Life-cycle Well Integrity Evaluation

AADE

Sandeep Gade
Baker Hughes Inc.

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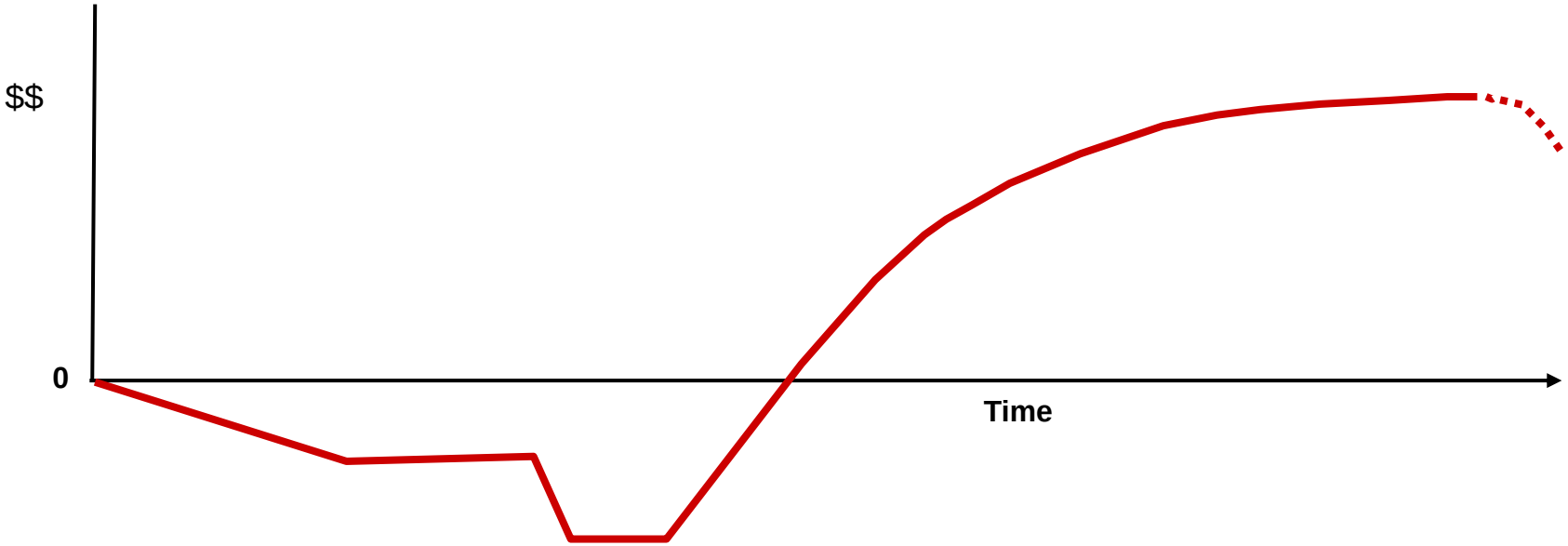
Oil / Gas well life cycle



Drilling

- Well Planning
- Drilling
- Pipe Recovery
- Formation Evaluation
- Casing & Cementing
- Cement evaluation

Completion

- Well Integrity
- Perforating

Production

- Production Logging
- Monitoring & Diagnostics
- Well Integrity
- Re-perforation

Workover

- Monitoring & Diagnostics
- Production Logging
- Well Integrity

Decommissioning

- Well Integrity
- Well Plugging & Abandonment (P&A)

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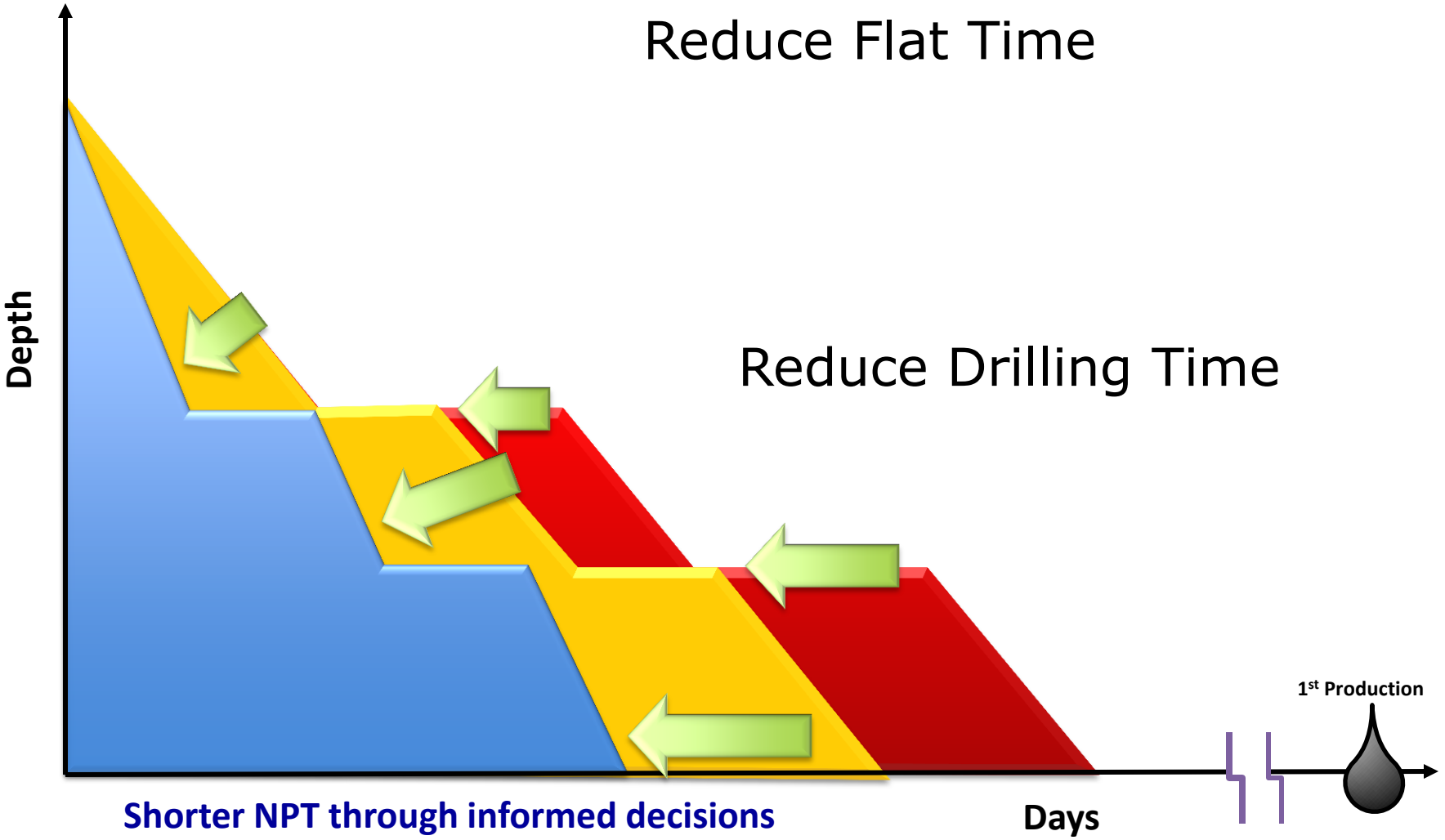
Non-Productive Time



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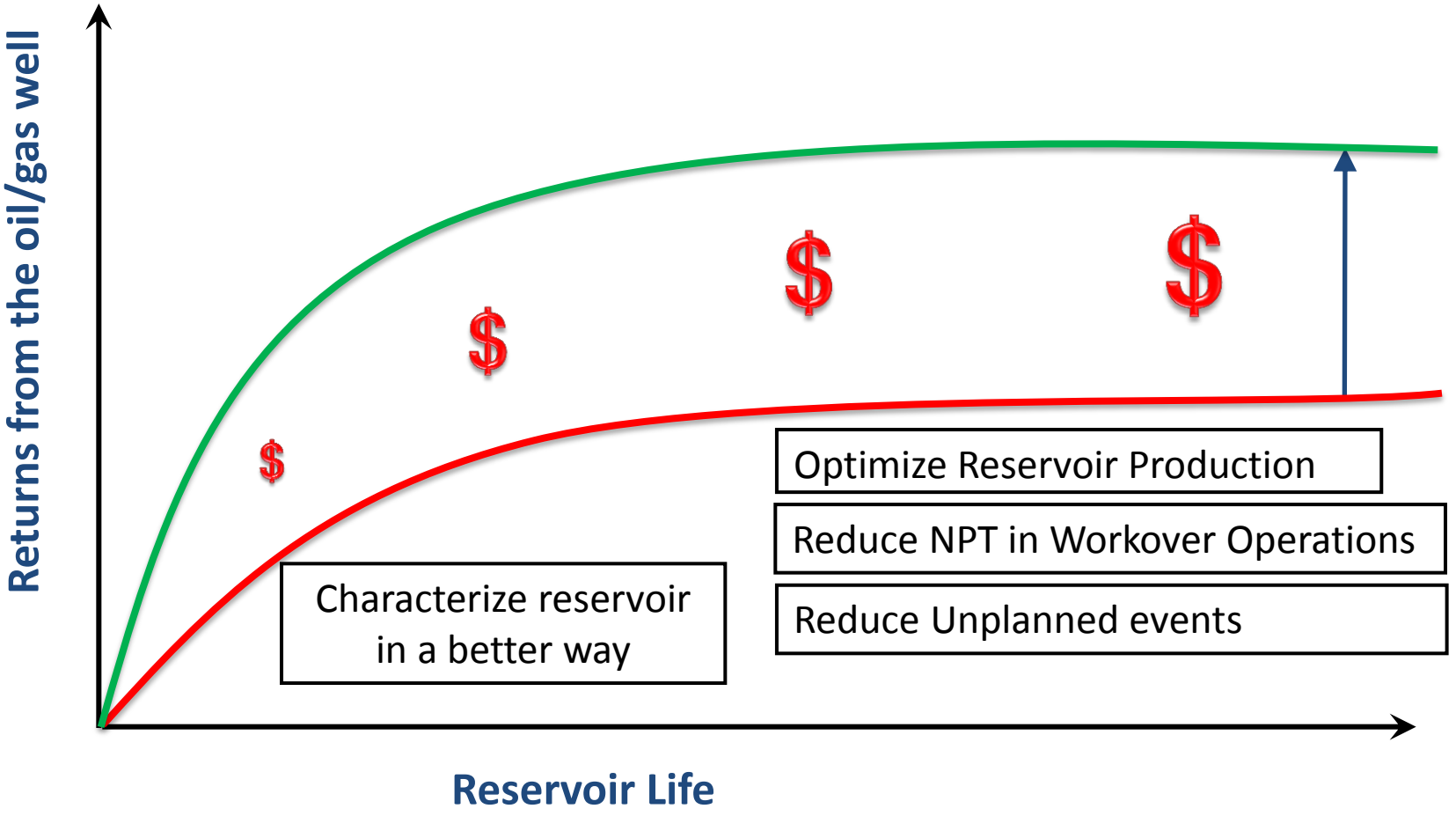
Optimize Reservoir Value



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Industry Drivers: More challenges

RELIABILITY AND SAFETY	➤	Ever increasing commitment to HSE. More demanding regulations
INCREASED RESERVOIR COMPLEXITY	➤	Deepwater HPHT Unconventionals
OPERATING ENVIRONMENT	➤	Deeper, hotter, harder, more hostile, more remote
PLUG AND ABANDON	➤	Reduce P&A cost, considerations in new well constructions, efficient casing strings removal, Improved verification of barriers
ESCALATING E&P COSTS (CAPEX AND OPEX) EXTREME PRESSURE ON PROFITABILITY AND CASH FLOW	➤	Technology Innovation Execution

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Challenges during Life cycle of a oil/gas well

Drilling

- Wellbore stability
- HS&E concerns regarding RA source deployment
- Pipe recovery options
- Cement bond evaluation in Large casing
- Cement bond evaluation in Light weight cement
- …

Completion

- Large casing cement evaluation
- Light weight cement evaluation
- Tubing/Casing recovery
- Gravel pack evaluation
- Sand screen evaluation
- Control lines identification
- Oriented perforations
- …

Production

- Production Monitoring
- Tubing/Casing leaks
- Channel identification
- Cement bond integrity
- Corrosion detection
- …

Workover

- Casing/Tubing recovery
- Pipe recovery options
- Control lines identification
- Casing/Tubing corrosion identification
- …

Decommissioning

- Cement bond integrity
- Multiple casing evaluation
- Channel identification
- Casing/tubing recovery
- …

"Well Integrity is of supreme importance in all stages of oil/gas well"

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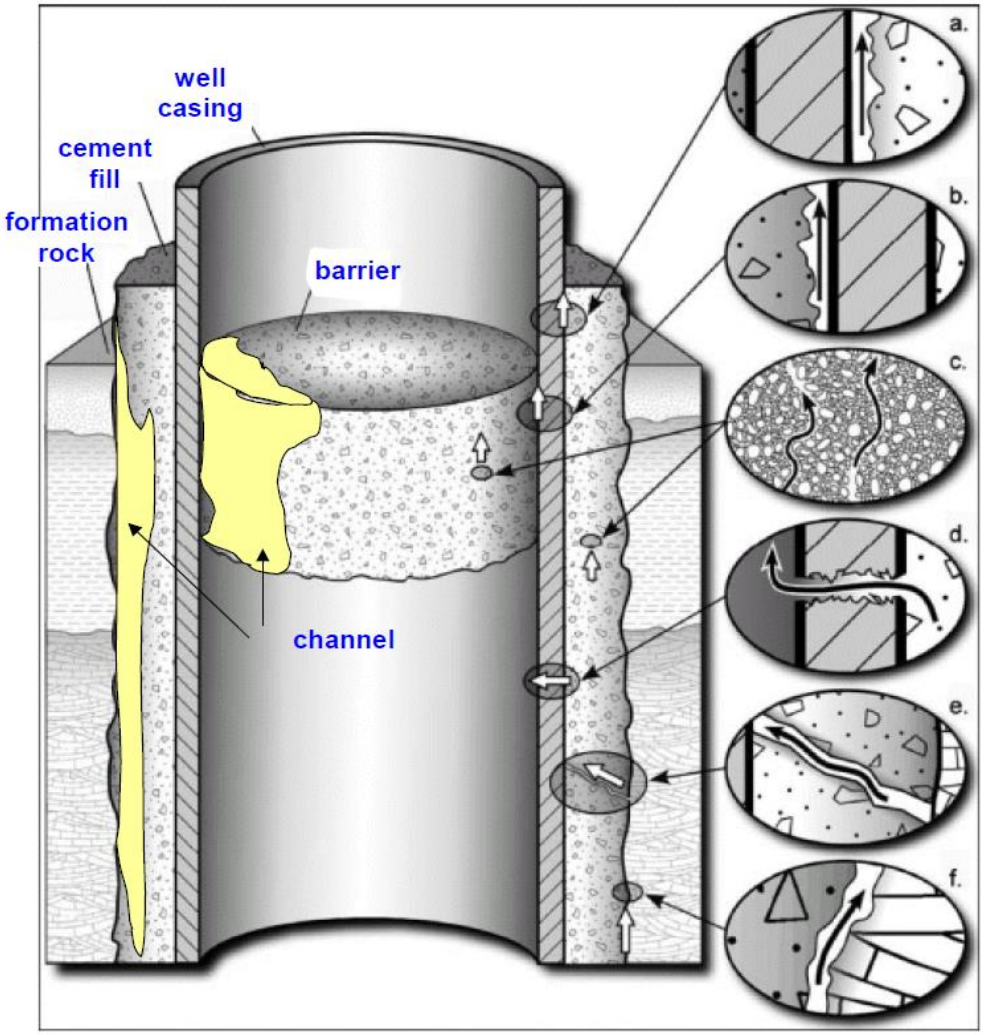
Cement bond evaluation challenges



Interface casing/cement
(micro-annulus, channel)

Interface casing/cement
(micro-annulus)
(wax, scale, oil, dirt, etc)

Bulk permeability
(connected pores, cracks, channels)

Leak in casing (connection)
(corrosion, deformation)

Annulus cement
(connected pores, cracks)

Interface rock/cement
(micro-annulus, channel)
(mudcake, cuttings, oil, etc)

Light weight Cement evaluation

Source: Oil & Gas UK, Guidelines on qualifications of materials for the suspension and abandonment of wells, Issue 1, July 2012

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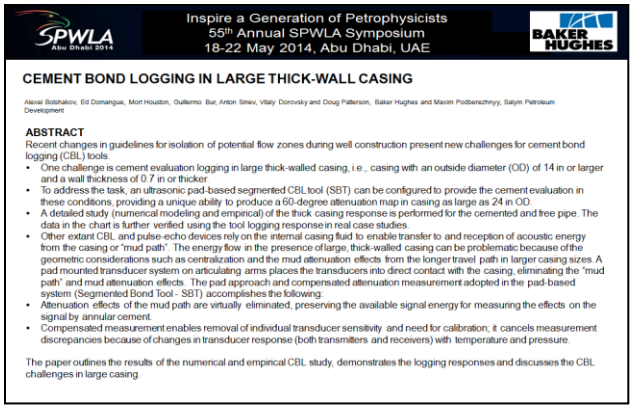
Cement Bond Integrity

Cement bond evaluation in Large casing, Heavy mud systems

- Challenges:
  - Large and/or thick-walled casing
  - Heavy mud systems
  - Deviated wells
  - Existing cement bond evaluation tools can provide answers up to 13 3/8” casing
- Solution:
  - SBT, SBT Beyond



SPWLA Abu Dhabi 2014

Inspire a Generation of Petrophysicists
55th Annual SPWLA Symposium
18-22 May 2014, Abu Dhabi, UAE

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CEMENT BOND LOGGING IN LARGE THICK-WALL CASING

Alexei Bolshakov, Ed Domangue, Mort Houston, Guillermo Bur, Anton Sinev, Vitaly Dorovsky and Doug Patterson, Baker Hughes and Maxim Podberezhnyy, Salym Petroleum Development

ABSTRACT

Recent changes in guidelines for isolation of potential flow zones during well construction present new challenges for cement bond logging (CBL) tools.

- One challenge is cement evaluation logging in large thick-walled casing, i.e., casing with an outside diameter (OD) of 14 in or larger and a wall thickness of 0.7 in or thicker.
- To address the task, an ultrasonic pad-based segmented CBL tool (SBT) can be configured to provide the cement evaluation in these conditions, providing a unique ability to produce a 60-degree attenuation map in casing as large as 24 in OD.
- A detailed study (numerical modeling and empirical) of the thick casing response is performed for the cemented and free pipe. The data in the chart is further verified using the tool logging response in real case studies.
- Other extant CBL and pulse-echo devices rely on the internal casing fluid to enable transfer to and reception of acoustic energy from the casing or "mud path". The energy flow in the presence of large, thick-walled casing can be problematic because of the geometric considerations such as centralization and the mud attenuation effects from the longer travel path in larger casing sizes. A pad mounted transducer system on articulating arms places the transducers into direct contact with the casing, eliminating the "mud path" and mud attenuation effects. The pad approach and compensated attenuation measurement adopted in the pad-based system (Segmented Bond Tool - SBT) accomplishes the following:
- Attenuation effects of the mud path are virtually eliminated, preserving the available signal energy for measuring the effects on the signal by annular cement.
- Compensated measurement enables removal of individual transducer sensitivity and need for calibration; it cancels measurement discrepancies because of changes in transducer response (both transmitters and receivers) with temperature and pressure.

The paper outlines the results of the numerical and empirical CBL study, demonstrates the logging responses and discusses the CBL challenges in large casing.

Introduced at SPWLA 2014 - Abu Dhabi, Paper # 1691

- Technology:
  - Ultrasonic Pad device
  - Characterized tool response for larger diameter & thick-walled casing
- Benefits:
  - Capable of evaluating cement bond behind large (up to 24” OD) and thick casings (up to 1” thickness)
  - Channel identification
  - Insensitive to moderate decentralization & mud weight
- Constraints:
  - Cement weight less than 12 ppg

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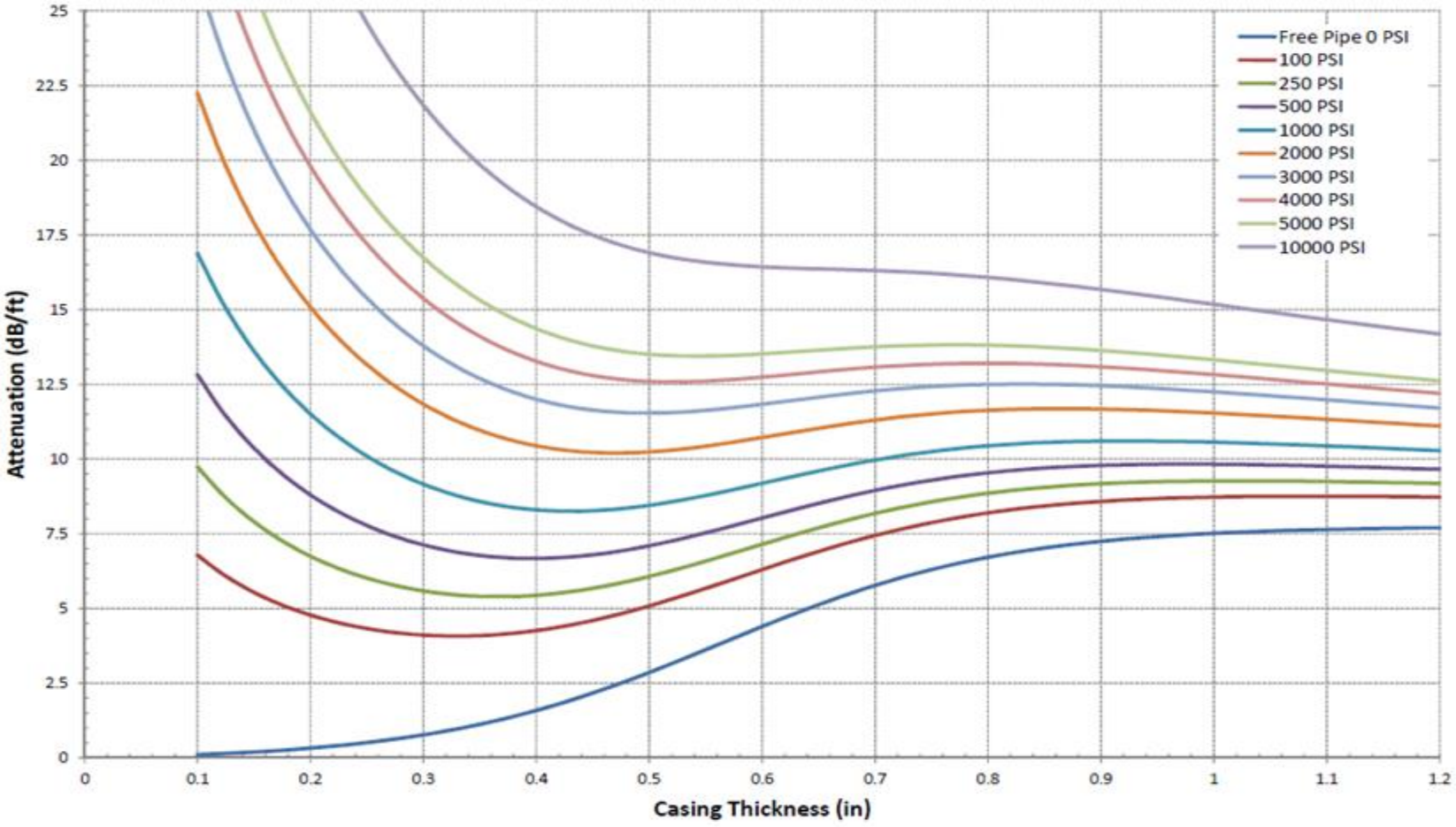
Cement Bond Integrity

Cement bond evaluation in Thick casing

SBT Characterization in Thick casing



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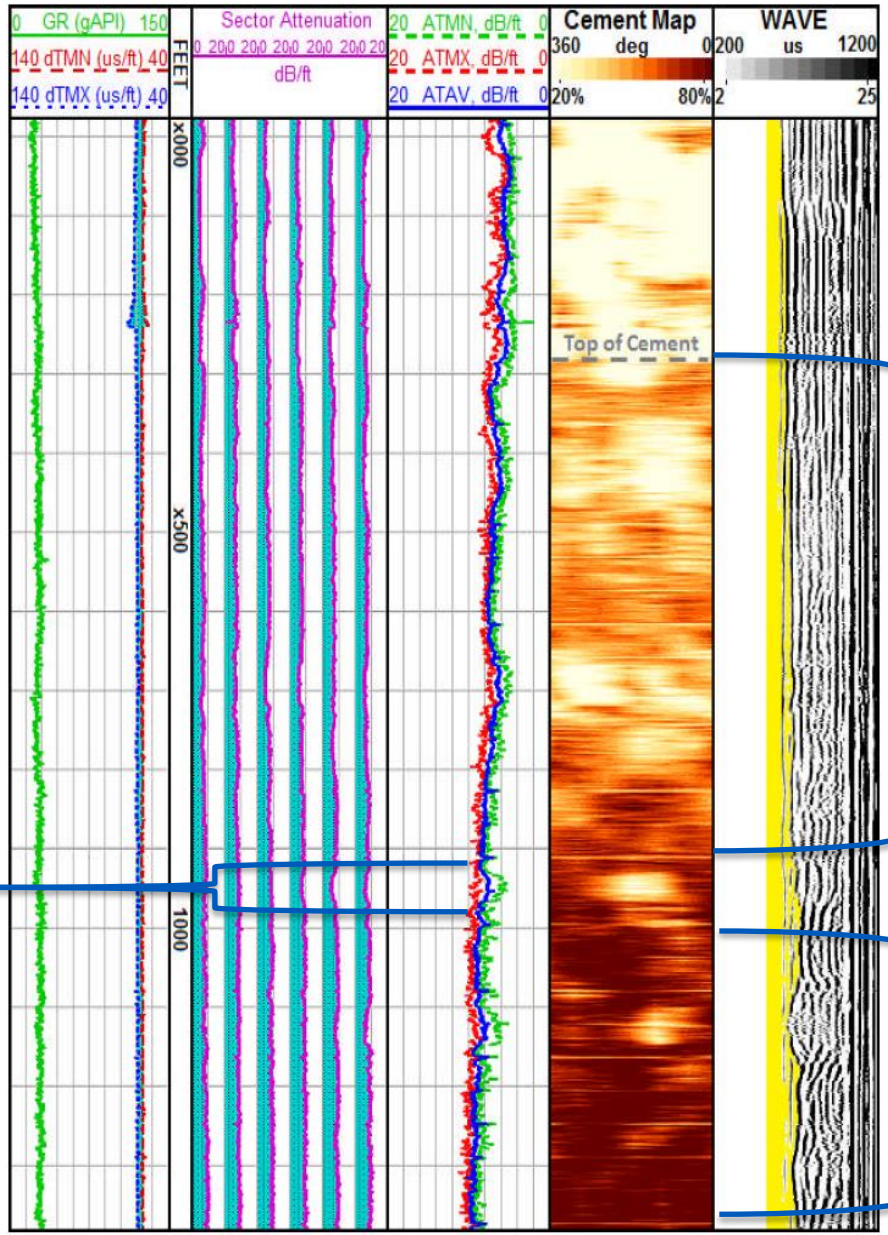
Cement Bond Integrity

Cement bond evaluation in Large & Thick casing

- 24” OD
  - 0.628” thickness
- 1500 PSI Cement



Potentially contaminated or uncured cement

Min/Max/Avg separation an indication of void

>1,000 psi cement with some small/isolated channeling

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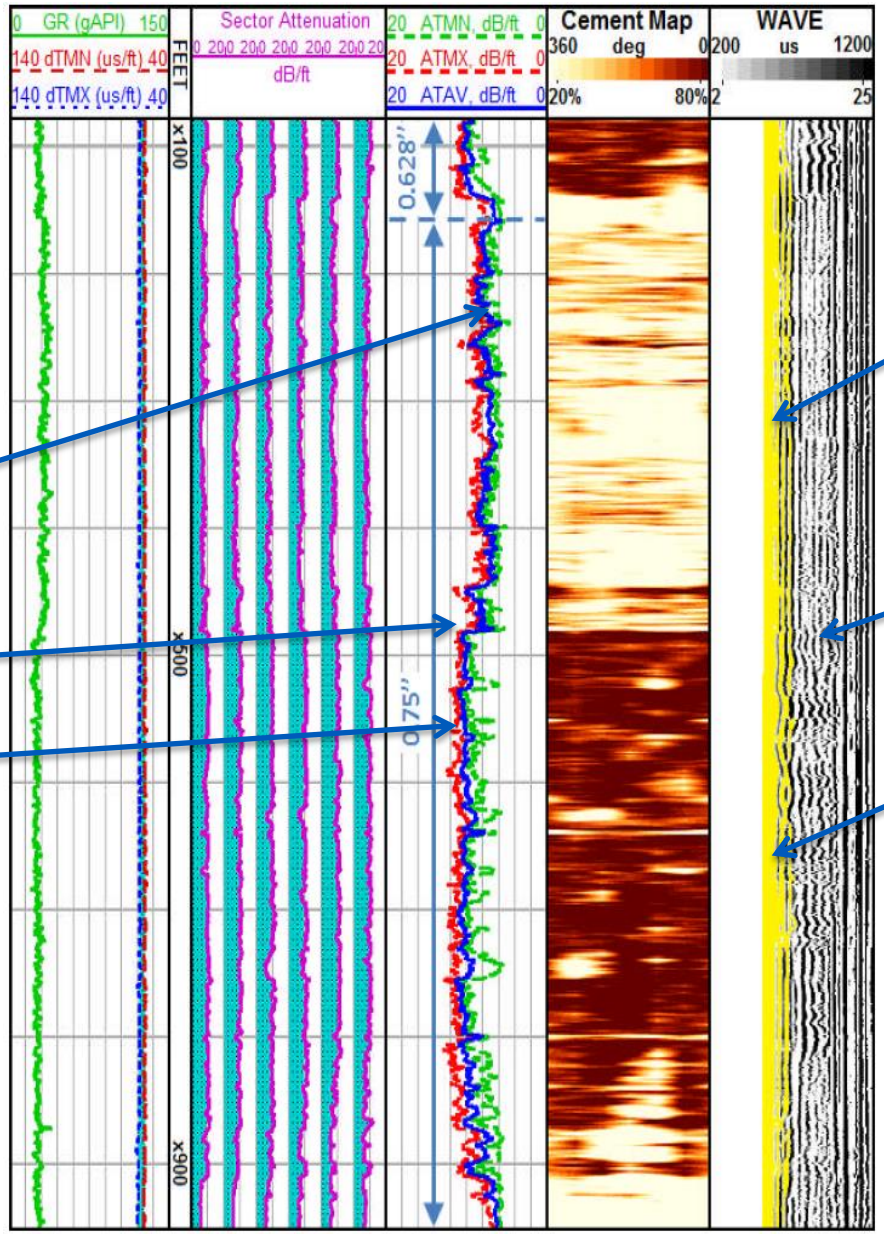
Cement Bond Integrity

Cement bond evaluation in Large & Thick casing

- 24” OD
  - 0.628” / 0.75” thickness
- 1500 PSI Cement



Near free-pipe response

Top of cement

~11 dB/ft = ~1500 PSI

Strong casing arrivals

Formation Arrivals

No casing arrivals

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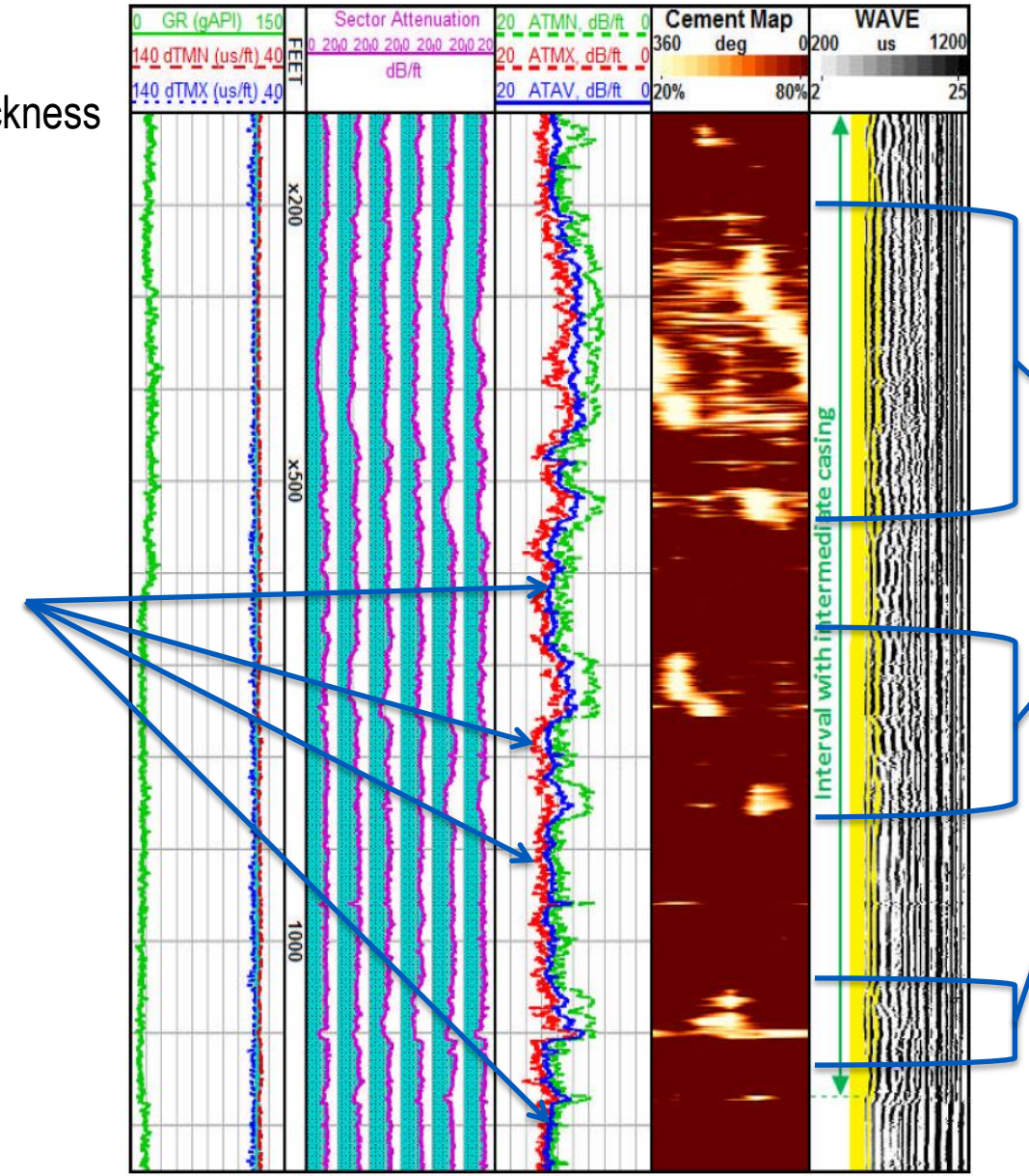
Cement Bond Integrity

Cement bond evaluation in Large & Thick casing

- 20” OD
  - 0.984” thickness



~13 dB/ft indicating
>3000 PSI cement

Isolated voids

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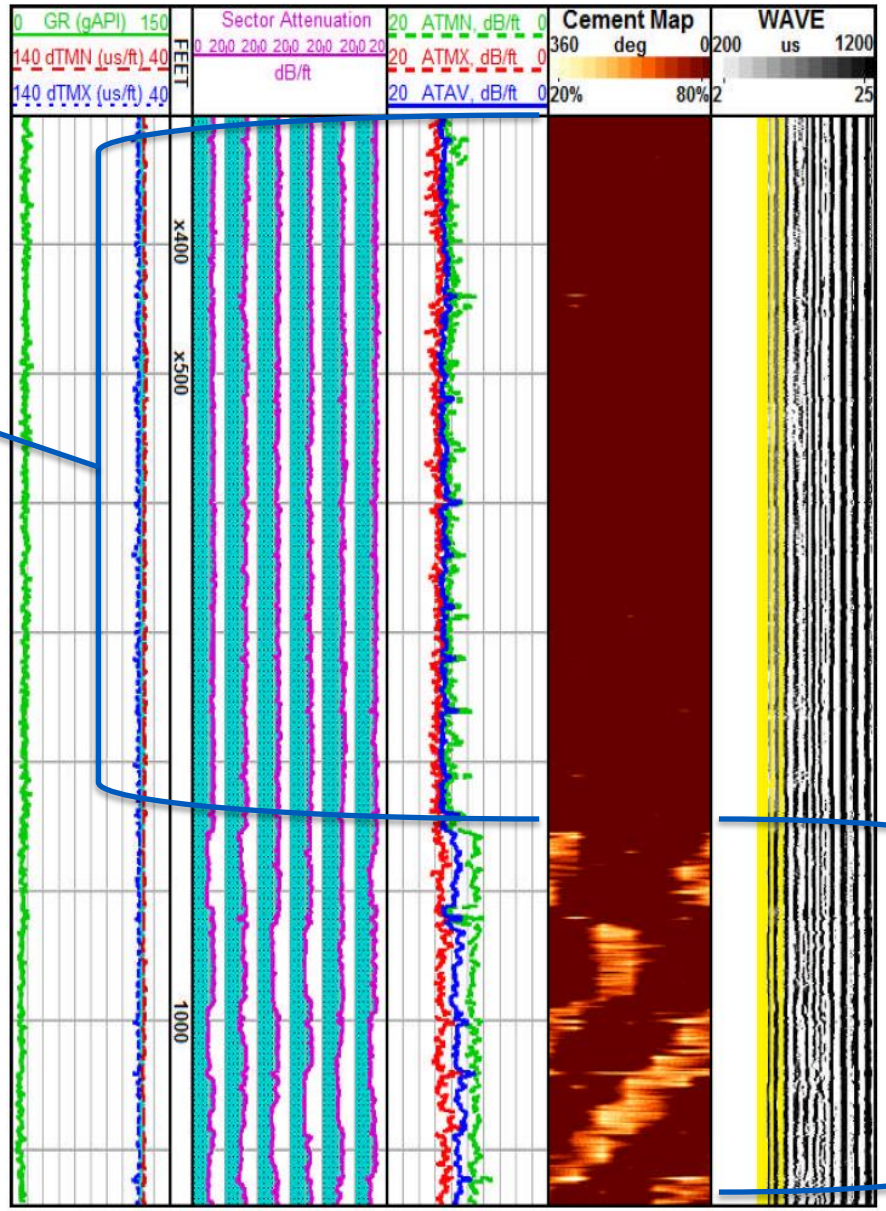
Cement Bond Integrity

Cement bond evaluation in Large & Thick casing

- 20” OD
  - 0.984” thickness



13 dB/ft indicating
>3000 PSI cement

Indication of
channeling

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Cement Bond Integrity

Light Weight Cement (LWC) bond evaluation

- Challenges:
  - Cement bond evaluation in Light weight Cement (LWC)
- Solution:
  - EMAT

- Technology:
  - Electromagnetic Acoustic sensors
- Benefits:
  - Evaluates cement bond in standard and low cement weights (as low as 7 ppg “floating cement”)
  - Evaluates cement in dry boreholes
  - No effect of microannulus
  - Provides casing thickness measurement

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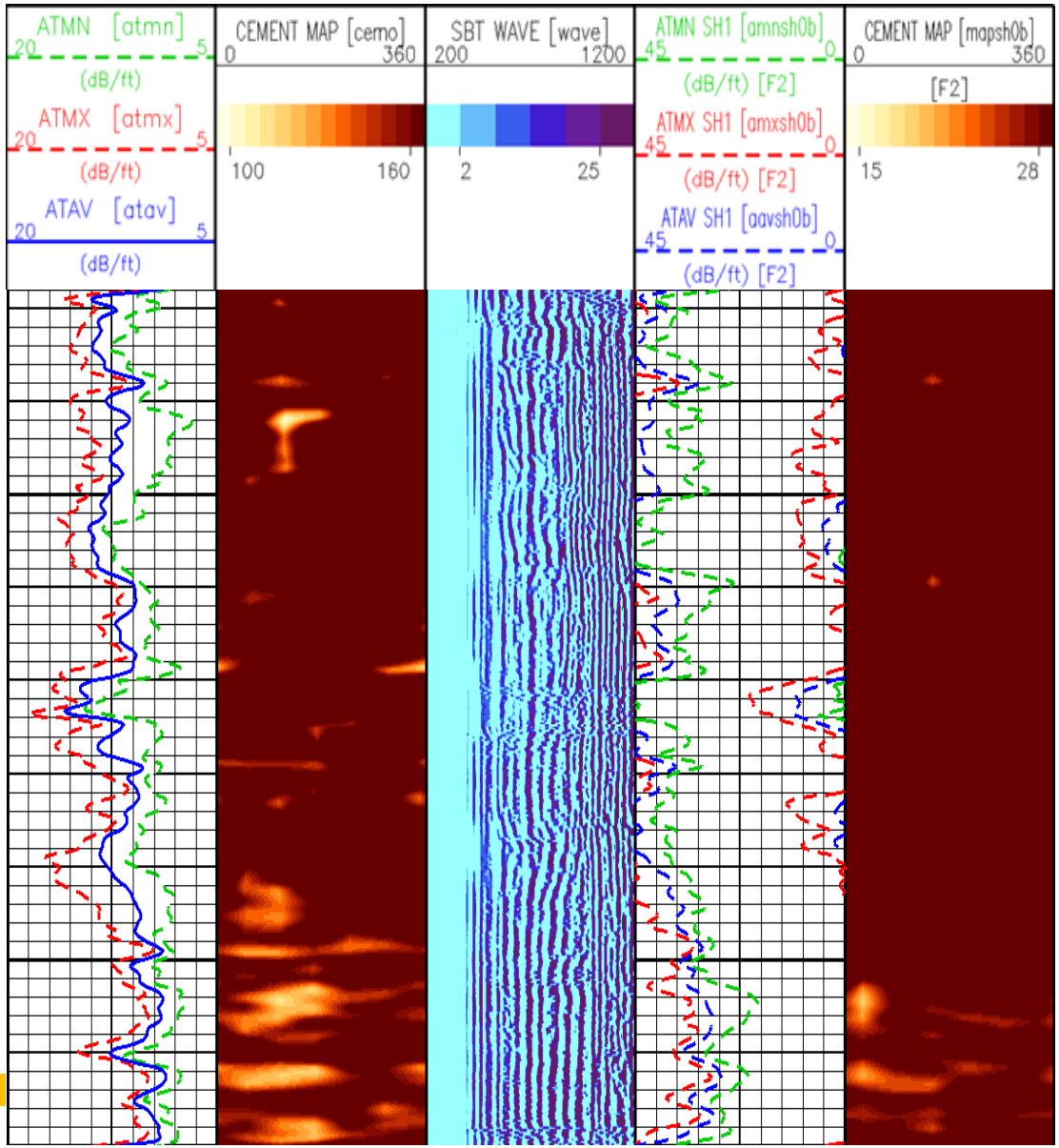
Cement Bond Integrity

Light Weight Cement (LWC) bond evaluation: Field test (Tail Slurry)



- 2 stage cementation:
  - 10ppg (lead) slurry
  - Class G 15.6ppg (tail slurry)

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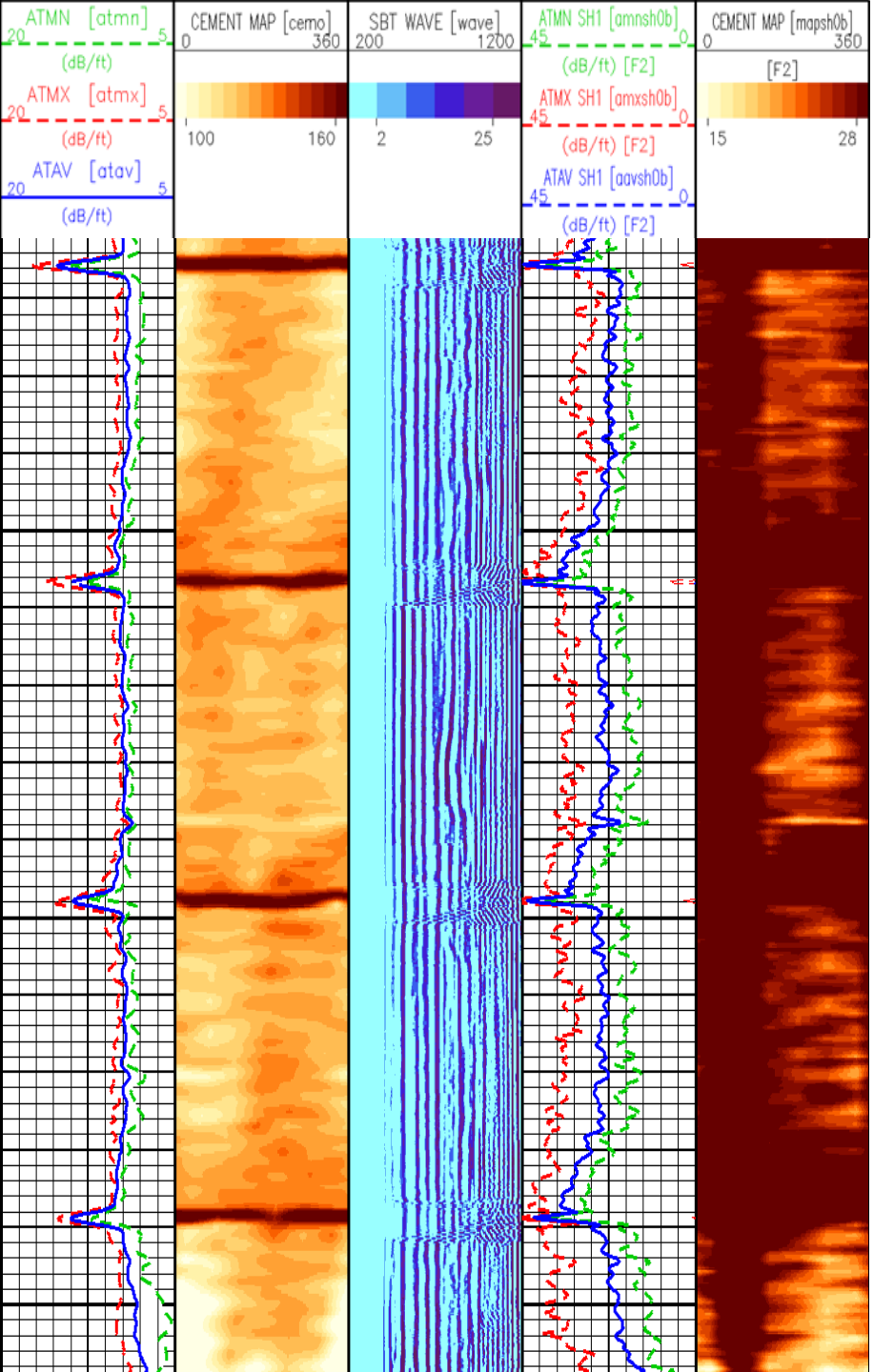
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(dB/ft)
ATMX [atmx]
20 5
(dB/ft)
ATAV [atav]
20 5
(dB/ft)
CEMENT MAP [cemo]
0 360
100 160
SBT WAVE [wave]
200 1200
2 25
ATMN SH1 [amnsh0b]
45 0
(dB/ft) [F2]
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(dB/ft) [F2]
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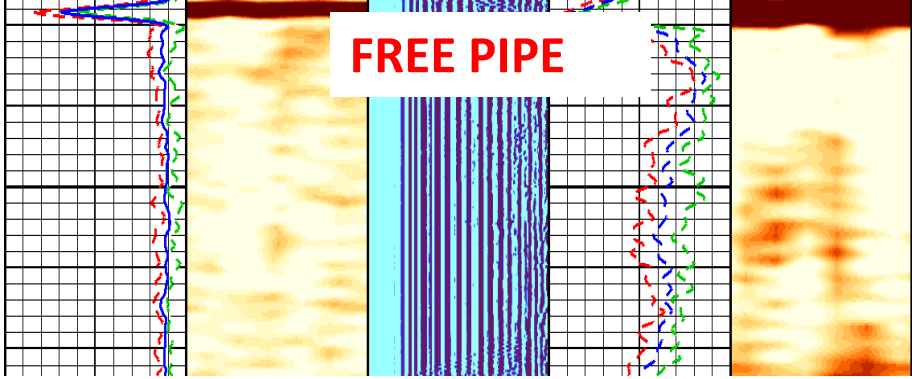
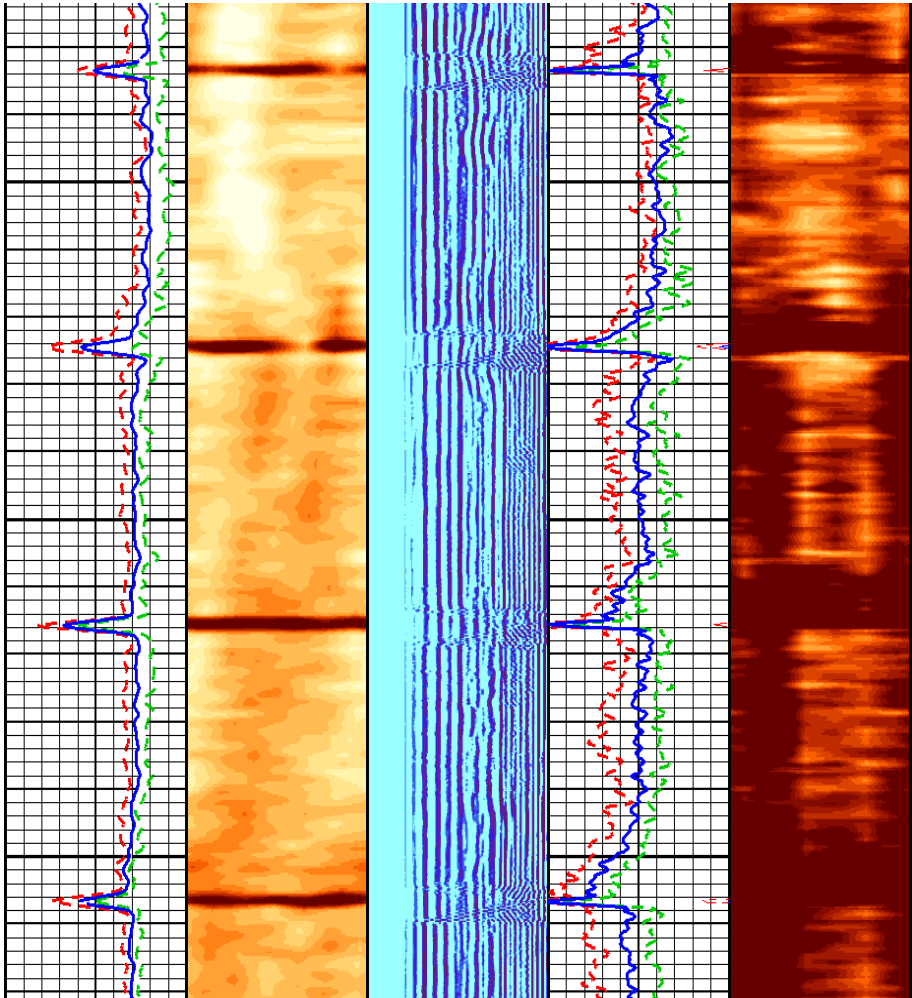
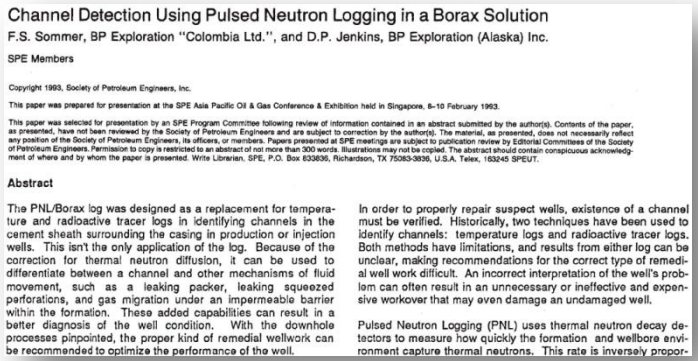

FREE PIPE



Cement Bond Integrity

Channel detection in Production / Injection wells

- Challenges:
  - Difficult to identify small channels
  - Temperature logs can be misleading
  - Radioactive tracer logs are not environmentally friendly
- Solution:
  - Pulsed neutron logging using a Borax solution



Channel Detection Using Pulsed Neutron Logging in a Borax Solution

F.S. Sommer, BP Exploration "Colombia Ltd.", and D.P. Jenkins, BP Exploration (Alaska) Inc.

SPE Members

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Abstract

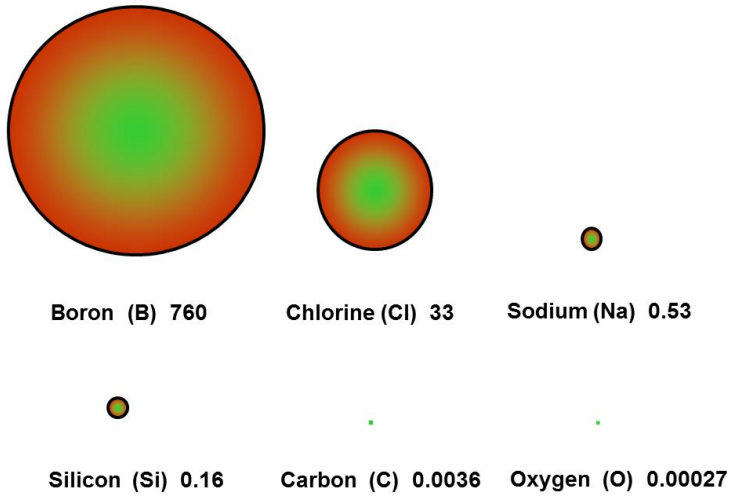
The PNL/Borax log was designed as a replacement for temperature and radioactive tracer logs in identifying channels in the cement sheath surrounding the casing in production or injection wells. This isn't the only application of the log. Because of the correction for thermal neutron diffusion, it can be used to differentiate between a channel and other mechanisms of fluid movement, such as a leaking packer, leaking squeezed perforations, and gas migration under an impermeable barrier within the formation. These added capabilities can result in a better diagnosis of the well condition. With the downhole processes pinpointed, the proper kind of remedial wellwork can be recommended to optimize the performance of the well.

In order to properly repair suspect wells, existence of a channel must be verified. Historically, two techniques have been used to identify channels: temperature logs and radioactive tracer logs. Both methods have limitations, and results from either log can be unclear, making recommendations for the correct type of remedial well work difficult. An incorrect interpretation of the well's problem can often result in an unnecessary or ineffective and expensive workover that may even damage an undamaged well.

Pulsed Neutron Logging (PNL) uses thermal neutron decay detectors to measure how quickly the formation and wellbore environment capture thermal neutrons. This rate is inversely propor-

SPE 25383

- Technology:
  - Monitor sigma changes due to injection of Borax solution
- Benefits:
  - Identifies small channels
  - Identifies leaking packer, leaking squeezed perforation and fluid migration under an impermeable barrier in the formation



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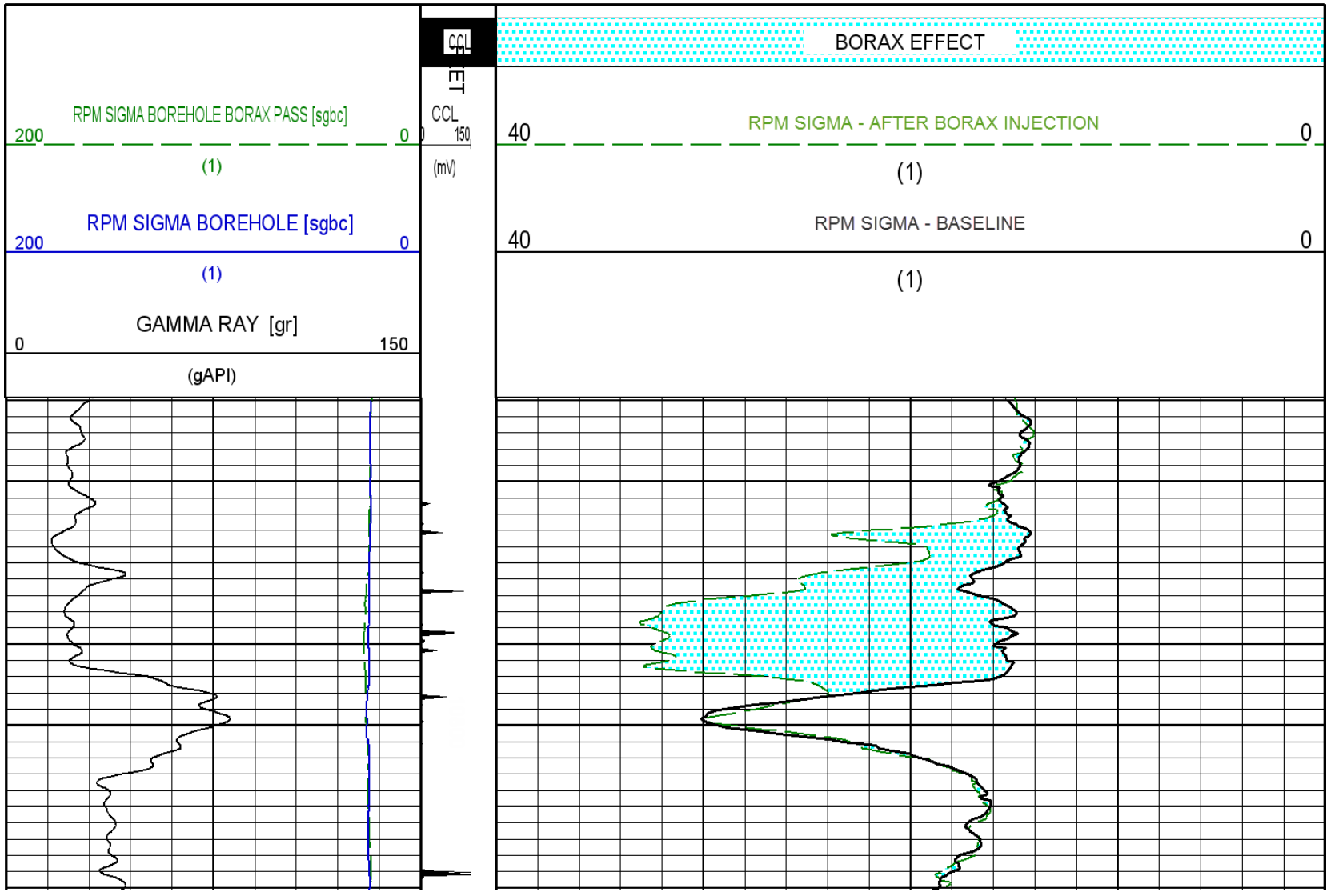
Cement Bond Integrity

Channel detection in Production / Injection wells



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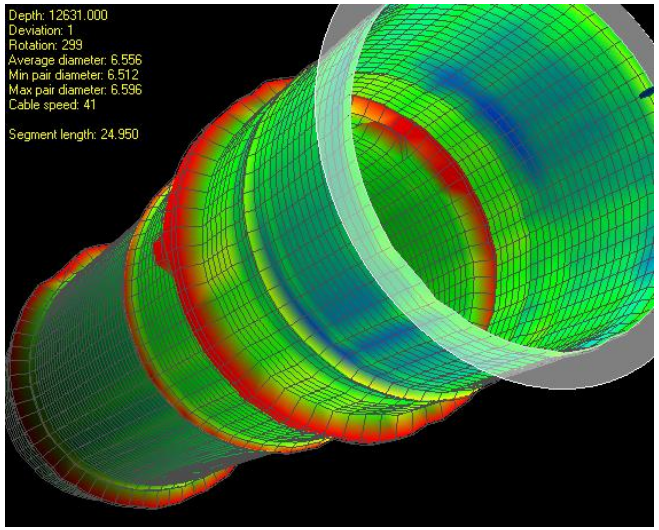
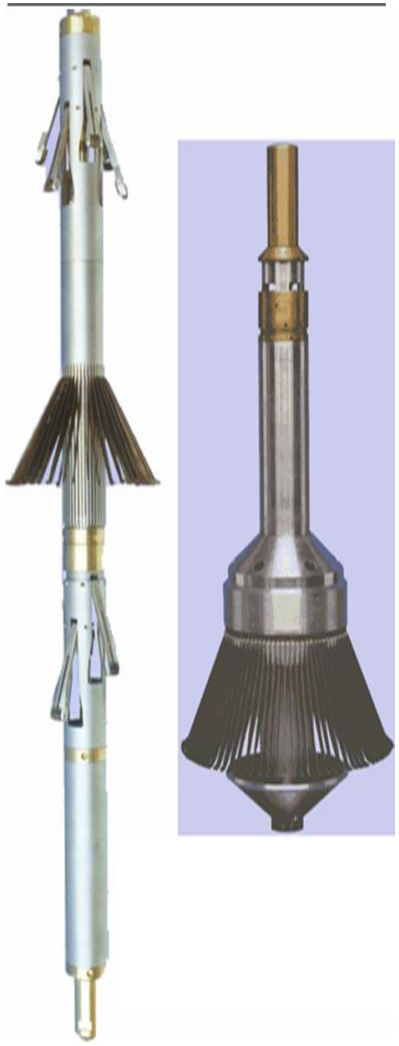
Casing/Tubing Integrity

Corrosion identification

- Challenges:
  - Identify casing/tubing corrosion to avoid pre-mature failure
- Solution:
  - Image Caliper



- Technology:
  - Multiple individual calipers
- Benefits:
  - Identifies Internal Pitting / Corrosion
  - Provides orientation and inclination
  - Casing/Tubing range: 2 3/8” to 20”
  - Identifies drill wear
- Constraints:
  - Can not identify external corrosion



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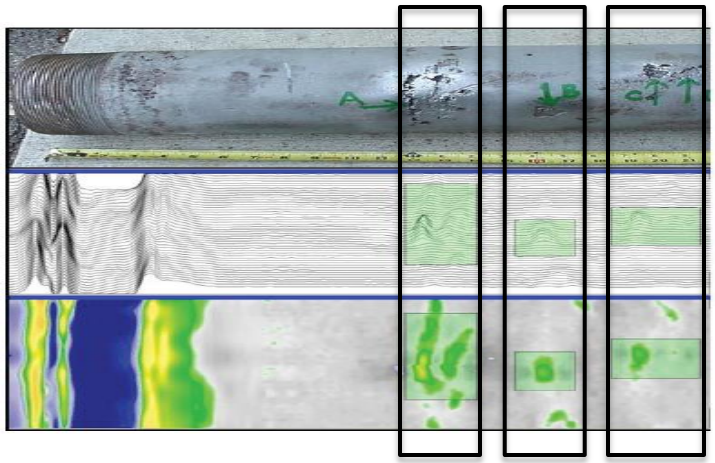
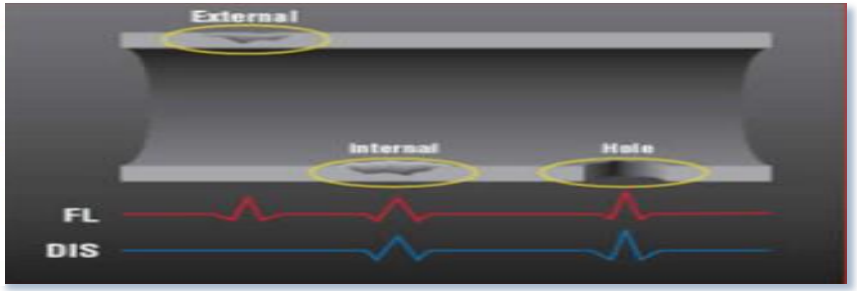
Casing/Tubing Integrity

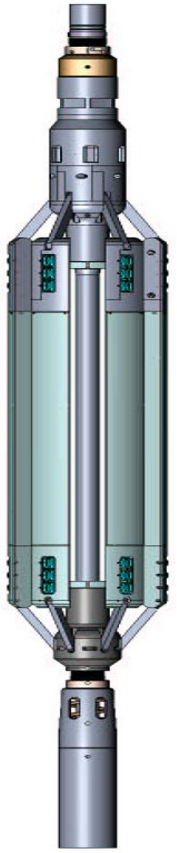
Corrosion identification

- Challenges:
  - Identify the internal or external corrosion
  - Identify burst pressure of casing/tubing
- Solution:
  - High resolution Vertilog (HRVRT™)

- Technology:
  - Changes in the magnetic field
- Benefits:
  - Circumferential and axial resolution
  - Multi-axial sensors for improved defect descriptions, accuracy and reliability
  - Burst pressure calculations
  - Casing range: 4 ½" to 9 $^{5}/_{8}$"
  - Memory acquisition capability







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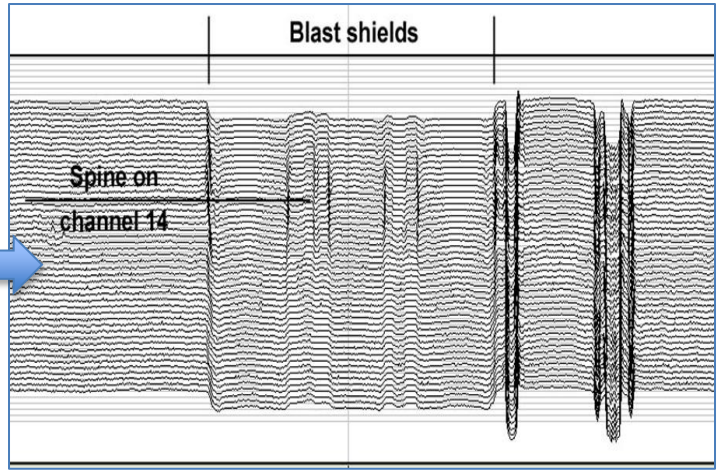
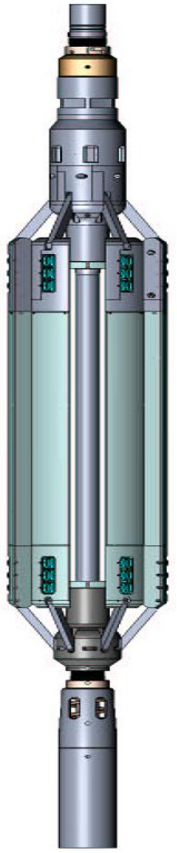
Workover operations

Control lines identification

- Challenges:
  - Identify the orientation of Control lines and Fiber optics cable, to avoid damage during perforation operations
- Solution:
  - ControlView™
- Technology:
  - Changes in the magnetic field
  - Uses HRVRT instrument
- Benefits:
  - Can be done during casing inspection operations simultaneously
  - Casing range: 4 ½" to 9 $^{5}/_{8}$"





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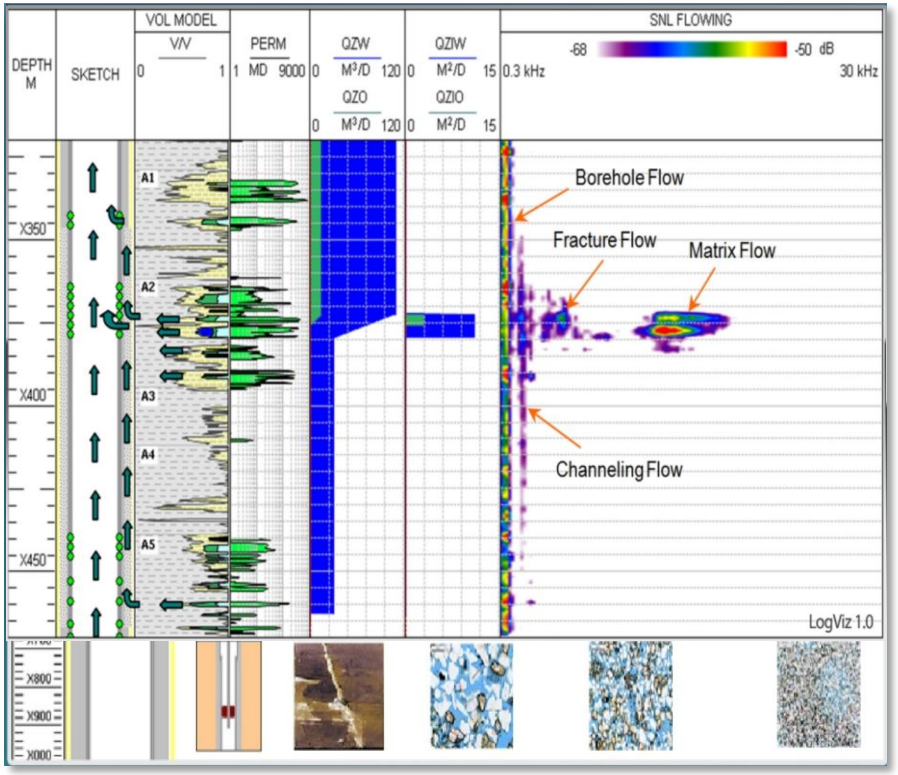
Workover operations

Leak detection

- Challenges:
  - Identify fluid flow behind casing/tubing
- Solution:
  - Noise / Temperature log



- Technology:
  - Acoustic sensors
  - Band pass filters separate sound frequency spectrum for analysis
- Benefits:
  - Determine fluid flow behind or inside casing.
  - Locate fluid flow in cement annulus channel.
  - Locate gas or liquid entry through casing leaks.
  - Locate gas/Liquid interface in wellbore.
  - Determine whether fluid flow is single or dual phase.

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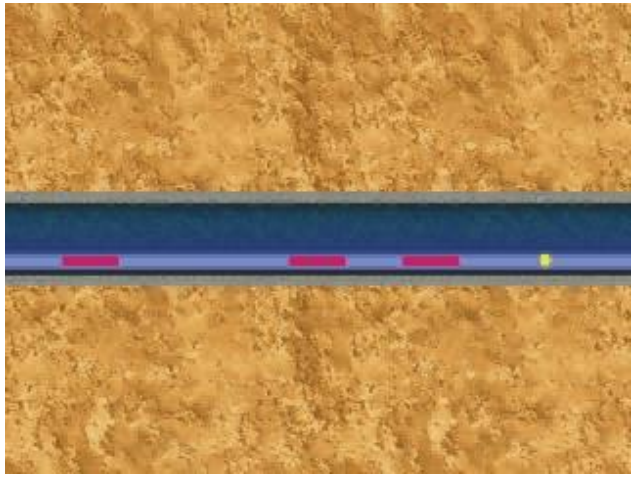
Workover operations / Well Integrity / Production stage

Water flow behind casing/tubing

- Challenges:
  - Identify fluid flow behind casing/tubing
- Solution:
  - Activation Water Flow
    - Hydrolog™
    - Annular Flow Log (AFL™)
    - FlowShot™



- Technology:
  - Uses Oxygen in water as a Tracer material to calculate water velocity
- Benefits:
  - Can identify water movement in annular space
  - Non-mechanical velocity measurement
  - Can measure water velocity in projection or injection wells
- Constraints:
  - Oil or Gas velocity can not be identified
    - 'Oxygen' presence is essential

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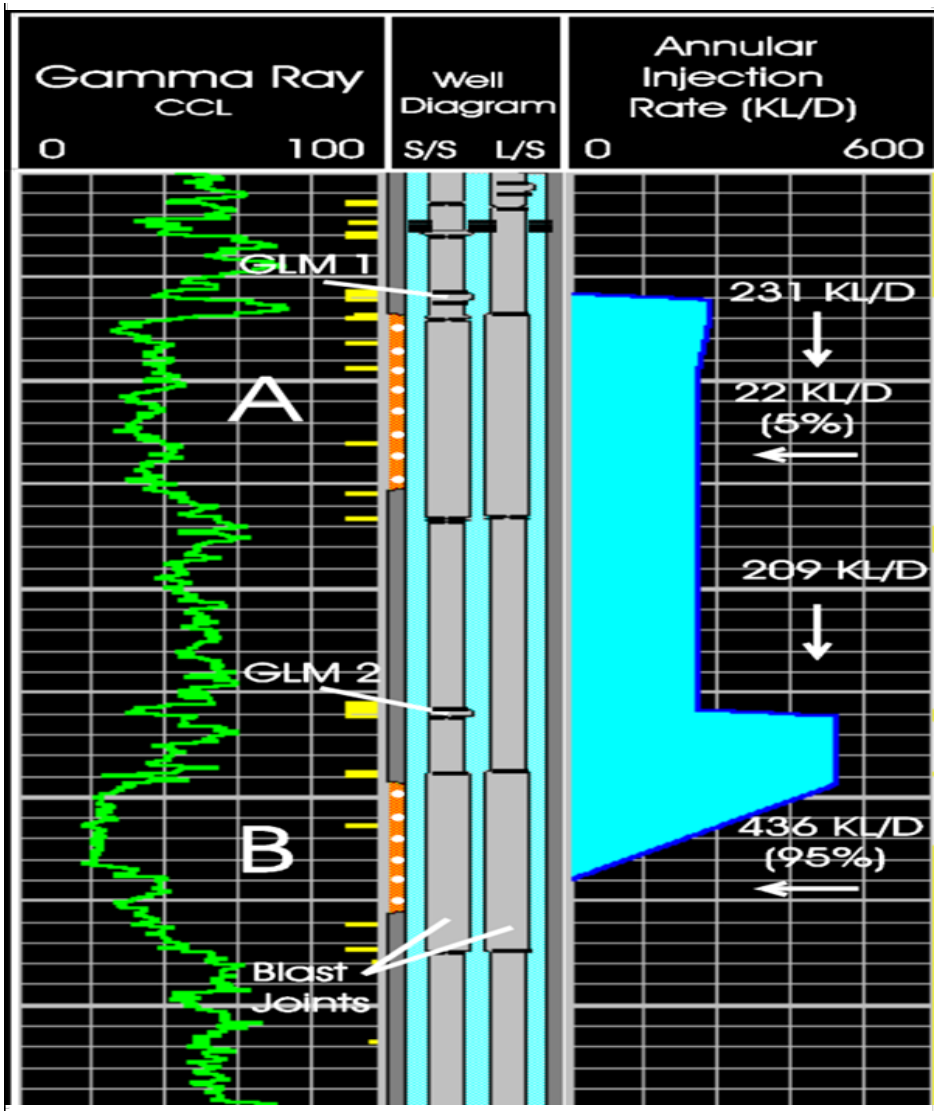
Workover operations / Well Integrity / Production stage

Water flow behind casing/tubing: Case history

- Challenges:
  - Production wells converted into injection wells after wells started producing water
  - Multiple injections at the same time
  - Production from surrounding wells not matching the expected injection profile
- Solution:
  - Deployed AFL through the S/S tubing
  - Passes done at multiple speed to identify annular water velocity
- Results:
  - Identified that the bottom zone is fractured & taking ~95% of the injected fluid



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Workover operations

Non-ballistic Pipe recovery option

- Challenges:
  - Retrieve casing/tubing from well
  - Most of the solutions present in the industry use chemical or ballistic services, which are not environmentally friendly & can cause additional problems
- Solution:
  - Mechanical Pipe Cutter (MPC™)
- Technology:
  - Non-ballistic mechanical cutter
  - Wireline deployed
- Benefits:
  - Cuts pipe ranging from 2 $^{7}/_{8}$" to 7" OD
  - Clean, precision cut with minimum debris
  - Cuts wide range of drill pipe/tubing/casing e.g. J-55, 13Cr, 25Cr, Inconel, Monel, etc
  - No limit on deviation of well
  - Rated up to 200^{0}C, 20k psi
  - Cuts control lines
  - No mud weight limitation

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Questions?

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