

Import SEG-2 & WET S-Wave VSP BOATSH26 AMBROGEO Twin borehole geophone 5.02 :

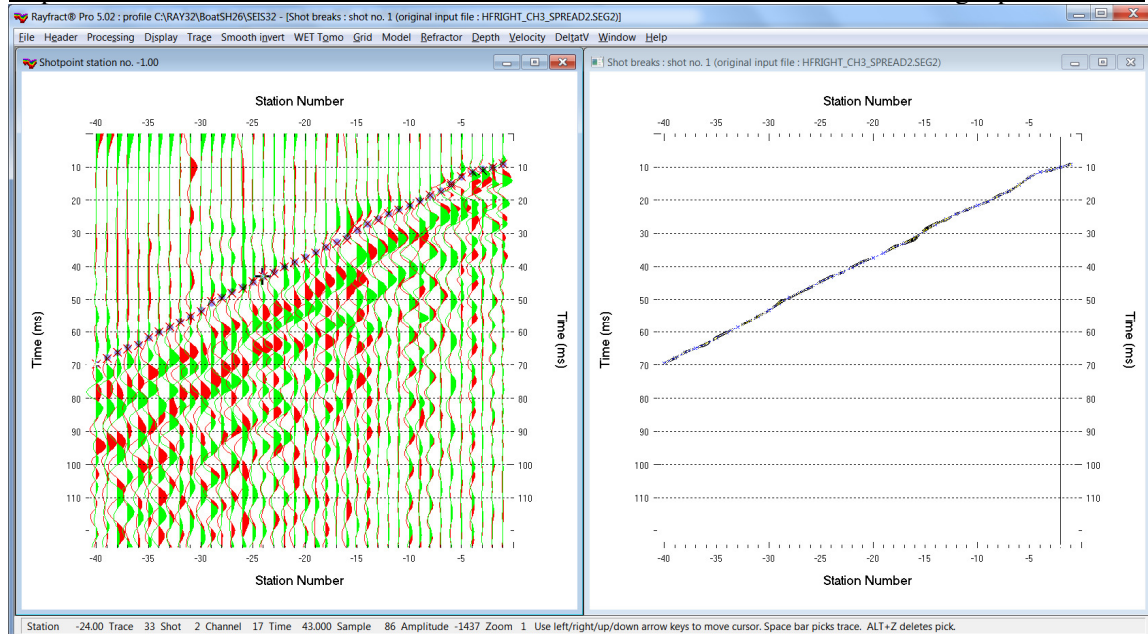


Fig. 1 : Left : *Trace/Shot point gather*, right : *Refractor/Shot breaks*. Shows fit between picked times (solid curve, red crosses) and modeled times (dashed blue curve, blue dots).

To create the profile database, aggregate the SEG-2 channels, import the aggregated .SEG2 and view the two imported aggregated .SEG2 shear-wave shots do these steps :

1. **File\New Profile...**, set **File name** to **BOATSH26** 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/BOATSH26.zip> with SEG-2 .SEG2 receiver channel files & files COORDS.COR & SHOTPTS.SHO & BREAKS.LST in profile directory C:\RAY32\BOATSH26
5. download installer <https://rayfract.com/tools/SEG2HoleMerge.exe> and run on your PC where you are running our Rayfract® 5.01 or 5.02 Standard or Pro software.
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\BOATSH26\INPUT. At right bottom of dialog select **DMT files (*.SEG2)**.
9. click **2HFRIGHT.SEG2** (receiver channels for elevation -2.0, right shear-wave) and click **Open** button
10. in frame **Determine geophone channel number to be merged** click radio button **S-wave recorded with third horizontal y channel**. See Fig. 5.
11. in frame **Determine distance unit : meters or feet** click radio button **Meters**
12. click radio button **Do extract 3 channels for 2nd receiver into separate SEG-2 channel file**. See Fig. 5.
13. set **Double geophone receiver separation [m]** to 1. See Fig 5.
14. in frame **Determine aggregated receiver geometry for vertical borehole** set **Deepest receiver depth below topo [m]** to 40. Set next field **Receiver spacing [m]** to 1. See Fig. 5.
15. 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.
16. click button **Setup output directory** to set frame **Select output directory** to C:\RAY32\BOATSH26\INPUT2 .
17. click button **Aggregate SEG-2 files**. Confirm prompts (Fig. 6). Click **Close** button.
18. the aggregated SEG-2 receiver spread file **HFRIGHT_ch3_Spread2.SEG2** is written into folder C:\RAY32\BOATSH26\INPUT2 .
19. repeat steps 6. to 18. for C:\RAY32\BOATSH26\INPUT\2HFLeft.SEG2. See Fig. 9. In step 9. select **2HFLeft.SEG2**. In step 10. click radio button **S-wave recorded with third horizontal y channel**. See Fig. 9. In step 18. the aggregated SEG-2 file **HFLeft_ch3_Spread2.SEG2** is written into folder C:\RAY32\BOATSH26\INPUT2 .
20. click on title bar of our opened Rayfract® 5.02
21. select import option **File\SEG-2 import settings and commands\Receiver coordinates specified**

22. select **File\Import Data...** . Set *Import data type* to **SEG-2**. See Fig. 3.
23. click *Select button* and navigate into **C:\RAY32\BOATSH26\INPUT2**
24. set *Files of type* to **DMT files (*.SEG2)** and select file **HFRight_ch3_Spread2.SEG2** & click *Open*
25. set *Take shot record number from* to **Job number**
26. leave *Default spread type* at **10: 360 channels**. Click radio button **Overwrite all**.
27. click **Import shots button** and confirm prompt
28. in Fig. 7 with title **Import C:\RAY32\BOATSH26\INPUT2\HFLeft_ch3_Spread2.SEG2** ... set *Shot Number* to 2 and click *Read button*. Click *Skip button* to skip other aggregated .SEG2 files.
29. with updated title **Import C:\RAY32\BOATSH26\INPUT2\HFRight_ch3_Spread2.SEG2**... set *Shot Number* to 1 and click *Read button*. Click *Skip* or *End button* to skip all other aggregated .SEG2 files.
30. select **File\Update header data\Update First Breaks**. Select file **BREAKS.LST** & click *Open*.
31. select **Trace\Shot point gather** and **Refractor\Shot breaks** and **Window\Tile** to obtain Fig. 1
32. click on title bar of **Refractor\Shot breaks** window (Fig. 1 right). Press ALT+P. Edit *Maximum time* to 125 ms. Press **ENTER** key to redisplay. Do the same for **Trace\Shot point gather** window (Fig. 1 left).
33. click on title bar of **Trace\Shot point gather** window and press CTRL+F1 to zoom trace amplitude
34. press CTRL+F3 to toggle trace wiggle display mode. Uncheck **Display\Color trace outline**.
35. press SHIFT+Q and edit *band pass filter* as in Fig. 8 . Click *Filter button*.
36. 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 : in prompt **Force first receiver at station number 1 ?** 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.

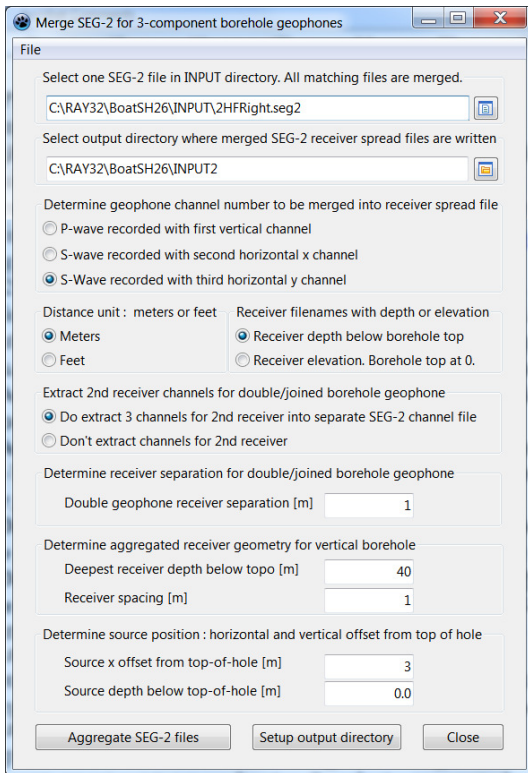


Fig. 5 : click SEG2 HoleMerge 5.02 icon. Edit as shown. Click buttons *Setup output directory* and *Aggregate SEG-2 files*.

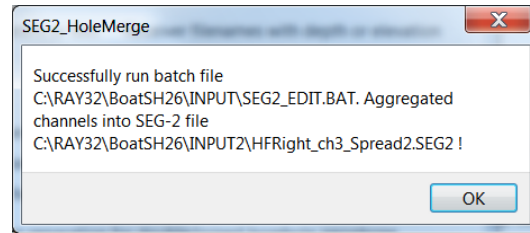


Fig. 6 : click *OK button* to dismiss success prompt.

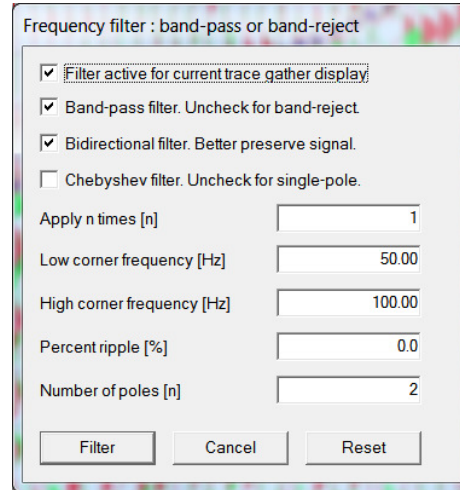


Fig. 8 : Band-pass filter dialog shown with SHIFT+Q. Edit as shown and click *Filter* button.

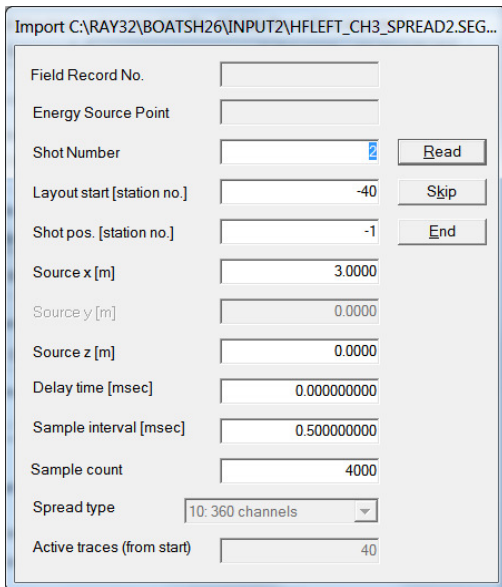


Fig. 7 : click *Read* button to import the two aggregated .SEG2 borehole receiver spreads. Click *Skip* button to skip all other .SEG2 spread files.

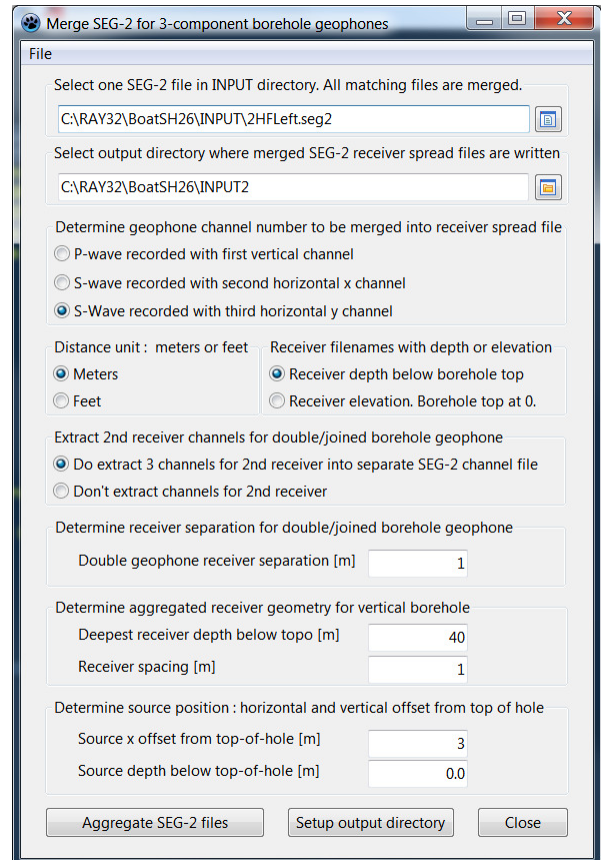


Fig. 9 (right) : click SEG2 HoleMerge 5.02 icon. Edit as shown. Click buttons *Setup output directory* and *Aggregate SEG-2 files*.

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 ***discard 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\BOATSH26\HOLETOMO*. Select *CONSTVEL.GRD* starting model grid.
- click button *Edit velocity smoothing*. Edit as in Fig. 12 right. Click button *Accept parameters*.
- click button *Edit grid file generation*. Edit as in Fig. 15. Click button *Accept parameters*.
- click button *Start tomography processing* and confirm prompts to obtain Fig. 13 (center and right)
- select *Grid\Export grid file to ASCII.TXT*. Edit dialog as in Fig. 17 and click button *Export to .TXT*.
- open *c:\Ray32\BOATSH26\HOLETOMO\VELOIT999.TXT* in Microsoft Notepad editor as in Fig. 18

Edit Surfer plot limits

Plot Limits

☒ Plot limits active ☐ Use data limits

Min. offset: 0.000 [m]

Max. offset: 3.000 [m]

Min. elevation: -40.000 [m]

Max. elevation: 0.000 [m]

Min. velocity: 200 [m/sec.]

Max. velocity: 1000 [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: -40 [station no.]

Station interval: 4 [station no.]

☐ Use station index or station no. offset

Buttons: OK, Cancel, Reset, 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 **discard WET smoothing and WDVS smoothing after modeling**. Click OK.

Edit WET Wavepath Eikonal Traveltime Tomography Parameters

Specify initial velocity model
 C:\RAY32\BoatSH26\HOLETOMO\CONSTVEL.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 = 20 iterations
☐ or WET inversion runs longer than 100 minutes

WET regularization settings
Wavepath frequency : 50.00 Hz
Ricker differentiation [-1:Gaussian, -2:Cosine] : 0 times
Wavepath width [percent of one period] : 8.0 percent
Wavepath envelope width [% of period] : 0.0 percent
Min. velocity : 10 Max. velocity : 6000 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 : 0 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. 12 : WET Tomo/Interactive WET main dialog (left). Click *Select* button. Navigate into folder C:\Ray32\BOATSH26\HOLETOMO. Select CONSTVEL.GRD starting model grid. Edit velocity smoothing (right).

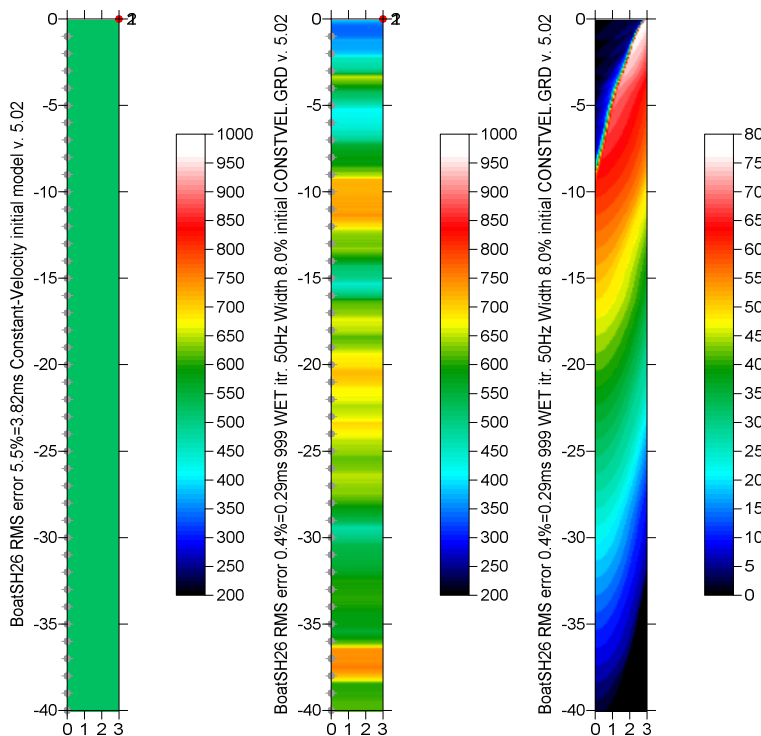


Fig. 13 : constant-velocity initial model (left). Steepest-Descent WET inversion after 999 iterations (center) with **discard WET smoothing** checked in *Model/WDVS Smoothing* (Fig. 11).

We left WET **wavepath frequency** at 50Hz and left WET **wavepath width** at 8 percent (Fig. 12 left). We increased **Number of WET iterations** to 999 from default 20 iterations. We left the **Max. WET velocity** at 6,000 m/s.

We use a **Ricker wavelet** for WET update weighting across the wavepath (**Ricker differentiation** 0 in Fig. 12 left; Schuster 1993) and **manual WET smoothing** (Fig. 12 right) with smoothing filter **half-width** 50 grid columns and **half-height** 0 grid rows. 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**

Fig. 14 (left) : *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 Shot - browse with F7/F8, enter changes with RETURN
 ShotNo. 1 Time of Acquisition
 Type Crosshole shot Date 11/05/2025
 Delay 0.000000 Time 11:17:08
 Import data type SEG-2
 Field Record No. No. Energy Source Point No. No.
 Shot Station [station no.] Pos. -1.0 Sample Interval msec. 0.500000
 Source Coords. [m] Offset from Shot Station [m]
 x 3.0000 dx 3.0000
 y 0.0000 dy 0.0000
 z 0.0000 dz 1.0000
 Source Type Hammer Sample Count 4000
 Source elevation [m] 0.0000
 Uphole time correction term [msecs.] 0.000000
 Original filename HFRIGHT_CH3_SPREAD2.SEG2
 Trigger delay [msecs.] 0.000000

Fig. 14 (left) : *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).

Fig. 15 (above) : *WET Tomo/Interactive WET/Edit grid file generation*. Edit as shown and click *Accept parameters* button.

Edit WET Tomography Intermediate Grid File Generation
 Delete traveltimes grid files for shots and receivers
☒ Delete traveltimes grid files for last WET iteration
 Generate intermediate WET grid files for last iteration
 Write wavepaths to disk for shot no. : -1
 Write misfit gradients to disk for shot no. : -1
 Write profile coverage and update for each WET iteration
☐ Write section velocity update grids after each iteration
☒ Write section coverage grids after each iteration
 Store each nth iteration only : n = 50
☐ Write grids for Line Search during Conjugate Gradient
 Accept parameters Reset parameters

Fig. 15 (above) : *WET Tomo/Interactive WET/Edit grid file generation*. Edit as shown and click *Accept parameters* button.

Fig. 16 (left) : *Header/Station*. Use F7/F8 keys to browse to *Station position [station no.] -1.0* as referenced in above *Header/Shot* (Fig. 14).

Edit Stations - browse with F7/F8
 Station position [station no.] Pos. -1.0
 Station Coordinates [m]
 x 0.0000
 y 0.0000
 z -1.0000
 Weathering velocity [m/sec.] v0
 v0 from CMP v0 from Shots
 Reset v0 Correct breaks
 Reset coordinates and v0
 Interpolate coordinates and v0
 Correct x Correct y
 Interpolate v0 only
 Force interpolate coordinates

Fig. 16 (left) : *Header/Station*. Use F7/F8 keys to browse to *Station position [station no.] -1.0* as referenced in above *Header/Shot* (Fig. 14).

Fig. 17 (above) : select *Grid/Export grid file to ASCII.TXT*. Edit as shown and click button *Export to .TXT*. Open *VELOIT999.TXT* in Microsoft Notepad editor as in Fig. 18.

Export Surfer .GRD to ASCII .TXT with x/y/z coordinates
 Select input .GRD and output .TXT files
 Select grid file C:\RAY32\BoatSH26\HOLETOMO\VELOIT999.GRD
 Select .TXT file C:\RAY32\BoatSH26\HOLETOMO\VELOIT999.TXT
 Specify velocity range to export to .TXT
☐ Export velocity range
 Min. velocity [m/sec.] Max. velocity [m/sec.]
 Export to .TXT Cancel Reset

Fig. 17 (above) : select *Grid/Export grid file to ASCII.TXT*. Edit as shown and click button *Export to .TXT*. Open *VELOIT999.TXT* in Microsoft Notepad editor as in Fig. 18.

Fig. 18 : Open Windows Explorer window. Navigate into C:\Ray32\BOATSH26\HOLETOMO folder. Right-click *VELOIT999.TXT* and select *Open with* and Notepad.

VELOIT999.TXT - Notepad
 File Edit Format View Help

| X | Y | Z | Velocity(m/s) | horz. offset from 1st rcvr | station no. |
|--------|--------|----------|---------------|----------------------------|-------------|
| 0.0000 | 0.0000 | -40.0000 | 623.7199 | 0.0000 | -21.0 |
| 0.0000 | 0.0000 | -39.9231 | 623.5688 | 0.0000 | -21.0 |
| 0.0000 | 0.0000 | -39.8462 | 623.6391 | 0.0000 | -21.0 |
| 0.0000 | 0.0000 | -39.7692 | 623.3486 | 0.0000 | -21.0 |
| 0.0000 | 0.0000 | -39.6923 | 623.0370 | 0.0000 | -21.0 |
| 0.0000 | 0.0000 | -39.6154 | 622.7115 | 0.0000 | -21.0 |
| 0.0000 | 0.0000 | -39.5385 | 622.6152 | 0.0000 | -21.0 |
| 0.0000 | 0.0000 | -39.4615 | 622.2716 | 0.0000 | -21.0 |
| 0.0000 | 0.0000 | -39.3846 | 622.1255 | 0.0000 | -21.0 |
| 0.0000 | 0.0000 | -39.3077 | 621.7757 | 0.0000 | -21.0 |
| 0.0000 | 0.0000 | -39.2308 | 616.6431 | 0.0000 | -21.0 |
| 0.0000 | 0.0000 | -39.1538 | 615.2892 | 0.0000 | -21.0 |

Fig. 18 : Open Windows Explorer window. Navigate into C:\Ray32\BOATSH26\HOLETOMO folder. Right-click *VELOIT999.TXT* and select *Open with* and Notepad.

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

https://www.dropbox.com/scl/fi/76lv0gp5xui4wpeb15aws/BoatSH26_Aug1_2025.rar?rlkey=yz4na9i6iq8thakwm840ms5xp&st=0e6gru4x&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 S-wave VSP processing for another borehole.

See also our 2024 P-wave downhole 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 https://seg.org/wp-content/uploads/2023/06/Downhole_Shearwaves.pdf
- we allow picking of shear waves on shot traces recorded with reversed shot polarity in our *TraceShot point gather* display. See above and our manual <https://rayfract.com/help/rayfract.pdf> chapter *Shear wave picking* and our S-wave refraction tutorial https://rayfract.com/tutorials/SH_60m.pdf.

Discussion

We show gathering of SEG-2 channels recorded using [AMBROGEO 3D twin/double borehole geophone](#) and PASI seismograph into SEG-2 receiver spread files sorted by channel number and receiver elevation. **We assume that the receiver channel files are named <receiver_depth><optional wave identifier>.DAT / .SG2 / .SEG2.** 1.SEG2 / 1HFRight.SEG2 / 1HFLeft.SEG2 means the borehole receiver was located at elevation -1m with the borehole top at elevation 0m.

40.SEG2 / 40HFRight.SEG2 / 40HFLeft.SEG2 means the borehole receiver was positioned at elevation -40m. Rename your SEG-2 receiver channel files in Windows Explorer to match this file naming convention. For double-geophone channel files the filename should include the **receiver_depth** of the lower geophone of the double geophone.

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 999 Steepest-Descent iterations. We weight the velocity update across the wavepath using a Ricker 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 reseller Ing. Kofi Boateng at HGL Consult Ltd. 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 update our SEG2_HoleMerge program to support the AMBROGEO 3D twin/double borehole geophone and for his feedback regarding interpretation of this borehole VSP data set with our latest version 5.02 software.

References

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<https://www.researchgate.net/publication/242072938> .

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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>

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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>

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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>