Quantifying the Impact of Induced Asymmetric Fracturing from Horizontal Development Wellbores; a Geostatistical Perspective

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Summary

Sufficient production and fracture mapping evidence across North America was examined, and clearly demonstrates that groups of delineation and development wells often underperform when there is substantial production time (months or years) between the completions of the two wells. Though induced asymmetric fracturing has been attributed as a possible root cause of underperformance for a number of years, this study advanced the state of certainty of that conclusion to a higher level, and confirms the most frequent cause of incremental losses in reserves.

It is shown that the asymmetric fracturing into lower stress and lower pressure drained volumes can materially impact reserves and rate of recovery if the acreage position of a given project is substantial. It is demonstrated that the overall stimulated reservoir system permeability, the degree of permeability contrast between reservoir layers, and the degree of asymmetry are all factors that have an impact on the degree to which long-term time between completions affects recovery of hydrocarbons over and above simple volumetric depletion. Several scenarios for preventing extreme asymmetric fracturing are discussed.

Introduction

The identification of the top technical drivers with the highest net present value (NPV) impact on large unconventional (ultra-low permeability) hydrocarbon extraction efforts have been studied by numerous authors. One of those key technical drivers relates to the mitigation of the negative effects of reduced productivity between offset laterals when there are long periods of time between adjacent completions[1-5].

Various operators have recognized that groups of delineation (parent) and development (child) horizontal lateral wells often underperform when the delineation wellbores produce substantial volumes prior to stimulation and completion of the of adjacent development wellbore(s). Initially, the industry reaction was to attribute the loss of reserves to inter-well communication across the two induced fracture networks, and focus on methods that might prevent that communication, such as adjusting lateral spacing and/or decreasing stimulation volumes pumped per unit of lateral length[6]. Reducing the stimulation volumes per unit of lateral length has an undesirable side effect of reducing the total exposed induced fracture surface area, which in turn can negatively impact the rates and volumes of reserves recovered. Increasing parallel lateral spacing to the degree that there is minimal or no communication between conductive fracture networks will most often leave a strip of unstimulated or understimulated reservoir volume in between the two wells. Contributing causes here are likely the simplification of fractures or fracture networks with increased distance normal to each wellbore, and/or uneven induced fracture lengths.

Comprehensive amalgamated microseismic records from North America over a 14-year period were examined. Results of this effort have provided confirmation that there is a statistically valid relationship between reduced proximate reservoir pressure and asymmetric induced fracturing trending toward the rock volume with the lower pressure. **Figure 1** is a synthetic summary graphic of this scenario. Numerous authors have demonstrated that asymmetric fracturing in the direction of a reduced pressure reservoir is likely if other Darcy and geomechanical parameters are held constant, but there has been some hesitation by operators to make fiscal decisions that assumed the validity of the theoretical geomechanics.

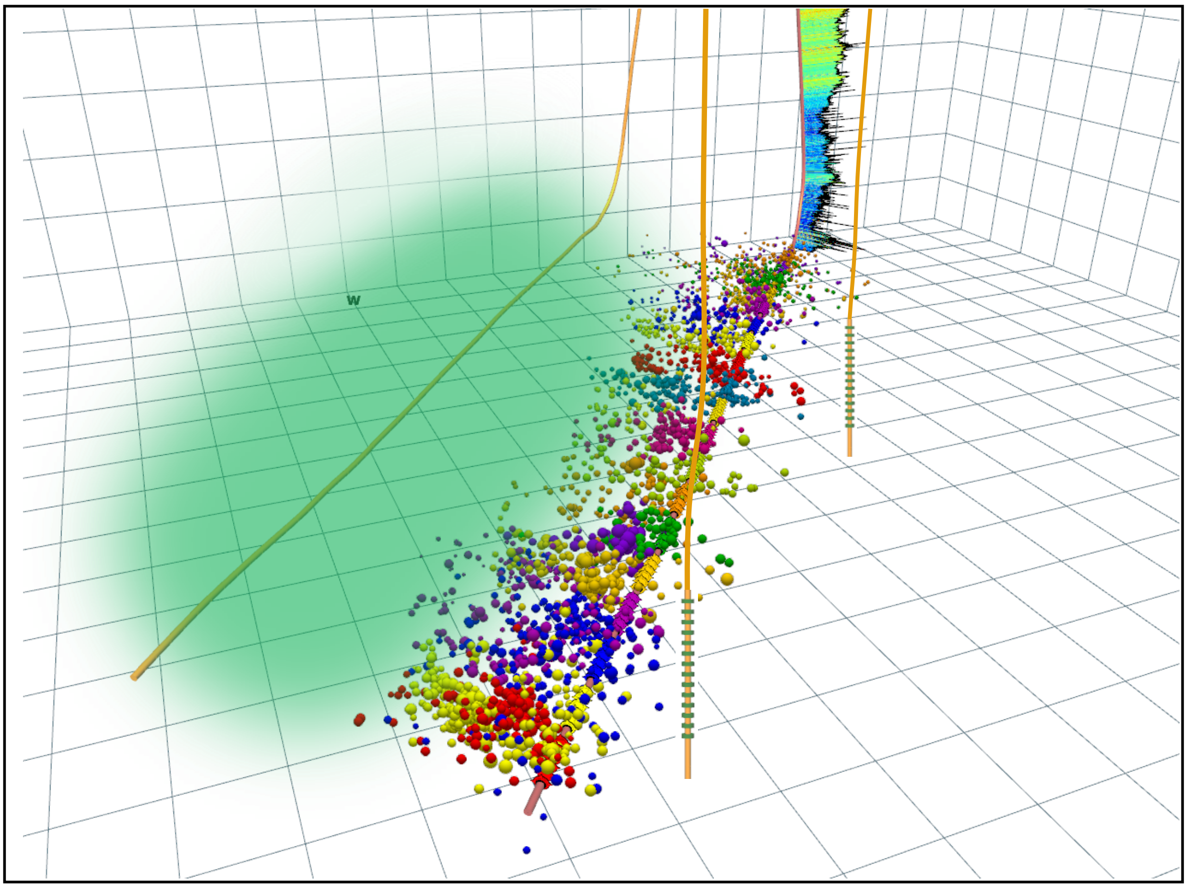

Figure 1. Synthetic representation of a typical scenario where microseismic activity suggests asymmetric fracturing towards a lower pressure A_D

Method and Results

Two approaches were taken in the study. First, the amalgamated microseismic and microdeformation results from plays across North America were examined to statistically verify that the geomechanical assumptions were correct. Second, a series of computational reservoir simulations were undertaken[7-9] to assist in verification that the asymmetric fracturing logically resulted in production underperformance.

The fracture mapping data archives suggest that some unconventional horizontal plays typically experience asymmetric fracturing in the direction of lower-pressure drained area A_D to a higher degree than other plays. The oil window of the Eagle Ford Shale and the Bakken/Three Forks are two examples where fracture asymmetry can be so extreme that induced fractures can cross multiple proximate parallel wellbores on their path to a lower pressure (and therefore lower stress) zone. Other plays can experience the asymmetry to a substantially lesser degree, suggesting that there may be fundamental physical realities that control the degree to which asymmetric fracturing can be a problem.

Mitigation of Asymmetric Fracturing

There is sufficient hard evidence that says *<u>asymmetric fracturing is the primary root cause of underperformance</u>* of a child well when a parent well has previously produced significant quantities of hydrocarbons and/or water. The fiscal impact of unmitigated asymmetric fracturing can be substantial. There is quite a bit of variation from play to play across North America, and some plays are virtually impossible to quantify due to the vulgarities of infrequent well testing and unreliable liquid hydrocarbon allocation. However, more reliable North Dakota data suggested underperformance by approximately 27%, and several gas plays across the US were in the 28 – 35% range. Recently, a number of operators in the

Permian Basin (Delaware and Midland) cited ± 30% differentials between delineation and development laterals.

There are several well-known mitigation processes that have been employed[10-12], but none of them on their own are a catch-all:

a - Minimize the time and production volumes between delineation and development by aggressively manipulating the D&C schedule (a number of larger majors and independents are actively practicing). This is a relatively capital-intensive process, but is extremely effective for up to approximately 75% of wellbores drilled on a given acreage position.

b - Parent well re-pressurization fracs without proppant. These may not be quite as effective as many in the industry are claiming. High rate and no diversion are causing most fluids to exit casing in a limited percentage of the lateral. Not enough volume is pumped to re-pressurize original induced fractures and any reasonable percentage of adjacent matrix volume, or too much total original production from the parent well makes re-pressurization of original induced fractures and/or a measureable percentage of matrix unlikely.

c - Parent well re-pressurization fracs with proppant. Very few of these are being performed in North America. Same scenario as (2) above, but with the added complication of sand fallout in pipe at low velocity is exaggerating the problem in (b) above. There may be sufficient evidence to suggest that mitigating the sand fallout with occasional viscous sweeps and/or washouts might result in more effective coverage along the lateral.

d - Low-rate, high volume parent well re-pressurization. A number of operators across North America are experimenting with this technique. Though there is not enough hard public data to verify the relative degree of its effectiveness, there are signs that the practice could become more widespread over the next several years. The suggestion is that pumping these at lower rates over a long period of time could increase the percentage of fluid re-pressurizing a portion of matrix normal to existing induced and propped fractures.

e - Combinations of low-rate, high volume parent well re-pressurization, followed by high-rate re-fracturing with proppant. Some very limited experimentation is ongoing across North America; no good public data verification is available. Presumably, there is a dual benefit --- the prevention of asymmetric fracturing from the child or development well, and new incremental reserves produced from the parent well. Diversion is often involved. Again, like (c) above, mitigating the sand fallout with occasional viscous sweeps and/or washouts might result in more effective coverage along the lateral.

f - "EOR", for cases where the primary hydrocarbon is a black oil with a bubble point
Parent well repressurization with unprocessed field gas off a gathering line, followed by either immediate production, or by a refracturing operation. Like (d) and (e) above, there is potentially some good degree of matrix repressurization, leading to the dual benefit of both asymmetric fracturing prevention and lifting of incremental hydrocarbons (due to miscibility of the gas and lifting of localized static pressures back above the bubble point). If the repressurization effort is followed by a propped re-fracturing effort, then a third benefit could be realized ---- the incremental recovery of reserves that were not accessible by the original stimulation treatment. There are a number of large independents and major operators across North America that are actively experimenting with various manifestations of this.

Conclusions

Asymmetric fracturing into previously produced reservoir volumes *is* the primary root cause of underperformance of development wells. Though there are other contributing or casual causes, the interaction of development well induced fractures with partially drained reservoirs results in underperformance that can be fiscally material to companies with large acreage positions.

Underperformance can be mitigated via a number of proactive D&C and subsurface strategies.

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