

Import DMT SUMMIT .SEG2 & WET inversion for granitic basement imaging, version 4.02 :

Fig. 1 : top : *Trace*|*Shot gather*, bottom : *Refractor*|*Shot breaks*. Shows fit between picked times (solid colored curves, red circles) and modeled times (dashed colored curves, blue crosses) obtained for Smooth invert output (Fig. 8)

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

- File New Profile ..., set File name to Test21 and click Save button
- in the prompt (Fig. 23) click *No* button to leave *Profile start* and first receiver at station no. 0.
- 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. With free trial check option Smooth invert|Smooth inversion Settings|Extra-large cell size instead.
- unzip archive <u>Test21.zip</u> with seg-2 .seg2 shot files & first breaks file breaks.lst in directory C:\ray32\test21\input
- select File|SEG-2 import settings |Receiver Coordinates specified in SEG-2 trace headers
- select File|SEG-2 import settings|Ignore SEG-2 station numbers in trace headers
- select *File Import Data*... and set *Import data type* to seg-2. See Fig. 3.
- click *Select button* and navigate into C:\ray32\test21\INPUT
- set Files of type to DMT (*. SEG2). Select any file e.g. Rec_00001.seg2 & click button Open (Fig. 22).
- leave Default spread type at 10: 360 channels
- click Import shots button . Click Read button for each shot displayed.
- select File|Update header data|Update First Breaks. Select file BREAKS.LST & click Open button
- select *Trace*|Shot gather and select Window|Tile horizontal to obtain Fig. 1
- click on title bar of *Trace*|*Shot gather* window and press F1 to zoom time axis (Fig. 1 top)
- 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 breaks* window (Fig. 1 bottom) and press ALT+P. Edit *Maximum time* to 100 ms & hit ENTER key to redisplay. Do the same for *Trace*|*Shot gather* window (Fig. 1 top).

To configure and run Smooth inversion :

- select *Grid*|*Surfer plot Limits*. Edit fields as in Fig. 4. Click *OK button*.
- check Grid|GS CENTERED font for receivers to work around Surfer 11 issues with receiver display
- check Grid Receiver station ticks on top axis to show stations on top and inline offset (m) at bottom
- uncheck WET Tomo|WET tomography Settings|Blank below envelope after last iteration
- select *Model WDVS Smoothing*. Edit dialog as in Fig. 16. Click radio button *discard WET smoothing*.

- select Smooth invert|WET with 1D-gradient initial model
- wait for the 1D-gradient starting model to display as in Fig. 6
- confirm prompt to continue with WET inversion to obtain WET output shown in Fig. 7

Edit Profile				
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			~	Const
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Min. horizontal sep	paration [%]		25	✓ Force grid cell size
Profile start offset [[m]		0.0000	Cell size [m] 0.5000
First receiver [stati	on number]		0	Force first receiver
Add borehole line	es for WET tomo	ograph	у	
Borehole 1 line	Select			
Borehole 2 line	Select			
Borehole 3 line	Select			
Borehole 4 line	Select			
ОК	Cancel		Reset	

Import shots					
Import data type	SEG-2				
Input directory : select one data file. All data files will be imported					
Select	D:\ray32\Test21\INPUT\				
Take shot record number from	DOS file name				
Optionally select .HDR batch file .HDR batch	and check Batch import				
Write .HDR batch file listing shot	s in input directory				
Output .HDR					
Write .HDR only	Import shots and write .HDR				
Overwrite existing shot data					
Maximum offset imported [station nos.] 1000.00					
Default shot hole depth [m]	Default spread type				
0.00	10: 360 channels 💌				
Target Sample Format	16-bit fixed point				
☐ Turn around spread during import ☐ Reverted spread layout ☐ Correct picks for delay time (use e.g. for .PIK files)					
Default sample interval [msec]	0.10000000				
Default sample count	20000				
Import shots Ca	ncel import <u>R</u> eset import				

Fig. 3 : File|Import Data

Edit WDVS (Zelt & Chen 2016)					
Edit parameters for wavelength-dependent velocity smoothing					
WDVS frequency 120.00	[Hz]				
Angle increment between scan lines 7	[Degree]				
Regard nth node along scan line 3	[node]				
Parameters for Cosine-Squared weighting function (Chen and Ze a : Cosine argument power 1.000 b : Cosine-Squared power 1.000	elt 2012) [power] [power]				
Modify WET smoothing mode : discard after forward modeling C discard WET smoothing and WDVS smoothing after modeling Image: Im					

Fig. 5 : *Model*|*WDVS Smoothing* for Fig. 9 and 10. Check radio button *discard WDVS smoothing only*.

Edit Surfer plot limit	ts		
Plot Limits	1		ОК
Min. offset	-15.000	[m]	Cancel
Max. offset	160.000	[m]	Reset
Min. elevation	-20.737	[m]	Reset to grid
Max. elevation	2.000	[m]	Redisplay grid
Min. velocity	200	[m/sec.]	
Max. velocity	6500	[m/sec.]	
Plot Scale Proportional XY	Scaling neter. Uncheck	; for inch.	
X Scale length	6.000	[inch]	
Y Scale length	2.000	[inch]	
Color Scale	le		
Scale height	2.050	[inch]	
Velocity interval	200	[m/sec.]	
Coverage interval	5	[paths/pixel]	
-Receiver labeling-			
First station	0	[station no.]	
Station interval	3	[station no.]	
Use station inde	x or station no	offset	

Fig. 2 : Header|Profile

Fig. 4 : Grid|Surfer plot Limits

To display the 1D-gradient starting model in Fig. 6 using plot limits edit in Fig. 4 :

- > select Grid|Image and contour velocity and coverage grids
- navigate into directory c:\ray32\test21\gradtomo
- select file gradient.grd



Fig. 6 : 1D-gradient starting model obtained with Smooth invert|WET with 1D-gradient initial model



Fig. 7 : Smooth invert|WET with 1D-gradient initial model & starting model shown in Fig. 6. 20 WET iterations@50Hz using Steepest Descent method & Gaussian update weighting & full WET smoothing. WDVS@120Hz as in Fig. 16. Discard WET smoothing and WDVS smoothing after forward modeling. Compare with Fig. 18.



Fig. 8 : obtained with *WET Tomo*|*Interactive WET tomography* (Fig. 12 left) : 100 WET iterations@30Hz & 1D-gradient starting model shown in Fig. 6. Wavepath frequency set to 30Hz. Minimal WET smoothing (Fig. 12 right). WDVS@120Hz as in Fig. 5. Discard WDVS smoothing only and restore WET smoothing. Compare with Fig. 7 and 19.







Fig. 10 : same as Fig. 8 but setting *WET Tomo|Interactive WET|Number of WET tomography iterations* (Fig. 12 left) to 50 WET iterations only instead of 100 WET iterations used for Fig. 8.



Fig. 11 : WET wavepath coverage plot obtained with Fig. 10. Unit is wavepaths per pixel.

Now we try increasing the WET resolution by increasing the iteration count and tuning the smoothing :

- select Model WDVS Smoothing. Edit as in Fig. 5. Click radio button Discard WDVS smoothing only.
- select WET Tomo Interactive WET tomography
- ▶ increase Number of WET tomography iterations to 100 from default 20 iterations. See Fig. 12 (left).
- decrease Wavepath frequency to 30Hz from default 50Hz for deeper imaging
- set Max. velocity to 5,500m/s
- click button *Edit velocity smoothing*. Edit as in Fig. 12 (right). Click Accept parameters.
- click button Start tomography processing to obtain WET output shown in Fig. 8 and Fig. 9

Above we show WET+WDVS imaging of a strongly weathered granitic basement in Australia with local velocity inversions in overburden.

The RMS error of 6.7% shown on top of Fig. 8 and Fig. 10 is almost as high as 6.8% shown for Fig. 7. However Fig. 8 and Fig. 10 seem to show more details after 50 and 100 WET iterations with *minimal WET smoothing* and *Adapt shape of filter* unchecked instead of default 20 WET iterations and default full WET smoothing used for Fig. 7.

For instructions on tuning the *WDVS frequency* see our *Help menu*, Contents, Forward model traveltimes. Scroll down to section *WDVS velocity smoothing*. We recommend first leaving WDVS parameters in *Model*|*WDVS smoothing* at their default settings with WDVS frequency at 200Hz. Then increase/decrease *WDVS frequency* using these heuristics :

- for a short line (100m or 200 long) with shallow high-velocity basement increase WDVS frequency to 400Hz or higher. See our Broad Epikarst tutorial.
- for a short line with thick and low-velocity overburden as above decrease WDVS frequency to 100Hz or 150Hz
- for a long line up to 1km or 2km long : decrease WDVS frequency to 50Hz or 60Hz. See our <u>Aaknes-1</u> <u>tutorial</u>.
- if you lower the WDVS frequency too much then the top-of-basement is imaged too shallow and overburden velocity anomalies show too strong magnitude. Compare Fig. 8 and Fig. 10 with Fig. 7.

also the *RMS error* shown on top of WET tomograms increases too much with too low *WDVS frequency*.

Edit WET Wavepath Eikonal Traveltime Tomography Parameters	Edit WET Tomography Velocity Smoothing Parameters			
Specify initial velocity model Select D:\ray32\Test21\GRADTOMO\GRADIENT.GRD	Determination of smoothing filter dimensions The smoothing after each tomography iteration			
Stop WET inversion after	 Minimal smoothing after each tomography iteration Manual specification of smoothing filter, see below 			
Number of WET tomography iterations : 100 iterations Image: or RMS error gets below 2.0 percent Image: or RMS error does not improve for n = 20 iterations	Smoothing filter dimensions Half smoothing filter width : 3 columns			
WET inversion runs longer than 100 minutes	Half smoothing hiter height: 0 grid rows Suppress artefacts below steep topography Adopt shapp offilter. Lipsback for hottor receivition			
Wavepath frequency : 30.00 Hz Iterate Ricker differentiation [-1:Gaussian,-2:Cosine] : -1 times Wavepath width [percent of one period] : 8.0 percent	Maximum relative velocity update after each iteration Maximum velocity update : 25.00 percent			
Wavepath envelope width [% of period] : 0.0 percent Min. velocity : 10 Max. velocity : 5500 m/sec.	Smooth after each nth iteration only Smooth nth iteration : n = 1 iterations			
Width of Gaussian for one period [sigma]: 3.0 sigma Gradient search method C Conjugate Gradient	Smoothing filter weighting C Gaussian © Uniform I No smoothing Used width of Gaussian 1.0 sigma			
Conjugate Gradient Parameters	Uniform central row weight 1.0 [1100]			
CG iterations 10 Line Search iters. 2 Tolerance 0.001 Line Search tol. 0.0010	Smooth velocity update before updating tomogram			
Initial step 0.10 Steepest Descent step	Damping of tomogram with previous iteration tomogram Damping [01] 0.000 Damp before smoothing			
Edit generation Start tomography processing Reset Cancel	Accept parameters Reset parameters			

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

Frequency filter : band-pass or band-reject	Frequency filter : high-pass or low-pass
Filter active for current trace gather display	Filter active for current trace gather display
✓ Band-pass filter. Uncheck for band-reject.	High-pass filter. Uncheck for low-pass.
 Bidirectional filter. Better preserve signal. 	Bidirectional filter. Better preserve signal.
Chebyshev filter. Uncheck for single-pole.	Chebyshev filter. Uncheck for single-pole.
Apply n times [n] 1	Apply n times [n] 1
Low corner frequency [Hz] 50.00	Cutoff frequency [Hz] 50.00
High corner frequency [Hz] 100.00	Percent ripple [%] 0.0
Percent ripple [%] 0.0	Number of poles [n] 2
Number of poles [n] 2	
Filter Cancel Reset	Filter Cancel Reset

Fig. 13 : Trace|Shot gather SHIFT+Q Bandpass

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To optimize frequency filtering in Trace|Shot gather display (Fig. 1 top) or in Trace|Offset gather :

- > select *Trace*|*Shot gather*. Press SHIFT+Q keyboard shortcut and edit bandpass as in Fig. 13
- > press ALT+Q and edit low-pass filter as in Fig. 14

Bandpass filtering and low-pass filtering are done in sequence for trace display in *Trace*|Shot gather or *Trace*|Offset gather.



Fig. 15 : check reciprocal picking errors in *Trace*|*Offset gather* (left). Browse shots in *Trace*|*Shot gather* (right). Display reciprocal picking error export dialog with *Trace*|*Export reciprocal errors*.

We recommend checking reciprocal picking errors in *Trace|Offset gather* (Fig. 15) as in our <u>Slope1</u> <u>tutorial</u>. Export reciprocal picking errors to file **RECIPROCAL.ERR** in *Trace|Export reciprocal errors*.

Import **RECIPROCAL.ERR** into Microsoft Excel spreadsheet and sort by column **reciprocal_error(%)** or **absolute_error(ms)** to identify trace pairs in *Trace*|*Offset gather* display that need to be repicked.

Edit WDVS (Zelt & Chen 2016)					
Edit parameters for wavelength-dependent velocity smoothing					
✓ fast WDVS : less accurate mapping of scan line nodes	to grid nodes				
WDVS frequency 120.0	0 [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 1.00	0 [power]				
b : Cosine-Squared power 1.00	0 [power]				
Modify WET smoothing mode : discard after forward modeling					
Idiscard WET smoothing and WDVS smoothing after modeling					
C discard WDVS smoothing only and restore WET smoothing					
OK Cancel Reset					

Fig. 16 : *Model*|*WDVS Smoothing* used for Fig. 7. Check radio button *discard WET smoothing and WDVS smoothing after modeling*.

Next we show using our pseudo-2D DeltatV starting model instead of the laterally averaged 1D-gradient starting model (Sheehan 2005).



Fig. 17 : pseudo-2D DeltatV starting model obtained with DeltatV|Automatic DeltatV and WET inversion



Fig. 18 : DeltatV|Automatic DeltatV and WET inversion & starting model shown in Fig. 17. 20 WET iterations@50Hz using Steepest Descent method & Gaussian update weighting & full WET smoothing. WDVS@120Hz as in Fig. 16. Discard WET smoothing and WDVS smoothing after forward modeling. Compare with Fig. 7.



Fig. 19 : obtained with WET Tomo|Interactive WET tomography (Fig. 21 left) : 100 WET iterations@30Hz & 1D-gradient starting model shown in Fig. 17. Wavepath frequency set to 30Hz. Minimal WET smoothing (Fig. 21 right). WDVS@120Hz as in Fig. 5. Discard WDVS smoothing only and restore WET smoothing. Compare with Fig. 8 and 10.



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

Edit WET Wavepath Eikonal Traveltime Tomography Parameters	Edit WET Tomography Velocity Smoothing Parameters		
Specify initial velocity model Select D:\ray32\Test21\TOMO\DELTATV.GRD	C Full smoothing after each tomography iteration		
Stop WET inversion after	Minimal smoothing after each tomography iteration		
Number of WET tomography iterations : 100 iterations	C Manual specification of smoothing filter, see below		
or RMS error gets below 2.0 percent	Smoothing filter dimensions Half smoothing filter width : 3 columns		
or RMS error does not improve for n = 20 iterations or WET inversion runs longer than 100 minutes	Halfsmoothing filter height: 0 grid rows		
WET regularization settings	Suppress artefacts below steep topography		
Wavepath frequency : 30.00 Hz Iterate	Adapt shape of filter. Uncheck for better resolution.		
Ricker differentiation [-1:Gaussian,-2:Cosine] : -1 times	Maximum relative velocity update after each iteration		
Wavepath width [percent of one period] : 8.0 percent Iterate	Maximum velocity update : 25.00 percent		
Wavepath envelope width [% of period] : 0.0 percent	Smooth after each nth iteration only		
Min. velocity : 10 Max. velocity : 5500 m/sec.	Smooth nth iteration : n = 1 iterations		
Width of Gaussian for one period [sigma] : 3.0 sigma	Smoothing filter weighting		
Gradient search method	● Gaussian C Uniform I No smoothing		
Steepest Descent C Conjugate Gradient	Used width of Gaussian 3.0 sigma		
Conjugate Gradient Parameters	Uniform central row weight 1.0 [1100]		
CG iterations 10 Line Search iters. 2	Smooth velocity update before updating tomogram		
Tolerance 0.001 Line Search tol. 0.0010	Smooth update Smooth nth 🔽 Smooth last		
Initial step 0.10 Steepest Descent step	Damping of tomogram with previous iteration tomogram		
Edit velocity smoothing Edit grid file generation	Damping [01] 0.000 Damp before smoothing		
Start tomography processing Reset Cancel	Accept parameters Reset parameters		

Fig. 21 : WET Tomo|Interactive WET main dialog (left). Edit velocity smoothing dialog (right).

Note: The select one file is the select one select one file is the select one file is the s	n Data Import Direc	tory. All files will be imported.					x
Look in:	🗼 INPUT		•	← 🖻 🖻	* 📰 🔻		
Recent Places	Name Rec_00001.set Rec_00002.set Rec_00003.set Rec_00004.set	22 22 22 22 22 22 22			Date modi 6/18/2021 6/18/2021 6/18/2021 6/18/2021	fied 10:26 PM 12:10 PM 12:11 PM 12:14 PM	-
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Network	File name:	DMT files (*.SEG2) Seismic data files (*.DAT) ABEM files (*.SG2) DMT files (*.SEG2)]	•	<u>O</u> pen Cancel	

Fig. 22 : in *File*|*Import Data* set *Import data type* to sEG-2. Click *Select* button. Click on down arrow in *Files of type* dropdown field and select entry DMT files (*.SEG2). Select any .SEG2 file e.g. Rec_00001.seg2 and click *Open*.



Fig. 23 : click No button to leave **Profile start** and first receiver station at station no. 0.

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 more recommendations on optimal application of WDVS and tuning of WDVS frequency see our <u>SAGEEP 2021 expanded abstract</u> and <u>slides</u>, and our <u>EGU 2021 online abstract</u>.

Optimal tuning of *WDVS frequency*, *WET wavepath frequency*, WET smoothing and number of WET iterations is subjective and should be based on a-priori knowledge of the imaged subsurface section, obtained from boreholes, trenching etc. The WDVS frequency should be about two to four times the predominant frequency in the first break waveforms or WET wavepath frequency or higher. Lowering the WET wavepath frequency corresponds to increasing the *WET wavepath width*.

As shown above in Fig. 5 and Fig. 16 we recommend enabling option *discard WET smoothing and WDVS smoothing* in *Model*|*WDVS Smoothing* dialog for our *Smooth inversion* or *Automatic WET inversion* only. When using our *WET Tomo*|*Interactive WET inversion* and minimizing the *WET smoothing* (Fig. 12) we strongly recommend checking option *restore WET smoothing and discard WDVS smoothing only* instead to prevent high-velocity artefacts below the shot points in the resulting WET tomogram.

The theory for WDVS Wavelength-Dependent Velocity Smoothing is described in (Zelt and Chen 2016).

References

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