

WET tomographic inversion and dynamic Poisson's ratio imaging for data sets WAVE_P and WAVE_SH as sent by Dr. Anibaldi, Geomethodo s.r.l. in 2004 with Rayfract® 4.04 and Surfer 23 in June 2023 :

Data import into Rayfract™ profile database

Download ASCII .ASC formatted files WAVE_P.ASC and WAVE_SH.ASC from our web site :

<https://rayfract.com/tutorials/poisson.zip> .

Now create two new Rayfract™ profile databases named WAVE_P and WAVE_SH, as described in our short manual as available at <https://rayfract.com/help/manual.pdf> . When prompted in version 4.05 to force first receiver station number to 1 click *Yes* button (Fig. 24).

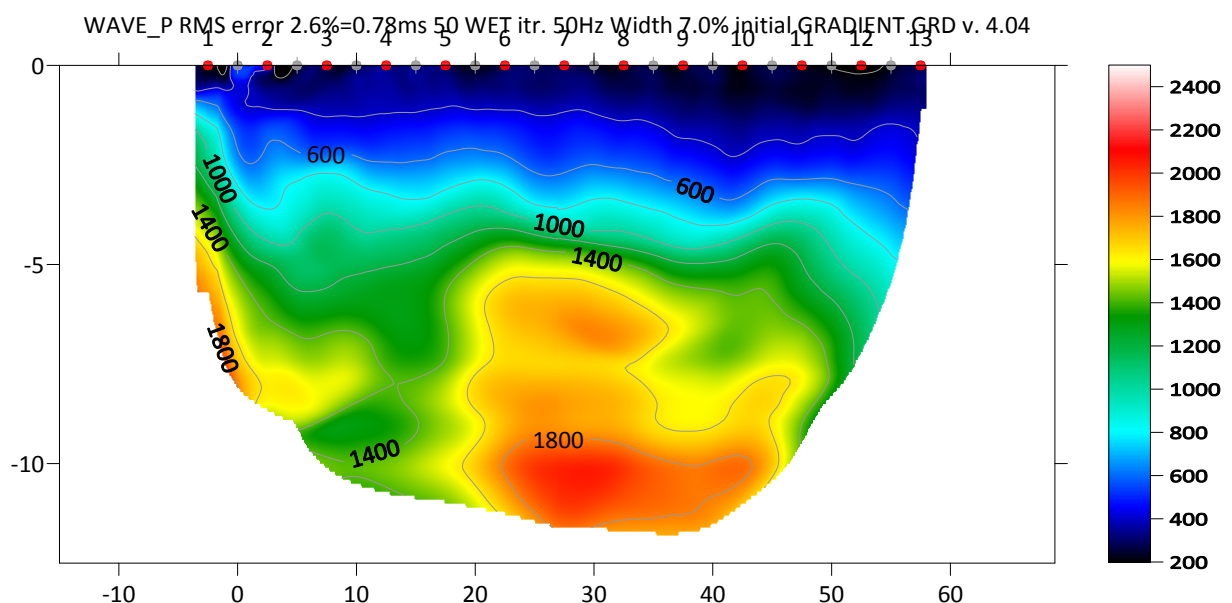
Specify a *Station spacing* of 5 meters in *Header|Profile*.

Then copy file WAVE_P.ASC into directory \RAY32\WAVE_P\INPUT, and copy WAVE_SH.ASC into directory \RAY32\WAVE_SH\INPUT using Windows Explorer.

Now import these ASCII .ASC files into their respective profile databases, as described in above manual. Specify import data type ASCII column format, and use the default receiver spread type 01: 24 channels. Check option "Batch import", so you don't need to confirm layout start and shot position etc. for each individual shot.

WET tomography processing WAVE_P line with 1D-gradient initial model and 50 WET iterations

- open profile C:\RAY32\WAVE_P with *File|Open Profile*
- select *Header|Profile* and check box *Force grid cell size*. Set *Cell size* to 0.1m (Fig. 12)
- select *Model|WDVS Smoothing* and uncheck option *use WDVS* (Fig. 13)
- check option ***Discard WET smoothing and WDVS smoothing after modeling***. Click button OK.
- select *Smooth invert|Custom 1D-gradient velocity profile* and edit as in Fig. 14
- check option *Force grid limits*. Set field *Grid bottom elevation [m]* to -12.5m. Click button OK.
- select *Smooth invert|WET with 1D gradient initial model*
- confirm the following prompt to obtain our default interpretation based on 20 WET iterations
- select *Grid|Surfer plot Limits* and edit as in Fig. 15
- select *WET Tomo|Interactive WET tomography...* and set parameter *Number of WET tomography iterations* to 50. Set *Wavepath envelope width* to 2% (Fig. 16).
- click button *Start tomography processing*. You will obtain the following P-wave tomogram :



Next we compute the S-wave tomogram with profile WAVE_S opened

- open profile C:\RAY32\WAVE_SH with *File|Open Profile*
- select *Header|Profile* and check box *Force grid cell size*. Set *Cell size* to 0.2m (Fig. 12)
- select *Smooth invert|WET with 1D gradient initial model*
- confirm the following prompt to obtain our default interpretation based on 20 WET iterations
- select *Grid|Surfer plot Limits* and edit as in Fig. 18.
- select *WET Tomo|Interactive WET tomography...* and set parameter *Number of WET tomography iterations* to 50 (Fig. 17)
- click button *Start tomography processing*. You will obtain the following S-wave tomogram :

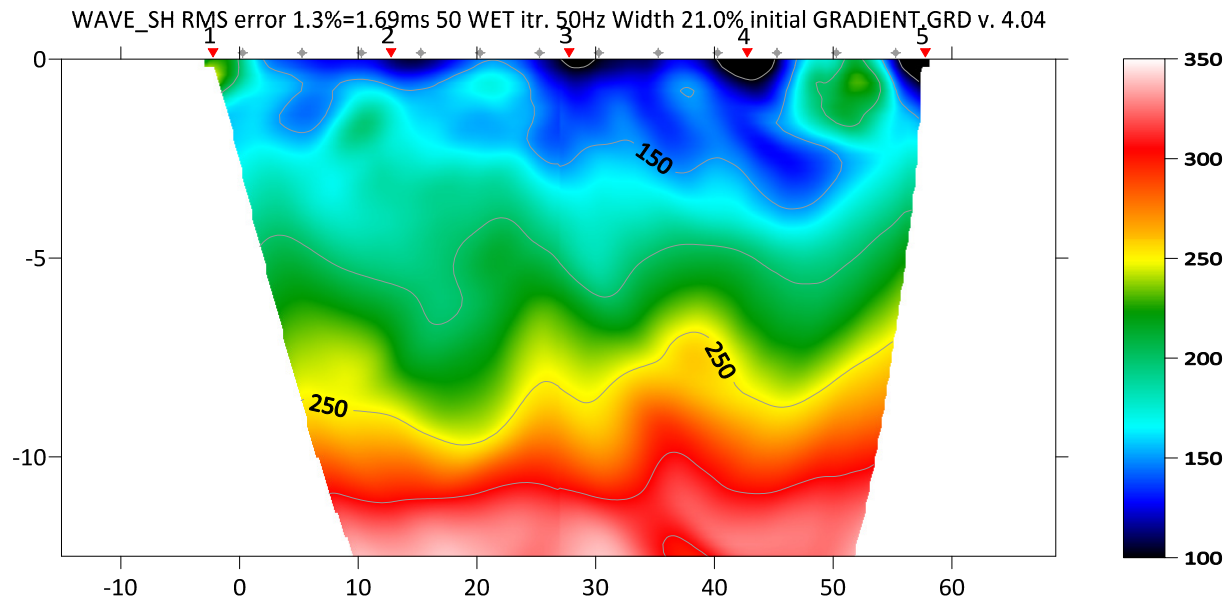


Fig. 2 : 50 WET iterations with 1D-gradient initial model for line WAVE_SH. Discard WET smoothing. WDVIS disabled. Full WET smoothing. WET wavepath width 21%. WET frequency 50Hz. WET wavepath coverage plot shown in Fig. 20.

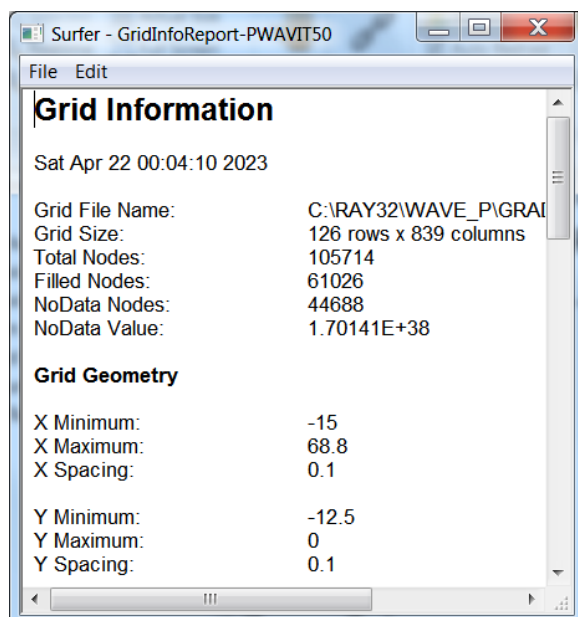


Fig. 3 : Grid Info PWAVIT50.GRD

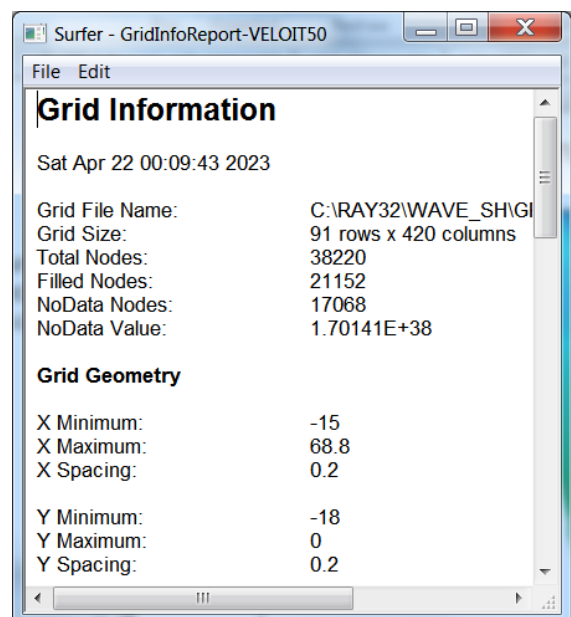


Fig. 4 : Grid Info SHWVIT50.GRD

Construction of dynamic Poisson's ratio image map for lines WAVE_P and WAVE_SH

Here we show how to image dynamic Poisson's ratio with Surfer 23 operations Extract Grid, Grid Mosaic and Grid Math. See your Surfer 23 manual for more details on these grid operations.

- open a Windows Explorer window with Windows Start menu / magnifier search icon in Start menu
- change into directory \RAY32\WAVE_P\GRADTOMO and copy file VELOIT50.GRD to PWAVIT50.GRD.
- change into directory \RAY32\WAVE_SH\GRADTOMO and copy file VELOIT50.GRD to SHWVIT50.GRD.
- start up Surfer 23 via desktop icon
- in box **Search commands and help** at top of Surfer main window enter search term **grid info**
- select topmost match **Grid Info**. Click **Browse** button and select above PWAVIT50.GRD.
- click **Open** button and **OK** button to obtain Fig. 3.
- repeat the last 3 steps with above SHWVIT50.GRD to obtain Fig. 4.

To be able to carry out Grid Math operations based on above two grids, we first need to resize and resample SHWVIT50.GRD to the size and density (row, column count and cell size) of PWAVIT50.GRD.

- in Surfer main window select *File|New|Plot Document*
- enter search term **Extract** at top and select topmost match **Extract**
- click **Browse** and select SHWVIT50.GRD and edit field „First row“ to 28, as shown below. I.e. vary this field until „Minimum y“ optimally fits the minimum y value of PWAVIT50.GRD amounting to -12.5.
- click on the Folder icon to the right of edit field Output Grid and enter file name SHWVCLIP.GRD.
- click on **Save**, and then click on **OK** to generate the clipped grid file (Fig. 5)

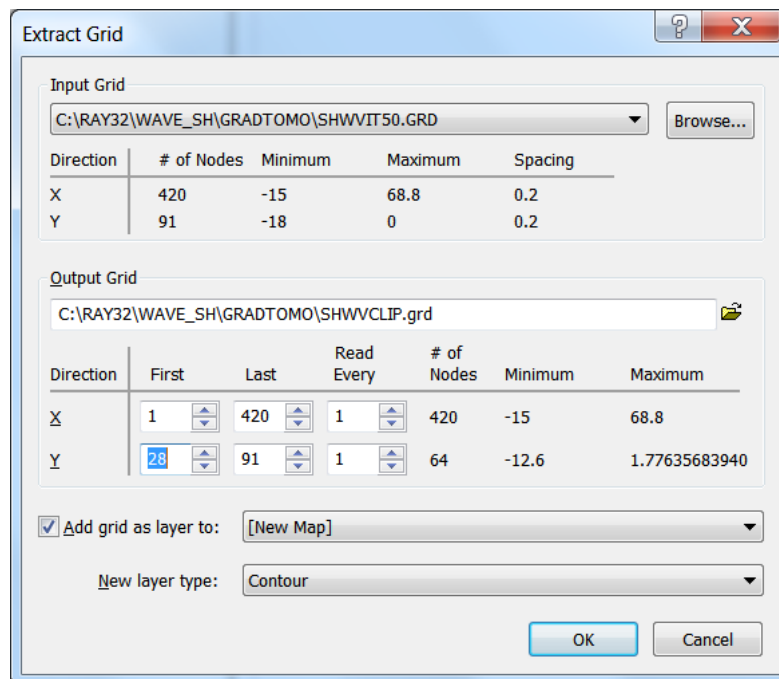


Fig. 5 : Extract S-wave grid matching size of P-wave grid.

- select *File|New|Plot Document*
- enter search term **Mosaic** at top and select topmost match **Mosaic**
- select SHWVCLIP.GRD and click **Open** button
- edit the dialog as shown below in Fig. 6 : set Output Grid to SHWVSIZE.GRD.
- set X # of Nodes to 839, and set Y # of Nodes to 126, i.e. to the same values as for PWAVIT50.GRD. Then click on **OK** to generate the resampled grid file :

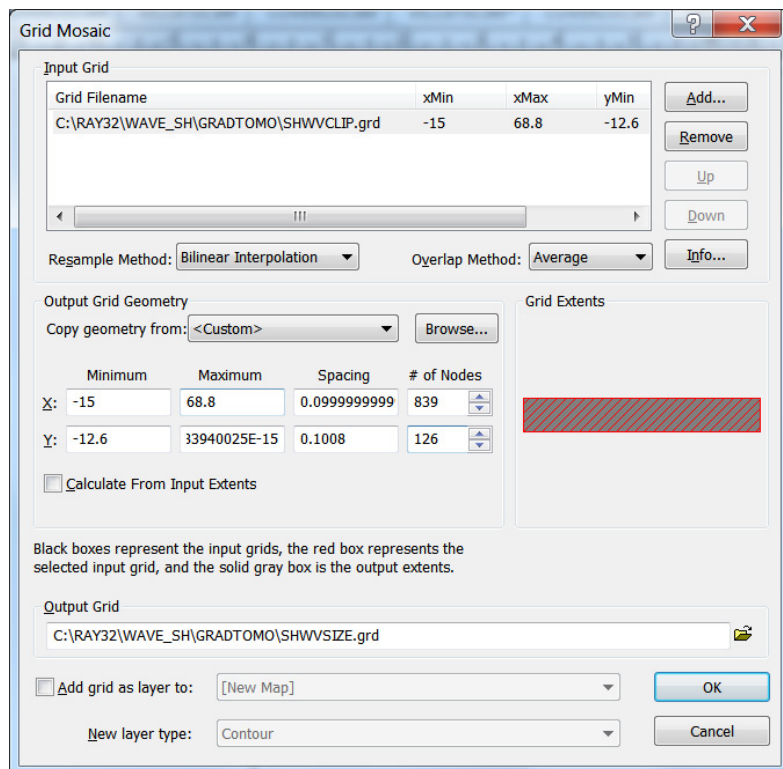


Fig. 6 : resample clipped S-wave grid to P-wave grid cell size of 0.1m using Mosaic dialog.

- select *File|New|Plot Document*
- enter search term **Math** at top and select topmost match **Math**
- click button Add Grids and select PWAVIT50.GRD (Fig. 7)
- click Add Grids again and select SHWVSIZI.GRD
- set Output Grid to C:\RAY32\WAVE_SH\GRADTOMO\RATIO.GRD
- set “Enter a function of the form f(A,B) “ to A / B and click on OK. Confirm the following prompt to generate a grid containing the ratio of P-wave velocity to S-wave velocity :

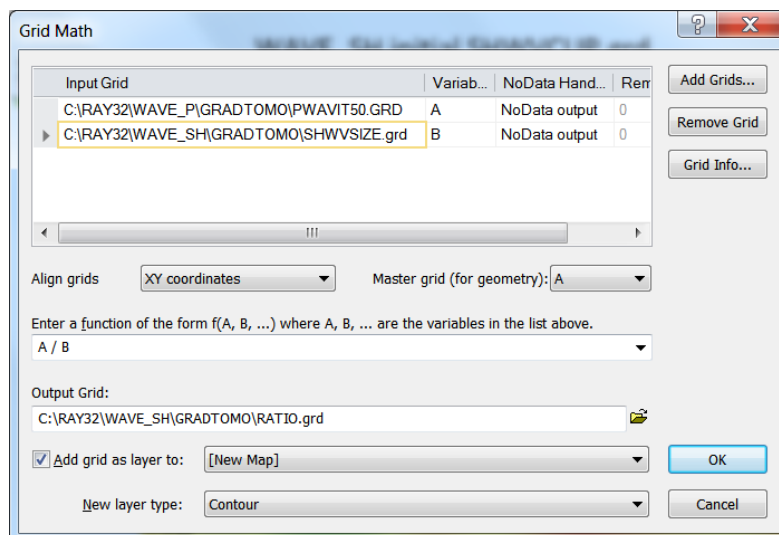


Fig 7 : determine ratio of P-wave grid to S-wave grid and save to RATIO.GRD

- in our Grid menu select command Surfer plot Limits
- check new option **Use data limits** and click OK button (Fig. 18)
- in same Grid menu select new command **Image Surfer .GRD file without .PAR file**
- select C:\RAY32\WAVE_SH\GRADTOMO\RATIO.GRD to obtain Fig. 8 showing the velocity ratio

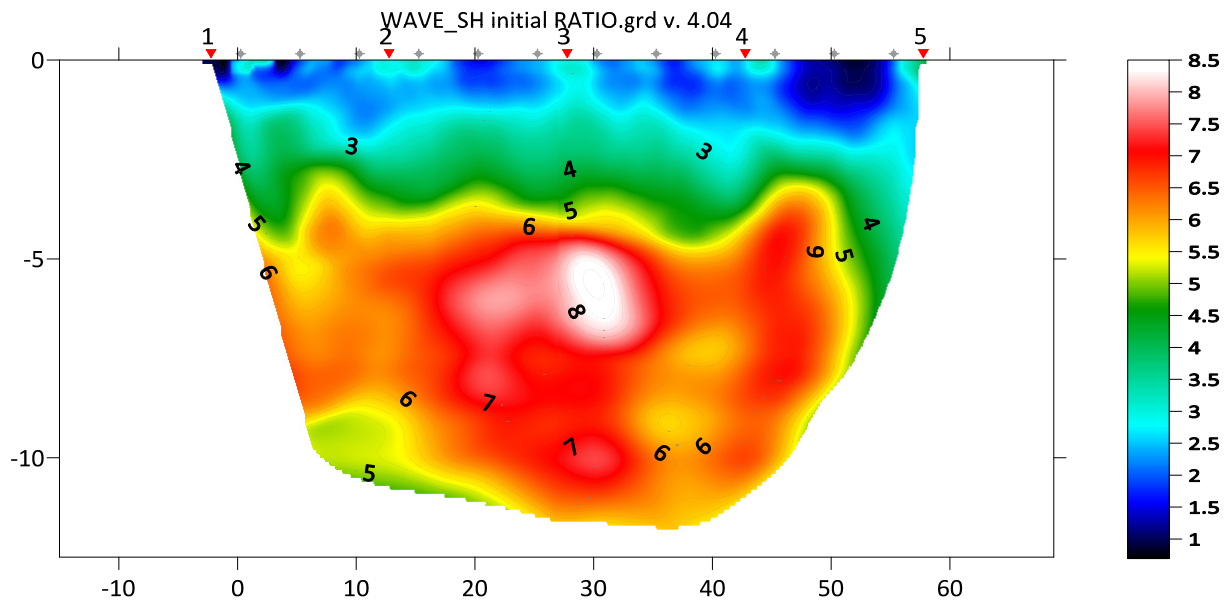


Fig. 8 : image P-wave to S-wave velocity ratio obtained as in Fig. 7. Compare to our [original POISSON tutorial](#).

- select *File|New|Plot Document*
- enter search term **Math** at top and select topmost match **Math**
- click button Add Grids and select PWAVIT50.GRD (Fig. 9)
- click Add Grids again and select SHWVSIZE.GRD
- set Output Grid to C:\RAY32\WAVE_SH\GRADTOMO\POISSON.GRD
- set “Enter a function of the form f(A,B)” to $(\text{pow}(A,2) - 2*\text{pow}(B,2)) / (2*(\text{pow}(A,2) - \text{pow}(B,2)))$ and click on OK
- confirm the prompt to generate a grid containing the Dynamic Poisson’s ratio (Fig. 10)

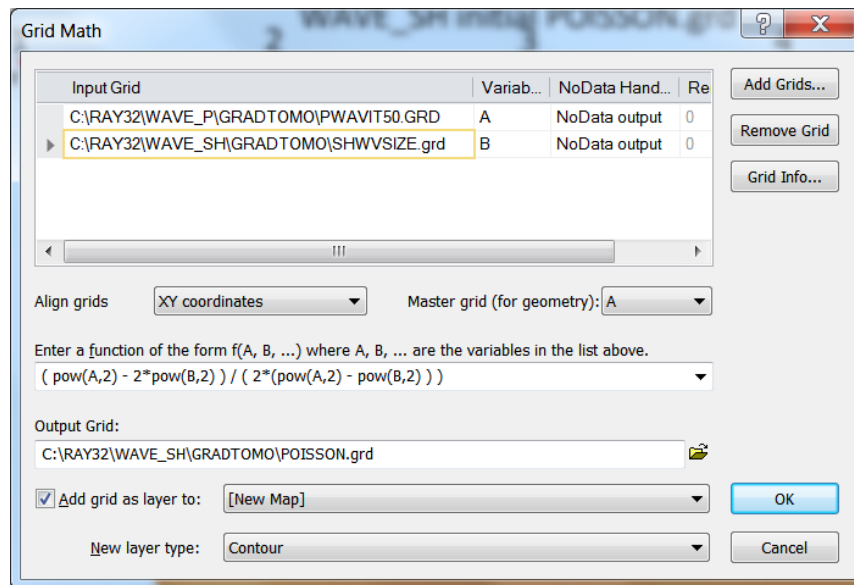
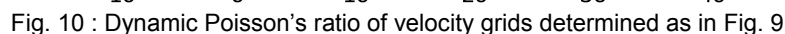


Fig 9 : determine dynamic Poisson’s ratio of velocity grids and save to POISSON.GRD

- in our Grid menu select command Image Surfer .GRD file without .PAR file
- select C:\RAY32\WAVE_SH\GRADTOMO\POISSON.GRD to obtain Fig. 10 showing the dynamic Poisson’s ratio
- in Surfer plot / Contents tab select item Color Relief-POISSON.GRD (Fig. 11 at left)
- in Properties window / General tab click button ... at end of Colors row
- uncheck option “Use data limits”. Set Minimum to 0 and Maximum to 0.7. Of course the real maximum value is 0.5, but the display looks better with 0.7.
- move the “Color spectrum” nodes for yellow and red closer together, to obtain a display as in Fig. 10



The abnormally low Poisson's ratio (approaching 0) just below the topography at the right end of the section can be explained by too early picks for traces 10 & 11 of shot nr. 5 of line WAVE_SH. The corresponding high velocity anomaly is clearly visible in the earlier S-wave velocity tomogram.



We thank Dr. Anibaldi at Methodo s.r.l. for making available in 2004 above consistently picked .ASC profiles.

Edit Profile

Line ID: Time of Acquisition: Date: Time:

Line type:

Job ID:

Instrument:

Client:

Company:

Observer:

Note:

Time of Processing: Date: Time:

Units: Sort: Const:

Station spacing [m]: ☐ Left handed coordinates

Min. horizontal separation [%]:

Profile start offset [m]:

☒ Force grid cell size Cell size [m]:

☐ Force first receiver station number for profile First receiver [station number]: ☐ Force first receiver

☐ Extrapolate starting models and WET tomograms Extrapolate [station spacings]: ☐ Extrapolate tomograms

☐ Add borehole lines for WET tomography

Borehole 1 line:

Borehole 2 line:

Borehole 3 line:

Borehole 4 line:

Fig. 12 : Header|Profile

Replace gradient velocity profile

Force limits of starting model grid

☒ Force grid limits

Grid bottom elevation: Grid top elevation [m]:

Left limit of grid [m]: Right limit of grid [m]:

Replace computed velocity gradient with user velocity profile

☐ Replace velocity active

Select velocity profile:

Force velocity for constant-velocity starting model

☐ Force constant velocity

Forced velocity:

Fig. 14 (above) : Smooth invert|Custom 1D-gradient velocity profile for profile WAVE_P

Fig. 15 (right) : Grid|Surfer plot Limits for profile WAVE_P

Edit WDVS (Zelt & Chen 2016)

Edit parameters for wavelength-dependent velocity smoothing

☐ Use WDVS for forward modeling of traveltimes

☒ fast WDVS : less accurate mapping of scan line nodes to grid nodes

☒ add nodes once only with overlapping scan lines for velocity averaging

☐ add all velocity nodes within WDVS area with radius of one wavelength

☐ pad WDVS area border with one grid cell

WDVS frequency: [Hz]

Angle increment between scan lines: [Degree]

Regard nth node along scan line: [node]

Parameters for Cosine-Squared weighting function (Chen and Zelt 2012)

a : Cosine argument power: [power]

b : Cosine-Squared power: [power]

Modify WET smoothing mode : discard after forward modeling

☒ discard WET smoothing and WDVS smoothing after modeling

☐ restore WET smoothing and discard WDVS smoothing only

Fig. 13 : Model|WDVS Smoothing

Edit Surfer plot limits

Plot Limits

☒ Plot limits active ☐ Use data limits

Min. offset: [m]

Max. offset: [m]

Min. elevation: [m]

Max. elevation: [m]

Min. velocity: [m/sec.]

Max. velocity: [m/sec.]

Plot Scale

☐ Proportional XY Scaling

☐ Page unit centimeter. Uncheck for inch.

X Scale length: [inch]

Y Scale length: [inch]

Color Scale

☒ Adapt color scale

Scale height: [inch]

Velocity interval: [m/sec.]

Coverage: [paths/pixel]

Receiver labeling

First station: [station no.]

Station interval: [station no.]

☐ Use station index or station no. offset

Edit WET Wavepath Eikonal Traveltime Tomography Parameters

Specify initial velocity model
Select C:\RAY32\WAVE_P\GRADTOMO\GRADIENT.GRD

Stop WET inversion after
Number of WET tomography iterations : 50 iterations
☐ or RMS error gets below 2.0 percent
☐ or RMS error does not improve for n = 20 iterations
☐ or WET inversion runs longer than 100 minutes

WET regularization settings
Wavepath frequency : 50.00 Hz Iterate
Ricker differentiation [-1:Gaussian,-2:Cosine] -1 times
Wavepath width [percent of one period] : 7.0 percent Iterate
Wavepath envelope width [% of period] : 2.0 percent
Min. velocity 10 Max. velocity 6000 m/sec.
Width of Gaussian for one period [SD] : 3.0 sigma

Gradient search method
☒ Steepest Descent ☐ Conjugate Gradient

Conjugate Gradient Parameters
CG iterations 10 Line Search iters. 2
Tolerance 0.001 Line Search tol. 0.0010
Initial step 0.10 ☐ Steepest Descent step

Edit velocity smoothing Edit grid file generation
Start tomography processing Reset Cancel

Edit WET Tomography Velocity Smoothing Parameters

Determination of smoothing filter dimensions
☒ Full smoothing after each tomography iteration
☐ Minimal smoothing after each tomography iteration
☐ Manual specification of smoothing filter, see below

Smoothing filter dimensions
Half smoothing filter width : 18 columns
Half smoothing filter height : 1 grid rows

Suppress artefacts below steep topography
☒ Adapt shape of filter. Uncheck for better resolution.

Maximum relative velocity update after each iteration
Maximum velocity update : 25.00 percent

Smooth after each nth iteration only
Smooth nth iteration : n = 1 iterations

Smoothing filter weighting
☐ Gaussian ☒ Uniform ☐ No smoothing
Used width of Gaussian 1.0 [SD]
Uniform central row weight 1.0 [1..100]

Smooth velocity update before updating tomogram
☒ Smooth update ☐ Smooth nth ☒ Smooth last

Damping of tomogram with previous iteration tomogram
Damping 0.000 ☐ Damp before smoothing

Accept parameters Reset parameters

Fig. 16 : WET Tomo|Interactive WET tomography main dialog for WAVE_P (left). Edit velocity smoothing (right).

Edit WET Wavepath Eikonal Traveltime Tomography Parameters

Specify initial velocity model
Select C:\RAY32\WAVE_SH\GRADTOMO\GRADIENT.GRD

Stop WET inversion after
Number of WET tomography iterations : 50 iterations
☐ or RMS error gets below 2.0 percent
☐ or RMS error does not improve for n = 20 iterations
☐ or WET inversion runs longer than 100 minutes

WET regularization settings
Wavepath frequency : 50.00 Hz Iterate
Ricker differentiation [-1:Gaussian,-2:Cosine] -1 times
Wavepath width [percent of one period] : 21.0 percent Iterate
Wavepath envelope width [% of period] : 0.0 percent
Min. velocity 10 Max. velocity 6000 m/sec.
Width of Gaussian for one period [SD] : 3.0 sigma

Gradient search method
☒ Steepest Descent ☐ Conjugate Gradient

Conjugate Gradient Parameters
CG iterations 10 Line Search iters. 2
Tolerance 0.001 Line Search tol. 0.0010
Initial step 0.10 ☐ Steepest Descent step

Edit velocity smoothing Edit grid file generation
Start tomography processing Reset Cancel

Edit WET Tomography Velocity Smoothing Parameters

Determination of smoothing filter dimensions
☒ Full smoothing after each tomography iteration
☐ Minimal smoothing after each tomography iteration
☐ Manual specification of smoothing filter, see below

Smoothing filter dimensions
Half smoothing filter width : 9 columns
Half smoothing filter height : 1 grid rows

Suppress artefacts below steep topography
☒ Adapt shape of filter. Uncheck for better resolution.

Maximum relative velocity update after each iteration
Maximum velocity update : 25.00 percent

Smooth after each nth iteration only
Smooth nth iteration : n = 1 iterations

Smoothing filter weighting
☐ Gaussian ☒ Uniform ☐ No smoothing
Used width of Gaussian 1.0 [SD]
Uniform central row weight 1.0 [1..100]

Smooth velocity update before updating tomogram
☒ Smooth update ☐ Smooth nth ☒ Smooth last

Damping of tomogram with previous iteration tomogram
Damping 0.000 ☐ Damp before smoothing

Accept parameters Reset parameters

Fig. 17 : WET Tomo|Interactive WET tomography main dialog for WAVE_SH (left). Edit velocity smoothing (right).

Edit Surfer plot limits

Plot Limits

☒ Plot limits active: ☐ Use data limits

Min. offset: -15.000 [m]

Max. offset: 68.750 [m]

Min. elevation: -12.500 [m]

Max. elevation: 0.000 [m]

Min. velocity: 100 [m/sec.]

Max. velocity: 350 [m/sec.]

Plot Scale

☐ Proportional XY Scaling

☐ Page unit centimeter. Uncheck for inch.

X Scale length: 6.000 [inch]

Y Scale length: 3.000 [inch]

Color Scale

☒ Adapt color scale

Scale height: 3.000 [inch]

Velocity interval: 50 [m/sec.]

Coverage: 5 [paths/pixel]

Receiver labeling

First station: 1 [station no.]

Station interval: 1 [station no.]

☐ Use station index or station no. offset

OK
Cancel
Reset
Reset to grid
Redisplay grid

Fig. 18 (left) : *Grid|Surfer plot Limits* for line WAVE_SH

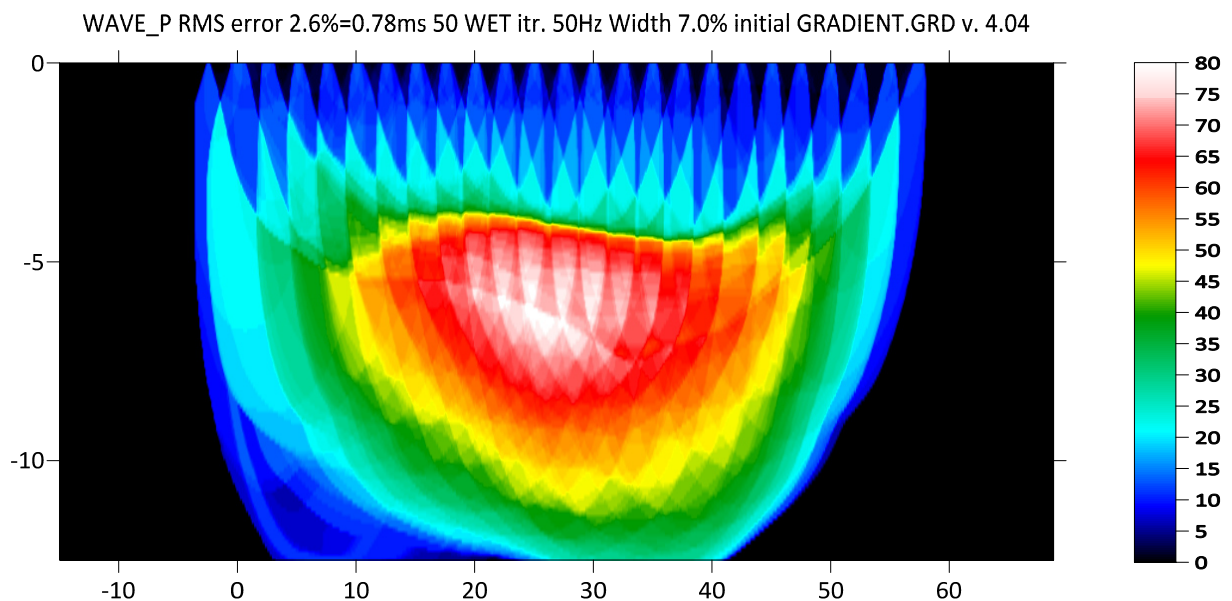
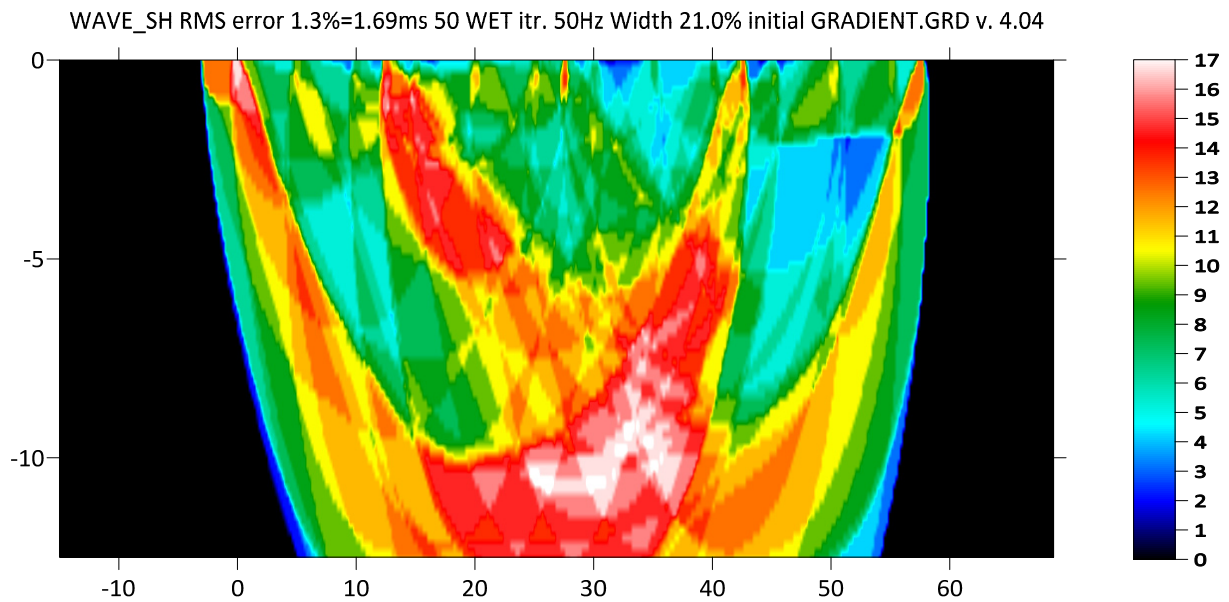


Fig. 19 : WET wavepath coverage plot line WAVE_P obtained with Fig. 1. Unit is wavepaths per pixel.



See also our [original tutorial](#) created in 2004 and edited in 2009.

Here is the Dropbox link to [profile folder for line WAVE_P](#) .

Here is the Dropbox link to [profile folder for line WAVE_SH](#) .

Next we show how to plot your reciprocal traveltimes 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). See [Whiteley J. et al. 2020](#) : Landslide monitoring using seismic refraction tomography – The importance of incorporating topographic variations :

- select **Trace|Export reciprocal traveltimes and update database**
- click button *Select error file* and click *Save* button (Fig. 23)
- 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 4.04 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 for current shot gather with arrow-left and arrow-right keys
- if a reciprocal pick was matched to the current trace then this is plotted as a green dot on the trace
- also we show **Reciprocal Shot/Channel** and **Reciprocal offset[m]/CMP** in status bar at bottom of window if a reciprocal pick is available in the .ERR file for the current trace

Fig. 21 shows reciprocal traveltimes for profile WAVE_P. Fig. 22 shows reciprocal traveltimes for profile WAVE_SH.

The Shot CM breaks display was described by [Brueckl 1987](#) : The Interpretation of Traveltime Fields in Refraction Seismology . First breaks for shot-sorted traveltimes are displayed at CMP station positions instead of receiver station positions.

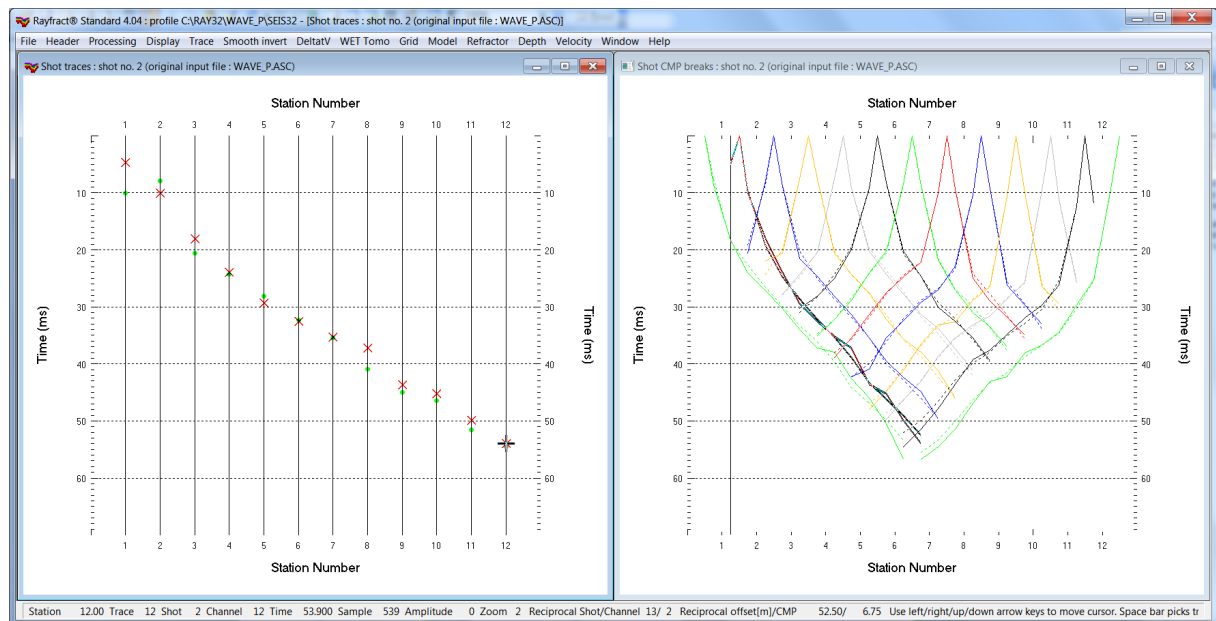


Fig. 21 : *Trace|Shot gather* (left). Red crosses are your traveltime picks. Green dots are your reciprocal picks matched to traces via *Trace|Export reciprocal errors and update database*. *Refractor|Shot CMP breaks* (right).

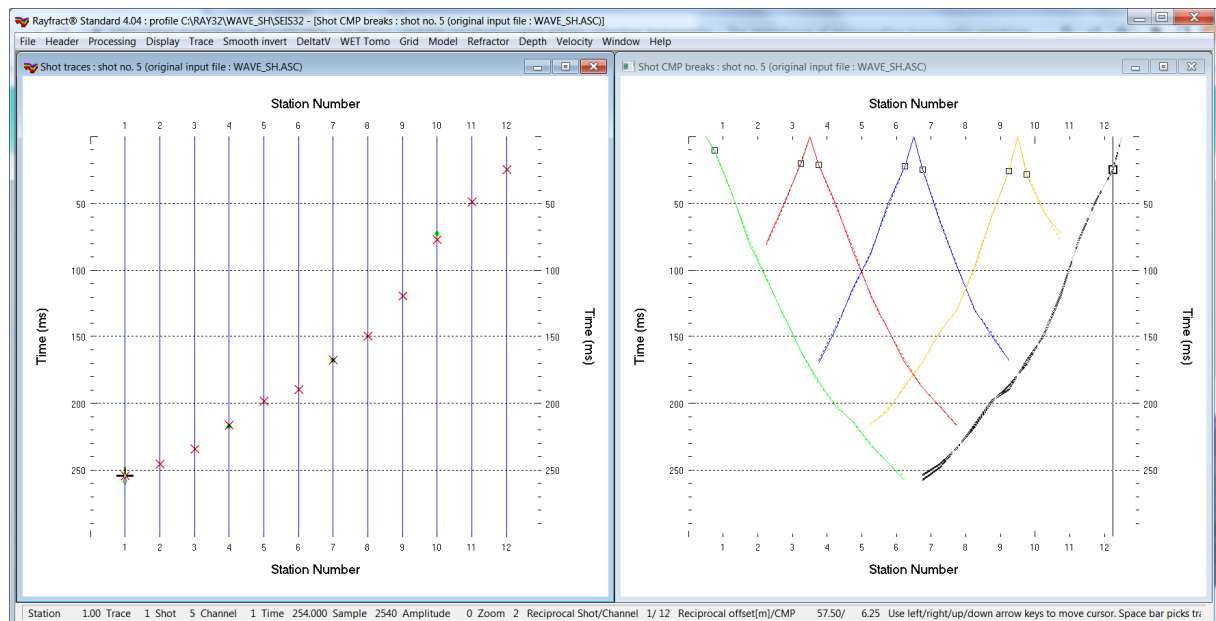


Fig. 22 : *Trace|Shot gather* (left). Red crosses are your traveltime picks. Green dots are your reciprocal picks matched to traces via *Trace|Export reciprocal errors and update database*. *Refractor|Shot CMP breaks* (right).

Edit parameters for reciprocal error file (Jim Whiteley 2020)

Select output.ERR file

Select error file

Sort lines in .ERR file by decreasing reciprocal error

☐ Sort .ERR lines by relative reciprocal error

☐ Sort .ERR lines by absolute reciprocal error in ms

☒ Sort .ERR lines by offset and CMP (as in Trace|Offset gather display)

CMP interval for mapping common-offset sorted traces to same midpoint

Reciprocal CMP interval [station no.] to search for reciprocal traces

Fig. 23 : *Trace|Export reciprocal errors and update database*.

Increase parameter *Reciprocal CMP interval* for wide shot spacing to 1.0 or 2.0 station numbers so approximately reciprocal trace pairs can still be determined. This may not work in case of strong topography or with strongly undulating refractors.

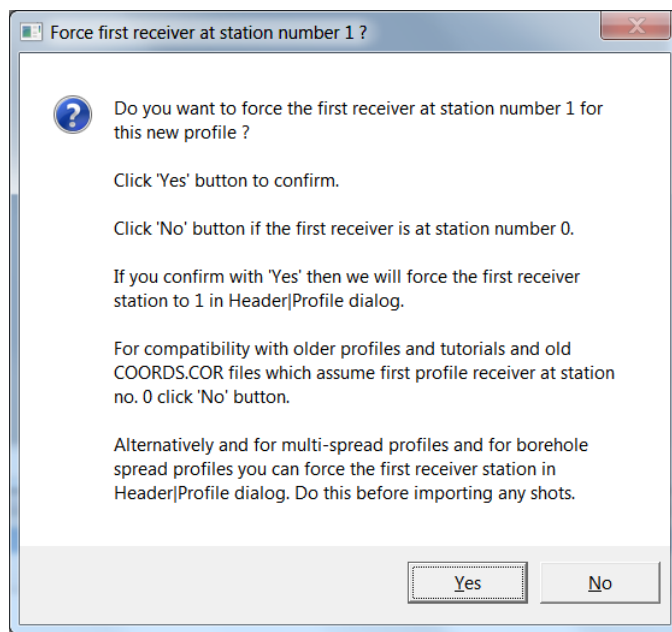


Fig. 24 : click Yes button to force profile start / first receiver station number at station no. 1.

For compatibility with older profiles and tutorials and old COORDS.COR files which assume first profile receiver at station no. 0 click No button.

Alternatively force the first receiver station in Header|Profile dialog. Do this before importing any shots via File|Import Data dialog.

We thank Dr. Anibaldi at Methodo s.r.l. for making available in 2004 above consistently picked .ASC profiles.