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Borehole seismic data processing and interpretation: New free software

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ABSTRACT

Vertical Seismic Profile (VSP) surveying is a vital tool in subsurface imaging and reservoir characterization. The technique allows geophysicists to infer critical information that cannot be obtained otherwise. MVSP is a new MATLAB tool with a graphical user interface (GUI) for VSP shot modeling, data processing, and interpretation. The software handles VSP data from the loading and preprocessing stages to the final stage of corridor plotting and integration with well and seismic data. Several seismic and signal processing toolboxes are integrated and modified to suit and enrich the processing and display packages. The main motivation behind the development of the software is to provide new geoscientists and students in the geoscience fields with free software that brings together all VSP modules in one easy-to-use package. The software has several modules that allow the user to test, process, compare, visualize, and produce publication-quality results. The software is developed as a stand-alone MATLAB application that requires only MATLAB Compiler Runtime (MCR) to run with full functionality. We present a detailed description of MVSP and use the software to create synthetic VSP data. The data are then processed using different available tools. Next, real data are loaded and fully processed using the software. The data are then integrated with well data for more detailed analysis and interpretation.

In order to evaluate the software processing flow accuracy, the same data are processed using commercial software. Comparison of the processing results shows that MVSP is able to process VSP data as efficiently as commercial software packages currently used in industry, and provides similar high-quality processed data.

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1. Introduction

VSP surveying is a vital tool in subsurface imaging and reservoir characterization. The technique has made significant advances since the 1930s, when geophysicists lowered the first geophone down a borehole to better investigate rock velocity. VSPs allow geophysicists to infer critical information that cannot be obtained otherwise. With VSPs, geophysicists can record waves traveling both down into the earth (direct and downgoing multiples) and back toward the surface (primaries and upgoing multiples). They add the depth dimension to seismic data, which enables several approaches to velocity estimation and deconvolution (Oristaglio, 1985). Borehole seismic measurements have also overcome difficulties faced by both seismic processers and interpreters. They provide direct access to the measurement of attenuation (Q), estimation of geometric divergence, identification of multiples, correction of well data and their integration with seismic data, and the phase analysis of seismic data (Campbell et al., 2005).

Most analyses of geophysical data involve the application of sophisticated and multistage processing and inversion. This particularly applies to VSP data processing and interpretation. However, as most of VSP data processing software packages are used for industrial and commercial purposes, the use of such packages can be difficult for students and geoscientists in the education and research fields. An affordable software package that includes the main VSP processing and interpretation tools would help facilitate technology transfer and train graduate students and newly graduated geoscientists.

It is worth noting that DSISoft (Beaty et al. 2002), developed at the Geological Survey of Canada, is known to be the first free software developed for VSP data processing. The software is written in MATLAB. However, the package is provided in the form of scripts and functions that require advanced knowledge of the MATLAB programming language. Furthermore, the user needs to invoke special plotting functions at every processing step, making quality control (QC) of the sequence a time-consuming and error-prone process. MVSP is free software, developed to complement the work described in Beaty et al. 2002. The package comprises tools with interactive GUIs for loading and editing data in different formats (Segy, SU, Mat, LAS), data processing, comparison, visualization, and interpretation.

In this paper, we present a detailed description of the software. The software is used to create synthetic VSP data, and a full processing sequence is applied to the data. Real data are then processed using MVSP. The processing results are analyzed and compared with results from commercial software.

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Table 1
List of available modules in MVSP.

Module	Description
Project	
1. New	Creates new project
2. Save session	Saves project
3. Open project	Restores saved project
Files	
1. Import Segy data	Imports Segy data and converts them to DSI format
2. Import SU data	Imports SU data and converts them to DSI format
3. Import Mat data (DSI)	Imports Mat data
4. Import well data (LAS)	Imports well data
5. View Segy	Displays Segy data and checks headers
6. Delete selected file	Deletes file selected by user
7. Delete all	Deletes all files in workspace or variables list
8. View trace header	Opens trace header in Excel file for editing
9. Import trace header	Imports trace header from Excel file
10. View file header	Opens file header in Excel file
11. Import file header	Imports file header from Excel file
Processing	
1. AGC	Performs AGC
2. Energy balance	Performs energy balancing
3. True amplitude recovery	Compensates for amplitude attenuation
4. BP filter	Performs band-pass filtering
5. Predictive Decon.	Performs predictive deconvolution
6. Wiener Decon.	Performs Wiener deconvolution
7. FK filtering	Performs FK filtering
8. Median	Performs median filtering
9. Trim statics	Performs residual static corrections
10. Top muting	Mutes noise before first breaks
11. Bottom muting	Mutes noise after time picks
Tools	
1. Separate components	Separates different x, y, and z components
2. First breaks picking	Picks and interpolates first break times from first to last trace
3. Time picking	Picks event and interpolates between picks
4. Flattening	Flattens data at defined time t(s)
5. Unflattening	Flattens data to field record time and to two-way-time
6. Subtraction	Removes undesired data from input data
7. Outside corridor	Produces outside corridor (header word)
8. Inside corridor	Produces inside corridor (header word)
9. Stacking	Stacks VSP section and displays in (n) repeated traces
10. Comparing corridors	Compares corridors
11. Compare datasets	Compares datasets
12. Calculate attenuation (Q)	Calculates Q factor from VSP
13. Static corrections	Calculates true vertical depth, time–depth function, and velocities; displays survey geometry (KB)
14. Frequency analysis	Calculates and displays frequency content of traces
15. Corridors	Defines corridors for muting and stacking
Interpretation	
1. Composite plot	Integrates VSP section, corridor stacks, and well logs
2. Velocities	Calculates velocities
3. Compare datasets	Compares different datasets
4. Calculate Vp/Vs	Calculates Vp to Vs ratio
Modeling	
1. Velocity model	Creates velocity model
2. Synthetic seismogram	Creates synthetic seismogram using defined velocity model
3. Ray tracing	Calculates and displays ray tracing
View	
1. Wiggle plot	Displays data in wiggle form
2. Image plot	Displays data in image form
3. First break	Displays first break on VSP section
4. Double plot	Displays two VSP sections
5. Multiple plot	Displays three VSP sections
Export data	
1. Segy format	Exports Mat data in Segy format
2. SU format	Exports Mat data in SU format
3. Mat file	Exports data as Mat file

2. MATLAB GUI

The use of MATLAB (short for Matrix Laboratory) in research and educational applications is rapidly increasing. The program provides a rich technical computing environment that combines numerical computation, visualization, and a higher-level programming language.

A GUI is a software environment in which information is arranged on a computer screen in a way that makes the program easy to understand