

A Regional Flow Model for the Weyburn CO₂ Storage Site

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The Permedia Research Group

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The University of Edmonton



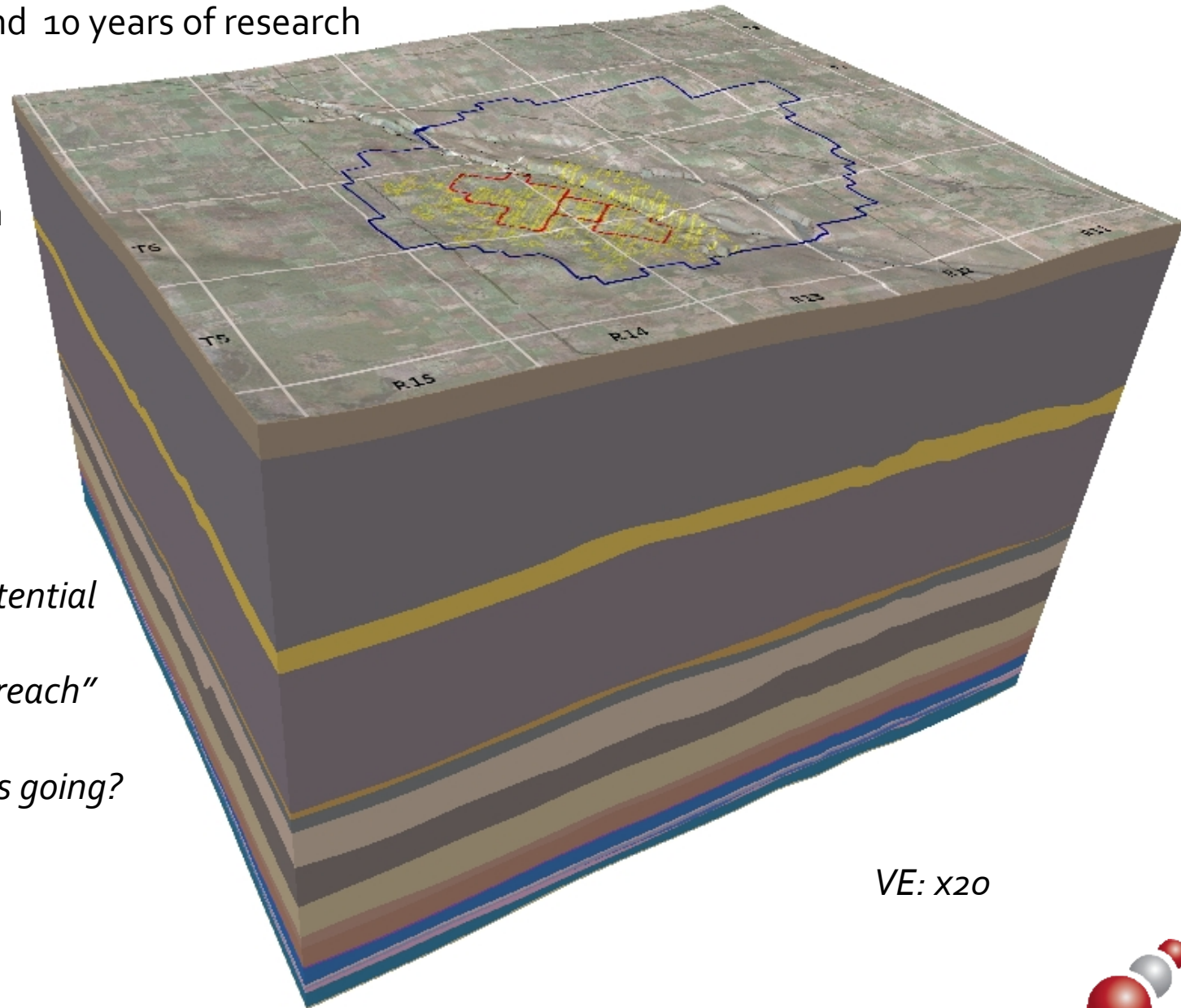
A Regional Flow Model...

The Weyburn storage site, SW Saskatchewan, Canada

- To date: 17 Mt of CO₂ and 10 years of research
- Planned: 35 Mt by 2035
- Storage at 1.4 km depth
- Four overlying aquifers
- Model area: 40x50 km²
- Thousands of wells

Model aim: "Assess the potential behavior of migrating CO₂ in the event of a caprock breach"

... where does it go if it gets going?



VE: x20



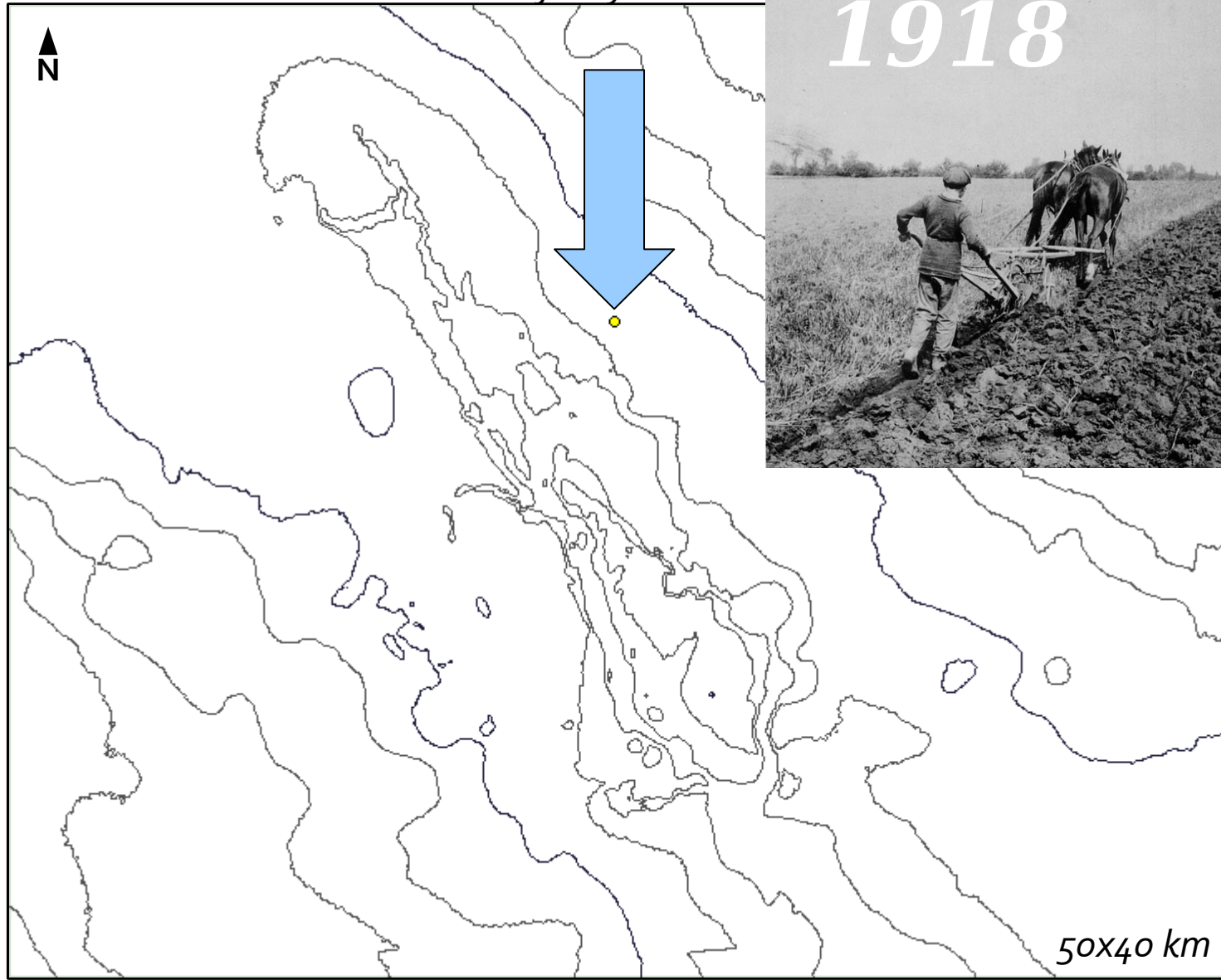
1. Build a well database: oil producers, water and CO₂ injectors
2. Risk the well population by category
3. Assign category flow properties
4. Model the region at high-resolution
5. Assess shale breach criteria
6. Predict secondary storage potential



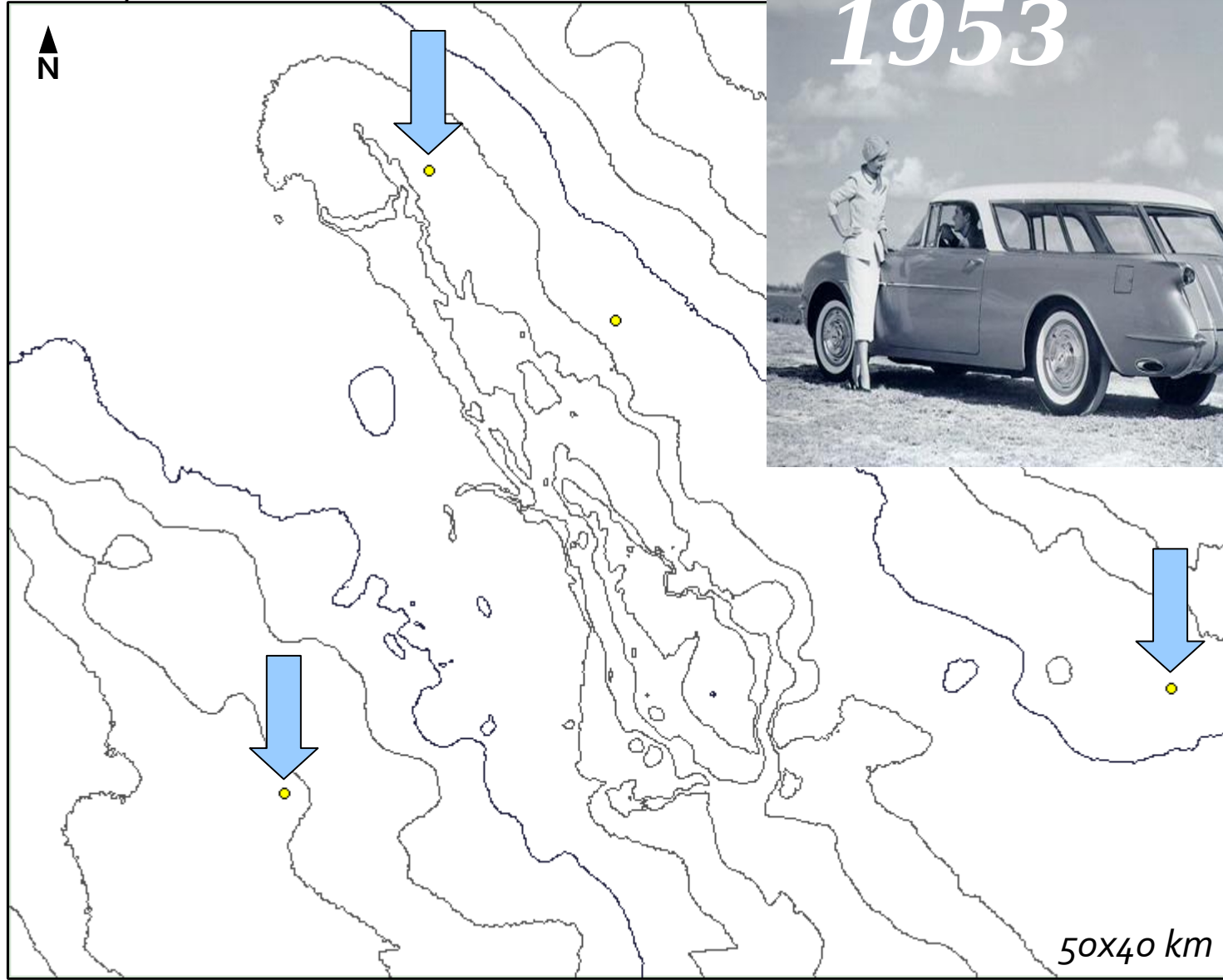
Weyburn oil producer, 2009



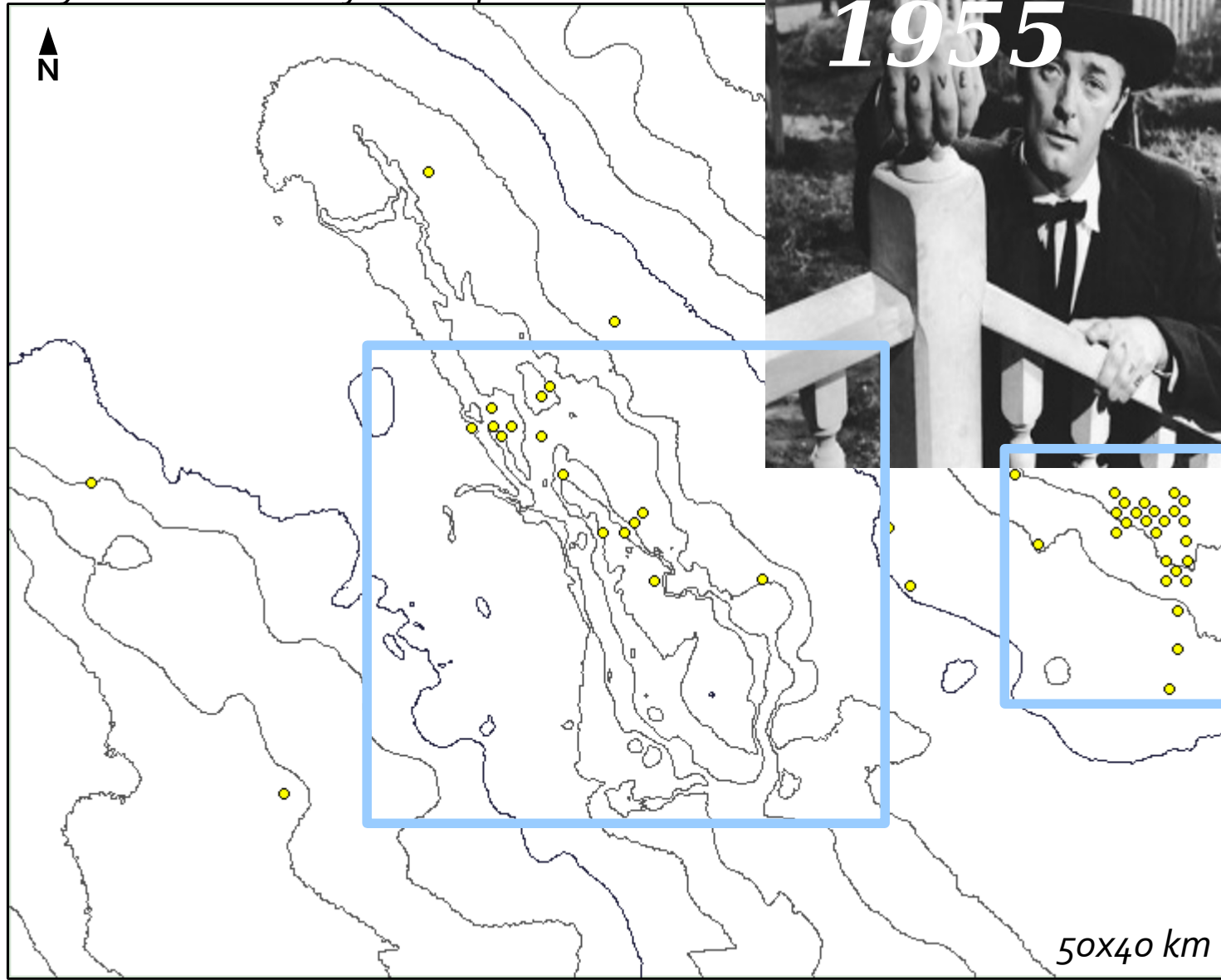
Shallow water well to the north of Weyburn



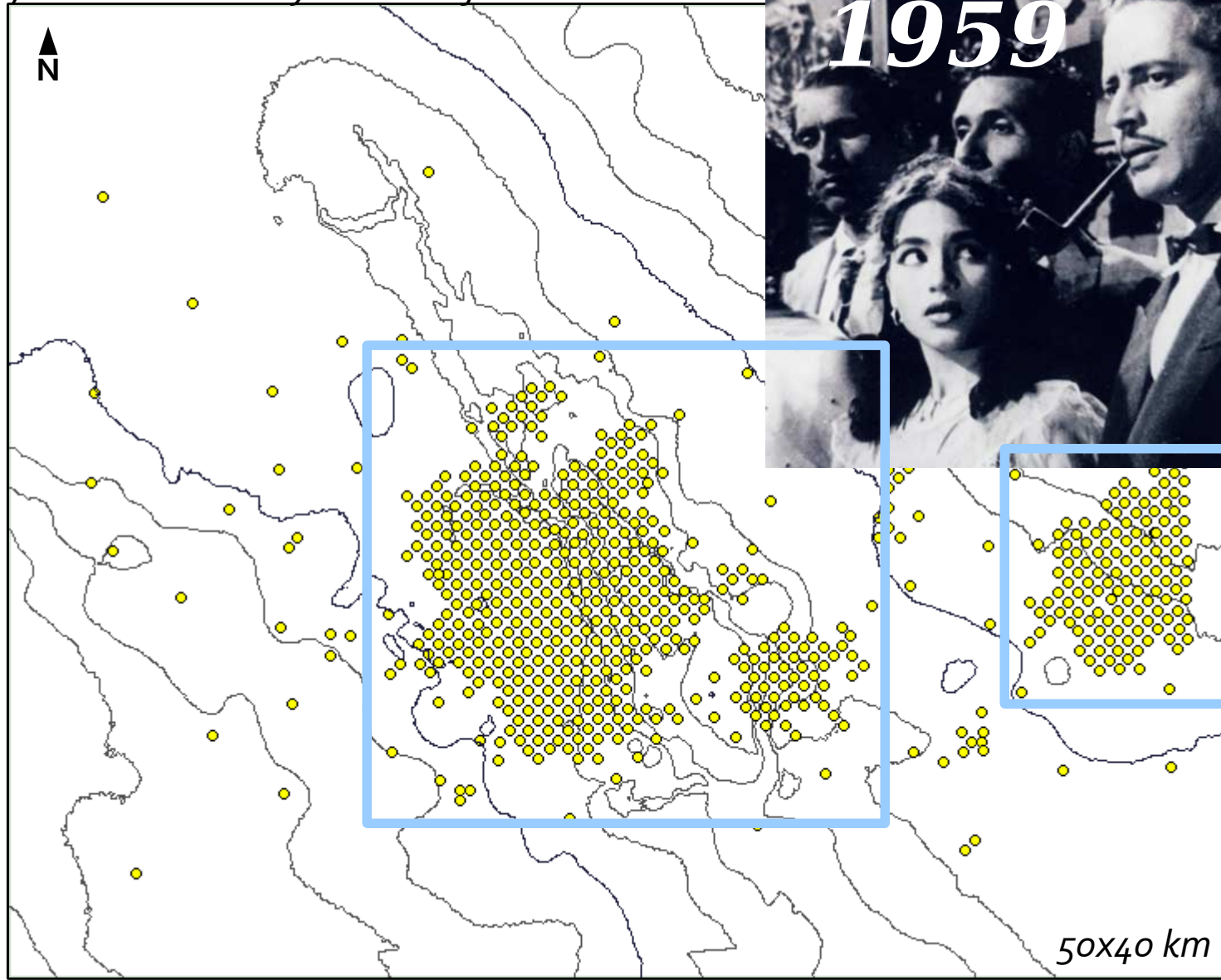
First exploration wells close to towns and roads



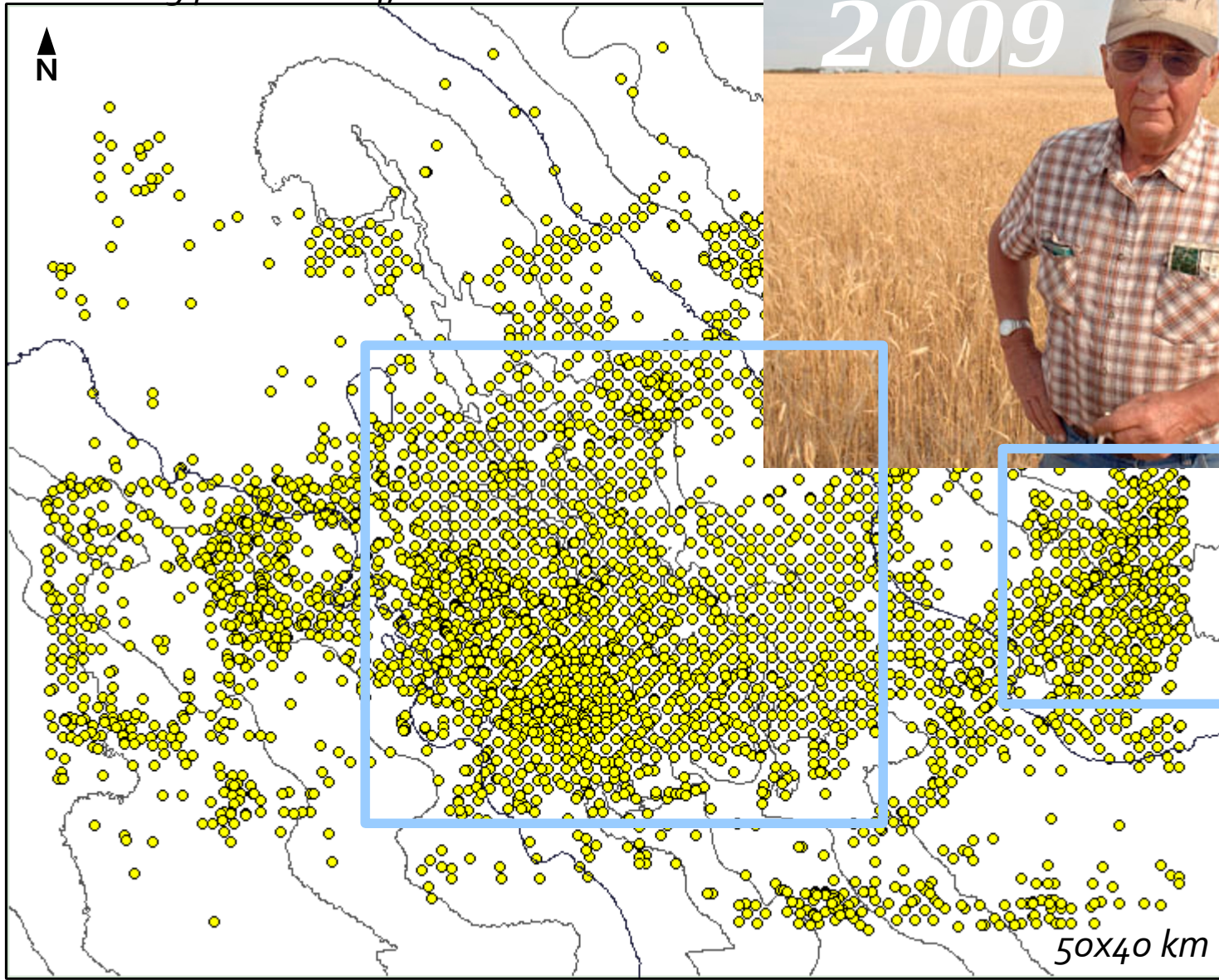
Weyburn and Midale fields in production



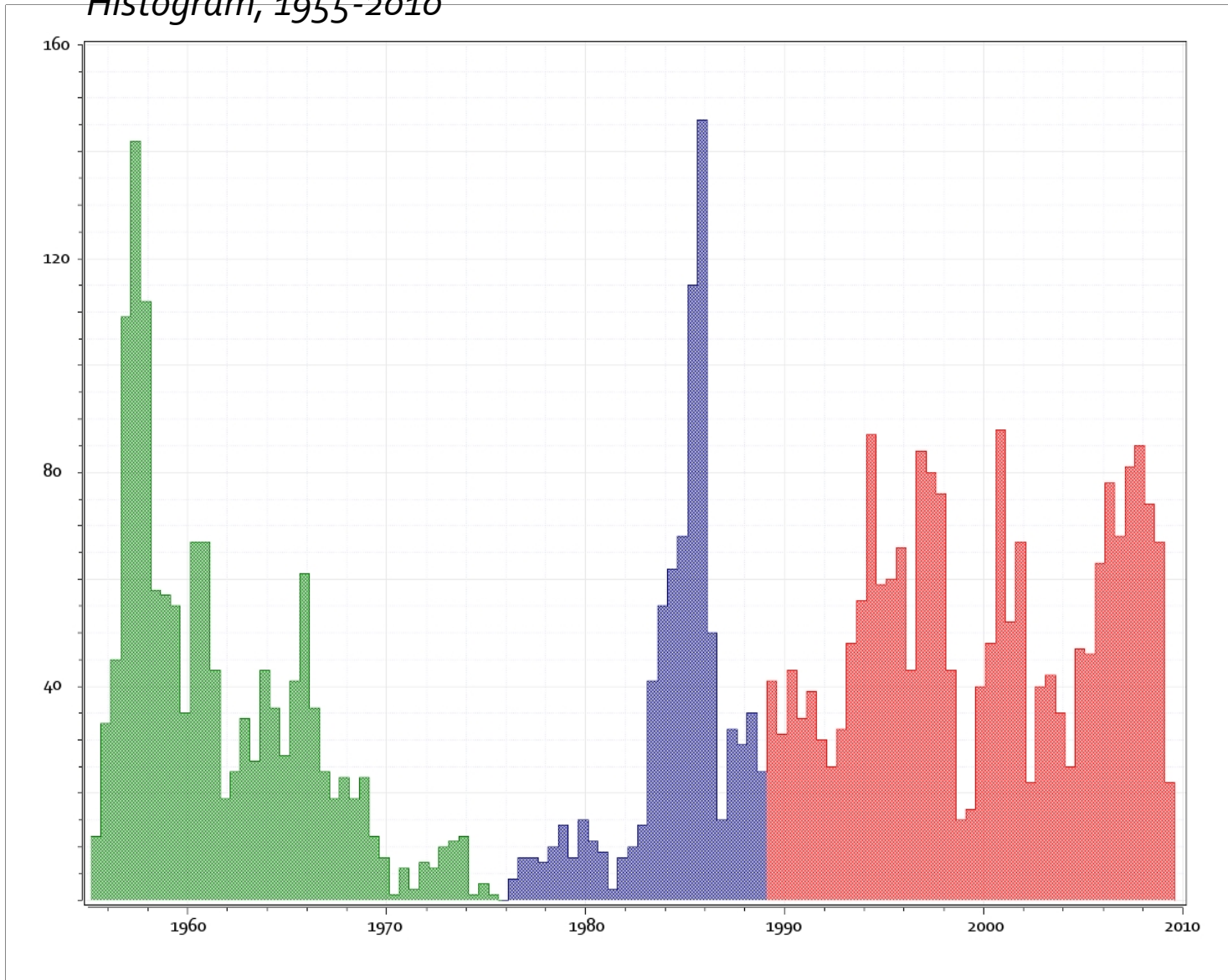
700 wells drilled by the end of the decade



The drilling passes the 4,000 mark



Histogram, 1955-2010



Well population: 4112

1953-1975

● 1374 early vertical ~34%

1976-2009

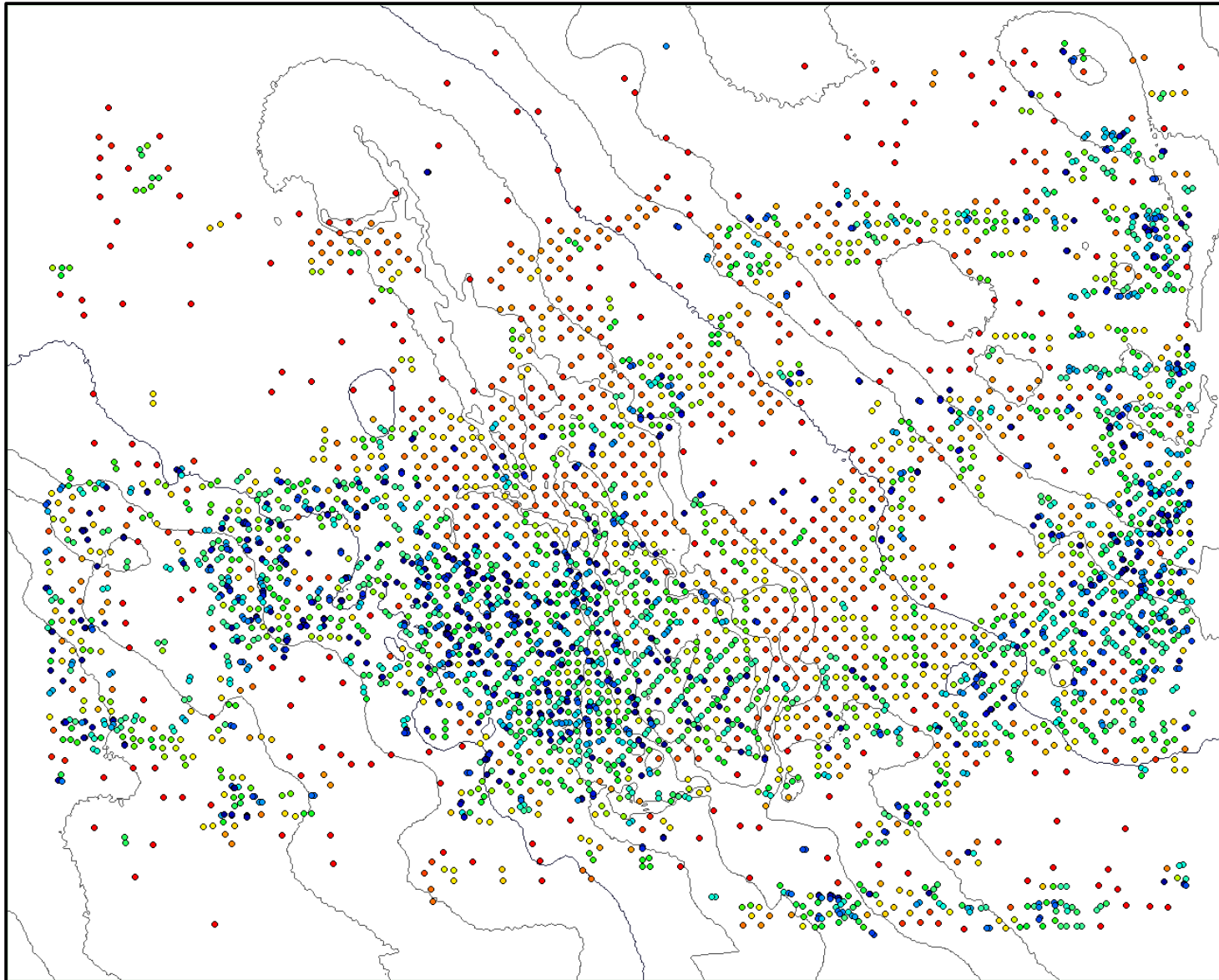
● 1325 late vertical ~32%

1989-2009

● 1413 horizontal ~34%



Well population by proximity



Well population: 4112

Low Proximity:

● More than 600 m: ~5%

Mean Proximity:

● Average for wells: 275 m

High Proximity:

● Less than 25 m: ~5%

Optimal mesh resolution:

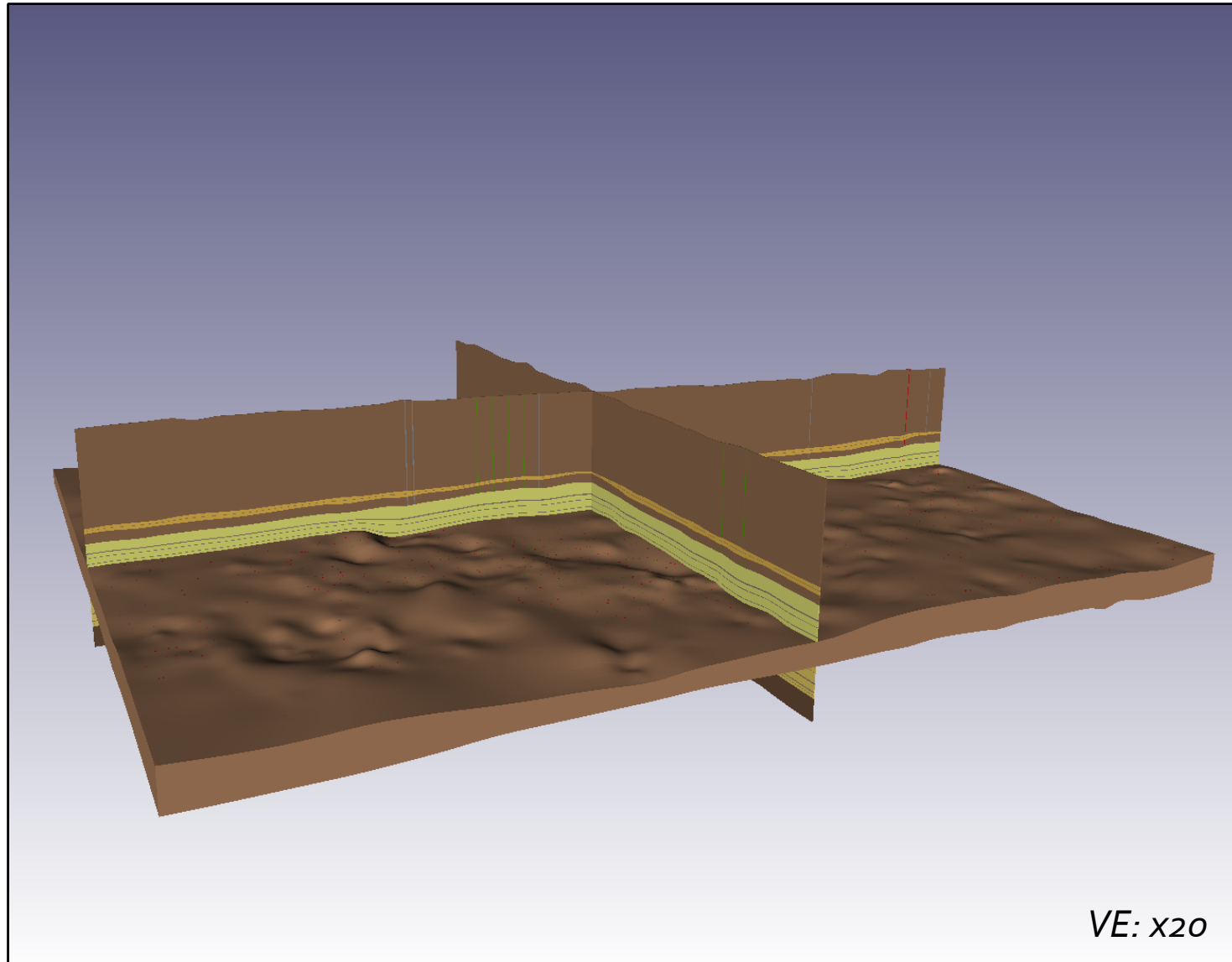
● 25 x 25 m²

Mesh size:

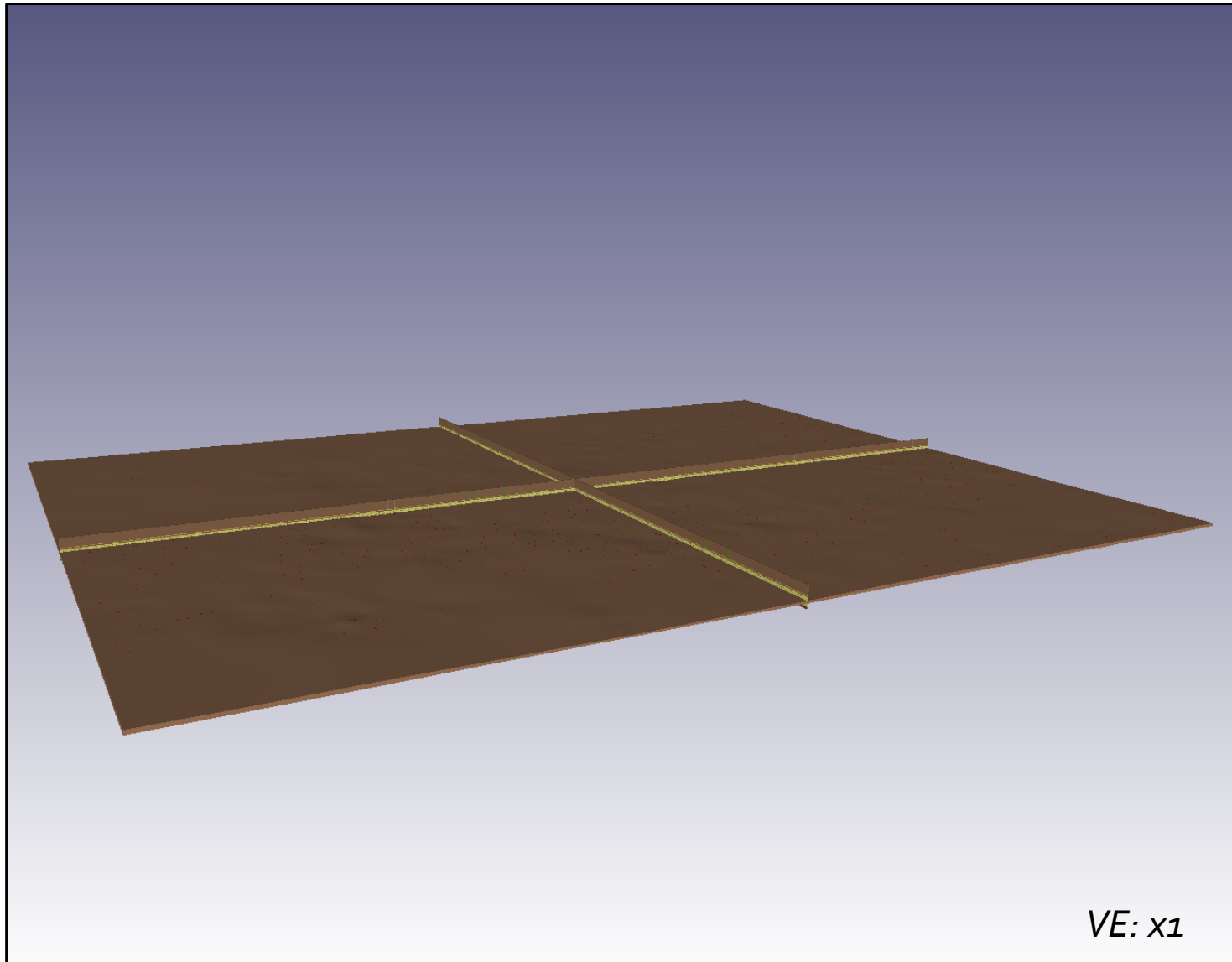
● 22 million grid cells



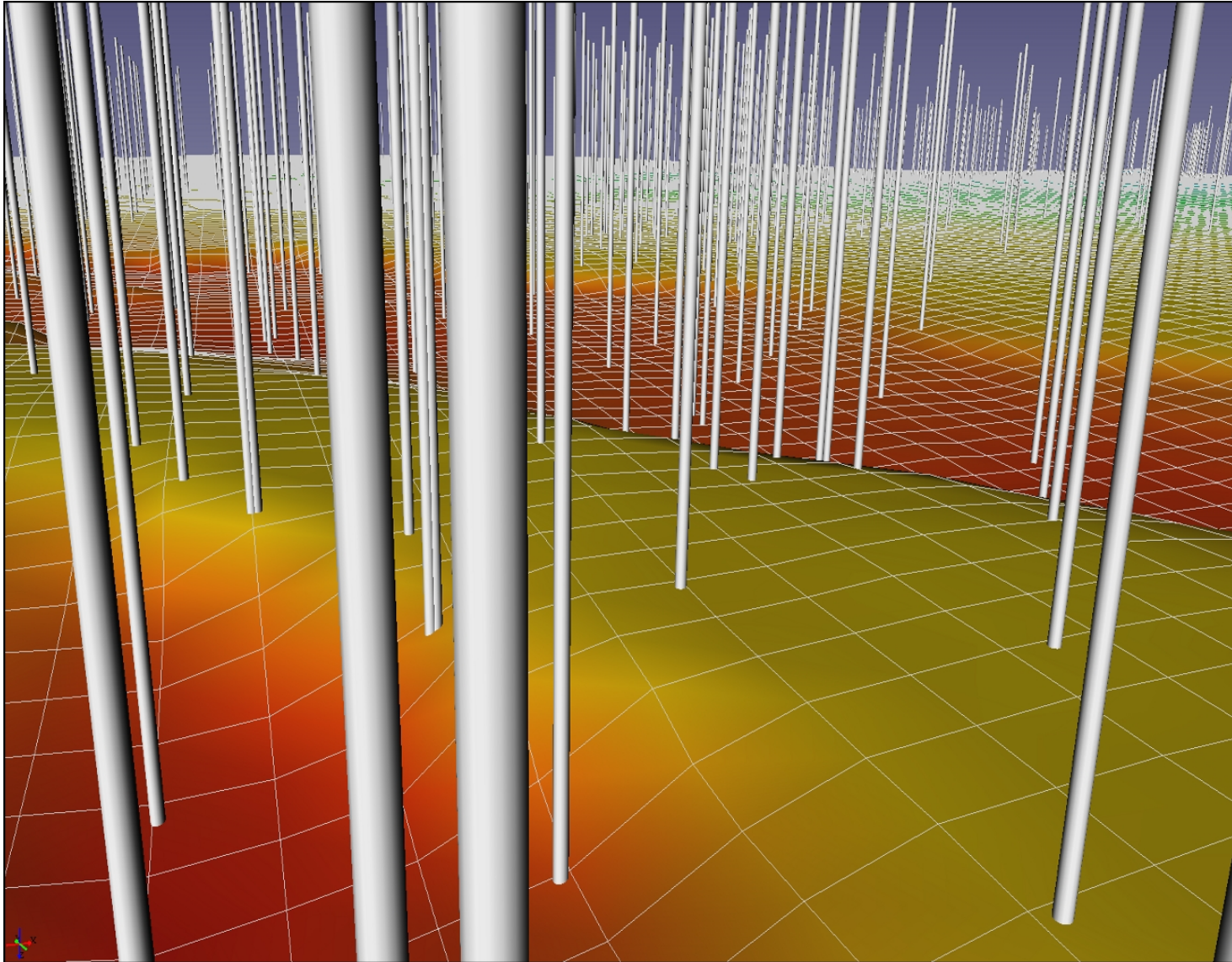
Mesh: 22 million elements



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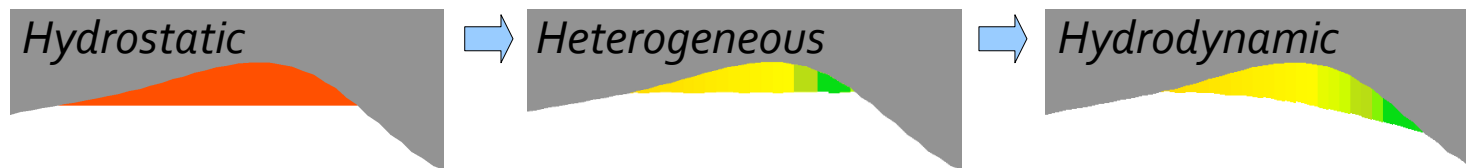


Mesh: 22 million elements (4,112 wells within a region of 2,000 km²)



4112 regional wells grouped by age and type
4 regional aquifers with low relief and gentle dip to south

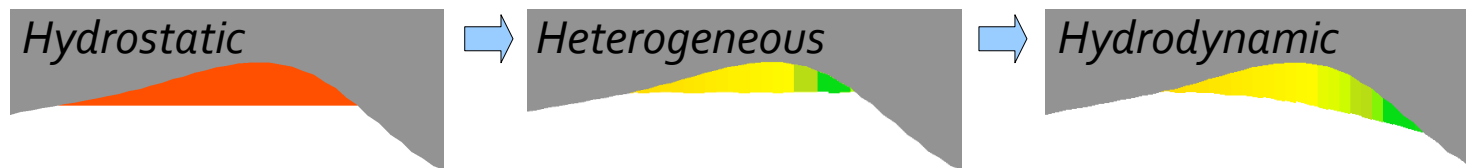
Migration pathways and juxtaposition of pools with wells,
risked for potential breach associated with well path



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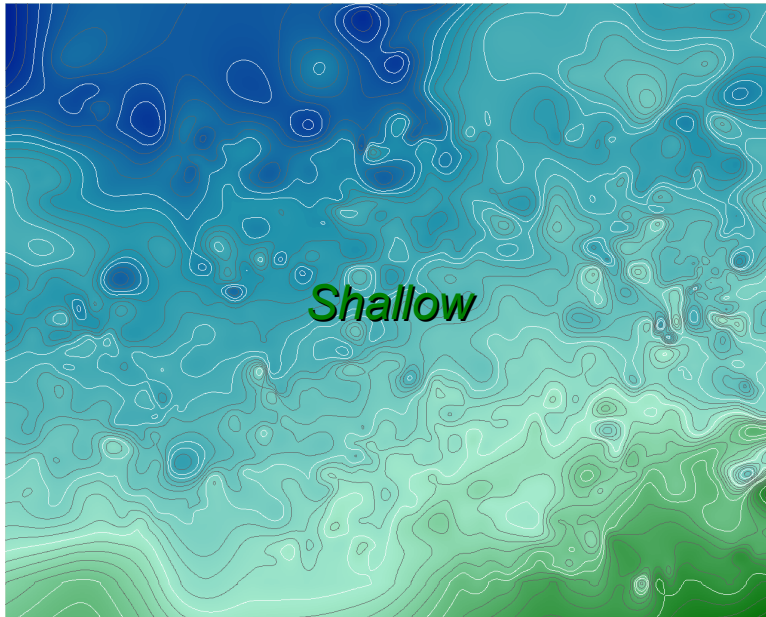
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Under hydrostatic conditions?

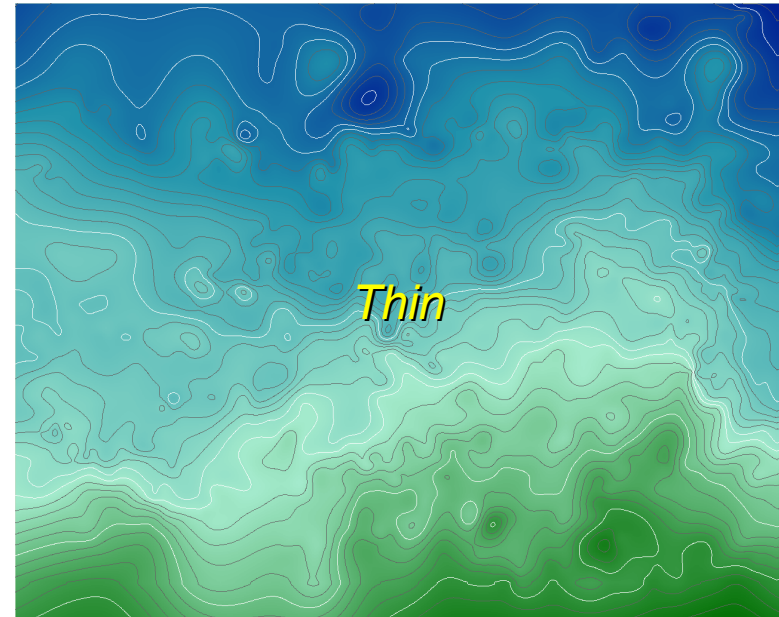


Fill-Spill Analysis

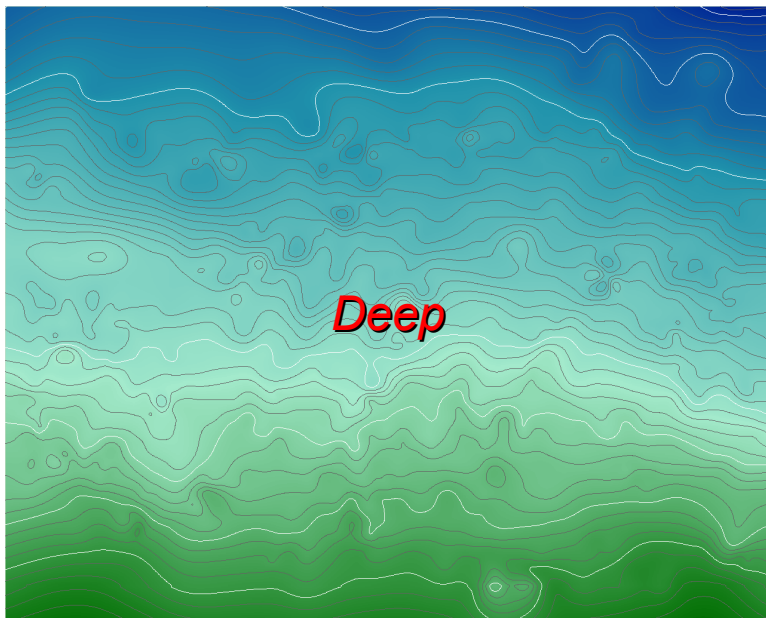
- Belly River Formation (55 m thick)



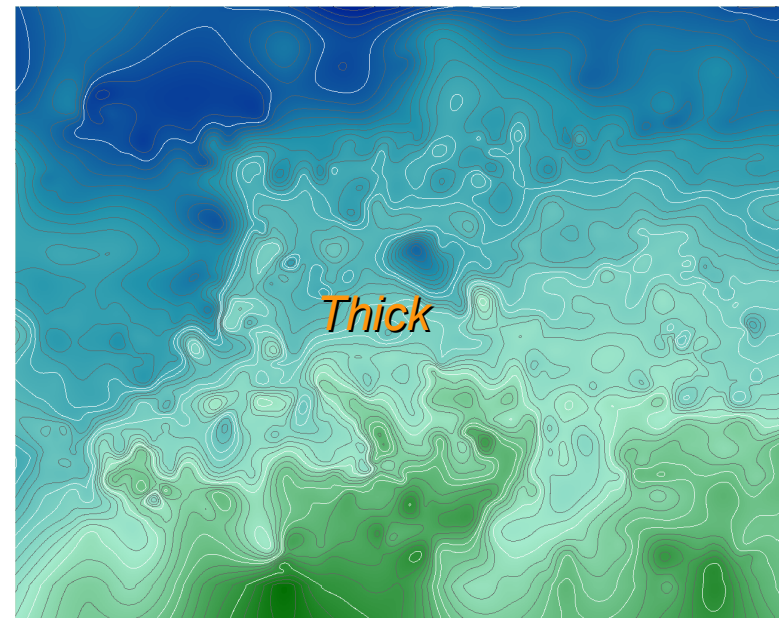
- Newcastle Formation (22 m thick)



- Jurassic Formation (122 m thick)



- Mannville Formation (123 m thick)

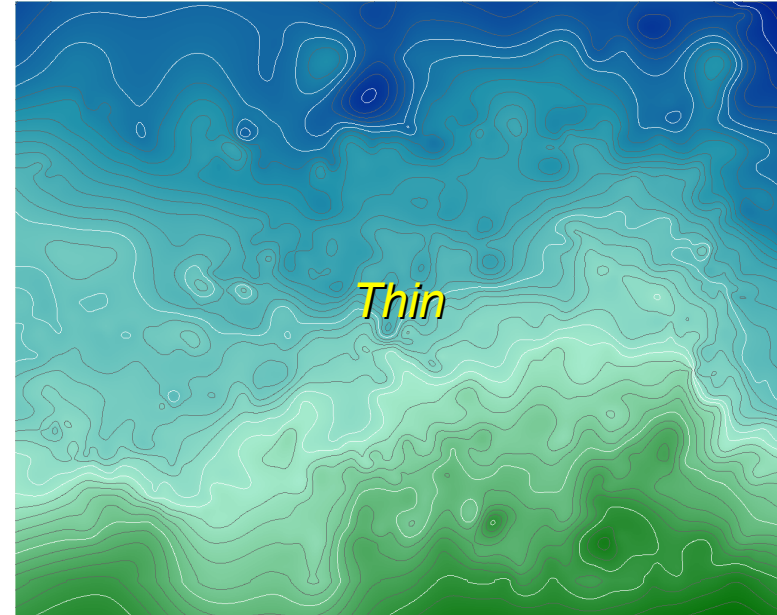


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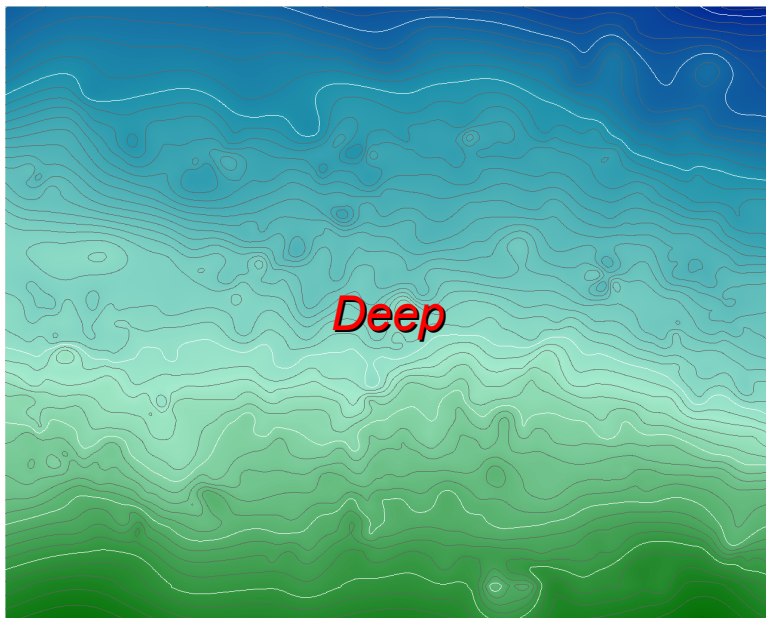
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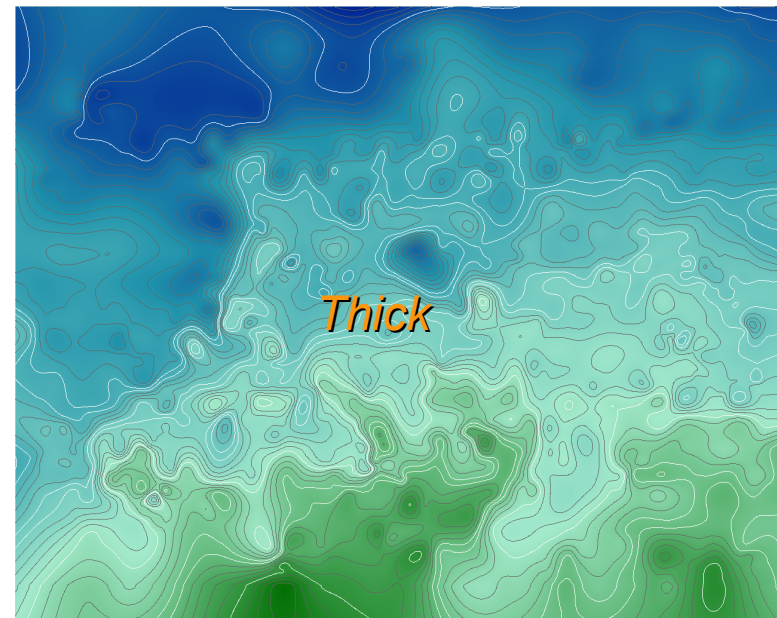
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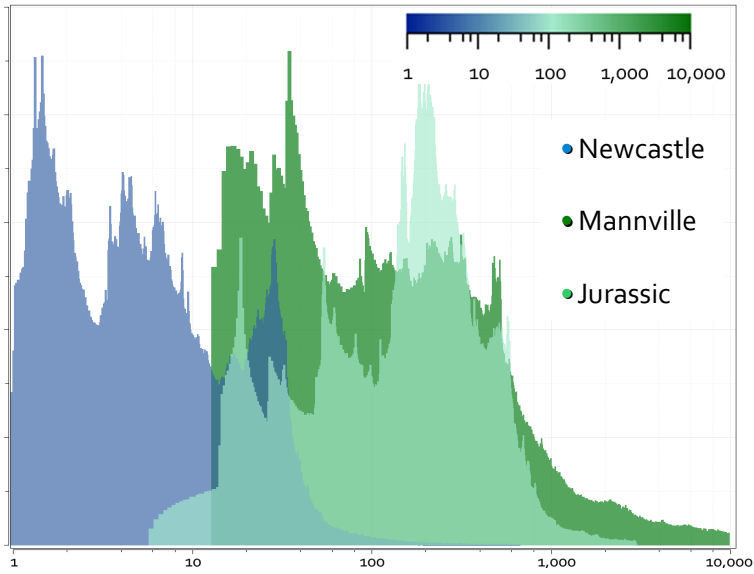


- Mannville Formation (123 m thick)

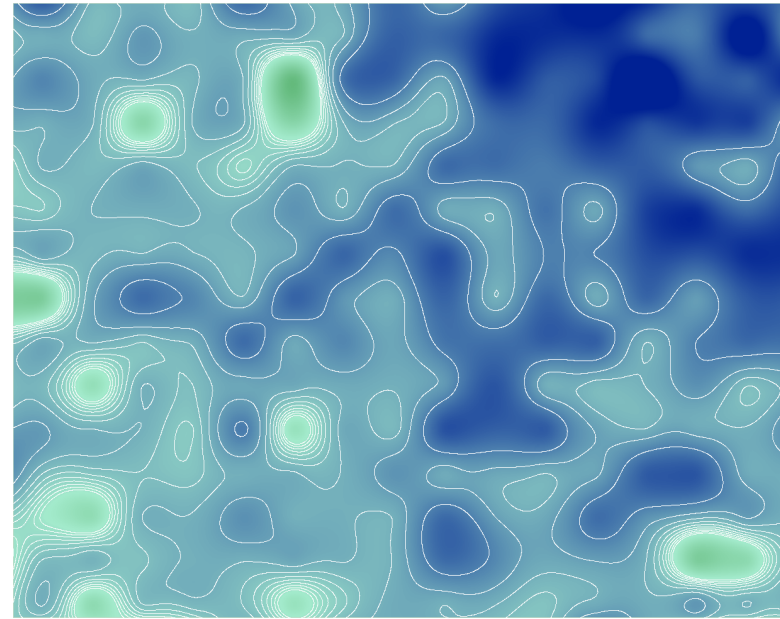


Permeability and Pressure

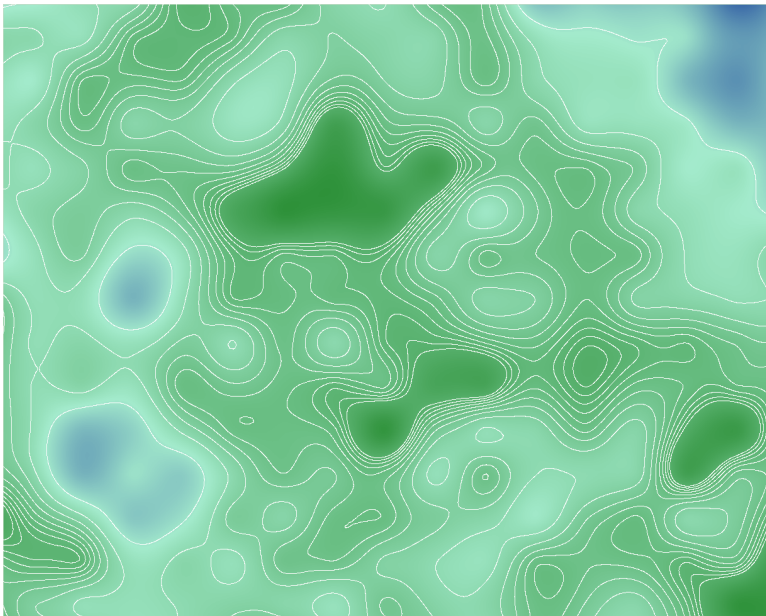
Aquifer permeabilities



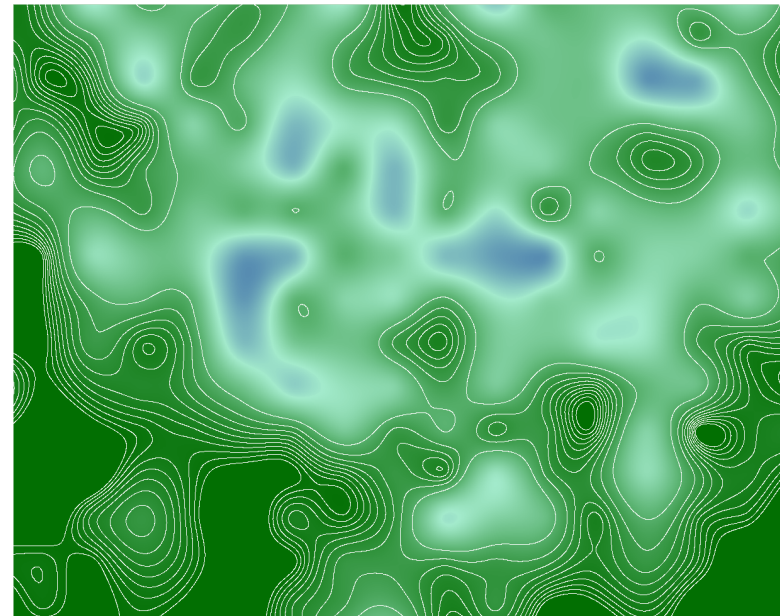
• Newcastle: 10-100 mD



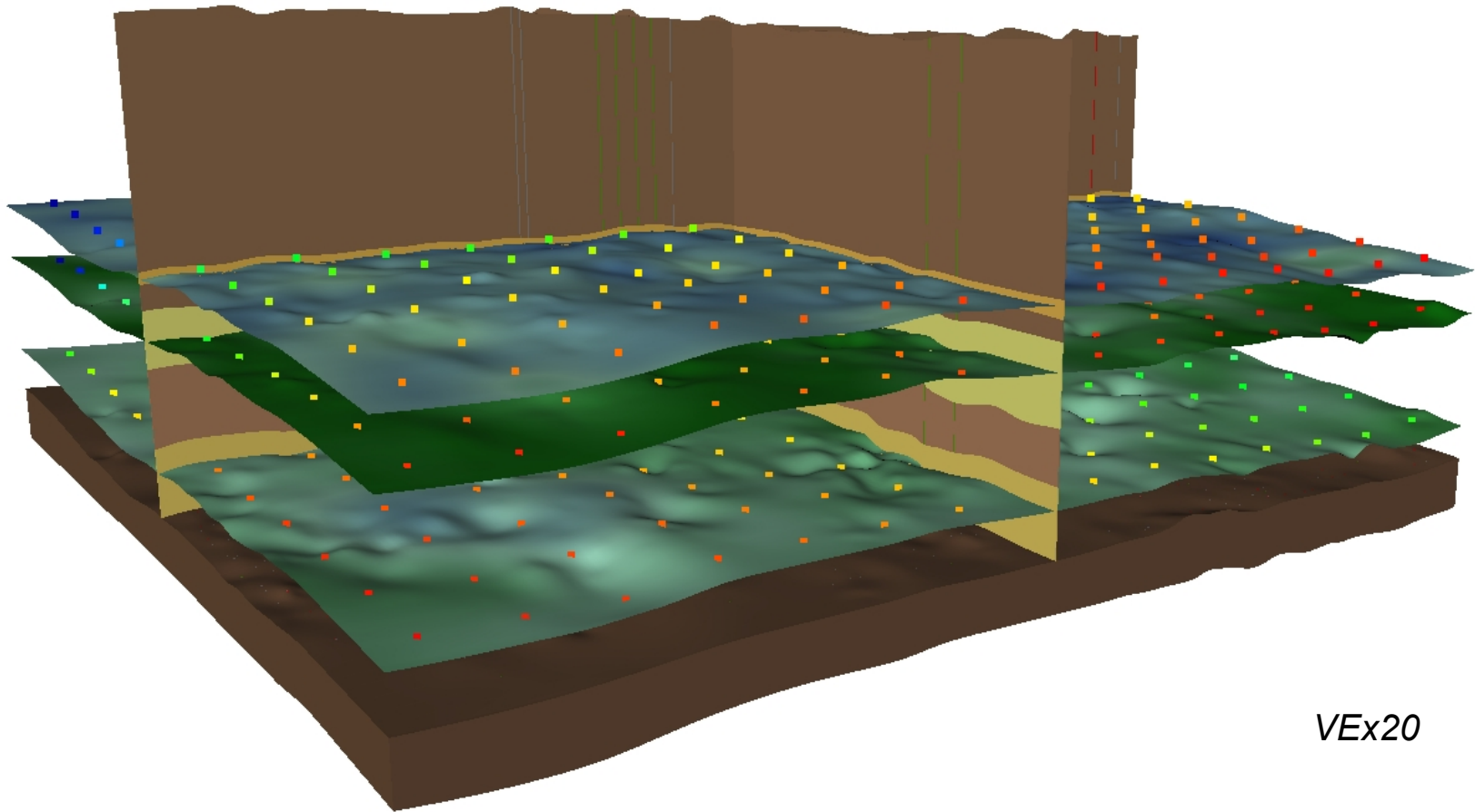
• Jurassic: 100-1,000 mD



• Mannville: 1-10 D



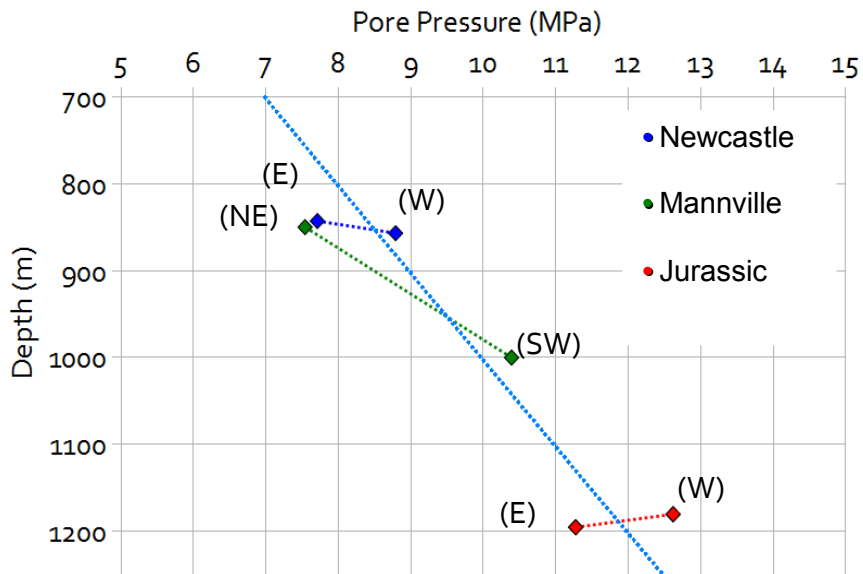
Pressure seeding the mesh: 540 points (13.5 to 7.5 MPa)



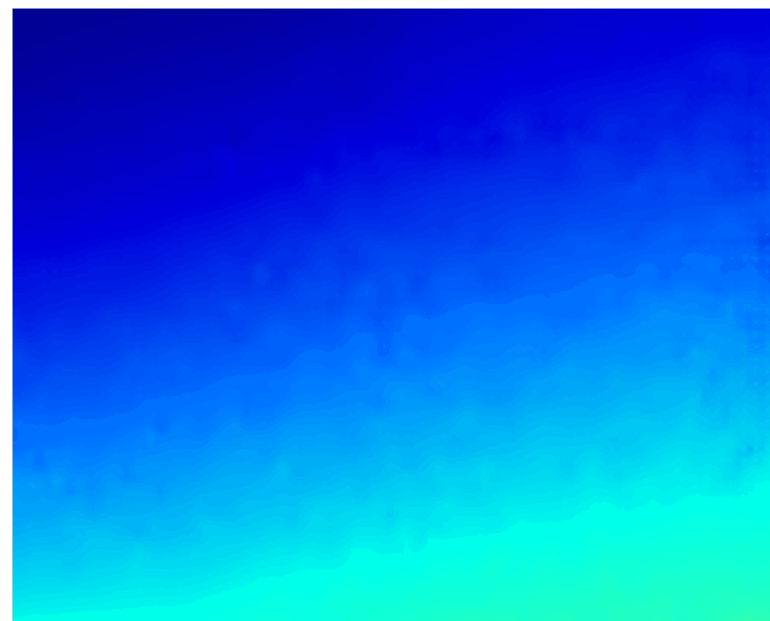
VEx20



Permeability and Pressure



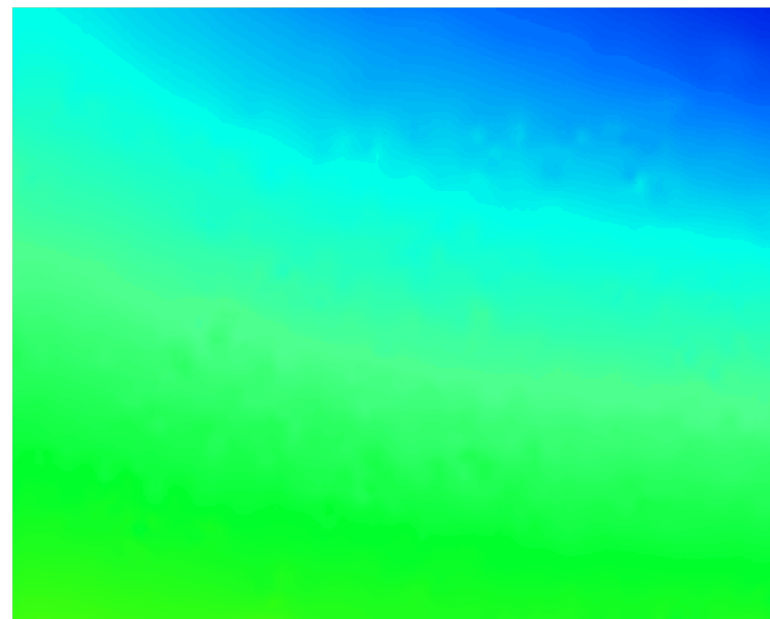
• Newcastle: 9 to 7 MPa

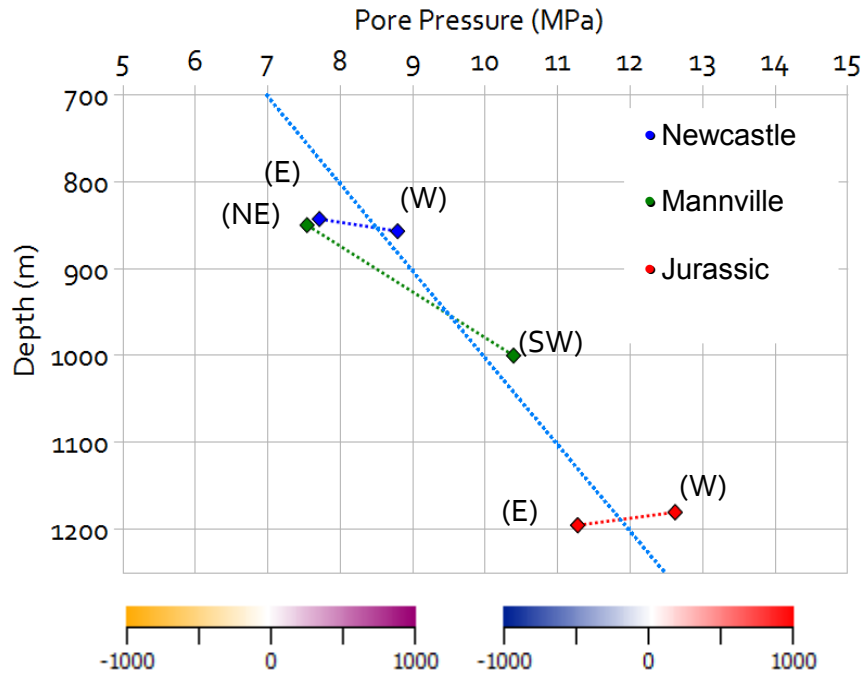


• Jurassic: 13 to 10 MPa

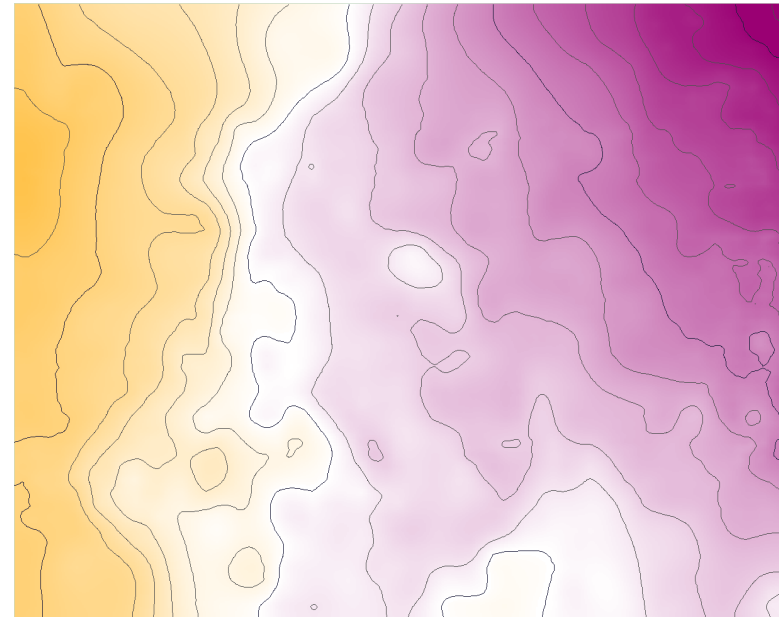


• Mannville: 11 to 8 MPa

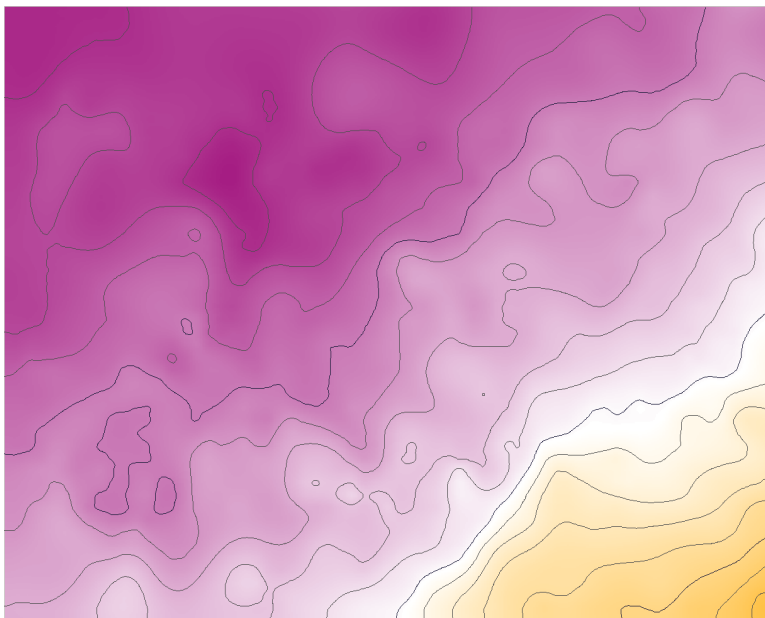




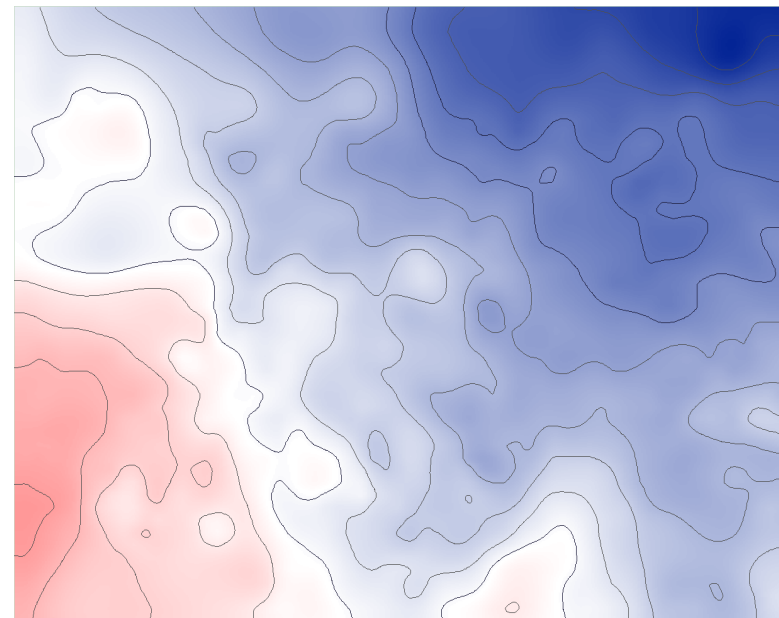
• Newcastle: rel. overpressure (± 1 MPa)

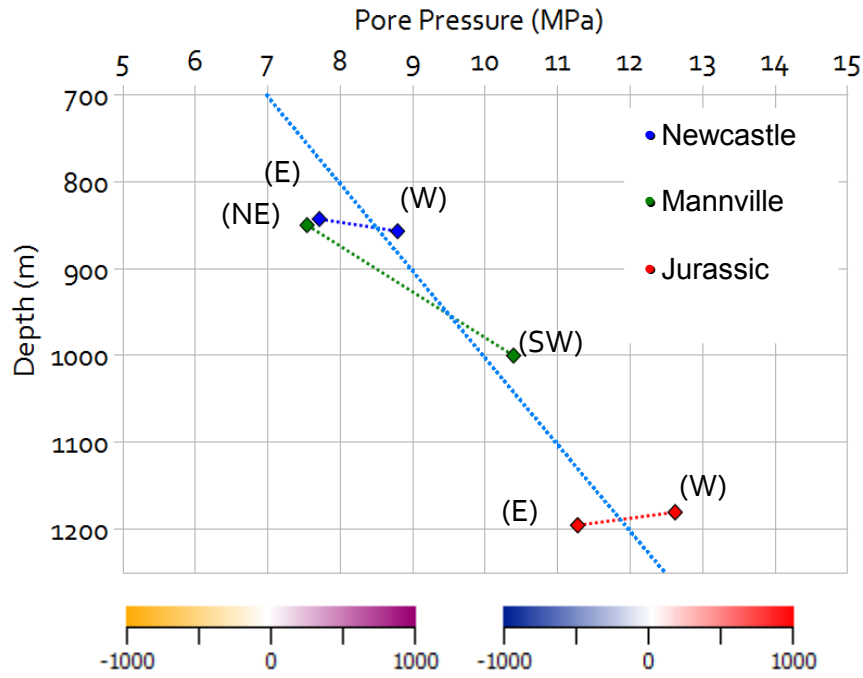


• Jurassic: rel. overpressure (± 1 MPa)

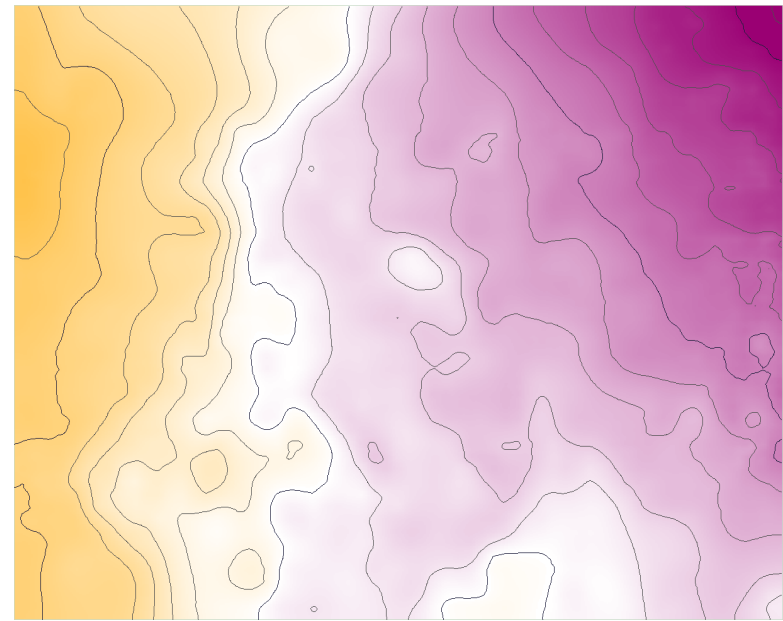


• Mannville: overpressure (± 1 MPa)

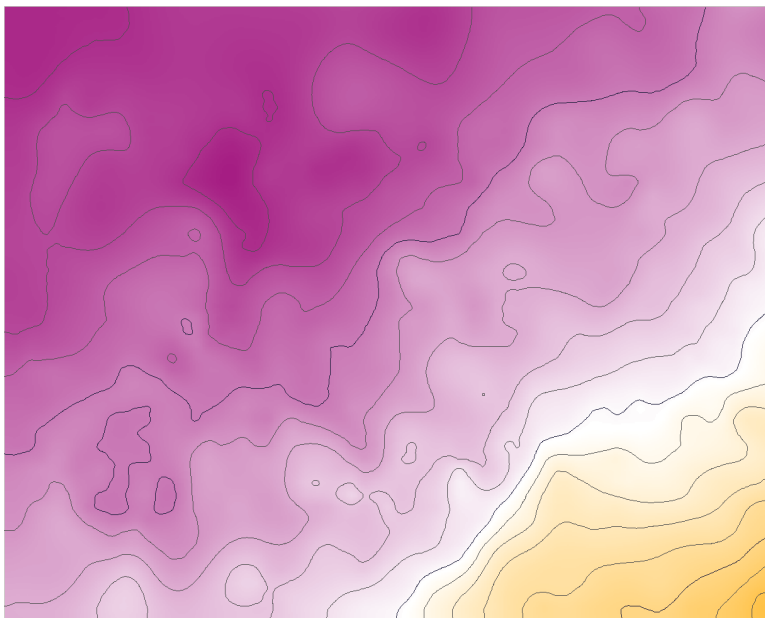




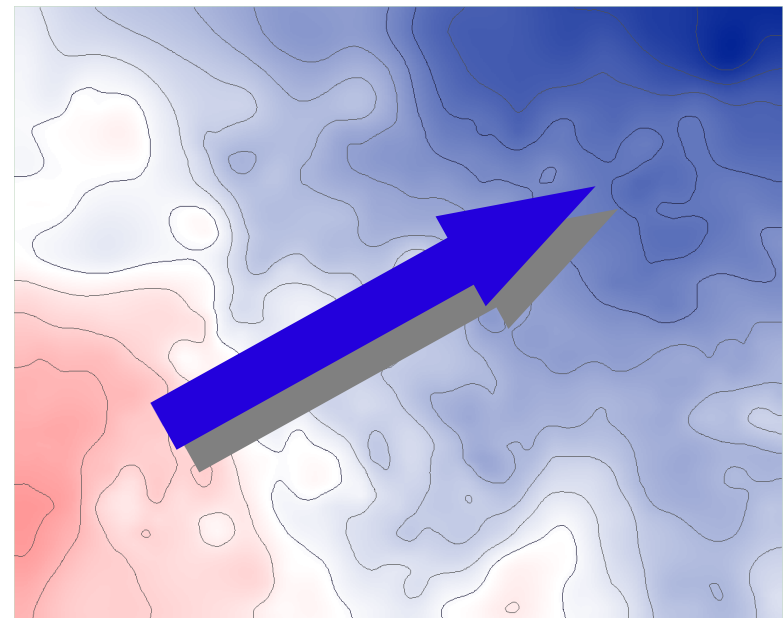
• Newcastle: rel. overpressure (± 1 MPa)



• Jurassic: rel. overpressure (± 1 MPa)



• Mannville: overpressure (± 1 MPa)



Well Properties

- Scenario 1: 1 micron fractures (50 μ D)
- Scenario 2: 3 micron fractures (0.5 mD)
- Scenario 3: 8 micron fractures (5 mD)

Model Questions

- 1) *What is the secondary storage potential above the site?*
- 2) *Which wells are in possible breach locations?*
- 3) *Under what conditions will these well pathways breach?*

Model Results

- *Stochastic analysis across the range of behavior to establish a general pattern*





Storms Shown

Loading hurricane data...

Landfall (in continental U.S.)

- made landfall
- no landfall
- all storms

Hurricane Strength

Saffir-Simpson Scale

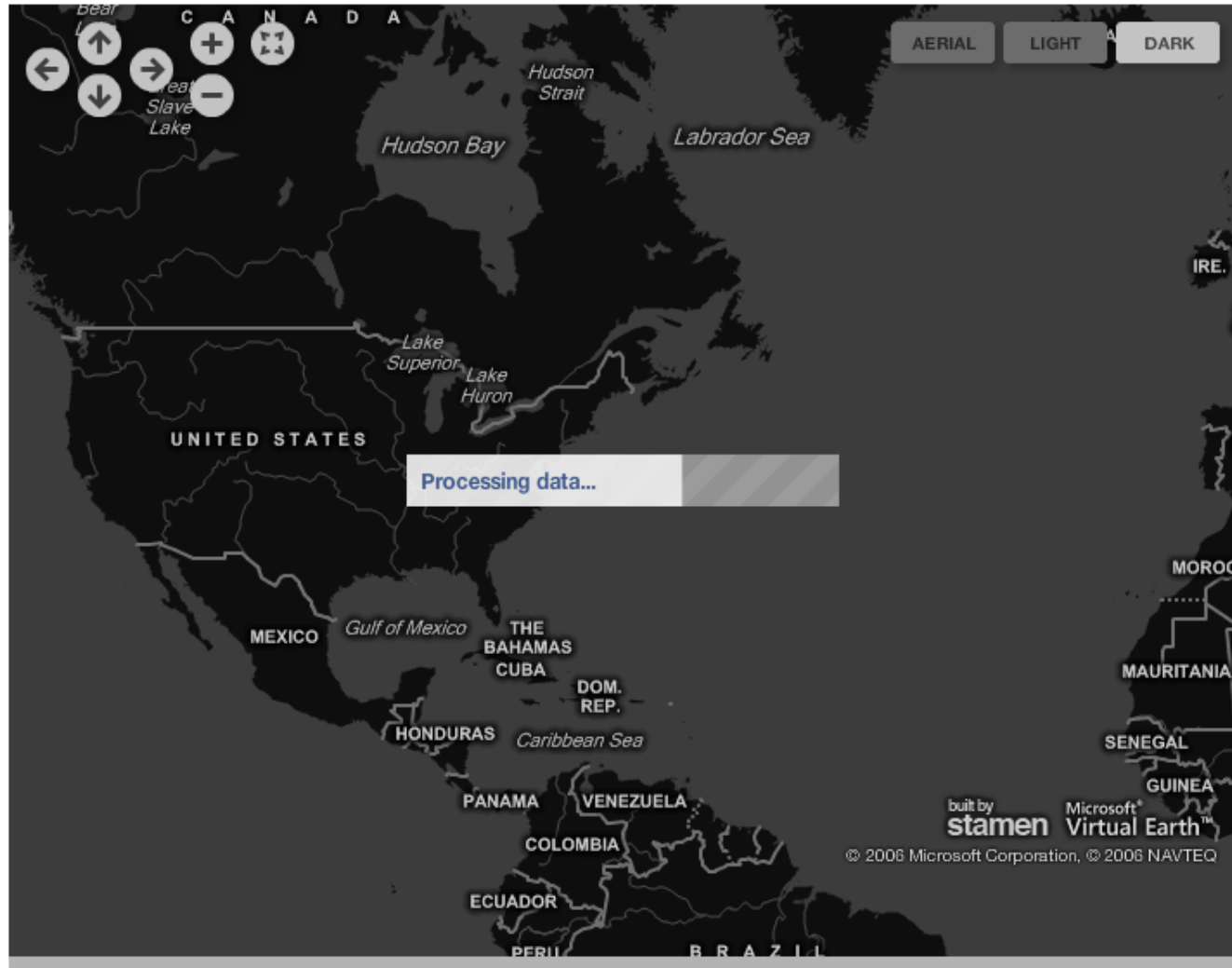


Hurricane Name

Location Search

About the Data

Data shown here are derived from the National Hurricane Center's North Atlantic hurricane database. [Read more...](#)





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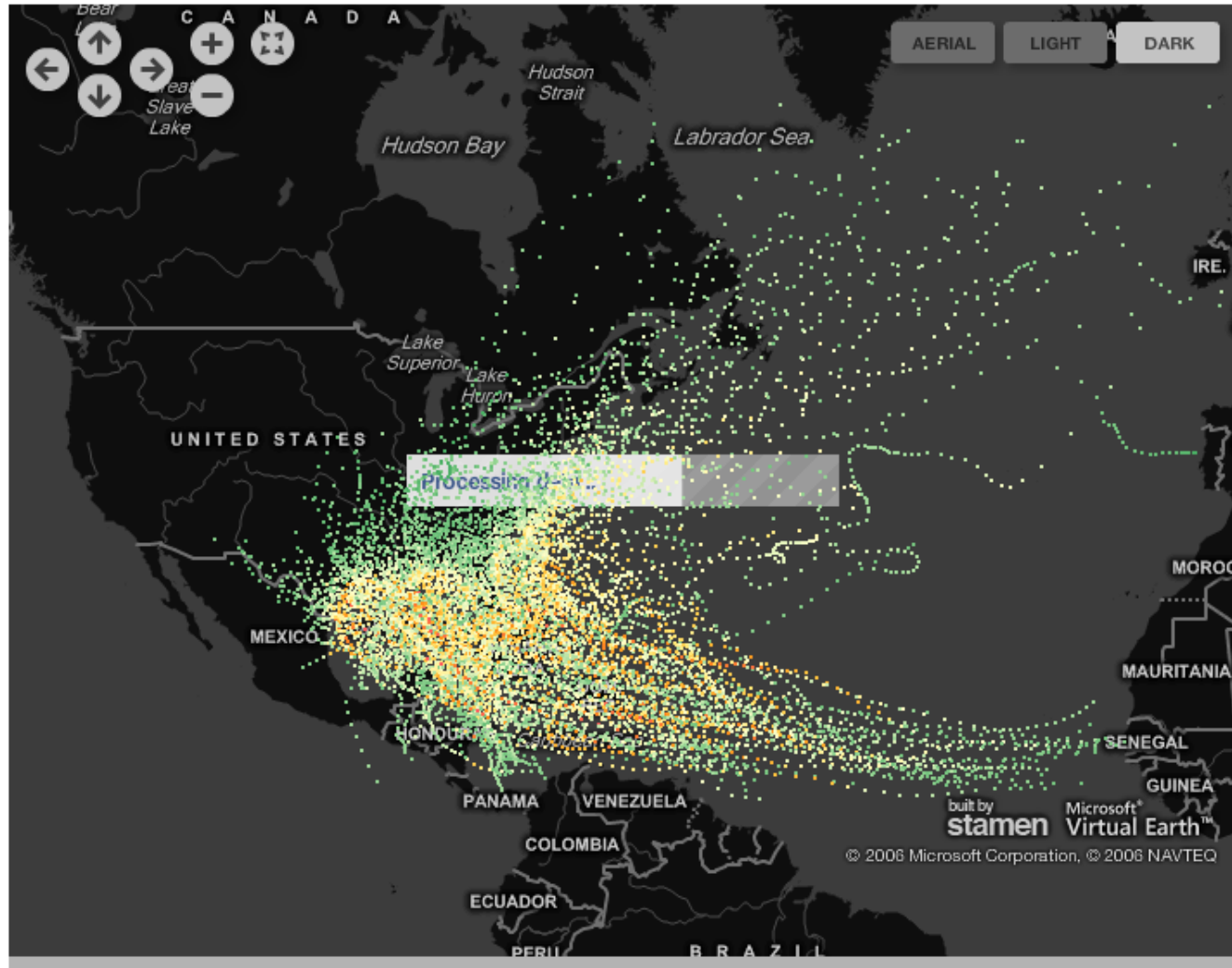


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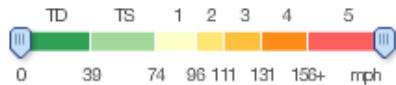
284 storms that occurred between 1851 and 2010 reached a maximum wind speed between 0 and 196 mph and made landfall in either Maine, New Hampshire, Massachusetts, Rhode Island, Connecticut, New York, New Jersey, Delaware, Maryland, Virginia, North Carolina, South Carolina, Georgia, Florida, Alabama, Mississippi, Louisiana or Texas.

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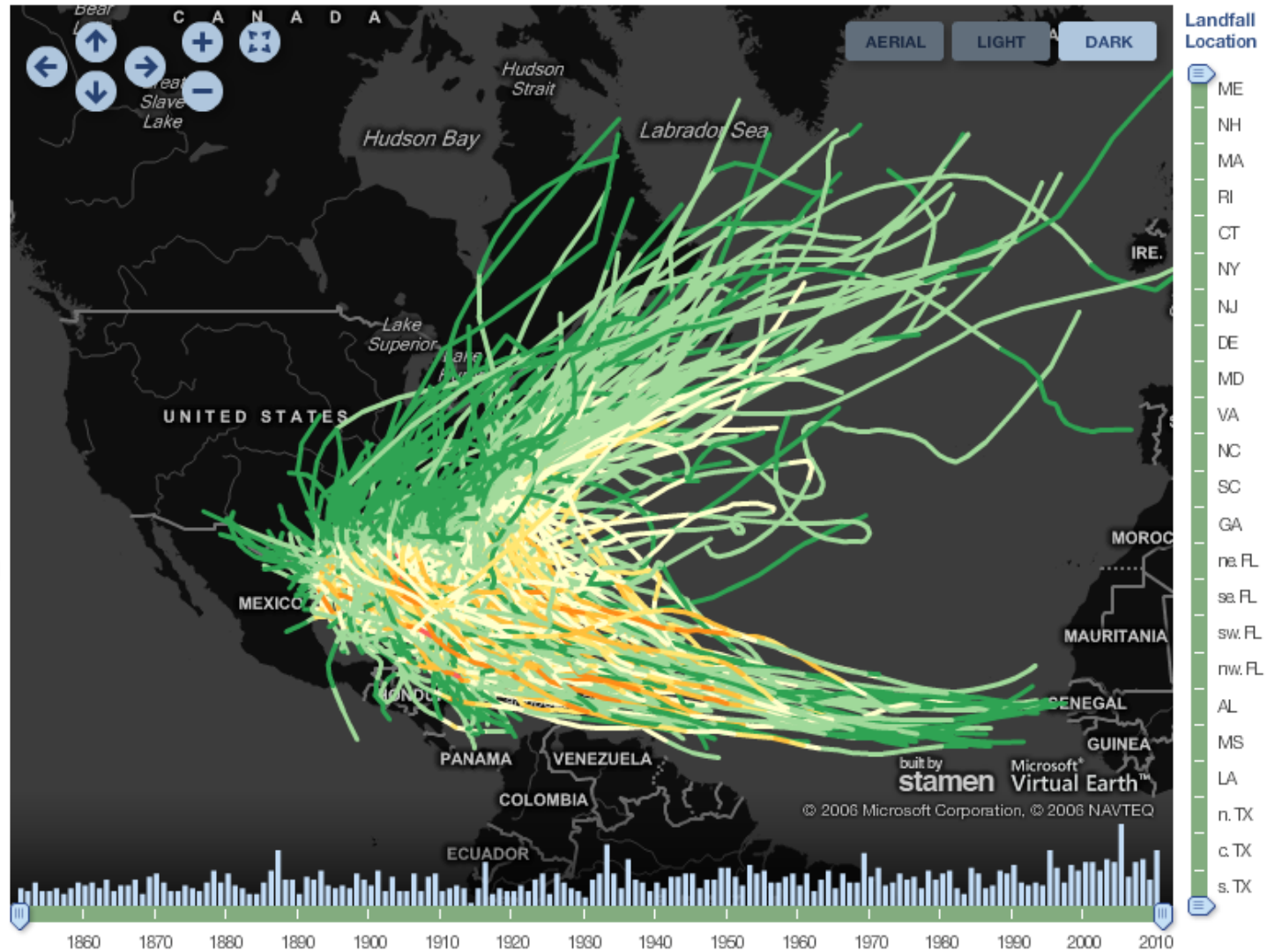


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Migration Results

First scenario: 1 micron fractures

Containment: *Jurassic aquifer*

Newcastle: ---

Mannville: ---

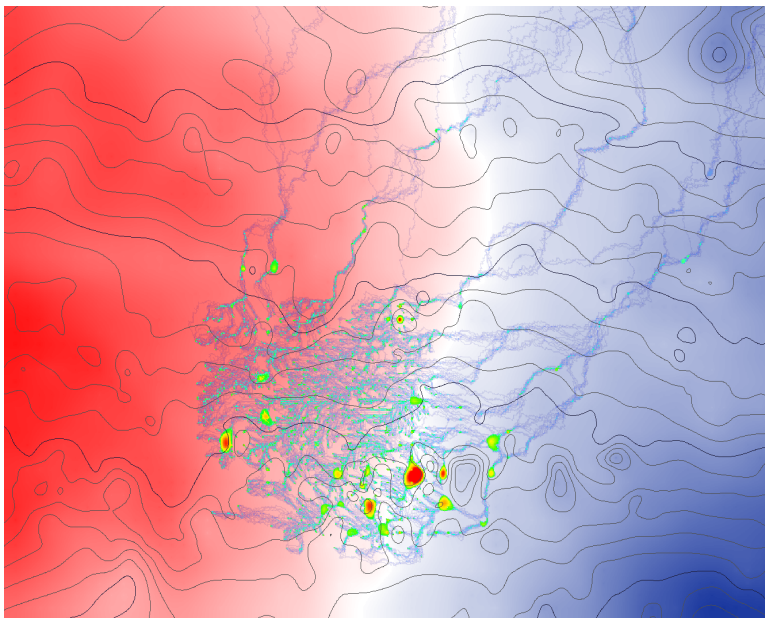
Jurassic: 1.4 Mt

Newcastle ---

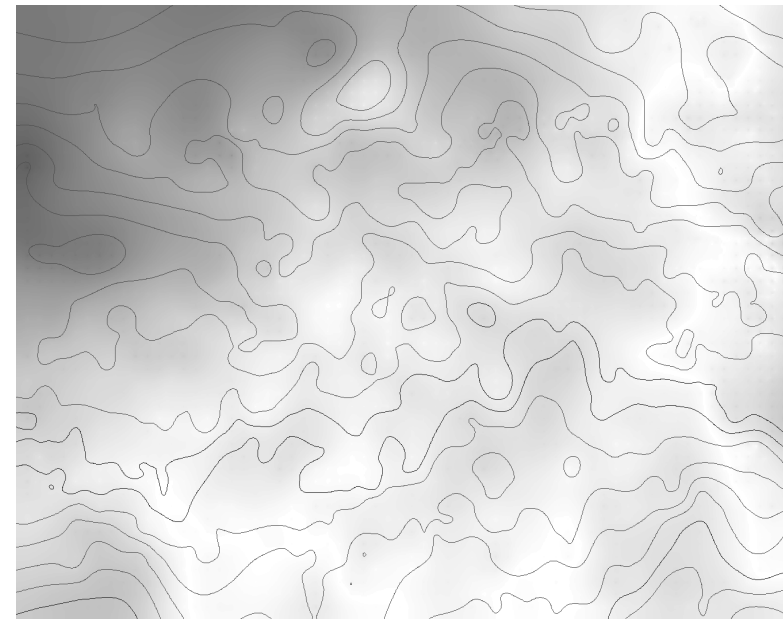
Mannville ---

Jurassic 20 largest pools: 1.3 Mt

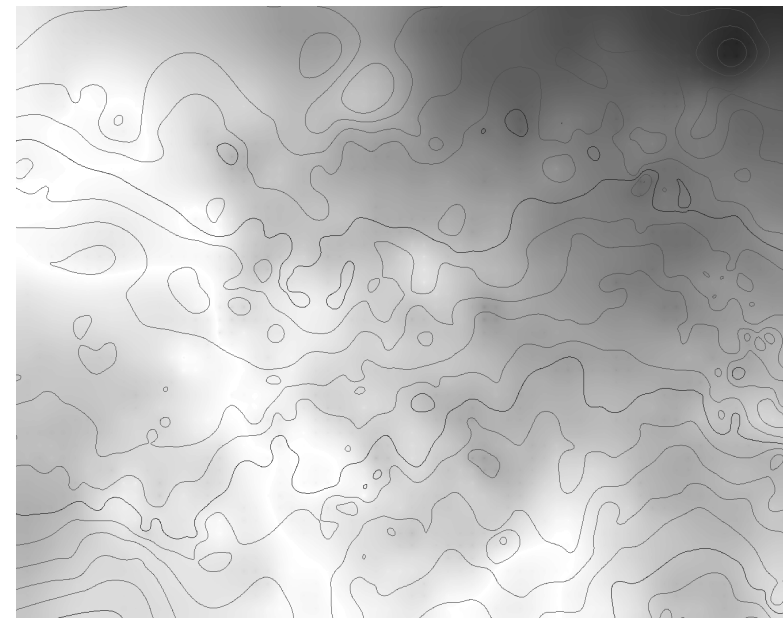
• Jurassic: small pools, migrates NE



• Newcastle



• Mannville



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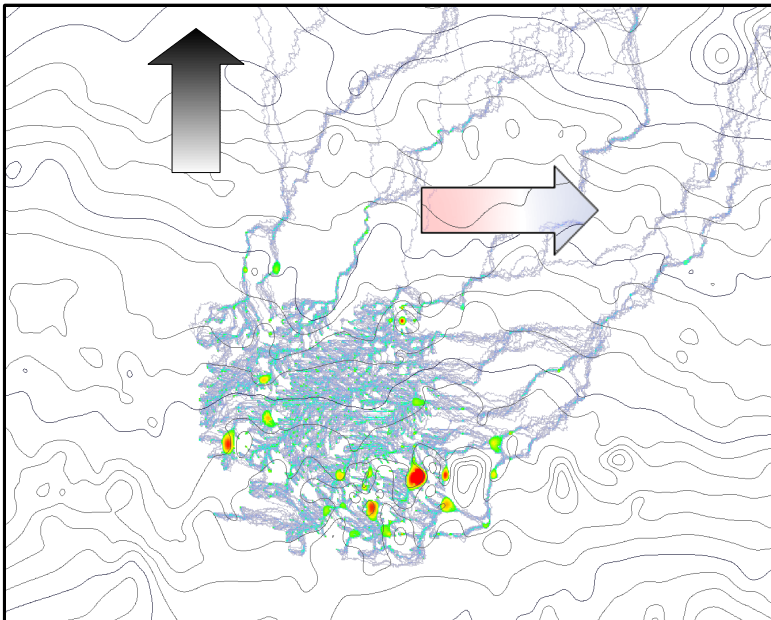
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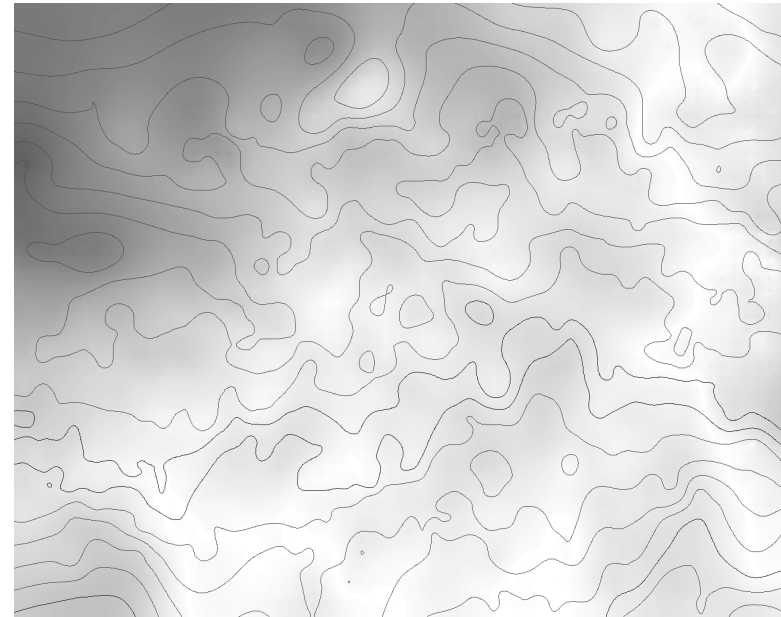
Mannville ---

Jurassic 20 largest pools: 1.3 Mt

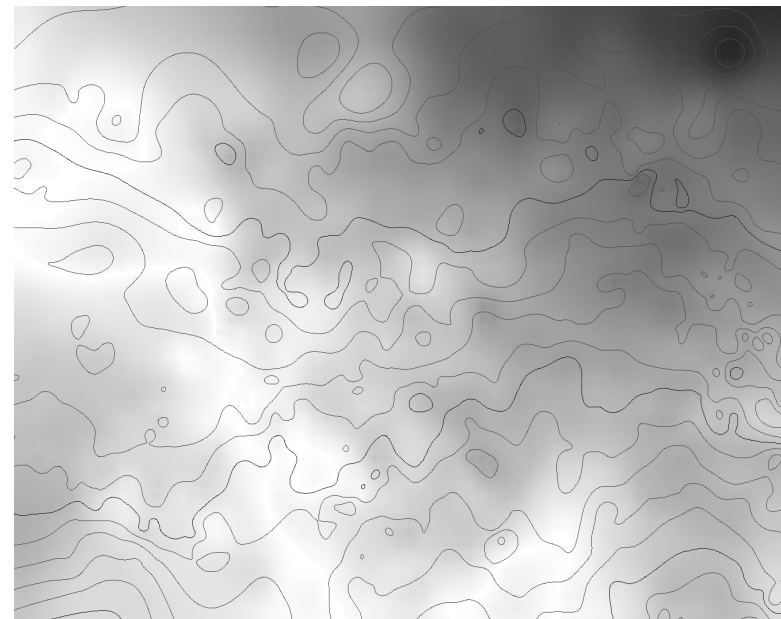
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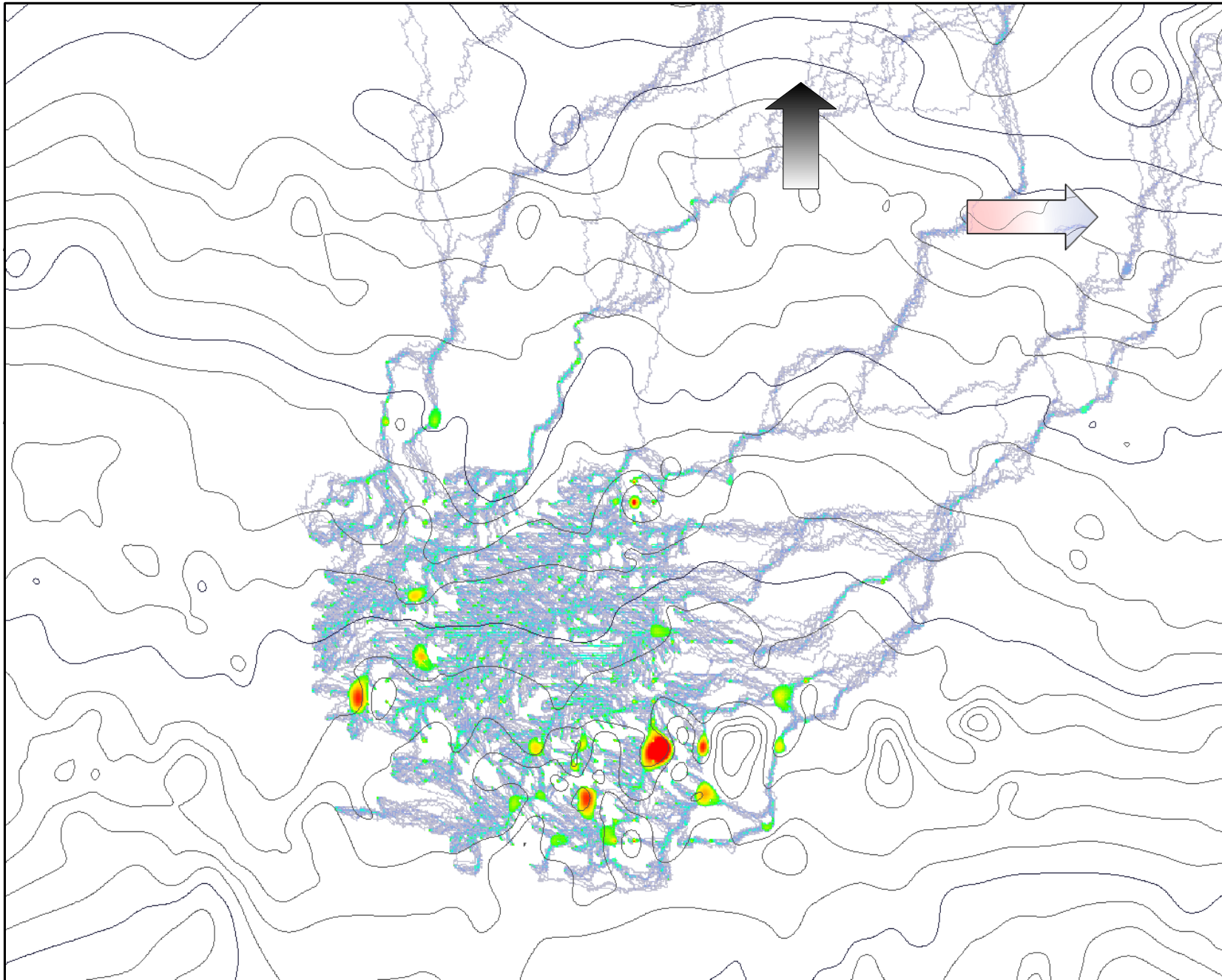
• Newcastle



• Mannville



First scenario: 1 micron fractures



Migration Results

Second scenario: 3 micron fractures

Containment: *Jurassic and Mannville*

Newcastle: ---

Mannville: 2.2 Mt

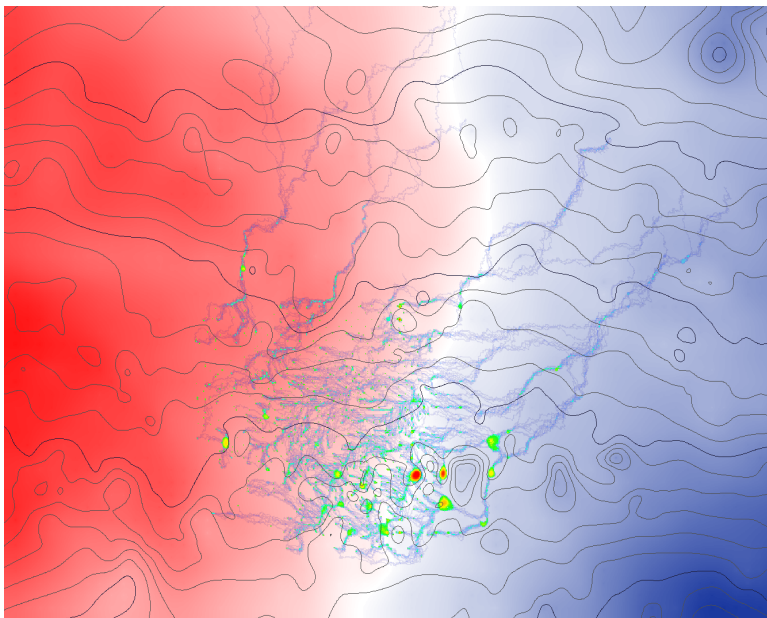
Jurassic: 0.4 Mt

Newcastle: ---

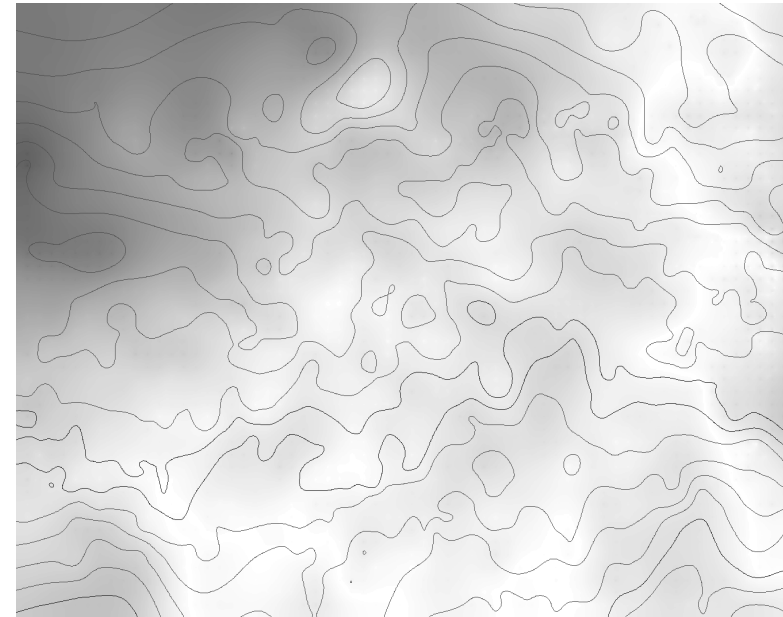
Mannville: 18 of 20 largest pools: 1.7 Mt

Jurassic: 10th and 12th largest: 0.1 Mt

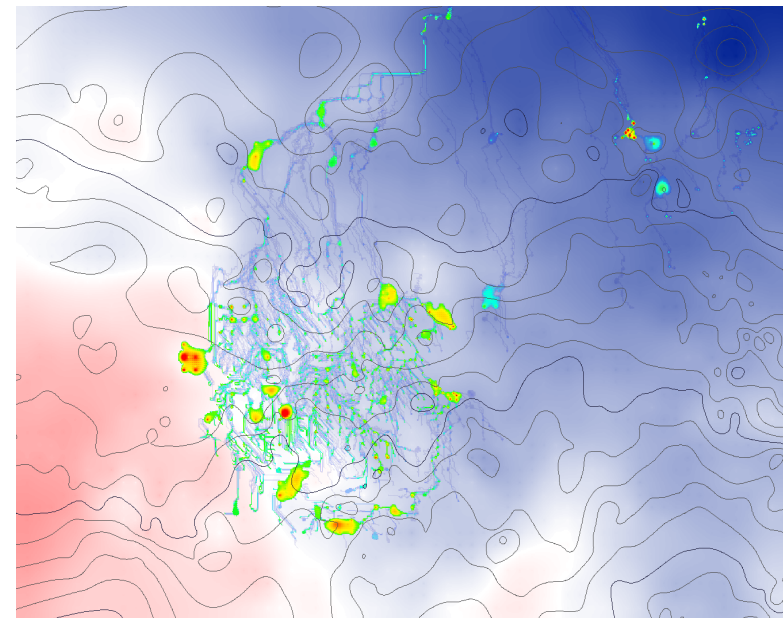
- Jurassic: small pools, breach locally



- Newcastle



- Mannville: 20 pools, N-NE migration



Migration Results

Second scenario: 3 micron fractures

Containment: *Jurassic and Mannville*

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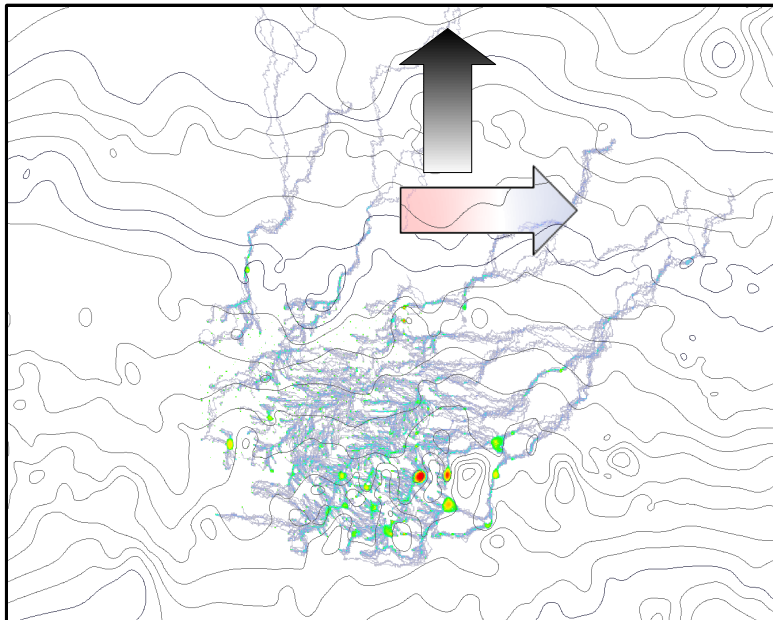
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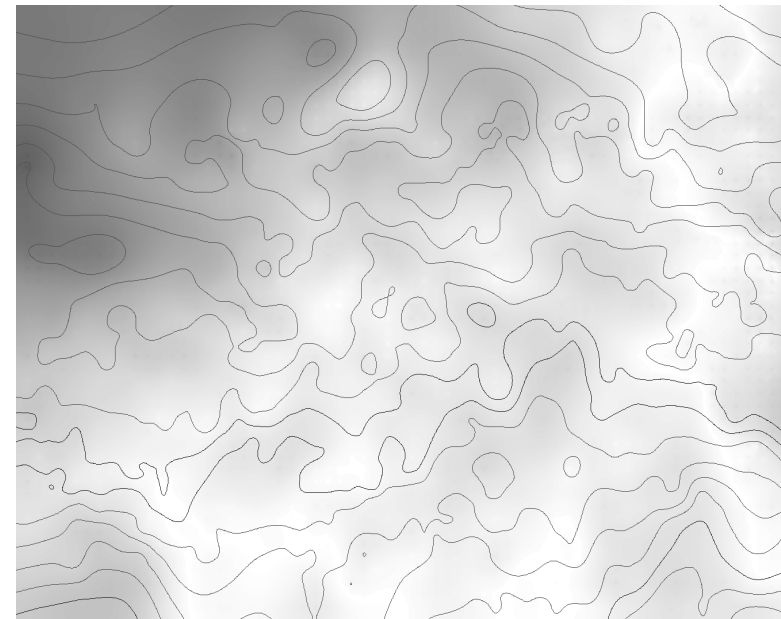
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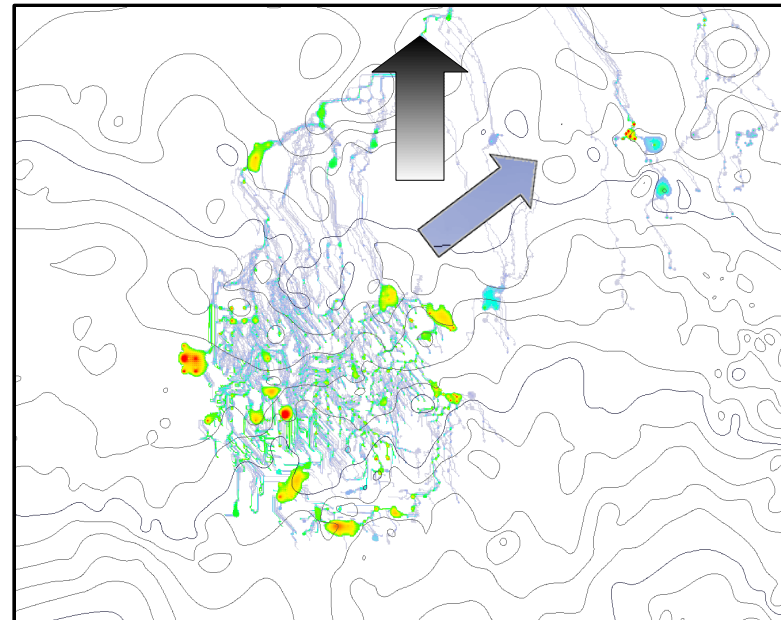
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Migration Results

Third scenario: 8 micron fractures

Breach: Colorado, 75 wells

Newcastle: 60 kt

Mannville: 2.4 Mt

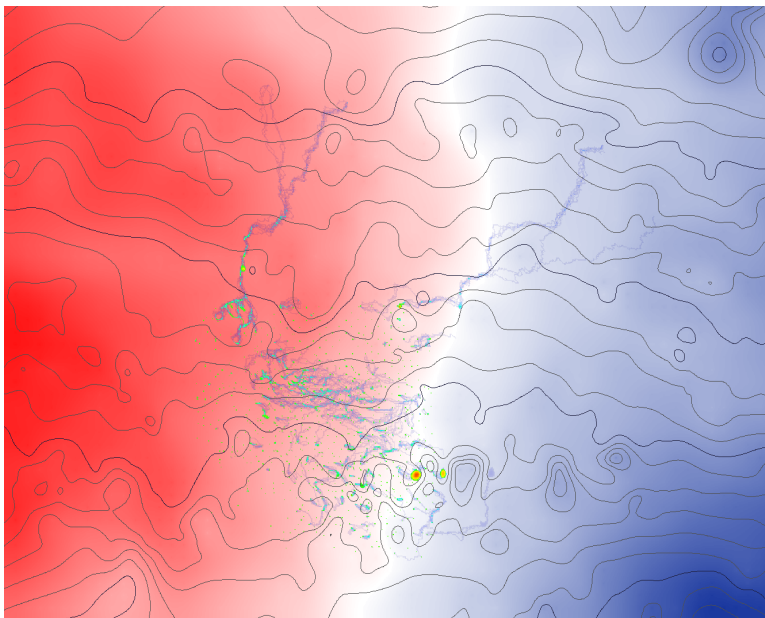
Jurassic: 340 kt

Newcastle: 2 small pools, 60 kt

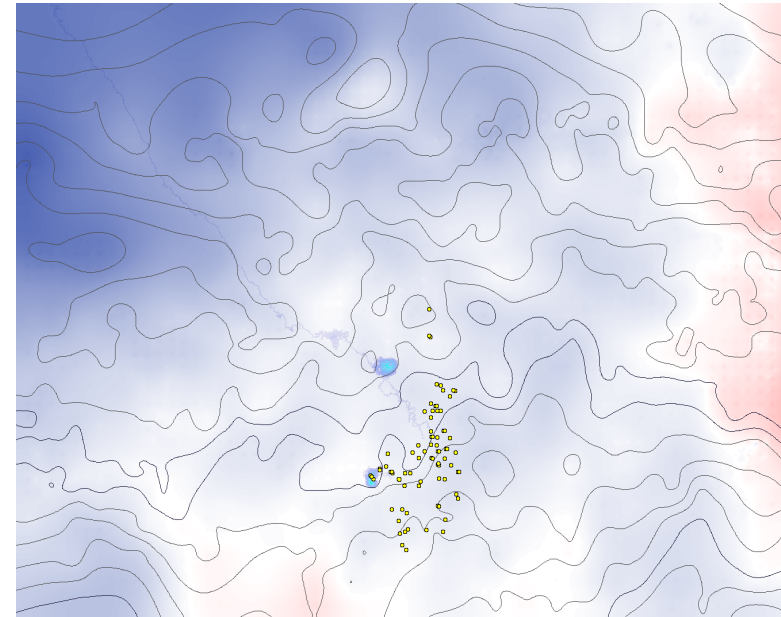
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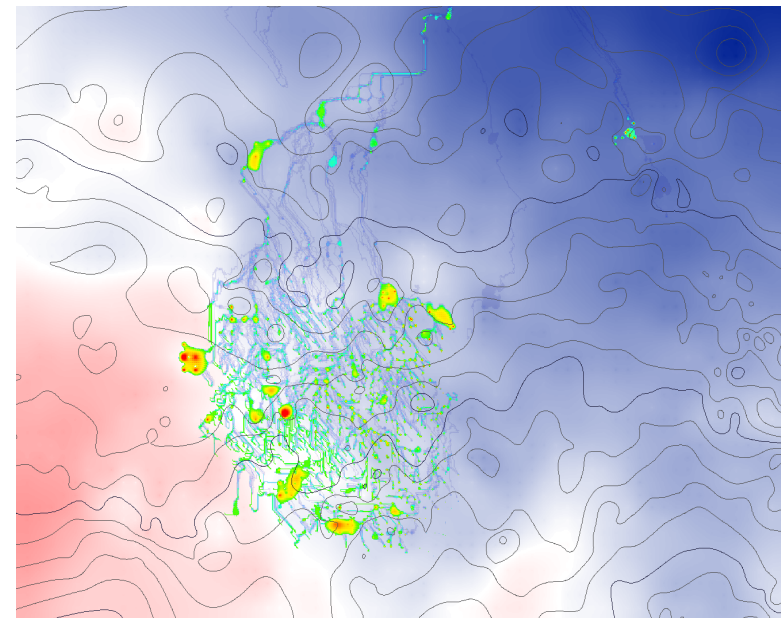
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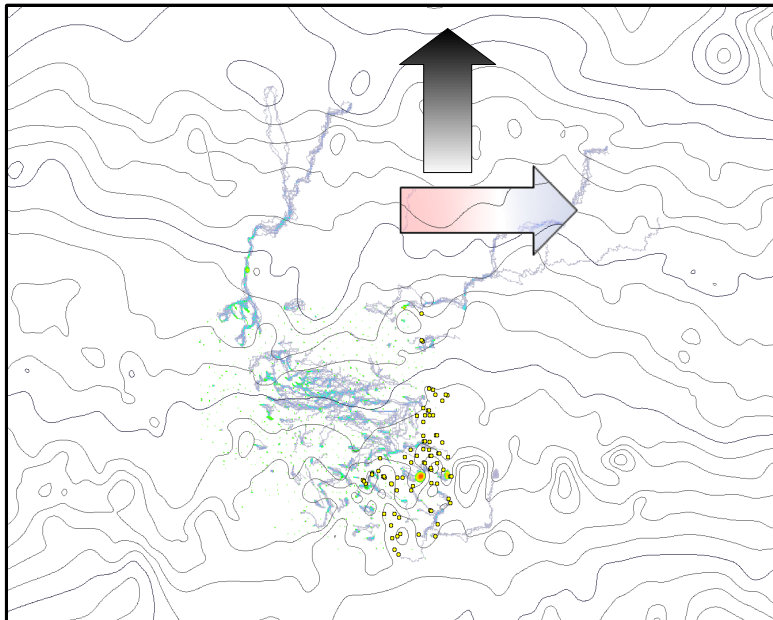
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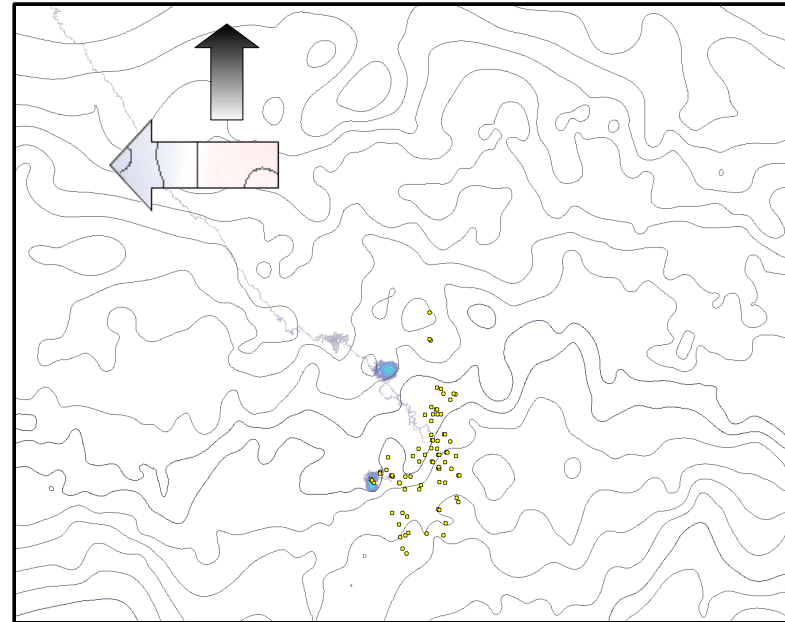
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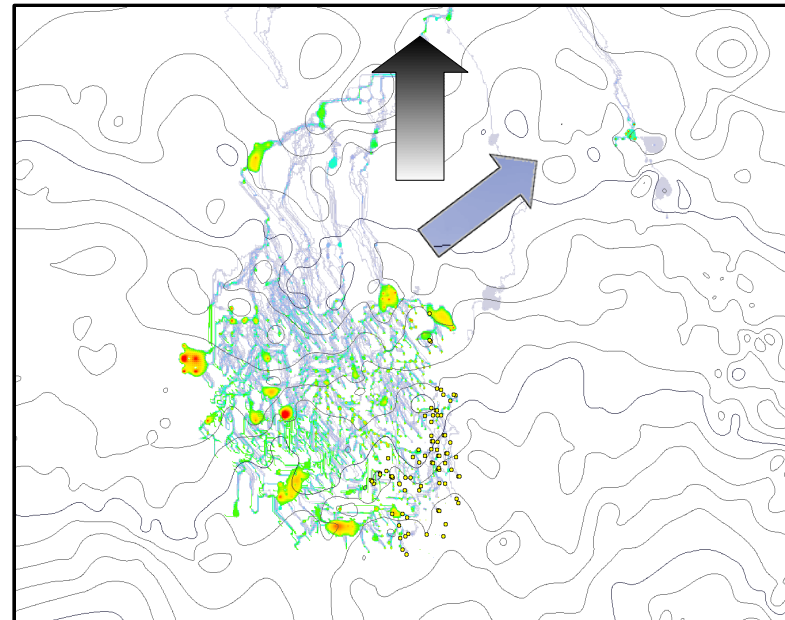
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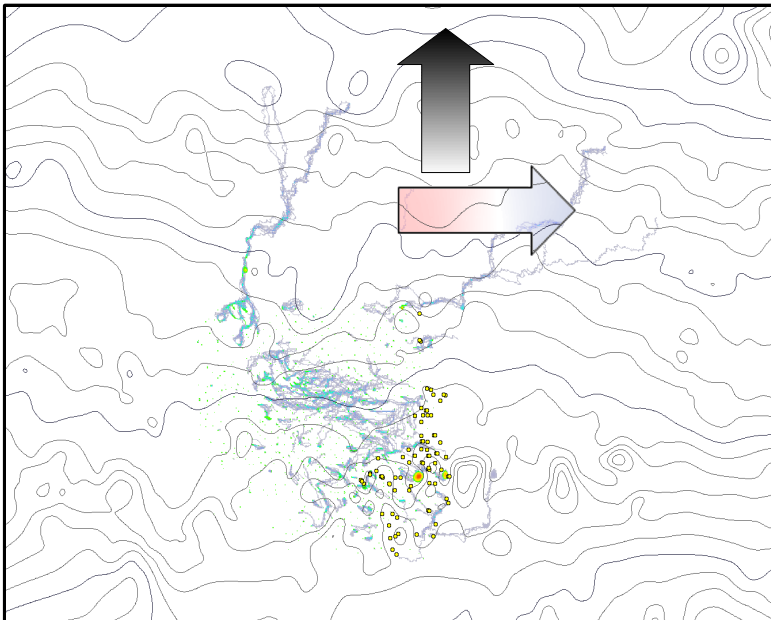
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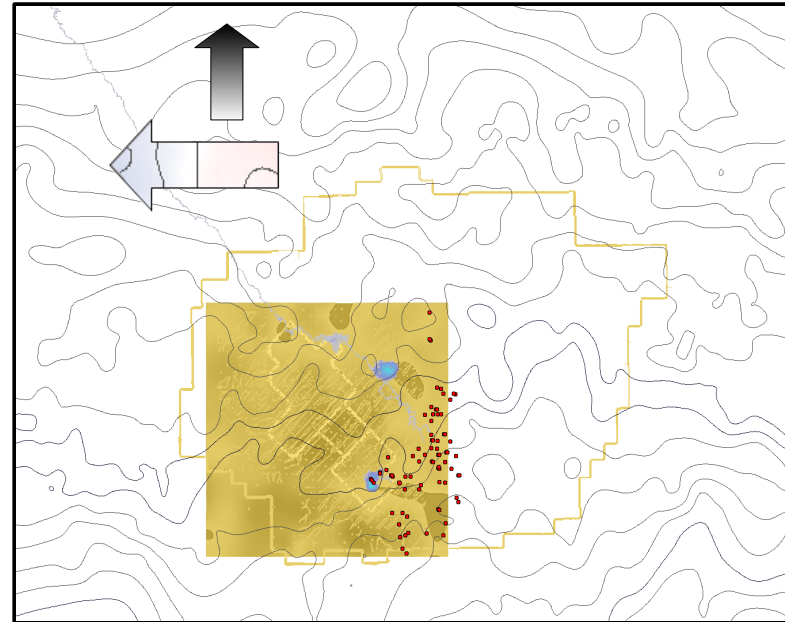
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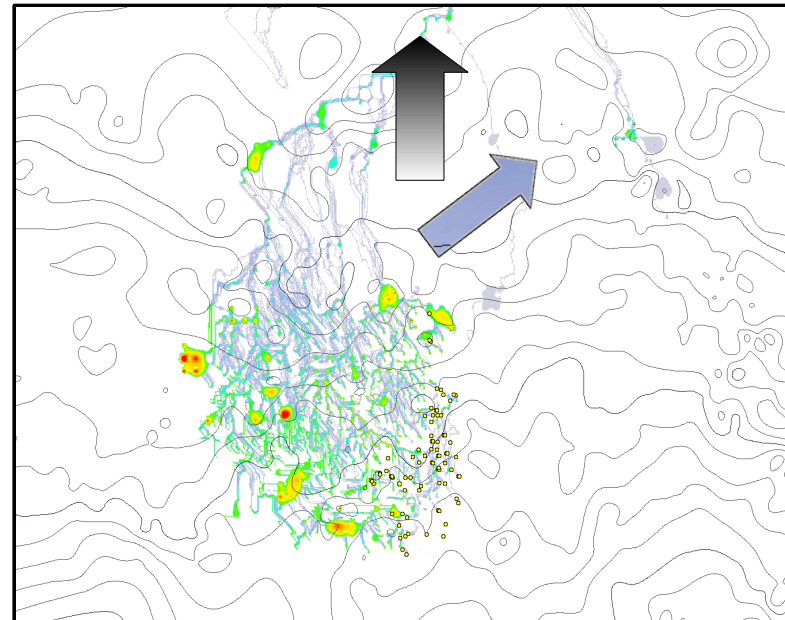
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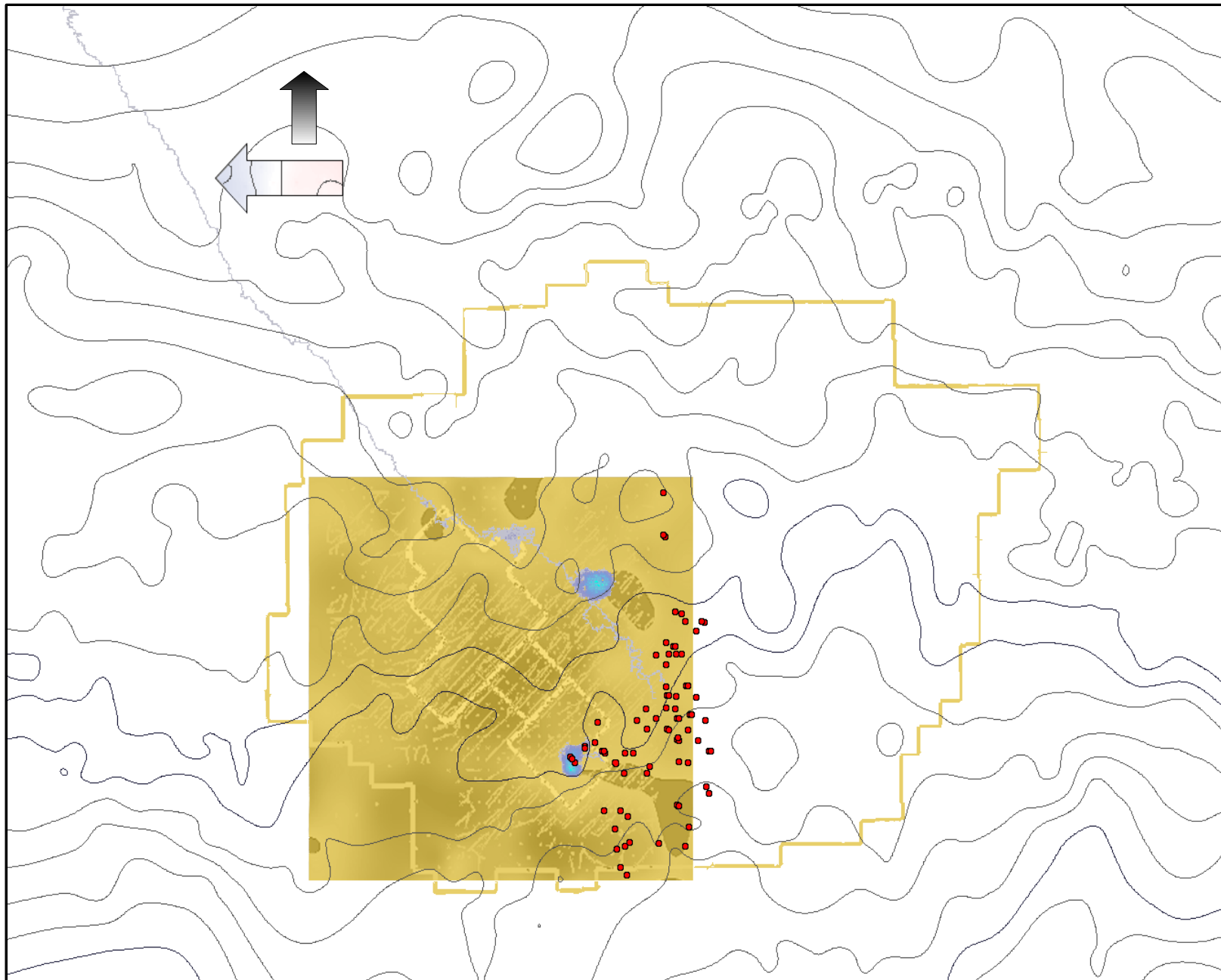
- Newcastle: 2 pools, 75 wells breach



- Mannville: 20 pools, N-NE migration



Third scenario: 8 micron fractures



1) What is the secondary storage potential above the site?

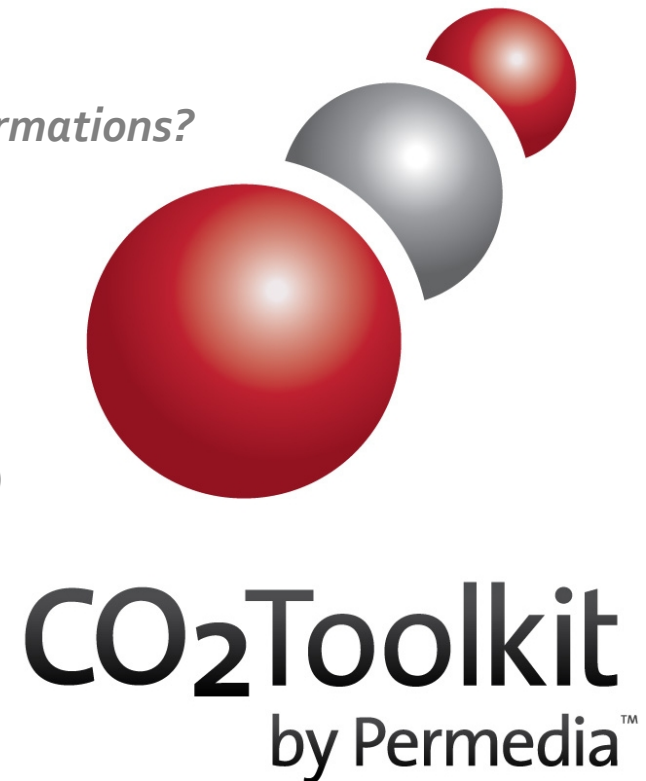
- In the megatonne range: around 1.5 to 3 Mt for large pools, depending on the scenario

2) Which wells are in possible breach locations?

- 75 wells identified: clustered on eastern edge of the CO₂ storage area

3) Under what conditions might CO₂ move into shallower formations?

- Critical range: 1 to 10 micron fractures (10 μ D to 10 mD)
- 1 micron fractures spill NE (Jurassic aquifer only)
- 3 micron fractures spill NE (Jurassic) and NNE (Mannville)
- 8 micron fractures breach the Newcastle seal



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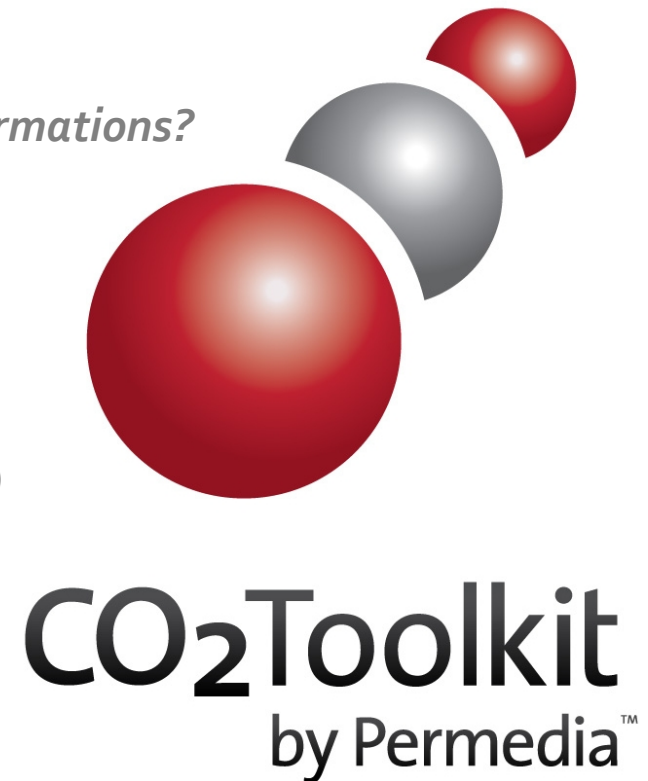
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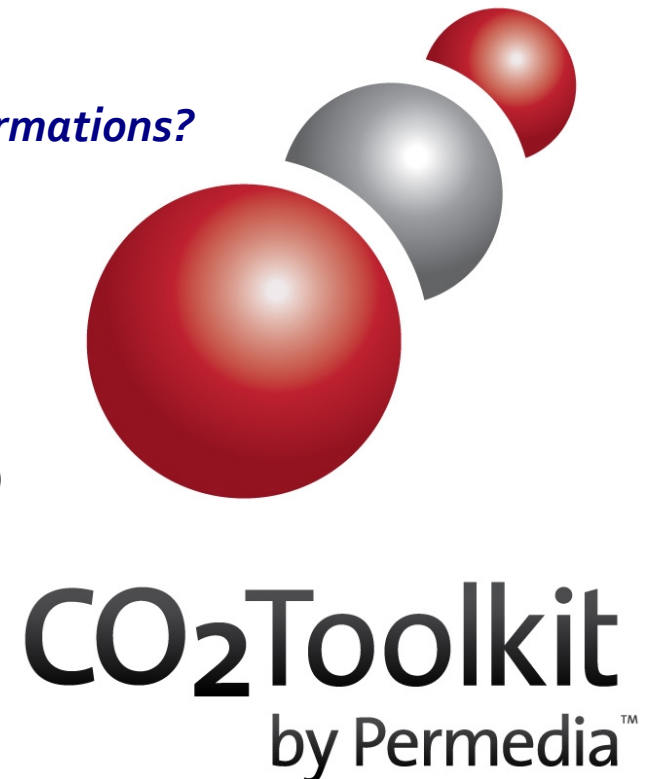
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- Critical range: 1 to 10 micron fractures (10 μ D to 10 mD)
- 1 micron fractures spill NE (Jurassic aquifer only)
- 3 micron fractures spill NE (Jurassic) and NNE (Mannville)
- 8 micron fractures breach the Newcastle seal

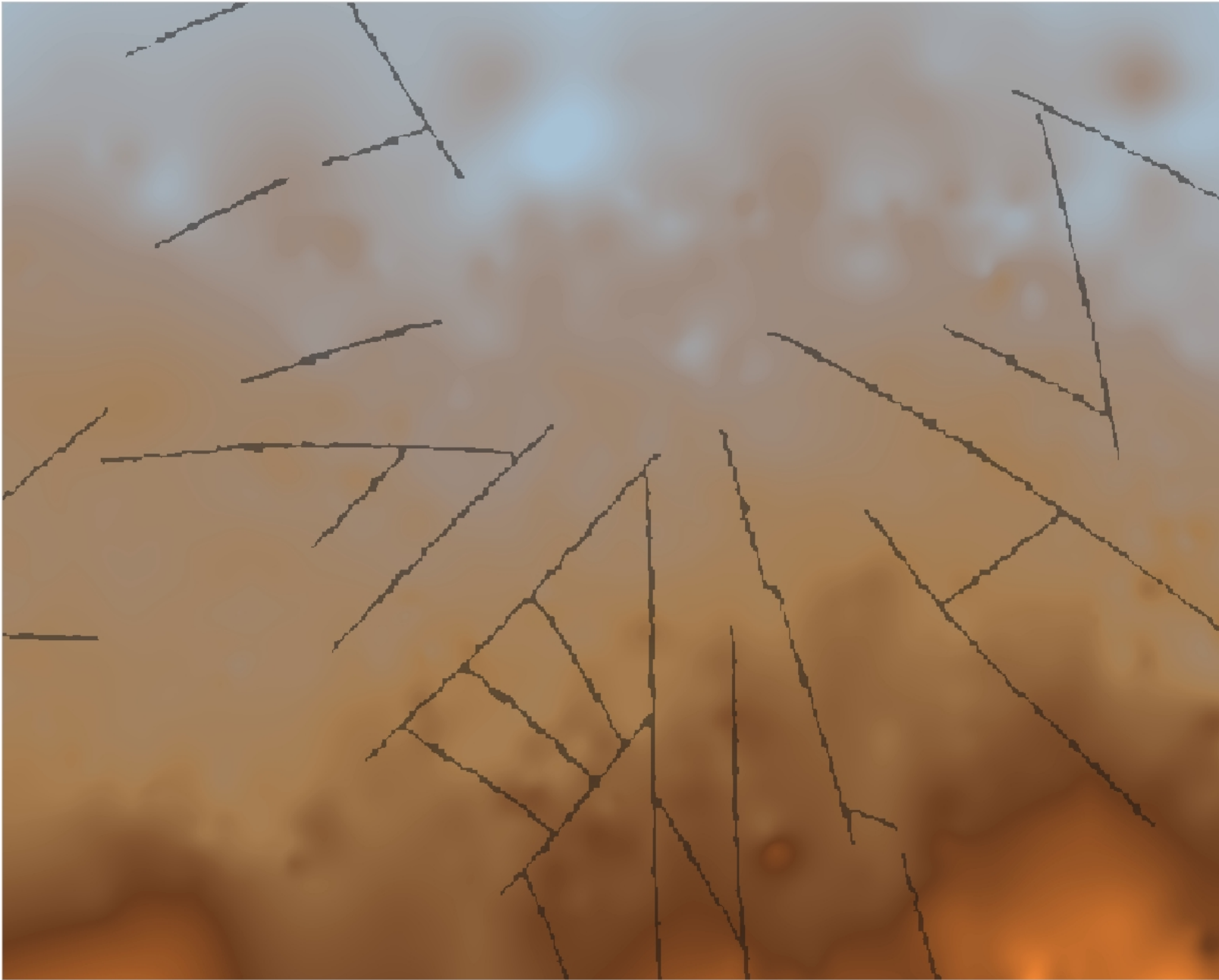




Faulted Scenario

A

- Manville, 1 micron fractures + regional faults (Kv x 100, Kh x 0.01)



Faulted Scenario

B

- Manville, 1 micron fractures + regional faults = 5 Mt (3 Mt, largest 20 bodies)

