Multiscale Steepest Descent
SAGEEP11 with Rayfract® 3.34

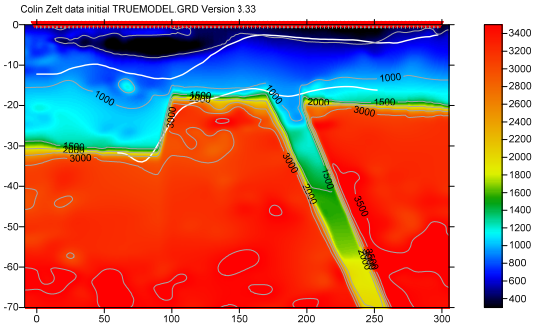

Fig. 1 : Basement step with fault model. See Zelt et al. 2013 : blind test of refraction methods.

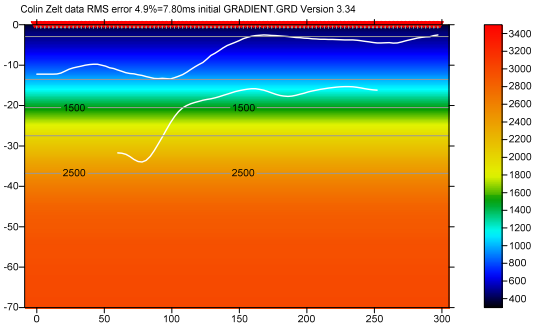

Fig. 2 : 1D-Gradient starting model : laterally average DeltatV inversion. RMS error 4.9%=7.80 ms.

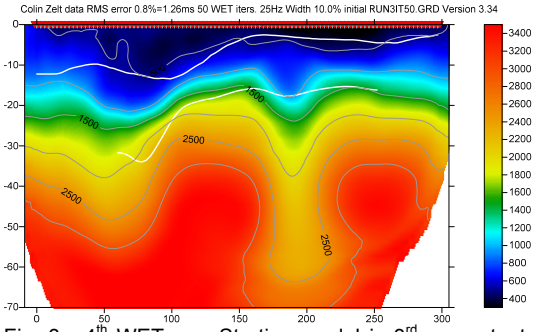

Fig. 3 : 4th WET run. Starting model is 3rd run output. Wavepath width 10%. RMS error 0.8%=1.26ms.

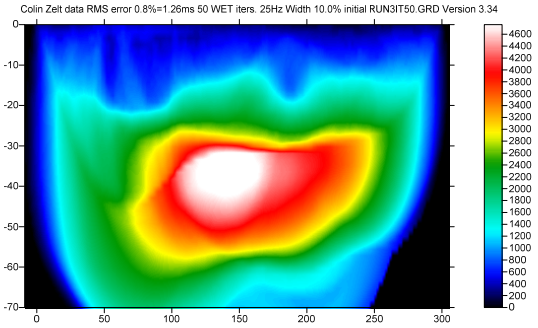

Fig. 4 : WET wavepath coverage plot for Fig. 3. Unit is wavepaths per pixel. Wavepath width 10%@25Hz.

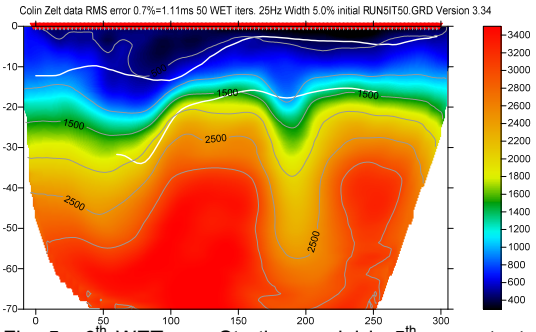

Fig. 5 : 6th WET run. Starting model is 5th run output. Wavepath width 5%. RMS error 0.7%=1.11ms.

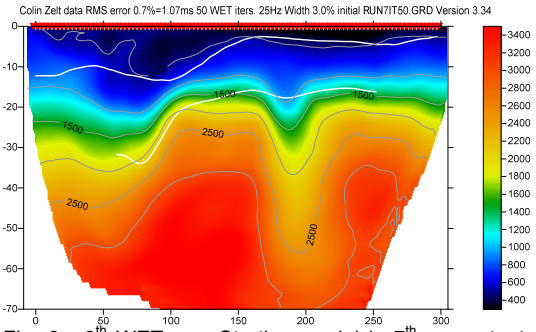

Fig. 6 : 8th WET run. Starting model is 7th run output. Wavepath width 3%. RMS error 0.7%=1.07ms.

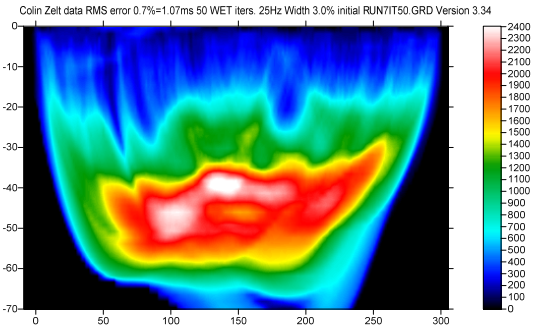

Fig. 7 : WET wavepath coverage plot for Fig. 6. Unit is wavepaths per pixel. Wavepath width 3%@25Hz.

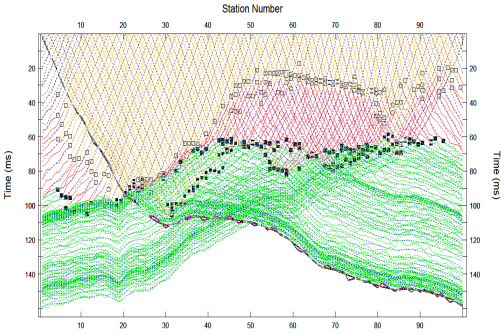

Fig. 8 : True times (colored solid curves forward modeled for Fig. 1 **with added Gaussian noise**) and inverted times (dashed blue curves for Fig. 6)

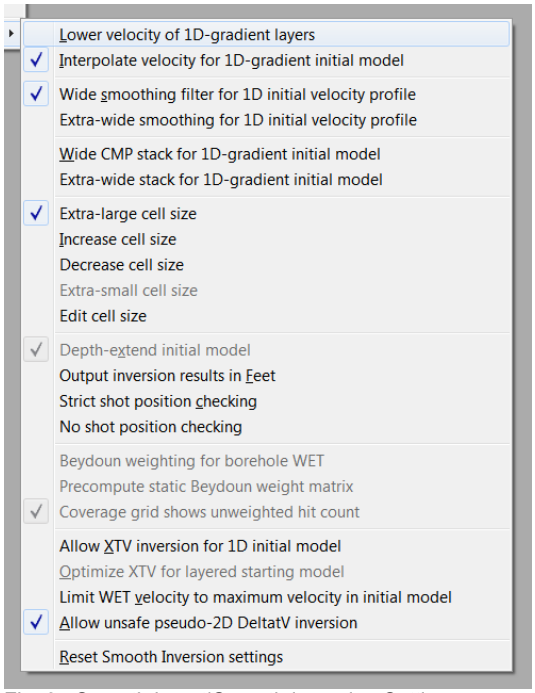

Fig. 9 : Smooth invert|Smooth inversion Settings

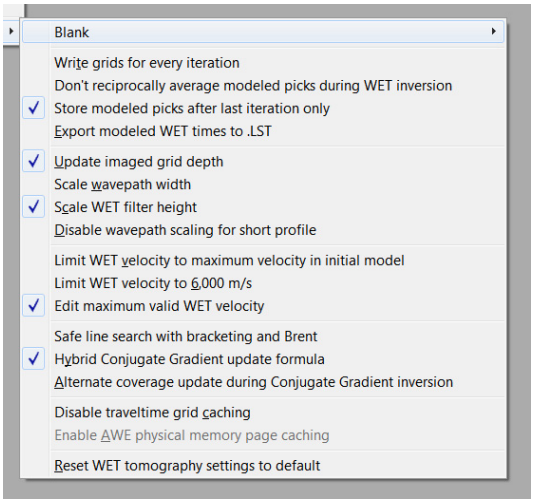

Fig. 10 : WET Tomo|WET tomography Settings

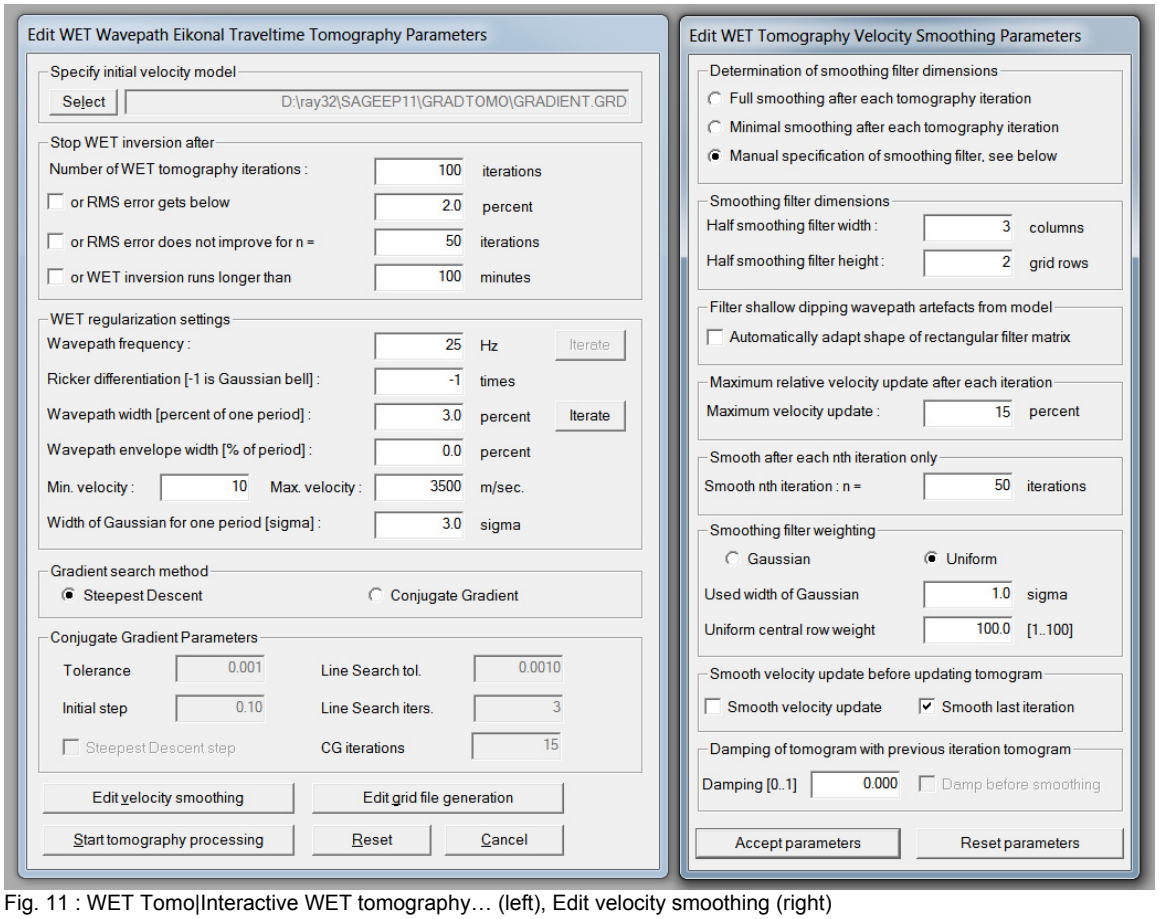

Fig. 11 : WET Tomo|Interactive WET tomography… (left), Edit velocity smoothing (right)

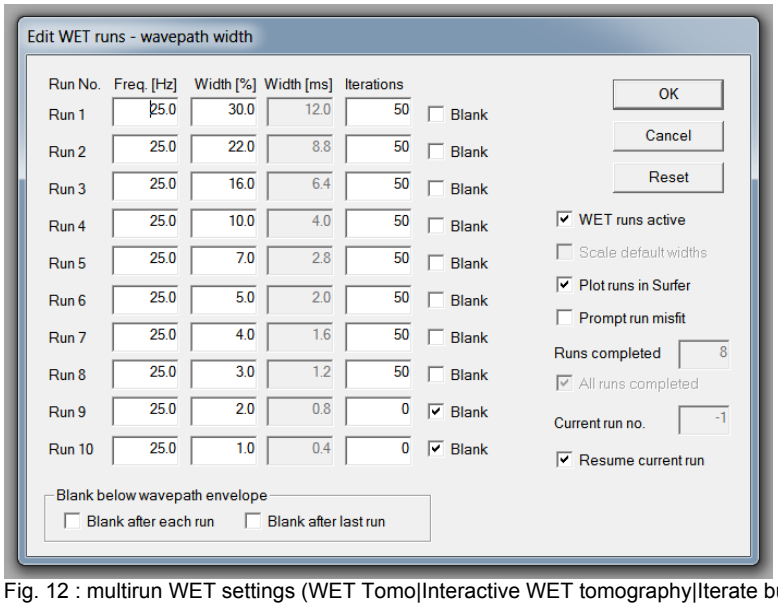

Fig. 12 : multirun WET settings (WET Tomo|Interactive WET tomography|Iterate button)

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

- Download 334GradSDWETGrad smooth50 seis32.zip archive and unzip into directory `C:\RAY32\SAGEEP11`
- Select *File|Open Profile…* & database schema `C:\RAY32\SAGEEP11\SEIS32.DBD` . Click *Open button*.
- Check *Smooth invert|Smooth inversion Settings|Extra-large 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***
- Uncheck *WET Tomo|WET tomography Settings|**Scale wavepath width***
- Check *WET Tomo|WET tomography Settings|**Edit maximum valid WET velocity***
- Check *WET Tomo|WET tomography Settings|Store modeled picks after last iteration only*
- 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\SAGEEP11\GRADTOMO\GRADIENT.GRD`
- Check *box **Skip every 2nd shot for forward modeling*** and click *button Accept parameters*
- Set *edit field **Wavepath frequency*** to 25Hz and set ***Max. velocity*** to 3,500m/s
- Click *radio button Steepest Descent* and 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 3 columns and *Half smoothing filter height* to 2 grid rows
- Uncheck box *Automatically adapt shape of rectangular filter matrix*
- Set *Maximum velocity update* to 15% and *Damping* to 0.0
- Set ***Smooth nth iteration : n** =* to 50 and click *radio button Uniform*
- Set *Uniform 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 click *Reset button* in *Edit WET runs dialog*
- Check ***box WET runs active*** and uncheck *box Blank after last run*
- Change ***Iterations** column* fields for *Run 1* to *Run 8* from default 20 to new value 50
- Edit other fields in *Edit WET runs dialog* as in Fig. 12 and click *OK button*
- Click *Edit grid file generation button* and set *Store each nth iteration only : n* = 50.
- Click *Accept parameters 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 raytraced traveltimes*

With these velocity smoothing settings (Fig. 11) we obtain robust convergence of *multirun WET inversion* with RMS error quasi-monotonically decreasing from Fig. 2 (4.9%=7.80ms) through Fig. 6 (0.7%=1.07ms). In particular we specify :

- ***Wavepath frequency of 25Hz*** instead of default 50Hz. This makes multirun WET more robust.
- ***Max. velocity = 3,500m/s***. This prevents unrealistic oscillation of WET modeled velocity in basement.
- ***Maximum velocity update = 15%*** instead of default 25%
- ***Damping = 0.0*** equals default 0.0 for *Steepest Descent method*
- ***Smooth nth iteration : n = 50*** instead of default 1
- ***Uniform 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 = 3 columns*** and ***Half-height = 2 rows***
- ***No smoothing of velocity update*** before applying the update to the current velocity tomogram

Fig. 3 (wavepath width 10%) is a 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 15% we keep the long wavelength features from Fig. 3 and add shorter wavelength resolution through all WET runs up to Fig. 6.

As stated in Zelt et al. 2013 "Uncorrelated Gaussianly-distributed noise with a mean of zero and a standard deviation of 1 ms was added to the synthetic data". This ***added Gaussian noise*** prevents our WET inversion from reaching an even better resolution in the final tomogram Fig. 6.

Runtime for above 8 WET runs 50 WET iterations each = 400 iterations was about ***8 minutes on an Apple iMac*** late 2012 with 2.7 GHz Intel Core i5 processor. Grid size is 80 rows x 200 columns. X spacing & Y spacing are 1.58m. One grid cell is 1.58m square. This short run time enables quasi-interactive variation of *WET smoothing parameters* (Fig. 11). Output of above WET run no. 8 is available in archive `334SDWETGrad_smooth50_run8.rar` .

To import the ASCII data obtained from http://terra.rice.edu/department/faculty/zelt/sageep2011/ :

- Start up Rayfract® via desktop icon. Select *File|New Profile…* .
- Set *File name* to SAGEEP12 and click *Save button*. Set *Station spacing* to 3 m in *Header|Profile* .
- Unzip archive `sageep11_ascii.zip` in directory `\RAY32\SAGEEP12\INPUT`
- Select *File|Import Data…* and specify *Import data type* ASCII column format
- Click *button Select* and select file `ASCII.ASC` in directory `\RAY32\SAGEEP12\INPUT`
- Check option *Batch import*. Leave *Default spread type* at *10: 360 channels* .
- Click *button Import shots* and confirm prompt
- Unzip archive `334SDWETGrad_smooth50_run8.rar` in `\RAY32\SAGEEP12\WETRUN8`
- Select *Grid|Reset DeltatV and WET settings to .PAR file*
- Select `\RAY32\SAGEEP12\WETRUN8\VELOIT62.GRD` and click *Open button*

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). Sheehan et al. 2005 evaluate our 1D-Gradient starting model with synthetic data generated for known subsurface models.

Our 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.

In tutorial http://rayfract.com/tutorials/sageep11_16.pdf we show using the *Conjugate Gradient* method instead of *Steepest Descent* method for multiscale tomography with above data.

For description of *WET parameters* you can navigate to the relevant field in WET dialogs and press F1 function key for popup help. Or navigate our *Help menu*. Or refer to our .pdf reference at http://rayfract.com/help/rayfract.pdf .