Array analysis of surface microseismic data from the Rolla Microseismic Experiment

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Summary

A surface array of vertical and 3C geophones was deployed to monitor passive - seismic events during a hydraulic fracture treatment of the Montney Formation in northeastern BC. Four days of continuous recording provided over 3600 potential events, from which 30 events were analyzed to determine backazimuth and apparent velocity. This was accomplished by using a velocity analysis procedures similar to the velocity spectral analysis (VESPA) method, based on fitting picked first-arrival times using computed arrival-time curves. The investigated events are generally characterized by apparent velocities of 1500 m/s or less, and so are interpreted as waves trapped in the near surface (e.g. ground roll).

Introduction

Monitoring of passive seismic events is used in the hydrocarbon industry, mining and underground carbon and nuclear waste storage. Its low environmental impact and effectiveness in mapping fracture network, size and orientation, fluid presence and faults has motivated many companies to develop projects for microseismic use and testing. While borehole arrays are still more extensively used in western Canada, surface sensors provide a potentially more economically viable and easier-to-deploy option that, in some cases, may also reduced impact on environment. In this study, we present preliminary analysis of microseismic data collected using a surface array as part of the Rolla Microseismic Experiment. This experiment was acquired in August 2011, to record a multistage hydraulic fracture treatment in northeastern B.C., Canada. Borehole microseismic data were also recorded as part of this experiment, providing an opportunity for future comparisons between surface and borehole results.

A few previous studies have been undertaken to assess the effectiveness of surface microseismic acquisition compared to a borehole microseismic array. For example, a project was carried out in the foothills of Western Canada, where passive seismic emission tomography (PSET) was used to monitor fracture and production flow testing in a gas well. An array of nine three-component geophones was deployed, centered on target well. The time of the events occurrence agreed with the fracturing time and the fracturing direction was in the maximum principal stress direction at the well (Duncan, 2005). Another study was performed by Eisner et.al (2010) during hydraulic fracture treatment of shale formation where the data from 5 stages were recorded on a linear downhole array of 3C geophones and compared with a star-shaped surface array of vertical component geophones. Only the best signal-to-noise (S/N) ratio events were considered. The event locations identified by the surface array were found to be offset compared to those obtained using the deep borehole array, but the shift was constant for all events. The raw data were not processed by the same companies, rendering it difficult to verify the source of this systematic difference.

Method

In order to characterize the recorded wavefield using a surface array, we make use of a method similar to the velocity spectral analysis (VESPA) method. An advantage of using the whole array for this type of analysis is that the S/N increases due to stacking of individual traces (Rost and Thomas, 2009). The VESPA process allows for a quick identification of signals, including those approaching with different phase velocities but arriving on the same backazimuth (Davies, Kelly and Filson, 1971).

Examples

During a hydraulic fracture treatment to enhance production from tight gas reservoir in Montney Formation a surface and borehole arrays of geophones were set up to monitor the production. This process generated numerous microseismic events. A surface cross-arm array of 8-recievers was used to identify the detected events (Figure 1). The array's configuration is described in Table 1.

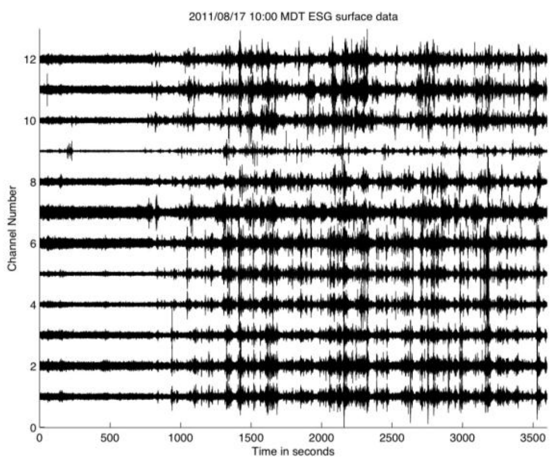


Fig. 1. One-hour time window of data recorded using the surface geophone array.

Table 1. Surface-array parameters.

Type of array	Cross-arm
Sample rate	0.5 ms
Number of geophones	8
3 component geophones	2
Vertical component geophones	6
Overall number of traces	12
Spacing	20 meters apart
Geophone frequency	10 Hz
Depth of deployment	80 cm
Recording dates	15-18 August, 2011
Recorded continuously	
Data stored on hard drive while recording	

An automatic event-detection algorithm using an amplitude-threshold approach (Eaton et al., 2011) was applied to the data. This resulted in the detection of ~ 3600 potential events during 4 days of the fracture treatment while this system was in operation. These potential events were analyzed using an interactive script (QC_edit) developed in matlab. A total of 190 good-quality events were selected for further processing, based on visual signal coherency. Examples of 'good' and 'bad' events are given in Figures 2 and 3, below.

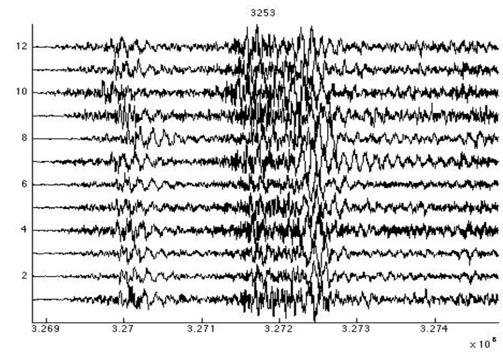


Fig. 2. Example of one or more good event(s). The time window presented is 1.5 s long. The numbers on the left show 12 channels used for this array.

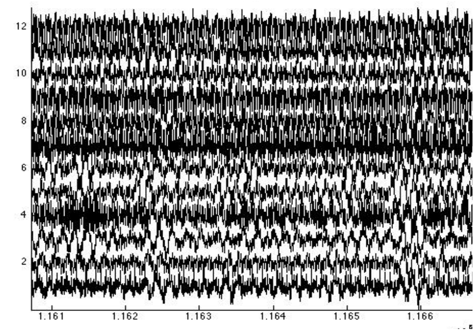
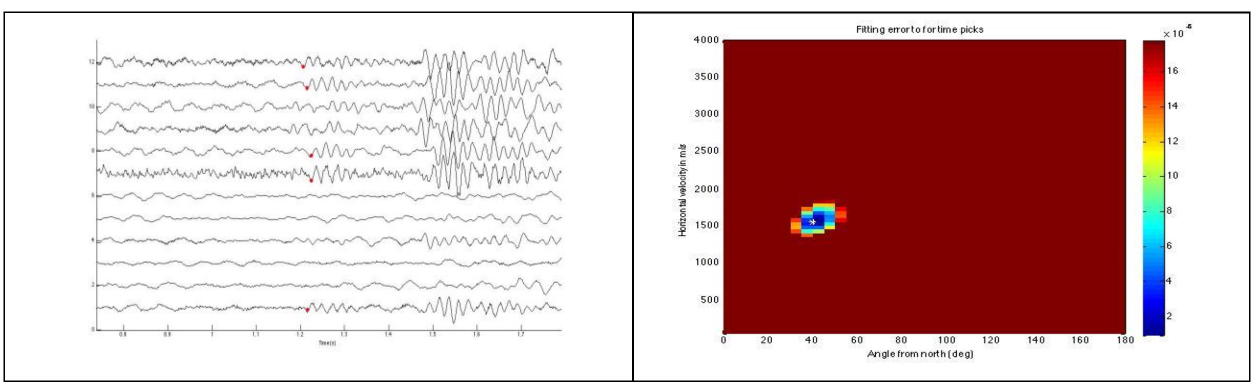


Fig. 3. Example of a bad event. The time window presented is 1.5 s long. The numbers on the left show 12 channels used for this array.

To obtain information about the velocity of the arrivals and their direction (back-azimuth), a matlab-based velocity analysis algorithm was used. This algorithm scans clockwise over a 180 degree range of arrival angles starting from 0 degrees (north-south propagation). Our method requires interactive picking of arrival times, which are then fit using computed arrival-time curves based on back-azimuth and horizontal velocity. These calculations incorporate the geometry of the receiver array. The back-azimuth and velocity associated with the smallest least-squares error provided the solution. In addition, error plots provide a measure of the level of uncertainty in these parameters. Several examples of the velocity analysis procedure are graphed in figures 4 and 5.



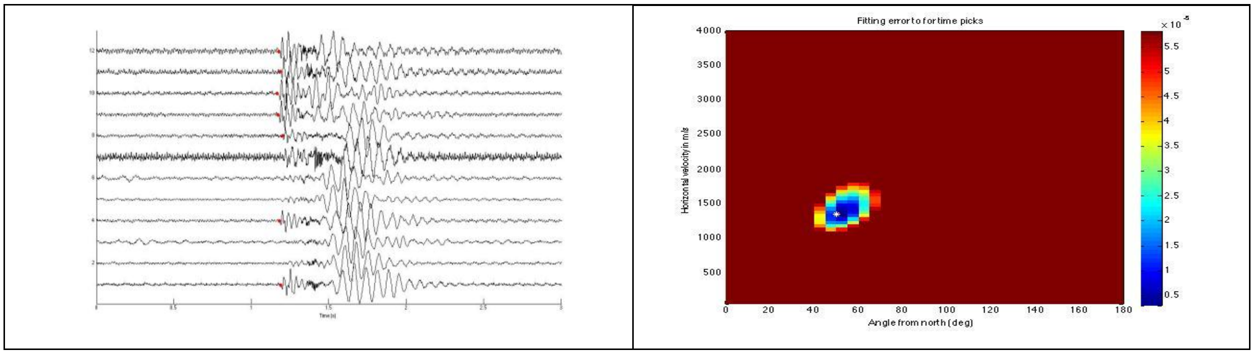


Fig. 4. Examples of velocity analysis applied to a selection of the highest S/N events in the dataset. Velocities and arrival angles are as follows: 1550 m/s, 35 degrees; 1550 m/s, 40 degrees and 1900 m/s, 45 degrees respectively)

Conclusions

A surface array of eight geophones was used for analysis of passive seismic data recorded during a hydraulic fracturing treatment. Of ~3600 potential events obtained by an automatic picking algorithm, 30 were identified for velocity analysis using an array-based method similar to VESPA analysis. All of the waves investigated here have apparent horizontal velocities of 1500 m/s or less and a backazimuth that is predominantly in the NNW to NW, or SSE to SE due to a 180^{o} ambiguity in this type of analysis. Because of the slow apparent velocity of the observed arrivals, they most likely represent wave modes that are trapped in the near surface such as ground roll.

Acknowledgements

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