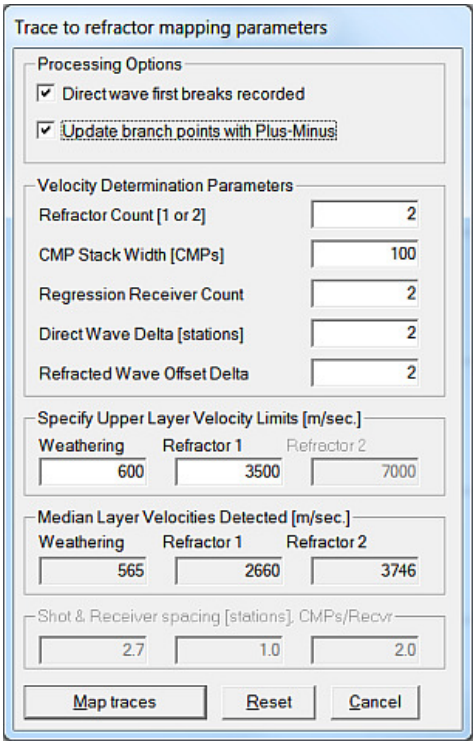
Open the *Refractor|Midpoint breaks display* :



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*** :



Edit the following parameters :

- ***Direct wave first breaks recorded*** Uncheck if the shot-receiver spacing is 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.
- ***Update branch points with Plus-Minus*** Automatically update branch points in *Refractor|Shot breaks* display during Plus-Minus and Wavefront methods using Midpoint breaks mapping. See our tutorial https://rayfract.com/tutorials/Line3.pdf .
- ***Refractor Count*** How many refractors are being modeled. Enter 1 for a 2-layer case (weathering layer, and 1 refractor). Enter of 2 for a 3-layer case (weathering layer, and 2 refractors).
- ***CMP Stack Width*** How many adjacent CMP positions are considered when constructing the averaged CMP traveltime curve at the current CMP position. Increasing the stack width means more lateral smoothing.
- ***Regression Receiver Count*** 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.

- ***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.
- ***Refracted Wave Offset Delta*** Valid values : 3 to 20. Specifies the offset range considered when determining a local apparent CMP refractor velocity from a CMP traveltime curve, for a given CMP position and unsigned trace offset.
- ***Weathering layer velocity limit*** 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.
- ***Refractor 1 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.

Check option ***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 https://rayfract.com/tutorials/NORCAL14.pdf .

Check ***Update branch points with Plus-Minus*** to automatically update branch points in *Refractor|Shot breaks* display. With this option checked we update branch points in *Refractor|Shot breaks* display once you click button *Map Traces* and next select *Depth|Plus-Minus* or *Depth|Wavefront* layered refraction method in our ***Depth menu***. Next you can interactively improve these updated branch points in our *Refractor|Shot breaks* display.

This option ***Update branch points with Plus-Minus*** is reset/unchecked once it has been applied during Time-to-Depth conversion. Next you can interactively improve your updated branch points in our *Refractor|Shot breaks* display, remap traces to refractors with ALT+L and redo the Time-to-Depth conversion via our *Depth menu*. Backup your branch points with *File|Export header data|Export refractor branches to .BRN*. Restore branch points with *File|Update header data|Update refractor branches from .BRN… .* This works best with option *Mapping|Pick branch points between Receivers* unchecked. See our new 2023 tutorial https://rayfract.com/tutorials/Line3.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 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 orange or blue. Segments assigned to refractor 1 are displayed in red. Segments assigned to refractor 2 are displayed in green.

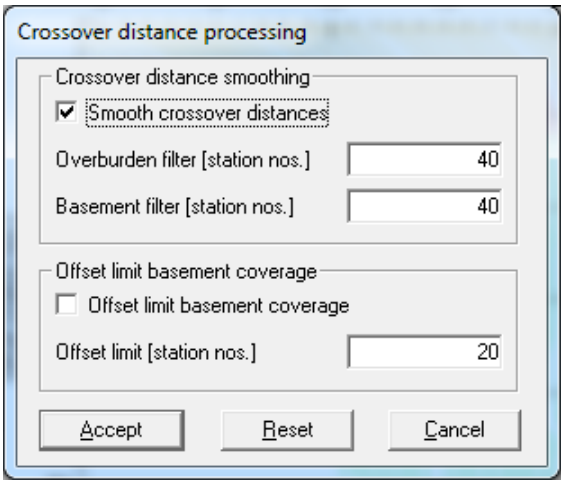
Optimal mapping of first breaks to refractors

An **optimal mapping of first breaks to refractors** has been obtained 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**.

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* :

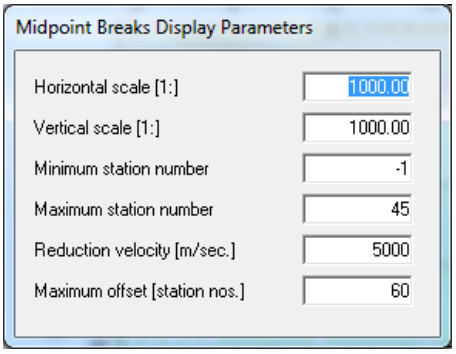


The ***Crossover distance processing*** dialog offers these parameters :

- ***Smooth crossover distances*** : Check to laterally smooth *crossover distances* with irregular colored region (refractor) boundaries in *Midpoint breaks traveltime field* . First breaks mapped to one region i.e. one refractor are displayed in the same color. These boundaries are defined by the laterally varying vertical offset (crossover distance) of the color change below *Common Mid Points* (CMP)'s of a profile. *CMP traveltime curve* segments with the same color should have a similar dip since they are mapped to the same refractor.
- ***Overburden filter*** : Filter width (in station numbers) for smoothing the laterally varying crossover distance separating first breaks mapped to the direct wave from first breaks mapped to the first refractor.
- ***Basement filter*** : Filter width (in station numbers) for smoothing the laterally varying crossover distance separating first breaks mapped to the first refractor from first breaks mapped to the second refractor. With a *Refractor Count* of 1 this parameter will override your *Overburden filter* setting.
- ***Offset limit basement coverage*** : Check 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.
- ***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 during time-to-depth conversion with *Offset limit basement coverage* checked.

Midpoint breaks display parameters dialog

Scale/zoom the *Refractor|Midpoint breaks* display via the *Display parameter dialog* shown with **ALT+P** :

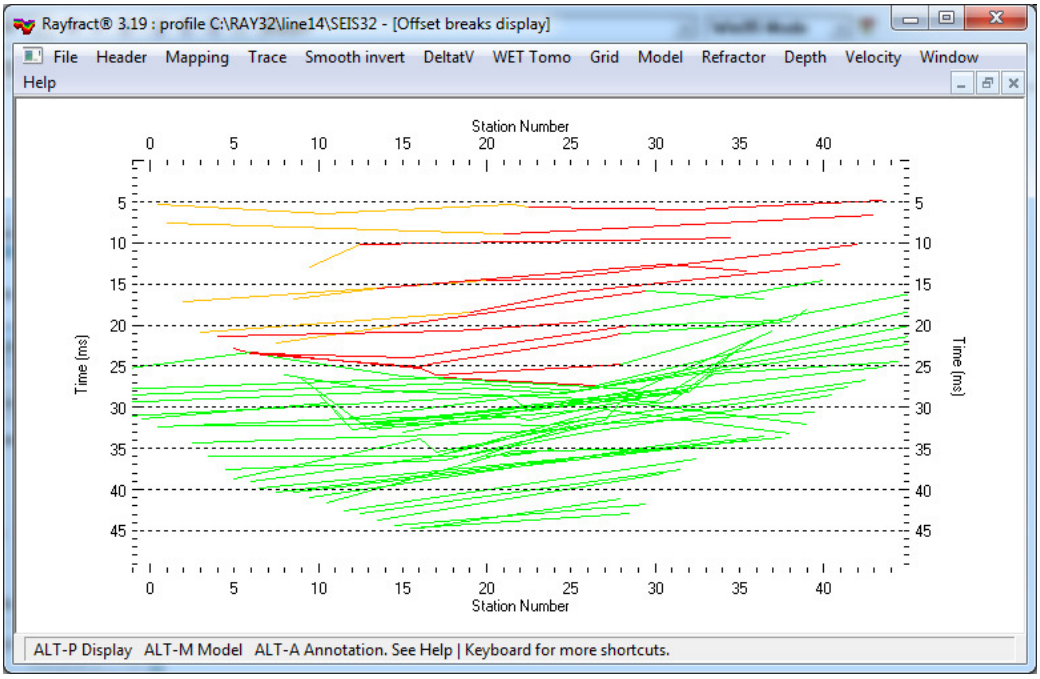


Edit field *Reduction velocity* lets you zoom the slope of CMP traveltime curves.

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 .

Common Offset time section

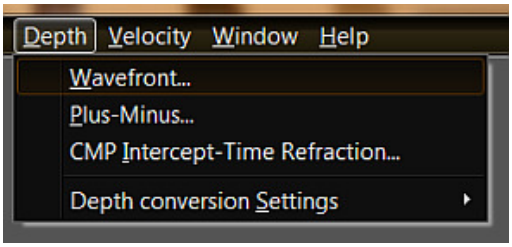
Display your traveltime field in a coordinate system with CMP station number as horizontal axis and recording time as vertical axis with *Refractor|Offset breaks* :



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. Our Common-offset dip estimation dialog (available with our Pro license only) lets you estimate and use the dip of common-offset sorted traveltime curves to improve DeltatV inversion output in case of steeply dipping refractors.

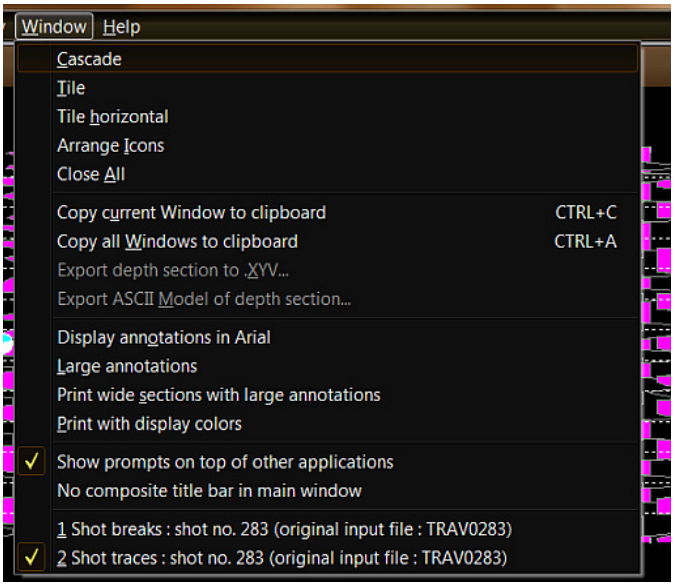
Time-to-depth conversion

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…* .

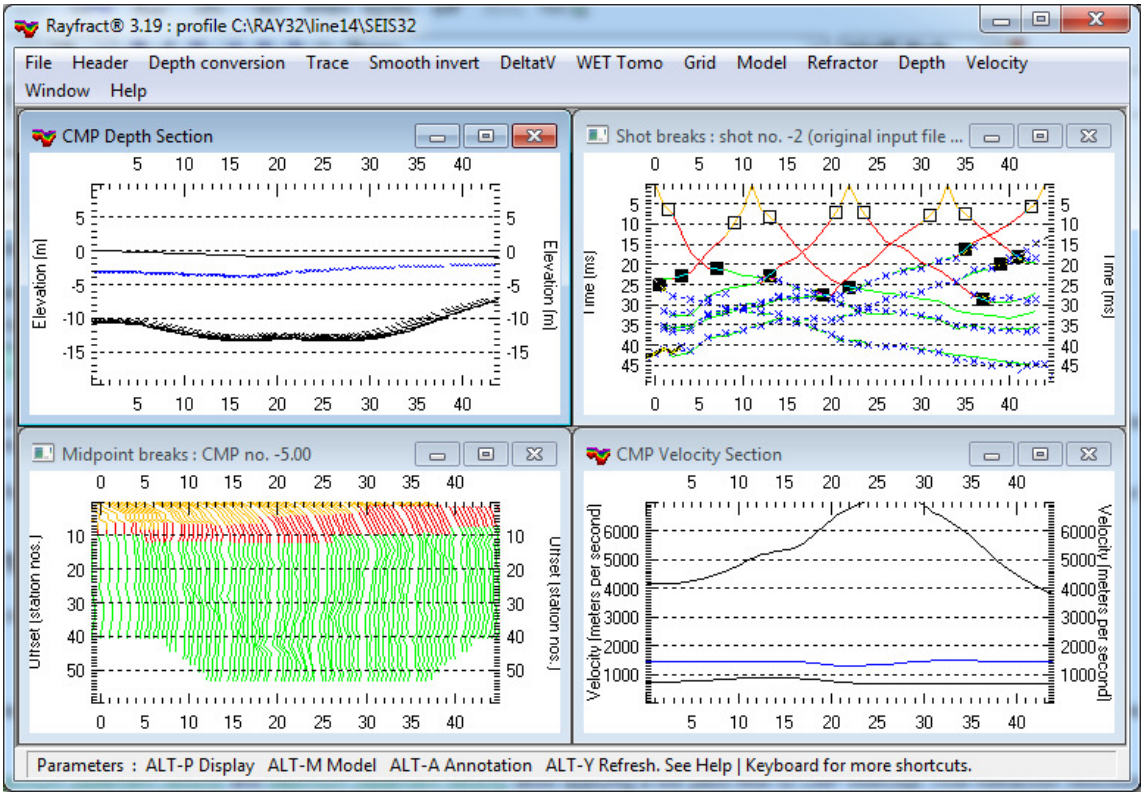


When displaying sections on screen, you may **lay out up to three sections adjusted vertically and displayed below each** other by selecting *Windows|Tile horizontally*. Be careful to specify the same profile section limits for all three sections. These limits may be specified in the *Display parameters 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.

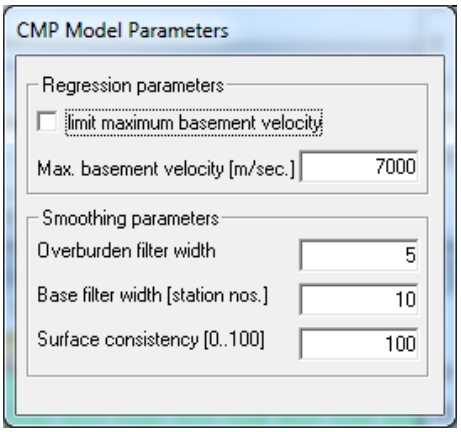
CMP Intercept Time Refraction processing

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*** :

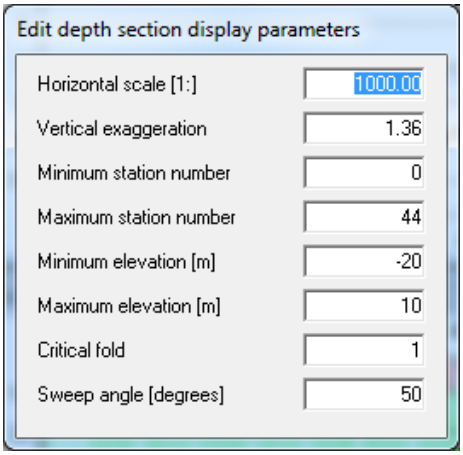


Parameters *limit maximum basement velocity* and *Maximum basement velocity* allow applying a low pass filter to CMP Intercept Time Refraction velocities estimated for the basement. When the estimated velocity at a station number exceeds the maximum velocity specified, no velocity and depth estimations are output for that station. Velocity and depth are

interpolated/extrapolated from neighboring stations with valid results, instead. This may help in situations of strong refractor curvature.

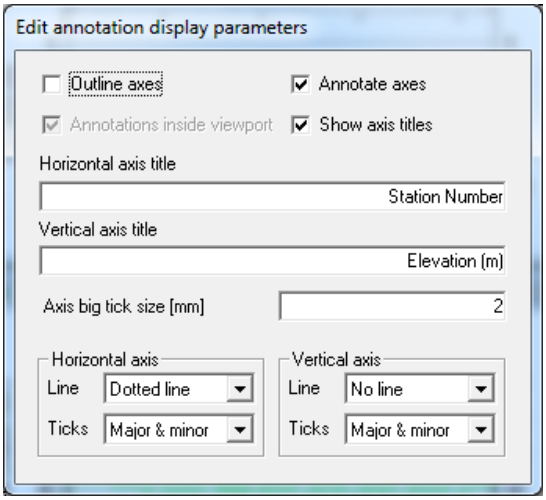
Parameters ***Overburden filter*** and ***Base filter width*** specify widths of smoothing filters (in station numbers; running average), for smoothing elevation and velocity of refractor 1 or 2, respectively. You may want to increase the default values (5, 10) to higher values, for difficult data and 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.

Click on the *CMP Depth section* and press **ALT+P** to show the ***Display parameters dialog*** :



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*** :

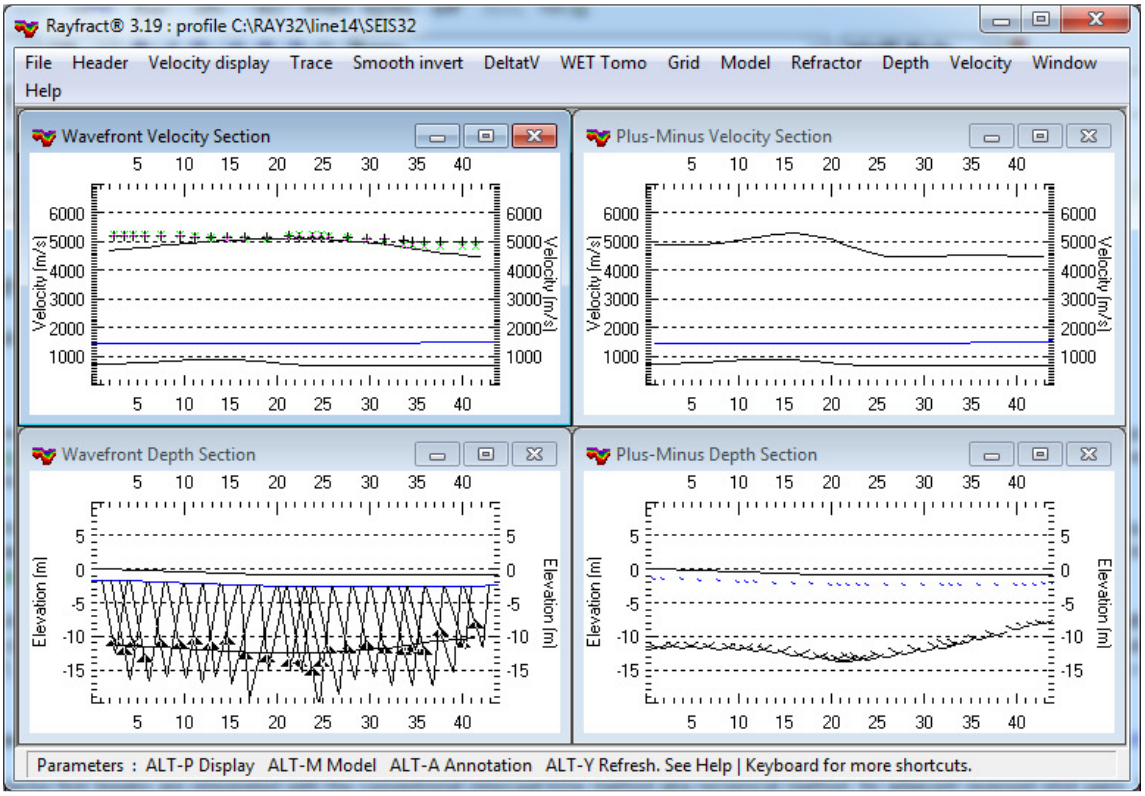


This lets you specify *horizontal axis title* and *vertical axis title* texts. Also, this dialog lets you specify if axes should be drawn with a solid pen via option *Outline axes*. Use options *Annotate axes*, *Show axis titles*, and *Axis big tick size* to further customize your section display.

Plus-Minus and Wavefront processing

Close all section windows with *Window|Close All*.

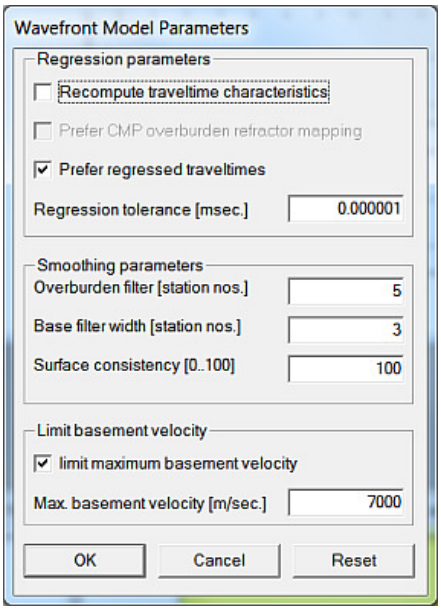
Select *Depth menu items Depth|Plus-Minus*, *Velocity|Plus-Minus*, *Depth|Wavefront* and *Velocity|Wavefront* :



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 applies for sample profile GEOXMERC, see

https://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.

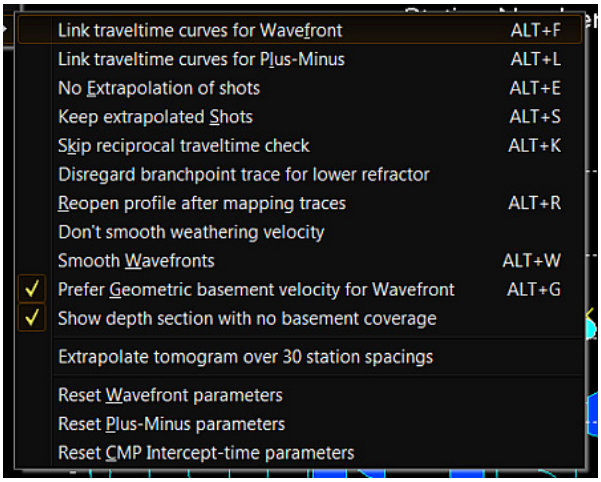


Two additional parameters for these methods are *check box Prefer regressed traveltimes*, and *edit field Relative regression tolerance*. In low-coverage situations, always toggle *Prefer regressed traveltimes*, and compare the two resulting depth sections. A **significant difference in refractor depth** 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.

Parameters ***Overburden filte*r** 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. For more robust basement refractor determination with our Wavefront method increase *Overburden filter* to 15 and decrease *Base filter width* to 5 or so station numbers.

Since version 4.03 we offer additional controls ***limit maximum basement velocity*** and ***Max. basement velocity [m/sec.]*** .

Configure depth section display with menu Depth|Depth Conversion Settings :



Wavefront and Plus-Minus inversion may abort with a **message saying "Refractor coverage may be too low or too short"**. Please 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 set 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, this reduction algorithm may not be able to reduce the data set.

For conventional **Wavefront method interpretation tutorials**, see https://rayfract.com/help/manual.pdf chapter 1.8 and following, and https://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 theoretically has a systematically 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 with 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 Wavefront and Plus-Minus iteratively minimizes 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

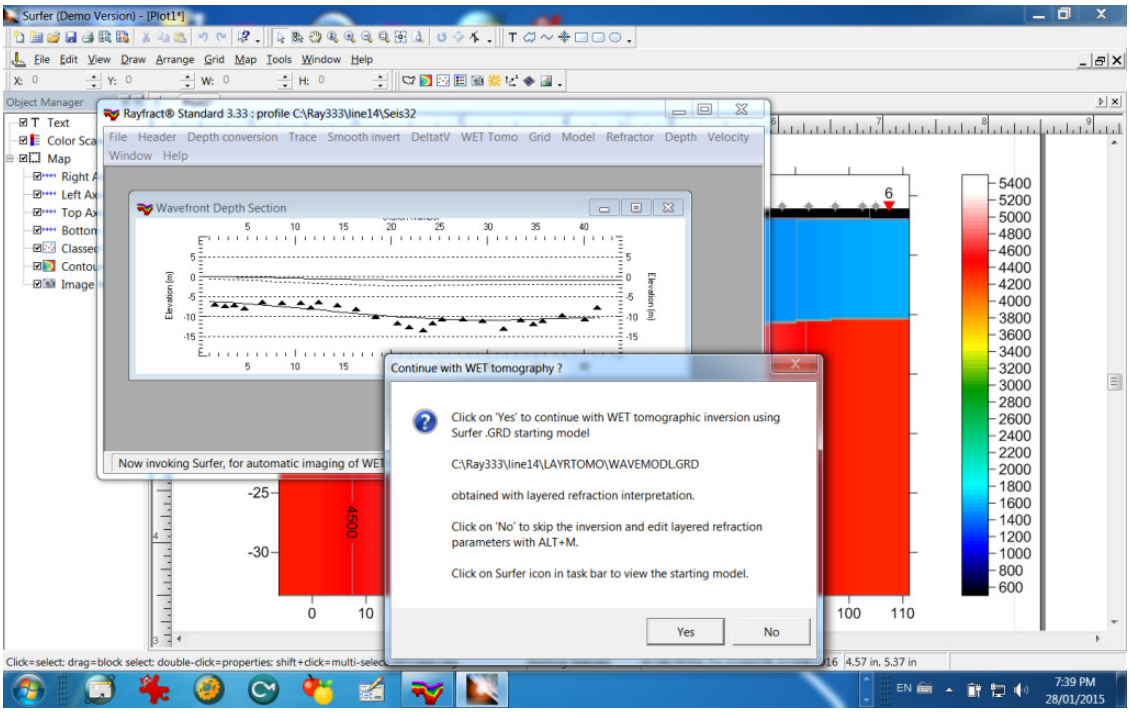
want to reduce the number of refractors being mapped from the default value 2 to the new value 1. See parameter *Refractor Count* in Mapping traces to refractors above. Above all, we strongly advise you to apply our **Smooth inversion method** (*Smooth inversion*|*WET with 1D initial model*) if coverage is high enough (at least about 5 to 10 shots per receiver spread, one shot at every 3rd receiver) in such difficult situations.

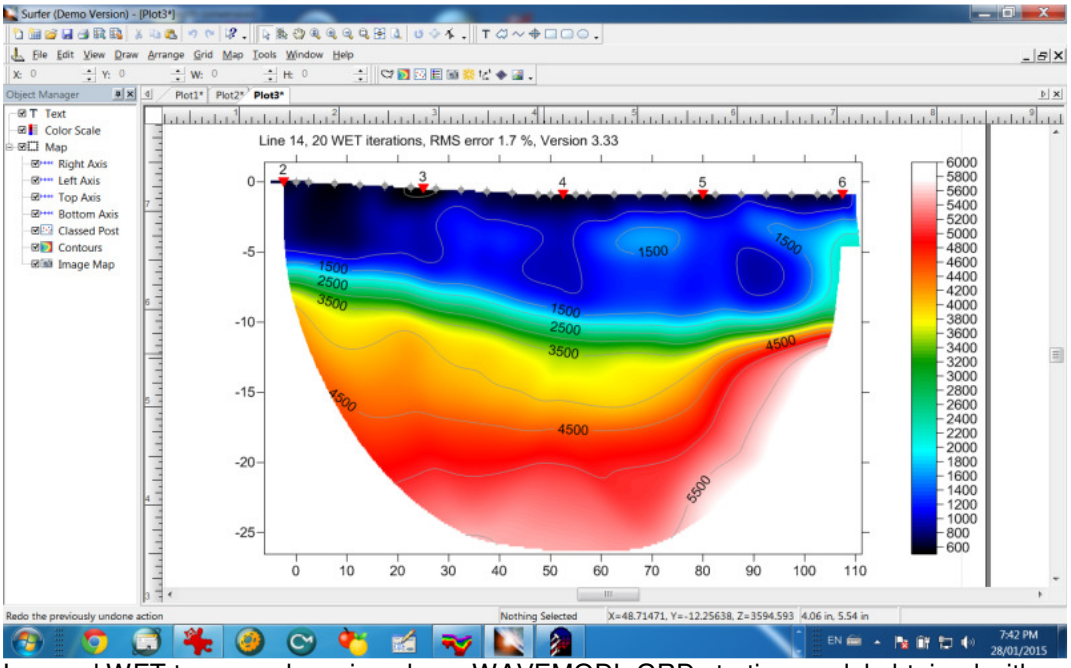
To get more robust traveltime field regression and better Wavefront method & Plus-Minus method output for tutorials https://rayfract.com/samples/GEOXMERC.pdf, https://rayfract.com/tutorials/ot0608.pdf, Val de Travers https://rayfract.com/tutorials/tra9002.pdf and most other profiles :

- backup your first break picks with *File*|*Export header data*|*Export First Breaks to .LST* to **BREAKS.LST**
- backup station coordinates with *File*|*Export header data*|*Export Station Coordinates* to **COORDS.COR**
- backup shot point coordinates with *File*|*Export header data*|*Export Shot Point Coordinates* to **SHOTPTS.SHO**
- check *File*|*Import data Settings*|*Round shot station to nearest whole station number*
- reimport your shots with *File*|*Import Data…*
- reapply **COORDS.COR** station coordinate file with *File*|*Update header data*|*Update station coordinates…*
- reapply **SHOTPTS.SHO** shot point coordinates file with *File*|*Update header data*|*Update Shotpoint coordinates...*
- update first breaks with *File*|*Update header data*|*Update First Breaks* and above **BREAKS.LST**
- uncheck *Mapping*|*Weigh CMP binned picks for mapping*
- remap traces to refractors in *Refractor*|*Midpoint breaks* with **ALT+M** mapping dialog
- check/uncheck *Depth*|*Depth conversion Settings*|*Prefer geometric basement velocity for Wavefront*
- select *Depth*|*Wavefront* to rerun Wavefront refraction method

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.

WET inversion with layered refraction starting model





Layered WET tomography using above WAVEMODL.GRD starting model obtained with *Depth*|*Wavefront* method

Since version 3.32 we allow **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. 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 in depth section window, 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 tutorials https://rayfract.com/tutorials/NORCAL14.pdf and https://rayfract.com/tutorials/P6.pdf .

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 NotePad. 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 e.g. using our .HDR batch file format.

Station coordinate files

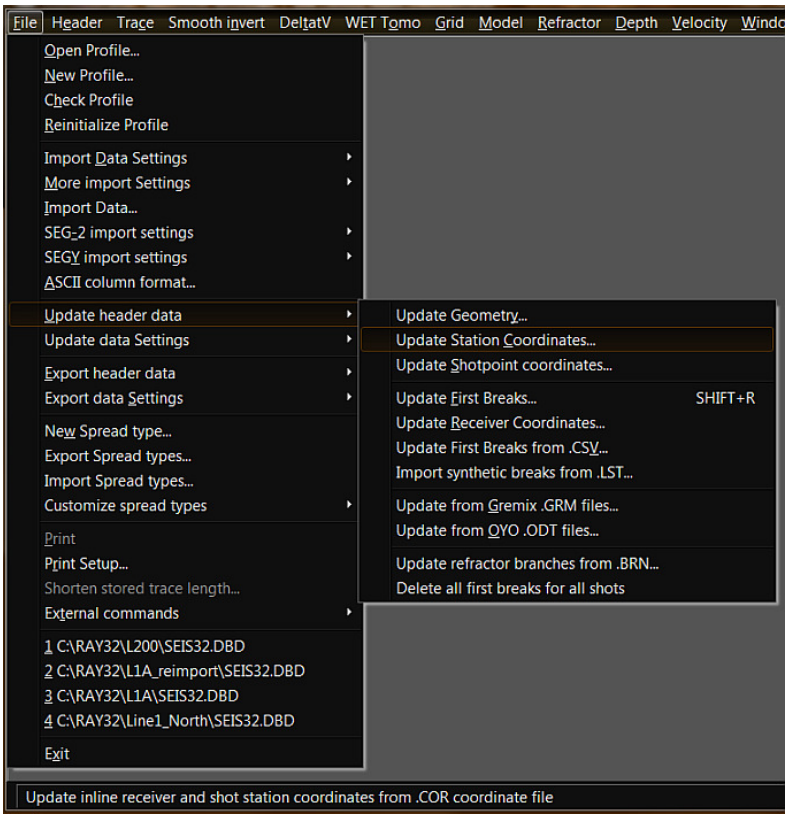
Station coordinate files have file extension .COR and are per default named COORDS.COR . They contain four columns of data :

Column 1	Column 2	Column 3	Column 4
Station number	x coordinate[m]	y coordinate[m]	z coordinate[m]

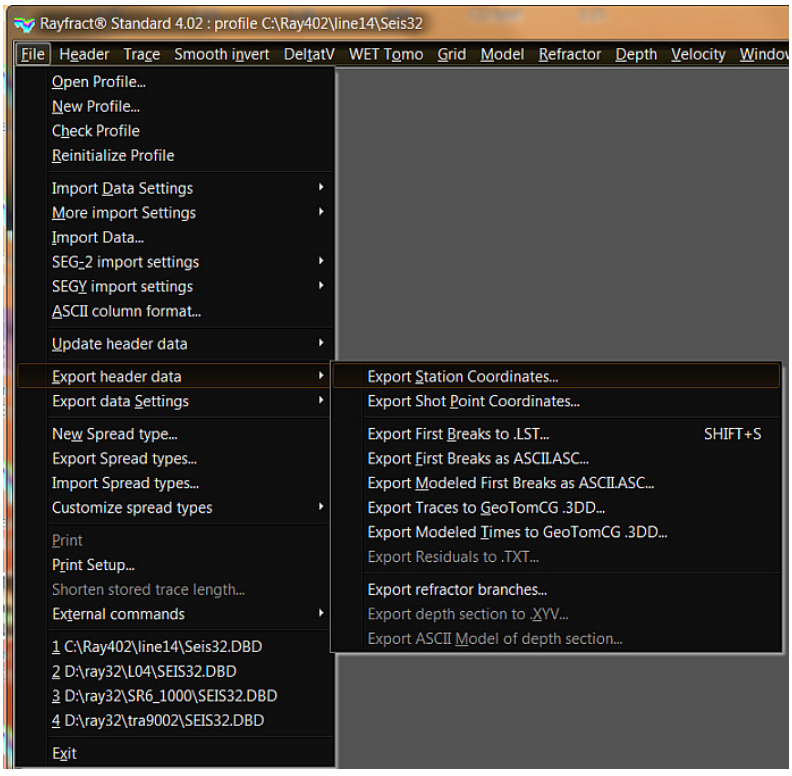
Column values are separated by semicolons ";". Here we show the first few lines of the sample COORDS.COR file in your \RAY32\DOC directory, as generated from sample profile \RAY32\LINE14 :

```
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 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 offset[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[ms] Correction[ms] 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.

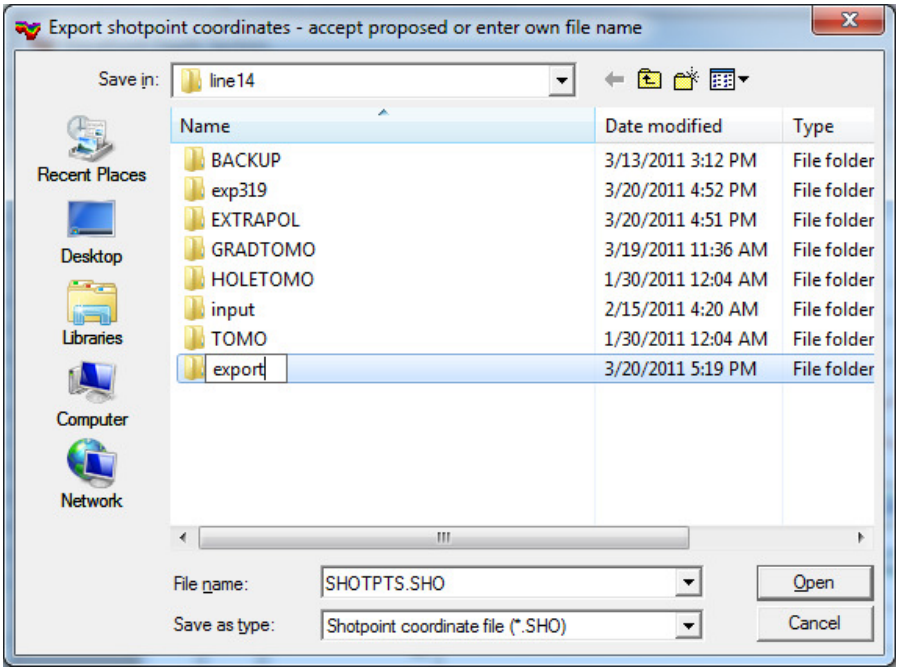
Column 7 of the SHOTPTS.SHO lists the ***uphole time correction term***. This correction term is used to identify uphole shots, with a value different from 0 e.g. 0.01 ms. The *Shot type* shown in *Header*|*Shot* is updated accordingly, during *File*|*Update header data*|*Update Shot Point Coordinates...* . Specify the ***absolute uphole time*** in 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.

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 in .SHO file (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 line 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 Notepad or WordPad text editor
- for refraction lines ensure for all shotNr values (column 1) that shotX, shotY and shotZ (columns 2 to 4) specify shot point coordinates at interpolated receiver elevation
- fix shotZ to shot point elevation at interpolated receiver line elevation 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 shot hole depth means source is located above the receiver line elevation. This can happen if the source is laterally offset from line or for marine refraction lines with sources above the hydrophone streamer or above the static receiver array planted on sea floor. See our tutorial https://rayfract.com/tutorials/SR6.pdf .
- for off-end shots (located beyond receiver spread) recorded for land seismic refraction surveys set shotX/shotY/shotZ to true source coordinates and set hole depth in column 5 to 0.0. See our tutorial https://rayfract.com/tutorials/NGU_G1.pdf .
- 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…* and during *File|Reinitialize 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 and receiver coordinates 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 12 columns of data :

Column 1 shot no.	Column 2 trace no.	Column 3 pos.[station]	Column 4 time[ms]	Column 5 synthetic[ms]
Colum 6 recvr_x[m]	Column 7 recvr_y[m]	Column 8 recvr_z[m]	Column 9 shot pos.[station]	Column 10 shot_offset_cor[ms]
Column 11 residual[ms]	Column 12 abs(residual)[ms]			

Column values are separated by space or tab characters.

When updating trace headers with *File|Update header data|Update First Breaks* we regard the first four data columns in the .LST only. Columns 5 to 12 are optional with this update command.

Your BREAKS.LST must specify first breaks for all traces of all shots in column no. 4. Specify a time[ms] of -1 to signal "trace not picked".

Here we show the first few lines of the BREAKS.LST file generated for your \RAY32\LINE14 sample profile with *File|Export header data|Export First Breaks to .LST...* :

First breaks stored in profile database C:\RAY32\line14\Seis32

shot/channel/pos./time/synthetic/recvr_x/recvr_y/recvr_z/shot pos.[station]/shot_offset_cor[ms]/residual/abs(residual)

1	0	-11.00	0.000	-1.000	-29.9955	0.0000	0.5000	-11.00	0.000	-1.000	-1.000
1	1	1.00	26.250	-1.000	0.0000	0.0000	0.0000	-11.00	26.250	-1.000	-1.000
1	2	2.00	28.000	-1.000	2.5000	0.0000	0.0000	-11.00	28.000	-1.000	-1.000
1	3	4.00	28.625	-1.000	7.4990	0.0000	-0.1000	-11.00	28.625	-1.000	-1.000
1	4	6.00	29.500	-1.000	12.4980	0.0000	-0.2000	-11.00	29.500	-1.000	-1.000
1	5	8.00	31.000	-1.000	17.4970	0.0000	-0.3000	-11.00	31.000	-1.000	-1.000
1	6	10.00	31.375	-1.000	22.4960	0.0000	-0.4000	-11.00	31.375	-1.000	-1.000
1	7	12.00	32.375	-1.000	27.4940	0.0000	-0.5000	-11.00	32.375	-1.000	-1.000
1	8	14.00	32.250	-1.000	32.4930	0.0000	-0.6000	-11.00	32.250	-1.000	-1.000
1	9	16.00	34.250	-1.000	37.4920	0.0000	-0.7000	-11.00	34.250	-1.000	-1.000
1	10	18.00	35.875	-1.000	42.4910	0.0000	-0.8000	-11.00	35.875	-1.000	-1.000
1	11	20.00	37.500	-1.000	47.4900	0.0000	-0.9000	-11.00	37.500	-1.000	-1.000
1	12	21.00	38.750	-1.000	49.9900	0.0000	-0.9000	-11.00	38.750	-1.000	-1.000
1	13	23.00	39.000	-1.000	54.9900	0.0000	-0.9000	-11.00	39.000	-1.000	-1.000
1	14	24.00	39.875	-1.000	57.4900	0.0000	-0.9000	-11.00	39.875	-1.000	-1.000
1	15	26.00	40.250	-1.000	62.4900	0.0000	-0.9000	-11.00	40.250	-1.000	-1.000
1	16	28.00	40.250	-1.000	67.4900	0.0000	-0.9000	-11.00	40.250	-1.000	-1.000
1	17	30.00	41.000	-1.000	72.4900	0.0000	-0.9000	-11.00	41.000	-1.000	-1.000
1	18	32.00	41.625	-1.000	77.4900	0.0000	-0.9000	-11.00	41.625	-1.000	-1.000
1	19	34.00	42.625	-1.000	82.4900	0.0000	-0.9000	-11.00	42.625	-1.000	-1.000
1	20	36.00	42.875	-1.000	87.4900	0.0000	-0.9000	-11.00	42.875	-1.000	-1.000

1	21	38.00	43.750	-1.000	92.4900	0.0000	-0.9000	-11.00	43.750	-1.000	-1.000
1	22	40.00	44.375	-1.000	97.4900	0.0000	-0.9000	-11.00	44.375	-1.000	-1.000
1	23	42.00	44.750	-1.000	102.4900	0.0000	-0.9000	-11.00	44.750	-1.000	-1.000
1	24	43.00	44.625	-1.000	104.9900	0.0000	-0.9000	-11.00	44.625	-1.000	-1.000
2	0	0.00	0.000	-1.000	-2.5000	0.0000	0.0000	0.00	0.000	-1.000	-1.000
2	1	1.00	5.375	4.409	0.0000	0.0000	0.0000	0.00	5.375	0.966	0.966
2	2	2.00	7.625	8.265	2.5000	0.0000	0.0000	0.00	7.625	-0.640	0.640
2	3	4.00	17.125	16.970	7.4990	0.0000	-0.1000	0.00	17.125	0.155	0.155
2	4	6.00	20.875	20.477	12.4980	0.0000	-0.2000	0.00	20.875	0.398	0.398
2	5	8.00	21.375	20.848	17.4970	0.0000	-0.3000	0.00	21.375	0.527	0.527
2	6	10.00	22.750	22.160	22.4960	0.0000	-0.4000	0.00	22.750	0.590	0.590
2	7	12.00	23.250	23.347	27.4940	0.0000	-0.5000	0.00	23.250	-0.097	0.097
2	8	14.00	23.750	23.660	32.4930	0.0000	-0.6000	0.00	23.750	0.090	0.090
2	9	16.00	26.000	25.513	37.4920	0.0000	-0.7000	0.00	26.000	0.487	0.487
2	10	18.00	26.500	27.153	42.4910	0.0000	-0.8000	0.00	26.500	-0.653	0.653
2	11	20.00	28.500	29.508	47.4900	0.0000	-0.9000	0.00	28.500	-1.008	1.008
2	12	21.00	29.500	30.464	49.9900	0.0000	-0.9000	0.00	29.500	-0.964	0.964
2	13	23.00	31.375	31.827	54.9900	0.0000	-0.9000	0.00	31.375	-0.452	0.452
2	14	24.00	32.125	31.983	57.4900	0.0000	-0.9000	0.00	32.125	0.142	0.142
2	15	26.00	32.125	32.049	62.4900	0.0000	-0.9000	0.00	32.125	0.076	0.076
2	16	28.00	31.875	32.048	67.4900	0.0000	-0.9000	0.00	31.875	-0.173	0.173
2	17	30.00	33.000	33.038	72.4900	0.0000	-0.9000	0.00	33.000	-0.038	0.038
2	18	32.00	33.875	34.599	77.4900	0.0000	-0.9000	0.00	33.875	-0.724	0.724
2	19	34.00	35.875	35.962	82.4900	0.0000	-0.9000	0.00	35.875	-0.087	0.087
2	20	36.00	35.375	35.725	87.4900	0.0000	-0.9000	0.00	35.375	-0.350	0.350
2	21	38.00	36.375	35.946	92.4900	0.0000	-0.9000	0.00	36.375	0.429	0.429
2	22	40.00	36.000	35.938	97.4900	0.0000	-0.9000	0.00	36.000	0.062	0.062
2	23	42.00	36.000	35.434	102.4900	0.0000	-0.9000	0.00	36.000	0.566	0.566
2	24	43.00	35.250	35.303	104.9900	0.0000	-0.9000	0.00	35.250	-0.053	0.053
3	1	1.00	23.500	23.012	0.0000	0.0000	0.0000	11.00	23.500	0.488	0.488
3	2	2.00	23.500	23.348	2.5000	0.0000	0.0000	11.00	23.500	0.152	0.152
3	3	4.00	22.125	22.202	7.4990	0.0000	-0.1000	11.00	22.125	-0.077	0.077
3	4	6.00	16.875	17.368	12.4980	0.0000	-0.2000	11.00	16.875	-0.493	0.493
3	5	8.00	12.875	12.936	17.4970	0.0000	-0.3000	11.00	12.875	-0.061	0.061

- *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
- receiver station x coordinate or receiver x coordinate is listed in column 6, in m. Toggle with *File|Export data Settings|Export receiver coordinates to .3DD and .LST*
- receiver station y coordinate or receiver y coordinate is listed in column 7, in m. Toggle with *File|Export data Settings|Export receiver coordinates to .3DD and .LST*
- receiver station z coordinate or receiver z coordinate is listed in column 8, in m. Toggle with *File|Export data Settings|Export receiver coordinates to .3DD and .LST*
- *shot position* [station no.] is listed in column 9
- picked first break time corrected for offset of shot point from *shot station* is listed in column 10, in ms
- traveltime residual : column 4 minus column 5 is listed in column 11, in ms
- absolute residual : abs(column 11) is listed in column 12, 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.

To update individual receiver coordinates for each trace and channel select *File|Update header data|Update Receiver Coordinates...* and your exported and/or edited BREAKS.LST file. Receiver station coordinates are re-centered to average of coordinates for all receivers linked to that station. See Header|Receiver dialog. This linking of receivers to receiver stations is done during import of shots with File|Import Data... .

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	receiver station	first break (s)	receiver elevation	shot elevation

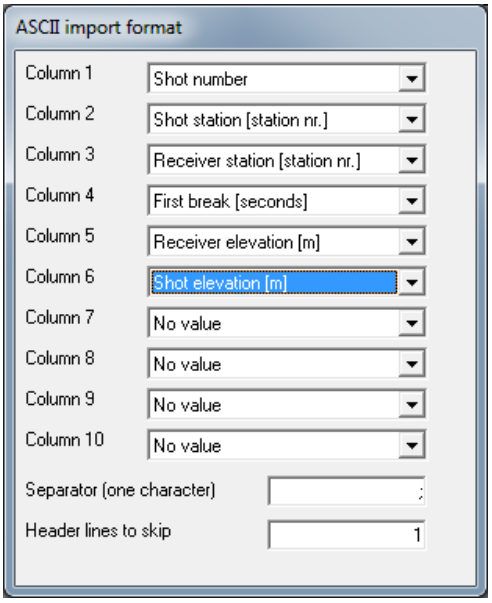
Column values are separated by semicolon ';' characters. Above columns 5 and 6 are optional. Specify the column order and contents of ASCII.ASC with *File|ASCII column format... dialog*.

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;1.00;0.026250
1;-11.00;2.00;0.028000
1;-11.00;4.00;0.028625
1;-11.00;6.00;0.029500
1;-11.00;8.00;0.031000
1;-11.00;10.00;0.031375
1;-11.00;12.00;0.032375
1;-11.00;14.00;0.032250
1;-11.00;16.00;0.034250
1;-11.00;18.00;0.035875
1;-11.00;20.00;0.037500
1;-11.00;21.00;0.038750
1;-11.00;23.00;0.039000
1;-11.00;24.00;0.039875
1;-11.00;26.00;0.040250
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
```

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
Station 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
```

`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).

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 Notepad or 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.

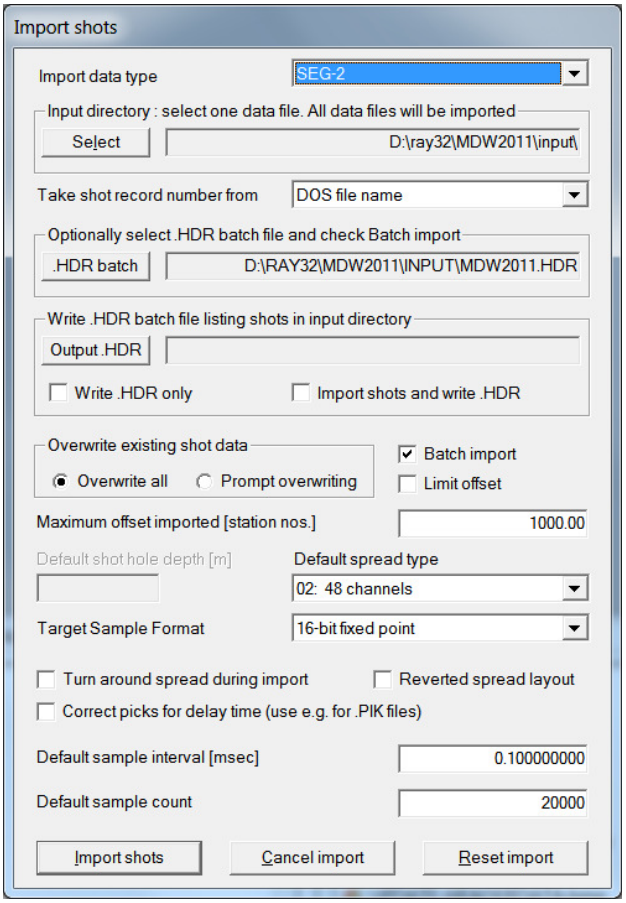
.HDR files contain 11 columns of data. See e.g. https://rayfract.com/help/2lamb15.hdr, as shown below :

```
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 source below topography, at `Shot Pos. plus Inline Offset`
- `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.

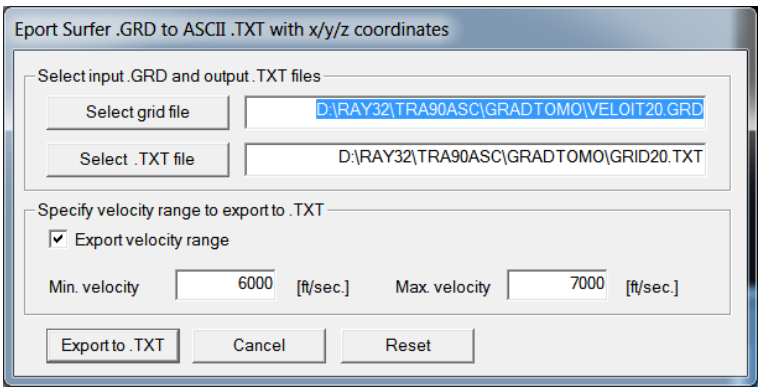
C:\RAY32\LINE14\INPUT\BATCH.HDR

- 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\BATCH.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

See tutorials https://rayfract.com/tutorials/P6.pdf and https://rayfract.com/tutorials/Line3.pdf showing creation and usage of BATCH.HDR batch file.

Convert Surfer .GRD 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 :



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

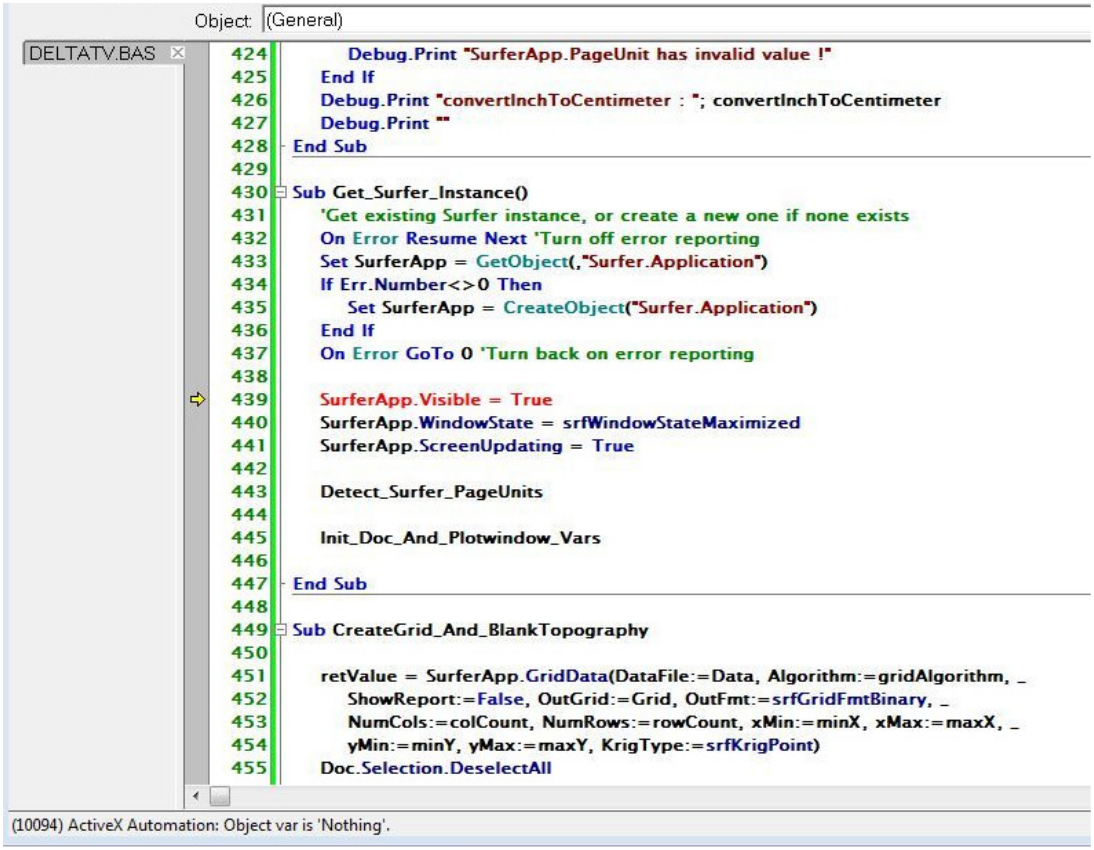
See (Oyan 2019) Use of seismic refraction in determining rock mass anisotropy. https://egrove.olemiss.edu/cgi/viewcontent.cgi?article=2775&context=etd on page 78 for detailed instructions on how to import Surfer .GRD tomogram files into Golden Software Voxler.

To keep the size of the resulting **.TXT** small you can **down-sample the Surfer .GRD before exporting to ASCII** as shown 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 to 26 through their Scripter utility. Here are a few steps to try if Scripter can't call Surfer when running our **DELTATV.BAS** or **AUTOTOMO.BAS** scripts showing error message **"(10094) ActiveX Automation: Object var is 'Nothing'" or similar :**

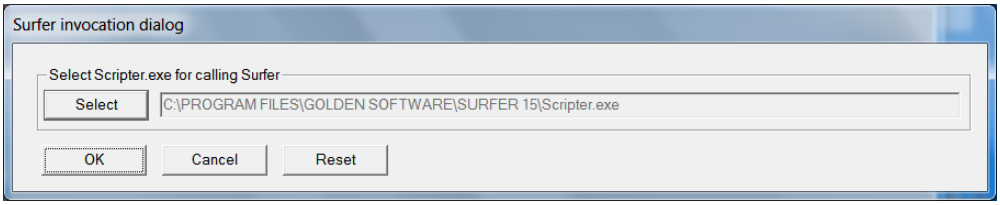


- **in Windows Control Panel, Programs and Features double-click Surfer, check "Repair" option and click "Next".**
- **try to run our scripts again e.g. via our *Smooth invert*/*WET with 1D-gradient initial model***
- when you install multiple versions of Golden Software Surfer® on the same Windows PC then this may corrupt the previously installed Surfer version. To fix the previous installation select *Windows Control Panel, Programs and Features.* Double-click Surfer ad check *Repair radio button* and *Next button*.

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 by e.g. running `Surfer15_Demo_Installer.exe` or `s11demo.exe` installer as Admin : right-click installer in Windows Explorer and select "Run as administrator"**
- **reboot your PC**

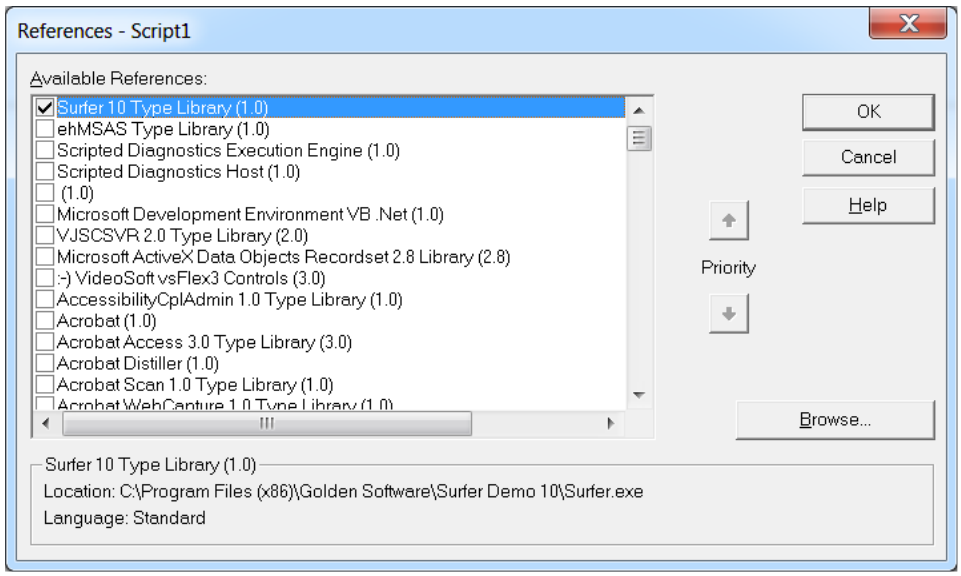
- **first open Surfer(R) by right-clicking desktop icon and selecting "Run as administrator"**
- **now open Rayfract(R) by right-clicking desktop icon and selecting "Run as administrator"**
- **try to run our scripts again e.g. via our *Smooth invert*|*WET with 1D-gradient initial model***
- **if required select the correct Scripter version in *Grid*|*Surfer invocation dialog*** :



For Surfer 15 and later **`Scripter.exe`** is located in Surfer main directory. For all earlier Surfer versions **`Scripter.exe`** is located in Scripter subdirectory of Surfer main directory.

See also Golden Software Surfer FAQ at https://support.goldensoftware.com/hc/en-us/articles/360006089653-Surfer-Automation-Errors . To prevent these errors **don't install multiple versions of Surfer on the same Windows PC**.

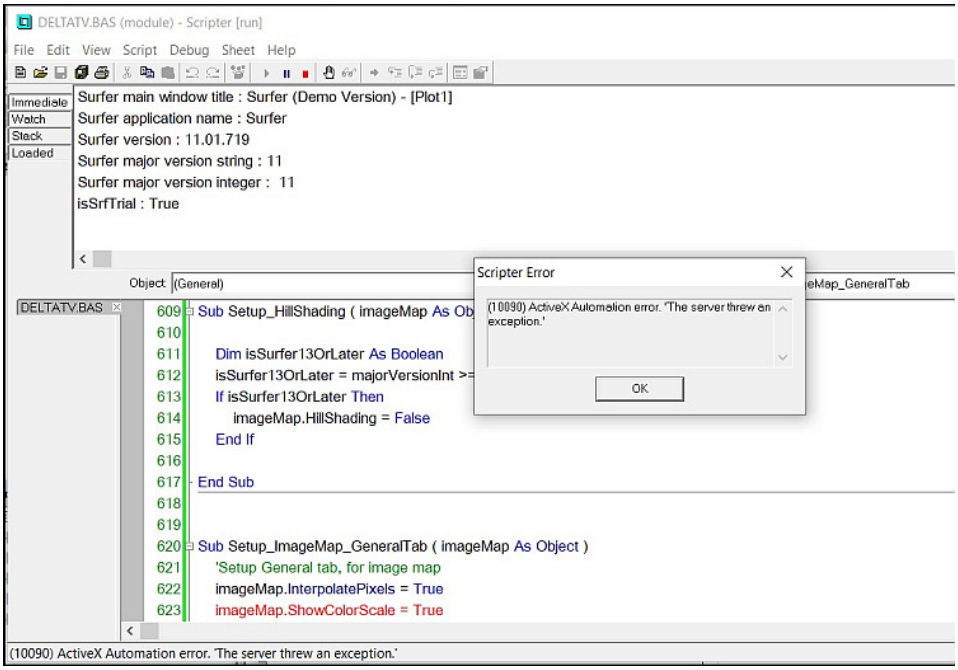
If all of the above does not help also try **adding Surfer directly as a reference in Scripter** :



- 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 and 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
- **or try to update your .BAS scripts in C:\RAY32\DAT with https://rayfract.com/common/BasConvrt.exe utility**
- **run BasConvrt.exe and set "Destination Location" to C:\RAY32 to convert your .BAS scripts to latest Surfer 15 Basic language version**
- **.BAS scripts updated with BasConvrt.exe will continue to work with earlier Surfer and Scripter versions**
- **if after repairing Surfer 11 in Control Panel AUTOTOMO.BAS crashes at statement "imageMap.ShowColorScale = True" : uninstall Surfer 15 or higher**



Try these steps as a last resort and after consulting with your Systems Admininstrator :

- **backup your Windows Registry. See https://support.microsoft.com/en-us/help/322756/how-to-back-up-and-restore-the-registry-in-windows .**
- **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, 16, 17, 18, 20, 21, 22, 23, 24, 25, 26)

- **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 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

Old versions of WibuKey runtime installer

Since Oct 2021 we host **old versions of the WibuKey runtime installer** on our website. Use link

https://rayfract.com/WibuKey_6.51/WkRuntime.exe

to download WibuKey 6.51 runtime installer for Windows 7 to 11 64-bit Pro. Use link

https://rayfract.com/WibuKey_5.20b/WkRuntime.exe

to download WibuKey 5.20b runtime installer for 32-bit Windows XP. This works with Rayfract(R) version 3.15 and earlier.

Using LPT parallel port WIBU key dongle

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. Close WIBU-KEY applet. Don't skip this essential step.
- uninstall WIBU-KEY driver with Control Panel/Add/Remove Software/WIBU-KEY Setup Remove
- now reboot your PC
- reinstall the WIBU-KEY driver with latest WkRuntime.EXE downloaded from wibu.com at download page http://www.wibu.com/downloads-user-software.html
- reinsert the USB key
- note bubble "Found New Hardware" or "Installing driver software" at bottom-right corner of screen
- 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 WibuKey dongle driver will not be installed correctly and our software cannot recognize the green USB dongle.

See also https://rayfract.com/help/Uninstall%20&%20reinstall%20WibuKey%206.40.pdf

If you see error prompt Code Integrity check failed -> Application is terminated! e.g. with transparent green WibuKey USB dongle under Windows 10/11 64-bit with USB 3.0 port :

- add exclusion in Windows Defender for file C:\RAY32\BIN\RAYFRACT32.EXE
- add exclusion in Windows Defender for folder C:\RAY32
- see also chapter Installation and licensing

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 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 latest WkRuntime.EXE obtained from wibu.com 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 https://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"
- then 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.

Contact WIBU U.S. for support

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 WIBU U.S. Their numbers are :

+1.800.6.Go.Wibu or +1.800.646.9428 or +1.425.775.6900

A contact form is available at https://www.wibu.com/us/contact.html .

You may go to https://www.wibu.com. You will find current drivers, answers to FAQ's (frequently asked questions), documentation .pdf etc. on that site. Current drivers are available with installers for Windows OS, macOSX and Linux.

Processing and interpretation controls

.3DD shot traces sorted by receiver offset

Check this option in menu File|More import Settings 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. ***Our .3DD import assumes that traces in .3DD input files are sorted by common shot number as primary key since the .3DD format does not contain a column with the shot number***. During .3DD import shots are numbered sequentially starting at one. With this option checked our .3DD import assumes ***additionally*** that all traces for same shot (listed sequentially in the .3DD) are sorted by receiver offset along line : x coordinate for *Line type* refraction spread/line and *horizontal borehole surveys* or z coordinate for vertical borehole spread/line or receiver inline offset for *circular borehole surveys* .

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 quasi-vertical 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. Shown 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.

Acquisition time

Time of recording of seismic data. Shown 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.

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 Receiver station coordinates

Re-center each receiver station at end of import to average of coordinates for all receivers linked to this station. Helps with importing of irregularly spaced streamer data in formats SEG-2, SEGY, Geogiga DWTOMO .TTX, PlotRefa .VS and GeoTomCG .3DD. This linking of receivers to receiver stations is done during import of shots with ***File|Import Data…*** . See ***Header|Receiver*** dialog in chapter Editing header data and our marine streamer tutorial https://rayfract.com/tutorials/SR6.pdf .

Adjust X coordinate to fit Y and elevation

Select this radio button in ***File|Update header data|Update Station Coordinates*** 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 in ***File|Update header data|Update Station Coordinates*** 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

Check this box in WET starting model dialog shown when you click *Select button* in WET Tomo|Interactive WET dialog to allow grid columns with no velocity values between the first and last grid columns with velocity values. This may be necessary e.g. when your refraction profile crosses a river or a road. We recommend to leave this option at its default setting i.e. disabled.

Allow missing traces for SEG-2, SEGY, SeisImager .VS, SeisOpt, Gremix, .3DD and .TTX

Check this option in menu ***File|Import Data Settings*** to enable import of ***File|Import***

Data|Import data type SEG-2, SEGY, Geometrics SeisImager .VS, Optim SeisOpt, Interpex Gremix .GRM, GeoTomCG .3DD and Geogiga DWTomo .TTX files ***with missing unpicked or dead traces e.g. when crossing a street***. Also check import option *Use bent line inline offset for shot pos. and layout start* if appropriate. If there are traces missing from such input files, we insert blank/dead traces during import for the active part of the *Default spread type* specified. This option is checked/enabled per default, when creating a new profile database. When importing SEG-2 .DAT or .SG2 files with this option checked and with SEG-2 import setting *Receiver Coordinates specified in .SG2 or .DAT* checked we determine the channel number of the *Default spread type* from SEG-2 trace header fields RECEIVER_STATION_NUMBER or RECEIVER_LOCATION. If these SEG-2 fields have bad values you may see an error prompt during import. Try checking *File|SEG-2 import settings|Ignore SEG-2 station numbers*. Or try unchecking this *Allow missing traces* option, and retry import with correct *Default spread type*. When importing SEGY .SGY files check or uncheck option *File|SEGY import settings|No receiver coordinates specified* before opening the File|Import Data... dialog. For ***File|Import Data|Import data type*** ASCII.ASC, BISON-2 9000, Terraloc Mk III we do NOT regard this import setting.

Allow shot inline offset from shot station larger than two spacings

Allow inline offset of shot point from shot station exceeding two station spacings. This invalidates DeltatV method interpretation.

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.

Alternate coverage update during Conjugate Gradient inversion

Check this WET setting for alternate blanking at tomogram bottom during *Conjugate Gradient* WET inversion.

Angle increment between scan lines

Edit this field in *Model|WDVS Smoothing* dialog to determine the angular separation between straight scan lines radiating outwards from the current grid node when determining the WDVS averaged velocity at that node. Increase this parameter to speed up WDVS. Specify in degrees : 1 to 10 degrees. Default is 7 degrees.

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. Press ALT+A in depth section or velocity section to show this dialog.

Annotations inside view port

Check this option in *Annotations parameters* dialog to display annotations such as axis calibration and axis title inside the coordinate system. This option has been disabled since a few versions and is always checked.

Anomaly magnitude

This field in *Model|Create Checkerboard grid* lets you edit the magnitude of the checker anomaly in percent of the background velocity in the input grid .GRD file. See our tutorial https://rayfract.com/tutorials/TRA9002_resolution_test.pdf .

Anomaly length

This field in *Model|Create Checkerboard grid* lets you edit the length of the checker anomaly in meters or feet.

Anomaly height

This field in *Model|Create Checkerboard grid* lets you edit the height of the checker anomaly in meters or feet.

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.

Assume regular/equidistant receiver spacing

Uncheck ***File|Import Data Settings|Assume regular/equidistant receiver spacing*** to better support import of irregularly spaced receivers e.g. with GeoTomCG .3DD import into *Line type* **`Borehole spread/line`**. Uncheck to minimize the offset between receiver coordinates and

receiver stations as shown in *Header|Receiver*. Check if all receiver spacings are multiples of *Header|Profile|Station spacing*. This option is unchecked per default. Check to restore import behavior as with versions older than 4.01.

Assumed velocity

Edit this field in Trace|Shot gather|Processing|Edit trigger jitter removal dialog to specify the assumed weathering or overburden velocity directly below shot points. This velocity is used to compute the hypothetical delay of the direct wave between shot point and adjacent trace in ms, regarding the actual source-receiver offset. Next the trigger jitter is determined by subtracting the actual delay (first break pick time) at the same adjacent trace from this hypothetical delay. Finally the shot's current *trigger delay* is increased by this trigger jitter.

regard two closest receivers at source

Check this box in Trace|Shot gather|Processing|Edit trigger jitter removal dialog to average the trigger jitter determined from *Assumed velocity* over two closest traces to shot point. Alternatively check radio button *regard closest receiver at source* or *regard receivers within maximum offset*.

Automatically adapt shape of rectangular filter matrix

Check this item in *WET Tomo|Interactive WET tomography|Edit velocity smoothing* 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.

Average higher with lower estimate for true refractor velocity

Check this box in *DeltatV|Common-offset dip estimation* dialog to activate averaging of higher with lower estimate for true refractor velocity based on apparent CMP velocity and offset dip during pseudo-2D DeltatV inversion (Gebrande and Miller 1985; Gebrande 1986). There exist two possible solutions to the quadratic equation for true refractor velocity. These two solutions and estimates are computed using the standard **Quadratic formula method** see https://www.wikihow.com/Solve-Quadratic-Equations . Uncheck this box to regard the higher estimate for true refractor velocity only.

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.

Backup times

Click this button in *Trace*|*Shot gather*|*Processing*|*Edit trigger jitter removal* dialog to backup station coordinates, shot point coordinates including time terms delay time and trigger delay, and first breaks to files COORDS.COR, SHOTPTS.SHO and BREAKS.LST in Backup subdirectory of currently opened profile. To undo your later trigger jitter correction(s) : first select *File*|*Update header data*|*Update Shotpoint coordinates* and file SHOTPTS.SHO in Backup directory. Next select *File*|*Update header data*|*Update First Breaks* and file BREAKS.LST in Backup directory.

Band-pass filter

Check this box in *Trace*|*Shot gather*|*Processing*|*Bandpass filter* dialog to apply a band-pass frequency filter to traces before displaying them. Uncheck for band-reject filter. See Steven W. Smith, Digital Signal Processing.

Base filter width

This parameter in *Model parameters dialog* opened with ALT+P in *Depth*|*Plus-Minus* and *Depth*|*Wavefront* displays 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 in File|Import Data dialog 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 needing to confirm shot data in the *Import shot dialog*. See chapter File formats.

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.

Blank initial model

Check this box in WET Tomo|WET velocity constraints dialog to blank the initial model selected in WET Tomo|Interactive WET tomography during WET inversion with the .BLN file

selected in WET velocity constraints dialog. Alternatively blank the initial model with *Grid|Blank polygon area in grid*

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 blanking menu 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 outside polygon

Check this box in *WET Tomo|WET velocity constraints* dialog 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.

Blank polygon area in grid

Blank velocity or reset to constant the velocity in VELOITXY.GRD in polygon area specified in Surfer .BLN *blanking file*. For negative shot hole depth used with marine surveys you can generate a water-layer blanking file with *Grid|Generate blanking file between sources and receivers*.

Blanking file

Surfer format .BLN blanking file selected with button *Select blanking file* in *WET Tomo|WET velocity constraints* or with *Grid|Blank polygon area in grid*. This .BLN 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 NotePad 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 NotePad to blank outside the polygon.

Or select *Grid|Generate blanking file between sources and receivers* with marine refraction survey and sources positioned above receivers for water-layer blanking.

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.

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.

Cell size

In *Header|Profile* 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.

CG iterations

Use this field in *WET Tomo|Interactive WET main dialog* to 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**.

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Check all shots for station spacing

Check all shot files in input directory for station spacing and propose adjustment of profile's station spacing if required. Uncheck to propose adjustment for first shot file only.

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 determine the **lateral smoothing in DeltatV velocity plot**. You can 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 is **CMP count = (station nr. range covered) * 2** with all shots positioned at shot station .5. As a rule of thumb set this stack width to (line length in station numbers)/5. E.g. with line length of 500m assuming a *Station spacing* of 2m set *CMP curve stack width* to 50. For line length of 2km set to 200. With a station spacing of 4m set to (line length in meters)/20. But set to at least 20, especially for short receiver spreads.

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. For short lines up to 200m long set to about 20 or 30, for medium lines up to 500m long increase up to 50 or so. For long lines exceeding one or two km set to 100 or 200. Increasing the stack width means more lateral smoothing.

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 multiple first break are mapped to the same unsigned trace offset during construction of the stacked traveltime curve, these picks are averaged out numerically.

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 in *Header|Profile* dialog. 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 may require more tuning of WET smoothing e.g. smoothing every 5th or 10th iteration only. Be sure to leave *Damping* at default value of 0.9 for *Conjugate Gradient* method so WET inversion can converge towards a realistic tomogram and minimized RMS error. Default *Steepest Descent search method* is more robust in case of noisy first break picks with reciprocal traveltime errors and recording geometry specification errors. When enabling WDVS in Model|WDVS Smoothing dialog we recommend using default *Steepest Descent* search method for better WET conversion toward a reliable tomogram with minimized RMS error. When using Conjugate-Gradient search method with WDVS enabled be sure not to use option *discard WET smoothing*. Instead use default option *discard WDVS smoothing only* so WET can converge towards a meaningful tomogram and minimized RMS error.

Conjugate Gradient tolerance

Use this field in *WET Tomo|Interactive WET main dialog* to specify 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.

Constant

This value in *Header|Profile* dialog must be a positive decimal number of 12 or fewer digits.

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. Since Apr 6, 2018 *Grid|Convert .CSV layer model to Surfer .GRD* allows for maximum of 7 layers : 6 overburden layers & one basement half-space layer when converting the .csv to .GRD format, instead of former 3 layers.

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

Check this box in WET starting model dialog shown when you click *Select button* in WET Tomo|Interactive WET dialog to reduce all grid node velocities in the Surfer® .GRD grid file by 10 percent before forward modeling during the first WET iteration.

Correct basement velocities for DeltatV systematic errors

Check this box in WET starting model dialog shown when you click *Select button* in WET Tomo|Interactive WET dialog to reduce basement grid node velocities in the Surfer® .GRD grid file by 15 percent before forward modeling during the first WET iteration. "Basement" just means high velocity regions as indicated by velocity 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 box in File|Import Data is unchecked per default. 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. With this option checked we add the shot's *delay time* to all first break pick times when importing the shot into the profile database.

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 in WET Tomo|Coverage plot setup dialog 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.

Customize default spread type

Check option ***File|Import data Settings|Customize Default spread type*** to automatically customize selected *Default spread type* to match irregular receiver layout with missing traces. Minimizes recording geometry modeling errors. Enabling this option will cause database revision to fail when opening this profile with earlier 3.36 or earlier version of our software. With this option checked we store a separate receiver spread instance for each imported variation of missing channels.

Cutoff frequency

This specifies the frequency separating the bassband from the stopband, of this filter.

Damping

This field in WET Tomo|Interactive WET tomography|Edit velocity smoothing dialog 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 (E. Cardarelli). Increasing the *Damping* makes WET inversion more robust especially with our *Conjugate Gradient* option and bad picks and when using our *multirun WET* / multiscale tomography

option. The default setting for *Damping* is 0.9 when you select *Conjugate Gradient* option in WET Tomo|Interactive WET tomography main dialog. For *Steepest Descent* option the default setting for *Damping* is 0.0. Regard the reciprocity principle when picking first breaks. Check your picks for violations of reciprocity principle in *Trace|Offset gather* display. See our tutorial https://rayfract.com/tutorials/Slope1.pdf . Also correctly specify the recording geometry used to record your data in the field. See our tutorial https://rayfract.com/tutorials/Aaknes-1.pdf .

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 imported with *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.

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

Use this control in *File|Import Data dialog* to specify the receiver spread type to be used for importing your shot files. *Spread types* are named by convention "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 for Standard license and up to 999 receivers per spread for Pro license. 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 you may need to define your own *spread type*. See help topic Defining your own layout types . Since version 3.36 we also offer option *File|Import data Settings|Allow missing traces* to import shot files with irregular receiver spacing and missing traces. Specify the minimum receiver separation with Header|Profile dialog field *Station spacing.* We assume that adjacent receivers in the same receiver spread layout are separated by an integer multiple of this spacing. If not so then the receiver coordinates shown in Header|Receiver will not exactly coincide with the receiver station coordinates shown in same dialog. Leave *Default spread type* at "10: 360 channels" (or "999:999 channels" for Pro license) with this *Allow missing traces* option checked.

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.

Default sample interval

This value in File|Import Data dialog is used when importing shot files without seismograph traces e.g. for ASCII.ASC, Interpex Gremix .GRM, SeisImager PlotRefa .VS or Geogiga DWTomo .TTX to determine the time scale in *Trace*|*Shot gather* and *Refractor*|*Shot breaks* using *Default sample count*.

Default sample count

This value in File|Import Data dialog is used when importing shot files without seismograph traces e.g. for ASCII.ASC, Interpex Gremix .GRM, SeisImager PlotRefa .VS or Geogiga DWTomo .TTX to determine the time scale in *Trace*|*Shot gather* and *Refractor*|*Shot breaks* using *Default sample interval*.

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 read-only field shown in Header|Shot 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), that positive delay is shown in this field, in milliseconds. If the recording of samples starts BEFORE the shot is fired, the time difference is 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. The delay time may be edited during (re)import of the shot optionally using our .HDR batch import or with *File*|*Update header data*|*Update Shotpoint coordinates*. Correct the actual delay time by editing field *Trigger delay* interactively in Header|Shot. Use our Trigger jitter removal dialog and menu items in Processing menu in *Trace*|*Shot gather* display to automatically adjust *Trigger delay* assuming a constant overburden velocity at shot points.

Delete traveltime grid files for last WET iteration

Uncheck this option if you want to keep Surfer® .GRD files with traveltime fields computed by Eikonal Solver for each shot during last WET iteration. These grid are files are named S1.GRD for shot number 1 etc.

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.

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.

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.

discard WET smoothing and WDVS smoothing after modeling

With this radio button checked in *Modeling|WDVS Smoothing* dialog we restore the unsmoothed WET velocity grid after forward modeling during WET inversion, discarding both the WDVS smoothing and the WET smoothing at this time. With this button unchecked we restore the WET smoothed velocity grid when discarding the WDVS smoothed velocity grid after forward modeling (Zelt and Chen 2016). For consistently picked traces with small reciprocal traveltime picking errors and with correctly specified recording geometry try enabling this option for more detailed WET tomograms and possibly higher resolution, with default *Steepest Descent* search method for WET inversion and minimal WET smoothing. We use this option in our https://rayfract.com/tutorials/ot0608.pdf tutorial. Don't discard WET smoothing when using *Conjugate Gradient* search method for WET inversion, to ensure that WET converges towards a meaningful tomogram and minimized RMS error. **Use Trace menu item Export reciprocal errors...** to compute and export reciprocal traveltime picking errors to ASCII .ERR file. Import the .ERR file into Microsoft Excel and sort by any column.

discard WDVS smoothing only and restore WET smoothing

With this radio button checked in *Modeling|WDVS Smoothing* dialog we restore the WET smoothed velocity grid when discarding the WDVS smoothed velocity grid after forward modeling (Zelt and Chen 2016). Check radio button *discard WET smoothing and WDVS smoothing after modeling* to discard both WDVS smoothing and WET smoothing after forward modeling of traveltimes during WET inversion. *discard WDVS smoothing only* is checked per default.

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 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.

Don't blank above topography

Check this WET blanking setting to not blank above topography during WET inversion for *Header|Profile|Line type* **`Refraction spread/line`** .

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 1D-gradient starting model. Alternatively check *Header|Profile|Force grid cell size*. When you check this option all other cell size options in Smooth invert|Smooth inversion Settings and in DeltatV|DeltatV Settings will be unchecked and *Header|Profile|Force grid cell size* will be checked.

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 display the WET smoothing dialog. Determine the dimensions of the smoothing filter to be applied to the updated velocity model grid after each WET iteration using options *Full smoothing*, *Minimal smoothing* or *Manual smoothing*. Also you can decrease WET smoothing by setting control *Smooth nth iteration : n =* to 5 or 10 instead of default setting 1. Also, you may specify the *maximum allowed relative change* after one iteration, for velocity values of grid cells. 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 *Damping* and set to 0.9 when using *Conjugate-Gradient search method* for WET inversion. You can disable WET smoothing completely with option *No smoothing*.

Enable AWE physical memory page caching

Check this WET setting to use RAM memory above 4GB up to 1TB 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

. 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 3 or 4GB 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 in *WET Tom|Interactive WET main dialog* 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*.

Error file name

This text field in *Trace|Export reciprocal errors* dialog lets you specify the filename of the ASCII formatted .ERR file written to. Alternatively click button *Select error file* to select folder location and to specify filename of this .ERR file.

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***.See (Oyan 2019) Use of seismic refraction in determining rock mass anisotropy. https://egrove.olemiss.edu/cgi/viewcontent.cgi?article=2775&context=etd on page 78 for detailed Voxler import instructions.

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 Grid|Export grid file to ASCII.TXT dialog 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 Grid|Export grid file to ASCII.TXT dialog to export grid cells with velocity in range *Min. velocity* to *Max. velocity* to ASCII .TXT format with x/y/z/velocity (4 columns). Grid cells outside this velocity range are not exported to .TXT file if *Export velocity range* is checked.

Extrapolate receiver line coordinates

Check this option in *File|Import Data Settings* to extrapolate receiver line coordinates beyond first/last receiver station. Disable to set offend shot stations to absolute shot point coordinates.

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 https://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 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 output to all receivers

This option in *DeltatV|DeltatV Settings* menu 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 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.

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.

fast WDVS : less accurate mapping of scan line nodes

Check this option in *Modeling|WDVS Smoothing* dialog for faster but less accurate mapping of scan line nodes to grid nodes. This mapping is done when averaging velocity grid nodes along straight scan lines over an area with radius of one wavelength centered at current grid node. With this option checked we truncate the offset and elevation coordinates of scan line nodes (converted to grid column and row as floating point values) to next-lower integer value

when determining column and row index into the velocity grid. With this option unchecked we round these floating point indices to nearest whole integer column and row indices. Try checking/unchecking this option for your current profile and compare the obtained WET tomograms.

Filter active for current trace gather display

Check this box in *Trace|Shot gather|Processing|Bandpass filter* dialog 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 in *Trace|Shot gather|Processing|Trace processing* dialog 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) in *Trace|Shot gather|Processing|Automatic picking of first breaks* 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

This field in *Header|Receiver* lets you edit the 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 the first break time may be edited numerically in this field.Or select *File|Update header data|Update First Breaks* with file BREAKS.LST to update first breaks for all imported shots and traces.

First receiver [station number]

Edit this field in *Header|Profile* dialog and check box *Force first receiver* to force the layout

start (first receiver station number) for the first shot imported next time you import your shot files via File|Import Data.

First refractor velocity limit

This field in *Refractor*|*Midoint breaks*|*Trace to refractor mapping* dialog lets you specify 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.

Flip sign of X coordinate for all sources and receivers

This option in *File*|*More import Settings* menu lets you flip sign of x coordinate for all sources and receivers specified in trace input files. Use for SEG-2 and GeoTomCG .3DD formats. Use to turn around profile.

Flip sign of Y coordinate for all sources and receivers

This option in *File*|*More import Settings* menu lets you flip sign of y coordinate for all sources and receivers specified in trace input files. Use for SEG-2 and GeoTomCG .3DD formats.

Force constant velocity

Check this box in *Smooth invert*|*Custom 1D-gradient velocity profile* to use the value entered for the following field *Forced velocity* when generating the CONSTVEL.GRD starting model with *Smooth invert*|*WET with constant-velocity initial borehole model*.

Force first receiver

Check this box in *Header*|*Profile* and edit *First receiver [station number]* to force the *Layout start* (first receiver station number) of your first shot imported next time you import shot files via *File*|*Import Data*. For all other shots imported after the first shot in the same *File*|*Import Data* session we shift *Layout start* and *Shot pos*. (in station numbers) by the same amount applied to the first shot imported. *First receiver [station number]* is not forced during import with *.HDR batch* import enabled or with *File*|*Import Data Settings*|*Profile start is default layout start* checked or when importing ASCII.ASC files which specify fixed station numbers already.

Also if your SEG-2 shot files contain station numbers in trace header fields SOURCE_STATION_NUMBER and RECEIVER_STATION_NUMBER then we will keep these station numbers during import and will not force the layout start of the first shot imported.

Force grid cell size

Check this box in *Header*|*Profile* 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. When you check this box all other cell size options in Smooth invert|Smooth inversion Settings and in DeltatV|DeltatV Settings will be unchecked.

Force grid limit

Check this box in *Smooth invert|Custom 1D-gradient velocity profile* 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* .

Force interpolate coordinates

Click this button in *Header|Station* to re-interpolate coordinates and v0 for all stations and reset *shot dx/dy/dz* for all shots even without having edited anything in the current dialog session. Shot dx/dy/dz is reset to Cartesian offset from *shot station* based on *shot inline offset* and *lateral offset* from *shot station* shown in *Header|Shot*.

Forced velocity

Edit this field in *Smooth invert|Custom 1D-gradient velocity profile* to constant velocity to be used when generating the CONSTVEL.GRD starting model with *Smooth invert|WET with constant-velocity initial borehole 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 in *WET Tomo|Interactive WET|Edit velocity smoothing* dialog 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. Alternatively use *Minimal WET smoothing* or *Manual WET smoothing*. Use option *Smooth nth iteration* to smooth the WET tomogram after each nth iteration only.

Gaussian smoothing filter weighting

Check this radio button in *WET Tomo|Interactive WET|Edit velocity smoothing* dialog for Gaussian weighting of smoothing filter nodes, when smoothing the tomogram after each (nth) WET iteration.

Generate blanking file between sources and receivers

Select this menu item in *Grid menu* to generate a Surfer format .BLN blanking file for blanking

polygon area between all sources and receivers. Click *Save button* to save to .BLN file. Use e.g. for marine refraction surveys with sources positioned above receivers. Specify negative shot hole depth in *Header|Shot|Depth* control to move up the sources above receiver spread. The *blanking velocity* in header column no. 3 of the .BLN file is set to 1,500 m/s per default. Select this .BLN blanking file with button *Select blanking file* in *WET Tomo|WET velocity constraints* dialog.

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 command *Grid|Grid and image DeltatV .TXT file...* .

Grid bottom elevation

Use this field in *Smooth invert|Custom 1D-gradient velocity profile* to 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* from selected velocity .GRD file.

Grid top elevation

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|Interactive DeltatV|Export options* choice box. 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 shot points and receivers

Checking this option in *Grid menu* forces use of Surfer font `GS CENTERED` symbol no. 48 for plotting of receivers and symbol no. 37 for sources. Uncheck to use font `GSI Default Symbols` symbol no. 102 for receivers and no. 21 for sources.

Half smoothing filter height

This edit field in *WET Tomo|Interactive WET tomography|Edit velocity smoothing* dialog is

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 https://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. See also our tutorial https://rayfract.com/tutorials/P6.pdf .

Header lines to skip

Use this edit field in *File|ASCII column format* 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

Use this field in *Trace|Shot gather|Processing|Bandpass filter* to edit the high frequency limit of the passband for this bandpass filter, in Hz. See Smith Steven W. 1997, Digital Signal Processing.

High velocity limit

Upper bound of velocity range updated during WET inversion with *Keep velocity unchanged above* checked. Edit in *WET Tomo|WET Velocity constraints* dialog.

High-pass filter

Check this box in dialog *Trace|Shot gather|Processing|Frequency filter* 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 in Annotations parameters dialog. 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. Edit in *Trace*|*Shot gather*|*Display parameters* dialog shown with ALT+P.

Hybrid Conjugate Gradient update formula

This *WET Tomo*|*WET tomography Settings* 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

Check this option in menu *File*|*Import Data Settings* 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* to file formats COORDS.COR and SHOTPTS.SHO and edit with Windows Notepad. Update source and receiver

coordinates via *File*|*Update header data*|*Update Station coordinates* and *Update Shotpoint coordinates*. See chapter File formats and tutorial https://rayfract.com/tutorials/tunnel16.pdf .

Import data type

Select in this drop down list box in *File*|*Import Data* dialog 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 / Geogiga DWTomo .TTX / GeoTomo TimePicker .3DTT are supported. For SEG-2 import review and edit ***File*|*SEG-2 import settings*** . For SEGY import review and edit ***SEGY import settings***. For all data types review and edit *File*|*Import Data Settings* and *File*|*More import Settings* before importing shot trace files with ***File*|*Import Data*** dialog.

Import horizontal borehole survey

Check this option in menu ***File*|*Import Data Settings*** before importing .3DD GeoTomCG files into a profile with *Line type* **`Borehole spread/line`** with receivers in a horizontal borehole.

Import shot dialog

This dialog lets you edit the shot and trace header data before 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*. Be sure to correctly specify *Shot pos.[station no.]* and *Layout start[station no.]*.

Import shots

Click this buttons once you have specified values for all parameter fields in your *Import shots dialog* shown with ***File*|*Import Data*** command.

Import shots dialog

This dialog is displayed when selecting ***File*|*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.

Import shots and write .HDR

Check this box in ***File*|*Import Data*** dialog to import shots into your current database and list imported shots in *Output .HDR* file with button *Import shots*

Increase cell size

Check this option in ***Smooth invert*|*Smooth inversion Settings*** or ***DeltatV*|*DeltatV 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 in *WET Tomo*|*Interactive WET main dialog* 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 .GRD filename

Edit this text field in *Grid*|*Export grid file to ASCII.TXT* with keyboard or select with button *Select grid file* the binary Surfer format .GRD filename to be exported to ASCII .TXT format

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 grid .GRD

Edit this field in *Model*|*Create Checkerboard grid* to path including drive, directory and file name specifying the input grid .GRD file to which the checker pattern will be added and stored into output grid .GRD file. Or click button *Select input .GRD file* to select this .GRD file interactively.

Instrument

Edit this field in *Header*|*Profile* dialog to <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 in ***Header*|*Station*** 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 shot point elevation

Check this option in ***File|Import Data Settings*** menu to interpolate shot point elevation and hole depth, for Optim SeisOpt, GeoTomCG .3DD. These file formats do not specify the shot hole depth.

Interpolate velocity for 1D-gradient initial model

Check this option in ***Smooth invert|Smooth inversion Settings*** 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.

Interpolate v0 only

Click this button in *Header|Station* to interpolate weathering velocity v0 only and to not reset *shot dx/dy/dz* in *Header|Shot* to Cartesian offset from *shot station* based on *shot inline offset* and *lateral offset*. This preserves shot dx/dy/dz determined with *File|Update header data|Update Shotpoint coordinates*.

Inverse CMP offset power

This parameter in ***DeltatV|Interactive DeltatV|Static Corrections*** dialog lets you weight first break picks when stacking *CMP curves*. Allowed values are in range 0 to 1. Default value is 0.5. Decreasing this parameter to 0.1 or 0.2 means increasing the lateral smoothing in the DeltatV velocity plot. Increasing to 0.9 means decreasing the lateral smoothing in DeltatV plot. The lower this parameter, the more weight is given to picks recorded for CMP stations horizontally offset from the central CMP station, for each CMP curve stack with stack width *CMP curve stack width*.

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 in ***WET Tomo|Interactive WET tomography*** 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 https://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 in *Header*|*Profile* dialog. Names the job during which the seismic data was recorded, in the context of Line ID.

Profile start is default layout start

This ***File*|*Import Data Setttings*** menu option is unchecked per default, starting with version 3.07 and later. When using earlier versions, this option is checked 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 with ***File*|*SEG-2 import settings*|*Ignore SEG-2 station numbers*** unchecked. SOURCE_LOCATION and RECEIVER_LOCATION of the first trace are divided by the *profile's Station spacing* specified in *Header*|*Profile* to obtain *shot position* and *layout start* in station numbers.

If this option is checked our import routine sets layout start for first shot imported with *File*|*Import Data...* to 1.0 if option *Default layout start is 1* is checked.

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.

Keep WET smoothing record in database

This option is located in ***WET Tomography Settings*** menu, *Write* submenu. Check to keep WET smoothing record in database when changing *grid cell size*. Uncheck to delete smoothing record so WET smoothing is reset to default smoothing. Edit velocity smoothing in ***WET Tomo*|*Interactive WET Tomography***. If you checked *Full smoothing* or *Minimal smoothing*, the filter dimensions are reset when you reselect the regenerated starting model grid. If you checked *Manual smoothing*, the filter dimensions are kept unchanged/as specified, with *Keep WET smoothing* checked.

Layout start

Use this field in *Import shot dialog* to specify the profile-relative position of first / leftmost receiver of the *receiver spread* used for recording of displayed shot, in whole station numbers. See help chapter Station numbers and spread types.

Least deviations

Select this radio button in *DeltatV*|*Interactive DeltatV* main dialog to specify linear regression method **Least absolute deviations**. This method will be used to determine local apparent CMP velocities on CMP sorted and stacked traveltime curves. Velocity estimates may be more realistic than with method *least squares*. Processing for the whole DeltatV inversion is about ten times slower than with alternate/default option *least squares*. **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 realistic, giving equal weight to all first breaks available.

Least squares

When you select this radio button in *DeltatV*|*Interactive DeltatV* main dialog, local apparent velocities on CMP traveltime curves are determined by a least squares linear regression over traveltimes inside an offset interval with width *Regression over offset stations* and centered at the offset currently being evaluated.

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).

Left limit of grid

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*. Edit in ***Smooth invert*|*Custom 1D-gradient velocity profile***.

Limit DeltatV velocity exported to maximum 1D-gradient velocity

This ***DeltatV*|*DeltatV Settings*** option is enabled per default for version 3.31 and later. 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 actual 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

Check this box in ***Depth*|*CMP Intercept-Time Refraction*|*Model parameters*** dialog shown with ALT+M if you want to limit the estimated CMP basement velocity by the value specified with the next parameter. This filtering is done during CMP intercept time refraction time-to-depth conversion. It may be appropriate in case of steep / narrow synclinal refractor topography.

Limit maximum source-receiver offset

Check this box in ***Trace*|*Shot gather*|*Processing*|*Edit trigger jitter removal*** dialog to limit the maximum source-receiver offset for traces regarded for trigger jitter estimation using *Assumed velocity*. If no trace is within this offset limit for a particular shot then that shot's *trigger delay* remains unchanged.

Limit offset

Check this box in ***File*|*Import Data*** dialog to import shot traces with receiver offset from the shot position not farther than *Maximum offset imported* (in station numbers).

Limit velocity exported

Check this box in ***DeltatV*|*Interactive DeltatV*|*Export options*** dialog 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 in menu ***WET Tomo*|*WET tomography Settings*** 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. We recommend checking this option when engaging WDVS for WET inversion to suppress a WDVS bias towards too high basement velocities and to avoid imaging high-velocity anomalies in overburden with too much contrast.

Line ID

Free format text field in ***Header*|*Profile*** dialog. Names the seismic profile along which the data was recorded.

Line search iterations

Use this field in ***WET Tomo*|*Interactive WET*** *main dialog* to 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

https://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 in *WET Tomo*|*Interactive WET main dialog* depends on the line search method used. Per default we use the Secant method described by (Shewchuk, 1994). See

https://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

In *Header*|*Profile* select *Line type* **`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. Edit in ***Trace*|*Shot gather*|*Processing*|*Bandpass filter*** .

Low velocity limit

Lower bound of velocity range updated during WET inversion with *Keep velocity unchanged below* checked. Edit in ***WET Tomo*|*WET Velocity constraints*** dialog.

Lower velocity of 1D-gradient layers

Use this option in ***Smooth invert*|*Smooth inversion Settings*** 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.

Lowest true velocity in percent of apparent

Edit this field in ***DeltatV*|*Common-offset dip estimation*** dialog to specify the smallest accepted estimate for true refractor velocity, in percent of apparent CMP velocity measured on CMP sorted traveltime curves during pseudo-2D DeltatV inversion. If the estimated true velocity is smaller than this threshold then we take the apparent CMP velocity instead as estimate of true refractor velocity. Valid range for this parameter is 1..99 percent. Current default setting is 33 percent but we may decrease this default to 10 percent or even just one percent.

Manual specification of smoothing filter

Select this radio button in ***WET Tomo*|*Interactive WET Tomo*|*Edit WET smoothing*** dialog to explicitly specify the dimensions (half width and half height) of the smoothing filter to be applied after each WET iteration or after each *nth iteration*. We recommend using *full smoothing* or *minimal smoothing* for more reliable WET inversion, with WDVS enabled in ***Model*|*WDVS Smoothing*** dialog.

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

Check this option in ***File*|*Import data Settings*** menu to match BREAKS.LST traces to database traces by station number with *File*|*Update header data*|*Update First Breaks* . Uncheck to match .LST traces by 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

use this field in ***WET Tomo*|*Interactive WET Tomography*** *main dialog* to specify max. WET runtime, in minutes. Default is 100 minutes. Check box *or WET inversion runs longer than*, 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. Edit in ***Depth*|*CMP Intercept-Time Refraction*|*Model parameters*** dialog shown with ALT+M. Click *No button* in prompt ***Continue with WET tomography*** and press ALT+M.

Maximum elevation

Elevation isoline value for upper station number axis, in depth section display.

Maximum offset imported

Set this field in ***File*|*Import Data*** to maximum offset between receiver and shot position (in station numbers) regarded when importing shot files. With box *Limit offset* checked traces with receiver offset from the shot position farther than this parameter are not imported. If all traces of the shot are offset farther than this value then 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 Semi-automatic first break picking by interactively picking a polyline with the right mouse button, this parameter has no meaning. Edit in ***Trace*|*Shot gather*|*Processing*|*Automatic first break picking***.

Maximum station number

Constant station number location for displaying right vertical axis. Edit in depth section or velocity section with ALT+P.

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

Use this field in ***DeltatV*|*Interactive DeltatV*** *main dialog* to specify the maximum velocity regarded as valid when processing CMP curves. Apparent CMP velocities exceeding this value will be skipped during DeltatV inversion.

Max. velocity

Use this field in ***WET Tomo*|*Interactive WET*** *main dialog* to limit the maximum WET velocity modeled. This value overrides the *Maximum valid velocity* field as specified for the DeltatV inversion.

Maximum offset

Edit this field in ***Trace*|*Shot gather*|*Processing*|*Edit trigger jitter removal*** dialog to specify the maximum source-receiver offset regarded for traces adjacent to shotpoint when determining the trigger jitter via *Assumed velocity*.

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 in ***WET Tomo*|*Interactive WET tomography*|*Edit velocity smoothing*** dialog lets you specify the maximum allowed relative update of each velocity model cell, after one iteration. If computed relative WET velocity updates exceed this threshold value the applied update will be limited to 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 in *WET Tomo|Interactive WET main dialog* 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 in Edit velocity smoothing dialog 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 possibly more artefacts with noisy first breaks or errors in specification of used recording geometry, or with too wide shot spacing. You can try this option during the last few WET tomography iterations. Use option *Smooth nth iteration* to smooth the WET tomogram after each nth iteration only.
Also try enabling option *scale WET filter height*. Enable WDVS smoothing in Model|WDVS smoothing with *Minimal smoothing* for better convergence towards a meaningful tomogram and minimized RMS error, using default *Steepest Descent search method*.

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 each receiver not receiver stations

This option is in ***Model Menu***, submenu *Forward modeling Settings*. Check to forward-model traveltimes at receiver coordinates as shown in ***Header***|***Receiver***. Uncheck this option to forward-model at receiver station coordinates shown in *Header*|*Receiver*.

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. Select depth section in ***Depth menu***. Press ALT+M in shown depth section to bring up this dialog.

Negative depths

Check this box to write depths with a preceding minus "-" to DELTATV.TXT, in connection with radio button depth below topo.

No receiver coordinates specified in .SGY file

This option in ***File***|***SEGY import settings*** is checked per default when you create a new profile with *File*|*New Profile*. Uncheck this option for importing SEGY .SGY files with valid source and receiver coordinates. Uncheck this option to enable import settings *Allow missing traces* and to enable *Use bent line inline offset for shot pos. and layout start* for SEGY import.

No shot position checking

Check this ***Smooth invert***|***Smooth inversion Settings*** option as a last resort only to force import and interpretation of ill-formed traveltime curves where the shot position is not located at the traveltime minimum.

No smoothing

Check this box to completely disable WET smoothing. Enabled *No smoothing* option overrides all other parameters in ***WET Tomo***|***Interactive WET tomography***|***Edit velocity smoothing*** dialog except *Maximum velocity update* and *Damping*.

No static corrections

Click this radio button in ***DeltatV***|***Interactive DeltatV***|***Static Corrections*** dialog 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*.

Normalize RMS error with maximum picked time

This option is located in ***Model Menu***, submenu *Forward modeling Settings*. Check to normalize absolute RMS error with maximum picked time. Uncheck to normalize with averaged picked time. This option was implicitly checked with earlier versions.

Note

In ***Header***|***Profile*** you can edit this field 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 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.

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 in *WET Tomo*|*Interactive WET tomography* WET main dialog lets you specify the number of *WET tomography iterations* to be done with the parameters specified, once you click on button *Start tomography processing*. Increase to 50 or 100 iterations and optionally *decrease WET smoothing* 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 in ***Header***|***Profile***.

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 half-range to search for best curve

Edit this field in *DeltatV|Common-offset dip estimation* dialog to specify the ***number of adjacent offset gathers to search in both directions***, for given offset and CMP station during pseudo-2D DeltatV inversion. I.e. set this field to value 1 to regard both the offset gather with next-lower offset and the offset gather with next-higher offset, in addition to central offset gather. The central offset gather is located as the gather with offset closest matching the current (unreduced) DeltatV offset when processing CMP sorted traveltime curves with DeltatV method. Valid range is 0 .. 5 .

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. Edit in ***Refractor|Midpoint breaks|Mapping|Crossover processing*** dialog once you mapped traces to refractors with ALT+M.

Offset limit basement coverage

Check this option in ***Refractor|Midpoint breaks|Mapping|Crossover processing*** dialog once you mapped traces to refractors with ALT+M. Use 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 with ***Depth menu***.

One spread per shot

Check option ***File|Customize spread types|One spread per shot*** if receiver coordinates vary for same spread layout between shots. With this option checked we store a separate receiver spread for each shot in the profile database. This minimizes modeling errors of the recording geometry but may increase the size of your profile database considerably.

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 in ***Smooth invert|Smooth inversion Settings*** 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-gradient 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 in *WET Tomo|Interactive WET main dialog* to stop WET inversion when the relative RMS error does not improve during *RMS error constant for n iterations* consecutive WET iterations. Default is 10 iterations.

or RMS error gets below

check this box in *WET Tomo*|*Interactive WET main dialog* 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 in *WET Tomo*|*Interactive WET main dialog* 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 File|Import Data to specify directory and filename of *.HDR batch file* to be written listing all shots found in matching input files in *Input directory*

Output .TXT filename

Edit this field in 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* Is updated to VELOITXX.TXT when you select VELOITXX.GRD with button *Select grid file.* .

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 grid .GRD

Edit this field in *Model*|*Create Checkerboard grid* dialog to path including drive, directory and filename to which the generated checkerboard grid .GRD will be written, based on *Input grid .GRD*. Alternatively update this field using button *Select output .GRD file* .

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.

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 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*. Also used for reduction of traveltimes to basement refractor, during Wavefront method interpretation.

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%). The default value for this parameter is 0%. See topic XTV inversion 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 in WET Tomo|Coverage plot setup dialog to 1 to plot wavepaths for every shot. Set to 2 to show wavepaths for every 2nd shot etc.

Polygon blanking active

Check this box in WET Tomo|WET velocity constraints dialog to enable blanking during WET inversion in the 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*.

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 geometric basement velocity for Wavefront

Check this option in *Depth|Depth conversion Settings* to compute the basement refractor velocity as described by (Jones and Jovanovich, 1985). Uncheck to set basement velocity to average of forward and reverse velocity obtained from traveltimes reduced to basement refractor level (E. Brueckl, 1987). This option added in version 3.35 of our software is checked per default. Uncheck for lines with steep topography or recording geometry errors for more robust velocity determination.

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.

Raise wavepath weight to power

Edit this field in *WET Tomo|Coverage plot setup* dialog to specify to what power the wavepath weight should be raised before summing weights over all wavepaths. Increase this parameter from 1.0 (use original weights) to 2.0 (squared weights) etc. Increase this parameter to improve visibility of low-coverage regions possibly related to low-velocity anomalies.

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 Coordinates specified in SEG-2 trace headers

Check this option *File|SEG-2 import Settings|Receiver Coordinates specified in .DAT or .SG2*

file to enable *File|Import data Settings|Allow missing traces* and to enable *Use bent line inline offset for shot pos. and layout start*. If both *File|Import Data Settings|Allow missing traces* and *File|SEG-2 import settings|Receiver Coordinates specified* are checked and the SEG-2 files are missing **RECEIVER_STATION_NUMBER** or **RECEIVER_LOCATION** in the trace headers during import with *File|Import Data...* then we prompt user about this, reset *File|Import Data Settings|Allow missing traces for SEG-2* and restart the import.

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 station ticks on top axis

Check this Grid menu item to show station numbers on top axis of tomograms plotted in Surfer. Uncheck to show horizontal inline offset from first profile receiver. Open *Grid|Surfer plot Limits* dialog to specify *First Station* to be labelled on top axis and *Station interval* used to determine following receiver stations to be labelled. Check box *Use station index or Station number offset* in case of irregular receiver spacing.

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.

Reciprocal CMP interval

Edit this number field in *Trace*|*Export reciprocal errors* dialog to specify the CMP interval [in station numbers] to search for pairs of reciprocal traces mapping to the same CMP (Common MidPoint). Default value is 0.5. Increase to 1.0 to list more trace pairs in .ERR file.

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.

Redisplay Grid

Click this button in *Grid*|*Surfer plot Limits dialog* to select a Surfer .GRD format tomogram file in your profile's ...\GRADTOMO, ...\LAYRTOMO, ...\TOMO or ...\HOLETOMO subdirectory. We then will call into Surfer to plot this .GRD with current limits as edited in this dialog.

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 CMP traveltime curve 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 closest receiver at source

Check this box in *Trace|Shot gather|Processing|Edit trigger jitter removal* dialog to determine the trigger jitter from *Assumed velocity* and offset and first break at closest trace to shot point. Alternatively check radio button *regard two closest receivers at source* or *regard receivers within maximum offset*.

Regard mapping for shot offset correction

Regard trace-to-refractor mapping and refractor velocities, for correction of first breaks for shot point offset from inline shot station. This correction of picked first breaks to shot station is done for DeltatV inversion and layered refraction interpretation with Plus-Minus, Wavefront and CMP intercept-time refraction only. 2D WET inversion forward models first breaks originating at true shot inline offset and specified shot depth including negative shot hole depth specified for marine refraction surveys. We do correct picked first breaks for lateral shotpoint offset from receiver line before WET inversion, projecting the shot point and picked first breaks onto the receiver line.

Regard negative shot depth

Check this option in *WET Tomo*|*WET tomography Settings*|*Blank* submenu to regard negative shot depth for DeltatV and WET inversion and forward modeling. This option disables default WET blanking above topography for marine surveys with sources located above receivers. Blank the water layer with .BLN selected in WET Tomo|WET velocity constraints dialog.

Regard nth node along scan line

Edit this field in *Model*|*WDVS Smoothing* dialog. Regard each nth node along current angle and scan line when determining WDVS velocity at current grid node via weighted average (Zelt and Chen 2016). Increase to speed up WDVS. Specify values 1 to 5. Default is 3. All nodes are regarded to determine time delay along scan line. Scan line nodes are separated by the *grid cell size* in m, as forced in Header|Profile.

regard receivers within maximum offset

Check this box in *Trace*|*Shot gather*|*Processing*|*Edit trigger jitter removal* dialog to average the trigger jitter determined from *Assumed velocity* over all traces within *Maximum offset* from shot point. Alternatively check radio button *regard closest receiver at source* or *regard two closest receivers at source*.

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

This parameter field in *DeltatV*|*Interactive DeltatV* main dialog lets you determine the **vertical smoothing of pseudo-2D velocity plot**. 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 with options *least squares* and *least deviation*. Increasing this parameters means more vertical smoothing of pseudo-2D velocity plot.

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 or ...\LAYRTOMO or ...\HOLETOMO subdirectories. *Replace 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, 26, 22, 18, 15, 12, 10, 8, 7, 6 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 Receiver Coordinates

Click this button in ***Header*|*Receiver*** dialog to reset all shown receiver coordinates to shown coordinates of their linked receiver stations.

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 in multi-run WET dialog 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.

Reverted spread layout

check this box in ***File*|*Import Data*** dialog if spread channel no. decreases with increasing inline offset along profile. Check for towed streamer with channel no. 1 closest to towing device and recorder. Also check *File*|*Import Data*|*Turn around spread during import* to unflip reverted spread for display and processing. Use with SEG-2 and SEGY formats or with DWTomo .TTX format.

Ricker differentiation

This parameter in ***WET Tomo*|*Interactive WET Tomo*** main dialog lets you specify how many times in time the Ricker wavelet used to modulate the amplitude of the wavepath misfit gradient should be differentiated, during back-projection of misfit for each trace and wavepath. Set this parameter to -1 for Gaussian weighting of velocity update across WET wavepath during WET inversion in back-projection stage. 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 leaving 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 https://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. See our tutorial https://rayfract.com/tutorials/1_1D.pdf . Ricker differentiation 0 can work well when imaging low-velocity anomalies : see our tutorial https://rayfract.com/tutorials/D1P2NO24.pdf .

Right limit of grid

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*. Edit in ***Smooth invert|Custom 1D-gradient velocity profile*** dialog.

RMS error constant for n iterations

Edit this field in ***WET Tomo|Interactive WET*** *main dialog* to specify the number of WET iterations to check for non-decreasing RMS error, with box *or RMS error does not improve for n =* checked.

RMS error threshold

edit this field in ***WET Tomo|Interactive WET*** *main dialog* to the desired relative RMS error threshold in percent, for stopping the WET inversion with box *or RMS error gets below* checked.

Round shot station to nearest whole station number

Uncheck this ***File|Import Data Setting*** option 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. Check this option to round shot stations to nearest whole station number during import. This may result in more robust traveltime field regression during Time-to-depth conversion with our Plus-Minus and Wavefront methods.

Safe line search with bracketing and Brent

Check this option in *WET Tomo|WET tomography Settings menu* to use bracketing and Brent's method as in http://www.numerical.recipes, 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 decrease faster during WET inversion, with fewer iterations. This option is checked per default, for profiles with 72 or more receiver stations.

Search adjacent offsets for traveltime curve with most traces picked

Check this box in *DeltatV|Common-offset dip estimation* dialog to activate search of common-offset curve with most traces picked, over *Offset half-range to search for best curve.* If you uncheck this box then we regard the one offset gather with offset closest matching the searched for offset only, during pseudo-2D DeltatV inversion. Unchecking this box has the same effect as checking this box and setting *Offset half-range to search for best curve* to value zero (0).

Search window width

This parameter in dialog *Trace|Shot gather|Processing|Automatic picking of first breaks* is used 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. Decrease this parameter in situations of a high degree of pre-first break noise, or weak first break signals. The smaller the parameter value, the closer the automatic pick will be to the linearized time defined by your picked polyline.

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 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 *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...

Use this *Grid menu* option to select a 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

https://rayfract.com/samples/jenny13.pdf

Select blanking file

Click this button in *WET Tomo|WET velocity constraints* dialog to select a Surfer format .BLN *blanking file* which contains the polygon to be blanked during WET inversion. Use *Grid|Generate blanking file between sources and receivers* for marine refraction surveys with sources located above the receiver spread.

Select coordinate file

Click on this button in *File|Update header data|Update Station Coordinates* dialog to bring up a file selection dialog, for specifying the coordinate file to be imported.

Select error file

Click this button in *Trace|Export reciprocal errors* dialog to navigate into the folder where you want to write the .ERR file and specify its filename. The resulting full filename including drive and directory is copied into field *Error filename*.

Select grid file

Click this button in *Grid*|*Export grid file to ASCII.TXT* dialog to select *Input .GRD filename* to be exported to ASCII .TXT format.

Select initial velocity model

Click on this button in *WET Tomo*|*Interactive WET tomography*|*Select* dialog to show a file open dialog, for selecting the initial / starting velocity model (formatted as a Surfer® .GRD file). If there does not exist a .PAR parameter file with the same name and in the same directory, you will be asked to select the .PAR file. You may specify .GRD files / velocity models obtained by previous WET tomography runs, i.e. refine the output of earlier WET processing. 1D-gradient starting model is file **C:\RAY32\<your profile>\GRADTOMO\GRADIENT.GRD** created with *Smooth invert* menu. Constant-velocity starting model is file **C:\RAY32\<your profile>\HOLETOMO\CONSTVEL.GRD** created with *Smooth invert* menu for *Line type* **Borehole spread/line**. DeltatV starting model is file **C:\RAY32\<your profile>\TOMO\DELTATV.GRD** created with *DeltatV menu*. Plus-Minus method starting model is **C:\RAY32\<your profile>\LAYRTOMO\PLUSMODL.GRD** created with *Depth*|*Plus-Minus*. Wavefront layered refraction method starting model is file **C:\RAY32\<your profile name>\LAYRTOMO\WAVEMODL.GRD** created with *Depth*|*Wavefront* . CMP Intercept-time method starting model is **C:\RAY32\<your profile>\LAYRTOMO\CMPMODL.GRD** created with *Depth*|*CMP Intercept-Time Refraction* .

Select input .GRD file

Click this button in *Model*|*Create Checkerboard grid* dialog to select the input WET tomogram .GRD in your ...\GRADTOMO, ...\LAYRTOMO, ...\TOMO or ...\HOLETOMO folder. E.g. select ...\GRADTOMO\VELOIT20.GRD .

Select mask grid file

Click this button in *WET Tomo*|*WET Velocity constraints* dialog 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 output .GRD file

Click this button in *Model*|*Create Checkerboard grid* dialog to interactively select the output .GRD file which will be updated with the *input .GRD file* with the checkerboard pattern applied.

Select Scripter

Click Select button in ***Grid*|*Surfer invocation*** dialog to select the Scripter.EXE needed for calling into Golden Software Surfer from our software via .BAS scripts DELTATV.BAS and AUTOTOMO.BAS. For Surfer 15 select Scripter.EXE in directory C:\Program Files\Golden Software\Surfer 15. Click Open & OK buttons. Now our software can invoke Surfer through our .BAS scripts and Scripter.

Specify starting velocity model

Click on this button in WET Tomo|Interactive WET to bring up the Forward modeling parameters dialog. This dialog lets you specify the initial / starting velocity model used for the WET tomography processing. Specify if velocities should be corrected for systematic DeltatV errors. Also specify if every second shot should be skipped during the WET inversion to reduce the processing time.

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 in ASCII format dialog. 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.

Sharpen wavepaths active

Check this box in *WET Tomo*|*Coverage plot setup* dialog to plot wavepath weights summed over all wavepaths instead of number of wavepaths per pixel, in WET coverage plots. Edit *Raise wavepath weight to power* to improve visibility of low-coverage regions possibly related to low-velocity anomalies.

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 true source elevation is higher than the elevation as shown in read-only field *Source elevation* (in *Header*|*Shot*) e.g. for marine refraction survey with sources positioned above the receiver spread. 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. *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 in Header|Shot. 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 during import with File|Import Data dialog use this field to specify the correct shot number in *Import Shot dialog*.

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 https://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

Check this box in WET starting model dialog shown when you click *Select button* in WET Tomo|Interactive WET dialog to speed up WET inversion by skipping every second shot. This may result in a coarser / more uncertain WET tomogram.

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

Check this box in *WET Tomo*|*Interactive WET tomography*|*Edit velocity smoothing* dialog to smooth the tomogram obtained with the last WET iteration, regardless of setting of parameter *Smooth nth iteration*.

Smooth nth

Edit this parameter in *WET Tomo*|*Interactive WET tomography*|*Edit velocity smoothing* to smooth the tomogram after each nth WET iteration only. Increase for less smoothing. E.g. increase from default 1 to 10 or 15. The WET tomogram is smoothed using *Full smoothing*, *Minimal smoothing* or *Manual smoothing* as specified by the user.

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 update

Check this box in *Edit velocity smoothing* dialog to smooth the velocity update separately before applying it to the tomogram during WET inversion. With this box checked the velocity update is smoothed for each WET iteration. Check box *Smooth nth* to smooth the velocity update for each nth iteration only.

Sort .ERR lines by offset and CMP

Click this radio button in *Trace*|*Export reciprocal errors* dialog to sort ASCII text lines in the .ERR file by offset in meters (first column) and CMP station (second column).

Source shot no.

Edit this field in *Trace*|*Shot gather*|*Processing*|*Stack shots* dialog to the 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 in Header|Shot. The value of this field is regarded for traveltime curve coloring in *Refractor*|*Shot breaks*, with option *Mapping*|*Color picked curves by source type*.

Spread type

Use this former drop down list in File|Import Data dialog box to specify a spread type different from the *Default spread type*, as specified above 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 in WET Tomo|Interactive WET main dialog 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 interval for linear regression

Edit this field in *DeltatV*|*Common-offset dip estimation* dialog to specify the CMP station interval (in station numbers) used for linear regression over common-offset sorted picked traces to determine the dip of common-offset sorted traveltime curves for given offset and CMP station during pseudo-2D DeltatV inversion. Valid range is 2 .. 200. Default setting is 10

station numbers.

Station spacing

This edit field in *Header*|*Profile* dialog specifies how many meters correspond to one station number interval. With an equidistant receiver spread type (where all adjacent receivers are separated from each other by one station number interval) the station spacing is equivalent to the receiver spacing. We recommend leaving ***File*|*Import Data*|*Default spread type at default setting "10: 360 channels" and leaving File*|*Import Data Settings*|*Allow missing traces checked***. With these import settings our import routine matches actual receiver positions in the shot trace files to profile station numbers using this *Station spacing*. The actual receiver separation can deviate from an exact integer multiple of *Station spacing*. See our ***Header*|*Receiver*** dialog for deviation of receiver coordinates from receiver station coordinates. We ***re-center profile station coordinates by averaging coordinates over all receivers linked to that station*** at the end of our import.

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 is more robust with bad picks and recording geometry specification errors but Conjugate Gradient can give a lower RMS error and a sharper WET tomogram with optimized/decreased WET smoothing. When enabling WDVS in *Model*|*WDVS Smoothing* dialog we recommend using *Steepest Descent* search method for better WET conversion toward a reliable tomogram with minimized RMS error.

Steepest Descent step

check this box in *WET Tomo*|*Interactive WET main dialog* 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

Surfer® grid files are stored for each nth iteration only. Preserve free disk space. Default value is 10. For Smooth inversion Surfer® .GRD grid files are written to profile subdirectory GRADTOMO for *Line type* **`Refraction spread/line`** and HOLETOMO for *Line type* **`Borehole spread/line`**. 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 *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. 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.

Surface consistent

Check this option in *DeltatV|Interactive DeltatV|Static Corrections* dialog 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. This import option is not shown any longer since a few versions.

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 list control in ***File|Import Data*** dialog specifies how to determine the shot number of the shot currently being imported. It is preset according to the ***Import data type*** selected in ***File|Import Data***.

For ***Import data type*** SEG-2 the default choice is **DOS file name**. The SEG-2 filename is supposed to have the format "AAAXXXXX" plus the file extension .DAT or .SG2 or .SEG2. "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 we import the file. "XXXXX" stands for a number string from which the shot number is determined, i.e. "00101". The last three digits are regarded only to determine the shot number.

With choice **File number** selected for *Import data type* SEG-2 the database shot number starts at 1 and is increased sequentially during each import session with *File|Import Data…* . If you specify SEG-2 trace header key **SHOT_SEQUENCE_NUMBER** then we number imported shots using SHOT_SEQUENCE_NUMBER values instead with choice **File number** selected.

With *File|Import Data|Batch import* checked and your *.HDR batch file* selected with button *.HDR batch* we set the database shot number to values in colum no. 3 of your ***.HDR batch file*** for all import data types regardless of setting of control *Take shot record number from*.

Taper velocity steps at layer interfaces

Enabling this option in *DeltatV|DeltatV Settings* menu 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 with this list control in *File|Import Data* dialog the sample format for storing trace samples in the currently opened Rayfract® profile database when importing shots. 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. We support opening version 3.25 or earlier profiles with version 3.26 or later of our software. But ***if you use version 3.25 or lower to open a profile previously opened with 3.26 or later then you will loose all traces samples*** i.e. *Trace|Shot gather* will not show any traces any longer.

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 in *DeltatV|Interactive DeltatV|Static Corrections* dialog 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 in *Header|Shot* 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. The

delay time may be edited during (re)import of the shot, or with *File*|*Update header data*|*Update Shotpoint coordinates*. Use the Trigger jitter removal dialog in Processing menu to adjust the trigger delay automatically based on assumed weathering velocity.

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 during import

Check this option in *File*|*Import Data* dialog to store the first recorded trace (channel no. 1) at the last (right-most) active receiver position of the receiver spread type selected. Specify the *shot position* and *layout start* correctly when importing shots with this option. Also check box *Reverted spread layout* if appropriate. Check the imported shot in *Trace*|*Shot gather* and reimport with adjusted shot position and layout start if required. Skip all other shots in *Import shot dialog*. We recommend using our .HDR batch file format to specify *layout start* and shot position for all shots. See chapter *File formats*. See also our tutorial https://rayfract.com/tutorials/P6.pdf .

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 in *Header*|*Profile* dialog 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 in *WET Tomo*|*WET tomography Settings* menu 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 https://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 bent line inline offset for shot pos. and layout start

Check this option in *File*|*Import Data Settings* to use cumulative inline offset along bent line (regarding receiver x/y/z coordinates) to determine *Shot pos.* and *Layout start* in station numbers, for SEG-2 and SEGY import. For this option to be regarded during import you also need to check option *File*|*SEG-2 Settings*|*Receiver Coordinates specified in .DAT or .SG2 file* or uncheck option *No receiver coordinates specified in .SGY file*. Also you need to check option *Allow missing traces* for this option to be regarded. Uncheck this option to determine Shot pos. and Layout start from major coordinate X or Y and your *Station spacing*. The major coordinate for your profile is the one which increases fastest between adjacent receivers.

Use dip of common-offset curves to improve DeltatV velocities

Check this box in *DeltatV*|*Common-offset dip estimation* dialog to activate estimation of dip of common-offset sorted traveltime curves for given offset and CMP station during pseudo-2D DeltatV inversion and to improve DeltatV velocity estimation using this offset dip (Gebrande and Miller, 1985; Gebrande 1986).

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

use WDVS for forward modeling of traveltimes

Check this option in *Model*|*WDVS Smoothing* dialog to do WDVS velocity smoothing (Zelt and

Chen 2016) before running Eikonal solver during WET inversion or with *Model*|*Forward model traveltimes* to forward-model traveltimes over current velocity grid.

use receiver station coordinates

Check this radio button in *Trace*|*Shot gather*|*Processing*|*Edit trigger jitter removal* dialog to use receiver station coordinates as shown in *Header*|*Receiver* to determine the source-receiver offset and trigger jitter from *Assumed velocity* and first breaks at traces adjacent to shot point. Alternatively check radio button *use true receiver coordinates* .

use true receiver coordinates

Check this radio button in *Trace*|*Shot gather*|*Processing*|*Edit trigger jitter removal* dialog to use receiver coordinates as shown in *Header*|*Receiver* to determine the source-receiver offset and trigger jitter from *Assumed velocity* and first breaks at traces adjacent to shot point. Alternatively check radio button *use receiver station coordinates.*

Used width of Gaussian [SD]

Use this field in *WET Tomo*|*Interactive WET*|*Edit velocity smoothing* dialog to specify cutoff in Standard deviations or sigma for Gaussian bell function used for weighting of smoothing filter nodes. The lower this value, the flatter the smoothing filter will be. See https://en.wikipedia.org/wiki/Standard_deviation .

v0 from CMP

Click this button in *Header*|*Station* dialog 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 in *Header*|*Station* dialog 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 profile

Use this field in *Smooth invert*|*Custom 1D-gradient velocity profile* dialog to 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. Copy generated 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*.

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.

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 in *Annotation Parameters* dialog. 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 and to weight the velocity update during back-projection of misfit across wavepath. We usually leave this at the default value i.e. at 50 Hz. One period is 1/50Hz = 20ms. See (Schuster 1993) for details. Valid range is 0.01Hz to 10'000Hz.

Wavepath width

This edit field in *WET Tomo*|*Interactive WET tomography* main dialog 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. Increase the wavepath width for more reliable interpretation and less artefacts with uncertain first break picks due to noisy traces and with errors in specification of used recording geometry. See our tutorial https://rayfract.com/tutorials/Aaknes-1.pdf .

Wavepaths for every nth receiver

Set this parameter in *WET Tomo|Wavepath coverage setup* dialog to 1 to plot wavepaths for every receiver, of shot being plotted. Set to 2 to show wavepaths for every 2nd receiver etc.

WDVS frequency

Edit WDVS frequency with this field in *Model|WDVS Smoothing* dialog. Specify in Hz : 0.01Hz to 10'000 Hz. Used to determine the duration of one wavelength i.e. one period in time. Is set to 200Hz per default. Should be two to four or eight times the ***Wavepath frequency*** specified in WET Tomo|Interactive WET tomography… . See (Zelt and Chen 2016). Increase to decrease WDVS smoothing and to speed up WDVS.

Weathering crossover

Use this edit field in the *DeltatV|Interactive 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 in *Refractor|Midpoint breaks|Trace to refractor mapping parameters* dialog shown with ALT+M 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 in *DeltatV|Interactive DeltatV* main dialog to control weathering velocity estimation in situations of strong and 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. This median velocity is shown in *Refractor*|*Midpoint breaks*|*Trace to refractor mapping parameters* dialog shown with ALT+M.

Weigh CMP binned picks for mapping

This option in *Refractor*|*Midpoint breaks*|*Mapping* menu was added with version 3.35 of our software and is regarded when displaying CMP sorted traveltime curves in *Refractor*|*Midpoint breaks* display. For earlier versions we regard option *DeltatV*|*DeltatV Settings*|*Weigh picks in CMP curves* instead. Uncheck this option in case of noisy/inaccurate first break picks or recording geometry errors for more robust mapping of traces to refractors with **ALT+M** mapping dialog.

Weigh picks in CMP curves

We recommend to always enable this *DeltatV*|*DeltatV Settings* 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 in *DeltatV*|*DeltatV Settings* menu 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

Check this option in *Smooth invert*|*Smooth inversion Settings* menu to force vertical smoothing filter width = 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 [SD]

Use this field in *WET Tomo*|*Interactive WET* main dialog to specify the cutoff for Gaussian Bell function, in Standard deviations or sigma. See https://en.wikipedia.org/wiki/Standard_deviation . 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 [SD]* to 10.0 or 20.0 or 50.0 from default 3.0 for wide shot spacing and low-coverage lines e.g. tutorial https://rayfract.com/tutorials/jenny13.pdf to avoid artefacts at low frequency/for first few runs of multiscale tomography (at wide wavepath width). Also increase this parameter in case of near-surface velocity inversions. Or change *Ricker differentiation* from -1 [Gaussian bell] to 0 [Ricker wavelet].

Width%

This column in *WET Tomo*|*Interactive WET Tomo*|*Iterate* 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 *File*|*Import Data* dialog 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 in *WET Tomo*|*WET tomography Settings*|*Write* menu 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 in *WET Tomo*|*Interactive WET*|*Edit grid file generation* dialog 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 in *WET Tomo|Interactive WET|Edit grid file generation* dialog 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 new DeltatV settings to .PAR file

Check this option in *DeltatV|DeltatV Settings* menu to write new setting *Regard mapping for shot offset correction* to .PAR file. Uncheck so older version 3.36 builds of our software can still read .PAR files written with 3.36 build May 2020 and version 4.01 or later builds. .PAR files are generated during DeltatV inversion & Smooth inversion and are updated with WET settings during following WET inversion.

Write section coverage grids after each iteration

Enable this option in *WET Tomo|Interactive WET|Edit grid file generation* dialog to write Surfer® .GRD files with the coverage of each WET velocity grid cell with wavepaths, after each WET iteration..GRD files are named COVERG01.GRD for the first WET iteration etc. Unit is wavepaths per pixel.

Write section velocity update grids after each iteration

Enable this option in *WET Tomo|Interactive WET|Edit grid file generation* dialog to write Surfer® .GRD files with the velocity update to be applied to the output of the previous WET iteration. .GRD files are named VELUPD01.GRD for the first WET iteration etc.

Write wavepaths to disk for shot nr.

Shot number for which to generate .GRD files with the wavepaths for all receivers i.e. traces recorded for this shot. The resulting Surfer® .GRD files are 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 option checked in *File|Import Data Settings* menu our import routine will determine the ***inline offset between adjacent receivers*** with Pythagoras of true x (corrected for elevation change) 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.

Y coordinate is zero 0.0

Reset y coordinate to zero 0.0 during import for all shots and receivers. Use with SEG-2, SEGY and GeoTomCG .3DD import into *Header*|*Profile*|*Line type* **`Refraction spread/line`**. For *Line type* **`Borehole spread/line`** all y coordinates for all sources and receivers are reset to zero 0.0 during import independent of this option.