OGX Operating, LLC

P.O. Box 2064 • Midland, TX 79702 • (432) 685-1287 • Fax (432) 685-1320 • Fax (432) 686-7109

A Case Study for "Brady Sand"

Steve Douglas, Engineer, OGX Operating

April 22, 2019

OGX Operating, a Midland based E&P company with holdings throughout the Permian Basin was considering the value of utilizing sand from the Hickory Formation (typically known as Brady sand) versus the more expensive Northern White sand from mines located out of state. While determining the economic impact, there was also a very important performance aspect to OGX for the ultimate completion and production from their planned well.

In comparing the different characteristics of both sands, OGX determined that the Brady sand is shown to perform as well or at a minimum, "comparably" in terms of crush values and may perform better than N. White sand in conductivity creating a high level of permeability in the San Andres Rock formation which has low permeability.*(ref. article by Joel Schneyer and **Halliburton) Upon analysis of the Brady sand's proposed, OGX determined that sand from Permian FracSand contained the sphericity, crush and conductivity values to perform the work.

In their PASADENA #1H well, OGX requested bids from a minimum of 3 service companies to perform their hydraulic fracturing job. The well is located in Howard County, TX and was determined to be a San Andres, horizontal frac job that would utilize approximately 3 million pounds of 20/40 mesh sand. Two of the bids proposed supplying Brady sand and at least one bid proposed N. White sand to perform the work. While all bids were competitively priced for the work, there was a major economic difference between the bids proposing Brady sand and those proposing N. White sand. This "major" difference was mostly in the cost of the sand. The N. White sand cost was approximately $122,000 higher than the Brady sand. The cost of the N. White sand was determined to be a combination of a higher price per ton for the sand itself and additional costs of handling and freight from the mine to a transload facility near Midland and finally, re-handling and shipping from the transload facility to the wellsite. (ref. Fig. 1 & 2)

The frac job was successfully performed over a two-day period in January 2019 and completed 17 stages. The lateral was at 3,000ft. TVD for a total of 4,000ft. of lateral.

The intent of the well was to provide good permeability, and this was achieved as a result of the frac job utilizing the Brady Sand. Initial fluid recovery was 3,000 bbls/day for the first 60 days.

Conclusion:

OGX has determined that "Brady Sand" is an economical and technical alternative to N. White sand providing high performance at much lower costs. While this particular well was a relatively small frac job, the economics on a well utilizing only 1,500 tons of sand was considerable enough to make a value impact while maintaining and/or increasing expected performance. As we consider larger frac jobs that may require tens of thousands of tons of sand, we expect the economic savings from using Brady Sand to be impressive and "required use" in our overall cost reduction efforts.

References:

*Why don't sand companies readily provide detailed conductivity test results for each of their mines like Preferred Sand?

- Published on January 21, 2019

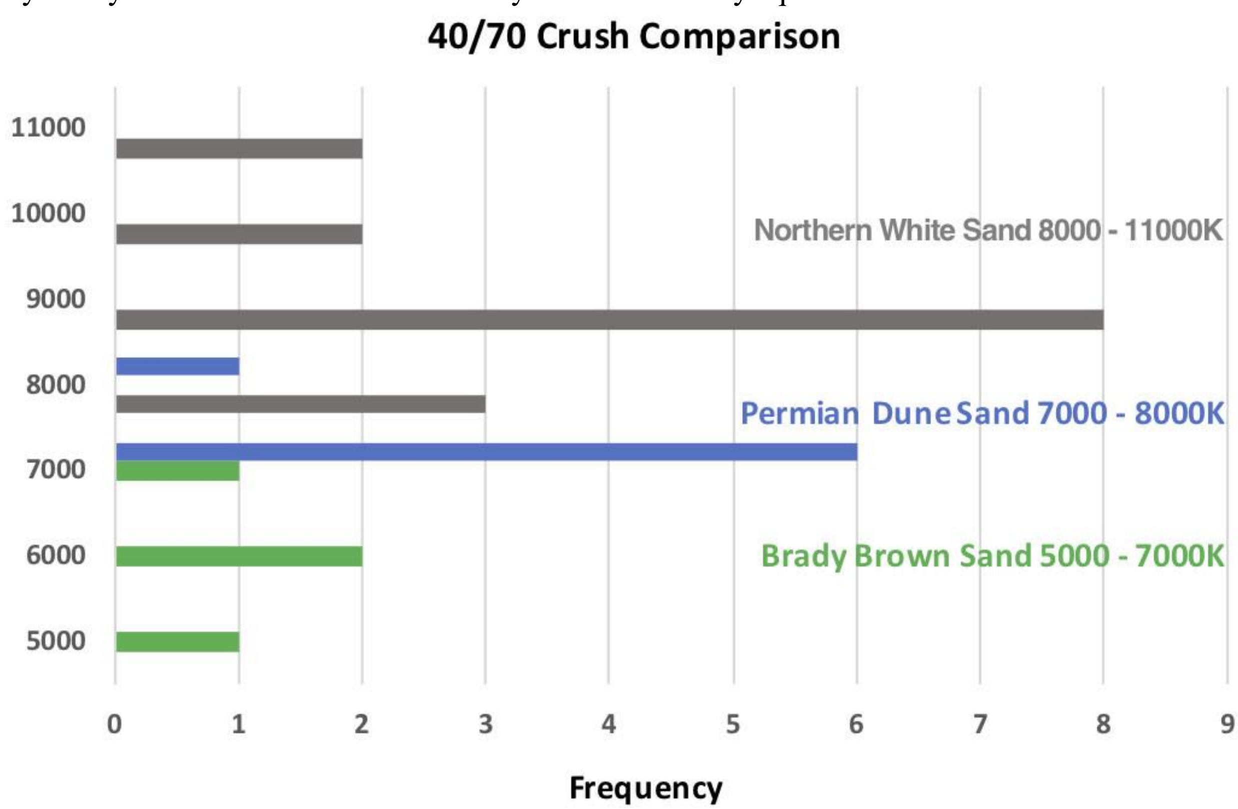
[Joel Schneyer]

Managing Director at Capstone Headwaters

We've all been there, wanting more information so that we can make an informed buying decision. Looking at the package ingredients at the grocery store, reviewing sales comps of a neighborhood before you put an offer on a house, comparing tire tread life before a purchase, or even buying sand. Much, of course, has been written about the latter, with the presumed best sand equating to the highest crush. For instance, in the February 2018 issue of the American Oil & Gas Reporter, it was stated that:

".... Permian sand is closer in color and quality to northern white mined in the Upper Midwest than the traditional Brady brown sand sourced in Texas."

Based on product information we were either able to download from the internet or acquire from sand producers directly, it is clear that in the 40/70 mesh size range, Northern White sand has the highest average reported crush, followed by Permian Dune sand, with the lowest crush exhibited by Brady brown sand. But does crush by itself necessarily equate to "best"?



References:

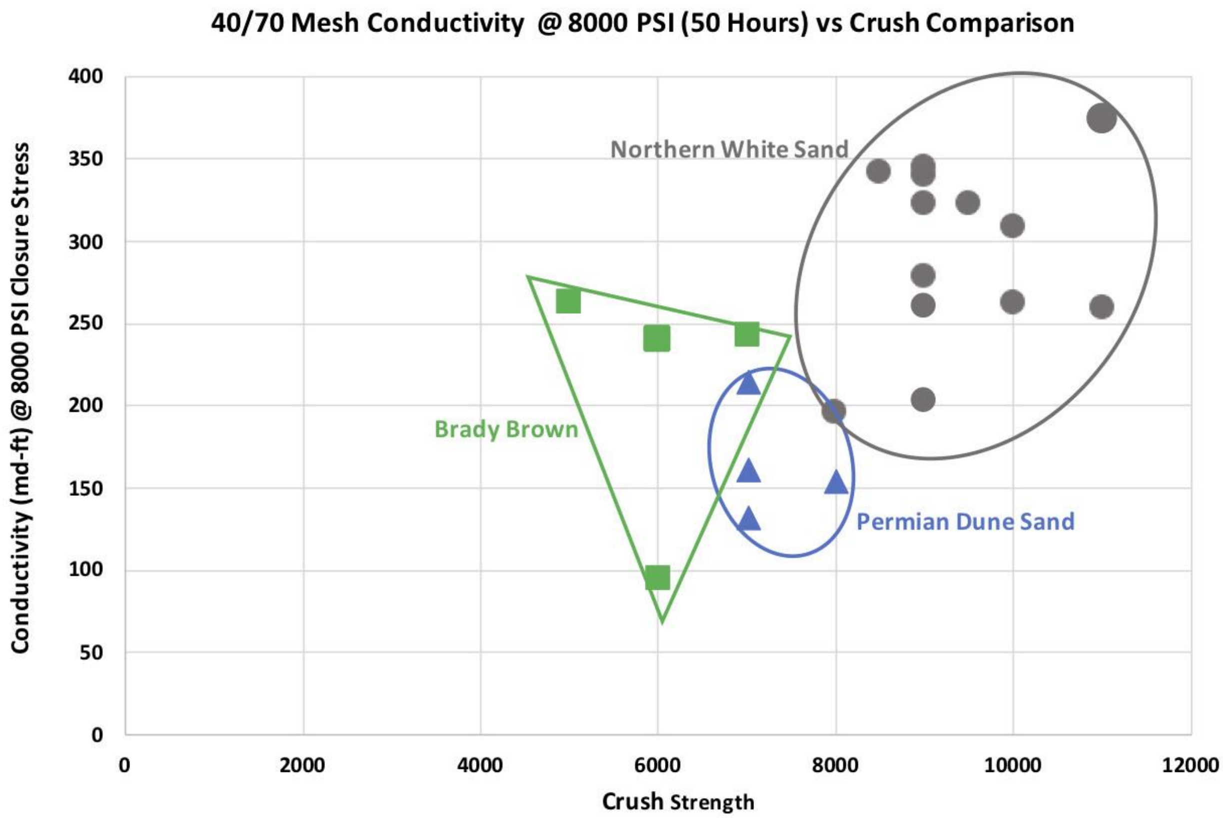
Everything we hear indicates that the "best" proppant in a mesh size range has the highest conductivity. Cross plotting the crush - conductivity "data pairs" in the figure below clearly shows that the average 40/70 Brady brown sand shows lower crush but higher conductivity than Permian Dune sand. Assuming last mile transportation charges being equal, I would buy any of the three Brady brown sands showing 250 md-ft over any of the Permian Dune sands showing higher crush. The fourth Brady brown showing 6000K crush and 100 md-ft, is not of much interest to me. Much like the wine connoisseur seeking to find that rare $10 bottle of French Bordeaux that has a Robert Parker rating of 90 points, there seems to be great differences in the technical specs across all sand groups which should be driving our buying decisions.

Which brings up the next point: the data pairs shown below were the only ones we were able to get. Obviously, there are many more mines selling sand, so why are so few conductivity results published? These are not state secrets after all. Rather it is what makes the product unique and different from the competitors' products. Based on the scatter graph, it is fair to assume that each sand mine has its own unique product signature based on sand provenance, sand size gradation within the deposit, grain distribution after hydrosizing and screening, the processing circuit used, amount of attrition scrubbing, and, of course, the people factor to run the operation correctly.

Yet here we are today; able to drill 10,000 vertical feet with a 8,000 foot horizontal leg driven at a variance of less than 10 feet from a 3-D block projection, but we are often unable to look back at the performance of the well and know with certainty the completion ingredient list. For example, what was the provenance of a 40/70 Northern White sand pumped into a well? Did it come from a mine in Missouri, Arkansas, Illinois, Wisconsin, or Minnesota? It could have had a crush anywhere between 8000 and 11000K and a conductivity between 200 and 370 md-ft @8000 PSI. Why can't buyers (and forensic reservoir engineers advising e&p's and service companies) know exactly what was used downhole? Was the sand co-mingled with lesser quality sand of similar crush in the transload silos or swapped out for sand from some other mine?

Sand producers need to provide more granular information and more transparency. And staying with the wine analogy, those sand producers that produce better vintages (i.e. higher conductivity) should be on the forefront of providing this data. We need better record keeping and more complete reporting to regulatory authorities of the proppant pumped down the wellbore. This is a shout out to Preferred Sand. I strongly suggest that the industry follow their lead in their Preferred Sand Product Guide where the technical product specs of each of the company's sand operations are clearly and proudly shown. Couple these types of disclosures with containerized proppant logistics solutions and blockchain-enabled chain of custody tracking of sand from mine to wellbore. Industry can then make better purchasing decisions to optimize well performance.

References:



40/70 Mesh Conductivity @ 8000 PSI (50 Hours) vs Crush Comparison
Northern White Sand
Brady Brown
Permian Dune Sand
Conductivity (md-ft) @ 8000 PSI Closure Stress
Crush Strength
0
50
100
150
200
250
300
350
400
0
2000
4000
6000
8000
10000
12000

References:

**

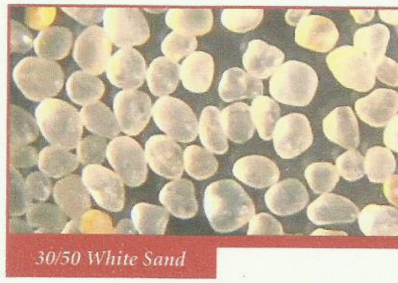
Stimulation

Choosing Fracturing Sand To Optimize Permeability Achieved vs Cost

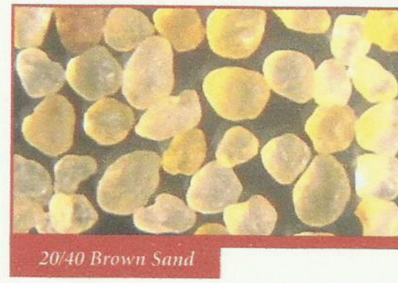
In low-closure-stress environments, brown sand may be a better choice than white sand.


HAL 13373

20/40 White Sand


HAL 13374

30/50 White Sand


HAL 13375

20/40 Brown Sand

Despite the significant amount of discussion and competitive wrangling in today's fracturing market over proppants, the proppants most widely used are the same that were used in the first fracturing treatment in 1947, namely, various types of sand.

Sand used for fracturing is mined from shallow deposits that include ancient river beds, Aeolian dunes and other depositional environments. In general, frac sand is used at net closure stresses below 6,000 psig and manmade proppants used at higher closure stresses. Whatever the proppant, it must adhere to strong rules and requirements as stipulated by the American Petroleum Institute (API).

In the lower closure stress environment (below 6,000 psi) significant differences, advantages and issues need to be considered when designing a propped frac treatment. The net closure stress is calculated by subtracting the producing wellbore pressure from the fracture stress. A safe method that some engineers apply is to simply use the fracture stress as a guideline when designing proppant packages. This approach is based on the idea that the producing pressure may be zero at some time, making the frac stress the upper limit the proppant might encounter.

Ottawa (White) Sand and Brady (Brown) Sand-What's the Difference?

Ottawa and Brady sands represent approximately 90% of the fracturing sand used in the petroleum industry.

Ottawa or White Sand

Ottawa is the general name for fracturing sands mined from deposits found in the northern portion of the United States. "White" and "northern" sands are other names used to identify Ottawa sand. These sands are considered by many to be the highest qualify fracturing sands. They are characterized by high purity, whiteness (although some variations in color do occur), high roundness and sphericity, and lack of dust. Ottawa sands are monocrystalline (single crystal phase) which results in individual grain strength exceeding nearly all other sands.

These sands were formed from quartz grains freed by the erosion of granites in the Canadian shield. The eroded sand grains accumulated on the beaches of an ancient Cambrian Sea where they were repeatedly washed, sifted, sorted and resorted by tides and winds over millions of years, before they were covered and protected from erosion and contamination. This repeated washing and sorting yielded deposits which were particularly suited for use as fracturing sands.

HALLIBURTON

References:

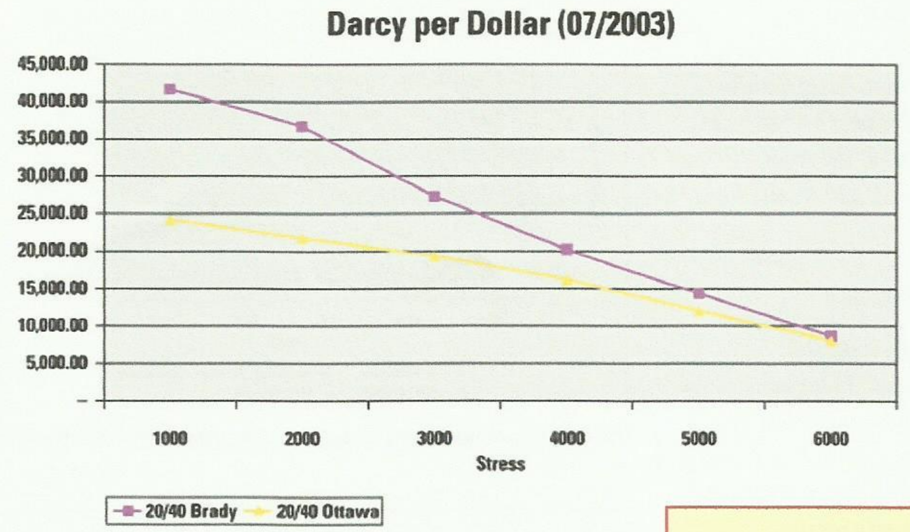


Figure 4 factors in the lower cost of brown sand in today's market. In terms of cost for permeability achieved, brown sand is clearly the better value at closure stresses below about 4,000 psi.

So, in today's market, brown sand should be considered for a fracturing operation with relatively low closure stresses.

All data provided in this brochure was obtained through strict adherence to American Petroleum Institute recommendations. Procedures employed include: "Recommended Practices for Testing of Sands Used in Hydraulic Fracturing Operations," RP-56 as well as recommendations of the API on Evaluation of Well Completions Materials and Measurement of Fracture Conductivity.

Note: High Flow Rates or Multiphase Flow May Indicate the Need for Man-made Proppants

High gas flow rates or different fluid phases in the fracture during production can have the effect of decreasing conductivity. The Forchheimer evaluation of conductivity measurements shows the effect of high flow rates. In very simple terms, beta refers to the inertial effect of gases as they expand and contract when flowing through the tortuous pathways in proppant packs. Stim-Lab's proppant and conductivity consortiums have generated data that show that high rates (near 1,000,000 ft^3/ft of proppant height) and multiphase flow (1 bbl liquid/mcf gas) can greatly reduce conductivity of a proppant pack. White sands will have lower betas than brown sands and present less flow restriction per unit of velocity; however, man-made proppants provide the lowest beta values. If it's determined that multiphase flow or high velocity will decrease the conductivity placed in the fracture in low stress regimes, it may be best to use man-made proppants rather than white fracturing sands.

For more information about optimizing your fracturing results, contact your local Halliburton representative or email stimulation@halliburton.com

www.halliburton.com

Produced by Halliburton Communications

HALLIBURTON

Production Optimization

H03562 9/05

References:

Frac Sand is a Commodity Subject to Market Pressures

Since frac sand is mined and not manufactured, the supply is limited. This causes temporary shortages from time to time based on the simple principles of supply and demand. For that reason, it is important to examine the most common mesh of proppant used today (20/40 mesh) from both white and brown sand.

Permeability Is A Key Factor

Permeability does not enter into the API tests and classifications. Figures 1 and 2* show that, in general, white sand provides higher permeability than brown sand. That is not the case though with 20/40 mesh at low closure stresses. Notice that below about 3,500 psi, the brown sand actually provides better permeability than the white sand.

Figure 3 compares both white and brown sand permeability and focuses on the lower pressure range. Note that brown sand provides essentially the same permeability as white sand all the way to 6,000 psi closure stress.

**Figures 1 and 2 are from the Stim-Lab Proppant Consortium – 2003.*

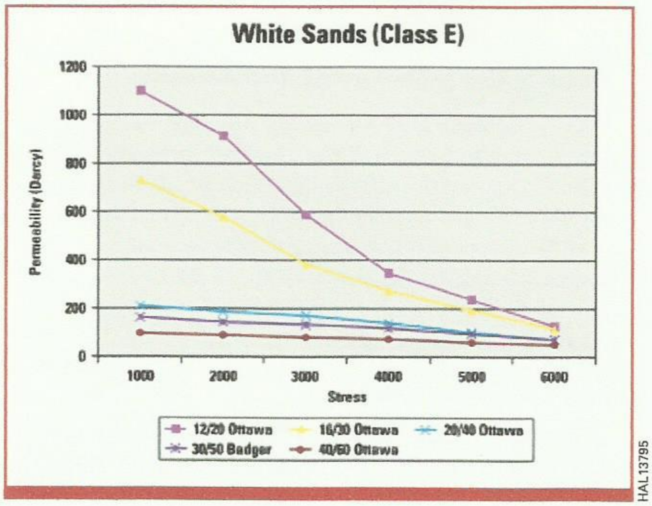


Figure 1

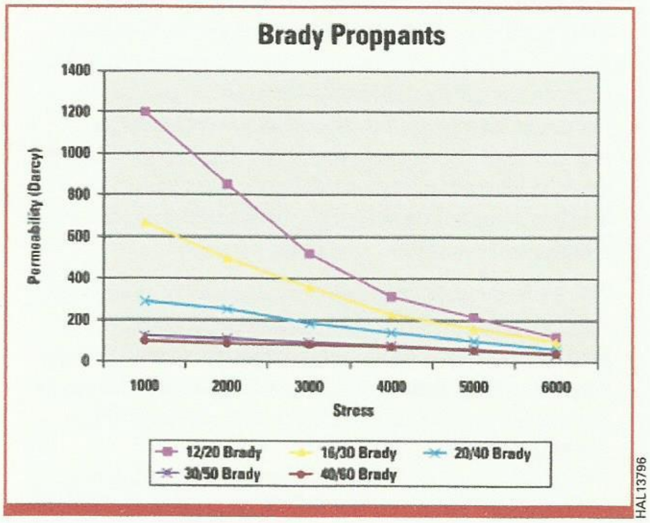


Figure 2

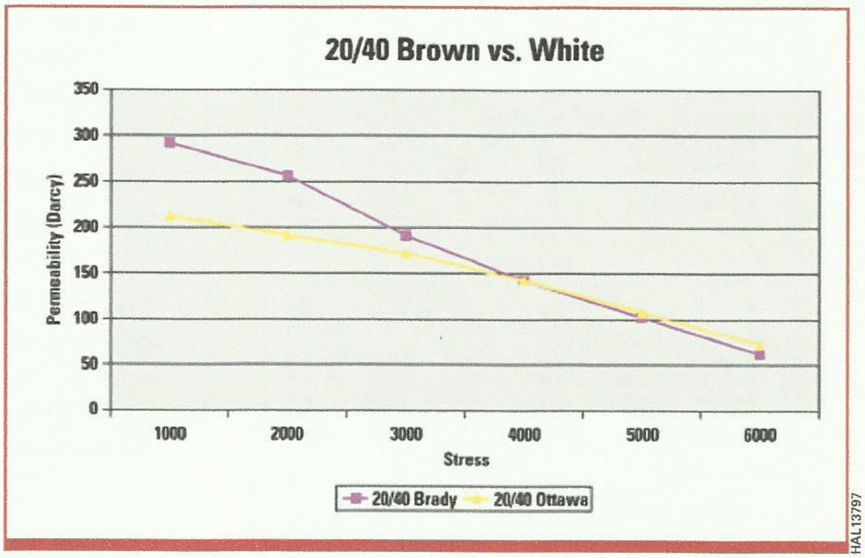


Figure 3

References:

What's the Difference? (continued)

Ottawa sands are mined primarily from the Saint Peter formation near Ottawa, Illinois, and the Jordan formation in south central Minnesota. To a lesser extent, the Galeville and Ironton formations in Wisconsin are used as sources of Ottawa sand. Generally, these formations yield a higher percentage of the smaller mesh sizes, but Ottawa Sands are available in 12/20, 16/30, 20/40 and 40/70 mesh sizes.

Brady or Brown Sand

Brady sand is mined from the Hickory formation which outcrops near Brady, Texas. Brady sand is slightly darker in color than Ottawa sand, hence, the name "brown" sand is often used when referring to Brady sand. Although viewed by some to be of slightly lesser quality than Ottawa sand for high stress applications, Brady sand is considered to be a high quality frac sand which meets or exceeds the API specifications for sands to be used in hydraulic fracturing. Brady sand does tend to be more angular than Ottawa sands, and the deposits themselves contain impurities, such as feldspars and clays, but the sands arc washed thoroughly during processing to create a high purity product.

The Hickory formation contains a variety of sand grain sizes; therefore, a number of mesh sizes is available. In general, larger frac sands are obtained from the Hickory formation than from the northern formations. The most commonly available mesh sizes include 8/16, 12/20, 16/30, and 20/40.

Ottawa Sand

	Mesh Size			
	12/20	16/30	20/40	40/70
Physical Data				
HF Solubility	1.30	0.50	1.20	1.30
Krumbein Roundness	0.80	0.80	0.80	0.80
Sphericity	0.80	0.80	0.80	0.80
Bulk Density (lb/ft3)	96.00	98.60	102.70	102.70
Specific Gravity	2.65	2.65	2.65	2.65
API Crushing Test				
Percent at 2,000 psi	—	—	—	—
Percent at 3,000 psi	2.38	3.95	—	—
Percent at 4,000 psi	—	7.55	1.82	—
Percent at 5,000 psi	—	—	—	2.05

HAL13793

Brady Sand

	Mesh Size			
	8/16	12/20	16/30	20/40
Physical Data				
HF Solubility	0.80	0.90	1.30	1.60
Krumbein Roundness	0.70	0.70	0.80	0.70
Sphericity	0.70	0.80	0.80	0.70
Bulk Density (lb/ft3)	98.00	100.00	101.00	101.50
Specific Gravity	2.65	2.65	2.65	2.65
API Crushing Test				
Percent at 2,000 psi	5.33	—	—	—
Percent at 3,000 psi	—	11.10	3.32	—
Percent at 4,000 psi	—	—	—	11.00

HAL13794

Factors other than stress must be considered when choosing a proppant for a frac treatment.

From the late 1970s through today, the industry started to understand several factors that affect flow through a porous media including proppant packs. These factors, non-Darcy flow and multiphase flow, should be taken into account when choosing a proppant. Simply picking a proppant based on permeability in a given stress environment may not be sufficient. Nevertheless, permeability is a key factor.

Conductivity and Permeability: Which one do I consider?

The answer is both; however, it is important to understand the simple relationship between conductivity and permeability.

Conductivity is defined as the product of the permeability of the proppant pack multiplied by the propped width. Conductivity has a direct effect on deliverability of fluids to the wellbore; however, since conductivity is heavily influenced by propped width (which can be only estimated until after the treatment), most engineers use actual proppant permeability to choose between two proppants. Taking conductivity out of the evaluation 'levels' the playing field so to speak and makes proppant evaluation considerably simpler.

Sand-based Proppants

In today's market, two major classifications of sand are used as proppant in fracturing treatments. These are commonly called "brown" and "white" based on the two sands' primary colors. But, color is not the only difference in these proppants.

API has classified brown sand as a grade "D" sand, meaning it fits certain roundness, acid solubility and other tests criteria that fit the "D" classification.

White sand is also known by more specific names including Ottawa and Jordan as well as names from the suppliers. These are classified as grade "E" sands and provide the highest quality in terms of chemical purity and resistance to crushing at stress.

References:

Fig. 1
Distance between Transload location compared to OGX Wellsite

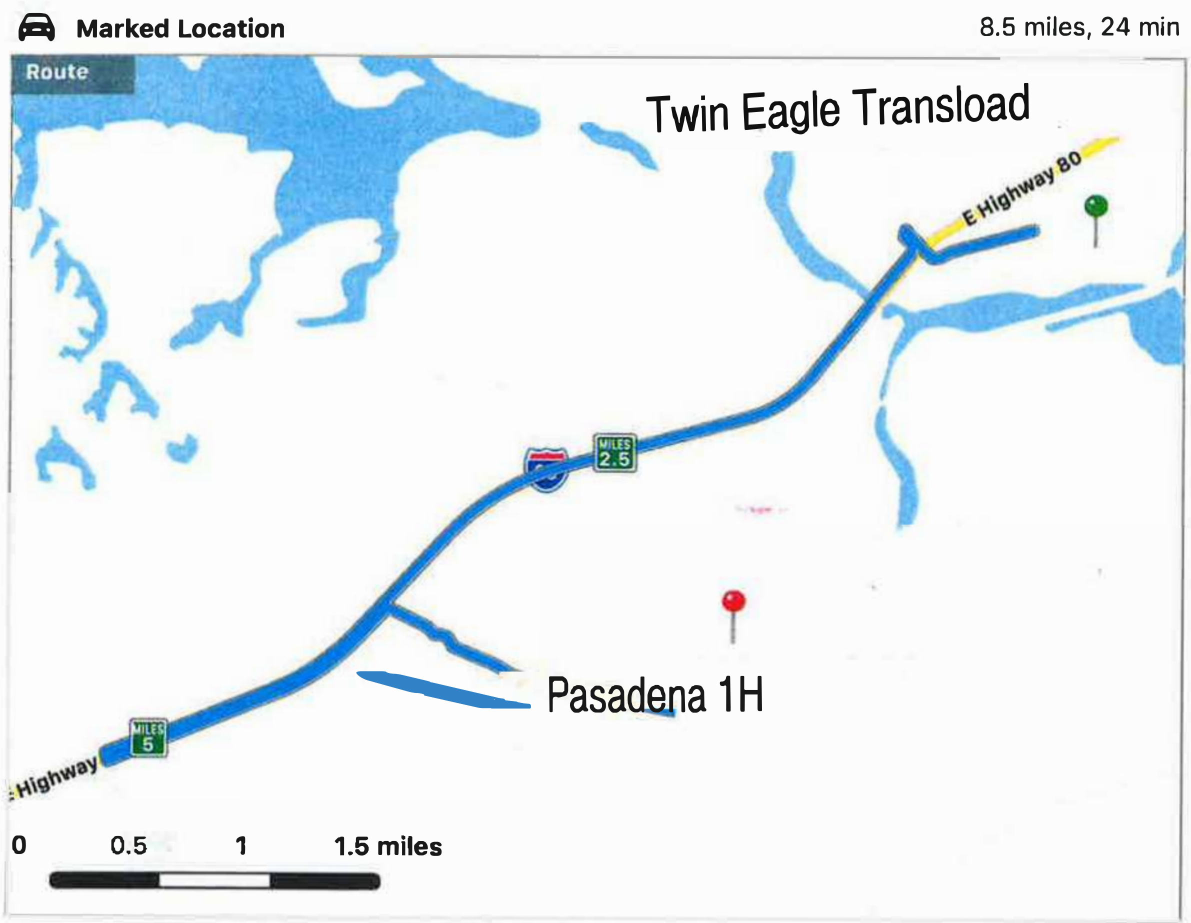


Fig. 2
Distance between Permian FracSand location, Voca, TX and OGX Wellsite