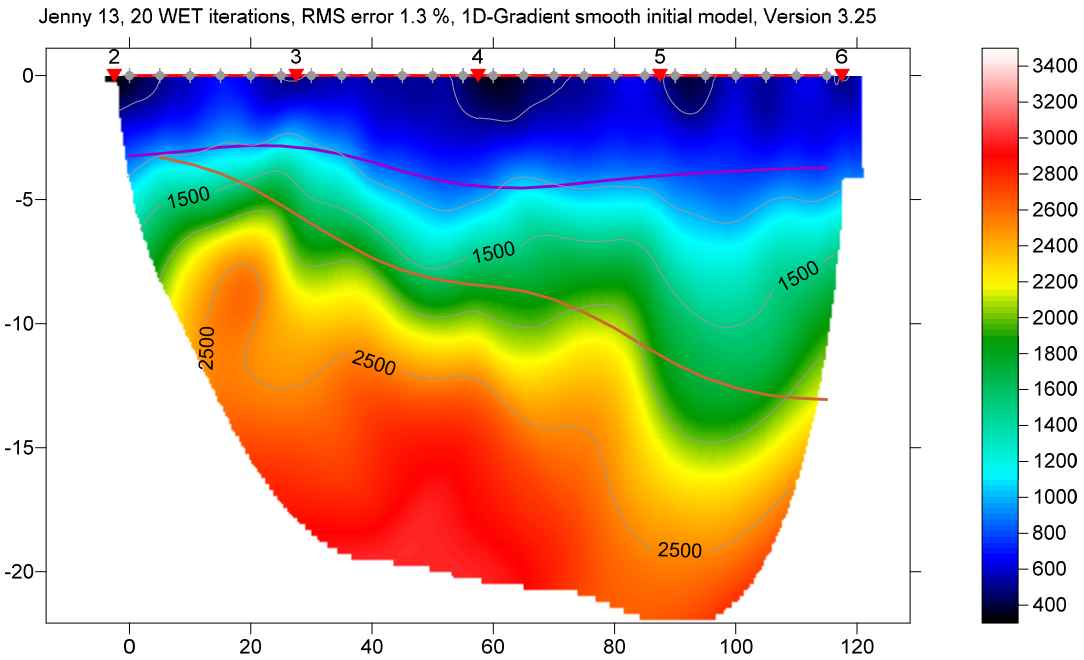

Fig. 1 : Velocity tomogram obtained with Smooth inversion with default settings and 20 WET iterations. Layer-based Plus-Minus refractors are plotted in magenta and brown, see Fig. 3 below.

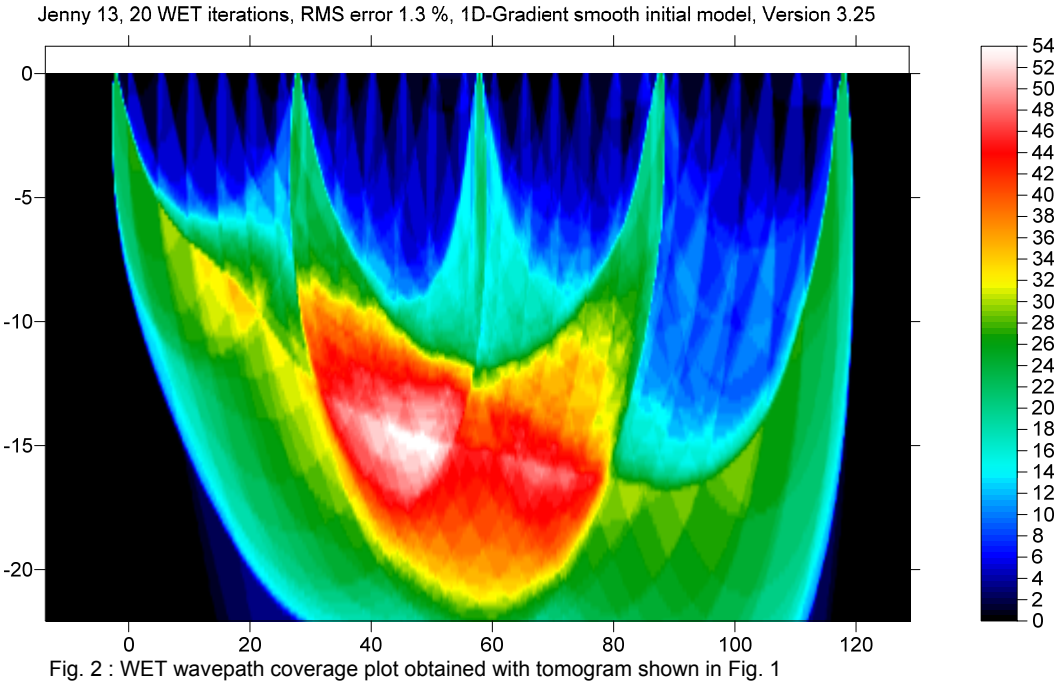

Fig. 2 : WET wavepath coverage plot obtained with tomogram shown in Fig. 1

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*
- when prompted to force first receiver at station 1 click *Yes button* (Fig. 20)
- unzip jenny13.zip in \RAY32\JENNY13\INPUT directory
- specify a *Station spacing* of 5m in *Header|Profile* (Fig. 19) before importing the data.
- select *File|Import Data…* and specify *Import data type* SEG-2

- set *Default spread type* to 01: 24 channels.
- click *Select button*, navigate into \RAY32\JENNY13\INPUT and select 2001.DAT
- 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*
- edit *Grid|Surfer plot Limits* dialog as in Fig. 21
- 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 with branch points in *Refractors|Shot breaks*, select *Depth|Plus-Minus* and *Velocity|Plus-Minus* until *Plus-Minus interpretation* (Fig. 3) matches *Smooth inversion* tomogram (Fig. 1).

When prompted to continue with WET inversion after display of Plus-Minus starting model in Surfer click *No button*. See Fig. 18.

Click on title bar of *Plus-Minus Depth Section window*, 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 *Grid menu options* (Fig. 6) for plotting of refractors on WET tomograms. To redisplay the WET tomogram with Plus-Minus refractors :

- check *Grid|Plot refractors on tomogram* 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

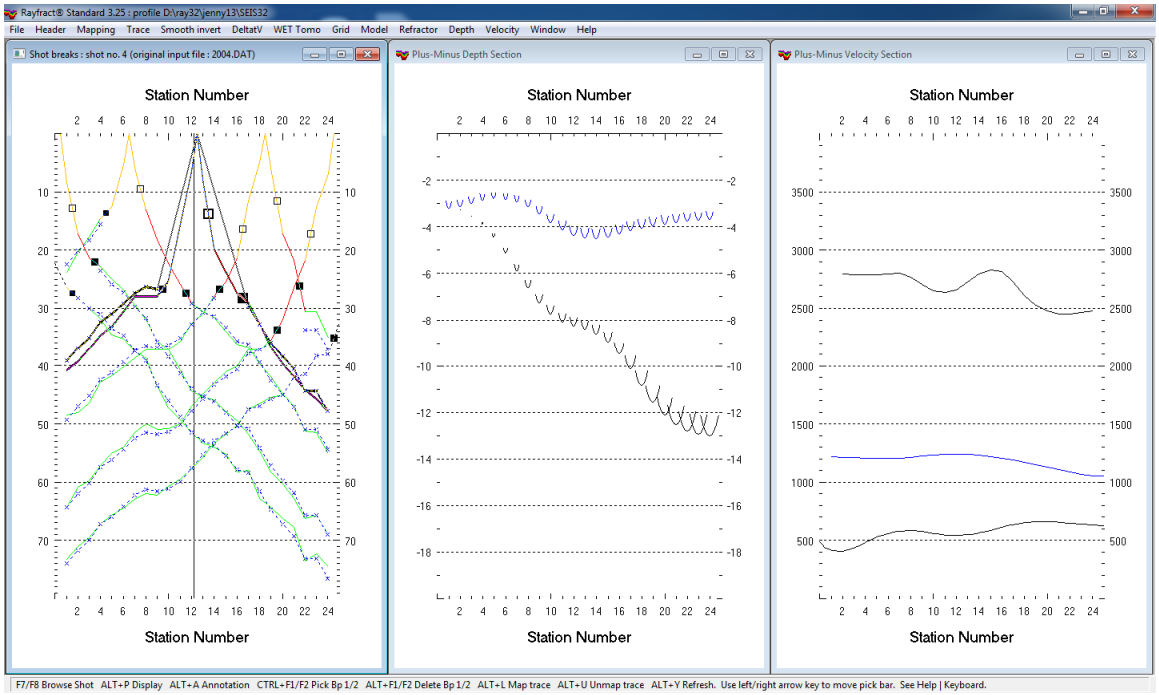

Fig. 3 : Layer-based Plus-Minus refraction interpretation, 3 layers. Left : interactively map traces to refractors using branch points. Center : Depth section obtained with Plus-Minus method. Right : Plus-Minus Velocity section.

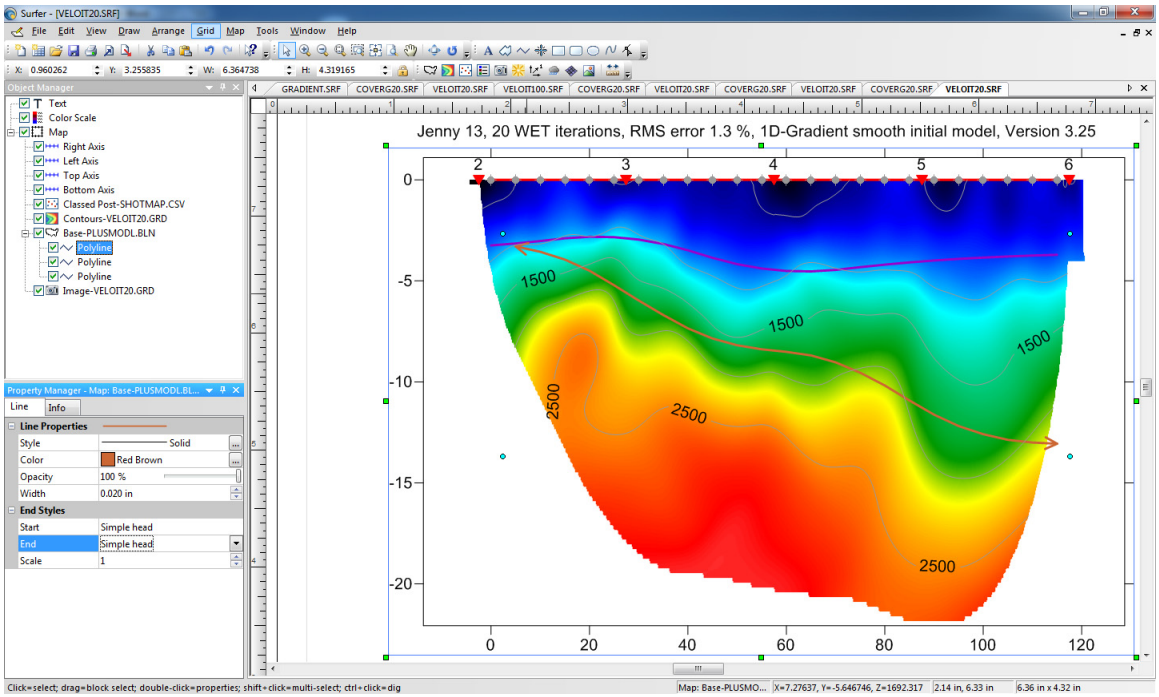

Fig. 4 : Edit Base map and refractor polyline properties in Surfer's Object Manager.

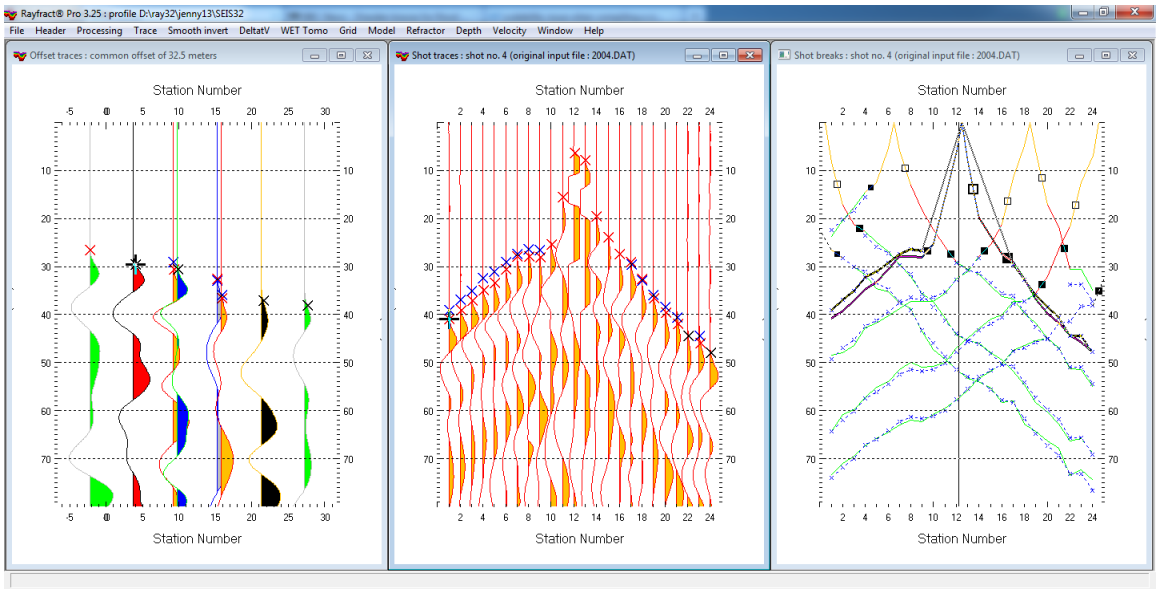

Fig. 5 : *Trace*|*Offset gather* (left), *Trace*|*Shot gather* (center), *Refractor*|*Shot breaks* (right). Browse offset gathers with F7/F8 in *Trace*|*Offset gather*, to quality-check for reciprocal traveltime errors. Note asymmetry of first breaks for shot no. 4 (center), relative to shot point (station 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 traveltime errors in *Trace*|*Offset gather*, see Fig. 5. and Slope1 tutorial. Browse common-offset sorted trace gathers with F7/F8 function keys.

Our latest version 4.06 allows plotting of your reciprocal traveltime picks on shot gather traces. See our tutorials Gasch23 and Line3 and MDW2011_23. Reciprocal traces are shown in status bar. This allows for easy identication of bad picks. **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.

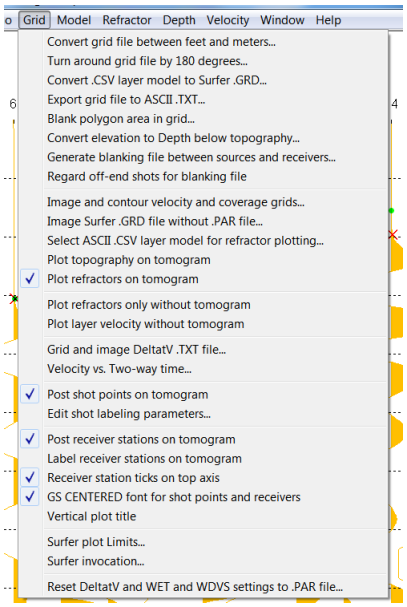

Fig. 6 : Grid menu options, for Rayfract® version 4.06

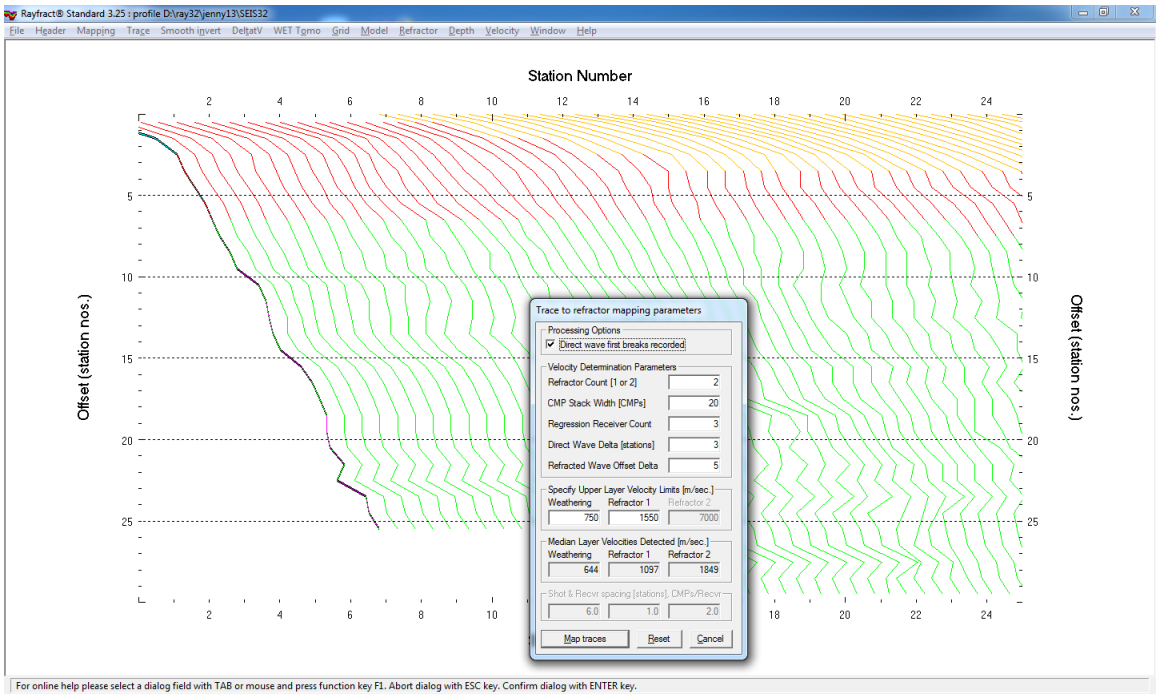

Fig. 7 : *Refractor|Midpoint breaks*, mapping traces to refractors with ALT+M and 1D velocity model

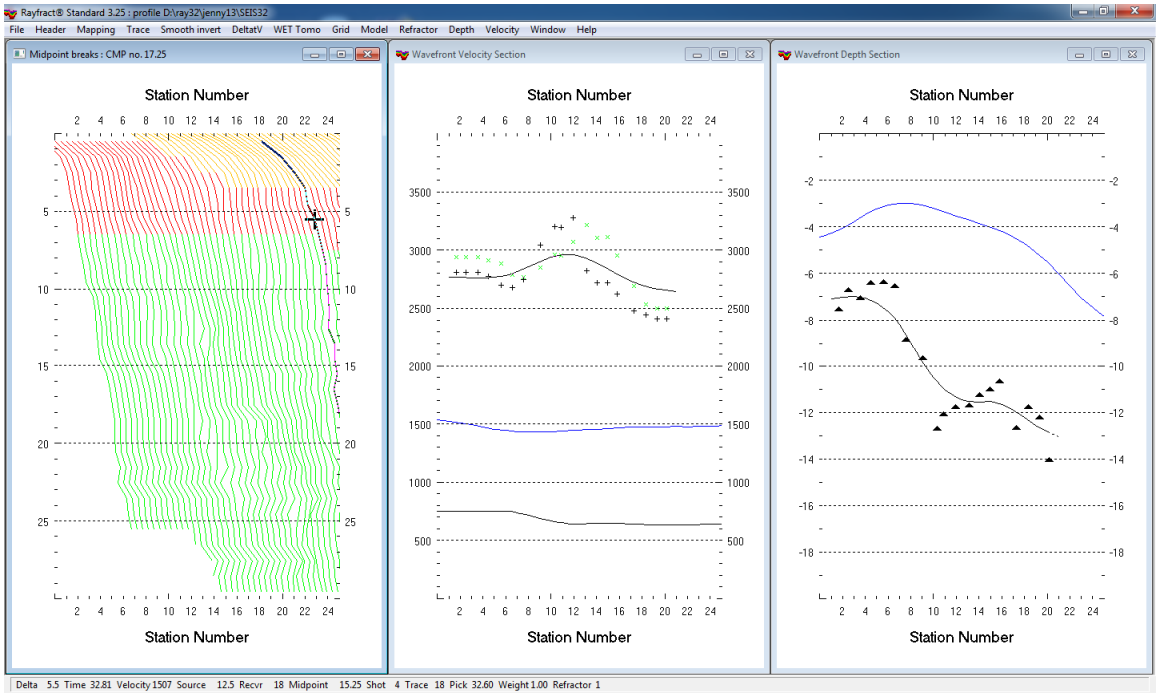

Fig. 8 : left : *Refractor|Midpoint breaks*, center : *Velocity|Wavefront*, right : *Depth|Wavefront*

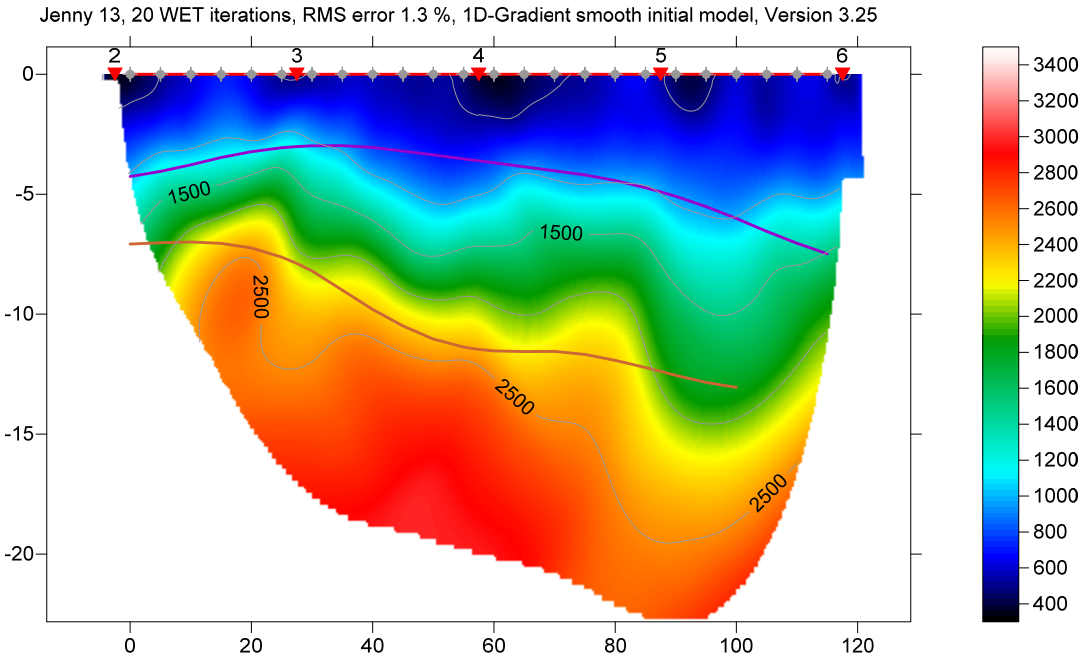

Fig. 9 : Velocity tomogram obtained with Smooth inversion with default settings and 20 WET iterations. Layer-based Wavefront method refractors are plotted in magenta and brown. Compare Fig. 8.

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
- click *Map traces button* 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*. When prompted to continue with WET inversion click *No button*.

- click on title bar of *Wavefront Depth Section* window
- press ALT+M, edit model parameters as in Fig. 11
- set both *Overburden filter* and *Base filter width* to 6 station number intervals
- click *OK button* to recompute Wavefront depth section using above parameters
- when prompted to continue with WET inversion click *No button*
- select *Velocity|Wavefront* and *Window|Tile* to obtain Fig. 8
- check *Grid|Plot refractors on tomogram* 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

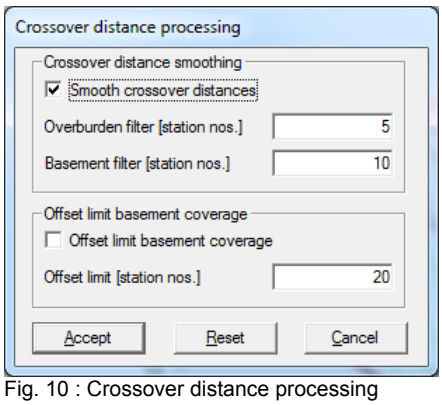

Fig. 10 : Crossover distance processing

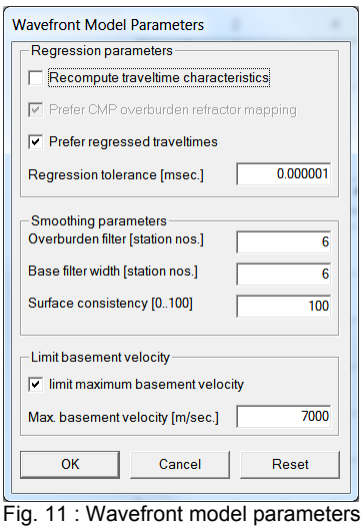

Fig. 11 : Wavefront model parameters

For an explanation of *Refractor|Midpoint breaks* display of CMP sorted traveltime curves (Fig. 7) see our DeltatV paper, Fig. 2. The steeper the local dip of a CMP sorted traveltime 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 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 traveltime 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 .

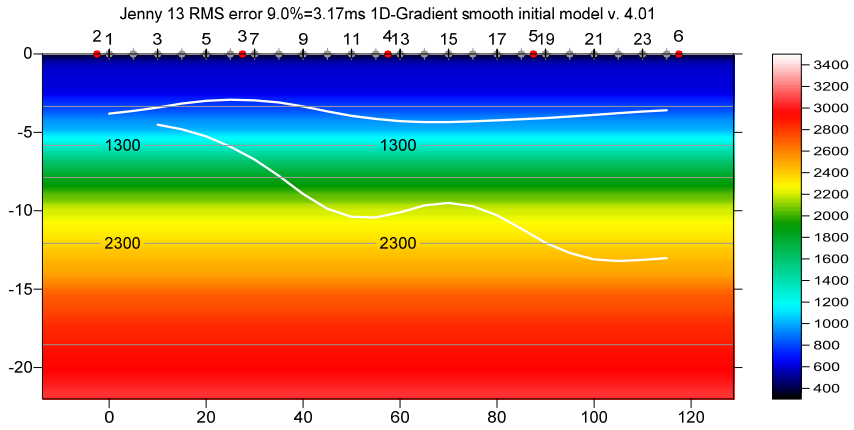

Fig. 12 : Smooth invert|WET with 1D-gradient initial model : 1D-gradient starting model version 4.01 obtained by laterally averaging pseudo-2D DeltatV inversion output (Sheehan et al. 2005). Layered XTV enabled for DeltatV inversion.

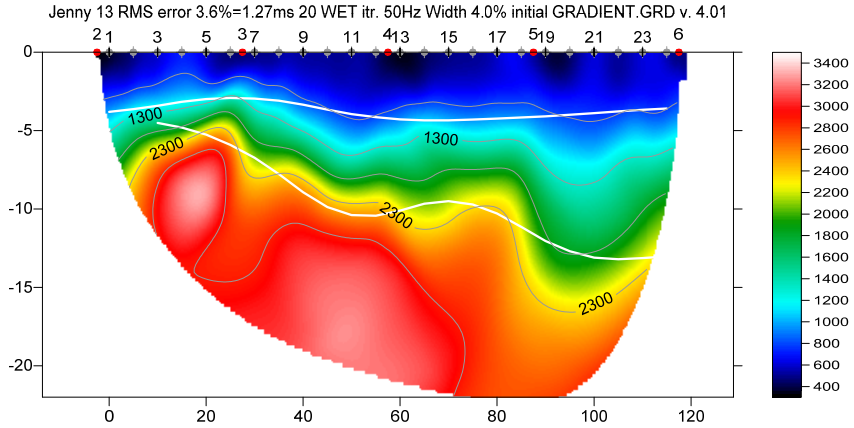

Fig. 13 : Smooth invert|WET with 1D-gradient initial model version 4.01. WDVS enabled (Fig. 15) Starting model Fig. 12. White lines are refractors from Plus-Minus method mapping traces to refractors in Refractor|Shot breaks (Fig. 5).

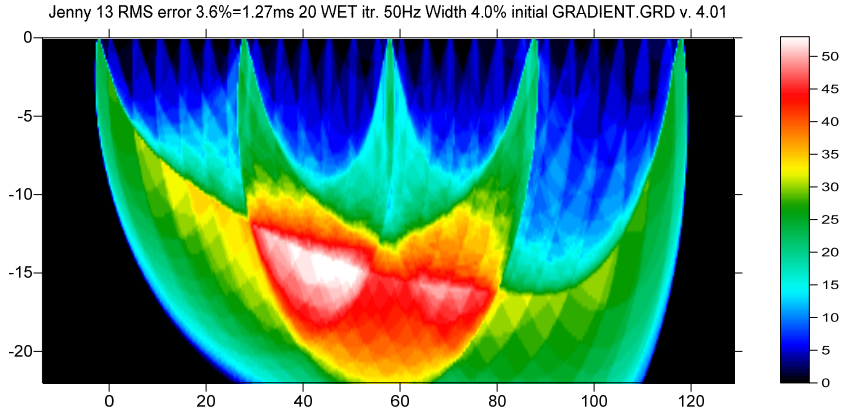

Fig. 14 : WET wavepath coverage plot obtained with Fig. 13. Unit is wavepaths per pixel.

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

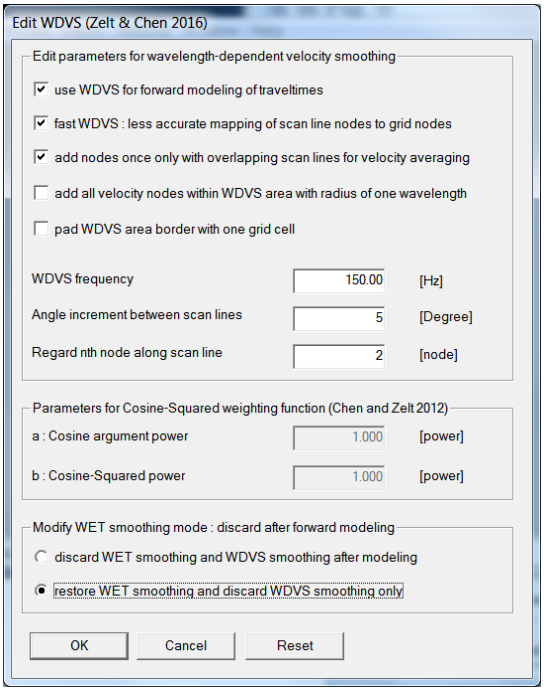

Fig. 15 : ***Model|WDVS Smoothing***

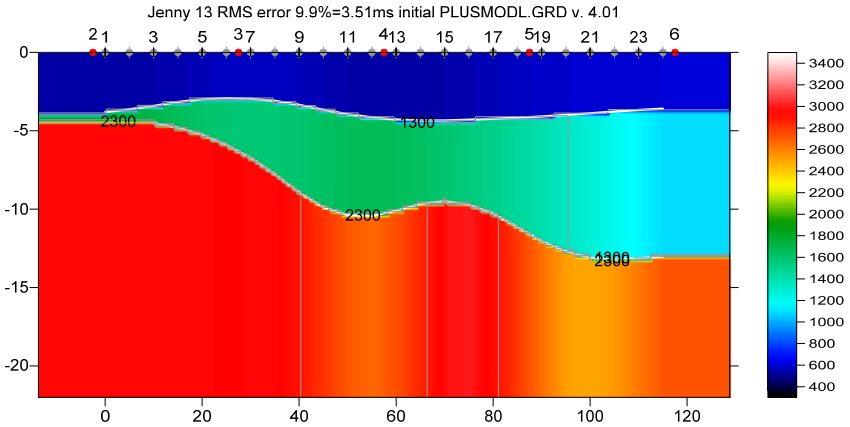

Fig. 16 : Plus-Minus method starting model obtained with Depth|Plus-Minus. Traces are mapped to refractors in Refractor|Shot breaks (Fig. 5). Edit refractor smoothing as in Fig. 18.

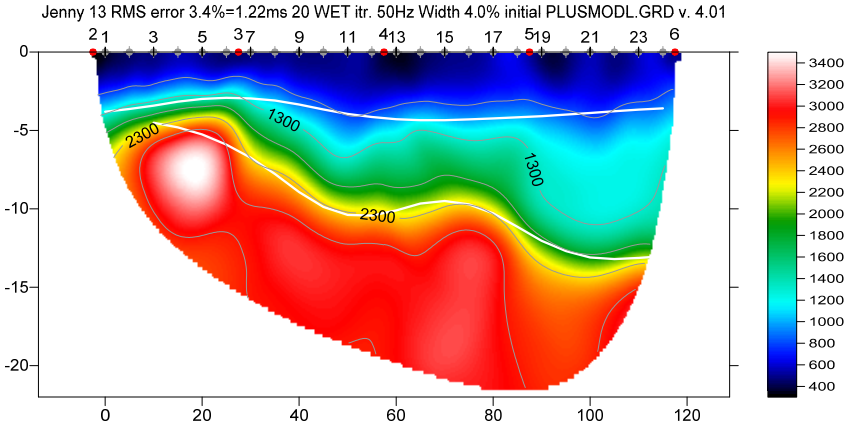

Fig. 17 : WET Tomo|Automatic WET tomography using Plus-Minus starting model (Fig. 16) with WDVS enabled (Fig. 15).

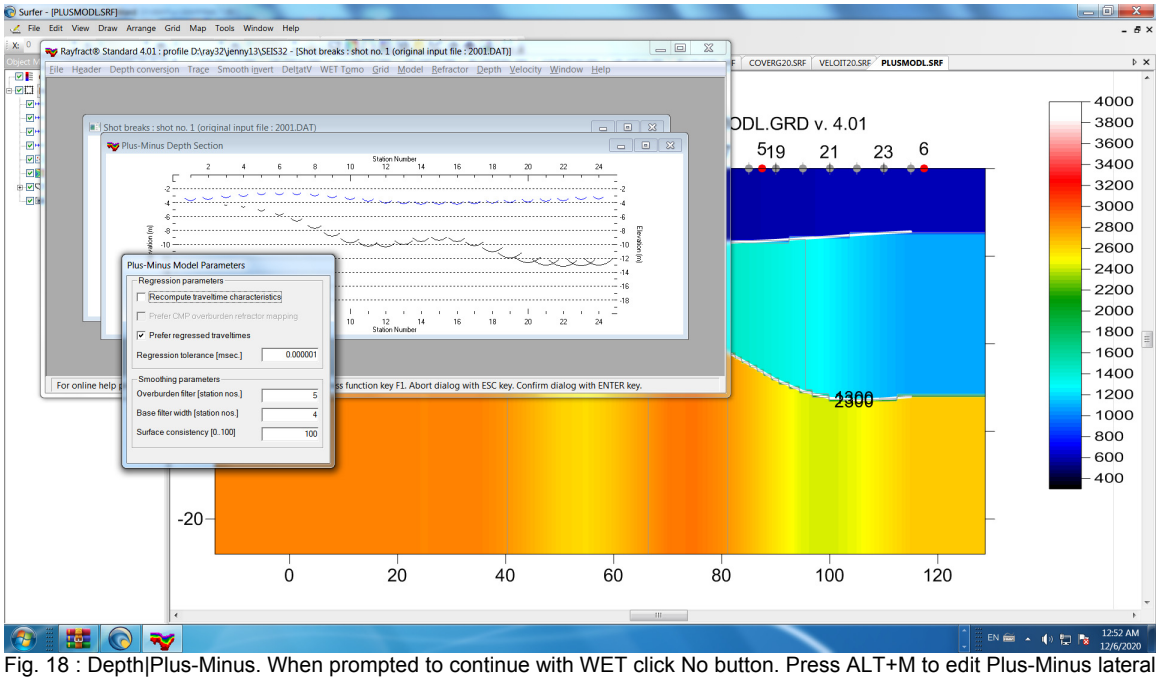

Fig. 18 : Depth|Plus-Minus. When prompted to continue with WET click No button. Press ALT+M to edit Plus-Minus lateral refractor smoothing parameters Overburden filter=5 & Base filter width=4. Press ENTER key to confirm & redo Plus-Minus. When prompted to continue with WET click Yes button to obtain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

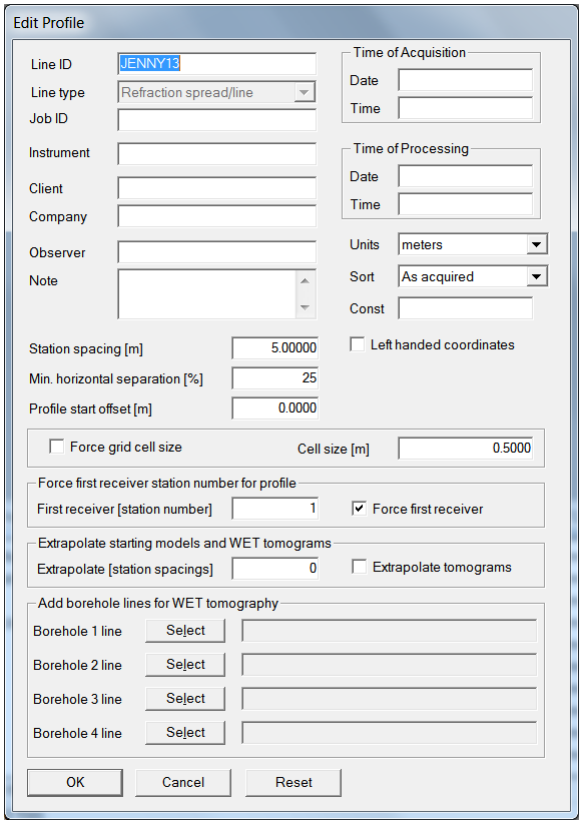

Fig. 19 : ***Header|Profile***. Set Station spacing to 5.0m

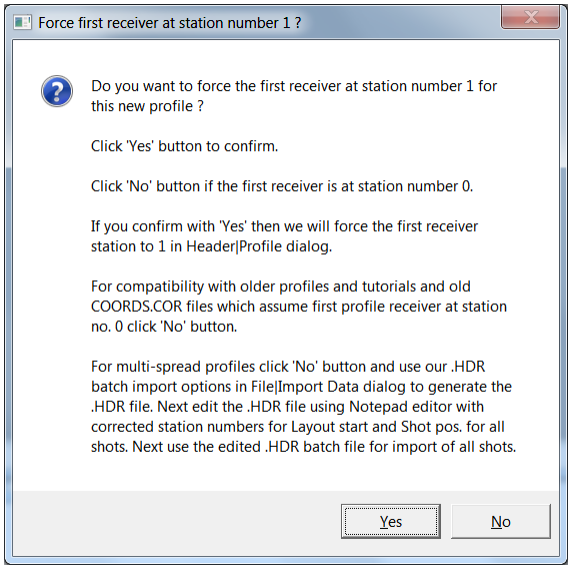

Fig. 20 : click ***Yes button*** to force profile start / first receiver station number at station no. 1.

For compatibility with older profiles and tutorials and old COORDS.COR files which assume first profile receiver at station no. 0 click No button.

For multi-spread profiles click ***No button*** and use our .HDR batch import options in ***File|Import Data*** dialog to generate the .HDR file. Next edit the .HDR file using MS Notepad editor with corrected station numbers for *Layout start* and *Shot pos.* for all shots. Next use the edited .HDR batch file for import of all shots.

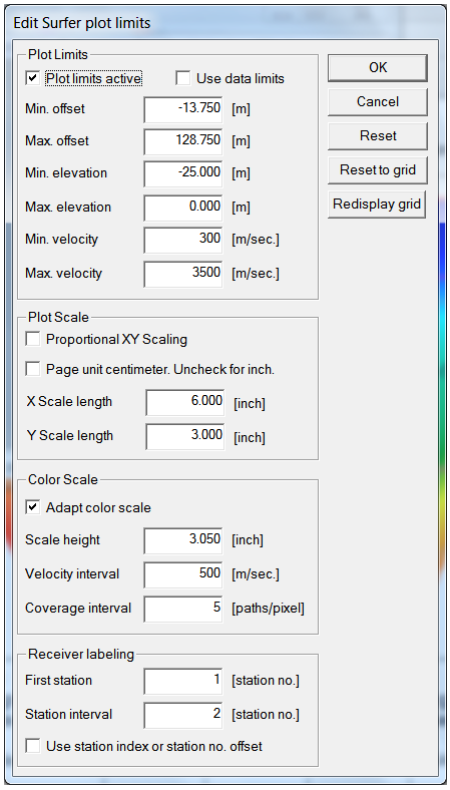

Fig. 21 : ***Grid|Surfer plot Limits*** dialog.

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 WDVS 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 WDVS :

http://rayfract.com/tutorials/epikinv.pdf
http://rayfract.com/tutorials/camp1.pdf
http://rayfract.com/tutorials/11REFR.pdf
https://rayfract.com/tutorials/MDW2011_23.pdf
https://rayfract.com/tutorials/Gasch23.pdf
https://rayfract.com/tutorials/Line3.pdf

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 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 .

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 traveltime 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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