Accounting for Uncertainty in Dual Porosity Descriptions of Fractured Systems

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Two Worlds

Models **built** by Geologists

Models **used** by Engineers
Naturally Fractured Reservoirs

The Purpose:
- Uncertainty Quantification
- History Matching

The Challenge:
- Geologically consistent
- Field Scale
- Integration with existing Software
... this morning: Scenario Uncertainty

Rejection of Geological Scenarios / Training Images based on the data

Hyucksoo Park, Céline Scheidt and Jef Caers
Can we build Training Images for Fractures?
General Overview of Methodology

- Geostatistics
- History Matching
- PPM
- …

Complex Fracture Models

Limited / Manageable Set of flow-based scenarios for Training Images
The Idea

- Generate Discrete Fracture Network (FracMan)
- Upscale to Effective Properties (grid)
- Decide which cells are Dual-Porosity → pattern
- Run Streamline Simulation (3DSL)
- Select flow responses via pattern-based distances
Upscaling Fracture Model (DFN) to Flow Model

**Fracture Model**

- "Oda (Gold)" (analytical), BlockK (flow based), ...
- "Shape Factor" fracture/matrix interaction Sigma, Gilman & Kazemi, ...
- Fracture Volume

**Effective Properties**

- Permeability $K_{x,y,z}$
- Sigma
- Porosity

1 grid block
**DP model: ON/OFF**

**Effective Properties**
- Permeability $K_{x,y,z}$
- Porosity $\phi$
- Sigma $\sigma$

Threshold: $(K_x,K_y,K_z,\phi,\sigma) > \varepsilon$

**DPNUM pattern**
- ON: fractured
- OFF: non-fractured
DPNUM pattern

SP Model

all cells OFF/ non-fractured

ON: fractured

OFF: non-fractured

all cells ON/ all fractured
Streamline Simulation Model

NX*NY*NZ: 102*86*5
Injectors: 18
Producers: 27
Building the Illustration Case

Varied Fracture Parameters:
- intensity
- size (distribution)
- trend (azimuth)
- orientation (distribution)
- constrained to structure
- 2\textsuperscript{nd} fracture set
→ 96 combinations

Fixed: hydraulic parameters

Fracture Models

Flow Responses

DPNUM pattern

Upscaling to Effective Properties & Threshold
pattern from different perspectives
96 patterns through parameter variation

varied parameters:
- intensity
- size
- trend (azimuth)
- orientation
- cond. to fold
- 2\textsuperscript{nd} fracture set

fixed parameters:
- permeability
- aperture
96 Field Responses: sensitivity to DFN input parameters

Trend (Azimuth) of Fractures

Intensity constraint to structure: yes/no

surface water production

time

surface water production

time
Let's try an approach based on the patterns
Patterns clustered by Modified Hausdorff Distance
96 Field Responses by pattern
Illustration 2
Spatial Uncertainty
Spatial Uncertainty

- Pick 4 DFN parameter sets (distinct patterns)
- Apply 3 variations (trend of fractures)
- Run 10 Realizations of DFN per parameter set
  → 120 Flow Responses
- Group Flow Responses by parameter set
Spatial uncertainty of patterns

12 patterns

conditioned to fold

2nd fracture set

conditioned to fold and 2nd fracture set

10 realizations
Field response by parameter set / pattern

input parameter uncertainty > spatial uncertainty
Patterns clustered by Modified Hausdorff Distance
Field response by pattern

- **Update**: The chart illustrates the field response by pattern over time, with surface water production measured in stb/d. The data is color-coded by pattern, with different colors representing different patterns identified as MHD8, 4, 1, 2, and 3. The x-axis represents time, from 1955 to 1963, in increments of one year.
establishing a new workflow

Fractures

Fracture Model

Upscaling to Flow Model

Effective Properties

Flow Response

aim: translate / replace

complex & CPU demanding

Training Images

• Geostatistics
• MPS
• PPM
• ...

DPNUM pattern

Flow Response
establishing a new workflow

- bypass complexity of DFN modeling & upscaling
- by using fracture patterns as training images
- conserve geologic realism via training images
- simulate fracture patterns directly
- less CPU demanding

training images for fractures

Training Images

- Geostatistics
- MPS
- PPM
- ...

DPNUM pattern

Flow Response

reasonably capture uncertainty
scale?
possible approach

Mariethoz and Kelly (2011)
DOI: 10.1029/2011WR010412
Conclusions

- Translation of DFN Models to Grid/Pattern Domain
- Training Images for Fractures
- Preservation of Geological Realism
- Easy Integration with existing Software
Acknowledgments

FracMan (Golder Associates)

- Neal Josephson
- Aaron Fox
- Glori Lee
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