# Geomechanics for Unconventionals Series, Vol XII:

## *It's the Rock Fabric, Stupid !*

***By Dr. Neal B. Nagel***

The phrase "It's the economy, stupid" is attributed to the political consultant James Carville during the 1992 United States presidential campaign between George Bush and Bill Clinton. While it is now considered a cliché, the original purpose was to focus the public on the state of the economy as the primary issue in the election. Similarly, "It's the Rock Fabric, Stupid" is my (poor?) attempt to draw attention to what is likely the central issue in completion design and completion optimization in Unconventionals.

What is it that makes Unconventionals, "unconventional"? It can't be the horizontals. We drop horizontal wells in all types of reservoirs now. It can't be hydraulic fracturing. We've had commercial hydraulic fracturing operations since 1949. It can't be the permeability. We produce from very tight sandstones and have done so for several decades. What about natural fractures? Are they the key to Unconventionals? Well, we have produced from large naturally fractured carbonates, like Cantarell and KMZ in Mexico, for decades. These fields are not considered unconventional. So what really is "unconventional" about Unconventionals?

A related issue – and a rabbit hole I do not plan on venturing into – is the use of type-curves for production estimation in Unconventionals. Perhaps the "need" to use type-curves suggests to us why Unconventionals are "unconventional". Ok, so does Darcy's law not work in Unconventionals? No, not that I'm aware of. To my knowledge, the principles of fluid flow in porous media still apply in Unconventionals. If so, then why are type-curves used … and allowed to be used for reporting purposes to governmental agencies? Obviously, type-curves are much easier to develop and use than conventional numerical flow modeling … but when was the last time the government did something or allowed something simply because it was easier? So…clearly something else is going on with Unconventionals.

Let me suggest that, at the core of the issue, what makes Unconventionals "unconventional", and, for example, what drives the industry to use type-curves, is the role and importance of rock fabric. Not the mere existence of rock fabric, but the impact it has on well construction, well completion, and, ultimately, production.

So what is (geomechanical) rock fabric? In many of our early papers on the role of rock fabric in Unconventionals, we used "natural fractures" as a catch-all. Most people understand that rocks have fractures, they are easy to conceptualize and, particularly from a geomechanics standpoint, are easy to model (at least in the abstract). However, several years ago we met with a client working the Eagle Ford and repeatedly used "natural fractures" as a proxy for rock fabric in a presentation. We went on to lose the project and were later told that, since the client did not believe (at the time) that the Eagle Ford had natural fractures, they did not agree with our presentation. So, "rock fabric" it is.

But, again, what is rock fabric? I define geomechanical rock fabric as the variation in mechanical rock properties in a formation. The astute among us might think "Ah-ha, you are supporting Brittleness!". Well….not exactly. Rock fabric does encompass variations in the matrix elastic properties of the rock – but it is so much more! Rock fabric includes variations in rock strength (which, likely, dominates the impact of rock fabric in Unconventionals) as well as any deformational behavior including plasticity and creep (time-dependent plasticity). So "rock fabric" does incorporate elastic behavior (Brittleness) but the (purely) elastic behavior of the formations in Unconventionals has, most often, a second order – and largely trivial – impact on completions and production.

## ***Rock Fabric – The Good, The Bad, and The Ugly***[1]

So "rock fabric" represents the spatial variation (i.e., not just vertically, by layer, but also laterally within a given rock formation) of the behavioral properties of rock, especially the variation in strength and potential for time-dependent deformation. Natural fractures, bedding planes, and laminations are clear features reflecting rock fabric since these are more readily associated with changes in rock strength and deformation properties. Layering would also be considered an obvious potential indicator of rock fabric.

The goal or point of evaluating rock fabric – which should be part and parcel of a reservoir characterization effort – is to evaluate those rock behavioral variations that impact well

[1] *Hat tip to the spaghetti western aficionados who know the source of this title.*

construction, well completion, and production operations. Note that stress variations, pressure variations, and geometrical issues also play a major role in the behavior response of the formation, but these are issues for a separate discussion.

A critical point about rock fabric is that, unlike in the typical conventional oil and gas play, the impact of rock fabric for Unconventionals is neither solely limited to matrix rock properties nor dominated by these properties. Rather, for Unconventionals rock fabric is dominated by the weak strength features (e.g., natural fractures, bedding and laminations) and, often to a lesser degree, the time-dependent behavior of the rock. This is, often, why the most common definitions of Brittleness (and with upwards of 40 or more published equations for Brittleness, Brittleness itself is a moving target) fail to fulfill their purpose; that is, they focus on the matrix properties of the formation, which, again, are typically second order effects to well construction, completions, and production efforts in Unconventionals. This is also why a core-based or log-based evaluation of rock matrix behavioral features (e.g., core-based Young's modulus, Poisson's ratio and UCS evaluations) often fails to materially impact decisions regarding well construction, completions or production operations.

The evaluation of the role of rock fabric must include both the potentially positive as well as negative impacts it may have. Years ago, when making a presentation to an overseas client about Unconventionals and the role of rock fabric (at the time, "natural fractures"), someone in the group postulated that rock fabric was unimportant and that well production could be fully explained by using the matrix perms and hydraulic fracture dimensions (as well as reservoir pressure and the rest that were not part of the discussion). About the same time, I attended a conference at which the late Michael Economides commented that he, too, could match well production by changing hydraulic fracture dimensions (implying he did not need rock fabric to match production). Perhaps in some cases this is true, but in the majority of Unconventionals this is not the case.

I have long thought that a necessary part of a pilot well evaluation for Unconventionals is to evaluate the potentially positive impact of rock fabric on production. Just as would be done in a Conventional play, a production history match would be conducted based upon the best available data (with uncertainties) in order to not only make future production and reserves predictions but also to highlight, in for example a tornado diagram, the contribution and impact of uncertainty of various parameters on production. The history match would include the best available data on, for example, matric perms and pumped hydraulic fracture dimensions rather than use these as history matching parameters. In this way, the impact of rock fabric from actual production could be bracketed. Equally important, if a good-faith effort showed that rock fabric did not contribute much to production, its characterization could be reduced or, conversely, if it was shown to have a potentially significant impact on production this could be factored into both the characterization efforts as well as completion optimization efforts.

This brings us back to a glaring limitation of type-curves. Because they are, essentially, correlation-without-causation, type-curves, by themselves, have no forward modeling (i.e., prediction) capability. With type-curves, even if we wanted to evaluate the contribution of rock fabric (or, for that matter, pressure or porosity or permeability) we could not.

Particularly in the form of open natural fractures, rock fabric can be thought to provide a positive contribution to production via an increase in effective permeability of the formation or through an increase in surface flow area from the matrix (akin to the surface flow area from a hydraulic fracture). Many of the early flow modeling efforts with Unconventionals attempted to evaluate the benefits of rock fabric through an increase in the effective permeability within a drainage volume. These were met with only modest success. However, whether through effective perms or flow surface area, each approach has limitations for forward modeling efforts, and only an effective rock fabric characterization effort will provide the input for forward modeling efforts.

Assuming for a moment that rock fabric does contribute to production, then this must be accounted for in the completion design. Historically, in most hydraulic fracture designs rock fabric (i.e., natural fractures) were viewed negatively. When rock fabric was present, efforts were focused on plugging these (often with 100 mesh sand) in order to reduce fluid leakoff from the hydraulic fracture thereby promoting an increase in the dimensions of the hydraulic fracture and a corresponding increase in the flow area for the hydraulic fracture for hydrocarbon production. However, if the rock fabric does contribute to production, then a goal of the stimulation has to be to not only retain access to the rock fabric (i.e., not plug it off with 100 mesh) but perhaps stimulate the rock fabric by increasing the surface area and/or maintaining access to this surface area with proppant.

At least as partial confirmatory evidence that the industry has not understood, or at least not embraced, the benefit of rock fabric on production is the current trends in increased production with reducing cluster spacing, increasing fluid volumes and increase sand volumes (seen in nearly every major Unconventional play). This observation, after 20 years of the development of Unconventionals, is directly attributable to the inability to characterize and forward model the main contributors to production in Unconventionals (often driven by rock fabric).

While rock fabric has clearly been shown to increase production, unfortunately rock fabric also has a dark side. Rock fabric can wreak havoc on hydraulic fracture propagation, ultimately impacting our ability to develop and stimulate a drainage volume.

Since the early hydraulic fracture research and modeling, the influence of stress and rock fabric have been acknowledged. It is well understood that hydraulic fracture length growth is related to hydraulic fracture height growth and, where height growth is restricted – largely due to a higher stress in an overlying formation – hydraulic fracture length is enhanced. Likewise the impact of Young's modulus on fracture width (and growth) and the impact of fracture toughness on fracture net pressure have been widely understood. Unfortunately, while rock fabric varies spatially in three dimensions, it was simplified and homogenized in the early hydraulic fracture simulators. Rock fabric, via only elastic Young's modulus and fracture toughness, was allowed to vary only by vertical layers and assumed to be laterally homogeneous from the perforations. Furthermore, natural fractures, bedding planes and laminations – central to production from Unconventionals – were largely, if not completely, ignored. As a result, the early hydraulic fracture models showed that, except in extreme cases, hydraulic fracture propagation was dominated by the stress field and rock fabric was, at best, a second order effect.

Particularly with the work, for example, of Stanford researchers Renshaw and Pollard in the mid-1990s, a more complete picture of the impact of rock fabric on hydraulic fracture propagation developed. As Renshaw and Pollard showed, based upon a very simple laboratory setup, rock fabric (in this case an actual rock fracture) could completely prevent fracture propagation, hold-up propagation with an offset, or have no impact at all on fracture propagation simply as a function of the stress field and frictional properties along the fracture. This work, as well as the subsequent work on the impact of rock fabric on hydraulic fracture propagation by a number of researchers over the last decade, conclusively shows the potential negative impacts of rock fabric on fracture propagation and, largely, has been the driver for the new generation of hydraulic fracture simulation tools allowing for the forward modeling of hydraulic fracturing in the presence of rock fabric. But….

While rock fabric can be the dominant factor in fracture propagation in Unconventionals – as opposed to the Conventional hydraulic fracturing paradigm where stress dominates fracture propagation - the proper characterization of rock fabric is not trivial. Not only is the geometry (including the aperture of open fabric) of the rock fabric necessary – via a discrete fracture network (DFN), for example – but the mechanical properties of the fabric is needed including, for example, the strength properties of the natural fractures (both open and cemented), bedding planes, and laminations, the stiffness properties of the open natural fractures (to evaluation flow as natural fracture aperture changes), and deformation properties, potentially over multiple scales and as a function of time.

This challenge, coupled with the cost challenges in Unconventionals (imposed directly by commodity prices and indirectly by a desire to move towards factory-type operations), has resulted in limited field efforts to effectively evaluate the complete role that rock fabric plays in hydrocarbon production from Unconventionals and led the industry to largely ignore the new hydraulic fracture simulation tools, except in pilot or experimental efforts. Nonetheless, the challenges in Unconventionals attributable to rock fabric will not go away.

And the challenges posed by rock fabric in Unconventionals are expanding. Rock fabric plays a significant role in the evaluation and mitigation of casing deformations and failure in Unconventionals. Rock fabric also likely plays a significant role in understanding and preventing frac hits. Furthermore, rock fabric impacts the evaluation and mitigation of potential seismic events. Finally, just as rock fabric can impact completion design from a single lateral, this impact is potentially greatly expanded in stack and/or cube developments.

***Summary***

Here I have attempted to define rock fabric as well as illustrate its importance to Unconventionals, at least in a qualitative sense. The good news is that there are increasing developments in the tools, techniques and procedures to evaluate rock fabric. In addition, the models and simulators required to capture the physics involved with rock fabric behavior also continue to advance.

## See all the articles in the OFG "Geomechanics for Unconventionals Series":

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V. *"Stress Shadows Explained: What It Is, What It Isn't, And Why You Should Care"*
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IX. *"Completion Engineer for a Day"*
X. *"On The Geomechanics of Refracturing"*
XI. *"Sand Volume per Unit of Lateral Length: Is There a Geomechanical Justification?"*
XII. *"It's the Rock Fabric, Stupid!"*