JOANNEUM OT0608 refraction line : Smooth inversion vs. 1.5D XTV inversion :

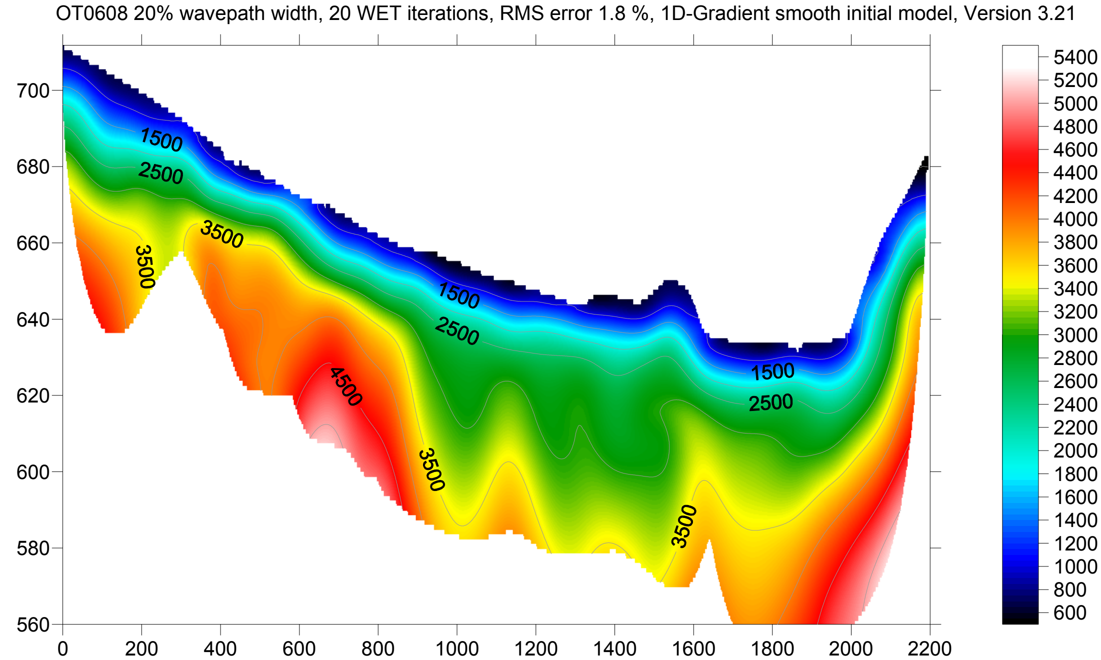

Fig. 1 : Smooth inversion 3.20, wavepath width 20%, 20 WET iterations. Fig. 3 shows 1D initial model used for Fig. 1.

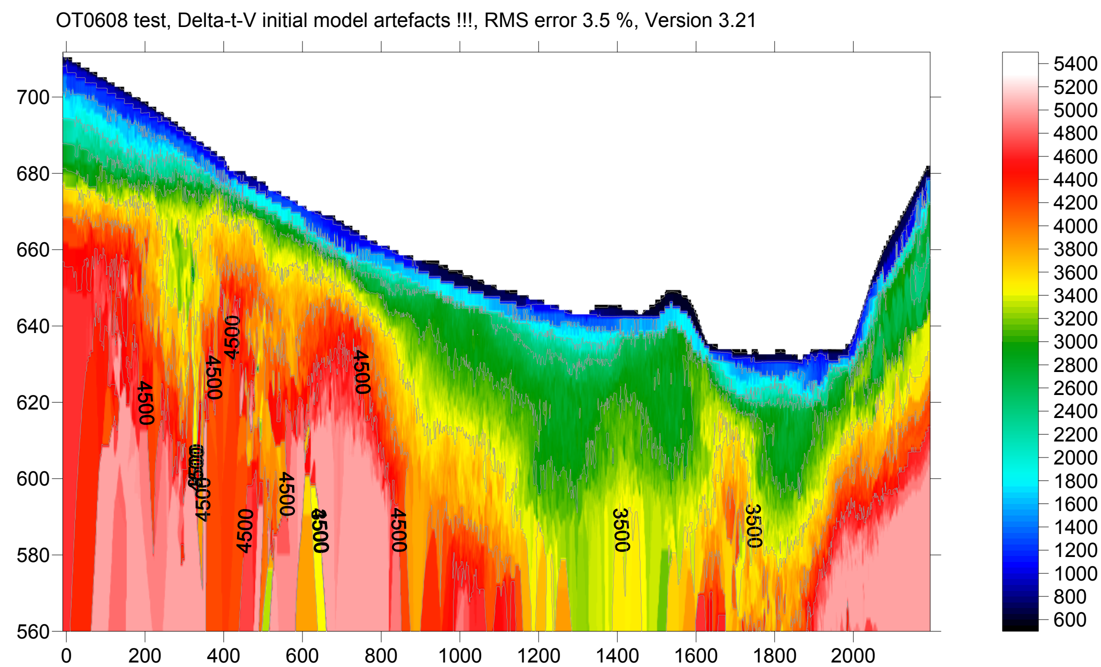

Fig. 2 : XTV inversion OT0608, with Rayfract® version 3.20 . CMP stack width 150, Inverse CMP offset power 0.20, Surface-consistent static corrections. Enabled Dix inversion, Intercept-time inversion in addition to DeltatV inversion for gradient layers. See http://rayfract.com/xtv_inversion.pdf . For all parameter settings see XTV .par file in ot0608.zip .

We thank Dr. Grassl, JOANNEUM RESEARCH Forschungsges.mbH, Austria, for making available this dense and consistently picked data set, with 275 shots into 200 or more channels. For .ASC, .COR and .SHO files see ot0608.zip . Process as gs0801.pdf . Set *Station spacing* to 3m in *Header|Profile*, then import .ASC , and update with .COR and .SHO.

See Fig. 3 for 1D initial model, obtained during Smooth inversion and resulting in Fig. 1. Fig. 4 shows WET wavepath coverage, also obtained with Smooth inversion and Fig. 1.

OT0608 smooth DeltatV, 1D-Gradient smooth initial model, RMS error 4.4 %, Version 3.21

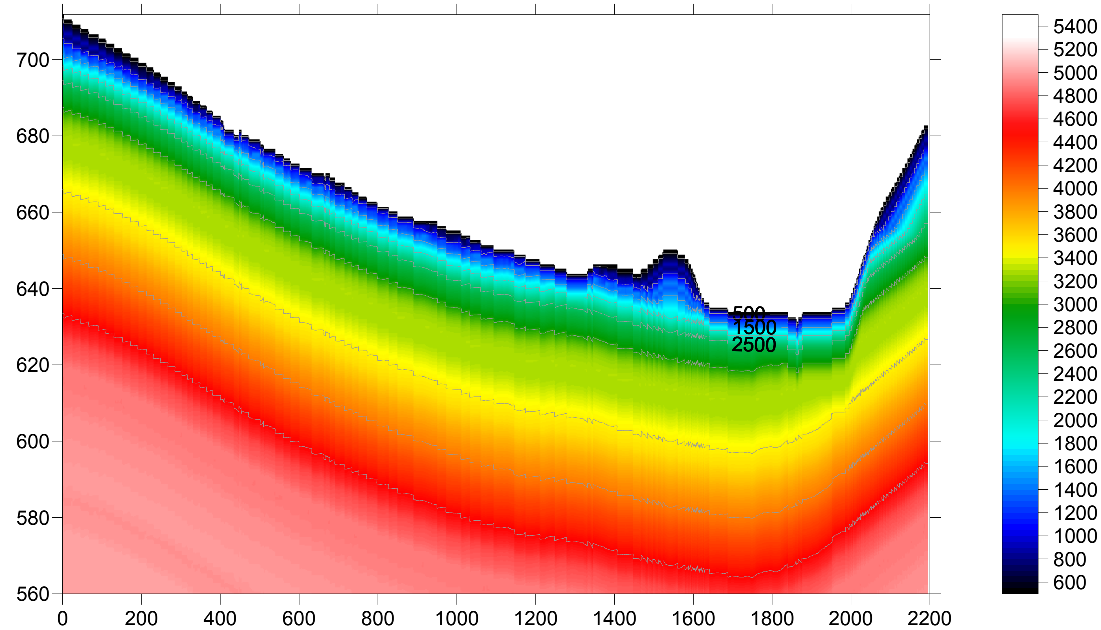

Fig. 3 : 1D initial model used for Fig.1, with Smooth inversion. Lateral DeltatV averaging, smooth DeltatV settings.

OT0608 wavepath width 20%, 20 WET iterations, RMS error 1.8 %, 1D-Gradient smooth initial model, Version 3.21

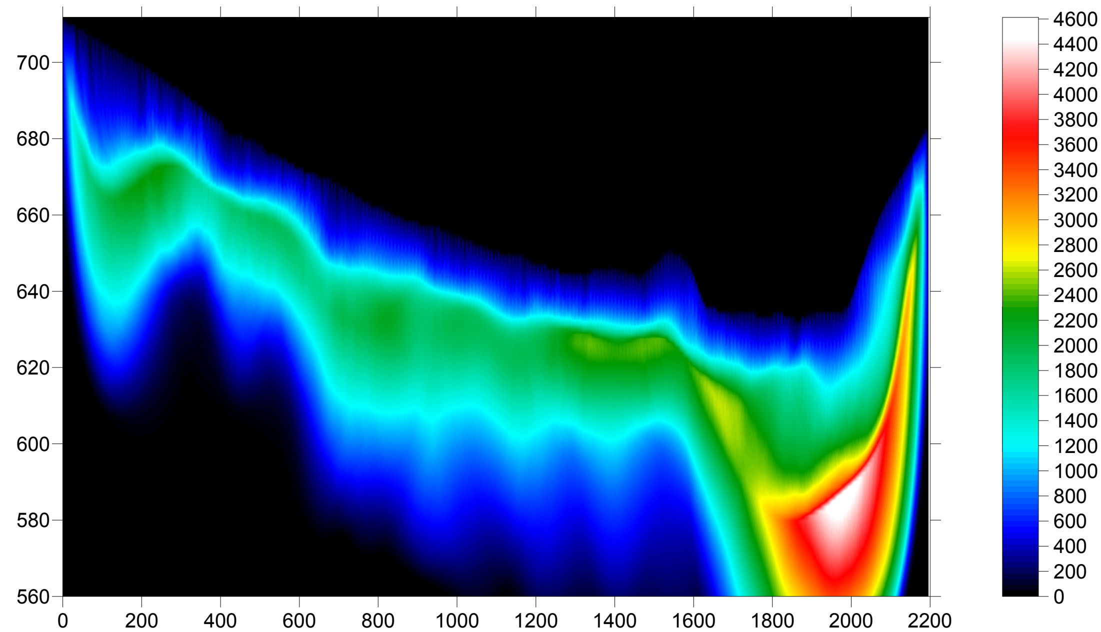

Fig. 4 : WET wavepath coverage, obtained with Smooth inversion (Fig. 1). Coverage of subsurface with first break energy.

Note the low wavepath coverage at offset 1000m and elevation 580m (Fig. 4). This is the only location where Fig. 1 and Fig. 2 differ. Low wavepath coverage means locally higher uncertainty, in the obtained WET velocity tomogram (Fig. 1). Wavepaths are almost vertical, similar to reflected rays (Fig. 4).

Processing time for default Smooth inversion (Fig. 1) was about 1 hour on an Intel Core i3. Fig. 2 was obtained in minutes. But DeltatV parameters need to be tuned, to approach Smooth inversion output. So DeltatV imaging is an iterative and more interactive process, when compared to Smooth inversion.

The good match between Fig. 1 and Fig. 2 confirms these two interpretations, obtained with quite different methods.

On the next page, we detail all processing steps required to obtain above output :

First, import the data and review shot-sorted traveltime curves :

- Start up Rayfract® via desktop icon. Select *File|New Profile…*
- Set *File name* to OT0608 and click *Save button*
- Specify *Station spacing* of 3 m in *Header|Profile*
- Unzip archive ot0608.zip in directory \RAY32\LINE8\INPUT
- Uncheck *File|Import Data Settings|Round shot station to nearest whole station number*
- Select *File|Import Data…* and specify *Import data type* ASCII column format
- Click *button Select* and select file OT0608_ASCII.asc in directory \RAY32\OT0608\INPUT
- Check option *Batch import* . This option is supported for ASCII.ASC files only.
- Leave *Default spread type* at *10: 360 channels*
- Click *button Import shots*, and confirm prompt
- *File|Update header data|Update Station Coordinates*... with \RAY32\OT0608\INPUT\OT0608_COR.COR
- *File|Update header data|Update Shotpoint coordinates…* with \RAY32\OT0608\INPUT\OT0608_SHO.SHO
- Select *Refractor|Shot breaks* to display traveltime curves

Now run Smooth inversion, with default parameters :

- Select *Smooth invert|WET with 1D-gradient initial model*, and obtain 1D initial model
- Confirm prompts, for default WET output after 20 iterations (Fig. 5 and 6)
- Note artefact in Fig. 5, at offset 500m and elevation 600m. This is due to low wavepath coverage (Fig. 6).

Next, configure smoother DeltatV settings (Fig. 7) :

- Check *Smooth invert|Smooth inversion Settings|Wide CMP stack for 1D-gradient initial model*
- Check *Smooth invert|Smooth inversion Settings|Allow unsafe pseudo-2D Delta-t-V inversion*
- Check *DeltatV|DeltatV Settings|Enforce monotonically increasing layer bottom velocity*
- Check *DeltatV|DeltatV Settings|Suppress velocity artefacts*
- Check *DeltatV|DeltatV Settings|Process every CMP offset*
- Check *DeltatV|DeltatV Settings|Smooth CMP traveltime curves*

Select *DeltatV|Interactive DeltatV…* and confirm prompt. Configure smoother *DeltatV Static corrections* (Fig. 8) :

- Click button *Static corrections*
- *Check Surface consistent corrections*
- Increase *Weathering crossover* to 20 stations
- Increase *Topography filter* to 200 stations
- Decrease *Inverse CMP offset power* to 0.2, click *Accept button*
- Click Esc key, to exit from *interactive DeltatV inversion* without running it

Redo Smooth inversion with **smoother DeltatV initial model**, and **increased WET wavepath width 20%** :

- Select *Smooth invert|WET with 1D-gradient initial model*, obtain 1D initial model (Fig. 3)
- When prompted to continue with *WET tomography*, click *No button*
- Select *WET Tomo|Interactive WET tomography…*
- Set *Wavepath width* to 20%, click *button Start tomography processing*
- Confirm prompts to obtain smooth WET output with 20 iterations (Fig. 1 and 4)
- Note **removed artefact** at offset 500m and elevation 600m. Also note **deeper imaging**, compared to Fig. 5.
- Uncheck *DeltatV|DeltatV Settings|Enforce monotonically increasing layer bottom velocity*

Select *DeltatV|XTV parameters for constant-velocity layers*, and configure *XTV options* as follows (Fig. 9) :

- Check *Enable Modified Dix layer inversion*
- Check *Enable Intercept time layer inversion*
- Check *Allow adjacent Intercept layer inversion*
- Check *Prefer measured layer top velocity over inverted*

Select *DeltatV|Interactive DeltatV…* and confirm prompt. Reconfigure *DeltatV Static corrections* (Fig. 8) :

- Click button *Static corrections*
- Leave *Surface consistent corrections* checked
- Reset *Weathering crossover* to 10 stations
- Reset *Topography filter* to 100 stations
- Leave *Inverse CMP offset power* at 0.2, click *Accept button*

Now configure and run *DeltatV inversion*, with XTV inversion enabled :

- Set *CMP curve stack width* to 150
- Set *Export Options|Gridding method* to *Nearest Neighbor*, click *Accept button*
- Click *button DeltatV inversion*, and confirm prompts, to obtain Fig. 2

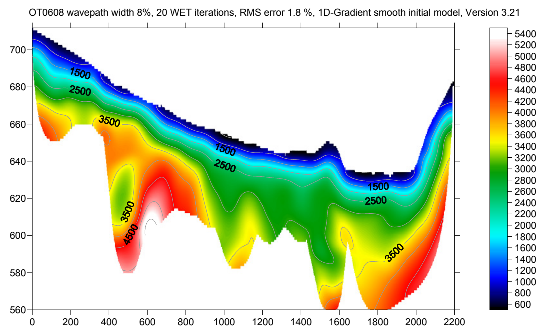

Fig. 5 : Default *Smooth inversion*, wavepath width 8%

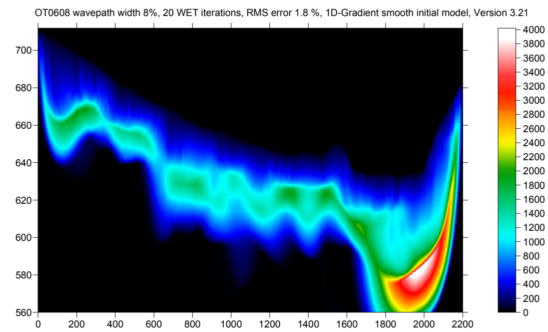

Fig. 6 : wavepath coverage obtained with Fig. 5

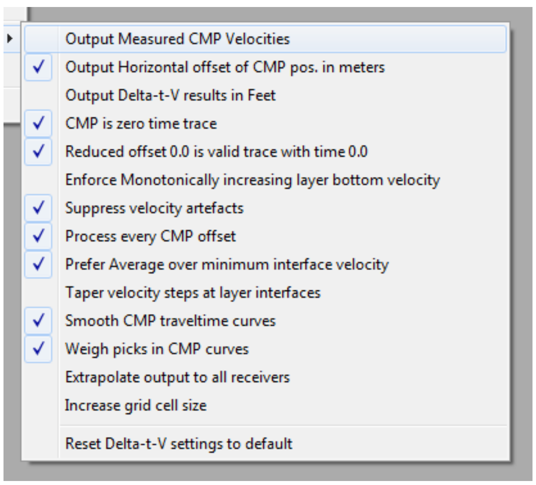

Fig. 7 : *DeltatV|DeltatV settings*

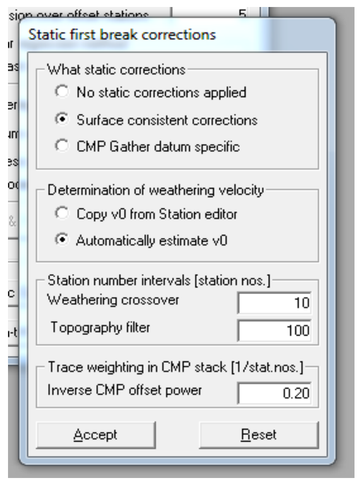

Fig. 8 : *DeltatV|Interactive DeltatV…|Static Corrections*

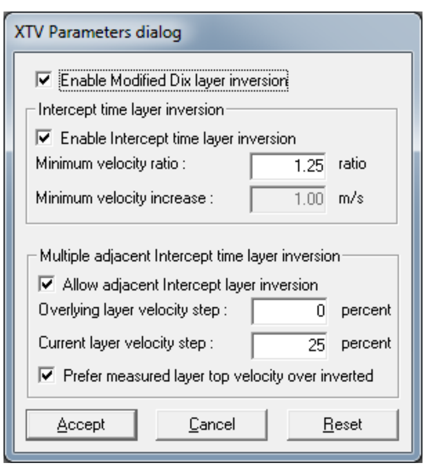

Fig. 9 : *DeltatV|XTV parameters*

For Wavefront refraction method interpretation :

- Select *Refractor|Midpoint breaks*
- Press ALT+M, to edit *Mapping dialog* (Fig 10)
- Click *Map traces button*, confirm prompt
- Press ALT+G, to edit *Crossover dialog* (Fig. 11)
- Click *Accept*, to smooth refractors (Fig. 10)
- Check *Depth|Depth conversion Settings|Link traveltime curves for Wavefront*
- Select *Depth|Wavefront…* (Fig. 13)
- ALT+P, set *min./max. elevation* to 580/700m
- ALT+M, edit *Wavefront parameters* (Fig. 12)
- Select *Velocity|Wavefront…* (Fig. 13)
- ALT+P, set *maximum velocity* to 5000 m/s

Note the good match between Wavefront refraction (Fig. 13), WET inversion (Fig. 1) and XTV (Fig. 2).

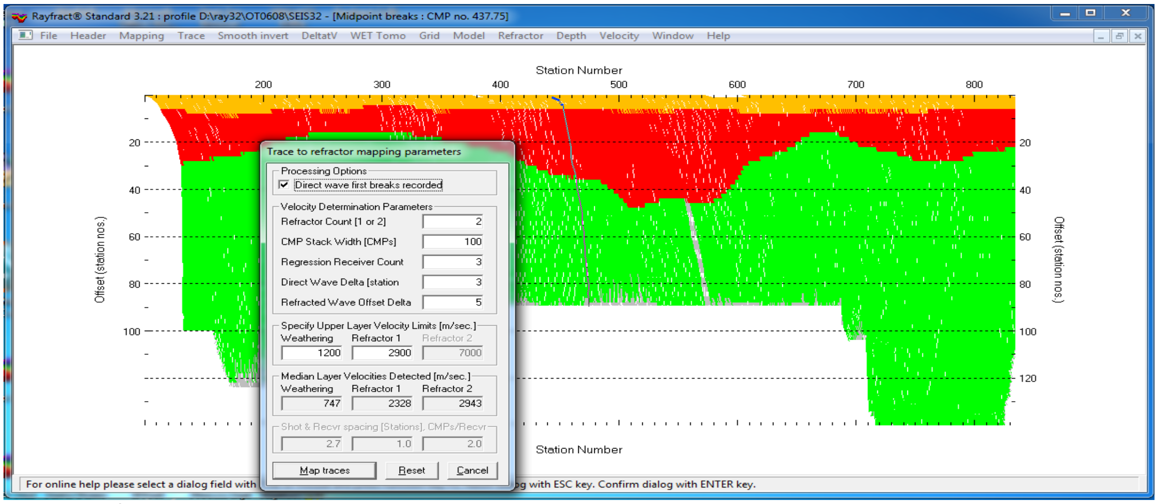

Fig. 10 : *Refractor|Midpoint breaks*, press ALT+M to edit *mapping dialog*

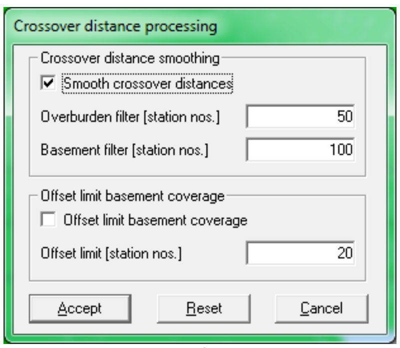

Fig. 11 : press ALT+G to edit *crossover dialog*

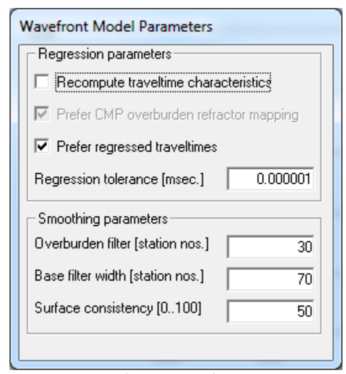

Fig. 12 : ALT+M for *Wavefront params*.

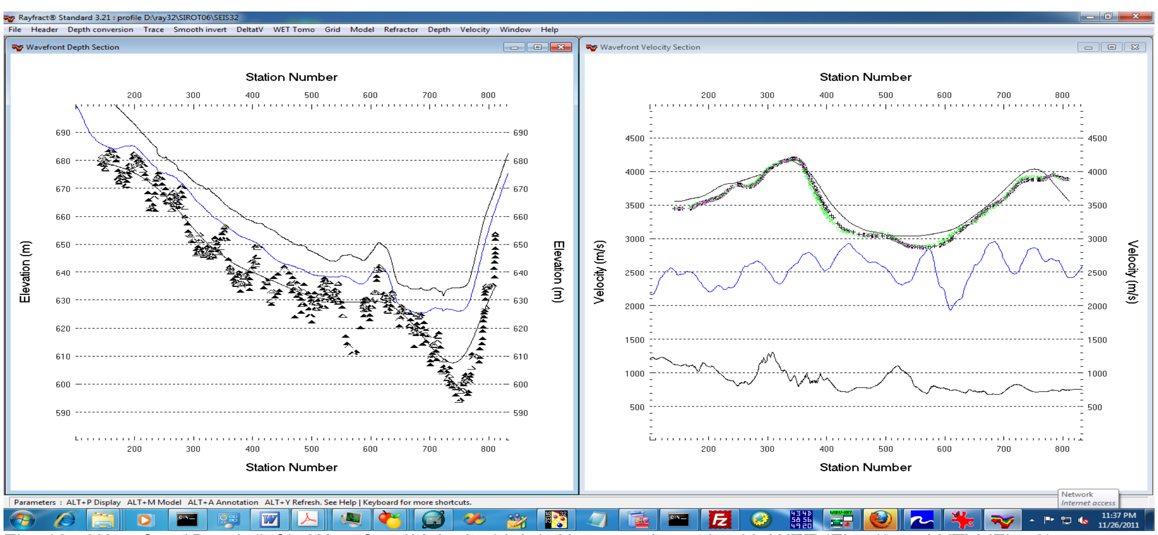

Fig. 13 : *Wavefront|Depth* (left), *Wavefront|Velocity* (right). Note good match with WET (Fig. 1) and XTV (Fig. 2).

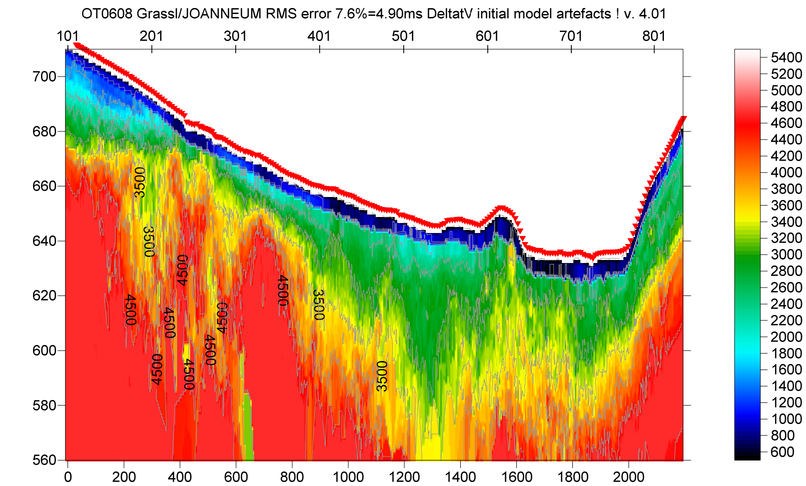

Fig. 14 : pseudo-2D DeltatV inversion with version 4.01 done in June 2020. Layered XTV inversion enabled. DeltatV stack width 147. Surface-consistent static corrections. Topography smoothing : 15 stations. Smooth CMP curves. Suppress DeltatV artefacts. Process every CMP offset. Limit DeltatV velocity exported to maximum 1D-gradient velocity.

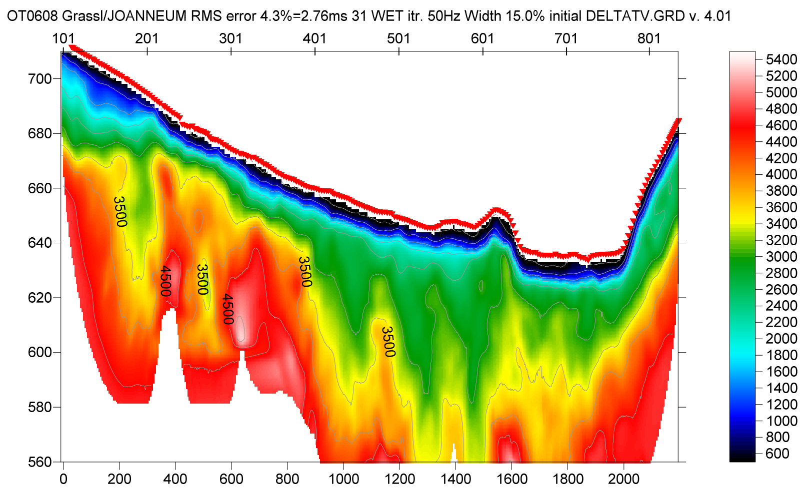

Fig. 15 : 2D Conjugate-Gradient single-run WET inversion using Fig. 14 as starting model. Minimal WET smoothing. Smooth every 5th iteration. Gaussian smoothing. Wavepath width 15%. Cosine-Squared WET update weighting. 10 Conjugate-Gradient iterations. 2 Line Search iterations. See Fig. 17. Compare with Fig. 1 Smooth inversion.

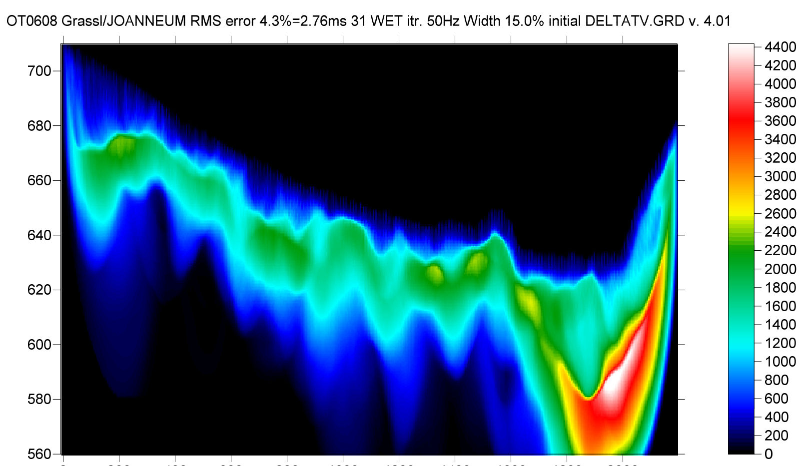

Fig. 16 : WET wavepath coverage plot obtained with Fig. 15. Unit is wavepaths per pixel.

Here are the SEIS32.* profile database files for Fig. 15. Here are the Surfer .GRD files & .PAR files & Surfer 11 .SRF for Fig. 15.

Compare Fig. 15 DeltatV + WET with Fig. 1 : Smooth inversion using 1D-gradient starting model done in 2011. In Fig. 15 the transition from bottom of overburden to top-of-basement is much sharper. In the basement the lateral velocity variation is also much sharper than in Fig. 1 and in Fig. 5.

Our version 3.36 and 4.01 WET inversion normalizes the ***RMS error*** by average picked traveltime instead of maximum picked traveltime, as used for earlier versions. This is the reason why the RMS error shown on top of Fig. 15 is 4.3% vs. 1.8% shown on top of Fig. 1.

Check option ***Model|Normalize RMS error with maximum picked time*** to restore the method used for earlier versions. Now use command *Model|Forward model traveltimes* with …\TOMO\VELOIT32.GRD to redetermine the relative RMS error as for earlier versions.

The ***absolute RMS error*** for Fig. 15 is 2.76ms vs. 3.79ms for Fig. 1. So the ***Conjugate-Gradient WET and optimized WET smoothing plus Cosine-Squared update weighting*** used for Fig. 15 as shown in Fig. 17 really help to decrease the RMS error / to improve the traveltime misfit between picked and modeled times.

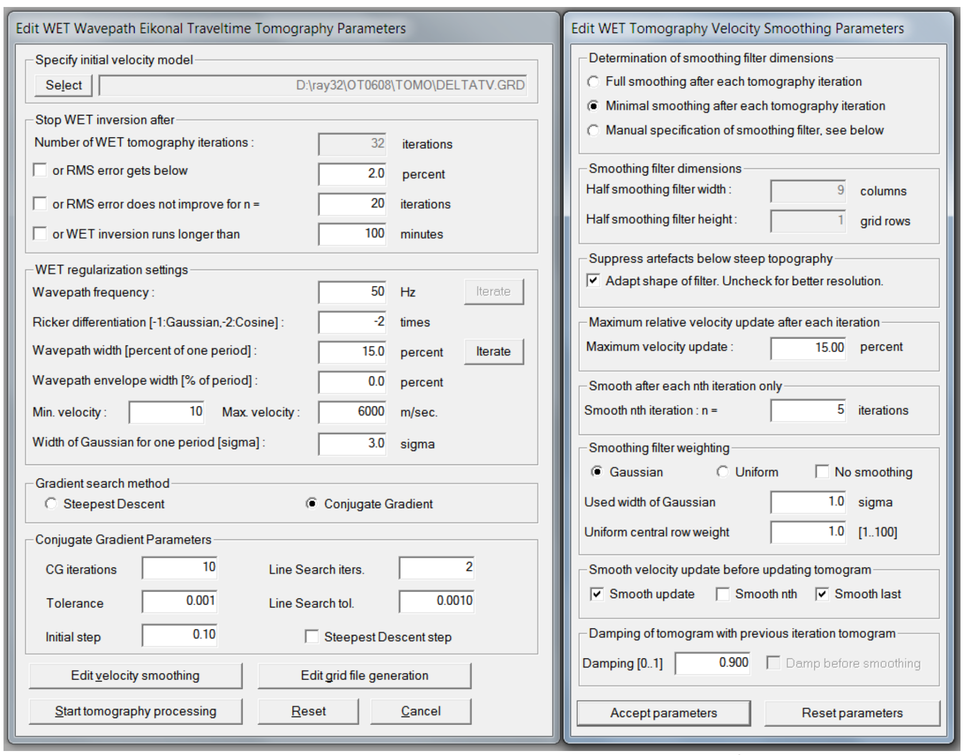

Fig. 17 : interactive WET and WET smoothing settings used to obtain Fig. 15 & 16

With *grid cell size* forced to 1.2m in *Header|Profile* the 32 WET iterations required to obtain Fig. 15 took ***28 minutes on 2017 iMac with Intel Core i5*** @ 2.3 GHz running Windows 7 64-bit Pro in Parallels Desktop 14 using MacOS High Sierra, using 4 logical CPU cores in parallel. Our Pro version allows using up to 16 CPU cores in parallel for faster WET inversion. We also fully support running our latest software version 4.01 under latest Windows 10 64-bit Pro.

Below we show reprocessing of this line with our version 4.01 software with WDVS (Zelt and Chen 2016) enabled, as done in Feb 2021. 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

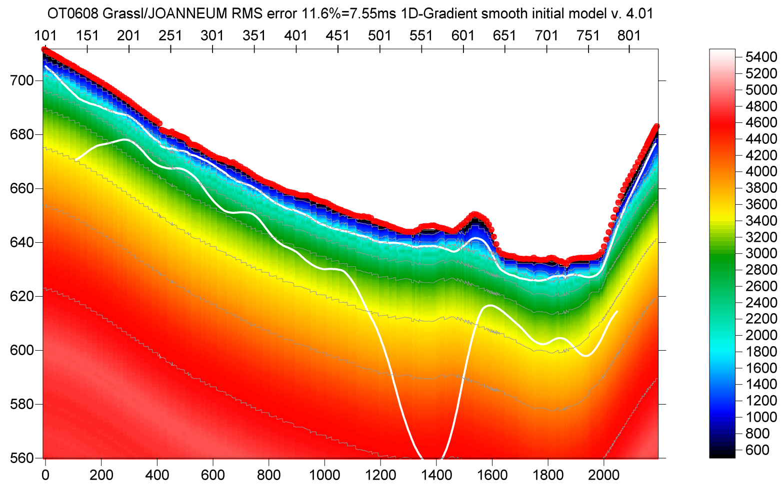

Fig. 18 : 1D-gradient starting model obtained by laterally averaging DeltatV method output (Sheehan 2005) with Smooth invert|WET with 1D-gradient initial model. Default Smooth inversion and DeltatV settings. Cell size forced to 1.2m.

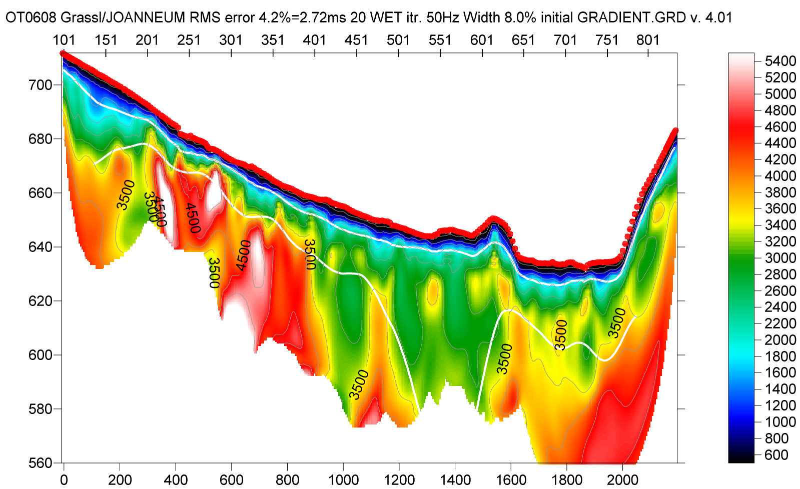

Fig. 19 : 20 Steepest-Descent WET iterations with minimal WET smoothing (Fig. 22) and WDVS engaged at 90Hz, discard WET smoothing after forward modeling (Fig. 21). 1D-gradient starting model shown in Fig. 18. Wavepath width 8%. Gaussian WET update weighting. Smooth every iteration. Uniform smoothing filter weighting. Blank no coverage after last iteration. RMS error 4.2%=2.72ms. White lines are refractors obtained with Wavefront method (Fig. 25). Compare with Fig. 15 obtained without WDVS smoothing and with XTV method starting model Fig. 14.

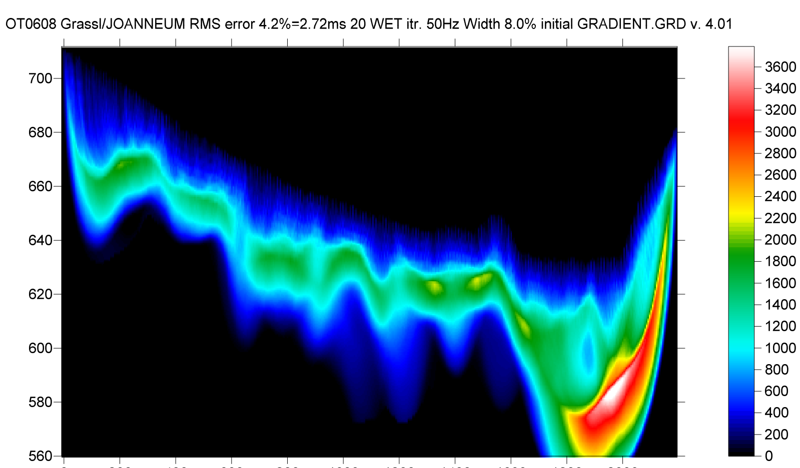

Fig. 20 : WET wavepath coverage plot obtained with Fig. 19. Unit is wavepaths per pixel.

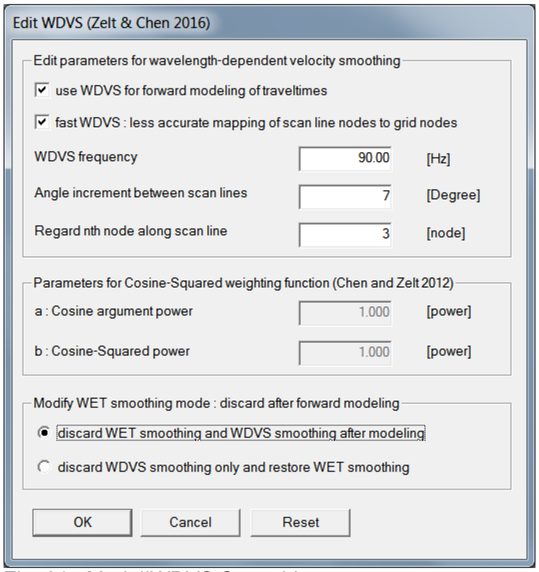

Fig. 21 : Model|WDVS Smoothing.

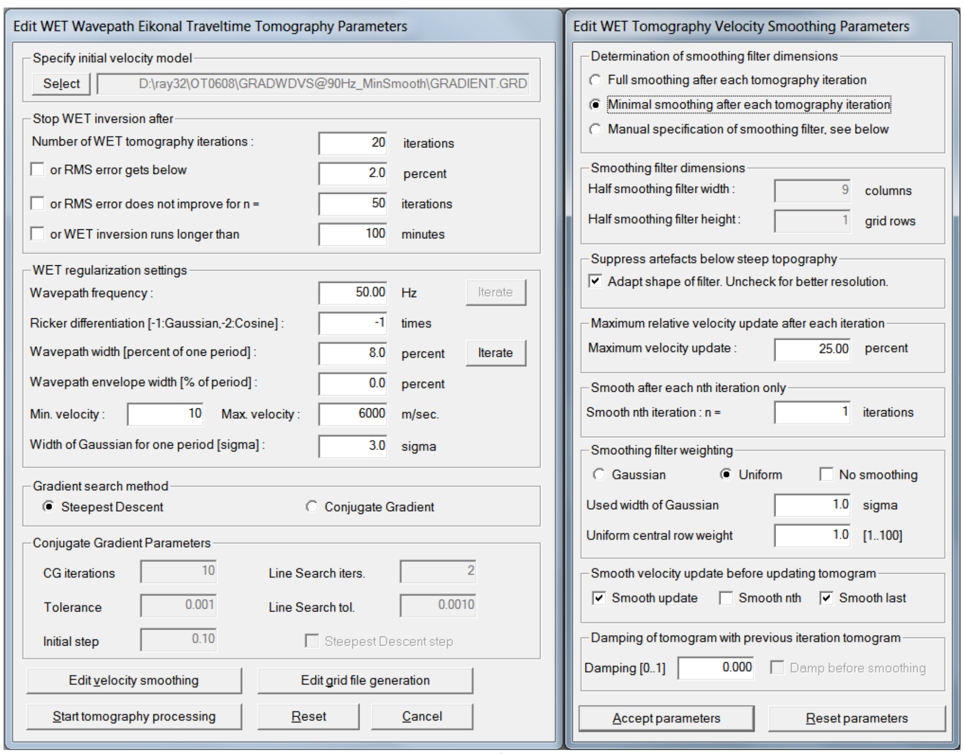

Fig. 22 : WET Tomo|Interactive WET main dialog (left). Edit velocity smoothing (right).

Here are the SEIS32.* profile database files for Fig. 19. Here are the Surfer .GRD files & .PAR files & Surfer 11 .SRF for Fig. 19.

Note the more shallow top-of-basement in Fig. 19 and stronger velocity contrast at top-of-basement compared to Fig. 15 obtained without WDVS smoothing before forward modeling.

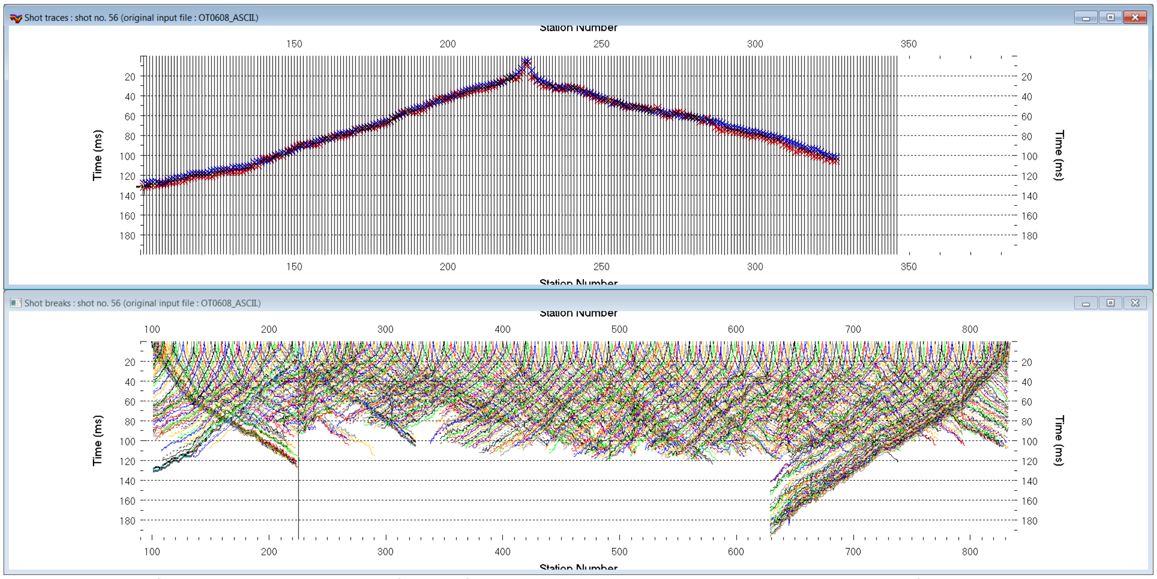

Fig. 23 : Trace|Shot gather (top) and Refractor|Shot breaks (bottom). Red crosses are picked first breaks, blue crosses are modeled traveltimes (top). Solid curves are picked traveltime curves, dotted curves are modeled traveltime curves (bottom).

In Fig. 23 we show a sample shot gather (top) and all shot-sorted traveltime curves (bottom). Note the good fit between modeled and picked traveltimes (top). Also note highly parallel traveltime curves between adjacent shot points (bottom).

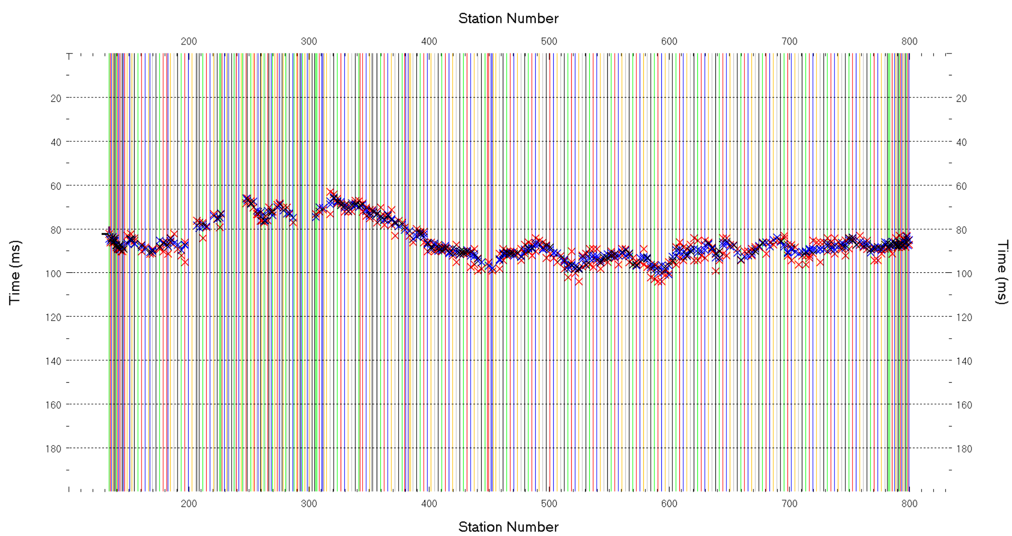

Fig. 24 : Trace|Offset gather (common offset 207m). Red crosses are picked first breaks, blue crosses are modeled traveltimes.

We have shown that for long lines with homogeneous overburden and without strong lateral velocity variation in overburden our 1.5D XTV inversion method can work well to obtain a realistic starting model (Fig. 14) which is close to the final WET tomogram (Fig. 15). Also the final WET tomogram is quite independent of the starting model, compare Fig. 19 with Fig. 15.

Layered refraction interpretation with Plus-Minus and Wavefront methods is more difficult for this long line due to discontinuous basement refractor (Fig. 13) but works as well (Fig. 25).

In general we recommend using our 1D-gradient starting model as shown in Fig. 18 and Fig. 19 to avoid DeltatV and XTV artefacts in the initial model due to strong lateral velocity variation in overburden (Sheehan, 2005) or due to strong topography. See our EPIKINV tutorial.

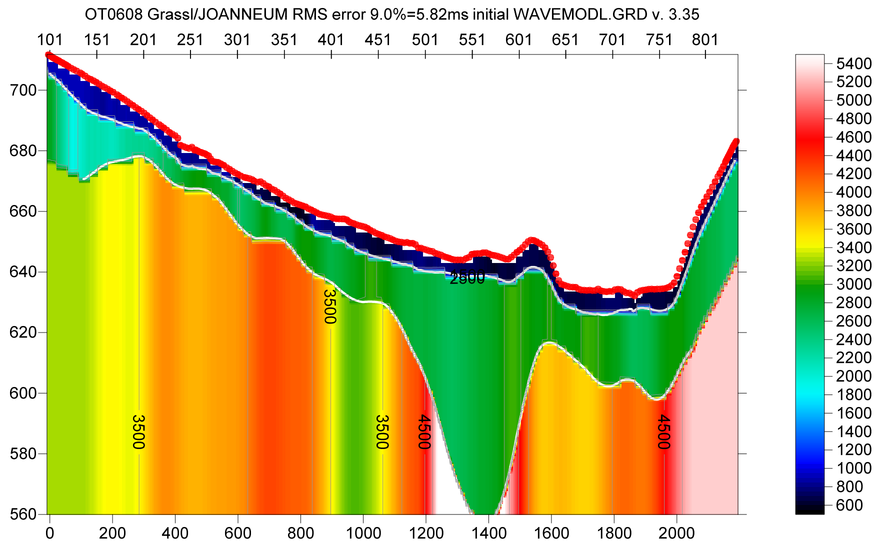

Fig. 25 : layered refraction interpretation with Wavefront method. Traces are mapped to refractors and time is converted to depth as shown in Fig. 10 to Fig. 13.

With *grid cell size* forced to 1.2m in *Header|Profile* the 20 Steepest-Descent WET iterations required to obtain Fig. 19 took ***16 minutes on 2017 iMac with Intel Core i5*** @ 2.3 GHz running Windows 7 64-bit Pro in Parallels Desktop 16 using MacOS High Sierra, using 4 logical CPU cores in parallel.

The same WET inversion took ***12 minutes on 2020 macMini with 3.0 GHz Intel Core i5 processor using all 6 cores*** running native Windows 10 64-bit Pro installed via Boot Camp Assistant using our Pro version.

We again thank Dr. Grassl formerly at JOANNEUM RESEARCH Forschungsges.mbH, Austria, for making available this dense and consistently picked data set, with 275 shots into 200 or more channels.