

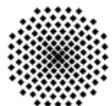


NUMERICAL SIMULATION OF CO₂ SEQUESTRATION CONSIDERING THE EXAMPLE OF CO₂SINK

A. Kopp, A. Bielinski, H. Class, R. Helmig

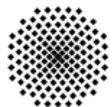
*Institut of Hydraulic Engineering
Dept. of Hydromechanics and Modeling of Hydrosystems
Universität Stuttgart, Germany*

EURO-Conference on Rock Physics and Geomechanics
Ile d'Oléron, France, 2005



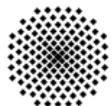
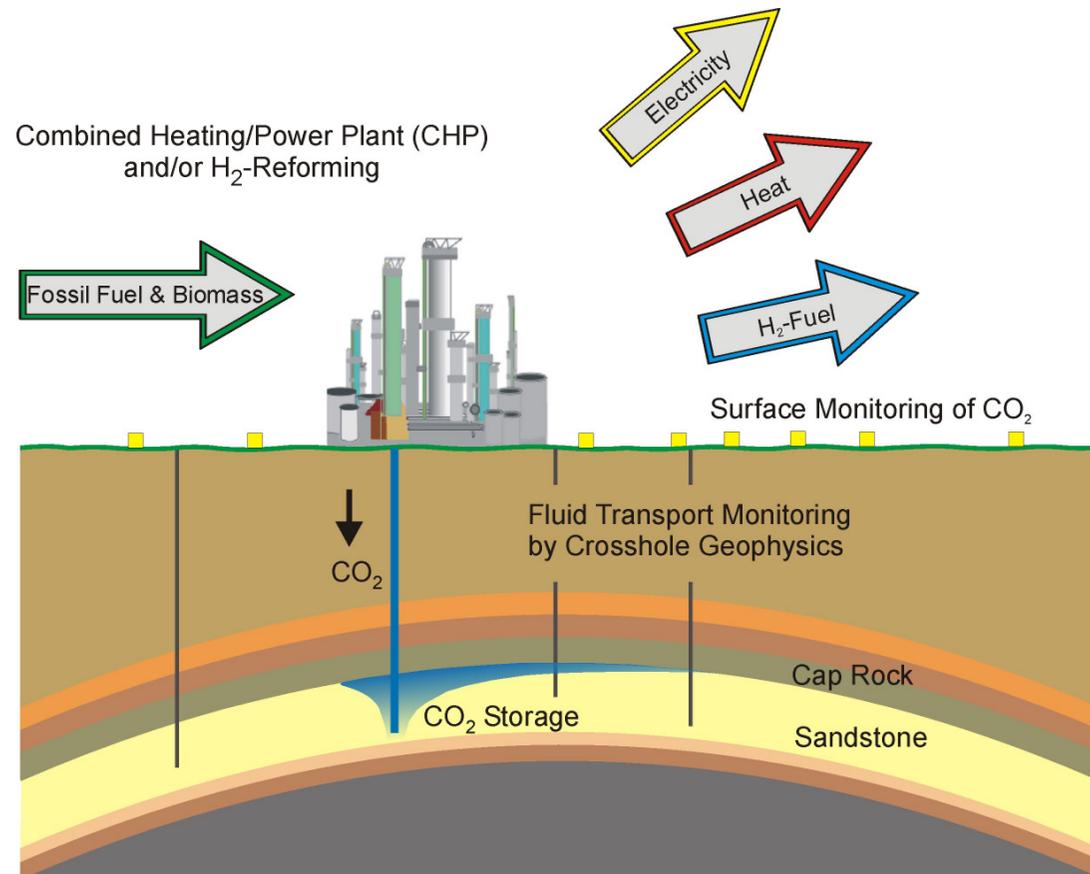
Outline

- CO₂SINK Project
- Geology
- Modelling Concept
- Sensitivity Study
- Outlook

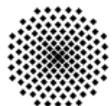
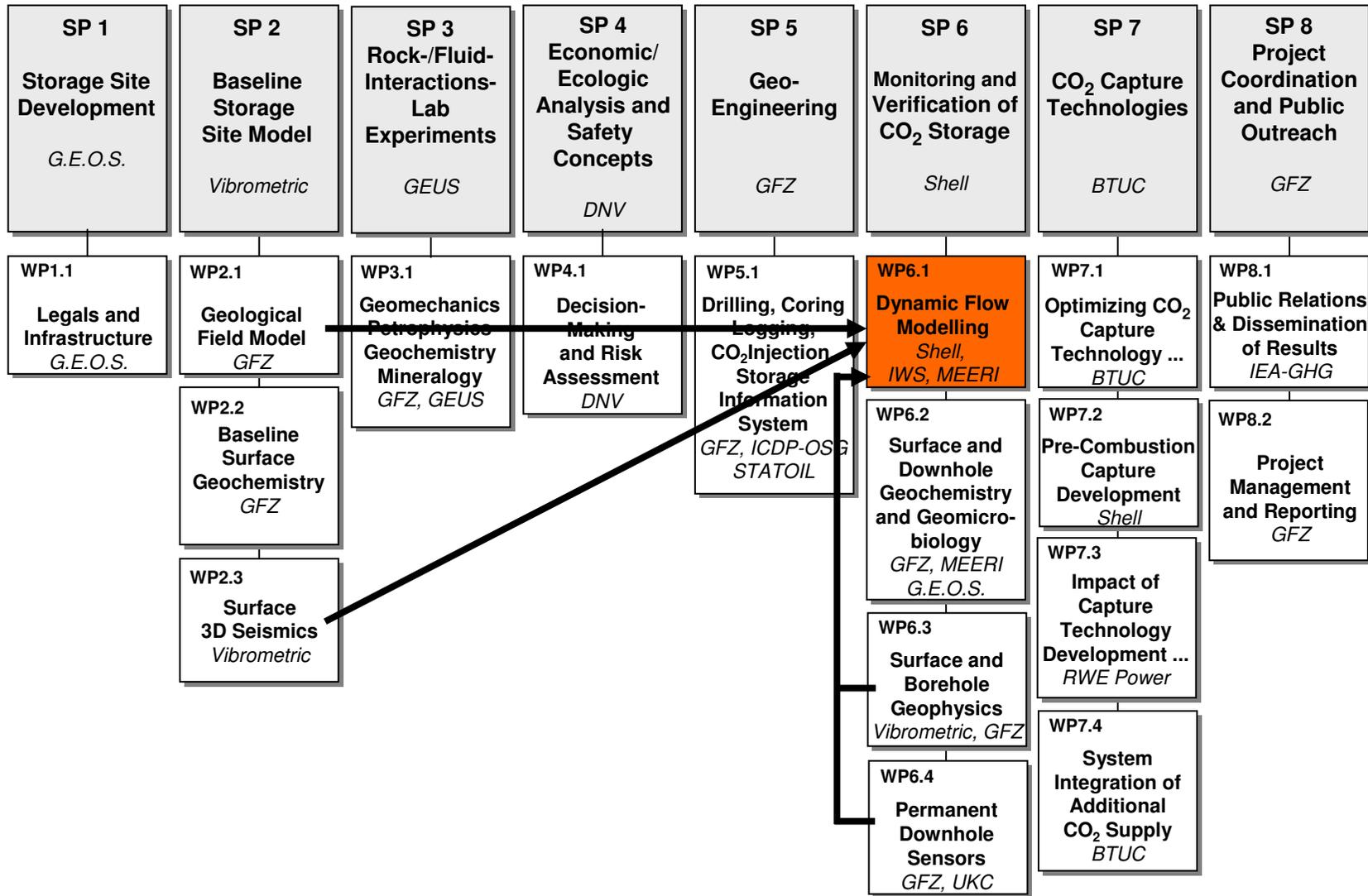


CO2SINK Project: Main Objectives

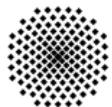
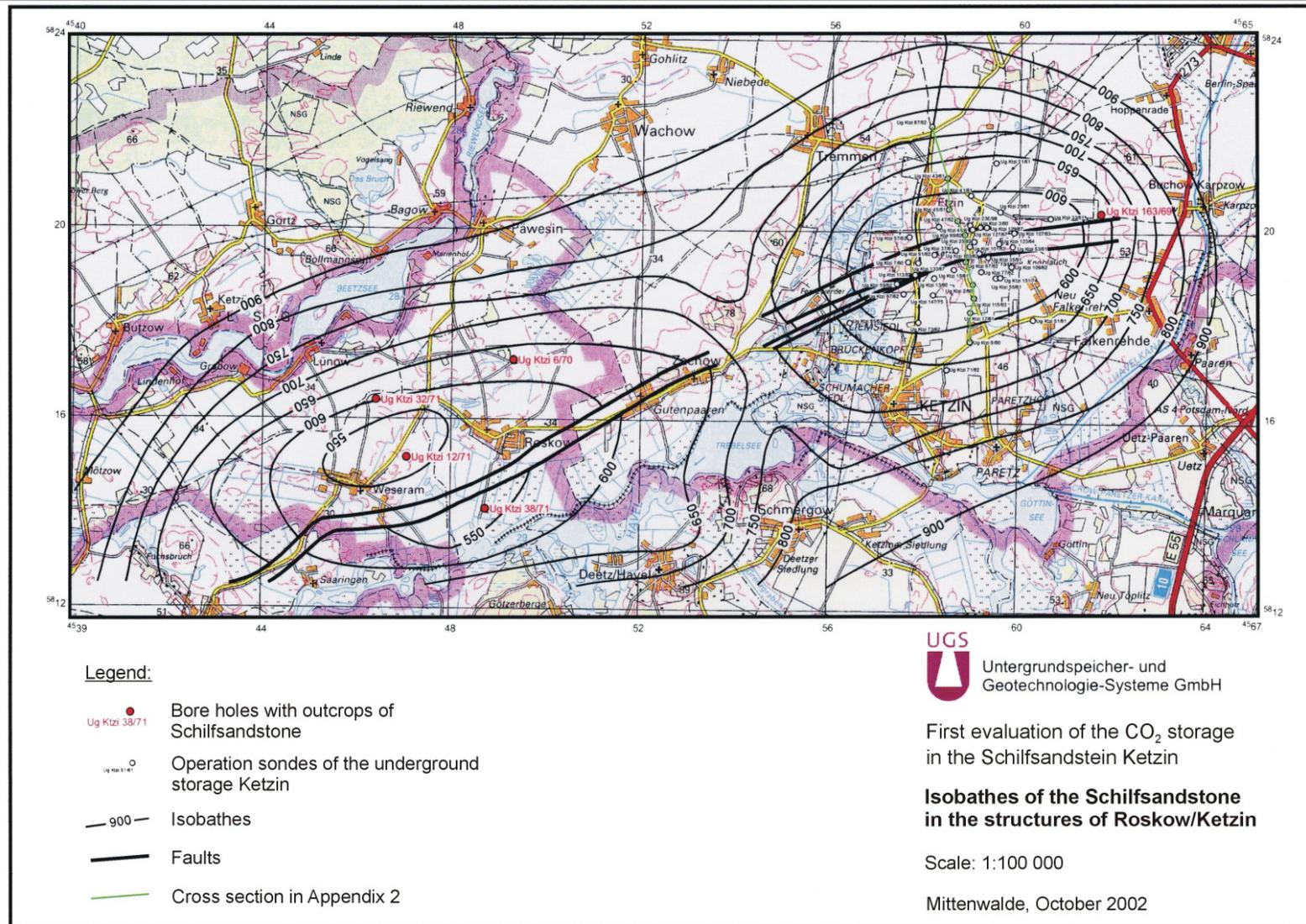
- Underground sequestration of CO₂
- Monitoring of CO₂ at depth and at the surface
- Development and verification of safety concepts
- Modelling chemical and physical processes



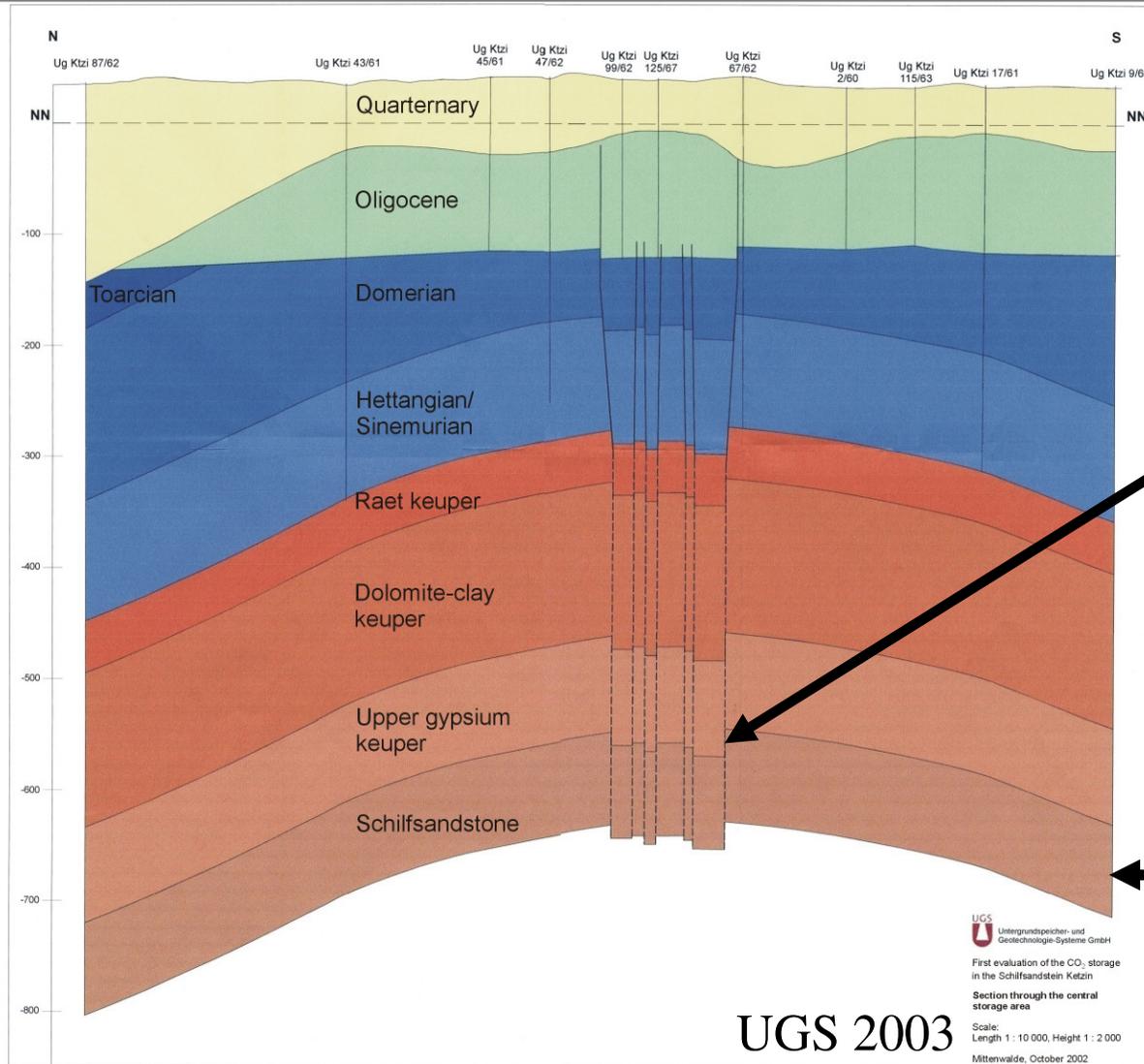
CO2SINK Project: Structure



Geology: Existing Information

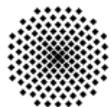


Geology: Uncertain Information



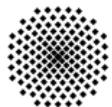
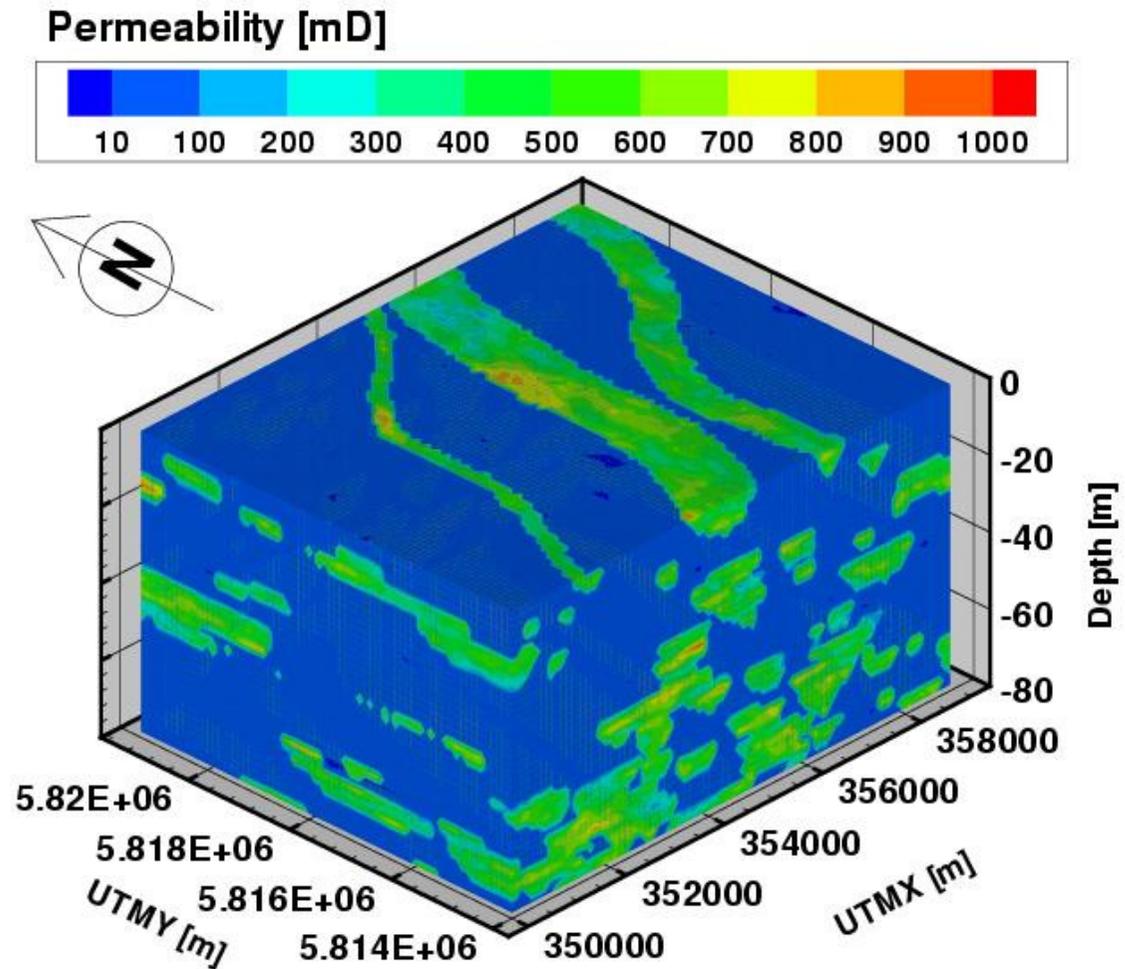
Faulting of caprock

Stuttgart Formation Porosity: 21-27%

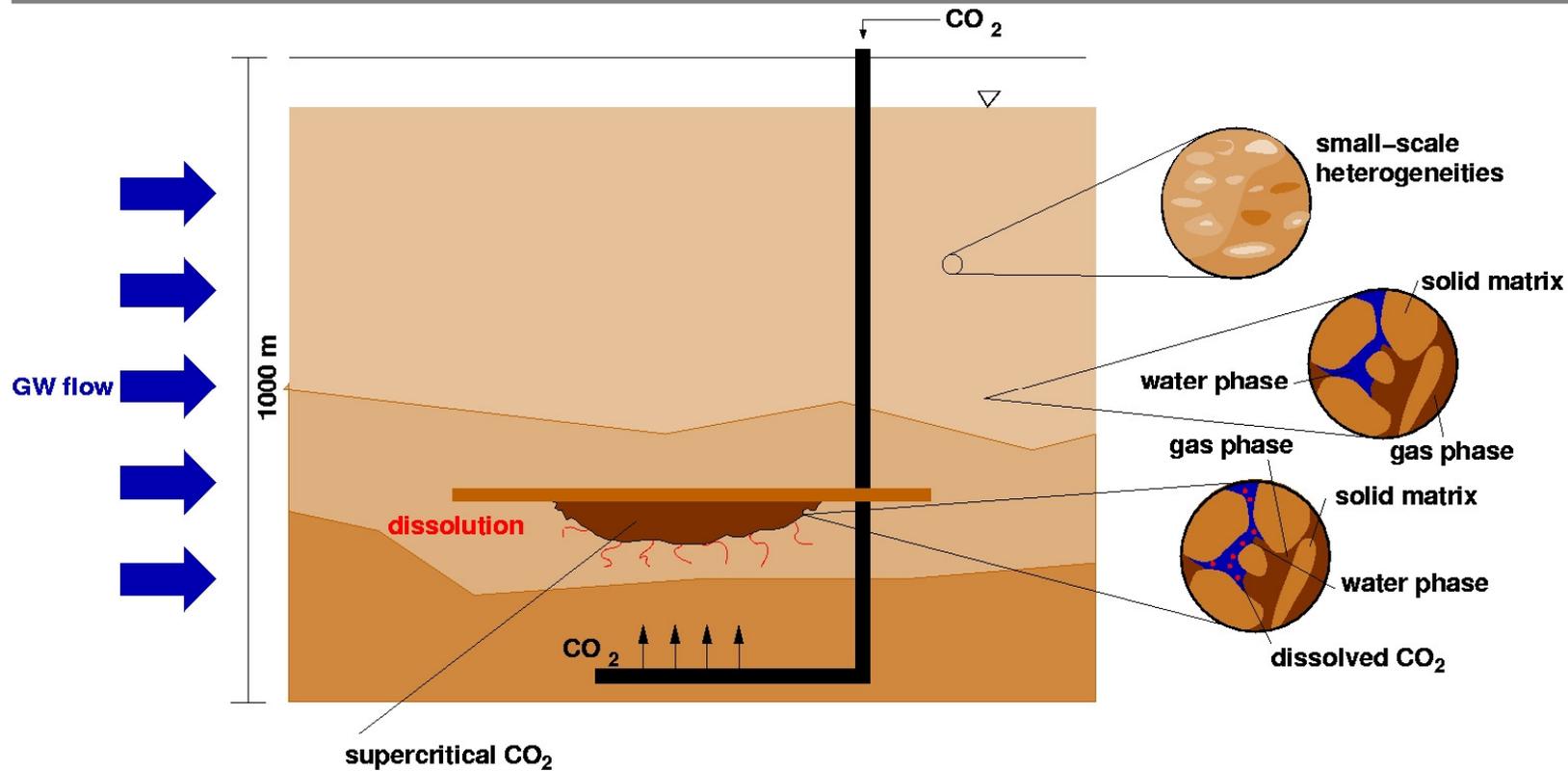


Geology: FluvSim Model

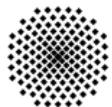
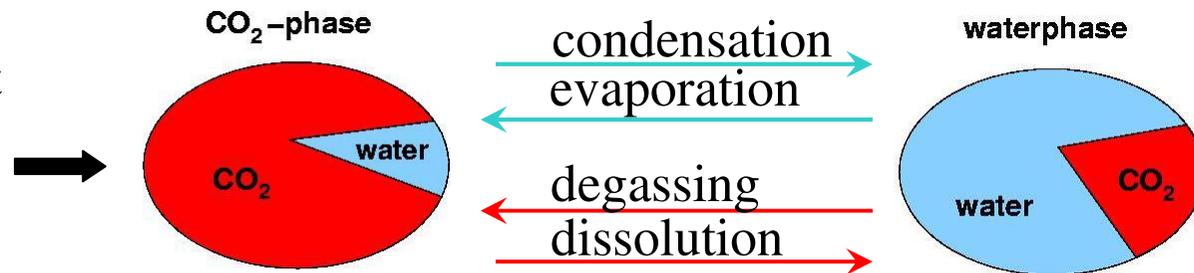
- Hierarchical object based modelling scheme (*Deutsch & Wang 1996*)
- Background matrix of non-channel facies (flood plain)
- Objects of channel facies in this matrix



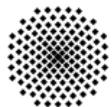
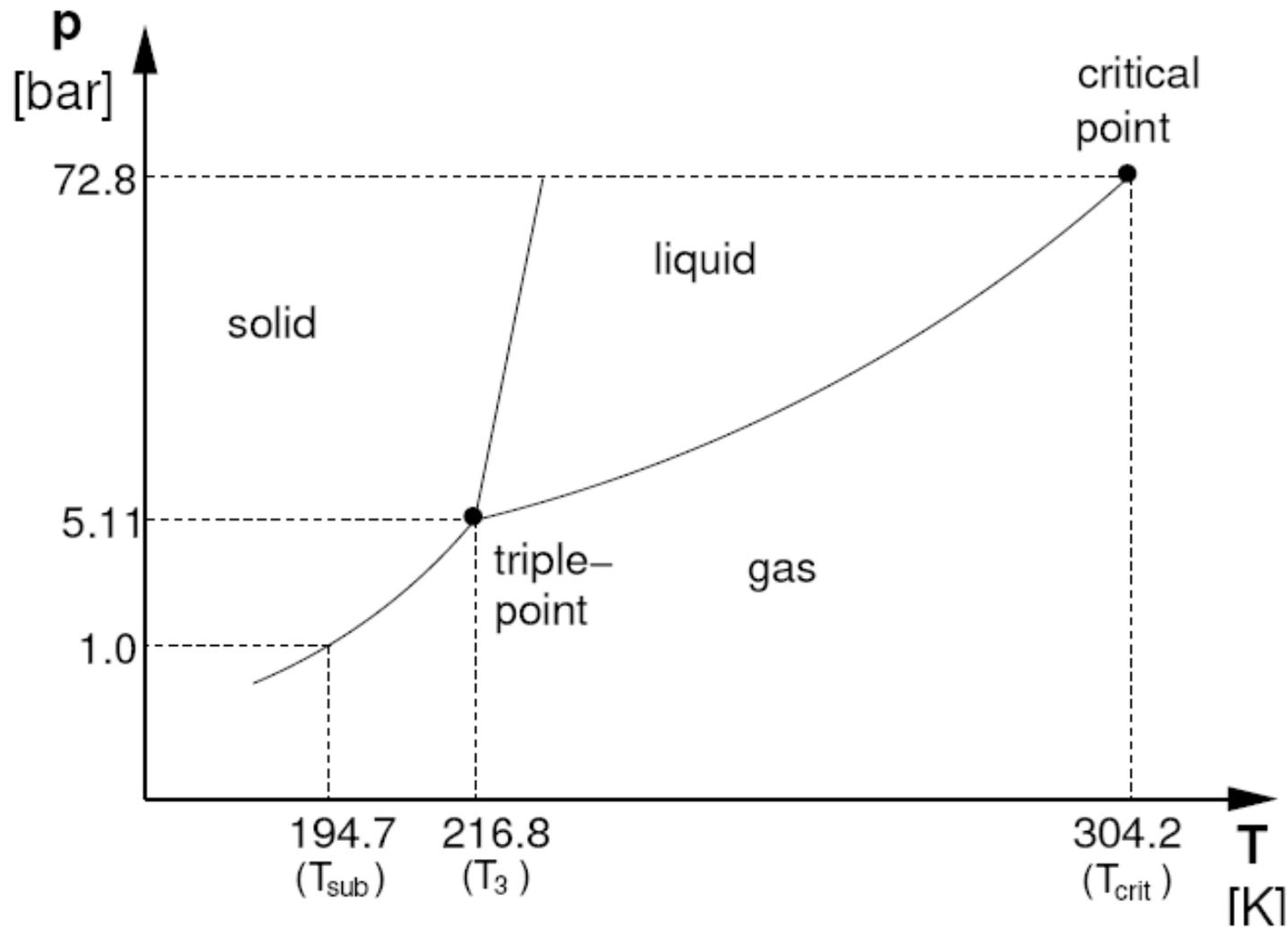
Modelling: Processes / Concept



2 phase 2 component
non-isothermal
modelling concept



Modelling: Phase diagram of CO₂



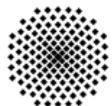
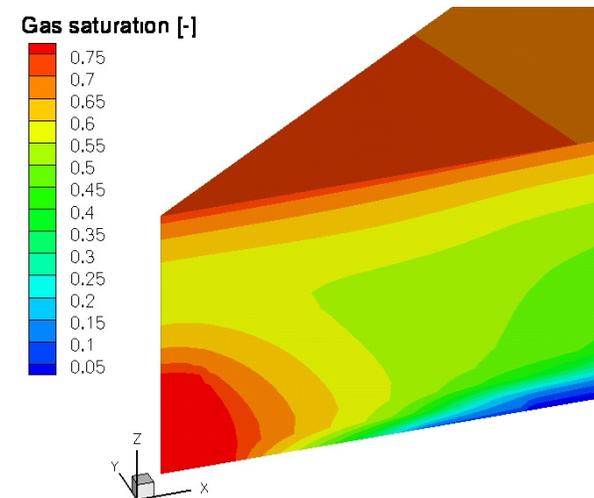
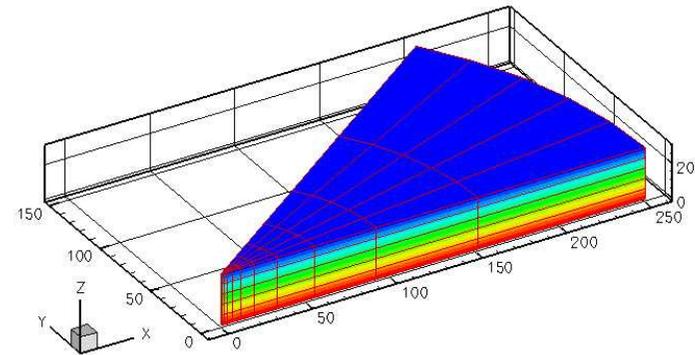
Modelling: Sensitivity Study : Setup

Motivation:

Determine the influence of the various input parameters on saturation evolution, pressure build up, storage capacity etc.

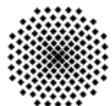
Setup:

- radial symmetric domain
(30m high, lateral extent 500m – 5000m)
- reservoir cap rock 730m below surface
- use characteristics of Ketzin site
(permeability, porosity, brine density etc.)
- injection of 1 kg/s supercritical CO₂
in screened section of well (5m) for
2 years

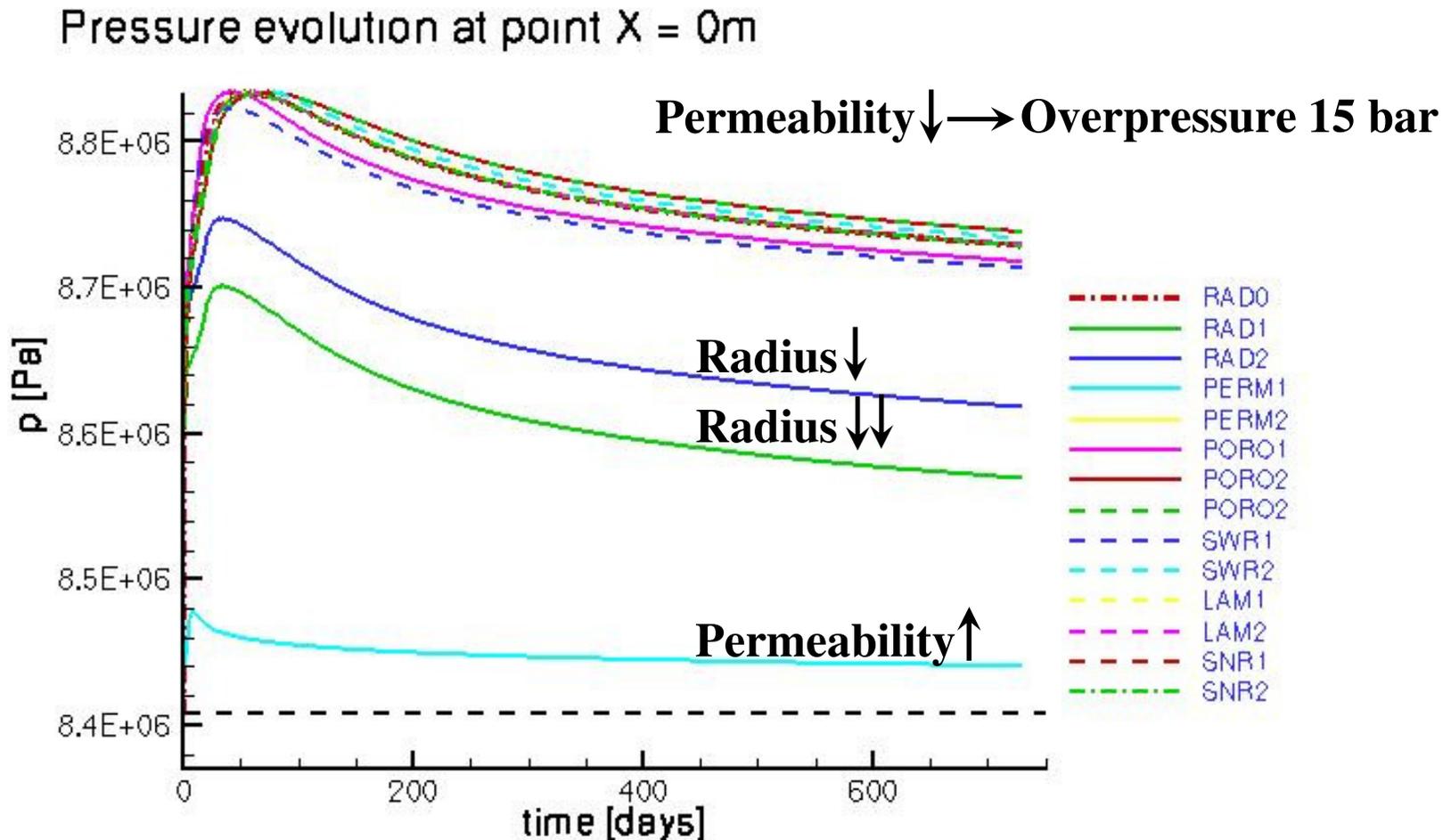


Modelling: Sensitivity Study : Setup

Case Name	Domain Radius [m]	Permeability [m ²]	Porosity [-]	Residual Water Saturation [-]	λ	Residual Gas Saturation [-]
RAD0	5000	$1 \cdot 10^{-13}$	0.2	0.1	2	0.05
RAD1	500	$1 \cdot 10^{-13}$	0.2	0.1	2	0.05
RAD2	1000	$1 \cdot 10^{-13}$	0.2	0.1	2	0.05
PERM1	5000	$1 \cdot 10^{-12}$	0.2	0.1	2	0.05
PERM2	5000	$1 \cdot 10^{-14}$	0.2	0.1	2	0.05
PORO1	5000	$1 \cdot 10^{-13}$	0.15	0.1	2	0.05
PORO2	5000	$1 \cdot 10^{-13}$	0.25	0.1	2	0.05
SWR1	5000	$1 \cdot 10^{-13}$	0.2	0.0	2	0.05
SWR2	5000	$1 \cdot 10^{-13}$	0.2	0.4	2	0.05
λ_1	5000	$1 \cdot 10^{-13}$	0.2	0.1	1.5	0.05
λ_2	5000	$1 \cdot 10^{-13}$	0.2	0.1	3	0.05
SNR1	5000	$1 \cdot 10^{-13}$	0.2	0.1	2	0.0
SNR2	5000	$1 \cdot 10^{-13}$	0.2	0.1	2	0.2

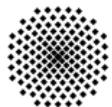


Modelling: Sensitivity Study : Gas Pressure Evolution



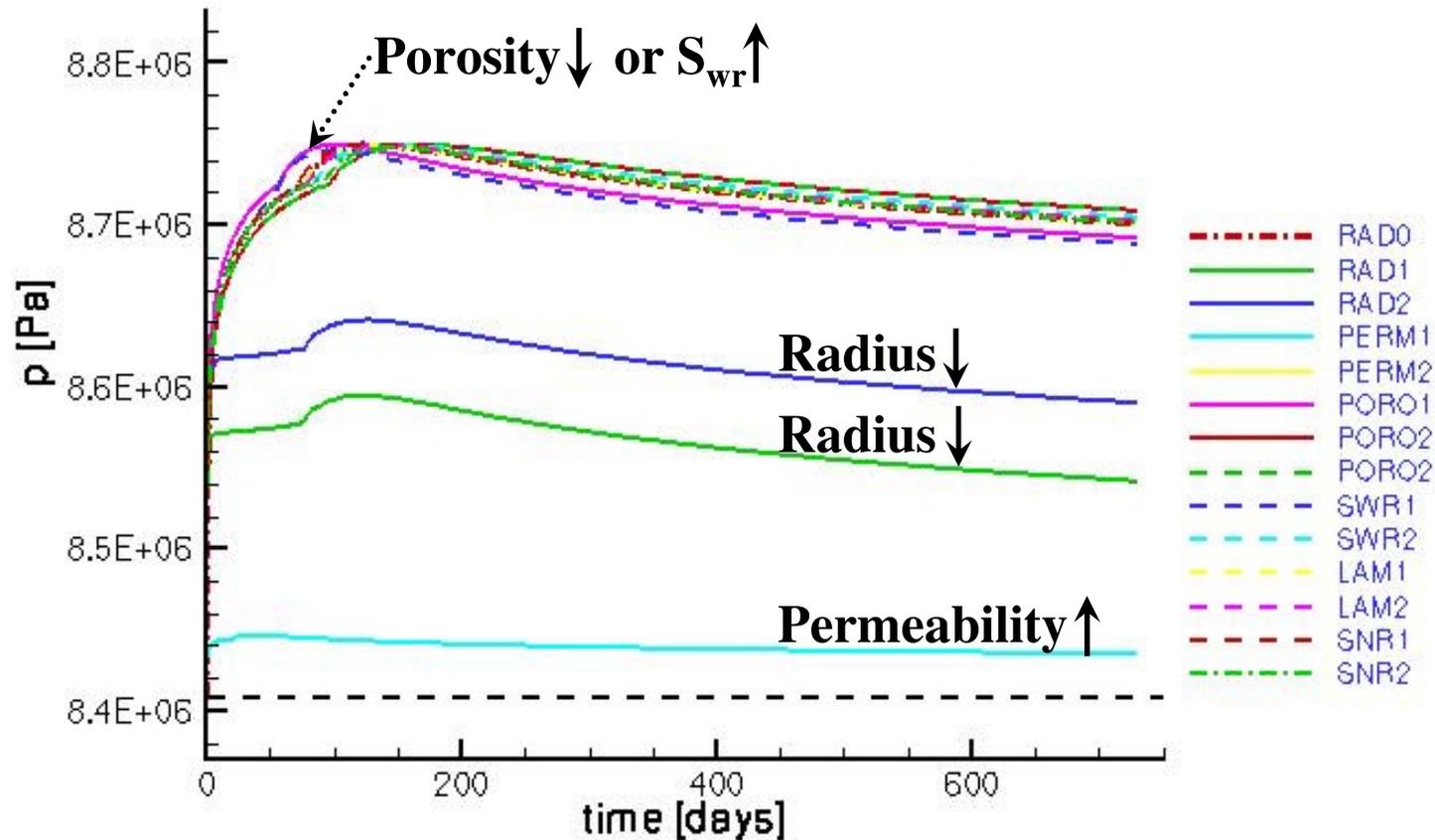
Basecase: R = 5000m; PHI = 0.2; Swr = 0.1; Snr = 0.05; lambda = 2

RAD1: r = 500m	PORO2: PHI = 0.25	Swr1: 0.4	LAM2: 3.0
RAD2: r = 1000m	PERM1: K = 1E-12m ² /s	Swr2: 0.0	Snr1: 0.0
PORO1: PHI = 0.15	PERM2: K = 1E-14m ² /s	LAM1: 1.5	Snr2: 0.2



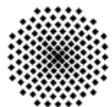
Modelling: Sensitivity Study : Gas Pressure Evolution

Pressure evolution at point X = 50m



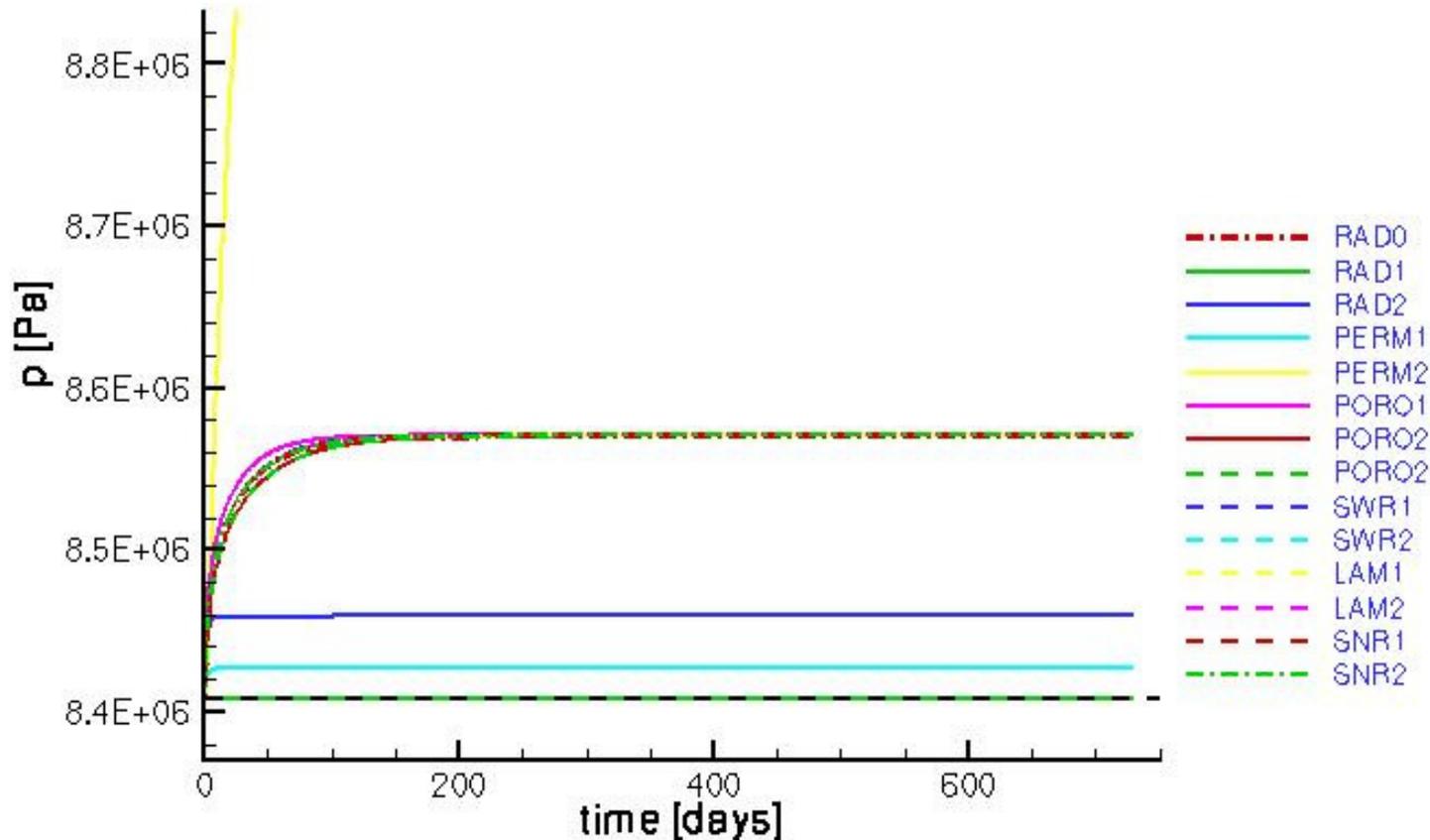
Basecase: $R = 5000\text{m}$; $\text{PHI} = 0.2$; $S_{wr} = 0.1$; $S_{nr} = 0.05$; $\text{lambda} = 2$

RAD1: $r = 500\text{m}$	PORO2: $\text{PHI} = 0.25$	Swr1: 0.4	LAM2: 3.0
RAD2: $r = 1000\text{m}$	PERM1: $K = 1\text{E-}12\text{m}^2/\text{s}$	Swr2: 0.0	Snr1: 0.0
PORO1: $\text{PHI} = 0.15$	PERM2: $K = 1\text{E-}14\text{m}^2/\text{s}$	LAM1: 1.5	Snr2: 0.2



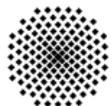
Modelling: Sensitivity Study : Gas Pressure Evolution

Pressure evolution at point X = 500m



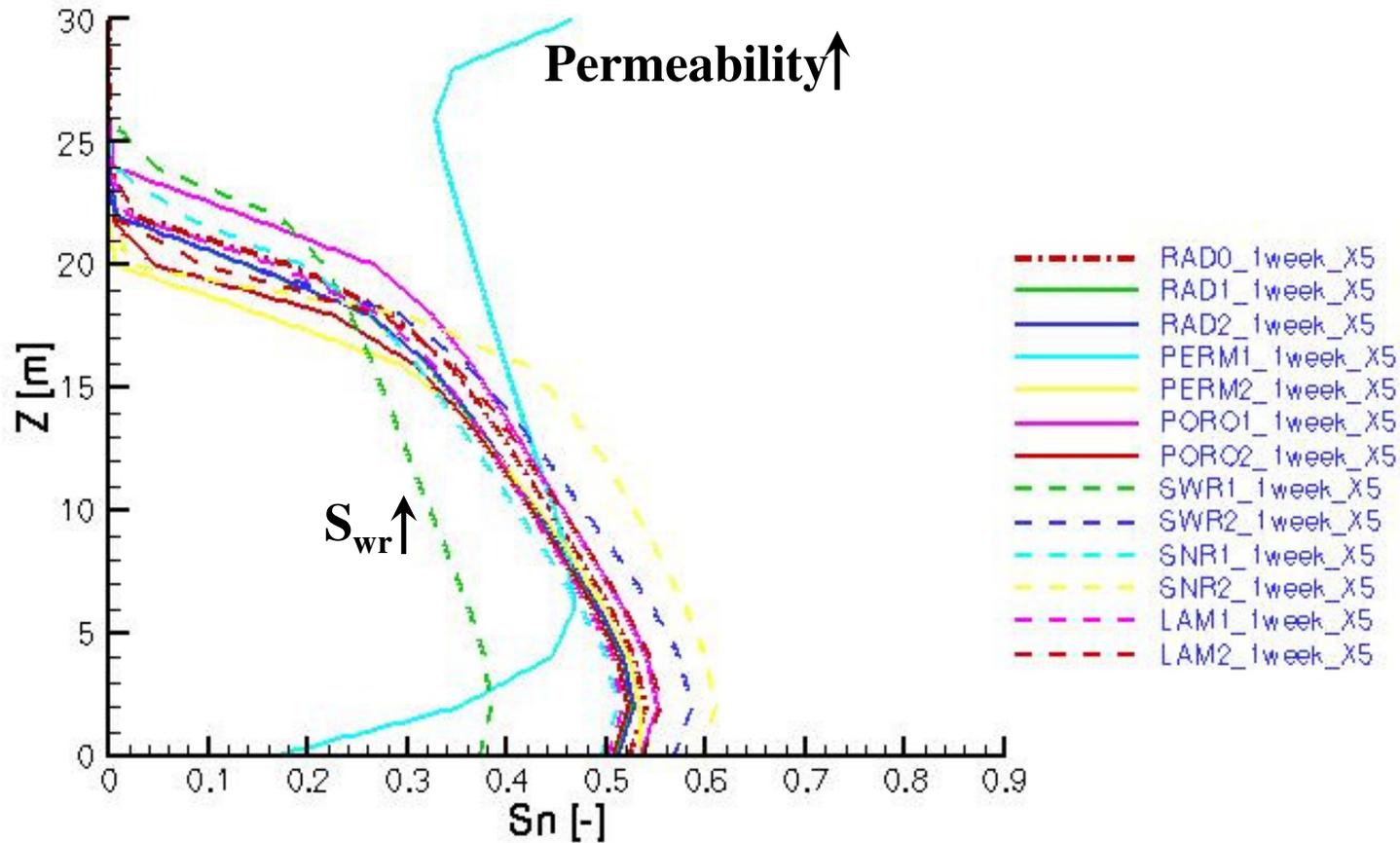
Basecase: R = 5000m; PHI = 0.2; Swr = 0.1; Snr = 0.05; lambda = 2

RAD1:	r = 500m	PORO2:	PHI = 0.25	Swr1:	0.4	LAM2:	3.0
RAD2:	r = 1000m	PERM1:	K = 1E-12m2/s	Swr2:	0.0	Snr1:	0.0
PORO1:	PHI = 0.15	PERM2:	K = 1E-14m2/s	LAM1:	1.5	Snr2:	0.2



Modelling: Sensitivity Study : Saturation Distribution

CO2 Saturation [-], slice at X = 5m at time T = 1week



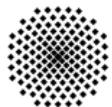
Basecase: R = 5000m; PHI = 0.2; Swr = 0.1; Snr = 0.05; lambda = 2

RAD1: r = 500m
 RAD2: r = 1000m
 PORO1: PHI = 0.15

PORO2: PHI = 0.25
 PERM1: K = 1E-12m2/s
 PERM2: K = 1E-14m2/s

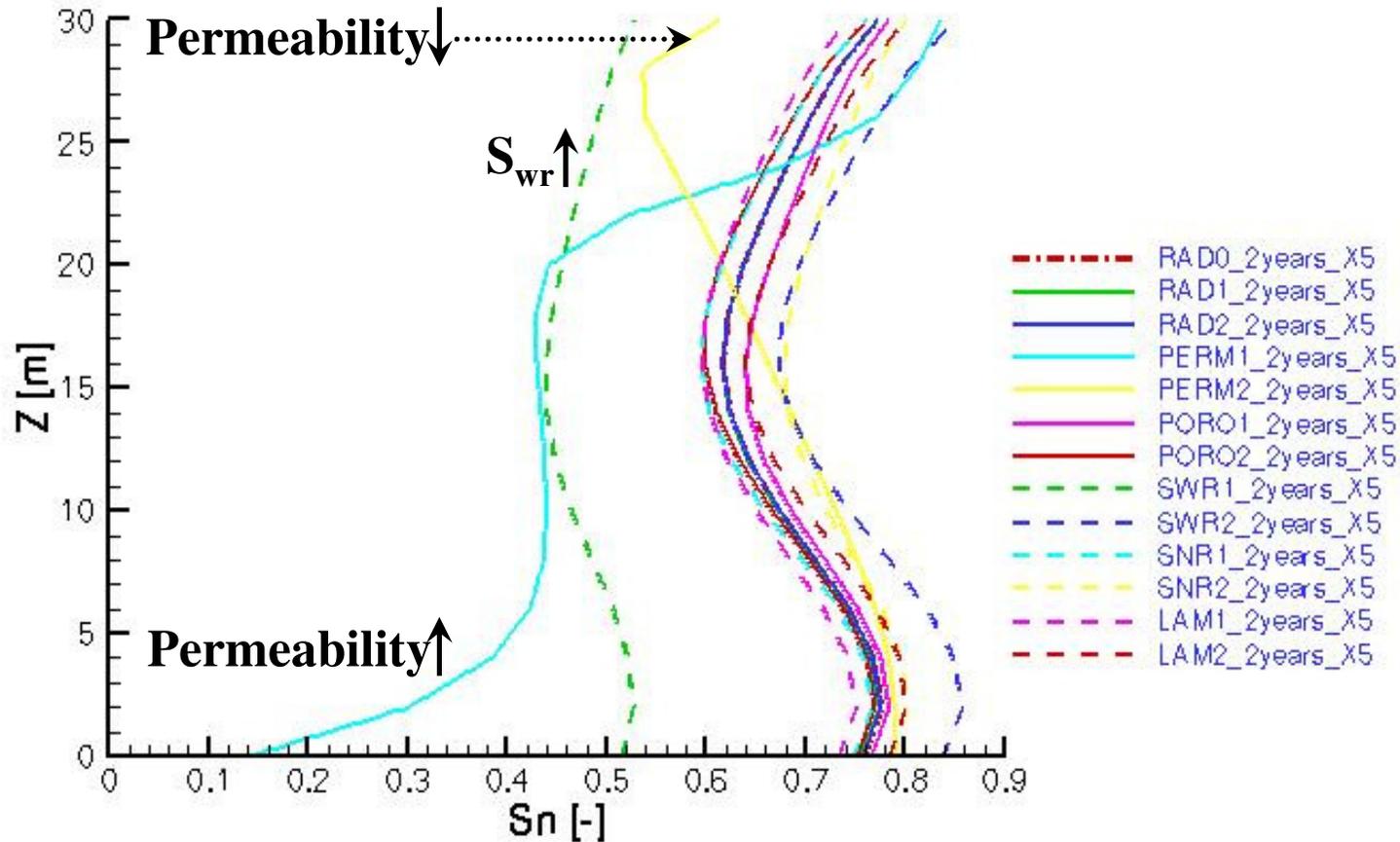
Swr1: 0.4
 Swr2: 0.0
 LAM1: 1.5

LAM2: 3.0
 Snr1: 0.0
 Snr2: 0.2



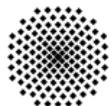
Modelling: Sensitivity Study : Saturation Distribution

CO2 Saturation [-], slice at X = 5m at time T = 2years



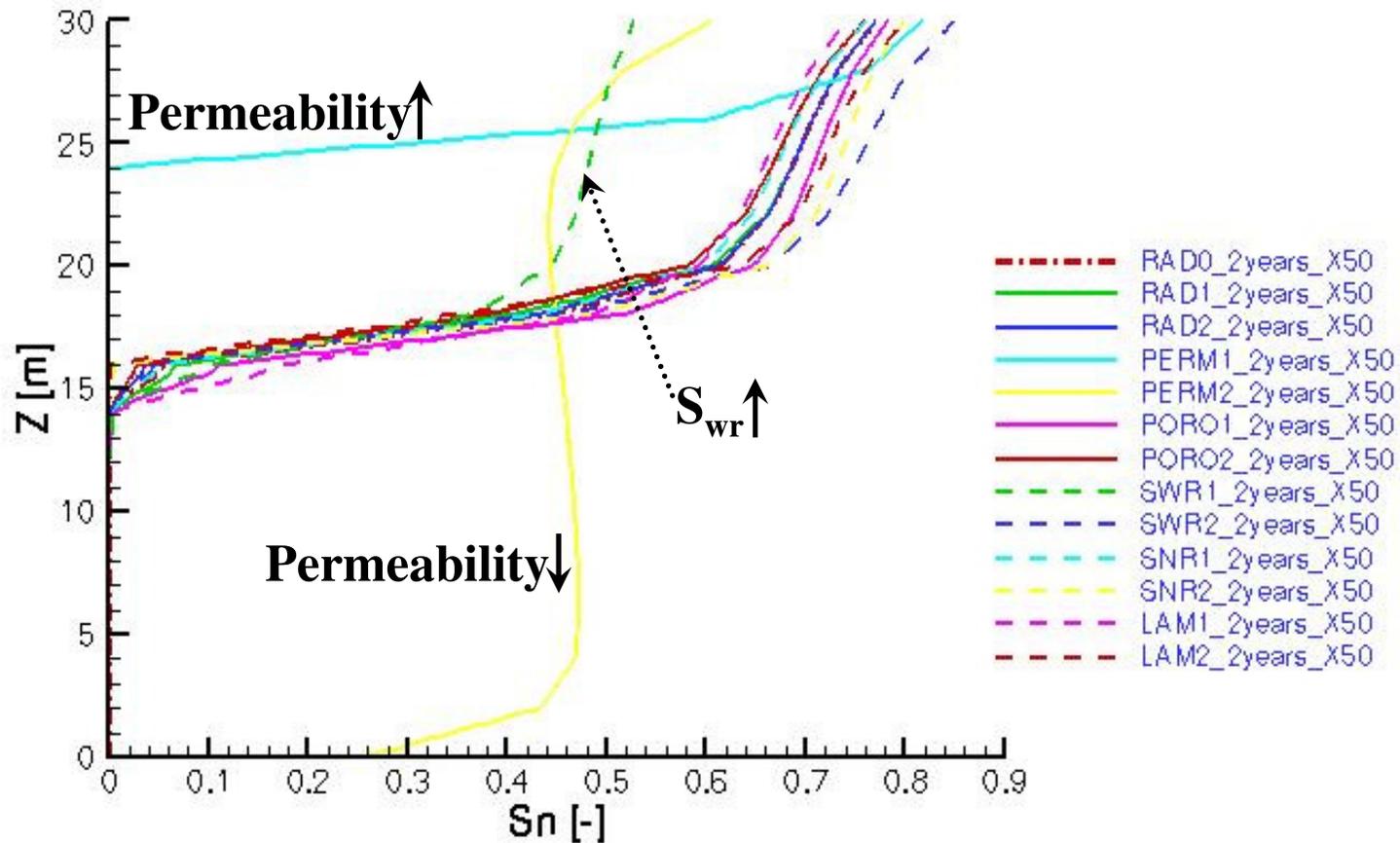
Basecase: R = 5000m; PHI = 0.2; Swr = 0.1; Snr = 0.05; lambda = 2

RAD1: r = 500m	PORO2: PHI = 0.25	Swr1: 0.4	LAM2: 3.0
RAD2: r = 1000m	PERM1: K = 1E-12m2/s	Swr2: 0.0	Snr1: 0.0
PORO1: PHI = 0.15	PERM2: K = 1E-14m2/s	LAM1: 1.5	Snr2: 0.2



Modelling: Sensitivity Study : Saturation Distribution

CO2 Saturation [-], slice at X = 50m at time T = 2years



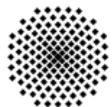
Basecase: R = 5000m; PHI = 0.2; Swr = 0.1; Snr = 0.05; lambda = 2

RAD1: r = 500m
 RAD2: r = 1000m
 PORO1: PHI = 0.15

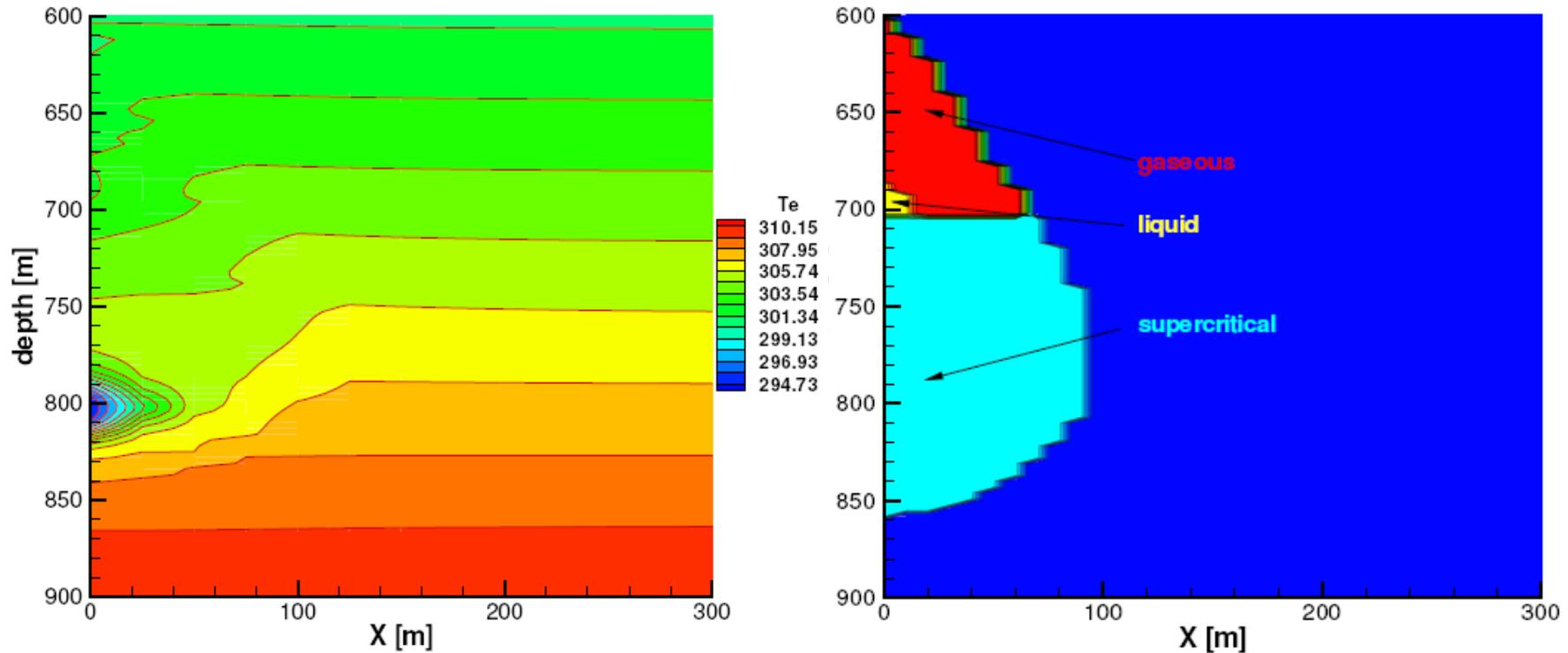
PORO2: PHI = 0.25
 PERM1: k = 1E-12m²/s
 PERM2: k = 1E-14m²/s

Swr1: 0.4
 Swr2: 0.0
 LAM1: 1.5

LAM2: 3.0
 Snr1: 0.0
 Snr2: 0.2

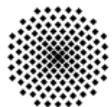


Modelling: Temperature Effects



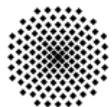
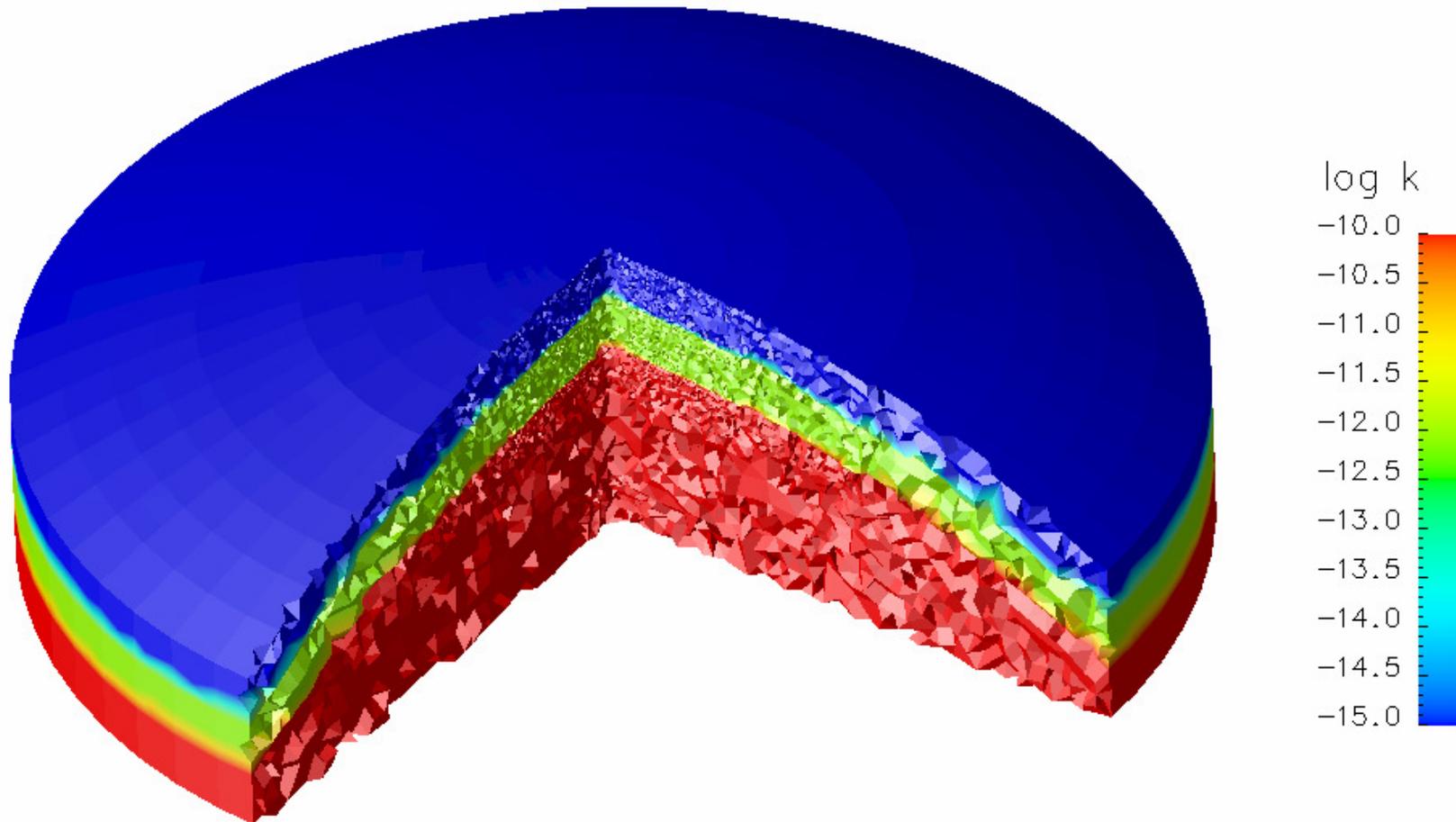
Cooling due to Joule-Thompson effect

Ebigbo, A. (2005)
Master Thesis



Outlook: Complex Model Setup

Adequate representation of reservoir (CAD) incl. fractures, geological FluvSim model (channels, geostatistical permeability distribution).

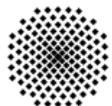


Outlook: Sensitivity Analysis: Parameters/Properties

Parameter of observation: CO₂-Leakage as f(time)

Parameters / Properties of variation / consideration:

- Model concept : Displacement Process, mass transfer, phase state, diffusion, dispersion, ...
- Geological : Permeability, Porosity, Depth_{Reservoir} Fractures, Sandstone Channels
- CO₂ (Liquid/Gas/SC) : Viscosity, Density, Pressure, Temperature, Diffusion coeff.
(+properties of water and brine)
- Injection : Depth_{Well}, Location_{Well}, Massflux
- Application Scenarios: Abandoned wells





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Thank you for your attention!