

We recommend shooting at every 3rd receiver, not just every 6th receiver. Import the data into a Rayfract® profile and run our *Smooth inversion* and *Plus-Minus* methods, with our [free trial](#) :

- create a new profile with *File|New Profile...*, set *File name* to JENNY13 and click *Save button*
- unzip [jenny13.zip](#) in \RAY32\JENNY13\INPUT directory
- specify a *Station spacing* of 5m in *Header|Shot*, before [importing the data](#).
- check *File|Import Data Settings|Default layout start is 1.0*
- select *File|Import Data...* and specify *Import data type* SEG-2

- click upper *Select* button, navigate into \RAY32\JENNY13\INPUT and select 2001.DAT
- set *Default spread type* to 01: 24 channels
- click *Open* button and *Import shots* button
- leave *Layout start* at 1 for all shots
- specify *Shot pos. [station no.]* -5.5, 0.5, 6.5, 12.5, 18.5, 24.5, 30.5, click *Read* for shots 1 to 7
- select *File|Update header data|Update First Breaks...*
- navigate into \RAY32\JENNY13\INPUT directory and select file BREAKS.LST, click *Open*
- select *Smooth invert|WET with 1D-gradient initial model...*
- confirm prompts for 1D starting model, WET tomogram and wavepath coverage (Fig. 1, Fig. 2)

Iteratively vary [mapping of traces to refractors](#) in *Refractors|Shot breaks*, select *Depth|Plus-Minus* and *Velocity|Plus-Minus* until *Plus-Minus interpretation* (Fig. 3) matches *Smooth inversion tomogram* (Fig. 1).

In *Depth|Plus-Minus*, press ALT+M keyboard shortcut and decrease *Base filter width [station nos.]* to 5, from default value 10. Hit ENTER key to recompute and redisplay *Plus-Minus* depth and velocity sections.

See our [release notes](#) for version 3.25 and *Grid menu options* (Fig. 6) for plotting of refractors on WET tomograms. To redisplay the WET tomogram with Plus-Minus refractors :

- select *Depth|Plus-Minus* and *File|Export header data|Export ASCII Model of depth section...*
- click *Save* button to export Plus-Minus refractors and layer velocities to file PLUSMODL.CSV
- select *Grid|Select ASCII .CSV layer model for refractor plotting...* and above PLUSMODL.CSV
- check *Grid menu options* for refractor plotting as shown in Fig. 6
- select *Grid|Image and contour velocity and coverage grids...*
- select tomogram grid file \RAY32\JENNY13\GRADTOMO\VELOIT20.GRD to obtain Fig. 1

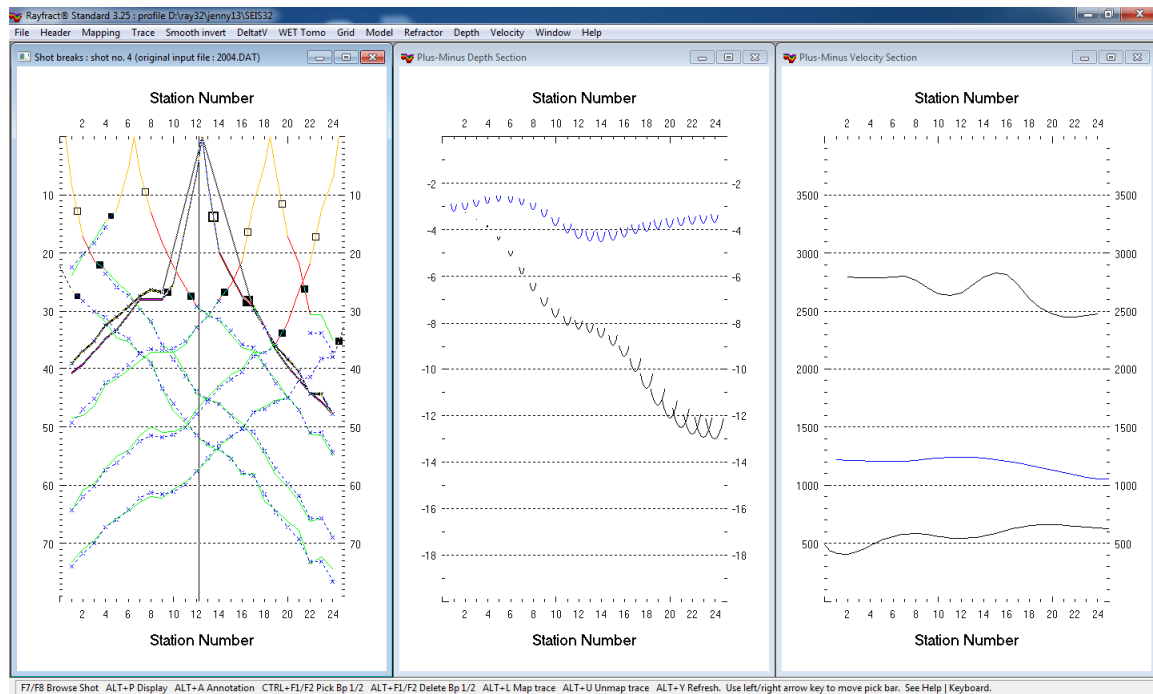


Fig. 3 : Layer-based Plus-Minus refraction interpretation, 3 layers. Left : interactively map traces to refractors. Center : Depth section obtained with Plus-Minus method. Right : Plus-Minus Velocity section.

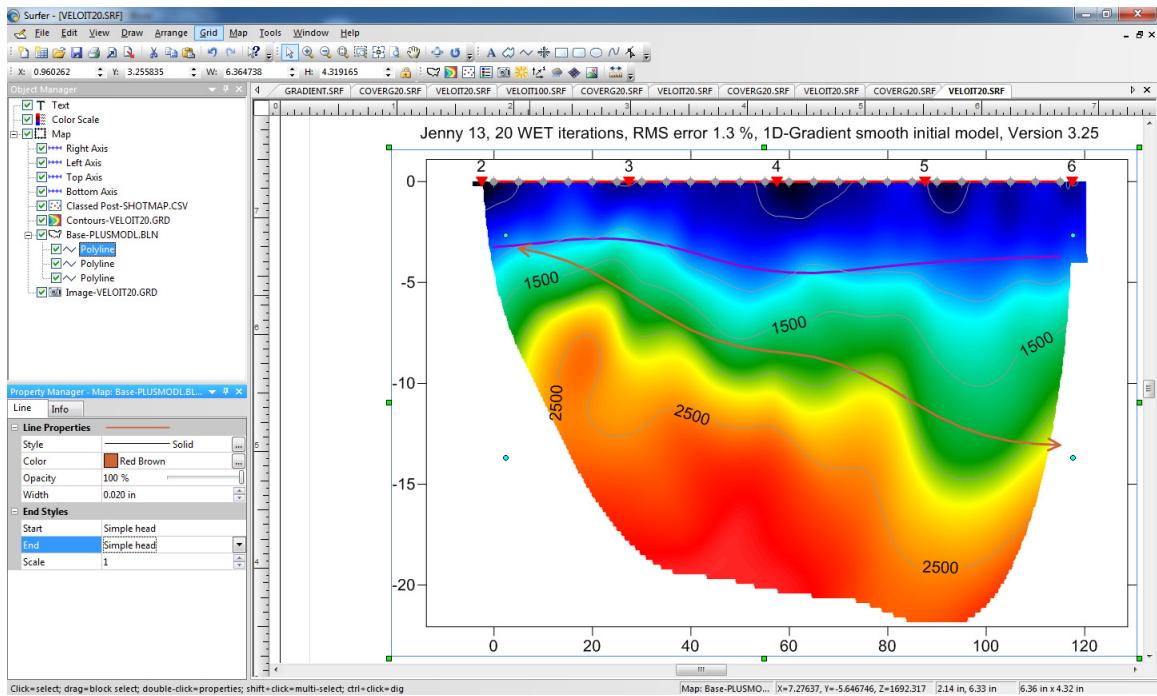


Fig. 4 : Edit Base map and refractor polyline properties in Surfer's Object Manager.

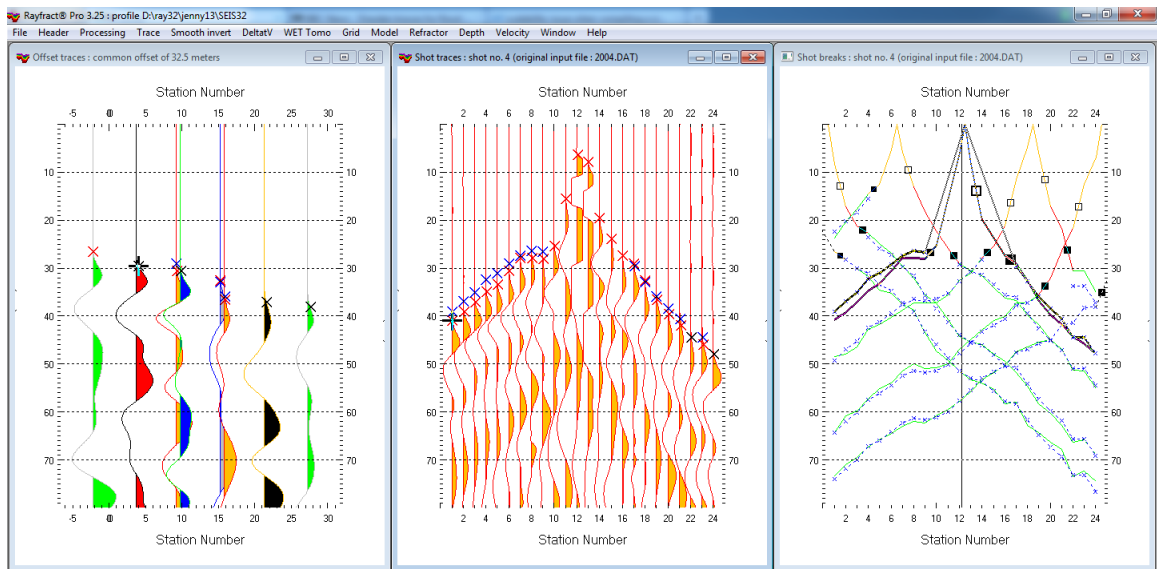


Fig. 5 : *Trace|Offset gather* (left), *Trace|Shot gather* (center), *Refractor|Shot breaks* (right). Browse offset gathers with F7/F8 in *Trace|Offset gather*, to quality-check for reciprocal traveltimes errors. Note asymmetry of first breaks for shot no. 4 (center), relative to shot point (station no. 12.5). This indicates a dipping basement refractor, as indicated in *Trace|Offset gather* (left) and *Refractor|Shot breaks* (right).

Quality-check your first break picks for reciprocal traveltimes errors in *Trace|Offset gather*, see Fig. 5. and [Slope1](#) tutorial. Browse common-offset sorted trace gathers with F7/F8 function keys.

Edit refractor polyline properties line style, color, width and end styles as in Fig. 4, in Golden Software Surfer's Object Manager.

Our layer-based Plus-Minus refraction (Fig. 3), Wavefront refraction and CMP Intercept-time refraction methods can use **far-offset shots** no. 1 and no. 7 positioned at station nos. -5.5 and 30.5.

Offset shots no. 1 and no. 7 cannot be used for 2D WET inversion, since there are no receivers near these shot points, at station no. -5.5 and 30.5 . Use [overlapping receiver spreads](#), for our WET inversion to be able to use profile-internal offset shots.

Also see our [pdf reference](#) topics [Mapping traces to refractors](#), [Time-to-depth conversion](#) and [Overlapping receiver spreads](#).

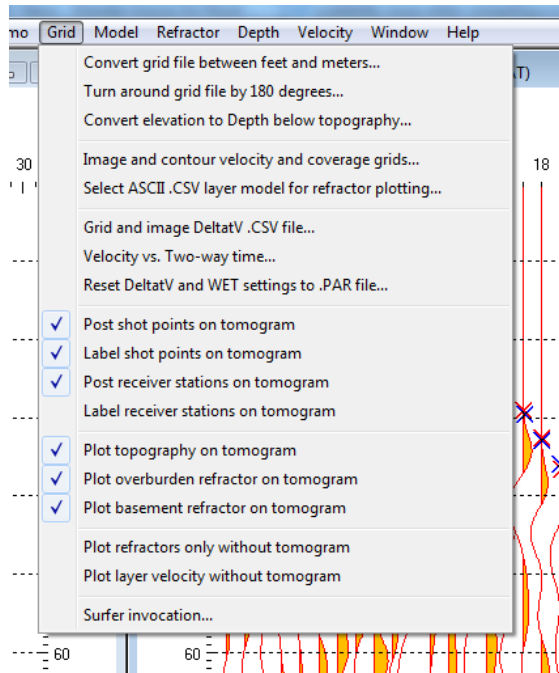


Fig. 6 : Grid menu options, for Rayfract® version 3.25

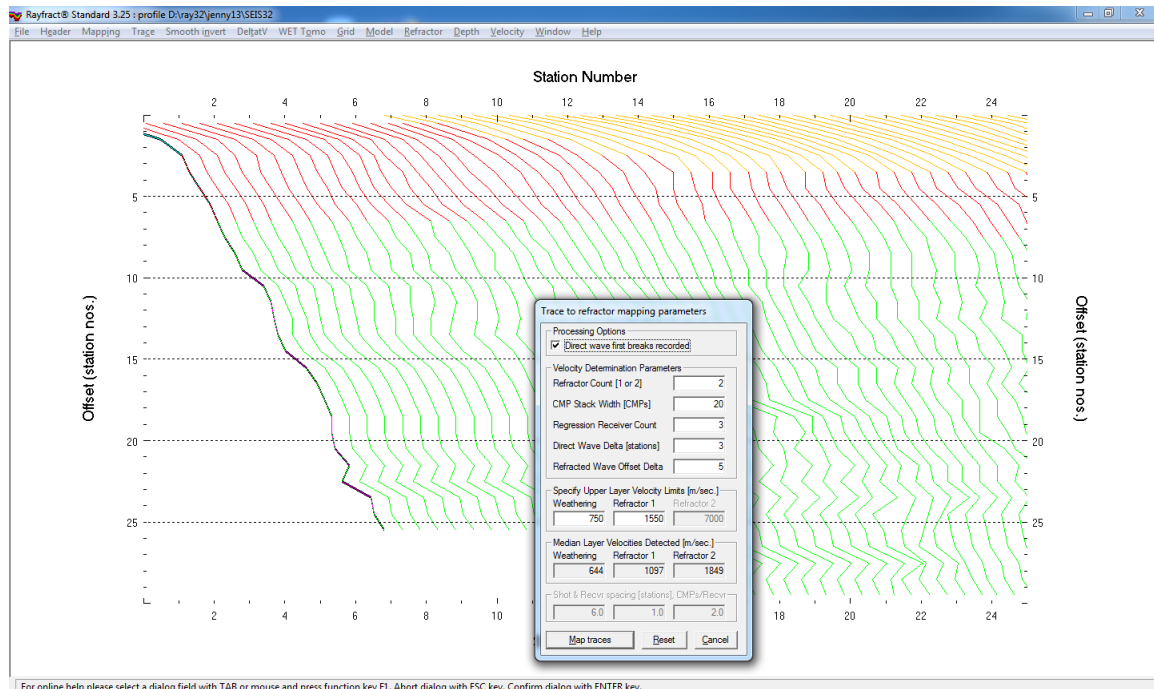


Fig. 7 : Refractor|Midpoint breaks, mapping traces to refractors with ALT+M and 1D velocity model

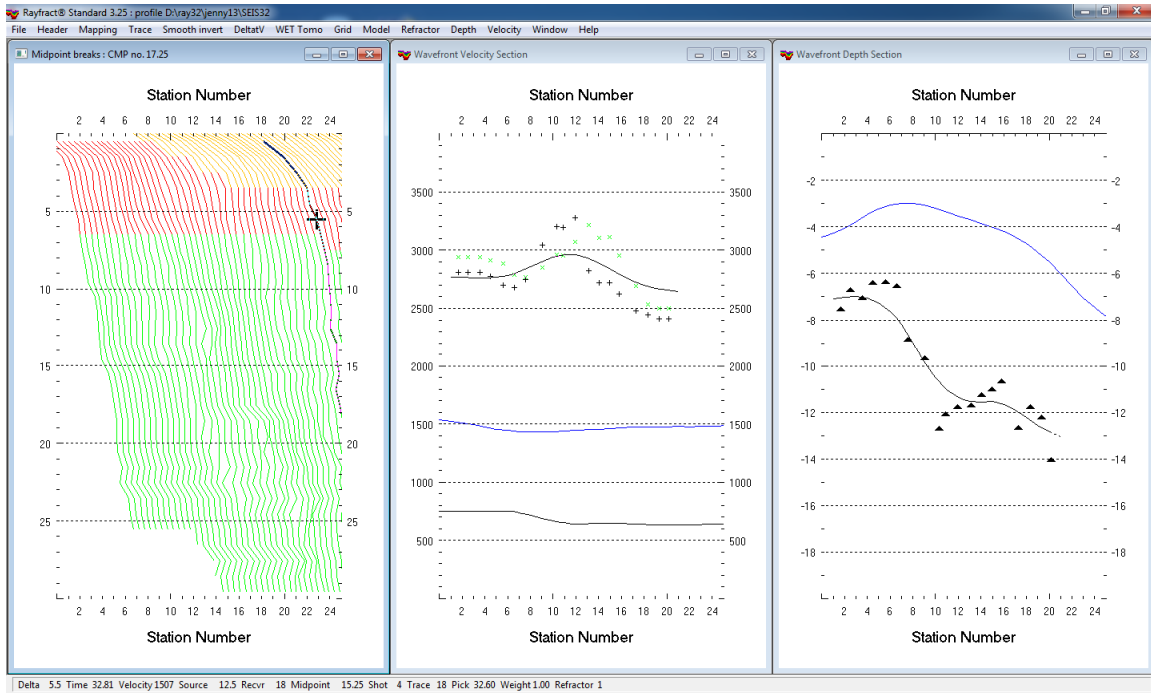


Fig. 8 : left : Refractor|Midpoint breaks, center : Velocity|Wavefront, right : Depth|Wavefront

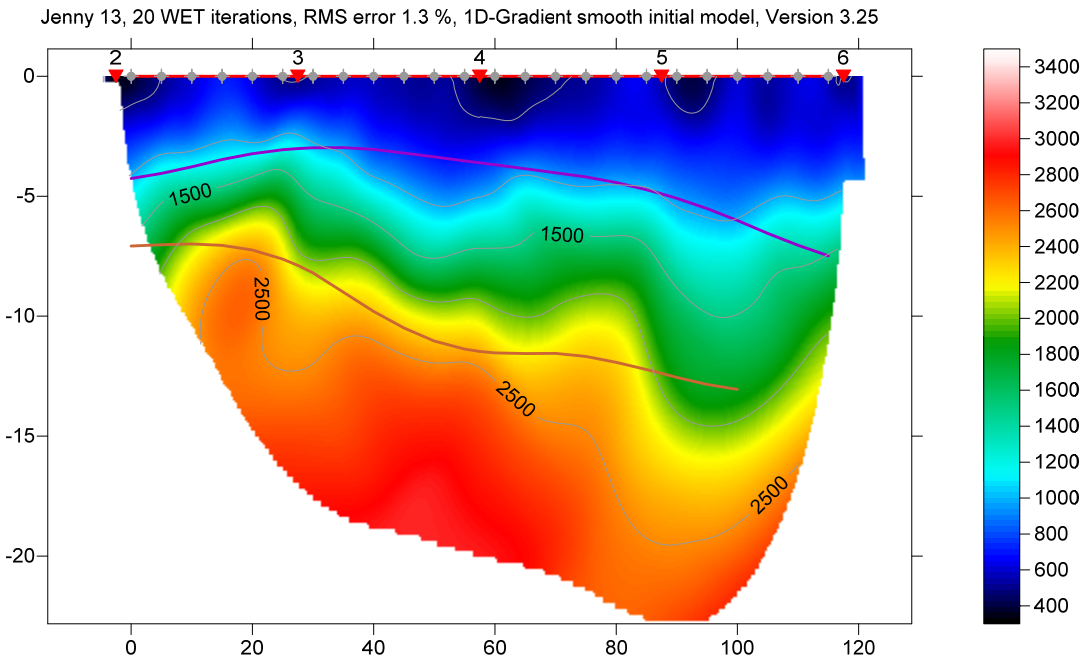


Fig. 9 : Velocity tomogram obtained with Smooth inversion with default settings and 20 WET iterations. Layer-based Wavefront method refractors are plotted in magenta and brown. Compare Fig. 8.

To obtain Fig. 9 overlaying Wavefront method refractors on WET tomogram :

- select *Refractor|Midpoint breaks*, press ALT+M. Edit *mapping parameters* as in Fig. 7
- set *Refracted Wave Offset Delta* to 5, *Weathering* to 750 m/s and *Refractor 1* to 1550 m/s
- hit ENTER key to map traces to refractors.
- press ALT+G for *Crossover distance processing dialog*, edit as in Fig. 10
- leave *Basement filter [station nos.]* at 10, click *Accept button* to smooth crossover distance
- press CTRL+F1 to zoom dip of CMP curves in Fig. 7
- select *Depth|Wavefront*, press ALT+M, edit model parameters as in Fig. 11

- set both *Overburden filter* and *Base filter width* to 6 station number intervals
- hit ENTER key to recompute Wavefront depth section using above parameters
- select *Velocity|Wavefront* and *Window|Tile* to obtain Fig. 8
- select *Depth|Wavefront* and *File|Export header data|Export ASCII Model of depth section...*
- click *Save button* to export Wavefront refractors and layer velocities to file WAVEMODL.CSV
- select *Grid|Select ASCII .CSV layer model for refractor plotting...* and above WAVEMODL.CSV
- check *Grid menu options* for refractor plotting as shown in Fig. 6
- select *Grid|Image and contour velocity and coverage grids...*
- select tomogram grid file \RAY32\JENNY13\GRADTOMO\VELOIT20.GRD to obtain Fig. 9

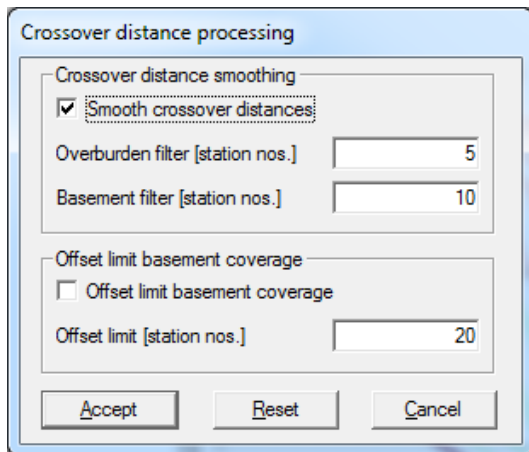


Fig. 10 : Crossover distance processing

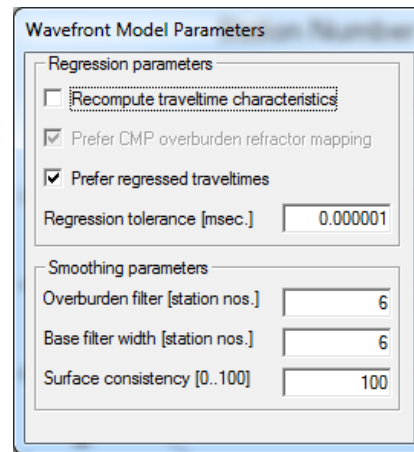


Fig. 11 : Wavefront model parameters

For an explanation of *Refractor|Midpoint breaks* display of CMP sorted traveltimes curves (Fig. 7) see our [DeltatV paper](#), Fig. 2. The steeper the local dip of a CMP sorted traveltimes curve, the higher the local apparent velocity.

See [jenny10.pdf](#) for our interpretation of a synthetic layer-based data set.

We thank our reseller Jacques Jenny at [Geo2X](#) in Oulens-sous-Echallens, Switzerland for making available these data sets.

Below we show reprocessing of this line with our version 4.01 software with WDVS (Zelt and Chen 2016) enabled, done in Dec 2020.

WDVS Wavelength-Dependent Velocity Smoothing is described in

[Zelt, C. A. and J. Chen, Frequency-dependent traveltimes tomography for near-surface seismic refraction data, Geophys. J. Int., 207, 72-88, 2016](#)

Compare WDVS enabled Fig. 13 with Fig. 1 and Fig. 9 showing interpretation with version 3.25 done in 2013 without WDVS. Enabling WDVS (Fig. 15) can improve the WET resolution. The 1D-gradient starting model shown in Fig. 12 is obtained by laterally averaging 1D [DeltatV](#) velocity vs. depth profiles obtained below each CMP (Common MidPoint). See

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.

See <https://dx.doi.org/10.2113/JEEG10.1.21> and http://rayfract.com/srt_evaluation.pdf .

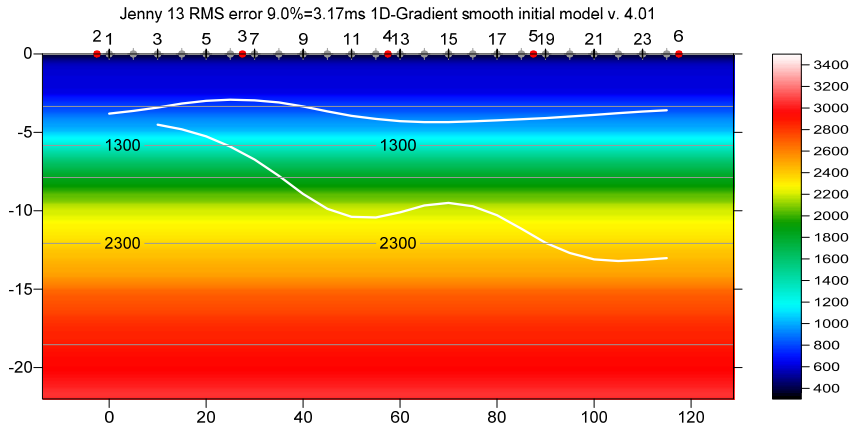


Fig. 12 : Smooth invert|WET with 1D-gradient initial model : 1D-gradient starting model version 4.01 obtained by laterally averaging pseudo-2D DeltatV inversion output ([Sheehan et al. 2005](#)). Layered XTV enabled for DeltatV inversion.

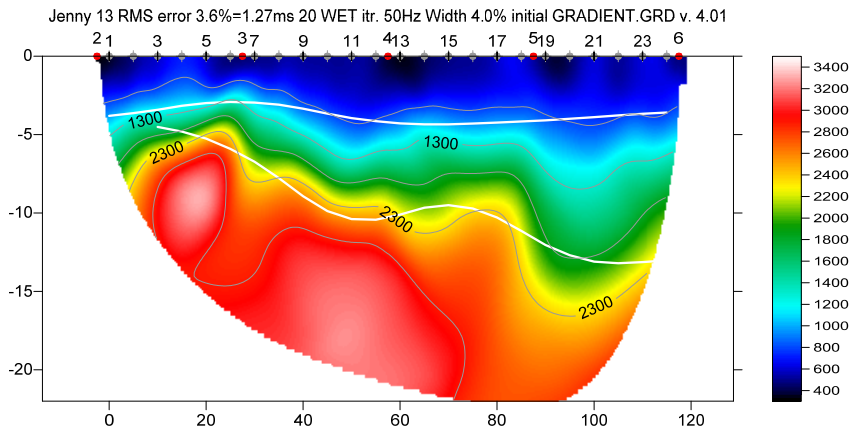


Fig. 13 : Smooth invert|WET with 1D-gradient initial model version 4.01. WDVS enabled (Fig. 15) Starting model Fig. 12. White lines are refractors from Plus-Minus method mapping traces to refractors in Refractor|Shot breaks (Fig. 5).

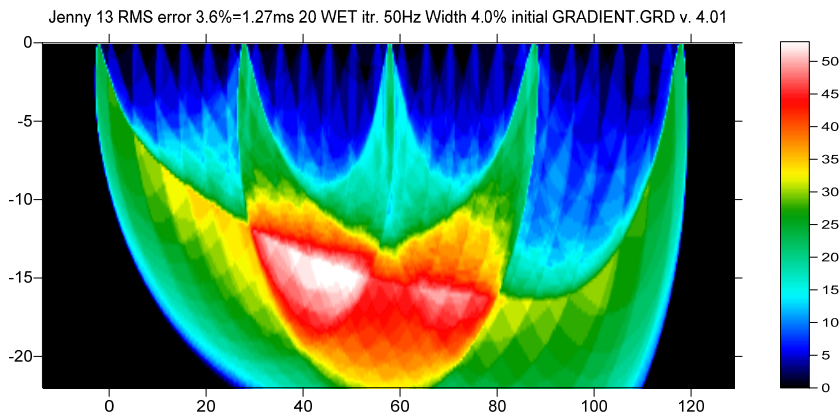


Fig. 14 : WET wavepath coverage plot obtained with Fig. 13. Unit is wavepaths per pixel.

Here is the [archive with seis32.* profile database files for Fig. 12 and Fig 13](#)

Here is the [archive with Surfer 11 .GRD and .SRF and .PAR files for Fig. 12 and Fig. 13](#)

Here is the [archive with seis32.* profile database files for Fig. 16 and Fig 17](#)

Here is the [archive with Surfer 11 .GRD and .SRF and .PAR files for Fig. 16 and Fig. 17](#)

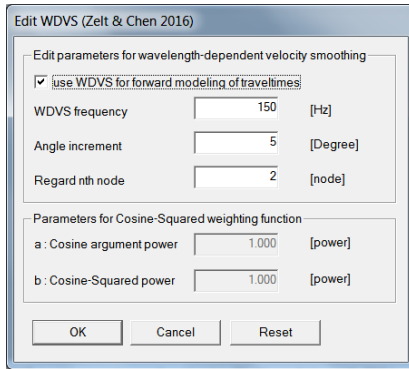


Fig. 15 : Edit Model|WDVS Smoothing. Check Model|Fast WDV Smoothing.

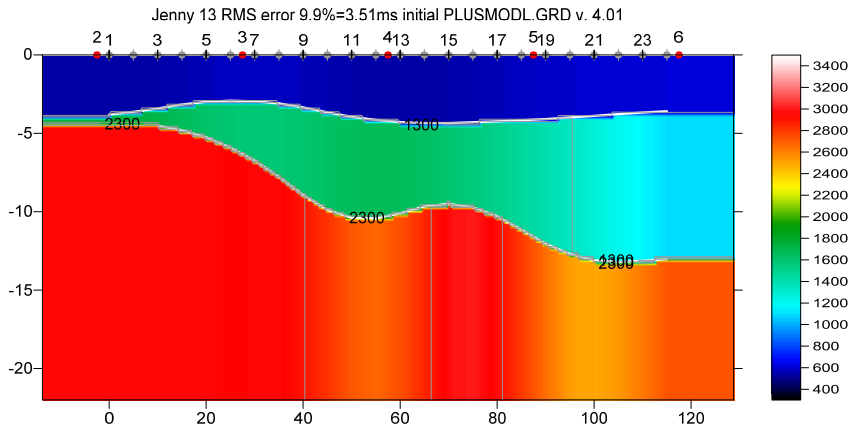


Fig. 16 : Plus-Minus method starting model obtained with Depth|Plus-Minus. Traces are mapped to refractors in Refractor|Shot breaks (Fig. 5). Edit refractor smoothing as in Fig. 18.

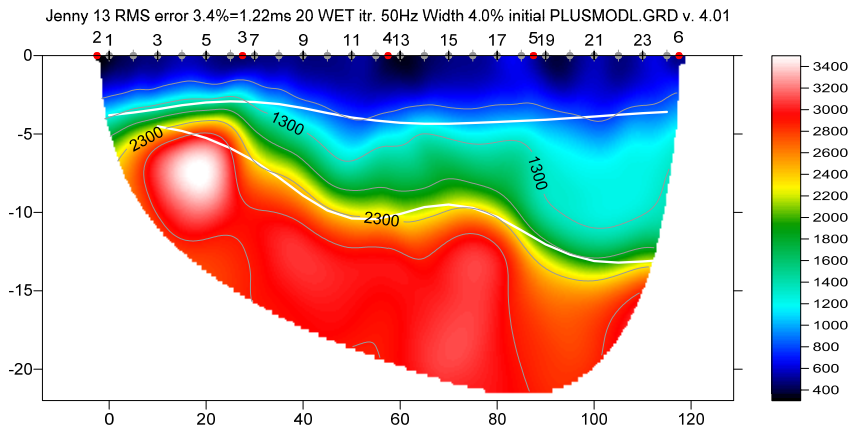


Fig. 17 : WET Tomo|Automatic WET tomography using Plus-Minus starting model (Fig. 16) with WDV enabled (Fig. 15).

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](#)

See our updated [help file](#) for description of WDV parameters in chapter *Forward model traveltimes*. Press F1 function key in *Model|WDVS Smoothing dialog* (Fig. 15) to display popup help window for current control. Use TAB key to switch focus between controls. See our updated tutorials showing WDV :

<http://rayfract.com/tutorials/epikinv.pdf>
<http://rayfract.com/tutorials/camp1.pdf>
<http://rayfract.com/tutorials/11REFR.pdf>

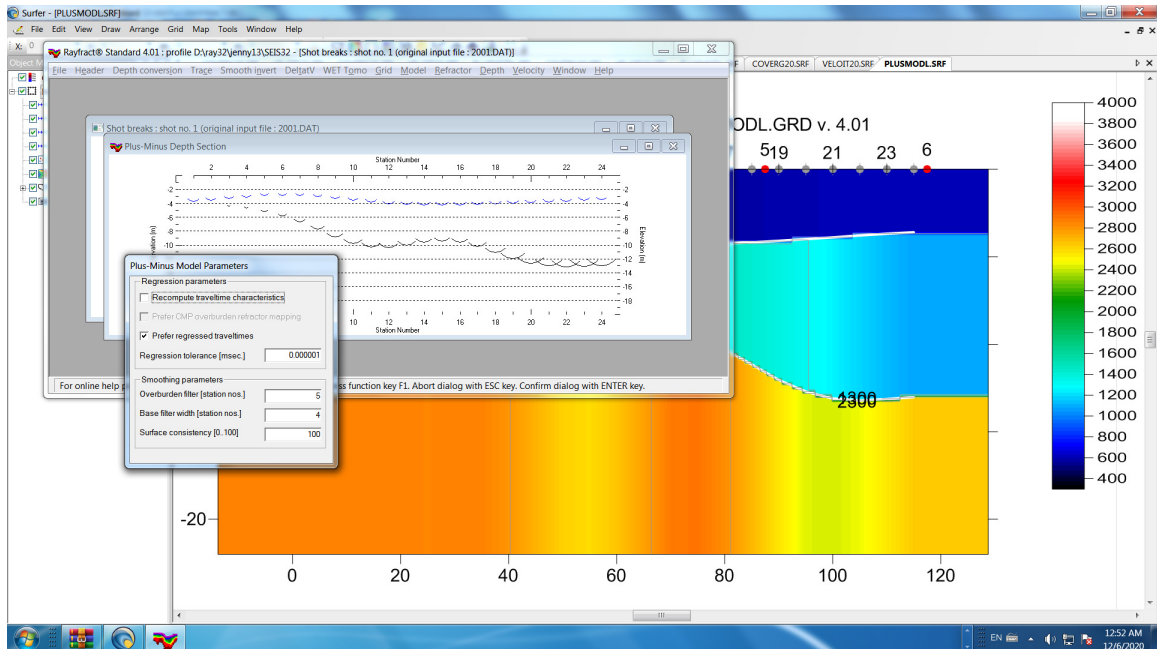


Fig. 18 : Depth|Plus-Minus. When prompted to continue with WET click No button. Press ALT+M to edit Plus-Minus lateral refractor smoothing parameters Overburden filter=5 & Base filter width=4. Press ENTER key to confirm & redo Plus-Minus. When prompted to continue with WET click Yes button to obtain Fig. 17.

Here we give some up-to-date heuristics for improving WET inversion and resolution :

to speed up WDVS enabled WET force a larger grid cell size in *Header|Profile* as done in [camp1.pdf](#).

Limit the *maximum WET velocity* as in [epikinv.pdf](#) Fig. 5 to suppress a WDVS bias towards too high basement velocities. The lower your WDVS frequency (Fig. 15) the stronger this bias will be and the shallower the basement top is imaged. So you really need to experiment with varying this WDVS frequency to obtain a satisfying interpretation with reasonably small RMS error.

For typical field surveys with reciprocal traveltimes 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>.

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 version 4.01 WDVS settings) with default DeltatV and WET settings works 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. Try varying the WDVS frequency e.g. 150Hz vs. 200Hz. Increase the default WET wavepath width e.g. from 4% to 10% for noisy or sparse data. Enable WDVS and decrease the WET smoothing for consistent data with enough shots. Try using minimal WET smoothing for consistently picked traveltimes with correctly specified recording geometry and close enough shot spacing only. See e.g. our [camp1 tutorial](#).

The higher the targeted resolution, the higher the uncertainty in WET results will be especially with realistic field data with [reciprocal traveltimes picking errors](#) and recording geometry specification errors. Avoid over-fitting noisy or sparse data with too wide shot spacing as above. Again see

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

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