

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

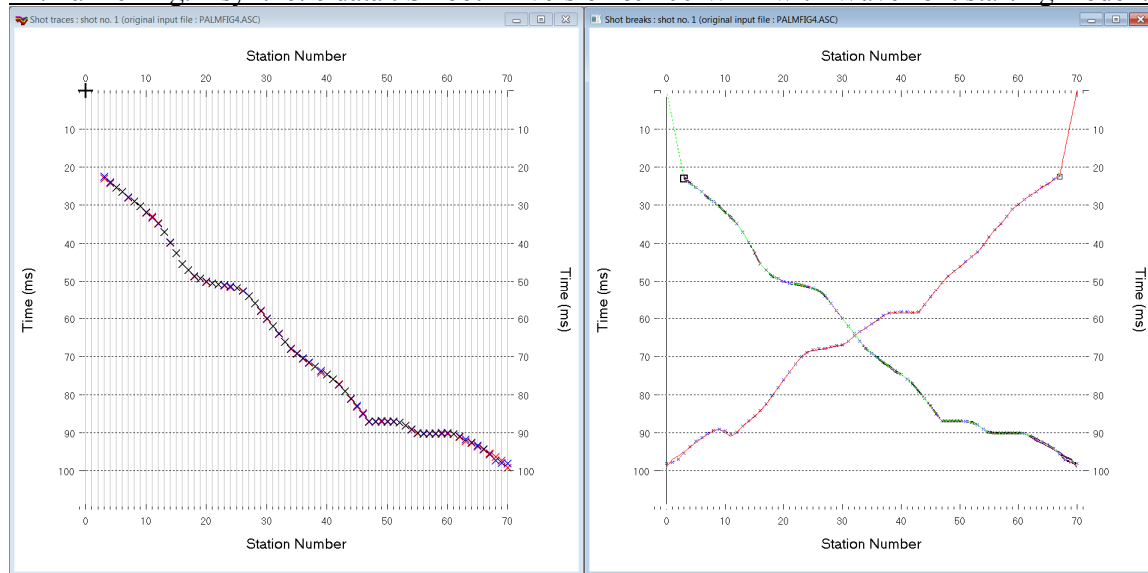


Fig. 1 : left : *Trace|Shot gather*, right : *Refractor|Shot breaks*. Shows fit between picked times (solid colored curves, red crosses) and modeled times (dashed colored curves, blue crosses) obtained with 100 WET iterations (Fig. 6)

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.

Edit Profile

Line ID: Time of Acquisition: Date: Time:

Line type: Time of Processing: Date: Time:

Job ID:

Instrument:

Client:

Company:

Observer:

Note:

Units: Sort: Const:

Station spacing [m]: ☐ Left handed coordinates

Min. horizontal separation [%]: ☒ Force grid cell size

Profile start offset [m]: Cell size [m]:

First receiver [station number]: ☐ Force first receiver

Add borehole lines for WET tomography

Borehole 1 line:

Borehole 2 line:

Borehole 3 line:

Borehole 4 line:

Import shots

Import data type:

Input directory: select one data file. All data files will be imported

Select:

Take shot record number from:

Optionally select .HDR batch file and check Batch import

.HDR batch:

Write .HDR batch file listing shots in input directory

Output .HDR:

☐ Write .HDR only ☐ Import shots and write .HDR

Overwrite existing shot data: ☒ Overwrite all ☐ Prompt overwriting ☐ Batch import ☐ Limit offset

Maximum offset imported [station nos.]:

Default shot hole depth [m]: Default spread type:

Target Sample Format:

☐ Turn around spread during import ☐ Reverted spread layout

☐ Correct picks for delay time (use e.g. for .PIK files)

Default sample interval [msec]:

Default sample count:

Fig. 2 : Header|Profile

Fig. 3 : File|Import Data

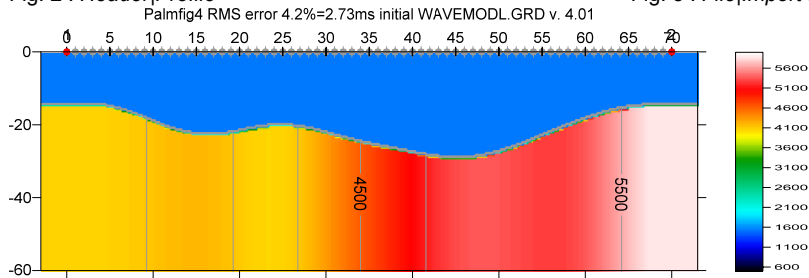


Fig. 4 : select *Depth|Wavefront* and confirm prompts to obtain Wavefront method depth section.

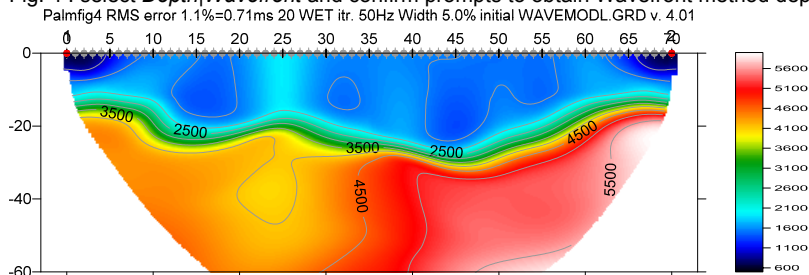


Fig. 5 : Smooth inversion with Wavefront method starting model shown in Fig. 4. WDVS enabled @300Hz (Fig. 10).

Derecke Palmer RMS error 0.4%=0.27ms 100 WET itr. 50Hz Width 5.0% initial WAVEMODL.GRD v. 4.01

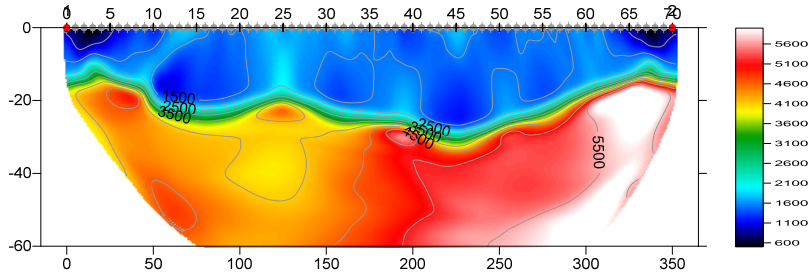


Fig. 6 : 100 WET iterations, starting model Fig. 4, WDVS@300Hz. Minimal WET smoothing, smooth nth=5 (Fig. 11).

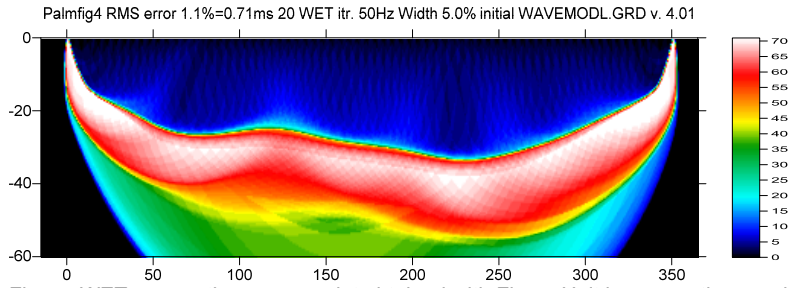


Fig. 7 : WET wavepath coverage plot obtained with Fig. 5. Unit is wavepaths per pixel.

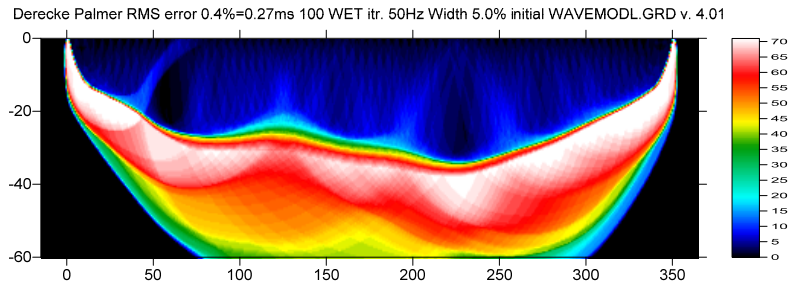


Fig. 8 : WET wavepath coverage plot obtained with Fig. 6. Unit is wavepaths per pixel.

Edit Stations - browse with F7/F8

Station position [station no.]
Pos. 0.0

Station Coordinates [m]
x 0.0000
y 0.0000
z 0.0000

Weathering velocity [m/sec]
v0 1500.0000
v0 from CMP v0 from Shots

Reset v0 Correct breaks

Reset coordinates and v0

Interpolate coordinates and v0

Correct x Correct y

Interpolate v0 only

Force interpolate coordinates

Fig. 9 : Header|Station

Edit WDVS (Zelt & Chen 2016)

Edit parameters for wavelength-dependent velocity smoothing

☒ use WDVS for forward modeling of traveltimes

☒ fast WDVS : less accurate mapping of scan line nodes to grid nodes

WDVS frequency 300.00 [Hz]

Angle increment between scan lines 7 [Degree]

Regard nth node along scan line 3 [node]

Parameters for Cosine-Squared weighting function (Chen and Zelt 2012)

a : Cosine argument power 1.000 [power]

b : Cosine-Squared power 1.000 [power]

Modify WET smoothing mode : discard after forward modeling

☐ discard WET smoothing and WDVS smoothing after modeling

☒ discard WDVS smoothing only and restore WET smoothing

OK Cancel Reset

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.

Edit WET Wavepath Eikonal Traveltime Tomography Parameters

Specify initial velocity model
 D:\ray32\palmfig4\LAYRTOMO\WAVEMODL.GRD

Stop WET inversion after
 Number of WET tomography iterations : iterations
☐ or RMS error gets below percent
☐ or RMS error does not improve for n = iterations
☐ or WET inversion runs longer than minutes

WET regularization settings
 Wavepath frequency : Hz
 Ricker differentiation [-1:Gaussian,-2:Cosine] : times
 Wavepath width [percent of one period] : percent
 Wavepath envelope width [% of period] : percent
 Min. velocity : Max. velocity : m/sec.
 Width of Gaussian for one period [sigma] : sigma

Gradient search method
☒ Steepest Descent ☐ Conjugate Gradient

Conjugate Gradient Parameters
 CG iterations Line Search iters.
 Tolerance Line Search tol.
 Initial step ☐ Steepest Descent step

Edit WET Tomography Velocity Smoothing Parameters

Determination of smoothing filter dimensions
☐ Full smoothing after each tomography iteration
☒ Minimal smoothing after each tomography iteration
☐ Manual specification of smoothing filter, see below

Smoothing filter dimensions
 Half smoothing filter width : columns
 Half smoothing filter height : grid rows

Suppress artefacts below steep topography
☒ Adapt shape of filter. Uncheck for better resolution.

Maximum relative velocity update after each iteration
 Maximum velocity update : percent

Smooth after each nth iteration only
 Smooth nth iteration : n = iterations

Smoothing filter weighting
☐ Gaussian ☒ Uniform ☐ No smoothing
 Used width of Gaussian sigma
 Uniform central row weight [1..100]

Smooth velocity update before updating tomogram
☒ Smooth update ☐ Smooth nth ☒ Smooth last

Damping of tomogram with previous iteration tomogram
 Damping [0..1] ☐ Damp before smoothing

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

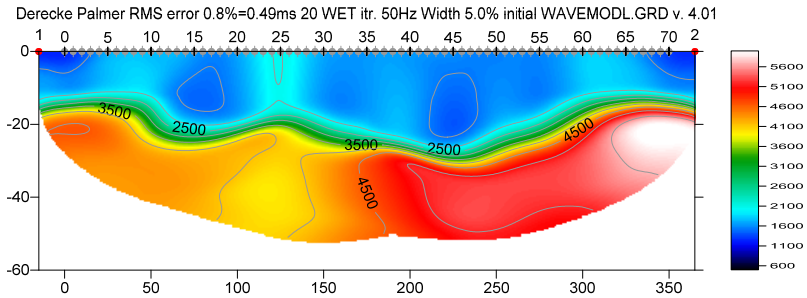


Fig. 12 : same as Fig. 5 but with shot pos. 1 inline offset shifted by -15m and shot pos. 2 inline offset shifted by 15m.

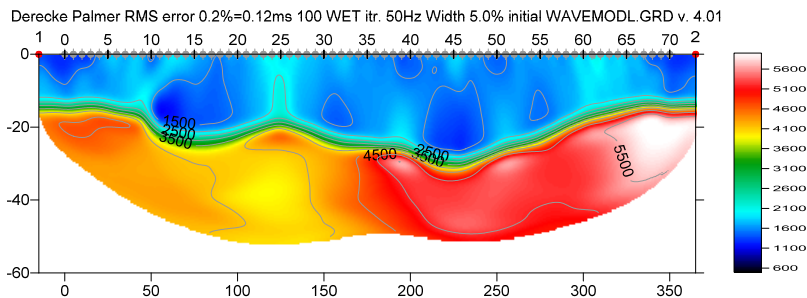


Fig. 13 : same as Fig. 6 but with inline offset for shot pos. 1 shifted by -15m and shot pos. 2 shifted by 15m (Fig. 15). Compare with Fig. 6 replicated below. Note the improved velocity imaging directly below the two shot points.

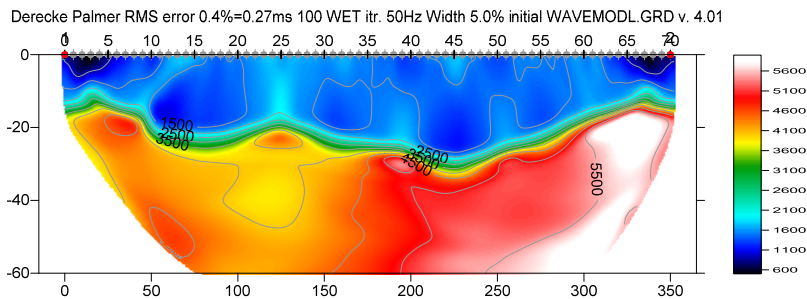


Fig. 6 : 100 WET iterations, starting model Fig. 4, WDV@300Hz. Minimal WET smoothing, smooth nth=5 (Fig. 11).

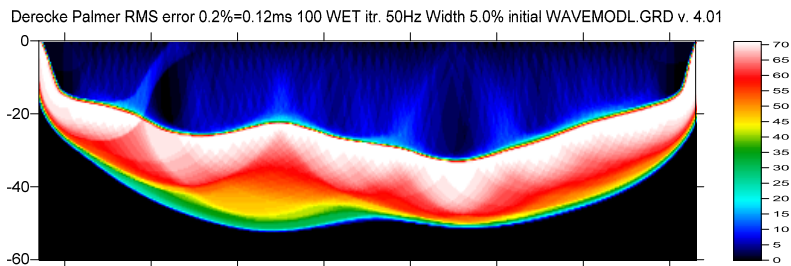


Fig. 14 : WET wavepath coverage plot obtained with Fig. 13. Unit is wavepaths per pixel.

- this again demonstrates the importance of correctly specifying the used recording geometry to obtain meaningful WET inversion results. Also see NGU line [Aaknes-I tutorial](#).

Edit Shot - browse with F7/F8, enter changes with RETURN

ShotNo. <input type="text" value="1"/>	Time of Acquisition
Type <input type="button" value="Refraction shot"/>	Date <input type="text"/>
Delay <input type="text" value="0.000000"/>	Time <input type="text"/>
Import data type <input type="button" value="ASCII column format"/>	
Field Record No. <input type="text"/>	Energy Source Point No. <input type="text"/>
No. <input type="text"/>	No. <input type="text"/>
Shot Station [station no.]	Sample Interval
Pos. <input type="text" value="0.0"/>	msec. <input type="text" value="0.100000"/>
Offset from Shot Station [m]	Offset Coordinates [m]
Inline <input type="text" value="-15.0000"/>	dx <input type="text" value="-15.0000"/>
Lateral <input type="text" value="0.0000"/>	dy <input type="text" value="0.0000"/>
Depth <input type="text" value="0.0000"/>	dz <input type="text" value="0.0000"/>
Source Type <input type="button" value="Hammer"/>	Sample Count <input type="text" value="1100"/>
Source elevation [m] <input type="text" value="0.0000"/>	
Uphole time correction term [msecs.] <input type="text" value="0.000000"/>	
Original filename <input type="text" value="PALMFIG4.ASC"/>	
Trigger delay [msecs.] <input type="text" value="0.000000"/>	

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

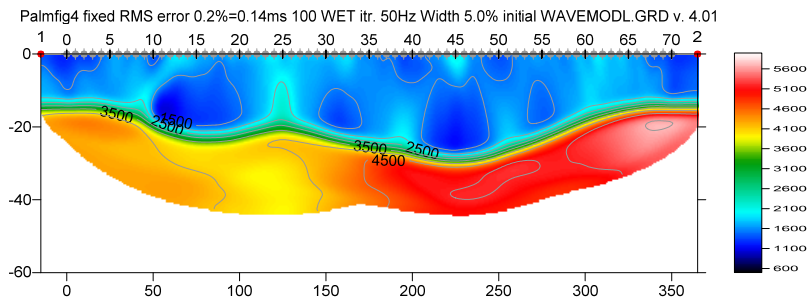


Fig. 16 : same as Fig. 13 but with *WDVS* disabled. Note the too smooth shape of top-of-basement compared to Fig. 13 and compared to true model (Palmer 1980 Fig. 4).

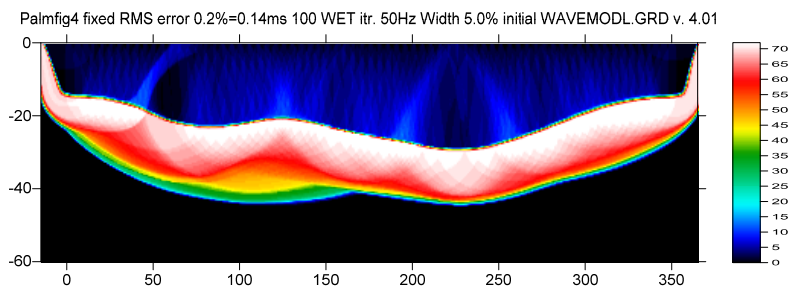


Fig. 17 : WET wavepath coverage plot obtained with Fig. 16. Unit is wavepaths per pixel.

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.

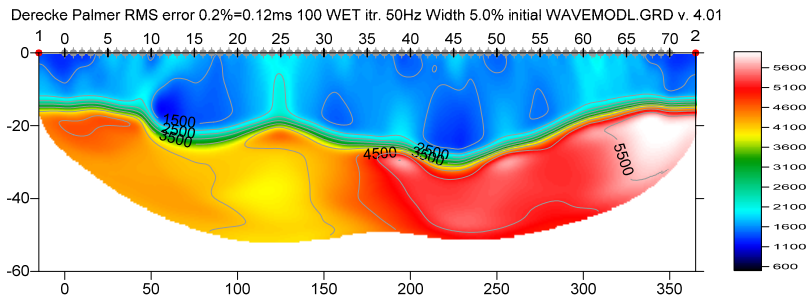


Fig. 13 : same as Fig. 6 but with inline offset for shot pos. 1 shifted by -15m and shot pos. 2 shifted by 15m (Fig. 15). WDVS enabled @300Hz (Fig. 10). WET parameters shown in Fig. 11.

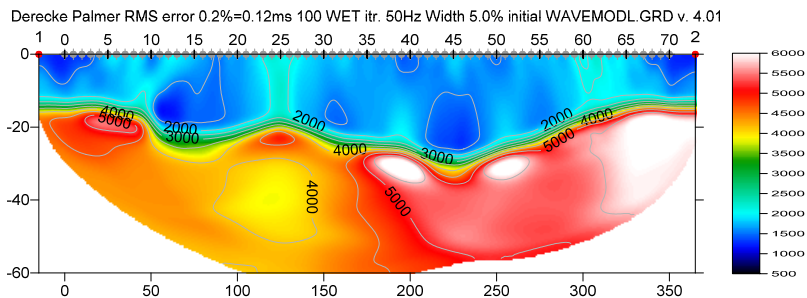


Fig.18 : same WET inversion as Fig. 13 but WDVS frequency of 200Hz instead of 300Hz (Fig. 10). WET parameters shown in Fig. 11. Note improved basement refractor shape at inline offsets 50m and 225m (Palmer 1980, Fig. 4).

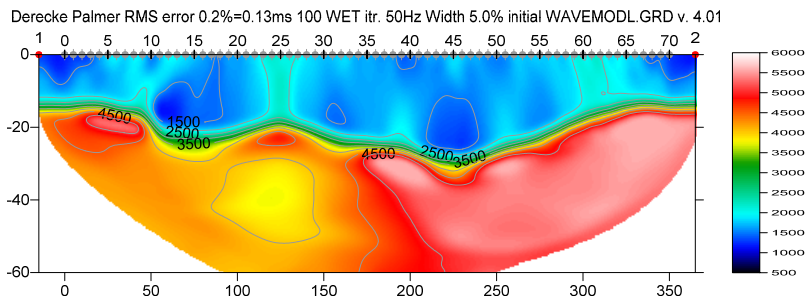


Fig. 19 : same WET inversion as Fig. 18 but max. WET velocity limited to 5,500m/s instead of 6,000m/s (Fig. 11).

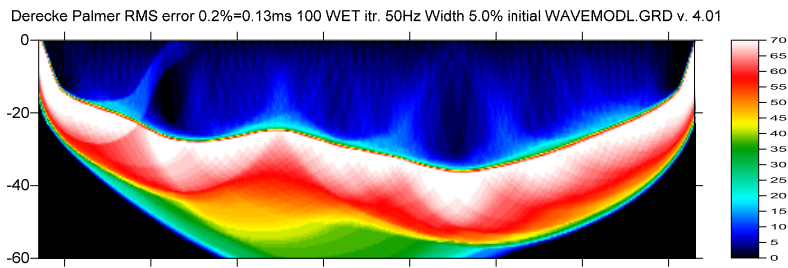


Fig. 20 : WET wavepath coverage plot obtained with Fig. 19. Unit is wavepaths per pixel.

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.