Characterization of type I source rock by pore-scale simulations
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Introduction
Deposits of oil shale occur around the world and the estimates range from 4.8 to 5 trillion barrels of oil in place. Oil shale is a compact (very low permeability, very low porosity), laminated rock containing an organic matter called kerogen. In-situ upgrading process uses heat to decompose the solid kerogen through a series of chemical reactions, the pyrolysis, into liquid and gas hydrocarbons. During the heat-up stage some micro-cracks will propagate wherein the mixture will flow.

There are different origins to this creation of porosity:
- At high temperature, the kerogen starts to transform into volatile matter (pyrolysis),
- Fracturing due to the temperature induces brittle behavior of the solid,
- Fracturing due to the excessive pore-pressure.

We want to represent explicitly the crack propagation and the mixture flowing through the generated micro-fractures.

Modeling strategy

CFD model for oil shale pyrolysis
The model is based on a Darcy-Brinkman formulation in a fixed grid that allows the use of the same formulation both in the fractured area and the solid kerogen.

\[
\frac{\partial \varepsilon_k \rho}{\partial t} = - \dot{m},
\]

\[
\frac{\partial \varepsilon_f \rho_f}{\partial t} + \nabla \cdot (\rho_f \mathbf{u}_f) = \dot{m},
\]

\[
0 = -\nabla p_f + \mu_f \nabla^2 \mathbf{u}_f - \mu_f k^{-1} \mathbf{u}_f
\]

\[
\rho C_p \frac{\partial T}{\partial t} + \rho_f C_{pf} \mathbf{u}_f \nabla T = \nabla \cdot \left( \lambda \nabla T \right) - \Delta H_{pyr} \frac{\partial \rho_k \varepsilon_k}{\partial t}
\]

\[
\dot{m} = \alpha \exp \left( -\frac{E_a}{RT} \right) \varepsilon_k \rho_k
\]

Pyrolysis in existing fracture network
Simulation of 1mm x 0.25mm fractured oil shales when homogeneously heat up at 570 K during 8 min.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>(\rho_k)</td>
<td>1500 kg/m³</td>
</tr>
<tr>
<td>(C_{pk})</td>
<td>2700 J/kg/K</td>
</tr>
<tr>
<td>(C_{pf})</td>
<td>1800 J/kg/K</td>
</tr>
<tr>
<td>(\mu_f)</td>
<td>10^{-5}</td>
</tr>
<tr>
<td>(k_f)</td>
<td>2.5</td>
</tr>
<tr>
<td>(M_{pf})</td>
<td>20</td>
</tr>
<tr>
<td>(E_a)</td>
<td>160x10^6 J/kgmol</td>
</tr>
<tr>
<td>(\Delta H_{pyr})</td>
<td>375x10^6 J/kgmol</td>
</tr>
<tr>
<td>(\lambda)</td>
<td>10^{-13}</td>
</tr>
<tr>
<td>(\varepsilon_k)</td>
<td>10^{-1}</td>
</tr>
</tbody>
</table>

Lattice-Discrete Element Method
In this method, the solid phase is represented by a lattice of springs. When a spring breaks, it is replaced by two sphere elements in contact with each other.

Next steps
- Couple fluid flow and rock mechanics,
- Comparison with ongoing experiments,
- Upscale the results to a Darcy’s scale model.

References
Kobchenko et al., Drainage fracture networks in elastic solids with internal fluid generation, Europhysics Letters (2013)

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