Import SEG-2 .DAT & Update header data & multiscale WET inversion GASCH23 v. 4.05 :

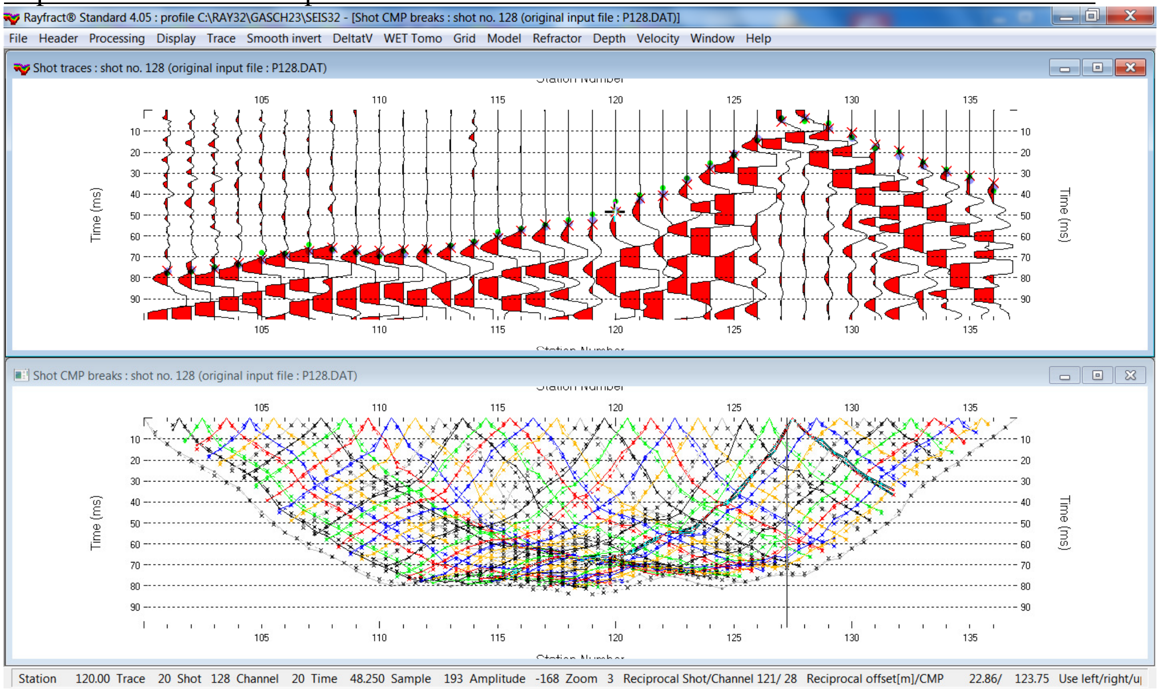

Fig. 1 : check *Trace|Open Refractor|Shot CMP breaks*. Top : *Trace|Shot gather*, bottom : *Refractor|Shot CMP breaks*. Shows fit between picked times (solid colored curves, red crosses) and modeled times (dashed blue curves, blue dots). Green dots are your reciprocal picks.

To create the profile database, import the data and browse the imported shots do these steps :

- ***File|New Profile***…, set *File name* to **`GASCH23`** and click *Save button*
- in the prompt shown next (Fig. 4) click ***No*** button to leave ***Profile start*** / first channel at station no. 101 as specified by SEG-2 trace headers RECEIVER_STATION .
- in ***Header|Profile***… set *Line type* to **`Refraction spread/line`** . Set *Station spacing* to 3.048 m. See Fig. 2.
- unzip archive **`https://rayfract.com/tutorials/GASCH23_INPUT.zip`** with **`SEG-2 .DAT`** shot files & files **`COORDS1.COR & BREAKS.LST`** in directory **`C:\RAY32\GASCH23\INPUT`**
- check *File|SEG-2 import settings|Get distance unit from user*
- check *File|Import Data Settings|Default distance unit is meter*
- select ***File|Import Data***… and set *Import data type* to **`SEG-2`**. See Fig. 3.
- click *Select button* and navigate into **`C:\RAY32\GASCH23\INPUT`**
- set *Files of type* to **`Seismic data files (*.DAT)`** and select a file e.g. **`P101.DAT`** & click *Open*
- leave *Default spread type* at **`10: 360 channels`**
- click ***Import shots button*** . Click *Read button* once for each shot displayed in *Import shot* dialog.
- select *File|Update header data|Update Station Coordinates* & **`COORDS1.COR`**. Click *Import & Reset*.
- select *File|Update header data|Update First Breaks*. Select file **`BREAKS.LST`** & click *Open*.
- select option *Trace|Open Refractor|Shot CMP breaks with Shot gather*
- select *Trace|Shot gather* to obtain Fig. 1
- click on title bar of *Trace|Shot gather* window and press CTRL+F1 to zoom trace amplitude
- browse shots in *Trace|Shot gather* window with F7/F8 (Fig. 1 top)
- click on title bar of *Refractor|Shot CMP breaks* window (Fig. 1 bottom) and press ALT+P. Edit *Maximum time* to 100 ms & press ENTER key to redisplay. Do the same for *Trace|Shot gather* window (Fig. 1 top).

To configure and run our default fail-safe *Smooth inversion* :

- check option *Grid|Receiver station ticks on top axis*
- check option *Grid|CS_CENTERED font for shot points and receivers* to workaround Surfer symbol display issues
- edit *Grid|Surfer plot Limits* as in Fig. 8
- check option *Model|Forward modeling Setting|Normalize RMS error with maximum picked time*
- select *Model|WDVS Smoothing* and check box *Discard WET smoothing and WDVS smoothing after forward modeling*. Leave box *use WDVS for forward modeling of traveltimes* unchecked (Fig. 9).
- select ***Smooth invert|WET with 1D-gradient initial model***
- wait for the 1D-gradient starting model to display as in Fig. 5
- confirm prompt to continue with WET inversion to obtain WET output shown in Fig. 6 & 7

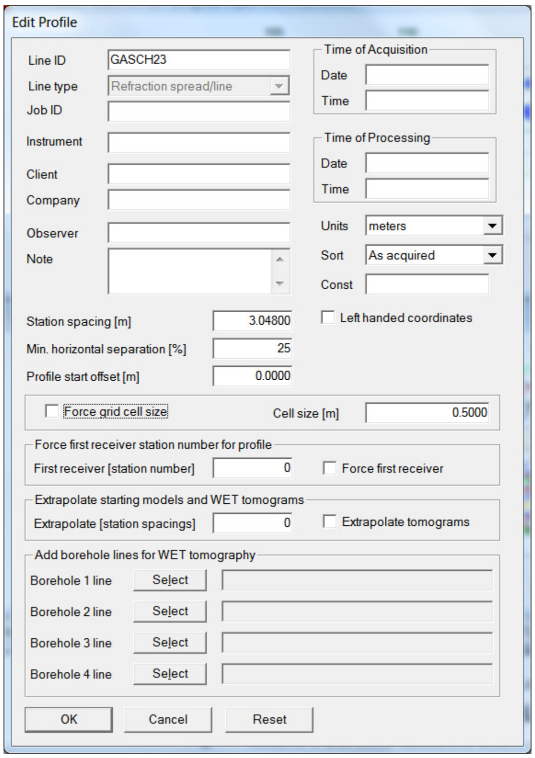

Fig. 2 : *Header|Profile*

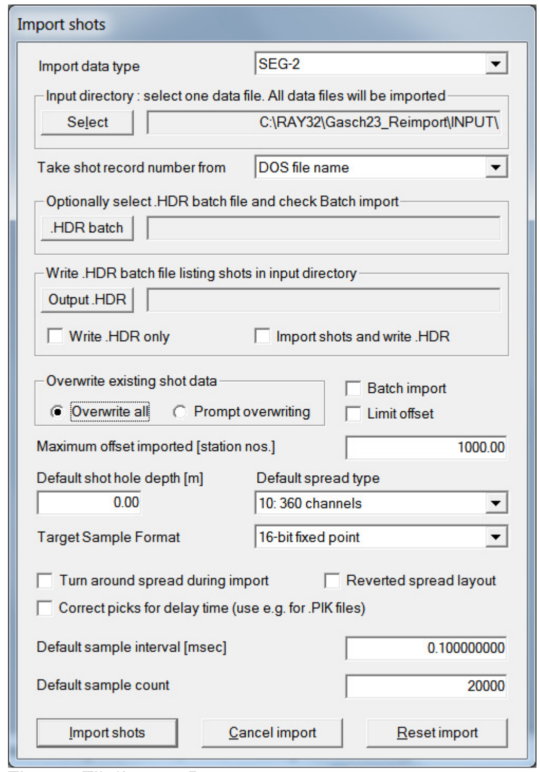

Fig. 3 : *File|Import Data*

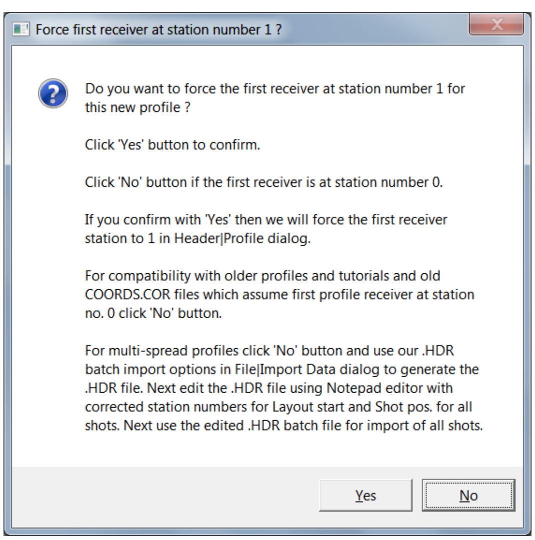

Fig. 4 : click *No* button to to leave first channel at station no. 101 as specified by SEG-2 trace headers RECEIVER_STATION .

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.

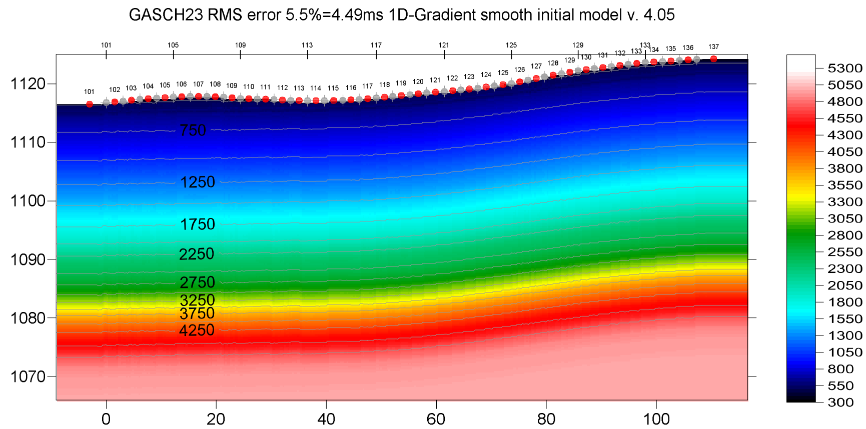

Fig. 5 : 1D-gradient starting model obtained with *Smooth invert|WET with 1D-gradient initial model.*

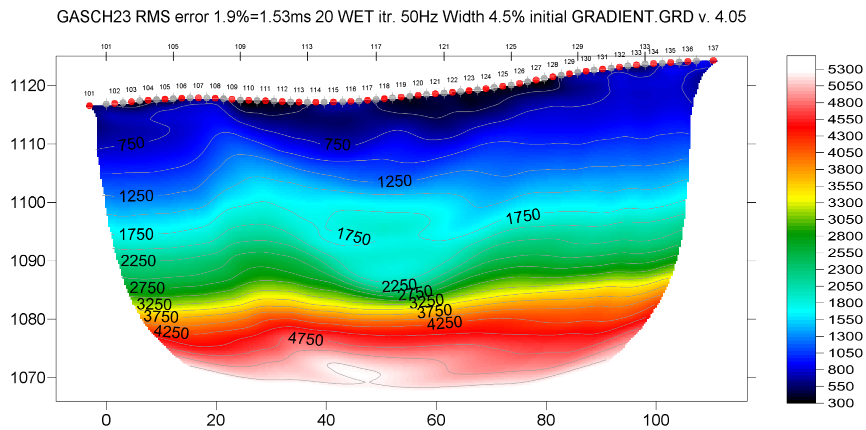

Fig. 6 : 2D WET output obtained with *Smooth invert|WET with 1D-gradient initial model* & starting model shown in Fig. 5. 20 WET iterations using Steepest Descent method & Gaussian update weighting & full WET smoothing. Discard WET smoothing after forward modeling. Leave WDVS disabled (Fig. 9).

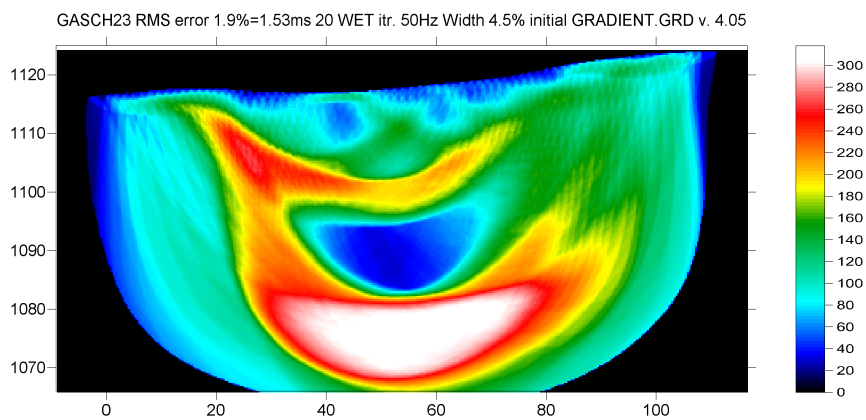

Fig. 7 : WET wavepath coverage plot obtained with Fig. 6. Unit is wavepaths per pixel.

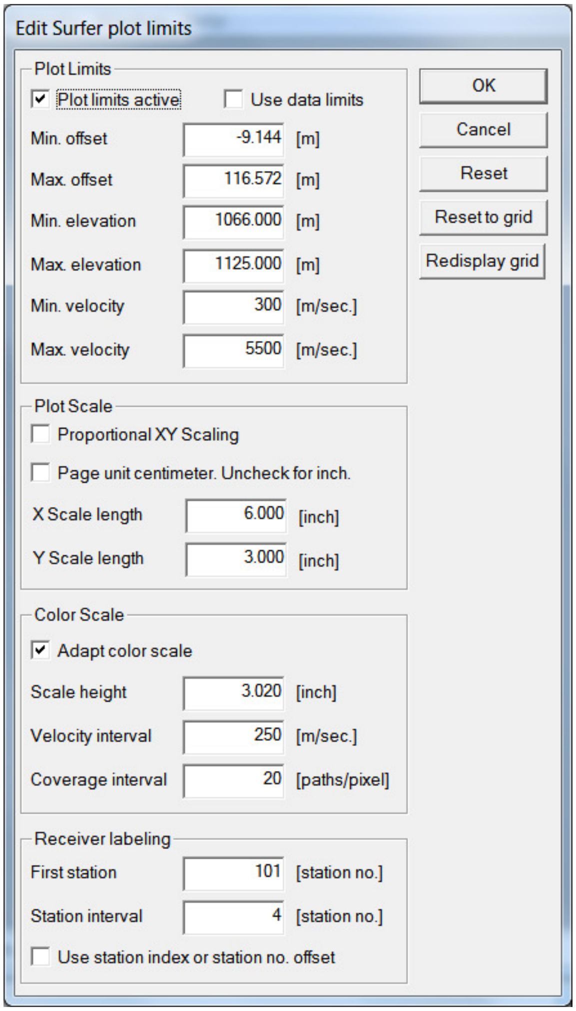

Fig. 8 (left) : Grid|Surfer plot Limits dialog .

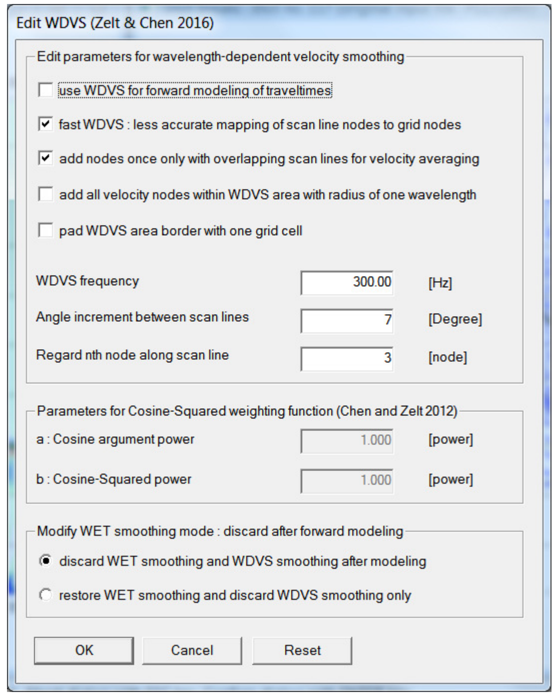

Fig. 9 : Model|WDVS Smoothing dialog .

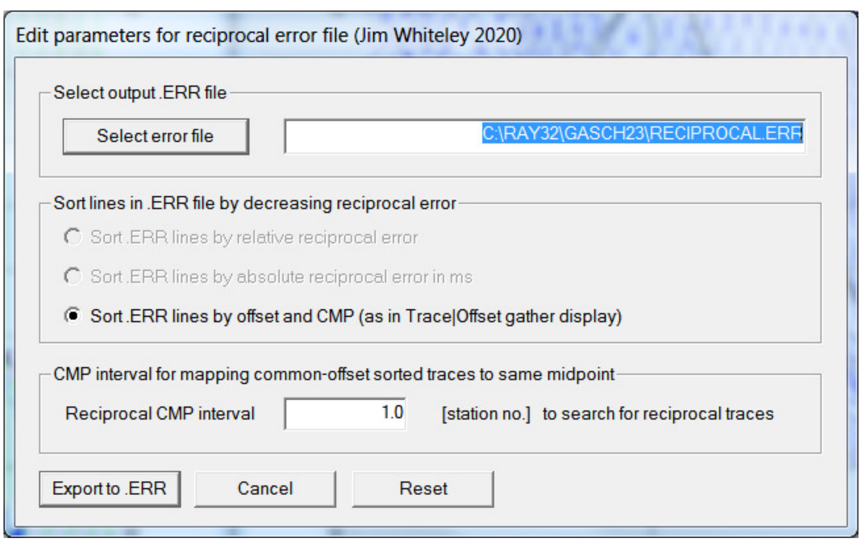

Fig. 10 : Trace|Export reciprocal errors and update database

How to plot your reciprocal traveltime picks on shot-sorted trace gathers :

Next we show how to plot your reciprocal traveltime picks on shot-sorted trace gathers. This lets you quality-control your first break picks and check the validity of your recording geometry specification (shot station numbers and receiver station numbers). See Whiteley J. et al. 2020 : Landslide monitoring using seismic refraction tomography – The importance of incorporating topographic variations :

- select ***Trace|Export reciprocal traveltime picks and update database***
- click button *Select error file* and click *Save* button (Fig. 10)
- click button *Export to .ERR*
- optionally check new option ***Trace|Open Refractor|Shot CMP breaks with Shot gather***
- select *Trace|Shot gather* to obtain a window display as in our Fig. 1
- check new version 4.05 option ***Display|Show reciprocal picks on Shot Gather***
- browse and zoom trace gathers with function keys F7/F8, F1/F2 etc. as usual
- navigate traces with arrow-left and arrow-right keys
- if a reciprocal pick was determined/matched to the current trace then this is plotted as a green dot on the trace
- also we show ***Reciprocal Shot/Channel*** and ***Reciprocal offset[m]/CMP*** in status bar at bottom of window (Fig. 1) if a reciprocal pick is available in the .ERR file

How to run multiscale WET inversion using our 1D-gradient initial model :

- select *WET Tomo|Interactive WET*
- click on ***Iterate*** button
- edit WET runs as shown in Fig. 11. Set runs no. 8/9/10 to 20 WET iterations each. Click *OK* button.

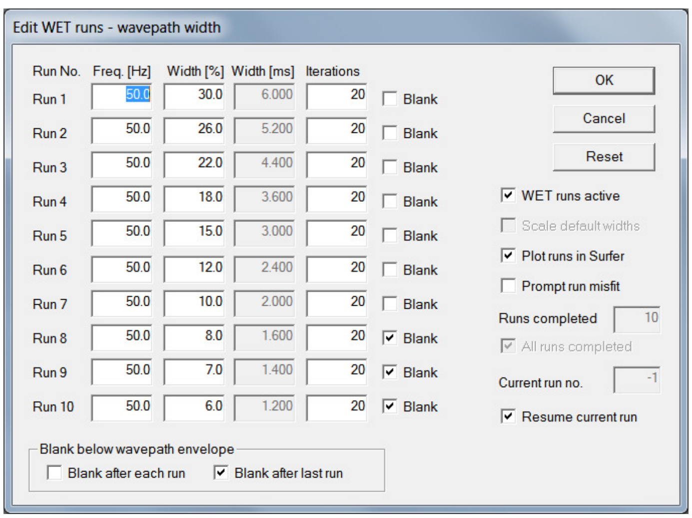

Fig. 11 : WET Tomo|Interactive WET|Iterate .

Edit WET runs dialog. Edit as shown and click OK button.

- reselect *WET Tomo|Interactive WET*
- click button *Edit velocity smoothing* (Fig. 12)
- click radio button *Minimal smoothing after each tomography iteration* (Fig. 12)
- click button *Accept parameters*
- in WET main dialog click button *Start tomography processing* to obtain Fig. 13 and Fig. 14 after 10 WET runs with 20 WET iterations per each run as specified in Fig. 11
- note the improved imaging of the landslide sliding plane and related velocity inversion in Fig. 13 compared to Fig. 6 . The recorded profile crosses the landslide.

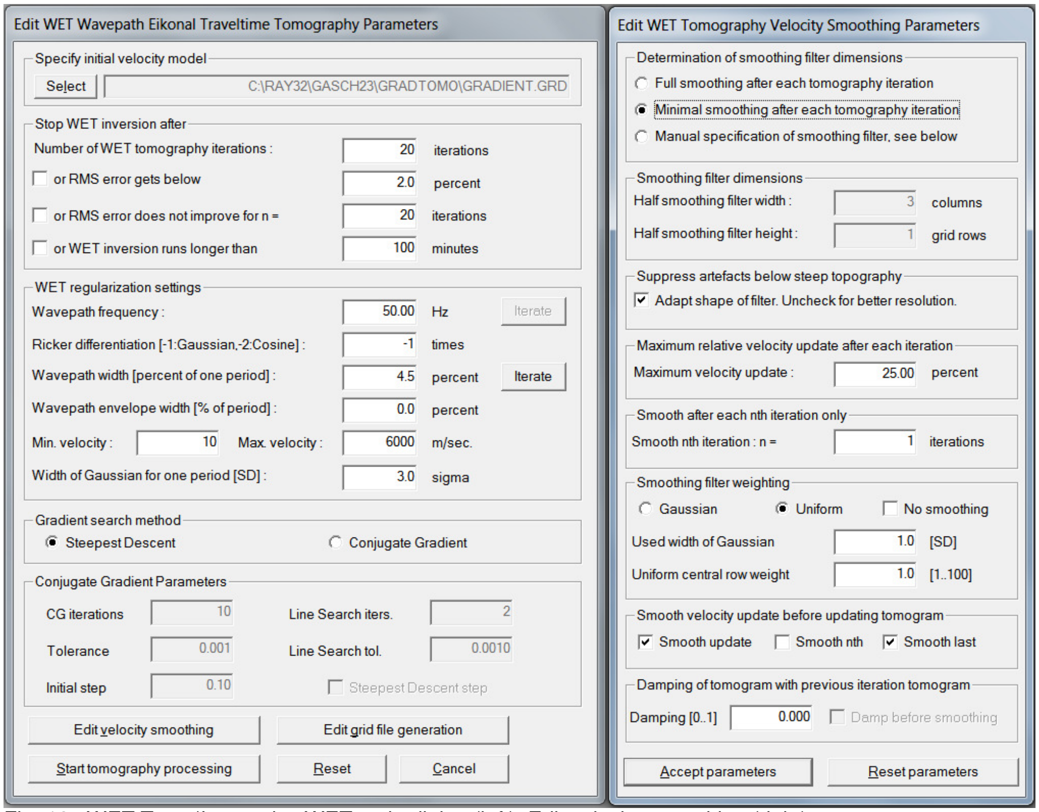

Fig. 12 : WET Tomo|Interactive WET main dialog (left). Edit velocity smoothing (right).

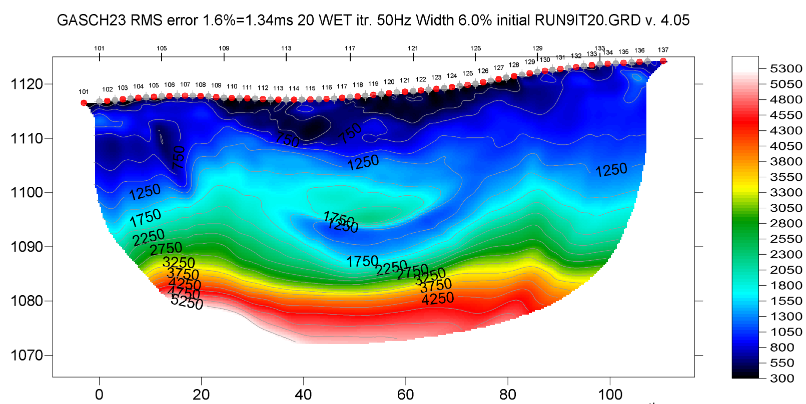

Fig. 13 : Multiscale Steepest-Descent WET inversion. Output of 10th WET run shown. Starting model for 1st run is Fig. 5. Discard WET smoothing after forward modeling. Leave WDVS disabled (Fig. 9). Minimal WET smoothing (Fig. 12).

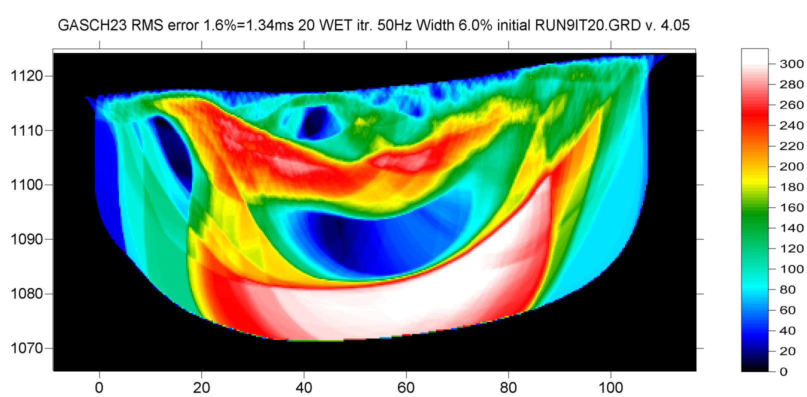

Fig. 14 : WET wavepath coverage plot obtained with Fig. 13. Unit is wavepaths per pixel.

Here is the link to the .RAR archive with the GASCH23 profile folder for above Fig. 13 :

https://www.dropbox.com/scl/fi/2zq6lvktfx6w06wxtd0rl/GASCH23_Dec3_2023.rar?rlkey=i4wwrg40f6x9k8xosvlou9xj8&dl=0

Select above link and copy with CTRL+C. Then paste the link into your web browser with CTRL+V and press RETURN key to download the .RAR archive.

How to obtain layered refraction starting model using our CMP Intercept-Time refraction method :

Next we show layered refraction interpretation with our CMP Intercept-Time refraction method and using this as starting model for multiscale WET inversion with WDVS enabled :

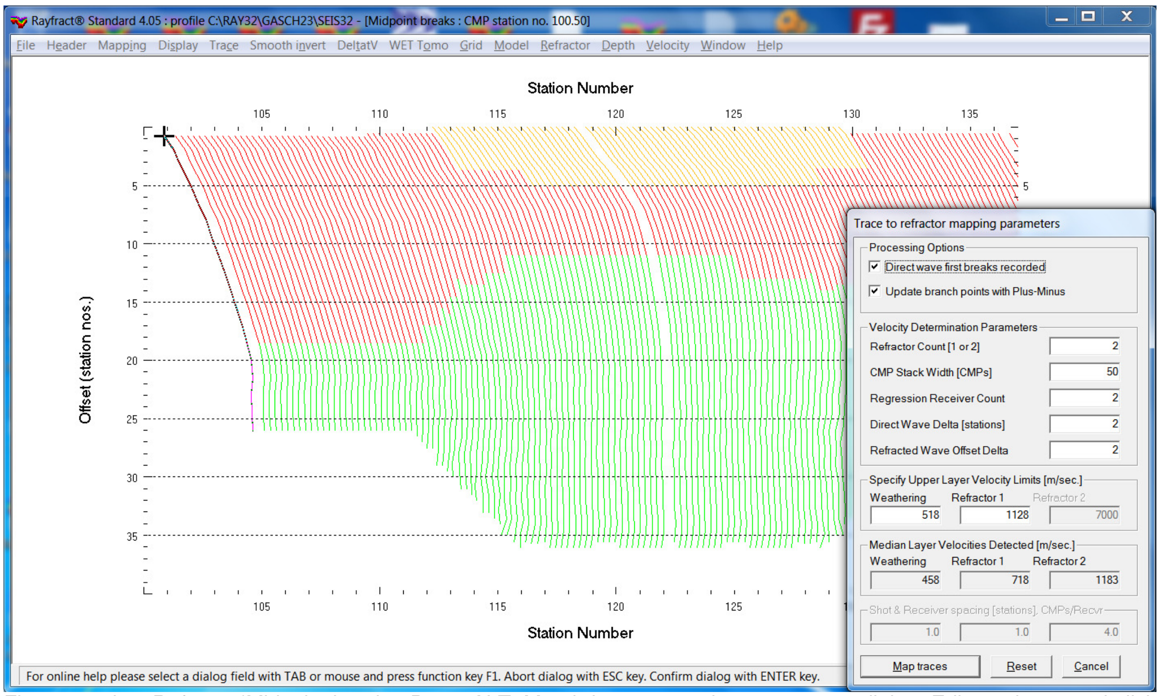

Fig. 15 : select Refractor|Midpoint breaks. Press ALT+M to bring up mapping parameters dialog. Edit as shown and click button Map traces.

- select *Refractor|Midpoint breaks* (Fig. 15)
- press ALT+M and edit mapping parameters (Fig. 15)
- click button *Map traces to refractors*
- select *Depth|CMP Intercept-Time Refraction*
- confirm warning prompt about artefacts to obtain layered refraction starting model (Fig. 17)
- when prompted to continue with WET inversion click *No* button
- click on title bar of *CMP Depth Section* window
- press ALT+M and edit *CMP Model Parameters* as shown in Fig. 16
- click *OK* button to obtain Fig. 17

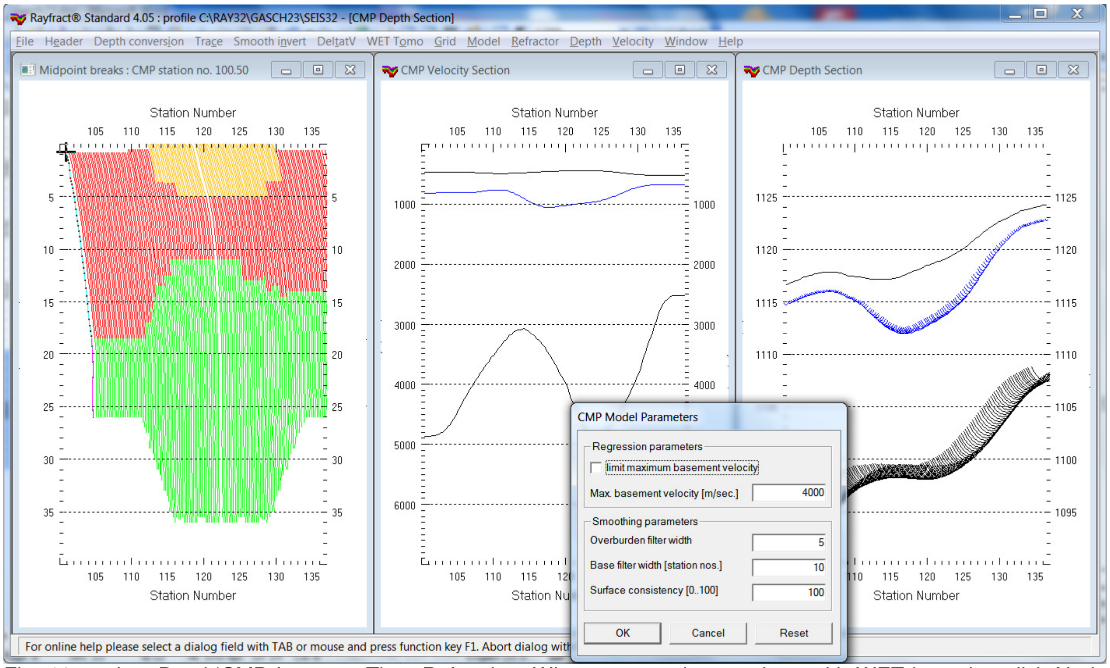

Fig. 16 : select Depth|CMP Intercept-Time Refraction. When prompted to continue with WET inversion click No button. Click on title bar of CMP Depth Section window. Press ALT+M and edit CMP Model Parameters as shown. Click OK.

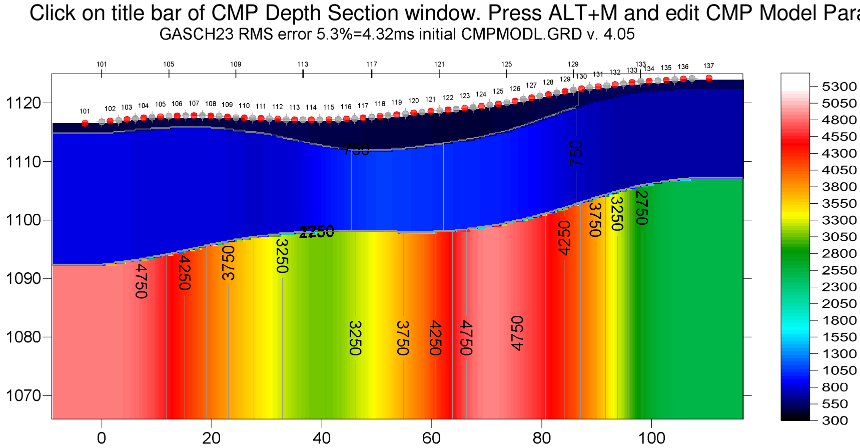

Fig. 17 : select Depth|CMP Intercept-Time Refraction after mapping traces to refractors (Fig. 15). Confirm warning prompt about artefacts with strong refractor curvature. When prompted to continue with WET inversion click No button. Edit CMP Model Parameters (Fig. 16) and click OK button to obtain our CMP Intercept-Time refraction starting model.

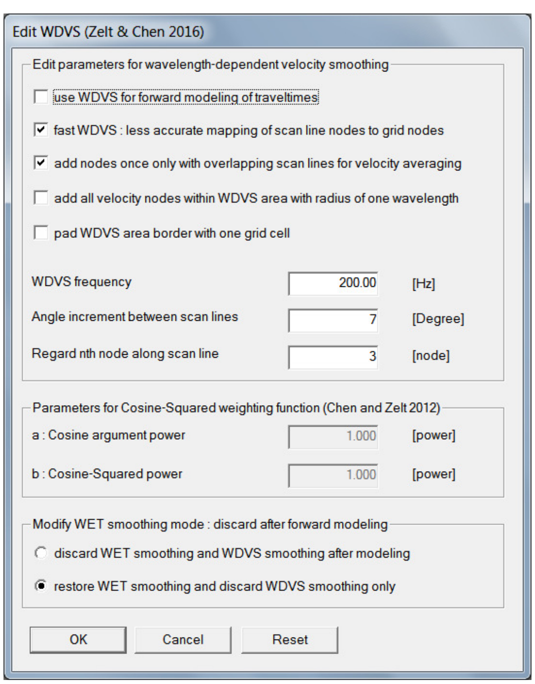

Fig. 18 : select Model|WDVS Smoothing. Edit as shown and click OK button.

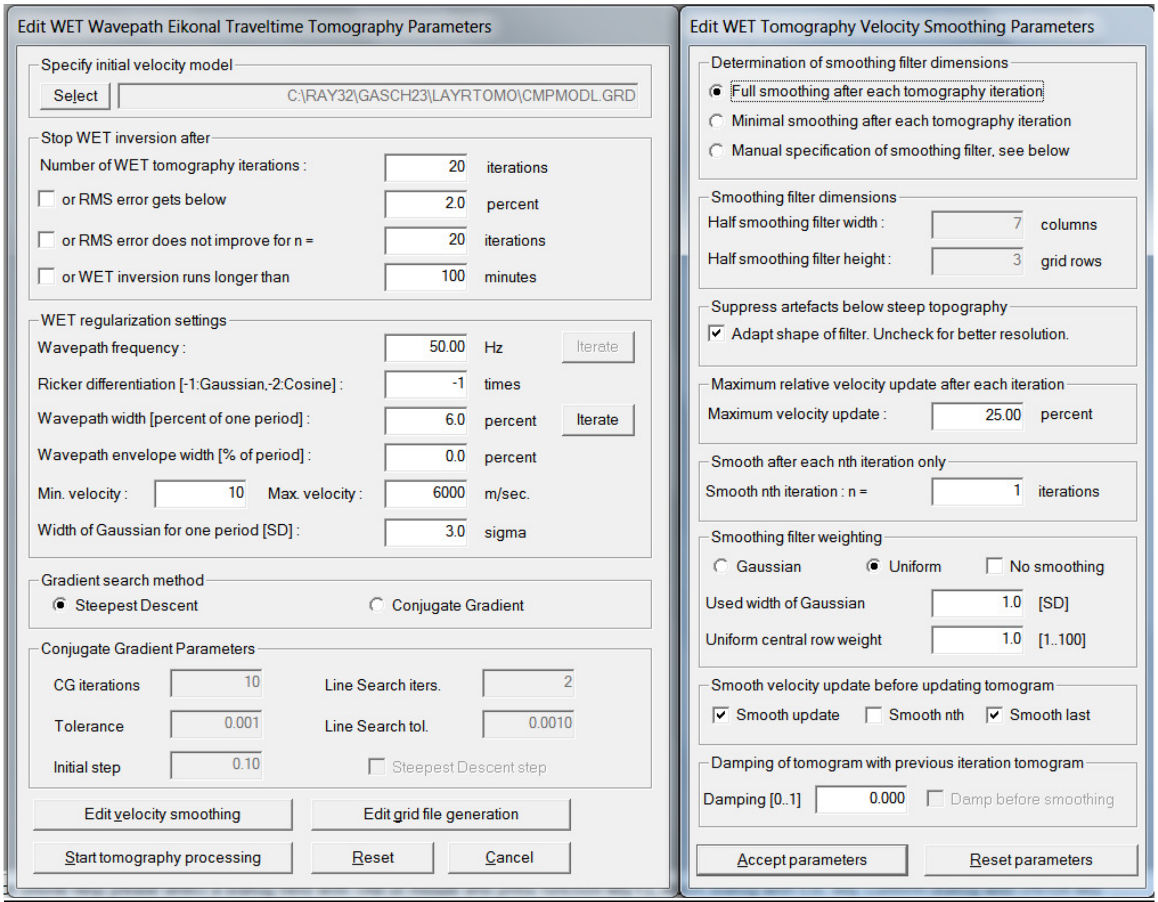

Fig. 19 : select WET Tomo|Interactive WET to display WET main dialog (left). Edit velocity smoothing (right).

<u>How to run multiscale WET inversion using our CMP Intercept-Time Refraction starting model :</u>

- select *Model|WDVS Smoothing*. Edit as in Fig. 18 and click *OK* button.
- check option *Model|Forward modeling Settings|Normalize RMS error with maximum picked time*
- select *WET Tomo|Interactive WET* (Fig. 19 left)
- click button ***Iterate*** and edit WET runs as in Fig. 11. Click *OK* button.
- click button *Edit velocity smoothing* and edit as in Fig. 19 at right
- click buttons *Accept parameters* and *Start tomography processing* (Fig. 19) to obtain Fig. 20 & 21

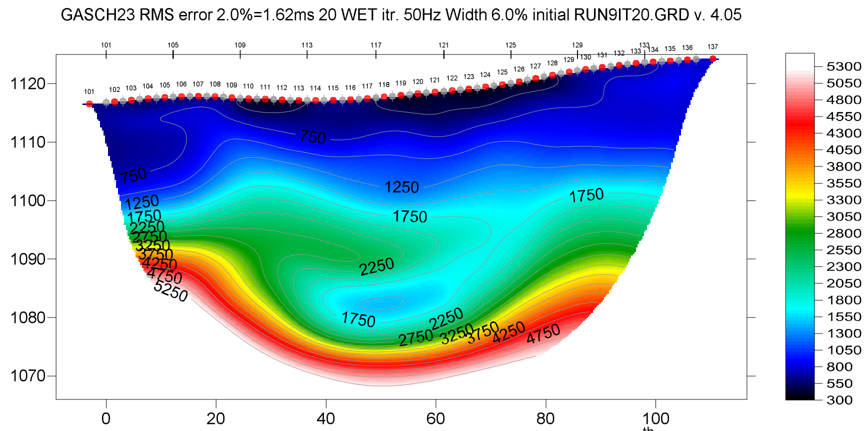

Fig. 20 : Multiscale Steepest-Descent WET inversion. Output of 10th WET run shown. Starting model for 1st run is Fig. 17. Don't discard WET smoothing after forward modeling. Disable WDVS (Fig. 18). Full WET smoothing (Fig. 19). Edit WET runs dialog as in Fig. 11.

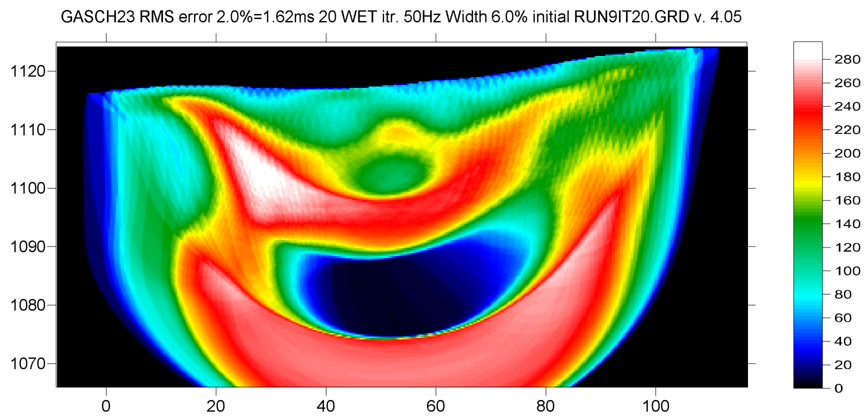

Fig. 21 : WET wavepath coverage plot obtained with Fig. 20. Unit is wavepaths per pixel.

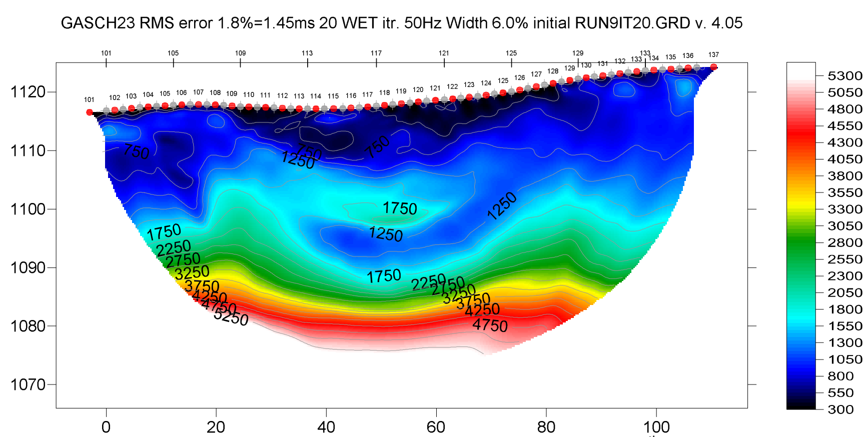

Fig. 22 : Multiscale Steepest-Descent WET inversion. Output of 10th WET run shown. Starting model for 1st run is Fig. 5. Discard WET smoothing after forward modeling. Enable WDVS at 200Hz (Fig. 9). Minimal WET smoothing (Fig. 12).

Here is the link to the .RAR archive with the GASCH23 profile folder for above Fig. 20 :

https://www.dropbox.com/scl/fi/cljr106rewsy0uymo2al7/GASCH23_LAYRTOMO_Dec12_NoWDVS_FullWETSmoothing.rar?rlkey=x7014z07cpbs54r5slh2t56me&dl=0

Select above link and copy with CTRL+C. Then paste the link into your web browser with CTRL+V and press RETURN key to download the .RAR archive.

Note the non-uniqueness when interpreting refraction profiles with strong velocity inversions. Compare Fig. 20 with Fig. 22 and with Fig. 13. The final WET tomogram after 10 WET runs depends on both the starting model and on the WET smoothing. Also the WDVS smoothing and restoring or discarding of WET smoothing after forward modeling play a role in determining the WET output.

We recommend restoring WET smoothing after forward modeling (Fig. 18) when using a layered starting model such as for Fig. 20. Also we recommend using *Full WET smoothing* (Fig. 19) with a layered starting model. These settings help to obtain a realistic WET interpretation with fewer artefacts and without getting stuck in a local minimum of the traveltime misfit function when using a layered starting model.

We thank our client Gasch Geophysical Services, Inc. in Rancho Cordova, California for making available the above landslide profile and for their permission to use this profile for a tutorial.

For an overview of our WDVS (Wavelength-Dependent Velocity Smoothing; Zelt and Chen 2016) see these publications :

Zelt, C. A. and J. Chen 2016. Frequency-dependent traveltime tomography for near-surface seismic refraction data, Geophys. J. Int., 207, 72-88, 2016. See https://dx.doi.org/10.1093/gji/ggw269 and https://www.researchgate.net/publication/305487180_Frequency-dependent_traveltime_tomography_for_near-surface_seismic_refraction_data .

Rohdewald S.R.C. 2021a. Improving the resolution of Fresnel volume tomography with wavelength-dependent velocity smoothing, Symposium on the Application of Geophysics to Engineering and Environmental Problems Proceedings : 305-308. https://doi.org/10.4133/sageep.33-169 . Slides at https://rayfract.com/pub/SAGEEP%202021%20slides.pdf

Rohdewald S.R.C. 2021b. Improved interpretation of SAGEEP 2011 blind refraction data using Frequency-Dependent Traveltime Tomography, EGU General Assembly 2021, online, 19–30 Apr 2021, EGU21-4214, https://doi.org/10.5194/egusphere-egu21-4214

For an objective comparison of tomographic refraction analysis methods see these publications :

Zelt, C.A., Haines, S., Powers, M.H. et al. 2013. Blind Test of Methods for Obtaining 2-D Near-Surface Seismic Velocity Models from First-Arrival Traveltimes, JEEG, Volume 18(3), 183-194. https://scholarship.rice.edu/handle/1911/72113?show=full .
https://www.researchgate.net/publication/267026965 .

Hiltunen, D. R., Hudyma, N., Quigley, T. P., & Samakur, C. 2007. Ground Proving Three Seismic Refraction Tomography Programs. Transportation Research Record, 2016(1), 110–120. https://doi.org/10.3141/2016-12 . https://www.researchgate.net/publication/242072938 .

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. https://dx.doi.org/10.2113/JEEG10.1.21 . https://rayfract.com/srt_evaluation.pdf .
https://www.researchgate.net/publication/242159023 .

More references :

Whiteley J. et al. 2020. Landslide monitoring using seismic refraction tomography - The importance of incorporating topographic variations. Engineering Geology 2020.
https://www.researchgate.net/publication/339280163