

NGU G4 NGU report 2020_044 : import data, update header data, remodel synthetic breaks, run DeltatV & Plus-Minus & Smooth inversion with Rayfract® version 4.03 released in Dec 2022 :

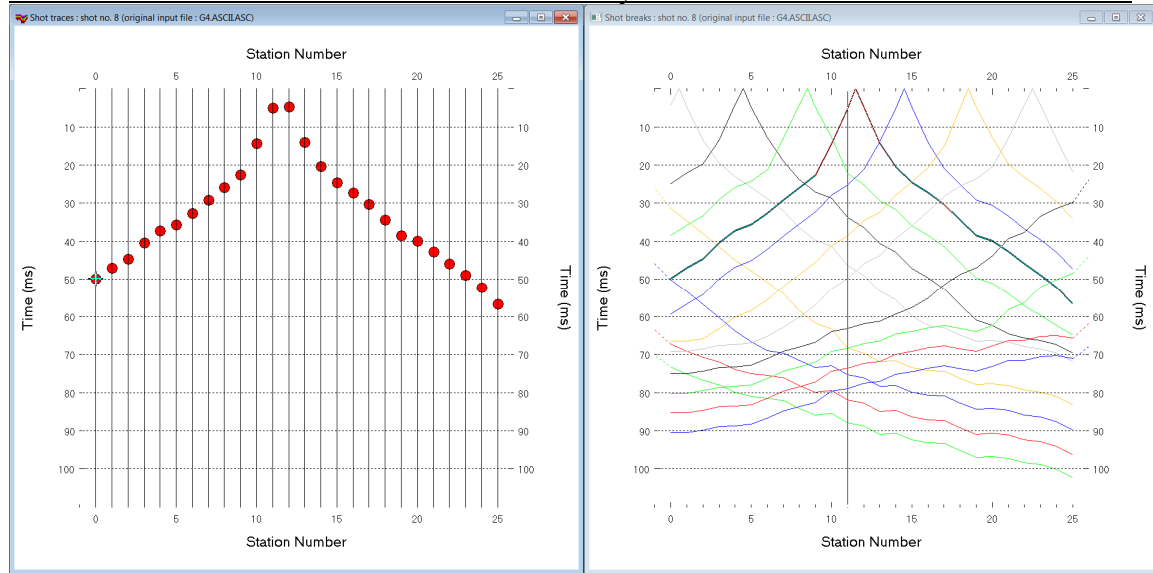


Fig. 1 : left : *Trace|Shot gather*, right : *Refractor|Shot breaks*. Traveltimes shown are synthetic times obtained after redoing synthetic forward modeling over G4_SYNTHETIC.GRD with correct off-end shot point elevations.

To create the profile database and import the data with latest Rayfract® version 4.03 Dec 2022 :

- **File|New Profile...**, set *File name* to **NGU_G4** and click *Save button*
- in the prompt (Fig. 37) click **No** button to leave **Profile start** and first receiver at station no. 0.
- in **Header|Profile...** set *Line type* to **Refraction spread/line**. Set *Station spacing* to 5.0 m.
- check box *Force grid cell size* and set *Cell size[m]* to 0.5m. See Fig. 2.
- check box *Extrapolate tomograms* and edit *Extrapolate [station spacings]* to 30. Click button **OK**.
- unzip [input ngu g4.zip](#) with files **G4.ASCII.ASC**, **G4.COORDS.COR**, **G4.SHOTPTS.SHO**, **G4.SHOTS.COR**, **G4_SYNTHETIC.GRD** & **G4.BRANCHES.BRN** in directory **C:\RAY32\NGU_G4\INPUT**
- leave **File|Import Data Settings|Extrapolate receiver line coordinates** unchecked as per default
- select **File|Import Data...** and set *Import data type* to **ASCII column format**. See Fig. 3.
- leave *Default spread type* at 10: **360 channels**
- click **Select button**, navigate into **C:\RAY32\NGU_G4\INPUT** and select file **G4.ASCII.ASC**
- set *Default sample count* to 1100 to setup the y scale for *Trace|Shot gather* & *Refractor|Shot breaks*
- check options *Batch import* and *Overwrite all*
- click **Import shots button**. All shots in the **G4.ASCII.ASC** file are imported automatically.
- select **File|Update header data|Update Station Coordinates** with **G4.SHOTS.COR** containing shot point elevations at off-end shot stations. Click **Open button** and **Import and Reset**.
- **File|Update header data|Update Shotpoint coordinates** with **G4.SHOTPTS.SHO**. Click **Open button**.

Next we redo forward modeling of synthetic traveltimes with correct shot point elevation for off-end shots :

- select **Model|Model synthetic shots** & **C:\RAY32\NGU_G4\INPUT\G4_SYNTHETIC.GRD**. Click **Open**.
- select **Trace|Shot gather** and **Window|Tile** to obtain Fig. 1.
- browse shots in Fig. 1 with F7/F8 function keys
- select **File|Export header data|Export First Breaks as ASCII.ASC**
- navigate into folder **C:\RAY32\NGU_G4\ExpJan9**. Click **Save button**.

Edit Profile

Line ID:

Line type:

Job ID:

Instrument:

Client:

Company:

Observer:

Note:

Time of Acquisition
Date:

Time
Time:

Time of Processing
Date:

Time
Time:

Units:

Sort:

Const:

Station spacing [m]:

Min. horizontal separation [%]:

Profile start offset [m]:

First receiver [station number]:

Left handed coordinates

Force grid cell size

Cell size [m]:

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:

OK Cancel Reset

Fig. 2 : Header|Profile

Import shots

Import data type:

Input directory: select one data file. All data files will be imported

Select:

Take shot record number from:

Optionally select .HDR batch file and check Batch import

.HDR batch:

Write .HDR batch file listing shots in input directory

Output .HDR:

Write .HDR only Import shots and write .HDR

Overwrite existing shot data

Overwrite all Prompt overwriting

Batch import Limit offset

Maximum offset imported [station nos.]:

Default shot hole depth [m]:

Default spread type:

Target Sample Format:

Turn around spread during import Reverted spread layout

Correct picks for delay time (use e.g. for .PIK files)

Default sample interval [msec]:

Default sample count:

Import shots Cancel import Reset import

Fig. 3 : File|Import Data

Edit Surfer plot limits

Plot Limits

Plot limits active

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 interval: [paths/pixel]

Receiver labeling

First station: [station no.]

Station interval: [station no.]

Use station index or station no. offset

OK Cancel Reset Reset to grid Redisplay grid

Fig. 4 : Grid|Surfer plot Limits

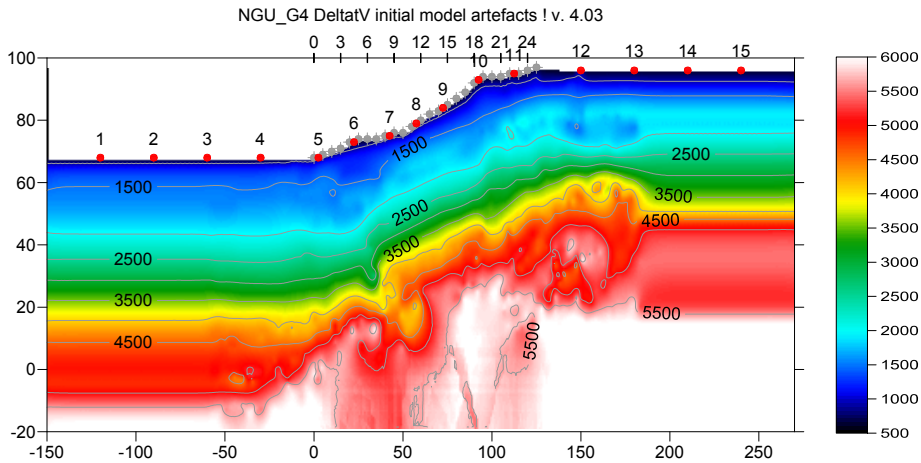


Fig. 5 : *DeltatV*|*Automatic DeltatV* inversion. Default *DeltatV* settings. Extrapolate tomogram over 30 station spacings. Max. velocity exported 5,800m/s (Fig 9). Don't limit *DeltatV* velocity to max. 1D-gradient velocity.

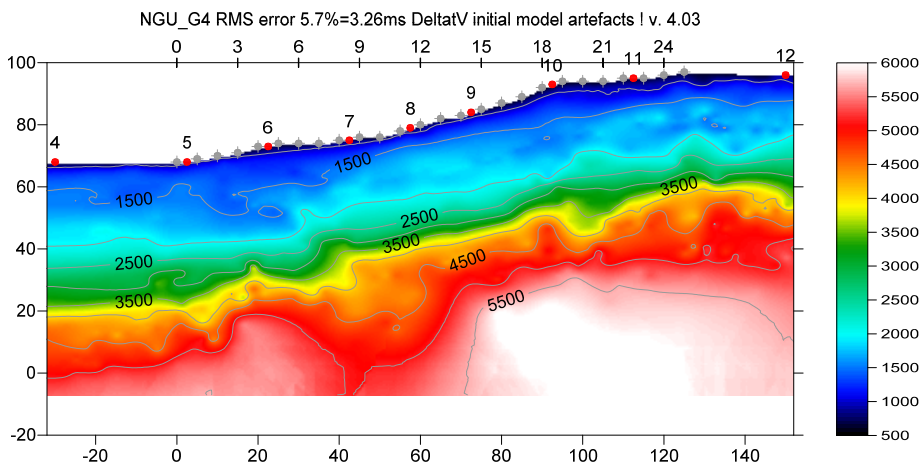


Fig. 6 : *DeltatV* options *Suppress velocity artefacts* and *Process every CMP offset* (Fig. 8). Max. velocity exported 5,800m/s (Fig 9). Don't limit *DeltatV* velocity to max. 1D-gradient velocity. *Grid*|*Surfer plot limits* as in Fig. 4.

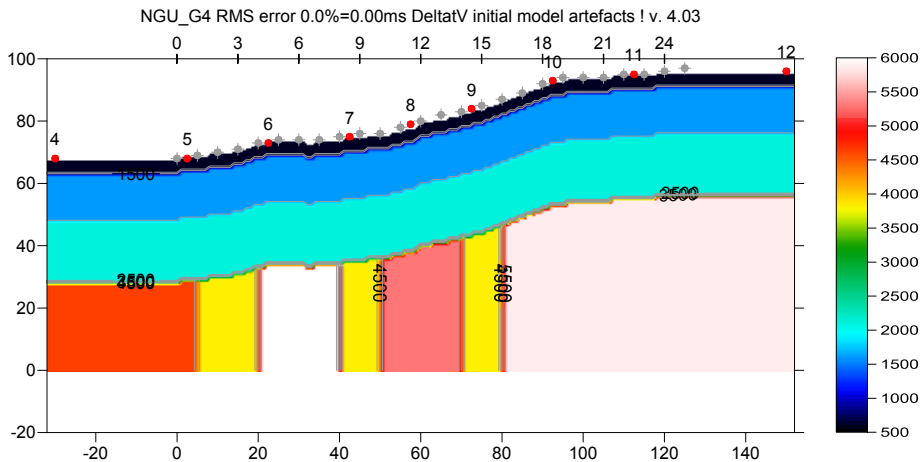


Fig. 7 : select *Grid*|*Image* and contour velocity and coverage grids & C: \RAY32\NGU_G4\INPUT\G4_SYNTHETIC.GRD

- select *DeltatV*|*Automatic DeltatV* and confirm artefacts warning prompt (Fig. 14) to obtain Fig. 5.
- select *Grid*|*Surfer plot Limits* and edit as in Fig. 4. Click button *OK*.
- uncheck *DeltatV*|*DeltatV settings*|*Limit DeltatV velocity exported to maximum 1D-gradient velo.* (Fig. 8)
- check *DeltatV*|*DeltatV settings*|*Suppress velocity artefacts* (Fig. 8)
- check *DeltatV*|*DeltatV settings*|*Process every CMP offset* (Fig. 8)

- select *DeltatV\DeltatV Export options*. Set *Max. velocity exported* to 5,800m/s (Fig. 9). Click button *Accept*. Select *DeltatV\Automatic DeltatV* and confirm prompts.
- select *Model\Forward model traveltimes & C:\RAY32\NGU_G4\TOMO\DELTATV.GRD*
- select *Grid\Image and contour velocity & C:\RAY32\NGU_G4\TOMO\DELTATV.GRD* to obtain Fig. 6
- select *Grid\Image and contour velocity & C:\RAY32\NGU_G4\INPUT\G4_SYNTHETIC.GRD* to obtain Fig. 7

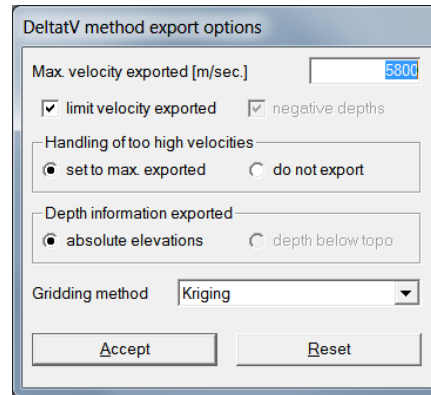
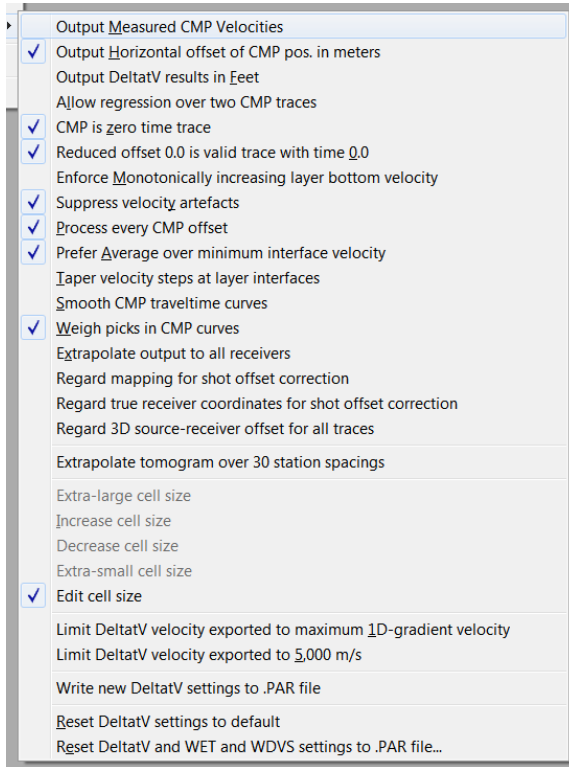


Fig. 9 : *DeltatV\DeltatV Export Options*. Increase *Max. velocity exported* to 5,800m/s. Click button *Accept*.

Fig. 8 (left) : *DeltatV\DeltatV Settings*. Check options *Suppress velocity artefacts & Process every CMP offset*. Uncheck the two options *Limit DeltatV velocity exported to...*

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 [LOKENOTE.pdf](#).

For processing of densely recorded lines longer than the recommended minimum of 500m with our *DeltatV* method see [OT0608.pdf](#) & [GEOXMERC.pdf](#) & [3016.pdf](#). *DeltatV* and *Smooth inversion* using *1D-gradient starting model* obtained by [laterally averaging DeltatV](#) match each other nicely as shown in these .pdf tutorials.

Above receiver spacing of 5m and a shot at every 4th receiver only are both too wide for *DeltatV*.

For detailed description of our *DeltatV* method and other inversion methods see our [manual](#).

On the next page we show layered refraction interpretation of above synthetic picks for NGU_G4 with conventional *Plus-Minus* method (Fig. 10). Note the good fit between synthetic picks and modeled traveltimes (Fig. 12) forward-modeled over the *Plus-Minus* .GRD file (Fig. 10) with RMS error 2.2%.

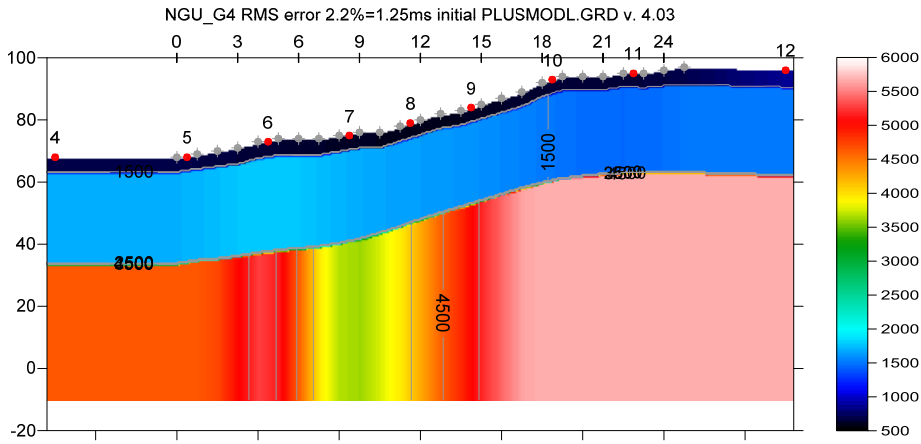


Fig. 10 : Plus-Minus method interpretation as 3-layer case. RMS error is 2.2%/1.25ms. For *Plus-Minus model parameters* see Fig. 13. *Overburden filter 5. Base filter width 3. Max. basement velocity 5,500 m/s.* For branch points see Fig. 12.

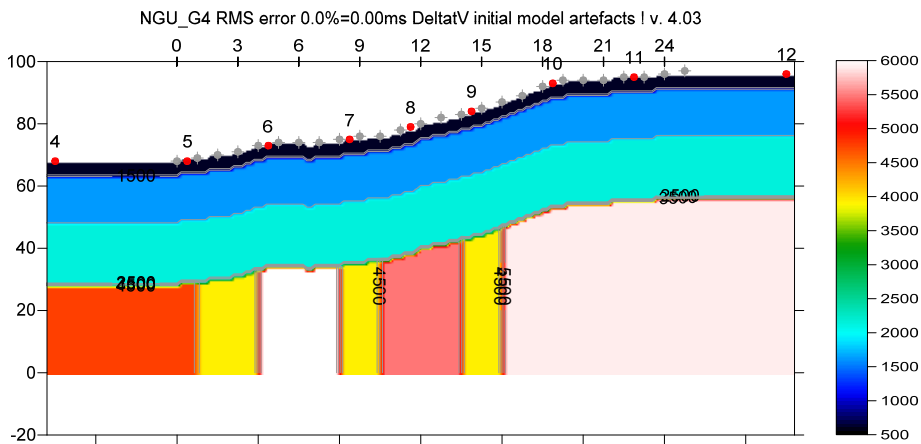


Fig. 11 : `c:\RAY32\NGU_G4\INPUT\G4_SYNTHETIC.GRD` plotted at same scale and color scale as Fig. 10.

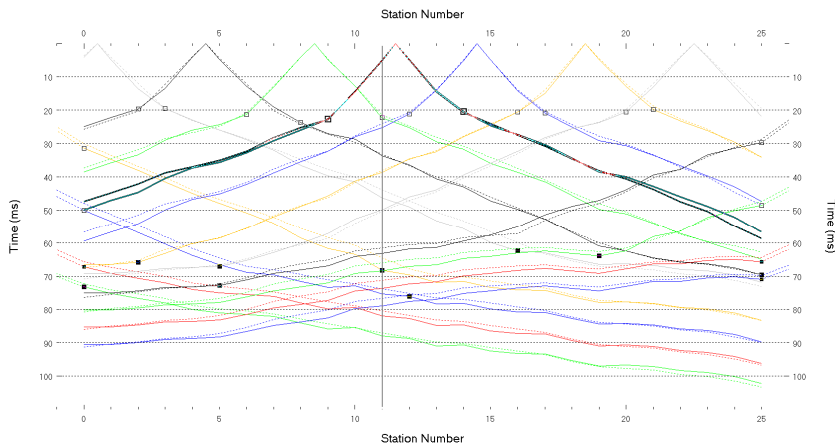


Fig. 12 : *Refractor/Shot breaks.* Solid curves are synthetic traveltimes curves. Dashed curves are traveltimes forward modeled over `c:\RAY32\NGU_G4\LAYRTOMO\PLUSMODL.GRD` (Fig. 10). Hollow squares are branch points separating the direct wave from first refractor. Black filled squares are branch points separating first refractor from 2nd refractor. Update with `File|Update header data|Update refractor branches from .BRN... & G4.BRANCHES.BRN`. Press **ALT+L** to remap traces to refractors. See [.pdf help](#) chapter *Mapping traces to refractors*.

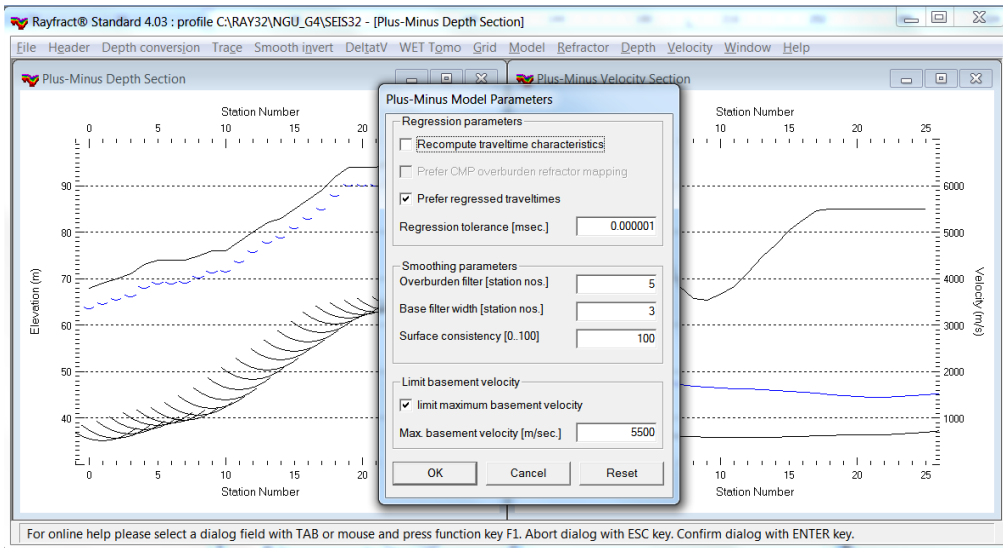


Fig. 13 : select *Depth|Plus-Minus*. When prompted to continue with WET inversion click *No* button. Reselect *Depth|Plus-Minus* and press **ALT+M** to show *Plus-Minus Model Parameters* dialog. Set *Overburden filter* to 5. Set *Base filter width* to 3. Check box *limit maximum basement velocity*. Set *Maximum basement velocity [m/s]* to 5500. Edit as shown and click *OK* button or press **ENTER** key to obtain Fig. 10.

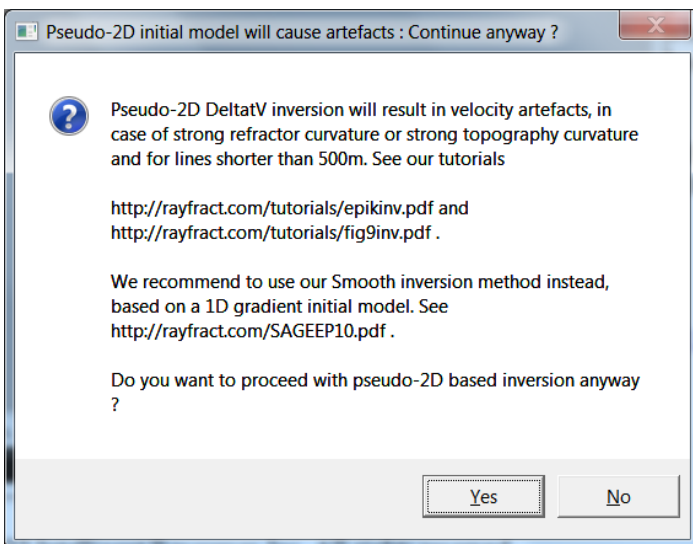


Fig. 14 : artefact warning prompt shown when user selects *DeltatV* menu items, recommending using *Smooth* inversion method instead.

As shown above our *pseudo-2D DeltatV* method can give reasonable output even for too short profiles with too wide receiver and shot spacing, as long as there is no strong lateral velocity variation in overburden and with not too strongly undulating topography.

NGU shows their *DeltatV* interpretation of above synthetic fault zone data in [NGU report 2020_044](#) in

their Fig. 11 in the rightmost column.

As shown in our earlier tutorial [NGU_G1_remodeled_traveltimes.pdf](#) NGU did not regard the off-end shot point station elevations for their forward modeling of synthetic traveltimes. Also NGU used non-default/bad settings for *DeltatV static corrections*. See our tutorial for [NGU_G1](#) model also shown in their Fig. 11 in the leftmost column.

We ask NGU to stop their misrepresentation of the *DeltatV* method (Gebrande and Miller 1985; Gebrande 1986; [Colombo 2016](#); [Gibson et al. 1979](#)) and to start following instructions in our [manual](#) and [tutorials](#), including using default *DeltatV settings* with our *Automatic DeltatV* inversion and also showing our *Smooth inversion* method using our *1D-gradient starting model* (Fig. 15 and Fig. 16). See also our earlier [Aaknes-1 tutorial](#), our [3016 tutorial](#) and [Line14 tutorial](#). This reminds us of earlier publications by Dr. Palmer discrediting our software and also completely ignoring our fail-safe default [Smooth inversion](#) method available since 2005 in his 2010 EAGE publication <https://dx.doi.org/10.1111/j.1365-2478.2009.00818.x>.

In general we always recommend preferring our default and fail-safe ***Smooth inversion*** method as shown on next page ([Sheehan et al. 2005](#)). See the warning prompt shown with *DeltatV* menu items (Fig. 14).

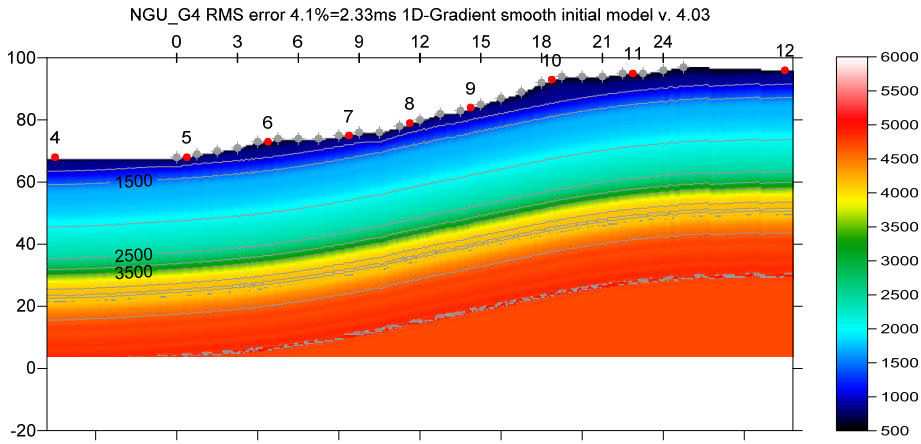


Fig. 15 : Smooth invert|WET with 1D-gradient initial model gives 1D-gradient initial model with Smooth inversion Settings Allow XTV inversion for 1D initial model & Optimize XTV for layered starting model (Fig. 20). RMS error is 2.33ms.

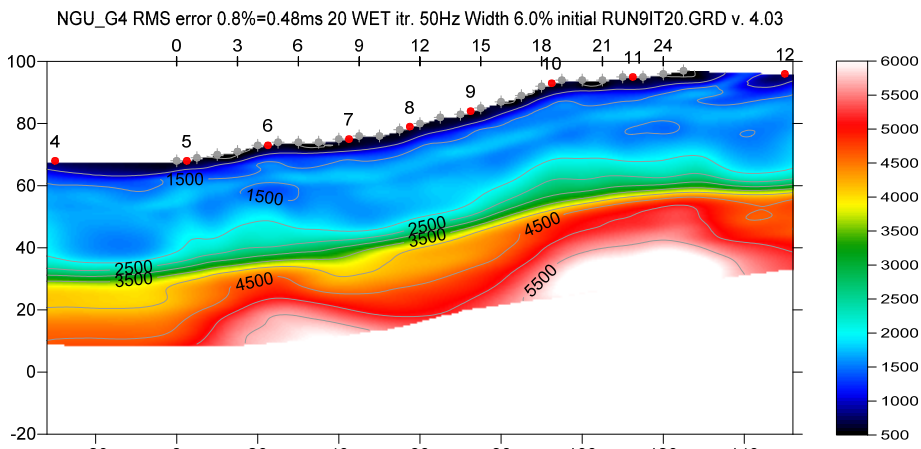


Fig. 16 : Multiscale Steepest-Descent WET inversion with WET Tomo|Interactive WET (Fig. 21 & 22). 1D-gradient starting model (Fig. 15). Model|WDVS Smoothing|Discard WET smoothing checked. WDVS activated at 500Hz (Fig. 19). Minimal WET smoothing (Fig. 22).

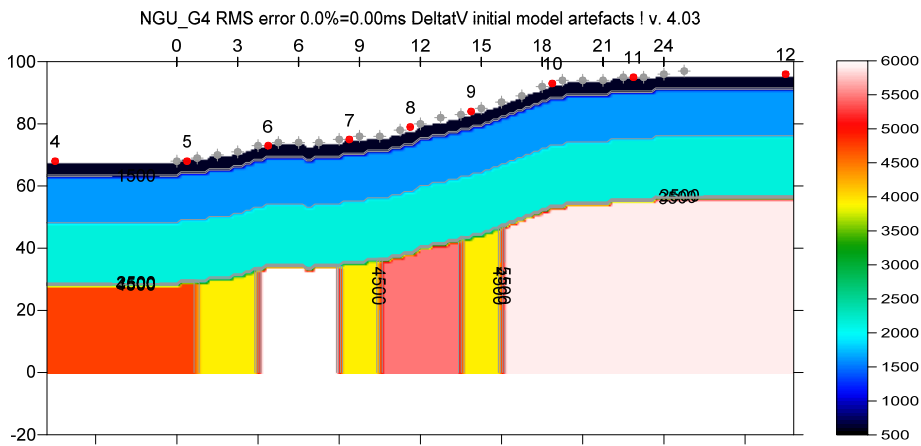


Fig. 17 :Grid|Image and contour velocity with c : \RAY32\NGU_G4\INPUT\G4_SYNTHETIC.GRD plotted at same scale as Fig. 16 using Grid|Surfer plot Limits shown in Fig. 4.

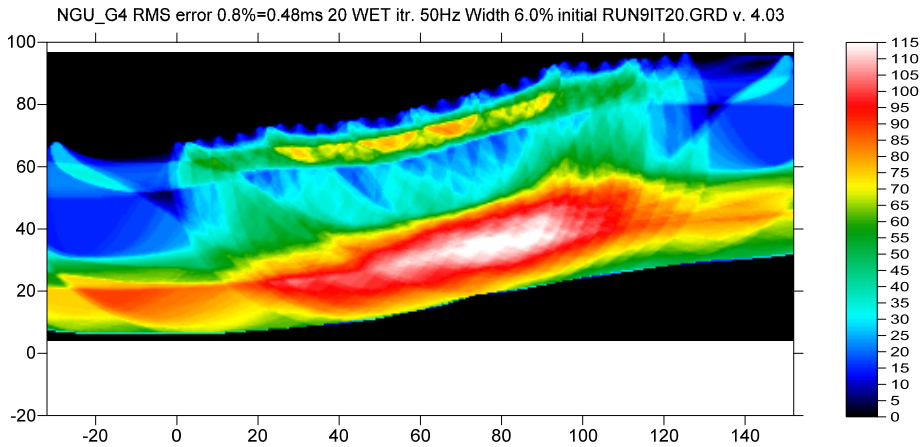


Fig. 18 : WET wavepath coverage plot obtained with Fig. 16. Unit is wavepaths per pixel.

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

OK Cancel Reset

Fig. 19 : Model\WDVS Smoothing...

Lower velocity of 1D-gradient layers

- Interpolate velocity for 1D-gradient initial model
- Wide smoothing filter for 1D initial velocity profile
Extra-wide smoothing for 1D initial velocity profile
- Wide CMP stack for 1D-gradient initial model
Extra-wide stack for 1D-gradient initial model
- Extrapolate tomogram over 30 station spacings
- Extra-large cell size
- Increase cell size
- Decrease cell size
- Extra-small cell size
- Edit cell size
- Depth-extend initial model
- Output inversion results in Feet
- Strict shot position checking
- No shot position checking
- Beydoun weighting for borehole WET
- Precompute static Beydoun weight matrix
- Coverage grid shows unweighted hit count
- Allow XTV inversion for 1D initial model
- Optimize XTV for layered starting model
- Limit WET velocity to maximum velocity in initial model
- Allow unsafe pseudo-2D DeltatV inversion

Reset Smooth Inversion settings

Fig. 20 : Smooth invert\Smooth inversion Settings

Edit WET runs - wavepath width

Run No.	Freq. [Hz]	Width [%]	Width [ms]	Iterations	
Run 1	<input type="text" value="50.0"/>	<input type="text" value="30.0"/>	<input type="text" value="6.000"/>	<input type="text" value="20"/>	<input type="checkbox"/> Blank
Run 2	<input type="text" value="50.0"/>	<input type="text" value="26.0"/>	<input type="text" value="5.200"/>	<input type="text" value="20"/>	<input type="checkbox"/> Blank
Run 3	<input type="text" value="50.0"/>	<input type="text" value="22.0"/>	<input type="text" value="4.400"/>	<input type="text" value="20"/>	<input type="checkbox"/> Blank
Run 4	<input type="text" value="50.0"/>	<input type="text" value="18.0"/>	<input type="text" value="3.600"/>	<input type="text" value="20"/>	<input type="checkbox"/> Blank
Run 5	<input type="text" value="50.0"/>	<input type="text" value="15.0"/>	<input type="text" value="3.000"/>	<input type="text" value="20"/>	<input type="checkbox"/> Blank
Run 6	<input type="text" value="50.0"/>	<input type="text" value="12.0"/>	<input type="text" value="2.400"/>	<input type="text" value="20"/>	<input type="checkbox"/> Blank
Run 7	<input type="text" value="50.0"/>	<input type="text" value="10.0"/>	<input type="text" value="2.000"/>	<input type="text" value="20"/>	<input type="checkbox"/> Blank
Run 8	<input type="text" value="50.0"/>	<input type="text" value="8.0"/>	<input type="text" value="1.600"/>	<input type="text" value="20"/>	<input checked="" type="checkbox"/> Blank
Run 9	<input type="text" value="50.0"/>	<input type="text" value="7.0"/>	<input type="text" value="1.400"/>	<input type="text" value="20"/>	<input checked="" type="checkbox"/> Blank
Run 10	<input type="text" value="50.0"/>	<input type="text" value="6.0"/>	<input type="text" value="1.200"/>	<input type="text" value="20"/>	<input checked="" type="checkbox"/> Blank

Blank below wavepath envelope

- Blank after each run
- Blank after last run

OK Cancel Reset

- WET runs active
- Scale default widths
- Plot runs in Surfer
- Prompt run misfit

Runs completed:

All runs completed

Current run no.:

- Resume current run

Fig. 21 : WET Tomo\Interactive WET Tomography\Iterate. Edit runs for multiscale WET.

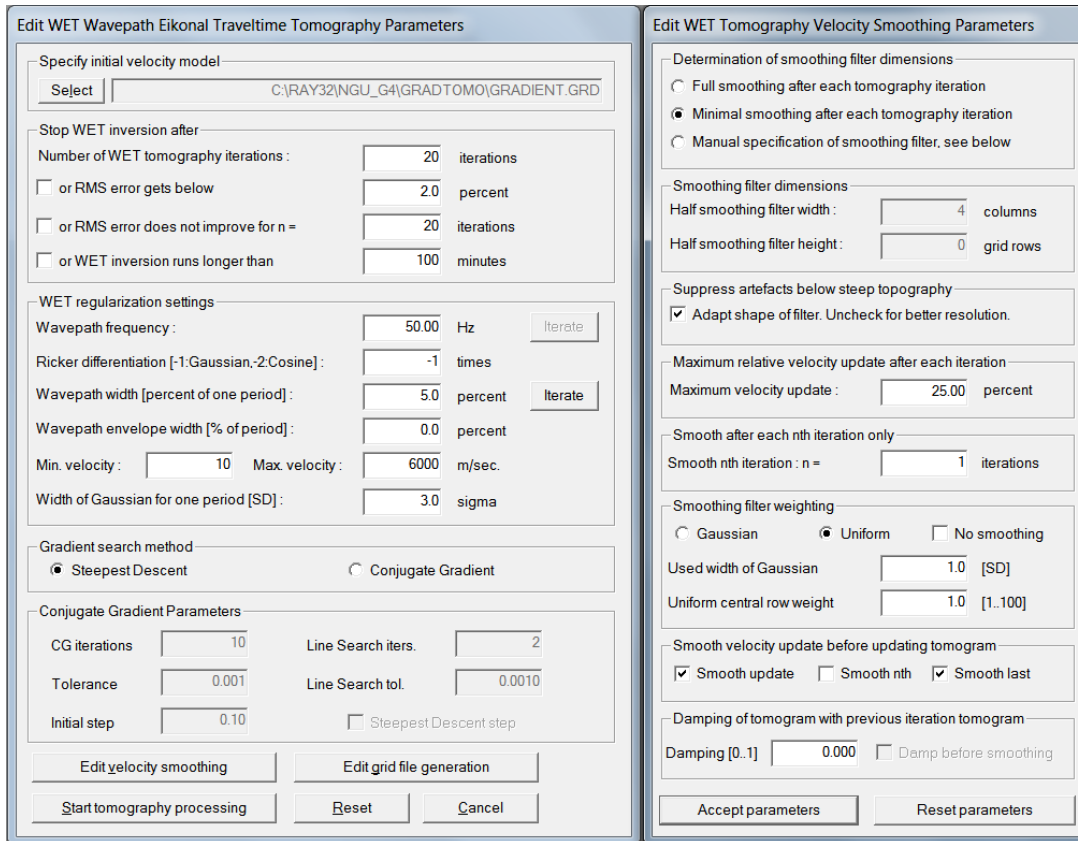


Fig. 22 : WET Tomo|Interactive WET main dialog (left). Edit velocity smoothing (right).

Next we show further optimized *interactive DeltatV* inversion with layered XTV settings in version 4.03 of our software :

- check *DeltatV|DeltatV settings|Taper velocity steps at layer interfaces* (Fig. 26)
- check *DeltatV|DeltatV settings|Suppress velocity artefacts* (Fig. 26)
- check *DeltatV|DeltatV settings|Process every CMP offset* (Fig. 26)
- uncheck ...*|DeltatV settings|Limit DeltatV velocity exported to maximum 1D-gradient velo.* (Fig. 26)
- select *DeltatV|XTV parameters* and edit as in Fig. 27. Set *Minimum velocity ratio* to 1.10.
- select *DeltatV|Interactive DeltatV*. Leave main dialog settings at defaults (Fig. 28).
- click button *Static Corrections*. Leave at defaults (Fig. 29) and click button *Accept*.
- click button *Export Options*. Increase *Max. velocity exported* to 5,800 m/s (Fig. 9) and click *Accept*.
- click button *DeltatV Inversion* (Fig. 28)
- in *Save DeltatV output* dialog move mouse cursor over yellow *Create New Folder* icon at top right
- left-click this icon. Edit name of new folder to ...*\Intercept1.10_Jan9*. Press **ENTER** key.
- double-click this new folder *c:\RAY32\NGU_G4\Intercept1.10_Jan9* & click *Save* button.
- select *Model|Forward model traveltimes & c:\RAY32\NGU_G4\Intercept1.10_Jan9\DELTATV.GRD*
- select *Grid|Image and contour velocity & ...\Intercept1.10_Jan9\DELTATV.GRD* to obtain Fig. 25
- obtain Fig. 23 as Fig. 25 but with *DeltatV|XTV parameters|Minimum velocity ratio* 1.05 (Fig. 27)

At offset range 0m to 80m Fig. 23 and Fig. 25 better match the true model (Fig. 24) than Fig. 6 for which *XTV parameters* (Fig. 27) were implicitly set to option *Gradient model* during *DeltatV|Automatic DeltatV*.

To the right of offset 80m Fig. 23 and Fig. 25 show more artefacts at top-of-basement than Fig. 6 & 10. These artefacts are due to strong refractor curvature and strong topography curvature and missing receivers to the right of station no. 25. See our [broadepi tutorial](#) and *DeltatV* artefact warning prompt (Fig. 14).

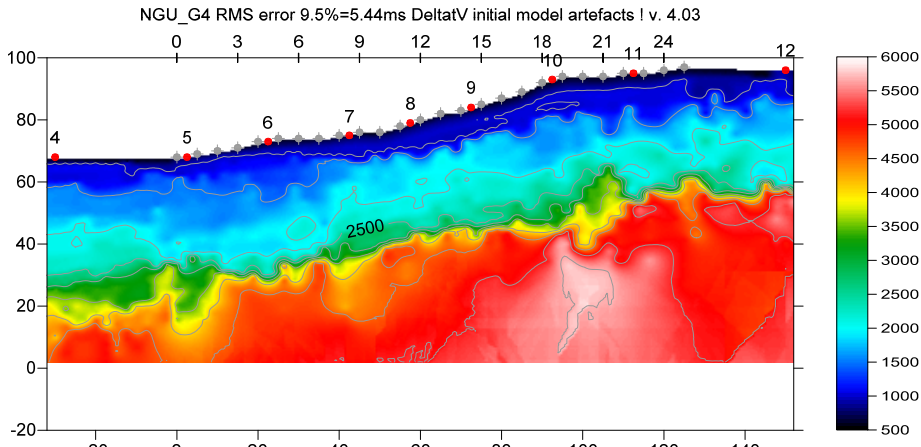


Fig. 23 : check DeltatV options *Suppress velocity artefacts*, *Process every CMP offset*, *Taper velocity steps at layer interfaces*. Uncheck *Limit DeltatV velocity to maximum 1D-gradient velocity* (Fig. 26). Increase *Max. velocity exported* to 5,800m/s (Fig. 9). Activate *Surfer plot limits* (Fig. 4). Layered XTV with *Minimum velocity ratio* 1.05 (Fig. 27).

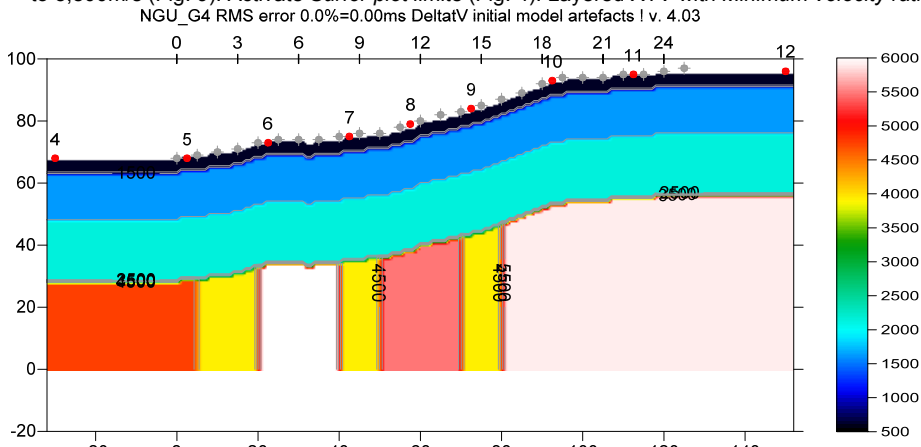


Fig. 24 : True model. *Grid/Image and contour velocity* with `C:\RAY32\NGU_G4\INPUT\G4_SYNTHETIC.GRD` plotted at same scale as Fig. 23 using *Grid/Surfer plot Limits* shown in Fig. 4.

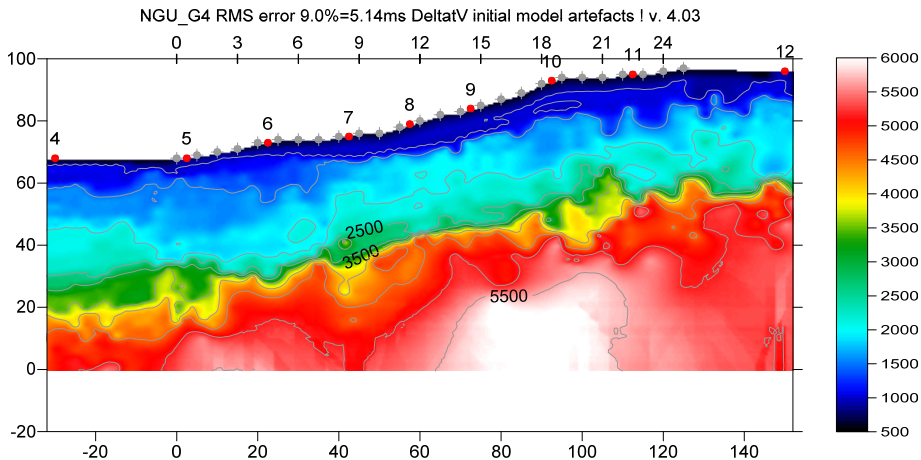


Fig. 25 : Default *Weathering crossover* 10 stations (Fig. 29). Default *Topography filter* 15 stations (Fig. 29). Check DeltatV options *Suppress velocity artefacts*, *Process every CMP offset*, *Taper velocity steps at layer interfaces*. Uncheck *Limit DeltatV velocity to maximum 1D-gradient velocity* (Fig. 26). Increase *Max. velocity exported* to 5,800m/s (Fig. 9). Activate *Surfer plot limits* (Fig. 4). Layered XTV with *Minimum velocity ratio* 1.10 (Fig. 27).

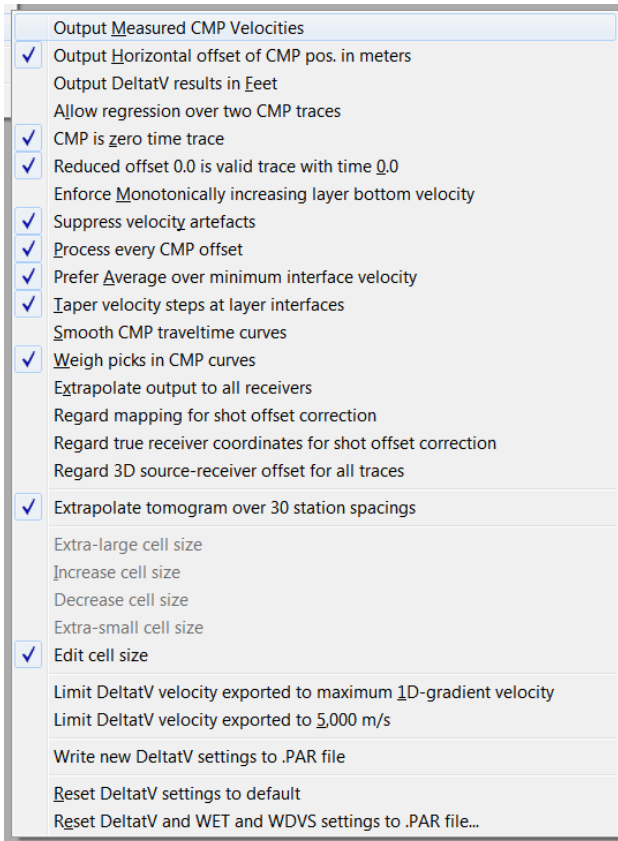


Fig. 26 : DeltatV\DeltatV Settings for Fig. 23 & Fig. 25

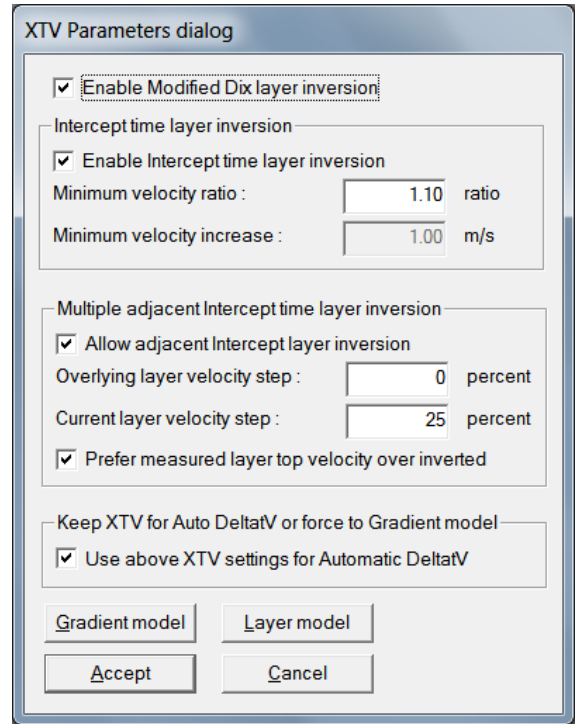


Fig. 27 : DeltatV\XTV parameters for Fig. 23 & 25. For Fig. 23 set *Minimum velocity ratio* to 1.05.

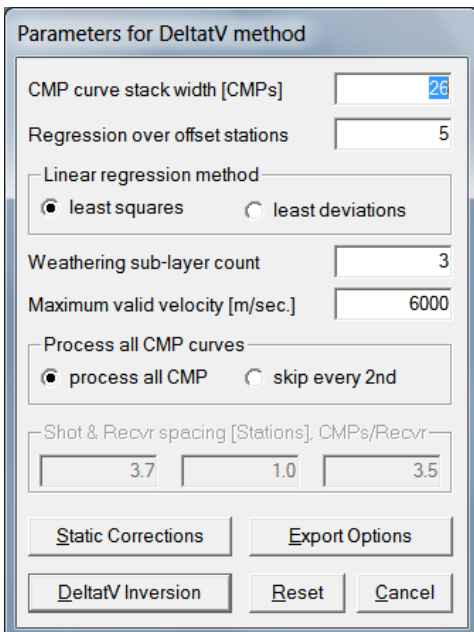


Fig. 28 : DeltatV\Interactive DeltatV main dialog. Default settings for Fig. 23 and Fig. 25.

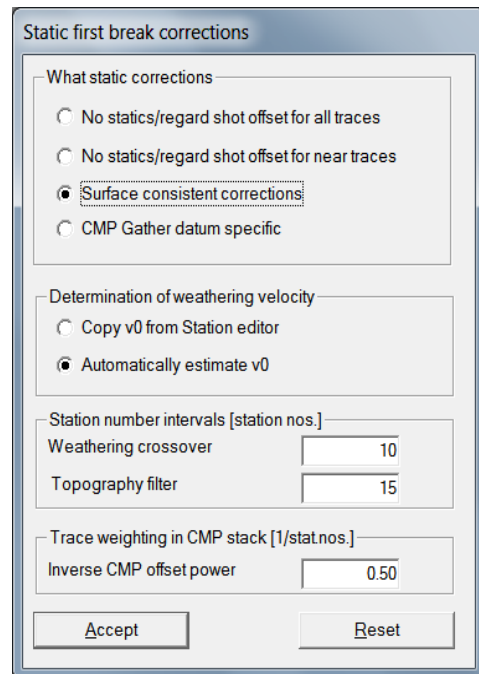


Fig. 29 : DeltatV\Interactive DeltatV\Static Corrections. Default settings for Fig. 23 and 25.

For recommended default settings for DeltatV static corrections dialog see our .pdf help <https://rayfract.com/help/rayfract.pdf> chapter *DeltatV Static Corrections* on page 208. For latest description see https://rayfract.com/help/DeltatV_Static_Corrections_July12_2022.jpg .

For recommended default settings in interactive DeltatV main dialog see our .pdf help <https://rayfract.com/help/rayfract.pdf> chapter *Interactive DeltatV* on page 206. For latest description see https://rayfract.com/help/DeltatV_Interactive_Main_Dialog_July12_2022.jpg .

For latest version of our help chapter on pseudo-2D DeltatV inversion see https://rayfract.com/help/DeltatV_Inversion.pdf .

For latest version of our help chapter on XTV inversion see https://rayfract.com/help/XTV_inversion_July_2022.pdf .

DeltatV interpretations shown in Fig. 23 and Fig. 25 display a realistic shape of the top-of-basement in offset range 0m to 80m when compared to the traditional Plus-Minus interpretation (Fig. 10). DeltatV interpretations are a bit too deep compared to the true model (Fig. 24) and include noise and artefacts especially before first/after last profile receiver and at the location of strong refractor curvature.

To the right of offset 80m Fig. 23 and Fig. 25 show more artefacts at top-of-basement than Fig. 6 & 10. These artefacts are due to strong refractor curvature and strong topography curvature and missing receivers to the right of station no. 25. See our [broadepi tutorial](#) and DeltatV artefact warning prompt (Fig. 14).

Our latest version 4.03 released in Dec 2022 offers a new option at bottom of *DeltatV\XTV parameters* dialog named *Use above XTV settings for Automatic DeltatV* (Fig. 27). Check this option to obtain Fig. 23 and Fig. 25 with *DeltatV\Automatic DeltatV* instead of *DeltatV\Interactive DeltatV*. You still first need to increase the *Max. velocity exported* in dialog *DeltatV\DeltatV Export Options* or in *DeltatV\Interactive DeltatV\Export Options* (Fig. 9).

Here is the .zip archive with [NGU model G4 model files](#) made available by NGU May 23, 2022

Here is the .zip archive with correctly [remodeled traveltimes files](#) done Jan 9, 2023

Here is the .rar archive with [DeltatV files for Fig. 6](#)

Here is the .rar archive with [Plus-Minus files for Fig. 10](#)

Here is the .rar archive with [multiscale inversion files for Fig. 16](#)

Here is the .rar archive with [DeltatV files for Fig. 25](#)

On the next page we show multiscale Steepest-Descent WET inversion using the DeltatV+XTV starting model shown in Fig. 23. We enable WDVS (Wavelength-Dependent Velocity Smoothing; Zelt and Chen 2016) to obtain sharper imaging of fault zones in the basement.

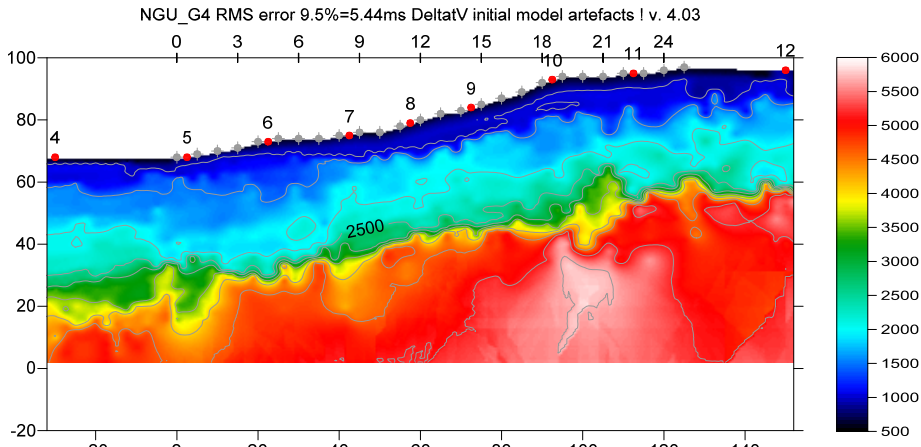


Fig. 30 (same as Fig. 23) : Layered XTV with *Minimum velocity ratio* 1.05 (Fig. 27). Default **Weathering crossover** 10 stations (Fig. 29). Default **Topography filter** 15 stations (Fig. 29). Check DeltatV options *Suppress velocity artefacts*, *Process every CMP offset*, *Taper velocity steps at layer interfaces*. Uncheck *Limit DeltatV velocity to maximum 1D-gradient velocity* (Fig. 26). Increase *Max. velocity exported to 5,800m/s* (Fig. 9). Activate *Surfer plot limits* (Fig. 4).

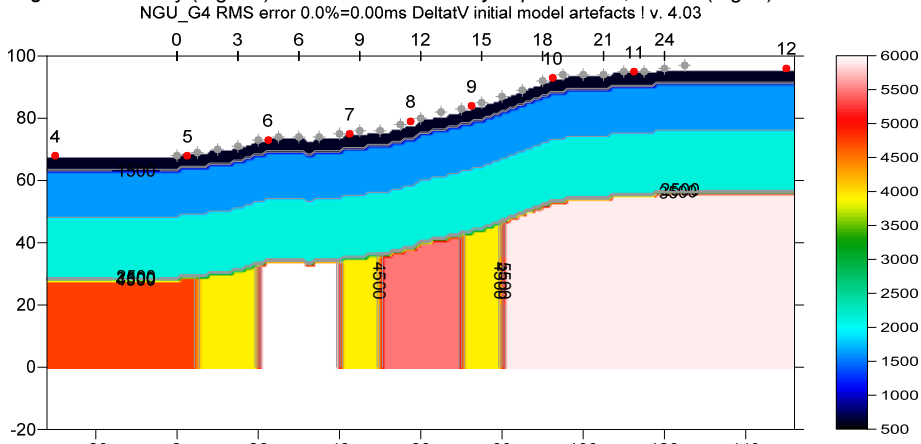


Fig. 31 : True model. *Grid/Image and contour velocity* with `C:\RAY32\NGU_G4\INPUT\G4_SYNTHETIC.GRD` plotted at same scale as Fig. 30 using *Grid/Surfer plot Limits* shown in Fig. 4.

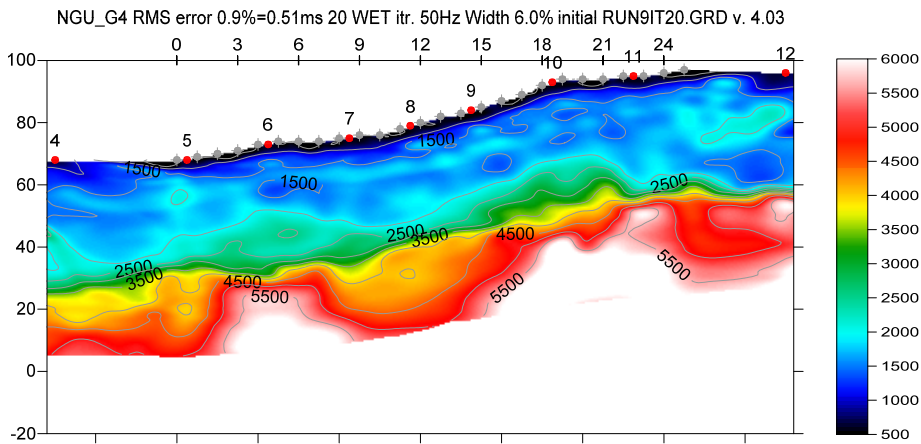


Fig. 32 : Multiscale Steepest-Descent WET. Output of 10th WET run shown. Starting model is Fig. 30. **WDVS @500Hz**. Discard WET smoothing after WDVS (Fig. 35). Minimal WET smoothing. Gaussian WET smoothing filter weighting. Used width of Gaussian 3.0 sigma (Fig. 34 right). Multirun WET schedule as in Fig. 36. Surfer plot Limits as in Fig. 4.

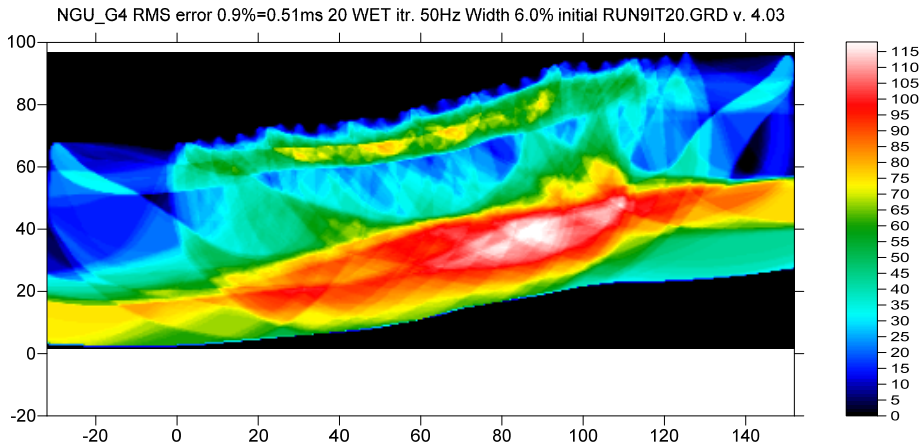


Fig. 33 : WET wavepath coverage for Fig. 32. Unit is wavepaths per pixel.

Edit WET Wavepath Eikonal Traveltime Tomography Parameters

Specify initial velocity model
 C:\RAY32\NGU_G4\Intercept_1.05_Jan9\DELTATV.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 [SD] : 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 [SD]

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. 34 : WET Tomo|Interactive WET main dialog (left). Edit velocity smoothing (right). Settings used for Fig. 32.

Here is the .rar archive with [10 WET runs for Fig. 32](#)

Here is the .rar archive with [seis32.* profile database files for Fig. 32](#)

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

OK Cancel Reset

Fig. 35 : *Model\WDVS Smoothing*. Settings used for Fig. 32. Use WDVS for forward modeling of traveltimes. WDVS frequency 500Hz. Discard WET smoothing after forward modeling.

Edit WET runs - wavepath width

Run No.	Freq. [Hz]	Width [%]	Width [ms]	Iterations	
Run 1	<input type="text" value="50.0"/>	<input type="text" value="30.0"/>	<input type="text" value="6.000"/>	<input type="text" value="20"/>	<input type="checkbox"/> Blank
Run 2	<input type="text" value="50.0"/>	<input type="text" value="26.0"/>	<input type="text" value="5.200"/>	<input type="text" value="20"/>	<input type="checkbox"/> Blank
Run 3	<input type="text" value="50.0"/>	<input type="text" value="22.0"/>	<input type="text" value="4.400"/>	<input type="text" value="20"/>	<input type="checkbox"/> Blank
Run 4	<input type="text" value="50.0"/>	<input type="text" value="18.0"/>	<input type="text" value="3.600"/>	<input type="text" value="20"/>	<input type="checkbox"/> Blank
Run 5	<input type="text" value="50.0"/>	<input type="text" value="15.0"/>	<input type="text" value="3.000"/>	<input type="text" value="20"/>	<input type="checkbox"/> Blank
Run 6	<input type="text" value="50.0"/>	<input type="text" value="12.0"/>	<input type="text" value="2.400"/>	<input type="text" value="20"/>	<input type="checkbox"/> Blank
Run 7	<input type="text" value="50.0"/>	<input type="text" value="10.0"/>	<input type="text" value="2.000"/>	<input type="text" value="20"/>	<input type="checkbox"/> Blank
Run 8	<input type="text" value="50.0"/>	<input type="text" value="8.0"/>	<input type="text" value="1.600"/>	<input type="text" value="20"/>	<input checked="" type="checkbox"/> Blank
Run 9	<input type="text" value="50.0"/>	<input type="text" value="7.0"/>	<input type="text" value="1.400"/>	<input type="text" value="20"/>	<input checked="" type="checkbox"/> Blank
Run 10	<input type="text" value="50.0"/>	<input type="text" value="6.0"/>	<input type="text" value="1.200"/>	<input type="text" value="20"/>	<input checked="" type="checkbox"/> Blank

Blank below wavepath envelope

Blank after each run Blank after last run

OK
Cancel
Reset

WET runs active

Scale default widths

Plot runs in Surfer

Prompt run misfit

Runs completed

All runs completed

Current run no.

Resume current run

Fig. 36 : *WET Tomo\Interactive WET Tomography\Iterate*. Edit runs for multiscale WET for Fig. 32.

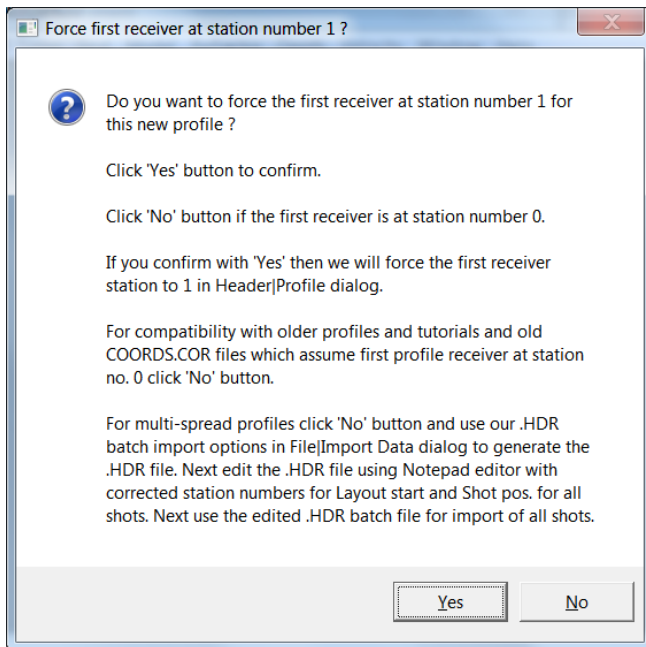


Fig. 37 : click No button to leave profile start / first receiver station number at station no. 0.

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.

We thank NGU for making available above synthetic data and model files.

As shown in our companion [short tutorial](#) you need to correctly specify off-end shot elevations to obtain correct synthetic first breaks picks with *Model|Model synthetic shots* over NGU G4_SYNTHETIC.GRD model.

See also our updated [Aaknes-1 tutorial](#) showing optimized (Fig. 29) and pessimized (Fig. 28) *DeltatV* interpretation of field-recorded data from Norway.

Next we show ***Automatic WET inversion*** using our Plus-Minus layered refraction starting model (Fig. 10). We discard WET smoothing after forward modeling (Fig. 35) for improved resolution but leave WDVS disabled :

- select *Model|WDVS Smoothing*
- uncheck box *use WDVS for forward modeling of traveltimes* (Fig. 35)
- check box *discard WET smoothing and WDVS smoothing after modeling* (Fig. 35). Click *OK*.
- select ***WET Tomo|Automatic WET tomography...***
- navigate into folder `c:\RAY32\NGU_G4\LAYRTOMO`
- select file ***PLUSMODL.GRD*** and click *Open* button
- confirm prompt showing fit between modeled and picked traveltimes with *OK* button
- confirm completion prompt with *OK* button
- click on Surfer icon in task bar to view the WET tomogram (Fig. 40) obtained with default WET parameters : 20 *Steepest-Descent* WET iterations, *Wavepath frequency* 50Hz, *Ricker differentiation -1* (Gaussian), *Full WET smoothing*.

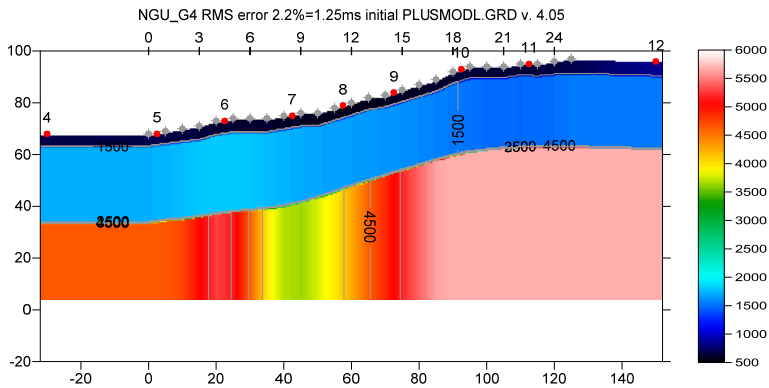


Fig. 39 : Plus-Minus method starting model. Same as Fig. 10.

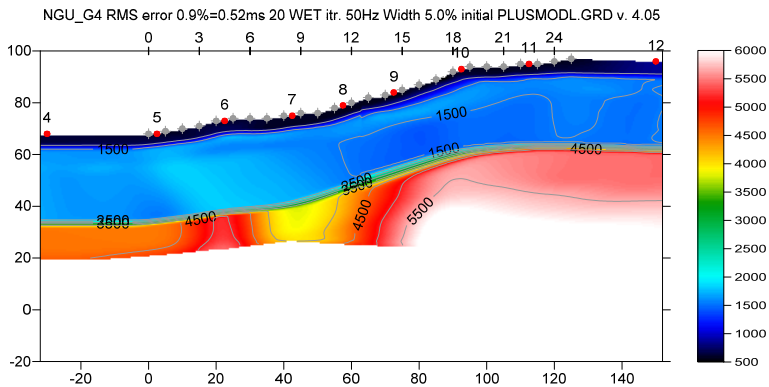


Fig. 40 : WET Tomo|Automatic WET. Starting model Fig. 39. Discard WET smoothing (Fig. 35) but don't enable WDV.S.

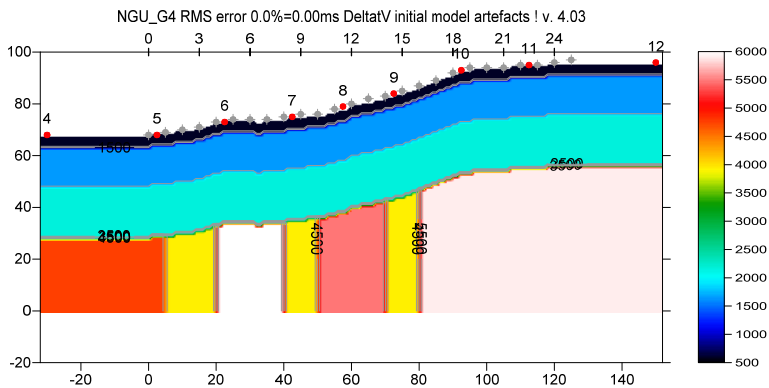


Fig. 41 : synthetic model used for forward modeling of synthetic traveltimes. Made available by NGU.

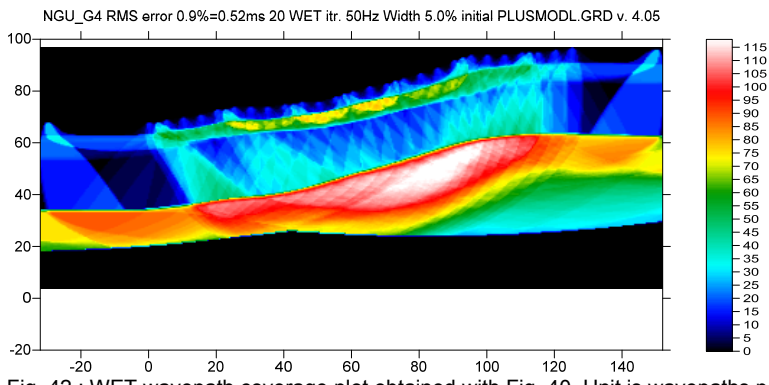


Fig. 42 : WET wavepath coverage plot obtained with Fig. 40. Unit is wavepaths per pixel.

Here is the .rar archive with [LAYRTOMO folder](#) for Fig. 40 .
Here is the .rar archive with [seis32.* profile database files](#) for Fig. 40 .

For an overview of our WDVS (Wavelength-Dependent Velocity Smoothing; [Zelt and Chen 2016](#)) see these publications :

Zelt, C. A. and J. Chen 2016. 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 .

Rohdewald S.R.C. 2021a. Improving the resolution of Fresnel volume tomography with wavelength-dependent velocity smoothing, *Symposium on the Application of Geophysics to Engineering and Environmental Problems Proceedings* : 305-308. <https://doi.org/10.4133/sageep.33-169> . Slides at <https://rayfract.com/pub/SAGEEP%202021%20slides.pdf>

Rohdewald S.R.C. 2021b. Improved interpretation of SAGEEP 2011 blind refraction data using Frequency-Dependent Traveltime Tomography, *EGU General Assembly 2021*, online, 19–30 Apr 2021, EGU21-4214, <https://doi.org/10.5194/egusphere-egu21-4214>

For an objective comparison of tomographic refraction analysis methods see these publications :

Zelt, C.A., Haines, S., Powers, M.H. et al. 2013. Blind Test of Methods for Obtaining 2-D Near-Surface Seismic Velocity Models from First-Arrival Traveltimes, *JEEG*, Volume 18(3), 183-194. <https://www.researchgate.net/publication/267026965>

Hiltunen, D. R., Hudyma, N., Quigley, T. P., & Samakur, C. 2007. Ground Proving Three Seismic Refraction Tomography Programs. *Transportation Research Record*, 2016(1), 110–120. <https://doi.org/10.3141/2016-12> . <https://www.researchgate.net/publication/242072938> .

Sheehan J.R., Doll W.E. and Mandell W.A. 2005a. An Evaluation of Methods and Available Software for Seismic Refraction Tomography. *Journal of Environmental and Engineering Geophysics*, volume 10, pp. 21-34. ISSN 1083-1363, Environmental and Engineering Geophysical Society. *JEEG* March 2005 issue. <https://dx.doi.org/10.2113/JEEG10.1.21> . https://rayfract.com/srt_evaluation.pdf . <https://www.researchgate.net/publication/242159023> .

We thank NGU for making available above synthetic data and model and parameter files.