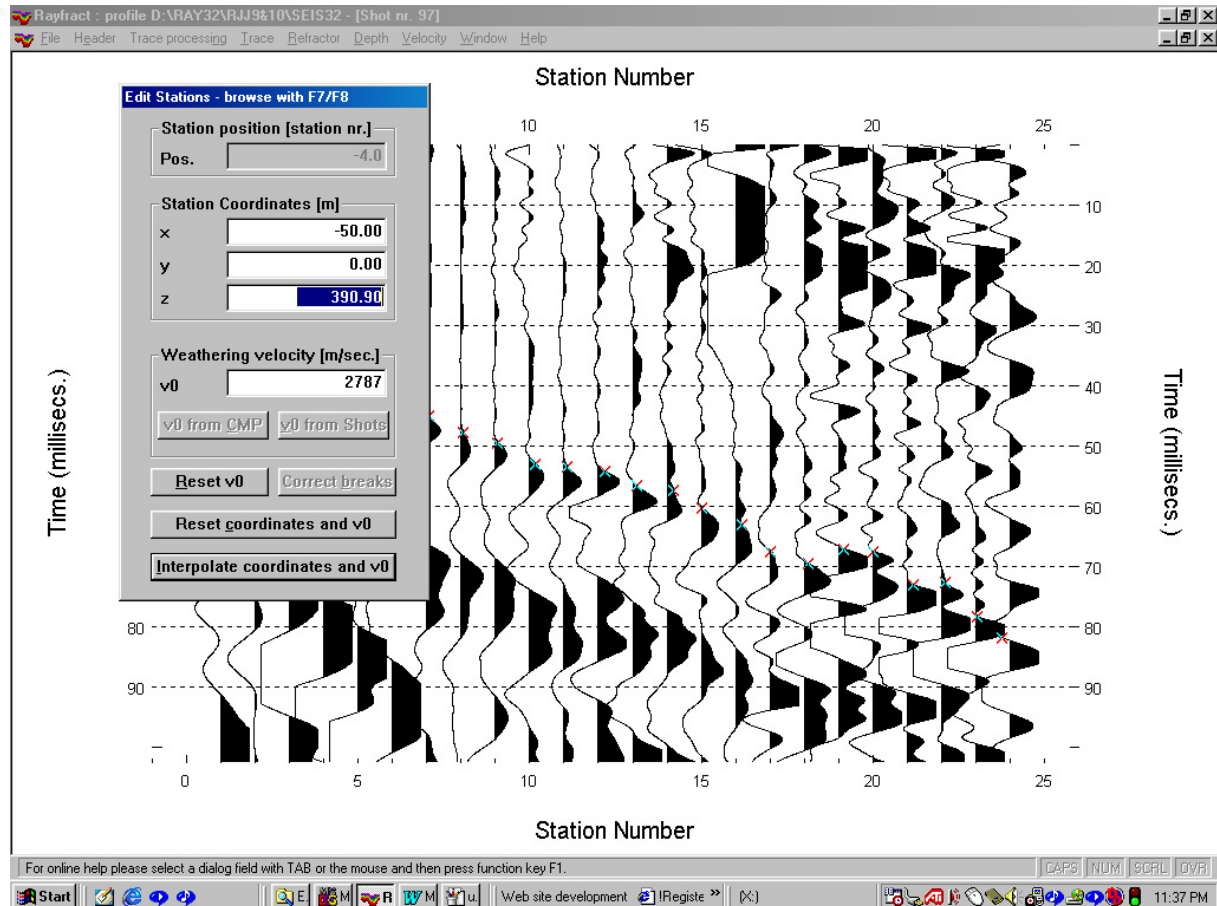


WET inversion of profile RJJ9TO10 in 2000 and in 2021 with version 4.01 with WDV5 enabled :

This tutorial assumes that you have already imported successfully shots 97 to 107, into a newly created Rayfract profile. Reopen that profile with your Rayfract software (File|Open). Verify that the Receiver spacing (Header|Profile) is set to 10 meters.

Now open the Station & Shotpoint editor with Header|Station. Then correct the z (elevation) at station nr. -4 to a value of 390.9 meters, as shown here :



Now page forward once with F8. Confirm the prompt regarding change of the coordinates (for station nr. -4). Then enter a z value of 378.1 meters, for station nr. 0. Now page to the last profile station with ALT-END, and enter a z value of 401 meters, for station nr. 29. Then page one station backward with F7. Now enter a z value of 387.3, for station 24. Then close the Station Editor by hitting RETURN once or by clicking on button Interpolate Coordinates and v0.

Now make sure that Depth|Output Horizontal Offset of CMP pos. in meters is checked. If not so, select that menu item to check it. Now initiate the Delta-t-V inversion with Depth|CMP Velocity vs. Depth (Delta-t-V)... . Accept the default processing parameters by hitting RETURN. The routine will generate a file named DELTATV.CSV and another file named DELTATV.PAR.

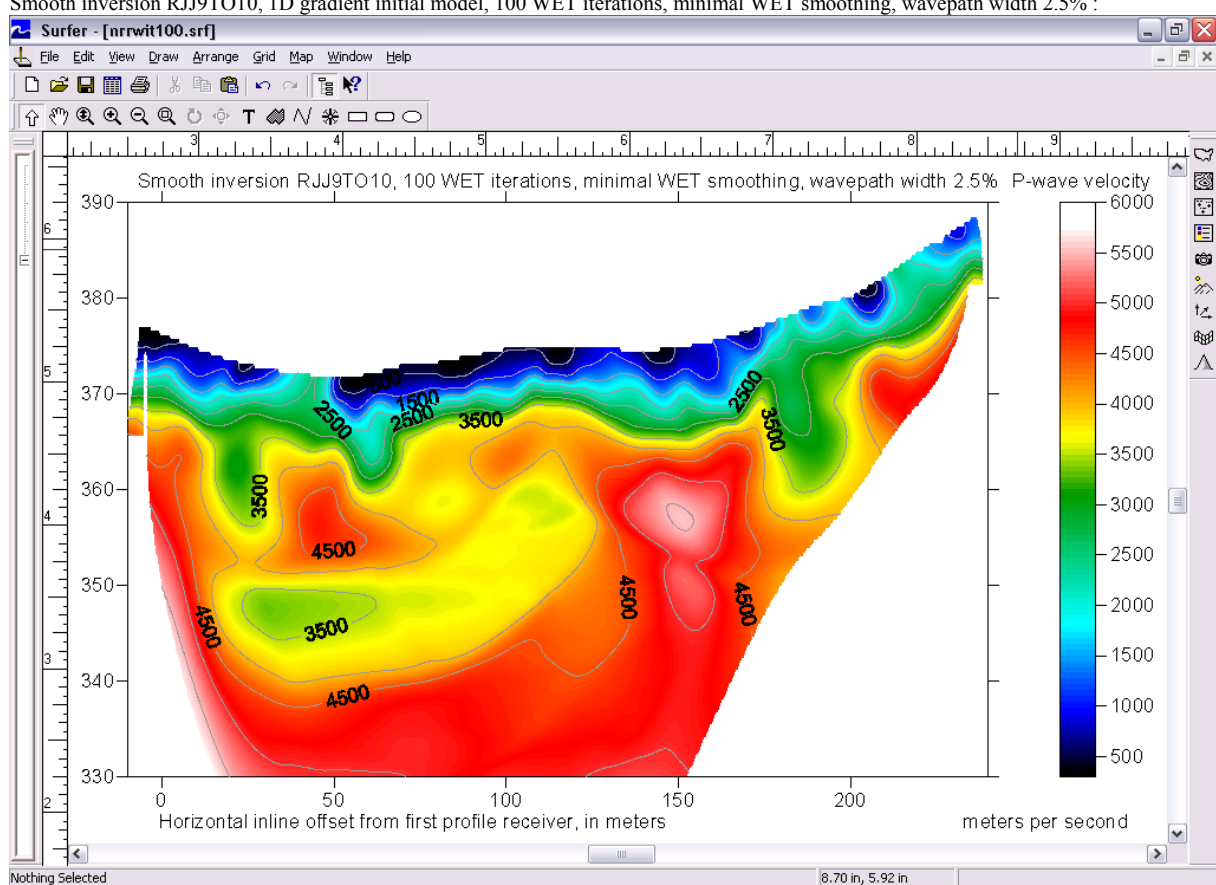
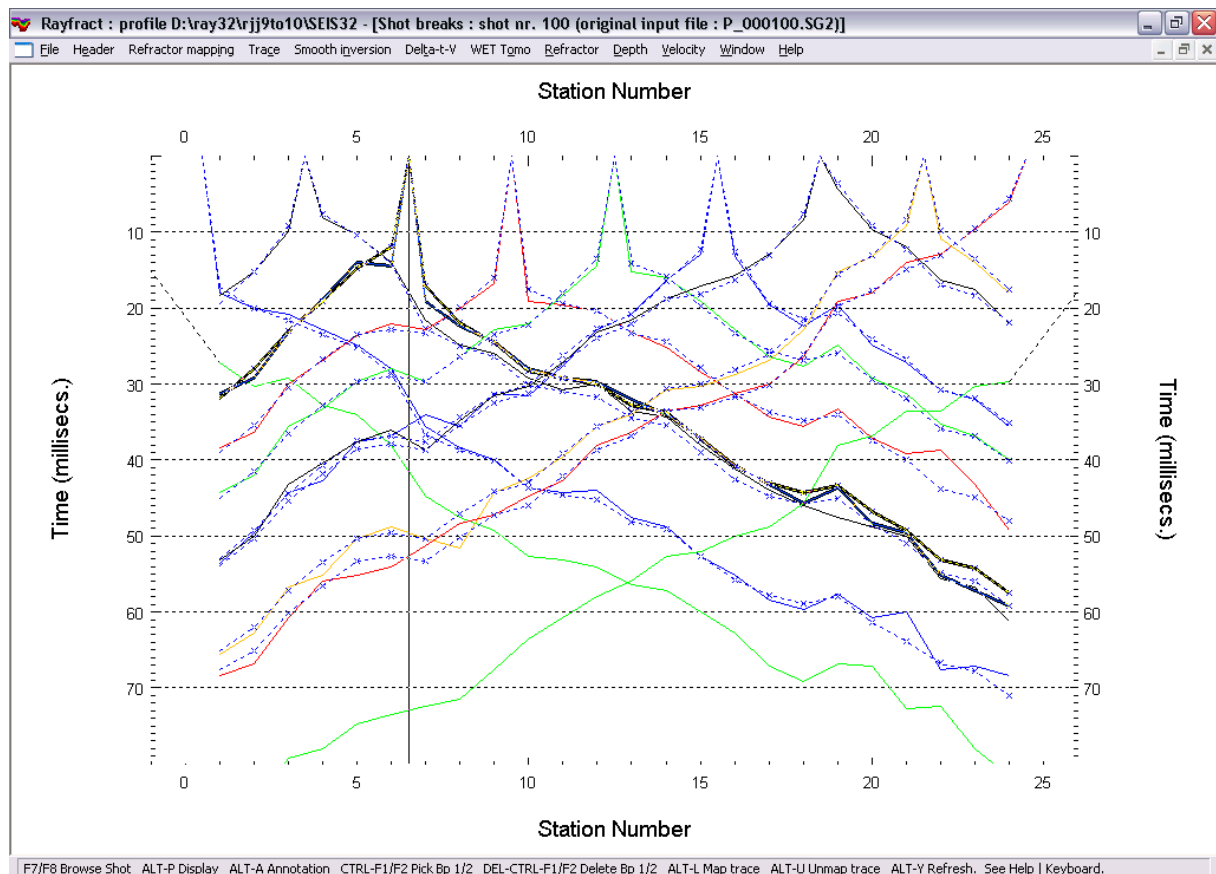
Now start up Surfer and select Grid|Data. Then select file \RAY32\RRJ9TO10\DELTATV.CSV. Change values for the two edit fields in column „# of Lines“ for rows „X Direction“ and „Y Direction“ to 800 and 205, respectively. Note the high resolution which makes sense in order to optimally image the very shallow and sharp contact zone between overburden and basement, as visible on the traveltime curves below. Now click on the OK button, of the „Scattered Data Interpolation“ dialog.

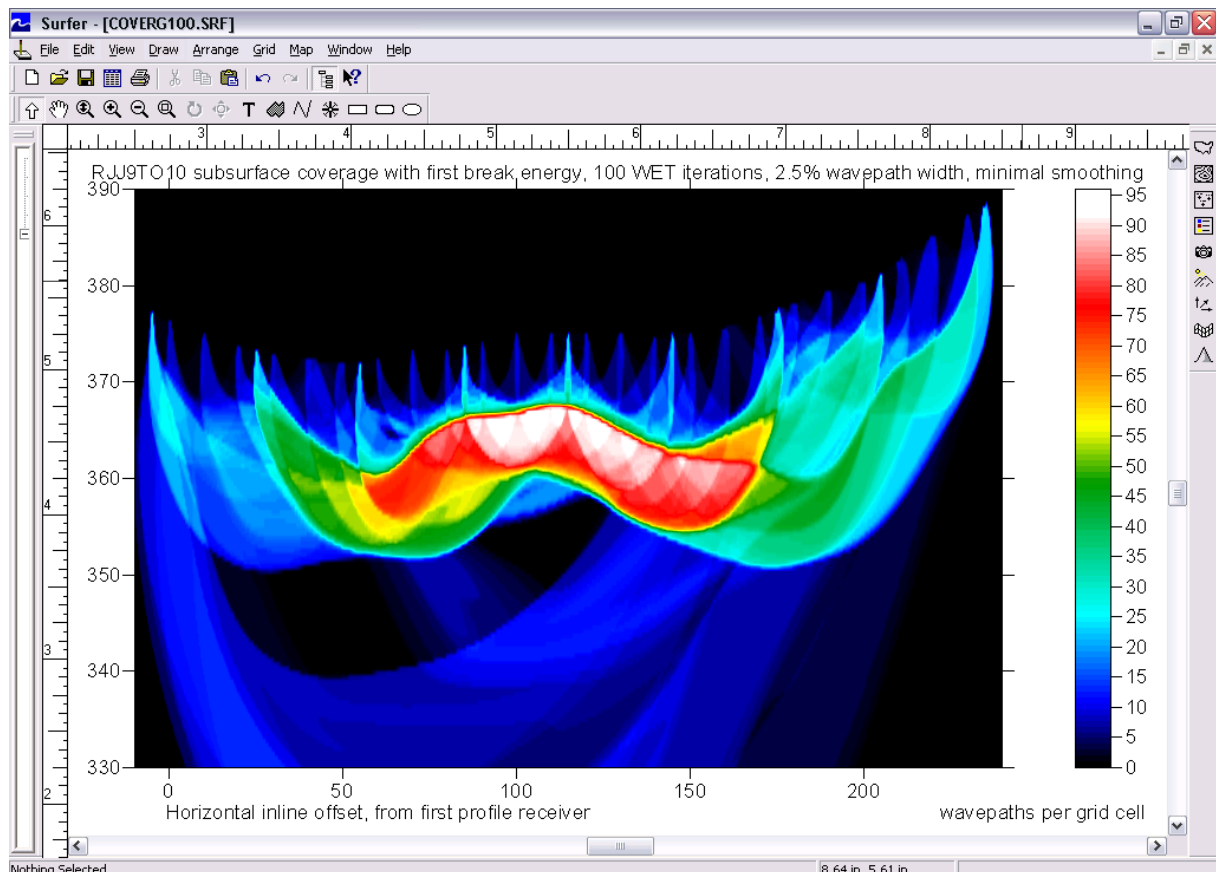
Once Surfer announces with three beeps that the gridding / kriging of the data (Delta-t-V output) has been done, select Grid|Blank... and then file \RAY32\RRJ9TO10\DELTATV.GRD. Then select file \RAY32\RRJ9TO10\SEIS32.BLN as Surfer Boundary File. This file specifies the line geometry in Surfer compatible format. Now specify \RAY32\RRJ9TO10\DELTATV.GRD as output file. Confirm the prompt to overwrite the existing DELTATV.GRD.

Refining Delta-t-V velocity model with tomography processing

Now select Depth|Tomography processing of traveltimes Then click on button „Select“ and specify the DELTATV.GRD file as generated above. Activate check box „Correct basement velocities for systematic Delta-t-V error“ in addition to „Correct all velocities for systematic Delta-t-V error“. Click on button „Accept parameters“. Now click on button „Edit velocity smoothing“ and then select radio button „Minimal smoothing after each tomography iteration“. Click on „Accept parameters“. Click on button „Edit grid file generation“ and enable option „Write section coverage grids after each iteration“. Click on „Accept parameters“. Set parameter „Number of WET tomography iterations“ to 20. Now click on button „Start tomography processing“.

Once the tomography processing has terminated after 20 iterations and about 10 minutes of processing time (on Pentium III processor at 500 MHz), select Refractors|Shot breaks to display picked and synthesized traveltimes (blue crosses) together as shown below :





Subsurface coverage with first break energy, 1D gradient initial model, 100 WET iterations, 2.5% wavepath width, minimal smoothing.

The SEG-2 formatted binary trace data files, ABEM .FIR first break files and the .COR coordinate file are available on our web site as archive

<http://rayfract.com/tutorials/rjj9to10.zip> .

Start by creating the profile (as described in e.g. line14.pdf, as available in TUTORIAL.ZIP on our web site), with a receiver spacing of 10 metres and profile database name / DOS subdirectory name RJJ9TO10. Then create a directory named \RAY32\RJJ9TO10\INPUT. Now copy rjj9to10.zip as downloaded via above link into that INPUT subdirectory and unzip it. Then import the .SG2 binary trace data files, with the default spread type of 24 receivers. The ABEM .FIR first break files will be imported automatically at the same time. Then import the coordinate file rjj9to10.cor, with File|Update Station Coordinates... . Now proceed as outlined in this tutorial, from the beginning.

For theoretical background of our WET tomography algorithm, see

[Wavepath eikonal traveltime inversion: Theory](#) (Gerard T. Schuster and Aksel Quintus-Bosz 1993, GEOPHYSICS VOL. 58 NO. 9 September 1993, P. 1314 – 1323) .

For more information regarding our Rayfract™ software, please go to our web site

<http://rayfract.com> .

Below we show reprocessing of this data with our version 4.01 software with WDVS enabled, done in Jan 2021. We forced the *grid cell size* to 0.5m in *Header|Profile* to speed up WDVS enabled WET inversion.

WDVS Wavelength-Dependent Velocity Smoothing is described in

[Zelt, C. A. and J. Chen, Frequency-dependent traveltime tomography for near-surface seismic refraction data, Geophys. J. Int., 207, 72-88, 2016](#)

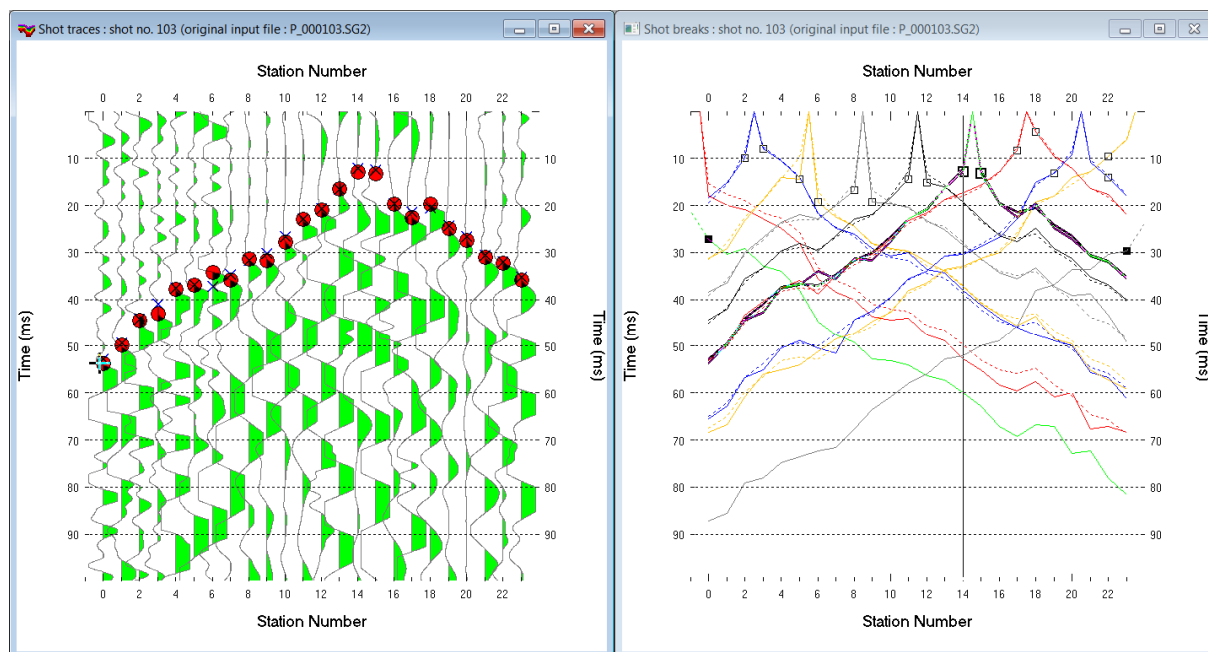


Fig. 1 : Map traces to refractors in Refractor|Shot breaks (right). Pick first and second branch points with CTRL+F1 and CTRL+F2. Press ALT+L to map traces to refractors.

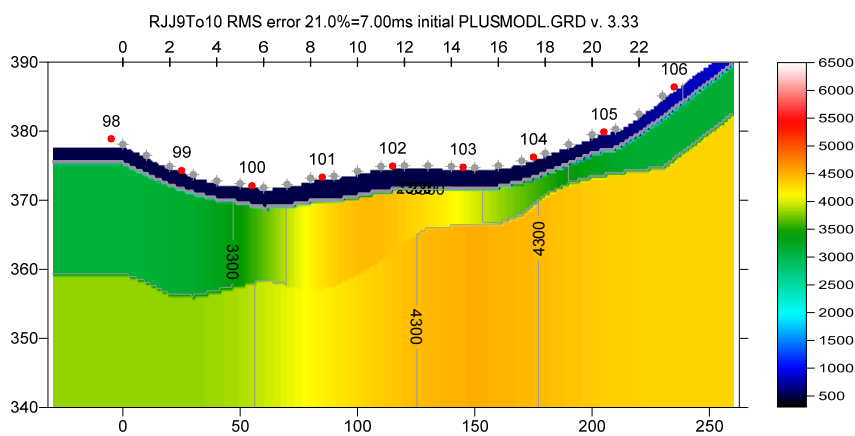


Fig. 2 : Plus-Minus method starting model obtained with Depth|Plus-Minus after mapping traces to refractors as in Fig. 1. Overburden filter 5, Base filter 10 stations.

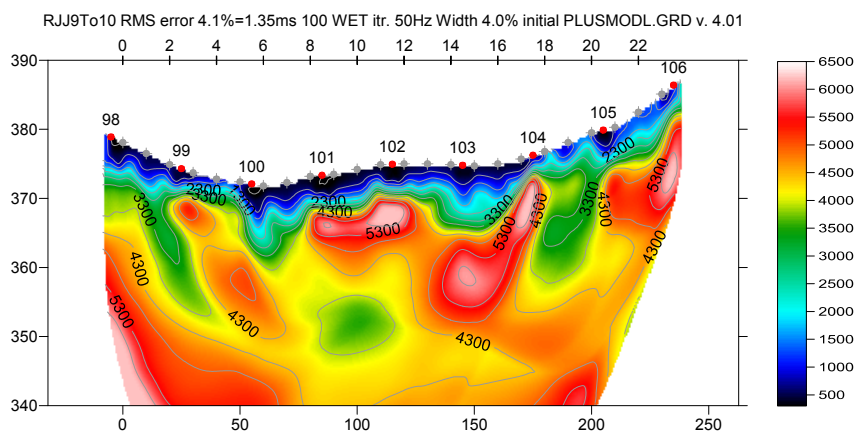


Fig. 3 : 100 Steepest-Descent WET iterations with starting model Fig. 2. Max. WET velocity limited to 6,000 m/s and minimized WET smoothing (Fig. 8). WDV5 engaged at 250Hz (Fig. 7).

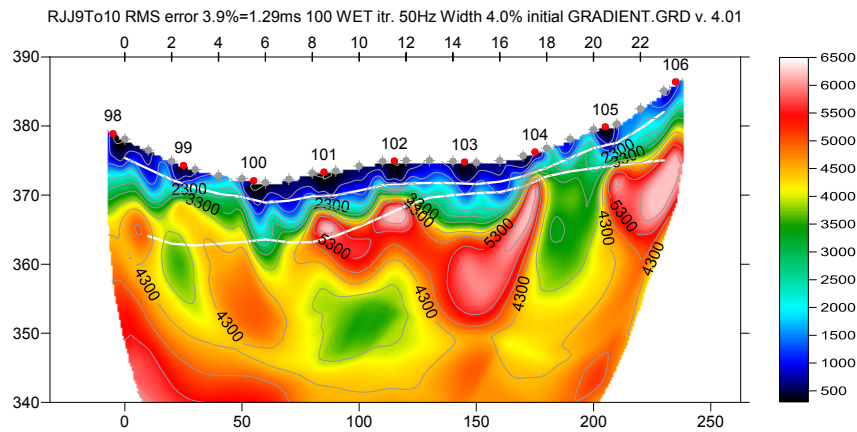


Fig. 4 : 100 Steepest-Descent WET iterations with starting model Fig. 6. Max. WET velocity limited to 6,000 m/s and minimized WET smoothing (Fig. 8). WDV5 engaged at 250Hz (Fig. 7).

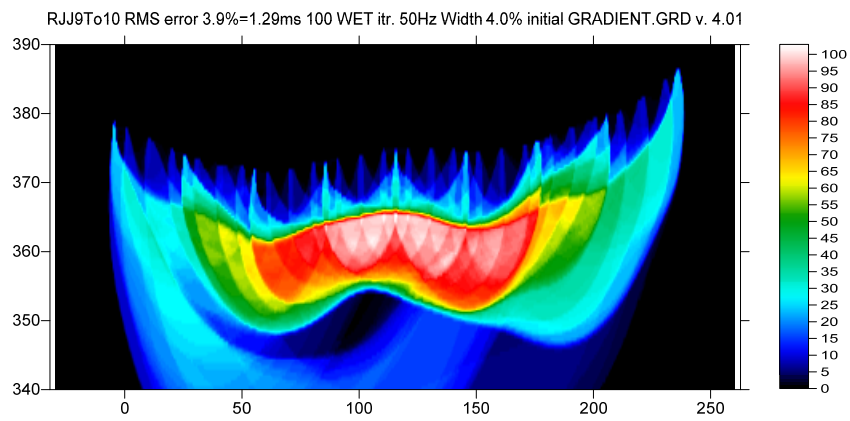


Fig. 5 : WET wavepath coverage plot obtained with Fig. 4. Unit is wavepaths per pixel.

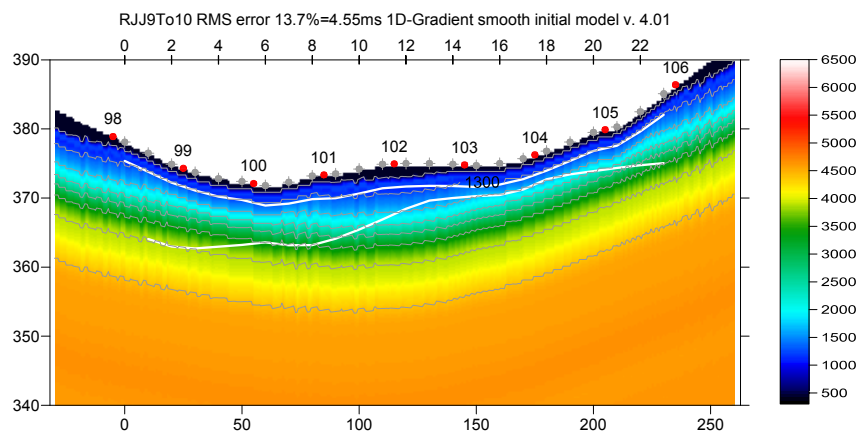


Fig. 6 : Smooth invert[WET with 1D-gradient starting model. Enabled layered XTV inversion.

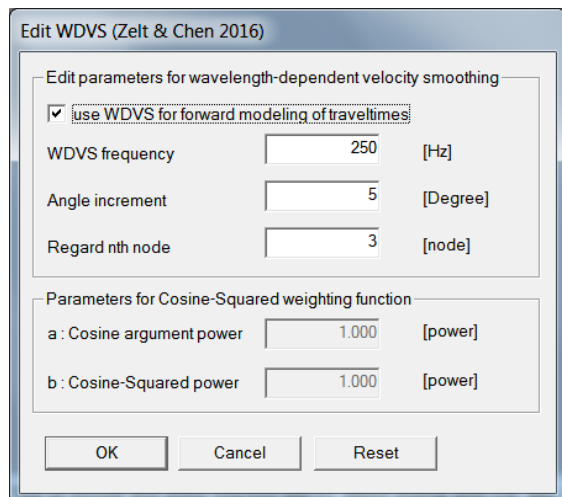


Fig. 7 : Model\WDVS Smoothing. Check Model\Fast WDVS Smoothing.

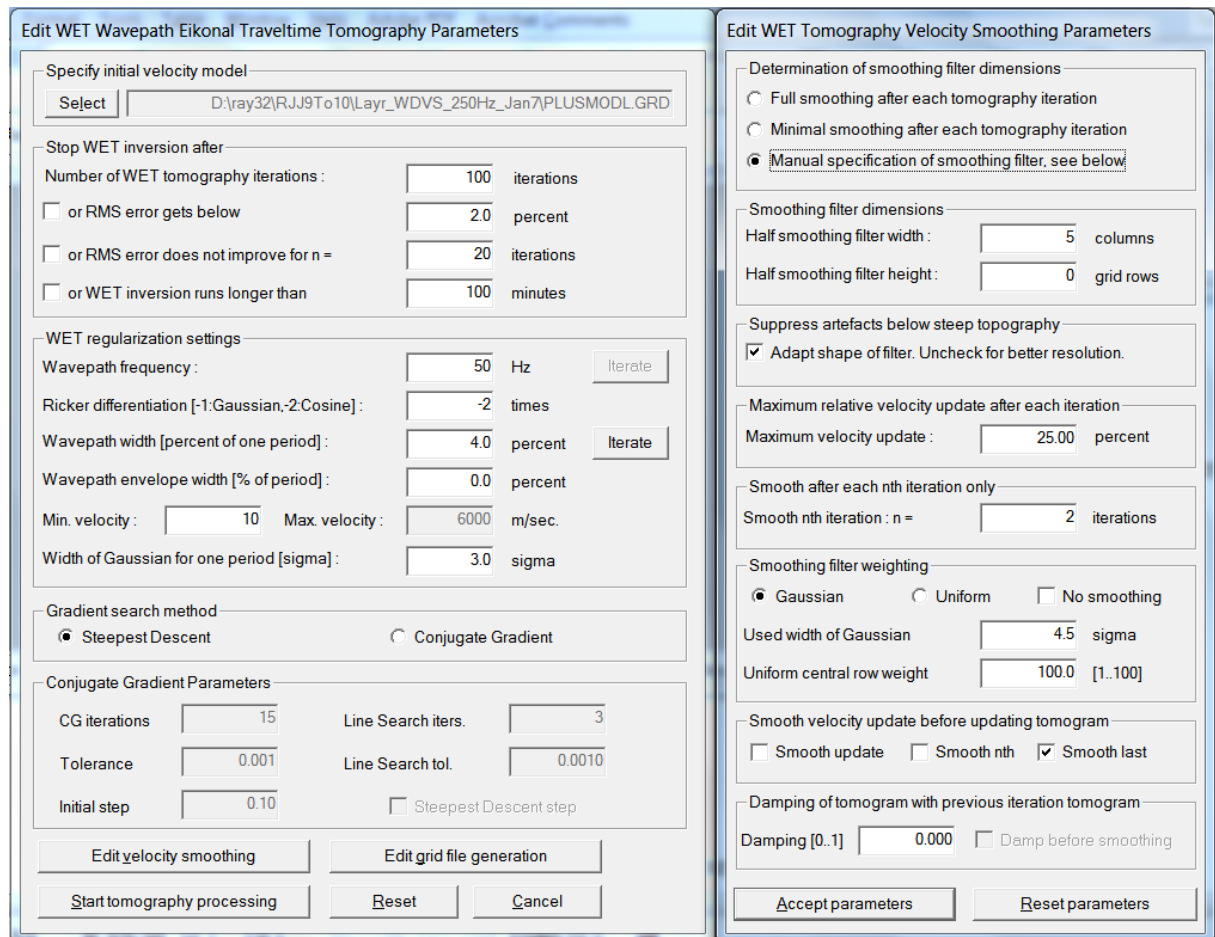


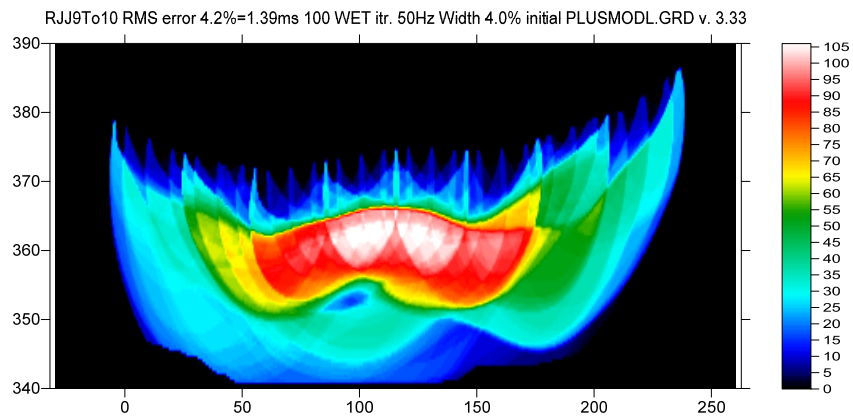
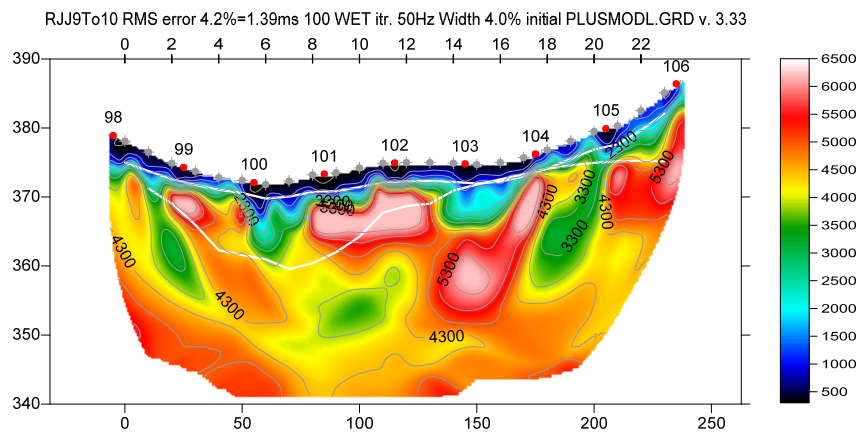
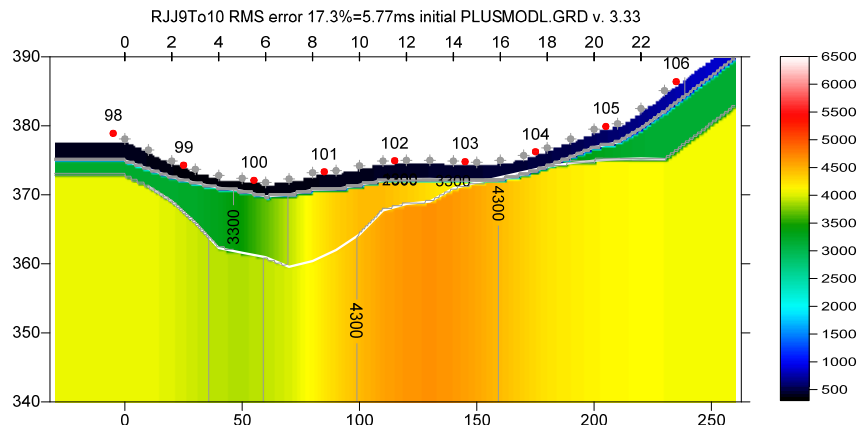
Fig. 8 : WET Tomo|Interactive WET main dialog (left). Edit velocity smoothing (right).

Here we give links to .RAR archives with relevant files for above figures :

SEIS32.* files for Fig. 3 : http://rayfract.com/tutorials/RJJ9To10_seis32_WDVS_250Hz_Jan7_2020.rar

Surfer files for Fig. 3 : http://rayfract.com/tutorials/Layr_WDVS_250Hz_Jan7.rar

Surfer files for Fig. 4 : http://rayfract.com/tutorials/Grad_WDVS_250Hz_Jan7.rar



Edit WET Wavepath Eikonal Traveltime Tomography Parameters

Specify initial velocity model
 D:\ray32\RJJ9To10\Layer_WDVS_SmoothUpdate\PLUSMODL.GRD

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

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

Gradient search method
☒ Steepest Descent ☐ Conjugate Gradient

Conjugate Gradient Parameters
CG iterations Line Search iters.
Tolerance Line Search tol.
Initial step ☐ Steepest Descent step

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 : columns
Half smoothing filter height : 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 : percent

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

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

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

Damping of tomogram with previous iteration tomogram
Damping [0..1] ☐ Damp before smoothing

Fig. 12 : WET Tomo|Interactive WET main dialog (left). Edit velocity smoothing (right).

SEIS32.* profile database files for Fig. 10 :

http://rayfract.com/tutorials/RJJ9To10_seis32_WDVS_SmoothUpdate_Jan6_2020.rar

Surfer files for Fig. 10 :

http://rayfract.com/tutorials/Layr_WDVS_SmoothUpdate_Jan6th_2020.rar

We thank Goran Mitrovic at Civil Engineering Institute of Croatia for making available above data. Here are his comments on the geological setting of this line : „It is indeed a karstified rock, limestone in the substrate at the site in question. Fault zones can be seen laterally on both sides, and the central part of the profile is interesting due to the inversion of velocities related to the fractured zones of larger caverns in some places.”