

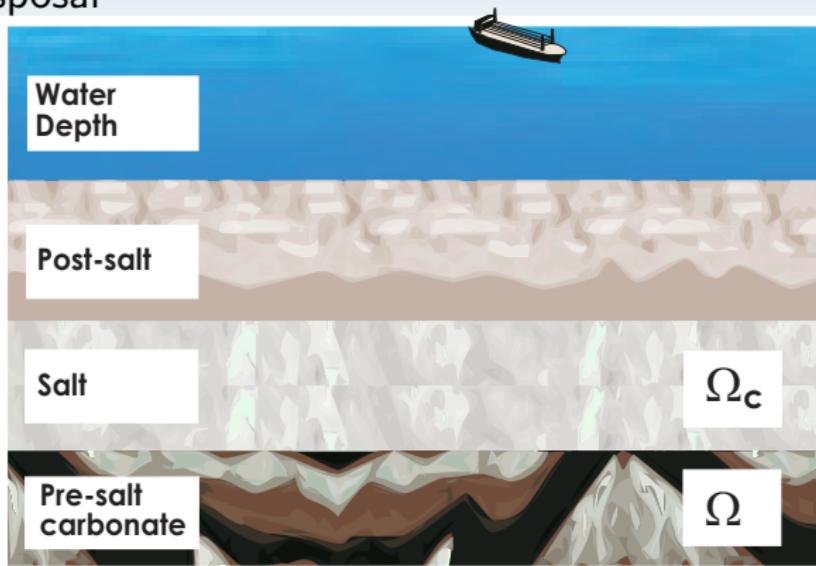
Workshop Sinergia LNCC-EMPRESAS

Marcio A. Murad
COMOD-LNCC

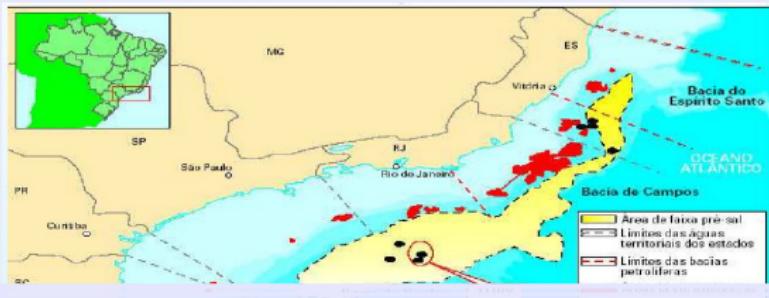


Scientific Challenges

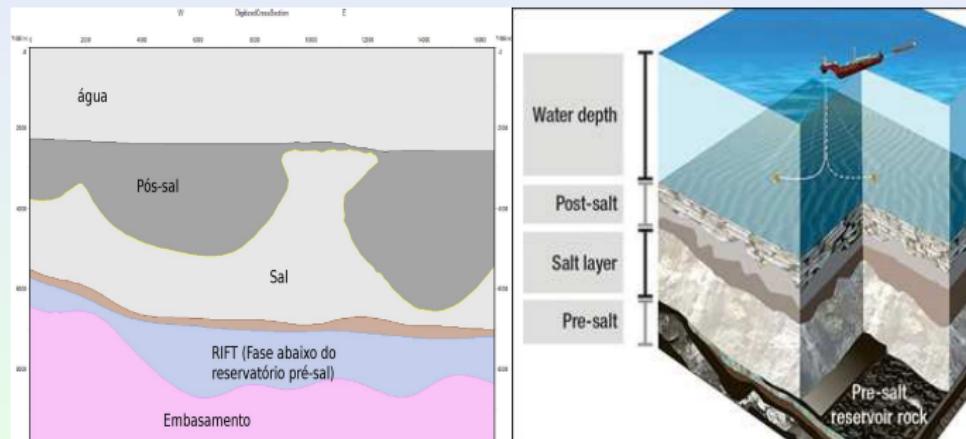
- Deep Offshore Exploration
- Carbonate Rocks: Heterogeneity
- Geological Complexity
- Fractures, Faults, Vugs, Cave Network
- CO_2 disposal



Pre-Salt Reservoirs: Carbonate Rocks



Hidro-Geomechanical Coupling Scenario

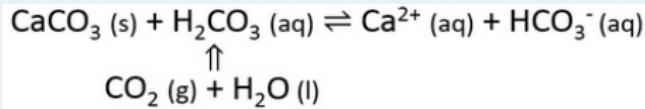


Trapping Mechanisms: iv) Mineral Trapping

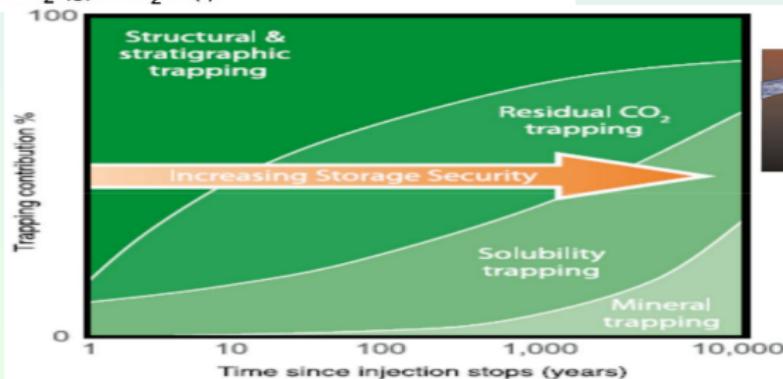
- Solubility → Acidification → Weak carbonic acid



- Trigger Dissolution – Precipitation Geochemical Reactions



Time Scales

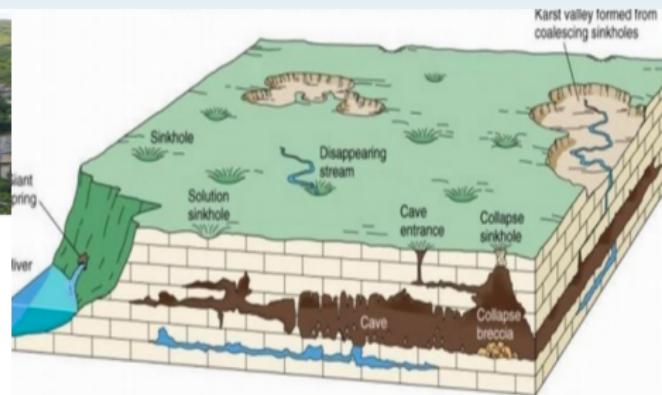
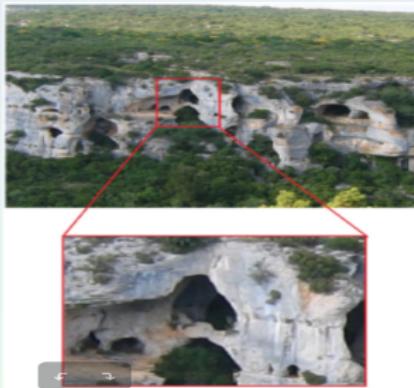


Presence of a Cave Network

Karst Conduits

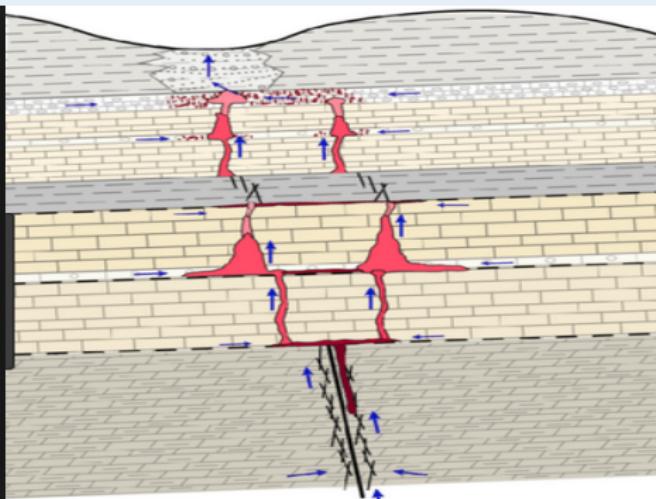
- Fractured Corridors. Enlarged due to Dissolution Collapse

Análogo
de
Rocha
Karstificada

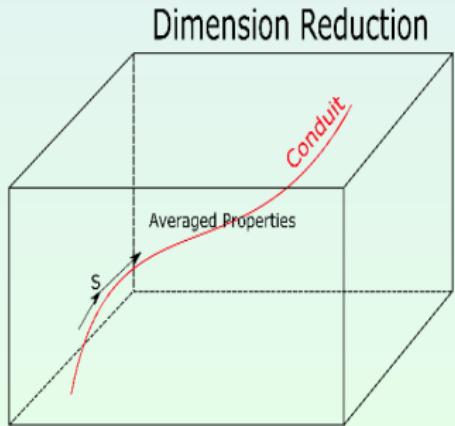
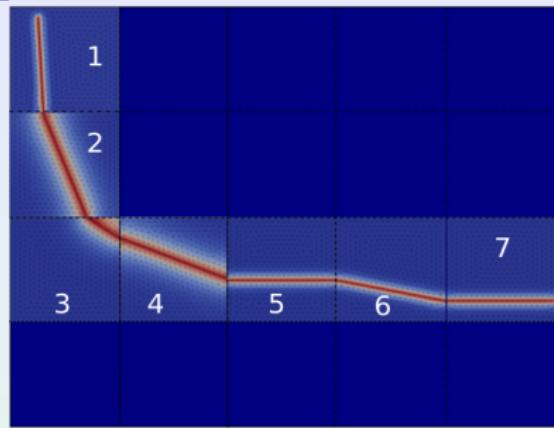


Presence of a Cave Network

Karst Conduits



Coupled 3D - 1D Model



$$\beta_r \frac{\partial P_r}{\partial t} + \nabla \cdot \mathbf{v}_d = KI(P_r - P_c)\delta_\Delta \quad \text{in } \Omega$$
$$\mathbf{v}_d = -K\nabla P_r$$

Coupled System

$$\beta_c \frac{\partial P_c}{\partial t} + \frac{dv_c}{ds} = -\frac{KI}{A_c}(P_r - P_c)$$

$$v_c = -K \frac{dp_c}{ds} \quad \text{in } \Gamma_c$$

Summary - High-Fidelity (Fine-Scale) Model

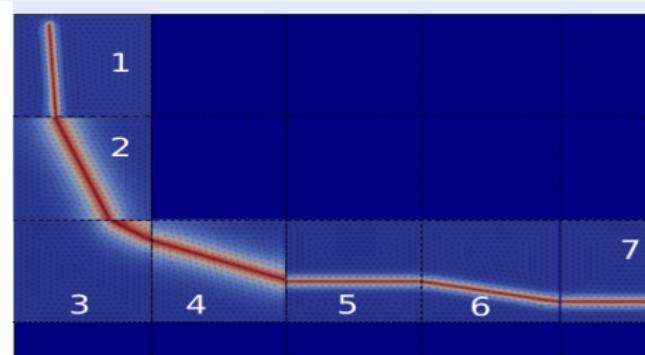
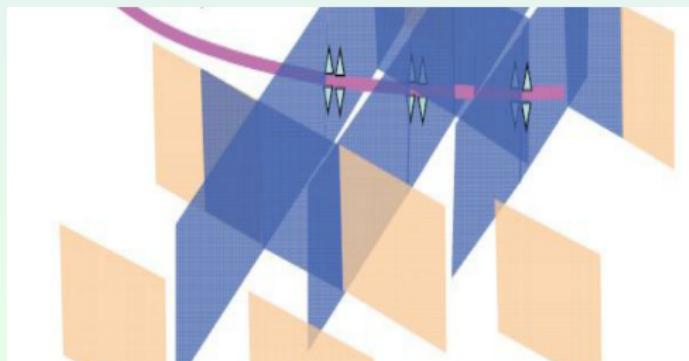
$$\beta_m \frac{\partial P_m}{\partial t} - \nabla \cdot (K_m \nabla P_m) = \textcolor{red}{KI}(P_m - P_c)\delta_\Delta \quad \Omega \subset \mathbb{R}^3$$

$$\beta_f \frac{\partial P_f}{\partial t} - \nabla_\tau \cdot (K_f \nabla_\tau P_f) = (\mathbf{v}_m^+ - \mathbf{v}_m^-) \cdot \mathbf{n} \quad \Gamma \subset \mathbb{R}^2$$

$$\beta_c \frac{\partial P_c}{\partial t} + \frac{dv_c}{ds} = -\frac{\textcolor{red}{KI}}{A_c}(P_r - P_c)$$

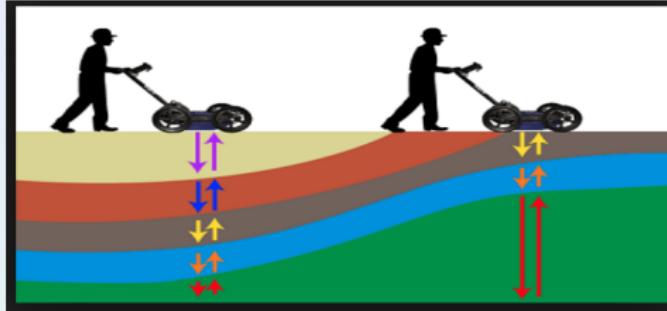
$$v_c = -K_c \frac{dp_c}{ds} \quad \text{in} \quad \gamma_c \quad \mathbb{R}^1$$

δ_Δ – Dirac line source



III Incorporate Outcrop Data

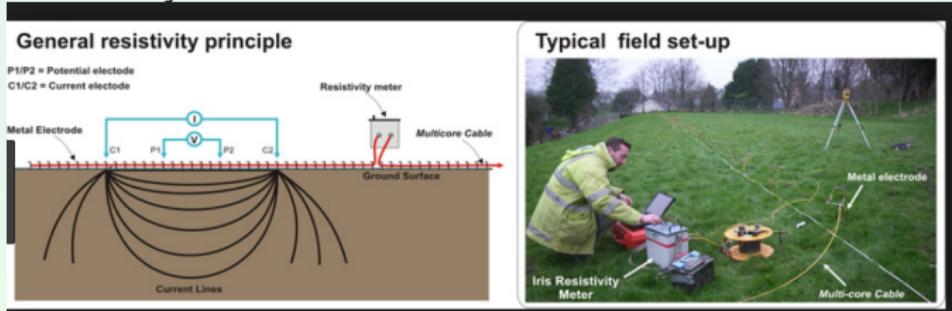
- GPR – Electro-Magnetic Waves



- Near-Surface Seismic Acoustic Waves

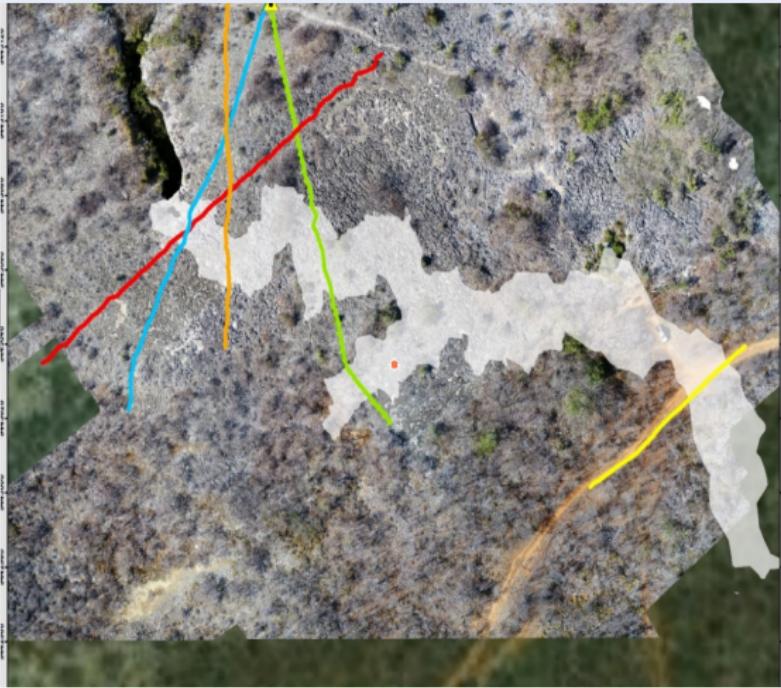


- Electro-Resistivity – Electric Current – Electrodes

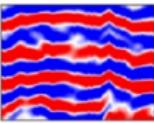
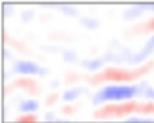
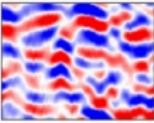


- Joint Work with F Hilario Bezerra and F Pinheiro (UFRN)

Outcrop FURNA FEIA



RADAR FACES

RADARFÁCIES	TIPO DE REFLETOR
R1	
R2	
R3	

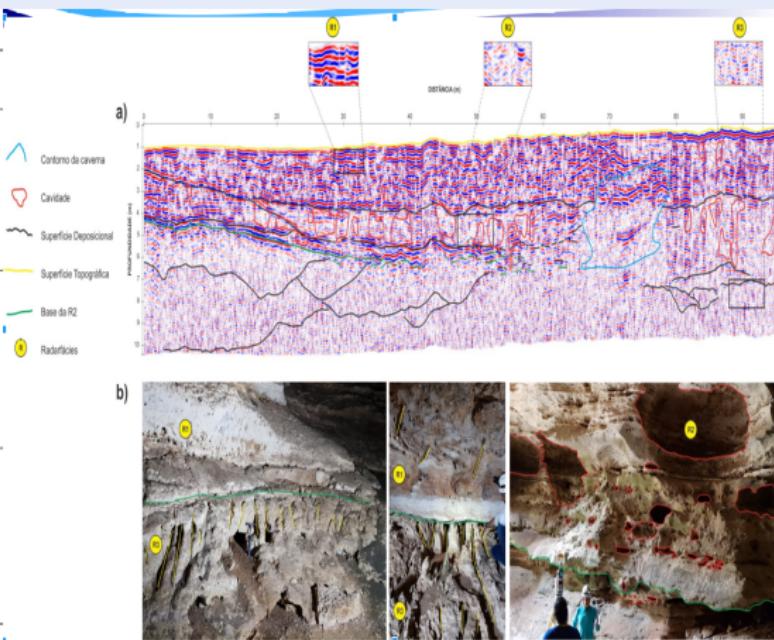
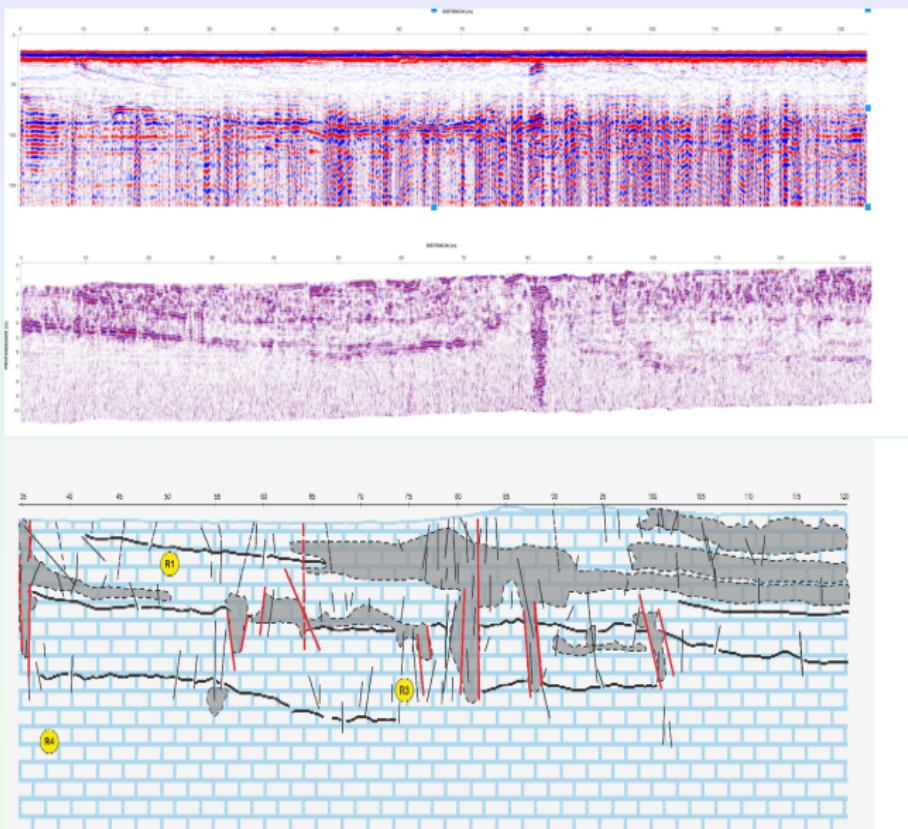
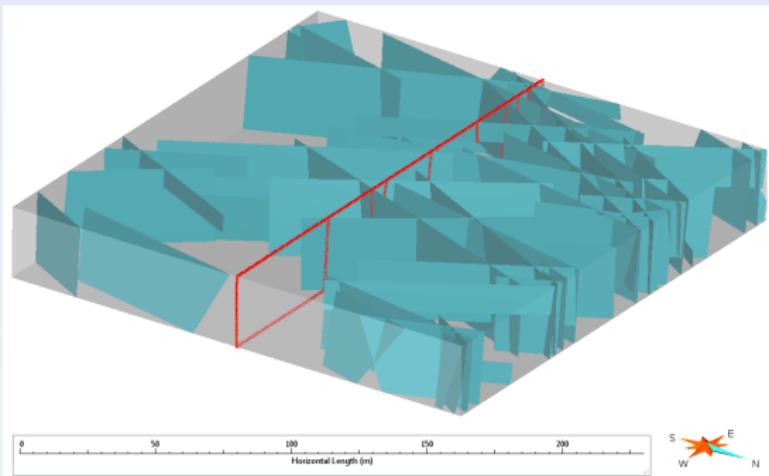


IMAGE PROCESSING

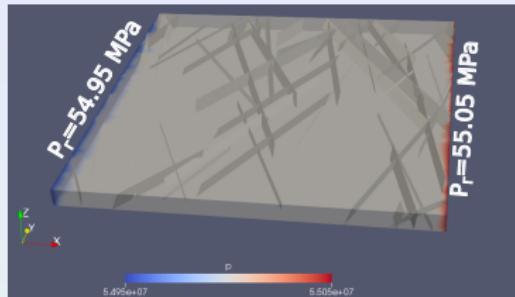


Extension to 3D Scenarios

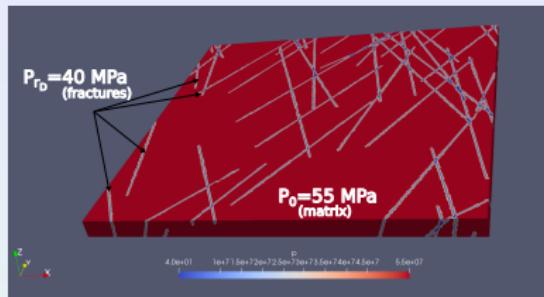


- Preliminary Results– One-Way Formulation
- Given a Homogeneous Initial Total Stress
- BB Normal Contact Stress Given
- $\sigma_n^{BB} = (\sigma_T + \alpha p)n$

Pre-Processing Approach



Steady state simulations
to compute equivalent permeabilities

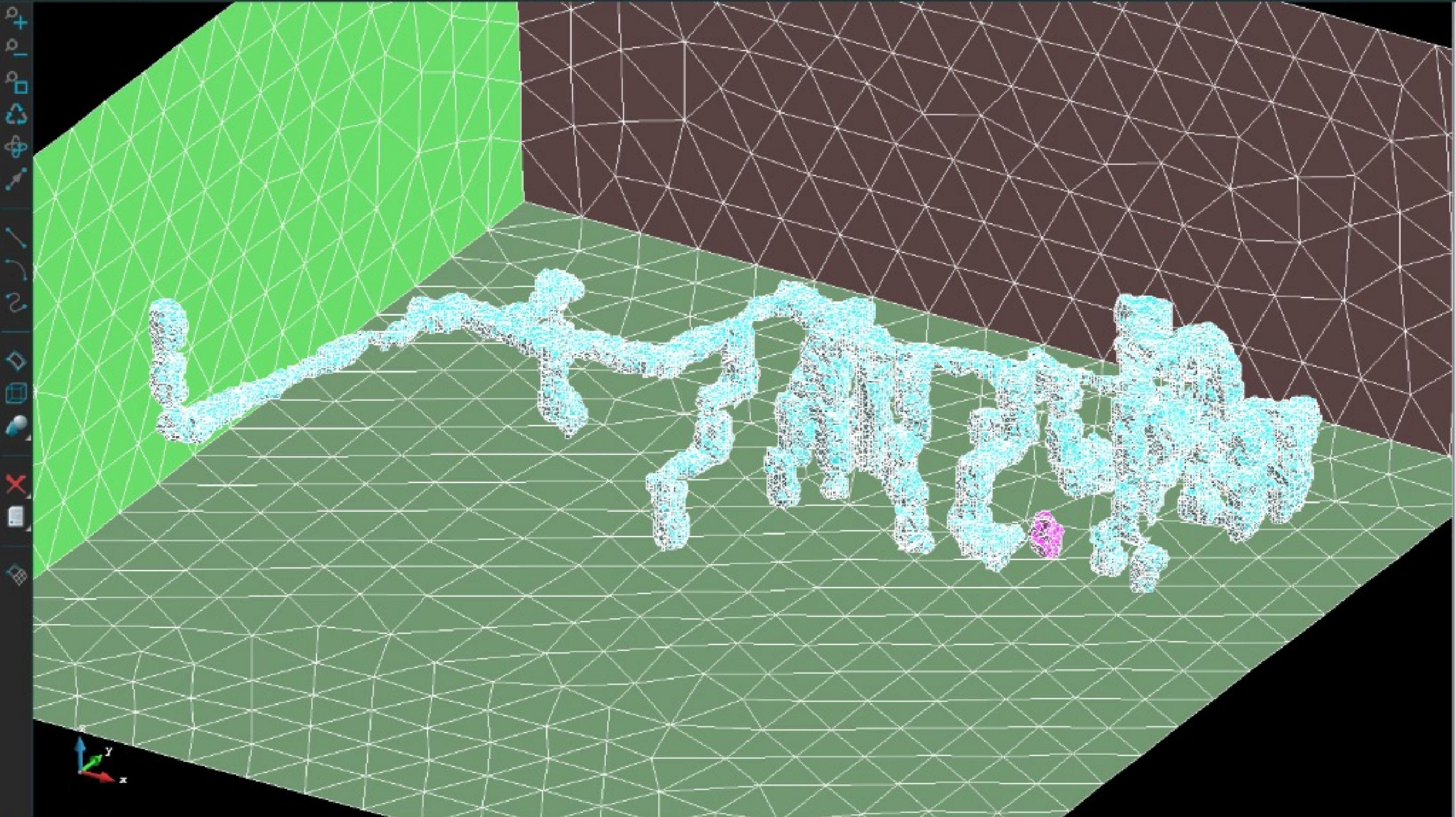


Transient simulation
to compute exchange coefficient

Input Data

	$K_x(\text{mD})$	$K_y(\text{mD})$	$K_z(\text{mD})$	$K_f(\text{D})$ (avg)	β_m^* (Pa^{-1})	β_f^* (Pa^{-1})
Mat+Fract	343.29	343.29	0.026	5522.21		
Matrix	343.29	343.29	0.026	0.0		
Fractures	0.0	0.0	0.0	5522.21		
Exch Coeff	343.29	343.29	0.026	0.0	7.1×10^{-11}	8.7×10^{-16}

Files View Geometry Utilities Data Mesh Calculate Help



Leaving change layers
Layer rochalintacta is OFF

Command:

Zoom: x2.1

Nodes: 78K, Elements: 478K

Render: flat

Layers: 13(Off: 4)

(-651715, 9388644, 0)

Pre

Double click here to tear off the window

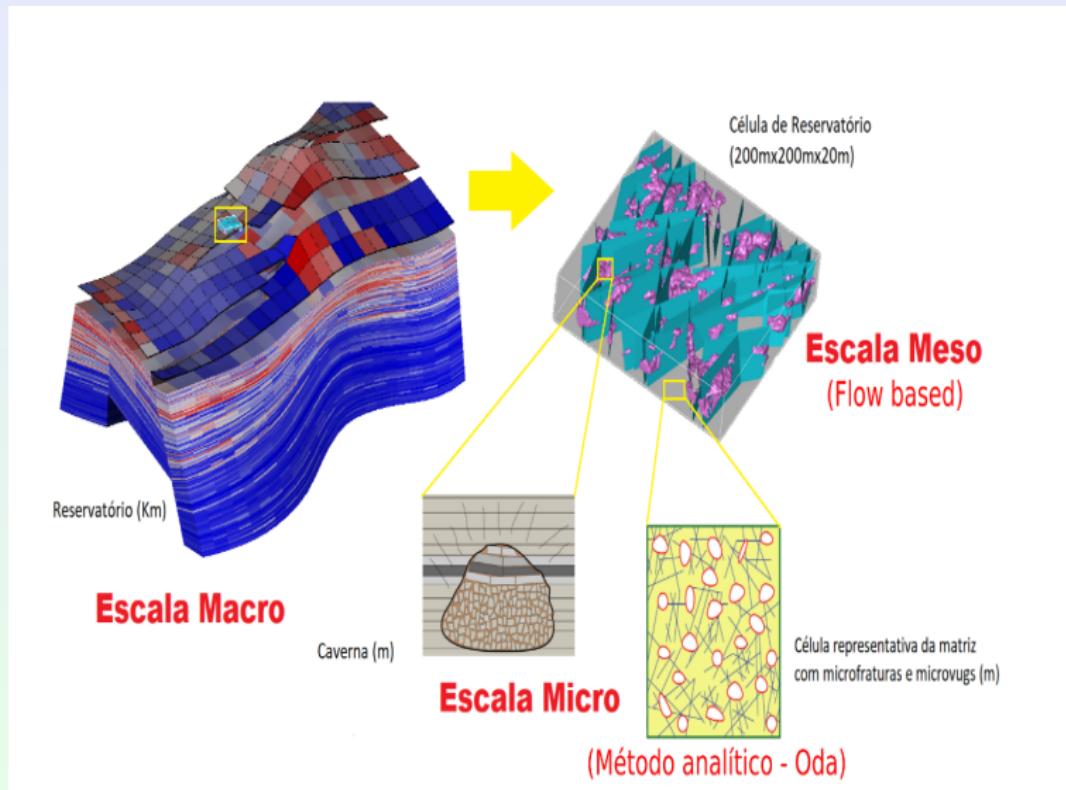
Layers Groups

Name	C I/O F/U Tr B
bordas	✓
- 1	
- 2	
- 3	
- 4	
- fundo	
- topo	
- Carste_Hipo_part_1	
- Carste_Hipo_part_2	
- rochalintacta	✓
secos	
- volume_p1	
- volume_p2	

Color legend:

- Dark purple/black: 'rochalintacta'
- Dark red: 'volume_p1'
- Dark green: 'volume_p2'
- Dark blue: 'fundo'
- Dark grey: 'topo'
- Light blue: 'Carste_Hipo_part_1' and 'Carste_Hipo_part_2'
- Light green: 'bordas'
- Light blue-grey: 'secos'
- Light yellow: '1', '2', '3', '4'

NEED FOR UPSCALING



PLUG-IN : UPSCALING

Plugins for the gOcad software

RINGToolKit

RING Team main Gocad/Skua plugin (in development)

[Gocad plugins](#)

SCube



SCube is a SKUA-GOCAD plugin to perform stochastic multi-well correlations.

With a set of rules, it computes the cost of the association of each pair of units on two different wells and then outputs the correlation of the wells with the least expensive associations.

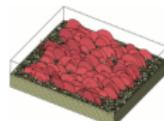
The rules that can be chosen are various such as the size of the units, the depth, the facies,... or also the frequency of observation of the association in a training forward model.

It can be used for multi-well correlation and it is possible to automatically build stratigraphic grids from these correlations.

[Gocad plugins](#) [SCube](#)

[Read more ...](#)

FractCar



FractCar is a module of the gocad software that allows to generate discrete fracture networks. The project aims at characterizing natural fracture networks in order to reproduce their organization and connectivity at various scales in fractured reservoir modeling workflow.

Contact: [Francois Bonneau](#)

Sponsor's menu

- Ring Meeting papers
- Plugins
- Trainings
- RING Meeting

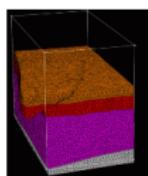
PLUG-IN : UPSCALING

GRGLib

Base plugin.

[Gocad plugins](#) [GRGLIB](#)

RestorationLab



RestorationLab is a research plugin which aims at removing deformations undergone by rocks to get the paleogeometry of a geological model. It is a great tool able to perform 3D restoration on both implicit and explicit geological models.

Concretely it unfolds and removes the displacement due to the faults. It solves mechanics-based problem using finite element element and Dirichlet/Neumann boundary conditions. This plugin can also decompact a model after removal of a layer using classical porosity laws. Since Gocad 14 this plugin uses [RIMGMecha](#), therefore restoration can be applied independently to Gocad by command lines.

Contact : [Benjamin P. Chauvin](#).

[Geomechanics](#) [Restoration](#) [Gocad plugins](#) [RIMGMecha](#) [RestorationLab](#)

» [Read more ...](#)

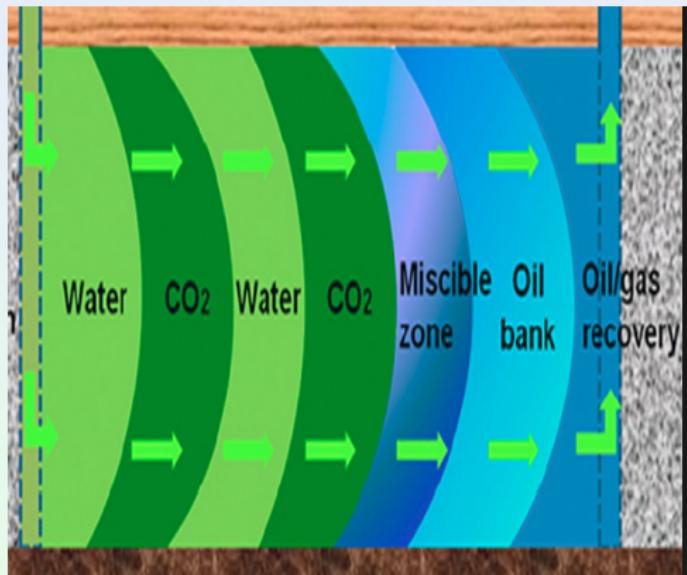
KarstMod

KarstMod is a plugin developped for **3D karstic network simulations**. It is currently available on the Gocad 2009.4 platform and will soon be moved to Gocad 2014.

[Gocad plugins](#) [KarstMod](#)

» [Read more ...](#)

Water Alternate Gas Injection WAG



Summary

- LNCC team responsible for the High-Fidelity Model
- Need for UPSCALING
- Development of Plug-Inw for bridging LNCC work and Coarse-Scale Commercial Simulators

