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New Analytical Techniques To Help Improve Our Understanding of Hydraulically Induced Microseismicity and Fracture Propagation

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Abstract

A multistage hydraulic fracture treatment was performed on a producing well in a mature tight gas field in West Texas and induced microseismic activity was monitored from a nearby observation well. The objective of this microseismic monitoring campaign was to determine the overall geometry of the hydraulically induced fractures in the Canyon sandstone formation. Information and results initially derived from the microseismic interpretation were used to provide the operator with recommendations for reservoir management such as drilling patterns, new well placement, and completion practices.

Microseismic events were located with a newly developed location technique based on *S*-wave back-azimuth. While originally a couple of hundreds of induced events per stage were mapped, this new processing technique leads to the detection and location of several thousands of events per stage. This increase of mapped microseismic events provides following insights into reservoir management.

First, initial gaps in located seismicity appear to be artifacts owing to the monitoring geometry, not shear shadow as commonly interpreted. The additional located microseismic events show greater fracture system length and height, thus confirming the effectiveness of the treatment. We also show that the upward component of the vertical propagation is more developed than the downward component, resulting in vertical connection of the first three stages of the stimulation.

Second, the high density of located microseismic events allows us to define the velocity of the fracture system propagation along both the horizontal and the vertical directions. On average, the fracture system propagates horizontally at 12–15 ft/min eastward. The observed hydraulic fracture systems propagated slower toward the west, resulting in an asymmetric fracture with twice shorter western wing. Vertical propagation speed of fracture propagation is similar in sandstone layers, however it slowdown in the vicinity of shale barriers as expected.

Analysis of the source mechanisms of induced seismic events reveals that more than 80% of the representative events have a nonshear component of source mechanisms. This observation implies that the induced microseismic events are directly connected with the created fracture and represent movement of the injected fluids.

Introduction

Canyon sandstone formation of West Texas contains significant resources of the tight gas, however, the existing reservoirs require stimulation by hydraulic fracturing to be produced economically. Due to a complex geological history and low permeability of the Canyon sandstones in this region (Marin et al., 1993) the hydraulic fracture stimulations are complex and frequently monitored for induced seismicity (Cipolla et al., 2005).

We have analyzed one hydraulic fracture treatment that was carried out in a nearly vertical borehole at depth intervals between 4,980 and 6,095 ft. The map view of the treatment and monitoring wells is shown in Fig. 1 along with the initial locations of the largest events in the third stage of this treatment. Six injection stages lasting about 30 minutes each were utilized to stimulate the six depth intervals ranging between 30 to 100 ft in length. The well casing in these intervals was perforated and sealed off by packers from previously perforated intervals (starting from the deepest depth interval). In order to decrease fluid loss the viscosity of the injected brine was increased by adding low concentration of polymer and CO_2. In the beginning of each stage, the injection rate was increased stepwise up to 45 bbl/min to result in a final wellhead pressure between 5 and 6 kPsi. After more than 10 minutes of injection, 20/40-mesh size proppant was added to the fracturing fluid. The proppant concentration was gradually increased up to the final 5 ppa. In each stage, more than 800 bbl of fracturing fluid and about 200 bbl of sand was placed into the reservoir formation.

In this study we show results of advanced analyses of the four stages of the hydraulic fracture stimulation in this formation. The newly developed advanced analyses of seismic monitoring reveal detailed structure of the hydraulic fracture