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Real Time Microseismic Monitoring in China: A Case Study

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Summary

Two horizontal wells in China were completed using hydraulic fracturing technology. In order to better understand the reservoir response to this completion activity, surface microseismic monitoring was employed. These microseismic analyses were performed in real time allowing viewing of the reservoir's microseismic reaction to treatment within approximately 15 minutes of an event occurring. This gave the operator unprecedented control of their treatment. Real time feedback was available to allow changes and decisions to be made with almost immediate effect when they are needed. The real time monitoring of these wells detected several sub-seismic faults that were not previously identified from active reflection seismic in the area.

Introduction

In order to monitor the two horizontal wells two separate, but nearly identical, surface seismic monitoring arrays were used. The data from these arrays were monitored in real time from Houston by way of a field processing unit (FPU). The data is recorded and collected with a standard acquisition system in continuous recording mode, then transferred to and processed on servers in the FPU by an analyst via satellite connection. This setup allows immediate, complete data processing with the analyst providing ongoing quality control of results and updating processing parameters if needed.

The wells were completed by China National Petroleum Company in China (Figure1). The horizontals for well 1 and well 2 were ~2000m long and drilled to a depth of ~3500m at an azimuth of ~300° with well 2 being located approximately 11 kilometers west of well 1. Hydraulic fracture monitoring (HFM) was acquired using a surface star-like design consisting of several thousand geophones laid out on the surface in 10 lines radiating out from the wellhead. The passive seismic data was recorded using a Sercel 428 XL system, and transferred to a processing trailer on site. The data was processed under the control of a processing geophysicist in Houston in real time and microseismic event results were transferred to Houston for QC and further analysis. This analysis revealed the presence of a large fault feature influencing well 1. The operator was then able to skip a stage in real time to avoid over-stimulation and loss of fluid and proppant into this feature.

Results

Passive monitoring of the two separate wells revealed similar results in terms of large well defined trends and features but with slightly rotated azimuths (figure 2). Well 1 showed two large well defined features trending slightly NNE while well 2 also showed 2 large features but rotated NNW as well as a third smaller less energetic trend oriented ENE.

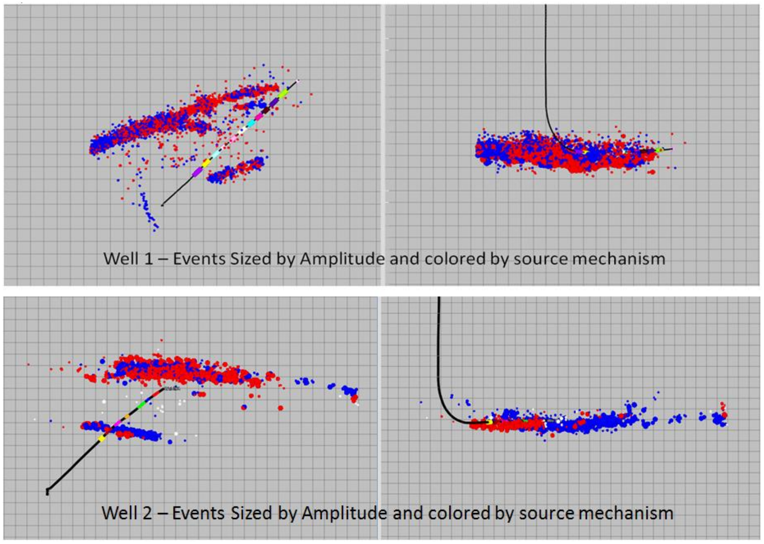
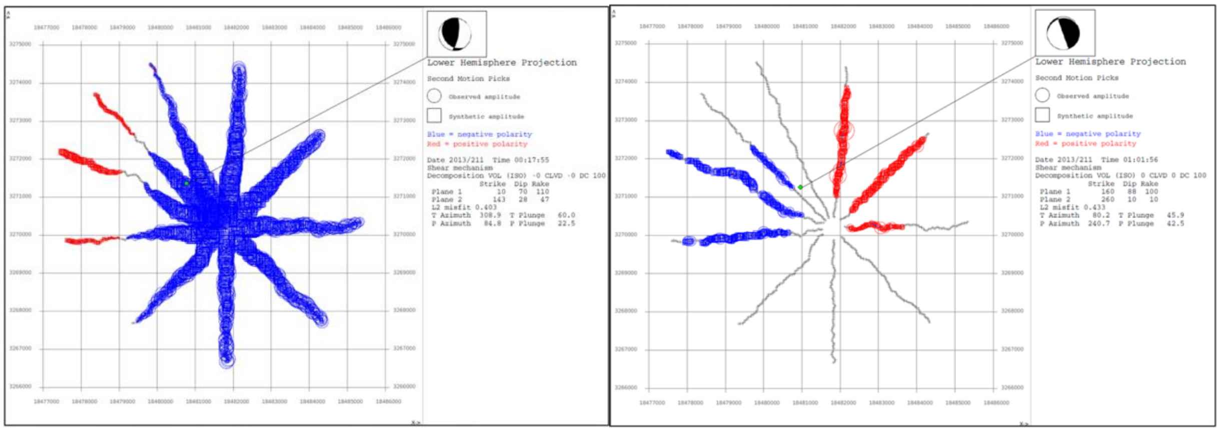


Figure 1 Microseimic results from monitoring of Well 1 and Well 2

Passive monitoring with a wide azimuth, large aperture, high fold surface array allows for the determination of source mechanism. The source mechanism solution for microseismic events is derived by assuming a point source and using a least squares inversion of the observed P-wave amplitudes (DeLaPena et.al., 2011). Using the full moment tensor solution from this algorithm then invert from a point source relationship between observed amplitudes on point source A and moment tensor components M_{jk}:

$$A = G_{3j,k} M_{jk} ,$$

Where $G_{3j,k}$ are vertical components of the derivative of the Green's function (Aki and Richards, 1980). This inversion is then completed via grid search for shear mechanisms. P-wave amplitudes are sufficient for moment tensor inversion as the large aperture of the surface array allows for a robust solution. For this project three distinct source mechanism were observed during these treatments, striking 10° dipping 70°, striking 160° dipping 88°, and striking 192° dipping 62° (figure 3a-3c).



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Shear mechanism
Decomposition VOL (ISO) -0 CLVD -0 DC 100
                Strike  Dip Rake
 Plane 1          10    70  110
 Plane 2         143    28   47
 L2 misfit 0.403
 T Azimuth  308.9  T Plunge   60.0
 P Azimuth   84.8  P Plunge   22.5
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Date 2013/211  Time 01:01:56
Shear mechanism
Decomposition VOL (ISO) 0 CLVD 0 DC 100
                Strike  Dip Rake
 Plane 1         160    88  100
 Plane 2         260    10   10
 L2 misfit 0.433
 T Azimuth   80.2  T Plunge   45.9
 P Azimuth  240.7  P Plunge   42.5
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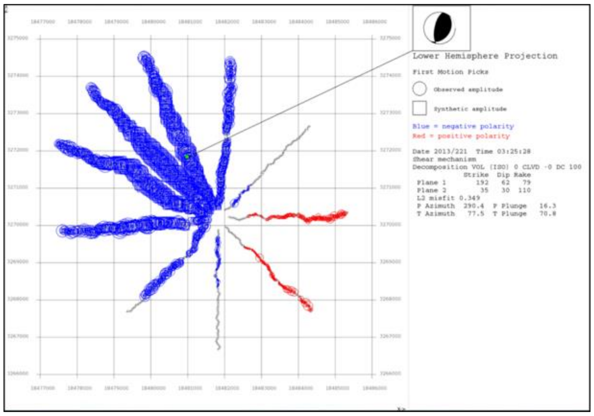
Figure 1a, 3b. Radiation pattern of first p-wave arrivals on array for source mechanism calculation

The strikes of these three source mechanisms correspond well with the azimuths of the large trends observed in the data. This provides a unique view into the stress regime behind the natural features reactivated by the hydraulic fracture treatment.



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Date 2013/221  Time 03:25:28
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Decomposition VOL (ISO) 0 CLVD -0 DC 100
                Strike  Dip Rake
 Plane 1         192    62   79
 Plane 2          35    30  110
 L2 misfit 0.349
 P Azimuth  290.4  P Plunge   16.3
 T Azimuth   77.5  T Plunge   70.8
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Figure 3c. Radiation pattern of first p-wave arrivals on array for source mechanism calculation

Real time monitoring of treatment occurred in the field. A minimally staffed trailer containing a field processing unit (FPU) was placed near the recording truck. Data was transferred as it was recorded by the acquisition system for processing with a passive seismic emission tomography algorithm (Lakings, et al, 2006) that interacts via satellite with a remote access terminal screen at a processing center in Houston where an analyst may monitor status, settings, and results. In this way the results may be determined in the field, rather than expending time to transfer data, while still keeping a trained analyst in control for continuous, optimum quality. Once checked by an analyst, the results were presented on a live feed to any computer with a secure internet connection for the operator to view within fifteen minutes of each event occurinence.

Examples

In this case study wellbores were drilled NW-SE in order to be perpendicular to S_{Hmax} which was shown by the world stress map and surface fault expressions to be ~38° in this area.

This is roughly parallel to the observed microseismic trends created with the stimulation of the large pre-existing features which were oriented approximately N-S. The largest of these features extended ~1700m in length. Microseismic monitoring revealed these events to be mechanically independent and once activated continued to propagate regardless of pumping (Kratz et.al., 2012). These NNE-SSW oriented reverse dip-slip failure planes are rotated into a suboptimal orientation relative to the wellbore, a stress rotation that would not have been known without microseismic monitoring.

Conclusions

This paper demonstrates the feasibility and capabilities of real time HFM as applied to international operations. The system described allows for the possibility monitoring HFM operations from every corner of the world in real time. The analysis capabilities of real time HFM demonstrates its value in these applications and the need for these types of analysis to be performed in real time. The information made available in these studies is especially invaluable abroad where basins are still relatively unknown and the need for optimization of treatments is in high demand.

References

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