

Import ASCII.ASC & Update header data & Steepest-Descent WET inversion LINE23 v. 5.01 :

Station 323200 Trace 54 Shot 100 Channel 54 Time 117200 Sample 1172 Amplitude 0 Zoom 2 Reciprocal Shot/Channel 77/148 Reciprocal offset(m/L/CMP 235:00/ 3275:30 Use left/nght/up/down arrow keys to move cursor. Space bar pick trace. ALT-2 delet 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.

Create the profile database, import the data and browse the imported shots :

- File New Profile..., set File name to LINE23 and click Save button
- in the prompt shown next (Fig. 4) click *No* button to leave *Profile start* / first receiver at station no. 3101 as specified in LINE23.ASC for first shot no. 1
- in *Header* |*Profile*... set *Line type* to Refraction spread/line . Set *Station spacing* to 5m. See Fig. 2.
- in *Header*|*Profile*... check *Force grid cell size* and set *Cell size* [*m*] to 2m
- check Extrapolate tomograms. Set Extrapolate [Station spacings] to 30. Click OK
- unzip archive <u>https://rayfract.com/tutorials/LINE23_INPUT.zip</u> with LINE23.ASC shot file & files LINE23.COR & LINE23.BRN in directory C:\RAY32\LINE23\INPUT
- select *File Import Data*... and set *Import data type* to ASCII COLUMN FORMAT. See Fig. 3.
- click *Select button* and navigate into C:\RAY32\LINE23\INPUT
- select file LINE23.ASC and click Open
- leave Default spread type at 10: 360 channels
- check *Batch import*. Click *Import shots* button.
- select File|Update header data|Update Station Coordinates & LINE23.COR. Click Import & Reset.
- select option *Trace*|*Open Refractor*|*Shot CMP breaks with Shot gather*
- select *Trace*|*Shot gather* to obtain Fig. 1
- browse shots in *TracelShot 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 250 ms & press ENTER key to redisplay. Do the same for *Trace*|*Shot gather* window (Fig. 1 top).

Configure and run our default fail-safe Smooth inversion :

- check option Grid|Receiver station ticks on top axis
- check Grid/CS_CENTERED font for shot points and receivers to fix Surfer symbol display issues
- edit Grid|Surfer plot Limits as in Fig. 8
- uncheck WET Tomo|WET tomography Settings|Blank|Blank below envelope after last iteration
- select Model/WDVS Smoothing and check box Discard WET smoothing and WDVS smoothing after forward modeling. Check box use WDVS for forward modeling of traveltimes (Fig. 9).
- check DeltatV|DeltatV Settings|Suppress velocity artefacts
- check Smooth invert|Smooth inversion Settings|Allow XTV inversion for 1D initial model
- check Smooth invert|Smooth inversion Settings|Optimize XTV for layered starting model
- 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

dit Profile					
Line ID Lin	e23			Date	of Acquisition
Line type Re Job ID	fraction spread	J/line	<u></u>	Time	
Instrument				- Time (of Processing
Client Company			_	Time	
Observer				Units	meters 💌
Note			* 	Sort Const	As acquired 💌
, Station spacing [m	1]		5.00000	🗌 Lef	t handed coordinates
Min. horizontal sep	aration [%]		25		
Profile start offset [m]		0.0000		
Force grid	cell size		Cell si	ze [m]	2.0000
Force first receiv	er station numb ition number]	er for pr	ofile 0	∏ Fo	rce first receiver
Extrapolate starti Extrapolate [stati	ng models and on spacings]	WET to	omograms 30	I▼ Ex	trapolate tomograms
Add borehole lin	es for WET ton	nograph	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	ASCII column format					
Input directory : select one data file. All data files will be imported						
Select	C:\RAY32\Line23\INPUT\					
Take shot record number from Record number						
Optionally select .HDR batch fil	e and check Batch import					
.HDR batch						
Write .HDR batch file listing sho	ts in input directory					
Write .HDR only	Import shots and write .HDR					
Overwrite existing shot data	Satch import					
Overwrite all O Prompt	overwriting					
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 in	nport Reverted spread layout use e.g. for .PIK files)					
Default sample interval [msec]	0.100000000 Force sample interval					
Default sample count	20000 Force sample count					
Import shots	ancel import <u>R</u> eset import					

Fig. 3 : File/Import Data

Fig. 2 : Header/Profile



Fig. 4 : click *No* button to to leave first receiver at station no. 3101 as specified in LINE23.ASC for shot no. 1.

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. WDVS enabled at default 300Hz (Fig. 9).



Line23 RMS error 1.6%=3.66ms 20 WET itr. 50Hz Width 9.5% initial GRADIENT.GRD v. 5.01

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

Edit Surfer plot limit	ts								
Plot Limits			OK	Fig. 8 (left) : GridlSurfer plot Limits dialog .					
Plot limits active	Use Use	data limits							
Min. offset -193.567 [m] Cancel				Edit WDVS (Zelt & Chen 2016)					
Max. offset	2394.433	[m]	Reset	Edit parameters for wavelength-dependent velocity smoothing					
Min. elevation	350.000	[m]	Reset to grid	v use WDVS for forward modeling of traveltimes					
Max. elevation	555.000	[m]	Redisplay grid	▼ fast WDVS : less accurate mapping of scan line nodes to grid nodes					
Min. velocity	200	[m/sec.]		✓ add nodes once only with overlapping scan lines for velocity averaging					
Max. velocity	6000	[m/sec.]		add all velocity nodes within WDVS area with radius of one wavelength					
Dist Saala	,			pad WDVS area border with one grid cell					
Proportional XY	Scaling			WDVS frequency 300.00 [Hz]					
Page unit centim	neter. Uncheck	for inch.		Angle increment between scan lines 7 [Degree]					
X Scale length	6.000	[inch]		Regard nth node along scan line 3 [node]					
Y Scale length	3.000	[inch]		Parameters for Cosine-Squared weighting function (Chen and Zelt 2012)					
- Color Scale				a : Cosine argument power 1.000 [power]					
Adapt color sca	le			b : Cosine-Squared power 1.000 [power]					
Scale height	3.075	[inch]		- Modify WET smoothing mode : discard after forward modeling					
Velocity interval	500	[m/sec.]		discard WET smoothing and WDVS smoothing after modeling					
Coverage interval	200	[paths/pixel]		○ restore WET smoothing and discard WDVS smoothing only					
Receiver labeling				OK Cancel Reset					
First station	3101	[station no.]							
Station interval	44	[station no.]							
Use station inde	x or station no	. offset		Fig. 9 : Model WDVS Smoothing dialog .					

Select output .El	≀R file		C:\	RAY32\LINE23\RECIPROCAL.EF
Sort lines in .ERI	R file by decreasing r	reciprocal e	error	
C Sort.ERR li	nes by relative recip	rocal error		
C Sort.ERR li	nes by absolute reci	procal erro	r in ms	
Sort.ERR li	nes by offset and CN	1P (as in Tra	ace Offset ga	ther display)
CMP interval for	mapping common-o	ffset sorted	traces to san	ne midpoint
Reciprocal CN	P interval	2.0	[station no.] to search for reciprocal traces

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

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).

- > select TracelExport 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 *TracelOpen RefractorlShot 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 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 Shot gather window (Fig. 1) if a reciprocal pick is available in the .ERR file

Run interactive WET inversion using our 1D-gradient initial model and optimized WET settings :

- ➢ select WET Tomo\Interactive WET
- ▶ set *Number of WET tomography iterations* to 50 instead of default 20. See Fig. 11.
- > set *Wavepath frequency* to 20Hz instead of default 50Hz for long profile and low-velocity overburden
- > increase Wavepath width to 20 percent from default 9.5 percent for this profile with velocity inversion
- set Ricker differentiation to -2 for Cosine-Squared weighting of the WET velocity update across the wavepath between source and receiver pair for each trace (Schuster 1993) See Fig. 11.
- ➢ set Max. velocity to 5,500 m/sec
- click button Start tomography processing to obtain Fig. 12 and Fig. 13

Edit WET Wavepath Eikonal Traveltime Tomography Parameters	Edit WET Tomography Velocity Smoothing Parameters				
Specify initial velocity model	Determination of smoothing filter dimensions				
Select C:\RAY32\Line23\GRADTOM0\GRADIENT.GRD	Full smoothing after each tomography iteration				
Stop WET inversion after	O Minimal smoothing after each tomography iteration				
Number of WET tomography iterations : 50 iterations	C Manual specification of smoothing filter, see below				
or RMS error gets below 20 percent	Smoothing filter dimensions				
	Half smoothing filter width : 16 columns				
or Rivis error does not improve for h = 20 iterations	Half smoothing filter height : 1 grid rows				
or WET inversion runs longer than 100 minutes					
WET regularization settings	Suppress artefacts below steep topography				
Wavepath frequency : 20.00 Hz Iterate	Adapt shape of filter. Uncheck for better resolution.				
Ricker differentiation [-1:Gaussian,-2:Cosine] : -2 times	Maximum relative velocity update after each iteration				
Wavepath width [percent of one period] : 20.0 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 [SD] : 3.0 sigma	Smoothing filter weighting				
- Cradient coards method	C Gaussian 💿 Uniform 🗌 No smoothing				
Steepest Descent Conjugate Gradient	Used width of Gaussian 1.0 [SD]				
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	I Smooth update				
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. 11 : select WET Tomo/Interactive WET to display main dialog and edit as shown (left). Edit velocity smoothing (right). Click buttons Accept parameters and Start tomography processing to obtain Fig. 12 and 13.





Fig. 12 : 50 Steepest-Descent WET iterations. Starting model is Fig. 5. Discard WET smoothing after forward modeling. WDVS enabled at 300 Hz (Fig. 9). Full WET smoothing (Fig. 11 right). WET wavepath frequency 20Hz. WET wavepath width 20 percent. Ricker differentiation -2 [Cosine-Squared]. Max. WET velocity 5,500 m/s (Fig. 11 left).



Fig. 13 : WET wavepath coverage plot obtained with Fig. 12. Unit is wavepaths per pixel.

Here is the link to the .RAR archive with the LINE23 profile folder for above Fig. 12 :

https://www.dropbox.com/scl/fi/4dnnao07j4xx6drxpgegf/Line23_Sep26_2024_SmoothInvert_WithOffend Shots.rar?rlkey=48sxmx6xw67t032b52cldmui7&st=i3q07aky&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.

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 interactive WET inversion with WDVS enabled :



Fig. 14 : select Refractor|Midpoint breaks. Press ALT+M to bring up mapping parameters dialog. Edit as in Fig. 15 and click button Map traces. Press ALT+G to bring up Crossover smoothing dialog. Edit as in Fig. 16 and click Accept button.

- select Refractor Midpoint breaks (Fig. 14)
- > press ALT+M and edit mapping parameters (Fig. 15) and click button Map traces
- > press ALT+G to edit the Crossover smoothing (Fig. 16). Edit as shown and click Accept button.
- select Depth|CMP Intercept-Time Refraction
- ▷ confirm warning prompt about artefacts to obtain layered refraction starting model (Fig. 17 and 18)
- ▶ when prompted to continue with WET inversion click *No* button. Redo mapping in Fig. 14/15/16.
- ▶ reselect *Depth*|*CMP* Intercept-Time Refraction. Click on title bar of *CMP* Depth Section window.
- > press ALT+M and edit *CMP Model Parameters* as shown in Fig. 17
- click OK button to obtain updated Fig. 17 and Fig. 18



Fig.	15	:	press	ALT+N	l in
Refra	ctor	Mid	point	breaks.	Edit
as sh	own	and	l click	Map trace	es.

ssover distance smoothing	
Crossover distance smoothing	
Smooth crossover distances	
Overburden filter [station nos.]	20
Basement filter [station nos.]	20
Offset limit basement coverage	
Offset limit basement coverage	
Offset limit [station nos.]	20
Accept Reset	Cancel

Fig. 16 : press ALT+G. Edit crossover smoothing parameters as shown. Click Accept button.



Fig. 17 : 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. 18 : select Depth|CMP Intercept-Time Refraction after mapping traces to refractors (Fig. 14/15/16). When prompted to continue with WET inversion click No button. Redo mapping in Fig. 14/15/16. Reselect Depth|CMP Intercept-Time Refraction. Press ALT+M and edit CMP Model Parameters (Fig. 17) and click OK button to obtain our CMP Intercept-Time refraction starting model.



Fig. 19 : select Model|WDVS Smoothing. Edit as shown and click OK button.

Edit WET Wavepath Eikonal Traveltime Tomography Parameters	Edit WET Tomography Velocity Smoothing Parameters
Specify initial velocity model	Determination of smoothing filter dimensions
C:\RAY32\Line23\LAYR10M0\CMPM0	DLGRD Minimal smoothing after each temperaphy iteration
Stop WET inversion after	Minimal smoothing after each tomography iteration
Number of WET tomography iterations : 50 iterations	C Manual specification of smoothing litter, see below
or RMS error gets below 2.0 percent	Smoothing filter dimensions
or RMS error does not improve for n = 20 iterations	Half smoothing filter width : 6 columns
or WET inversion runs longer than 100 minutes	Half smoothing filter height : 0 grid rows
WET regularization settings	Suppress artefacts below steep topography
Wavepath frequency : 20.00 Hz	Iterate Adapt shape of filter. Uncheck for better resolution.
Ricker differentiation [-1:Gaussian,-2:Cosine] : -2 times	Maximum relative velocity update after each iteration
Wavepath width [percent of one period] : 20.0 percent	tterate 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 [SD]: 3.0 sigma	Smoothing filter weighting
Gradient search method	C Gaussian 🔍 Uniform 🗌 No smoothing
Steepest Descent Conjugate Gradient	Used width of Gaussian 1.0 [SD]
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

Fi	g. 20	: select l	NET	Tomo/Int	eractive	WET	to displa	y WET	main	dialog	and	edit a	is sho	wn	(left).	Edit	velocity	smooth	hing
	(right). Click b	utton	s Accept	paramet	ters an	d Start t	omogra	aphy p	rocess	ing t	o obta	ain Fig	. 21	and	22.			

Run interactive WET inversion using our CMP Intercept-Time Refraction starting model :

- > select *Model*|*WDVS Smoothing*. Edit as in Fig. 19 and click *OK* button.
- select WET Tomol Interactive WET (Fig. 20 left). Edit main dialog as shown.
- > click button *Edit velocity smoothing* and edit as in Fig. 20 at right.
- click buttons Accept parameters and Start tomography processing (Fig. 20) to obtain Fig. 21 & 22





Fig. 21 : 50 Steepest-Descent WET iterations. Starting model is Fig. 18. Don't discard WET smoothing after forward modeling. WDVS enabled at 300 Hz (Fig. 19). Minimal WET smoothing (Fig. 20 right). WET wavepath frequency 20Hz. WET wavepath width 20 percent. Ricker differentiation -2 [Cosine-Squared]. Max. WET velocity 5,500 m/s (Fig. 20 left).



Fig. 22 : WET wavepath coverage plot obtained with Fig. 21. Unit is wavepaths per grid cell.

Here is the link to the .RAR archive with the LINE23 profile folder for above Fig. 21 :

https://www.dropbox.com/scl/fi/wr8i2nwcntp7hby4h5zrl/Line23_Sep26_2024_CMPIntercept_WET_With OffendShots.rar?rlkey=82t6341ias2te9k4tk19s2jzh&st=h2stknlr&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.

We recommend restoring WET smoothing after forward modeling (Fig. 19) when using a layered starting model such as for Fig. 21. We use *Minimal WET smoothing* (Fig. 20) with our CMP Intercept-Time Refraction layered starting model to realistically model the sudden velocity increase between bottom of overburden and top of basement based on the layered refraction starting model.

Determine Wavefront method layered refraction alternative starting model :

- check or uncheck options in Depth Depth conversion Settings as shown in Fig. 23
- > check *Refractor*|*Shot breaks*|*Mapping*|*Delete branchpoint 2 if velocity inversion* for this line
- > select *Refractor*|*Midpoint breaks*. Press ALT+U to undo current mapping of traces to refractors.
- > press ALT+M to display mapping parameters dialog. Edit as in Fig. 24. Click button *Map traces*.
- select Depth|Wavefront. Confirm prompts to obtain Wavefront starting model plot in Surfer.
- ▶ when prompted to continue with WET inversion click *No* button

- click on title bar of Wavefront Depth Section window. Press ALT+M and edit as in Fig. 26.
- ▶ click OK button. Confirm prompts to obtain updated Wavefront model (Fig. 25).
- ▶ when prompted to continue with WET inversion click *No* button
- select *Refractor*|Shot breaks. Note the updated branch points separating refractors (Fig. 1 bottom).
- press ALT+L to remap traces to refractors. Fix branch point error messages by repicking branch points for the shot numbers indicated in the error prompts. Redo ALT+L to remap traces until no more errors.
- or select File|Update header data|Update refractor branches from .BRN
- and click on the LINE23.BRN in folder C:\RAY32\LINE23\INPUT and click Open button
- ▶ select *Refractor*|*Shot breaks*. Remap traces to refractors with ALT+L (Fig. 1 bottom).
- select Depth Wavefront and confirm prompts to obtain Fig. 25 showing the updated Wavefront model.

_		
	Link traveltime curves for Wavefront	ALT+F
	Link traveltime curves for Plus-Minus	ALT+L
\checkmark	No Extrapolation of shots	ALT+E
	Keep extrapolated Shots	ALT+S
\checkmark	Skip reciprocal traveltime check	ALT+K
_	Disregard branchpoint trace for lower refractor	
	Reopen profile after mapping traces	ALT+R
	Don't smooth weathering velocity	
\checkmark	Smooth Wavefronts	ALT+W
	Prefer Geometric basement velocity for Wavefront	ALT+G
\checkmark	Show depth section with no basement coverage	
	Extrapolate tomogram over 30 station spacings	
	Reset Wavefront parameters	
	Reset Plus-Minus parameters	
	Reset CMP Intercept-time parameters	

- Fig. 23 (above) : *Depth/Depth conversion Settings*. Edit as shown.
- Fig. 24 (right) : press ALT+M in *Refractor/Midpoint breaks*. Edit as shown. Click button *Map traces*.

Trace to refractor mapping parameters								
Processing Options								
Direct wave first breaks recorded								
Update branch points with Plus-Minus								
Velocity Determination Pa	rameters -							
Refractor Count [1 or 2]		2						
CMP Stack Width [CMPs]		800						
Regression Receiver Cou	int	3						
Direct Wave Delta [station	s]	3						
Refracted Wave Offset De	lta	5						
Specify Upper Layer Velo	city Limits [r	m/sec.]						
Weathering Refractor	1 Ref	ractor 2						
1000	1000 2500 7000							
Median Laver Velocities Detected [m/sec.]								
Weathering Refractor	Weathering Refractor 1 Refractor 2							
591 2091 0								
Shot & Receiver spacing [stations], CMPs/Recvr								
2.0	1.0	2.0						
<u>Map traces</u>	<u>R</u> eset	<u>C</u> ancel						



Fig. 25 : Wavefront method layered refraction starting model obtained with *Depth/Wavefront. Depth/Depth conversion Settings* as in Fig. 23. Map traces to refractors in *Refractor/Midpoint breaks* with ALT+M (Fig. 24). Select *Depth/Wavefront* to obtain first version of Wavefront model. Select *File/Update header data/Update refractor branches from .BRN* and LINE23.BRN. Select *Refractor/Shot breaks* (Fig. 1 bottom). Remap traces to refractors with ALT+L. Reselect *Depth/Wavefront*. When prompted to continue with WET inversion click *No* button. Click on title bar of *Wavefront Depth Section*. Press ALT+M. Edit parameters as in Fig. 26 and Fig. 27. Click *OK* to obtain updated Wavefront model.

Wavefront Model Parameters
Regression parameters
Recompute traveltime characteristics
Prefer CMP overburden refractor mapping
▼ Prefer regressed traveltimes
Regression tolerance [msec.] 0.000001
Smoothing parameters
Overburden filter [station nos.] 20
Base filter width [station nos.] 25
Surface consistency [0100] 100
Limit basement velocity
✓ limit maximum basement velocity
Max. basement velocity [m/sec.] 5200
OK Cancel Reset

Fig. 26 :_select *Depth/Wavefront*. Confirm prompts to obtain Fig. 25. When prompted to continue with WET inversion click *No* button. Click on title bar of *Wavefront Depth Section*. Press Alt+M. Edit model parameters as shown and click *OK* button to obtain updated Wavefront model (Fig. 25).



Fig. 27 : select *Depth/Wavefront*. Confirm prompts to obtain Fig. 25. When prompted to continue with WET inversion click *No* button. Click on title bar of *Wavefront Depth Section*. Press Alt+M. Edit model parameters as shown (Fig. 26) and click *OK* button to obtain updated Wavefront model (Fig. 25).

Run interactive WET inversion using our Wavefront method layered refraction starting model :

- ▶ select *Model*|*WDVS Smoothing*. Edit as in Fig. 19 and click *OK* button.
- ▶ select WET TomolInteractive WET (Fig. 28 left). Edit as shown.
- click button *Edit velocity smoothing* and edit as in Fig. 28 at right.
- click buttons Accept parameters and Start tomography processing (Fig. 28) to obtain Fig. 29 & 30

Edit WET Wavepath Eikonal Traveltime Tomography Parameters	Edit WET Tomography Velocity Smoothing Parameters
Specify initial velocity model Select C:\RAY32\Line23\LAYRTOMO\WAVEMODL.GRD	Determination of smoothing filter dimensions G Full smoothing after each tomography iteration
Stop WET inversion after Number of WET tomography iterations : 50 iterations	 Minimal smoothing after each tomography iteration Manual specification of smoothing filter, see below
or RMS error gets below 2.0 percent or RMS error does not improve for n = 20 iterations	Smoothing filter dimensions Half smoothing filter width : 6 columns Half smoothing filter height : 0
WET regularization settings Wavepath frequency : 20.00 Hz	Suppress artefacts below steep topography
Ricker differentiation [-1:Gaussian,-2:Cosine] : -2 times Wavepath width [percent of one period] : 20.0 percent Iterate	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
Width of Gaussian for one period [SD]: 3.0 sigma Gradient search method © Steepest Descent © Conjugate Gradient 	Smoothing filter weighting C Gaussian I Uniform No smoothing Used width of Gaussian 1.0 [SD]
Conjugate Gradient Parameters	Uniform central row weight 1.0 [1100]
Tolerance 0.001 Line Search tol. 0.0010	Smooth update Smooth nth 🔽 Smooth last
Initial step 0.10 Steepest Descent step Edit velocity smoothing Edit grid file generation	Damping of tomogram with previous iteration tomogram Damping [01] 0.000 Damp before smoothing
Start tomography processing Reset Cancel	Accept parameters Reset parameters

Fig. 28 : select WET Tomo/Interactive WET to display main dialog (left). Edit as shown. Click button Edit velocity smoothing and edit as shown (right). Click Accept parameters and Start tomography processing to obtain Fig. 29 and Fig. 30.



Fig. 29 : WET Tomo/Interactive WET (Fig. 28) using Wavefront method starting model (Fig. 25). 50 Steepest-Descent WET iterations. Don't discard WET smoothing after forward modeling. WDVS enabled at 300 Hz (Fig. 19). Minimal WET smoothing (Fig. 28 right). WET wavepath frequency 20Hz. WET wavepath width 20 percent. Ricker differentiation -2 [Cosine-Squared]. Max. WET velocity 5,500 m/s (Fig. 28 left).





Here is the link to the .RAR archive with the LINE23 profile folder for above Fig. 29 :

https://www.dropbox.com/scl/fi/6t6rnxecuddek7m7tou23/Line23_Sep29_2024_WaveModel_WET_WithO_ffendShots.rar?rlkey=y9q4mydllkxzh3lv9ynpugedx&st=pqrw3ux8&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.

We recommend restoring WET smoothing after forward modeling (Fig. 19) when using a layered starting model such as for Fig. 29. We use *Minimal WET smoothing* (Fig. 28) with our Wavefront refraction method layered starting model to realistically model the sudden velocity increase between bottom of overburden and top of basement based on the layered refraction starting model.



Fig. 31 : select *Refractor/Midpoint breaks*. Press ALT+U to undo current trace-to-refractor mapping. Press ALT+M to show *Trace mapping parameters* dialog. Edit as in Fig. 24. Click button *Map traces*.

Since the basement refractor coverage is quite short and with gaps we change *Refractor*|*Midpoint breaks*|*ALT+M Trace mapping parameters* dialog (Fig. 24 and Fig. 31) compared to Fig. 15 :

- Iower Refractor 1 Velocity Limit to 2,500 m/s from 2,700 m/s
- ▶ increase CMP Stack Width [CMPs] to 800 from 250
- edit Depth/Depth conversion Settings as in Fig. 23 before selecting Depth/Wavefront

Configure and run pseudo-2D Automatic DeltatV inversion :

- edit Grid|Surfer plot Limits as in Fig. 8
- uncheck WET Tomo|WET tomography Settings|Blank|Blank below envelope after last iteration
- select Model/WDVS Smoothing and check box Discard WET smoothing and WDVS smoothing after forward modeling. Check box use WDVS for forward modeling of traveltimes (Fig. 9).
- check DeltatV\DeltatV Settings\Suppress velocity artefacts
- select DeltatV|Automatic DeltatV and WET inversion
- confirm prompts to obtain pseudo-2D DeltatV starting model (Fig. 32)
- when prompted to continue with WET inversion click No button





Run interactive WET inversion using our pseudo-2D DeltatV starting model :

- ▶ select WET TomolInteractive WET (Fig. 33 left). Edit as shown.
- > click button *Edit velocity smoothing* and edit as in Fig. 33 at right.
- click buttons Accept parameters and Start tomography processing (Fig. 33) to obtain Fig. 34 & 35

Edit WET Wavepath Eikonal Traveltime Tomography Parameters	Edit WET Tomography Velocity Smoothing Parameters
Specify initial velocity model Select C:\RAY32\Line23\TOMO\DELTATV.GRD	Determination of smoothing filter dimensions Full smoothing after each tomography iteration
Stop WET inversion after	 Minimal smoothing after each tomography iteration Manual specification of smoothing filter, see below
or RMS error gets below 2.0 percent	Smoothing filter dimensions Half smoothing filter width : 16 columns
or RMS error does not improve for n = 20 iterations or WET inversion runs longer than 100 minutes	Half smoothing filter height: 1 grid rows
WET regularization settings Wavepath frequency : 20.00 Hz Iterate	Suppress artefacts below steep topography Adapt shape of filter. Uncheck for better resolution.
Ricker differentiation [-1:Gaussian,-2:Cosine] : -2 times Wavepath width [percent of one period] : 20.0 percent Iterate	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 [SD]: 3.0 sigma	Smoothing filter weighting
Gradient search method	Used width of Gaussian (• Uniform) No smoothing
Conjugate Gradient Parameters	Uniform central row weight 1.0 [1100]
Tolerance 0.001 Line Search tol. 0.0010	I Smooth update ☐ Smooth nth I Smooth last
Initial step 0.10 Steepest Descent step	Damping of tomogram with previous iteration tomogram Damping [01] 0.000 Damp before smoothing
Edit grid file generation Start tomography processing Reset Cancel	Accept parameters Reset parameters

Fig. 33 : select WET Tomo/Interactive WET to display main dialog (left). Edit as shown. Click button Edit velocity smoothing and edit as shown (right). Click Accept parameters and Start tomography processing to obtain Fig. 34 and Fig. 35.



Line23 RMS error 1.5%=3.48ms 50 WET itr. 20Hz Width 20.0% initial DELTATV.GRD v. 5.01

Fig. 34 : WET Tomo/Interactive WET (Fig. 33) using DeltatV starting model (Fig. 32). 50 Steepest-Descent WET iterations. Discard WET smoothing after forward modeling. WDVS enabled at 300 Hz (Fig. 9). Full WET smoothing (Fig. 33 right). WET wavepath frequency 20Hz. WET wavepath width 20 percent. Ricker differentiation -2 [Cosine-Squared]. Max. WET velocity 5,500 m/s (Fig. 33 left).



Line23 RMS error 1.5%=3.48ms 50 WET itr. 20Hz Width 20.0% initial DELTATV.GRD v. 5.01

Here is the link to the .RAR archive with the LINE23 profile folder for above Fig. 34 :

https://www.dropbox.com/scl/fi/bgj979xh7keld6t51vueg/Line23_Sep23_2024_CMP_DeltatV_SDWET.rar ?rlkey=z0a1uzjzz0gn0v3thvt0b1ghn&st=vyfjt4p5&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.

We discard WET smoothing after forward modeling (Fig. 9) for our DeltatV starting model. We use *Full WET smoothing* (Fig. 33 right) with our pseudo-2D DeltatV starting model to smooth over or remove DeltatV artefacts during the WET inversion.

Compare Fig. 34 with Fig. 29. The lateral velocity variation in the basement is quite similar between Fig. 34 using our DeltatV starting model and Fig. 29 using our Wavefront method layered refraction starting model.

Results

The imaged basement depth has been confirmed with 5 boreholes. Bedrock was found at depths between 76 m and 99 m below line topography. The maximum difference between the SRT interpretation and drilled top-of-bedrock was 9 m (roughly 10%), normally between 2 and 4 m (3 to 5%). There is a confirmed velocity inversion in the overburden : soft lacustrine sediments below stiff gravel.

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