EVALUATION OF WELL SPACING AND ARRANGEMENT FOR IN-SITU THERMAL TREATMENT OF OIL SHALE USING HPC SIMULATION TOOLS

MICHAL HRADISKY - JENNIFER SPINTI - PHILIP J. SMITH

INSTITUTE FOR CLEAN AND SECURE ENERGY - UNIVERSITY OF UTAH

34TH OIL SHALE SYMPOSIUM

COLORADO SCHOOL OF MINES, GOLDEN, CO

OCT. 13-15, 2014

OVERVIEW

Oil Shale/Oil Sands program

Simulation tool / HPC

Co-Simulation

Well spacing study

What’s next ...

OIL SHALE / OIL SANDS PROGRAM

Mission: Pursue research that improves industry's ability to utilize the vast energy stored in oil shale and oil sands resources with minimal environmental impact

Three main research areas:

1. Basin scale simulation of environmental and economic impacts of oil shale and oil sands development
2. Secure liquid fuel production by in-situ thermal processing of oil shale and oil sands
3. Environmental, legal, economic and policy issues

OIL SHALE / OIL SANDS PROGRAM

Research topics such as:

Multiscale thermal processes

Reservoir simulations

In-situ pore physics

Experimental characterization of oil shales and kerogens

Geomechanical reservoir state

Developing a predictive geologic model of the Green River oil shale in Uinta Basin

Development of HPC simulation tools

CAPSTONE PROJECT

Collaborated with American Shale Oil LLC to further develop simulation tools on a realistic problem

STAR-CCM+

Commercially-available engineering process tool for solving problems involving flow, heat transfer, and stress developed by CD-adapco

Designed for problems involving multi-physics and complex geometries

Build-in 3D CAD package to create complex geometry and interface with external commercial CAD packages

Supports parallelism

Supports user code for expanded applicability


12,348 CORES
4.5 PB

CO-SIMULATION

Capability added during Capstone project

Addresses the need to capture and couple small convective scales with larger conductive scales

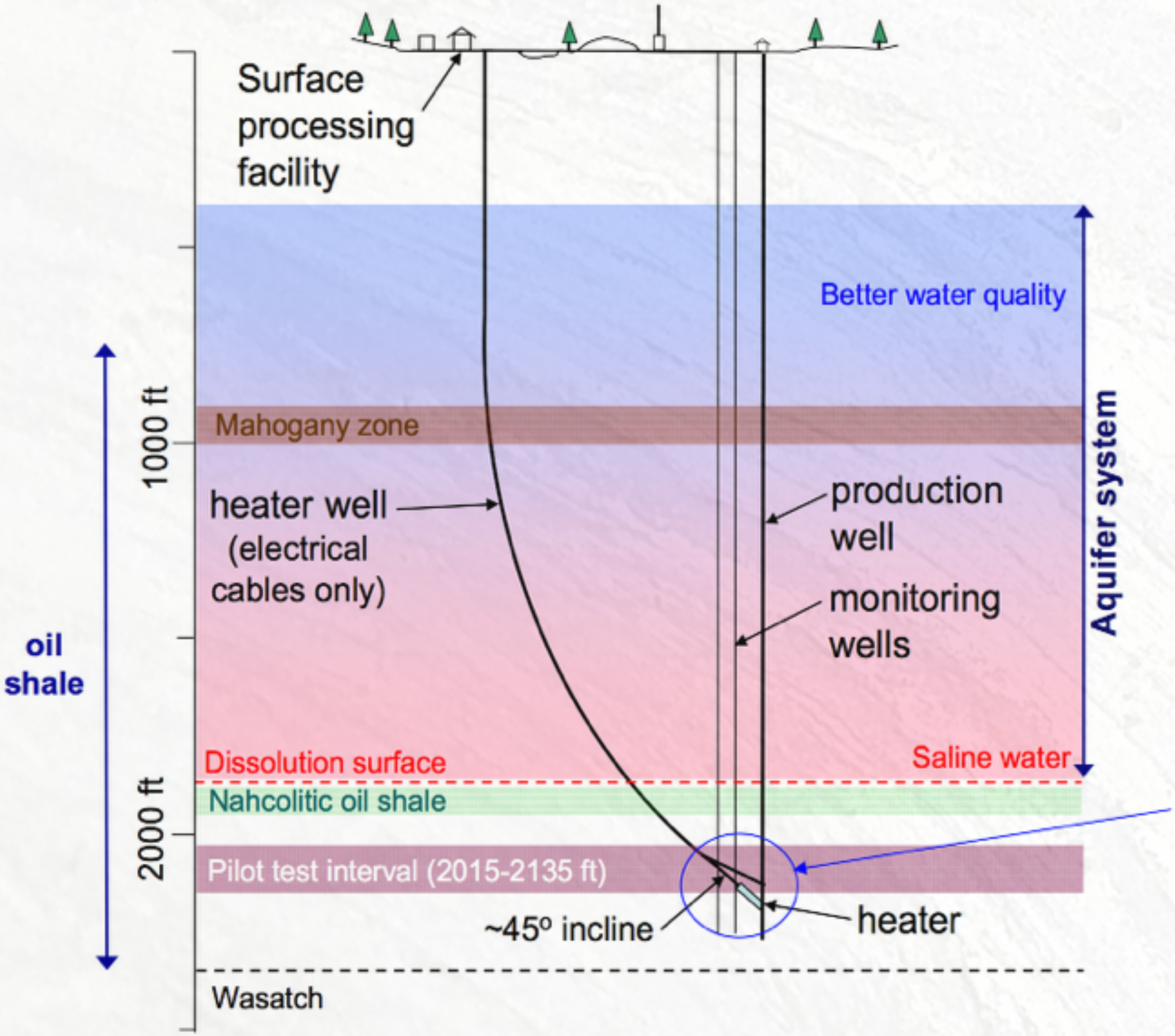
Used data shared by AMSO to simulate certain aspects of their pilot tests

Last year: Two separate simulations

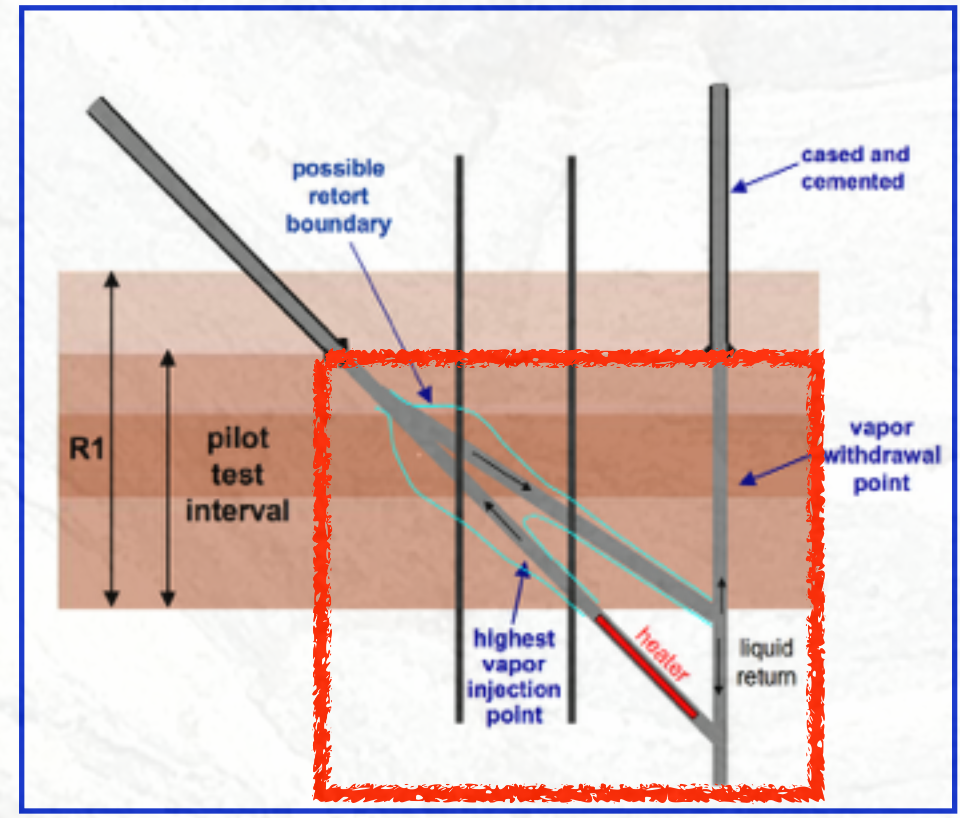
1. Resolve refluxing throughout the heater well
2. Perform conduction-only study to capture thermal diffusion throughout the formation

This year: Coupled both simulation

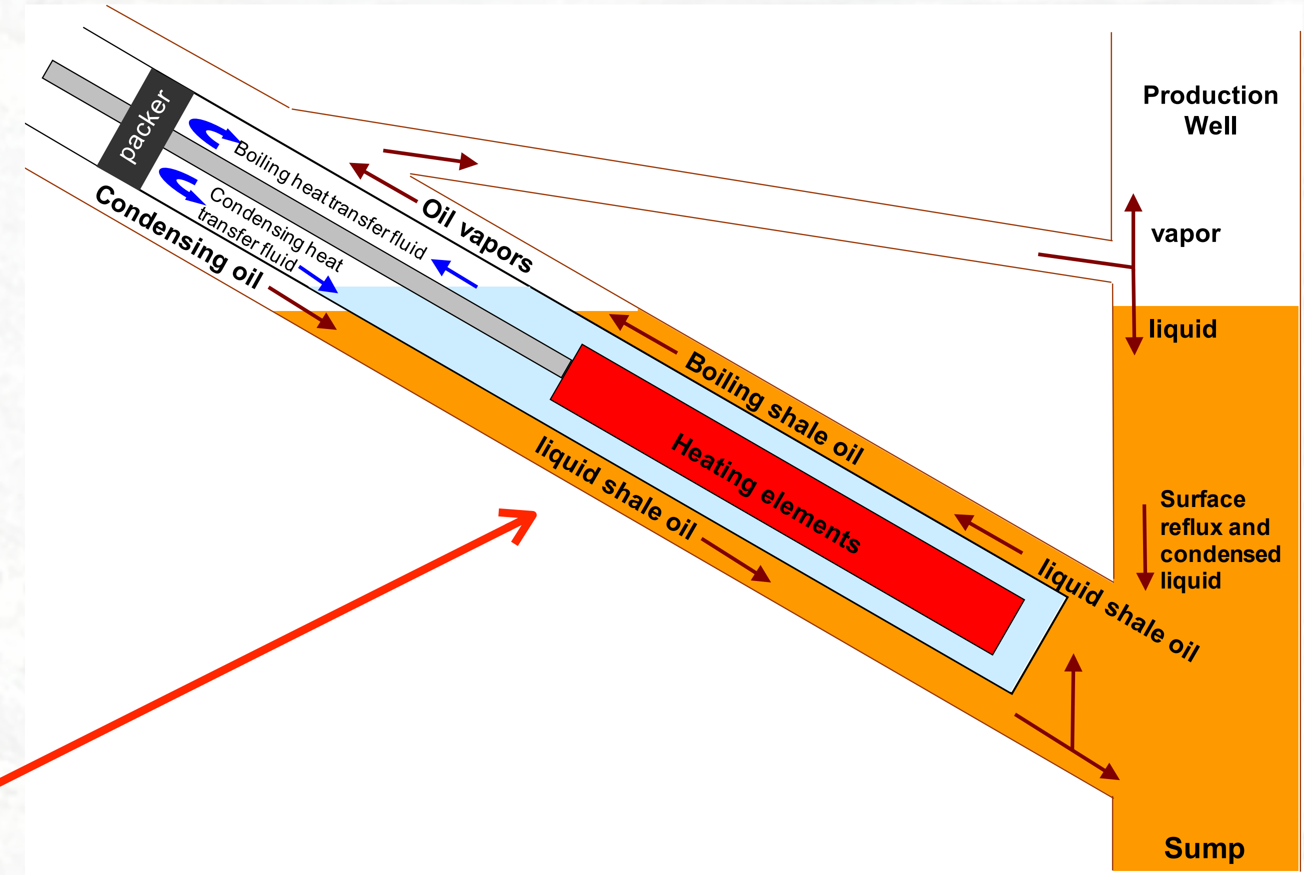
AMSO PROCESS



Triangular
convection loop



Simulation
Domain



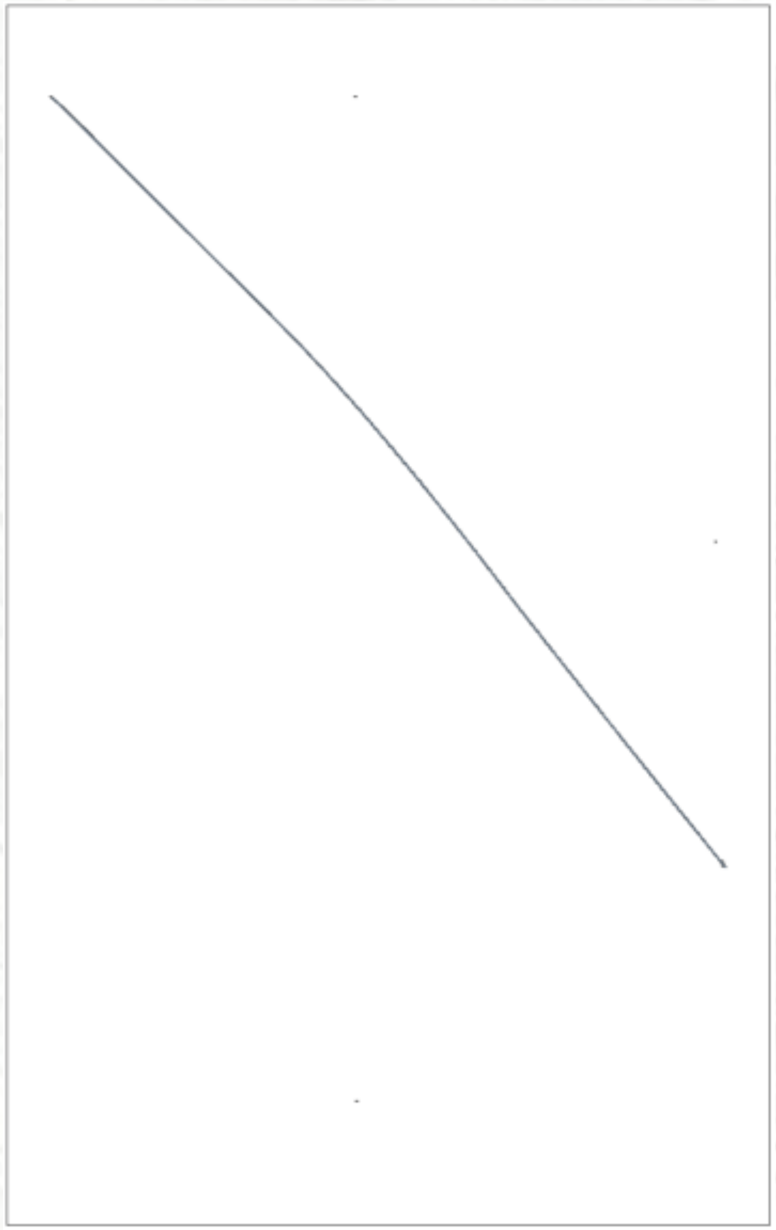
Heater in the lower lateral well

Side View of Simulation Domain

CO-SIMULATION

SOLID

\+



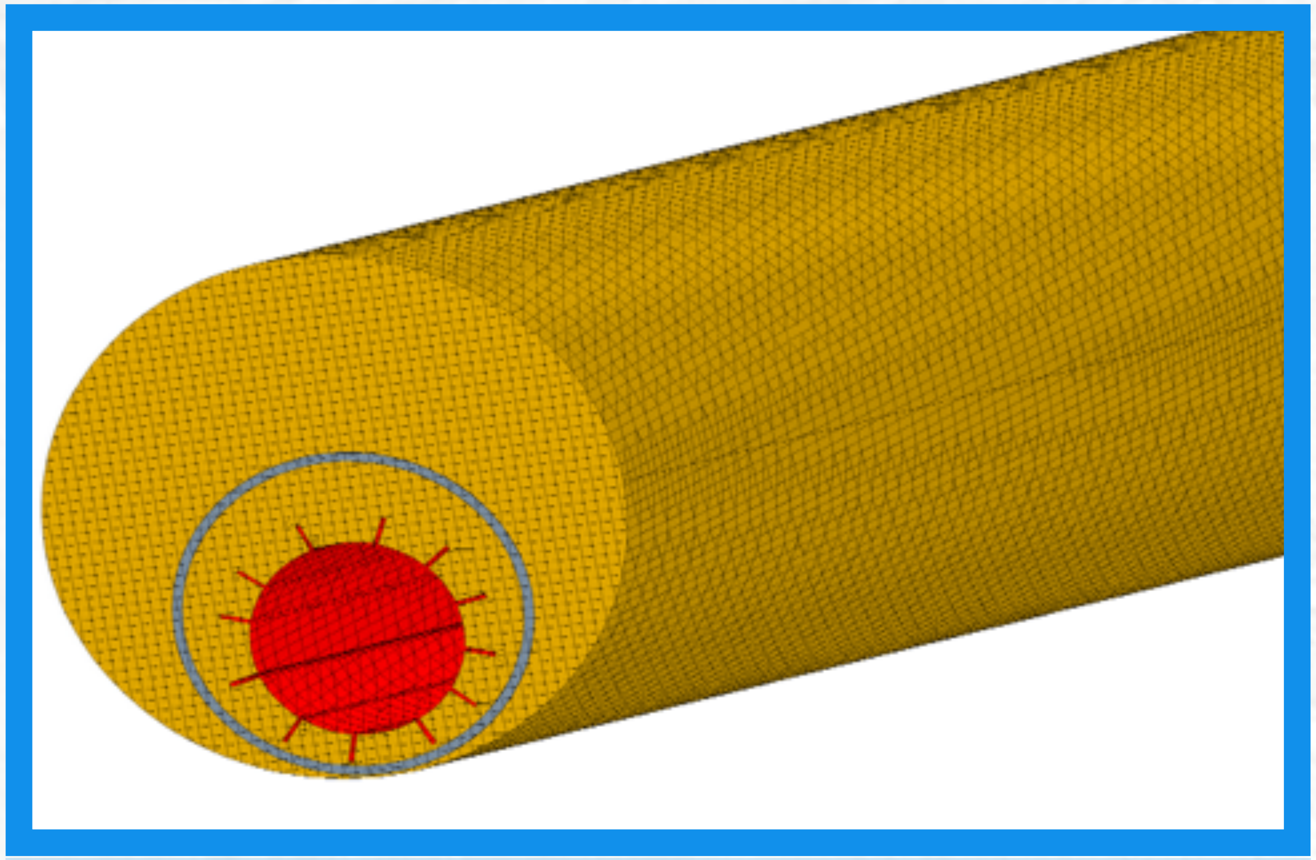
FLUID

TIME SCALES:
~ DAYS

SPATIAL SCALES:
~ 1M

TIME SCALES:
~ SECONDS

SPATIAL SCALES:
~ 1 CM



Fluid

LES: 17 mil cells

Solid

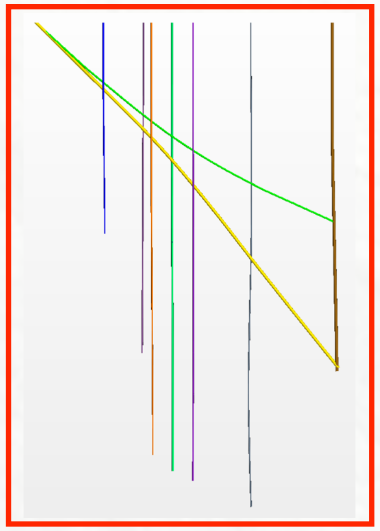
Conduction only: 2.4 mil cells

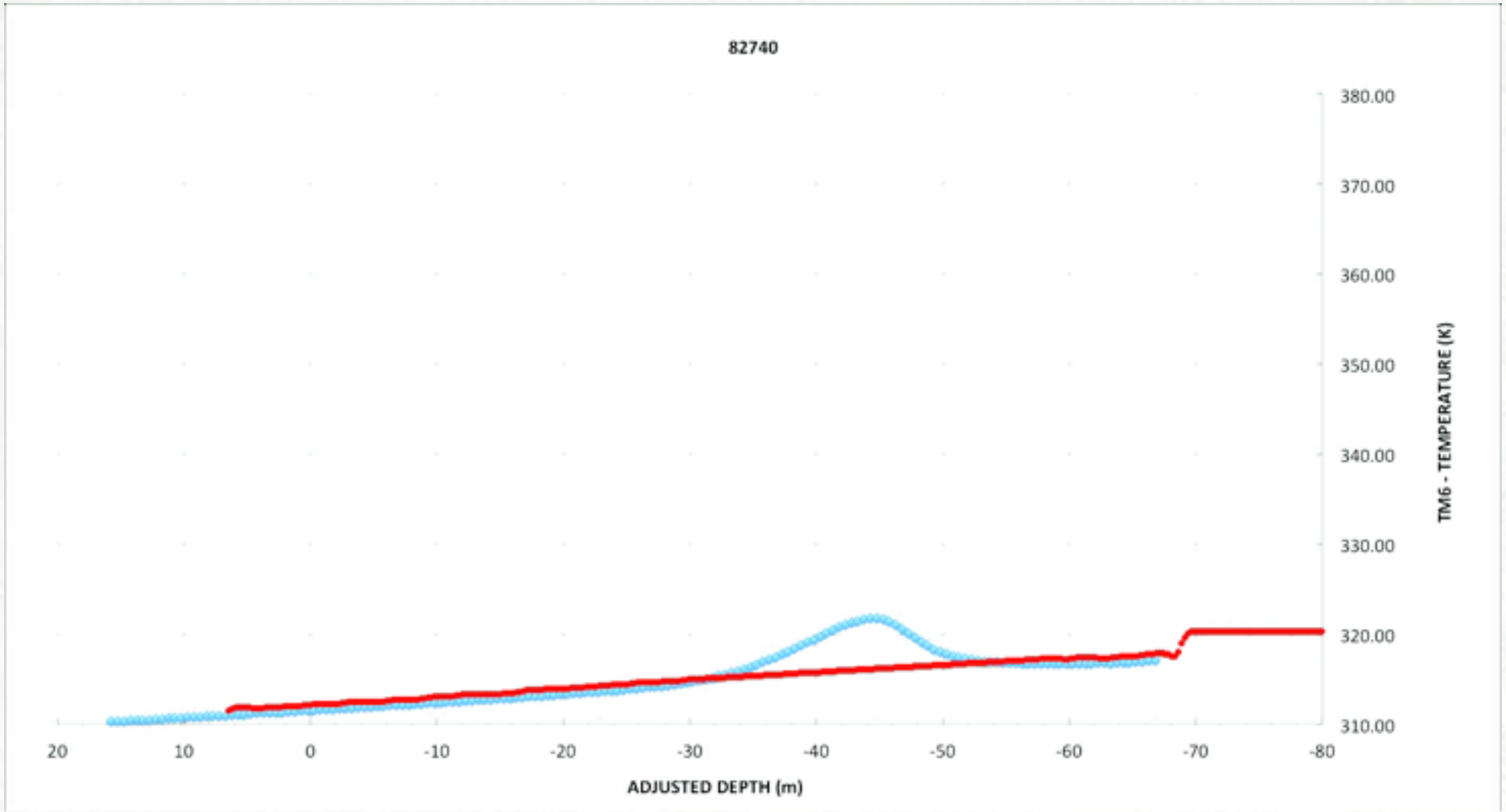
720 cores **480 cores**

HEATER TEST RESULTS ~ 3 MONTHS

NO CO-SIMULATION

Side View





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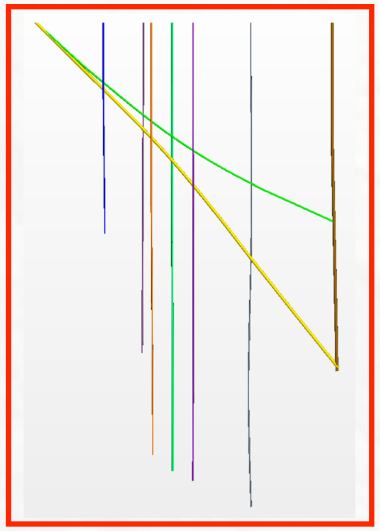
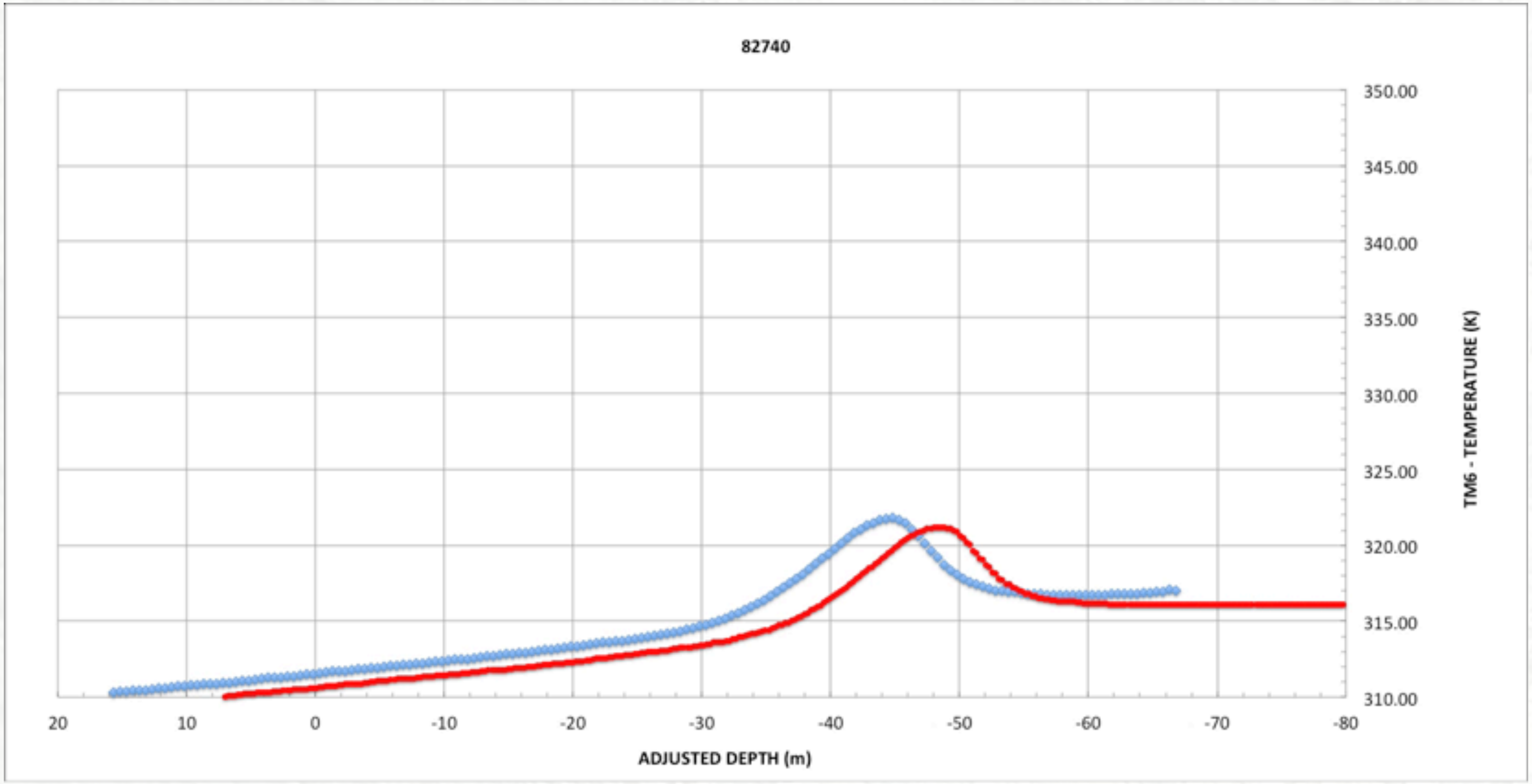
HEATER TEST RESULTS ~ 3 MONTHS

WITH CO-SIMULATION

Side View





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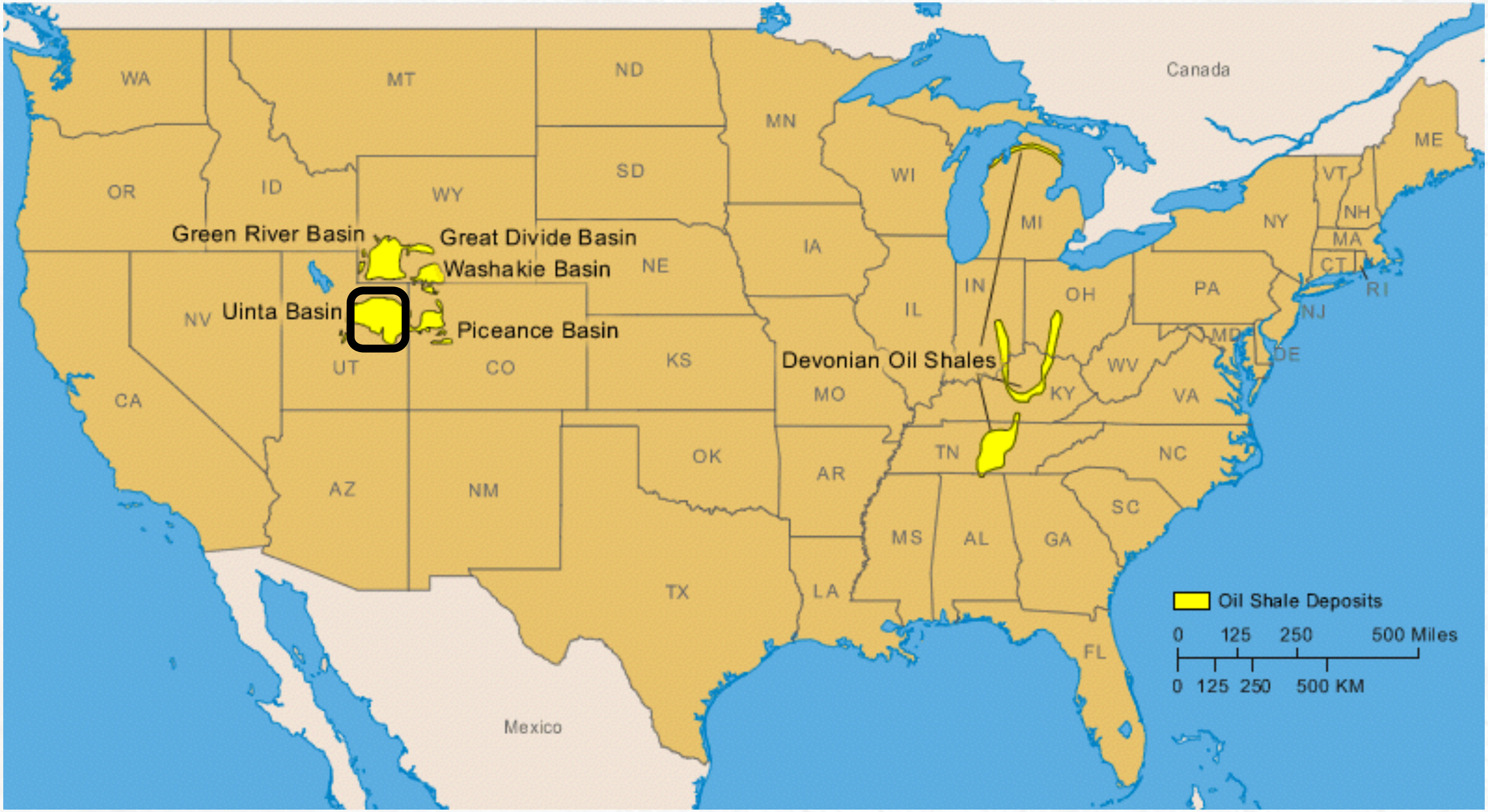
STUDY AREA - UINTA BASIN
"WHAT IF" SCENARIO



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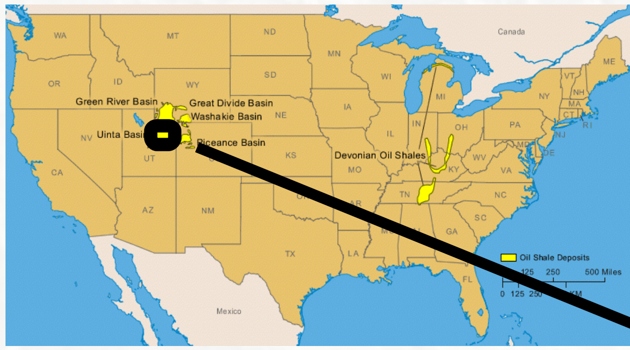

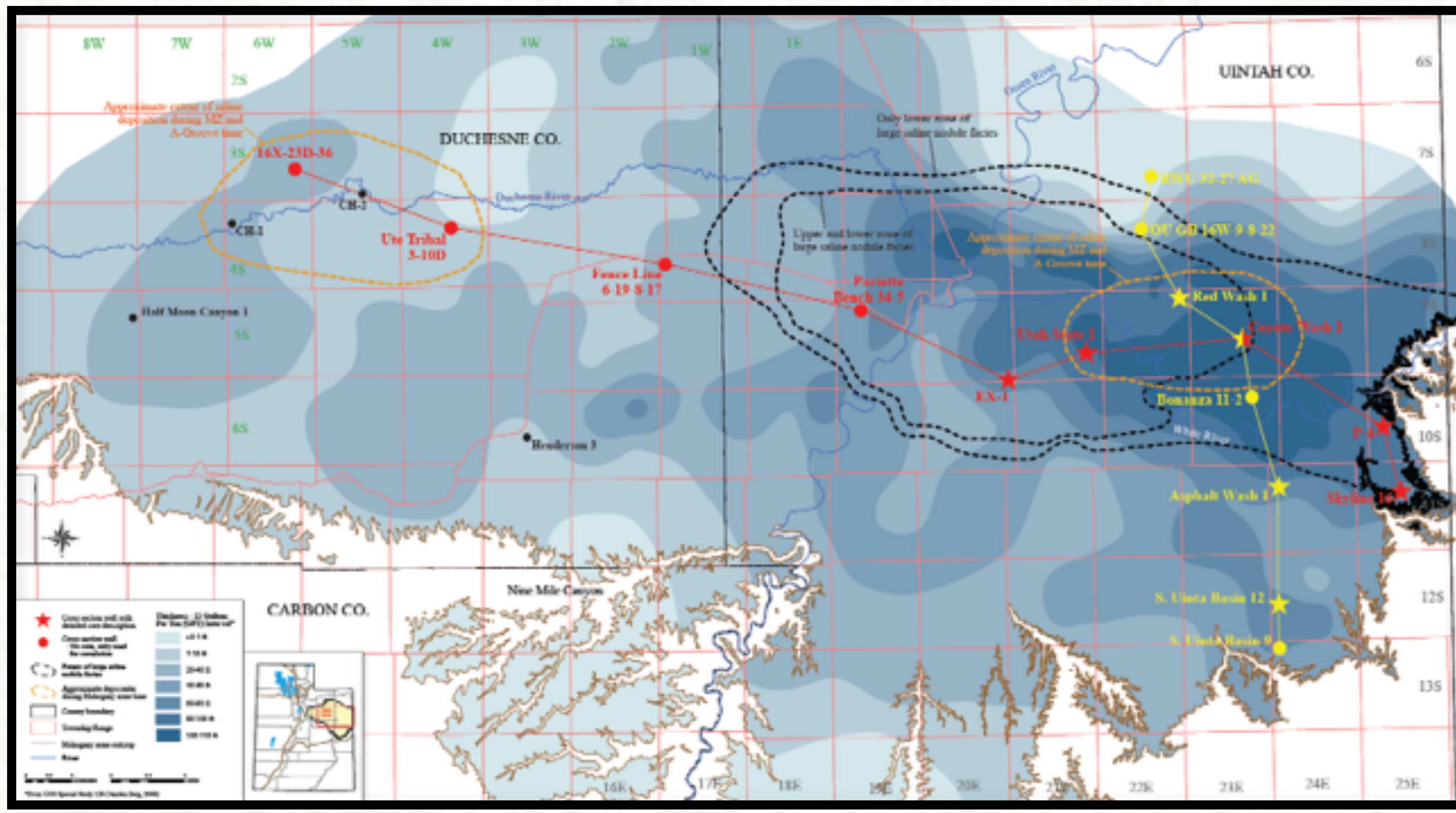

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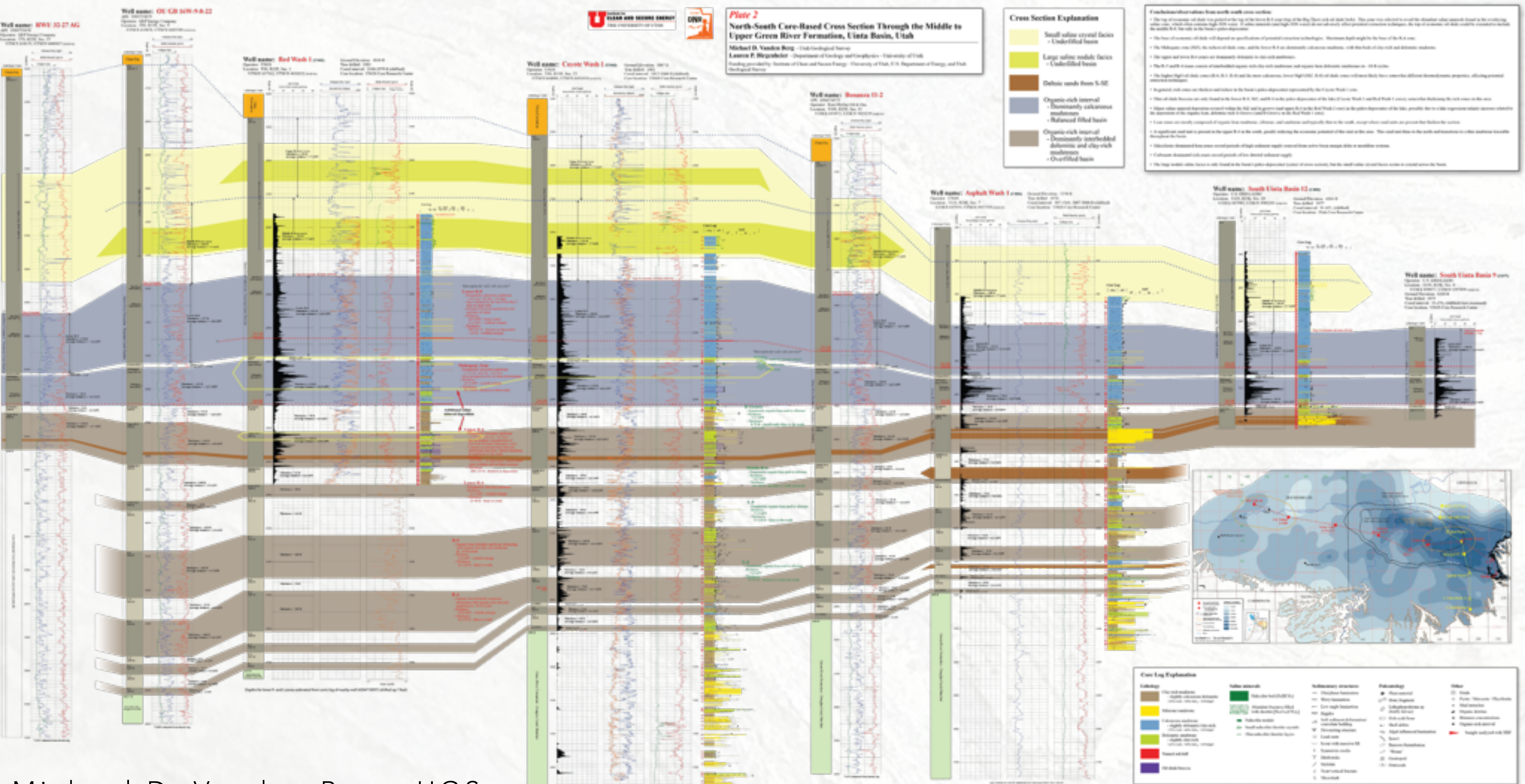

Michael D. Vanden Berg, UGS
Lauren P. Birgenheier, U of U

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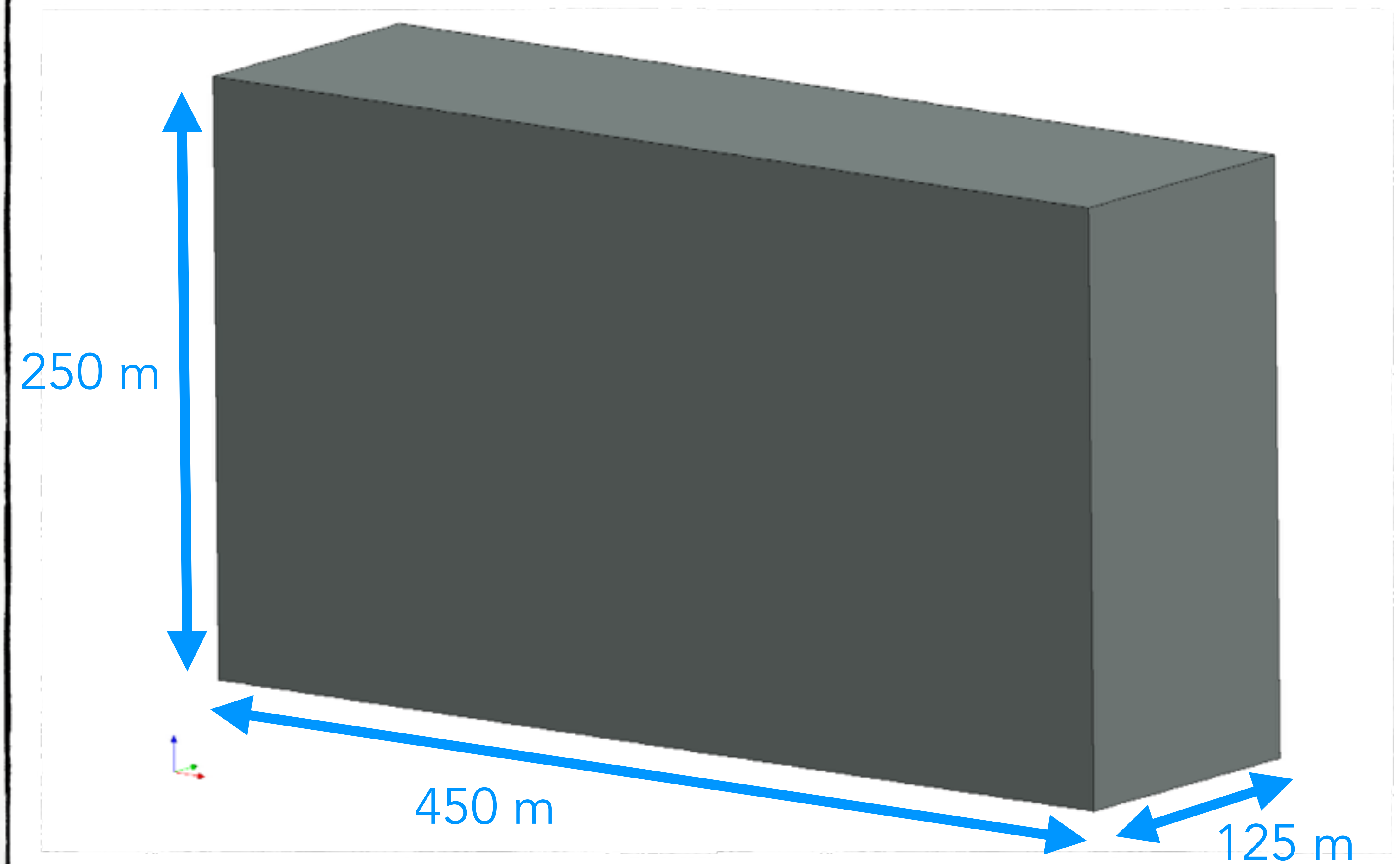
STUDY DOMAIN



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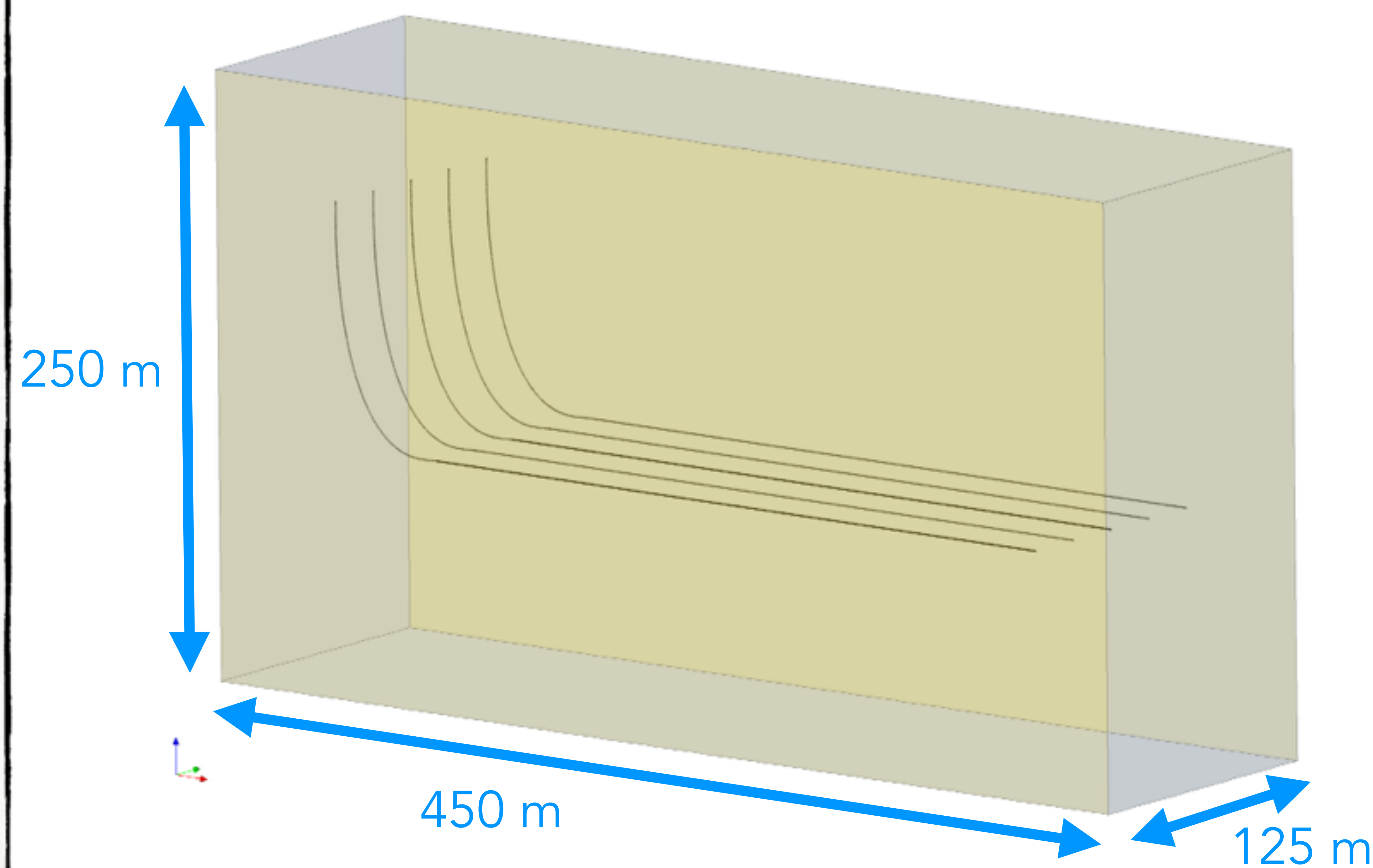
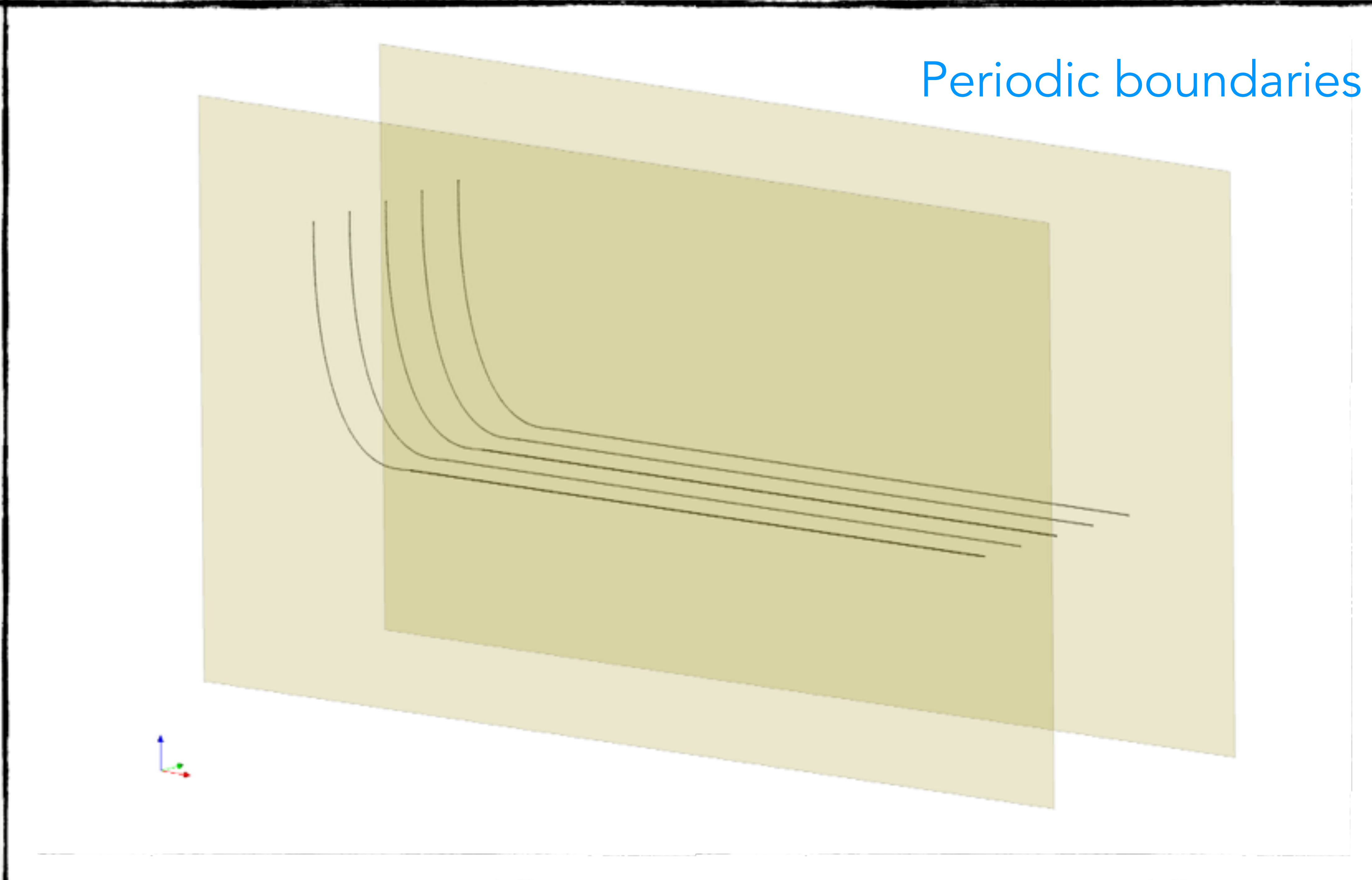


BOUNDARY CONDITIONS



Results can be scaled up

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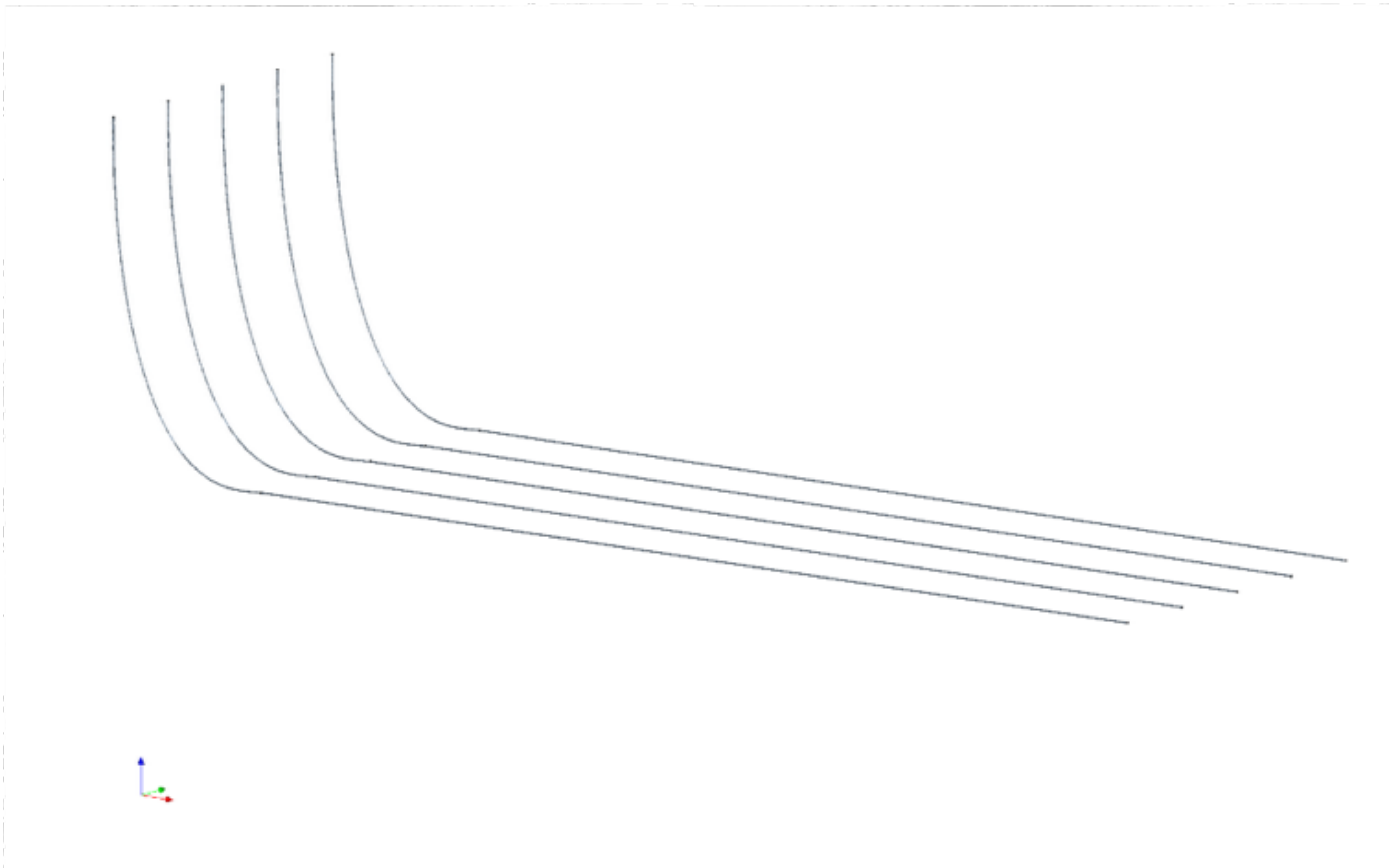
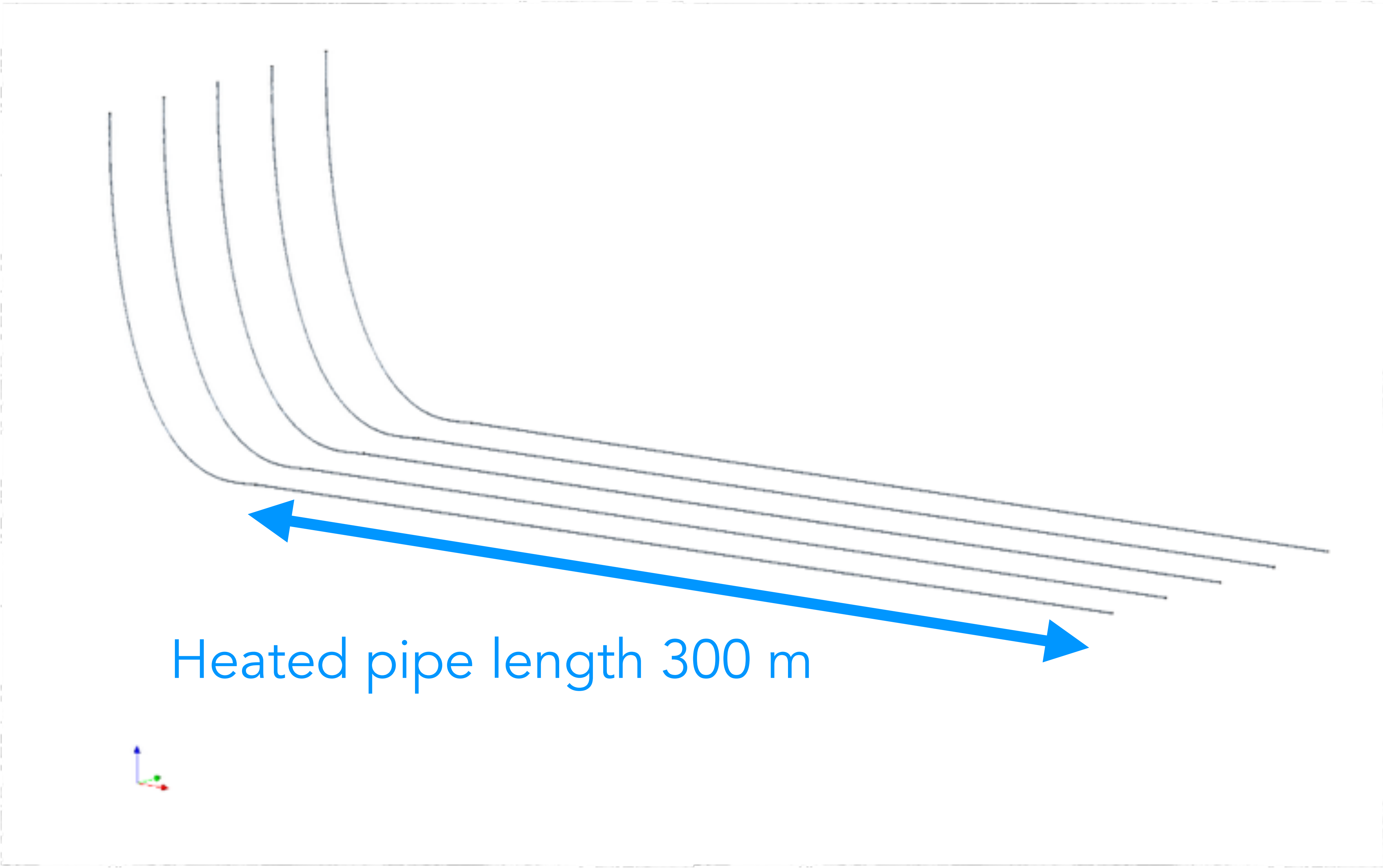
STUDY SCENARIOS



Case 1: 25 m lateral well spacing (5 wells)

STUDY SCENARIOS



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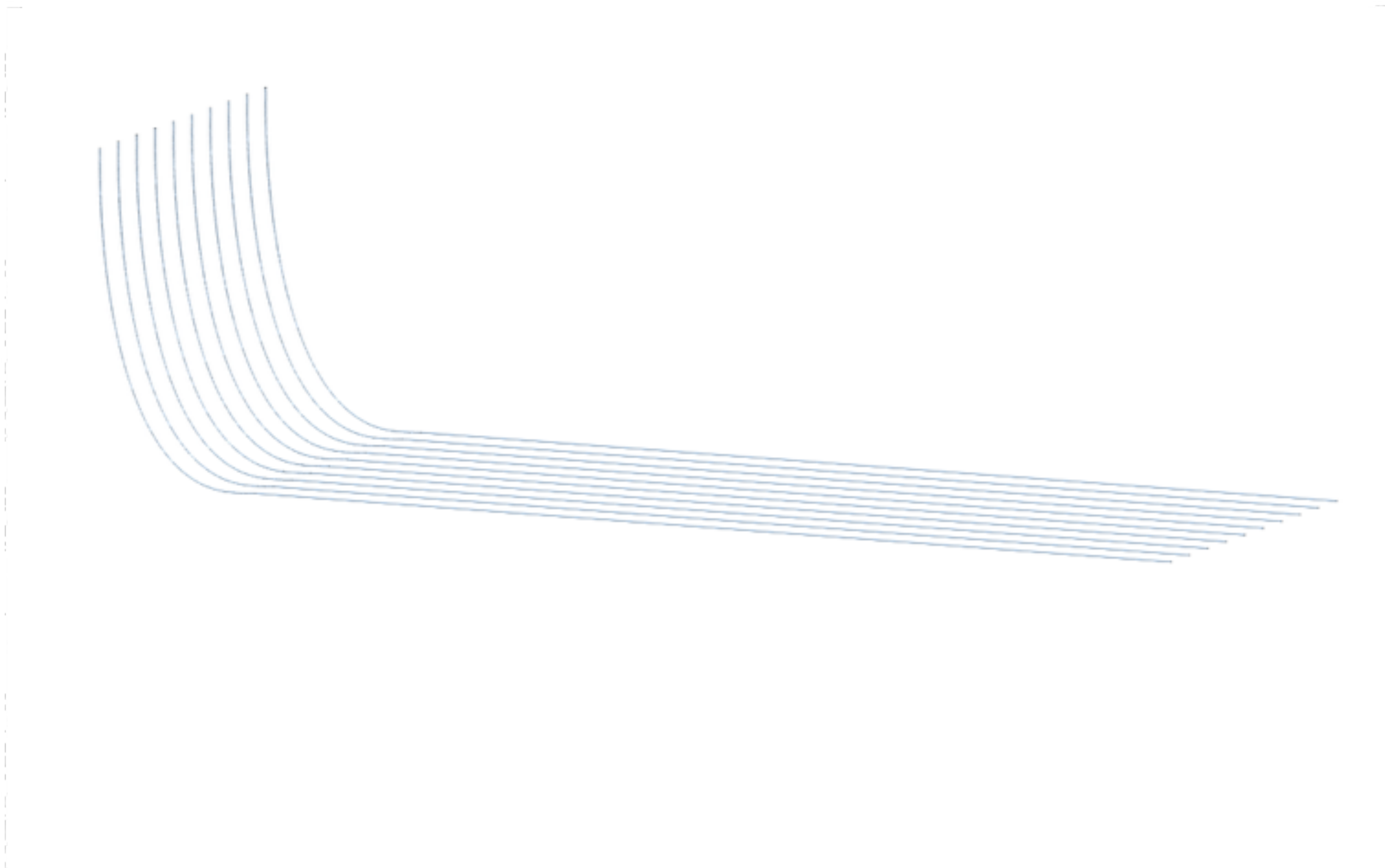
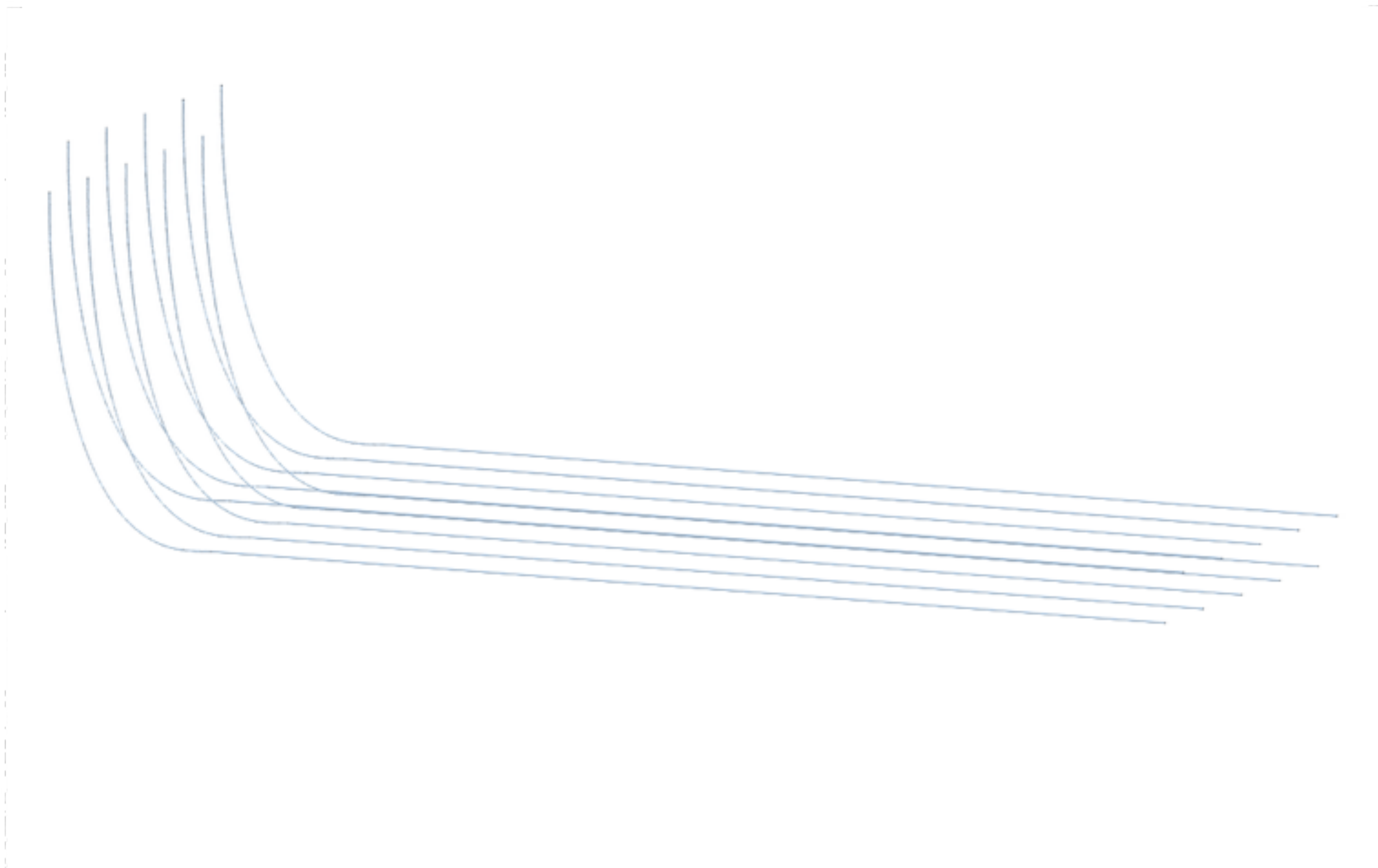


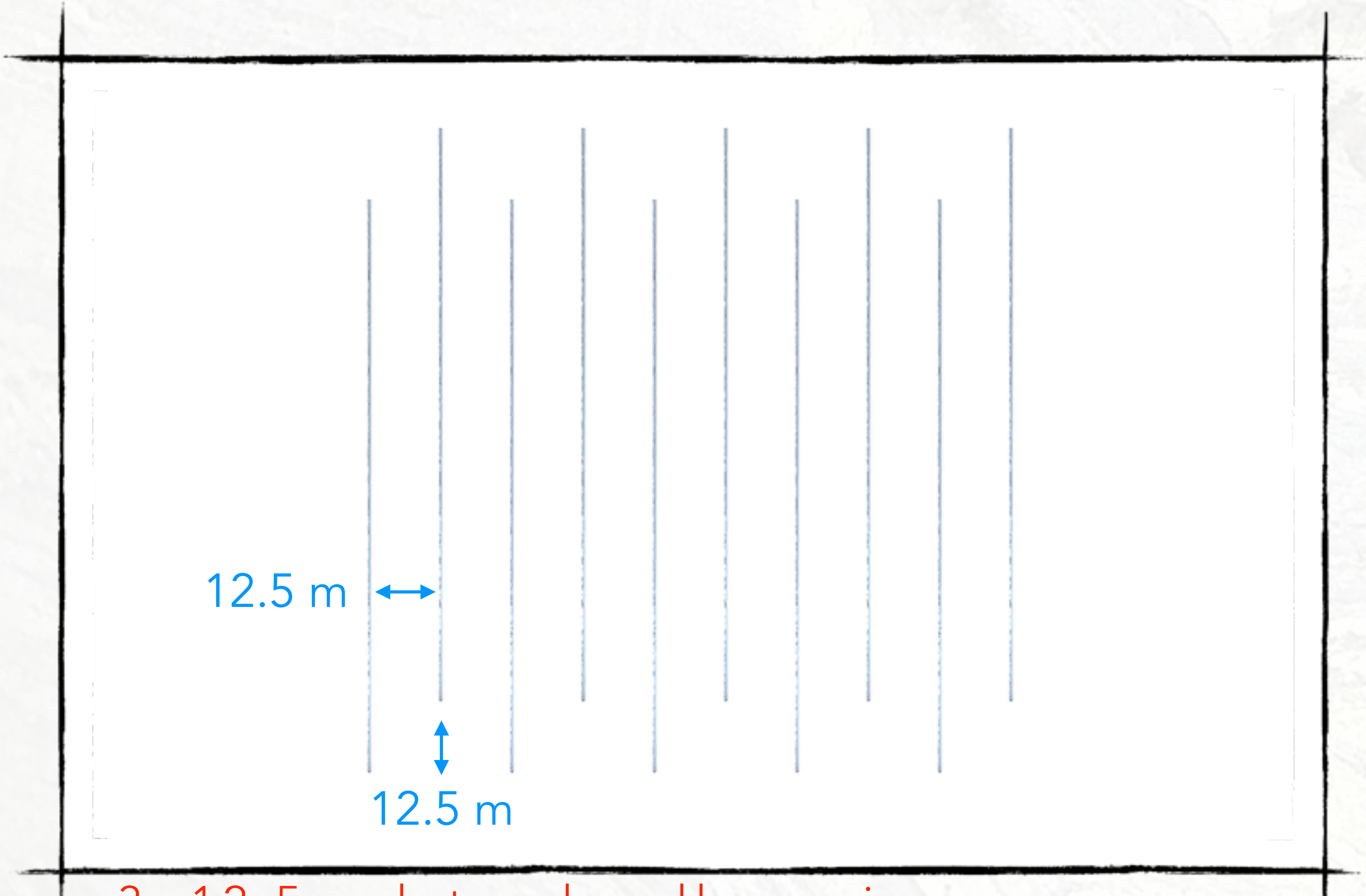
Case 2: 12.5 m lateral well spacing (10 wells)

STUDY SCENARIOS



Case 3: 12.5 m lateral well spacing,
every other well is offset vertically 12.5 m (10 wells)

STUDY SCENARIOS



Case 3: 12.5 m lateral well spacing,
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SIMULATION SETTINGS

Conduction only

No collector well inside the geometry

- What is produced is what is collected

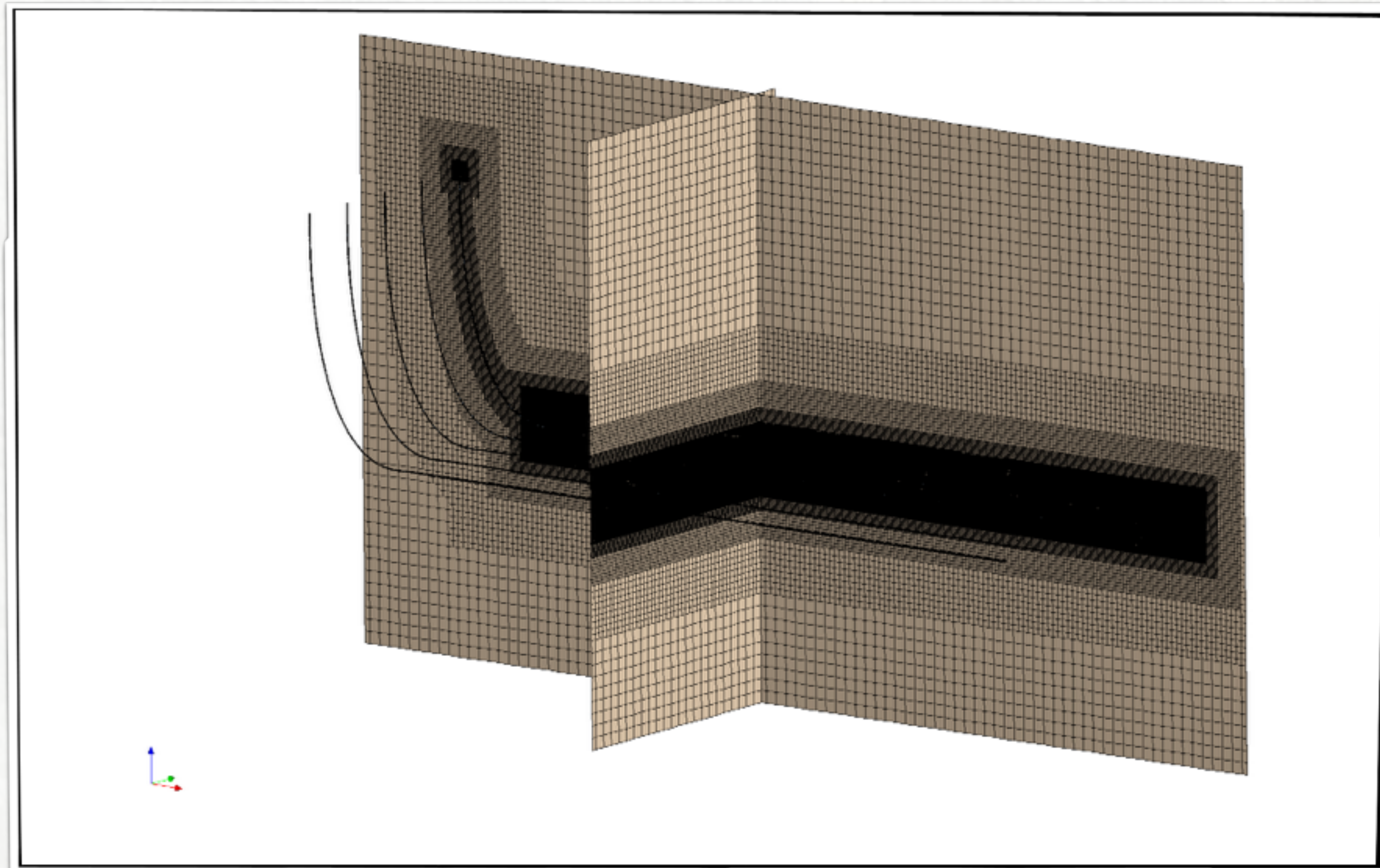
Constant heating temperature 675K for the entire length of the horizontal well

Diameter of horizontal well: 0.5m

Oil shale kinetics based on sample from Uinta Basin (Dr. Tom Fletcher, BYU)

- A=9.5e13 1/s   E=221 kJ/mol

SIMULATION MESH



Total cell count ~50 mil

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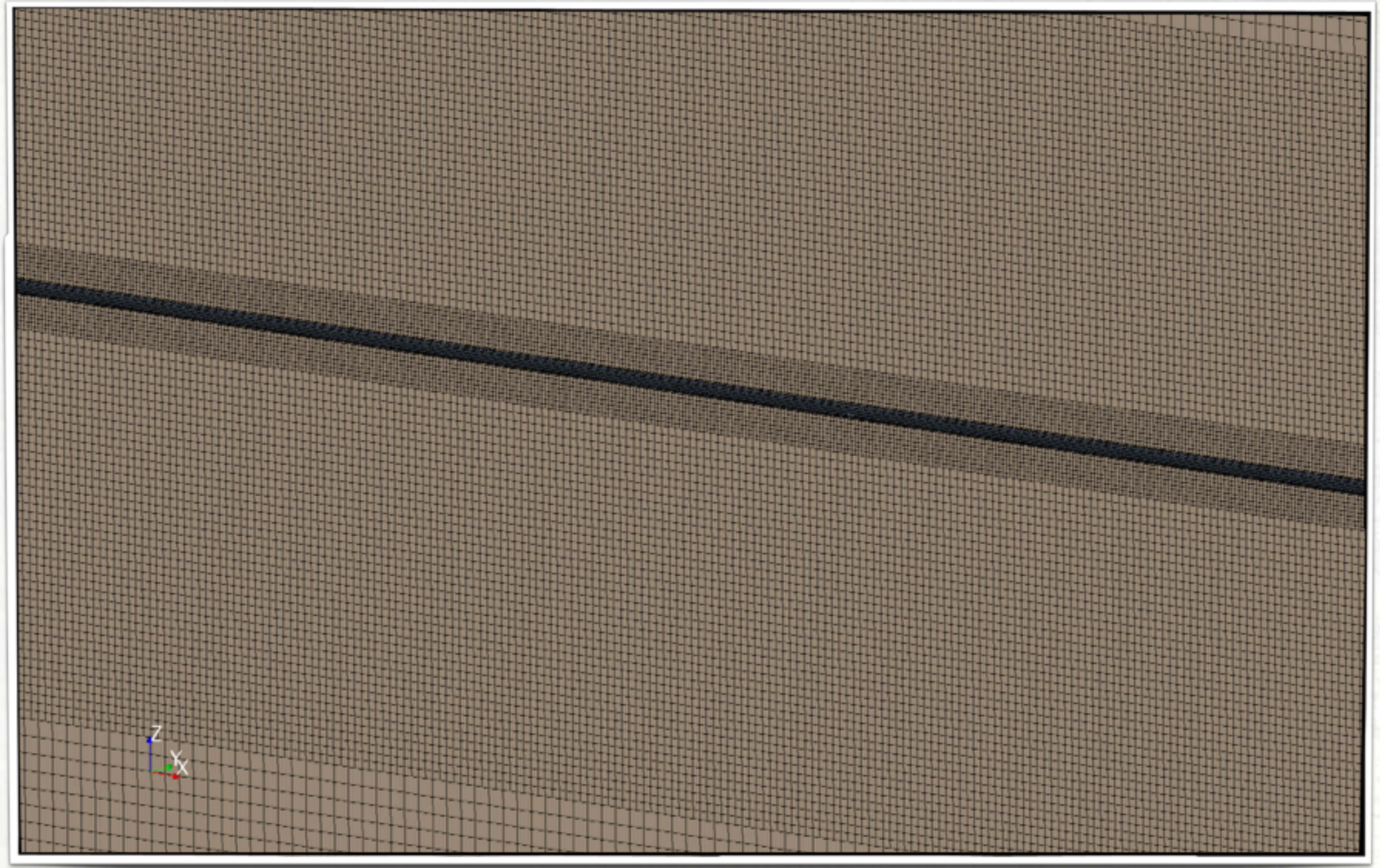

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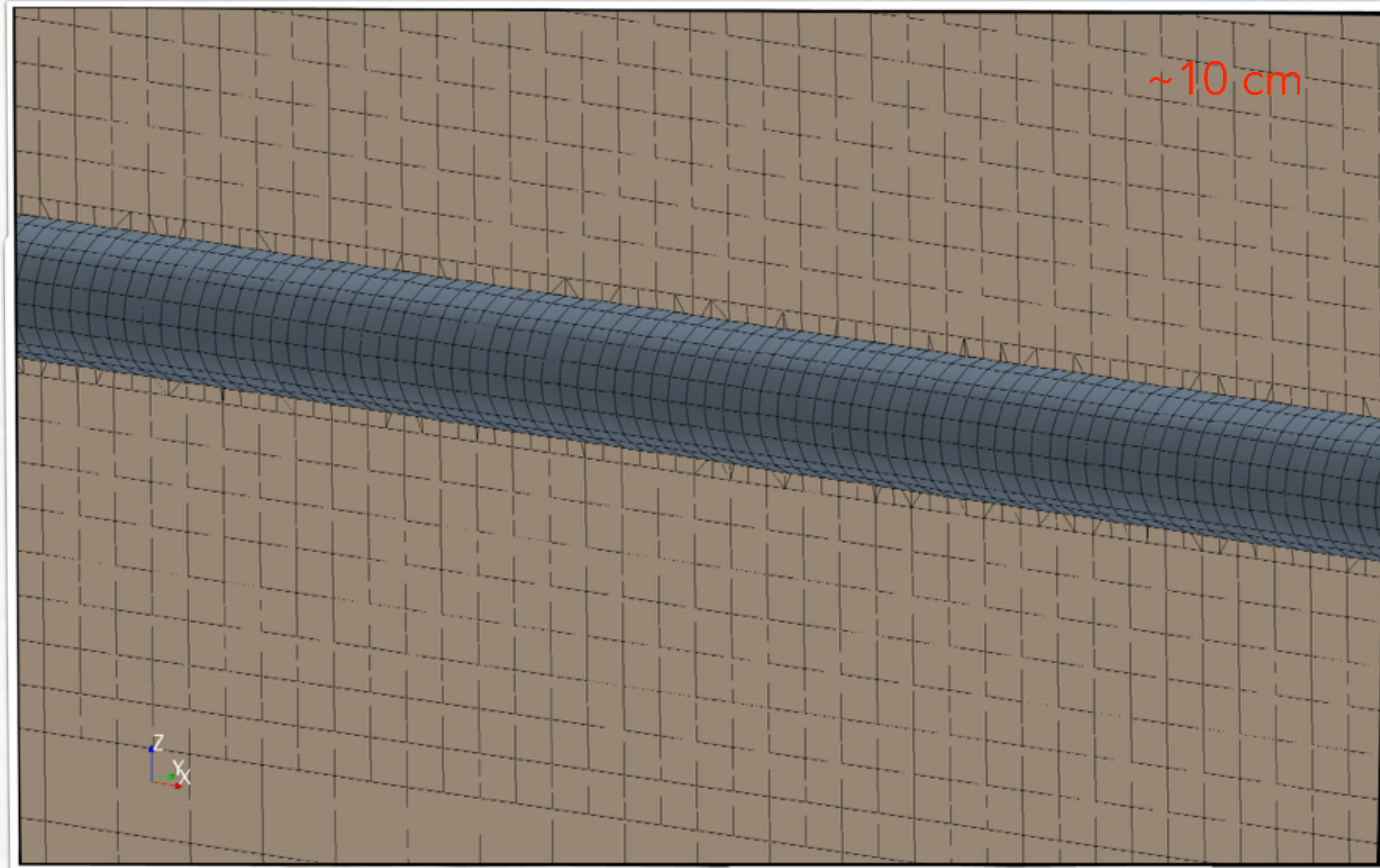

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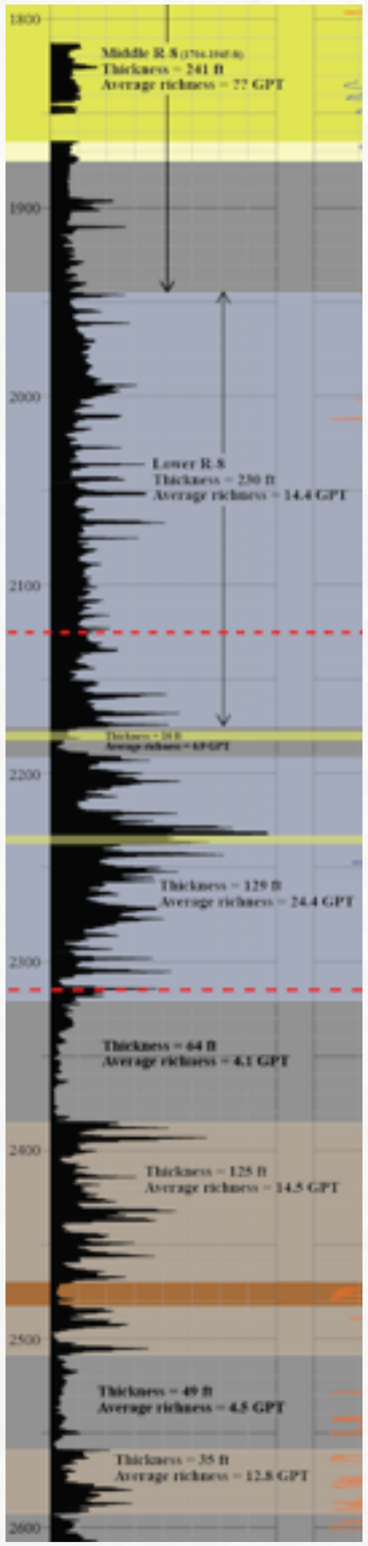
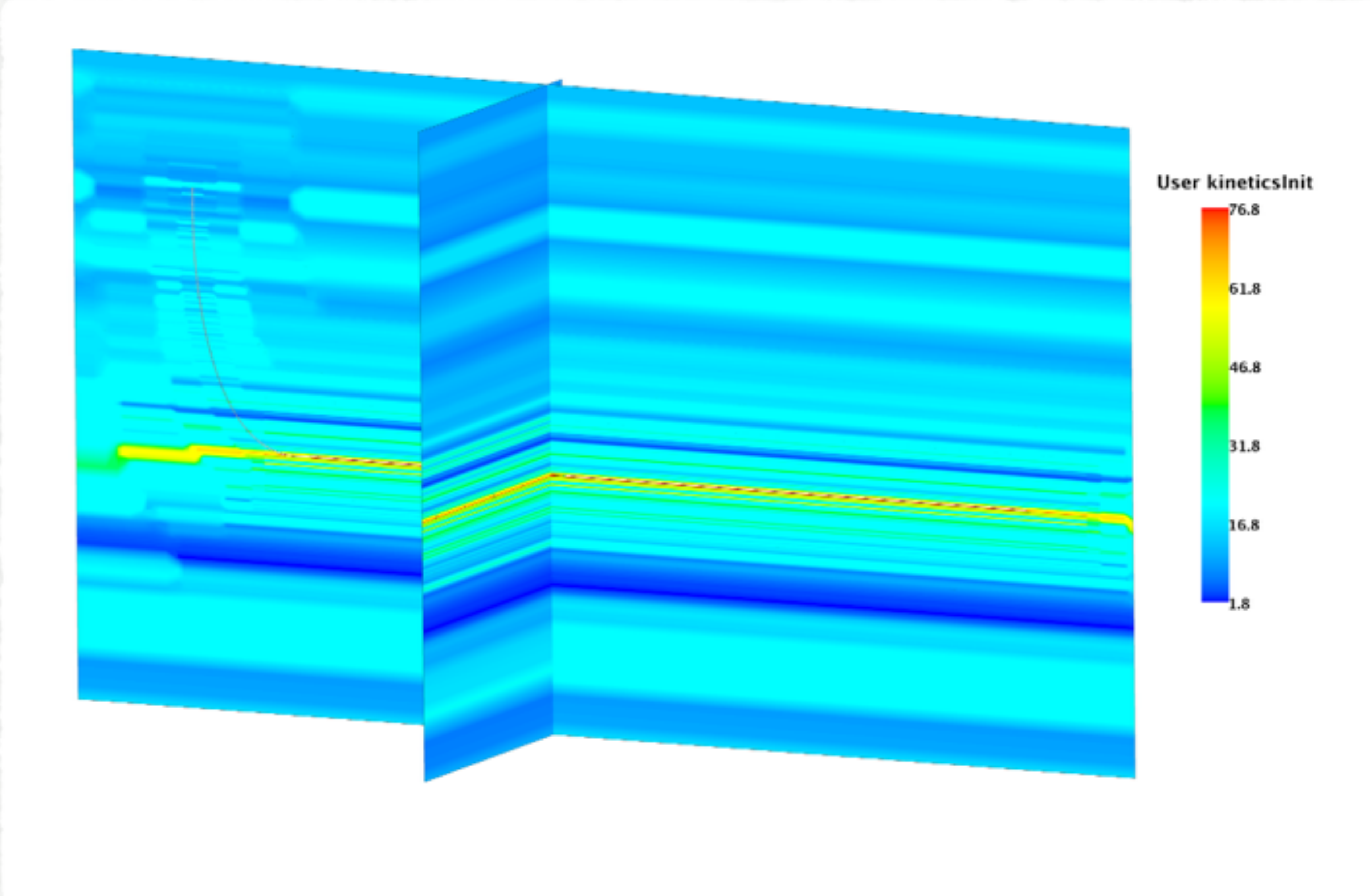
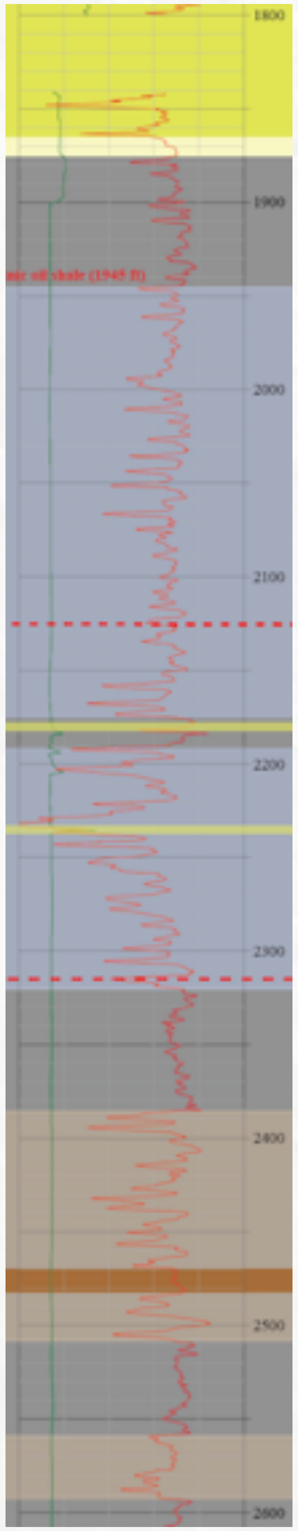
SIMULATION PROPERTIES

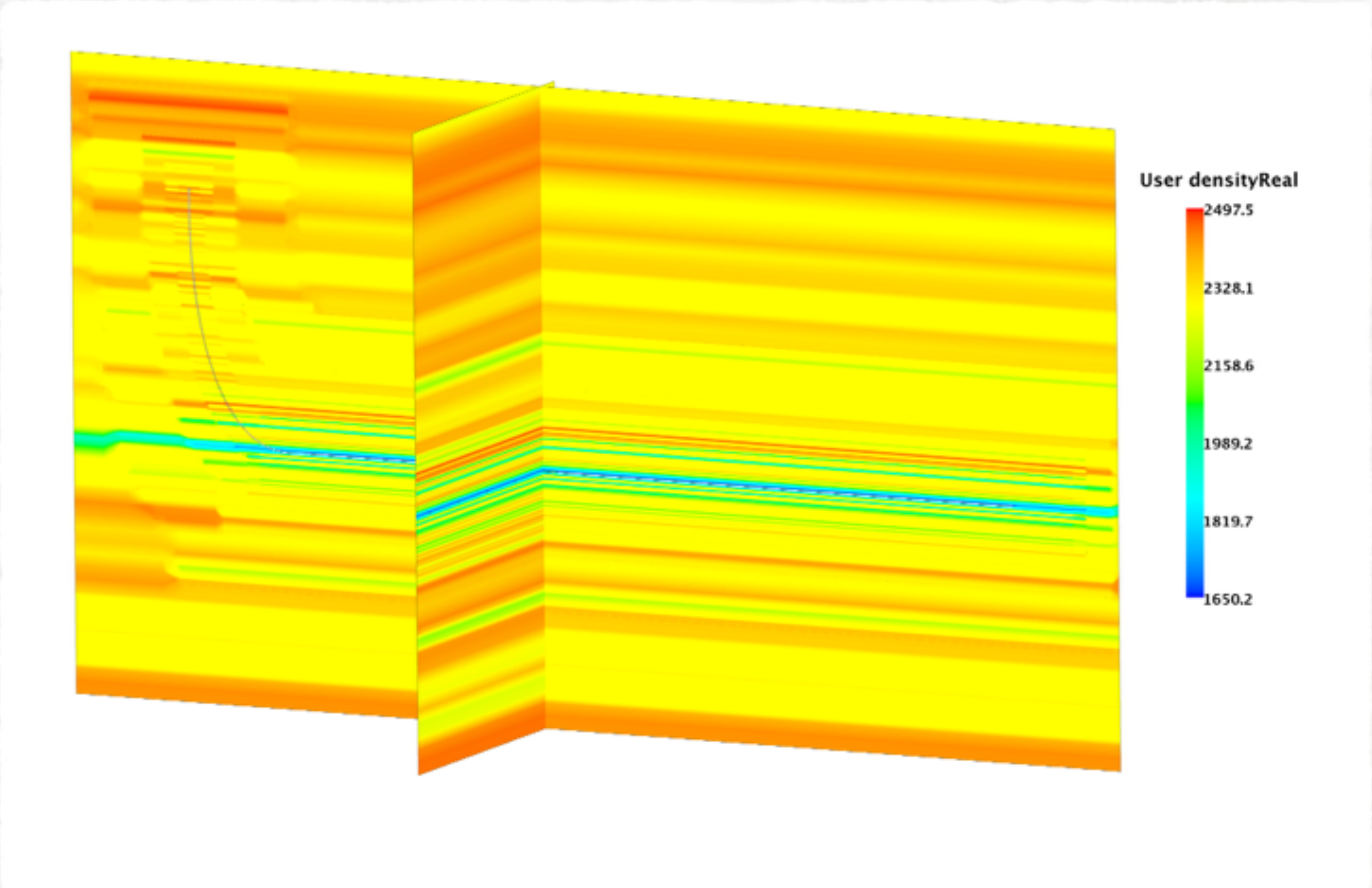




Oil shale grade (GOPT)

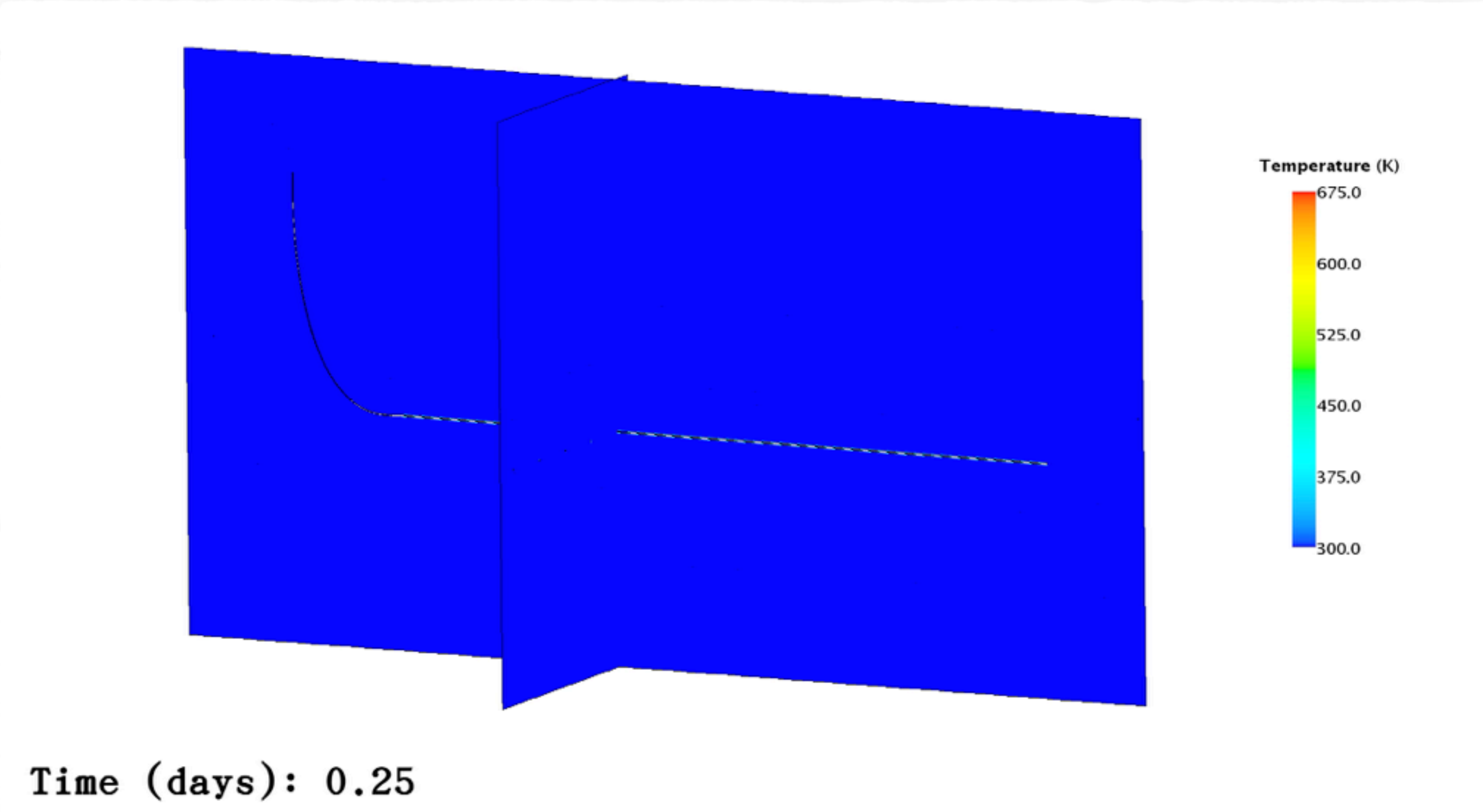
SIMULATION PROPERTIES



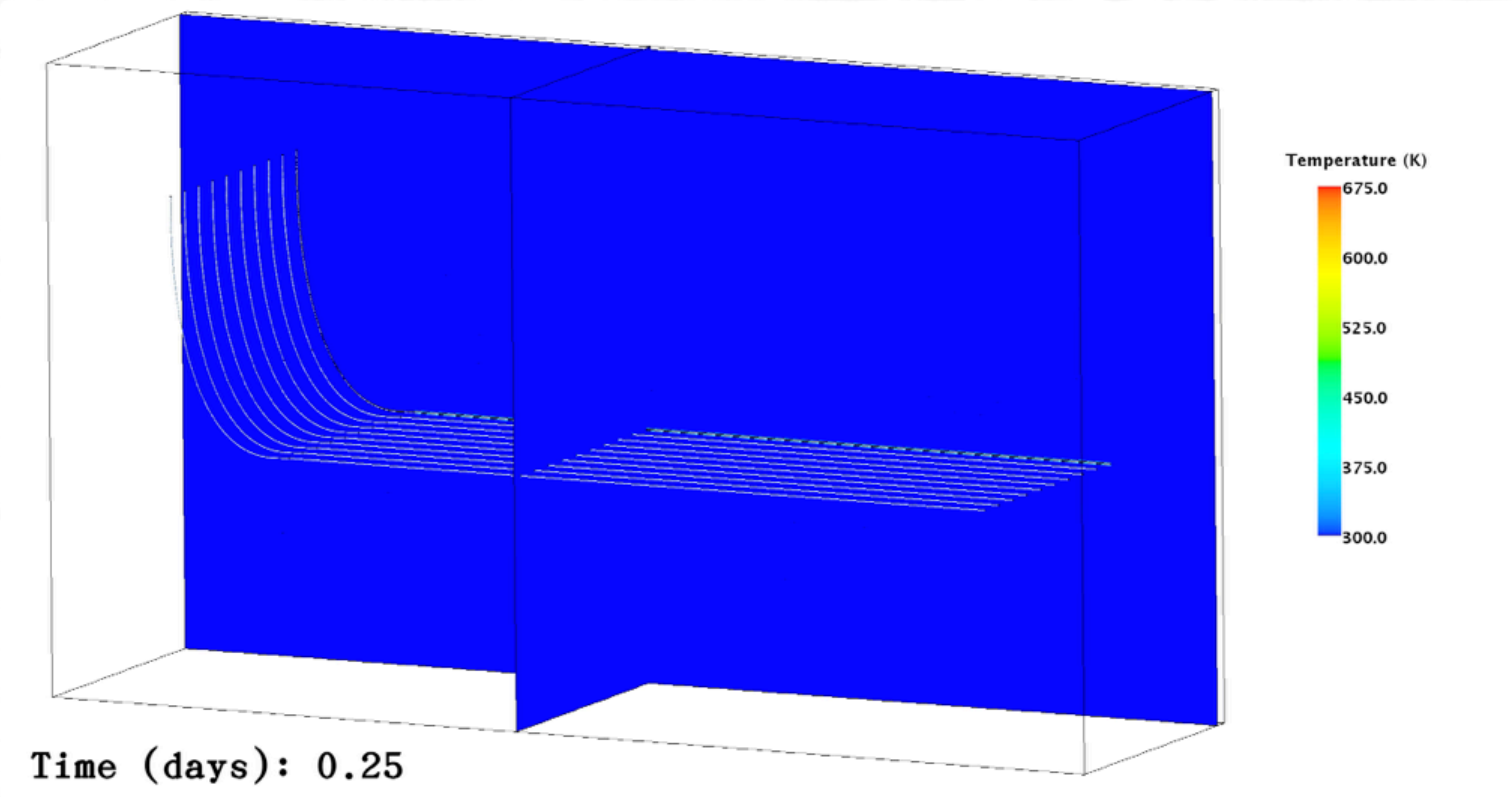


Density (kg/m^3)

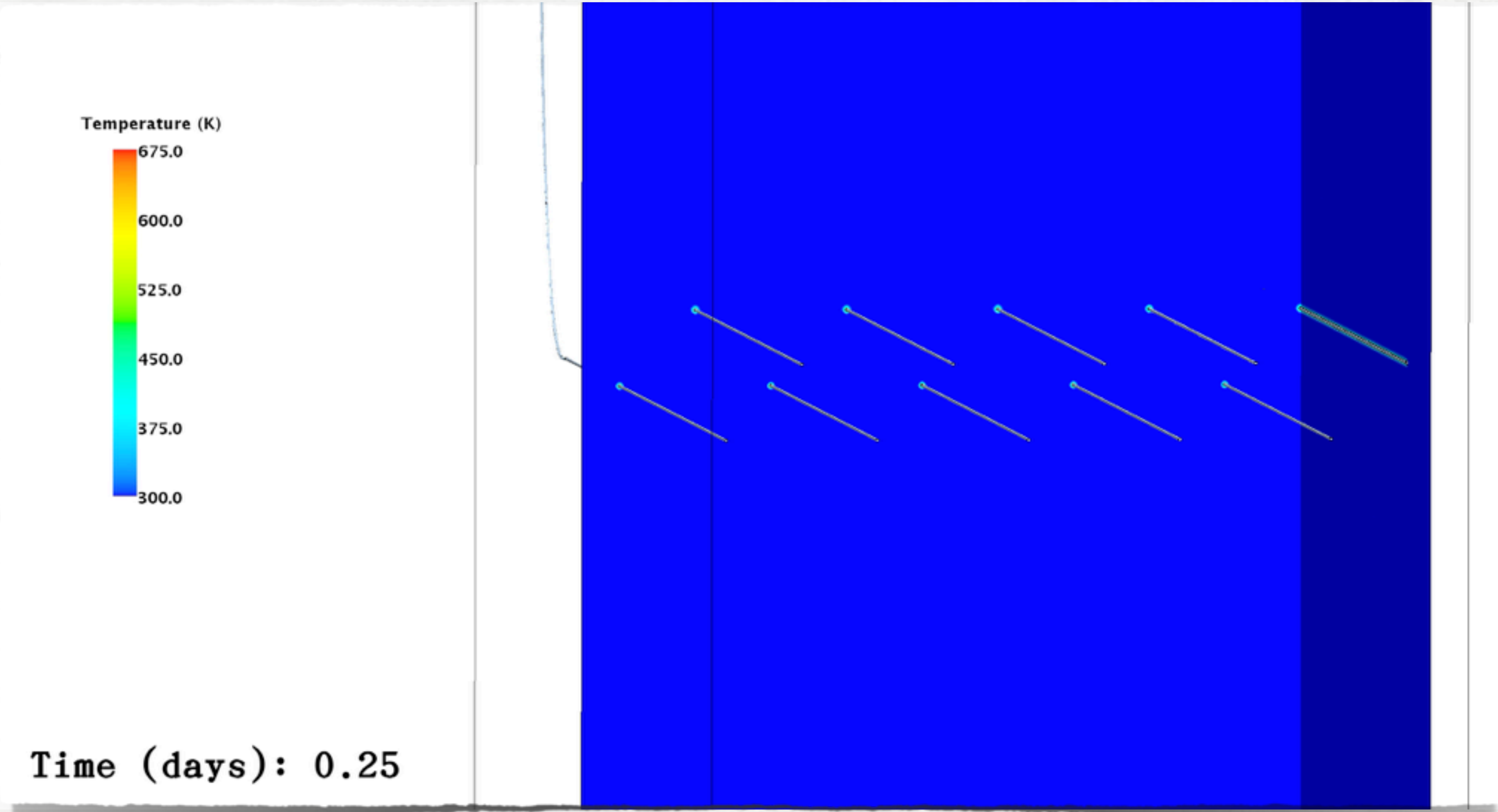
RESULTS: CASE 1



RESULTS: CASE 2



RESULTS: CASE 3



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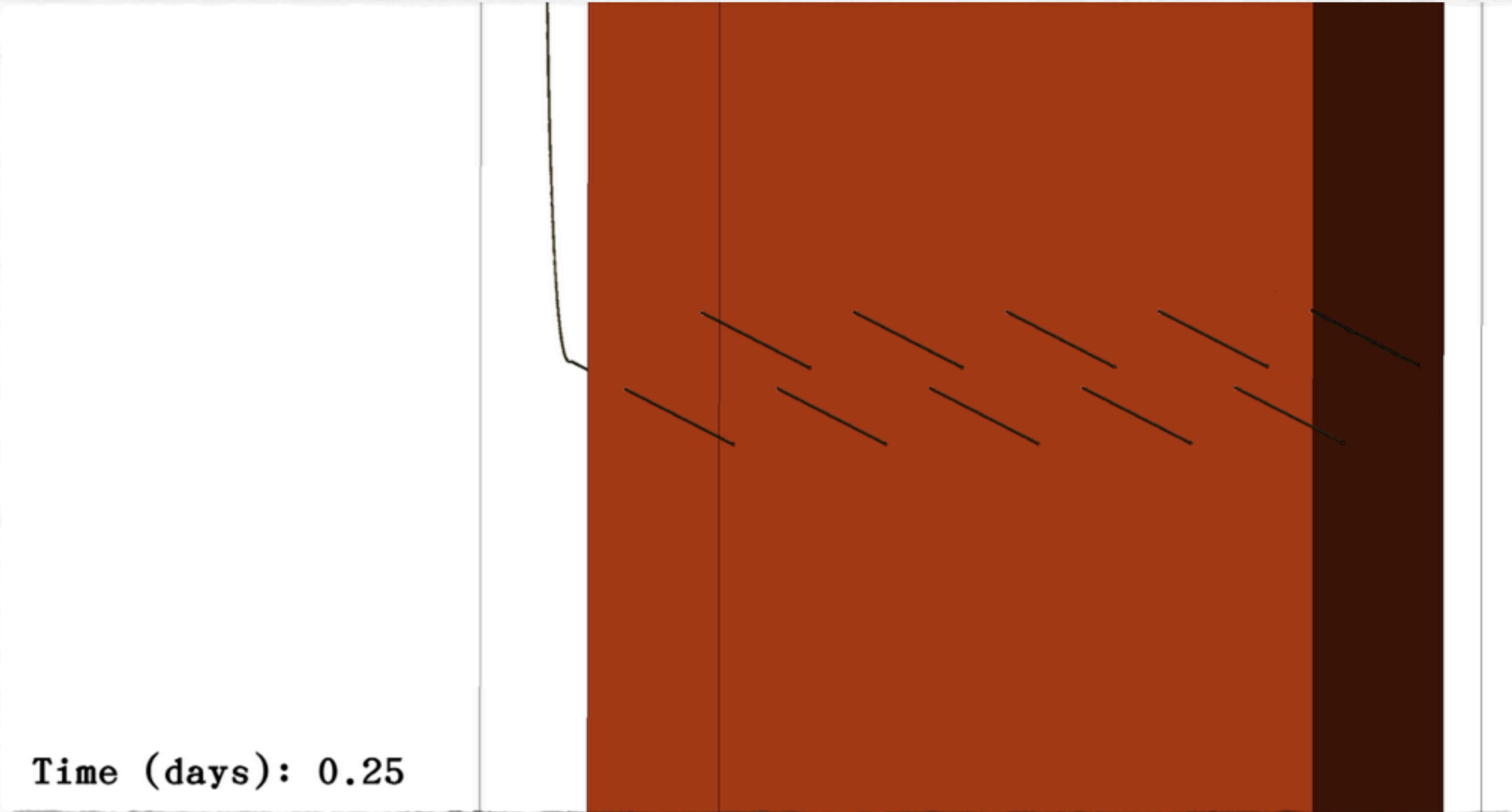
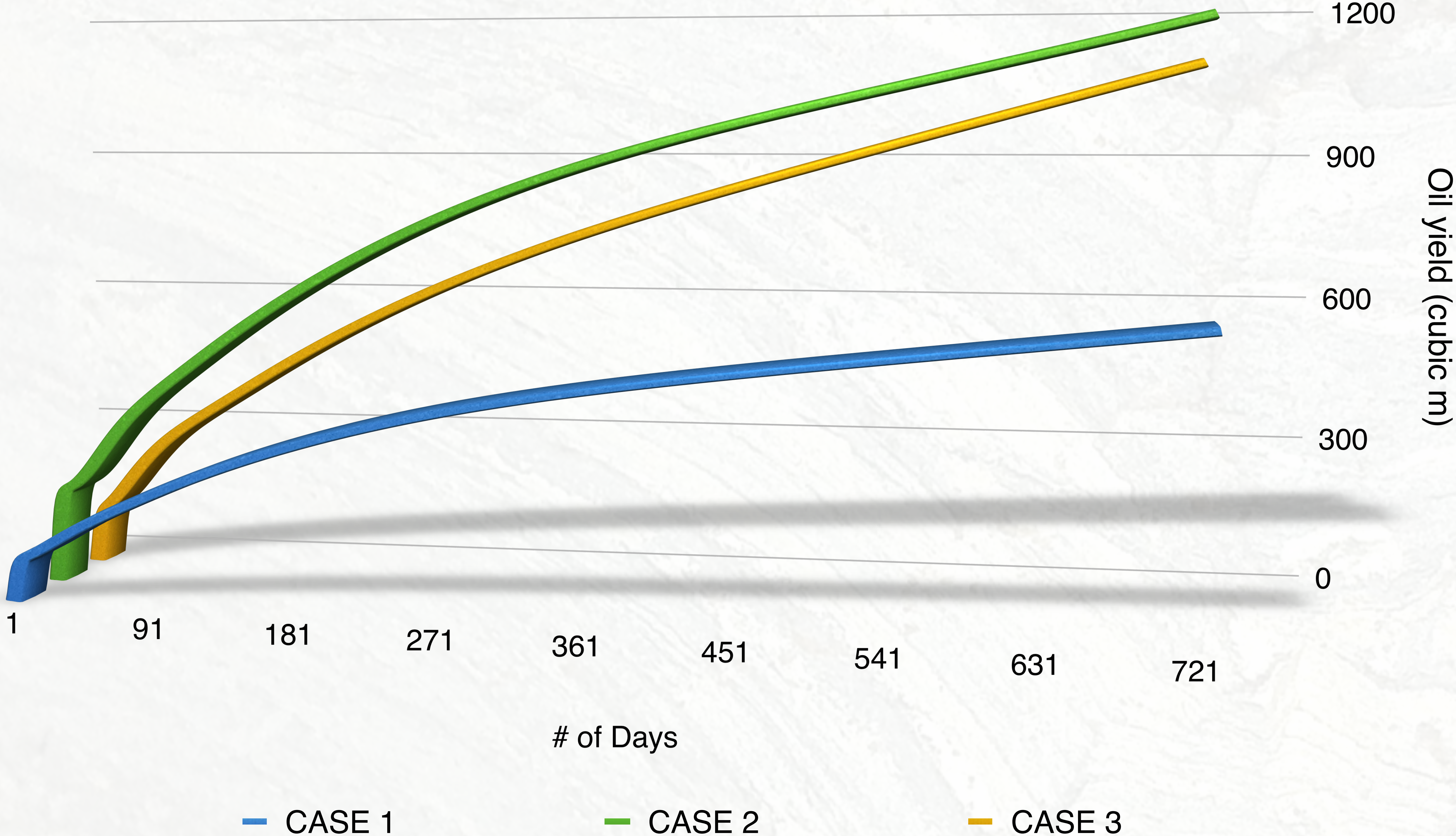


PRODUCT YIELD



ENERGY RATIO - 2 YRS HEATING

	Energy In (x10	Oil Yield (m	Oil equivalent Energy Out (x10	NG equivalent Energy Out (x10	Energy In/ Energy Out
Case 1	13.9	592	6.33	6.84	2.03 - 2.20
Case 2	27.3	1,175	12.6	13.6	2.00 - 2.17
Case 3	43.2	1,120	12.0	12.9	3.35 - 3.60

CONCLUSIONS

Used simulations to look at "what if" scenarios located in the Uinta Basin

For conductive heat transfer retorting

1. Required power input exceeds energy content of product
2. Majority of heat is used to heat distant surrounding rock to low temperatures

Using simulations can evaluate strategies to increase product yield

1. Drill additional wells to provide more heat
2. Increase temperature in the heating well

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2. Increase temperature in the heating well

Need to introduce convective heat transfer to increase the rate of heating

CONCLUSIONS

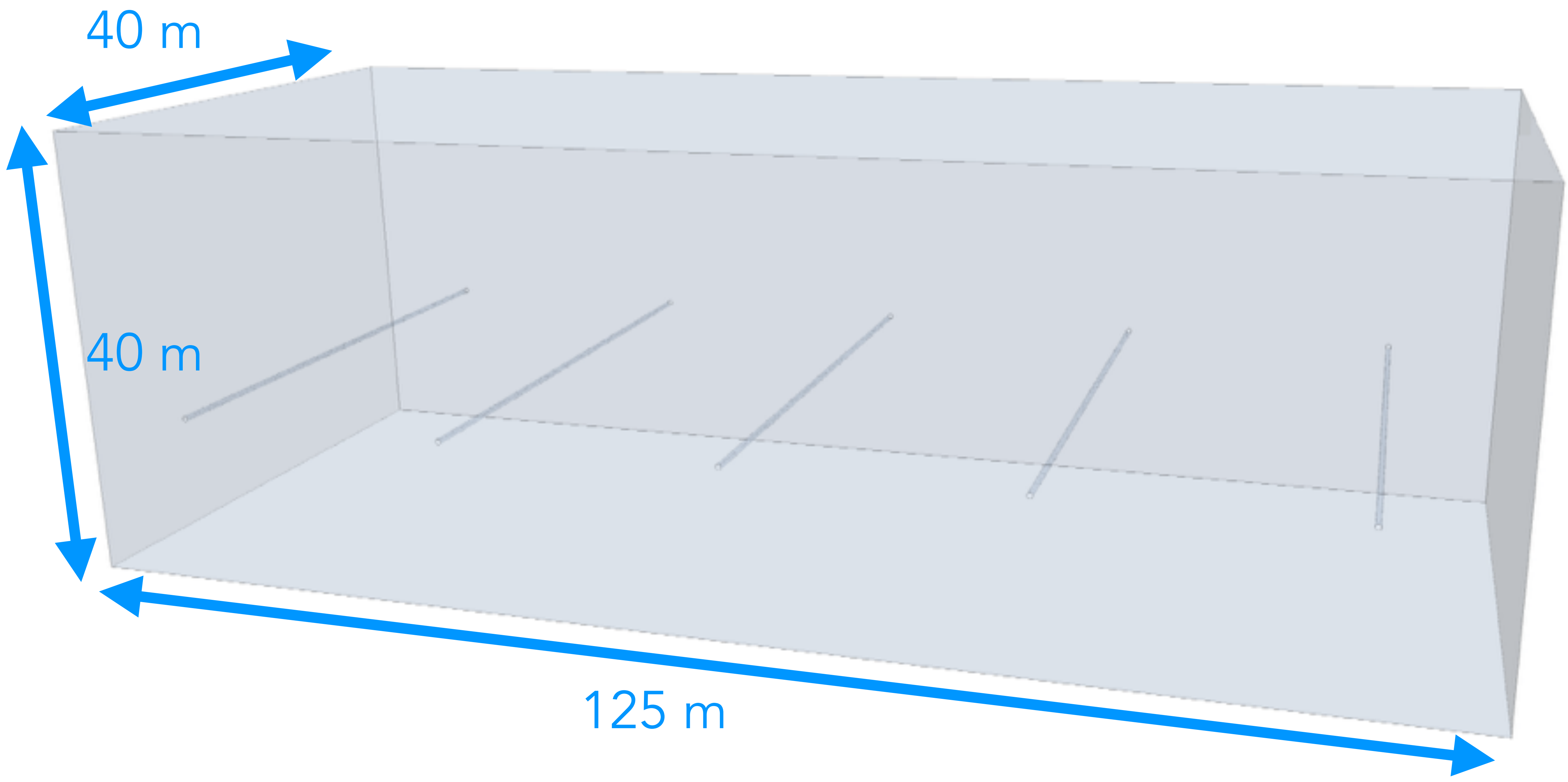
HPC simulations can provide high fidelity over long time periods

1. Can resolve localized heat transfer
2. Comes at a cost
   - approx. 150,000 CPU-hr per computation

$\boxed{\text{~520 days on 12-core workstation}}$

- The rate-limiting step is the rate of heat transfer during thermal treatment process
  - Need to get the heat transfer right
- Developing CFD-based simulation tool
  - Using CFD-based tools on a reservoir scale
  - Offers potential for future enhancements to capture important physics in a realistic domain
  - Offers better strategy for designing/evaluating technologies
  - Help to maximize economic return and minimize risk

WHAT'S NEXT …



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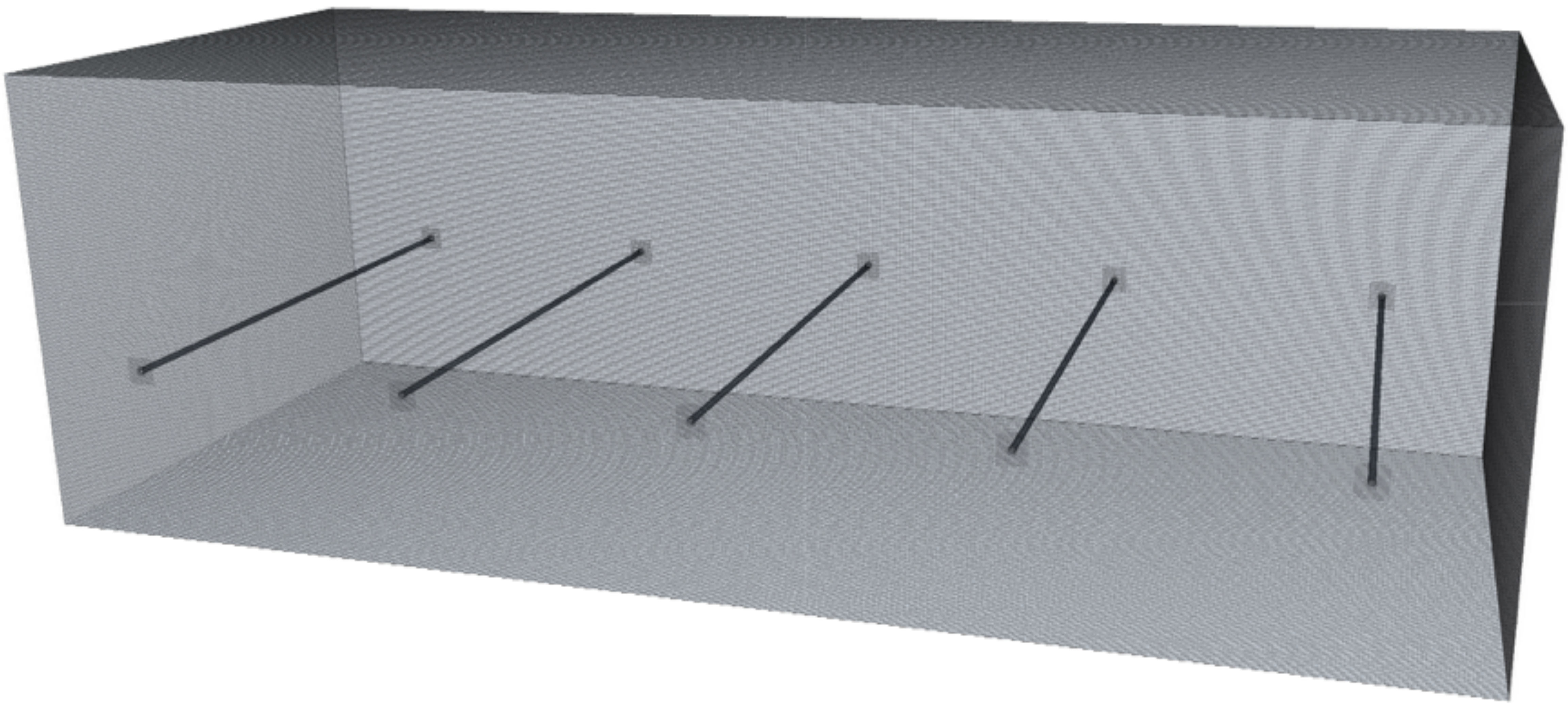

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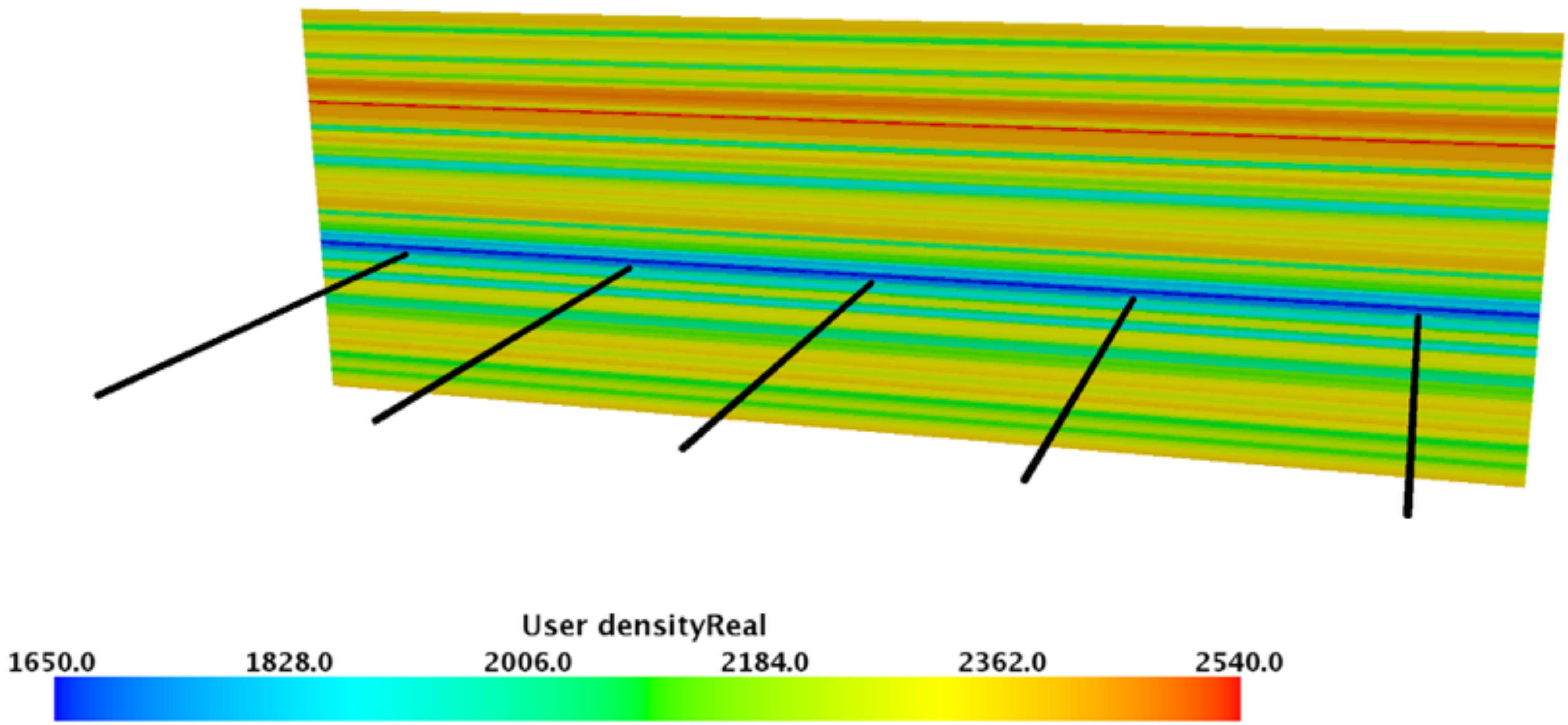

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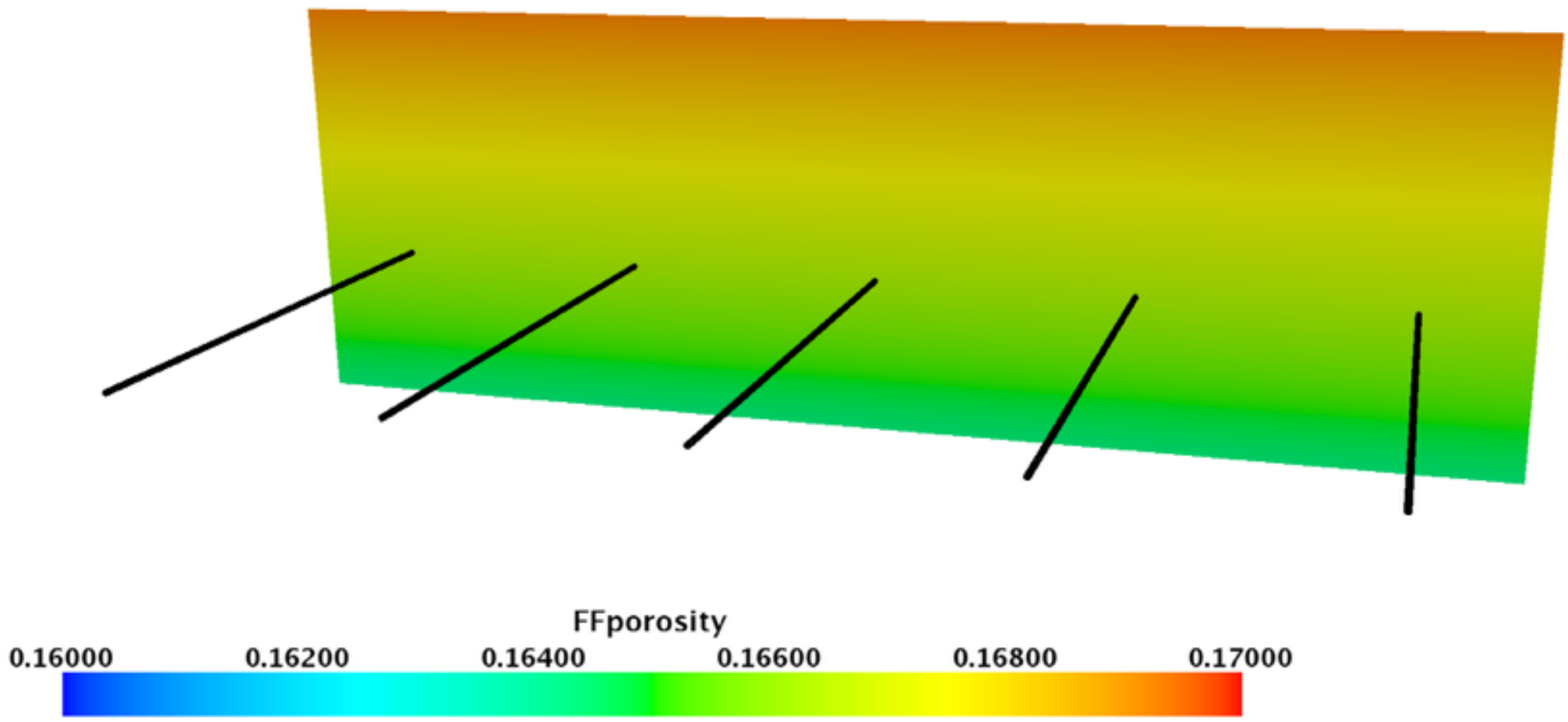

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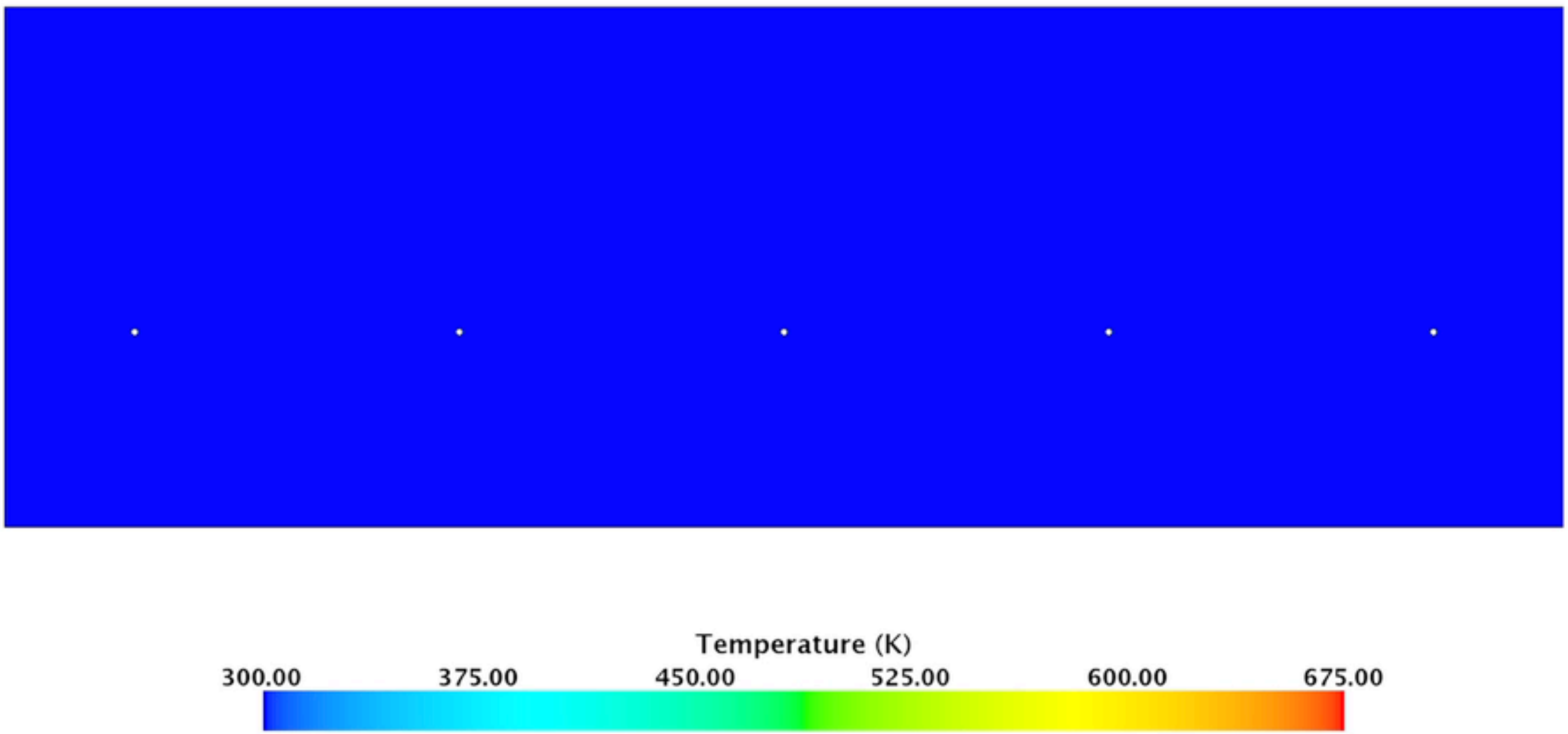

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