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SPE 155640

Gas Flow Tightly Coupled to Elastoplastic Geomechanics for Tight and Shale Gas Reservoirs: Material Failure and Enhanced Permeability

Jihoon Kim and George J. Moridis
Lawrence Berkeley National Laboratory

Motivation

- Geomechanical responses driven by flow
  - ✓ Subsidence, material failure, geological instability
- Changes in flow by geomechanics
  - ✓ Pore volume, permeability
- Geomechanics and flow closely interrelated
  - ✓ Strain vs. pore volume, failure vs. permeability

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Objectives

- Model accurate coupling of geomechanics and flow for extremely low permeability reservoirs
- Update flow and geomechanical properties and variables dynamically
- Consider permeability change driven by geomechanical failure
- Employ a sequential model or implicit method to make use of existing flow and geomechanics simulators

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Modeling of Coupling

Pore volume

$$\delta\sigma = \overbrace{\mathbf{C}_e\delta\varepsilon_e}^{k\omega} - \alpha\delta p\mathbf{1} - 3\alpha_T K_{\mu}\delta T\mathbf{1},$$

$$\delta\zeta = \alpha\delta\varepsilon_v + \frac{1}{M}\delta p - 3\alpha_m\delta T$$

Permeability

$$k_p = k_0\omega_p, \quad \omega_p\begin{cases} = 1 & \text{if not failed} \\ >> 1 & \text{if failed} \end{cases}$$

Tight coupling between fluid flow and geomechanics

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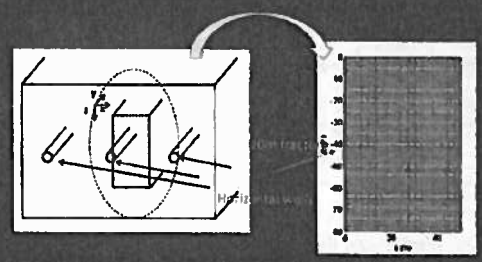
Domain of Simulation



Symmetry & plane strain geomechanics: 3D → 2D

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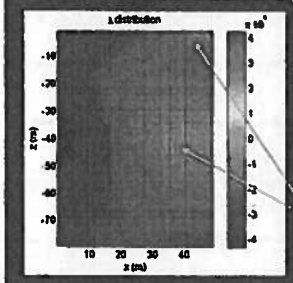
Estimation by Elasticity



Mohr-Coulomb model

$$\lambda = \frac{\sigma'_n - \sigma'_m \sin\Psi_f - c_0\cos\Psi_f}{\sqrt{\sin^2\Psi_f + 1}}$$

Positive values indicate potential failure areas

Failure is anticipated away from the well

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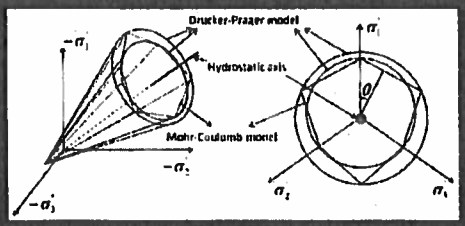
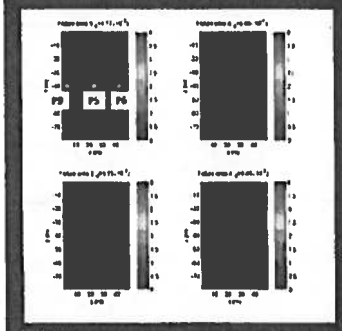
Plastic Models



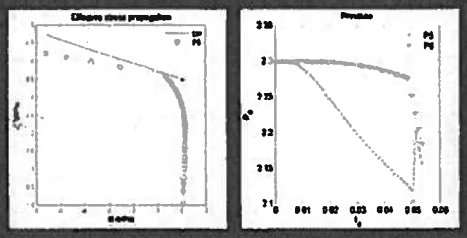
Use Drucker-Prager & Mohr-Coulomb models

Drucker-Prager Model

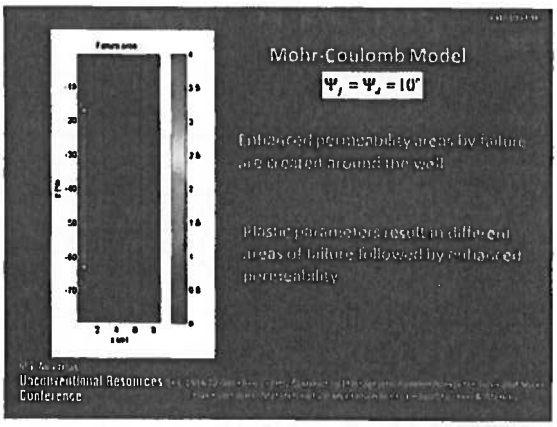


$\Psi_f = \Psi_d = 28.9°$

Enhanced permeability areas by failure propagate from the right boundary



Rock matrix enters plasticity, and then it return to elasticity, resulting in enhanced permeability


Mohr-Coulomb Model
$\Psi_f = \Psi_d = 10°$
Enhanced permeability areas by failure are created around the well
Plastic parameters result in different areas of failure followed by enhanced permeability
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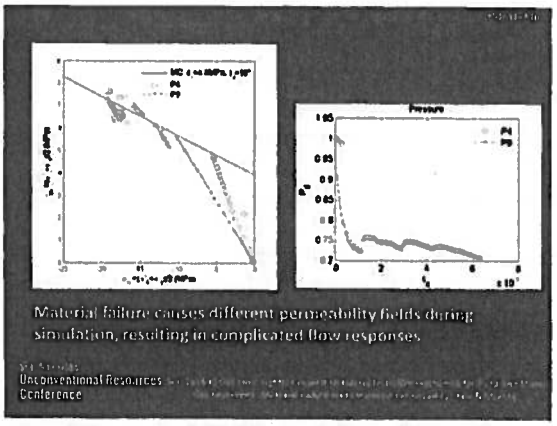
Material failure causes different permeability fields during simulation, resulting in complicated flow responses
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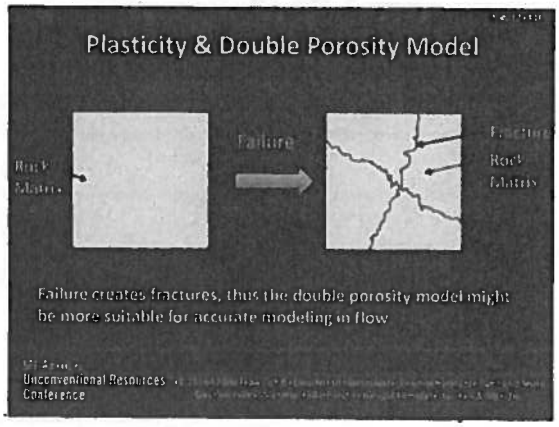
Plasticity & Double Porosity Model
Failure
Rock Matrix
Fracture
Rock Matrix
Failure creates fractures, thus the double porosity model might be more suitable for accurate modeling in flow
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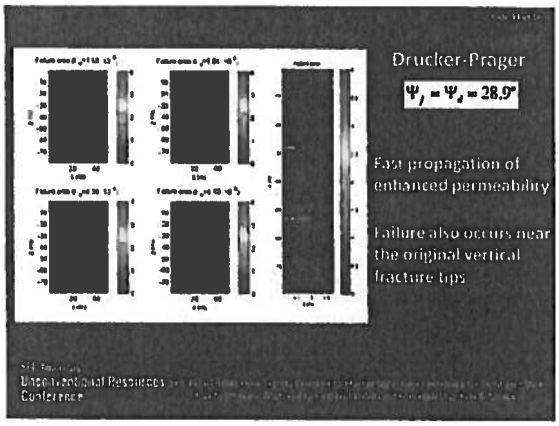
Drucker-Prager
$\Psi_f = \Psi_d = 28.9°$
Fast propagation of enhanced permeability
Failure also occurs near the original vertical fracture tips
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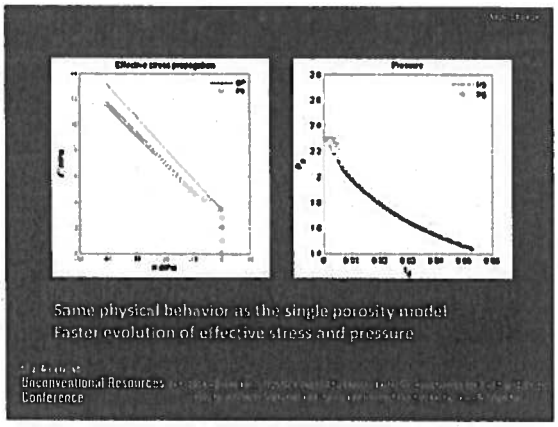
Effective stress propagation
Pressure
Same physical behavior as the single porosity model
Faster evolution of effective stress and pressure
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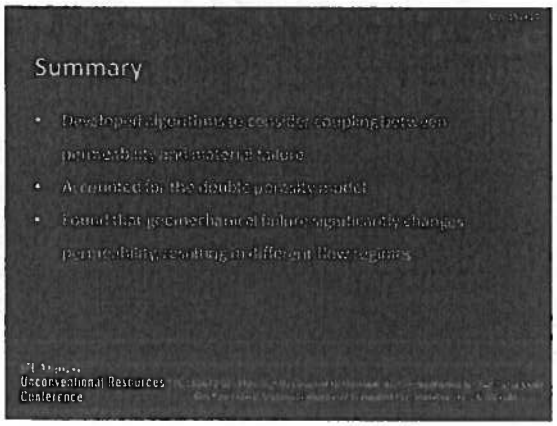
Summary
Developed algorithms to consider coupling between permeability and material failure
Accounted for the double porosity model
Found that geomechanical failure significantly changes permeability, resulting in different flow regimes
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Acknowledgements

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Thank You

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