

Hydrogeological modeling of CO₂ storage at the basin scale: preliminary results on the Paris basin

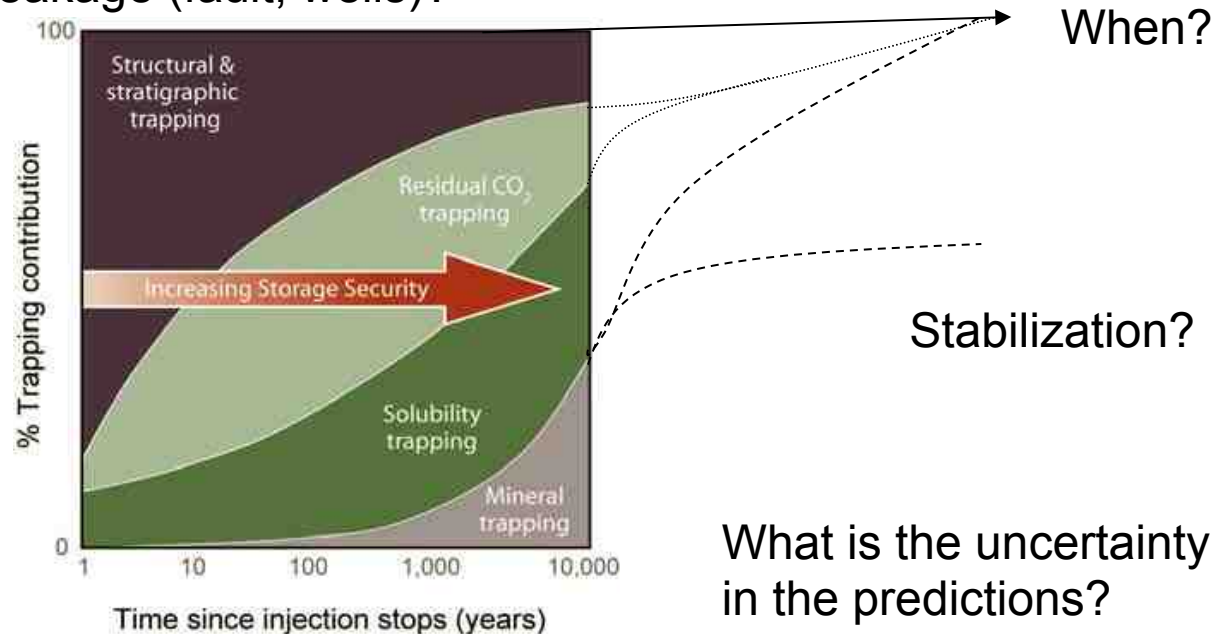
ULTimateCO2

**“Understanding the Long Term fate
of geologically stored CO₂”**

Objective of the UltimateCO2 project

- Significantly advance our knowledge of processes that may affect the understanding of the long-term fate of geologically stored CO₂
- Yield validated tools for predicting long-term storage site performance
- Develop guidelines **for operators and regulators to enable a robust demonstration of the long-term storage site performance assessment**

What if leakage (fault, wells)?



How in a real injection site (gravity effect, brine migration)? www.ultimateco2.eu

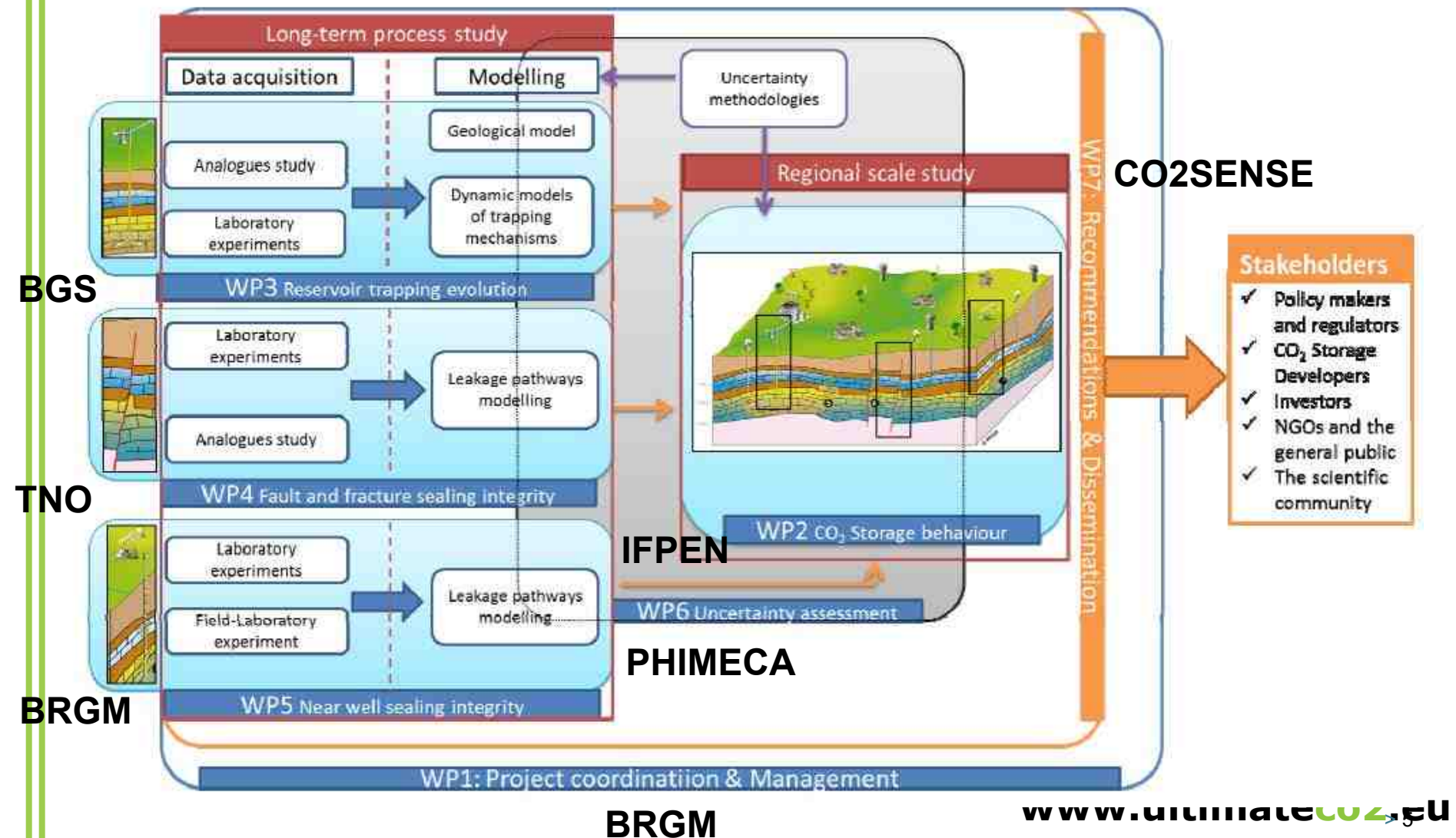
- Laboratory, field and modelling studies of:
  - trapping mechanisms in the reservoir (structural, dissolution, residual and mineral [SDRM])
  - fluid-rock interactions and effects on mechanical integrity of the caprock
  - leakage associated with mechanical and chemical damage in the well vicinity
- Predictions more robust by
  - addressing the **uncertainty** associated with numerical modelling at all stages
- Integration of the results
  - into assessing the overall long-term behaviour of storage sites at basin scale in terms of efficiency and security

List of participant



CONSORTIUM				ADVISORY BOARD				
R & D Institutes	Academia	Company	SME	Data Providers	CSLF Members	Industry	Dissemination stakeholders	National regulatory authorities
• BGR • BGS • BRGM • GEUS • IFPEN • IGG • TNO • EIFER	• Utrecht University	• GEOGREEN	• CO2sense • Phimeca	• National Grid • Arcelor Mittal Geolorraine • Swisstopo	• Alberta Innovates • Lawrence Berkeley National Laboratory	• Veolia	• ZERO • IEAGHG • Réseau Action Climat	• UK: OCCS (DECC) • France: DGEC (Ministry of Ecology)

ULTimateCO2 Project structure and WP Leaders

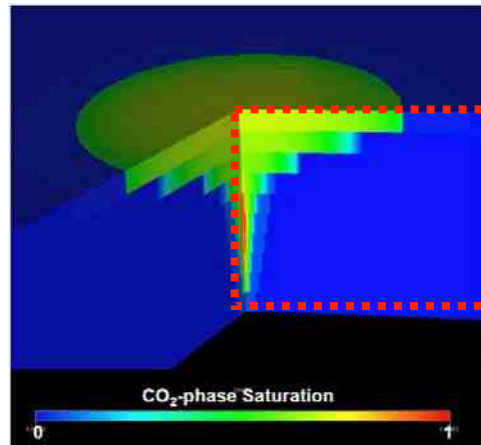
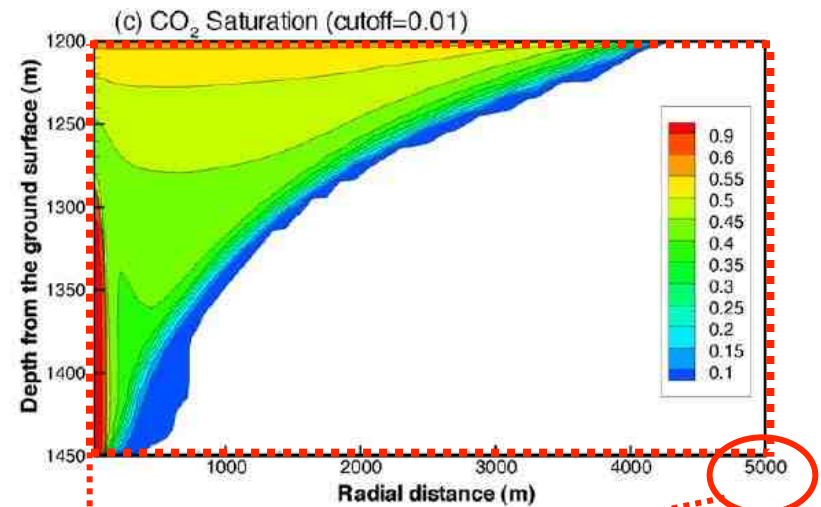
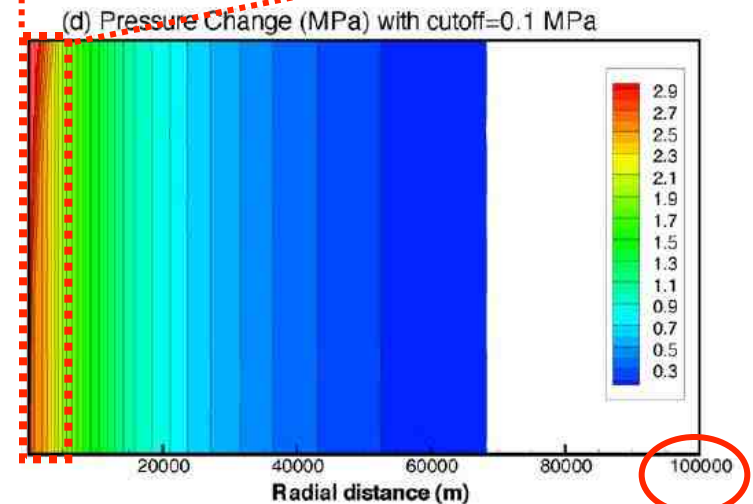


Hydrogeological modeling of the Paris basin

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X. Guichet, B. Doligez, N. Maurand, V. Teles

CO2 plume vs Pressure pulse

100 km radial extent

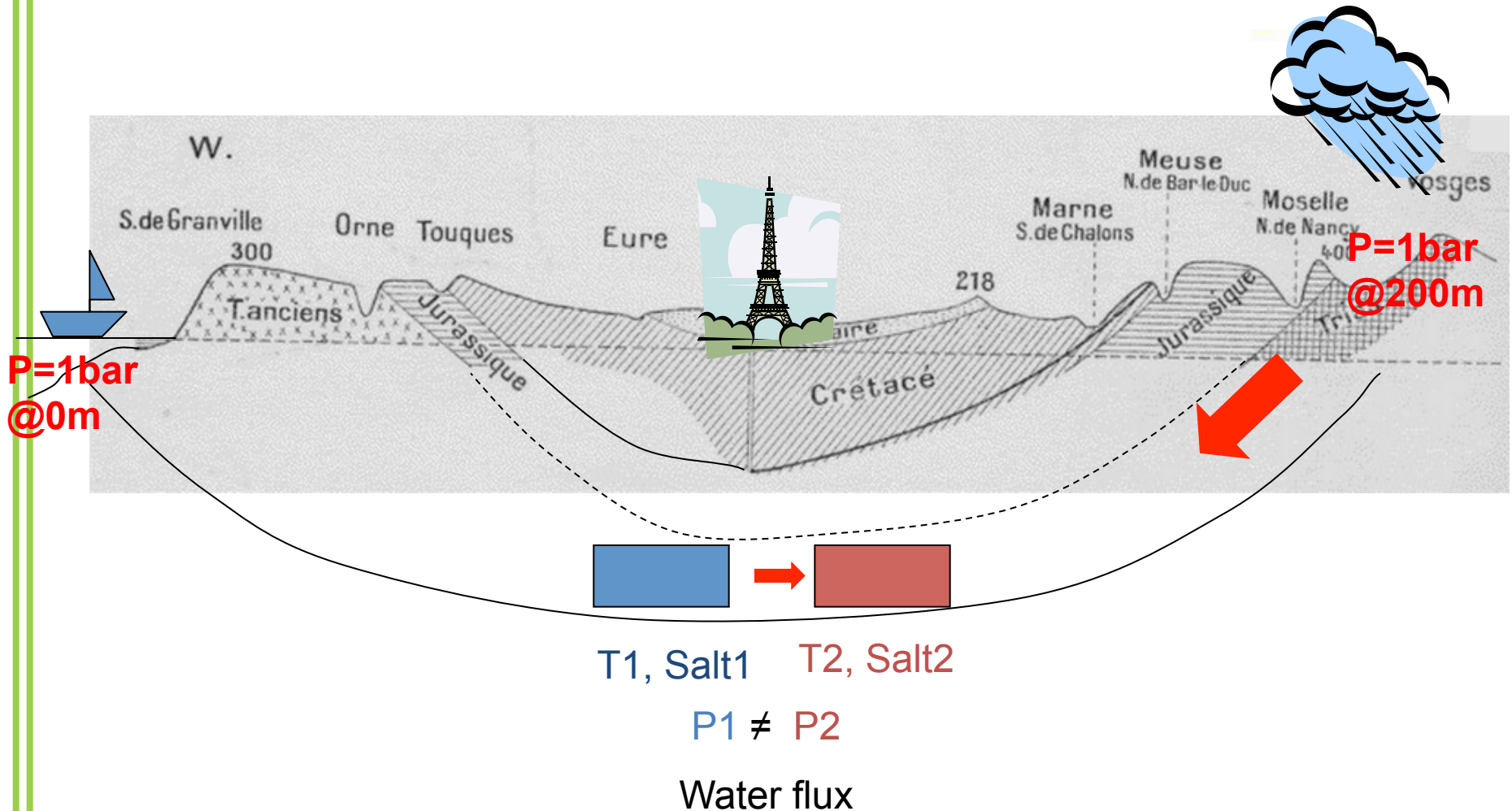


Pressure disturbance could extend far beyond CO2 plume

=> need large scale (basin) hydrogeological modelling

simulated after 30 years of CO₂ injection

Initial conditions issue



Reservoir and basin scale issue

- Use of traditional reservoir fluid flow simulator for basin purpose is not adapted to initiate large scale hydrodynamism.
  - compute initial state by hydrostatic equilibrium
  - $P=f(z, T, \text{salt})$
- At basin scale, due to variation of temperature, salinity, water entries depth
  - initial state by hydrostatic law will not represent basin state
  - need a dynamic equilibrium (run without injection/production) to stabilize pressure and flow can be long
- Basin pressure and salinity are the result of the basin history and may not be in equilibrium with present-day conditions (local overpressures, salinity anomalies)
- reach the limits of traditional fluid flow simulator
  - help of basin simulation for initial state computation

Objective



- WP2 – Coupling between basin simulation and reservoir simulation for CO2 modelling
  - Perform a basin simulation
    - provides temperature, pressure and salinity fields at regional scale by simulating thermal and burial history of the basin
    - Sets initial condition for the reservoir-scale model of CO2 injection
  - Perform a CO2 injection model at reservoir-scale with initial data from the basin model
  - Evaluate the pertinence of such coupled approach

Basin modelling

- Study and model the formation and evolution of sedimentary basins
- To assess the burial and thermal history of a basin
- Tool widely used in Petroleum industry :
  - To get burial and thermal history of source rocks as well as timing of hydrocarbons generation and migration paths of expelled hydrocarbons.

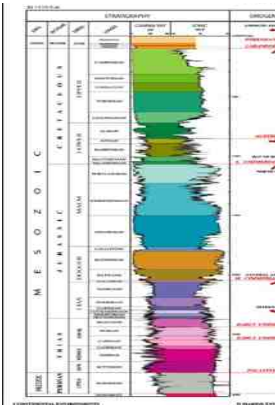
Basin modelling principles

- 1 - Reliable geological framework describing the present day geometry and lithology
  - Structural/Geometrical definition (well data, seismic, faults)
  - Stratigraphic sequence (porous/sealing layers, lithologies)
  - Constraining subsurface information (logs, pressures, fluid properties)
- 2 - Reconstruct the evolution through time
  - Sequence stratigraphy (geological scenario)
  - Geodynamical information (faults movements, uplift, erosion)
  - Backstripping method
- 3 - Simulate the basin history with coupled physical equations
  - Forward modelling of fully-coupled equations (flow, compaction, HC craking, migration)

Basin modelling principles

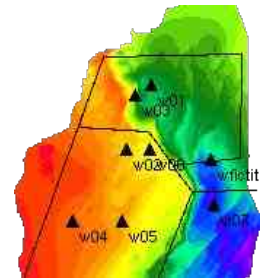
- 1 - Reliable geological framework describing the present day geometry and lithology

Stratigraphy



1. define horizons
in depth

Structure map



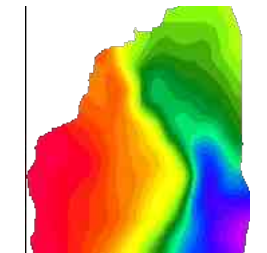
2. assign facies
to each layer

Lithology map



3. evaluate paleobathymetry
of each layer

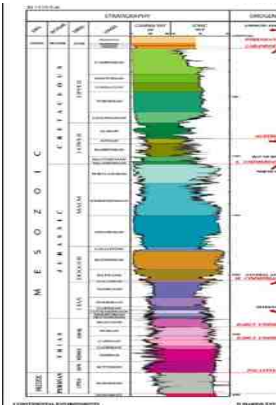
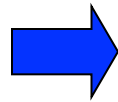
Paleotopography map



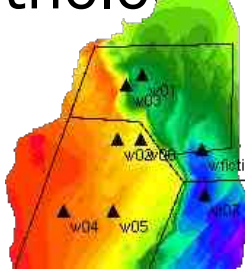
Basin modelling principles

- 1 - Reliable geological framework describing the present day geometry and lithology

Stratigraphy



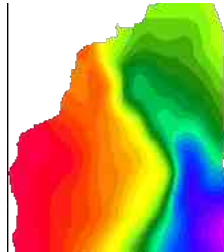
Structure map



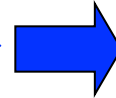
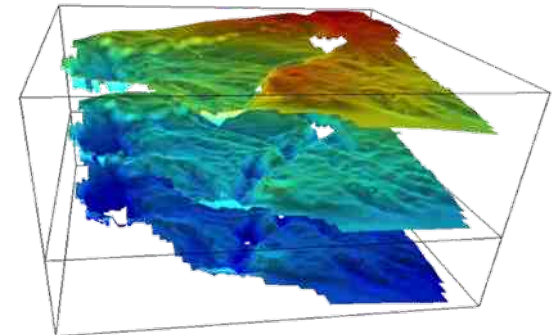
Lithology map



Paleotopography map



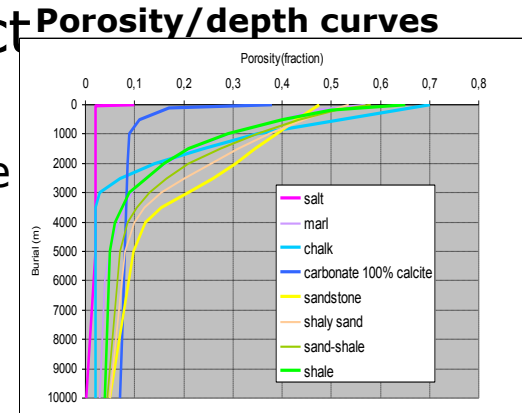
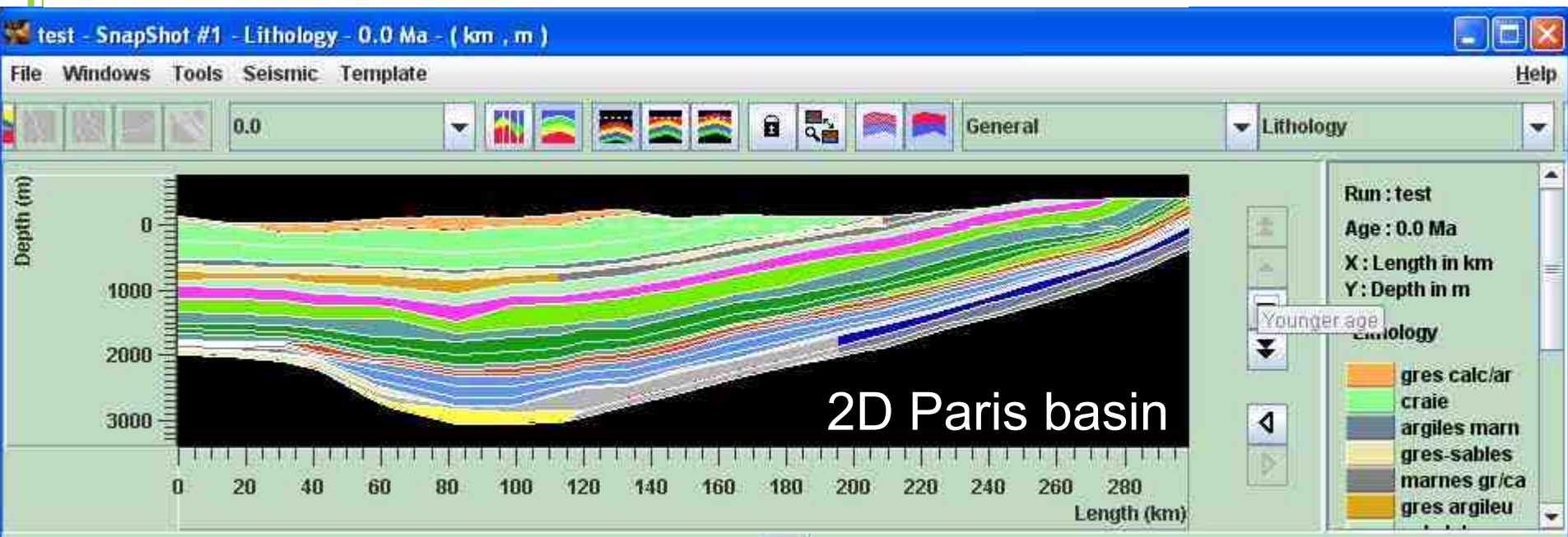
4. reconstruct the geometry



Geologic model

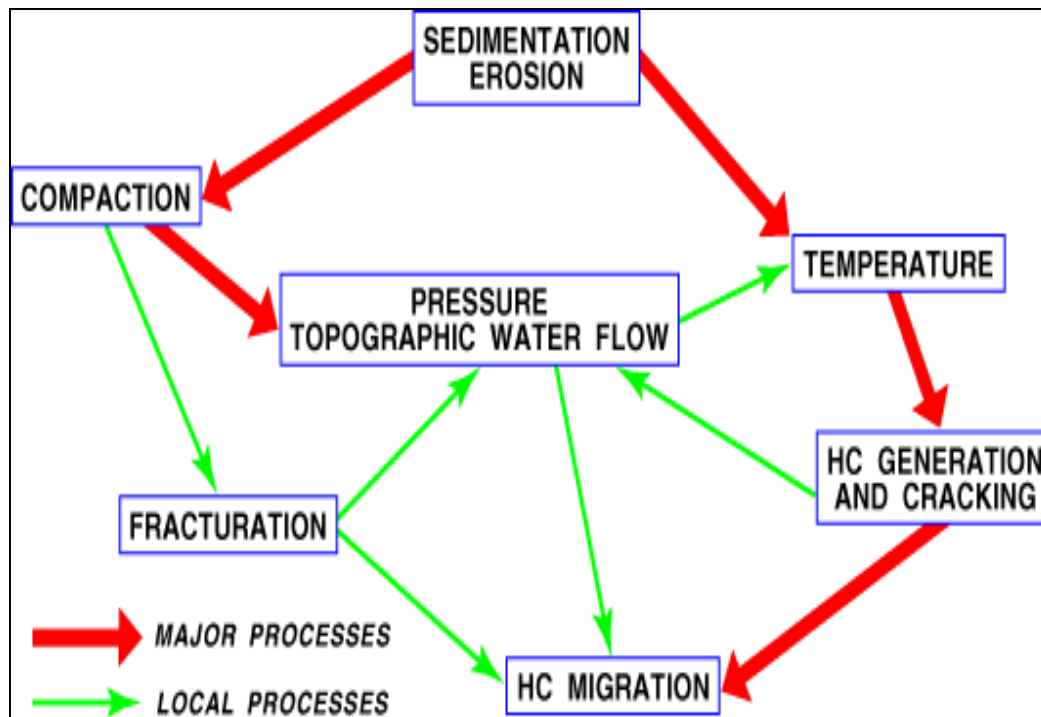
Basin modelling principles

- 2 - Backstripping - A method to reconstruct past geometries from present day data
  - Hypothesis = Deposition occurs on a horizontal surface
  - Assumes a preservation of solid volume through time by decompaction according to facies
  - Further need: Account for missing volumes= past erosions



Basin modelling principles

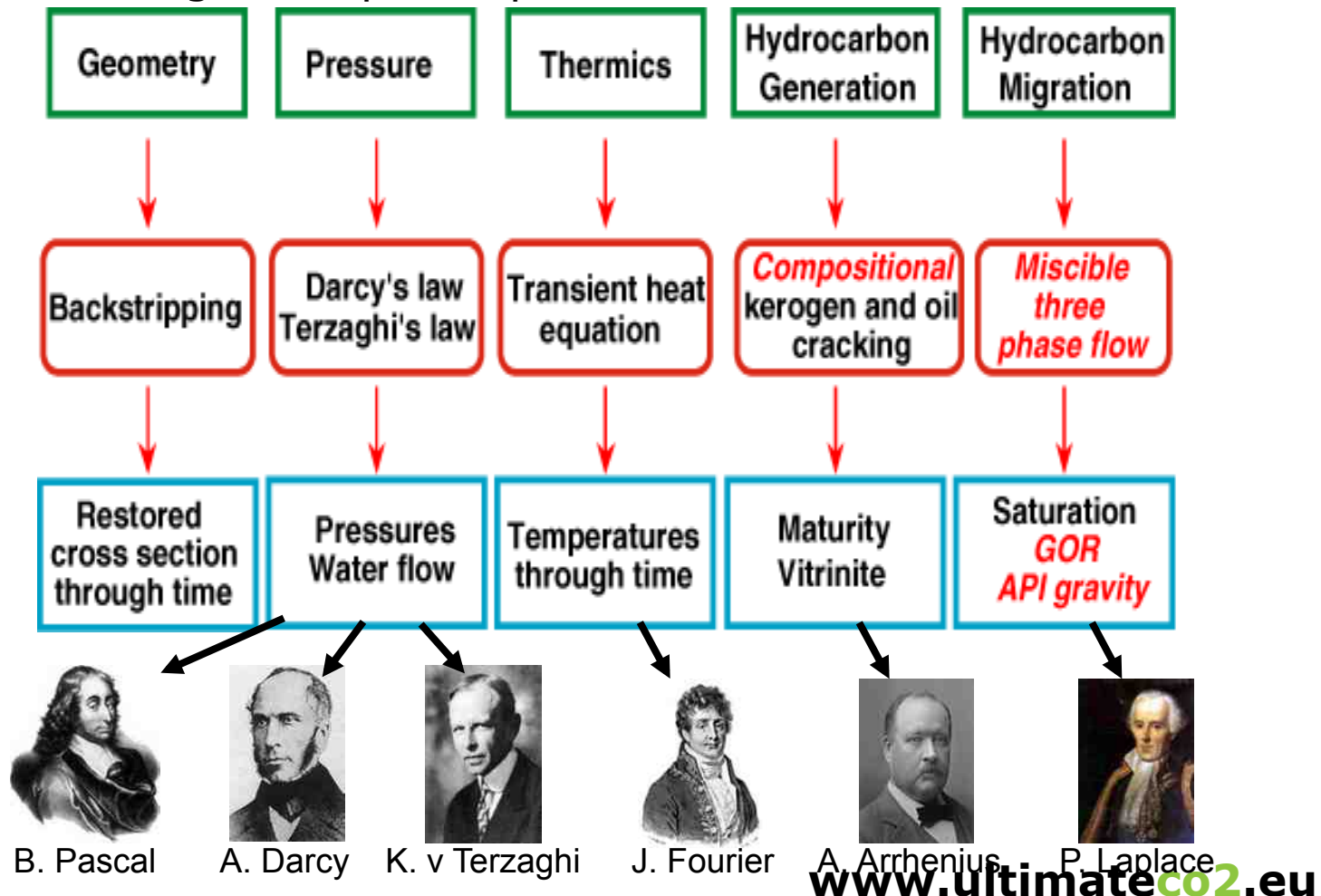
- 3 - Simulate the basin history with coupled physical equations
  - Forward modelling of coupled equations



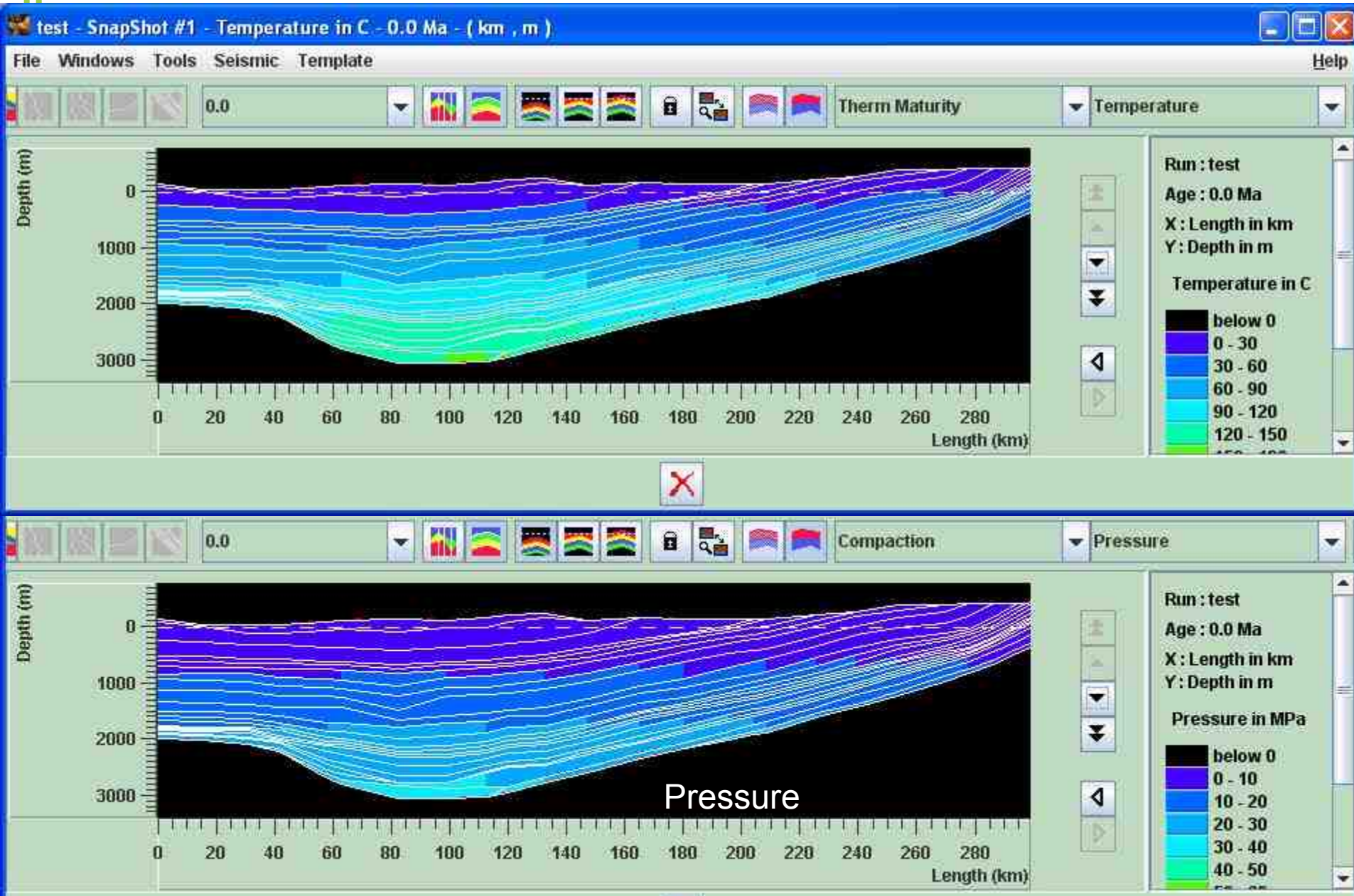
Interactions in a basin through geological time

Basin modelling principles

- 3 - Simulate the basin history with coupled physical equations
  - Forward modelling of coupled equations

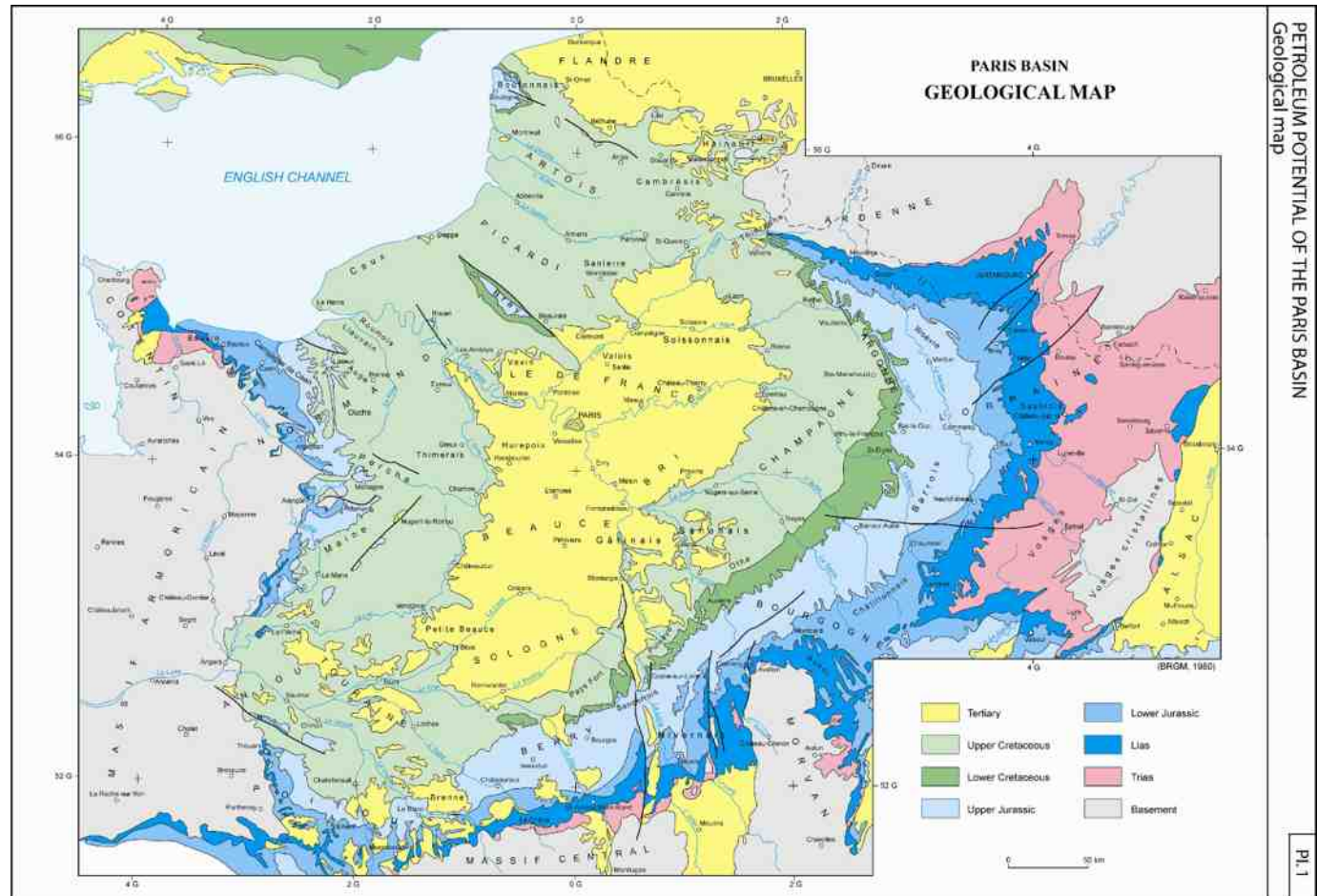


2D Paris Basin simulation - Temp & Pressure



UltimateCO₂ – WP2 – Task 1

Paris Basin 3D model

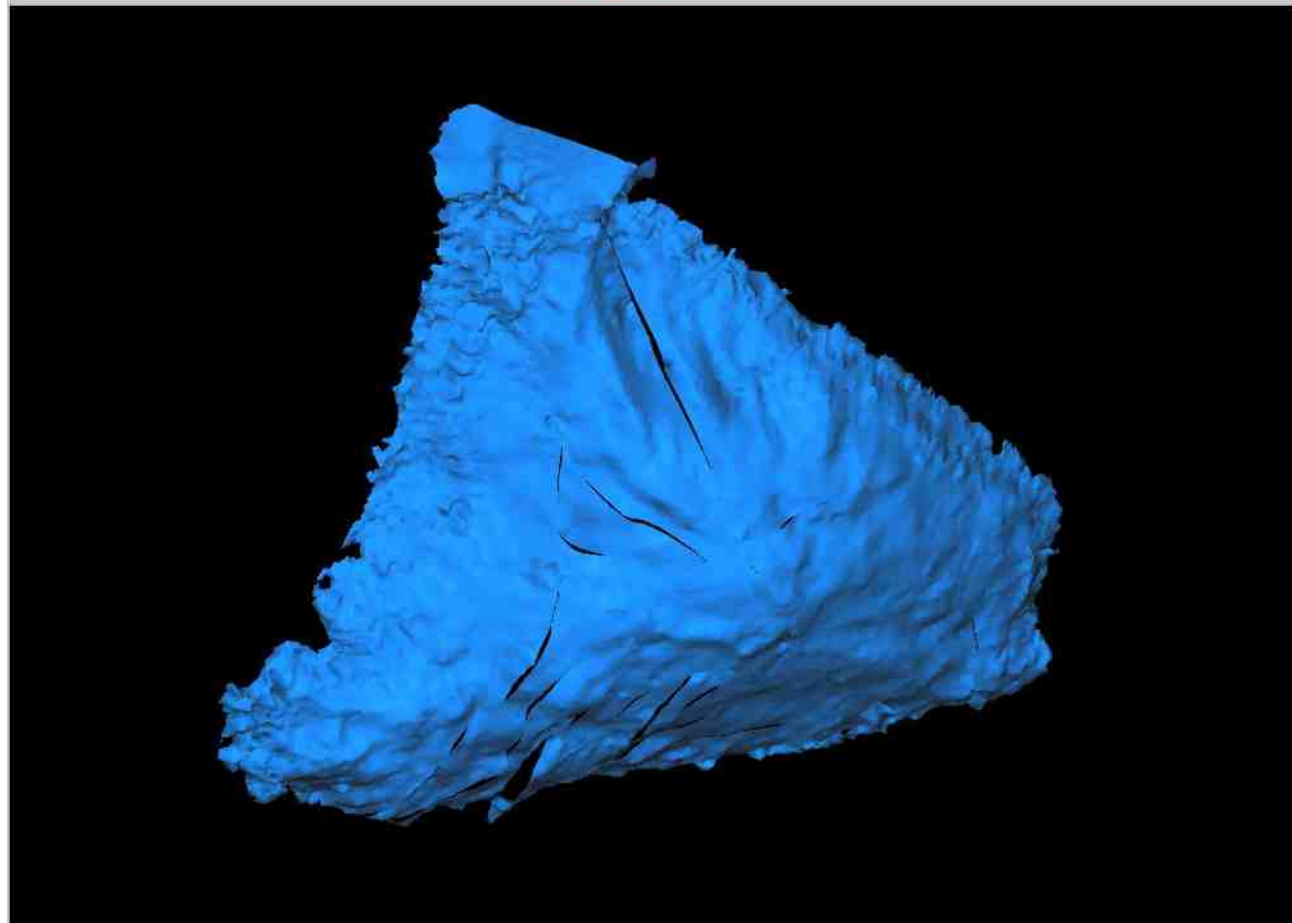


3D model of the Paris basin

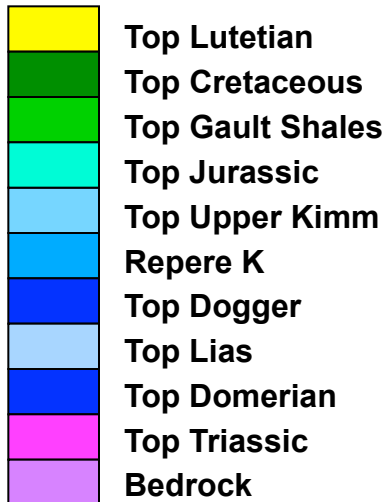
Available Data

- Outcrop maps
- Thousands of wells and markers
- Thickness maps
- Faults

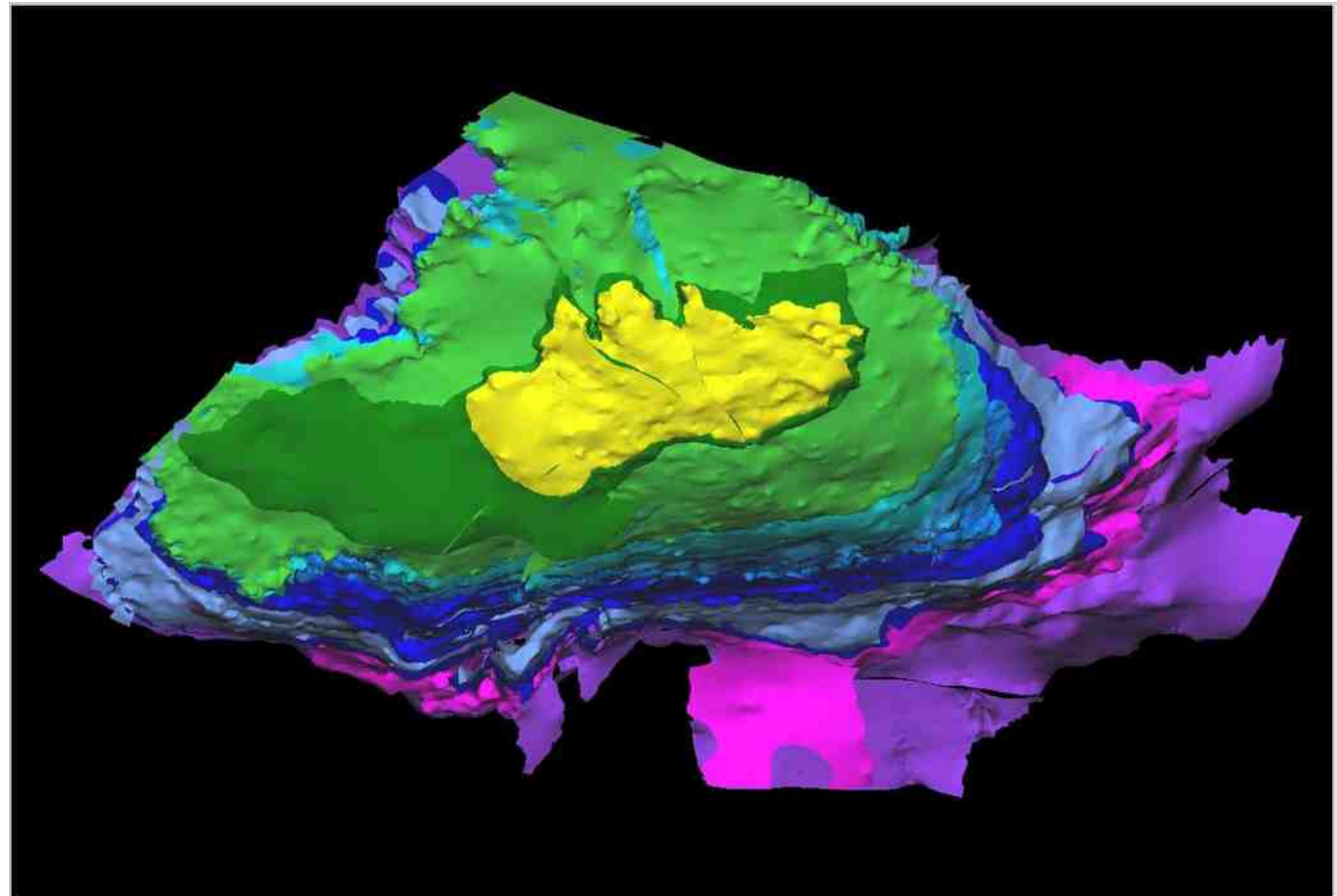
12 main horizons constructed with Skua™ software



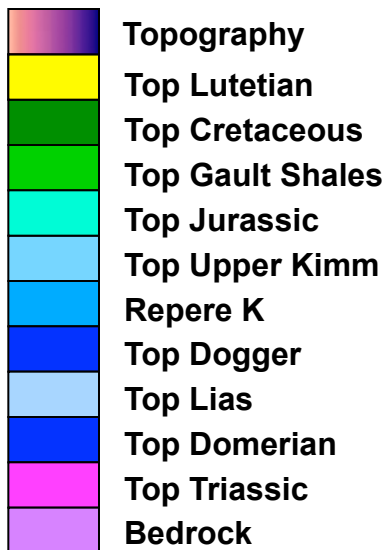
3D model of the Paris basin



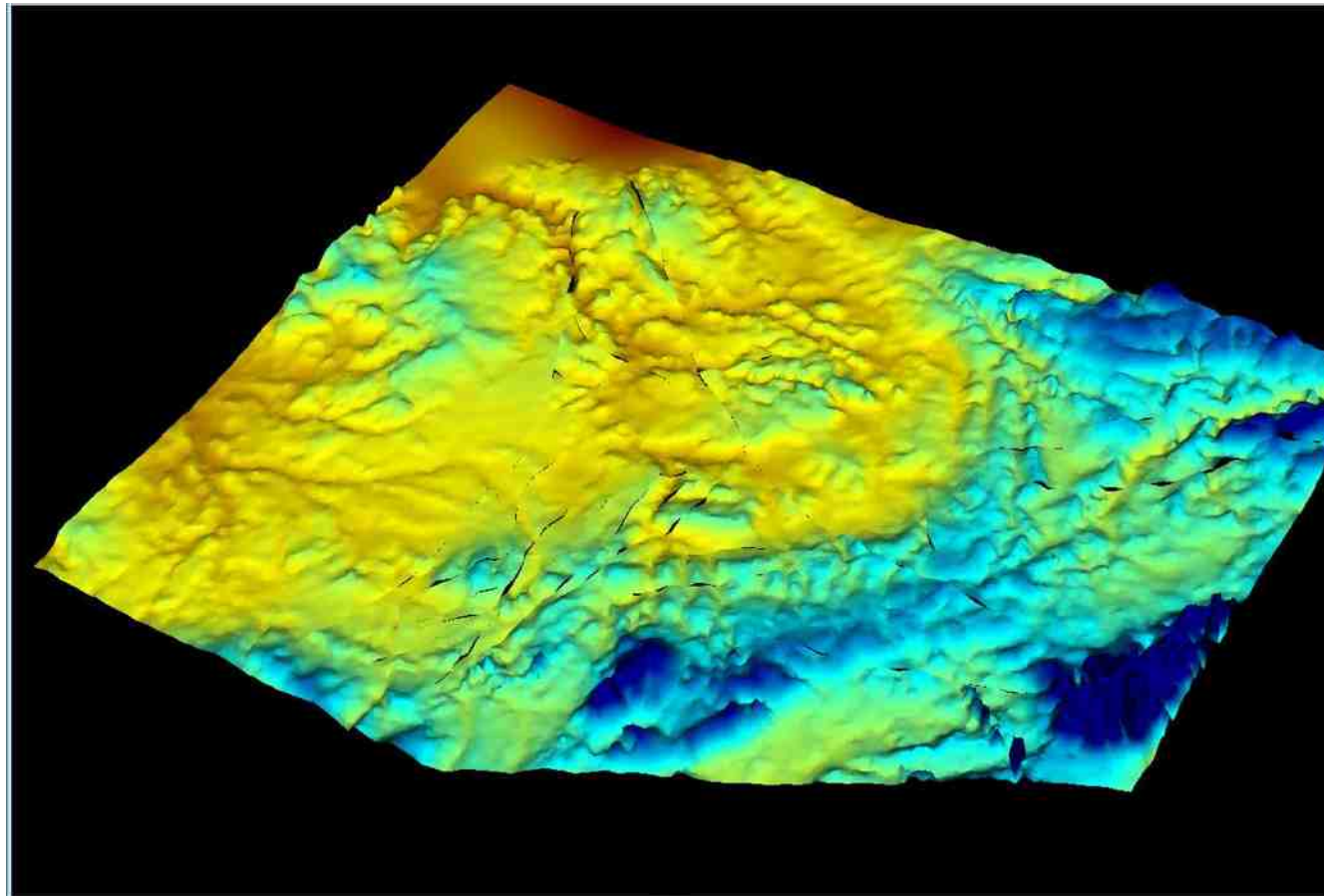
12 main horizons
constructed with
Skua™ software



3D model of the Paris basin



12 main horizons
constructed with
Skua™ software



3D model of the Paris basin

3000 m

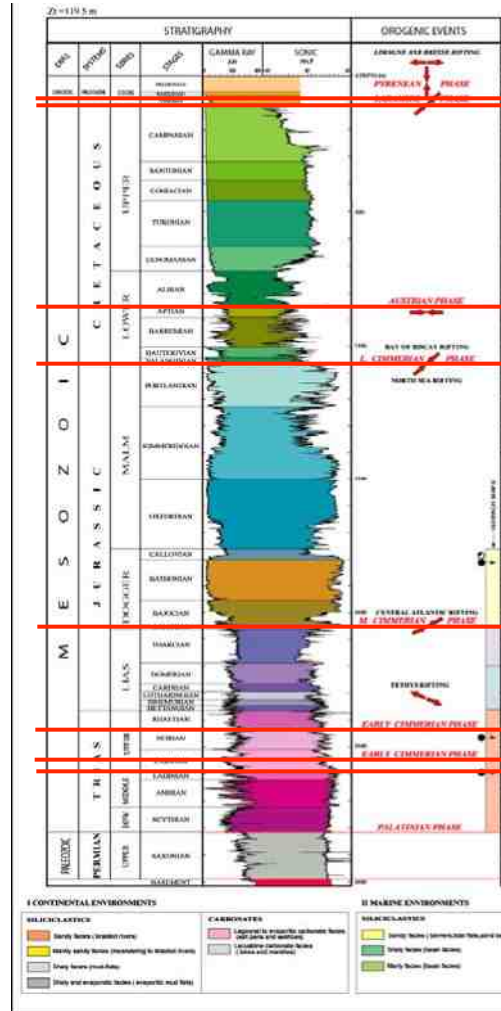
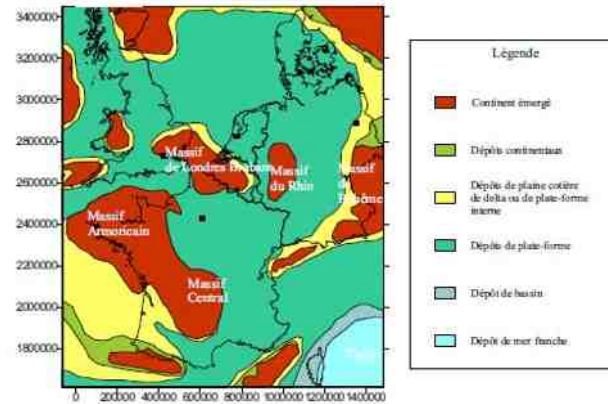
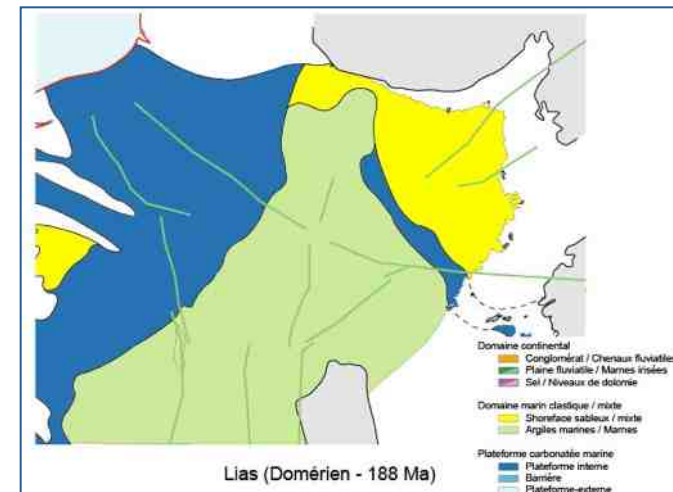


FIG. 1.9 - Paléogéographie du Rhétien (Ylmaz *et al.*, 1996)

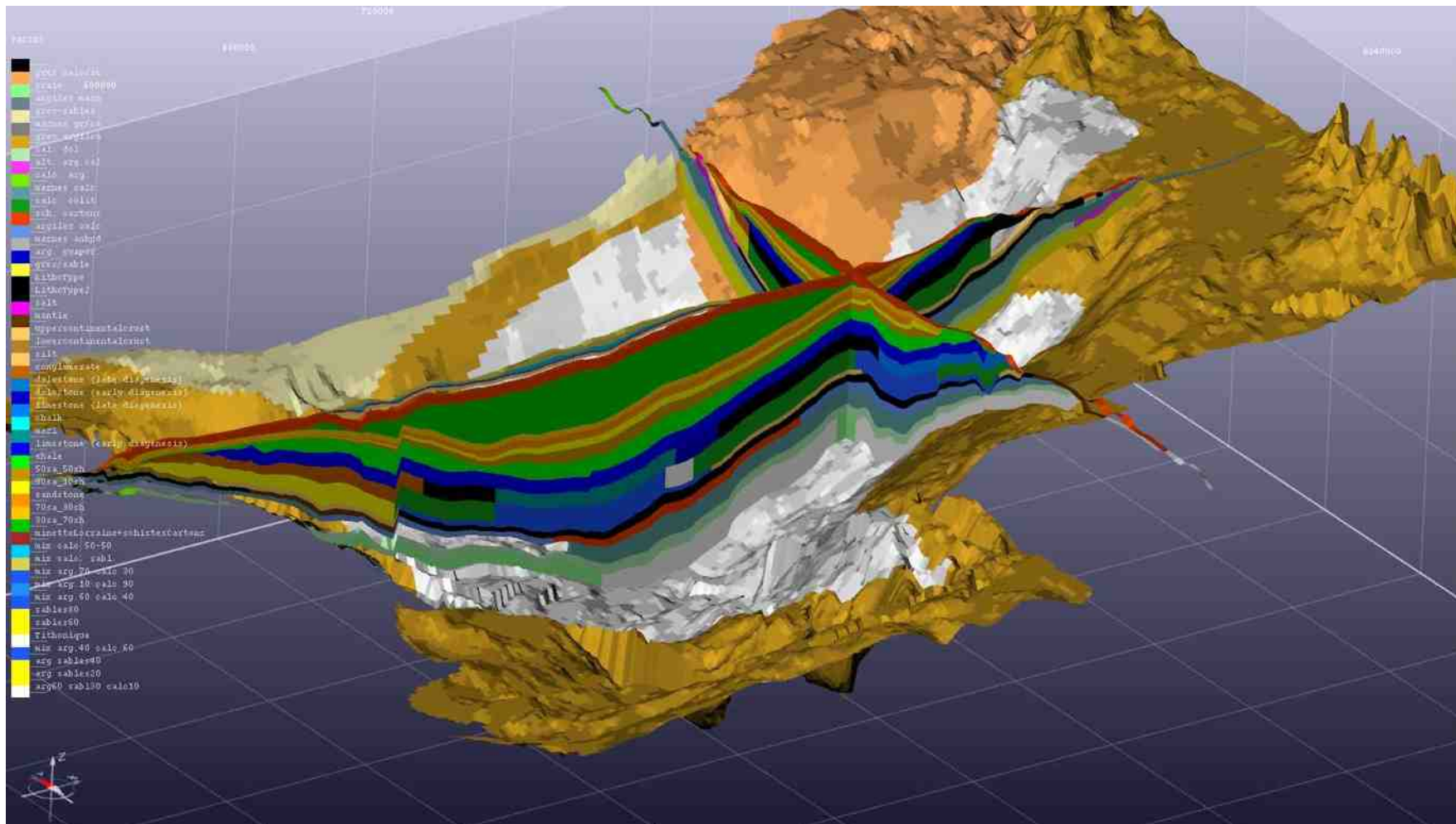
- Erosion maps for each discordance

- 15 Physiographic maps





ULTimate
CO₂



3D model of the Paris basin

Next steps

- Perform the basin modelling
  - Integrate all data in the Basin modelling software
    - Erosion, Lithology and Paleotopography maps
    - Porosity/Permeability vs depth laws from the 2D Paris model
  - Reconstruct the evolution through time = Backstripping method
  - Forward modelling of coupled equations
- Perform a CO₂ injection model at reservoir-scale with initial data from the basin model

Conclusion



- For a long term accurate understanding of CO₂ fate at large scale, we need to understand the geological history of the sedimentary basin
  - basin simulation is an option for a proper initialisation of CO₂ injection site hydrogeological properties
  - however, it requires a lot of data and geological knowledge which makes it difficult to standardise