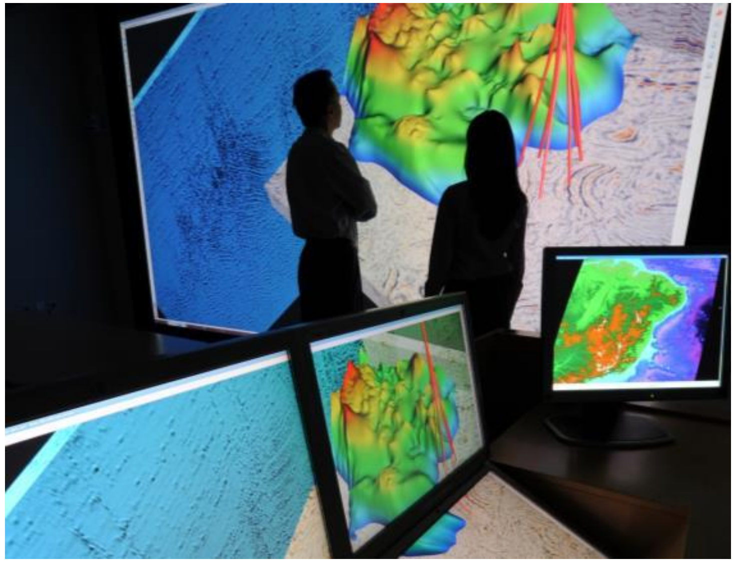
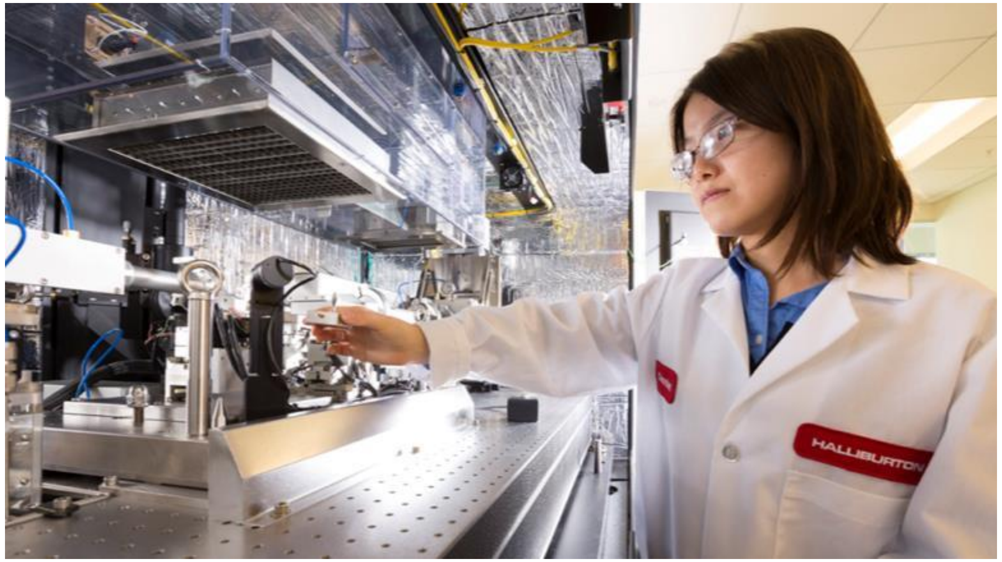



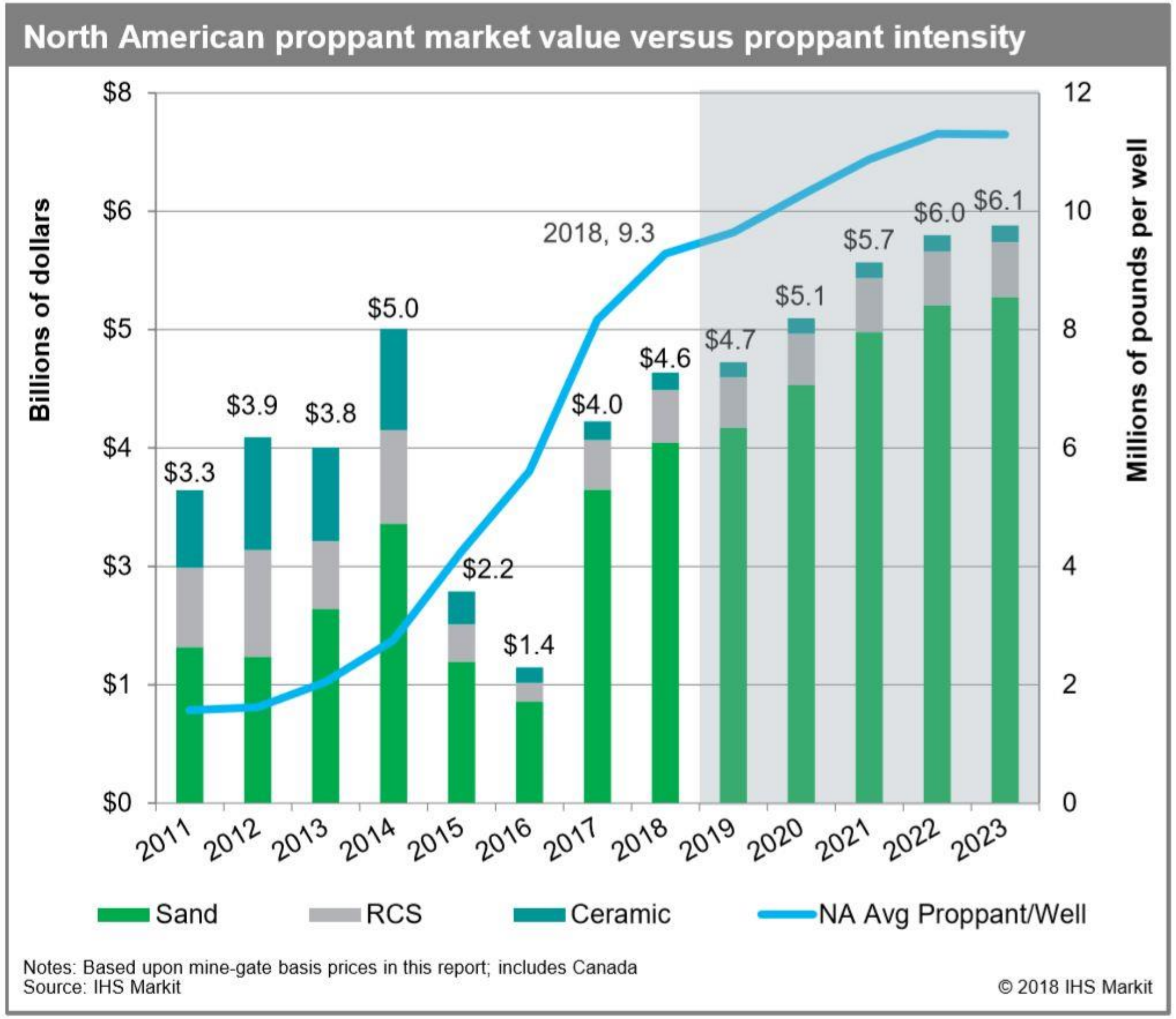
Why Local Sands Work

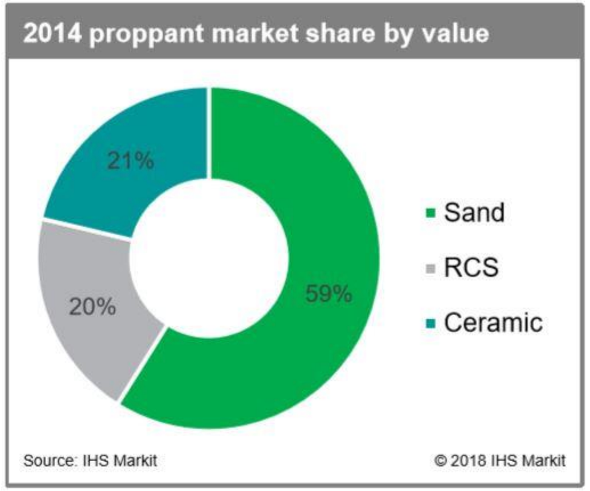
Philip Nguyen, Halliburton

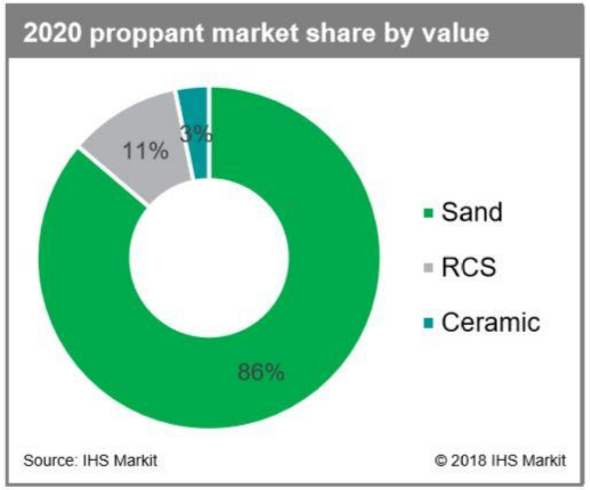
Why Local Sands Work

- Background
- Basic mechanics
- Literature review
- Field evidence
- Final thoughts
- Conclusion

Sands dominate proppant market share







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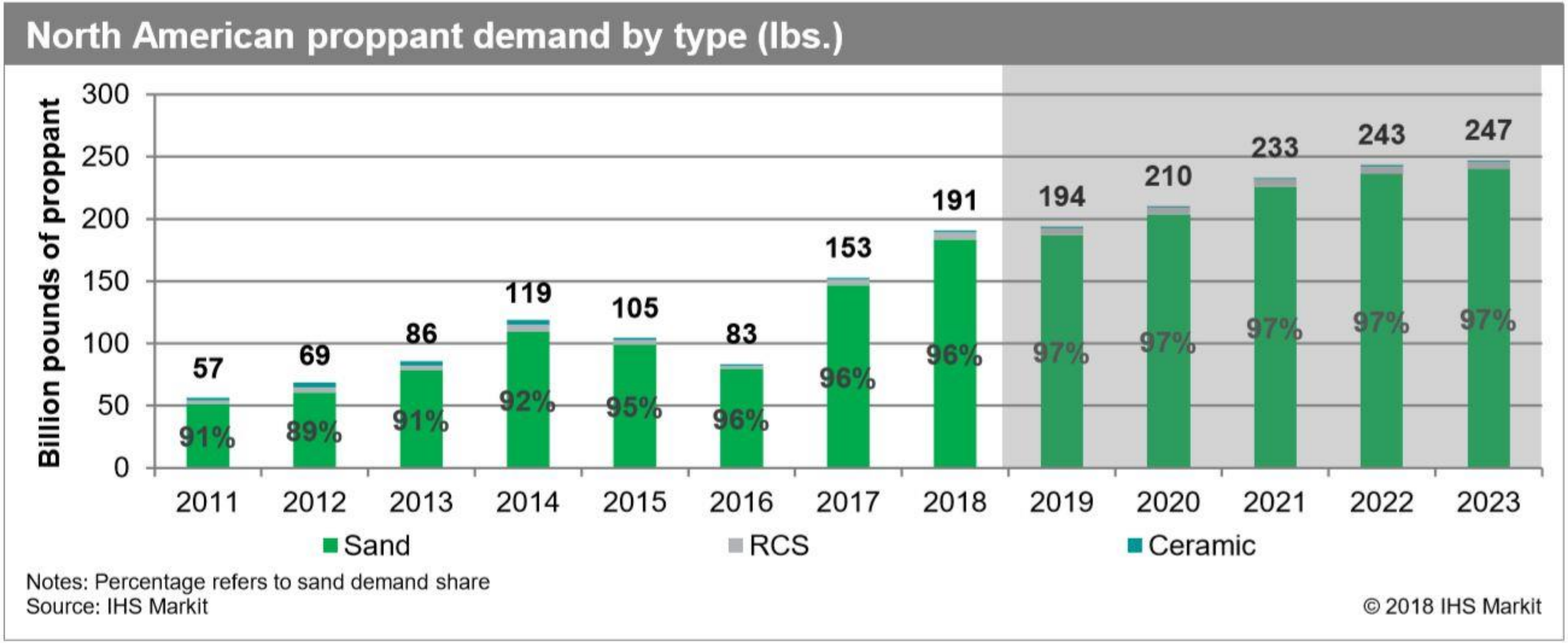
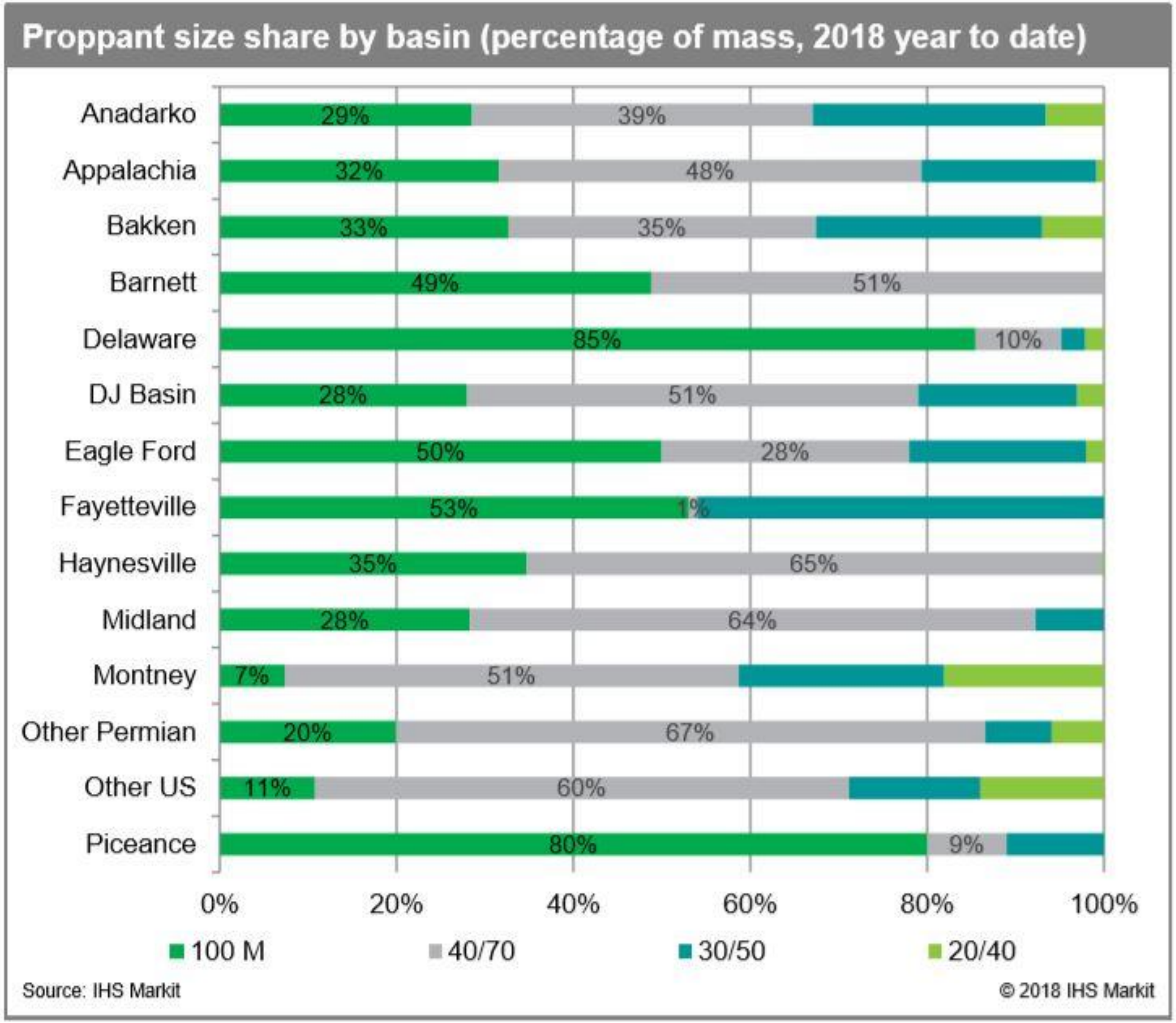

North American proppant demand by type (lbs.)
Billion pounds of proppant
300
250
200
150
100
50
0
57
69
86
119
105
83
153
191
194
210
233
243
247
91%
89%
91%
92%
95%
96%
96%
96%
97%
97%
97%
97%
97%
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021
2022
2023
Sand
RCS
Ceramic
Notes: Percentage refers to sand demand share
Source: IHS Markit
© 2018 IHS Markit



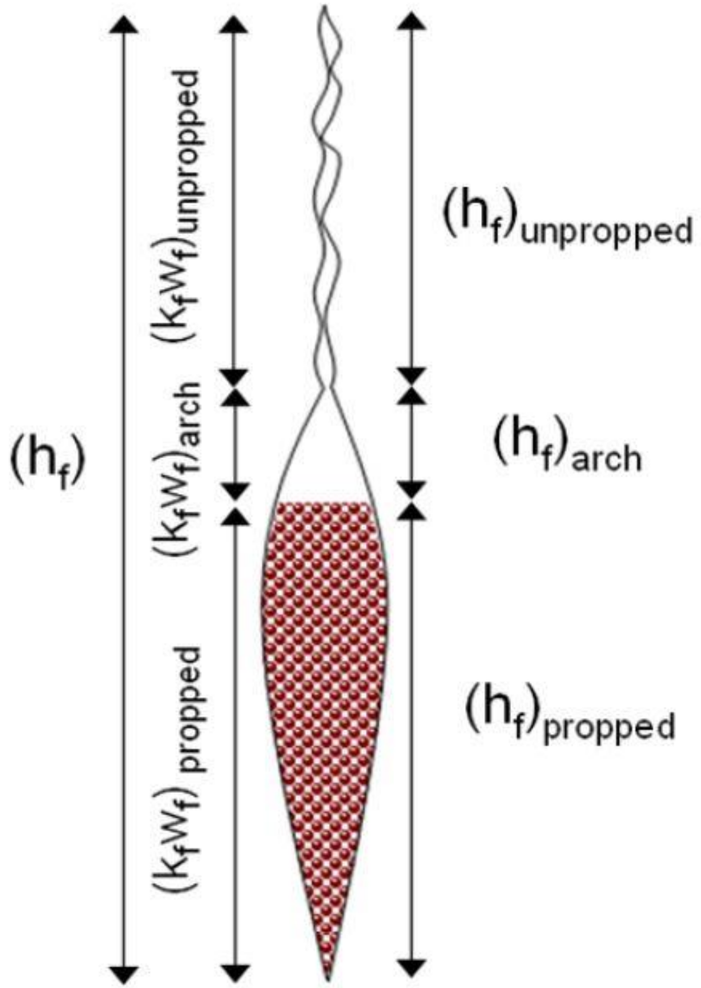
Proppant size share by basin (percentage of mass, 2018 year to date)
Anadarko
Appalachia
Bakken
Barnett
Delaware
DJ Basin
Eagle Ford
Fayetteville
Haynesville
Midland
Montney
Other Permian
Other US
Piceance
29%
39%
32%
48%
33%
35%
49%
51%
85%
10%
28%
51%
50%
28%
53%
1%
35%
65%
28%
64%
7%
51%
20%
67%
11%
60%
80%
9%
0%
20%
40%
60%
80%
100%
100 M
40/70
30/50
20/40
Source: IHS Markit
© 2018 IHS Markit

Current Sand Placement and Distribution In Shale Fractures

- Needs
  - Enhancing SRV
    - » Increasing fracture density
    - » Propped fracture network
      - High injection rates
      - Low viscosity fluid
- Issues
  - Slickwater
    - » Poor sand transport and suspension
  - Low-permeability formations
  - Slow fracture closure

- Frac sand placement
  - Most frac sand settled to bottom side of fractures
  - Most fracture height remained unpropped
    - » GTI study in Permian basin (JPT, Sept. 2018; URTeC 2902364)

Basic mechanics



	$k_f w_f$ (mD-ft)	w_f (ft)	h_f (ft)
Unpropped	0.5; 5	0.006	$300 - (h_f)_{arch} - (h_f)_{propped}$
Arch	42000000	0.018	3
Propped	270 (100 mesh) 8100 (20/40 Ceramic)	0.054	150 (50% fill) 75 (25% fill) 30 (10% fill)

Cipolla et al., SPE 119368

Wang et al., ARMA 18–111

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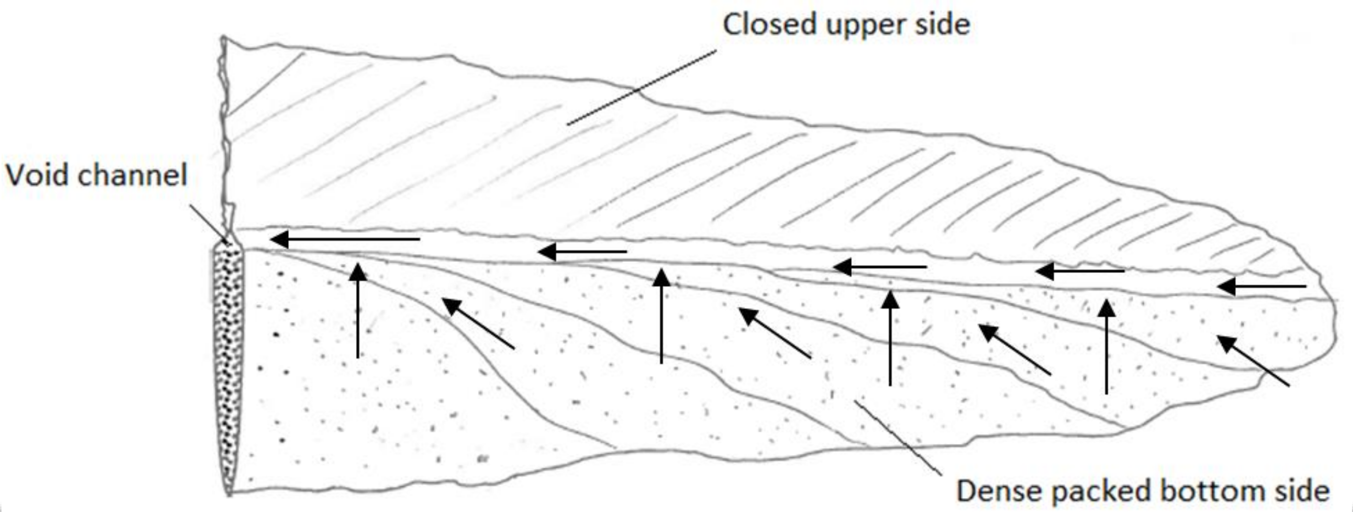
What happened to settled frac sand pack in fracture?

- Settled sand pack continues to be exposed to high closure stresses
  - Sand continues to get crushed
  - Sand pack's conductivity continues to diminish with time (*SPE-187451*)
- Only existing void channel on top of settled sand pack handles fluid production
  - Void channel connects fracture with wellbore
  - Fluid prefers to flow into this channel as path of least resistance rather than traveling through the entire length of sand pack



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SPE 170784 — *John Ely et al.*

- More than 100,000 frac stages
- “The infinite conductivity is due to creation of partial monolayers of the tiny proppant rather than the conventional packed proppant pack.”
- Enhanced surface area is “due to bridging and diverting in fractures which interconnect not only natural fractures but also creating complexity”.
- “The success of 100/200 mesh proppant at depth cannot be explained by packed proppant pack theory.”
- “The high rate of initial production and also sustained production can only be achieved with infinite conductivity fractures, NOT with high concentration proppant packs of extremely low conductivity proppant.”

SPE 187451—*Bob Duenckel et al.*

- Demonstrated the conductivity of a proppant pack under high closure stresses continues to decline with time – Pack conductivity never stop decreasing

  - 2 lb/ft^2 20/40-mesh white sand
  - 4,000 psi closure stress
  - 150°F

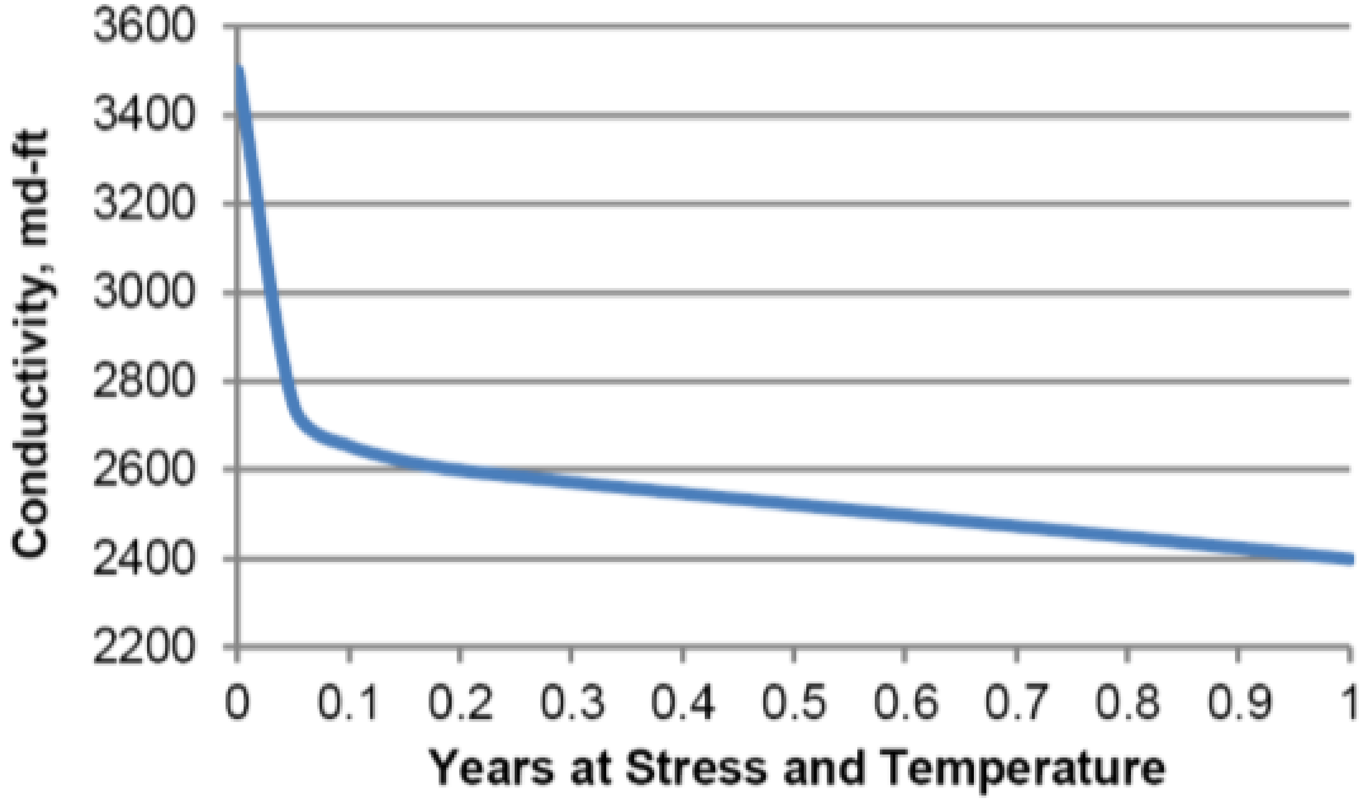


Figure 6—Conductivity degradation with time – 1 year

SPE 187451—*Bob Duenckel et al. (Cont'd)*

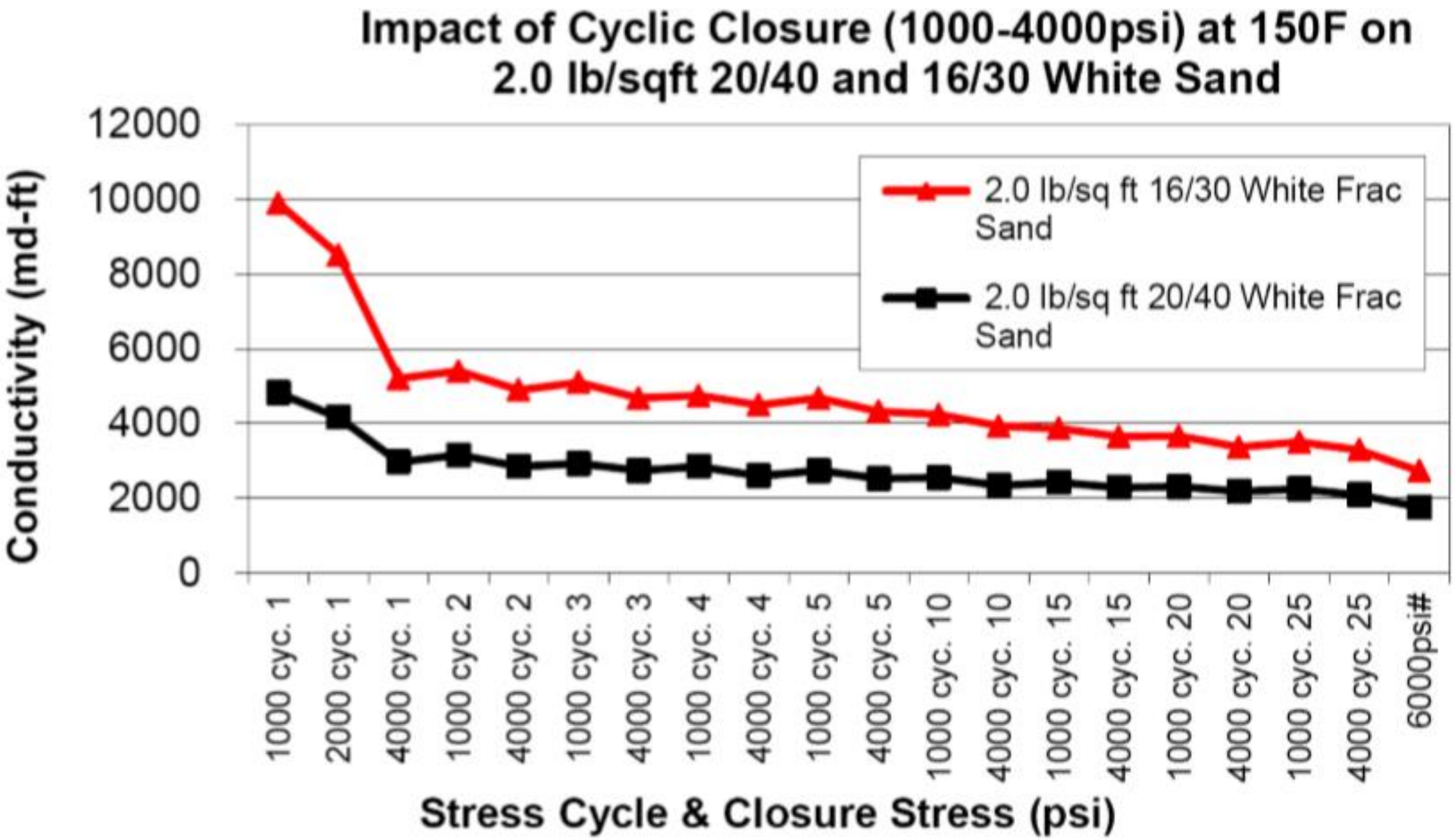


Figure 9—Impact of cyclic stress on conductivity

SPE-191423—*Alex Yang et al.*

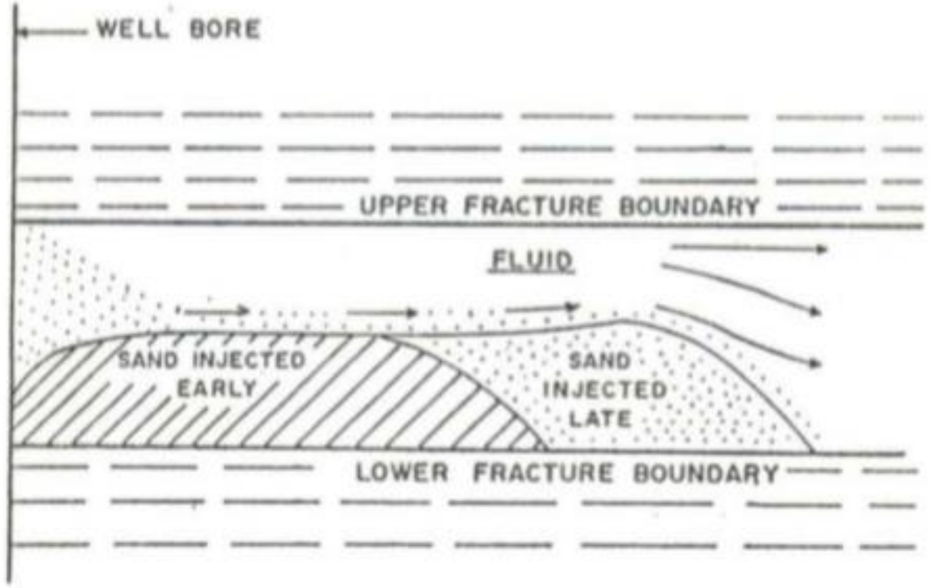
- "An increase of one thousand pounds of proppant was associated with a three barrel production increase over 14 months."
- "Brown sand has no significant effect on the odds of an oil well declining faster."
- "Gas and condensate decline rates, and cumulative production for wells fractured using local brown sands are comparable to those treated with white sand."

SPE-194382—*Bob Barree et al.*

- Wide PSD is acceptable
- There is no indication that a broad sieve distribution has any negative effect on pack permeability for the samples tested, where the particle diameter range varies by 4-fold.
- There is no indication that permeability at high stress is impaired by a broad sieve distribution.
- Mixing of 40/70 and 30/50 sands to produce a nominal 30/70 proppant increases permeability over the 40/70, well-sorted material, over the stress range tested up to 12000 psi.
- A proppant pack sieve distribution as broad as the 40/140 mesh sample yields conductivity within the range expected for nominal 40/70 sands.

SPE 194370—*John Ely et al.*

- CounterProp technique — Larger proppant, typically 40/70-mesh sand, was initially pumped, followed by the smaller 100-mesh (70/140) proppant, all in low viscosity fluid.
- The larger proppant not only settles at the wellbore, but actually tends to create more complexity due to near wellbore bridging, followed by the creation of more fractures within the network



Probable final position of sand injected late in treatment.

Figure 2—Proppant Transport
Secondary proppant (sand injected late) introduced during fracture treatment

SPE 194370—*John Ely et al. (Cont’d)*

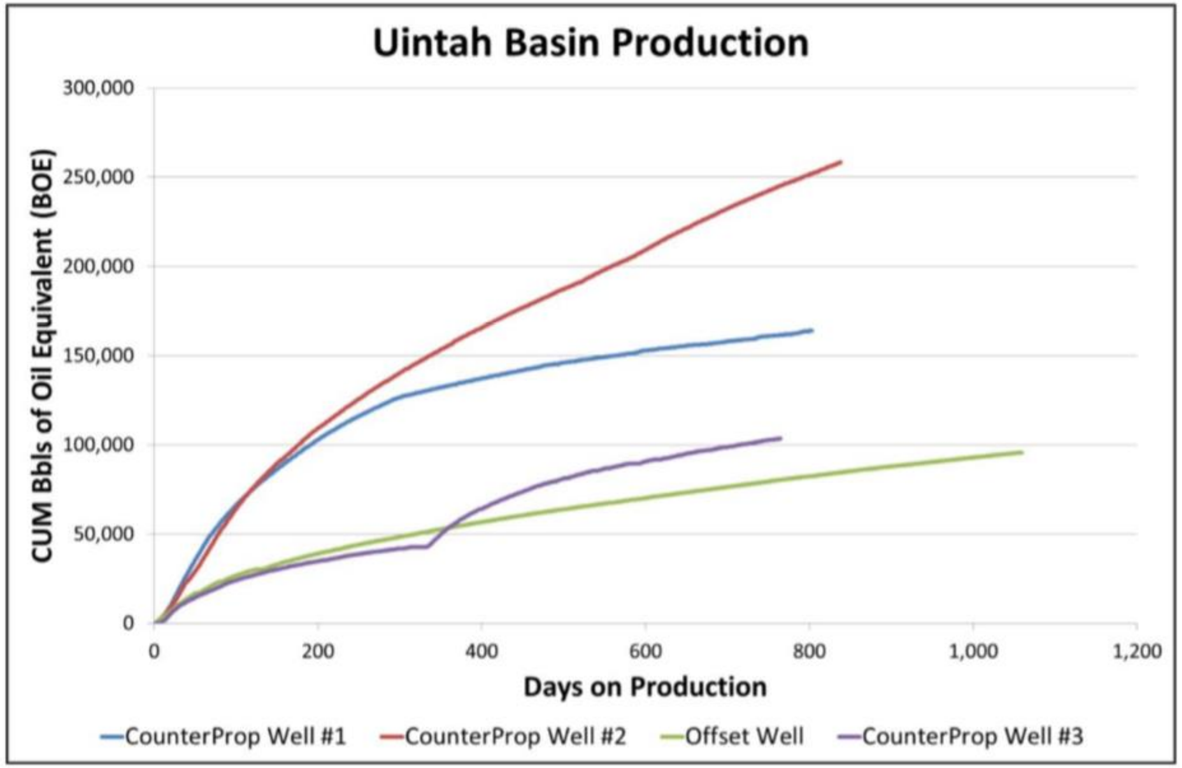


Figure 5—Uintah Basin Production
Comparison of Three CounterProp Wells and One Offset Well

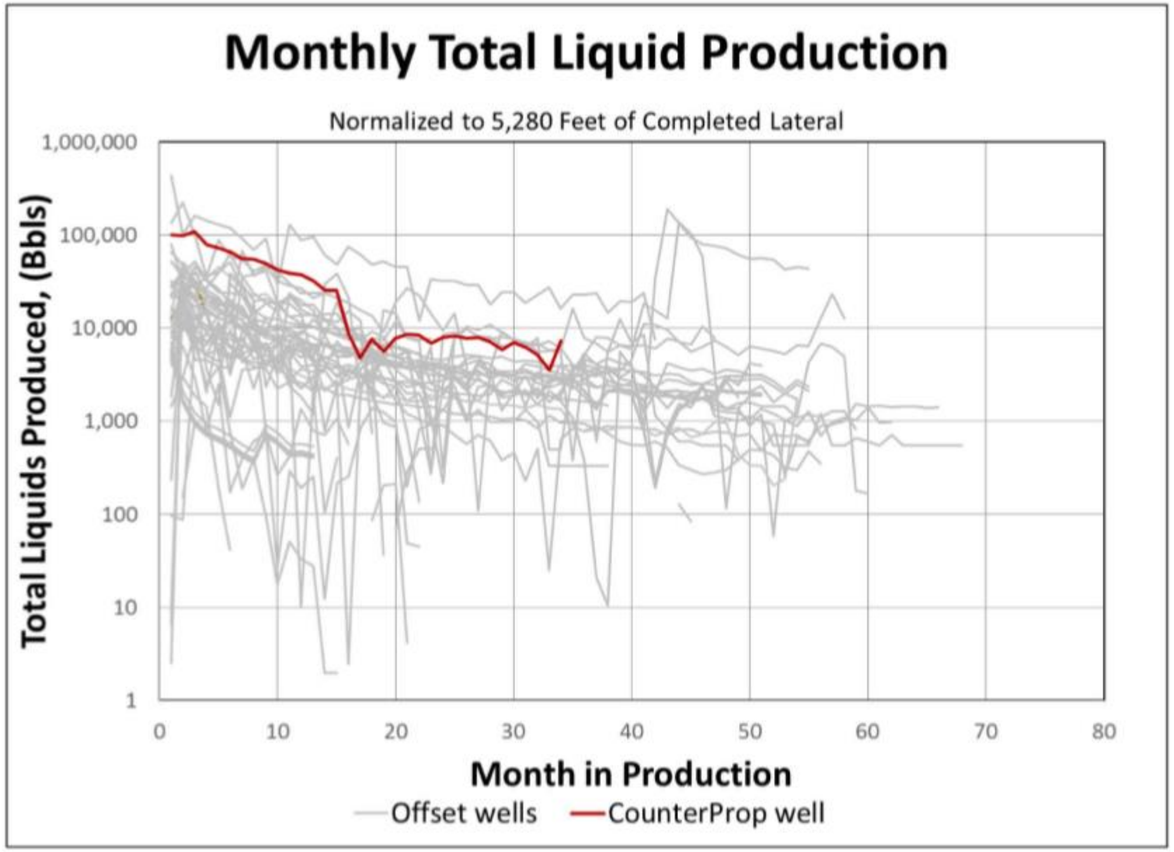


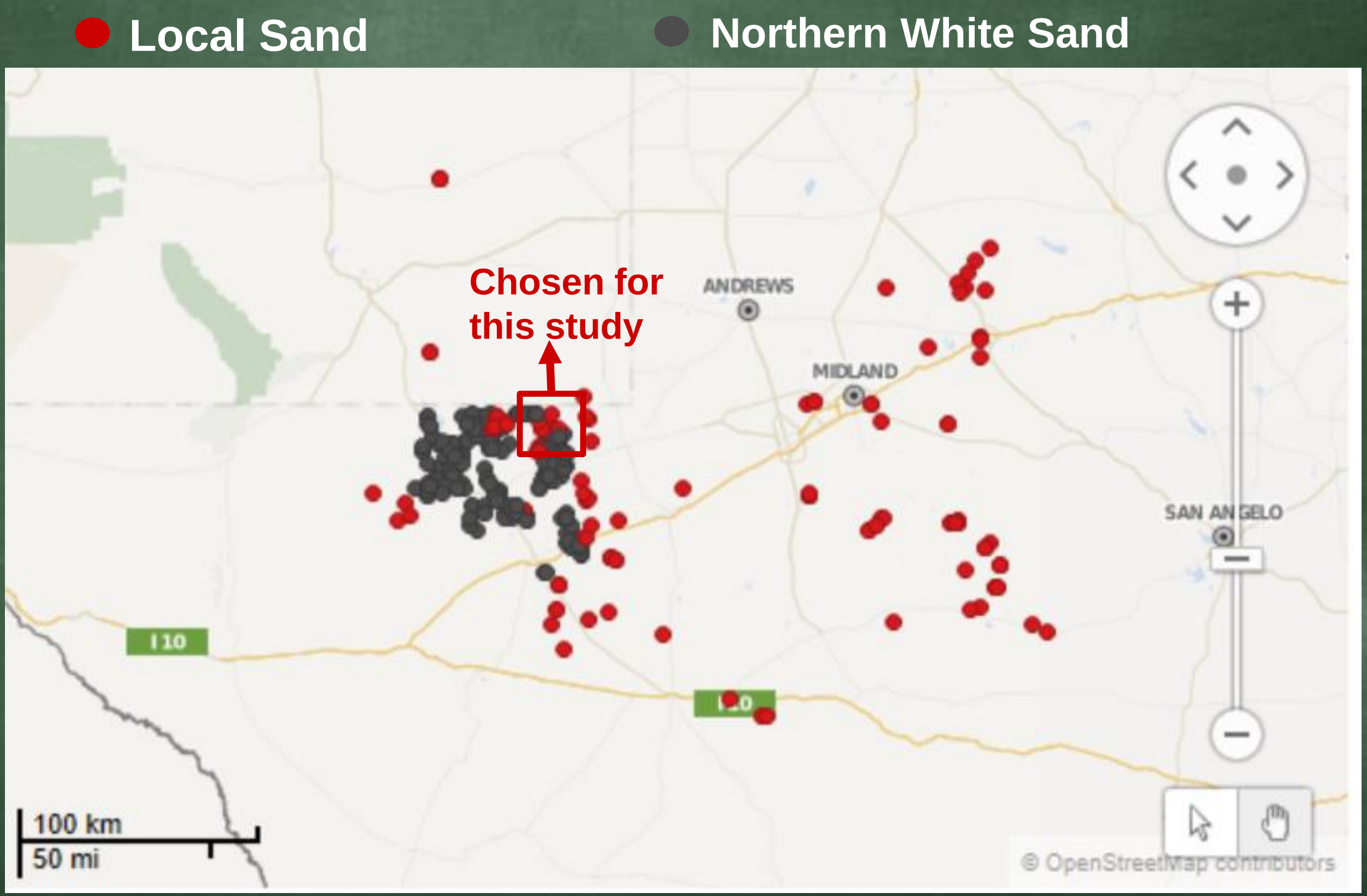
Figure 10—Eagle Ford Production Comparison

Permian Basin Wells with 100 Mesh Local Sand or Northern White

Northern White and Texas Sand Used for Analysis

Constraints/filters: Filter for wells with Northern White 100 mesh or Texas Sand 100 mesh as primary proppant for jobs after June 2017 (Source: FracFocus and DrillingInfo)

Results: A specific geographic region was chosen so that both proppants are represented in the region



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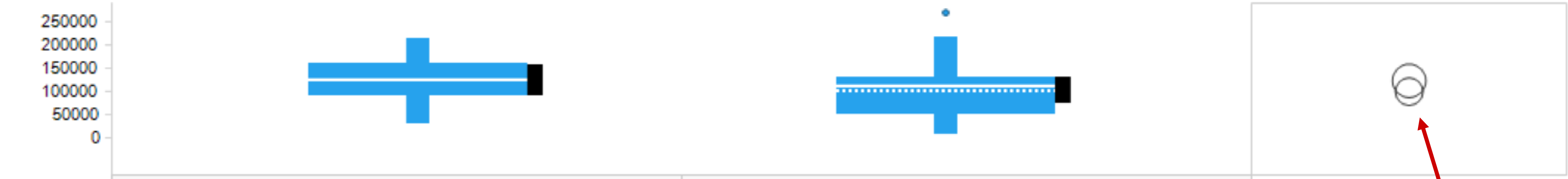
Similar 6-month Cumulative Production using 100-Mesh Local vs. Northern White

Cumulative BOE

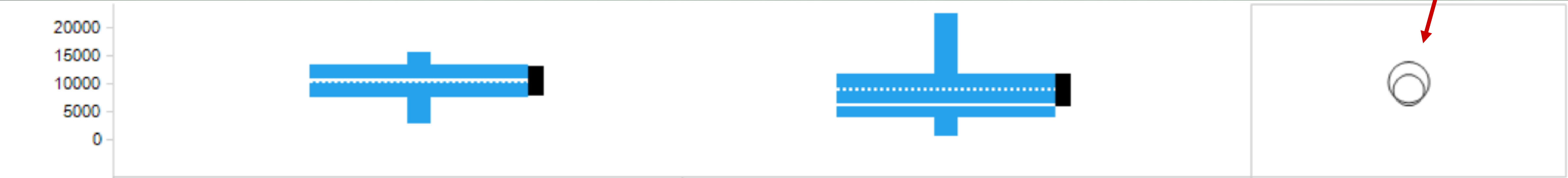


	Texas Sand 100 Mesh	Northern White Sand 100 Mesh
Count	13	19
Avg ▶	122.66k	100.74k
Median	121.52k	108.39k
Outliers	0	1

Alpha level = 0.05

Overlap in circles indicate group means are not significantly different

Cumulative BOE Normalized to Proppant Mass



	Texas Sand 100 Mesh	Northern White Sand 100 Mesh
Count	11	19
Avg ▶	10.34k	8.84k
Median	10.68k	6.25k
Outliers	0	0

Alpha level = 0.05
Root MSE = 5923.643
sqrt(2)q* = 2.897

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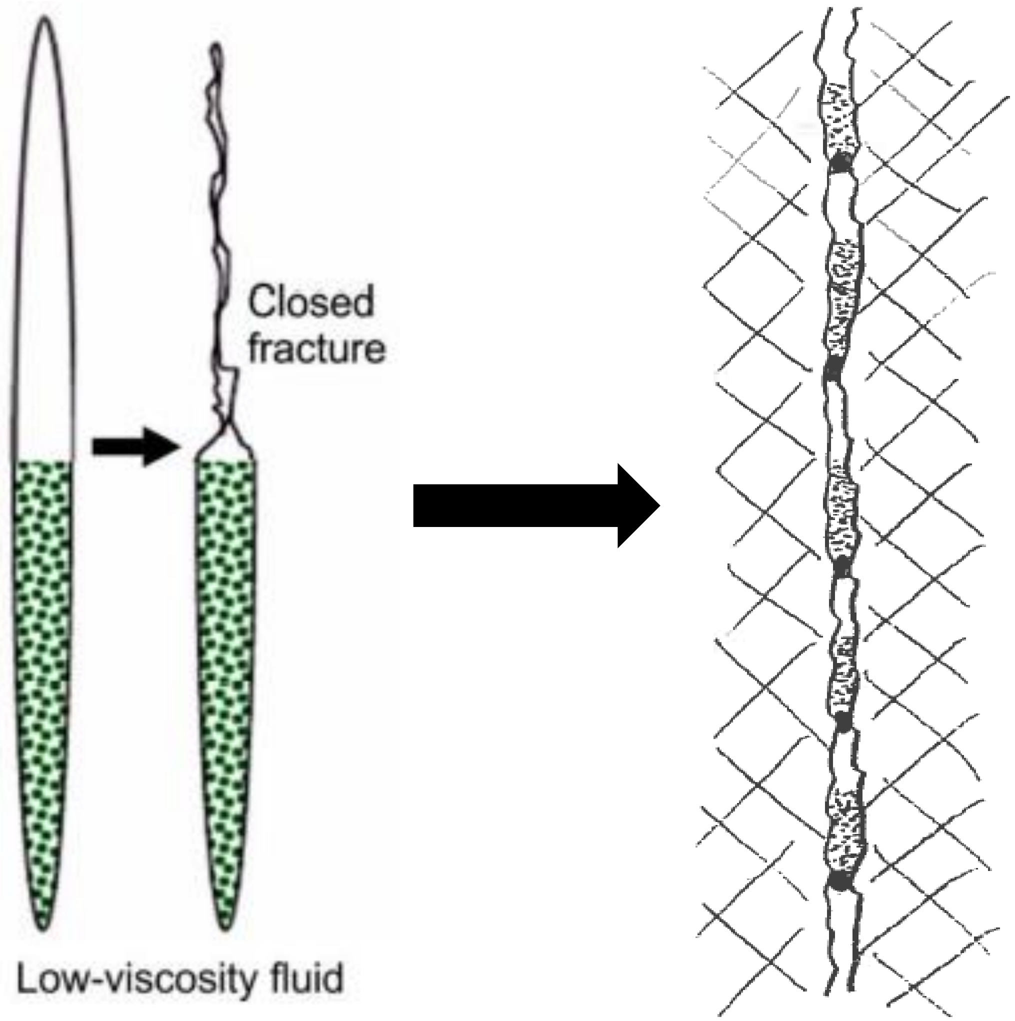
What need to be done?

- Taking advantages of:
  - Slickwater fracturing fluid
  - Narrow gap of dominant fracture width (i.e., < 1/8”, more likely <1/16”)
  - Roughness of fracture faces – existence of ridges, bumps, provides pinch-points along fracture height and length
  - A combination of settling effect and sand distribution enhancer



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Conclusion

- Local sands are here to stay

THANK YOU