Data processing from a single-well microseismic monitoring in western Canada using a newly developed MATLAB based package (CaMPS)

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Summary

Basic microseismic data processing for hypocentre location estimates is a pre-requisite to extracting valuable information about the stimulated reservoir volume as well as understanding the geomechanics of the fracturing process. In this paper, we present a processing case study of single-well microseismic monitoring data from western Canada using a newly developed MATLAB based processing package (Calgary microseismic processing software; CaMPS). The processing results are optimized in each step by selecting the parameters and algorithms with optimal performance. The results are compared with the independent processing of this dataset from an anonymous data processing services company.

Introduction

Estimation of hypocentre locations in a microseismic monitoring dataset requires some basic processing steps such as event-identification, arrival time picking, velocity model building and calibration etc. This is considered as a pre-requisite to extracting valuable information about the stimulated reservoir volume as well as understanding the geomechanics of the fracturing process. Basic processing of microseismic data is normally accomplished using any of the available commercial packages in the Industry. However, these commercial software packages might not be readily available to academic institutions for research purposes.

Calgary microseismic processing software (CaMPS) is a standalone MATLAB application for single-well microseismic data processing. The software package is equipped with multiple processing algorithms as well as with user-friendly interfaces containing visual aids in each module for better data analysis and processing parameter selection.

In this paper, we present a processing case study example from western Canada using CaMPS. The processing results are optimized in each step by choosing the algorithm with best performance. Finally, we compare the hypocentre location estimates with the ones obtained from the independent processing of an anonymous data processing services company (**M**).

Case study example from Western Canada

Background

A two-stage fracture treatment was conducted in the Cardium formation in western Canada. The Cardium formation which overlies the Blackstone formation is a late Cretaceous marine clastic and it includes repeated and stacked successions of silty mudstones through siltstones to very fine to fine grained sandstones, (Duhault, 2012 and references therein). Figure 1 shows the layout of microseismic monitoring survey. A total of 175m^3 of fluid was pumped at an average pressure of 33.1MPa. The monitoring well is approximately 150m south and 350m east of the hydraulic fracturing stages in the treatment well. The microseismic data were acquired with a sampling interval of 0.25ms using 12 three-component receivers, with 10m inter-receiver spacing.

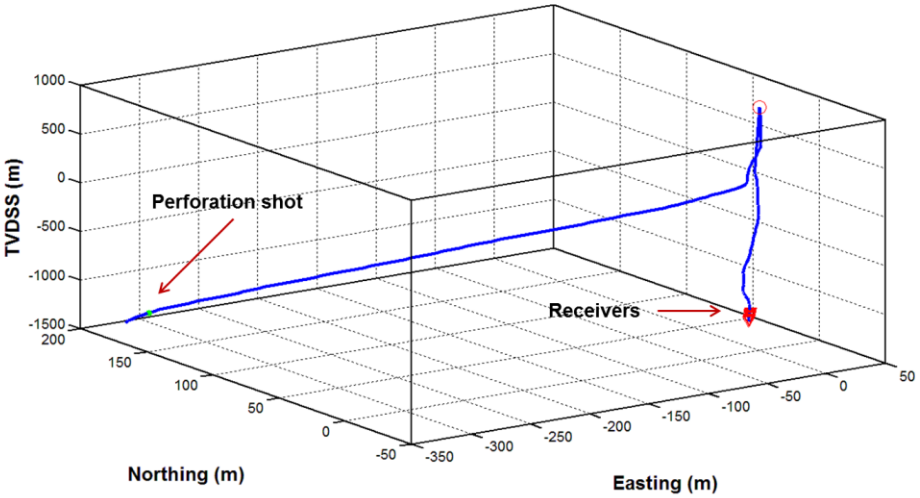


Figure 1: Microseismic monitoring survey layout.

Data processing

Figure 2 shows the workflow used for processing microseismic data in this paper. First step after pre-processing that includes data loading, removing DC component and band-pass filtering, was to determine the orientation of geophones. Each borehole geophone is oriented differently because it rotates around its axes on the wireline cable during the deployment of tool within a well (Daley et al., 1988). We have used both the maximum energy (Disiena et al., 1984) and covariance matrix (Jurkevics, 1988; Hendrick and Hearn, 1999) approaches to find the orientation from the sources with known locations such as perforation shots. Figure 3 shows the comparison of tool orientation from both methods with the ones obtained from **M**. The tool orientations are very consistent and are in good agreement.

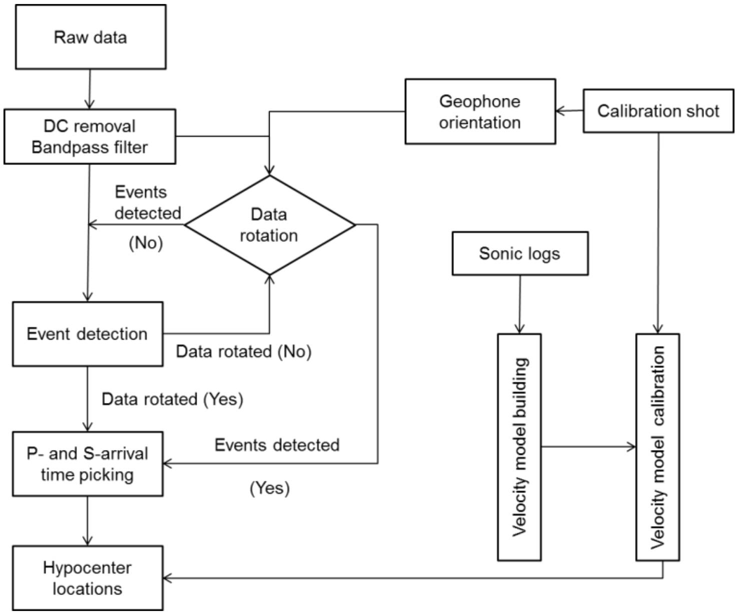


Figure 2: Downhole microseismic data processing workflow.

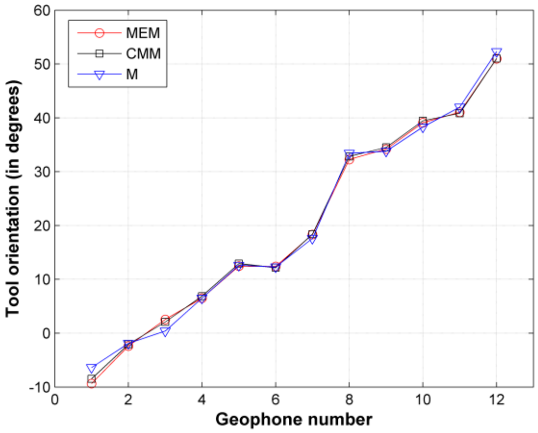
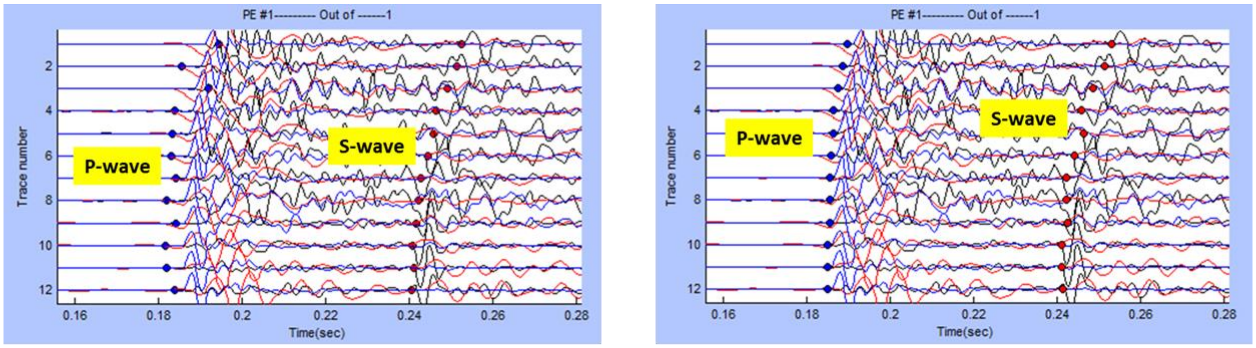


Figure 3: Comparison of tool orientation obtained using maximum energy method (MEM), covariance matrix method (CMM) and from the independent data processing of a services company.

Using the tool orientation, the filtered data were rotated into E-N-V, R-T-V and P-S1-S2 reference frames. The purpose of this rotation is to maximize P- and S-energy onto the radial and transverse components, respectively. This enables optimization of event-identification and arrival-time picking process by providing good waveform quality. Microseismic events were detected automatically using short and long-term average ratio (STA/LTA; Withers et al., 1997) with both static and dynamic threshold criteria (Akram et al., 2013). The static threshold was determined by visually inspecting the STA/LTA values for background noise at different times. These detected events are called as potential events as these could either represent actual microseismic events or noise depending on the event-detection algorithm's performance with the selected parameters.

The potential events were classified during a quality control process into three different categories based on the S/N and the visibility of P- and S-wave arrivals. To be qualified as a category-A event, both P- and S-wave arrival should be visible on the waveform datasets. A potential event was reclassified to category-B if P- and/or S-wave arrival couldn't be picked on one or more receivers or if the arrival time-picks were not deemed accurate considering the S/N and quality of the waveforms. The remaining picked events were classified as noise events.

P- and S-wave arrival time picking was performed on the microseismic events that passed the quality control check. Initial arrival-time picks were obtained using a single trace based algorithm such as STA/LTA. These time-picks were checked and corrected for quality control purposes. An iterative cross-correlation workflow (Akram and Eaton, 2014) was used to refine the time-picks using event's waveform similarity on all receivers. Figure 4 compares the arrival time-picks before and after running the iterative cross-correlation workflow. Another quality control check was performed to correct the time-picks with large deviations from the actual arrivals.



Initial time-picks

Final time-picks

Figure 4: An example of arrival-time picking. Initially picked arrival times were further refined using an iterative cross-correlation based workflow.

Sonic log in the vicinity of the survey area was pre-processed (de-spiked and averaged) and used to build an initial velocity model. Initial velocity model was calibrated with the recorded perforation shots using a non-linear optimization (pattern-search based) approach (Akram and Eaton, 2013).

A traveltime table on the entire search grid, also known as look-up table, was generated by forward modeling the traveltime for the calibrated model using Tian's ray tracing algorithm (Tian and Chen, 2005). The estimates for hypocentre locations were obtained using a grid-search approach that finds the minimum of the objective function containing observed and modeled traveltime differences in a least-square sense in the entire look-up table. This provides the depth information in the hypocentre location coordinates. Back-azimuth information from the polarization analysis of EW-NS oriented dataset is used to find the X and Y coordinates of the detected hypocentre.

Results

Figure 5 shows locations of category-A events for a single-treatment stage, obtained in this study (14) and from **M** (22). There exist several category-B events which are not shown in Figure 5. Due to lack of quantitative information about hypocentre location from the M’s processing results, only qualitative comparisons are made. The located events show good agreement with those obtained from **M**, since the fracture orientation (NE-SW trending) and fracture depths are similar. The results from current processing can be improved further. This requires more analysis of the data and is a subject of future research work.

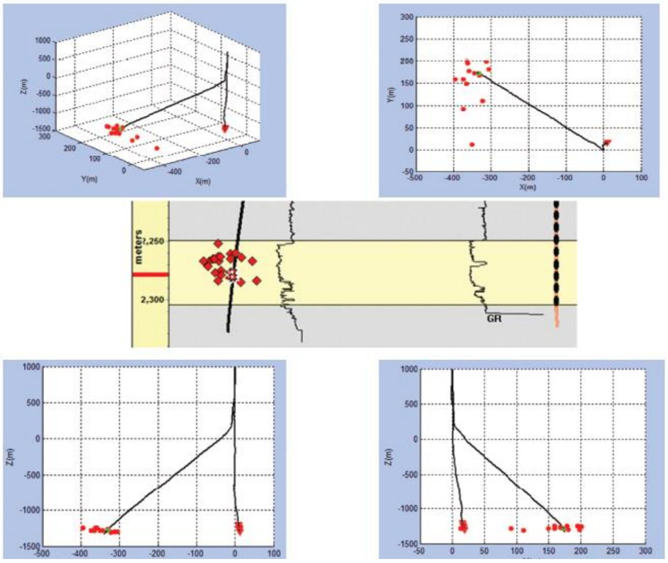


Figure 5: Hypocentre location estimates from a single-treatment stage.

Conclusions

We have presented a processing case study of a single-well microseismic monitoring data from Western Canada using newly developed MATLAB based software (CaMPS). The processing results presented in this study can be improved further, which is a subject of future research work.

Acknowledgements

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