Estimating Event Growth from Pumped Fluid Volumes*

Jonathan P. McKenna[1], Quynthy Bui[2], David Abbott[1], and Drew Domalakes[1]

Search and Discovery Article #41122 (2013)
Posted May 20, 2013

*Adapted from extended abstract prepared in conjunction with oral presentation at AAPG Annual Convention and Exhibition, Pittsburgh, Pennsylvania, May 19-22, 2013, AAPG©2013

[1]MicroSeismic, Inc., Denver, CO, United States (jmckenna@microseismic.com)
[2]Oasis Petroleum, Houston, TX, United States

Abstract

Microseismicity was detected during a hydraulic fracture stimulation of a 36-stage lateral well targeting the Middle Bakken Formation in July 2011. The objective of this study is primarily to correlate pumped fluid volume with horizontal and vertical microseismic event growth. Second, we devise a methodology for estimating the proppant-filled fracture volume resulting from the hydraulic-fracture stimulation.

The cumulative pumped volume and the perpendicular event distance form the wellbore (both vertical and horizontal) were collected for each microseismic event in the dataset. Vertical and horizontal event distances from the wellbore were plotted as a function of pumped fluid volume.

Analysis of all stages indicates that during the first half of the stage's pump schedule, horizontal and vertical event growth extended outward from the wellbore as a function of pumped slickwater fluid volume; creating a fracture network. This initial fracture network extended along two apparent trends with azimuthal orientations consistent with results from a temporal lineament analysis of the microseismic event trends as well as the two distinct focal mechanisms picked from the first motions in the raw seismic traces. Stress inversion of 24 focal mechanisms reveals the most likely nodal plane solutions that result in present day SH_{max} measurements, consistent with published values. After the fracture network was established from slickwater injection, cross-linked gel was introduced into the formation, accompanied by the majority of the proppant. This resulted in an increased frequency of microseismicity located close to the wellbore that progressively propagated outward. Correlations between fluid volume pumped and the outward distance from the wellbore allows the possibility to predict the total horizontal and vertical extent of microseismicity from the wellbore. This can be used to estimate the total perpendicular distances of fractured rock for future nearby stimulation treatments.

Since the microseismicity associated with the proppant-laden gel location can be tracked within the formation with time, we modeled the probable propped stimulated rock volume using both a pseudo-deterministic and stochastic discrete fracture modeling approach for this treatment.

Introduction

Microseismicity was detected during a hydraulic fracture stimulation of a 36-stage lateral targeting the Middle Bakken Formation in July 2011. Analysis of all stages indicates that, during the first half of the well treatment stages, horizontal and vertical event growth extended outward from the wellbore as a function of pumped slickwater fluid volume creating a fracture network. This initial fracture network extended along two apparent trends; these trends are consistent with both the azimuthal orientations from a temporal lineament analysis of the microseismic event trends, as well as the two distinct focal mechanisms picked from the first motions in the raw seismic traces. Stress inversion of 24 focal mechanisms reveals that the most likely nodal plane solutions result in present day SHmax values that are consistent with published values. After the fracture network was established from slickwater injection, cross-linked gel was introduced into the formation accompanied by most of the proppant. This resulted in an increased frequency of microseismicity close to the wellbore that progressively propagated outward. Correlations between fluid volume pumped and the outward distance from the wellbore potentially enables control of the total horizontal and vertical extent of microseismicity. This could be used to estimate the total perpendicular distances of fractured rock for future nearby stimulation treatments. Furthermore, since the microseismicity associated with the proppant-laden gel location can be tracked within the formation, we can use the microseismicity associated with the gel to model a probable propped inner stimulated rock volume (SRV) and use the remaining microseismicity to model an outer SRV.

Discussion

Results are consistent with analyses from four nearby wells also targeting the Bakken Formation. Figure 1 shows the combined results from all five wells. The slickwater treatment creates the initial fracture network that propagates from the wellbore as a function of cumulative pumped volume, with a peak occurring at ~1,000 bbls. This pumped volume is consistent with the average total pumped volume at the start of gel injection. The more viscous gel, carrying the majority of the proppant, exploits the initial fracture network and increases the fracture volume to accommodate the thicker fluid. This initially causes microseisms to occur closer to the wellbore and grow outward as the initial fracture network, created during the slickwater treatment, is replaced and enlarged by the viscous gel. The ultimate enlarged fracture network has a half-length that is ~80% of the average initial fracture network resulting from the slickwater portion of the treatment.

Conclusion

Injection of less viscous slickwater and more viscous gel results in two different signatures in the microseismic response (Figure 1). Microseismicity associated with the proppant and gel provides insight into the volume surrounding the wellbore that is propped. This is modeled as an inner SRV, which is expected to result in the greatest production from the reservoir. The modeled outer SRV, that likely contains less proppant, is expected to contribute to less of the overall production but could enhance longer-term production. These models can be used to better understand how formations respond to different stimulation treatments; and can be used to more accurately space wells to optimize economic hydrocarbon recovery from the treatment.

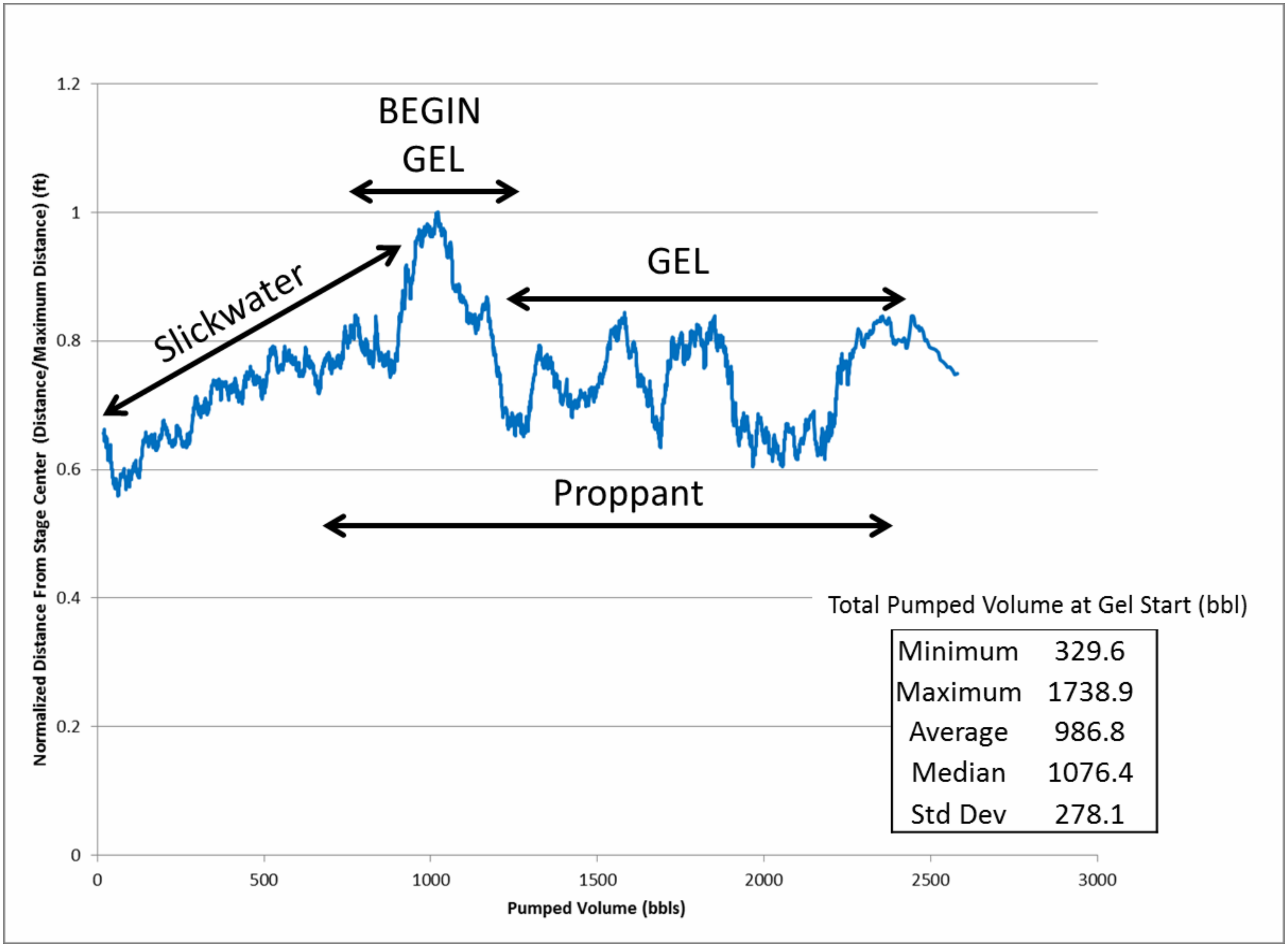

Figure 1. Cumulative pumped volume (bbls) as a function of normalized microseismic event distances from the wellbore as measured from their respective stage center locations. Volumes and distances are averaged over a moving window of ~50 bbls of pumped fluid volume. Microseismic event locations are normalized by dividing all distances by the average observed microseismic half-length. This figure can be used to predict the effective propped distance from the wellbore by multiplying the average microseismic half-length for all stages resulting from a hydro-fracture treatment by ~0.8.