Import ASCII.ASC & Update header data & Steepest-Descent WET inversion LINE23 v. 5.01 :

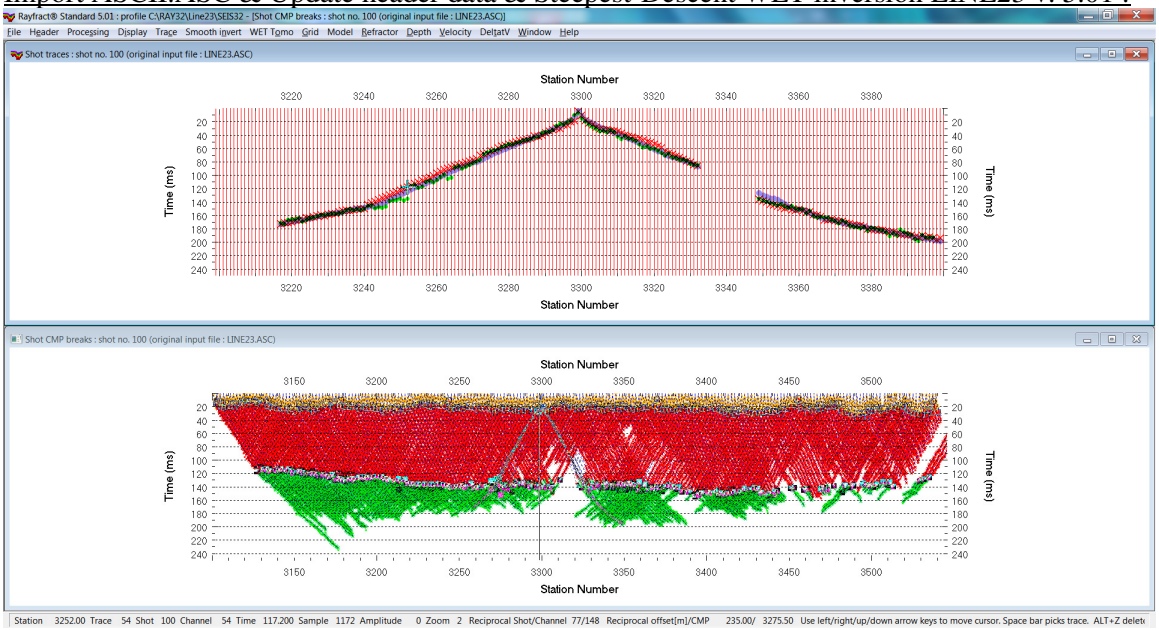


Fig. 1 : check *Trace|Open Refractor|Shot CMP breaks*. Top : *Trace|Shot gather*, bottom : *Refractor|Shot CMP breaks*. Shows fit between picked times (solid colored curves, red crosses) and modeled times (dashed blue curves, blue dots). Green dots are your reciprocal picks.

Create the profile database, import the data and browse the imported shots :

- ***File|New Profile***…, set *File name* to **`LINE23`** and click *Save button*
- in the prompt shown next (Fig. 4) click ***No*** button to leave ***Profile start*** / first receiver at station no. 3101 as specified in LINE23.ASC for first shot no. 1
- in ***Header|Profile***… set *Line type* to **`Refraction spread/line`** . Set *Station spacing* to 5m. See Fig. 2.
- in ***Header|Profile***… check *Force grid cell size* and set *Cell size [m]* to 2m
- check *Extrapolate tomograms.* Set *Extrapolate [Station spacings]* to 30. Click *OK*
- unzip archive **https://rayfract.com/tutorials/LINE23_INPUT.zip** with **`LINE23.ASC`** shot file & files **`LINE23.COR & LINE23.BRN`** in directory **`C:\RAY32\LINE23\INPUT`**
- select ***File|Import Data***… and set *Import data type* to **`ASCII COLUMN FORMAT`**. See Fig. 3.
- click *Select button* and navigate into **`C:\RAY32\LINE23\INPUT`**
- select file **`LINE23.ASC`** and click *Open*
- leave *Default spread type* at **`10: 360 channels`**
- check *Batch import*. Click ***Import shots*** button.
- select *File|Update header data|Update Station Coordinate*s & **`LINE23.COR`**. Click *Import & Reset*.
- select option *Trace|Open Refractor|Shot CMP breaks with Shot gather*
- select *Trace|Shot gather* to obtain Fig. 1
- browse shots in *Trace|Shot gather* window with F7/F8 (Fig. 1 top)
- click on title bar of *Refractor|Shot CMP breaks* window (Fig. 1 bottom) and press ALT+P. Edit *Maximum time* to 250 ms & press ENTER key to redisplay. Do the same for *Trace|Shot gather* window (Fig. 1 top).

Configure and run our default fail-safe Smooth inversion :

- check option *Grid|Receiver station ticks on top axis*
- check *Grid|CS_CENTERED font for shot points and receivers* to fix Surfer symbol display issues
- edit *Grid|Surfer plot Limits* as in Fig. 8
- uncheck *WET Tomo|WET tomography Settings|Blank|Blank below envelope after last iteration*
- select *Model|WDVS Smoothing* and check box *Discard WET smoothing and WDVS smoothing after forward modeling*. Check box *use WDVS for forward modeling of traveltimes* (Fig. 9).
- check *DeltatV|DeltatV Settings|Suppress velocity artefacts*
- 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***
- wait for the 1D-gradient starting model to display as in Fig. 5
- confirm prompt to continue with WET inversion to obtain WET output shown in Fig. 6 & 7

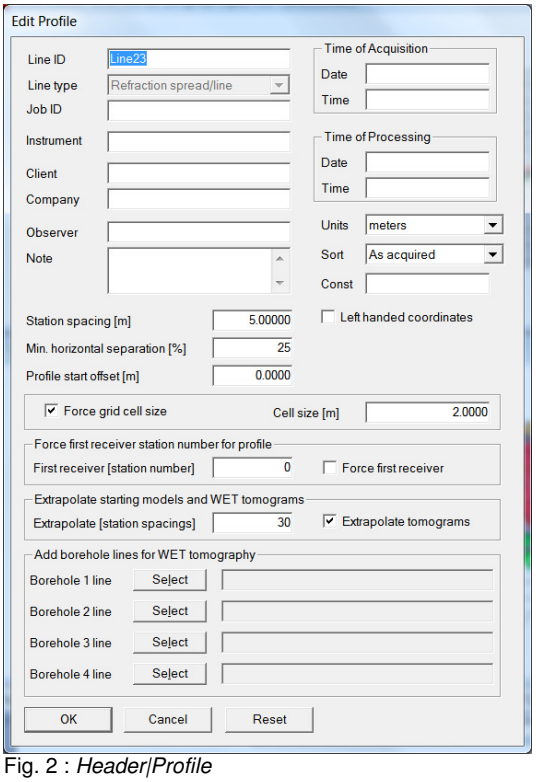


Fig. 2 : *Header|Profile*

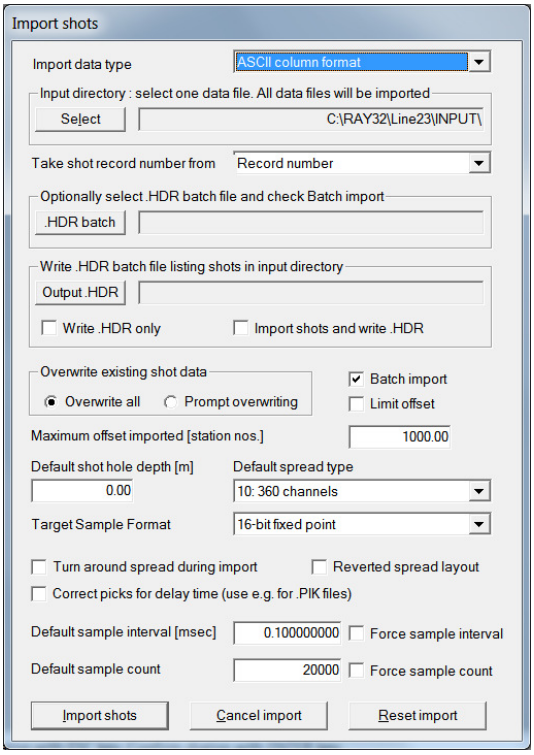


Fig. 3 : *File|Import Data*

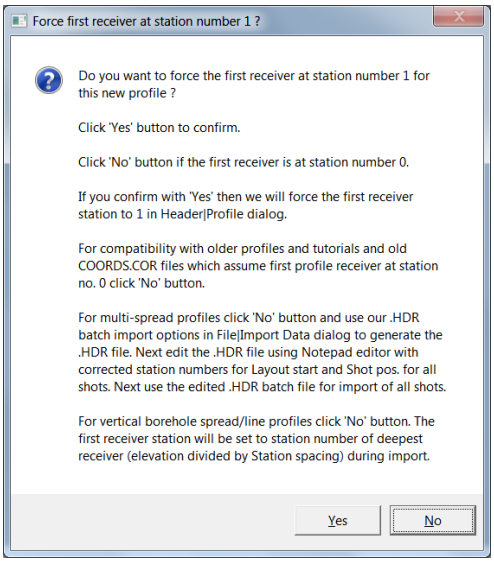


Fig. 4 : click *No* button to to leave first receiver at station no. 3101 as specified in LINE23.ASC for shot no. 1.

For compatibility with older profiles and tutorials and old COORDS.COR files which assume first profile receiver at station no. 0 click No button. For multi-spread profiles click No button and 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. Next use the edited .HDR batch file for import of all shots.

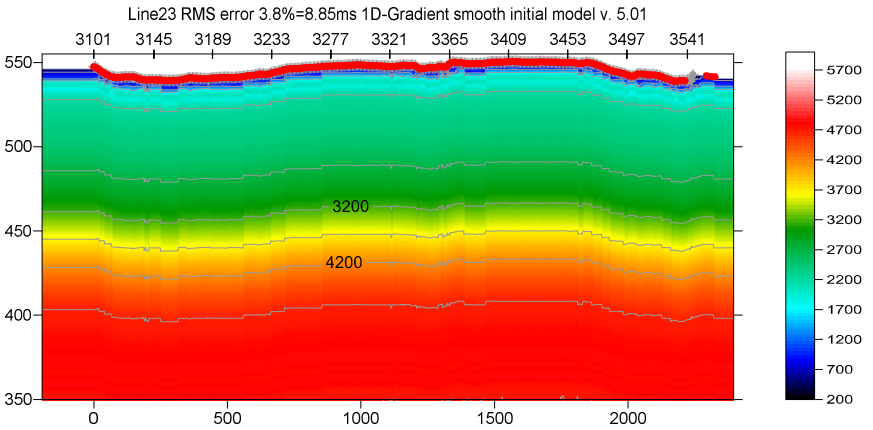


Fig. 5 : 1D-gradient starting model obtained with *Smooth invert|WET with 1D-gradient initial model.*

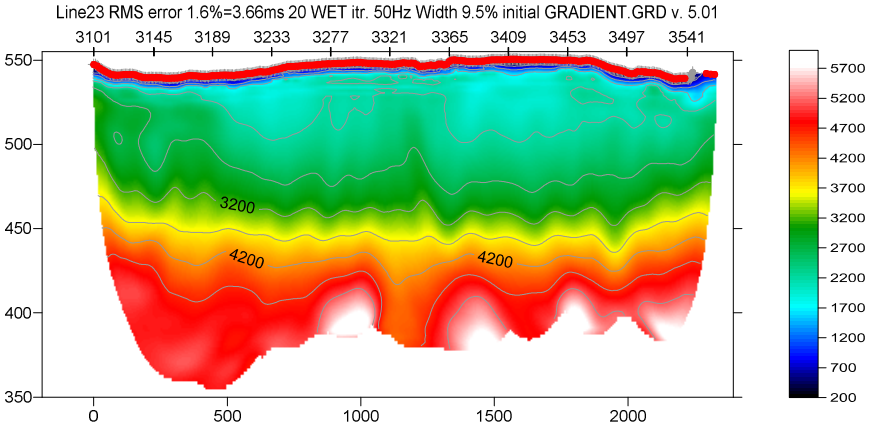


Fig. 6 : 2D WET output obtained with *Smooth invert|WET with 1D-gradient initial model* & starting model shown in Fig. 5. 20 WET iterations using Steepest Descent method & Gaussian update weighting & full WET smoothing. Discard WET smoothing after forward modeling. WDVS enabled at default 300Hz (Fig. 9).

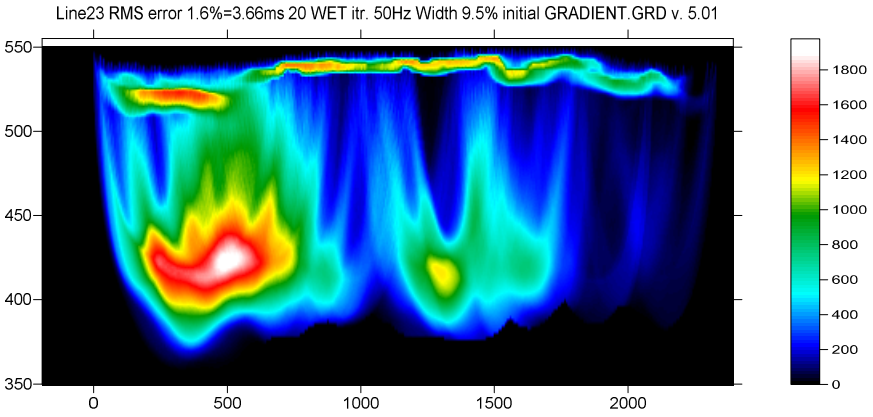


Fig. 7 : WET wavepath coverage plot obtained with Fig. 6. Unit is wavepaths per grid cell.

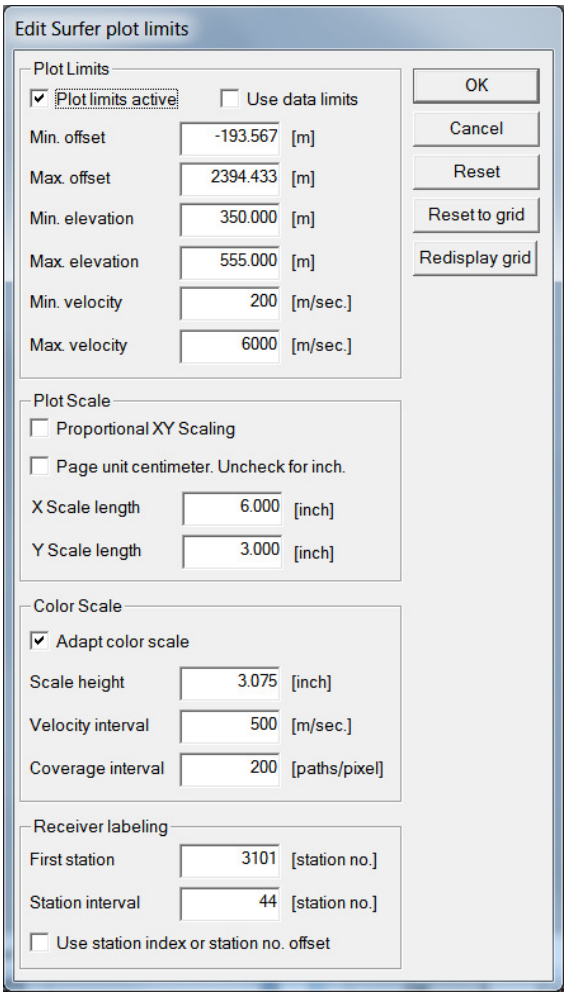


Fig. 8 (left) : Grid|Surfer plot Limits dialog .

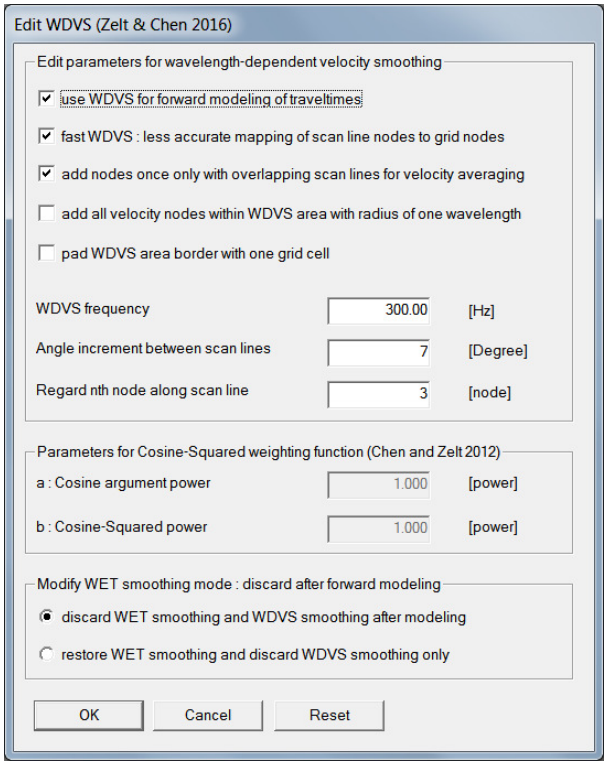


Fig. 9 : Model|WDVS Smoothing dialog .

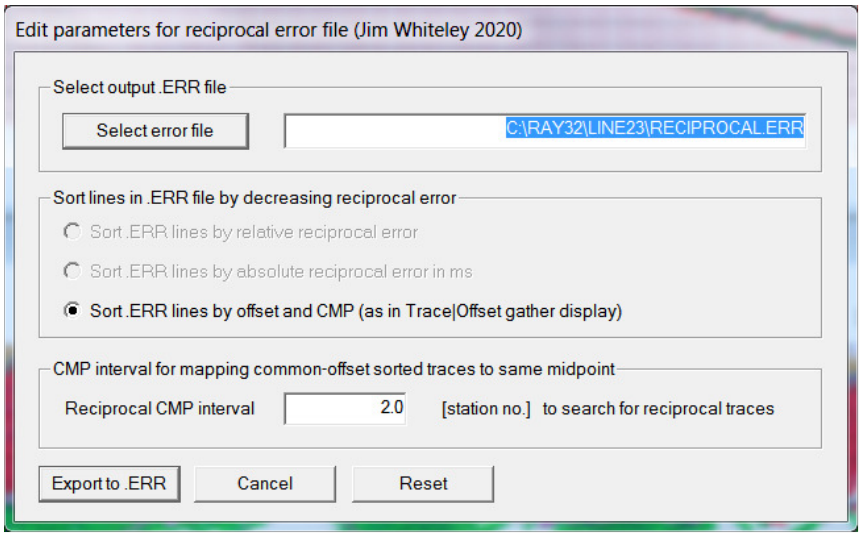


Fig. 10 : Trace|Export reciprocal errors and update database

Plot your reciprocal traveltime picks on shot-sorted trace gathers :

Next we show how to plot 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).

- select ***Trace\Export reciprocal traveltime picks and update database***
- click button *Select error file* and click *Save* button (Fig. 10). Click button *Export to .ERR*
- optionally check new option ***Trace\Open Refractor\Shot CMP breaks with Shot gather***
- select *Trace\Shot gather* to obtain a window display as in our Fig. 1
- check new version 4.05 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 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 *Shot gather* window (Fig. 1) if a reciprocal pick is available in the .ERR file

Run interactive WET inversion using our 1D-gradient initial model and optimized WET settings :

- select *WET Tomo\Interactive WET*
- set *Number of WET tomography iterations* to 50 instead of default 20. See Fig. 11.
- set *Wavepath frequency* to 20Hz instead of default 50Hz for long profile and low-velocity overburden
- increase *Wavepath width* to 20 percent from default 9.5 percent for this profile with velocity inversion
- set *Ricker differentiation* to -2 for Cosine-Squared weighting of the WET velocity update across the wavepath between source and receiver pair for each trace (Schuster 1993) See Fig. 11.
- set *Max. velocity* to 5,500 m/sec
- click button *Start tomography processing* to obtain Fig. 12 and Fig. 13

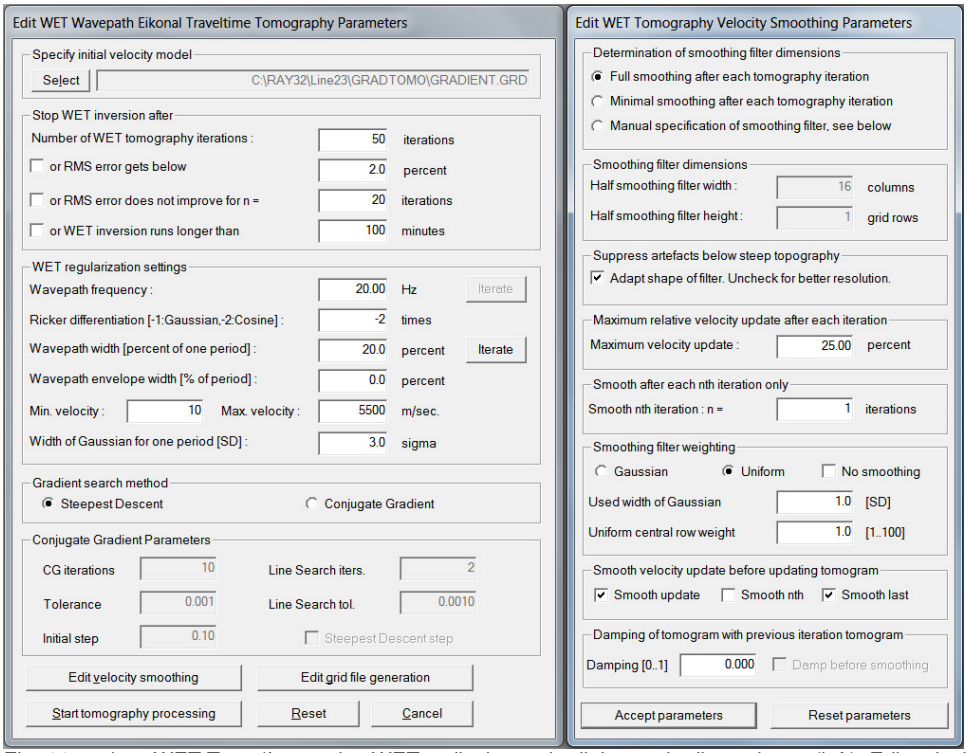


Fig. 11 : select *WET Tomo|Interactive WET* to display main dialog and edit as shown (left). Edit velocity smoothing (right). Click buttons *Accept parameters* and *Start tomography processing* to obtain Fig. 12 and 13.

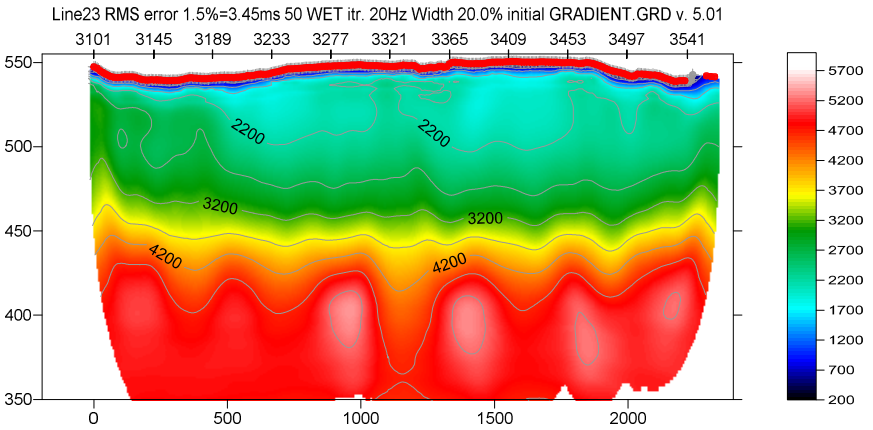


Fig. 12 : 50 Steepest-Descent WET iterations. Starting model is Fig. 5. Discard WET smoothing after forward modeling. WDVS enabled at 300 Hz (Fig. 9). Full WET smoothing (Fig. 11 right). WET wavepath frequency 20Hz. WET wavepath width 20 percent. Ricker differentiation -2 [Cosine-Squared]. Max. WET velocity 5,500 m/s (Fig. 11 left).

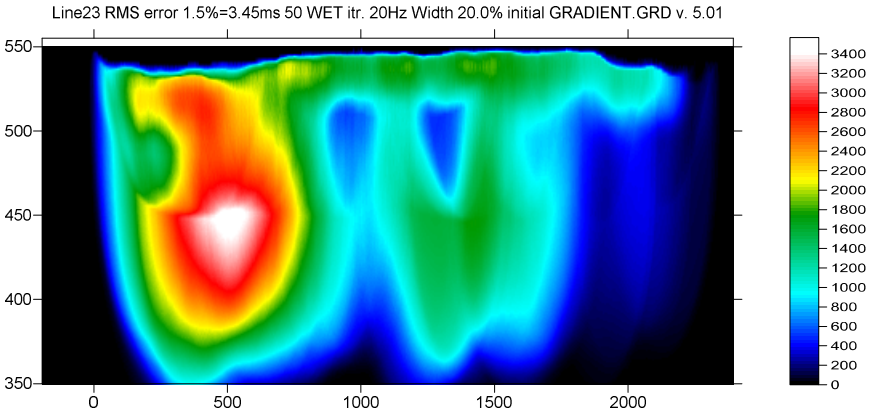


Fig. 13 : WET wavepath coverage plot obtained with Fig. 12. Unit is wavepaths per pixel.

Here is the link to the .RAR archive with the LINE23 profile folder for above Fig. 12 :

https://www.dropbox.com/scl/fi/4dnnao07j4xx6drxpgegf/Line23_Sep26_2024_SmoothInvert_WithOffendShots.rar?rlkey=48sxmx6xw67t032b52cldmui7&st=i3q07aky&dl=0

Select above link and copy with CTRL+C. Then paste the link into your web browser with CTRL+V and press RETURN key to download the .RAR archive.

Obtain layered refraction starting model using our CMP Intercept-Time refraction method :

Next we show layered refraction interpretation with our CMP Intercept-Time refraction method and using this as starting model for interactive WET inversion with WDVS enabled :

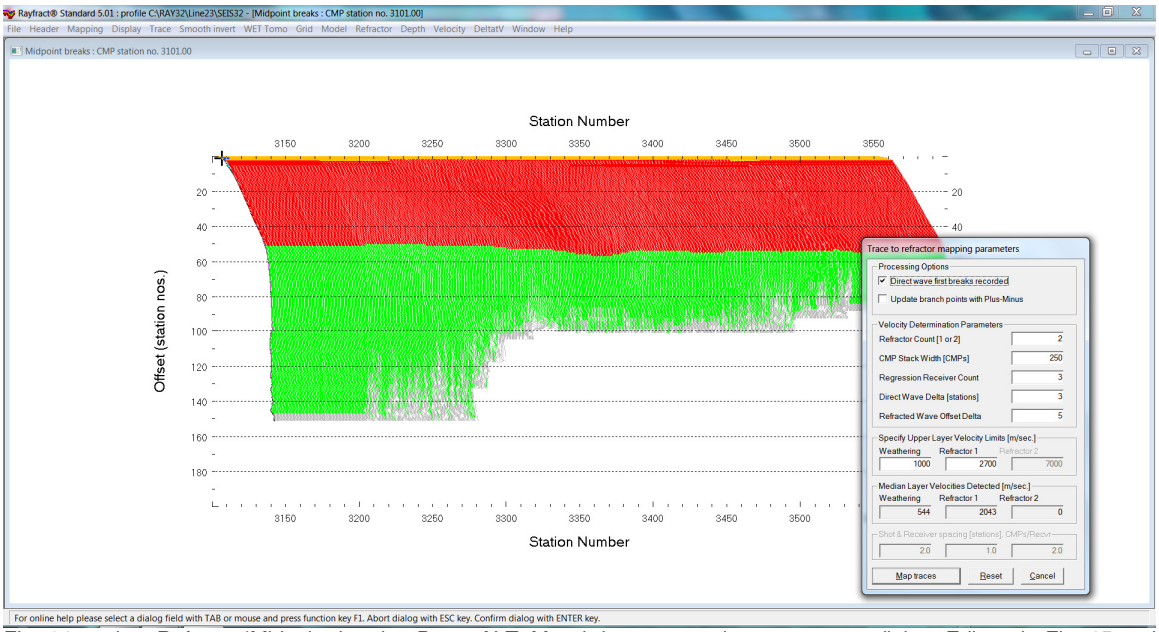


Fig. 14 : select Refractor|Midpoint breaks. Press ALT+M to bring up mapping parameters dialog. Edit as in Fig. 15 and click button Map traces. Press ALT+G to bring up Crossover smoothing dialog. Edit as in Fig. 16 and click Accept button.

- select *Refractor|Midpoint breaks* (Fig. 14)
- press ALT+M and edit mapping parameters (Fig. 15) and click button *Map traces*
- press ALT+G to edit the Crossover smoothing (Fig. 16). Edit as shown and click *Accept* button.
- select *Depth|CMP Intercept-Time Refraction*
- confirm warning prompt about artefacts to obtain layered refraction starting model (Fig. 17 and 18)
- when prompted to continue with WET inversion click *No* button. Redo mapping in Fig. 14/15/16.
- reselect *Depth|CMP Intercept-Time Refraction*. Click on title bar of *CMP Depth Section* window.
- press ALT+M and edit *CMP Model Parameters* as shown in Fig. 17
- click *OK* button to obtain updated Fig. 17 and Fig. 18

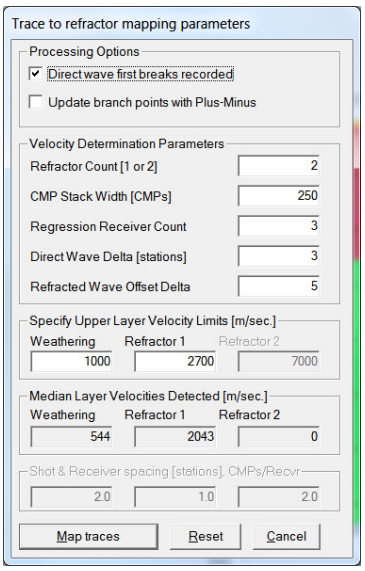


Fig. 15 : press ALT+M in Refractor|Midpoint breaks. Edit as shown and click Map traces.

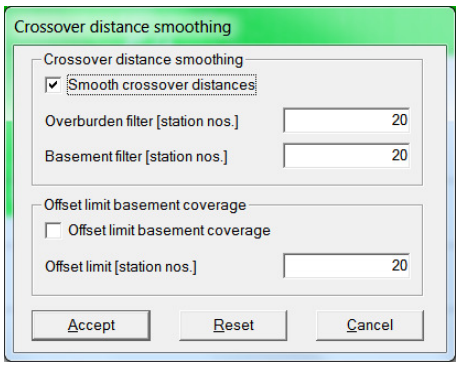


Fig. 16 : press ALT+G. Edit crossover smoothing parameters as shown. Click Accept button.

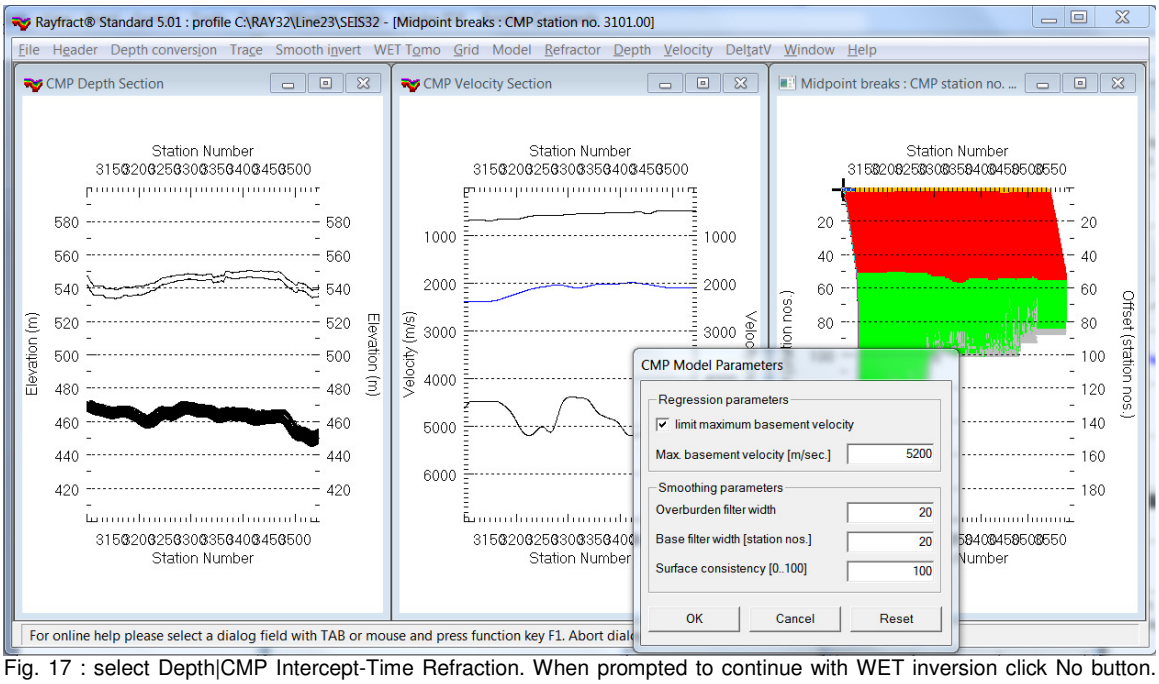


Fig. 17 : select Depth|CMP Intercept-Time Refraction. When prompted to continue with WET inversion click No button. Click on title bar of CMP Depth Section window. Press ALT+M and edit CMP Model Parameters as shown. Click OK.

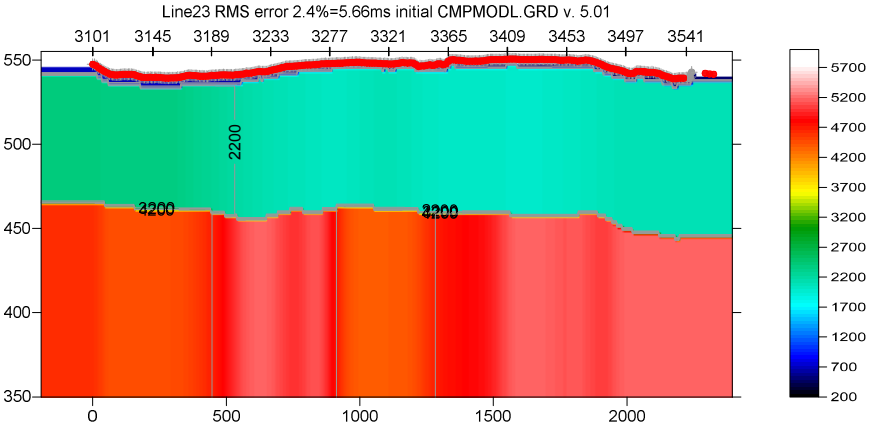


Fig. 18 : select Depth|CMP Intercept-Time Refraction after mapping traces to refractors (Fig. 14/15/16). When prompted to continue with WET inversion click No button. Redo mapping in Fig. 14/15/16. Reselect Depth|CMP Intercept-Time Refraction. Press ALT+M and edit CMP Model Parameters (Fig. 17) and click OK button to obtain our CMP Intercept-Time refraction starting model.

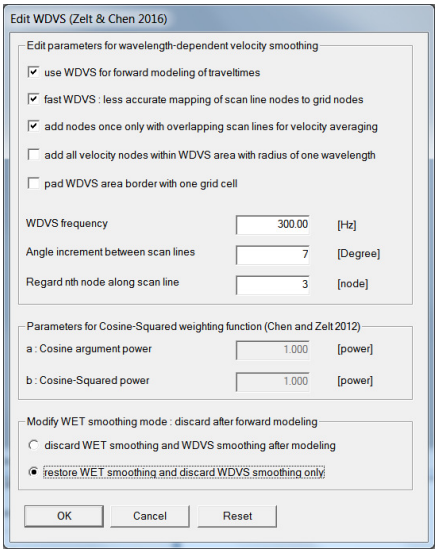


Fig. 19 : select Model|WDVS Smoothing. Edit as shown and click OK button.

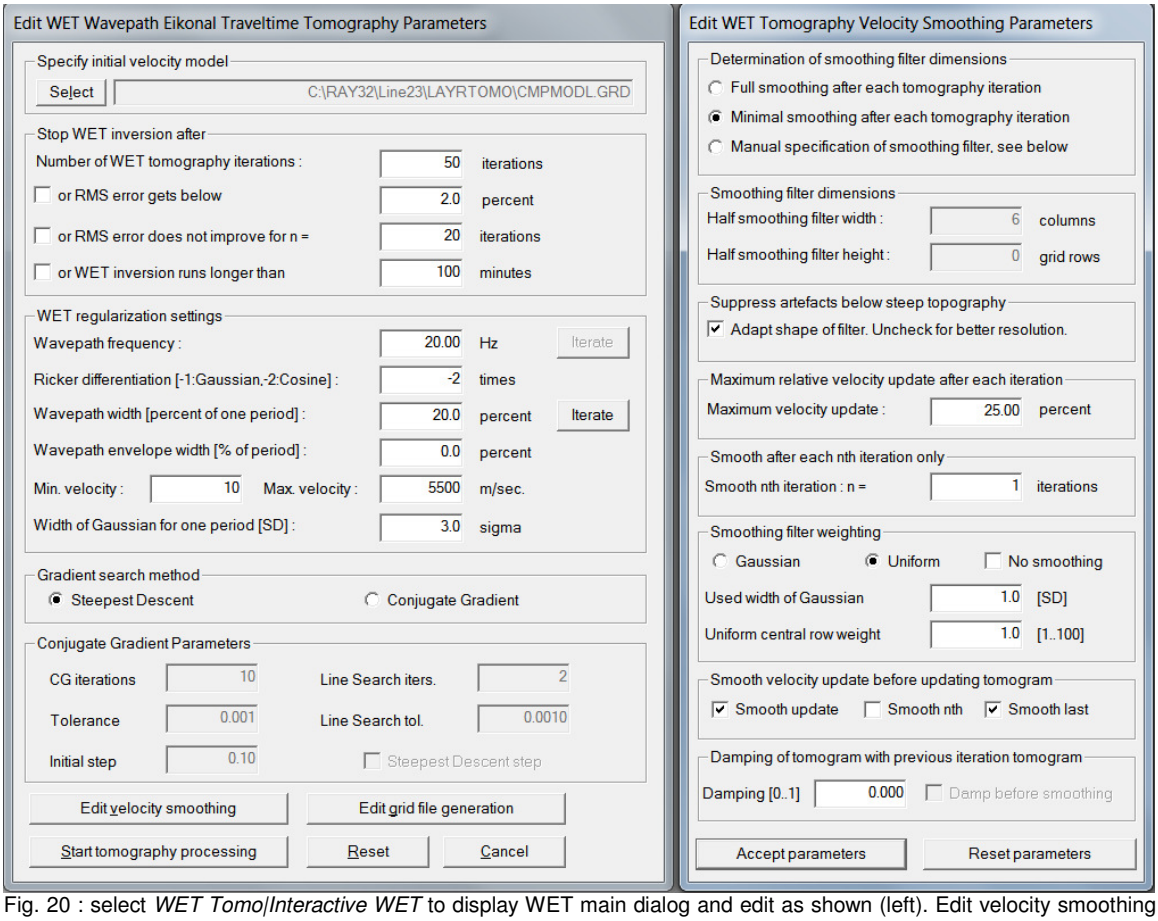


Fig. 20 : select *WET Tomo|Interactive WET* to display WET main dialog and edit as shown (left). Edit velocity smoothing (right). Click buttons *Accept parameters* and *Start tomography processing* to obtain Fig. 21 and 22.

<u>Run interactive WET inversion using our CMP Intercept-Time Refraction starting model :</u>

- select *Model|WDVS Smoothing*. Edit as in Fig. 19 and click *OK* button.
- select *WET Tomo|Interactive WET* (Fig. 20 left). Edit main dialog as shown.
- click button *Edit velocity smoothing* and edit as in Fig. 20 at right.
- click buttons *Accept parameters* and *Start tomography processing* (Fig. 20) to obtain Fig. 21 & 22

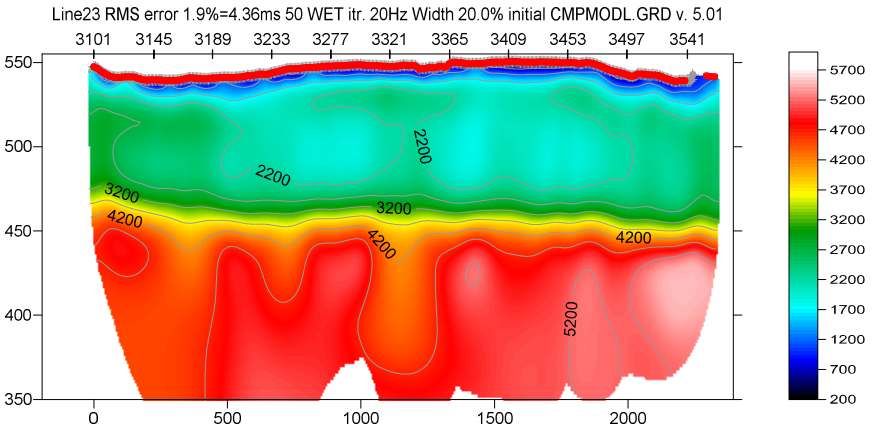


Fig. 21 : 50 Steepest-Descent WET iterations. Starting model is Fig. 18. Don't discard WET smoothing after forward modeling. WDVS enabled at 300 Hz (Fig. 19). Minimal WET smoothing (Fig. 20 right). WET wavepath frequency 20Hz. WET wavepath width 20 percent. Ricker differentiation -2 [Cosine-Squared]. Max. WET velocity 5,500 m/s (Fig. 20 left).

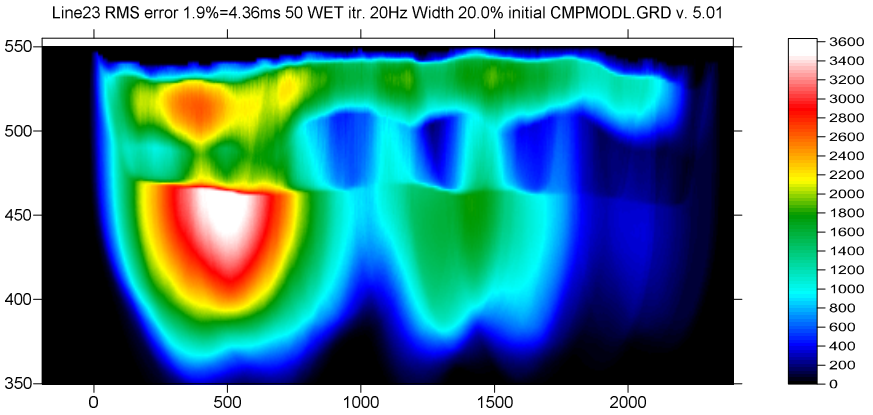


Fig. 22 : WET wavepath coverage plot obtained with Fig. 21. Unit is wavepaths per grid cell.

Here is the link to the .RAR archive with the LINE23 profile folder for above Fig. 21 :

https://www.dropbox.com/scl/fi/wr8i2nwcntp7hby4h5zrl/Line23_Sep26_2024_CMPIntercept_WET_WithOffendShots.rar?rlkey=82t6341ias2te9k4tk19s2jzh&st=h2stknlr&dl=0

Select above link and copy with CTRL+C. Then paste the link into your web browser with CTRL+V and press RETURN key to download the .RAR archive.

We recommend restoring WET smoothing after forward modeling (Fig. 19) when using a layered starting model such as for Fig. 21. We use *Minimal WET smoothing* (Fig. 20) with our CMP Intercept-Time Refraction layered starting model to realistically model the sudden velocity increase between bottom of overburden and top of basement based on the layered refraction starting model.

Determine Wavefront method layered refraction alternative starting model :

- check or uncheck options in *Depth|Depth conversion Settings* as shown in Fig. 23
- check *Refractor|Shot breaks|Mapping|Delete branchpoint 2 if velocity inversion* for this line
- select *Refractor|Midpoint breaks*. Press ALT+U to undo current mapping of traces to refractors.
- press ALT+M to display mapping parameters dialog. Edit as in Fig. 24. Click button *Map traces*.
- select *Depth|Wavefront.* Confirm prompts to obtain Wavefront starting model plot in Surfer.
- when prompted to continue with WET inversion click *No* button

- click on title bar of *Wavefront Depth Section* window. Press ALT+M and edit as in Fig. 26.
- click *OK* button. Confirm prompts to obtain updated Wavefront model (Fig. 25).
- when prompted to continue with WET inversion click *No* button
- select *Refractor|Shot breaks*. Note the updated branch points separating refractors (Fig. 1 bottom).
- press ALT+L to remap traces to refractors. Fix branch point error messages by repicking branch points for the shot numbers indicated in the error prompts. Redo ALT+L to remap traces until no more errors.
- or select *File|Update header data|Update refractor branches from .BRN*
- and click on the **`LINE23.BRN`** in folder **`C:\RAY32\LINE23\INPUT`** and click Open button
- select *Refractor|Shot breaks*. Remap traces to refractors with ALT+L (Fig. 1 bottom).
- select *Depth|Wavefront* and confirm prompts to obtain Fig. 25 showing the updated Wavefront model.

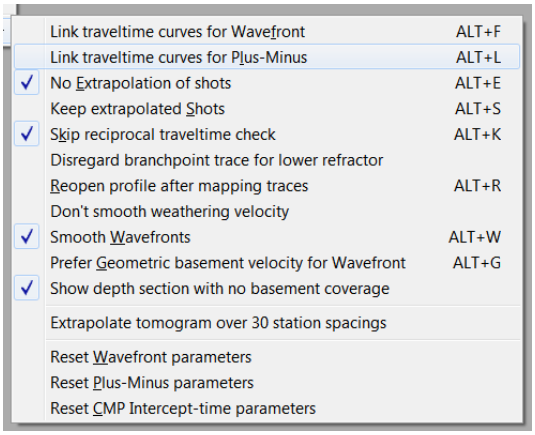
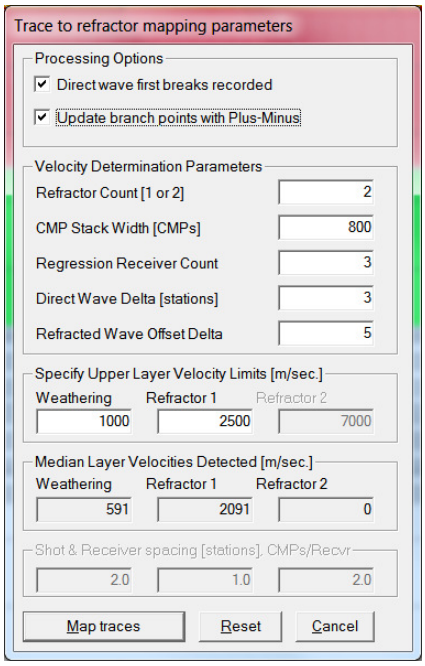


Fig. 23 (above) : *Depth|Depth conversion Settings*. Edit as shown.

Fig. 24 (right) : press ALT+M in *Refractor|Midpoint breaks*. Edit as shown. Click button *Map traces*.



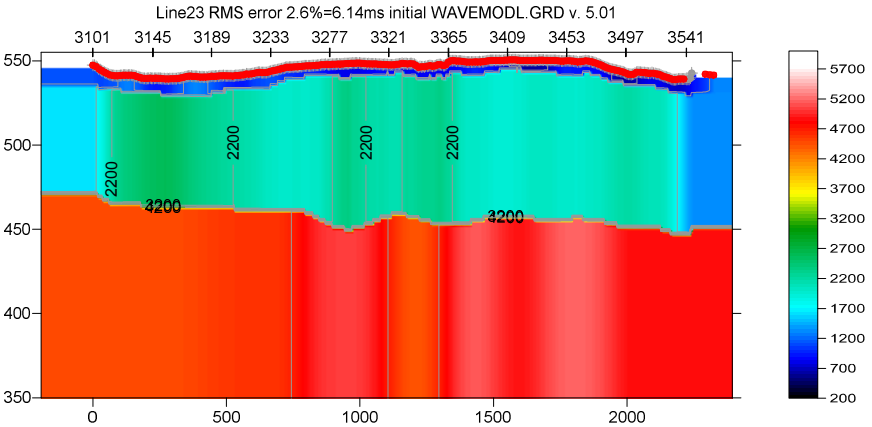


Fig. 25 : Wavefront method layered refraction starting model obtained with *Depth|Wavefront*. *Depth|Depth conversion Settings* as in Fig. 23. Map traces to refractors in *Refractor|Midpoint breaks* with ALT+M (Fig. 24). Select *Depth|Wavefront* to obtain first version of Wavefront model. Select *File|Update header data|Update refractor branches from .BRN* and LINE23.BRN. Select *Refractor|Shot breaks* (Fig. 1 bottom). Remap traces to refractors with ALT+L. Reselect *Depth|Wavefront*. When prompted to continue with WET inversion click *No* button. Click on title bar of *Wavefront Depth Section*. Press ALT+M. Edit parameters as in Fig. 26 and Fig. 27. Click *OK* to obtain updated Wavefront model.

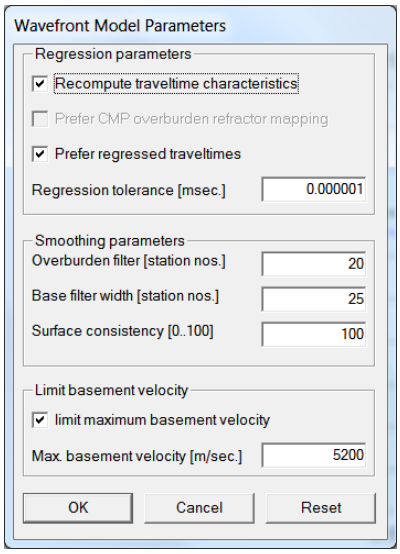


Fig. 26 :_select *Depth*|*Wavefront*. Confirm prompts to obtain Fig. 25. When prompted to continue with WET inversion click *No* button. Click on title bar of *Wavefront Depth Section*. Press Alt+M. Edit model parameters as shown and click *OK* button to obtain updated Wavefront model (Fig. 25).

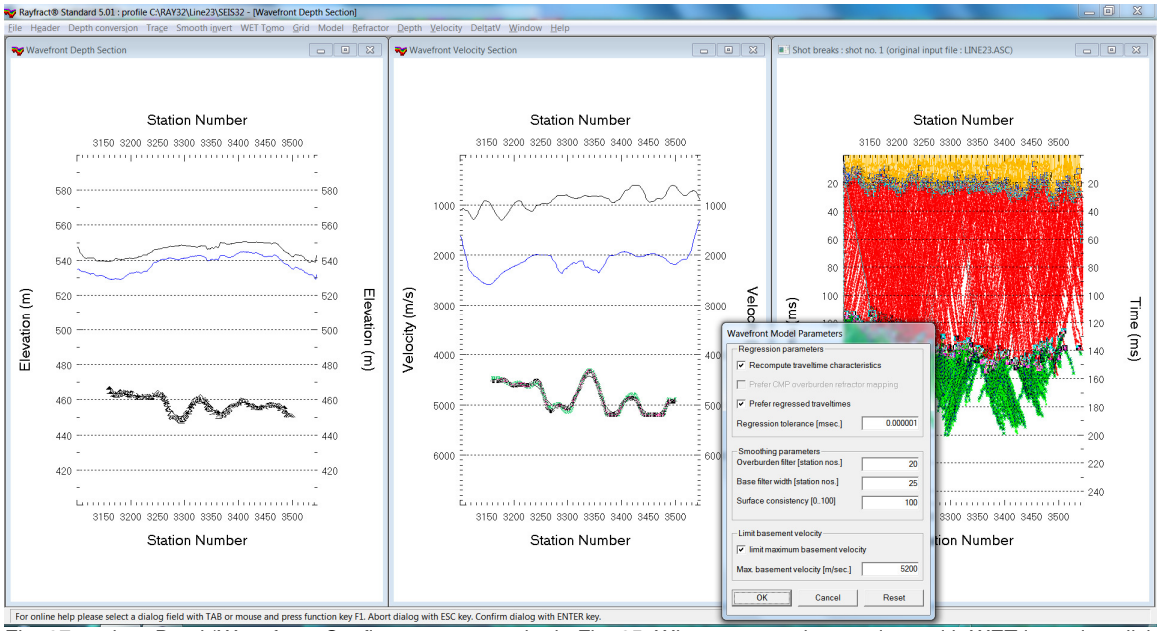


Fig. 27 : select *Depth*|*Wavefront*. Confirm prompts to obtain Fig. 25. When prompted to continue with WET inversion click *No* button. Click on title bar of *Wavefront Depth Section*. Press Alt+M. Edit model parameters as shown (Fig. 26) and click *OK* button to obtain updated Wavefront model (Fig. 25).

<u>Run interactive WET inversion using our Wavefront method layered refraction starting model :</u>

- select *Model*|*WDVS Smoothing*. Edit as in Fig. 19 and click *OK* button.
- select *WET Tomo*|*Interactive WET* (Fig. 28 left). Edit as shown.
- click button *Edit velocity smoothing* and edit as in Fig. 28 at right.
- click buttons *Accept parameters* and *Start tomography processing* (Fig. 28) to obtain Fig. 29 & 30

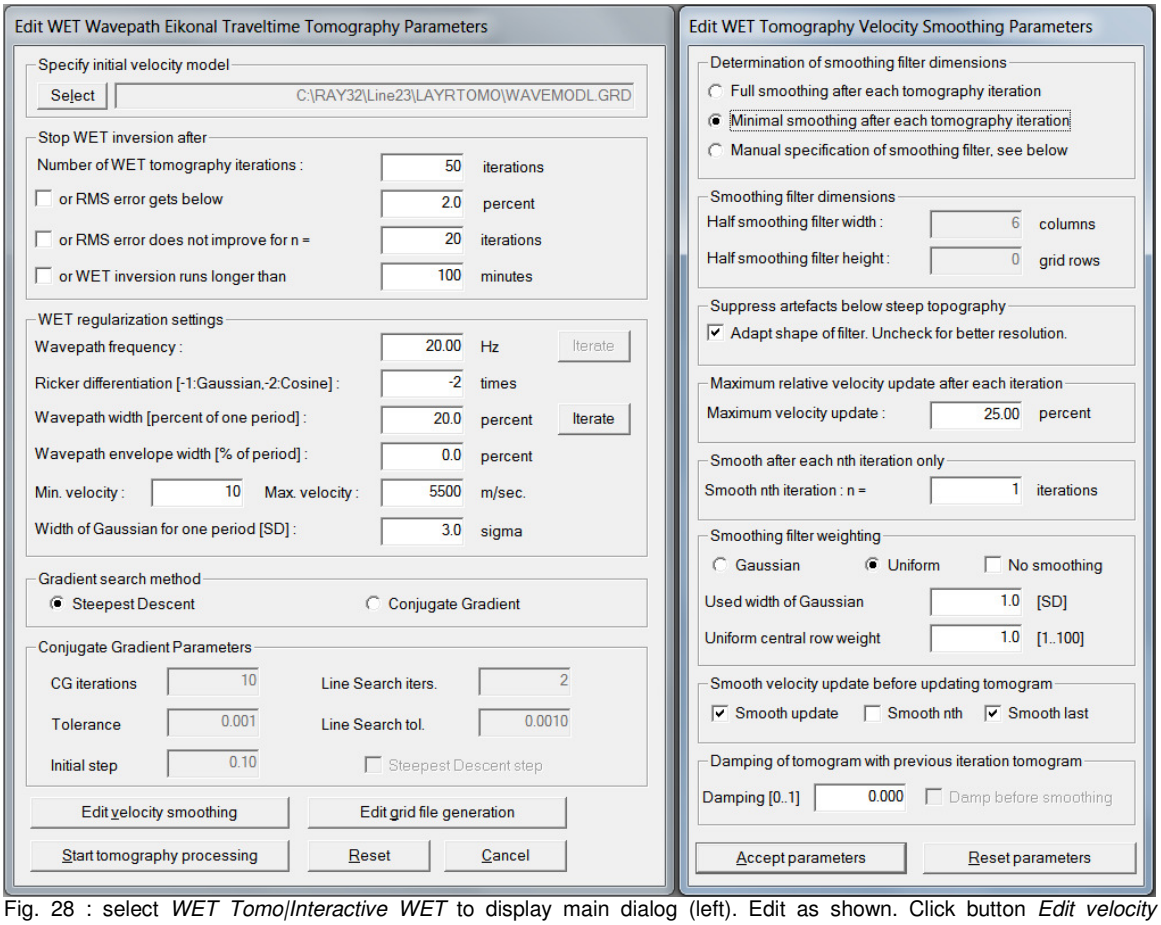


Fig. 28 : select *WET Tomo|Interactive WET* to display main dialog (left). Edit as shown. Click button *Edit velocity smoothing* and edit as shown (right). Click *Accept parameters* and *Start tomography processing* to obtain Fig. 29 and Fig. 30.

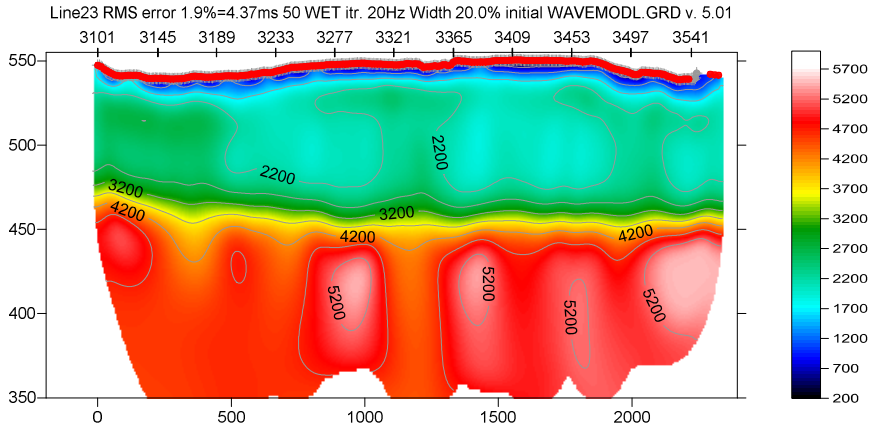


Fig. 29 : *WET Tomo|Interactive WET* (Fig. 28) using Wavefront method starting model (Fig. 25). 50 Steepest-Descent WET iterations. Don't discard WET smoothing after forward modeling. WDVS enabled at 300 Hz (Fig. 19). Minimal WET smoothing (Fig. 28 right). WET wavepath frequency 20Hz. WET wavepath width 20 percent. Ricker differentiation -2 [Cosine-Squared]. Max. WET velocity 5,500 m/s (Fig. 28 left).

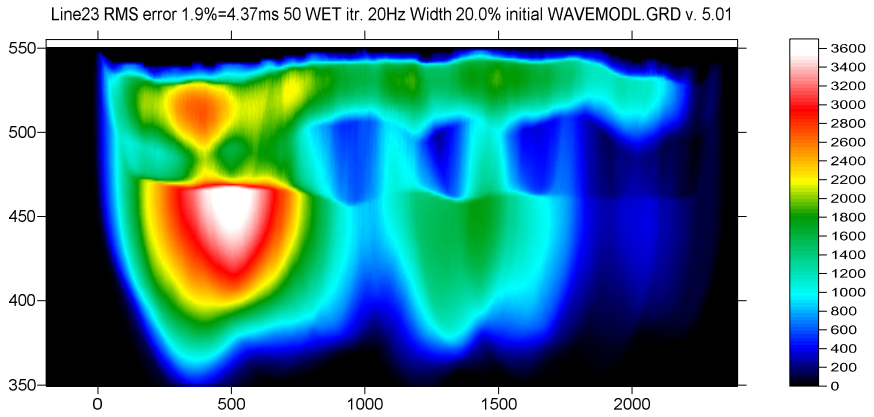


Fig. 30 : WET wavepath coverage plot obtained with Fig. 29. Unit is wavepaths per grid cell.

Here is the link to the .RAR archive with the LINE23 profile folder for above Fig. 29 :

https://www.dropbox.com/scl/fi/6t6rnxecuddek7m7tou23/Line23_Sep29_2024_WaveModel_WET_WithOffendShots.rar?rlkey=y9q4mydllkxzh3lv9ynpugedx&st=pqrw3ux8&dl=0

Select above link and copy with CTRL+C. Then paste the link into your web browser with CTRL+V and press RETURN key to download the .RAR archive.

We recommend restoring WET smoothing after forward modeling (Fig. 19) when using a layered starting model such as for Fig. 29. We use *Minimal WET smoothing* (Fig. 28) with our Wavefront refraction method layered starting model to realistically model the sudden velocity increase between bottom of overburden and top of basement based on the layered refraction starting model.

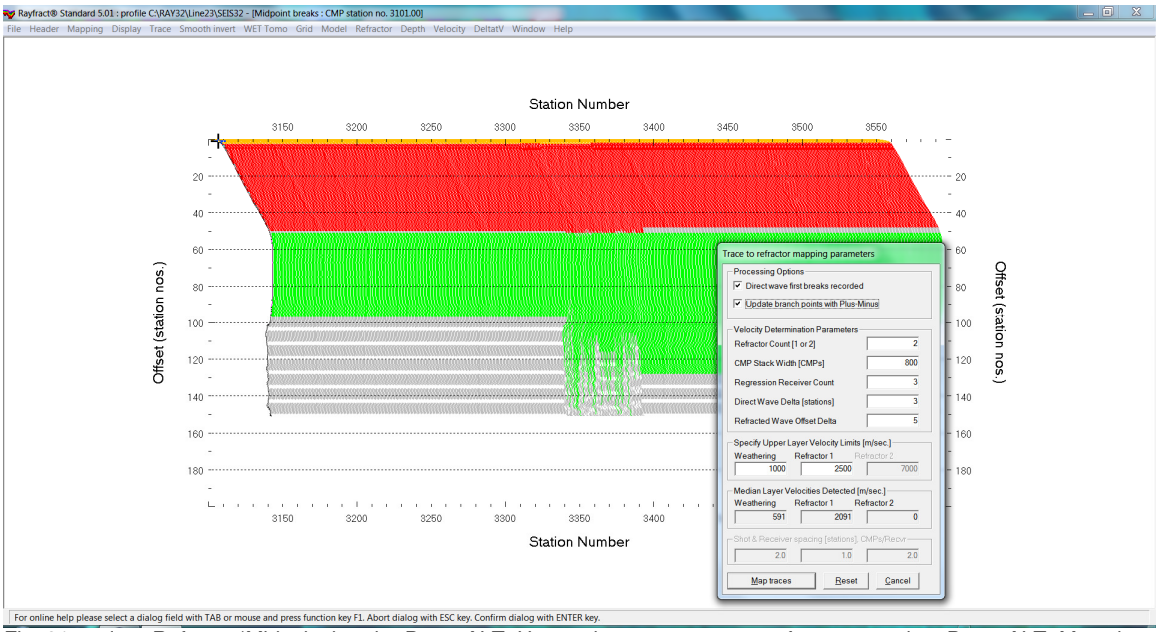


Fig. 31 : select *Refractor|Midpoint breaks*. Press ALT+U to undo current trace-to-refractor mapping. Press ALT+M to show *Trace mapping parameters* dialog. Edit as in Fig. 24. Click button *Map traces*.

Since the basement refractor coverage is quite short and with gaps we change *Refractor|Midpoint breaks|ALT+M Trace mapping parameters* dialog (Fig. 24 and Fig. 31) compared to Fig. 15 :

- lower *Refractor 1 Velocity Limit* to 2,500 m/s from 2,700 m/s
- increase *CMP Stack Width [CMPs]* to 800 from 250
- edit *Depth|Depth conversion Settings* as in Fig. 23 before selecting *Depth|Wavefront*

Configure and run pseudo-2D Automatic DeltatV inversion :

- edit *Grid|Surfer plot Limits* as in Fig. 8
- uncheck *WET Tomo|WET tomography Settings|Blank|Blank below envelope after last iteration*
- select *Model|WDVS Smoothing* and check box *Discard WET smoothing and WDVS smoothing after forward modeling*. Check box *use WDVS for forward modeling of traveltimes* (Fig. 9).
- check *DeltatV|DeltatV Settings|Suppress velocity artefacts*
- select *DeltatV|Automatic DeltatV and WET inversion*
- confirm prompts to obtain pseudo-2D DeltatV starting model (Fig. 32)
- when prompted to continue with WET inversion click No button

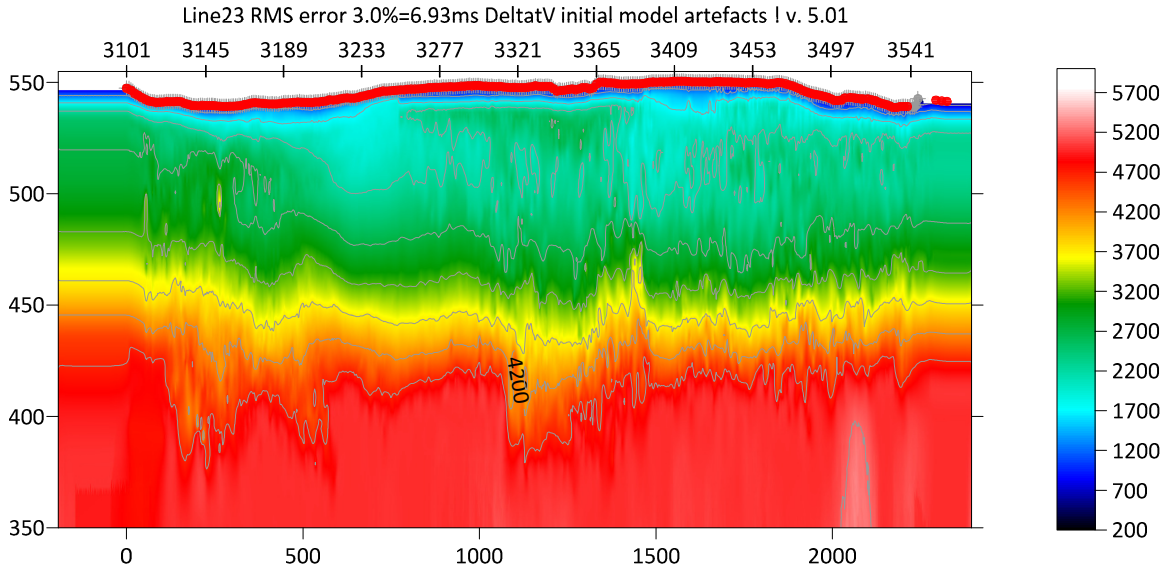


Fig. 32 : select *DeltatV|Automatic DeltatV and WET inversion*. When prompted to continue with WET inversion click *No* button. *DeltatV|DeltatV Settings|Suppress velocity artefacts* checked.

Run interactive WET inversion using our pseudo-2D DeltatV starting model :

- select *WET Tomo|Interactive WET* (Fig. 33 left). Edit as shown.
- click button *Edit velocity smoothing* and edit as in Fig. 33 at right.
- click buttons *Accept parameters* and *Start tomography processing* (Fig. 33) to obtain Fig. 34 & 35

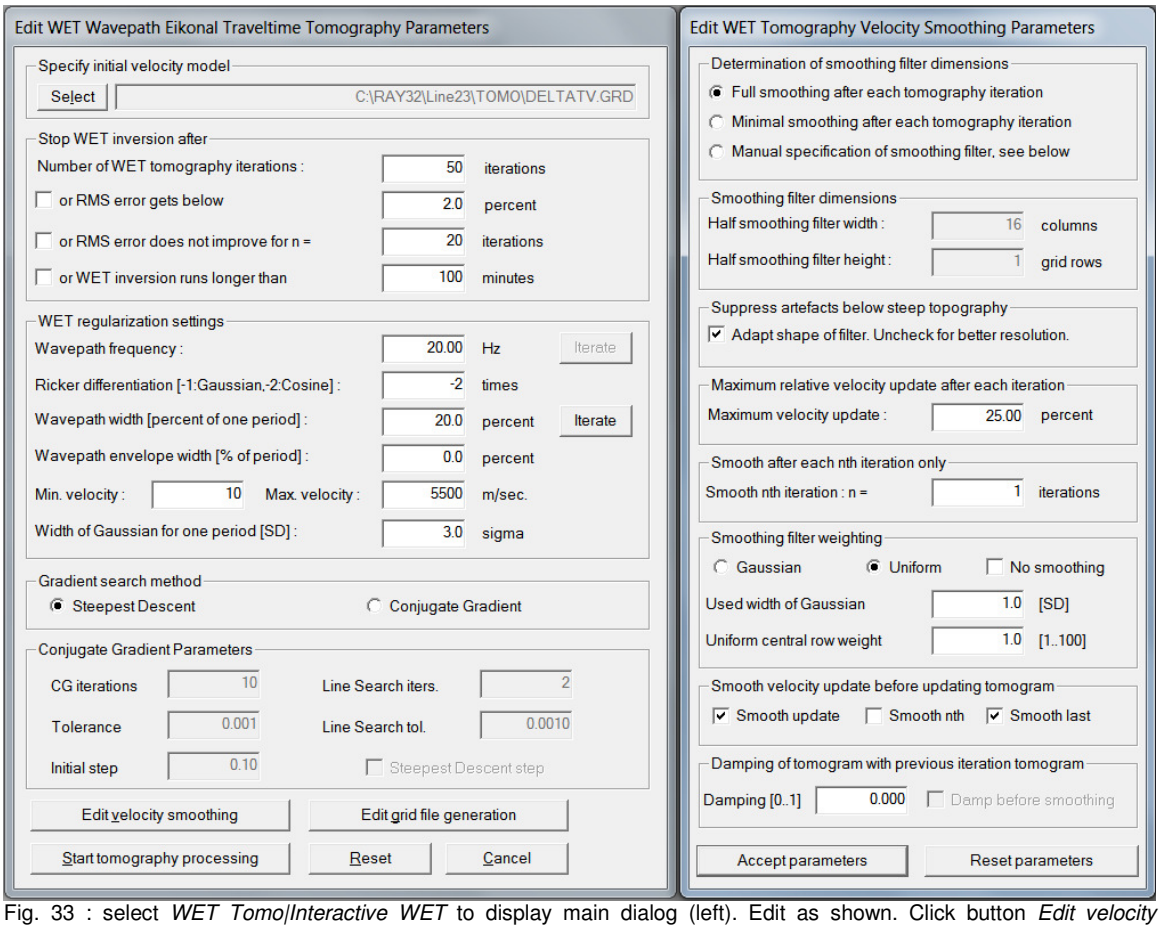


Fig. 33 : select *WET Tomo|Interactive WET* to display main dialog (left). Edit as shown. Click button *Edit velocity smoothing* and edit as shown (right). Click *Accept parameters* and *Start tomography processing* to obtain Fig. 34 and Fig. 35.

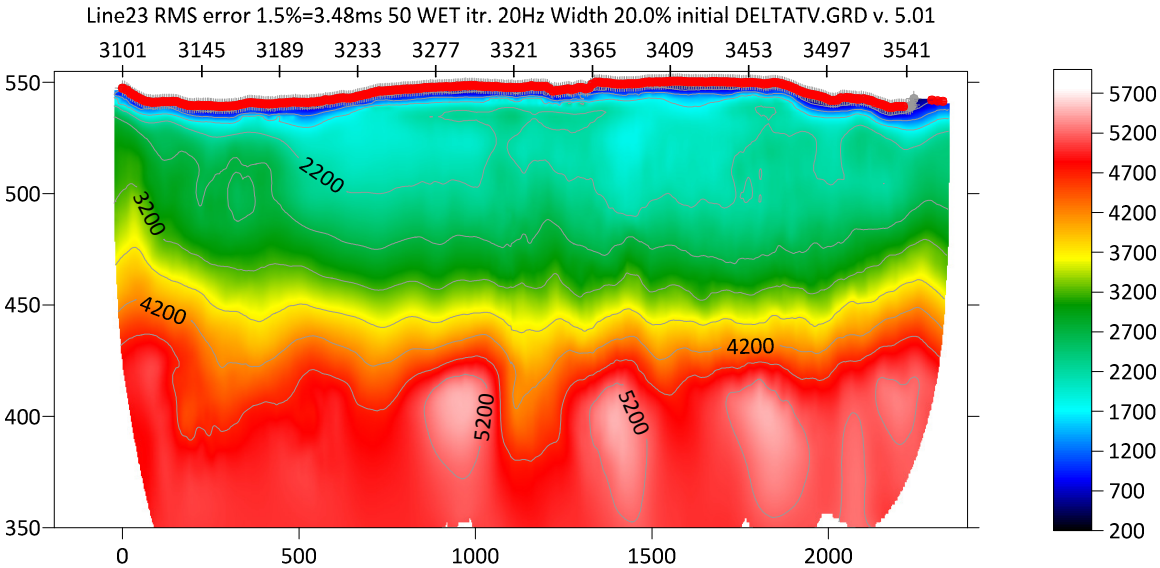


Fig. 34 : *WET Tomo|Interactive WET* (Fig. 33) using DeltatV starting model (Fig. 32). 50 Steepest-Descent WET iterations. Discard WET smoothing after forward modeling. WDVS enabled at 300 Hz (Fig. 9). Full WET smoothing (Fig. 33 right). WET wavepath frequency 20Hz. WET wavepath width 20 percent. Ricker differentiation -2 [Cosine-Squared]. Max. WET velocity 5,500 m/s (Fig. 33 left).

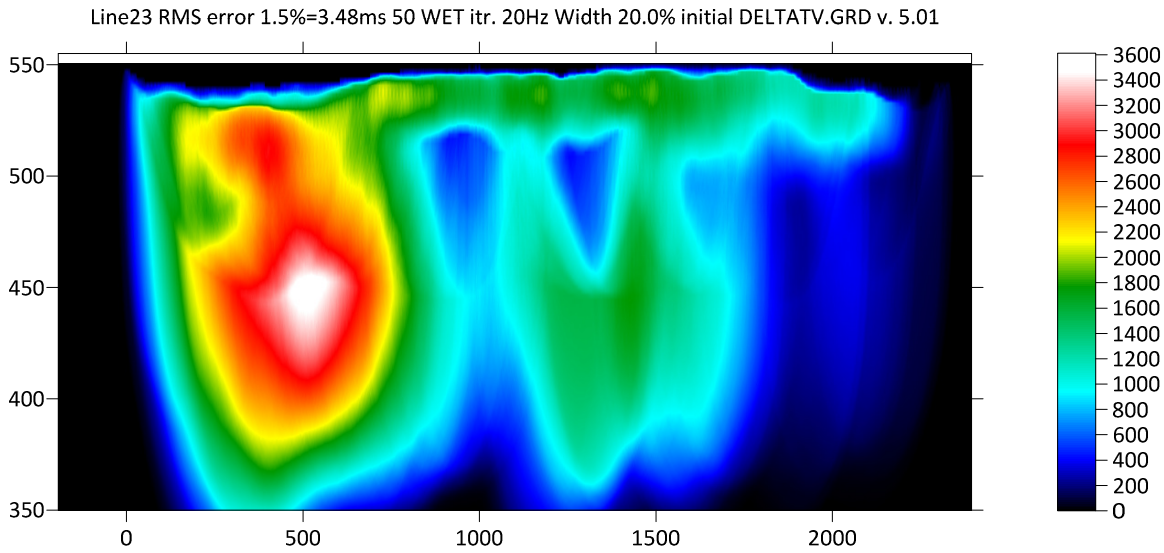


Fig. 35 : WET wavepath coverage plot obtained with Fig. 34. Unit is wavepaths per grid cell.

Here is the link to the .RAR archive with the LINE23 profile folder for above Fig. 34 :

https://www.dropbox.com/scl/fi/bgj979xh7keld6t51vueg/Line23_Sep23_2024_CMP_DeltatV_SDWET.rar?rlkey=z0a1uzjzz0gn0v3thvt0b1ghn&st=vyfjt4p5&dl=0

Select above link and copy with CTRL+C. Then paste the link into your web browser with CTRL+V and press RETURN key to download the .RAR archive.

We discard WET smoothing after forward modeling (Fig. 9) for our DeltatV starting model. We use *Full WET smoothing* (Fig. 33 right) with our pseudo-2D DeltatV starting model to smooth over or remove DeltatV artefacts during the WET inversion.

Compare Fig. 34 with Fig. 29. The lateral velocity variation in the basement is quite similar between Fig. 34 using our DeltatV starting model and Fig. 29 using our Wavefront method layered refraction starting model.

Results

The imaged basement depth has been confirmed with 5 boreholes. Bedrock was found at depths between 76 m and 99 m below line topography. The maximum difference between the SRT interpretation and drilled top-of-bedrock was 9 m (roughly 10%), normally between 2 and 4 m (3 to 5%). There is a confirmed velocity inversion in the overburden : soft lacustrine sediments below stiff gravel.

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