A SIMPLIFIED MODEL FOR MULTIPHASE LEAKAGE THROUGH FAULTS WITH APPLICATIONS FOR CO_2 STORAGE

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Summary

- We have input a **sub grid scale two phase fault leakage model** into **MRST co2lab**.
- This will provide a **fast and effective** way of including fault leakage in **vertical equilibrium** reservoir simulations.
- Future work is needed to account for **2D effects**, for instance faults spreading over several grid cells.
- We plan to use MRST to develop a **more detailed model for fault leakage** taking into account **different fault properties** and **different conceptual representations** of faults.

Introduction

- Faults are potential leakage pathways for CO_2 during geological CO_2 sequestration.
- Faults are very complex geological features. Simplified models are needed to include the effects of faults on flow in reservoir scale simulations.
- Vertical equilibrium (VE) is a type of reduced complexity modelling which takes advantage of the fact that the vertical fluid migration in the reservoir occurs on much shorter timescales than the horizontal fluid migration.
- VE modelling reduces the model dimensions by one by modelling vertical fluid distribution analytically instead of numerically, thereby reducing the computational cost of reservoir simulations.
- The *co2lab* model in the MATLAB Reservoir Simulation Toolbox (MRST) (Lie 2016) provides an open source VE modelling framework in which we implement our sub grid scale fault model.

Model implementation

MRST co2lab is used to model large scale CO_2 storage in saline aquifers.

MRST can be used on two levels:

- Reservoir simulations can be setup quickly and executed with a few simple commands and only basic knowledge of the source code.
- MRST is also designed to be easily modified, thus allowing users to test their own models and include other features if required. We have taken advantage of this fact when implementing our fault model.

To use our model in co2lab users must specify the grid cell containing the fault and the total leakage flux (the combined flux of both phases) through the fault.

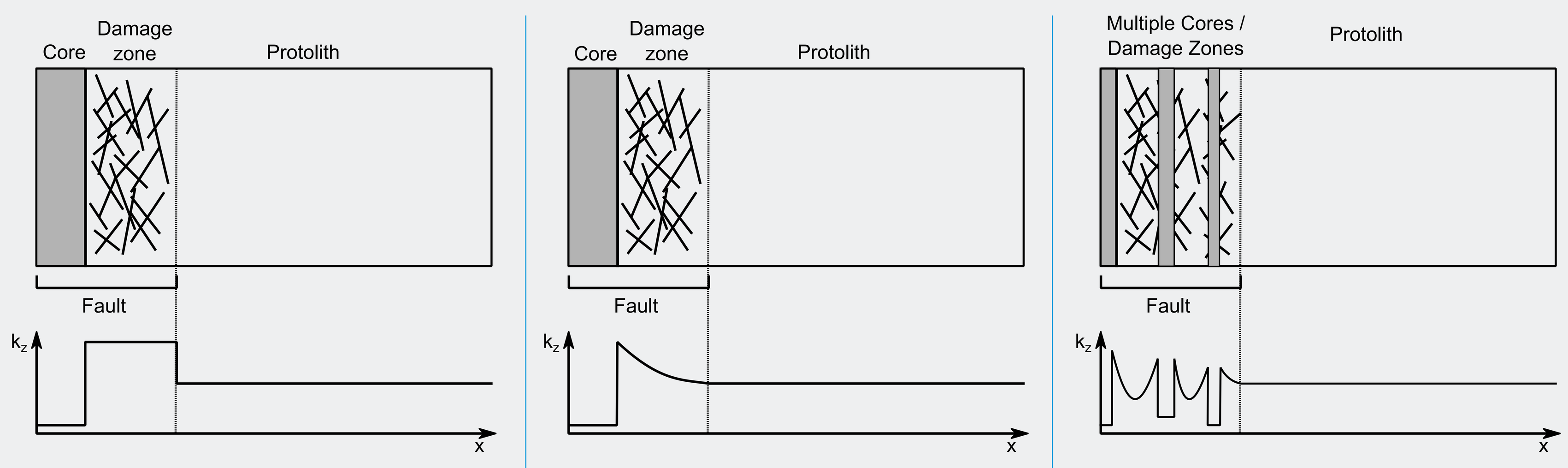
For each grid cell containing a fault the model does the following:

- Calculates leakage rates of CO_2 and brine through the fault using the desired fault model.
- Applies leakage rates as a sink term in the grid cell.

The sub grid scale fault model

- Various conceptual models of fault zones can be found in the literature (see e.g. Faulkner et al. 2010).

Figure 1 Conceptual Fault Models



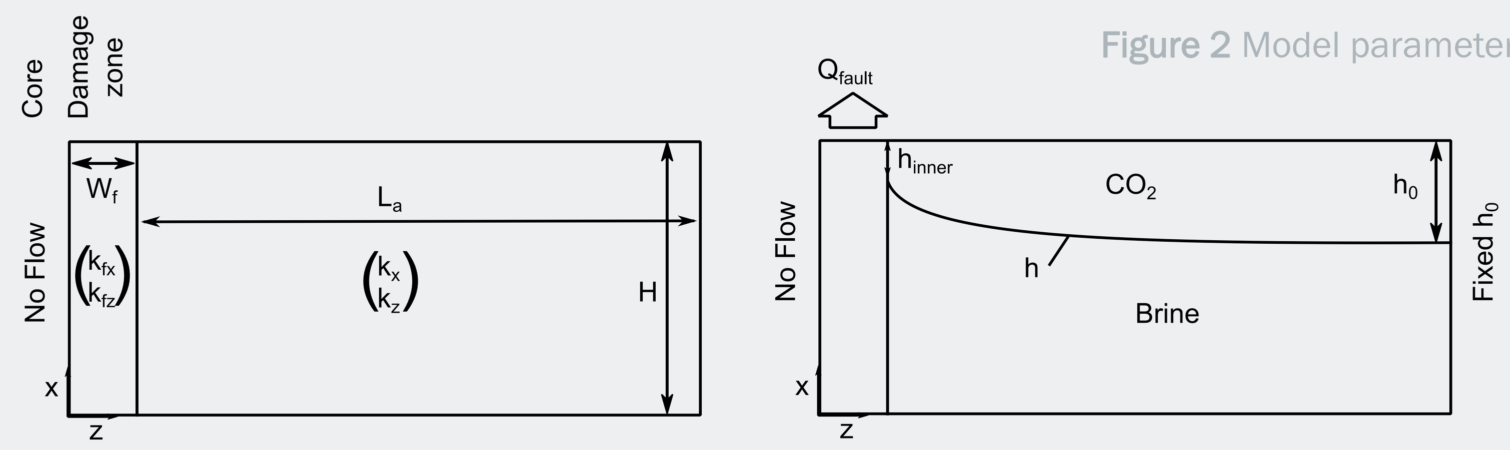
- **Model 1**
- Low k fault core
- High k damage zone
- Constant k_z

- **Model 2**
- Low k fault core
- High k damage zone
- Increasing fracture intensity towards fault core.
- Increasing k_z

- **Model 3**
- Multiple cores and damage zones.
- Varying k_z as a function of distance from core.

- Currently we are using a conceptual fault model based on model 1 above.
- A numerical model has been setup to represent the grid block containing the fault.
- The model for calculating the flux of each phase through the fault has been developed from the work of Kang et al. (2014).
- The fault core is represented by a no flow boundary on the RHS of the model.
- The damage zone is represented by an area with higher permeability compared to the rest of the reservoir.

Figure 2 Model parameters



- A suite of simulations have been run to develop a mathematical relationship where the proportion of each phase leaking through the fault can be calculated given fault properties, h_0 and Q_{fault} (the total leakage flux of both phases through the fault).
- In the VE simulation fault properties and Q_{fault} are specified by the user and h_0 is the value of h (the thickness of the CO_2 column) in the grid cell containing the fault, at each timestep.

Results

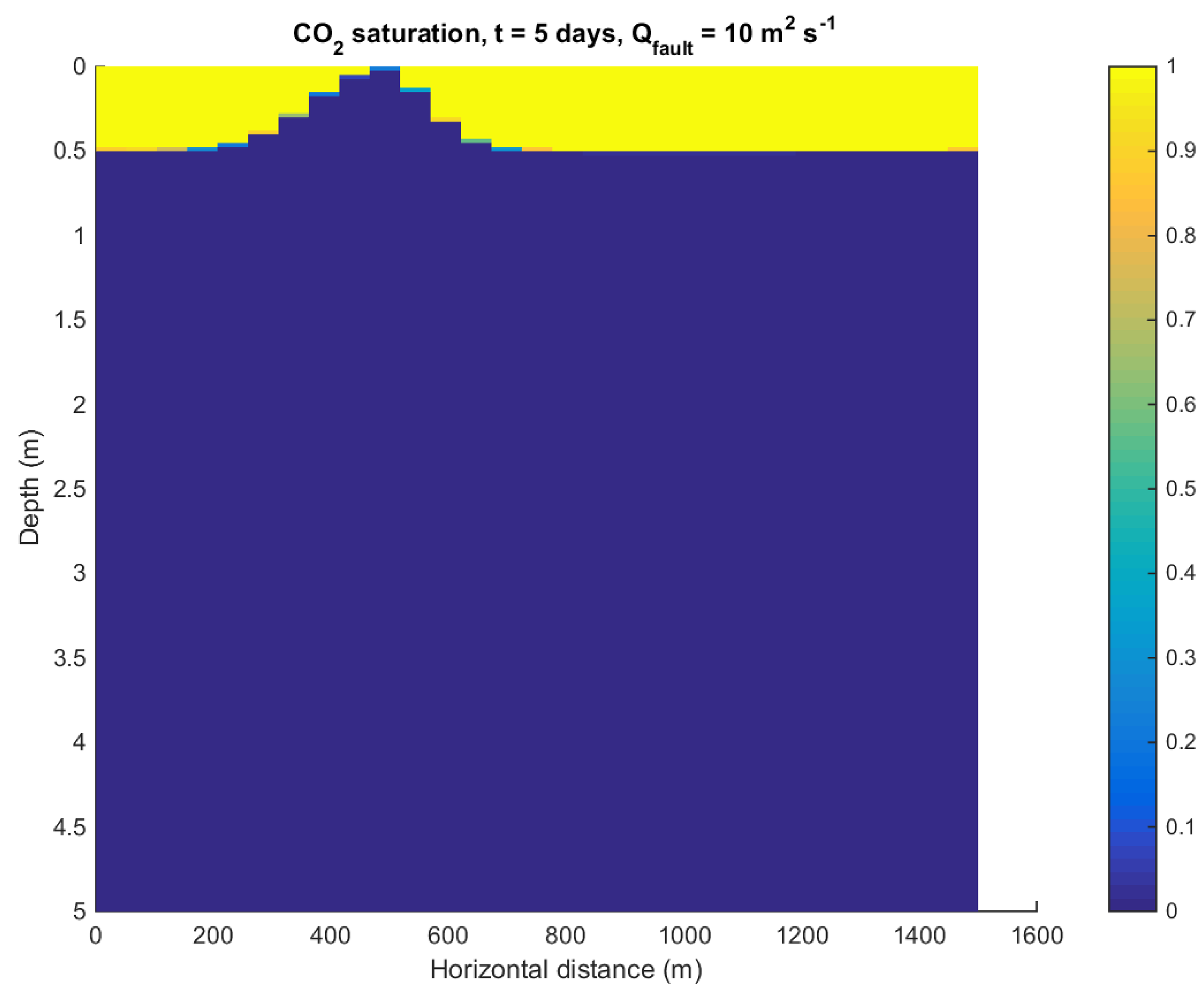


Figure 3 VE simulation results for fault in grid block at x = 500 m. Parameters as defined in Fig. 2 above: W_f = 0.4m, k_{fz} = k_{fx} = 5 D, k_x = 400 mD, k_z = 20 mD, Q_{fault} = 10 m^2 s^{-1}

Future work

- The fault model doesn't take into account the low permeability fault core – fluids are migrating towards the fault from both sides.
- In the future we need to use something **more sophisticated than a simple source** term which **includes the geometric parameters** of the fault in the subscale model.
- The fault model has only been implemented within 1D VE simulations (i.e. horizontal flow in the x direction plus VE solution in the z direction).
- Future work will involve developing a representation of **flow within the fault in 2D**.
- Only the simplest conceptual model has been considered so far.
- We will **develop further fault models** for **different conceptual fault representations** and fault properties.

Acknowledgements

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