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Dallas Section
Farmers Branch, TX
July 20, 2016

Bridging the Gap Between Drilling and Completions

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Society of Petroleum Engineers
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My Background

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BS Chemical Engineering, University of Oklahoma

11 years Halliburton Research Center

12 years international

- Leiden, The Netherlands
- Cairo, Egypt
- Copenhagen, Denmark

7 years with operating companies

- Maersk Oil, Danish Operations
- Chesapeake Energy, Fracturing Services
- Continental Resources, Bakken

Presentation Format

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- Define the challenge
- Evolution of technologies
- Establish today's baseline
- What does the future hold
- Conclusions

The Challenge

Economic development of unconventional reservoirs necessitated the development of leading edge horizontal drilling and well completion techniques.

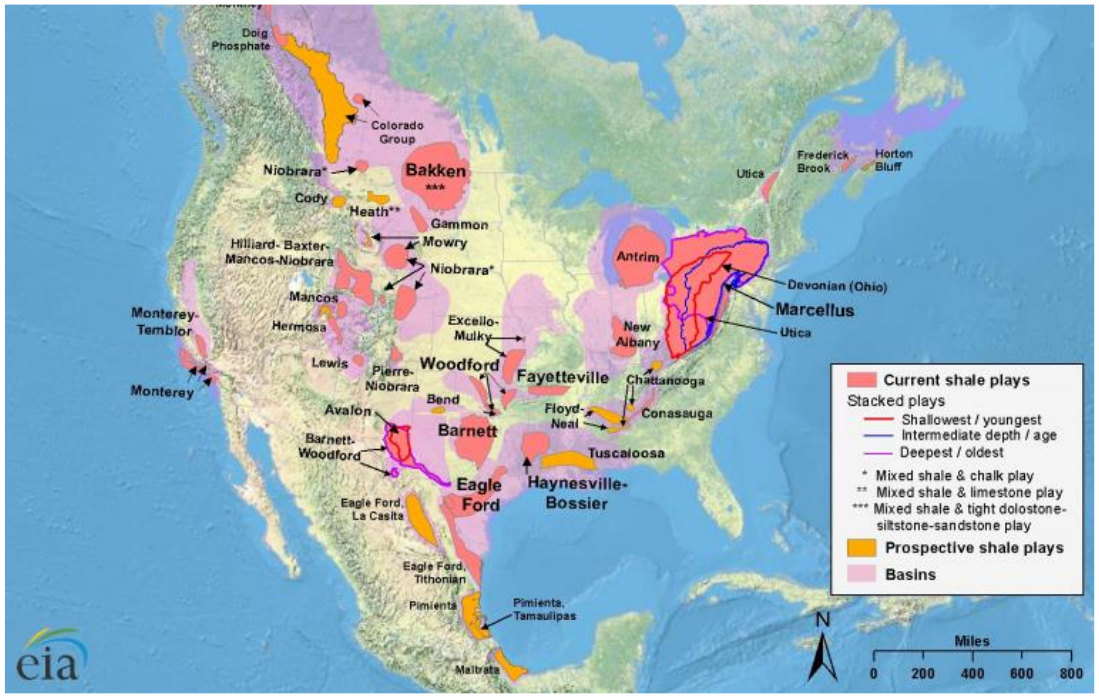

Photo courtesy of US Energy Information Association

The question for today

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Can we drill longer wells than we can effectively complete?

Scope: Stimulated horizontal wells

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Horizontal wells…

- Are getting longer and longer
- Require more stimulation stages
- Must be optimized; not just efficient and economical
- Environmental concerns can not be ignored

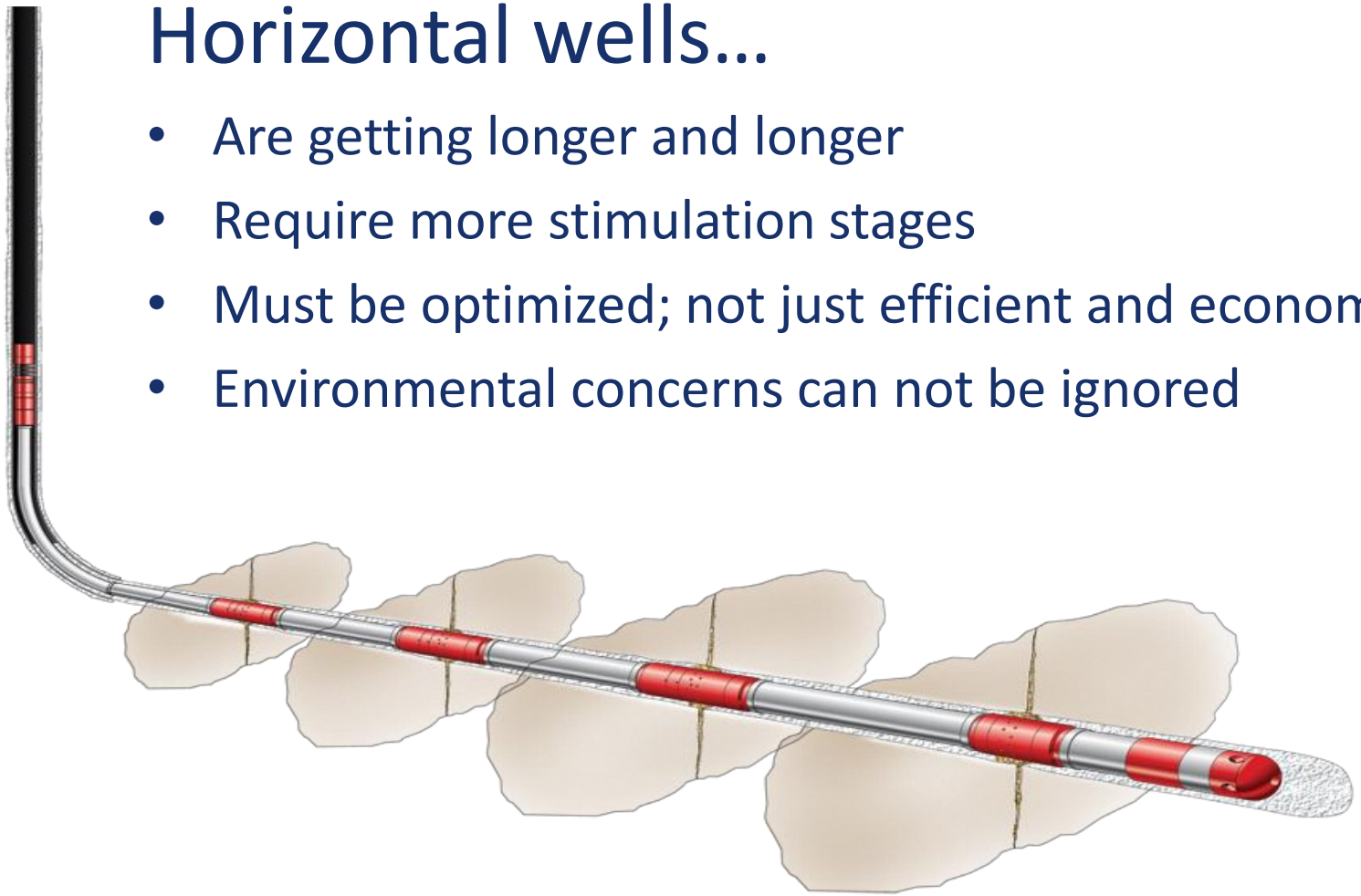

Photo courtesy of Halliburton Energy Services

Let’s start with some history

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1985	1987	1989	1991	1993	1995	1997	1999	2001	2003	2005	2007	2009	2011	2013	2015

The Dan Field Today

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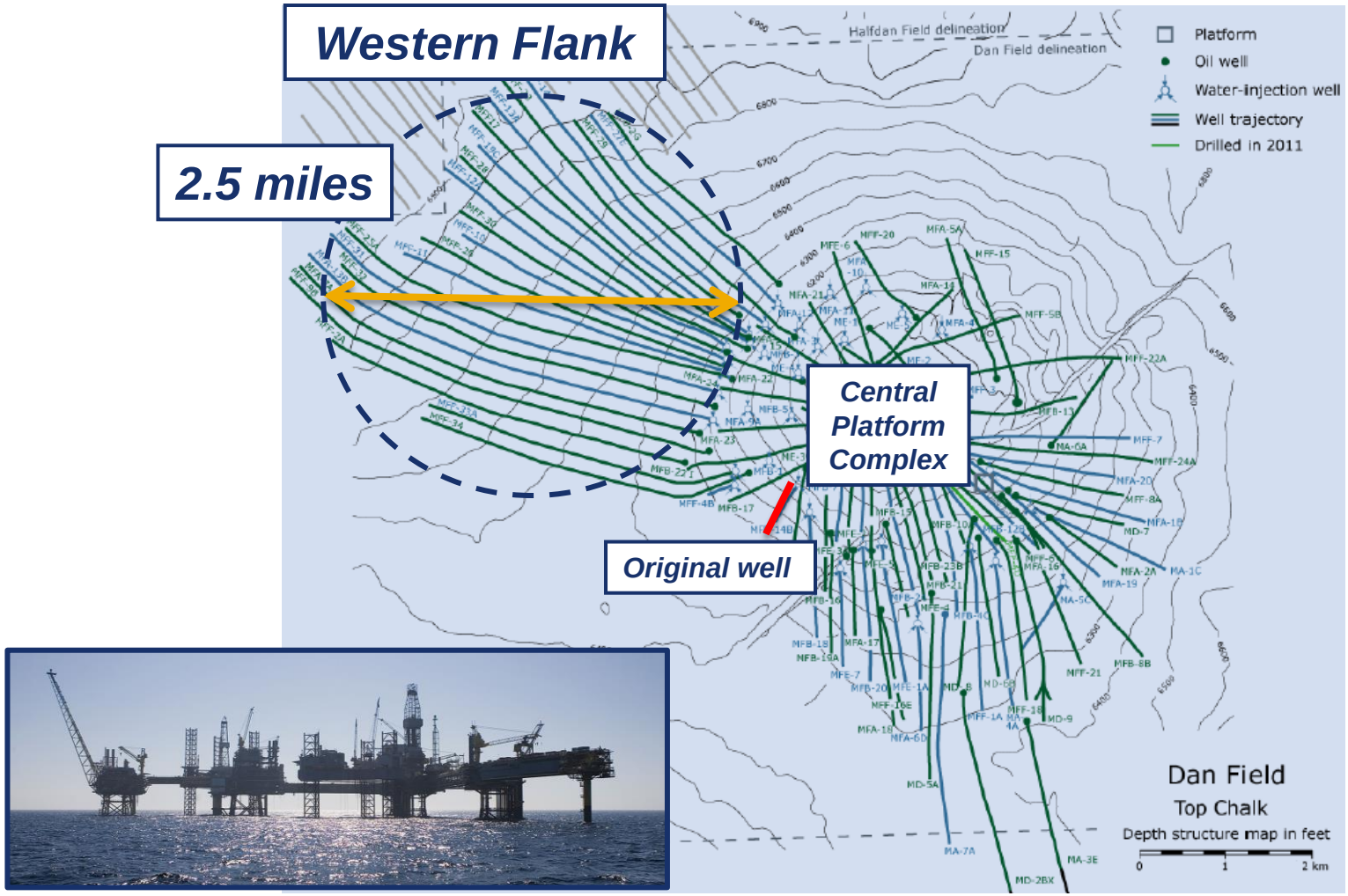

Reference: Danish Energy Agency "Oil and Gas Production in Denmark" (2013)

Halfdan Field (2000)

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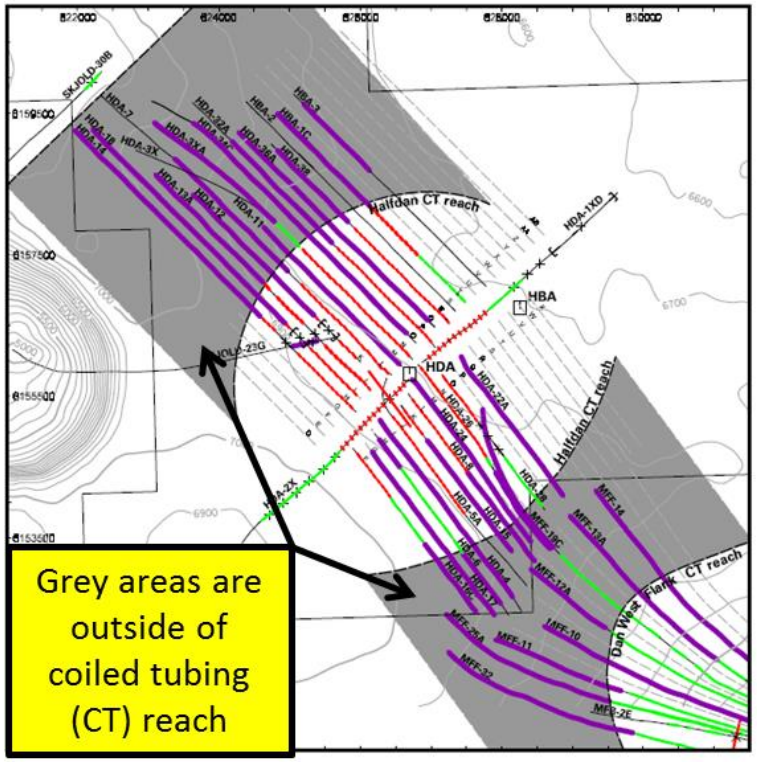
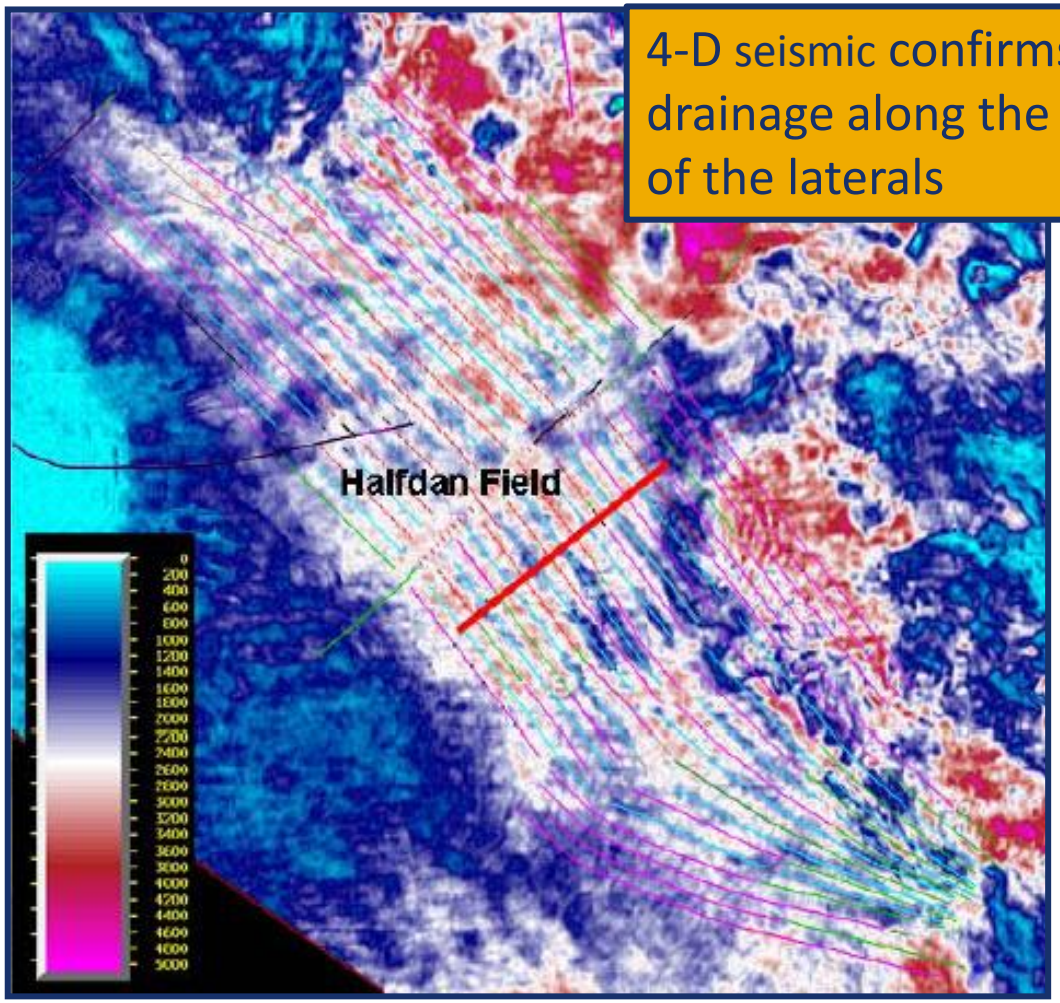
The Challenges

- Thin, flat reservoir requiring stimulation in order to produce at economical rates
- Lateral sections up to 20,000 ft
- > 50% of laterals outside of coiled tubing reach



Reference SPE 71322, 78220, 78318 and SPE 108531

The Halfdan Field Today



4-D seismic confirms effective drainage along the full length of the laterals

Reference SPE 71322, 78220, 78318. and SPE 108531

Unlocking reserves through horizontal drilling and completion technologies

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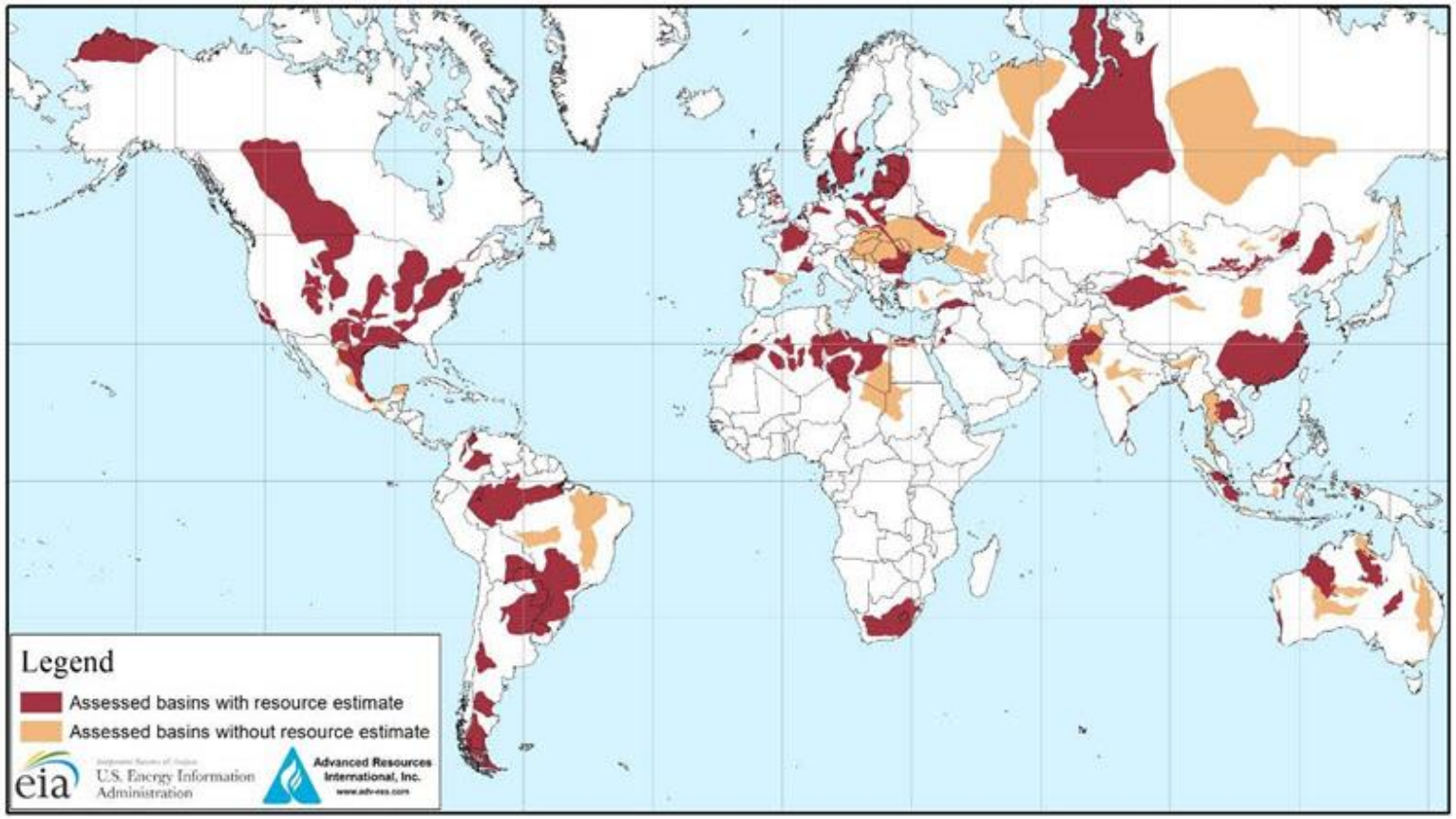
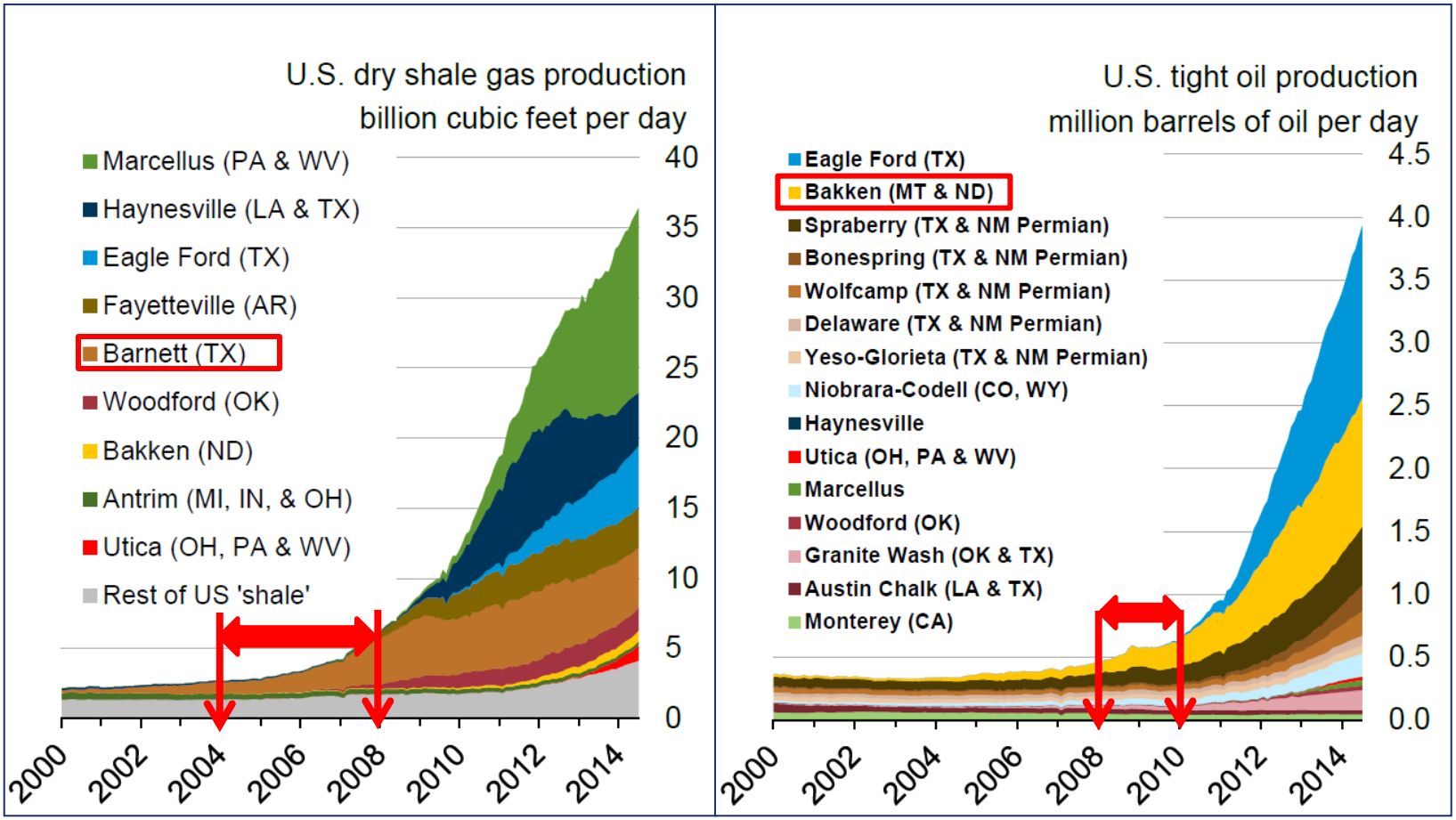


US Energy Information Administration: "Technically Recoverable Shale Oil and Shale Gas Resources: An Assessment of 137 Shale Formations in 41 Countries Outside the United States" (June 13, 2013)

Accelerating the learning curve



Source: EIA Energy Infrastructure Summit, September 2014

By 2010, 90% of the wells in the Bakken were horizontal with multi-stage fracs and the operators were preparing to ramp up in the Eagle Ford

Bridging the gap between drilling and completions

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What are today's challenges?

- Time and money
- Laterals are getting longer
- Availability of materials, especially water
- Public perception and environmental regulations
- Selecting the optimum completion for a given area
- Access to service providers

Brent Oil Spot Price ($/bbl)

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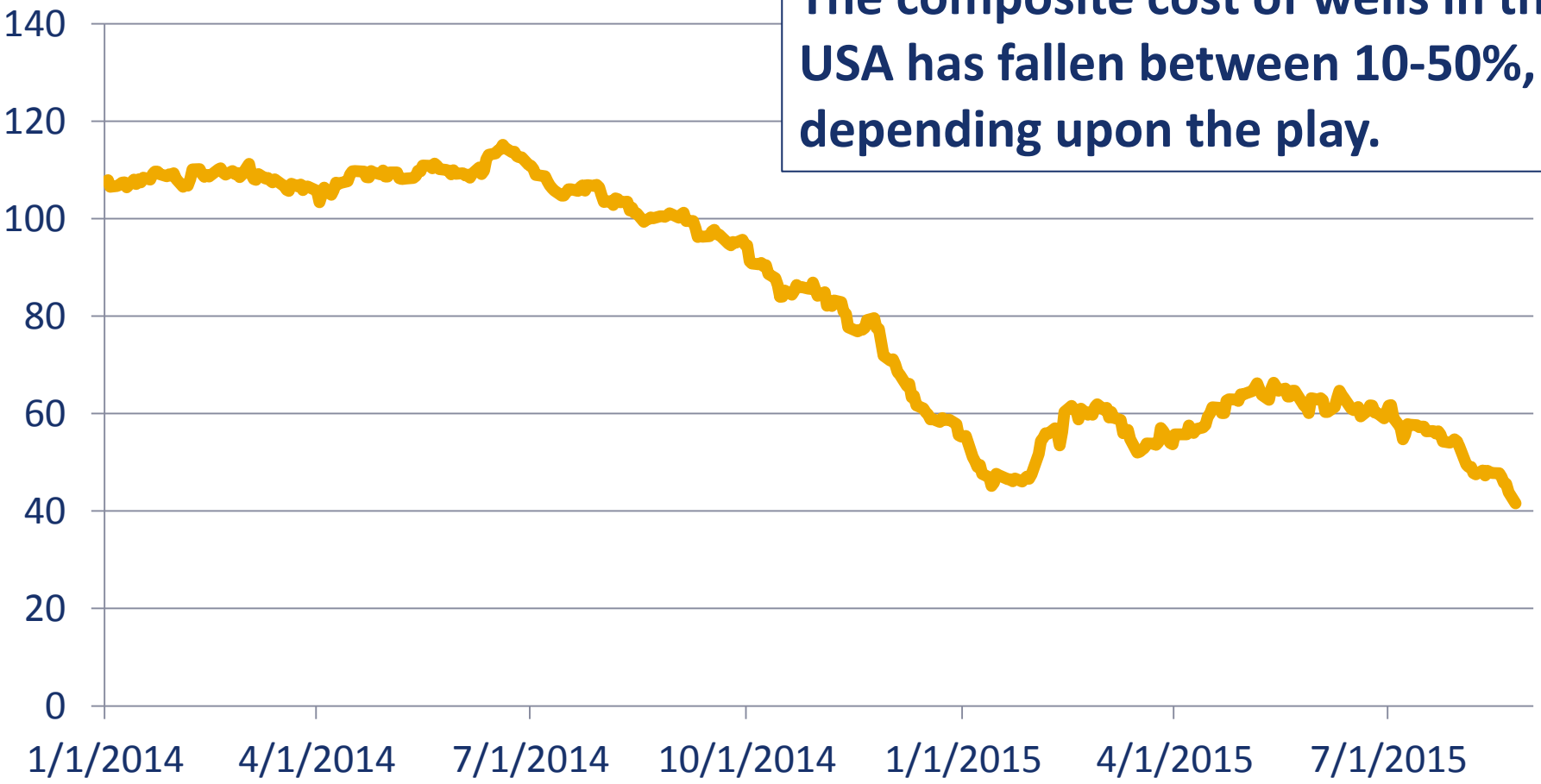
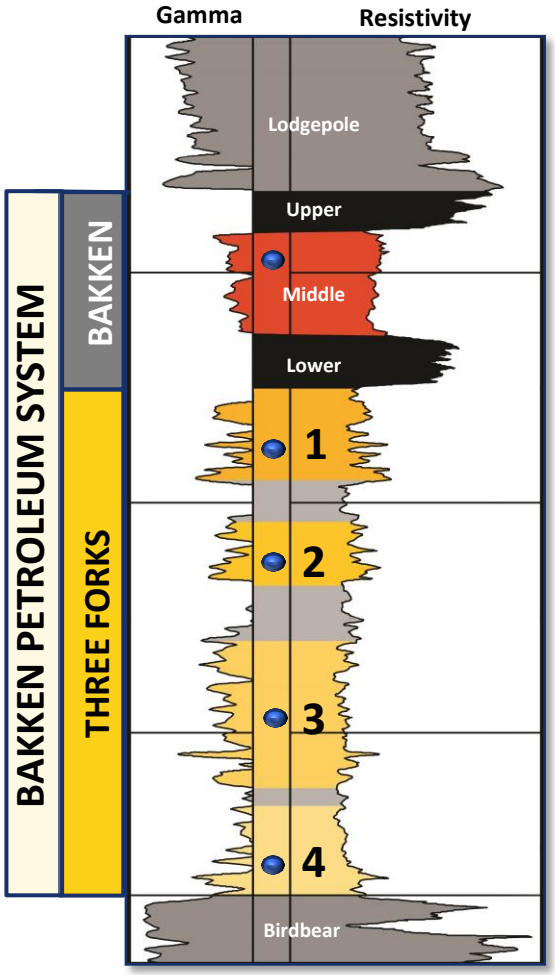
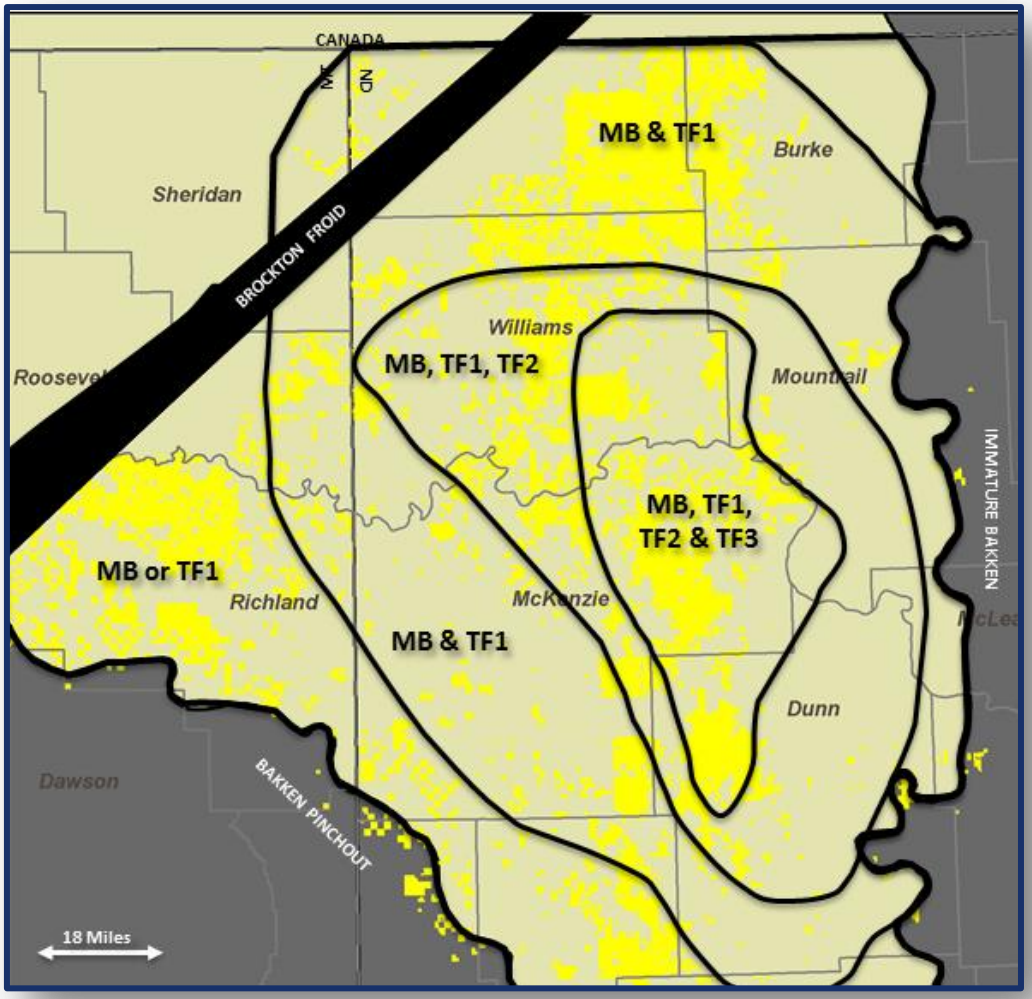
The composite cost of wells in the USA has fallen between 10-50%, depending upon the play.



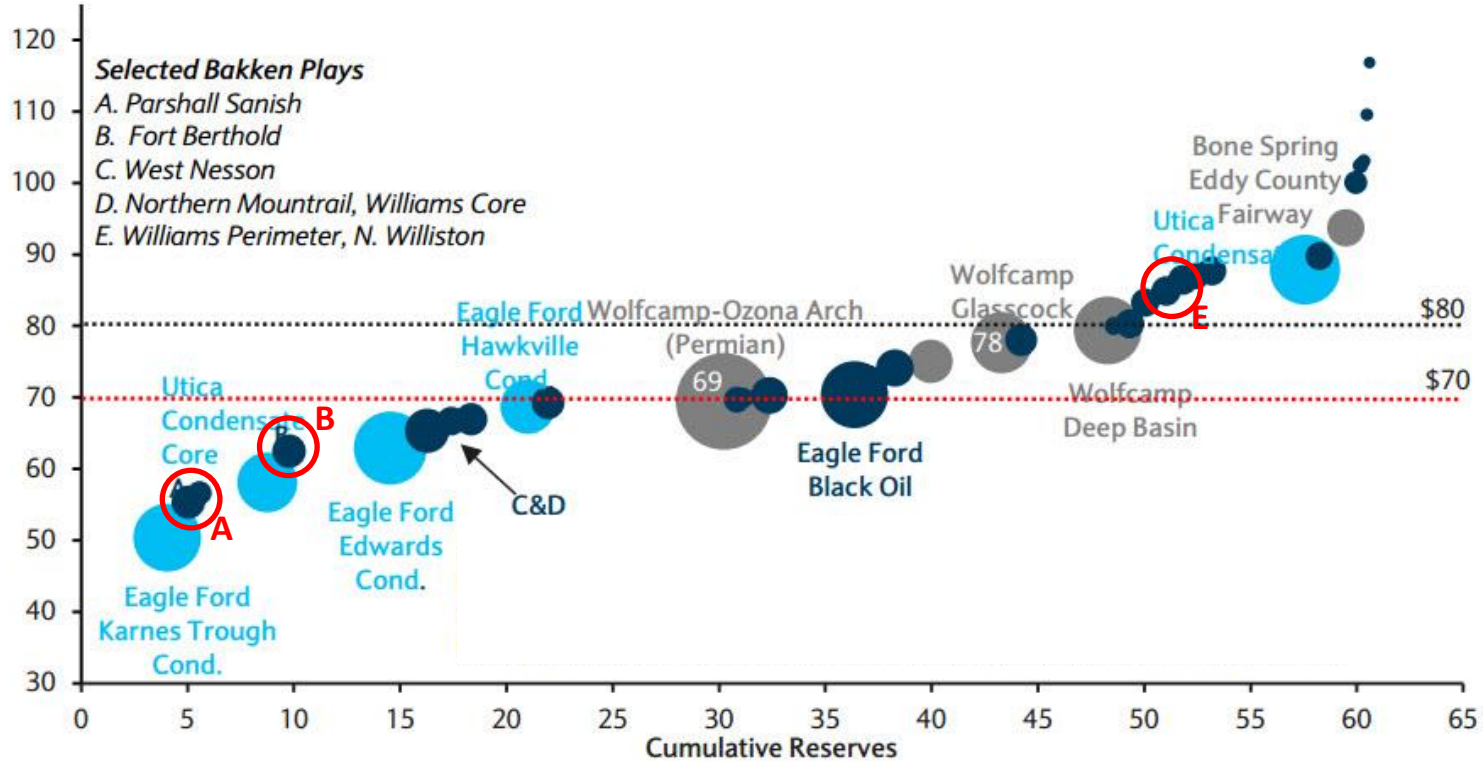
Brief Introduction to the Bakken





Tight Oil Breakeven Prices

2014 "High Grading" Example

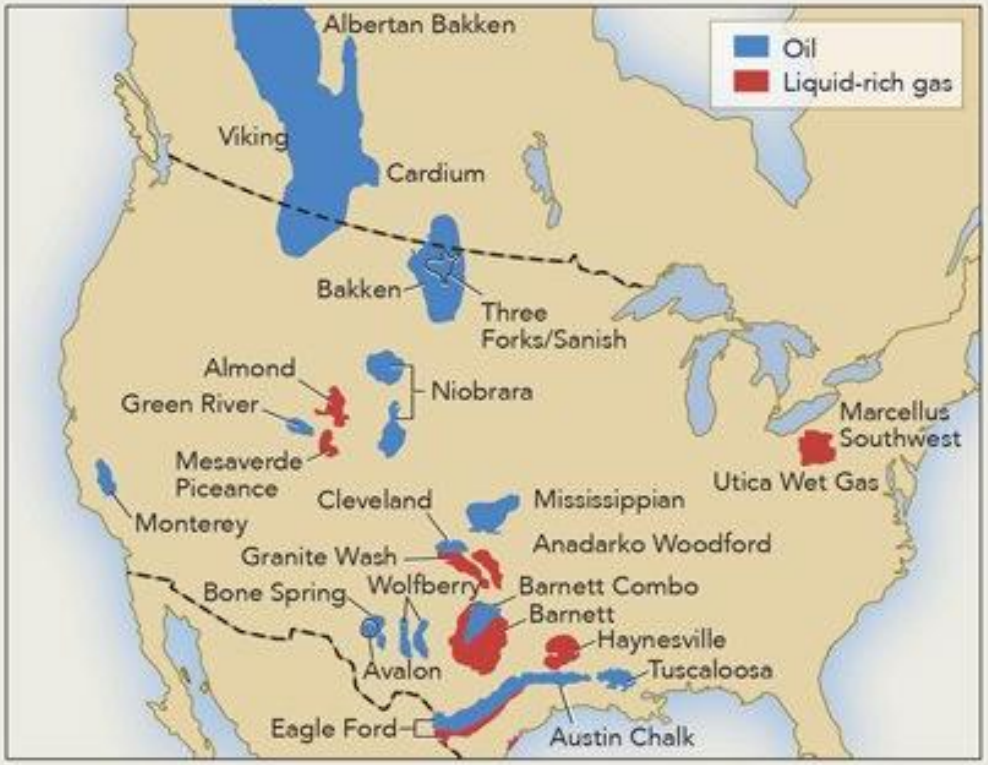


Source: WoodMackenzie, Barclays Research (November 2014)

Tight Oil Breakeven Prices

2016 "High Grading" Example

Unconventional oil plays



Likely 2016 breakeven estimates

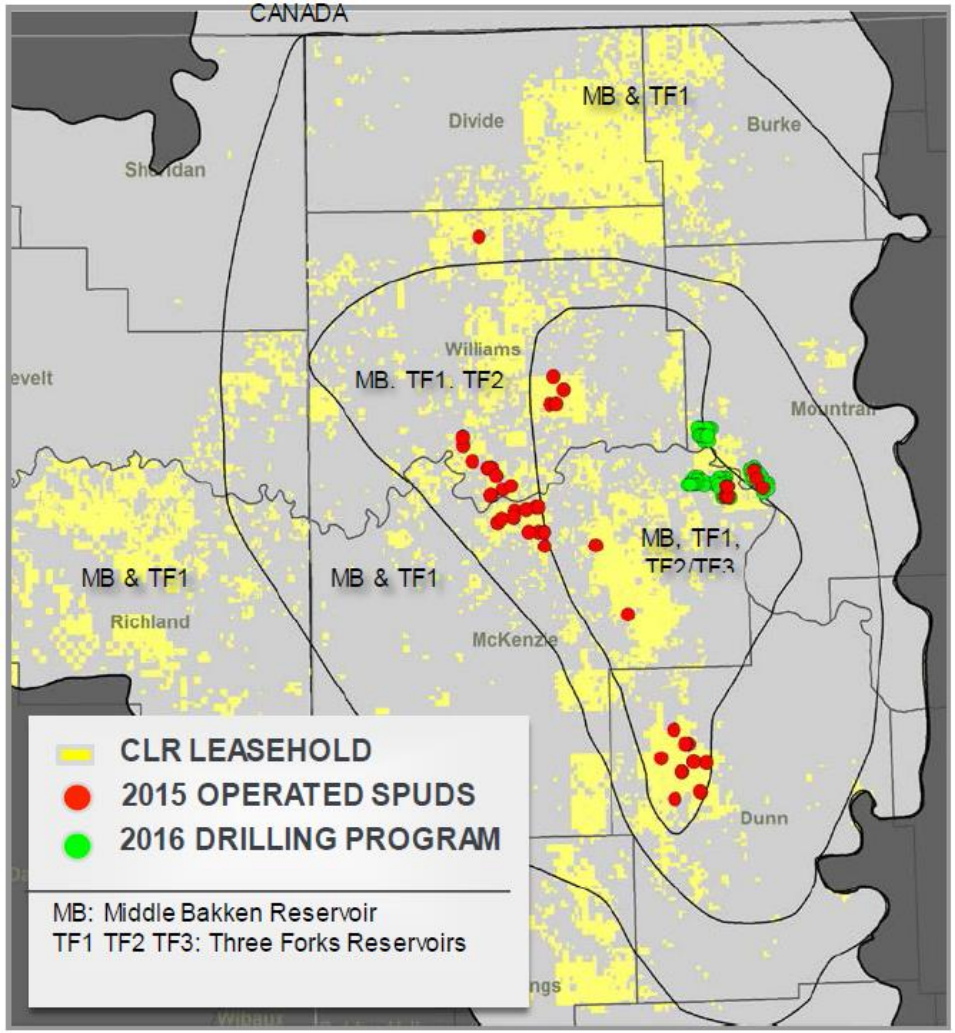
Basin/Play	Breakeven Range ($bbls)	
	Low	High
Niobrara	$32.50	$48.45
Anadarko	$32.91	$69.19
Marcellus	$33.18	$41.80
Eagle Ford	$37.12	$70.24
Bakken	$37.12	$65.55
Permian	$37.82	$75.97
Granite Wash	$38.52	$81.70
Mississippian	$47.23	$61.75
Utica	$50.56	$68.22
Barnett	$52.11	$62.66
Uinta	$56.88	$68.40
Tuscaloosa Marine	$65.57	$78.85

$30-$40/bbl
$50-$65/bbl
$65+/bbl

Source: Morgan Stanley, Rystad Energy, EIA, AlexPartners (March 2016)

Tight Oil Breakeven Prices

2015 vs. 2016 Well Spuds



Source: Continental Resources February 2016 Investor Presentation

What will happen in 2016, 2017?

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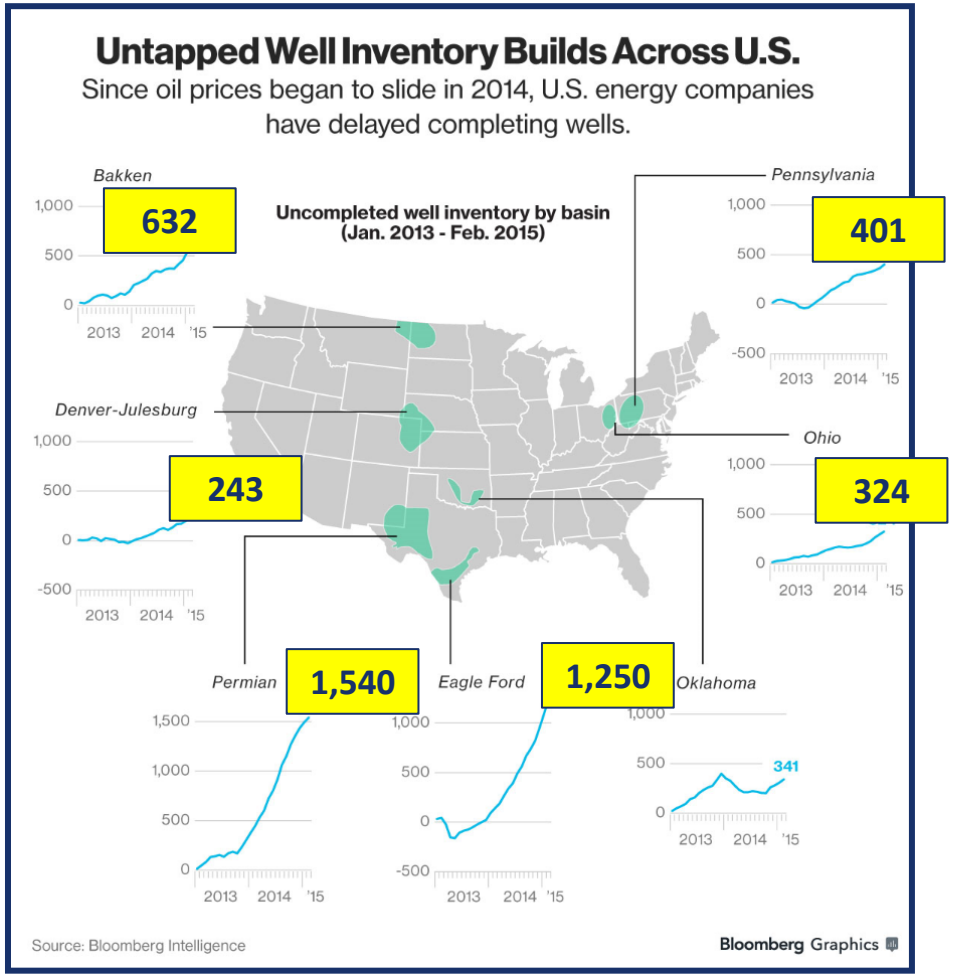
Drilled Uncompleted Wells

- 4,000 DUCs (~ 2 billion bbl oil)
  - 930 DUCs in Bakken
- 800 less DUCS by year end*
  - 300,000-350,000 BPD

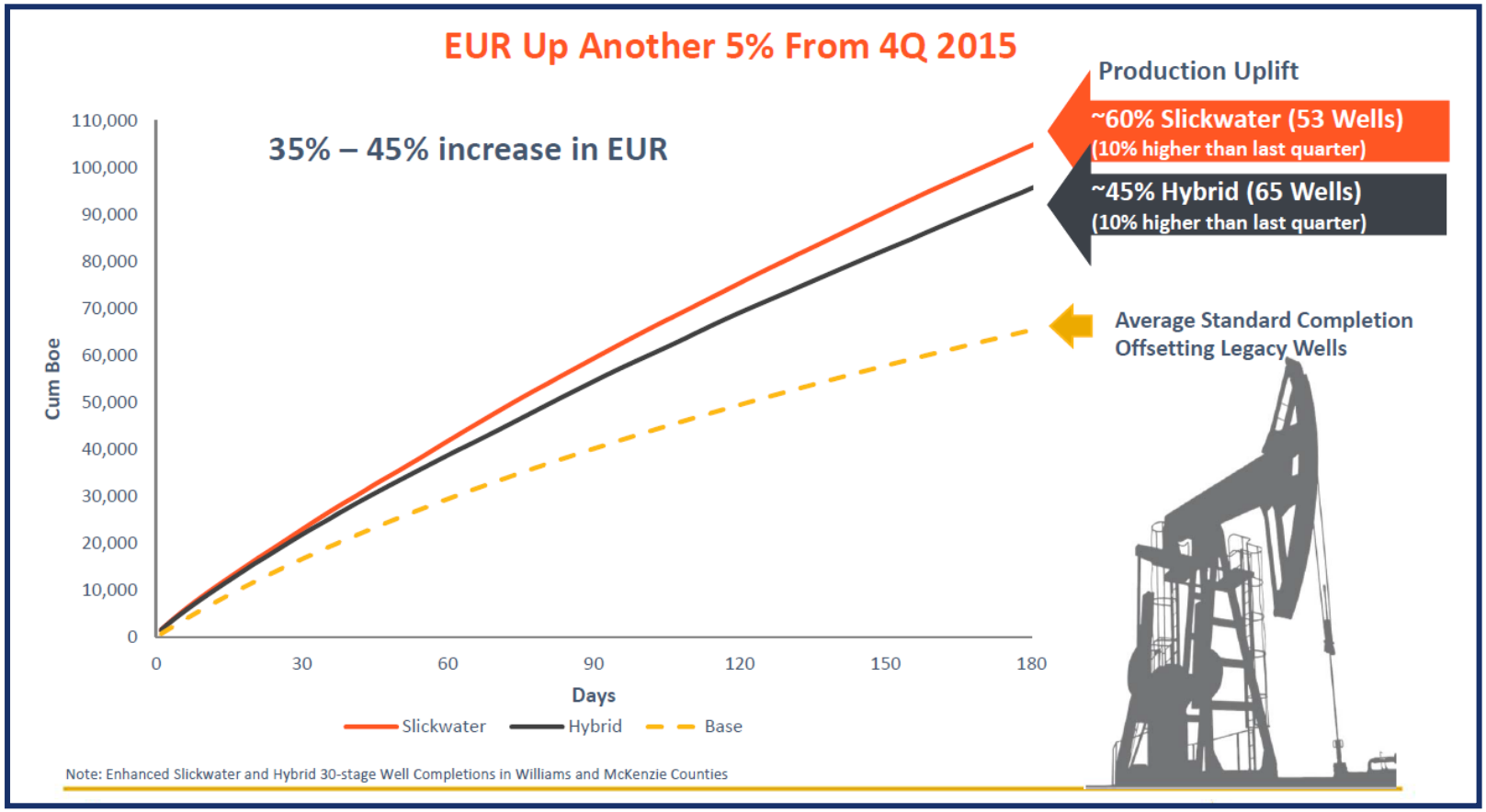
Important questions:

- Where is the opportunity in this challenge?
- How do we prepare for the recovery when it happens?



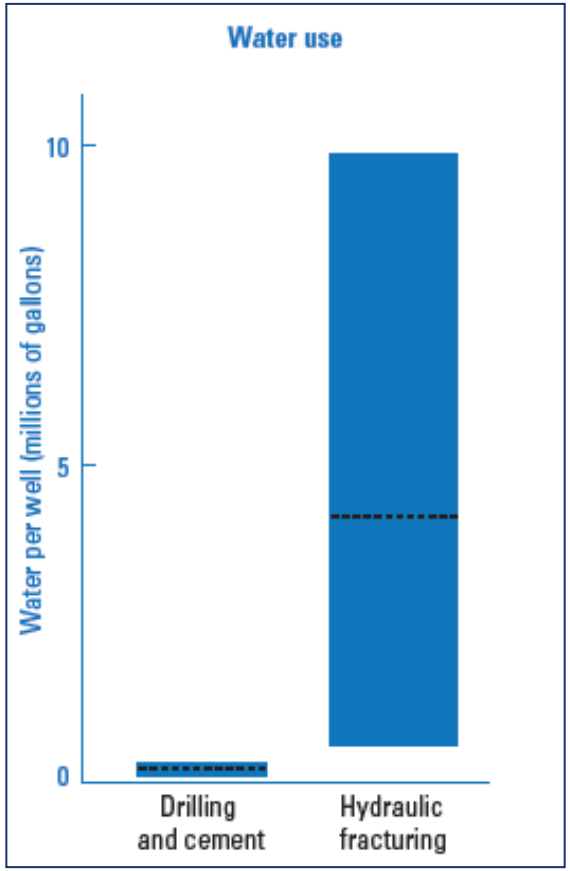
Oil and Gas Journal (July 4, 2016) page 9

Enhanced Completions



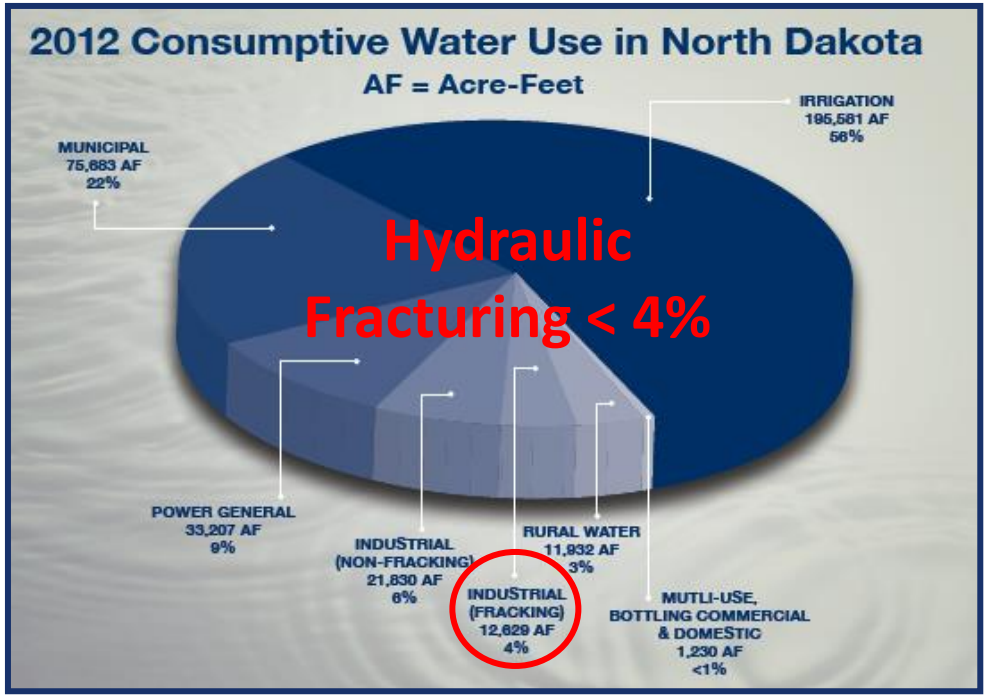
Source: Continental Resources May 2016 Investor Presentation

Water Requirements – Horizontal Wells
Drilling vs. Completions



Source: US Geological Survey Fact Sheet 2014-3010 (March 2014)

- Significantly more water is used during completion compared to drilling; however,
- The amount is a small percentage of all industrial water usage



Source: North Dakota State Water Commission

Produced Water Recycling Facility

Reference SPEPOS Panel Session on Water Management for Hydraulic Fracturing, March 2015

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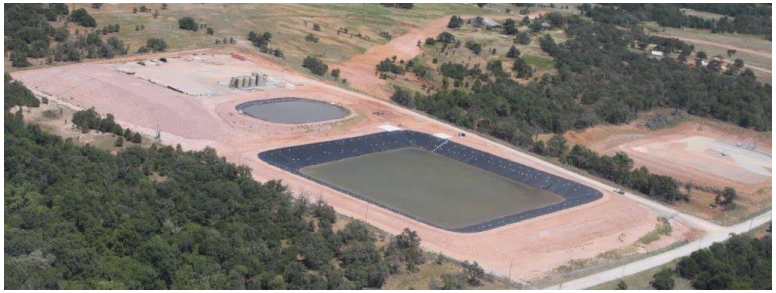
Components

- Produced water storage
- Skim or flocculation
- Treatment to remove organics
- Underground water transfer pipelines

50,000 bbl/day Recycling Capacity and 1,500,000 bbl Useable Storage

Economic Benefits

- Low OPEX ~ $0.30-$0.50/bbl
- Facilities generate revenue
- Minimizes salt water disposal
- 30% reduction in fresh water consumption



10,000 bbl/day Recycling Capacity and 500,000 bbl Useable Storage

Note: Temporary recycling facilities are available which do not require CAPEX
OPEX is $2.50-$3.60/bbl, depending upon produced water quality and throughput

Pushing the limits of lateral length

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1st 3-mile lateral

1st 2-mile lateral

1st horizontal Bakken well with multiple frac stages

1985	1987	1989	1991	1993	1995	1997	1999	2001	2003	2005	2007	2009	2011	2013	2015

Drilling Efficiency Gains with Longer Laterals

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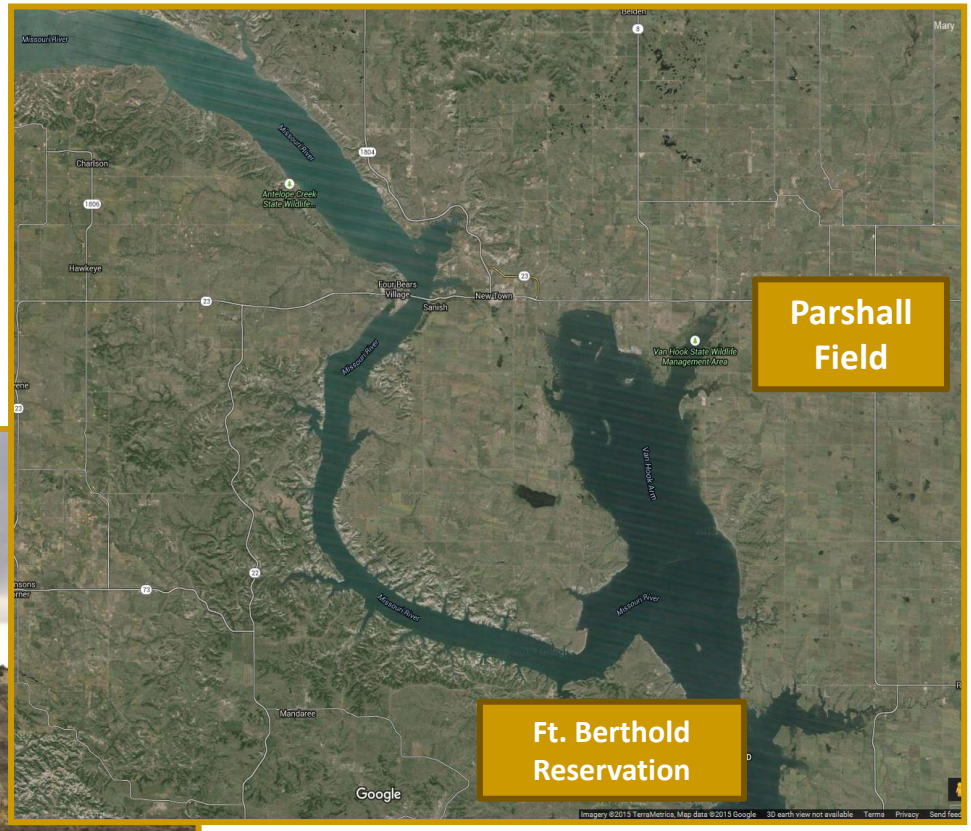
Challenge:

- Accessing "offshore reserves"
- Surface constraints



Drilling Efficiency Gains with Longer Laterals

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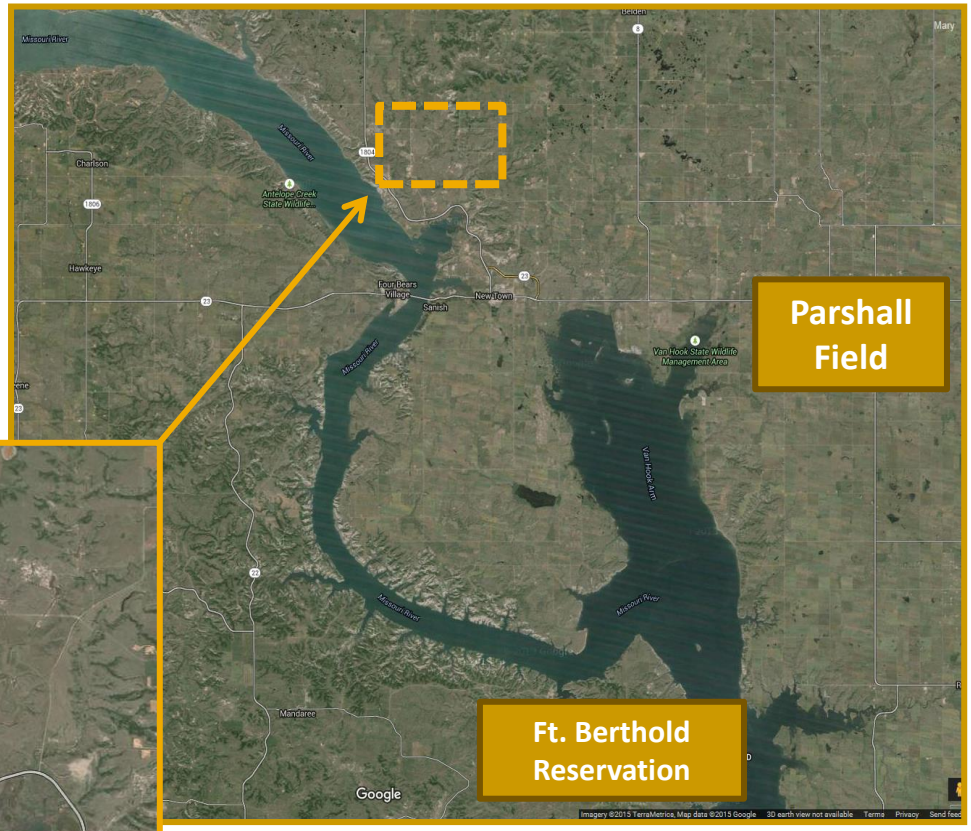
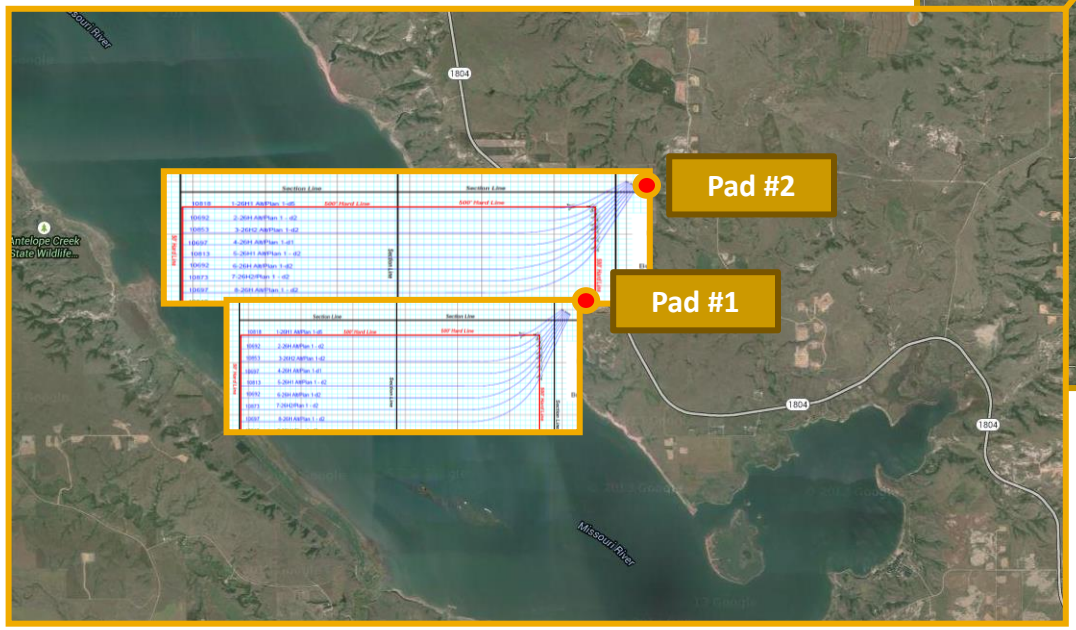
Solution:

- Directional drilling
- Extended lateral developments





Chasing the drilling rig

- Steering the lateral
- Where to perforate
- Toe stimulation
- Stage isolation
- Post frac cleanout

Challenge: Steering the Lateral

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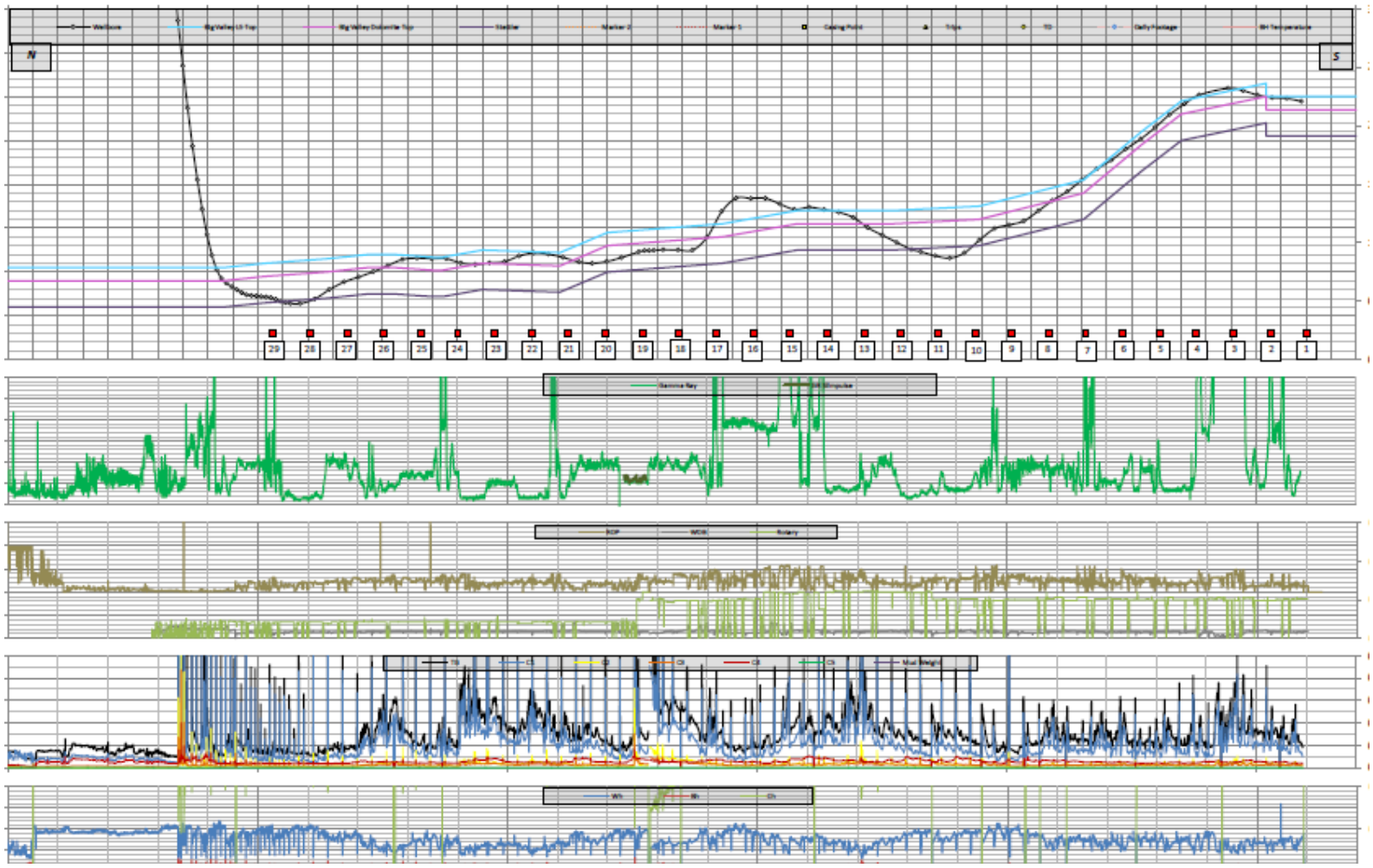
- Geo-steering
- Mud logging
- Cuttings analysis
- Gas analysis
- Biostratigraphy
- Logging while drilling
- Thru-bit logging
- Paleo-environmental analysis

Is this what your lateral looks like?

Challenge: Steering the Lateral



Challenge: Quantifying rock properties

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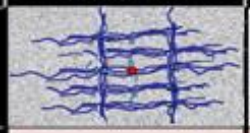
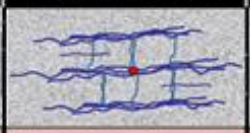
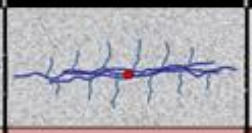
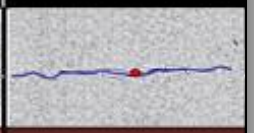
Is your rock brittle or ductile?

	Complex Systems	Complex Planar w/ Fissures	Complex Planar	Planar w/ Fissures	Planar
Fracture Geometry					
Stress Anisotropy	LOW				HIGH
Brittleness	8 BRITTLE 0.18		YM PR		2 DUCTILE 0.35
Completion Focus	STRESS INDUCED COMPLEXITY	RESERVOIR DIVERSION	RESERVOIR DIVERSION	RESERVOIR DIVERSION	FRACTURE INTENSITY
Reservoirs	Barnett Woodford	Marcellus Eagle Ford Gas	Eagle Ford Oil Bakken	Haynesville	Montney

Reference SPE 115258, 152704, 164271, 167726, 168763

Challenge: Completing the lateral

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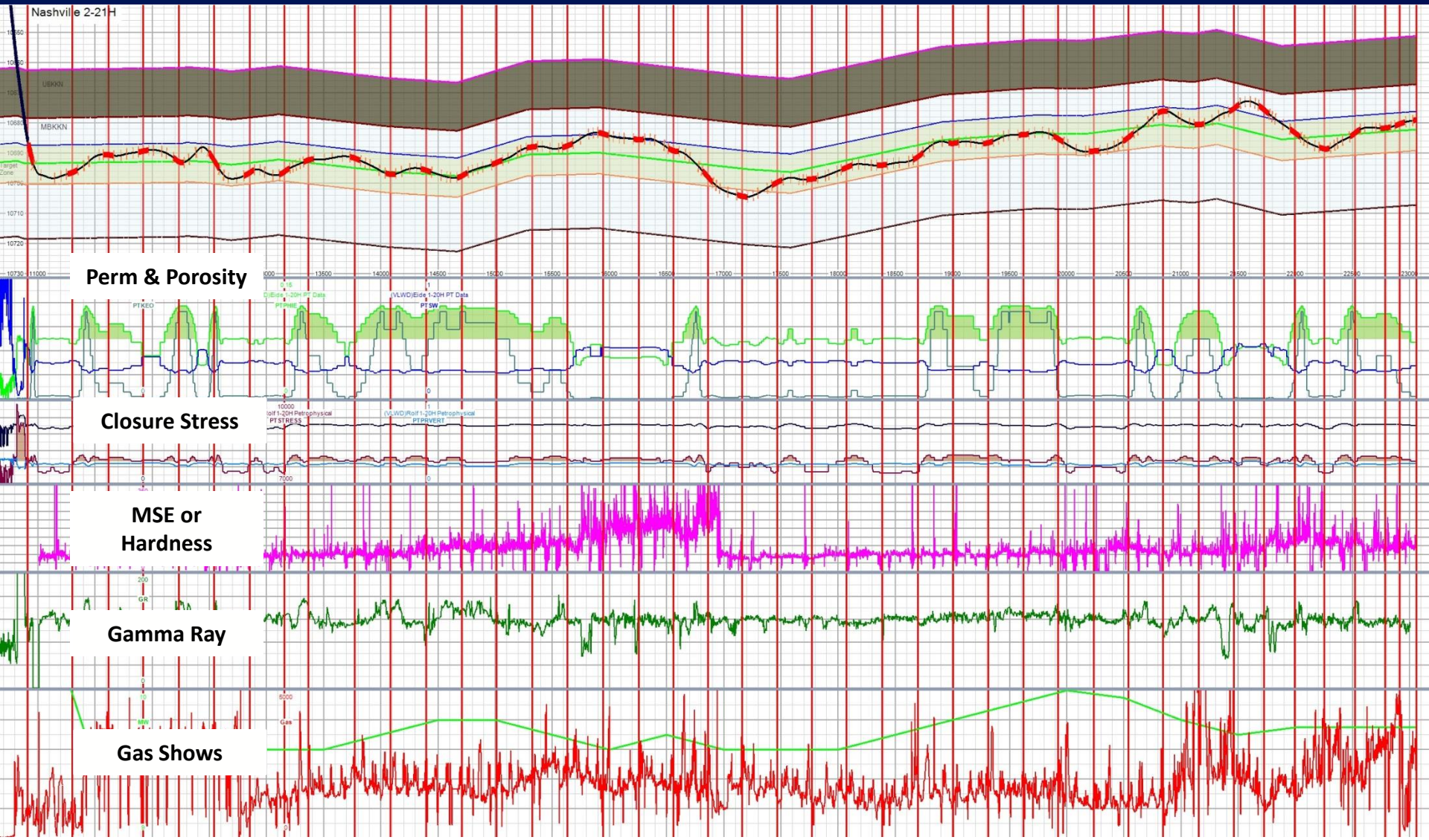
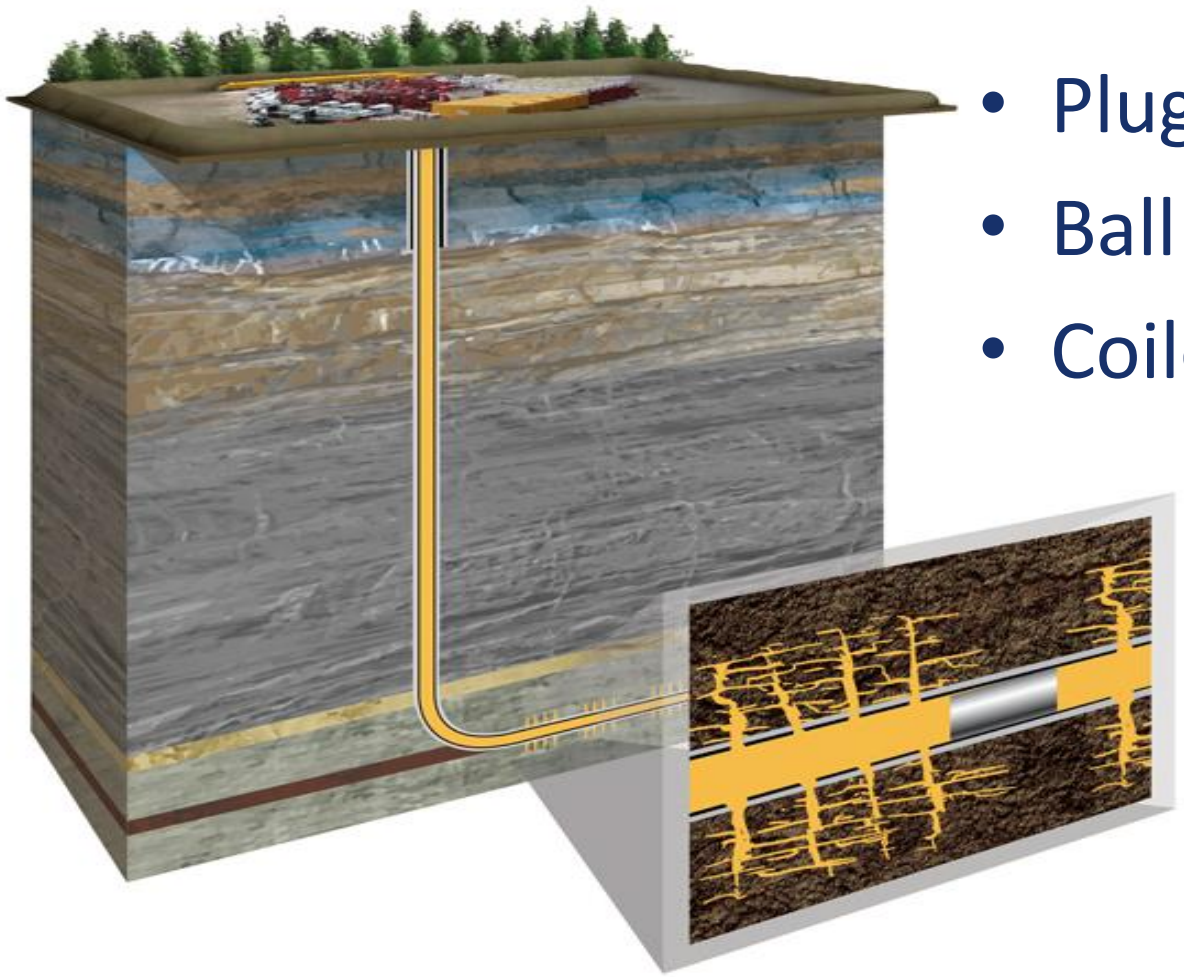


Challenge: Stage Isolation



- Plug-and-perf
- Ball activated sleeves
- Coiled tubing activated

Plug-and-Perf Completions

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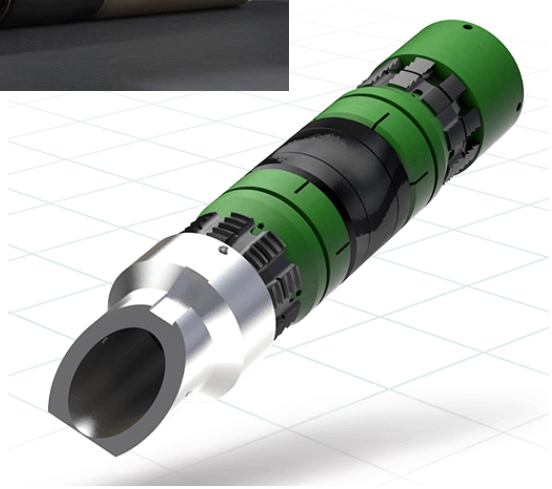
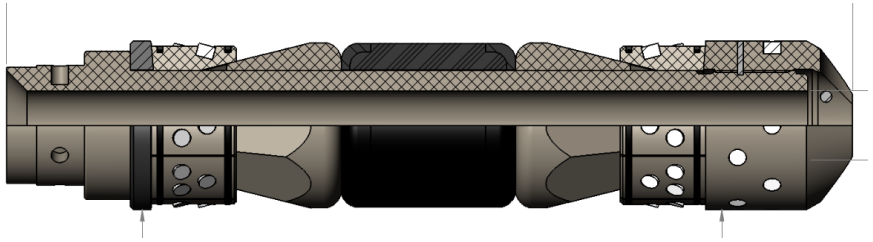
P'n'P; along with "zipper fracturing" reduced completion times significantly

Challenge: Frac plug mill-out

Solutions:

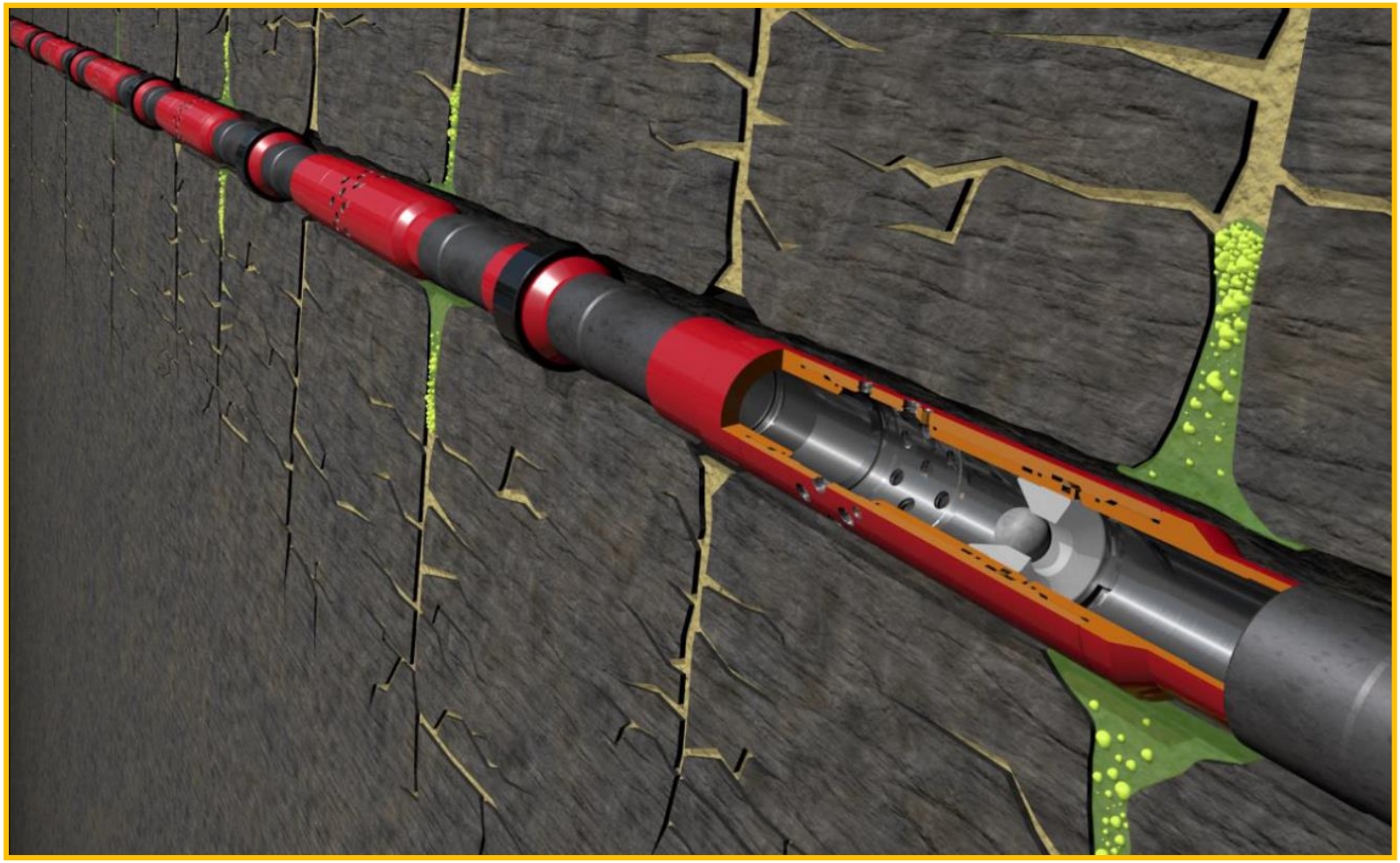
- Larger ID coiled tubing
- Large ID frac plugs
- Dissolvable frac plugs





Images courtesy of Halliburton Energy Services, Baker Hughes, Magnum Tools, and Schlumberger

Challenge: Reducing Completion Time



Images courtesy of Halliburton Energy Services

Ball Activated Sleeves Systems

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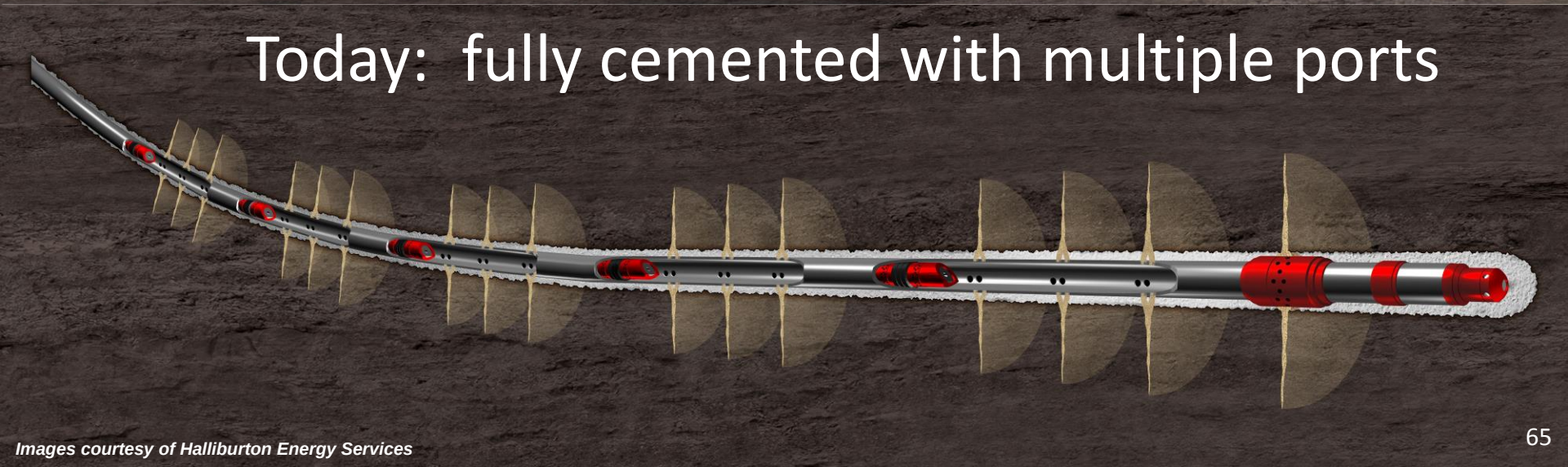

Images courtesy of Halliburton Energy Services

Coiled Tubing Fracturing

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Sleeves are run in the liner, then shifted with coiled tubing during stimulation operations

Coiled Tubing Fracturing

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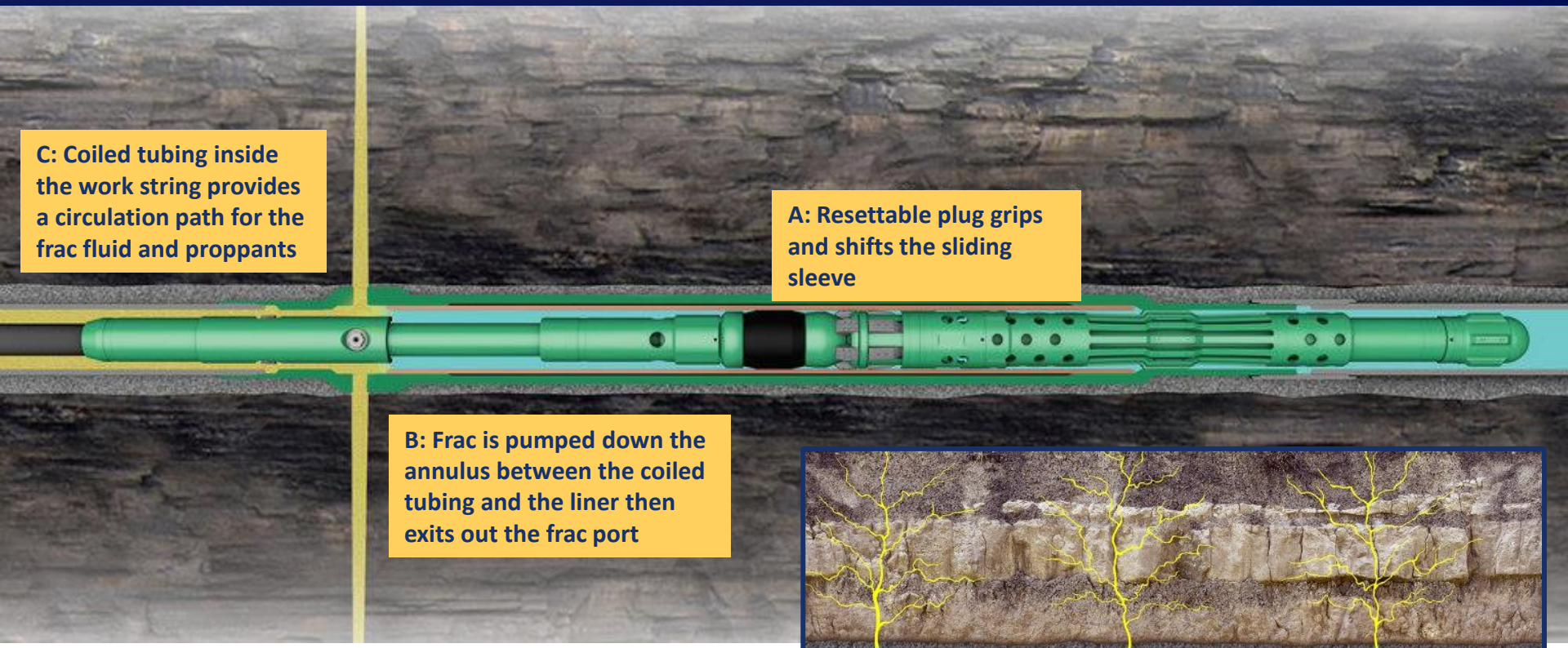
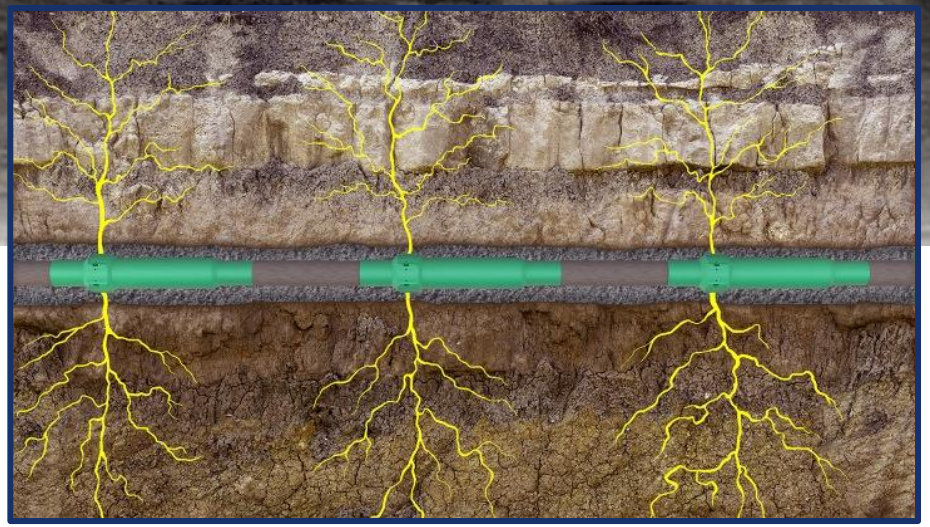


Images courtesy of NCS Energy Services



D: Precise fracture placement, with theoretically unlimited stages

Full circle in horizontal well completion technologies

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Today and Future:

Completion technologies developed onshore being applied offshore

North Sea:

- Directional drilling
- Extended reach wells
- Horizontal wells with multi-stage stimulations

2000 - 2020

1980 - 2000

Unconventionals:

- Fracturing technologies
- Completion techniques
- Completion hardware

Onshore conventional reservoirs:

- Tight gas
- Mature fields
- Horizontal wells
  - Austin Chalk, Texas
  - North Slope, Alaska

Inspiration credit: Martin Rylance, JPT, April 2015

Technology sharing

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- Collaborate
  - All disciplines: geosciences, drilling, completions, production
  - With service providers and other operators
- Accelerate learning curve
  - Learn from both successes and failures
  - Think outside the box when looking for analogs
- Be prepared
  - There will be a shortage of skilled people
  - Keep focus on being effective not just efficient

In conclusion:

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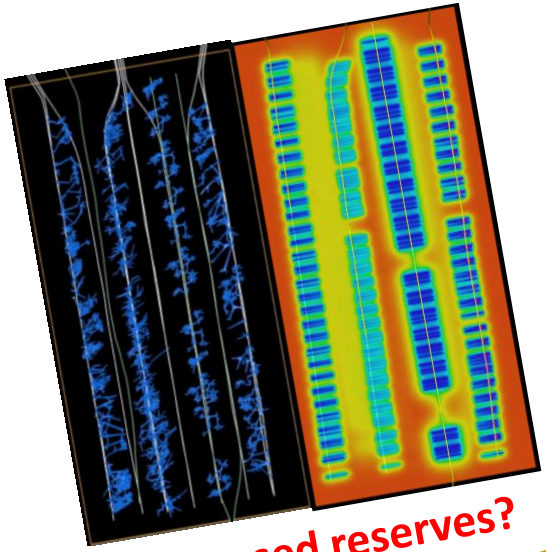
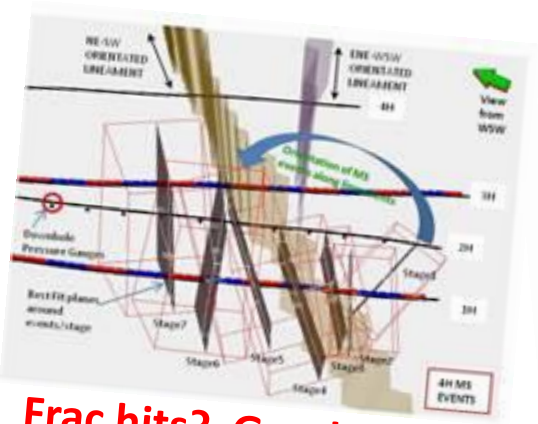
Does completion technology lag behind drilling technology?

- Drilling envelope is pushed first
- Completion technology is a fast follower

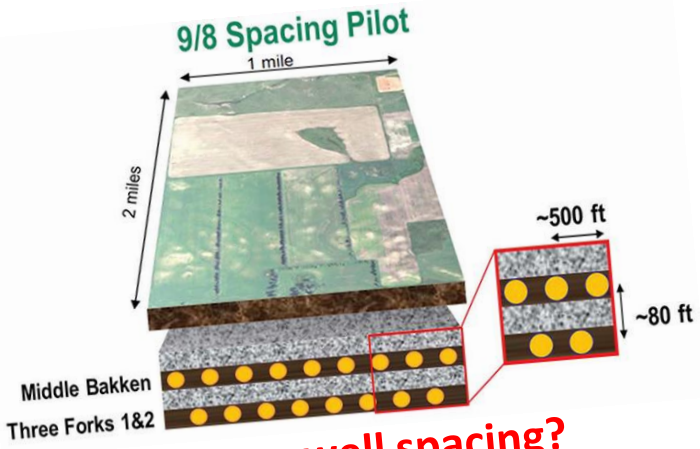
What keeps you awake at night?



By-passed reserves?

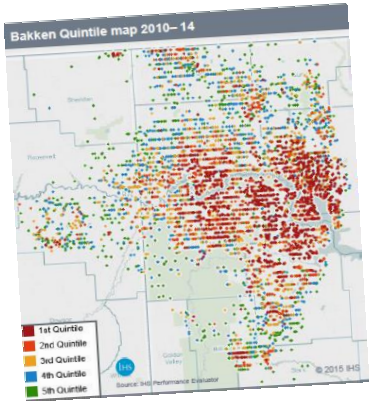


Frac hits? Good or bad?



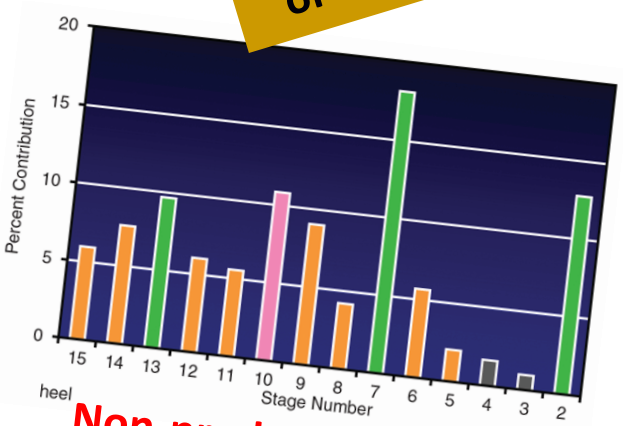
Optimum well spacing?

More proppant or more fluid?



Where to drill?

Plug-and-Perf or Ball-and-Sleeves?



Non-productive stages?

Growing inventory of drilled but uncompleted wells

Drilling and completion SIMOPS?