Computational Modeling of Porous Materials

Comopore Team:

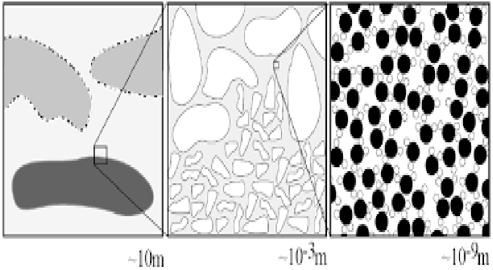
Marcio Murad, Tuane Lopes,
Patricia Pereira, Josue Barroso,
Sidarta Lima, Marcio Borges,
Eduardo Castro, Tayná Lobo
Liliane Rodrigues, Emanuel Gomes

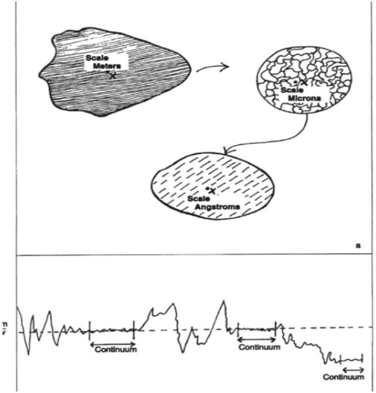
CoMoPore
Computational Modeling of Porous Materials

Laboratório Nacional de Computação Científica
UNIDADE DE PESQUISA DO MCTIC

Porous Media Science: Intrinsically Multi-Disciplinary

- Depending on the Observation Scale Every System is a Porous Medium

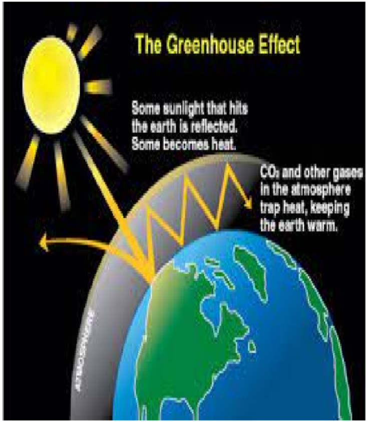


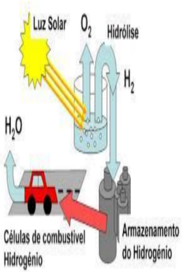


Strong Theoretical Basis – Real Applications – Impact Society
Subsurface CO_2-sequestration and Cyclic Hydrogen Storage

The Good Guy and the Bad Guy

CO_2 – Greenhouse gas (TRAPS HEAT): H_2 CLEAN



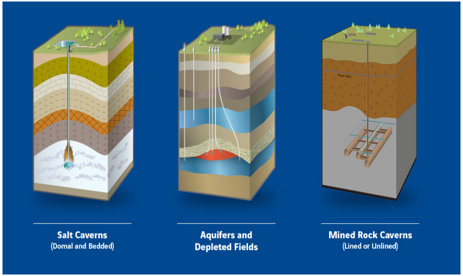


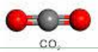
Hydrogen Cycle

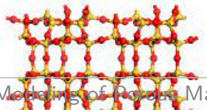
Geological Sequestration / Utilization

CCUS: Large and Small Length Scales

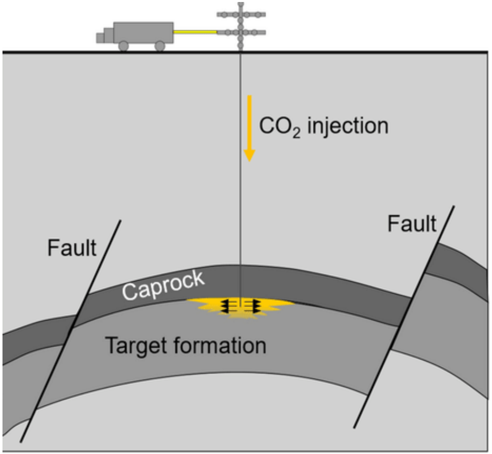
- Geological Sequestration: Oil and gas fields: Deep Saline Aquifers: Coal beds; Salt Caverns
- CO_2 adsorption in Zeolites

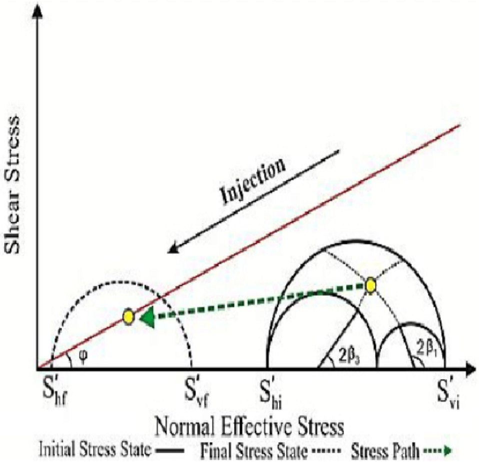






Carbon Dioxide Storage: Fault Reactivation



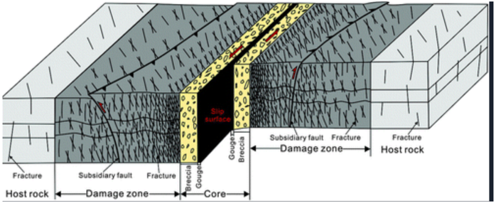


Open Topic: Complex Fault with Multiple Zones

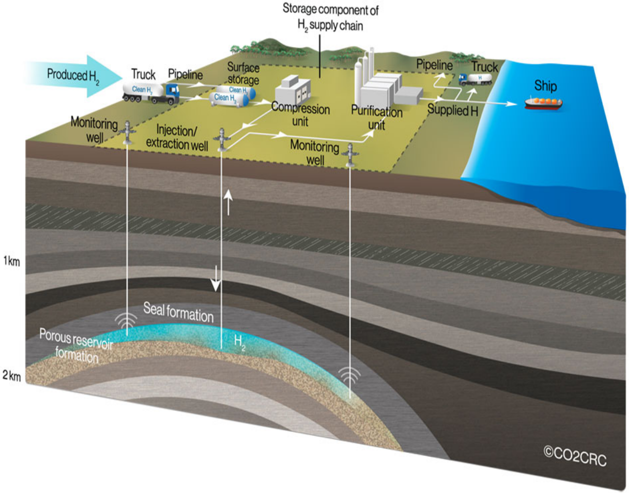
Window of Opportunity for Cooperation

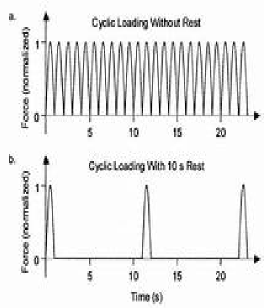
Implementation in GEOS:

- i) Dependency of Fault Transmissibilities on the Stress State
- ii) Reduced Flow Model with Multiple Zones

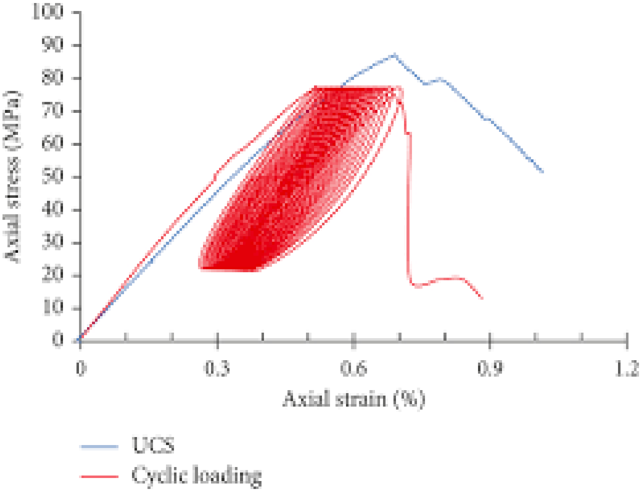


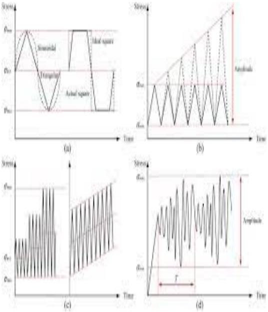
Hydrogen Storage and Withdrawal: Cyclic Loading: Hysteresis





Cyclic Loading Damage Fatigue



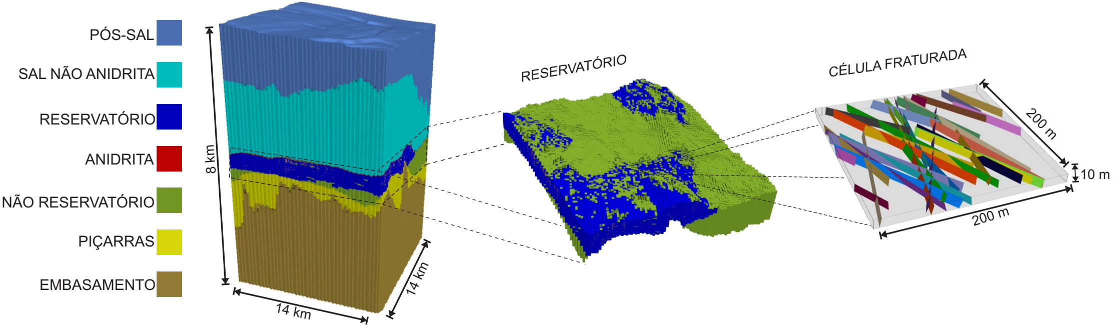


II: Main Achievements

Tools

Two Computational Tools Delivered to Petrobras

I): Fracture Geomechanics: Buzios Reservoir



Collaboration With Total Energies

Proposed Topics

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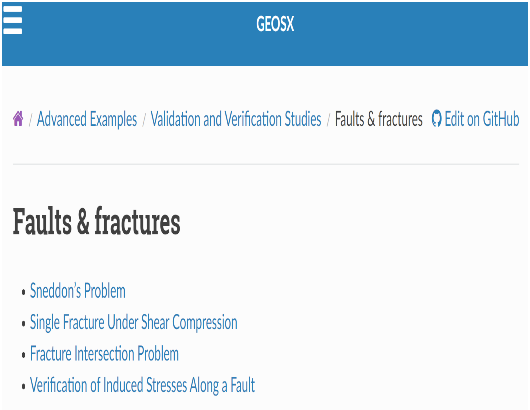
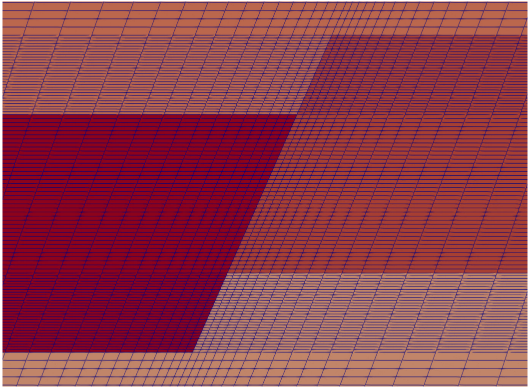
TotalEnergies

Incorporate Geomechanical Effects in Embedded Discrete Fractured Model (EDFM)
Include Faults with Multiple Zones

Simplifed Fault zone

GEOS:





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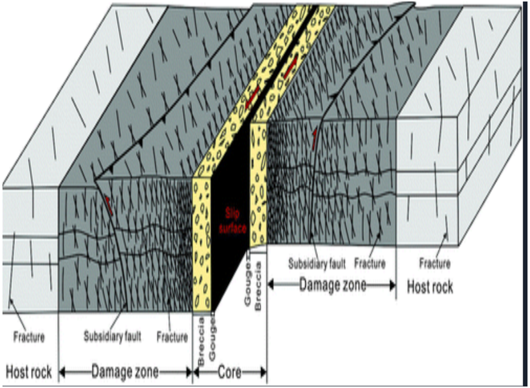
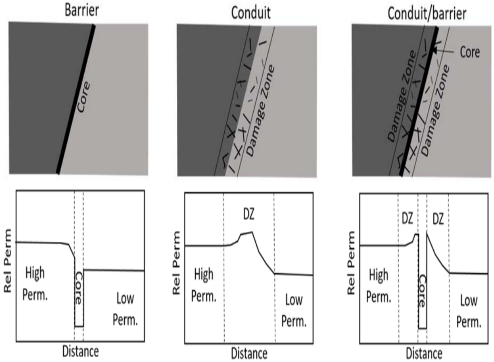
II: Incorporate Fault Architecture

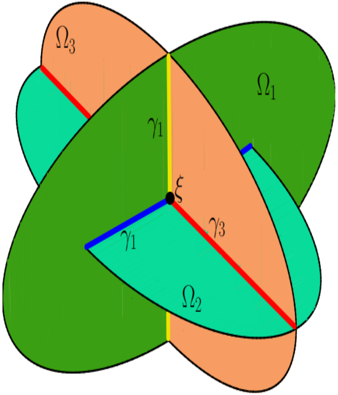
A fault is more than a two-dimensional slip plane





- Fault Mechanical and Petrophysycal Properties depending on the local fault characteristics
- Core, Inner and Outer Damage Zones, Shale Gouge Ration, Fracture Density etc...

Problems Governed by Mixed-Dimensional PDE's



$$
\begin{aligned}
-\nabla_{\omega\boldsymbol{\tau}} \cdot (K_{\omega\boldsymbol{\tau}} \nabla_{\omega\boldsymbol{\tau}} p_\omega) = q_\omega - [\boldsymbol{\nu}_{\hat\omega} \cdot K_{\hat\omega\boldsymbol{\tau}} \nabla_{\hat\omega\boldsymbol{\tau}} p_{\hat\omega}]_\omega \text{ in } \omega \in \Omega_n, \\
p_\omega = p_D \text{ at } \partial\omega_D, \\
-\boldsymbol{\nu}_\omega \cdot K_{\omega\boldsymbol{\tau}} \nabla_{\omega\boldsymbol{\tau}} p_\omega = g_N \quad \text{at} \quad \partial\omega_N, \\
\boldsymbol{\nu}_\omega \cdot K_{\omega\boldsymbol{\tau}} \nabla_{\omega\boldsymbol{\tau}} p_\omega = 0 \quad \text{at} \quad \partial\omega_I, \\
n = 1, \ldots, N; \\
\boldsymbol{\nu}_{\hat\omega} \cdot K_{\hat\omega\boldsymbol{\tau}} \nabla_{\hat\omega\boldsymbol{\tau}} p_{\hat\omega} = K_{\omega\boldsymbol{\nu}}(p_\omega - p_{\hat\omega}) \text{ on } \omega, \quad \hat\omega \in \hat\partial(\omega), \\
\omega \in \Omega_n,\ n = 0, \ldots, N-1,
\end{aligned}
$$

Main Feature: Jump in the Normal Flux as a Source

Featured Papers (2023)

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Research paper

Reduced flow model and transmissibility upscaling in multi-layered faulted reservoirs

Eduardo S. Castro, Josué S. Barroso, Marcio A. Murad *, João N.C. Guerreiro

Laboratório Nacional de Computação Científica, LNCC - Petrópolis, RJ, Brazil

ARTICLE INFO

Keywords:
Reduced flow models
Upscaling
Fault zones
Transmissibility multiplier
Discontinuous finite elements

ABSTRACT

We construct a new three-scale model for single phase incompressible flow in faulted rocks containing multiple damage zones. At the finer scale ($\mathcal{O}(1\text{m})$), flow is influenced by the high-contrast layered heterogeneities inherent to the core and adjacent damage zones, which are populated by geological anomalies, such as compaction bands, debris, and fine sediments and joints. In the first stage of the reiterated homogenization procedure, we construct a lower-dimensional reduced model, where the discontinuity is envisioned as $(n-1)$-dimensional manifold ($n = 2,3$), topologically attached to multiple layered structures, with flow patterns characterized by various jumps in pressure and velocity fields. Subsequently, by aligning the fault with the interface between adjacent simulation cells of a coarse grid, the upscaling of the reduced flow model gives rise to transmissibility multipliers, whose constitutive response stems naturally from the local flow patterns, exhibiting improved accuracy compared to the traditional harmonic mean, inherent to the two-point flux approximation. Computational simulations obtained with the finite element method with localized discontinuous spaces illustrate the ability of the three-scale model to provide further insight into the behavior of the transmissibility multipliers, which capture the effects of fault zone texture upon the flow discretization. The methodology proposed herein shows enormous potential for the development of more accurate transmissibility preprocessors at relatively low computational costs, consequently overcoming the shortcomings of a direct application of the local high-fidelity approach.

Computational Geosciences
https://doi.org/10.1007/s10596-023-10229-y

ORIGINAL PAPER

Check for updates

A new computational model for karst conduit flow in carbonate reservoirs including dissolution-collapse breccias

Isamara Landim[1] · Marcio A. Murad[2] · Patricia Pereira[2] · Eduardo Abreu[1]

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Abstract

We construct a new computational model to describe coupled 3D/1D flow in carbonate rocks intertwined by a network of karst cave conduits. The proposed approach shows ability to incorporate pointwise velocity-dependent jumps in the pressure field arising from localized partial obstructions due to the presence of collapse-breccia within the discrete conduit network. At the microscale, we postulate single phase viscous flow governed by the Navier-Stokes equations in the conduit network coupled with Darcian flow in the rock matrix and supplemented by transmission conditions at the common interface. Subsequently, we proceed by constructing a sharper lower-dimensional reduced model wherein, in addition to the usual high geometric aspect ratio between the length and hydraulic diameter of the cave system, we introduce an additional small parameter containing the ratio between the localized width of the perturbed flow region, in the vicinity of each breccia, and characteristic length of the network. The asymptotic behavior gives rise to a coupled mixed-dimensional flow, where 1D sub-manifolds appear embedded in the 3D carbonate matrix with coupling ruled by a mass exchange line-source δ-function, acting synergistically with discrete non-linear pressure jumps of Robin type at the discrete set of breccia locations. The mixed-dimensional flow

Featured Paper on CO_2 Storage

Collaboration with LEMTA in France

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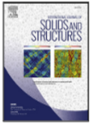

Upscaling poromechanical models of coalbed methane reservoir incorporating the interplay between non-linear cleat deformation and solvation forces

Quoc D. Ha[a], Tien D. Le[a], Irina Panfilov[a], Christian Moyne[a], Marcio A. Murad[b,*]

[a] *LEMTA, University of Lorraine, CNRS, Nancy, France*

[b] *LNCC, Laboratório Nacional de Computacao Cientifica, Petrópolis, RJ, Brazil*

A R T I C L E   I N F O

Keywords:
Three-scale poromechanical model
Enhanced coalbed methane recovery

A B S T R A C T

We construct herein a three-scale coupled mechanical model for naturally fractured coalbed methane reservoir with the ability of describing the stress balance between the solvation force, arising from the gas adsorption in nanopores, and the restoration stress stemming from the elastic response of the cleats. To determine the