

Import SEG-2 .SG2 & Update header data & WET P-Wave VSP profile PW27 TEST v. 5.02 :

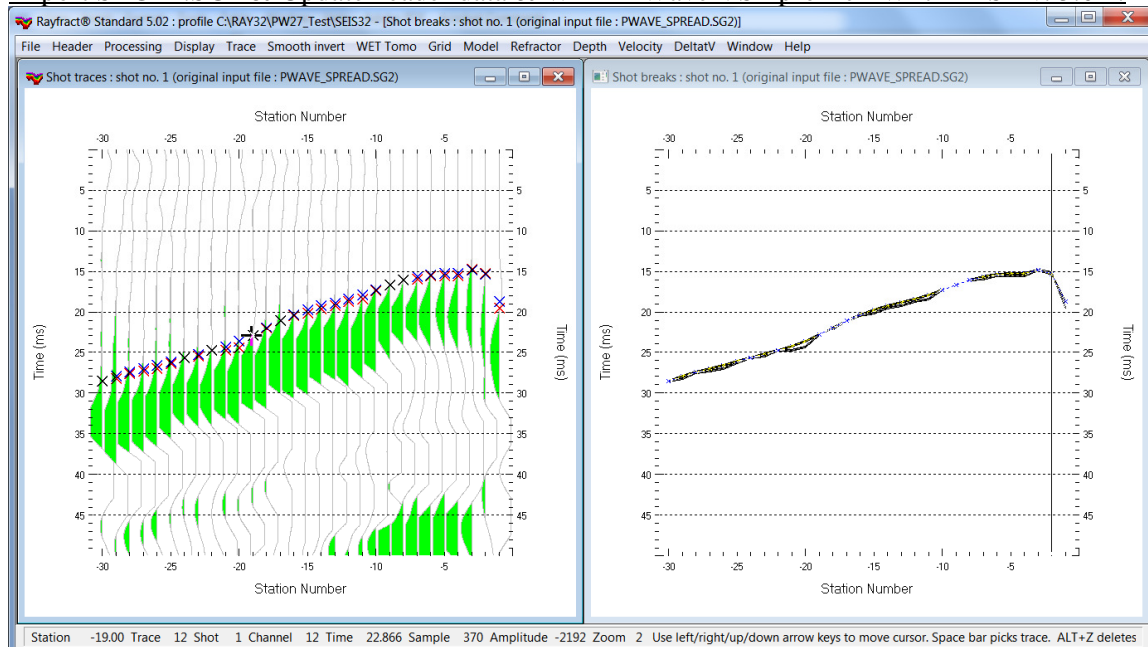


Fig. 1 : Left : *Trace/Shot gather*, right : *Refractor/Shot breaks*. Shows fit between picked times (solid curve, red crosses) and modeled times (dashed blue curve, blue crosses).

To create the profile database, aggregate the SEG-2 channels, import the aggregated .SG2 and view the imported aggregated .SG2 shot do these steps :

- **File/New Profile...**, set **File name** to **PW27_TEST** and click **Save button**
- in the prompt shown next (Fig. 4) click **No** button .
- in **Header/Profile...** set **Line type** to **Borehole spread/line** . Set **Station spacing** to 1.0m. See Fig. 2.
- unzip archive https://rayfract.com/tutorials/PW27_TEST.zip with SEG-2 .SG2 receiver channel files & files COORDS.COR & SHOTPTS.SHO & BREAKS.LST in directory C:\RAY32\PW27_TEST\INPUT
- download installer <https://rayfract.com/tools/SEG2HoleMerge.exe> and run on your PC where you are running our Rayfract® version 5.01 or 5.02
- open SEG2 HoleMerge 5.02 program via desktop icon. See Fig. 5
- click on file icon besides uppermost field **Select one SEG-2 file in INPUT directory**
- navigate into folder C:\RAY32\PW27_TEST\INPUT. At right bottom of dialog select **ABEM files (*.SG2)**
- click on one file e.g. -1.SG2 (receiver channels for elevation -1.0) and click **Open button**
- in frame **Determine geophone channel number to be merged** click radio button **P-wave recorded with first vertical channel**. See Fig. 5.
- in frame **Determine distance unit : meters or feet** click radio button **Meters**
- in frame **Determine aggregated receiver geometry for vertical borehole** set **Deepest receiver depth below topo [m]** to 30. Set next field **Receiver spacing [m]** to 1. See Fig. 5.
- in frame **Determine source position : horizontal and vertical offset from top of hole** set **Source x offset from top-of-hole [m]** to 3. Leave **Source depth below top-of-hole [m]** at 0.0.
- click button **Setup output directory** to set frame **Select output directory** to C:\RAY32\PW27_TEST\INPUT2 .
- click button **Aggregate SEG-2 files**. Confirm prompts (Fig. 6).
- the aggregated SEG-2 receiver spread file **PWave_Spread.SG2** is written into folder C:\RAY32\PW27_TEST\INPUT2 .
- click on title bar of our opened Rayfract® 5.02
- select import option **File/SEG-2 import settings and commands/Receiver coordinates specified**
- select **File/Import Data...** . Set **Import data type** to **SEG-2**. See Fig. 3.

- click *Select* button and navigate into C:\RAY32\PW27_TEST\INPUT2
- set *Files of type* to **ABEM files (*.SG2)** and select file **PWave_Spread.SG2** & click *Open*
- leave *Default spread type* at **10: 360 channels**. Click radio button **Overwrite all**.
- click **Import shots** button and confirm prompt
- in Fig. 7 dialog with title **Import C:\RAY32\PW27_TEST\INPUT2\PWave_Spread.SG2...** click *Read* button. Use *Skip* or *End* button to skip all other aggregated .SG2 receiver spreads files.
- select *File\Update header data\Update First Breaks*. Select file **BREAKS.LST** & click *Open*.
- select *Trace\Shot gather* and *Window\Tile* to obtain Fig. 1
- click on title bar of *Refractor\Shot breaks* window (Fig. 1 right) and press ALT+P. Edit *Maximum time* to 50 ms & press ENTER key to redisplay. Do the same for *Trace\Shot gather* window (Fig. 1 left).
- click on title bar of *Trace\Shot gather* window and press CTRL+F1 to zoom trace amplitude
- press CTRL+F3 to toggle trace wiggle display mode in *Trace\Shot gather* window.
- press SHIFT+Q and edit *band pass filter* as in Fig. 8 . Click *Filter* button.
- select *Display\Show picks on time axis*

Fig. 2 : Header\Profile

Fig. 3 : File\Import Data

Fig. 4 : click *No* button.

For vertical borehole/spread line profiles click 'No' button. The first receiver station will be set to station number of deepest receiver (elevation divided by *Station spacing*) during import.

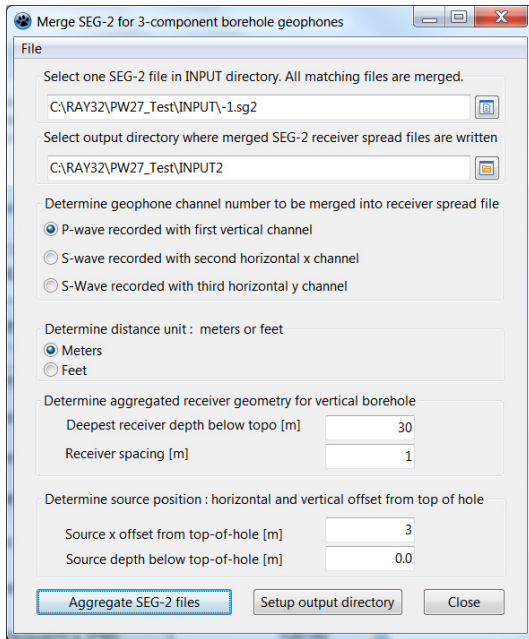


Fig. 5 : click SEG2 HoleMerge 5.02 icon. Edit as shown. Click buttons *Setup output directory* and ***Aggregate SEG-2 files***.

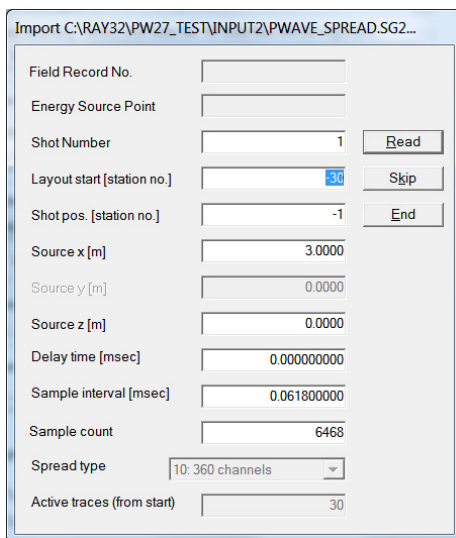


Fig. 7 : Import shot dialog. Click *Read* button. Then click *End* to skip all other aggregated .SG2.

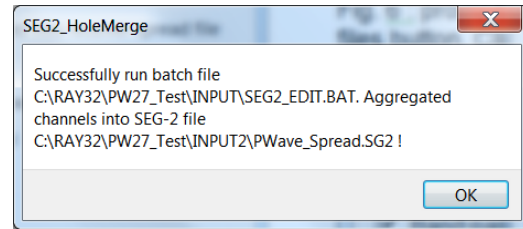


Fig. 6 : prompt shown after click on **Aggregate SEG-2 files** button. Click OK to dismiss prompt.

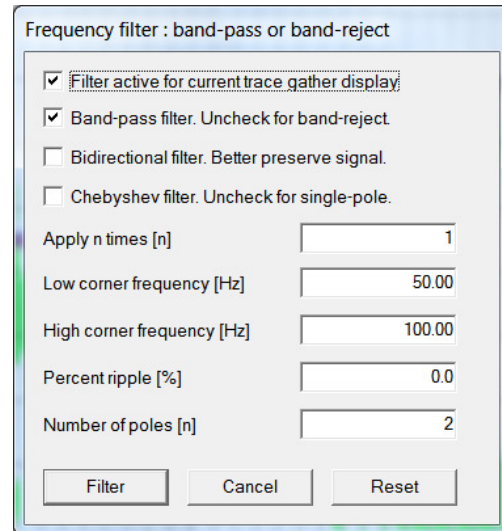
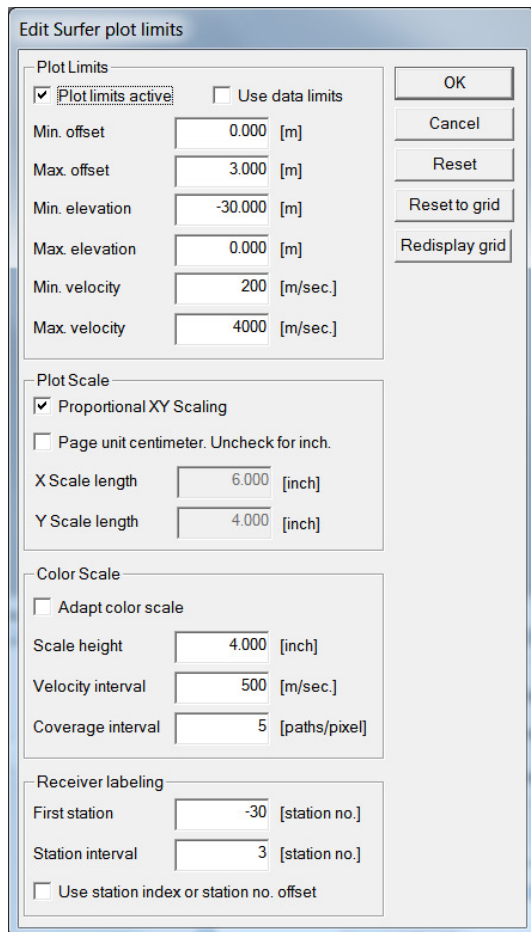


Fig. 8 : Band-pass filter dialog shown with SHIFT+Q. Edit as shown and click *Filter* button.

Configure and obtain constant-velocity starting model and run interactive WET inversion :

- check *Grid\Vertical plot title*. Check *Grid\GS CENTERED FONT* to fix Surfer 11 plot display.
- edit *Grid\Surfer plot Limits* as in Fig. 9
- select ***Smooth invert\WET with constant-velocity initial model***
- wait for the constant-velocity starting model to show as in Fig. 12 (left)
- in prompt to continue with WET inversion click *No* button
- uncheck all blanking options in *WET Tomo\WET tomography Settings\Blank* menu
- select *Model\WDVS Smoothing*. Click radio button ***Discard WET smoothing*** (Fig. 10). Click *OK*.
- check option *WET Tomo\WET tomography Settings\Scale wavepath width*
- check option *WET Tomo\WET tomography Settings\Scale WET filter height*
- select *WET Tomo\Interactive WET*. Edit main dialog as in Fig. 11 left.
- click *Select* button. Navigate into folder *C:\Ray32\PW27_Test\HOLETOMO*. Select *CONSTVEL.GRD* starting model grid.
- click button *Edit velocity smoothing*. Edit as in Fig. 11 right. Click button *Accept parameters*.
- click button *Start tomography processing* and confirm prompts to obtain Fig. 12 (center and right)



Edit Surfer plot limits

Plot Limits

☒ Plot limits active ☐ Use data limits

Min. offset: 0.000 [m]

Max. offset: 3.000 [m]

Min. elevation: -30.000 [m]

Max. elevation: 0.000 [m]

Min. velocity: 200 [m/sec.]

Max. velocity: 4000 [m/sec.]

Plot Scale

☒ Proportional XY Scaling

☐ Page unit centimeter. Uncheck for inch.

X Scale length: 6.000 [inch]

Y Scale length: 4.000 [inch]

Color Scale

☐ Adapt color scale

Scale height: 4.000 [inch]

Velocity interval: 500 [m/sec.]

Coverage interval: 5 [paths/pixel]

Receiver labeling

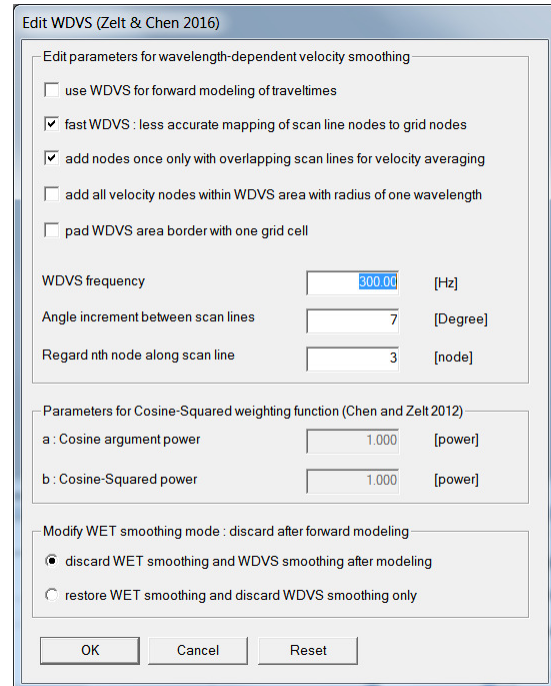
First station: -30 [station no.]

Station interval: 3 [station no.]

☐ Use station index or station no. offset

Buttons: OK, Cancel, Reset, Redisplay grid

Fig. 9 : Grid\Surfer plot Limits dialog. Check box **Limits active** and **Proportional XY scaling**. Edit as shown. Click OK button.



Edit WDVS (Zelt & Chen 2016)

Edit parameters for wavelength-dependent velocity smoothing

☐ use WDVS for forward modeling of traveltimes

☒ fastWDVS : less accurate mapping of scan line nodes to grid nodes

☒ add nodes once only with overlapping scan lines for velocity averaging

☐ add all velocity nodes within WDVS area with radius of one wavelength

☐ pad WDVS area border with one grid cell

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

☐ restore WET smoothing and discard WDVS smoothing only

Buttons: OK, Cancel, Reset

Fig. 10 : Model\WDVS Smoothing dialog. Click option **discard WET smoothing and WDVS smoothing after modeling**. Click OK.

Edit WET Wavepath Eikonal Traveltime Tomography Parameters

Specify initial velocity model
 C:\RAY32\PW27_Test\HOLETOMO\CONSTVEL.GRD

Stop WET inversion after
Number of WET tomography iterations : 500 iterations
☐ or RMS error gets below 2.0 percent
☐ or RMS error does not improve for n = 20 iterations
☐ or WET inversion runs longer than 100 minutes

WET regularization settings
Wavepath frequency : 50.00 Hz
Ricker differentiation [-1:Gaussian, -2:Cosine] : -1 times
Wavepath width [percent of one period] : 5.0 percent
Wavepath envelope width [% of period] : 0.0 percent
Min. velocity : 10 Max. velocity : 3000 m/sec.
Width of Gaussian for one period [SD] : 3.0 sigma

Gradient search method
☒ Steepest Descent ☐ Conjugate Gradient

Conjugate Gradient Parameters
CG iterations 10 Line Search iters. 2
Tolerance 0.001 Line Search tol. 0.0010
Initial step 0.10 ☐ 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 : 50 columns
Half smoothing filter height : 1 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 : 25.00 percent

Smooth after each nth iteration only
Smooth nth iteration : n = 1 iterations

Smoothing filter weighting
☐ Gaussian ☒ Uniform ☐ No smoothing
Used width of Gaussian 1.0 [SD]
Uniform central row weight 1.0 [1..100]

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

Damping of tomogram with previous iteration tomogram
Damping [0..1] 0.000 ☐ Damp before smoothing

Fig. 11 : WET Tomo/Interactive WET main dialog (left). Click **Select** button. Navigate into folder C:\Ray32\PW27_Test\HOLETOMO. Select CONSTVEL.GRD starting model grid. Edit velocity smoothing (right).

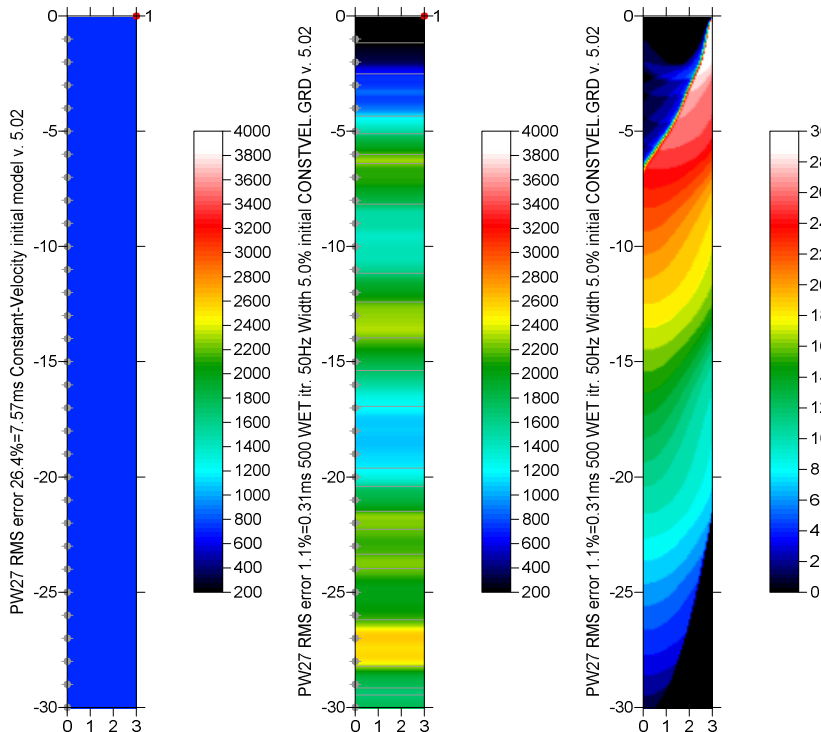


Fig. 12 : constant-velocity initial model (left). Steepest-Descent WET inversion after 500 iterations (center) with **discard WET smoothing** checked in *Model/WDVS Smoothing* (Fig. 10).

We left WET **wavepath frequency** at 50Hz and left WET **wavepath width** at 5 percent (Fig. 11 left). We increased **Number of WET iterations** to 500 from default 20 iterations. We limited the **Max. WET velocity** to 3,000 m/s.

We use a **Gaussian wavelet** for WET update weighting across the wavepath (**Ricker differentiation -1** in Fig. 11 left) and **manual WET smoothing** (Fig. 11 right) with smoothing filter **half-width** 50 grid columns and **half-height** 1 grid row. We uncheck option **Adapt shape of filter**. This manual WET smoothing filter results in horizontal layering in WET tomogram (center). Surfer plot limits as in Fig. 9.

WET wavepath coverage plot is shown at right. Unit is wavepaths per grid cell.

In menu *WET Tomo/WET tomography Settings* we checked the two options

- **Scale wavepath width**
- **Scale WET filter height**

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

ShotNo. <input type="text" value="1"/>	Time of Acquisition Date <input type="text"/>
Type <input type="text" value="Crosshole shot"/>	Time <input type="text"/>
Delay <input type="text" value="0.000000"/>	
Import data type <input type="text" value="SEG-2"/>	
Field Record No. No. <input type="text"/>	Energy Source Point No. No. <input type="text"/>
Shot Station [station no.] Pos. <input type="text" value="-1.0"/>	Sample Interval msec. <input type="text" value="0.061800"/>
Source Coords. [m] x <input type="text" value="3.0000"/> y <input type="text" value="0.0000"/> z <input type="text" value="0.0000"/>	Offset from Shot Station [m] dx <input type="text" value="3.0000"/> dy <input type="text" value="0.0000"/> dz <input type="text" value="1.0000"/>
Source Type <input type="text" value="VibroSeis"/>	Sample Count <input type="text" value="6468"/>
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="PWAVE_SPREAD.SG2"/>	
Trigger delay [msecs.] <input type="text" value="0.000000"/>	

Fig.13 : Header/Shot. Check if fields x and z in frame Source Coords. [m] match the Source x-offset from top-of-hole and Source depth below top-of-hole as specified in SEG2_HoleMerge program (Fig. 5).

Edit Stations - browse with F7/F8

Station position [station no.] Pos. <input type="text" value="-1.0"/>
Station Coordinates [m] x <input type="text" value="0.0000"/> y <input type="text" value="0.0000"/> z <input type="text" value="-1.0000"/>
Weathering velocity [m/sec.] v0 <input type="text"/>
<input type="text" value="v0 from CMP"/> <input type="text" value="v0 from Shots"/>
<input type="button" value="Reset v0"/> <input type="button" value="Correct breaks"/>
<input type="button" value="Reset coordinates and v0"/>
<input type="button" value="Interpolate coordinates and v0"/>
<input type="button" value="Correct x"/> <input type="button" value="Correct y"/>
<input type="button" value="Interpolate v0 only"/>
<input type="button" value="Force interpolate coordinates"/>

Fig. 14 : Header/Station. Use F7/F8 keys to browse to Station position [station no.] -1.0 as referenced in above Header/Shot (Fig. 13).

Download the .rar archive of the profile folder obtained with above processing from DropBox link

https://www.dropbox.com/scl/fi/wz60q1r4kt69otulrw4wa/PW27_Test.rar?rlke=y=fnjw01xq6s7xyoviyzjdovhww&st=kzqah887&dl=0

See also our updated 2024 manual <https://rayfract.com/help/rayfract.pdf>

chapter *Crosshole survey interpretation* and chapter *Downhole VSP interpretation*.

See also our twin VSP tutorial https://rayfract.com/tutorials/SH27_Test.pdf showing shear-wave VSP processing for the same borehole.

See also our 2024 VSP tutorials <https://rayfract.com/tutorials/TTBM6.pdf> and <https://rayfract.com/tutorials/TTBM4.pdf> and our earlier VSP tutorial <https://rayfract.com/tutorials/vsp.pdf>.

See also our crosshole tutorials https://rayfract.com/tutorials/MDW2011_23.pdf and <https://rayfract.com/tutorials/b8b9.pdf>

and our walkaway VSP tutorial <https://rayfract.com/tutorials/walkaway.pdf>

and our joint inversion of surface refraction spread with borehole receiver spread tutorial

<https://rayfract.com/tutorials/11REFR.pdf>

and our tutorial with receivers in 3 boreholes <https://rayfract.com/tutorials/KING17.pdf>.

- Doug Crice describes cross-hole and down-hole shear wave recording geometry in his paper http://geostuff.com/Downhole_Shearwaves.pdf
- we allow picking of shear waves on shot traces recorded with reversed shot polarity in our *Trace\Shot point gather* display. See our shear-wave VSP tutorial https://rayfract.com/tutorials/SH27_Test.pdf and our manual <https://rayfract.com/help/rayfract.pdf> chapter *Shear wave picking* and our refraction shear-wave tutorial https://rayfract.com/tutorials/SH_60m.pdf.

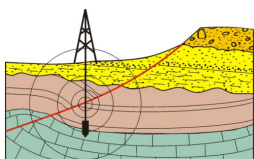
Discussion

We show gathering of SEG-2 channels recorded with AMBROGIO STRUMENTI PER LA GEOFISICA DI ALESSANDRO AMBROGIO 3-component borehole geophone into SEG-2 receiver spread files sorted by channel number and receiver elevation. **We assume that the 3-channel receiver trace files are named <receiver_elevation><optional wave type identifier>.DAT / .SG2 / .SEG2.** -1.SG2 means borehole receiver was located at elevation -1m with the borehole top at elevation 0m. -30.SG2 means borehole receiver was positioned at elevation -30m. Rename your SEG-2 receiver channel files in Windows Explorer to match this file naming convention.

Next we import the aggregated SEG-2 files into a Rayfract(R) borehole profile database. Next we apply frequency filtering and pick the P-wave first breaks. Finally we run our WET inversion using 500 Steepest-Descent iterations. We weight the velocity update across the wavepath using a Gaussian wavelet (Schuster 1993). Also we use a custom WET smoothing filter to obtain a horizontal layering in the final WET velocity tomogram. We scale the WET wavepath width with the picked time for each trace for improved weathering resolution. Also we scale the WET smoothing filter height with the grid row depth below topography.

Acknowledgements

We thank our client Dr. Carabella at Studio GeoCar Explorer di Carabella Antonio for giving us permission to use the above SEG-2 files for this tutorial and to make them available on our website. Also we thank him for giving us the impulse to write our new SEG2_HoleMerge program and for his feedback regarding interpretation of this borehole VSP data set with our latest version 5.02 software. I quote : “The sliding surface of the landslide, according to inclinometer data of the S2 survey, was detected at - 4.5 meters. In general, the consistency of the clay formation increases with depth. During the drilling phase, in the S1 survey, a possible aquifer was detected in a sandy level between -9 and -12 meters.” See Fig. 15 and Fig. 16 for the annotated geotechnical core stratigraphy for this downhole VSP survey.



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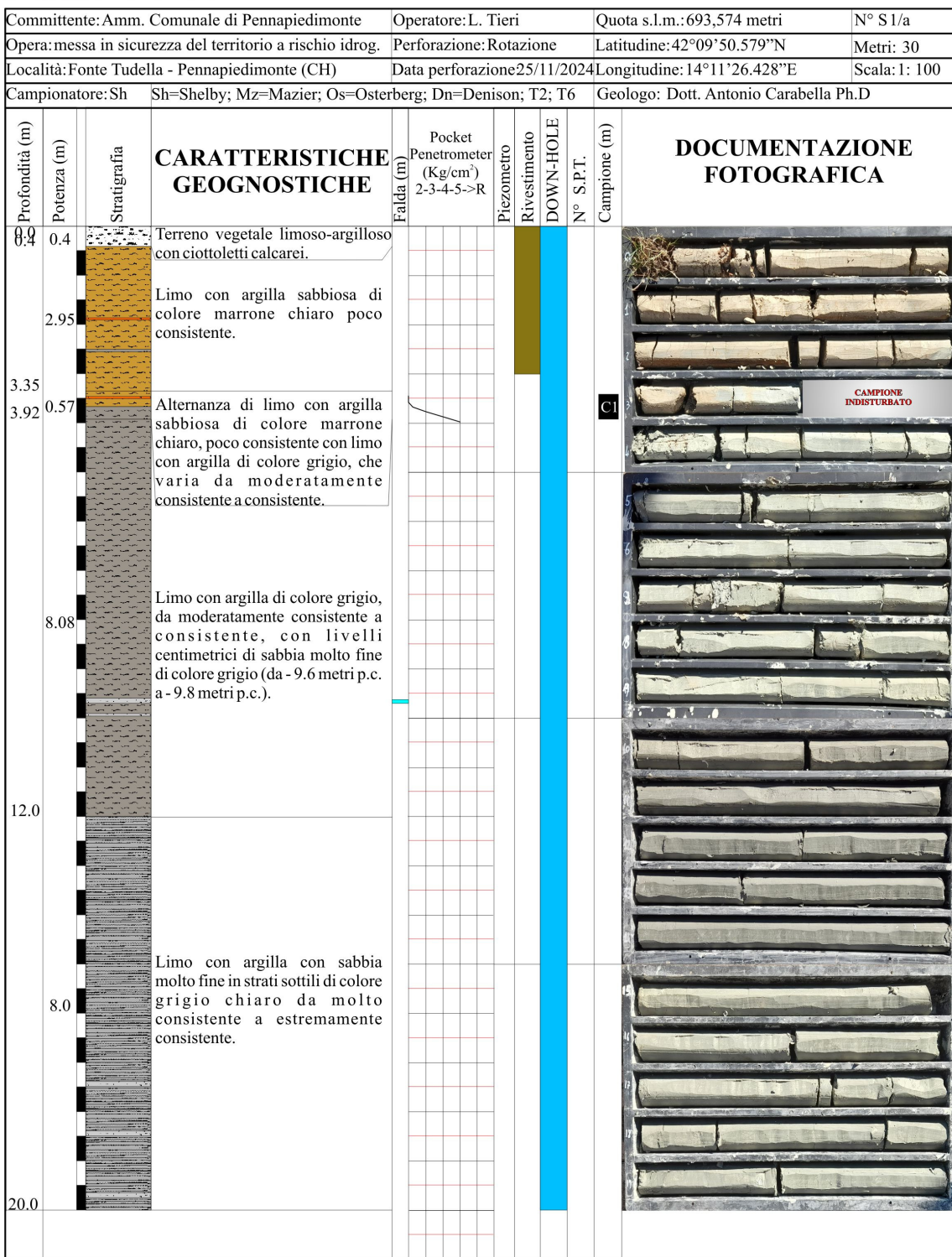
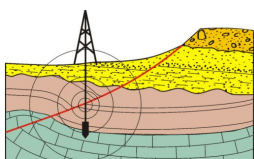


Fig. 15 : geotechnical core stratigraphy for S1 downhole VSP seismic survey. Included with permission given by Dr. Carabella.



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Dott. Geol. Antonio CARABELLA Ph.D

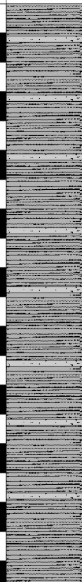








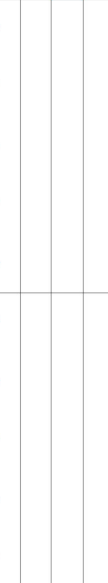




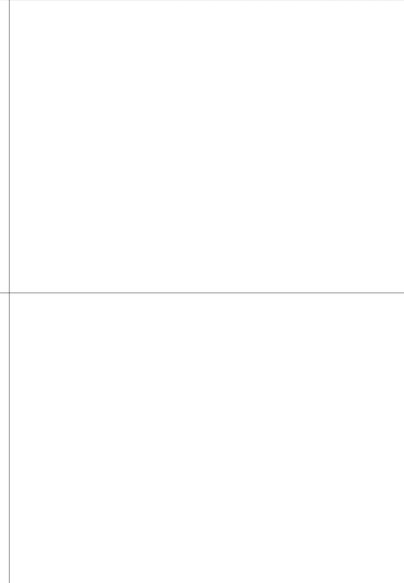
Committente: Amm. Comunale di Pennapiedimonte				Operatore: L. Tieri		Quota s.l.m.: 693,574 metri		N° S1/b															
Opera: messa in sicurezza del territorio a rischio idrog.				Perforazione: Rotazione		Latitudine: 42°09'50.579"N		Metri: 30															
Località: Colle - Pennapiedimonte (CH)				Data perforazione: 25/11/2024		Longitudine: 14°11'26.428"E		Scala: 1: 100															
Campionatore: Sh		Sh=Shelby; Mz=Mazier; Os=Osterberg; Dn=Denison; T2; T6				Geologo: Dott. Antonio Carabella Ph.D																	
Profondità (m)		Potenza (m)		Stratigrafia		CARATTERISTICHE GEOGNOSTICHE		Falda (m)		Pocket Penetrometer (Kg/cm²) 2-3-4-5->R		Piezometro		Rivestimento		DOWN-HOLE		N° S.P.T.		Campione (m)		DOCUMENTAZIONE FOTOGRAFICA	
20.0		N.D.				<p>Limo con argilla da molto consistente a estremamente consistente con strati sottili di sabbia molto fine di colore grigio chiaro.</p>																	
30.0						FONDO FORO																	

Fig. 16 : geotechnical core stratigraphy for S1 downhole VSP seismic survey. Continuation of Fig. 15. Included with permission given by Dr. Carabella.

References

Hiltunen, D. R., Hudyma, N., Quigley, T. P., & Samakur, C. 2007. Ground Proving Three Seismic Refraction Tomography Programs. Transportation Research Record, 2016(1), 110–120. <https://doi.org/10.3141/2016-12>
<https://www.researchgate.net/publication/242072938> .

Rohdewald, S.R.C. 2021a. Improving the resolution of Fresnel volume tomography with wavelength-dependent velocity smoothing, Symposium on the Application of Geophysics to Engineering and Environmental Problems Proceedings : 305-308. <https://doi.org/10.4133/sageep.33-169> . Slides at <https://rayfract.com/pub/SAGEEP%202021%20slides.pdf>

Rohdewald, S.R.C. 2021b. Improved interpretation of SAGEEP 2011 blind refraction data using Frequency-Dependent Traveltime Tomography, EGU General Assembly 2021, online, 19–30 Apr 2021, EGU21-4214, <https://doi.org/10.5194/egusphere-egu21-4214>

Schuster, Gerard T. and Quintus-Bosz, Aksel 1993. Wavepath eikonal traveltime inversion : Theory. Geophysics, volume 58, pp. 1314-1323. <https://dx.doi.org/10.1190/1.1443514>

Sheehan J.R., Doll W.E. and Mandell W.A. 2005a. An Evaluation of Methods and Available Software for Seismic Refraction Tomography. Journal of Environmental and Engineering Geophysics, volume 10, pp. 21-34. ISSN 1083-1363, Environmental and Engineering Geophysical Society. JEEG March 2005 issue. <https://dx.doi.org/10.2113/JEEG10.1.21> . https://rayfract.com/srt_evaluation.pdf
<https://www.researchgate.net/publication/242159023>

Watanabe Toshiki et al. 1999. Seismic traveltime tomography using Fresnel volume approach. SEG Houston 1999 Meeting, Expanded Abstracts. <https://www.researchgate.net/publication/240735641> .
<https://dx.doi.org/10.1190/1.1820777>

Zelt, C. A. and J. Chen 2016. Frequency-dependent traveltime tomography for near-surface seismic refraction data, Geophys. J. Int., 207, 72-88, 2016. See <https://dx.doi.org/10.1093/gji/ggw269> and <https://www.researchgate.net/publication/305487180> .

Zelt, C.A., Haines, S., Powers, M.H. et al. 2013. Blind Test of Methods for Obtaining 2-D Near-Surface Seismic Velocity Models from First-Arrival Traveltimes, JEEG, Volume 18(3), 183-194. <https://www.researchgate.net/publication/267026965>