2019 NAPS

NORTH AMERICA PERFORATING SYMPOSIUM

AND SAFETY FORUM

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Dynamic Overbalance vs. Dynamic Underbalance:

API 19b Section IV testing of encapsulated shaped charges compared to conventional hollow steel carrier guns

2019-NAPS-2.3

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Dynamic Overbalance vs. Dynamic Underbalance

Overview

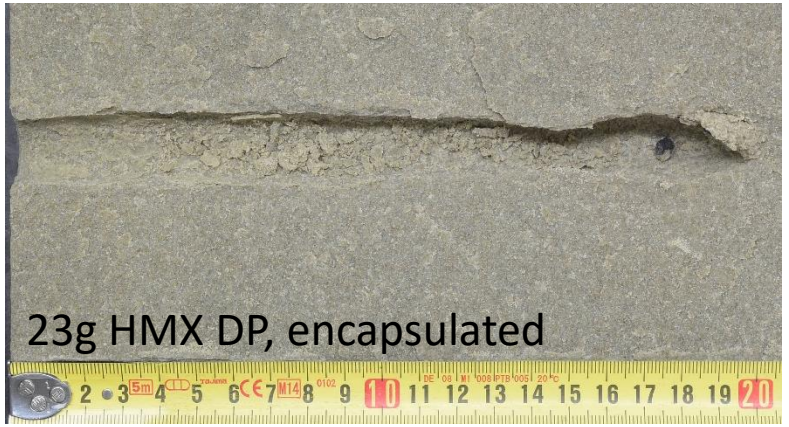
- Motivation
- Description of the test setup
- Dynamic Overbalance vs. Dynamic Underbalance vs. Extreme Dynamic Underbalance
- Differences in Productivity
- Summary and Outlook

Dynamic Overbalance vs. Dynamic Underbalance

Motivation

- Previous tests of encapsulated 23g HNS DP charges before and after temperature exposure revealed clean, open tunnels on Bentheimer Gildehaus Sandstone
- The same was observed for encapsulated 23g HMX DP charge on Berea under very high overburden pressure (20kpsi)
- Other studies also observed clean tunnels in conjunction with dynamic overbalance (SPE 189490)
- Systematic Research on the influence of DOB vs. DUB
  - Influence of DOB and DUB on tunnel geometry and flow?
  - How does the permeability and porosity of the rock influence the results?

Bentheimer



Berea

Dynamic Overbalance vs. Dynamic Underbalance

Test Setup

- Shaped Charge: 15g HMX, Deep penetrating, standard and encapsulated

Rocks	UCS [psi]	Porosity [%]	Permeability [mD]
Bentheimer	3.500 - 4.500	20 - 22	800 - 1.600
Berea	8.000 - 9.000	17 - 18	95 - 120
Roter Bunt	9.000 - 10.500	10 - 14	3 - 20

Free Gun Volume (FGV)	Equivalent to
1130 cm^3	0.66 spf in a 2 7/8" Gun
	2 spf in a 4.5" Gun
125 cm^3	6 spf in a 2 7/8" Gun
	18 spf in a 4.5" Gun
0 cm^3	Encapsulated charge system

Dynamic Overbalance vs. Dynamic Underbalance

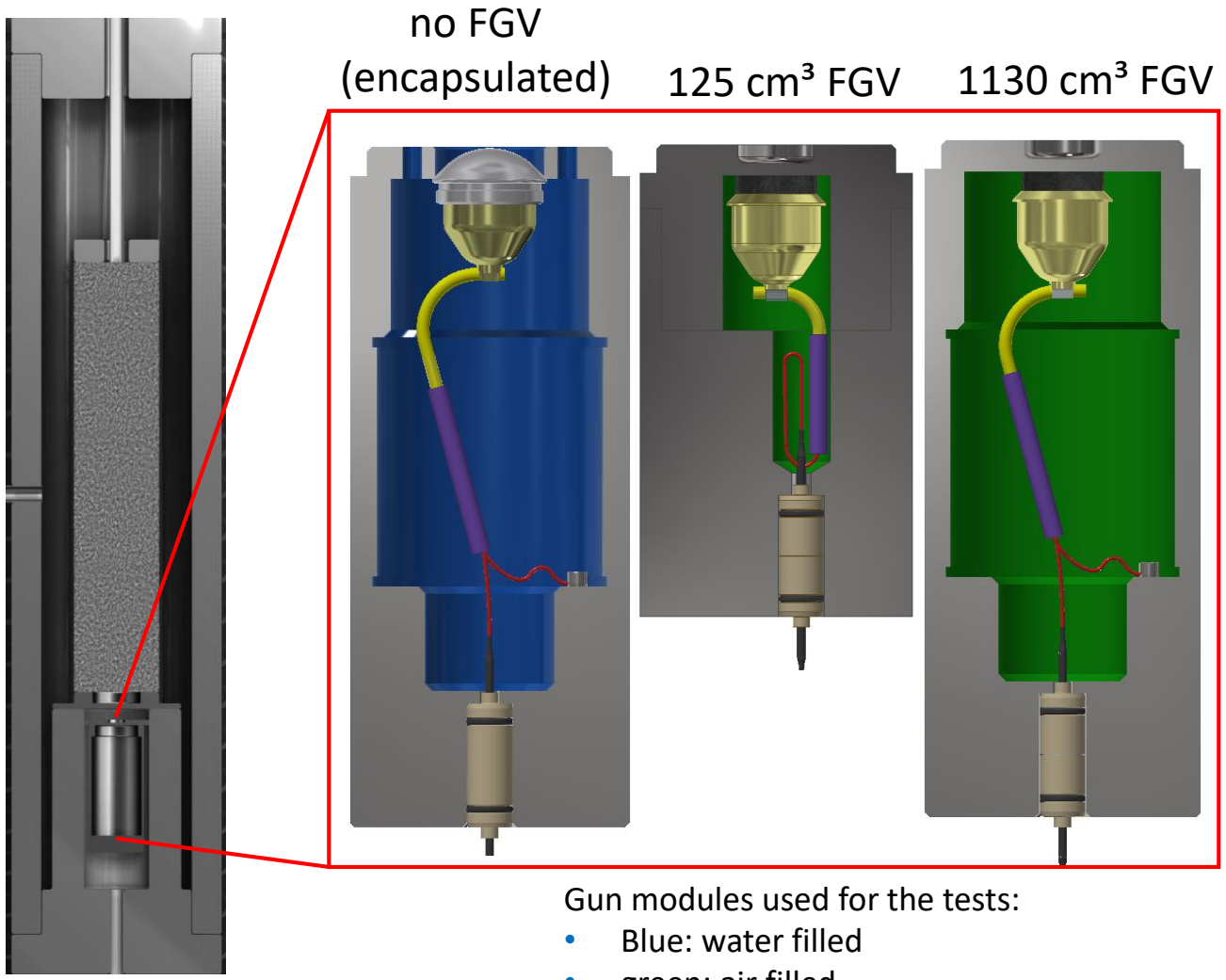
Test Setup

Balanced conditions:

- Overburden Pressure: 6500 psi
- Pore pressure: 3000 psi
- Wellbore pressure: 3000 psi
- Fluid: OMS
- Accumulators activated

Gun volumes:

- Extreme DUB: 1130cm³
- Conventional DUB: 125cm³
- DOB: Encapsulated charge directly in fluid

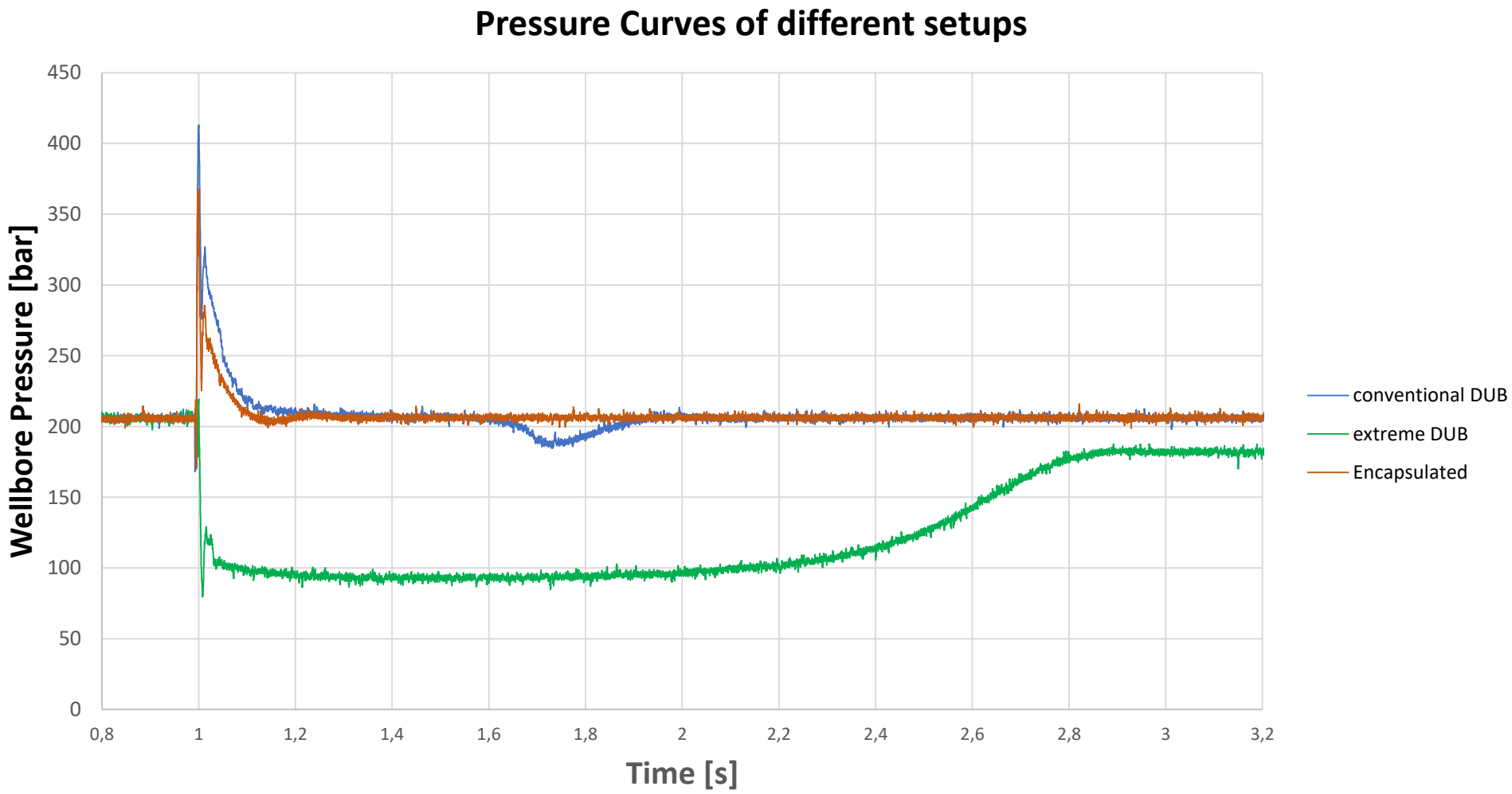


Gun modules used for the tests:

- Blue: water filled
- green: air filled

Dynamic Overbalance vs. Dynamic Underbalance

Results



Dynamic Overbalance vs. Dynamic Underbalance

Results – Extreme DUB

Bentheimer

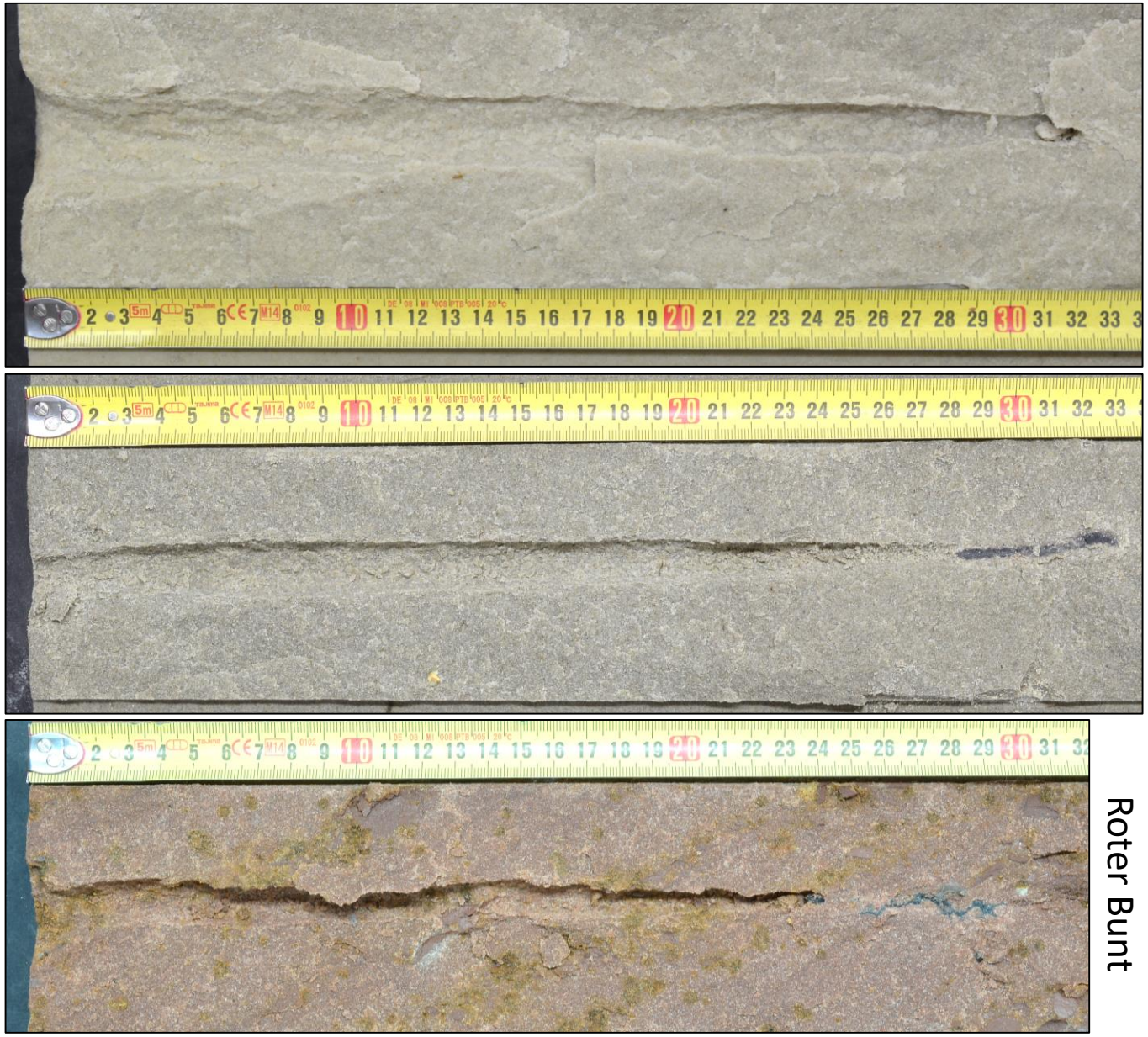
- TTP: 14.44”
- Clear Tunnel Depth: 14.44”
- Tunnel Volume: 113.0 cm³

Berea

- TTP: 14.20”
- Clear Tunnel Depth: 12.35”
- Tunnel Volume: 41.5 cm³

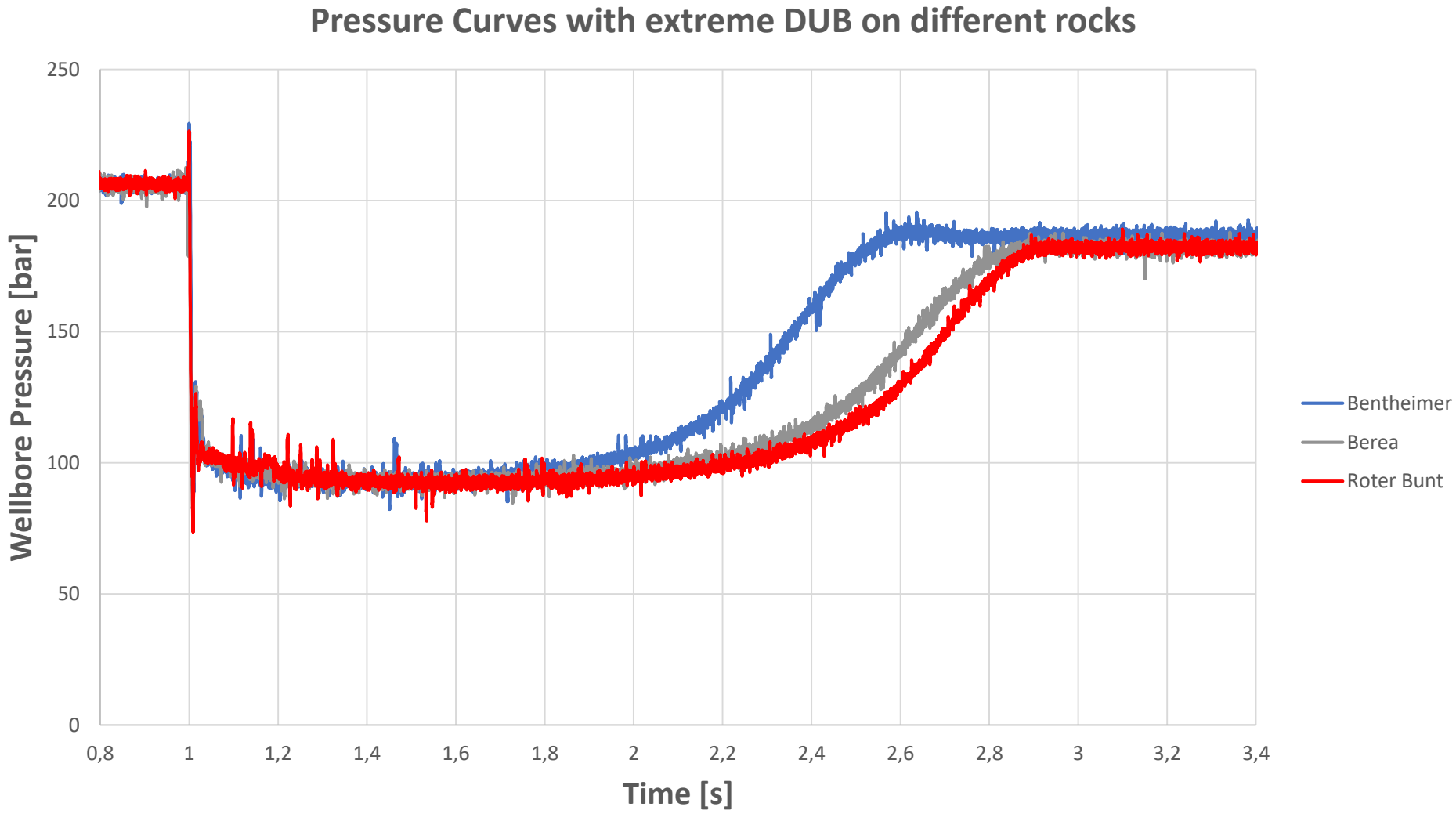
Roter Bunt

- TTP: 12.98”
- Clear Tunnel Depth: 10.66”
- Tunnel Volume: 20.6 cm³



Dynamic Overbalance vs. Dynamic Underbalance

Results – Extreme DUB



Dynamic Overbalance vs. Dynamic Underbalance

Results – normal DUB

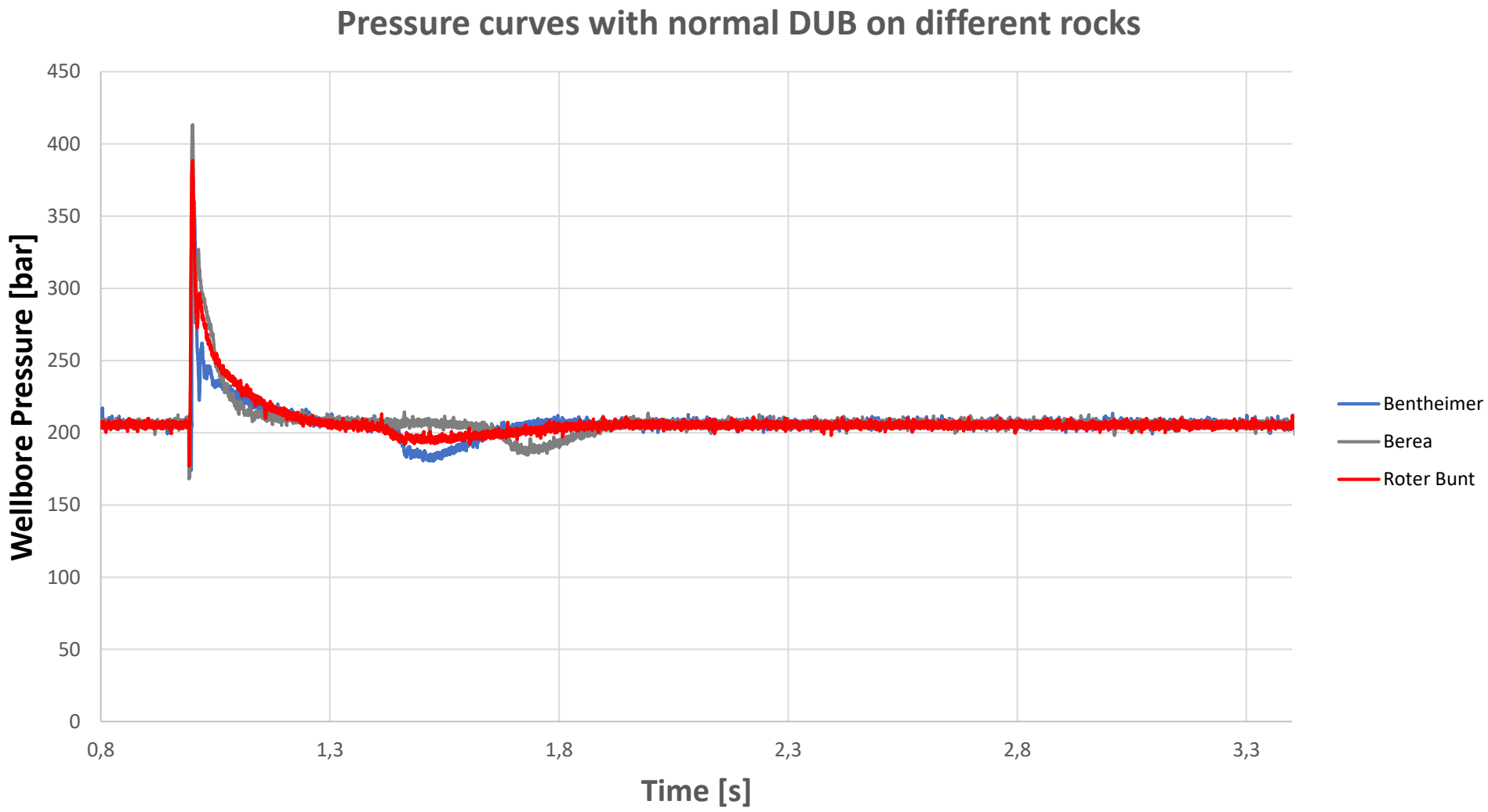
Bentheimer
- TTP: 13.84”
- Clear Tunnel Depth: 4.52”
- Tunnel Volume: 49.0 cm³

Berea
- TTP: 12.66”
- Clear Tunnel Depth: 8.27”
- Tunnel Volume: 35.1 cm³

Roter Bunt
- TTP: 13.57”
- Clear Tunnel Depth: 7.51”
- Tunnel Volume: 23.0 cm³

Dynamic Overbalance vs. Dynamic Underbalance

Results – normal DUB



Dynamic Overbalance vs. Dynamic Underbalance

Results – DOB

Bentheimer

- TTP: 14.36”
- Clear Tunnel Depth: 14.36”
- Tunnel Volume: 101.0 cm³

Berea

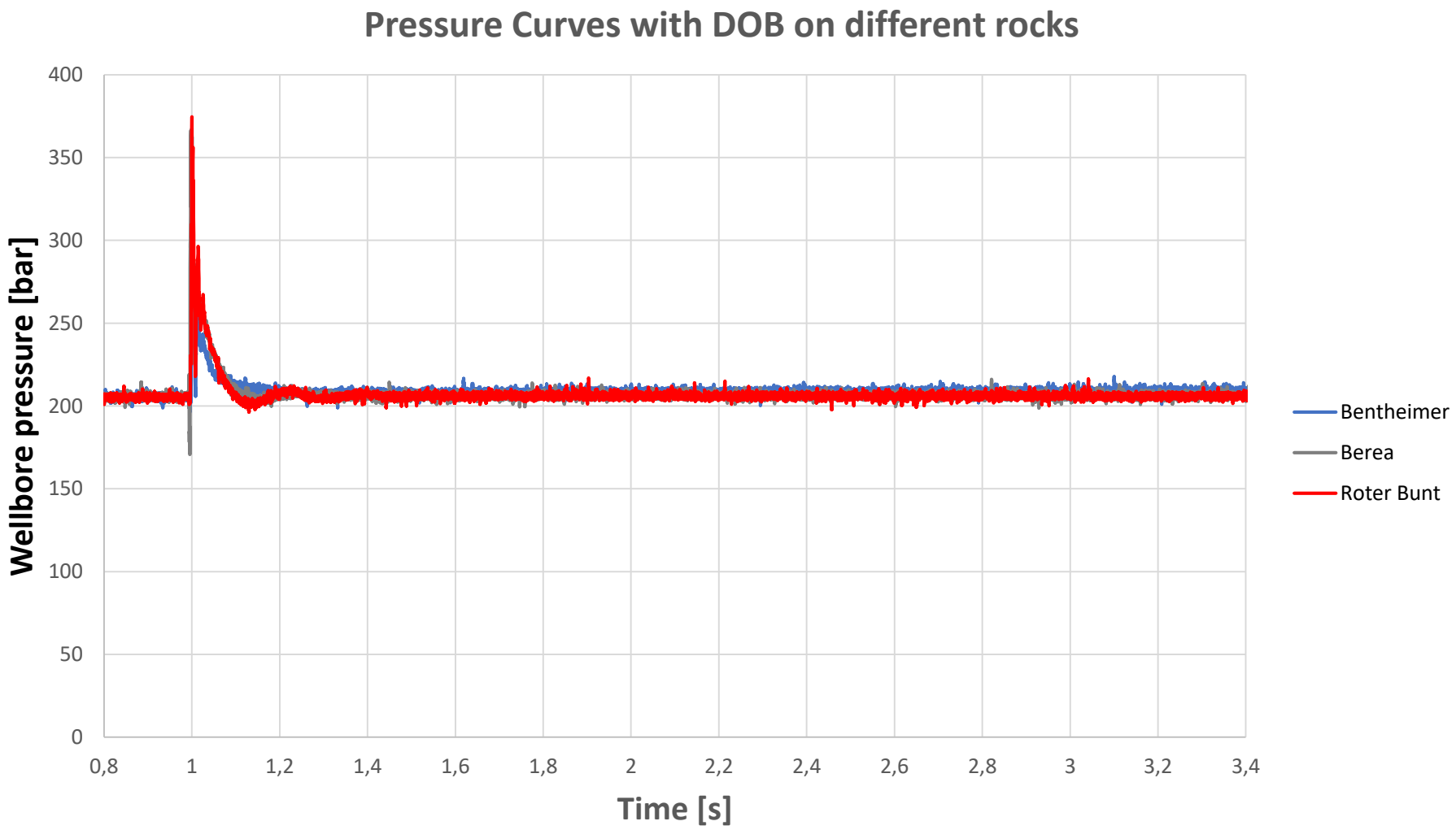
- TTP: 12.39”
- Clear Tunnel Depth: 12.39”
- Tunnel Volume: 46.9 cm³

Roter Bunt

- TTP: 12.47”
- Clear Tunnel Depth: 3.30”
- Tunnel Volume: 6.1 cm³

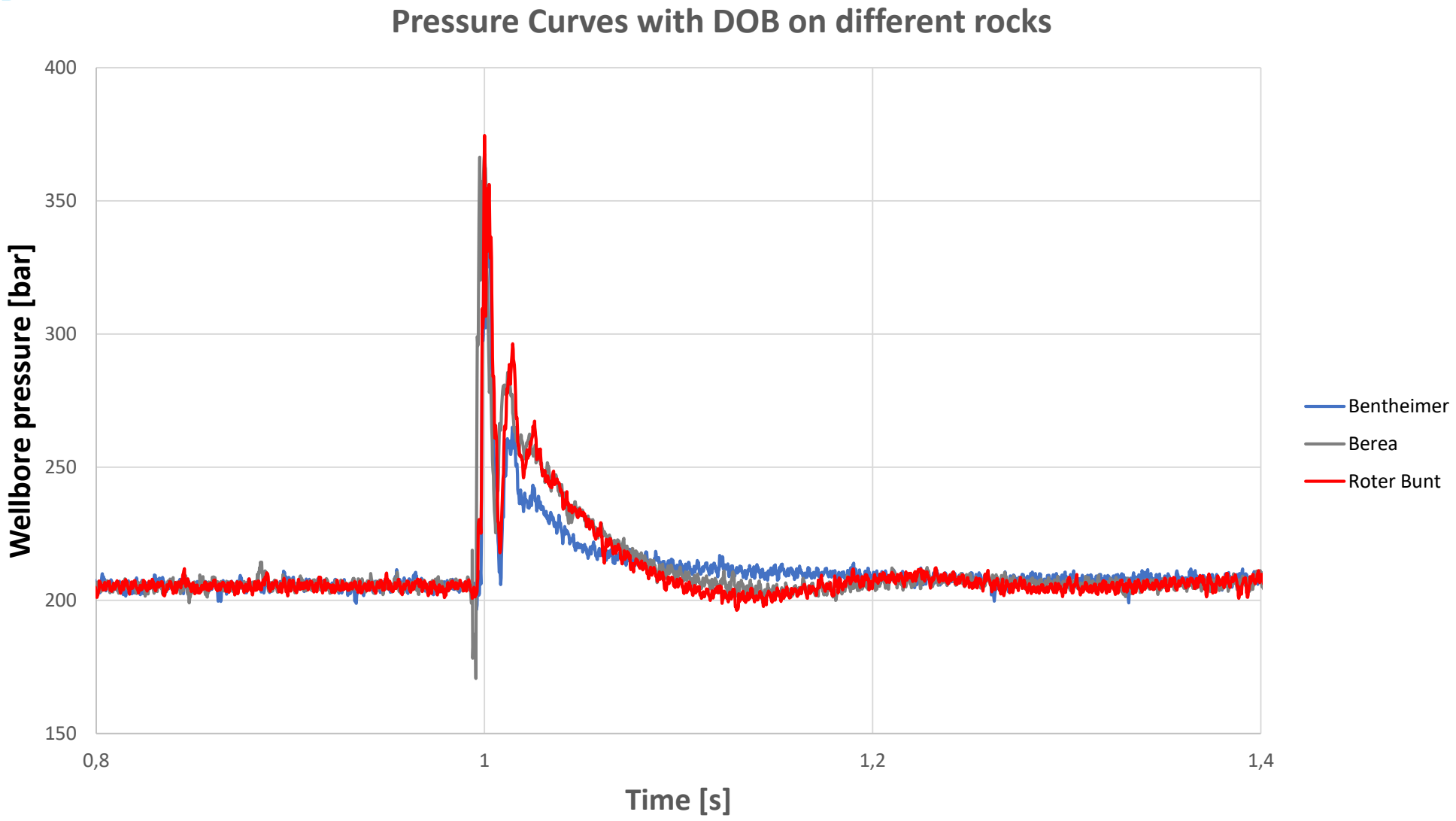
Dynamic Overbalance vs. Dynamic Underbalance

Results – DOB



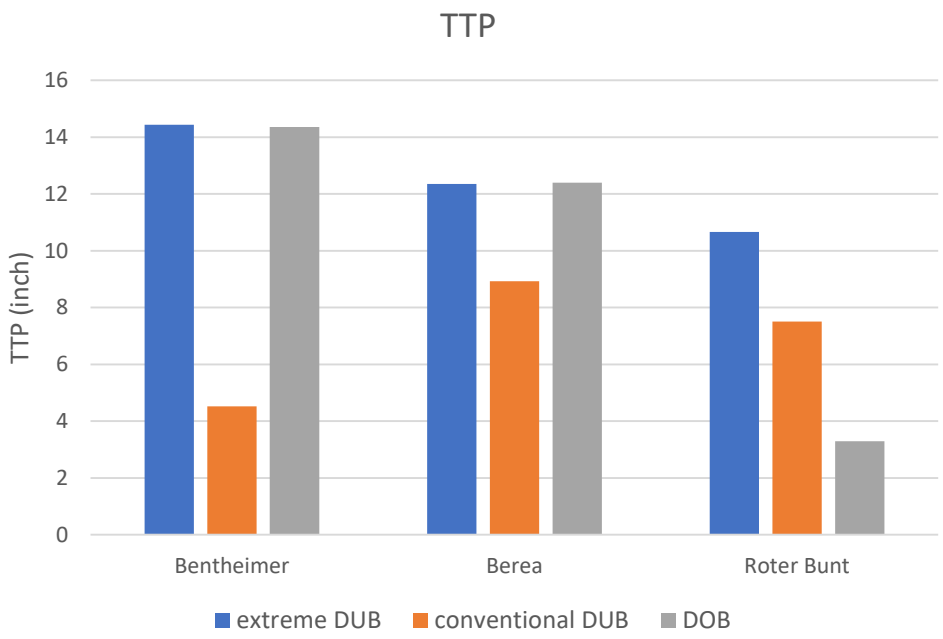
Dynamic Overbalance vs. Dynamic Underbalance

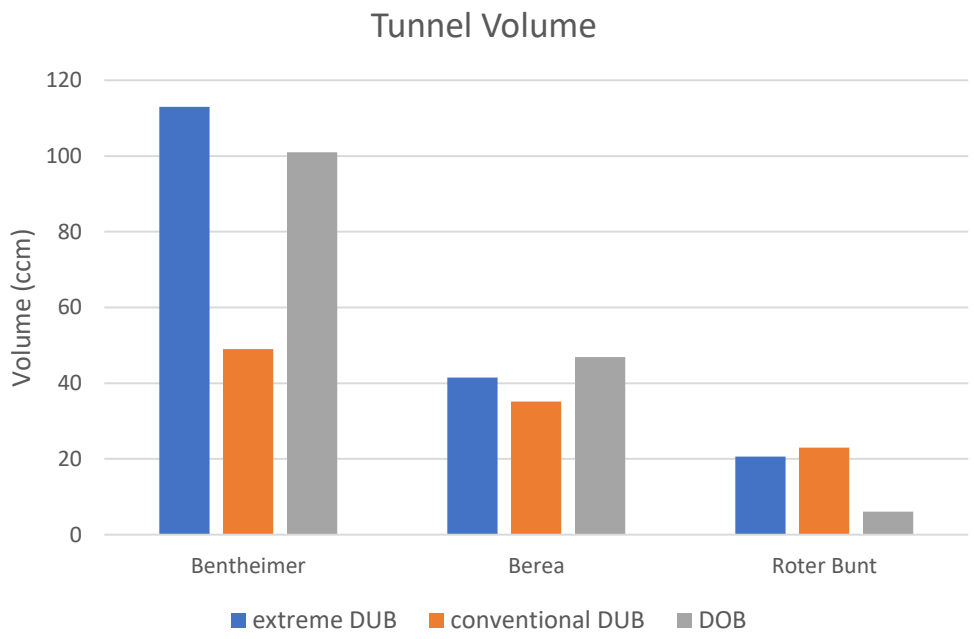
Results – DOB



Dynamic Overbalance vs. Dynamic Underbalance

Results





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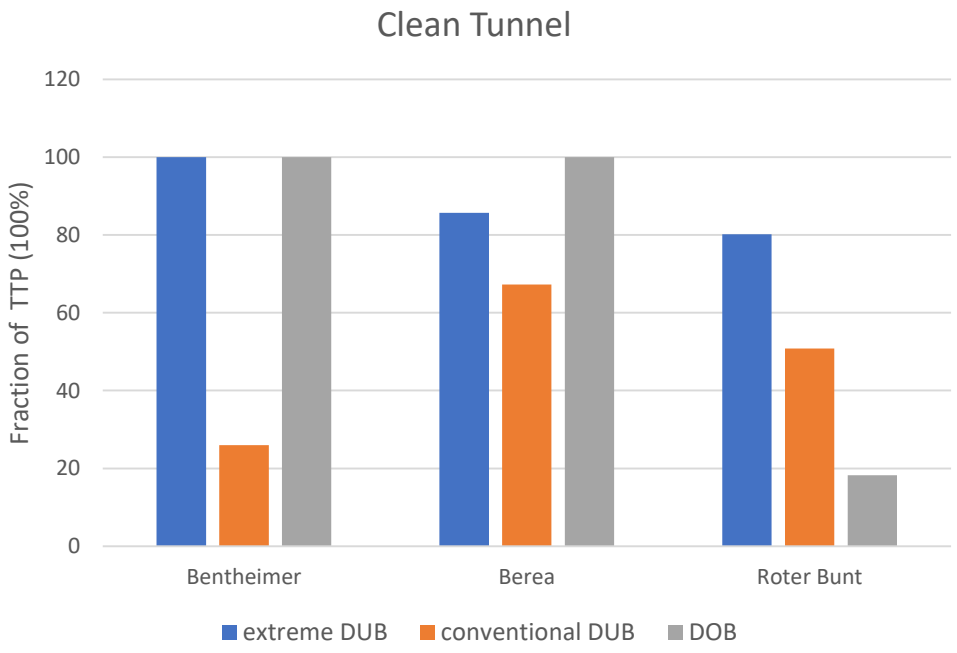
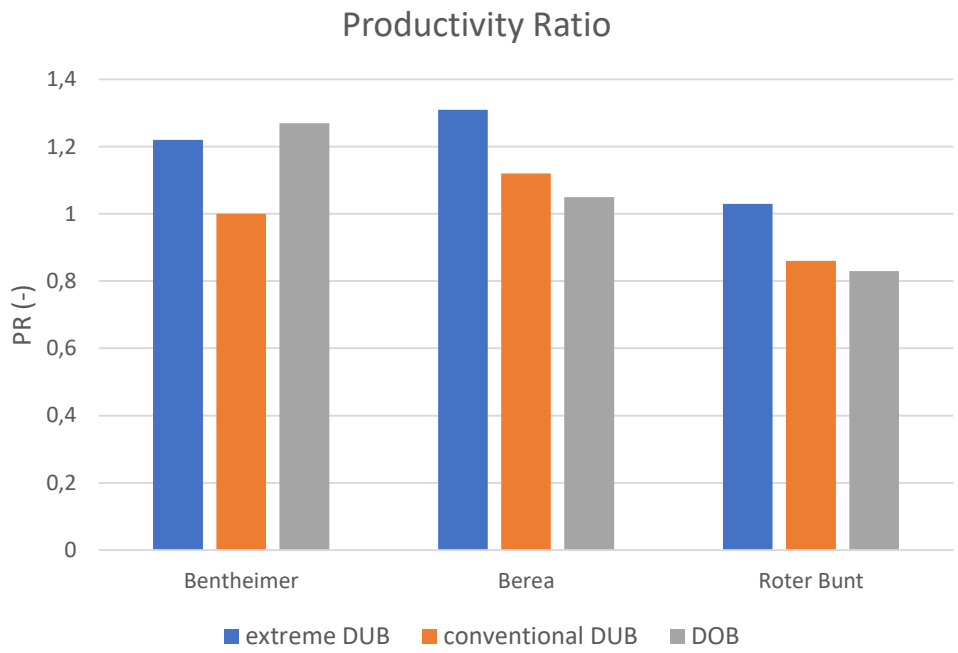
Results





Dynamic Overbalance vs. Dynamic Underbalance

Observations

- As expected a more realistic free gun volume lead to a reduction in DUB and free tunnel length compared to tests with very large free gun volumes.
- Encapsulated charges create an dynamic overbalance which is comparable to conventional hollow carrier guns with 6spf, but without any DUB
- However encapsulated charges created on average cleaner tunnels than charges shot in normal guns
- Hypothesis: for conventional guns the gas stream escaping through the gun scallop hole disturbs flow dynamics
- Positive effect of DOB on free tunnel length decreases with decreasing permeability
- Transient behavior of DUB and DOB depend on rock permeability
- No obvious tip fractures visible on sandstone for all setups

Dynamic Overbalance vs. Dynamic Underbalance

Outlook

- Broaden the study to different rocks, like carbonates, quartzite and other
- Deduce CFE values
- Research on the underlying physics
  - FEM Modelling of the fluid dynamics
  - Petrophysical investigation of differences in crushed zone strength (SPE 122845)
- Review the influence of the test setup

References

- Satti, R., White, R., Ochsner, D., Sampson, T., Zuklic, S., & Geerts, S. (2018, February 7). A Flow Laboratory Study of an Enhanced Perforating System Designed for Well Stimulation. Society of Petroleum Engineers. doi:10.2118/189490-MS
- Heiland, J. C., Grove, B. M., Harvey, J. P., Walton, I. C., & Martin, A. J. (2009, January 1). New fundamental insights into perforation-induced formation damage. Society of Petroleum Engineers. doi:10.2118/122845-MS

QUESTIONS?

THANK YOU

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