Complex Downhole Optimization in Permian Delaware Basin

SPE Gulf Coast Section Annual Drilling Symposium

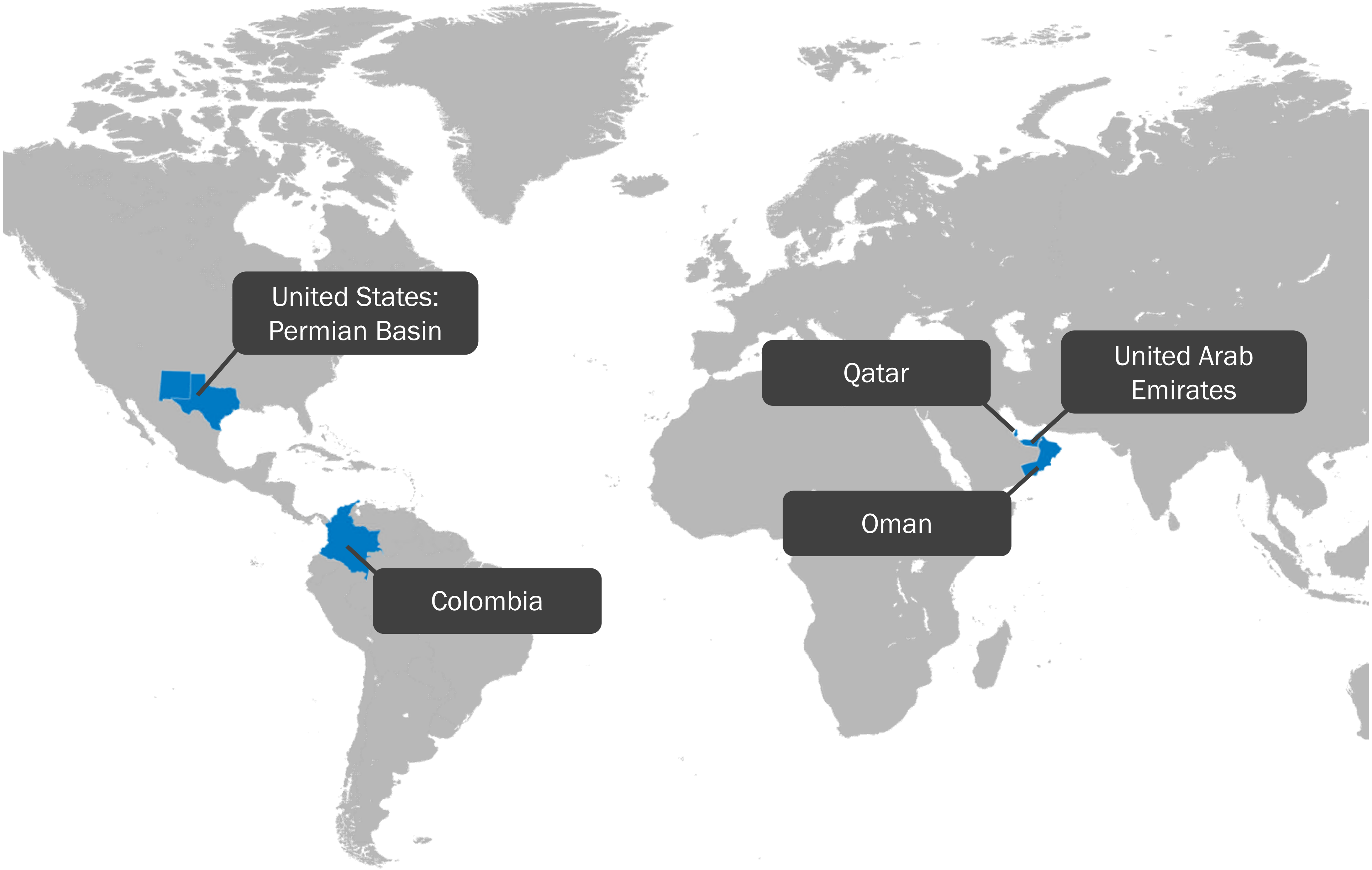
John Willis, D&C Manager, New Mexico

April 14, 2017

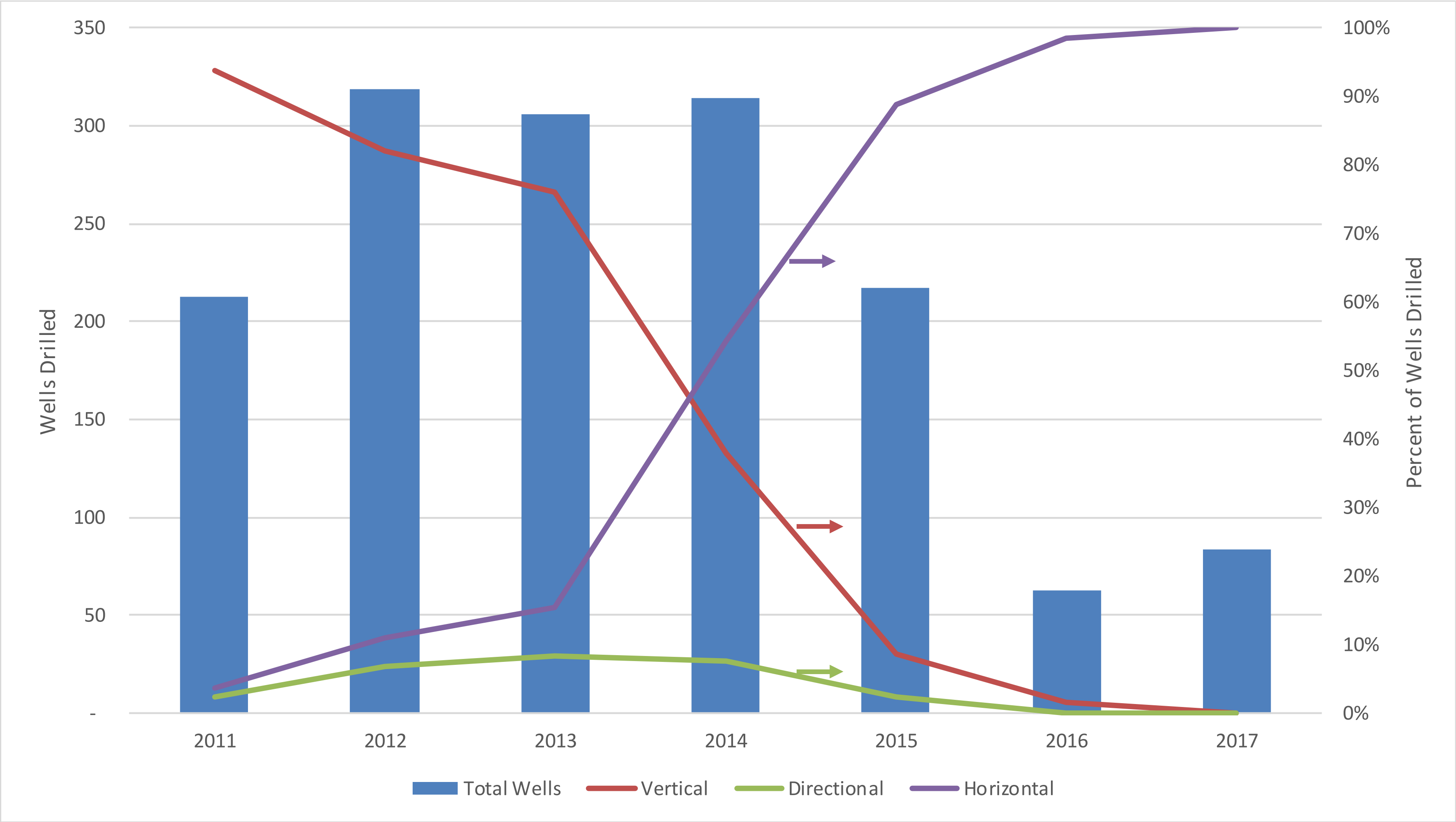
OXY

Occidental Petroleum

Oxy Worldwide Oil and Gas Focus Areas

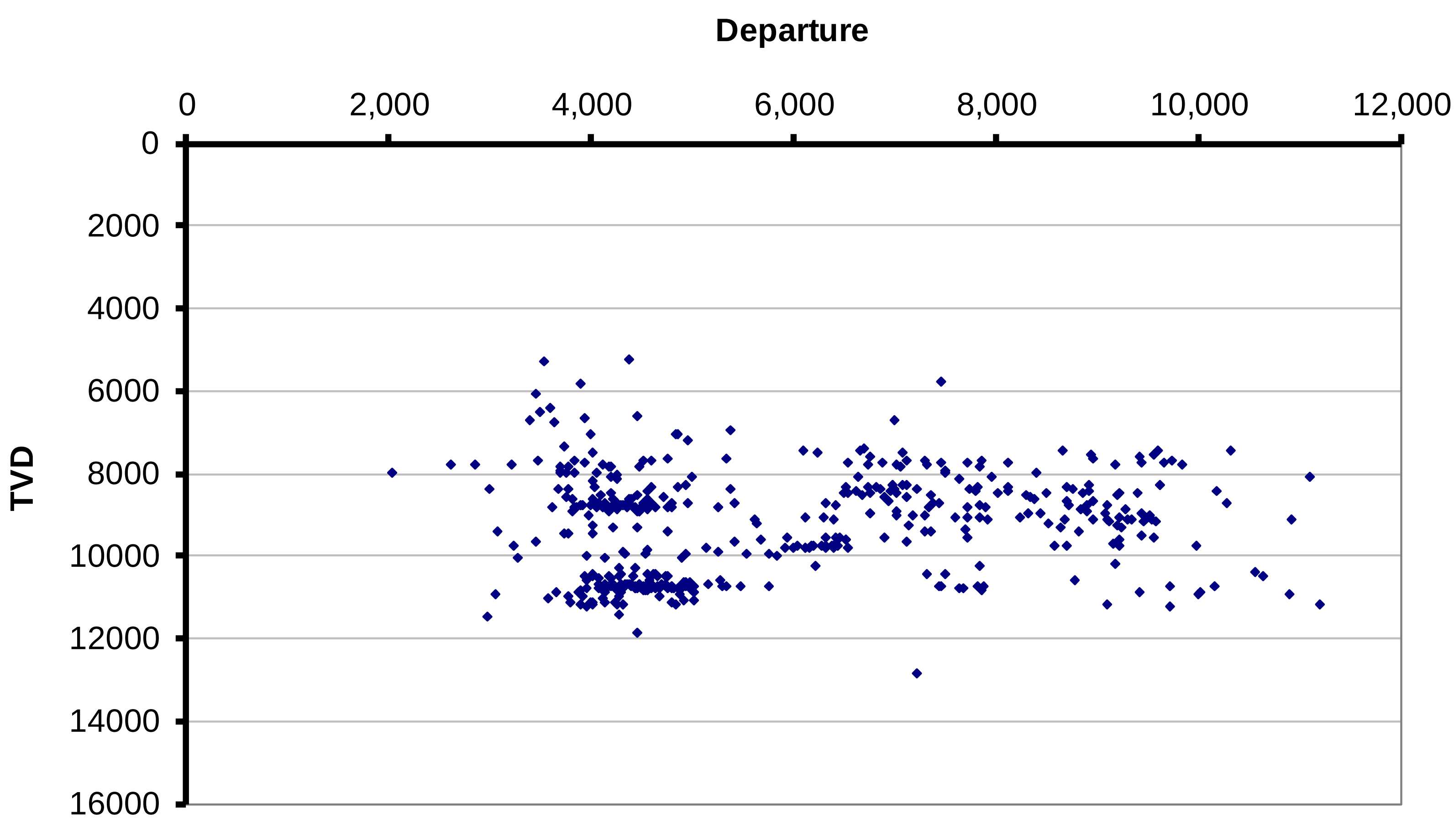


Permian Wells Mix



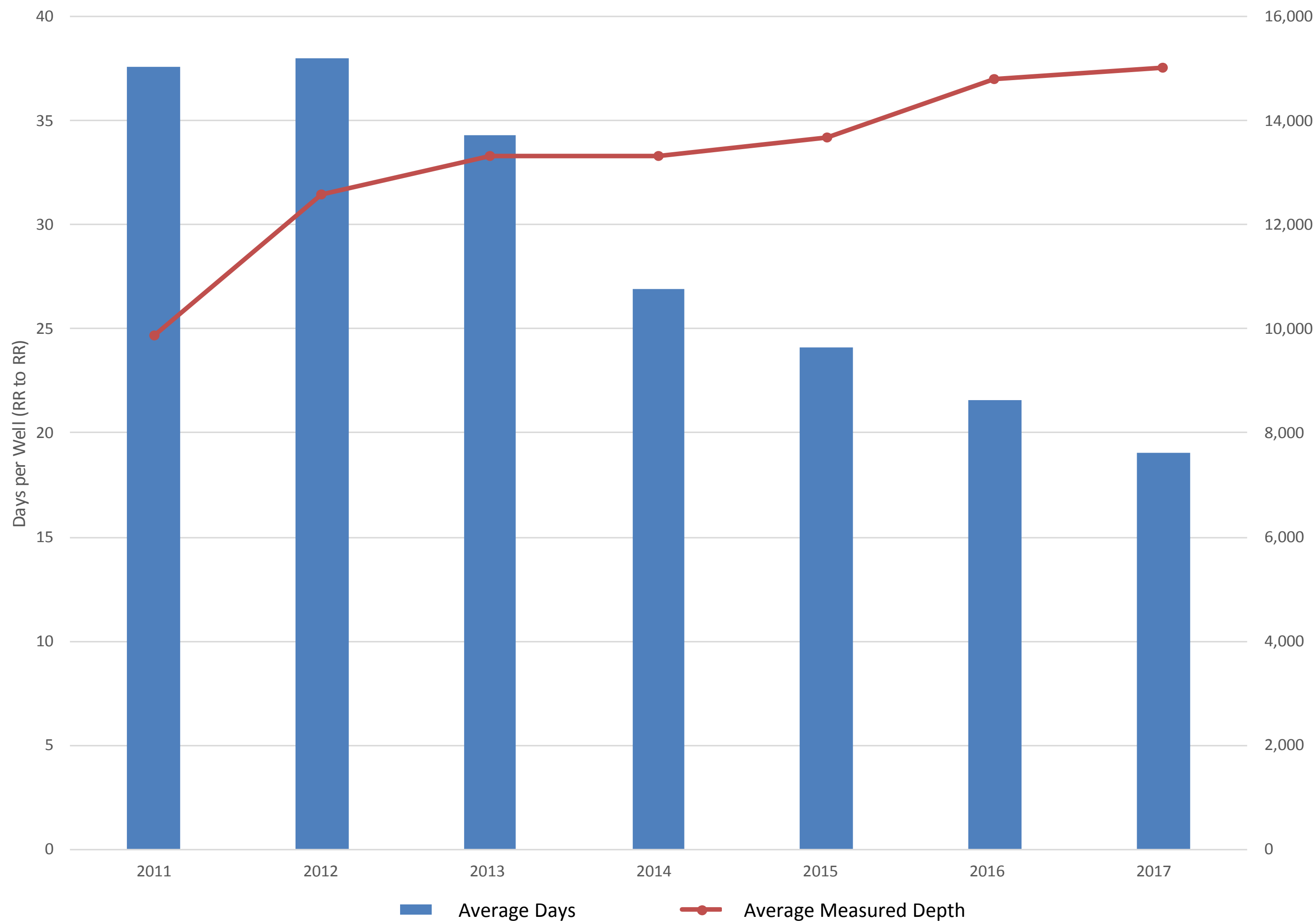
Selected wells from Oxy Permian Resources Business Units. 2017 well count estimated.

Permian Horizontal Wells



Selected wells from Oxy Permian Resources Business Units

Permian Wells Days



Selected wells from Oxy Permian Resources Business Units. 2017 performance through March.

Permian Drilling Optimization

- Reduced drilling time ~50%
- Complex – implementation and optimization
- Still room for improvement

Industry Publications on Improving ROP

SPE 102210, Dupriest, F. E., “Comprehensive Drill-Rate Management Process To Maximize Rate of Penetration”

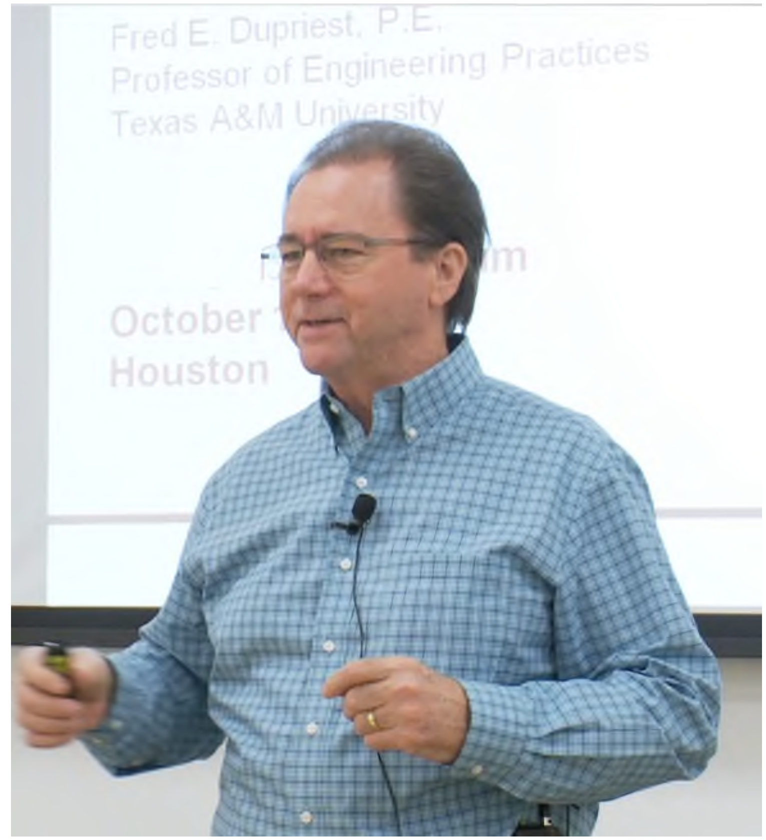
SPE/IADC 92194, Dupriest, F. and Koederitz, W., “Maximizing Drill Rates with Real-Time Surveillance of Mechanical Specific Energy”

SPE 24584, Pessier, R. C. and Fear, M. J., “Quantifying Common Drilling Problems with Mechanical Specific Energy and Bit-Specific Coefficient of Sliding Friction”

IPTC 10607, Dupriest, F. E., Witt, J. W. , and Remmert, S. M., “Maximizing ROP With Real-Time Analysis of Digital Data and MSE”

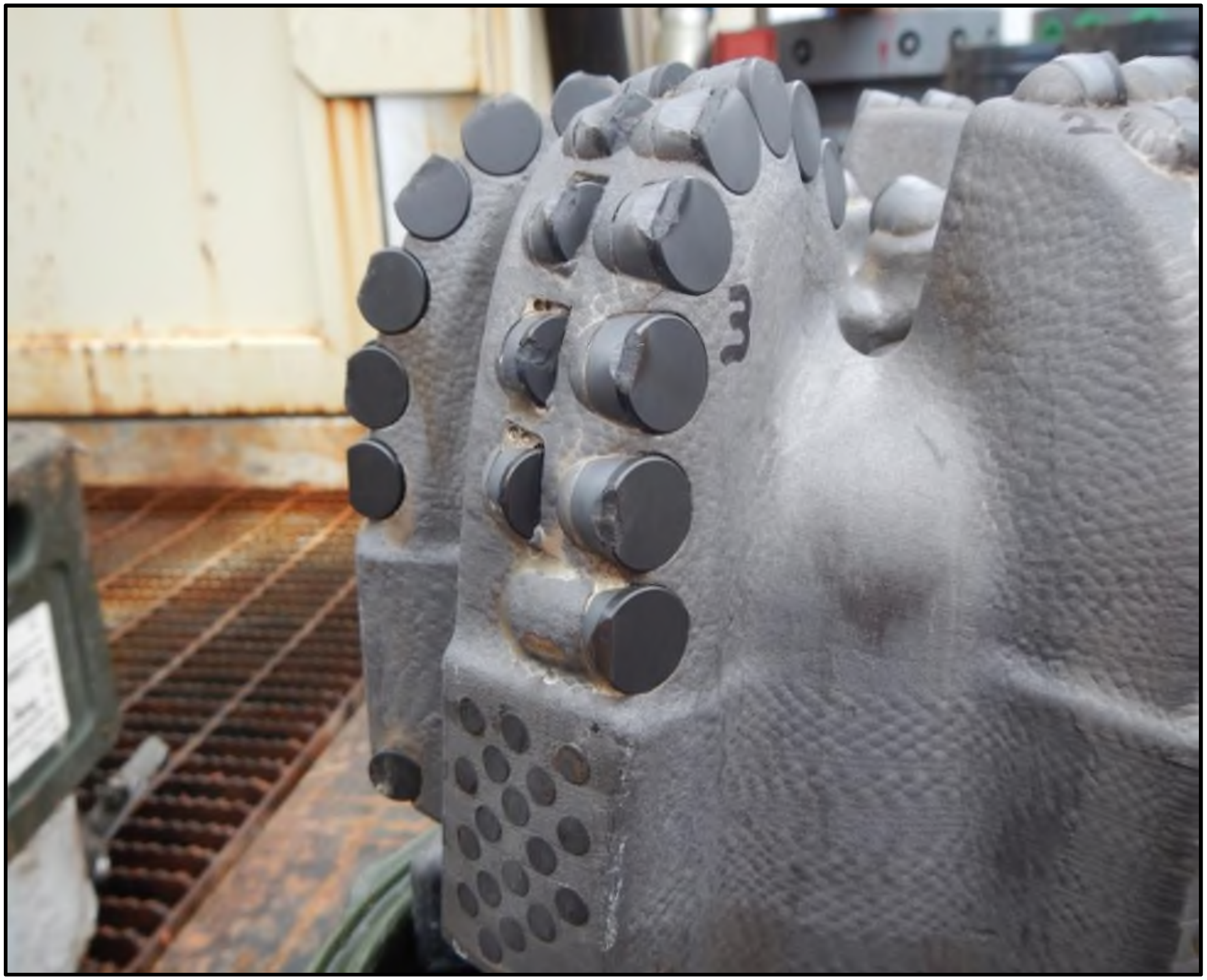
IADC/SPE 112650, Bailey, J. R. et al, “Drilling Vibrations Modeling and Field Validation”

And many others…



Fred Dupriest

Problem: Vibration Damage – Common



Solution: Run High Weight-on-Bit

High WOB is OK!

- **9-7/8” PDC**
- **70 klbs WOB**
- **(Recommended maximum: 55 klbs)**

Solution: Monitor Bit Performance with "MSE"

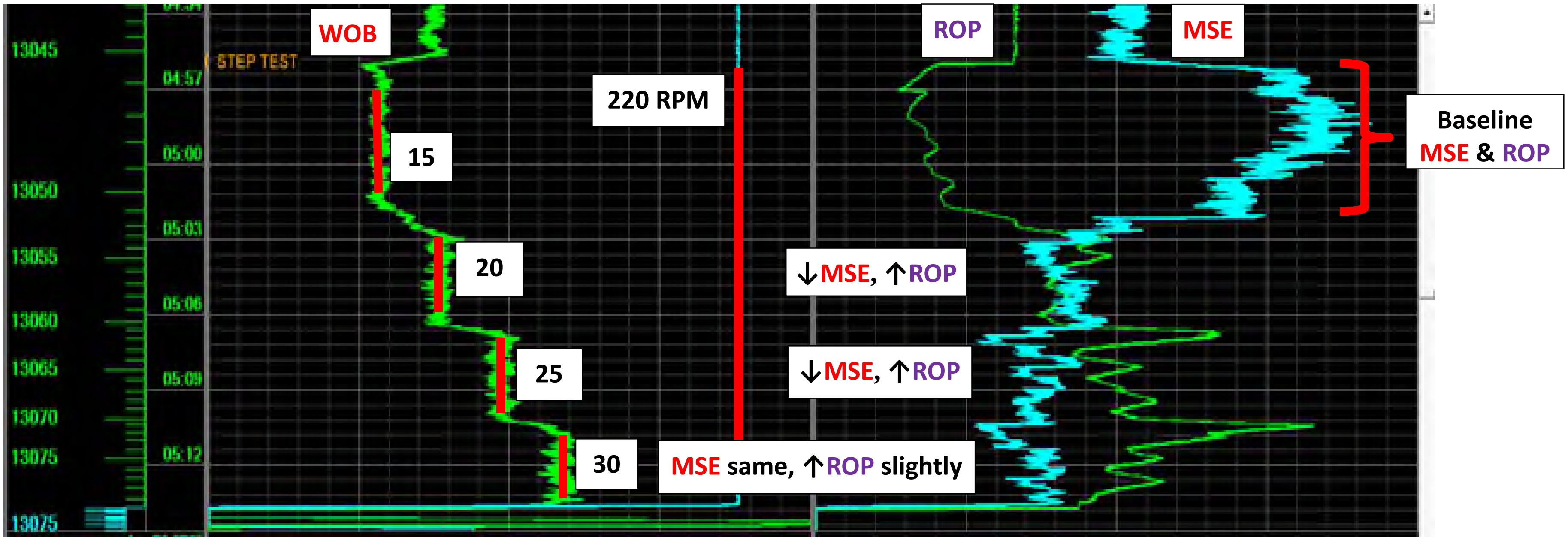
- Measures **drilling efficiency**
  - Mechanical specific energy to destroy rock ("MSE")

$$\boldsymbol{MSE = \frac{Input\ Energy}{Resulting\ ROP}}$$ *(WOP, RPM, Torque)*

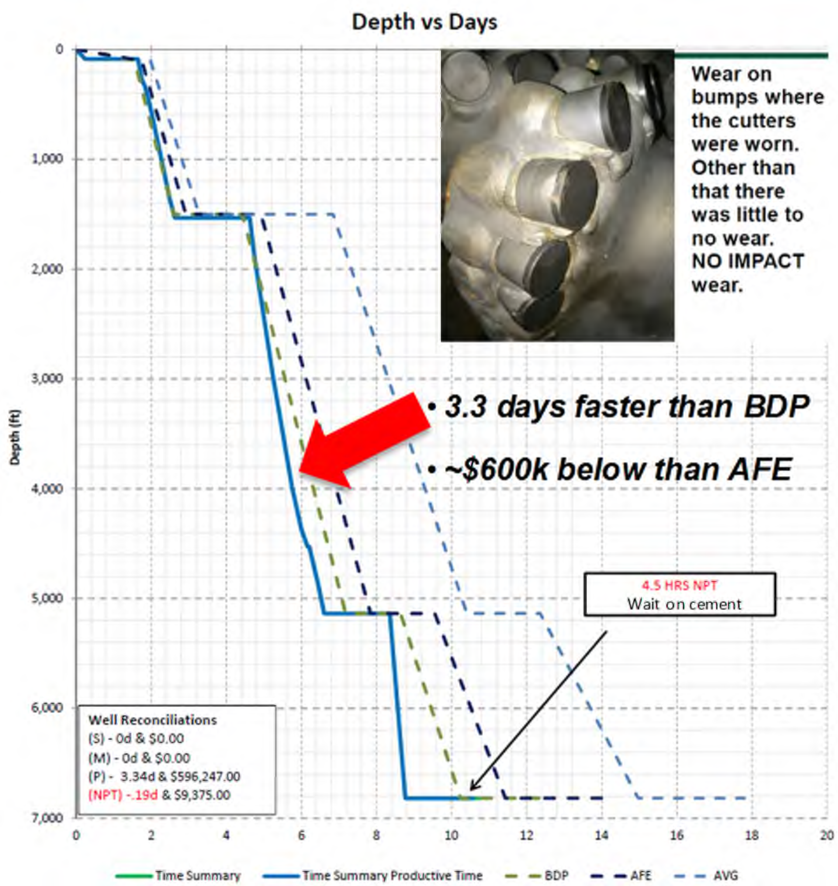
- Diagnostic tool for bit dysfunction
- Tells if the bit is more or less efficient parameters are changed

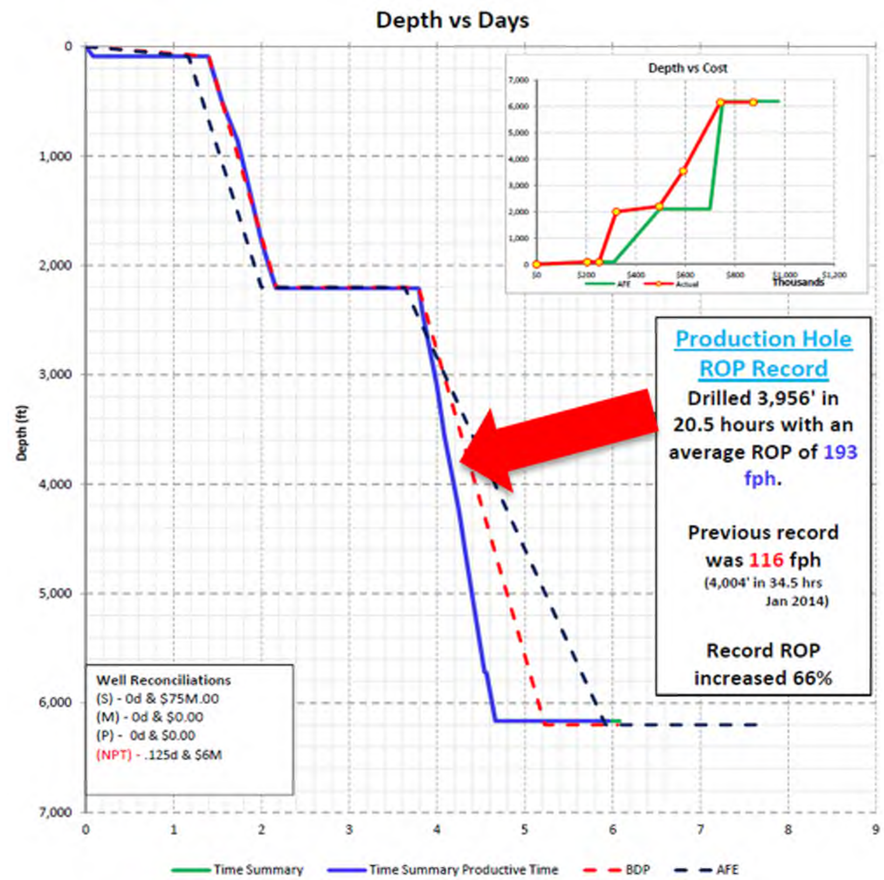
MSE Response to Change	Action
Increases	Stop, go the other way
Decreases	Do more the same way
Stays the same	Increase WOB or RPM

Solution: Find best WOB Using MSE



Results: Early Success on Simple Wells





"Mile a Day" Wells

Well	24 hr Footage
1	**5,690'**
2	**5,293'**
3	**5,511'**
4	**5,746'**

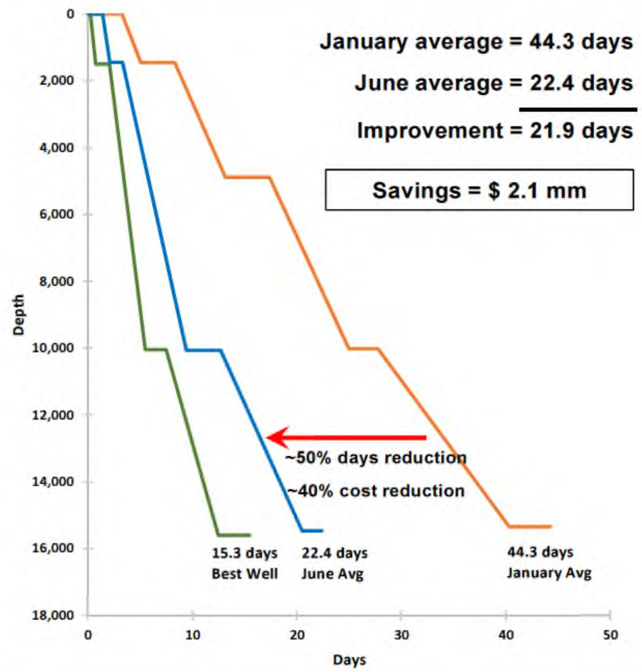
All sections 9-7/8" hole

Widespread Results

Second Quarter 2015 Earnings
Permian Resources – Drilling Efficiency

Delaware Basin Wolfcamp A well drilling time reduced by ~50% and costs by ~40%

Technology	Days
Multi-well pad, reduced move time	1.8
High-resolution benchmarking	1.5
Advanced mud system to eliminate casing across salt interval	5.1
Oxy Drilling Dynamics	8.5
Curve building optimization	1.2
Vibration reduction to eliminate downhole tool failures	1.7
Rig site crew efficiency	2.1
Total Days Reduction	**21.9**



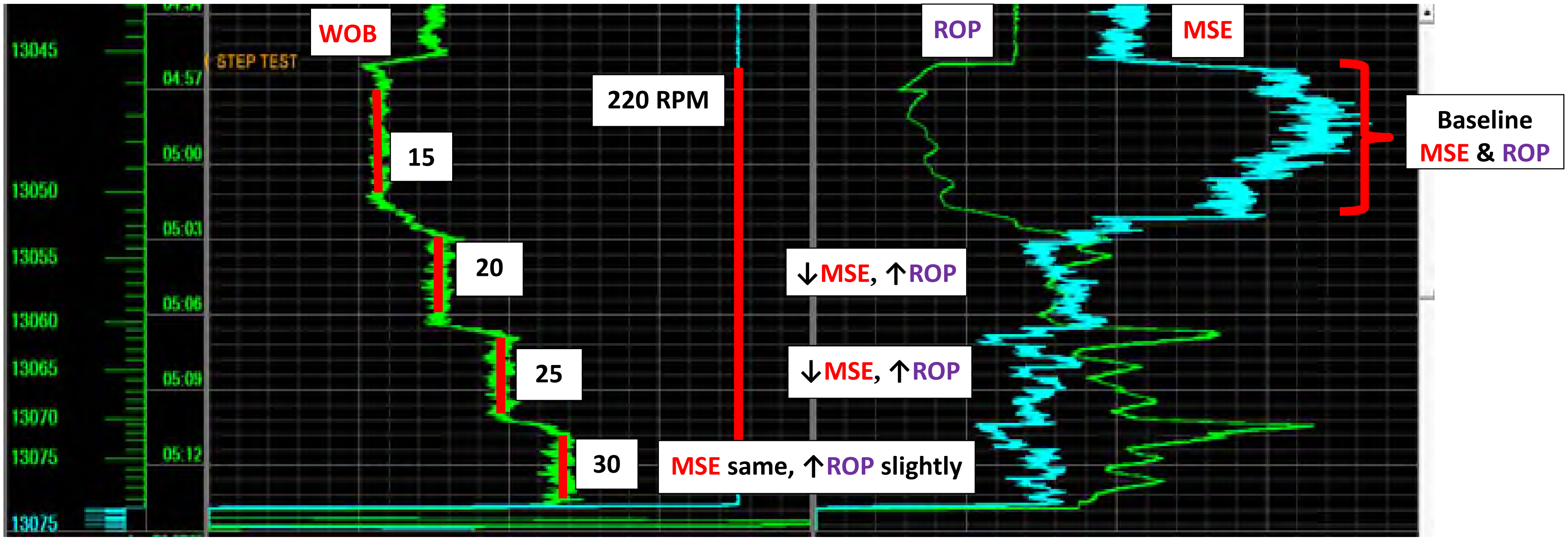
27

Occidental Petroleum Corp Second Quarter 2015 Earnings Call Slides

Some Components of Program

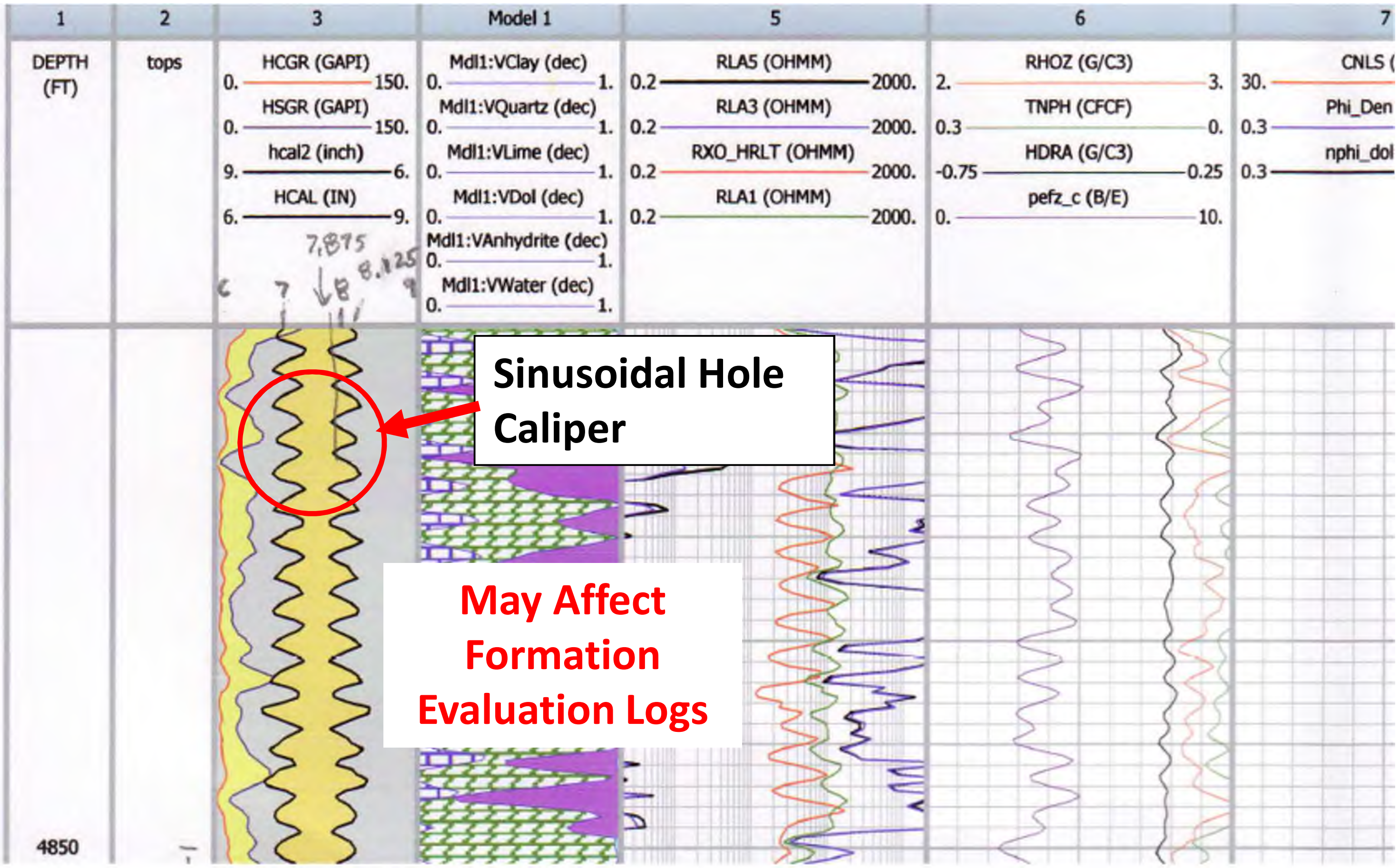
- MSE
- Bit design
- Drill String Design
  - Vibration analysis
  - Tools
- Engineering tools
  - Tool face
  - MSE comparison
  - Parameter analysis
- Engineering analyses
  - Buckling
  - BHA data sub analyses
  - Weight transfer
- New tools and systems
- Training for Drilling Engineers, Drill Site Managers, contractors
- Continuous rig site support

MSE: Monitor Bit Dysfunction



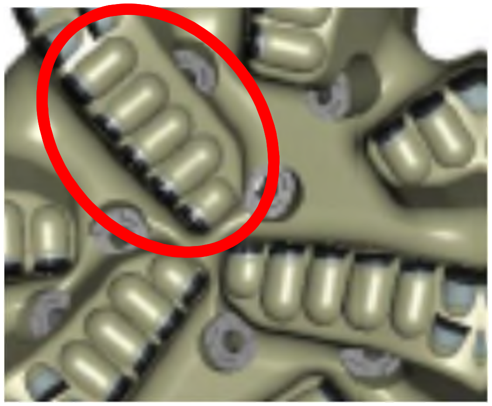
Bit Design: Long Gauge

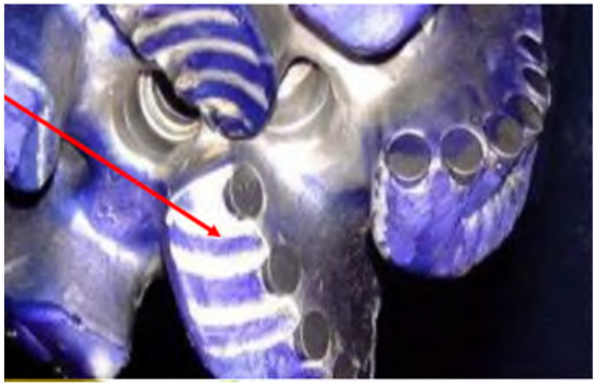
Long gauge reduces spiraling



Bit Design: Depth-of-Cut Control

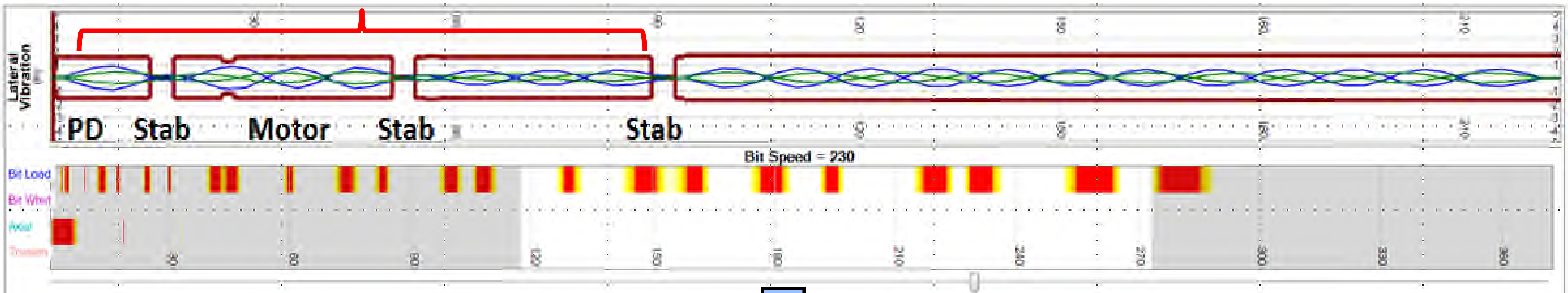
- Enable high WOB
- Manageable torque



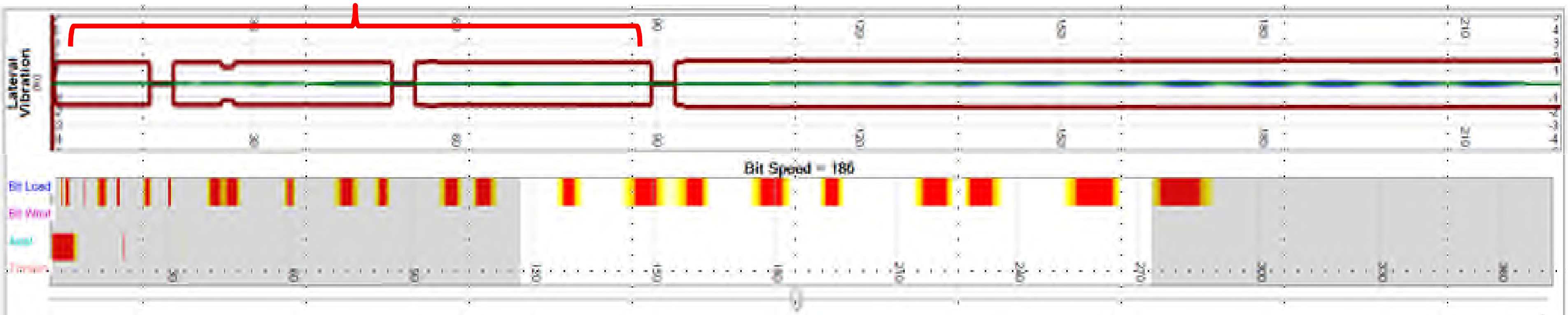


Drill String Design: Vibrations Modeling

Significant BHA Vibrations



No BHA Vibrations



Drill String Design: BHA

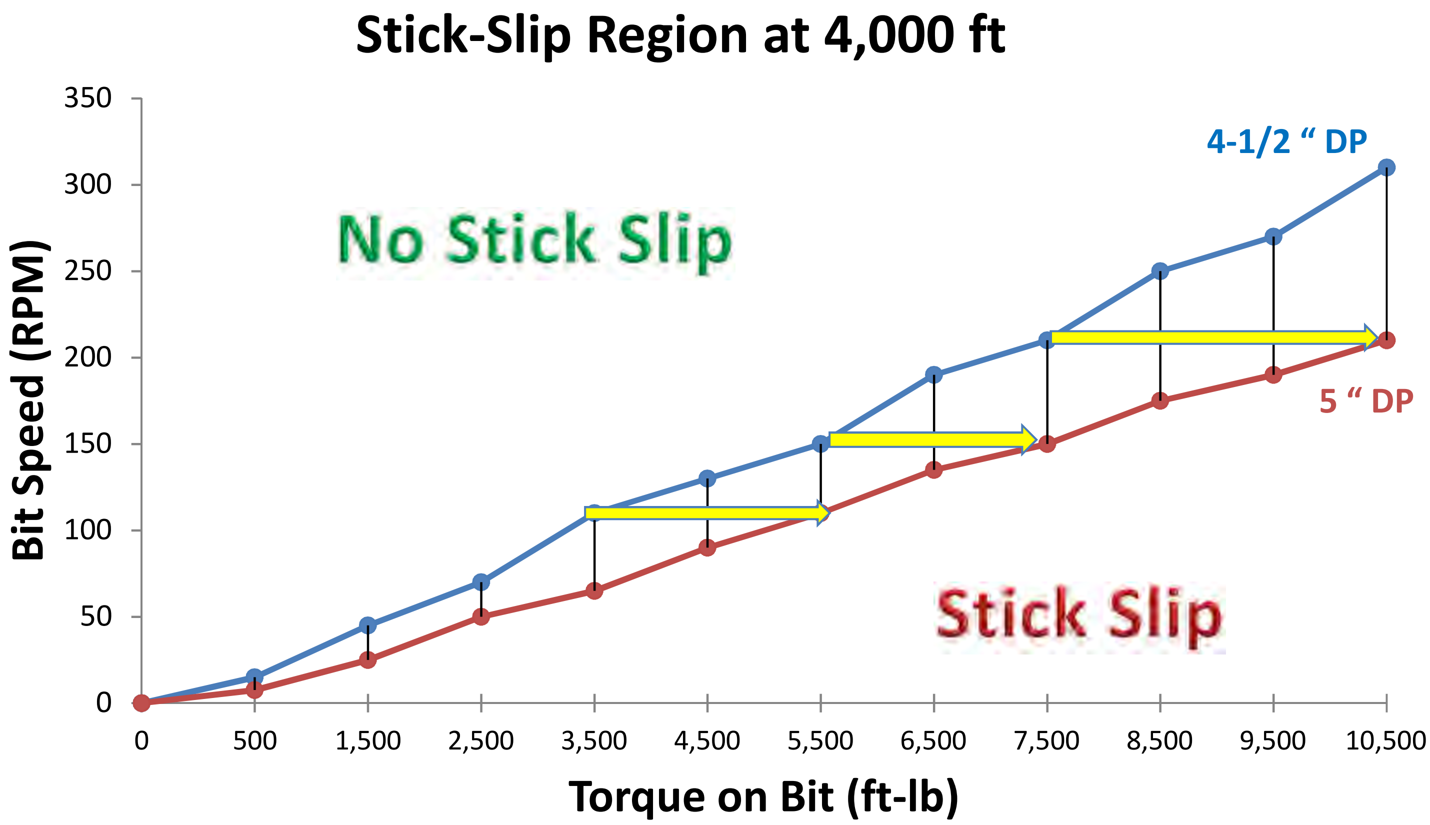
- Stabilizer designed to slide
- Stabilization reduces vibration and related tool failures

Drill String Design: Stabilization

- WOB increased 50% with stabilized BHA
- 49% fewer BHA runs
- ROP up 114%

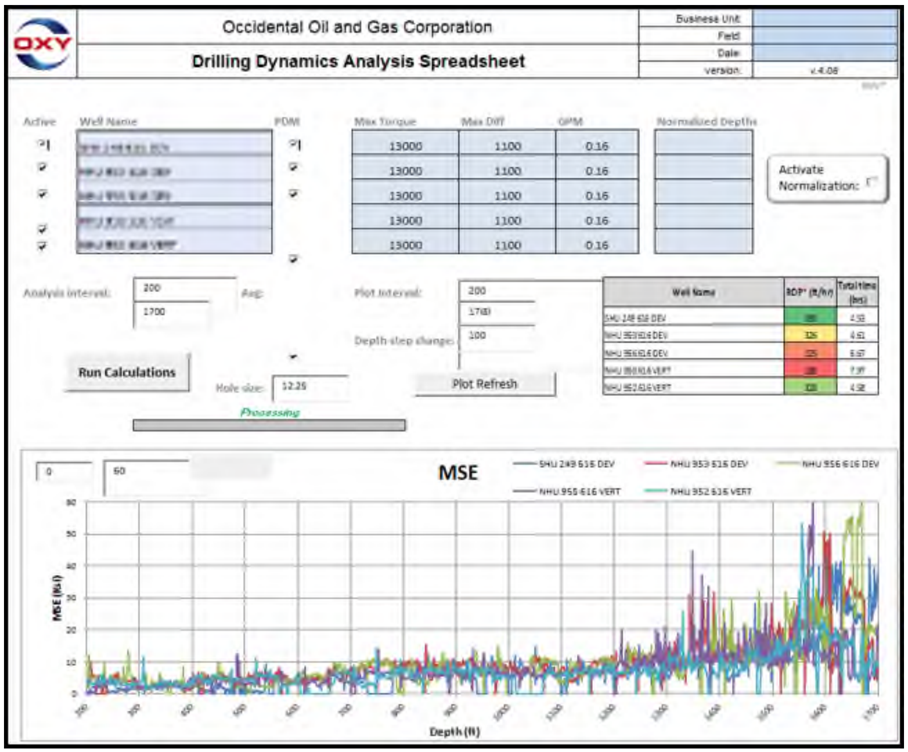
		Time-Based %	Depth-Based %	Average ROP	Average WOB	BHAs / 9000'	Overall Average ROP
Past Motor Performance A	Sliding	25%	12%	38 ft/hr	27 klb	3.4	63 ft/hr
	Rotating	75%	88%	84 ft/hr	20 klb		
Current Motor Performance A	Sliding	14%	11%	75 ft/hr	42 klb	1.72	182 ft/hr
	Rotating	86%	89%	204 ft/hr	31 klb		
Past Motor Performance B	Sliding	22%	9%	32 ft/hr	25 klb	2.48	110 ft/hr
	Rotating	78%	91%	120 ft/hr	25 klb		
Current Motor Performance B	Sliding	25%	11%	66 ft/hr	43 klb	1.28	188 ft/hr
	Rotating	75%	89%	209 ft/hr	35 klb		

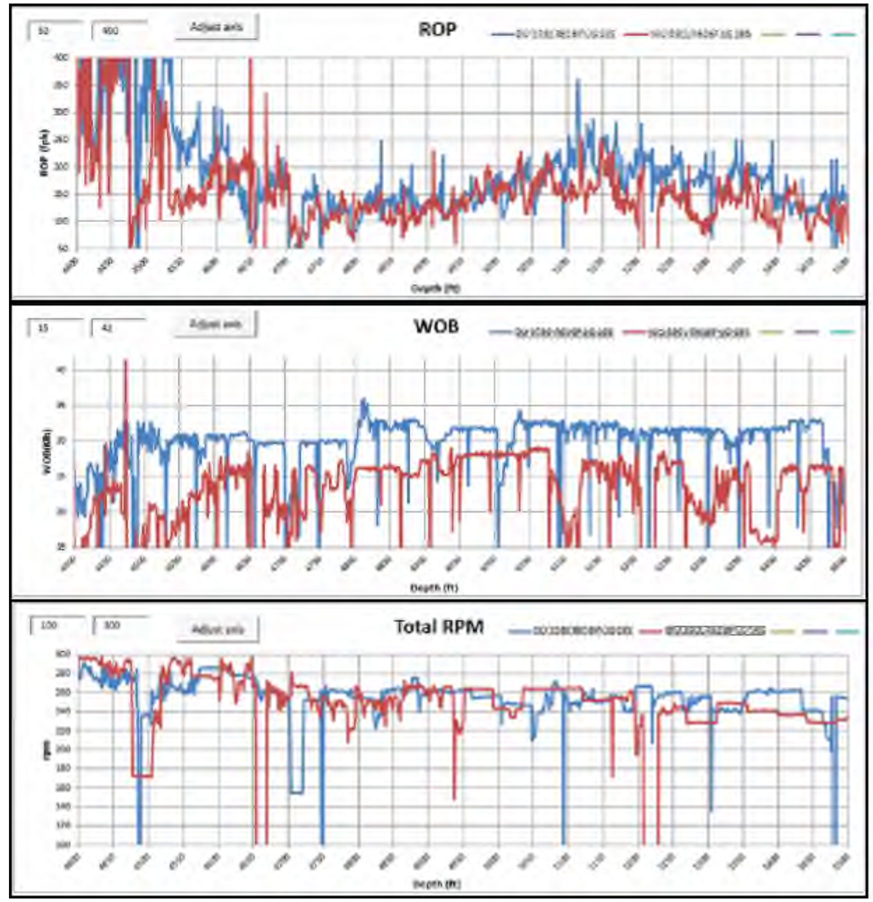
Drill String Design: Bigger Drill Pipe



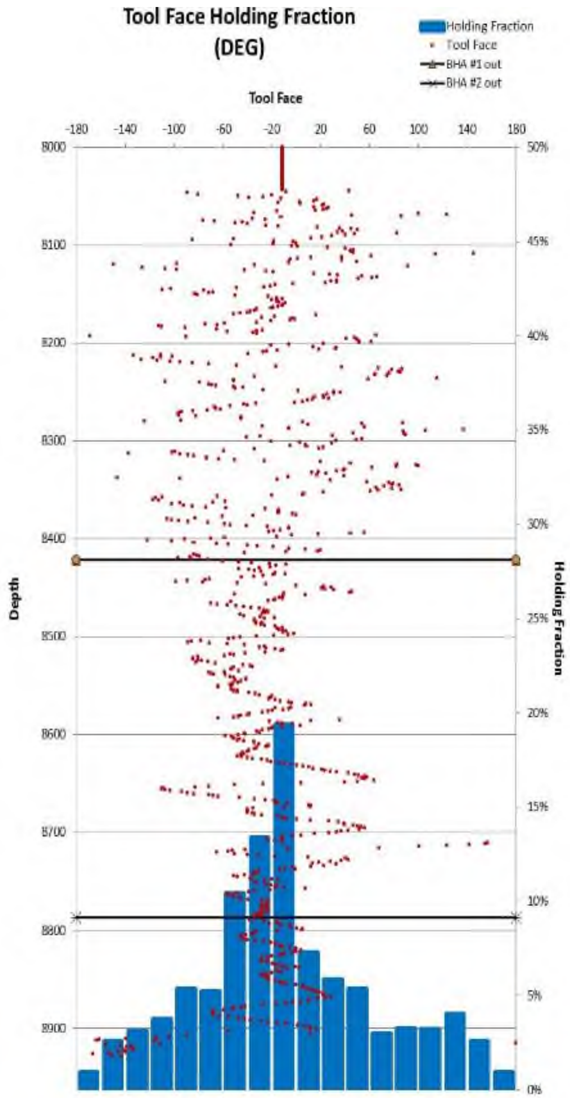
Engineering Tools

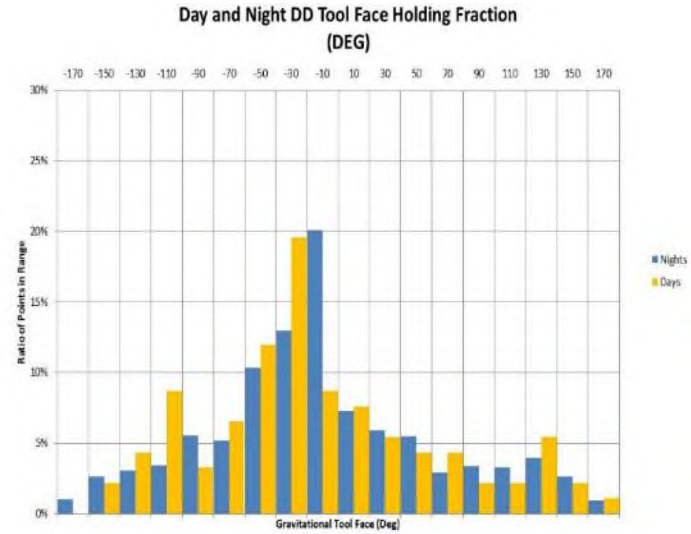
- In-depth high-res data analysis

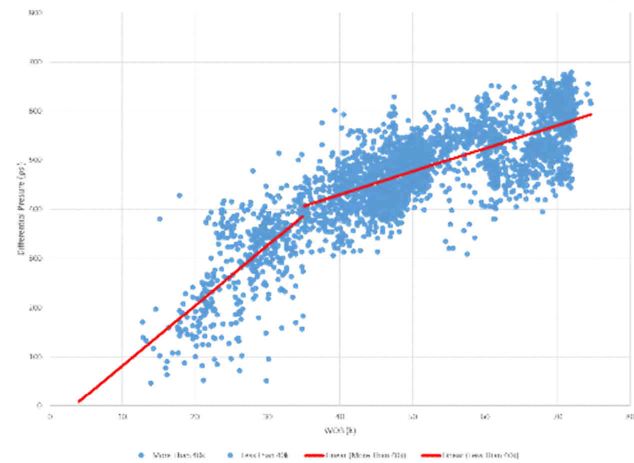




Engineering Tools

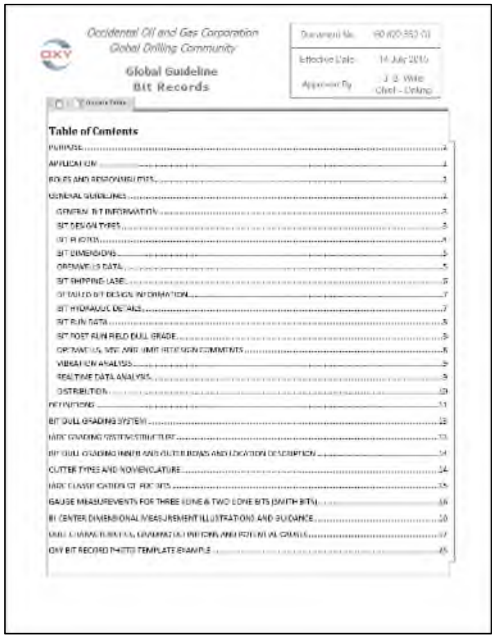






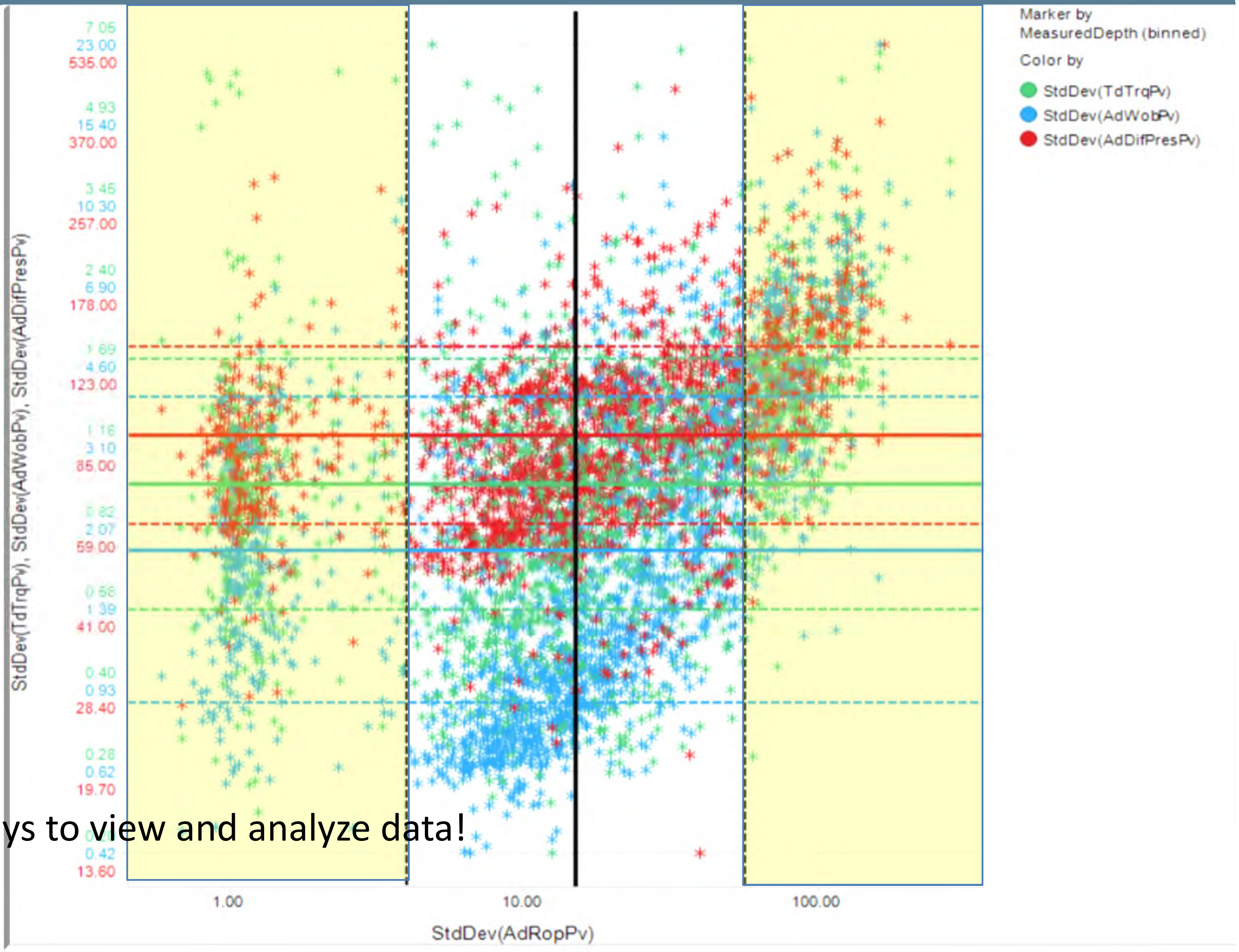
Engineering Tools

- Survey Quality
- Photo Bit Record
- Stabilizer Guideline
- Bit Record Guideline



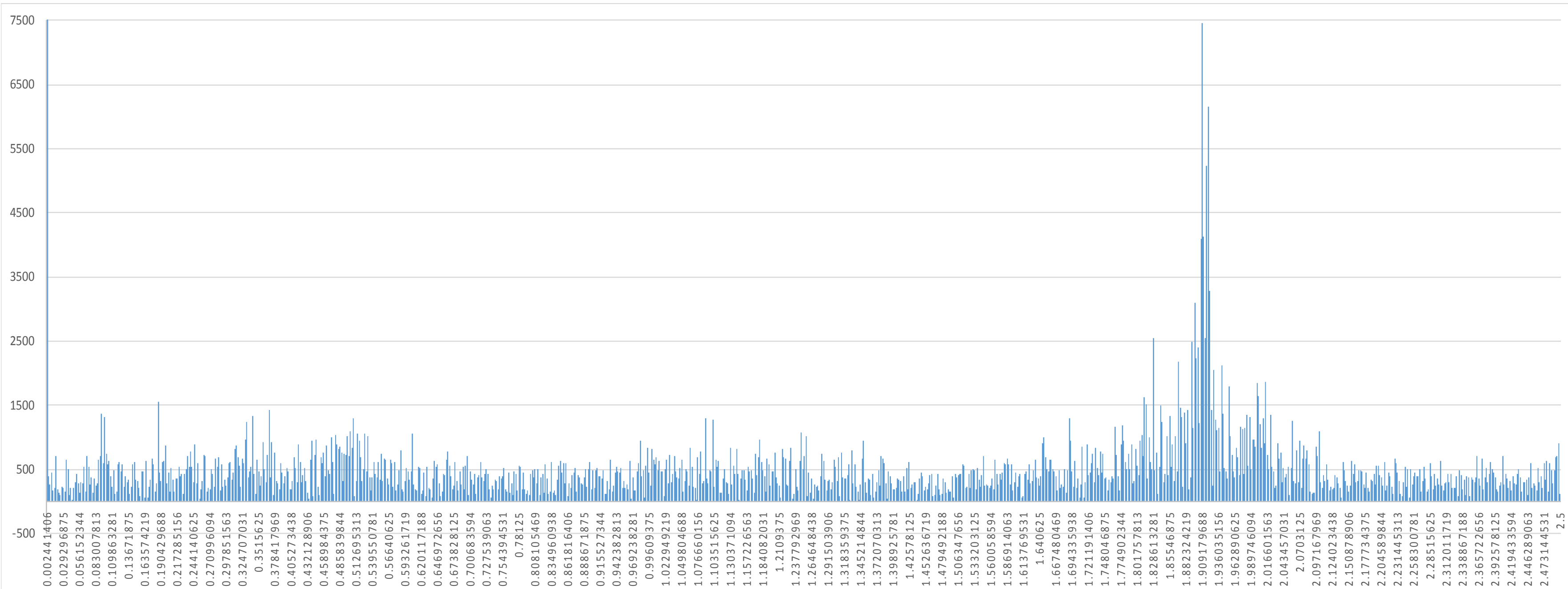
Engineering Analysis: Auto-Driller

What is going on at the edges of this scatter plot?



Finding new ways to view and analyze data!

Engineering Analysis: Fourier Transform

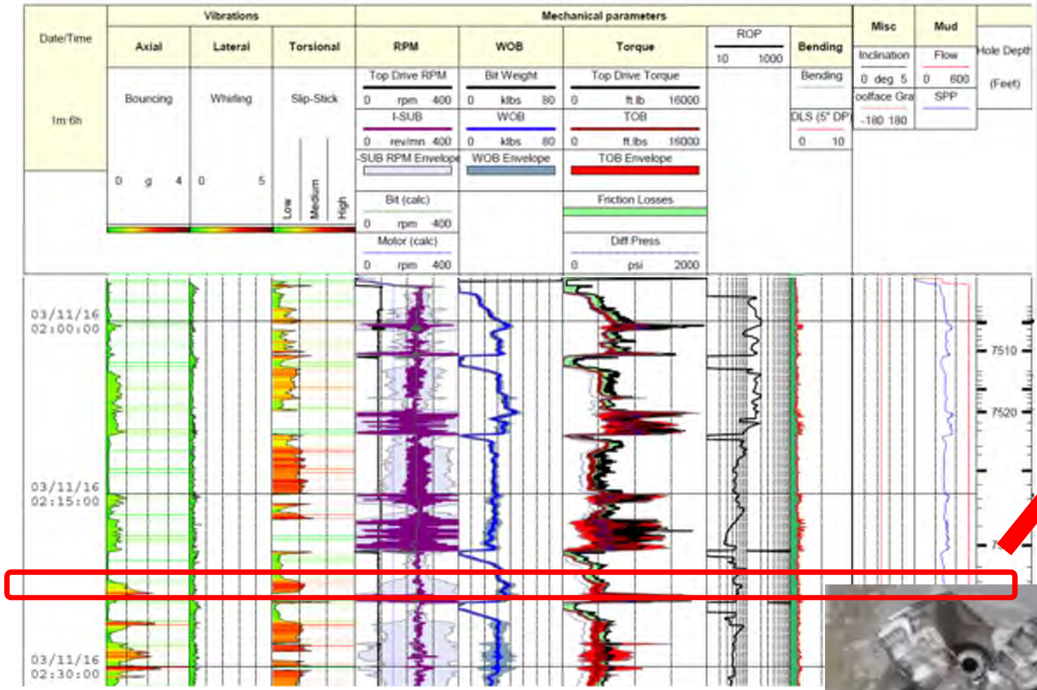


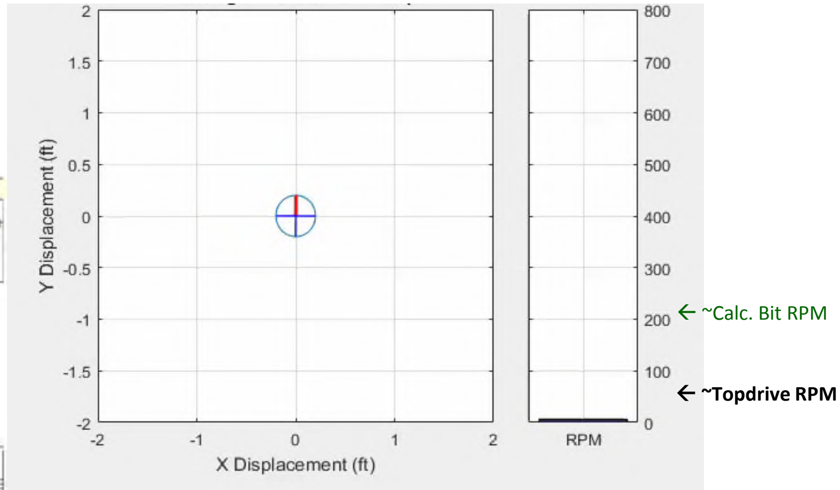
Finding new ways to view and analyze data!

New Systems: Sensor above the bit (Stick-Slip)

Section / BHA: Vertical / Steerable Motor

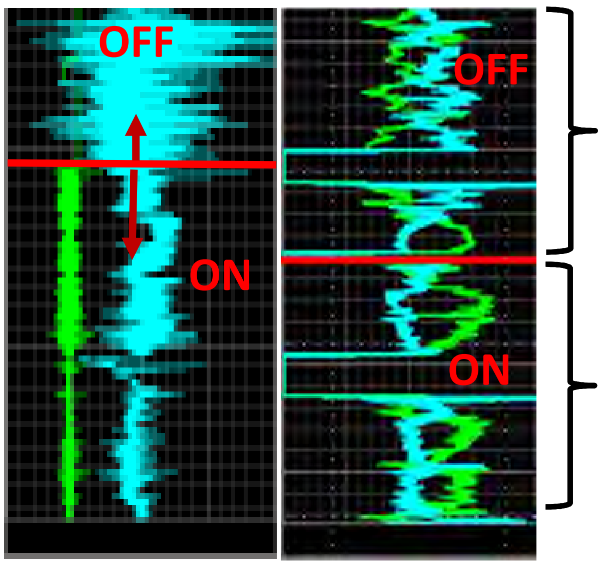
Bit: 7-7/8” with 6” gauge





New Systems: Slip-Stick Control

Torque response
with & without
control system



MSE = 75ksi

MSE = 45ksi

Some Components of Implementation Program

- Training for Drilling Engineers
  - Bit design
  - Vibrations
  - Engineering analysis
- Drill Site Managers, contractors
- Continuous rig site support

Training: Advanced Bit Design

- Industry schools too basic
- Advanced PDC design concepts
  - Extended gauge length
  - Depth of cut control
- Drilling Engineer actions
  - Evaluate previous run
  - Evaluate damage
  - What to change - specifically?

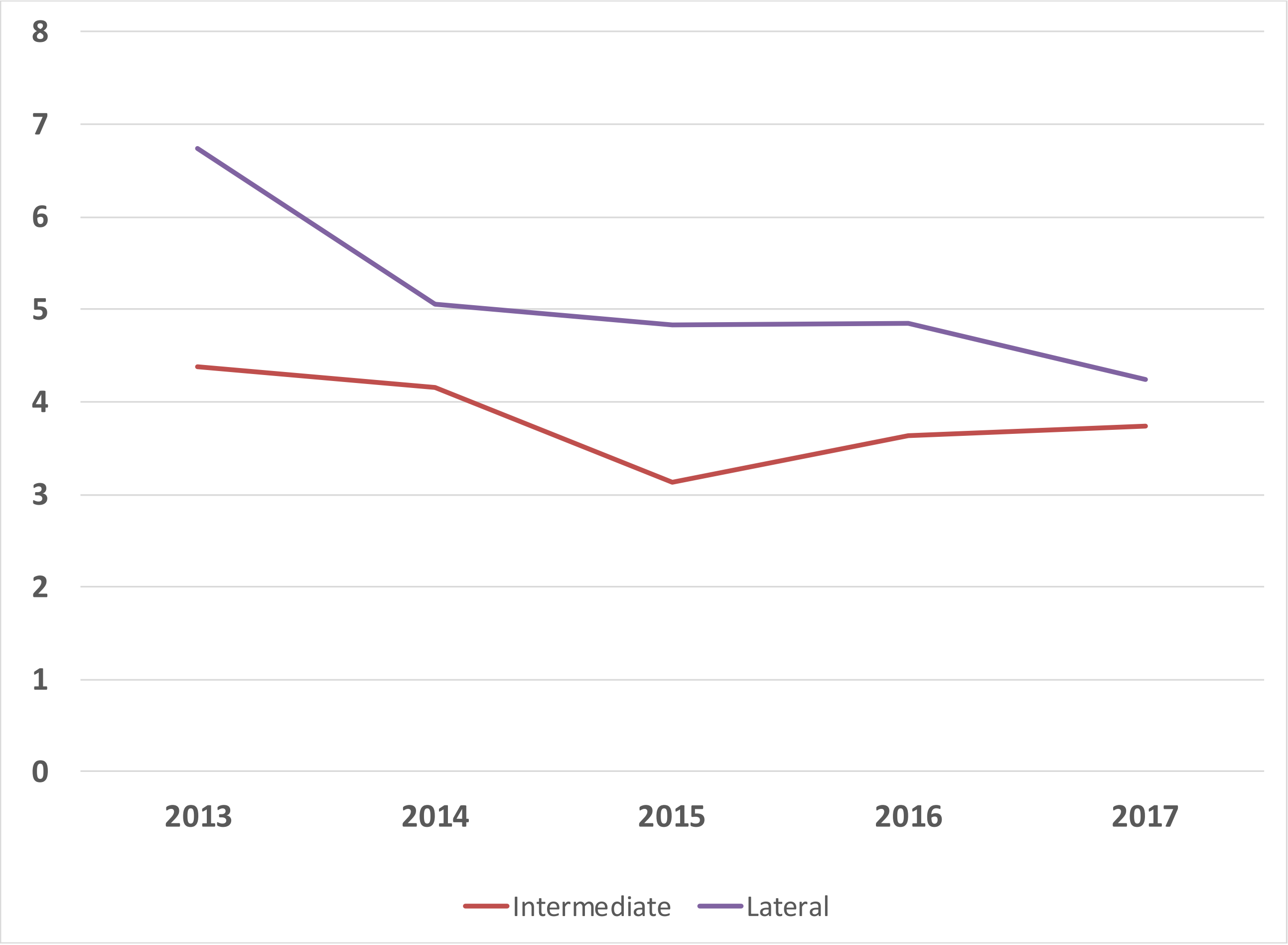
Training: Vibrations

- Types of vibrations
- Source and how to mitigate
- Vibration modeling capabilities

Training: Rig Site

- All rigs, multiple visits
- Workshops, rig floor
- Drill Site Managers, drillers, directional drillers

Bits per 10K Feet



Bits Then and Now

Then:
Slow ROP,
Short life

Now:
Fast ROP,
Short life

Complications

- Hard formations
- Laminated formations (“interfacial severity”, stick-slip)
- Directional paths (back-build, anti-collision)
- High-pressure flows, injection zones
- Drawn-down formations
- ROP control for rotary-steerable performance
- Tool-face control for steerable motors

Still potential for significant performance improvement!