Acquiring Formation Pressure Data in Low Permeability Reservoirs as an Aid to Evaluating Reservoir Connectivity*

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Abstract

The data provided by wireline formation testers (WFT) is critical to the evaluation and understanding of petroleum reservoirs. Pretest pressures, gradients and mobilities are generally regarded as essential inputs to the reservoir evaluation model. However, acquiring this data in low permeability reservoirs can prove challenging. There is no stable flowing pressure during the pretest, build-up times can be long and the confidence level of the final pressure is often uncertain

New generation formation testing tools that extend the range of pretest rates and volumes have greatly improved the quality of WFT data acquired in low permeability reservoirs. Job design and planning have always been important for the proper acquisition of formation test data. Several new options, made available through the enhanced capabilities of the new generation of tools, make packer/probe and parameter selection even more critical. Additionally, the challenges of the low permeability environment require specific attention to real time quality control and evaluation of the test data as it is acquired.

In this paper we use examples to discuss best practices for formation testing in low permeability reservoirs. We show the pitfalls that can arise with incorrect test design as well as the improvements brought by the latest tools when correctly configured. While there is usually confidence in the mobility data from high permeability reservoirs the numbers generated from low permeability reservoirs are often suspect: pretest volumes are typically very low and there is no stable flowing pressure.

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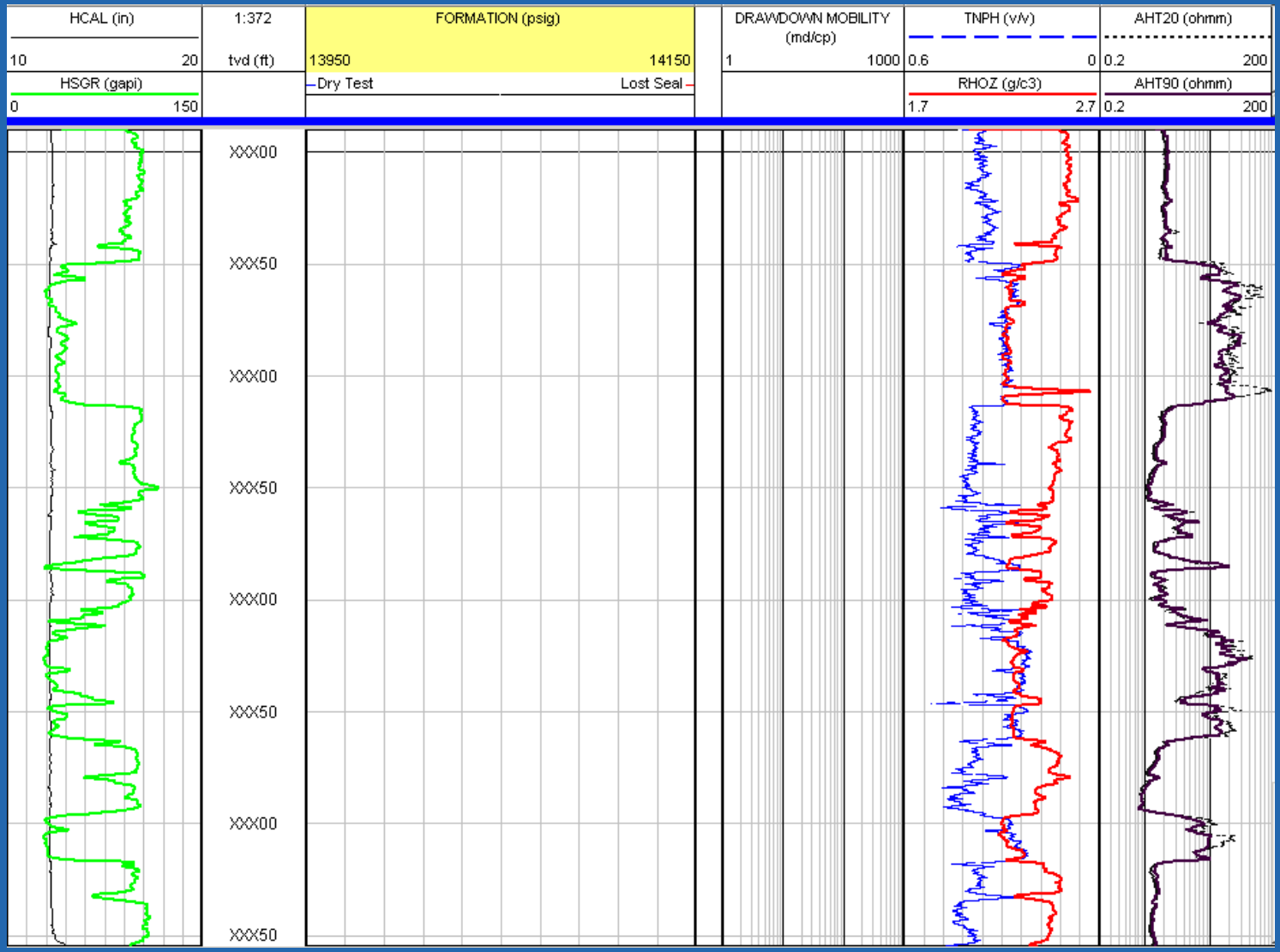
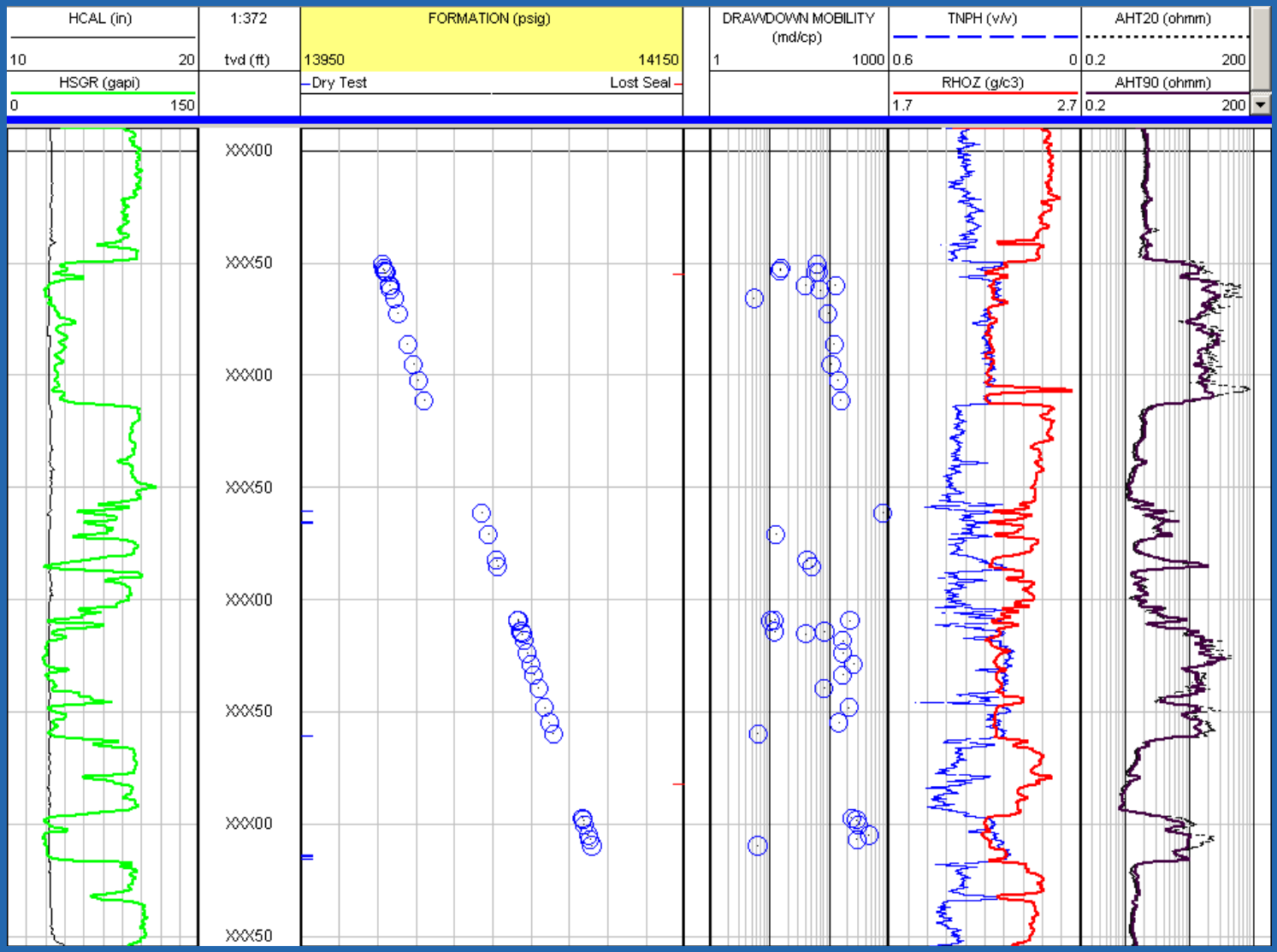
Outline

- Pretests, gradients and connectivity
- Pretesting in low mobility environments
  - Tool design
  - Pretest design
- Examples

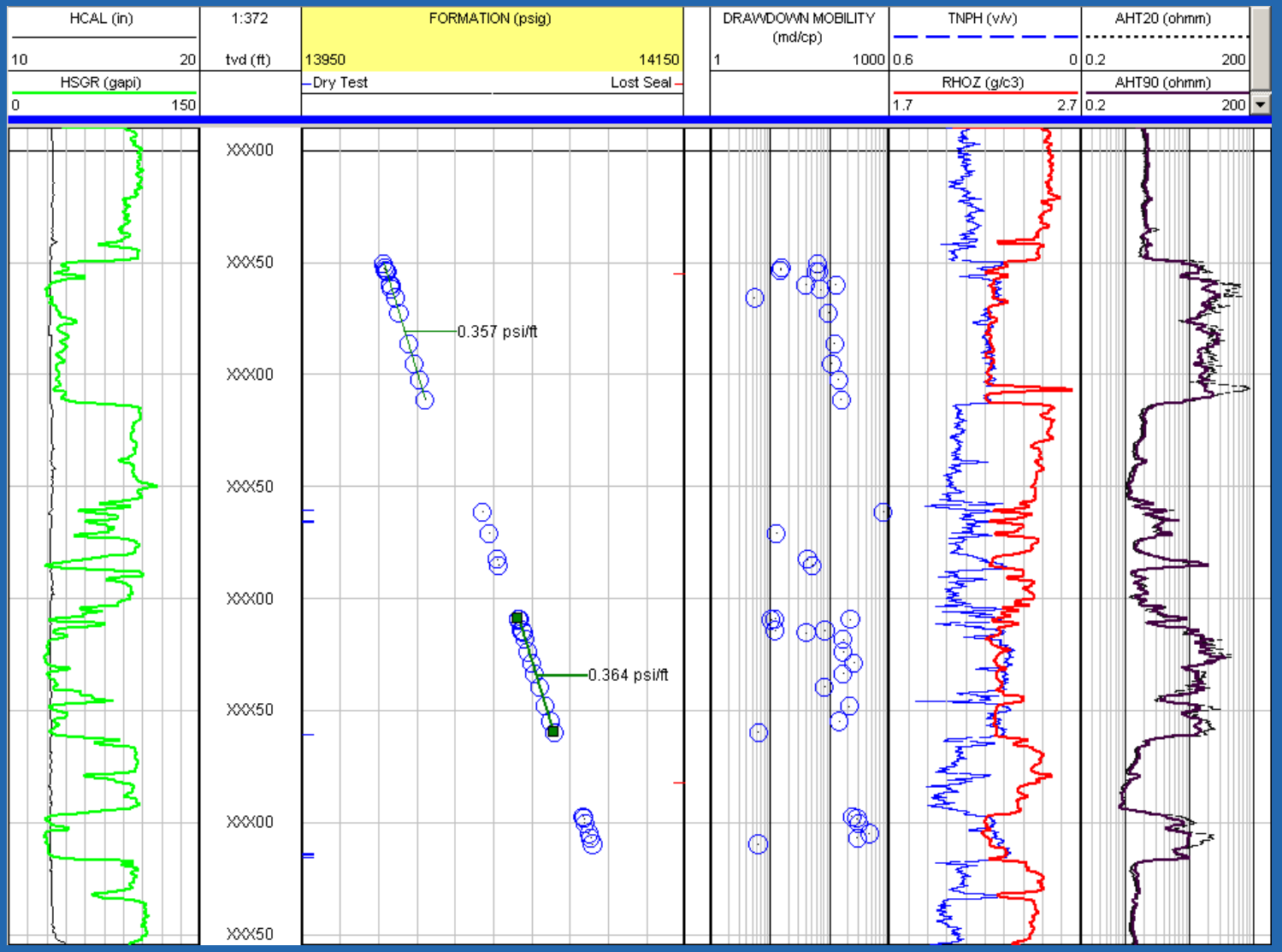
Intra-well Connectivity



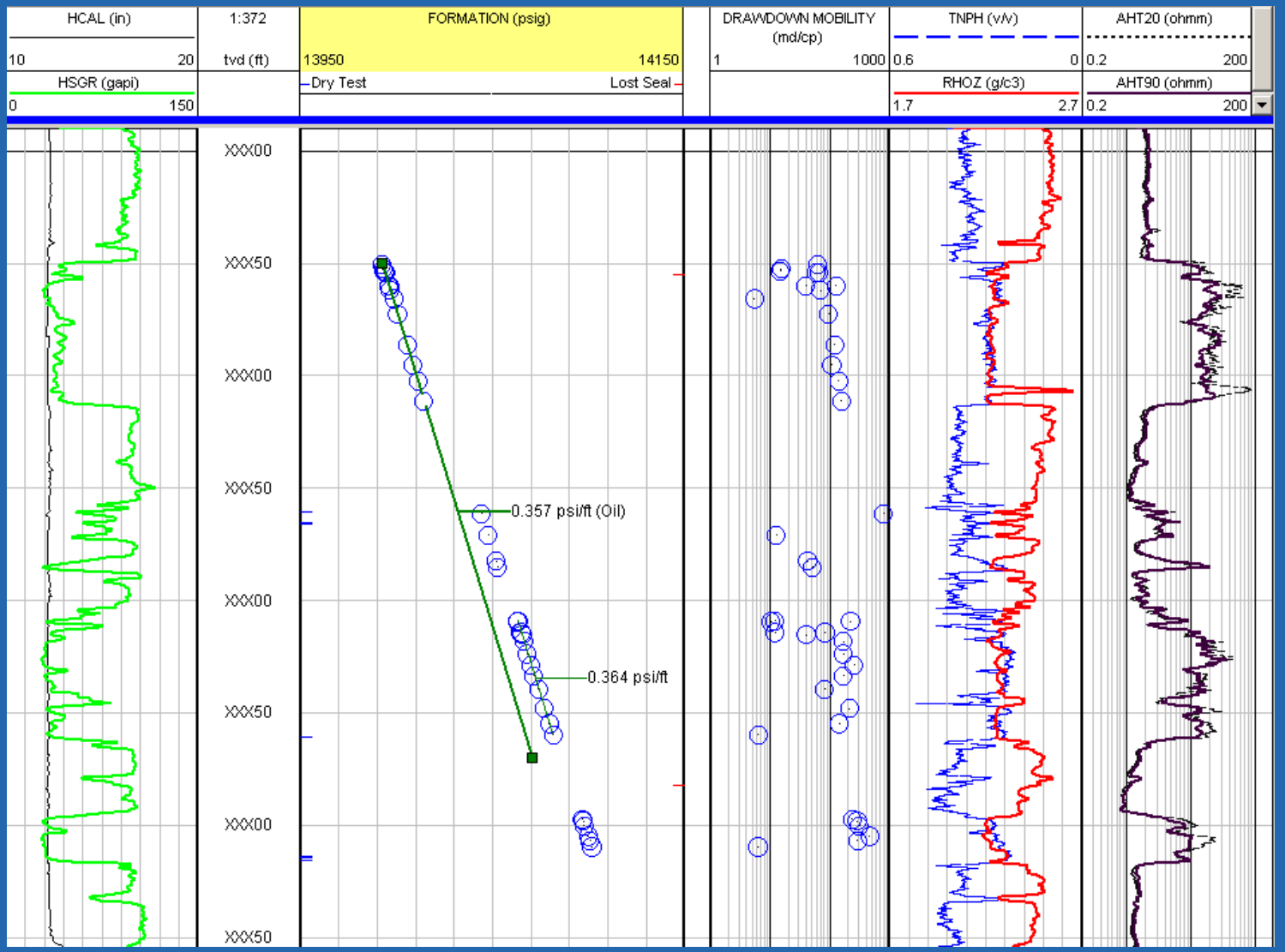
Formation Pressures



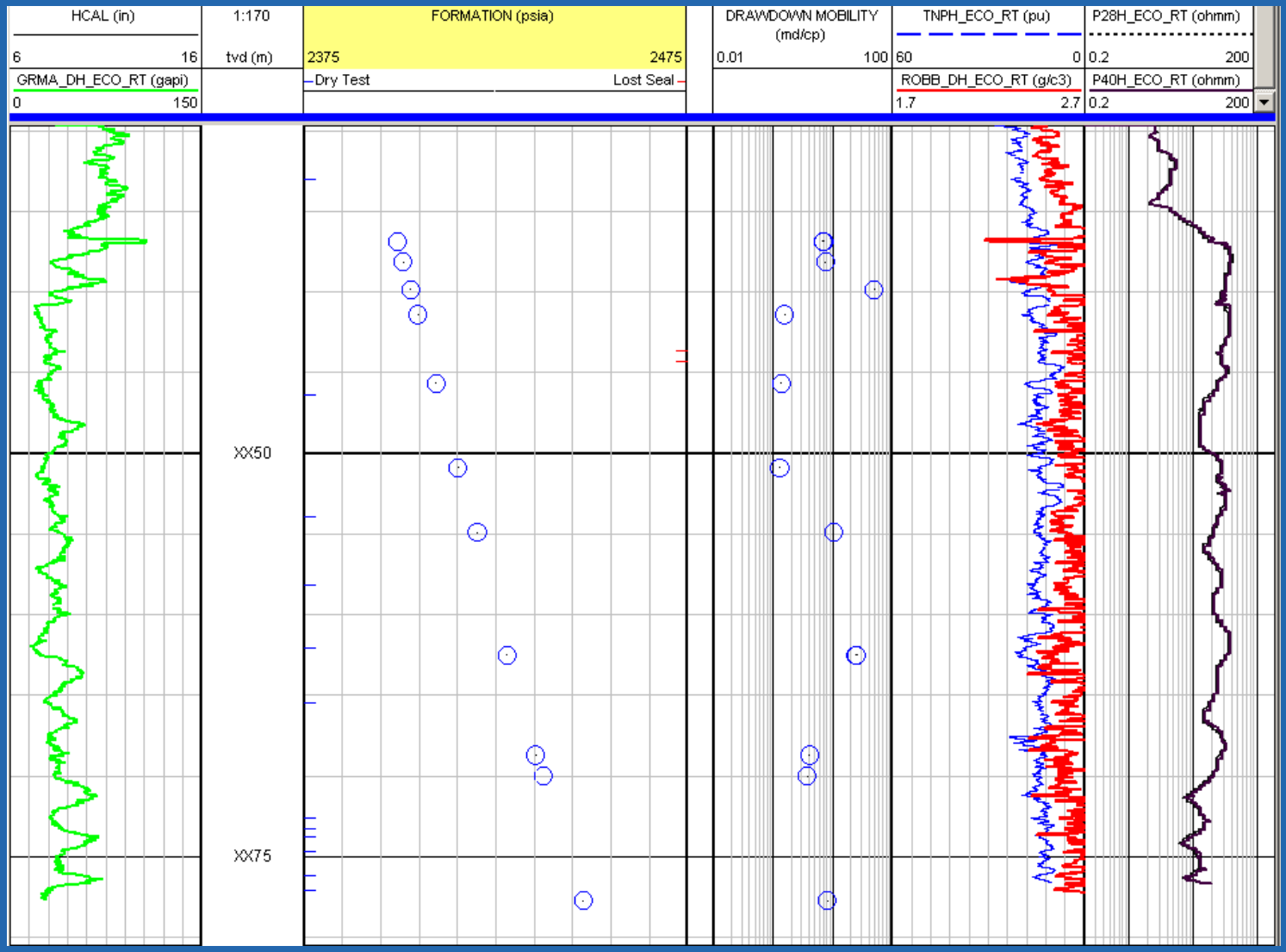
Gradients


HCAL (in)
10
20
HSGR (gapi)
0
150
1:372
tvd (ft)
FORMATION (psig)
13950
14150
Dry Test
Lost Seal
DRAWDOWN MOBILITY (md/cp)
1
1000
TNPH (v/v)
0.6
0
RHOZ (g/c3)
1.7
2.7
AHT20 (ohmm)
0.2
200
AHT90 (ohmm)
0.2
200
XXX00
XXX50
XXX00
XXX50
XXX00
XXX50
XXX00
XXX50
0.357 psi/ft
0.364 psi/ft

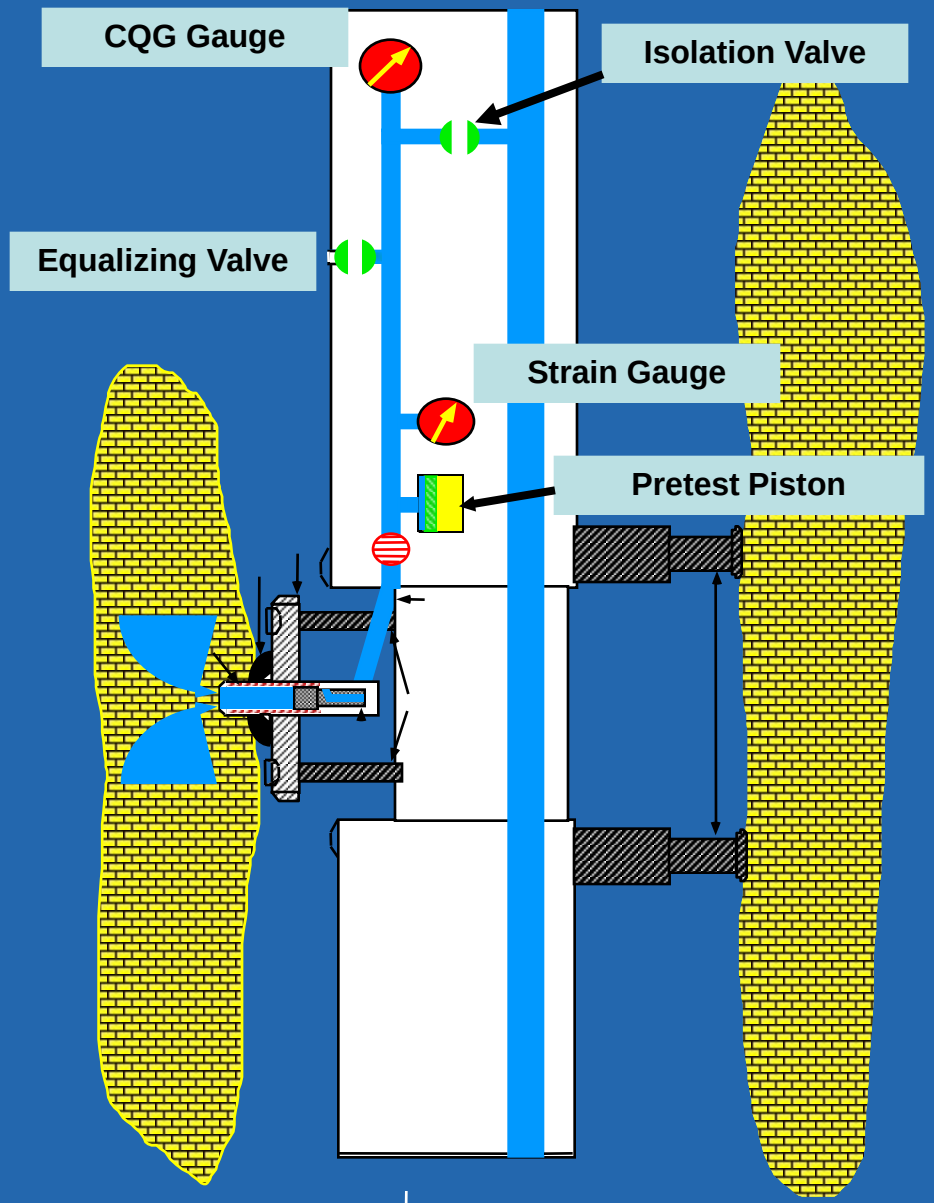
Extended Gradient



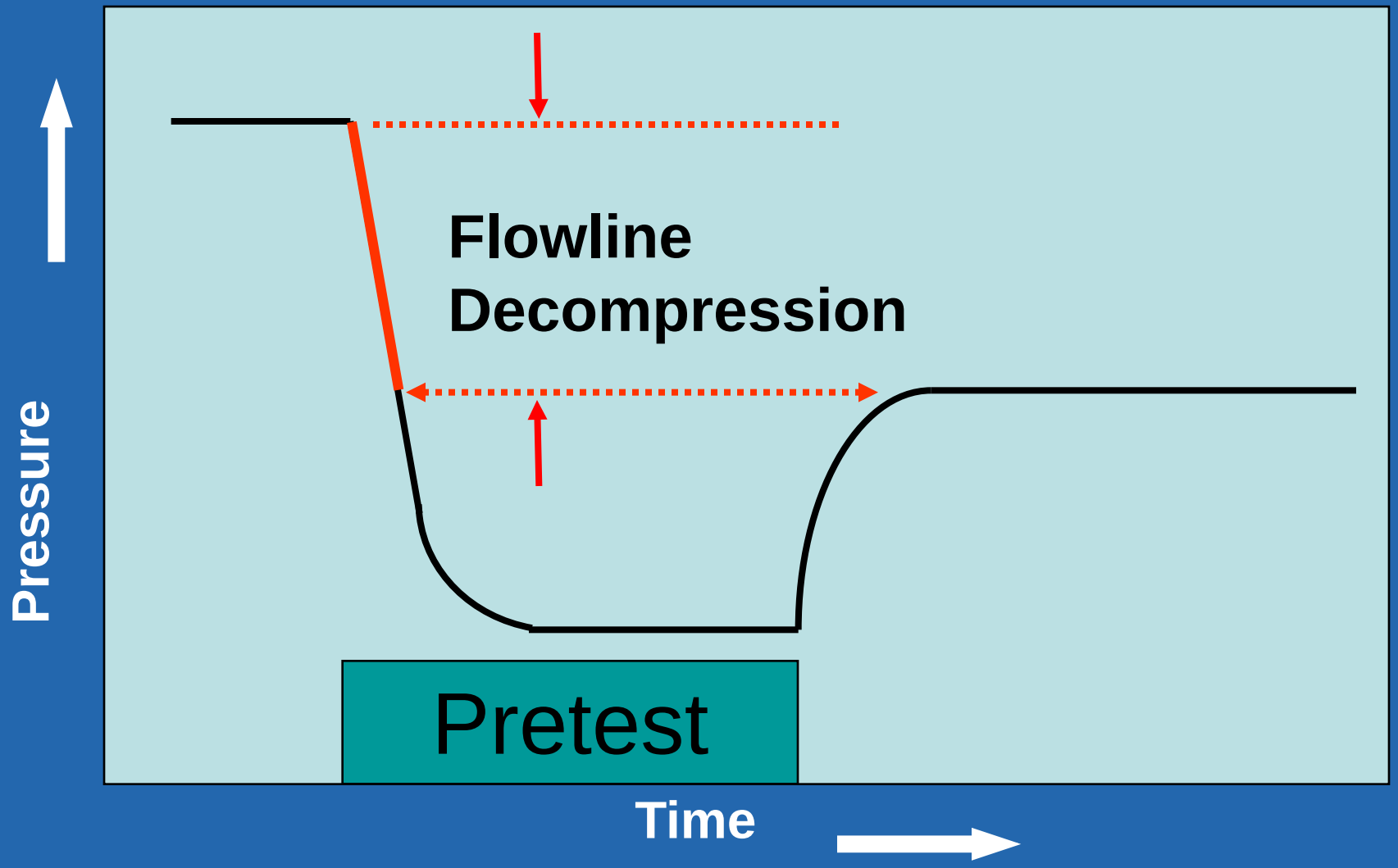
Low Mobility Environment



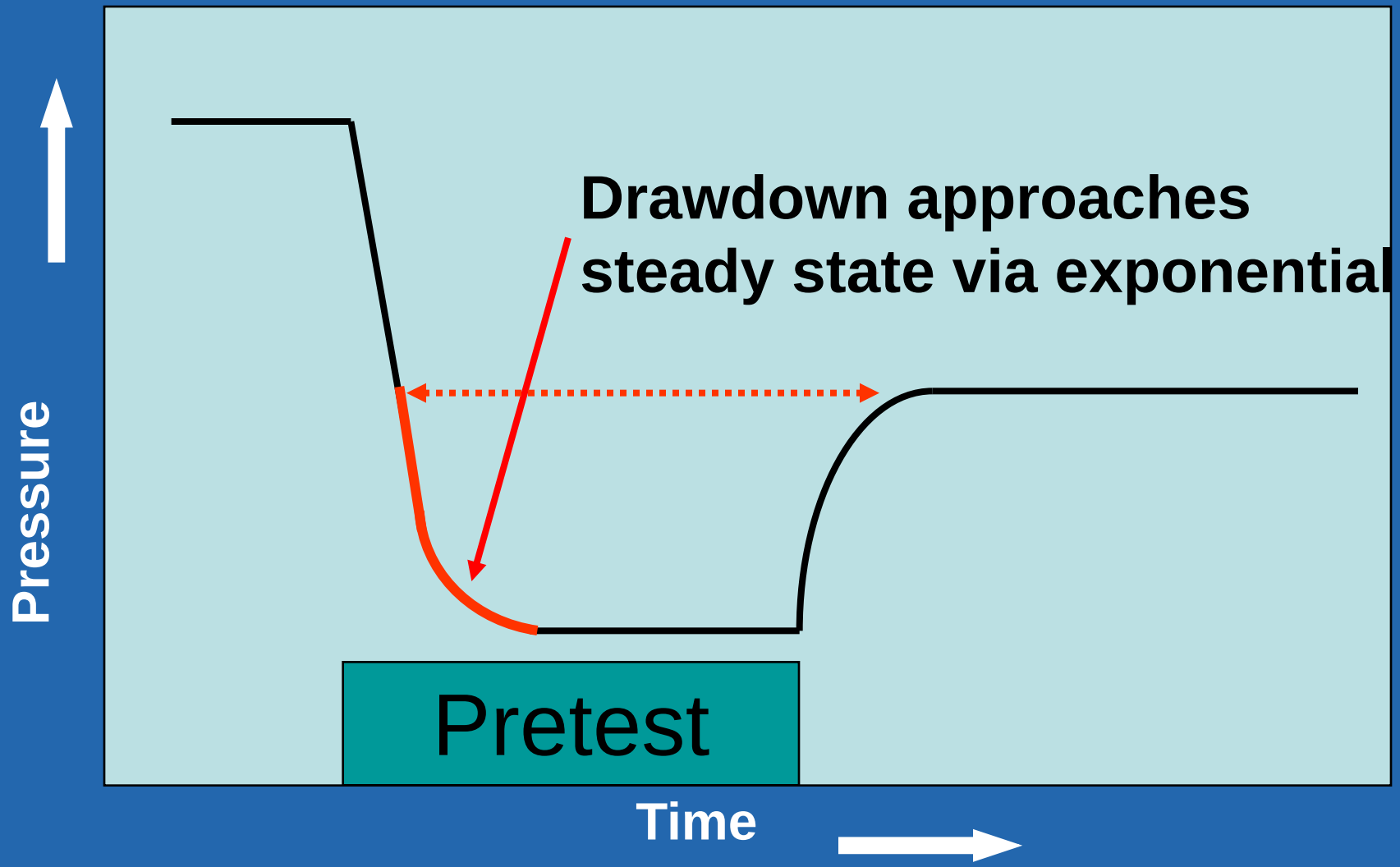
Pretesting


CQG Gauge
Isolation Valve
Equalizing Valve
Strain Gauge
Pretest Piston

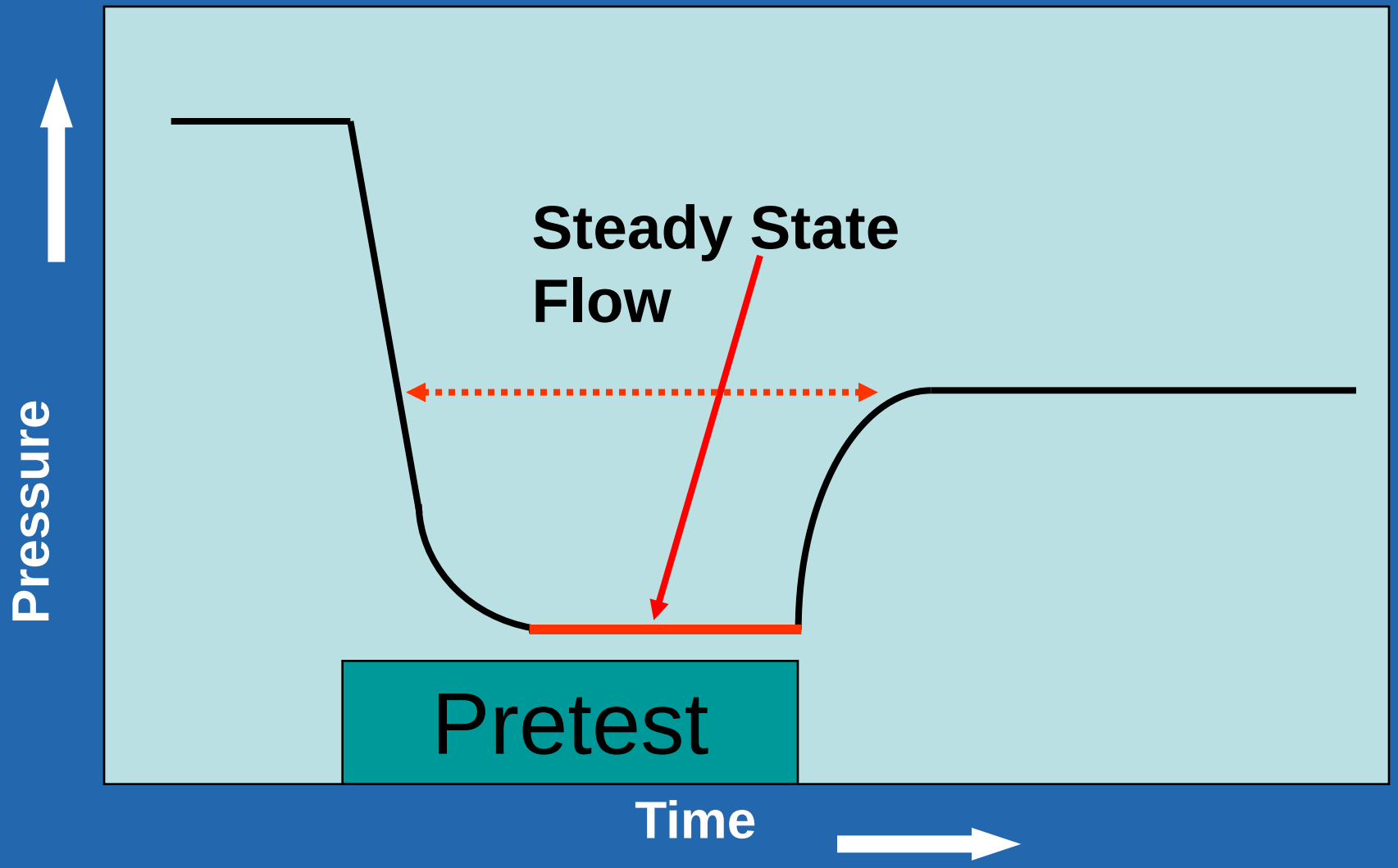
High Perm Pretest



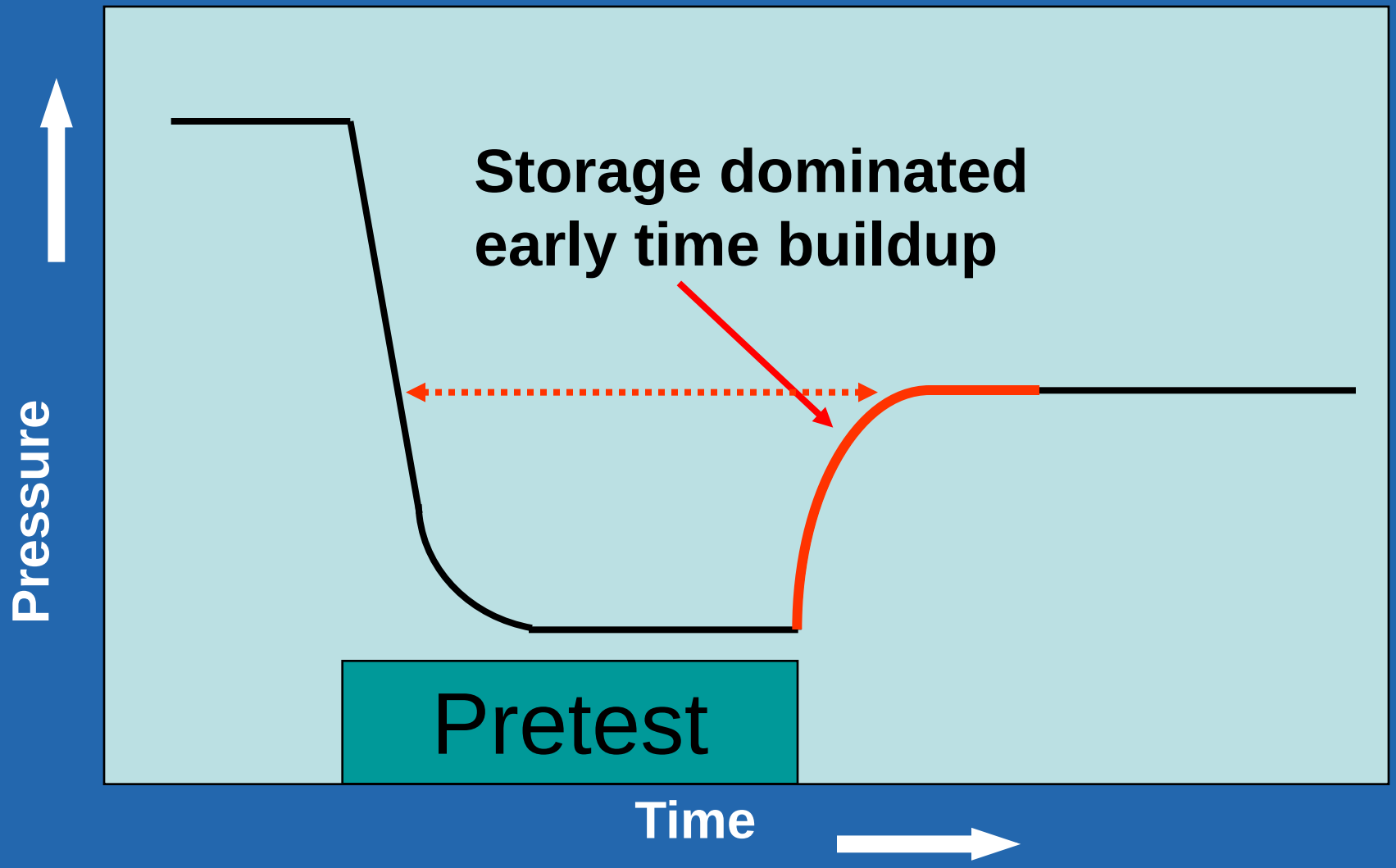
High Perm Pretest



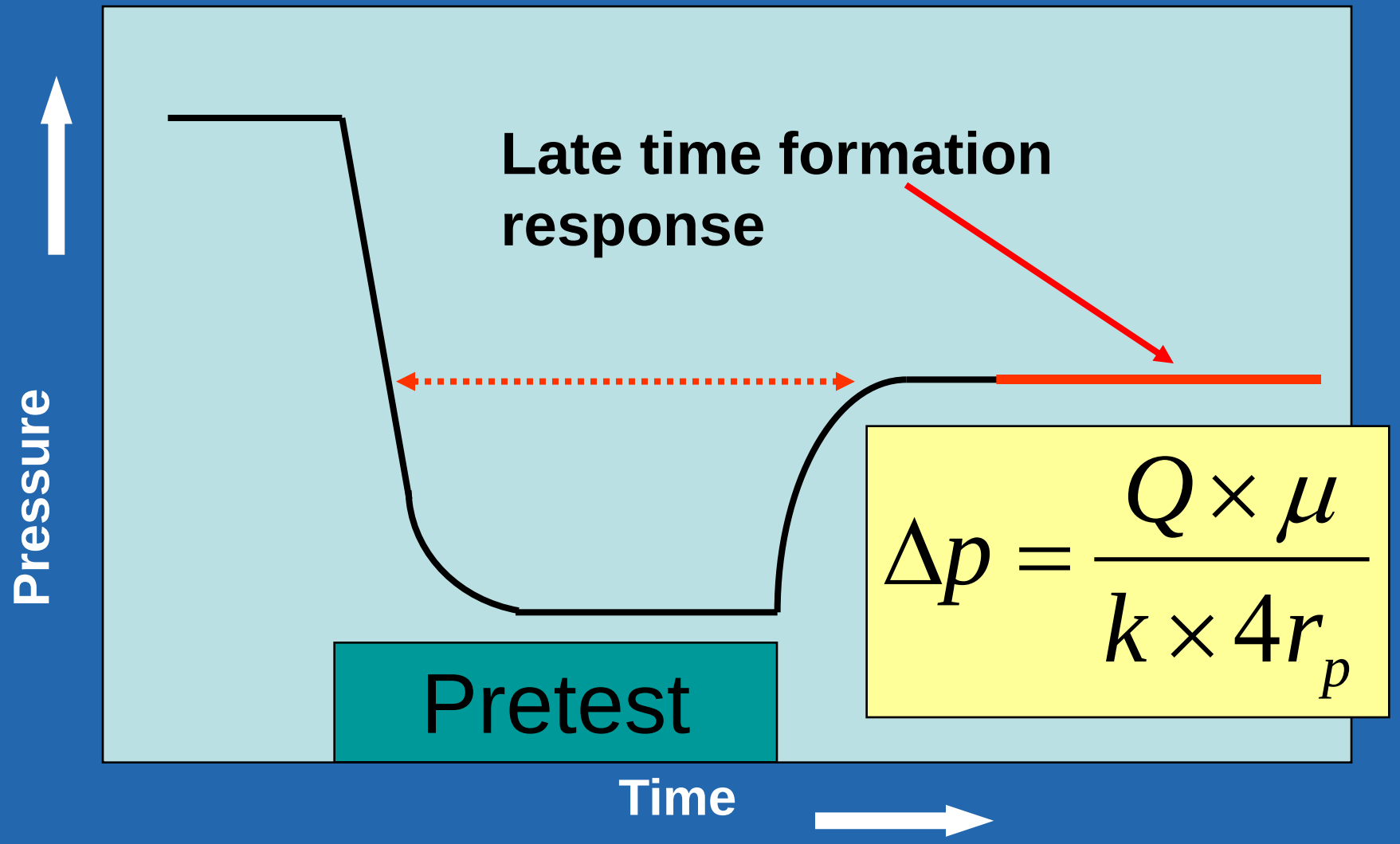
High Perm Pretest



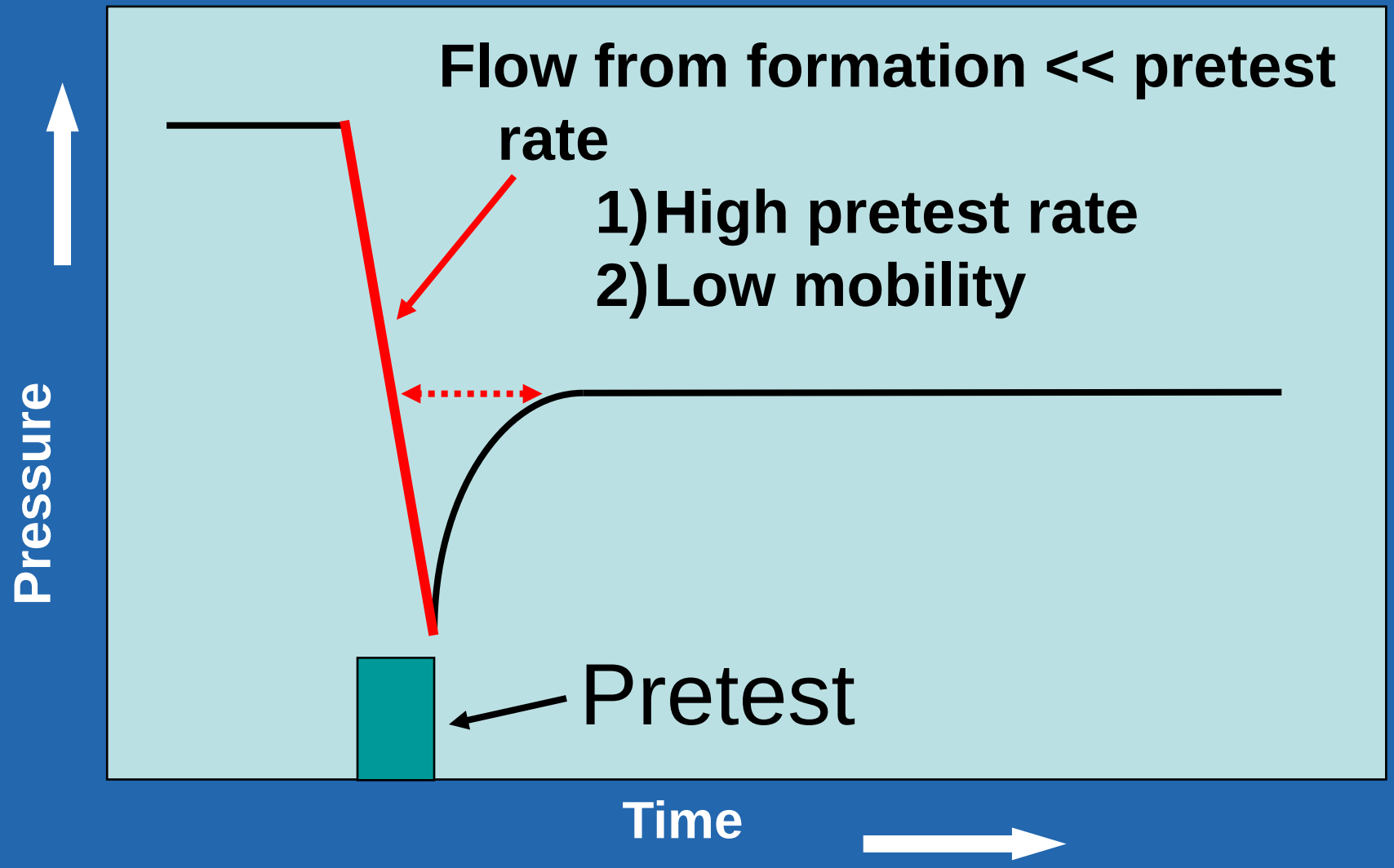
High Perm Pretest



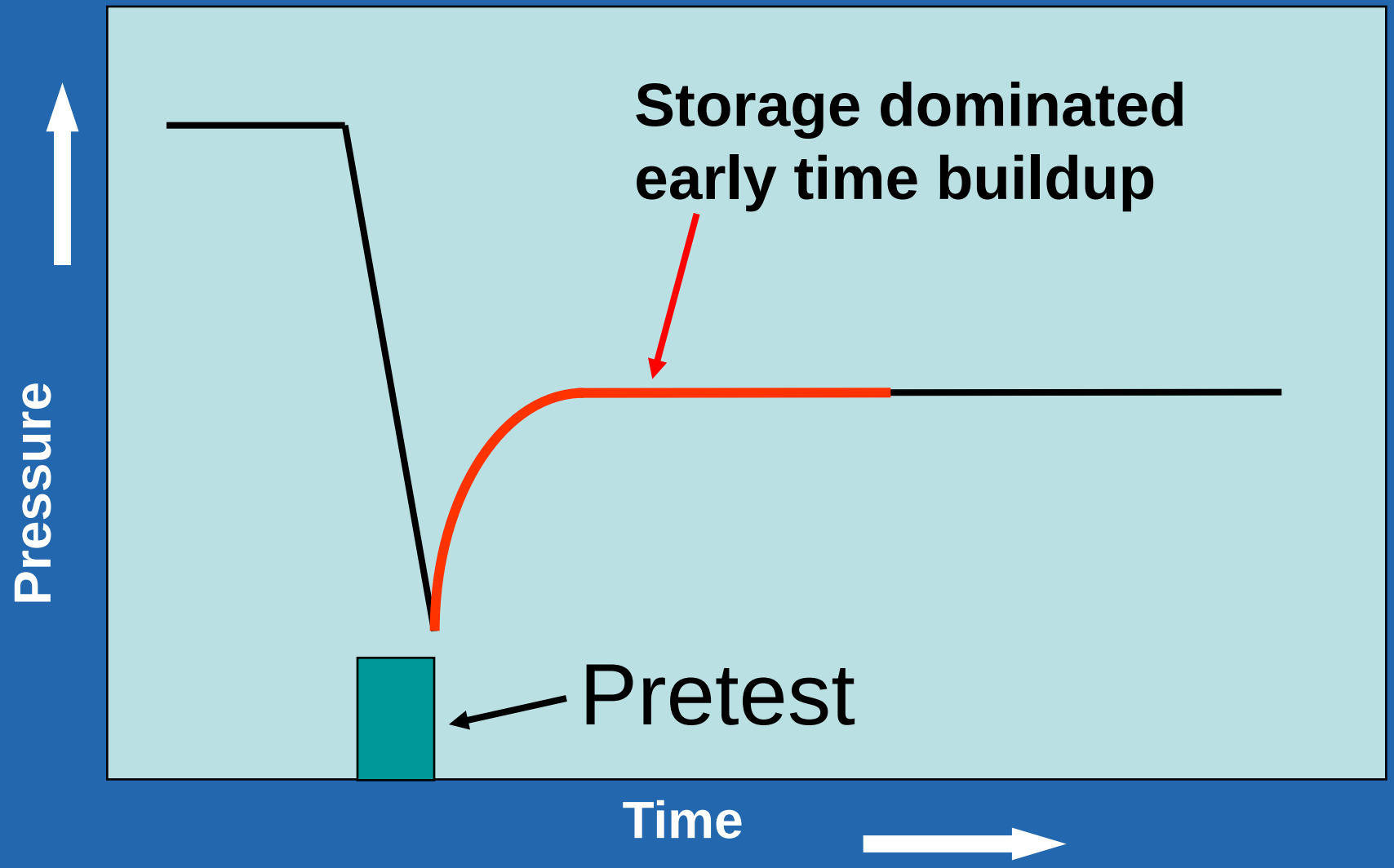
High Perm Pretest



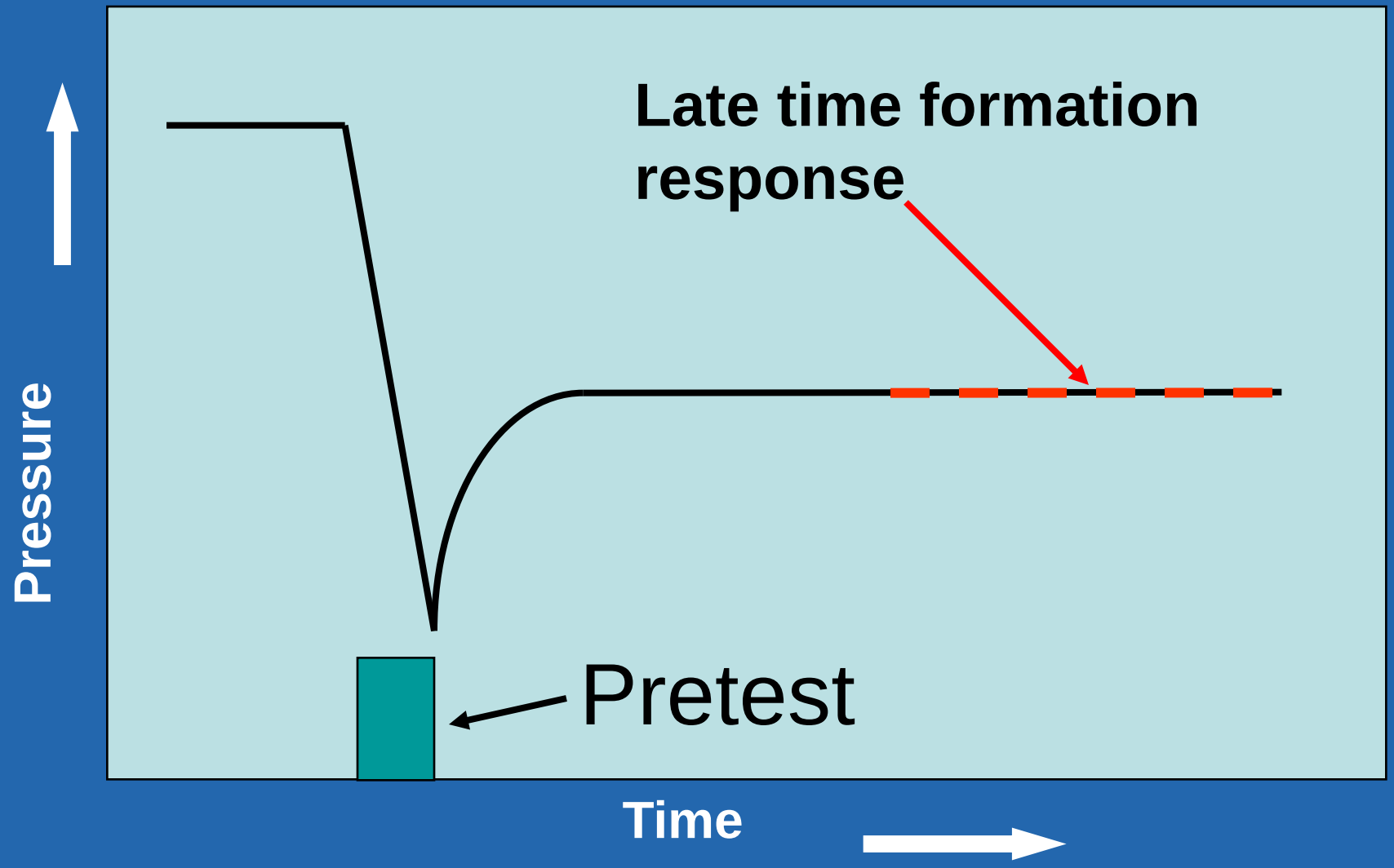
Very Low Perm Pretest



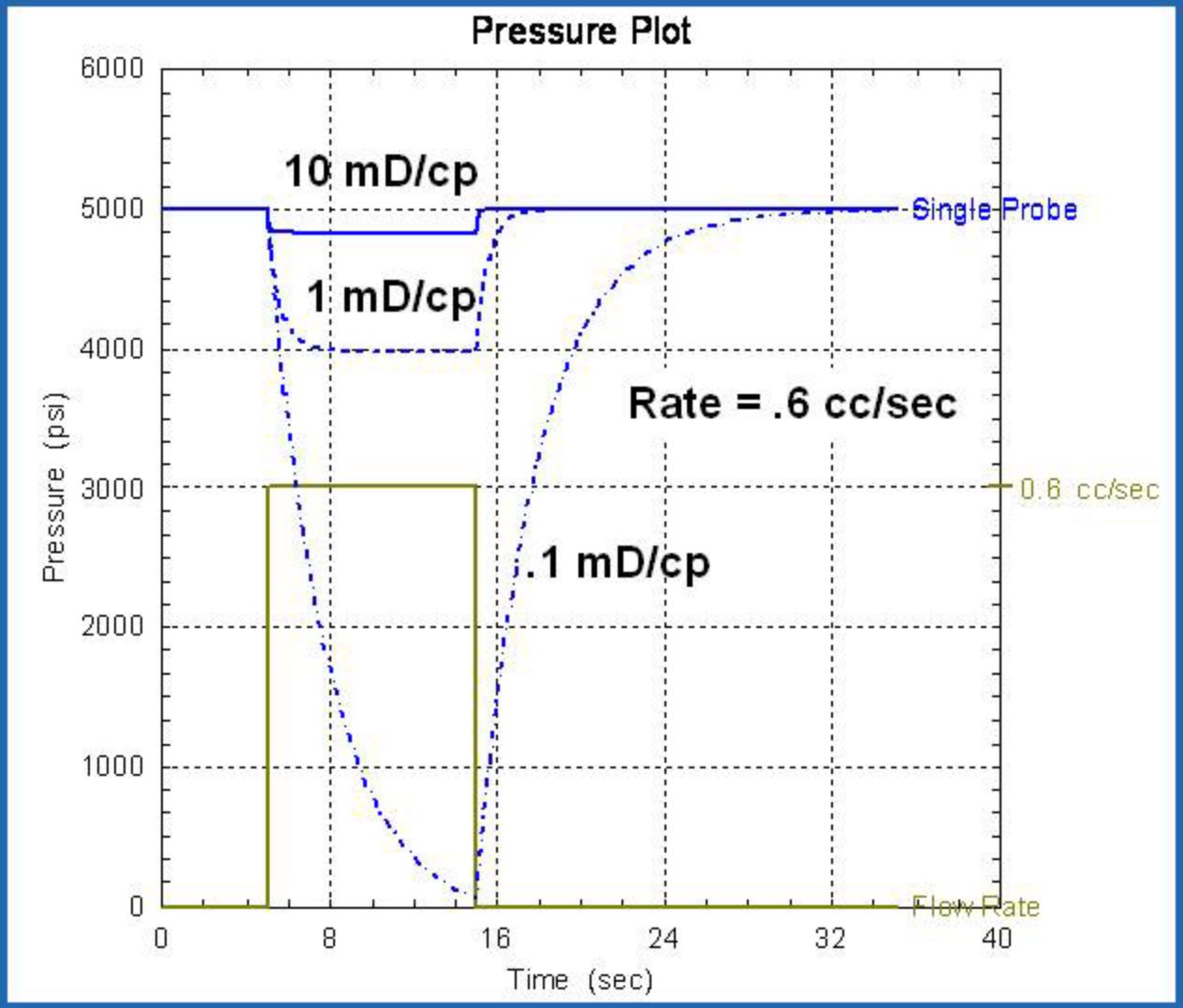
Low Perm Pretest



Low Perm Pretest



Mobility for Steady State Flow



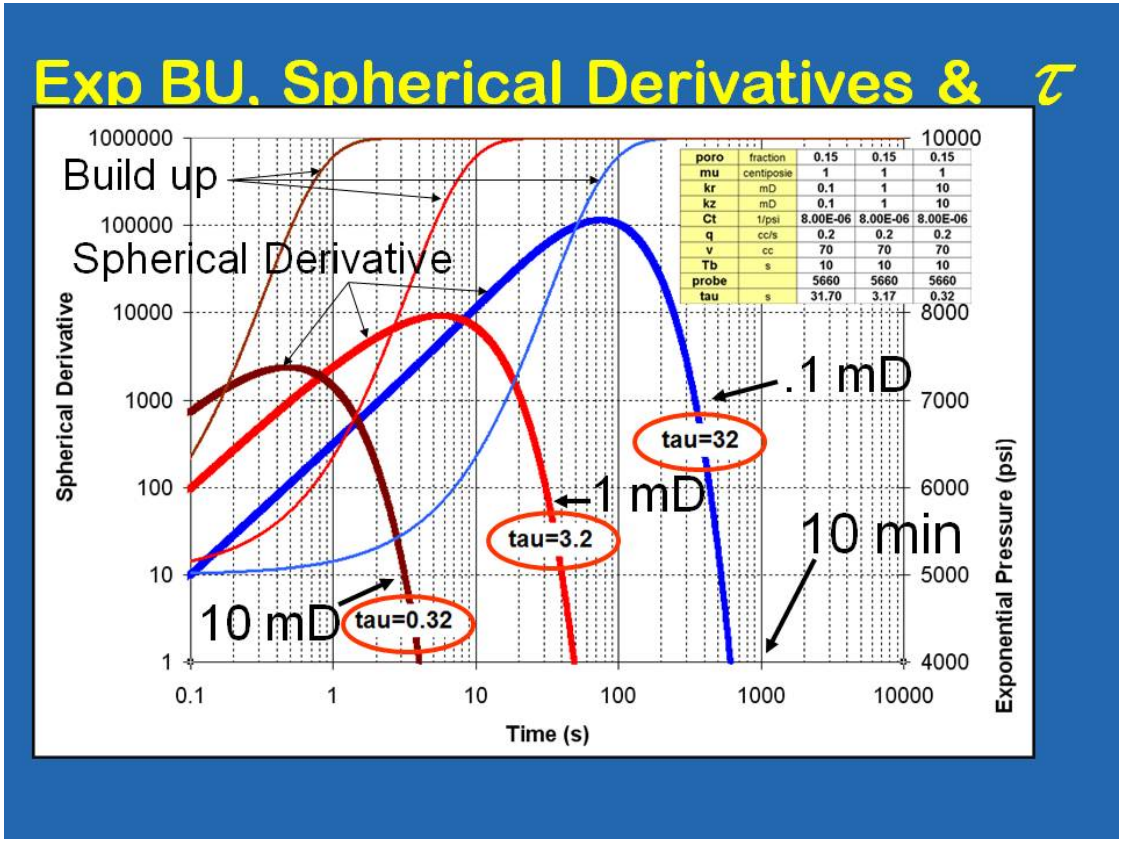
Storage Dominated Early Time Buildup

$$\Delta p(t) = \Delta p_{\max} e^{-t_b/\tau}$$

Equation 3 – Exponential form of the build-up

$$\tau = 1446 \frac{\mu}{k \times r_p} \times C_{eff} \times V_{tool}$$

Equation 4 – Tool Time Constant



Notes by Presenter:

So if we plot just this build-up function, for a given case---with no formation response, varying only formation perm we get the following pressure build ups---We can then plot the spherical derivatives for each, in the thick lines and we show the corresponding values of Tau.

As you can see in 10 md the storage effect lasts for seconds, 1 md tens of seconds, .1 md hundreds of seconds and if I plotted .01 md it could last thousands of seconds and could mask any formation effects we may be looking for like spherical and radial flow.

So one of the keys to minimizing build-up time in low perm is to keep Tau low.

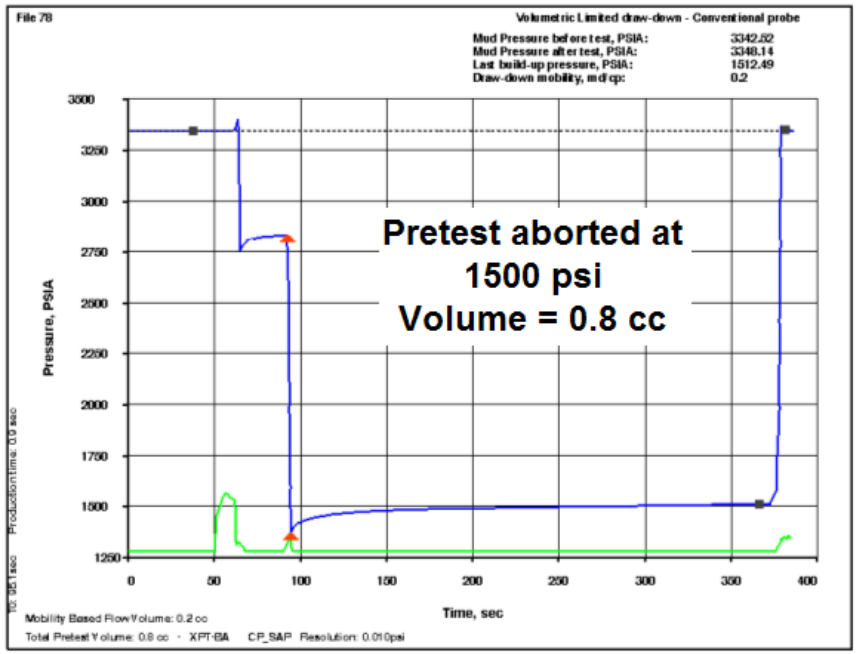
τ Parameters under our control

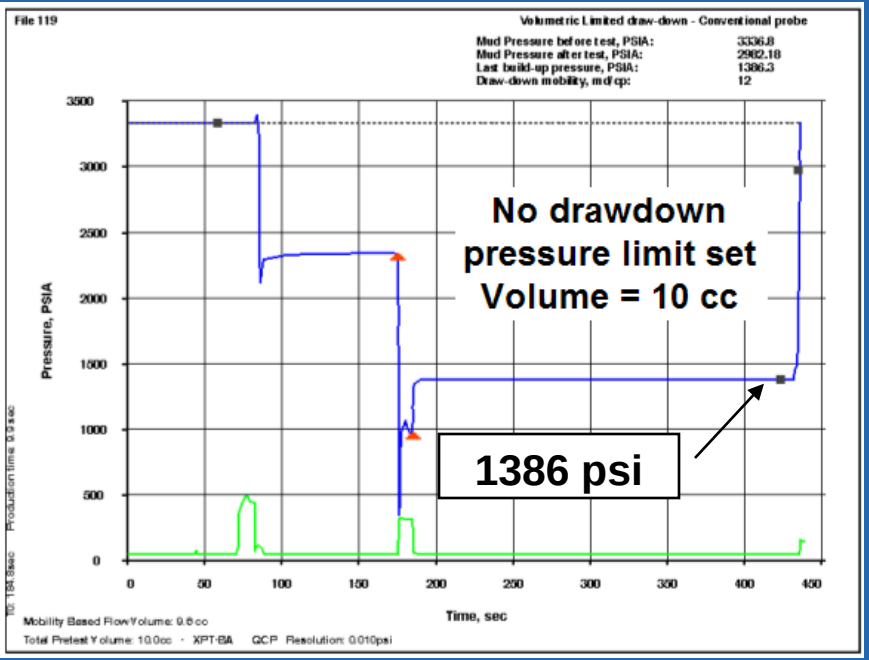
$$\tau = 1446 \frac{\mu}{k \times r_p} \times C_{eff} \times V_{tool}$$

- Probe radius
- Effective System Compressibility (fluid + tool)
- Volume of tool (flowline + pretest)

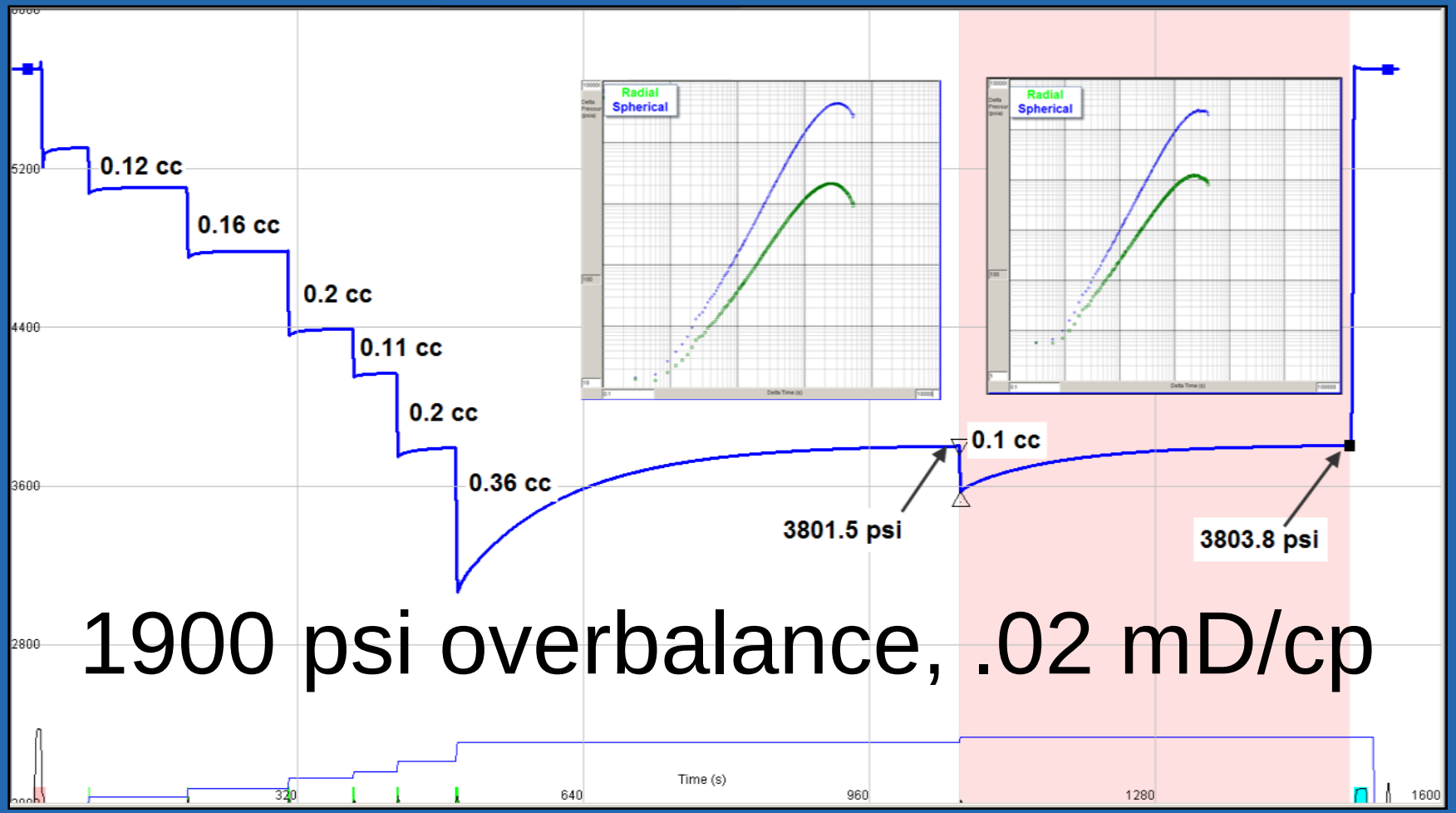
Ensuring Flowline Decompression

Lowest expected pressure 1800 psi



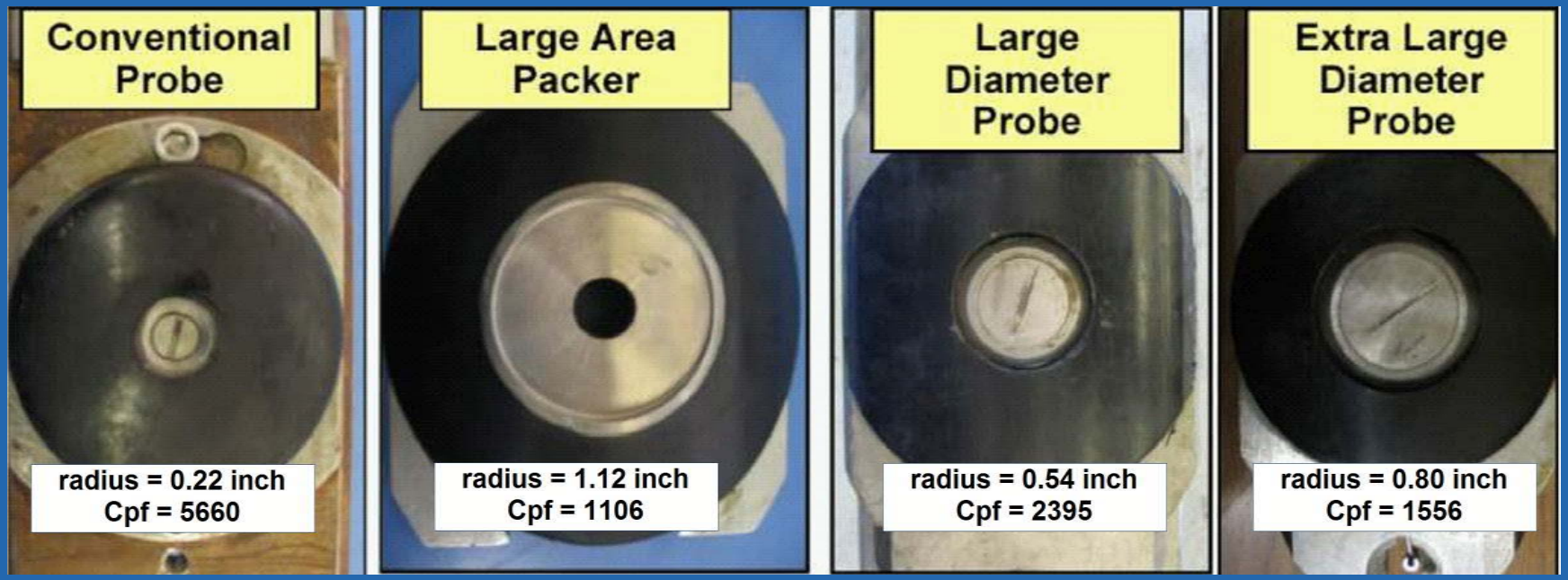


Low Mobility



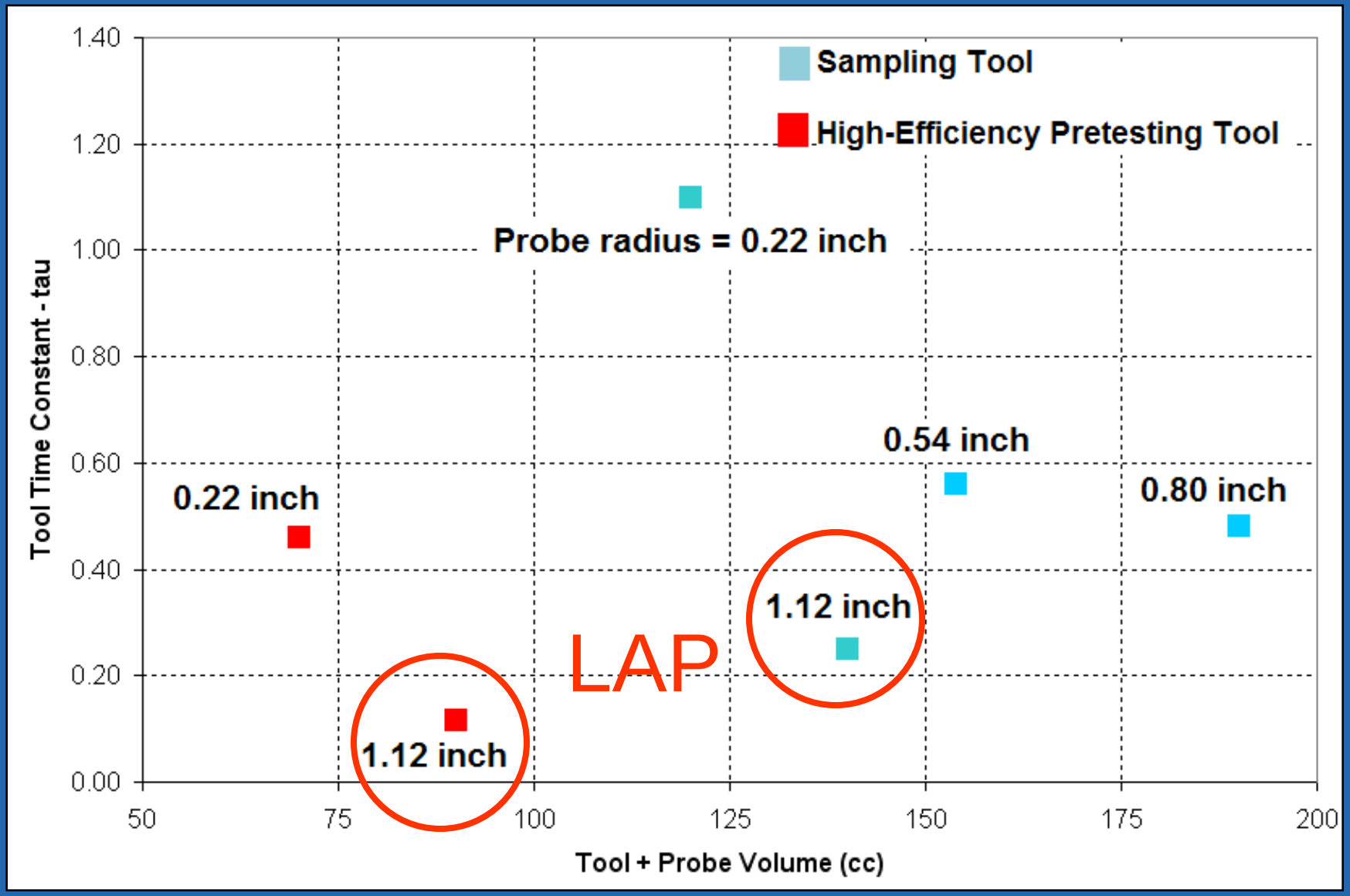
1900 psi overbalance, .02 mD/cp

Various Probes and Packers

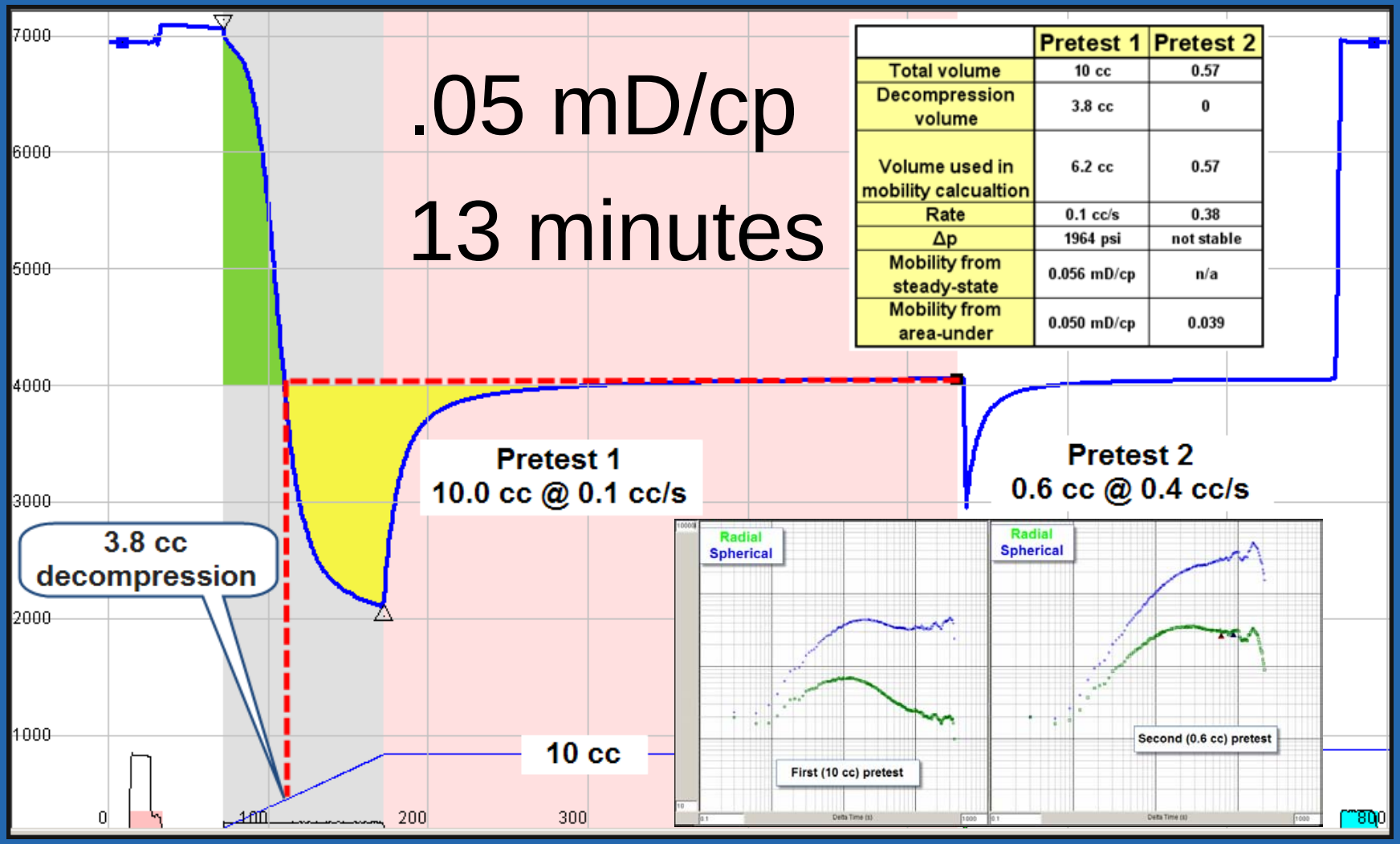


$$\tau = 1446 \frac{\mu}{k \times r_p} \times C_{eff} \times V_{tool}$$

τ verses Flowline Volume

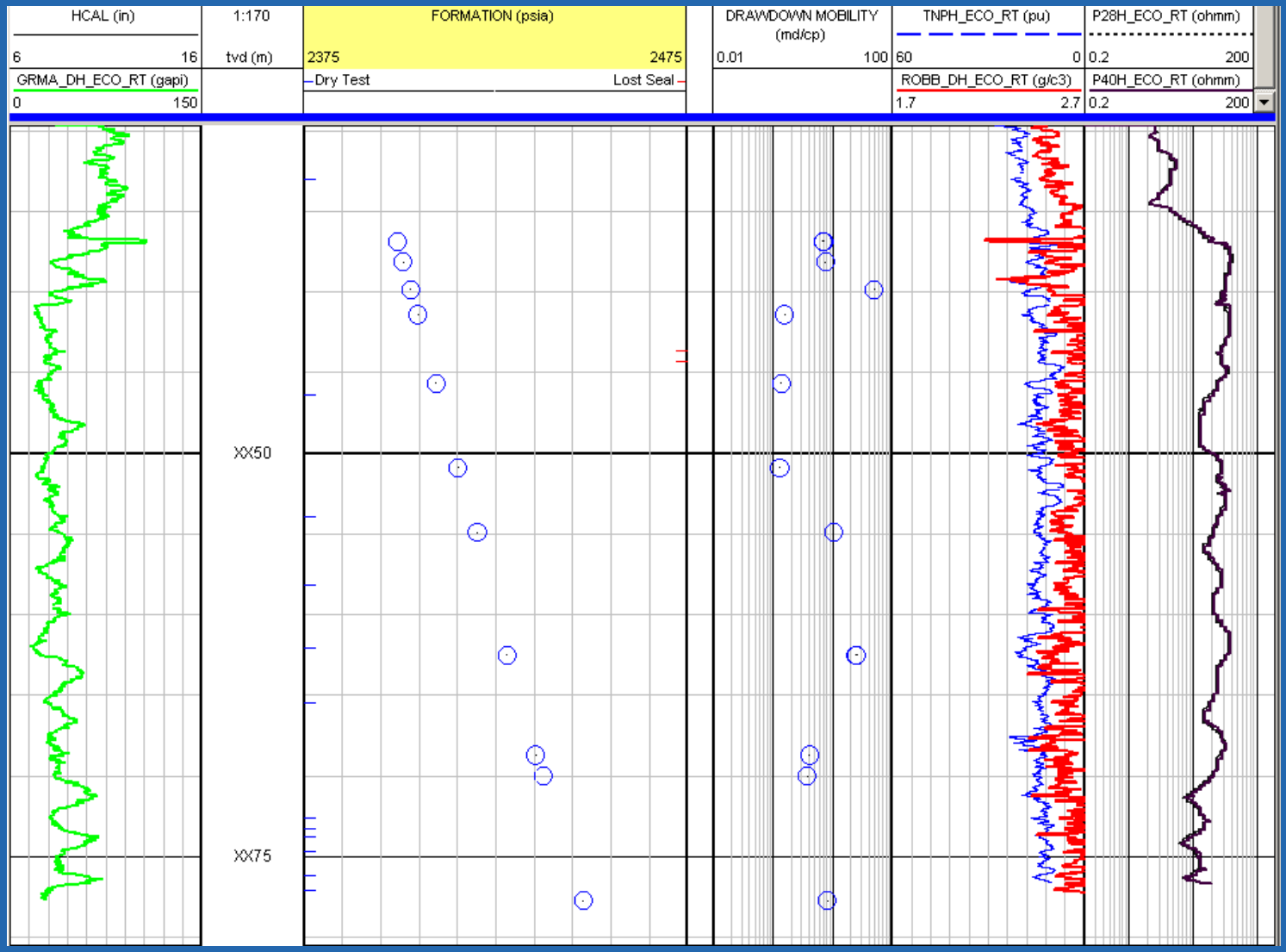


LAP – Low Mobility Example

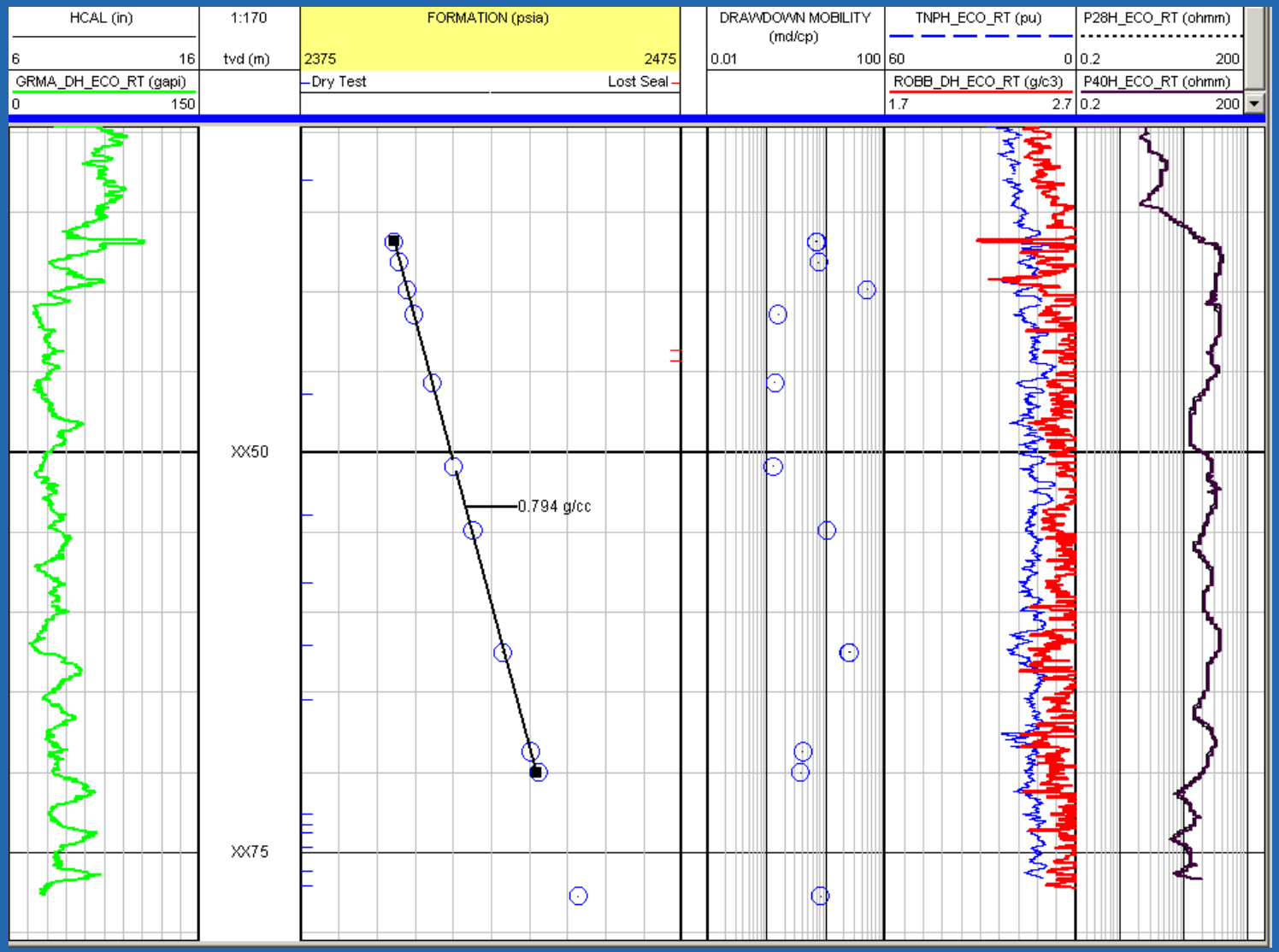


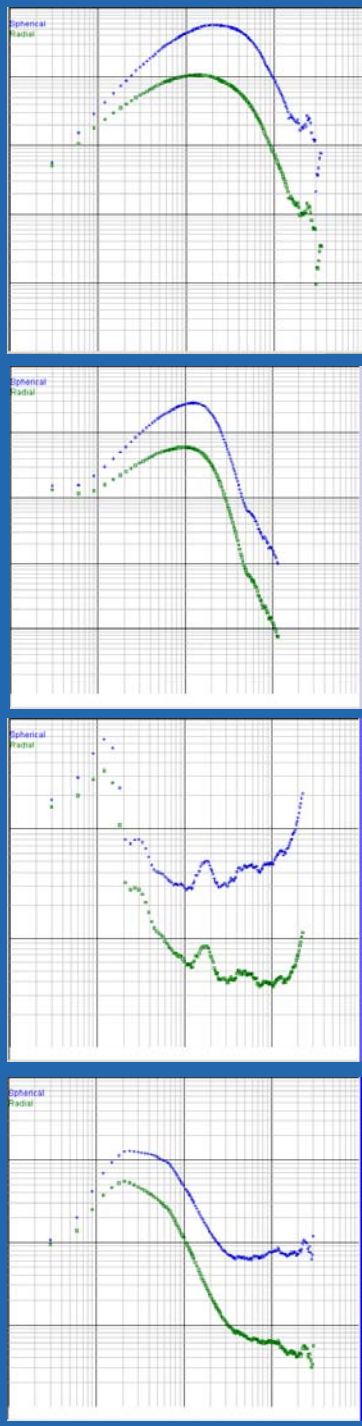
	Pretest 1	Pretest 2
Total volume	10 cc	0.57
Decompression volume	3.8 cc	0
Volume used in mobility calcualtion	6.2 cc	0.57
Rate	0.1 cc/s	0.38
Δp	1964 psi	not stable
Mobility from steady-state	0.056 mD/cp	n/a
Mobility from area-under	0.050 mD/cp	0.039

Low Mobility Environment



Low Mobility – Single Gradient





Conclusions

- Pretest formation pressures are crucial for evaluating reservoir connectivity
- Low mobility environments require careful pretest planning and execution
- A combination of improved tool design and pretest parameters can extend the limits of low mobility pretesting