Sustained Casing Pressure

What's working? and Why?

October 2020

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A little about me…

GEOFF LANDRY

Family

Woodworking

LSU TIGERS

SCHLUMBERGER JOURNEY

- **12 YRS**: Field | Operations | Management | Technical
- **LOCATIONS:** Multiple States and Regions in the US

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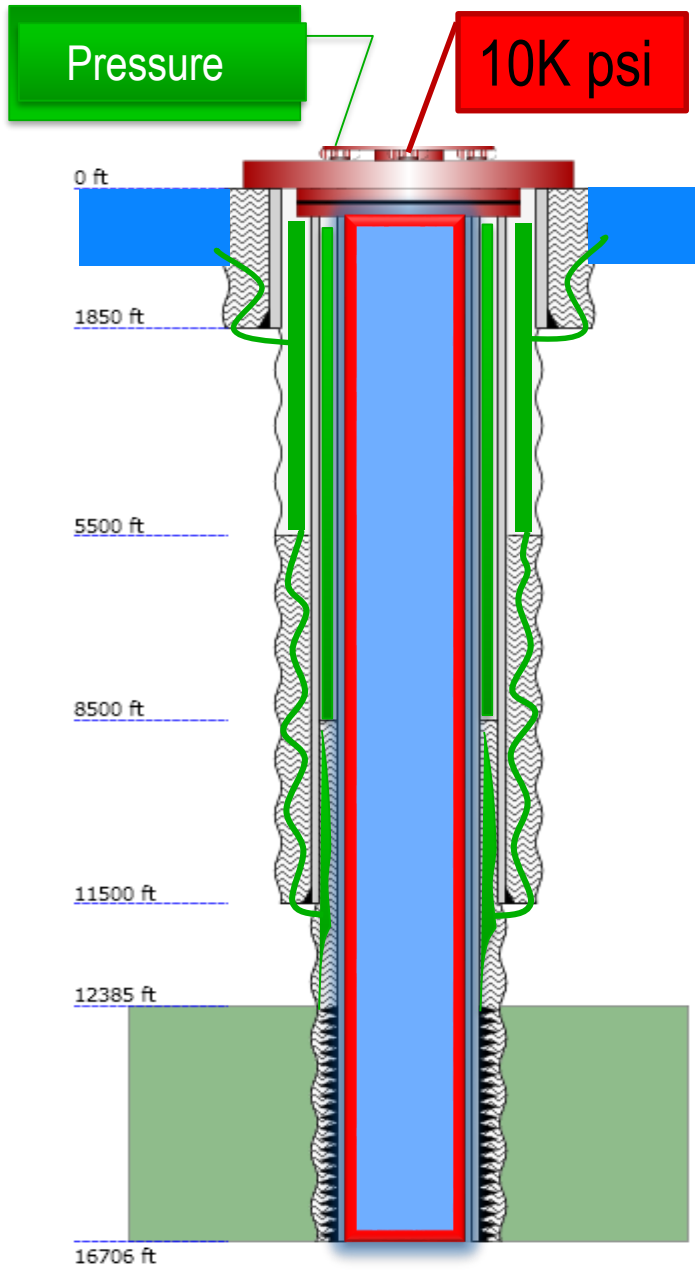
Sustained Casing Pressure

WHAT IS SUSTAINED CASING PRESSURE (SCP)

- SCP is defined as any measurable casing pressure that rebuilds after being bled down, attributable to cause(s) other than artificially applied pressures or temperature fluctuations in the well.

FAILURE MECHANISMS

- Low Cement Top
- Channeling
- Micro annulus
- Gas Migration
- Cement Damage [Cyclic Loading]



Why should we care?

- Production and Financial Reasons

- Social License to Operate (SLO)
  - Our ability to operate as an industry is no longer decided by regulators, margins, or even the rock.
  - Industry wide… **Effects us all!**

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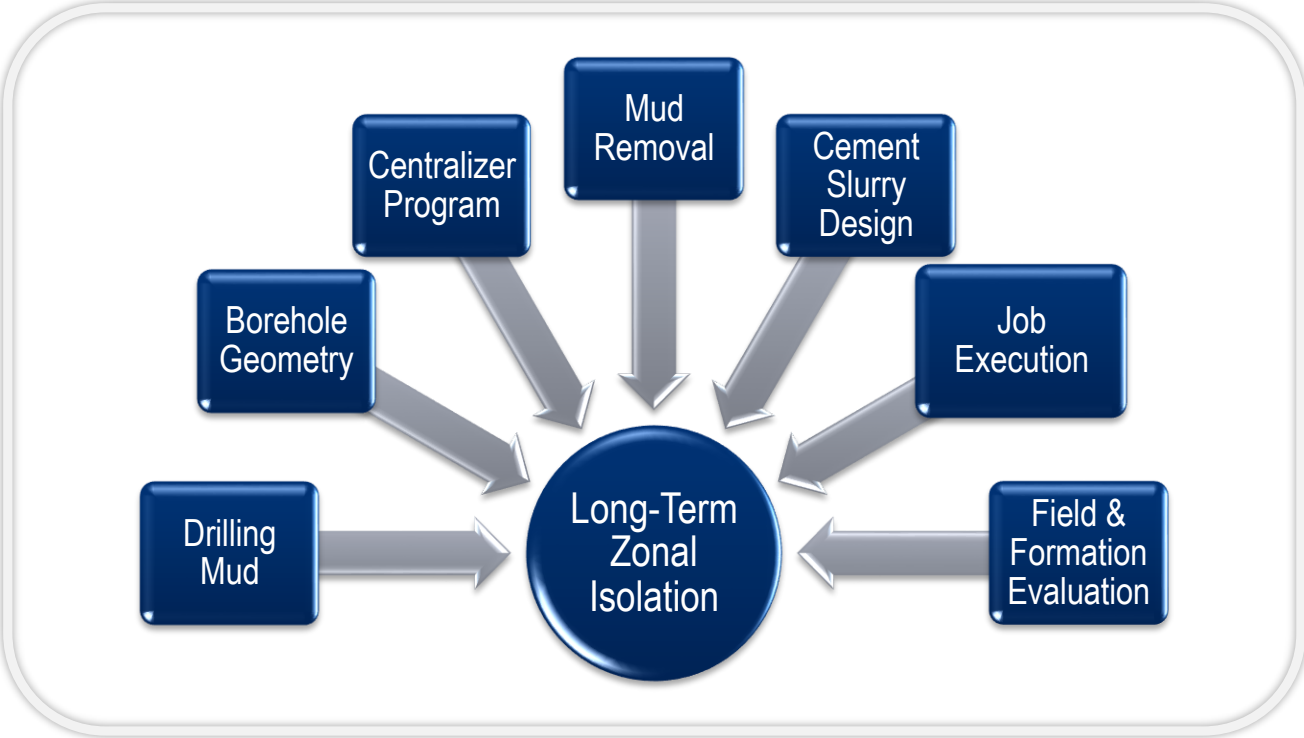
Today's Challenges… Tomorrow's Problems

- Pre – Placement
- Cement Placement
- Post - Placement



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Today's Challenges… Tomorrow's Problems

PRE - PLACEMENT

- Mud Conditioning
- Centralization
- Borehole Quality

CEMENT PLACEMENT

- Mud Removal
- Tight Pore & Frac Gradients
- Losses & Influx - Depleted Zones, Salt Water Formations, Gas Formations
- Water Wetting
- High temperature differentials for critical cement
- Extended Horizontal Laterals

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Today's Challenges… Tomorrow's Problems

CENTRALIZATION

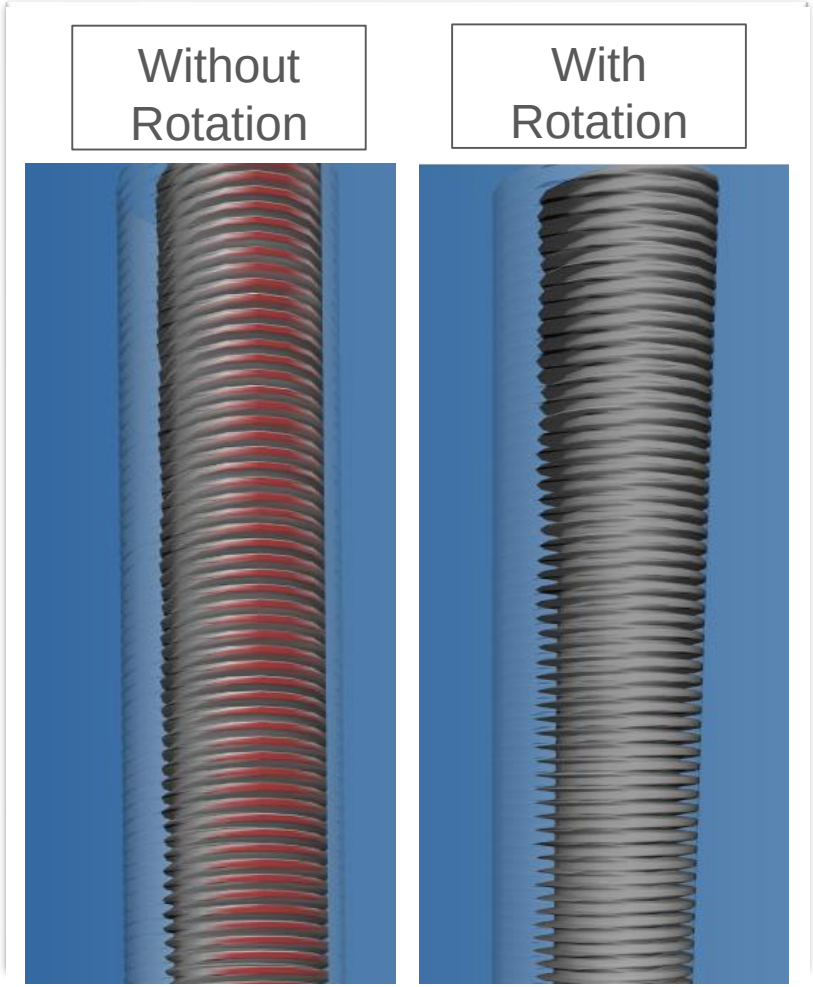
- Standoff vs placement

SPACER FORMULATION

- Volume for long lateral
- NAF Cleaning/ demulsifying
- Water Wetting

PIPE ROTATION

- Removal of mud pockets
- Improved fluid tops | Contamination
- Most impactful for reduction of lateral contamination



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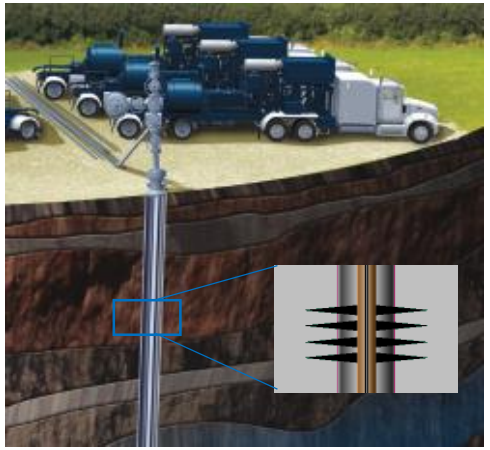
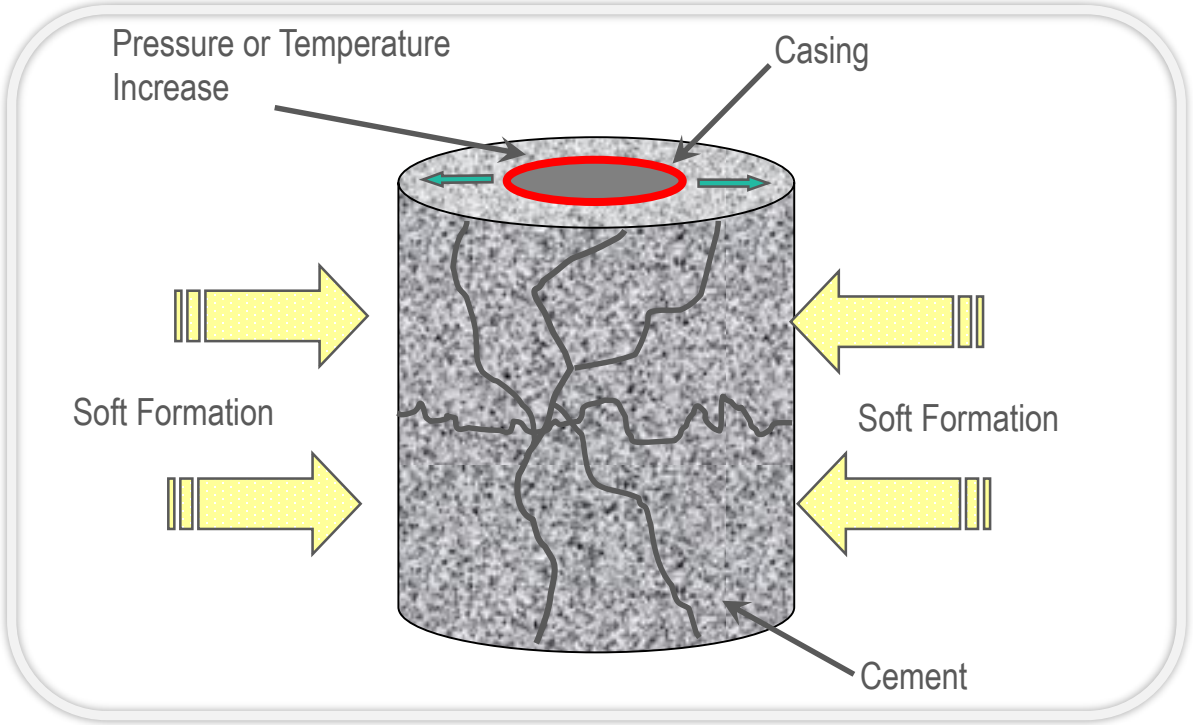
Today's Challenges… Tomorrow's Problems

Bumping the plug is just the beginning!!

POST PLACEMENT

- Casing Corrosion Protection – Sulfates, CO2
- Gas Migration
- Stimulation
- Logging
- Cyclic Loads
- **Cement failure is one of the leading causes of SCP**





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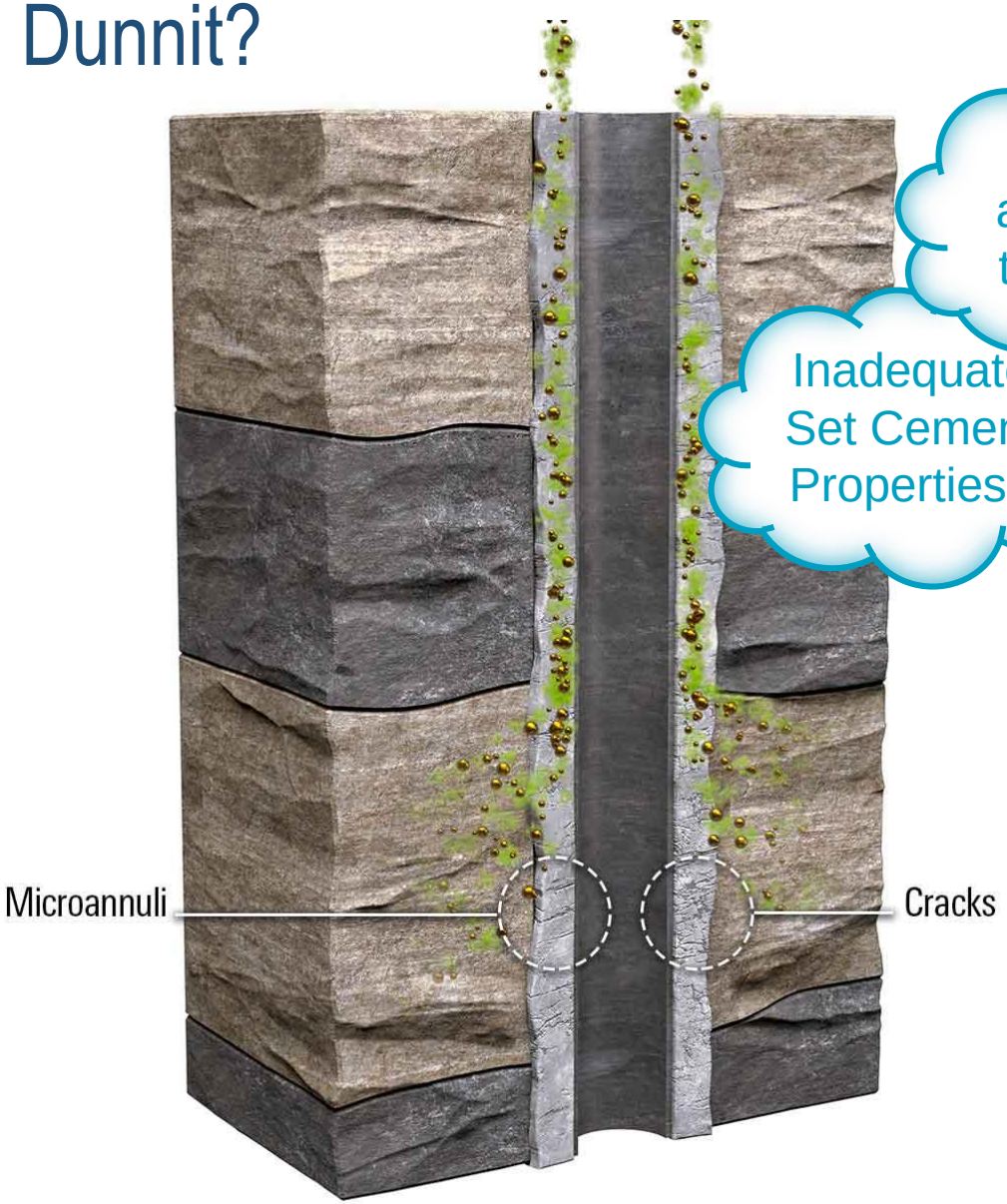
Who Dunnit?



Loss zones?

Field adherence to design?

Lack of Centralization?

Inadequate Set Cement Properties?

Gas Migration?

Poor Mud Removal?

Poor well conditioning?

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Cement Job Evaluation

WHAT'S THE BIG IDEA?

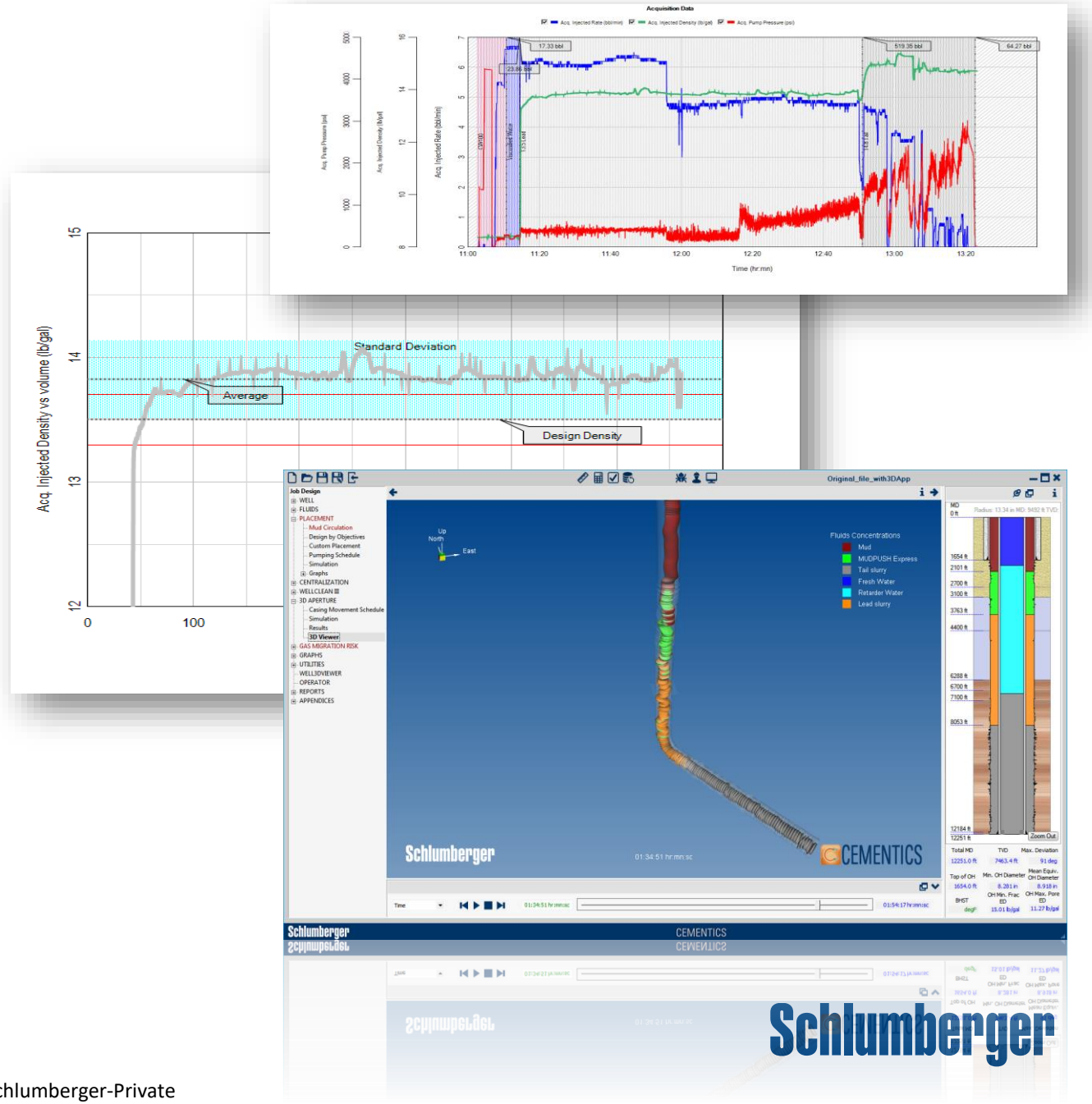
- Cement job evaluation is analogous to detective work
- A combination of clues and evidence help to provide evidence and support for analysis
- The more data available, the more accurate the insight

WHAT CAN WE ANALYZE?

- Cement job data
- Rig data correlation
- Wireline logging data

WHY GO THROUGH THE TROUBLE?

- Identify design vs. actual discrepancies
- Determine failure points
- Optimize costs for over/under-engineered aspects
- Re-iterative process to continuously improve and advance



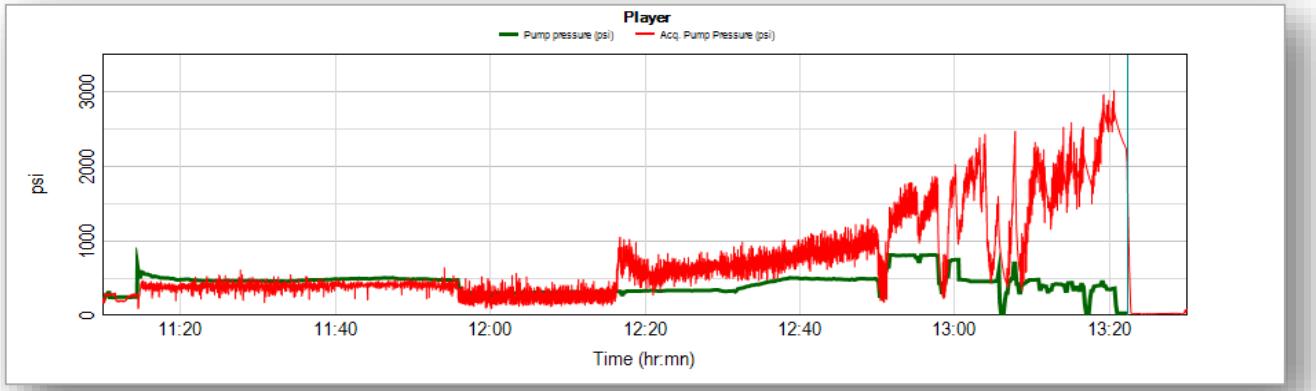
Pressure-matching – more than just plotting two lines on one chart

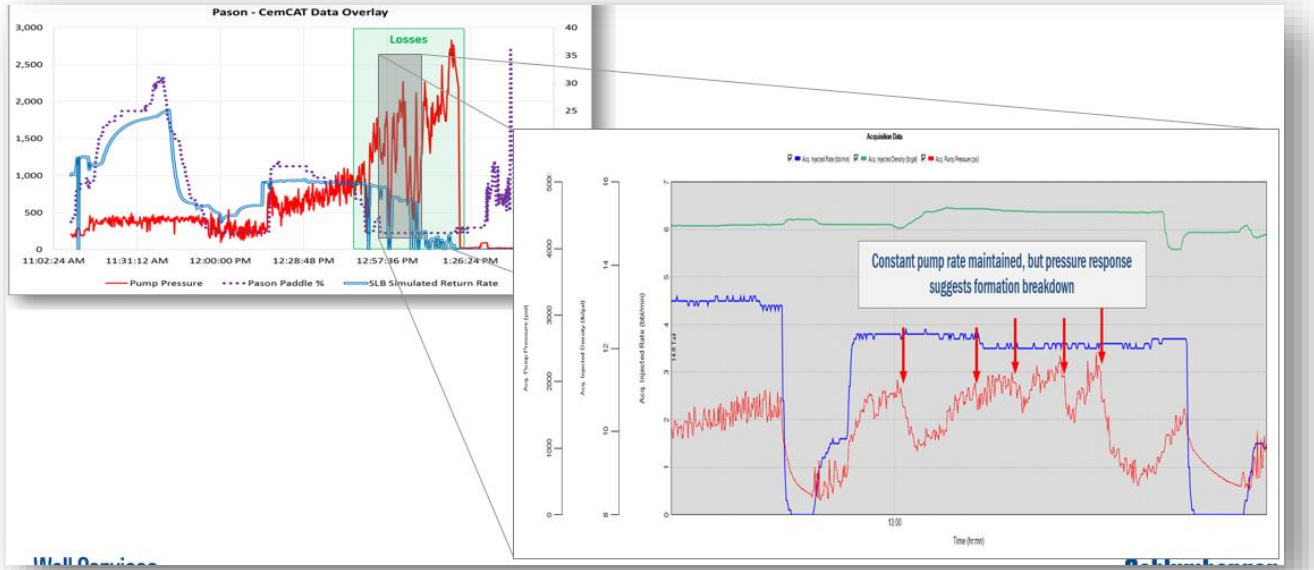
TYPES OF PRESSURE-MATCHING

- Quick analysis
  - Plot design and actual pressure data points
  - Rough comparison to identify any outstanding inconsistency
  - Rough TOC estimation in some cases
  - Complete in a few hours
- Detailed analysis
  - Plot design and actual pressure data points
  - Attain actual job data on parameters
  - Post-job testing for actual cement data
  - Analyze pressure-trends and pressure-signature down to 1-second data
  - Re-run advanced software simulation using pressure-matched data
  - Complete in a few hours to several days

WHAT CAN THE RESULTS TELL US?

- Identify potential points of failure
- Placement integrity of dynamic phase





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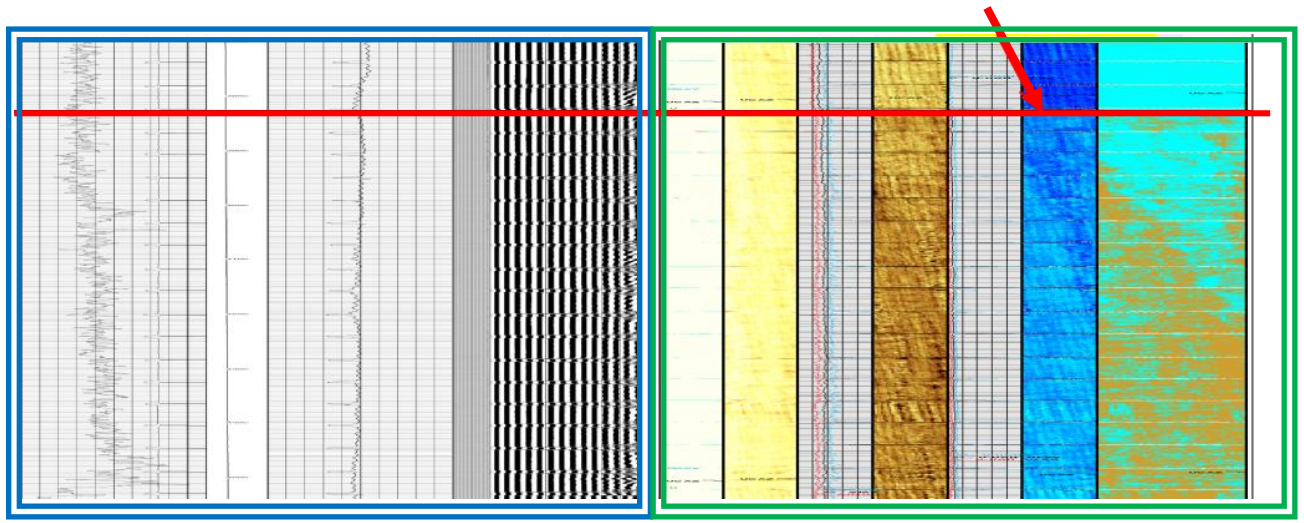
Wireline Logging Evaluation

TYPES OF LOGS

- Cement bond log
  - Conventional
  - Heavy cement TOC
- Ultrasonic Imager
  - High resolution channel evaluation
  - 360 degrees impedance mapping
  - Medium to Heavy cement
- Isolation Scanner
  - Lightweight cement, partially set and/or contaminated cement
  - Flexural attenuation
  - Third Interface Echo
  - Casing centralization

Example of CBL blind to lightweight cement, but visible on Isolation Scanner



WHAT CAN THE RESULTS TELL US?

- Competency of cement sheath and weak points yielding to SCP potential
- Problem areas that may develop throughout the lift of the well

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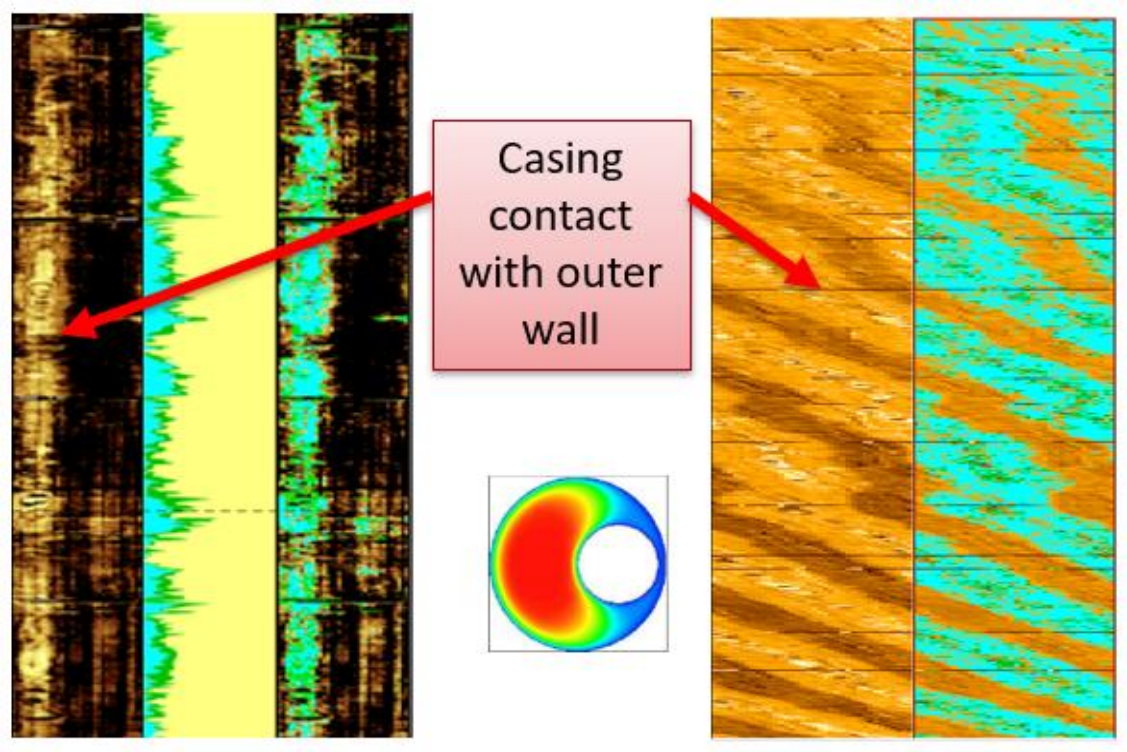
Wireline Logging – Examples of Channeling

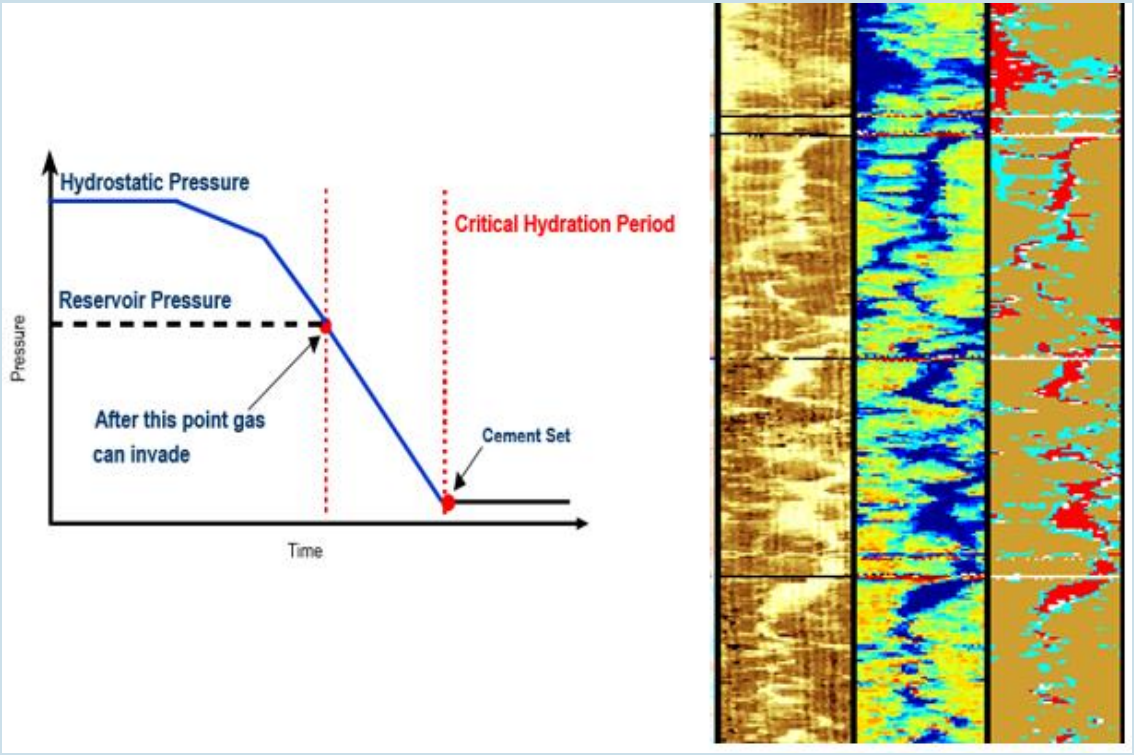
Low Side Channeling (Dynamic Phase)

- Poorly centralized casing resulting in mud channel left behind
- Pathway created for pressure communication

Post-Placement Channeling (Static Phase)

- Inadequate gas migration control during cement setting
- Can occur independent of dynamic placement quality





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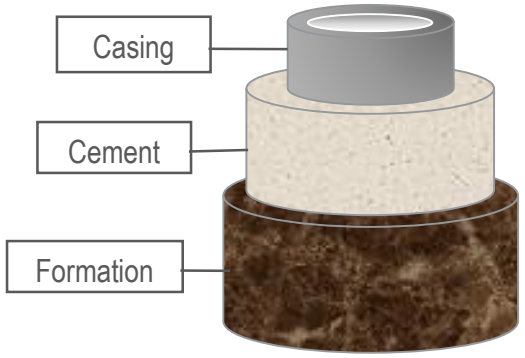
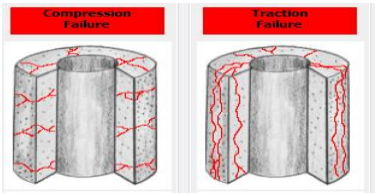
Not all gray matter is created equal

Prevention



Pressure	Conventional
3,000 psi	

Mitigation

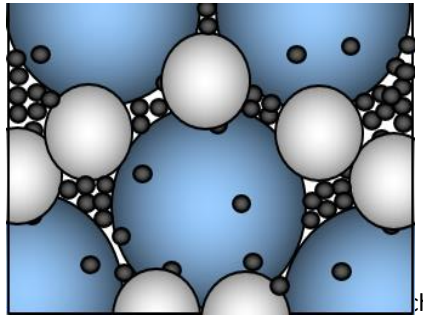
Flexible cement

Multi-modal blend

High SVF

- Improve mud removal
- Higher compressive strength
- Decrease porosity and permeability

Low Young's Modulus



Self-healing cement

- All benefits of flexible cement
- Effectively heals when exposed to liquid ***and gas!*** hydrocarbons

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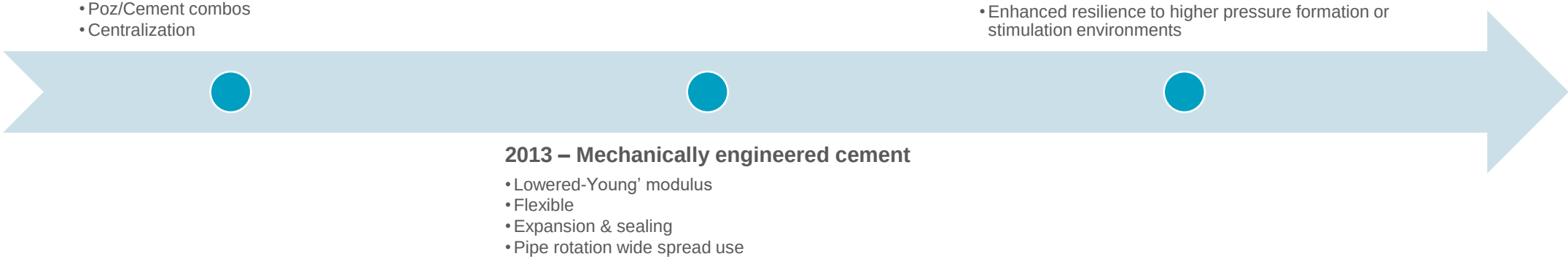
Evolution of US Land Lateral Cementing Solutions (actual used)

There are an abundance of novel ideas and solutions out there, but what are the fit-for-purpose solutions actual operators use with field-proven results?



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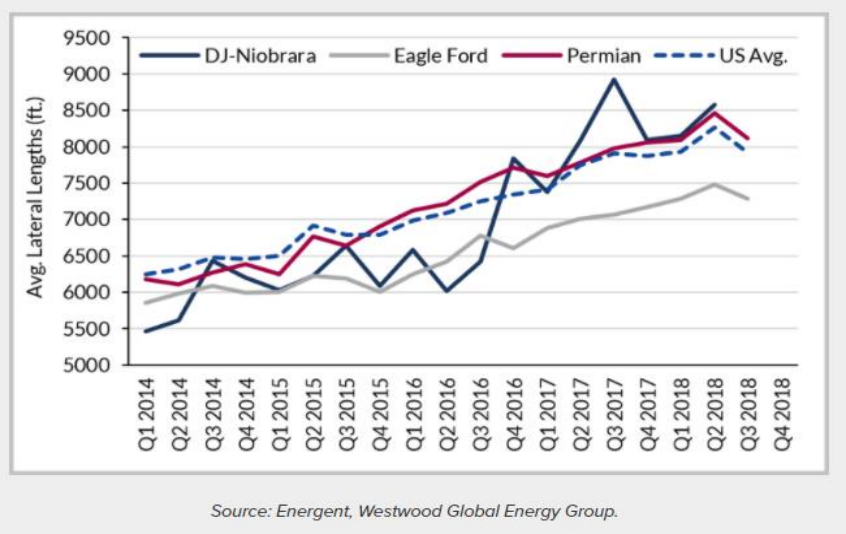
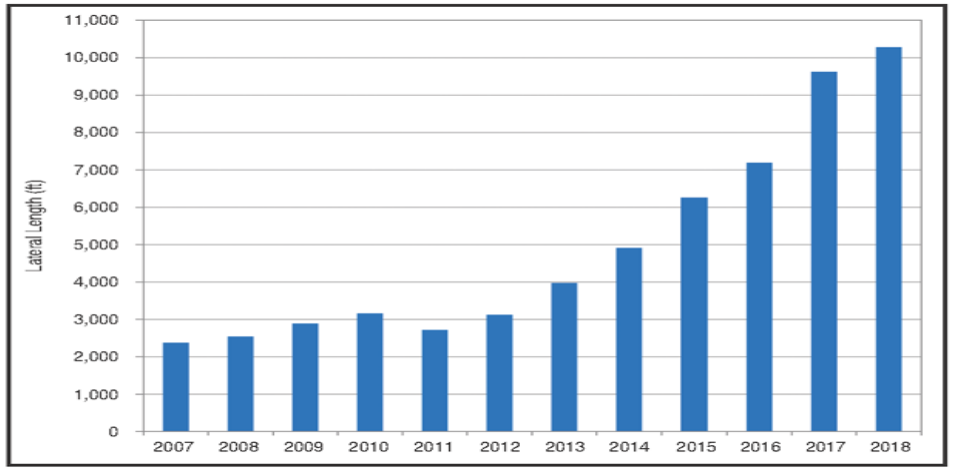
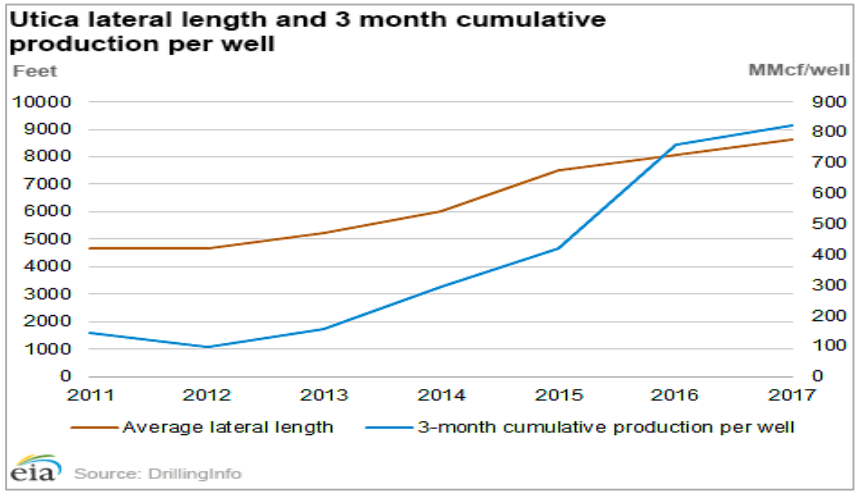
Wells are outgrowing their conventional cement designs



Source: Energent, Westwood Global Energy Group.



Source: American Oil & Gas Reporter



PRESSURE LIMITATIONS

- Lowered pump rates
- ECD management heightened

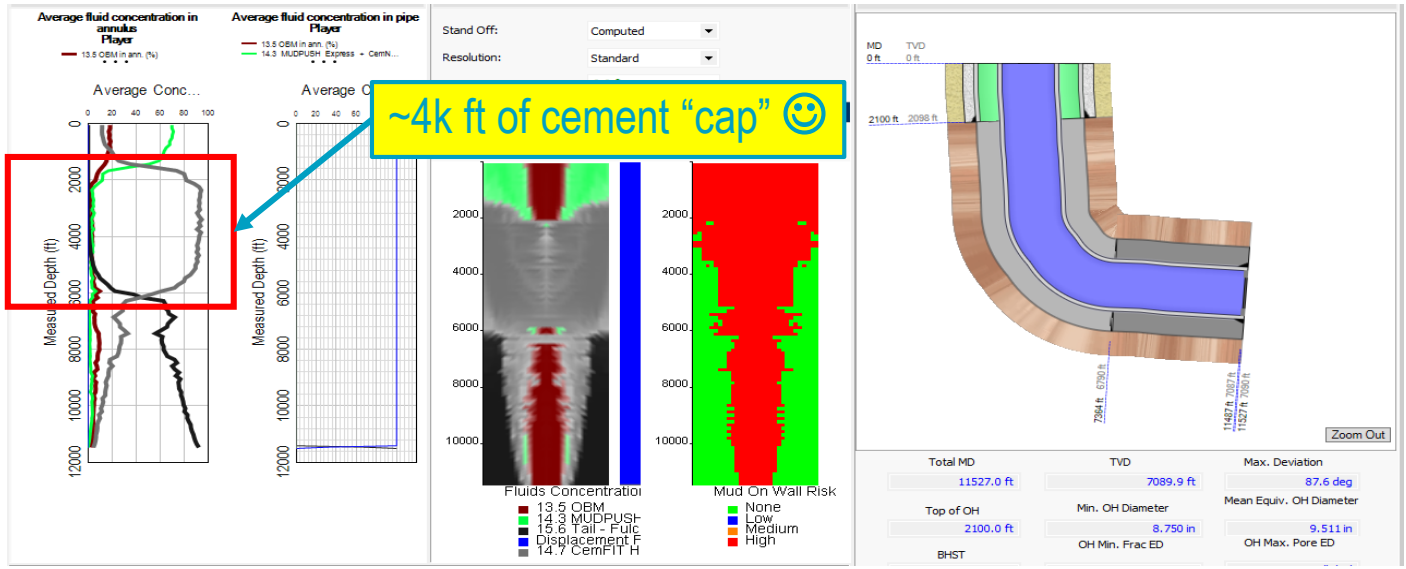
CENTRALIZATION & Pipe Movement

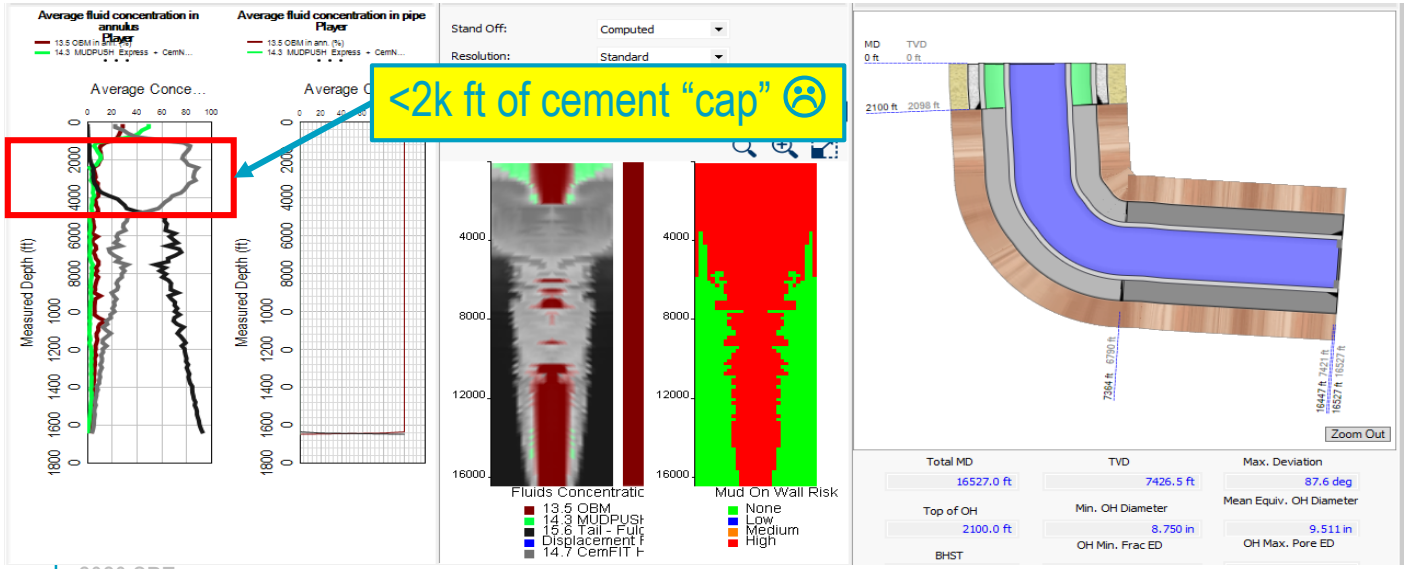
- Lateral centralization minimal or non-existent
- Pipe rotation becoming increasingly more difficult/impossible

SPACER FORMULATION

- Insufficient volumes
- Inadequate density & rheological hierarchy
- Fluid contamination exposure increased

Same Cement Design, Different Lateral Lengths





ORIGINAL LATERAL LENGTH – 5k ft

- Optimized cement design
- Robust azimuthal cement coverage above productive zone
- Slurry contamination minimized in design

EXTENDED LATERAL LENGTH – 10k ft

- Same cement design no longer optimal
- Significantly reduced azimuthal cement coverage above productive zone
- Slurry contamination worsened

2 to 3 mile laterals are more and more common today!

What can we do to improve the cement job?

DYNAMIC PHASE

WELL CONDITIONING

- Cure losses
- Condition mud prior to cementing

CENTRALIZATION

- Optimized cement design
- Robust azimuthal cement coverage above productive zone
- Focus the vertical section where a “cap” can be achieved

FLUID INFLUX

- Manage hydrostatics & ECDs to reduce fluid inflow/outflow
- Address gas migration w/ adequate preventive & mitigative measures

ENGINEERED CEMENT DESIGN

- Optimize mud removal and spacer design
- Run hydraulic simulations with advanced fluid instability simulation software to minimize contamination and optimize placement to meet zonal isolation targets

STATIC PHASE

SET CEMENT PROPERTIES

- Optimize cement for expected performance conditions
- Determine if conventional cement performance is adequate for post-job well activity
- Cement cracking due to well stresses
- Micro-annular development due to cement shrinkage or stresses

GAS MIGRATION PREVENTION

- Optimized cement design
- Robust azimuthal cement coverage above productive zone

EVALUATION

- Wireline logging combine with cement job pressure-matching can provide insights to further improve.
- Determine whether design is over-engineered and need to step back on costs, or whether under-engineered and additional investment is needed to effectively prevent SCP.

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What's on the Horizon?

OPTIMIZE FOR LONG-LATERALS

- Revisit the vertical section
- Re-establish the "cap"

DECOUPLE THICKENING-TIME FROM SLURRY STRENGTH DEVELOPMENT

- Static gel-strength enhancers
- Enable long working time, without compromising slurry strength development

UTILIZING MUD CHANNELS

- If you can't fight it join it—turn left behind mud into competent well barriers

IMPROVE BOND LOGS

- Next generation expansion additives

Key Takeaways

AS DRILLING TECHNIQUES ADVANCE, CEMENT DESIGNS NEED TO ADVANCE AS WELL

- Conventional designs no longer fit the bill
- Advanced cement formulations improve placement and long-term resilience
- Lateral lengths can and do have drastic affects on zonal isolation and SCP

THERE IS NO "I" IN "TEAM"

- SCP can result from one or a combination of the many aspects involved in the life of the well
- A collaborative effort in addressing all aspects is key to eliminating SCP

AN OUNCE OF PREVENTION IS WORTH A POUND OF CURE

- Advanced remediation technology can cure SCP, but comes at a hefty cost
- Doing it right from the start enables financially beneficial and socially responsible outcomes for a sustainable hydrocarbon energy future.

TODAY'S CHALLENGES CAN BE TOMORROW'S SOLUTIONS!

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