Masterclass in Spectral Acoustics

Evaluating Reservoir & Completion Performance, Barrier Verification for P&A

Remke Ellis, Brisbane

Spectral Acoustics

TGT

History & Fundamentals

Applications in Reservoir & Production

Applications in Well Integrity & PnA

Questions

Acoustic Logging

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Passive Acoustic Logging

Nicolas Kotlar

KAPPA

1. Introduction

Intuitively, if we want to spy on the neighbors next door, we make silence and put the ear on the wall. We do not emit any type of pulse, wave or energy, but simply listen. This is the principle of *Passive Acoustic Logging*, where a listening device similar to a microphone records the different sounds downhole.

Listening to….

History of Acoustic Logging

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Passive Acoustic Logging

Nicolas Kotlar

1. Introduction

Intuitively, if we want to spy on the neighbors next door, we make silence and put the ear on the wall. We do not emit any type of pulse, wave or energy, but simply listen. This is the principle of *Passive Acoustic Logging*, where a listening device similar to a microphone records the different sounds downhole.

The sounds or noises are generated mainly as turbulent dissipation in response to fluid flow. The flow may occur behind the pipe, and with these tools, we can obtain information about flow through the cement or in the formation, locations where conventional flowmeters cannot. As large turbulence dissipation will be generated at the leaks and perforations these tools can allow us to locate fluid entries. Flow inside the pipe, including liquids, gas and solids (i.e. sand) will also generate a characteristic sound, which can be used to quantitatively or qualitatively describe the wellbore conditions. To understand the sound and identify its source, it is best to analyze the spectral frequency response.

These types of logs are not new. Enright (1955) proposed the use of listening devices for locating leaks. Since then, both the sensors and the signal processing techniques have greatly evolved. These types of sensors are known as Noise, Spectral Noise or Acoustic Energy logging tools, and are the focus of this document (Section 2). Towards the end (Section 5), two other passive techniques will be presented: fiber optics DAS and acoustic sand detectors.

History of Acoustic Logging

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JOURNAL PAPER | MARCH 01 1973

The Structure and Interpretation of Noise From Flow Behind Cemented Casing

R.M. McKinley; F.M. Bower; R.C. Rumble

J Pet Technol 25 (03): 329–338.
Paper Number: SPE-3999-PA

https://doi.org/10.2118/3999-PA Article history

Here is a noise-logging technique for finding behind-casing leaks. The leak source is located from a noise-amplitude log and the type of leak (single- or two-phase flow) is determined from a spectrum of noise at the source. Appropriate frequency cuts are then used to estimate leak rates.

Introduction

A noise-logging technique described in this paper has proved useful in searching for fluid movement in proved useful in searching for fluid movement in channels in the cement behind the casing of oil and gas wells. Such channels, of course, provide undesirable paths of communication between sands of different pressure. The idea of noise logging is old. In 1955, Enright qualitatively described a procedure for locating down hole, with an appropriate listening device, the peak noise associated with the point of origin of a leak. Korotaev and Babalov Used a noise detector to locate gas-producing zones in thick, open intervals. Stein et al. described the interesting procedure of listening opposite a productive zone in a flowing gas well for the "pinging" of sand grains against the producing string, thereby determining the maximum rate permitted before sand production begins. permitted before sand production begins. In spite of these applications, the general industry attitude still seems to be that a noise log is no better than or not even as useful as a temperature log - the traditional leak detector. This attitude is not entirely justified since there are instances in which noise logging has clear advantages over temperature logging. For example, it is seldom possible to flow a potential blowout well at a rate sufficient to give a definitive temperature anomaly. Likewise, a leak behind casing in a producing

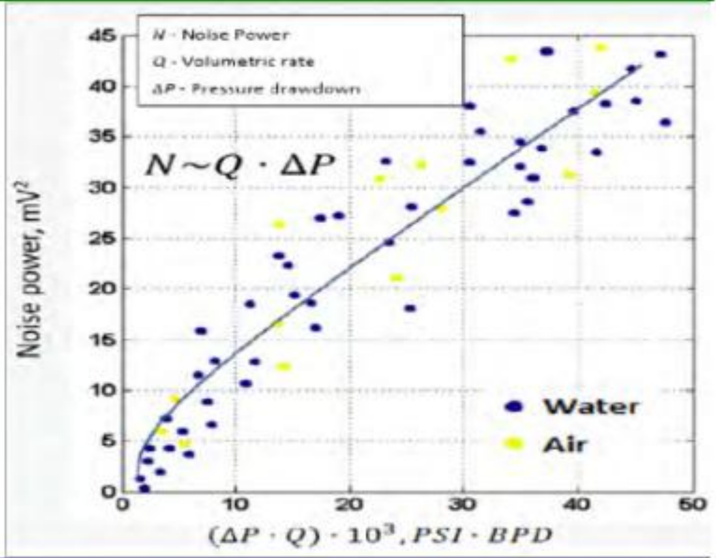


Fig 2: First realization of linear Q.dP vs NP relationship (McKinley[2])

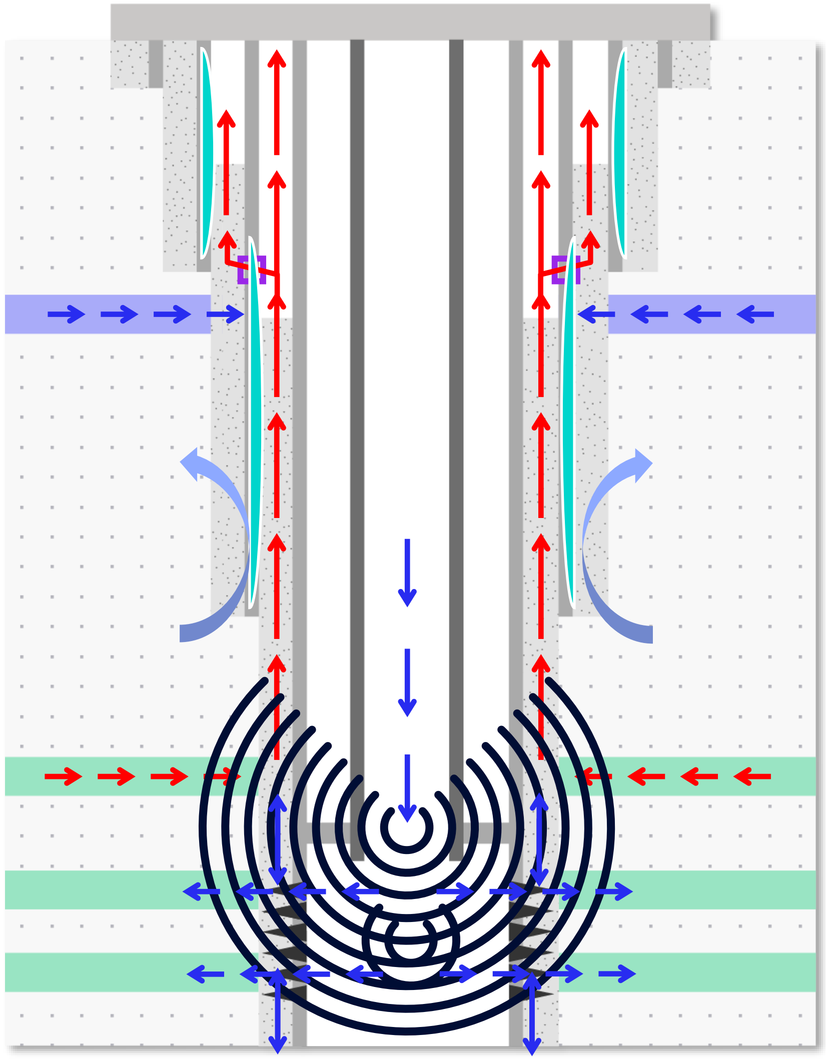
Spectral Acoustics; Through-Barrier Well Diagnostics

Reservoir & Production:

- Out of zone injection
- Out of zone production (leaking cement / packers)
- Target zone performance (perforation quality)

Well Integrity & PnA:

- Identifying source and route of SCP fluids
- Cross flow between overburden units
- Leaking tubulars, packers, seal assemblies
- Barrier Verification



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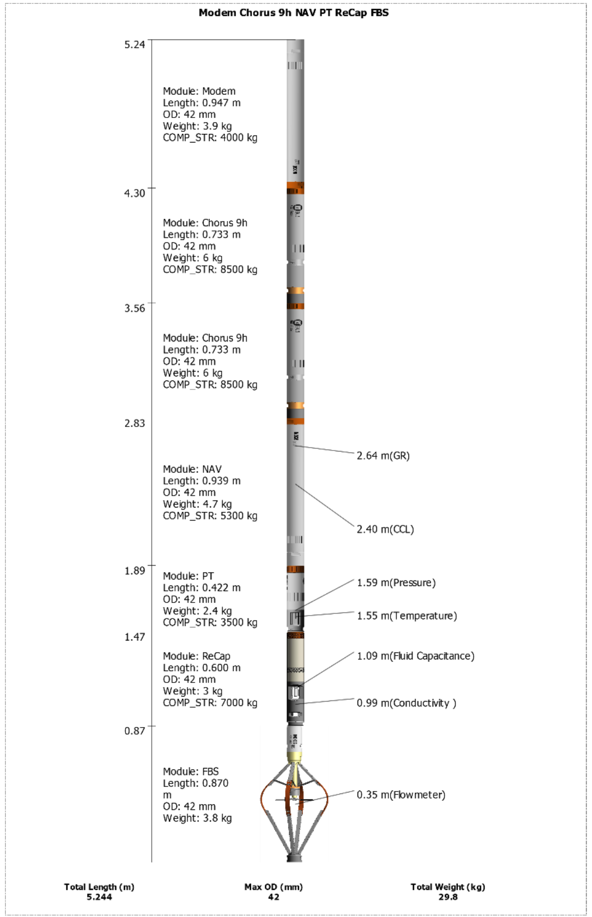
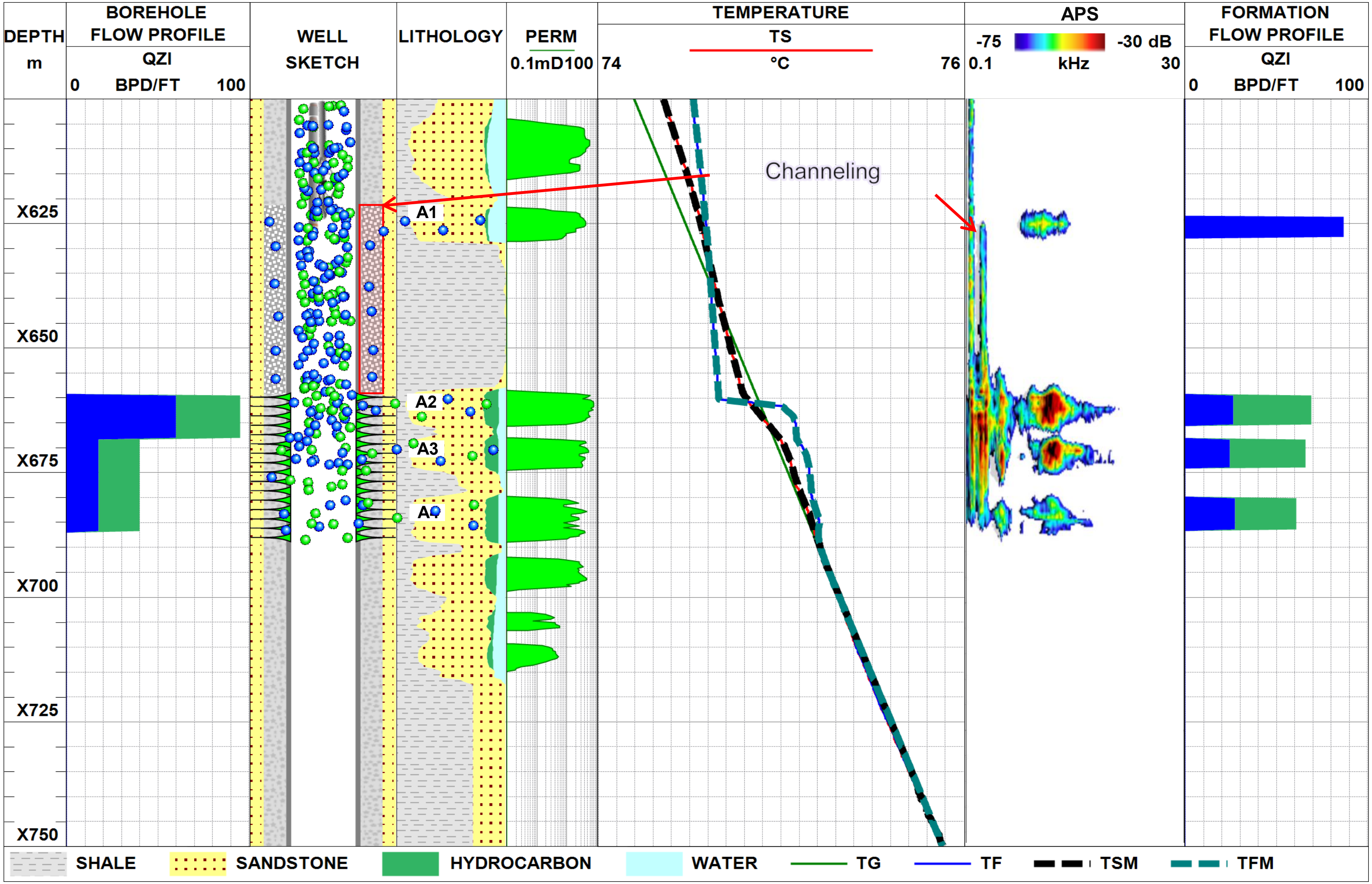
Total Flow—Producer—Case study

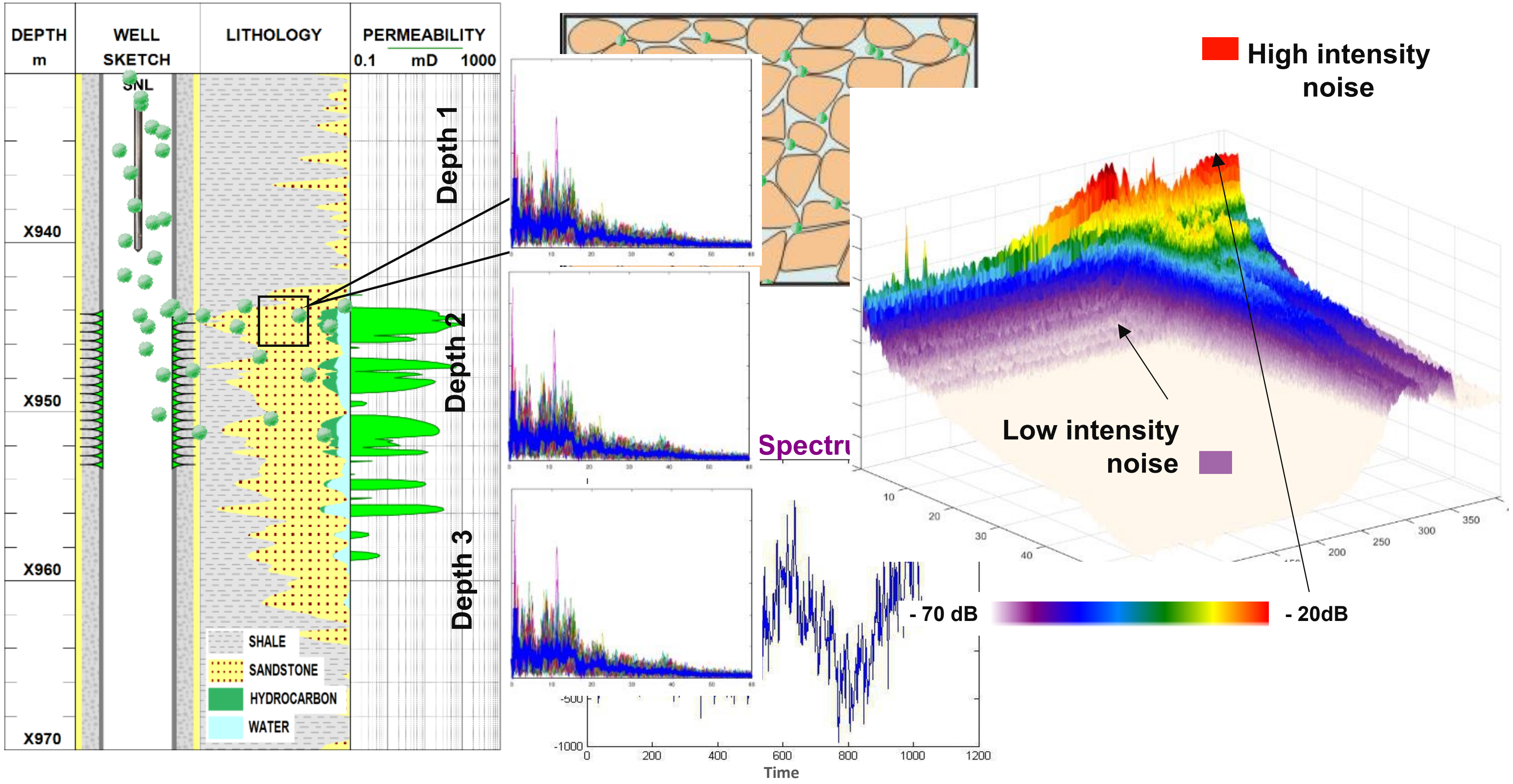
Revealing true source of excess water production.

Well type Producer





Operations, Data Acquisition & Processing



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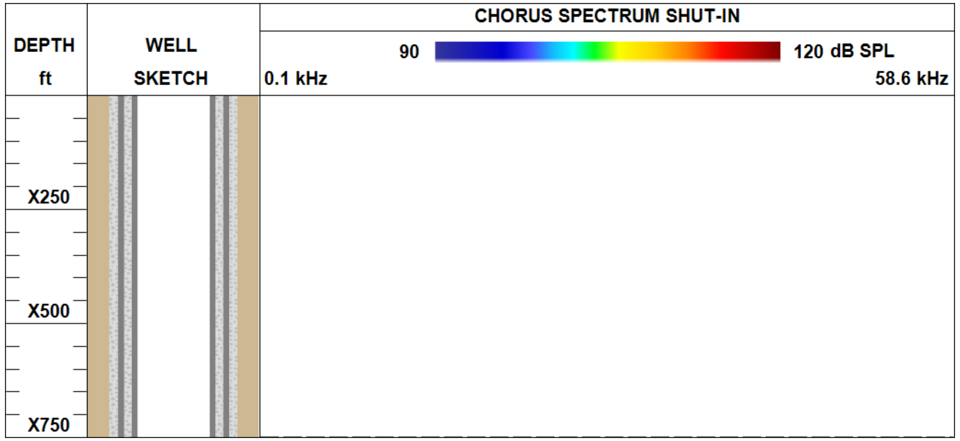
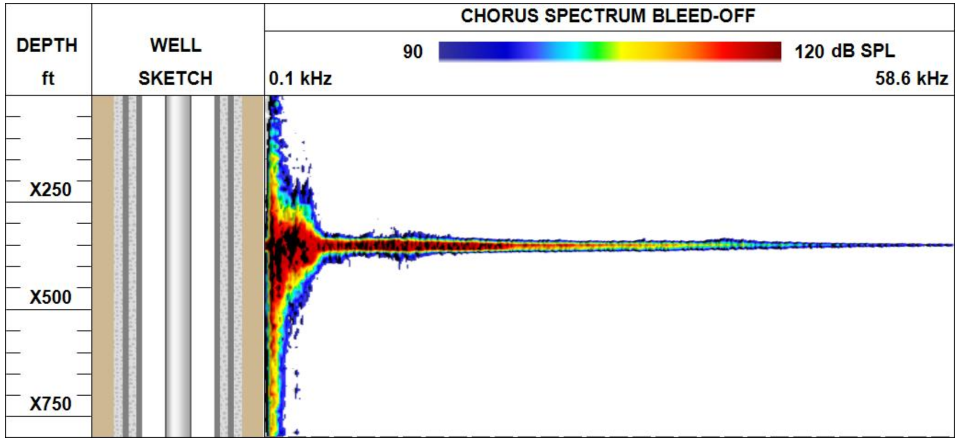
Typical acoustic responses

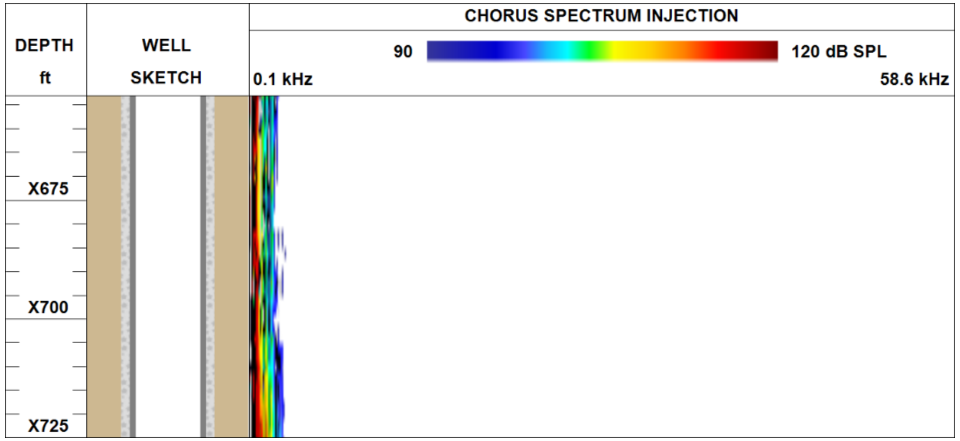
No flow



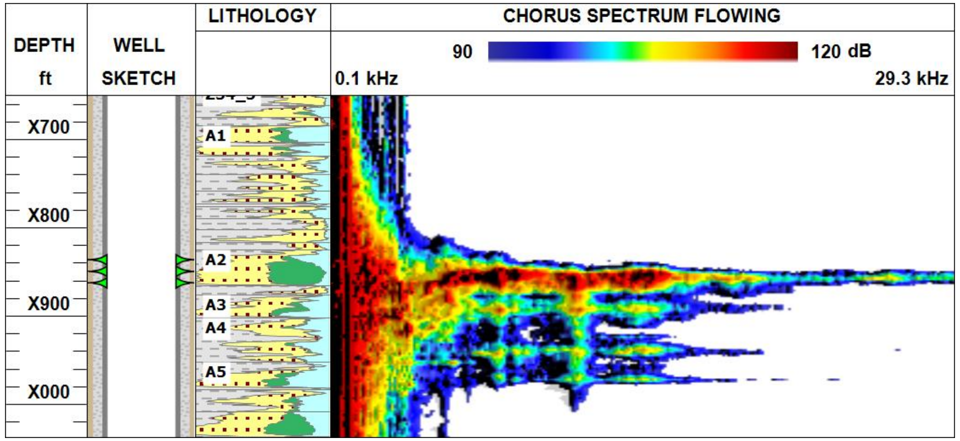
Leak



Borehole Flow



Reservoir Flow



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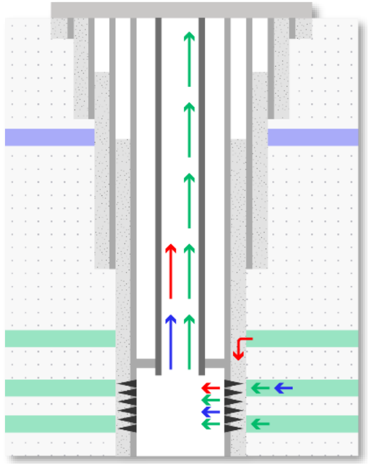
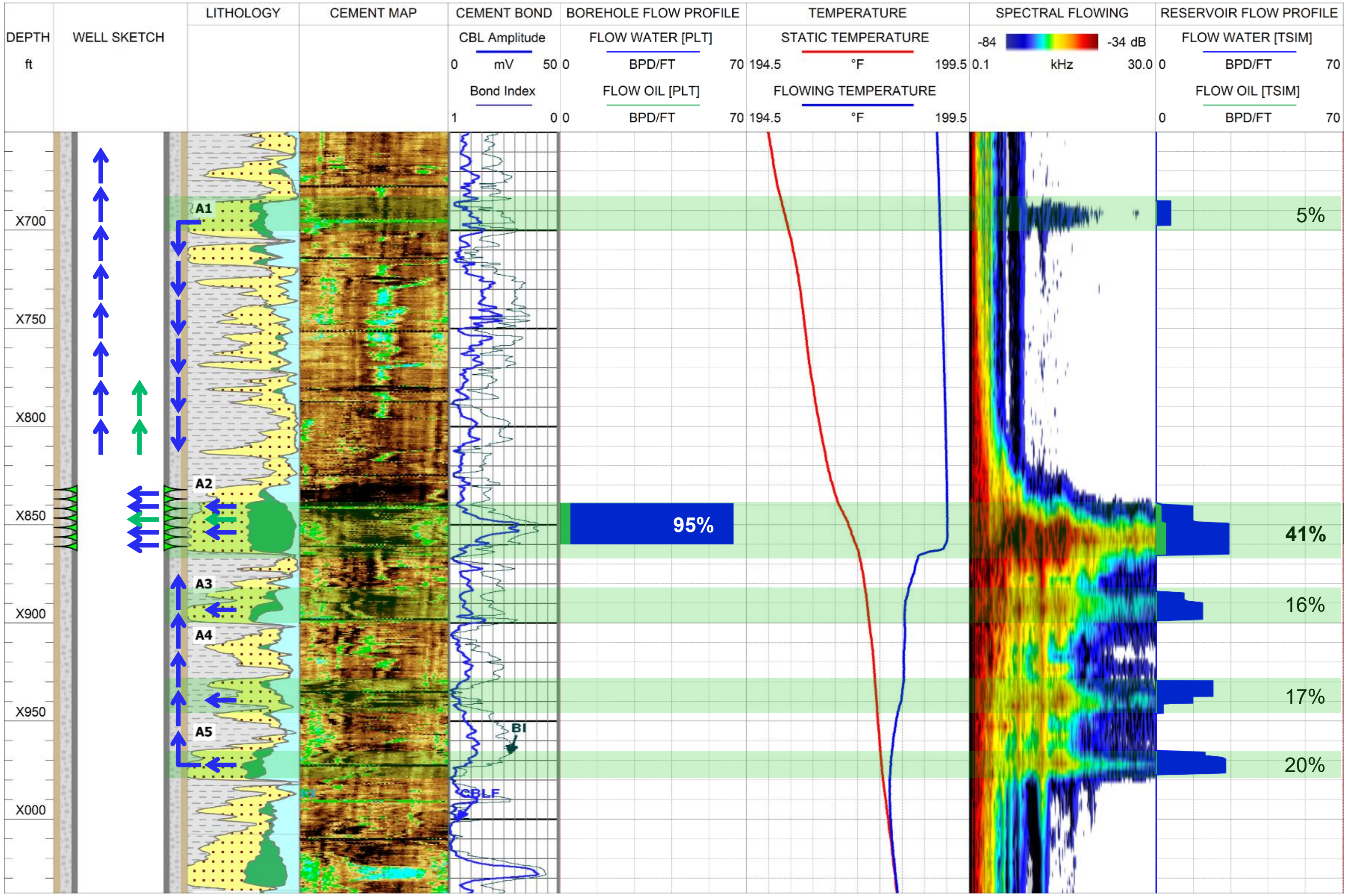
Acoustics in Reservoir

Total Flow—Producer

Revealing true source of excess water production.

Location Kuwait
Customer Kuwait Oil Co.
Well type Producer
Reference SPE-187561





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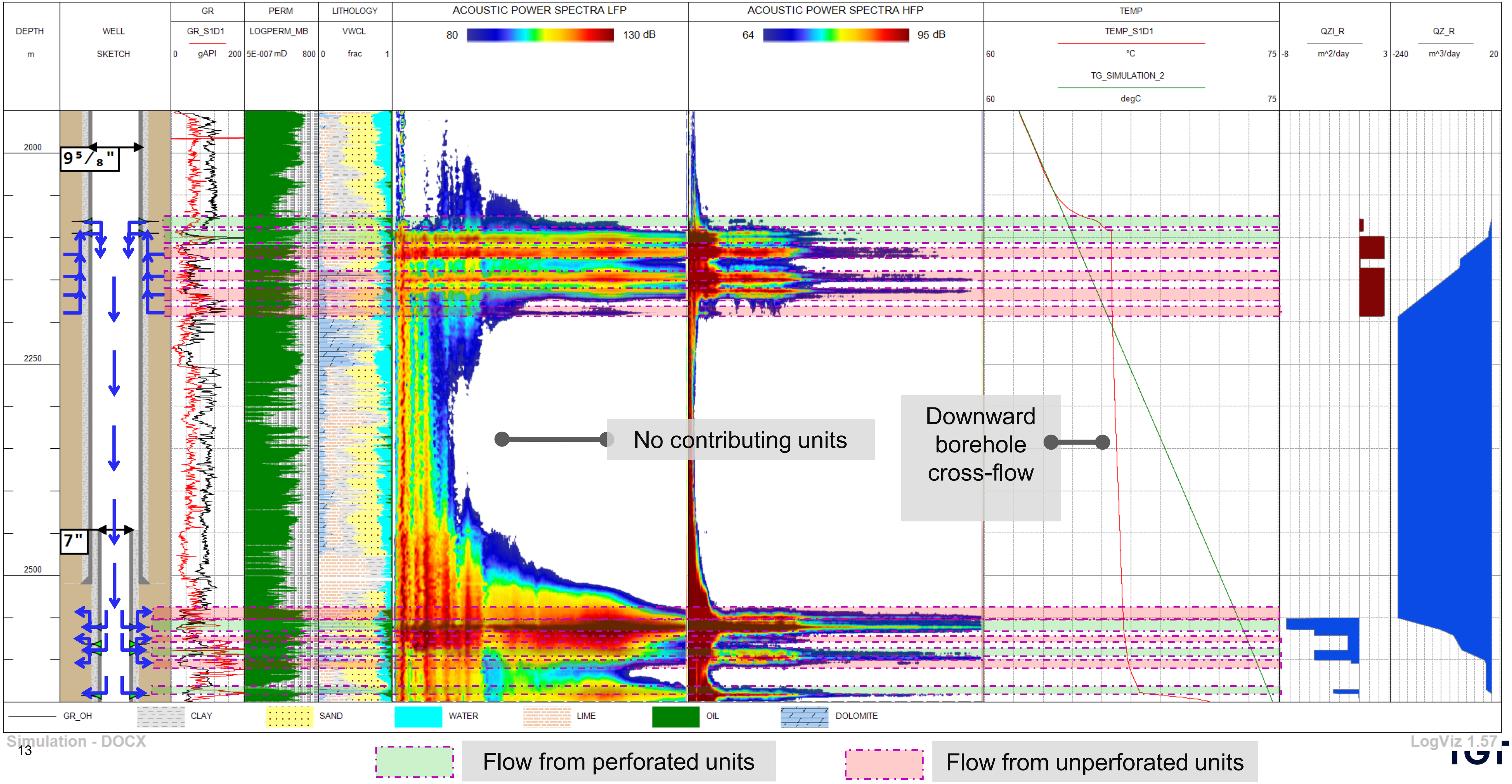
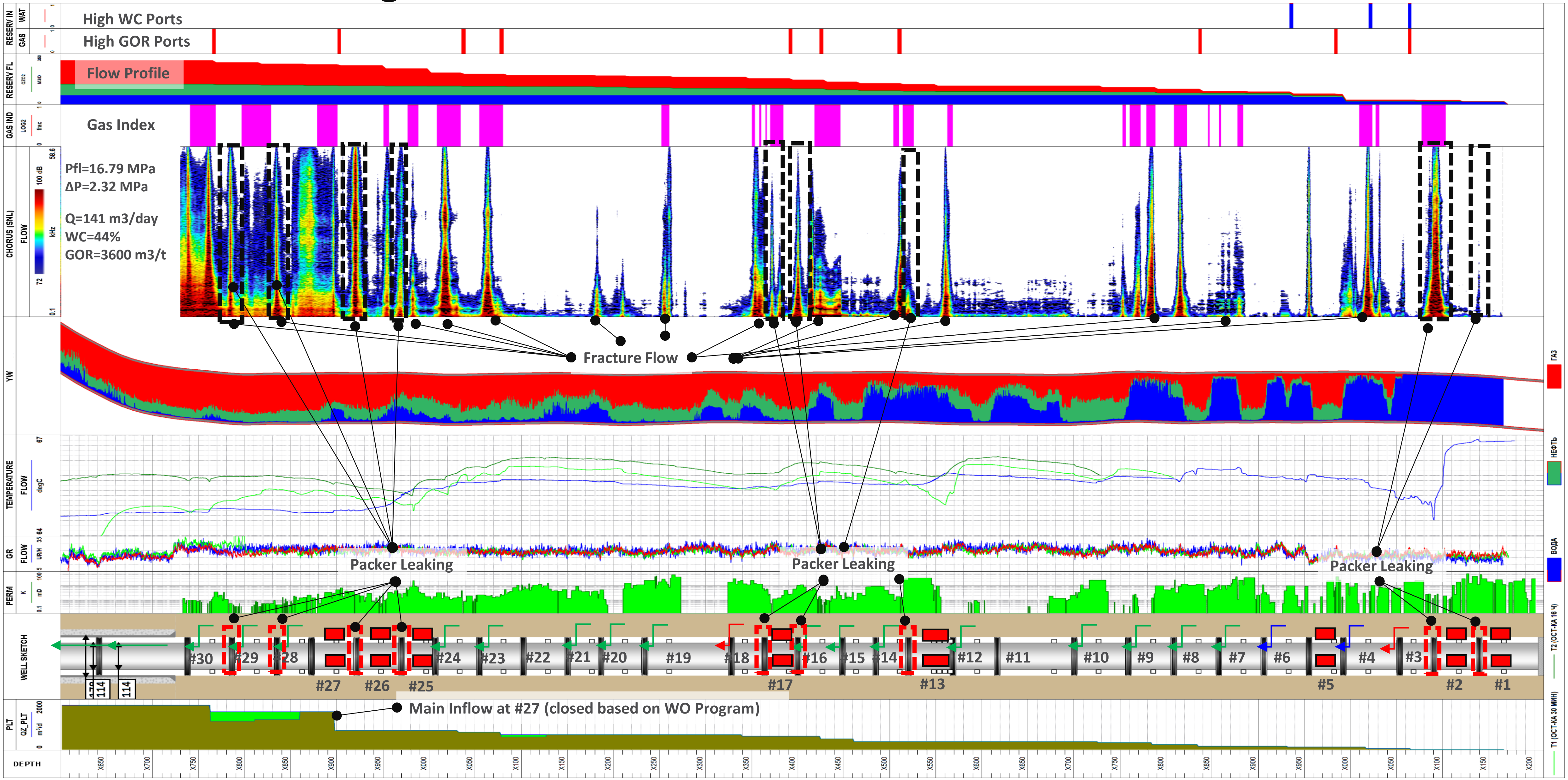
Unwanted Flow Behind Pipe—Case study



Multi-Zone Production & Failing Packers

True Flow Monitoring for Effective Workover



SPE-196834-MS Efficiency Analysis of 30-Stage Fracturing in a Horizontal Well to Oil Rims Based on Through-Barrier Diagnostics

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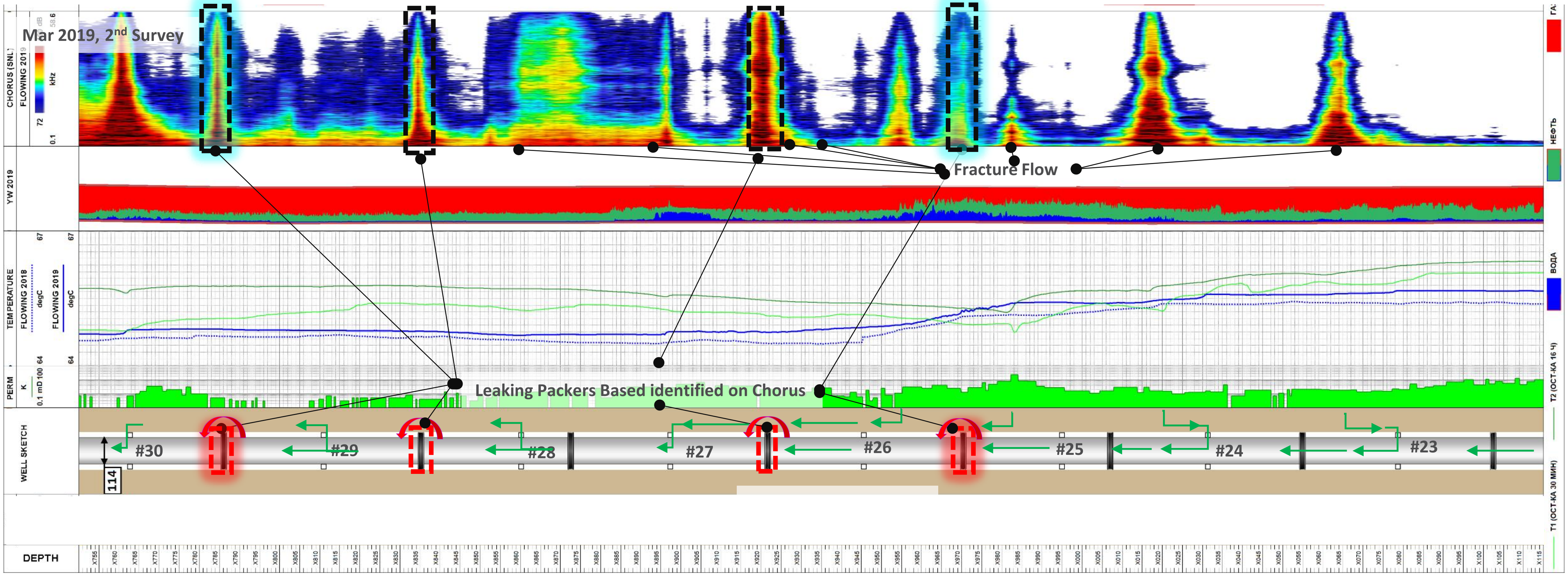
Zonal Contributions and Interzonal Flow (Packer & Cement Integrity)



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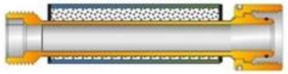
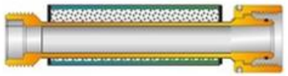
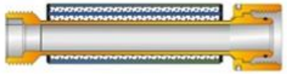
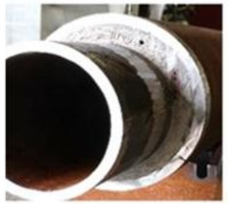
Acoustics in P&A

Independent Barrier Verification Tests

Norce test 2017*

No cement • 7" tubing + 9 5/8 casing • Tubing eccentricity: 10.4mm (9.6%)	 Test Section Length: 284cm Make-up Length: 330cm	
Cemented - free of defects • 7" tubing + 9 5/8 casing • Tubing eccentricity: 10.4mm (9.6%) • Class G cement (expanding), 1.92 s.g.	 Test Section Length: 148cm Make-up Length: 187cm	
Cemented - microannulus • 7" tubing + 9 5/8 casing • Effective micro-annulus: 56µm • Tubing eccentricity: 10.4mm (9.6%) • Class G cement (regular), 1.92 s.g.	 Test Section Length: 172cm Make-up Length: 263cm	
Cemented - hole mid cement • 7" tubing + 9 5/8 casing • 5 mm axial hole • Tubing eccentricity: 10.4mm (9.6%) • Class G cement (expanding), 1.92 s.g. • Sealed control lines	 Test Section Length: 150cm Make-up Length: 180cm	

PETROLEUM SAFETY AUTHORITY NORWAY

ConocoPhillips

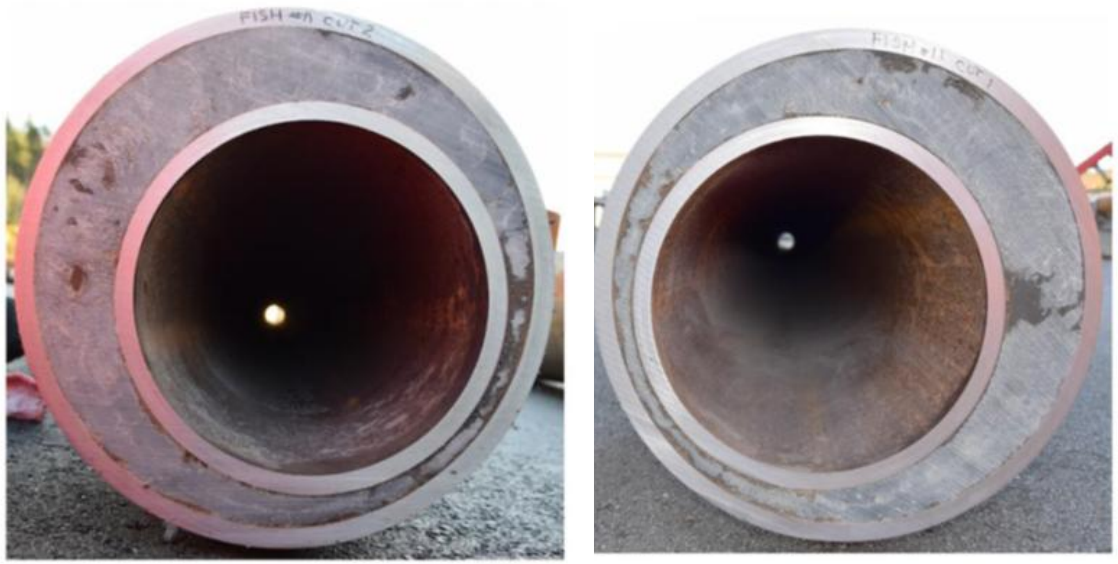
equinor

AkerBP

TOTAL

PETROBRAS

Norce test 2019



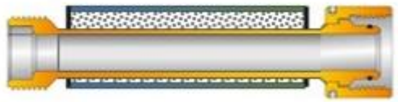
***IADC/SPE-194075-MS**
Barrier Verification during Plug and Abandonment Using Spectral Noise Logging Technology, Reference Cells Yard Test

NORCE 2017 - Independent Barrier Verification Tests

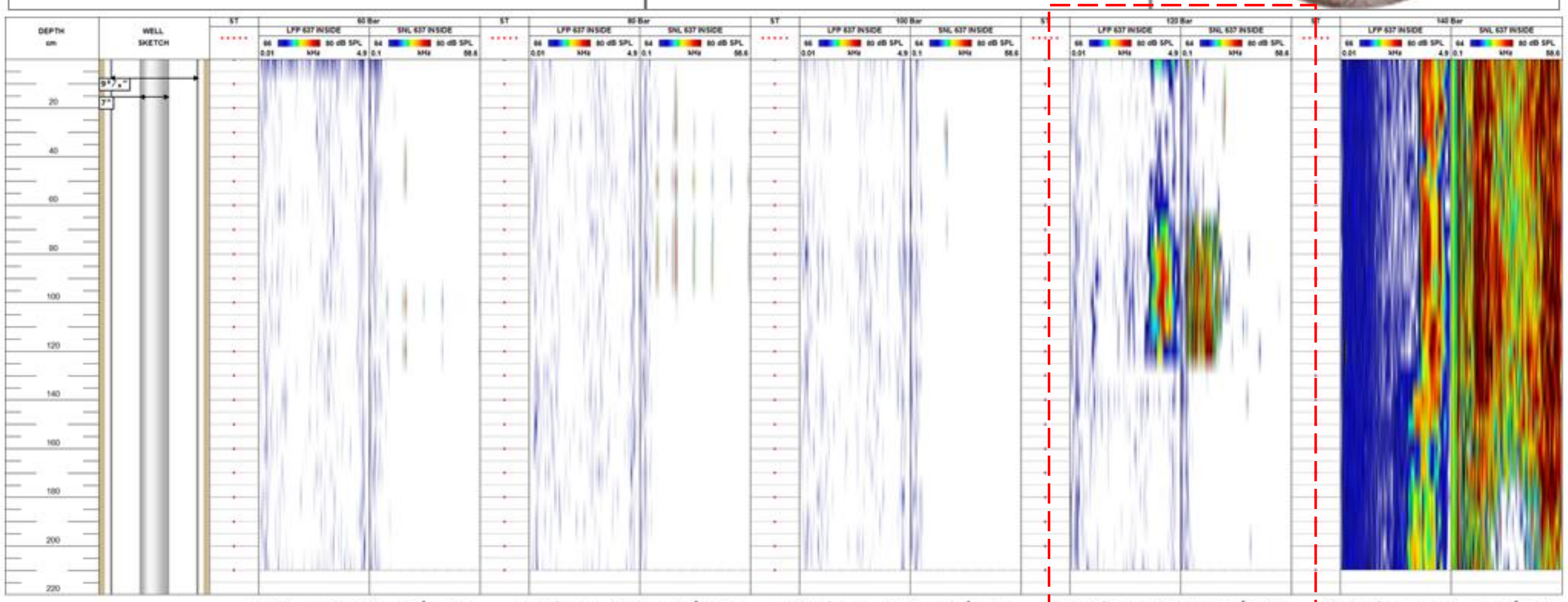
Cement sealing failure identified at **9.7mL/min** leak rate

Cemented - free of defects

- 7" tubing + 9 5/8 casing
- Tubing eccentricity: 10.4mm (9.6%)
- Class G cement (expanding), 1.92 s.g.



Test Section Length: 148cm
Make-up Length: 187cm



Norsok D-010

Features	Acceptance criteria	See
D. Initial test and verification	1. Internal WBE shall be verified using at least one of the methods below: a) Pressure test, either in the direction of flow or from above. If the WBE is set on a pressure tested foundation, a pressure test is not required. It shall be verified by tagging; b) Tag/load test with drill pipe or wireline; c) Any other alternative verification method that is documented and proven to be suitable for the particular type of alternative barrier material being used. 2. External WBE shall be verified using at least one of the methods below: d) Bonding logs. Logging methods/tools shall be selected based on ability to provide data for verification of bonding. The measurements shall provide azimuthal/segmented data. The logs shall be verified by qualified personnel and documented; e) Application of a pressure differential across the interval; f) Downhole acoustic leak-off test; g) Any other alternative verification method that is documented and proven to be suitable for the particular type of alternative barrier material being used 3. The installation of the alternative material WBE shall be verified through evaluation of job execution	
E. Use	None	
F. Monitoring	Monitoring required in the following scenarios: a) First use of a new alternative barrier material b) Temporary Abandonment (wells with monitoring) and suspension	
G. Common well barrier	To be evaluated on a case by case basis after performing an engineering review and a risk assessment.	

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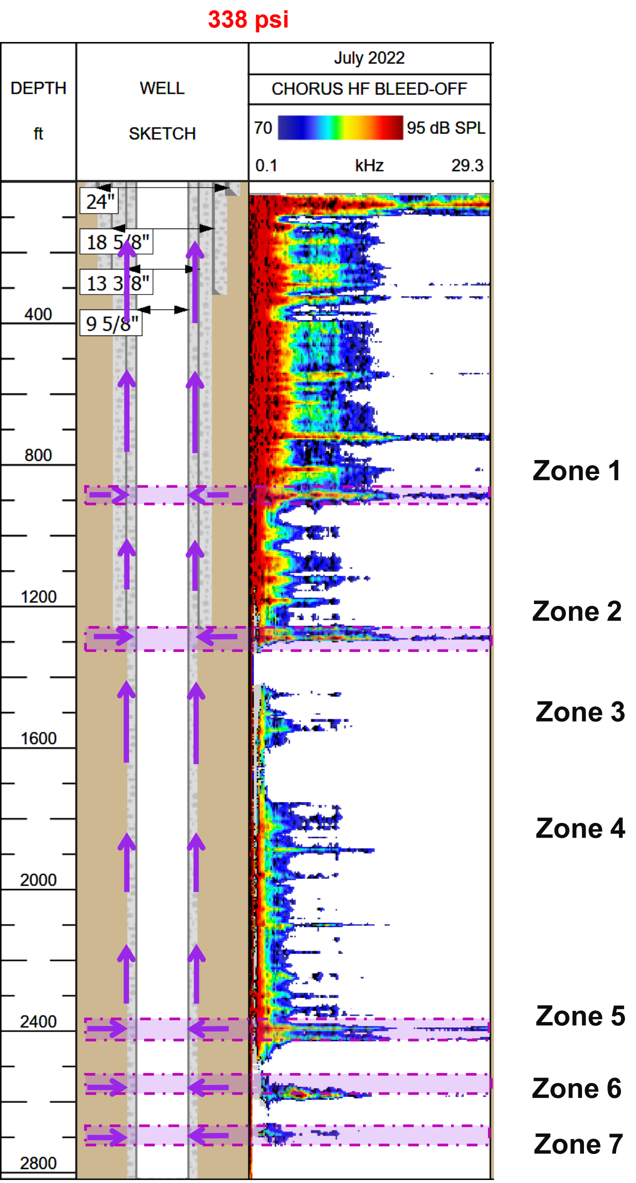
Find, Fix and Confirm in P&A



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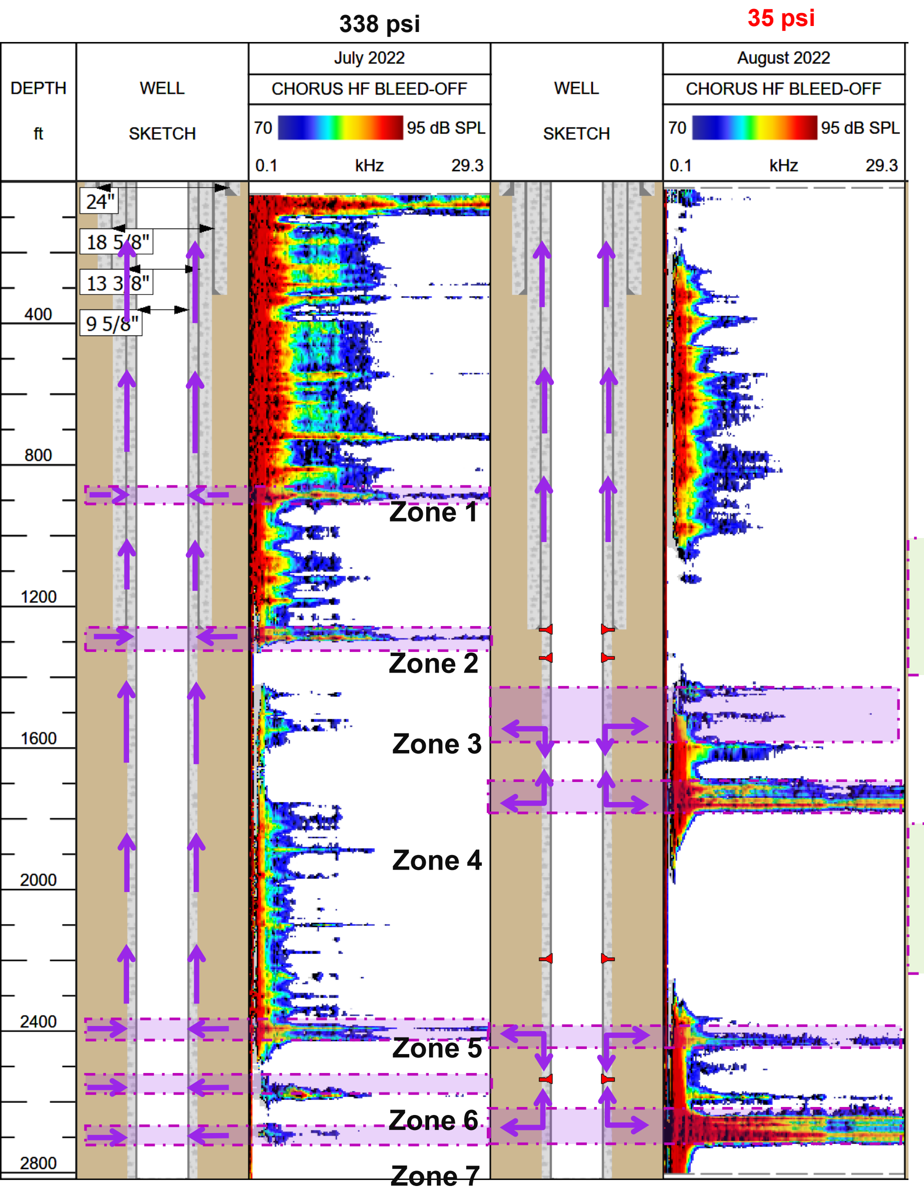

No annular flow across squeezed zones (~1270 ft, ~1350 ft)

Zone 3

Zone 4

No annular flow across squeezed zones (~2200 ft)

Zone 5

Zone 6

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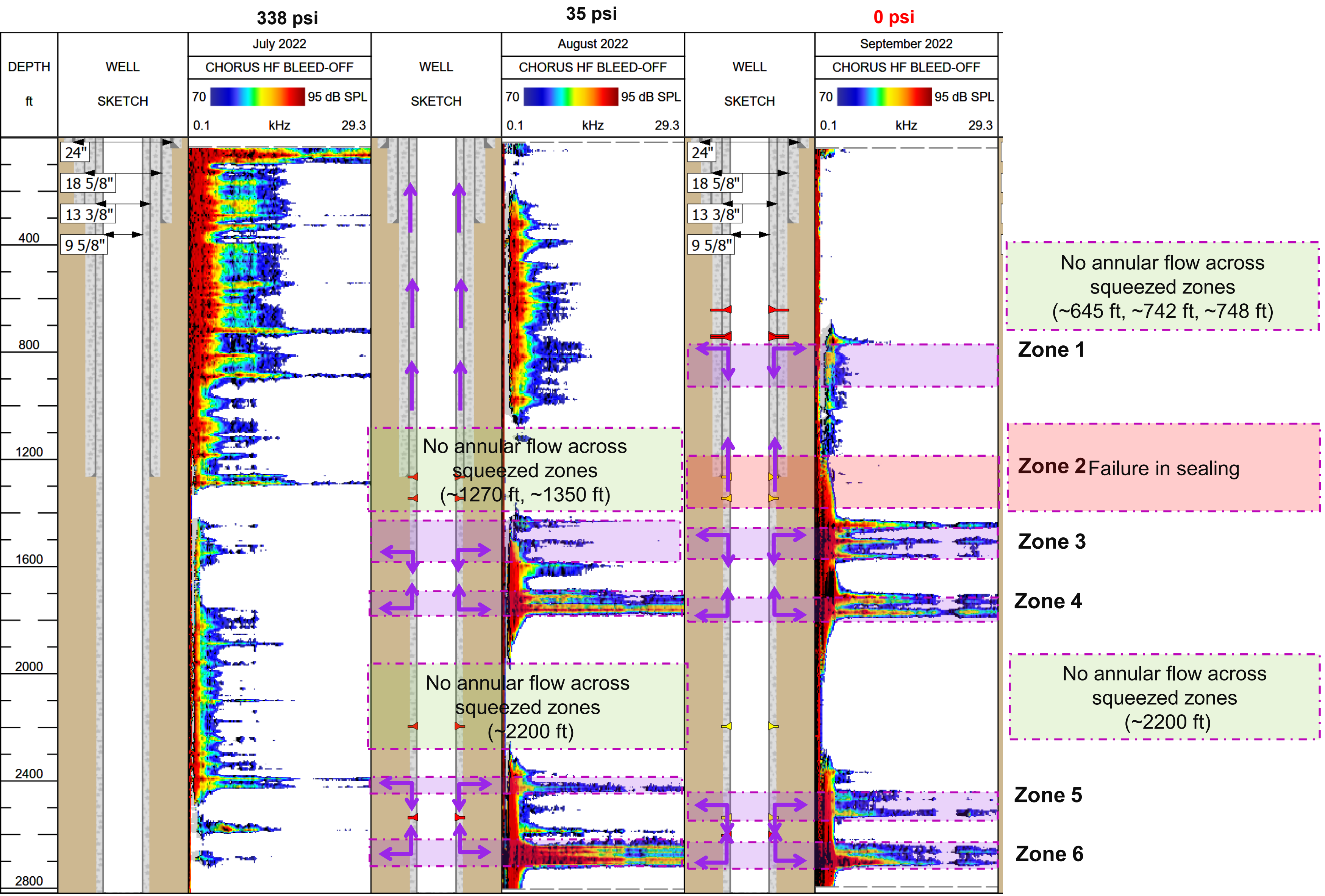
Find, Fix and Confirm in P&A



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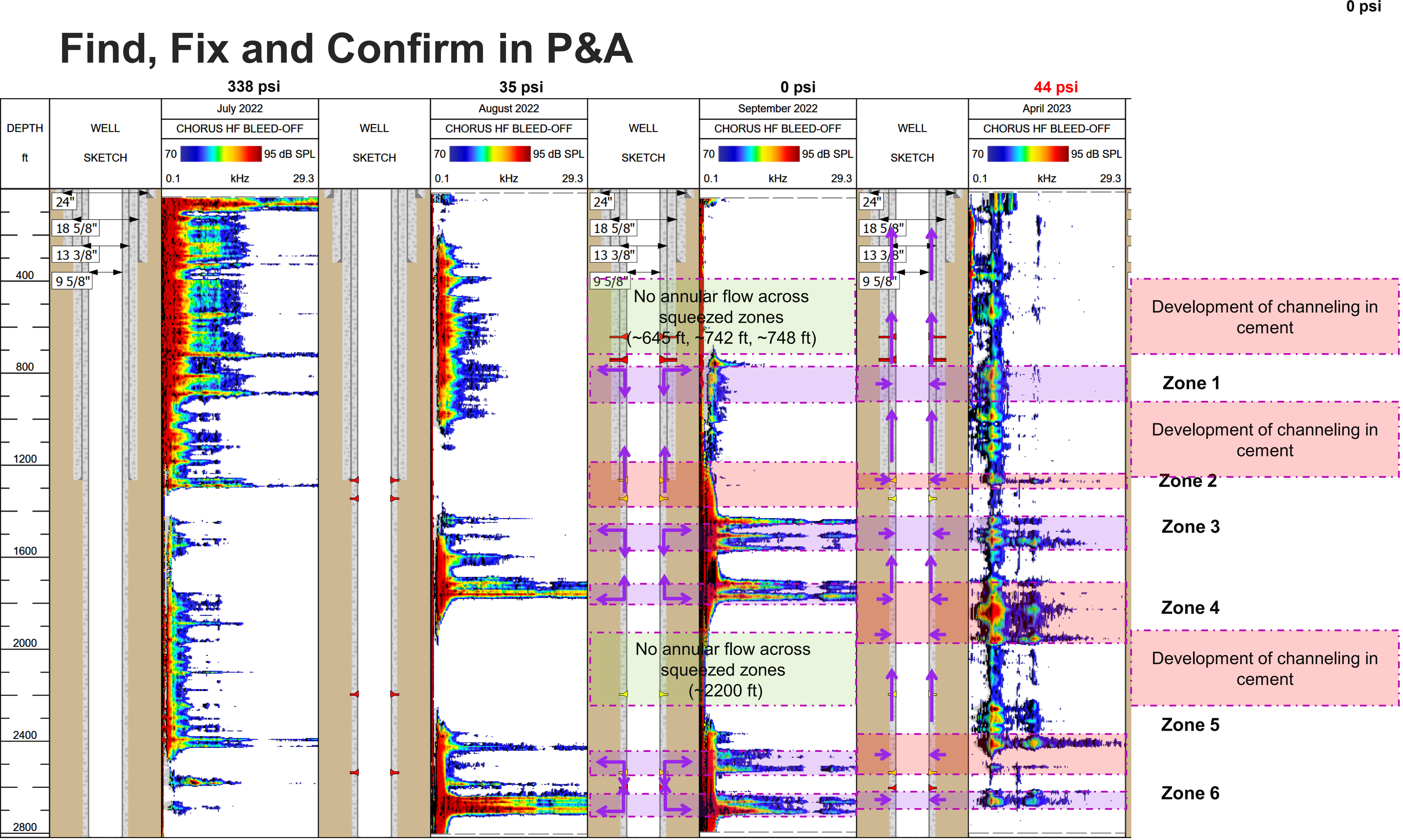

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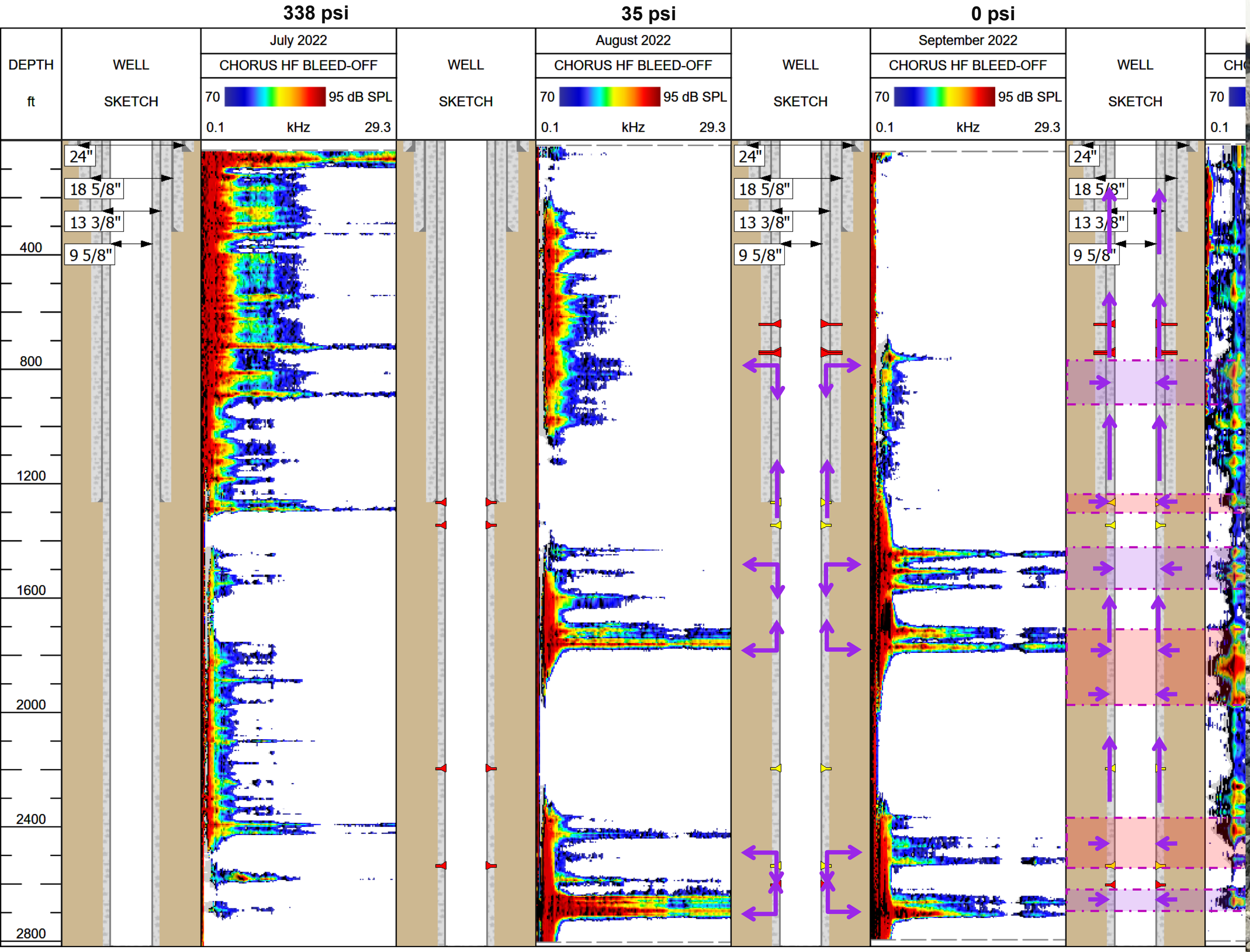
0 psi 0 psi

Find, Fix and Confirm in P&A



Conclusions

Spectral acoustics long and evolved history

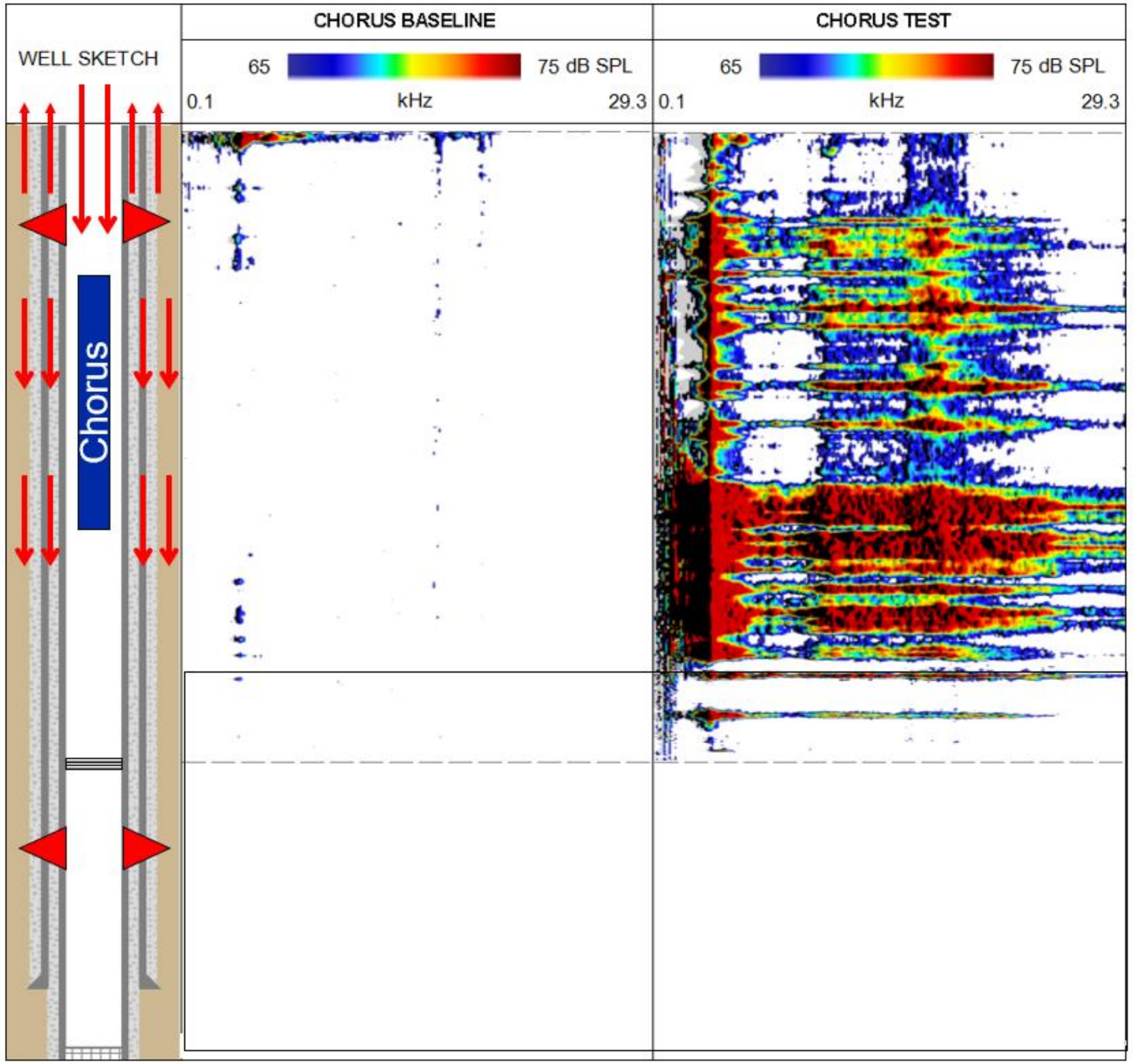
- NOT just a “Noise” tool

Spectral acoustics have wide range of applications

- Reservoir and Completion performance
- OOZI / OOZP / target zone

Spectral acoustics in P&A

- Barrier Verification
- Find, Fix & Confirm



Appreciating….