

VSP constrained refraction tomography with Rayfract® version 3.35 :

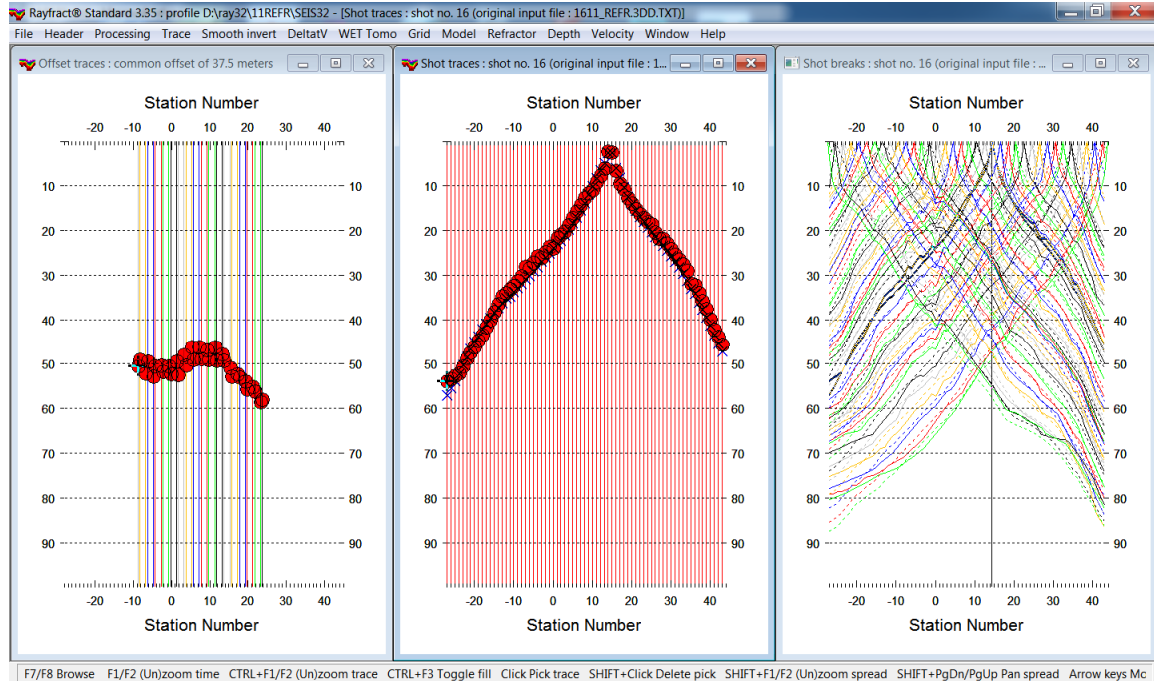


Fig. 1 : left : Trace|Offset gather, center : Trace|Shot gather, right : Refractor|Shot breaks. Shows fit between picked times (solid colored curves) and modeled times (dashed colored curves) obtained by forward modeling over Fig. 2.

- File|New Profile..., set File name to 11REFR and click Save button
- set Station spacing to 1.0m in Header|Profile... . Set Profile start offset[m] to -28.0 .
- set Cell size [m] to 0.5 . Check box Force grid cell size.
- unzip 1611_refr.3dd.rar with 1611_refr.3dd.txt in C:\RAY32\11REFR\INPUT
- check File|Import Data|Settings|Import horizontal borehole survey or .3DD refraction survey
- check File|Import Data Settings|X coordinate is corrected for topography already
- select File|Import Data... and set Import data type to Tweeton GeoTomCG .3DD
- leave Default spread type at 10: 360 channels. Set Default sample count to 2000 .
- click upper Select button, navigate into C:\RAY32\11REFR\INPUT and select file 1611_refr.3dd.txt
- click Open button, Import shots button. The Import shot dialog is shown for each shot in the .3DD file.
- for each shot leave Layout start and Shot pos. at shown values and click Read button
- select Trace|Shot gather, Trace|Offset gather and Window|Tile to obtain Fig. 1
- for each window click title bar, press ALT+P, set Maximum time to 100 ms and hit ENTER key
- for Trace|Shot gather & Trace|Offset gather click title bar. Uncheck Processing|Use red cross for picked first breaks. Check Processing|Solid color pick display & Picks always cover traces.
- click title bar of Refractor|Shot breaks window. Uncheck Mapping|Display raytraced traveltimes.
- check Mapping|Color picked traveltimes curves
- uncheck WET Tomo|WET tomography Settings|Blank|Blank below envelope after last iteration
- check WET Tomo|WET tomography Settings|Edit maximum valid WET velocity
- create borehole profile 1611HOLE and import VSP shots as described in tutorial 1611HOLE.pdf
- in Header|Profile click topmost Select button and select C:\RAY32\1611HOLE\SEIS32.DBD . See Fig. 5 .
- select Smooth invert|WET with 1D-gradient initial model and confirm for default interpretation
- select Grid|Surfer plot Limits. Set X Scale to 4.5 inch. Click button Reset to grid and select C:\RAY32\11REFR\GRADTOMO\VELOIT20.GRD . Check box Plot limits active.
- set Min. velocity to 200m/s and Max. velocity to 5000m/s. Click OK button.

LINE 11 RMS error 5.0%=4.32ms initial GRADIENT.GRD Version 3.35

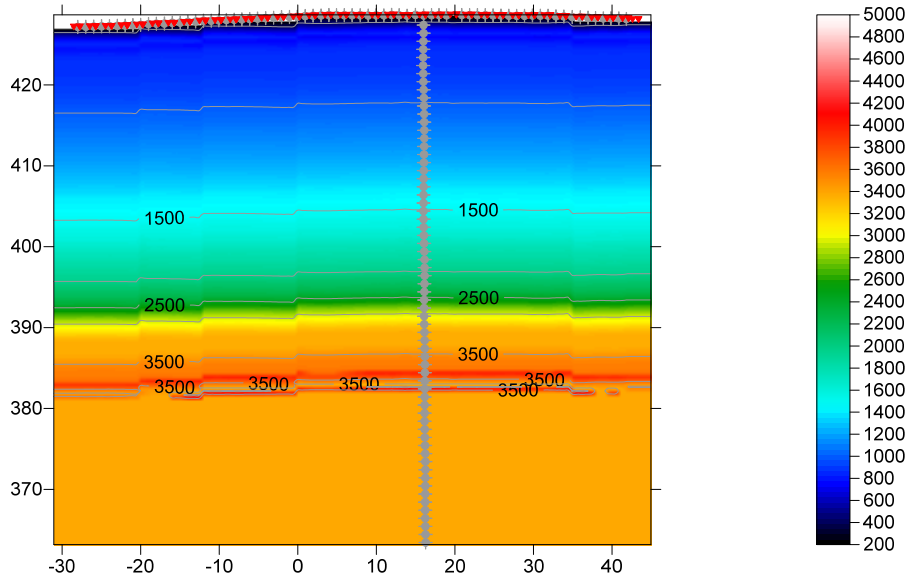


Fig. 2a : 1D-gradient starting model, obtained by horizontally averaging DeltatV inversion output. Default Smooth inversion settings, default DeltatV settings.

LINE 11 RMS error 2.1%=1.85ms 100 WET iters. 50Hz Width 19.0% initial GRADIENT.GRD Version 3.35

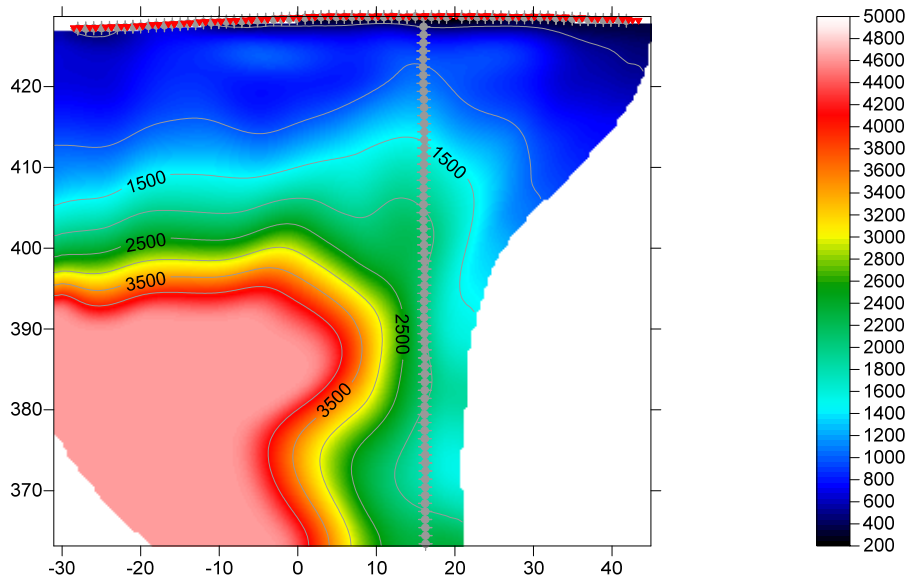


Fig. 2b : Tomogram with 1D-gradient starting model Fig. 2a, 100 Steepest Descent WET iterations, default WET settings. Wavewidth 19%, Max. velocity 4,500 m/s. WET settings as in Fig. 4.

- set *WET Tomo|Interactive WET tomography|Number of iterations* to 100. Set *Wavewidth* to 19% and *Max. velocity* to 4500m/s. See Fig. 4. Click *Start tomography processing* to obtain Fig. 2 & 3.
- for *WET parameters* used see archive [GRAD335 Width19% 100Iters.rar](#) with starting model files GRADIENT.GRD & GRADIENT.PAR, VELOIT100.GRD & .PAR and .SRF Surfer 11 plots
- click *WET Tomo|Interactive WET tomography|Iterate* and specify multiscale tomography parameters as shown in Fig. 6
- check box *WET runs active*, click *OK button* and *Start tomography processing button* for Fig. 7 & 8

For help on *WET inversion* parameters see [pdf reference](#) chapter *WET Wavewidth Eikonal Traveltime tomography*.

LINE 11 RMS error 2.1%=1.85ms 100 WET iters. 50Hz Width 19.0% initial GRADIENT.GRD Version 3.35

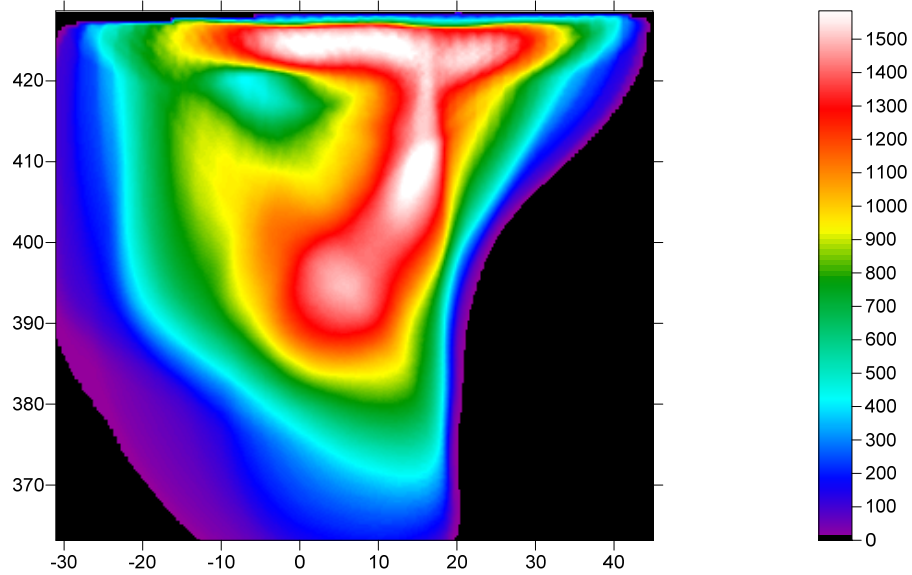


Fig. 3 : WET wavepath coverage plot obtained with Fig. 2b. Shows number of wavepaths per pixel.

Edit WET Wavepath Eikonal Traveltime Tomography Parameters

Specify initial velocity model
 D:\RAY32\11REFR\GRADTOMO\GRADIENT.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 is Gaussian bell] : 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
 Tolerance Line Search tol.
 Initial step Line Search iters.
 Steepest Descent step CG iterations

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

Filter shallow dipping wavepath artefacts from model
 Automatically adapt shape of rectangular filter matrix

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
 Used width of Gaussian sigma
 Uniform central row weight [1..100]

Smooth velocity update before updating tomogram
 Smooth velocity update Smooth last iteration

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

Fig. 4 : WET parameter settings for Fig. 2 & 3. left : main interactive WET dialog. right : edit velocity smoothing

Edit Profile

Line ID:

Line type:

Job ID:

Instrument:

Client:

Company:

Observer:

Note:

Station spacing [m]:

Min. horizontal separation [%]:

Profile start offset [m]:

Time of Acquisition
Date:

Time:

Time of Processing
Date:

Time:

Units:

Sort:

Const:

Left handed coordinates

Force grid cell size

Cell size [m]:

Add borehole lines for WET tomography

Borehole 1 line:

Borehole 2 line:

Borehole 3 line:

Borehole 4 line:

Fig. 5 : *Header|Profile* dialog. Easily add borehole line(s) with *Select button(s)*.

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="23.0"/>	<input type="text" value="4.600"/>	<input type="text" value="20"/>	<input type="checkbox"/> Blank
Run 4	<input type="text" value="50.0"/>	<input type="text" value="20.0"/>	<input type="text" value="4.000"/>	<input type="text" value="20"/>	<input type="checkbox"/> Blank
Run 5	<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 6	<input type="text" value="50.0"/>	<input type="text" value="16.0"/>	<input type="text" value="3.200"/>	<input type="text" value="20"/>	<input type="checkbox"/> Blank
Run 7	<input type="text" value="50.0"/>	<input type="text" value="13.0"/>	<input type="text" value="2.600"/>	<input type="text" value="20"/>	<input type="checkbox"/> Blank
Run 8	<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 9	<input type="text" value="50.0"/>	<input type="text" value="2.0"/>	<input type="text" value="0.400"/>	<input type="text" value="0"/>	<input checked="" type="checkbox"/> Blank
Run 10	<input type="text" value="50.0"/>	<input type="text" value="1.0"/>	<input type="text" value="0.200"/>	<input type="text" value="0"/>	<input checked="" type="checkbox"/> Blank

WET runs active

Scale default widths

Plot runs in Surfer

Prompt run misfit

Runs completed:

All runs completed

Current run no.:

Resume current run

Blank below wavepath envelope

Blank after each run Blank after last run

Fig. 6 : *WET Tomo|Interactive WET tomography|Iterate* . Specify parameters for multiscale tomography.

LINE 11 RMS error 2.0%=1.75ms 20 WET iters. 50Hz Width 10.0% initial RUN7IT20.GRD Version 3.35

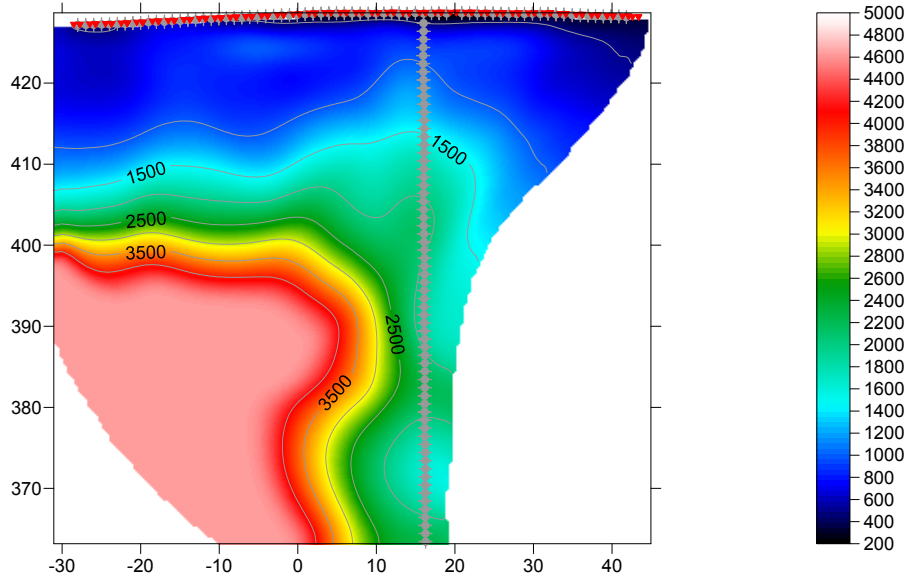


Fig. 7 : multiscale tomography obtained with multirun WET parameters shown in Fig. 6

LINE 11 RMS error 2.0%=1.75ms 20 WET iters. 50Hz Width 10.0% initial RUN7IT20.GRD Version 3.35

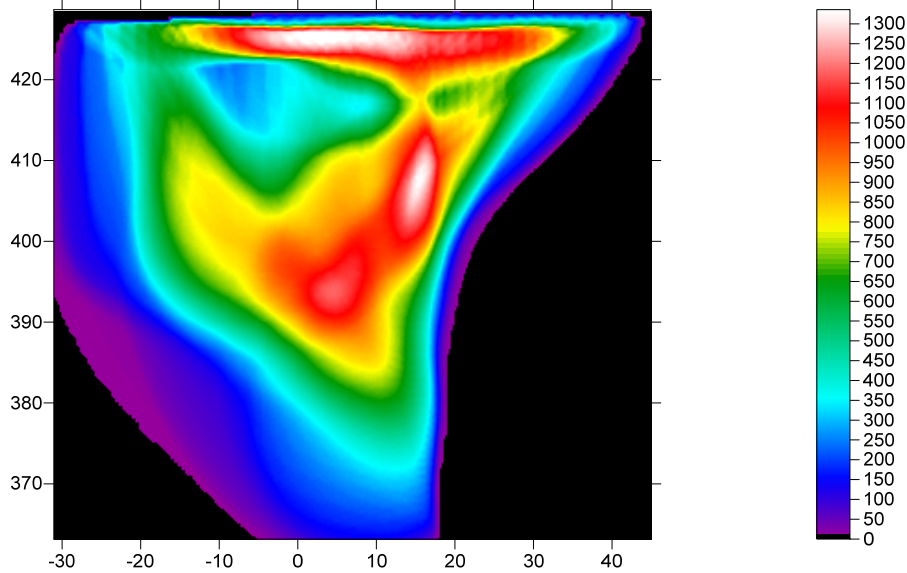


Fig. 8 : WET wavepath coverage plot obtained with Fig. 7. Unit is wavepaths per pixel.

Note the improved vertical resolution at top of basement in Fig. 7 showing [multiscale tomography](#) when compared to Fig. 2b showing single-run WET inversion.

[WETRUN8 Gradient Start.rar](#) contains files for Fig. 7. [WETRUN8 ConstVelo Start.rar](#) contains the same files obtained with *constant-velocity starting model*. See [WETRUN1 Gradient Start.rar](#) and [WETRUN1 ConstVelo Start.rar](#) for starting models and tomograms obtained with first WET run.

Next we disregard VSP shots and invert first break picks for refraction shots only :

- select *Header|Profile* (Fig. 5). Click *Reset* to delete all borehole line selections. Click *button OK*.
- select *Smooth invert|Custom 1D-gradient velocity profile*
- click *button Reset limits to grid* and select `C:\RAY32\11REFR\GRADTOMO\VELOIT100.GRD`
- check *box Force grid limits* and click *button OK*

LINE 11 RMS error 1.8%=1.56ms 100 WET iters. 50Hz Width 19.0% initial GRADIENT.GRD Version 3.35

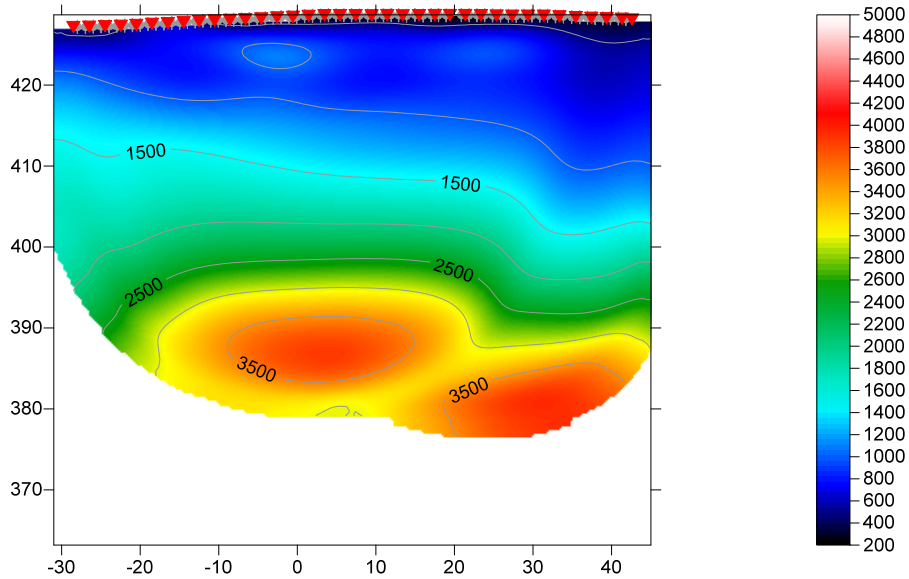


Fig. 9 : WET inversion of refraction shots only, disregard VSP shots

LINE 11 RMS error 1.8%=1.56ms 100 WET iters. 50Hz Width 19.0% initial GRADIENT.GRD Version 3.35

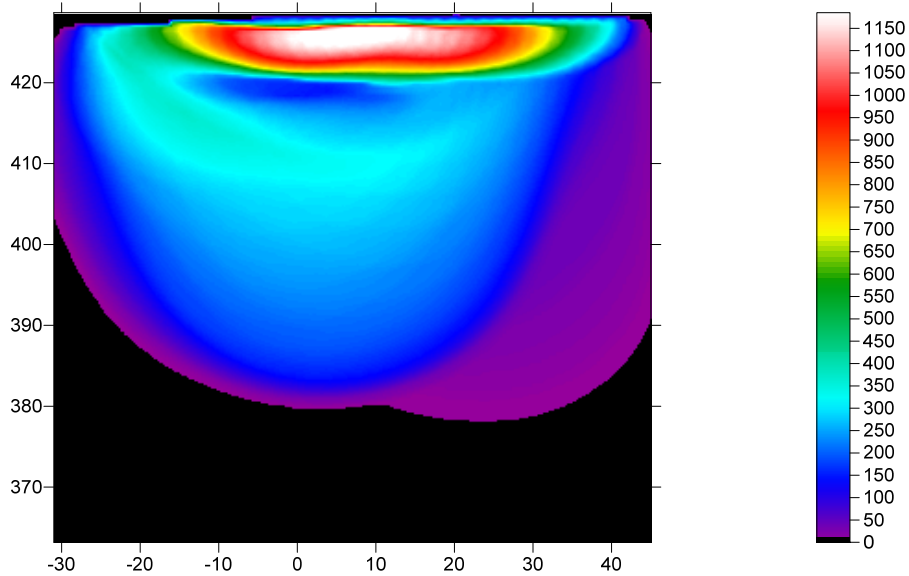


Fig. 10 : Wavepath coverage plot obtained with Fig. 9. Unit is wavepaths per pixel.

- select *Smooth invert|WET with 1D-gradient initial model* and confirm for default interpretation
- set *WET Tomo|Interactive WET tomography|Number of iterations* to 100. See Fig. 4.
- set *Wavepath width* to 19% and *Max. velocity* to 4500m/s. See Fig. 4.
- click *Iterate* and uncheck *WET runs active*. Click *OK* and *Start tomography processing* for Fig. 9&10.

Note the limited depth penetration in Fig. 9&10 due to the shallow high-velocity layer at elevation 425m and lower-velocity region below this layer. Classic refraction theory states that you cannot image below a velocity inversion. As shown we still get a meaningful estimate of top of bedrock with *WET inversion*.