Oxand
Asset, Ageing & Risk Management

COMSOS-2 project

Risk-based Well Integrity Management

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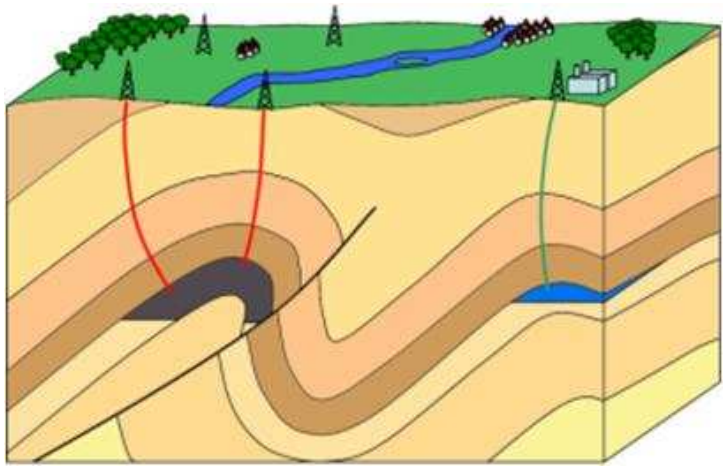
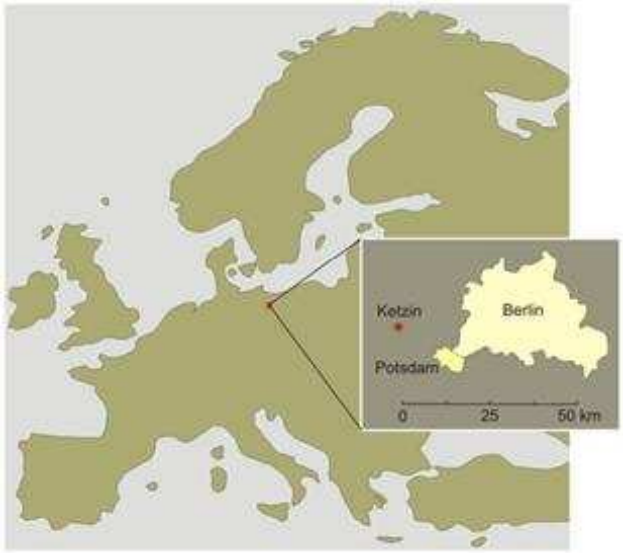
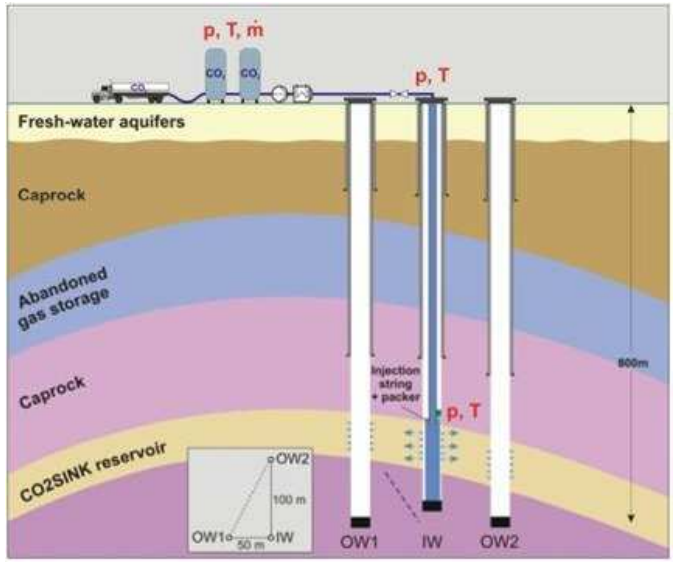


COSMOS2 project shares CO2sink injection site

- **Ketzin storage site:**
  - Injection into a saline aquifer
  - Food-grade CO_2 : 99.9%
  - 60kt of CO_2 over 2 years
  - www.co2sink.org

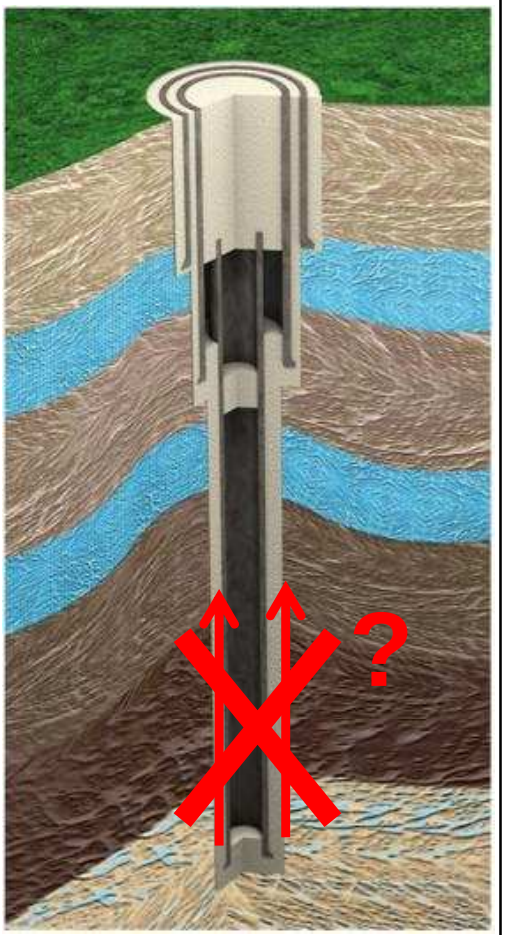


- **COSMOS2: CO2 Storage, Monitoring and Safety Technology**
  - Monitoring of CO_2 migration in the reservoir
  - Study Cap Rock Integrity
  - Field Implementation
  - **Study Wellbore Integrity**



Well Integrity Objectives

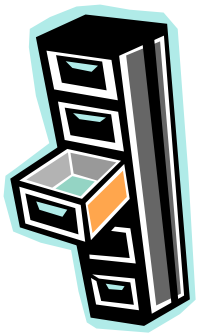
- Over the long term, could the injection well act as a conduit for CO2 to migrate from the reservoir to the surface?
- If so, what specific aspects of the well induce risk into the sequestration system? (Cements, casings, degradations…?)
- Depending on the well's parameters, what is the distribution of the risks and the evolution of leakage over time?
- What can be done to mitigate these risks?

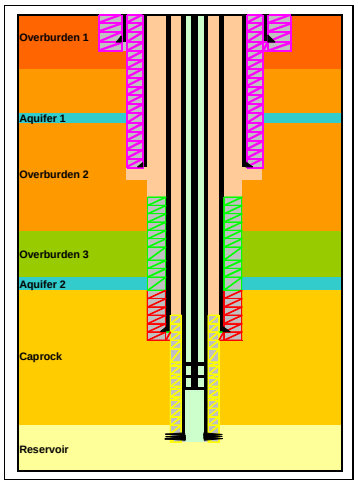


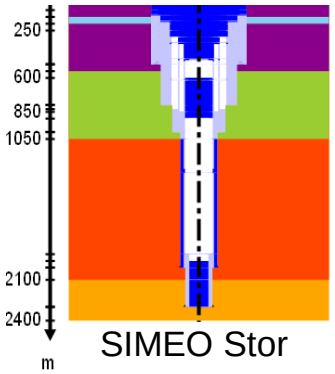
Performance and Risk Management of Injection Well Integrity (P&R™)

Approach for well integrity assessment

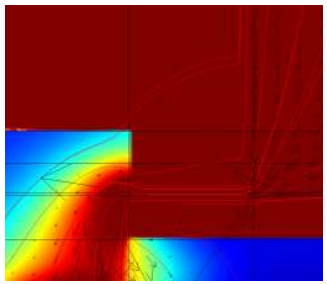
Well data Collection & Interpretation → **Models and scenarios construction** → **CO_2 flow model and simulations** → **Risk assessment** → **Recommendations** **Mitigation options**



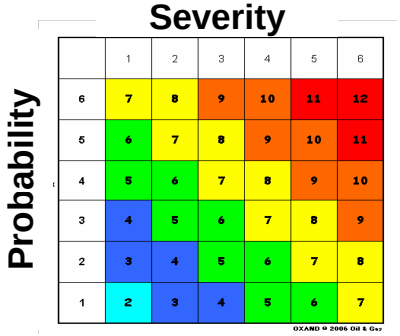




SIMEO Stor



COMSOL

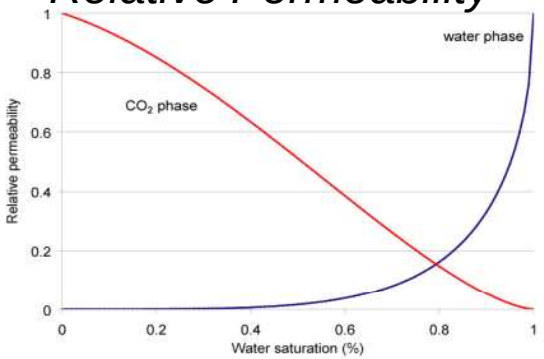


1. Charaterization / Inspection
2. Design optimization
3. Modification of operational conditions
4. Monitoring program

CO_2 migration modeling tool
SIMEO Stor™

- **2 phase flow: aqueous phase + CO_2 (Darcy law)**
  - Relative permeability values: Van Genuchten and Mualem's model
  - Compressive fluids
- **Detailed modeling of well components : axial and radial flows**
- **Degradation processes:**
  - cement carbonation and leaching,
  - casing corrosion,
  - thermo-mechanical stresses
- **Probabilistic approach, Monte Carlo**

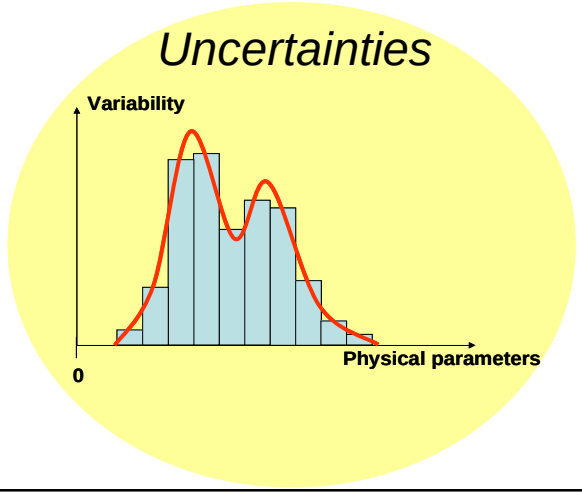
Relative Permeability



Casing

Cement

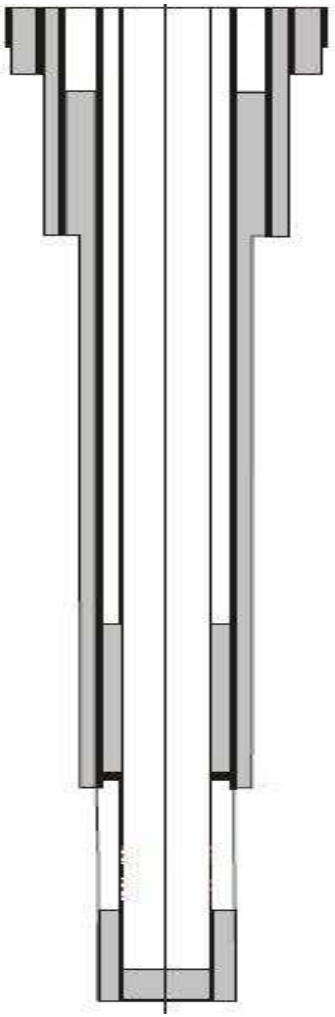
Uncertainties



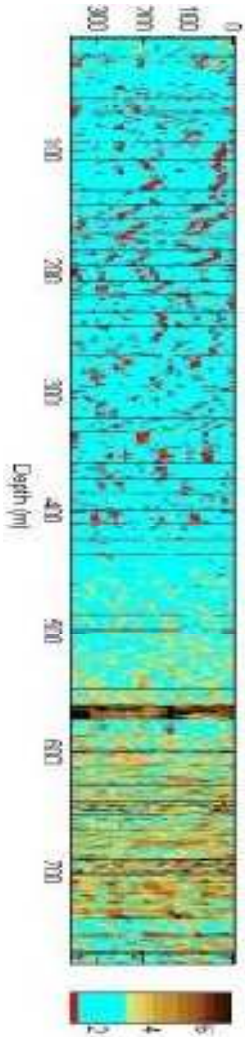
Ktzi-201 Static & Dynamic Model

Geology

Well geometry

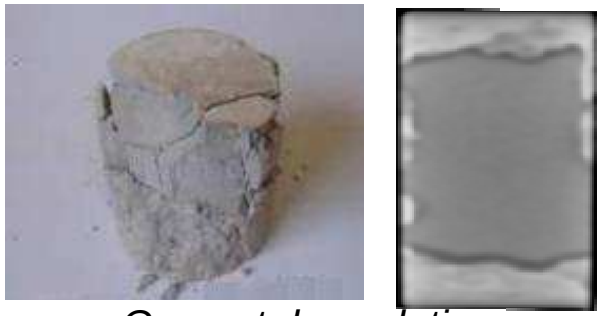


Cement quality



Courtesy of Schlumberger

Material Degradation



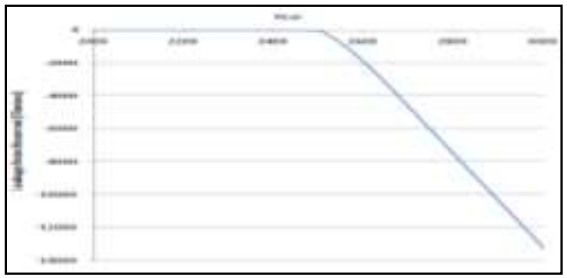
Cement degradation:

$e_{lixi} = a \cdot \sqrt{t}$

Casing Corrosion

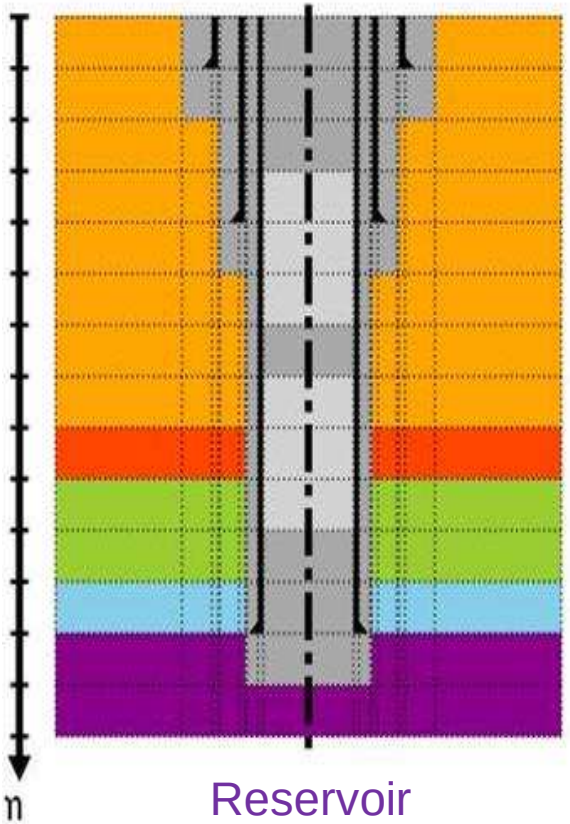
$e_{cor} = b.t$

Pressure conditions



Well model (not at scale!)

Surface

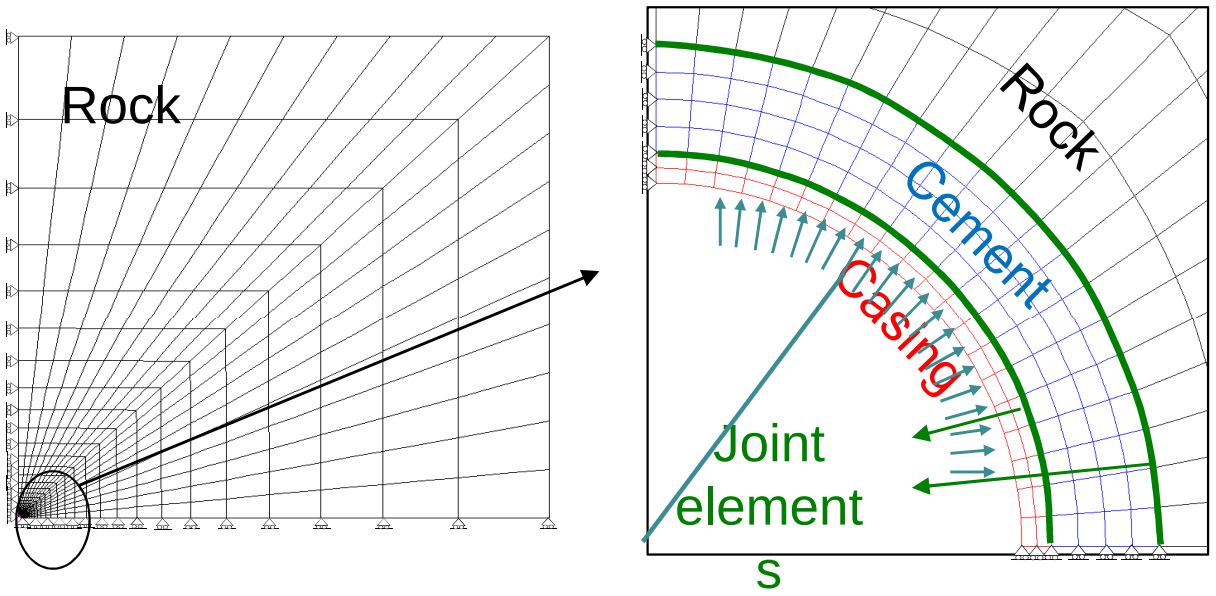


Reservoir

Thermo mechanical impact

- **Objectives:Study mechanical integrity of the well focusing on cement failure and micro annulus opening between different materials and estimate impact well properties**

2D FEM simulation



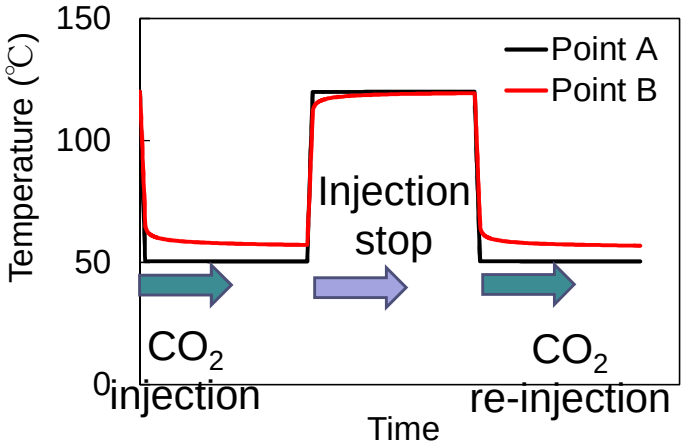
CO_2 temperature and injection pressure are applied to casing surface.

- Thermo-elastic model for casting, cement and rock without failure
- Joint element for each interface based on Mohr-coulomb criterion with zero normal bond strength

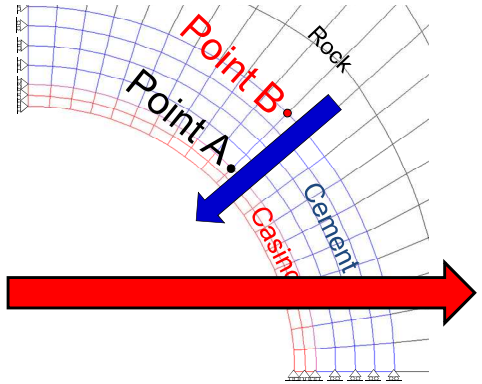
Simulation results

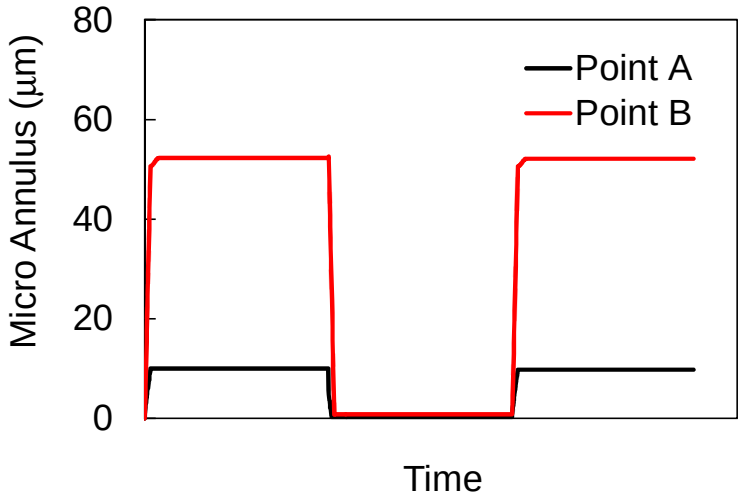
Temperature and stress evolution, crack and micro-annulus width)

Point A: Inner point in cement
Point B: Outer point in cement



Casing can shrink and swell faster than cement and rock.

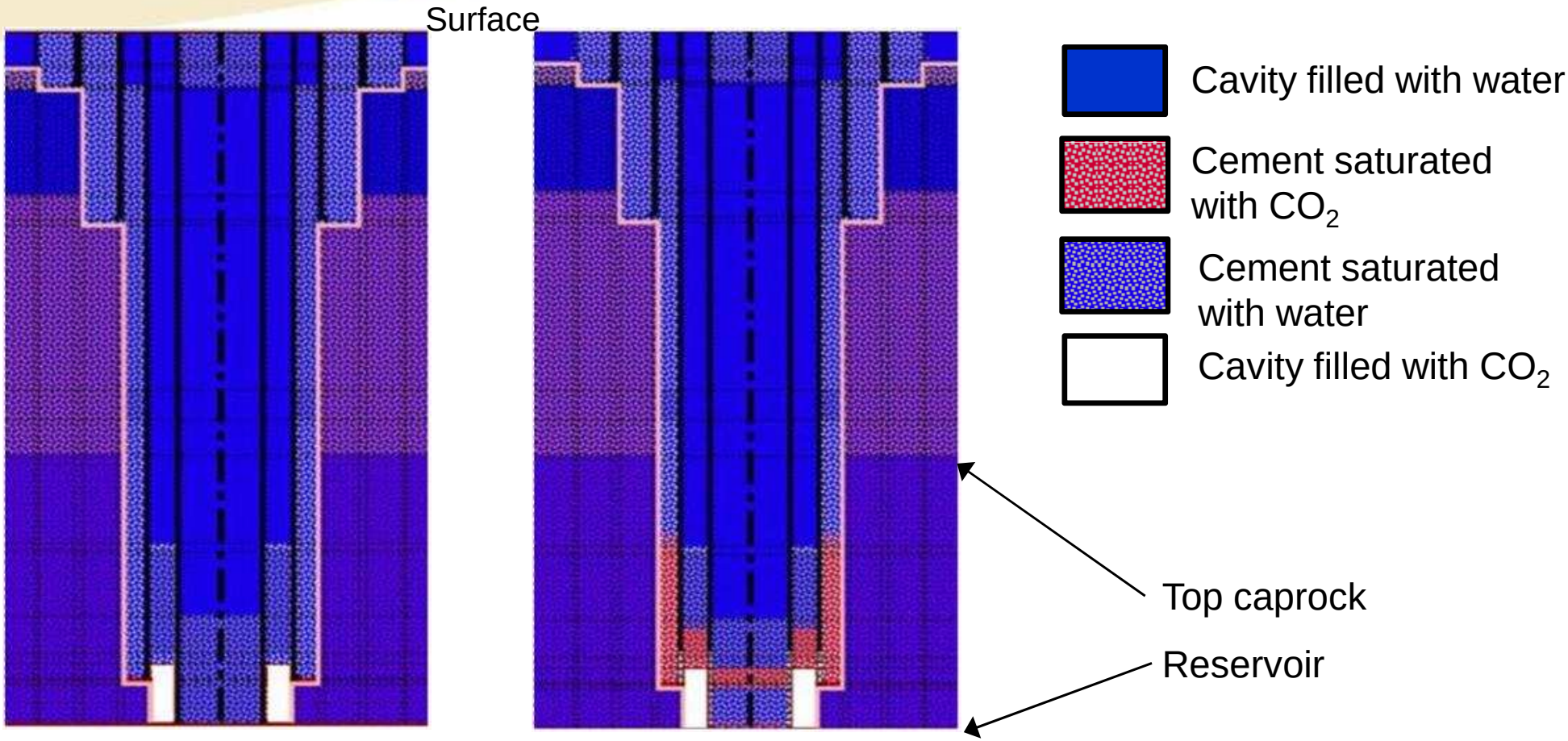




- **Micro-annuluses opening between casing and cement / rock and cement** arising from different thermal shrinkage during injection
- **Larger annulus at the interface of cement/rock** due to more gradual thermal shrinking of rock
- Creation of **potential leakage pathways** for CO_2 with transport properties
- New limit conditions for **faster degradation processes**

Ktzi-201 CO_2 Migration Results
Pilot scale (low) reservoir pressure

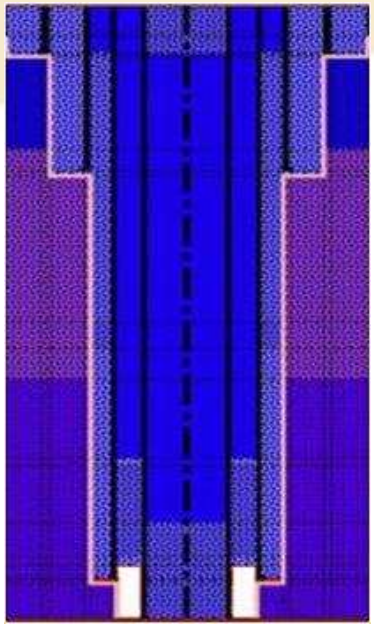
Injection start **1000 Years**



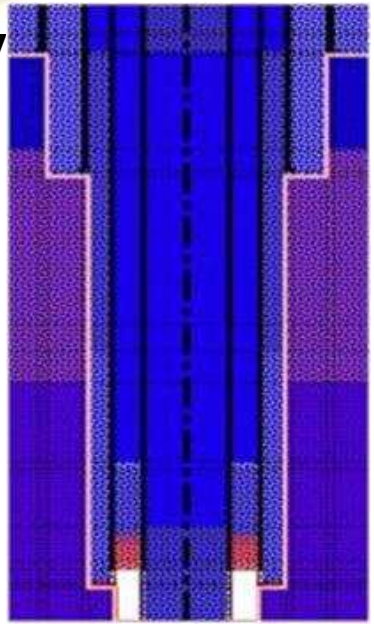
- CO2 migration along 5½" and 9⅝" cement sheath
- Corrosion at the bottom of 5½" and 9⅝" casings
- Top CO_2 is below top of the caprock → no CO_2 migration outside the storage complex

Ktzi-201 CO_2 Migration Results Industrial (high) reservoir pressure

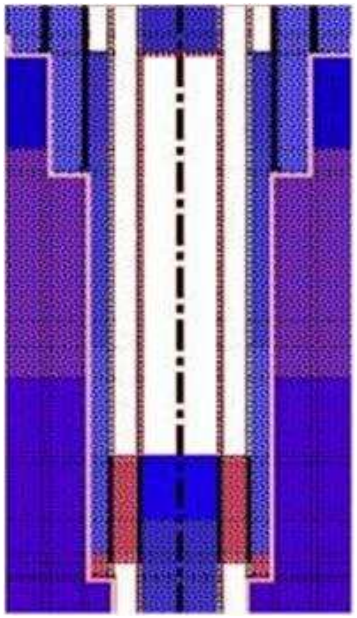
t = 0 y



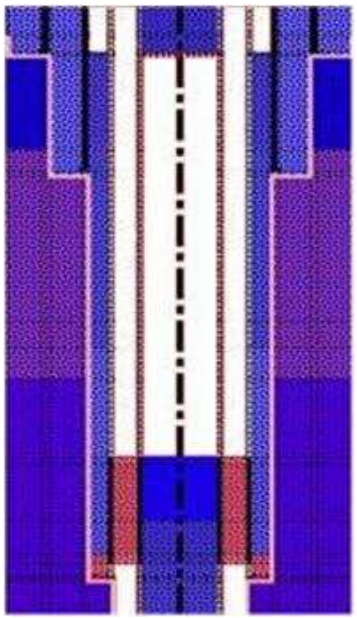
t = 250 y



t = 500 y



t = 1000 y



Cavity filled with water

Cement saturated with CO_2

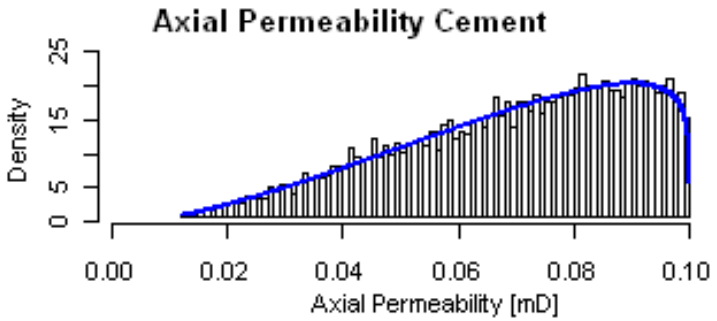
Cement saturated with water

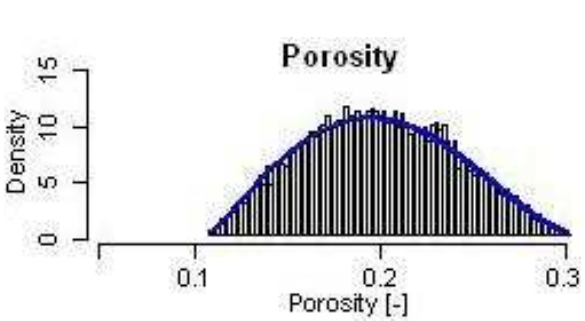
Cavity filled with CO_2

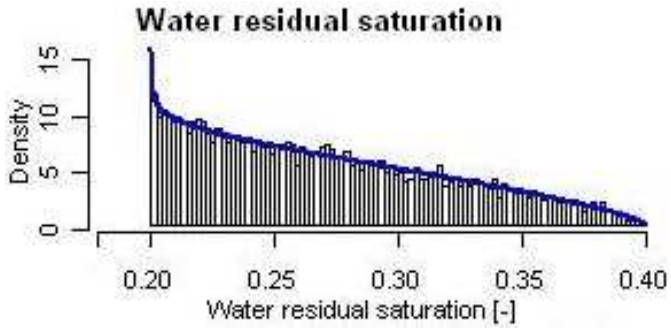
- CO_2 migration through the 5½ “ and 9⅝” cement annuli
- Top cement plug is ineffective

Probabilistic results
Sensitivity analysis

- **Objectives:**
  - Assess probabilistic distribution of CO_2 leakage at each time step, variability of CO2 migration
  - Ranking of parameters regarding their impact on CO_2 migration → identification of risk sources
- **Parameters considered for the analysis:**
  - axial and radial permeability values of 5 cement zones, 3 degradation kinetics (cement and casing), water saturation, stand-off, capillary pressure, porosity, etc.

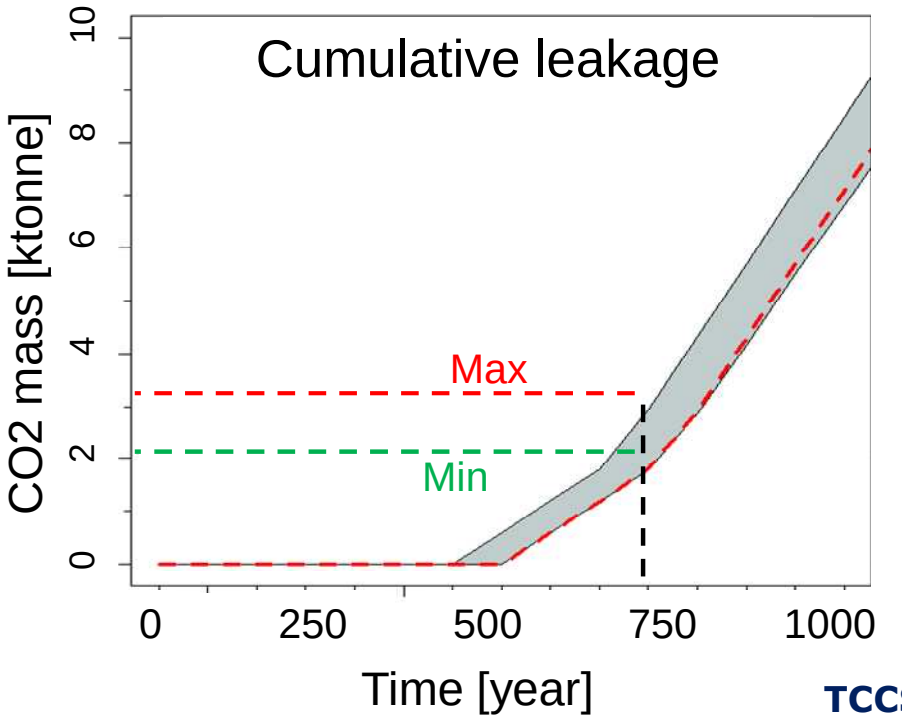


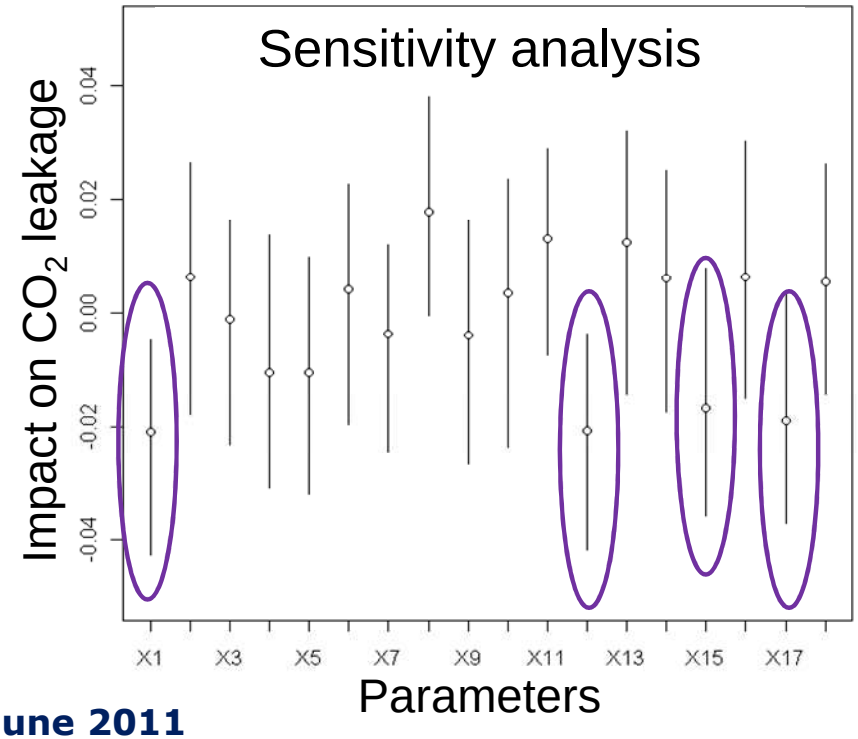




Probabilistic results
Sensitivity analysis

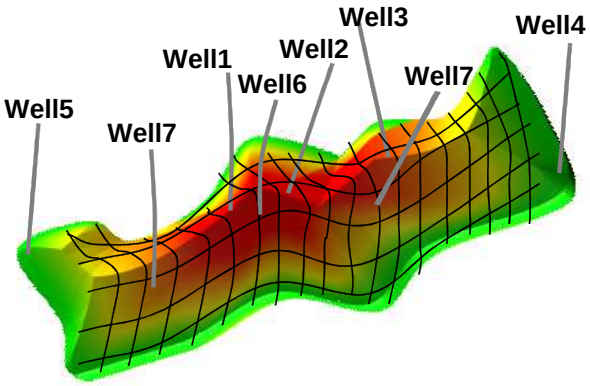
- **Range of cumulative CO_2 mass values migrating out of the reservoir instead of a series of discrete values**
- **Level of confidence (probability) associated with CO2 mass**
- **Ktzi-201 :**
  - Greater impact of 5½" bottom and mid-9⅝" cement sheath (lower permeability values) compared to other cement zones (18⅝", 13⅜", top 5½")
  - High impact of reservoir pressure at the bottom of the well
  - Low impact of stand off, and cement plugs permeabiilty





Conclusions

- **Detailed analysis of wells integrity is required**
  - Well components properties
  - Thermo-mechanical impact
  - Impact of surrounding geology
- **Support for decision making regarding well integrity (project management) and safety demonstration for authorities**
  - Definition of treatment actions plans, and MVA : additional studies, experimental programs, well characterization, monitoring…
- **On-going developments:**
  - Robustness of analysis and tools used (benc
  - Well integrity management at field scale



Thank you for your attention

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