Dr. Palmer Fig. 4 synthetic data : Smooth inversion & 100 WET with Wavefront starting model :

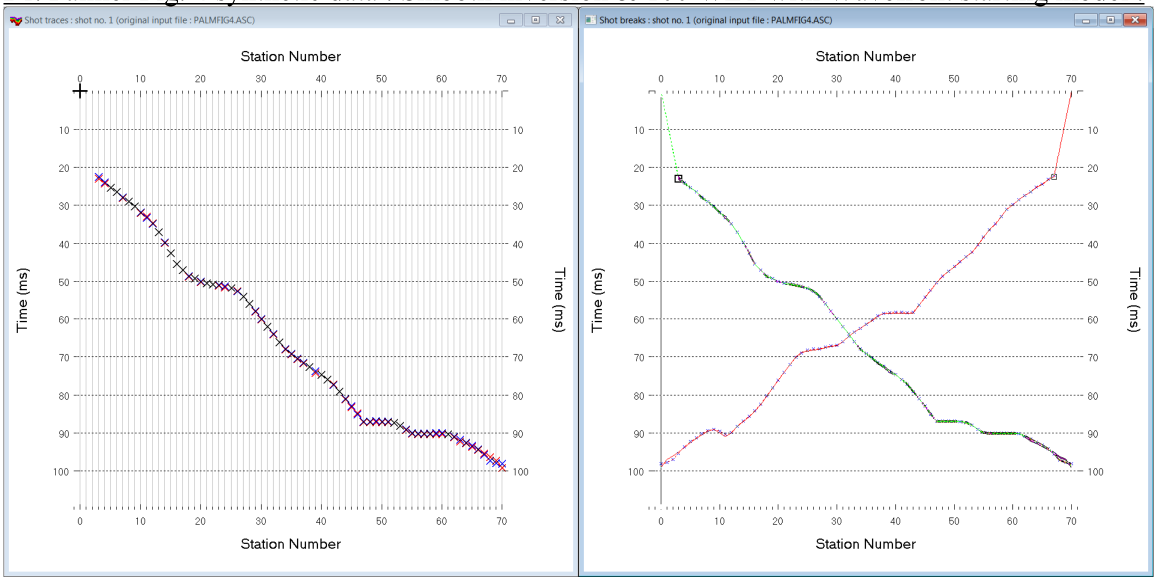

Fig. 1 : left : *Trace|Shot gather*, right : *Refractor|Shot breaks*. Shows fit between picked times (solid colored curves, red crosses) and modeled times (dashed colored curves, blue crosses) obtained with 100 WET iterations (Fig. 6)

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

- ***File|New Profile****…*, set *File name* to **`PALMFIG4`** and click *Save button*
- in ***Header|Profile****…* set *Line type* to **`Refraction spread/line`** . Set *Station spacing* to 5.0 m.
- check *box Force grid cell size* and set *Cell size[m]* to 0.5m. See Fig. 2.
- download & unzip [**`PALMFIG4_ASCII.zip`**]() with **`PALMFIG4.ASC`** in directory **`C:\RAY32\PALMFIG4\INPUT`**
- select ***File|Import Data****…* and set *Import data type* to **`ASCII column format`**. See Fig. 3.
- leave *Default spread type* at **`10: 360 channels`**
- click *Select button*, navigate into **`C:\RAY32\PALMFIG4\INPUT`** and select file **`PALMFIG4.ASC`**
- set *Default sample count* to 1100 to setup the y scale for *Trace|Shot gather* & *Refractor|Shot breaks*
- click ***Import shots button***. The *Import shot dialog* is shown for each shot in the **`.ASC`** file.
- for each shot leave *Layout start* and *Shot pos.* at shown values and click *Read button*
- select *Trace|Shot gather* and *Window|Tile* to obtain Fig. 1

To configure WDVS, map traces to refractors, display the Wavefront model and run Smooth inversion :

- select *Model|WDVS Smoothing*. Check box *use WDVS for forward modeling of traveltimes*.
- edit *WDVS frequency* to 300Hz and click *button OK.* See Fig. 10.
- uncheck *WET Tomo|WET tomography Settings|Blank|Blank below envelope after last iteration*
- select *Refractor|Shot breaks*. Click on *Maximize icon* in title bar of Shot breaks window.
- uncheck *Mapping|Automated updating of station V0*
- select *Header|Station* and click button *Reset v0*. Confirm prompt.
- edit field *v0* to 1,500 m/s and click button *Interpolate v0 only.* See Fig. 9.
- select shot no. 1 with F7/F8. Position vertical pick bar at station no. 3 with arrow-right key.
- press CTRL+F1 to pick branch point separating direct wave from first refractor for shot no. 1.
- select shot no. 2 with F7/F8. Position vertical pick bar at station no. 67 with arrow-left key.
- press CTRL+F1 to pick branch point separating direct wave from first refractor for shot no. 2.
- press ALT+L to map traces to refractors based on above branch points
- select *Depth|Wavefront* and confirm prompts to obtain Wavefront method depth section (Fig. 4)
- click *Yes* in *Continue with WET tomography* prompt. Confirm warning about too wide shot spacing.
- view resulting Smooth WET tomogram in Fig. 5 and WET coverage plot in Fig. 7.

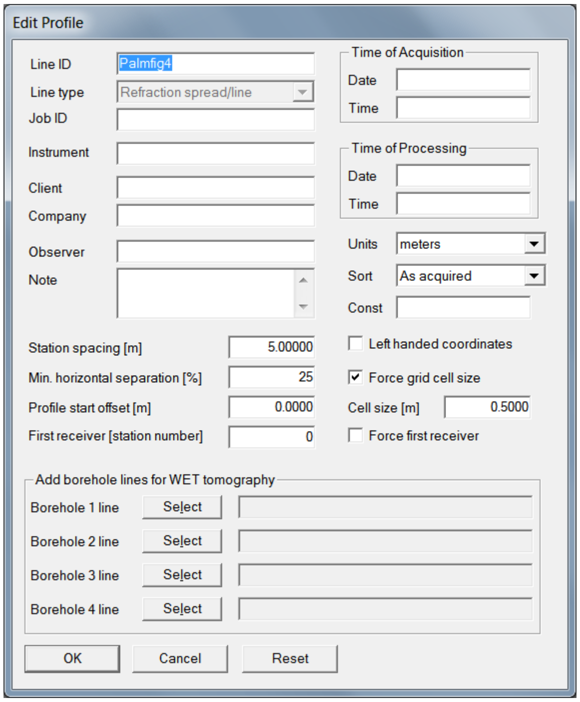

Fig. 2 : *Header|Profile*

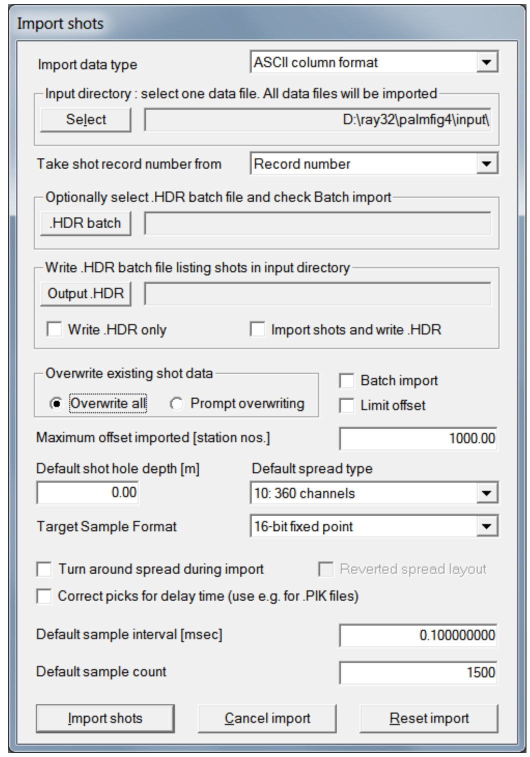

Fig. 3 : *File|Import Data*

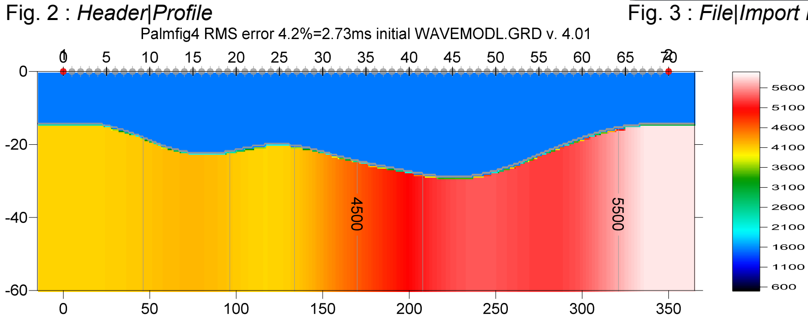

Fig. 4 : select *Depth|Wavefront* and confirm prompts to obtain Wavefront method depth section.

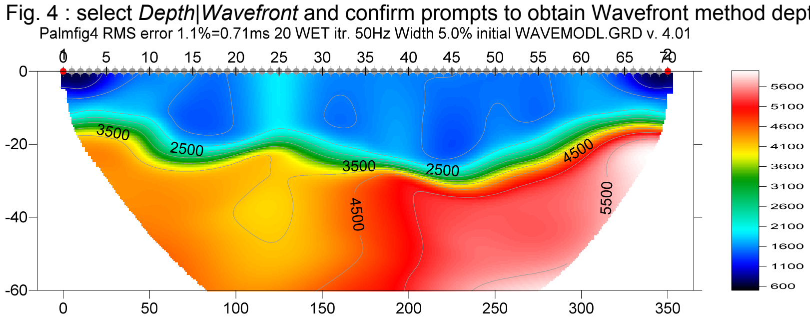

Fig. 5 : Smooth inversion with Wavefront method starting model shown in Fig. 4. WDVS enabled @300Hz (Fig. 10).

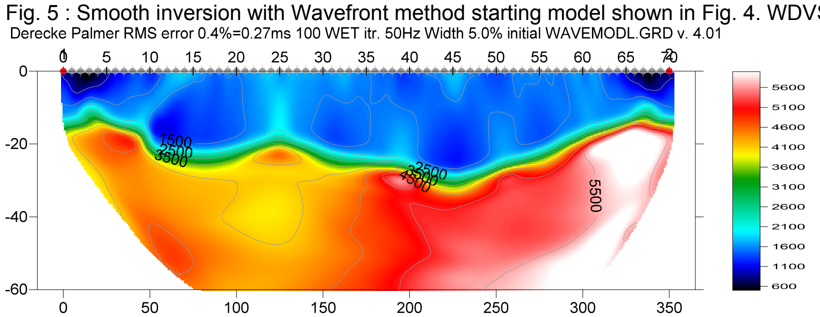

Fig. 6 : 100 WET iterations, starting model Fig. 4, WDVS@300Hz. Minimal WET smoothing, smooth nth=5 (Fig. 11).

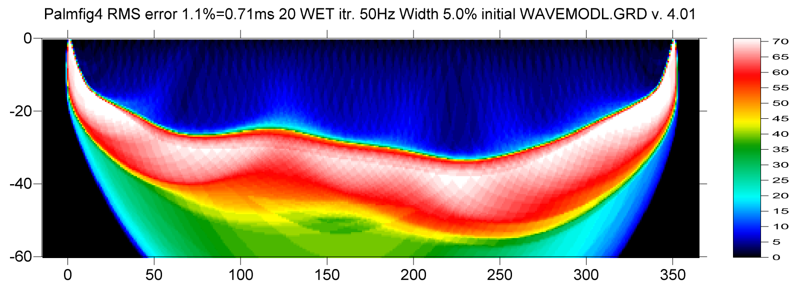

Fig. 7 : WET wavepath coverage plot obtained with Fig. 5. Unit is wavepaths per pixel.

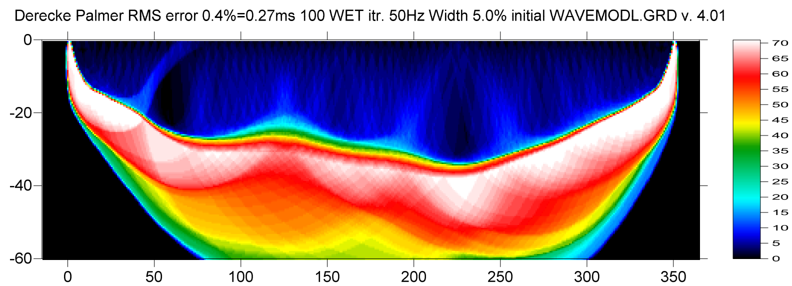

Fig. 8 : WET wavepath coverage plot obtained with Fig. 6. Unit is wavepaths per pixel.

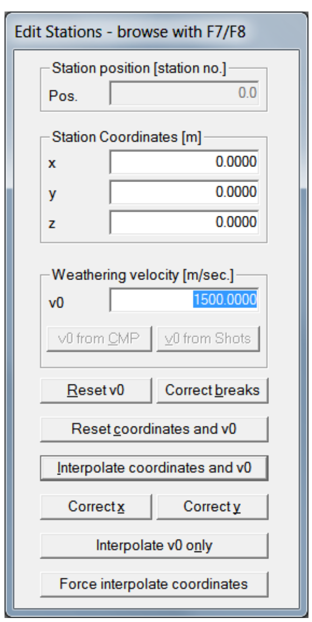

Fig. 9 : *Header|Station*

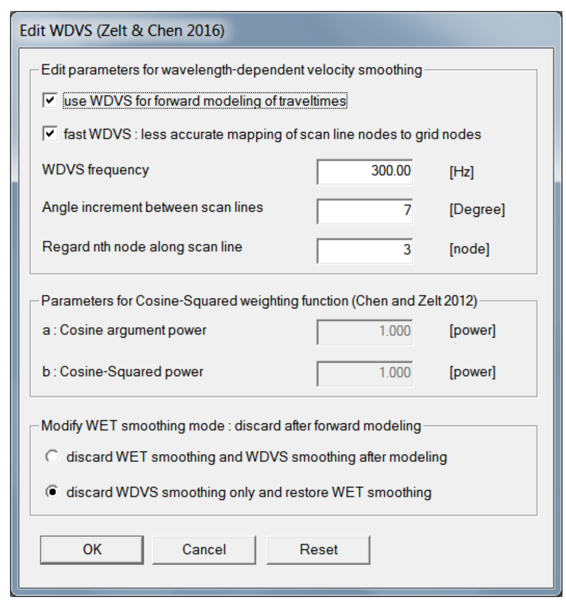

Fig. 10 : *Model|WDVS Smoothing*

Next we try to increase the resolution at top-of-basement by increasing the WET iteration count and minimizing WET smoothing :

- select *WET Tomo|Interactive WET tomography*
- edit *Number of WET tomography iterations* to 100 (Fig. 11)
- click button *Edit velocity smoothing*. Click radio button *Minimal smoothing*.
- set *Smooth nth iteration : n* = 5. Click button *Accept parameters*.
- click button *Start tomography processing* and confirm prompts to obtain Fig. 6
- compare Fig. 6 with Fig. 5. We got better resolution at top-of-basement but also slightly more artefacts both in overburden and in basement. We like the improved resolution.

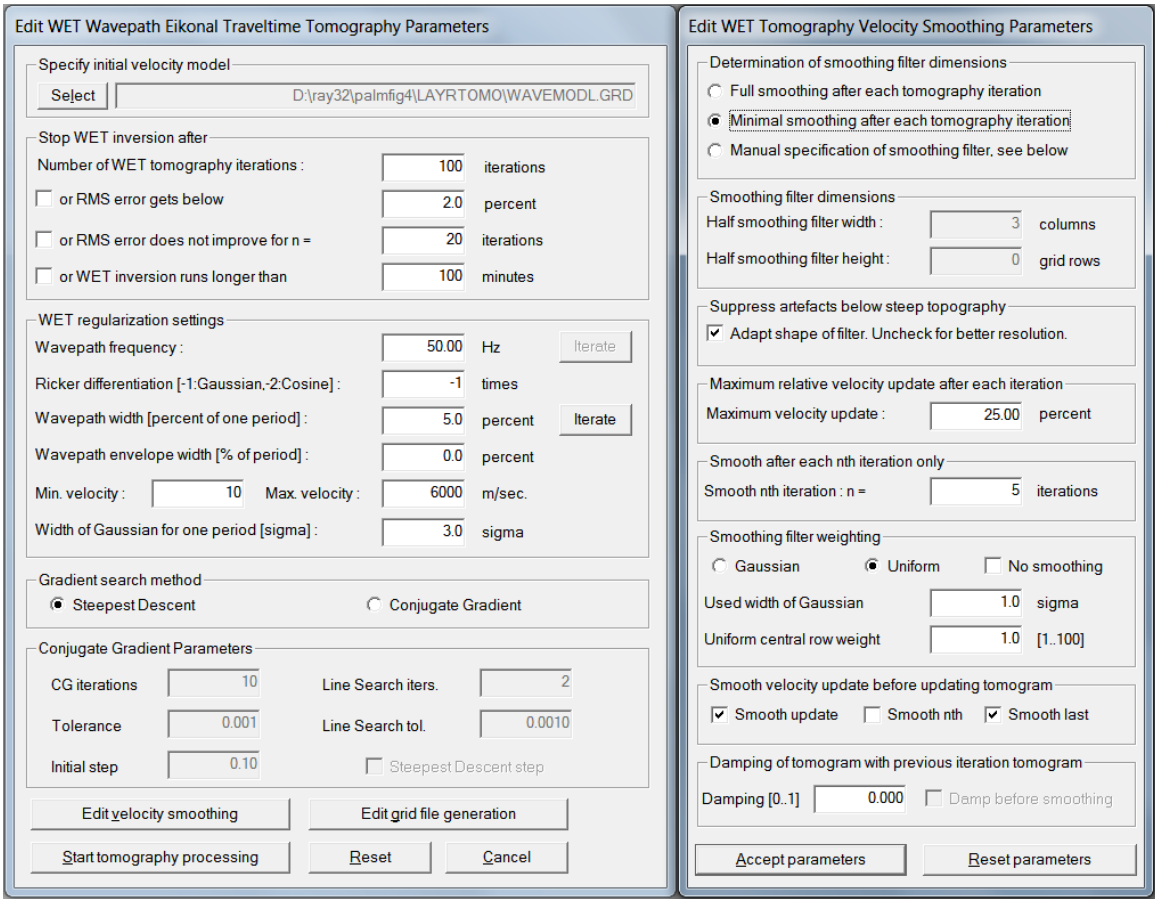

Fig. 11 : WET Tomo|Interactive WET main dialog (left). Edit velocity smoothing (right).

Compare Fig. 6 with Derecke Palmer 1980. The Generalized Reciprocal Method Of Seismic Refraction Interpretation. Society of Exploration Geophysicists, Tulsa. ISBN 0-931830-14-1 : Fig. 4 on page 17.

Here is the LAYRTOMO subdirectory archive for Fig. 6 with **WAVEMODL.GRD** starting model and WET inversion results : http://rayfract.com/tutorials/LAYRTOMO_WDVS@300Hz_Mar6_2021.rar

Here is the profile database archive for Fig. 6 : http://rayfract.com/tutorials/palmfig4_seis32_WaveWDVS@300Hz_Mar6_2021.rar.

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](#)

Next we try to improve accuracy of velocity imaging directly below the two shot points. Here the weathering velocity is too low and the basement gets pulled up to much (Fig. 6).

Dr. Palmer does not specify the shot positions for his Fig. 4 model and synthetic traveltime data. These shot positions have to be guessed at by looking at the traveltime curves and resulting interpretation. So we moved position of shot no. 1 15m to left and position of shot no.2 15m to right (Fig. 15) :

- check *File|Import data Settings|Allow shot inline offset from shot station larger than two spacings*
- select *Header|Shot*. Position shot no. 1 with F7/F8. In frame *Offset from shot station* set *Inline* to -15m.
- position shot no. 2 with F7/F8. In *Offset from shot station* set *Inline* to 15m. Press ENTER to confirm.
- select *WET Tomo|Automatic WET*. Navigate into **C:\RAY32\PALMFIG4\LAYRTOMO** folder and select starting model grid **WAVEMODL.GRD**.

- click *Open* button and confirm prompt to obtain Fig. 12. Compare with Fig. 5.
- select *WET Tomo|Interactive WET*. Make sure all parameters are set as in Fig. 11.
- click button *Start tomography processing* to obtain Fig. 13. Compare with Fig. 6.
- note the more realistic velocity imaging below shot points in Fig. 13 compared with Fig. 6
- also note the 50% smaller *RMS error* on top of Fig. 13 compared with Fig. 6

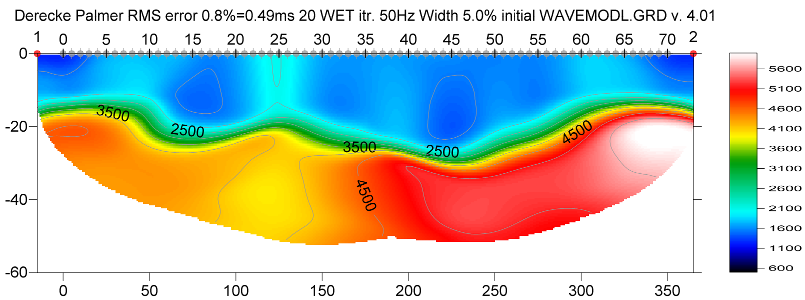

Fig. 12 : same as Fig. 5 but with shot pos. 1 inline offset shifted by -15m and shot pos. 2 inline offset shifted by 15m.

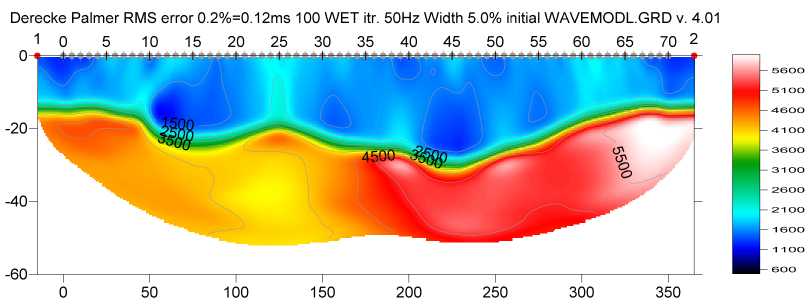

Fig. 13 : same as Fig. 6 but with inline offset for shot pos. 1 shifted by -15m and shot pos. 2 shifted by 15m (Fig. 15). Compare with Fig. 6 replicated below. Note the improved velocity imaging directly below the two shot points.

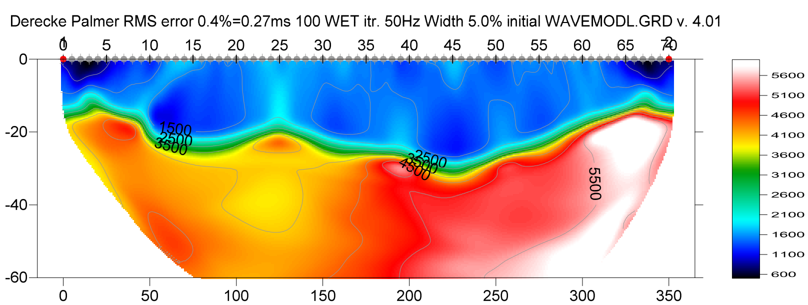

Fig. 6 : 100 WET iterations, starting model Fig. 4, WDVS@300Hz. Minimal WET smoothing, smooth nth=5 (Fig. 11).

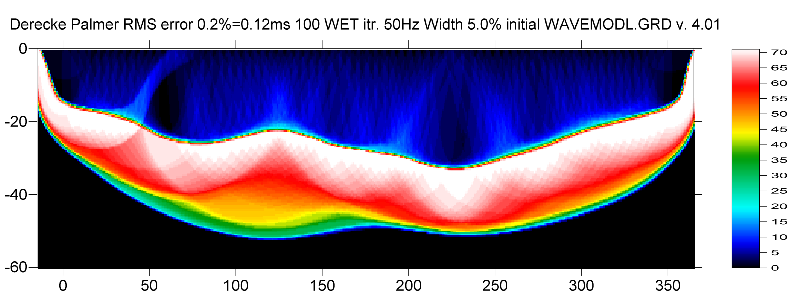

Fig. 14 : WET wavepath coverage plot obtained with Fig. 13. Unit is wavepaths per pixel.

- this again demonstrates the importance of correctly specifying the used recording geometry to obtain meaningful WET inversion results. Also see NGU line Aaknes-1 tutorial.

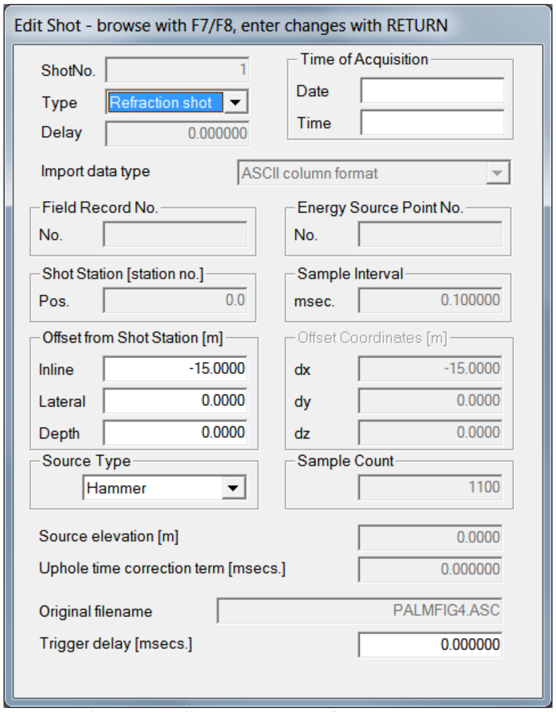

Fig. 15 : fix inline offset in *Header|Shot*

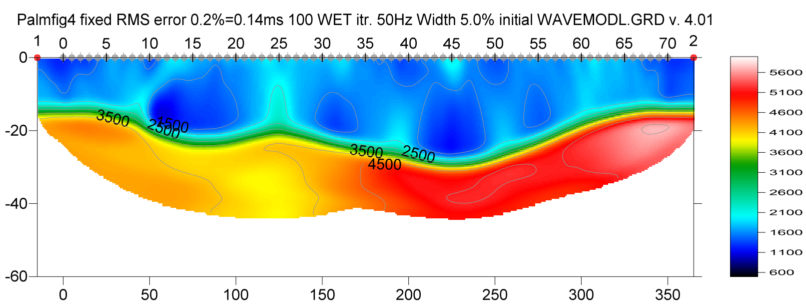

Fig. 16 : same as Fig. 13 but with WDVS disabled. Note the too smooth shape of top-of-basement compared to Fig. 13 and compared to true model (Palmer 1980 Fig. 4).

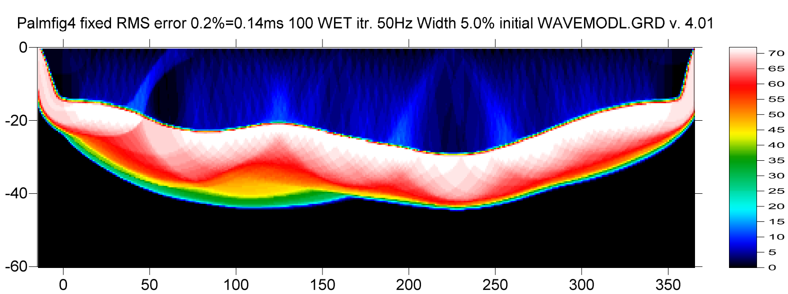

Fig. 17 : WET wavepath coverage plot obtained with Fig. 16. Unit is wavepaths per pixel.

Next we decrease the ***WDVS frequency*** from 300Hz to 200Hz to possibly further improve the sharpness of the top-of-basement :

- select *Model|WDVS Smoothing*. Set *WDVS frequency* to 200Hz (Fig. 10) and click *OK button*.
- select *WET Tomo|Interactive WET* and click *Start tomography processing* button.
- confirm prompts to obtain Fig. 18. Compare with Fig. 13.
- note improved shape of basement at inline offsets 50m and 225m in Fig. 18 (Palmer 1980, Fig. 4).

- contrast at corners at top-of-basement and inline offsets 30m, 200m and 250m is too strong in Fig. 18 compared to Fig. 13 and Fig. 4 in (Palmer, 1980).
- lowering the *WDVS frequency* (Fig. 10) increases the contrast and magnitude of velocity anomalies at top-of-basement and in overburden.

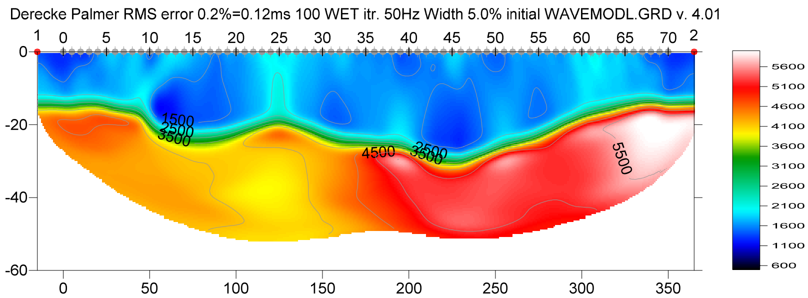

Fig. 13 : same as Fig. 6 but with inline offset for shot pos. 1 shifted by -15m and shot pos. 2 shifted by 15m (Fig. 15). WDVS enabled @300Hz (Fig. 10). WET parameters shown in Fig. 11.

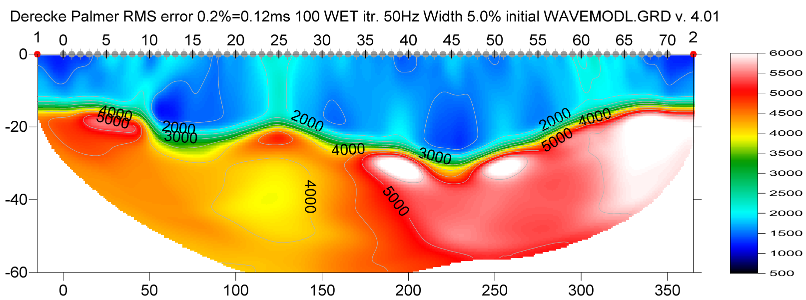

Fig.18 : same WET inversion as Fig. 13 but WDVS frequency of 200Hz instead of 300Hz (Fig. 10). WET parameters shown in Fig. 11. Note improved basement refractor shape at inline offsets 50m and 225m (Palmer 1980, Fig. 4).

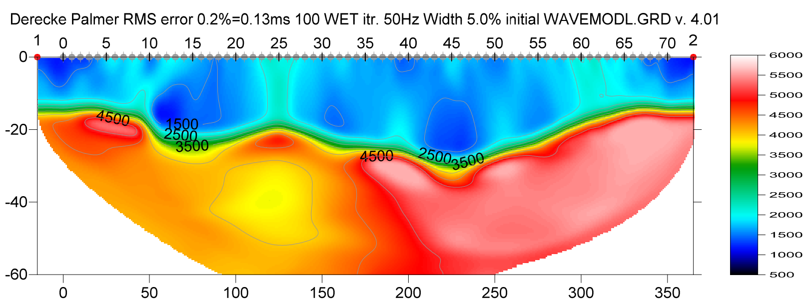

Fig. 19 : same WET inversion as Fig. 18 but max. WET velocity limited to 5,500m/s instead of 6,000m/s (Fig. 11).

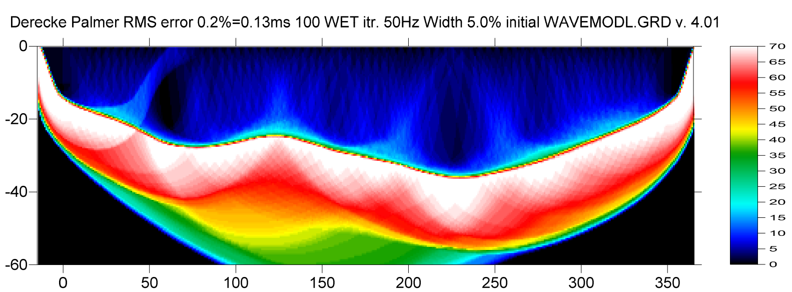

Fig. 20 : WET wavepath coverage plot obtained with Fig. 19. Unit is wavepaths per pixel.

Next we suppress the too strong magnitude of velocity anomalies by limiting the maximum WET velocity :

- select *WET Tomo|Interactive WET*. Edit *Max. velocity* to 5,500m/s (Fig. 11).
- click button *Start tomography processing* to obtain Fig. 19.
- note the suppression of too high velocity anomalies in Fig. 19 compared to Fig. 18.

Conclusions :

- ✓ we have demonstrated that enabling WDVS can give more detailed and more realistic top-of-basement imaging even when using just two shots
- ✓ lowering the *WDVS frequency* increases the contrast and magnitude of velocity anomalies at top-of-basement and in overburden
- ✓ limiting the maximum WET velocity can give more realistic tomograms when using WDVS
- ✓ we have shown the importance of correctly specifying in our software the field recording geometry (shot positions and receiver positions) used when recording the data
- ✓ for field surveys we strongly recommend recording more shots using a closer shot spacing, to compensate for decreasing signal-to-noise ratio with increasing source-receiver offset
- ✓ for above tutorial *WET inversion* regards shots offset up to 3 *station spacings* from first/last profile receiver station, due to the up-dipping basement refractor both at profile start and end.
- ✓ in general our *WET inversion* will regard offset shots distanced up to two *station spacings* from first/last profile receiver station.