Integrated Reservoir Modeling Supports a Culture of Continuous Improvement

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In shale, operational efficiency, downhole tools, fracture design, fracture diagnostics, and reservoir engineering have all improved dramatically over time. These improvements have paid off with better production and lower cost. For example, the figure below shows improving production over time from different generations of wells in the Bakken.

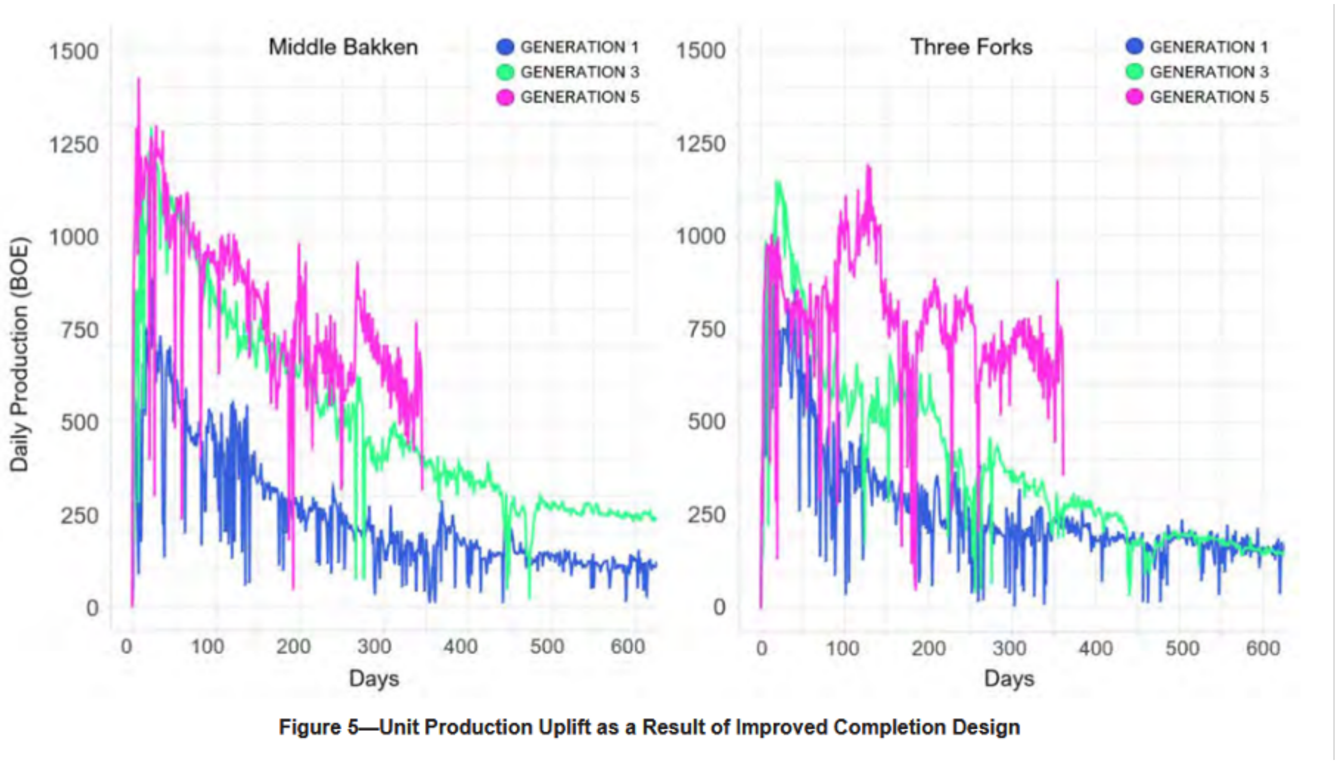

Figure 1: Evolution of well performance over time in the Bakken (Bommer et al. 2020)

Shale plays are well-suited for continuous improvement. There is only mild to moderate geologic variability from well to well. Wells are impacted by their near-neighbors but are otherwise mostly independent from each other. With 3-6 months of production, there is enough information to draw conclusions about the well's long-term performance. Since the slickwater fracs in the Barnett in the late 1990s, there have been generations of wells fractured and produced, each giving feedback and information that is fed into the fracturing of the next round of wells. This ability to run (relatively) similar and independent tests and get back performance feedback within 3-6 months is a huge advantage for shale, which drives innovation.

Aided by this continuous feedback, companies are always tinkering. Changes are driven by new downhole tools, new data collection, new understanding, moving to new acreage, and changing prices. New challenges arise over time. For example, as plays mature, the percentage of new wells that are 'infill' wells has increased dramatically.

Balancing long-term objectives with the short-term goal of maximizing cash flow.

Of course, companies operate under a variety of constraints and have different business strategies. The long-term benefit of innovation must be balanced against the short-term need to maximize cash flow. As a result, different companies have different attitudes about experimentation and innovation strategy. In my experience, companies that are too cautious tend to use older, less-efficient designs. But iteration is not a panacea. Companies must maximize value by designing trials, tracking performance, and communicating internally.

How do companies decide what changes to make from iteration to iteration?

Companies use a combination of field trials, physics-based numerical simulation, statistical lookbacks, field data collection, laboratory studies, and expert opinion. But – *there is no silver bullet*. Shale has not come this far solely because of numerical simulation, machine learning, geophysical imaging, or hard-working engineers. Those things have all helped. Improved downhole tools have been especially important.

BUT AT A DEEPER LEVEL, THE KEY DRIVER OF INNOVATION HAS BEEN THAT EVERY FEW MONTHS, A NEW GENERATION OF WELLS GOES ON PRODUCTION AND COMPANIES GET FEEDBACK ABOUT WHAT WORKS AND WHAT DOESN'T. AND COMPANIES ITERATE.

Operators are constantly bombarded by messages from service companies that overpromise what is possible. Operators are skeptical and rightly so! All of the tools at their disposal have drawbacks:

- Numerical models cannot reproduce every detail of the subsurface.
- Statistical lookbacks and machine learning are vulnerable to the effect of variables that aren't included in the analysis; they can't predict 'out of sample' behavior, and they may be too 'high-level' to address granular engineering decisions.
- Field data often requires processing and interpretation that is inexact and subjective.
- It is challenging or impossible to reproduce field-scale processes in the lab.
- Experts can offer great advice, but they are also human-beings subject to cognitive bias and mistakes, just like everybody else.

Operators understand all these things intuitively and exercise critical thinking and judgment in evaluating all the available information and deciding what to do next.

Our mission – helping operators continuously improve, supported through integrated reservoir modeling.

Within ResFrac, our company's product and culture are built around helpings operators address these challenges. Our purpose is to assist operators in their process of continuous improvement and making science-based decisions. We address questions such as:

- How should we mitigate problems that arise from infill drilling? Should we change well spacing? Use far-field diverter? Preload? Perform real-time adjustments on the fly? If so, how?
- With lower oil prices, should we modify well spacing? Modify stage length? And if so, are other designs changes needed in concert?
- Secondary and tertiary recovery hugely increase recovery in conventional reservoirs. They have unique challenges in shale, but huge potential. How should pilots be designed?

ResFrac is the industry's only commercial combined hydraulic fracturing and reservoir simulator. Our workflow is designed to synthesize knowledge – integrating all available sources of information – and put it into a single, internally consistent representation of reality that embodies all of the key physics (McClure et al., 2020; Fowler et al., 2020).

We urge users to look carefully at the model results and ask: "what happened and why?" Unexpected simulation results are often the most valuable.

With a ResFrac simulation, we can view a 3D image of the simulation results, zoom in and rotate, plot different properties, and really dig in to understand the results. In our consulting work, when we simulate alternative frac designs and present the results to operators, they are almost always inspired to think of yet more alternative designs that we could test. The first set of simulations leads the team to identify new designs that they hadn't considered initially.

If a model is a black box, then you can't assess 'why' things happen. If you don't understand it and can't explain it, then the modeling results will be unlikely provide value. This is why we provide a **detailed technical writeup of ResFrac**, provide **videos explaining the key physics**, and work closely with ResFrac users (McClure et al., 2021). All stakeholders should know exactly what ResFrac does and why: what was the thought-process for that modeling decision? Why did that happen in the simulation? These topics generate a lot of discussion and critical thinking, and that's the point! We constantly reevaluate ResFrac's performance and make tweaks as needed.

We recently developed a new 'A to Z Guide' to ResFrac. It's built on our own internal 'best practices' guide for consulting projects. It provides nuggets on the modeling process, communication, structuring 'checkpoint' meetings along the way, and how to interpret and use simulation results. It also provides detailed, step-by-step advice on how to perform different workflows and optimizations. The goal is to not only deliver the technology of the simulator, but also to help facilitate its use in a workflow that maximizes the value that it brings to operators.

By integrating a 'true' hydraulic fracturing simulator with a reservoir simulator, we've built a technology that is a step-change improvement in physical realism.

The simulator's technical approach prioritizes integration of all the key physics (McClure et al., 2020; McClure et al., 2021). Conventionally, hydraulic fracturing simulators and reservoir simulators have been separate pieces of software. This legacy approach has severe limitations for simulating most of the subsurface processes that dominate the present and future of the industry in shale. Consider processes such as frac hits, or EOR. They involve multiphase flow within fractures, fracture reopening and stress shadowing, proppant remobilization, chemical damage from frac hits, complex compositional processes in EOR, among others. All of these processes occur simultaneously and interact. It is impossible to simulate them realistically if you only include some of the relevant physics.

We model 'hydraulic fractures' as 'hydraulic fractures!' That might sound obvious, but there are several simulators that market themselves as combined fracturing and reservoir simulators, but that are actually just conventional geomechanics reservoir simulators that mimic cracks as slabs of high permeability rock. They tout how fast they are. But if you don't have the right physics, what's the point in quickly arriving at the wrong answer?

Our **2019 Diagnostic Fracture Injection Testing (DFIT) Industry Study** is an example of the value of integrated physics. Conventionally, DFITs had been modeled with separate 'preclosure' and 'postclosure' calculations. Turns out, this approach misses key aspects of the physics, and leads to systematic inaccuracies. This has substantial practical impact on operator decision-making and economics (McClure et al., 2019; Fowler et al., 2019). By continuously simulating the before, during, and after-closure behavior, we were able to develop key improvements to the interpretation procedure. The modeling predictions have been confirmed by subsequent field data collection (McClure, 2020; McClure et al., 2021).

This month, we are launching our second collaborative industry study, focused on mitigating parent/child challenges. The study includes ten different field-scale datasets from seven different operators.

We are driven every day by our mission to accelerate the process of continuous improvement. We help operators synthesize information, make changes, and explore options. By integrating a 'true' hydraulic fracturing simulator with a reservoir simulator, we've built a technology that is a step-change improvement in physical realism. But just as importantly, we focus on bringing the right mindset to the industry – working collaboratively, constantly reevaluating our assumptions, and helping operators synthesize information and think critically. We believe that innovation is driven by applying the right approach with the right technology.

REFERENCES

Bommer, P., Iriarte, J., Bayne, M. et al. 2020. Leveraging Cloud-Based Analytics in Active Well Defense Projects and Automated Pressure Response Analyses. Paper presented at the SPE Hydraulic Fracturing Technology Conference and Exhibition, The Woodlands, Texas, USA, 4-6 February. SPE-199735-MS. https://doi.org/10.2118/199735-MS.

Fowler, G., McClure, M., and Cipolla, C. 2019 A Utica Case Study: The Impact of Permeability Estimates on History Matching, Fracture Length, and Well Spacing. Paper presented at the SPE Annual Technical Conference and Exhibition, Calgary, Alberta, Canada, 30 September. SPE-195980-MS. https://doi.org/10.2118/195980-MS.

Fowler, G., McClure, M., and Cipolla, C. 2020. Making Sense Out of a Complicated Parent/Child Well Dataset: A Bakken Case Study. SPE Annual Technical Conference and Exhibition, Virtual, 26-29 October. SPE-201566. https://doi.org/10.2118/201566-MS.

McClure, M., Bammidi, V., Cipolla, C., Cramer, D., Martin, L., Savitski, A., Sobernheim, D., and Voller, K. 2019. A Collaborative Study on DFIT Interpretation: Integrating Modeling, Field Data, and Analytical Techniques. Unconventional Resources Technology Conference, Denver, CO, 22-24 July. URTeC-2019-123. https://doi.org/10.15530/urtec-2019-123.

McClure, Mark. 2020. **Another Boulder on the Pile of Evidence Against the Tangent Method of Picking Fracture Closure.** ResFrac Blog Post.

McClure, Mark. Matteo Picone, Garrett Fowler, Dave Ratcliff, Charles Kang, Soma Medam, and Joe Frantz. 2020. **Nuances and Frequently Asked Questions in Field-Scale Hydraulic Fracture Modeling.** SPE-199726-MS. Paper presented at the SPE Hydraulic Fracturing Technology Conference and Exhibition, The Woodlands, TX.

McClure, Mark, Charles Kang, Chris Hewson, and Soma Medam. 2021. **ResFrac Technical Writeup**. arXiv:1804.02092.

McClure, Mark, Garrett Fowler, and Matteo Picone. 2021. Best Practices in DFIT Interpretation: Comparative Analysis of 62 DFITs from Nine Different Shale Plays. Paper SPE-205297-MS presented at the SPE International Hydraulic Fracturing Technology Conference and Exhibition, Muscat, Oman.