

A Reservoir Study: Hydraulic Fracturing in the White Speckled Shale Formation

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Summary

A study was conducted in the Second White Speckled (2WS) Shale Formation to understand hydraulic fracture behavior. Stress, material, rock and fluid property analysis obtained from petrophysical data were used as input to the fracture model. Numerical simulation was undertaken to determine the impact on fracture height and length with varying injection volume, fluid properties and pump rate. The model results prior to conducting the job suggested that a high viscosity fluid coupled with high rate will promote height growth and that little value was gained by increasing total volume of fluid pumped. Real time mapping of microseismic data in the field revealed upward height growth for each stage along the horizontal treatment well. This result was observed when the treatment volume reached approximately 500 m³. This observation suggested that the total fluid volume size can be reduced in order to prevent excessive height growth, but could sacrifice in-zone simulated reservoir volume (SRV). Post job analysis integrated the microseismic mapping results with geological and petrophysical data to provide insights into the mechanisms and environmental conditions that control fracture growth in the 2WS interval. The measured fracture geometries were used to perform history matches of the actual production and pressure response from this well. The mapping results were incorporated into several fracture modeling scenarios which consider one or more planar fractures in order to relate fracture geometry to treatment size, rate, fluids and perforating strategies. Many factors such as the presence of natural fractures, stress contrasts and changing material and reservoir elastic and fluid properties influence height growth. Characterising the cause of height growth is important to optimizing zonal coverage, improving stimulation techniques and well performance.

Introduction

The Second White Speckled Shale of the Upper Cretaceous Colorado Group in the Canadian Sedimentary Basin is an unconventional source and reservoir rock described by Hicks (2011) as containing a variety of play types including biogenic gas, shale oil and light oil. While this reservoir has been characterized as a zone with numerous hydrocarbon sightings, to date it has not shown the repeatable success needed to establish a resource play (MacKay, 2014). A factor thought to be important to the producibility of the 2WS are natural fractures as identified by Cho et. al (2011) through seismic imaging. They appear to create permeable pathways for fluid flow. Intersecting and opening these natural fracture systems by generating induced hydraulic fractures is believed to maximize permeability and hydrocarbon production.

Hydraulic fractures are manufactured flow paths by which hydrocarbons are efficiently extracted from low-permeability rocks (Fisher and Warpinski, 2012). A horizontal well landed in the 2WS formation containing multiple stages was completed with perforations. An adjacent dedicated wellbore with a straddling vertical borehole monitoring array was used for microseismic mapping of several hydraulic fracture treatments. The objective of microseismic monitoring was to measure fracture geometry (i.e. height, length and azimuth), determine fracture coverage within the pay zone in map view and estimate SRV. Since vertical height growth was a concern, the vertical monitoring well was optimally positioned to image the evolving fracture.

The purpose of this study was to model various model scenarios in order to relate fracture geometry to treatment size, rate, fluids and perforating strategies. The outcome will help to understand the fracture behavior and the underlying mechanisms that control fracture growth in the 2WS which will lead to design improvements and increased production.

Theory and/or Method

A sensitivity study was conducted prior to the field job to evaluate the potential for the produced fractures to grow out of zone as a function of fluid pump rate, volume and properties. Petrophysical analysis was used to construct a geologic profile as input to the hydraulic fracture model. The modeling results were used to design the treatment schedule that was executed in the field (e.g. see sample treatment curves in Figure 2). Microseismic monitoring was employed to monitor fracture evolution, measure geometry, estimate SRV and completion efficiency (e.g. see sample microseismic event locations in Figure 2).

History matching of production and pressure were later performed to optimize well completion. Then Mapping results were incorporated with engineering data to relate fracture geometry and well performance to treatment size, rate, fluids and perforating strategies. Lastly, the microseismic results were integrated with geological and petrophysical data to gain insight into the physical, mechanical and geological hydraulic fracture constraints.

Example

Figure 1 shows an image of a simulated hydraulic fracture with propped height and effective half-length modeled prior to the field treatment. The color scale is proppant concentration. Hydraulic half-length corresponds to the edge of the green colored contour and the propped half-length corresponds to approximately the outer edge of the yellow colored contour. The image to the left was modeled with a low volume and high pump rate and the image to the right used a high volume and same pump rate as the model to the left. Significantly more upward growth was predicted and the propped half-length was increased for the larger volume job.

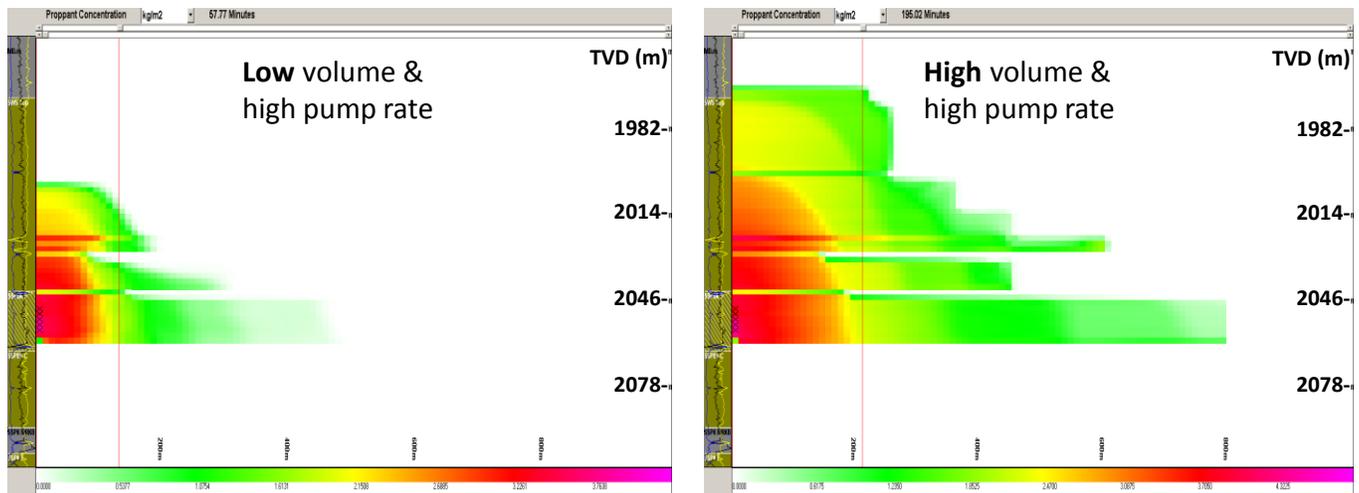


Figure 1 Pre-job fracture model shows propped half-length and upward height growth. Significantly more upward growth was observed and the propped half-length was increased for the high volume job. The color scale is proppant concentration. Hydraulic half-length corresponds to the edge of the green colored contour and the propped half-length corresponds to approximately the outer edge of the yellow colored contour.

Microseismic events from a single stage in a horizontal treatment well are shown in Figure 2. The Upper panel shows microseismic event locations for a single hydraulic fracture treatment in a horizontal wellbore looking end on. The color scale is in TVD KB (m) where blue equates to deep and red indicates shallow events. The lower panel shows the microseismic histogram correlated with the treatment curves versus time. The black vertical dashed line indicates the time when height growth above the payzone initiated. The magenta, cyan and green colored curves represent Surface Pressure (MPa), Slurry Flow Rate (m^3/min) and Proppant Concentration (kg/min^3) respectively. This image shows that once the treatment reached a certain cumulative volume, the fracture preferentially grew upward.

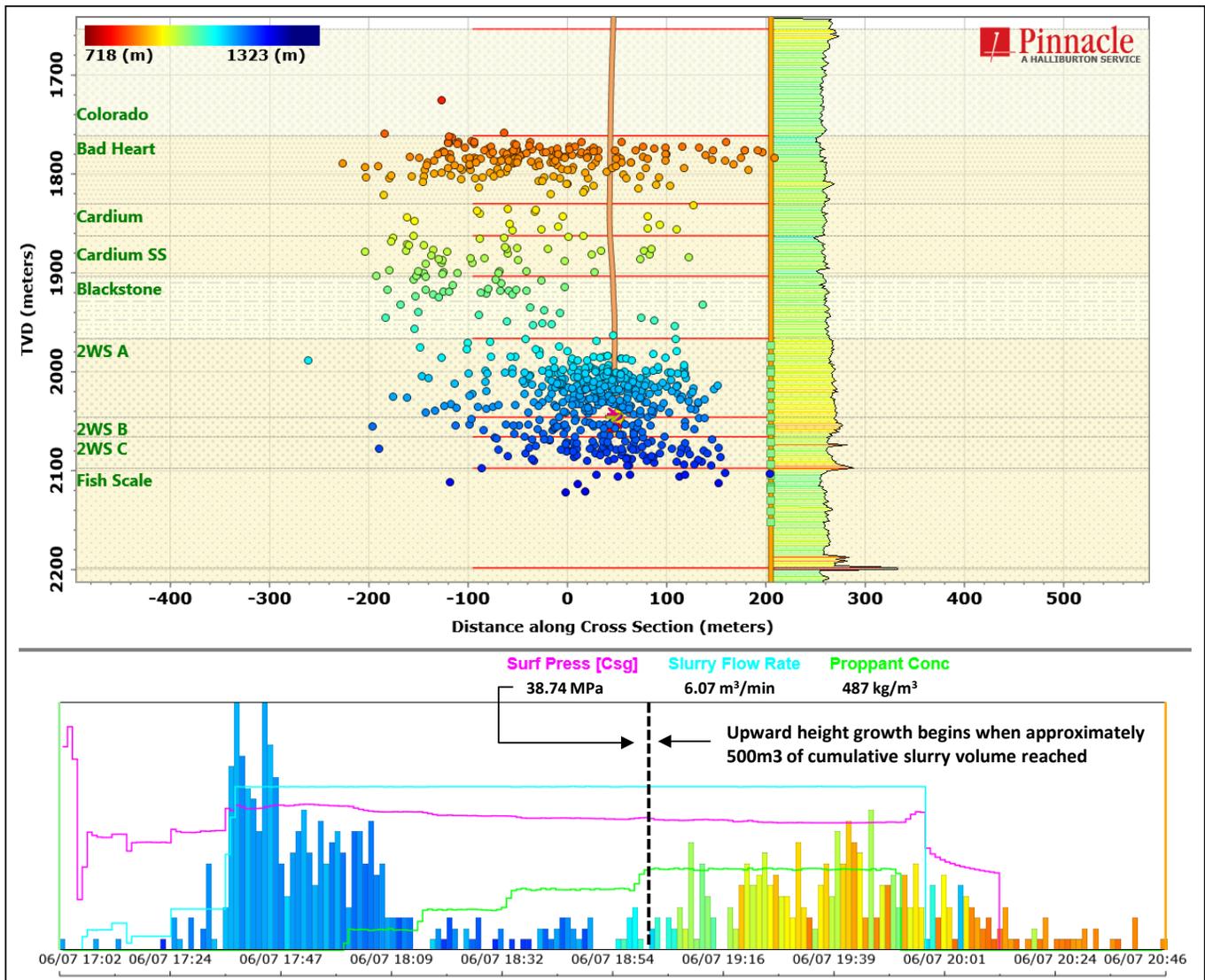


Figure 2 Upper panel shows microseismic event locations for a single hydraulic fracture treatment in a horizontal wellbore. The color scale is in TVD depth (m) where blue = deep and red = shallow events. The lower panel shows the microseismic histogram correlated with the treatment curves versus time. The black vertical dashed line indicates the time when height growth above the payzone initiated. The magenta, cyan and green colored curves represent Surface Pressure (MPa), Slurry Flow Rate (m^3/min) and Proppant Concentration (kg/min^3) respectively. This image shows that once the treatment reached a certain total volume in time, the fracture preferentially grew upward. In this example, in-zone SRV was achieved therefore smaller total fluid volumes could be pumped to avoid out-of-zone height growth.

Conclusions

Prior to a hydraulic fracture treatment, several modeling scenarios should be run to understand the effect of treatment parameters on fracture geometry. Microseismic mapping of hydraulic fractures is an excellent way to monitor the behavior of the fracture(s) as it evolves and grows. In the example shown, the pre-job modeling showed significant upward growth with increased job fluid volume and the microseismic observations supported this prediction. As a result, smaller volumes could be pumped to avoid out-of-zone height growth, but could sacrifice in-zone SRV. Calibrated fracture models will be aimed at adjusting treatment parameters to obtain optimal zonal coverage and the geometry obtained from microseismic mapping will be used to conduct history matching to understand in-zone SRV. Natural fracture networks, stress and material property contrasts are equally important to characterize as they either suppress or enhance hydraulic fracture propagation and will be investigated.

References

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