Forecasting Productivity of a Hydraulically Fractured Well using a Detailed Mapping of its Proppant Conductivity Distribution*

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Abstract

The primary purpose of fracture conductivity left after a fracture treatment is to increase the contact area between reservoir rock matrix and wellbore, and hence enhancing the productivity of a hydraulically fractured well. Historically, most developed productivity enhancement relationship of stimulated wells and still used extensively, McGuire & Soukora, Cincoley, Prats, the fracture conductivity (FC) appears as a single value. However, most fracture geometry stimulation models show that the fracture conductivity inside the fracture is not even, and its distribution relies greatly on many factors. Hence, the final conductivity distribution is rarely evenly distributed across the entire fracture surface. In hydraulic fracture simulators, the conductivity distribution depends greatly on the proppant settling models, which are governed by the proppant type, leak-off, fracture fluids type, as well as pumping rate of fracture fluid applied in the treatment. In addition, in the unconventional reservoirs, we believe over-displacement practices can also affect greatly the fracture conductivity near the wellbore and would have an adverse effect on well productivity.

Introduction

The industry continues to struggle to pin point the factors that directly contribute to the productivity behavior of hydraulically fractured wells especially those drilled horizontally, and multiple staged fractured, in the unconventional resources. For example, on the top of the list examined for poorly productive wells are well location (unfavorable geology), and the second factor is the completion, and the stimulation in particular. We feel that to increase the understanding of the connection between stimulation and well productivity, we need to dig deeper into the generated fracture conductivity and its effect on the well behavior.

This study is conducted in order to understand and quantify the effect of fracture conductivity distribution of a transversely fractured horizontal well as simulated by hydraulic fracture models on the horizontal well productivity. The study will quantify the following issues:

- Whether it is possible to represent fracture conductivity distribution by a single number fracture conductivity value.

- The effect of various fracture conductivity pattern produced by various settling models on well productivity.
- The effect of fracture over displacement of the flush on well productivity with possible residual conductivity magnitudes around the wellbore.
- The effect of completion location in terms of the proppant settlements and hence conductivity distribution which is related to the horizontal well landing depth and the treatment size

Methodology of the Study

The work is conducted in two steps; first step is to simulate a fracture design using hydraulic fracture simulator MFrac to obtain various fracture properties including fracture conductivity distribution. Map the fracture conductivity generated by the fracture simulator into the reservoir simulator grid. Second step is to conduct reservoir simulation using CMG Imex on various sensitivity cases for fracture conductivity distribution to understand its effect on the well performance. Effect of wellbore landing depth is simulated in the reservoir model by moving the perforated cell relative to the proppant mass. Details of each case study will be given in the body of the main paper showing exact location of the well and distribution of residual conductivities around the wellbore intersection in case of the over-displacement cases. Figure 1 describes the workflow of the methodology of the study.

The Field Properties Selected for the Study and Problem Schematic

Published data for the Bakken shale reservoir is used to construct the main dimensions of the models; fracture simulations and the reservoir simulations. In addition, available reservoir fluid properties were used for the study. The results of various cases were compared based on arbitrary selection of cumulative of oil at end of three years. Detailed reservoir properties used and the generated fracture geometry for various cases will be given in the full body of the paper. The configuration of the problem studies is depicted in Figure 2.

Figure 3 shows an example of one case of transporting of fracture conductivity distribution generated by hydraulic fracture simulator (MFrac) into the reservoir simulator (CMG). A complete attributes of the reservoir models, grids, and boundary conditions will be detailed in the paper.

Cases Description

The cases were selected based on two major factors: 1) Type of fracture conductivity and 2) Type of proppant settling. The first factor, Type of fracture conductivity was further categorized as 1.a) Single number fracture conductivity; 1.b) Uneven distribution of fracture conductivity. The second factor, Type of proppant settling was further categorized as 2.a) Empirical Settling; 2.b) Cluster Settling. The cases were designed by mix and matching the above two categories. These cases were further investigated based on various location of the completion (wellbore landing depth) in terms of the cluster of the proppant settlement. Cases for completion with over-displacement were generated by adding a 20 bbls to the flush in MFrac and assigned residual conductivities to the over-displaced proppant area around the wellbore. Detail description of each case including MFrac plots will be provided in the paper.

Results and Discussion

The study indicated the following:

- For a perfect proppant transport, as MFrac produced it by empirical settling option, or manually setting the no settling option, the well forecast is similar, for detailed conductivity versus one single number conductivity simulations.
- For a cluster settling transport option, the reservoir simulator forecasted that when the wellbore landing depth is outside (above) the settled cluster, the well productivity could be as low as 36% of that a single conductivity number. This reduction improves as the landing depth gets closer to the settled proppant pack. The relationship between wellbore depth and the propped body of the fracture will be shown in the paper.
- In the over-displacement cases, the productivity can be as low as 30% of the single number case. The improvement of well productivity depends greatly on the residual conductivity. A detailed relationship will be presented in the paper.

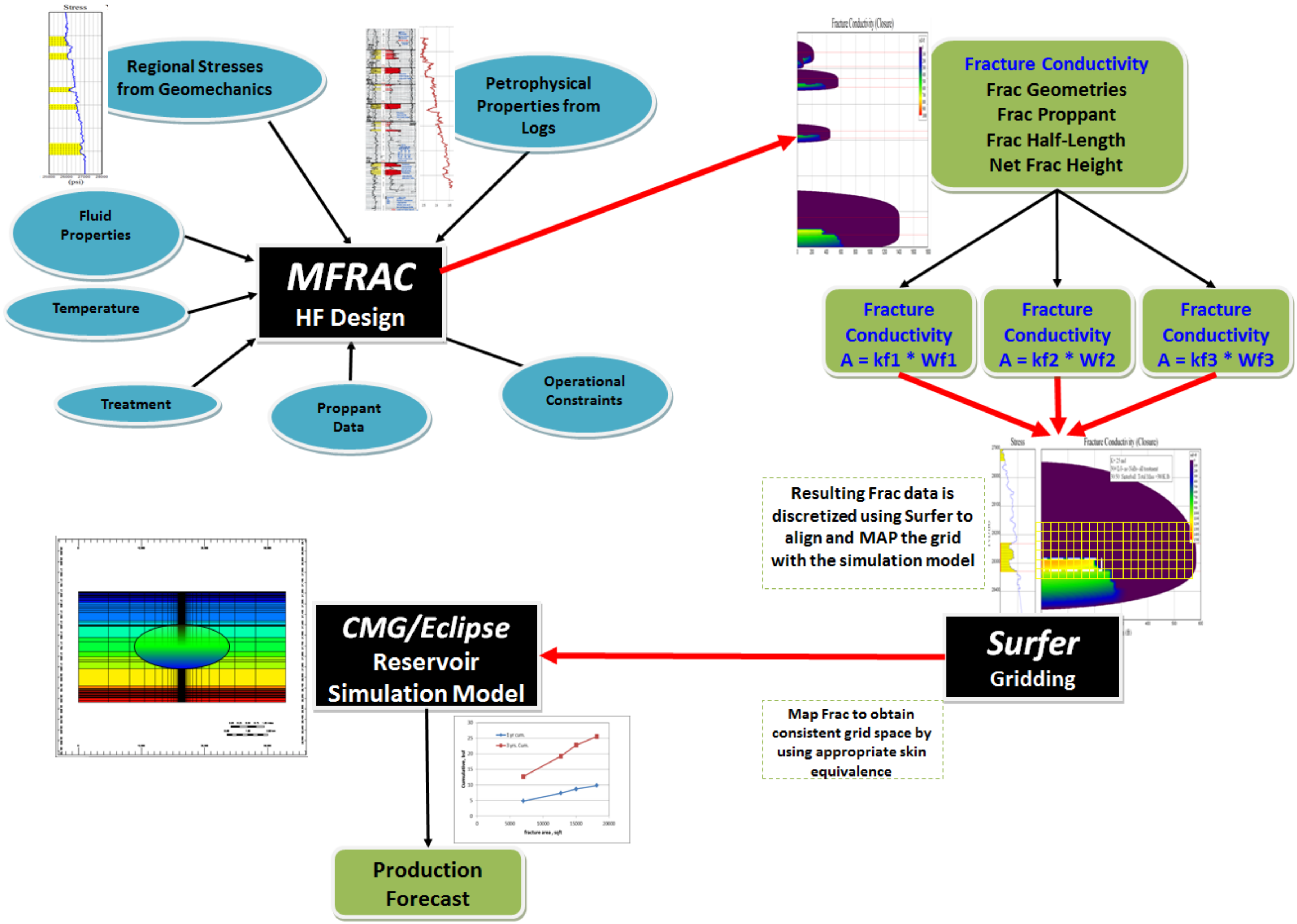

Figure 1. Schematic showing the methodology and the workflow of the study.

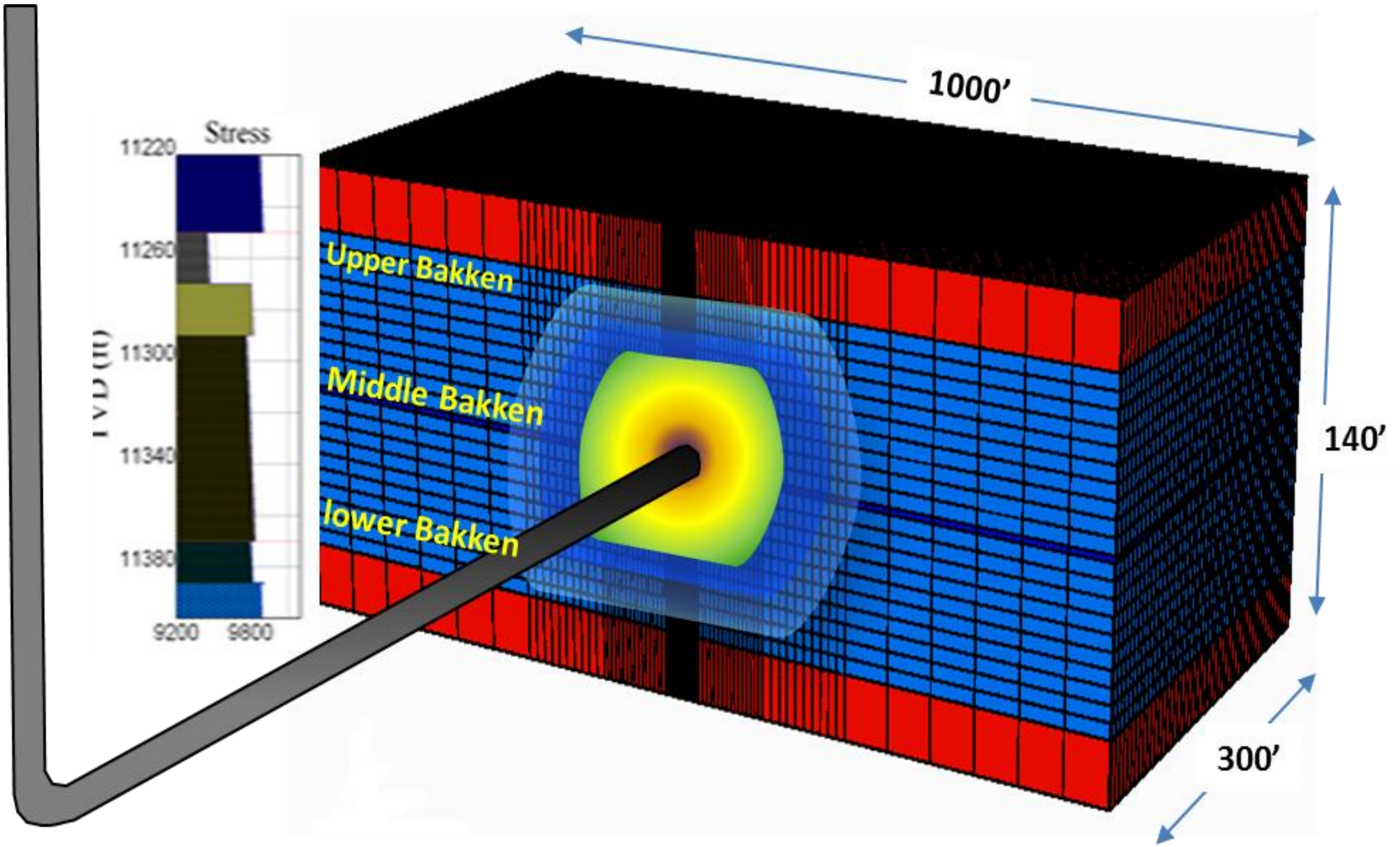

Figure 2. Problem schematic showing the dimensions and configuration of the problem for one fracture stage initiated from the middle Bakken.

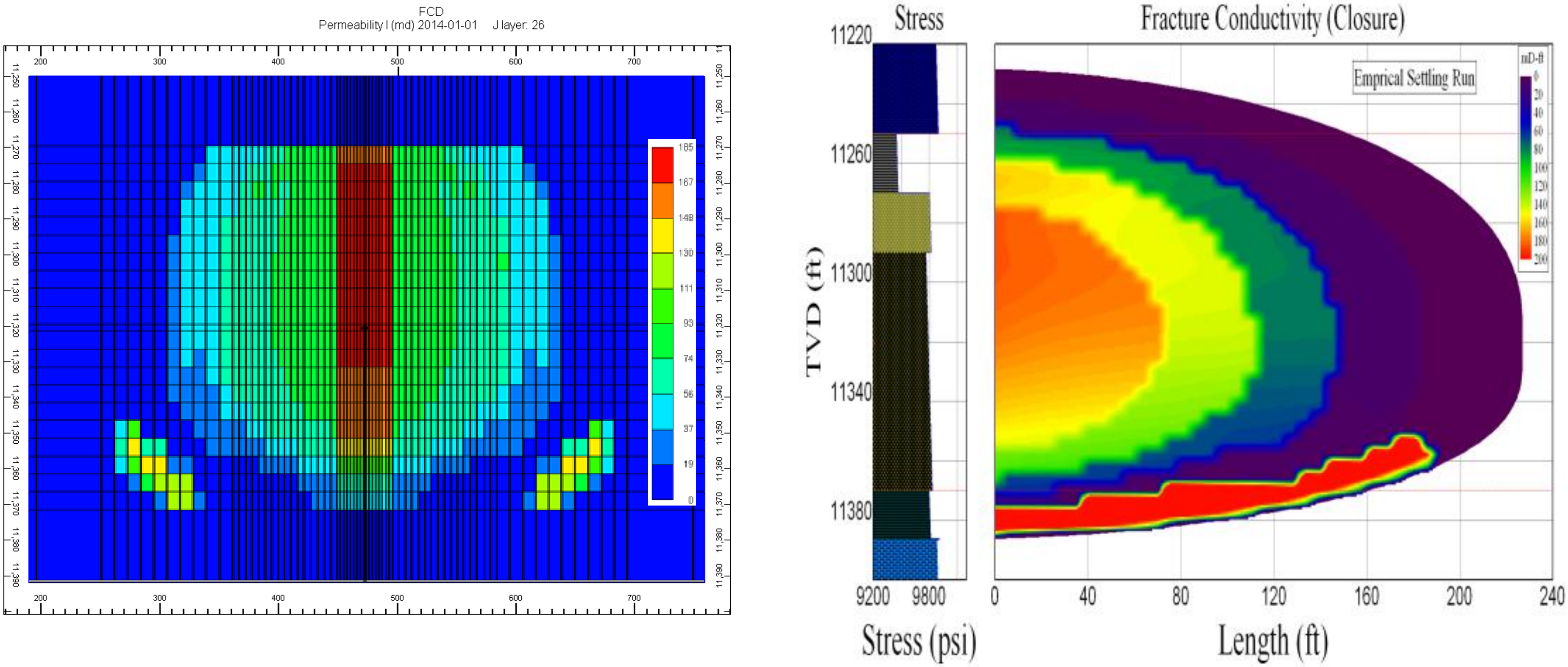

Figure 3. Fracture as seen in Hydraulic Fracture Simulator and conductivity transported to the Reservoir Simulator (Cross Section).