

## Import SEG-2 .SG2 & Update header data & WET Shear-Wave VSP line SH27 TEST v. 5.02 :

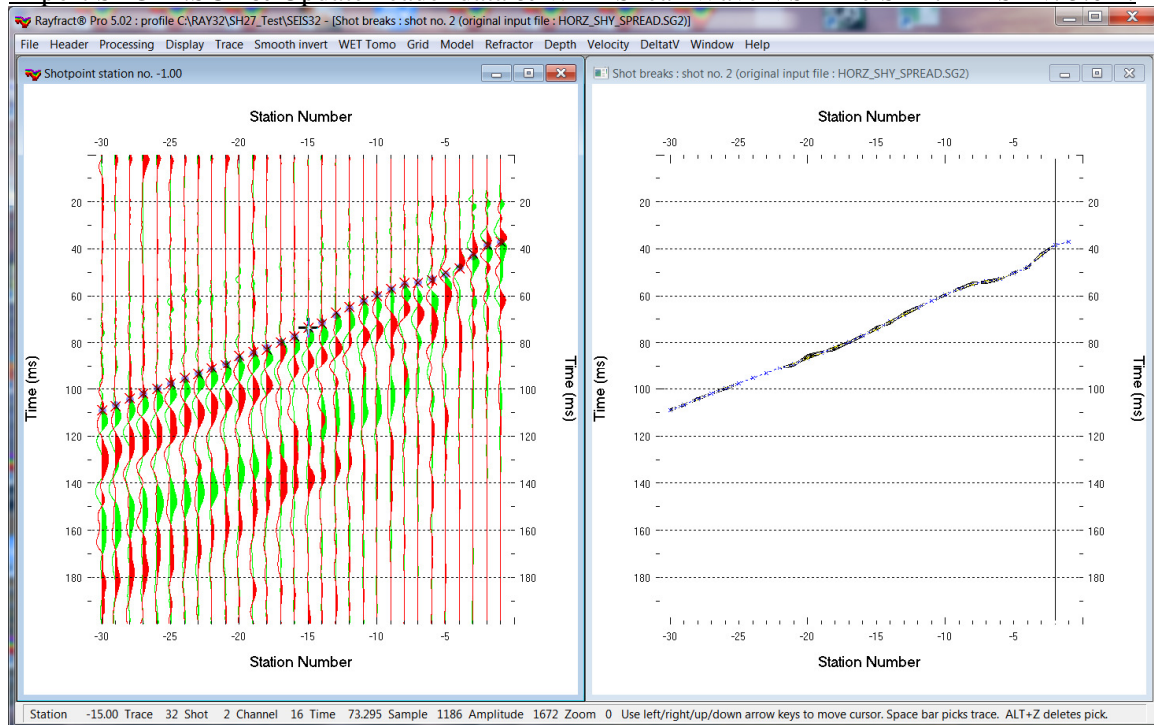


Fig. 1 : Left : Trace/Shot point gather, right : Refractor/Shot breaks. Shows fit between picked times (solid curve, red crosses) and modeled times (dashed blue curve, blue dots).

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

1. **File/New Profile...**, set **File name** to **SH27\_TEST** and click **Save**
2. in the prompt shown next (Fig. 4) click **No** button .
3. in **Header/Profile...** set **Line type** to **Borehole spread/line** . Set **Station spacing** to 1.0m. See Fig. 2.
4. unzip archive [https://rayfract.com/tutorials/SH27\\_TEST.zip](https://rayfract.com/tutorials/SH27_TEST.zip) with SEG-2 .SG2 receiver channel files & files COORDS.COR & SHOTPTS.SHO & BREAKS.LST in profile directory C:\RAY32\SH27\_TEST
5. 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
6. open SEG2 HoleMerge 5.02 program via desktop icon. See Fig. 5 .
7. click on file icon besides uppermost field **Select one SEG-2 file in INPUT directory**
8. navigate into C:\RAY32\SH27\_TEST\SH27\_DX. At right bottom of dialog select **ABEM files (\*.SG2)**
9. click on one file e.g. **-1sx.SG2** (receiver channels for elevation -1.0) and click **Open** button
10. in frame **Determine geophone channel number to be merged** click radio button **S-wave recorded with second horizontal x channel**. See Fig. 5.
11. in frame **Determine distance unit : meters or feet** click radio button **Meters**
12. 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.
13. 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.
14. click button **Setup output directory** to set frame **Select output directory** to C:\RAY32\SH27\_TEST\INPUT2 .
15. click button **Aggregate SEG-2 files**. Confirm prompts (Fig. 6). Click **Close** button.
16. the aggregated SEG-2 receiver spread file **Horz\_SHX\_Spread.SG2** is written into folder C:\RAY32\SH27\_TEST\INPUT2 .
17. repeat steps 6. to 16 for C:\RAY32\SH27\_TEST\SH27\_DY. See Fig. 9. In step 8. navigate into C:\RAY32\SH27\_TEST\SH27\_DY . In step 9. select **-1sy.SG2**. In step 10. click radio button **S-wave recorded with third horizontal y channel**. See Fig. 9. In step 16. the aggregated SEG-2 file **Horz\_SHY\_Spread.SG2** is written into folder C:\RAY32\SH27\_TEST\INPUT2 .
18. click on title bar of our opened Rayfract® 5.02

19. select import option *File\SEG-2 import settings and commands\Receiver coordinates specified*
20. select **File\Import Data...** . Set *Import data type* to **SEG-2**. See Fig. 3.
21. click *Select button* and navigate into **C:\RAY32\SH27\_TEST\INPUT2**
22. set *Files of type* to **ABEM files (\*.SG2)** and select file **Horz\_SHX\_Spread.SG2** & click *Open*
23. set *Take shot record number from* to **Job number**
24. leave *Default spread type* at **10: 360 channels**. Click radio button **Overwrite all**.
25. click **Import shots button** and confirm prompt
26. in Fig. 7 with title **Import C:\RAY32\SH27\_TEST\INPUT2\Horz\_SHX\_Spread.SG2...** set *Shot Number* to 1 and click *Read button*.
27. with updated title **Import C:\RAY32\SH27\_TEST\INPUT2\Horz\_SHY\_Spread.SG2...** set *Shot Number* to 2 and click *Read button* again. Click *Skip* or *End* button to skip all other aggregated .SG2 files.
28. select *File\Update header data\Update First Breaks*. Select file **BREAKS.LST** & click *Open*.
29. select *Trace\Shot gather*. Use F7/F8 to browse to shot no. 1. Select *Processing\Reverse Shot polarity* for the displayed shot no. 1 to enable shear-wave picking in *Trace\Shot point gather*.
30. select *Trace\Shot point gather* and *Refractor\Shot breaks* and *Window\Tile* to obtain Fig. 1
31. click on title bar of *Refractor\Shot breaks* window (Fig. 1 right). Press ALT+P. Edit *Maximum time* to 200 ms. Press **ENTER** key to redisplay. Do the same for *Trace\Shot point gather* window (Fig. 1 left).
32. click on title bar of *Trace\Shot point gather* window and press CTRL+F1 to zoom trace amplitude
33. press CTRL+F3 to toggle trace wiggle display mode. Uncheck *Display\Color trace outline*.
34. press SHIFT+Q and edit *band pass filter* as in Fig. 8 . Click *Filter* button.
35. select *Processing\Pick all shots, in shot point gather*. 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.

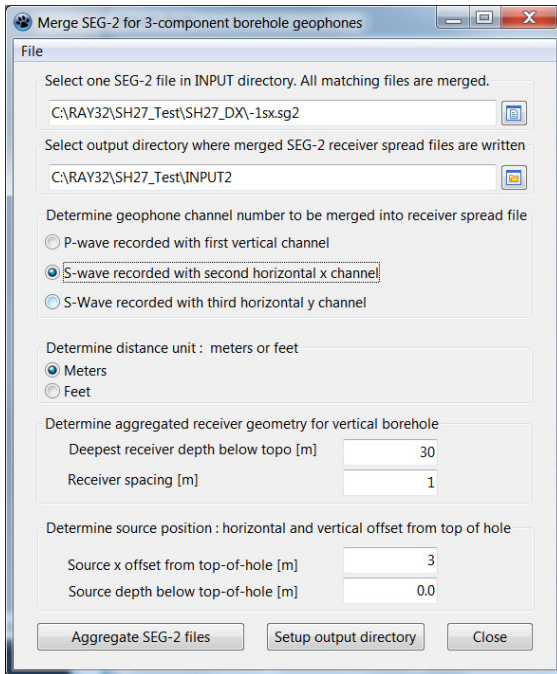


Fig. 5 : click SEG2 HoleMerge 5.02 icon. Edit as shown. Click buttons *Setup output directory* and *Aggregate SEG-2 files*.

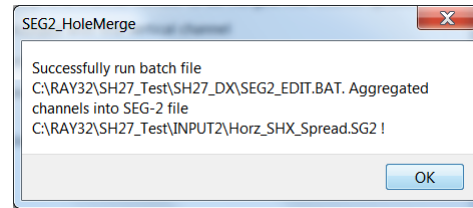


Fig. 6 : prompt shown after click on *Aggregate SEG-2 files* button. Click OK to dismiss prompt.

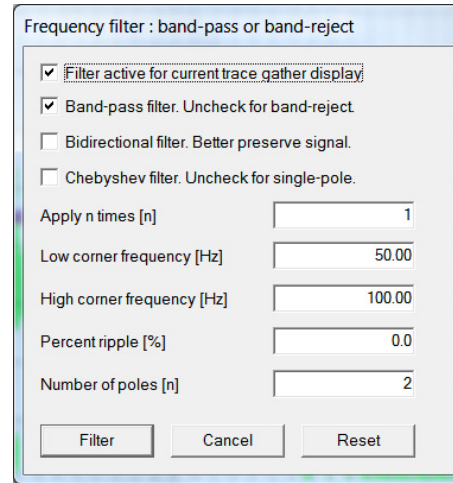


Fig. 8 (above) : Band-pass filter dialog shown with SHIFT+Q. Edit as shown and click *Filter* button.

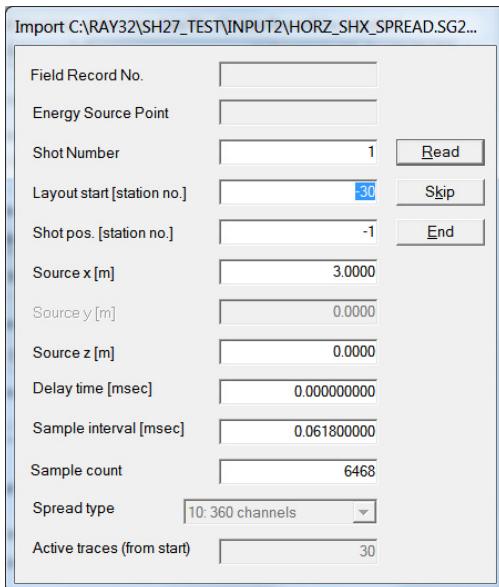


Fig. 7 (left) : click *Read* button twice to import the two aggregated .SG2 borehole receiver spreads.

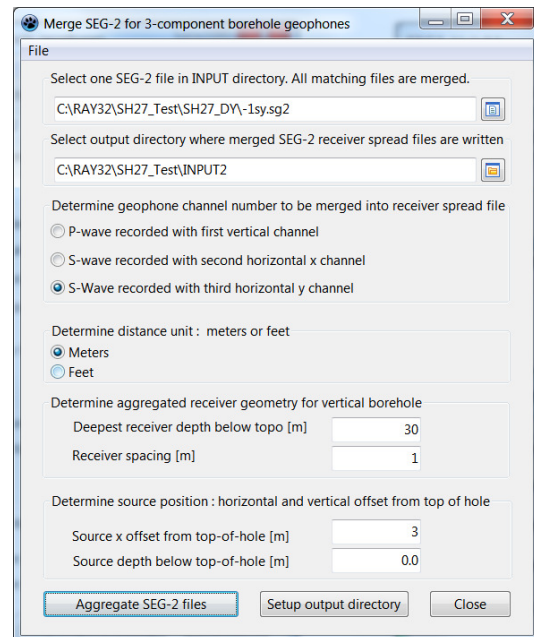
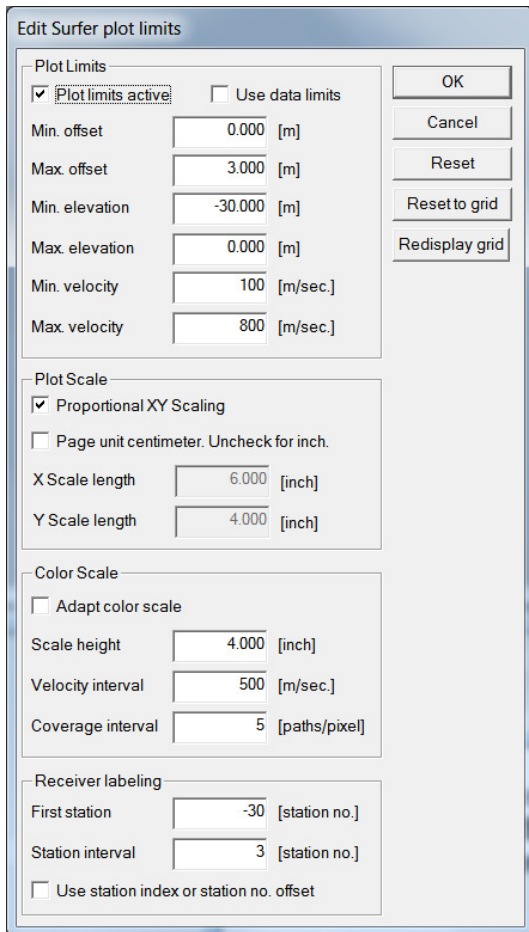


Fig. 9 : click SEG2 HoleMerge 5.02 icon. Edit as shown. Click buttons *Setup output directory* and *Aggregate SEG-2 files*.

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

- edit *Grid\Surfer plot Limits* as in Fig. 10
- check *Grid\Vertical plot title*. Check *Grid\GS CENTERED FONT* to fix Surfer 11 plot display.
- select ***Smooth invert\WET with constant-velocity initial model***
- wait for the constant-velocity starting model to show as in Fig. 13 (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 ***restore WET smoothing*** (Fig. 11). 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. 12 left.
- click *Select* button. Navigate into folder *C:\Ray32\SH27\_Test\HOLETOMO*. Select *CONSTVEL.GRD* starting model grid.
- click button *Edit velocity smoothing*. Edit as in Fig. 12 right. Click button *Accept parameters*.
- click button *Start tomography processing* and confirm prompts to obtain Fig. 13 (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: 100 [m/sec.]

Max. velocity: 800 [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**

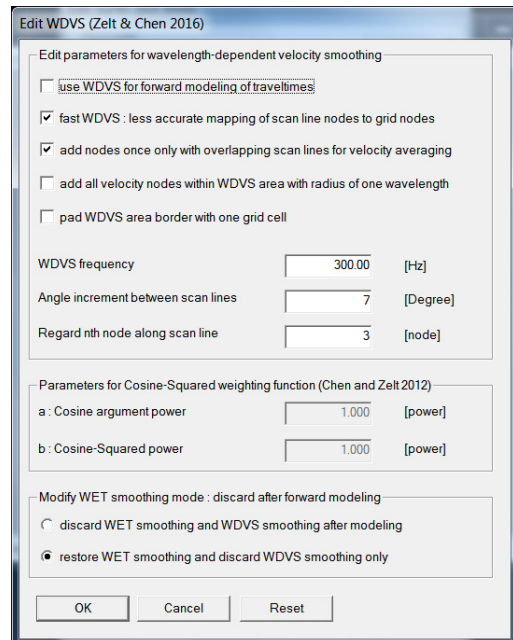
First station: -30 [station no.]

Station interval: 3 [station no.]

☐ Use station index or station no. offset

Buttons: OK, Cancel, Reset, Reset to grid, Redisplay grid

Fig. 10 : *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

☒ fast WDVS : 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. 11 : *Model\WDVS Smoothing* dialog. Click option **restore WET smoothing discard WDVS smoothing only**. Click OK.



### Edit WET Wavepath Eikonal Traveltime Tomography Parameters

Specify initial velocity model  
Select C:\RAY32\SH27\_Test\HOLETOMO\CONSTVEL.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 Iterate  
Ricker differentiation [-1:Gaussian, -2:Cosine] :  times  
Wavepath width [percent of one period] :  percent Iterate  
Wavepath envelope width [% of period] :  percent  
Min. velocity :  Max. velocity :  m/sec.  
Width of Gaussian for one period [SD] :  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 velocity smoothing Edit grid file generation  
Start tomography processing Reset Cancel

### 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  [SD]  
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

Accept parameters Reset parameters

Fig. 12 : WET Tomo/Interactive WET main dialog (left). Click **Select** button. Navigate into folder C:\Ray32\SH27\_Test\HOLETOMO. Select CONSTVEL.GRD starting model grid. Edit velocity smoothing (right).

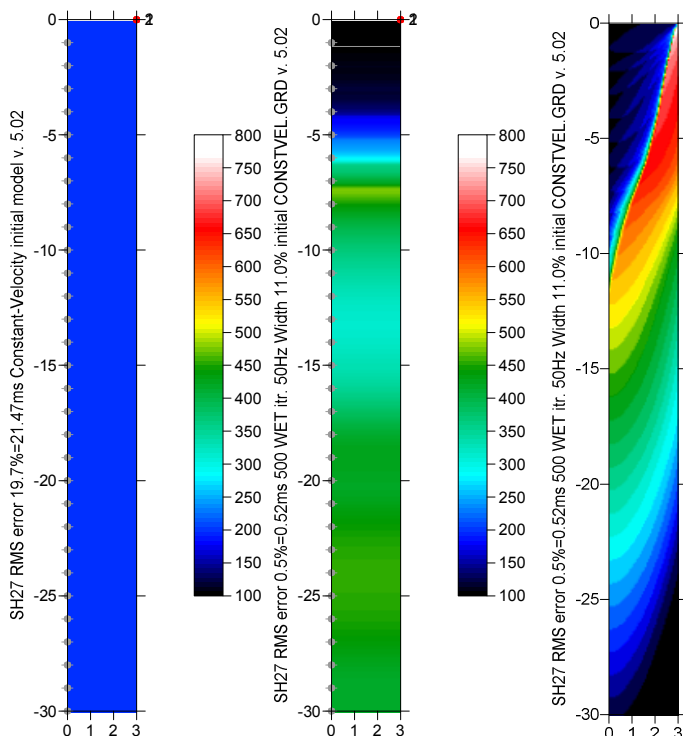


Fig. 13 : constant-velocity initial model (left). Steepest-Descent WET inversion after 500 iterations (center) with **restore WET smoothing** checked in Model/WDVS Smoothing (Fig. 11).

We left WET **wavepath frequency** at 50Hz and left WET **wavepath width** at 11 percent (Fig. 12 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. 12 left) and **manual WET smoothing** (Fig. 12 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. 10.

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
Type <input type="text" value="Crosshole shot"/>	Date <input type="text"/>
Delay <input type="text" value="0.000000"/>	Time <input type="text"/>
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]	Offset from Shot Station [m]
x <input type="text" value="3.0000"/>	dx <input type="text" value="3.0000"/>
y <input type="text" value="0.0000"/>	dy <input type="text" value="0.0000"/>
z <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="HORZ_SHX_SPREAD.SG2"/>	
Trigger delay [msecs.] <input type="text" value="0.000000"/>	

Fig. 14 : 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="button" value="v0 from CMP"/> <input type="button" 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. 15 : Header/Station. Use F7/F8 keys to browse to *Station position [station no.] -1.0* as referenced in above Header/Shot (Fig. 14).

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

[https://www.dropbox.com/scl/fi/er9c2n33v2m34nndepho7/SH27\\_Test.rar?rlk=va7mwtextnh8up2ufy931ix97p&st=xhgjc0xs&dl=0](https://www.dropbox.com/scl/fi/er9c2n33v2m34nndepho7/SH27_Test.rar?rlk=va7mwtextnh8up2ufy931ix97p&st=xhgjc0xs&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/PW27\\_Test.pdf](https://rayfract.com/tutorials/PW27_Test.pdf) showing P-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](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](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 above and our manual <https://rayfract.com/help/rayfract.pdf> chapter *Shear wave picking* and our tutorial [https://rayfract.com/tutorials/SH\\_60m.pdf](https://rayfract.com/tutorials/SH_60m.pdf).

## Discussion

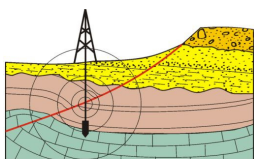
We show gathering of SEG-2 channels recorded with AMBROGEO STRUMENTI PER LA GEOFISICA DI ALESSANDRO AMBROGIO 3-component borehole geophone into SEG-2 receiver spread files sorted by channel number and receiver elevation. **We assume that the 3-channel receiver trace files are named <receiver\_elevation><optional wave identifier>.DAT / .SG2 / .SEG2.** -1.SG2 / -1sx.SG2 / -1sy.SG2 means the borehole receiver was located at elevation -1m with the borehole top at elevation 0m.

-30.SG2 / -30sx.SG2 / -30sy.SG2 means the 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 two aggregated SEG-2 borehole receiver spread files into a Rayfract(R) borehole profile database. Next we apply frequency filtering and pick the shear-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. 16 and Fig. 17 for the annotated geotechnical core stratigraphy for this downhole VSP survey.



**STUDIO GeoCar Explorer**  
Dott. Geol. Antonio CARABELLA Ph.D


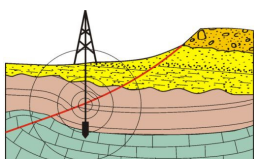
Committente: Amm. Comunale di Pennapiedimonte			Operatore: L. Tieni			Quota s.l.m.: 693,574 metri			N° S1/a		
Opera: messa in sicurezza del territorio a rischio idrog.			Perforazione: Rotazione			Latitudine: 42°09'50.579"N			Metri: 30		
Località: Fonte Tudella - Pennapiedimonte (CH)			Data perforazione 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					
<div><div><div>Profondità (m)</div><div>Potenza (m)</div><div>Stratigrafia</div></div><div><div>CARATTERISTICHE GEOGNOSTICHE</div><div>Terreno vegetale limoso-argilloso con ciottolotti calcarei.</div><div>Limo con argilla sabbiosa di colore marrone chiaro poco consistente.</div><div>Alternanza di limo con argilla sabbiosa di colore marrone chiaro, poco consistente con limo con argilla di colore grigio, che varia da moderatamente consistente a consistente.</div><div>Limo con argilla di colore grigio, da moderatamente consistente a consistente, con livelli centimetrici di sabbia molto fine di colore grigio (da - 9.6 metri p.c. a - 9.8 metri p.c.).</div><div>Limo con argilla con sabbia molto fine in strati sottili di colore grigio chiaro da molto consistente a estremamente consistente.</div></div><div><div>Falda (m)</div><div>Pocket Penetrometer (Kg/cm²) 2-3-4-5-&gt;R</div><div>Piezometro</div><div>Rivestimento</div><div>DOWN-HOLE</div><div>N° S.P.T.</div><div>Campione (m)</div></div><div><div>DOCUMENTAZIONE FOTOGRAFICA</div><div><div><div>0.4</div><div>0.4</div><div>2.95</div><div>3.35</div><div>3.92</div><div>0.57</div><div>8.08</div><div>12.0</div><div>8.0</div><div>20.0</div></div><div><div>CL</div><div>CAMPIONE INDISTURBATO</div></div><div></div></div></div></div>											

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





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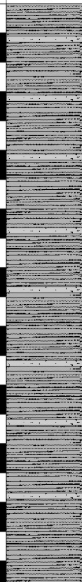








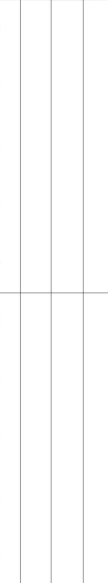




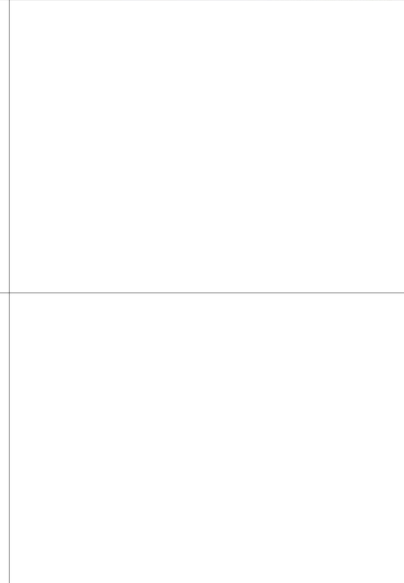
Committente: Amm. Comunale di Pennapedimonte				Operatore: L. Tieri		Quota s.l.m.: 693,574 metri		N° S1/b					
Opera: messa in sicurezza del territorio a rischio idrog.				Perforazione: Rotazione		Latitudine: 42°09'50.579"N		Metri: 30					
Località: Colle - Pennapedimonte (CH)				Data perforazione 25/11/2024		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.		Limo con argilla da molto consistente a estremamente consistente con strati sottili di sabbia molto fine di colore grigio chiaro.										
30.0			FONDO FORO										

Fig. 17 : geotechnical core stratigraphy for S1 downhole VSP seismic survey. Continuation of Fig. 16. 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> .

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