



U N I V E R S I T Y O F B E R G E N

Department of Physics and Technology

# CO<sub>2</sub> for Methane Production from Hydrate Reservoirs

research for  
Energy Production and CO<sub>2</sub> storage

Geir Ersland

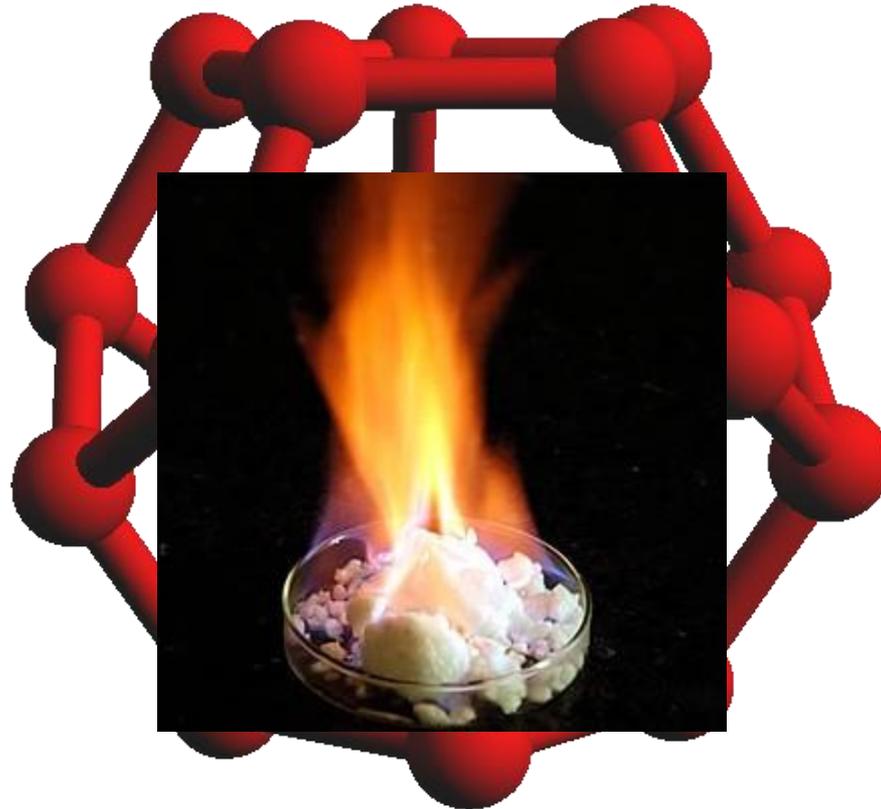
Assoc. Prof. Dept. of Physics and Technology

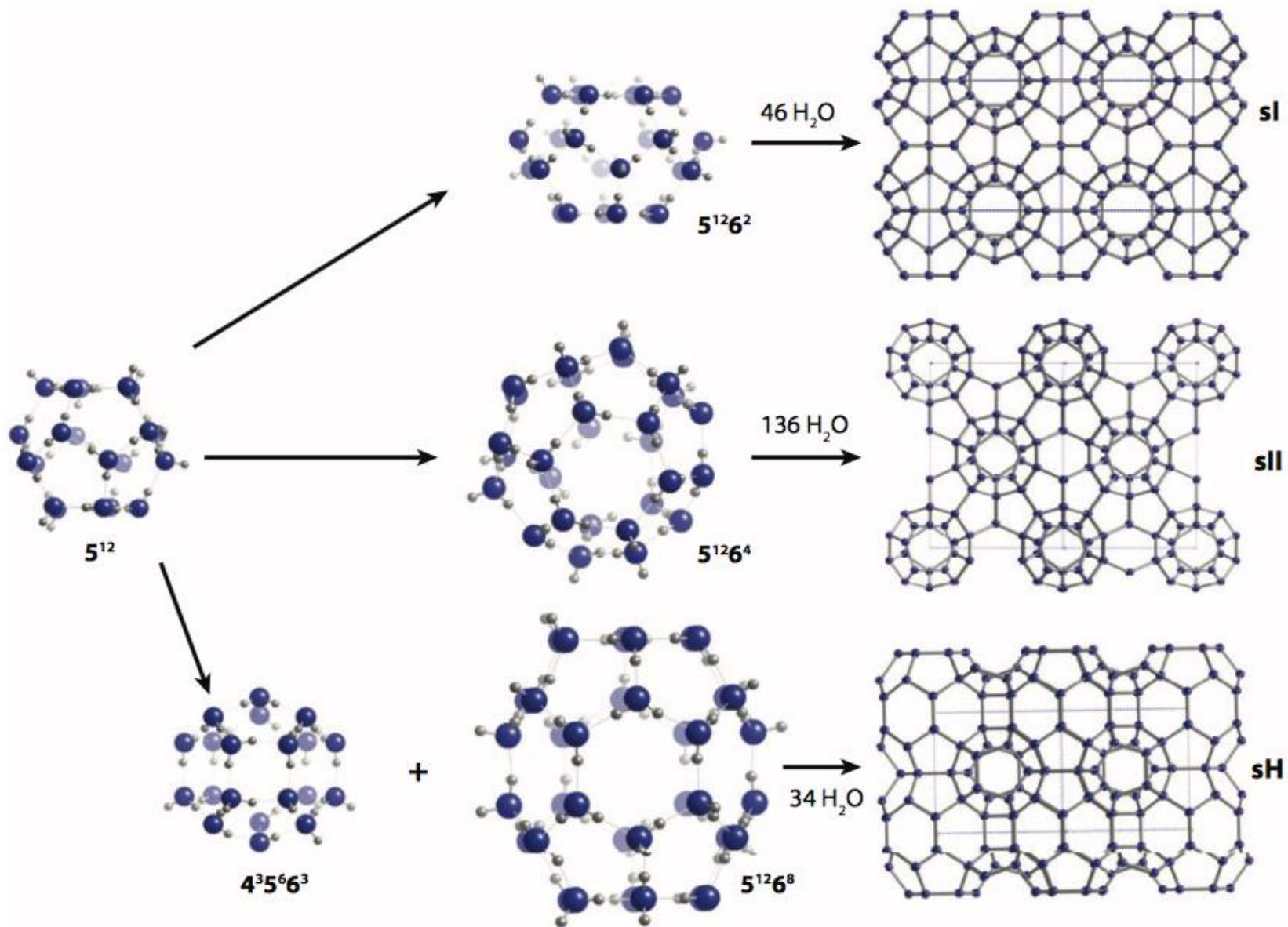
University of Bergen



Houston, December 05.10, 2017

- Water molecule cages encapsulating a foreign molecules (e.g. methane)



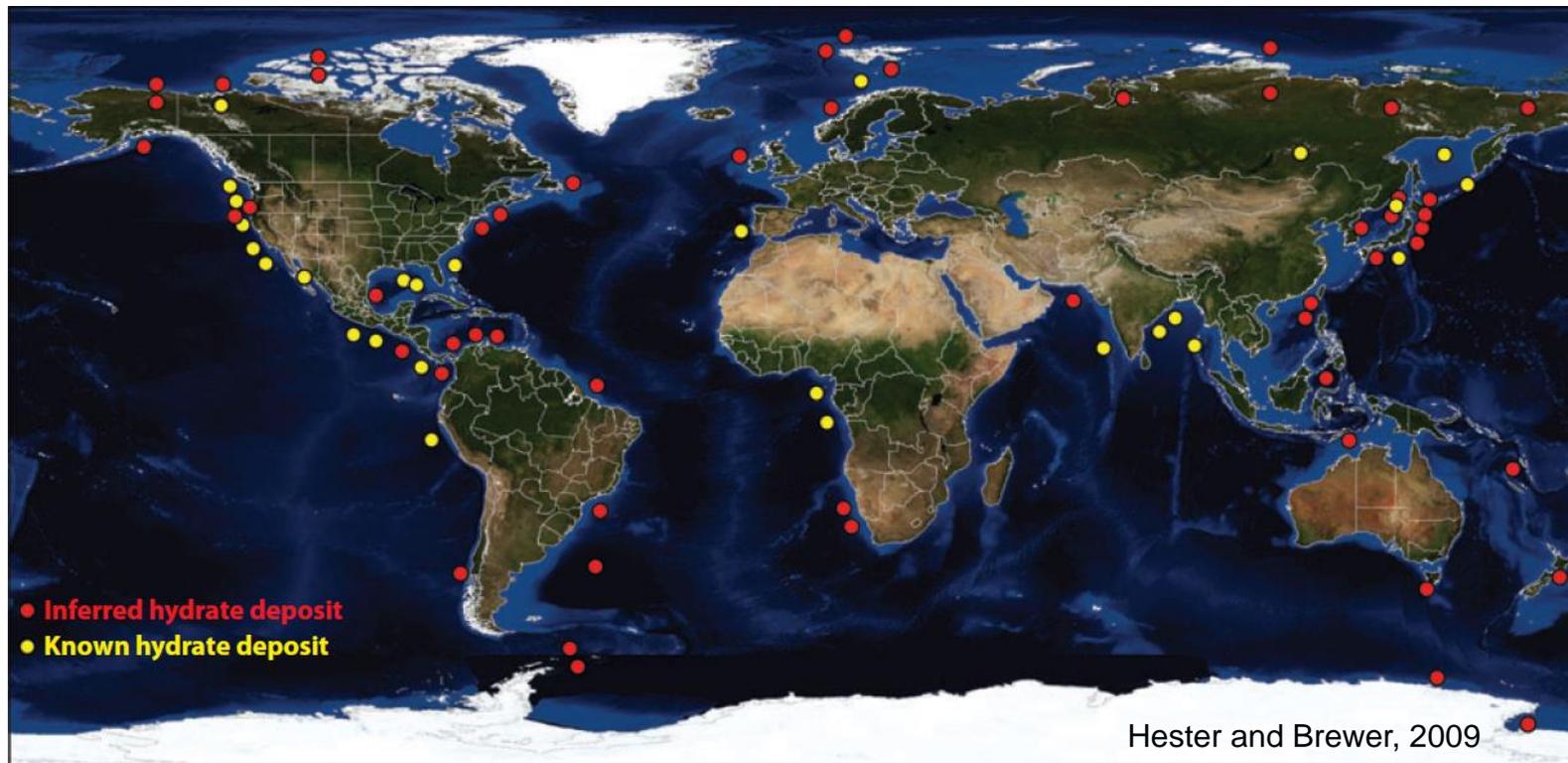


Hester, 2009



# Renewed interest

- Significant amount of energy
  - Permafrost regions
  - Marine environments (high water column)





2002/2008

2011

Iqnik Sikumi #1

Prudhoe Bay Unit L-pad

2017



Hydrate-bearing conglomerate  
Canada - Maillik



Hydrate-bearing turbidite sand  
Japan - Nankai



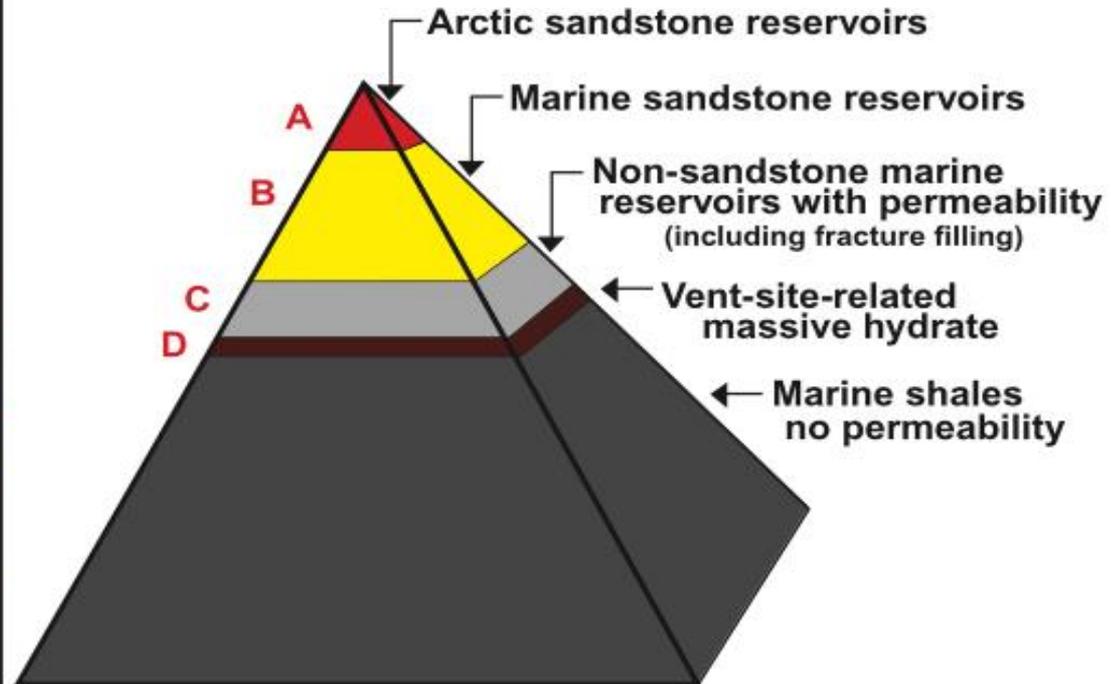
Hydrate filled fracture  
India - Bay of Bengal



Hydrate sea-floor mound  
USA - Gulf of Mexico



# The Gas-hydrate Resource Pyramid

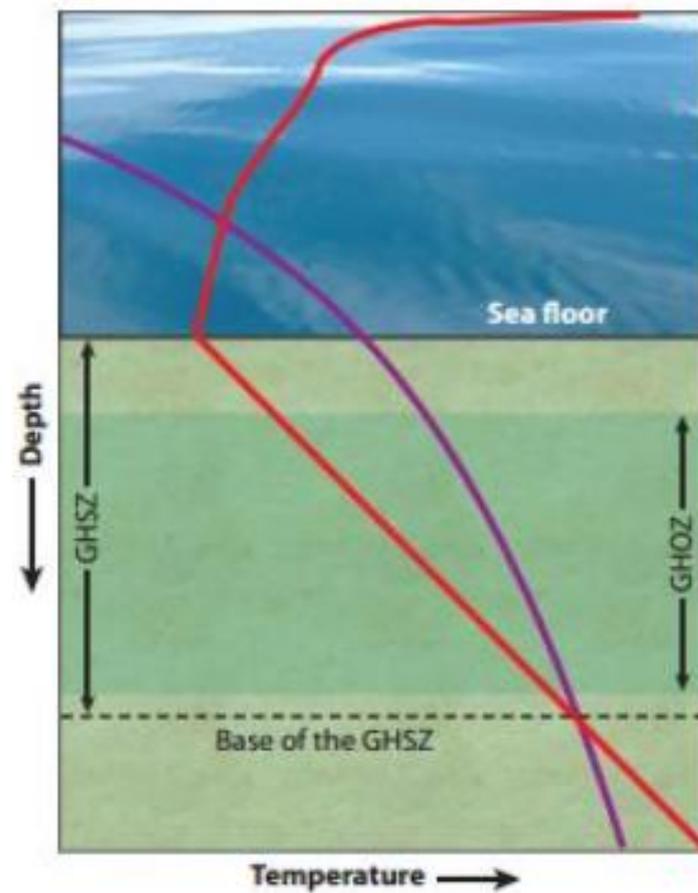
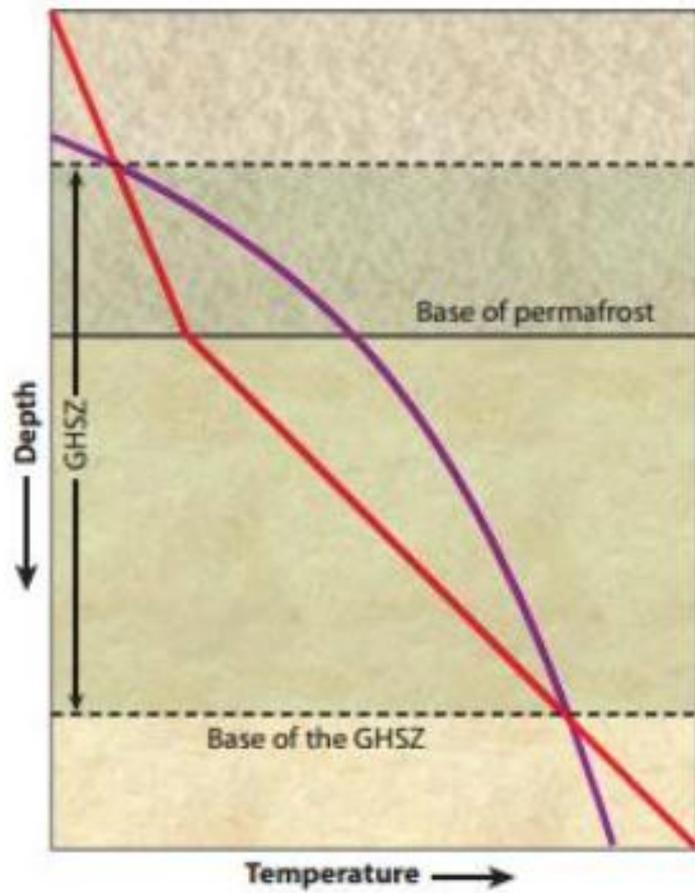


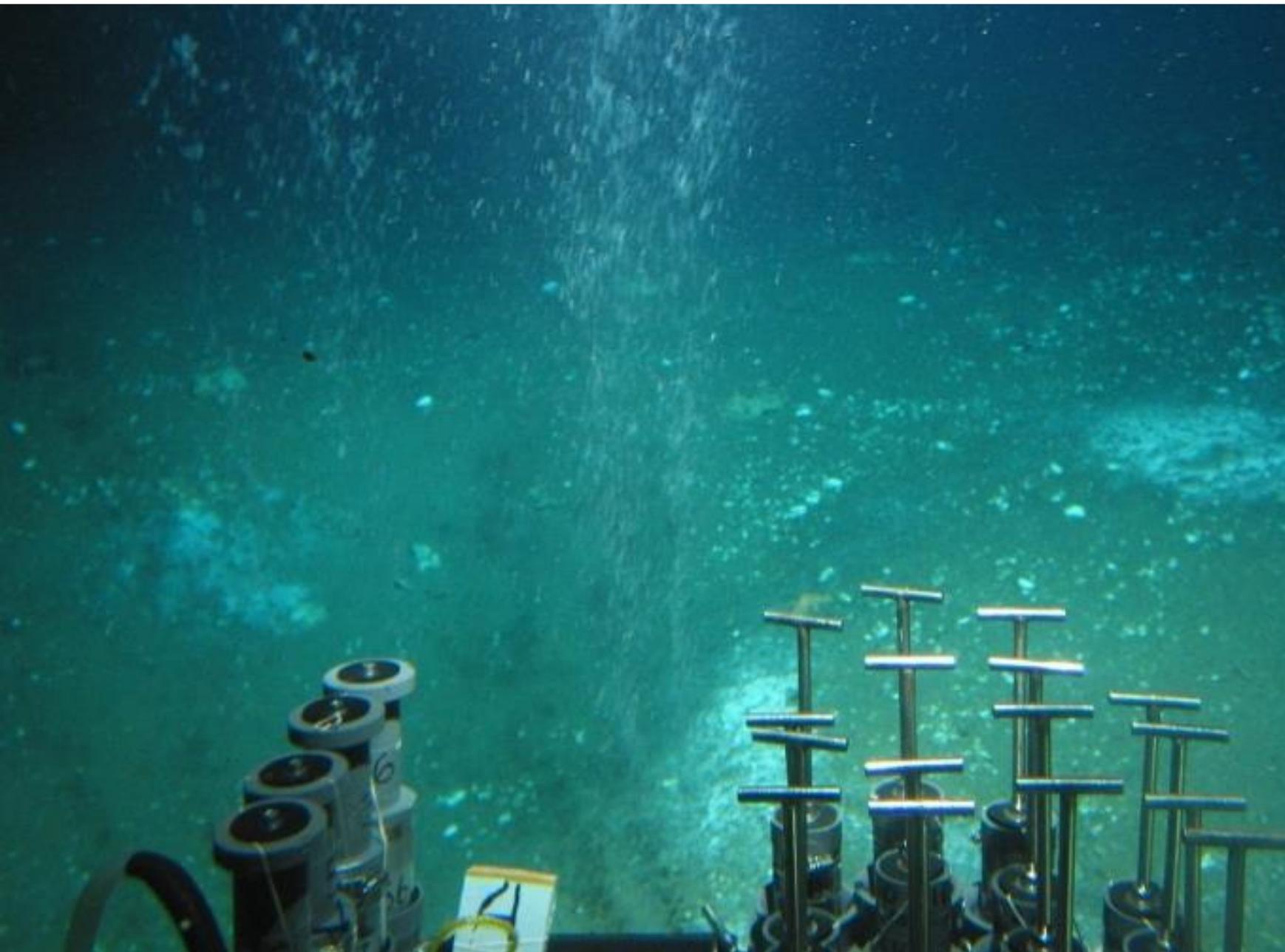
Boswell & Collett, 2006



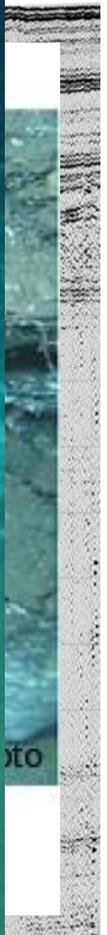
- Increasing in-place resources
- Decreasing reservoir quality
- Decreasing confidence in resource estimates
- Increasing production challenges
- Likely decreasing percent recovery







NNE

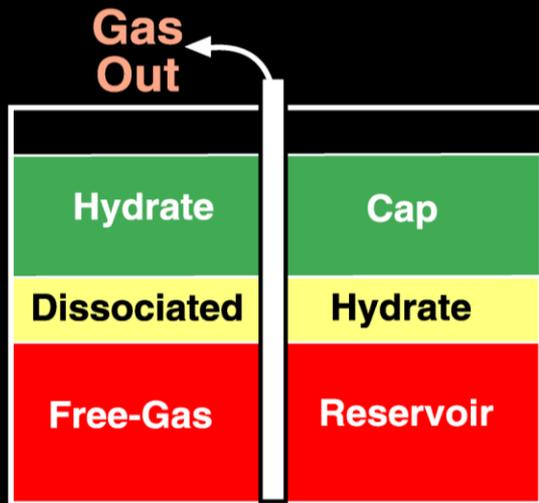


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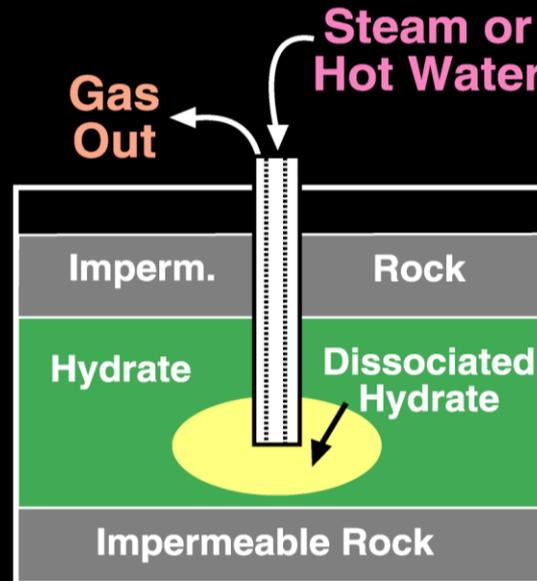


# Gas Hydrate Production Methods

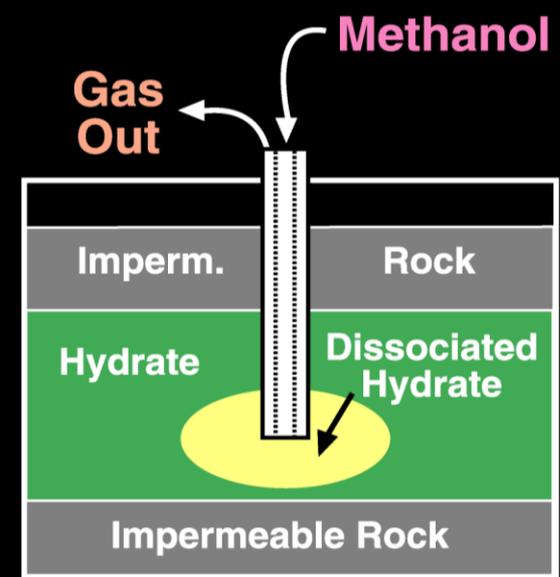
## Depressurization



## Thermal Injection



## Inhibitor Injection

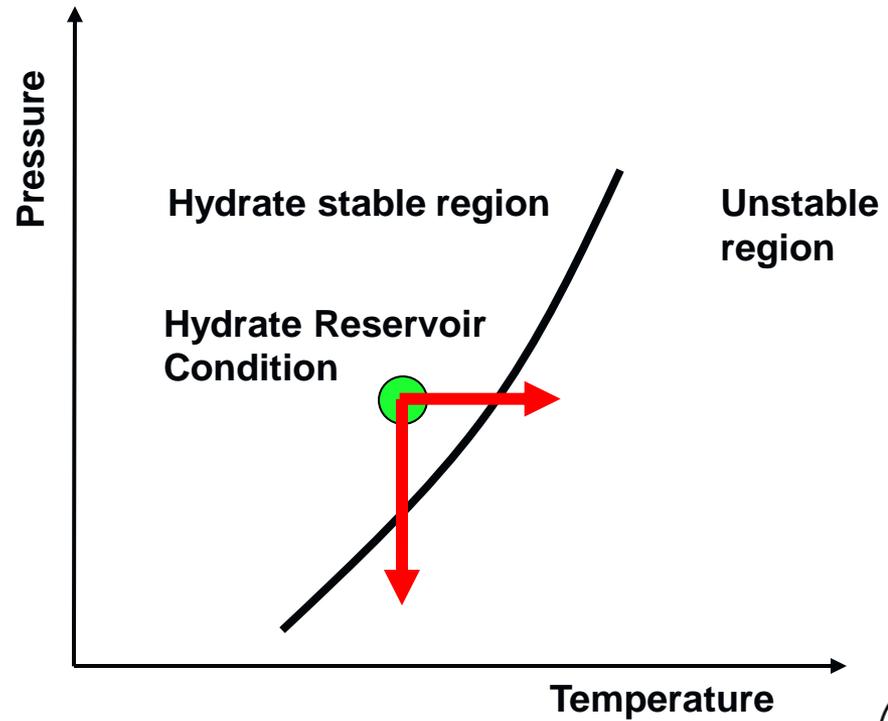


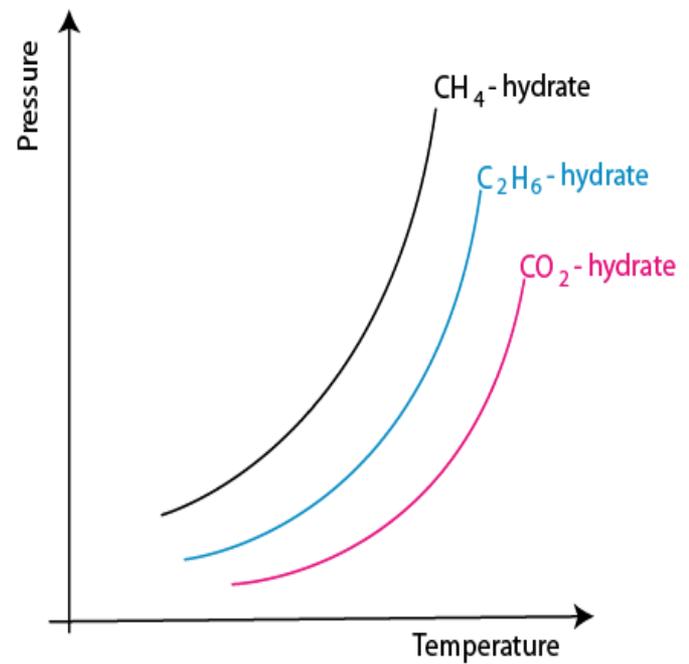
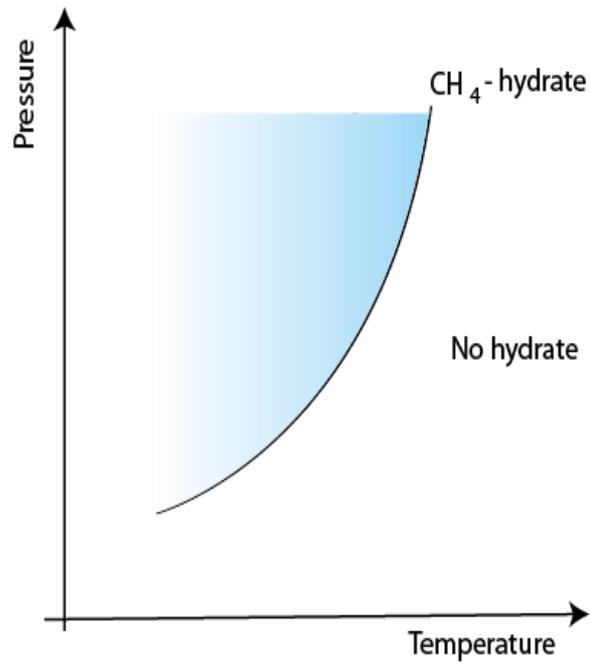
Modified from "GAS HYDRATES OF NORTHERN ALASKA", January 2005



# GAS HYDRATE PRODUCTION METHODS

- Move the gas hydrate outside its stability region
  - Depressurization
  - Thermal stimulation
  - Hydrate inhibitors
- **CO<sub>2</sub> exchange**

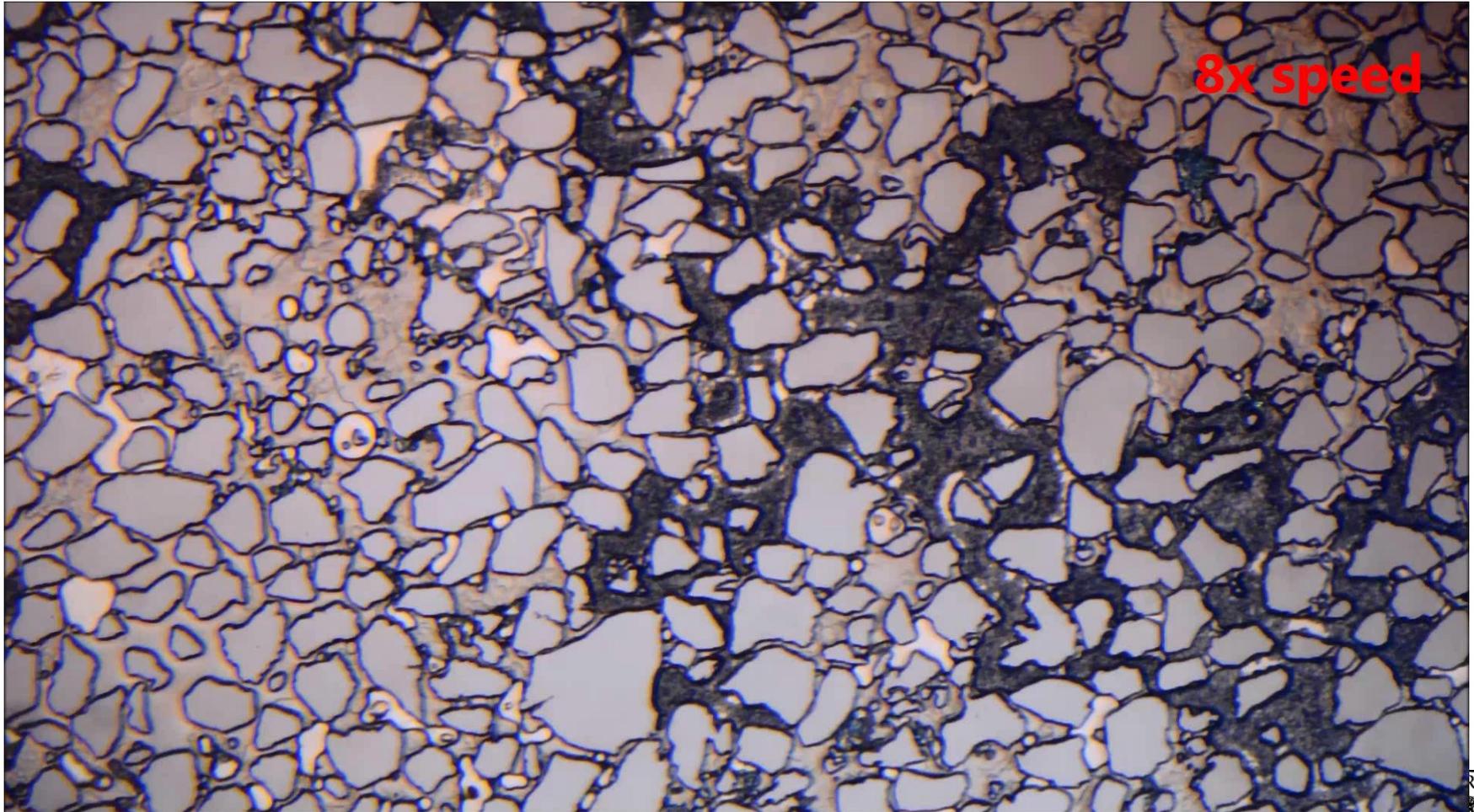




Væland, 2017



# PORE-SCALE DISSOCIATION OF METHANE HYDRATE



$P = 8 \text{ MPa}$ ,  $T = 12 \text{ }^\circ\text{C}$



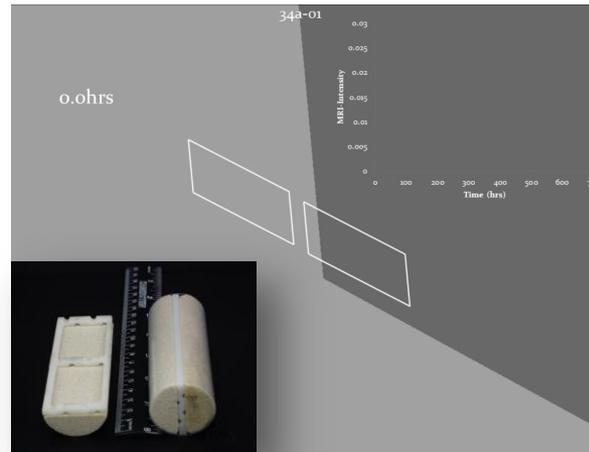
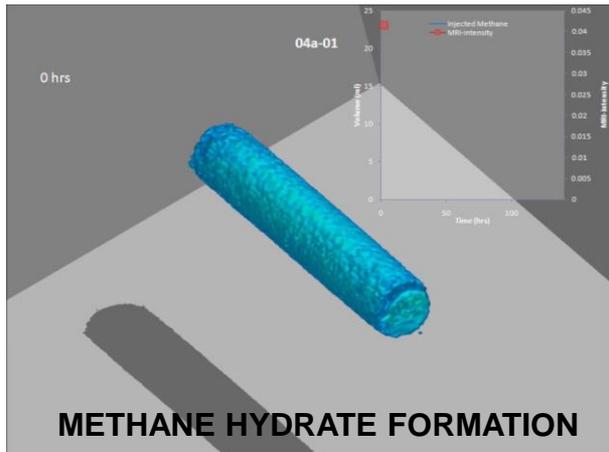
# Energy for the Future

## CO<sub>2</sub> Sequestration in Hydrates with Associated Gas Production

### RESEARCH MOTIVATION

Energy bound in hydrates compares to energy in conventional oil, gas and coal reserves

### Laboratory Verification of CO<sub>2</sub>/CH<sub>4</sub> Exchange Through MRI imaging



### BENEFITS

Simultaneous gas production and CO<sub>2</sub> sequestration

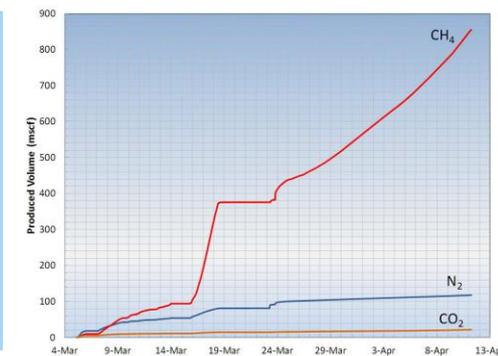
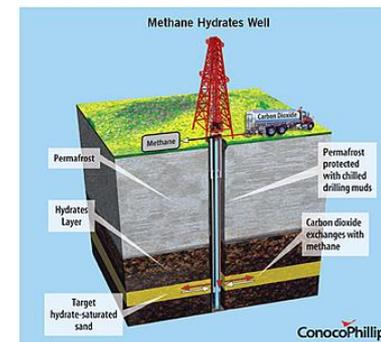
Need no hydrate melting or heat stimulation

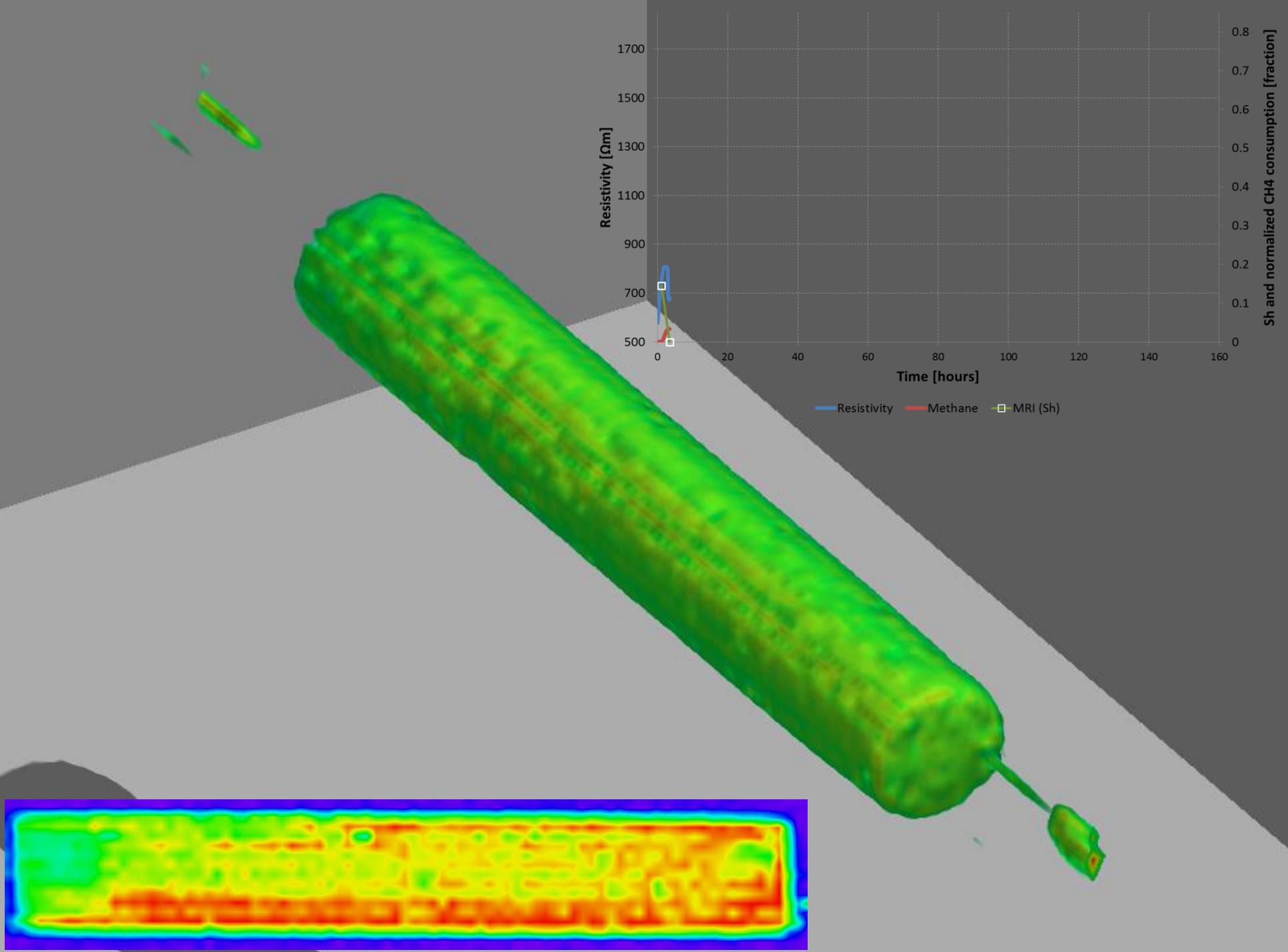
Spontaneous process and keeps formation integrity

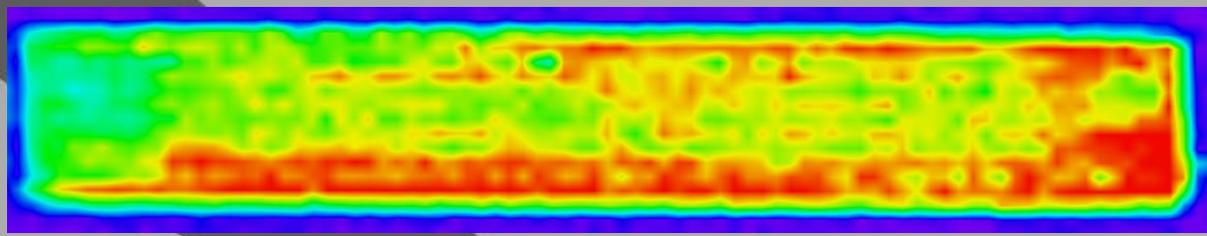
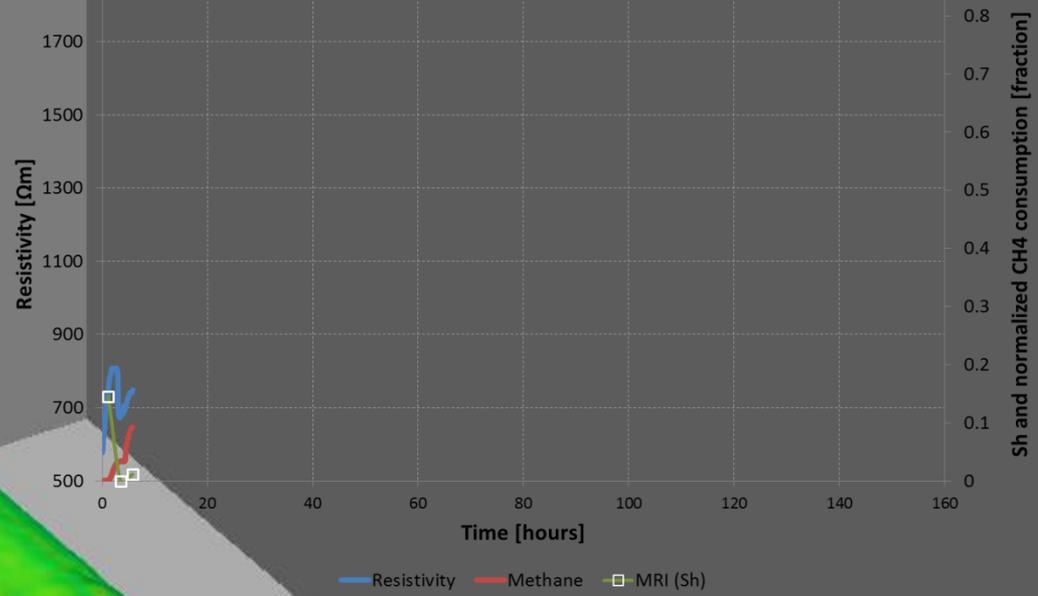
No associated water production

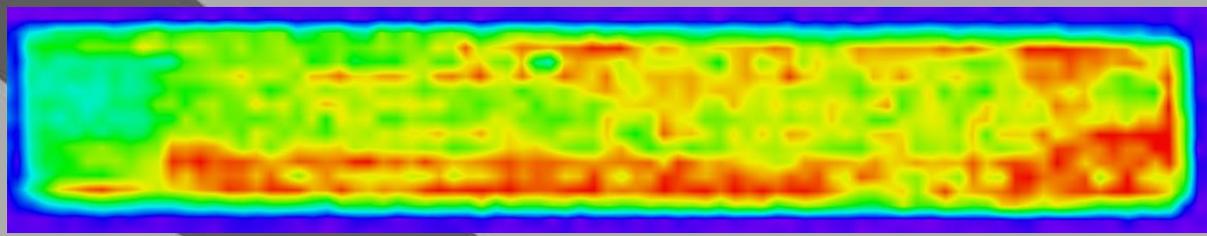
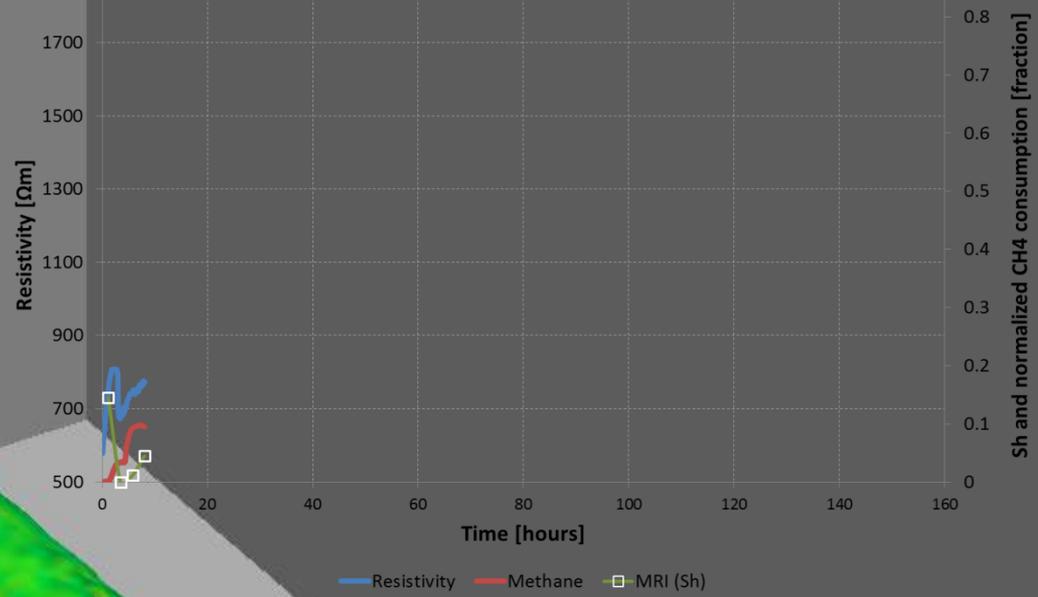
### STATUS

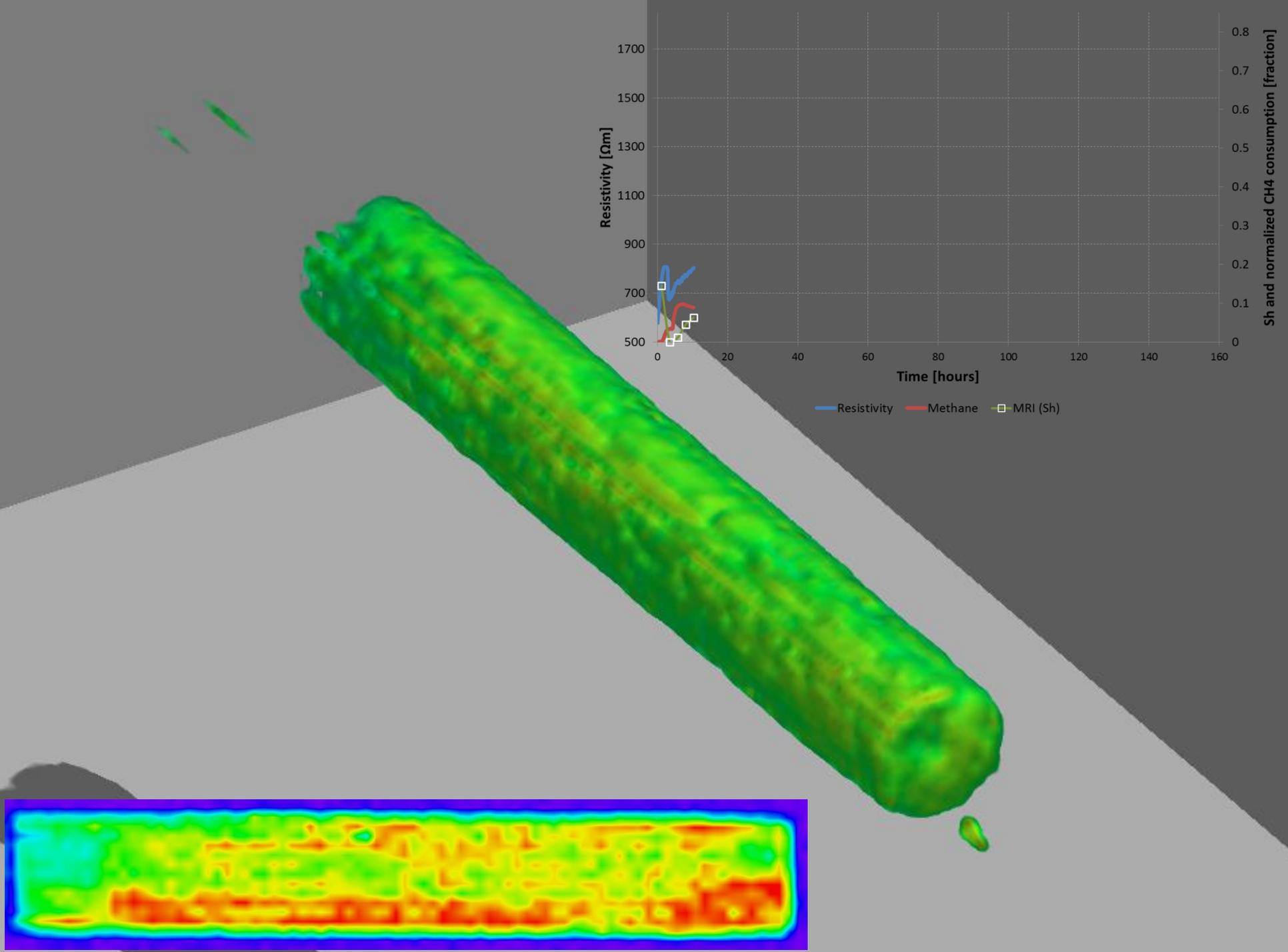
- Alaska Field Injection Test 2011-2012
- ConocoPhillips, US DOE and JOGMEC
- US\$11.6 mill funding from US DOE
- Total cost ca. US\$30mill

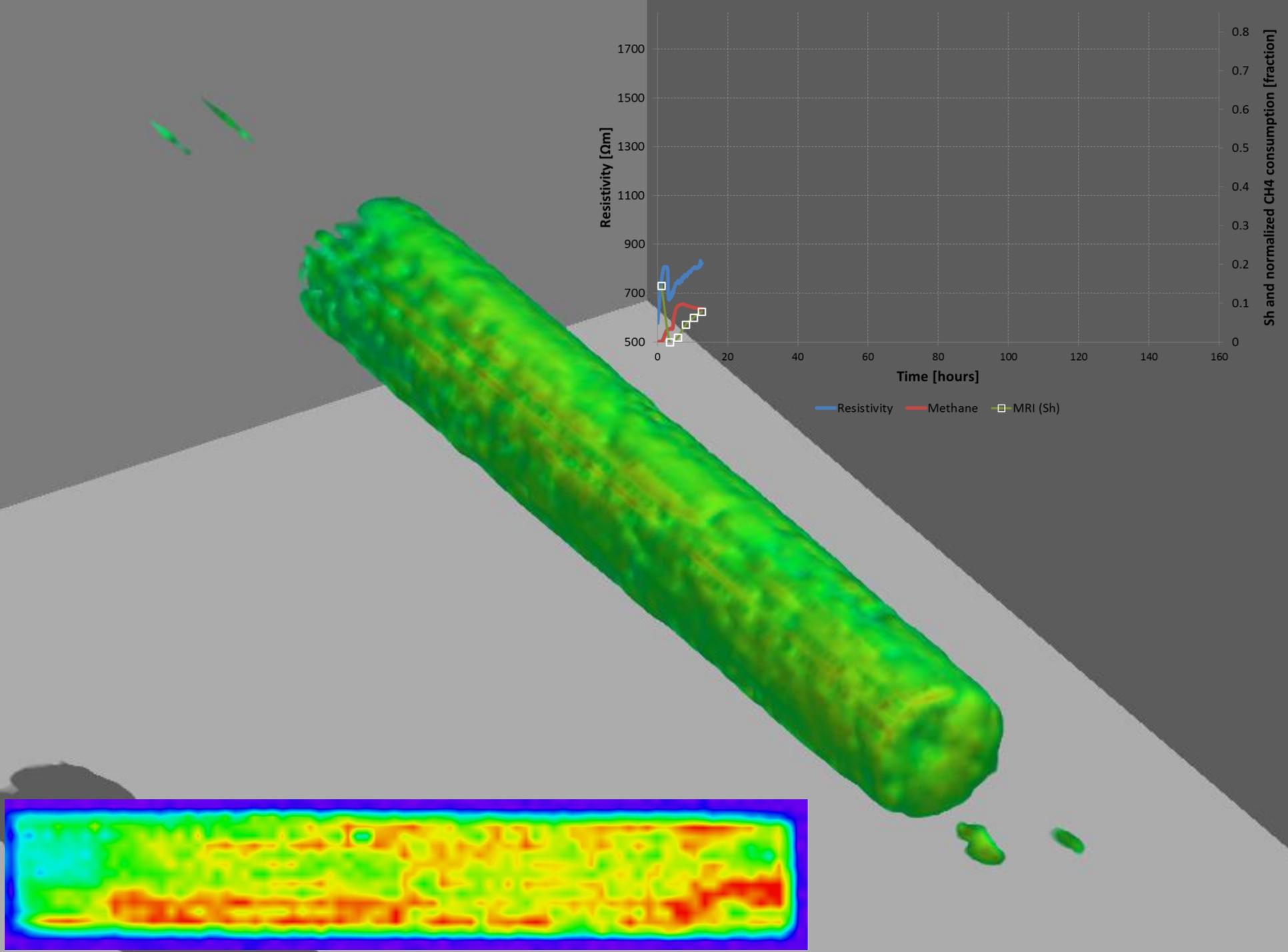


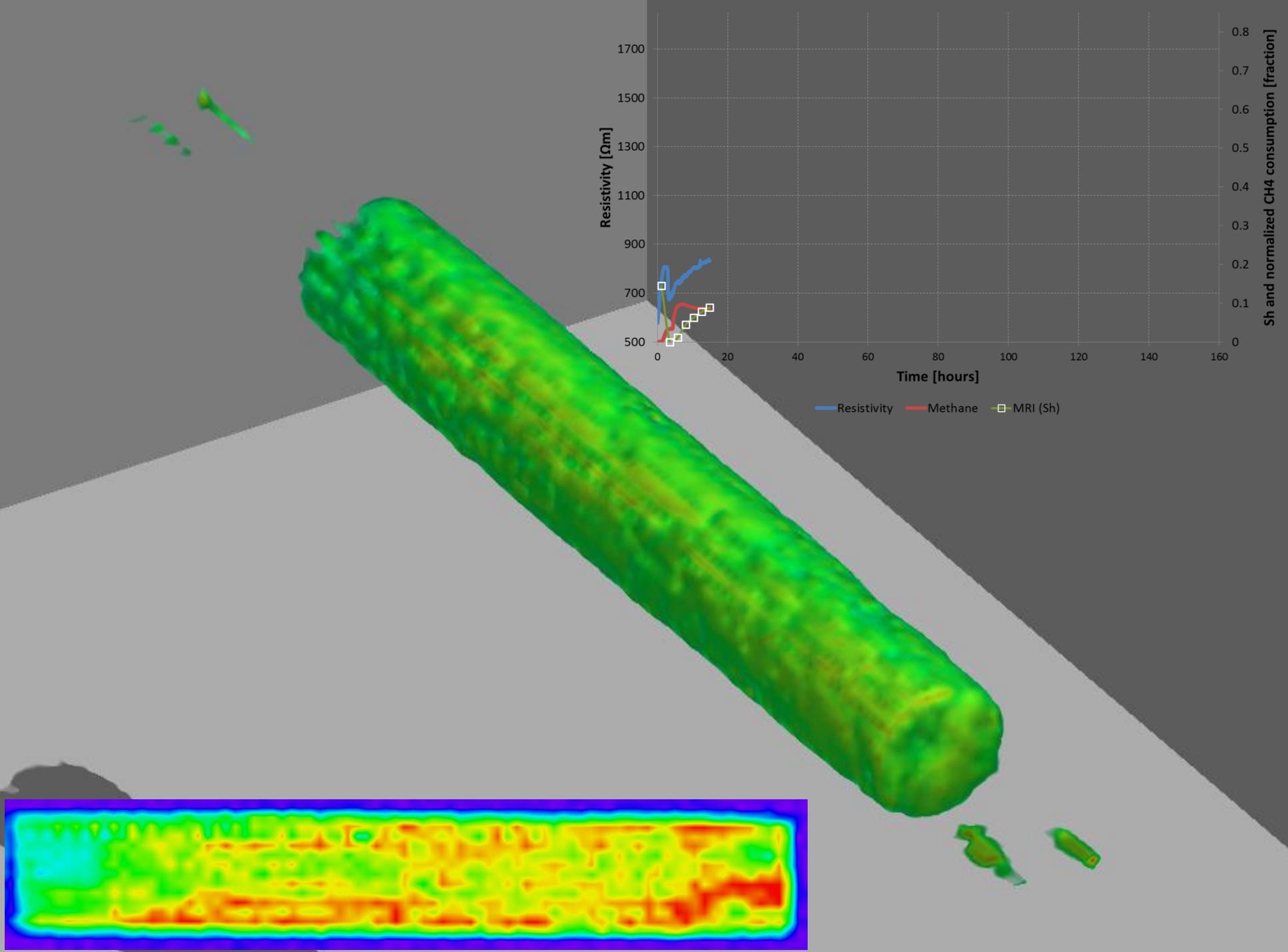


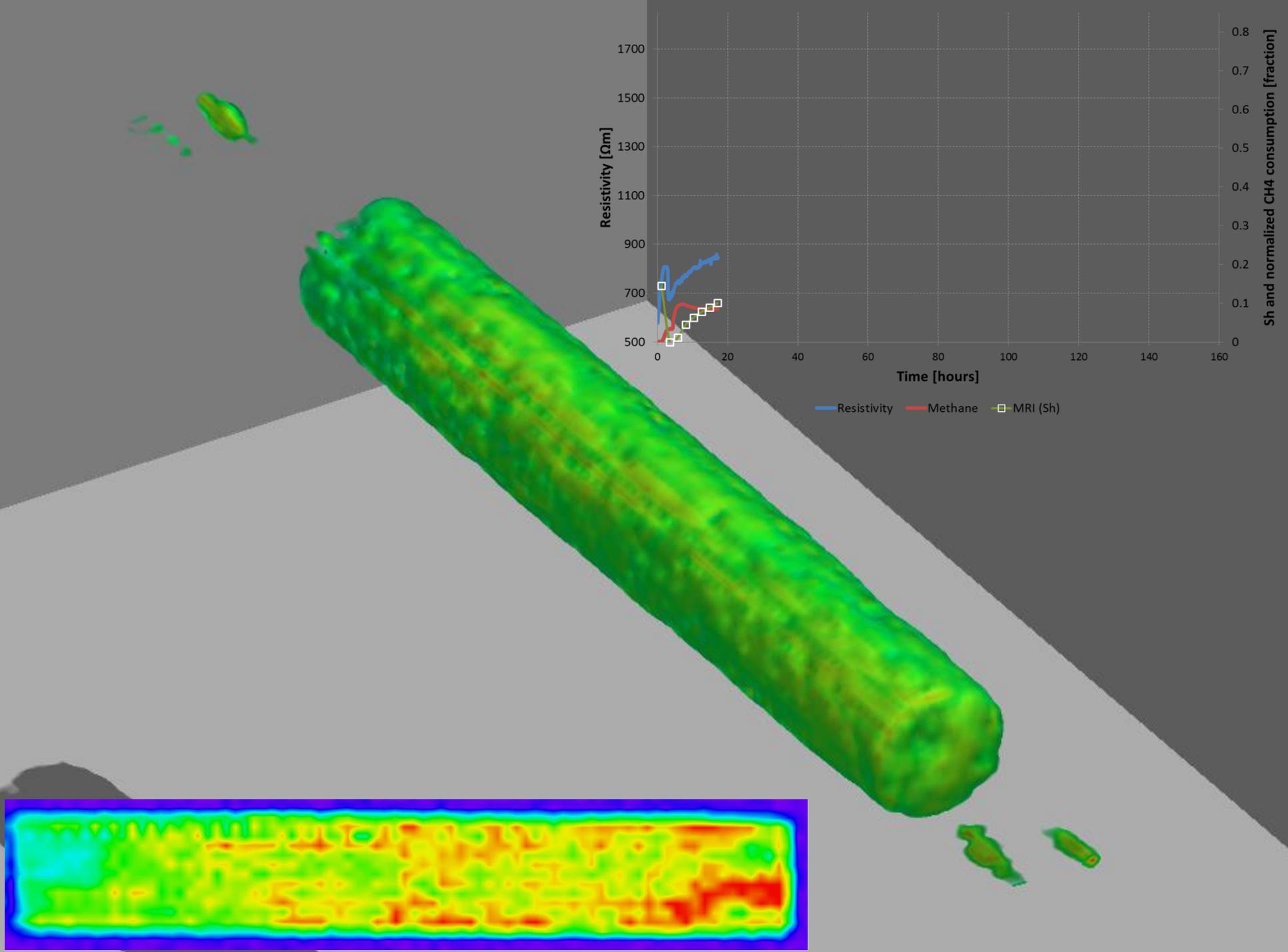


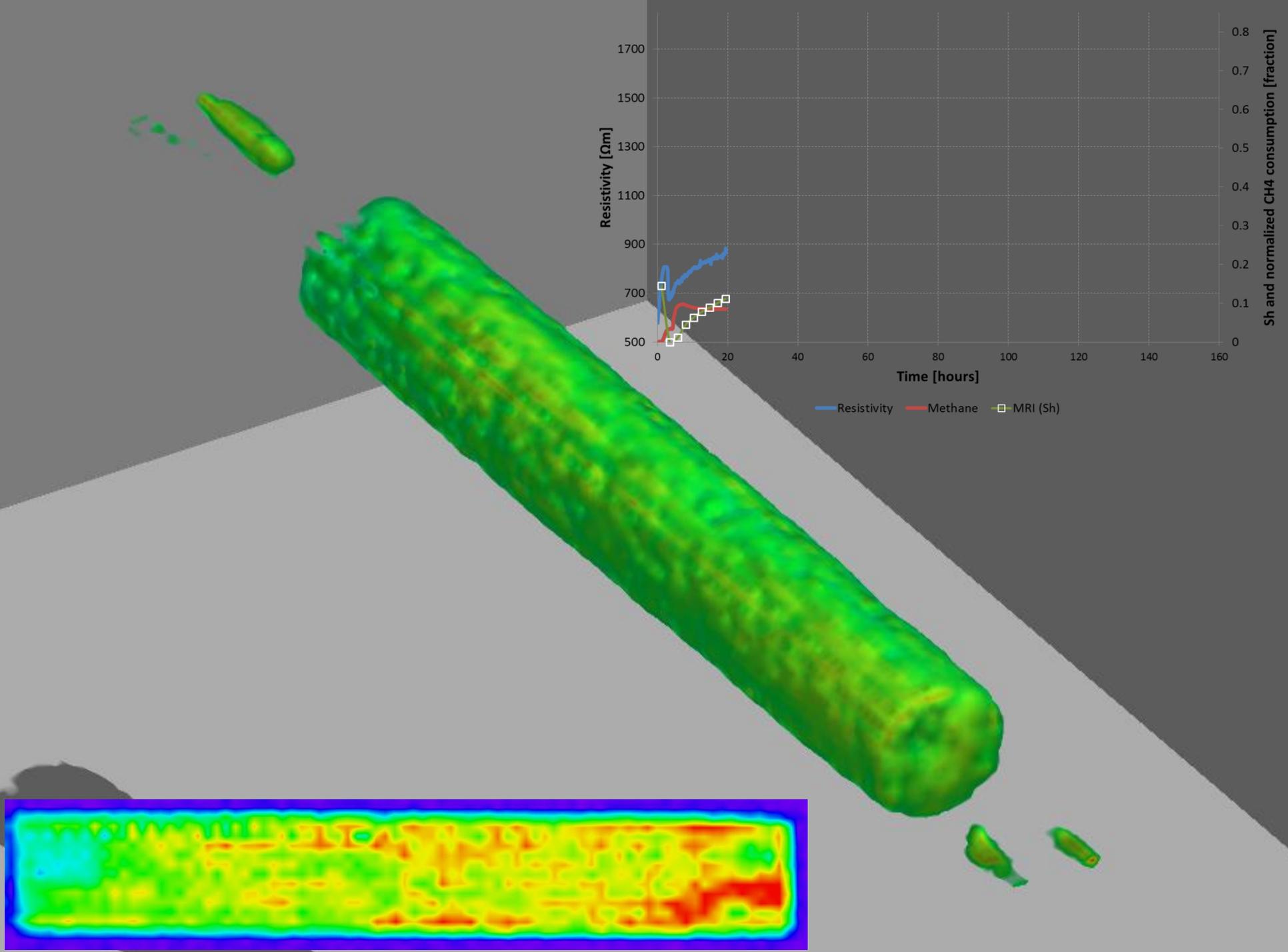


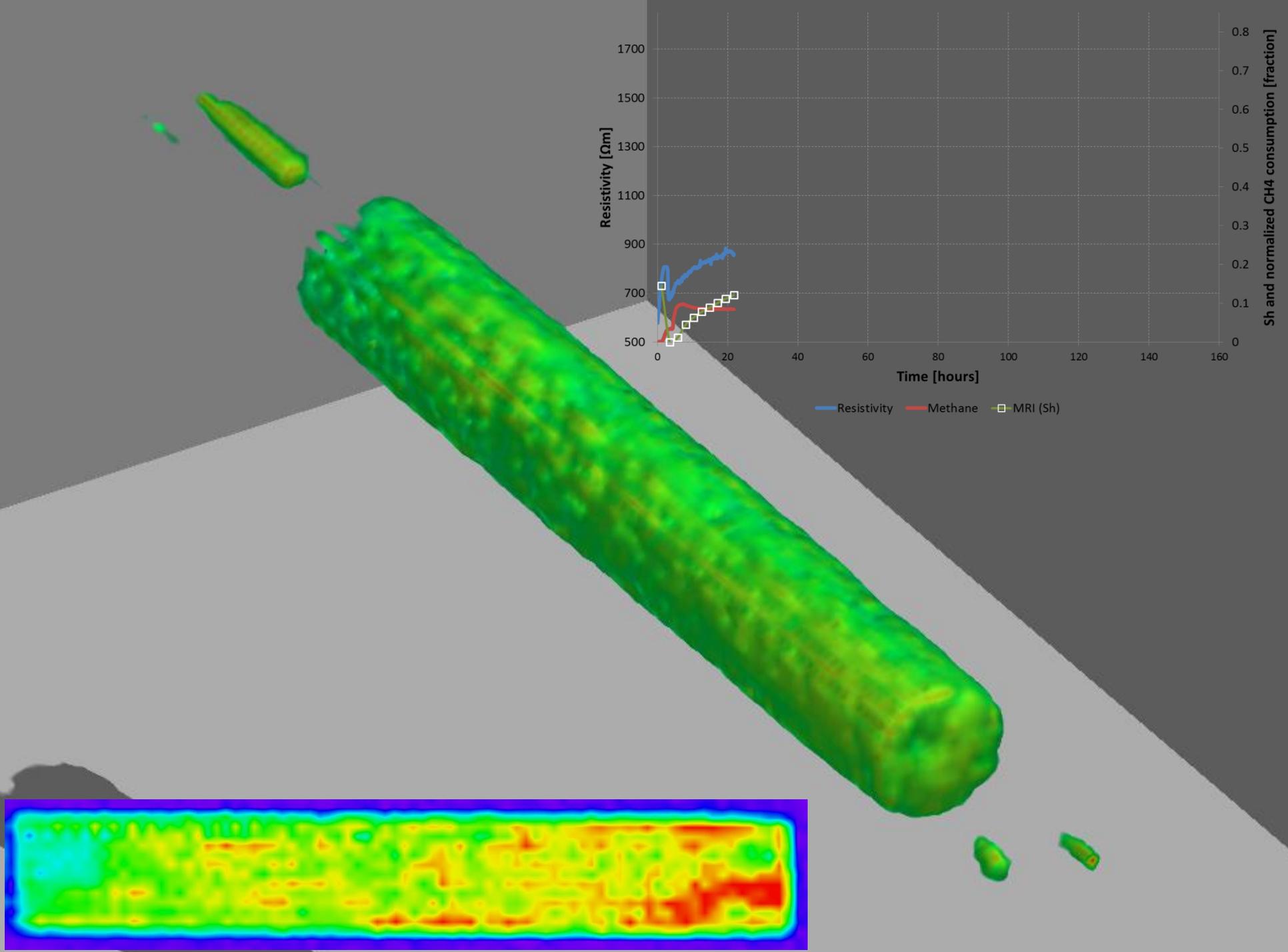


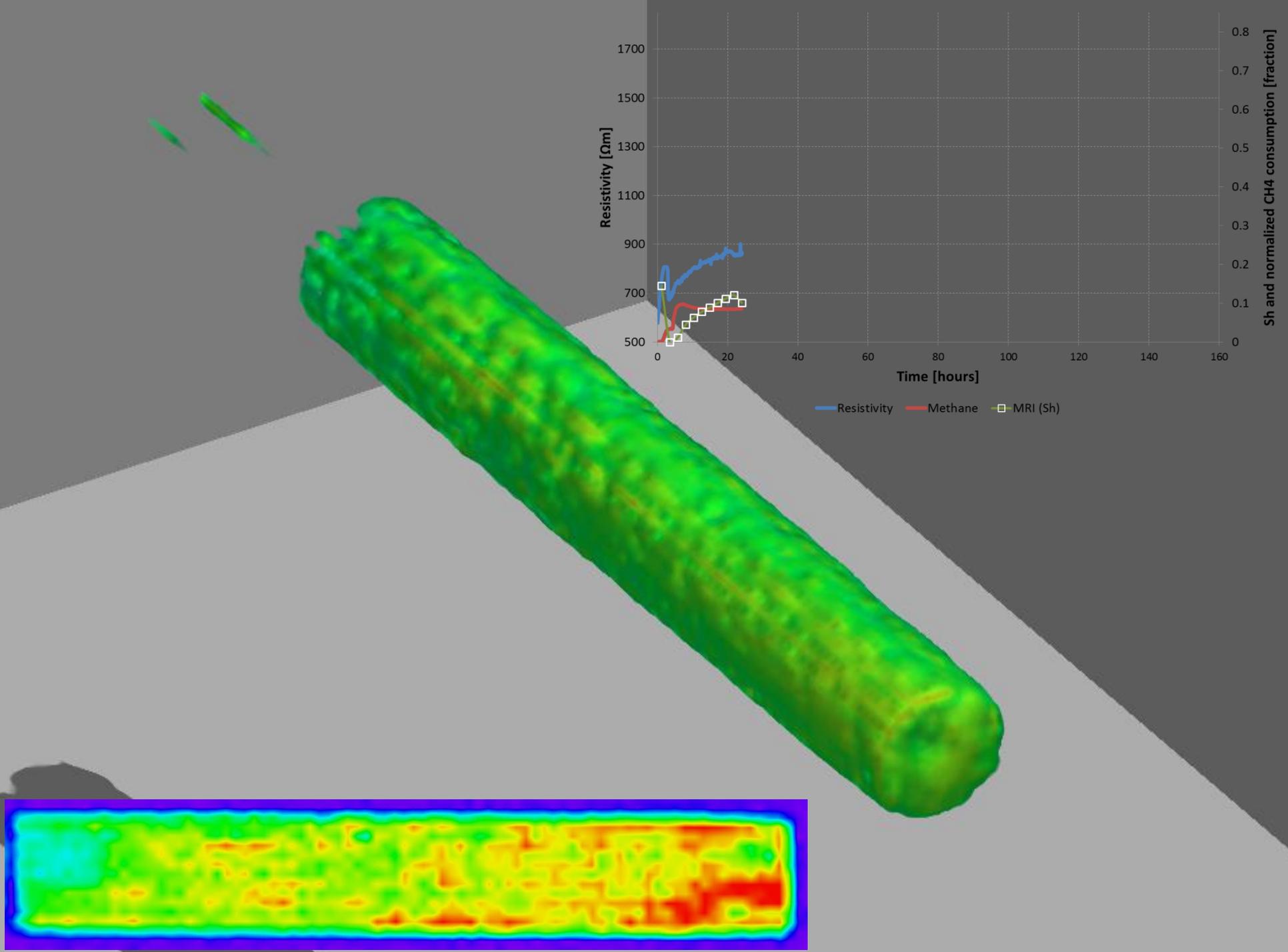


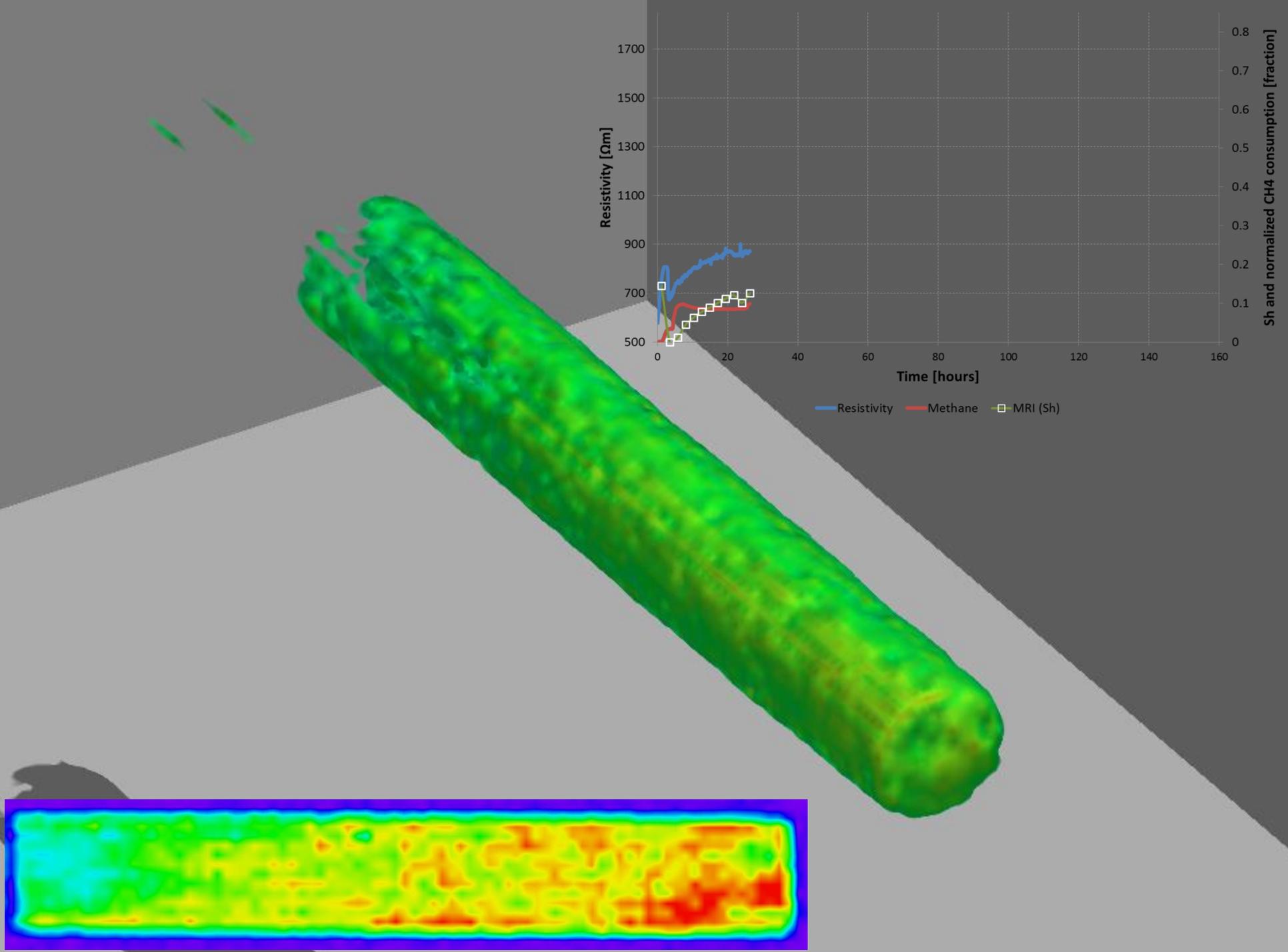


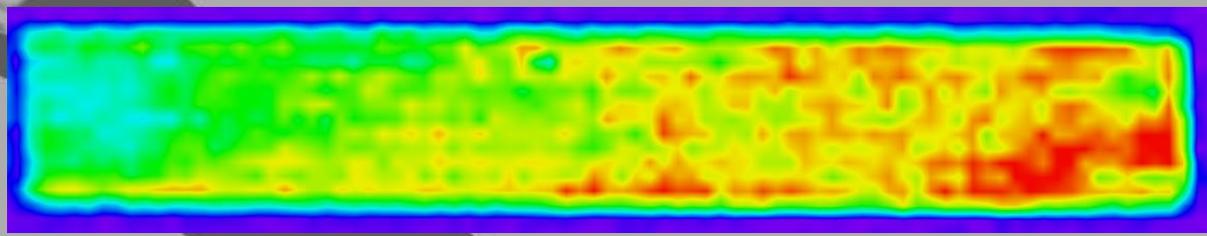
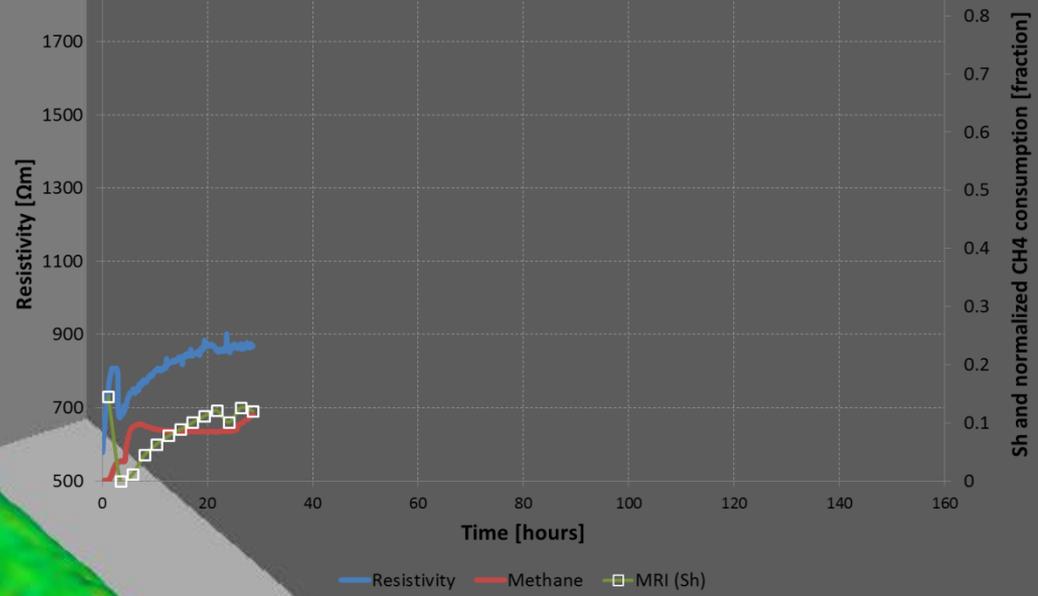


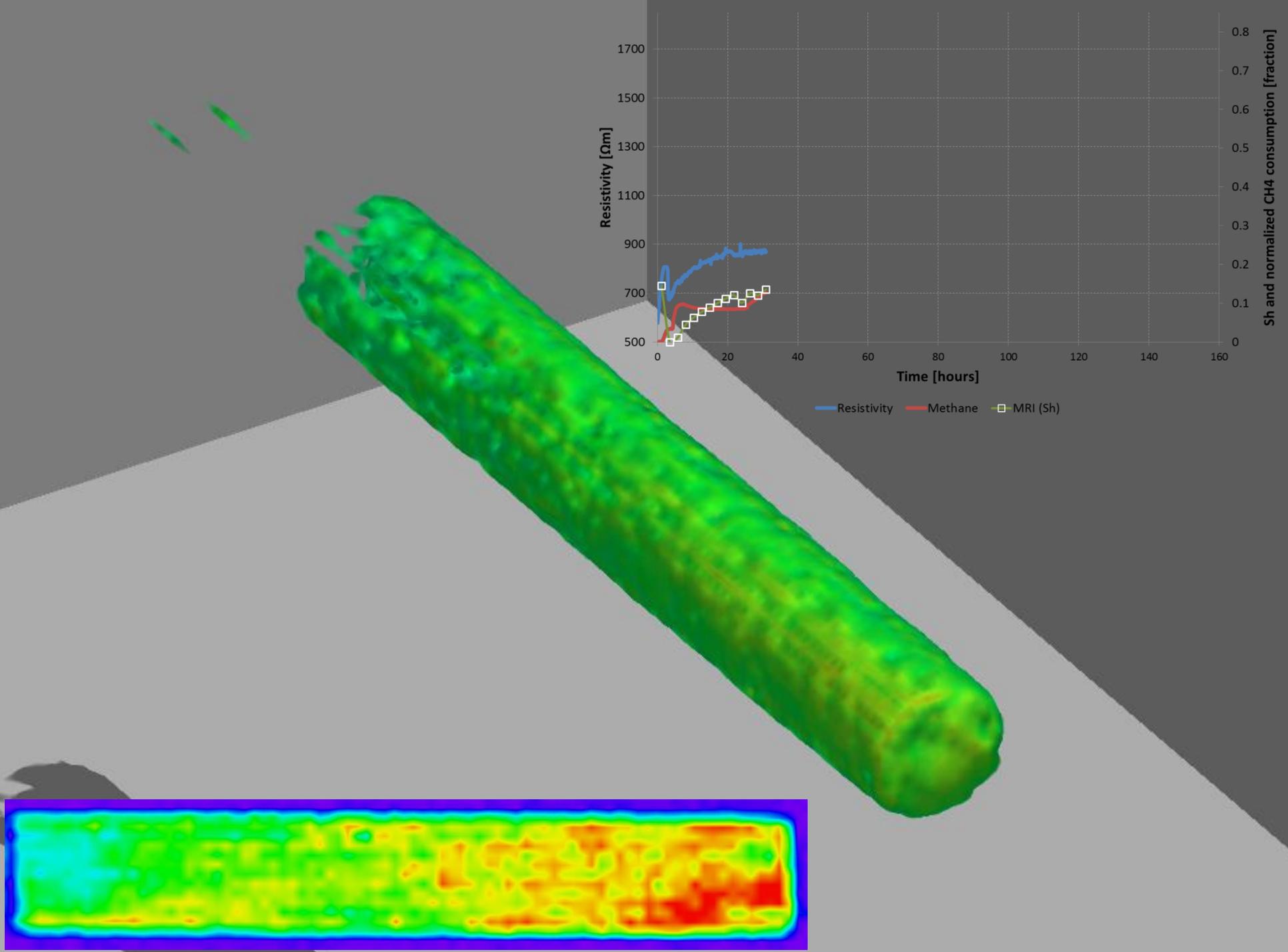


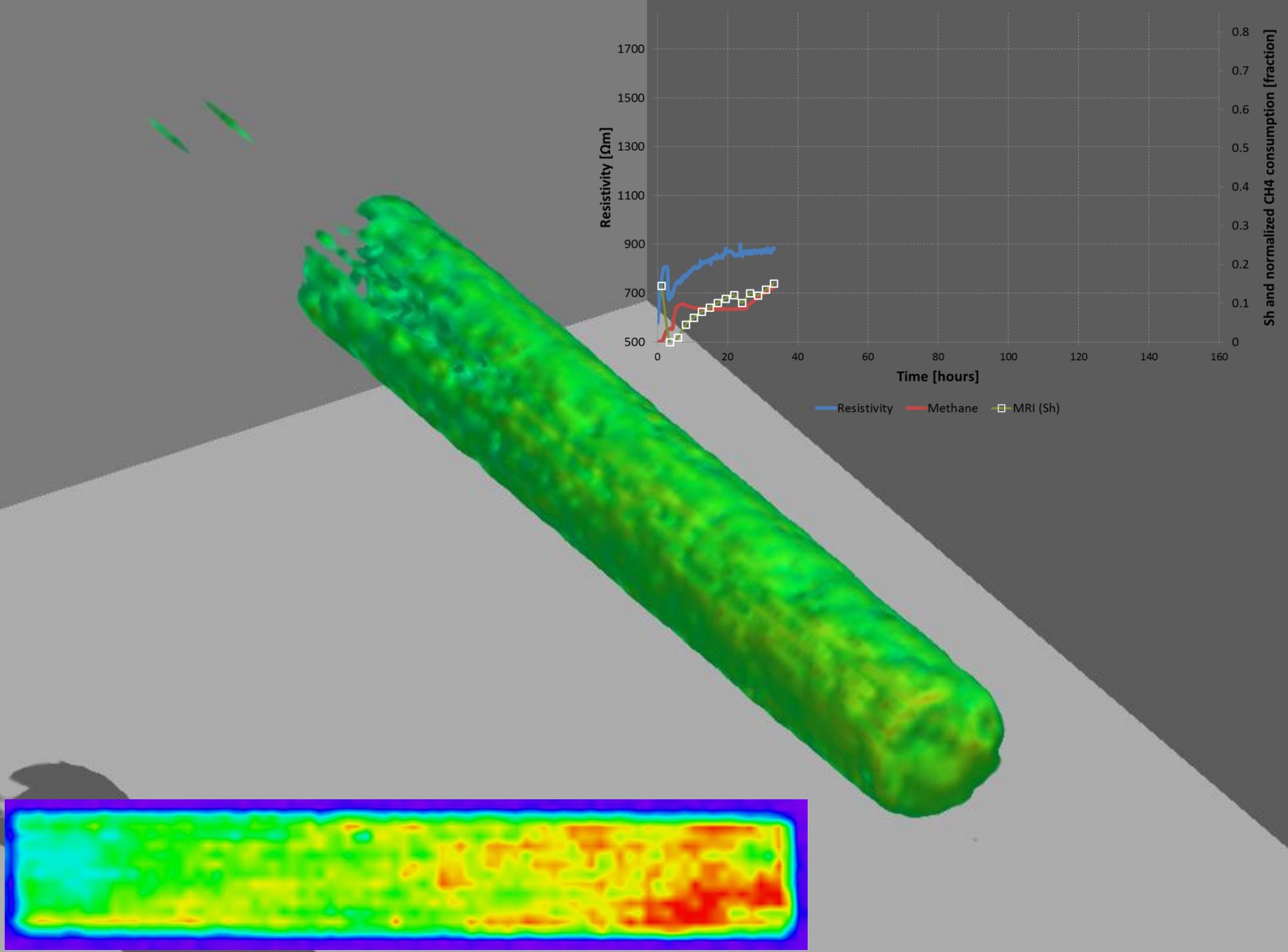


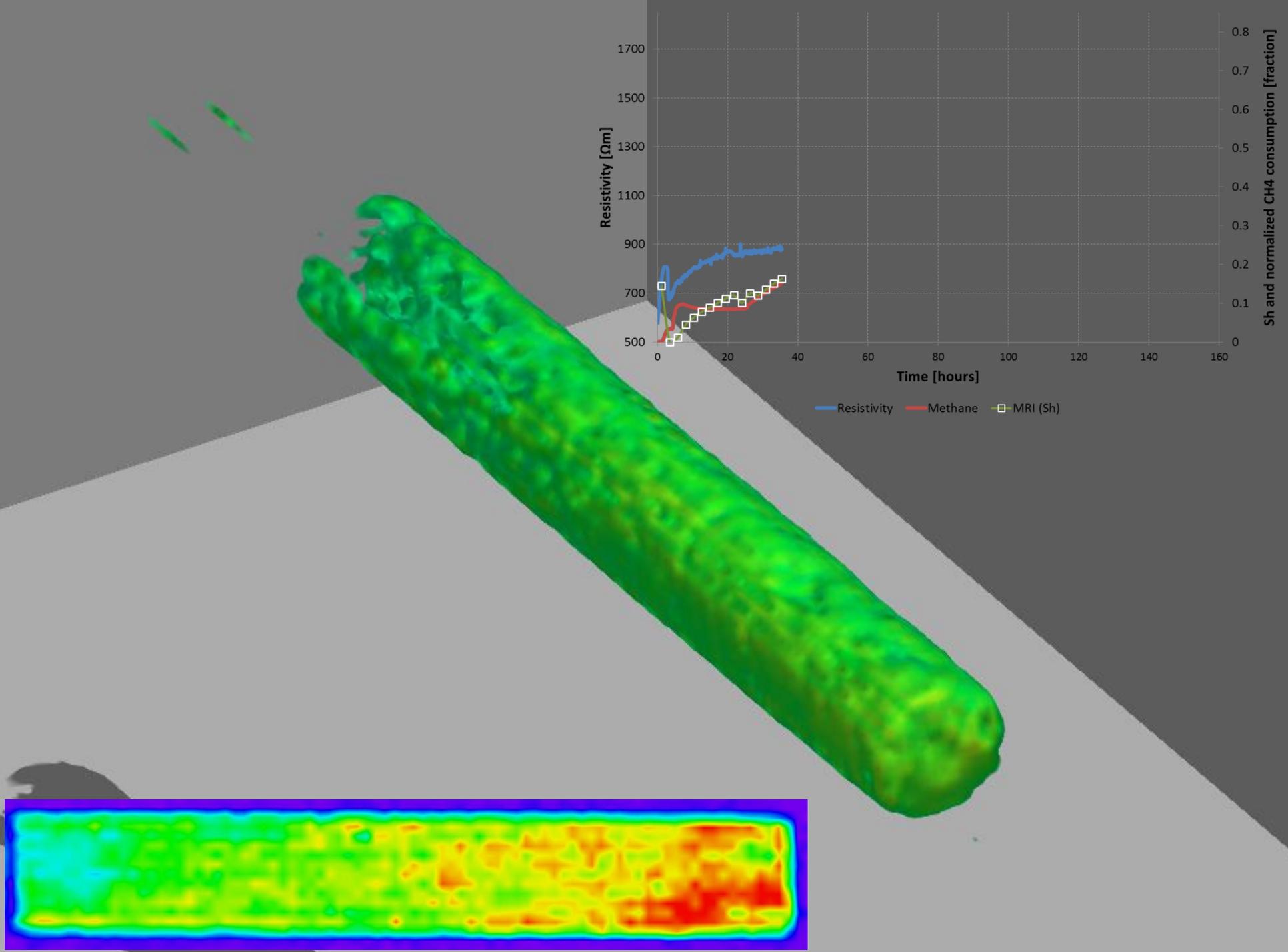


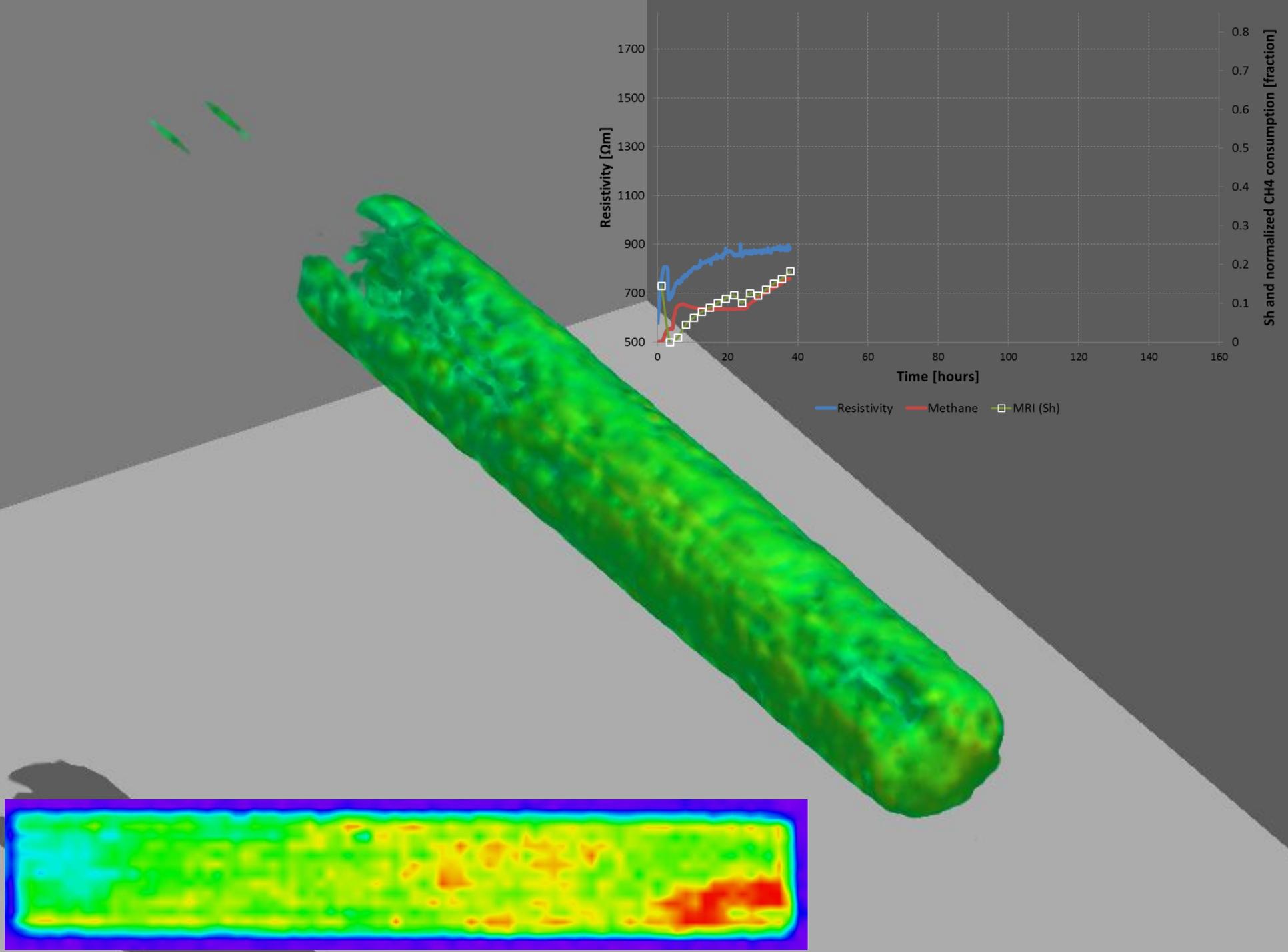


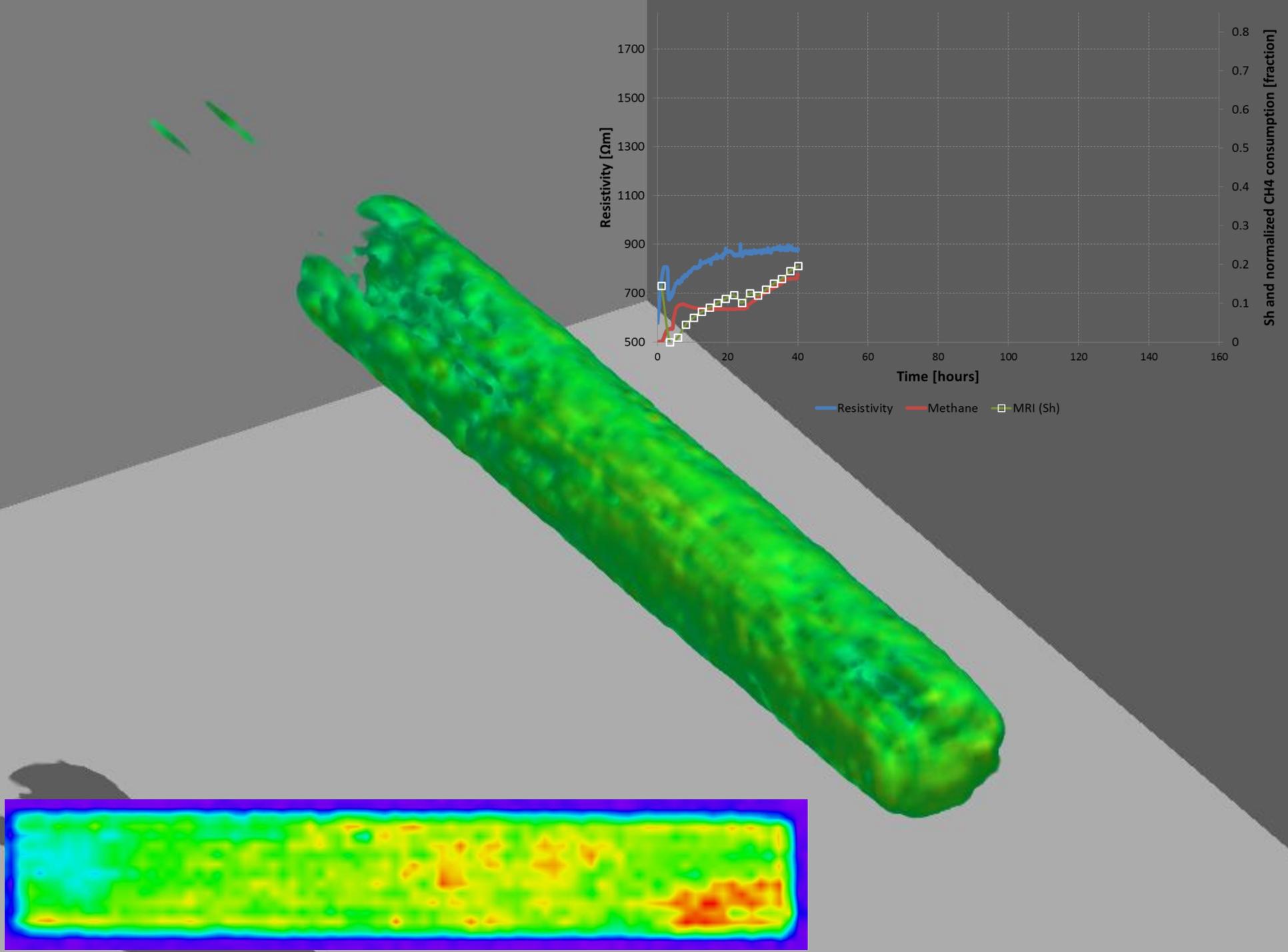


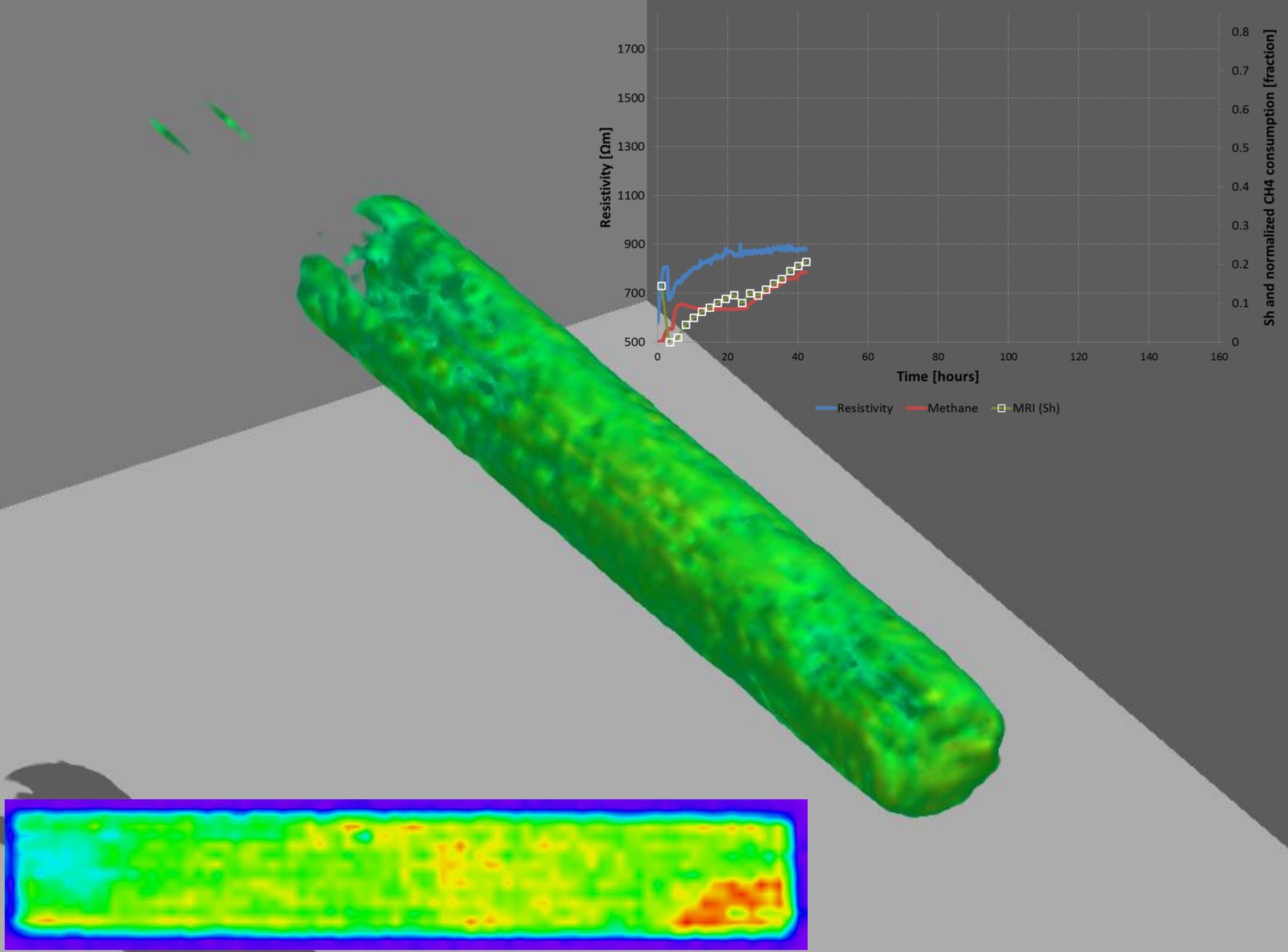


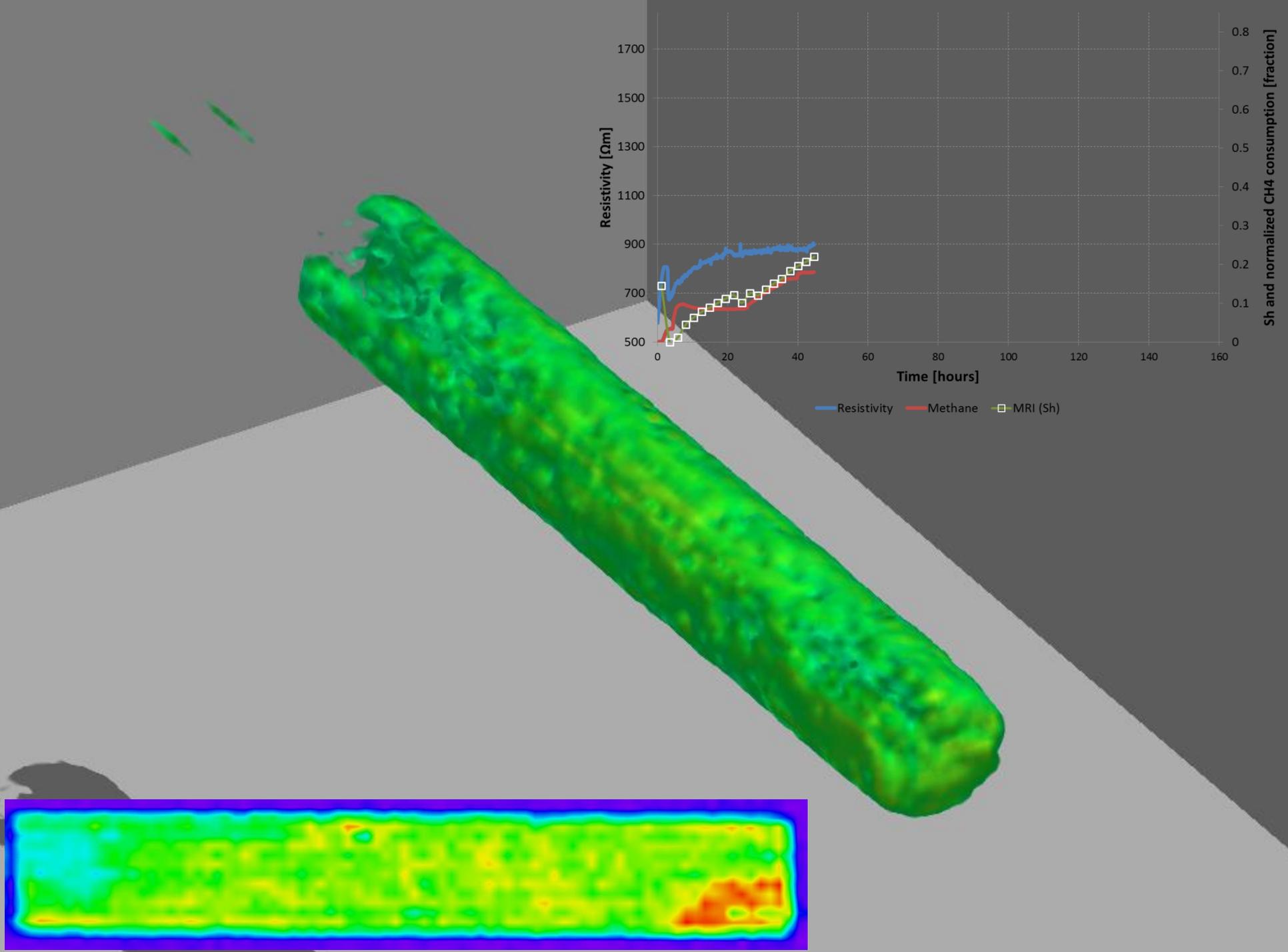


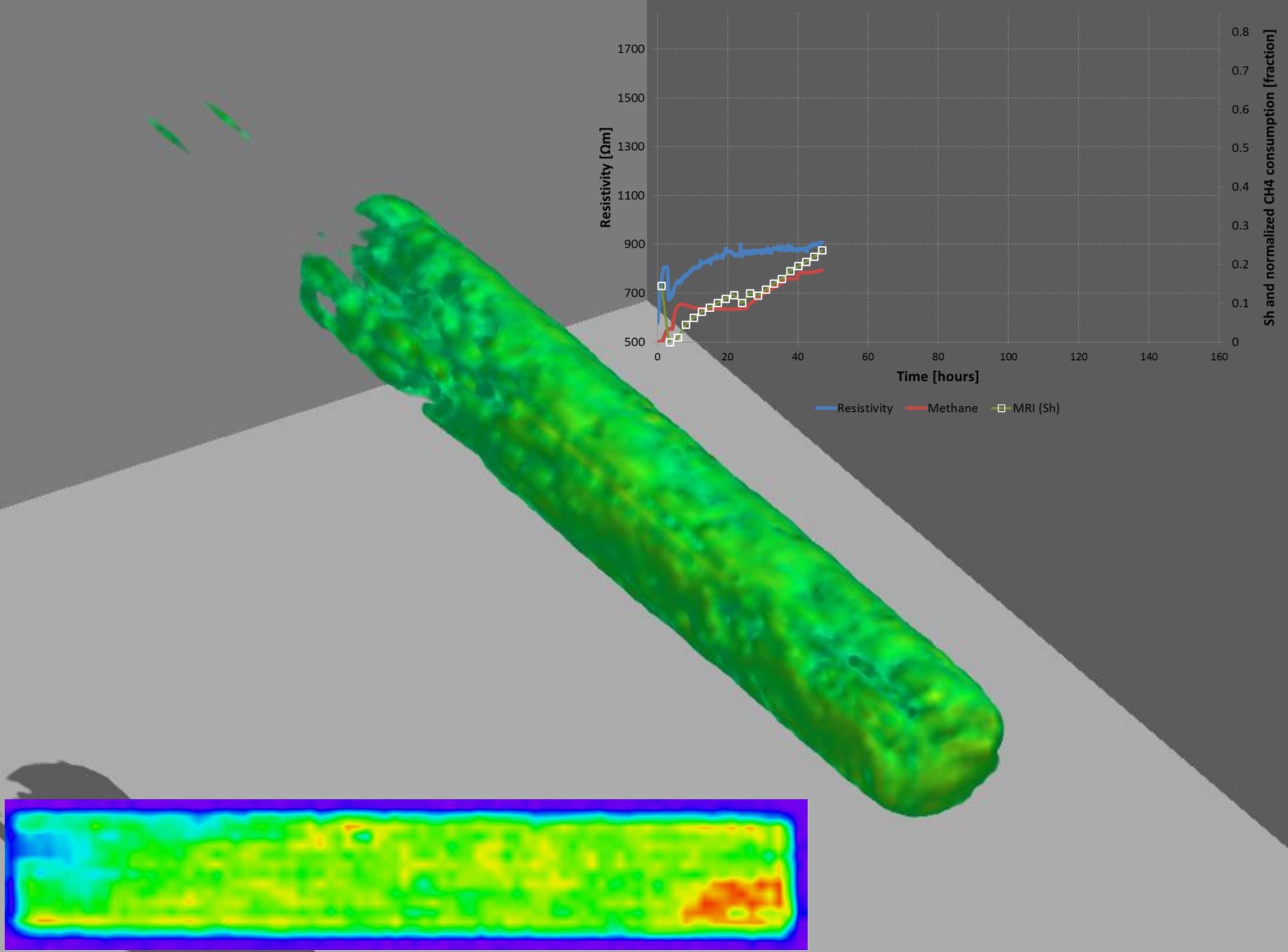


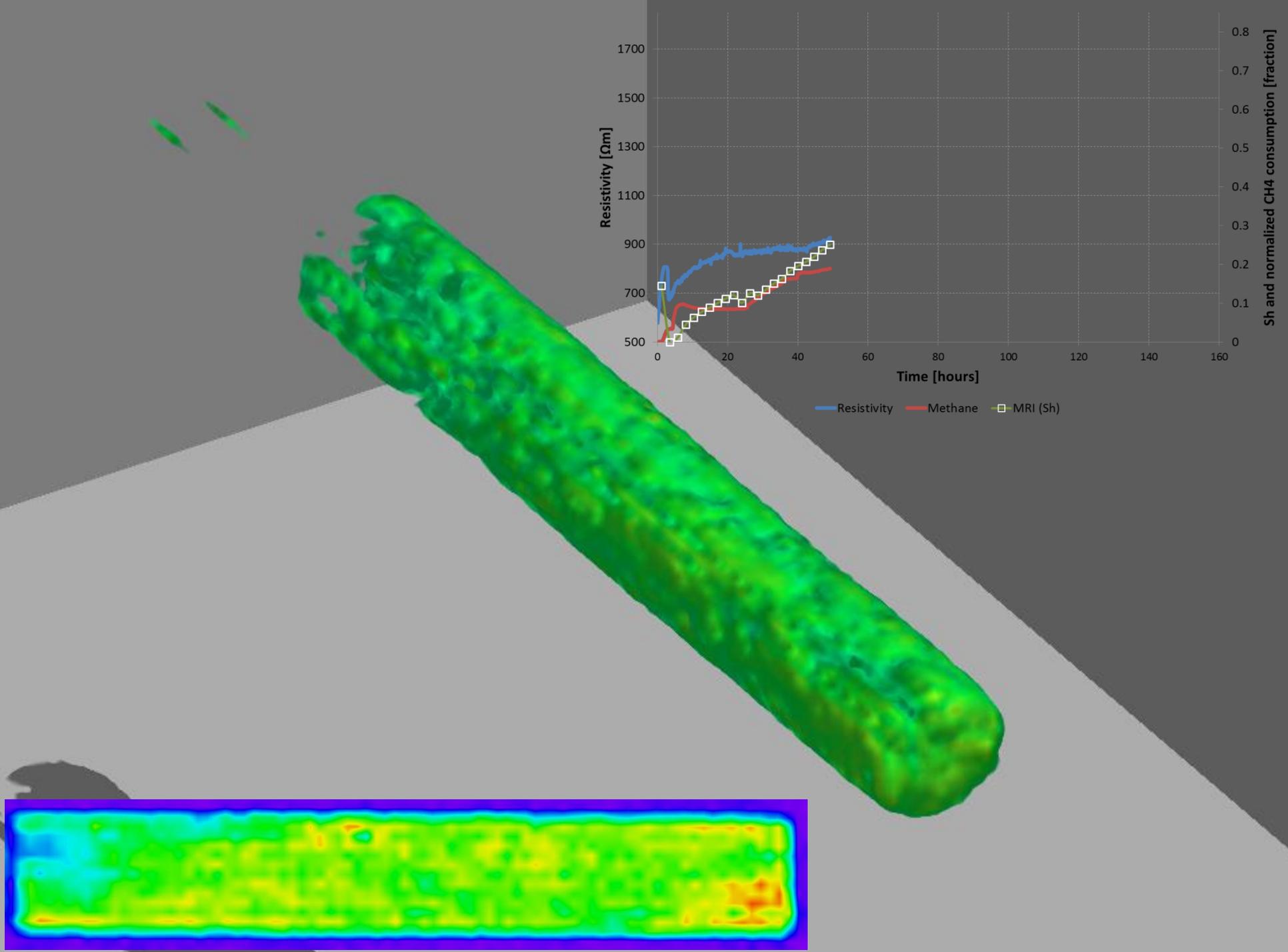


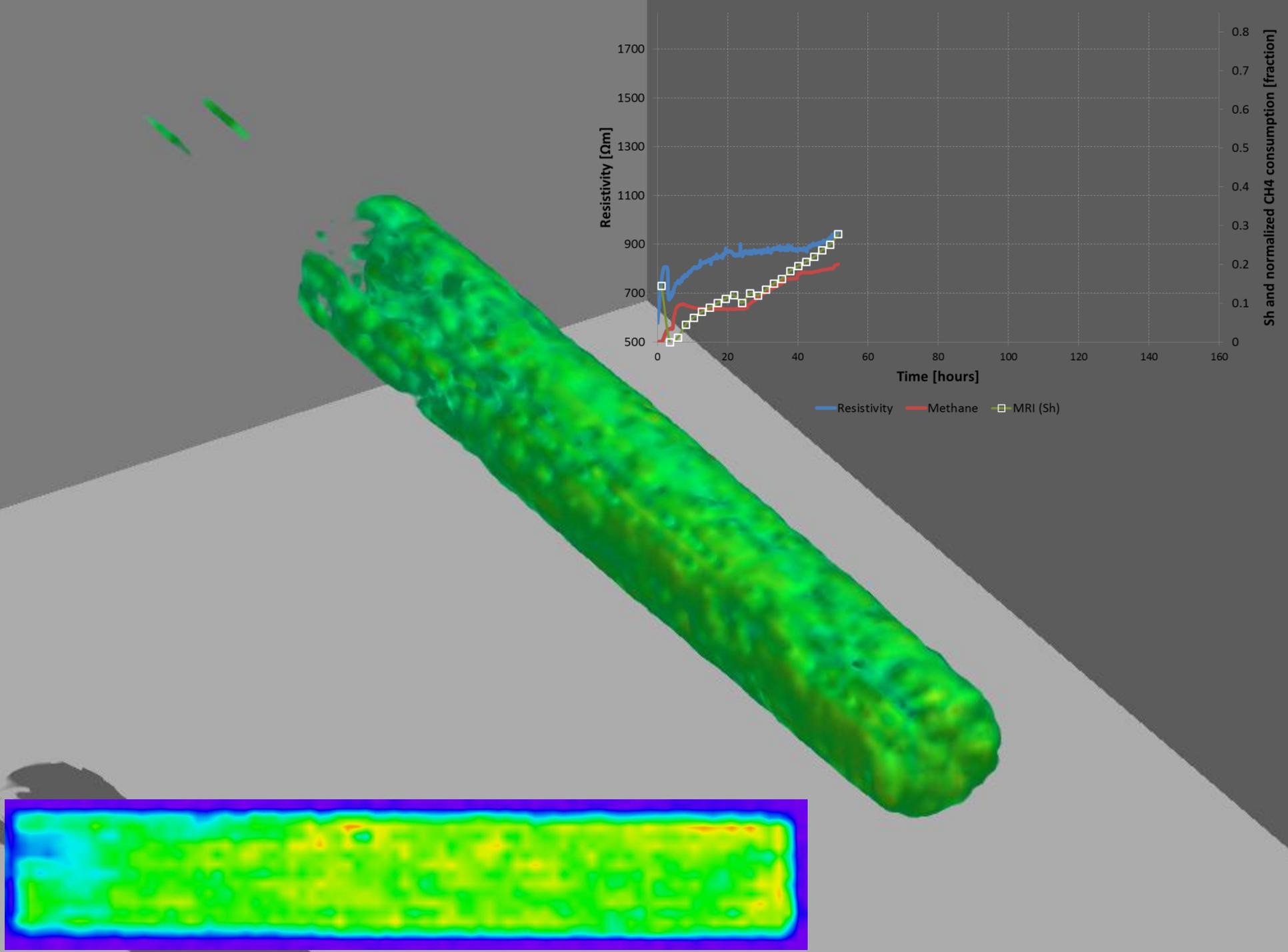


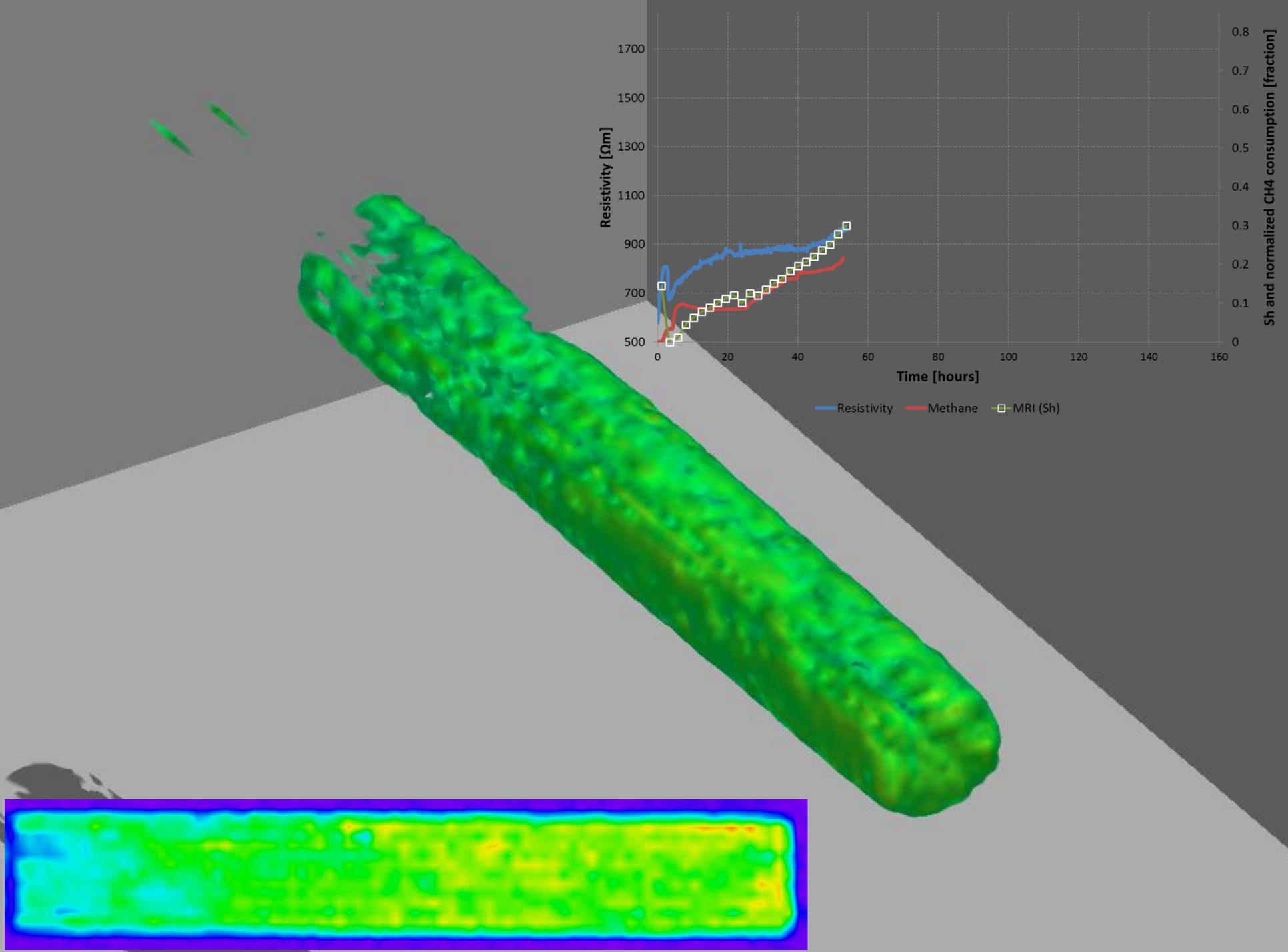


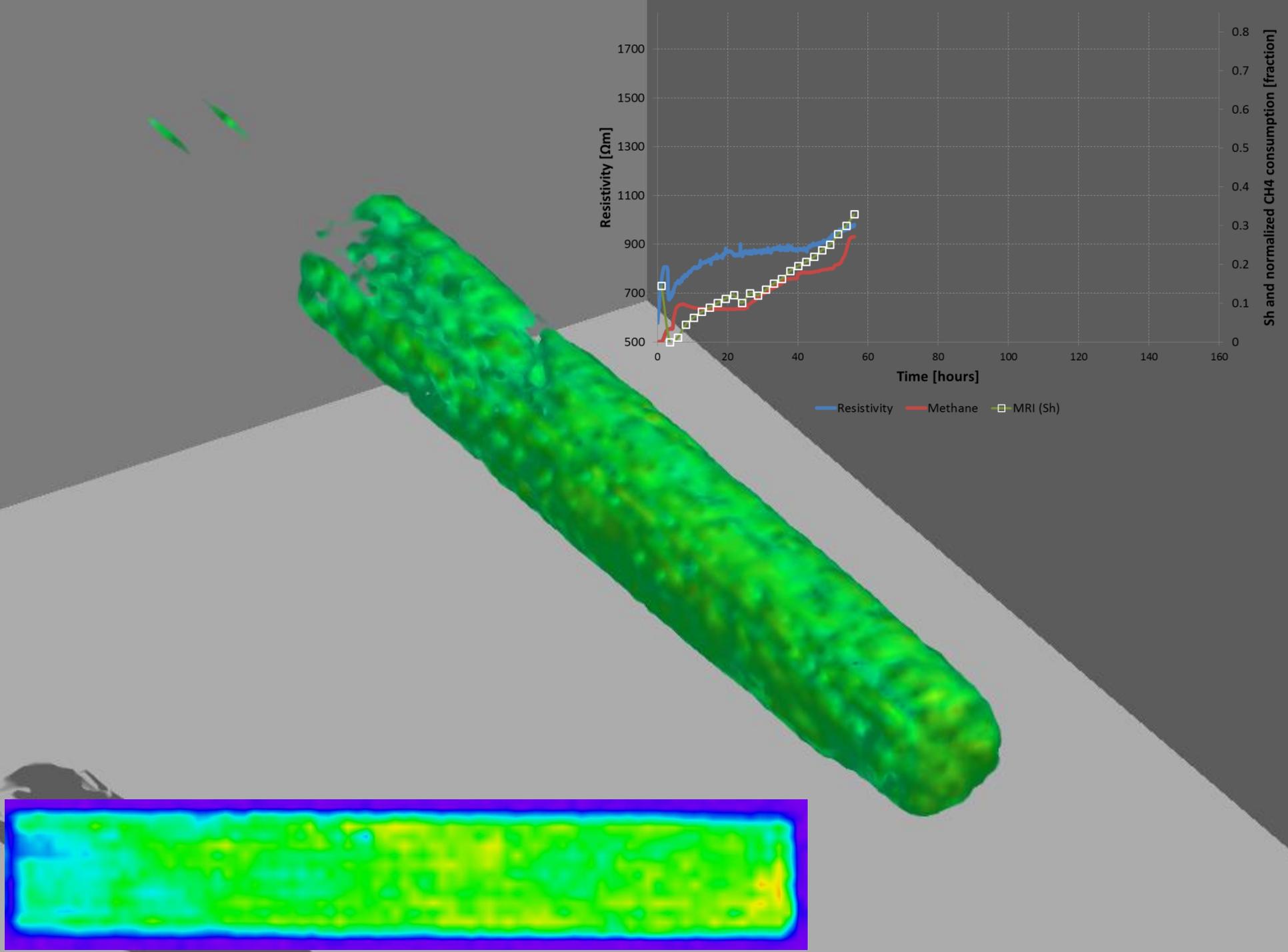


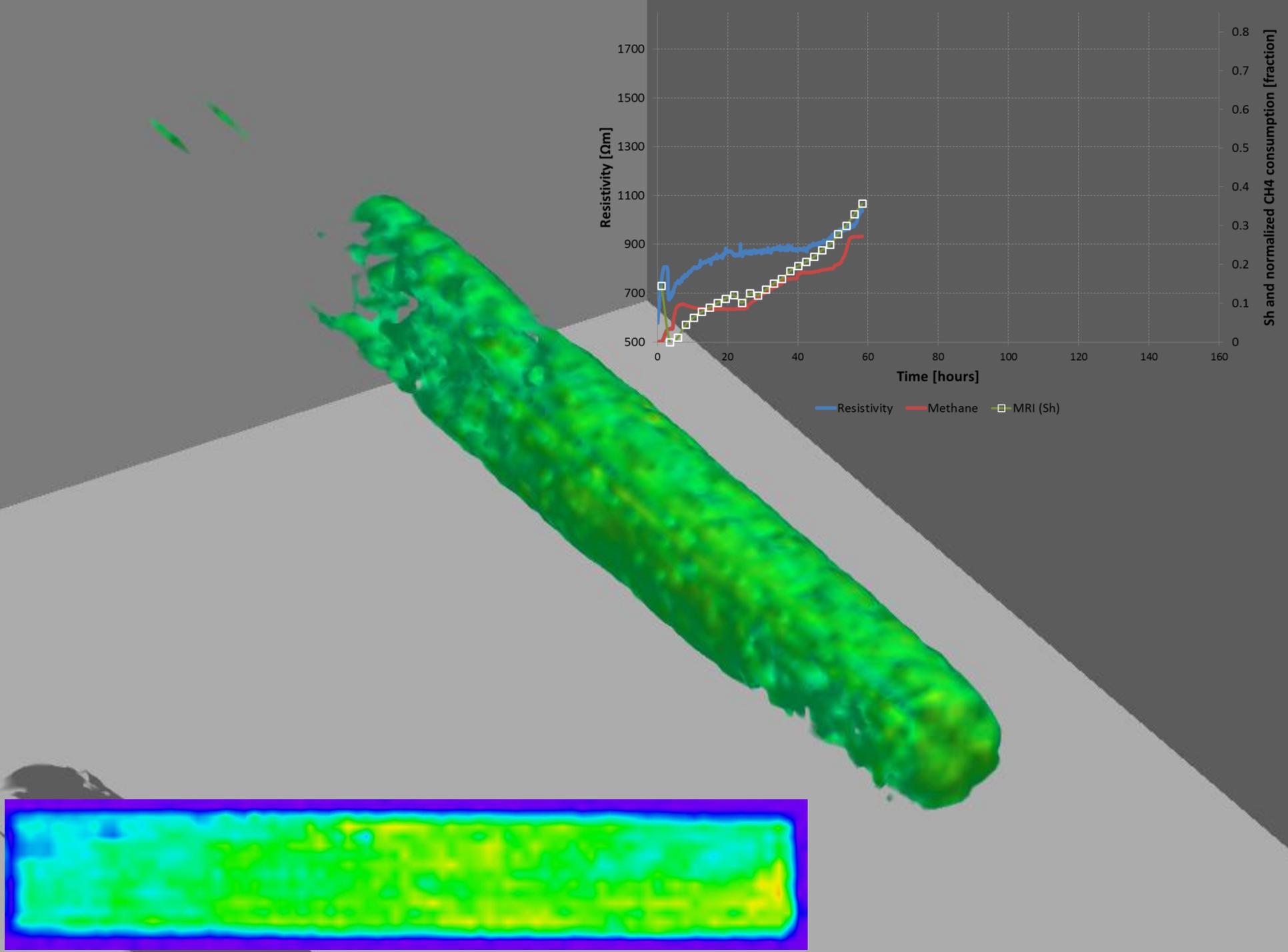


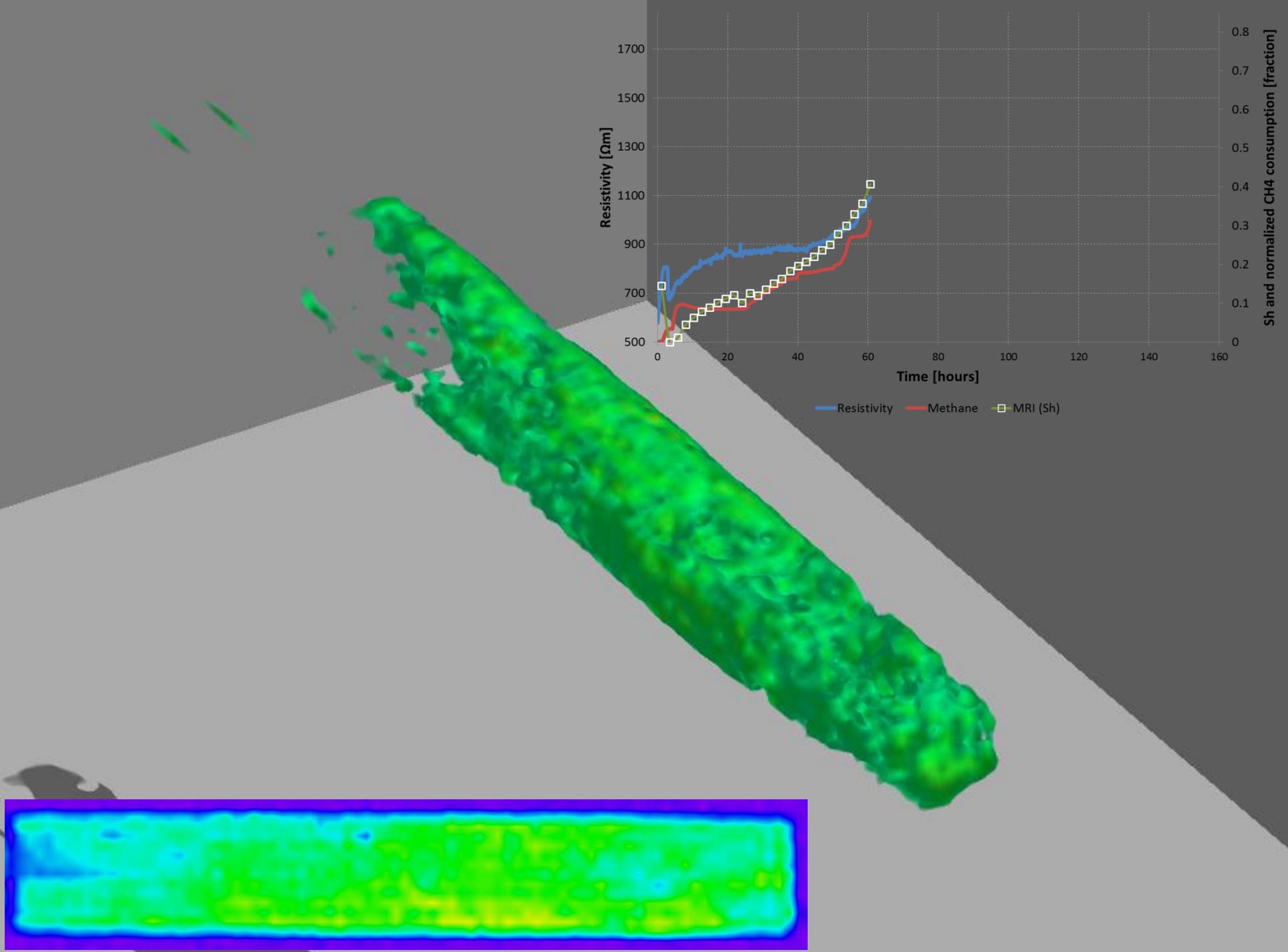


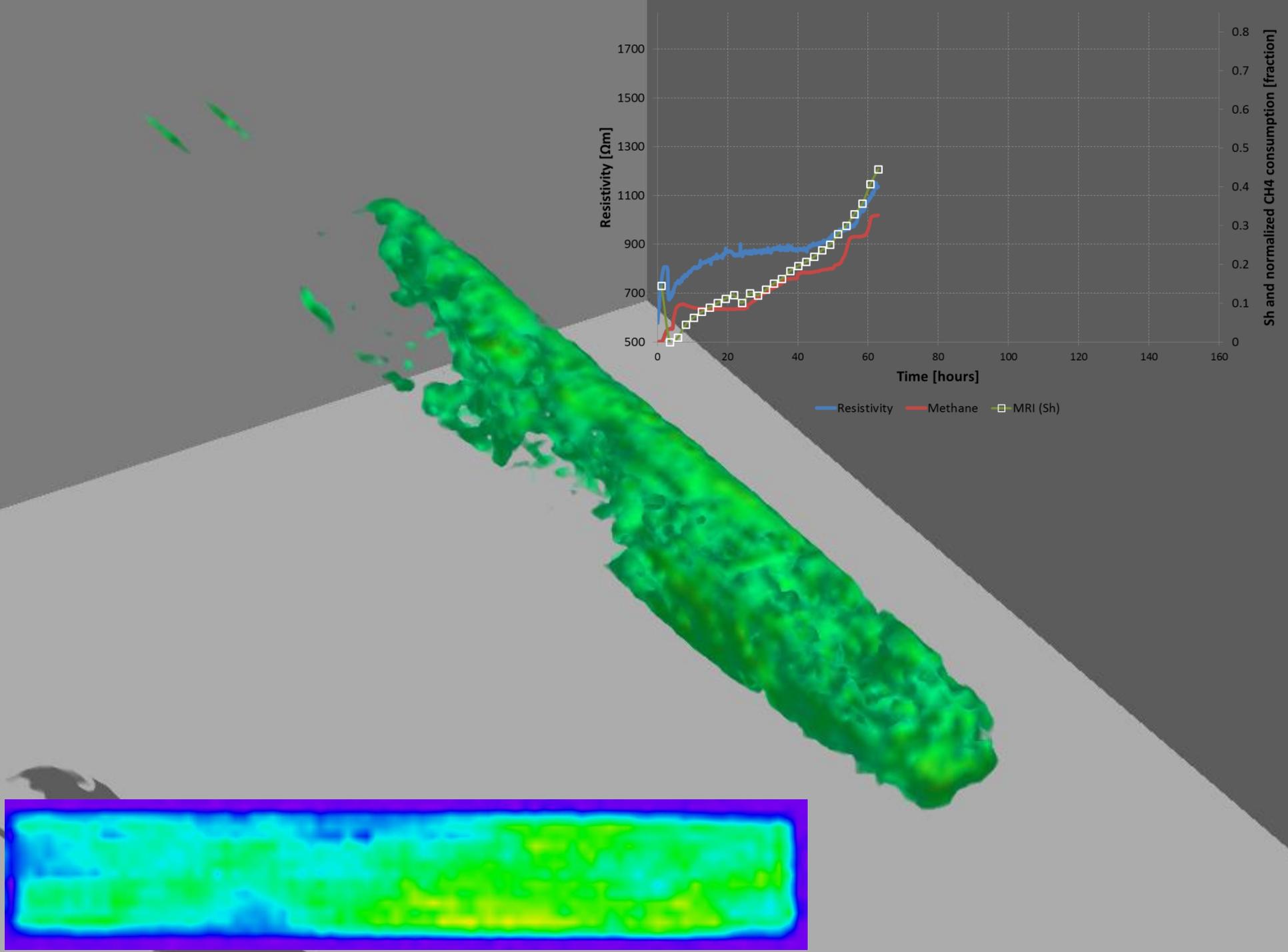


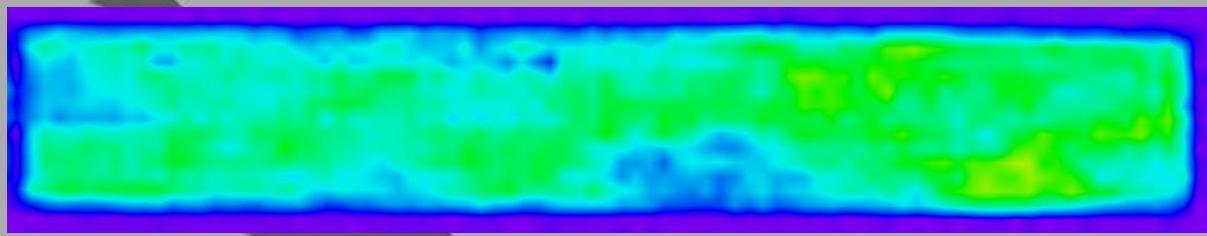
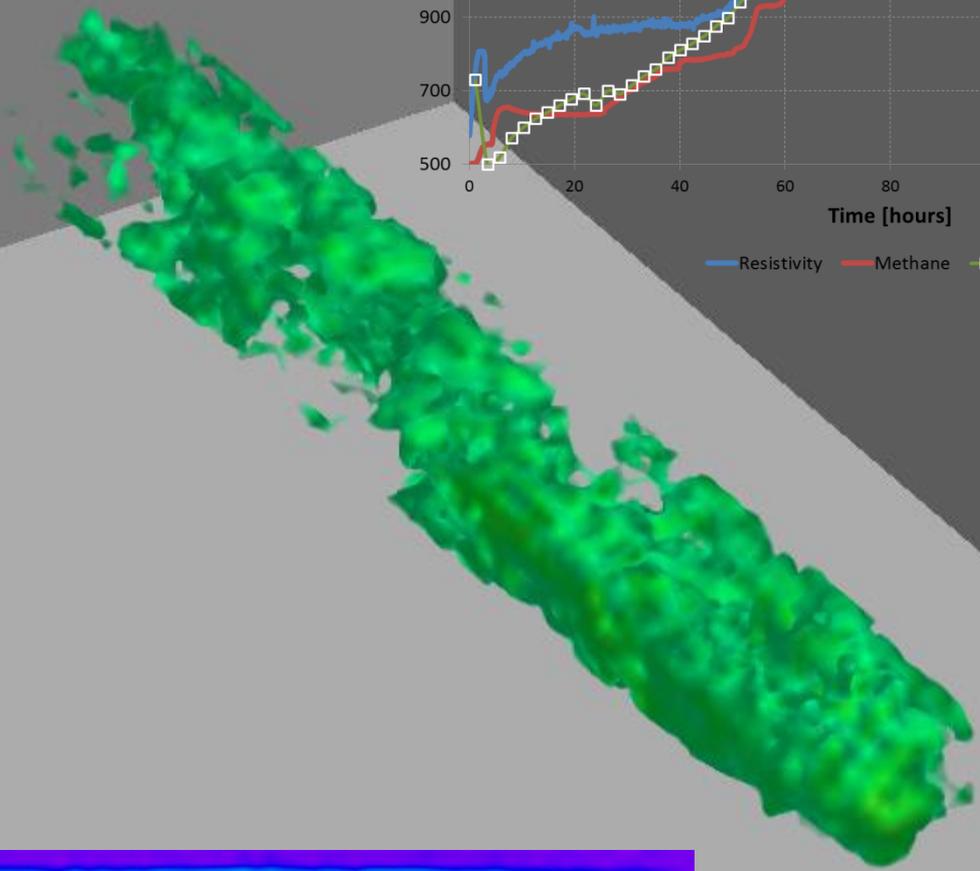
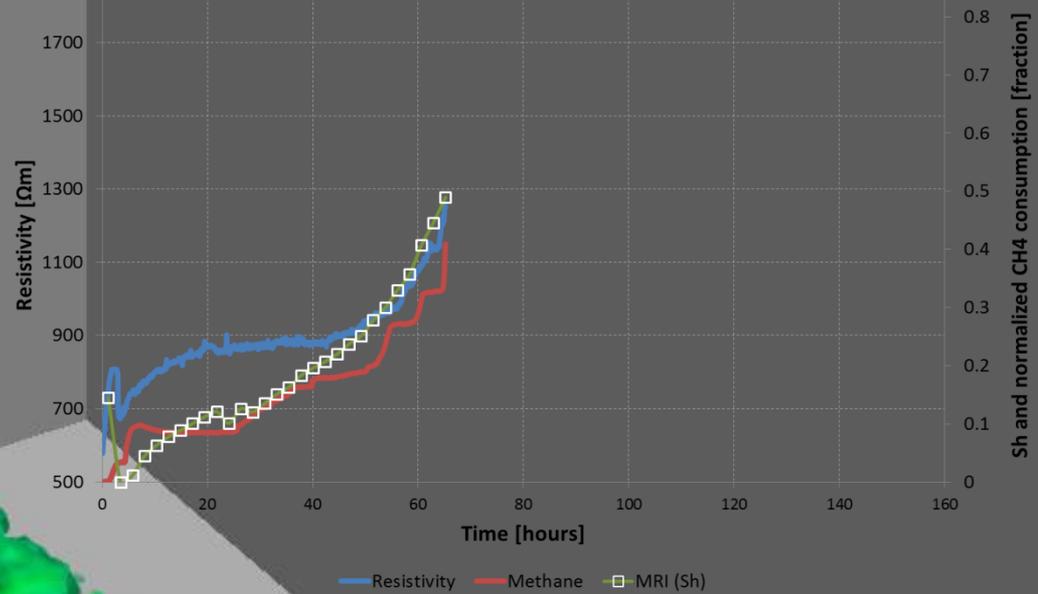


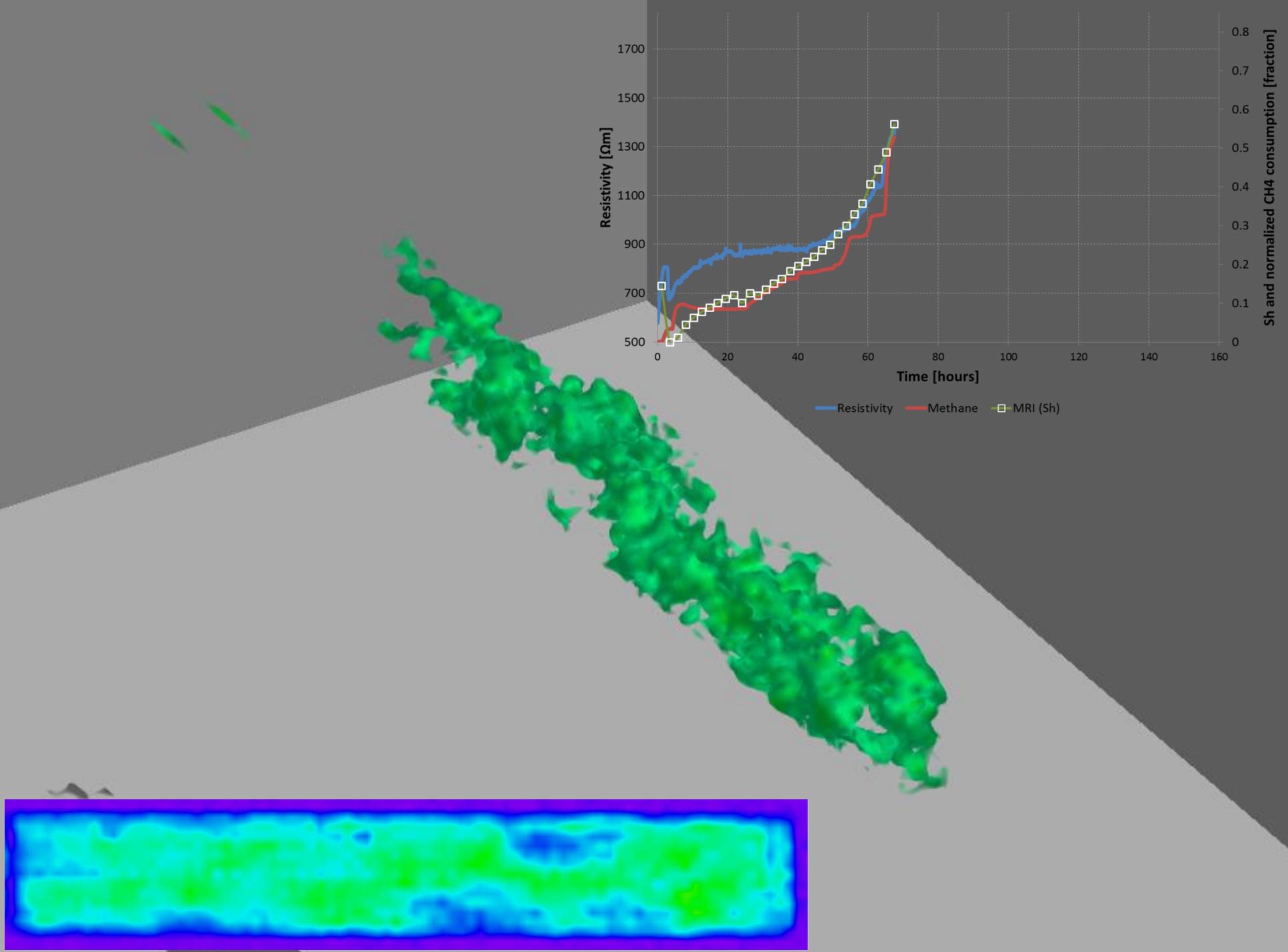


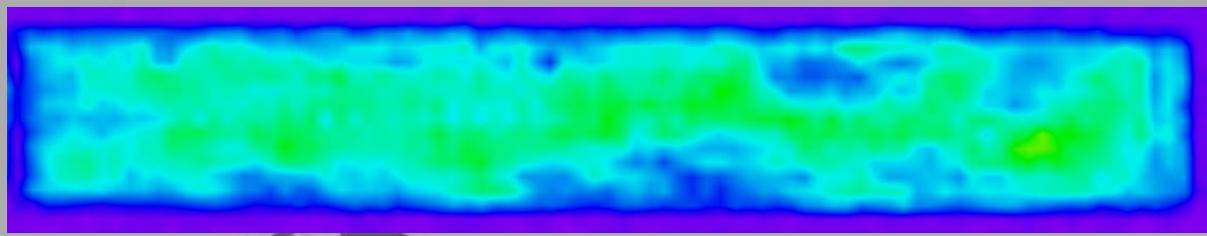
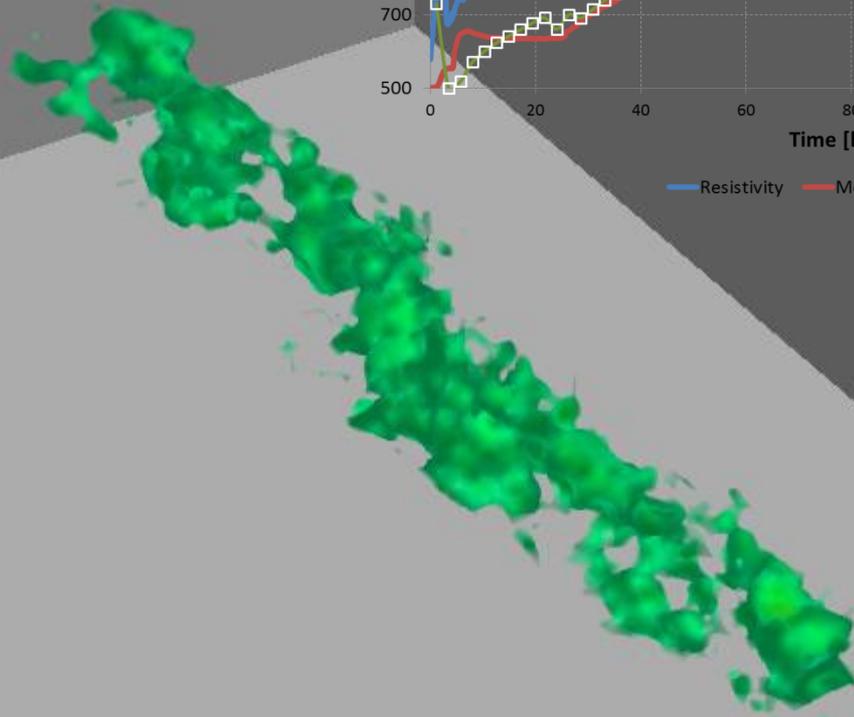
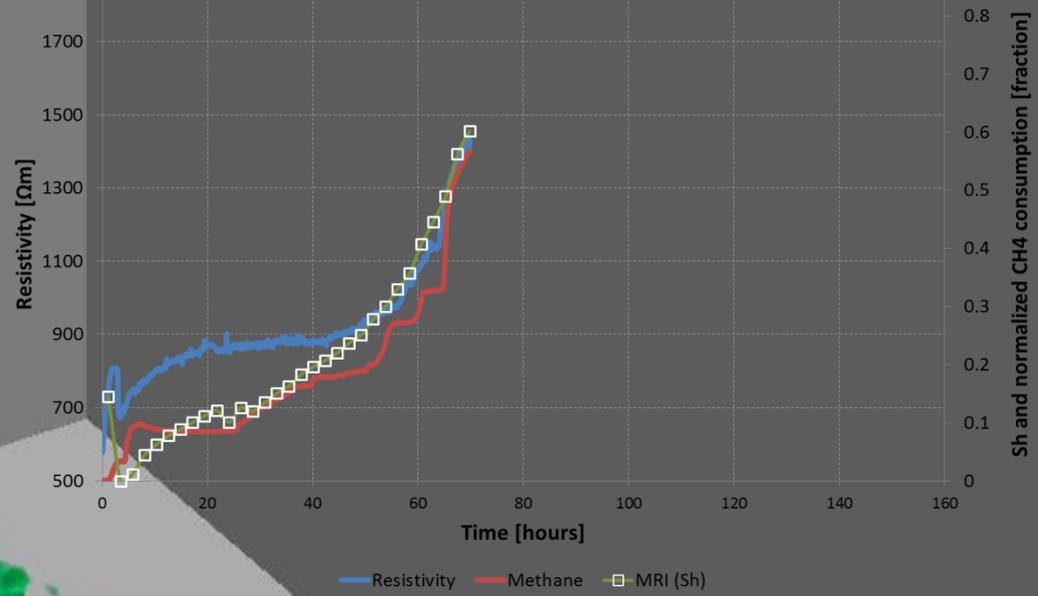


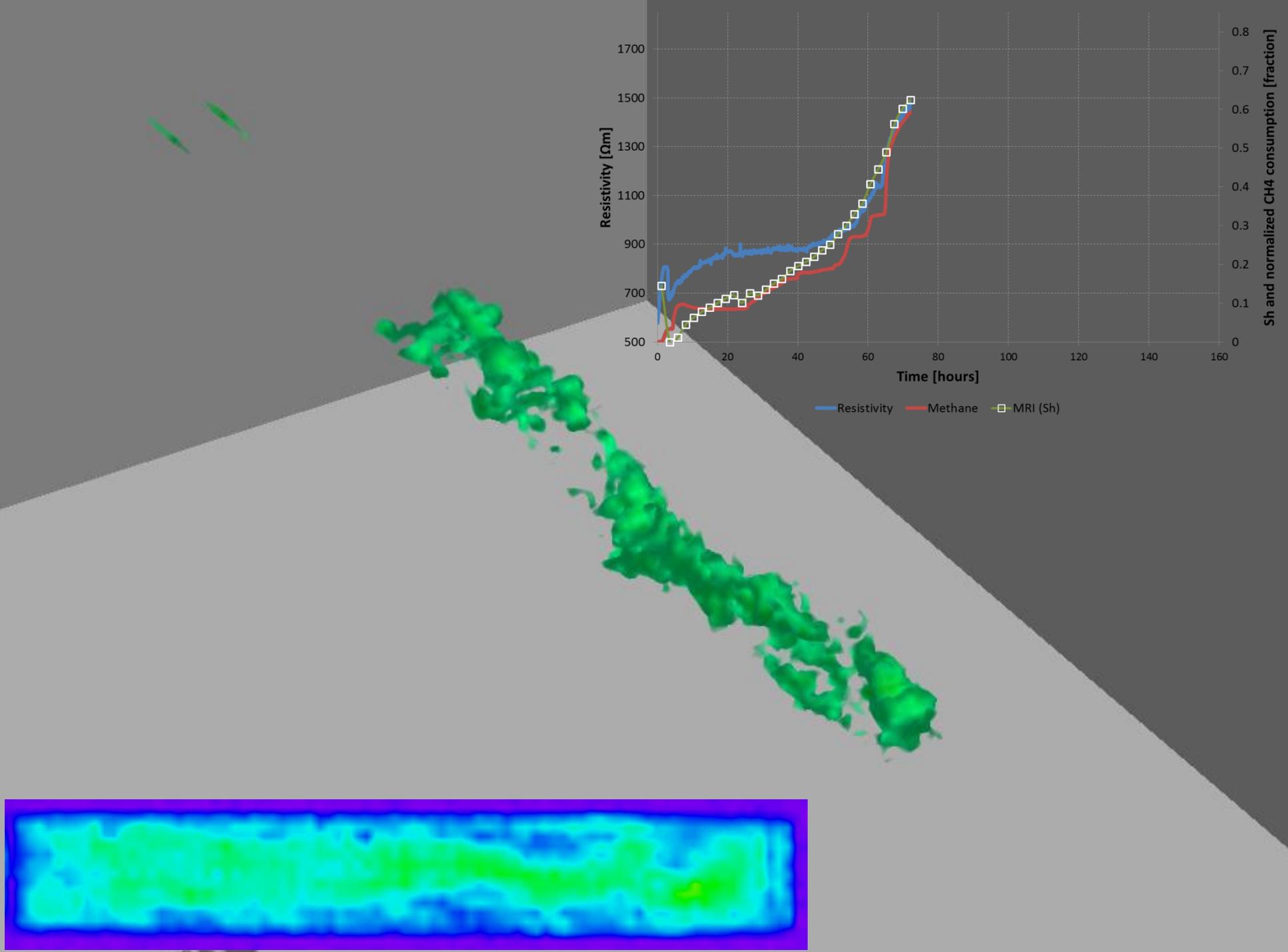


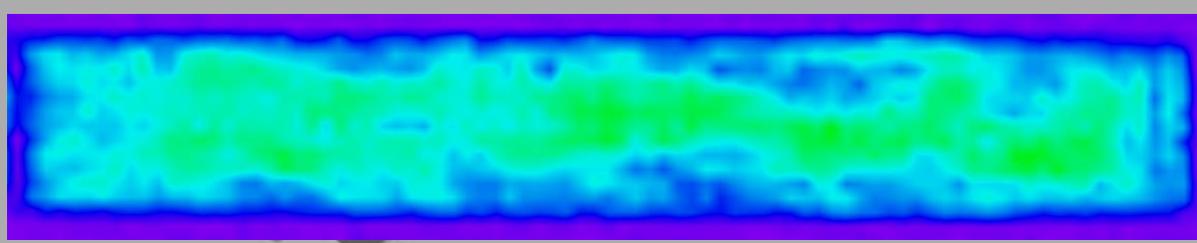
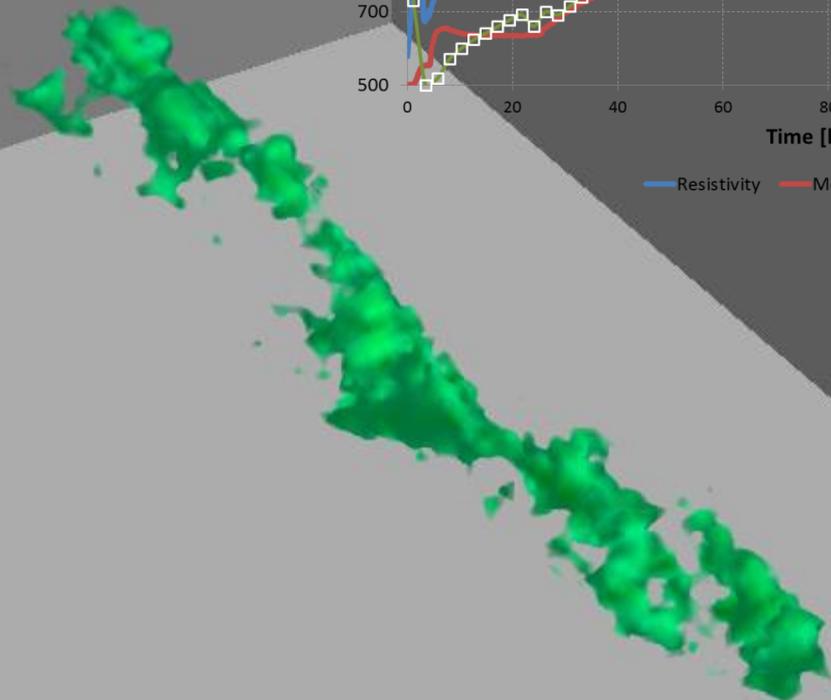
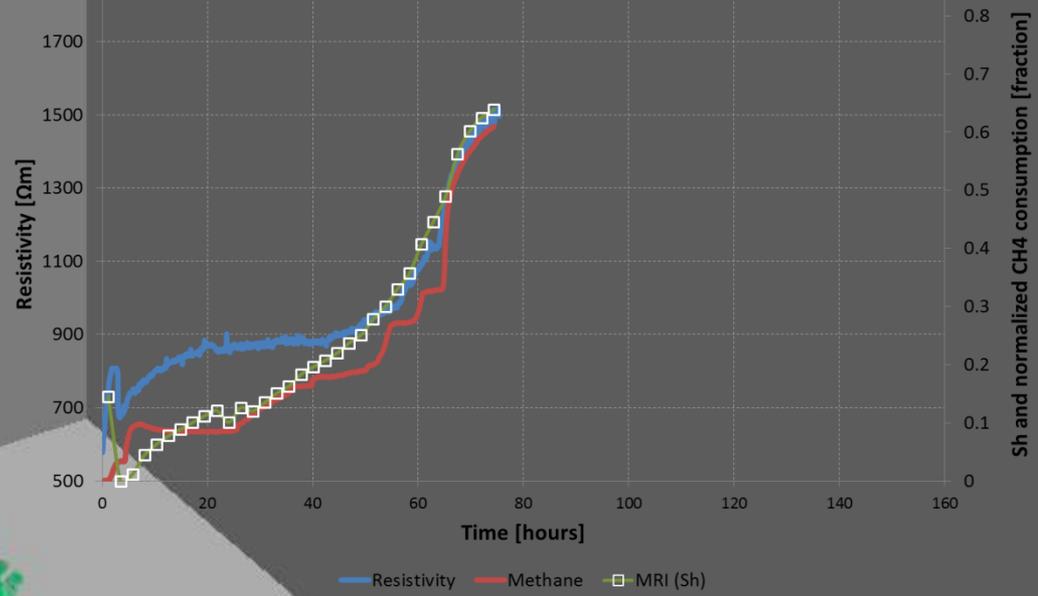


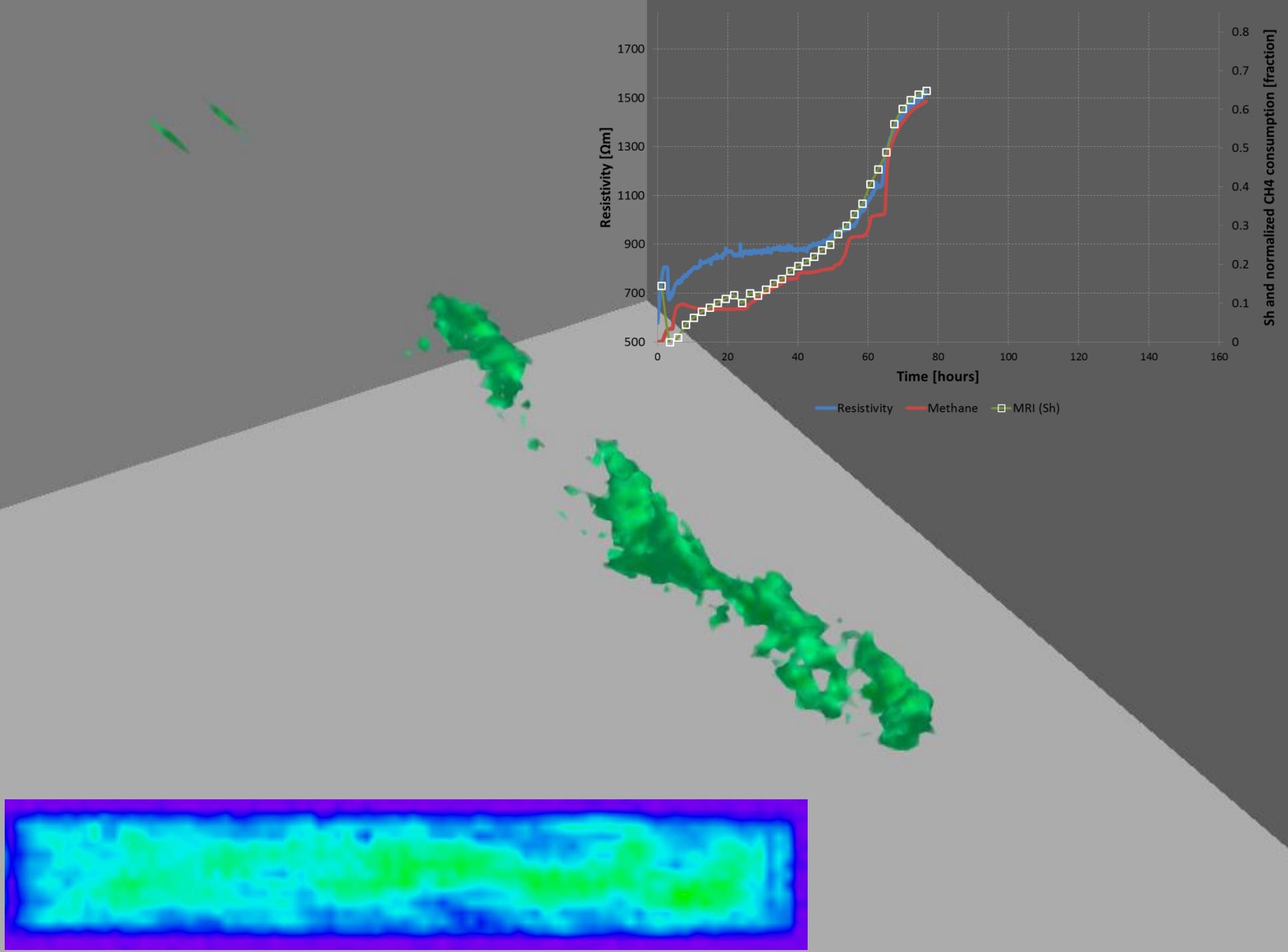


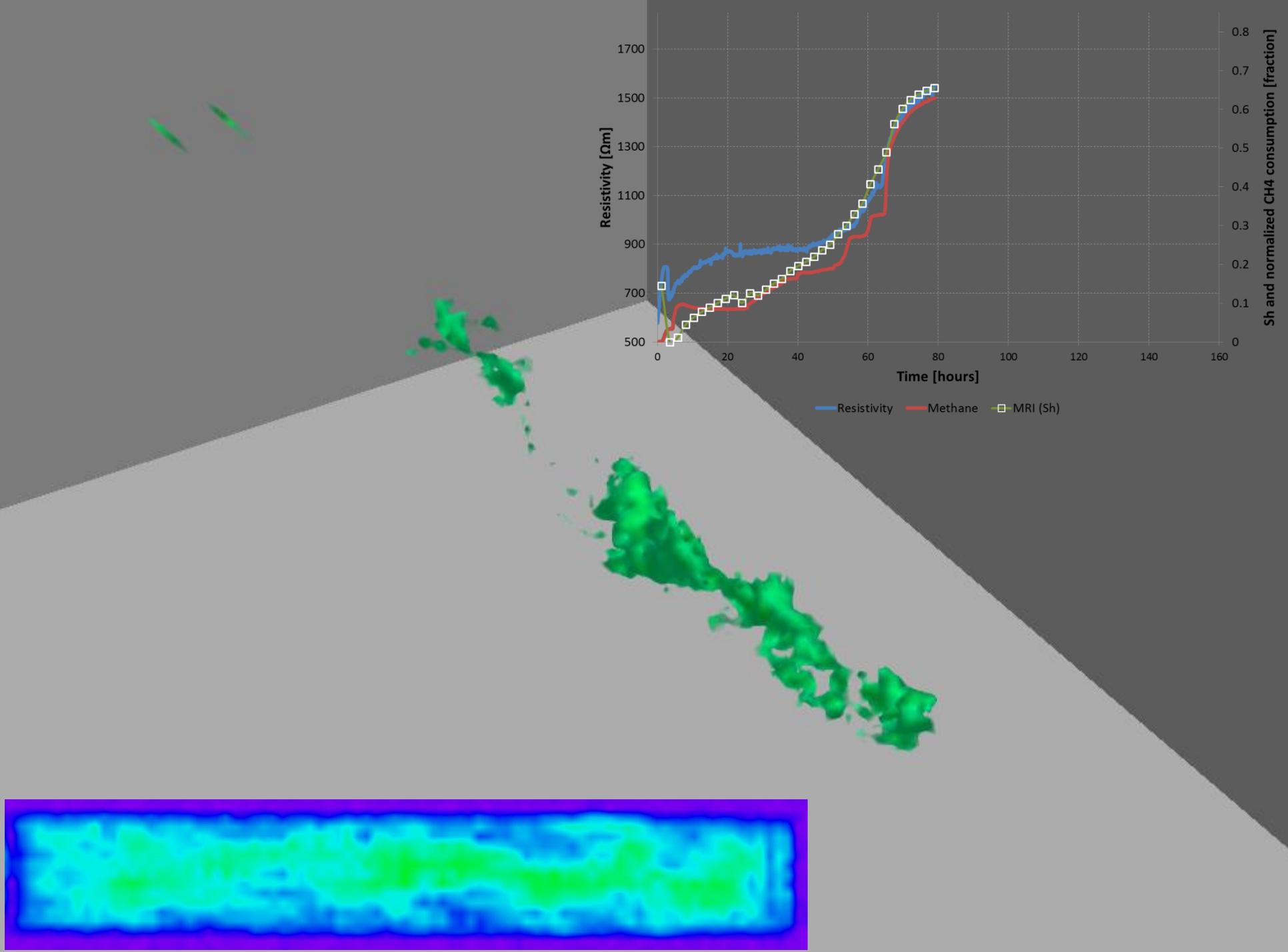


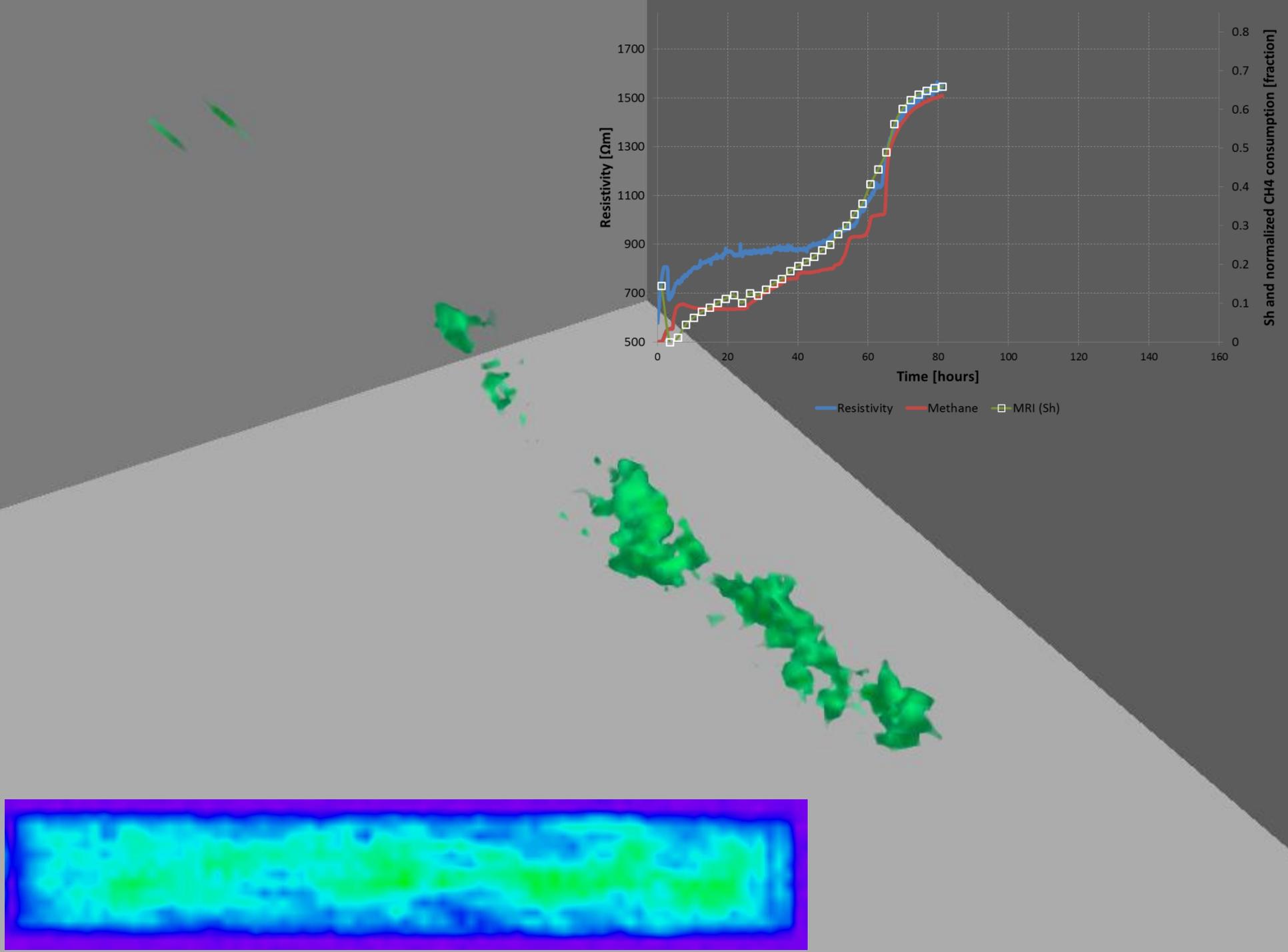
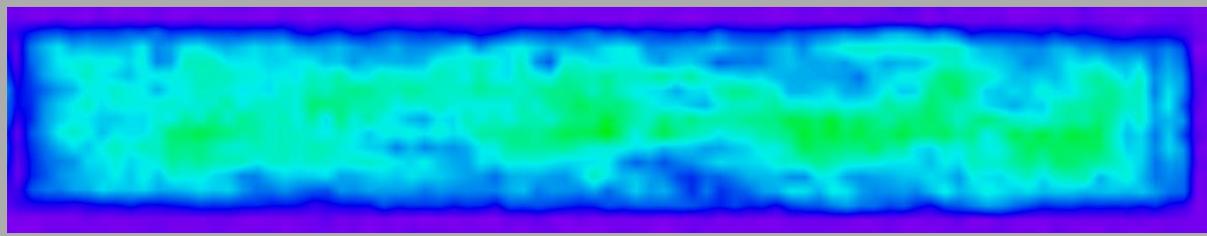
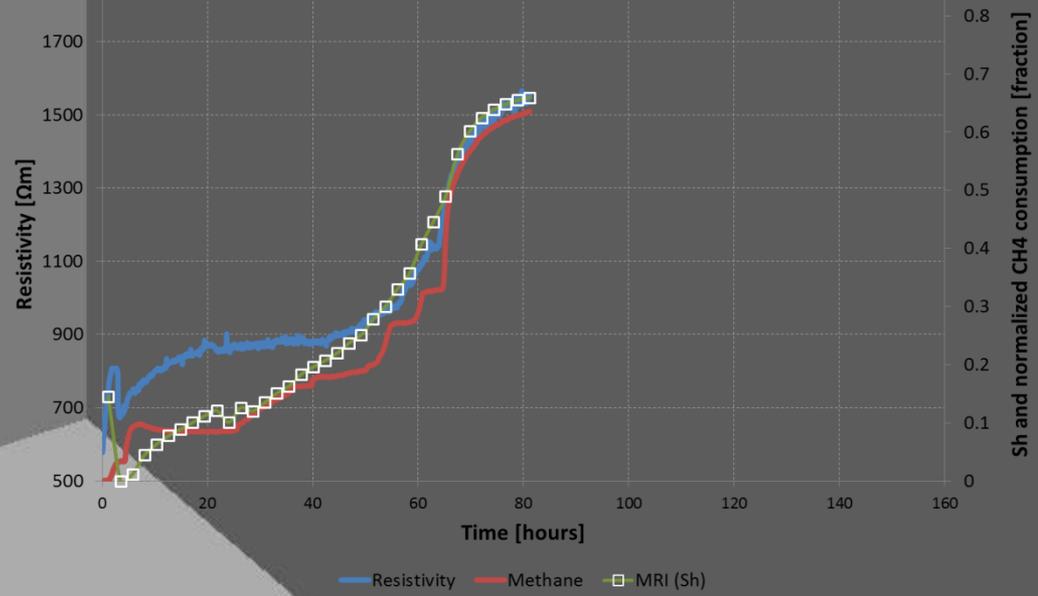


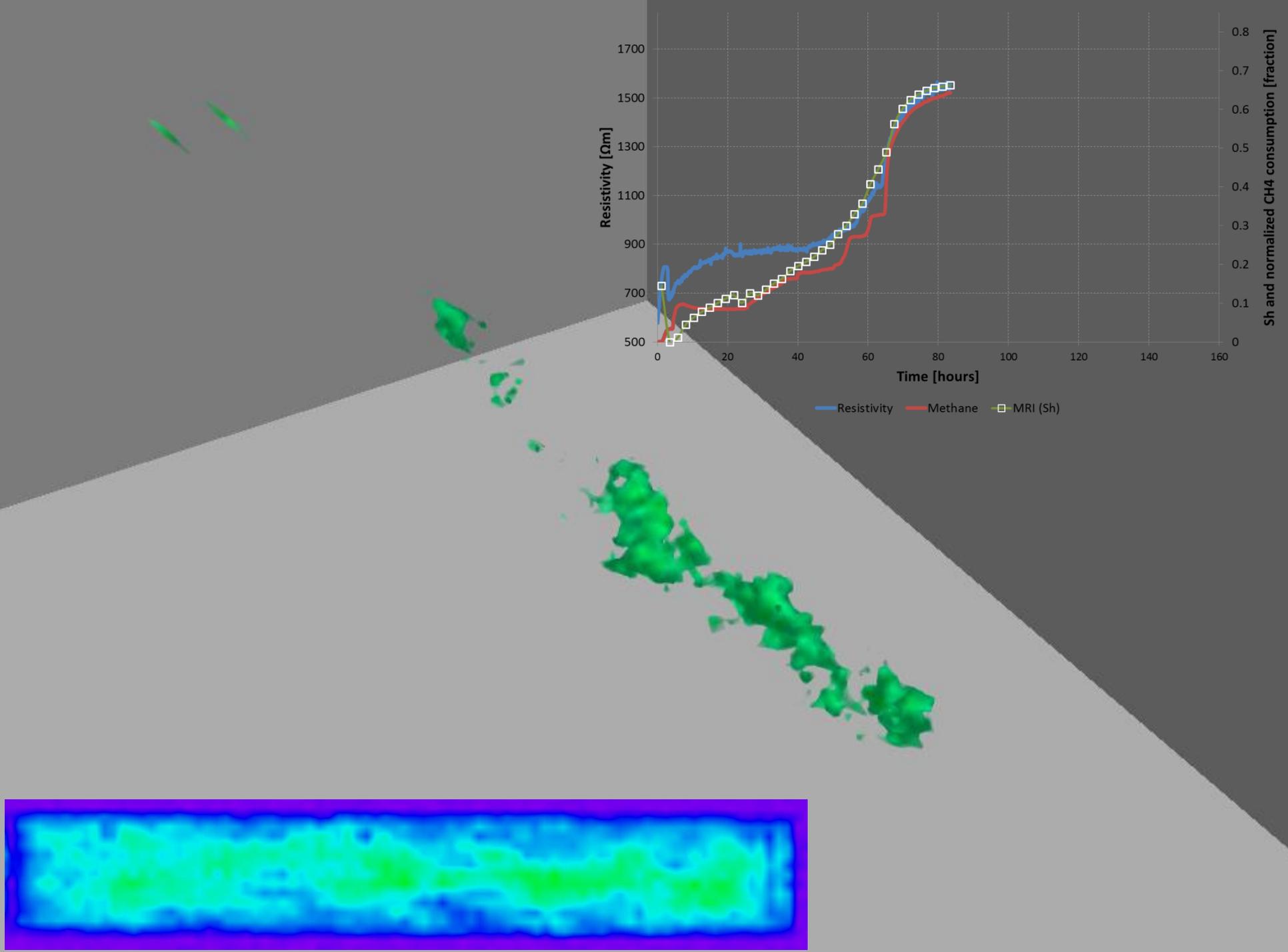


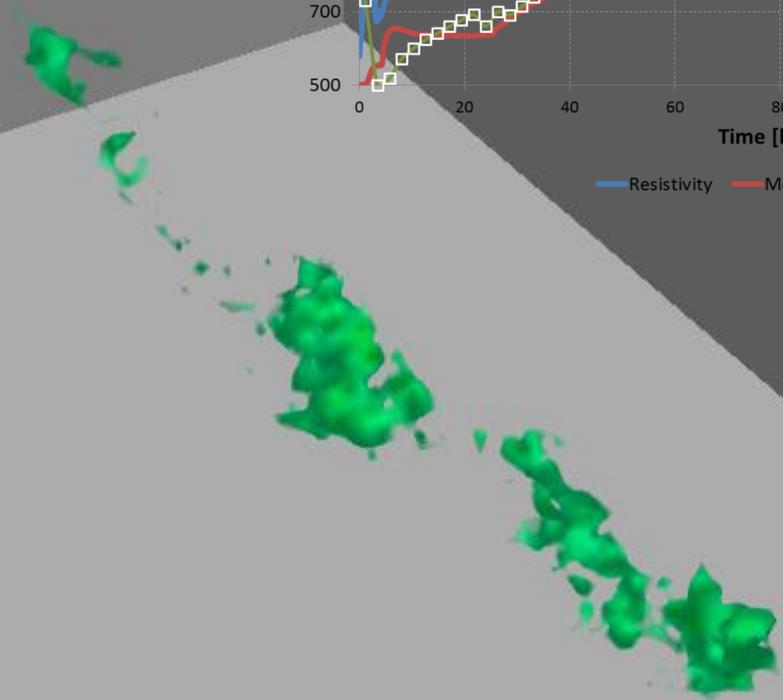
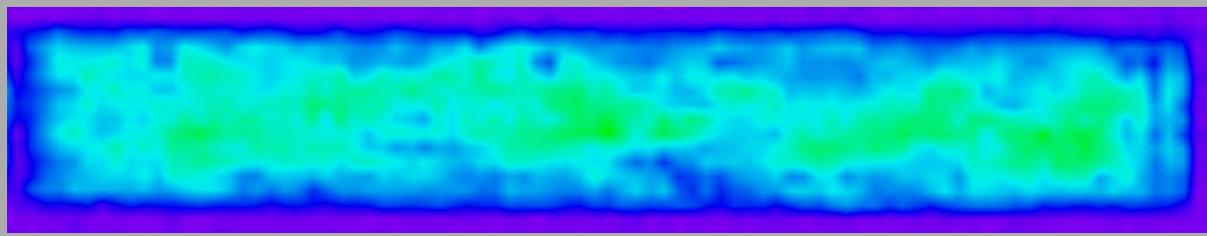
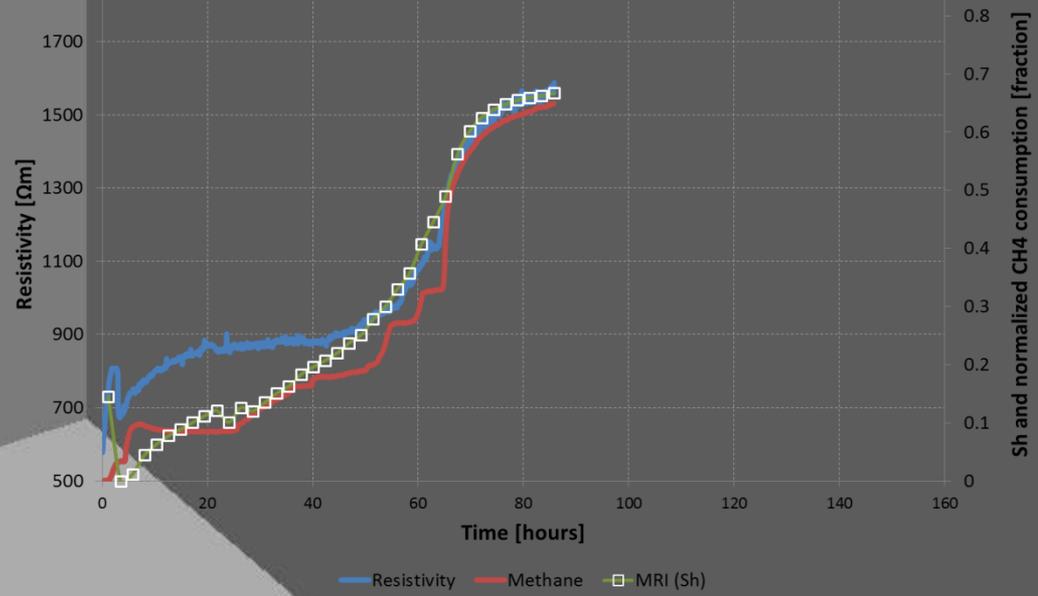


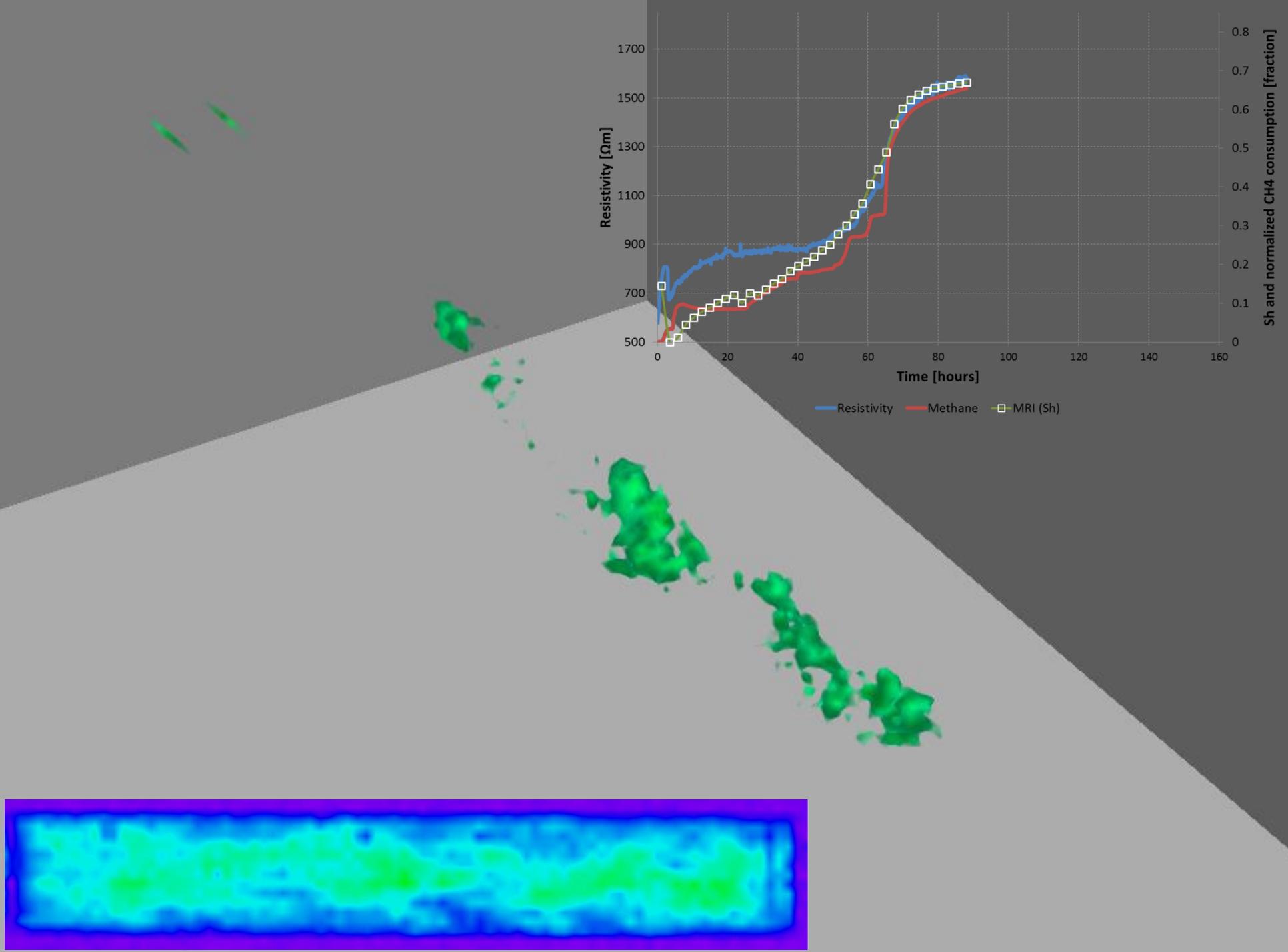
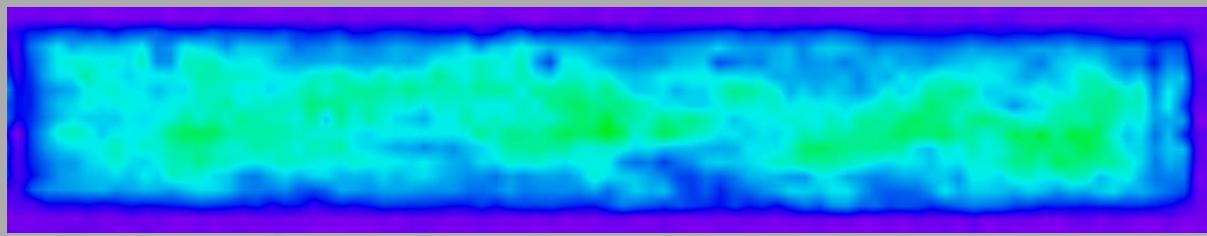
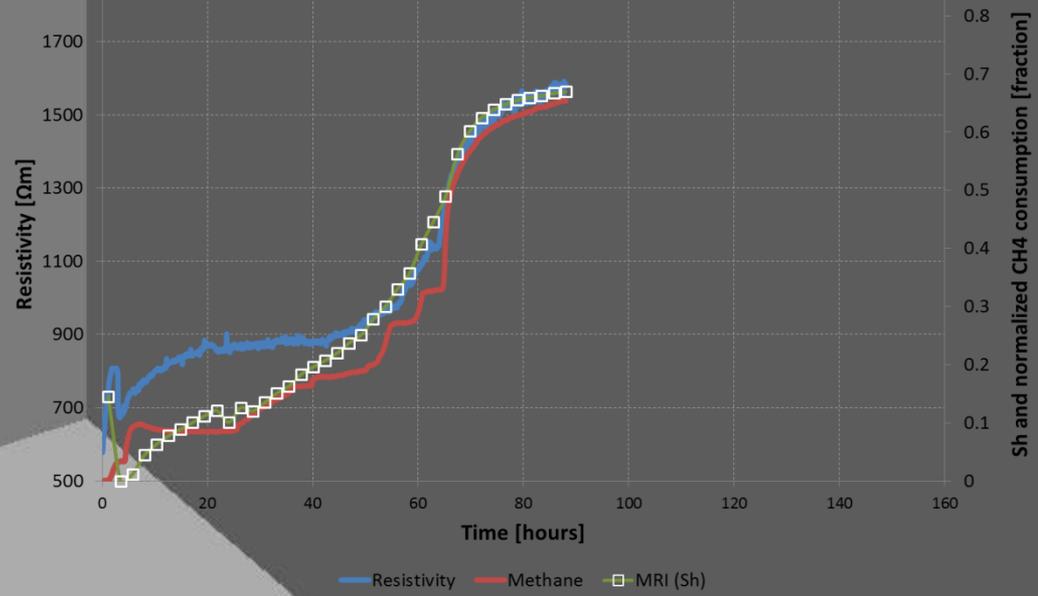


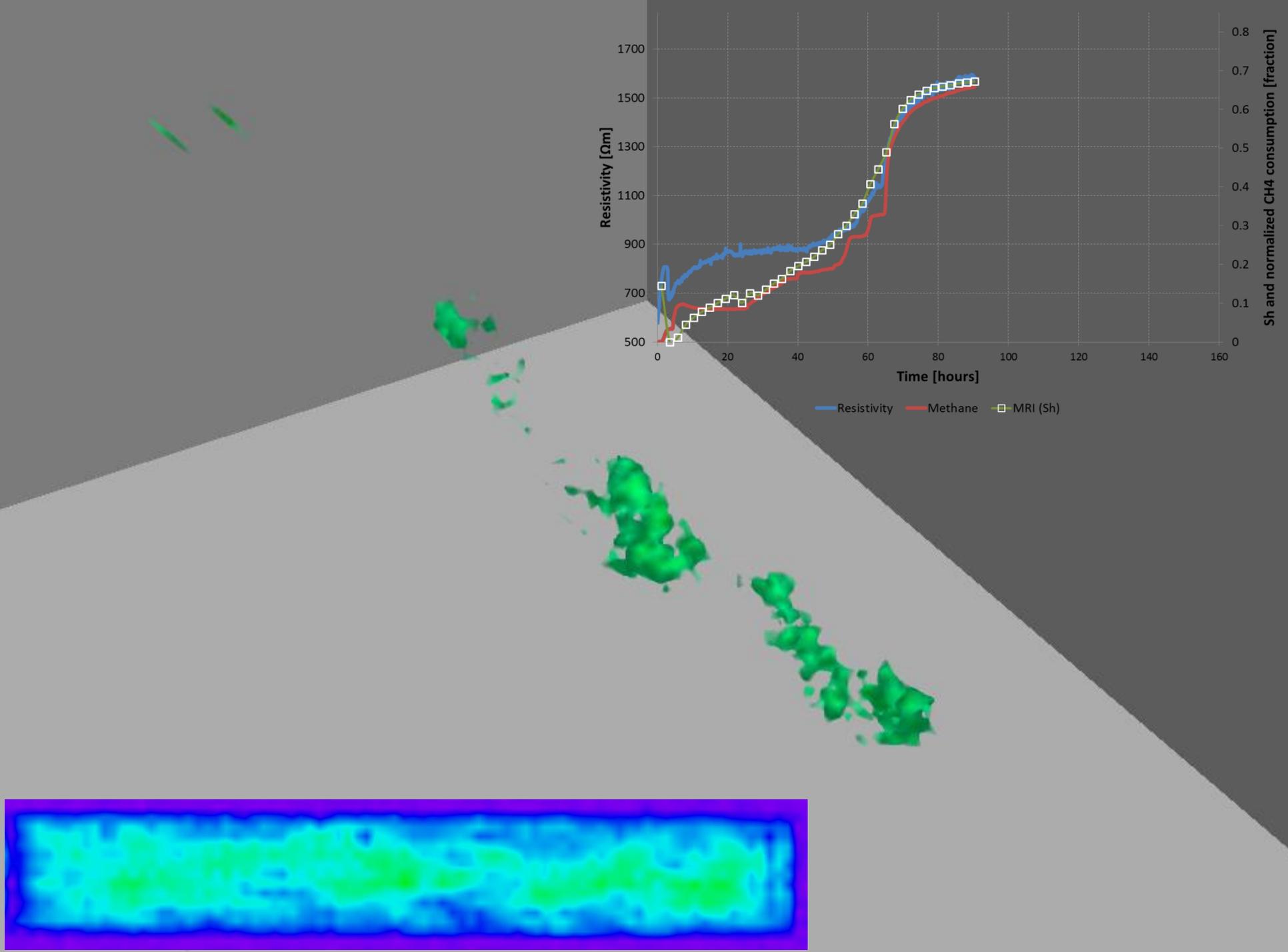
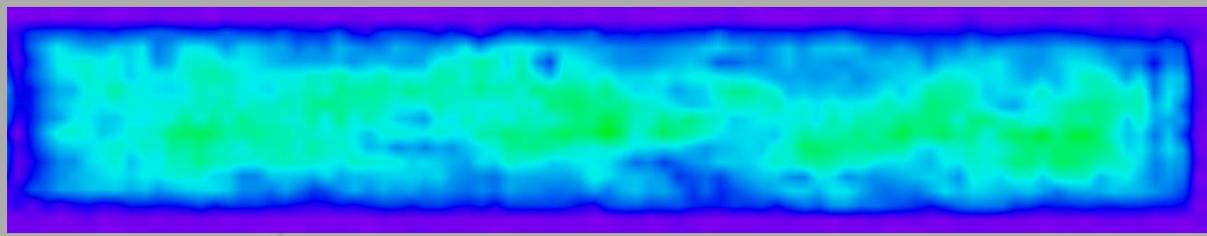
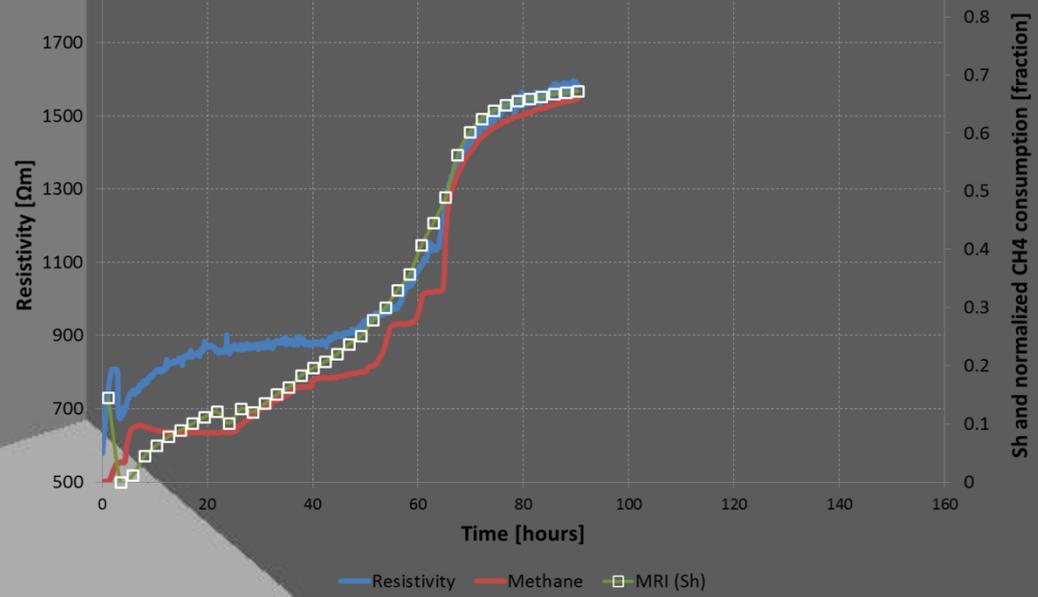


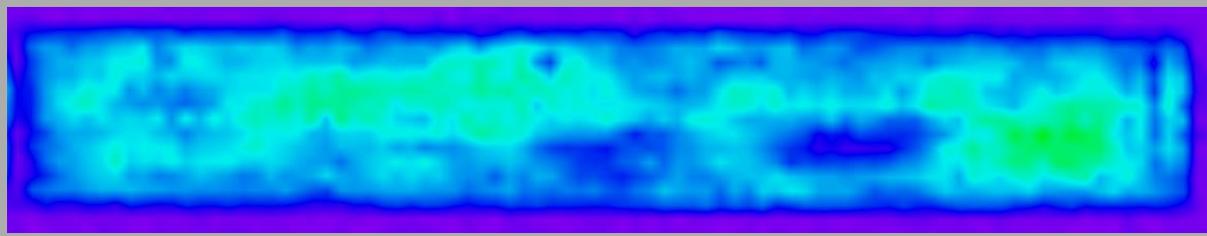
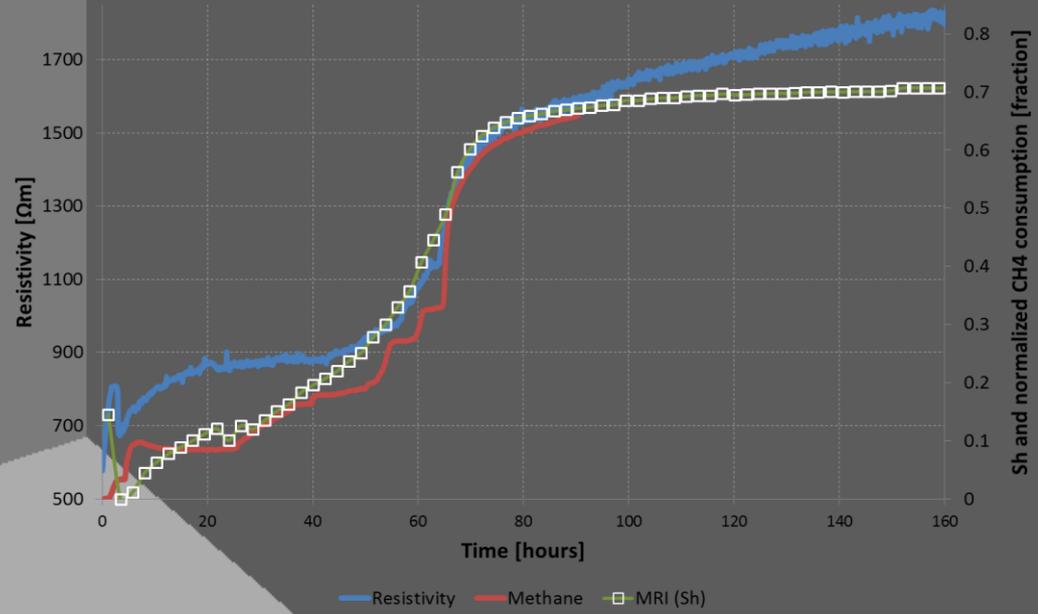










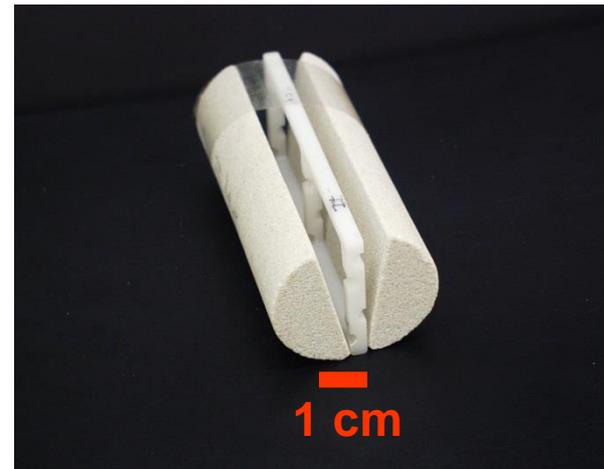
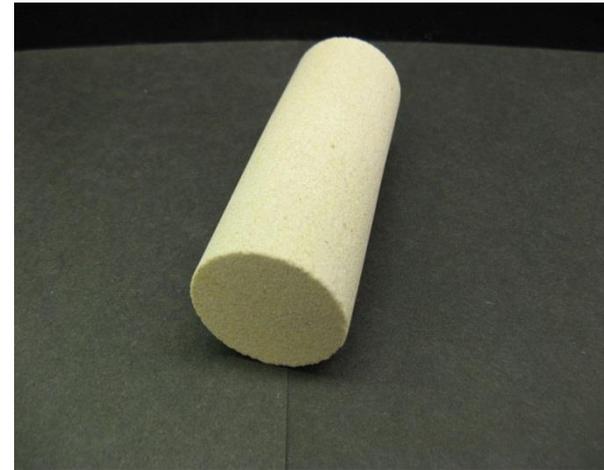


# CO2 replacement exp.

## Bentheim Sandstone

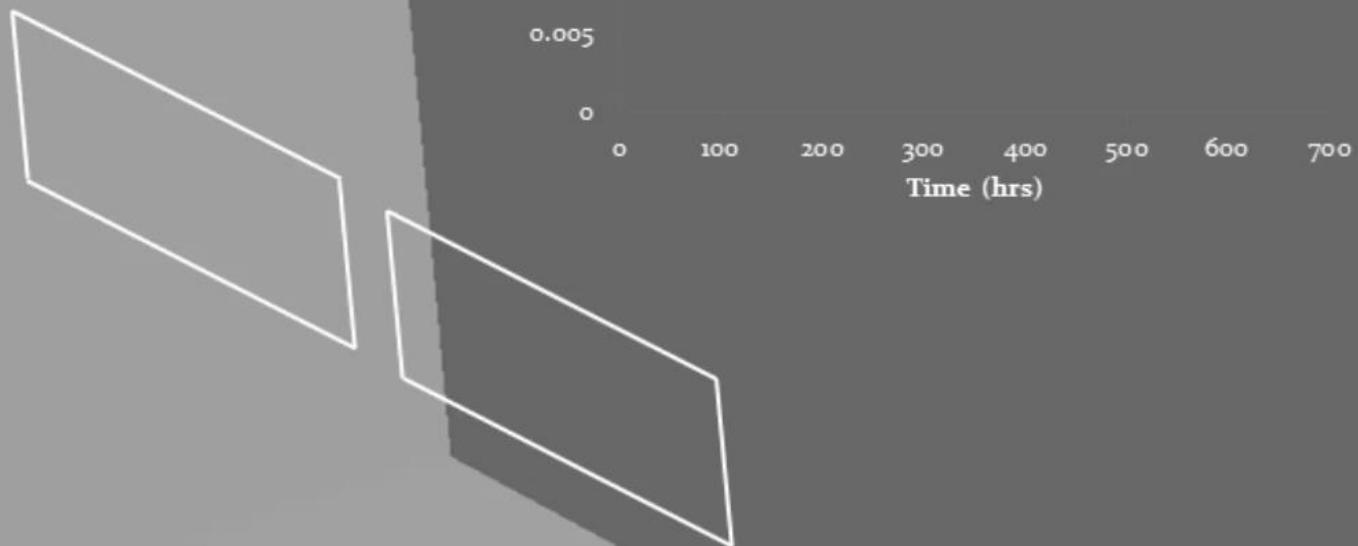
$\Phi = 20-25\%$ ,  $k \sim 1.1 D$

- Whole Core
- Longitudinal Cut – Fitted Spacer Simulates Open Fracture.



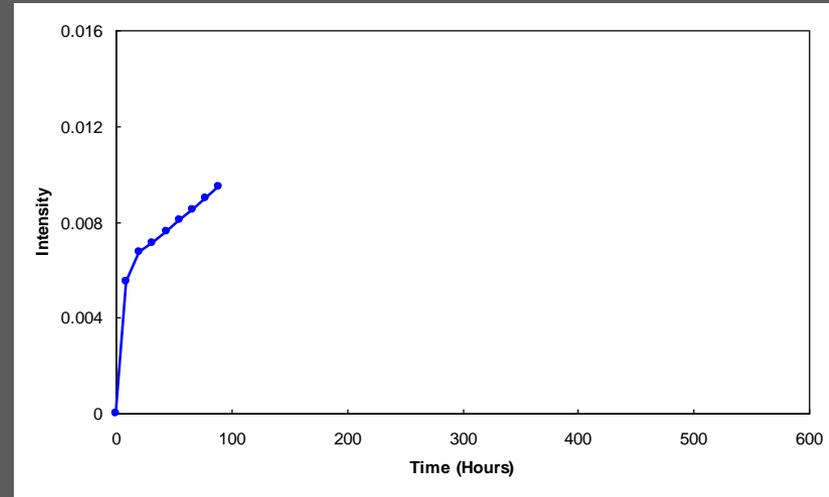
34a-01

0.0hrs



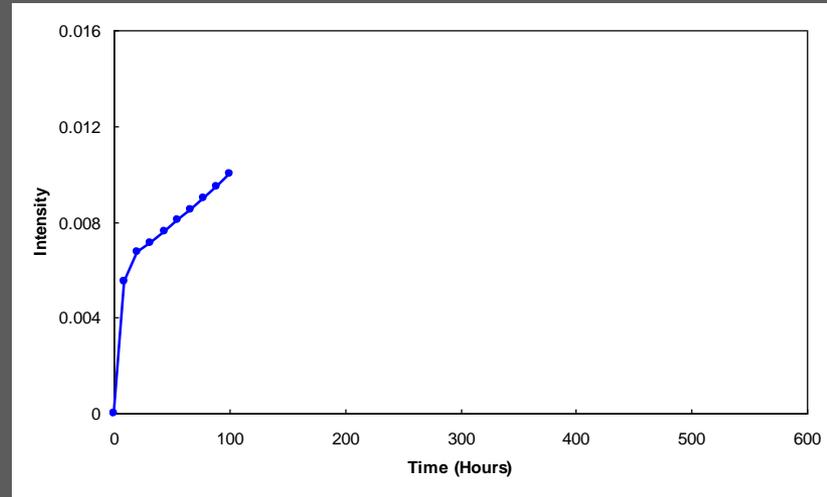
34b-07

89.2 hrs



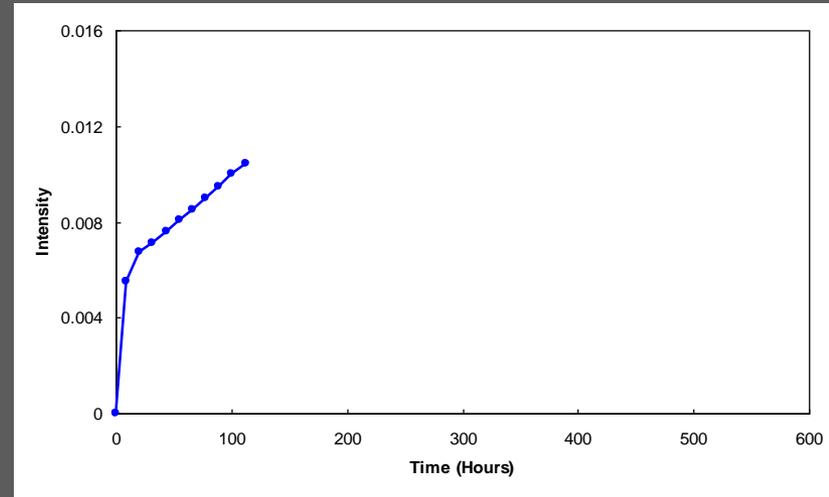
34b-08

100.6 hrs



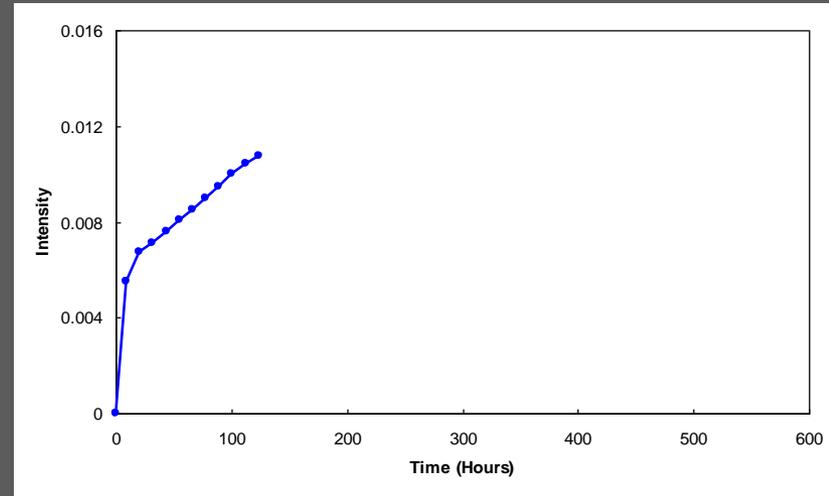
34b-09

112.1 hrs



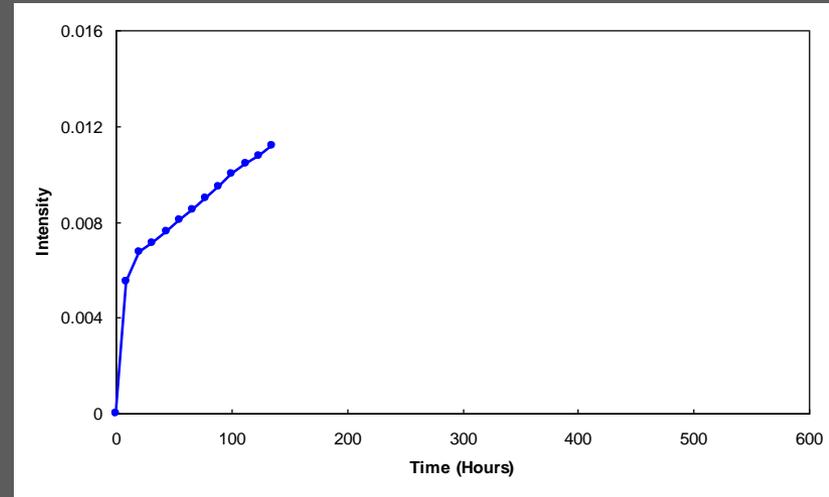
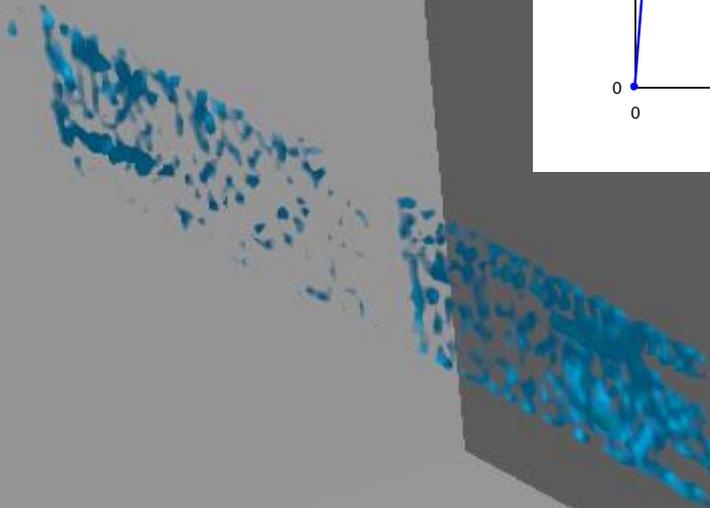
34b-10

123.5 hrs



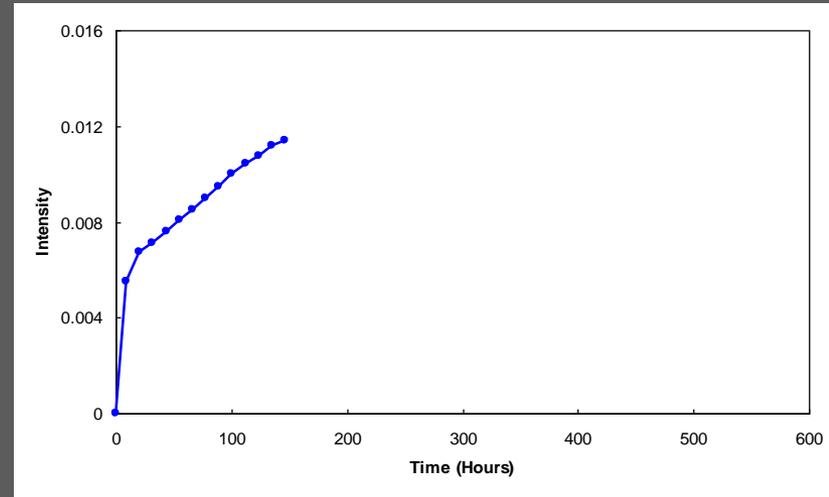
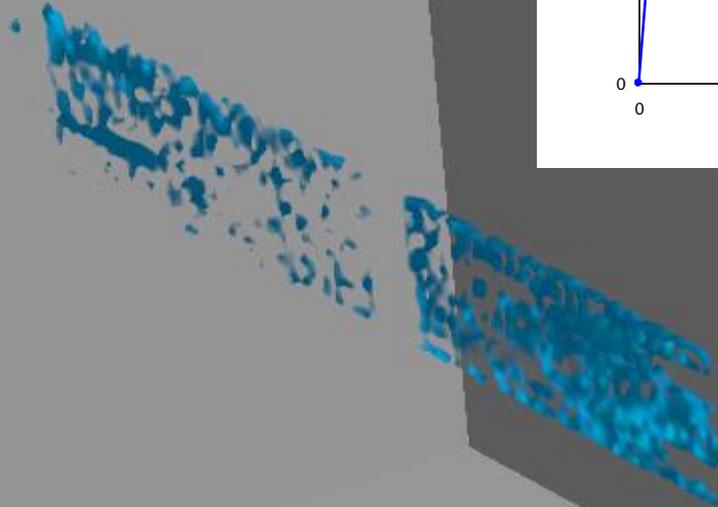
34b-11

135.0 hrs



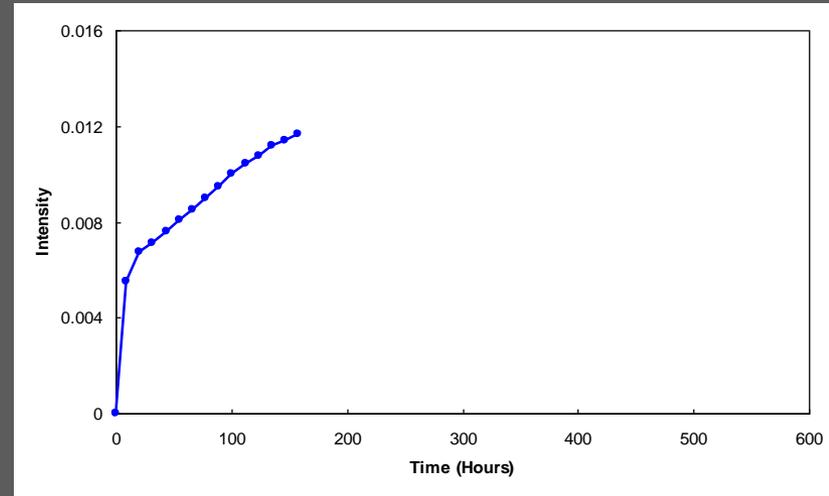
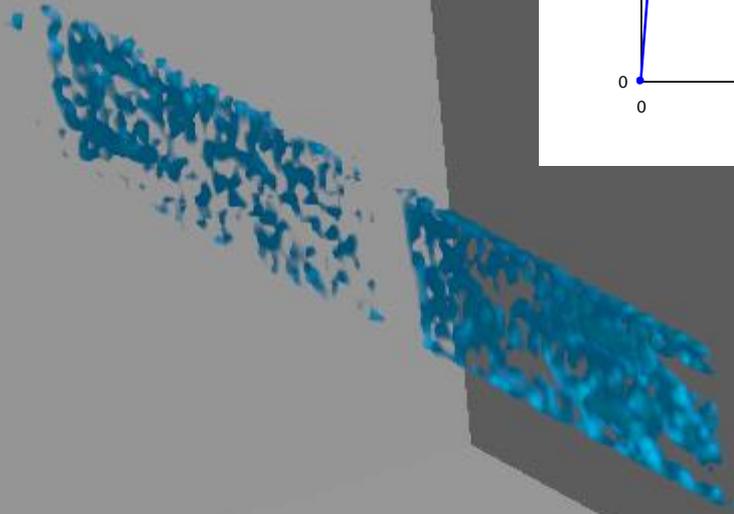
34b-12

146.4 hrs



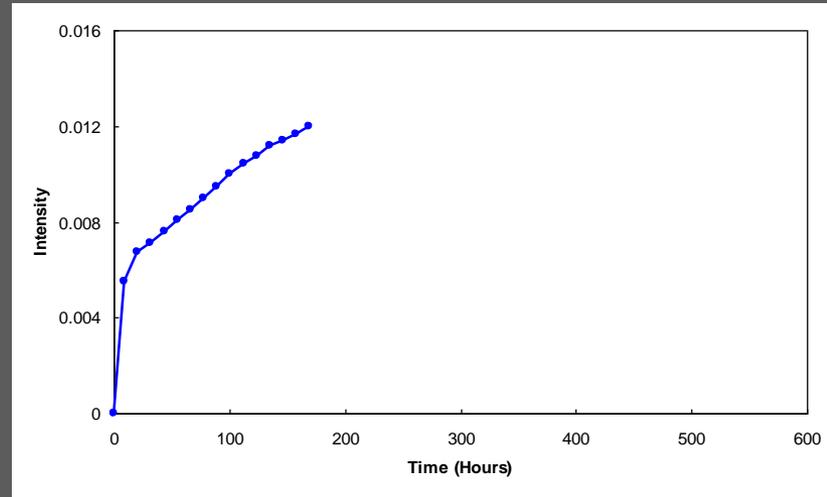
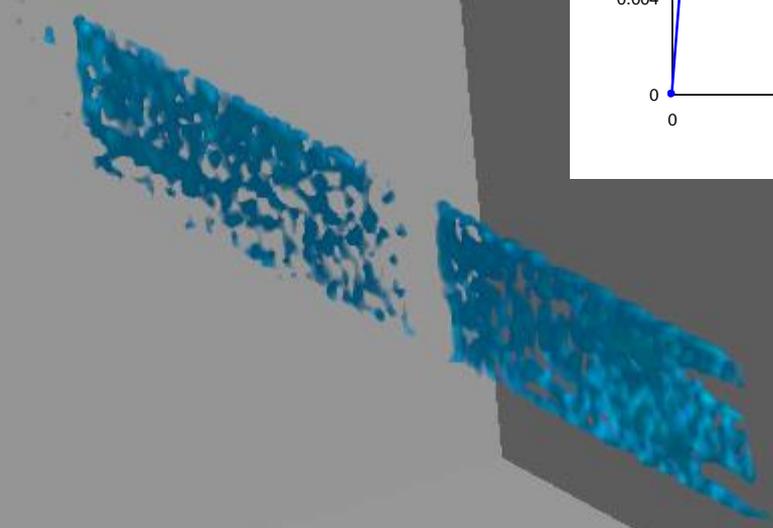
34b-13

157.8 hrs



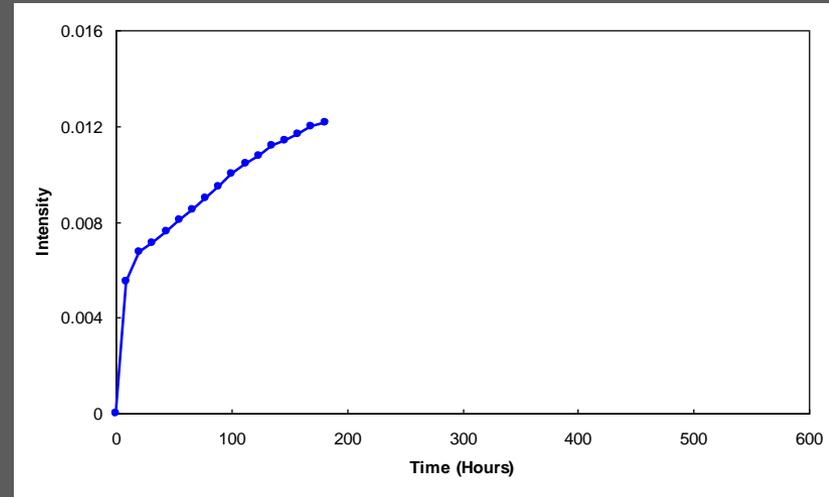
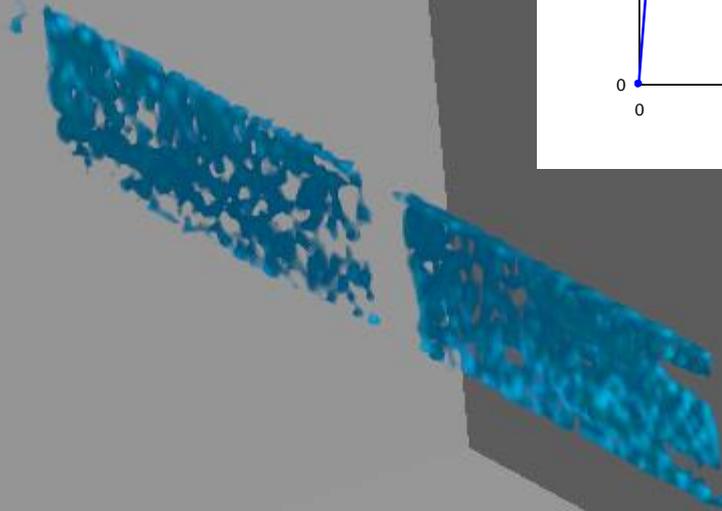
34b-14

169.3 hrs



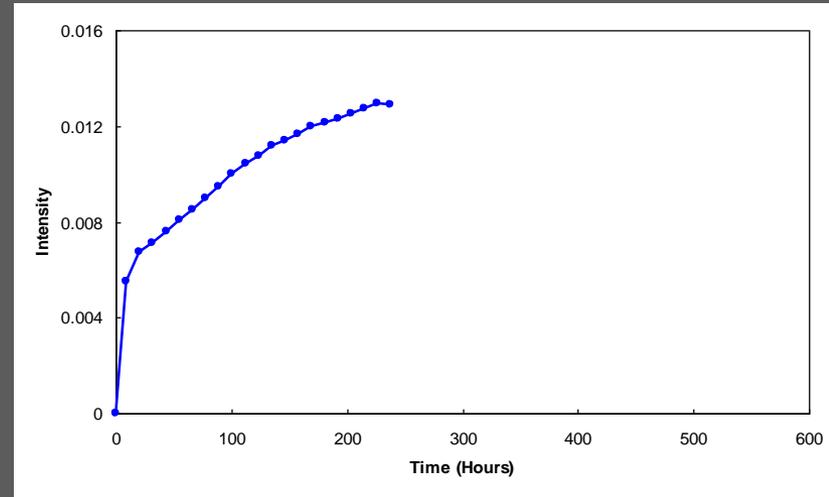
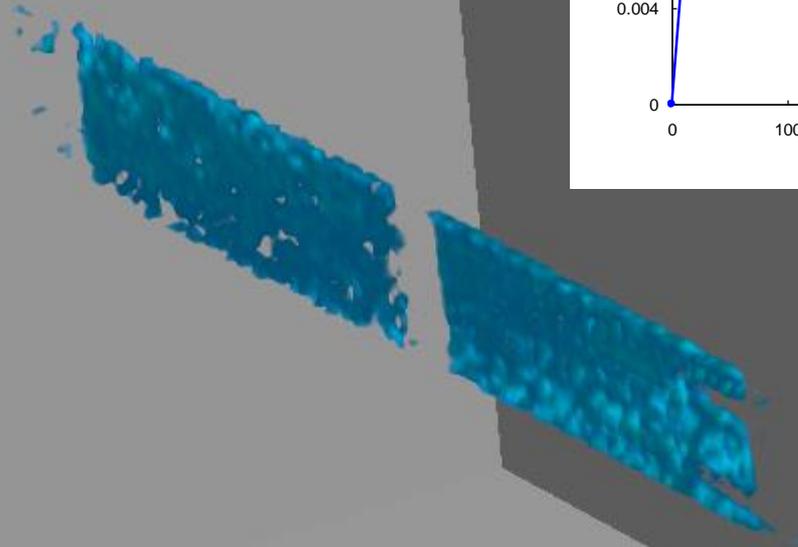
34b-15

180.7 hrs



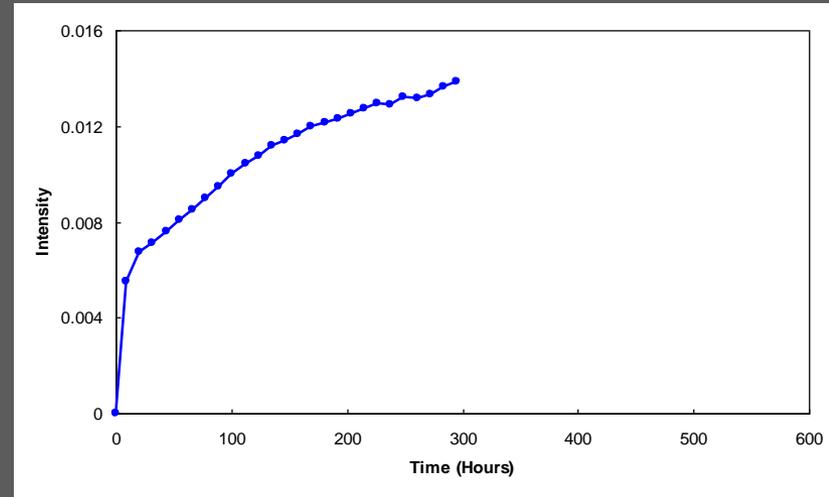
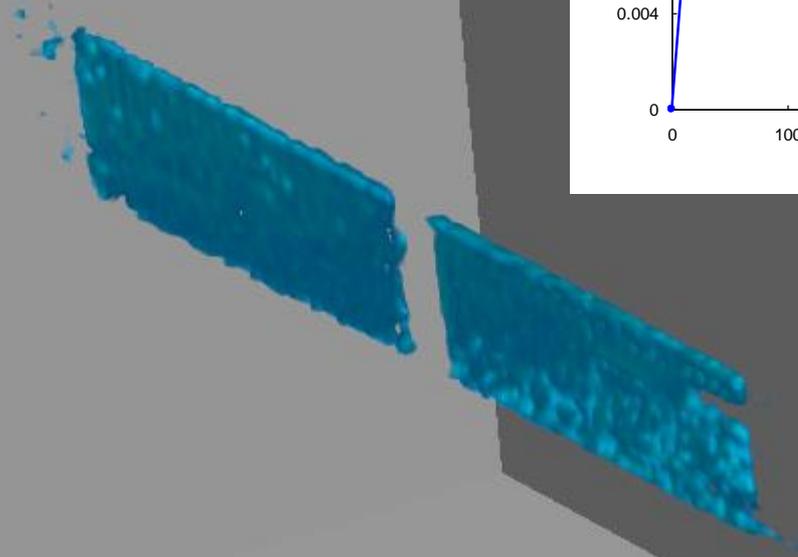
34b-20

237.9 hrs



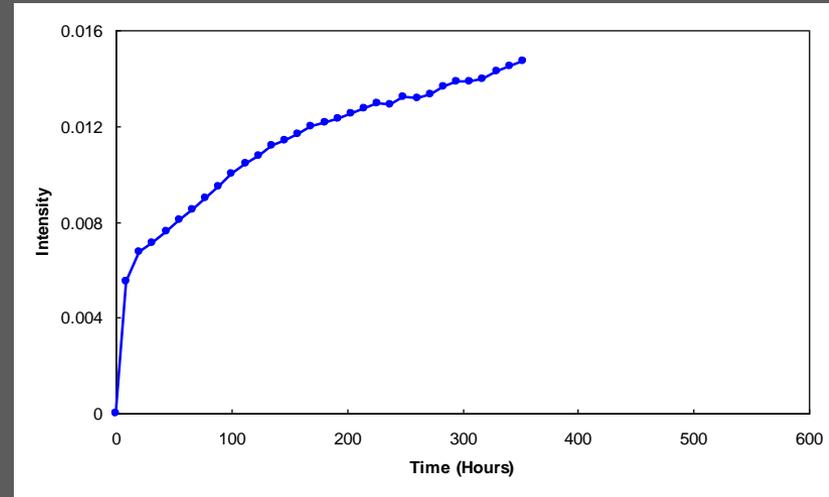
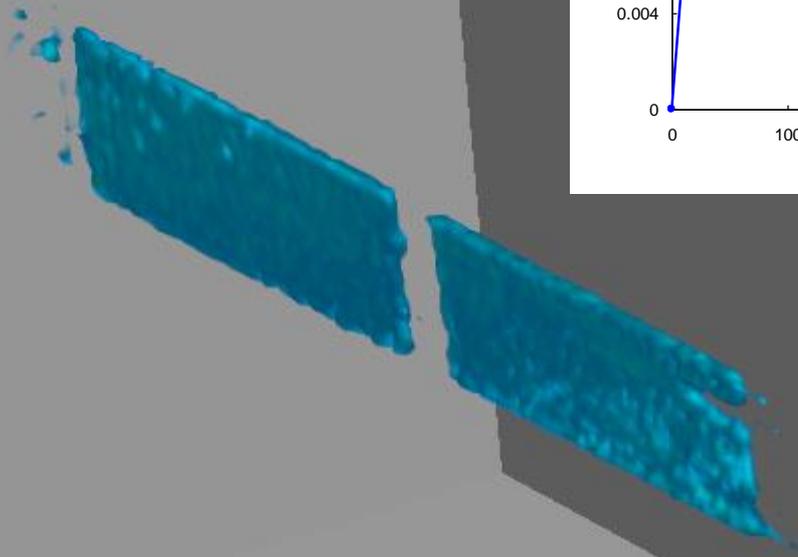
34b-25

295.1 hrs



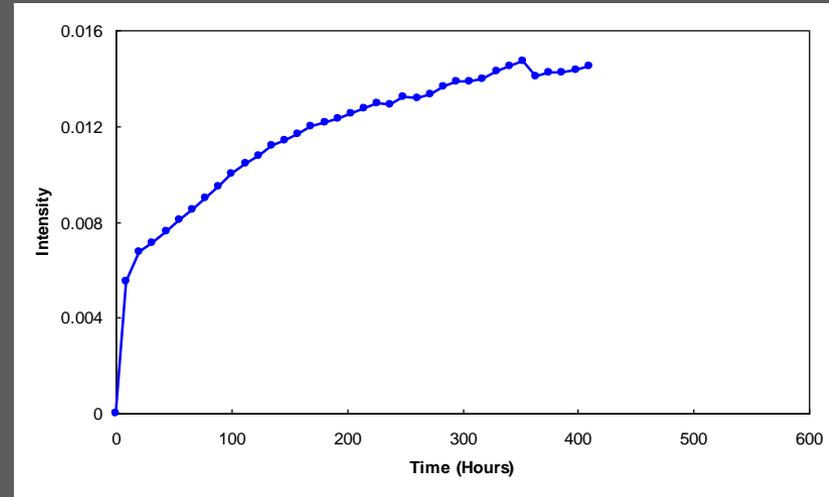
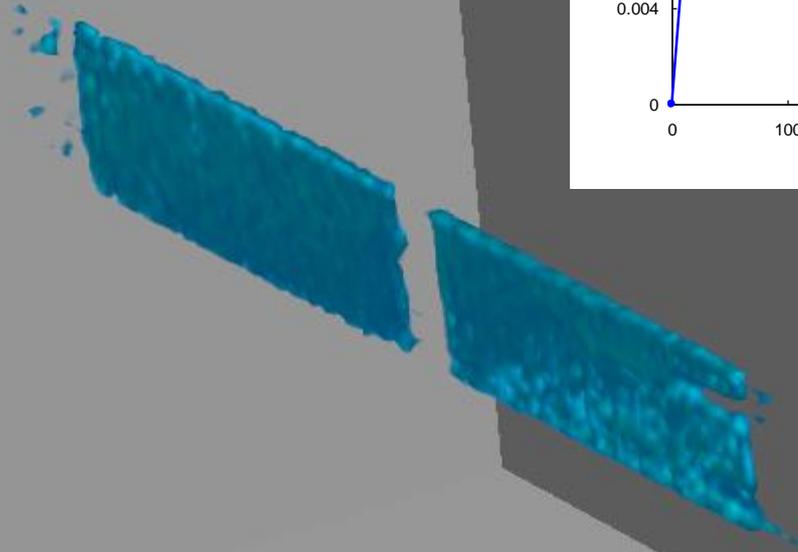
34b-30

352.3 hrs



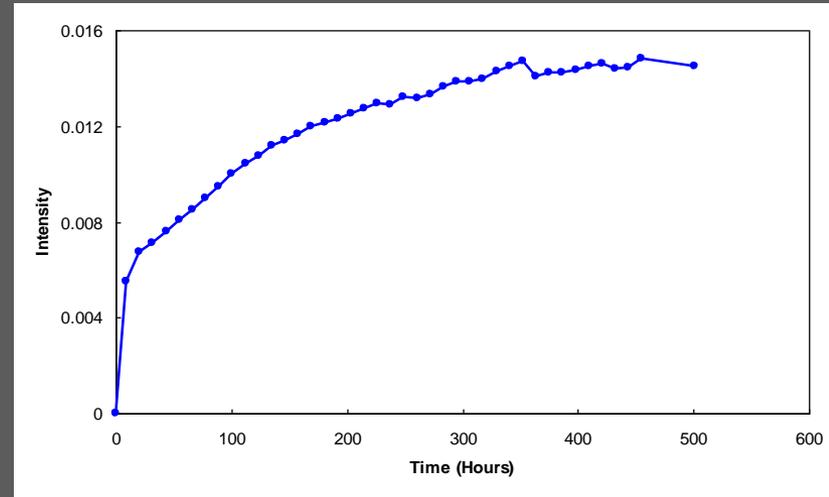
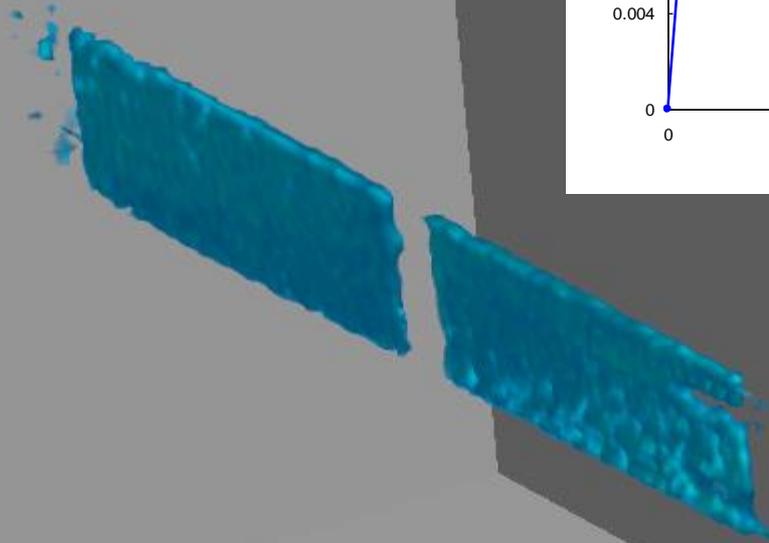
34b-35

409.5 hrs



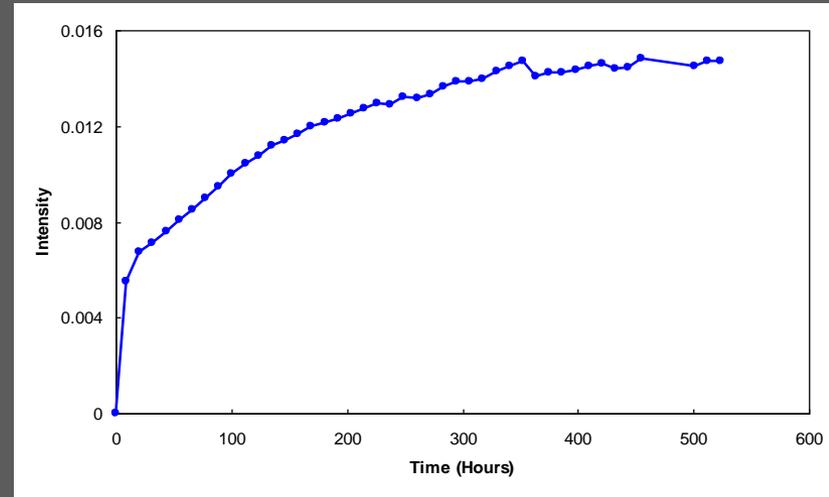
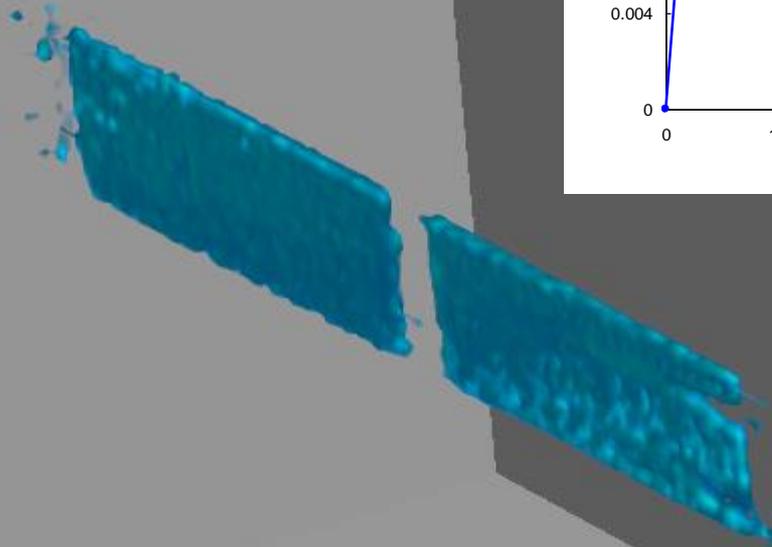
34b-40

501.0 hrs



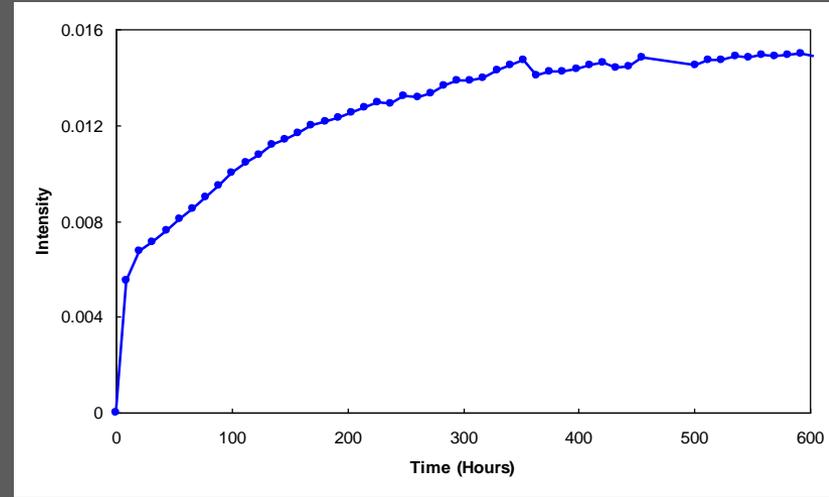
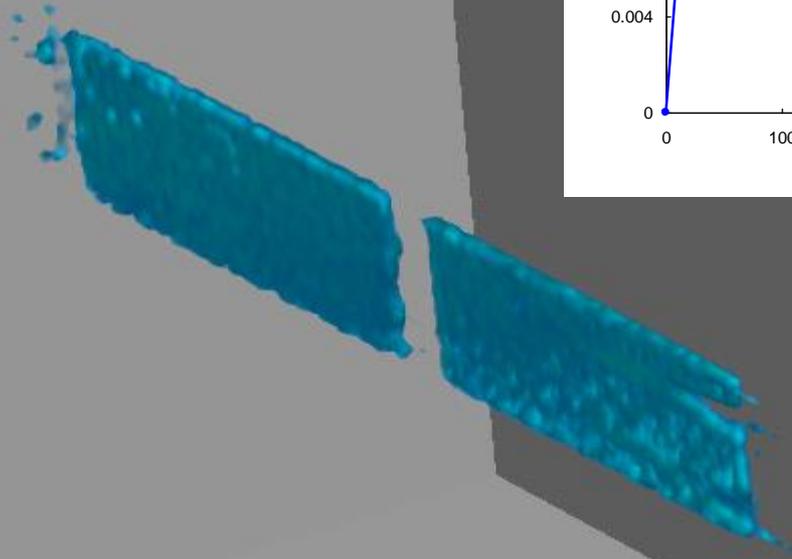
34b-45

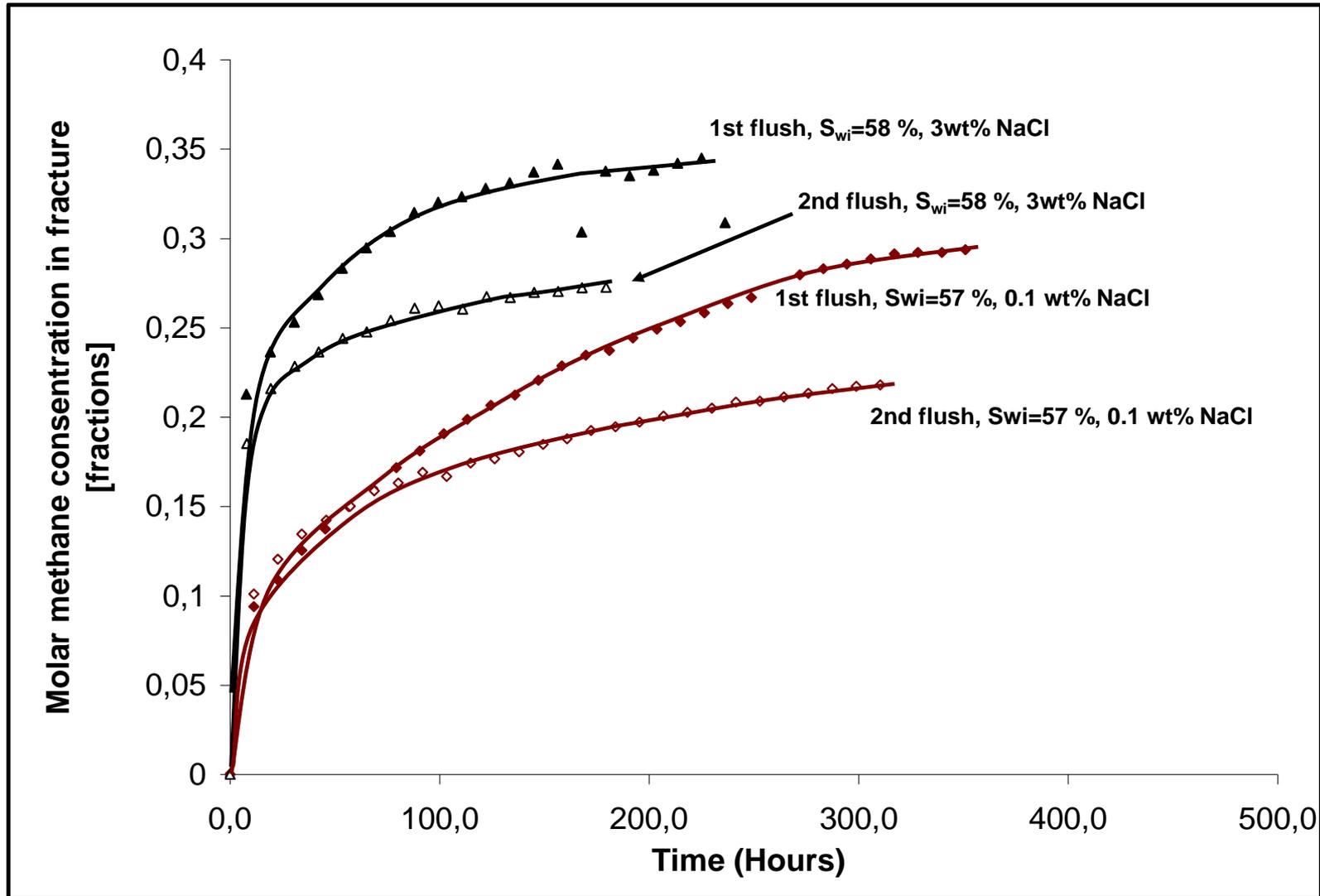
523.8 hrs



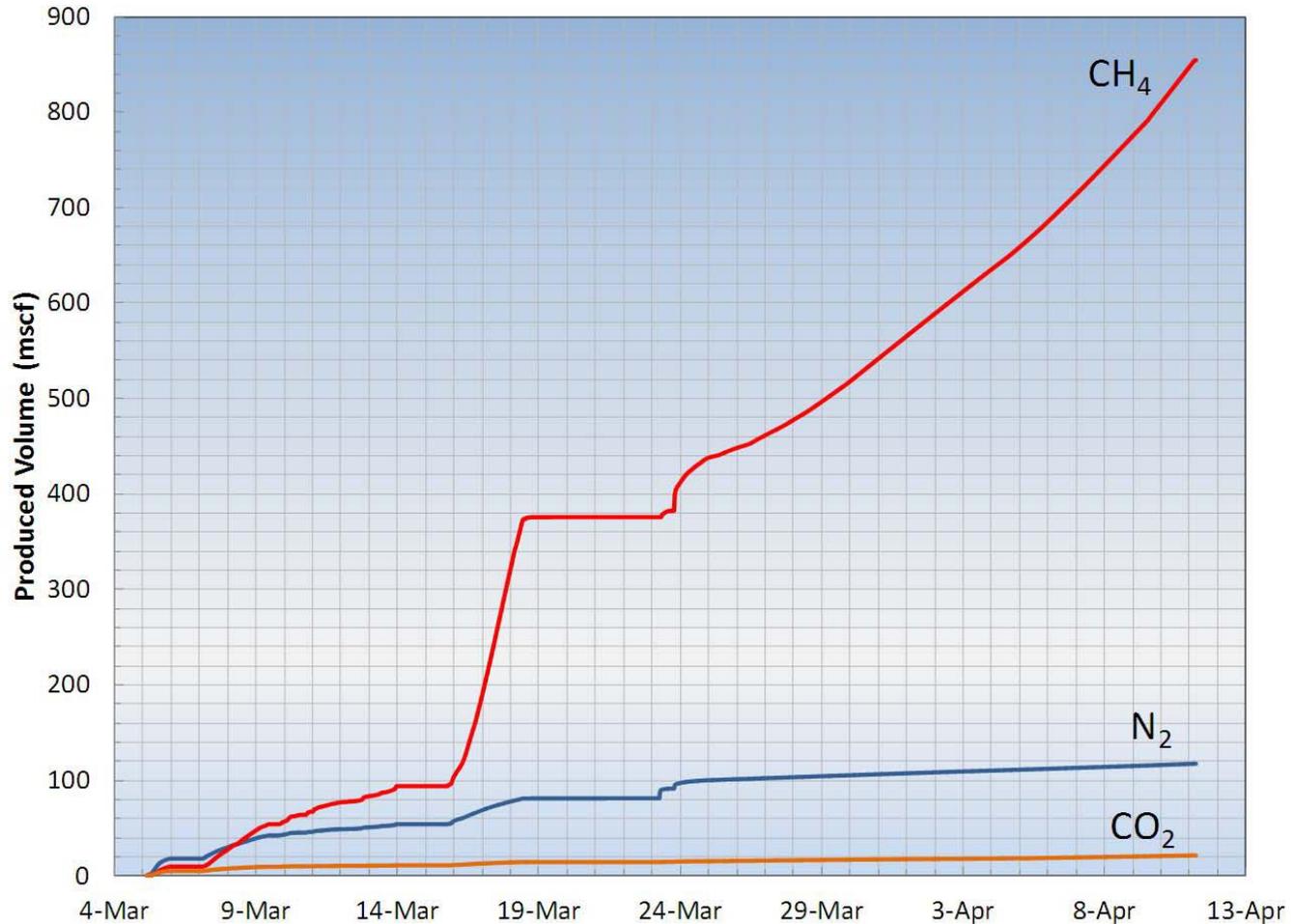
34b-52

603.9 hrs





# Gas Production from the Field Test



## Ignik Sikumi #1 Flowback/Drawdown: Gas composition

Schoderbek, 2012





UNIVERSITY OF BERGEN  
*Department of Physics and Technology*