

Tutorial on VSP Data Processing in the RadExPro software

(Revised 21.04.2022)

RADEXPRO EUROPE OÜ Järvevana tee 9-40 11314 Tallinn, ESTONIA

RADEXPRO SEISMIC SOFTWARE LLC 29, Tornike Eristavi str. Nadzaladevi district, Tbilisi, Georgia

Visiting address: 26, S. Tsintsadze st. <u>Saburtalo, Tbilisi, G</u>eorgia

t: +995 557 659 289 www.radexpro.com

E-mails: support@radexpro.com sales@radexpro.com

Table of Contents

TABLE OF CONTENTS	2
INTRODUCTION	3
INPUT DATA	4
CREATING RADEXPRO PROFESSIONAL PROJECT	4
ZERO-OFFSET VSP PROCESSING	9
Data input into the project (010 – data load)	9
Data visualization (020 – view data)	
Picking P-wave first arrivals (030 – fbpick)	23
Orienting towards the source point and picking S-wave first arrivals (040 – 3C orientation+S	pick). 29
Using direct wave to determine the wavelet for deterministic deconvolution (050 - signature	re for
deconvolution)	
Testing deterministic deconvolution parameters (060 – deconvolution test.)	45
Reflected PP wave field separation (070 – ug PP)	
Building a velocity model (080 – velocity model)	71
Reflected wave field visualization and introduction of the NMO-corrections (090 - ug and u	ıg nmo
waves display)	76
Building a corridor stack trace (100 – cor stack trace and 110 – cor sum)	
Preparing VSP data for tying to seismic survey data (120 – ug vsp nmo waves for well tie and	1 1 30 -
cor stack for well tie)	
OFFSET VSP PROCESSING	90
Building migrated VSP and VSP-CMP sections (080 – migrations)	91
TYING VSP DATA TO SEISMIC DATA (WELL TIE)	94
Loading seismic data into the project (010 – seismic data load)	94
Tying VSP data to CMP seismic reflection survey data (020 – well tie)	96
Printing the processing results (030 – plotting)	101

Introduction

This Tutorial is intended for users making their first steps in processing of vertical seismic profiling (VSP) data with the RadExPro Professional. The Tutorial covers all standard stages of basic VSP processing, from data input to building a velocity model of the medium and tying VSP data to seismic survey data. It is assumed that the user is already familiar with the theory behind the VSP method and basic technologies employed to process such data. Information on the theoretical background of VSP and used processing procedures can be found, for example, in the following literature:

Hardage B.A. Vertical Seismic Profiling: Principles, Pergamon, 2000

All examples in this Tutorial are based on real data that can be downloaded from our website: <u>http://radexpro.ru/upload/File/tutors/vsp/InData.zip</u>

The archive contains the following source data for processing: offset and zero-offset VSP seismograms in the SEG-Y format (sp0_raw.sgy and sp1_raw.sgy), text files containing geometry (sp0_geom.txt and sp1_geom.txt), logging traces in the LAS format (AK.las and RK.las), and a synthetic seismogram in the SEG-Y format (seimic data.sgy) built based on logging data and used for VSP data tying.

In addition, you can download a finished project created by completing all the steps described in this Tutorial:

http://radexpro.ru/upload/File/tutors/vsp/MyVSPProject.zip

Please note that the program's facilities are not limited to the set of modules described in this document. Detailed information on module parameters as well as an overview of other functions offered by the RadExPro can be found in the RadExPro Professional User Manual available for download from our website.

Input data

Input data consist of the following files: Near shot point (SP):

sp0_geom.txt sp0_raw.sgy

Far SP:

sp1_geom.txt
sp1_raw.sgy

Logging data:

AK.las rk.las

Seismic data:

seismic data.sgy

Logging data should be presented in a special format. The first line should always start with an ~A symbol and should contain a DEPTH header (cable depths) followed by logging curve headers.

Creating RadExPro Professional project

All VSP data processing in the RadExPro Professional takes place within projects. A project is a combination of input data, intermediate and final processing results, and processing flows organized into a common database used by the RadExPro Professional seismic data processing package. Projects are stored in separate directories on the hard disk. When a new project is created, a project directory is automatically created for it. Projects can be moved between computers by simply copying the appropriate directory (provided that all used data are stored within that directory).

Let us create a new processing project. Launch the project manager by opening the Starter.exe file in the installed program folder, and for further convenience, it is recommended to pin this file to

the Quick Access Toolbar.

<mark></mark>	Manage RadExPro_2021.4	4		- 0	×
File Home Share	View Application Tools	Rew item ▼ 1 Easy access ▼	Copen ▼ Copen ▼ Copen ▼	Select all	^ 🕐
access Copy Paste	aste shortcut to v to v v Organize	folder New	Properties	Select	
$\leftarrow \rightarrow \checkmark \uparrow$ $\square \rightarrow$ This PC	> Local Disk (C:) > Program Files > RadExPro	o_2021.4 ∨ Č	Search RadExPro	_2021.4	
> 🖈 Quick access	Name Simponetan SrmpPred.dll	Date modified 12/20/2021 12:14 PM	Type Application externi	Size 255 KB	^
> OneDrive - Personal	 SrmpPred2.dll SrmpRet.dll 	12/20/2021 11:53 AM 12/20/2021 12:14 PM	Application exten Application exten	237 KB 102 KB	
> Network	SSAA.dll	12/20/2021 12:10 PM 12/20/2021 12:11 PM	Application exten	113 KB 129 KB	
-	Statics.dll	12/20/2021 12:08 PM	Application exten	174 KB 216 KB	
	StottSran	12/20/2021 12:10 PM	Application exten	69 KB	
	Subtr_m.dll	12/20/2021 12:10 PM	Application exten	118 KB	
	SweepGen.dll	12/20/2021 11:53 AM	Application exten	66 KB	
	swresample-2.dll	12/20/2021 12:11 PM 9/11/2016 2:57 PM	Application exten Application exten	72 KB 336 KB	- 8
	ାଷ୍ଟ୍ର swscale-4.dll ତ୍ରି SymbDef.dll	9/11/2016 2:57 PM 12/20/2021 12:07 PM	Application exten Application exten	518 KB 66 KB	
	 SymbolChooser.ocx R TapeLoader.exe 	12/20/2021 12:11 PM 12/20/2021 12:07 PM	ActiveX control Application	75 KB 113 KB	~
403 items 1 item selected 128	KB				

Launching the project manager opens a dialog box with a list of registered projects.

Į	RadExPro 2021.4 Project Manag	jer			_		×
	Registered						
	Project name	Date created	Date modified		Crea	ate new	
					Select	from disk.	
					Remo	ve from lis	t
	Save list Load list						
	Project directory:						_
				OK		Cancel	

Click the *Create new* button and select a parent directory on the hard disk where a project subdirectory will be created. Another dialog box will appear, prompting you to enter a project name.

New database	×
Title My VSP Project	
Create subfolder	
OK	Cancel

Make sure the *Create subfolder* option is checked and click the OK. A subdirectory with the same name as the project will be created in the selected directory. The project will also appear in the list of available (registered) projects.

唇 RadExPro 2021.4 Project Mana	iger		_		×
Registered					
Project name	Date created	Date modified]		
My VSP Project	11.03.2022 12:19	11.03.2022 12:19	Crea	ate new	
			Select	from disk.	
			Remo	ve from lis	t
Save list Load list.					
Project directory:					
E: Wy VSP Project		C	Ж	Cancel	

Select the project and click OK.

The main RadExPro window showing the project tree will appear. For now, the tree is empty.

www.radexpro.com

Processing Database Navigator				
roject tree	× Processing flow	×	All modules	
u s ≪			» «	
🖽 Area1			>	Data I/O
Y			>	Real-Time
Blow1			>	Static Corrections
			>	Geometry/Headers
			>	Interactive Tools
			>	Signal Processing
			>	Data Enhancement
			>	Deconvolution
			>	Velocity
			>	Stacking/Ensembles
			>	Migration
			>	Trace Editing
			>	VSP
			>	QC
			>	3C Processing
			>	Modeling
			>	Data Manipulation
			>	Auto Picking
			>	Interpolation
			>	Marine
			>	Surface Wave Analysis
ctions	× 📅 Flow status			Ð

The main RadExPro window contain:

- Window with project tree (Project tree)
- Window with processing flow (Processing flow)
- A window with a list of available processing modules (All modules)
- A window that shows all previous user actions (Actions)
- Flow execution status window (Flow status)

The RadExPro database has 3 structural levels. The upper level corresponds to the project area, the middle level – to the profile, and the lower level – to the processing flow. Each project can include multiple *Area*. Each Area can include several *profiles*, and finally, each profile includes several *flows*.

The project tree is located on the left side of the main window and by default contains an area with one profile and one processing flow (Area1, Line1, Flow1)

Project tree	×
»	
▲ 🔄 Areal	
🔺 🚍 Line1	
Flow1	

Right-click on the name of the Area (profile, flow) and rename it as you need (or you can use

the hot key F2). In our case, we will call My Borehole.

Project tree			×
» «	_ <u>ل</u>		
	Create line View map Set color Clear colo Rename Copy Paste Delete	e 	
Project tr	ee		×
» «	e		
~ ⋣ N	ly Borehole		
× [Line1		
	Flow1		

Then we will rename Line1 to our first profile after the name of the first shot point SPO:

Project tree	×
» ≈ [₽	
🗙 🛱 My Borehole	
✓	
Flow1	

By analogy with creating an area and a profile, create a processing flow 010 _ data_load

Project tre	e	×
» «	<u>ل</u>	
✓ ⋣ M	y Borehole	
~ \Box	SP0	
	010_data_load	

Due to the fact, that the RadExPro Professional program arranges the names of the structural elements of the database in alphabetical order, it is reasonable to number the flows so that they are displayed in the correct logical sequence.

Zero-offset VSP processing

The purpose of zero-offset VSP processing is to separate a reflected P-wave field, create a velocity model, and build a corridor stack trace.

Click the *010_data_load* flow in the project tree and pay attention to the center and right side of the main window

Processing flow	×	All modules	×
		» *	
		4	Data I/O 🔺
		Trace Input	
		Trace Output	=
		SEG-Y Input	
		SEG-Y Output	
		SEG-D Input	
		RAMAC/GPR	
		SEG-B Input	
		ЛОГИС	
		SEG-2 Input	
		GSSI Input	
		SCS-3 Input	
×	4	Super Gather	-

On the right side of the screen, a list of available processing modules is displayed, divided into groups, depending on their function: Data I/O (Data Input/Output), Geometry/Headers, Interactive Tools, Signal Processing. The flow itself is displayed on the left, which is still empty. We will add processing modules to the flow and then execute it.

Data input into the project (010 – data load)

Let us create a flow consisting of the SEG-Y Input, Trace Output and Screen Display modules

(the SEG-Y Input and Trace Output modules are located in the Data I/O group, the Screen Display module – in the Interactive Tools group). This flow will read data from a SEG-Y file stored on the hard disk and save them to the project database as a database object – "dataset".

Modules are added to the flow one by one. To add a module to the flow, simply drag it from the library on the right to the flow area on the left using the mouse. When you do it, a module setup dialog box will appear (this dialog box can also be opened later by double-clicking the module name in the flow). Modules that are already in the flow can be moved up and down by dragging them with the mouse.

Let us find the SEG-Y Input module in the Data I/O group and add it to the flow. When we add the module, a dialog box will open, prompting us to specify the data reading parameters. We will do it by selecting the Sp0_raw.sgy data file.



After we have done adding the SEG-Y Input module, let us add another module – Trace Output. This module will save the data read by SEG-Y Input to the database. Name the object that will contain these data sp0 – raw and place it on the second database level in the *Sp0* profile.

Note. Names of all database objects (seismic datasets, processing flows etc.) should reflect their nature and contents instead of being just a combination of a few letters. Names of seismic datasets should consist of two parts – the source data identifier and the current data processing stage. In our example, the name sp0 - raw was chosen for field data input.

Select dataset						×
Object(s): sp0_raw						
>> 🙁 🗋 Show objects from sublevels	Set fil	ter text (you can	use * and ? wildcard	s)		
✓ I My Borehole	Name	Location	Trace count	Sorted by	Created	
✓						
	< 	Ж Са	ncel	-		>

Advice: To avoid undesirable overwriting of the data in the sp0-raw dataset, comment out the Trace Output module after the first run.

To monitor flow execution, add the Screen Display module to the flow after the Trace Output module with parameters shown in the picture below:

💁 Display parameters	×
From t = 0.0 to 0.0 to t Scale 10 Number of traces 1000 X Scale 10 Rotate Ensemble boundaries	WT/VA display mode Normalizing factor Gain 0.3 C WT C None Bias(%) 0 C VA C Individual Show every N-th trace 1
Enable backward frame scrolling Ensembles to scroll Variable spacing Field Space to maximum ensemble width Ensembles' gap Muliple panels Use excursion 2.0 traces	Variable density display mode Normalizing factor Gain 0.3 © R/B © Custom Define © Entire screen Bias(%) 0 © None © Individual © Show palette Data/velocity © Display data Palette range © Display velocity Set velocity Min.vel (m/s) 500.0
Axis Show headers Plot headers Header mark Picks/polygons settings Save Template	ad Template Ok Cancel

The resulting flow should look like the following:

www.radexpro.com

RadExPro 2021.4 >>> My VSP Project				- 🗆 X
Database Options Tools Windows He	łp			
Processing Database Navigator				
Project tree ×	Processing flow >> My Borehole / SP0 / 010_data_load	×	All modules	×
» ≈ @		📒 🎞 🛛 LOG	»	
Y I My Borehole	SEG-Y Input <- sp0_raw.sgy		>	Data I/O
✓	Trace Output -> sp0_raw		>	Real-Time
@ 010 data load	Screen Display		>	Static Corrections
a oro_data_load			>	Geometry/Headers
			>	Interactive Tools
			>	Signal Processing
			>	Data Enhancement
			>	Deconvolution
			>	Velocity
			>	Stacking/Ensembles
			>	Migration
			>	Trace Editing
			>	VSP
			>	QC
			>	3C Processing
			>	Modeling
			>	Data Manipulation
			>	Auto Picking
			>	Interpolation
			>	Marine
			>	Surface Wave Analysis 🗸
Actions ×	📅 Flow status			8 ×
Add module Screen Display from the list				
Add module SEG-Y Input from the list				
Rename flow Flow1 -> 010 data load at t				
Load flow Flow1 < SP0 < My Borehole <				
MB1 - Move modules; Ctrl+MB1 - Copy modu	iles; MB1 x2 - Module parameters; MB2 - Toggle modules; Ctrl+	MB2 x2 - Cut module	s; Shift+MB1 - Paste modules	

To run the flow, select the *Run* menu command. The Screen Display window will open and show the input data as they are read from the file on the hard disk and saved to the database. The Screen Display window should look like this:



Note. When the amount of data read from the file is very big (approaching or exceeding the amount of RAM installed, or simply close to 1 Gb and over), the *Framed mode* should be used to read the data into the memory in frames rather than all at once. You can switch over to this mode and specify the frame size using the *Framed mode* menu item available in the flow editor.

Assigning geometry

The process of assigning geometry to VSP data consists of determining a number of values for each trace that are later stored in the specified dataset header fields in the project database. The list of necessary values and corresponding header fields is provided below:

- 1. Depth (DEPTH)
- 2. Surface elevation at the source position (SOU_ELEV)
- 3. Source position X coordinate (SOU_X)
- 4. Source position Y coordinate (SOU_Y)
- 5. Surface elevation at the receiver position (REC_ELEV)
- 6. Receiver position X coordinate (REC_X)
- 7. Receiver position Y coordinate (REC_Y)
- 8. Channel number (CHAN)

Virtually any combination of completed trace headers can be encountered in practice.

Import of source and receiver position coordinates from a text file

The *Geometry Spreadsheet* tool is used to manipulate seismic data header field values in the RadExPro, including import of values from text tables.

Select the Database/GeometrySpreadsheet menu item.



The picture below shows the Geometry Spreadsheet window.

Tools						
TRACENO	FFID	CHAN	OFFSET	SOU_X	REC_X	
not assigned	152	1	not assigned	not assigned	not assigned	
not assigned	151	1	not assigned	not assigned	not assigned	
not assigned	152	1	not assigned	not assigned	not assigned	
not assigned	151	1	not assigned	not assigned	not assigned	
not assigned	150	1	not assigned	not assigned	not assigned	
not assigned	149	1	not assigned	not assigned	not assigned	
not assigned	150	1	not assigned	not assigned	not assigned	
not assigned	149	1	not assigned	not assigned	not assigned	
not assigned	148	1	not assigned	not assigned	not assigned	
) not assigned	147	1	not assigned	not assigned	not assigned	
not assigned	148	1	not assigned	not assigned	not assigned	
not assigned	147	1	not assigned	not assigned	not assigned	
not assigned	146	1	not assigned	not assigned	not assigned	
not assigned	145	1	not assigned	not assigned	not assigned	
not assigned	146	1	not assigned	not assigned	not assigned	
not assigned	145	1	not assigned	not assigned	not assigned	
7 not assigned	144	1	not assigned	not assigned	not assigned	

When you click on the button in the toolbar on the right, a list with headings opens, the elements in which can be selected and dragged with the left mouse button to the table (For more information about working with the *Geometry Spreadsheet* editor, see the "User's Guide" for the program).

Let's add columns of those headers with which we will work now to the editor window. To do this, select the following headers from the list on the right (to select multiple headers, press and hold the Ctrl key): DEPTH (cable depth), SOU_X (source X coordinate), SOU_Y (source Y coordinate), SOU_ELEV (source absolute depth), REC_X(receiver X coordinate), REC_Y (receiver Y coordinate), REC_ELEV (receiver absolute depth), and CHAN (channel number).

As a result, the header editor window should look like the following:

1	Tools								
	DEPTH	SOU_X	SOU_Y	SOU_ELEV	REC_X	REC_Y	REC_ELEV	CHAN	
1	0.000000	not assigned	1						
2	20.000000	not assigned	1						
3	30.000000	not assigned	1						
4	40.000000	not assigned	1						
5	50.000000	not assigned	1						
6	50.000000	not assigned	1						
7	70.000000	not assigned	1						
8	30.000000	not assigned	1						
9	0.000000	not assigned	1						
1	00.00000	not assigned	1						
1	10.000000	not assigned	1						
1	20.000000	not assigned	1						
1	30.000000	not assigned	1						
1	40.000000	not assigned	1						
1	50.000000	not assigned	1						
1	60.000000	not assigned	1						
1	70.000000	not assigned	1						

To import header values from a text file, select the *Tools/Import* menu item. The import setup dialog box will appear. You will need to open the sp0_geom.txt file and describe the rules for header field completion in this dialog box.

орядочить 🔻 Новая	а папка				EE • 🔲
	Имя	Дата изменения	Тип	Размер	
🕈 Быстрый доступ	AK	09.11.2006 19:05	Конфигур	75 KE	
OneDrive - Personal	RK	13.11.2006 16:57	Конфигур	188 KE	
	🔀 seismic data	28.09.2009 13:58	Файл "SGY"	292 KE	
- этот компьютер	📓 sp0_geom	13.02.2008 13:04	Файл "ТХТ"	33 KE	
USB-накопитель (F:)	🔀 sp0_raw	13.02.2008 13:56	Файл "SGY"	13 897 KE	
Ceth	📓 sp1_geom	13.02.2008 13:19	Файл "ТХТ"	17 КБ	
	🔀 sp1_raw	13.02.2008 13:58	Файл "SGY"	3 529 KE	
Имаф	айла: sp0 geom		~	All files	

The contents of the file will be displayed in the import window:

hing fields	Assign fields	Lines		Load with 1D interpolation		ad with 2D interpolation —	
		Add From	0	Reference field	▼ Referer	nce field X	~
Delete		Delete To		Extrapolation	Deferer	ran Bald V	
				No extrapolation	Kererei		
Set column		at column		C Use edge values			
		Text table	type	C Extrapolate			
		Delimit	ed	Points to estimate trend 10			
Multiplier	Multiplier	C Fixed	width	,			
Column: 1]				
DEPTH	X 1102	V 1102		REC X	REC V		
10.00000	-108.88000	57.44000	-21.38000	0.00000	0.00000	-29.11000	
20.00000	-108.88000	57.44000	-21.38000	0.00000	0.00000	-19.11000	
30.00000	-108.88000	57.44000	-21.38000	0.0000	0.00000	-9.11000	
40.00000	-108.88000	57.44000 57.6600	-21.38000	0.00000	0.00000	-0.89000	
50.00000	-108.88000	57.44000 57 44000	-21.38000	0.00000	0.00000	20 88000	
70.00000	-108.88000	57.44000	-21.38000	0.00000	0.00000	30.88000	
80.00000	-108.88000	57.44000	-21.38000	0.0000	0.00000	40.87000	
90.00000	-108.88000	57.44000	-21.38000	0.00000	0.00000	50.87000	
100.00000	-108.88000	57.44000	-21.38000	0.00000	0.00000	60.86000	
110.00000		57.44000	-21.38000	0.00000	0.00000	70.86000	
120.00000	-108.88000	57.44000 57 JJ000	-21.38000	0.00000	0.00000	80.85000 98.85000	
140.00000	-108.88000	57.44000	-21.38000	6_ 66666	6.66666	100.84000	
150.00000	-108.88000	57.44000	-21.38000	0.00000	0.00000	110.84000	
160.00000	-108.88000	57.44000	-21.38000	0.0000	0.00000	120.83000	
170.00000	-108.88000	57.44000	-21.38000	0.00000	0.00000	130.83000	
100 00000	-108.88000	57.44000	-21.38000	0.00000	0.00000	140.83000	
100.00000	-108.88000	57.44000	-21.38000	0.00000	0.00000	150.83000	
190.00000	100 00000	L/ AAMM	-21.38000	0.00000	0.00000	100.82001	
190.00000 200.00000		57.44000	-24 20000	0 00000			
190.00000 200.00000 210.00000 220.00000	-108.88000 -108.88000 -108.88000	57.44000 57.44000 57.44000	-21.38000 -21.38000	0.00000	0.00000	180 82001	
196.00000 206.00000 216.00000 226.00000 230.00000	-108.88000 -108.88000 -108.88000 -108.88000	57.44000 57.44000 57.44000 57.44000	-21.38000 -21.38000 -21.38000	0.00000 0.00000 0.00000	0.00000 0.00000 0.00000	180.82001	

There are two lists in the upper part of the window (both are still empty): Matching fields sets

RadExPro seismic software

www.radexpro.com

the headers by which the program will find the required trace, and *Assign fields* are the headers of the found trace to which values will be assigned. We need to set both lists, and then assign each of the headers to the desired column in the file

To do this, add the DEPTH field to the *Matching fields* list (by clicking the corresponding Add button and selecting it from the list), and the SOU_X, SOU_Y, SOU_ELEV, REC_X, REC_Y, REC_ELEV fields to the *Assign Fields*. Then you will need to specify which text file columns the fields specified in the text lines above the *Set column* buttons should be read from. (By the way, if you place the cursor in the appropriate column and click *Set column*, the column number will be entered automatically). Finally, you will need to specify the range of lines from which the program will read values in the *Lines: From, To* parameter group. An example of correct parameter completion is shown in the picture below.

Import Headers							×
Matching fields DEPTH Add Delete Set colum	Assign fields SOU_X SOU_ELEV REC_X REC_Y REC_FY SOU_ELEV SOU_Y SOU_ELEV REC_FY REC_FY SOU_Y SOU_	Add Lines From Delete To t column - Text table to C Delete C Delete - Text table to C Delete - Text	223 293 ype ed	Load with 1D interpolation eference field DEPTH Extrapolation Use edge values Extrapolate Points to estimate trend 10	Referenc	with 2D interpolation e field X e field Y	A A
(293, 43) Column: 3 DEPTH 16.00000 30.00000 40.00000 50.00000 60.00000 80.00000 100.00000 100.00000 130.00000 130.00000 140.00000 150.00000 160.00000 160.00000 160.00000 170.00000 180.00000 200.000000 200.00000 200.000000 200.000000 200.000000 200.000000 200.000000 200.000000 200.000000 200.000000 200.000000 200.000000 200.000000 200.000000 200.000000 200.000000 200.0000000000	SOU_X -108.88000	SOU_Y 57.44000	S0U_ELEU -21.38000	REC_X 0.00000 0	REC_Y 6.000000 6.000000 6.000000 6.0000000000	REC_ELEU -29.11000 -19.11000 -0.89000 30.88000 30.88000 30.88000 30.88000 40.87000 50.87000 60.87000 60.87000 60.86000 79.86000 100.84000 110.84000 120.83000 130.83000 140.83000 1550.83000 150.82001 170.82001 170.82001 190.82001	~
OK Cancel					Load template	Save template	File

The program performs the following actions when importing header field values from a text file. All fields used to determine the trace (*matching fields*) as well as all fields to be changed (*assign fields*) are read from the specified columns in each text file line. All traces with header field values listed in *Matching fields* exactly matching the values read from the line are determined in the specified seismic dataset. Then the values read from the line are entered into the changed headerfields (*Assign fields*) for all these traces.

Before importing geometry, click Save template ... in the lower right corner of the dialog box. A

new dialog box will open. Select *My Borehole* in the *Location* field and enter the name - geometry_template in the *Object name* field. This will save all header values to the database as a template.

iert(s)			
	Set filter text (you can use * and	? wildcards)	
Y I My Borehole Y I SP0 I O10_data_load	Name	Location	

After saving the template, click the OK in the *Import Headers* dialog box. Double-click the DEPTH field in the *sp0_raw-Geometry Spreadsheet* window to sort the depth in the ascending order. As you can see now, each depth value is repeated 3 times for each channel.

DEPTH	SOU_X	SOU_Y	SOU_ELEV	REC_X	REC_Y	REC_ELEV	CHAN	
10.000000	-108.880000	57.440000	-21.379999	0.000000	0.000000	-29.110001	1	11
10.000000	-108.880000	57.440000	-21.379999	0.000000	0.000000	-29.110001	2	
10.000000	-108.880000	57.440000	-21.379999	0.000000	0.000000	-29.110001	3	
20.000000	-108.880000	57.440000	-21.379999	0.000000	0.000000	-19.110001	1	
20.000000	-108.880000	57.440000	-21.379999	0.000000	0.000000	-19.110001	2	
20.000000	-108.880000	57.440000	-21.379999	0.000000	0.000000	-19.110001	3	
30.000000	-108.880000	57.440000	-21.379999	0.000000	0.000000	-9.110000	1	
30.000000	-108.880000	57.440000	-21.379999	0.000000	0.000000	-9.110000	2	
30.000000	-108.880000	57.440000	-21.379999	0.000000	0.000000	-9.110000	3	
40.000000	-108.880000	57.440000	-21.379999	0.000000	0.000000	-0.890000	1	
40.000000	-108.880000	57.440000	-21.379999	0.000000	0.000000	-0.890000	2	
40.000000	-108.880000	57.440000	-21.379999	0.000000	0.000000	-0.890000	3	
50.000000	-108.880000	57.440000	-21.379999	0.000000	0.000000	10.880000	1	
50.000000	-108.880000	57.440000	-21.379999	0.000000	0.000000	10.880000	2	
50.000000	-108.880000	57.440000	-21.379999	0.000000	0.000000	10.880000	3	
60.000000	-108.880000	57.440000	-21.379999	0.000000	0.000000	20.879999	1	
60.000000	-108.880000	57.440000	-21.379999	0.000000	0.000000	20.879999	2	

You can save the changes to the database by using the *Edit/Save changes* menu option or clicking *Yes* in the dialog box prompting you to save the changes when exiting the *Geometry Spreadsheet*.



Data visualization (020 – view data)

Create a new flow in the project tree and name it 020 – view data.

This flow consists of two procedures:

RadExPro 2021.4 >>> My VSP Project Database Options Tools Windows Help		- 🗆 X
Processing Database Navigator		
Project tree ×	Processing flow >> My Borehole / SP0 / 020_view_data ×	All modules ×
» ≈ 但	▶ II • ₺ •	» *
✓ I My Borehole	Trace Input <- sp0_raw	> Data I/O ^
✓	Screen Display	> Static Corrections
🚳 010 data load		> Geometry/Headers
		> Interactive Tools
W 020_view_data		> Signal Processing
		> Data Enhancement
		> Deconvolution
		> Velocity
		> Stacking/Ensembles
		> Migration
		> Trace Editing
		> VSP ~
	📅 Flow status	E ×
Actions		
Add module Screen Display from the list		
Add module Trace Input from the list		
Constructions flow 2 > 0.00 since data at the liv ¥		

MB1 - Move modules; Ctrl+MB1 - Copy modules; MB1 x2 - Module parameters; MB2 - Toggle modules; Ctrl+MB2 x2 - Cut modules; Shift+MB1 - Paste modules

Trace Input

Select the dataset named sp0-raw in the module setup dialog box. Specify the CHAN and DEPTH headers in the *Sort Fields* field – data will be sorted by channel number at the flow input and by depth within each channel. Set the selection range in the Selection field: enter *:* (these symbols mean reading the entire data range for both headers).

Trace Input	×
Data Sets	Sort Fields
sp0_raw	CHAN DEPTH Wumber of Ensemble Fields 1 Note: Ensembles will be defined by this number of sort fields.
Add dataset Delete	
Datasets masks	Add Delete
	© Selection
	: ^
Add mask Delete	
Load headers only From batch list	Select from file
Memory resort Buffer size (MB)	C Database object Choose
OK Cancel	C Get all

Note

Input VSP data may consist of components (X, Y, Z), control instrument readings, and auxiliary channel records. All this information can be stored in headers (CHAN, COMP...). Generally, the X, Y, Z components can be selected from the dataset by sorting.

However, situation may occur when this will not be the case, and the Trace Header Math module used to perform mathematical operations on header values will be necessary to select the X, Y, Z components. Operations are specified in the form of equations (for a detailed module description, see the RadExPro Professional User Manual).

Let us assume we have a situation where channels 1 through 3 contain control instrument readings and all other channels contain information on the X, Y, Z components. We will construct the following expression allowing us to complete the comp header field with the X, Y, Z component indexes (if they haven't been completed already):

$$comp = cond(chan > 3, fmod(chan-(3+1),3)+1, -1)$$

In this case we are using the cond(c, x, y) function – if the condition is true, the function returns x, otherwise it returns y, – and the fmod(x, y) function returning the residue of division of x by y. Now the value of header field COMP=1 will correspond to the X component, COMP=2 – to the Y component, and COMP=3 – to the Z component. After these transformations, the next flows and modules working with the X, Y, Z components will use sorting by the COMP field.

This is a simplified example where the first channel (CHAN=1) corresponds to the X component, the second one – to the Y component, and the third one – to the Z component. Therefore, from now on we will use this header to sort our data.

Screen Display

The visualization parameters are shown below:

🚰 Display parameters			×
From t= 0.0 to 0.0 t t Scale 10 Number of traces 900 X Scale 10 Rotate Final Ensemble boundaries	WT/VA display mode C WT/VA C WT C VA C VA None	Normalizing factor C None Entire screen C Individual Show e N-th tra	Gain 0.3 as(%) 0 very 1
Enable backward frame scrolling Ensembles to scroll Variable spacing field Space to maximum ensemble width Ensembles' gap Muliple panels 0 Vse excursion 2,0 traces	Variable density display mode (Carey Carey Carey Custom Define Conne Data/velocity (Carea Data/velocity (Carea Data/velocity (Carea Data/velocity (Carea Data/velocity (Carea Data/velocity (Carea Data/velocity (Carea Data/velocity (Carea Data/velocity (Carea Data/velocity (Carea Data/velocity (Carea Data/velocity (Carea Data/velocity (Carea Data/velocity (Carea Data/velocity (Carea Data/velocity (Carea Carea Carea (Carea Carea Carea (Carea Carea (Care	Normalizing factor	Gain 0.3 as(%) 0 Show palette
Axis Show headers Plot headers Header mark Picks/polygons settings Save Template	d Template Ok	vlax,vel (m/s)	1500.0

Click the Axis button to set up axis parameters.

Axis Parameters	5	
Primary lines	Time dt Values Lines	Traces O Different dx Values DEPTH O Interval 400.0 O Multiple
Secondary lines	100.0	CHAN O Interval 100.0 Multiple
Font size 15	Cancel	Margins Left axis margin 20 mm Top axis margin 20 mm

To run the flow, select the *Run* menu command. The result should look like the following:

020_vie	w_data < S	P0 < My Bo	rehole < My	VSP Project	[11:30:01]											- 0	×
	mmon par	ameters		Exit/Stop		166			H A			$\langle \rangle \rangle$					неір ^
													,				
DEPTH		400 80	0 1200	1600 2	000 240	0 2800	400 80	0 1200	0 1600 20	000 2400	2800	400 8	00 12	00 1600	2000 240	00 2800	
CHAN	1					2					3						
0	1						E.					~					
200-		10			1		ða.										
600			Sec.														
800		2	1 - M							1	3				+		
1000					and the second		111									_	
1200						2						-1112					
1400						1	als all					199					
1600																	
1800						2											
2000												111					
2200						2											
2400	2																
2600	N.					×.					4.10						
2800-					1	<u></u>				1					-		
3200						2									1		
3400	新潟				1							200					
3600																	
3800																1	
1	A.F					1	Sar .					1					
Tr:659 Sam	n:0 Amp	:0 t:0m	5														//. *
<																	> .:

Here we see the data sorted by channels (components).

Picking P-wave first arrivals (030 – fbpick)

Create a new 030-fbpick flow consisting of the following procedures:

- Trace Input
- Resample
- Trace Length
- Screen Display

RadExPro 2021.4 >>> My VSP Project			- 🗆 ×
Database Options Tools Windows Help			
Processing Database Navigator			
Project tree ×	Processing flow >> My Borehole / SP0 / 030_fbpick ×	All modules	×
»	🖻 🔲 🕶 🖫 🖌 📒 🔚 🕮 LOG	» «	
 ゴ My Borehole 	Trace Input <- sp0_raw	>	Data I/O ^
✓	ReSample	>	- Static Corrections
🕸 010 data load	Trace Length	>	Geometry/Headers
a 020 view data	Screen Display	>	Interactive Tools
		>	- Signal Processing
O30_tbpick		>	Data Enhancement
		>	Deconvolution
		>	Velocity
		> §	tacking/Ensembles
		>	Migration
		>	Trace Editing
		>	VSP V
	₽ Flow status		e x
Actions ×	1		
Add module Screen Display from the list Add module Trace Length from the list			
Add module PoSample from the list > MB1 - Move modules: Ctrl+MB1 - Conv modules: M	B1 x2 - Module parameters: MB2 - Toggle modules: Ctrl+MB2	x2 - Cut modules: Shift+N	IB1 - Paste modules

Select the Trace Input module parameters as shown below. Select sorting by channel number and depth – CHAN:DEPTH – the same way you did for the previous flow. Only the Z component will be processed in this flow. This will be achieved by limiting the selection range to the third channel only – enter 3:* sorting in the *Selection* field.

Trace Input	×
Data Sets	Sort Fields
sp0_raw	CHAN DEPTH I Number of Ensemble Fields I Note: Ensembles will be defined by this number of sort fields.
Add dataset Delete	
Datasets masks	Add Delete
	Selection
	3:* ^
Add mask Delete	C Select from file File
Load headers only From batch list	
Memory resort Buffer size (MB) 0	Choose
OK Cancel	C Get all

To increase the accuracy of determining the first arrival times, it is advised to first resample the data to a considerably smaller sample interval. To do this, we will use the Resample module. Enter the *New sample rate* value -0.1 – in the module parameter dialog box.

左 ReSample	×
New sample rate:	0.1
Number of threads:	(auto)
ОК	Cancel

Since we are interested only in the first arrival times at this stage, we will limit the recording length to 2,000 ms to speed up the flow execution. Do this by specifying the appropriate value in the *New trace length* field of the Trace Length module.

Trace Length Parameters		_	×
New trace length:	2000.000000		

The last module in the flow is <u>Screen Display</u> which will allow us to view the first arrivals interactively in the module window. Specify the module parameters as shown in the picture below.

🚰 Display parameters	×
From t= 0.0 to 0.0 t Scale 10 Number of traces 300 X Scale 10 Image: Rotate Image: Rotate <th>WT/VA display mode Normalizing factor Gain 0.3 C WT C None Bias(%) 0 C VA C Individual C 0</th>	WT/VA display mode Normalizing factor Gain 0.3 C WT C None Bias(%) 0 C VA C Individual C 0
Ensemble boundaries	Show every 1 N-th trace
Enable backward frame scrolling Ensembles to scroll	Variable density display mode Orreg Orreg Orreg Gain O.3
✓ Variable spacing field ✓ Space to maximum ensemble width	C R/B C Entire screen Bias(%) C Custom Define C Individual
Ensembles' gap 2	Data/velocity © Display data
✓ Use excursion 2.0 traces	Display velocity Set velocity Min.vel (m/s) 500.0
Axis Show headers Plot headers Header mark Picks/polygons settings	Max.vel (m/s) 1500.0
Save Template Loa	ad Template Ok Cancel

Click *Run*. The results of executing the flow are presented below:



For first arrival picking, adjust the image zoom using the Zoom menu item.

The *Tools/Pick/New pick* (the hot key N) menu item allows creating a new pick. Use the *Tools/Pick/Picking parameters* menu item to select picking parameters.

www.radexpro.com

030_	_fbpick < SP0 < My Borehole < M	y VSP Project [11:58:44]							_		×
Zoom	Common parameters View	Tools Exit/Stop flow Exit									Help
\oplus		Approximate	>			\F [-1, +]	🔶 ca	\mathbb{R}	\gg		^
		Spectrum	>			50		\square			
		Pick	>	×	Edit picks	М					
		QC polygons	>		New pick	N					
DEPTH	200 400	Wells			Delete pick	Del	0 2400	2600	2800)	
0		Static corrections	>		Load pick	Ins					
		Apply procedure	>		Load pick w/interpolation						
200		Amplitude editing	>		Collect picks		1				
-		Trace Header Math			Save pick						
400		Syncronize	>		Save pick as	^S					
		Navigate	>		Load from header						
	149 C	Reflect header changes in			Save to header(dataset)						
600		Reflect ident. fields			Save to header(flow)						
		Text hint			Export pick						
800-		Save image parameters			Import pick						
		Save image	(Ctrl + I)		Pick headers						
1000-	111222				Picking parameters	А	Townson of	_			
1200	2004 M 10				Project					-	
1200	22024101				Smooth	0		~	-	-	
†	Section 1				111-	47		_			
1400	the state of the s		22		Undo	~Z					
				_	Kedo	~ ¥					
1600											
			~								
1000	and the second										
1800	the Local de la company										
				-	And a state of the			-			
Tr:68 S	am:0 Amp:0 t:0.0ms										//. *
<											> a

We will perform picking of the first zero crossing (from + to -) in phase auto-tracing mode between the points. To do this, set the following picking parameters (detailed information on picking parameters and working with picks is available in the RadExPro Professional User Manual):

Picking parameters	×
Mode C Manual C Hunt Auto - Fill C Draw C Linear Fill Eraser C Draw along phase	Hunt options Correlation Test Local maximum level 0 Halt threshold 0.6 Correlation window (ms) 50 Hunt direction < < <
Parameters C Peak C Zero: 1 C Trough C Zero: 1 Guide window length OK	Smoothing Window length Oos2Neg Drawing parameters O Marks only Line style Label picks

Perform picking of first arrivals as shown below:

www.radexpro.com



Use the *Tools/Pick/Save as* menu item to save the pick under the name of fbpick on the second database level (SP0). In the RadExPro picks are tied to traces by 2 headers, since two headers usually allow identifying a trace uniquely (for instance, channel number – cable depth in VSP or CMP number – offset in CMP seismic reflection surveys). However, in this case we want to create a pick that will be tied only to the cable depth so that it can be used for all components the same way. In *Pick headers* tab you need to select DEPTH headers containing cable depth values both in the left and right fields of this dialog box.

Save pick to						Х
Object(s): fbpick						
>> 🔹 🗌 Show objects from sublevels	Set fil	ter text (you can	use * and ? wildcards	5)		
✓	Name	Location	Length	Headers	Style	
 SPO 010_data_load 020_view_data 030_fbpick 						
 Save all Save selection 		P	ick headers: DEPTH	~ :	DEPTH	~
	С	K Ca	ncel			

Orienting towards the source point and picking S-wave first arrivals (040 - 3C orientation+S pick)

A convenient way of determining the first arrivals of P- and S-waves more accurately is to convert PM-VSP (polarization method) seismograms to the PRT system by orienting the P- component towards the maximum energy in the window. In such a system the P-component is oriented towards the source; this results in the maximum P-wave energy concentrated on the P- component. The perpendicular R-component contains the maximum S-wave energy, making it convenient to pick downgoing and reflected S-waves by this component. The T-component contains noise energy and a small amount of useful wave residual energy.

To convert a VSP seismogram to the PRT system and determine the S-wave first arrival times, create a 3C Orientation+S pick flow.

www.radexpro.com

RadExPro 2021.4 >>> My VSP Project		- 🗆 X
Database Options Tools Windows Help		
Processing Database Navigator		
Project tree ×	Processing flow >> My Borehole / SP0 / 040_3C_Orientation+S_pick ×	All modules ×
» ≈ 🤤	D 🛛 🕶 🖫 🔹 🔲	» *
 ゴ My Borehole 	Trace Input <- sp0_raw	> Data I/O ^
✓	SSAA	> Real-Time
010 data load	3C Orientation	> Static Corrections
	Trace Output -> sp0_PRT	> Geometry/Headers
020_view_data	Data Filter	> Interactive Tools
030_fbpick	Screen Display	> Signal Processing
040_3C_Orientation+S_pick		> Data Enhancement
		> Deconvolution
		> Velocity
		> Stacking/Ensembles
		> Migration
		> Trace Editing
		> VSP
		>QC
		> 3C Processing
		> Modeling
		> Data Manipulation
		> Auto Picking
		> Interpolation
		> Marine
		> Surface Wave Analysis 🗸
Actions ×	📅 Flow status	₽ ×
Add module Screen Display from the list		
Add module Data Filter from the list		
Add module Irace Output from the list		
Add module SCAA from the list		
< >		
MB1 - Move modules; Ctrl+MB1 - Copy modules; MB1 x2 - I	Iodule parameters; MB2 - Toggle modules; Ctrl+MB2 x2 - Cut modules; Shift+MB1	- Paste modules

The flow will consist of the following procedures:

- Trace Input
- SSAA
- 3C Orientation
- Trace Output
- Data Filter
- Screen Display

The main module of the flow – the 3C Orientation – allows converting PM-VSP seismograms to the PRT system by orienting the P-component towards the maximum energy in the window containing the downgoing P-wave.

To perform conversion to the PRT system, the module sequentially obtains traces corresponding to the same depths from the X, Y and Z components. The length of the window in which the energy is calculated is specified by the user in the module setup dialog box. The window for each trace starts with the P-wave first arrival time at the current depth. This time should be recorded in the FBPICK header field of each trace.

The procedure of orientation to the PRT system should be preceded by the Trace Input (to input properly sorted data into the flow) and SSAA (to move the first arrival pick to the FBPICK header field) modules in the flow. After conversion the seismic traces are saved to a new dataset, and the result is shown on the screen.

Select the sp0-raw dataset and DEPTH:CHAN sorting in the Trace Input module setup dialog

box as shown in the picture below.

Trace Input	×
Data Sets <u>sp0_raw</u> Add dataset Delete Datasets masks	Sort Fields DEPTH CHAN Image: CHAN Imag
	© Selection
Add mask Delete Load headers only From batch list Memory resort Buffer size (MB) OK Cancel	C Select from file File

The SSAA module is used to calculate seismic attributes within a specified-size window along the specified horizon. The calculated attributes are written to seismic trace headers. In our example we will use the module to write fbpick pick times to the FBPICK header field for each trace in the flow. To do this, select the *Pick amplitude time* attribute that will be calculated and saved to the FBPICK header field. Select a sufficiently small window width (0.0001 ms) to ensure that only the first arrival pick falls within the window.

The first tab of the Attributes module setup dialog box should look like the following:

SSAA				×
Attributes Horizon				
Attributes Trace header Attribute Trace header Peak frequency		RMS Amplitude Pick amplitude Peak amplitude time Trough amplitude time Max. absolute amp. time S/N Ratio Resolving power Time shift	FBPICK	
Window length 0.0001 ms				
• Symmetric O Up O Down				
	Save templat	e Load template	ок	Cancel

Select the fbpick horizon on the second *Horizon* tab as shown in the picture below:

SAA Attributes Horizon			>
Pick in database Select fbp Trace header Specify CDP O-50:500.70:300	bick Browse	-	
U-50:500,70:300			
	Save template Load ten	nplate OK	Cancel

Set the *Window length* value equal to 10 ms in the 3C Orientation setup dialog box. This is the size of the window (from the first arrival down) inside which the energy will be measured. The window width (offset from the first arrival in ms) should match the P-wave first arrival wavelet length. Choosing too small window size will result in unstable operation of the procedure. If the window is too large, it will include not only the downgoing P-wave, but also other waves such as those reflected from the adjacent boundaries or those refracted on the boundaries with mode- exchange.

All other parameters of this module (*XY Rotation, YZ Rotation, ZX Rotation*) should remain unchanged in this case. These parameters specified in degrees allow additional rotation of the coordinate system in the corresponding directions.

3C Orientation Parameters	_		\times
Window length:	10		
XY Rotation:	0.000000		
YZ Rotation:	0.000000	[
XZ Rotation:	0.000000]	
OK Cancel			

The module setup dialog box should look like the following:

As a result of running the procedure, traces with CHAN=3 will contain the P-component, traces with CHAN=2 will contain the R-component, and traces with CHAN=1 will contain the T- component.

Select Trace Output as the next procedure in the flow to save the orientation results to the database on the *SPO* level under the sp0-PRT name as shown in the picture below:

Select dataset						×
Object(s): sp0_PRT						
>> 😞 🗌 Show objects from sublevels	Set fil	ter text (you can	use * and ? wildcard	s)		
✓	Name	Location	Trace count	Sorted by	Created	
✓	🚔 sp0	SP0 < My	876	FFID : OFFSET	2022-03-11 1	2
😳 010_data_load						
😳 020_view_data						
030_fbpick						
040_3C_Orientation+S_pick						
	<					>
	(OK Car	ncel			

The rest of parameters ensure reliable display of the results on the screen. The Data Filter module allows selecting the necessary traces based on header field values. In our example we need to display the data for each component separately. The picture below shows the module parameters that allow selecting only the R-component from the data:

🥭 Data Filter	×
 No filter Match selection Do not match selection 	
chan 2	
Take values from file:	
OK Cancel	

The flow should end with the Screen Display procedure to visualize the data. The dialog box parameters are shown below:

🐼 Display parameters		×
From t= 0.0 to 0.0 t Scale 10 Number of traces 300 X Scale 10 Rotate Ensemble boundaries	WT/VA display mode	ormalizing factor Gain 0.3 None Bias(%) 0 Individual Show every 1 N-th trace 1
Enable backward frame scrolling Ensembles to scroll Variable spacing field Space to maximum ensemble width Ensembles' gap Muliple panels Use excursion 2.0 traces	Variable density display mode Grey C R/B C Custom Define Data/velocity Display data C Display velocity Set ve	ormalizing factor Gain 0.3 > Entire screen Bias(%) 0 > Individual Image: Show palette Show palette Show palette Show palette Show palette Show palette Show palette
Plot headers Header mark Picks/polygons settings Save Template	d Template Ok	Cancel

Axis Parameters	5	
Dimutan	Time dt Values Lines	Traces C Different dx Values
Primary lines	00.0 ▶	Multiple
Secondary lines	100.0	C Different field ○ Interval 100.0 ▼ C Multiple
Font size 15		Margins
Ok	Cancel	Left axis 20 mm Top axis 20 mm margin 20 mm

By changing the CHAN value in the Data Filter module, you can obtain corresponding P, R and T component images as shown in the pictures below:

CHAN=3 (P-component)



CHAN=2 (R-component)



CHAN=1 (T-component)



Let us use the results of data orientation to the PRT system to perform downgoing and reflected S-wave picking.

To trace S-wave first arrivals using the Data Filter module, select only the R-component and have it displayed on the screen in the Screen Display window.

Perform downgoing S-wave picking using the *Tools/Pick* menu commands in a similar way to downgoing P-wave picking described above. The result is shown in the picture.


Make sure that the S-wave pick is tied to cable depths (same as downgoing P-wave pick described above). Then save the pick under the S wave down going1 name:

Save pick to					×	
Object(s): S wave down going 1						
>> 🙁 🗋 Show objects from sublevels	Set filter to	ext (you can use * and ? wik	dcards)			
👻 💷 My Borehole	Name	Location	Length	Headers	Style	
✓	\land fbpick	SP0 < My Borehole	292	DEPTH : DEPTH		
010_data_load						
020_view_data						
030_fbpick						
040_3C_Orientation+S_pick						
	<				>	
Save all Append Save selection		Pick headers: D	EPTH	V : DEPTH	~	
	ОК	Cancel				

Using direct wave to determine the wavelet for deterministic deconvolution (050 – signature for deconvolution)

Create a 050 – signature for deconvolution flow consisting of the following modules:

- Trace Input
- Amplitude correction
- Apply Statics

- Amplitude Correction
- Screen Display
- Ensemble Stack
- Screen Display
- Trace Output

RadExPro 2021.4 >>> My VSP Project					-		×
Database Options Tools Windows Help							_
Processing Database Navigator							
Project tree ×	Processing flow >> My Borehole / SP0 / 050_signature_for_deconverted	olution	×	All modules			×
» ≈ 🤤		323 U	16	»			
✓ 車 My Borehole	Trace Input <- sp0_raw			>	Dat	a I/O	>^
✓	Amplitude Correction			>	Real-	Time	e
010 data load	Apply Statics <- fbpick			>	Static Correc	tions	5
@ 020 view data	Amplitude Correction			>	Geometry/He	aders	5
(a) 020_thenick	Screen Display			>	Interactive	Tools	ŝ
	Ensemble Stack			>	Signal Proce	ssing	1
<pre>040_3C_Orientation+S_pick</pre>	Screen Display			>	Data Enhance	ment	Ł
050_signature_for_deconvolution	Trace Output -> sp0_decon_impulse			>	Deconvol	ution	1
				<	Cts sking /Engen	ocity	<u>′</u>
				Ś	Stacking/Enser	ntion	`
				\$	Trace Ec	liting	
				>	nace Le	VSP	5
				>		- 00	-
				>	3C Proce	ssina	
				>	Mod	eling	i l
				>	Data Manipul	ation	'n
				>	Auto Pi	cking	,
				>	Interpol	ation	1
				>	M	arine	2
				>	Surface Wave An	alysis	5 🗸 🛛
	Flow status					8	×
MB1 - Move modules; Ctrl+MB1 - Copy modules; MB1 x2 - M	odule parameters; MB2 - Toggle modules; Ctrl+MB2 x2 - Cut modu	les; Shift+M	B1 -	Paste modules			

In this flow we will obtain a wavelet that will later be used in the deterministic deconvolution procedure. To obtain such a wavelet, we need to carry out a number of preliminary procedures: enter correction for spherical divergence into the data, shift the first arrivals by the same time using statistical corrections, and, if necessary, equalize the amplitudes displayed in the window for those areas where gain changed sharply for some reasons. After that we can sum all the traces in the flow in an in-phase way relative to the direct wave and build a resulting trace.

First, let us create a flow as shown below:

- Trace Input
- Amplitude correction
- Apply Statics
- Amplitude Correction
- Screen Display

Select the *CHAN:DEPTH* sorting in the Trace Input module setup dialog box. Specify the following selection ranges in the *Selection* field: 3:400-50000. The number "3" means that only the Z-

component recorded in traces with CHAN=3 will be processed. The depth selection range of 400-50000 was chosen to eliminate the uppermost traces with high amount of noise corresponding to cable depths up to 400 m. The lower limit of the range was chosen to be deeper than the maximum cable depth in the borehole.

Trace Input	×
sp0_raw Add dataset Delete	Sort Fields
Datasets masks	Add Delete (* Selection 3:400-500000 ^
Add mask Delete Load headers only From batch list Memory resort Buffer size (MB)	C Select from file File
OK Cancel	C Get all

The Amplitude Correction module is used here to make correction for spherical divergence. Enable the appropriate option in its dialog box:

	NOT	10		
Exponential corre	ction (dB/ms)	0.0		
Normalization	cuon (uo,)	0.0		
O None				
Constant time	0.0		0 - trace center	
			_	
O Header	AAXFILT			
Maximum application f Automatic gain co Operator length (0.0	ntrol ms) Type of	0.0 AGC scalar	0 - tra Basis for scalar ap CENTERED	plication
Maximum application i Automatic gain coo Operator length (0.0 Save AGC coeffici	ntrol ms) Type of MEAN ients to datas	0.0 AGC scalar	Basis for scalar ap	plication
Maximum application i Automatic gain co Operator length (0.0 Save AGC coeffici Trace equalization	ntrol ms) Type of MEAN ients to datas	AGC scalar	Basis for scalar ap	plication Dataset Location
Maximum application i Automatic gain co Operator length (0.0 Save AGC coeffici Trace equalization Basis for scaling	ntrol ms) Type of MEAN ients to datas	0.0 AGC scalar	Basis for scalar ap	plication Dataset Location Time gate end time (ms)
Maximum application i Automatic gain co Operator length (0.0 Save AGC coeffici Trace equalization Basis for scaling	ntrol ims) Type of MEAN ients to datas	0.0 AGC scalar	Basis for scalar ap	Dataset Location Time gate end time (ms)

Using the Apply Statics module, let us introduce static shifts into the traces in such a way as to match the direct wave with the same time everywhere (100 ms in this example). The shift introduced into each trace will be equal to the difference between the P-wave arrival time determined based on the fbpick pick and the specified constant time (100 ms). Set the module parameters as shown in the picture below:

Apply Statics	×
C Manual C Header Word Browse C Get from database Select fbpick C Use file File	
✓ Relative to time 100.00 □ Subtract static ✓ ✓ Apply fractional statics Maximum number of threads 0	
Save template Load template OK Cancel	

After shifting the traces we need to equalize their amplitudes since there are intervals with a substantially lower gain in the record. To do this, introduce another instance of the Amplitude Correction module into the flow and use its *Trace equalization* option in the 80-400 ms time window.

Time raised to pov	wer	1.0				
Exponential corre	ction (dB/ms)	0.0				
Normalization						
None						
Onstant time	0.0		0 - trace cer	nter		
🔘 Header	AAXFILT	\sim				
Maximum application	time	0.0	C) - trace	end	
Operator length (ntrol ms) Type of A	GC scalar	Basis for sca	lar applic	ation	
Automatic gain co Operator length (0.0 Save AGC coeffici	mtrol ms) Type of A MEAN ients to datase	GC scalar v	Basis for sca	lar applic	ation	
Automatic gain co Operator length (0.0 Save AGC coeffici	mtrol ms) Type of A MEAN ients to datase	GC scalar V	Basis for sca	lar applic	ation Dataset	Location
Automatic gain co Operator length (0.0 Save AGC coeffici	mtrol ms) Type of A MEAN ients to datase	GC scalar	Basis for sca	lar applic	ation Dataset	Location.
Automatic gain co Operator length (0.0 Save AGC coeffici Trace equalization Basis for scaling	ntrol ms) Type of A MEAN ients to datase	GC scalar	Basis for sca CENTERED	lar applic	ation Dataset	Location.
Automatic gain co Operator length (0.0 Save AGC coeffici Trace equalization Basis for scaling MEAN	ntrol ims) Type of A MEAN ients to datase	GC scalar	Basis for sca CENTERED te start time	lar applic	ation Dataset Time gate en 400	Location. d time (ms)

View the results of running the procedures using the Screen Display modules with parameters

shown below:

🛃 Display parameters	×
From t = 0.0 to 1000.1 T t Scale 10 Number of traces 300 X Scale 10 Rotate Final Rotate	WT/VA display mode Normalizing factor Gain 0.3 C WT C None Gain 0.3 C VA Entire screen Bias(%) 0 C None Show every 1
□ Enable backward frame scrolling Ensembles to scroll 1 □ Variable spacing field □ Space to maximum ensemble width Ensembles' gap 2 □ Muliple panels 0 ✓ Use excursion 2.0	Variable density display mode Normalizing factor Gain 0.3 © Grey © None Entire screen Bias(%) 0 © None © Individual © Show palette Data/velocity © Display data Palette range © Display velocity Set velocity Min.vel (m/s) 500.0
Axis Show headers Plot headers Header mark Picks/polygons settings Save Template	Max.vel (m/s) 1500.0 ad Template Ok Cancel

Run the flow. The result should look like the following:



Now we can sum the traces to obtain a seismic wavelet. Such summation will result in the inphase direct wave adding up while the majority of other waves and noises become suppressed.

Comment out the Screen Display module.

Add the Ensemble Stack module used to sum traces within ensembles to the flow. Select the

module parameters as shown below. The *Alpha trimmed* parameter allows removing the specified percentage of minimum and maximum amplitude values before summation, thus eliminating the impact of high-amplitude bursts and hurricane noises

Ensemble Stack		×
Mode Mean Median Median		
C Coherent stack	30 30 3	%
Filter length (ms)	60	
✓ Treat zero as resu	lt of muting	
Number of threads:	0	
ОК	Cancel	

In the RadExPro traces are combined into ensembles based on the same values of the first sorting field specified in the Trace Input module. In our case this is the CHAN header field. Since the value of this header is the same for all traces in the flow (equal to 3), all traces will be summed when we run this module.

Using the Trace Output module, save the generated dataset to the database under the sp0- decon impulse name.

Select dataset					×
Object(s): sp0_decon_impulse					
>>	Set filter text (you	u can use * and ? wildo	ards)		
🗙 📮 My Borehole	Name	Location	Trace count	Sorted by	c
✓	🗧 sp0_raw	SP0 < My	876	FFID : OFFSET	2022
😳 010_data_load	🚔 sp0_PRT	SP0 < My	876	DEPTH : CHAN	2022
😳 020_view_data					
030_fbpick					
040_3C_Orientation+S_pick					
050_signature_for_decon					
	<				>
	ОК	Cancel			

Use the Screen Display module with parameters shown in the picture below to visualize the results.

🛃 Display parameters			:
From t= 0.0 to 500.0 T t Scale 10 Number of traces 10 X Scale 10 Rotate From t= 0.0 to 500.0 t t Scale 10 From t = 0.0 to 500.0 t t Scale 10 From t = 0.0 to 500.0 t t Scale 10 From t = 0.0 to 500.0 t t Scale 10 From t = 0.0 to 500.0 t t Scale 10 From t = 0.0 to 500.0 t t Scale 10 From t = 0.0 to 500.0 t t Scale 10 From t = 0.0 to 500.0 t t Scale 10 From t = 0.0 to 500.0 t t Scale 10 From t = 0.0 to 500.0 t t Scale 10 From t = 0.0 to 500.0 t t Scale 10 From t = 0.0 to 500.0 t t Scale 10 From t = 0.0 to 500.0 t t Scale 10 From t = 0.0 to 500.0 t t Scale 10 From t = 0.0 to 500.0 t t Scale 10 From t = 0.0 to 500.0 t t Scale 10 From t = 0.0 t t Sc	WT/VA display mode WT/VA WT/VA WT VA None	Normalizing factor	Gain 0.3 Bias(%) 0 Show every 1
Enable backward frame scrolling Ensembles to scroll Variable spacing Field Space to maximum ensemble width Ensembles' gap Muliple panels Use excursion Log traces	Variable density display mod C Grey C R/B C Custom Define None Data/velocity C Display data C Display velocity	de Normalizing factor – C None Entire screen C Individual Set velocity	Gain 0.3 Bias(%) 0 Show palette
Axis Show headers Plot headers Header mark Picks/polygons settings Save Template	ad Template Ok	Cancel	

Select trace display using the combined wiggle trace/variable area method (select *WT/VA* in the *Display mode* field). The *Rotate* option allows displaying the trace horizontally.

Click the Axis button to set up axis parameters:

Axis Parameters	5	
Primary lines	Time dt Values Lines	Traces C Different dx Values
Secondary lines		CHAN C Interval Multiple O Multiple O Multiple
Font size 15	Cancel	Margins Left axis margin 20 mm Top axis margin 20 mm

The resulting flow should look like the following:

www.radexpro.com

RadExPro 2021.4 >>> My VSP Project			– 🗆 ×
Database Options Tools Windows Help			
Processing Database Navigator			
Project tree ×	Processing flow >> My Borehole / SP0 / 050_signature_for_deconvolution	×	All modules ×
»	D I - L -	L06	» *
✓ 車 My Borehole	Trace Input <- sp0_raw		> Data I/O ^
✓	Amplitude Correction		> Real-Time
🙆 010 data load	Apply Statics <- fbpick		> Static Corrections
[®] 0.20 view data	Amplitude Correction		> Geometry/Headers
	Screen Display		> Interactive Tools
🥹 030_торіск	Ensemble Stack		> Signal Processing
040_3C_Orientation+S_pick	Screen Display		> Data Enhancement
050_signature_for_deconvolution	Trace Output -> sp0_decon_impulse		> Deconvolution
			> Velocity
			> Stacking/Ensembles
			> Migration
			> Trace Editing
			> VSP
			>QC
			> 3C Processing
			> Modeling
			Data Manipulation
			Auto Picking
			Interpolation
			Marine
			Surface Wave Analysis
Actions ×	📅 Flow status		ē ×
Edit parameters of the module Screen Display			
Edit parameters of the module Screen Display			
Drag'n'drop modules			
Insert module Screen Display at position 6			
MB1 - Move modules; Ctrl+MB1 - Copy modules: MB1 x2 - M	odule parameters; MB2 - Toggle modules; Ctrl+MB2 x2 - Cut modules: Shift+I	- MB1 -	- Paste modules

Run the flow. The result is shown in the picture below.



Looking at the picture, we can assume that the wavelet length is about 80 ms, and the wavelet origin is located at 100 ms.

To view the amplitude spectrum of the resulting wavelet, select *Tools -> Spectrum ->Average*

in the visualization window parameters (hot key on toolbar). After that, you can select an area of the trace (or seismogram) by clicking the left mouse button. The spectrum of the selected area will be displayed in a pop-up window.



Testing deterministic deconvolution parameters (060 – deconvolution test.)

Create a 060-deconvolution test flow.

This flow will consist of the following modules:

- Trace Input
- Amplitude Correction
- Deconvolution
- Screen Display

RadExPro 2021.4 >>> My VSP Project				- 0	×
Database Options Tools Windows Help					
Processing Database Navigator					
Project tree ×	Processing flow >> My Borehole / SP0 / 060_deconvolution_test	×	All modules		×
» ≈ @	▶ II • t₀ •	33 LOG	» «		
 ・ ・ ・	Trace Input <- sp0_raw		>	Data I/	o ^
✓	Amplitude Correction		>	Real-Tim	ie 👘
010 data load	Custom Impulse Trace Transforms		>	Static Correction	ıs
@ 020 view data	Screen Display		>	Geometry/Header	rs
@ 020_fteide			>	Interactive Too	ls
₩ 030_твріск			>	Signal Processin	g
9 040_3C_Orientation+S_pick			>	Data Enhancemer	۱t
050_signature_for_deconvolution			>	Deconvolutio	n
060_deconvolution_test			>	Velocit	ÿ
			>	Stacking/Ensemble	25
			\$	Migratio	n
			\$		9
			\$		
			>	3C Processin	
			>	Modelin	9
			>	Data Manipulatio	'n
			>	Auto Pickin	g
			>	Interpolatio	'n
			>	Marin	ie
			>	Surface Wave Analys	is 🗸
	📅 Flow status			6	×
MB1 - Maye modules: Ctrl+MB1 - Conv.modules: MB1 v2 - M	ndule narameters: MR2 - Togole modules: Ctrl+MR2 v2 - Cut module	s: Shift+MR1	- Paste modules		

Set the Trace Input module parameters as shown in the picture below:

Trace Input	×
Data Sets	Sort Fields CHAN Image: CHAN DEPTH Image: CHAN Image: CHAN Image: CHAN
Datasets masks	Add Delete
Add mask Delete Load headers only From batch list Memory resort Buffer size (MB) OK Cancel	Select from file File Database object Choose Get all

Using the Amplitude Correction module, introduce correction for spherical divergence (enable the *Spherical divergence correction* option).

Time raised to po	wer	1	
Exponential corre	ction (dB/ms)	0.0	
Normalization			
None			
Constant time	0.0	0 - trace center	
O Header	AAXFILT	\sim	
Maximum application	time	0 - trace	and
availant application	une C	510 0 ddd	e en la
Automatic gain co	(ms) Type of AG	C scalar Basis for scalar app	ication
Automatic gain co Operator length (0.0 Save AGC coeffic	(ms) Type of AG MEAN ients to dataset:	C scalar Basis for scalar app	ication
Automatic gain co Operator length (0.0 Save AGC coeffic	(ms) Type of AG MEAN ients to dataset:	C scalar Basis for scalar appl	Dataset Locatio
Automatic gain cc Operator length (0.0 Save AGC coeffic	(ms) Type of AGG MEAN ients to dataset:	C scalar Basis for scalar app	Dataset Locatio
Automatic gain cc Operator length (0.0 Save AGC coeffic Trace equalization Basis for scaling	mtrol (ms) Type of AGC MEAN ients to dataset:	C scalar Basis for scalar app	Dataset Locatio
Automatic gain cc Operator length (0.0 Save AGC coeffic Trace equalization Basis for scaling MFAN	mtrol (ms) Type of AGG MEAN ients to dataset:	C scalar Basis for scalar app CENTERED Time gate start time (ms)	Dataset Locatio

Deterministic deconvolution can be performed using the Custom Impulse Trace transforms module. Specify the name of the file containing the wavelet in the module parameters. It should be a binary file using R4IEEE number presentation format without any headers. The trace with the wavelet should have the same sampling interval as the traces to which deconvolution will be applied. By

default, the RadExPro generates a binary file in the R4 IEEE format when creating an output dataset using the Trace Output module (headers are stored separately). Therefore, in our example you can directly select the file in the project directory corresponding to the dataset created during the previous step. This file should be easy to find – the project directory structure replicates the database structure.

The module parameters are shown in the picture below:

	My Borehole	SP0	\sp0_de	con_impu	ilse	Browse
Matching field	dt					Add
	Get time from	head	ers of im	pulse dat	taset	
t1	100			t2	180	
	Browse				Browse	
	Get time from	head	ler of im	ulse dat	aset	
zero	time 0			[Browse	1
	,					-
O Get in	pulse from file	2				
File						Browse
t1	0	_		t2 [1	1
dt	0.2	_	zero	time [0	-
	,					
Get ti	me from head	ers			Use t	apering
t1 0	1	t2	10000	00	🗖 Taj	per data
В	rowse		Brow	se	Window	0 %
Amplitud	e spectra —			Pha	se spectra —	
O No op	eration			0	No operation	
O Multip	ly			0	Add	
(•) Divide	·	_			Subtract	
0.000		3	Anna	Addi	tional phace	10

To display the results on the screen, add the Screen Display module to the flow. Select trace display using the variable density method in the grayscale palette (Gray) and set the number of traces on the screen equal to 300.

🐼 Display parameters	×
From t= 0.0 to 0.0 t Scale 10 Number of traces 300 X Scale 10 Rotate Ensemble boundaries	WT/VA display mode Normalizing factor Gain 0.3 C WT/VA C None Gain 0.3 C WT G Entire screen Bias(%) 0 C None Show every N-th trace 1
Enable backward frame scrolling Ensembles to scroll Variable spacing Space to maximum ensemble width Ensembles' gap Muliple panels Use excursion L0 traces	Variable density display mode © Grey © R/B © Custom Define © None © Entire screen © Individual © Display data © Display velocity © Display velocity Set velocity Min.vel (m/s) Son.0 Son.0 Son.0 Son.0 Min.vel (m/s) Son.0 Son.
Axis Show headers Plot headers Header mark Picks/polygons settings Save Template L	.oad Template Ok Cancel

To compare the results of applying deconvolution with the source data, comment out the Custom Impulse Trace transforms module and run the flow.

Before deconvolution, the data look like the following:



Now, without closing the Screen Display window, go back to the flow, uncomment the Custom Impulse Trace transforms module and run the flow once again. Another Screen Display window containing the deconvolution results will open:



Now, by switching between the windows, you can compare the data before and after deconvolution. To view record spectrums, use the *Tools/Spectrum/Average* menu command. You can synchronize windows with each other using the "sight" located on the quick access panel .

Reflected PP wave field separation (070 – ug PP)

Z-components will be used to separate reflected wave field. In general, the procedure of reflected wave separation consists of picking a travel time curve for a noise wave (any wave other than the reflected one), bringing the noise wave travel time curve to the vertical line using static corrections, subtracting this wave from the wave field using a two-dimensional spatial filter, and introducing inverse static corrections.

Create a new flow for reflected wave field separation: 070 - ug PP.

Let us analyze the input data. To do this, we will construct a flow consisting of the following procedures:

- Trace Input
- Amplitude Correction
- Screen Display

The procedure parameters are shown below.

Trace Input

Trace Input	×
Data Sets <u>sp0_raw</u> Add dataset Delete Datasets masks	Sort Fields CHAN DEPTH Image: Change of Ensemble Fields Image: Change of Ensembles will be defined by this number of sort fields. Add Delete Image: Change of Ensembles will be defined by this number of sort fields.
	3:0-50000
Add mask Delete Load headers only From batch list Memory resort Buffer size (MB) OK Cancel	C Select from file File

Amplitude Correction

- Time raised to power	1			
Exponential correction (dB/ms) 0.0			
Normalization				
O None				
Constant time 0.0	0 - tr	race center		
O Horizon				
O Header AAX	ilt ~			
Maximum application time	0.0	0 - trace	end	
Automatic gain control Operator length (ms) T	/pe of AGC scalar Basis	for scalar appli	cation	
Automatic gain control Operator length (ms) T 0.0 Save AGC coefficients t	rpe of AGC scalar Basis IEAN V CEN	for scalar applic	cation	
Automatic gain control Operator length (ms) T 0.0 Save AGC coefficients t	rpe of AGC scalar Basis IEAN CEN o dataset:	for scalar applie	Dataset	Location
Automatic gain control Operator length (ms) T 0.0 Save AGC coefficients t Trace equalization	rpe of AGC scalar Basis IEAN V CEN o dataset:	for scalar applic	Dataset	Location
Automatic gain control Operator length (ms) T 0.0 Save AGC coefficients to Trace equalization Basis for scaling	rpe of AGC scalar Basis IEAN CEN o dataset: Time gate sta	for scalar appli TERED	Dataset	Location
Automatic gain control Operator length (ms) T 0.0 Save AGC coefficients t Trace equalization Basis for scaling MEAN	rpe of AGC scalar Basis IEAN CEN o dataset: Time gate sta	for scalar applied for scalar ap	Dataset Time gate end	Location
Automatic gain control Operator length (ms) T 0.0 Save AGC coefficients b Trace equalization Basis for scaling MEAN Time variant scaling	rpe of AGC scalar Basis IEAN CEN o dataset: Time gate sta	for scalar appli TERED	Dataset Time gate end	Location

Screen Display

🐼 Display parameters		>
From t = 0.0 to 0.0 T t Scale 10	WT/VA display mode Normalizing factor © WT/VA Normalizing factor	Gain 0.3
Number of traces 300 X Scale 10	C VA C Individual	s(%) 0
Rotate	C None Show ev	erv 1
Ensemble boundaries	N-th trac	ce 1
Enable backward frame scrolling	Variable density display mode	
Ensembles to scroll	C Grey	Gain 0.3
Variable spacing field	C R/B C Entire screen Bias	s(%) 0
Space to maximum ensemble width	None Organite Organit Organit Organite Organite Or	how palette
Ensembles' gap 2	-Data kielority	
Muliple panels	Display data Display data	
✓ Use excursion 2.0 traces	C Display velocity Set velocity	500.0
	Introduction (m/s)	500.0
Axis Show headers	vlax.vel (m/s)	1500.0
Plot headers Header mark		
ricadersin ricader indikin		
Picks/polygons settings		
Save Template Lo	oad Template Ok Cancel	

The result of applying the procedures is shown in the picture:



We can see from the picture that the data includes waves of different types - downgoing and

reflected P- and S-waves. Besides, it is evident that the general amplitude level changes from trace to trace: the record includes traces with a substantially lower gain.

First of all, let us equalize trace gain using the *Trace equalization* option of the Amplitude Correction module. This function calculates average amplitude for each trace in the specified window, and then divides all trace samples by the average amplitude value. It is clear that in order for this procedure to perform correct equalization of different traces, it is necessary to ensure that events falling within the window in which the average amplitude is calculated are of the same type for all the traces.

We will equalize the amplitudes by the downgoing P-wave. To do this, we will first introduce static corrections to bring the wave to the vertical line, then perform trace amplitude balancing (*Trace Equalization*) in the window containing the direct wave, and finally return all waves to their correct times by applying inverse static corrections.

Let us add the following modules to the flow:

Apply Statics – select the fbpick first arrival pick and the time relative to which corrections will be made -100 ms. The shift introduced to each trace will be equal to the difference between the P-wave arrival time determined based on the pick and the specified constant time.

Apply Statics	Х
C Manual C Header Word Browse C Get from database Select fbpick C Use file File	
✓ Relative to time 100.00 ✓ Subtract static ✓ Apply fractional statics Maximum number of threads	
Save template Load template OK Cancel	

Amplitude Correction – enable the *Trace Equalization* option. Select the boundaries of the windows so that it includes the downgoing P-wave (this wave will be moved to the 100 ms constant time after introducing the static correction). The window should not be too narrow since this will cause average amplitude calculation to be unstable. Set the parameters as shows in the picture below:

Time raised to power	1.0	
Exponential correction (dB/ms)	0.0	
Normalization		
O None		
Constant time 0.0	0 - trace center	
O Horizon		
Header AAXFILT	~	
Maximum application time	0.0 0 - trace end	
Automatic gain control Operator length (ms) Type of A	AGC scalar Basis for scalar application	
Automatic gain control Operator length (ms) Type of <i>I</i> 0.0 MEAN Save AGC coefficients to datas	AGC scalar Basis for scalar application	
Automatic gain control Operator length (ms) Type of <i>I</i> 0.0 MEAN Save AGC coefficients to datase	AGC scalar Basis for scalar application CENTERED et: Dataset	ocation
Automatic gain control Operator length (ms) Type of A O.0 MEAN Save AGC coefficients to datas Type of A Trace equalization	AGC scalar Basis for scalar application CENTERED at: Dataset	ocation
Automatic gain control Operator length (ms) Type of <i>I</i> 0.0 MEAN Save AGC coefficients to datass Trace equalization Basis for scaling	AGC scalar Basis for scalar application CENTERED CENTERED Time gate start time (ms) Time gate end time	ne (ms)
Automatic gain control Operator length (ms) Type of <i>I</i> 0.0 MEAN Save AGC coefficients to datass Trace equalization Basis for scaling MEAN	AGC scalar Basis for scalar application CENTERED Dataset Lo Time gate start time (ms) Time gate end tim 80 400	ne (ms)

Add another instance of the Apply Statics module to introduce inverse static corrections. Its parameters should be the same as for the first instance, except for one difference: enable the *Subtract static* option to have the static corrections introduced with the opposite sign:

Apply Statics	\times
C Manual C Header Word Browse C Get from database Select fbpick C Use file File	
Image: Relative to time 100.00 Image: Subtract static Image: Subtract static Image: Relative to time Maximum number of threads Image: Relative to time Maximum number of threads	

At this stage, the flow should look like the following:

- Trace Input
- Amplitude Correction
- Apply Statics
- Amplitude Correction
- Apply Statics
- Screen Display



The results of flow execution are shown in the picture below:

We can see that gain of different traces was equalized as a result of applying the procedures.

Let us perform deterministic deconvolution of the data with the parameters selected for the previous flow. The result is shown in the picture:



Since deterministic deconvolution results in the downgoing P-wave wavelet becoming close to the zero phase wavelet, first arrival times now correspond to the central extremum of the waveletrather than the first zero crossing. Therefore, the first zero crossing becomes shifted to smaller times. Since the first arrival pick will be later used for muting, we will need to shift the pick to smaller times as shown in the picture below in order to ensure wavelet shape preservation after muting:



To do this, load the fbpick first arrival pick using the *Tools/Pick/Load pick* menu item. Then move the pick to the required location by simultaneously pressing and holding Shift and the right mouse button. Save the pick under the fbpick after deconvolution name on the second database level.

Save pick to					×
Object(s): fbpick_after_deconvolution					
>>	Set filter te	xt (you can use * and ? wik	dcards)		
✓ 単 My Borehole	Name	Location	Length	Headers	Style
✓	\land fbpick	SP0 < My Borehole	292	DEPTH : DEPTH	
😳 010_data_load	🔨 S wave	SP0 < My Borehole	292	DEPTH : DEPTH	
😳 020_view_data					
030_fbpick					
👶 040_3C_Orientation+S					
050_signature_for_dec					
🙆 060 deconvolution test 💙	<				>
Save all Append Save selection		Pick headers: D	epth	✓ : DEPTH	~
	ОК	Cancel			

Now let us remove downgoing P-waves from the record. To do this, we will need to bring the downgoing P-wave travel time curve to the vertical line using static corrections (Apply Statics), subtract this wave from the wave field using a two-dimensional spatial filter (2D Spatial Filtering), and introduce inverse static corrections (Apply Statics).

We will add procedures to the flow one after another and view the results of their execution: Apply Statics:

Apply Statics	×
C Manual C Header Word Browse C Get from database Select fbpick_after_deconvolution C Use file File	
Relative to time 100.00 Subtract static Subtract static Apply fractional statics Maximum number of threads	0
Save template Load template OK Can	cel

The result of applying the procedure is shown below:



2D Spatial Filtering:

Select the subtraction mode (*Filter mode: Subtraction*) in the module setup dialog box – in this mode the average value obtained in the window will be subtracted from the window's central sample. Select the *Alpha-Trimmed Mean* filter type to reduce the impact of accidental bursts on the result.

The result of applying the procedure is shown below:



We can see that the downgoing P-wave was successfully subtracted from the record.

Now we need to introduce the necessary inverse static corrections to return the remaining waves to their proper times. To do this, we will add another instance of the Apply Statics module to the flow:

Apply Statics	×
O Manual O Header Word Browse Image: Get from database Select fbpick_after_deconvolution O Use file File	
✓ Relative to time 100.00 ✓ Subtract static ✓ ✓ Apply fractional statics Maximum number of threads	
Save template Load template OK Cancel	

The result of running the procedures is shown below:



The processing flow should look like the following at this stage:

ject tree	Processing flow >> My Borehole / SP0 / 070_ug_PP	× All modules	
* P	D 🖬 🔹 👘 🔚 📰	2 LOG » «	
🗖 My Borehole	Trace Input <- sp0_raw	>	Data I/O
✓	Amplitude Correction	>	Real-Time
010 data load	Apply Statics <- fbpick	>	Static Corrections
0.20 view data	Amplitude Correction	>	Geometry/Headers
	Apply Statics <- fbpick	>	Interactive Tools
030_tbpick	Custom Impulse Trace Transforms	>	Signal Processing
040_3C_Orientation+S_pick	Apply Statics <- fbpick_after_deconvolution	>	Data Enhancement
050_signature_for_deconvolution	2D Spatial Filtering	>	Deconvolution
060_deconvolution_test	Apply Statics <- fbpick_after_deconvolution	>	Velocity
@ 070 ug PP	Screen Display	>	Stacking/Ensembles
		>	Migration
		>	Trace Editing
		>	VSP
		>	QC
		>	3C Processing
		>	Modeling
		>	Data Manipulation
		>	Auto Picking
		>	Interpolation
		>	Marine
		>	Surface Wave Analysis
		>	Refraction
	Flow status		ē

Note that the data fragment circled in red in the picture below contains a low-frequency component unlike the rest of the record.



Therefore we will need to apply band-pass filtering in the window before proceeding withnoise wave subtraction. To do this, we will first perform picking to select an area containing the low-frequency and high-frequency component, and then use the Nonstationary Predictive Deconvolution module. This module's function is to perform band-pass filtering in a window.

Create a pick limiting the low-frequency area as shown in the picture. Save the pick under the name of gate_for_filtering.



This pick has separated the data into 2 fragments. We want to process those fragments in different ways. To apply filtering to the selected fragment, set the following Time Variant Bandpass Filtering module parameters:

Time variant bandpass filtering			×
Use windows	Filter type		
	Ormsby bandpass filter		\sim
From pick ~	Filter parameters		
My Borehole\SP0\gate_for_filtering	Window usage:	1:1	0 - no operation 1 - filter
	Low-cut ramp: 0%	4:15	Hz
	100%	6:17	Hz
Add Delete	High-cut ramp: 100%	250 : 250	Hz
Tapering length: 10.00 % of window length	0%	250:250	Hz
Windows overlap: 10.00 ms	Number of threads: (au	ito) 🗘	
ОК	Cancel		

www.radexpro.com

Here the gate for filtering pick sets the boundary between the two windows – one to the left of the pick, and one to the right. Parameters for each window are entered into one line and divided by a colon. For both windows, it is specified whether filtering will be performed in the window (*Window usage* 1:1), further set the pass band equal to 4-250 Hz for the first window (before the pick) and 15-250 Hz for the second window (after the pick), as shown in the picture.

The result of applying the procedure is shown below:



Now let us subtract the downgoing S-wave from the wave field. We will do it by using the same approach we employed earlier when subtracting the P-wave. However, due to a large difference in transverse wave arrival times on upper and lower instruments bringing the wave to the vertical line may lead to data loss – some samples containing useful signals may become shifted outside the trace. To prevent this from happening, we need to increase the trace length before introducing static corrections.

To increase the trace length, add the Trace Length to the flow and set the new trace length equal to 9000 ms.

Trace Length Parameters	_		×
New trace length:	000.00000		

After that, bring the S-wave travel time curve to the vertical line (time = 2500 ms), subtract the

wave, and introduce inverse static corrections.

The resulting flow should look like the following at this stage:

- Trace Input
- Amplitude Correction
- Apply Statics
- Amplitude Correction
- Apply Statics
- Custom Impulse Trace Transform
- Apply Statics
- 2D Spatial Filtering
- Apply Statics
- Time Variant Bandpass Filtering
- Trace Length
- Apply Statics
- 2D Spatial Filtering
- Apply Statics
- Screen Display

Parameters of modules needed to subtract the S-wave are shown below:

Apply Statics

Apply Statics	×
C Manual C Header Word Browse C Get from database Select S wave down going 1	
C Use file	
Image: Relative to time 2500.00 Image: Subtract static 2500.00	
Apply fractional statics Maximum number of thread	ds 0
Save template Load template OK	Cancel

2D Spatial Filtering

2-D Spatial Filtering ×
Filter type © 2-D Mean
Weights: 💿 Box car 🔿 Triangle 🔿 Hamming
C 2-D Median
Alpha-Trimmed Mean
Rejection percentage 30
Filter size
Number of traces 11
Number of samples 1
-Filter mode
C Normal Subtraction
OK Cancel

Apply Statics

C Manual			
C Header Word Browse			
Get from database Sel O Use file File	ct S way	ve down going	1
✓ Relative to time 25 ✓ Subtract static	00.00		
Apply fractional statics	Maxir	mum number o	f threads 0
Save template Load tem	olate	ок	Cancel

The result of applying the procedures is shown in the picture below:



As we can see, the wave field still contains some downgoing S-wave fragments after downgoing S-wave subtraction. Perform picking on one of such fragments as shown in the picture below. Save the pick on the second project level under the S wave down going2 name.



Use the same set of modules to subtract those fragments: Apply Statics (S wave down going2 pick, Relative to time 4000), 2-D Spatial Filtering (filter type: *Alpha-Trimmed Mean*, window size: 9

traces per sample, *Subtraction* mode), and another Apply Statics (same parameters as for the first one, but with *Subtract Statics* enabled).

The result of applying the procedures is shown in the following picture:



Then let us add a number of "cosmetic" procedures to the flow in order to improve the signal to noise ratio and ensure proper reflection polarity.

We will use the Burst Noise Removal module to suppress high-amplitude localized burstnoises. The module parameters are shown below:

Burst Noise Removal		×	
Window size for average value calculation (traces)	11		
Rejection percentage (%)	20		
Do not change amplitudes lower than (%) of the average	5		
Modify values when exceed average in more than N times	3		
OK Cancel			

The result of running the procedure is shown in the picture below:



Now let us use the Bandpass Filtering module to apply band-pass filtering to the data in a wide frequency band. Select the Ormsby filter (*Ormsby Bandpass Filter*) with 5-10-70-150 Hz frequencies in the module setup dialog box.

Bandpass filtering			×
Filter type C Simple bandpass filter Ormsby bandpass filter C Butterworth filter	Filter parameters	5	(Hz) (Hz)
C Notch filter	High-cut ramp: 100%	70	(Hz) (Hz)
	Number of threads:	0	

To comply with the polarity convention adopted in exploration seismology (waves reflected from positive boundaries, i.e. boundaries corresponding to an increase of impedance in the lower medium relative to impedance in the upper medium, should be shown on Z-component seismograms using positive extremums), we need to invert the wave field phase, i.e. multiply the value of each trace by -1. We will do it by running the Trace Math module with the following parameters:

🥭 Trace Math	×
Mode:	
Trace/Scalar	O Trace/Trace
Operation:	
O Add Scalar	Add Traces
🔘 Scalar minus Sample	Subtract Traces
Multiply by Scalar	 Multiply Traces
O Divide Scalar by Sample	 Divide Traces
O Reverse Trace	Cross Correlation
Replace this Amplitude 0.0 by Scalar	
Scalar: -1.0	Honor ensemble boundaries
Header: AAXFILT	~
Division threshold: 0.01	
ОК	Cancel

Now perform seismic trace muting before the first arrivals by running the Trace Editing with the parameters shown below:

Trace Editing	×
Trace Editing parameters Horizon Second horizon	
Muting Top muting Bottom muting Muting in window Top muting ms	
Taper window length 0 ms	
C Zero padding C Inverse	
C Trace killing	
Save template Load template OK	Cancel

Use the first arrival pick shifted after deconvolution fbpick after deconvolution as the horizon defining the muting.

Frace Editing	u. L		>
Trace Editing parameters	Honzon Sec	cond horizon	
Pick in database	Select	fbpick_after_deco	nvolution
C Trace header		Browse	
0-50:500,	70:300		

The result of running the procedures is shown in the picture below:



Finally, save the resulting reflected P-wave field to the database under the name of sp0_PPwave_ug using the Trace Output module:

左 Select dataset					×
Object(s): sp0_P_wave_ug					
>>	Set filter text (you can	use * and ? wildcard	is)		
✓ I My Borehole	Name	Location	race cour	Sorted by	Crea
✓	🚔 sp0_raw	SP0 < My Bo	876	FFID : OFFSET	2022-03
😳 010_data_load	🚔 sp0_PRT	SP0 < My Bo	876	DEPTH : CHAN	2022-03
O20_view_data	sp0_decon_impulse	SP0 < My Bo	1	CHAN : DEPTH	2022-03
Ø 030_fbpick					
040_3C_Orientation+S_pick					
050_signature_for_decon					
060_deconvolution_test					
070_ug_PP			_		
	<				>
	OK Can	icel			

The resulting flow should look like the following:

- Trace Input
- Amplitude Correction
- Apply Statics
- Amplitude Correction
- Apply Statics
- Custom Impulse Trace Transform
- Apply Statics
- 2D Spatial Filtering
- Apply Statics
- Time Variant Bandpass Filtering
- Trace Length
- Apply Statics
- 2D Spatial Filtering
- Apply Statics
- Apply Statics
- 2D Spatial Filtering
- Apply Statics
- Burst Noise Removal
- Bandpass Filtering
- Trace Math
- Trace Editing
- Trace Output
- Screen Display

Note that the process of separation the reflected wave field may be improved by adding new procedures for subtraction of remaining noise waves (such as S-waves with inclination slightly different from the picked travel time curve). Therefore, the process of reflected wave field subtraction can be iterative.

Building a velocity model (080 – velocity model)

Let us create a new flow to build a velocity model based on the selected reflected wave field – 080 – velocity model. The flow will consist of the following modules:

- Trace Input
- SSAA
- Advanced VSP Display

RadExPro 2021.4 >>> My VSP Project		- □ >	<
Database Options Tools Windows Help			
Processing Database Navigator			
Project tree ×	Processing flow >> My Borehole / SP0 / 080_velocity ×	All modules X	¢
» ≈ [₽	🖻 🔲 🕶 🖫 👻 📒 📘 🔛	»	
 ゴ My Borehole 	Trace Input <- sp0_P_wave_ug	> Data I/O '	^
✓	SSAA	> Static Corrections	
010 data load	Advanced VSP Display	> Geometry/Headers	
		> Interactive Tools	
020_view_data		> ————————————————————————————————————	
030_fbpick		> Data Enhancement	
040_3C_Orientation+S_pick		> Deconvolution	
050_signature_for_deconvolution		> Velocity	
060_deconvolution_test		> Stacking/Ensembles	٩.
@ 070 µg PP		> Migration	
@ 090 velocity model		> Trace Editing	
tor 080_velocity_model		> VSP	
		>QC	
		> 3C Processing	
		> Modeling	·
	Flow status	- 'A	1
MB1 - Move modules; Ctrl+MB1 - Copy modules; MB1 x2 - Mo	lule parameters; MB2 - Toggle modules; Ctrl+MB2 x2 - Cut m	odules; Shift+MB1 - Paste modules	

In the Trace Input module, select the dataset created by the previous flow containing the reflected P-waves – $sp0_P_wave_ug$. Select one sorting key: DEPTH, and enter * in the Selection field since we are going to read the entire data range.

Trace Input Data Sets <pre>sp0_P_wave_ug</pre>	Sort Fields
Add dataset Delete	Add Delete
Add mask Delete Load headers only From batch list Memory resort Buffer size (MB) OK Cancel	C Select from file File File

The actual building of the velocity model takes place in the Advanced VSP Display module. The seismogram that is input into the module should contain downgoing P-wave first arrival timesin the FBPICK header field. We will use the SSAA module to copy those times from the fbpick pick.

Select the *Peak amplitude time* attribute (time corresponding to the maximum amplitude in the window) on the first tab of the SSAA module dialog box. Since we are interested in the exact pick time, enter 0 in the *Window length* field (search window length). Select the FBPICK header field where the values will be written from the drop-down list on the right.

CC4.4				~
SSAA				~
Attributes Horizon				
Attributes				
Attribute Trace he	ader			
Peak frequency	Ψ.	RMS Amplitude		-
Centroid frequency	Ŧ	Pick amplitude		-
Apparent frequency	Ψ.	Peak amplitude time	FBPICK	-
Visible frequency	Ŧ	Trough amplitude time		-
🔲 Bandwidth	Ŧ	Max. absolute amp. time		-
🗌 Peak amplitude	Ŧ	S/N Ratio		-
Trough amplitude	$\overline{\nabla}$	Resolving power		
Max. absolute amp.	-	Time shift		-
Window length 0 ms				
	ı			
	Save te	emplate Load template	ОК	Cancel

Specify the fbpick first arrival pick as the horizon on the second tab of the dialog window.
SSAA	×
Attributes Horizon	
Fick in database Select fbpick	
C Trace header B C Specify CDP 0-50:500,70:300	rowse
5	Save template OK Cancel

Now add the Advanced VSP Display to the flow. Select the following parameters:

VSP Display Parameters		×
Logging data (LAS) file	D:\InData\AK.las	Browse
LAS column name(s)	AK	Edit
]	
Load model file		Browse
Save model file	D:\InData\My VSP P-wave model.mdl	Browse
⊢Depth	Time	
Start Z (m)	0 Start time (ms)	0
End Z (m)	0 End time (ms)	3000
Altitude correction	0	
Trace Display		
Trace scale	0.5 Trace step (m)	10
Velocity	Attenuation	
Interval velocity calc. base (rec)	3 Get amplitudes from :	
Regularization parameter	0.15 CCP	Browse
	OK Cancel	

Specify the name of the file on the hard disk where the built model will be automatically saved in the *Save model file* field.

ATTENTION: After running the flow for the first time, it is recommended to specify the same model file name in the *Load model file* field as in the *Save model file* field. This will allow resuming the work from the last change point during subsequent runs. Besides, since the model output file is saved automatically when the user exits the Advanced VSP Display module, specifying it as the input file will help avoid undesirable loss of the previously created model.

Run the flow. An Advanced VSP Display module window similar to the one shown below willappear:



Building the velocity model includes adding and editing layer boundaries and working with rulers that allow changing the image scale.

Editing layer boundaries

Layer boundaries can be added, deleted or moved.

• To add a layer boundary, place the mouse cursor over the spot in the seismogram window where you want to add a boundary and click the left mouse button.

• To move a layer boundary, "grab" it using the left mouse button, drag the boundary to the newposition, and release the mouse button.

• To delete a boundary, double-click on it with the right mouse button.

Working with rulers

Depth, time and parameter value rulers are control elements that allow changing the appropriate scale. To adjust the scale, place the cursor over the start value of the ruler, press the left mouse button, move the cursor to the new end value while holding down the mouse button, and release the mouse button. To revert to the original scale on the selected axis, right-click on the appropriate ruler.

The results of building the velocity model should look like the following:



These results can be exported to a text file using the File/Export result menu item.



When you select this item, a dialog box will open, prompting the user to specify the names of text files where the results will be exported.

Export results files	×
Lay model file	Browse
Per-trace file	Browse
OK Cancel	

Lay model file – file containing the layer velocity model

Per-trace file – file containing the per-trace table with two-way vertical travel time curvevalues as well as average and layer velocity values.

Reflected wave field visualization and introduction of the NMO-corrections (090 – ug and ug nmowaves display)

RadExPro 2021.4 >>> My VSP Project		- 🗆 ×
Database Options Tools Windows Help		
Processing Database Navigator		
Project tree ×	Processing flow >> My Borehole / SP0 / 090_ug_and_ug_nm ×	All modules ×
» ≈ @		» <
✓ III My Borehole	Trace Input <- sp0_P_wave_ug	> Data I/O ^
✓	Amplitude Correction	> Static Corrections
010 data load	Trace Editing <- fbpick_after_deconvolution	> Geometry/Headers
@ 020 view data	VSP NMO	> Interactive Tools
020_view_data	Trace Length	> Signal Processing
	Trace Output -> sp0_ug_nmo	> Data Enhancement
<pre>040_3C_Orientation+S_pick</pre>	Screen Display	> Deconvolution
050_signature_for_deconvolution		Velocity
060_deconvolution_test		Stacking/Ensembles
070_ug_PP		Trace Editing
080_velocity_model		
090_ug_and_ug_nmo_waves_display		>
		> 3C Processing
		> Modeling
		> Data Manipulation
		> Auto Picking ~
	Flow status	E ×
MB1 - Move modules: Ctrl+MB1 - Copy modules: MB1 x2 - Module paran	neters: MB2 - Toggle modules: Ctrl+MB2 x2 - Cut modules: Shift+	MB1 - Paste modules

Create a new flow and name it 090 - ug and ug nmo waves display. The flow will contain the following modules:

- Trace Input
- Amplitude Correction
- Trace Editing
- VSP NMO
- Trace Length
- Resample
- Trace Output
- Screen Display

Specify the sp0_P_wave_ug dataset and sorting by the DEPTH field in the Trace Input module.

Trace Input	×
Data Sets	Sort Fields
sp0_P_wave_ug Image: Constraint of the second se	DEPTH Image: Second
Datasets masks	Add Delete
	© Selection
	* ^
Add mask Delete	C Select from file File
	O Database object Choose
Buffer size (MB) 0	
OK Cancel	S Get all

Enable *Automatic Gain Control* in the Amplitude Correction module and set the operator length equal to 200 ms.

We will use the Trace Editing module to mute the record in the interval before downgoing Pwave first arrivals. Select the *Top muting* option in the module setup dialog box and specify the fbpick after deconvolution pick as the horizon for muting.

Use the VSP NMO module to introduce Normal Move-Out (NMO) corrections into the VSP data. The module parameters are shown in the picture:

VSP NMO	×
Edit parameters New source/receiver position Source elevation Receiver elevation Source to receiver horizontal distance Speed model file	OK Cancel
D:\InData\My VSP P-wave model.mdl Browse	

After that and before saving the result to the database and displaying it on the screen, let us revert to the original trace length -4 s. We will do it with the help of the Trace Length module.

Trace Length Parameters		_	×
New trace length:	4000		

Using the Trace Output module, save the results to the sp0_ug_nmo dataset.

Select dataset					×
Object(s): sp0_ug_nmo					
>>	Set filter text (you can	use * and ? wildcard	ds)		
✓ I My Borehole	Name	Location	race cour	Sorted by	Crea
✓	🗧 sp0_raw	SPO < My Bo	876	FFID : OFFSET	2022-03
😳 010_data_load	≑ sp0_PRT	SP0 < My Bo	876	DEPTH : CHAN	2022-03
🍪 020_view_data	sp0_decon_impulse	SPO < My Bo	1	CHAN : DEPTH	2022-03
030_fbpick	≑ sp0 P wave ug	SP0 < My Bo	292	CHAN : DEPTH	2022-03
040_3C_Orientation+S_pick					
050_signature_for_decon					
060_deconvolution_test					
O70_ug_PP					
080_velocity_model					
090_ug_and_ug_nmo_wav					
	<				>
	OK Car	ncel			

For visual monitoring, insert the Screen Display module at the end of the flow with the following parameters:

🐼 Display parameters			;
From t = 0.0 to 4000.1 t Scale 10 Number of traces 300 X Scale 10	WT/VA display mode WT/VA WT/VA WT VA VA O VA O None	Normalizing factor - C None C Entire screen C Individual	Gain 0.3 Bias(%) 0
Ensemble boundaries	> NULE		Show every 1 N-th trace
Enable backward frame scrolling Ensembles to scroll Variable spacing Space to maximum ensemble width Ensembles' gap Muliple panels Use excursion 2.0 traces	Variable density display mod C Grey C R/B C Custom	Normalizing factor - C None Entire screen C Individual iet velocity	Gain 0.2 Bias(%) 0 Show palette
Axis Show headers Plot headers Header mark Picks/polygons settings Save Template	ad Template	Max.vv	el (m/s) 1500.0

The result of running the flow is shown in the picture below:



Using two picks, select the window for building a corridor stack trace as shown in the picture below:



Save the first arrival pick (shown in yellow in the picture) under the tw name, and the pick defining the width of the window used to build the corridor stack trace (shown in green in the picture) – under the cor summ name (save both picks to the second level of the project tree).

Building a corridor stack trace (100 - cor stack trace and 110 - cor sum)

The corridor stack trace is created by stacking the data in the specified window along the first arrival travel time curve. Create a new flow and name it 100 - cor stack trace.

RadExPro 2021.4 >>> My VSP Project Database Options Tools Windows Help		– 🗆 X
Processing Database Navigator		
Project tree ×	Processing flow >> My Borehole / SP0 / 100_cor_stack_trace ×	All modules ×
» ≈ @	▶ 🛛 • ≒ • 📒 🔛 🔟	»
✓ I My Borehole	Trace Input <- sp0_ug_nmo	> Data I/O ^
✓	Trace Editing <- tw	> Static Corrections
010 data load	Trace Editing <- cor_summ	> Geometry/Headers
@ 020 view data	Ensemble Stack	> Interactive Tools
@ 030 fbpick	Amplitude Correction	Signal Processing
040 2C Orientation - S nick	Trace Output -> sp0_cor_stack	Data Enhancement
© 040_SC_Otheritation+S_pick	screen Display	> Deconvolution
© 050_signature_tor_deconvolution		Stacking/Ensembles
060_deconvolution_test		> Migration
070_ug_PP		> Trace Editing
080_velocity_model		> VSP
090_ug_and_ug_nmo_waves_display		>QC
100_cor_stack_trace		> 3C Processing
		> Modeling
		> Data Manipulation
		> Auto Picking v
	Flow status	ē ×

The flow will contain the modules shown in the picture:

- Trace Input
- Trace Editing
- Trace Editing
- Ensemble Stack
- Amplitude Correction
- Trace Output
- Screen Display

In this flow we will read the NMO-corrected reflected P-wave field, select the interval along the first arrival travel time curve from the field using top and bottom muting, stack all traces to create a single trace, equalize the amplitude along the trace, and save the obtained results.

The Ensemble Stack module stacks the traces within the ensembles defined by the first sorting key.Since we want to sum all traces in this case, we should specify a header field that we know to be identical for all traces as the first sorting key in the Trace Input module. An example of such header field is DT – the sampling interval:

Trace Input	×
Data Sets <u>sp0_ug_nmo</u> Add dataset Delete Datasets masks	Sort Fields DEPTH Image: Sort Fields Image: Sort Fields
	© Selection
Add mask Delete Load headers only From batch list Memory resort Buffer size (MB) OK Cancel	C Select from file File C Database object Choose C Get all

The next two Trace Editing modules will be used to perform top and bottom muting in sequence. Top muting is performed along the wt pick, bottom muting – along the cor_summ pick.

2	
ace Editing parameters Horizon Second horizon	Trace Editing parameters Horizon Second horizon
Muting Top muting Bottom muting Muting in window Muting in window Muting in window Muting in window Muting in window 10 ms Taper window length C Surgical muting ms Taper vindow length C Surgical muting ms Taper vindow length C Surgical muting Muting in window Muting in window Muti	Pick in database Select tw Trace header Browse Specify CDP 0-50:500,70:300
C Trace killing Save template Load template OK C	ancel Save template Load template OK Cancel
:e Editing	X Trace Editing
ce Editing ace Editing parameters Horizon Second horizon	X Trace Editing 27
ce Editing ace Editing parameters Horizon Second horizon	Trace Editing Trace Editing parameters Horizon Second horizon Pick in database Select cor_summ
Ce Editing ace Editing parameters Horizon Second horizon Muting C Top muting C Surgical muting C Bettern muting	Trace Editing Trace Editing parameters Horizon Second horizon Pick in database Select cor_summ O Trace header Browse
Ce Editing ace Editing parameters Horizon Second horizon Muting C Top muting C Surgical muting Bottom muting C Muting in window 10 ms	X Trace Editing Trace Editing parameters Horizon © Pick in database Select cor_summ C Trace header Browse
Ce Editing ace Editing parameters Horizon Second horizon Muting C Top muting C Surgical muting C Muting in window 10 ms Taper window length 0 ms	X Trace Editing X Trace Editing parameters Horizon Second horizon Image: Constraint of the second horizon Image: Constraint of the second horizon Image: Constraint of the second horizon Image: Constraint of the second horizon Image: Constraint of the second horizon Image: Constraint of the second horizon Image: Constraint of the second horizon Image: Constraint of the second horizon Image: Constraint of the second horizon Image: Constraint of the second horizon Image: Constraint of the second horizon Image: Constraint of the second horizon Image: Constraint of the second horizon Image: Constraint of the second horizon Image: Constraint of the second horizon Image: Constraint of the second horizon Image: Constraint of the second horizon Image: Constraint of the second horizon Image: Constraint of the second horizon Image: Constraint of the second horizon Image: Constraint of the second horizon Image: Constraint of the second horizon Image: Constraint of the second horizon Image: Constraint of the second horizon Image: Constraint of the second horizon Image: Constraint of the second horizon Image: Constraint of the second horizon Image: Constraint of the second horizon Image: Constraint of the second horizon Image: Constraint of the second horizon Image: Constraint of the second horizon Image: Constraint of the second horizon Image: Co
Ce Editing ace Editing parameters Horizon Second horizon Muting Top muting C Surgical muting Bottom muting Muting in window 10 ms Taper window length 0 ms	X Trace Editing X Trace Editing parameters Horizon Second horizon Image: Constraint of the second horizon Image: Constraint of the second horizon Image: Constraint of the second horizon Image: Constraint of the second horizon Image: Constraint of the second horizon Image: Constraint of the second horizon Image: Constraint of the second horizon Image: Constraint of the second horizon Image: Constraint of the second horizon Image: Constraint of the second horizon Image: Constraint of the second horizon Image: Constraint of the second horizon Image: Constraint of the second horizon Image: Constraint of the second horizon Image: Constraint of the second horizon Image: Constraint of the second horizon Image: Constraint of the second horizon Image: Constraint of the second horizon Image: Constraint of the second horizon Image: Constraint of the second horizon Image: Constraint of the second horizon Image: Constraint of the second horizon Image: Constraint of the second horizon Image: Constraint of the second horizon Image: Constraint of the second horizon Image: Constraint of the second horizon Image: Constraint of the second horizon Image: Constraint of the second horizon Image: Constraint of the second horizon Image: Constraint of the second horizon Image: Constraint of the second horizon Image: Constraint of the second horizon Image: Co
Ce Editing Ce Editing parameters Horizon Second horizon Contract Top muting Contract Top muting Contract Muting in window Contract Top muting Cont	X Trace Editing Trace Editing parameters Horizon Image: Constraint of the second horizon Image: Constraint of the second horizon Image: Constraint of the second horizon Image: Constraint of the second horizon Image: Constraint of the second horizon Image: Constraint of the second horizon Image: Constraint of the second horizon Image: Constraint of the second horizon Image: Constraint of the second horizon Image: Constraint of the second horizon Image: Constraint of the second horizon Image: Constraint of the second horizon Image: Constraint of the second horizon Image: Constraint of the second horizon Image: Constraint of the second horizon Image: Constraint of the second horizon Image: Constraint of the second horizon Image: Constraint of the second horizon Image: Constraint of the second horizon Image: Constraint of the second horizon Image: Constraint of the second horizon Image: Constraint of the second horizon Image: Constraint of the second horizon Image: Constraint of the second horizon Image: Constraint of the second horizon Image: Constraint of the second horizon Image: Constraint of the second horizon Image: Constraint of the second horizon Image: Constraint of the second horizon Image: Constraint of the second horizon Image: Constraint of the second horizon Image: Constration horizon
Ce Editing C Editing parameters Horizon Second horizon Muting C Top muting C Surgical muting C Muting in window 10 ms Taper window length 0 ms Editing C Zero padding C Inverse	X Trace Editing Trace Editing parameters Horizon Image: Constraint of the second horizon Image: Constraint of the second horizon Image: Constraint of the second horizon Image: Constraint of the second horizon Image: Constraint of the second horizon Image: Constraint of the second horizon Image: Constraint of the second horizon Image: Constraint of the second horizon Image: Constraint of the second horizon Image: Constraint of the second horizon Image: Constraint of the second horizon Image: Constraint of the second horizon Image: Constraint of the second horizon Image: Constraint of the second horizon Image: Constraint of the second horizon Image: Constraint of the second horizon Image: Constraint of the second horizon Image: Constraint of the second horizon Image: Constraint of the second horizon Image: Constraint of the second horizon Image: Constraint of the second horizon Image: Constraint of the second horizon Image: Constraint of the second horizon Image: Constraint of the second horizon Image: Constraint of the second horizon Image: Constraint of the second horizon Image: Constraint of the second horizon Image: Constraint of the second horizon Image: Constraint of the second horizon Image: Constraint of the second horizon Image: Constraint of the second horizon Image: Constration horizon
Ce Editing Ce Editing Contract Editing Contract Top muting Contrac	X Trace Editing Trace Editing parameters Horizon Second horizon Image: Content of the second horizon C Trace header Content of the second horizon C Specify CDP 0-50:500,70:300 CDP CDP
Ce Editing Ce Editing Contract Top muting Cont	X Trace Editing Trace Editing parameters Horizon Image: Select Cor_summ Image: Cor_summ Trace header Image: Cor_summ Browse Image: Cor_summ CDP Image: Object Structure 0-50:500,70:300

Select the Alpha trimmed option in the Ensemble Stack module and set the trimming threshold equal to 30%. This will eliminate the impact of bursts on the summation results:

www.radexpro.com

Ensemble Stack		×				
Mode C Mean C Median						
Alpha trimmed						
	30	%				
C Coherent stack						
	30	%				
Window (traces)	3					
Filter length (ms)	60					
✓ Treat zero as result of muting						
Number of threads:	0					
ОК	Cancel					

Enable Automatic gain control in the Amplitude correction module (set 1000 ms operator length).

Time raised to pov	ver	2.0				
Exponential corre	ction (dB/ms)	0.0				
Normalization						
O None						
Onstant time	0.0		0 - trace ce	enter		
O Horizon						
Header	AAXEILT					
Maximum application	time	0.0		0 - trace	e end	
Automatic gain co Operator length (1000	ntrol ms) Type of A MEAN	IGC scalar ∽	Basis for sc	alar appl	ication	
Automatic gain co Operator length (1000 Save AGC coeffici	ntrol ms) Type of A MEAN ents to datase	GC scalar ~	Basis for sc CENTERED	alar appi	ication	
Automatic gain co Operator length (1000 Save AGC coeffici	ntrol ms) Type of A MEAN ents to datase	GC scalar ∽	Basis for sc	alar appi	Dataset	Location
Automatic gain co Operator length (1000 Save AGC coeffici Trace equalization	ntrol ms) Type of A MEAN ents to datase	IGC scalar ✓	Basis for sc CENTERED	alar appl	Dataset	Location
Automatic gain co Operator length (1000 Save AGC coeffici Trace equalization Basis for scaling	ntrol ms) Type of A MEAN ents to datase	GC scalar v et: Time g	Basis for sc CENTEREL	e (ms)	Dataset Time gate en	Location
Automatic gain co Operator length (1000 Save AGC coeffic Trace equalization Basis for scaling MEAN	ntrol ms) Type of A MEAN ents to datase	GC scalar	Basis for sc CENTERED	alar appl	Dataset Time gate en 0.0	Location d time (ms)
Automatic gain co Operator length (1000 Save AGC coeffic Trace equalization Basis for scaling MEAN	ntrol ms) Type of A MEAN ents to datase	GC scalar	Basis for sc CENTERED	alar appl	Dataset Time gate en 0.0	Location d time (ms)
Automatic gain co Operator length (1000 Save AGC coeffic Trace equalization Basis for scaling MEAN Time variant scaling	ntrol ms) Type of A MEAN ents to datase	GC scalar	Basis for sc CENTERED	alar appl	Dataset Time gate en 0.0	Location d time (ms)
Automatic gain co Operator length (1000 Save AGC coeffic Trace equalization Basis for scaling MEAN Time variant scalin Example format: t1ik	ntrol ms) Type of A MEAN ents to datase	IGC scalar	Basis for sc CENTEREC	e (ms)	Dataset Time gate en 0.0	Location

Using the Trace Output module, save the resulting trace to a separate dataset named sp0-cor stack.

Select dataset X									
Object(s): sp0_cor_stack									
>> Show objects from sublevels Set filter text (you can use * and ? wildcards)									
➤	^	Name	Location	race cour	Sorted by	Crea			
✓		🗧 sp0_raw	SP0 < My Bo	876	FFID : OFFSET	2022-03			
😳 010_data_load		≑ sp0_PRT	SP0 < My Bo	876	DEPTH : CHAN	2022-03			
😳 020_view_data		🗧 sp0_decon_impulse	SP0 < My Bo	1	CHAN : DEPTH	2022-03			
030_fbpick		sp0_P_wave_ug	SP0 < My Bo	292	CHAN : DEPTH	2022-03			
040_3C_Orientation+S		≑ sp0_ug_nmo	SP0 < My Bo	292	DEPTH	2022-03			
050_signature_for_dec									
© 070_ug_PP									
080_velocity_model									
090_ug_and_ug_nmo									
100_cor_stack_trace	~	<				>			
		OK Can	cel						

The Screen Display module at the end of the flow provides visual monitoring of the results. The result of running the flow is shown in the picture below:



The corridor stack trace we have created will be used for tying VSP data to seismic data. It is much more convenient to carry out such tying based on a "pseudo-section" consisting of several identical traces rather than just one trace. To generate such a "pseudo-section", let us create a new flow and name it 110 - cor sum.

Add several identical Trace Input modules to the flow. Each of those modules will load the same corridor stack trace into the flow.

Let us use the Trace Header Math module to assign a unique index to the reflected wave field – this will help us distinguish between different data types in the future when they are visualized together. To assign an index, select an empty header of integer type. In this example we used the trc_type header. Set its value equal to 2.

Trace Input	×
Data Sets sp0_cor_stack	Sort Fields Image: Number of Ensemble Fields Image: Note: Ensembles will be defined by this number of sort fields.
Add dataset Delete	Add Delete
	C Selection
	<u> </u>
Add mask Delete	C Select from file File
Memory resort Buffer size (MB)	C Database object Choose, Get all

Using the Trace Output module, save the result to a new dataset – sp0-cor summ.

Object(s): sp0_cor_summ									
>> 🔹 🗌 Show objects from sublevels	Set filter text (you can	use * and ? wildcard	is)						
✓ I My Borehole ^	Name	Location	race cour	Sorted by	Cr				
✓	≑ sp0_raw	SPO < My Bo	876	FFID : OFFSET	2022-				
😳 010_data_load	🗧 sp0_PRT	SPO < My Bo	876	DEPTH : CHAN	2022-				
🍪 020_view_data	sp0_decon_impulse	SPO < My Bo	1	CHAN : DEPTH	2022-				
030_fbpick	sp0_P_wave_ug	SPO < My Bo	292	CHAN : DEPTH	2022-				
040_3C_Orientation+S	🗧 sp0_ug_nmo	SPO < My Bo	292	DEPTH	2022-				
050_signature_for_dec	🚔 sp0_cor_stack	SP0 < My Bo	1	dt : DEPTH	2022-				
000_deconvolution_test									
080 velocity model									
090 ug and ug nmo									
100 cor stack trace	<								

Insert the Screen Display module at the end of the flow to display the dataset being saved on the screen. The flow will look like the following:

www.radexpro.com

RadExPro seismic software

Processing Database Navigator	V December flow >> Ms. Pershale (SD0 (110 recover	M All marked as	
 Processny	★ Processing flow>>> My Borchole / SP0 / 110_cor_sum Image: Space of the spa	X All modules 2:3 U.D.5 > > - - > - - > - - > - - > - - > - - > - - > - - > - - > - - > - - > - - > - -	Data I/O Static Corrections ieometry/Headers Interactive Tools Signal Processing Jata Enhancement Deconvolution Velocity acking/Ensembles Migration Trace Editing
	screen Display	> > > >	OC OC 3C Processing Modeling Data Manipulation Auto Picking
	50 Flow status		đ

The "pseudo-section" generated by the flow may look like this:

🛃 110	_cor_sur	n < SPO	< My Bo	rehole <	My VSP	Project	[15:36:	30]						-	- 0	×	
Zoom	Comm	on parar	neters	View	Tools	Exit/Stop	flow	Exit								He	lp
€ (<u>,</u>			R						\bigcirc		H	√-) (-/,+)		$\langle \langle \rangle$	\gg	^
0-			_														
	H .,	M.,	بد. بـ فري ما	H.,	H.,	بد	H ., F ., F .	H ., F ., F .	H., F. 1.	H.,							
		the star	44-44	the star		the star	the state	the state		the star							
			-yhdysedy	-yholynol,		-yhdysedy	h-h-h-h	yh-freedy	-shepedy	h-h-h-h							
1000-	-	ad the second	at the second	and the second		ad the second			ut the								
	1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1																
		, Andrews, A	and the second	-	and the second second	, Andrews	م. مرجع می است. م	ر میروند. مرکز استان میروند.	and a state of the	-							
				all for			all form	the second		all and							
2000	1 st	A.	A.			- 	A.	A.									
2000	1	MA	Will Have	William -	M	Will Have a	What we	(M)/M-1	M.	M							1
	- mm- mm- mm- mm- mm- mm- mm- mm- mm- m	appendant	- - - - 	ghudu	ganna	a finnhan	- mm	1 mil	1 mile	Almhh							
	1	Same A	1	<u> </u>	1 miles	1		~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~	<u> </u>	1 1 1							
2000	1 2 2	<u>}</u>	<u>}</u>	Ş	Š	<u>}</u>	\mathbf{x}	\mathbf{x}	<u>}</u>	Š							
3000-	1		-		-ter												
		- AW	st-w	~~~~	~~~~	~~~~	Speed of	Speed of	- 	~~~~							
		have	have a	the state	hard	-	the second	Mary -	have	have							
		Sarah -			state of the second sec	State of the			State of the								
Tr:9 S	Sam:0	Amp:0	t:0m	15	-	-	-	-	-	-						//.	~
<																>	

Preparing VSP data for tying to seismic survey data (120 – ug vsp nmo waves for well tie and 130 –cor stack for well tie).

Before tying VSP data (both reflected wave field and corridor stack trace) to land seismic survey data, we need to bring the VSP wave field as close to land seismic data in appearance as possible. This includes making sure that the VSP traces are recorded at the same sampling interval as the seismic data, and that they have the same length and similar frequency content.

To prepare the reflected wave field, let us create a flow and name it *120 - ug vsp nmo waves for well tie*. The flow will consist of the following modules:

- Trace Input
- Resample
- Trace Length
- Bandpass Filtering
- Trace Header Math
- Trace Editing
- Trace Output
- Screen Display

RadExPro 2021.4 >>> My VSP Project		– 🗆 X
Database Options Tools Windows Help		
Processing Database Navigator	December (1999) M. December (1990) (1990)	Allered In
Project tree X	Processing flow >> My Borehole / SPU / 120_ug_vsp_nmo_waves_for_wel X	All modules X
		» ×
Y III My Borehole	Irace Input <- sp0_ug_nmo	Data I/O
✓	Resample Trace Length	Static Corrections
010_data_load	Bandnass Filtering	Ceometry/Headers
020_view_data	Trace Header Math	> Interactive Tools
030_fbpick	Trace Editing <- tw	> Signal Processing
040_3C_Orientation+S_pick	Trace Output -> sp0_ug_nmo_for_well_tie	> Data Enhancement
050_signature_for_deconvolution		> Deconvolution
060 deconvolution test		> Velocity
@ 070 ug PP		> Stacking/Ensembles
@ 080 velocity model		> Migration
		Trace Editing
(a) 100 cor stack trace		VSP
100_cor_stack_trace		> 3C Processing
0 110_cor_sum		> Modeling
I20_ug_vsp_nmo_waves_for_well_tie		> Data Manipulation v
	Flow status	8 ×
MB1 - Move modules; Ctrl+MB1 - Copy modules; MB1 x2 - Module parameters	; MB2 - Toggle modules; Ctrl+MB2 x2 - Cut modules; Shift+MB1 - Paste mod	ules

Let us load the reflected NMO-corrected P-wave field into the flow using the Trace Input module.

Trace Input	×
Data Sets sp0_ug_nmo Image: Add dataset Delete	Sort Fields
Datasets masks	Add Delete
Add mask Delete Load headers only From batch list Memory resort Buffer size (MB) OK Cancel	C Select from file File

Then let us resample the VSP data to a new sampling interval (the same as for the land seismic survey data -2 ms) using the Resample module.

左 ReSample	×
New sample rate:	2.0
Number of threads:	(auto)
ОК	Cancel

And set the new trace length equal to 3700 ms using the Trace Length module.

Trace Length	Parameters		—		\times
New trace leng	gth:	3700.000000		_	
ОК	Cancel				

Now we will use the Bandpass Filtering module to adjust the frequency content of the VSPdata. As a rule, seismic data have a lower frequency spectrum than VSP data. Equalization of VSP and seismic data spectrums improves the quality of tying. The filter parameters should be determined experimentally based on seismic data analysis. In our example we chose the following filter parameters:

Bandpass filtering			×
Filter type Simple bandpass filter Ormsby bandpass filter	Filter parameters	5	(Hz) (Hz)
C Notch filter	High-cut ramp: 100%	50	(Hz)
Tapering 10 % of trace length	0%	150	(Hz)
	Number of threads:	0	
	OK Cancel		

Let us use the Trace Header Math module to assign a unique index to the reflected wave field – this will help us distinguish between different data types in the future when they are visualized together. To assign an index, select an empty header of integer type. In this example we used the *trc_type* header. Set its value equal to 3.

Then let us perform top muting using the Trace Editing module. Specify the first arrival pick after kinematic corrections -tw – as the horizon defining the muting.

race Editing parameters Horizon Second horizon	Trace Editing parameters Horizon Second horizon	
Muting C Surgical muting © Top muting C Surgical muting © Bottom muting Muting in window 10 ms Taper window length 0	Pick in database Select tw Trace header Browse Specify CDP 0-50:500.70:300	
Editing C Zero padding C Inverse C Trace killing		

Finally, let us save the data we have prepared under the name of sp0-ug nmo for well tie using the Trace Output module, and output them to the screen using the Screen Display module. The result of running the flow is shown in the picture below:



Preparation of the corridor stack trace section is done in a similar way. We will do it in a separate flow -130 - cor stack for well tie. This flow consists of the same modules with the same parameters, except for two differences: the corridor stack trace section is input into the flow, and the *trc_type* header in those traces is set equal to 2 using the Trace Header Math module. Let us save the results to the sp0-cor summ for WT dataset.



Offset VSP processing

The purpose of offset VSP processing is to select a reflected P-wave field and build migrated VSP and VSP-CMP sections. To process these data, let us create a second shot point in the project database – SP1. The offset VSP data processing flow structure is shown below:

	Y Description (law 22 Ma Perchala (CD1 (000 minutions	Y All and date
» ≈ [□	Processing now >> wy Borenole? 3+17 030_migrations	
My Borehole		> Data I
> = SP0		> Real-Tim
✓ □ SP1		> Static Correctio
010 data load		> Geometry/Heade
010_data_load		> Interactive Too
O20_view_uata O20_themists		> Signal Processi
		Data Enhanceme
040_3C_Orientation+S_pick		Veloci
050_signature_for_deconvolution		> Stacking/Ensembl
060_deconvolution_test		> Migrati
070_ug_PP		> Trace Editi
080_migrations		>V
		>
		> 3C Processi
		> Modeli
		> Data Manipulati
		> Auto Picki
		> Interpolati
		> Mari
		Surface wave Analy
	Elow status	

As we can see from the flow structure and the names of the flows, offset VSP data processing before migration is done generally in the same way as zero-offset VSP data processing – data are loaded, first arrivals are picked, components are oriented towards the source point, deconvolution parameters are tested, and a reflected wave field is selected as a result. The configuration of procedures

RadExPro seismic software

in the flows and their parameters are sometimes slightly different from those used in the previous case. Such changes are necessary due to specific properties of certain data, the nature of noise etc. However, the general processing logic remains the same, so we will skip those flows in this section and leave it up to you to familiarize yourself with them. Instead, we will proceed with the 120 - migrations flow which is used to build migrated sections and VSP-CMP sections.

Building migrated VSP and VSP-CMP sections (080 – migrations)

This flow will consist of the following modules:

- Trace Input
- 2D-3D VSP Migration
- Screen Display

Let us use the Trace Input module to read the reflected P-wave field generated by the previous flow:

Trace Input	×
Data Sets	Sort Fields
sp1_P_wave_ug	DEPTH Image: Second
Add dataset Delete	
Datasets masks	Add Delete
	200-10000
Add mask Delete	O Select from file
From Datch list	O Database object Choose
Memory resort Buffer size (MB) 0 OK Cancel	C Get all

Then we need to use the 2D-3D VSP Migration module – depending on the parameters, it allows performing either migration or VSP-CMP transformation.

Use the following parameters to obtain a migrated VSP section:

3D VSP Kirchhoff Migration	×
Model file D:\InData\My VSP P-wave model.mo	Browse
Z Start of the image 0 Z End of the image 4000 Sample interval of the image 2 Preferred boundary slope 0	PS waves migration □ 3D output □ Mute unaccesible area ▼ 3D velocity model □ Transform only, do not migrate □ Uneven velocities □ Straight rays □ Extract velocity □ Weights: ⓒ Kirchhoff, offset vsp Derivative: ⓒ none
2D output geometry	C Kirchhoff, walk away vsp C 1/2 C Inverse distance C 1 3D output geometry Grid origin X 0 dx': 5 Grid origin Y 0 dy': 5 Y' axis azimuth 0
automatidy, using depth 3000 dx: 10 Spline	Lx': 5 Ly': 200 OK Cancel

To obtain a VSP-CMP section, use the parameters shown in the picture below:

3D VSP Kirchhoff Migration	×
Model file D:\InData\My VSP P-wave model.m	dl Browse
Z Start of the image	PS waves migration 30 output
Z End of the image 4000 Sample interval of the image 2	Transform only, do not migrate 🔽 Uneven velocities
Preferred boundary slope 0 Preferred slope range 5	Straight rays Extract velocity Weights: • Kirchhoff, offset vsp • Derivative: • none • Non
2D output geometry C by points	C Inverse distance C 1 3D output geometry Grid origin X 0 dx': 5
	Grid origin Y 0 dy': 5 Y' axis azimuth 0 0 0
automatidy, using depth 3000	Lx': 5 Ly': 200
dx: 10 Spline	OK Cancel

The results of running the flow in both cases are shown below.

Migration result:



VSP-CMP transformation result:



Note. Data with properly assigned geometry as well as a correct velocity model are necessary for the 2D-3D VSP Migration module to run successfully.

Tying VSP data to seismic data (Well Tie)

RadExPro 2021.4 >>> My VSP Project				- 0	×
Database Options Tools Windows Help					
Processing Database Navigator					
Project tree ×	Processing flow >> My Borehole / Well_Tie / 020_well_tie	×	All modules		×
» ≈ 🕒	D	13 LOG	» «		
✓			>	Data I/	° 0
> = SP0			>	Real-Tim	1e
> - SP1			>	Static Correction	ns
			>	Geometry/Heade	rs
wein_me			>	Interactive Too	ls
@ 010_seismic_data_load			>	Signal Processin	ng
O20_well_tie			>	Data Enhanceme	nt
			>	Deconvolutio	on
			>	Veloci	ty
			>	tacking/Ensemble	es
			>	Migratio	on
			>	Trace Editin	ng
			>	VS	SP
			>	q	SC
			>	3C Processin	ng
			>	Modelin	ng
				Data Manipulatio	on
			×	Auto Pickin	19
			Ś	Maria	
			Ś	rface Wave Analys	ie
			>	Refractic	
	Flow status			ŧ	9 ×

Loading seismic data into the project (010 – seismic data load)

The flow will consist of the following modules with parameters shown below:

- Seg-Y Input
- Trace Header Math
- Trace Output

The SEG-Y Input module loads seismic data into the project from a SEG-Y file:

SEG-Y Input	×
File(s) D:\InData\seismic data.sgy Image: Contract of the seismic data.sgy	Sample format Sample interval 2 □ Take format from file Number of traces 35 □ I C I2 C I4 (• R4) Number of traces 35 □ Take byte order from file 12048 2048 □ Take byte order from file 0 2048 □ Take byte order from file 0 Use trace ○ Big-endian byte order □ Use trace Sorted by FFID:OFFSET □ • Get all C Selection *:* • 3D Survey C 2D Survey Profile ID 1 □ Remap header values RECNO,4I,,181/SOURCE,4I,,185/ILINE_NO,4I,,189/XLINE Recond,4I,,181/SOURCE,4I,,185/ILINE_NO,4I,,189/XLINE
File Mask Delete Load list Save list	I
From batch list 🗌 Use numeric sort 🗍 Save EBCDIC	headers to folder:
ОК	Cancel Load remap Save remap

Let us use the Trace Header Math module to assign a unique index to the seismic data. We will need this number to perform tying. Besides, since the DEPTH field is meaningless for seismic data, let us set its value equal to -1 (we will need it when printing the results in the 030 - plotting flow):

Trace Header Math	×
trc_type=1 depth=-1	
Line 2 Pos 9 OK Cancel Check syntax	Use # for comments Headers colored blue Errors colored red Load template

Now let us save the data to the project database using the Trace Output module:

Select dataset			×
Object(s): seismic_data			
>> 🙁 🗋 Show objects from sublevels	Set filter text (you can use * a	and ? wildcards)	
✓ ^{III} My Borehole	Name	Location	Trace count S
> 🖃 SPO			
> 🖃 SP1			
> 🖃 Well_Tie			
	<		>
	OK Cancel		

Tying VSP data to CMP seismic reflection survey data (020 – well tie)

The flow will consist of the following modules:

- Trace Input
- Trace Input
- Trace Header Math
- Apply Statics
- Trace Input
- Ensemble Equalization
- Trace Length
- Trace Output
- Screen Display

Let us sequentially read the seismic data (seismic data), the corridor stack trace set (sp0-cor summ for WT), and the NMO-corrected reflected wave field (sp0-ug nmo for well tie) using separate instances of the Trace Input module. Specify TRC_TYPE:DEPTH sorting for VSP data and TRC_TYPE:CDP sorting for seismic data. Specifying the TRC_TYPE header (where we have already entered a unique index for each data type) as the first sorting field allows the system to read every data type as a separate ensemble.

Then let us move to the Trace Header Math module and set the CDP header field value equal to -1 for VSP traces (we will need it when printing the results in the 030 - plotting flow).

The next module in the flow – Apply Statics – allows introducing a bulk shift into the data by shifting the VSP data relative to the seismic data. Let us leave it commented out for now – we willneed it later.

Since the VSP and seismic data may have (and do have) substantially different general gain levels, let us use the Ensemble Equalization module to equalize amplitudes between ensembles. The module parameters are shown below:

Ensemble Equalization	×
Start time: 0	
End time: 50000	
Norm	
RMS C Marrie	
C Max	
OK Cancel	

These parameters mean that ensembles will be normalized by RMS amplitudes calculated for the entire trace length (the window starts with 0 and ends with a value we know to be larger than the trace length).

Then the data will be trimmed to the length of 3500 (the Trace Length module), saved to the project database as a dataset named Tied data (the Trace Output module), and output to the screen using the Screen Display module with the following parameters:

Display parameters	×
From t = 0.0 to 4000.1 t Scale 10 Number of traces 400 X Scale 10 Rotate Final Ensemble boundaries	WT/VA display mode Normalizing factor Gain 0.3 C WT C None Bias(%) 0 C VA C Individual Show every 1
Enable backward frame scrolling Ensembles to scroll Variable spacing Field Space to maximum ensemble width Ensembles' gap Muliple panels 0 Use excursion 2.0	Variable density display mode Normalizing factor Gain 0.15 C Grey C None Bias(%) 0 C R/B C Entire screen Bias(%) 0 C None Individual Show palette Data/velocity O Display data Palette range C Display velocity Set velocity Min. vel (m/s) 500.0
Axis Show headers Plot headers Header mark Picks/polygons settings Save Template	vlax, vel (m/s) 1500.0

The result of running the flow is shown in the picture below:



We can see that seismic and VSP data are shifted relative to each other. We will need to introduce a constant shift into the VSP data in order to tie them to the seismic data. To determine the amount of shift, you can select the seismic data using the mouse and interactively move it up and down.

To select a trace range, place the mouse cursor at the range start position above the traces, press the left mouse button, move the cursor to the end of the range while holding down the mouse button, and then release the mouse button. The selected area will be highlighted in an inverse color palette. The process of selecting seismic data with the help of the mouse is shown in the following picture:

The Screen Display window with selected seismic traces looks like the following:



Now let us "grab" the selected area with the left mouse button and move it down in such away as to achieve the best possible match between reflections on seismic and VSP data. To make comparison easier, the selected area will be once again displayed in its normal colors when you "grab" it:



After making sure that the reflections match, we need to determine the shift amount by looking at the values displayed in the status bar. In this case we have shifted the seismic data by 100 ms.

Now let us use the Apply Statics module to introduce this shift with the opposite sign into the VSP data:

Apply Statics	×
Manual Header Word Browse Get from database Select Use file File	
Relative to time 0.00 Subtract static Apply fractional statics Save template Load template	Maximum number of threads 0

Running the flow with the Apply Statics module enabled should yield the following results:



Printing the processing results (030 – plotting)

This flow is used to output the results of VSP and CMP data tying to any printer compatible with the Windows operating system or to a standard text or image file format: *.pdf, *.jpg, *.tif, *.bmp etc.

The flow will consist of a single Plotting module (this is a so-called standalone module that generates the flow by itself). The module allows adjusting data visualization parameters (sorting, display method, scaling, amplification, pick and header plot printing, line width, font size etc.),printing text and graphic labels, and working with all standard print setup functions (including image preview before printing).

Set the **Plotting** module parameters as shown below:

Plotting parameters			×
Dataset Take from batch list My Borehole \Well_	_Tie\Tied_data		
Sort fields TRC_TYPE DEPTH Add	Selection	*;*;*	
Delete	From t=	0 to 0	(ms)
✓ Variable spacing	Additional scalar	0.3 Displa	ny mode /T/VA /T
Ensembles' gap 2 traces	Line width (mm)	0.01 0 0	A ray /B ustom Define
Normalizing Scales		General Layout	Horizons
O None I Scale 200 O Entire set X Scale 22	ms/cm traces/cm	T Axis	Plot headers
, Individual		X Axis	Header marks
	Dicolay tra	ces in Lavout Preview	Print setup
	File pr	inter setup,	Layout Preview
	DK Can	cel	

In the *Dataset* field, select the Tied data dataset generated by the previous flow. In the *Sort fields* field, select sorting by TRC_TYPE:DEPTH:CDP headers. The TRC_TYPE sorting key allows the system to read each data type as a separate ensemble and display data types in a certain order, i.e.: the seismic profile fragment (TRC_TYPE =1), the corridor stack trace set (TRC_TYPE =2), and the NMO- corrected reflected wave field (TRC_TYPE =3). The DEPTH sorting key allows us to achieve correct sorting of VSP data (this will not have any effect on seismic data since we have already set the value of this field equal to -1 for all seismic traces). The CDP key, in turn, ensures correct seismic data sorting and will have no effect on VSP data (since we have set the CDP field value equal to -1 for those data). To read all data, enter *:*:* in the *Selection* field.

Set the visualization parameters Ensemble boundaries, Additional scalar, Display mode, Normalizing, Scales as shown in the picture.

Use the *General Layout*... option to adjust label and margin parameters. Set the parameters as shown in the picture:

General Layout parameters			×
- General Margins			
1-0 10 mm			
Left 10 mm			
-			
Top 0 mm			
_1 >bel			
Lett side	Fields		
Right side	C	DECO Coophysical	
	Company name	Deco deopriysical	
Label font	Project Title	My VSP Project	
	riojectinac		
Text block width	Project Location	My Area	
100 mm	,	J	
100	Comments	Well Tie	~
Margins			
Left 10 mm			
Right 10 mm			
			× 1
Top 130 mm		<u> </u> <	>
Label Logo			
BMP file			
Logo Height 50 mm	n 🔽 Constrain prop	ortions Logo Position	
		🛈 Left	
Logo Width 30 mm	n	C Diabt	
,		 Right 	
	ОК	Cancel	

Using the *TAxis*... options, adjust the visualization and vertical axis title parameters as shown in the picture:

T Axis parame	ters				×
Show axis					
Major ticks					
Step	1000	Tick length (mm)	2	Show values	Scale font
		Tick line width (mm)	0.2	Show grid lines	
Minor ticks					
Number	10	Tick length (mm)	1.5	Show values	Scale font
per primary	,	Tick line width (mm)	0.1	Show grid lines	
Title					
Shov	v title	Title	t (ms)		Title font
		ОК	Cancel		

Using the *XAxis*... options, adjust the visualization and horizontal axis parameters as shown in the picture:

Axis parameter	rs						
Show axis							
• Linear axis	Field	DEPTH 💌	Step	200	Show values	Tick length (mm)	3
C Time avia	Hour			C Different	Show grid lines	Tick line width (mm)	0.1
Time axis	Hour	HOUR		C Interval		Axis width (mm)	15
	Minute	MINUTE		 Multiple 		, and more (miny	1.5
	Second	SECOND			Scale font	Title font	
Show axis							
Linear axis	Field	CDP 🔻	Step	10	Show values	Tick length (mm)	3
				C Different	Show grid lines	Tick line width (mm)	
🔿 Time axis	Hour	HOUR 👻		C Interval		natine maar (may	0.1
	Minute	MINUTE		Multiple		Axis width (mm)	15
	Second	SECOND 👻			Scale font	Title font	
Show avis							
 Linear axis 	Field		Step	10	Show values	Tick length (mm)	3
entour axio				10			
🔿 Time axis	Hour	HOUR 👻		C Different	Show grid lines	Tick line width (mm)	0.1
	Minute			C Multiple		Axis width (mm)	15
	Second	SECOND V			Scale font	Title font	
				ОК	Cancel		

Select the DEPTH and CDP header fields whose values will be displayed along the horizontal axis. We have set the tick step on the DEPTH axis equal to 200 and the tick step on the CDP axis equal to 10. This will result in DEPTH ticks being shown only for VSP traces (DEPTH= -1 for seismic data), and CDP ticks being shown only for seismic traces (CDP= -1 for VSP data). Set the grid line parameters, axis title and value mark fonts at your own discretion.

Select the printing device in the *Print setup*... field.

Use the Layout Preview... option to preview the image before printing.



If necessary, adjust the visualization parameters without closing the *Layout preview* window. Click the *Update preview* to redraw the preview window.

When you are satisfied with all your settings, close the preview window and click the OK in the module parameter dialog box. To start printing, run the flow using the *Run* menu command.

The resulting project tree should look like the following:

Project tree
» ∝ II.
× My Borehole
010_uata_toau
© 020_thenick
030_IDDICK
© 050 signature for desenvolution
© 050_signature_for_deconvolution
© 050_deconvolution_test
080_velocity_model 080_velocity_model
090_ug_and_ug_nmo_waves_display
100_cor_stack_trace
120_ug_vsp_nmo_waves_for_well_tie
V D CD1
© 010_data_load
😳 020_view_data
© 030_tbpick
040_3C_Orientation+S_pick
050_signature_for_deconvolution
© 060_deconvolution_test
070_ug_PP
080_migrations
✓
010_seismic_data_load
<pre>020_well_tie</pre>
030_plotting