Proppant Technology Advances and Reservoir Performance*

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Abstract

The use of proppants has expanded dramatically in the last few years as lower-quality shale reservoirs are being converted into economically viable operations, thanks to improved completion techniques, which include such factors as frac fluids, proppants, and frac design. Proppants have played an important role, and they are critical for keeping the induced fractures open so that the fractures continue to function as effective conduits for flow. They are also important in maintaining high levels of fracture conductivity and connectivity. While proppants have been effective, there are new game-changing opportunities. This presentation reviews proppant advances in the industry and with technological advances. It also proposes a new approach to proppants as a delivery mechanism for surfactants and other production-enhancing chemicals. It can be used to delivery the chemicals by means of blending the proppants with the chemicals, and also using coatings on the proppants, not only resin coating but also surfactants and other chemicals. A surfactant-coated proppant would be a "smart" proppant that would have a coating that would respond specifically to reservoir fluids and stimulate production.

The proppant coating needs to be a surfactant that is zwitterionic, and contains both cationic and anionic charges. The initial zwitterionic coating needs to crack, dissolve, disintegrate over time, and the second layer of coating needs to be either an inorganic or an organic salt (depends on the formation and the frac fluid). The goal is to generate heat and continue to accelerate adsorption. The resulting movement along the surfaces and the chemical processes will result in increased temperature and pressure, which will increase the flow rates of the CH4 chemicals. Warning: typical uncoated particles that are used in conjunction with viscoelastic surfactants (VES-based) and cross-linked gels can make the proppants act as barriers. Nanoparticles of SiO_2 can be interesting, especially if functionalized with boronic acid (charged, changes surface tension).

Temperature is important – a chemical reaction will increase in-situ temperature. Therefore, the second level coating needs to be something that will trigger a chemical reaction. An inorganic salt can be effective, especially if it results in reduction...and does not result in the "wrong" kind of proppant diagenesis. What we are doing is controlling proppant diagenesis – taking a natural reaction, guiding it, making it work for us. Surfactant molecules adsorb around nanoparticles – they can clear the path for CH_4 flow. Having a charged surface enhances conductivity of propped fractures by accelerating adsorption and eliminating the "barrier effect" that can happen with proppants, particularly when proppant embedment and diagenesis occur.

Selected References

Alfi, M., P. Da Silva, M. Barrufet, and R. Moreira, 2012, Utilization of Charged Particles as an Efficient Way To Improve Rheological Properties of Heavy Asphaltic Petroleum Fluids: Society of Petroleum Engineers, doi:10.2118/153528-MS

Aljamaan, H., C.M. Ross, and A.R. Kovscek, 2017, Multiscale Imaging of Gas Adsorption in Shales: Society of Petroleum Engineers, doi:10.2118/185054-MS

Al-Muntasheri, G.A., F. Liang, and K.L. Hull, 2017, Nanoparticle-Enhanced Hydraulic-Fracturing Fluids: A Review: Society of Petroleum Engineers, doi:10.2118/185161-PA

Dahl, J., P. Nguyen, R. Dusterhoft, J. Calvin, and S. Siddiqui, 2015, Application of Micro-Proppant to Enhance Well Production in Unconventional Reservoirs: Laboratory and Field Results: Society of Petroleum Engineers, doi:10.2118/174060-MS

Gaillard, N., A. Thomas, and C. Favero, 2013, Novel Associative Acrylamide-based Polymers for Proppant Transport in Hydraulic Fracturing Fluids: Society of Petroleum Engineers, doi:10.2118/164072-MS

Hull, K.L., M. Sayed, and G.A. Al-Muntasheri, 2015, Recent Advances in Viscoelastic Surfactants for Improved Production from Hydrocarbon Reservoirs: Society of Petroleum Engineers, doi:10.2118/173776-MS

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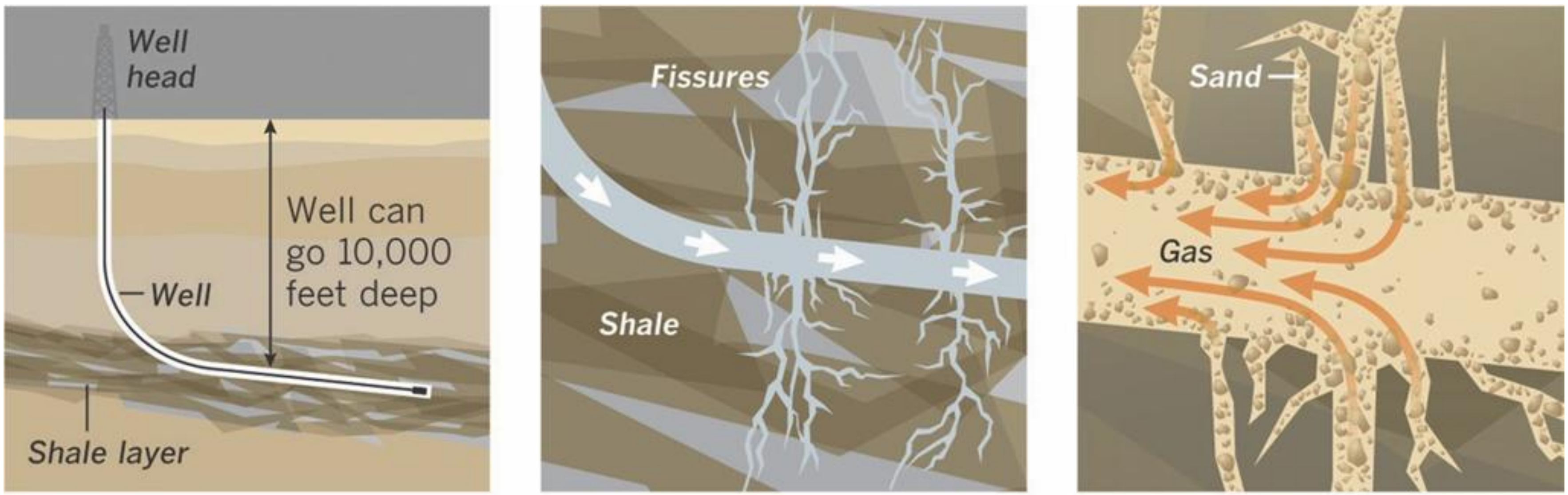
Overview of Proppants Uses



1. Well may be bored using directional drilling, a method that allows drilling in vertical and horizontal directions to depths of over 10,000 feet.

2. Large amounts of water, sand and chemicals are injected into the well at high pressure, causing fissures in the shale.

3. Sand flows into the fissures, keeping them open so that the oil or natural gas from the shale can flow up and out of the well.

graphic credit:
https://sanjaypaul70.files.wordpress.com/2012/11/fracking.jpg

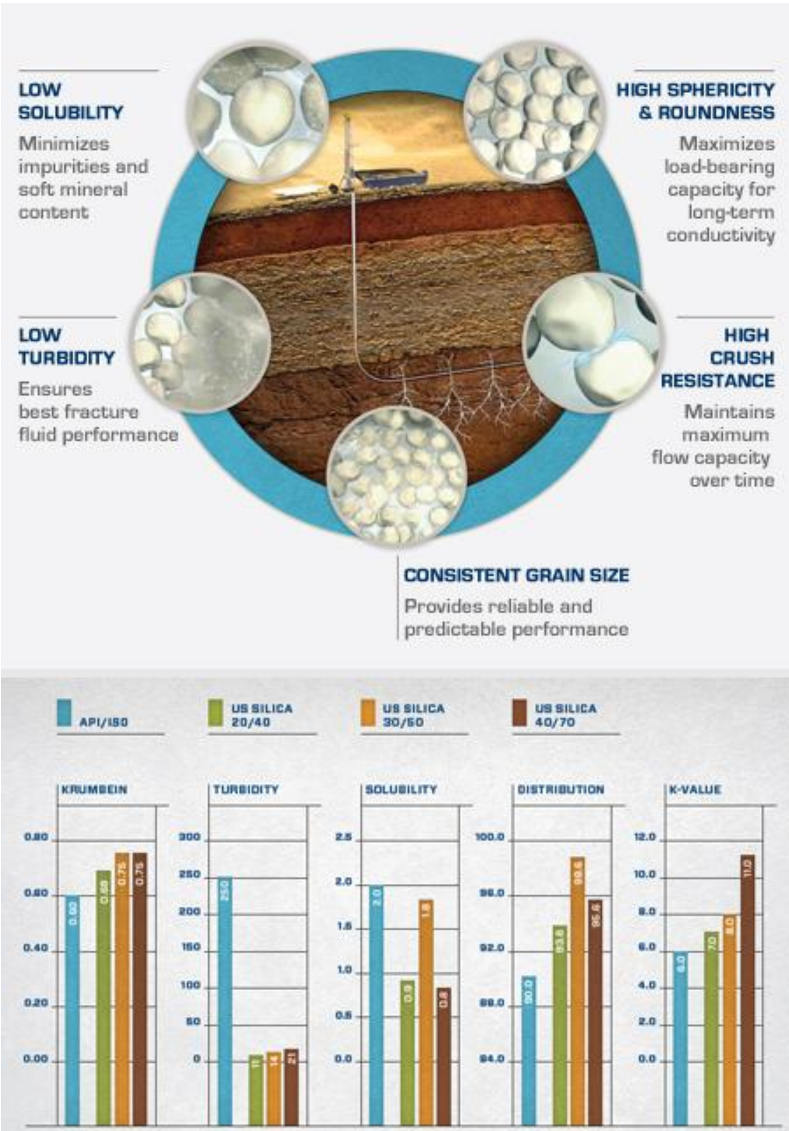
Industrial Sand Mining

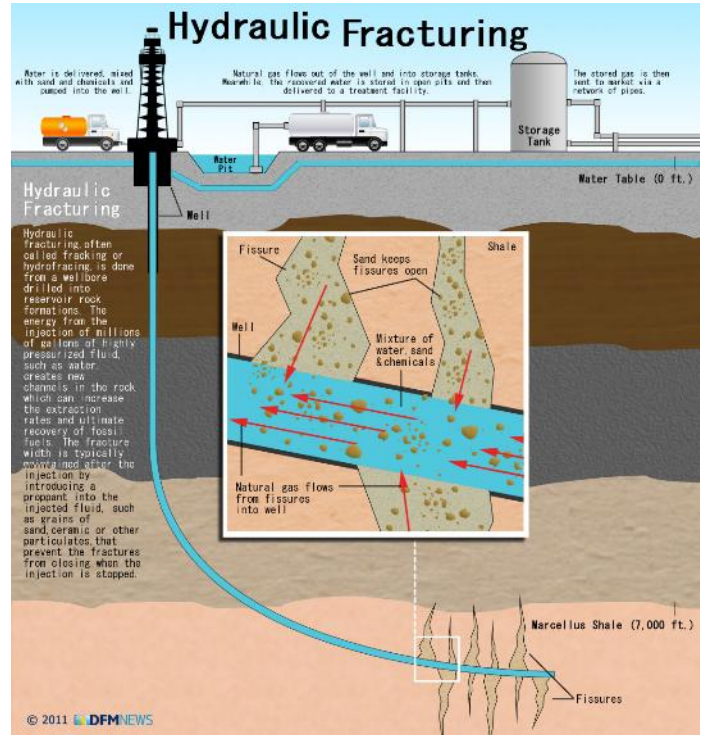
Top 10 Frack Sand Suppliers (2014)	
1.	Unimin Corp.
2.	Fairmount Santrol
3.	U.S. Silica Holdings LLC
4.	EOG Resources Inc.
5.	Emerge Energy Services LP
6.	Preferred Sands LLC
7.	Mississippi Sand LLC
8.	Badger Mining Corp.
9.	Hi-Crush Partners LP
10.	Buffalo Proppants LLC

Source: PacWest analysis; Industry sources; Company reports; Regulatory filings

Majority of proppant sand mines in the U.S. are in Wisconsin and Minnesota. (Mine shown is in Wisconsin. The map shows Unimin locations. Unimin is a subsidiary.)

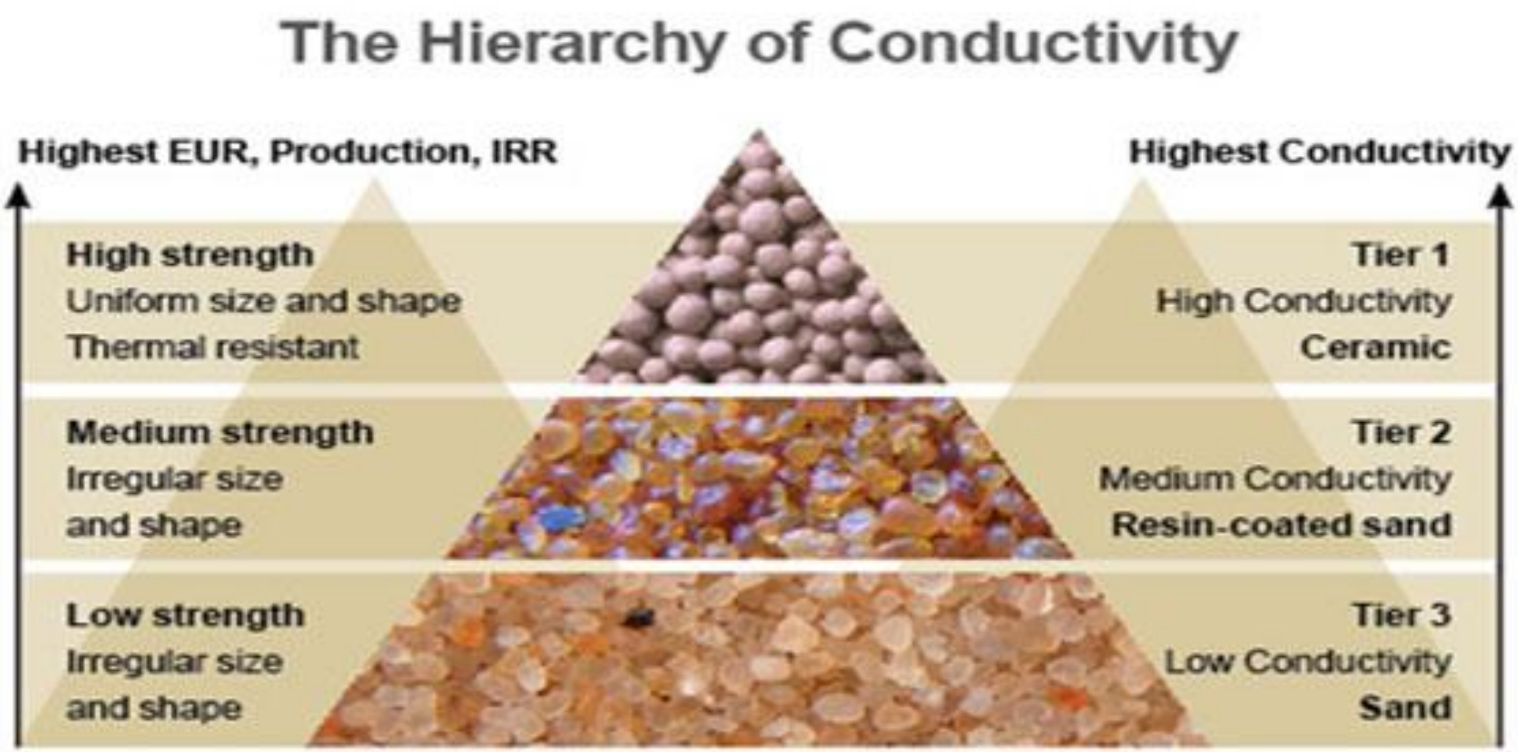
Qualities of Ideal Proppant Sand





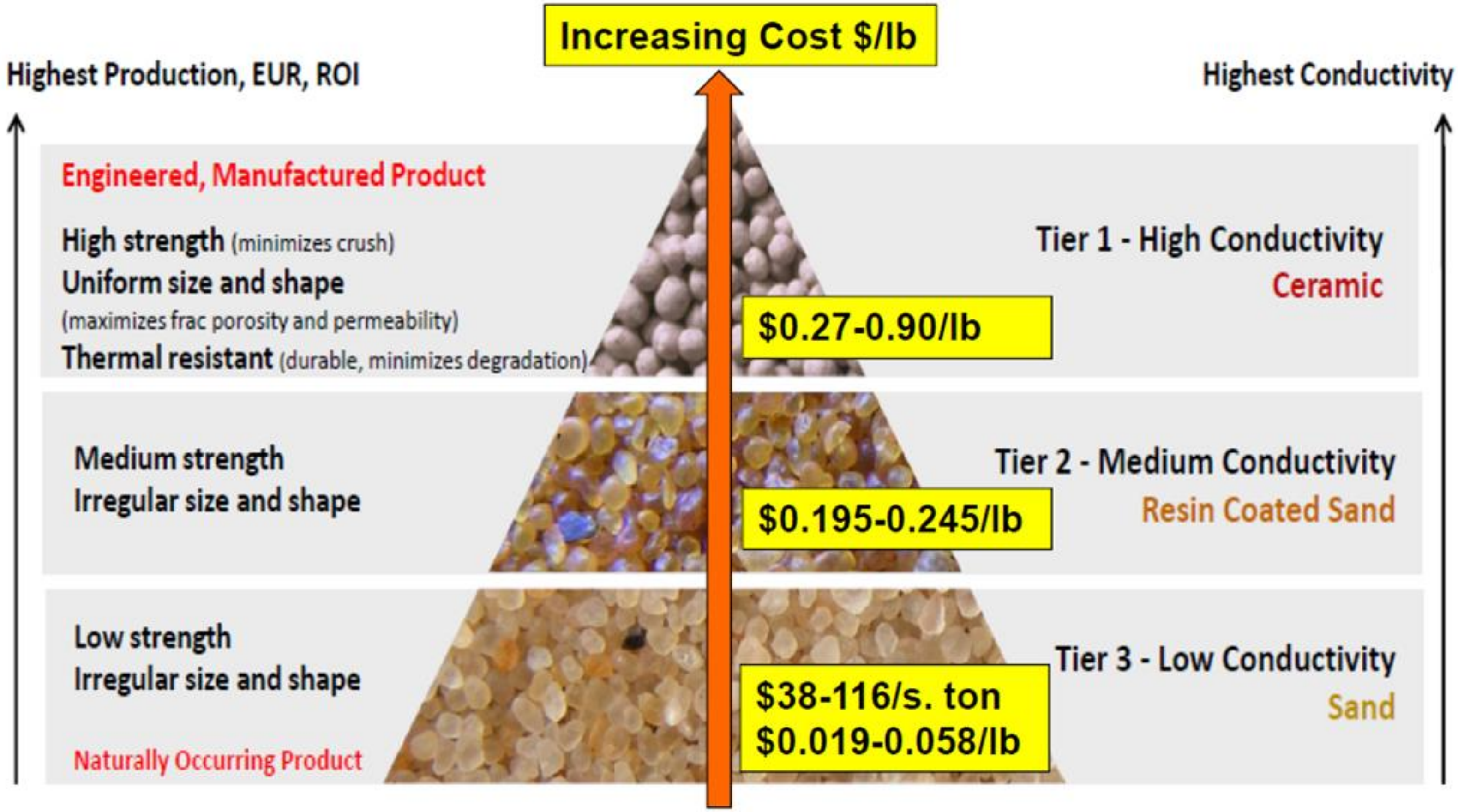
In addition, the conditions of original emplacement must be good.

Grading the Proppants



Dramatic differences in performance

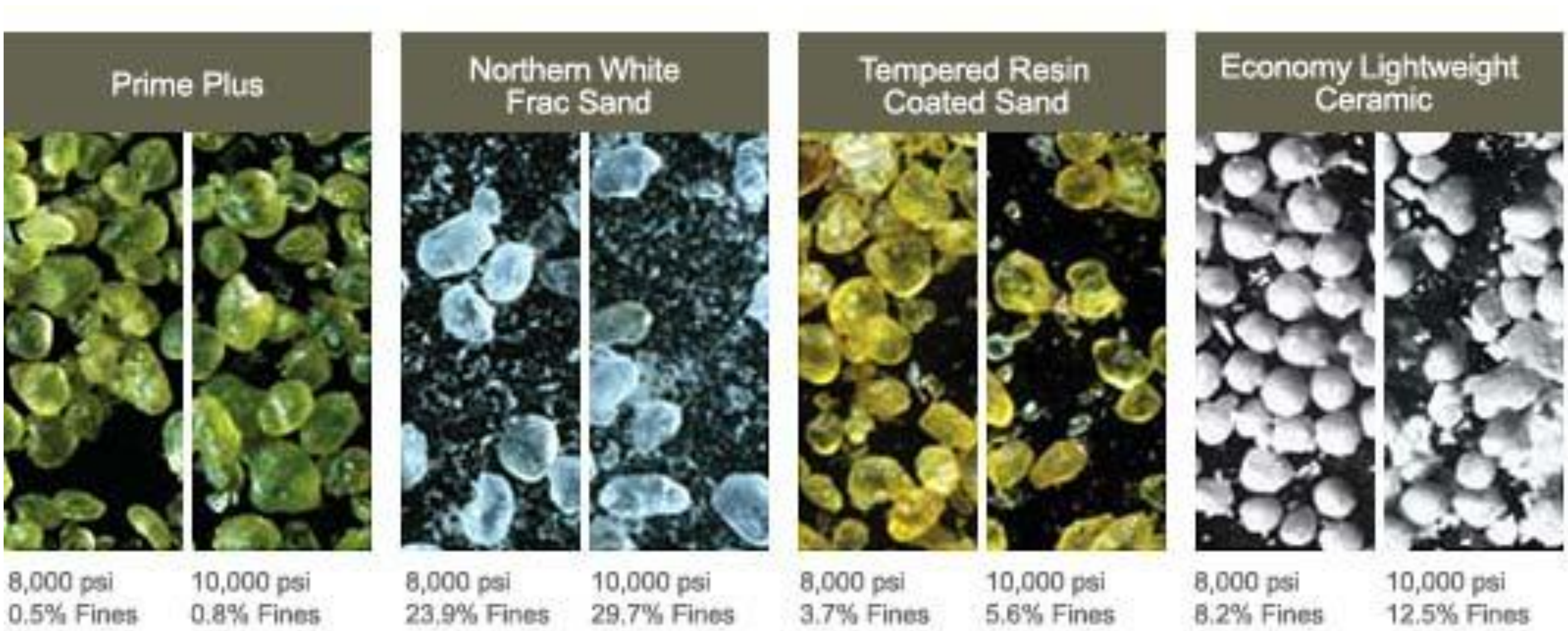
… and Price



Graphic credit:

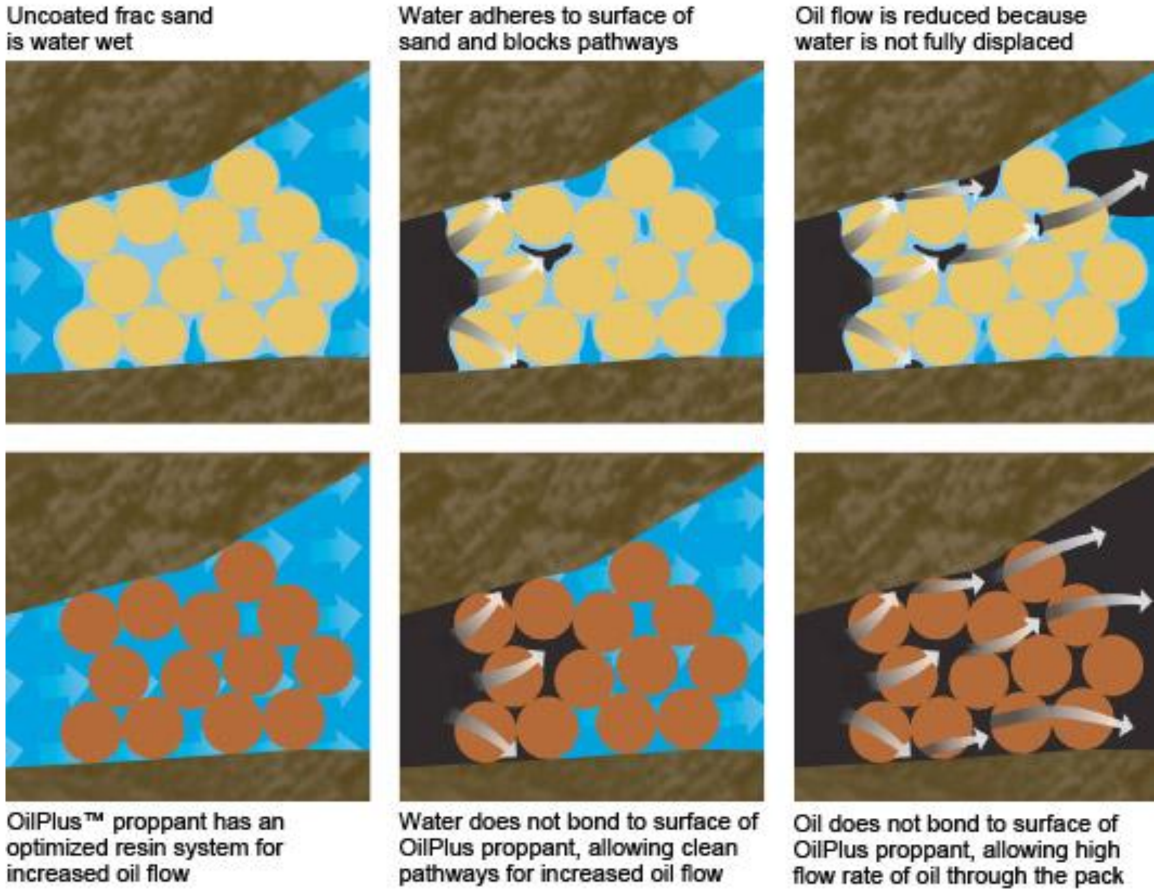
https://pnlintrade.files.wordpress.com/2014/01/proppant-selection-venezuela.png

Fines Greatly Reduce Permeability



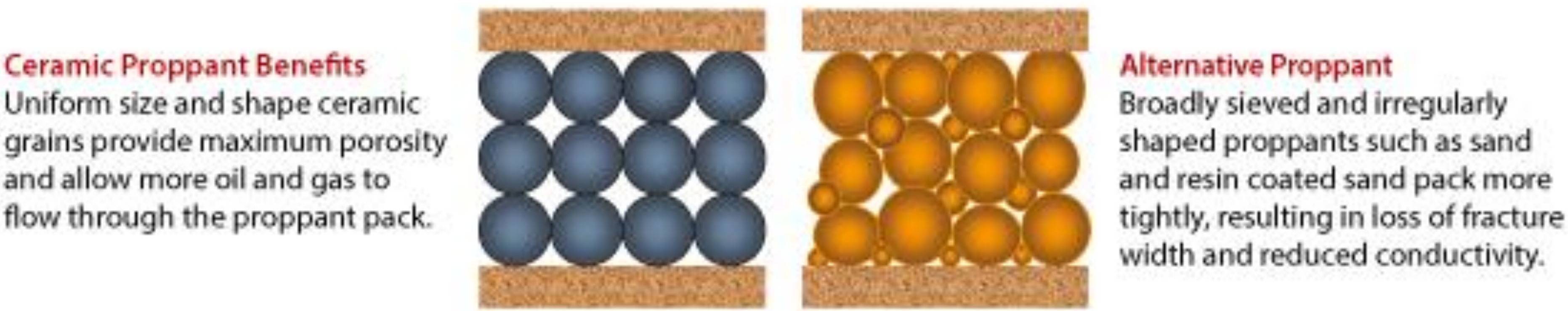
Crushing during the hydraulic fracturing process

Resin-coated proppants



Changing the permeability of the proppant pack

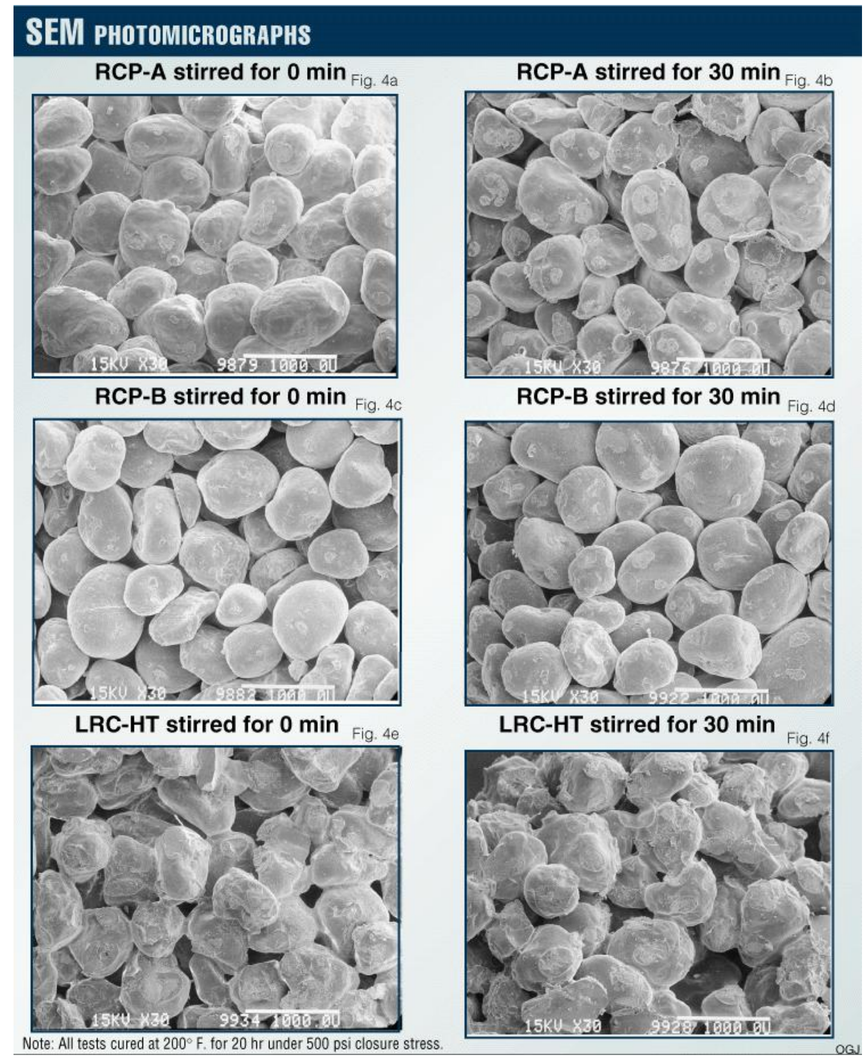
Engineered vs Natural



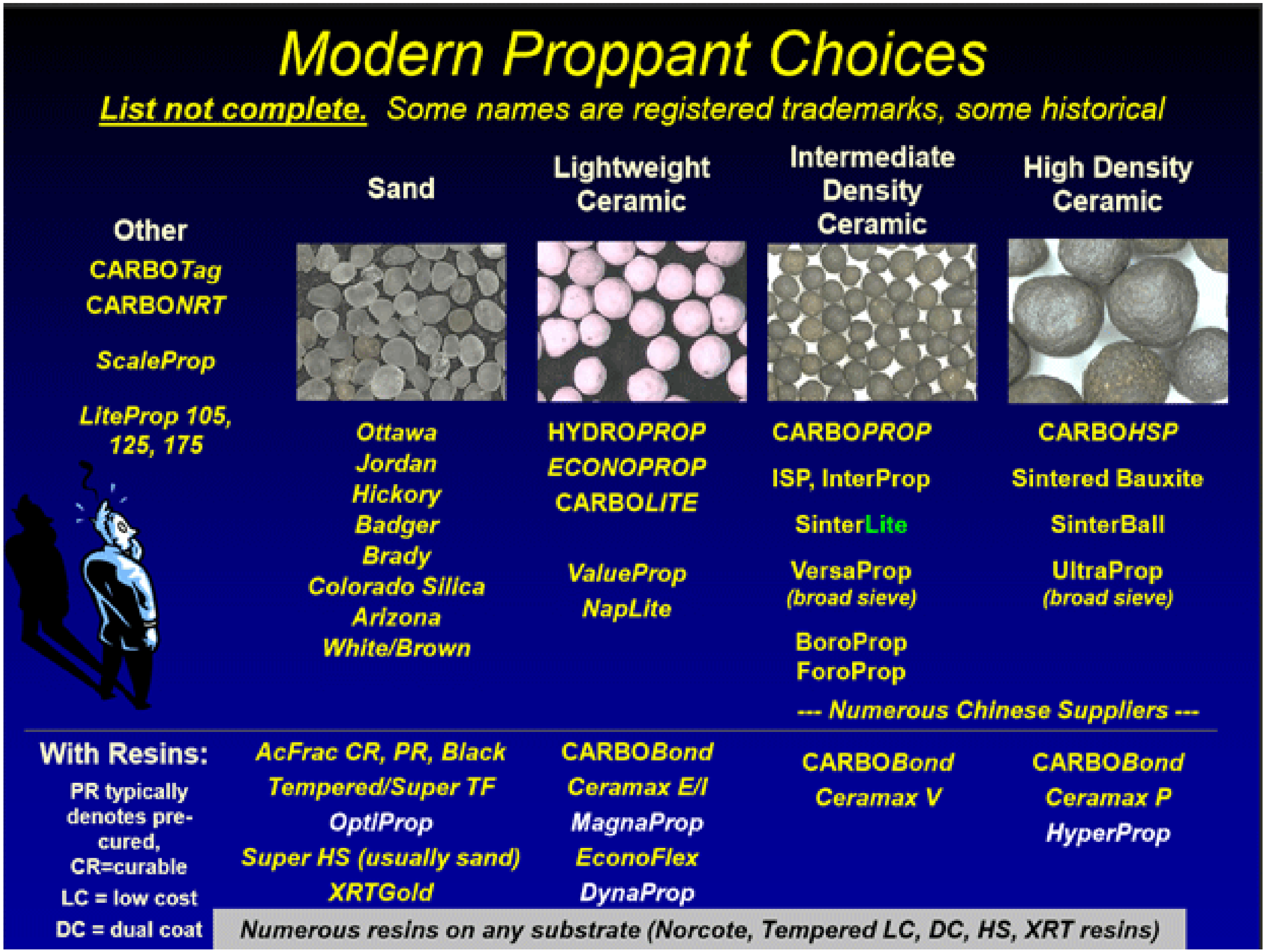
- Proppant size uniformity
- Consistent shape
- Crush resistant
- Even pore spaces

Resin-Coated Sand

Resin-Coated Sand consists of a silica sand core with a coating of resin to give it better compressive strength. It has a very low density, which makes it effective in propping up the induced fractures and keeping the flow moving.

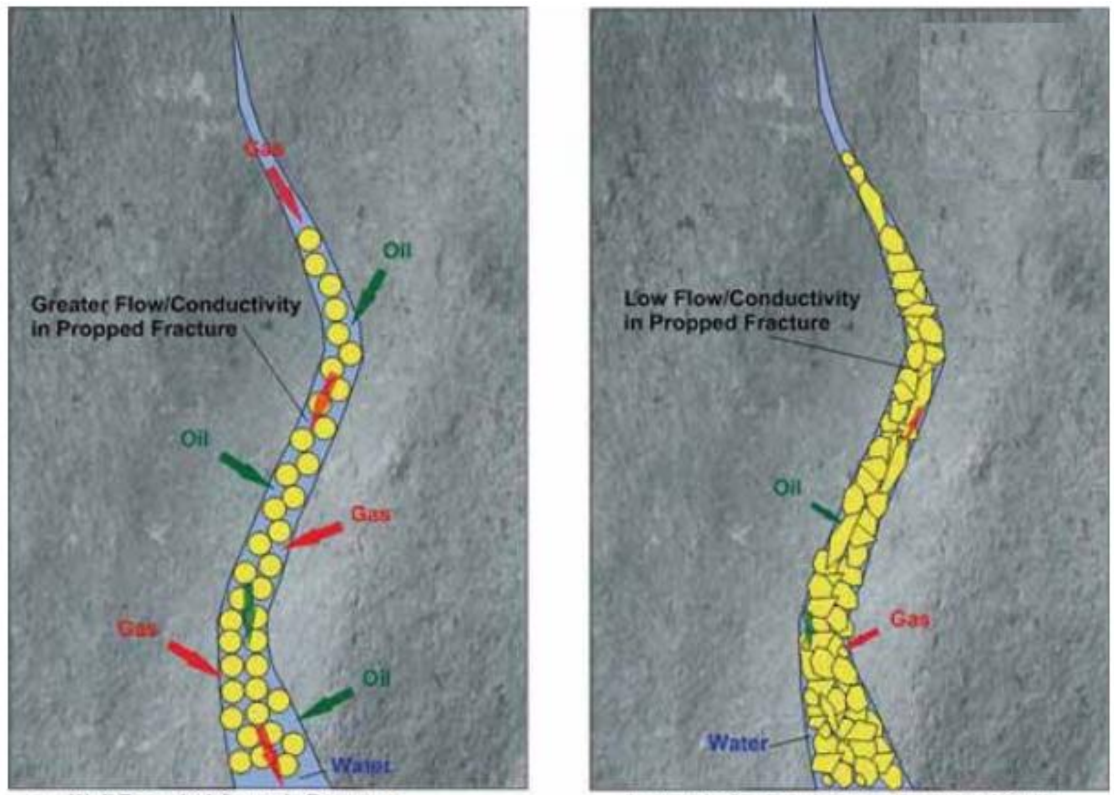


Proppant varieties...



Sand, lightweight ceramic, different density ceramics …

A Pro-Ceramic Proppant Argument



a. Well Rounded Ceramic Proppant b. Poorly Sorted Angular Proppant Sand

Well-sorted, uniform, well-rounded -- better flow and conductivity

Ceramic Proppants

Different sizes and coatings for strength

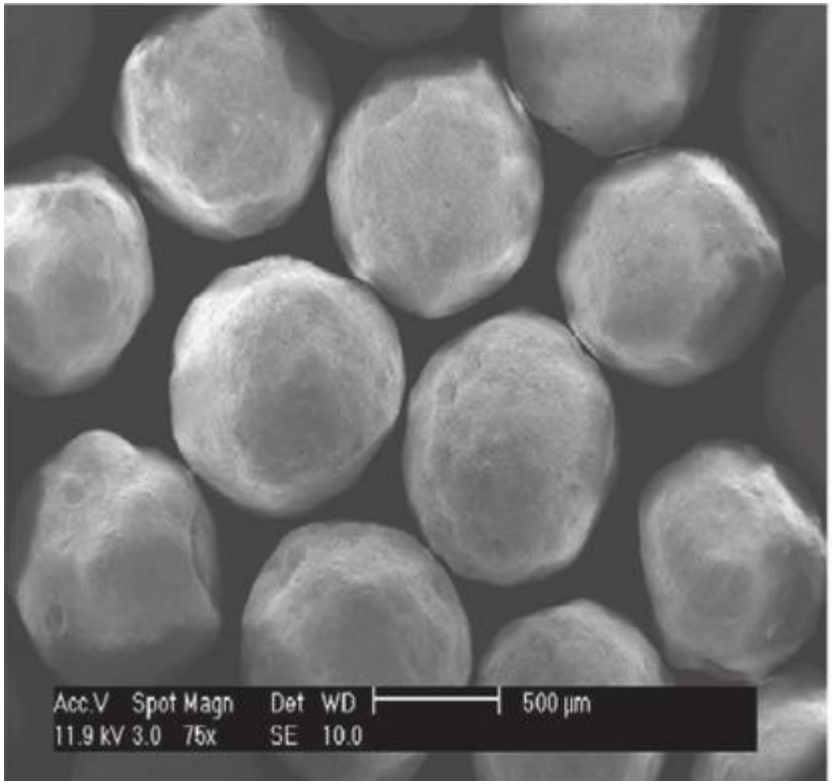
Ceramic Proppants

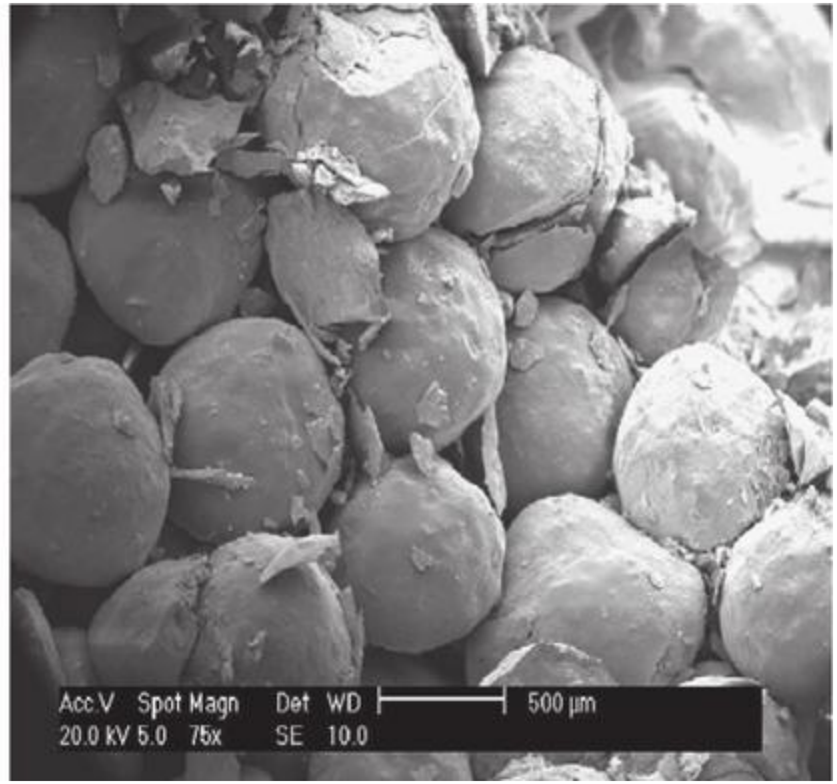
Ceramic proppants can come in a variety of materials and mesh sizes. They are custom-designed to withstand harsh downhole conditions, particularly with high pressure, high temperature, and potential H2S.

CARBO Ceramics

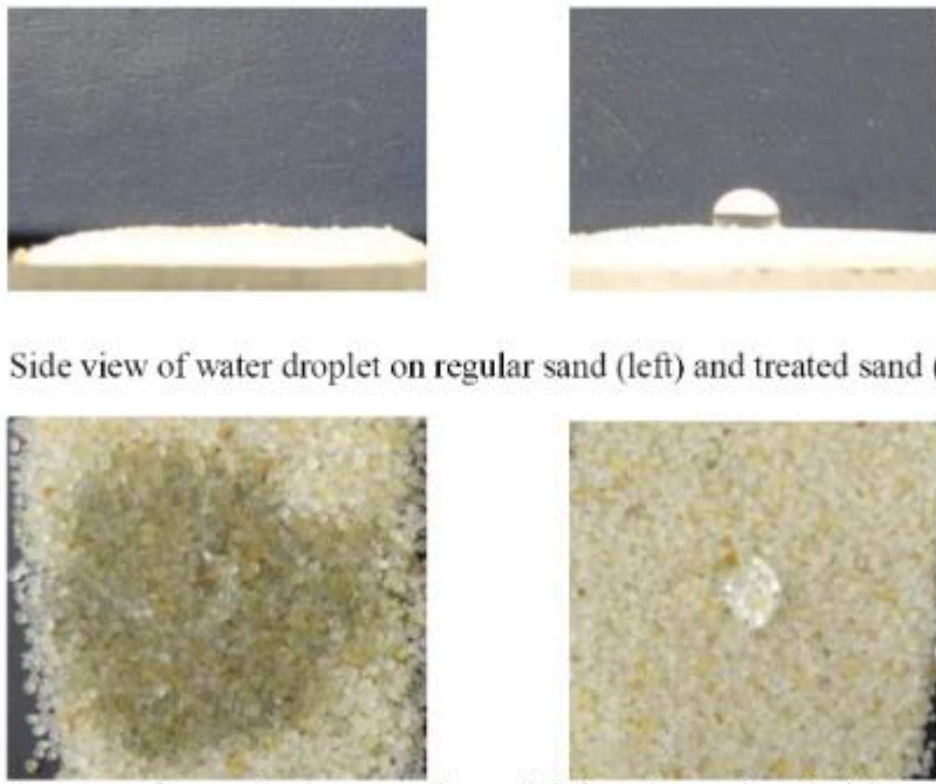
- Low-density ceramic
- Intermediate-density ceramic
- High-density sintered bauxite

Proppant Diagenesis





Proppant Improvements



a) Side view of water droplet on regular sand (left) and treated sand (right)

b) Top view of water droplet on regular sand (left) and treated sand (right)

Figure 1—Pictures of water droplet on regular and SUA treated sands.

Altering wettability with a "environmentally friendly" green fluids

Adsorption processes: Argument for a coated proppant

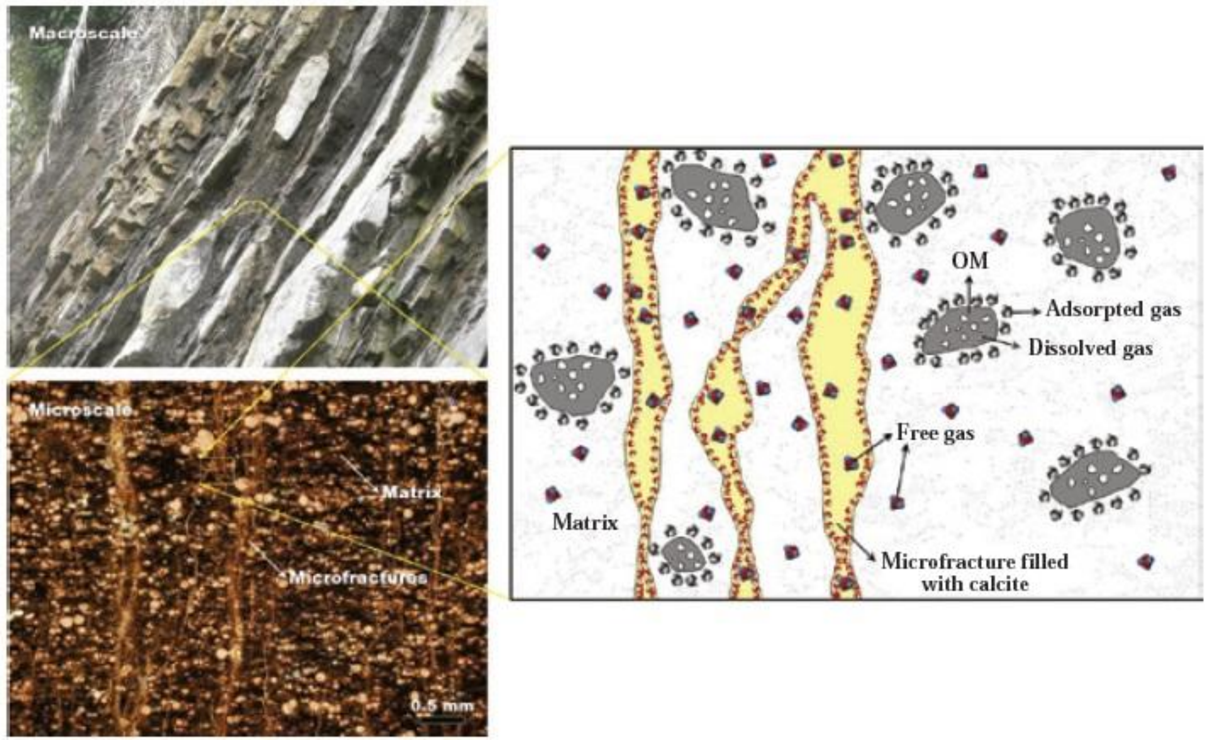


Figure 5. Conceptual model of gas distribution in the Galembo Member mudstones from macro-meter to micro-meter scale (adapted and modified from **Guo**, *et al.*, 2013).

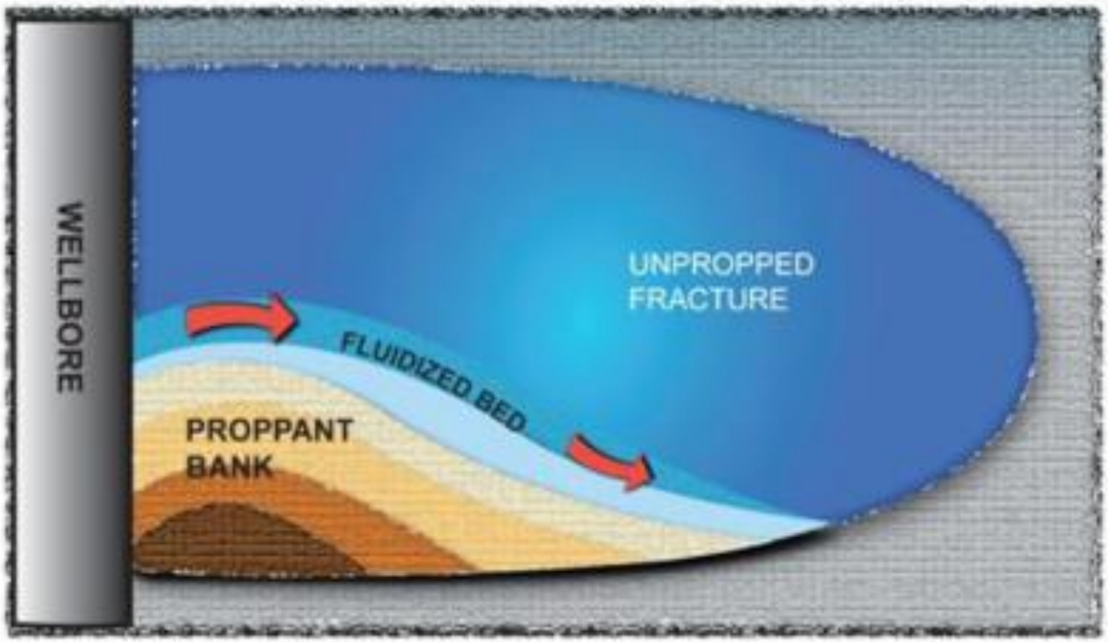
can proppants with surfactants help accelerate adsorption?
Move release methane from pore surfaces
Change pore pressure

Smart Proppants

- Using proppant to capture radium (in shale formations relatively rich in uranium and thorium ores)
- Using coated proppant for H2S capture

- *Benefits*
- Enable wastewater reusability
- Mitigate pipeline corrosion

Issues of Surface Tension

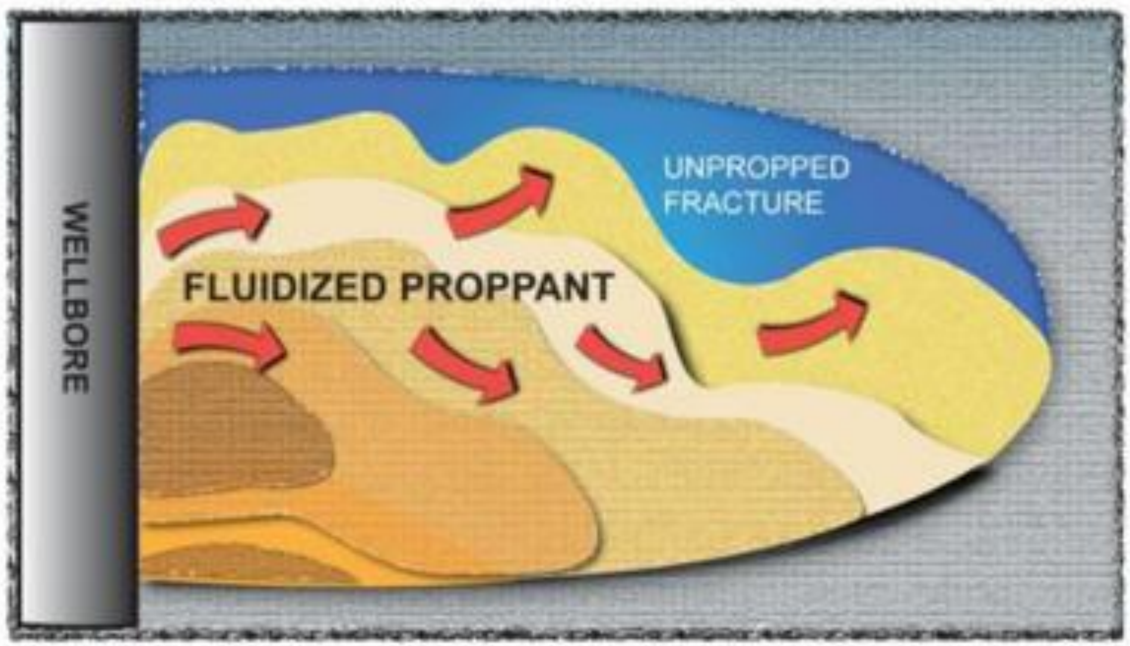


Fracture Cross-Section:
Conventional slick water

Figure 1—Conceptualized Proppant Flow in a Fracture

Altering interfacial tension

Issues of Surface Tension

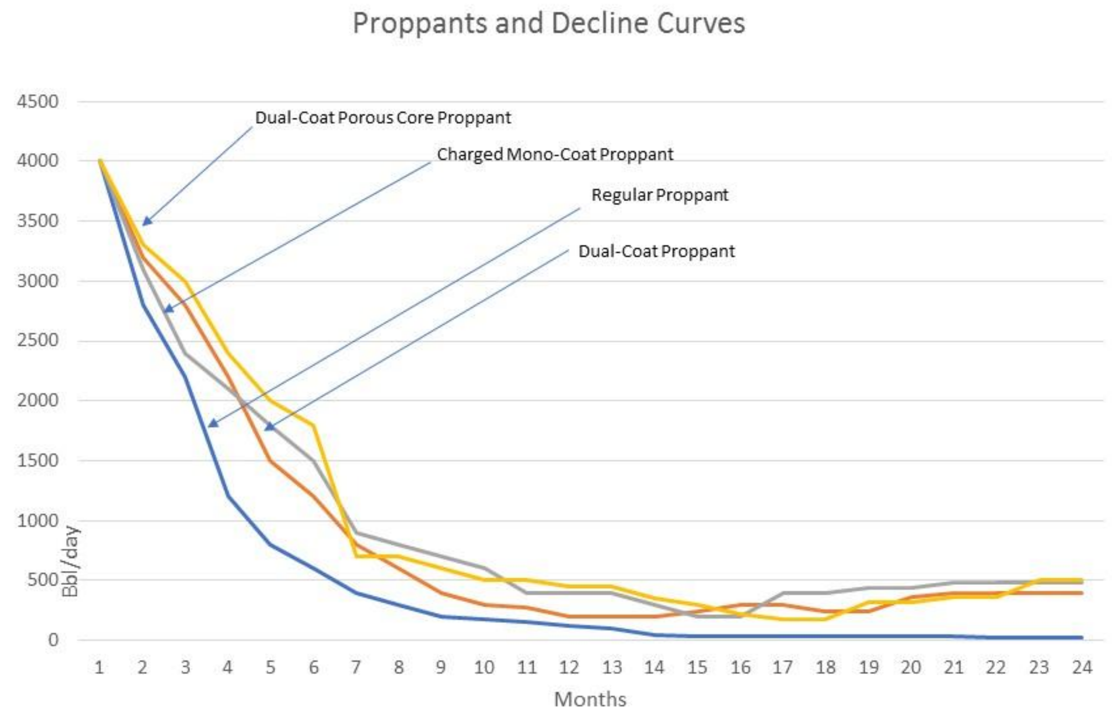


Fracture Cross-Section:
Slick water with proppant transportation modifier

Figure 2—Conceptualized PTM Enhanced Flow in a Fracture

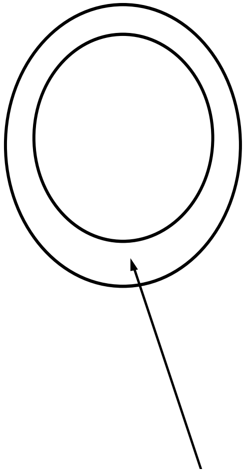
Proppant Transport Modifier results in enhanced flow

New Coated Proppants



Proppant Transport Modifier results in enhanced flow

Mono-Coating Proppant

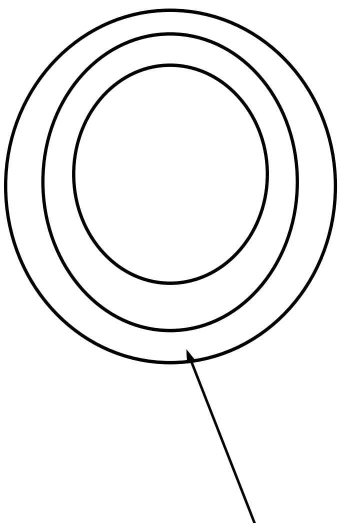


Zwitterionic surfactant coating with both cationic and anionic centers attached to the same molecule. By reducing surface tension on both sides, it is possible to accelerate the process of adsorption of CH4 molecules, which will increase nano-pressure, flow, and production.

Zwitterionic Coating: The coating changes a proppant from being a grain that props open a fracture (and potentially becoming a barrier) to being a flow enhancer and also an adsorption accelerant, with the result of having an increase in methane flow after 18 – 24 months, with a continuing internal stimulus, continuing to increase the flow in both the rate and also volume.

Dual-Coating Proppant

Inorganic salt (with magnesium chloride content) that triggers chemical reactions, increased temperature and pressure, and crystal surface production (additional surfaces), resulting in potential for more adsorption, and thus more movement of CH4 molecules.



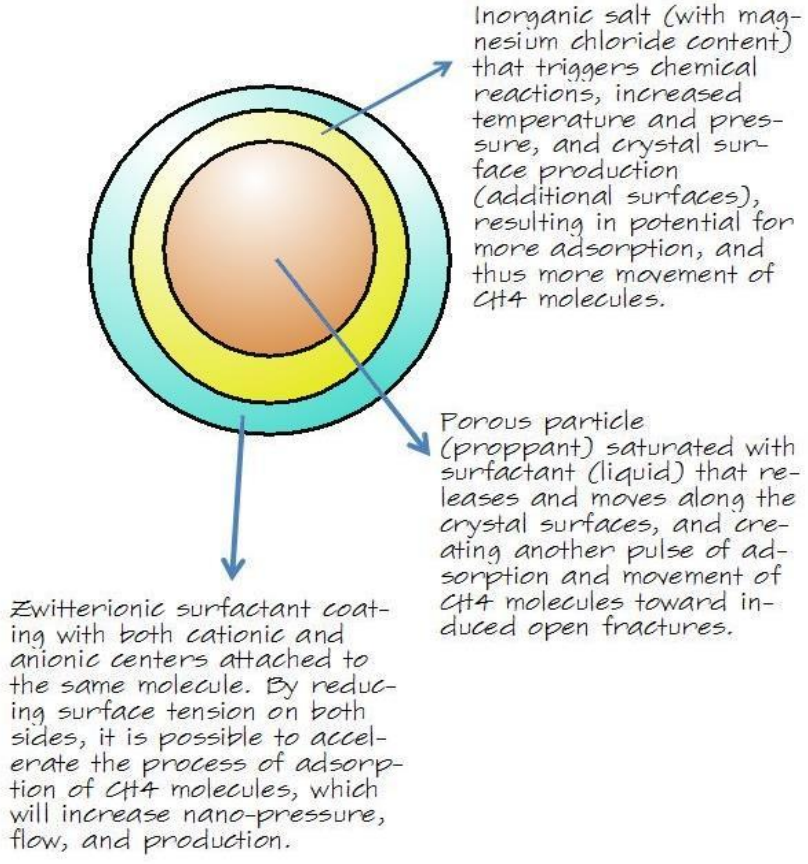
Zwitterionic surfactant coating with both cationic and anionic centers attached to the same molecule. By reducing surface tension on both sides, it is possible to accelerate the process of adsorption of CH4 molecules, which will increase nano-pressure, flow, and production.

Outside Coating: Zwitterionic

Inner coating: Inorganic salt that includes magnesium

- Triggers a chemical process
- Increases temperature and pressure with increase of expulsion of CH4
- Chemical process creates crystals and thus surface area
- Crystals – more volume for surfactants to work reducing tension
- More adsorption

Dual-Coating with Porous Proppant



Zwitterionic outer coating; inorganic salt inner coating, porous core.

The proppant is a delivery system as well as a physical proppant for induced fractures. The porous proppant grain is impregnated with a liquid surfactant (or potentially a catalyst) to accelerate adsorption as well as generation of methane, and also to dramatically increase (in the nano-scale) temperature and pressure.

Current and Future Trends

- Use the proppant as a delivery mechanism for surfactants and other chemicals that stimulate production
- Focus on wettability alteration
- Modify the proppant’s surface properties
- Use a novel surfactant that preferentially coats the surface