Multiscale tomography Basement Step model with Rayfract® 3.34
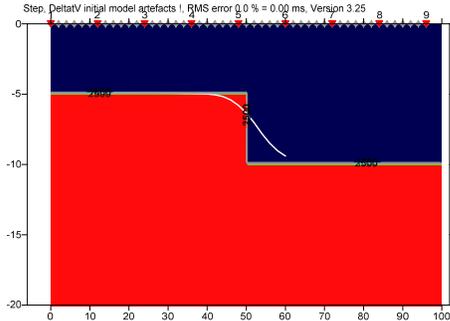

Fig. 1 : Basement step model. For instructions to build this model and the database see our Step tutorial .
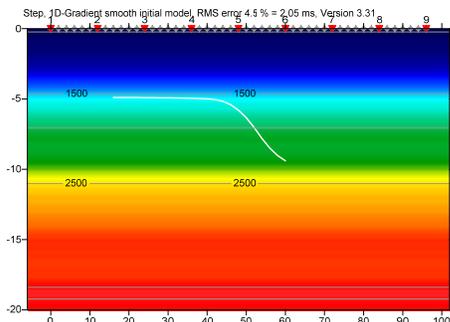

Fig. 2 : 1D-Gradient starting model : laterally average DeltatV+XTV inversion. RMS error 4.5%=2.05 ms.
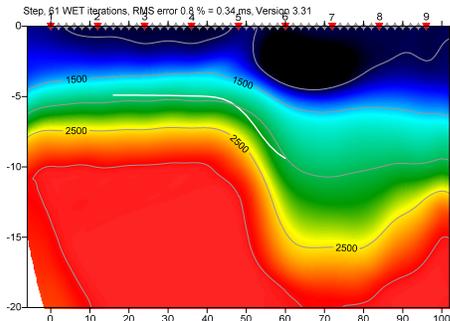

Fig. 3 : 2nd WET run. Starting model is 1st run output. Wavepath width 22%. RMS error 0.8%=0.34ms.
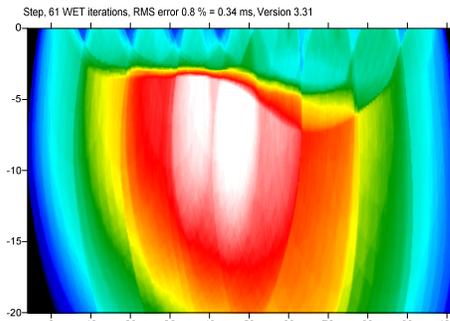
Fig. 4 : WET wavepath coverage plot for Fig. 3. Unit is wavepaths per pixel. Wavepath width 22%.

Fig. 5 : 6th WET run. Starting model is 5th run output. Wavepath width 5%. RMS error 0.4%=0.18ms.

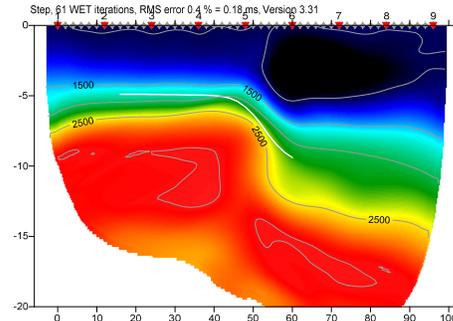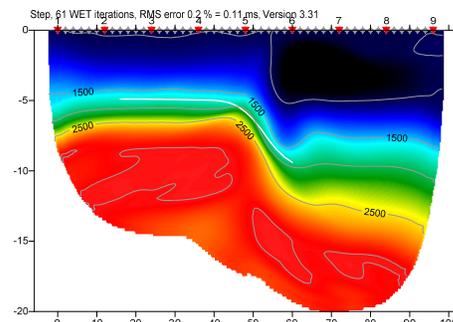Fig. 6 : 8th WET run. Starting model is 7th run output. Wavepath width 3%. RMS error 0.2%=0.11ms.
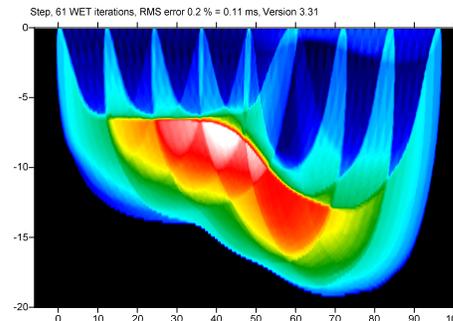

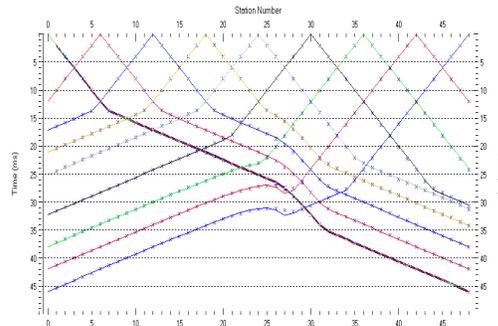Fig. 7 : WET wavepath coverage plot for Fig. 6. Unit is wavepaths per pixel. Wavepath width 3%.

Fig. 8 : True times (colored solid curves, for Fig. 1) and inverted times (blue crosses, for Fig. 6) .
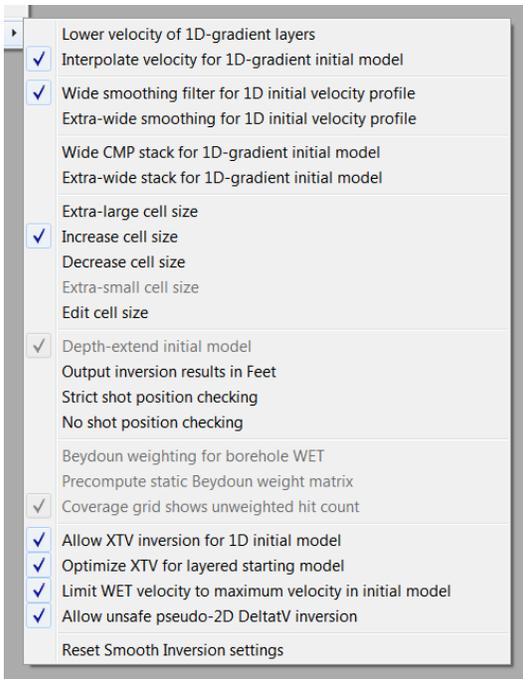
Lower velocity of 1D-gradient layers
✓ Interpolate velocity for 1D-gradient initial model

✓ 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

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. 9 : Smooth invert|Smooth inversion Settings

Blank

Write grids for every iteration
Don't reciprocally average modeled picks during WET inversion
✓ Store modeled picks after last iteration only
Export modeled WET times to .LST

✓ Update imaged grid depth
✓ Scale wavepath width
✓ Scale WET filter height
Disable wavepath scaling for short profile

✓ Limit WET velocity to maximum velocity in initial model
Limit WET velocity to 6,000 m/s
Edit maximum valid WET velocity

Safe line search with bracketing and Brent
✓ Hybrid Conjugate Gradient update formula
Alternate coverage update during Conjugate Gradient inversion

Disable traveltime grid caching
Enable AWE physical memory page caching

Reset WET tomography settings to default

Fig. 10 : WET Tomo|WET tomography Settings

Edit WET Wavepath Eikonal Traveltime Tomography Parameters

Specify initial velocity model
Select   D:\RAY32\STEP\334GRAD\GRADIENT.GRD

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

WET regularization settings
Wavepath frequency :   50   Hz   Iterate
Ricker differentiation [-1 is Gaussian bell] : -1   times
Wavepath width [percent of one period] :   3.0   percent   Iterate
Wavepath envelope width [% of period] :   0.0   percent
Min. velocity :   10   Max. velocity :   3038   m/sec.
Width of Gaussian for one period [sigma] :   3.0   sigma

Gradient search method
○ Steepest Descent   ● Conjugate Gradient

Conjugate Gradient Parameters
Tolerance   0.001   Line Search tol.   0.0010
Initial step   0.10   Line Search iters.   3
☐ Steepest Descent step   CG iterations   15

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

Edit WET Tomography Velocity Smoothing Parameters

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

Smoothing filter dimensions
Half smoothing filter width :   10   columns
Half smoothing filter height :   2   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 :   5   percent

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

Smoothing filter weighting
○ Gaussian   ● Uniform
Used width of Gaussian   1.0   sigma
Uniform central row weight   100.0   [1..100]

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

Damping of tomogram with previous iteration tomogram
Damping [0..1]   0.950   ☐ Damp before smoothing

Accept parameters   Reset parameters
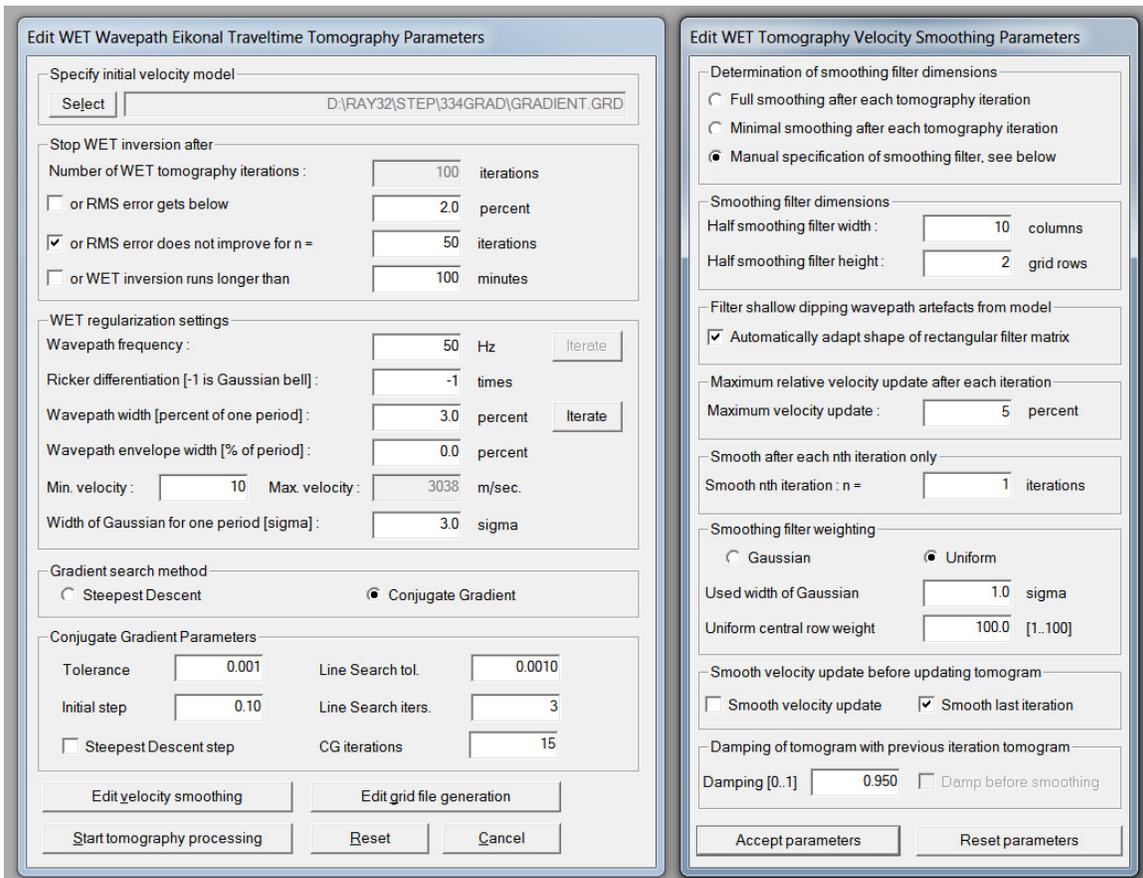
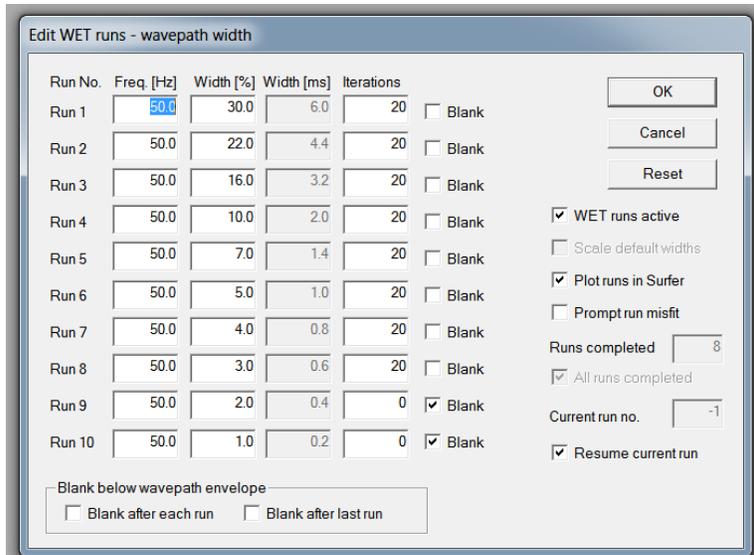Fig. 11 : WET Tomo|Interactive WET tomography… (left), Edit velocity smoothing (right)

Fig. 12 : multirun WET settings (WET Tomo|Interactive WET tomography|Iterate button)

To obtain Fig. 2 to Fig. 8 proceed as following :

➢ Build the synthetic model and the profile database as described in our Step tutorial or
➢ Download 334Grad_seis32.rar archive and unzip into directory C:\RAY32\STEP
➢ Select *File|Open Profile…* and database schema C:\RAY32\STEP\SEIS32.DBD . Click *Open button*.
➢ 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*
➢ Check *Smooth invert|Smooth inversion Settings|Increase cell size*
➢ Setup other settings in *Smooth invert|Smooth inversion Settings* as in Fig. 9
➢ Uncheck *WET Tomo|WET tomography Settings|Disable wavepath scaling for short profile*
➢ Setup other settings in *WET Tomo|WET tomography Settings* as in Fig. 10
➢ Select *Smooth invert|WET with 1D-gradient initial model* and confirm prompts to obtain 1D-gradient starting model (Fig. 2) and default Smooth inversion output after 20 WET iterations
➢ Select *WET Tomo|Interactive WET tomography…*
➢ Click *Select button* and select starting model C:\RAY32\STEP\GRADTOMO\GRADIENT.GRD
➢ Click *radio button* Conjugate Gradient
➢ Edit other fields in *WET main dialog* as in Fig. 11 (left)
➢ Click *button* **Edit velocity smoothing** and *radio button* **Manual specification of smoothing filter**
➢ Set *Half smoothing filter width* to 10 columns and *Half smoothing filter height* to 2 grid rows
➢ Set *Maximum velocity update* to 5% and *Damping* to 0.95
➢ Set *Central row weight* to 100 and uncheck *box Smooth velocity update*
➢ Edit other fields in *Velocity Smoothing Parameters dialog* as in Fig. 11 (right)
➢ Click *button Accept parameters*
➢ Click **Iterate** *button* in WET main dialog and check *box* **WET runs active**
➢ Uncheck *box Blank after last run*
➢ Edit other fields in *Edit WET runs dialog* as in Fig. 12
➢ Click *OK button* and *Start tomography processing button*
➢ Confirm prompts to obtain output as in Fig. 3 to Fig. 7
➢ Select *Refractor|Shot breaks* to obtain Fig. 8
➢ Uncheck *Mapping|Display synthesized traveltime curves*

With these velocity smoothing settings (Fig. 11) we obtain robust convergence of *multirun WET inversion* with RMS error quasi-monotonically decreasing from Fig. 2 (4.5%=2.05ms) through Fig. 6 (0.2%=0.11ms). In particular we specify :

- ➢ *Maximum velocity update = 5%* instead of default 25%
- ➢ *Damping = 0.95* instead of default 0.9 for *Conjugate Gradient method*
- ➢ *Central row weight = 100* instead of default value 1. This increases the vertical resolution in special case of quasi-horizontal layering in subsurface with *Uniform Smoothing filter weighting*.
- ➢ *Manual Smoothing filter specification* with *Half-width = 10 columns* and *Half-height = 2 rows*
- ➢ *No smoothing of velocity update* before applying the update to the current velocity tomogram

Fig. 3 (wavepath width 22%) is a first low-frequency approximation of the true model (Fig. 1) and shows long-wavelength features of the true model. Fig. 6 (wavepath width 3%) is the final high-frequency interpretation of the traveltime data and shows more detail (short wavelength scale). By using above *maximum velocity update* of 5% and *damping* of 0.95 we keep the long wavelength features from Fig. 3 and add shorter wavelength resolution through all WET runs up to Fig. 6. Also the over-estimated depth of the basement step (Fig. 3) is corrected in Fig. 6.

When using the *Conjugate Gradient search method* try enabling **WET Tomo|WET tomography Settings|Blank|Blank low coverage after last iteration** . This will blank out low-velocity edges at the bottom of the tomogram. These can occur because the Conjugate Gradient method combines previous velocity updates from all previous WET iterations (for current run) not just the last iteration to determine the update for the current iteration.

To understand the Conjugate Gradient theory regard the velocity update grid as a vector with as many dimensions as there are cells in the tomogram grid i.e.

vector dimensions = column count times row count of grid .

We have shown that using our default 1D-gradient starting model (Fig. 2) for multiscale tomography gives you a good vertical resolution (Fig. 6) comparable to the true model (Fig. 1). Also our earlier tutorial

http://rayfract.com/tutorials/step.pdf

written in 2013 using version 3.25 of our software shows that using our default 1D-Gradient starting model with Smooth inversion and 20 or 100 WET iterations gives a good vertical resolution.