Application of Stimulation Design to a Geothermal Project: The Draškovec Geothermal Pilot, Croatia*

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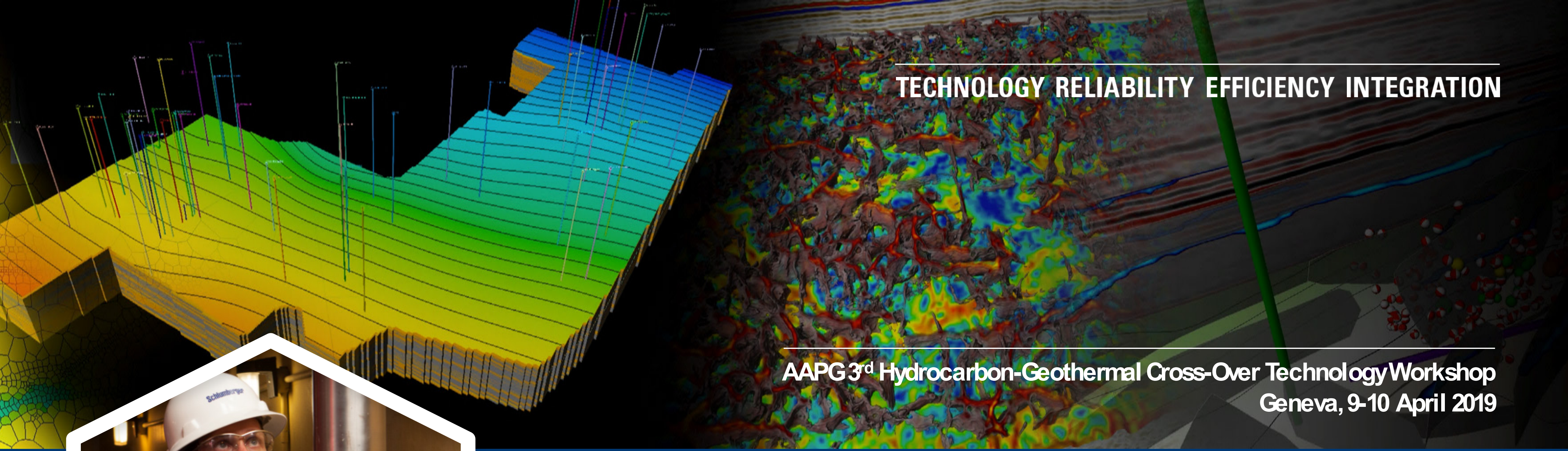
Abstract

The successful development and exploitation of a geothermal reservoir may have to rely on the enhancement of the natural permeability. This is typically achieved by stimulating the reservoir with the injection of high-pressure fluids. The oil and gas industry has used stimulation treatments to improve the production of petroleum reservoirs for decades. The techniques to develop specific stimulation fluids, to identify the stimulation targets, the design of the stimulation jobs and the operating procedures and tools have already been applied in several geothermal projects in Europe. We will present here an application of the use of reservoir modeling to design and optimize a stimulation treatment in a sandstone formation, as well as the forecast of the resulting production. This study demonstrates the successful use in a geothermal context of a software developed for the stimulation of unconventional hydrocarbons.

A hydraulic fracturing design and optimization study was carried out for one well in the Draškovec geothermal field in Croatia. The option of a "classical" hydraulic fracturing uncertainty study, disregarding geomechanics and using standard reservoir engineering software, was discarded in favour of a two-step approach: hydraulic fracturing design and optimization using a dedicated software, followed by production forecasting with a compositional reservoir simulator. Firstly, the stimulation intervals were selected based on the porosity observed in the wells. The propagation of hydraulic fractures was modeled based on the stress profile in the wells, so to maximize the lateral extent. Subsequently, the forecast of the production of water and natural gas and of the reinjection of water and CO_2 was simulated for a period of 25 years, comparing scenarios with or without stimulation treatment.



TECHNOLOGY RELIABILITY EFFICIENCY INTEGRATION

AAPG 3rd Hydrocarbon-Geothermal Cross-Over Technology Workshop
Geneva, 9-10 April 2019

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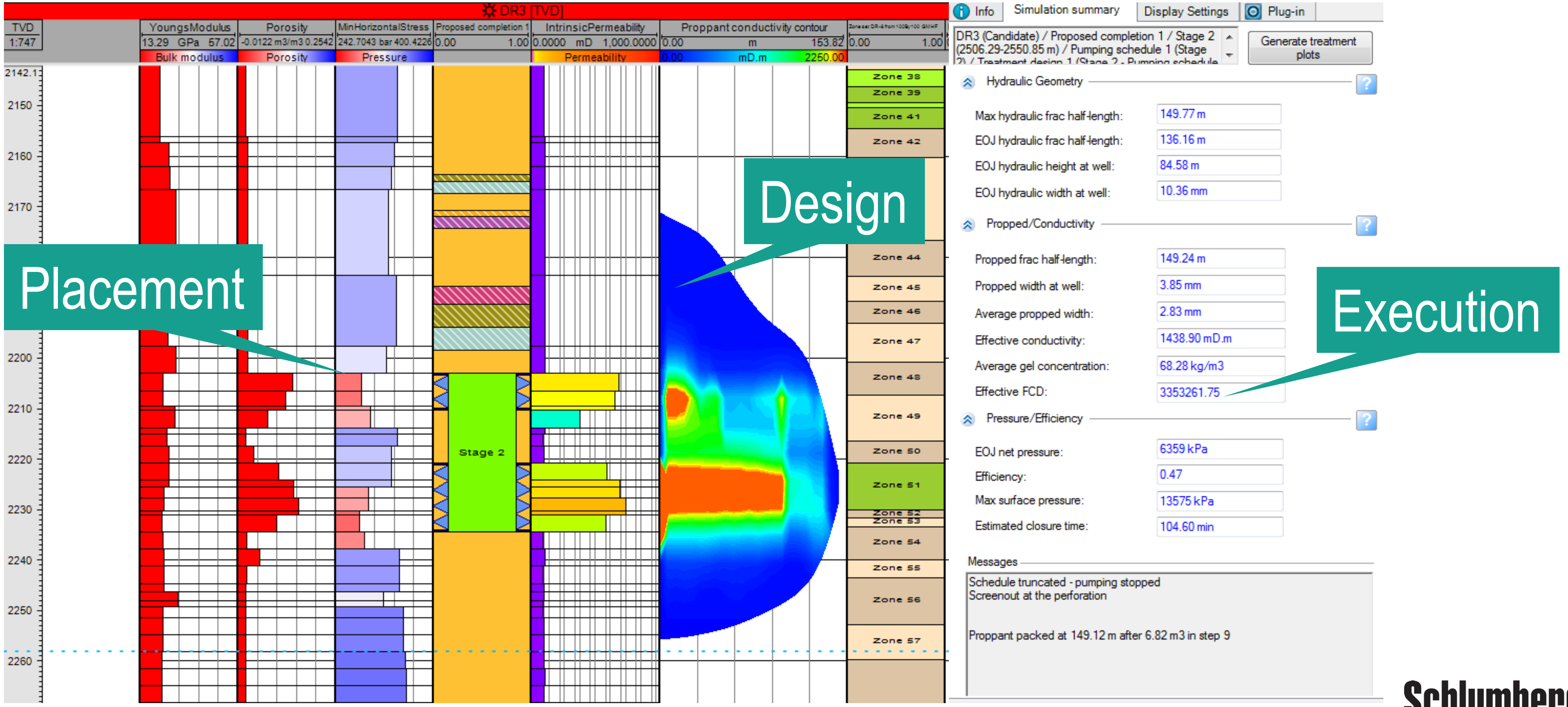
Stimulation “cross-overs”…



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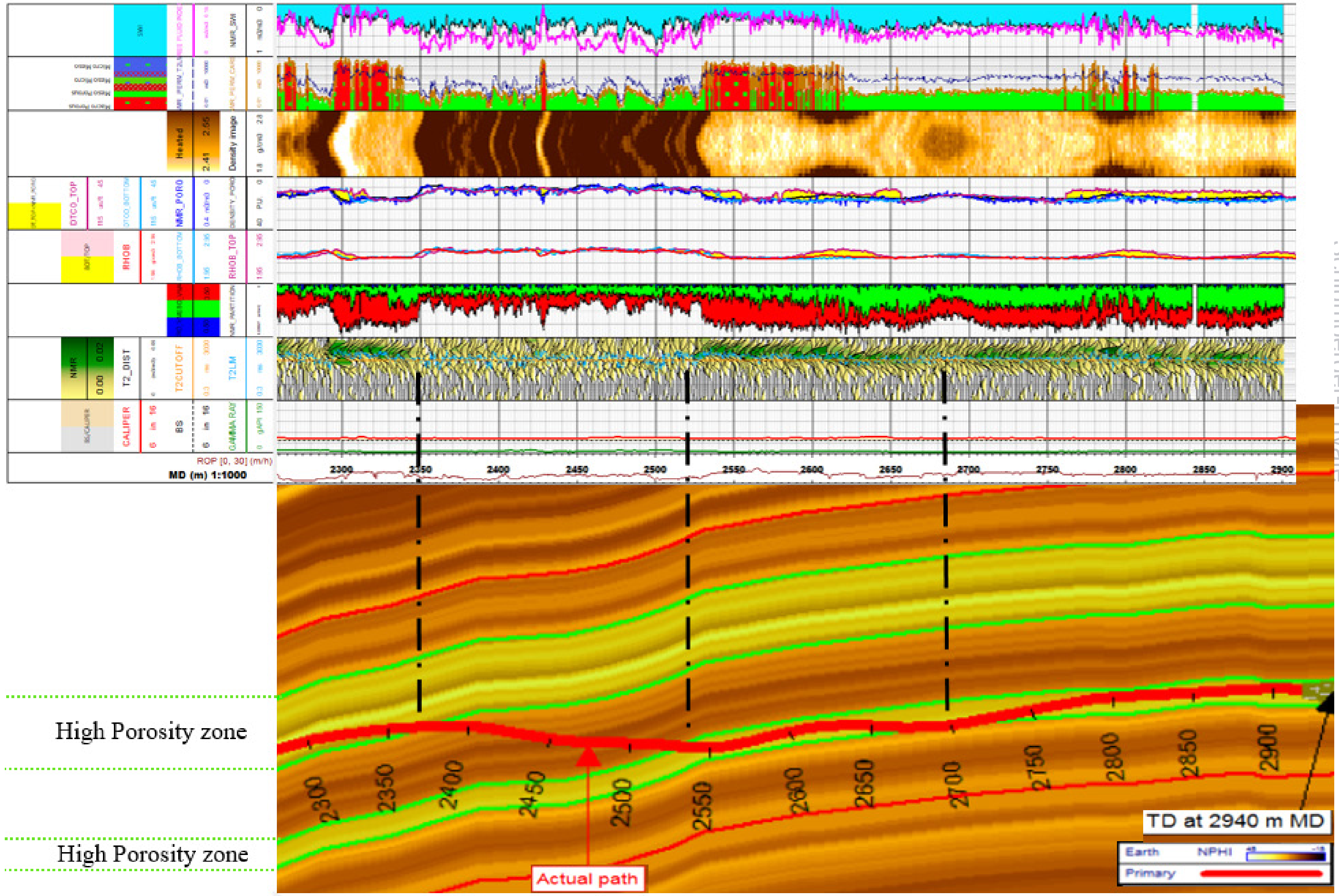
Stimulation placement

Advanced wireline logging

Case study: Cachan, France

- Heterogeneous carbonates, known but exploited uneffectively
- Correlation of porosity/permeability from advanced logs (sonic, NMR) allowed defining stimulation intervals
- Coiled tubing stimulation → 60% increase of flow rate
- 1 new doublet outperformed the 2 “traditional” doublets



Correlation of wireline logs

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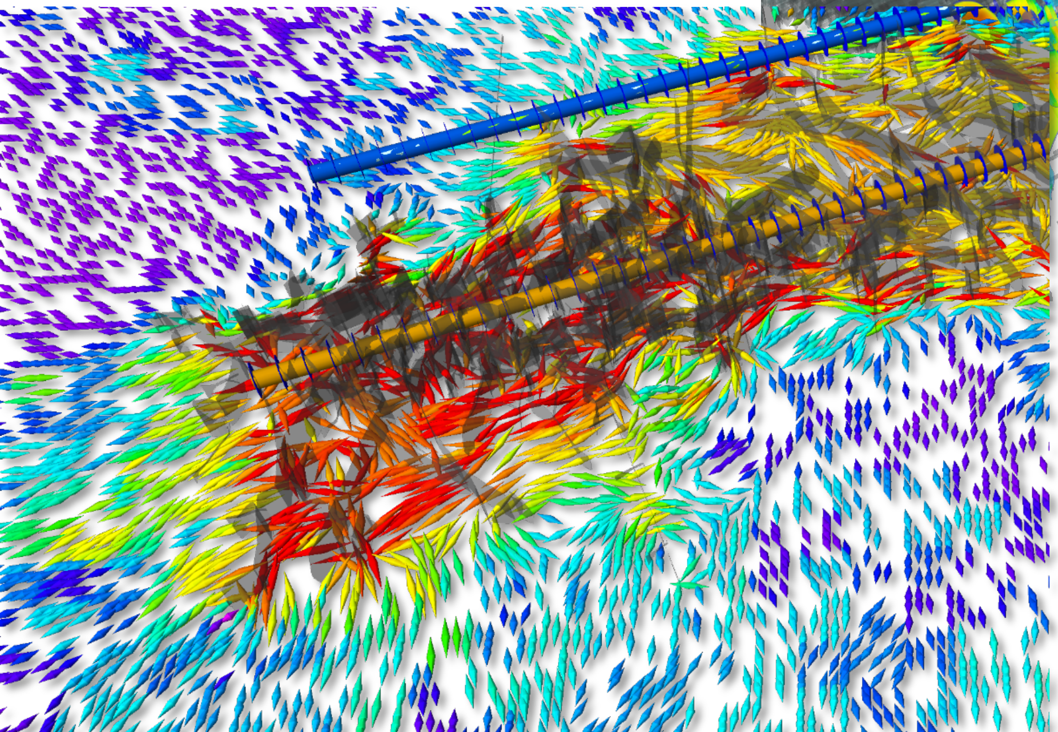
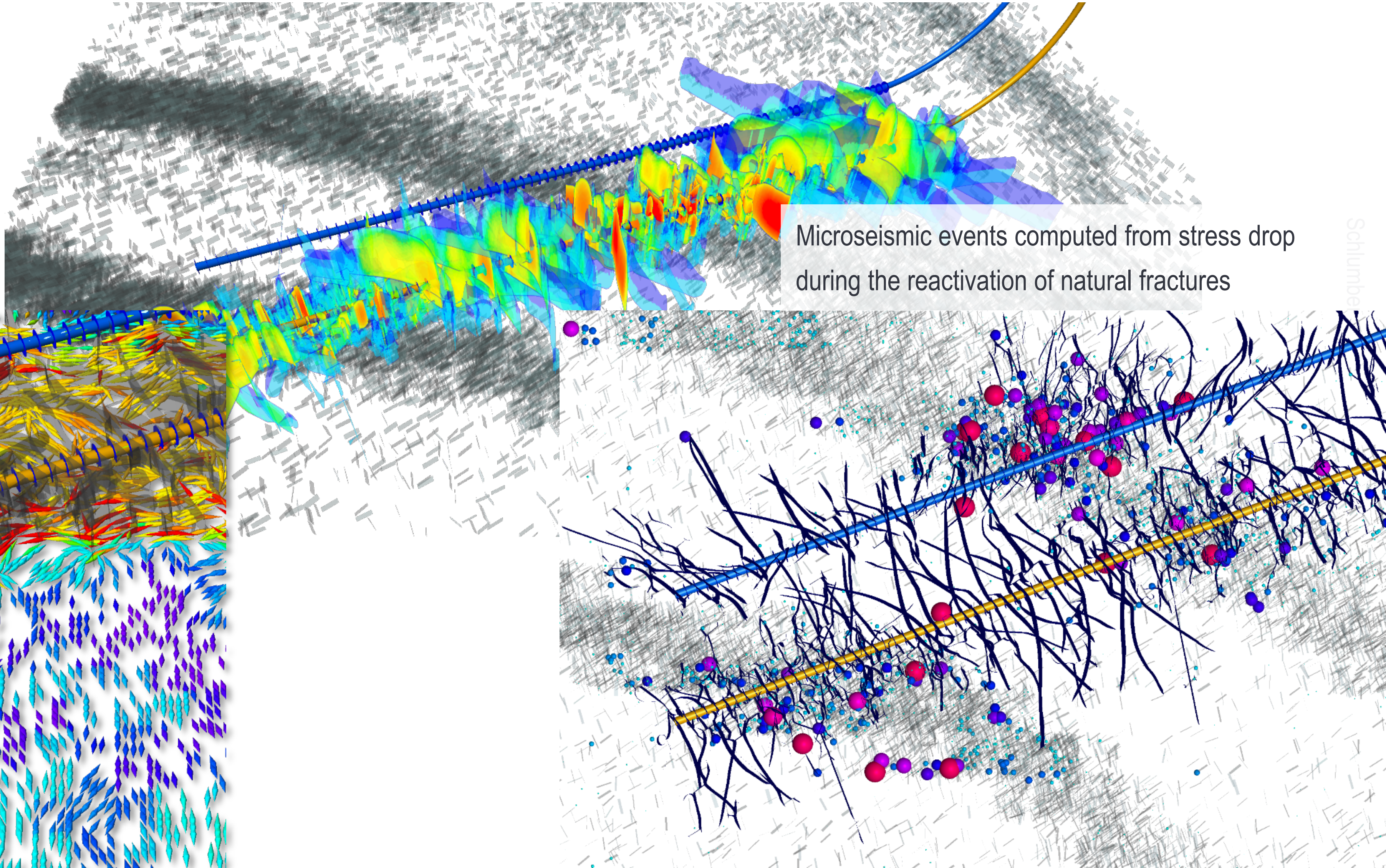
Stimulation design

Fracture modeling with geomechanics

UFM fracture simulation:
interaction of hydraulically-induced with pre-existing natural fractures

Prediction of 3D stress field changes (magnitude and orientation) during stimulation/production





Microseismic events computed from stress drop during the reactivation of natural fractures

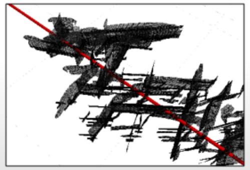
Stimulation design

Fracture modeling with geomechanics

Stimulation

T_0

Hydraulic Fracture Simulation



Fracture geometry
& fracture pressure
as stimulation result

Stimulation execution
New “green” fluid formulations

Pre-Improvement (2010)

Former Product	Overall Regulatory Rating
Friction Reducer	OPE, REACH regulated
Clay Stabilizer	N – R50; T – R25
Surfactant	T - R39/23/24/25
Biocide	N- R51/ R52
Temperature Stabilizer	N - R51/53
Crosslinker	T - R60; R61
Solvents	T

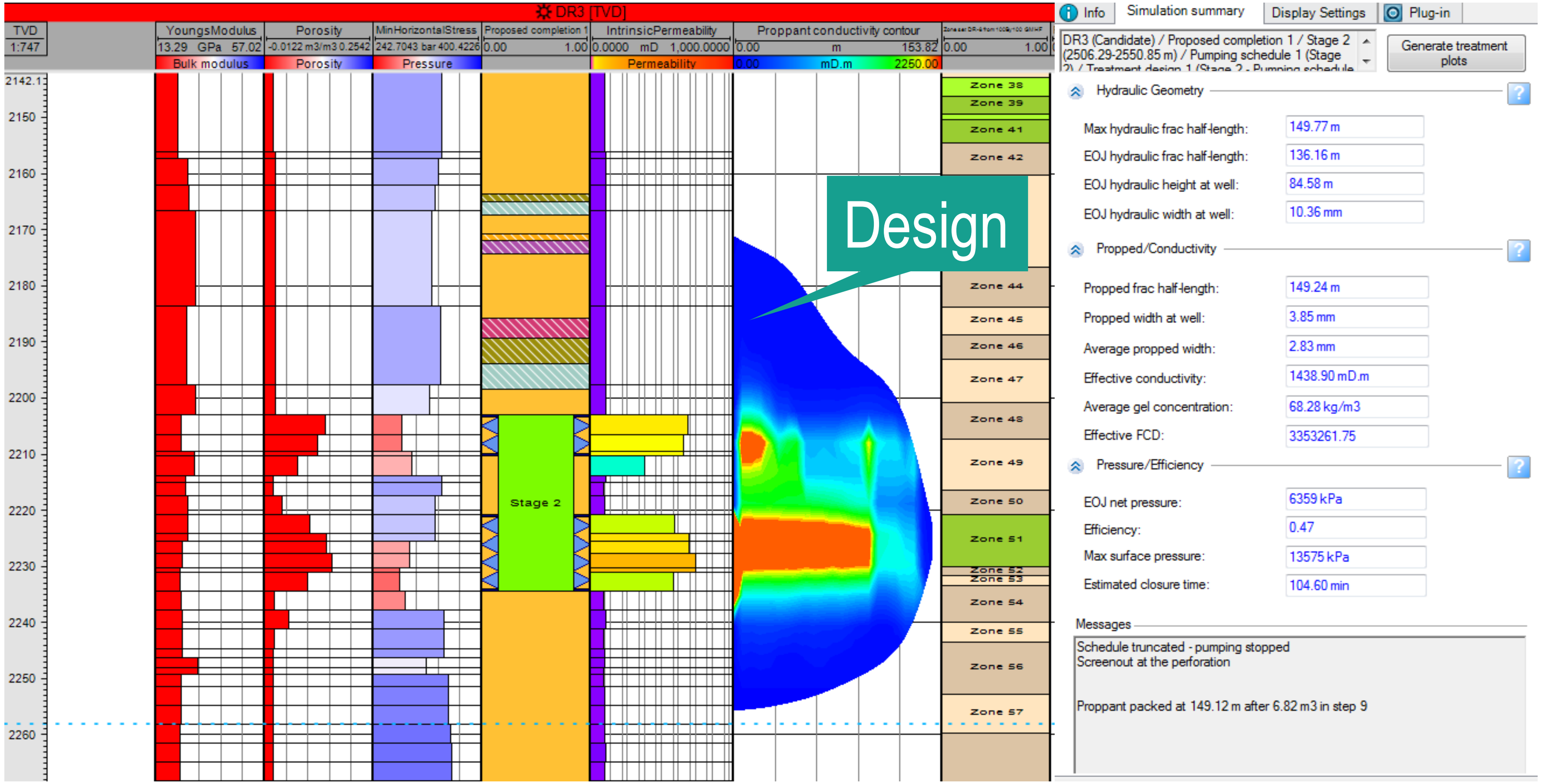
New Formulations (2014)

Replacement Product	Overall Regulatory Rating
Friction Reducer	Xi – Irritant
Clay Stabilizer	-
Surfactant	Xi – Irritant
Biocide	Xn- Harmful
High Temperature Stabilizer	-
Crosslinker	Xi- Irritant
Eliminated	

Continuous Improvement with the goal:

- No toxic chemicals (T)
- No chemicals hazardous to the environment (N)

Stimulation "cross-overs"…



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Stimulation design: a case study

Draškovec, Croatia

- Hydraulic fracturing design and optimization studies for 1 geothermal well
- Discarded "classical" hydraulic fracturing uncertainty study
  (i.e. disregarding geomechanics and using standard reservoir simulator)
  in favour of the following approach:

  1. Hydraulic fracturing design and optimization using a dedicated software
  2. Production forecasting with compositional simulator

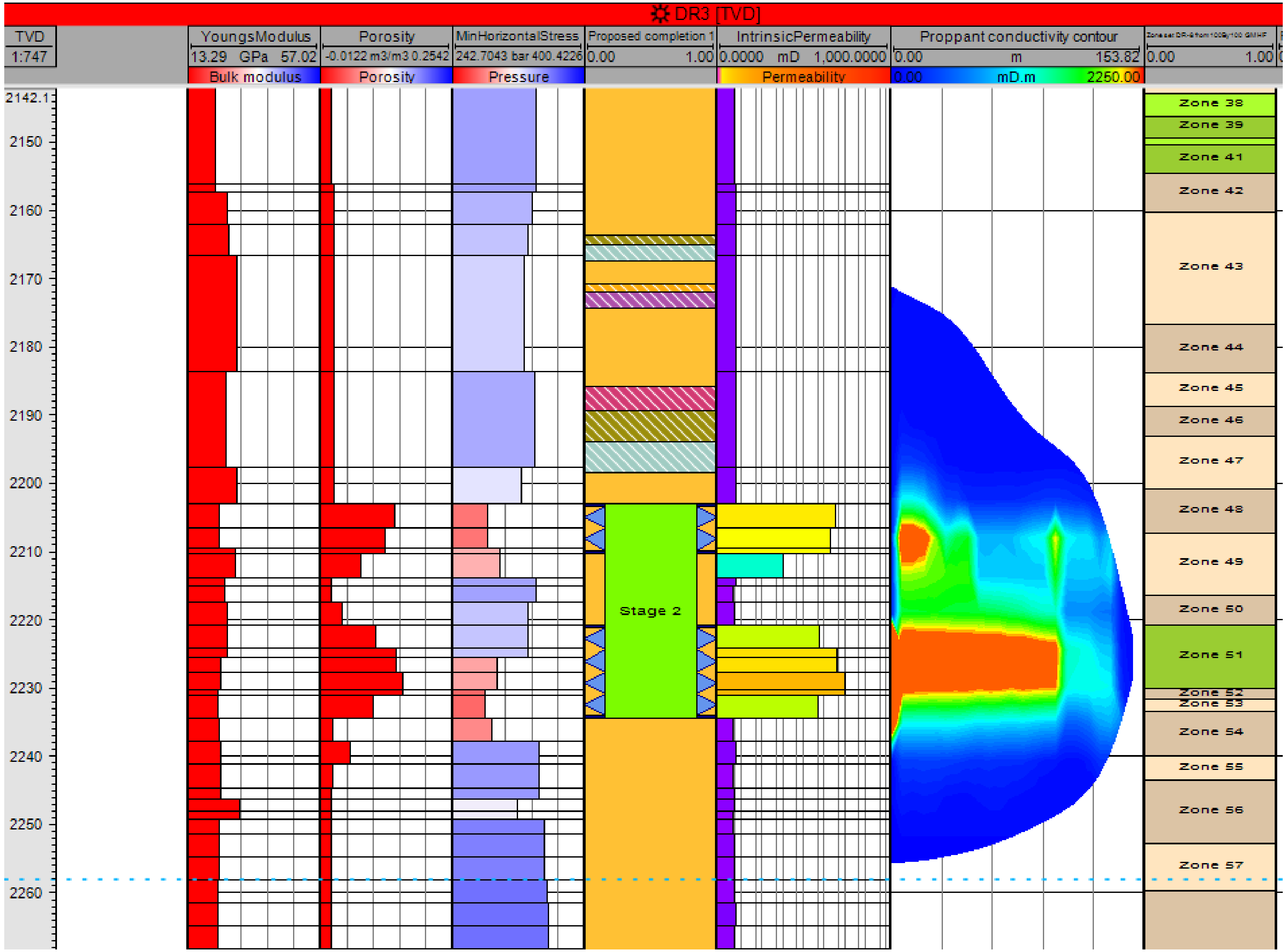
- Reservoir development scheme of the Draškovec geothermal field:
  4 wells (2 water/gas producers + CO_2 injectors)

1. Hydraulic Fracturing Design

Geomechanical Properties

1. Hydraulic Fracturing Design

Design Results: DR-3 Stage 2



Info | Simulation summary

DR3 (Candidate) / Proposed completion 1 / S... (2506.29-2550.85 m) / Pumping schedule 1 (Stage 2) / Treatment design 1 (Stage 2 - Pumping schedule

Generate treatment plots

Frac fluid, proppant, pumping rates… (per stage)

Hydraulic Geometry

Max hydraulic frac half-length:	149.77 m
EOJ hydraulic frac half-length:	136.16 m
EOJ hydraulic height at well:	84.58 m
EOJ hydraulic width at well:	10.36 mm

Propped/Conductivity

Propped frac half-length:	149.24 m
Propped width at well:	3.85 mm
Average propped width:	2.83 mm
Effective conductivity:	1438.90 mD.m
Average gel concentration:	68.28 kg/m3
Effective FCD:	3353261.75

Pressure/Efficiency

EOJ net pressure:	6359 kPa
Efficiency:	0.47
Max surface pressure:	13575 kPa
Estimated closure time:	104.60 min

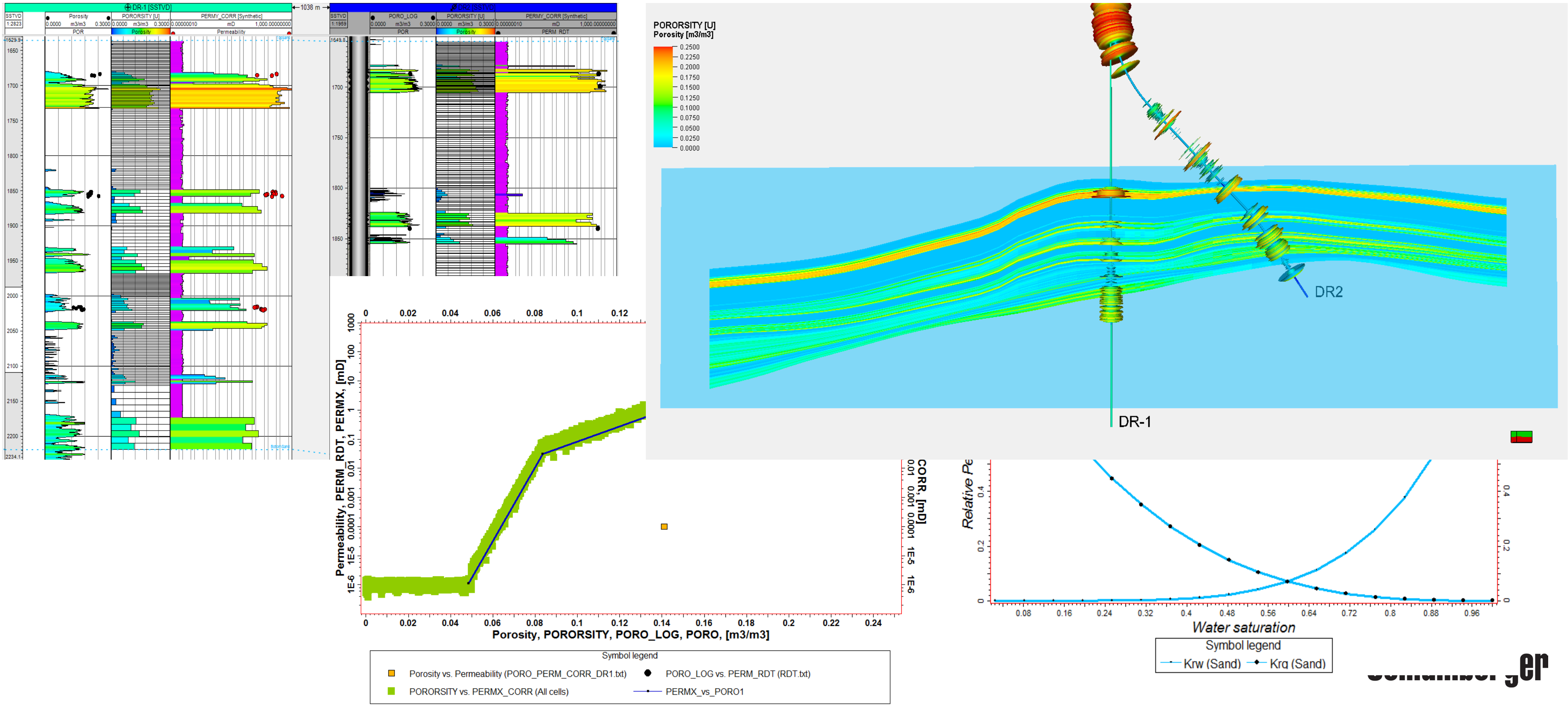
Messages

Schedule truncated - pumping stopped
Screenout at the perforation

Proppant packed at 149.12 m after 6.82 m3 in step 9

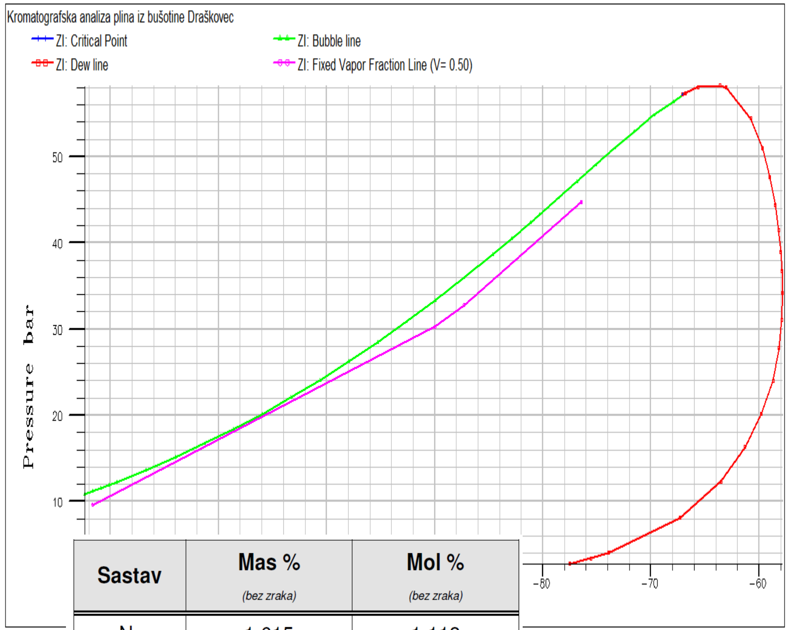
2. Production forecast

Reservoir model: Porosity and permeability

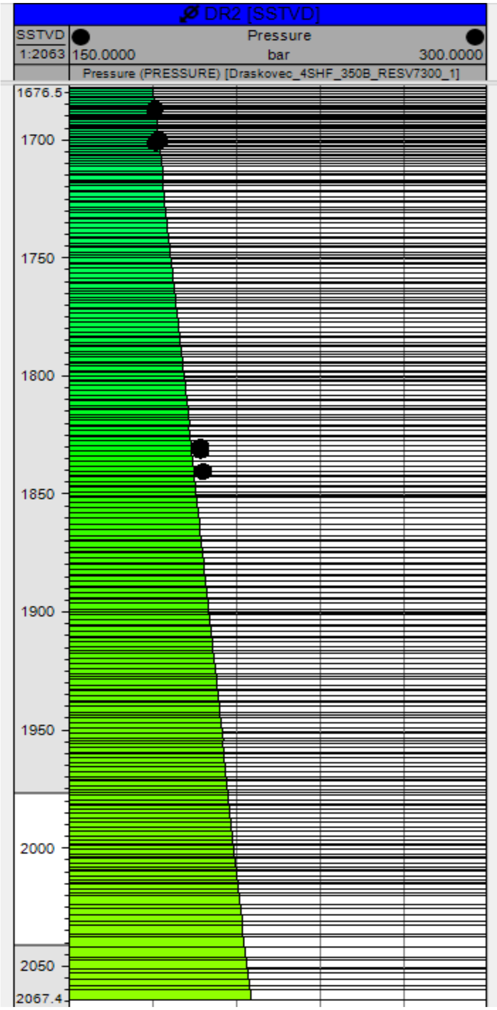


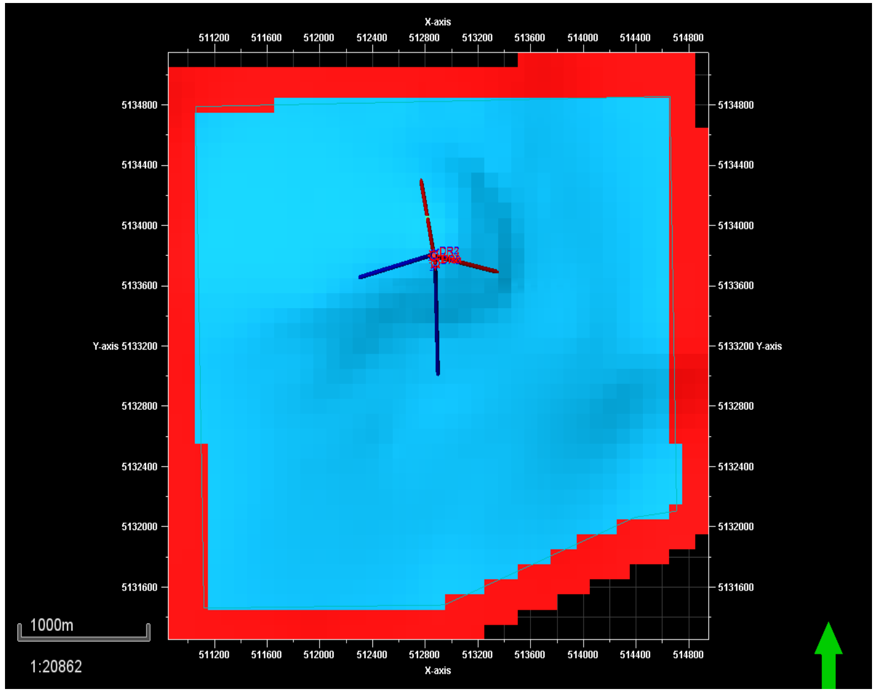
2. Production forecast

Dynamic model initialization and set-up



Sastav	Mas % (bez zraka)	Mol % (bez zraka)
N_2	1,615	1,113
CO_2	23,251	10,198
C_1	72,586	87,338
C_2	1,461	0,938
C_3	0,578	0,253
i-C_4	0,241	0,080
n-C_4	0,139	0,046
i-C_5	0,086	0,023
n-C_5	0,030	0,008
C_{6+}	0,013	0,003





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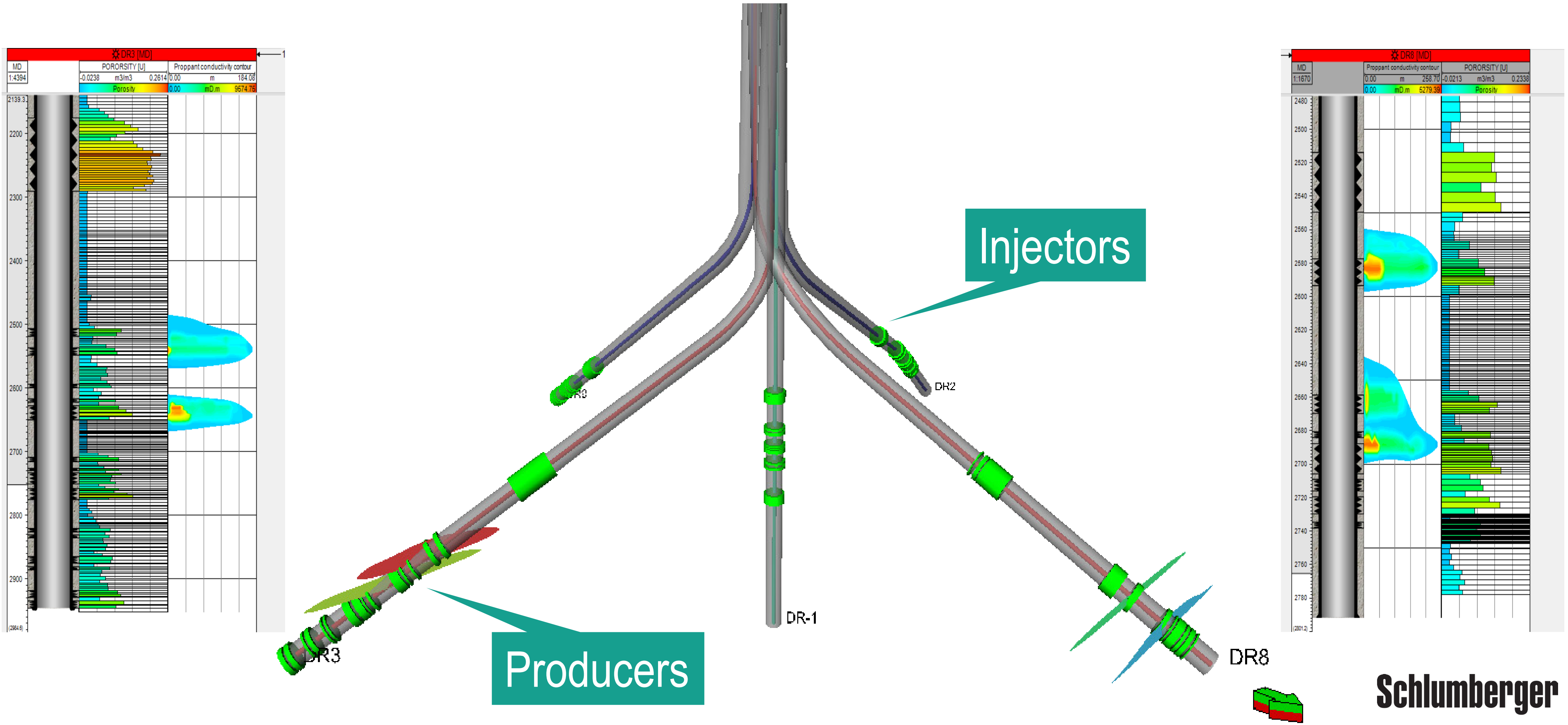
2. Production forecast

Dynamic model: perforation intervals and fracturing stages



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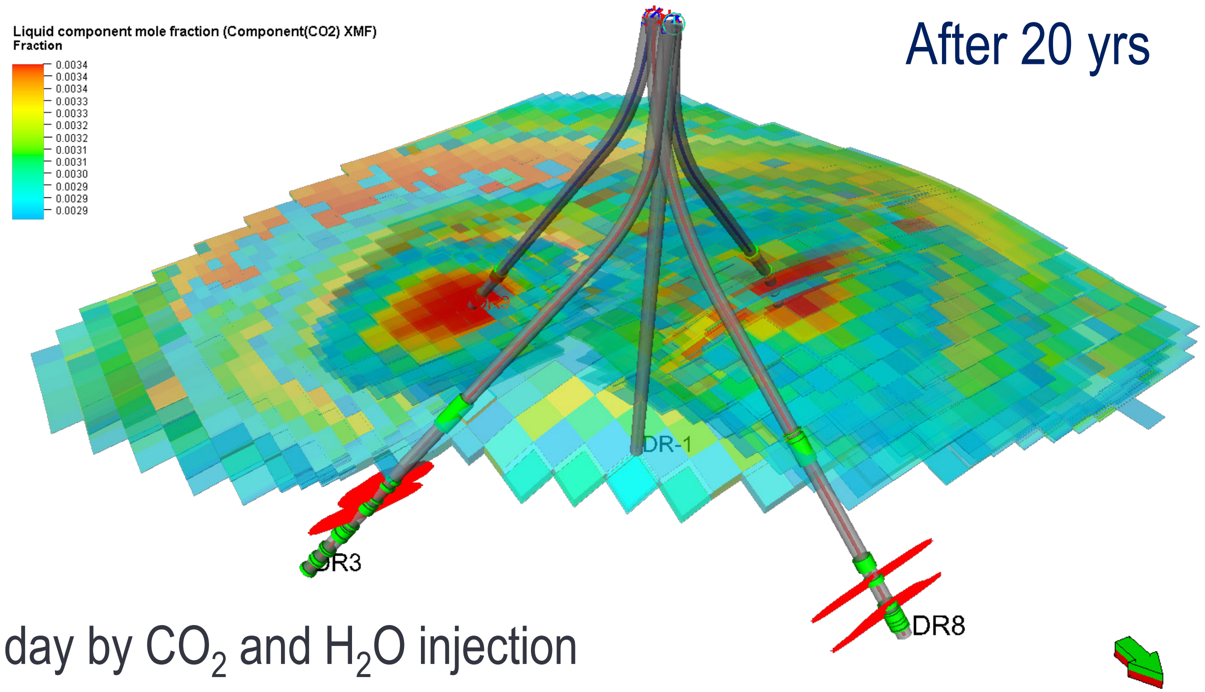
2. Production forecast

Subsurface development scenario: Base Case



Producers

- Two producers: DR3 and DR8
- Prediction period is 25 years
- Water Production Rate per well: 7300 sm³/d

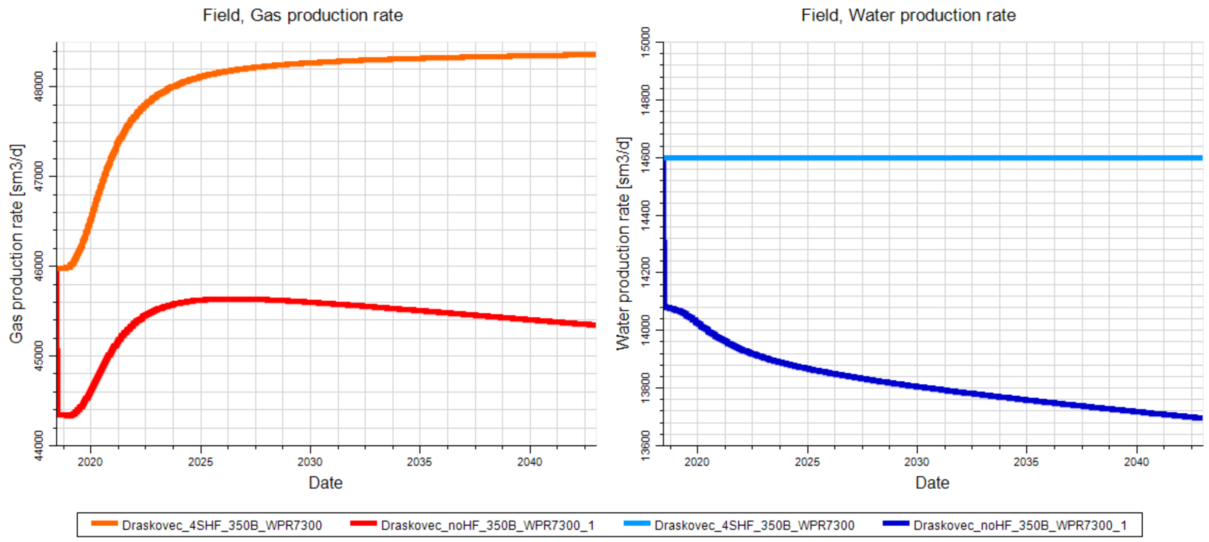
Injectors

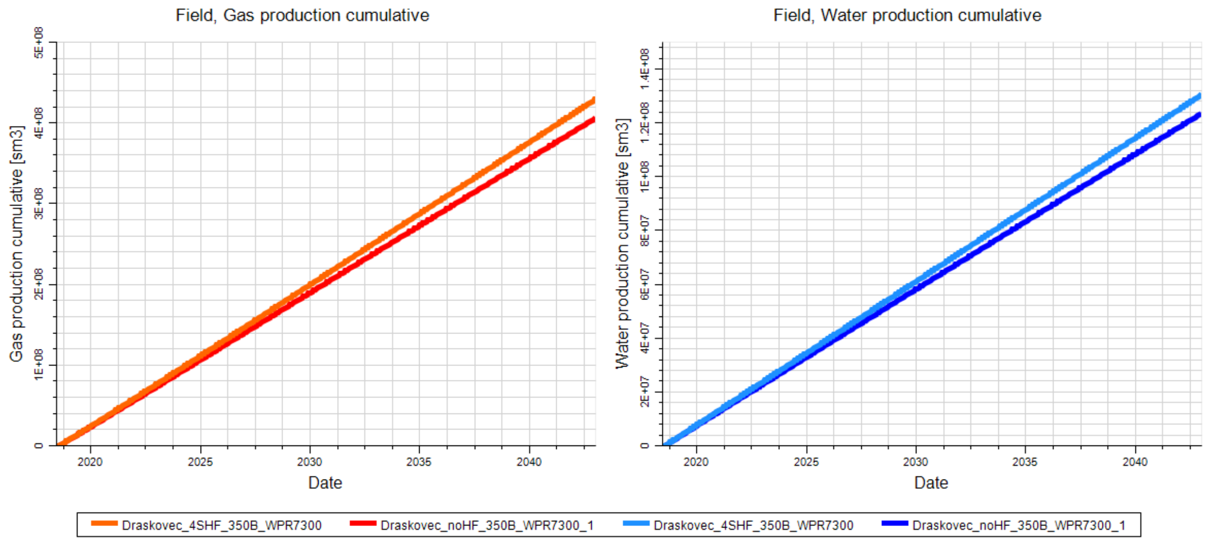
- Two CO_2 and H_2O injectors :DR2 and DR9
- Reservoir pressure maintenance planned from the first day by CO_2 and H_2O injection
- Reservoir Injection Rate per well: 7300 rm³/d
- CO_2 Volume to be injected per well: between 23850 and 26700 sm³/day
- Max injection BHP: 350 bars

2. Production forecast

Subsurface development scenario: Production Profiles

Cumulative Gas Production after 25 years: 131.1 Msm³ for the Hydraulically Fractured Case vs. 124.1 Msm³ for the non-stimulated case





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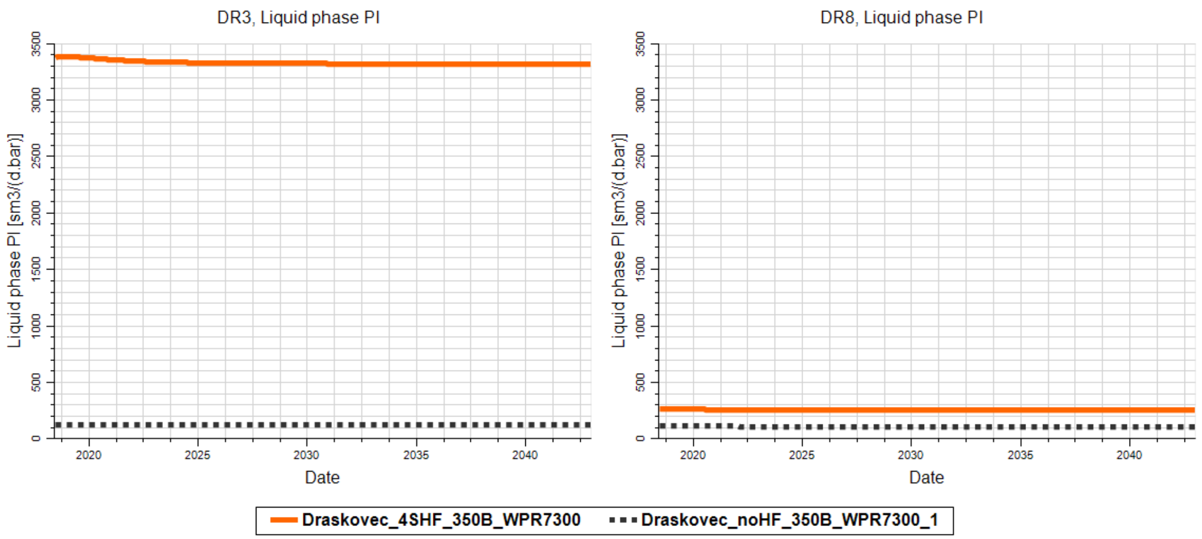
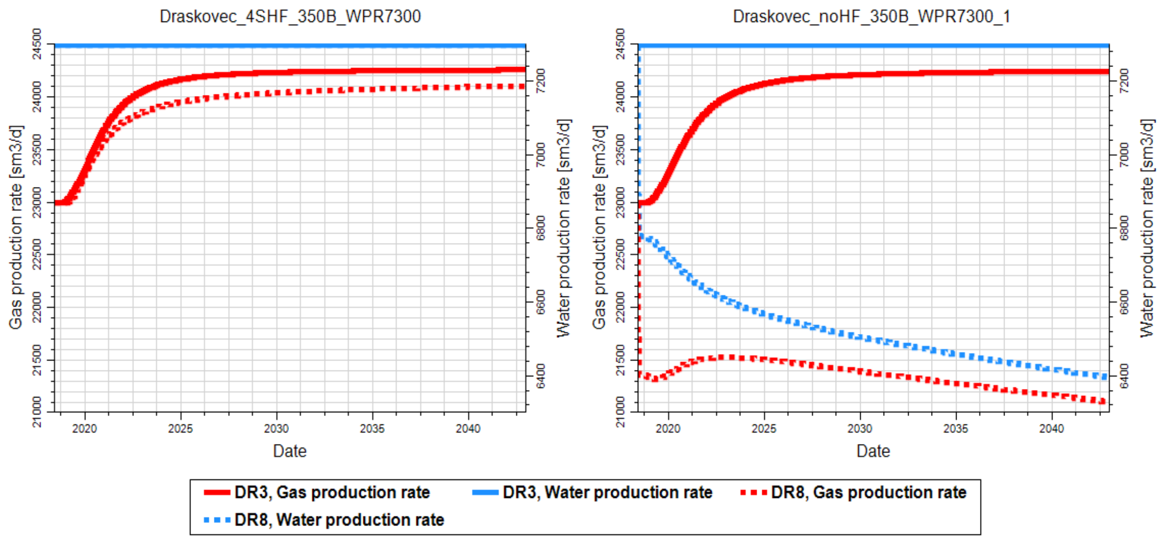
2. Production forecast

Subsurface development scenario: Productivity index

Draskovec_4SHF_350B_WPR7300		Draskovec_noHF_350B_WPR7300_1	
DR3	DR8	DR3	DR8
Liquid phase PI [sm3/(d.bar)]	Liquid phase PI [sm3/(d.bar)]	Liquid phase PI [sm3/(d.bar)]	Liquid phase PI [sm3/(d.bar)]
3380	268	221	115





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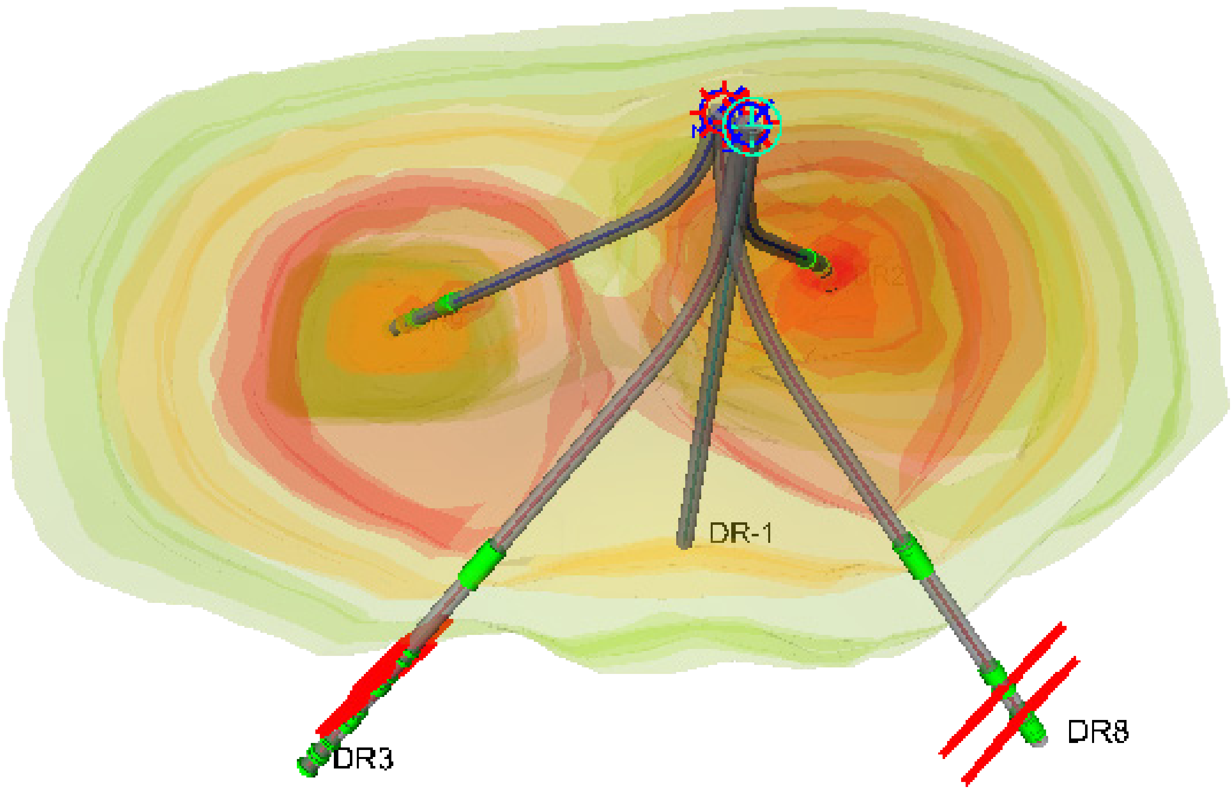
2. Production forecast

Subsurface development scenario: Injection profiles

CO_2 mole fraction vs time

	Show	Isovalue	Input
	Yes	0.0027	
	Yes	0.003	
	Yes	0.0034	



After 5 years of injection

2. Production forecast

Subsurface development scenario: Injection profiles

CO_2 mole fraction vs time

	Show	Isovalue	Input
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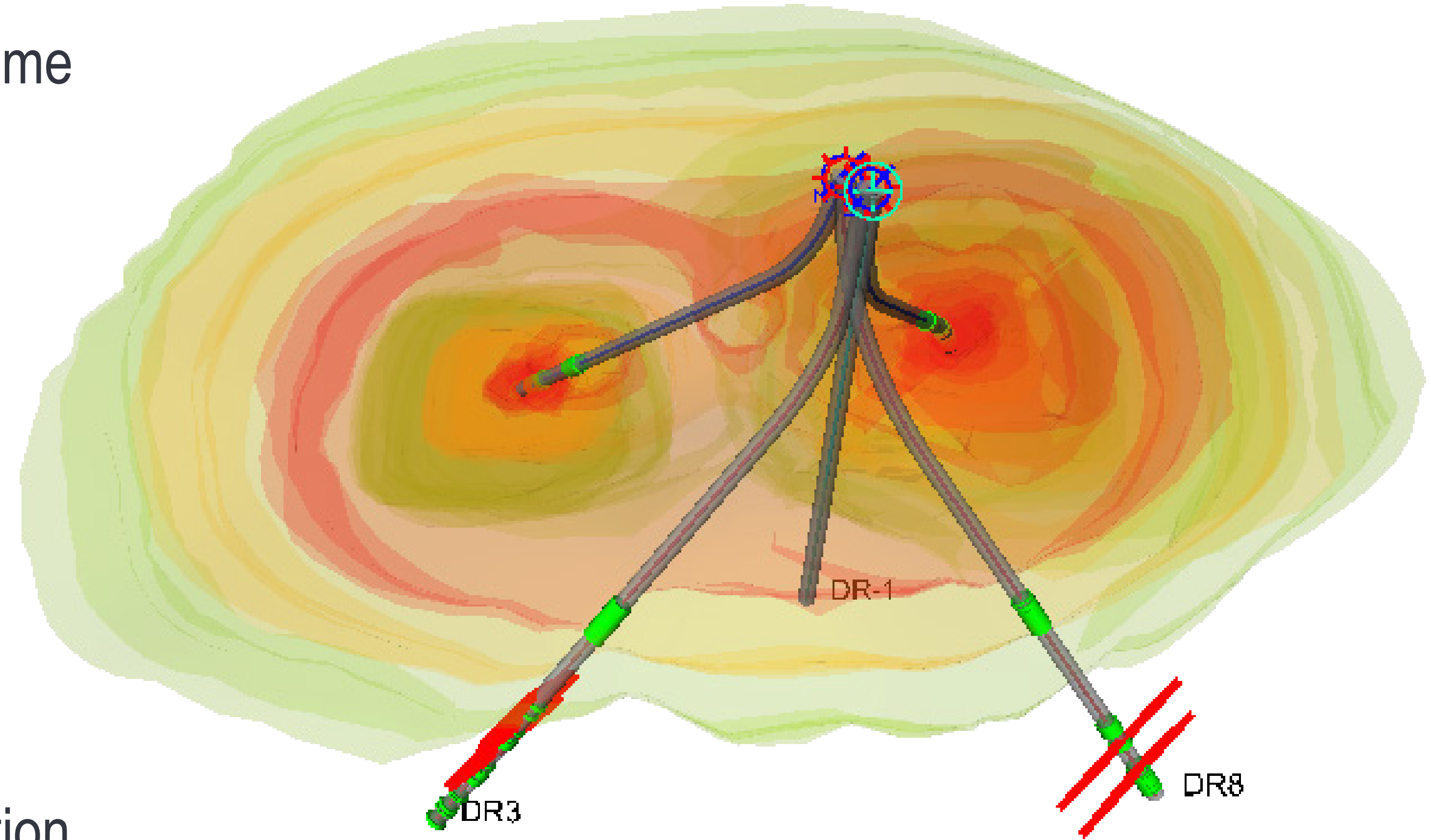
	Yes	0.003	
	Yes	0.0034	



After 10 years of injection

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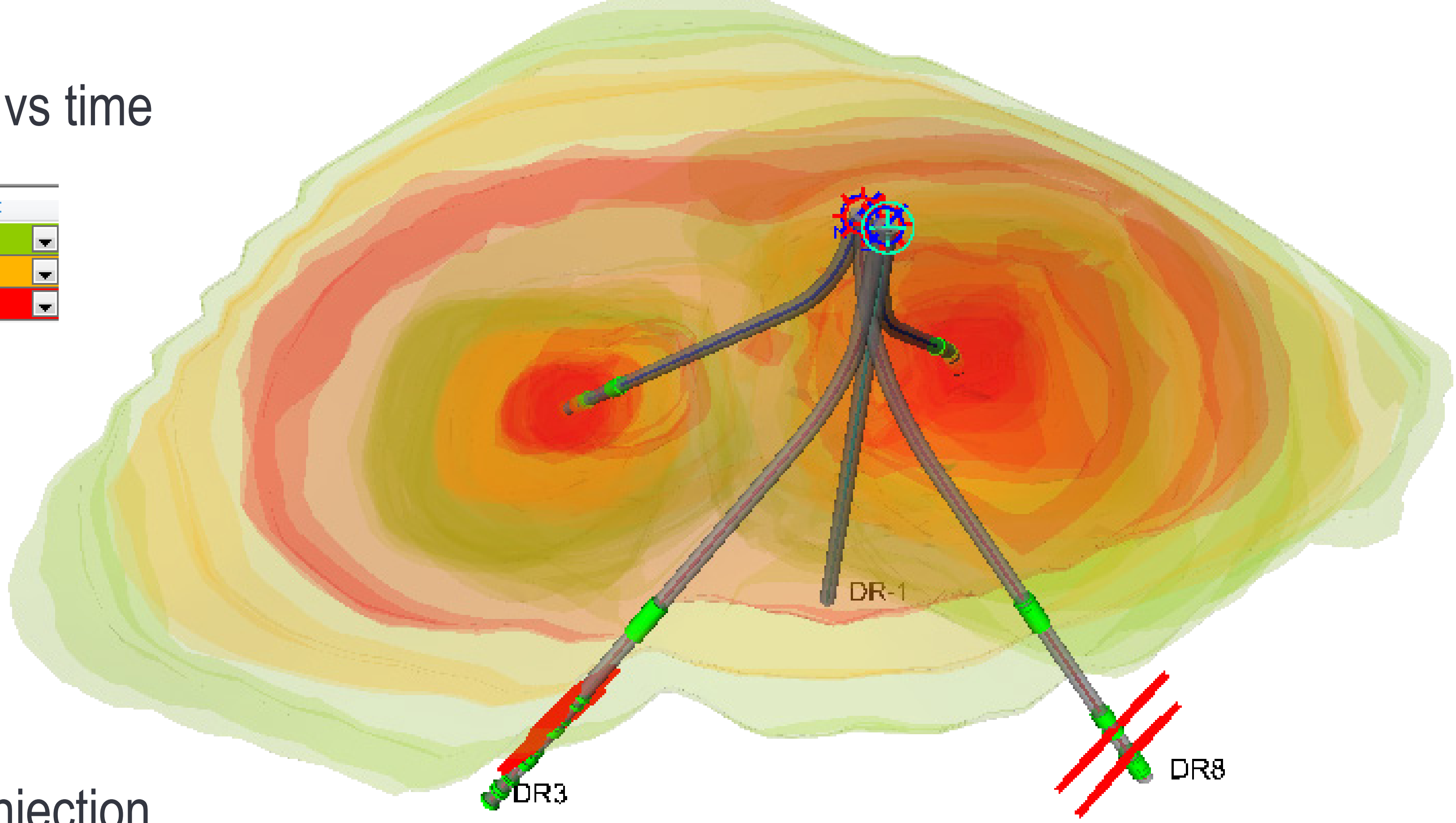
2. Production forecast

Subsurface development scenario: Injection profiles

CO_2 mole fraction vs time

	Show	Isovalue	Input
	Yes	0.0027	
	Yes	0.003	
	Yes	0.0034	



After 20 years of injection

Conclusions

- Technology cross-over: hydraulic fracture design workflow (including production forecast) applied to a geothermal project with CO_2 reinjection
- Forecasts were carried out for 25 years of production:
    - Cumulative Gas Production: 131.1 Msm^3 for the HF case (vs 124.1 Msm^3 without HF)
    - Productivity Index: up to 15 times higher for the HF case (in well DR3)
- Simulations show that suitable fracturing treatments can increase dramatically the production well performance for Draškovec field

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