WET inversion of reverse VSP survey, with Rayfract® 3.25

Start up Rayfract® Standard 3.25 via desktop icon. Select *File*|*New Profile*... . Set *File name* to ZIVKO13 and click *Save button*. Specify *Station spacing* of 5 m in *Header*|*Profile* (Fig. 1). Set *Line type* to Borehole spread/line.

Unzip archive <u>zivko13.zip</u> in directory \RAY32\ZIVKO13\INPUT.

Check File/Import data Settings/Keep same Layout start for consecutive shot files and check Import horizontal borehole survey or .3DD refraction survey (Fig. 2).

Select *File*|*Import Data...* (Fig. 3) and specify *Import data type* SEG-2. Click upper *Select button*, set *Files of type* to ABEM files (*.SG2) and select Shot0001.SG2 in \RAY32\ZIVKO13\INPUT.

Click lower *Select* and .HDR batch file \RAY32\ZIVKO13\INPUT\ZIVKO13.HDF. Check box Batch import. Set Default spread type to 01: 24 channels. Click button Import shots, to import all 48 shots specified in ZIVKO13.HDR.

Edit Profile	_	
Line ID Line type Job ID Instrument Client Company Observer Note	ZIVKO13 Borehole spread/line Import .SG2 .COR .SHO .LST Seismic Source GHD / Zivko Terzic	Time of Acquisition Date Time Time of Processing Date Time Units meters Sort As acquired
Station spaci Min. horizonta Profile start of Select borel Borehole 1 lii Borehole 2 lii	ng [m] 5.0000 al separation [%] 25 ffset [m] 0.0000 nole lines for WET tomography— ne Select — ne Select —	Left handed coordinates

Fig. 1 : Header|Profile, edit profile header data

۲	\checkmark	Allow missing traces for SeisImager, SeisOpt, Gremix and .3DD files	
F		Interpolate shot point elevation for SeisOpt and .3DD files	
×		X coordinate is corrected for topography already	
	\checkmark	Default distance unit is meter	
Þ	\checkmark	Default time unit is seconds	
	\checkmark	Keep same Sample count for consecutive shot trace files	
•	\checkmark	Keep same Layout start for consecutive shot files	
•	\checkmark	Default layout start is 1.0	
		Swap borehole x with z	
	\checkmark	Import horizontal borehole survey or .3DD refraction survey	
	\checkmark	Adjust profile station spacing	
ŕ		Match .LST traces by station number	
		Round shot station to nearest whole station number	
		Reset all Import Data settings to default value	

Fig. 2 : File Import Data Settings submenu

Uncheck blanking options WET Tomo|WET tomography Settings|Blank|Blank outside borehole tomogram and Blank below envelope after last iteration.

Select *Refractor*|*Shot breaks*. Press ALT+P. Set *Maximum time* to 70 ms. Hit ENTER key to redisplay traveltime curves. Select *Mapping*|*Color picked traveltime curves*.

Select *Trace*|*Shot gather*. Press ALT+P. Set *Maximum time* to 70 ms. Hit ENTER. Select *Window*|*Tile*. Browse shots with F7/F8 (Fig. 4b).

Import data type SEG-2 Input directory : select one data file. All data files will be imported					
Select D:\ray32\ZIVK013\INPUT\					
Take shot record number from DOS file name					
Optionally select .HDR batch file and check Batch import					
Select D:\RAY32\ZIVK013\INPUT\ZIVK013.HDR					
Overwrite existing shot data					
Overwrite all O Prompt overwriting Limit offset					
Maximum offset imported [station nos.] 1000.00					
Default shot hole depth [m] Default spread type					
01: 24 channels					
Target Sample Format 16-bit fixed point					
Turn around spread by 180 degrees during import					
Correct picks for delay time (use e.g. for .PIK files)					
Import shots Cancel import					

Fig. 3 : File|Import Data ...

Select *Smooth invert*|*WET with constantvelocity initial borehole model* and confirm prompt for Fig. 5. When you see the prompt "Continue with WET tomography ?" click *No button.*

Select WET Tomo|Interactive WET tomography and configure as in Fig. 4a. Click button Edit grid file generation. Set Store each nth iteration only : n = to 100. Click buttons Accept parameters and Start tomography processing for Fig. 6 and 7.



Fig. 4a : WET Tomo Interactive WET tomography...





ZIVKO13, Constant-Velocity initial model, RMS error 9.5 %, Version 3.25





ZIVKO13, 999 WET iterations, RMS error 1.4 %, Constant-Velocity initial model, wavepath width 20%, Version 3.25



- ≻ start Windows Explorer and create new subdirectory \RAY32\ZIVKO13\2NDRUN4%
- \triangleright copy \RAY32\ZIVKO13\HOLETOMO\VELOIT999.GRD into \RAY32\ZIVKO13\2NDRUN4%\ and rename to 1STRUNIT999.GRD
- copy \RAY32\ZIVKO13\HOLETOMO\VELOIT999.PAR into \RAY32\ZIVKO13\2NDRUN4%\ and rename to \geq 1STRUNIT999.PAR
- select WET Tomo Interactive WET tomography and configure as in Fig. 8 \triangleright
- click button Edit grid file generation. Set Store each nth iteration only : n = to 100 \triangleright
- click buttons Accept parameters and Start tomography processing for Fig. 10 and 11 ≻

Edit WET Wavepath Eikonal Traveltime Tomography Parameters				
Specify initial velocity model				
Select D:\RAY32\ZIVK013\2NDRUN4%\1STRUNIT999.GRD				
Stop WET inversion after				
Number of WET tomography iterations	: [999	iterations	
or RMS error gets below	2.0	percent		
or RMS error does not improve for n = 10			iterations	
or WET inversion runs longer than 100			minutes	
WET regularization settings				
Wavepath frequency :	Γ	50	Hz	
Ricker differentiation [-1 is Gaussian bell] : 0		times		
Wavepath width [percent of one period] : 4.0			percent	
Wavepath envelope width [% of period] : 0.0			percent	
Maximum valid velocity [m/sec.] :		6000	m/sec.	
Edit velocity smoothing	Edit	grid file ge	neration	
Start tomography processing	<u>R</u> ese	t	<u>C</u> ancel	



Fig. 9 : Surfer Options|Grid Info... for CONSTVEL.GRD

Fig. 8 : WET settings for 2nd run



ZIVKO13, 999 WET iterations, RMS error 1.3 %, 2nd run, wavepath width 4%, Version 3.25



The RMS error decreases only slightly from 1.4% (Fig. 6) to 1.3% (Fig. 10). But the "top of basement" looks more plausible in Fig. 10, and velocities at the receivers are closer to 1,500 m/s.

Next we build a 1D-gradient starting model with Surfer. We can't use our DeltatV method for this, since there are no surface shots recorded, between the receivers. Then we rerun WET inversion with Fig. 14 as starting model, and limit the max. velocity to 4,500 m/s :

- create new directory \RAY32\ZIVKO13\GRADIENTMODEL, in Windows Explorer
- > open \RAY32\ZIVKO13\HOLETOMO\CONSTVEL.GRD with Surfer
- select Options | Grid Info... in Surfer, to obtain Fig. 9
- ➢ select File|New|Plot in Surfer. Select Grid|Function... and edit as Fig. 12. Click button OK.
- using Windows Explorer, copy file \RAY32\ZIVKO13\HOLETOMO\CONSTVEL.PAR into directory \RAY32\ZIVKO13\GRADIENTMODEL and rename CONSTVEL.PAR to GRADIENT.PAR
- > in Rayfract® 3.25, select Model Forward model traveltimes... and your new GRADIENT.GRD
- select Grid Image and contour velocity and coverage grids... and your GRADIENT.GRD for Fig. 14

x(y + 30.0, 0.0) * 73	.3	- ОК
m: Ma <u>x</u> im	um: <u>I</u> ncren	ment: Cancel
167.99	0.486658	3
-0.01	0.4869	
	-0.01	-0.01 0.48659

Fig. 12 : Surfer Grid|Function ... settings

Edit WET Wavepath Eikonal Traveltime Tomography Parameters						
Specify initial velocity model						
Select D:\RAY32\ZIVKO13\MAXVEL4500\GRADIENT.GRD						
Stop WET inversion after						
Number of WET tomography iterations :	999	iterations				
C or RMS error gets below	2.0	percent				
□ or RMS error does not improve for n =	10	iterations				
or WET inversion runs longer than	100	minutes				
WET regularization settings	WET regularization settings					
Wavepath frequency :	50	Hz				
Ricker differentiation [-1 is Gaussian bell] :	0	times				
Wavepath width [percent of one period] :	4.0	percent				
Wavepath envelope width [% of period] :	0.0	percent				
Maximum valid velocity [m/sec.] :	4500	m/sec.				
Edit velocity smoothing	dit <u>a</u> rid file gen	eration				
Start tomography processing	set	Cancel				

Fig. 13 : WET settings for 1D-gradient starting model





▶ in Windows Explorer, create new directory \RAY32\ZIVKO13\MAXVEL4500

- > copy files GRADIENT.GRD, GRADIENT.PAR from directory ...\GRADIENTMODEL to ...\MAXVEL4500
- select WET Tomo Interactive WET tomography... and edit as Fig. 13, click button Start tomography processing...
- confirm prompts to obtain Fig. 15 and Fig. 16





Fig. 15 : WET with 1D-gradient starting model (Fig. 14), 999 iterations, wavepath width 4% (Fig. 13)



ZIVKO13, 999 WET iterations, RMS error 1.3 %, 1D-Gradient smooth initial model, max. velocity 4,500 m/s, Version 3.25

Fig. 15 with 1D-gradient starting model is not significantly different from Fig. 10, based on Fig. 6 and constantvelocity starting model. So our 1D-gradient starting model did speed up the convergence, but the final WET velocity tomogram (Fig. 15) is not significantly improved from Fig. 10. WET inversion is not dependent on the starting model, at least in this case.

WET inversion as shown in Fig. 13, 15 & 16 took 23 minutes (999 WET iterations, 49 shots into 24 receivers) on MacBook Air with 1.8 GHz Intel Core i7 processor, using two hyper-threaded CPU cores.

Shoot from more than two boreholes to increase angular coverage and robustness of the 2D WET Wavepath Eikonal Traveltime tomographic inversion (Schuster 1993).

We thank our client GHD and Zivko Terzic for making available above data.

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