Testing and Verification of Thermite Barrier Technology in a UKCS Well Abandonment Scenario - A Case Study

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The P&A Challenge & Thermite

Well abandonments - the future is now
Population of older wells increasing worldwide
Increasing costs compared to previous estimates
ABEX is a concern for operators and governments
Low commodity price environment

Why & How did Spirit Energy got involved with Thermite

- Thermite was a JIP by Interwell P&A, AkerBP and Equinor
- Field trials required but no wells were available.
- Spirit Energy offered to find suitable wells in Canada

The Challenge

- Introduction of Technology needs a new approach
- Innovative application of “old” technology with “revolutionary” approach
- Engaged with OGA and OGTC to develop the opportunity

Thermite Reaction

History

Hans Goldschmidt inventor of the Goldschmidt reaction in 1893
Aluminothermic Process patent no. 96317 in 1895 and
THERMIT® Registrated Trademark in 1900

Chemical reaction

Aluminium (Al) reduces the oxide from iron oxide (Fe_2O_3), to form Aluminium Oxide (Al_2O_3) and pure iron (Fe)
Reaction energy ~4000 kJ/kg
Reaction temperature ~2500 ºC

Original thermite reaction

$Fe_2O_3 + 2\ Al \rightarrow 2\ Fe + Al_2O_3 + \Delta H$

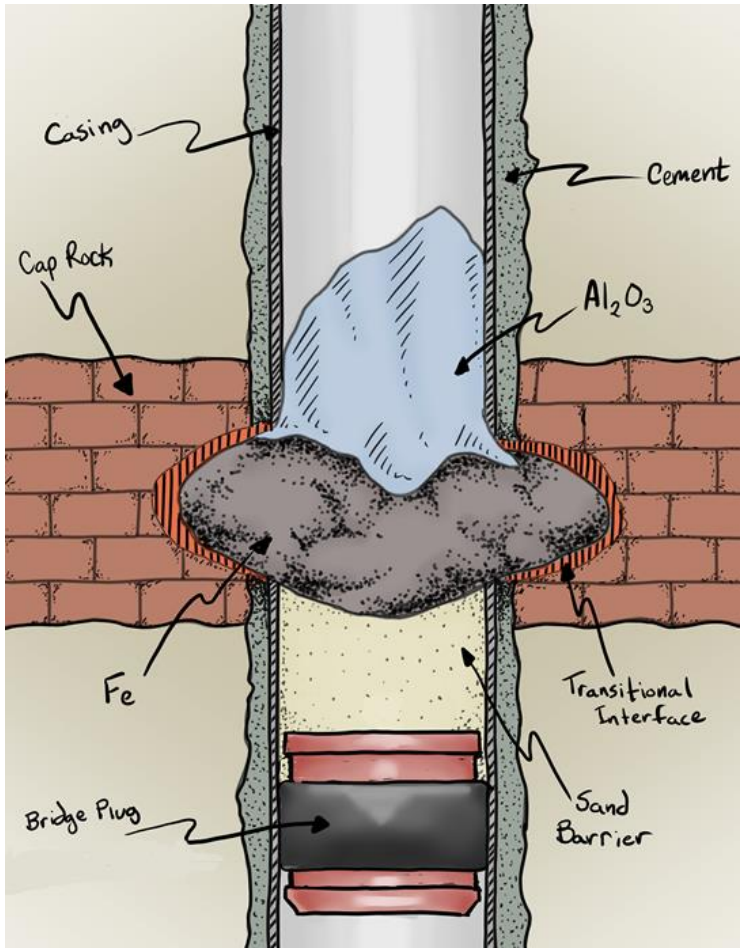
Hematite, rust, red color

What is an Exothermic Reaction;

Any mixture of two or more chemicals that produces heat when activated.

Why thermite is preferable;
Self sustained oxygen source (Iron Oxide)
High energy potential in both materials
Self sustained reaction after activation

Thermite Plug Deployment



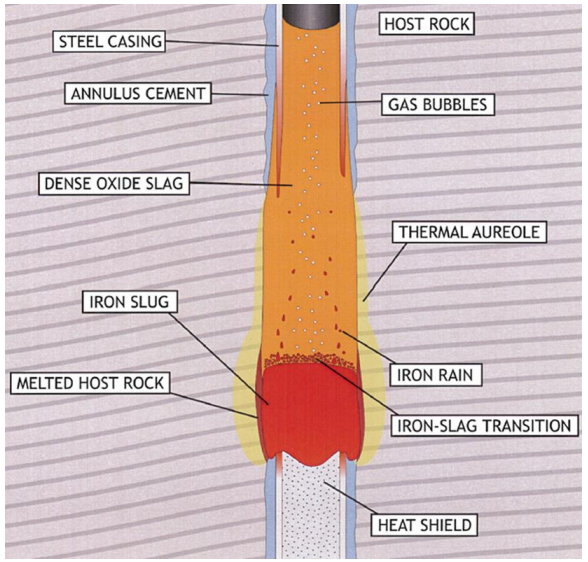
Thermite's original P&A Cartoon

A wireline conveyed tool containing heat generating material is lowered into well and ignited.

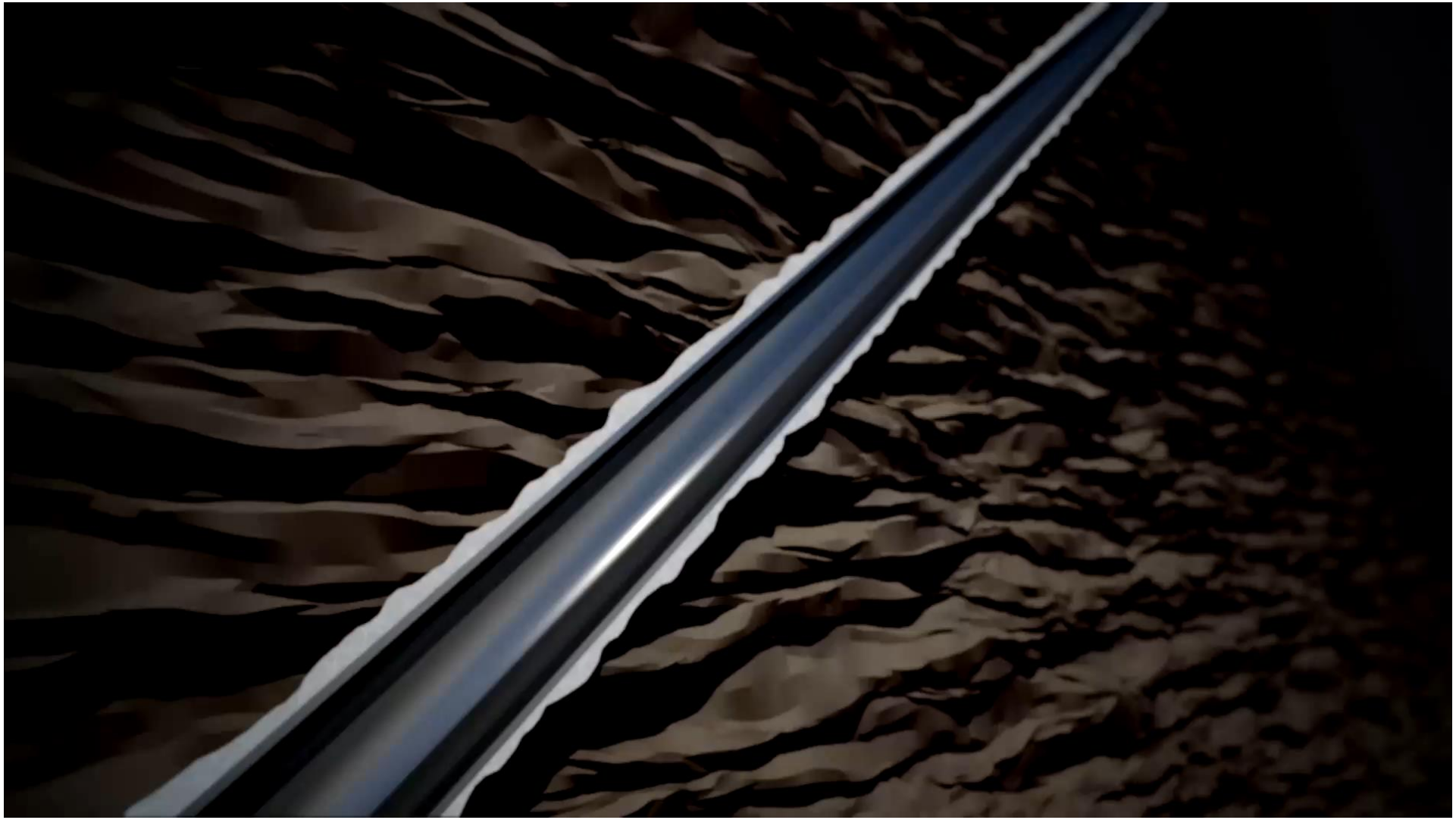
A column of molten magma is created - which will melt all wellbore elements and solidify into a permanent barrier in hours.

Thermite Technology aims to restore the caprock by forming a high integrity permanent barrier.

2019 update



Thermite barrier deployment video

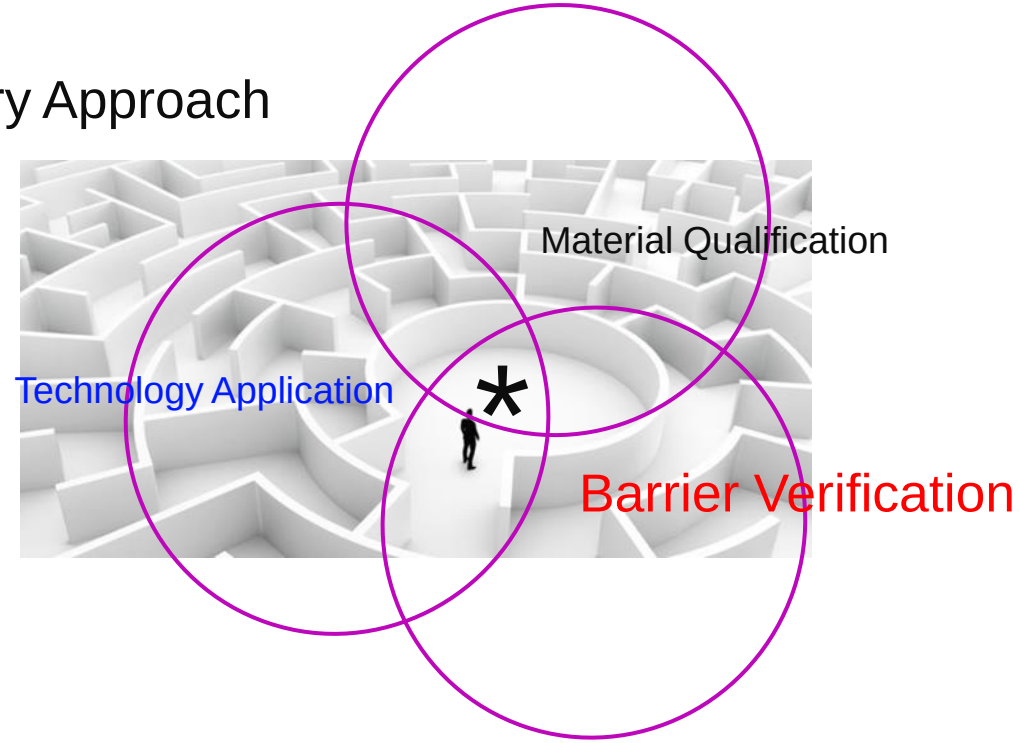


Thermite Deployment Experience

- World’s first field trial in 2016 in Whitehorse in Alberta Canada, followed by another in Benjamin.
- First European trial in England (Caythorpe) in May 2018.
- All three wells onshore with thermite set in 7 inch casing without tubing in the hole.
- Imperial, Shell, Eni, West Lake, Canlin, CNR have also carried out onshore trials
- First Offshore Deployment on Spirit Energy’s Audrey platform in the North Sea
- Extensive deployment experience (18 trials in total). Focus now on ‘verification like cement’……

Challenging process ahead

- Resistance to new technology
- Qualify ‘new’ material
- No access to wells for field trials
- Lack of funding for technology development
- Competing with cement
- Establish Common Industry Approach
- A new education process



Thermite Pre/Post Deployment Barrier Verification

Thermite Barrier Verification

establishing what 'good' looks like

Baseline phase

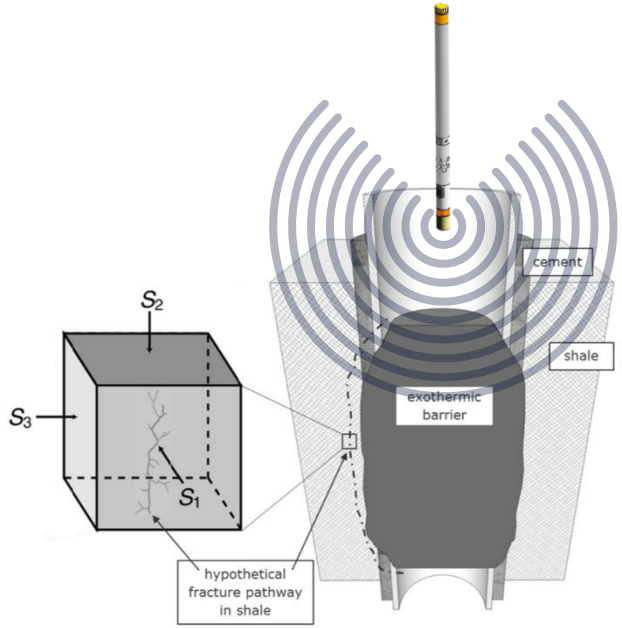
- Tubing pressure tests (pre-work)
- Casing integrity survey (wireline)
  - Ultra-Sound cement bond mapping
  - Passive Spectral Acoustic and High Precision temperature logging
  - Production logging using mechanical and heat exchange flowmeters

Deployment phase

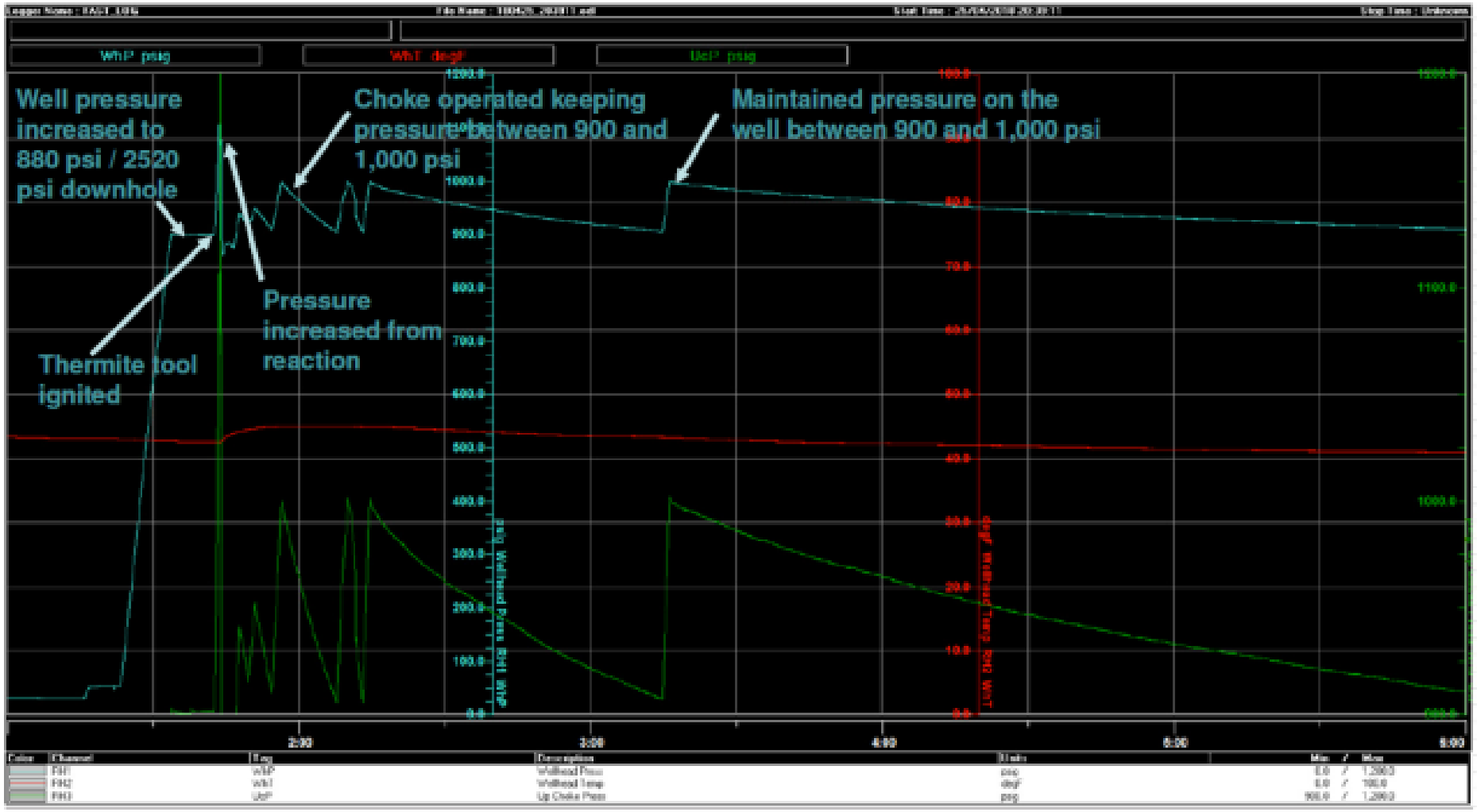
- Tool ignition signature (pressure wave)
- Positive pressure test (deferred as heatshield packer is used)

Post-Deployment phase

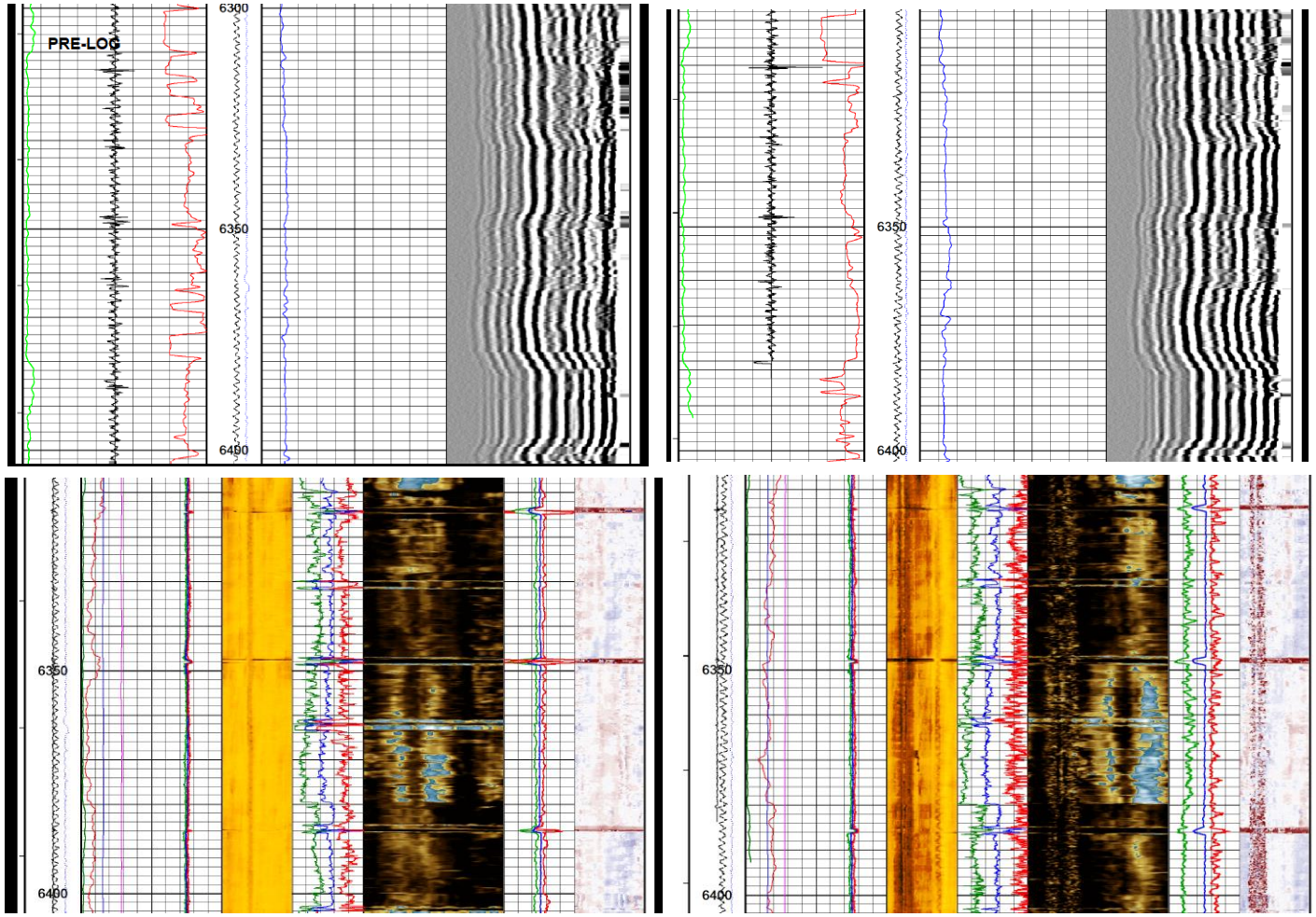
- Positive pressure test (drop off test = 122 bar static dP)
- Extended inflow test
- Thermite Barrier inspection
  - Camera survey
  - Ultra-Sound cement bond mapping
  - Passive Spectral Acoustic and High Precision temperature logging
  - Production logging using mechanical flowmeters



Deployment verification - Ignition Signature



Deployment verification - Cement Bond

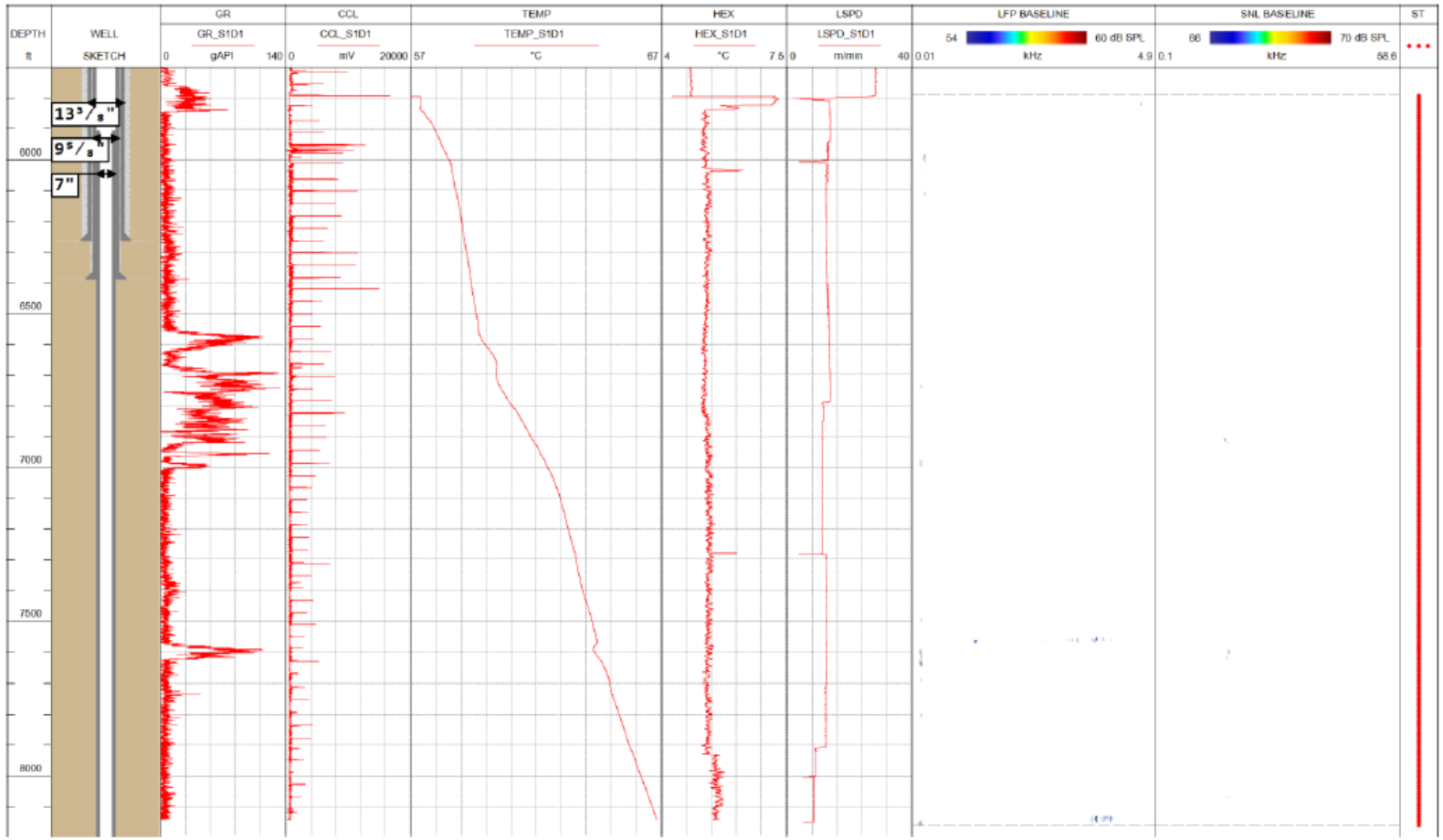


PRE-LOG

Cement bond & Ultra sound survey:

- Well bounded, heterogeneous, cement around the entire annulus with non-connected liquid pockets
- Well immediately above the plug un-affected by Thermite reaction

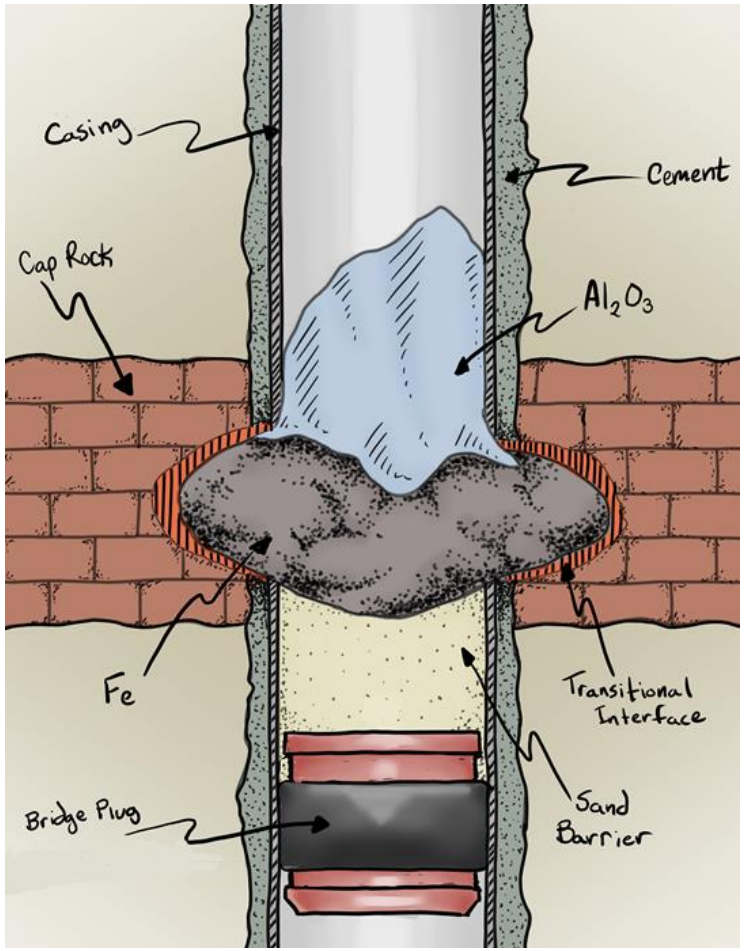
Deployment verification - Reservoir Isolation

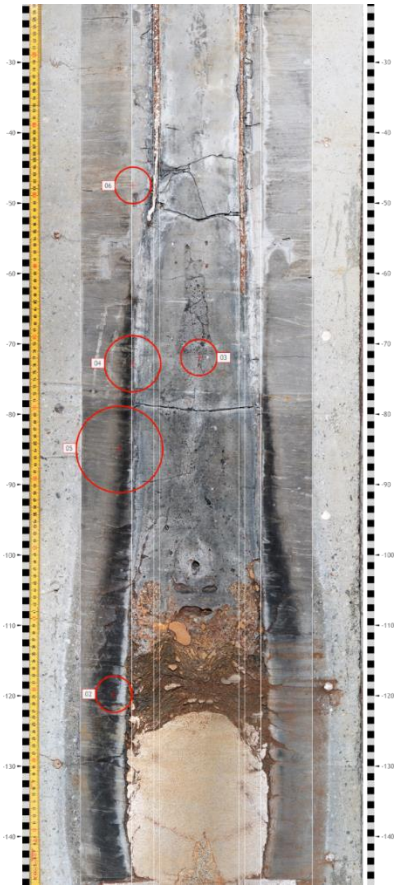


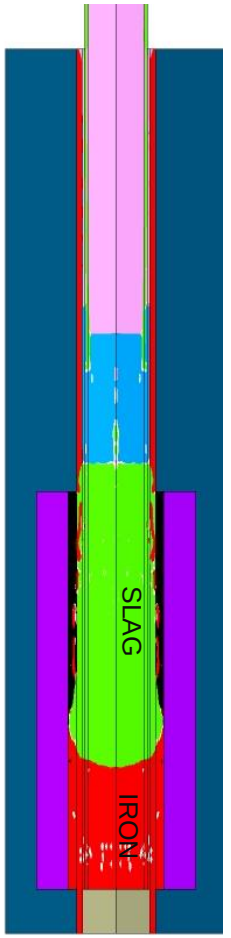
Baseline Chorus Survey Conclusion:

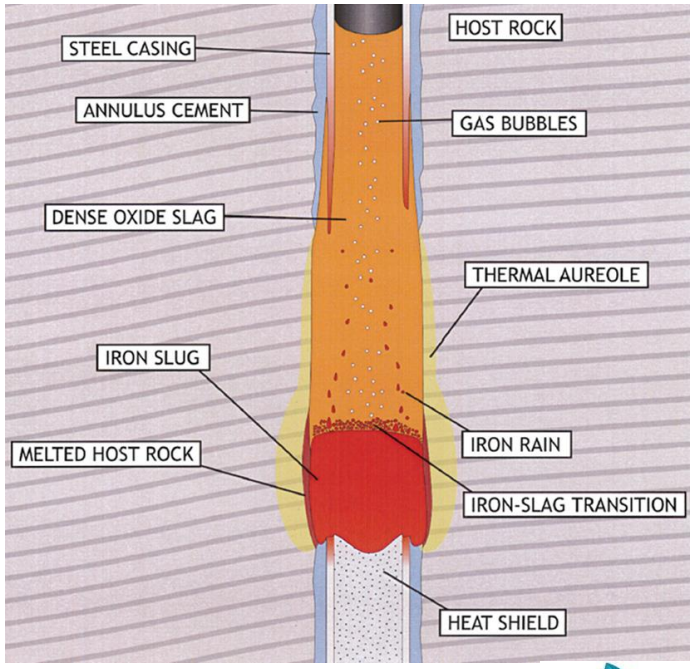
- No flow-related activity observed on Chorus (SNL)
- No flow-related activity observed on High Precision Temperature
- No flow-related activity observed on Indigo PLT log

Deployment verification - Thermal modelling





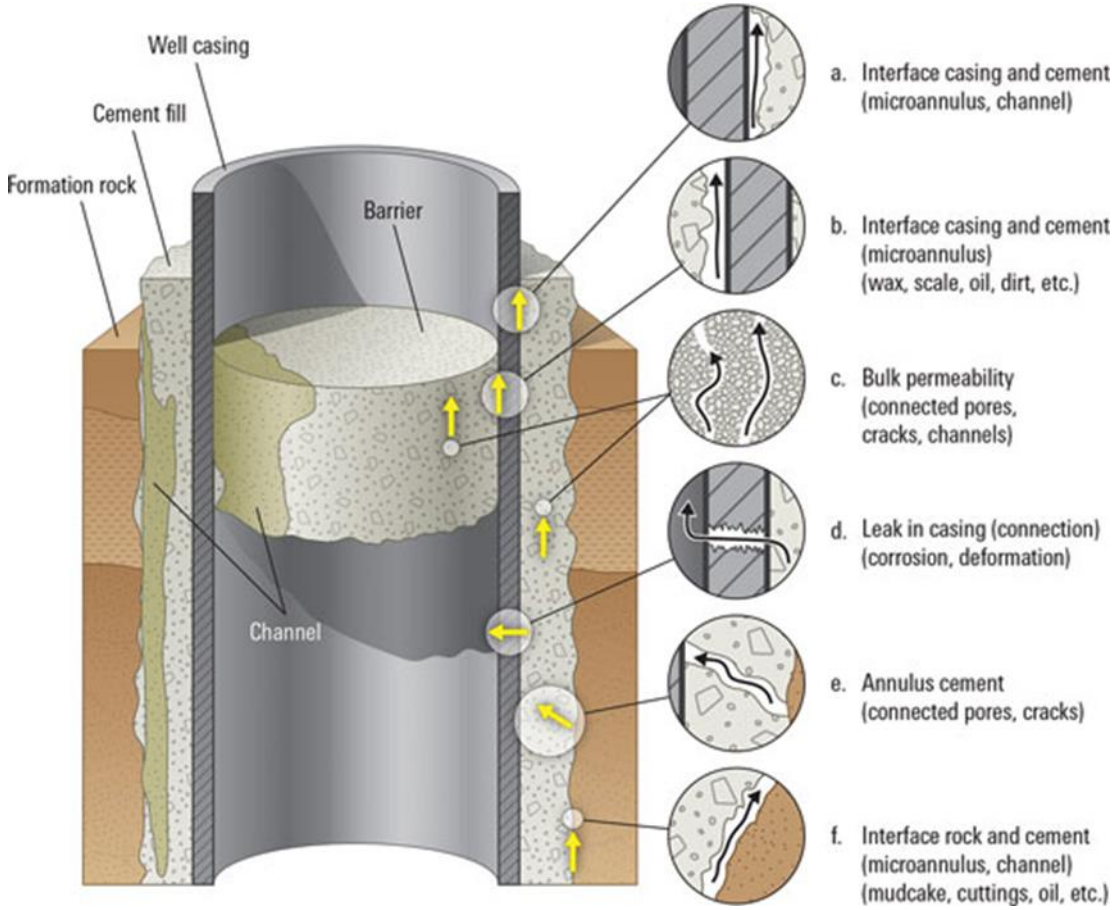




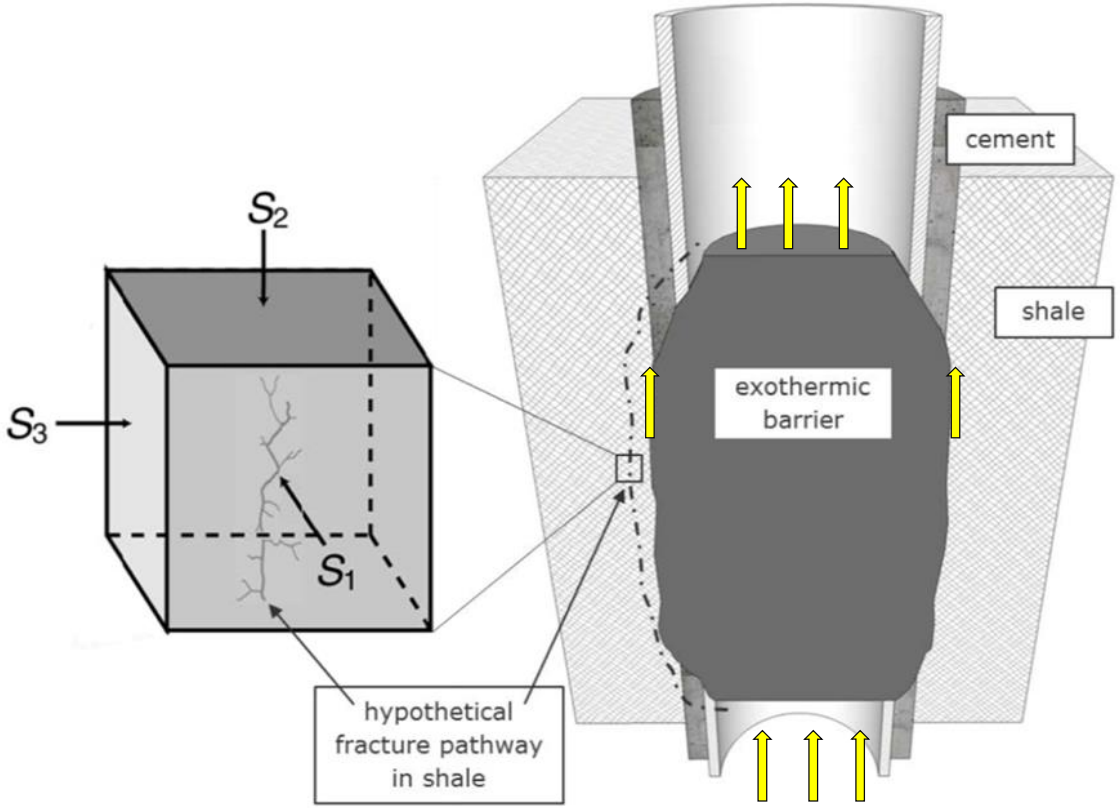
interwell

Failure models comparison

- Cement model

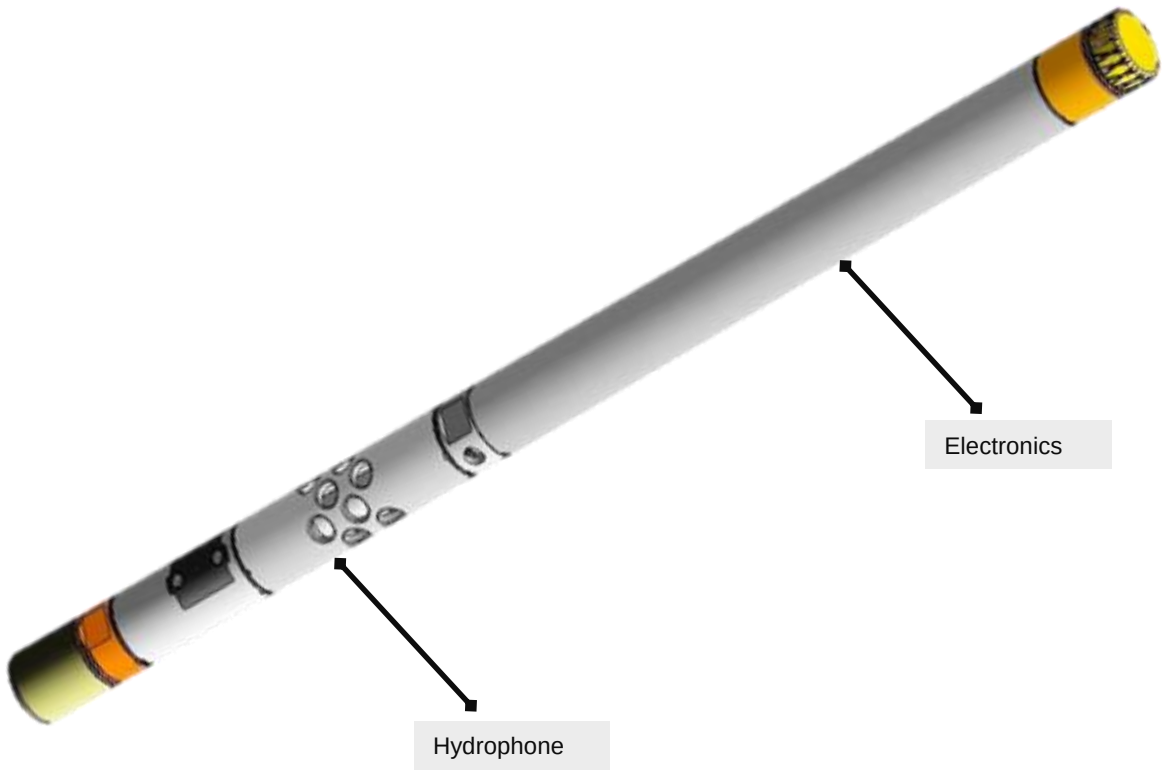


- Thermite model



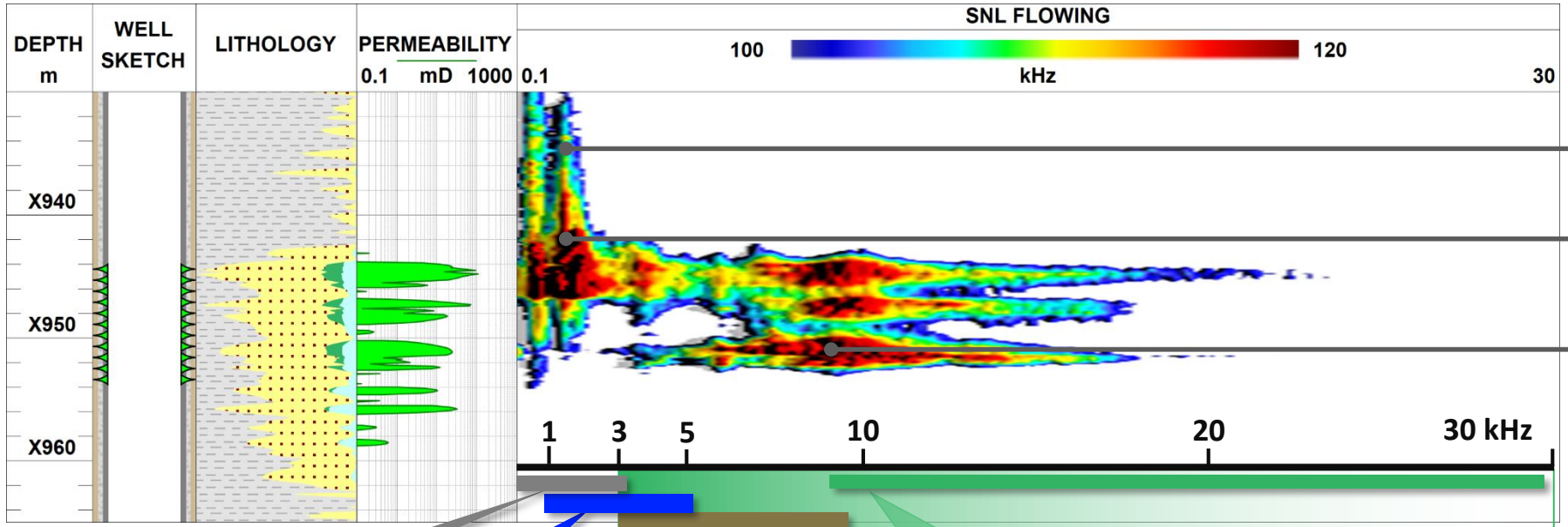
Thermite Post-Deployment - Downhole verification

Chorus



Parameter	Value
Temperature rating	0 to 150◦C (32 to 302°F)
Pressure rating	100 MPa (14 500 psi)
H_2S resistance	<30%
Frequency range	**8-60 000 Hz**
Dynamic range	**100 dB**
Recording time (mem. mode)	70h
Tool OD	38/42mm (1.5 / 1 11/16”)
Length	80cm (2.6’)
Weight	7 kg (15.4 pounds)

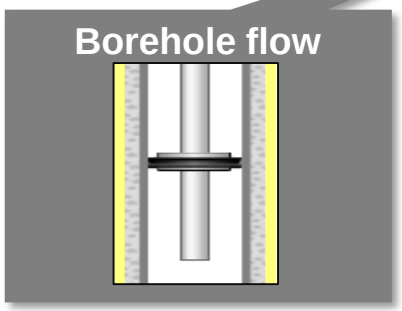
Noise (Chorus) Pattern Interpretation Library

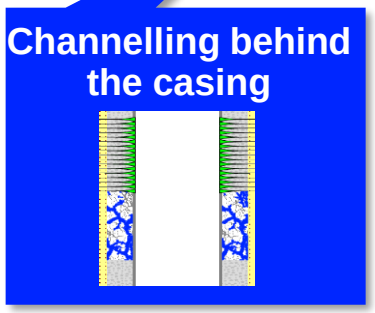


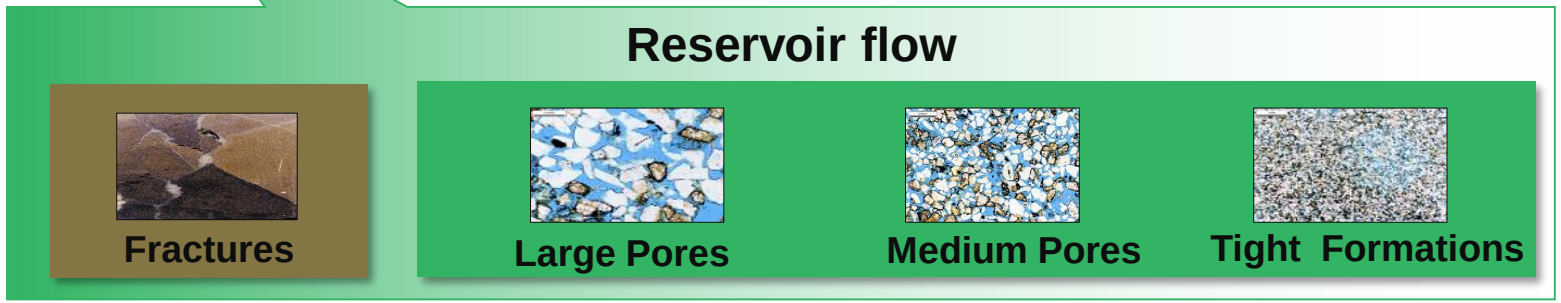
Channelling Behind Casing

Fracture Flow

Matrix Flow

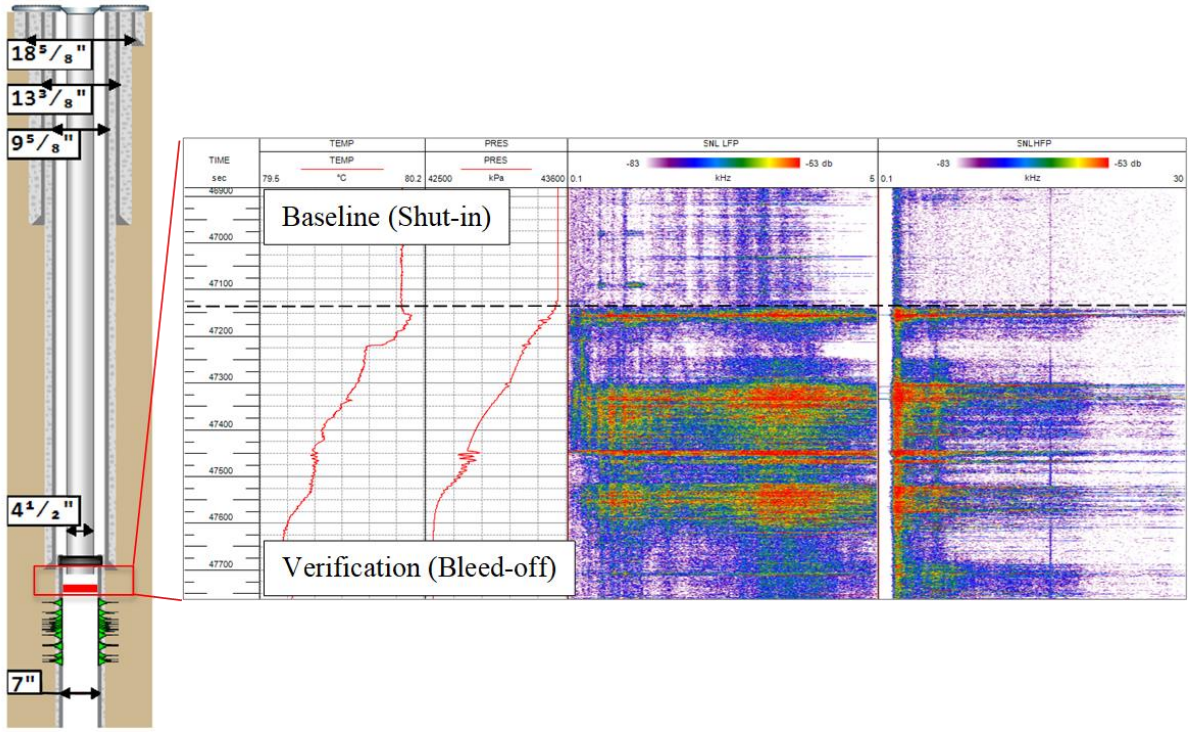




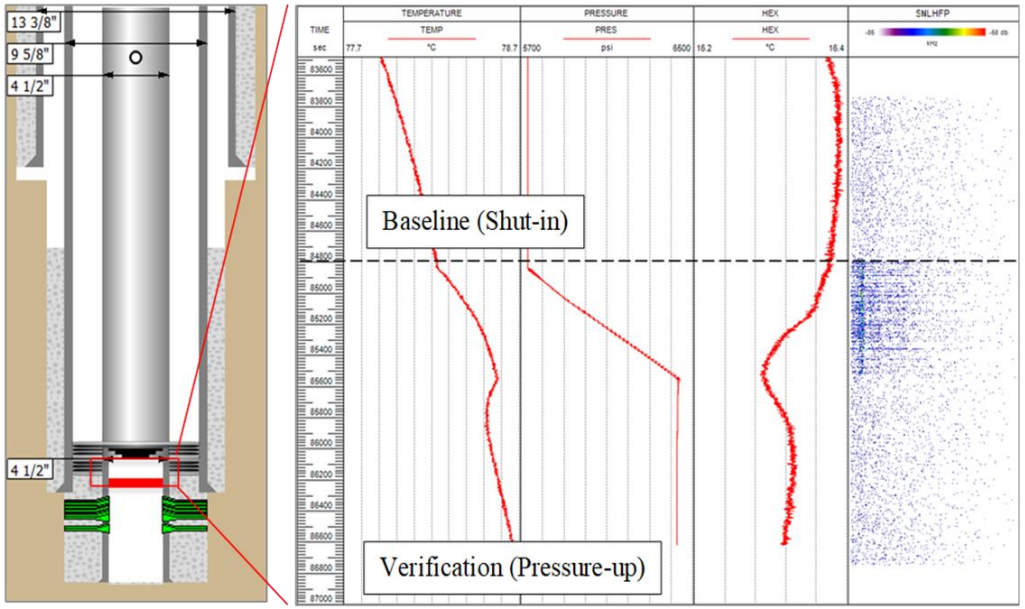


Post Well Schematics - Examples

Plug Failure



Plug Successful



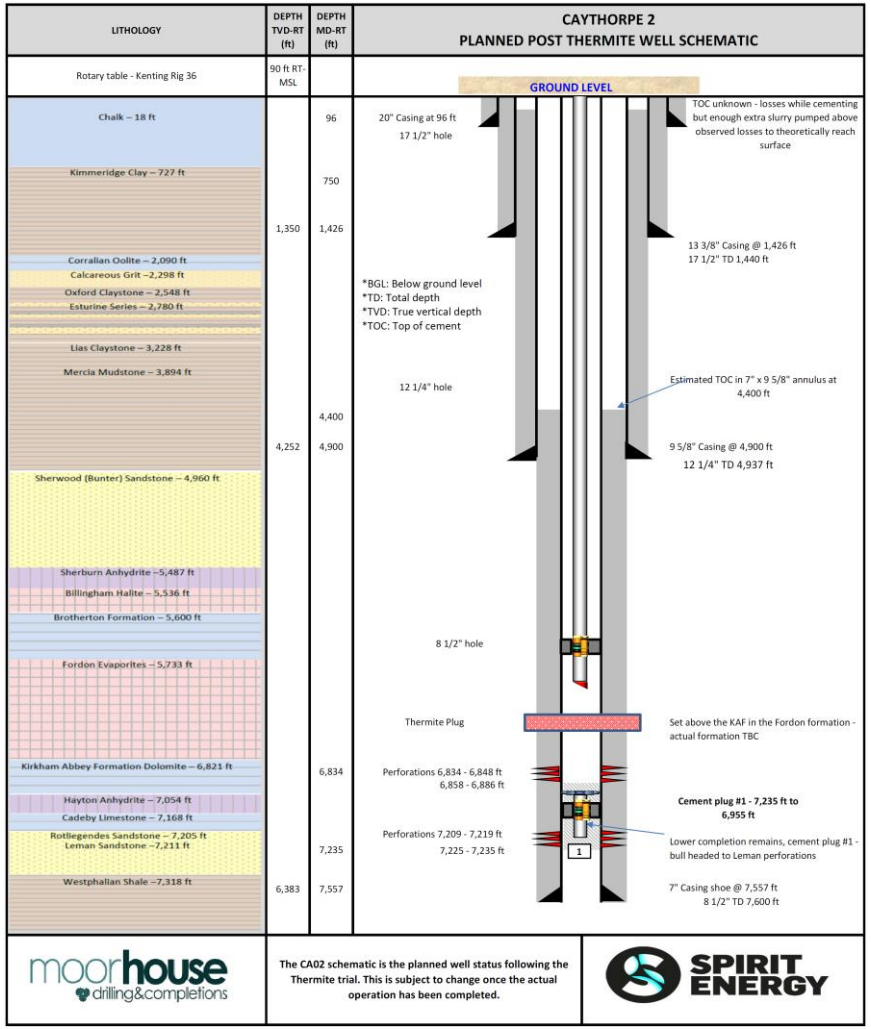
Caythorpe CA02 Thermite Trial

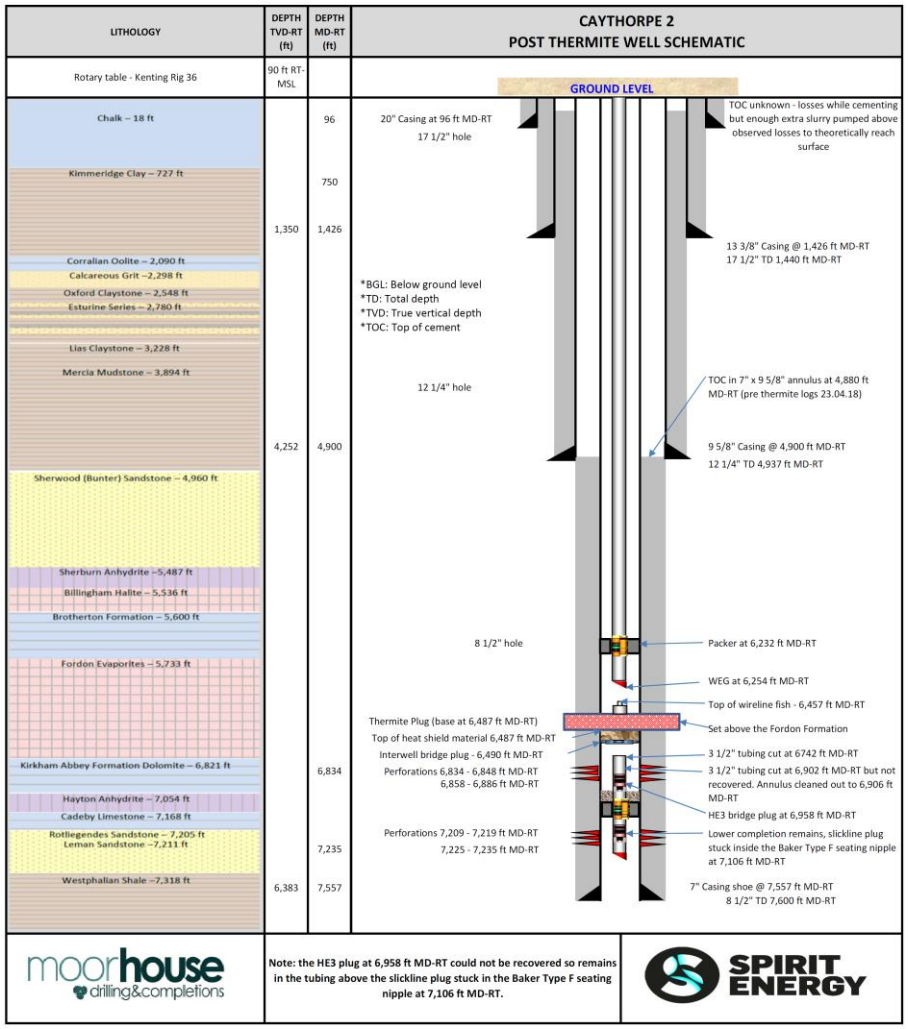
Caythorpe 2 Thermite Trial – BDF 28

Key Objectives of Onshore Thermite Trial

- First UK / European deployment of the Thermite plug, as part of the phased technology development programme (following the 2017 trials in Canada).
- Engage with EA, OGA and HSE to obtain regulatory consent to use the equipment onshore
- 1st trial for setting Thermite plug in Halite formation, common cap rock in UKCS SNS
- Establish common application method and verification programme for Thermite P&A technology
- Share the results with the Thermite Collaboration Forum to accelerate adoption of new P&A technology in the UKCS

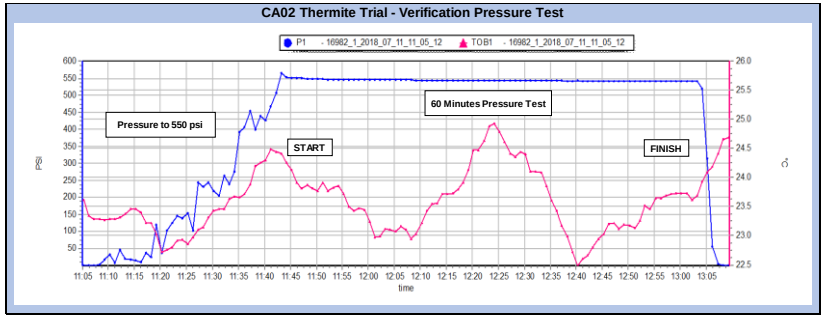
Post Well Schematics - Planned vs Actual

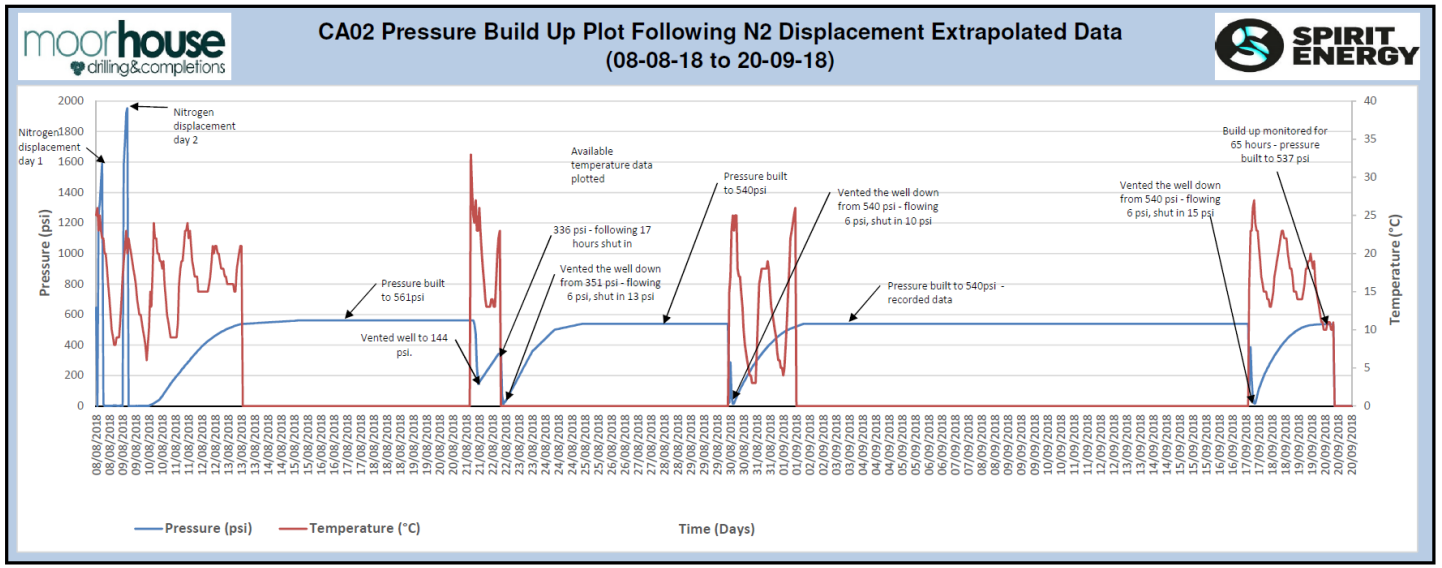




Well Re-entry & Preliminary results

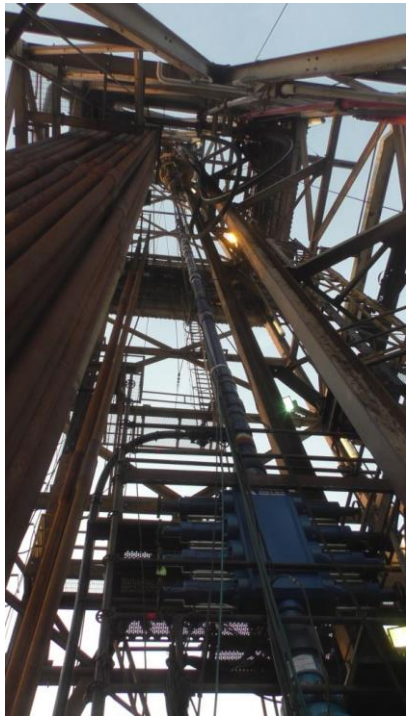
- Positive pressure test
- Displaced Well to Nitrogen
- Extended inflow test
- 14 psi / hr PBU rate
- (equivalent of 5 SCF/min leak)

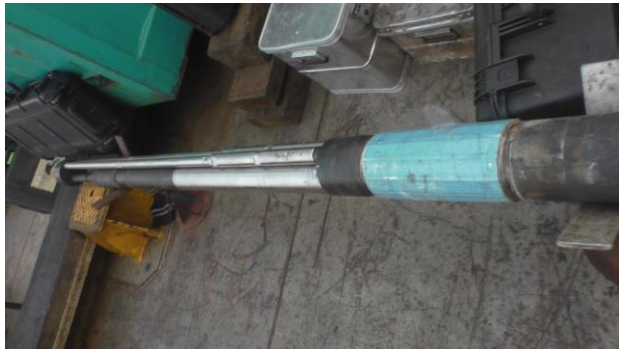




Audrey B1z Thermite Trial

Audrey B1z Thermite Trial

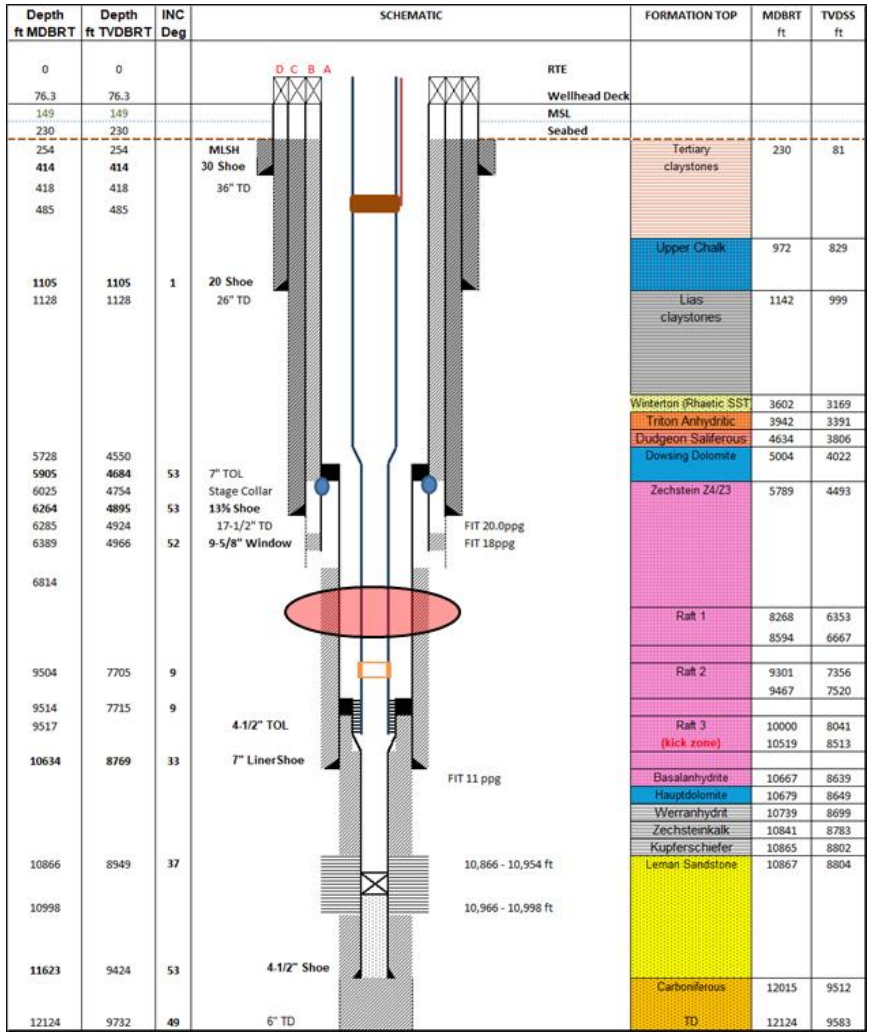


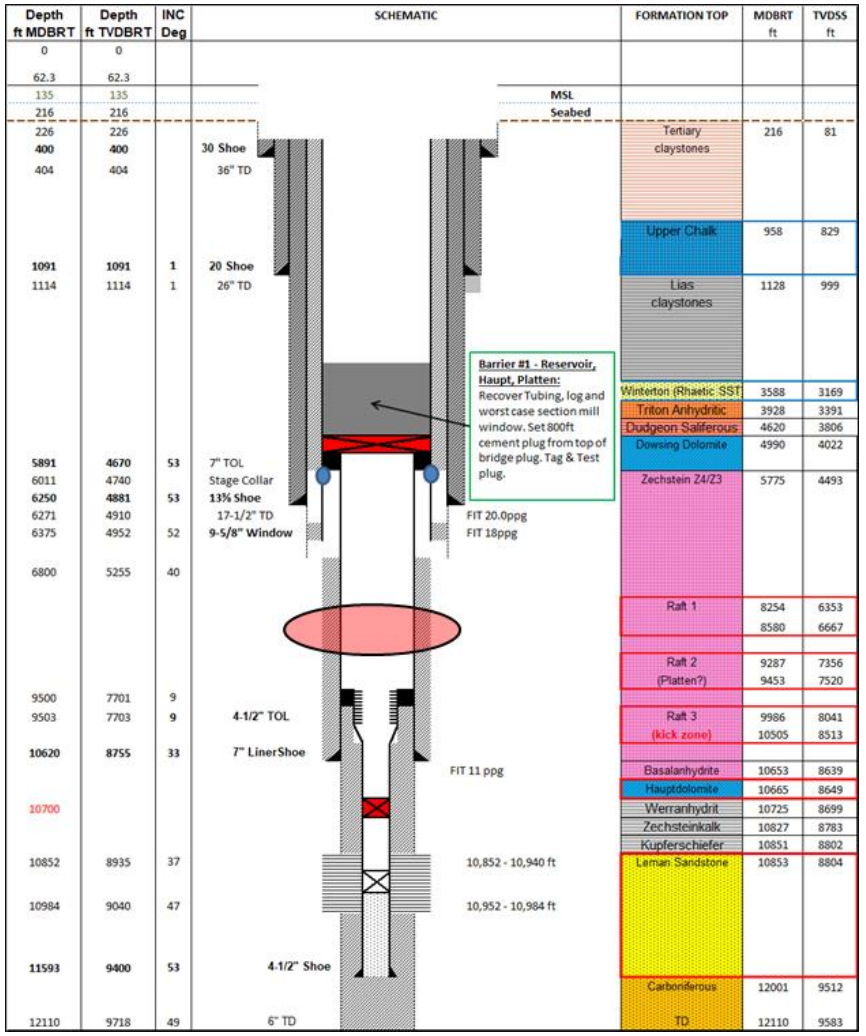




Key Objectives of Offshore Trial (Top 5)

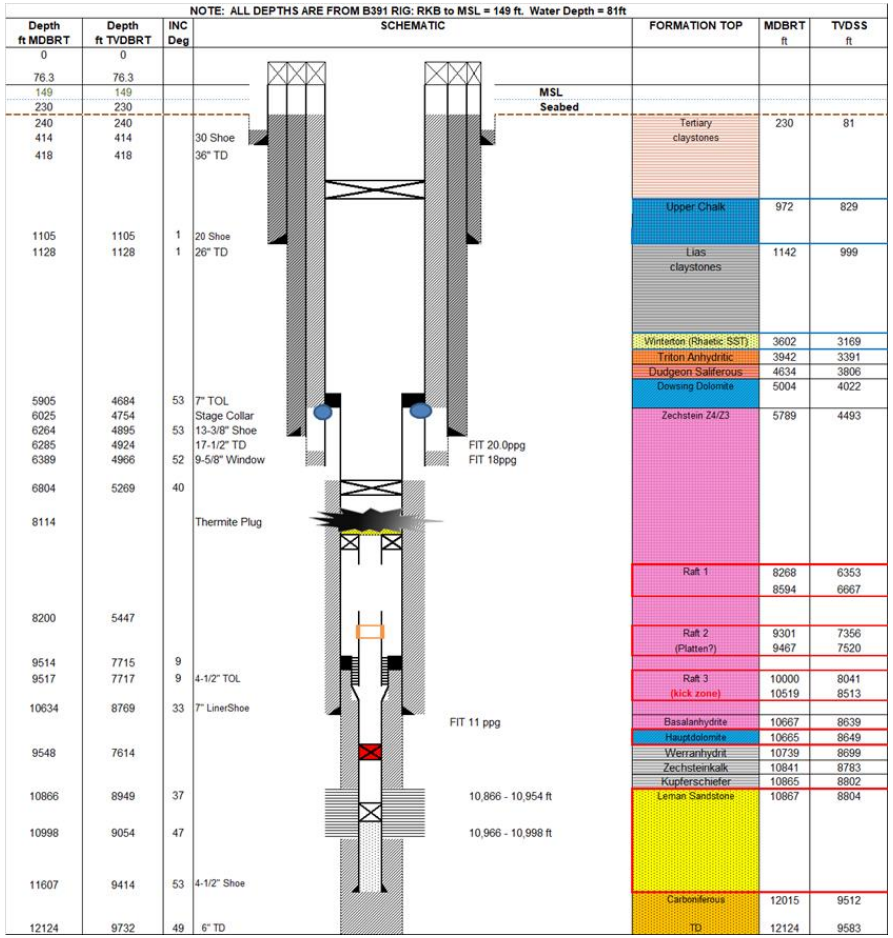
- First (global) offshore deployment of the Thermite plug, as part of the phased technology development programme.
- Engage with OGA, OPRED/BEIS and HSE to obtain regulatory consent to use the equipment offshore
- 2nd trial for setting Thermite plug in Halite formation, at lower angle compared with CA-02 (common SNS Caprock)
- Share the results with the Thermite Collaboration Forum to accelerate adoption of new P&A technology in the UKCS
- Progress Industry Common Verification road map for new P&A technology and barrier material.

Well Schematics - Planned P&A





Interim Well Status



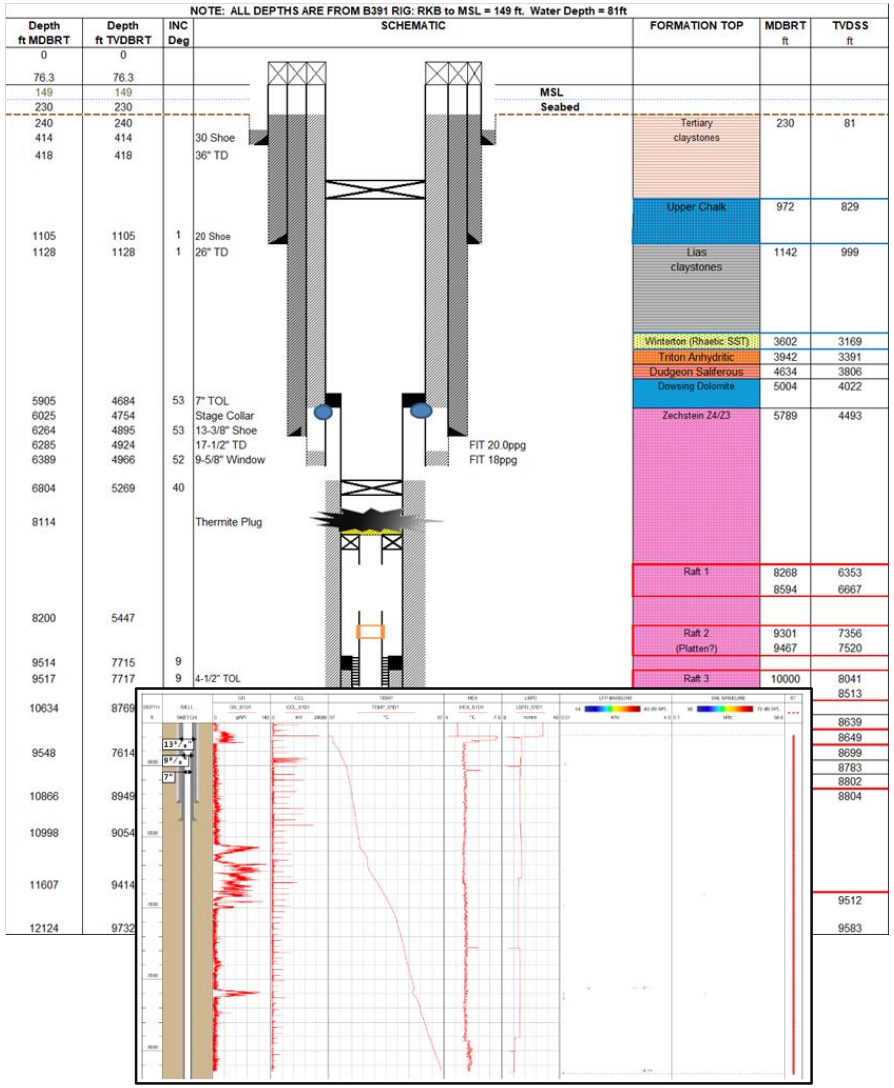
Suspension

- (100bbl/hr losses observed prior to setting Heatshield packer assembly)
- BVS w/ gauges & micro-smart valves set below Thermite plug
- Suspend B1z with deepset Interwell plug above Thermite, and shallow set Archer plug as 2nd barrier.

Next

- Verify integrity of Thermite plug with BVS receiver and repeat TGT SNL log.
- Continue with ‘Standard’ abandonment programme

Well Re-entry & Preliminary results



Re-entry

- Moved back to B1z & pulled suspension plugs
- Monitored wells for statics losses – 6 bbl/hr
- Decision made to curtail verification programme (exit strategy)
- Cancelled TGT Spectral Noise Log
- Cancelled Run BVS receiver log & pressure test
- Continued with P&A programme

Preliminary results

- Thermite successfully permitted / shipped offshore
- Successfully deployed without incident
- Losses at 100 bbl/hr prior to thermite plug
- Reduced to 6 bbl/hr after setting thermite plug
- Unable to carry out pressure test
- Washup & review with Interwell ongoing

TGT

Thank you

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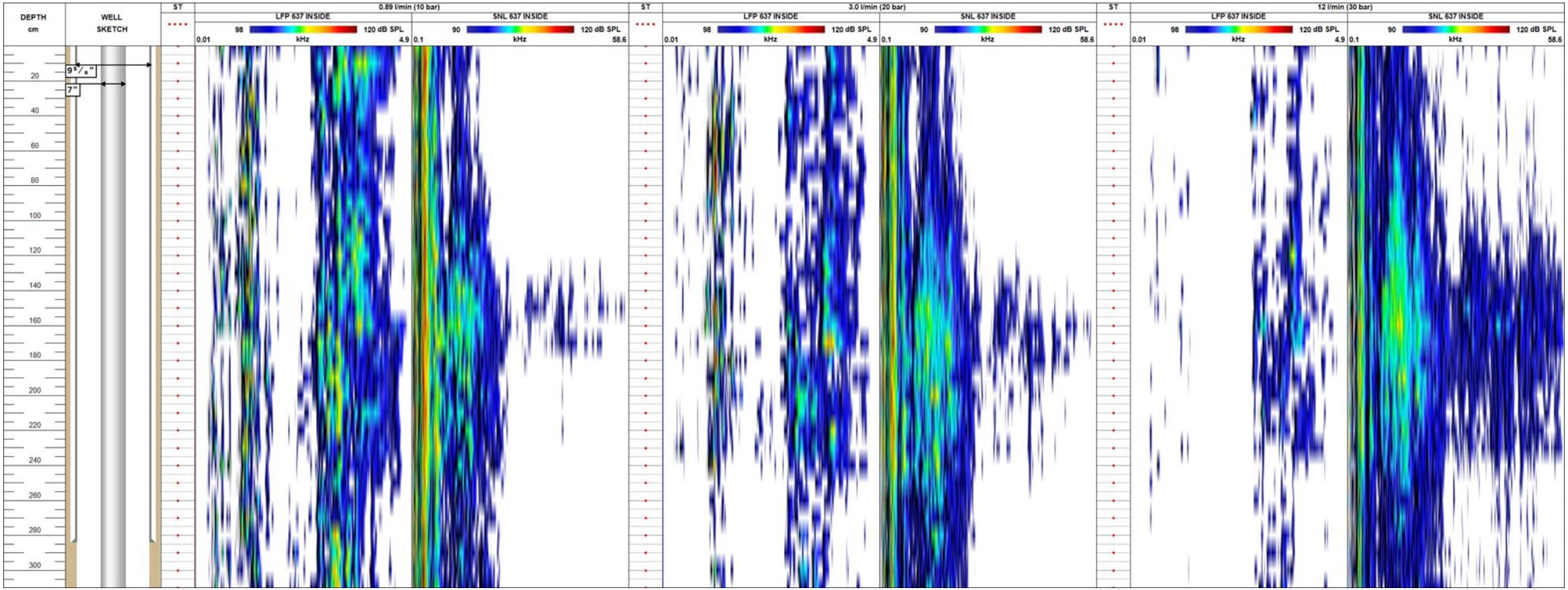
Micro-annulus cell - test with gas



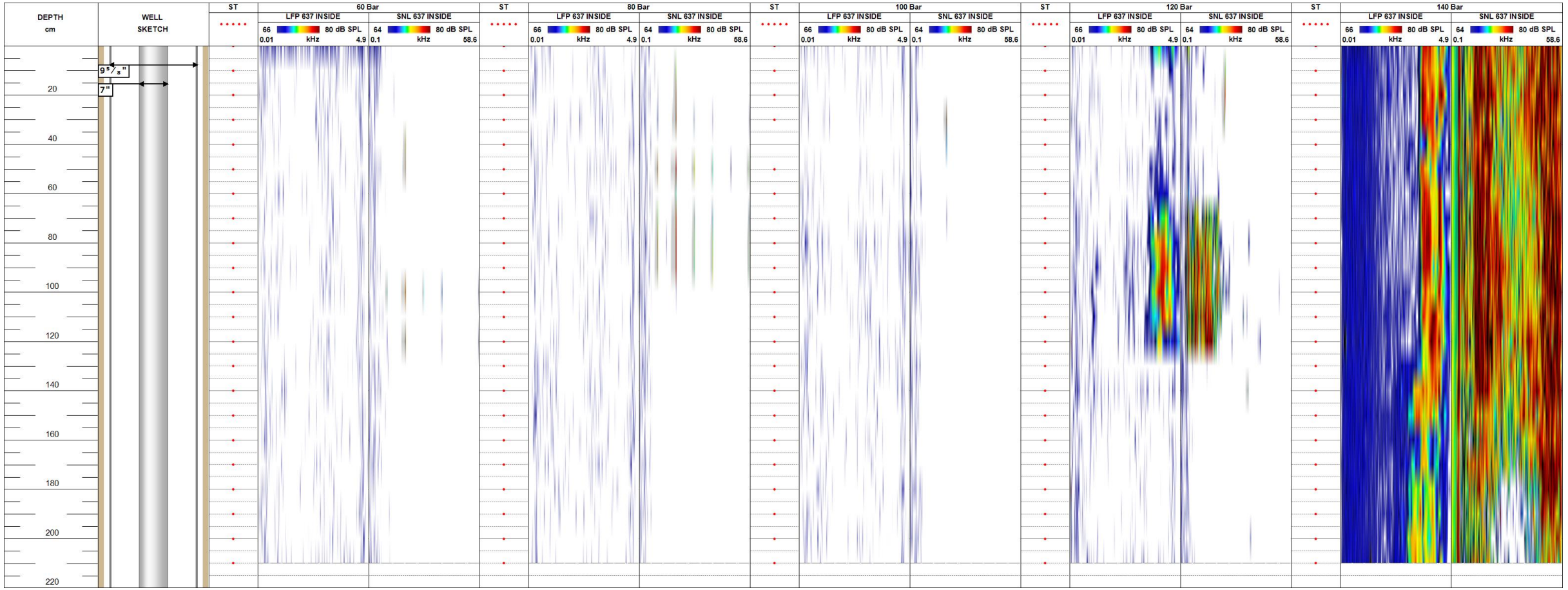
10bar, 0.9L/min

19.4bar, 3.0L/min

29.5bar, 12.0L/min

TGT

”Good” cement induced micro-annulus – test with water



60bar, 1.3mL/min 80bar, 1.7mL/min 100bar, 3.6mL/min 120bar, 9.7mL/min 140bar, 31 mL/min