GEUS

# Regional model development and study of pressure propagation

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Carsten M. Nielsen & Peter Frykman

Geological Survey of Denmark and Greenland
Ministry of Climate and Energy

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# Problem

- How to manage boundary conditions in simulations of $CO_2$ injection into a limited storage site model

  - Questions:
    - Pressure rise at well site – operational issue
    - Pressure under caprock – safety issue
    - Pressure rise away from site
    - Dynamic capacity estimation

# Solutions

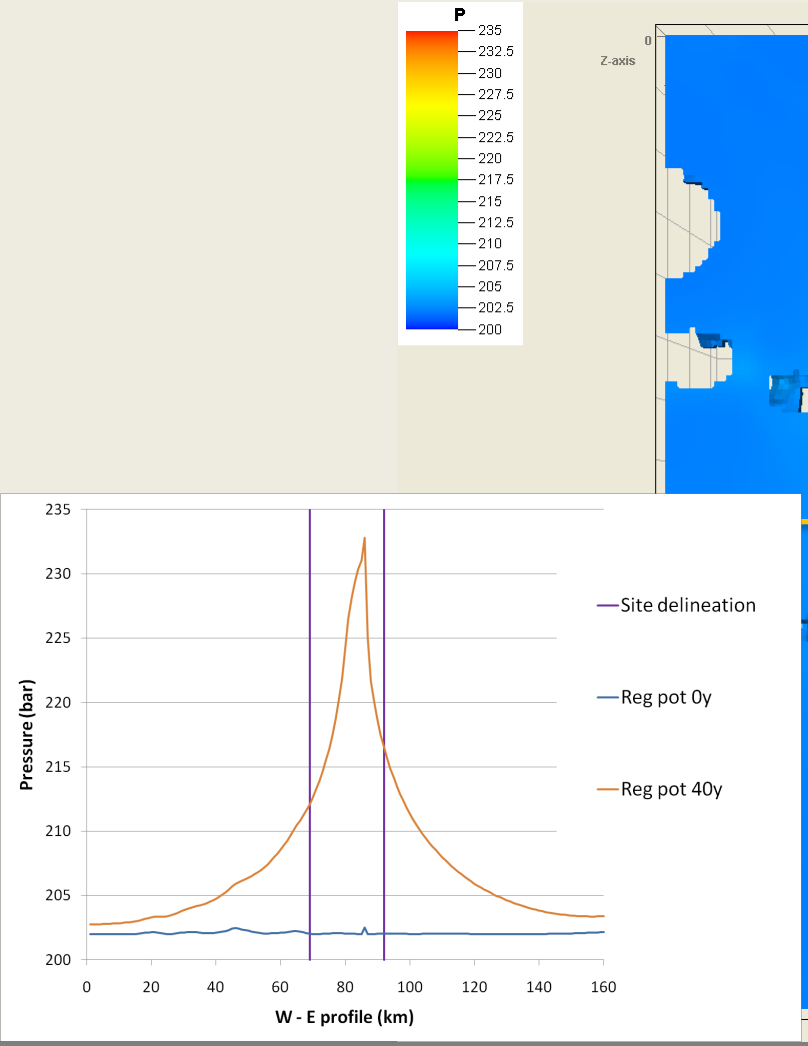
- **Closed boundaries**: Pressure rise in the site model, which will overestimate the pressure rise at the injection well during any safety threshold analysis.
- **Constant pressure boundaries**: Overpressure reaching the model boundary "falls over the edge" and an underestimate of pressure rise in the site model is the result.
- **Numerical aquifer extension**: Not an option for Eclipse_100 simulations as it only works on a water aquifer, and we use the oil/gas system to reflect the brine/ CO2 system.
- **Pore-volume multiplier** - MULTPV: Feature used to modify the model margin response by enlarging the possibility for fluid compressibility to absorb some of the margin overpressure. However, there exists no quantitative advice on the magnitude of pore volume enlargement for obtaining the best reflection of pressure dynamics. – Developments?
- **Flux Boundary Conditions option**: Fluxes at site model boundaries derived from regional model.

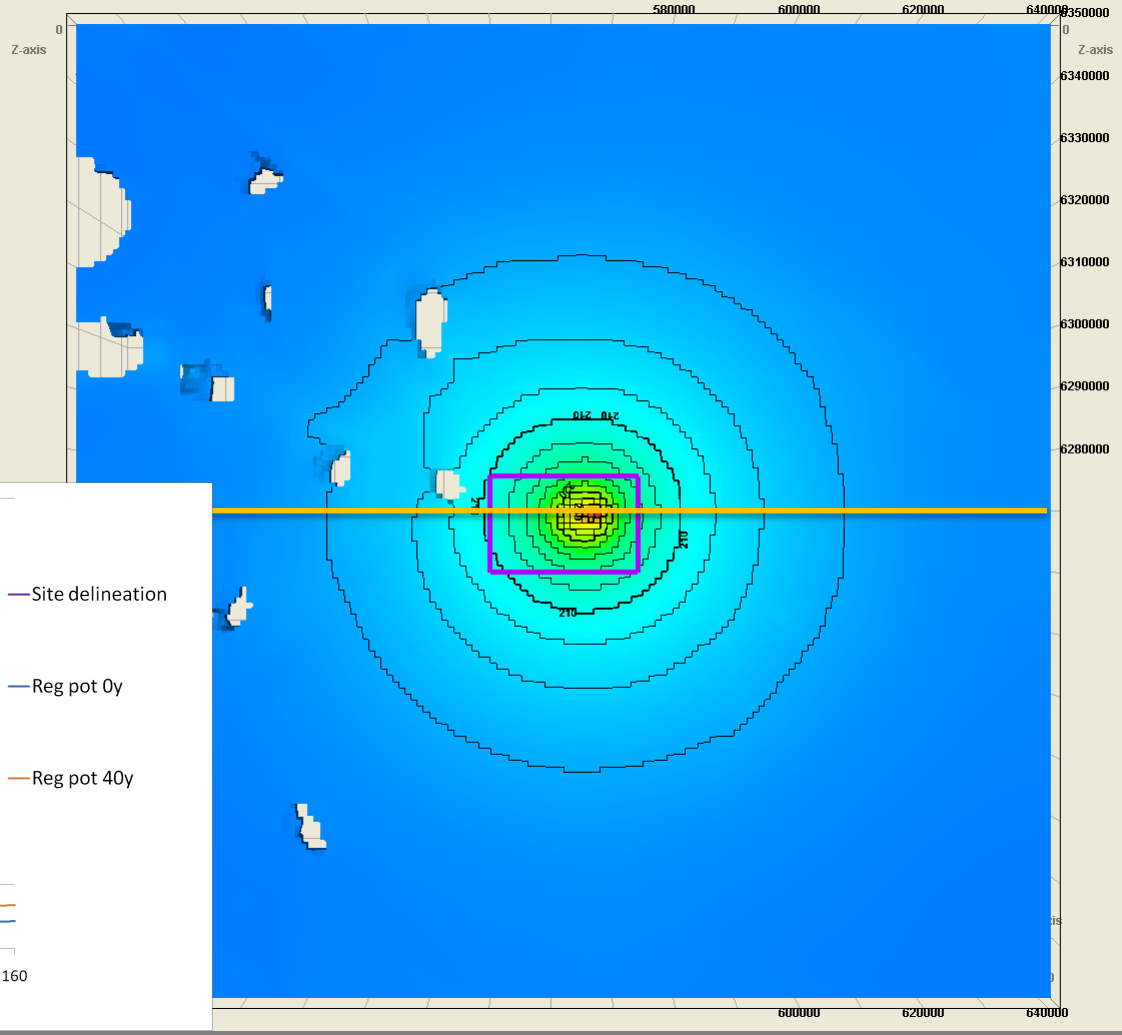
# Outline of process for managing boundary conditions in $CO_2$ injection simulations

- Development of a regional model surrounding a site model.
- Eclipse 100 simulations of a regional model + site model with MULTPV as boundary conditions.
- Compare pressure development in the two models.
- Match pressure development by adjusting MULTPV in iterative process.

# Simulated over-pressure (potential) distribution after 40 years of $CO_2$ injection (3.15 Mt/y) into a 160x160 km regional model

- Pressure increased far beyond the site delineation
- Site model boundary conditions must capture the pressure development



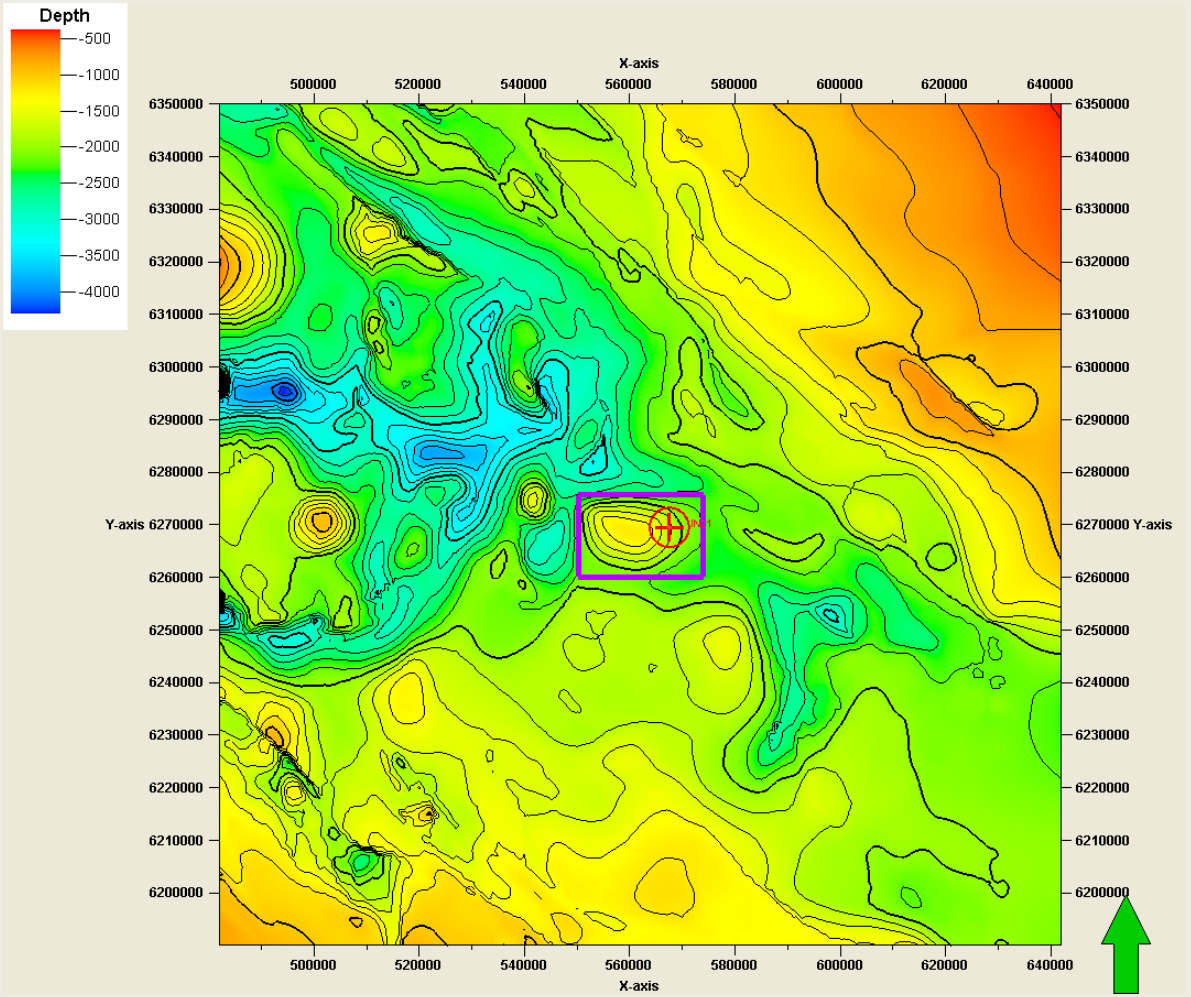
# Gassum Formation model (upper Triassic – lower Jurassic)

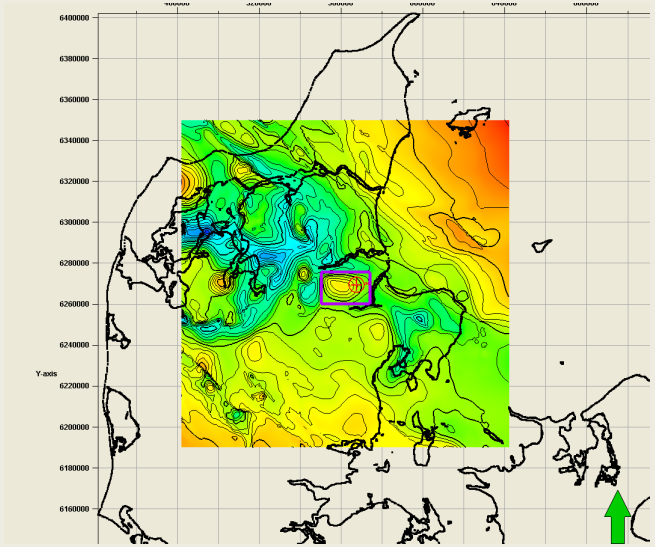
Regional model:
160 km x 160 km

Site model:
24 km x 16 km

Grid cell size (both models):
1 km x 1 km

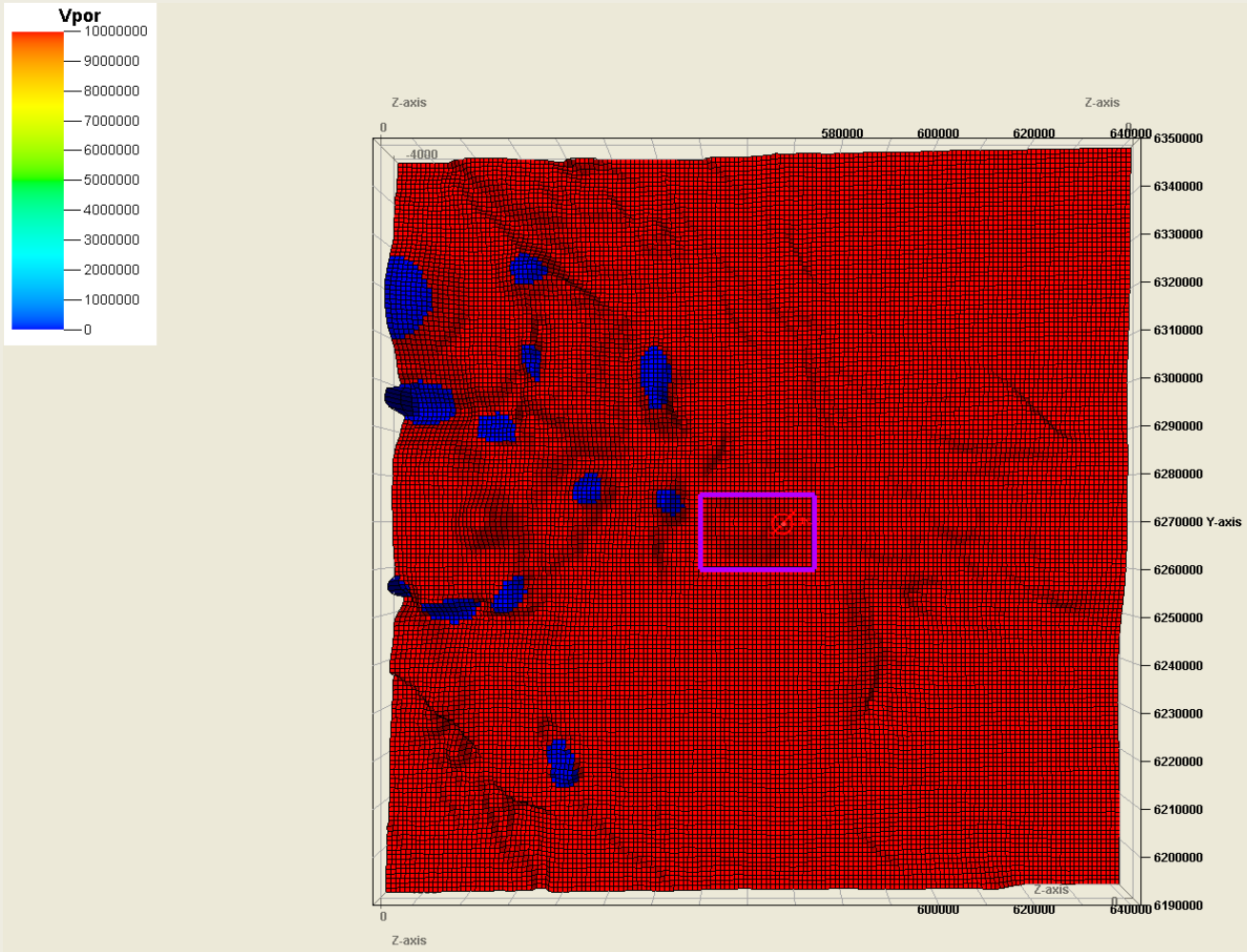
$CO_2$ injection:
3 Mt/y for 40 years



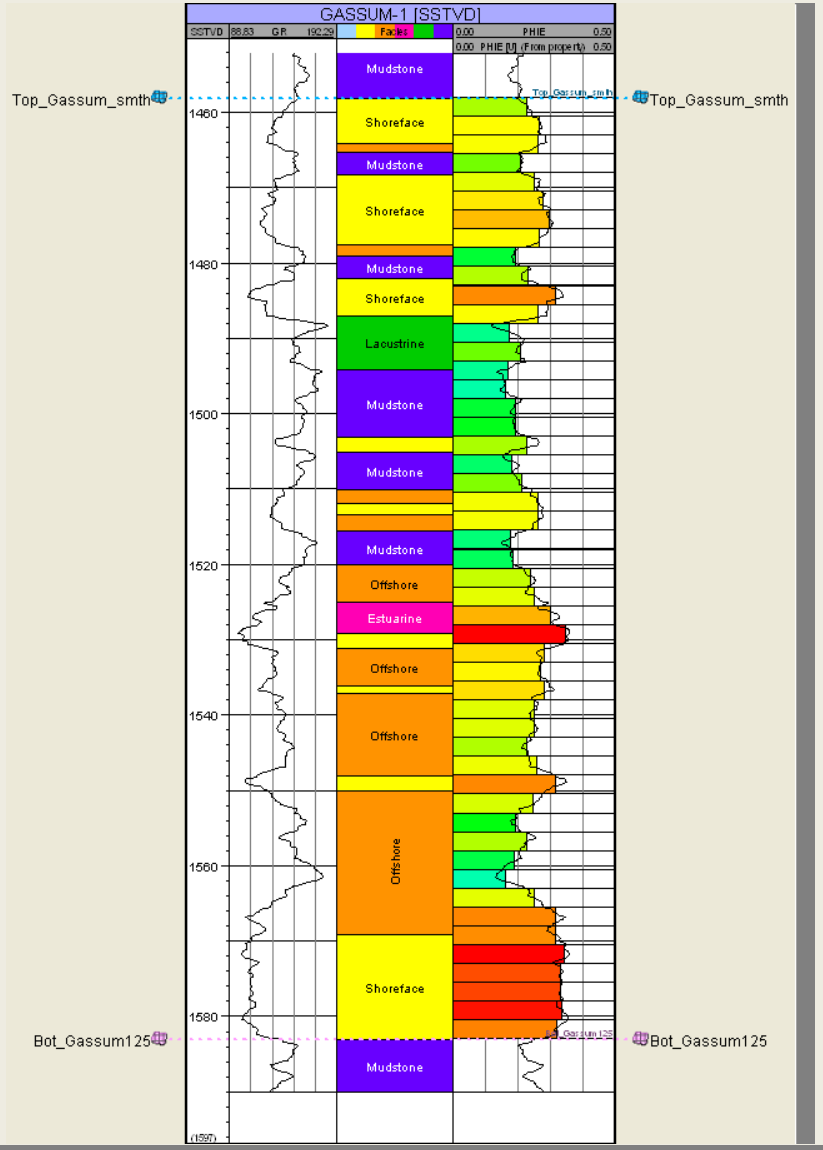
# Gassum Formation model

Salt diapirs are set to in-active in simulations with regional model, reflecting no-flow

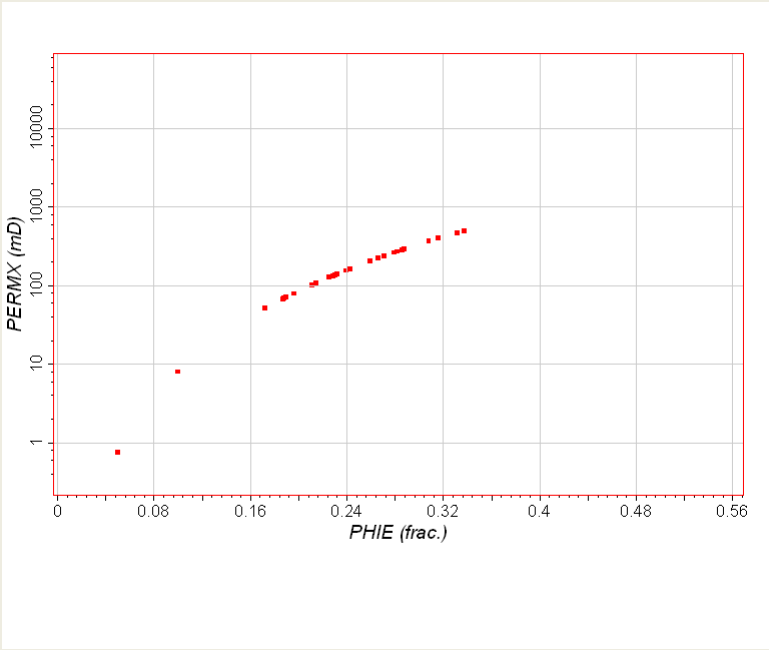


# Model input data

## Log derived Porosity

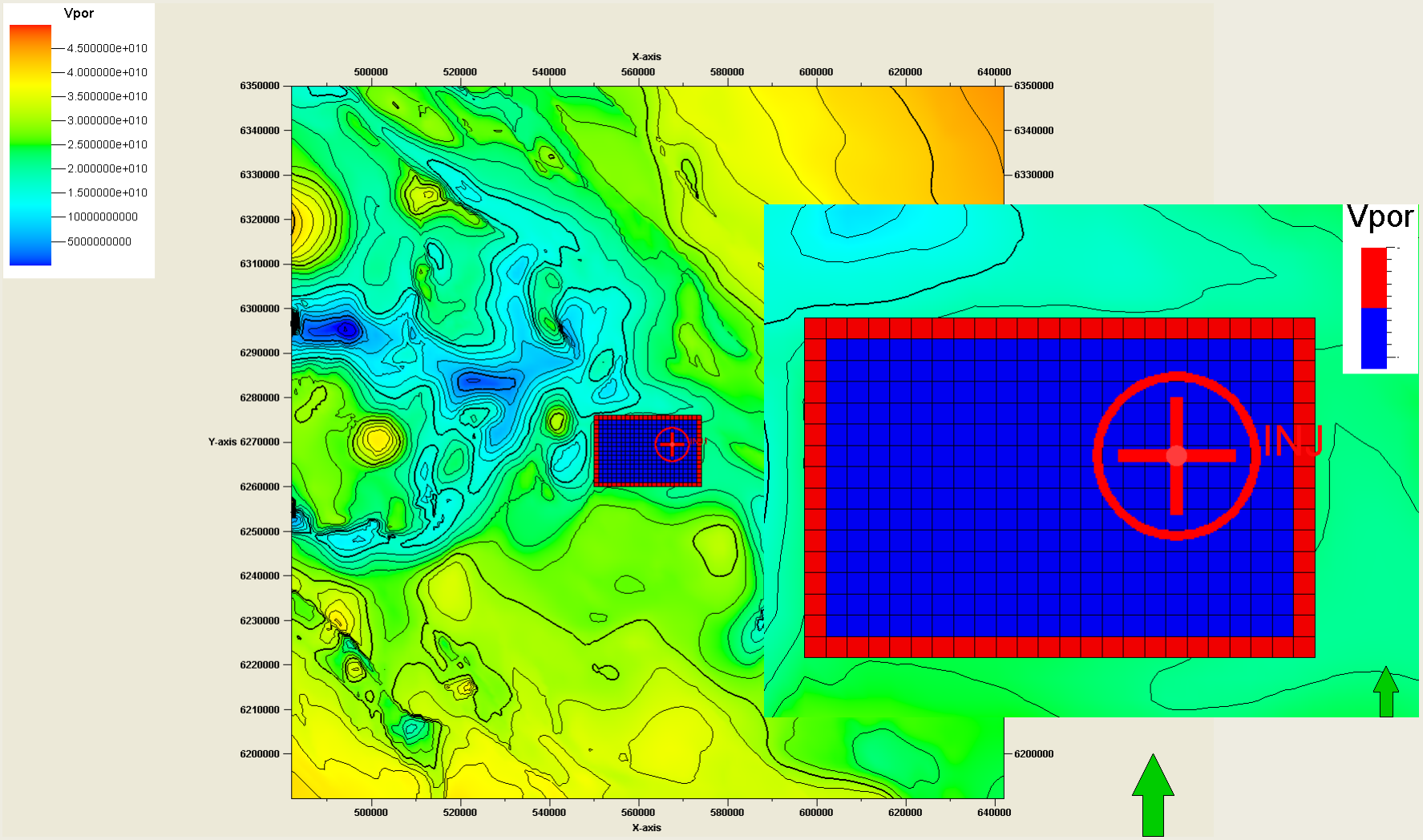



## Porosity to permeability

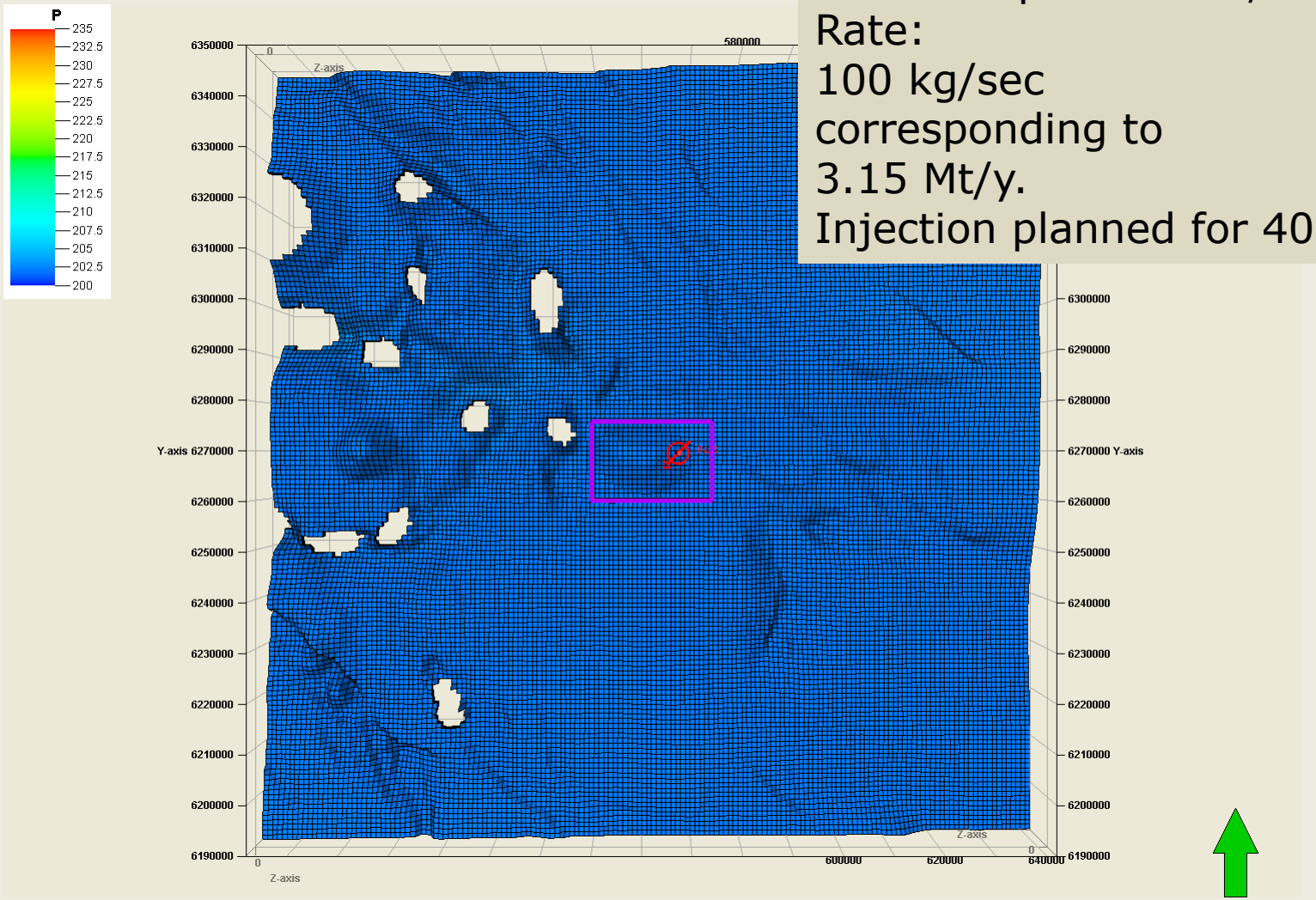


# Boundary conditions – Pore Volume multiplier "MULTPV" (Eclipse 100)

Pore volume for the outermost grid cells in the site model multiplied by high factor

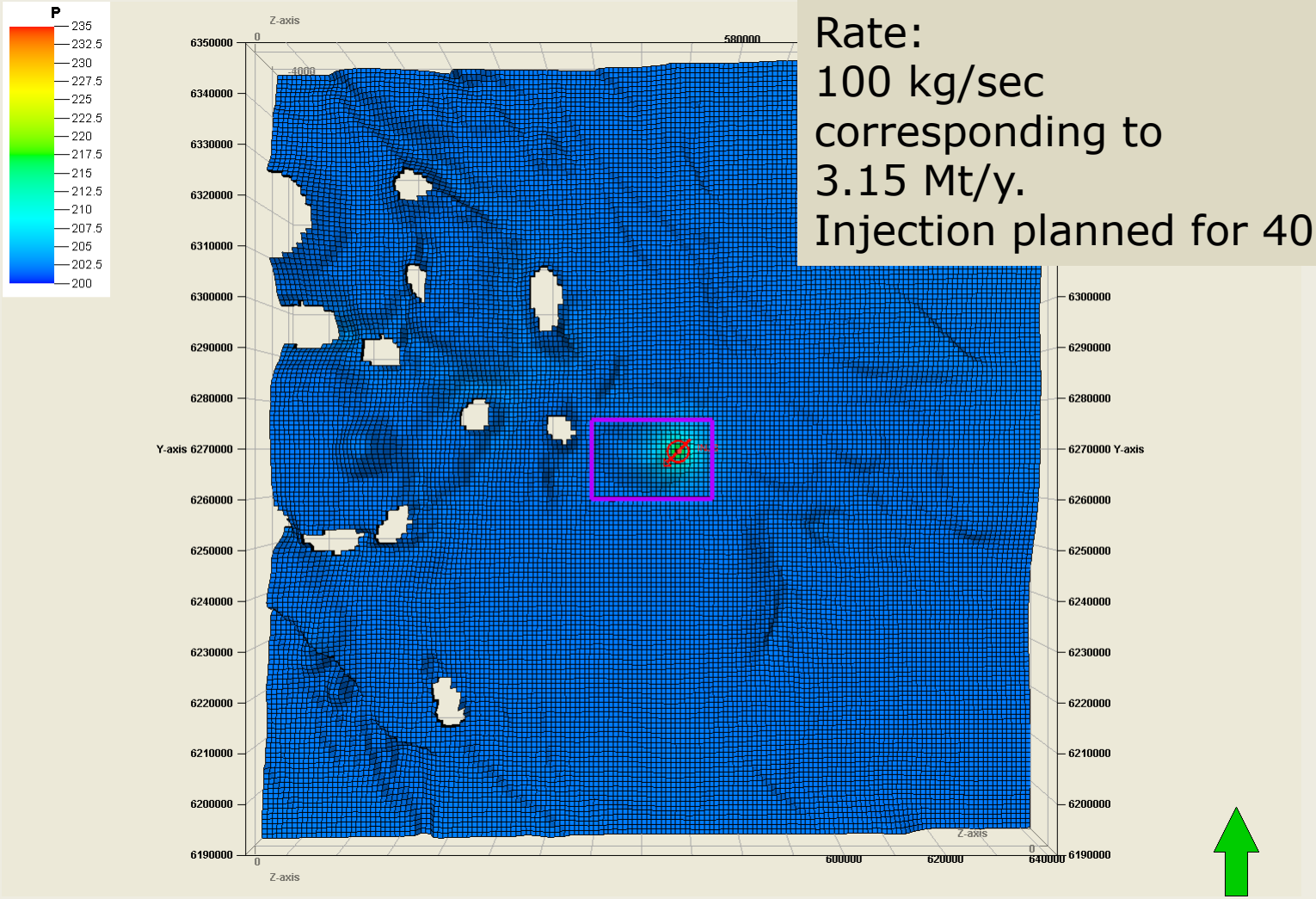


Start of $CO_2$ injection
Datum depth 1960m, P=202 ba
Rate:
100 kg/sec
corresponding to
3.15 Mt/y.
Injection planned for 40 years



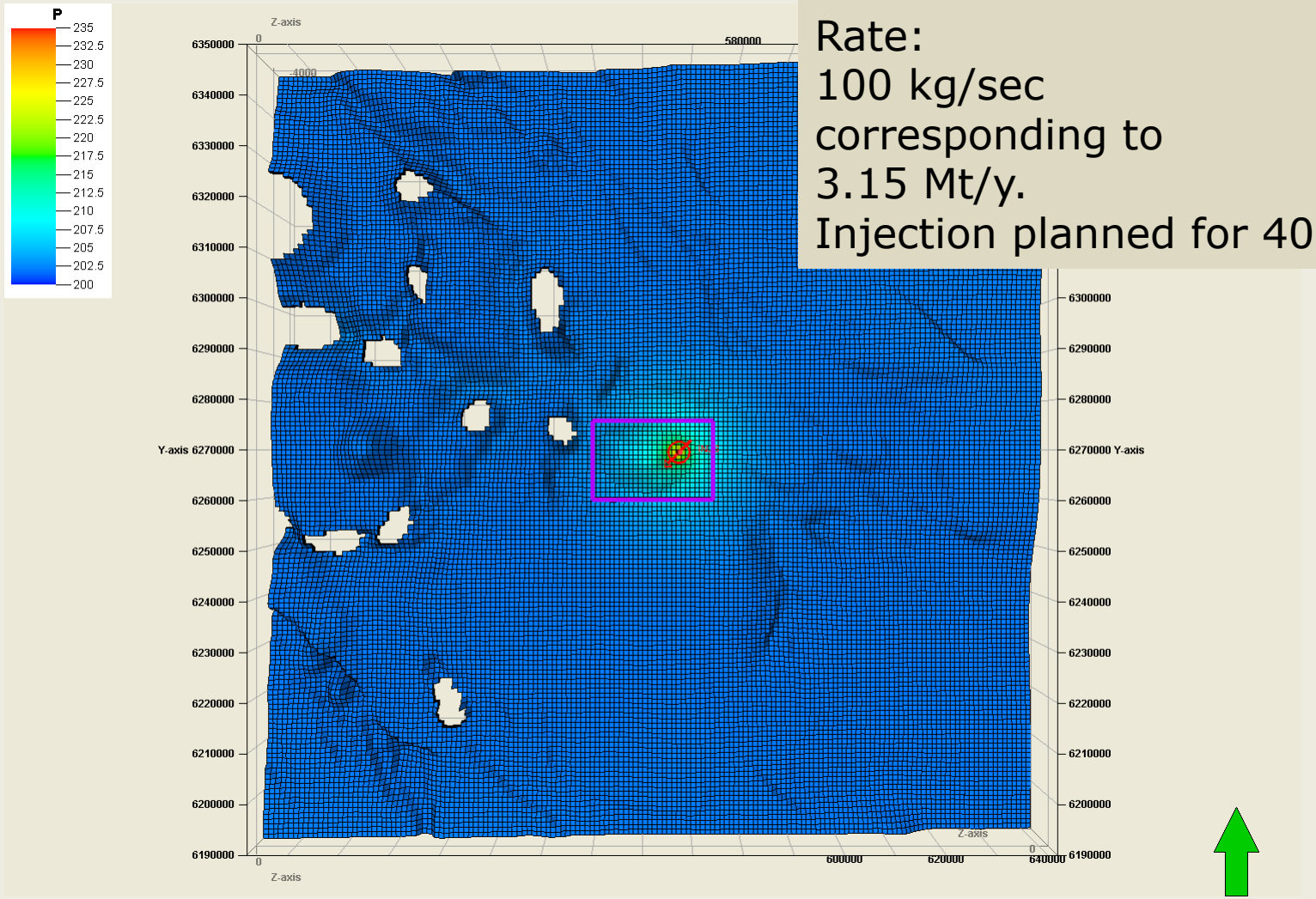
# 1 year of $CO_2$ injection

Rate:
100 kg/sec
corresponding to
3.15 Mt/y.
Injection planned for 40 years



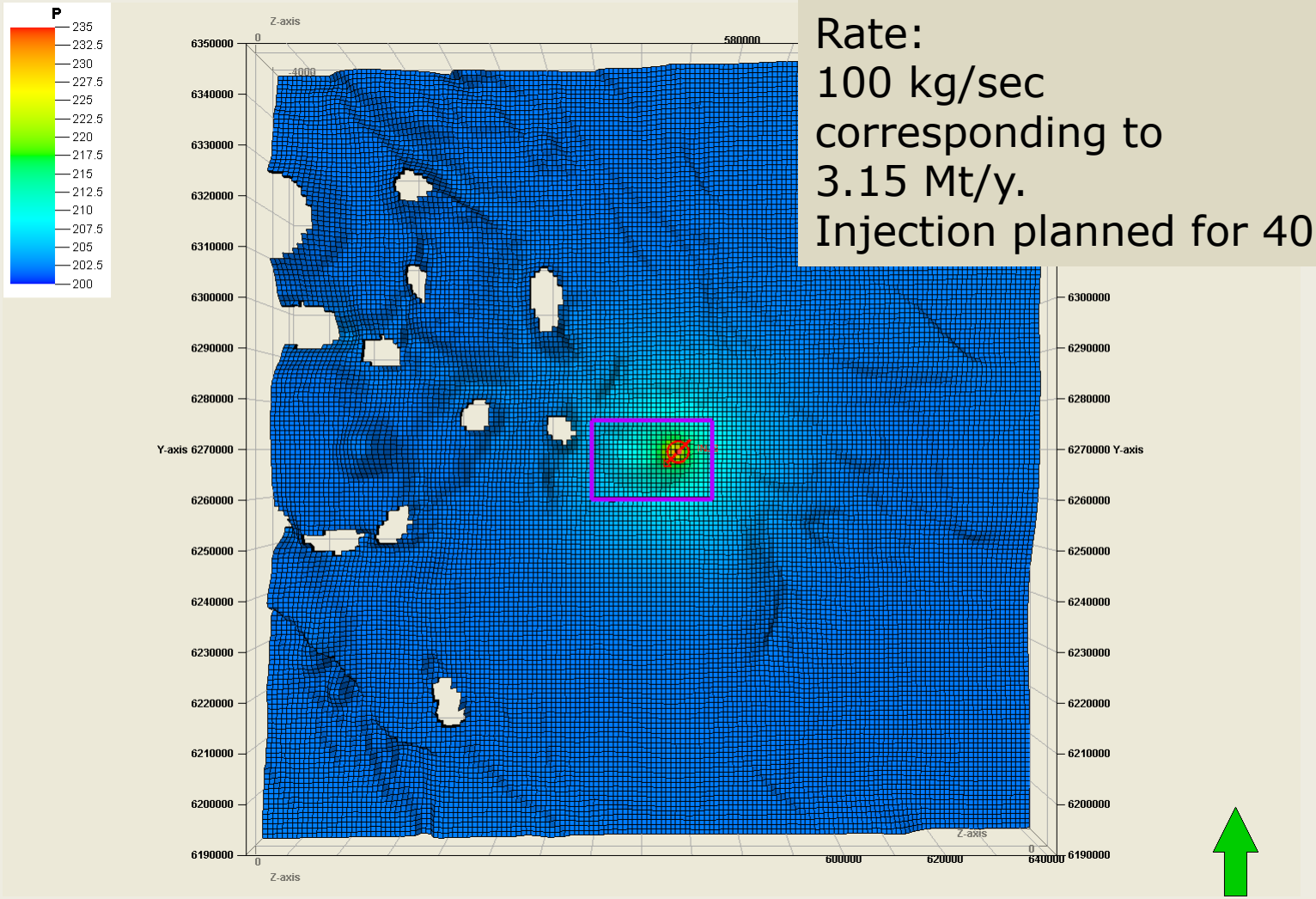
# 5 year of $CO_2$ injection

Rate:
100 kg/sec
corresponding to
3.15 Mt/y.
Injection planned for 40 years



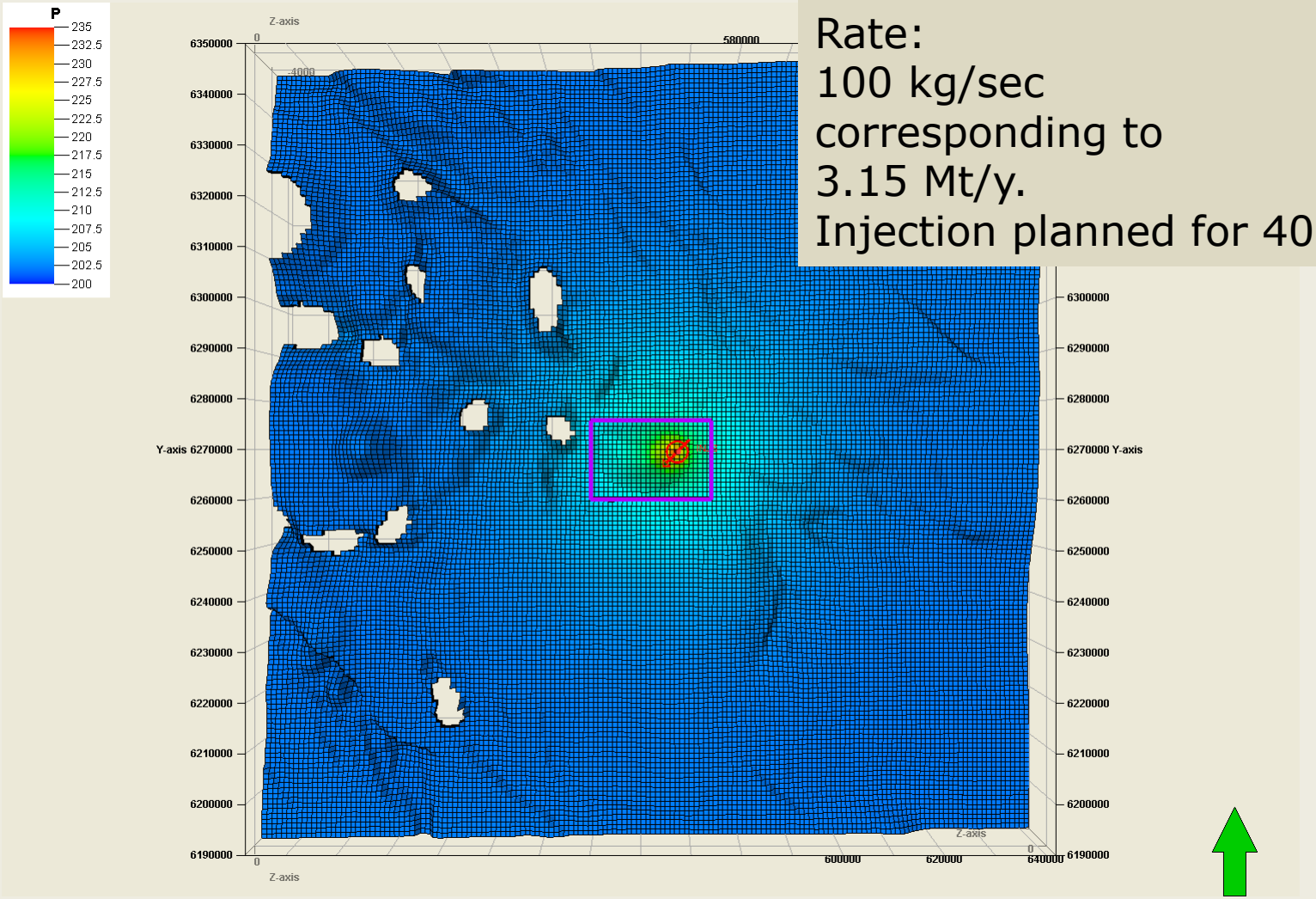
# 10 year of $CO_2$ injection

Rate:
100 kg/sec
corresponding to
3.15 Mt/y.
Injection planned for 40 years



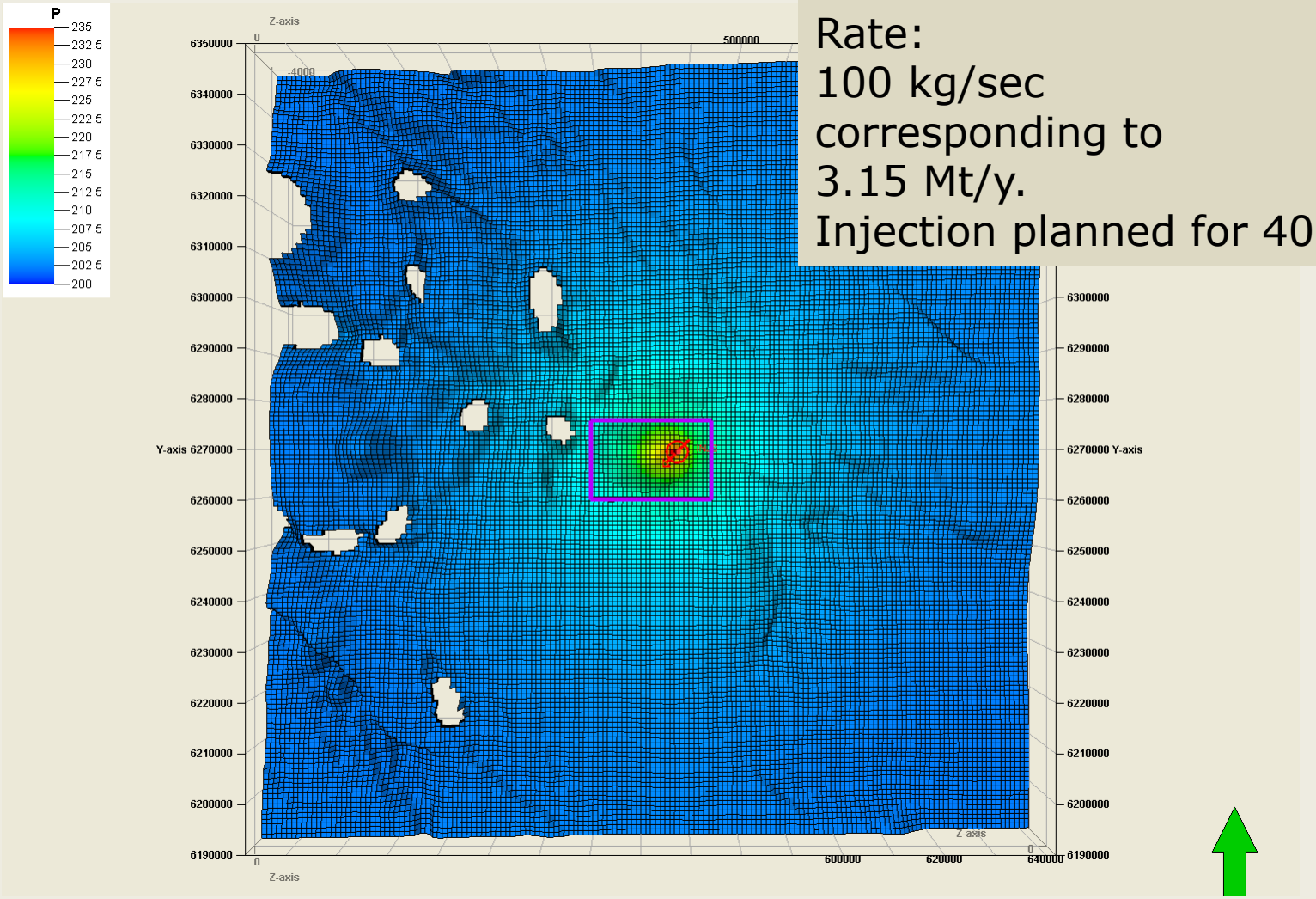
# 20 year of $CO_2$ injection

Rate:
100 kg/sec
corresponding to
3.15 Mt/y.
Injection planned for 40 years



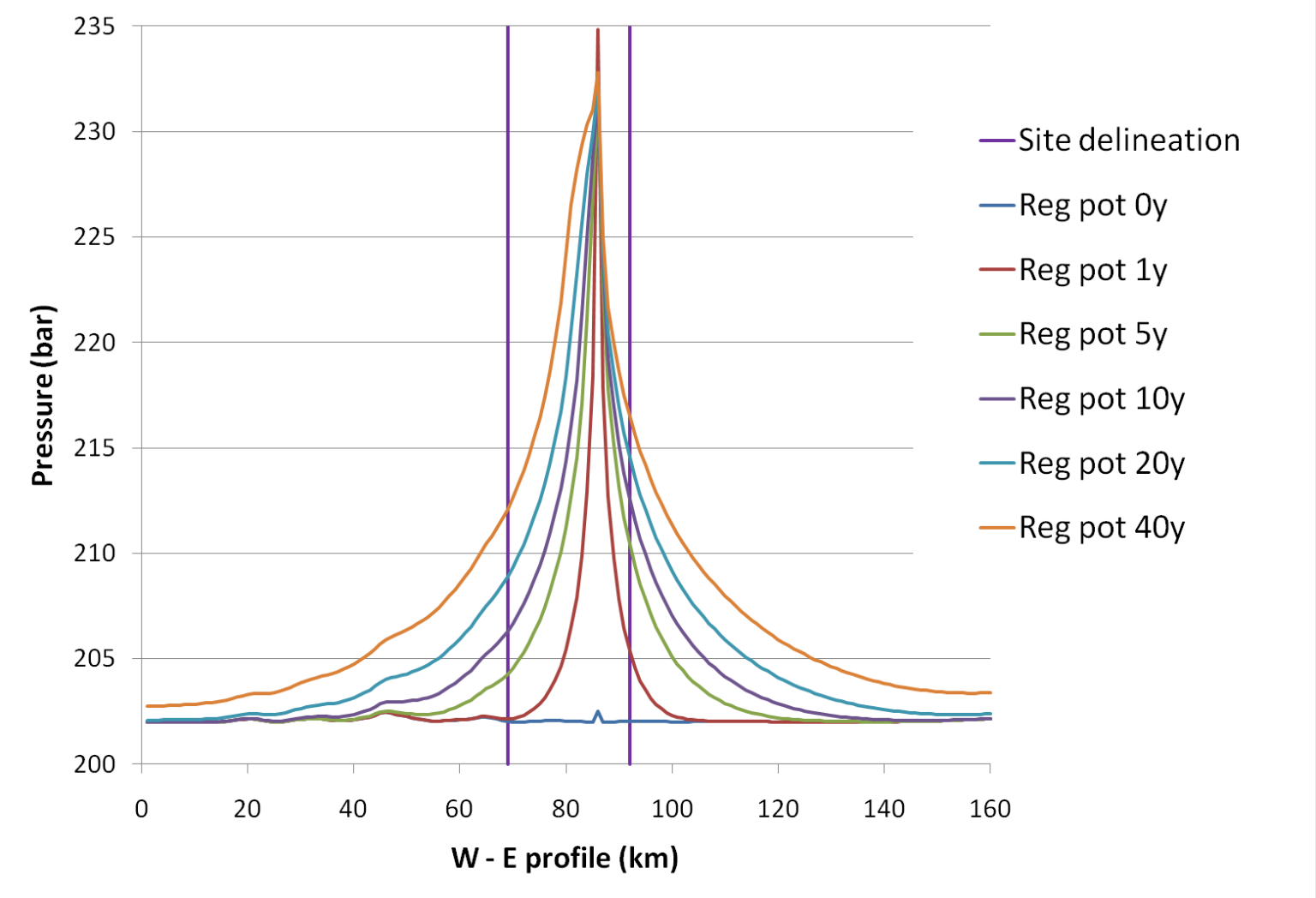
# 40 year of $CO_2$ injection

Rate:
100 kg/sec
corresponding to
3.15 Mt/y.
Injection planned for 40 years



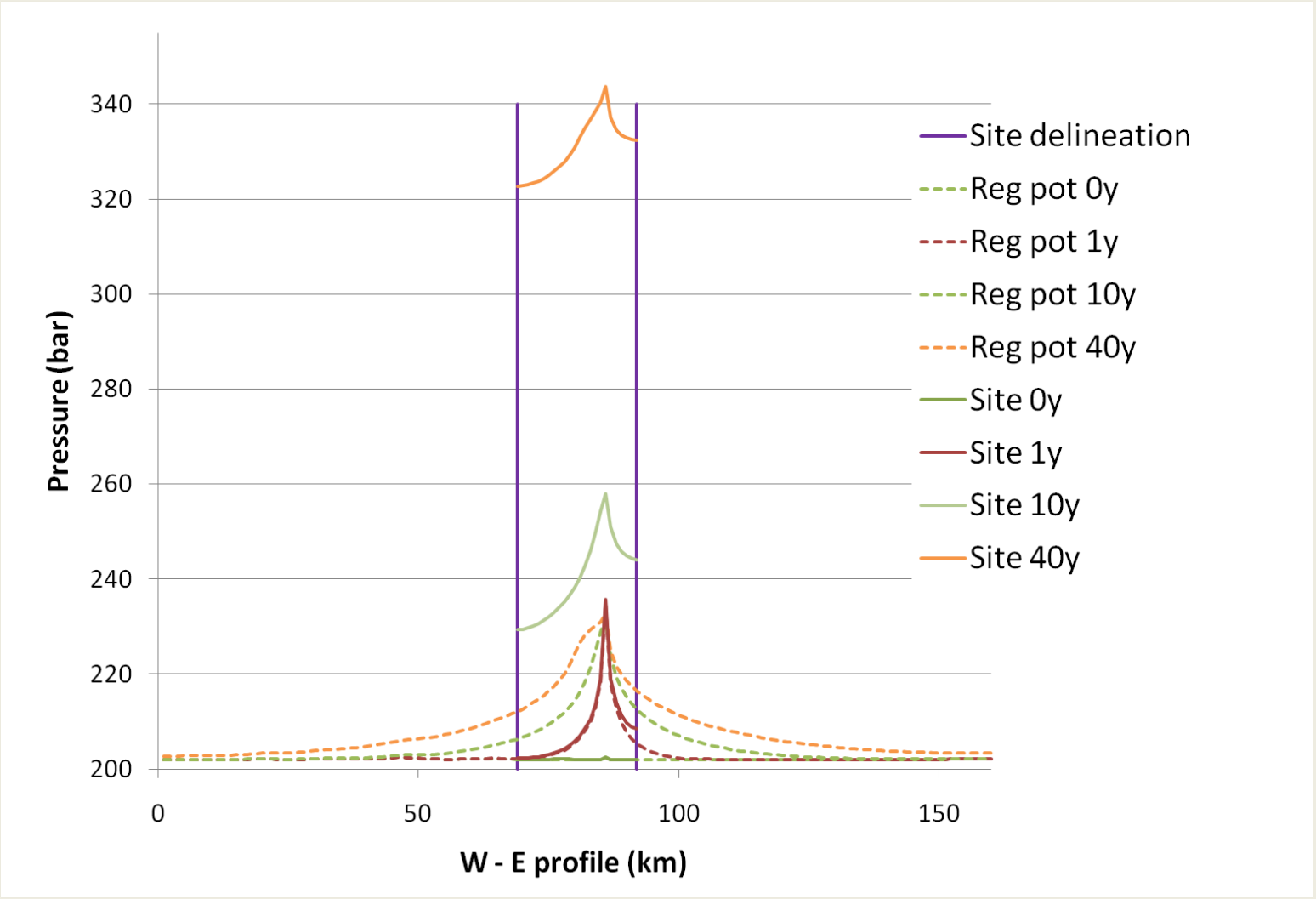
## Potential profiles (Datum depth 1960m, P=202 bar)

Pressure increase in regional model for a west-east profile through the injection site.



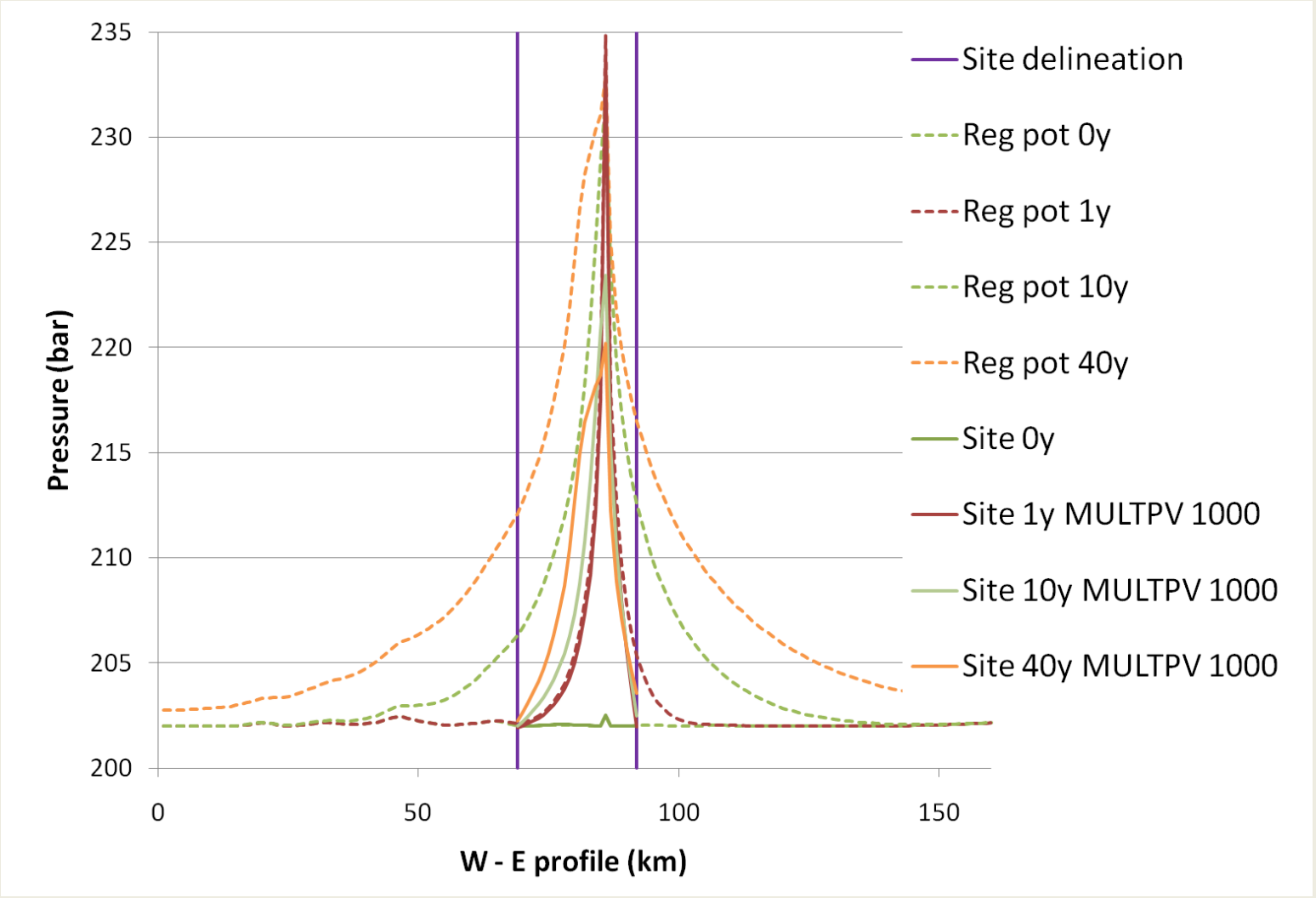
# Potential profiles (Datum depth 1960m, P=202 bar)

Pressure increase – site modelled as a closed container, i.e. closed Boundary, results in erroneously potential profile development



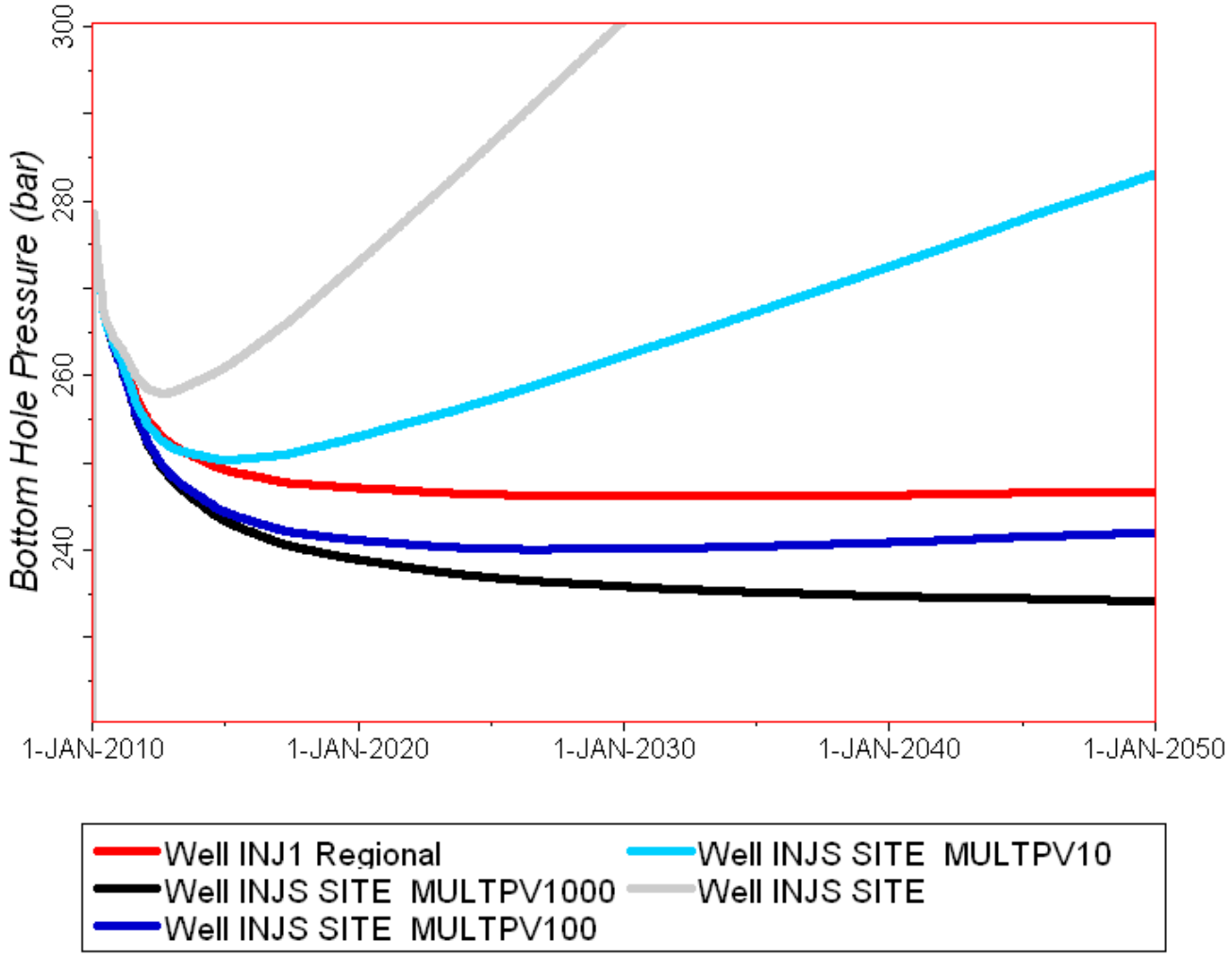
# Potential profiles (Datum depth 1960m, P=202 bar)

Pressure increase – to large a MULTPV i.e. all most constant pressure boundary conditions results in erroneously pot. profile development



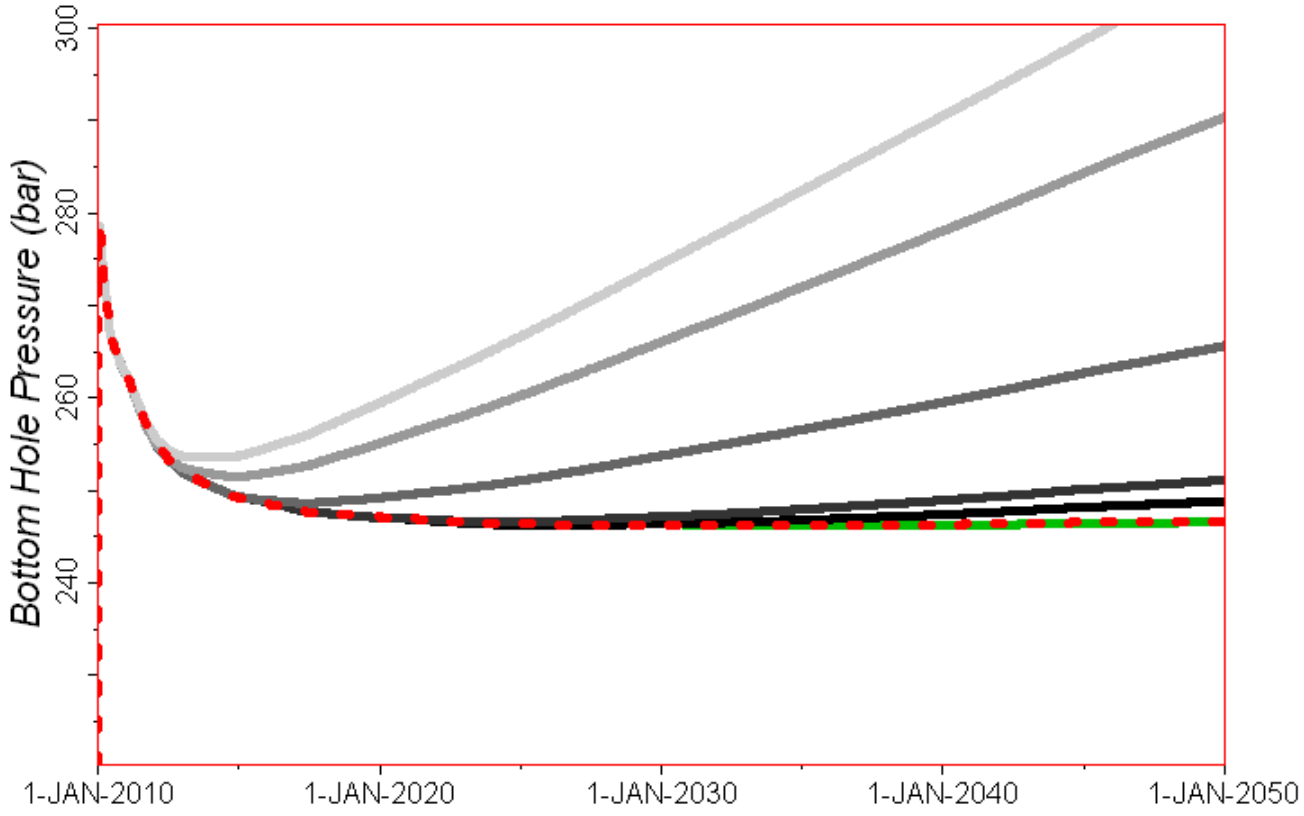
## Bottom Hole pressure vs. injection time (3.15 Mt/y $CO_2$ for 40 years)

Different MULTPV values for boundary conditions compared to regional model



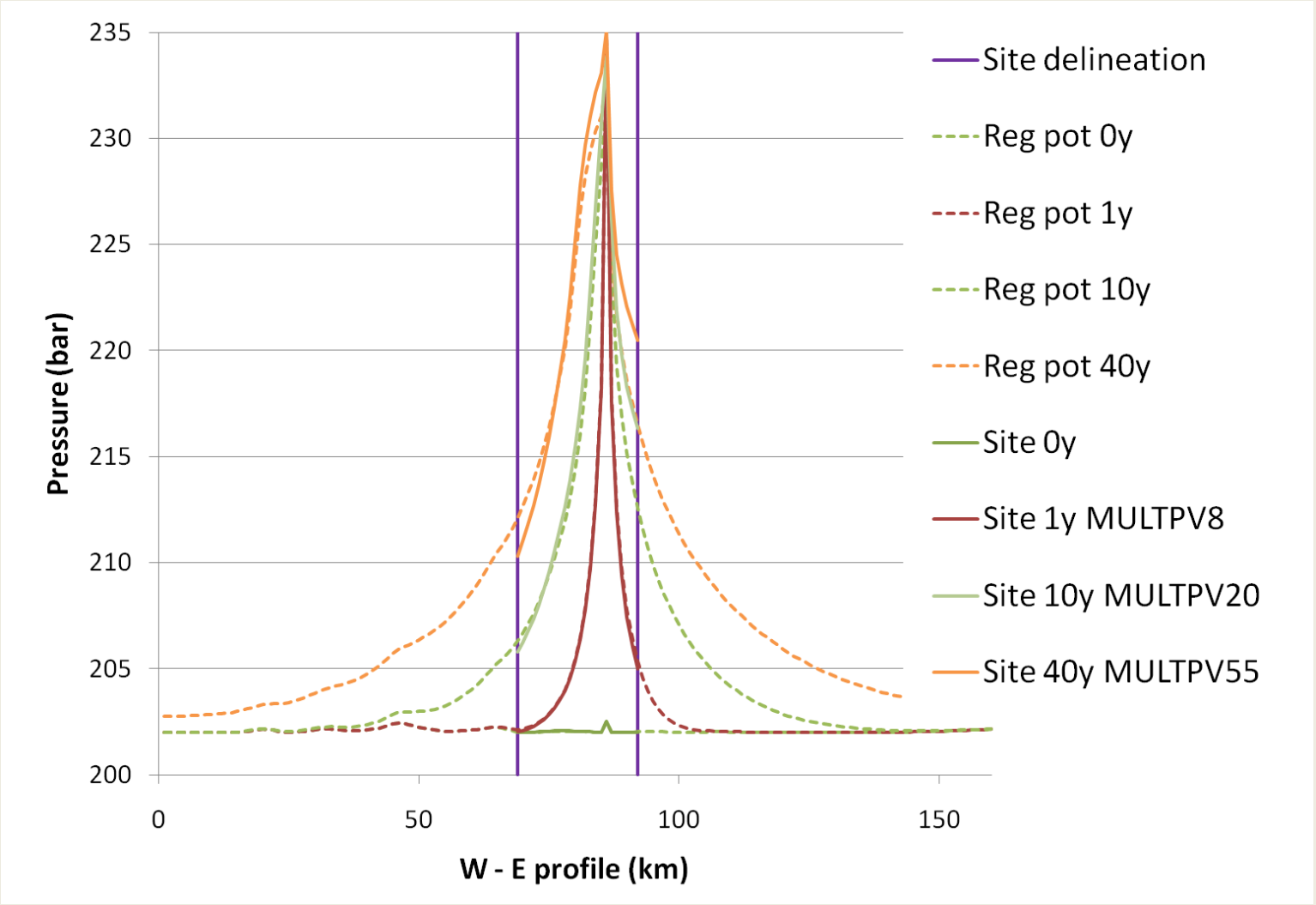
## Bottom Hole pressure vs. injection time (3.15 Mt/y $CO_2$ for 40 years)

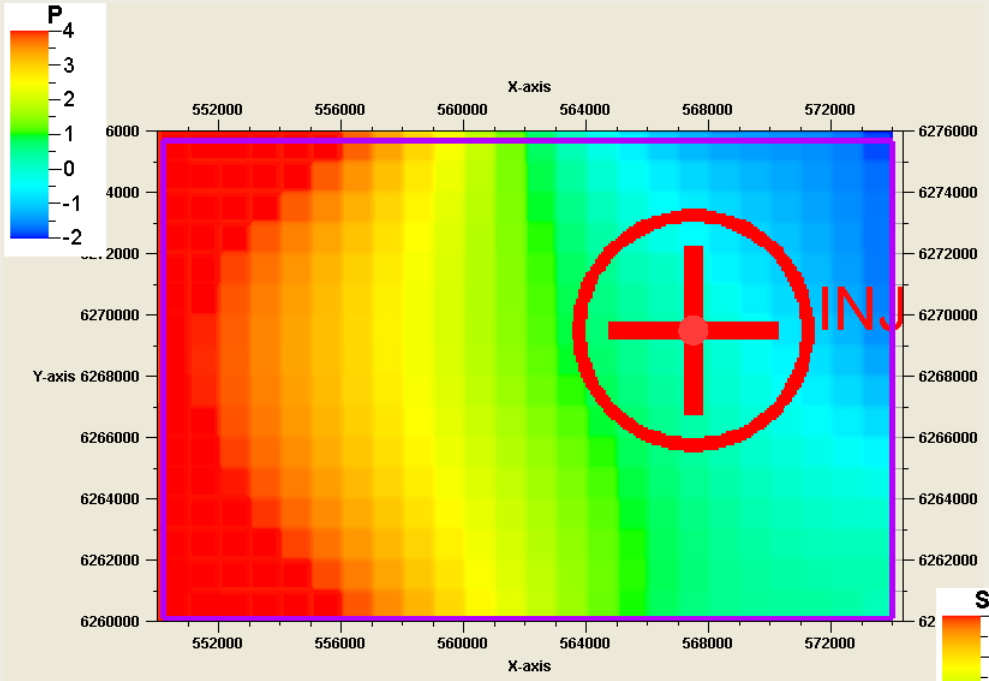
Matching BHP for site model to regional model by varying BC during injection



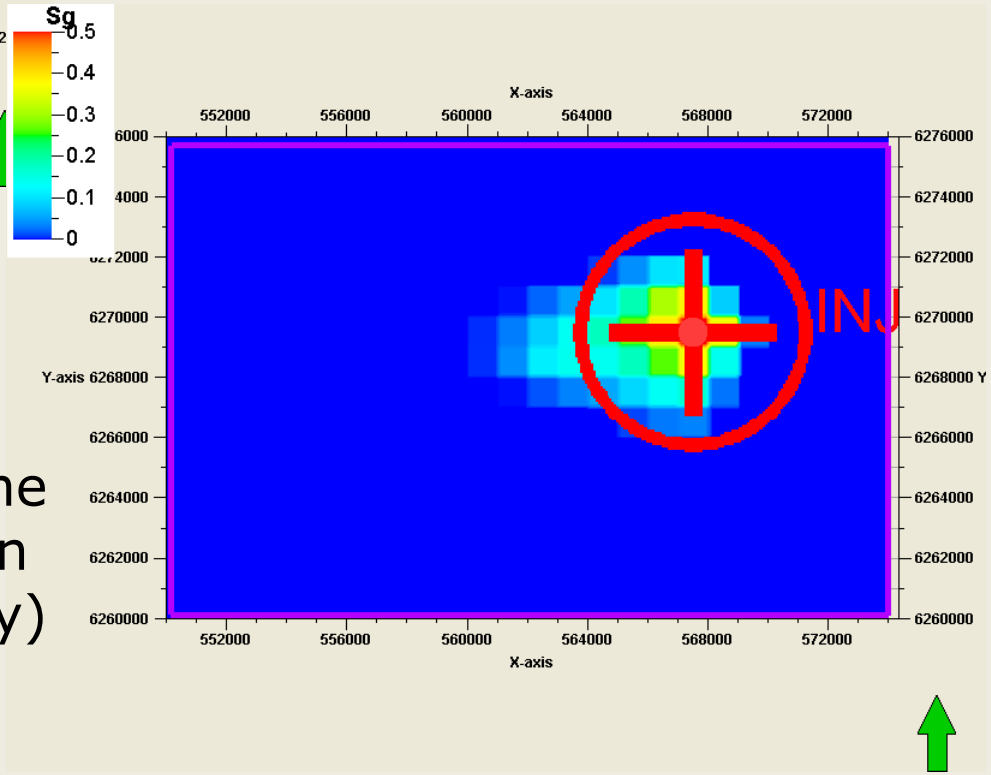
## Potential profiles (Datum depth 1960m, P=202 bar)

# Pressure increase – BHP for site model simulation runs match to BHP for regional model runs by different MULTPV vs. injection time

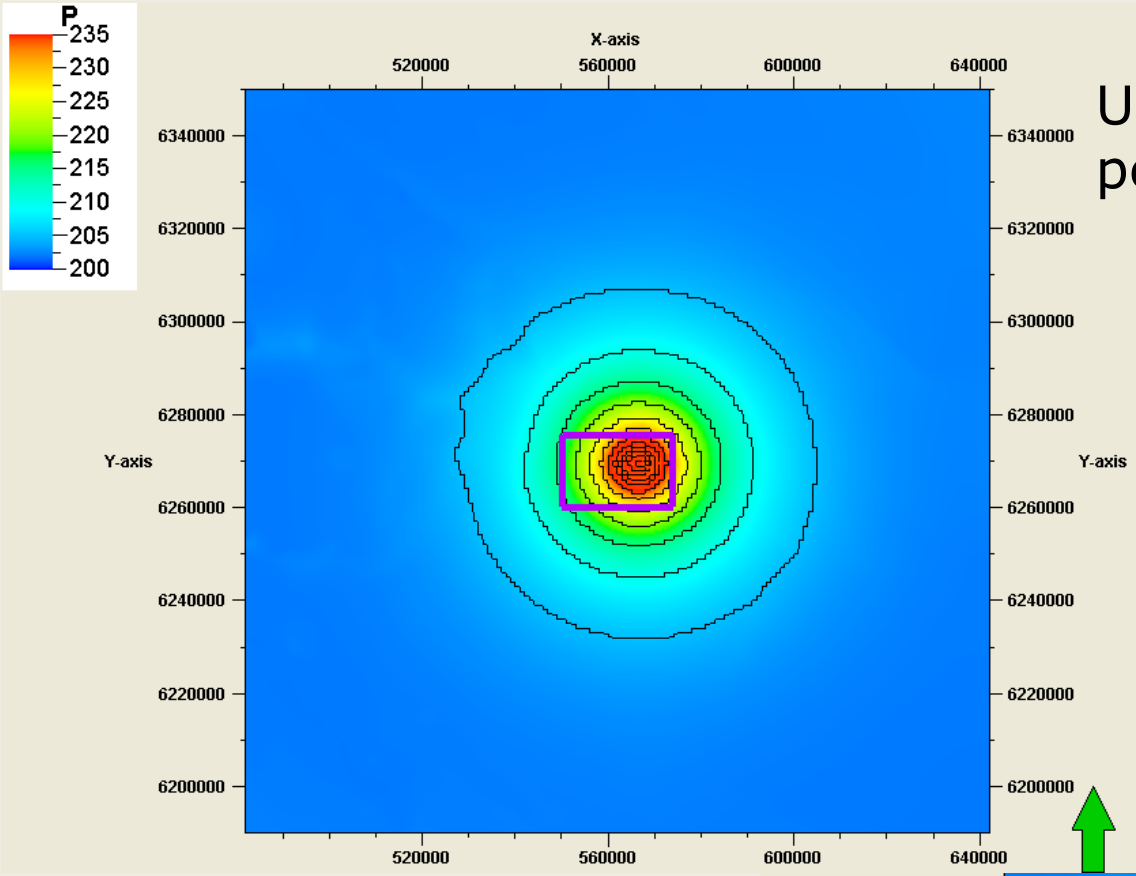




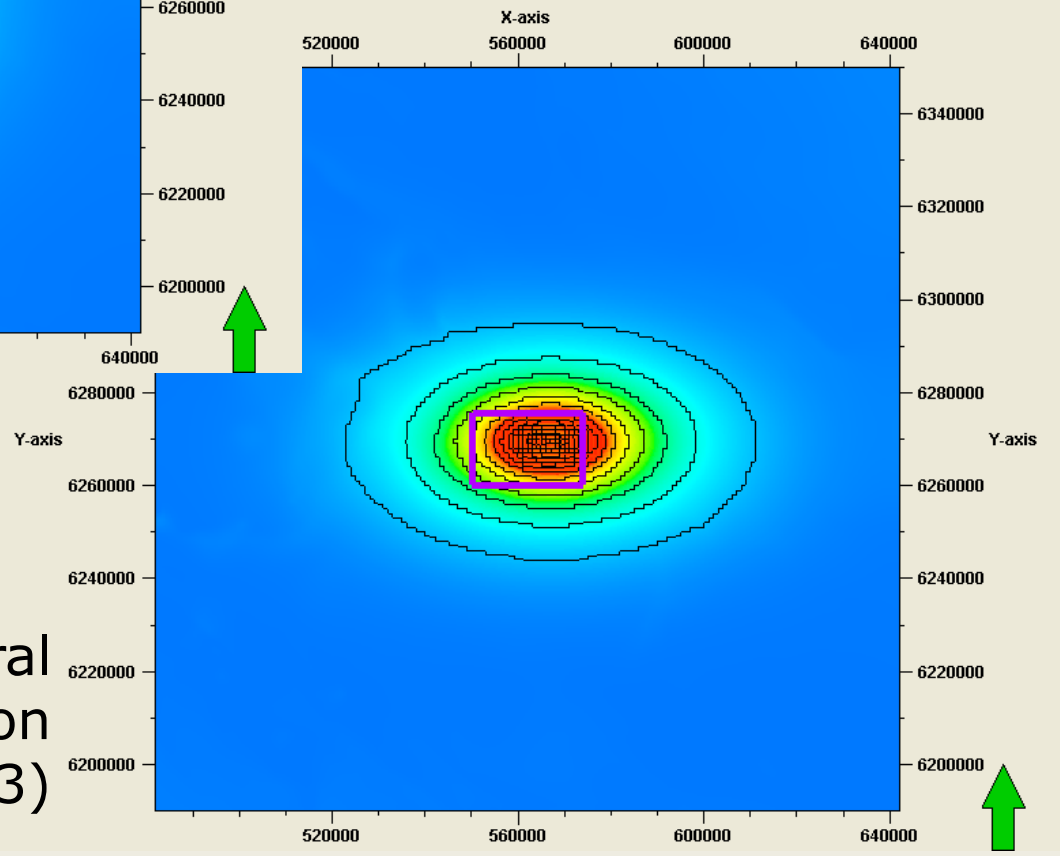

Difference between the potential distribution for the regional and the site model after 40 years injection. Difference not uniform distributed.




Delineation of the $CO_2$ plume after 40 years injection (3.15 Tonnes/y)




Uniform lateral permeability distribution




Biased lateral permeability distribution ($K_x/K_y=3$)

# Procedure for MULTPV boundary conditions method

1. Run regional model for injection scenario
2. Run site model with first guess on MULTPV
3. Compare BHP's and profiles of pressure potentials
4. Adjust MULTPV
5. Repeat step 2 – 4 until sufficient match obtained

# Conclusion

- Regional geological and dynamical understanding vital, as the pressure wave travels fast and extends much further than the $CO_2$ plume.
- No flow - and constant pressure boundary conditions don't replicate the pressure development.
- Pore volume multiplier (MULTPV) is an effective option in managing boundary conditions for a site model; but relevant values must be estimated from iterative match to regional pressure response.

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# Acknowledgements

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