Energized and Foam Fracturing Fluids for Liquids-Rich Organic Shale Reservoirs*

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Abstract

The majority of liquids-rich play fracs employ either slick water, linear gels, or crosslinked gels. In this article we discuss potential-productivity improvements from the use of energized fluids in these plays. Energized fluids also reduce water consumption and disposal requirements. Slick water has low viscosity and does not provide effective transport of proppant into the fracture when pay zones are thicker than the limited propped bed height. Vertical well 3D frac model simulations in organic shale plays indicate little variation in propped height with job volume, suggesting that a limit is approached. With gelled fluids, the propped heights typically improve. However, gel damage can negate the improved vertical coverage in low-water saturation reservoirs. Energized fluids can provide increased effective viscosity for improved proppant transport. They also significantly reduce gel volumes (or even completely eliminate them if a gel-free foam is used) and capillary phase trapping. In current practice, energized frac fluids are generally employed in underpressured dry gas reservoirs. This is based on the understanding that water can easily enter reservoir pores, and will be held there by capillary forces that the low-pressured natural gas of the reservoir cannot overcome alone. Due to N_2 or CO_2 present in an energized fluid, once pressure is released the fluid will rapidly come to the surface regardless of reservoir pressure. On the other hand, in normally and overpressured reservoirs, and especially in liquids-rich reservoirs, energized fluids are infrequently used vs slickwater and gel fracs. This approach is based on the ability of oil-wet surfaces to resist the entry of water into pores, and of normally or overpressured reservoir hydrocarbons to drive water out. However, there are limitations that can reduce productivity: (1) A large fraction of reservoir porosity may not be oil-wet and will take up water. For example, in the Marcellus shale, slickwater load recovery is often 20% or less. (2) If fracturing pressures are sufficiently high, water may be driven into pores where it is too strongly held to be driven out by reservoir pressure. The complex stress regime in horizontal well fracs results in fracture pumping pressures that may exceed twice the reservoir pressure. When reservoir permeabilities are in the microdarcy to nanodarcy range, capillary pressures may easily reach several thousand psi (GPa range). The threshold is low enough to allow entry of high pressure frac fluid into the small pore throats but too high to allow significant flowback from these pore throats with the lower pressure from the reservoir. In this paper our main focus is on the use of energized fluid fracs that provide a higher viscosity system for improved proppant transport. This aspect is particularly relevant for liquids-rich reservoirs and has not been extensively discussed previously. Rock properties and net pay profiles have been developed for several major liquids-rich shale reservoirs in the US to estimate proppant placement relative to the net pay using 3D hydraulic fracture simulators. A

comparison is made among the main fluid options for several liquids-rich shales in North America to demonstrate the benefits of energized fluids.

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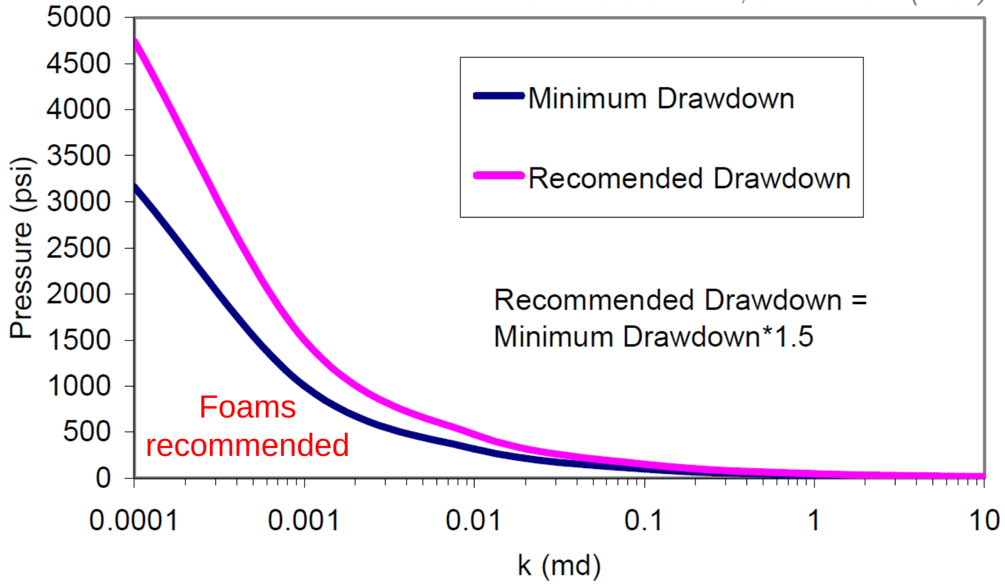
April 9, 2014

Energized & Foam Fluids in Hydraulic Fracturing

- The application of foam fluids to hydraulic fracturing of underpressured, dry gas wells is well known
  - Rapid clean-up
  - Reduced phase-trapping risk
  - Reduced water consumption

Friehauf and Sharma, SPE 124361 (2009)



- Should we recommend foams for liquids-rich, deeper, higher-pressured reservoirs?

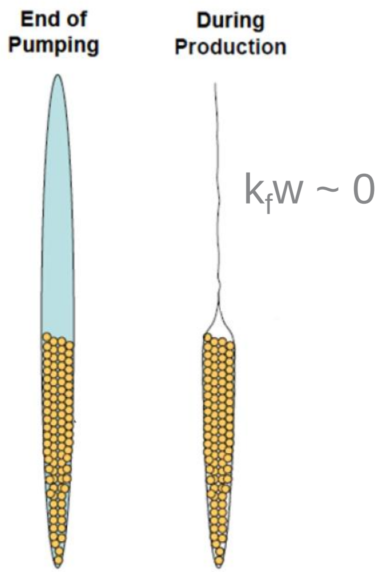
Expected benefits of foams in liquids-rich reservoirs

- Faster, easier clean-up
- Reduced phase-trapping of water
- Reduced gel damage
- Reduced damage in smectite-rich reservoirs
- Reduced embedment
- Improved proppant placement

In this presentation, we focus on proppant placement, using commercial software to examine whether expected benefits of foams are achievable

Examples in this presentation: Eagle Ford and Utica Shales

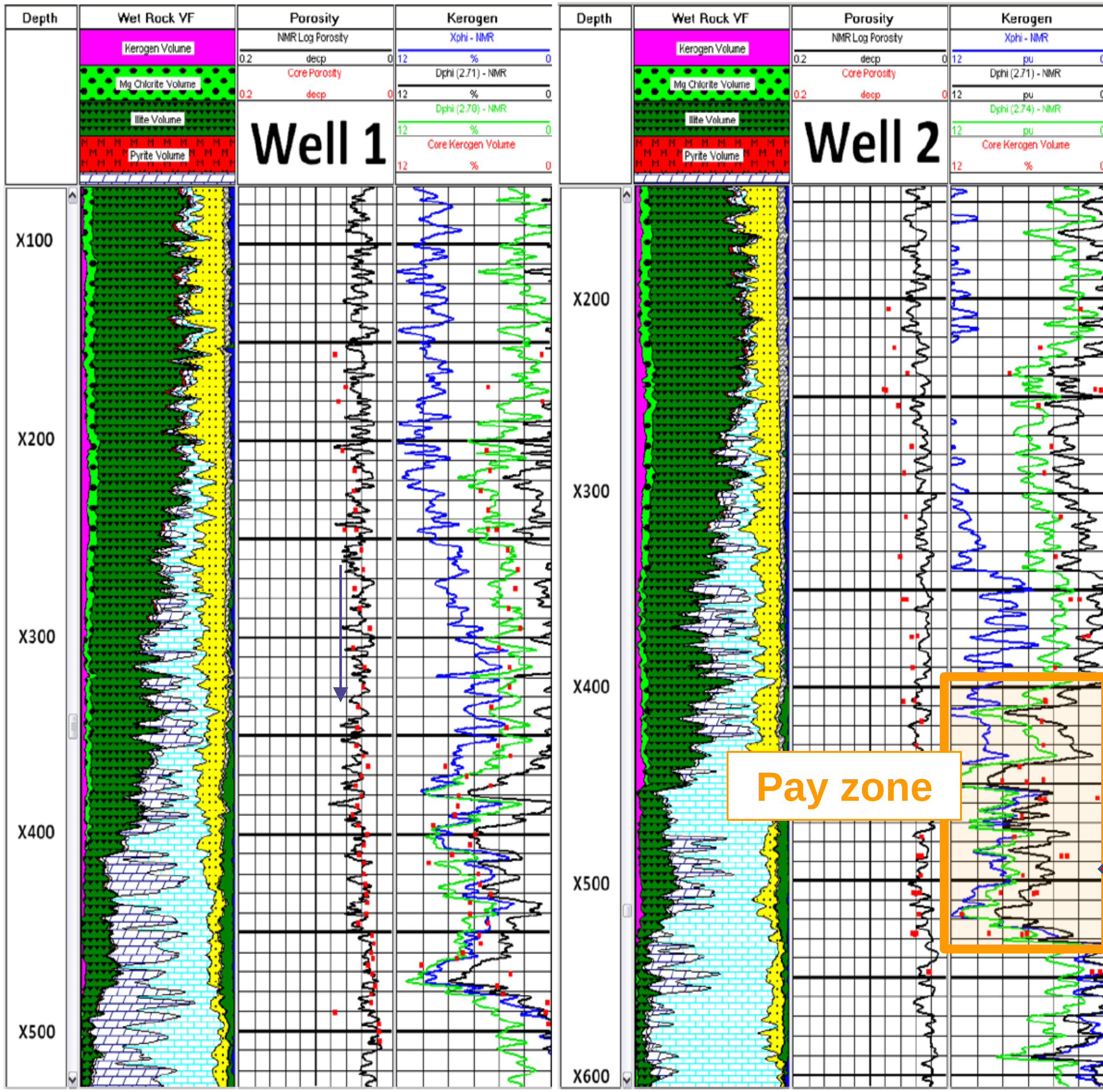
- Both are of current interest, liquids-rich and deep
  - Utica case ~ 6000 ft
  - Eagle Ford case ~ 14000 ft
- Reservoir properties required for simulation are available
- In both cases, reservoir rock is reported to be relatively ductile
  - Thus the assumption that unpropped height closes with zero conductivity seems reasonable
  - This assumption is probably incorrect for high-brittleness reservoirs (e.g., Barnett)
- For comparison purposes, we used identical total volumes and pumping schedules for all fluids; this would not be done in practice



Modified from Warpinski, SPE119350, 2009

Fracture Height Optimization: Utica Case

Logs From SPE 165682
Murphy et al..



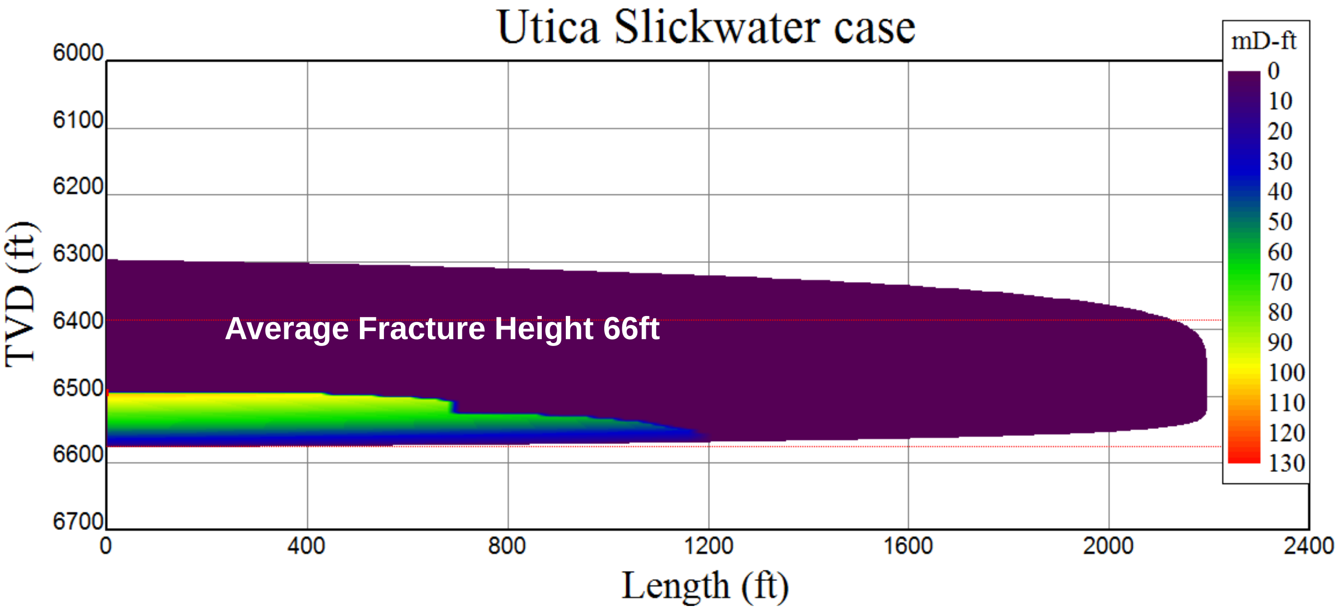
Parameter selection target = fully propped pay zone

6390 ft

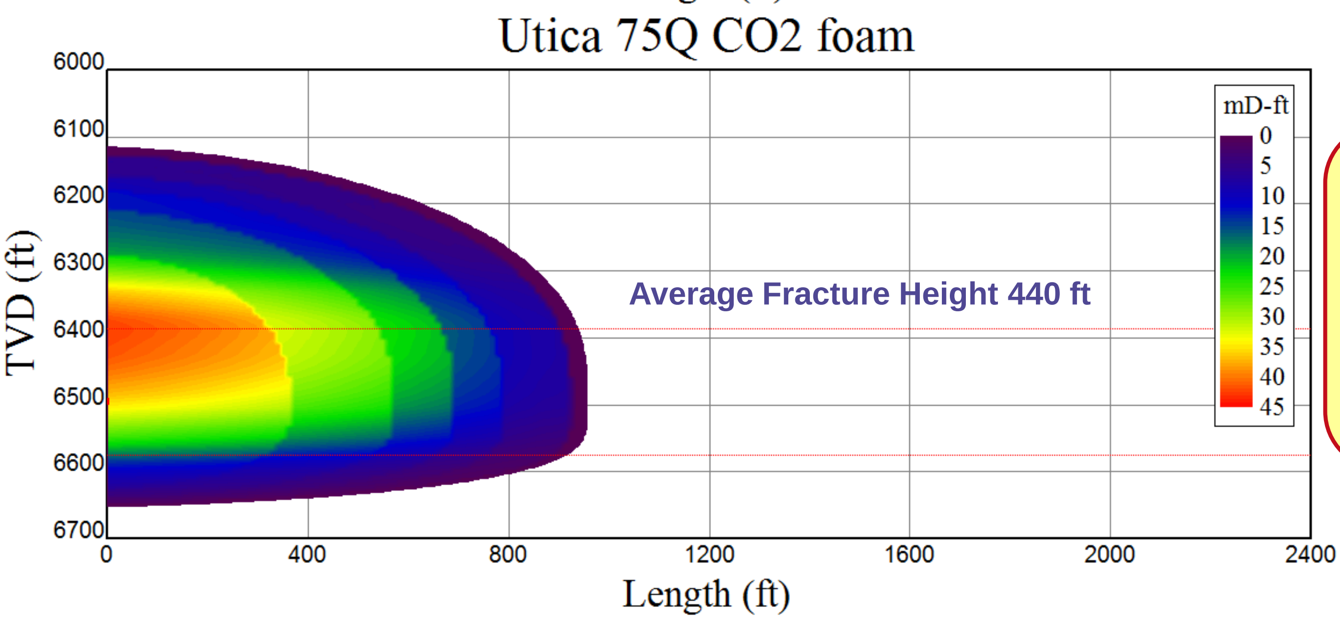
Perforation: 6490 – 6500 ft

6575 ft

Utica Case: Proppant Placement Slickwater vs. CO_2 foam

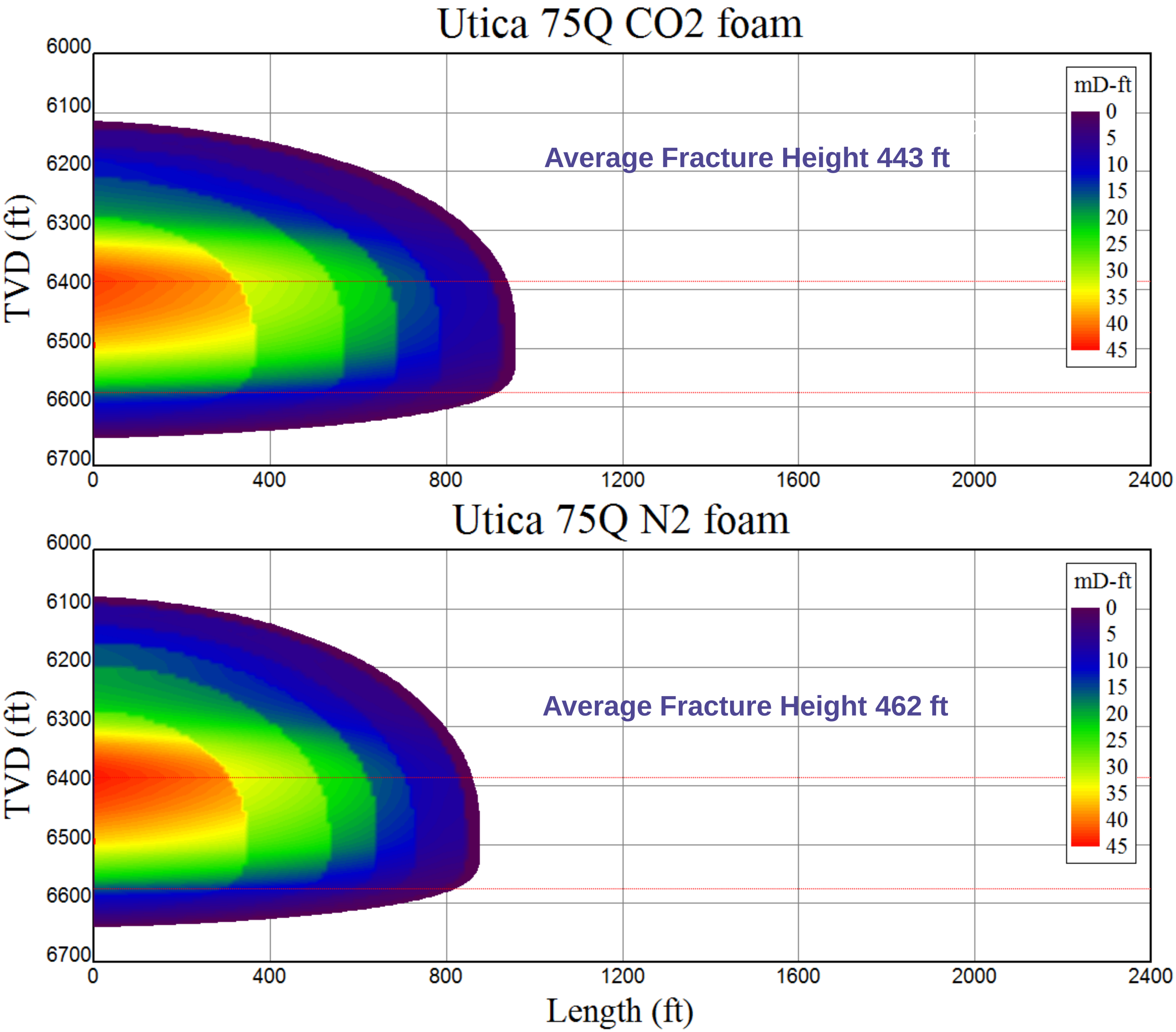


MFRAC simulation assuming convective proppant settling



Slickwater provides a longer fracture but does not deliver proppant over much of length and height

Utica Case: N_2 vs CO_2 foam



CO_2 and N_2 foams provide very similar proppant placement

Utica Case fracture dimensions

	Slickwater	CO_2 foam	N_2 foam
Avg propped height (pay zone) (ft)	60	189	189
Avg propped width (pay zone) (in)	0.07	0.06	0.06
Frac height-average(ft)	66	443	462
Frac length-created (ft)	2196	959	878
Frac length-propped (ft)	1174	791	731

Slickwater: Propped height **<** pay zone height

Foams: Propped height **>** pay zone height

Fluid consumption and pump requirements: Utica Case

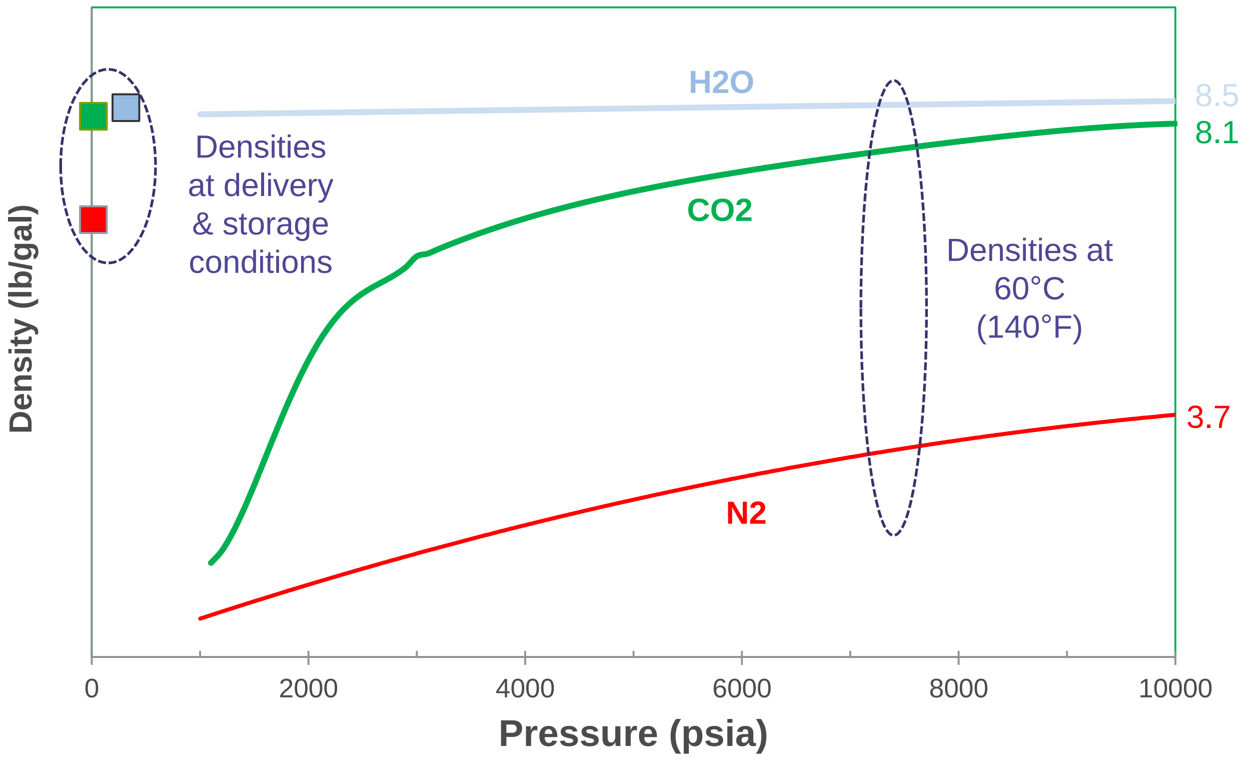
Consumption	Slickwater	CO_2 foam	N_2 foam
Proppant (lbs)	3.0E05	3.0E05	3.0E05
Total Water (gallons)	156,300	47,545	47,545
CO_2 or N_2 (US tons)	NA	340	149
CO_2 or N_2 Surface Volume (gallons)	NA	80,300	44,200
Surface pressure (psi)	3200	3800	4600

70% Reduction in water consumption with foams

N_2 requires more surface pressure but less storage than slickwater or CO_2 foam

Note: Consumption estimates above do not account for differences in leakoff effects, solubility, or cool-down requirements

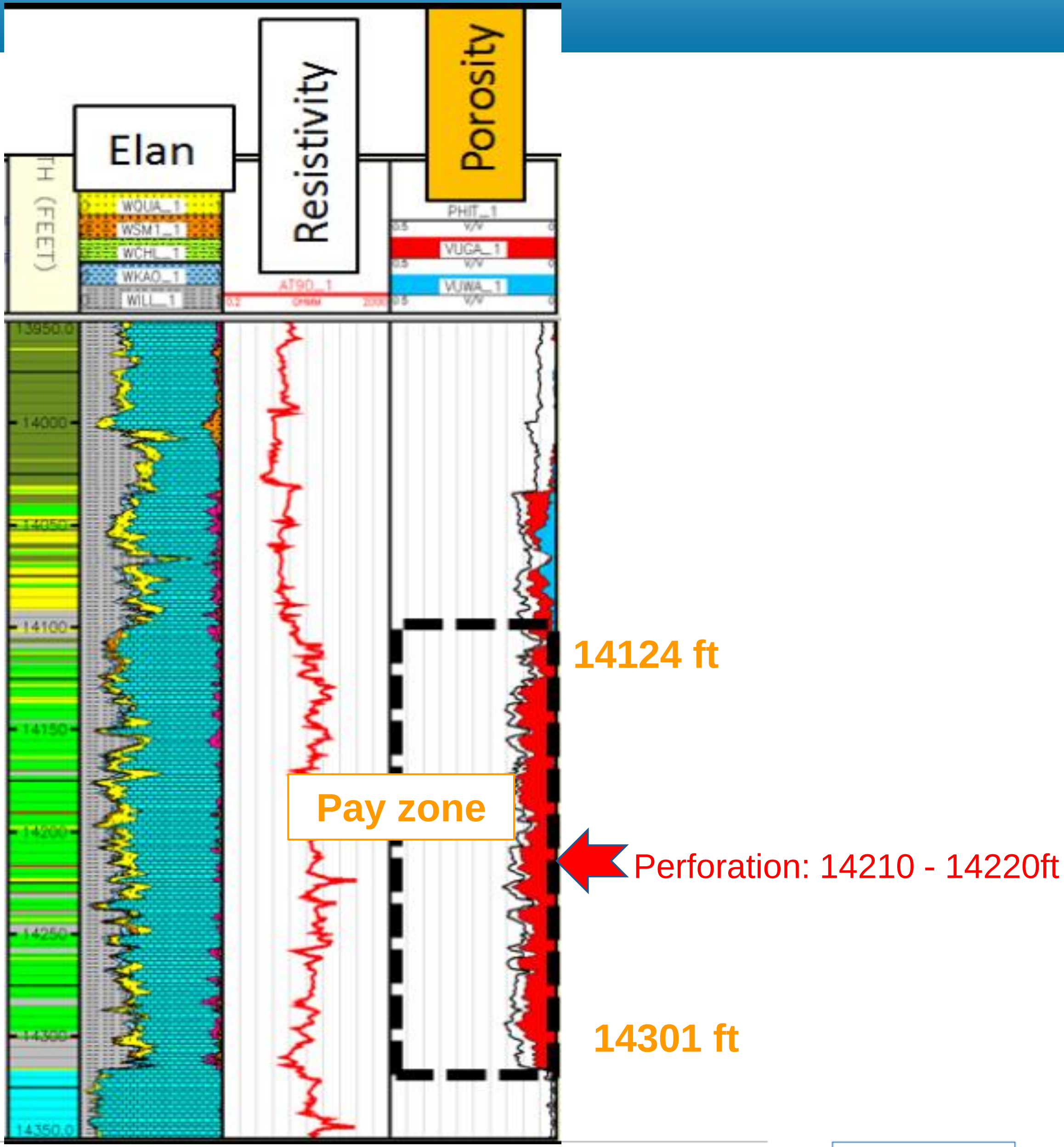
Less N_2 storage is needed due to density difference



Equivalent down-hole volumes translate to a lower N_2 volume at the surface

Eagle Ford Case

Log from Urtec 1581853
Bello et al.



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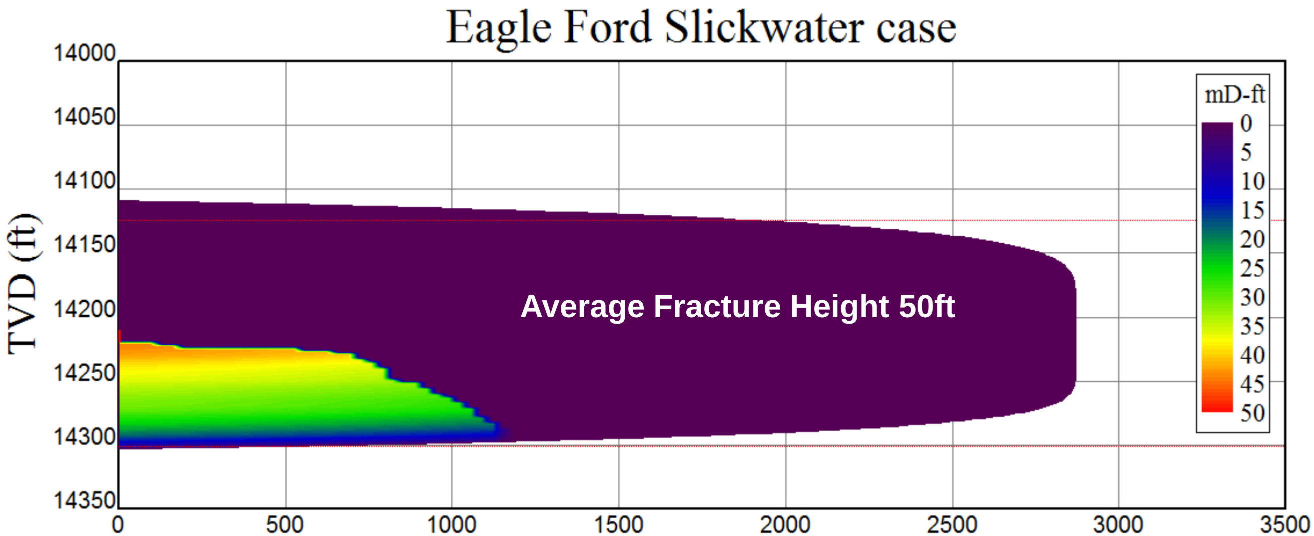
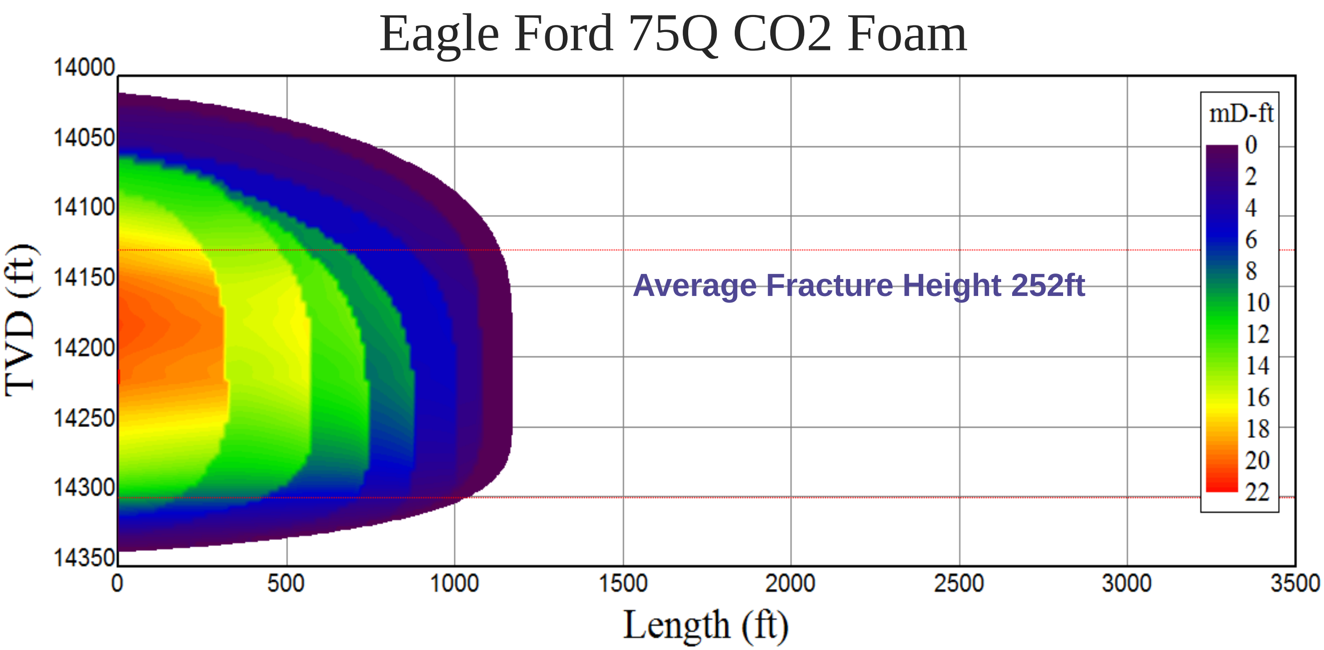
Proppant Placement: Eagle Ford example





Slickwater provides a longer fracture but does not deliver proppant over much of length and height

Eagle Ford fracture geometry

	Slickwater	CO_2 foam	N_2 foam
Average propped height (pay zone) (ft)	57	175	170
Average propped width (pay zone) (in)	0.07	0.08	0.09
Frac height-average(ft)	50	252	222
Frac length-created (ft)	2874	1173	1243
Frac length-propped (ft)	1127	1004	986

Slickwater: Propped height **<** pay zone height

Foams: Propped height **>** pay zone height

Fluid Consumption and pump requirements: Eagle Ford case

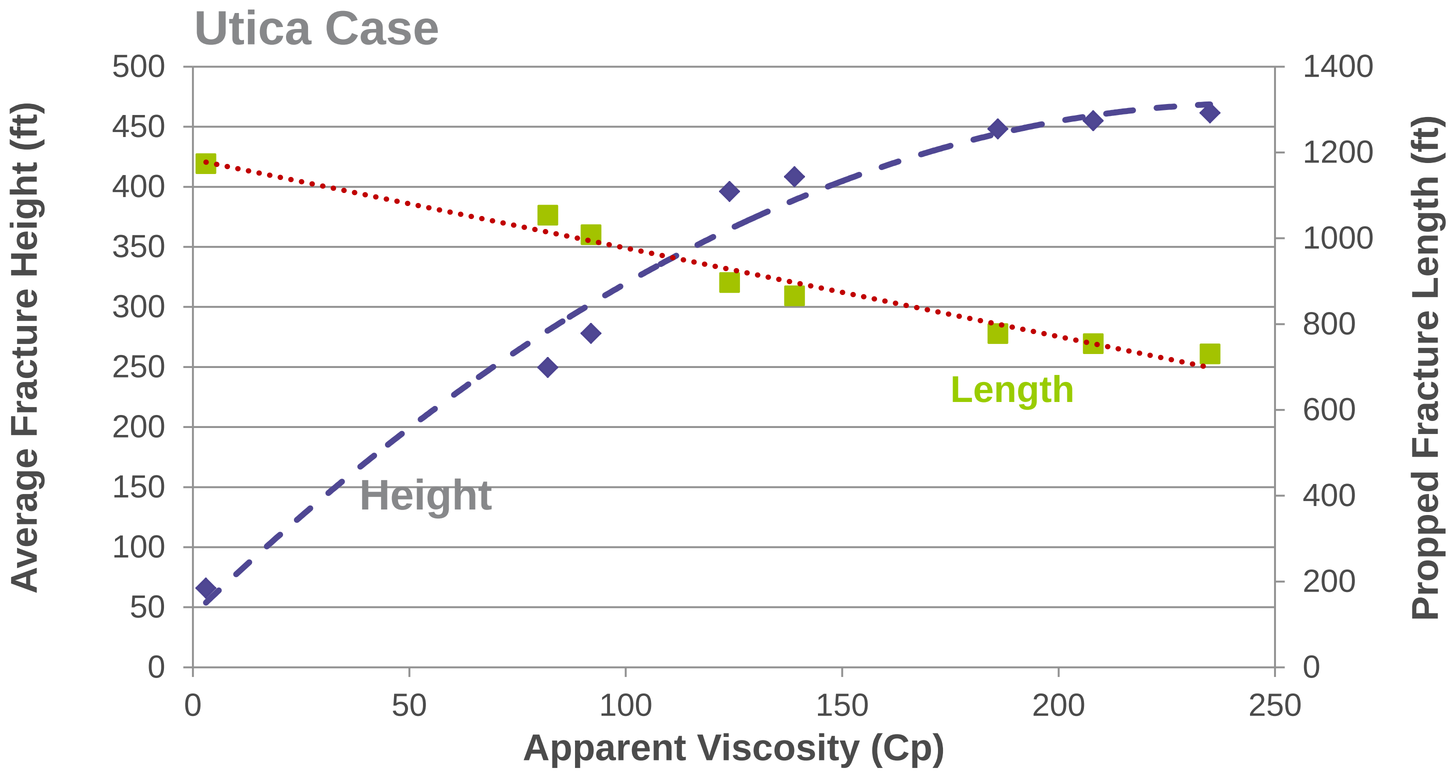
Consumption	Slickwater	CO_2 foam	N_2 foam
Proppant (lbs)	3.0E05	3.0E05	3.0E05
Total Water (gallons)	156,300	47,500	47,500
CO_2 or N_2 (US tons)	NA	500	260
CO_2 or N_2 Surface Volume (gallons)	NA	117300	75800
Surface pressure (psi)	8400	9100	10000

70% Reduction in water consumption with foams

N_2 requires more surface pressure but less storage than Slickwater or CO_2 foam

Note: Consumption estimates above do not account for differences in leakoff effects, solubility or cool-down requirements

Viscosity effect on fracture dimensions



As viscosity is increased, improvement in propped height decreases while there is a continuous decay in length

Summary & Conclusions

- Simulations confirm expected benefits of foams for proppant placement
  - Viscosity can be optimized to give desired propped height while maximizing fracture length
- 70% reduction in water consumption using 75Q foams
  - Does not include additional reduction due to leakoff effects
- CO_2 and N_2 show similar proppant placement performance
  - N_2 foams require less surface storage but higher surface pressure than CO_2 foams or slickwater
- Use of foam fracs in deep shales (14000 ft) appears feasible

Research & Development

Opening new ways

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