Hydrocarbon production characterization during huff-n-puff EOR using NMR and Hawk® pyrolysis.

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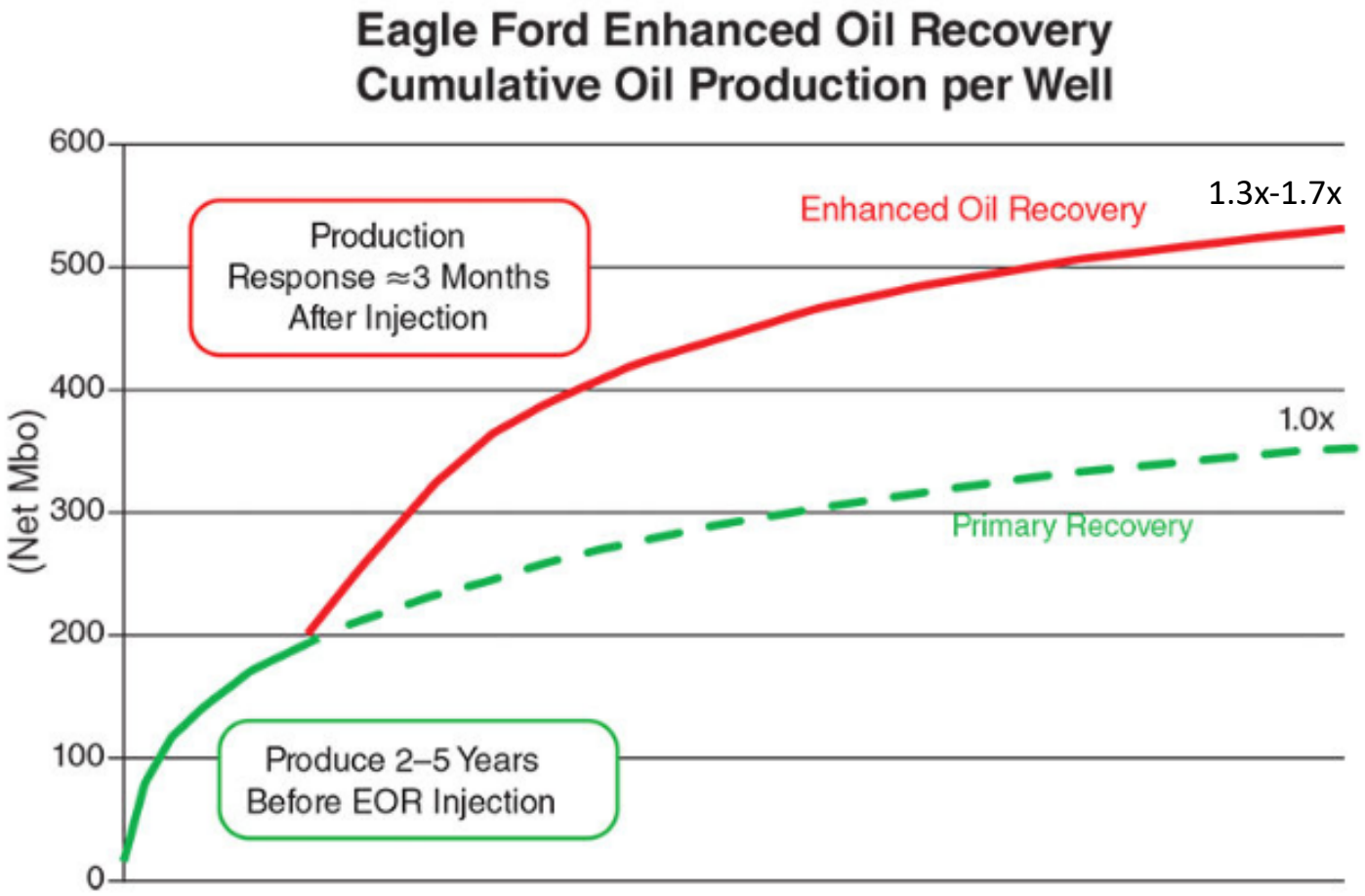
Introduction



EOG resources

EOG first company to achieve field scale EOR success in an unconventional play
Additional recovery from 32 wells (30-70%) improvement

?

Objectives

- Evaluate the effect of the type of solvent on EOR Huff-n-Puff.
- Provide EOR candidate selection using NMR and HAWK ® dry Pyrolysis.

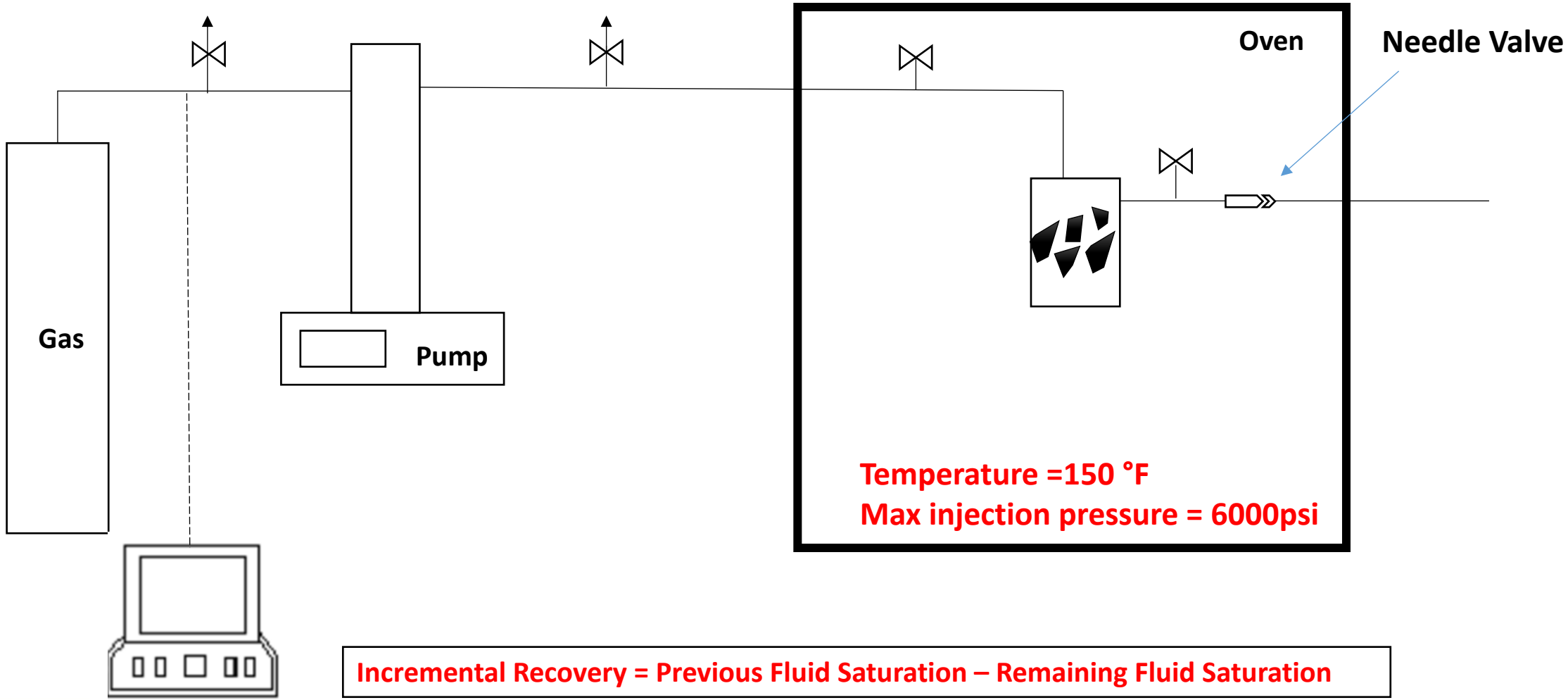
Sample description

Sample	Total Porosity (%)	TOC (wt.%)	Total Clays (wt.%)	Total Carbonates (wt.%)	Quartz+Feldspar (wt.%)	Others
Eagle Ford	5.1	4.9	16	62	13	8

Crushed sample (7-8mm)

Sample received in preserved state.

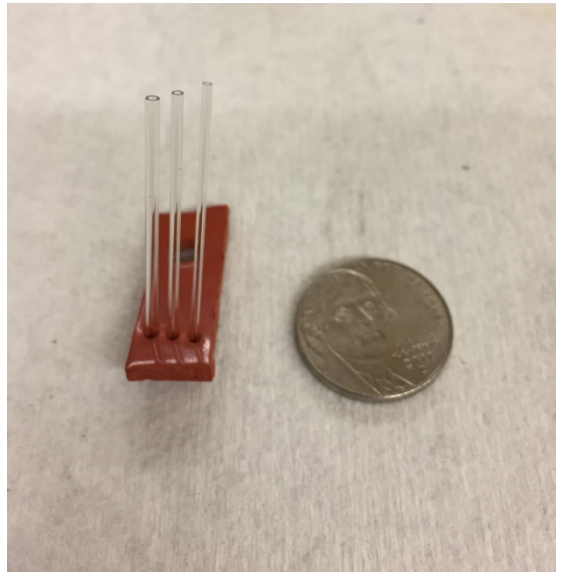
Huff-n-Puff experimental apparatus



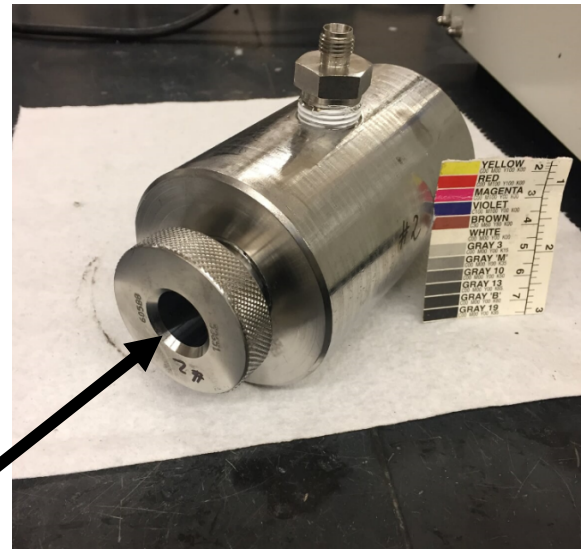
Incremental Recovery = Previous Fluid Saturation – Remaining Fluid Saturation

MMP studies

MMP is the pressure at which the interfacial tension between a gas and fluid disappear. (Rao et al,2000)



Capillary tubes

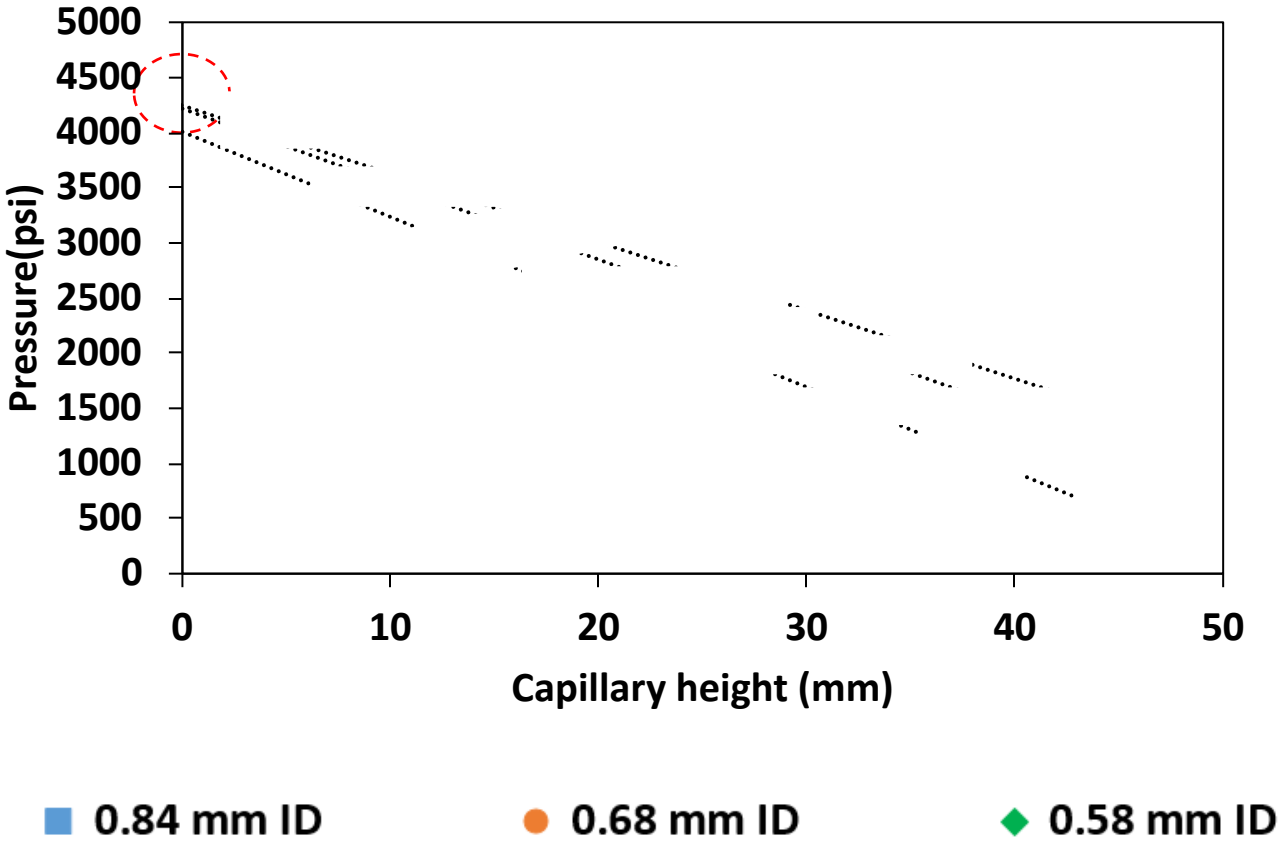


Window

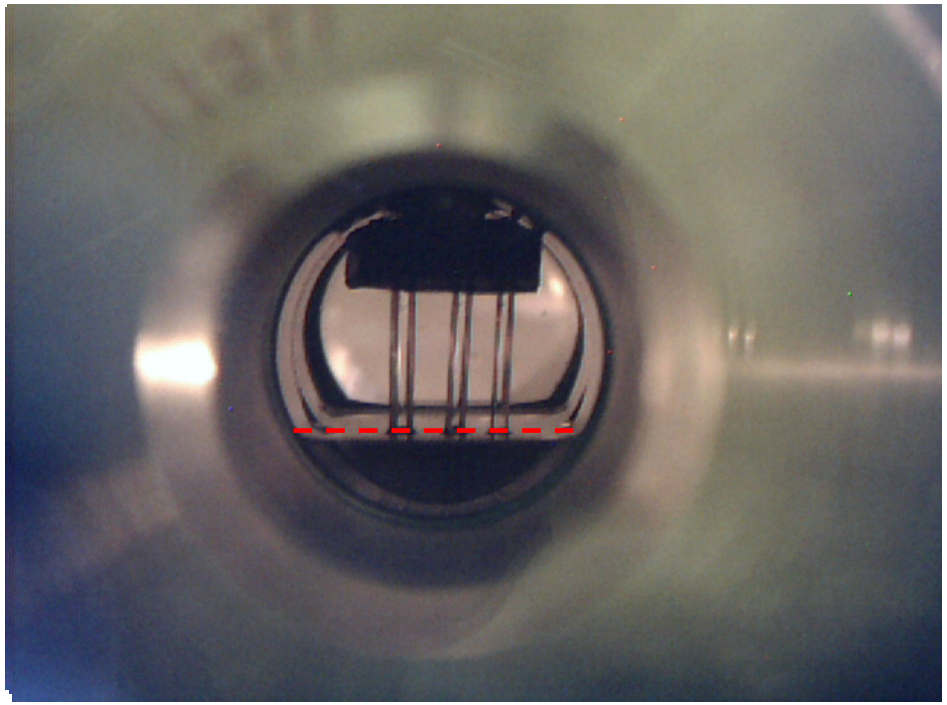
Sight feed indicator

Hawthorne et al, 2014

Minimum Miscibility Pressure –Vanishing Interfacial Tension



T= 150 ° F



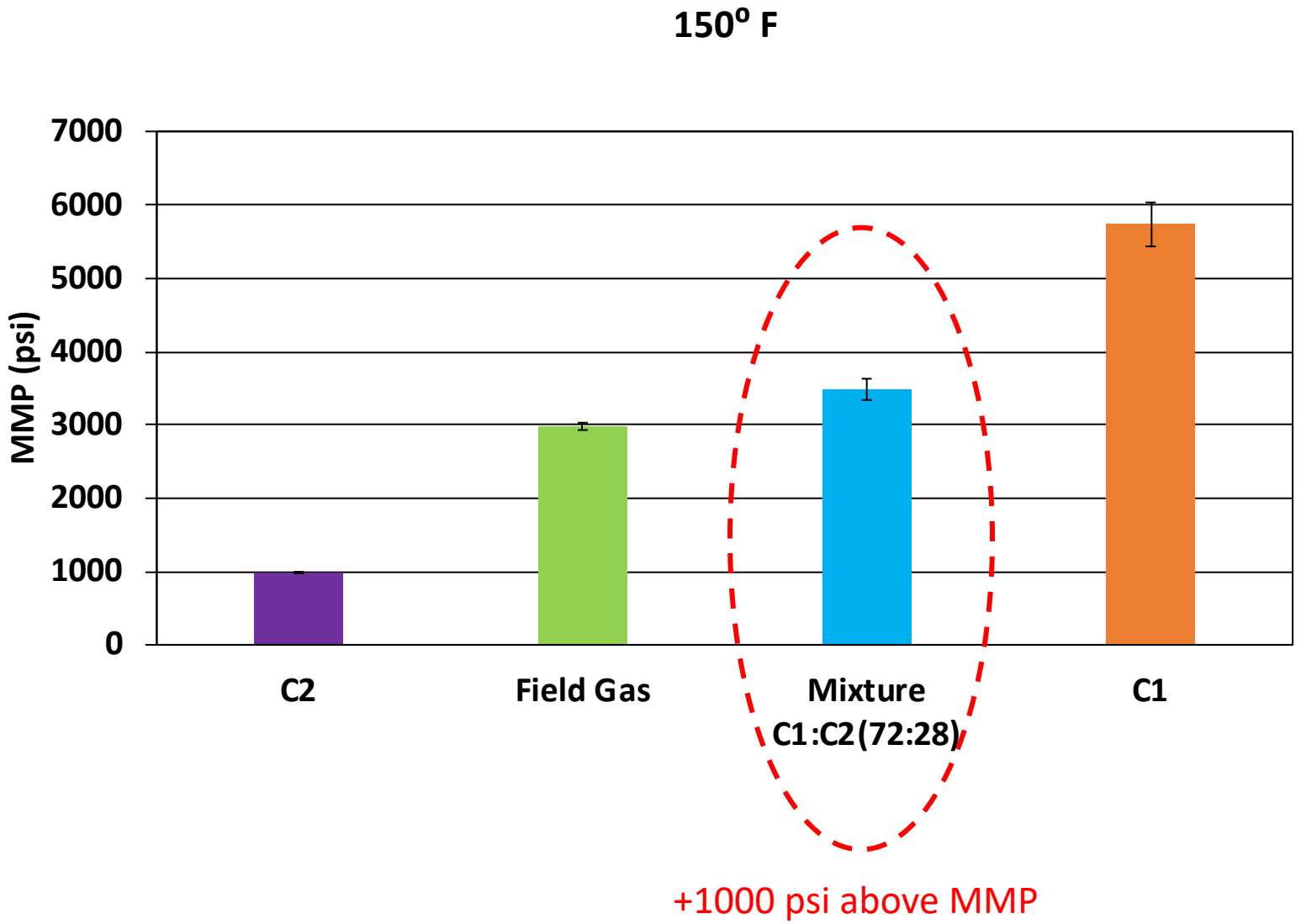
Dodecane
Methane injection

MMP(psi)	Error (psi)
4132	±140

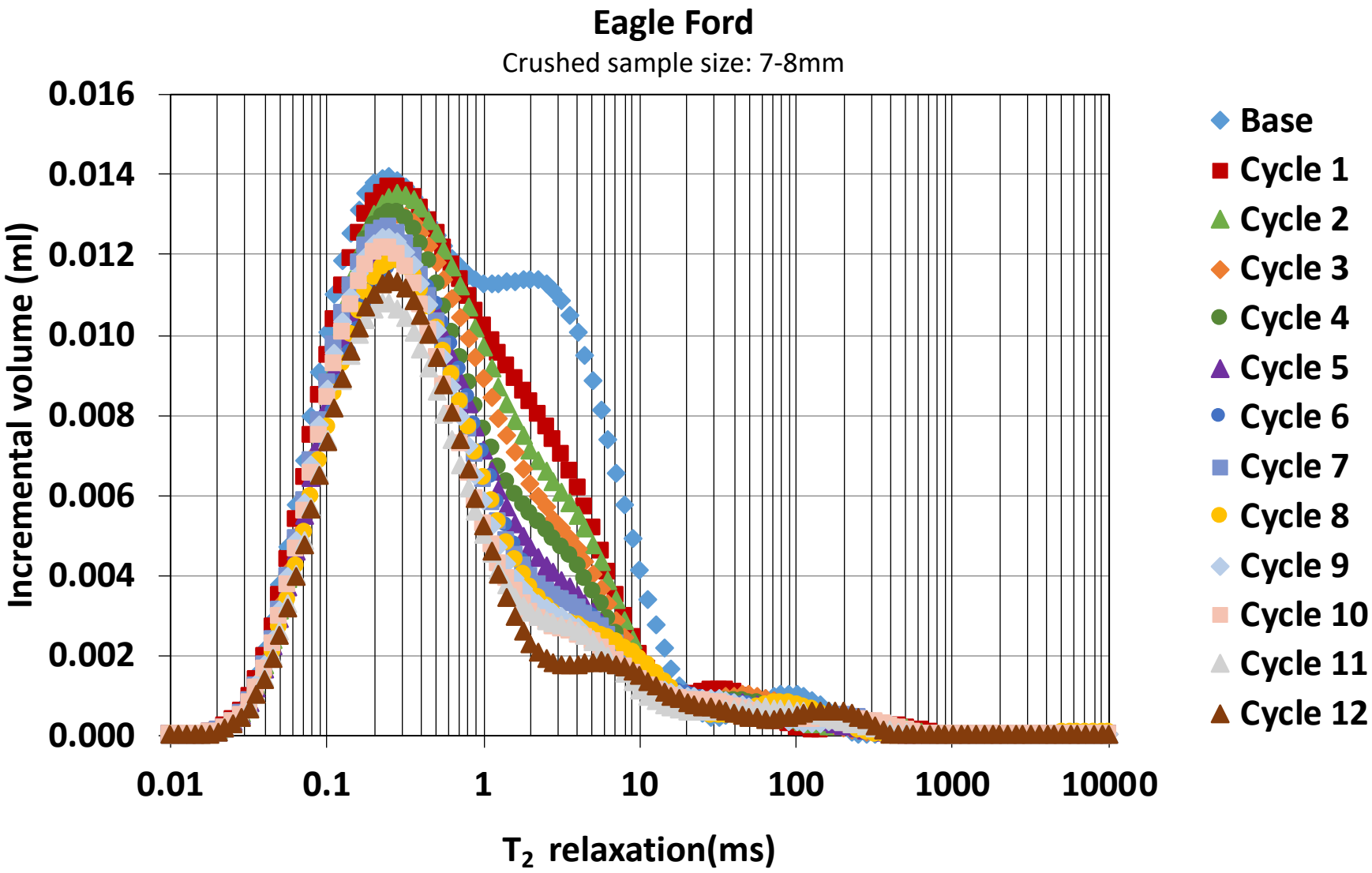
Multiple mixing cell
MMP = 4116 psi

Hawthorne, 2014

Minimum Miscibility Pressure –Vanishing Interfacial Tension



NMR responses during Huff-n-Puff



T=150 °F
Injection Pressure = +1000psi above MMP
Mixture C1:C2 (72:28)
1 hour soaking
1 hour production
22-25 grams

12MHz NMR
τ =57 µs
SNR>100

NMR responses during Huff-n-Puff

T=150 °F
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Mixture C1:C2 (72:28)
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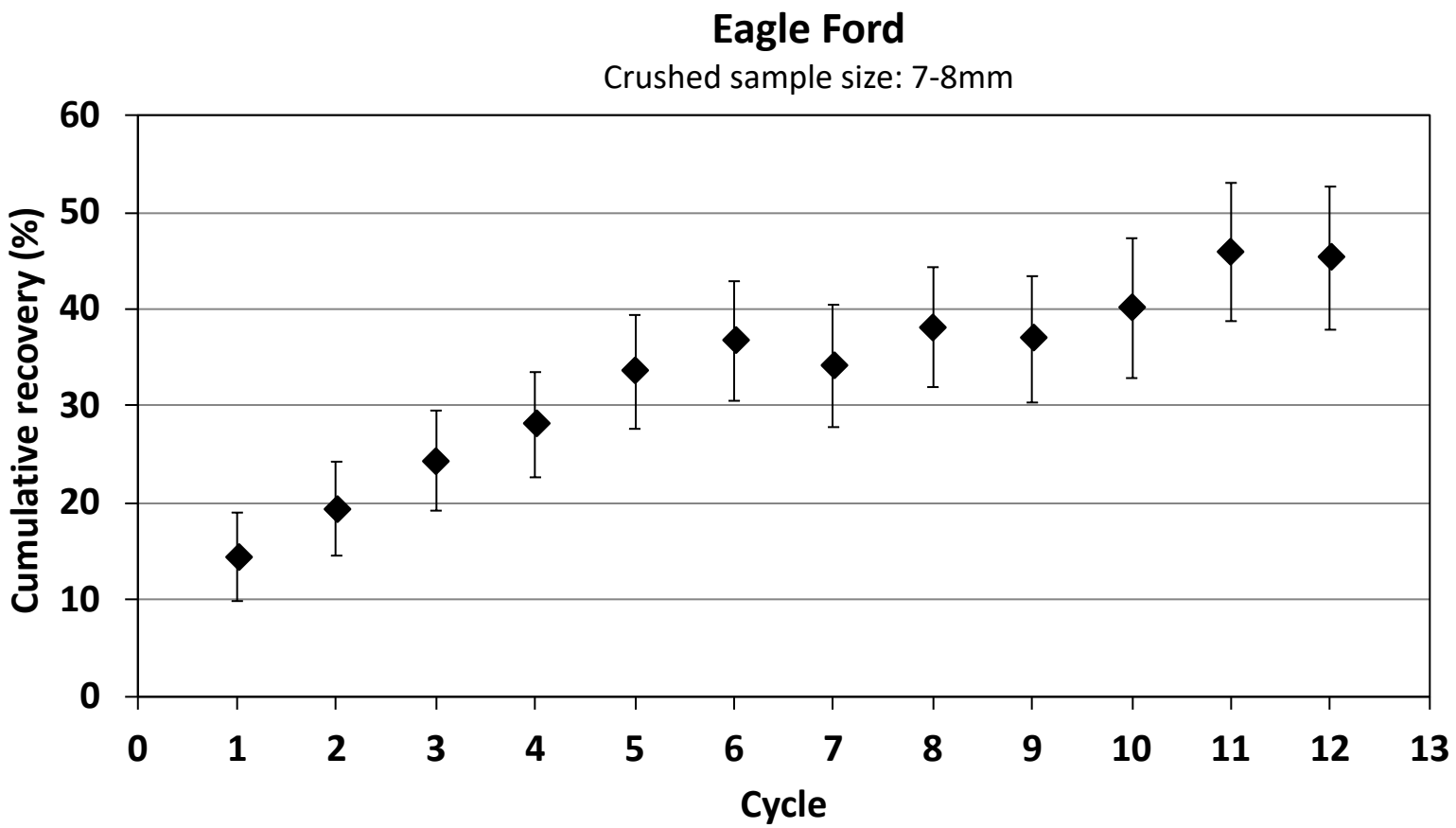


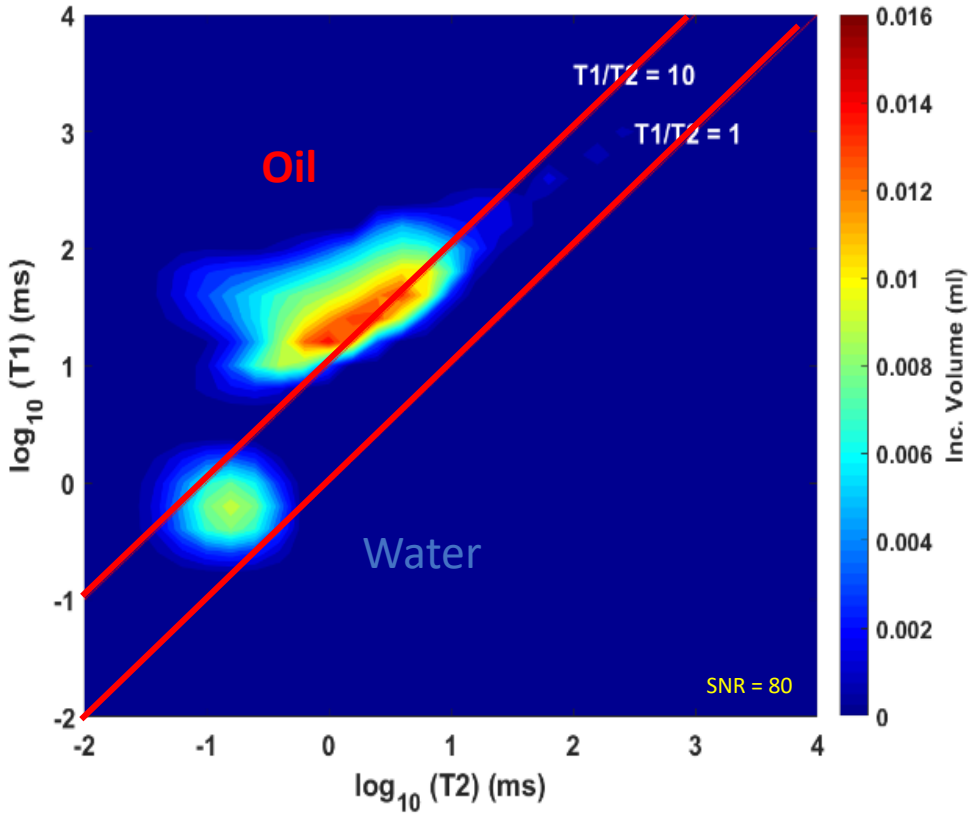
Maximum recovery of 45% after 12 cycles.

NMR T1-T2 fluid characterization after Huff-n-Puff

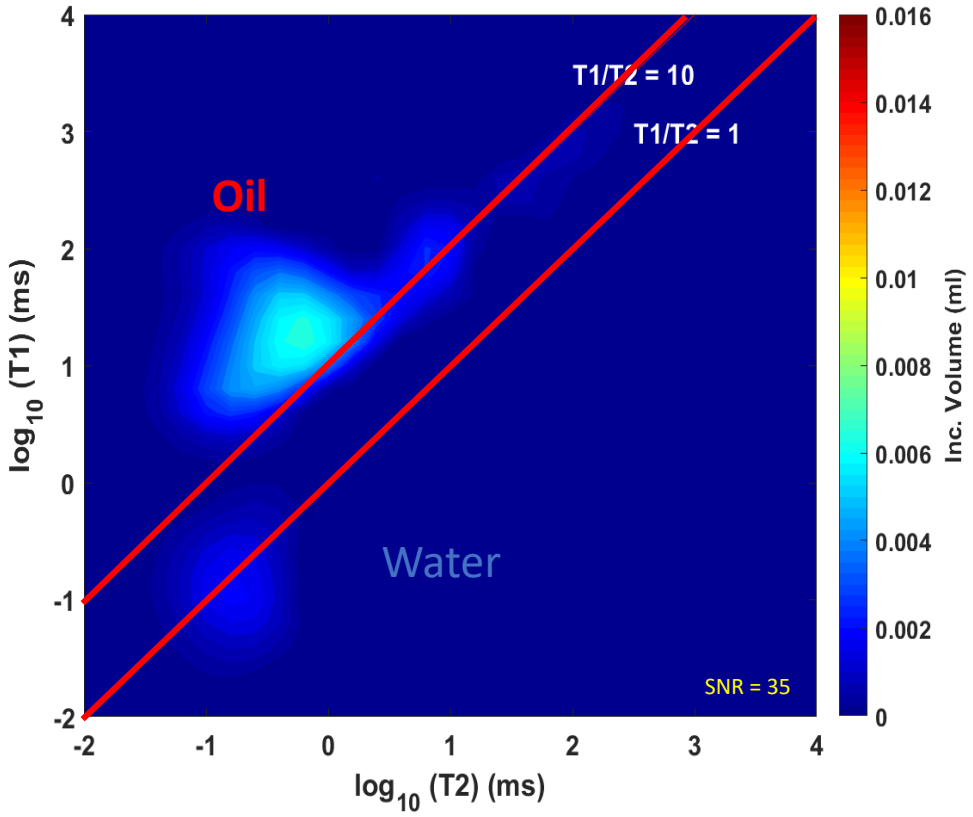
Eagle Ford

Crushed sample size: 7-8mm

Base



After 12 Cycles



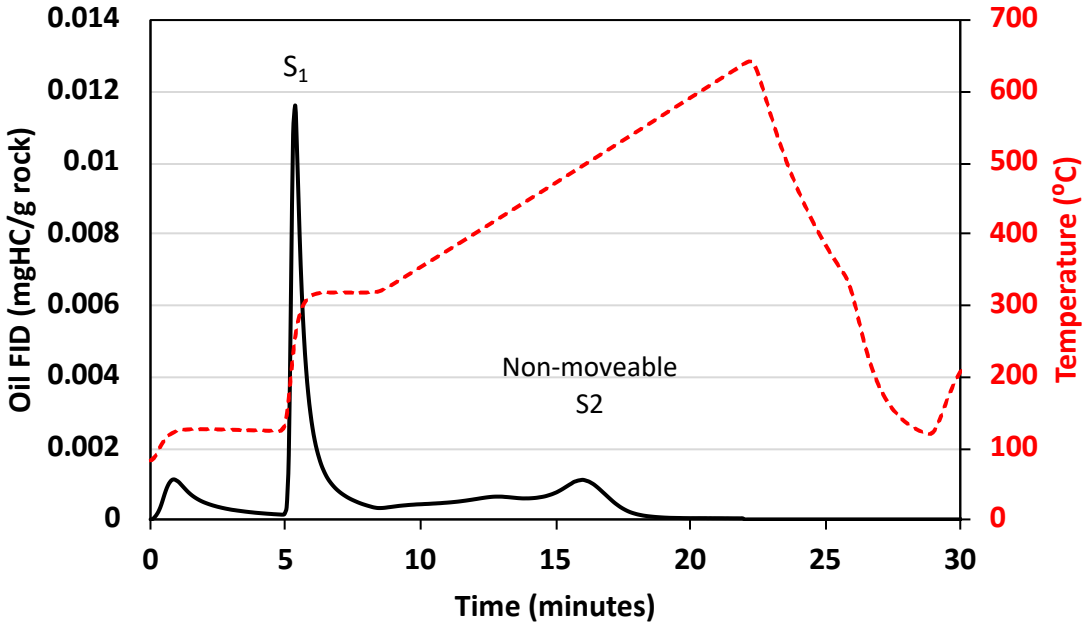
Mostly hydrocarbon is produced during the huff-n-puff.

12MHz NMR
τ =57 µs

HAWK ® dry pyrolysis-HC species characterization.

Shale Sample

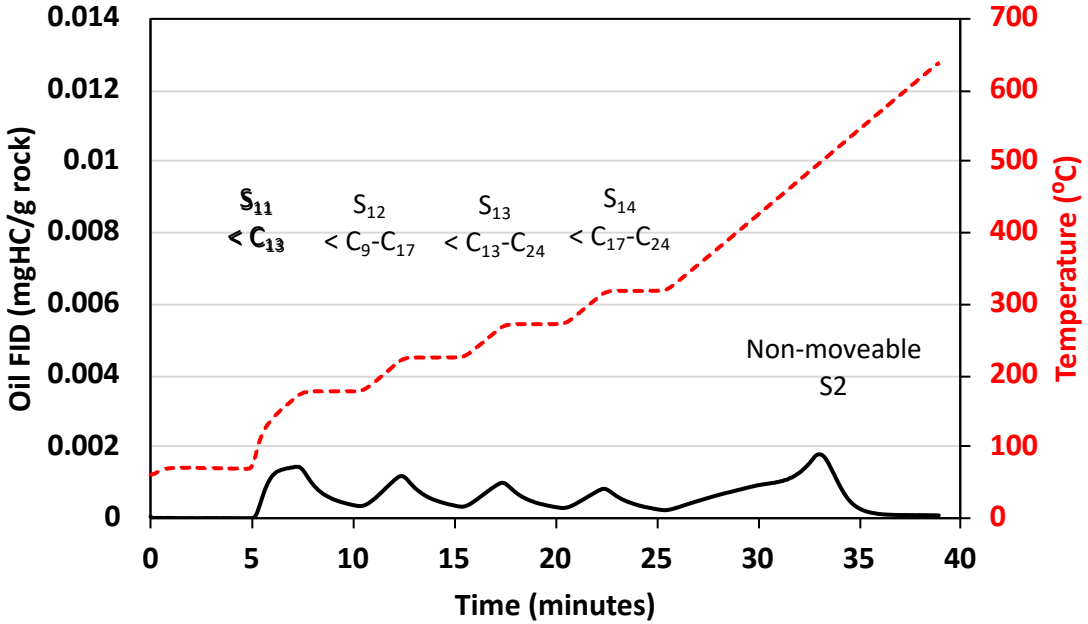
Traditional pyrolysis



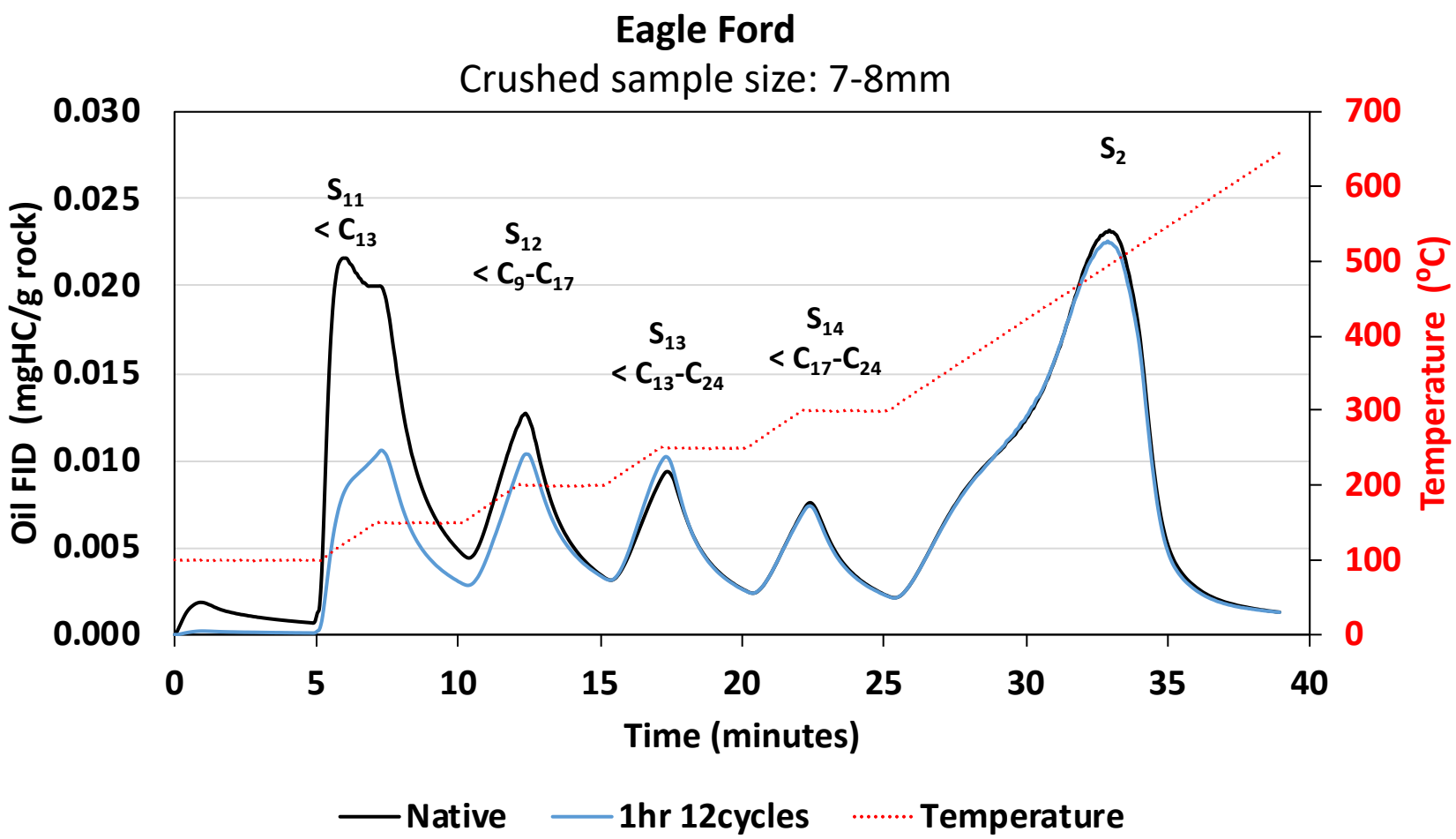
Peak	S_{11}	S_{12}	S_{13}	S_{14}
Temperature Step, °C	100-150	150-200	200-250	250-300
HCs cutoff	< C_{13}	C_9-C_{17}	C_{13}-C_{24}	C_{17}-C_{27}

Abrams et al., 2017

Modified HAWK® pyrolysis



HAWK ® dry pyrolysis- After Huff-n-Puff

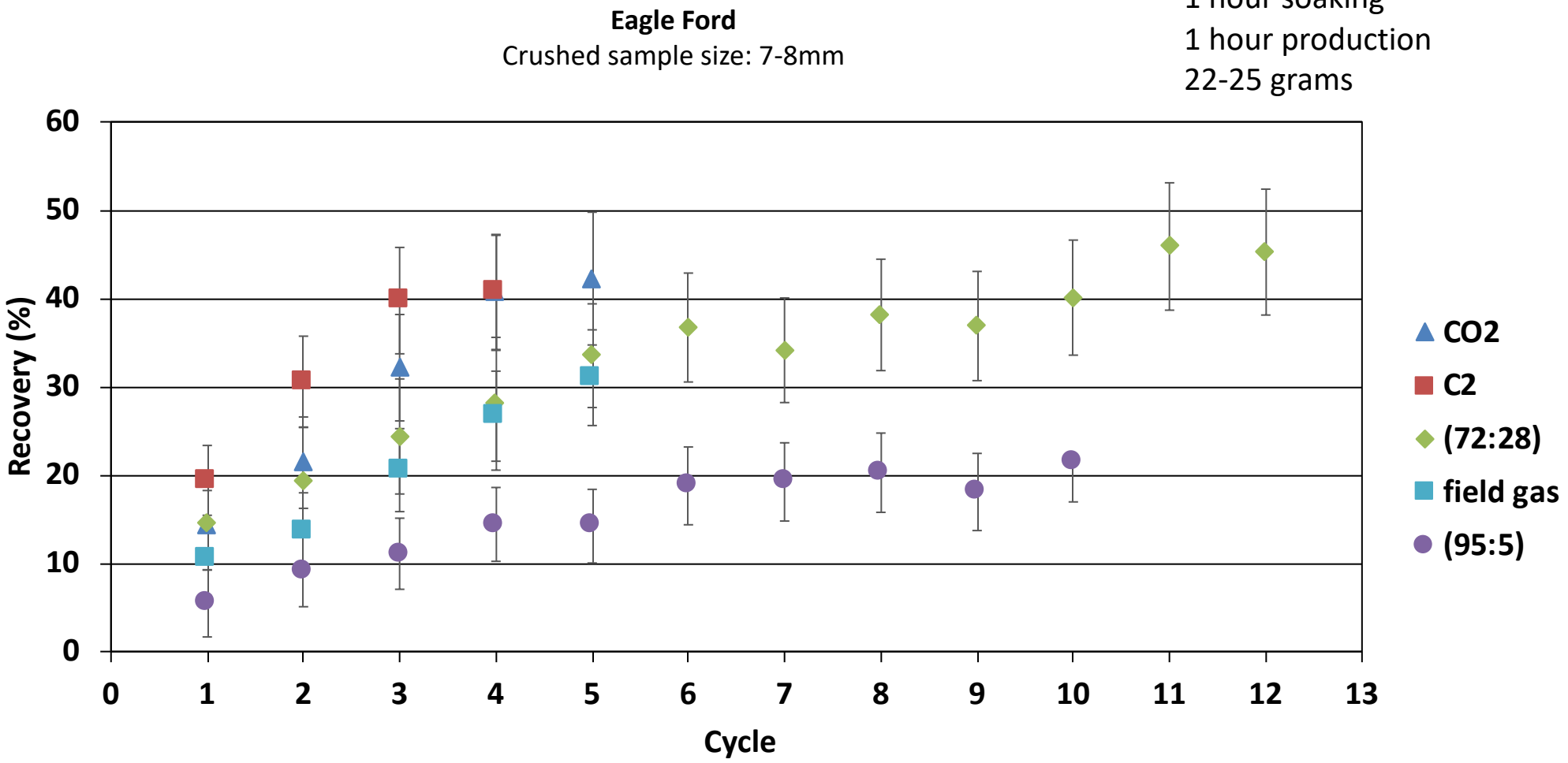


T=150 °F
Injection Pressure = +1000psi above MMP
Mixture C1:C2 (72:28)
1 hour soaking
1 hour production
22-25 grams

HCs up to C_{24} (S_{11}, S_{12} and S_{13}) were produced, but dominated by components lighter than C_{17} (S_{11} and S_{12}.)

Impact of solvent type on Huff-n-Puff

T=150 °F
Injection pressure = +1000 psi above MMP
1 hour soaking
1 hour production
22-25 grams



Performance in recovery efficiency at the same test configuration:
Ethane > CO2 > C1:C2(72:28)≈Field gas(C1:C2:C3+/76:14:10) > C1:C2(95:5)

Impact of solvent type on Huff-n-Puff

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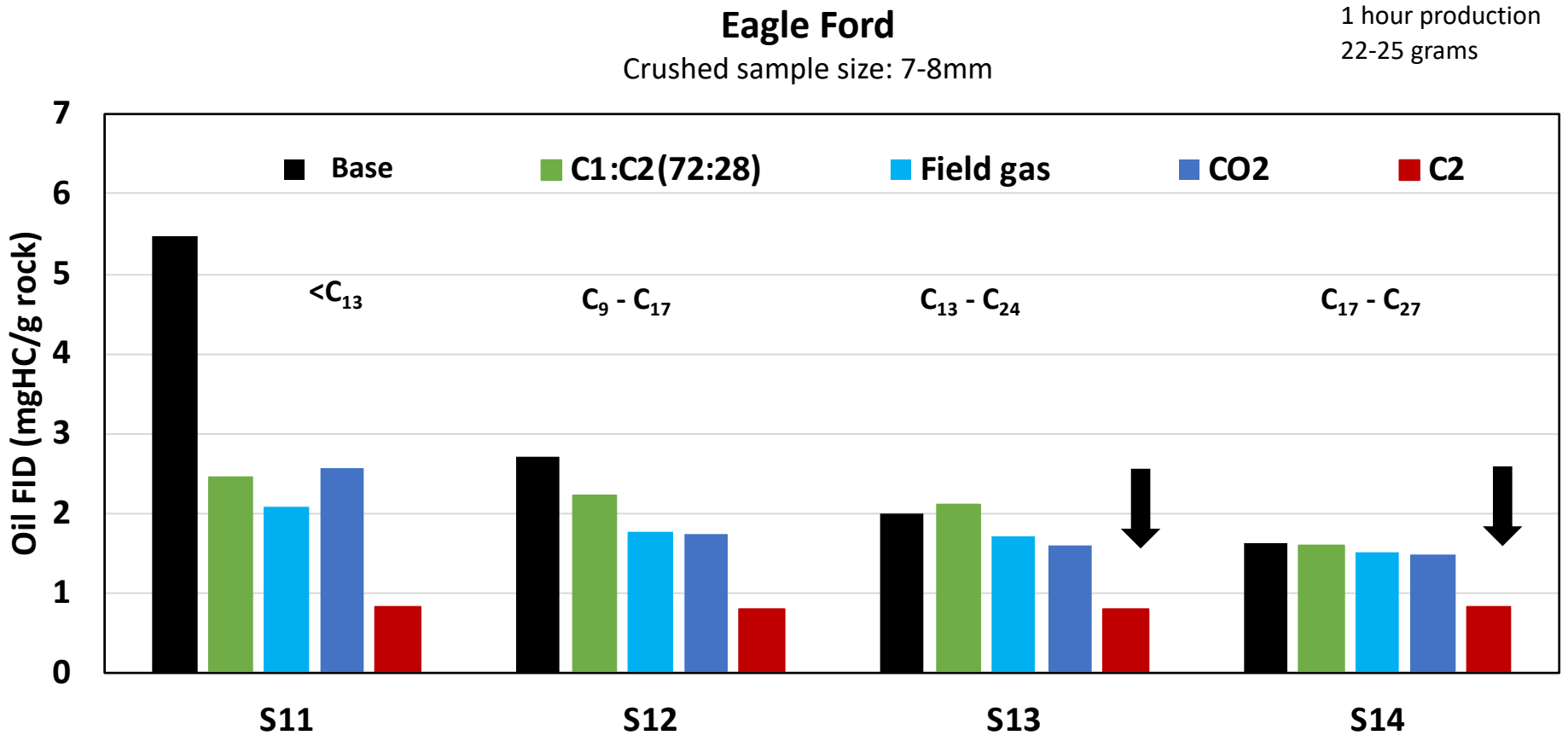
22-25 grams



Ethane is found to be more efficient in removing heavier HCs (up to C_{27}), compared to other gases.

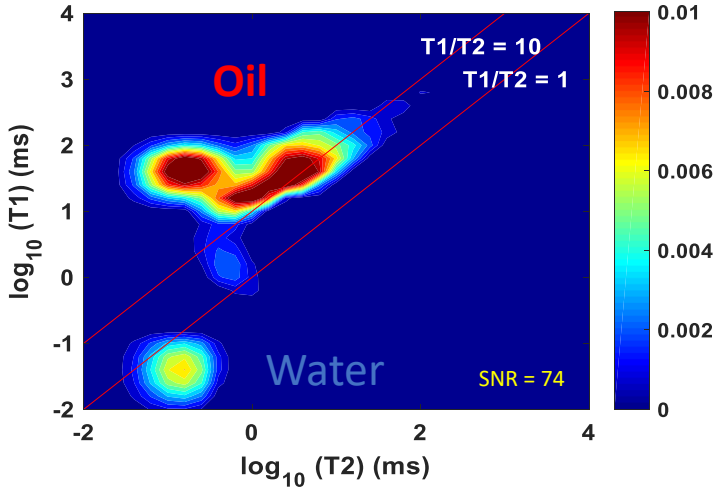
Impact of solvent type on Huff-n-Puff

Eagle Ford

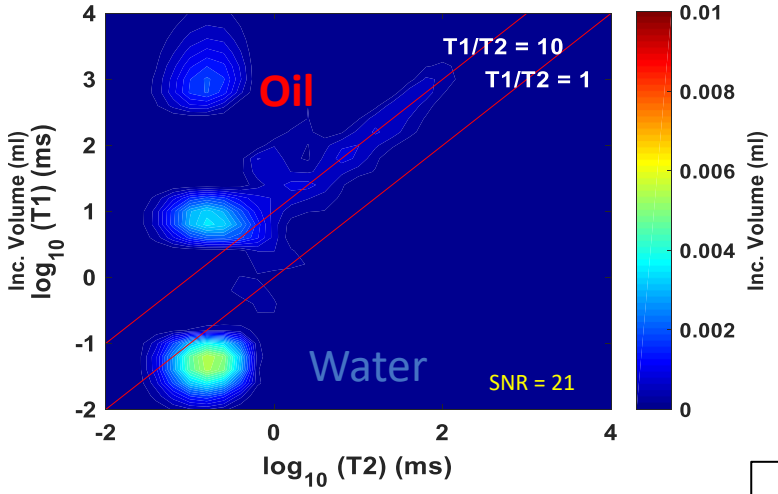
Crushed sample size: 7-8mm

Ethane

Base

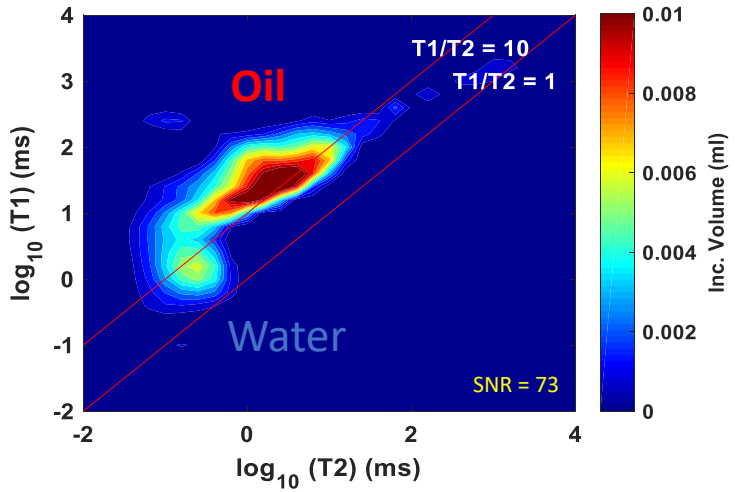


After 4 cycles

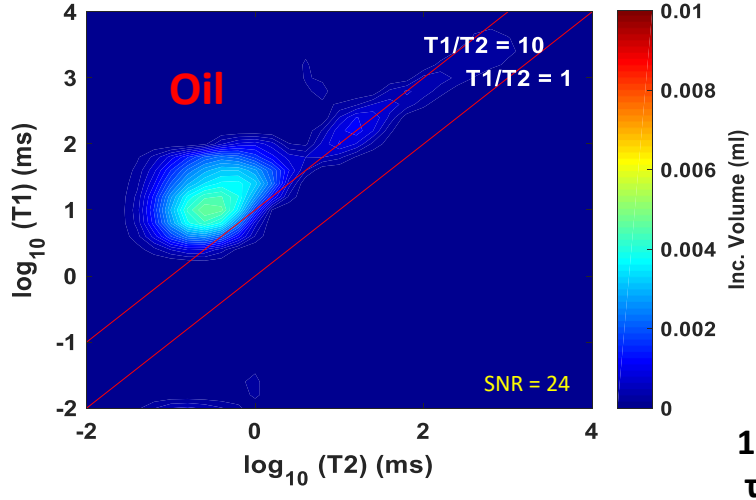


CO_2

Base



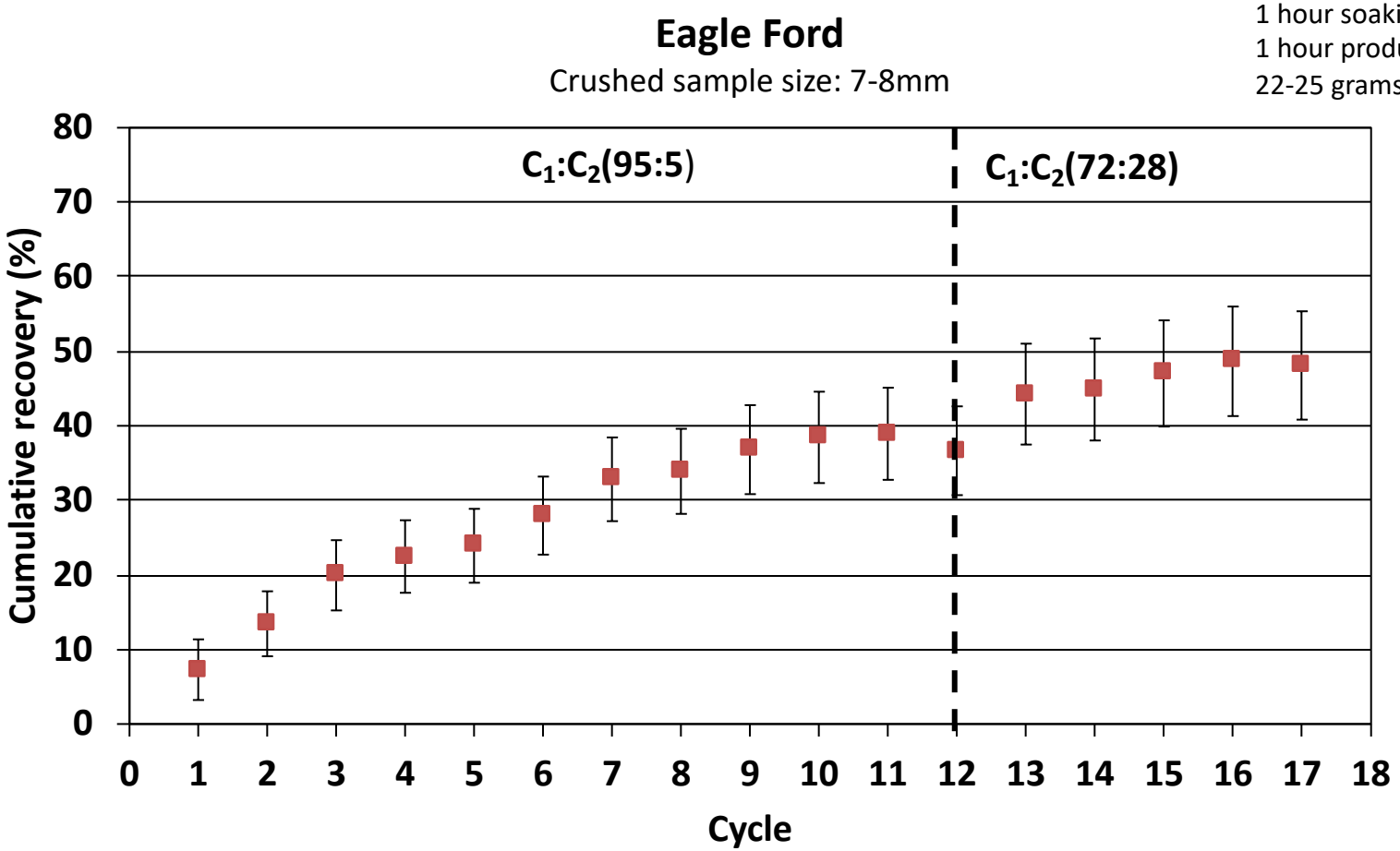
After 4 cycles



12MHz NMR
τ =57 µs

Solvent enrichment effect on Huff-n-Puff

T=150 °F
Injection pressure = +1000 psi above MMP
1 hour soaking
1 hour production
22-25 grams



12MHz NMR
τ =57 µs

Summary

- NMR results show that removable HC fractions come from both fast and slow relaxation regions (correspondingly small and large pores).

- Ethane was found to be more effective in mobilizing heavier HCs, up to C_{27}; while CO_2 and a mixture of methane: ethane (72:28 mol%) can only mobilize HCs up C_{17}.

- The results also show that CO_2 is more efficient at removing water compared to HC solvents.

- It is more beneficial to use enriched injectate from the beginning of the huff-n-puff operation, instead of progressively enriching the gas during EOR.

Questions ?

Acknowlegments

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References

Abrams, M. A., Gong, C., Garnier, C., and Stephenson, M. A. 2017. A new thermal extraction protocol to evaluate liquid rich unconventional oil in place and in-situ fluid chemistry. *Journal of Marine and Petroleum Geology* 88: 659-675.https://dx.doi.org/10.1016/j.marpetgeo.2017.09.014.

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