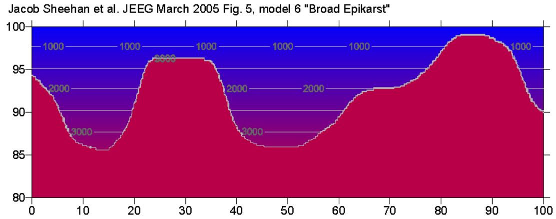
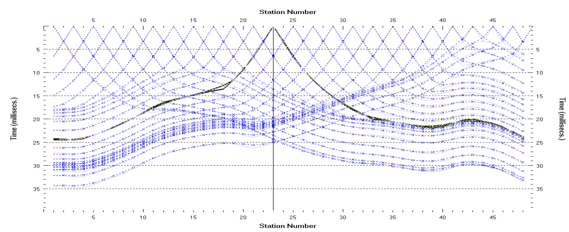
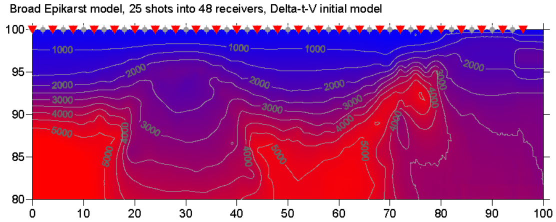
Interpretation of Sheehan Broad Epikarst Model, with Rayfract® 3.18 and 4.01+WDVS

We show interpretation of the broad epikarst model described by Jacob Sheehan in his JEEG March 2005 evaluation. We increase the number of shots, decreasing the shot spacing : shoot at every vs. at every 2nd receiver. Also, we decrease the receiver spacing from 2m to 1m. We refine the Delta-t-V pseudo-2D initial model with WET tomography, showing 20 and 100 WET iterations. Finally, we use our default Smooth inversion method, based on a 1D-Gradient initial model and 20 vs. 100 WET iterations.

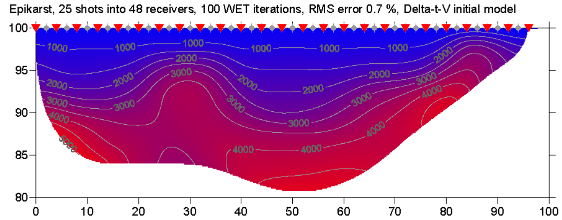


Jacob Sheehan et al. JEEG March 2005 Fig. 5, model 6 "Broad Epikarst"

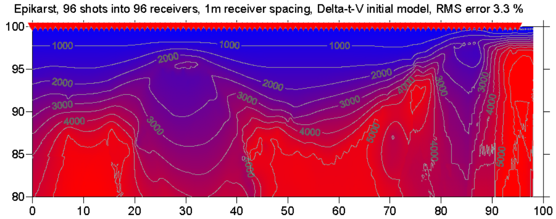




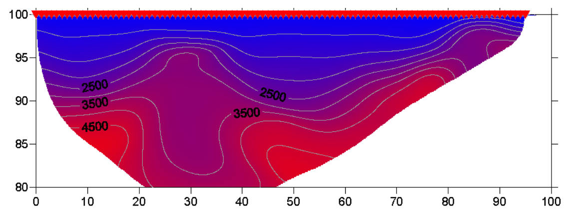
Broad Epikarst model, 25 shots into 48 receivers, Delta-t-V initial model



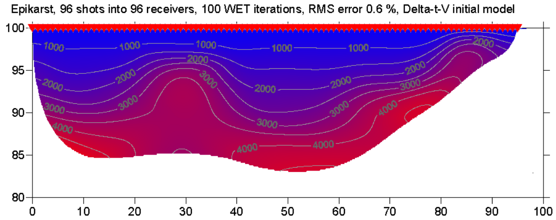
Epikarst, 25 shots into 48 receivers, 100 WET iterations, RMS error 0.7 %, Delta-t-V initial model



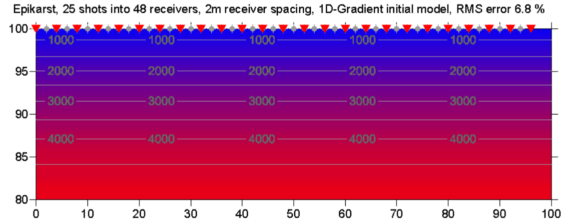
Epikarst, 96 shots into 96 receivers, 1m receiver spacing, Delta-t-V initial model, RMS error 3.3 %



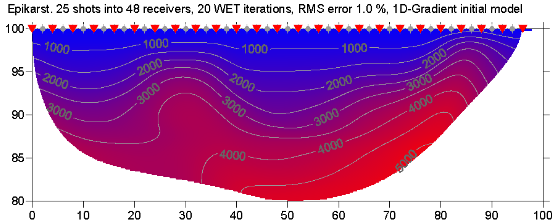
Epikarst, 96 shots into 96 receivers, 20 WET iterations, RMS error 0.9 %, Delta-t-V initial model



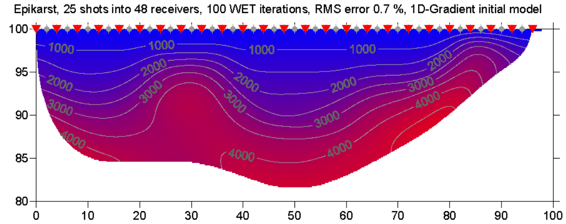
Epikarst, 96 shots into 96 receivers, 100 WET iterations, RMS error 0.6 %, Delta-t-V initial model



Epikarst, 25 shots into 48 receivers, 2m receiver spacing, 1D-Gradient initial model, RMS error 6.8 %



Epikarst. 25 shots into 48 receivers, 20 WET iterations, RMS error 1.0 %, 1D-Gradient initial model



Epikarst, 25 shots into 48 receivers, 100 WET iterations, RMS error 0.7 %, 1D-Gradient initial model

Above Delta-t-V interpretation does not improve much with more narrow spacing of shots and receivers. But default Smooth inversion with 1D-gradient initial model (at bottom) works reliably, with just 20 or with 100 WET iterations. Resolution of WET and seismic refraction tomography decreases with increasing imaged depth. See D.J. White 1989, J.G. Hagedoorn 1959 Fig. 1 , http://rayfract.com/tutorials/thrust.pdf and http://rayfract.com/tutorials/fig9inv.pdf.

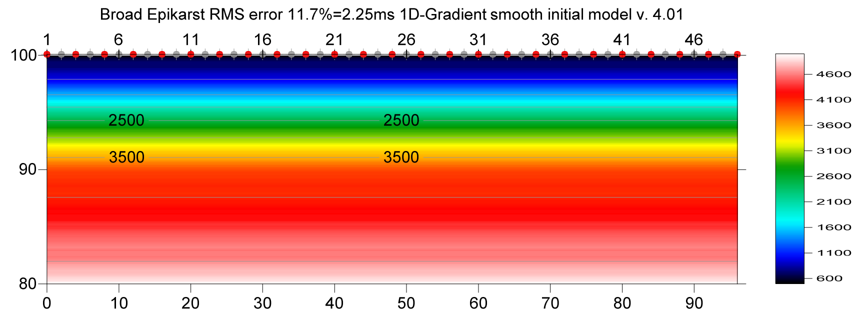


Fig. 1 : 1D-Gradient starting model obtained with Smooth invert|WET with 1D-gradient starting model. Layered XTV enabled in Smooth invert|Smooth inversion Settings. Grid cell size forced to 0.2m in Header|Profile.

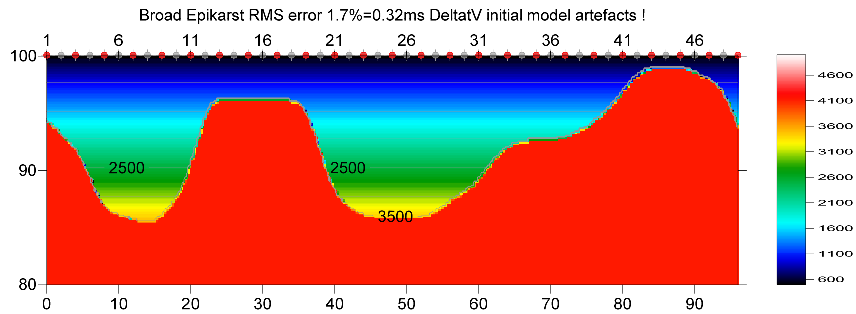


Fig. 2 : true synthetic model made available by Jacob Sheehan in 2005.

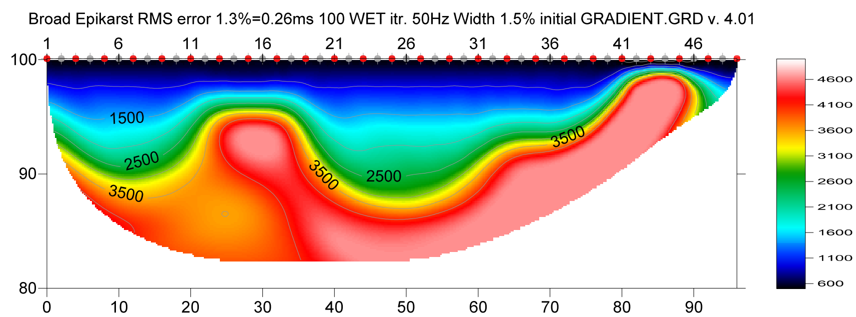


Fig. 3 : 100 Steepest-Descent WET iterations, minimal smoothing, wavepath width halved to 1.5%. Starting model Fig. 1. Wavepath frequency 50Hz. Ricker differentiation -2. Max. WET velocity 4,500 m/s. Don't smooth velocity update. Don't smooth last iteration (Fig. 5). WDVS frequency 400Hz. Angle increment 10 degrees. Regard nth node = 5 (Fig. 6).

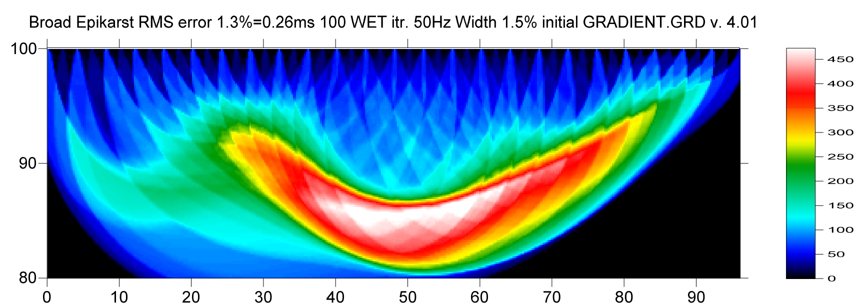


Fig. 4 : WET wavepath coverage plot obtained with Fig. 3. Unit is wavepaths per pixel.

WDVS Wavelength-Dependent Velocity Smoothing is described in Zelt, C. A. and J. Chen, Frequency-dependent traveltime tomography for near-surface seismic refraction data, Geophys. J. Int., 207, 72-88, 2016.

Narrowing the wavepath width from default 3% to 1.5% corresponds to increasing the WET frequency. Enabling WDVS and lowering the wavepath width gives higher resolution in overburden but also results in more artefacts in the basement : too high velocity in higher-coverage basement areas, too low velocity in lower-coverage basement areas (Fig. 3 & Fig. 4). We suppress a WDVS bias towards too high basement velocities by limiting the *max. WET velocity* to 4,500 m/s in *WET Tomo|Interactive WET* (Fig. 5).

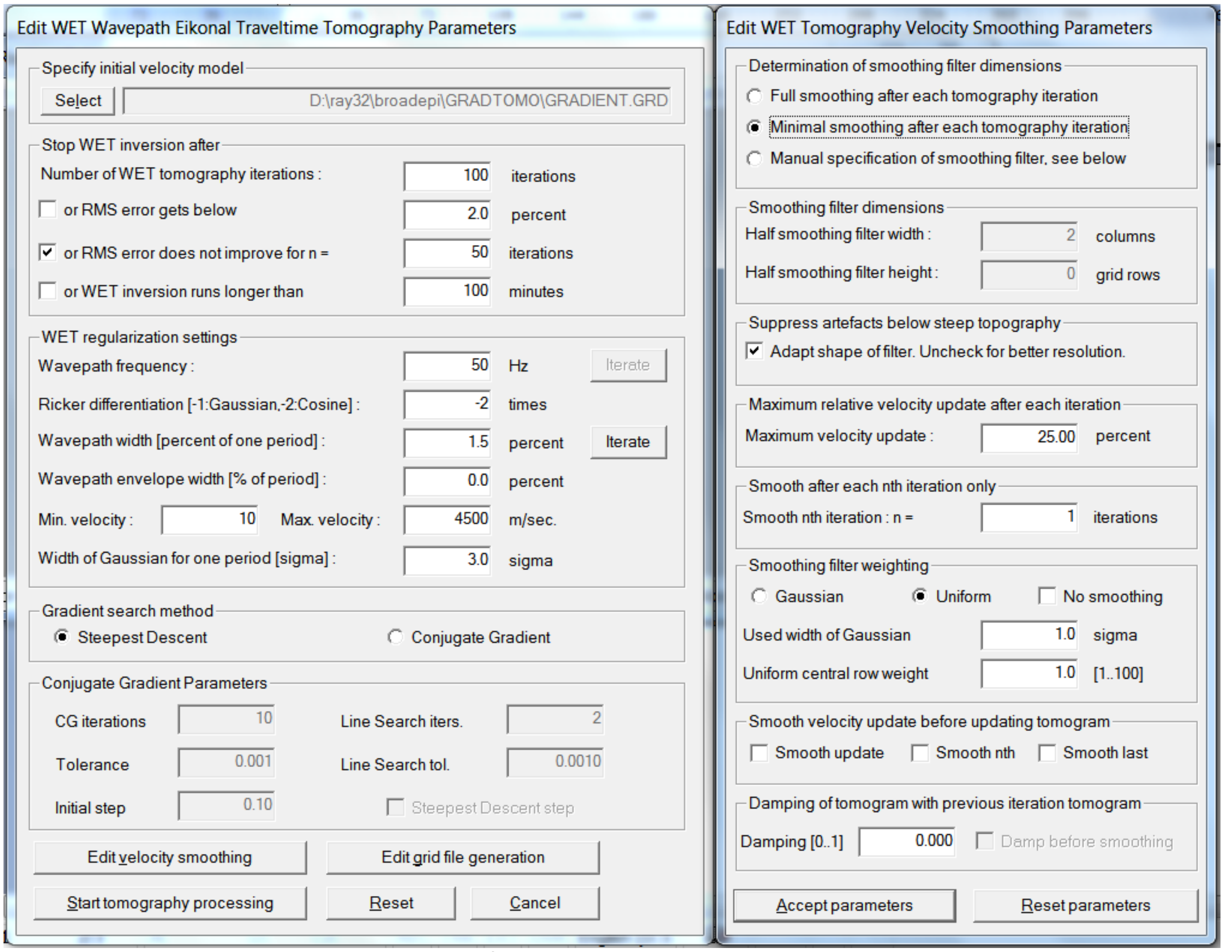


Fig. 5 : WET Tomo|Interactive WET tomography (left). Edit velocity smoothing (right).

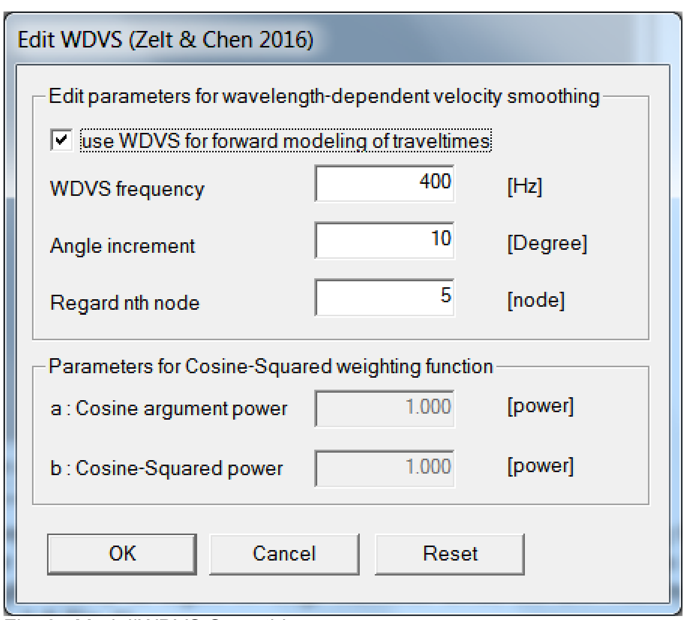


Fig. 6 : Model|WDVS Smoothing

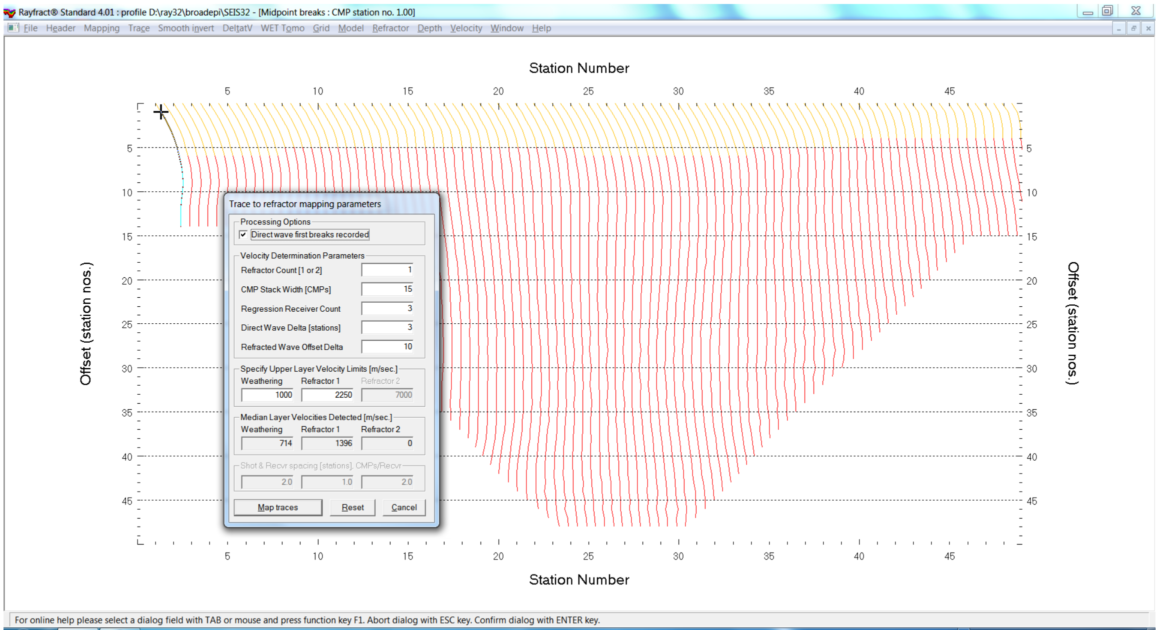


Fig. 7 : Map first breaks to refractors in Refractor|Midpoint breaks. Press ALT+M and edit 1D velocity model. Click Map traces. Press ALT+G and press ENTER to laterally smooth crossover distances.

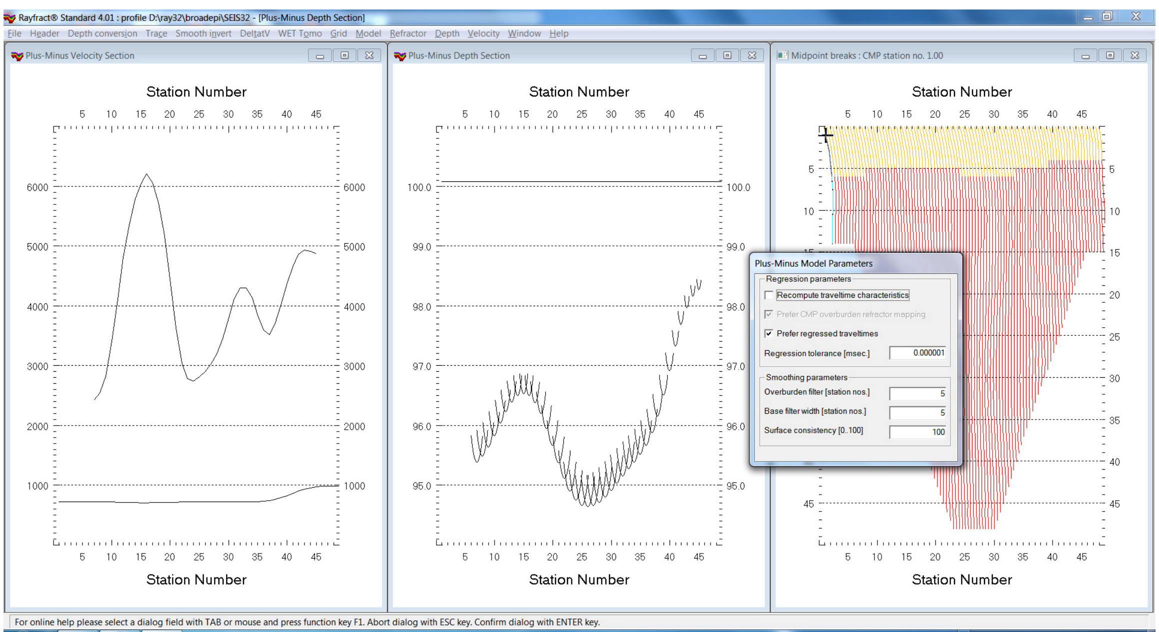


Fig. 8 : select Depth|Plus-Minus. When asked to continue with WET click No button. Press ALT+M to edit lateral refractor smoothing : decrease Base filter width from 10 station nos. to 5. Press ENTER to redisplay Plus-Minus starting model in Surfer (Fig. 9). When prompted to continue with WET click Yes button to obtain Fig. 10 and Fig. 11.

For typical field surveys with reciprocal traveltime picking errors and errors in recording geometry specification we recommend to increase the default WET wavepath width instead e.g. multiply by two. See our tutorial http://rayfract.com/tutorials/Aaknes-1.pdf .

When enabling WDVS as shown above we can minimize WET smoothing more than without WDVS. This results in sharper imaging of layer boundaries and increased resolution in the WET tomogram.

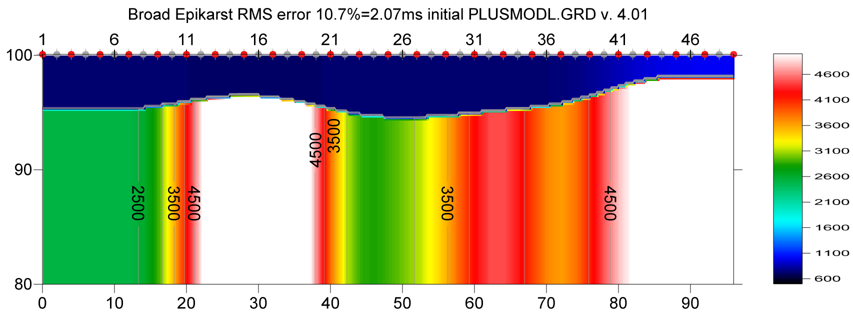


Fig. 9 : Plus-Minus method starting model obtained as in Fig. 8.

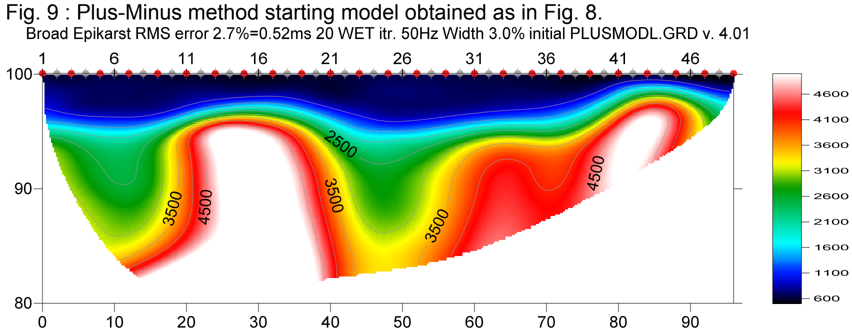


Fig. 10 : Smooth inversion with Plus-Minus starting model (Fig. 9). WDVS enabled (Fig. 6.).

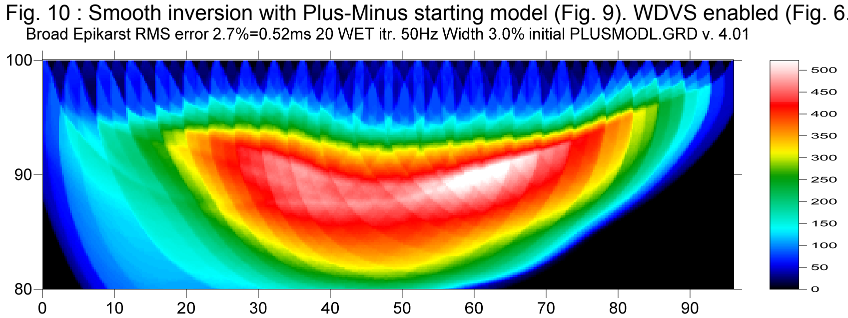


Fig. 11 : WET wavepath coverage plot obtained with Fig. 10. Unit is wavepaths per pixel.

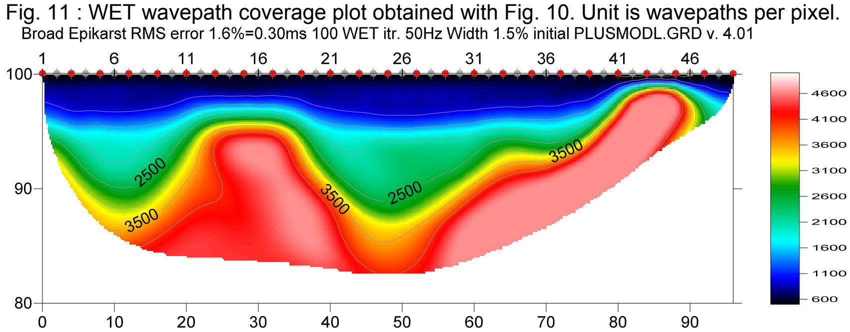


Fig. 12 : 100 Steepest-Descent WET iterations, minimal smoothing (Fig. 5). Starting model Fig. 9. WDVS frequency 400Hz (Fig. 6). Compare with Fig. 3 obtained with 1D-gradient starting model (Fig. 1).

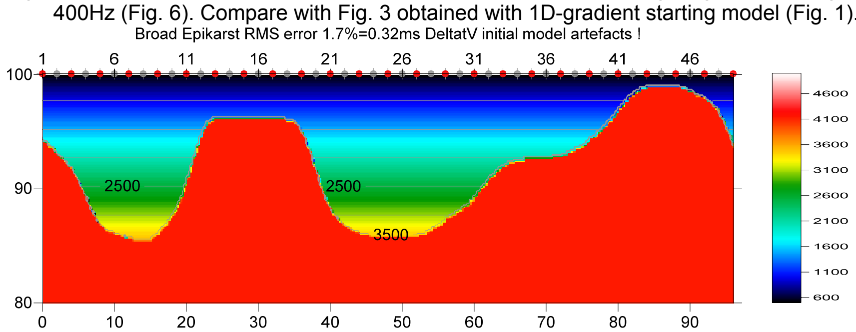


Fig. 13 : true synthetic model made available by Jacob Sheehan in 2005.

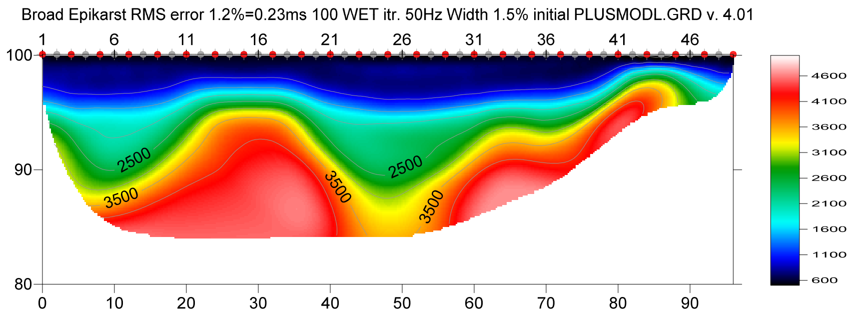


Fig. 14 : 100 Steepest-Descent WET iterations, minimal smoothing (Fig. 5). Starting model Fig. 9. WDVS disabled. Compare with Fig. 12 obtained with same WET settings and same starting model but with WDVS enabled (Fig. 6).

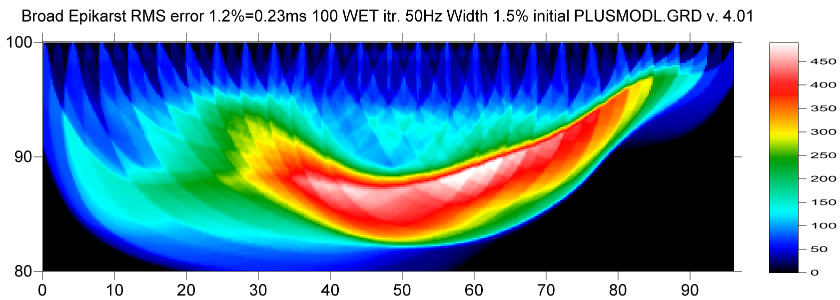


Fig. 15 : WET wavepath coverage plot obtained with Fig. 14. Unit is wavepaths per pixel.

In Fig. 7 and Fig. 8 we show mapping of traces to refractors and layered refraction interpretation with Plus-Minus method. We obtain the Plus-Minus starting model Fig. 9. Default Smooth inversion using starting model Fig. 9 and 20 Steepest-Descent WET iterations with full WET smoothing gives Fig. 10 and Fig. 11. Interactive WET (Fig. 5) with starting model Fig. 9 gives Fig. 12.

We have shown that WET inversion using 100 Steepest-Descent WET iterations with minimal WET smoothing and WDVS enabled is independent of the starting model and matches the true model.

Also we show 100 Steepest-Descent WET iterations without WDVS and with minimal smoothing and starting model Fig. 9 in Fig. 14. Compare with Fig. 12 showing same WET inversion with WDVS enabled.

Note the anomalously high apparent Plus-Minus velocity at station no. 15 in Fig. 8 and Fig. 9. This shows that Plus-Minus velocity is not always realistic with strong refractor curvature, as is pseudo-2D DeltatV velocity shown on first page.

Decreasing WDVS parameters *Angle increment* from 10 to 5 degrees and *Regard nth node* from 5 to 2 (Fig. 6) helps to slightly increase contrast in Fig. 3 just below topography at station no. 43 but increases WET inversion runtime.

See our updated help file for description of WDVS parameters in chapter ***Forward model traveltimes***. Press F1 function key in ***Model|WDVS Smoothing dialog*** (Fig. 6) to display popup help window for current control. Use TAB key to switch focus between controls.

Our default Smooth inversion based on a 1D-Gradient initial model and 20 or 100 WET iterations as detailed in our SAGEEP 2010 short course (without WDVS or with default WDVS settings) with default DeltatV and WET settings should work fine in most cases, to give a reliable but possibly low-resolution first interpretation.

If you want higher resolution then you will have to invest more time into tuning WET + WDVS settings and DeltatV settings for 1D-gradient starting model. As a first step increase the number of WET iterations from default 20 Steepest Descent iterations to 100 iterations. Optionally enable WDVS and decrease the WET smoothing for consistently picked traveltimes and with correctly specified recording geometry as shown above.

The higher the targeted resolution, the higher the uncertainty in WET results will be especially with realistic field data with reciprocal traveltime picking errors and recording geometry specification errors. Again see

http://rayfract.com/tutorials/Aaknes-1.pdf

Here is the .RAR archive with version 4.01 profile database for Fig. 3 :
http://rayfract.com/tutorials/broadepi_seis32_SDWET_Nov6_2020.rar

Here is the .RAR archive with Surfer 11 .GRD and .PAR files and .SRF plots for Fig. 3 and Fig. 4 :
http://rayfract.com/tutorials/GRADTOMO_WDVS_Nov6_2020.rar

Here is the .RAR archive with version 4.01 profile database for Fig. 9 to Fig. 12 :
http://rayfract.com/tutorials/broadepi_seis32_LayrTomo_Dec7_2020.rar

Here is the .RAR archive with Surfer 11 .GRD and .PAR files and .SRF plots for Fig. 9 to Fig. 12 :
http://rayfract.com/tutorials/LAYRTOMO_WDVS_Dec7_2020.rar

Here is the full link to our SAGEEP 2010 short course :
http://rayfract.com/SAGEEP10.pdf

Here is the link to Schuster 1993 WET theory paper :
http://library.seg.org/doi/abs/10.1190/1.1443514

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Also we thank Prof. Colin Zelt for describing the WDVS algorithm .

Edited in Vancouver, Canada on Dec 8, 2020 by Siegfried Rohdewald, Dipl. Informatik-Ing. ETH.