Microseismic Design Case Study: A Tool to Improve Microseismic Event Locations

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Summary

Microseismic monitoring is the only technology that can provide a real-time picture of fracture growth in the subsurface. However, just like other geophysical techniques, uncertainty associated with microseismic monitoring must be well understood to take maximum advantage of this technology. Therefore, a modeling study must be performed before acquiring the data, this will optimize the acquisition geometry, help understand and resolve the unexpected issues during processing.

Introduction

Microseismic monitoring is a valuable tool to evaluate the performance of the hydraulic fracturing of an unconventional reservoir. Microseismic monitoring involves the placement of geophones in the borehole or on the surface, which detects and records small earthquakes *(Maxwell, 2009)*. The outcome of the microseismic monitoring survey depends on several factors including acquisition geometry, velocity structure, target formation, and treatment parameters. Understanding of the microseismic activity has improved over time, thus raising the expectation significantly. In the recent past, modeling acquisition studies have been used to check if a given acquisition geometry can meet the survey objective as improved processing flows can not always improve the data (*Grechka, 2010*). These modeling studies not only help optimize the acquisition geometry but also understand some of the unexpected artifacts in the resulting event location, due to processing workflow. In this paper, we present a case study where a modeling study is performed to investigate the resulting event location artifacts and improve the processing workflow and suggest acquisition setup for future hydraulic fracturing experiments.

Model Setup

The microseismic data was recorded during hydraulic fracturing of three horizontal wells, by the recording array placed in the neighboring horizontal wells, such that fracturing interval and monitoring wells are at the same depth level. Analyzing the processing workflow and visual inspection of calculated initial event locations revealed locations artifacts (Figure 1). Microseismic event locations are expected to cluster in and around the area undergoing hydraulic fracturing, however, it is unrealistic for the events to be aligned horizontally or vertically along a straight line and called location artifacts. This leads to further investigation, by performing a modeling study and testing some of the possible factors that may be responsible for resulting event location artifacts. These factors are acquisition geometry, inaccurate velocity model or processing workflow.

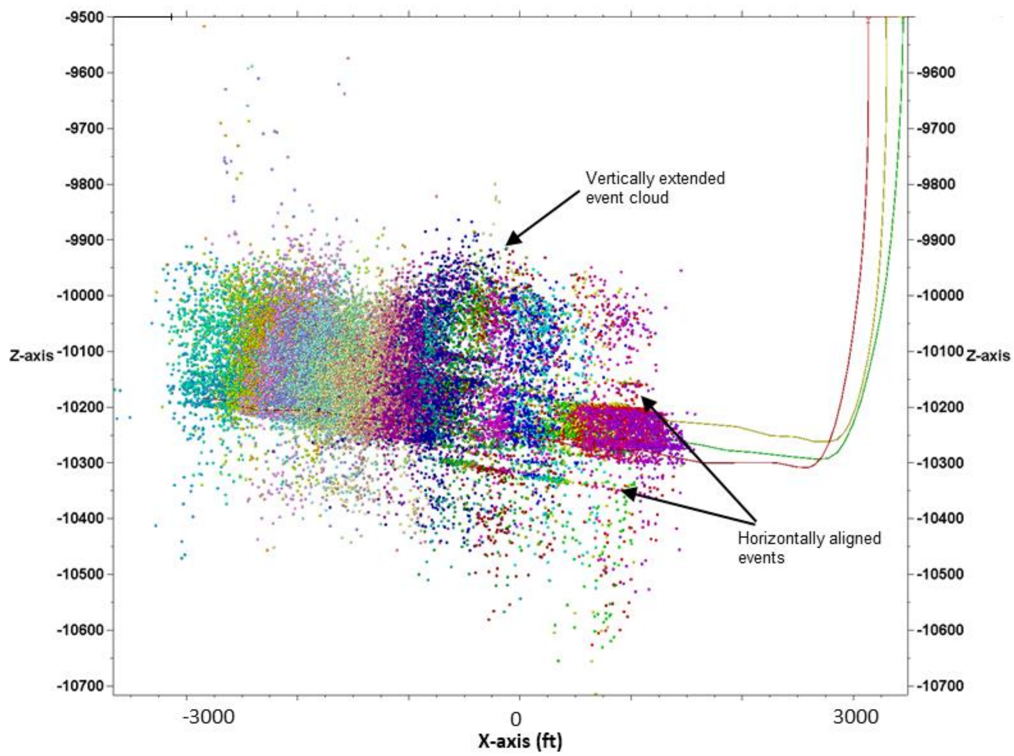

Figure 1: Cross sectional view of processed microseismic data showing event location artifacts.

We designed a modeling study by duplicating the field acquisition setup as shown in figure 2. The microseismic data was acquired by a combination of horizontal and vertical monitoring array, vertical arrays are located at the toe and heel end of the well approximately 7000ft away from each other and horizontal arrays are located parallel to the perforated intervals. This means that microseismic activity occurring closer to the toe and heel would be recorded by both vertical and horizontal array but as we move towards the center of the treatment wells, the microseismic activity would only be recorded by the horizontal array. Keeping this in mind we designed the modeling study to perform Monte Carlo simulation to investigate the impact of following on the resulting event location

1. The orientation of monitoring array
2. Velocity model
3. Event location algorithm

We assumed synthetic event locations along with the treatment well and perturbed the input parametres (P and S wave arrival time) and relocated the events, this is repeated a hundred times by changing the above-mentioned parameters, one at a time.

Results

Figure 2 shows the resulting perturbed event location when data was recorded by all, vertical and only horizontal geophones arrays only. The geophones are shown as triangles in figure 2, true event locations are marked as a red solid circle and perturbed event locations are marked as black solid circles. By comparing the event cloud of perturbed locations, it is observed that when events are located using all and vertical only receiver array, the resulting locations are much closer to the true event location. however, when events are located by using only the horizontal recording array the resulting locations form a bigger cloud around the true event location and also locations tend to align horizontally away from the true event location at a greater depth. Further investigating the event cloud, it was found that these events are located in a high-velocity layer. These results indicate that the horizontally aligned event locations are possibly due to the combined effect of the velocity layer and the events recorded by using only the horizontal array.

Conclusion

Based on the modeling study, it is concluded that the layering of microseismic events in the processed data was mostly because of the minimal vertical coverage of the monitoring array. Although the monitoring array weres placed in more than wells thus having enough spatial coverage but since the arrays were located in the horizontal section of the well thus limiting the vertical coverage. It is well understood that the depth component of the microseismic event location is most uncertain. Additionally, the velocity model and the number of velocity layers in the model also impacted the resulting locations, which was overcome by smoothing the velocity model but footprints of acquisition setup are difficult to remove completely, once the data has been acquired.

Acknowledgments

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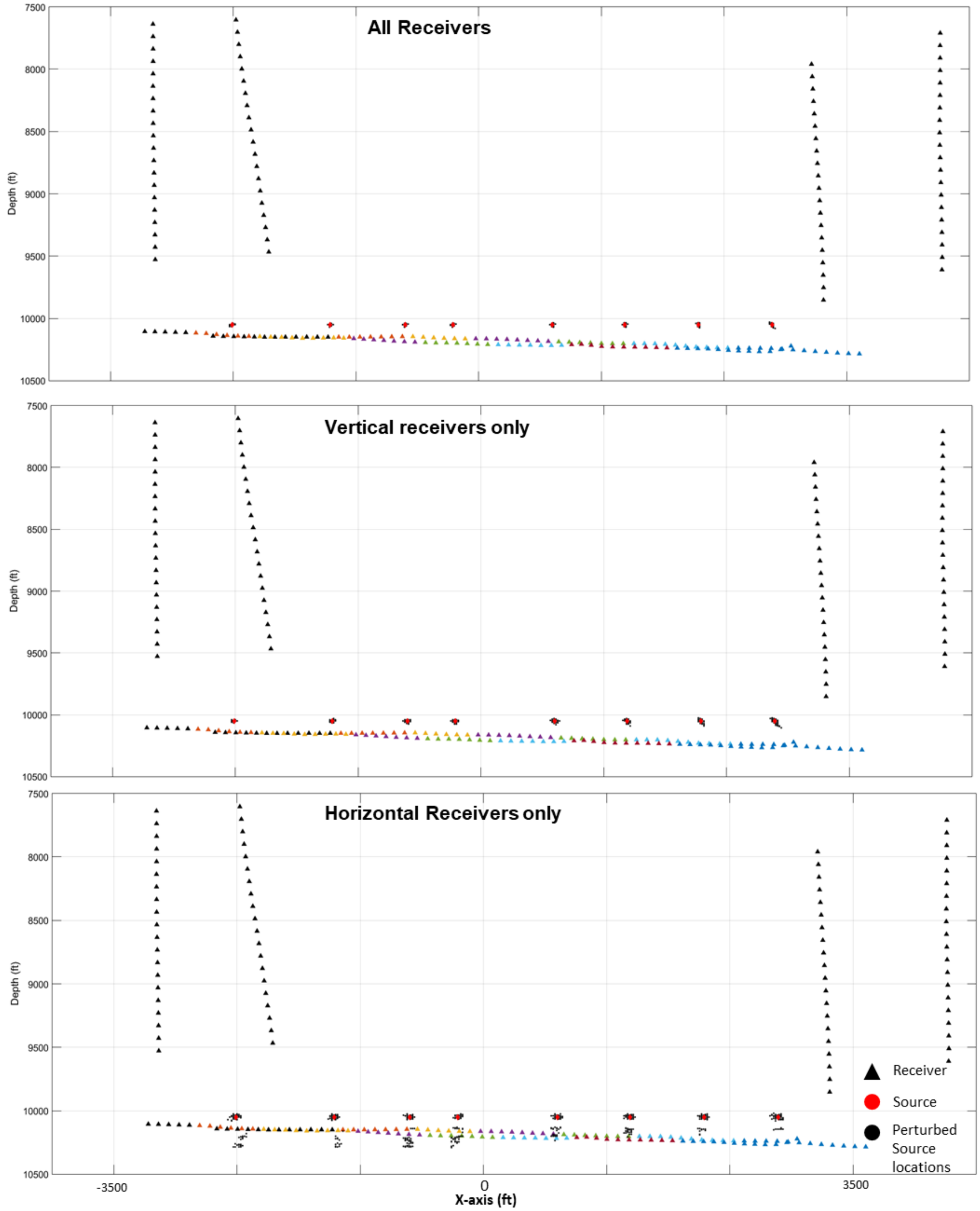

Figure 2: Figure showing Monte Carlo Simulation result for events recorded by all recording arrays (top), only vertical array (middle) and only horizontal.