Petroleum as Energy Security in the New Energy Mix Applications of CO2 as CCUS Enabler for Efficient, Cost Saving and More Sustainable Petroleum Production

"CO2 Foam EOR for Mobility Control – Preparations for Two Field Pilots in Texas"

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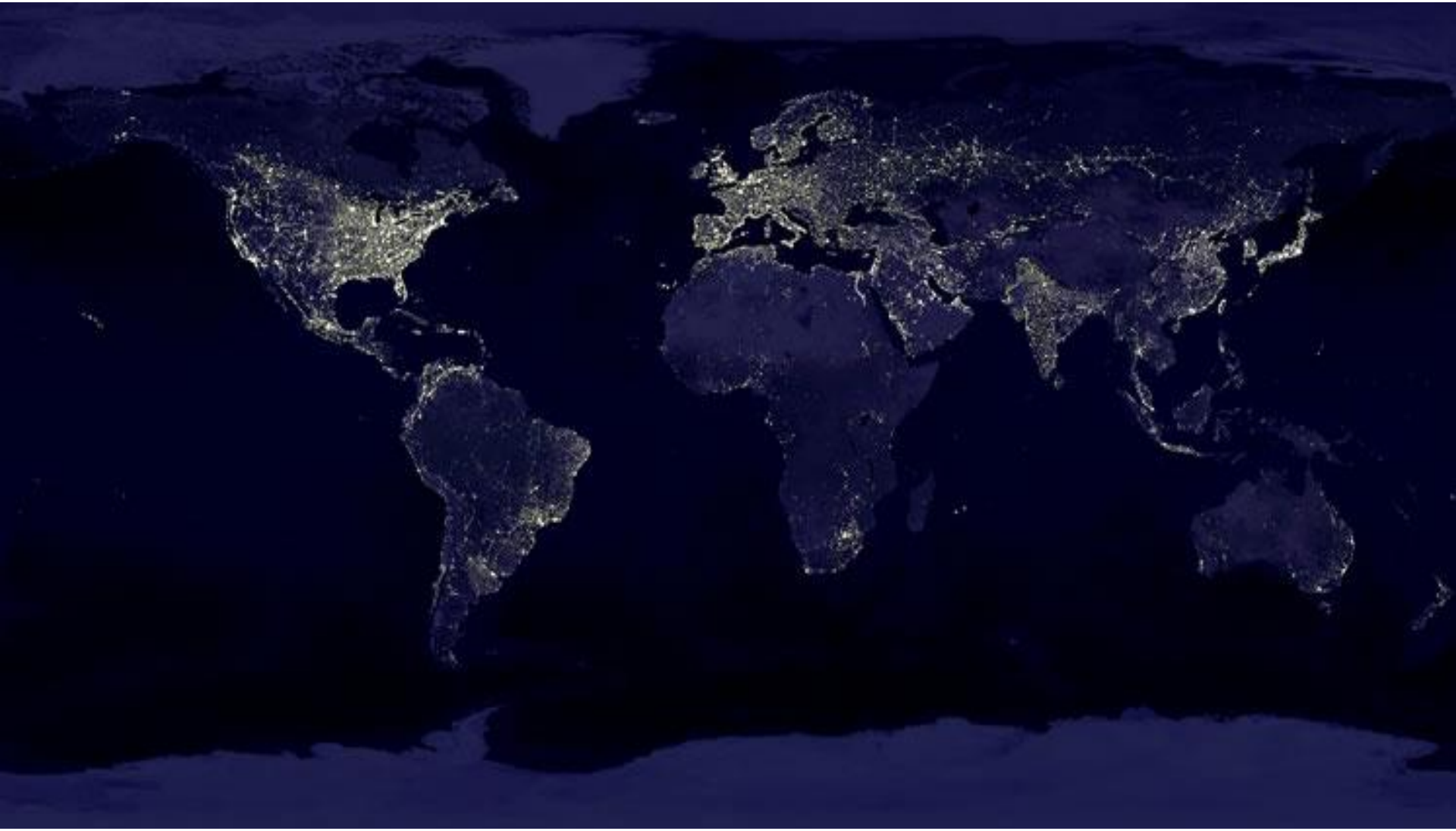
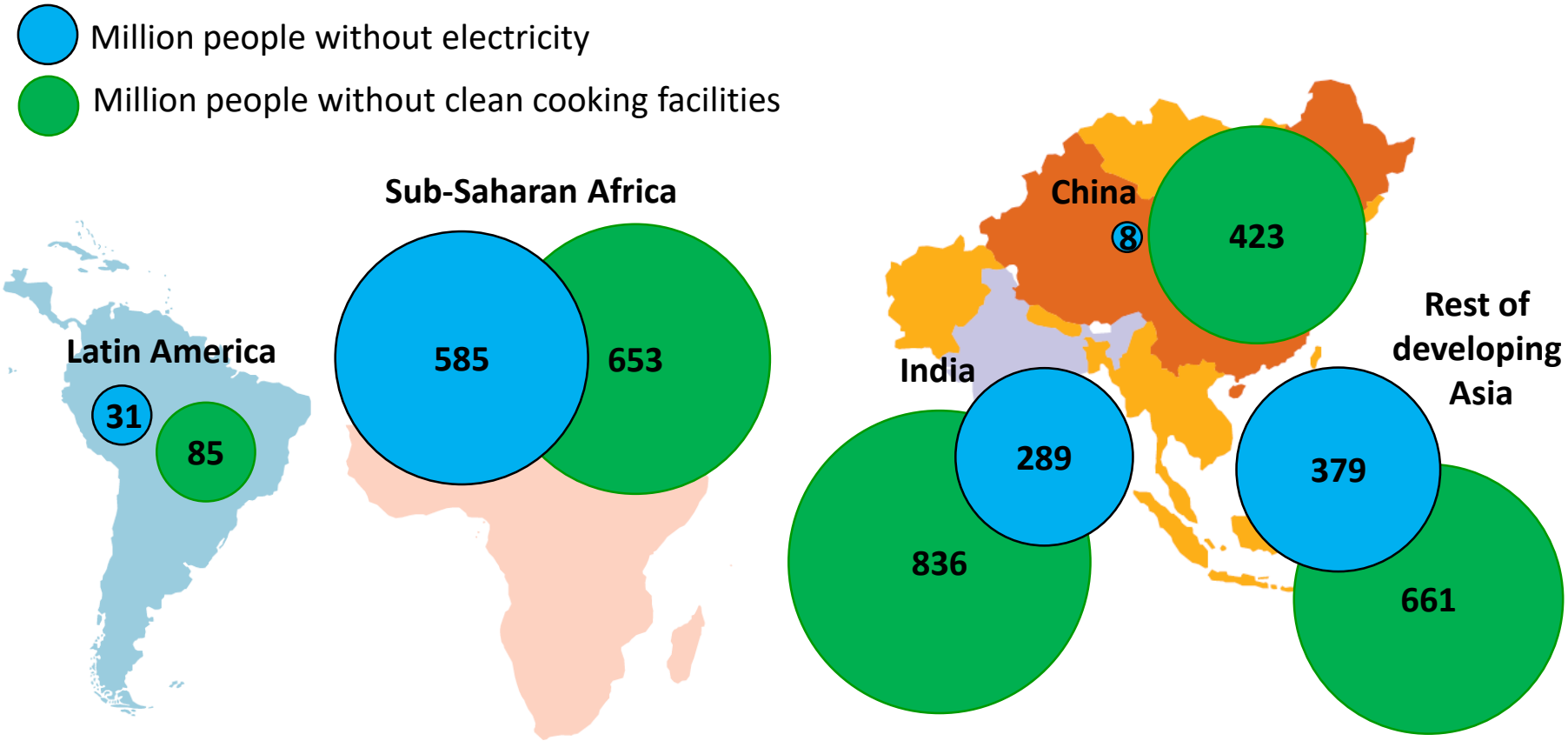
Dept. of Physics and Technology

University of Bergen, NORWAY

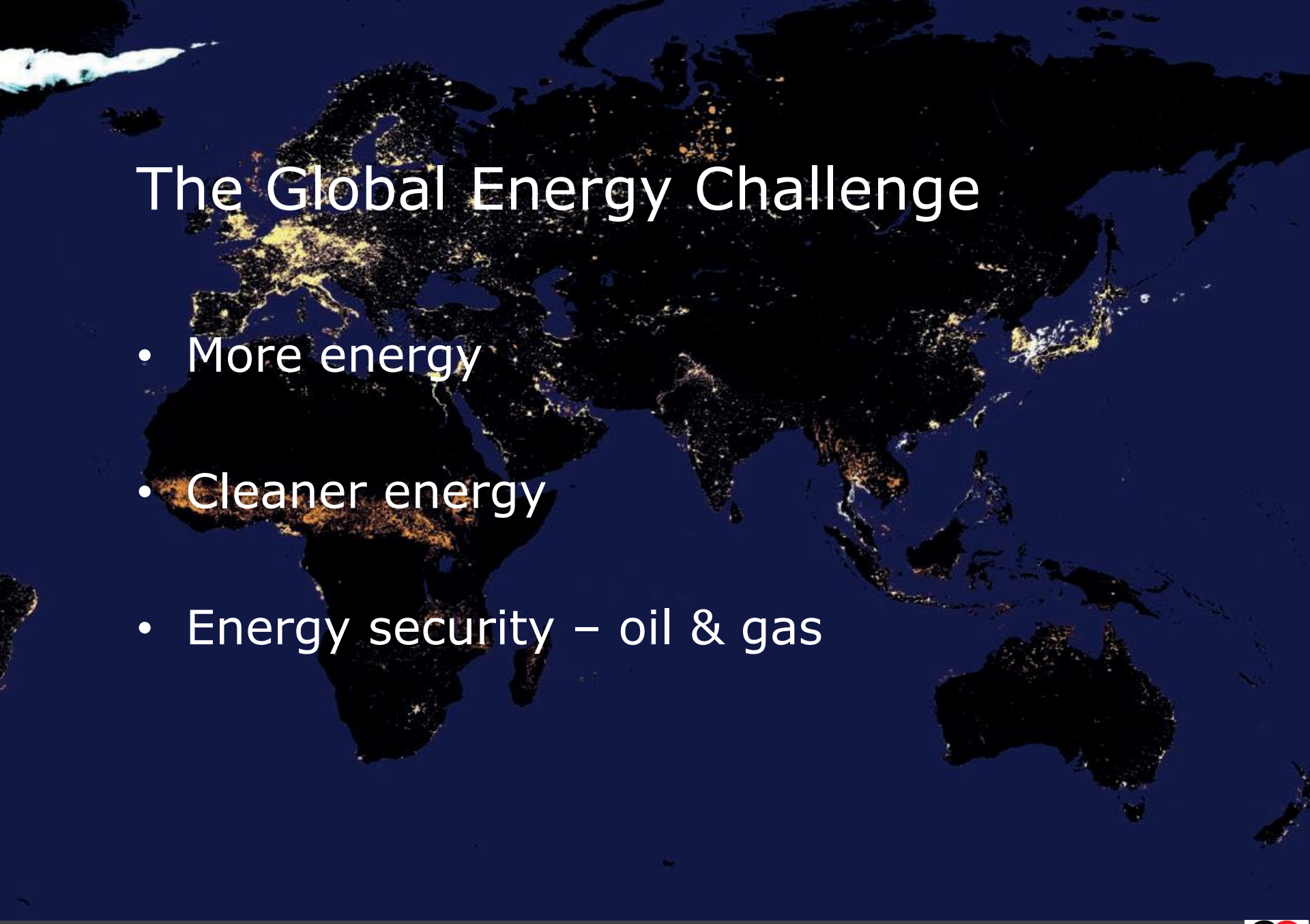
2016 CO2/ROZ Conference, Midland, TX, USA, Dec. 6-8th, 2016



Energy Poverty is Widespread

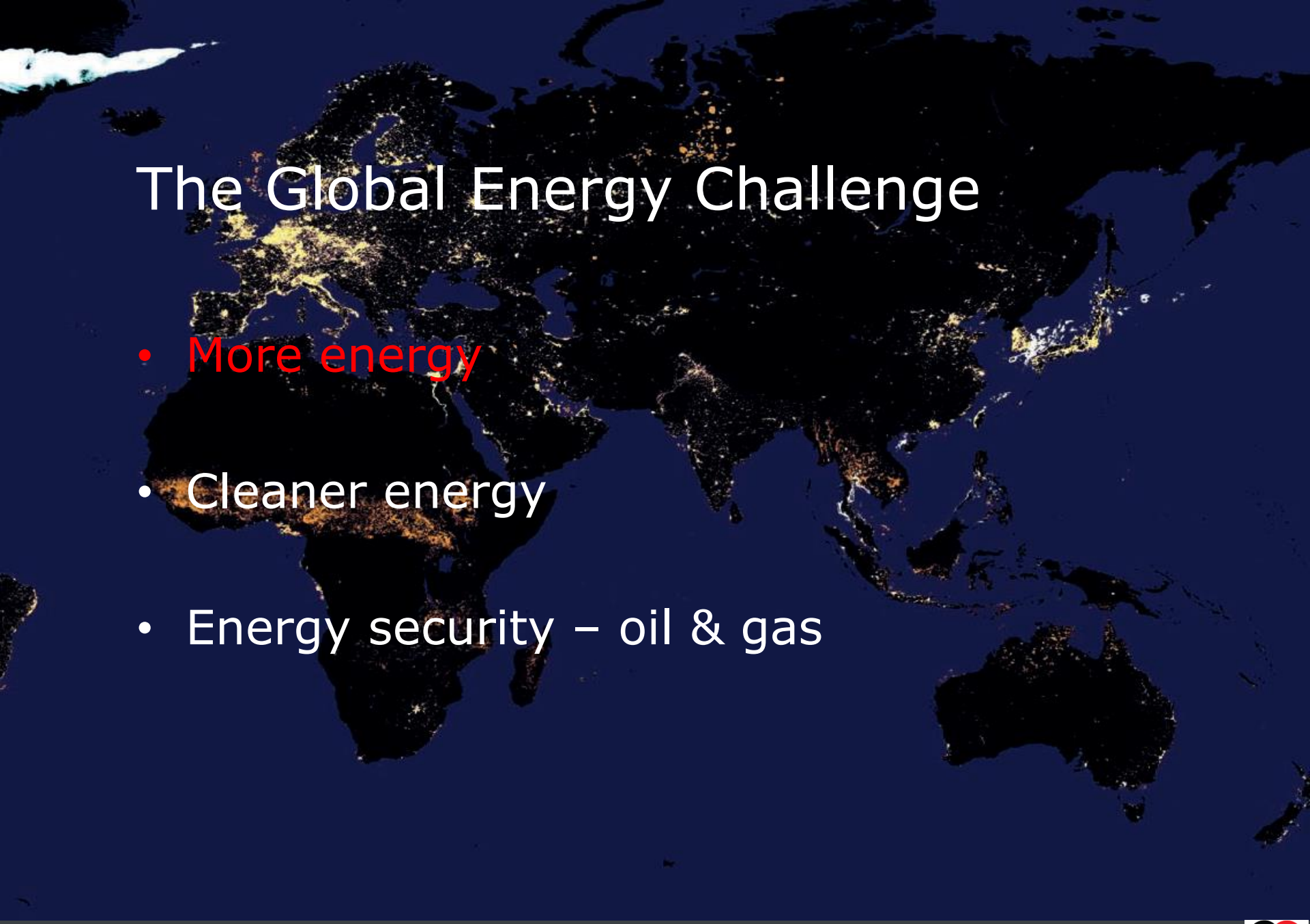


1.3 billion people in the world live without electricity
& 2.7 billion live without clean cooking facilities



The Global Energy Challenge

- More energy
- Cleaner energy
- Energy security – oil & gas

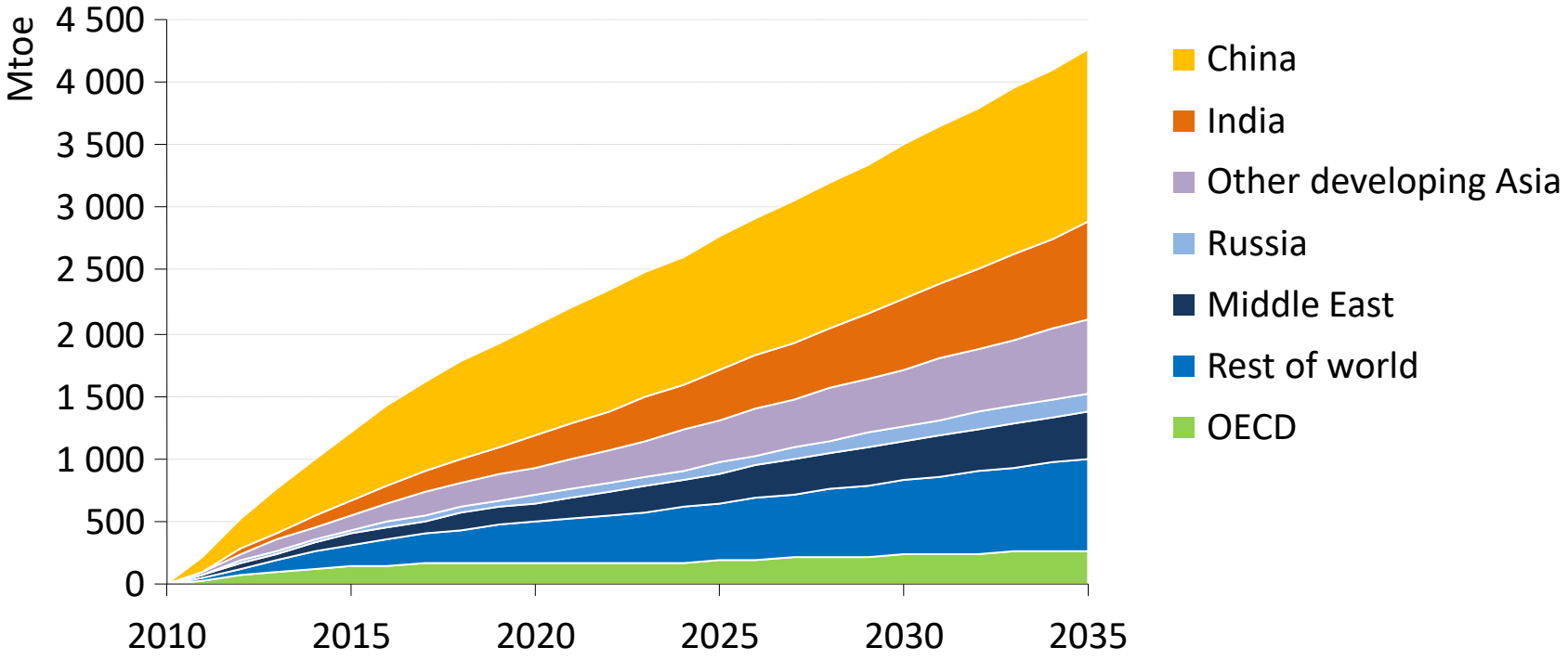


The Global Energy Challenge

- More energy
- Cleaner energy
- Energy security – oil & gas

The Global Need for Energy Continues to Rise

Growth in primary energy demand in the IEA's New Policies Scenario



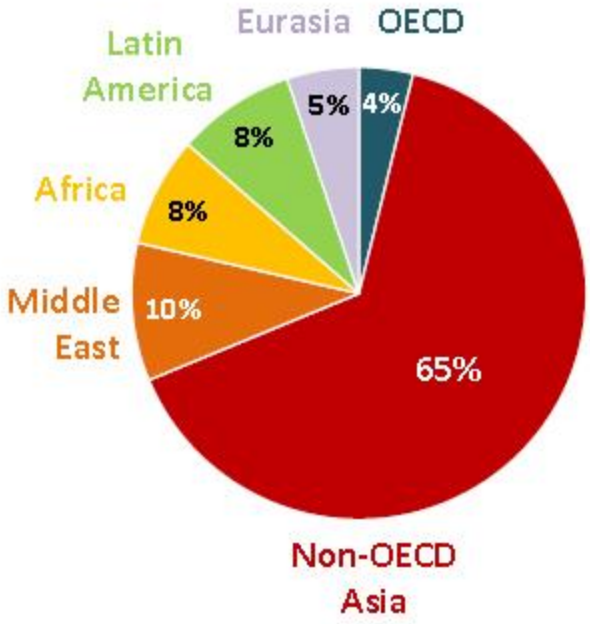
Source: International Energy Agency

The engine of energy demand growth moves to South Asia

WORLD ENERGY OUTLOOK 2013

Primary energy demand, 2035 (Mtoe)

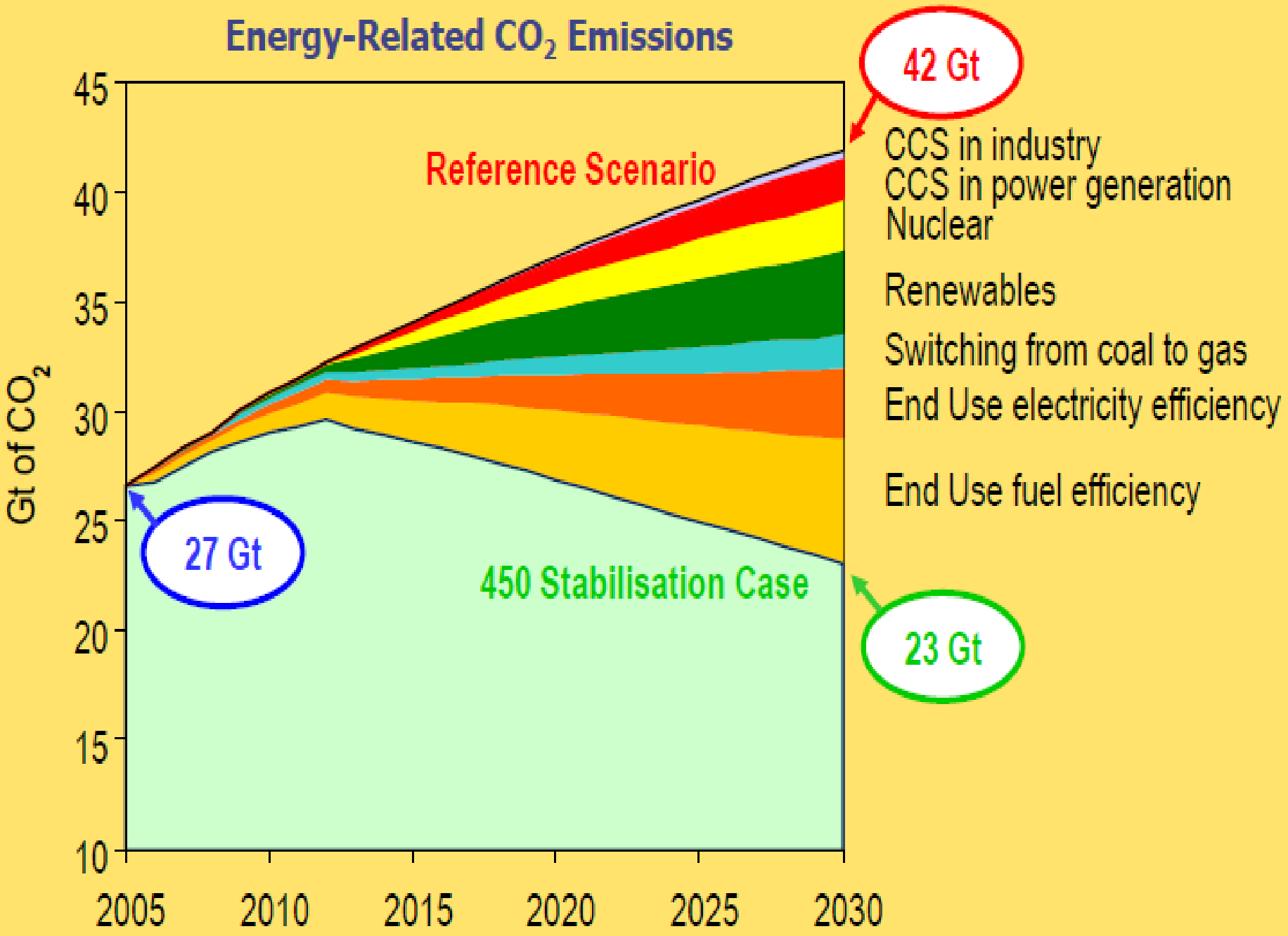
Share of global growth 2012-2035



China is the main driver of increasing energy demand in the current decade, but India takes over in the 2020s as the principal source of growth

The Global Energy Challenge

- More energy
- Cleaner energy
- Energy security – oil & gas


Energy-Related CO_2 Emissions
Gt of CO_2
45
40
35
30
25
20
15
10
2005
2010
2015
2020
2025
2030
Reference Scenario
450 Stabilisation Case
42 Gt
27 Gt
23 Gt
CCS in industry
CCS in power generation
Nuclear
Renewables
Switching from coal to gas
End Use electricity efficiency
End Use fuel efficiency

The Global Energy Challenge

- More energy
- Cleaner energy
- Energy security – oil & gas

CCUS:
Carbon Capture, Utilization and Storage

<u>Two Business Cases Enabling CO2 Sequestration:</u>

- Integrated EOR (IEOR) with CO2 injection
- Exploitation of Hydrate Energy using CO2

Sustainable Energy in India under the United Nations Framework Convention on Climate Change:

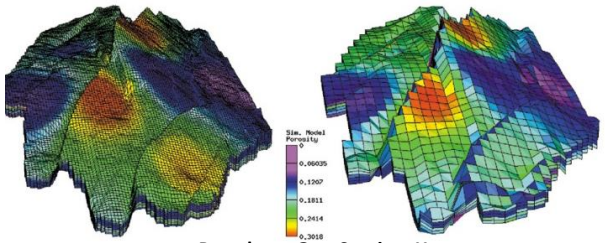
Carbon Neutral Natural Gas Production from Hydrates with Simultaneous CO2 Sequestration

- Prof. Arne Graue, Dept. of Physics and Technology, U. of Bergen, Norway
- Dr. Torsten Porwol, Bergen Technology Office

Advisory Committee Meeting, New Delhi, Dec. 1-2, 2016

Length Scales

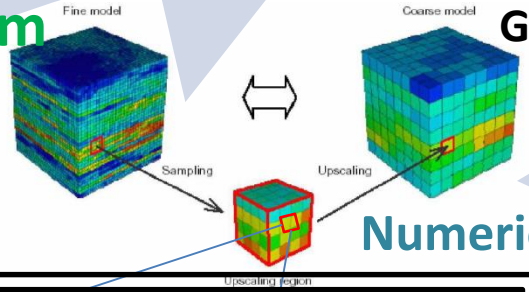
10^3-10^4m



Petroleum Geo-Services Homepage
www.pgs.com

10^1-10^2m

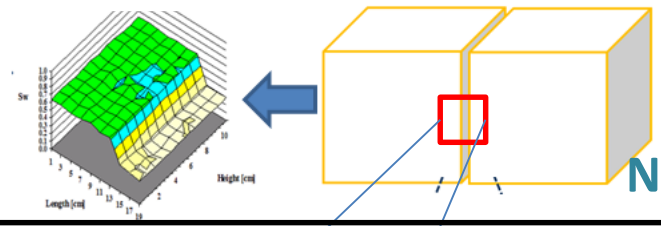
GRIDBLOCK SCALE



Numerical Simulations

10^{-1}-10^0m

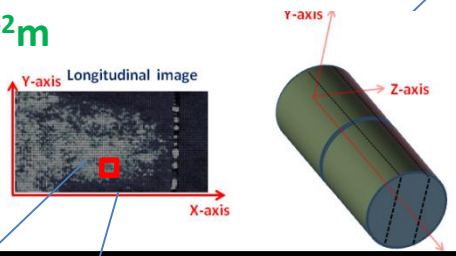
BLOCKSCALE



Nuclear Tracer

10^{-3}-10^{-2}m

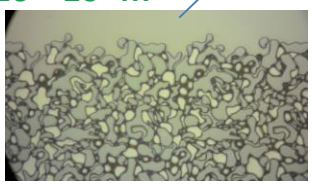
CORESCALE



MRI and CT

10^{-5}-10^{-3}m

MICROSCALE



Microscopy

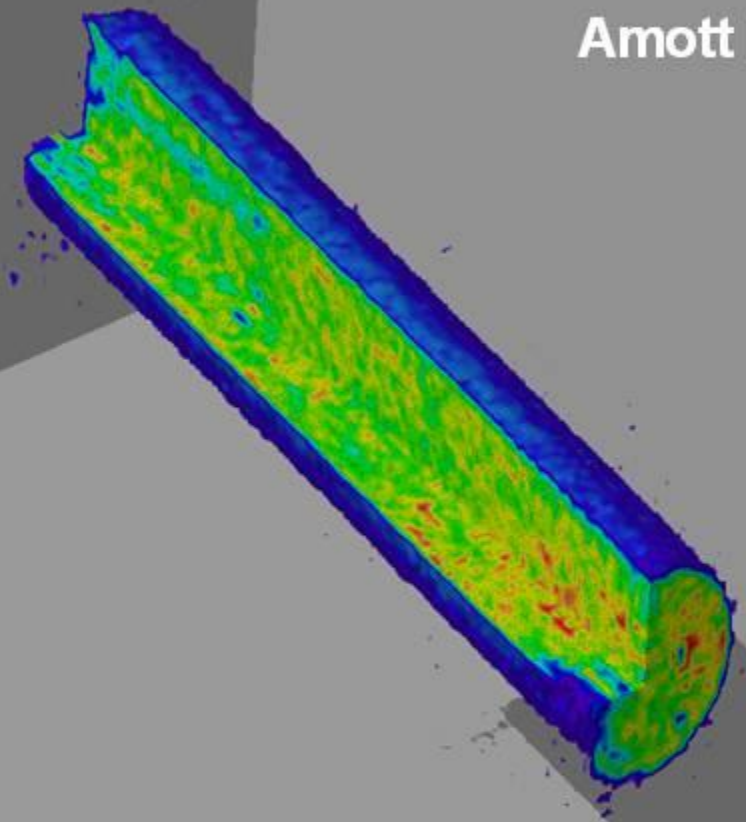
Imaging techniques

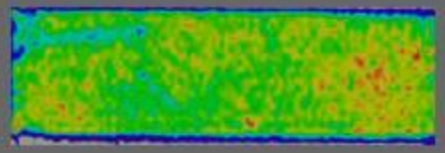
In-Situ Fluid Saturations by Magnetic Resonance Imaging (MRI)

Tertiary CO_2 Injection of Less Water-Wet Chalk

Temp.: 40^0C

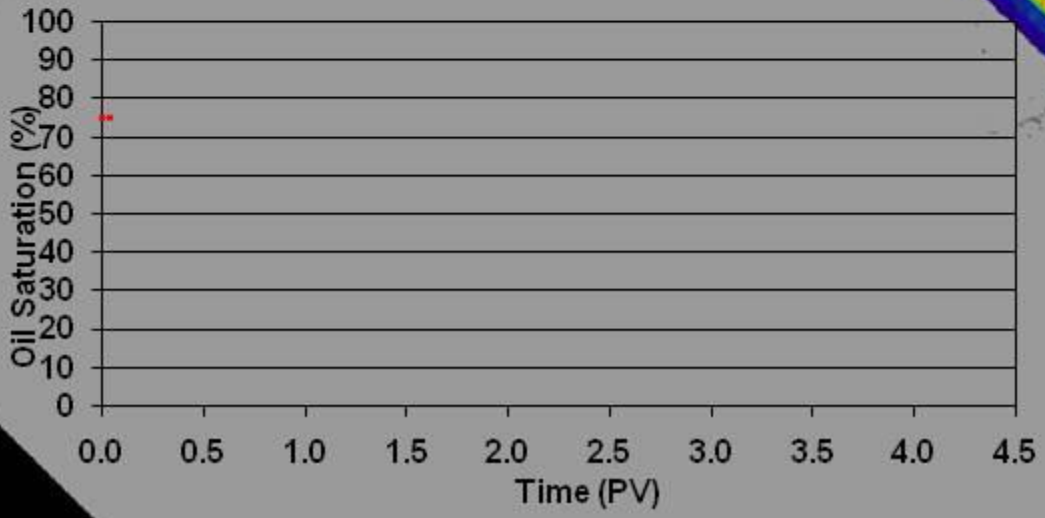
Amott Index 0.25



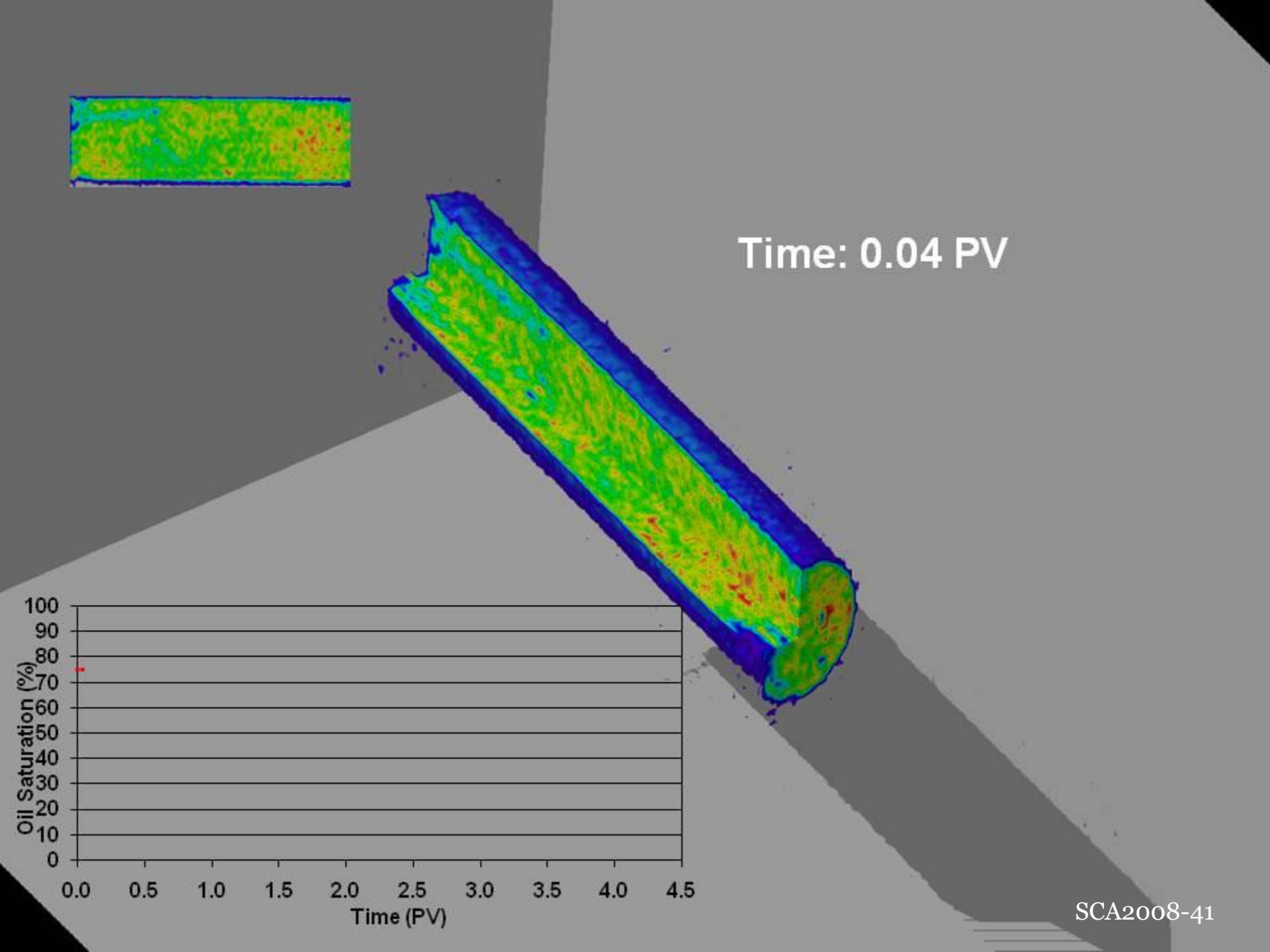


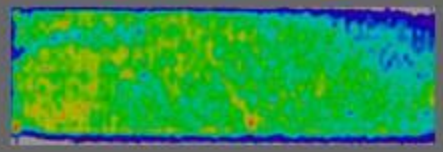
Time: 0.04 PV

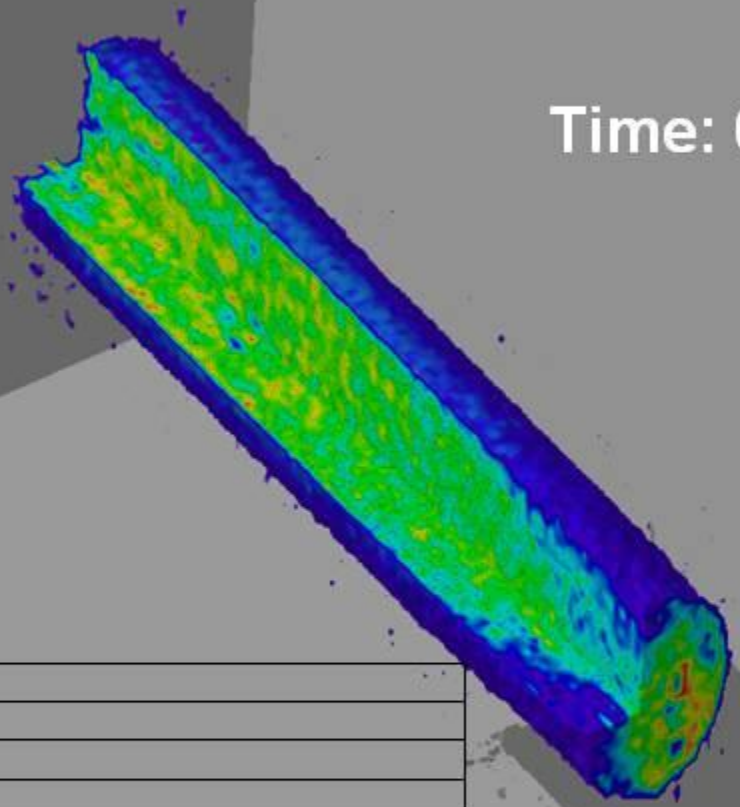
$S_{o,\,wi}$ = 75.0 %



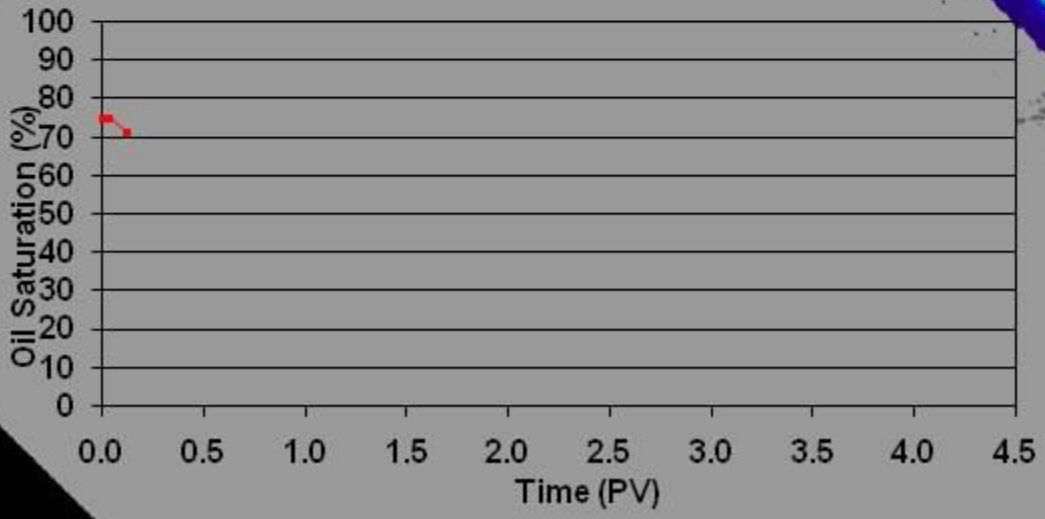
D_2O Injection

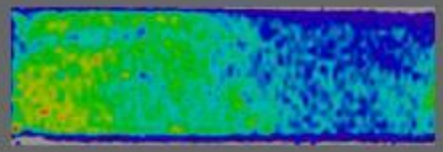

Time: 0.04 PV
Oil Saturation (%)
100
90
80
70
60
50
40
30
20
10
0
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
Time (PV)

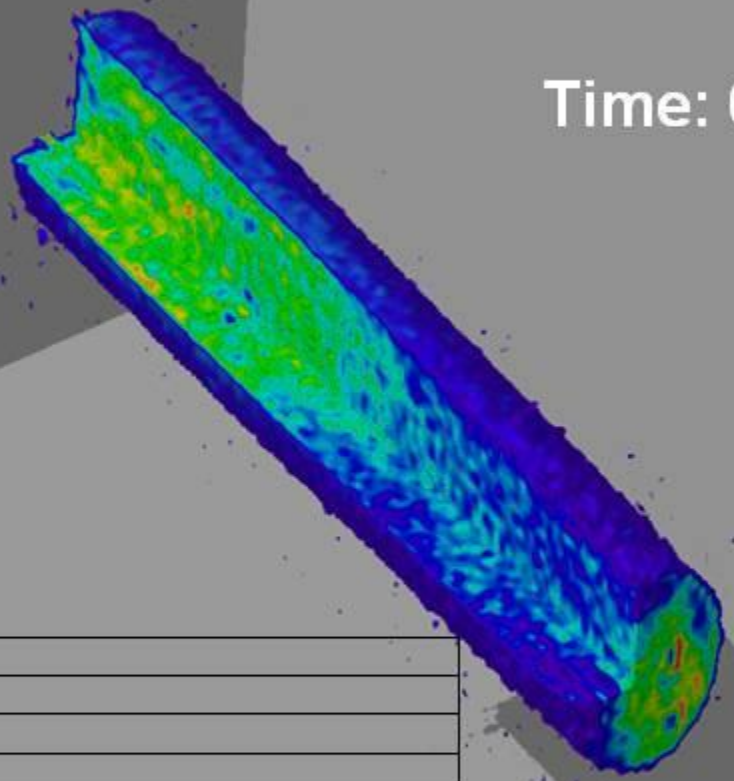




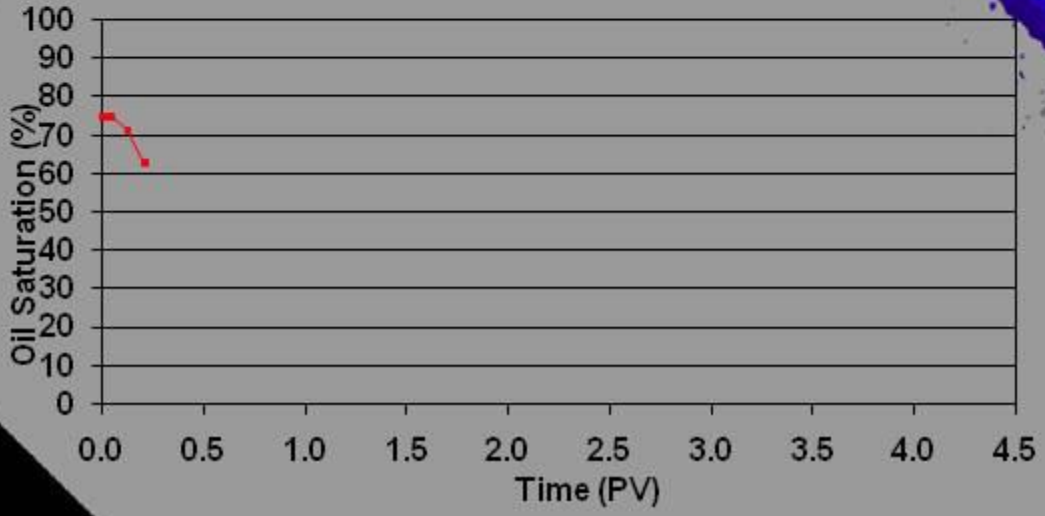
Time: 0.12 PV

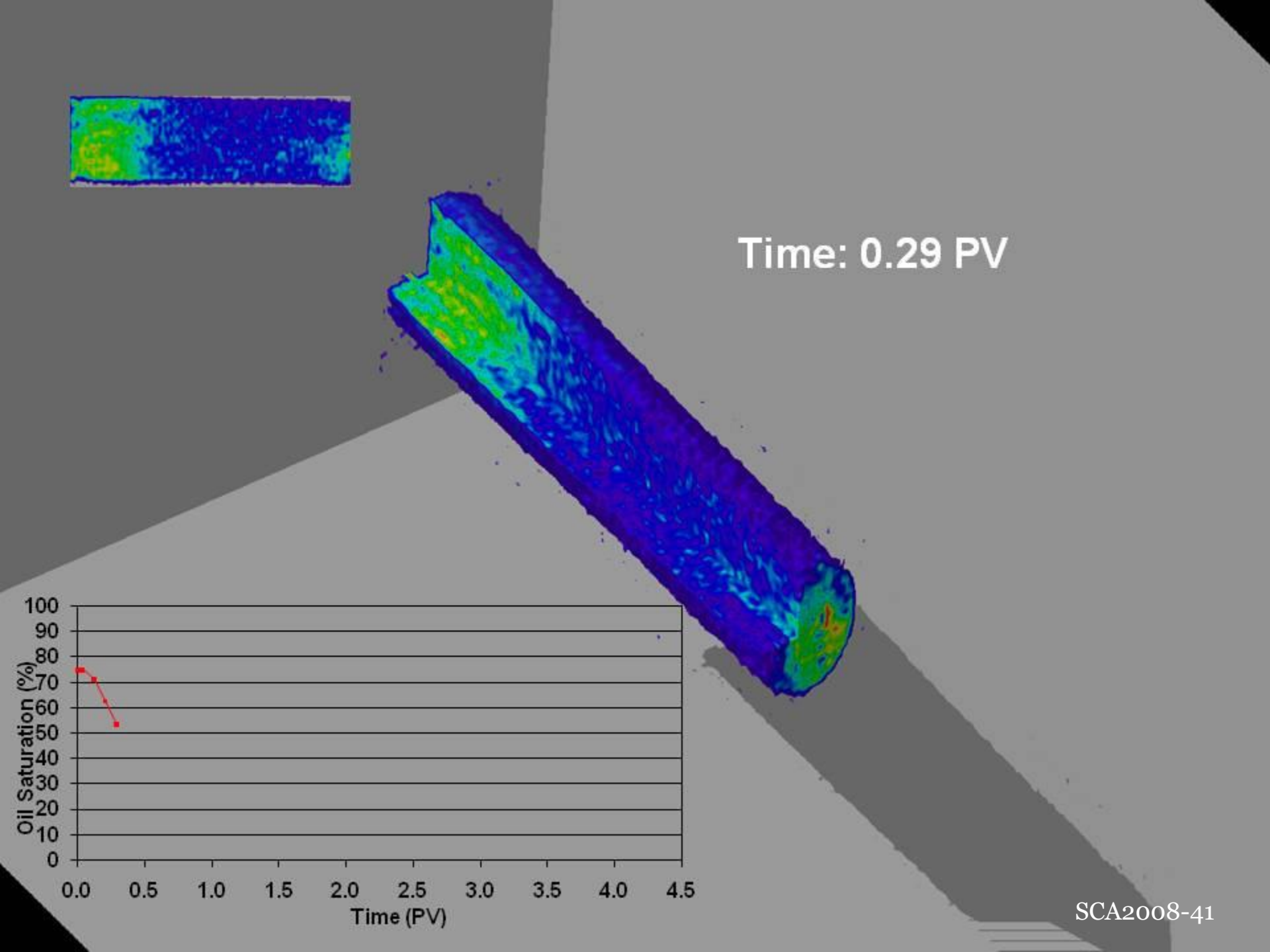

Oil Saturation (%)
100
90
80
70
60
50
40
30
20
10
0
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
Time (PV)

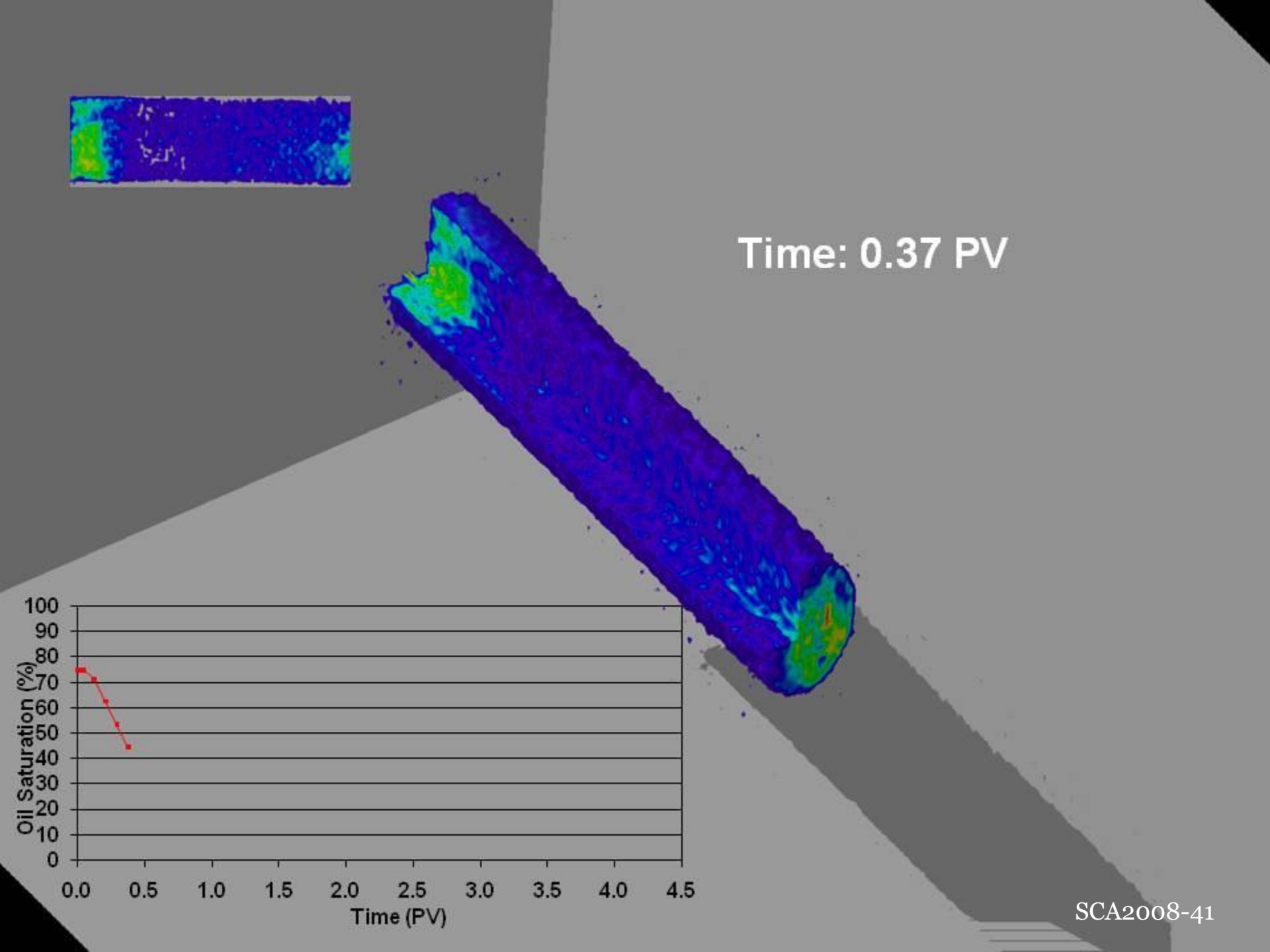


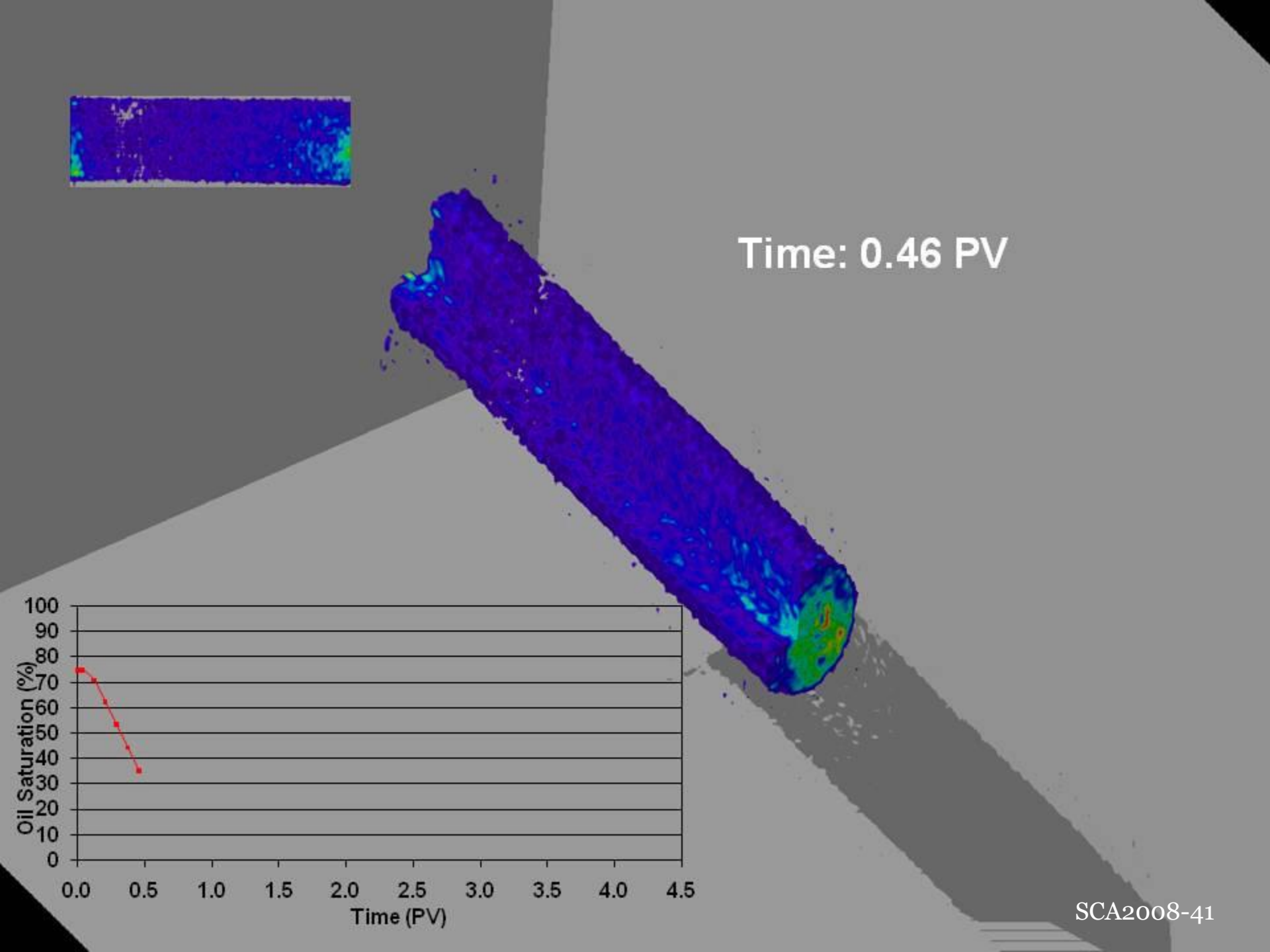


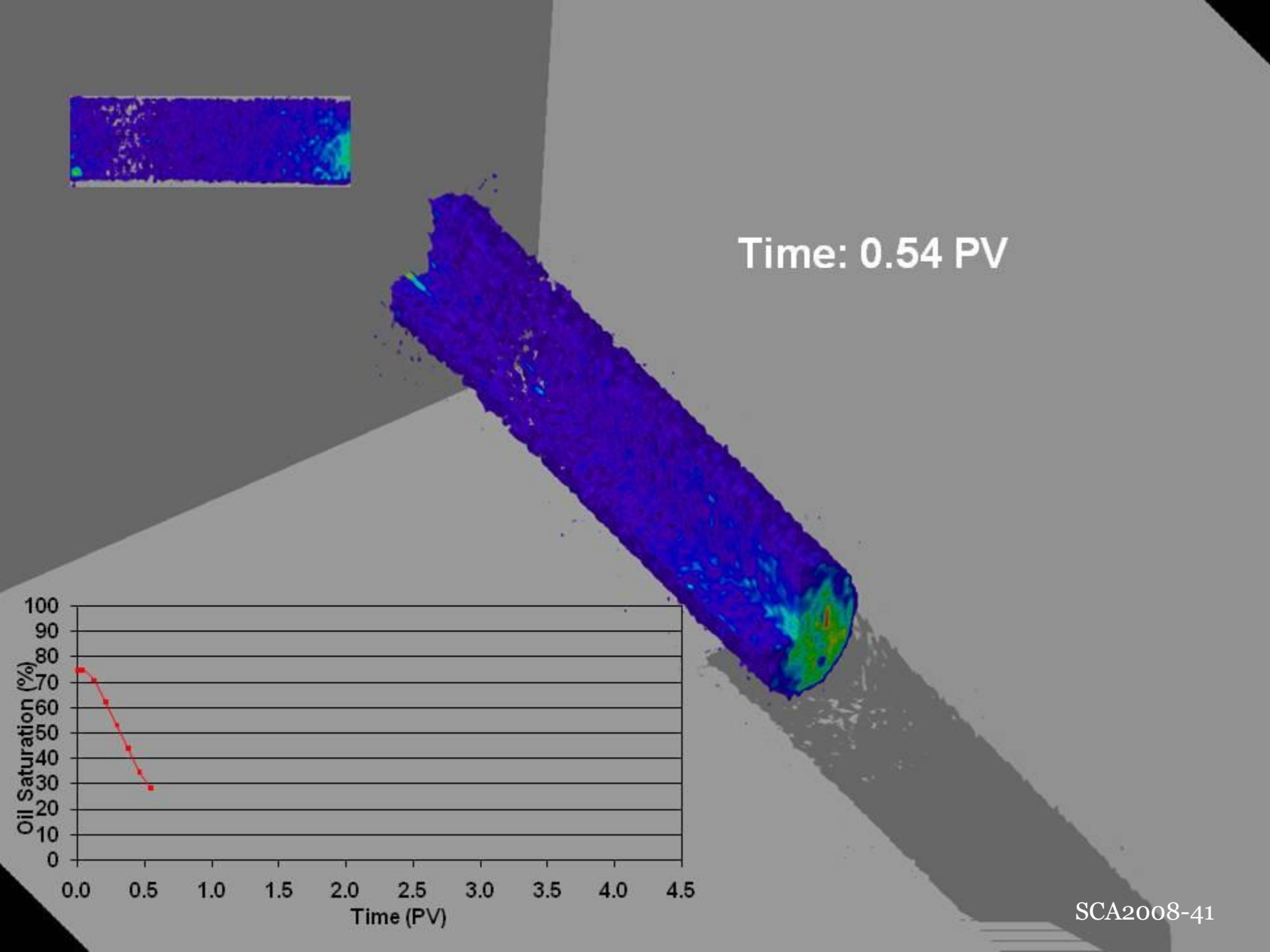
Time: 0.21 PV

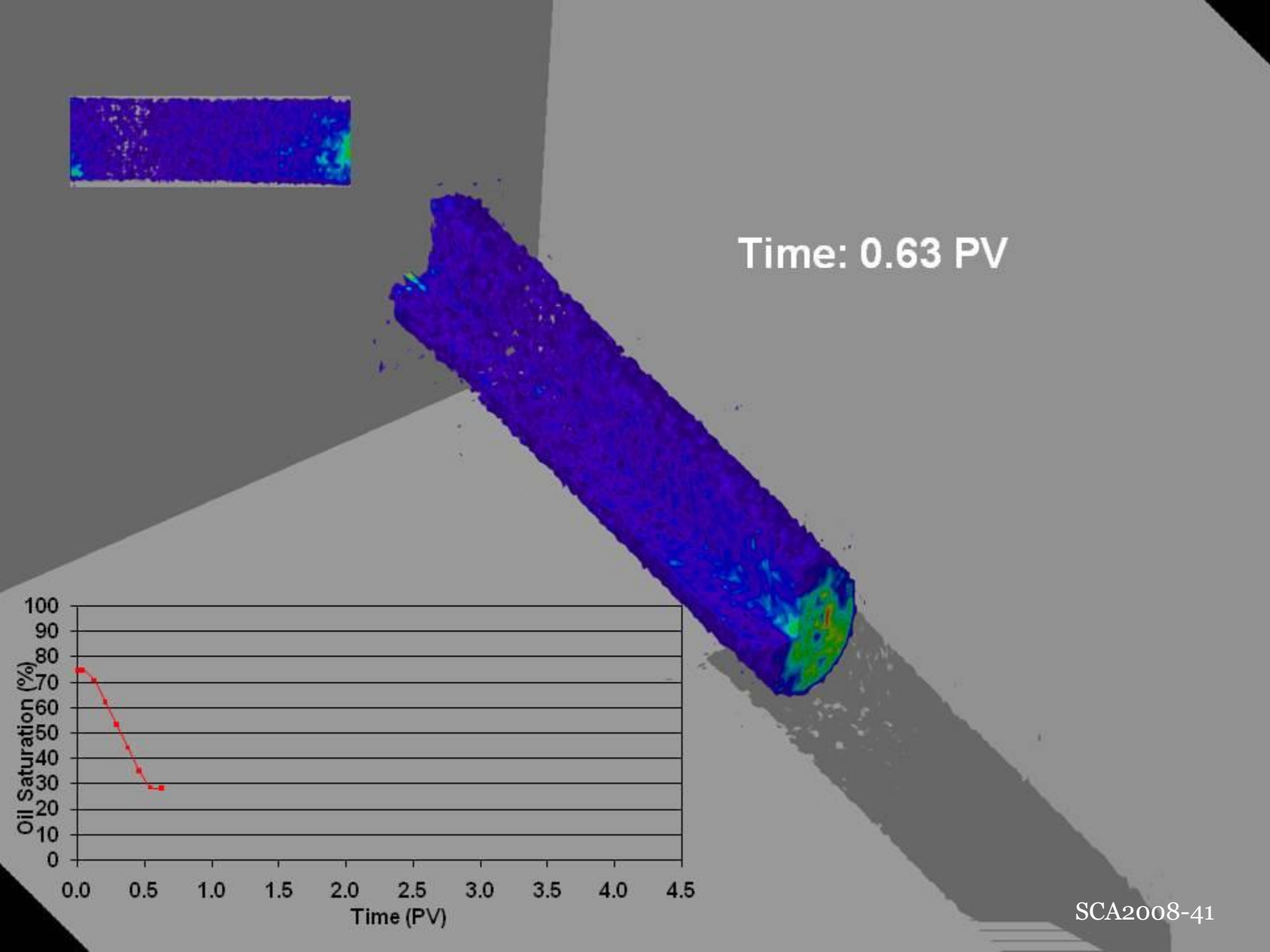

Oil Saturation (%)
100
90
80
70
60
50
40
30
20
10
0
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
Time (PV)

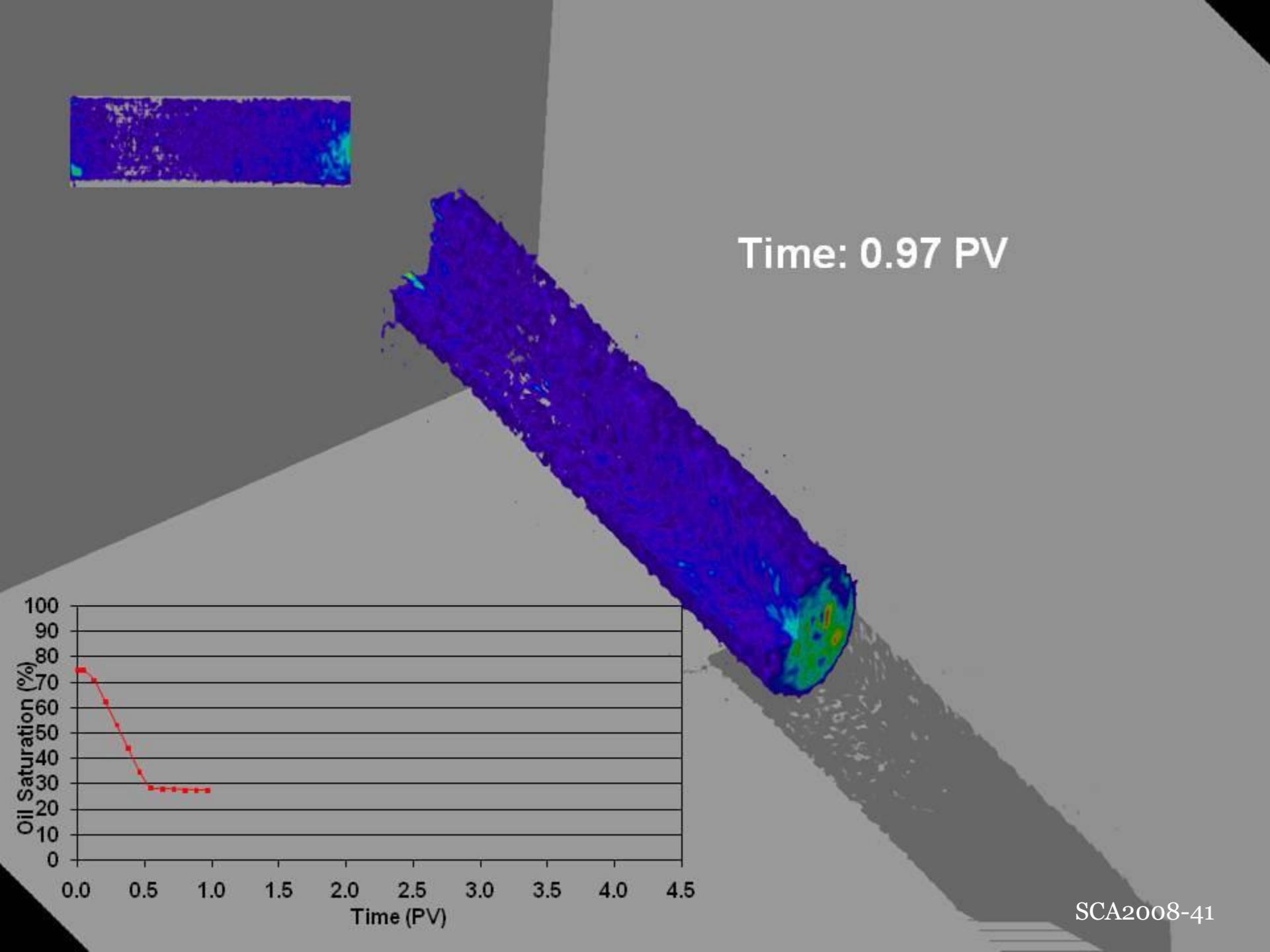

Time: 0.29 PV
Oil Saturation (%)
100
90
80
70
60
50
40
30
20
10
0
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
Time (PV)

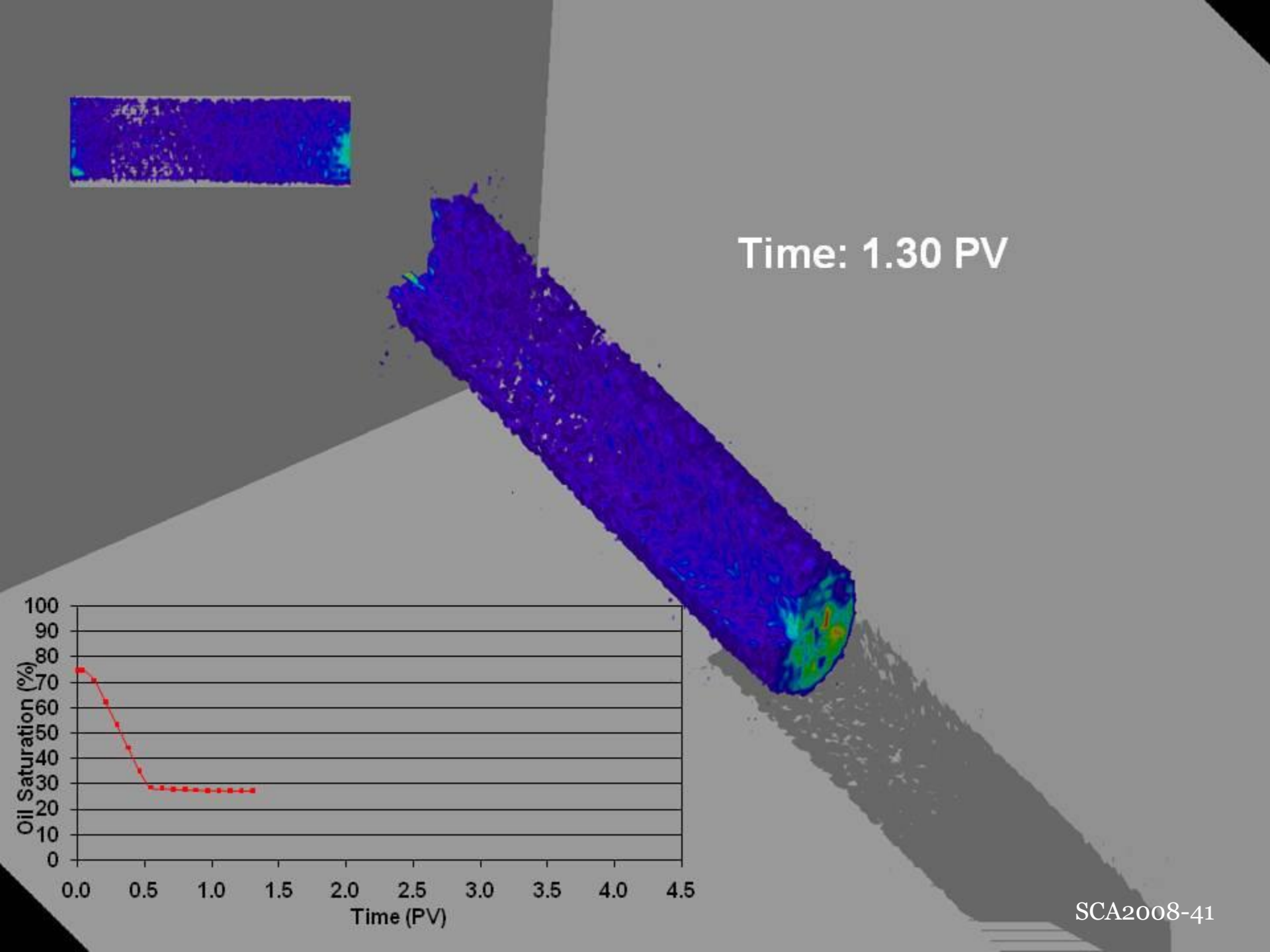

Time: 0.37 PV
Oil Saturation (%)
100
90
80
70
60
50
40
30
20
10
0
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
Time (PV)

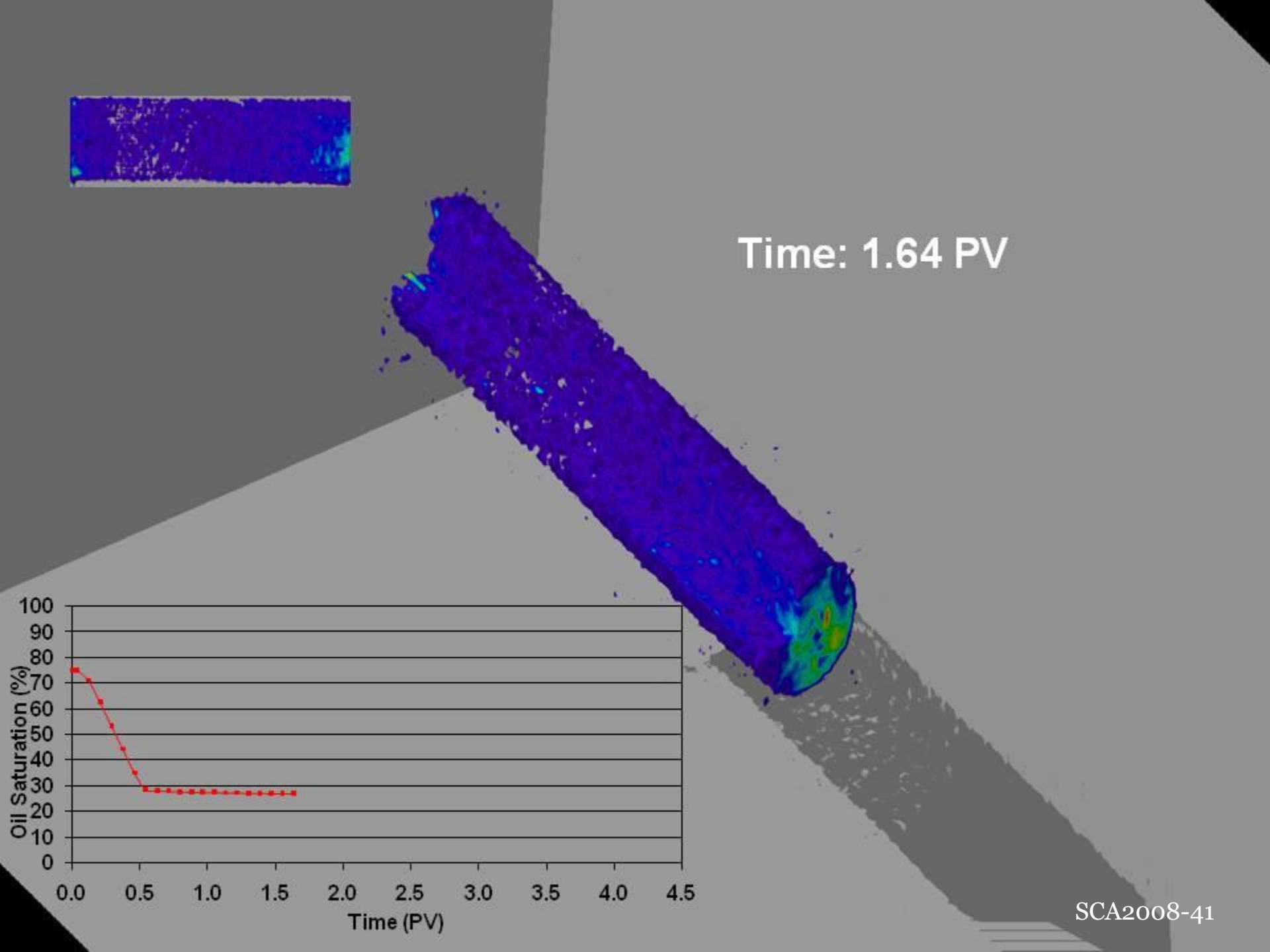

Time: 0.46 PV
Oil Saturation (%)
100
90
80
70
60
50
40
30
20
10
0
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
Time (PV)

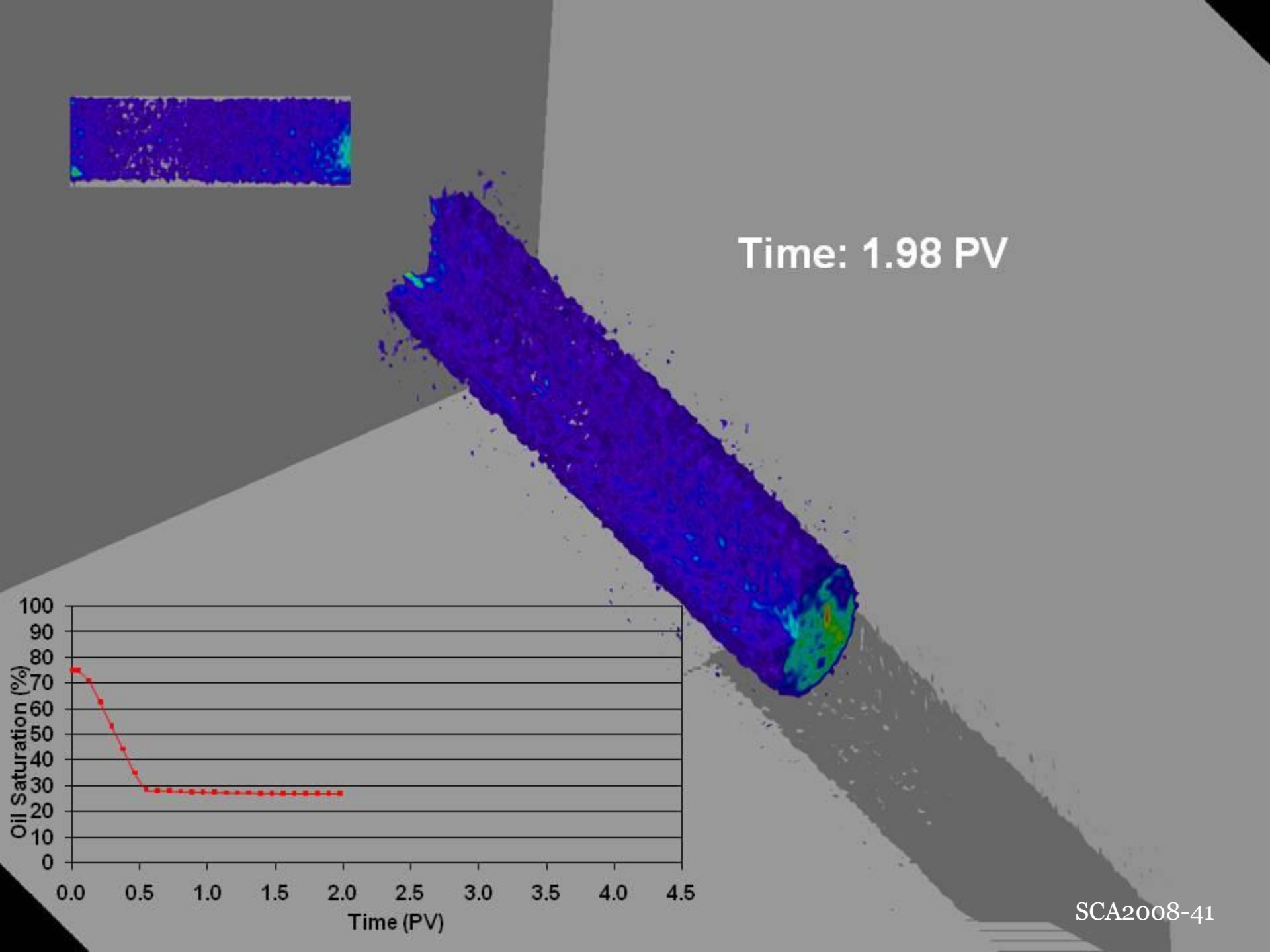

Time: 0.54 PV
Oil Saturation (%)
100
90
80
70
60
50
40
30
20
10
0
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
Time (PV)

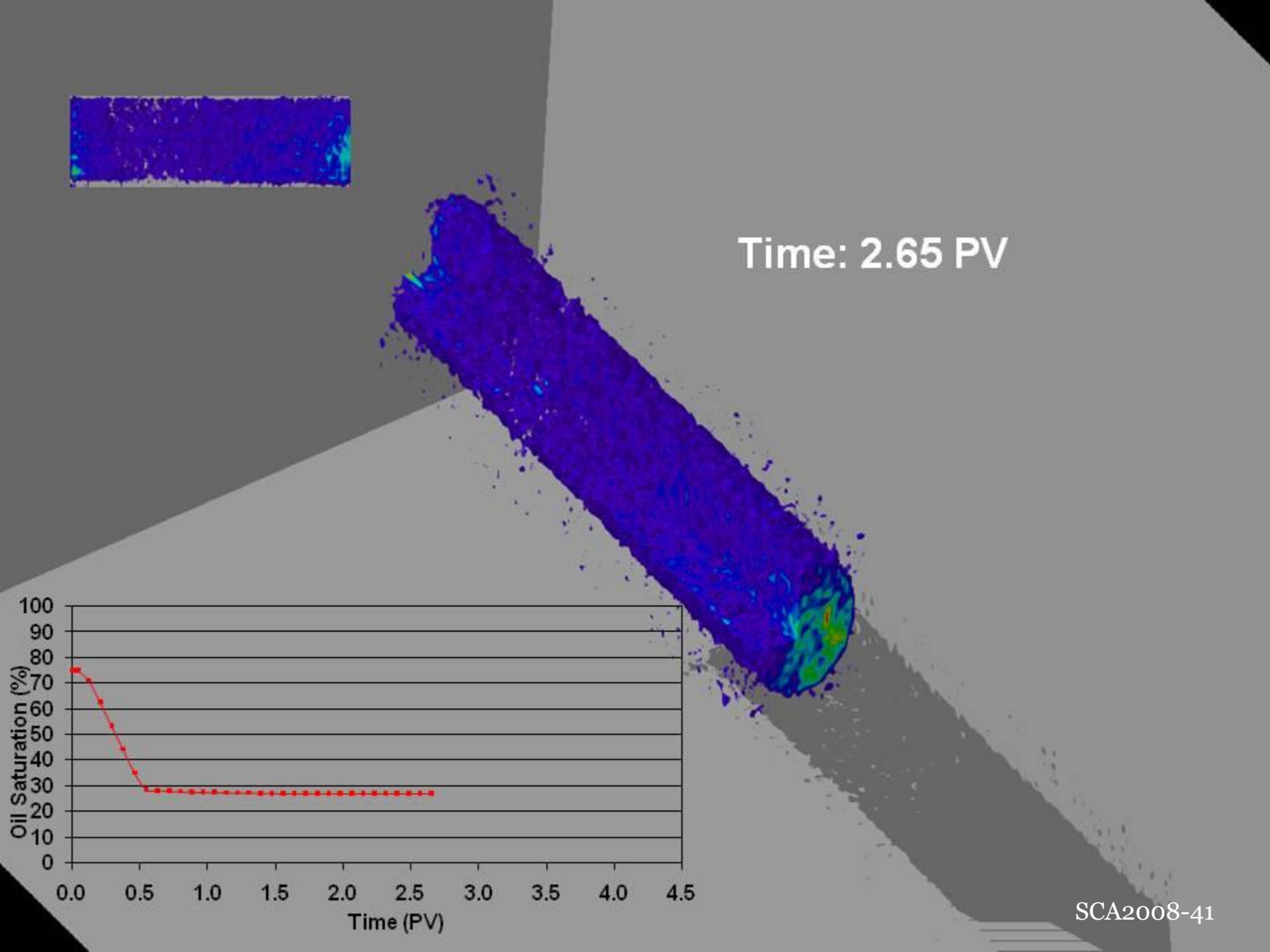

Time: 0.63 PV
Oil Saturation (%)
100
90
80
70
60
50
40
30
20
10
0
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
Time (PV)

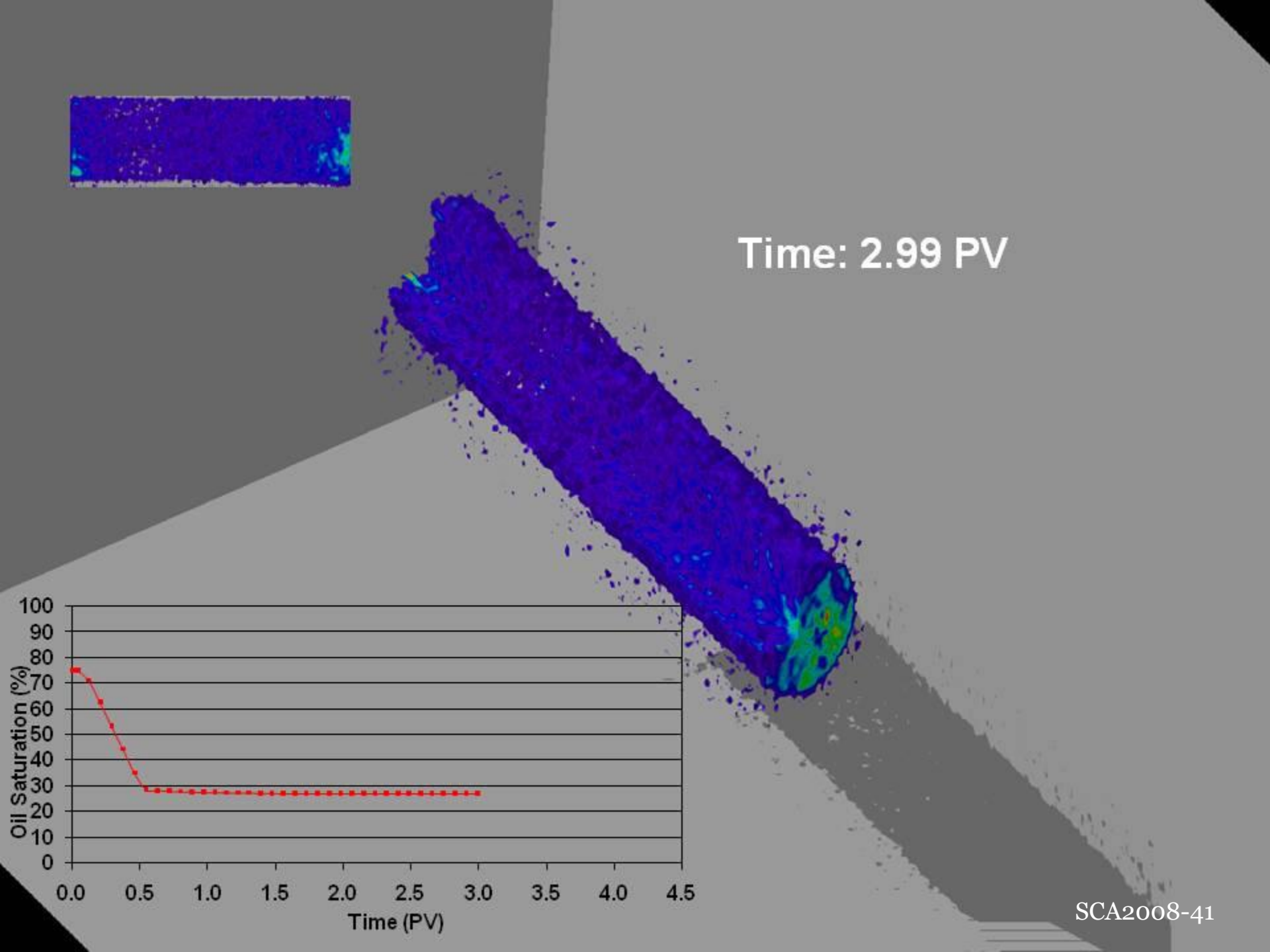

Time: 0.97 PV
Oil Saturation (%)
100
90
80
70
60
50
40
30
20
10
0
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
Time (PV)

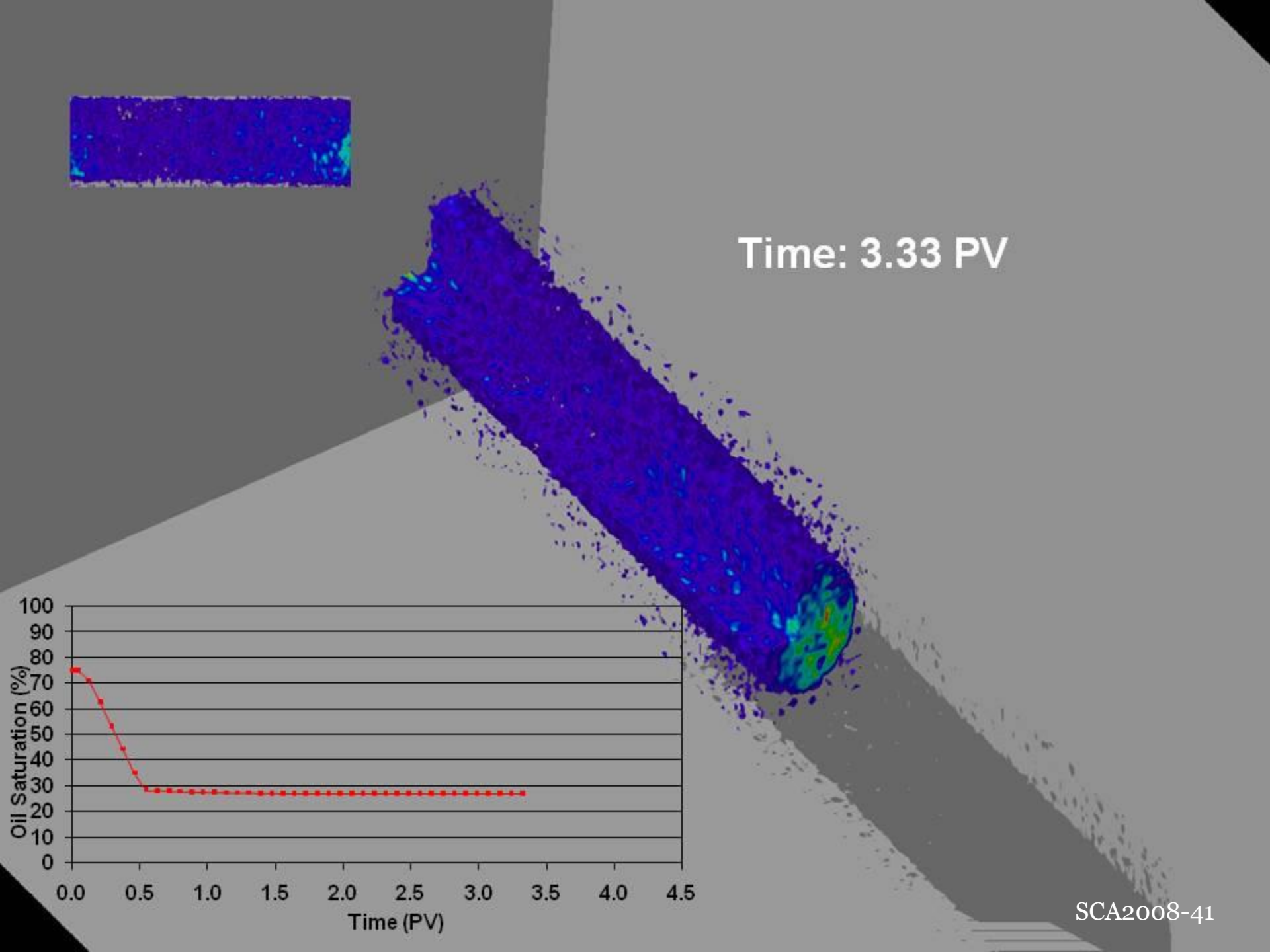

Time: 1.30 PV
Oil Saturation (%)
100
90
80
70
60
50
40
30
20
10
0
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
Time (PV)

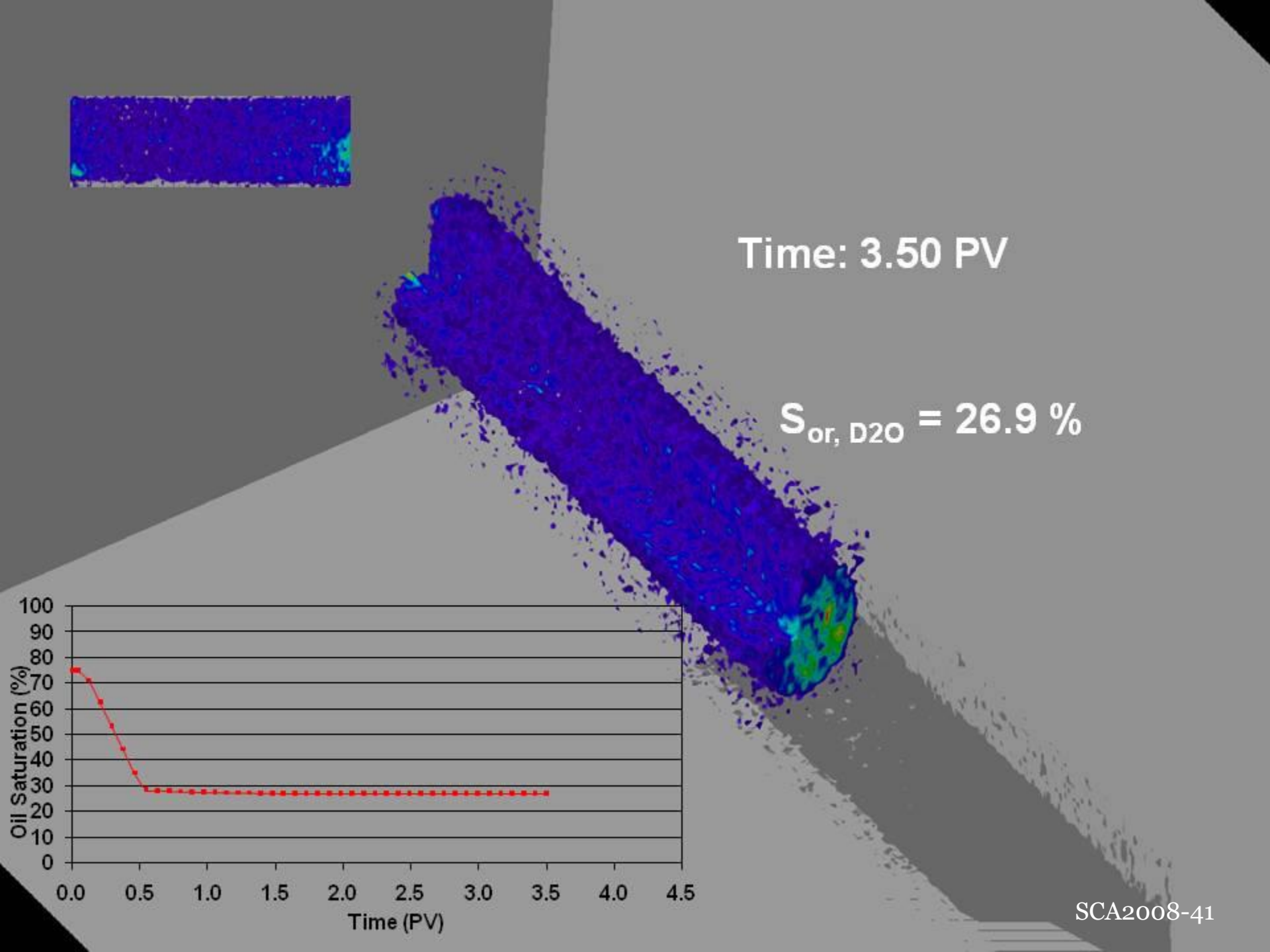

Time: 1.64 PV
Oil Saturation (%)
100
90
80
70
60
50
40
30
20
10
0
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
Time (PV)

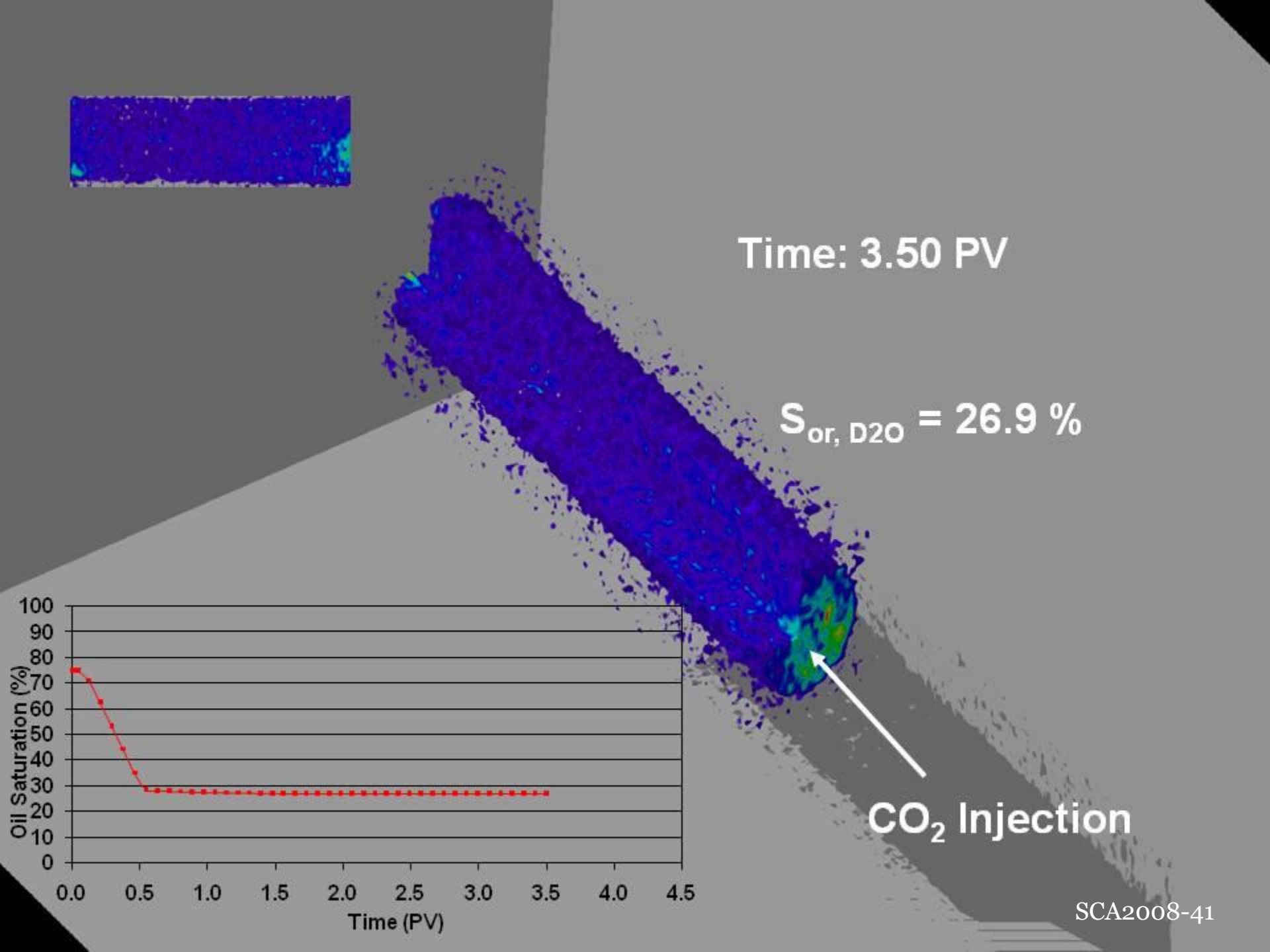

Time: 1.98 PV
Oil Saturation (%)
100
90
80
70
60
50
40
30
20
10
0
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
Time (PV)

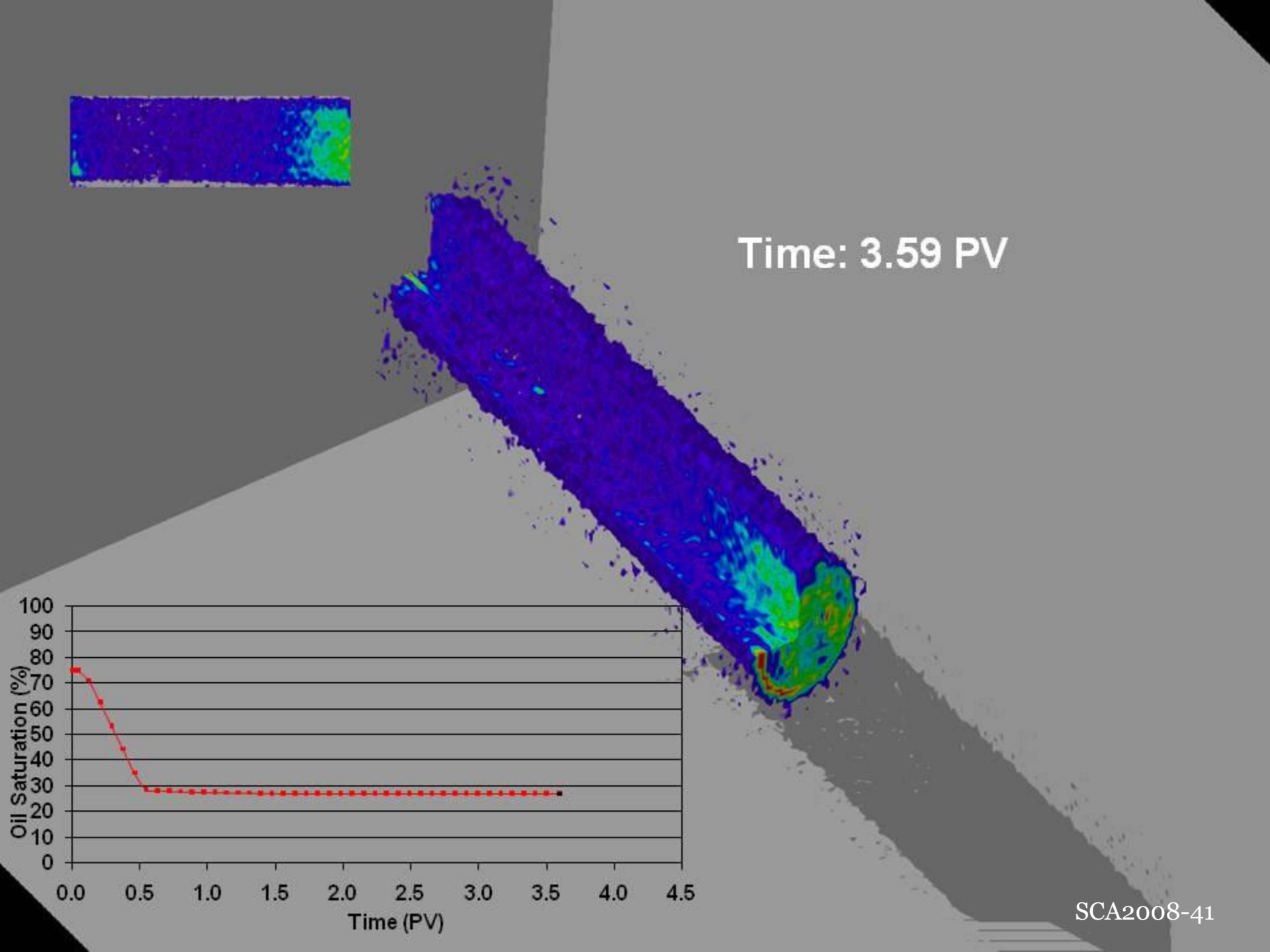

Time: 2.65 PV
Oil Saturation (%)
100
90
80
70
60
50
40
30
20
10
0
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
Time (PV)

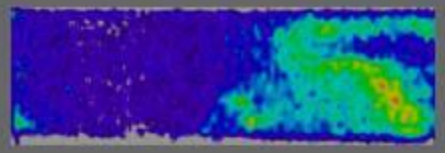

Time: 2.99 PV
Oil Saturation (%)
100
90
80
70
60
50
40
30
20
10
0
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
Time (PV)


Time: 3.33 PV
Oil Saturation (%)
100
90
80
70
60
50
40
30
20
10
0
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
Time (PV)

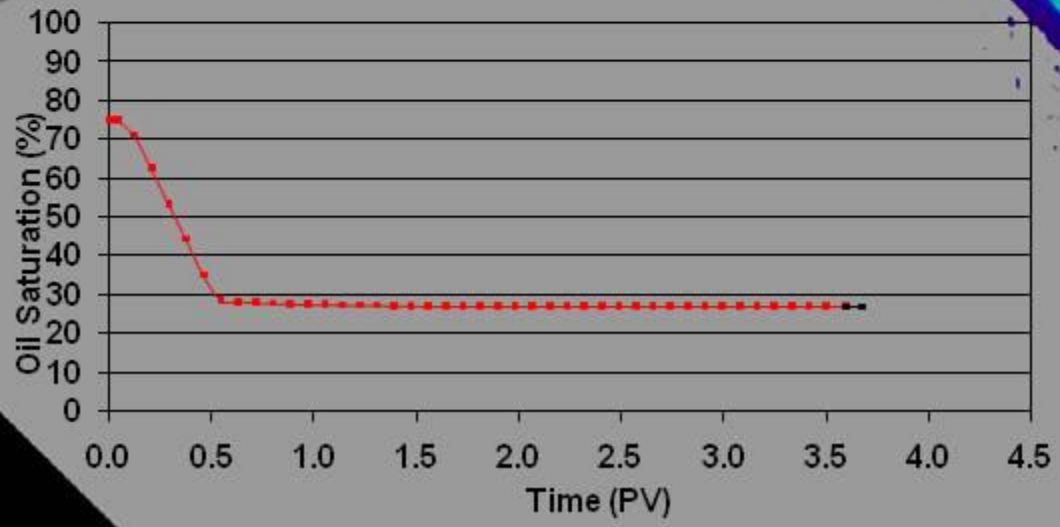

Time: 3.50 PV
$S_{or, D2O}$ = 26.9 %
Oil Saturation (%)
100
90
80
70
60
50
40
30
20
10
0
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
Time (PV)

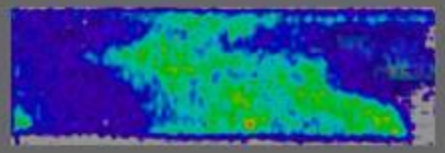

Time: 3.50 PV
$S_{or, D2O}$ = 26.9 %
CO_2 Injection
Oil Saturation (%)
100
90
80
70
60
50
40
30
20
10
0
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
Time (PV)


Time: 3.59 PV
Oil Saturation (%)
100
90
80
70
60
50
40
30
20
10
0
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
Time (PV)

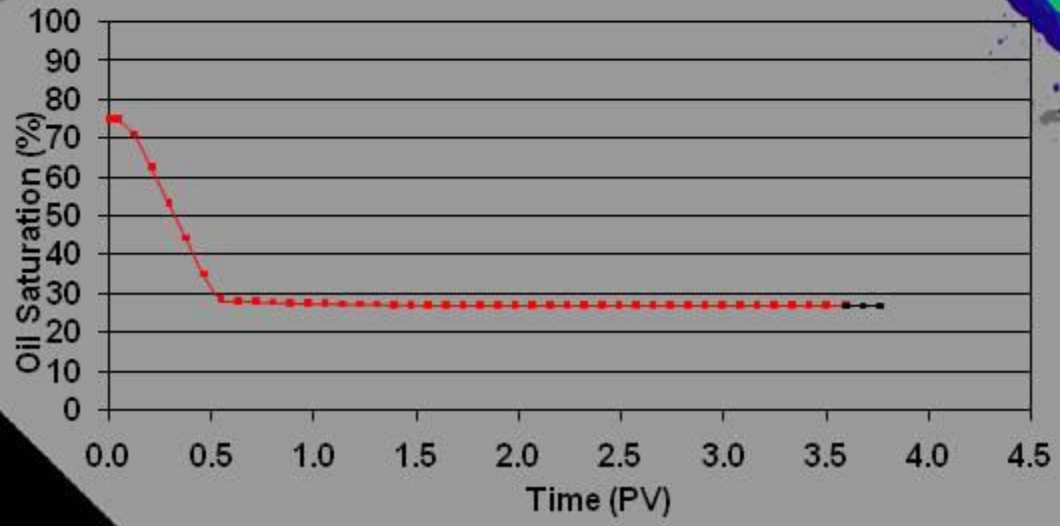


Time: 3.68 PV


Oil Saturation (%)
100
90
80
70
60
50
40
30
20
10
0
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
Time (PV)



Time: 3.76 PV


Oil Saturation (%)
100
90
80
70
60
50
40
30
20
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1.5
2.0
2.5
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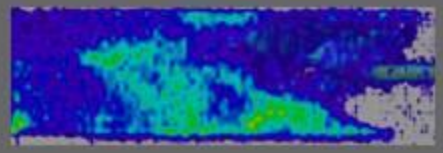
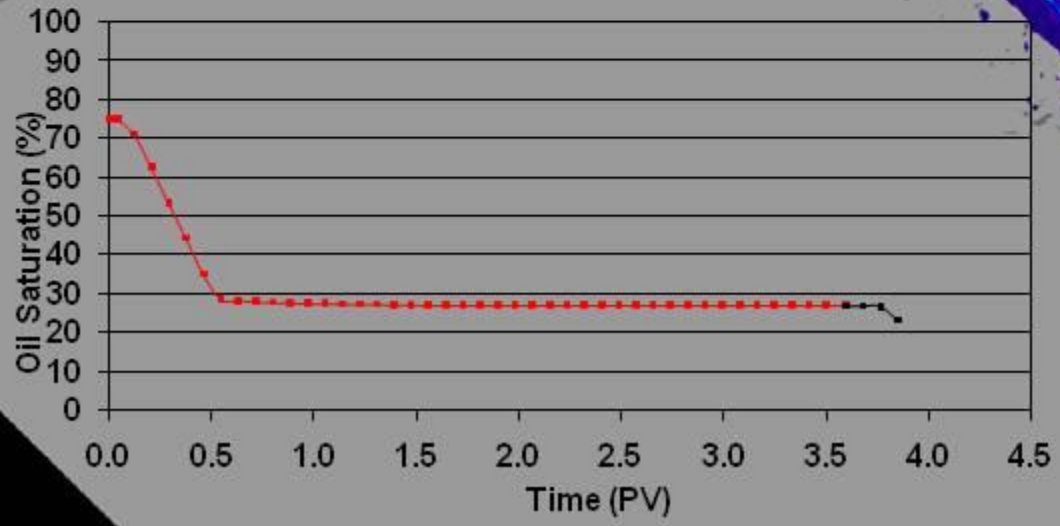
3.5
4.0
4.5
Time (PV)



Time: 3.85 PV


Oil Saturation (%)
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30
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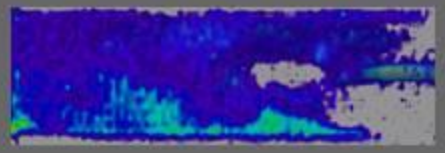
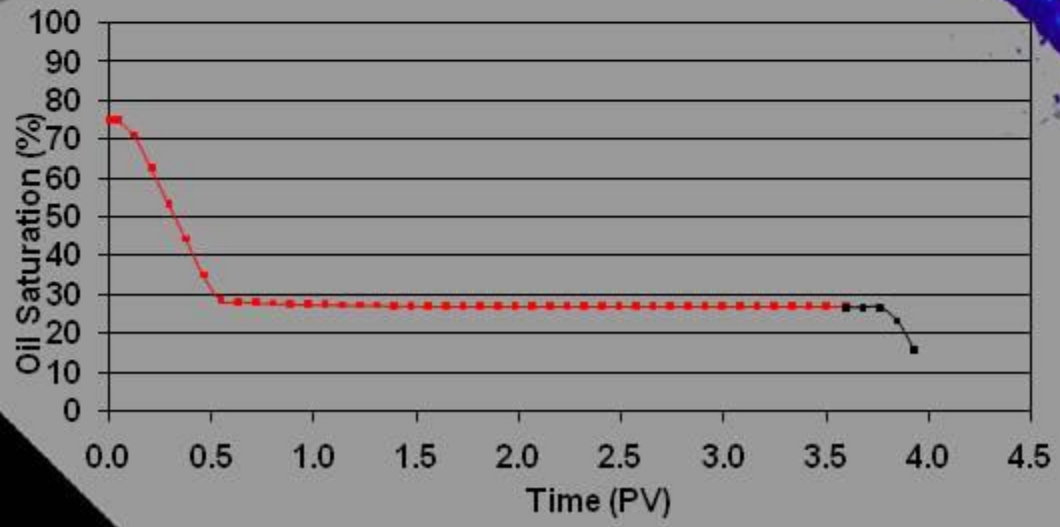
4.0
4.5
Time (PV)



Time: 3.93 PV


Oil Saturation (%)
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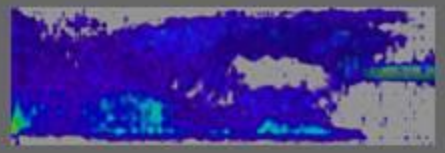
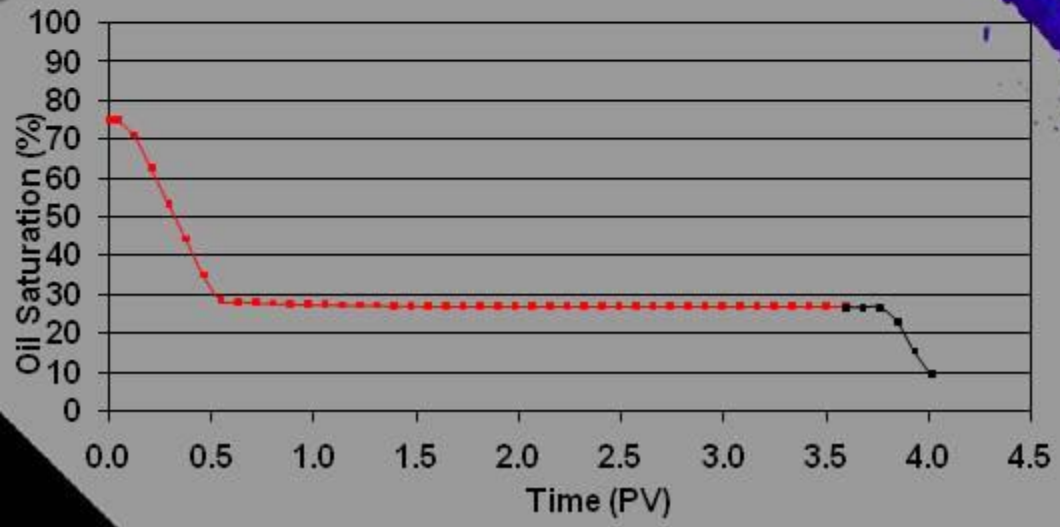
4.0
4.5
Time (PV)



Time: 4.02 PV


Oil Saturation (%)
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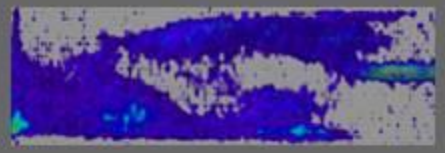
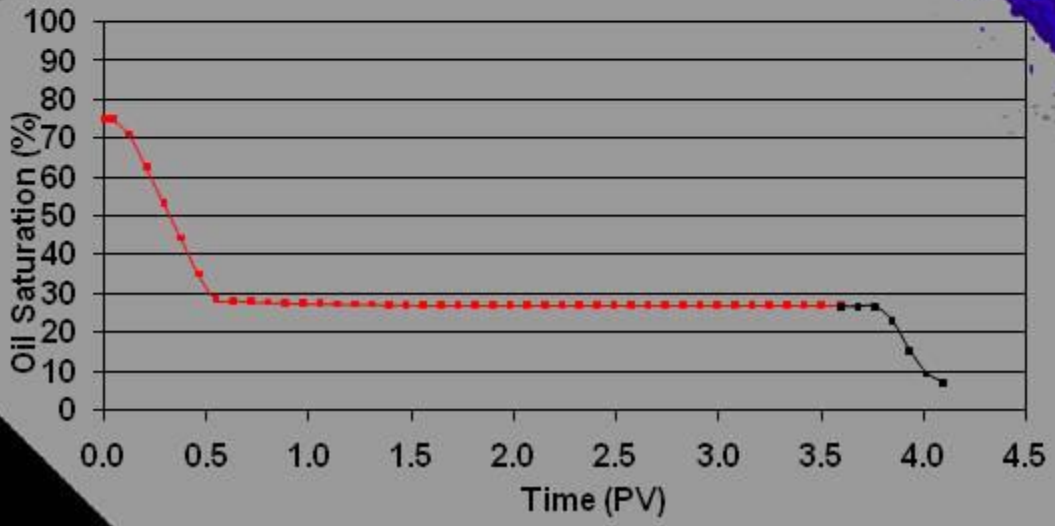
4.0
4.5
Time (PV)



Time: 4.10 PV


Oil Saturation (%)
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3.0
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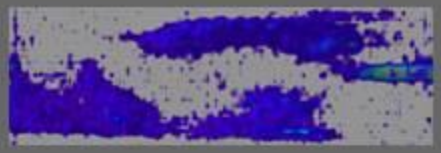
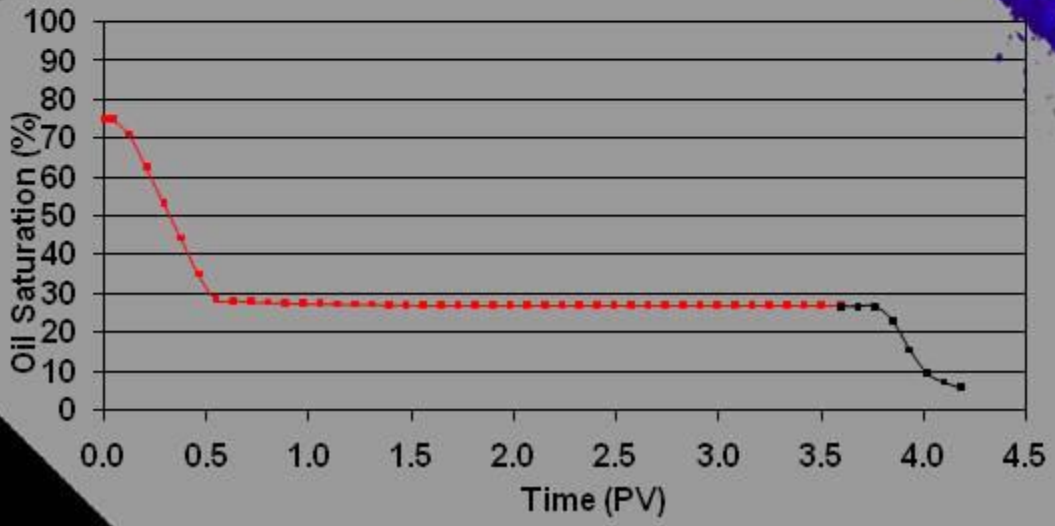
4.0
4.5
Time (PV)



Time: 4.18 PV


Oil Saturation (%)
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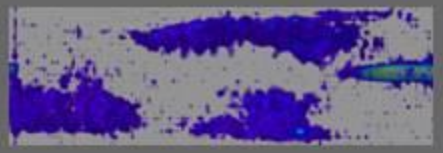
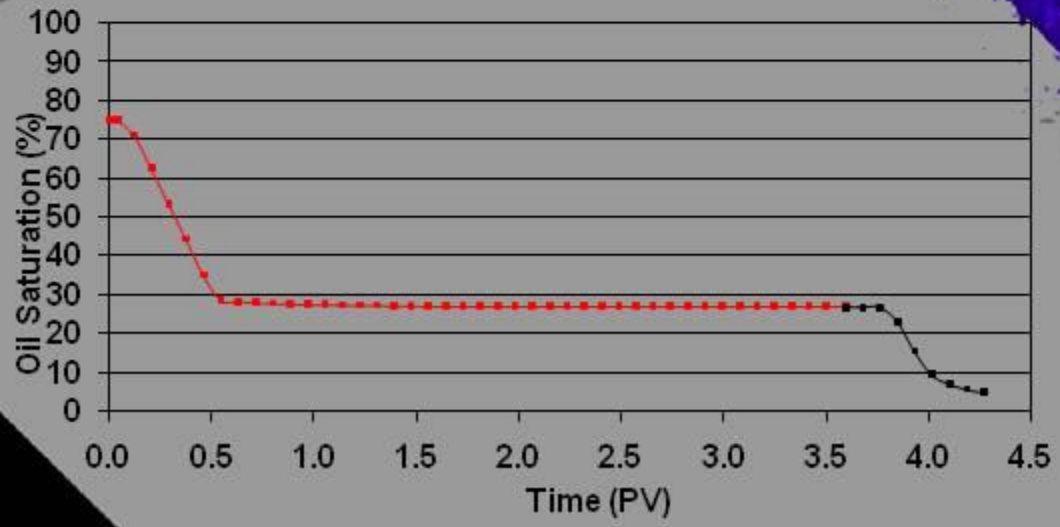
4.5
Time (PV)



Time: 4.27 PV


Oil Saturation (%)
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30
20
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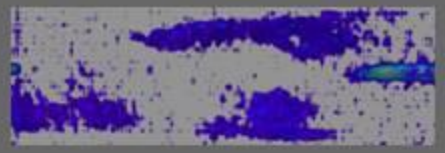
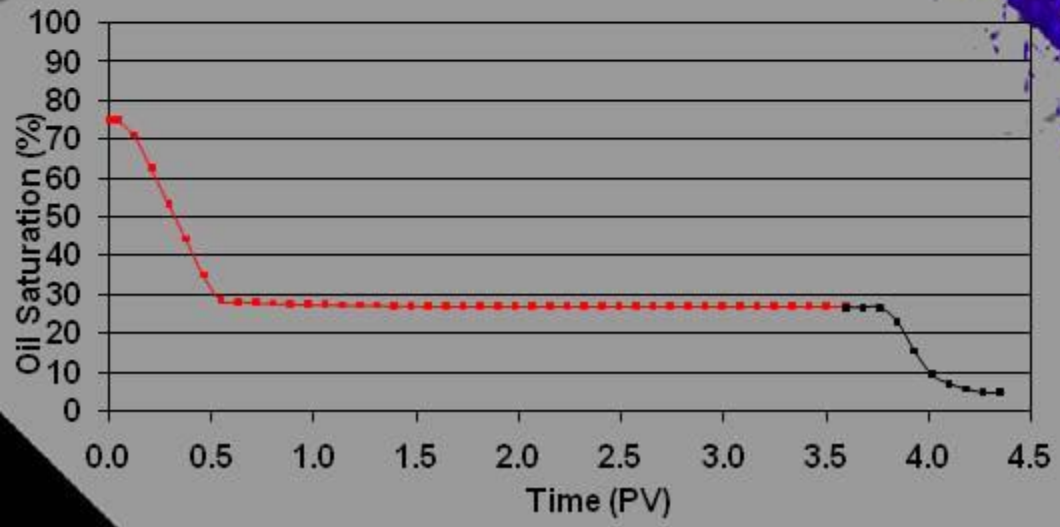
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
Time (PV)



Time: 4.35 PV


Oil Saturation (%)
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30
20
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1.0
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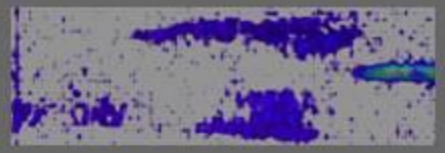
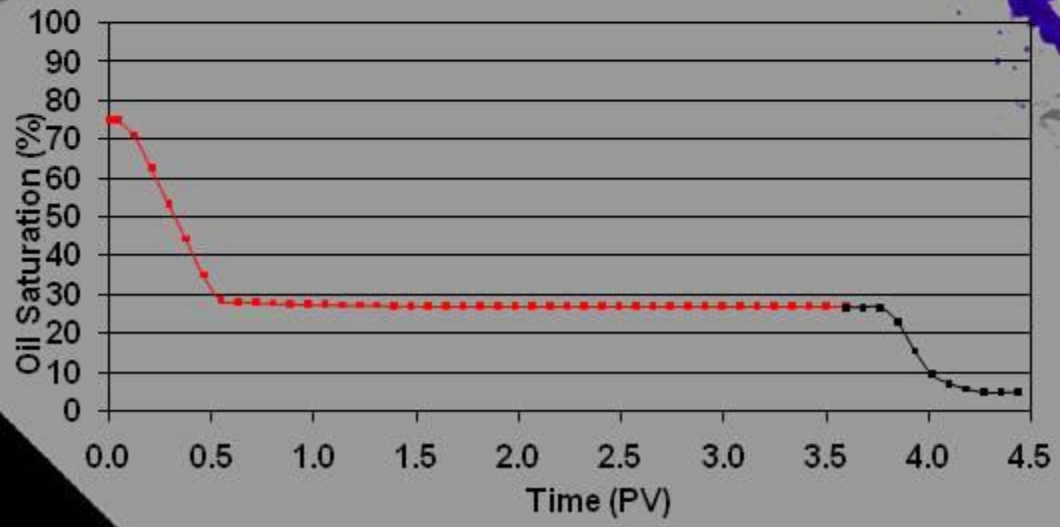
3.0
3.5
4.0
4.5
Time (PV)



Time: 4.44 PV

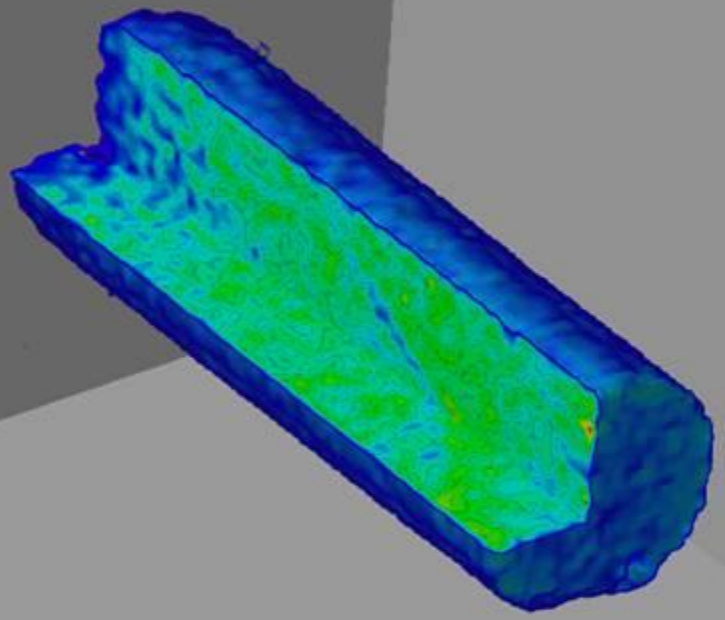
$S_{or,\ CO2}$ = 4.8 %

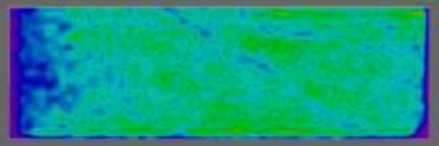


Tertiary CO_2 Injection of Neutral-Wet Chalk

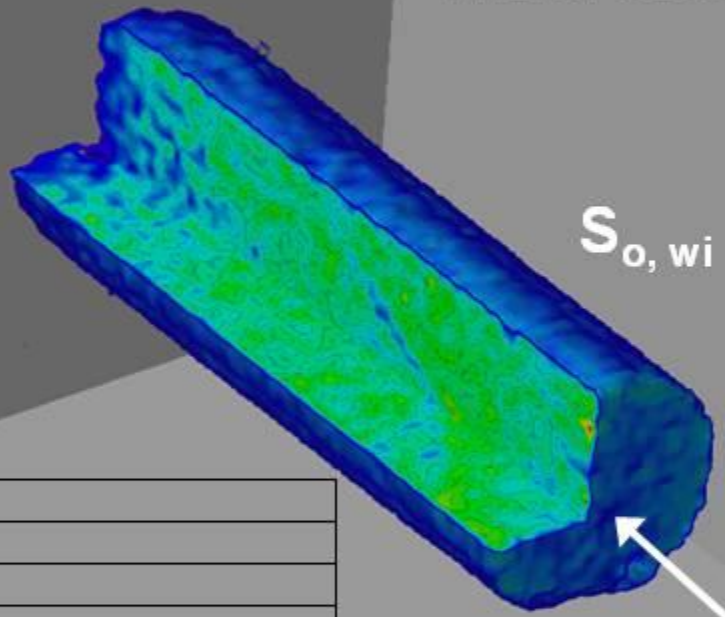
Temp.: 20^0C

Amott Index 0.15

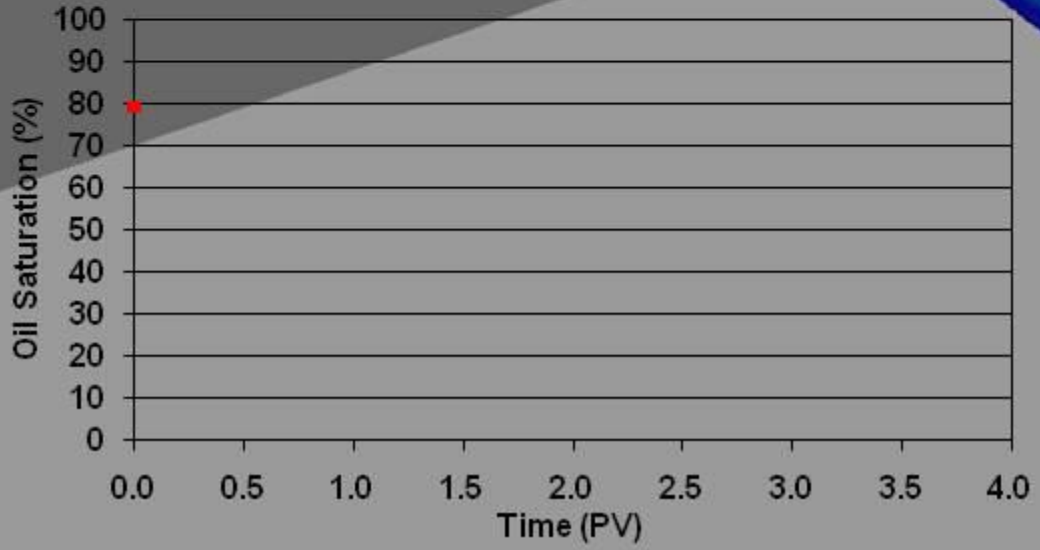




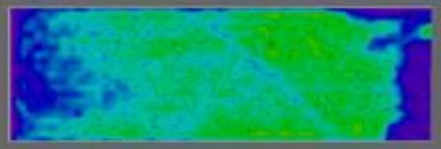
Time: 0.00 PV



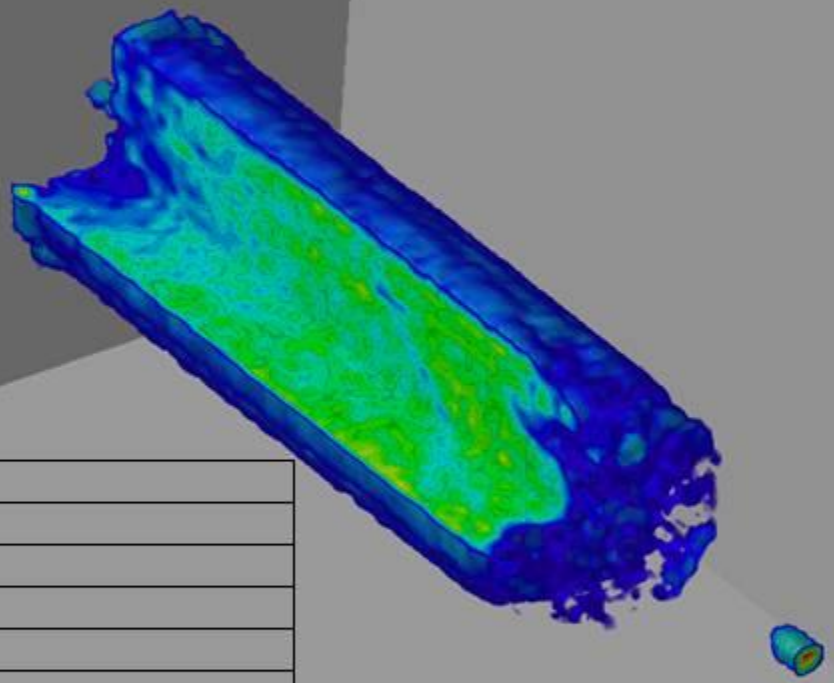
$S_{o,\,wi}$ = 79.9 %

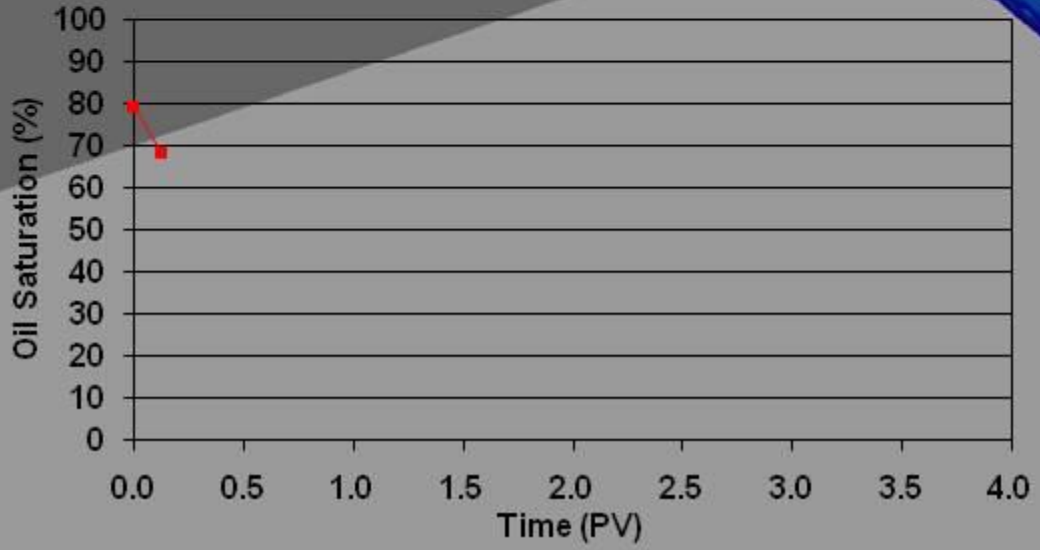


D_2O Injection



Time: 0.13 PV




Oil Saturation (%)
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0.5
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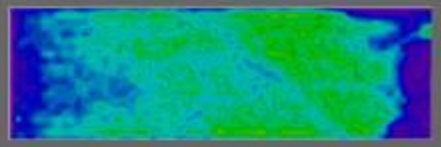
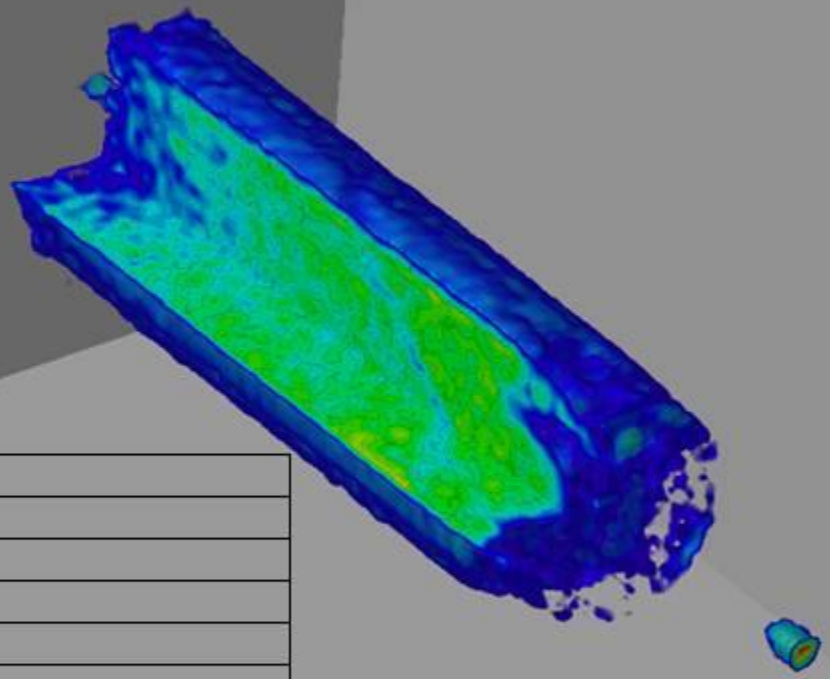
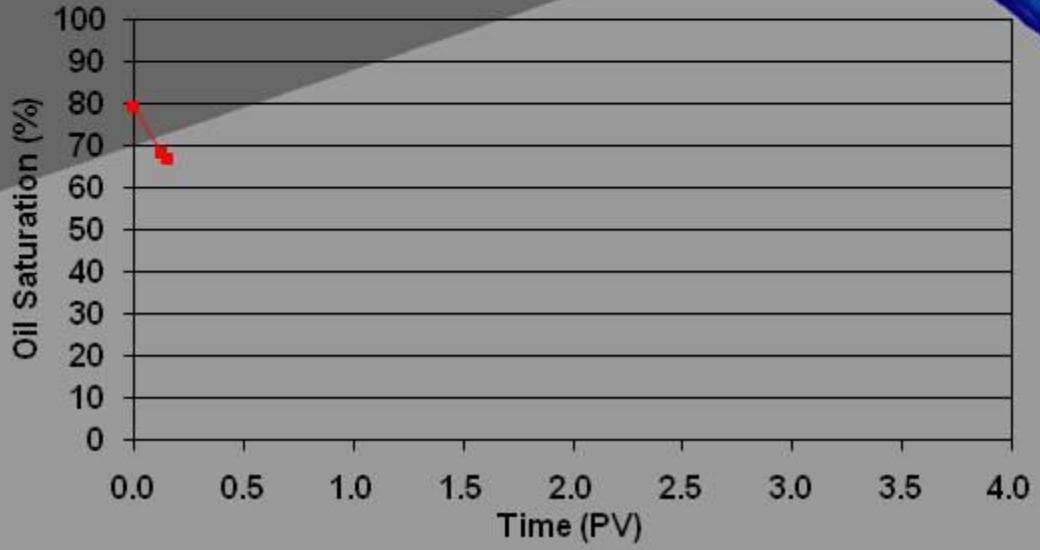
1.5
2.0
2.5
3.0
3.5
4.0
Time (PV)



Time: 0.15 PV




Oil Saturation (%)
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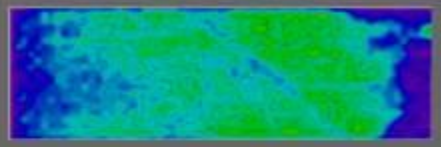
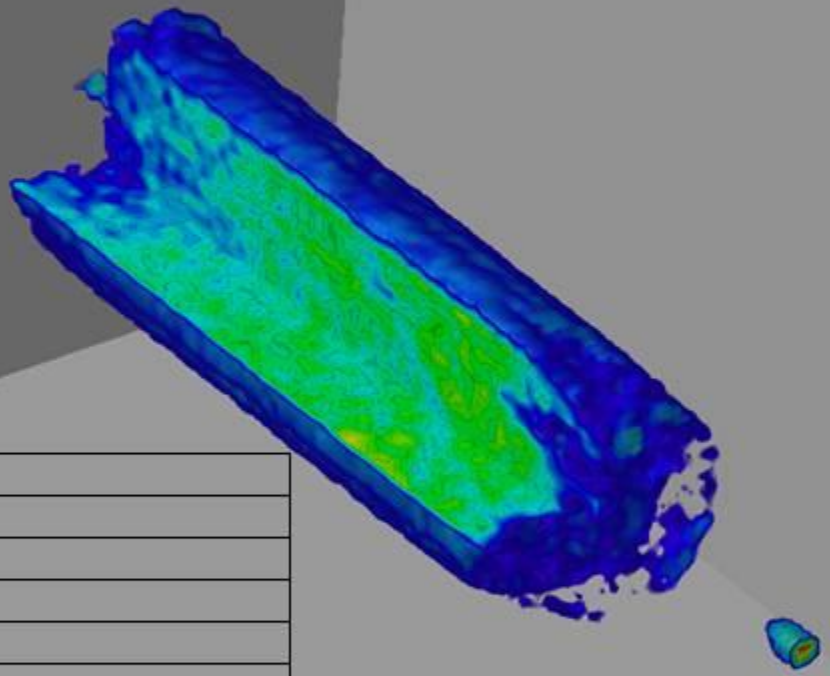
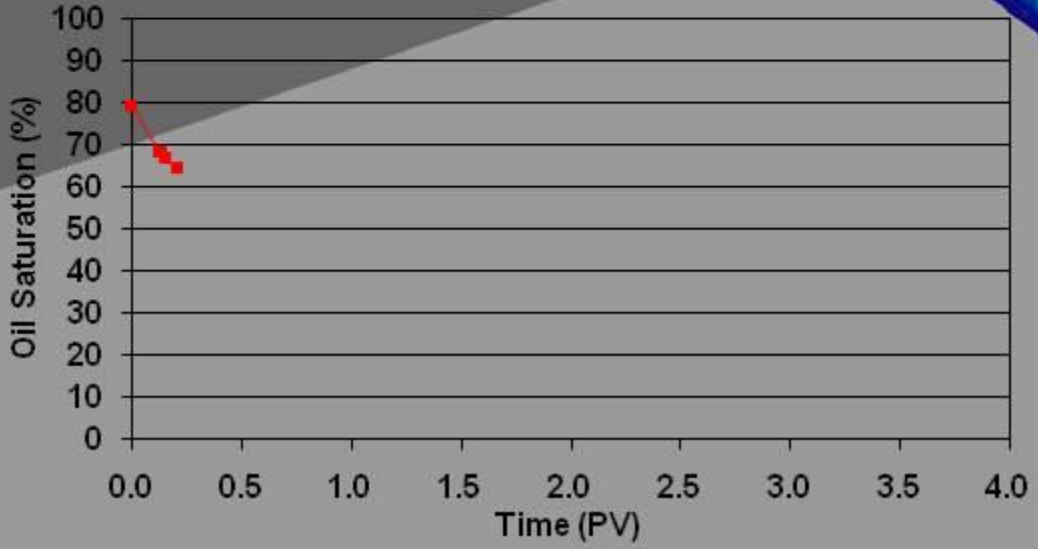
4.0
Time (PV)



Time: 0.20 PV




Oil Saturation (%)
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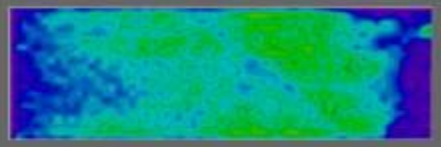
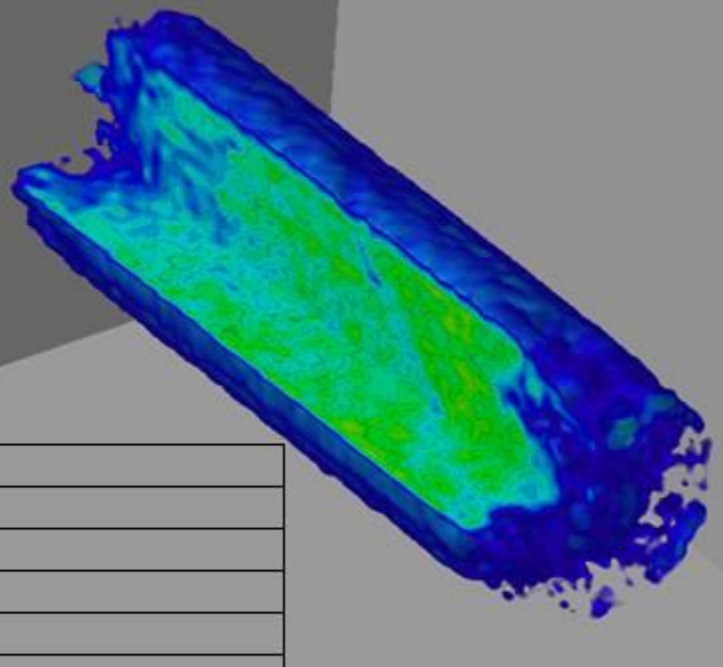
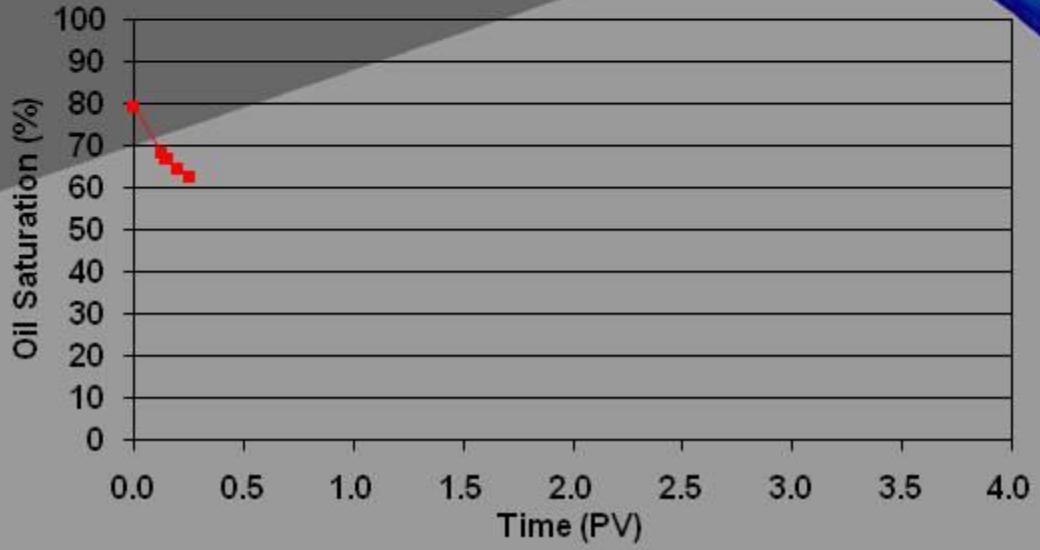
4.0
Time (PV)



Time: 0.25 PV




Oil Saturation (%)
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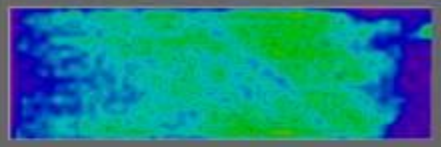
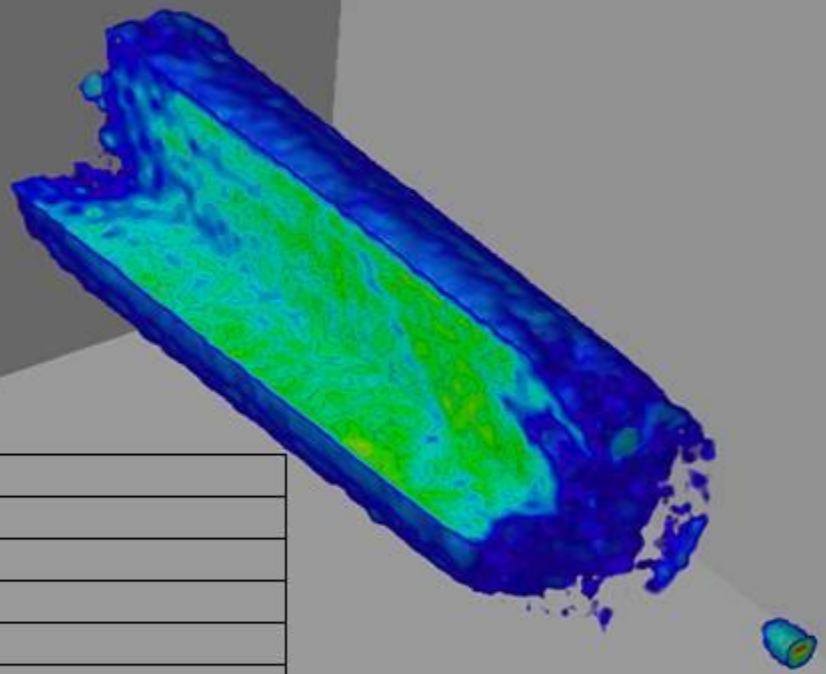
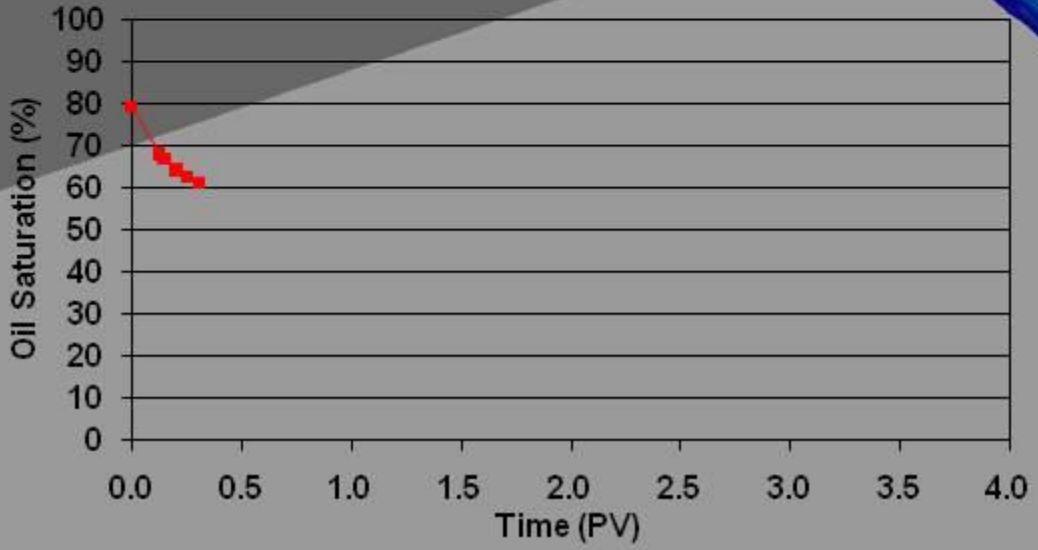
4.0
Time (PV)



Time: 0.31 PV




Oil Saturation (%)
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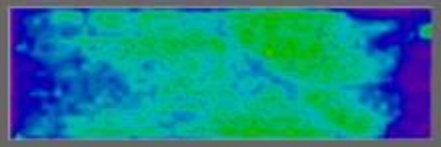
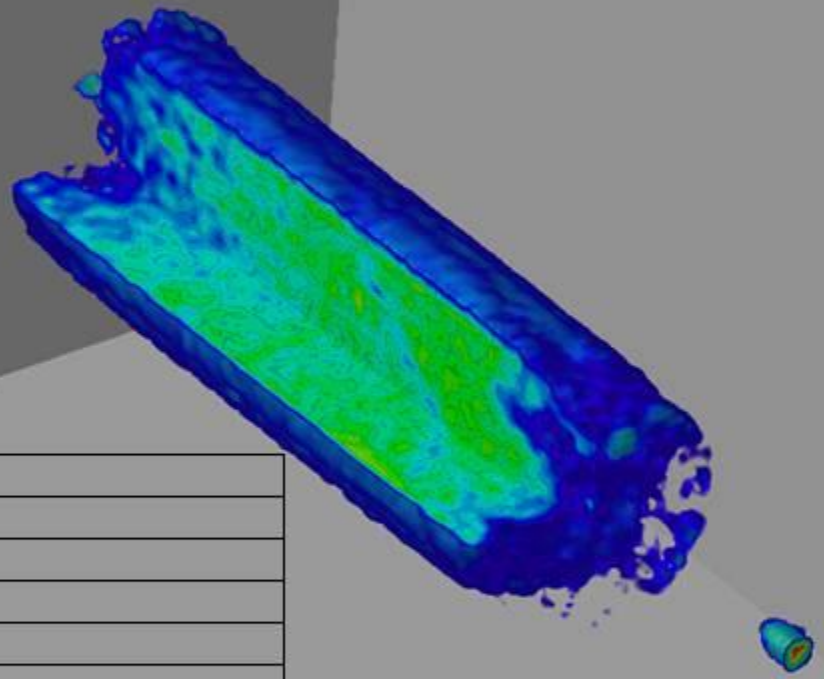
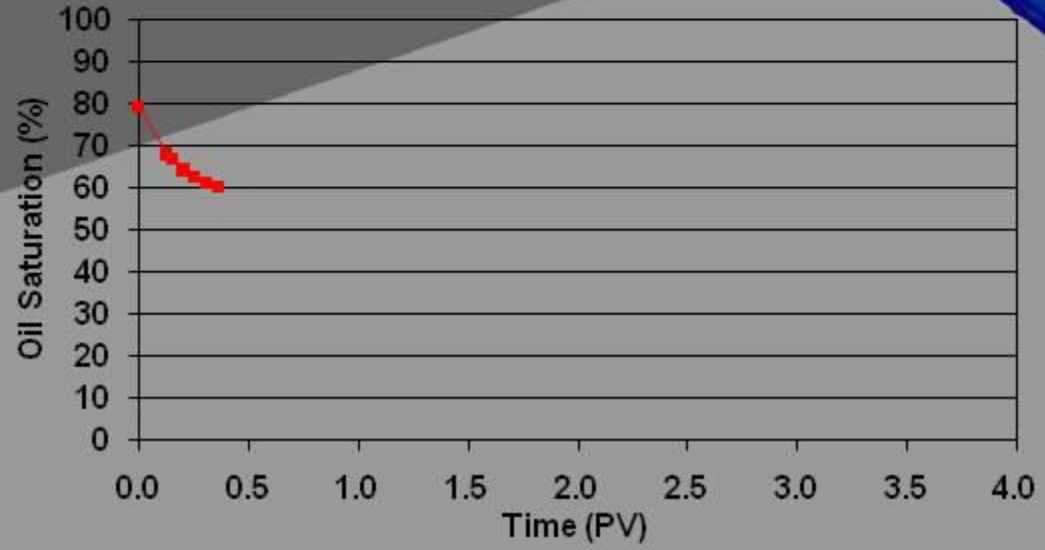
4.0
Time (PV)



Time: 0.36 PV

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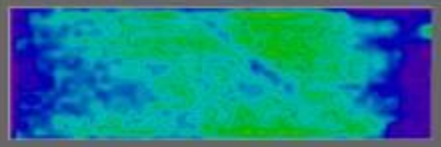
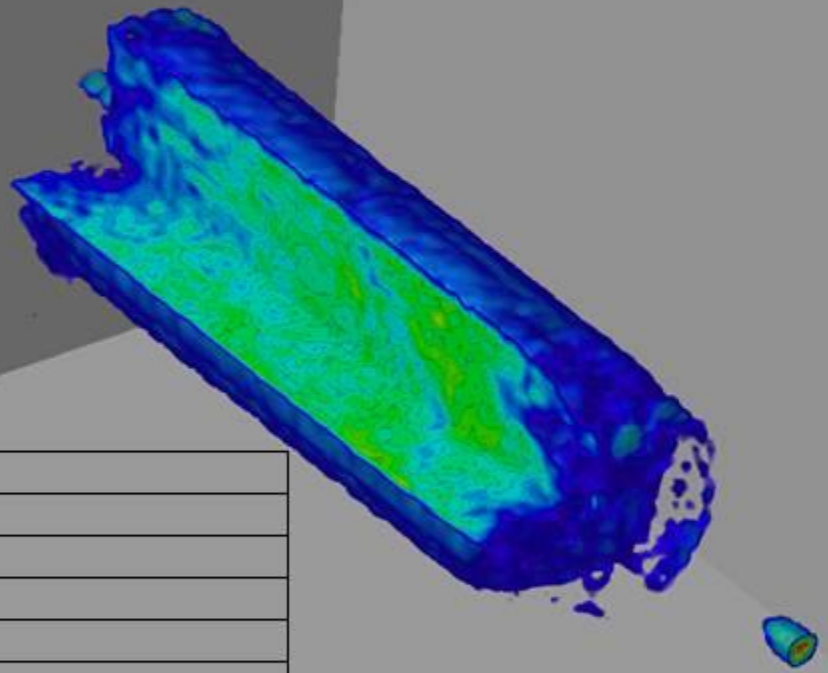
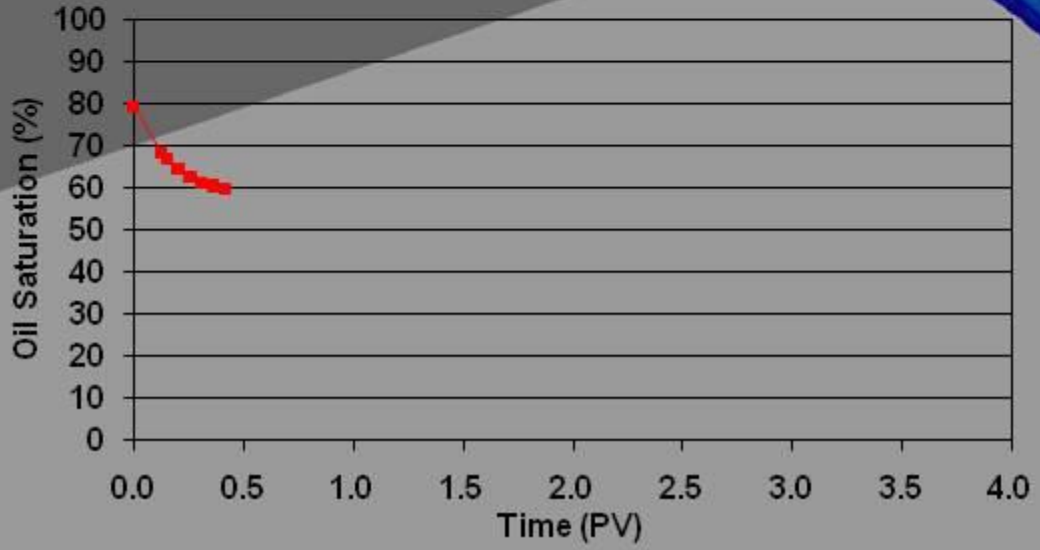
Time (PV)



Time: 0.41 PV




Oil Saturation (%)
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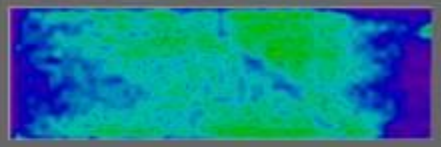
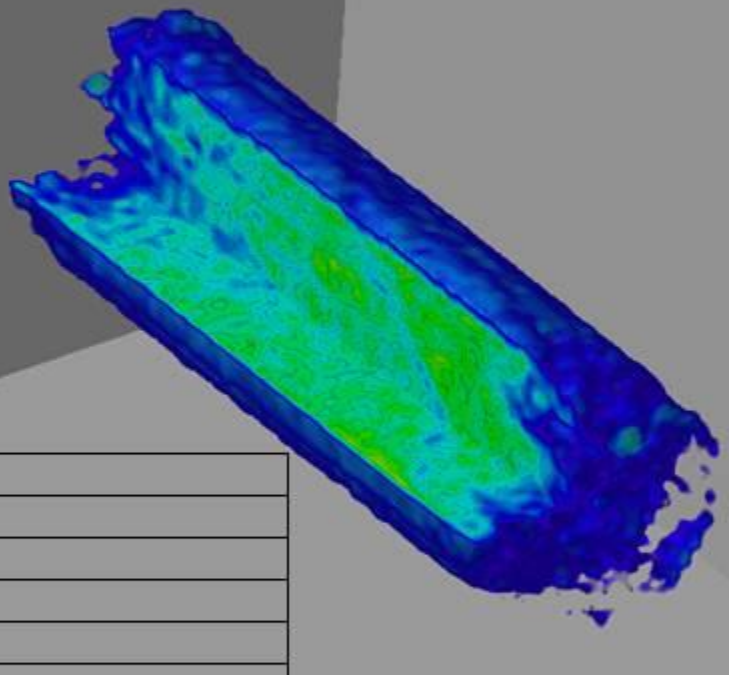
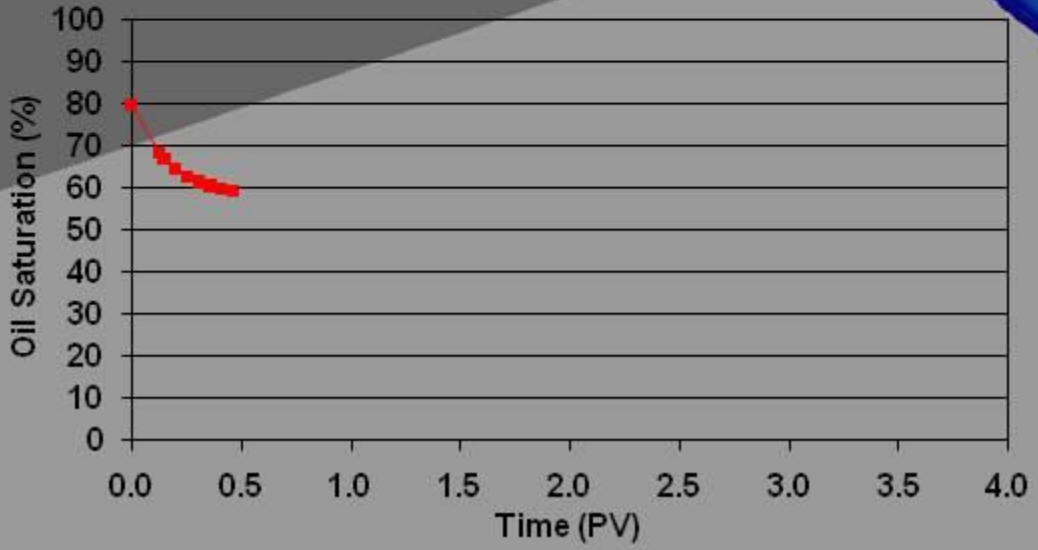
Time (PV)



Time: 0.46 PV




Oil Saturation (%)
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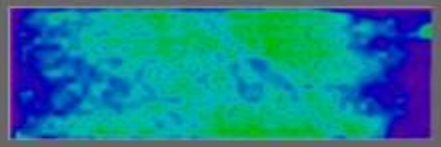
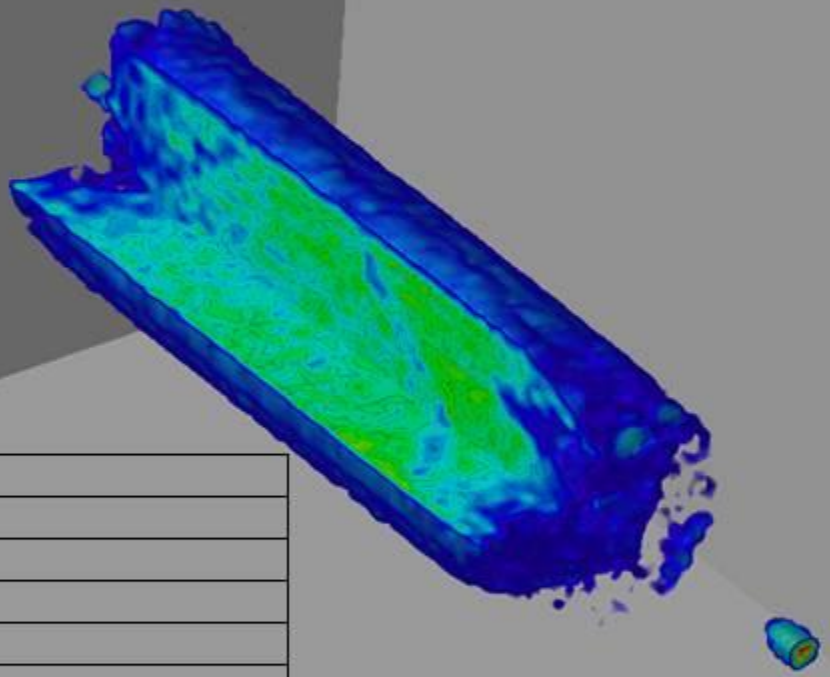
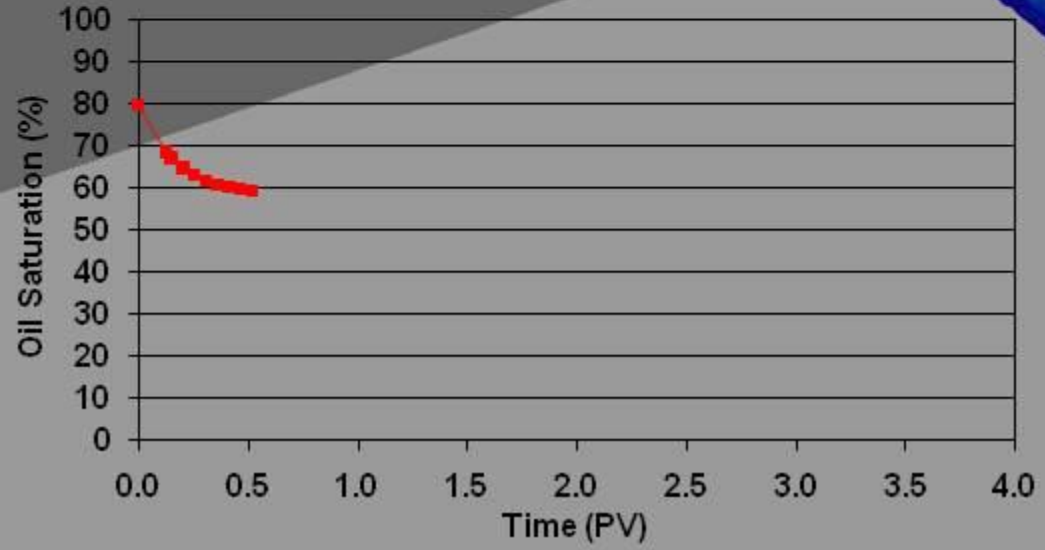
Time (PV)



Time: 0.52 PV




Oil Saturation (%)
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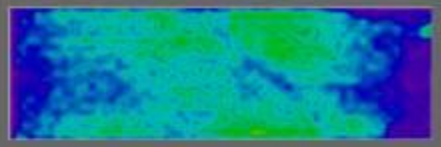
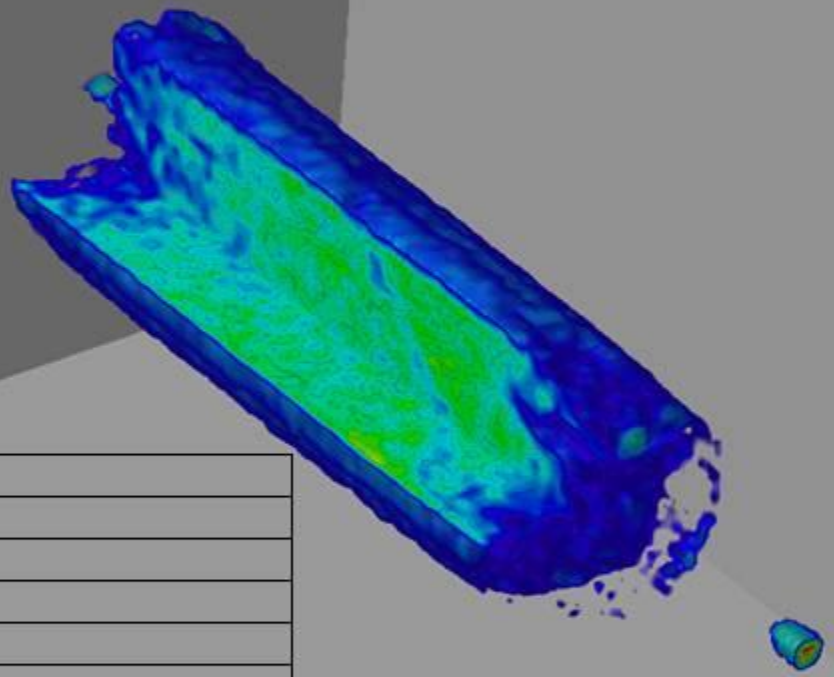
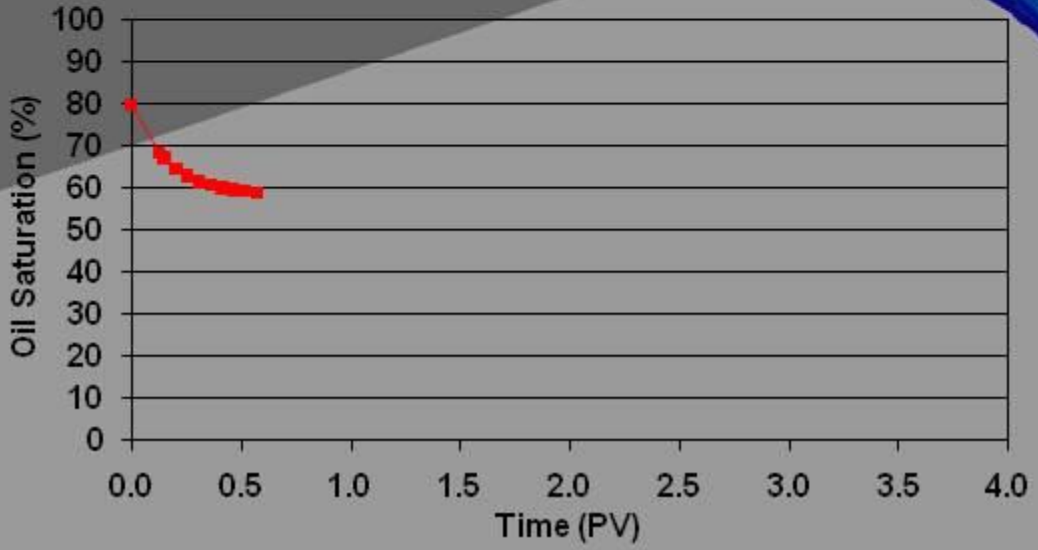
Time (PV)



Time: 0.57 PV

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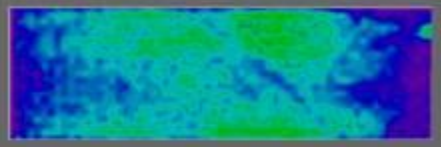
Time (PV)



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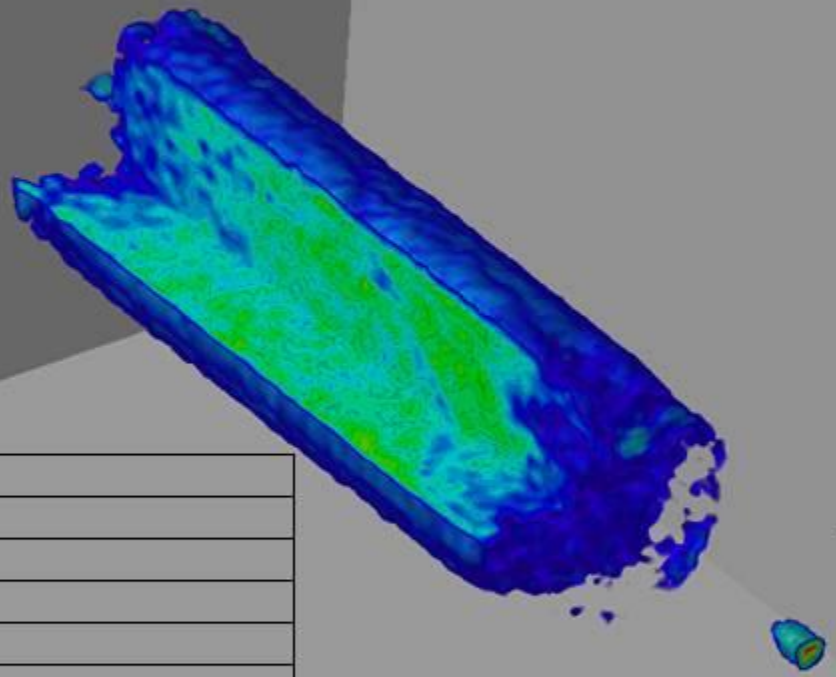

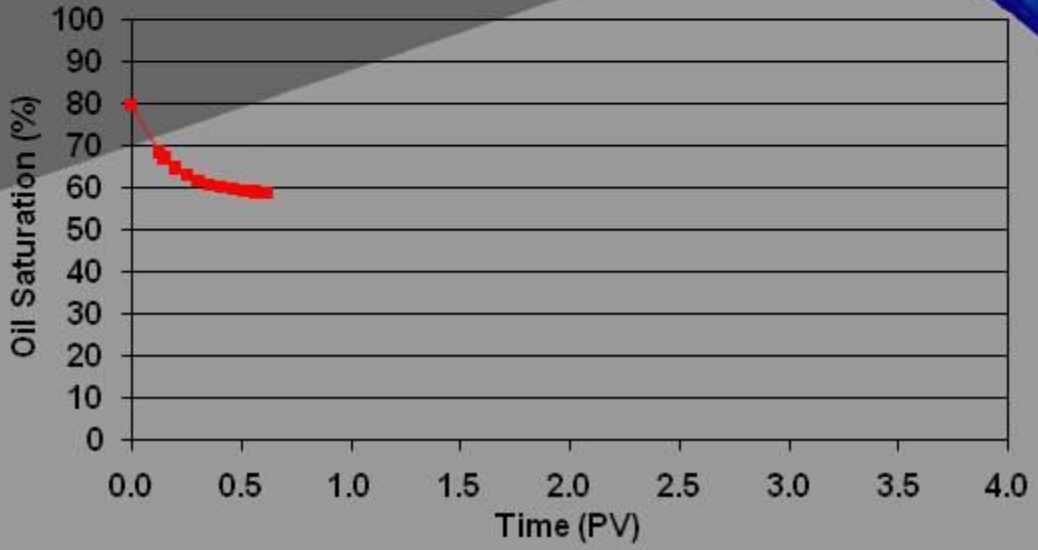
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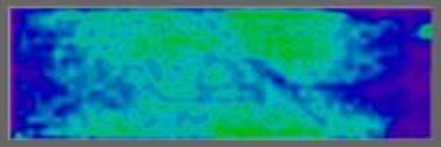
Time (PV)



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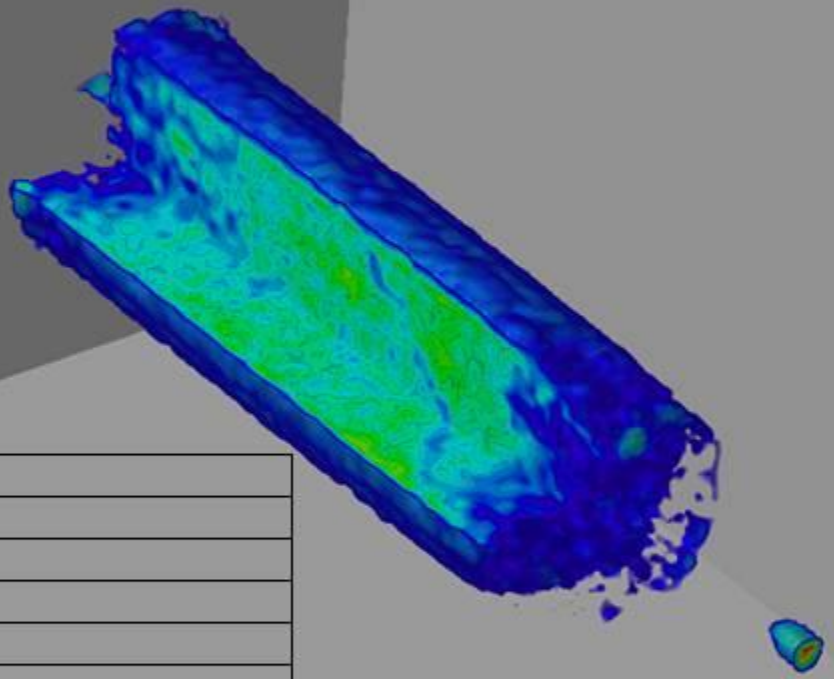

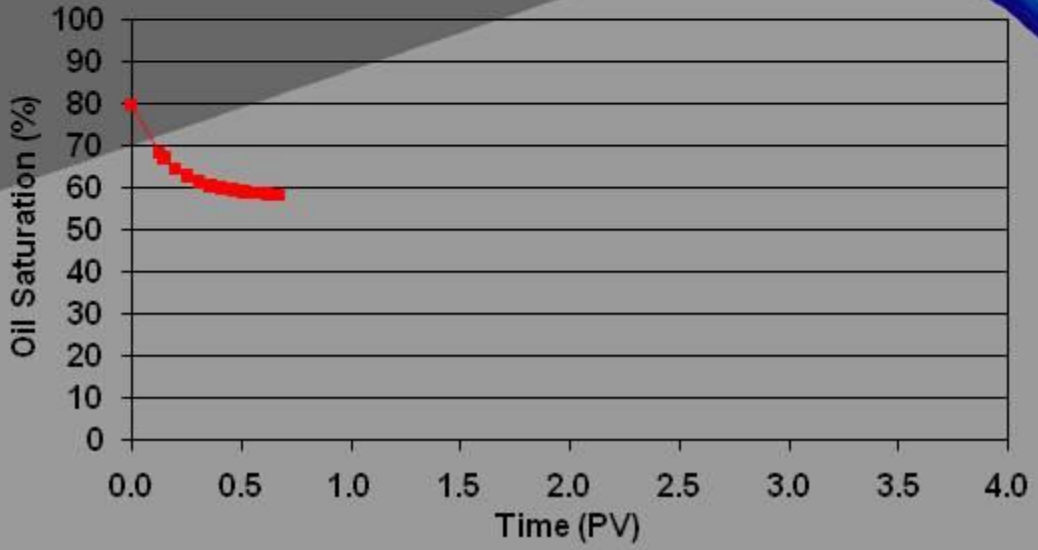
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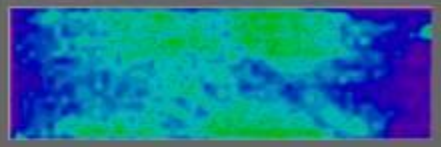
Time (PV)



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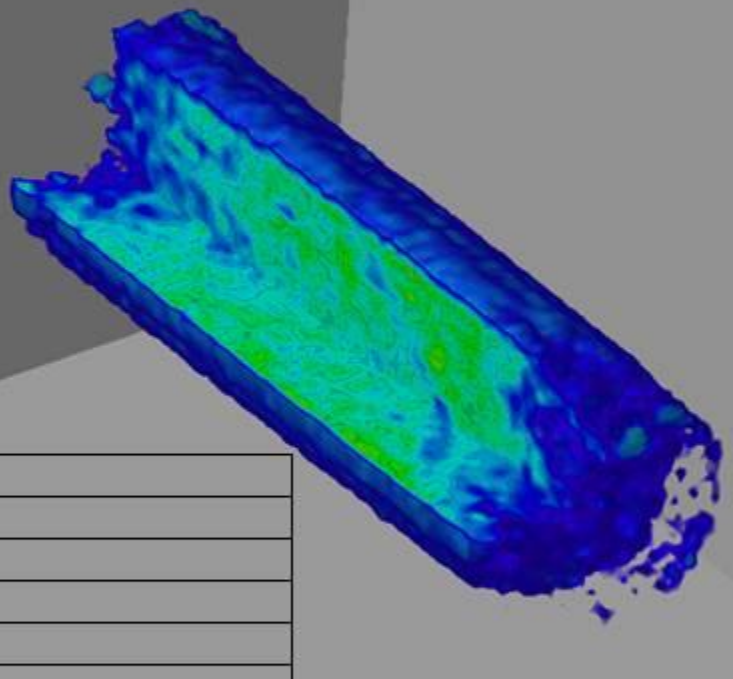

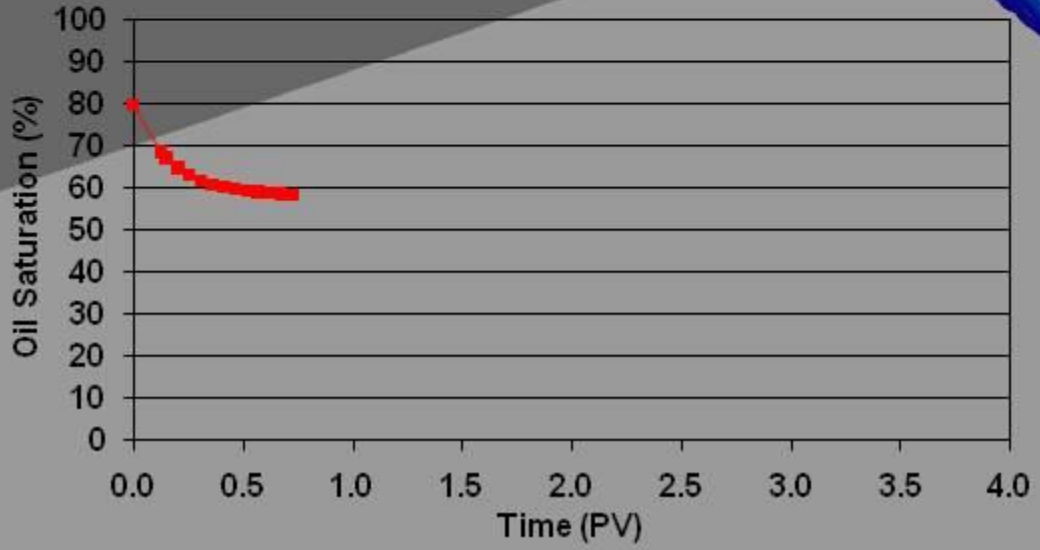
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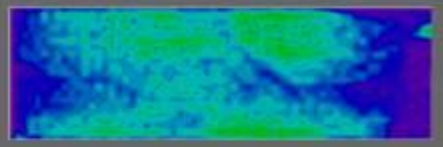
Time (PV)



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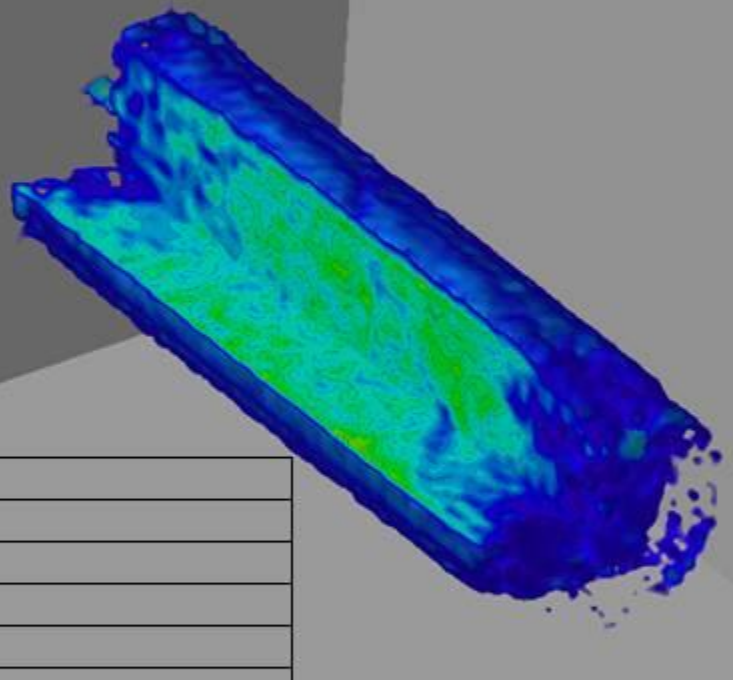

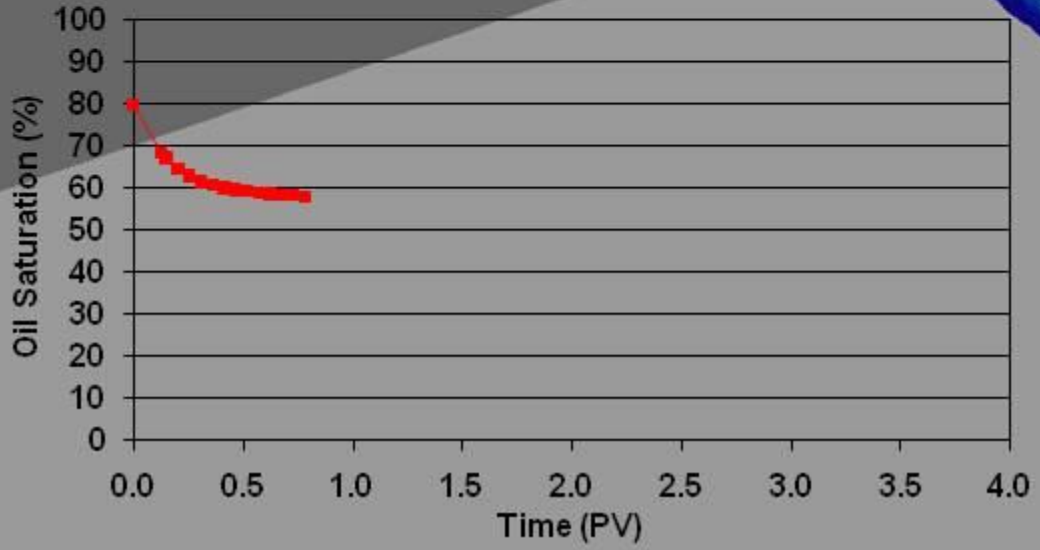
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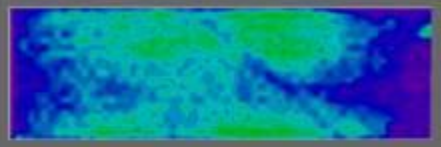
Time (PV)



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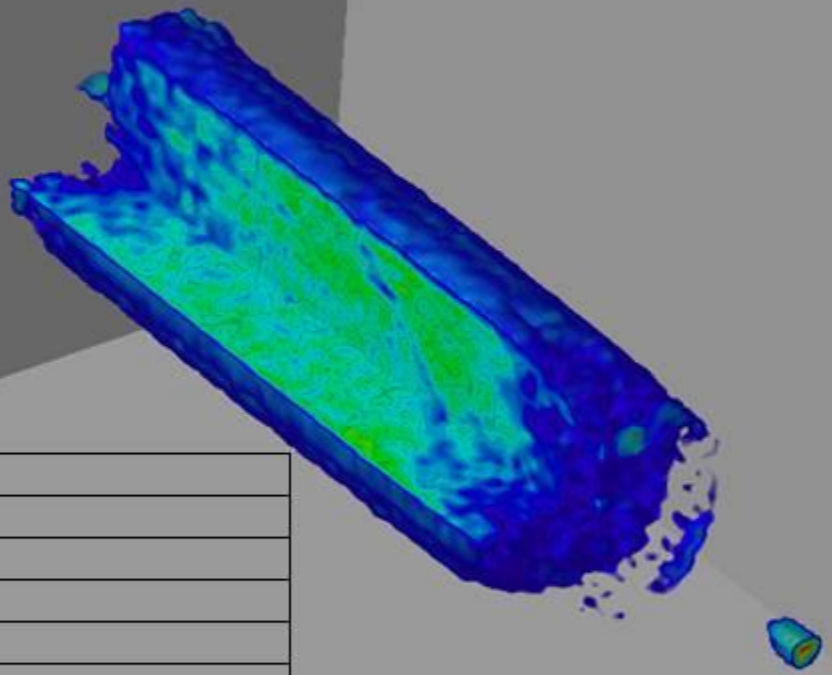

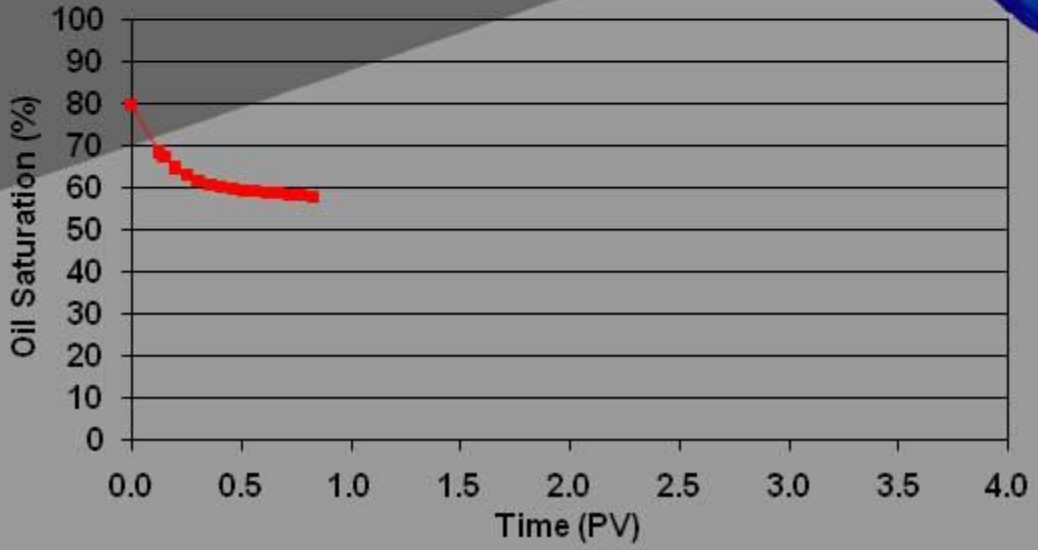
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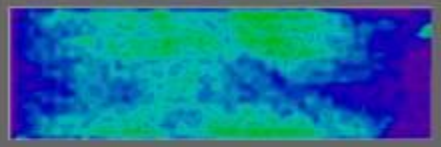
Time (PV)



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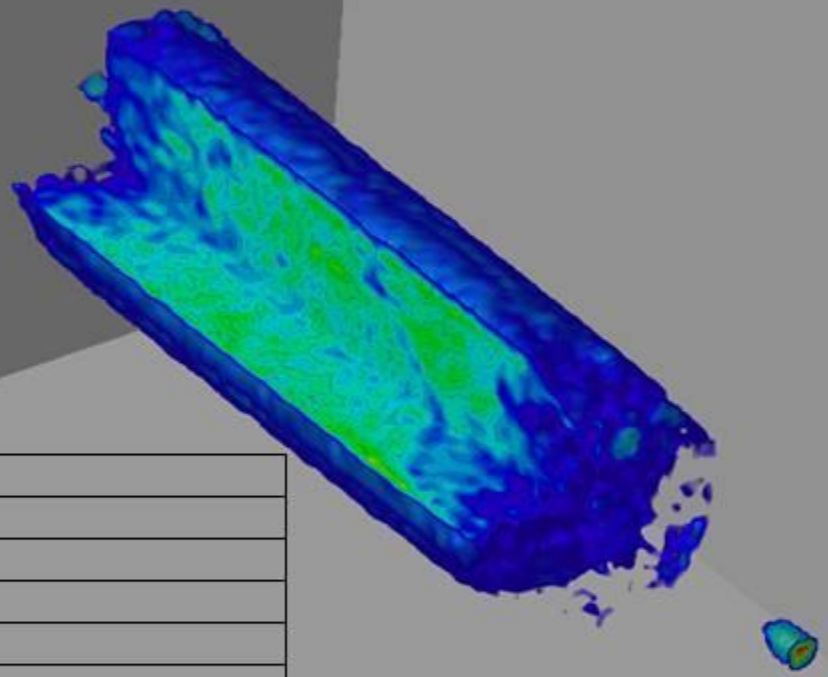

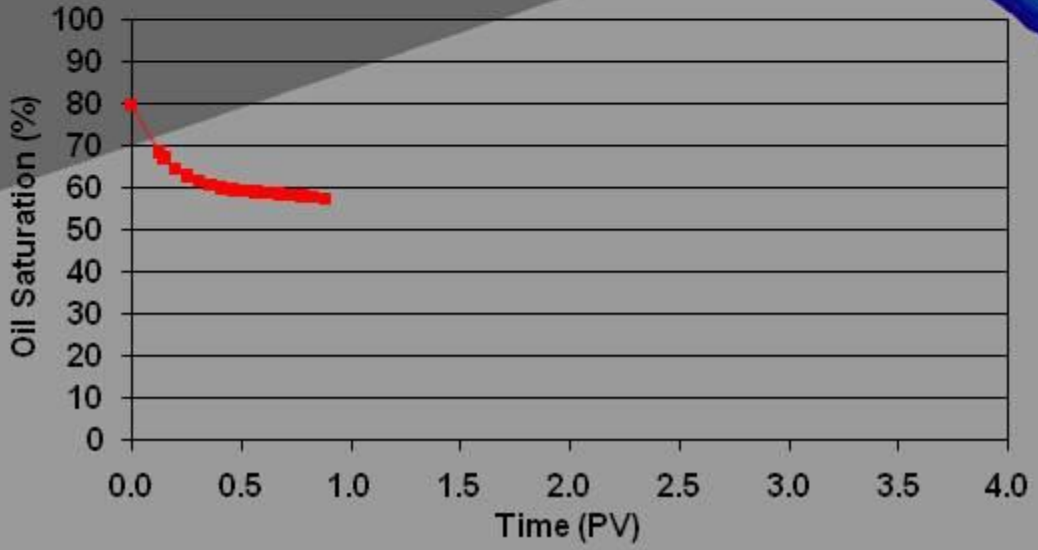
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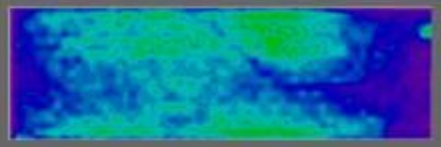
Time (PV)



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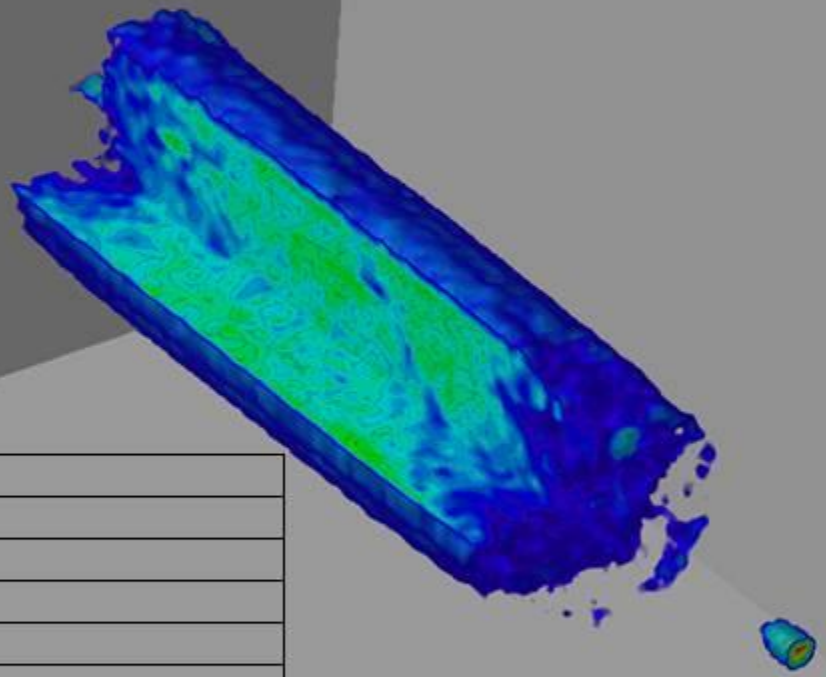

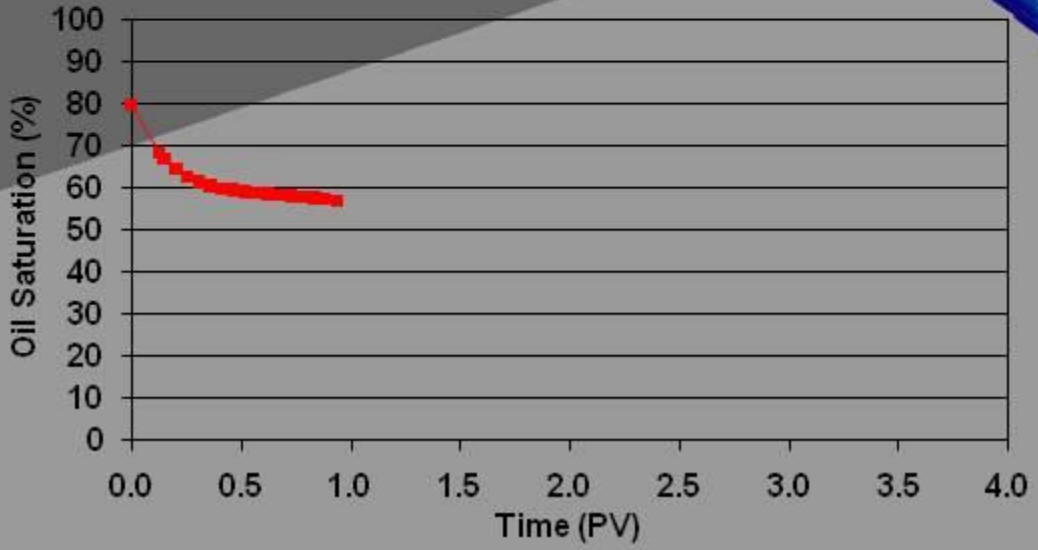
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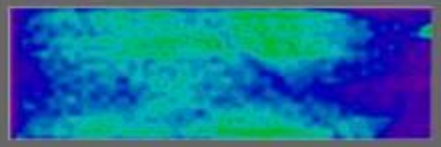
Time (PV)



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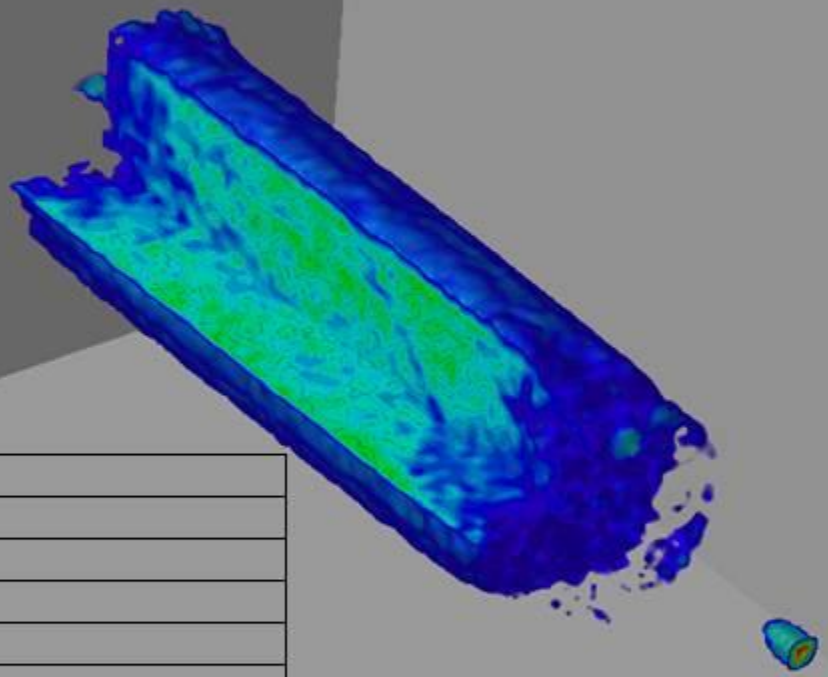

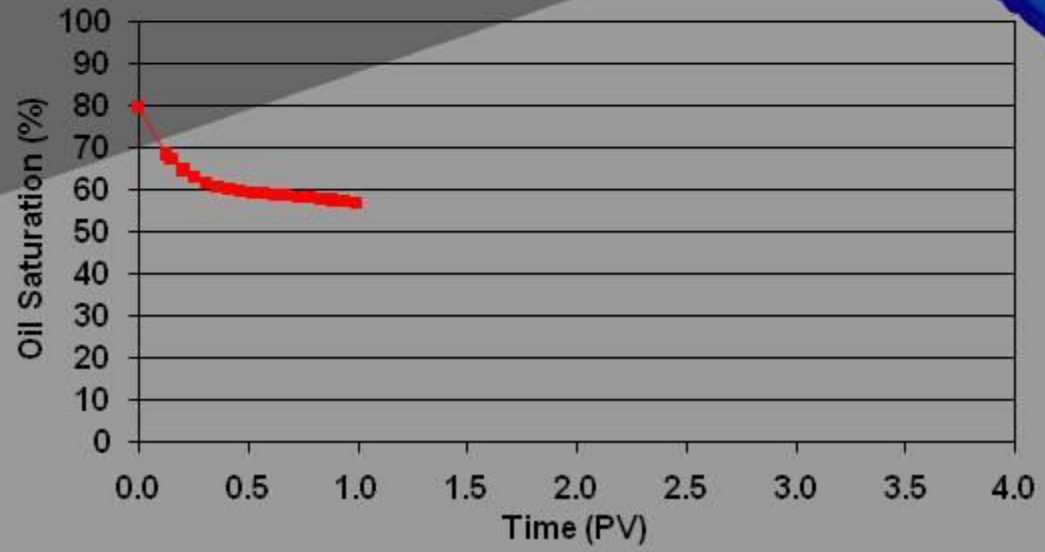
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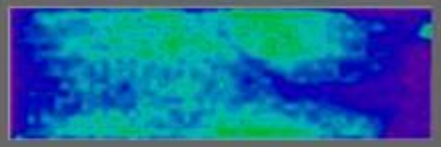
Time (PV)



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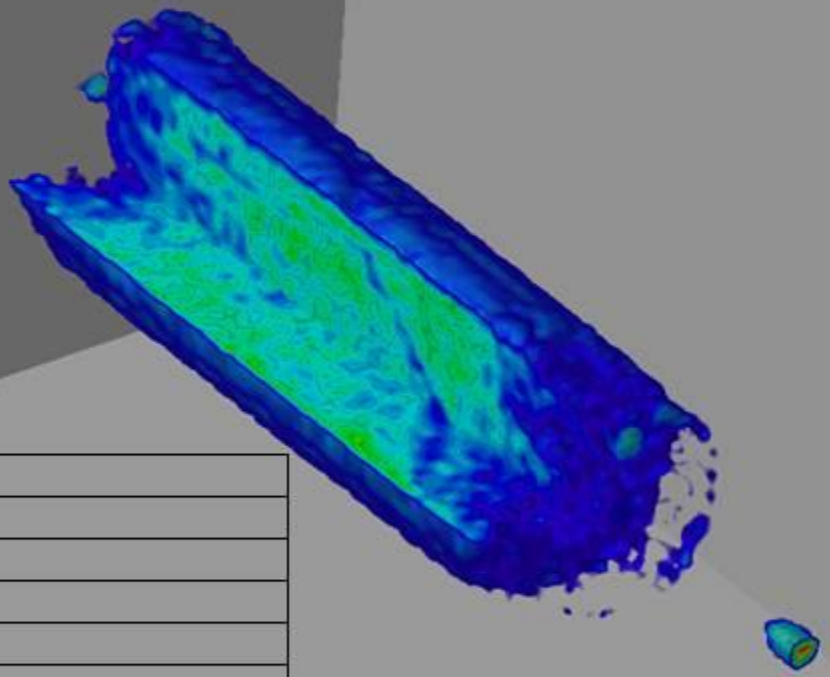

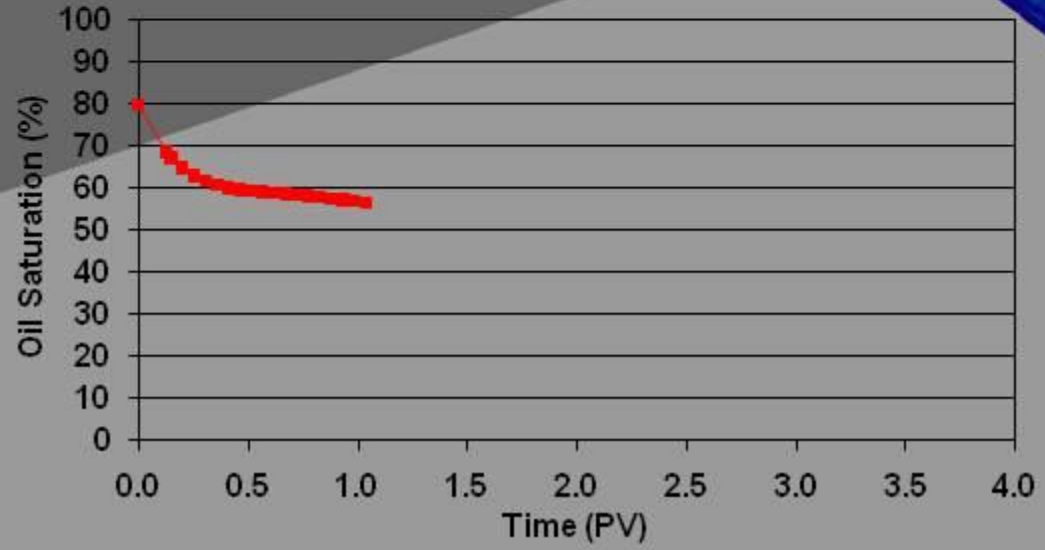
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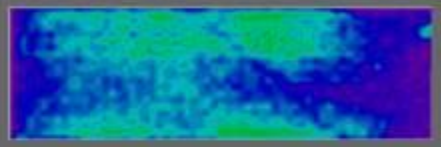
Time (PV)



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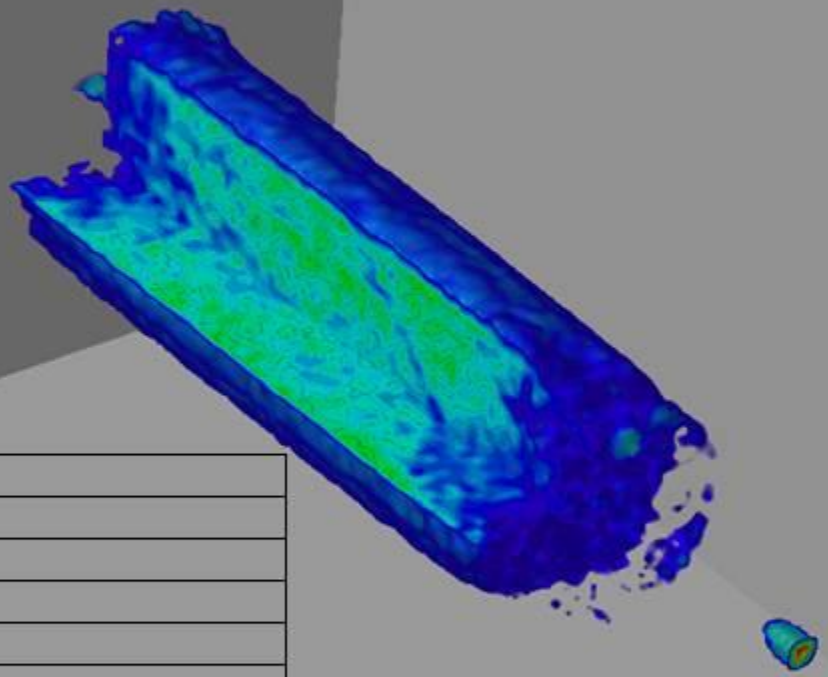

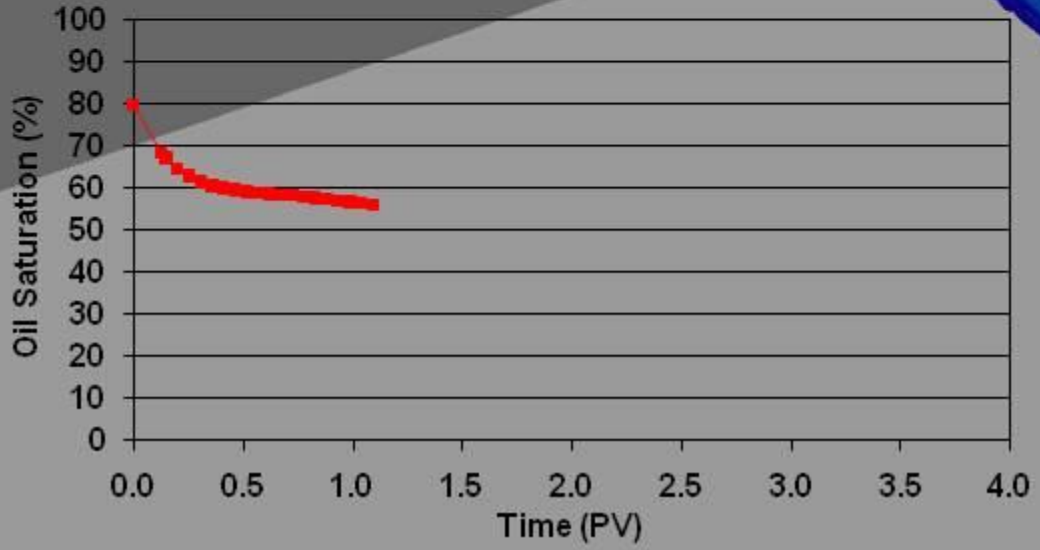
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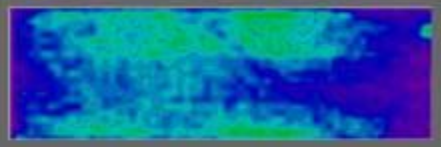
Time (PV)



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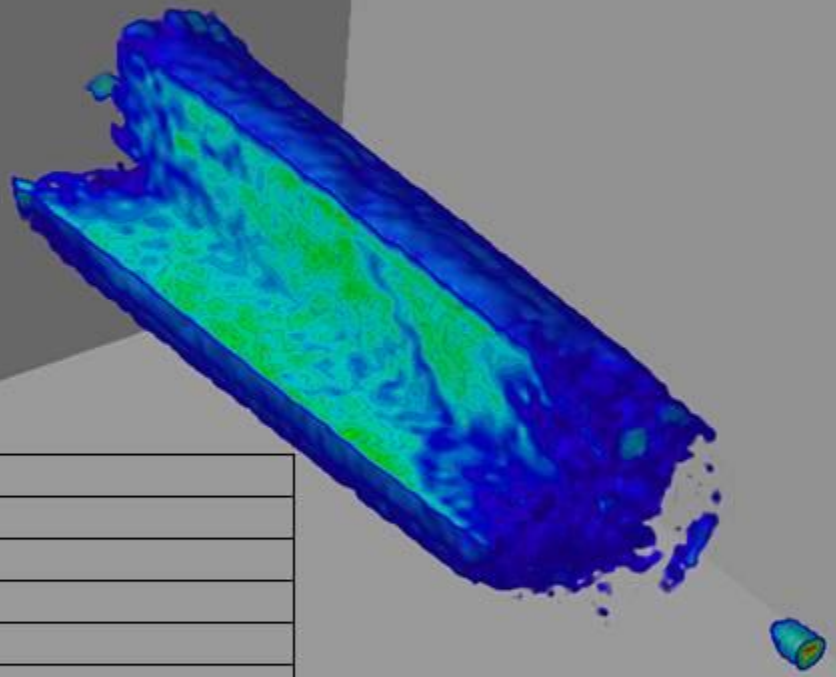

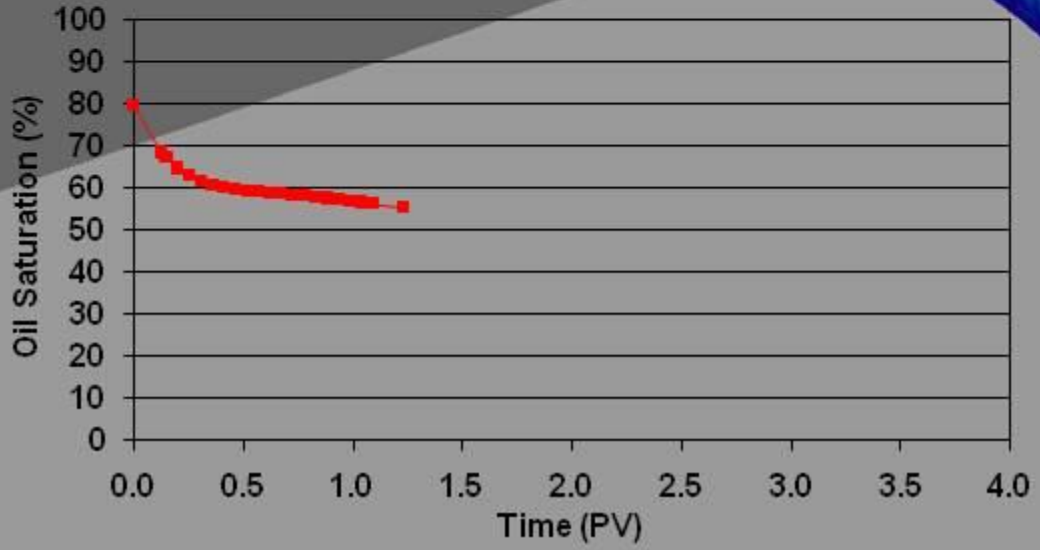
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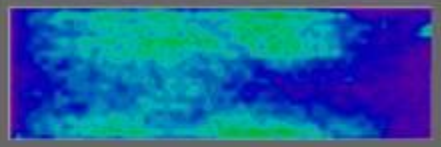
Time (PV)



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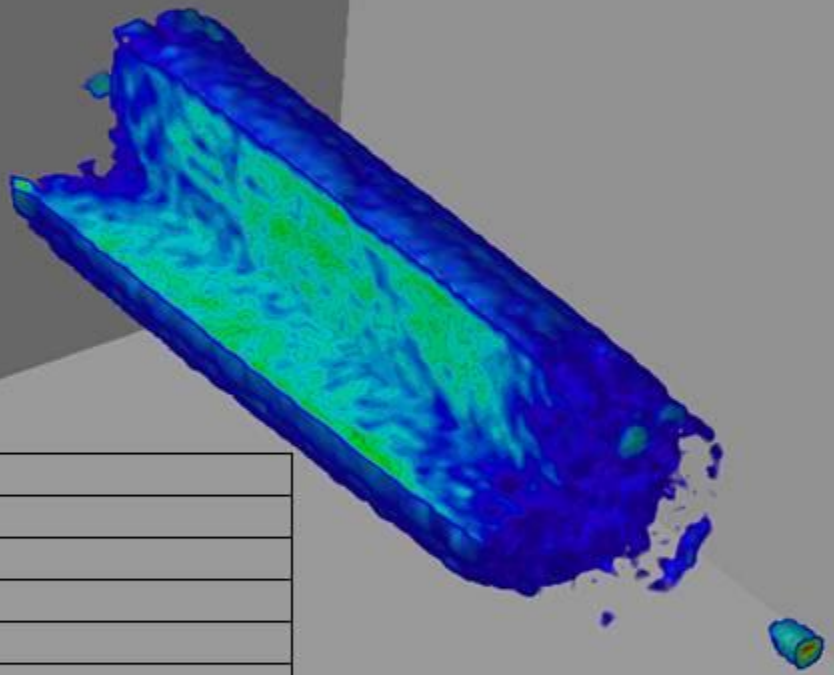

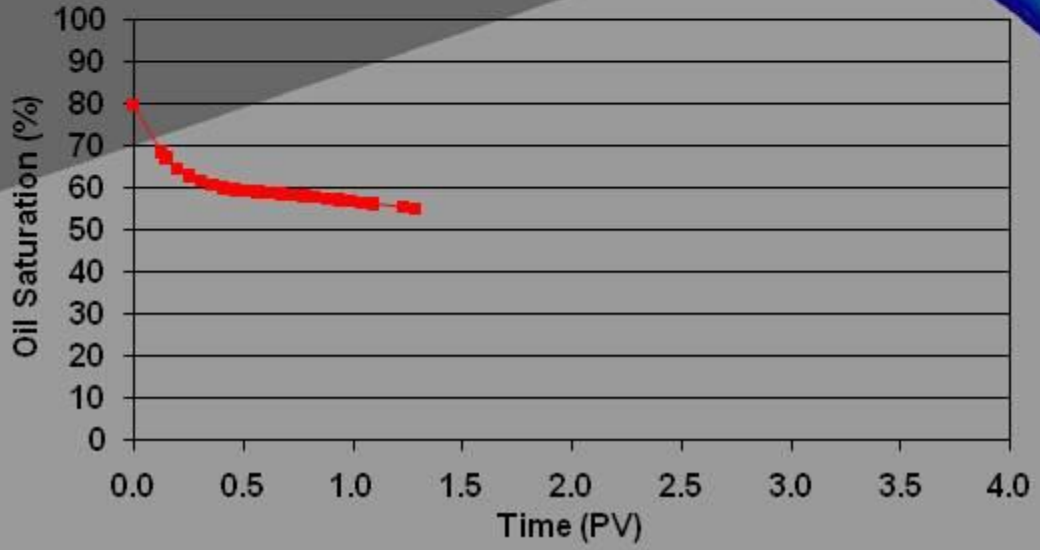
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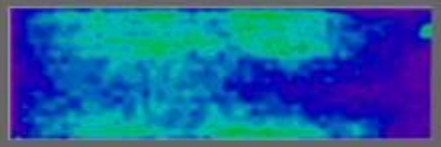
Time (PV)



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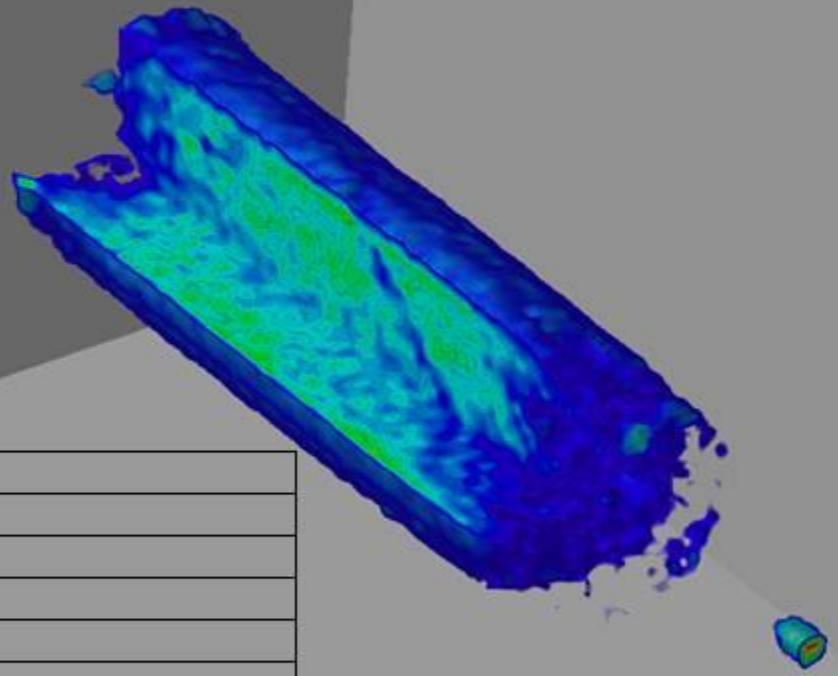

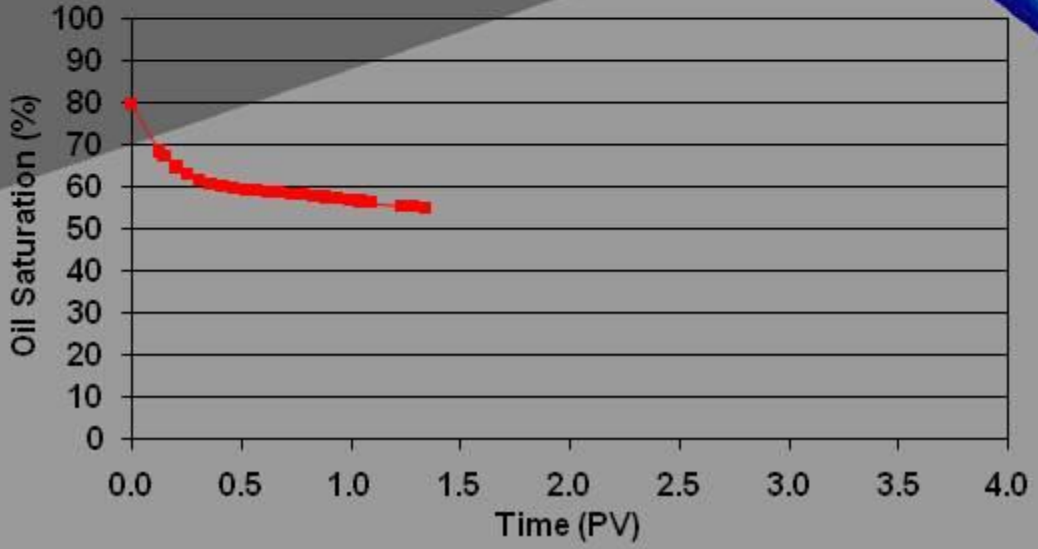
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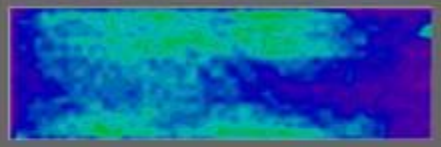
Time (PV)



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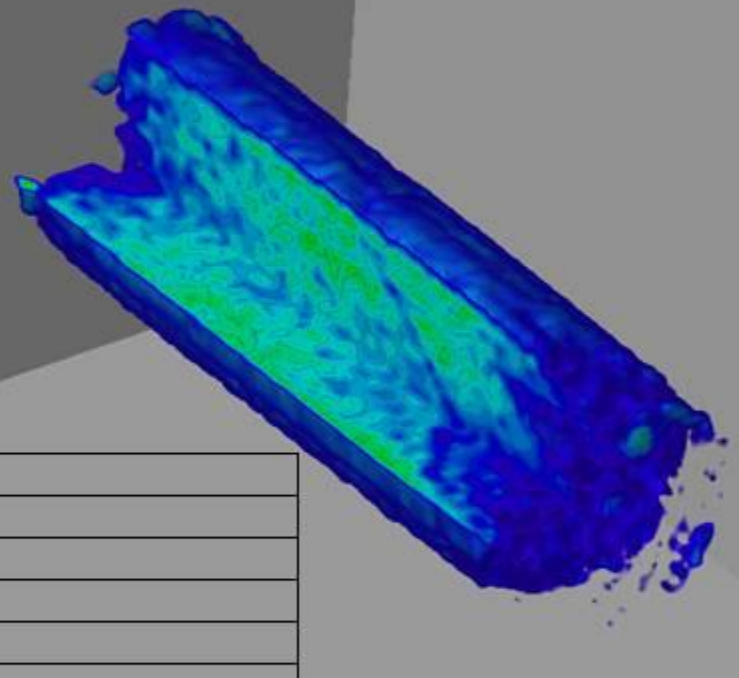

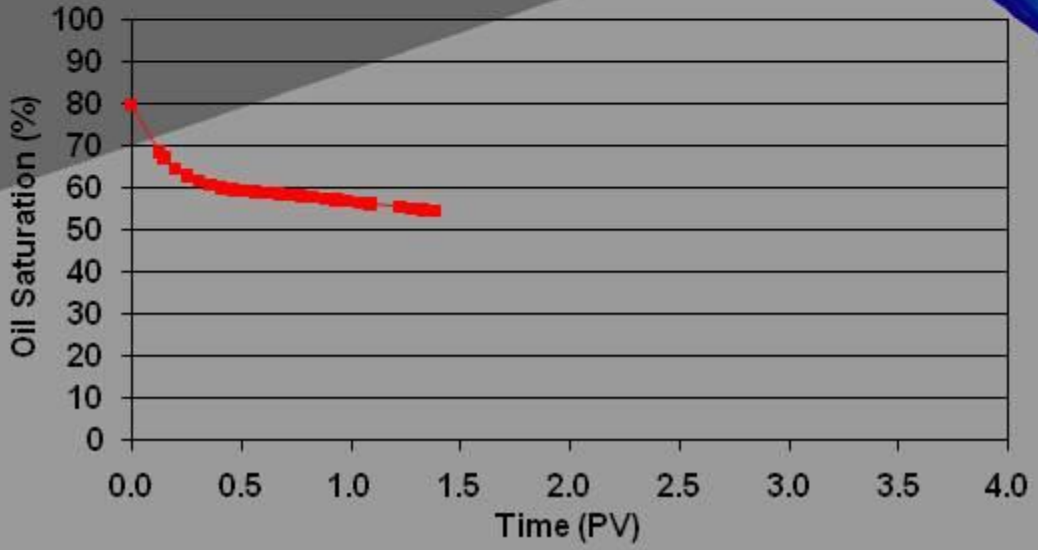
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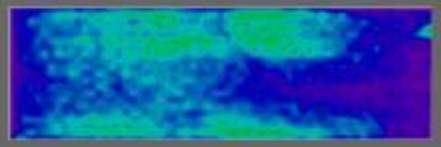
Time (PV)



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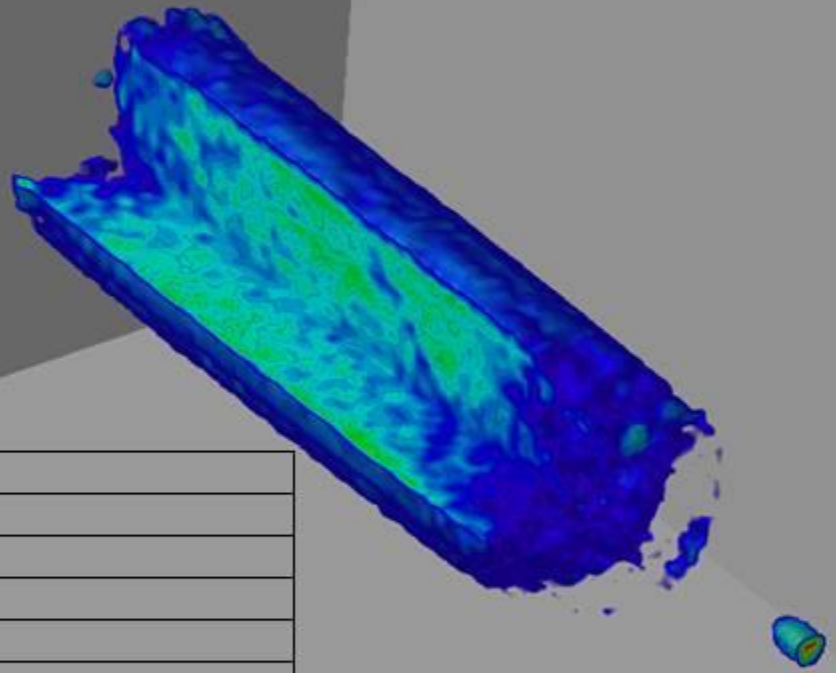

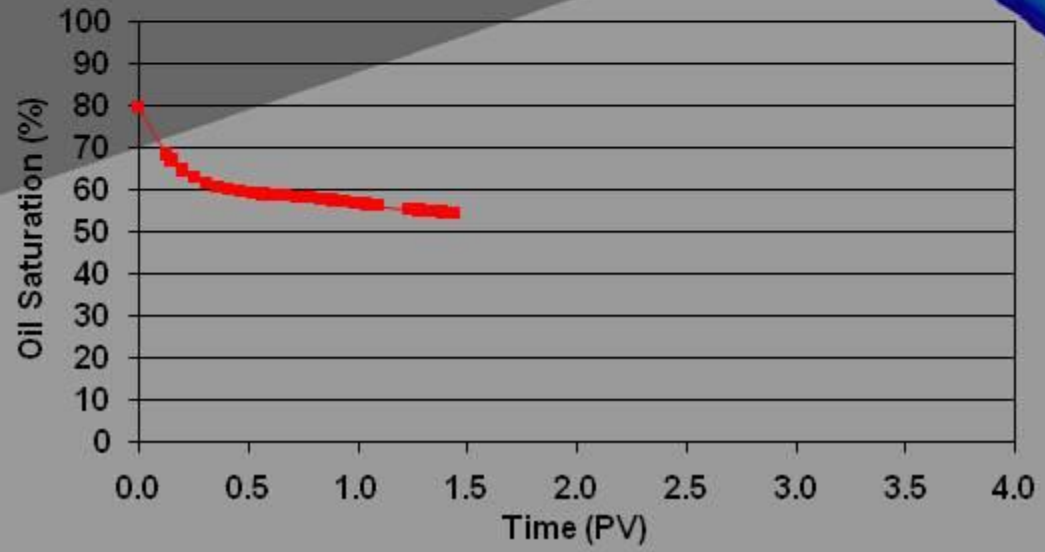
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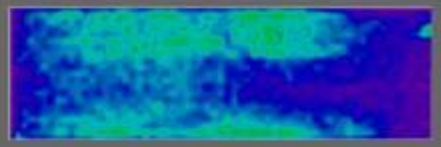
Time (PV)



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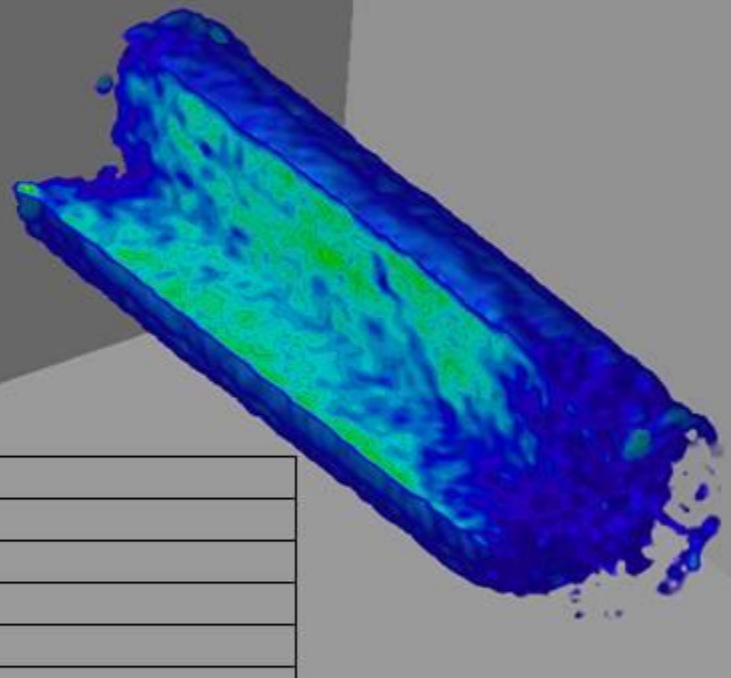

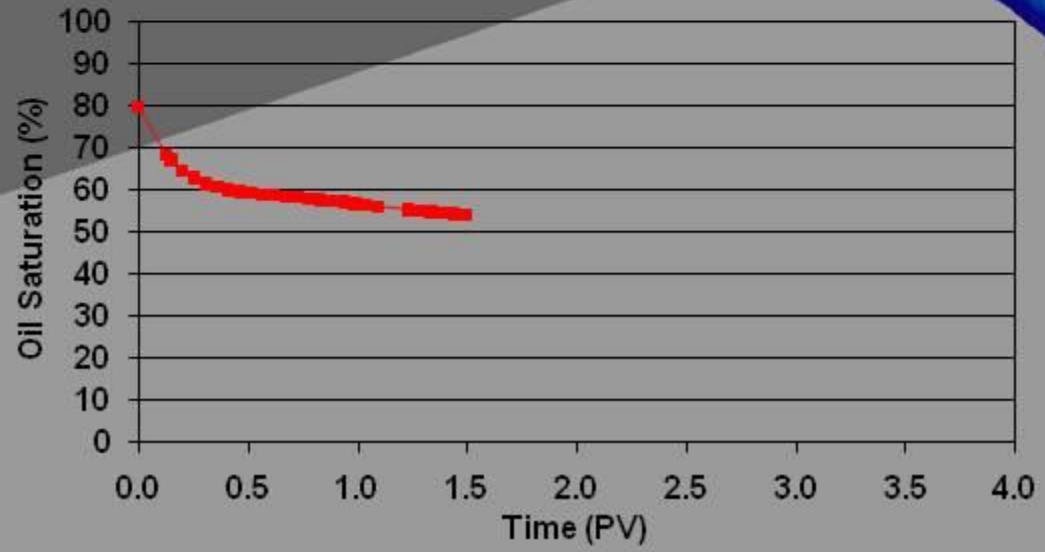
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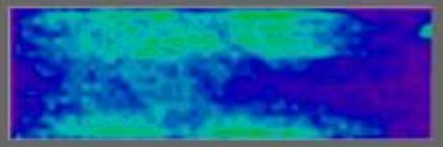
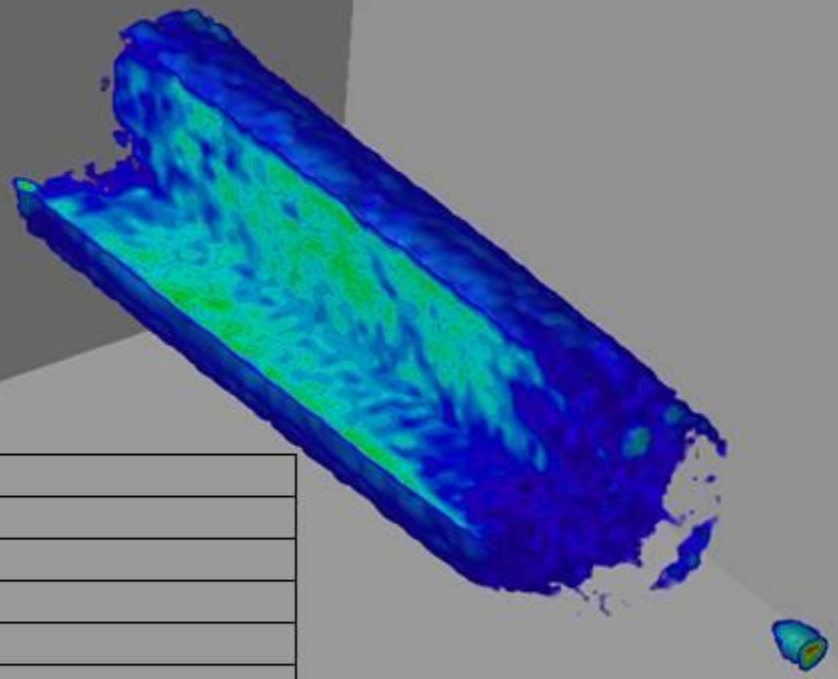
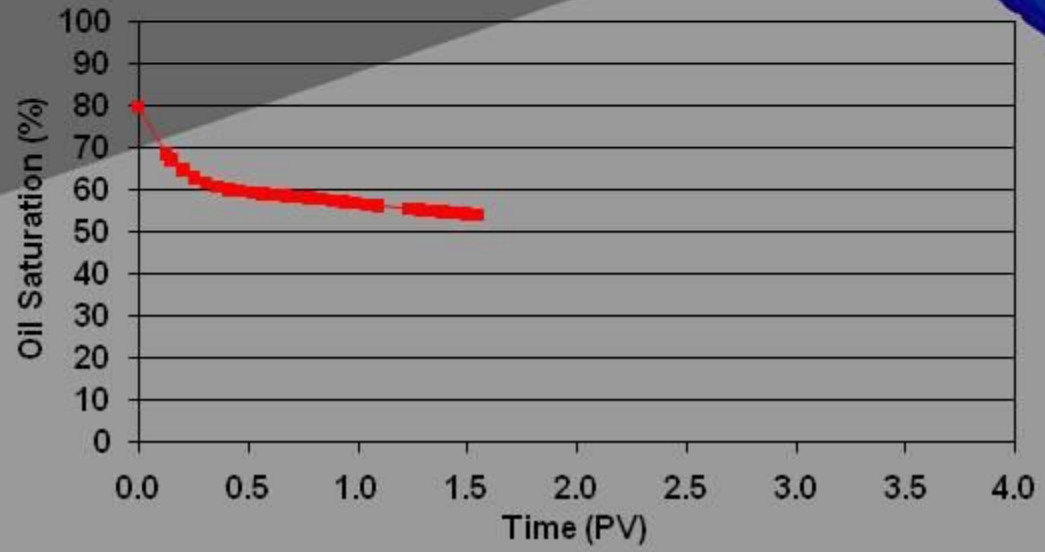
Time (PV)



Time: 1.54 PV




Oil Saturation (%)
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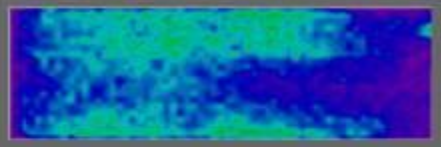
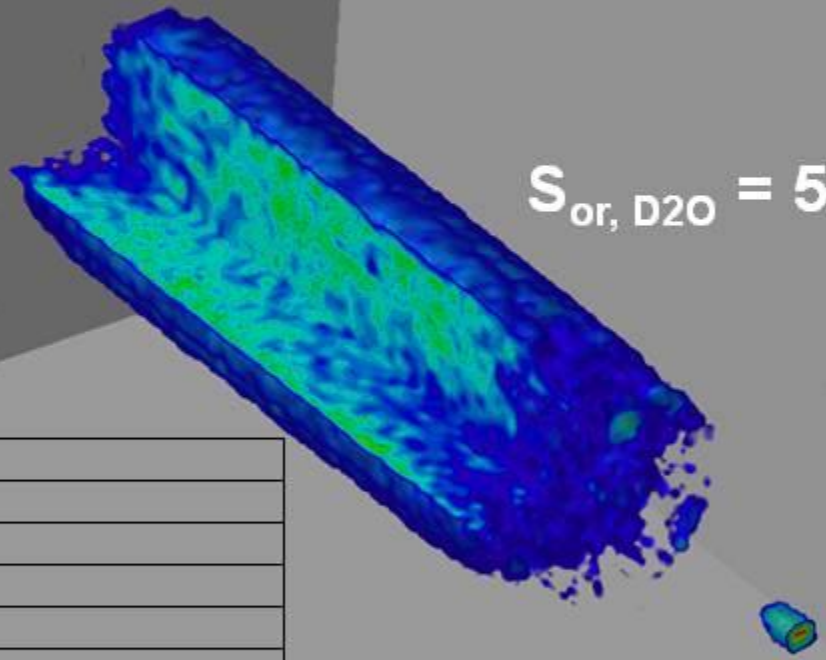
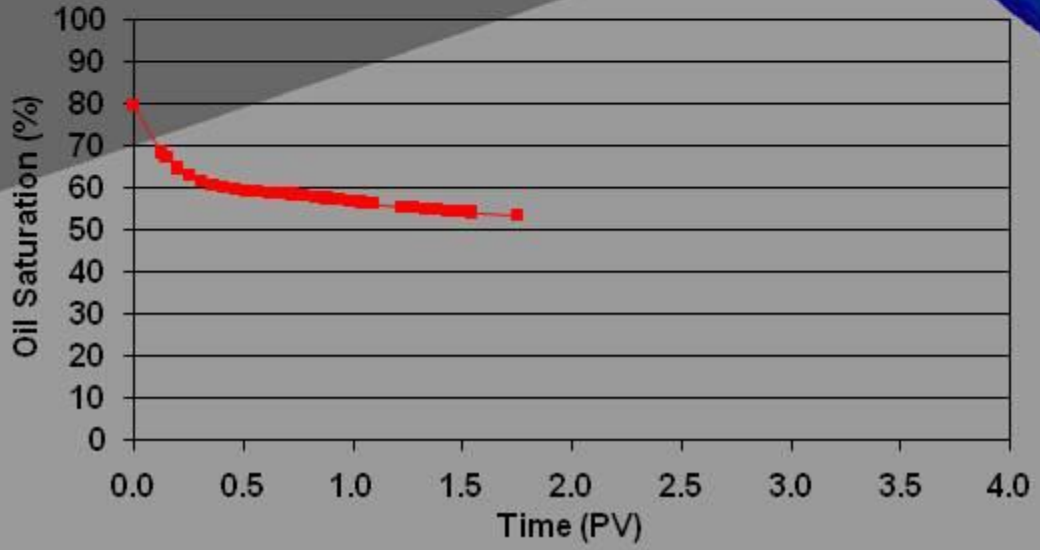
4.0
Time (PV)

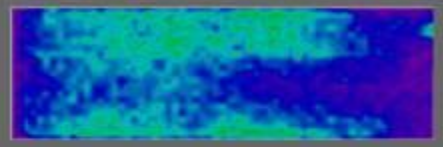


Time: 1.75 PV



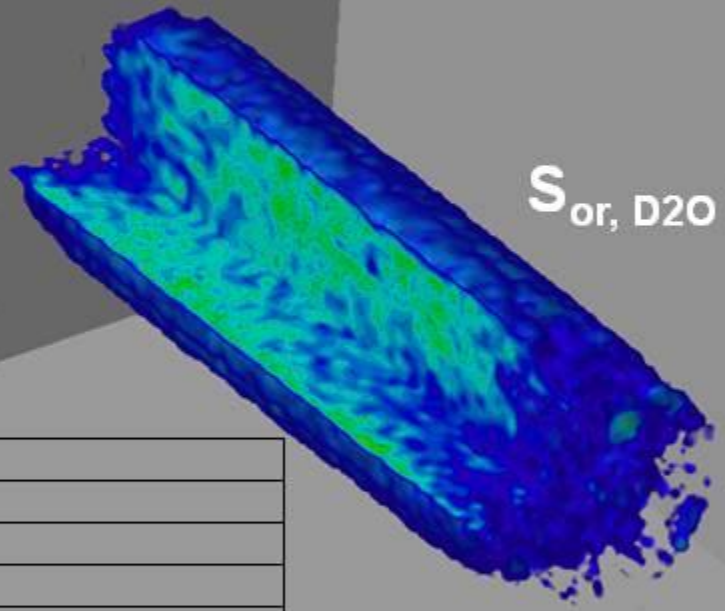
$S_{or,\ D2O}$ = 53.2 %

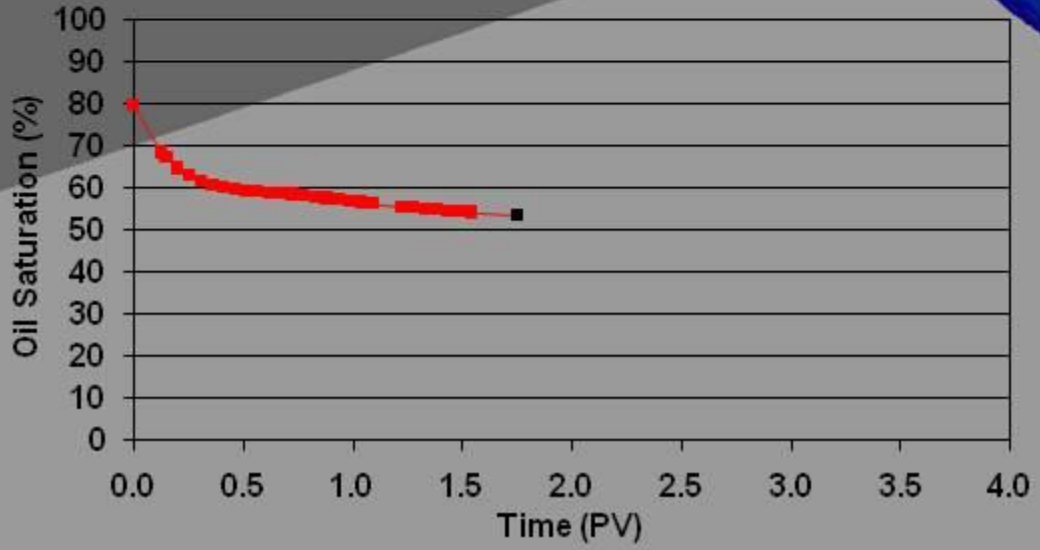




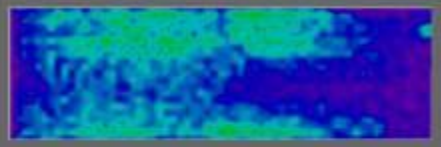
Time: 1.75 PV

$S_{or,\ D2O}$ = 53.2 %

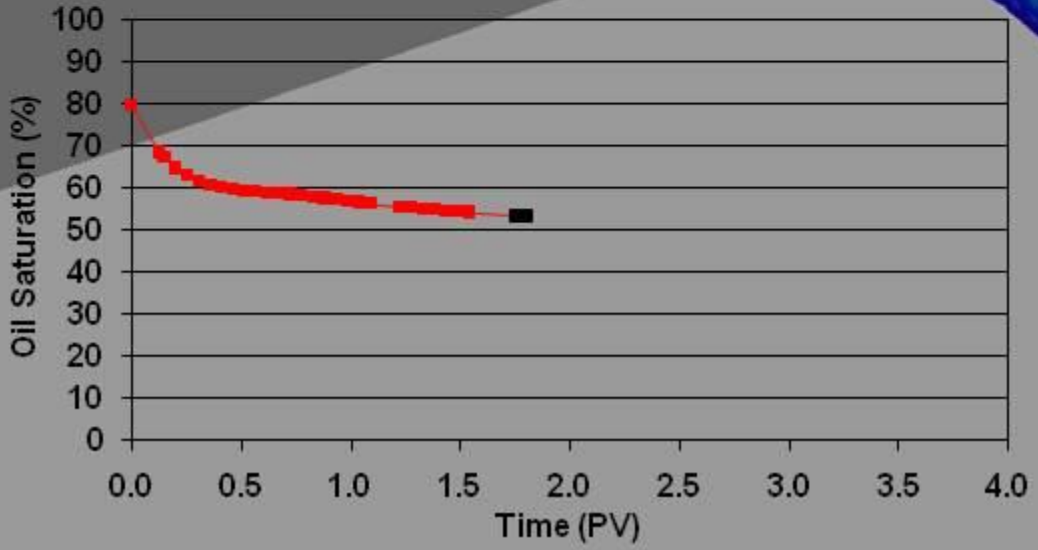




CO_2 Injection



Time: 1.80 PV



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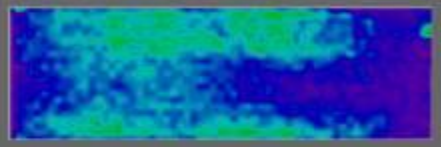
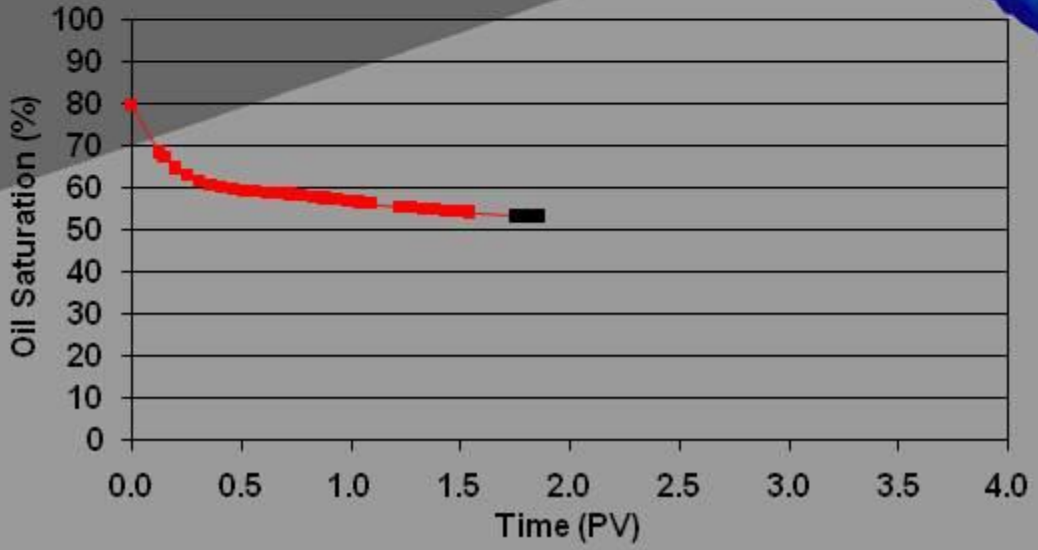


Time: 1.86 PV



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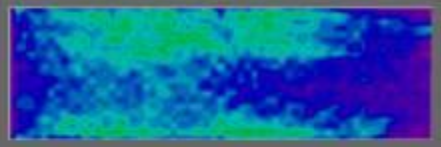
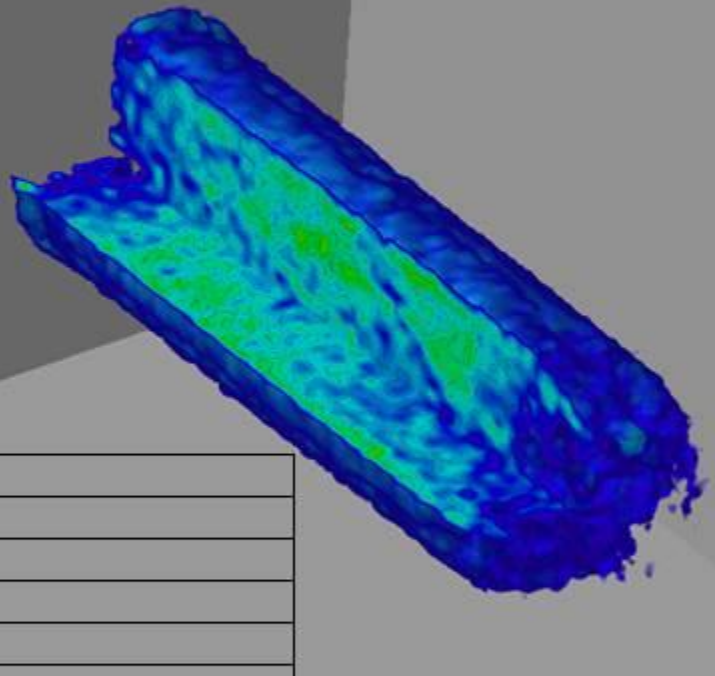
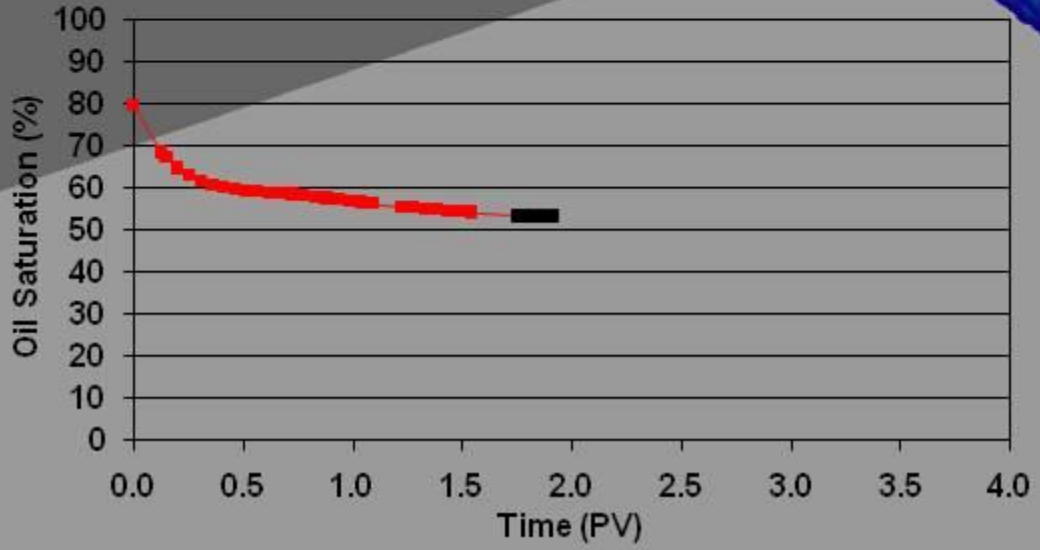


Time: 1.91 PV




Oil Saturation (%)
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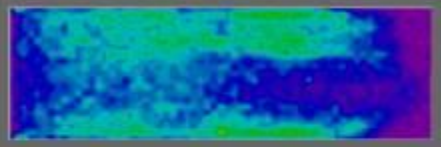
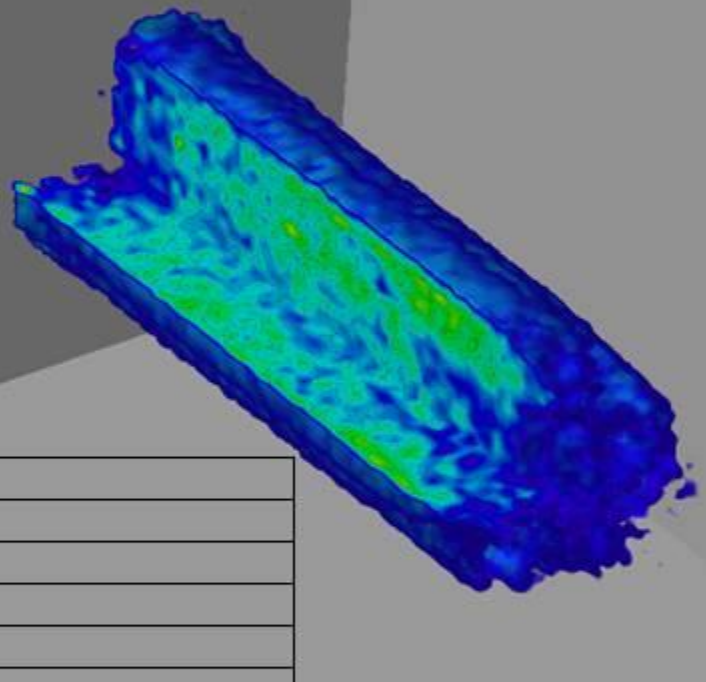
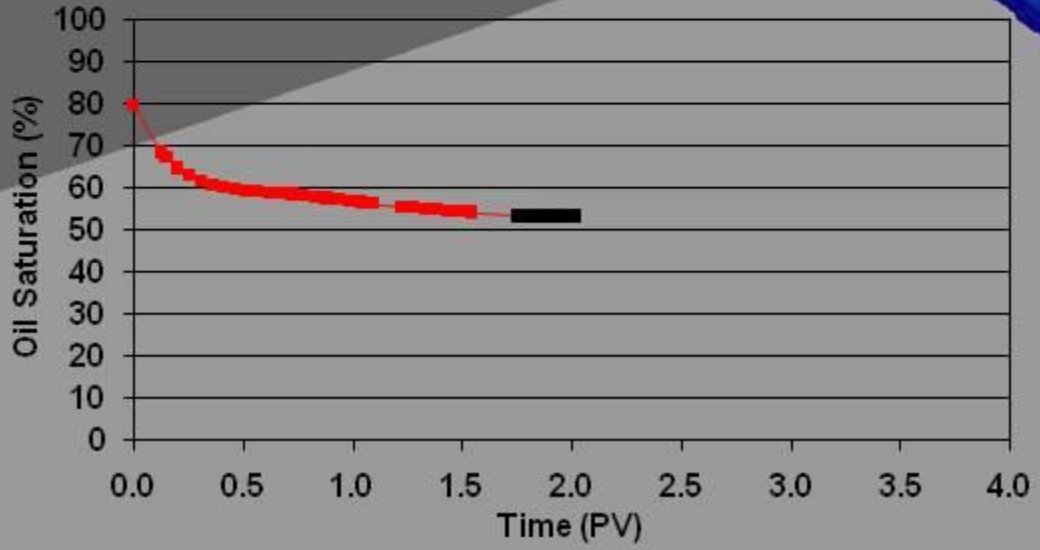
Time (PV)



Time: 2.01 PV




Oil Saturation (%)
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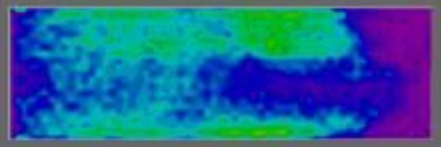
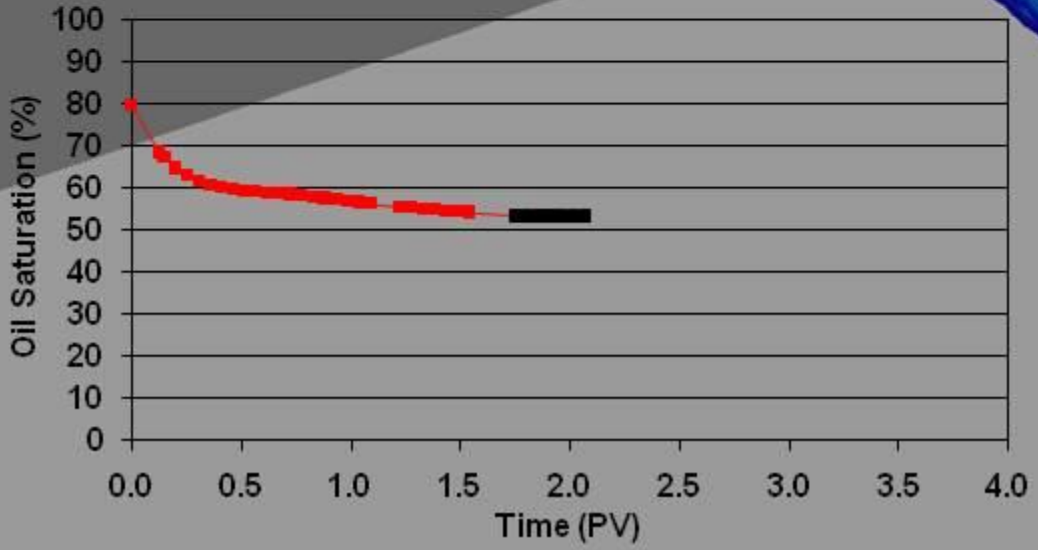
Time (PV)



Time: 2.07 PV


Oil Saturation (%)
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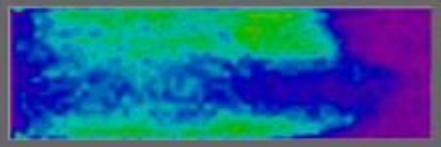
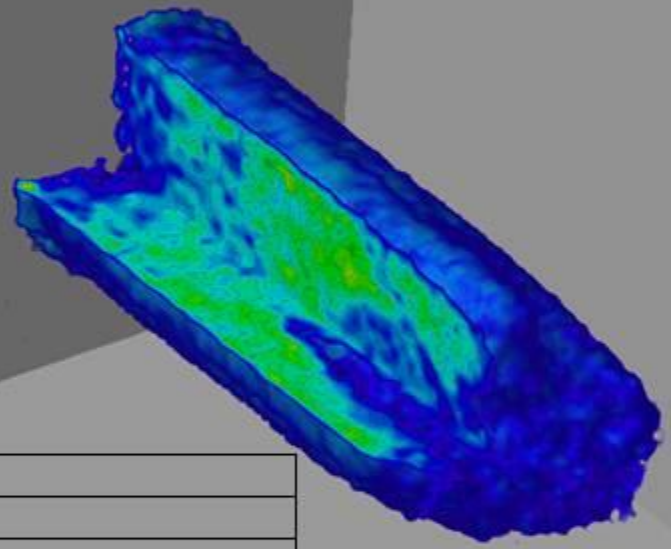
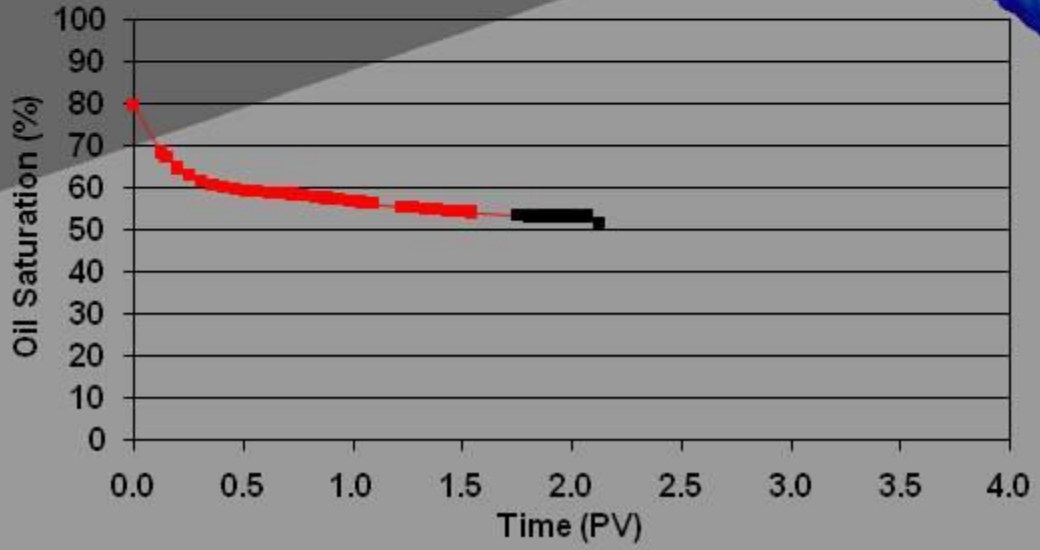
Time (PV)



Time: 2.12 PV





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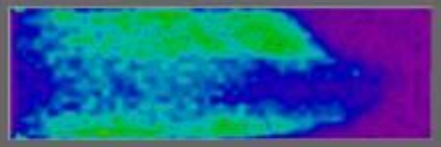

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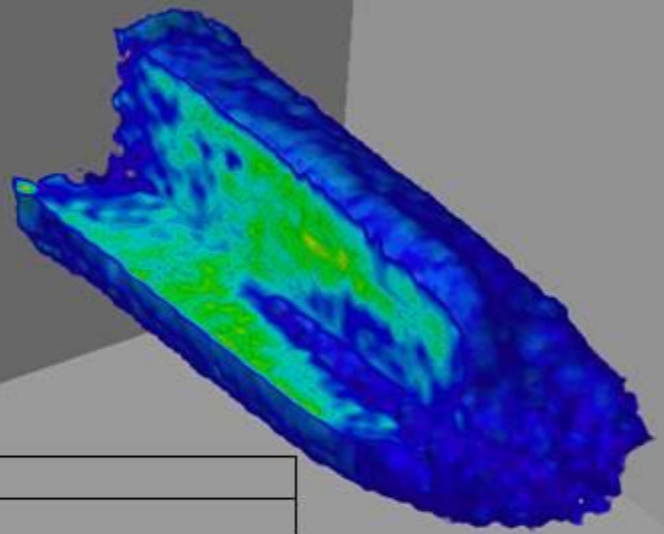

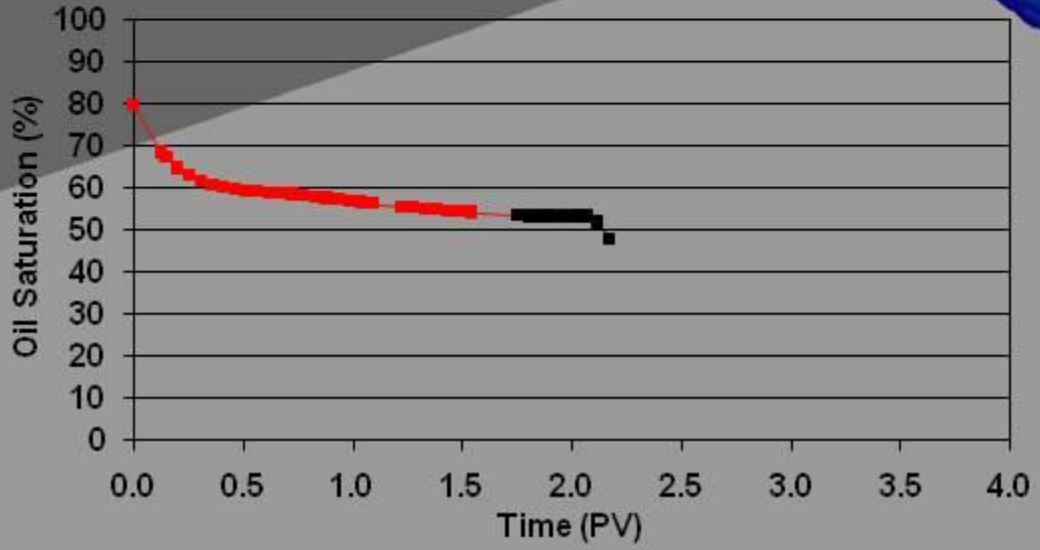

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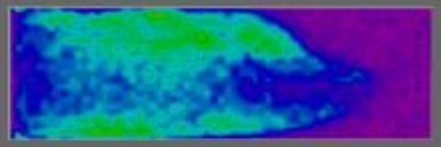

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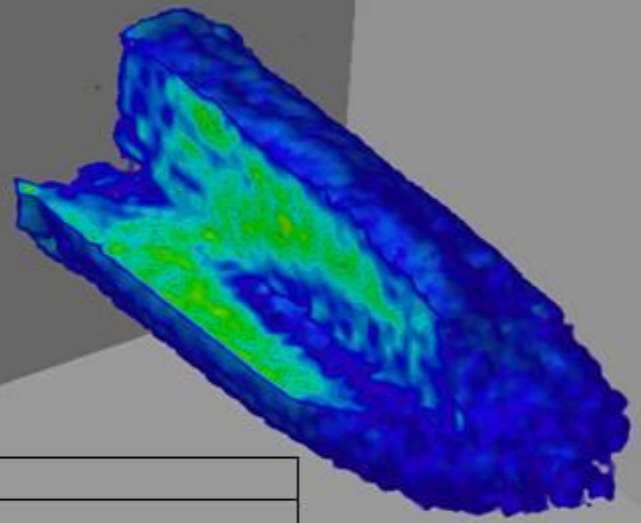

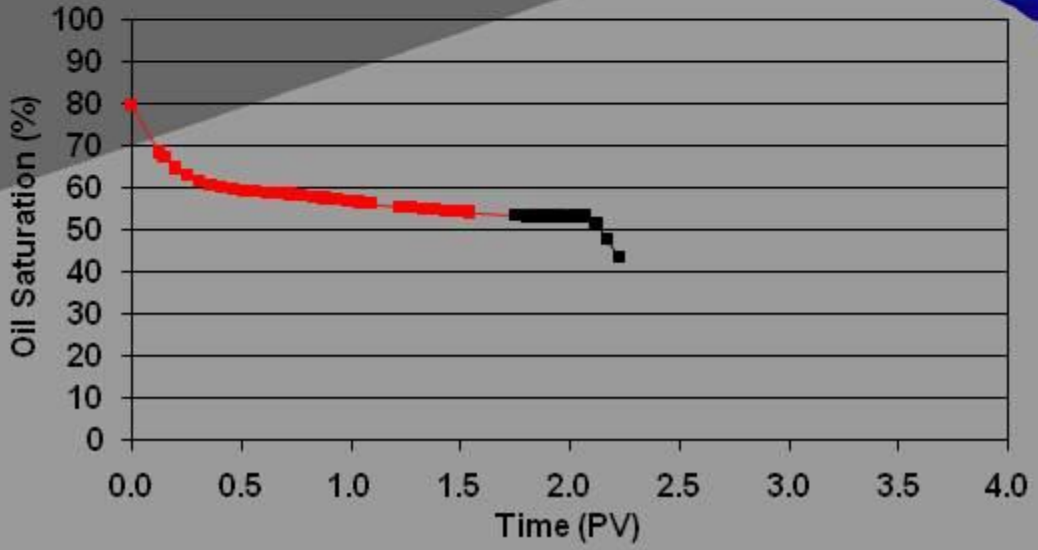
Oil Saturation (%)
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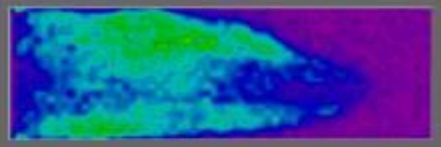
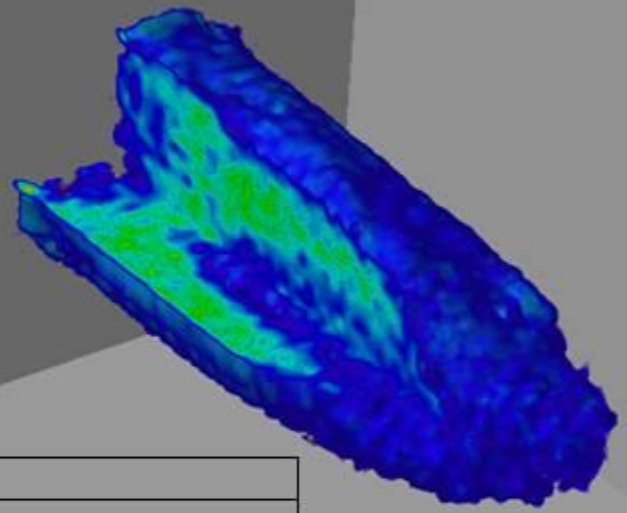
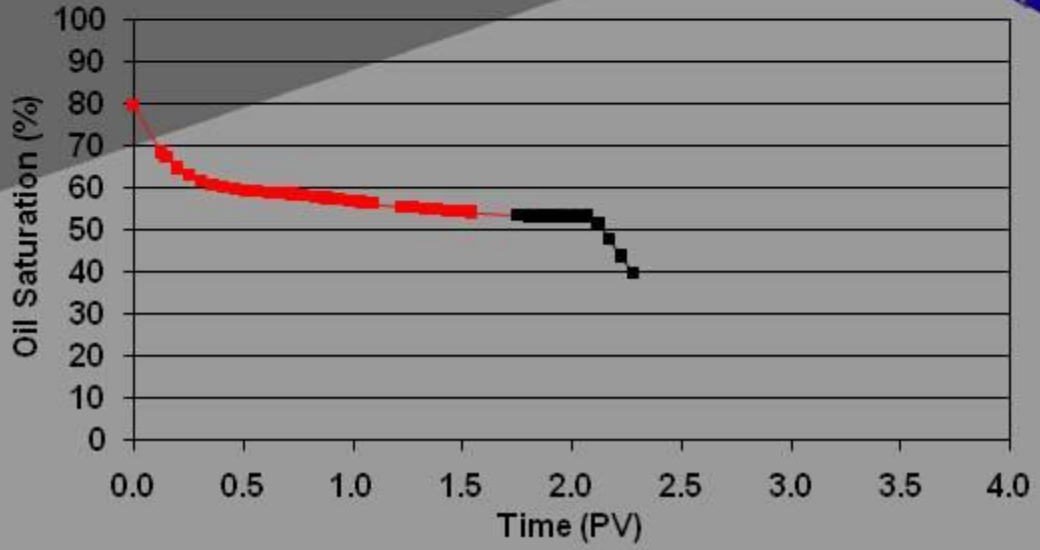
Time (PV)



Time: 2.27 PV




Oil Saturation (%)
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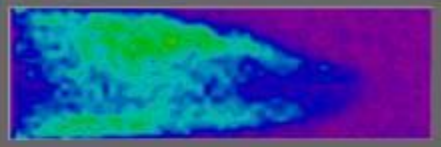
Time (PV)



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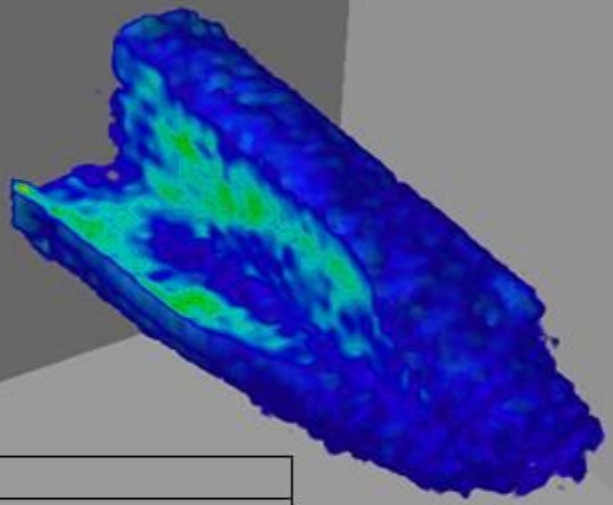

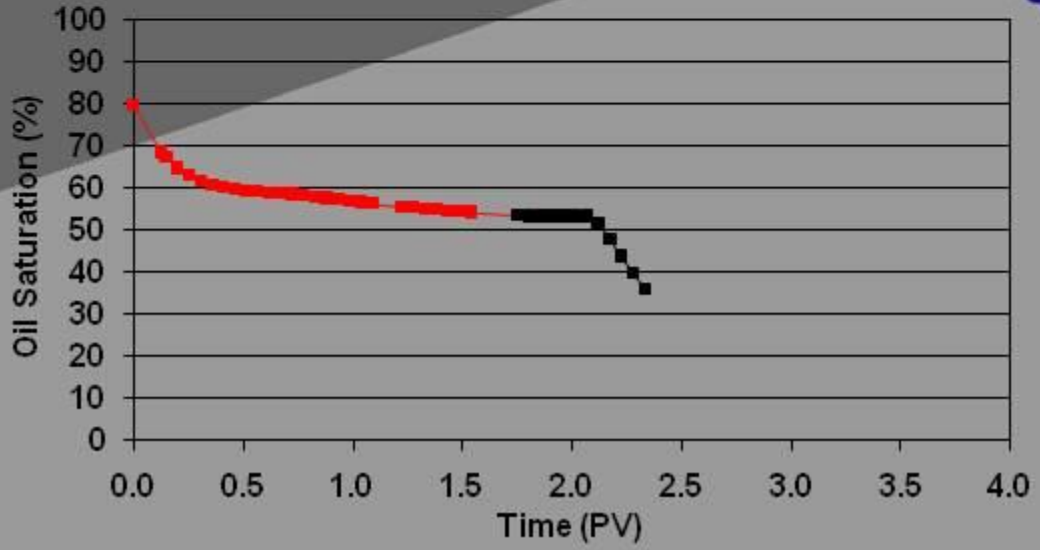
Oil Saturation (%)
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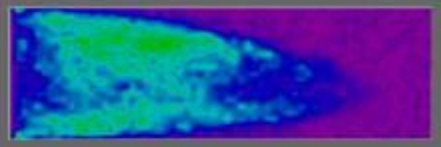
Time (PV)



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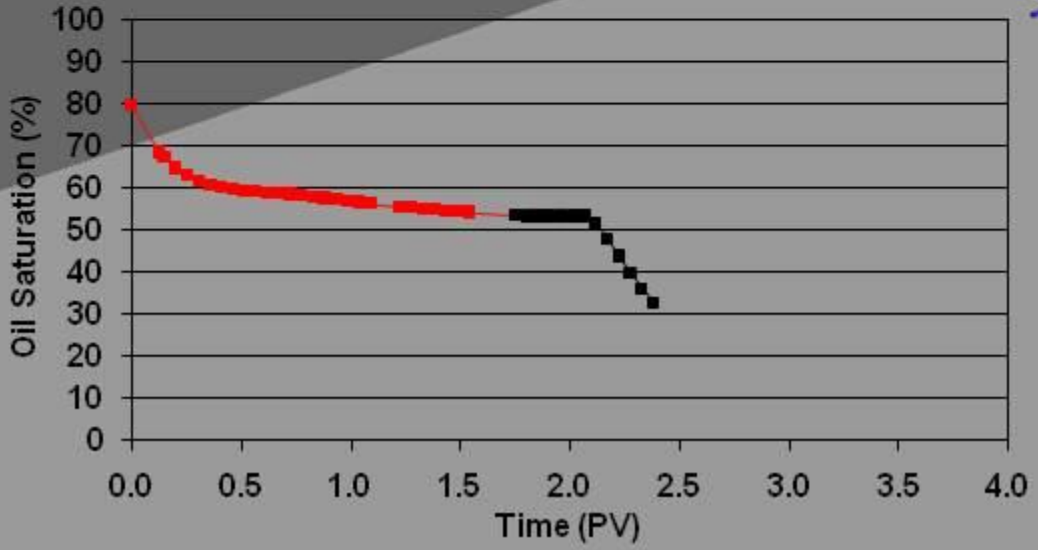
Oil Saturation (%)
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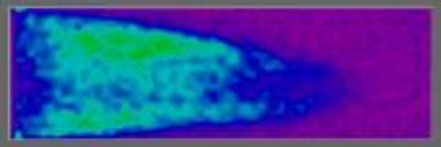
Time (PV)



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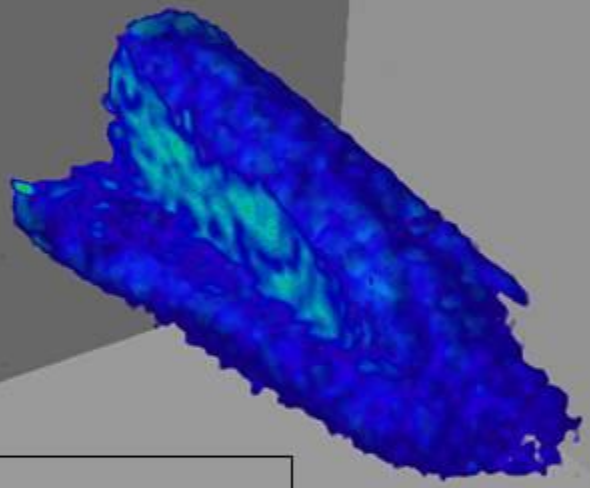

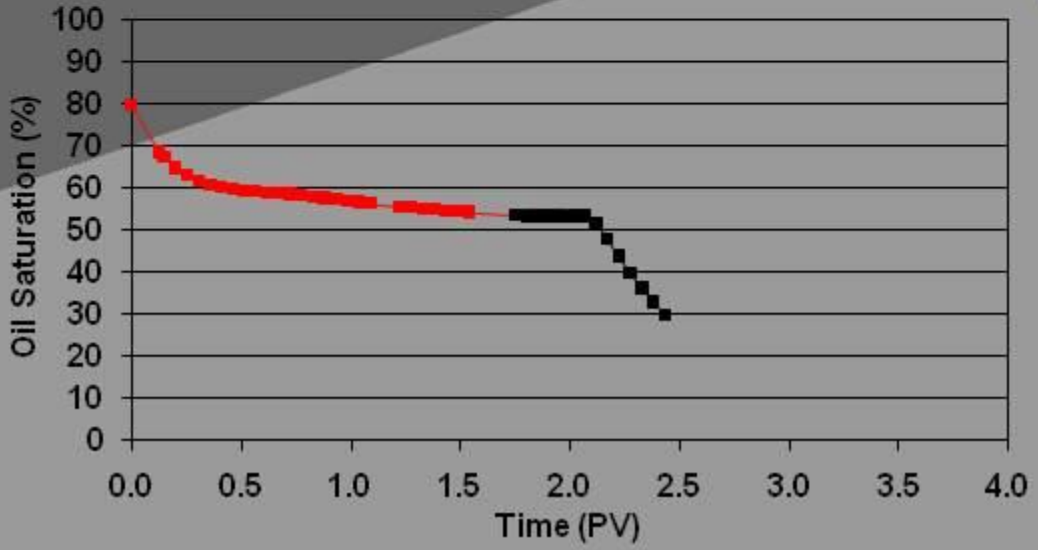
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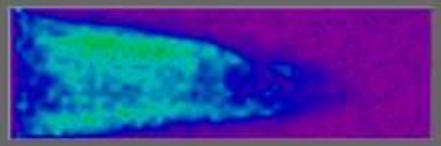
Time (PV)



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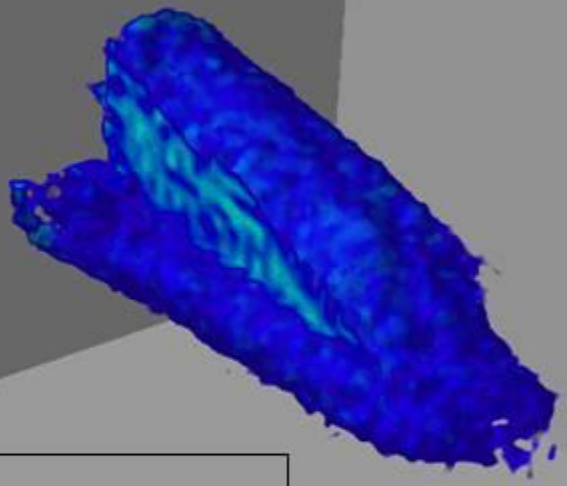

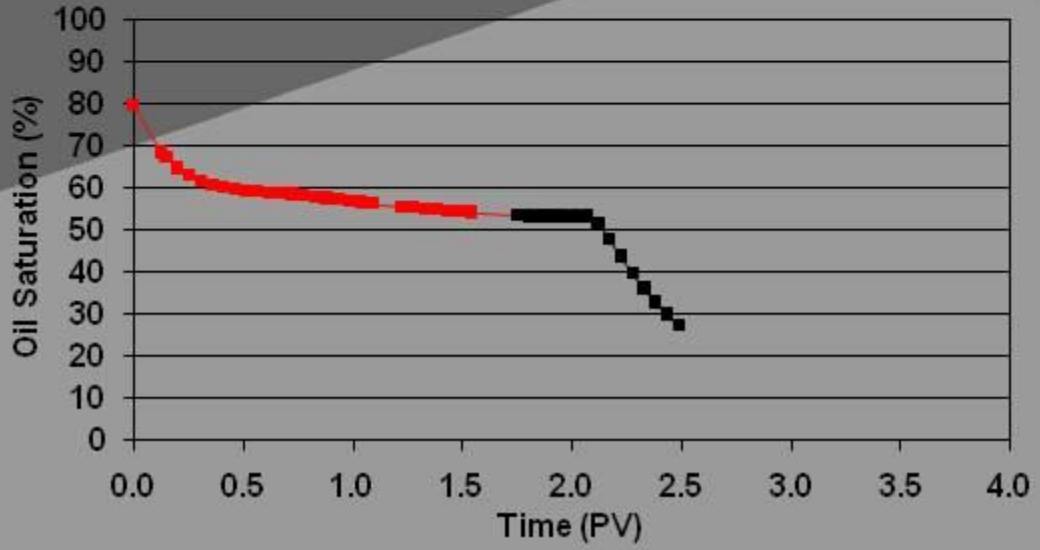

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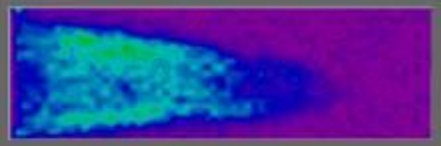
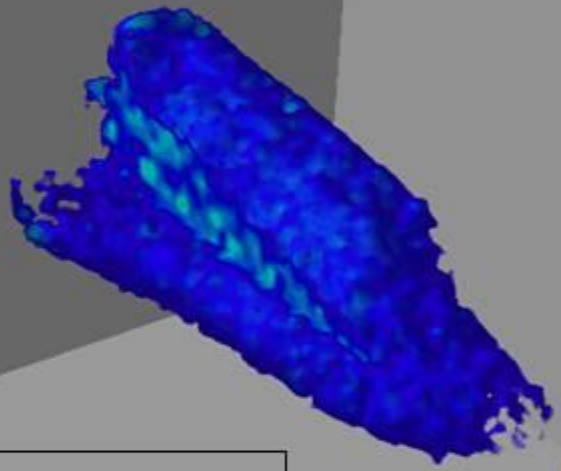
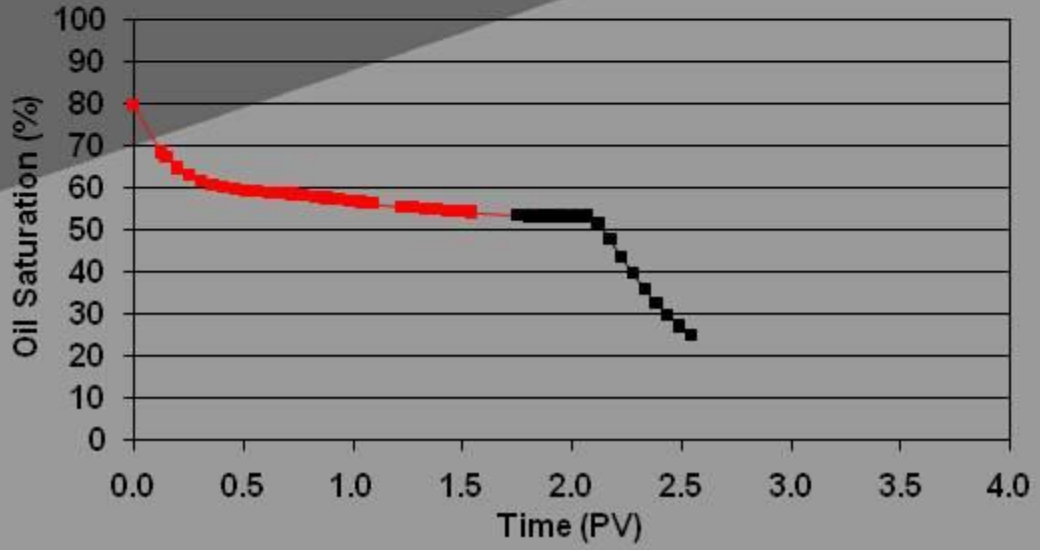


Time: 2.54 PV





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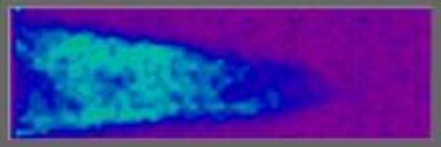
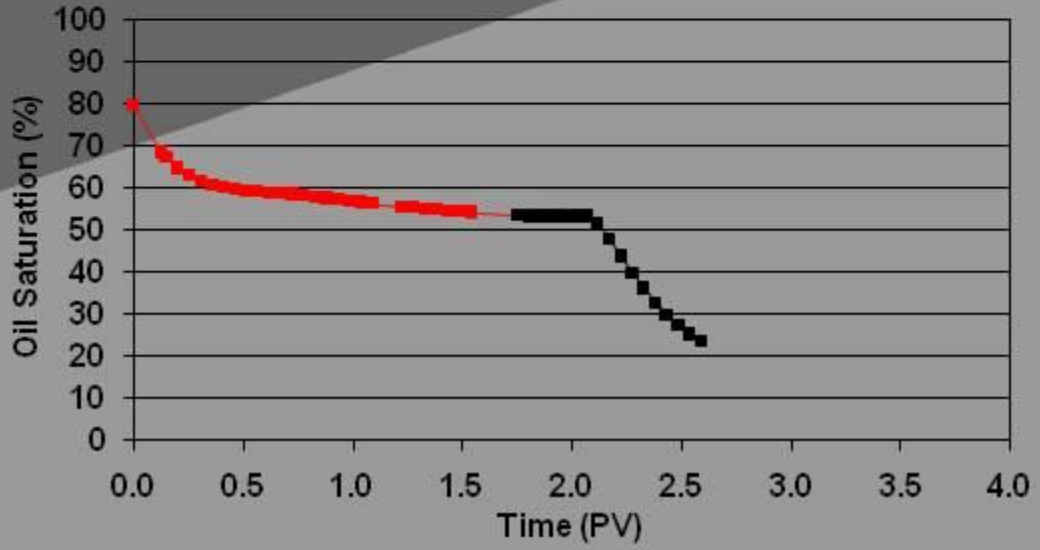


Time: 2.59 PV


Oil Saturation (%)
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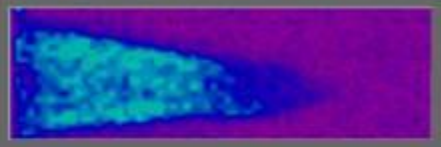
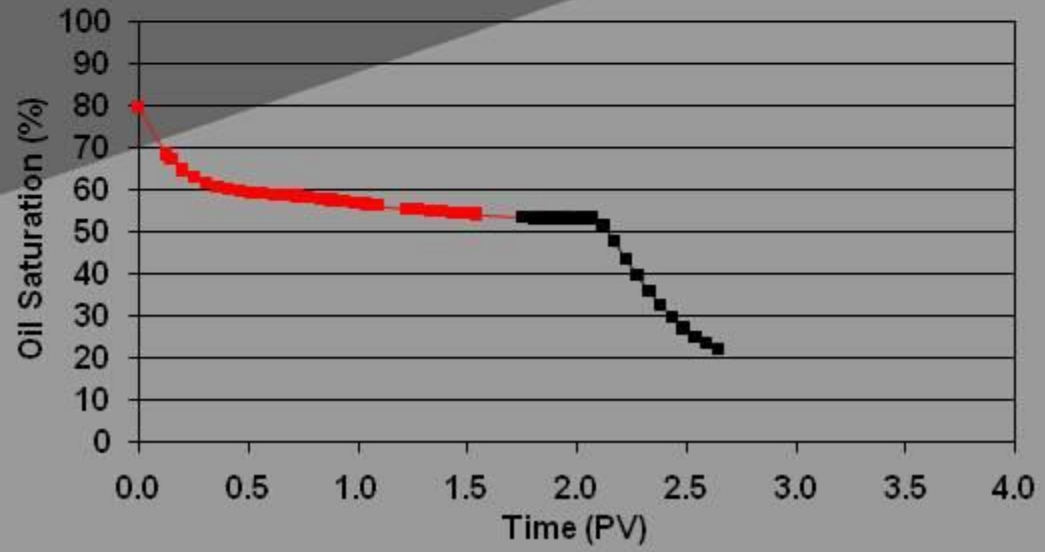
Time (PV)



Time: 2.64 PV


Oil Saturation (%)
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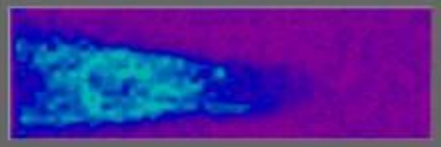
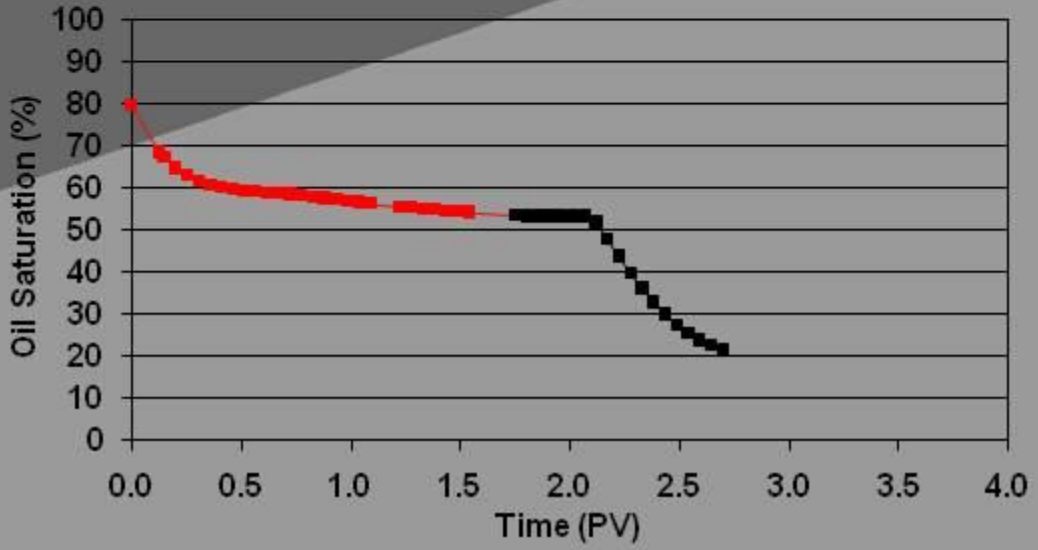
Time (PV)



Time: 2.69 PV


Oil Saturation (%)
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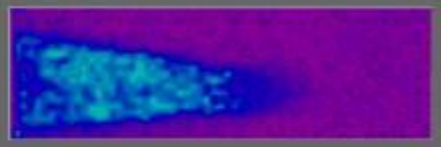
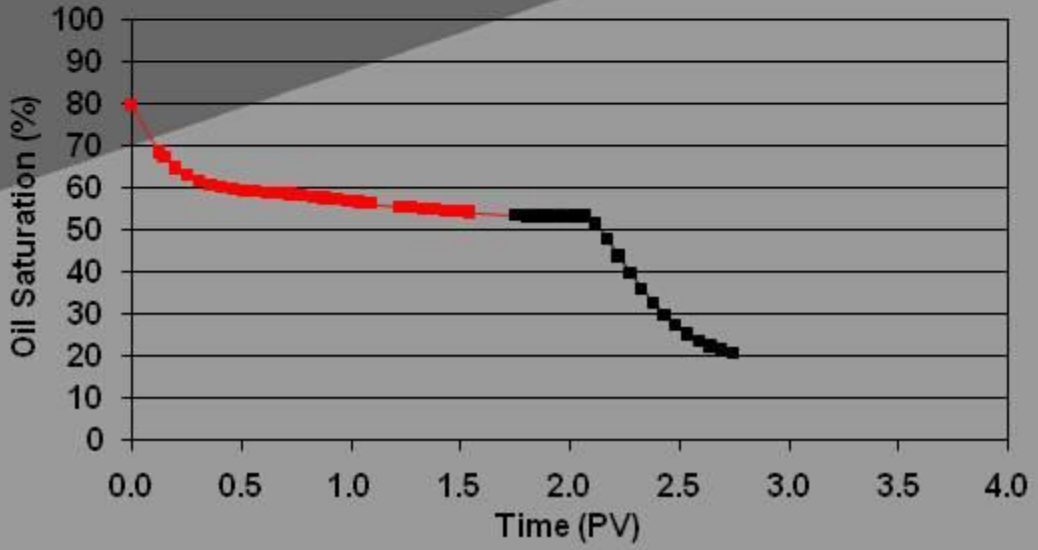
2.5
3.0
3.5
4.0
Time (PV)



Time: 2.75 PV


Oil Saturation (%)
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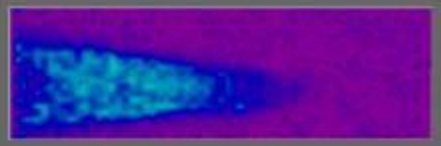
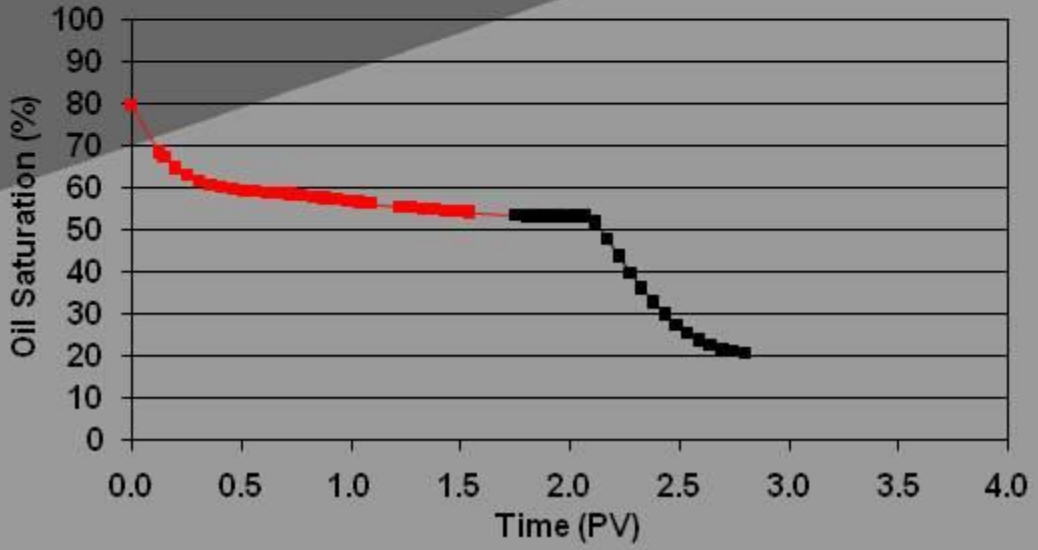
1.5
2.0
2.5
3.0
3.5
4.0
Time (PV)



Time: 2.80 PV


Oil Saturation (%)
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60
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40
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10
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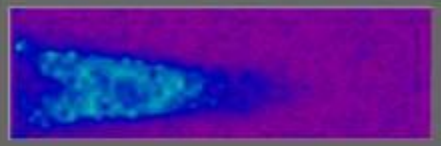
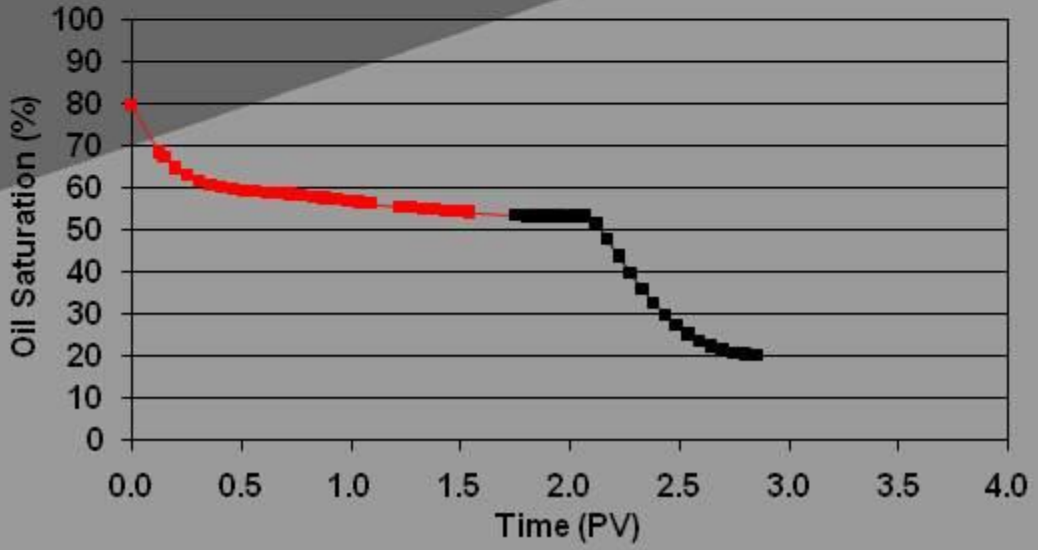
1.0
1.5
2.0
2.5
3.0
3.5
4.0
Time (PV)



Time: 2.85 PV


Oil Saturation (%)
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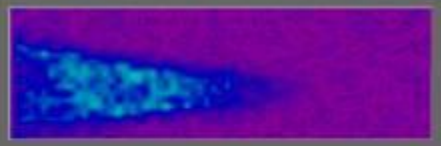
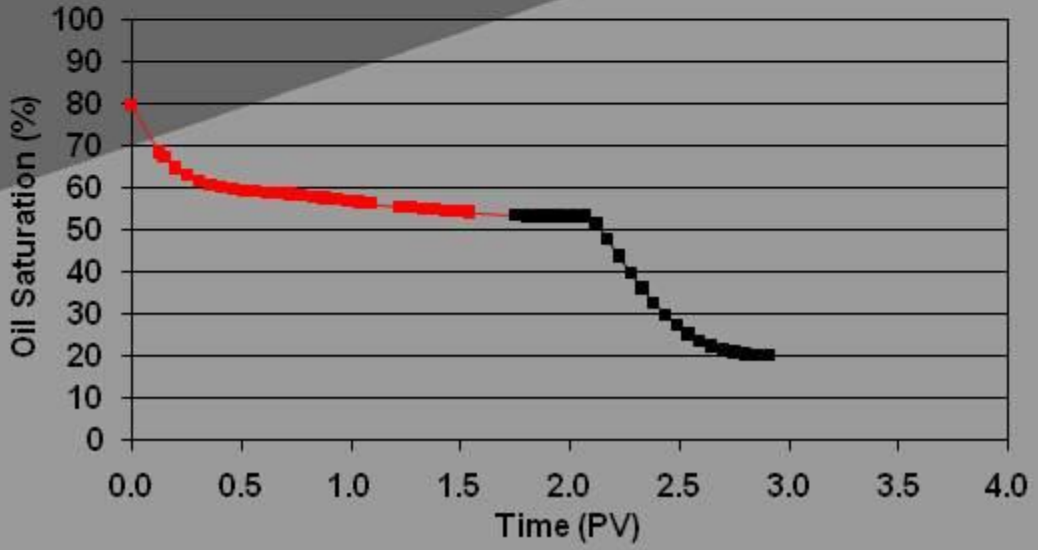
1.5
2.0
2.5
3.0
3.5
4.0
Time (PV)



Time: 2.90 PV


Oil Saturation (%)
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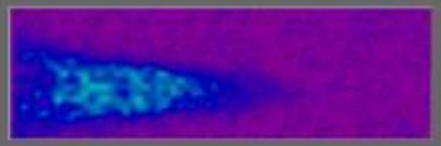
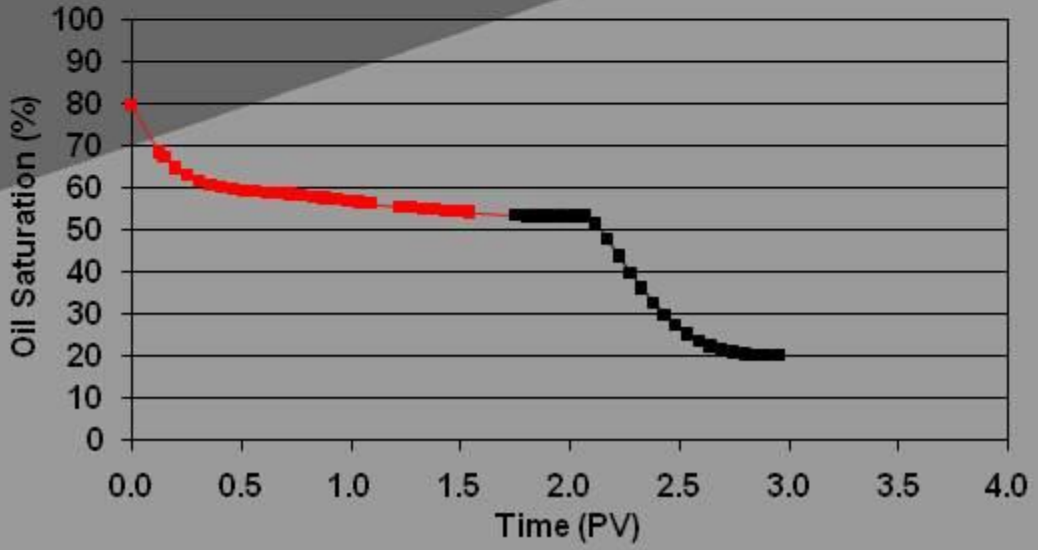
1.0
1.5
2.0
2.5
3.0
3.5
4.0
Time (PV)



Time: 2.95 PV


Oil Saturation (%)
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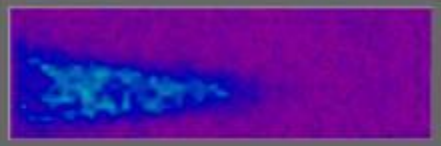
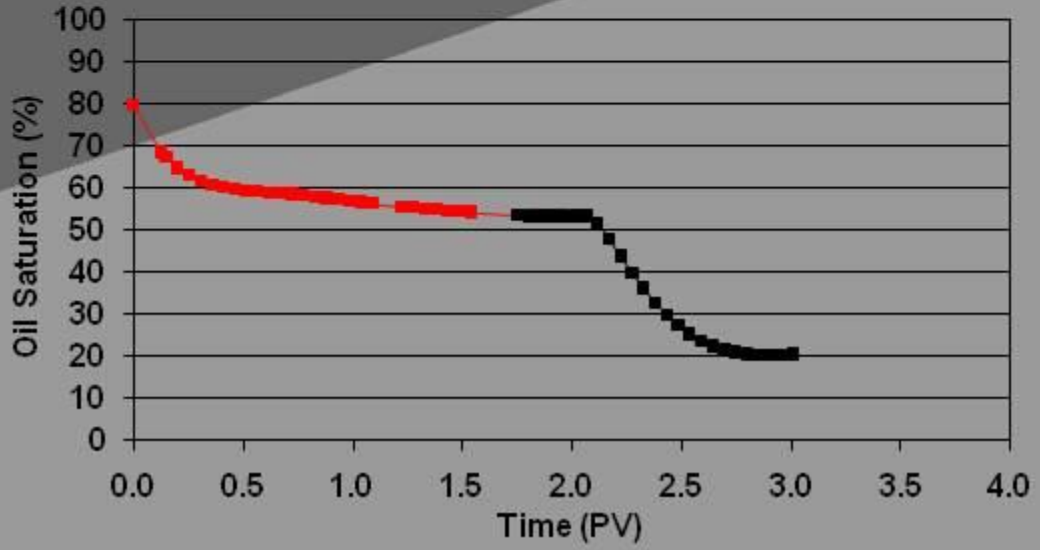
1.0
1.5
2.0
2.5
3.0
3.5
4.0
Time (PV)



Time: 3.01 PV


Oil Saturation (%)
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30
20
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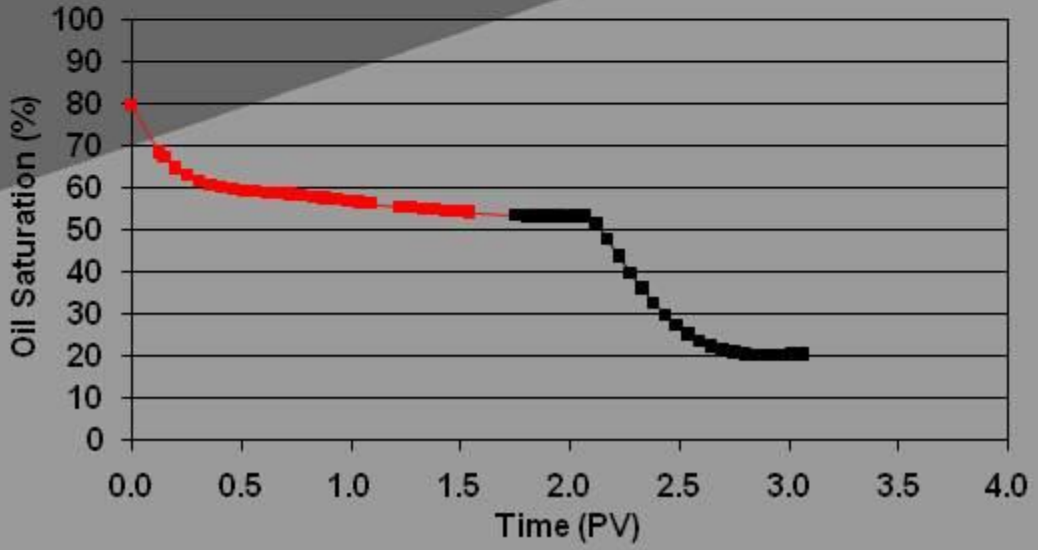
1.0
1.5
2.0
2.5
3.0
3.5
4.0
Time (PV)

Time: 3.06 PV


Oil Saturation (%)
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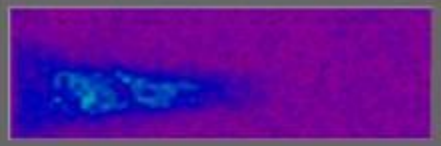
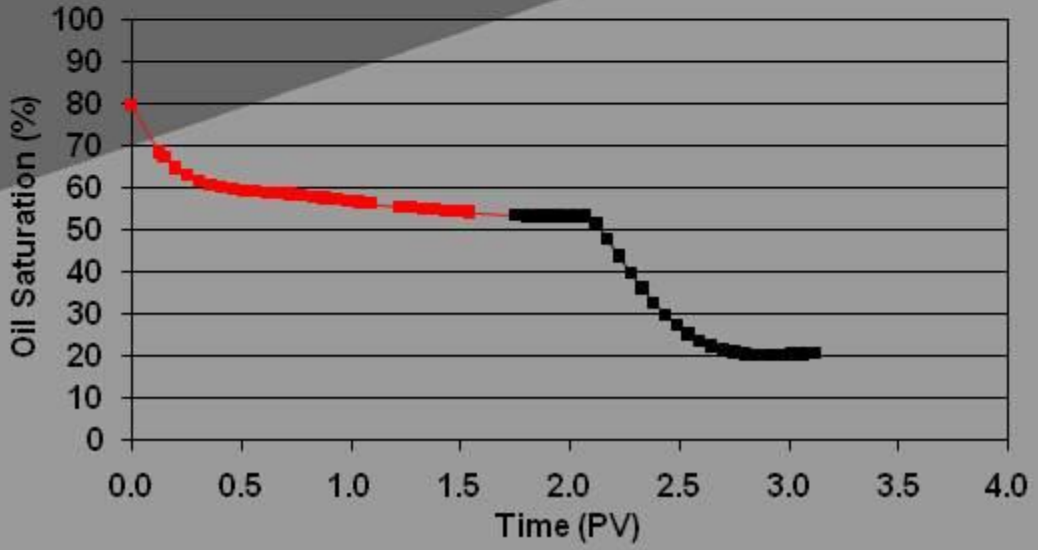
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
Time (PV)



Time: 3.11 PV


Oil Saturation (%)
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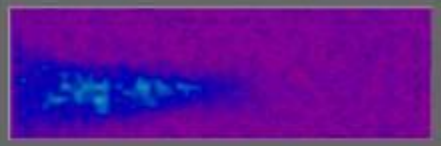
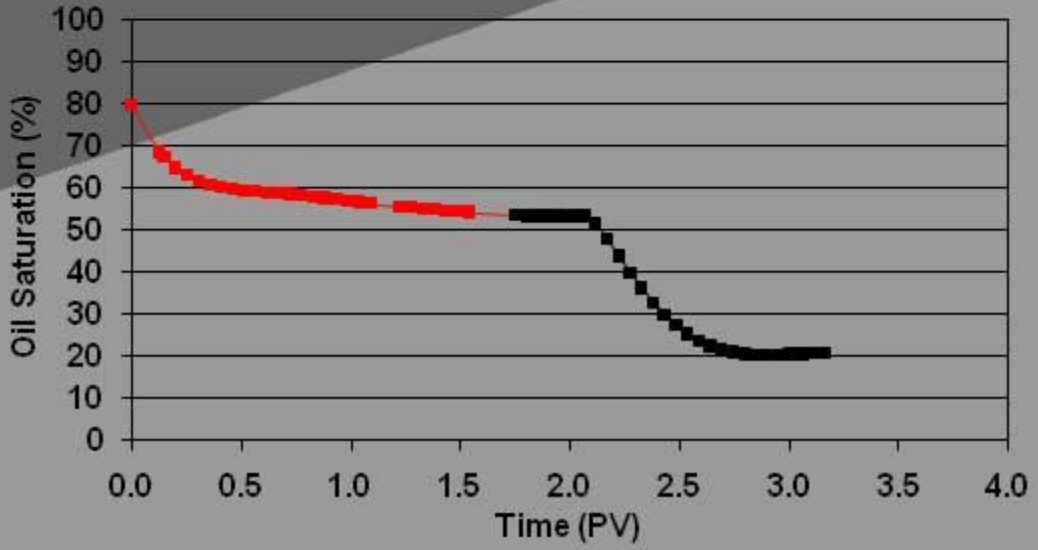
1.5
2.0
2.5
3.0
3.5
4.0
Time (PV)



Time: 3.16 PV


Oil Saturation (%)
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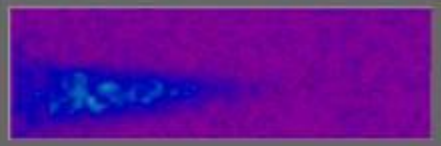
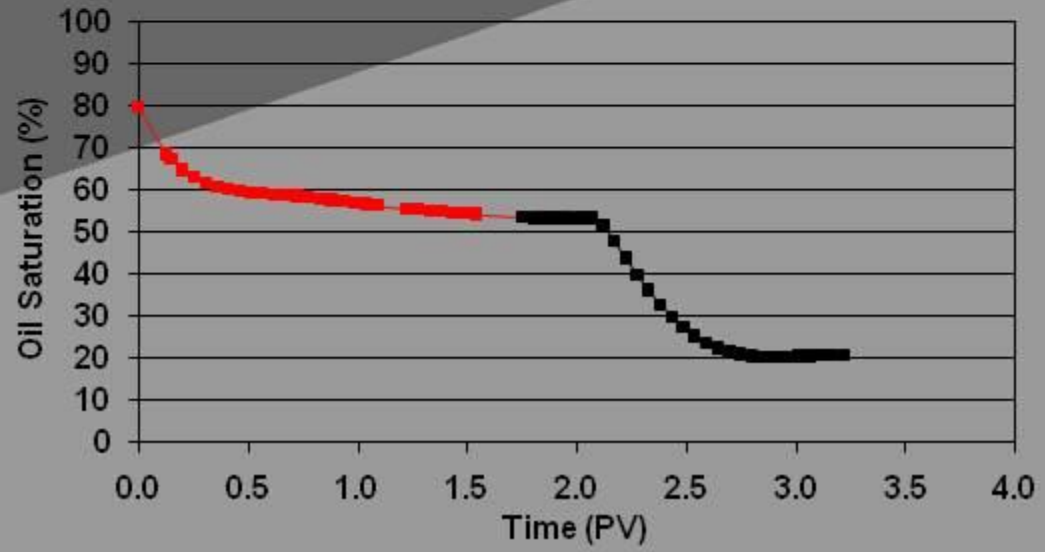
1.5
2.0
2.5
3.0
3.5
4.0
Time (PV)



Time: 3.22 PV


Oil Saturation (%)
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60
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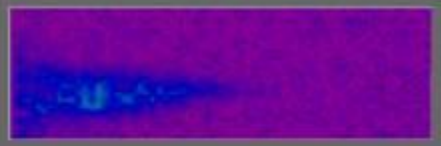
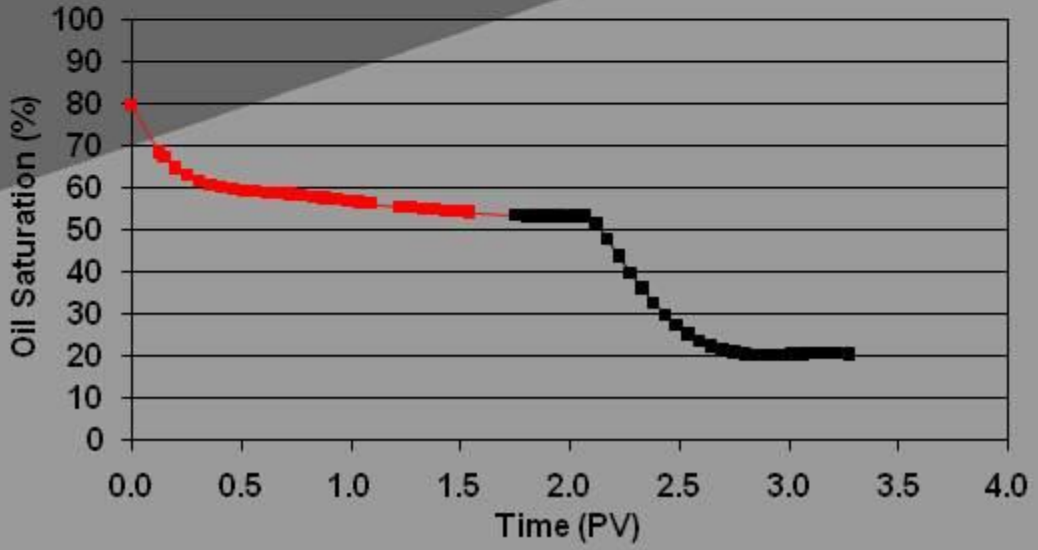
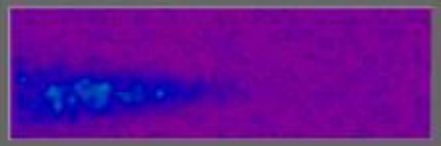
1.0
1.5
2.0
2.5
3.0
3.5
4.0
Time (PV)



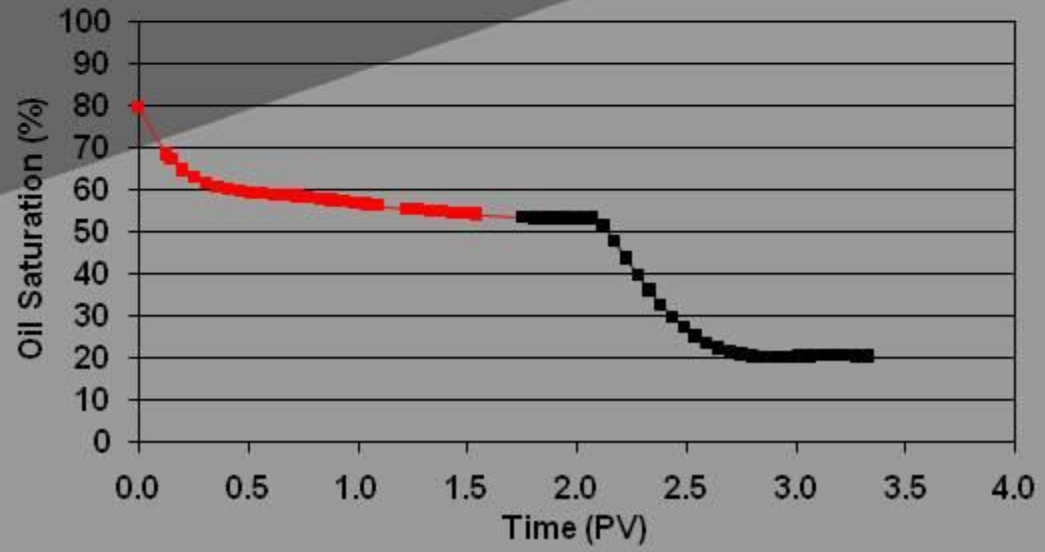
Time: 3.27 PV



SCA2008-41



Time: 3.32 PV


Oil Saturation (%)
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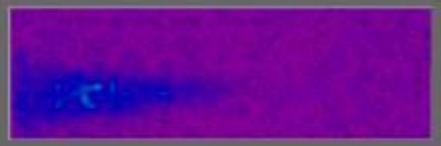
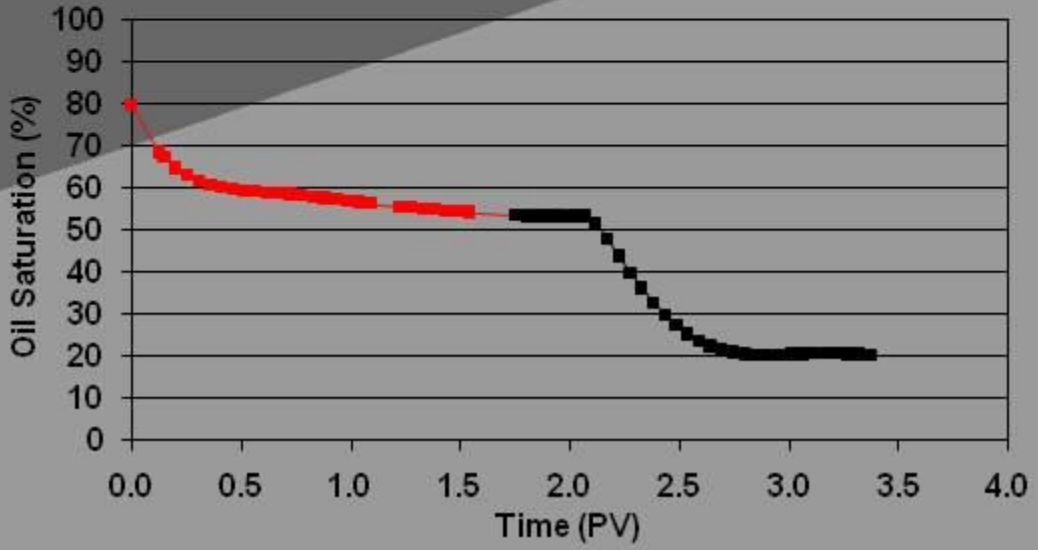
1.0
1.5
2.0
2.5
3.0
3.5
4.0
Time (PV)



Time: 3.37 PV


Oil Saturation (%)
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60
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40
30
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10
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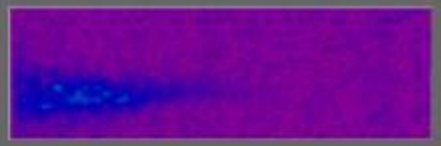
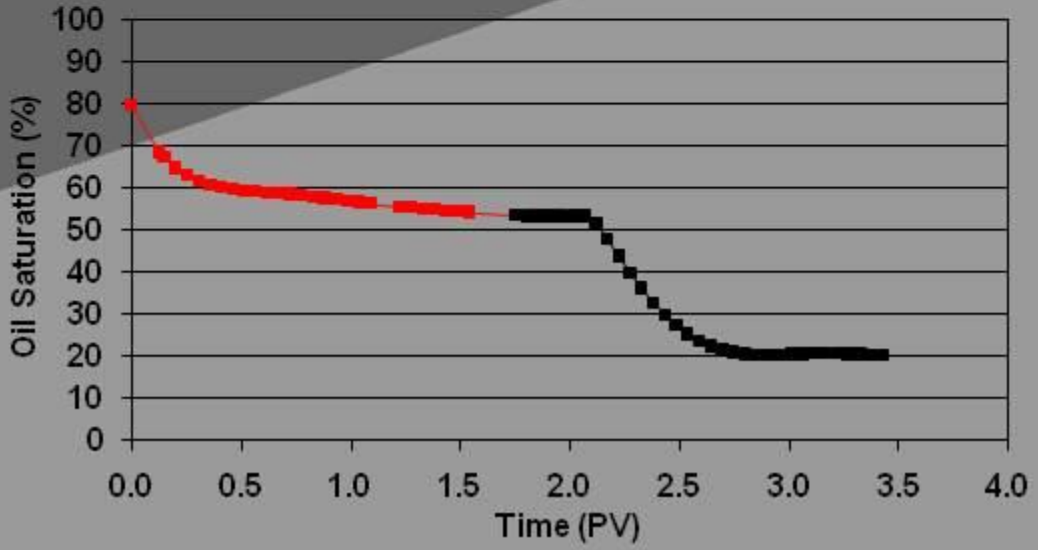
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
Time (PV)



Time: 3.43 PV


Oil Saturation (%)
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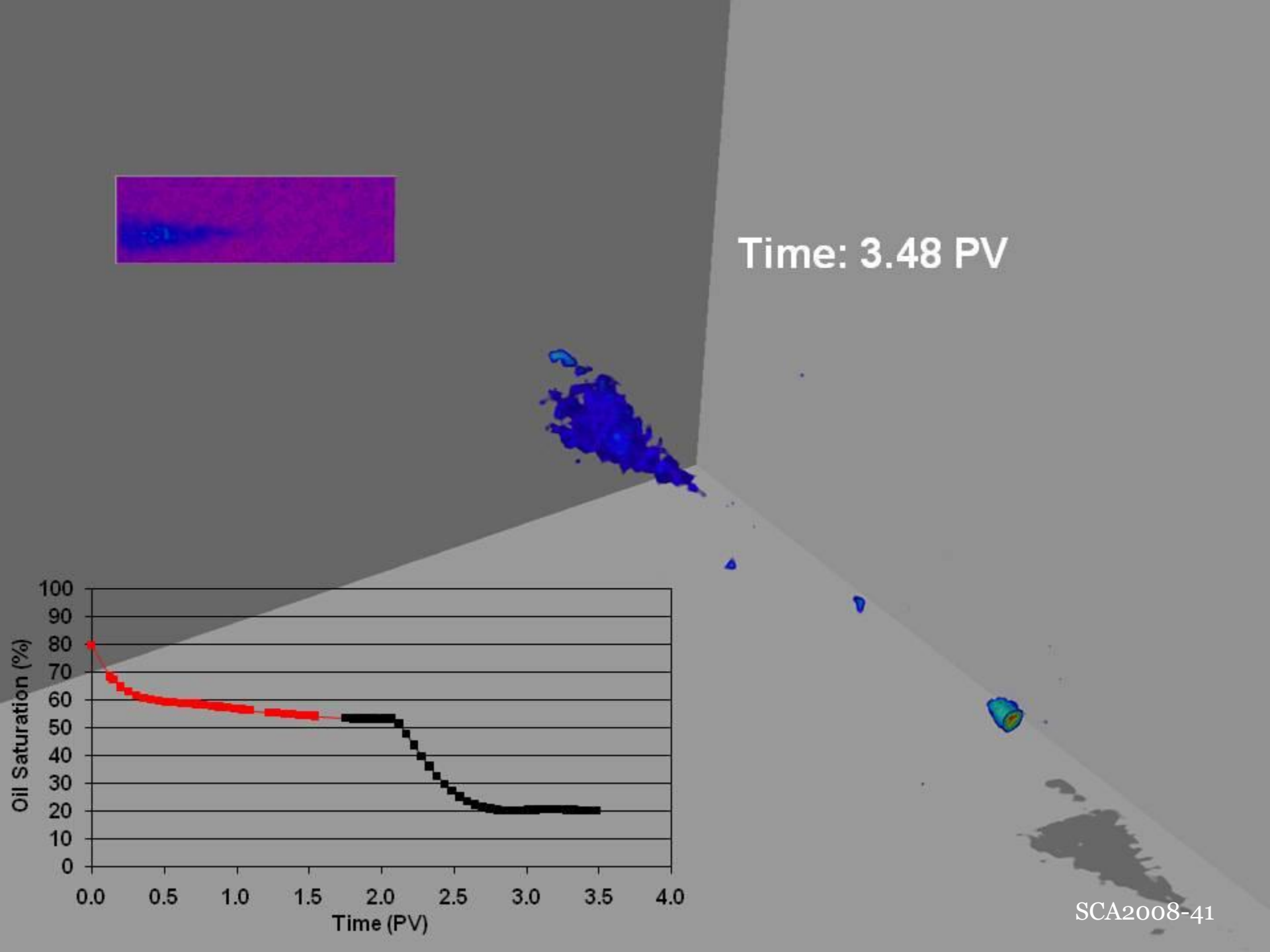
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
Time (PV)


Time: 3.48 PV
Oil Saturation (%)
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30
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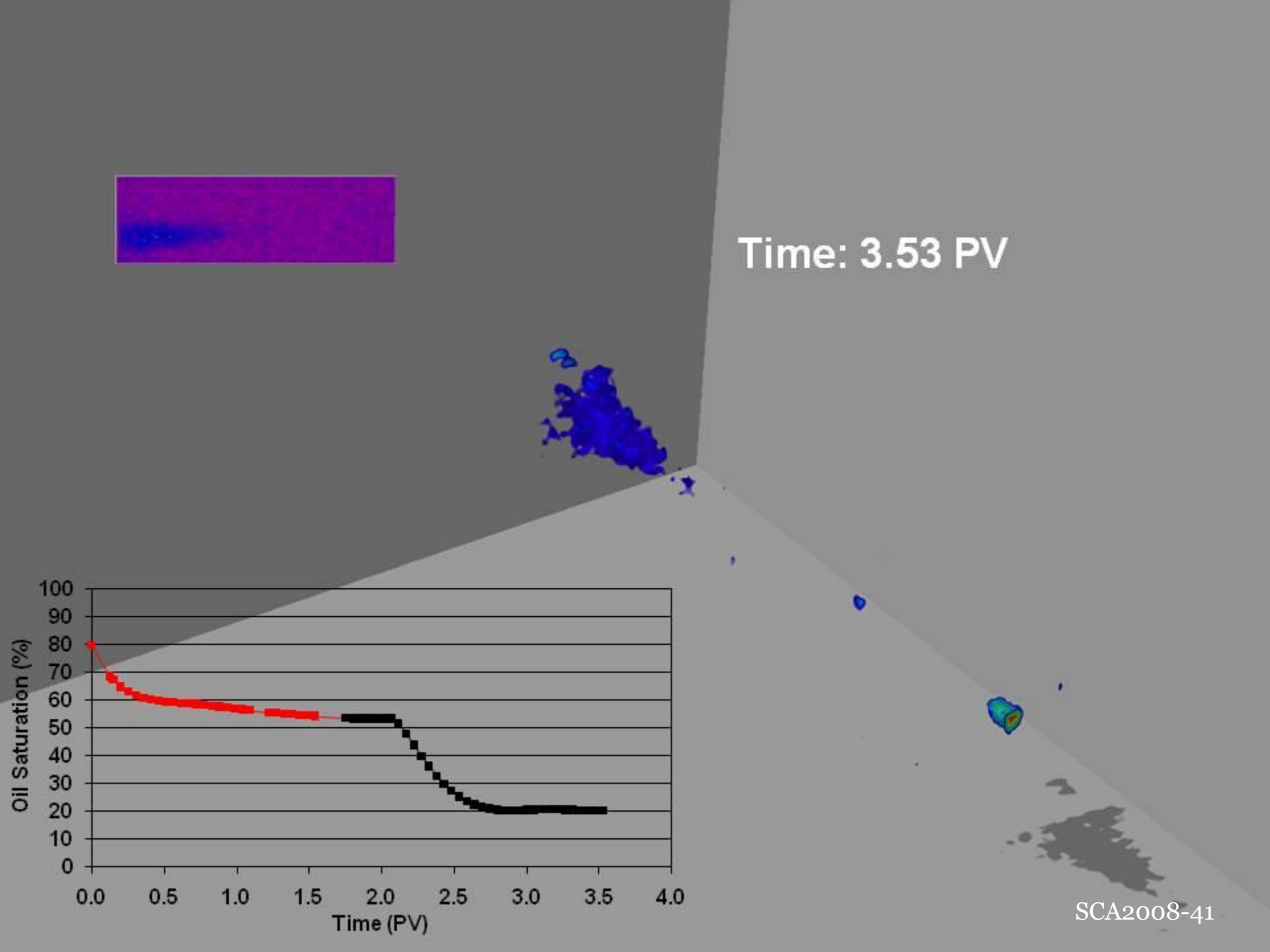
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
Time (PV)


Time: 3.53 PV
Oil Saturation (%)
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40
30
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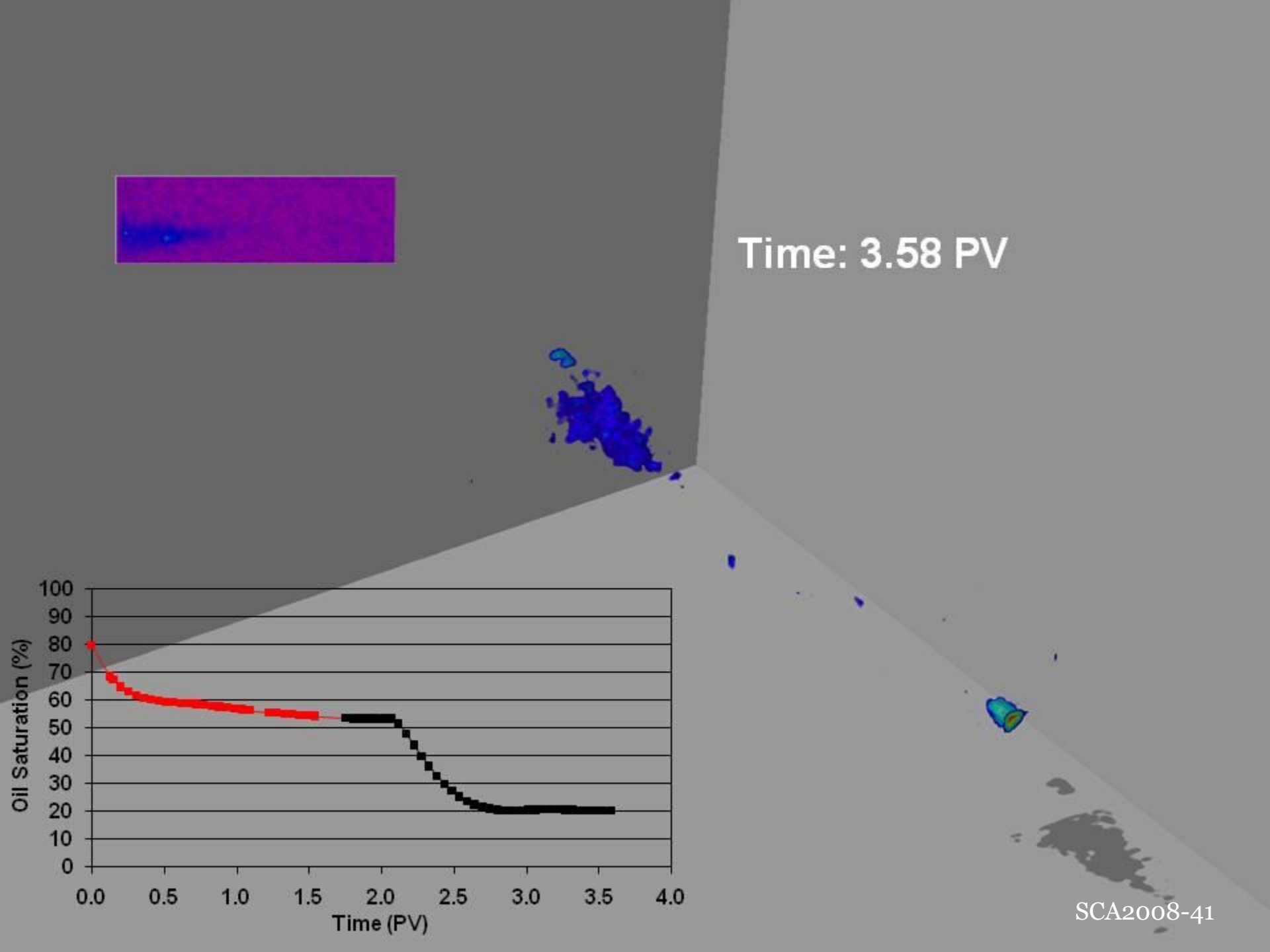
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
Time (PV)


Time: 3.58 PV
Oil Saturation (%)
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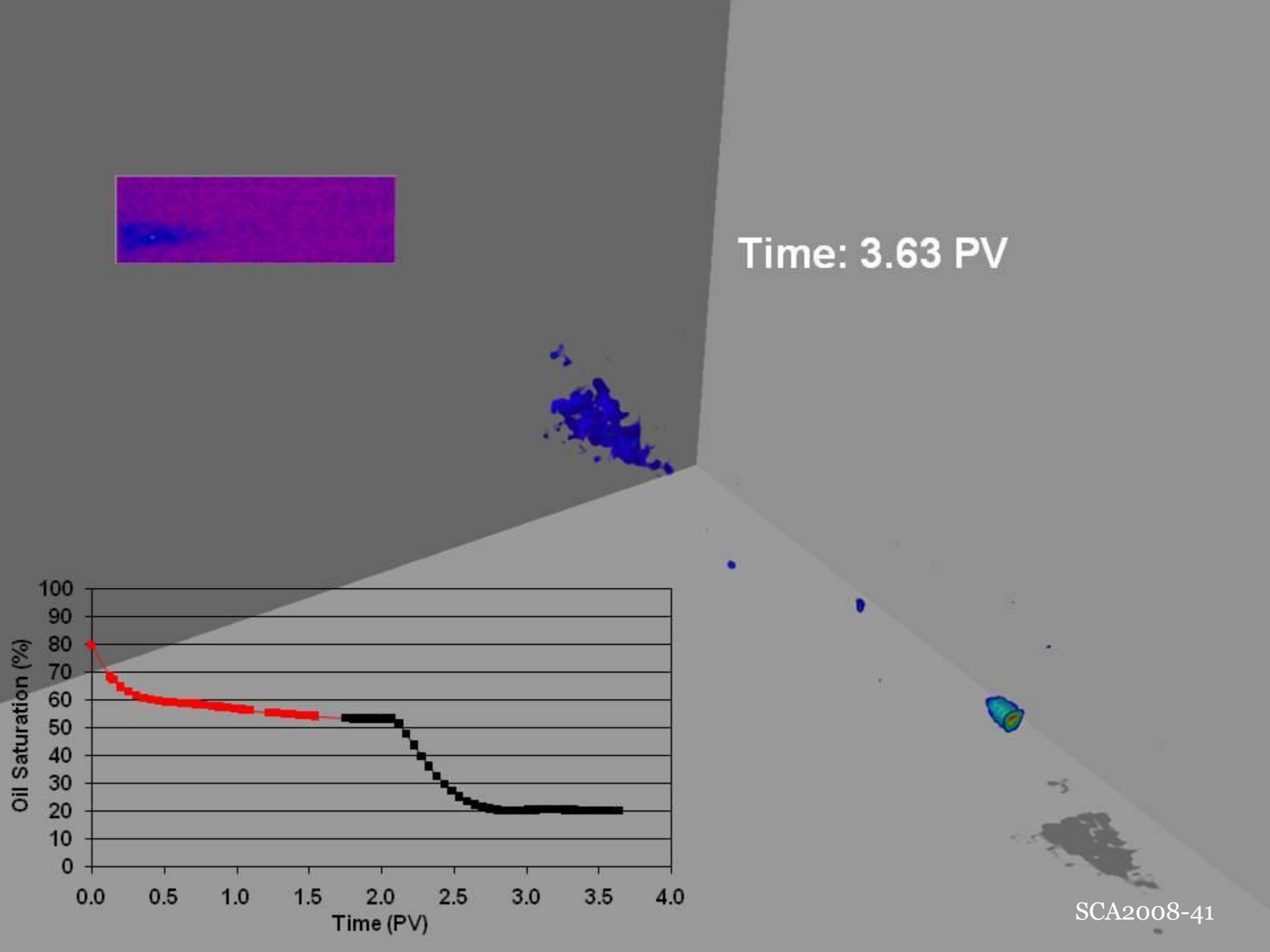
1.0
1.5
2.0
2.5
3.0
3.5
4.0
Time (PV)


Time: 3.63 PV
Oil Saturation (%)
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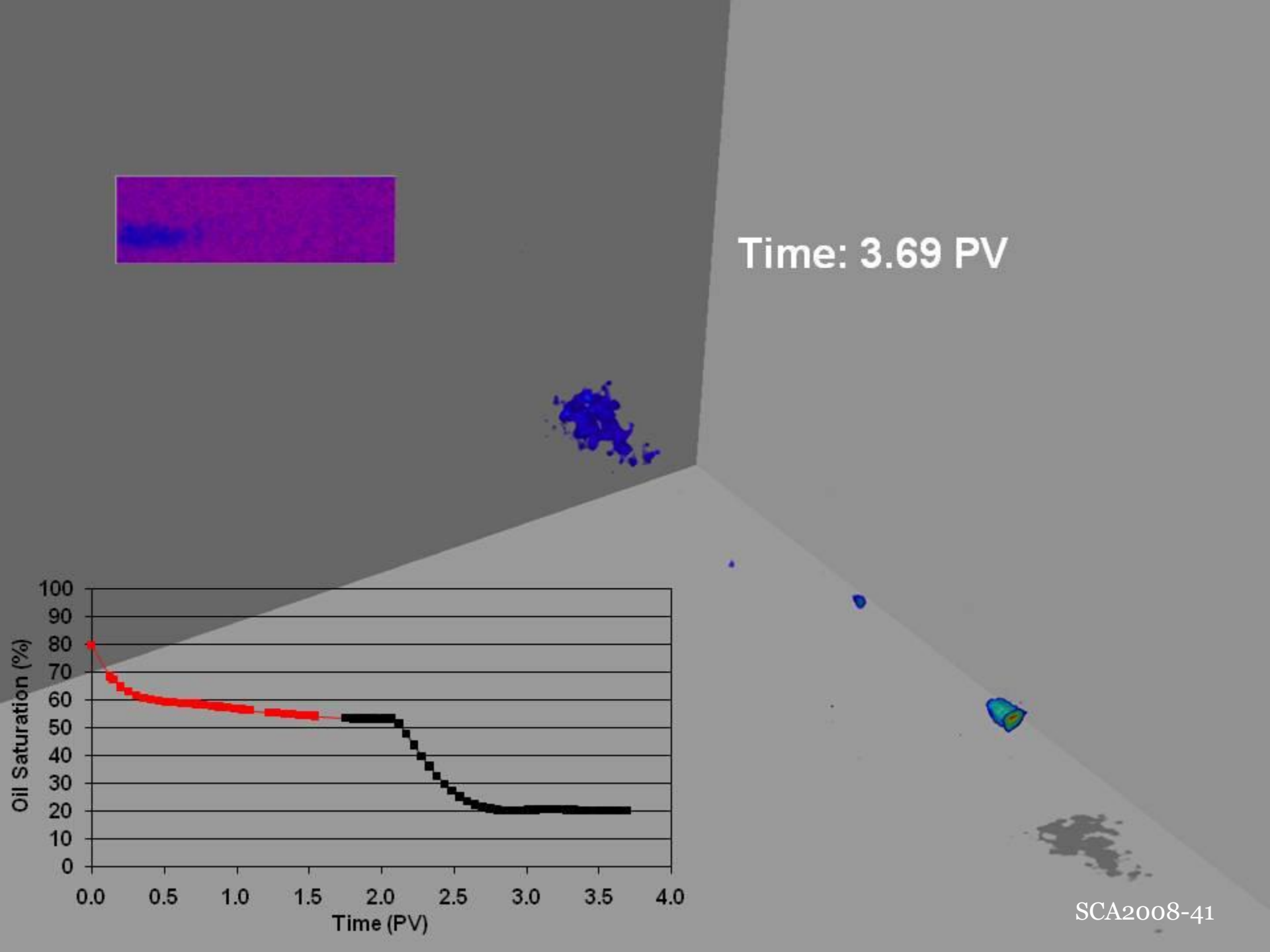
1.0
1.5
2.0
2.5
3.0
3.5
4.0
Time (PV)


Time: 3.69 PV
Oil Saturation (%)
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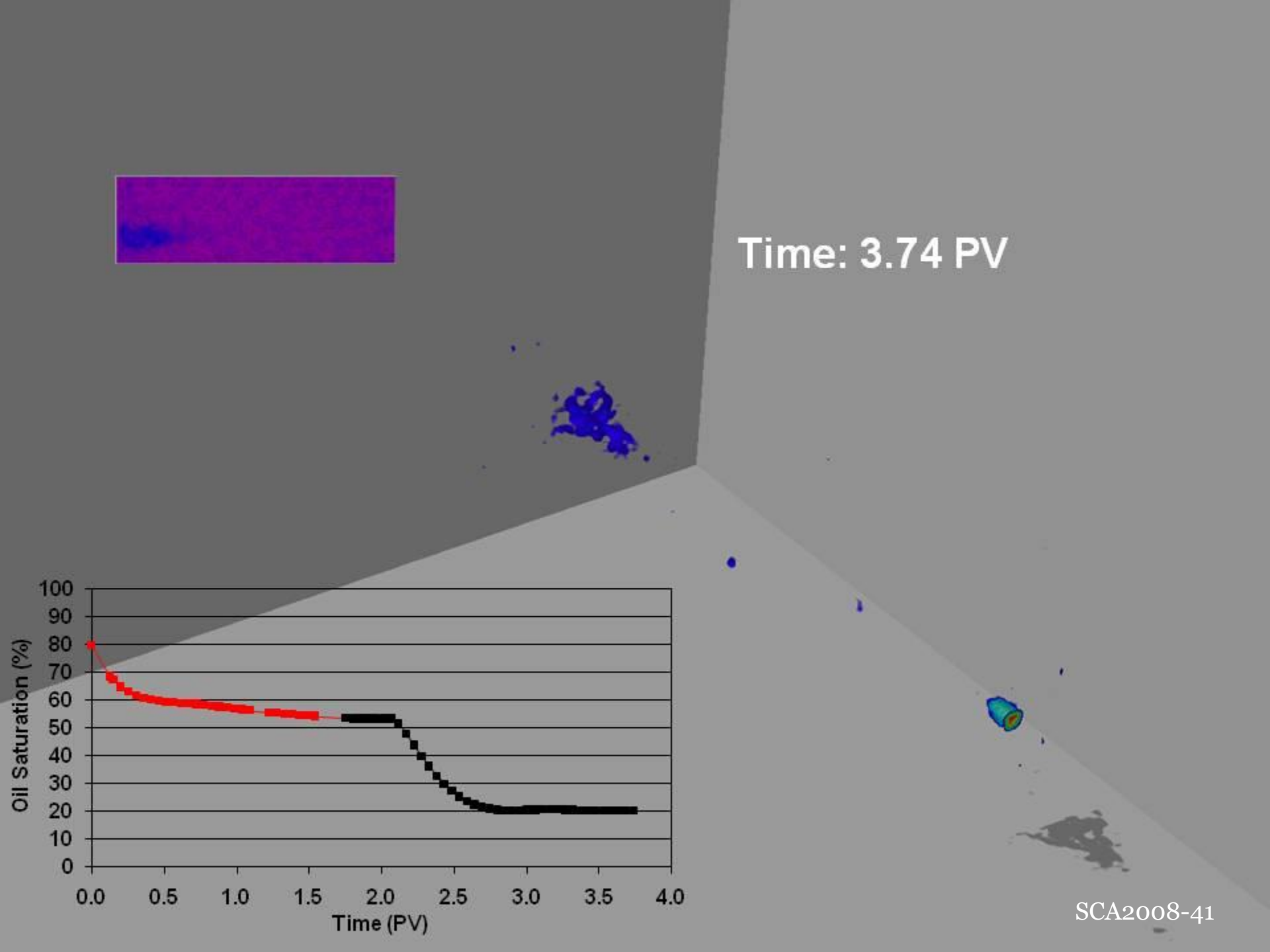
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
Time (PV)


Time: 3.74 PV
Oil Saturation (%)
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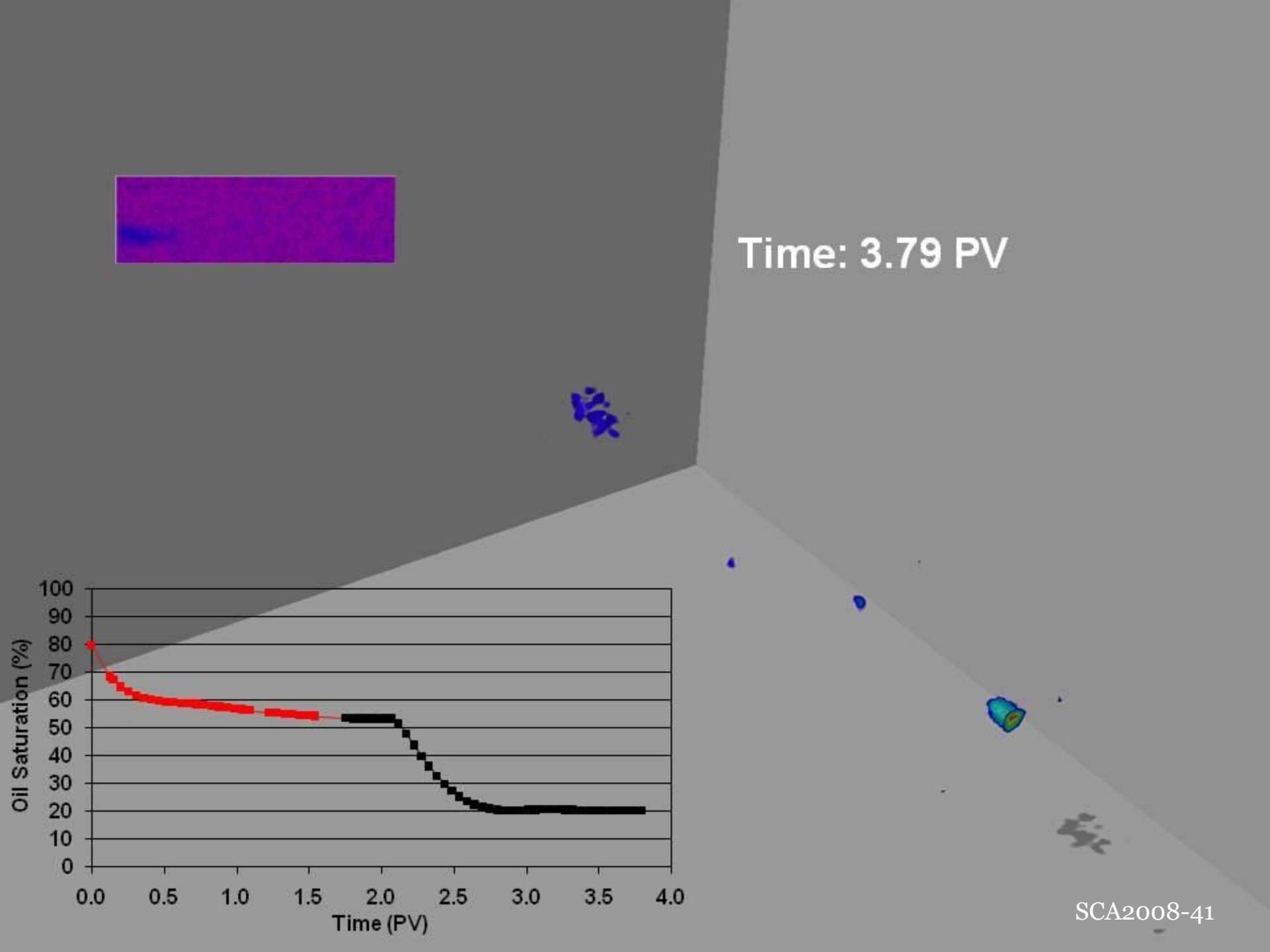
1.0
1.5
2.0
2.5
3.0
3.5
4.0
Time (PV)


Time: 3.79 PV
Oil Saturation (%)
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50
40
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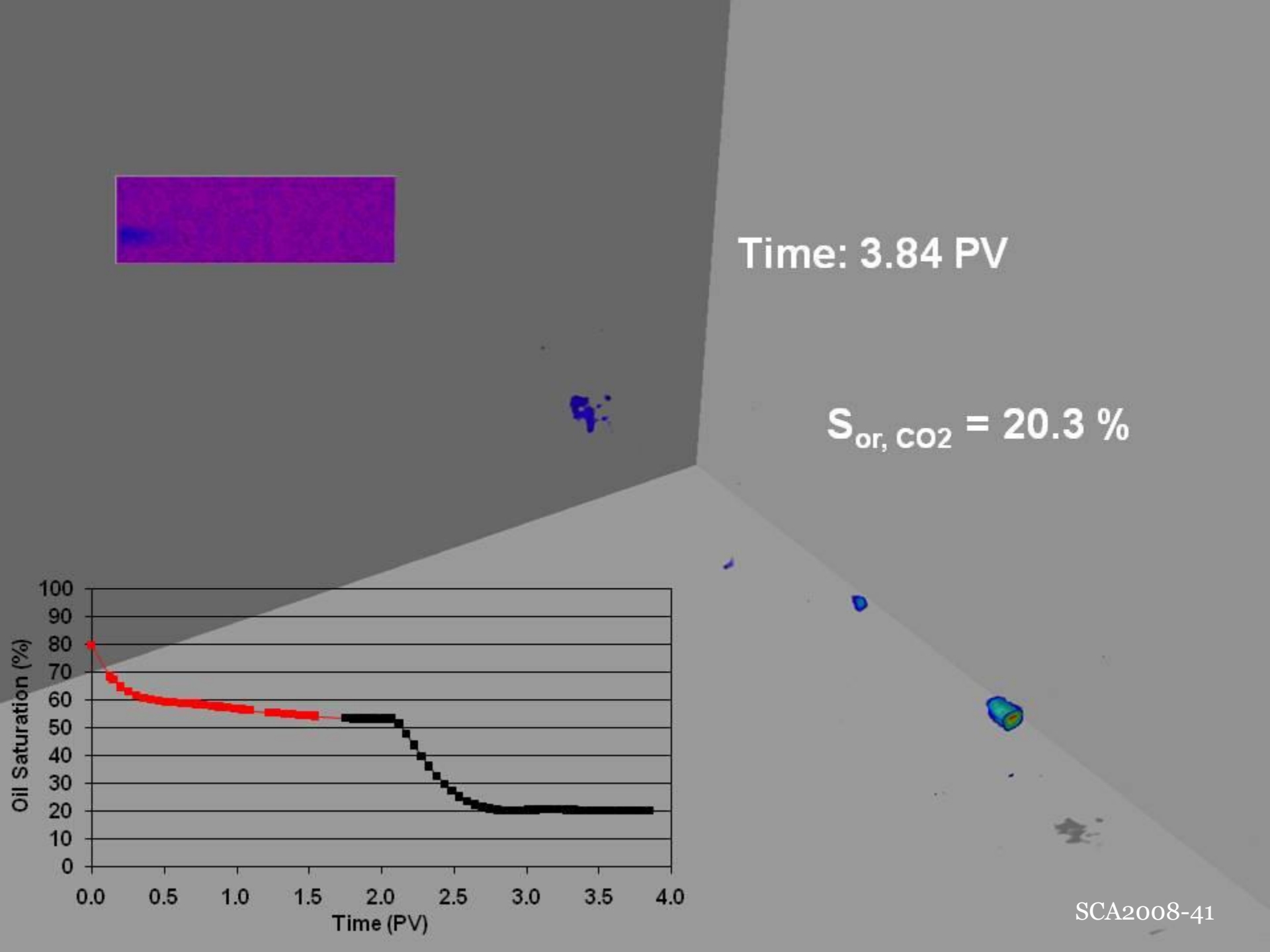
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
Time (PV)


Time: 3.84 PV
$S_{or, CO2}$ = 20.3 %
Oil Saturation (%)
100
90
80
70
60
50
40
30
20
10
0
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
Time (PV)

EOR Enables CCUS:

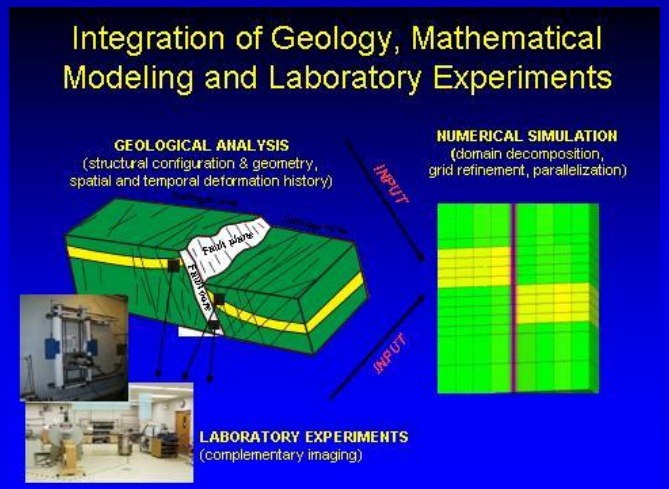
Integrated EOR (IEOR) for CO_2 Sequestration

CO_2 Foam for Mobility Control for EOR in Fractured Reservoirs in Texas

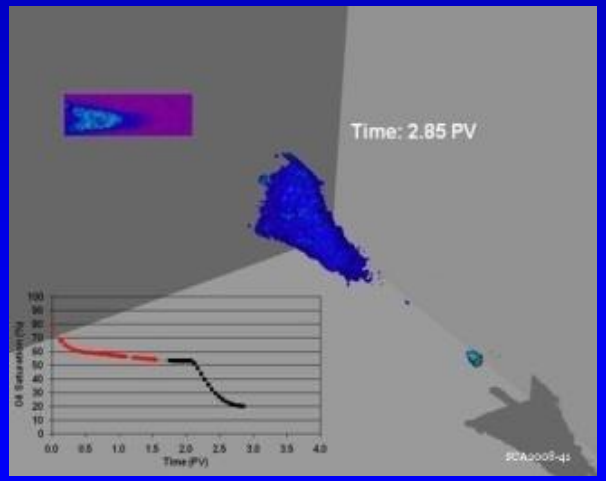
Collaboration: 11 Universities in France, The Netherlands, UK, USA and Norway

Coordinator: Arne Graue, Dept. of Physics, University of Bergen, NORWAY

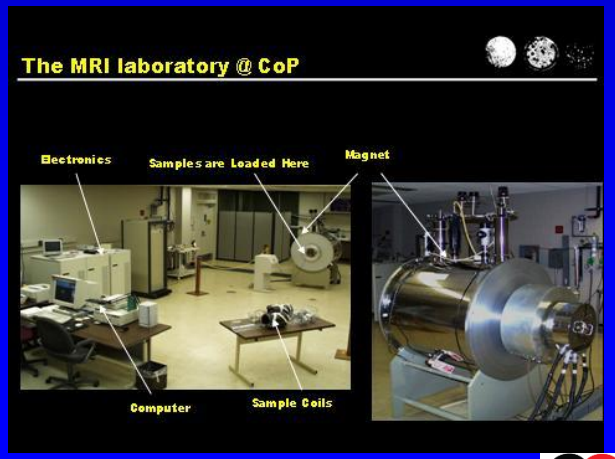
Funding: The Research Council of Norway and oil companies



Lab to pilot field test



MRI of CO_2 injection



Complementary NTI & MRI facilities

CO_2 Foam for Mobility Control for EOR in Fractured Reservoirs in Texas

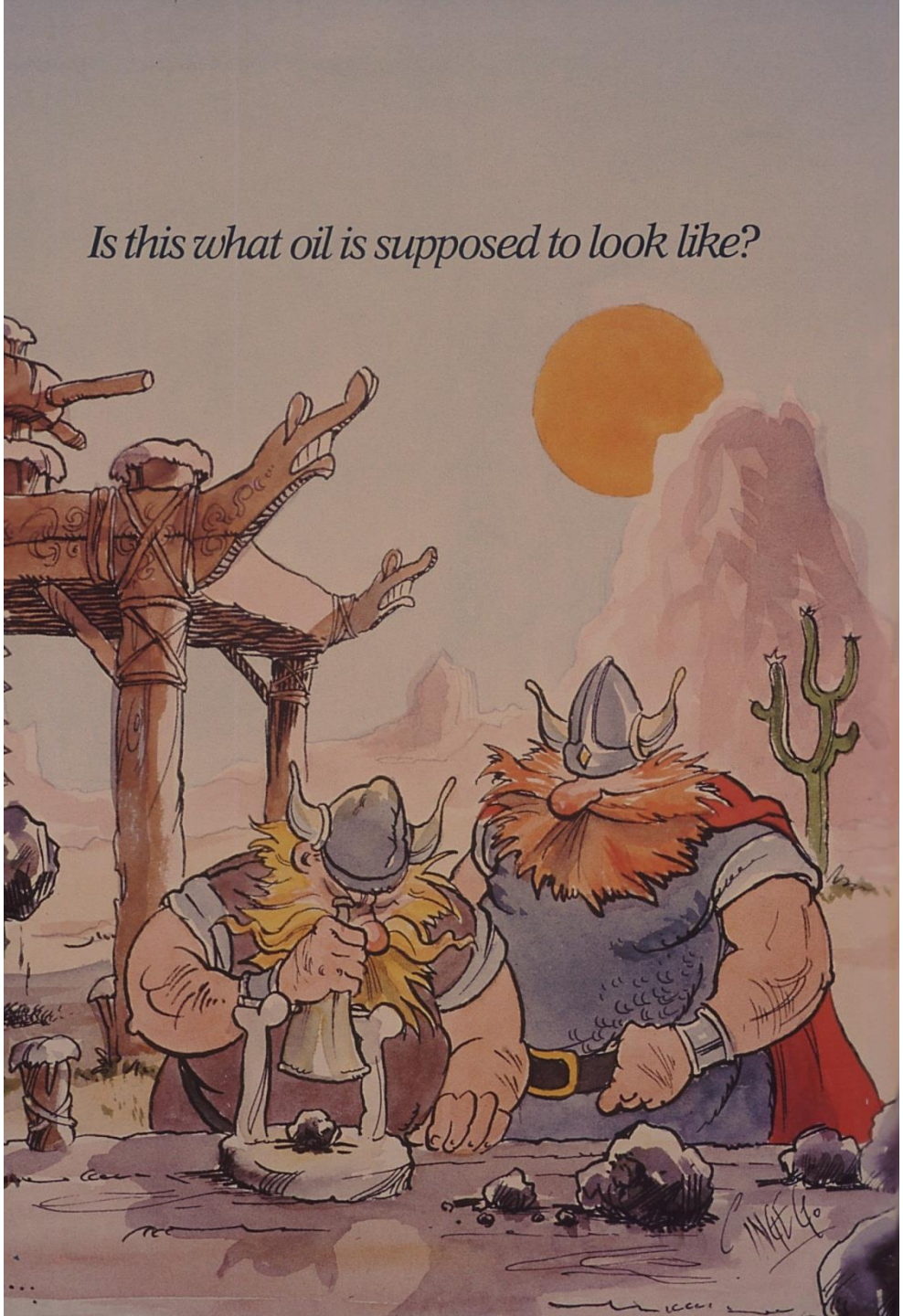
Project advantages:

- CO_2 is commercially available
- Foam as mobility control
- Researchers from 11 reputational universities
- Up-scaling; major challenge in oil recovery
- Fraction of costs of off-shore field tests
- Fast results: short inter-well distances
- 30 years experience in Texas on CO_2 EOR
- 4D seismic establishes a field laboratory

Large Scale Collaboration Emphasizing Mobility Control and CO2 EOR in Field Pilots in Texas

Collaboration: 11 universities

- Rice University
- University of Texas at Austin
- Texas A&M U.
- Stanford U.
- Imperial College, London
- TREFLE, Bordeaux, France
- New Mexico Tech
- TU Delft, The Netherlands
- NTNU, Trondheim, Norway
- University of Stavanger, Norway
- University of Bergen, Norway


Is this what oil is supposed to look like?


SBU 03

Next Generation CO_2 Flooding

- Main challenges in CO_2 EOR:
  - Early CO_2 breakthrough and poor sweep efficiency
  - Up-scaling laboratory EOR to field performance

- US White Paper:
  - Mobility control in CO_2 EOR, USDOE/Advanced Resource International Inc.
  - Target: 137 Billion bbl

- US import of foreign oil may be reduced by 30%

- “Next generation CO_2 EOR technology" based on mobility control

- 68 billion barrels of oil: 1,35 billion bbl of oil every year for 50 years

- Similar results in the North Sea; pilot in the Snorre Field

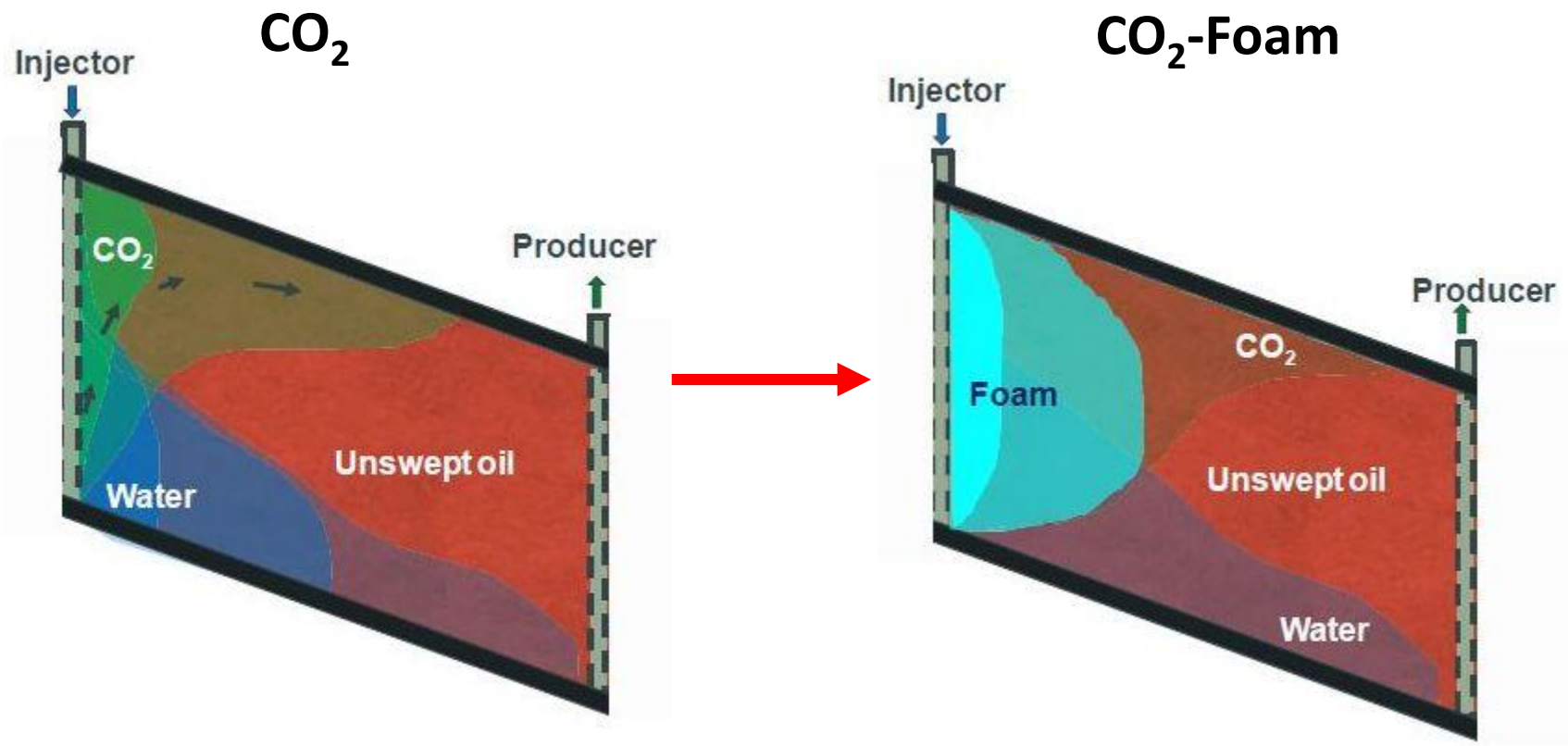
- Economic at oil price of US$ 85 and CO_2 price of US$ 40/ton

- Need more CO2

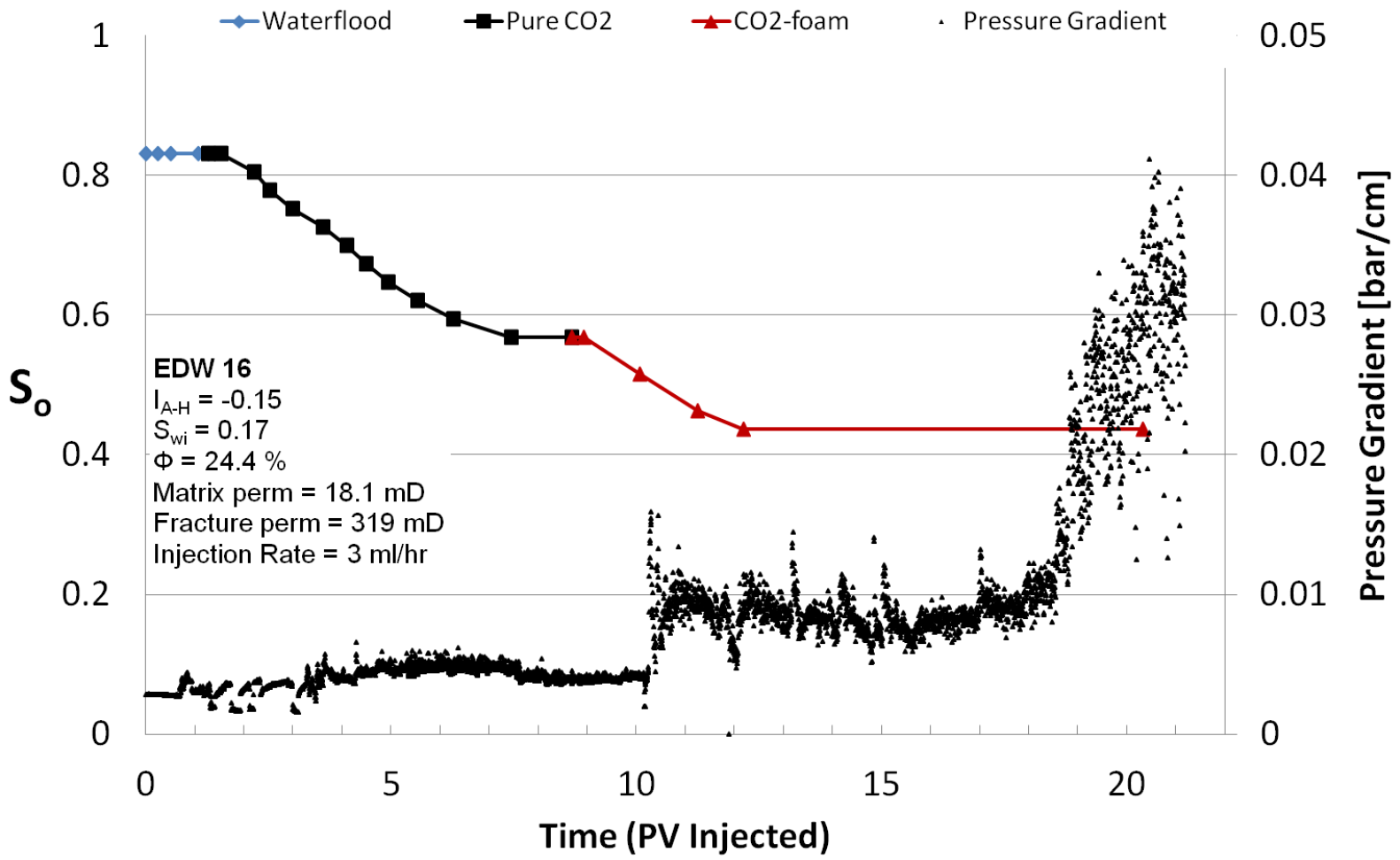
- Carbon Capture Utilization and Storage (CCUS) a win-win situation

CO_2-foam

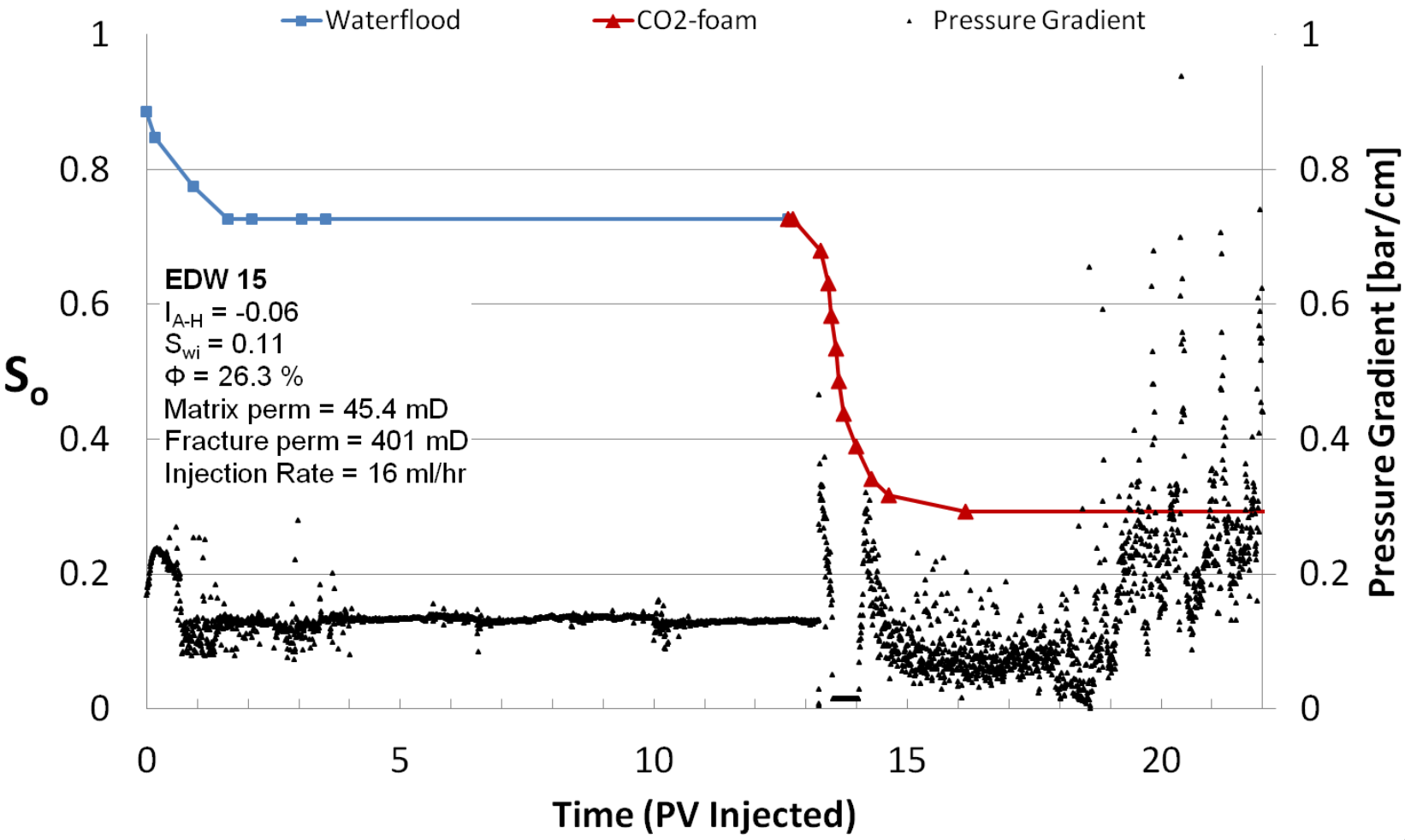
- Mitigates gravity override
- Improves sweep efficiency



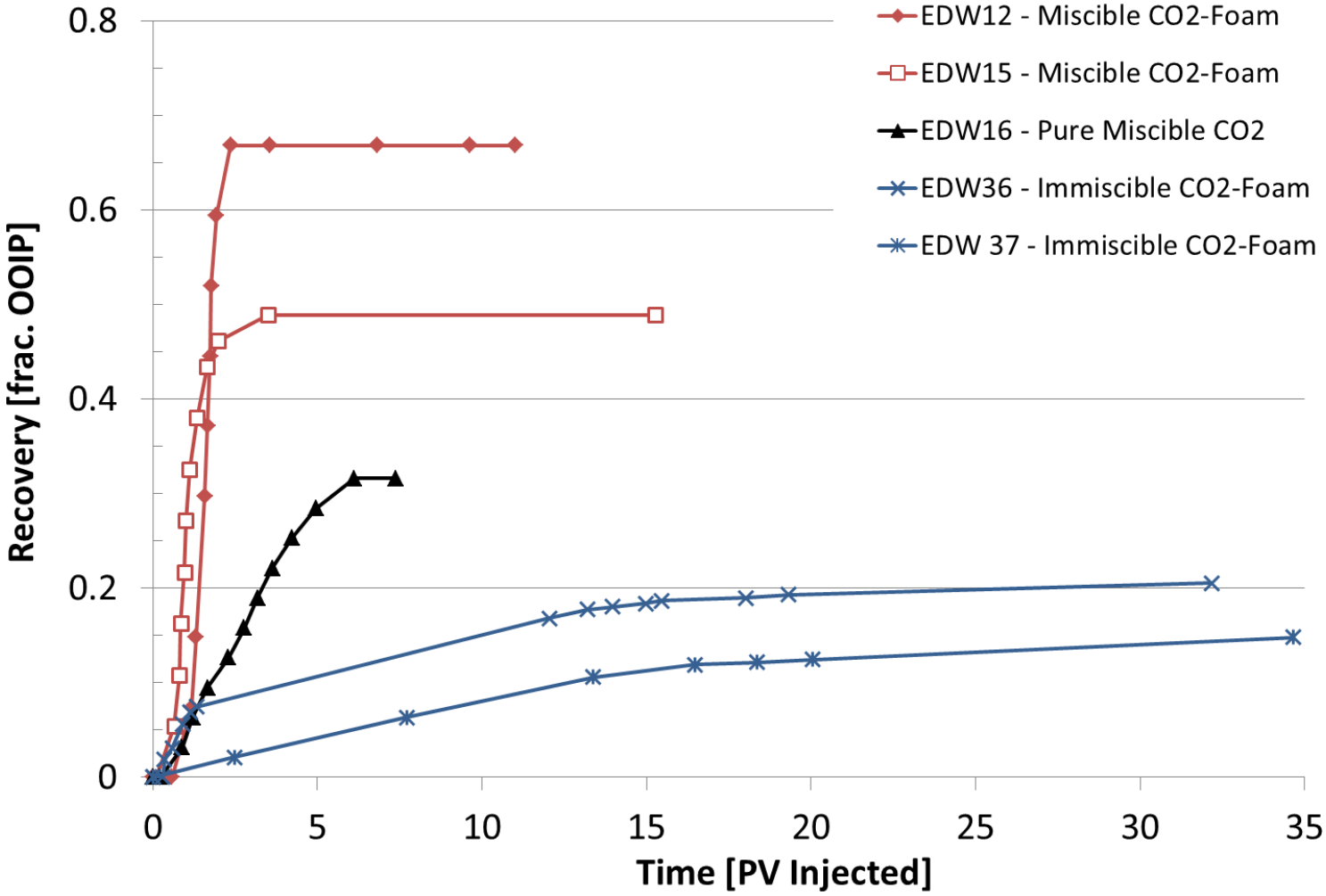
Oil-Wet Carbonate Core Plugs: IEOR (WF + CO_2 + CO_2-foam)

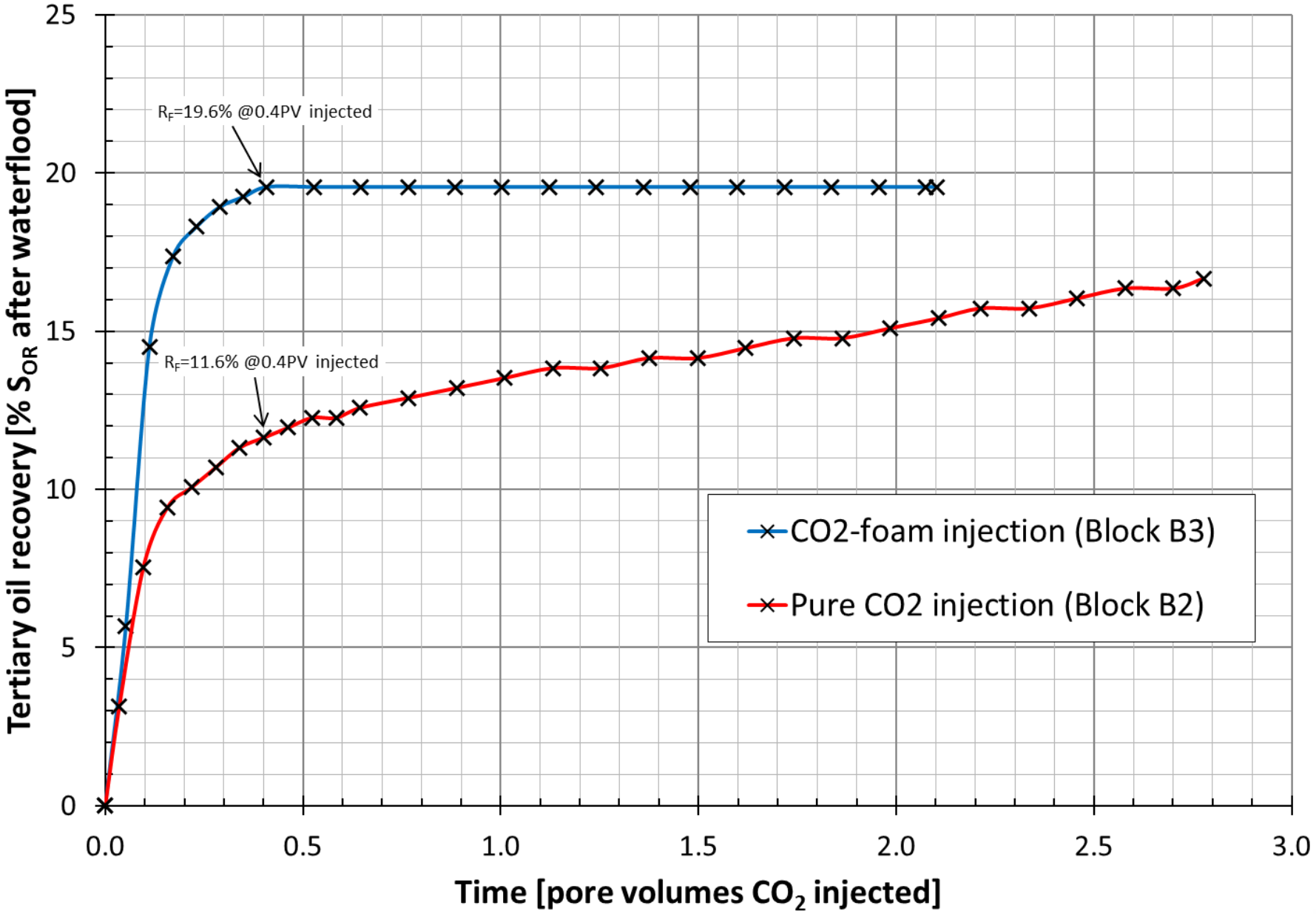


Oil-Wet Carbonate Core Plugs: IEOR (WF+CO_2-foam)

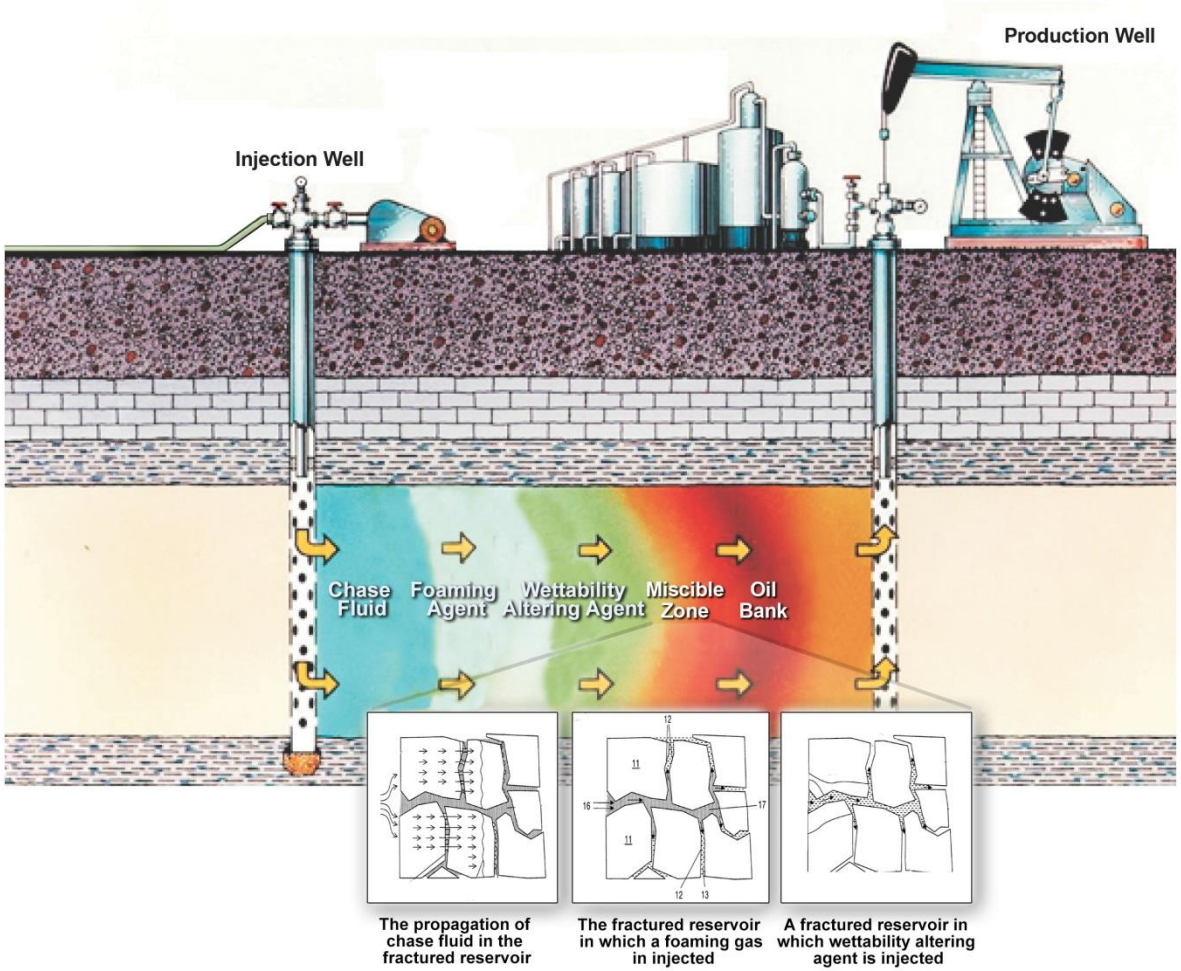


Comparison between miscible CO_2 injection and immiscible and miscible CO_2-foam

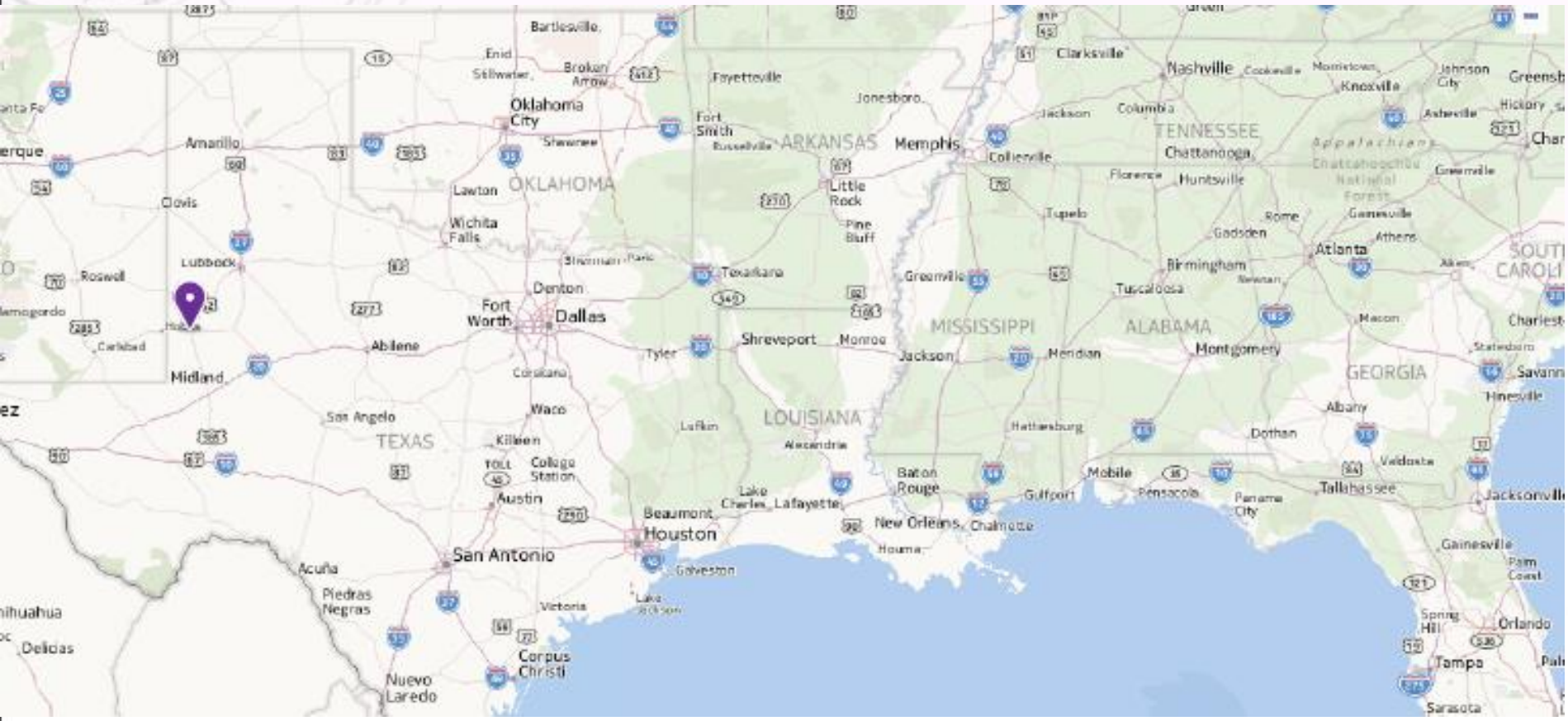



25
20
15
10
5
0
0.0
0.5
1.0
1.5
2.0
2.5
3.0
Tertiary oil recovery [% S_{OR} after waterflood]
Time [pore volumes CO_2 injected]
R_F=19.6% @0.4PV injected
R_F=11.6% @0.4PV injected
CO2-foam injection (Block B3)
Pure CO2 injection (Block B2)

Integrated CO_2-EOR provides the possibility of CO_2 long-time storage



Source: USDOE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Enid
Stillwater
Broken Arrow
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Oklahoma City
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Fort Smith
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ARKANSAS
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Clarksville
Nashville
Cookeville
Morristown
Knoxville
Johnson City
Greensb
Columbia
TENNESSEE
Chattanooga
Asheville
Hickory
Char
Appalachian
Chattahoochee National Forest
Greenville
Florence
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Collierville
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OKLAHOMA
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Little Rock
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Tupelo
Rome
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Sarasota

Results by Fall, 2016

Laboratory results:

- **More Oil Produced**: Laboratory results show that CO2 Foam EOR utilizing mobility control produces 10-30% additional oil after waterflooding compared to 5-10% by conventional CO2 flooding

- **Reduced Production Time**: Mobile oil is produced in lab experiments within 0.5PV CO2 injected when CO2 Foam EOR is applied; indicating that operational times may be reduced by up to 90%.

- **More CO2 may be stored:** Lab results show that less CO2 is needed for the oil production, but as mobile water also is displaced, more CO2 may be sequestered.

Field Pilot Results:

- **Two CO2 Foam EOR Field Pilots have started**: Currently two field pilots have been started in Texas, one in a carbonate reservoir and one in a sandstone reservoir.

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Thank you!