Regional CO_2 Storage Capacity and Uncertainty Assessment in Geological Formations using Experimental Designs

Antonio Hurtado
Sonsoles Eguilior

International Conference on Deep Saline Aquifers for Geological Storage of CO_2 and Energy
IFP, Rueil-Malmaison, France, 27 - 29 May 2009

Objectives	Methodology	Application	Results	Conclusions

Objectives

$$Q = V_T \cdot \varphi \cdot \rho_{CO_2} \cdot h_{st_r} \pm \epsilon$$

- Set Objectives:
  - Capacity
  - Uncertainties
  - Identify which factors/effects are more important (uncertainties)
    - Methodology developed:
      - » G.I.S
      - » Relationship Density-Porosity-Depth

Methodology

Design of Experiments

- Stage of the Studies
- Objectives
- Nature of the model and available information and the cost to improve them

Select an experimental design:

- Plausibility physical arguments
- Experimental available values

Making provision for ranges

– 4 factors
– Screening Objective

Full Factorial Design

The full factorial design doesn´t have confounding patterns. It allows to determinate the main effects and interactions without ambiguity

=> Is it correct suppose interaction 1-2-3-4 less than others?

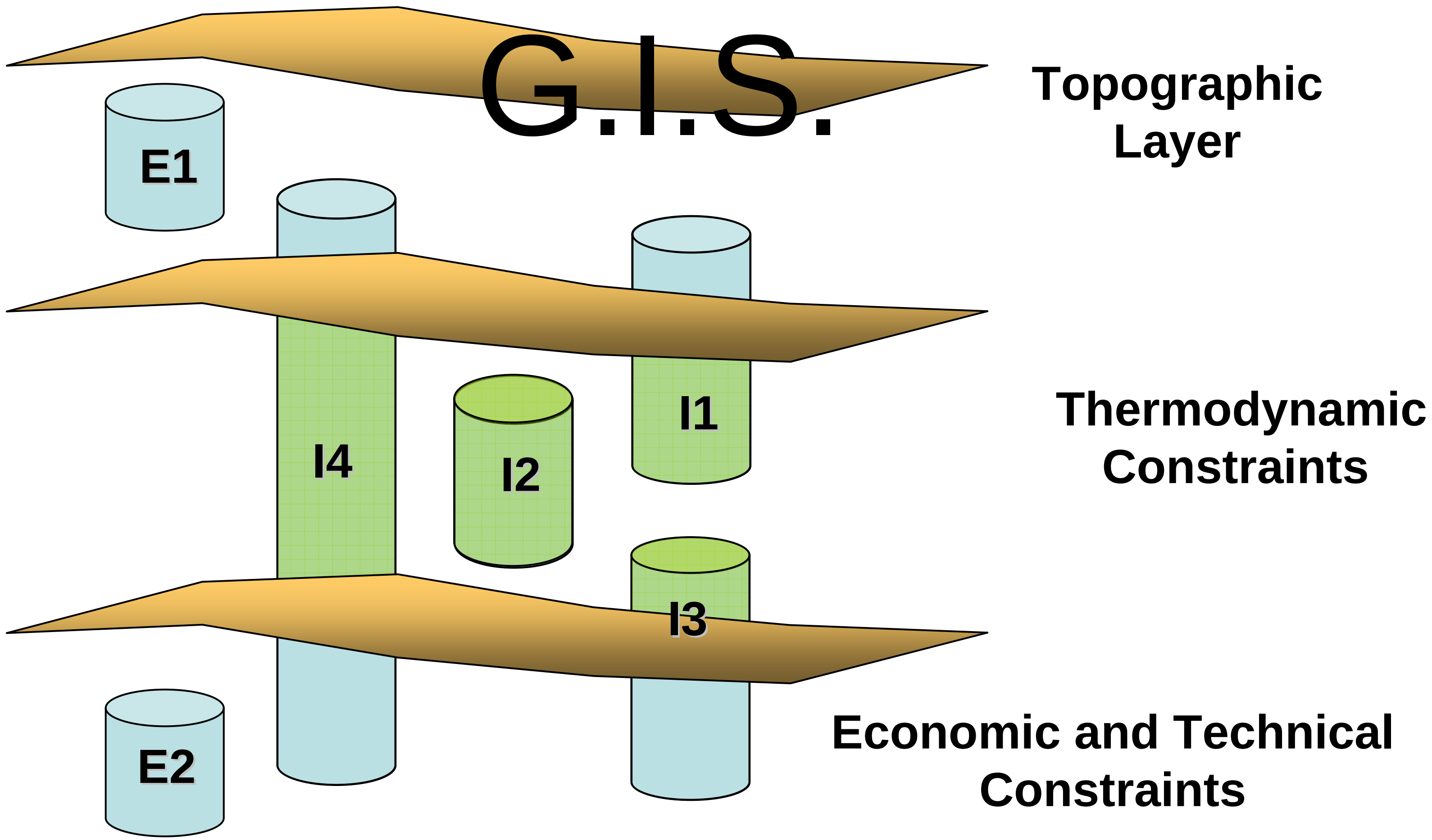
=> Especially interesting in our case the response is obtained by multiplying all the factors

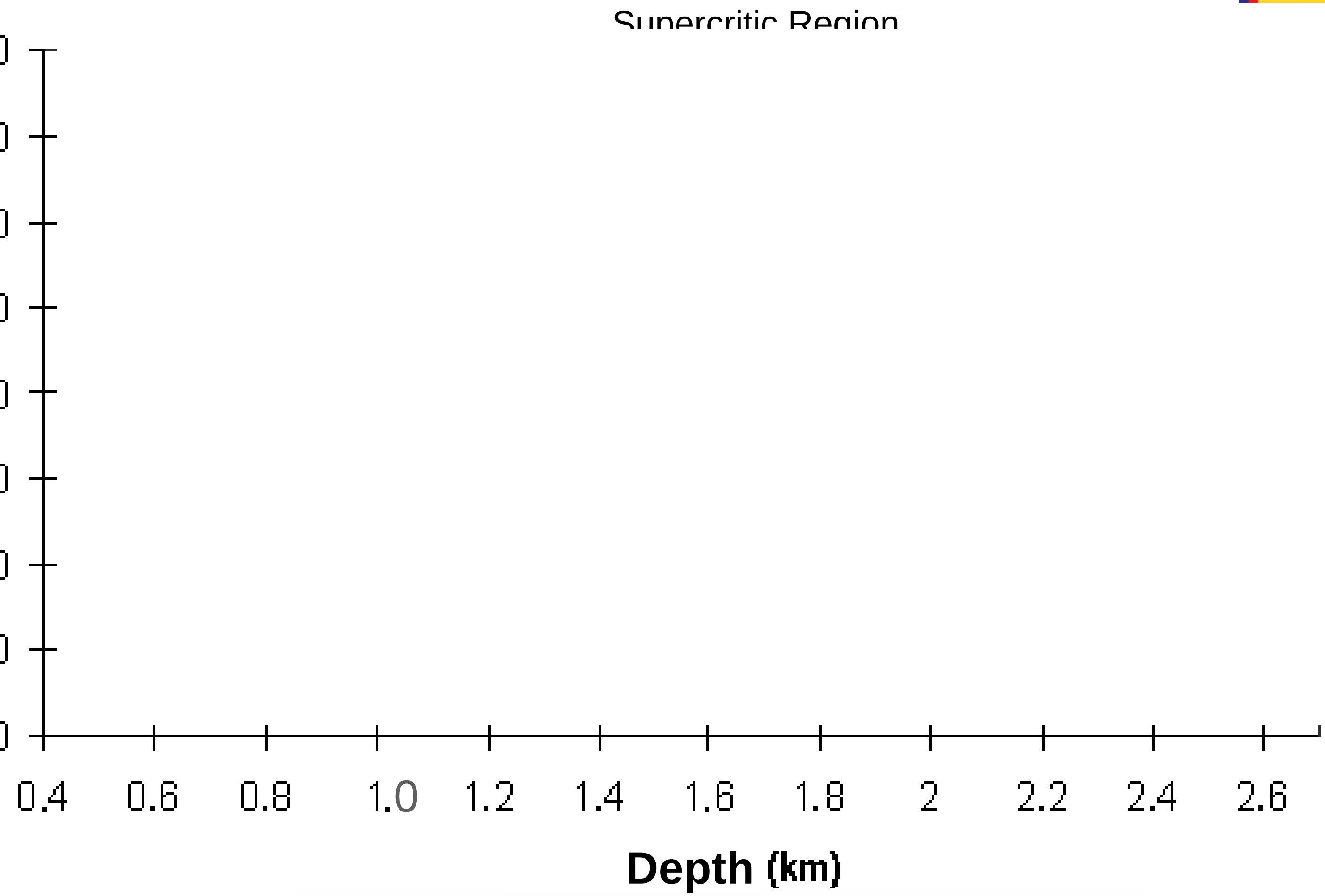
Full factorial 4 factors - 2 levels: $2^4 = 16$ experiments

- Process variables: capacity factors
  - Porosity
  - Storage Efficiency
  - Volume: range determinated by Geostatistics (DTM) & Error Propagation
  - CO_2 Density => two description
    - General supercritical range
    - Two models based on the application of EoS

Two-level designs "high" and "low" setting for each factor

$$Q = \textcircled{V_T} \cdot \varphi \cdot \rho_{CO_2} \cdot h_{st_r} \pm \epsilon$$





$$\frac{a^r(T,\rho)}{R\cdot T} = a_1\cdot\rho - \frac{1}{a_2} + (\sum_{i=2}^{6} a_i\cdot\rho^{i-2})^{-1} -$$

$$Q = V_T \cdot \varphi \cdot \rho_{CO_2} \cdot h_{st_r} \pm \epsilon$$

onship Density-Depth

ta of the distribution of porosity (Intervals of Variation)

ity data from outcrops

ity data from extracting core samples

$$\iiint_{\delta V} \varphi(z) \cdot \rho_{CO_2}(z) \cdot h_{st_r} \cdot dx \cdot dy \cdot dz \pm \epsilon \pm \epsilon$$

$$Q = \iiint_{\delta V} \varphi(z) \cdot \rho_{CO_2}(z) \cdot h_{st_r} \cdot dx \cdot dy \cdot dz \pm \epsilon$$

$$Q = \varphi \cdot h_{st_r} \cdot \Sigma_j A_j \int_{z_t}^{z_s} \rho_{CO_2}(z_j) \cdot dz \pm \epsilon$$

$$\ldots nc\Big) + \left(z_{s_j} - z_{t_j}\right) \cdot a \cdot f_{2_j} \pm \epsilon$$

$$\Big(\Big(\rho_{CO_{2t}} - a\Big) \quad \Big(\rho_{CO_{2s}} - a\Big)\Big) \quad \Big(\quad \Big)^2$$

$$Q = \varphi \cdot h_{st_r} \cdot \Sigma_j A_j \cdot \left(\frac{\rho_{CO_{2z(t_j)}} - \rho_{CO_{2z(s_j)}}}{lnc} + a \cdot (z_{t_j} - z_{s_j})\right)^2 \pm \epsilon$$

$$\cdot h \cdot lnc -$$

$$-2 \cdot \left(\rho_{CO_{2t_j}} - \rho_{CO_{2s_j}}\right) + \left(z_{s_j}^2 - z_{t_j}^2\right) \cdot a \cdot lnc^2 \pm \epsilon$$

Application of the Methodology

Largest Cenozoic basin on the Iberian Peninsula (>50,000 km^2)

Intraplate basin of complex evolution

Origin:

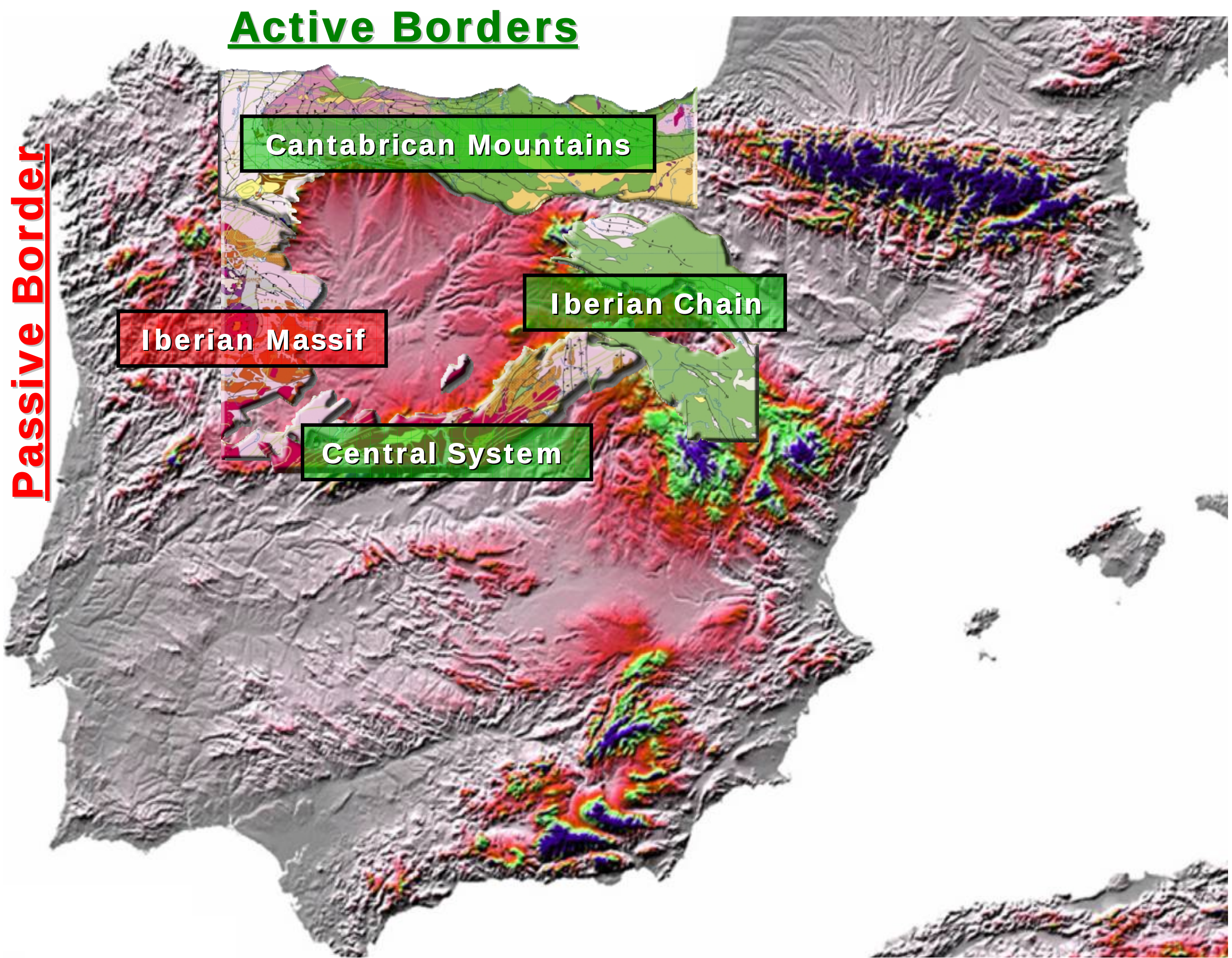
- Finicretaceous – Paleocene
- Reactivation of tardihercynian fractures

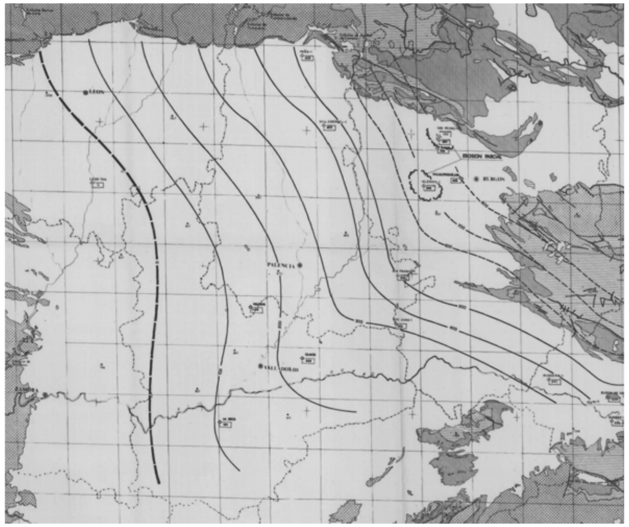
Asymmetric

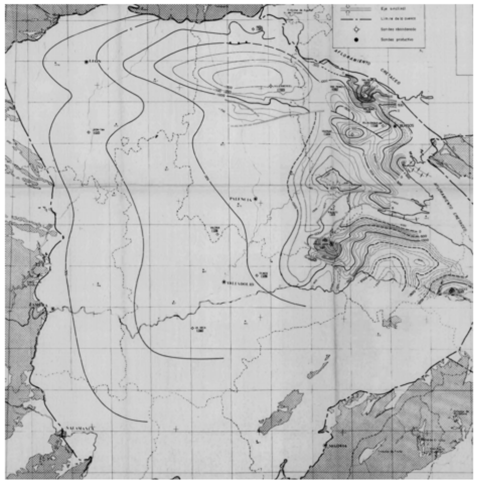
Bounded by several structural units

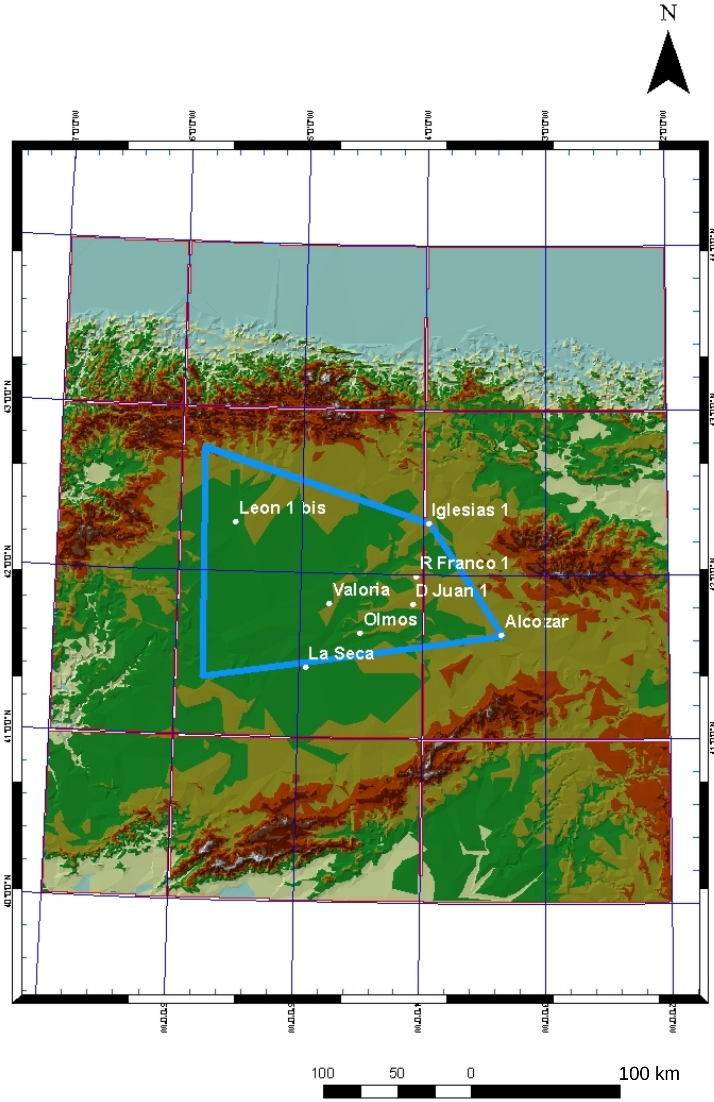
GOBIERNO DE ESPAÑA
MINISTERIO DE CIENCIA E INNOVACIÓN

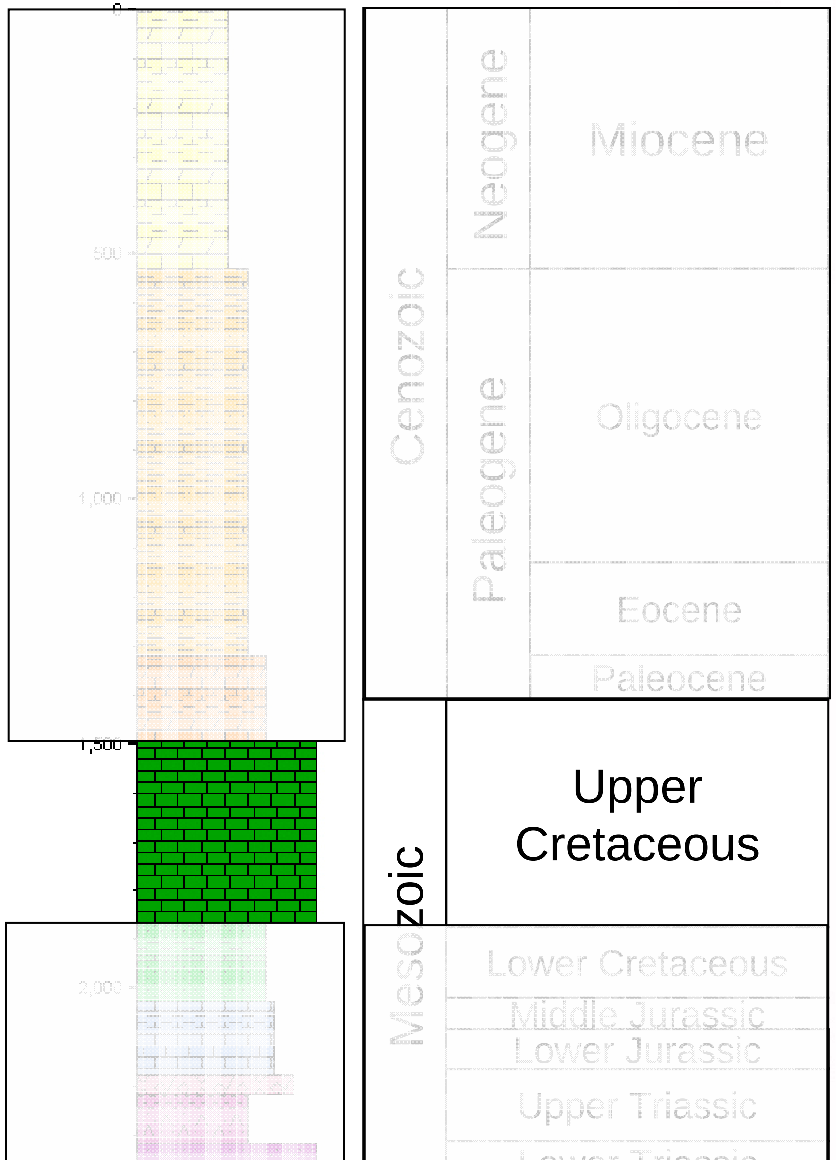
Ciemat
Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas








N
Leon 1 bis
Iglesias 1
R Franco 1
Valoria
D Juan 1
Olmos
Alcozar
La Seca
100
50
0
100 km



Cap Rock

Clay and/or gypsum formations belonging to the Tertiary materials

Stratigraphical Type Column

Storage formation

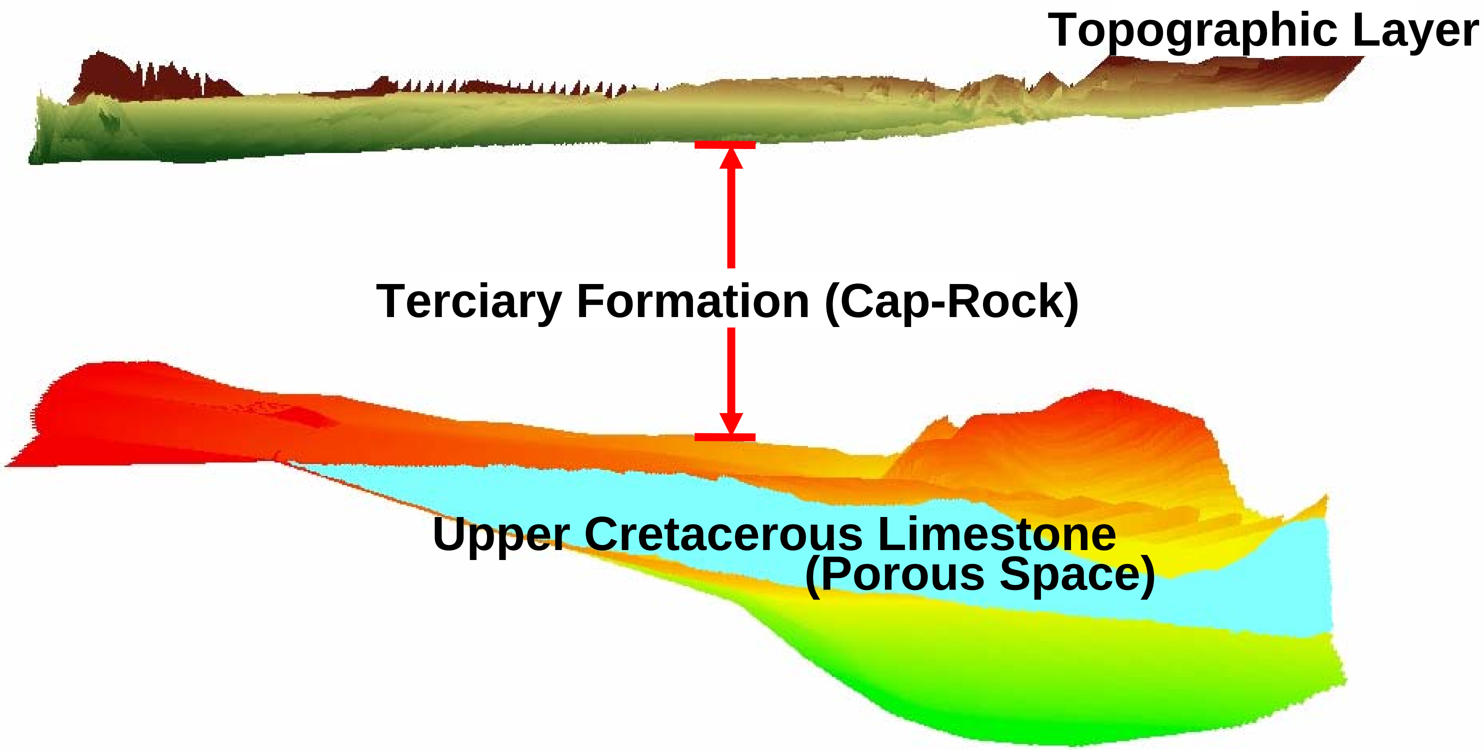
Upper Cretaceous Limestone

Process variables: capacity factors

- Volume: range determinated by Geostatistics & Error Propagation
- Porosity: no quantitative data available; qualitative between medium and high=>[10-20]% & [5-20]%
- Storage Efficiency: no quantitative data available => Literature => [2-8]% & [1-4]%
- CO_2 Density => two description:
  - General supercritical range: 600 – 800 kg/m^3
  - Two models based on the application of EoS

Two-level designs “high” and “low” setting for each factor

DIGITAL MODEL

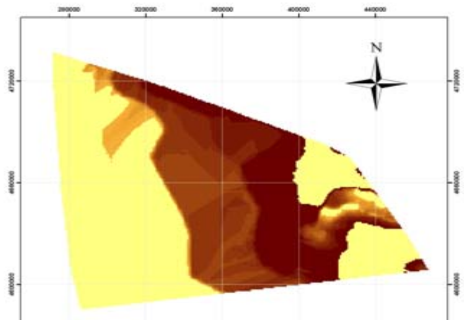


+

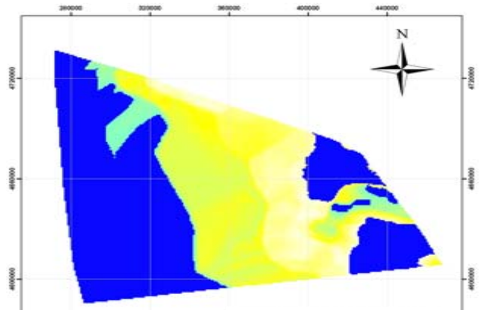
Boundary Conditions

GOBIERNO DE ESPAÑA MINISTERIO DE CIENCIA E INNOVACIÓN

Ciemat
Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas

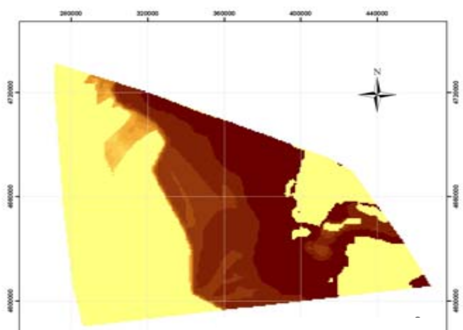


Layer of the Density of the Upper of the Upper Carbonated Cretaceous (kg/m^3)

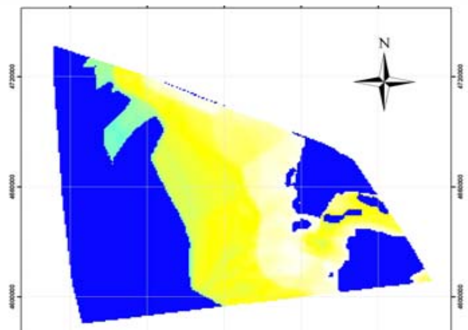


Layer of the Depth of the Upper of the Upper Carbonated Cretaceous (m)

$$= \varphi \cdot h_{st_r} \cdot \Sigma_j A_j \cdot \left(\frac{\rho_{CO_2 z_{(t_j)}} - \rho_{CO_2 z_{(s_j)}}}{lnc} + a \cdot (z_{t_j} - z_{s_j}) \right)$$



Layer of the Density of the Bottom of the Upper

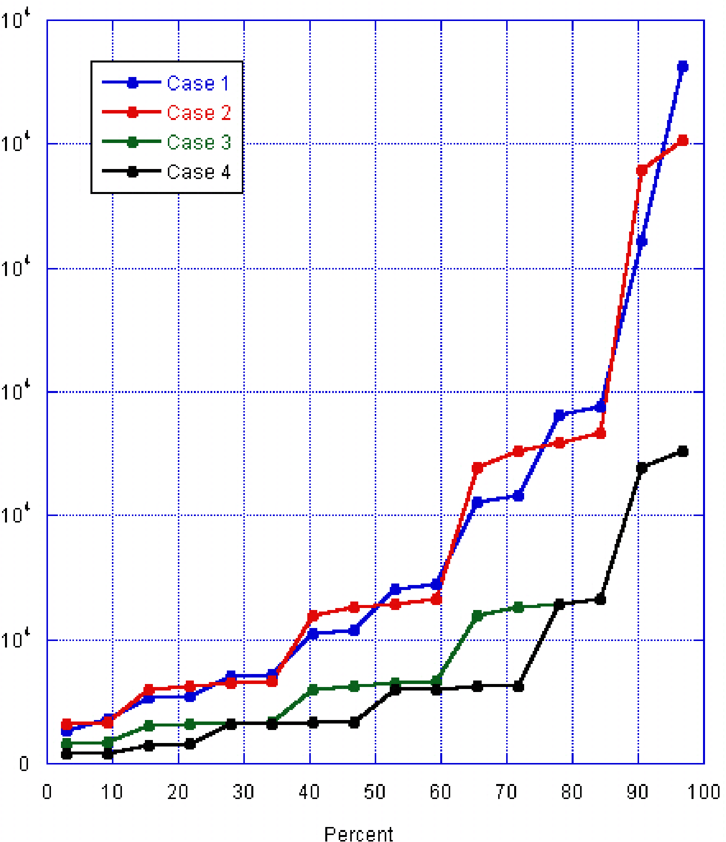


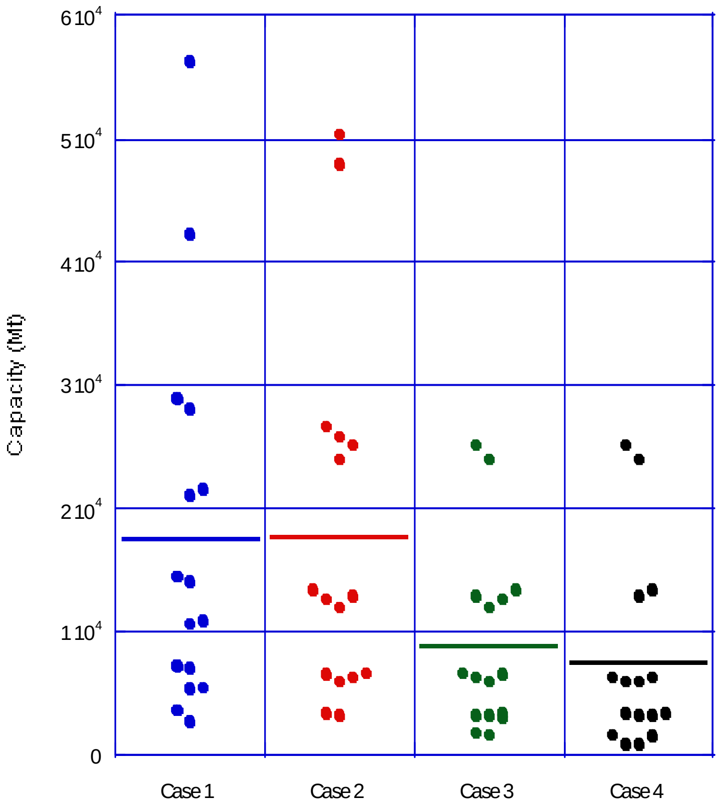
Layer of the Depth of the Bottom of the Upper

Results

Results

Capacity & Uncertainty Determination





Main Factors and Influences

Conclusions

Conclusions (1/2)

- The Duero basin has a high potential for CO_2 storage.
- Design of Experiments has proven useful for determining the uncertainties and ranking the influence of factors => It is not necessary to apply PDF´s => No transmission of uncertainty.
- These results have proven to be robust to variations within the ranges that can be expected in the factors of interest.

Conclusions (2/2)

The description of the behavior of the Density of CO_2 through EoS eliminates its impact on the uncertainties of the system without using the more complex EoS (Altunin, Span and Wagner, etc.).

Given the significant impact of Storage Efficiency factor in the uncertainties an effort to improve the estimation of Storage Efficiency is needed especially because it is the variable with the lowest level of variability of all:

– The characterization of the Volume via geostatistical tools shows a moderate impact on the uncertainties always less than the impact of the Storage Efficiency and Porosity.

– The worst for the porosity has been selected.

Thank you
for your time