Using Microseismic Event Radiation Patterns and Source Parameters to Better Estimate Stimulated Reservoir Volumes*

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Abstract

Microseismic (MS) surveys have been a useful tool in answering basic fracture orientation questions. As the technology advances more and more, work is being done to bridge the gap between the geophysicists and engineers looking at the data. With all these advancements, stimulated rock volume (SRV) estimates being output by MS surveys are still the center of much debate. A MS survey can tell you where formation activity is occurring, but many events may not be related to formation fracturing and even more will not be filled with proppant. The use of moment tensor inversion has been looked at as the solution to this issue, but there is still work to do before this method is proven and relied upon. By controlling the events that are used in the SRV analysis and making assumptions related to event energy and S/P ratio we hope to find a more realistic estimate for fracture growth.

Introduction

Microseismic surveys produce a large number of event parameters that are related to the waveform. These parameters are crucial in determining event error and moment magnitude plots. Beyond that, event energy and S/P ratio (shear energy/compressional energy) may hold information that helps us determine which events are aiding in the process of putting proppant in the formation. It should be noted that we are not trying to determine which events are directly produced by proppant injection, rather we want to try to categorize events that are related to the direct path of fluid from the wellbore into the formation. We started off by analyzing two datasets and comparing the S/P ratio relative to the azimuth of the events. That was then compared to theoretical values. If a dataset can be shown to have a less dominant shear fracture presence, then comparing event energy and S/P ratio becomes a more informative process. Filtering events that are used when looking at stimulated rock volume is another important concept that should be used more often than it is. There is always a level of processing that is done with any surface seismic acquisition; if processing was not done accurately, interpreting the seismic becomes increasingly difficult. Therefore, it should not come as a surprise that filtering out microseismic events is a necessary step to accurately calculate SRV. Both datasets provided unique characteristics that led to a varying success rate for predicting a more realistic SRV.

Method

Before using any source parameters for interpretation, it is important to understand the radiation patterns created by shear events. Rutledge and Phillips (2003) looked at a dataset collected in the Cotton Valley and determined that there was a significant shear component to that particular dataset. This was found by graphing the S/P ratio as a function of azimuth (between event and geophone). It was found that the measured data followed the theoretical plot of a completely shear fracture at varying azimuths. The assumption was born that most hydraulic fractures created have a strong shear component. I performed the same analysis on two datasets with varying results. Figure 1 and Figure 2 show the two different datasets, and it can be seen that dataset #2 has a higher correlation to the theoretical values relative to dataset #1. Those results suggest that the events in dataset #1 may have a larger tensile component to the events. Knowing that, we can perform more analysis regarding event energy and S/P ratios without the concern of knowing the exact source mechanism.

The first step for analyzing dataset #1 was to focus our attention on the events that will actually have an impact on the SRV. Events are not always related to formation fracturing and therefore not all events should be looked at as such. The first step in filtering the events is to remove any event that does not occur within an error range of the zone of interest; in this case we used events ±15 meters from treatment well. From there, we introduced an energy threshold, meaning we only looked at events that were greater than a particular energy level. This was done because we assume that the high energy events cause the largest fractures and would produce more surface area/volume that could be filled with proppant. Furthermore, increasing the energy threshold appears to bring the data from event clouds to linear trends extending from the wellbore, as seen in Figure 3. Maxwell (2011) showed that events which have a 50/50 shear-tensile component could produce events with an S/P ratio around 5. Filtering the data further to only include events with an S/P ratio below 5 removed some of the outliers seen in Figure 3. Lastly, we included only the events that occurred while the pumps were operating at a maximum. Figure 4 shows the final results from this analysis and filtering of the data.

The result of this process shows events that form a linear trend from the wellbore. The assumption could be made that these events are related to the direct fluid flow from the treatment well into the formation giving us a better estimate of actual fracture length. The original dataset had events propagating as far as 250 meters away from the wellbore to the South and 200 meters to the North. Filtering the events in the manner shown above allowed for a better estimate for fracture length that can be used in the SRV calculations and hopefully provid useful information for future development plans for the operator.

While dataset #2 (Figure 5) was shown to have the characteristics of a shear dominate fracture system, we can still find useful information embedded in it; stages 1-3 do not follow the theoretical line as closely as stages 4-6. Using that information I increased the energy threshold and found that stages 1-3 produced more linear trends, as seen in dataset #1, while stages 4-6 still produced a cloud of events. Stages 2 and 3 see an effect related to previous treatment of the monitor well, but even ignoring events on the west side of the monitor well confirms a linear trend for those stages. Even though we cannot use the S/P ratio on this dataset, by simply increasing the energy threshold we might be able to infer a better estimate for SRV. The cloud of events that is seen in stages 4 and 5 may have a relation to the actual SRV for that stage.

Increasing event energy threshold among datasets with a low shear component produces a linear trend that can be used to measure effective fracture growth while doing the same in a dataset with a high shear component produces a cloud of events that may have a direct correlation to the actual SRV.

Conclusion

Until more evidence is provided for a concrete method of calculating SRV, it is the responsibility of the interpreters to make sure everyone looking at the microseismic data understands the short comings of the technology in terms of calculating SRV. With that said, by filtering the events used, and looking deeper into the event parameters, we can make assumptions that allow us to come up with more reasonable numbers for fracture growth and ultimately SRV. If a dataset does not display signs of having a strong shear component you can compare event energy with the S/P ratio to determine which events are more likely to be associated with the direct fluid movement from the wellbore. Even if the dataset does have a dominate shear mechanism in the recorded fractures, there is still useful information to be had when looking at event energies. While this approach does not provide a scientific breakthrough in the calculation of SRV, it offers insight into a simple approach that can be used to come up with better estimates for effective stimulated fracture volumes.

Acknowledgments

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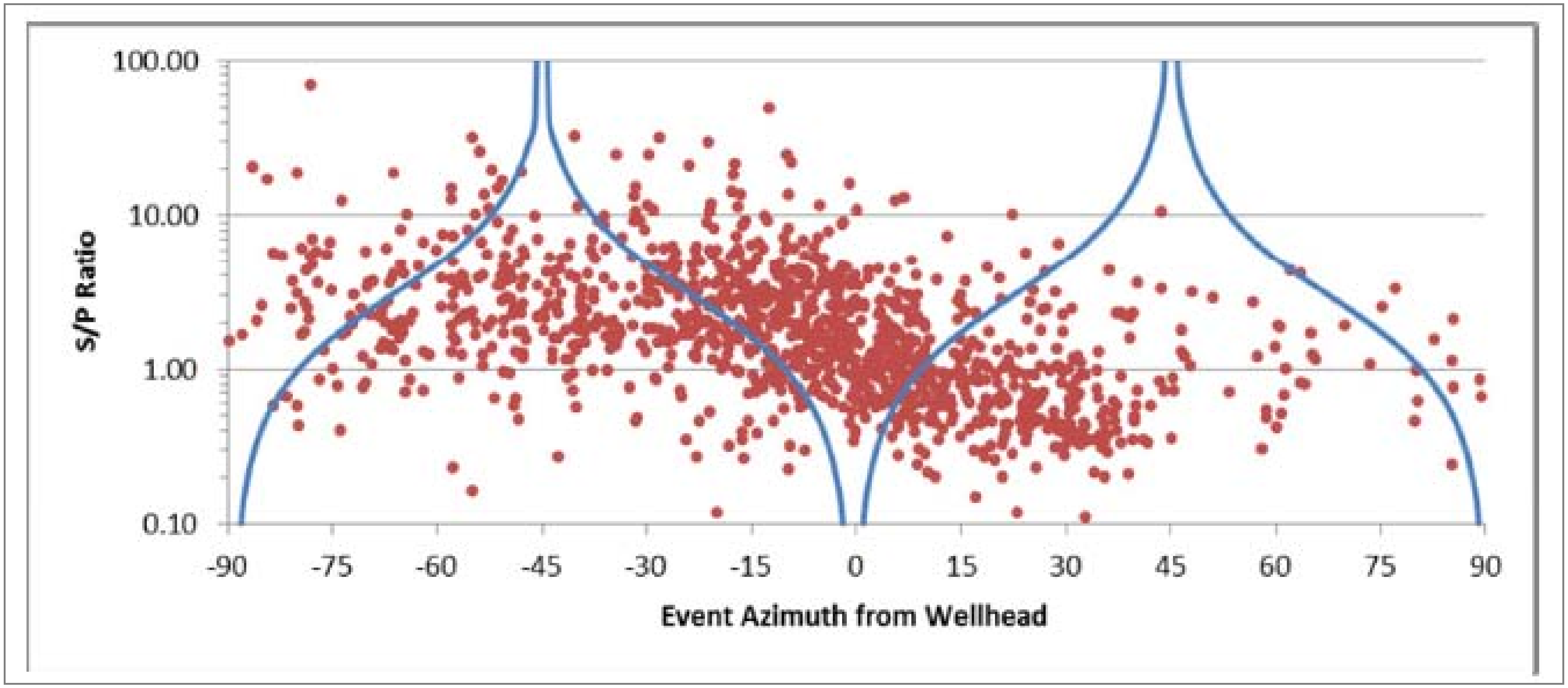

Figure 1. S/P ratio as a function of azimuth for dataset #1, with the blue line representing the theoretical S/P ratio for a shear event.

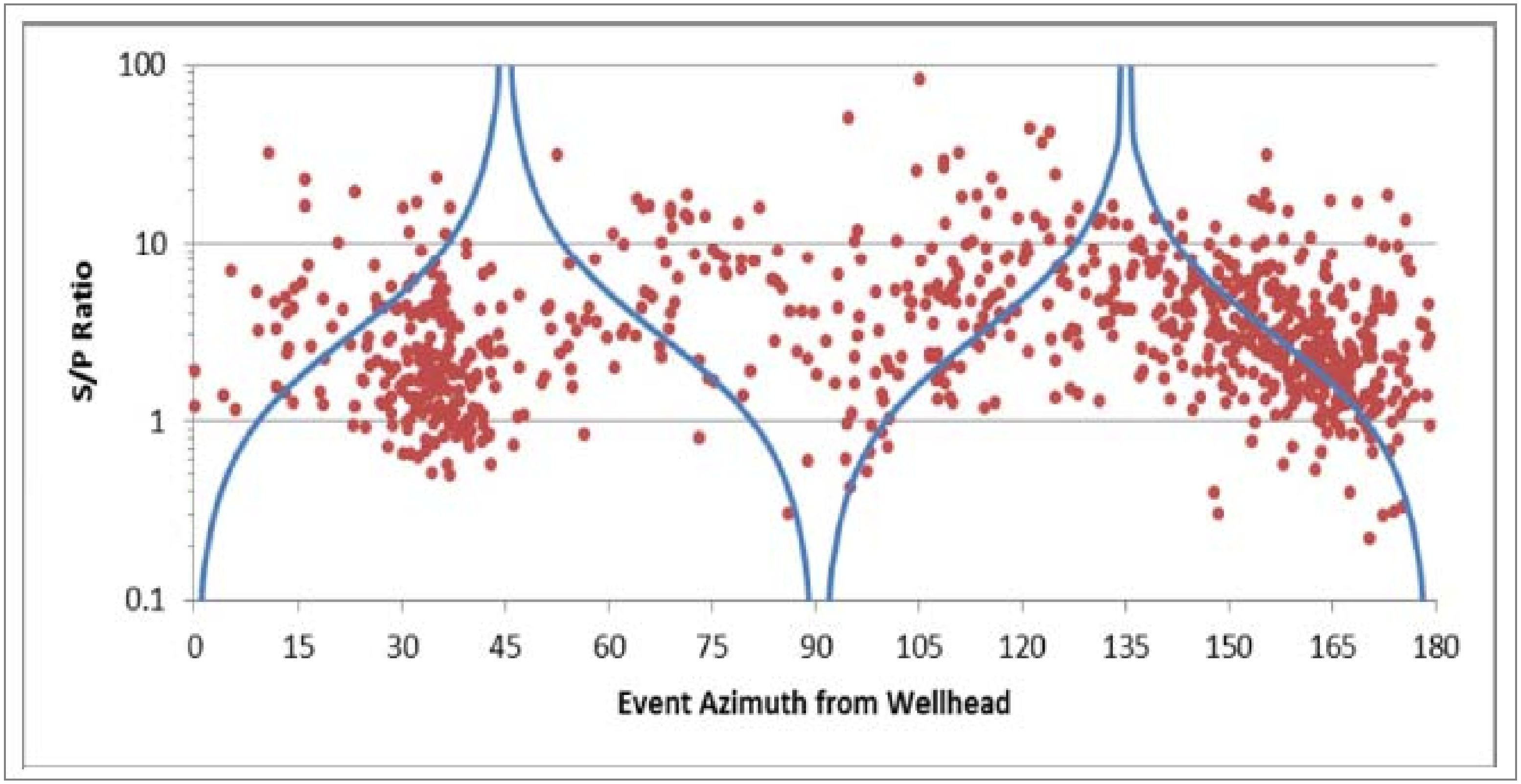

Figure 2. S/P ratio as a function of azimuth for dataset #2, with the blue line representing the theoretical S/P ratio for a shear event.

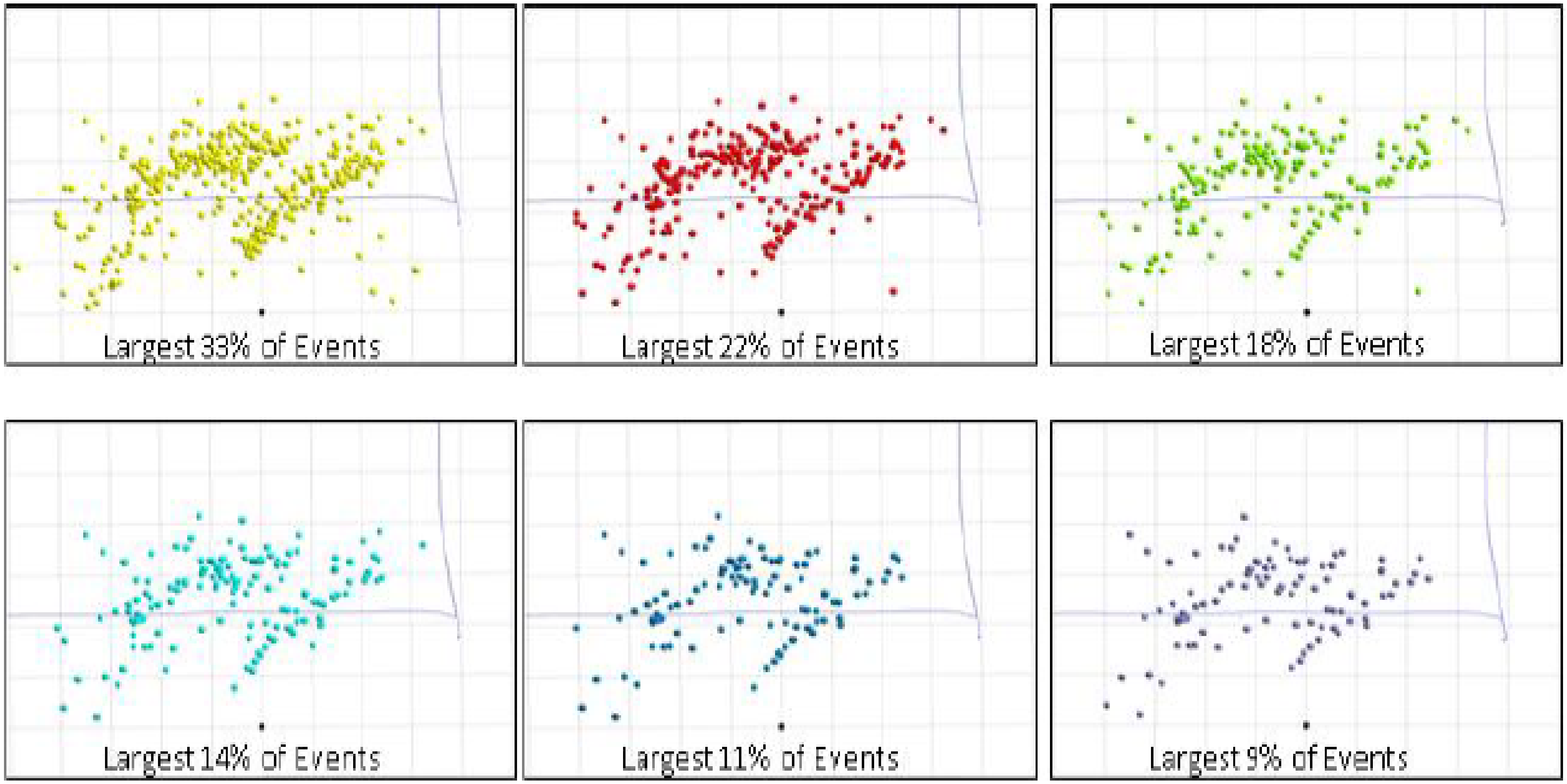

Figure 3. Stepping through dataset #1 as the energy threshold increases. Linear trends develop through the cloud of events.

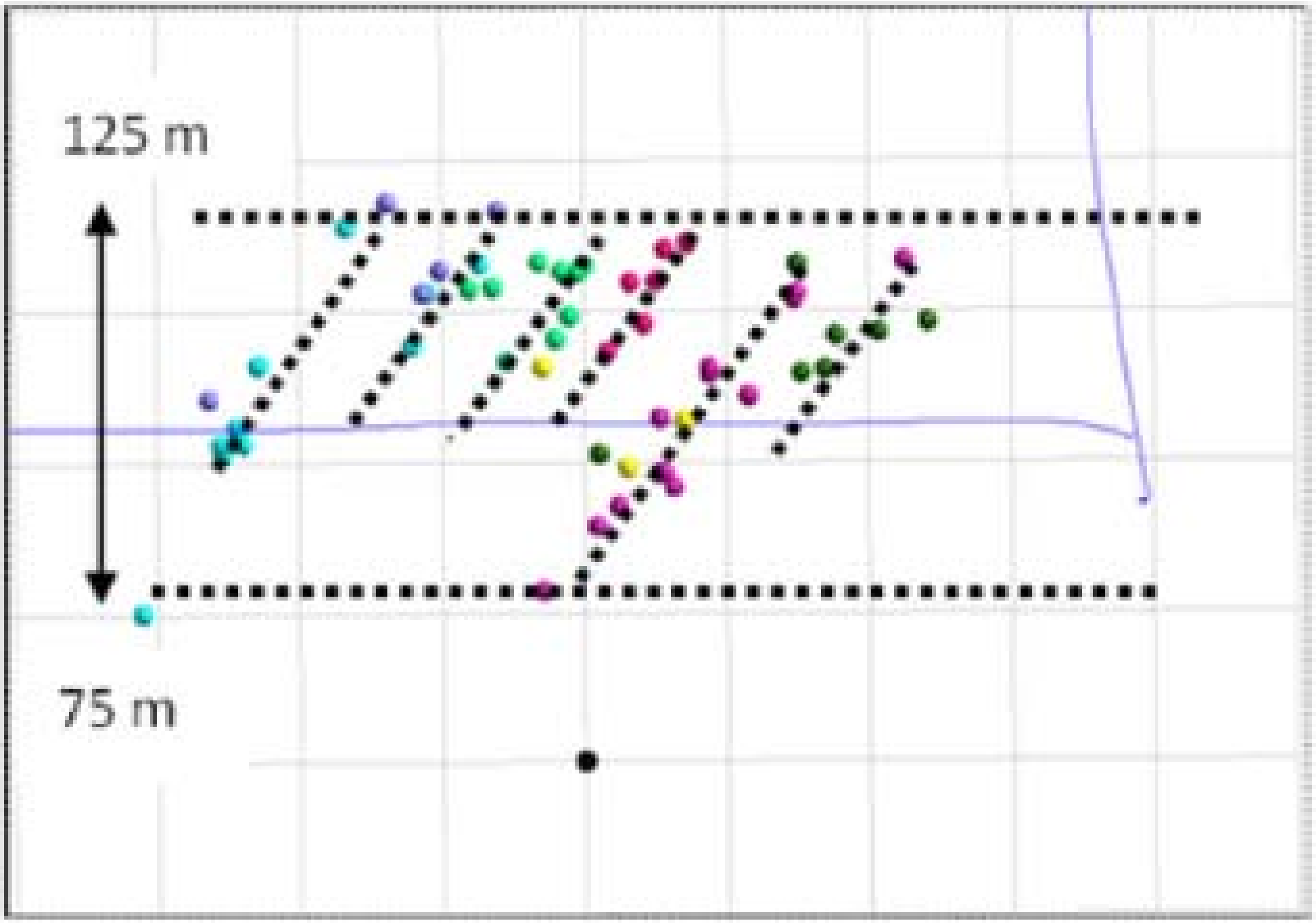

Figure 4. Final result for dataset #1 showing the result of the event filtering that was done.

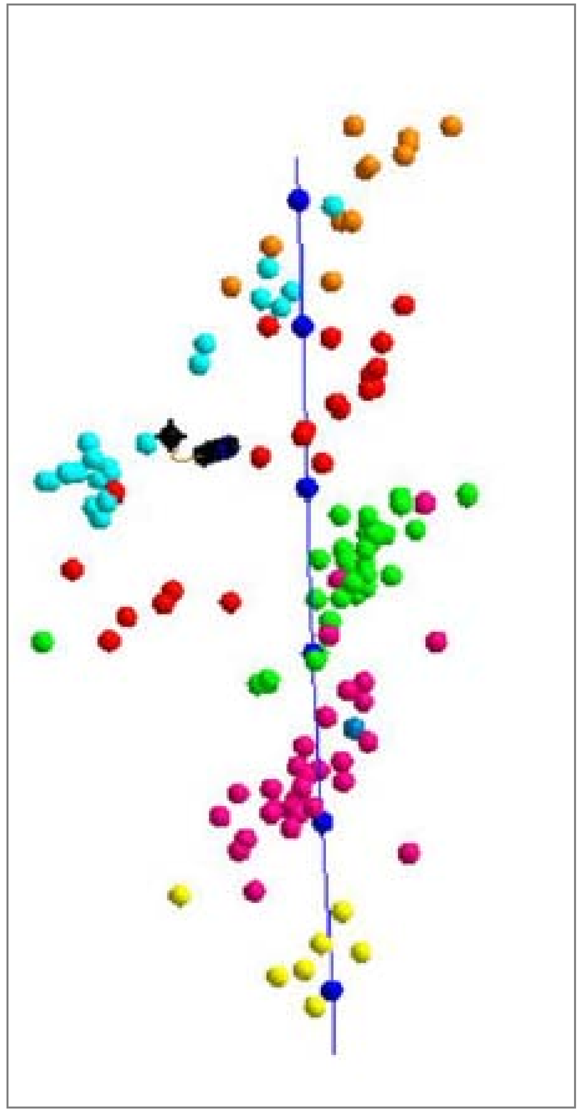

Figure 5. Dataset #2 with only the strongest 20% of the events.