Shale Assets: Applying the Right Technology for Improving Results*

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Introduction

The current practice commonly used in shale gas and oil wells is to use very simple tools to position and evaluate wells. This practice follows a statistical approach that accepts a considerable amount of variation in results. With competitive natural-gas pricing, every effort is made to keep costs under control, which precludes applying a more rigorous approach to realizing the value of these assets.

Several alternative approaches have been proposed by interested parties to improve individual well results. The tie-in of petrophysical properties to production results has been elusive, which has made innovation and improving recovery difficult. The unconventional resource is much more complicated than the simplistic models suggest, which, in turn, leads to considerable variation in individual well performance. A review of recent wells in a major U.S. shale play shows that the variation in production results can approach unacceptable levels in terms of risk.

A new model for tackling these plays is proposed. Proactively placing wells to a specific rock property, predetermined to represent the most important characteristic that influences production, can have a significant impact on the ability of individual wells to produce. Using the limited, but focused, data set allows for the optimization of processes throughout the well-construction cycle, thereby impacting the completion process, reducing the risk of a poorly-performing well, and improving asset performance.

This article describes the process by providing field examples and validation mechanisms and explains how integrating the workflow from pre-drill to post-well production logs can have a substantial impact on unconventional asset value.

Current Practice

The unconventional shales discussed here are limited in scope to shale formation that typically have a Brinell hardness of less than 50 (Modeland et al., 2011). These shales are characterized as having relatively high clay contents that significantly impact production. These fields include some of the very well-known U.S. shale plays, such as the Haynesville, Eagle Ford, and Marcellus plays.

Typical practice in these fields is to drill a horizontal well that is positioned against stratigraphy using a simple pattern- recognition approach. Once drilling is finished, a solid completion string is run into the wellbore and cemented in place. The well is then stimulated using a multi-stage stimulation process that is performed using high-pressure pumping equipment. The stages are usually determined by the simple expedient of taking the lateral length and dividing it into equal stages or set length. A predetermined recipe of water, proppant, and some chemicals are then injected into the well to break the formation and improve secondary permeability. The resulting production from this style of operation in the Haynesville is shown in Figure 1.

As can be seen in the scatter plot, regardless of the number of stages stimulated by this process, there is a large variation in production results owing to a myriad of factors, many of which are controlled by basin geology and lithofacies. What is apparent is that the large variation in production from well to well implies large inherent commercial risk associated with this type of well.

Alternative Approach

For most of the shale wells drilled today, very little information is collected either during the drilling process or post-drilling. Typically, a simple gamma-ray tool is used for correlation against offset logs to determine stratigraphic position and to aid geosteering. Unfortunately, the gamma-ray tools cannot shed light on important rock characteristics that can have a substantial impact on production, such as clay type, clay content, free-gas content, and porosity. Geomechanical properties, such as Young's Modulus and Poisson's Ratio are not measured, and these properties have a direct bearing on successful stimulation and production (Figure 2). Near-wellbore brittleness is derived from the geomechanical properties (Rickman et al., 2008) and is a major controller of individual-stage-stimulation success.

A method of geosteering wells according to the geomechanical properties of the formations encountered while drilling has already been developed (Market et al., 2010) and refined (Pitcher et al., 2011), based on acoustic measurements made in real time while drilling. The concept of brittleness has also been extended to incorporate sonic anisotropy as a result of the layering effect that also impacts successful stimulation (Buller, Hughes, et al., 2010). This provides a simple index that is used to determine the suitability of the formation for stimulation, known as a Frac Index. The Frac Index has been demonstrated to be effective in assisting well-placement geologists in determining if the well is in a suitable position in the stratigraphy for stimulation, rather than relying on correlation with offset logs that do not represent the area because of lateral heterogeneity (Buller, Hughes, et al., 2010).

While using an approach that requires a higher cost in terms of well construction, the production advantages that accrue as a result of placing the well in better rock from a stimulation standpoint offset the increased costs with higher returns on production. An example comparing two wells of similar construction and stimulation costs is shown in Figure 3.

Integrated Approach

Acquiring petrophysical and geological data in real time and using it appropriately has a direct impact on the production of fluids from these types of wells. Given this type of data, completion and stimulation teams would then have the ability to effect a change in their respective programs geared towards deriving better value from those operations.

Taking the Haynesville well B from Figure 3 as an example, completion engineers have an along-wellbore map of the rock mechanical properties. This allows for a design philosophy change, promoting the concept of isolating zone of similar properties for stimulation. Instead of a simplistic, equally-spaced isolation model, the data allows for design changes as depicted in Figure 4.

This technique is already being trialed using data acquired from cased-hole logs, but if the data is acquired as part of a well-placement program, the integration drives better value from the evaluation program.

The next part of the integrated approach is to begin to change the stimulation design according to the mapped rock properties. This design change is achieved empirically by using different formulations and proppant characteristics (Figure 5) and was originally proposed by Rickman et al. (2008) for categorizing the differences between shale basins, but it has distinct application in considering the most appropriate stimulation treatment for different rock properties encountered along a horizontal well path.

Brittleness of shale has an impact on proppant embedment and maintaining fracture connectivity to the wellbore. This relationship is such that clay-rich lithologies with low Young's Modulus and, by extension, low brittleness index and Frac Index, require larger proppant sizes to maintain effective fracture communication with the wellbore (Figure 6). Conversely, with more brittle sections, a finer proppant is more suitable to maintain connectivity (Figure 7).

Conclusions

The current practice of not taking the changing rock properties along the well path into consideration at any stage of the well-construction life cycle is having a major impact on the potential of these assets to produce over the long term. By using appropriate measurements, an individual well can be better placed in productive lithologies that are best suited to the completion and stimulation process. The data acquired has longevity beyond simply drilling the well. By using that data to better complete and stimulate the well, the cost of the data acquisition becomes minor in terms of the value derived from the data. Decisions on stimulation design, on a per stage basis, become critical to gain the maximum value out of the stimulation process, and those decisions need to be based on appropriate data. Integrating the workflow, from data acquisition, through completion, stimulation and ultimately production, helps to deliver real value to unconventional shale plays.

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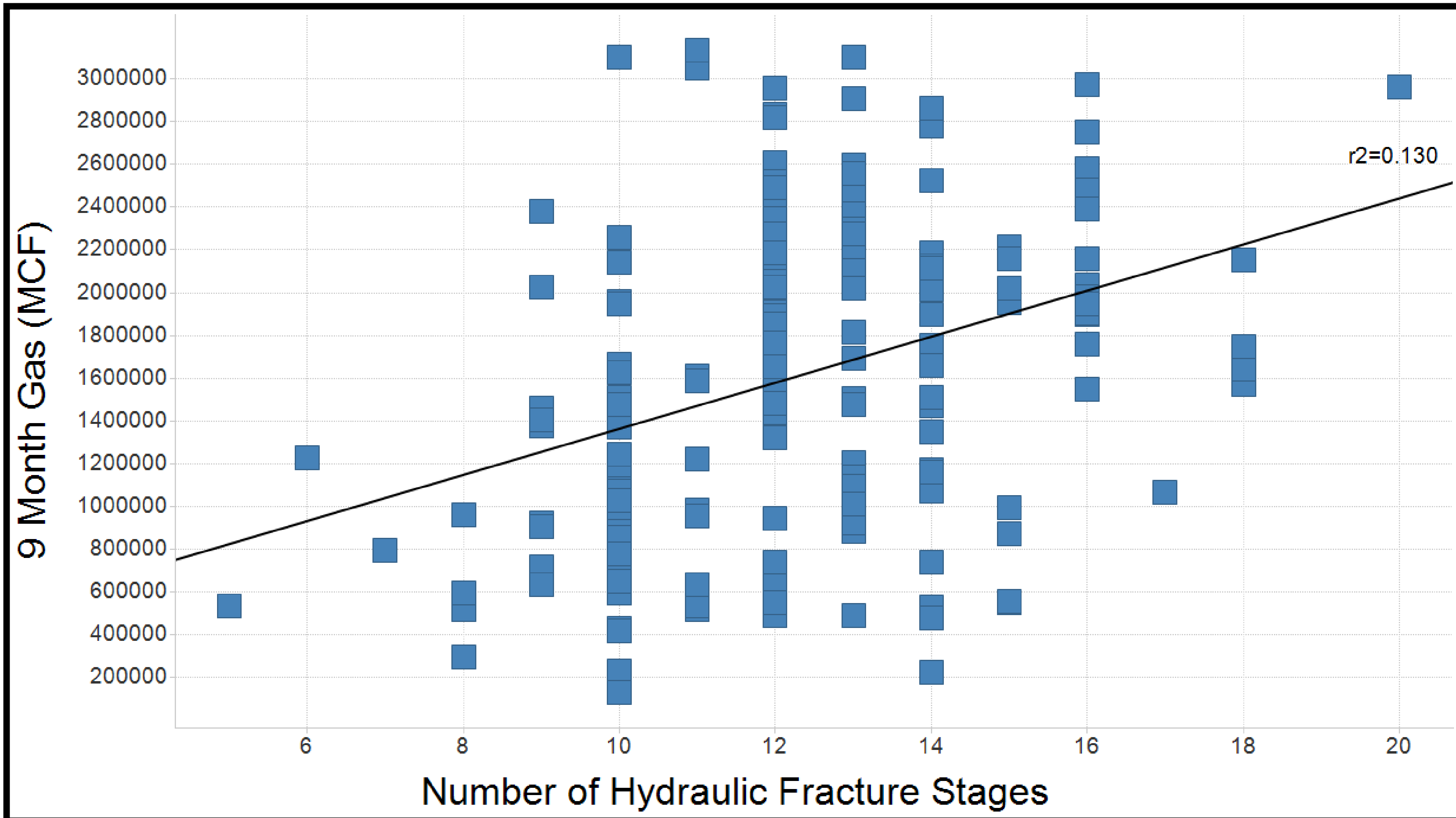


Figure 1. Scatter plot depicting the variability in cumulative production for Haynesville shale wells (from Modeland et al., 2011).

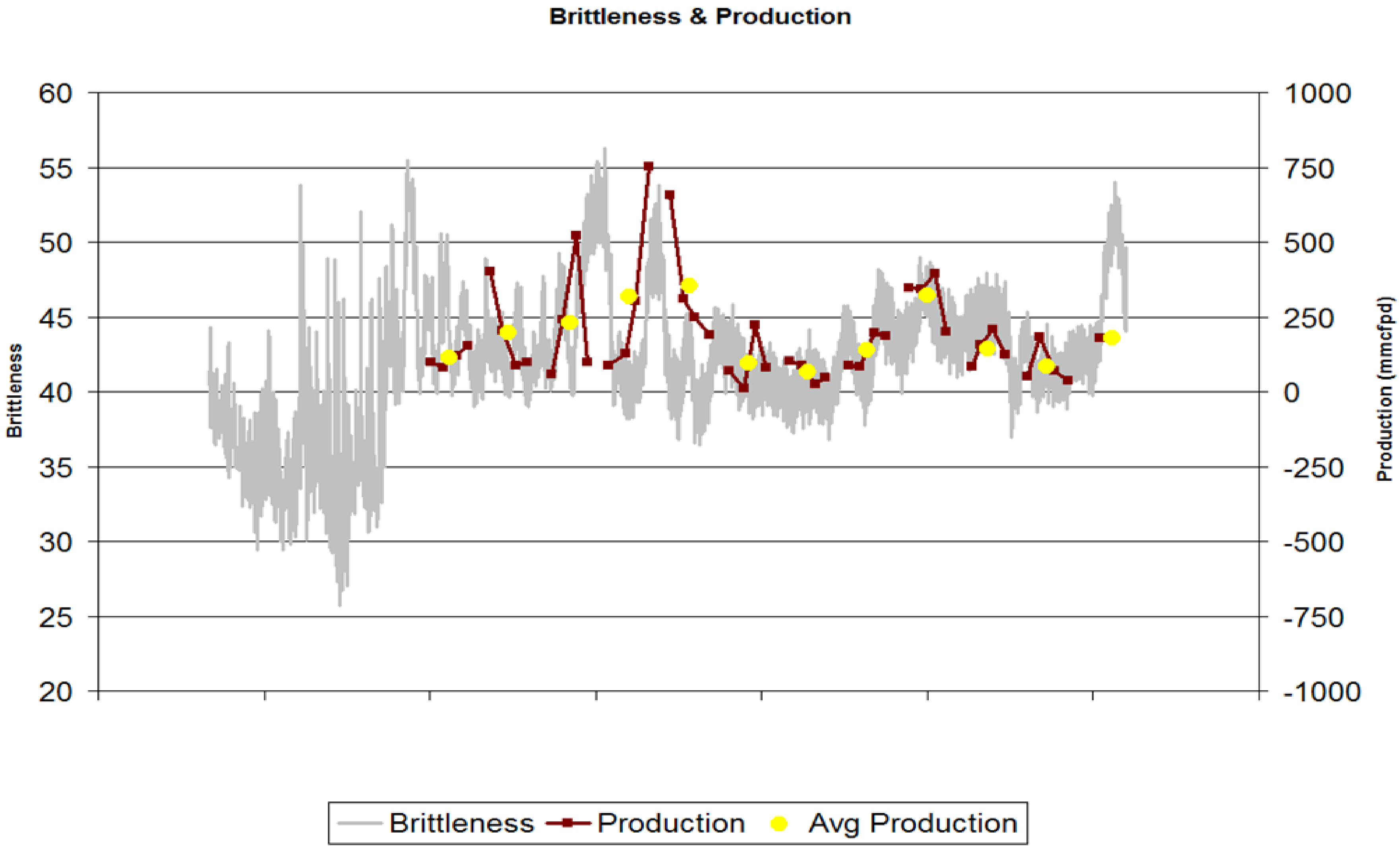
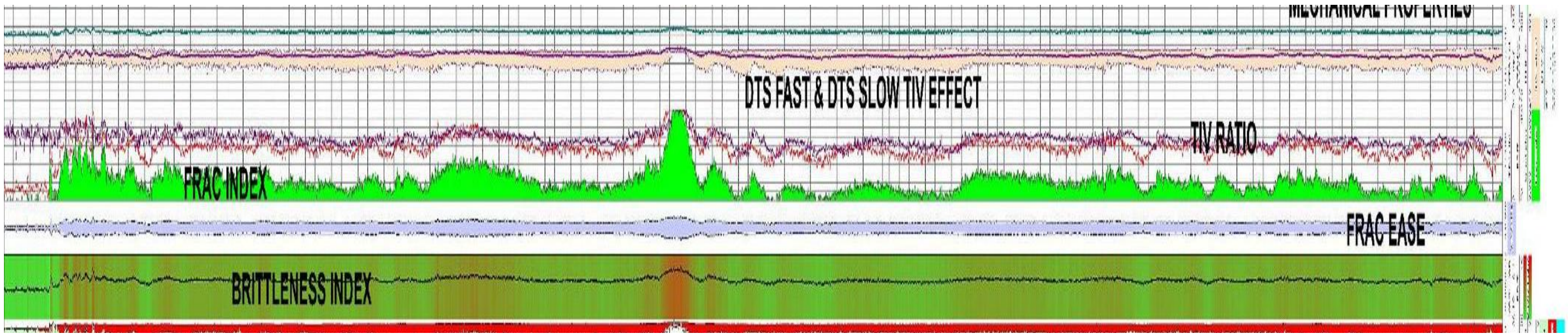


Figure 2. Relationship between near-wellbore brittleness and production (from Buller et al., 2010).

Well A – 9 of 10 Water Fracs Placed – PL rate 8.2 MMCF/D



Well B – 6 of 10 Fracs Placed > 50% – PL rate 4.5 MMCF/D

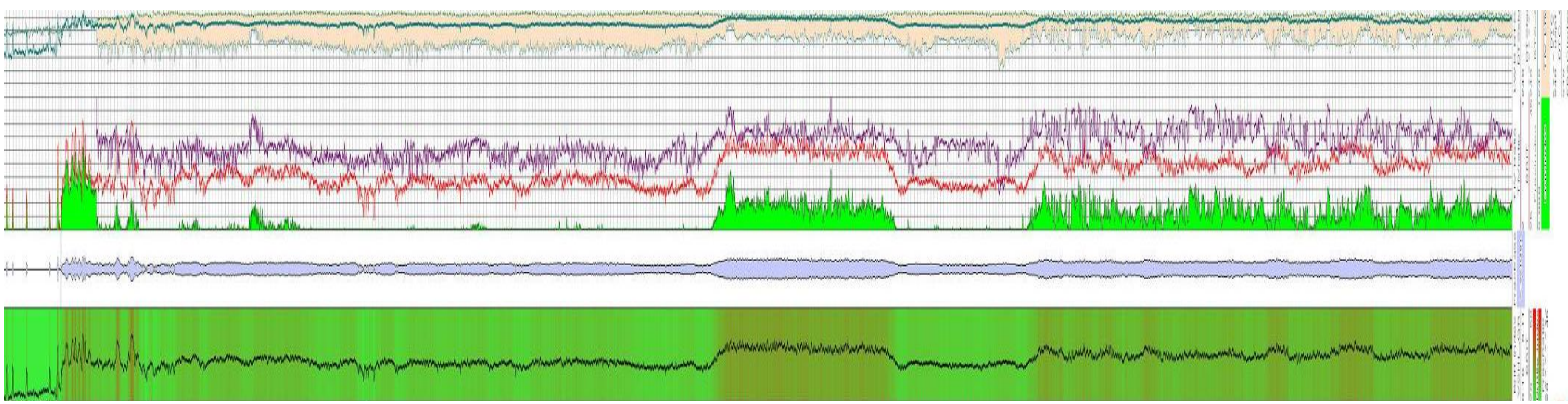


Figure 3. Well comparison with Frac Index and brittleness (after Buller, Hughes, et al., 2010).

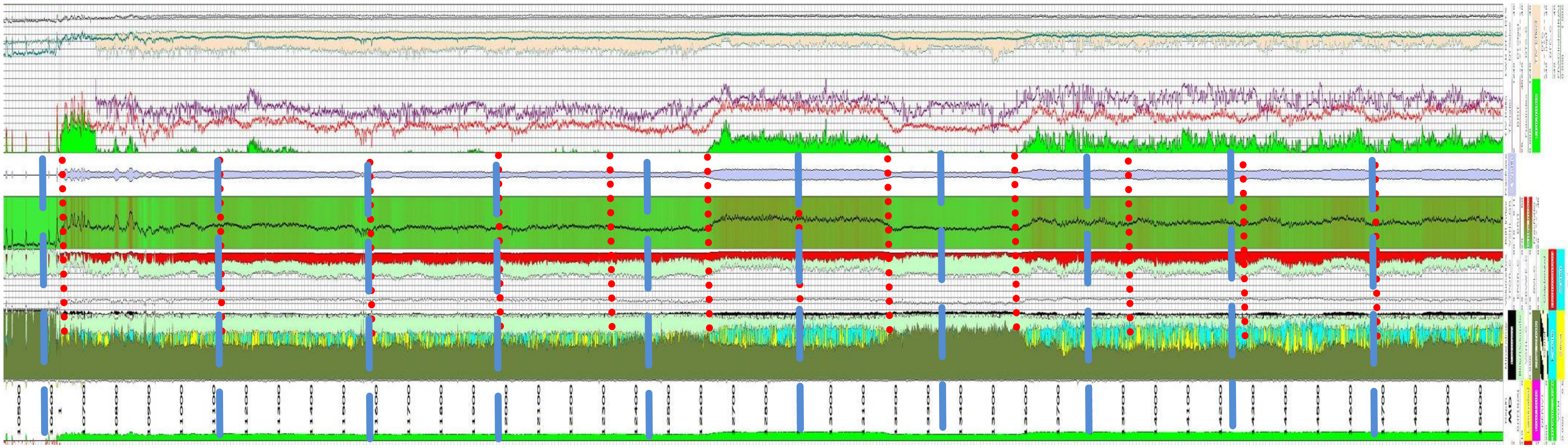


Figure 4. Optimizing completion spacing according to log input data. Blue dashed lines are conventional 10-stage spacings; red-dotted lines are 12 stages targeted at similar properties.

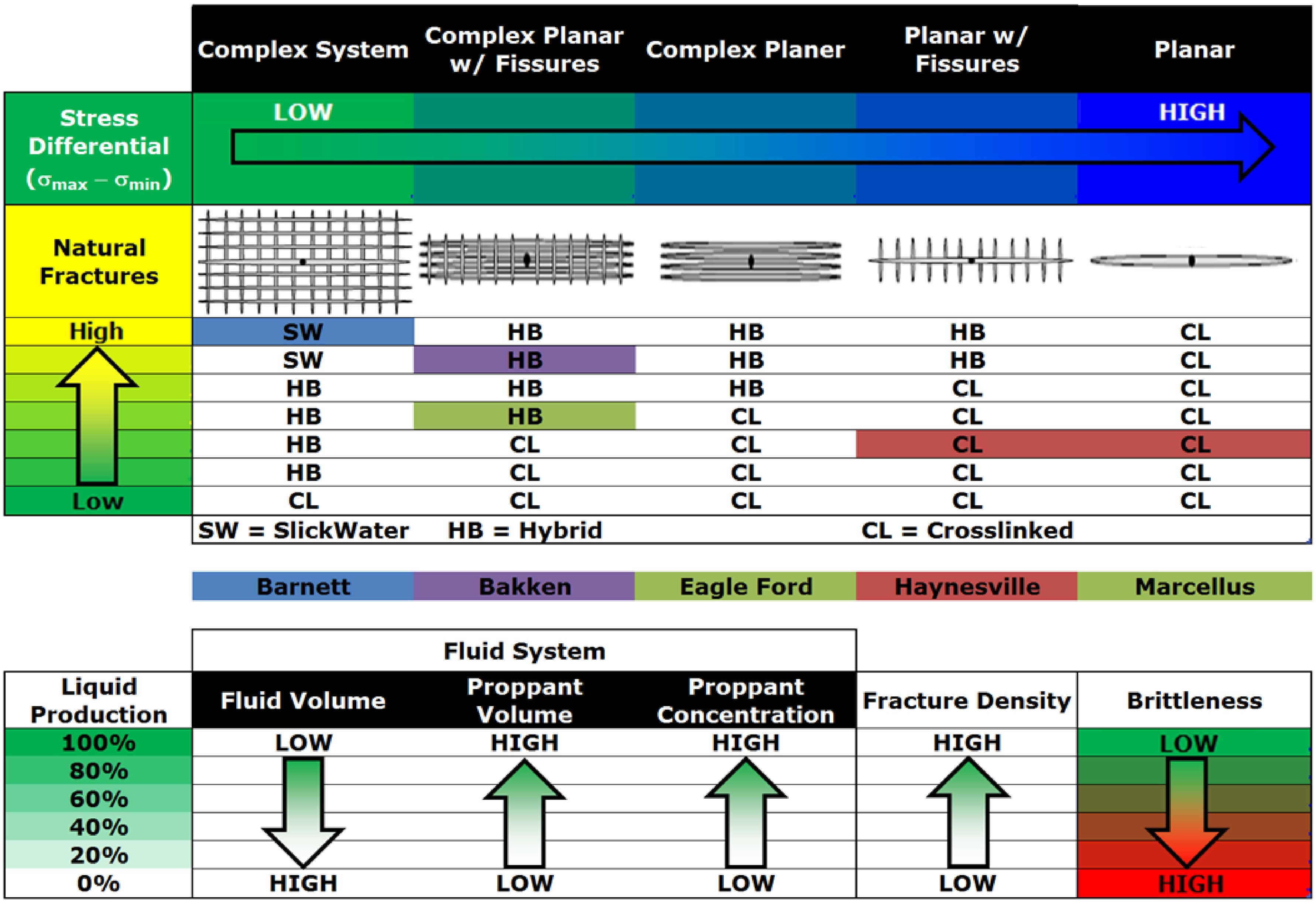


Figure 5. Relationship between stimulation design and rock properties (after Rickman et al., 2008).

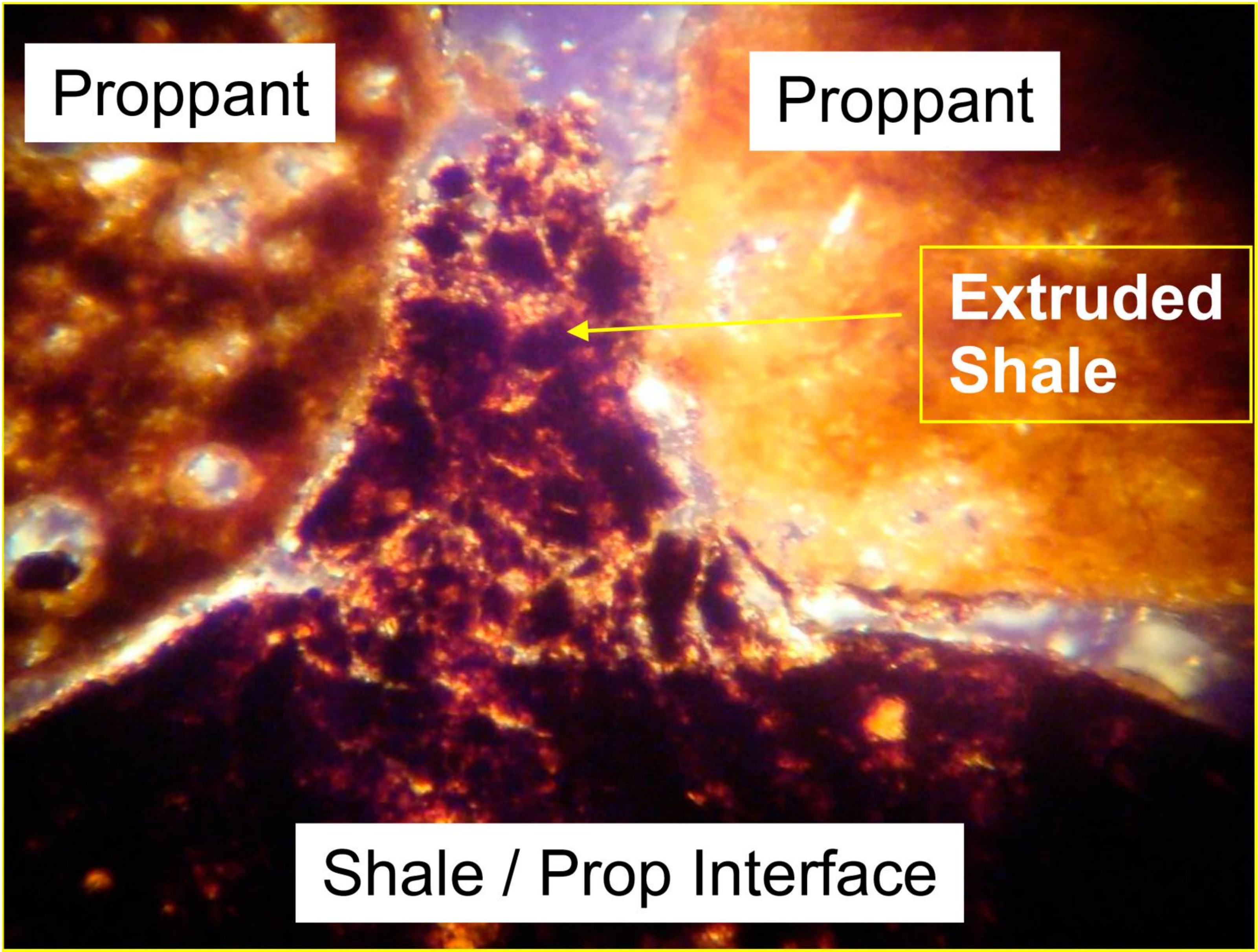


Figure 6. Photomicrograph of proppant grain/shale interface in ductile rock.

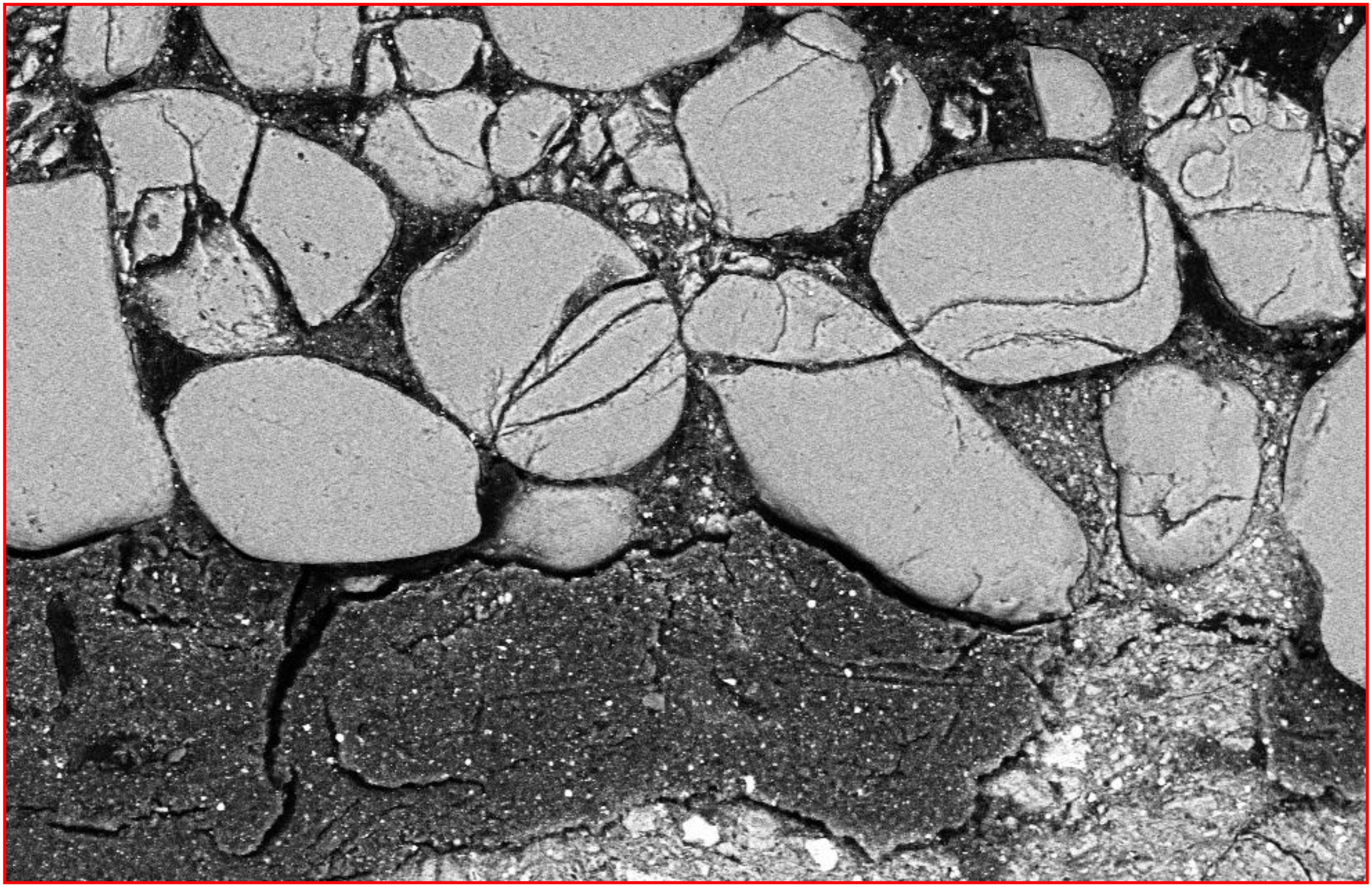


Figure 7. Photomicrograph of proppant grain/shale interface in brittle rock.