Chemical degradation of a numerical material - Application to a Fontainbleau sandstone
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Carbon Capture and Storage (CCS) consists of injecting large quantities of CO₂ in supercritical form directly into deep geological formations e.g. saline aquifers. During geological storage, chemical dissolution induces important and irreversible changes of the rock properties.

Objective: to propose a methodology which allows us to predict the evolution of effective mechanical behaviour of saline aquifers caused by microstructural changes due to CCS.

Advanced Morphological Analysis of Sandstone

The starting point is CT scan of microstructure of Fontainebleau sandstone of size 256x256x 256 px, where 1 px = 5.01 microns.

Numerous types of morphological descriptors: porosity, sizing (granulometry), covariance function, connectivity (tortuosity).

Granulometry Function:
\[ G_r(X) = 1 - \frac{|X \circ B_r|}{|X|} \]
- \( X \) solid phase
- \( B_r \) structuring element of size \( r \)
- \( \circ \) erosion/dilation
- \( |\cdot| \) measure

Covariance Function:
\[ C(X, h) = P \left\{ x \in X, x + h \in X \right\} \]
- \( P(\cdot) \) probability
- \( X \) porous phase
- \( x \) arbitrary point
- \( h \) translation vector

Numerical Dissolution by Morphological Dilation

Chemical dissolution of porous matrix is homogeneous at sample scale [Egermann et al, 2006]. We investigate two different scenarios of dissolution:

Isotropic: \( X_i = X_{i-1} \oplus B \)

Percolated Network: \( X_i = \{X \circ E\} \oplus B \)

Normalized elastic moduli

\[ P(M) = P_0 + \frac{\alpha}{M} \]
- \( P(M) \) computed elastic moduli
- \( M \) resolution
- \( P_0 \) searched value

CT scan is naturally discretised (regular cubic mesh). The influence of such discretization on the estimation of elastic moduli is given by [Garboczi and Day, 1995]:

Permeability - Elasticity Coupling

Darcy’s law:
\[ K = \frac{\mu Q L}{\Delta P A} \]
- \( K \) permeability
- \( \mu \) dynamic viscosity
- \( Q \) flux
- \( A \) surface area
- \( L \) sample length
- \( \Delta P \) grad. of pressure

Coupling: \[ P(K) = 1 - \frac{K^K}{\alpha} \]

Constant characteristic size

Increasing characteristic size