An Integrated Approach to Interpretation of Microseismic Data Including Source Mechanism Inversion, Structural Mapping of 3D Seismic Data, Geometric Attributes, and Production Data

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Summary

The use of microseismic techniques to map hydraulic fracture treatments has increased dramatically in recent years. During this time, microseismic monitoring has grown from a technical curiosity into an established method for determining the spatial distribution and therefore effectiveness of well completions in tight reservoirs. While both surface and downhole microseismic monitoring techniques are widely used throughout the industry, surface microseismic methods have typically been met with more skepticism. We present a case study from West Texas in which surface microseismic results from two adjacent wells are validated by incorporating data from numerous sources including structural mapping from 3D seismic data, calculated geometric attributes, and production data. We also integrate source mechanism inversion for a few microseismic events as this provides valuable information about the strike, dip, and sense of slip on the ruptured fracture plane.

Introduction

In 2007, Chesapeake Energy re-entered the Sunray 72-3 #1 well in Reeves County, TX with the purpose of completing the well in the Barnett and Woodford shale formations. During the same time period, Chesapeake drilled the MBF 72-4 #1 vertical well to target the same formations approximately 4000 ft to the west of the Sunray. Both wells were drilled vertically to a depth of approximately 13,000 ft. Over a period of weeks, a four stage completion was performed on each well. The Sunray was completed with primarily slickwater and the MBF was completed with primarily crosslinked gel. During each frac stage, microseismic data was recorded using a dual FracStar surface array which consisted of geophones arranged in a radial pattern extending out from the well pad. The total array consisted of 18 arms with 100 ft group spacing and a maximum recorded offset of 900 feet. A total of 853 and 1925 events were recorded for the MBF 72-4 #1 and Sunray 72-3 #1 wells respectively using PSET® technology developed by Microseismic, Inc.

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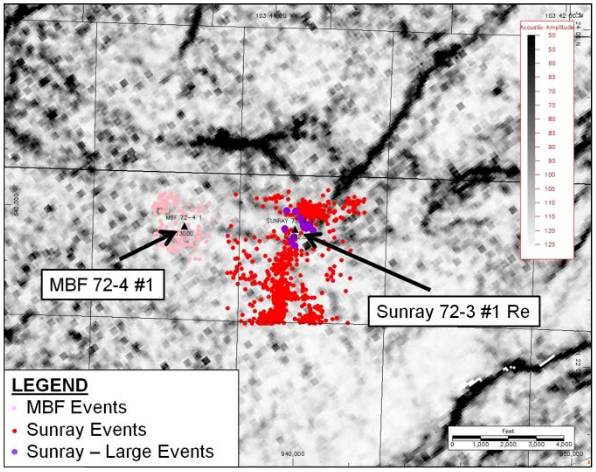

Figure 1: Surface microseismic event distributions for the Woodford completion stage in the MBF 72-4 #1 well (pink dots) and the Sunray 72-3 #1 (red dots). Base Woodford coherence map calculated from the 3D seismic volume is shown in grayscale (faults/discontinuties appear black). Microseismic events associated with the Sunray 72-3 #1 are aligned parallel to a major NE-SW trending fault that is easily mapped on 3D seismic and is clearly visible on the coherence map as well. This observation coupled with unusually large events (purple dots), high event count, and increased water production suggest the hydraulically induced fracture system generated with the Sunray completion intersected this fault.

Discussion

Based on FMI data collected in these wells and several other wells in the surrounding area, the minimum horizontal stress direction in this area is constrained to be approximately N40°E. Prior to the collection of microseismic data, it was expected that the hydraulically induced events would be aligned along a roughly NW-SE azimuth, perpendicular to minimum horizontal stress.

However, the surface microseismic results show vastly different event distributions for the two wells (Figure 1). The MBF 72-4 #1 distribution is relatively tightly confined around the well and shows little azimuthal preference. On the other hand, the Sunray 72-3 #1 distribution covers a much larger area and shows a strong preferential orientation roughly parallel to the minimum horizontal stress direction, perpendicular to pre-frac expectations. A conjugate NW-SE trend can also be seen in the data but is much weaker than the overall NE-SW trend. This result is extremely puzzling in the absence of 3D seismic, and indeed, the microseismic data was processed prior to delivery of the 3D seismic volume.

When placed in geological context with the 3D seismic data, these microseismic event distributions become much easier to interpret. A NE-SW trending fault that extends to the Sunray well location can be easily mapped on the 3D seismic volume. This fault runs parallel to the Sunray microseismic distribution and is also clearly visible as a NE-SW trending black discontinuity on the coherence map shown in Figure 1. Several unusually large magnitude events were also recorded during the Sunray completion (purple dots, Figure 1), and this may be indicative of reactivation of pre-existing fracture planes associated with the main fault. In addition, more than twice as many events were recorded in the Sunray as in the MBF completion. While some of this may be due to differences in frac fluid and proppant concentration, the difference in event count may also be influenced by the complexity of the fracture network that was created near the Sunray as a result of interactions with pre-existing faults and fractures.

Production data from the two wells also corroborates the idea that the Sunray completion encountered a major fault. After roughly 2 years of production, the Sunray had produced approximately 30% more gas and nearly 20 times more water than the MBF.

Conclusions

Surface and downhole microseismic monitoring are rapidly developing and emerging technologies, but surface microseismic has generally been approached with more skepticism than downhole methods. This case history illustrates how microseismic data, when taken out of context, can be confusing and possibly misleading. However, when placed into context with 3D seismic and production results, we have clearly shown for this case the increased event count, increased event size, and increased water production that can be expected in this area if a fault is encountered during a frac treatment.

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