New Technologies in the Development of Unconventional Resources in the U.S.*

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Abstract

Unconventional plays have become successful due to the implementation of new technologies, which include new methods for exploring for preferentially enriched (and exploitable) horizontal drilling, hydraulic fracturing, innovative proppants, specially formulated drilling and fracturing fluids, and analytics. With capital expenditures slated to rise 20% in 2018 among U.S. shale producers, the need is greater than ever for excellent decision-making tools, knowledge, and information.

Implications:

Alternative ways to pay for operations: Debt and equity financing are expensive, and you may lose control of your destiny.

Opportunities emerge in times of acreage optimization: Financing the 20% increase in capital expenditure by selling non-core assets can be effective. It also creates an opportunity for other companies to launch new initiatives.

Optimizing Operations: Efficiency, cost-cutting, and economies of scale are key factors.

Geology More Critical Than Ever: One must understand the reservoir very well in order to drill and complete efficiently. Geology is critical, and it needs to be integrated with other information.

Optimizing Experience via the "Pure Play": Pure Plays are efficient, and they allow operators to take advantage of their specialized knowledge and experience. But, they are not diversified, and there are vulnerabilities that have to do with being concentrated in a single play.

Avoiding the technology "stand-alone" mindset: Knowing where and when to deploy new technologies can make all the difference in recovering more hydrocarbons, and also minimizing costs. Clear workflows need to be developed with the understanding that new technologies are not "stand-alones" and must be incorporated carefully.

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NEW TECHNOLOGIES IN DEVELOPMENT OF UNCONVENTIONAL RESOURCES IN THE U.S.

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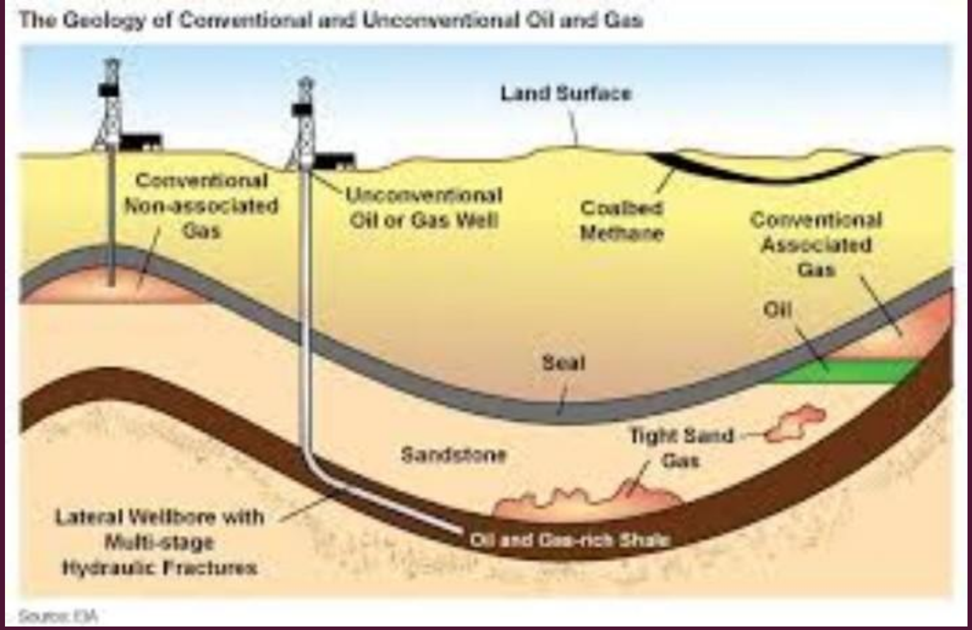
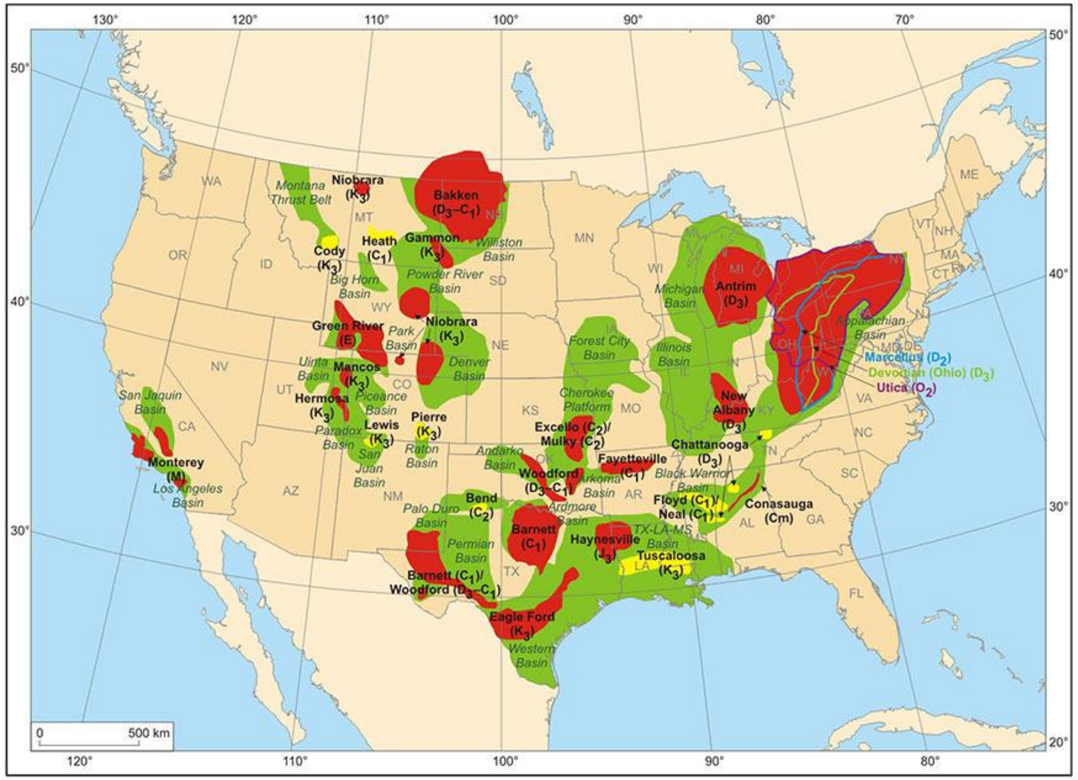


TYPES OF UNCONVENTIONAL PLAYS

- Low permeability oil
- Tight gas sands
- Gas shale
- Oil sands and heavy oil
- Coalbed methane
- Oil shale
- Gas hydrates



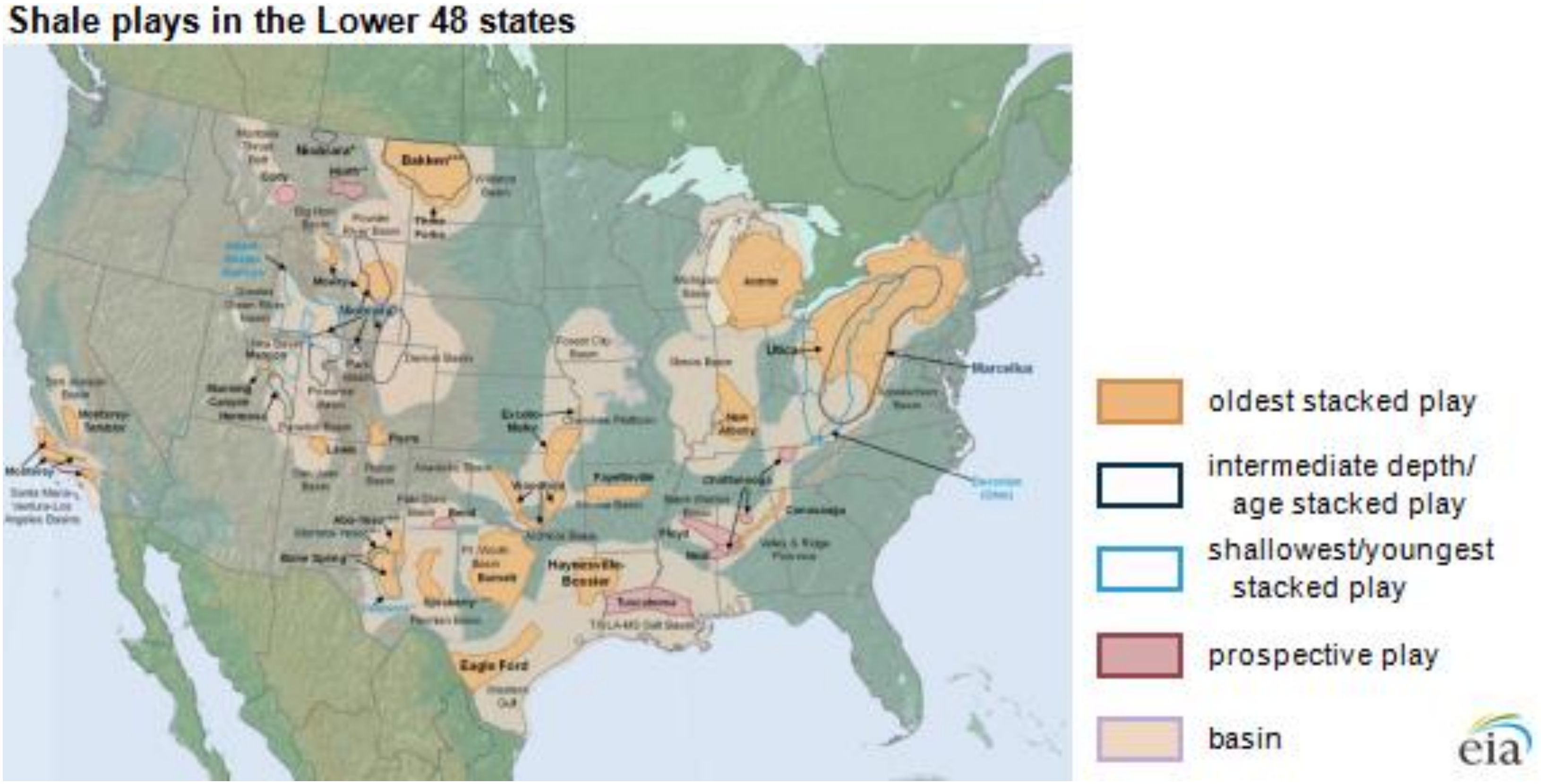
currently exploited shale formations

shale gas perspective area

sedimentary basins

SUCCESSFUL UNCONVENTIONAL PLAYS

- Woodford
- Eagle Ford
- Meramec
- Marcellus
- Bakken
- Haynesville
- Wolfcamp
- Link to map



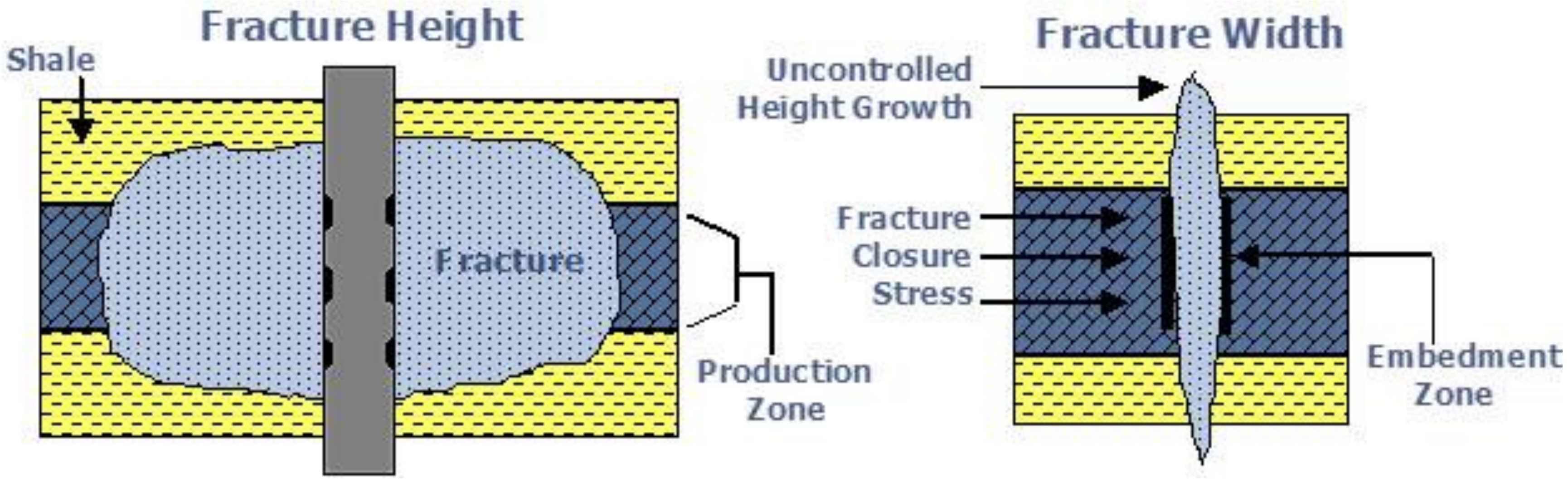
WORKFLOWS & NEW TECHNOLOGIES

- For optimal results, incorporate new technologies in the workflows
- New technologies are never "stand-alones"

Example: Using drones
and robotics for site development and inspections

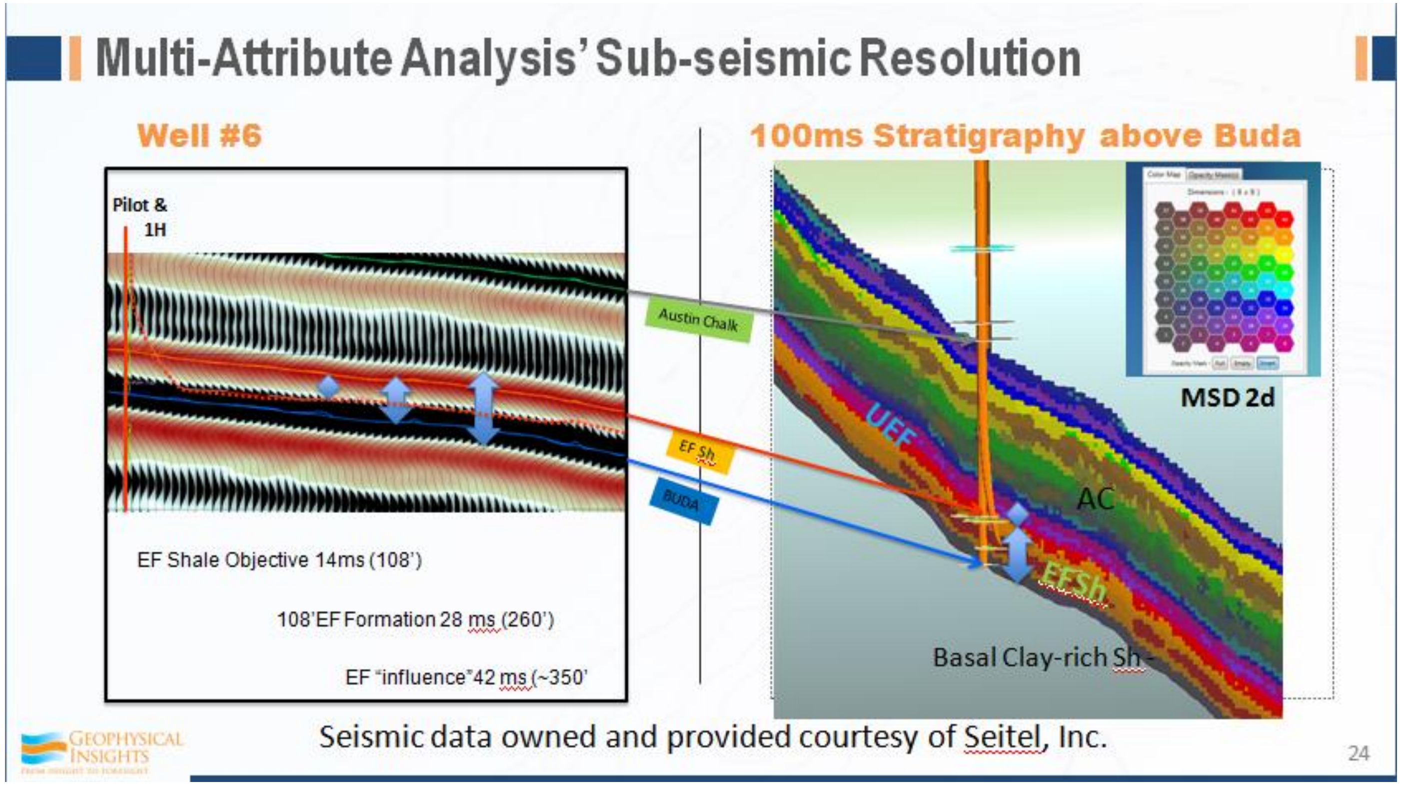
METHODS: EXPLORATION PHASE

- Petroleum Systems and Regional Geology
- Sequence Stratigraphy
- Core Analysis and Petrophysics
- Geochemistry
- (TOC)
- Seismic Survey
- Kerogen Typing



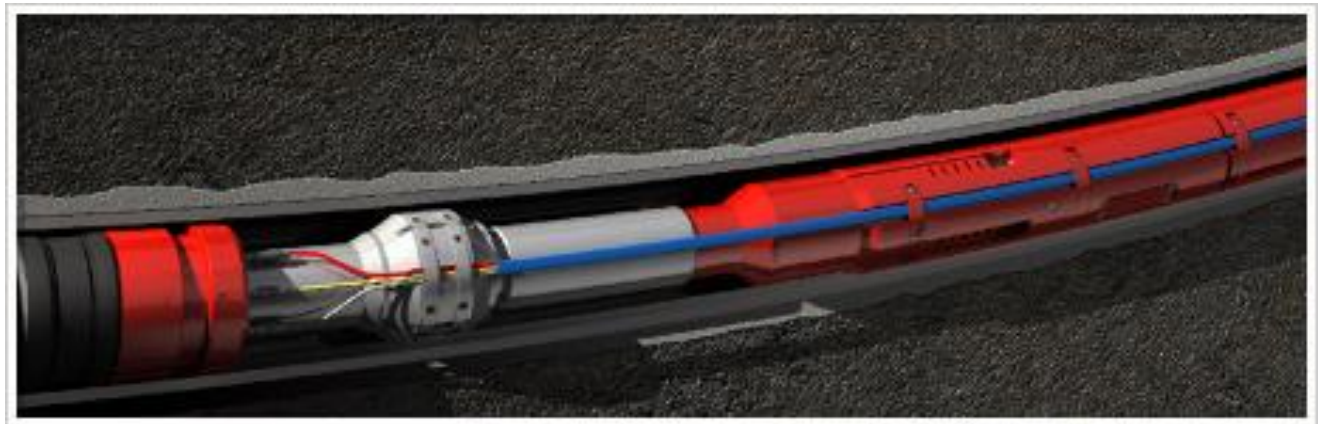
METHODS: EVALUATION PHASE

- Core analysis (pore architecture / fracture typing)
- Wireline logging / petrophysics
- Seismic attributes (ex. Paradise)
- Seismic inversion



METHODS: DRILLING & COMPLETION PHASE

- Horizontal and vertical wells
- Geosteering
- Well placement
- Hydraulic fracturing



Halliburton's SmartWell® system intelligent completion technology helps operators to optimize production without costly well intervention. Reliable and fit-for-purpose SmartWell systems enable operators to collect, transmit and analyze downhole data; remotely control selected reservoir zones; and maximize reservoir efficiency. http://www.halliburton.com/en-US/ps/well-dynamics/well-completions/intelligent-completions/default.page?node-id=hfqel9vs&nav=en-US_completions_public

METHODS: PRODUCTION

- Production logging
- Productive data analysis and optimization
- Analytics
- Link to DecisionSpace Unconventionals

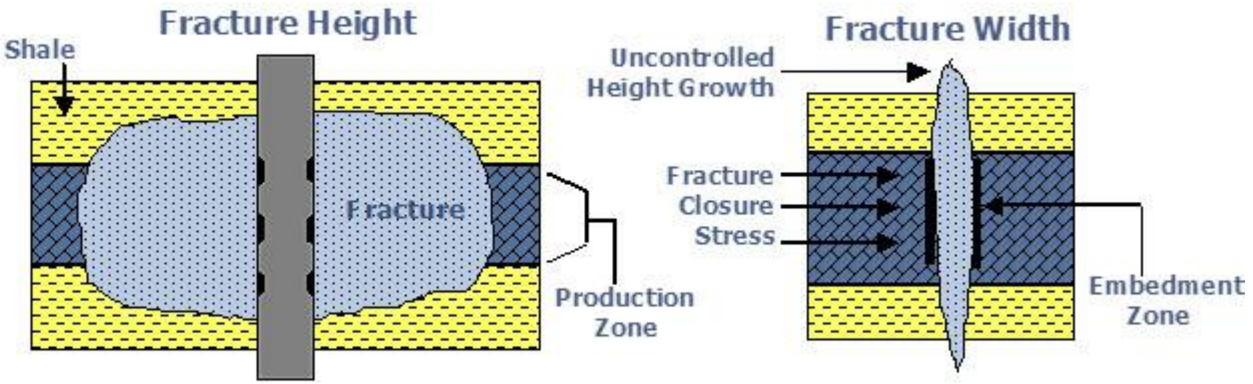
ISSUES & KEY PARAMETERS: EXPLORATION PHASE

- Total Organic Content (TOC)
- Thermal Maturity / Vitrinite Reflectance
- Adsorption
- Expulsion vs retention
- Reservoir continuity / heterogeneity
- Preferential enrichment (sweet spots)
- Seismic Attributes

ISSUES & KEY PARAMETERS: EVALUATION PHASE

- Geomechanics (Young's Modulus / Poisson's Ratio)
- Minerology and lithofacies
- Pore architecture / porosity typing
- Fracture characterization
- Stress anisotropy

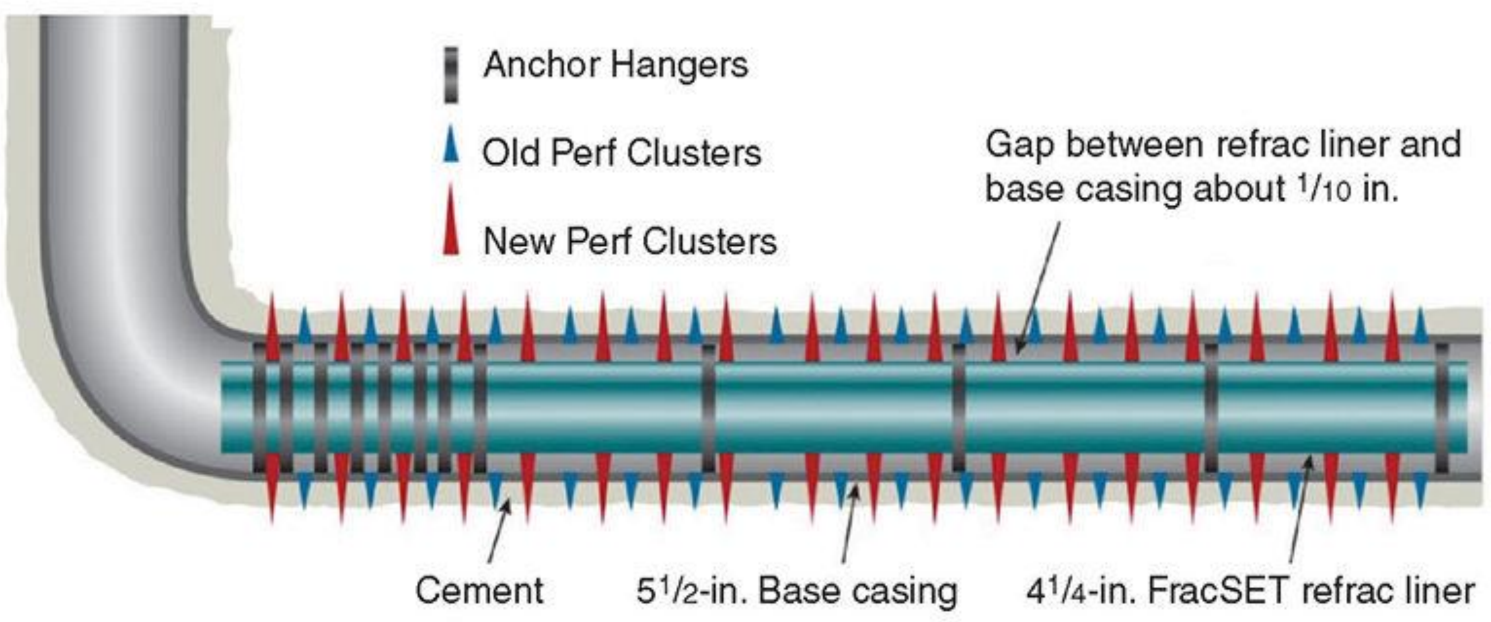
ISSUES & KEY PARAMETERS: DRILLING & COMPLETION PHASE



- Wellbore stability
- Well spacing
- Lateral length
- Proppant type and quantity
- Number of frac stages
- Perf clusters
- Fracture conductivity
- Water issues & environment

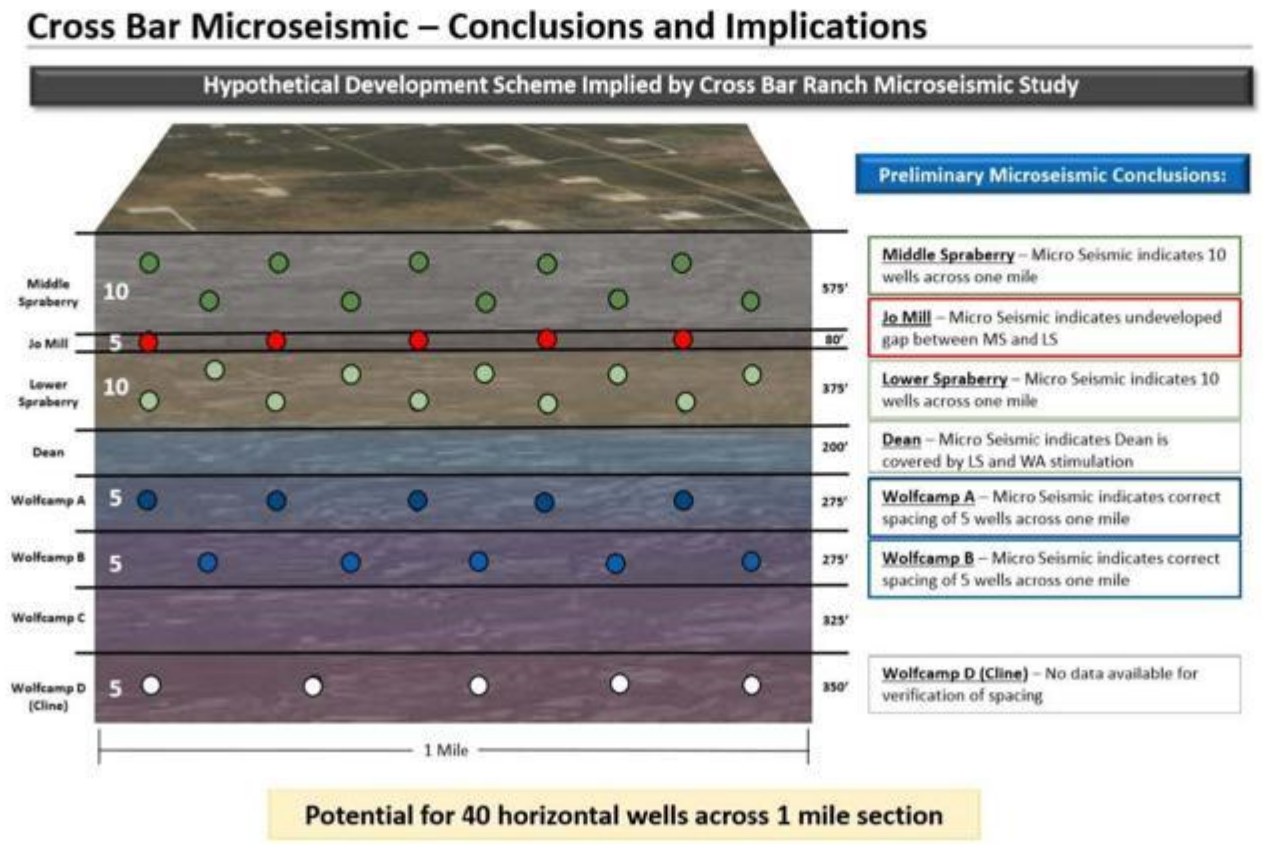
ISSUES & KEY PARAMETERS: PRODUCTION

- Simulation
- Optimization
- Refracturing
- Artificial lift
- Water management
- Flowback management
- History matching



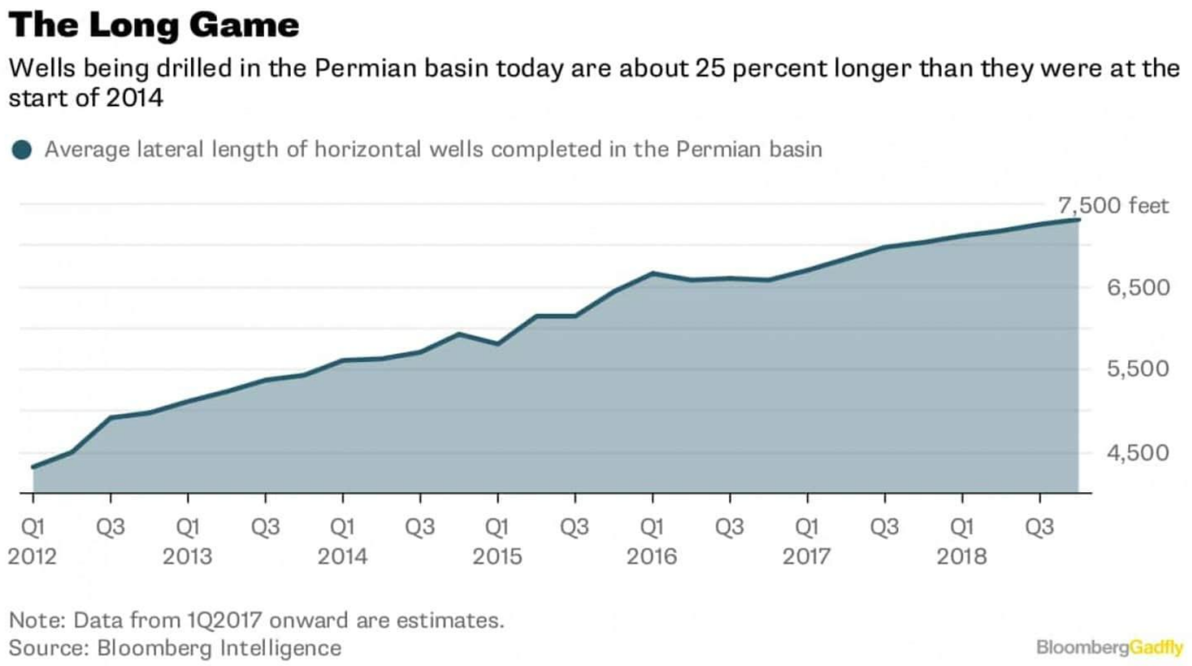
CONSIDERATIONS: WELL SPACING

- Impacts production
- Spacing developed in conjunction with reservoir quality and fracture design



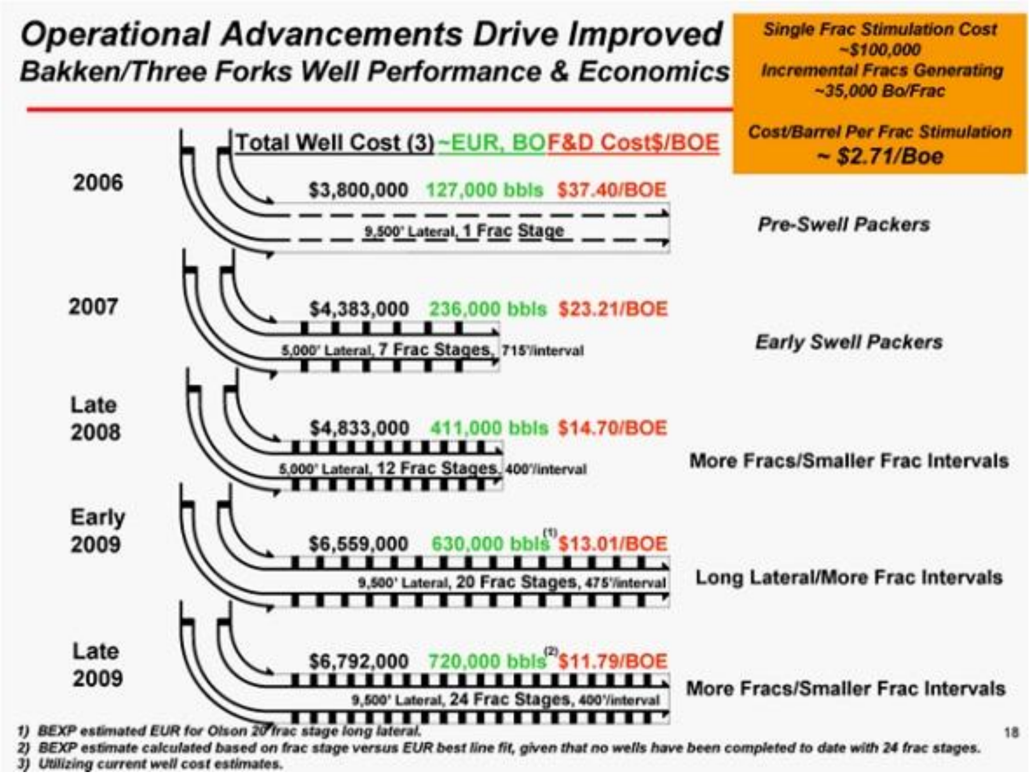
CONSIDERATIONS: LATERAL LENGTH

- Impacts the contact area between the wellbore and the formation
- A key determinant of production
- Designed in conjunction with number of stages



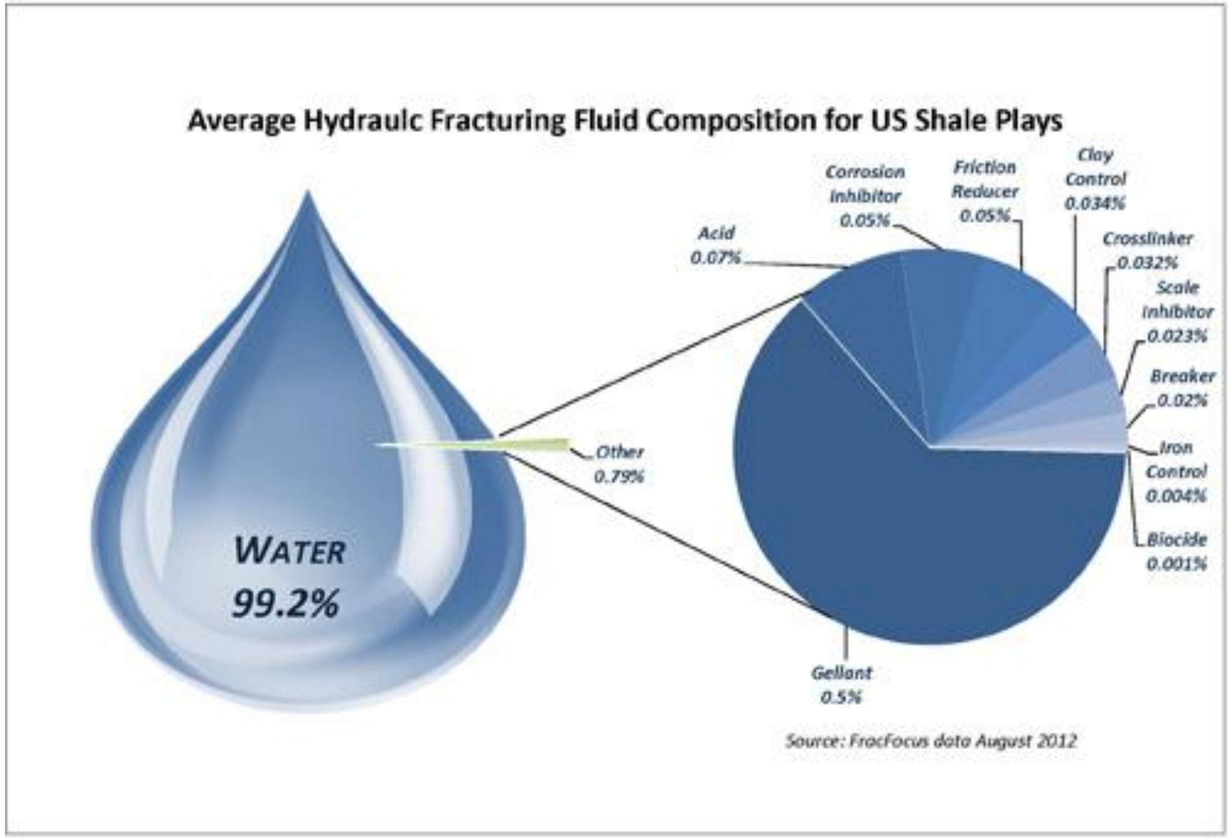
CONSIDERATIONS: FRACTURE SPACING

- Should be optimized with several variables
- Consider reservoir quality
- Completion quality
- Proppant effectiveness
- Likely frac height and propagation



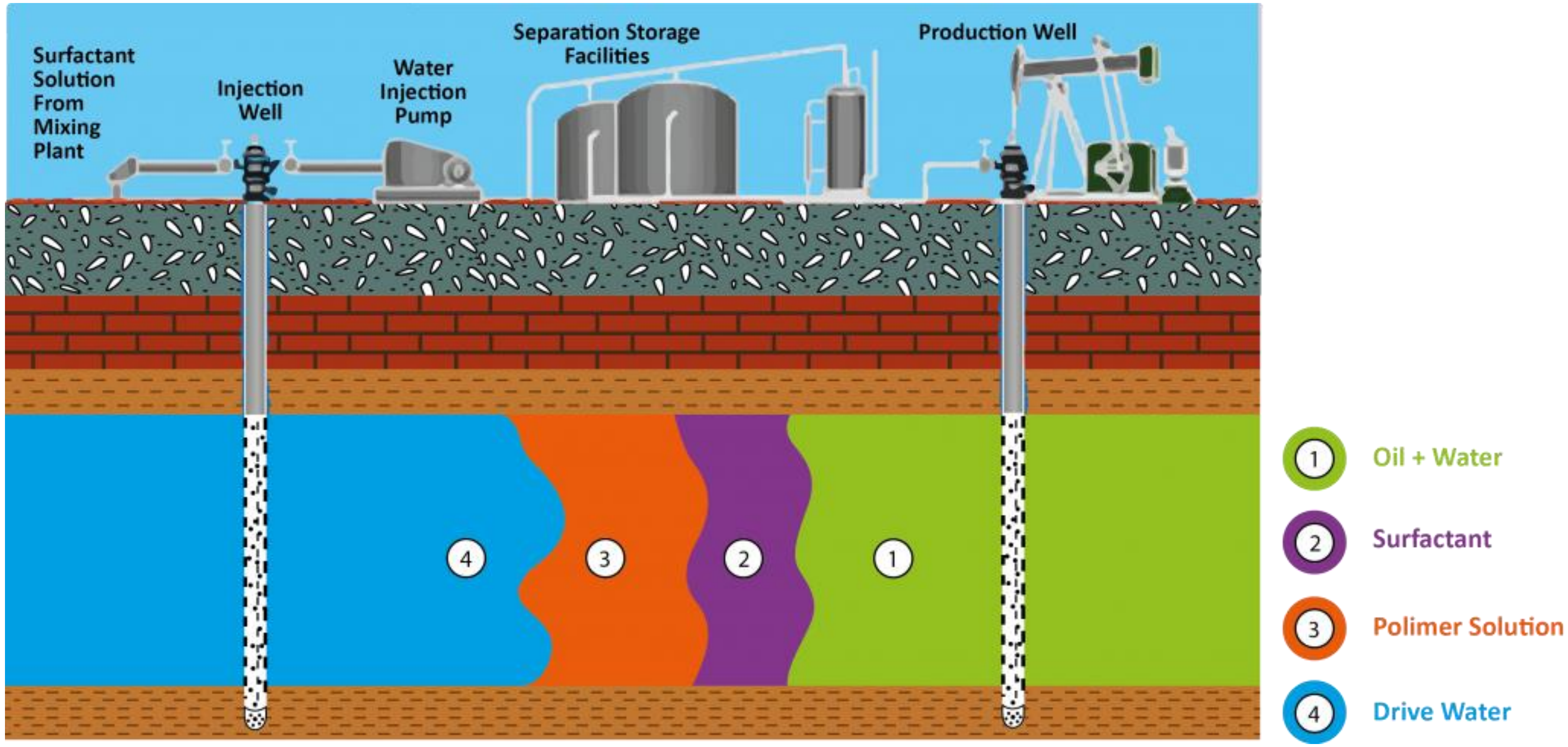
CONSIDERATIONS: FRACTURING FLUIDS

- Fluids are used to create fractures in the formation
- They carry proppant into the fractures to prop them up
- Slickwater most common
- Others: cross-linked gel, gas-assisted, hybrid fluids



CONSIDERATIONS: CHEMICAL ADDITIVES

- Friction reducer
- Oxygen scavenger
- Scale inhibitor
- Surfactants



CONSIDERATIONS: INDUCED VS NATURAL FRACTURES

- Open and closed fractures
- Fracture geometry
- Fracture complexity
- Fracture modeling to avoid frac interference (FracGeo)

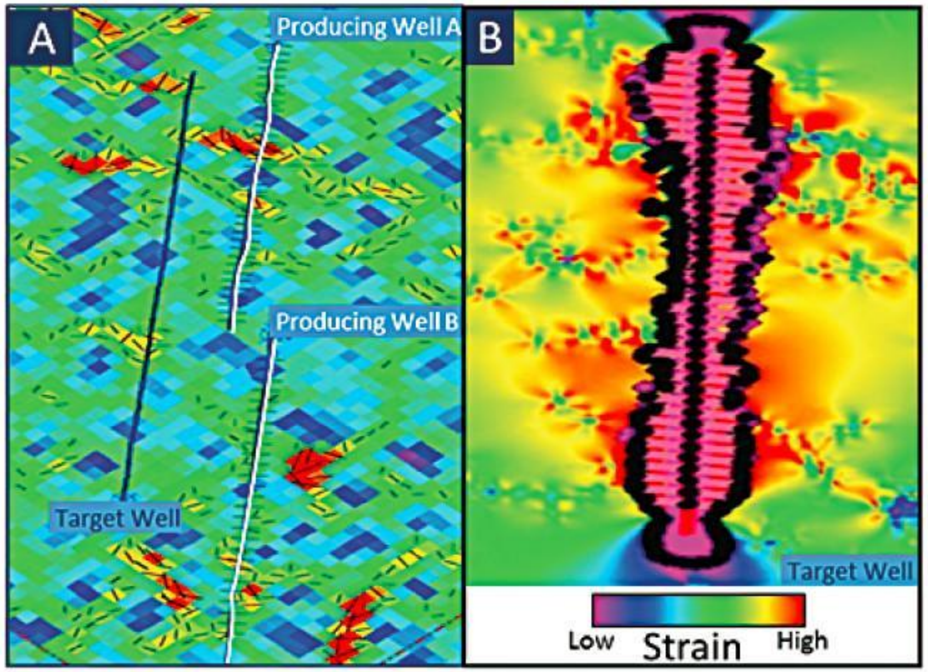
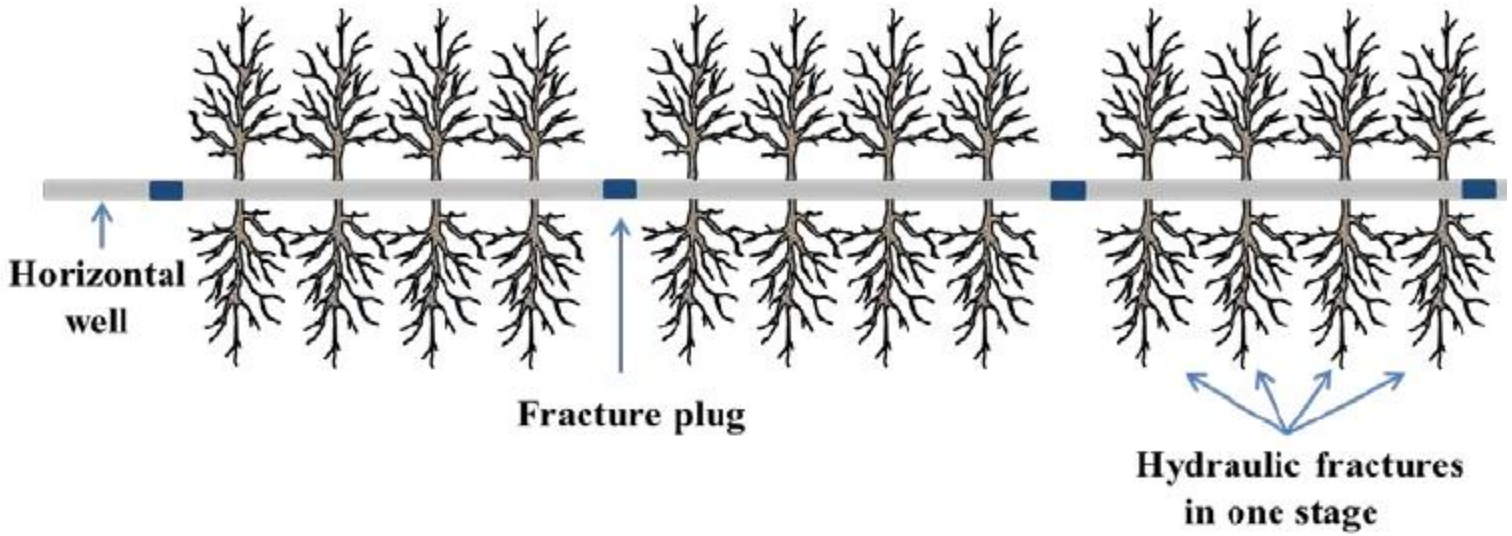


FIGURE 1. A) An equivalent fracture model was derived from seismic curvature and used as input in the geomechanical workflow. B) A strain map was derived after putting pressure in 40 frack stages. Red values represent high strain values indicating successful stimulation, while pink values represent the estimated geomechanical asymmetric half-lengths based on strain. (Source: FracGeo)

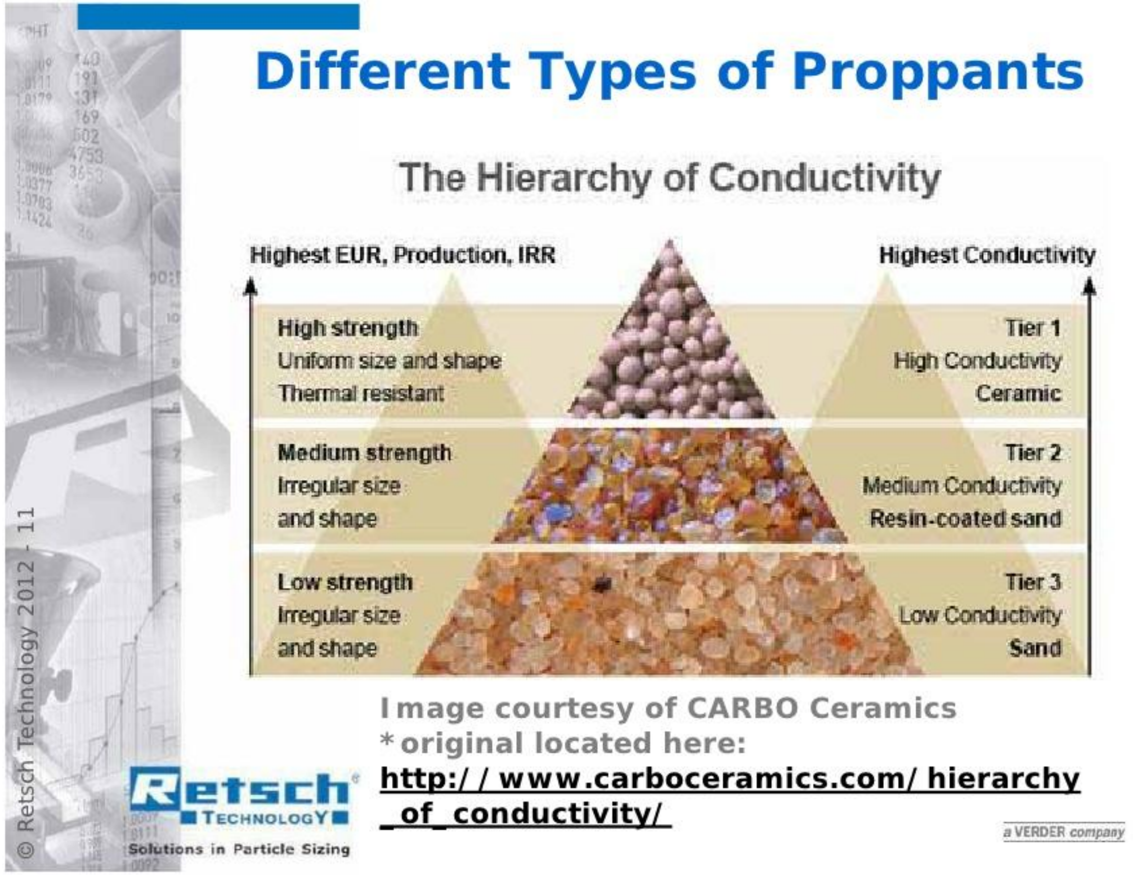
CONSIDERATIONS: PERFORATIONS

- Placement determination
- Perforation clusters
- Distance between perf clusters
- Shot density
- Charge type



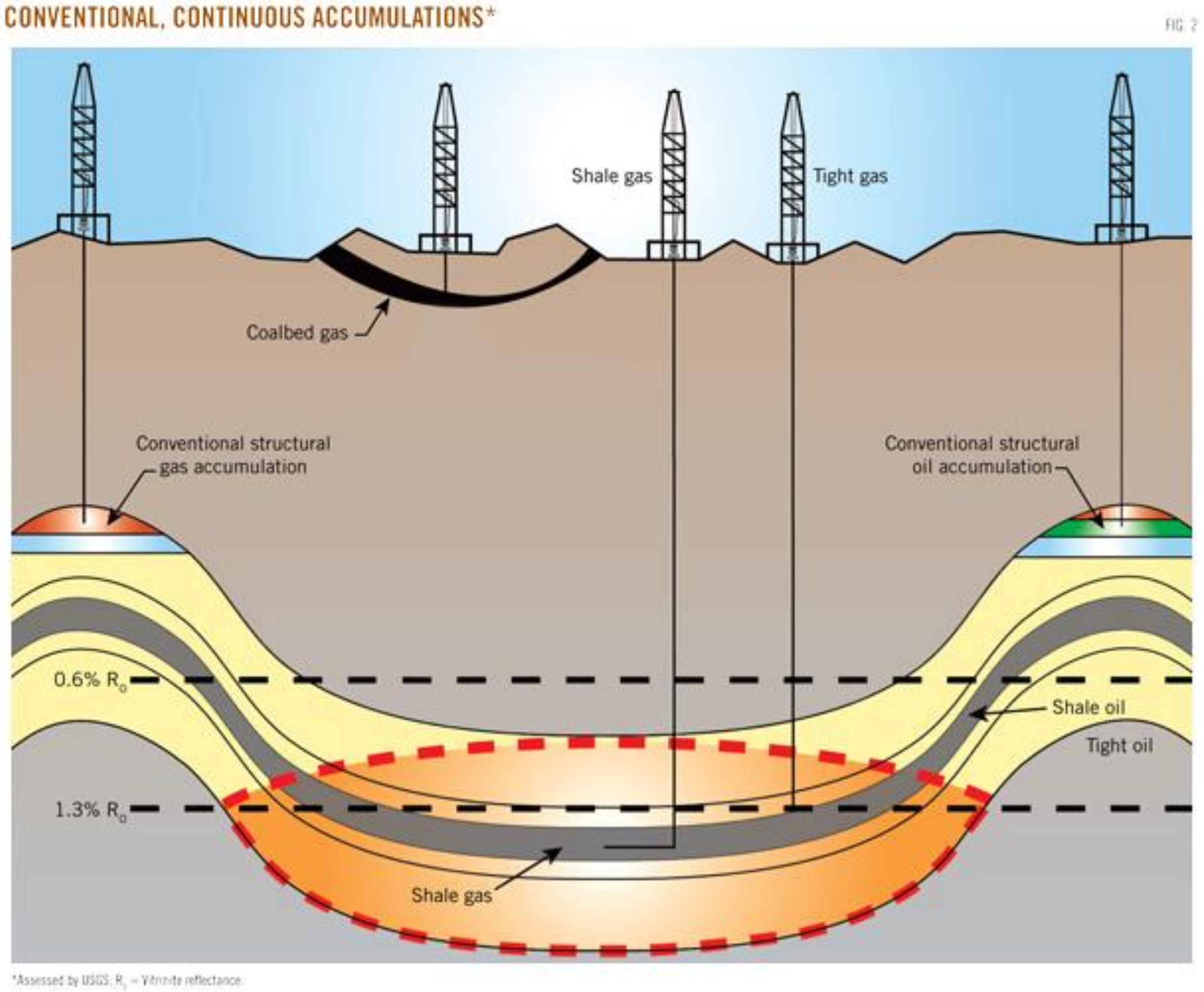
CONSIDERATIONS: PROPPANTS

- Type and amount of proppant
- Sand proppant
- Coated proppants / ceramic proppants
- Correct size for propping open fractures
- Use as a mechanism for delivering surfactant and optimizing production



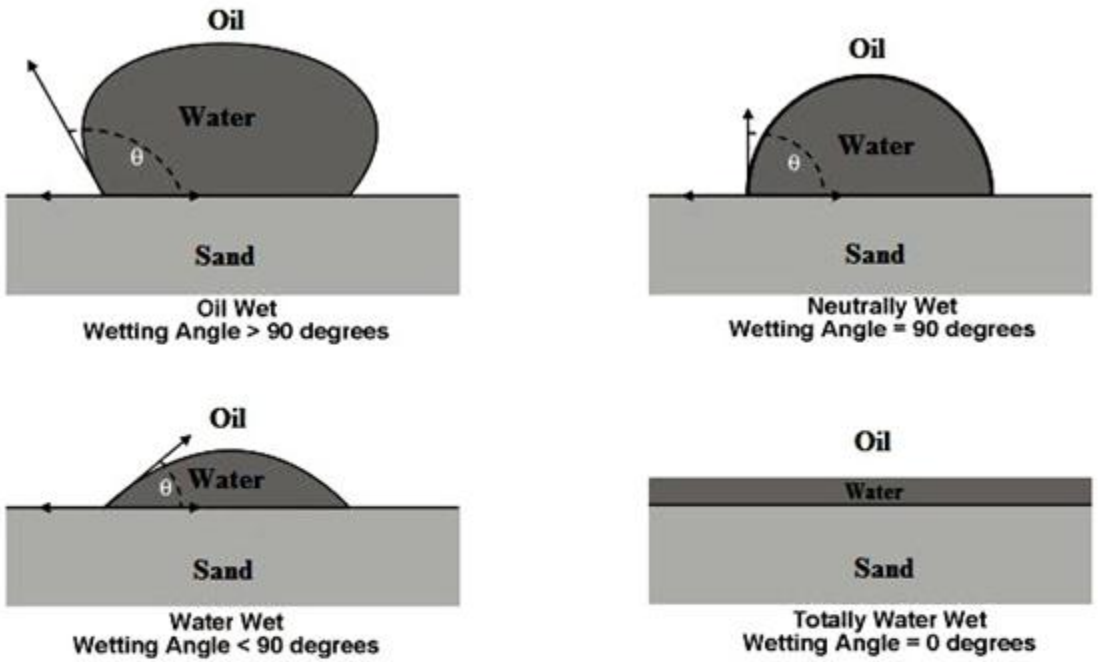
PRODUCTION DRIVERS FOR WELL PERFORMANCE I

- Petroleum system and charge access:
  - Geochemistry (kerogen type, maturity)
  - Pore pressure
- Formation continuity (degree of heterogeneity)
  - Thickness
  - Fracture networks



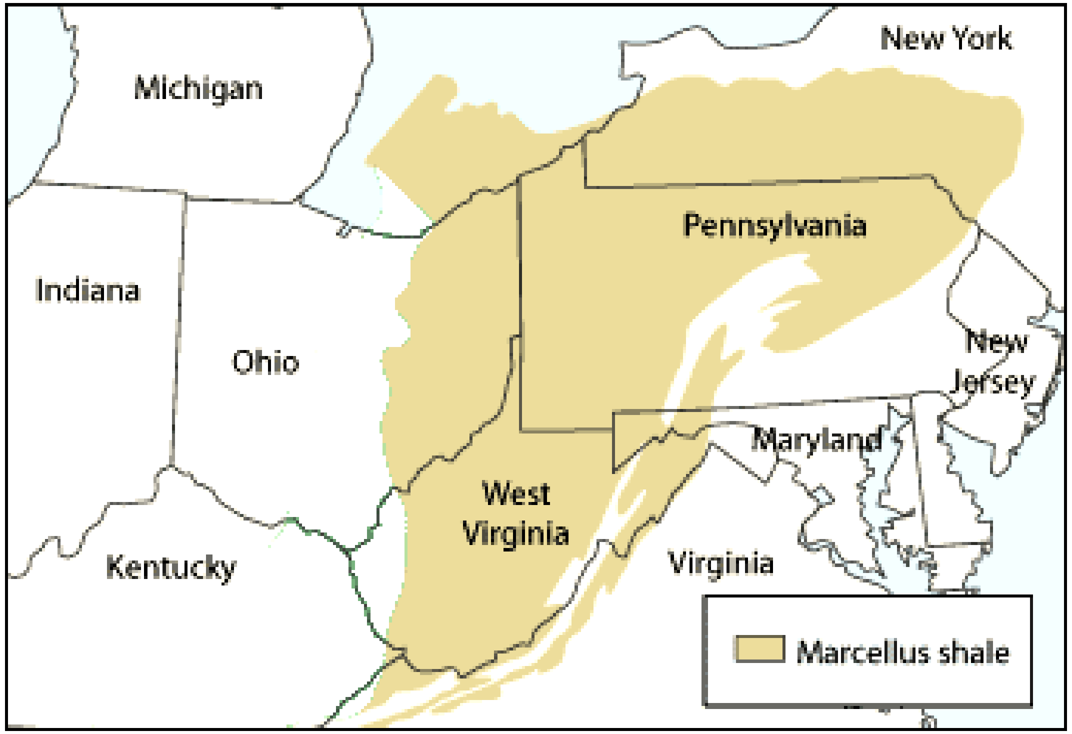
PRODUCTION DRIVERS FOR WELL PERFORMANCE 2

- Matrix and fracture permeability
- Mechanical properties and stress field
- Pore pressure and wellbore stability
- Wettability
- Geosteering (staying in zone)
- Frac interference



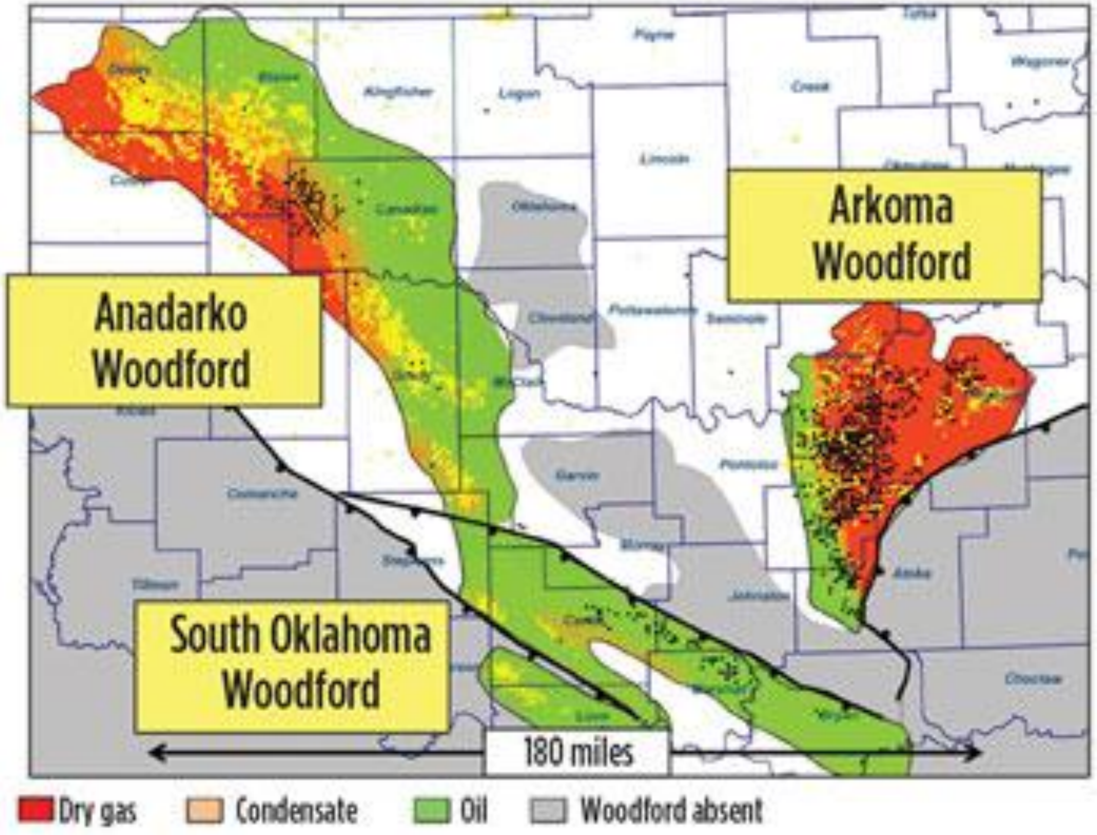
MARCELLUS SUCCESS FACTORS

- Largest volume of technically recoverable natural gas in the United States
- New technology solution? Better reservoir modeling that incorporates all the data (production, well logs, petrophysics, geomechanics)



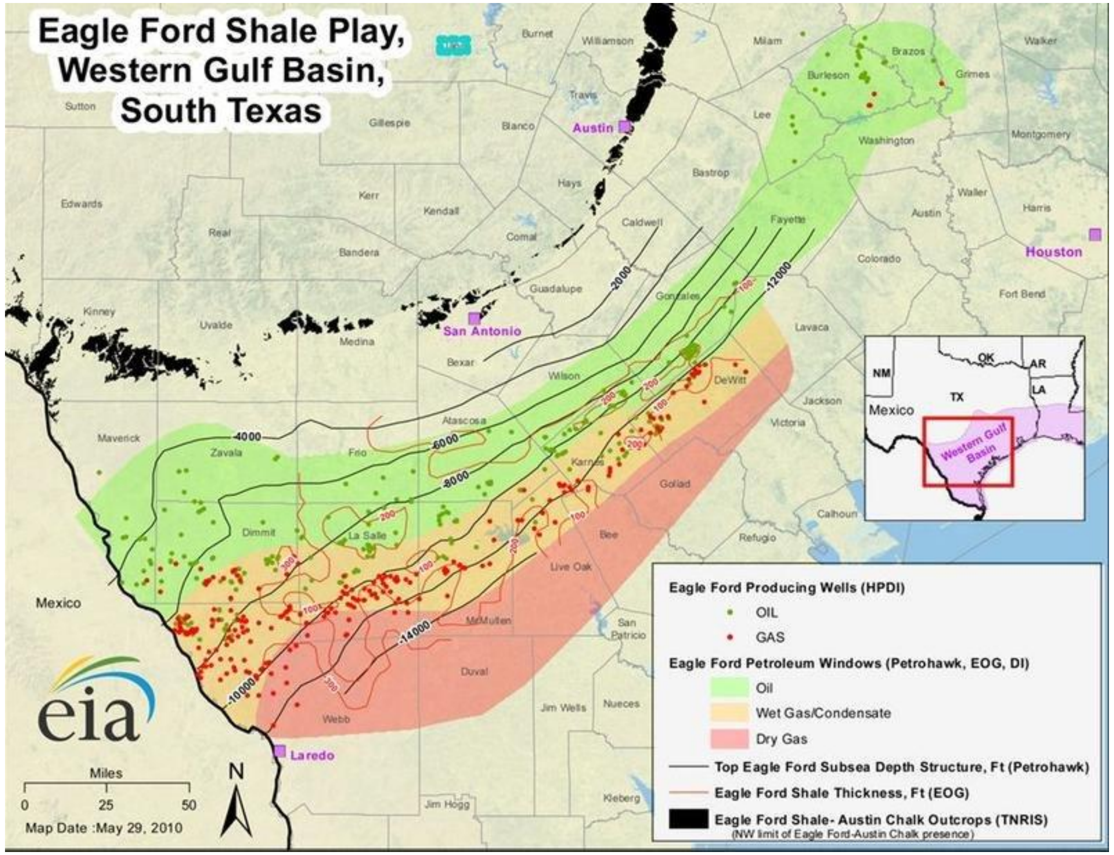
WOODFORD SUCCESS FACTORS

- Important source rock for Anadarko Basin
- Need to understand the relative “fracability” in the play
- New technology solution? New ways to identify thickness, TOC & brittleness



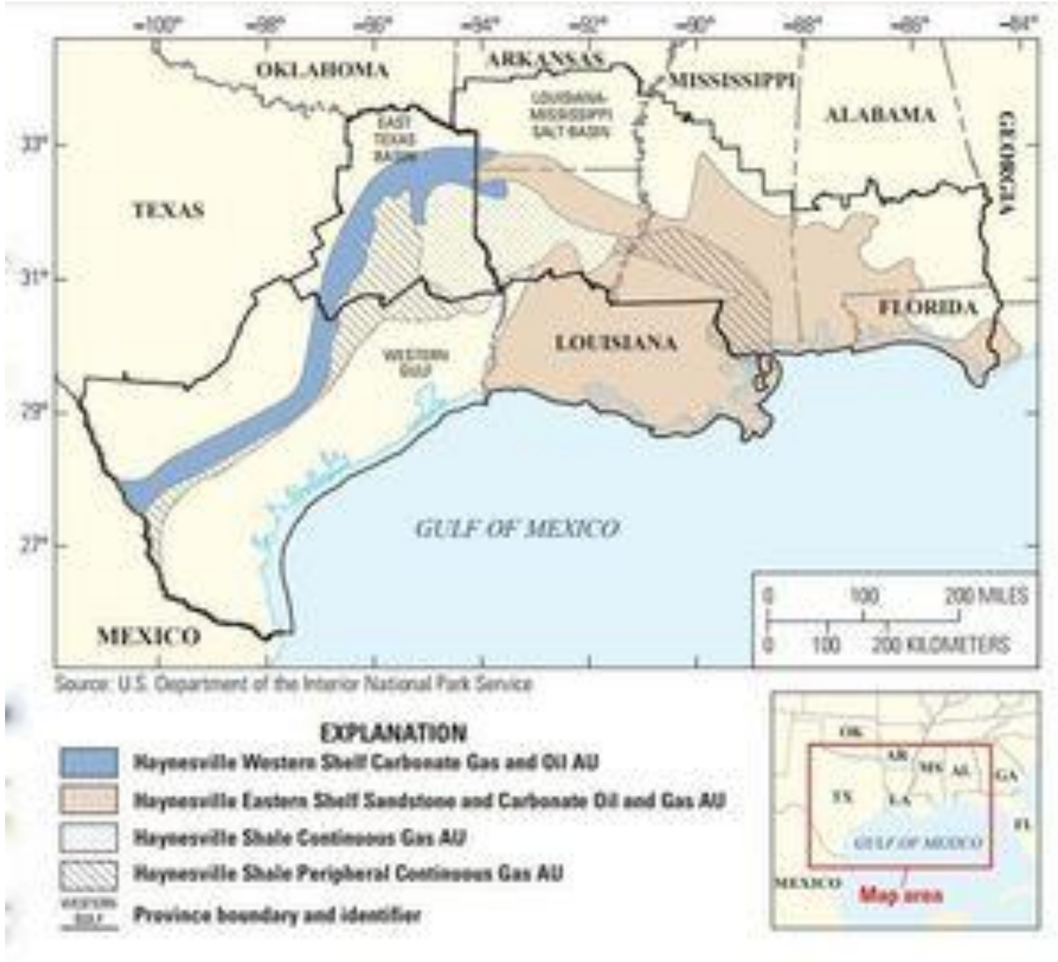
EAGLE FORD SUCCESS FACTORS

- Different regimes with highly variable composition of hydrocarbons (gas, liquids-rich, oil)
- New technology solution? Multiple designs for different temperatures, better fluids and proppants for high temperatures



HAYNESVILLE SUCCESS FACTORS

- Pressure – using the right kind of proppant
- Frac design for high-temperature environments
- New technology solution? High-tech ceramic proppants coated with surfactants



BAKKEN SUCCESS FACTORS

- Highly variable thickness – MUST stay in the zone
- Not all zones equally frackable
- Harsh winter conditions
- New technology solution? Robotics for better geosteering

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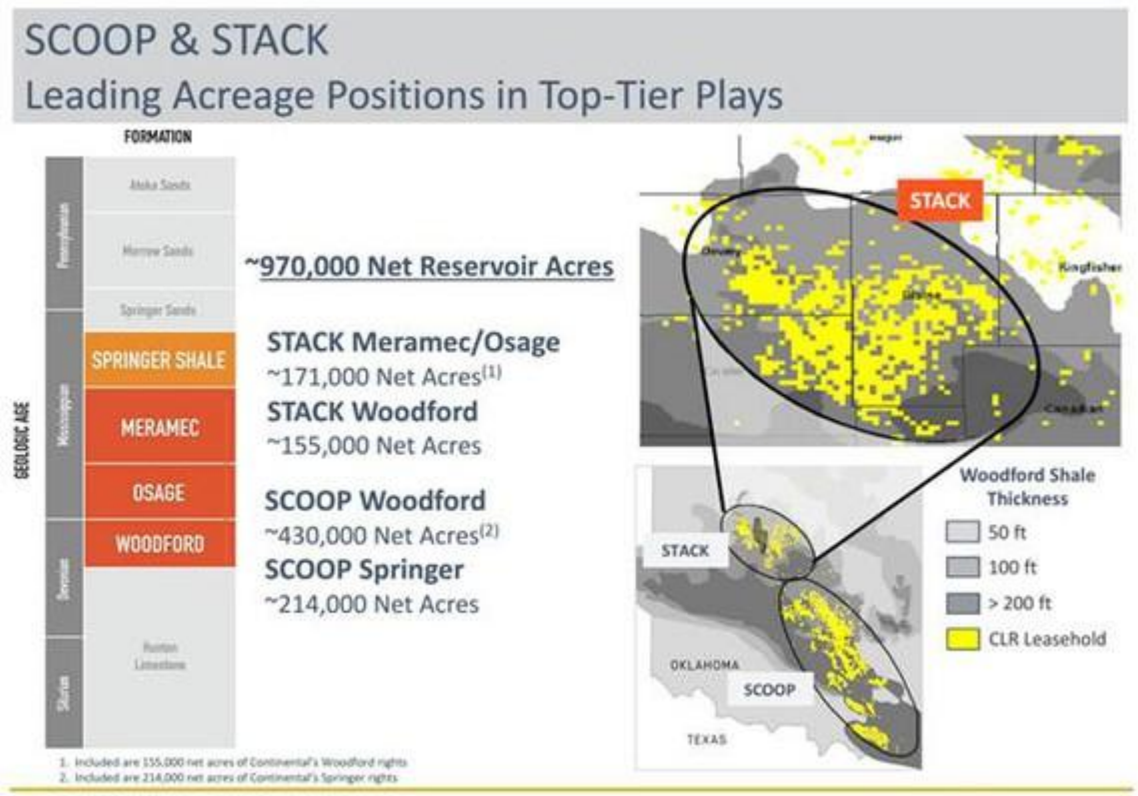
SPRINGER SUCCESS FACTORS

- An intercalated, thin-bedded shale / sand play
- Excellent storage, but not always recoverable
- New technology solution? Artificial intelligence and "deep learning" to reprocess well logs for better depositional environment modeling



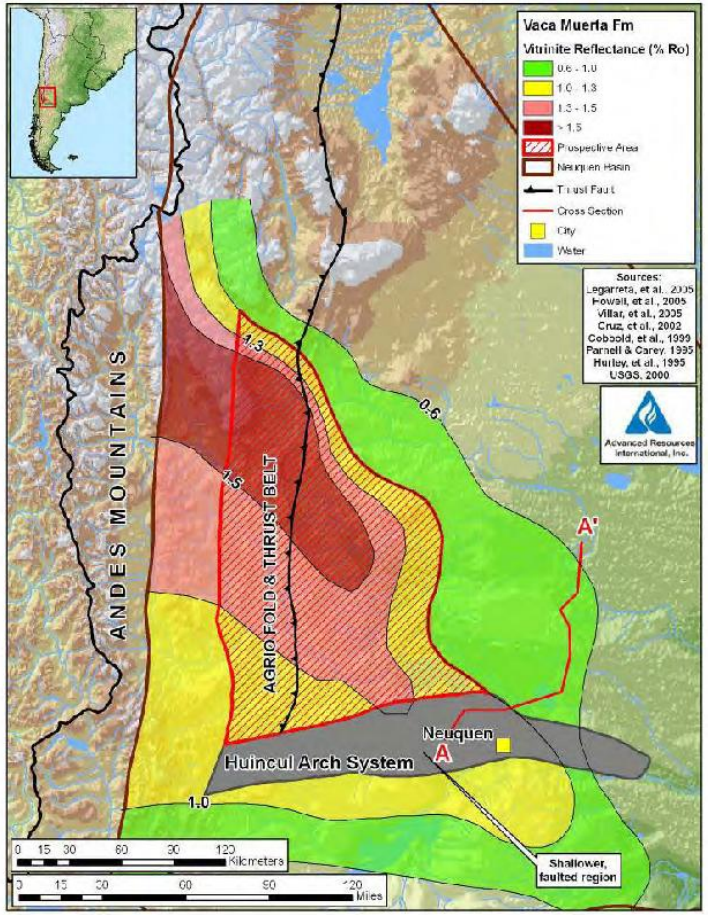
VACA MUERTA SUCCESS FACTORS

- Thickness & TOC
- Fracture networks
- New technology solution? "Smart fracs" that automatically adjust based on pressures and flowback chemistry
- Experience since 2012

OTHER SHALES' SUCCESS FACTORS

- Water solutions: Reprocessing to avoid using too much water
- "Smart injection mechanics" to avoid induced seismicity
- Inject with foam, CO_2, gas? Sometimes works

Figure IV-5. Vaca Muerta Fm, TOC, Thermal Maturity, and Prospective Area, Neuquen Basin



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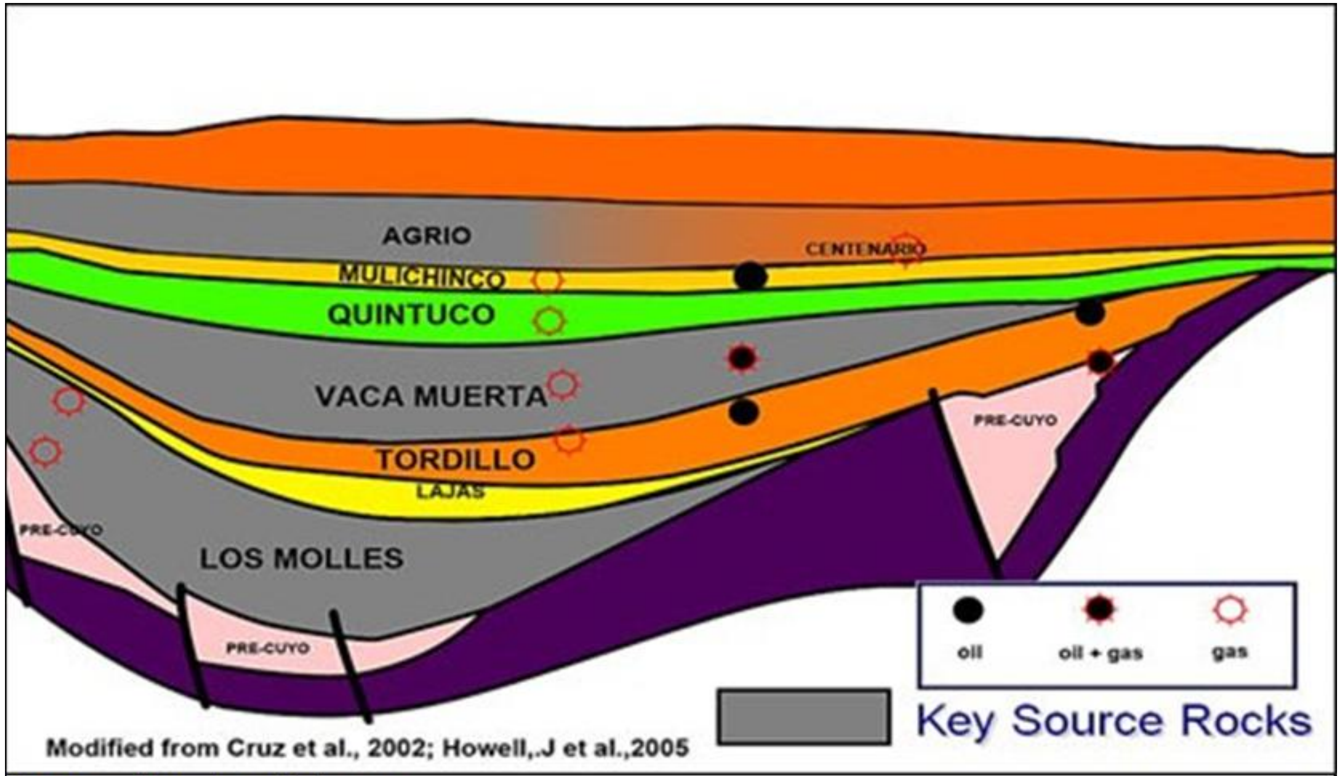
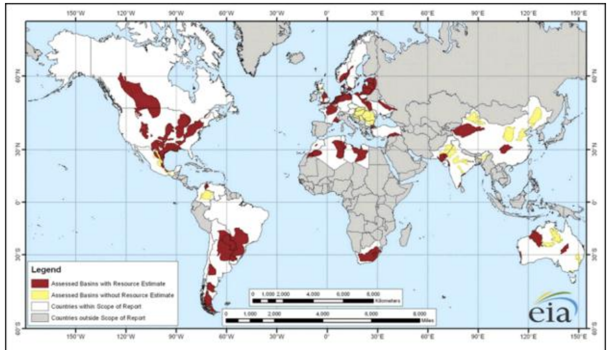


Source: Americas Petrogas

FUTURE POTENTIAL

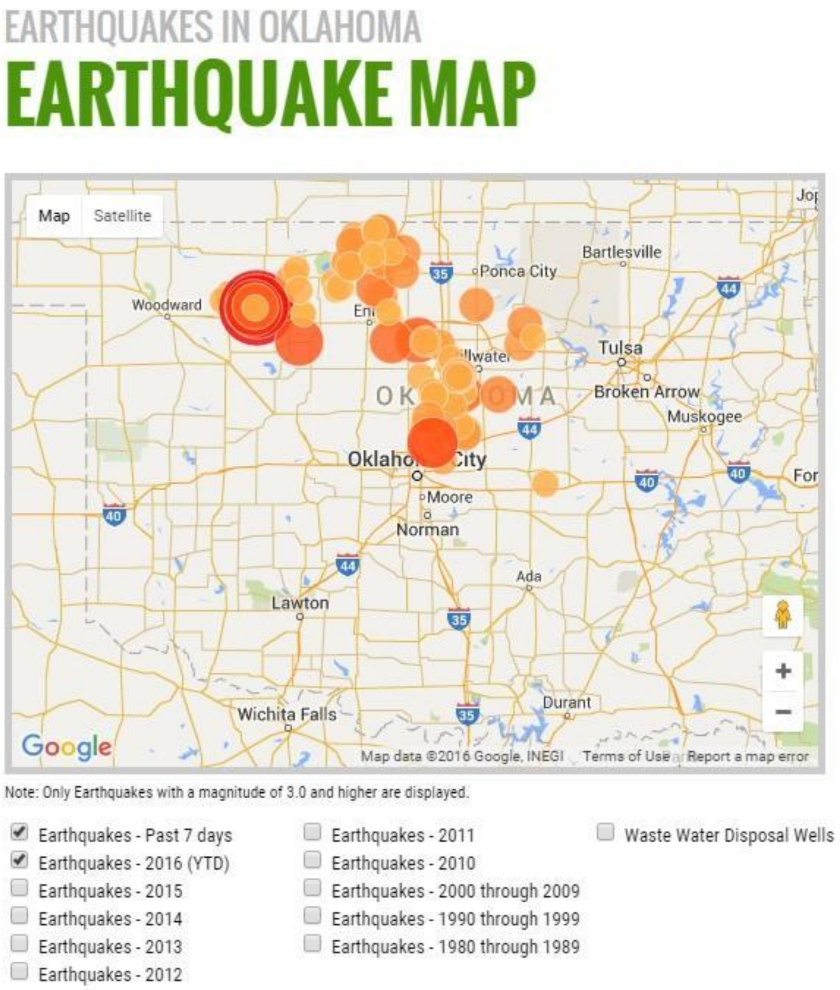
- Combining mining and petroleum exploration techniques and knowledge
- Thermal history (maturation / diagenesis) & fault / fracture systems
- Proximity to volcanic ash beds for rare minerals that function as catalysts
- Zones of preferential enrichment
- Use gravity / magnetics, plus seismic (identify for density differences the altered zones which point to porosity development and maturation)



Source: EIA

COMPLETION SUCCESS FACTORS

- Water solutions: Reprocessing to avoid using too much water
- "Smart injection mechanics" to avoid induced seismicity
- Inject with foam, CO_2, gas? Sometimes works



CONCLUSIONS

- Bigger is not always better (frac design)
- “Smarter” is always better (reservoir modeling, completion, etc.)
- Analytics are important at all phases of exploration, development, and production
- New chemicals, equipment, are making a difference
- Interdisciplinary approach is a “must” (geoscience / engineering / mathematical methods)