A RETURN TO QUALITY

THE KEY TO SUCCESS IN SHALE'S NEXT CYCLE

Rystad Energy study links proppant type to decreased production and profitability. 85% of operators studied are on track to realize a negative impact in first year of operation.

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The potential impact is not only on investors, short-term economic decisions could affect long-term prospects for energy independence, American jobs, and billions of dollars for investors & mineral rights holders.

Accelerating decline rates in unconventional shale wells has caught everyone's attention. Many theories have been posed such as well spacing, reservoir pressure draw downs etc., but one clear potential cause has been virtually ignored since the hydraulic fracturing revolution began.

Increased gas to oil ratio means increased flaring and wasted resources

Hydraulic fracturing, informally referred to as "fracking," is an oil and gas well development process that typically involves injecting water, sand, and chemicals under high pressure into a shale bedrock formation via the well. Over the past several years, industry observers have recognized well production decline rates are accelerating at a higher rate than ever. The quickening decline rates the industry is seeing have occurred nearly simultaneously with the migration away from higher quality proppants. A proppant is a solid material, typically sand, intended to keep the fracture open, during and following a fracturing treatment, allowing hydrocarbons to flow out of the bedrock and up to the surface.

In a rush to return cash to investors, lower silica content, mixed mineral, angular sands found closer to the basins (known as In-basin-sand) is now being used instead of the proven pure, stronger, and highly rounded quartz sand known as Northern White Sand (NWS) that the shale revolution was built on.

85% OF OPERATORS STUDIED ARE ON TRACK TO REALIZE A NEGATIVE IMPACT IN FIRST YEAR OF OPERATION

The short-term incentive for the switch was understandable since proppant sand cost usually makes up 10% of the completion costs of a horizontal well. High quality NWS is most often railed or barged in to the play. By avoiding the rail or barge costs, operators can save up to $300-$500k per well initially, or around 3-5% (inclusive of drilling costs).

But according to findings in a recent Rystad Energy study, what looked like a good business decision in the near term may have ended up causing significant negative impact on long term outcomes, should well productivity rates continue to decline at the rates we are seeing recently (ref WSJ, Deloitte, McKinsey, Rystad Energy, IHS Markit, etc...$60 bil over 30 years).

WISA Believes that while some may attribute the accelerating declines to phenomena like parent-child relationships (wells drilled near another well), the fundamental

NWS (Northern White Sand) is a very clean, spherical quartz sand, with very high crush resistance.

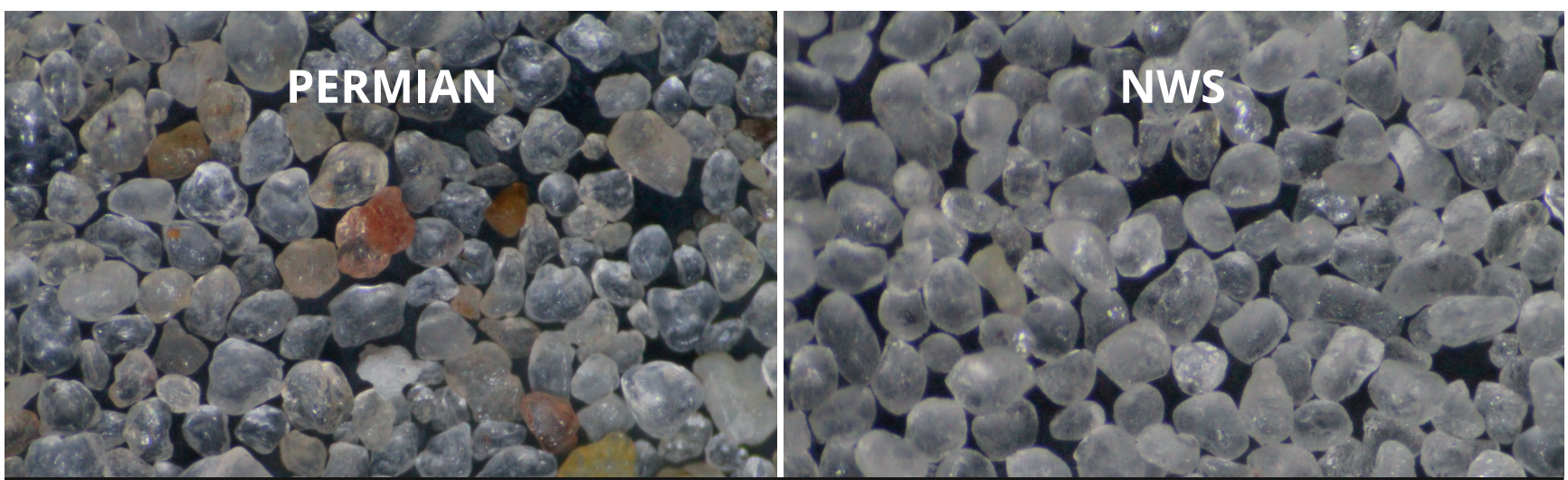
impact that proppants have on hydrocarbon flow and production could be the single most significant factor.

According to the recent Rystad Energy study that examined some 800 wells across 7 operators in the Permian basin, close to 50% of the operators have seen negative economic impact as compared to wells completed with NWS and up to 85% are on the verge, on wells with less than only 1 year of production. That is to say, the upfront savings does not appear to be worth the impact, even in the first year of the well's life.

It's all just sand so, what's the difference?

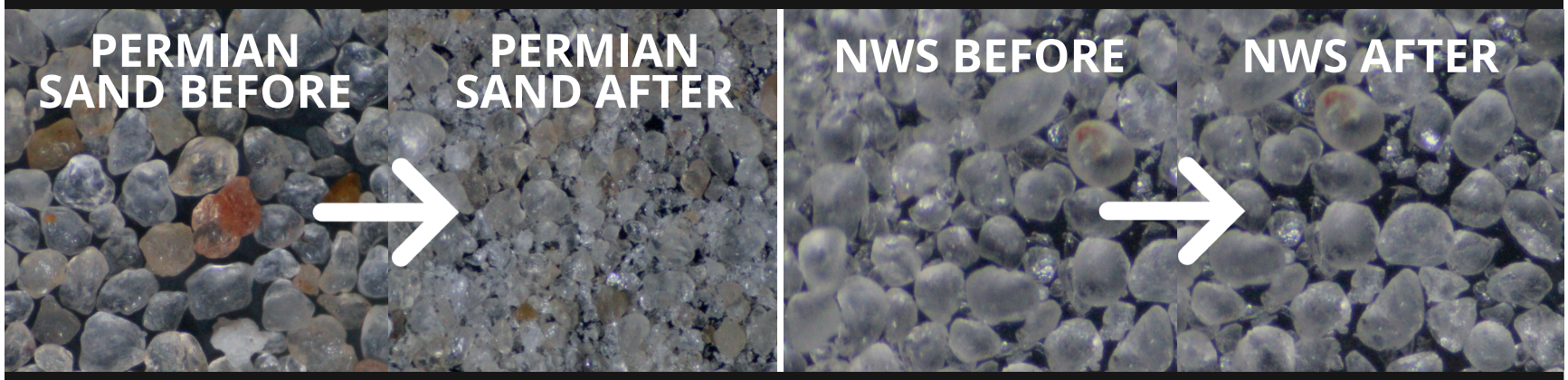
The answer lies in the ability of the material to retain its characteristics when subjected to the extreme operating conditions found deep within the earth's surface. Frac sand is subjected to performance tests to measure at what pressure the grains breakdown beyond a certain point, however this is a five-minute test to indicate product performance over years. As grains break, the spaces between them become occluded or "choked off" with the broken pieces of grain (sometimes referred to as 'fines') which reduces the permeability of the fracture. Hydrocarbons must pass through the proppant in the fracture to make it to the well bore and then the surface. As permeability is reduced over time, flow is impeded. Think about how easy water can flow through a cylinder filled with golf balls versus the flow rate of that same volume of water through a cylinder filled fine, angular gravel.

This seems to be more



Contrast permian sand on the left, and NWS on the right. NWS is very high quality, very pure silica sand.

14 day 6000psi conductivity test images comparing Permian sand to NWS



Permian Sand Before (left) and After 14 day conductivity test (Right). It was reduced to an impermeable powder

NWS before (Left) and after 14 day conductivity test (Right) NWS remains largely intact and permeable

pronounced for oil than for gas, as the added viscosity of the fluid makes it harder to liberate in an environment that has been occluded by fines.

NWS is comprised of nearly pure rounded quartz grains and it has a much longer endurance. it retains its natural permeability significantly longer because of its physical properties.

NWS is very pure, in-basin-sand is typically quite impure, and includes other minerals (clays, feldspars etc). When additional minerals such as these are present in a proppant, the endurance of that proppant is significantly reduced.

Lab testing can measure the ability for fluid to move through a proppant pack. This is often referred to as conductivity (which is a measure of liquid permeability under predetermined stress and temperature conditions). Normal conductivity tests require approximately 50 hours at a given pressure.

Longer term (14 day) 6000psi conductivity testing illustrates that in short order, in-basin sands are reduced from a permeable proppant pack to a nearly impermeable powder.

Grain size plays a role as well.

> IN-BASIN WAS REDUCED TO AN IMPERMEABLE POWDER WHILE NWS REMAINED HIGHLY PERMEABLE

Coarse grain sands allow for more hydrocarbon flow as the spaces between them are larger. Many incorrectly consider a coarse grade 'weak. This stems from a misunderstanding of what is being measured. In fact, a 'fine' from a 30/50 sand is likely still coarser than the coarsest grains in a 100-mesh product. Thus, the coarser material retains a higher level of permeability. (See this article published by Hart Energy in 2019 for more information).

Following this logic, let's look at the change in permeability that has taken place in the shale revolution over the past decade or so (ref IHS Markit Dec 2019 article):

2009-2012 – 20/40 (grain size) NWS, Resin-coated, and Ceramic proppants requiring expensive gels to deliver into the fracture – most expensive but most permeable.

2013-2015 – Migration to NWS 30/50 and 4070 begins, cheaper slick water becomes more dominant and results are virtually the same from a proppant efficiency standpoint.

2015-2016 – Migration to NWS 100 mesh as the theory that more proppant of any type is better.

2017-2018 – Mass adoption begins for In-basin 100 mesh, and increasing proppant intensity. Incidentally, when 40/70 In-basin sand is available, it is often preferred for the higher permeability. This shows certain industry participants acknowledgment that sand grain shape & size matters.

Over 5 years, proppant type (substrate), size, concentration have changed dramatically. If industry observers are saying decline rates have increased over the same 5 years, but proclaim it to everything but proppant type, perhaps they are ignoring a significant variable that has changed, over the same

In-basin sand is typically impure and significantly less permeable, and less durable than NWS.

period.

Unit of measure also matters

It would be a significant error to simply look at production in terms of BOE (barrel of oil equivalent) which measures oil and gas together based on heat content, and not economic value.

As the mesh size has become smaller, the production of gas has increased relative to oil in areas where a movement away from more permeable sand has been widespread.

This has drastically increased the rate of flaring in many plays, and overall profitability. A BOE is measured on a 6:1 basis of gas to oil. This is not an economic comparison as realized gas prices would need to be over $5.00 per MCF at $35 WTI (the spread only widens as WTI increases).

As gas is still just a fraction of that, gas to oil ratio changes impact the overall profitability and cash flow of a shale well from first production. More gas out of an oil well means less revenue.

As the change in ratio of oil to gas also seems to coincide with the reduction in permeability of proppants, it can be surmised that proppant choice is causing the viscus liquid oil to remain trapped while gas is free to flow (A watertight vessel is easier to create than an airtight one).

Consider this: What if your family held the mineral rights to a piece of land that provided royalties on oil or gas production. So far, technology has proven that we can only frac a well up to two times (Re-Frac) without damaging the reservoir. So, you really only get one shot, two at most, to maximize the value. If the well ceases production too early as a result of inferior sand usage, that money could be lost forever. This could mean millions, if not billions of dollars lost (ref IHS Markit) across just the Permian basin, not to mention impact on national security.

Proppant is the only additive during the completions process which is placed in the well with the express purpose of it remaining there after the frac crew leaves. The only job it performs is to enhance production by holding open fractures in the shale. Because of this, the efficiency of that material over the life of the well has to matter.

Like anything in engineering, there is a balance in terms of cost and performance.

The industry pendulum has swung

The change in ratio of oil to gas seems to coincide with the reduction in permeability of proppants. NWS appears to be superior to in-basin sand.

dramatically to the low-cost side while ignoring the impacts to efficiency and production.

The evidence correlates with the data, but are we too busy keeping our heads in the sand to notice?

Consider the impact of a premature end to the shale energy renaissance. The negative impact on GDP, the loss of jobs. The national security issues that occur when we rely on foreign energy have proven to be catastrophic.

Our energy independence became obvious during the Saudi/Iran bombing in 2019. Oil prices did not soar higher like they have in the past.

If companies, mineral rights holders, and all stakeholders are looking for a larger income stream and longer term free cash flows, completing wells in a manner that enables longer-term production is a good thing.

Industry continues to cut costs and that is perfectly understandable. It is also understandable why industry migrated to lower quality sands. According to the Rystad Energy study, initial production does not show much of an impact, whether a well is completed with a higher quality proppant or not. Nobody blames the business leaders for making the best decisions they could with the information they had.

Now that the study has taken a long, deep look at the production data, it indicates that industry professionals should give all completion techniques another look.

The Rystad Energy study should encourage more focus on all variables in individual well engineering including; pressure, permeability, proppant intensity, chemicals, fluid types, and the rock itself. These all have impact on well performance. According to an October 2019 Deloitte Insights article: "our meta-analysis on two of the most prolific shale basins, the Permian and Eagle Ford, highlight opportunities of enhancing O&G recovery (EUR) per unit well cost by 19–23 percent".

With so much at stake and scientific evidence to back it up, analysts, investors, mineral rights holders, and governments should demand data. The Rystad Energy study is not the answer to all the questions, but the correlations of how proppant size and type have changed at a similar rate of the accelerating decline rate cannot be ignored.

The Rystad Energy study should motivate more discussion, more investigation, and more accountability to all stakeholders. The Federal government may want to consider a minimum engineering design standard on all federal lands. If private well owners do not want their wells completed to the highest standards, the tax payers likely do.

Railroads may also want to re-examine their role in helping maintain North American energy independence (perhaps price like grain, rather than the historic frac sand premium). During the switch to greener energy, oil and gas will still be around for quite a while. We should try to make it last as long as we can.

As operators move out of their best acreage and in to more challenging shale, quality will likely become more important than ever. With so much at stake, let's hope industry is not stepping over a dollar to pick up a dime by ignoring data that can help slow production decline and return the shale revolution in to the power house it can be.

Note: The Rystad Energy Study can be found here