Refining the Tactics: Current Approaches to Exploration and Development of Shale Plays in the U.S.*

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Abstract

This paper presents the results of an analysis of the current state of shale play development in the United States in order to determine the recent advances in the understanding of reservoir behaviors and the most effective uses of new techniques and technologies. Essentially a transcript of an oral presentation, this article takes an informal approach to encourage the exchange of ideas. It emphasizes reservoir optimization and the application of new technologies and techniques to reduce costs and to improve recoverability of hydrocarbons and thereby to improve ultimate recoverable reserves. It specifically addresses issues of decline curves, stranded pay between laterals, stacked pay logistics, and pad drilling. In addition, the presentation looks at sweet spot optimization, effective investments, hydraulic fracturing, and geomechanics.

Presentation slides with notes

Next Phases of Shale Play Development

Optimizing shale plays is no longer just a North American concern. In China's Sichuan Province, which contains the Fuling Field, companies such as Sinopec, in conjunction with Chengdu University of Petroleum, and the State Key Labs, and partners, such as Chevron and ExxonMobil, are diligently seeking ways to overcome the very significant logistical challenges. Further, the conventional wisdom of "bigger is better" is challenged as costs escalate.

Across the border from prolific Eagle Ford shale wells in south Texas, teams of Mexican geologists have focused on the potential for exploiting the stratigraphic equivalents in northern Mexico. The newly passed Energy Reform has opened the possibility of significant investment in these plays. However, no one wants to repeat costly errors or persist in using technologies and approaches that result in vast percentages of the oil in place being left behind.

Needless to say, as a global community of geoscientists, we must join forces to solve technical problems. Certainly there will always be issues of intellectual property and also ownership of property, or market-making events in the case of a public company. Those issues notwithstanding, we do need to find ways to accelerate our knowledge. If we do not, we shall not make much of a dent on recoverable reserves, decline curves, or water-disposal challenges. Further, without combining forces for breakthroughs, we shall not get ahead of the costs and without breakthroughs, there will be no way to outrun the avalanche of costs.

Stranded Pays: Between the Laterals

Despite efforts, the decline curves for oil and gas production from shales continues to be steep and rapid. Within 36 months, many wells are no longer producing, despite the fact that a single horizontal well may penetrate many sweet spots directly, and in other cases, may drill through the edge of a lenticular, isolated sweet spot "pod." The sweet spots that are on the edge of the laterals are not easily produced, and as a result, there may be pay that is left behind. It could be considered "stranded pay."

We are used to looking at "stranded pay" as pay that might be technically recoverable, but it is not economic due to location, etc.

- Not just for mature fields or uneconomic isolates
- Stranded pay within the laterals: going back to the early laterals (the mainly depleted ones in order not to disturb ongoing production)
- "Offsets" or "whipstocks" out from the laterals to enter the sweet spots that contain "stranded pay" (identified by microseismic or geochemical methods)

Note: Halliburton already has a whipstock tool to re-enter laterals … just a matter of putting all the puzzle pieces together.

To reiterate, as we enter a new phase of shale play production in which a pad may have 10 laterals, if the pad has been there for 3 or 4 years, you can bet that at least one or two of the laterals are no longer productive, since declines tend to be steep and are essentially at stripper level within 36 months or so.

We know that some formations are extremely heterogeneous, and in a 5000-foot lateral, there may be a 300-400 foot section that is on the edge of a very nicely fractured "pod" that has excellent accessible porosity thanks to induced fracture. However, the lateral just grazed the edge of it. It did not drain well. Therefore, the pod (lenticular unit) has what we can safely call "stranded pay." How can we recover the oil and/or gas?

That is where innovative drilling and completion can play an important role. The crux of the challenge is this: how do we recover the oil and gas we know is in relatively porous and permeable zones on the edge of a lateral?

Sweet Spot Optimization: Whipstocked Laterals

The "stranded pay" are sweet spots. They can be imaged fairly accurately when there are XRF, XRD, microseismic, geochemical analyses, mudlogs, and more available. The fact that they are available after the fact of completion is not a bad thing if we have the ability to go back in – re-enter the lateral, and then whipstock off into the heart of the sweet spot.

In theory, if we drill a directional offset through a lateral, and/or whipstock into a highly fractured sweet spot (fractured in the original completion), it will not be necessary to re-stimulate the well.
However, in some cases, it probably would not be a bad idea to give it a shot of acid or to explore the possibility of an open hole completion. This is speculation on my part; I shall leave that to the engineers.

To summarize, here are some of the techniques needed in sweet-spot optimization:

- Better integration with sequence stratigraphy, geochemistry, imaging, XRF, etc.
- Under development: Whipstocking the sweet spots
- Whipstock directional drilling for better penetration of sweet spots
- Whipstock off the lateral where microseismic indicates a fracture pod
- Packers or sliding sleeves to perf within the whipstocked part of the lateral?

Cost Reductions

If one looks at the Analyst Day presentations of companies that are operating in shale plays, you will find a common theme, which tends to center on cost reductions. Companies, such as SandRidge, have been able to reduce drilling, completion, and operating costs significantly. Many would argue that this is extremely important – especially in pad drilling.

Some companies have invested heavily in core studies in order to focus their efficiencies in the completion / stimulation phases. Others have looked ahead to stacked pays, and have invested in taking the time to study the other uphole potentially producing zones.

- Frac efficiency improvements (better pressure management, frac height control)
- Proppant, fluid, water management, pad drilling, logistics improvements
- Water management / water re-use
- Stacked pays (Bakken, Permian, Oklahoma)

Cost Intensifications

In a very counter-intuitive manner, some companies, such as Continental Resources, have aggressively attacked the concept of technology and efficiencies and have decided to invest in additional technologies that will improve recoverability and will allow additional zones, new laterals, new stages, and whipstocks to be utilized. So, their costs seem to be very high, but in the end, the ROI will be significantly higher if the ultimate recoverable reserves are significantly higher – e.g., instead of 15% they go up to 20 or 25%.

- Here are a few of the technologies that cost more money, but pay off in the end.
- Microseismic sensor arrays (10-well installation)
- 3D visualization
- Goal: improve hydraulic fracturing, determine frac heights
    - Find where the sweet spots are (lenticular units with communication)
    - Return to drill additional laterals, or whipstock into the heart of the pods

Hydraulic Frac "Prepping"

Even though it is in the "fringe" area, this has so much breakthrough potential that we could be looking at a huge game-changer, in fact, a potential paradigm shift in terms of how we currently conduct hydraulic fracturing operations. First, in consideration of the realities, we know that the main reason that shale plays decline so rapidly is because the clay minerals reseal themselves and bind up the hydrocarbons. This is especially the case when the hydrocarbons have been generated in the same formation, but it also applies to hydrocarbon that has migrated there from a different source.

How can we work with the clay minerals to "condition" them to make them more likely to release the gas, or, even, to accelerate the process of hydrocarbon generation? The answer may lie in clay mineralogy and what is known as the CEC – or, "Cation Exchange Capacity. If you can destabilize the matrix by manipulating the CEC, especially potassium, then it is likely that the chemical bonds will be perturbed to the point that they are released more easily.

Sometimes this manifests as a perturbation of surface tension, but sometimes it has to do with the process of adsorption. In either case, the result is that there is electrochemical stimulation rather than physical stimulation, as in the case of hydraulic fracturing. In an ideal world, the "electrochemical stimulation" (CEC-based) would condition the clays so that when the hydraulic fracturing takes place, it will be dramatically more effective / efficient.

Instead of pumping more proppant to solve the problem, we can throw salt and electrolytes at it. We can pump Gatorade down the hole. (Not really. That was an attempt at light humor.)

- Drilling Fluids that help "Prep" the clays for hydraulic fracturing
- Cation Exchange Capacity
    - Understand the clays – destabilize the matrix by manipulating the CEC (especially as it relates to Potassium … K+)
    - Accelerate adsorption by deliberately utilizing fluids with electrolytic elements that open up the clays and release the gas molecules
- Clay chemistry

Geomechanics and More

One of the fastest-growing areas of geosciences today is the area of geomechanics. In the past, geomechanics was often relegated to structural geology and geophysics, with the main goal of being able to predict pore pressure and avoid hole instability.

However, today geomechanics is considered absolutely critical in designing a drilling program as well as a completion / stimulation program, which includes cluster spacing and orientation.

- Stress fields in the natural fractures and how to optimize induced fractures
- Pore pressure (borehole stability)

Pre-Stack Seismic Inversion and Reservoir Characterization in Unconventionals

The two key properties derived from seismic are Young's modulus and Poisson's ratio. In addition, azimuthal inversion and AVO can be used to determine:

Principal stresses
Differential horizontal stress ratio

The benefits include:

- Sweet spot identification
- Well location optimization
- Completions optimization
- Geochemistry (reservoir characterization – what do you have?)
- Basin analysis (big picture)
- XRD / XRF (while drilling)
- Drilling fluid optimization

Necessity of Completion Technologies

Each play has a different approach. The lucky ones are able to have great results with open-hole completions. The Bakken has been quite amenable to open-hole packers and sliding sleeves.
But, each play is different. The key is to get a sense of what works in the play you are in.

- Sliding sleeve? Open hole (packers plus?)
- Proppant optimization
- Frac fluid optimization

New Reservoir Stimulation Approaches

As mentioned earlier, but as reinforcement, about new approaches to reservoir stimulation, ones that use geochemistry and geomechanics together to "condition" the hole using chemicals and electrical charges, rather than relying solely sheer force, are essential.

Also, it is quite interesting to look at deliberately planning frac interference. Instead of trying to keep the clusters spaced so that the induced fractures do not touch each other, there is one school of thought that looks at the opposite side of the equation and attempts to maximize frac interference.

We need to look more closely at what is currently being done in terms of sending charged nano-particles into the interstices of the clay minerals in order to stimulate them and speed up the process of releasing gas molecules. It is potentially as easy as sending nano-surfactants, or as complicated as emulating potassium – a kind of nano-K+ effect.

Caveat -- very much in developmental stages

- Cation exchange capacity (salinity issues)
- Charged particles (nano-stimulation)
- Production issues (attacking the decline curve)
    - Pressure controls / gas drive maintenance
    - Punctuated refracturing at certain intervals
    - Cluster spacing analysis
    - Frac interference by design

North American Plays: "Best Practices"

Reforma Energética in Mexico and the fact that the Eagle Ford formation does not stop at the border indicate that Mexico is well aware of its significant shale play potential. Many parts of Mexico are extremely prospective, not just for new production but also for going into mature fields and recovering what has been left behind, using whatever EOR method seems most appropriate.

- Bakken and Three Forks
- Eagle Ford
- Marcellus
- Mississippian Lime
- Woodford Shale

Bakken & Three Forks

The main lessons learned have to do with pushing the limits of pad drilling and stacked pays. The fact that the decline curves are steep is a pesky and ,up to now, intractable issue. However, that can definitely change.

- Pushing the limits of pad drilling and laterals
- Optimizing infrastructure
- What do you do when you have 10 laterals, 20,000-foot laterals? *(new monitoring and smart operations)*
    - Proppant optimization
    - Frac fluid optimization
    - Frac height determination
    - Frac interference determination

Eagle Ford

The Eagle Ford is very complicated, and there are vast barren areas, along with significant sweet spots. Further, the Eagle Ford is very heterogeneous, and so it is important to integrate all possible data sources.

Geosteering using "logging while drilling" and image logs is very important.

- XRD / XRF: Geosteering for sweet spots

- Microseismic for determining fracture heights
- Sequence stratigraphic correlations: 3D seismic and depositional modeling

Marcellus and Utica

The Marcellus is a fascinating play – geochemistry is absolutely critical, especially if you are trying to work the system and produce just the right mix of gas and liquids.
A few of the "must have" elements and the "best practices" in the play include:

- Gas – liquids boundary determinations
- Gas typing and understanding the migration history / patterns / mixing
- Accessible and non-accessible porosity
- Pore typing (tie back to regional studies)
- CT scans on the cores

Mississippian Lime

One of the puzzling questions in this play is: "Why is the oil cut 2 percent here, but 15 percent a mile away?" The answer lies in the tectonic history as well as the thermal history. One created fracture networks. The other created hydrothermal alteration and diagenesis—commonly chertification and dolomitization.

There are even more relationships in the Mississippian. There is the "King Kong Meets Godzilla" phenomenon as a petroleum system meets Mississippi Valley-type mineralization. Hot, rich fluids are pumped through an organics-rich sedimentological system. The result is spectacular.

In order to characterize the reservoirs, the following are needed:

- Image logs for fracture networks
- Basin-level analyses
    - Petroleum generation
    - Expulsion / flow
    - Structure (faults / fracture networks)
    - Convergence with Mississippi Valley-type mineralization

Woodford Shale

The Woodford shale, found over a large geographical extent, must be studied very carefully.

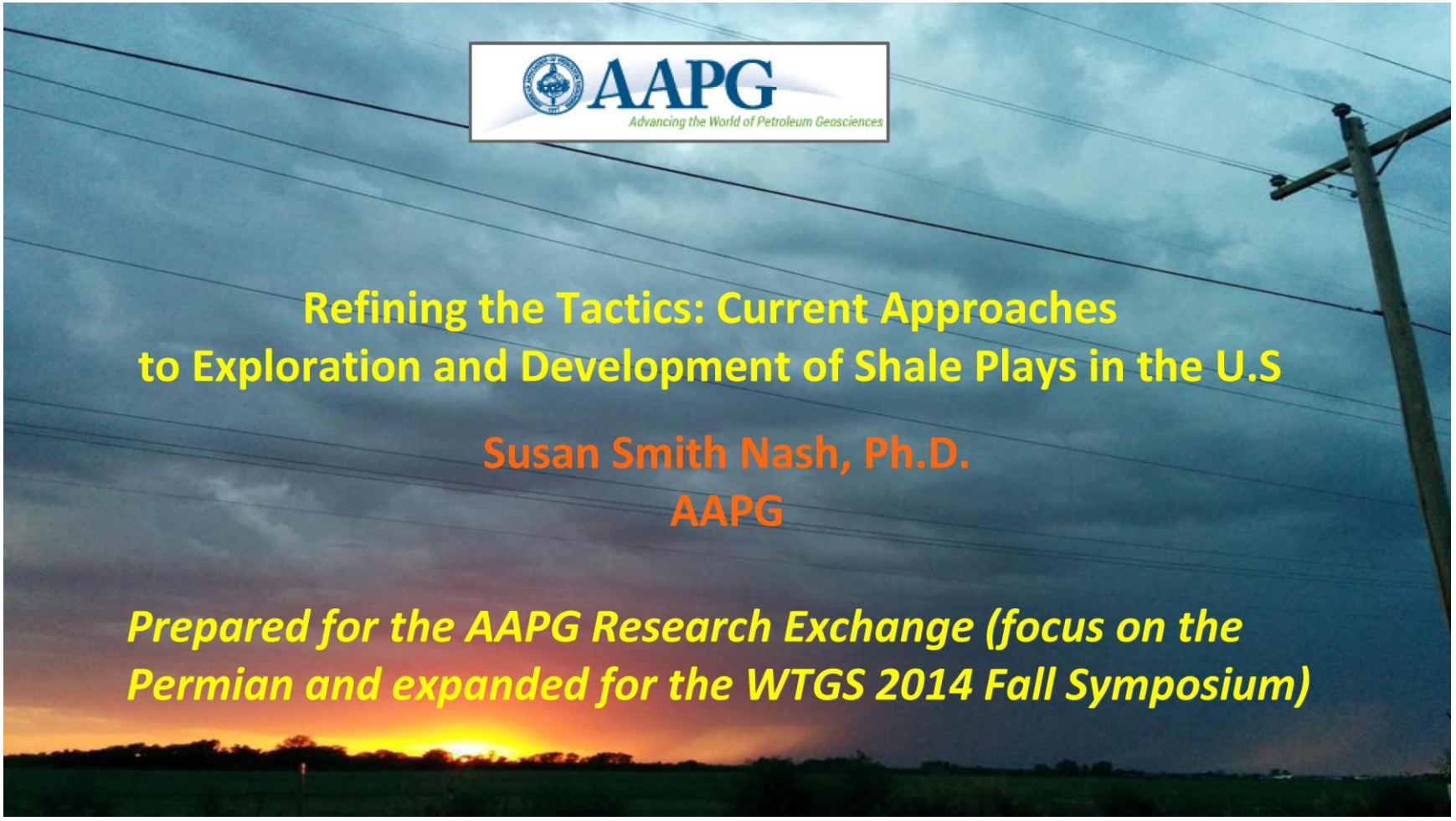
- Geomechanics
  - Pore pressure regimes
  - Nano-geomechanics (cation exchange capacity)
  - Fracture typing / characterization
  - Fracture networks
  - Brittleness & Fracability determination

The work of USGS and Brian Cardott at the Oklahoma Geological Survey is very impressive, including the latter's careful and detailed work on kerogen typing and vitrinite reflectance and how this can help a company form its own drilling program.

- Geochemistry
  - TOC evaluations
  - Kerogen typing
  - Maturity / vitrinite reflectance
  - Gas fingerprinting
  - Migration patterns
  - Indicator minerals / deformations
  - Adsorption factors
  - Pyritization

Conclusions

- New technologies and new techniques evaluated every day
- New approaches to sweet spots (whipstocked laterals)
- New stacked pays (follow the migration paths)
- Manipulating the clay minerals on a nano level to "unbind" the matrix and allow more accessible porosity



Presenter's notes: The purpose of this presentation is to review some of the lessons learned and challenges facing shale plays right now, both liquids-rich and primarily gas. We'll see where technology has taken us so far, for better or for worse, and how efforts are being made to push the envelope and move forward.

While the technologies are being used in all shale plays, pretty much across the board, the "learnings" and the experimentation is moving along at different paces, much of which is constrained by the nature of the play, the infrastructure, and also the nature of the plays and the other formations (potential bail-out zones or "stacked pays").

This presentation does not address any of the shales (Cline or Avalon) in the Permian Basin.

Presenter's notes: The background of this slide is from a conference that took place in Chengdu, China, in July 2014 with the Chengdu University of Technology, the State Key Labs, and also China's Southwest University. Chengdu is in the Sichuan Province, which is the site of one of the major shale discoveries in China, the Fuling Field. There is a sense of urgency to develop the gas and oil resources, but China, as in the U.S. and other locations, faces significant logistical challenges. Further, the costs of shale plays, utilizing the current technologies (bigger fracs, more proppants, longer laterals), constitute a challenge in and of themselves.
It is my opinion that in order to solve these problems, we must join forces to solve technical problems. Certainly there will always be
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issues of intellectual property and also ownership of property, or market-making events in the case of a public company. Those issues notwithstanding, we do need to find ways to accelerate our knowledge. If we do not, we won't make much of a dent on recoverable reserves, decline curves, or water-disposal challenges.

Further, without combining forces for breakthroughs, we won't get ahead of the costs … and without breakthroughs, there will be no way to outrun the avalanche of costs.

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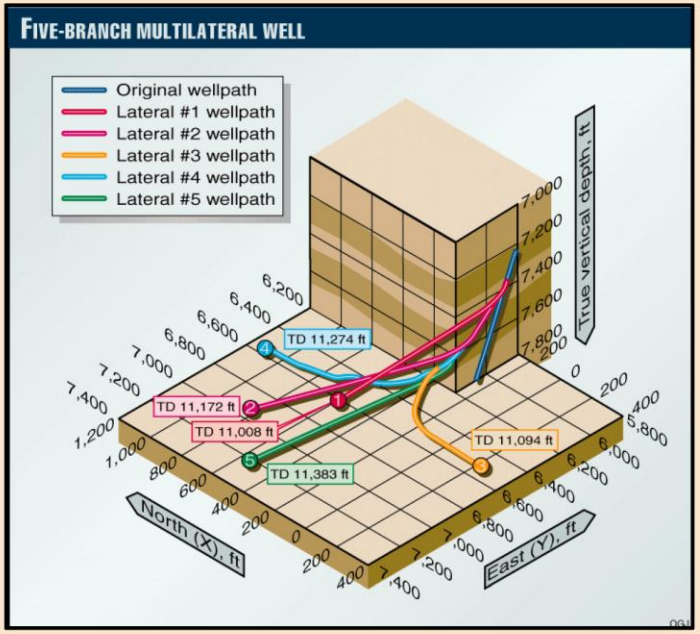

Presenter's notes: Focus now is on what many companies are seeing as a way to materially improve recovery rates, and to take advantage of existing infrastructure on the leases.
The first is "stranded pay." We're used to looking at "stranded pay" as pay that might be technically recoverable, but it's not economic due to location, etc.
As we get into a phase of shale play production in which a pad may have 10 laterals, if the pad has been there for 3 or 4 years, you can bet that at least one or two of the laterals is no longer productive, since declines tend to be steep and are essentially at stripper level
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within 24 months or so. We know that some formations are extremely heterogeneous, and in a 5000-foot lateral, there may be a 300-400 foot section that is on the edge of a very nicely fractured "pod" that has excellent accessible porosity thanks to induced fracture. However, the lateral just grazed the edge of it. It did not drain well. So – the pod (lenticular unit) has what we can safely call "stranded pay". How can we recover the oil and/or gas?

That is where innovative drilling and completion can play an important role.
Challenge – how do we recover the oil and gas we know is in relatively porous and permeable zones on the edge of a lateral?

Sweet Spot Optimization: Whipstocked Laterals

- Better integration with sequence stratigraphy, geochemistry, imaging, XRF, etc.
- Under development: Whipstocking the Sweet Spots
- Whipstock directional drilling for better penetration of sweet spots
- Whipstock off the lateral where microseismic indicates a fracture pod
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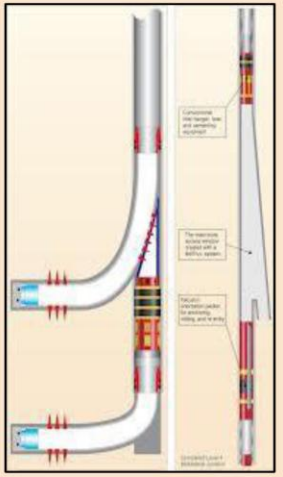

Image:
drillingcontractor.com

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Cost Reductions

- Frac efficiency improvements (better pressure management, frac height control)
- Proppant, fluid, water management, pad drilling, logistics improvements
- Water management / water re-use
- Stacked pays (Bakken, Permian, Oklahoma)

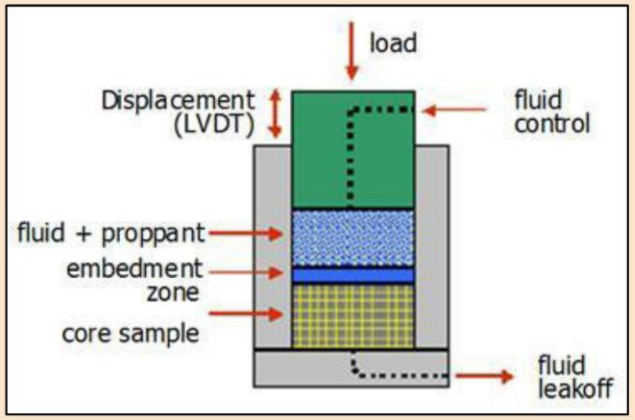


Image: CoreLab

Presenter's notes: If you look at Analyst Day presentations, you'll find a common theme in shale plays, which tends to center on Cost Reductions. Companies such as SandRidge have been able to reduce drilling, completion, and operating costs significantly.
I would argue that this is extremely important – especially in pad drilling.
Some companies have invested heavily in core studies in order to focus their efficiencies in the completion / stimulation phases.
Others have looked ahead to stacked pays and have invested in taking the time to study the other uphole, potentially producing zones.

Cost Intensifications

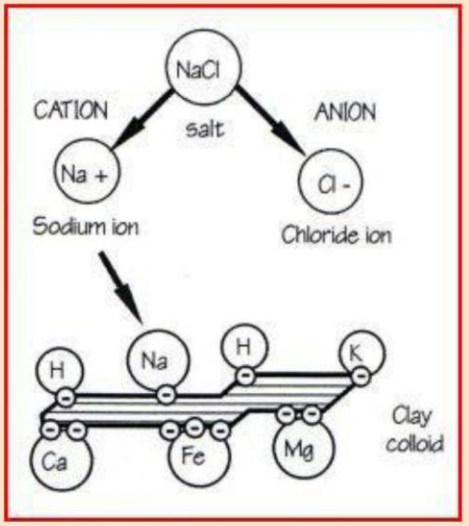
- Microseismic sensor arrays (10-well installation)
- 3D visualization
- Goal: improve hydraulic fracturing, determine frac heights
  - Find where the sweet spots are (lenticular units with communication)
  - Return to drill additional laterals, or whipstock into the heart of the pods

Presenter's notes: Cost Intensifications

In a very counter-intuitive manner, some companies such as Continental Resources, have aggressively attacked the concept of technology and efficiencies and have decided to invest in additional technologies that will improve recoverability and will allow additional zones, new laterals, new stages, and whipstocks to be utilized. So, their costs seem to be very high, but in the end, the ROI will be significantly higher if the ultimate recoverable reserves are significantly higher – say, instead of 15%, they go up to 20 or 25%. In this slide, I've listed a few of the items that cost more money, but pay off in the end.

Hydraulic Frac "Prepping"

- ***Drilling Fluids that help "Prep" the clays for hydraulic fracturing***
- Cation Exchange Capacity
  - Understand the clays – destabilize the matrix by manipulating the CEC (especially as it relates to Potassium … K+)
  - Accelerate adsorption by deliberately utilizing fluids with electrolytic elements that open up the clays and release the gas molecules
- The clay chemistry factor



Presenter's notes: Although this is "fringe" area, it has so much breakthrough potential that we could be looking at a huge game-changer – and, in fact, a potential paradigm shift in terms of how we currently conduct hydraulic fracturing operations.
First, let's consider the realities. We know that the main reason that shale plays decline so rapidly is because the clay minerals reseal themselves and bind up the hydrocarbons. This is especially the case when the hydrocarbons have been generated in the same formation, but it also applies to hydrocarbons that have migrated there from a different source.
So – how can we work with the clay minerals to "condition" them to make them more likely to release the gas, or, even, to accelerate the process of hydrocarbon generation? *(Presenter's notes continued on next slide)*

(Presenter's notes continued from previous slide)

The answer lies in clay mineralogy and what is known as the CEC – or, "Cation Exchange Capacity" –
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In an ideal world, the "electrochemical stimulation" (CEC-based) would condition the clays so that when the hydraulic fracturing takes place, it will be dramatically more effective / efficient.

So – instead of throwing more proppant at the problem, we can throw salt and electrolytes at it. We can pump Gatorade down the hole. (okay, that was an attempt at light humor)

Geomechanics & More

- Stress fields in the natural fractures and how to optimize induced fractures
- Pore pressure (borehole stability)

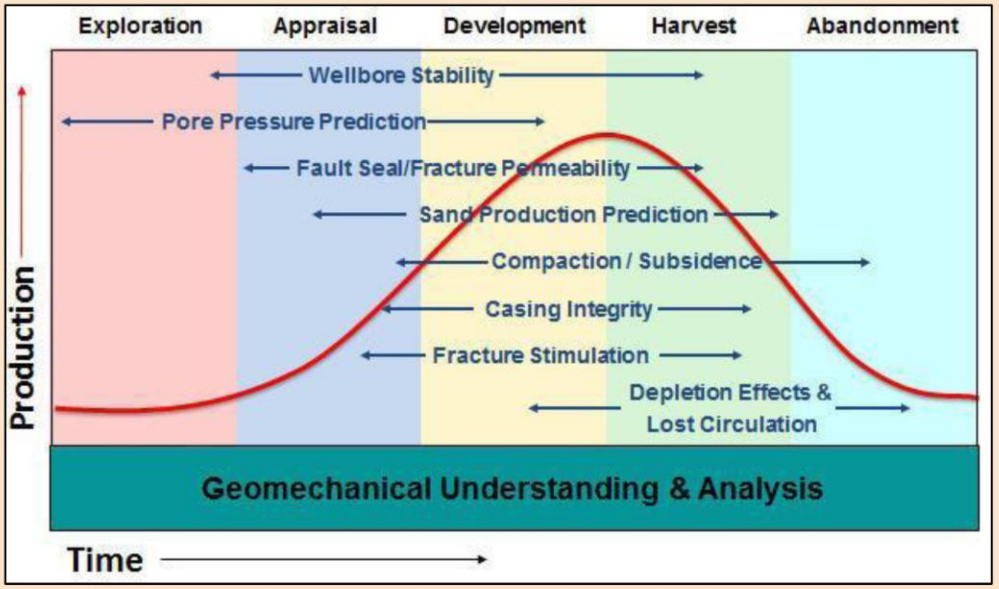

Image: Mark Zoback / ztopics.com

Presenter's notes: One of the fastest-growing areas of geosciences today is the area of geomechanics. In the past, geomechanics was often relegated to structural geology and geophysics, with the main goal of being able to predict pore pressure and avoid hole instability.
However, today geomechanics is considered absolutely critical in designing a drilling program as well as a completion / stimulation program, which includes cluster spacing and orientation.

Must-Have Technologies

- Geochemistry (reservoir characterization – what do you have?)
- Basin analysis (big picture)
- XRD / XRF (while drilling)
- Drilling fluid optimization

Presenter's notes: A list of "must-have" technologies – these are considered important for all shale play developments, whether large or small.
First, we need to look at basin analysis and have a sense of the geological history, depositional environment, thermal history, and tectonics. Thankfully, you don't have to go out and do all the field and core work yourself, along with the analytics. The USGS has completed a number of really interesting studies – the one that comes to mind first is Deborah Higley's work on the Anadarko Basin in which she, along with a team of USGS specialists, examined an amazing array of data from wells and other sources in order to
(Presenter's notes continued on next slide)

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develop a model that explains the process of HC generation in the Anadarko Basin, even with maps of expulsion patterns and discussion of trapping mechanisms. It is absolutely amazing, and if you look at various companies' leasing strategies, you'll find that they essentially are an overlay of the maps produced by the USGS.

Pre-Stack Seismic Inversion & Reservoir Characterization in Unconventionals

The two key properties derived from seismic are Young's modulus and Poisson's ratio.

Azimuthal inversion and AVO can be used to determine:

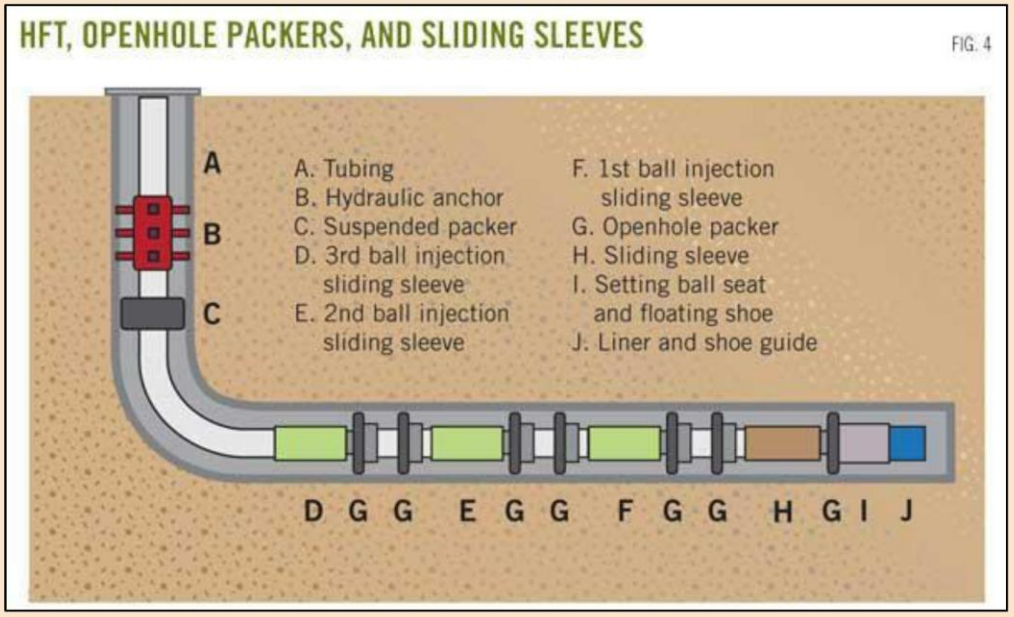
- Principal stresses
- Differential horizontal stress ratio

Benefits:

- Sweet spot identification
- Well location optimization
- Completions optimization

Must-Have Completion Technologies

- Sliding sleeve? Open hole (packers plus?)
- Proppant optimization
- Frac fluid optimization



What is next? Image: OGJ

Presenter's notes: Each play has a different approach. The lucky ones are able to have great results with open-hole completions. The Bakken has been quite amenable to open-hole packers and sliding sleeves. But, each play is different. The key is to get a sense of what works in the play you're in.

New Reservoir Stimulation Approaches

Caveat -- very much in developmental stages

- Cation exchange capacity (salinity issues)
- Charged particles (nano-stimulation)
- Production issues (attacking the decline curve)
  - Pressure controls / gas drive maintenance
  - Punctuated refracturing at certain intervals
  - Cluster spacing analysis
  - Frac interference by design

Presenter's notes: This slide essentially repeats and/or reinforces noted earlier about new approaches to reservoir stimulation – ones that use geochemistry and geomechanics together to "condition" the hole, using chemicals and electrical charges, rather than relying solely sheer force.

What is pointed out here is that it's quite interesting to look at deliberately planning frac interference. Instead of trying to keep the clusters spaced so that the induced fractures do not touch each other, there is one school of thought that looks at the opposite side of the equation and attempts to maximize frac interference. *(Presenter's notes continued on next slide)*

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I'd also like to take a close look at what is currently being done in terms of sending charged nano-particles into the interstices of the clay minerals in order to stimulate them and speed up the process of releasing gas molecules. It's potentially as easy as sending nano-surfactants, or as complicated as emulating potassium – a kind of nano-K+ effect. I know I'm talking Jules Verne here, but it's something the physical chemists and chemical engineers can really sink their teeth into.

Presenter's notes: A quick look at Best Practices. This photo is of an agave farm near Guadalajara, Mexico. I'm including it because of the new Reforma Energetica in Mexico and the fact that the Eagle Ford formation does not stop at the border. Mexico has significant shale-play potential. Now, this area near Guadalajara may not have so much … lots of volcanics.
But, other parts of Mexico are extremely prospective, not just for new production but also for going into mature fields and recovering what's been left behind, using whatever EOR method seems most appropriate.

Bakken & Three Forks

- Pushing the limits of pad drilling & laterals
- Optimizing infrastructure
- What do you do when you have 10 laterals, 20,000-foot laterals? *(new monitoring & smart operations)*
  - Proppant optimization
  - Frac fluid optimization
  - Frac height determination
  - Frac interference determination

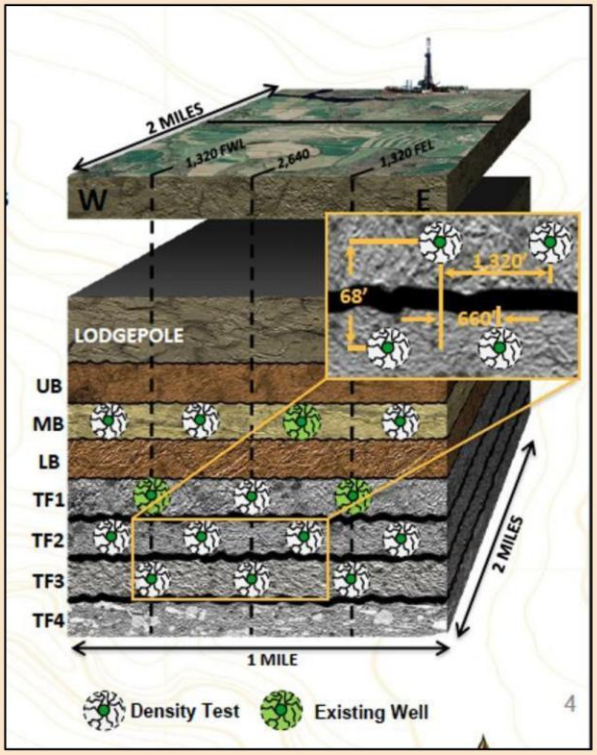


Image: Continental Resources

Presenter's notes: I am listing a few of key lessons learned and "must know" factors – I'll provide a set of articles and readings that will help you gain good sense of the best practices and current beliefs for each individual play.
Right now, the main lessons learned have to do with pushing the limits of pad drilling and stacked pays. The fact that the decline curves are steep is a pesky and up to now, intractable issue. But – that can definitely change.

Bakken & Three Forks

- Stacked Pay exploitation: Where / When & how
  - Bakken – middle member
  - Three Forks
  - Others? (what are the constraints? When do you NOT stack the pays?)

Presenter's notes: Stacked pay is a fantastic concept and very practical. However, there are a few issues that need to be considered. First, the more you have going on in a single pad, the more you run the risk of not optimizing the recovery for each lateral. Stacked pay sounds great, and it is, but some operators are finding that logistics in the pads are resulting in accelerated decline curves – mainly due to poor recovery.
When do you NOT stack pay? I would argue that it's really a matter of understanding the heterogeneity of the various pays and being willing to be very selective in targeting the sweet spots, and taking much care in the stimulation design.

Eagle Ford

- XRD / XRF: Geosteering for sweet spots
- Microseismic for determining fracture heights
- Sequence Stratigraphic correlations: 3D seismic & depositional modeling

Geosteering with while-drilling data. Image: UOGC

Presenter's notes: The Eagle Ford is very complicated, and there are vast barren areas, along with significant sweet spots.

Further, the Eagle Ford is very heterogeneous, and so it is important to integrate all possible data sources.
Geosteering using "logging while drilling" and image logs are very important.

Eagle Ford

- Determining the productive extent of Cretaceous stratigraphic equivalents
  - Eagle Ford
  - Eaglebine
  - Tuscaloosa Marine Shale
  - Haynesville
- Implications of other formations: Pearsall, Buda, Austin Chalk

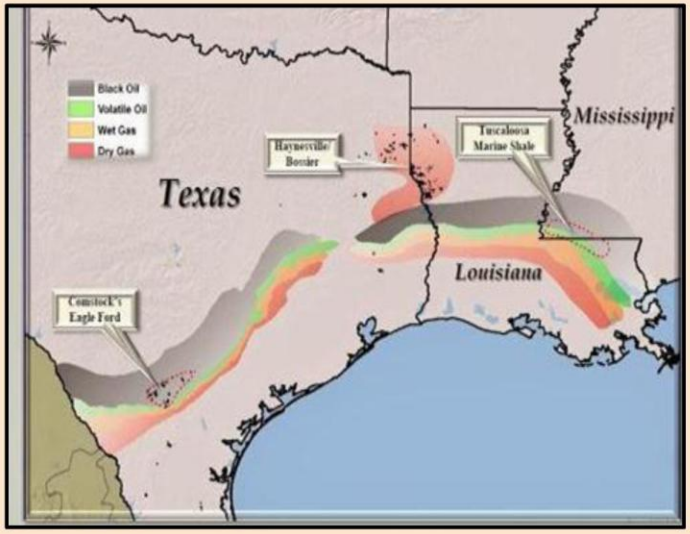
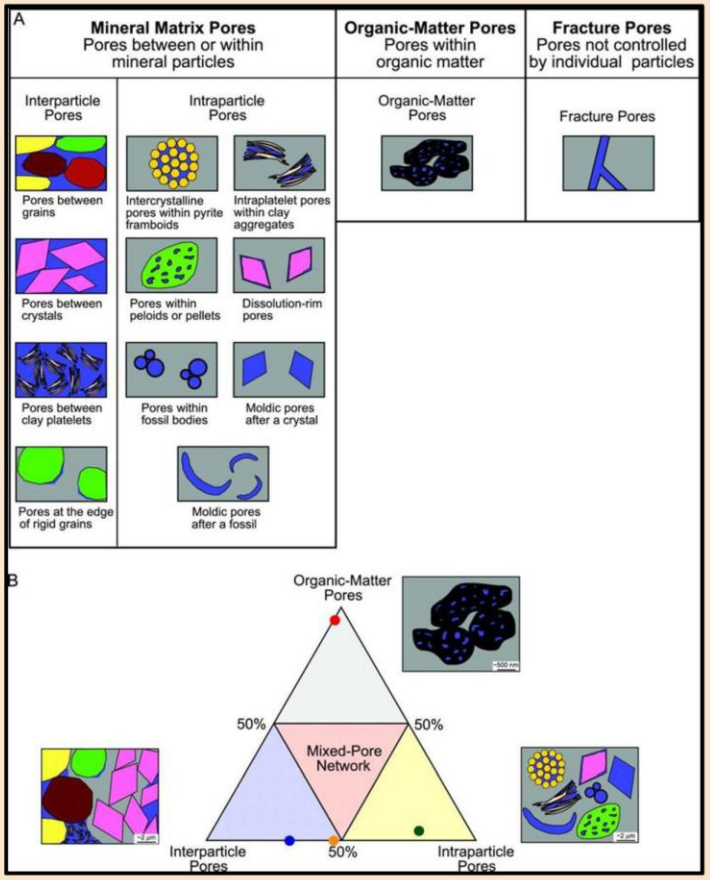


Image: Comstock Resources

Presenter's notes: One of the factors that makes the Eagle Ford so attractive to Wall Street is the fact that it's part of a regional picture – that is, the geological history, namely, the Cretaceous onlap, is vitally important, and the syndepositional plays are, in theory, prospective. So – one can connect the dots – and, it's just a matter of determining the productive extent of each.

Marcellus & Utica

- Gas – Liquids boundary determinations
- Gas typing and understanding the migration history / patterns / mixing
- Accessible and non-accessible porosity
- Pore typing (tie back to regional studies)
- CT scans on the cores



Presenter's notes: The Marcellus is a fascinating play – geochemistry is absolutely critical, especially if you're trying to work the system and produce just the right mix of gas and liquids. This slide lists a few of the "must have" elements and the "best practices" in the play.

Mississippian Lime

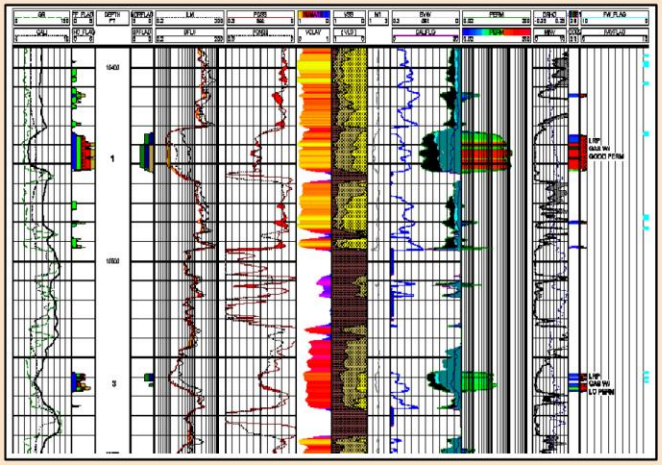


Image Logs for Fracture networks

Basin-Level Analyses

- Petroleum Generation
- Expulsion / Flow
- Structure (Faults / Fracture Networks)
- Convergence with Mississippi Valley-Type Mineralization

Presenter's notes: I am fascinated by the Mississippian Lime of Kansas and Oklahoma, and it is here, although it is not a shale.
If you've ever worked the Mississippian, you, too, are probably mesmerized by the puzzling realities such as "Why is the oil cut 2 percent here, but 15 percent a mile away?" The answer lies in the tectonic history as well as the thermal history. One created fracture networks. The other created hydrothermal alteration – and diagenesis .. Often chertification and dolomitization.
There's even more afoot in the Mississippian, though – we've got "King Kong Meets Godzilla" in the form of a Massive Petroleum System Meets Mississippi Valley Type Mineralization. Think hot, rich fluids being pumped through a fairly boring sedimentological system. The result is spectacular.

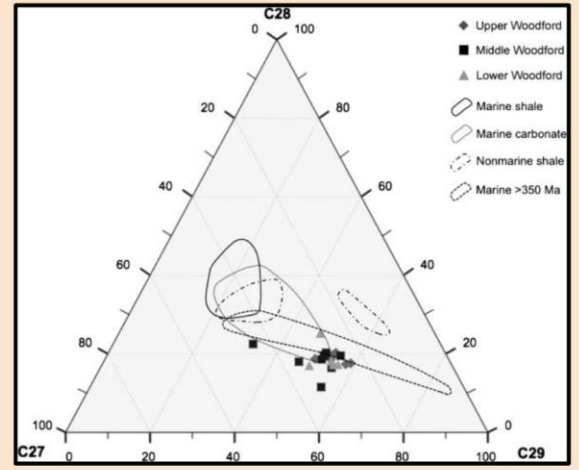
Woodford Shale

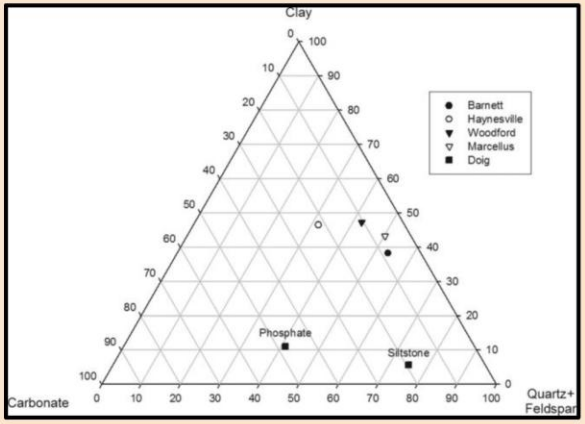
- Geomechanics
  - Pore pressure regimes
  - Nano-geomechanics (cation exchange capacity)
  - Fracture typing / characterization
  - Brittleness & Fracability determination

Presenter's notes: We've already covered most of the topics on this screen. We have not gone into much detail about how, exactly, to estimate pore pressure – so, I'd like to do that now.

Woodford Shale

- Geochemistry
  - TOC evaluations
  - Kerogen typing
  - Maturity / Vitrinite reflectance
  - Indicator minerals / deformations
  - Adsorption factors
  - Pyritization





Images: AAPG / Moldowan

Presenter's notes: I'd like to point you to the USGS work and also Brian Cardott's work at the Oklahoma Geological Survey. I'm very impressed with his careful and detailed work on kerogen typing and vitrinite reflectance – and, very impressively – how this can help a company form its own drilling program.

Niobrara

- Petrophysical Integration
  - Triple combo logs
  - Reprocessing sonic logs & seismic
  - Pilot well tie-ins to old wells
  - Data mining

Presenter's notes: Success in that notoriously fickle formation seems to have to been to relax and go with the flow – perhaps the Niobrara will emerge as the new best thing … all depends on technology and ultimate recoverability.

Conclusions

- ➔ New technologies and new techniques evaluated every day
- ➔ New approaches to sweet spots (whipstocked laterals)
- ➔ New stacked pays (follow the migration paths)
- ➔ Manipulating the clay minerals on a nano level to “unbind” the matrix and allow more accessible porosity


Thank you!!