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Introducing geomechanics and discrete fracture capabilities into STOMP to understand the first 10-100m of UNE signal transport

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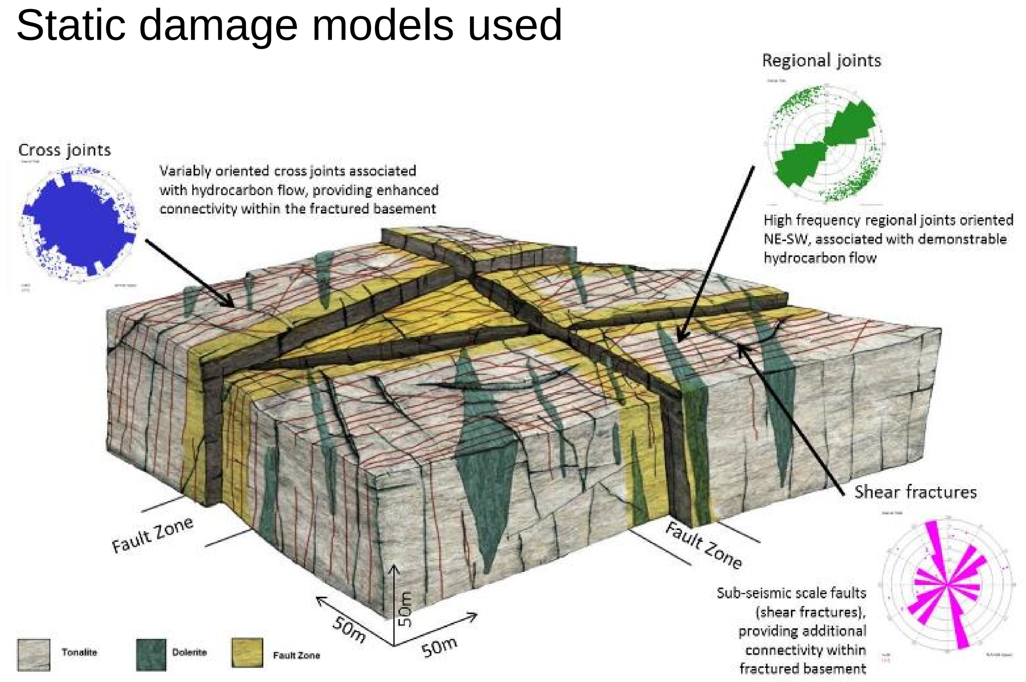
We discuss how the additions of direct geomechanical stress and discrete fracture simulation capabilities into transport codes like STOMP are critical to furthering understanding of early time evolution of radionuclide signatures in the immediate vicinity of a UNE.

Problem Statement

A critical gap remains in end-to-end models of Underground Nuclear explosions (UNEs) with respect to early time material signature transport.

Flow and transport codes generally treat early time material propagation by:

- Starting material inventory concentrated in a tiny, discrete volume
- High temperature and pressure initial condition
- Static damage models used



Various types of "fractures" encountered in UNE scenarios.

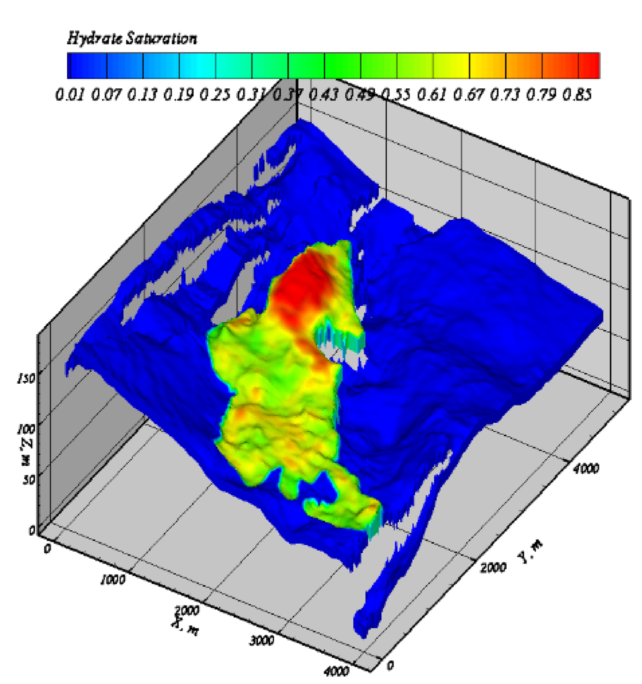
Goals for this work:

Improve Subsurface Transport Over Multiple Phases (STOMP) to improve simulation of early time UNE signatures through:

- Geomechanical stress response
- Discrete fracture modeling

STOMP

STOMP is a suite of computer codes developed at PNNL to simulate coupled thermal, hydrologic, geomechanical, and geochemical processes in geologic media. It has been used to simulate mass transport in a wide range of situations including environmental remediation, reactive barriers, and geothermal reservoirs.



STOMP simulation of contaminant flow.

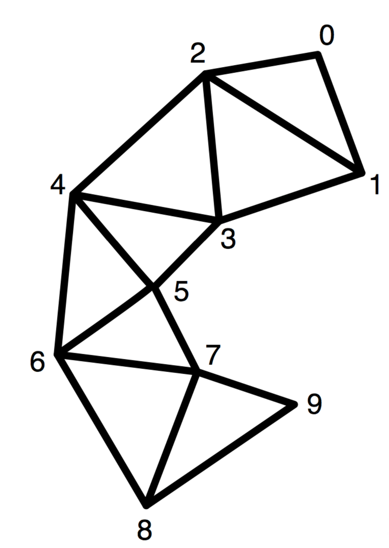
Implementation of Geomechanical Stress and Discrete Fractures

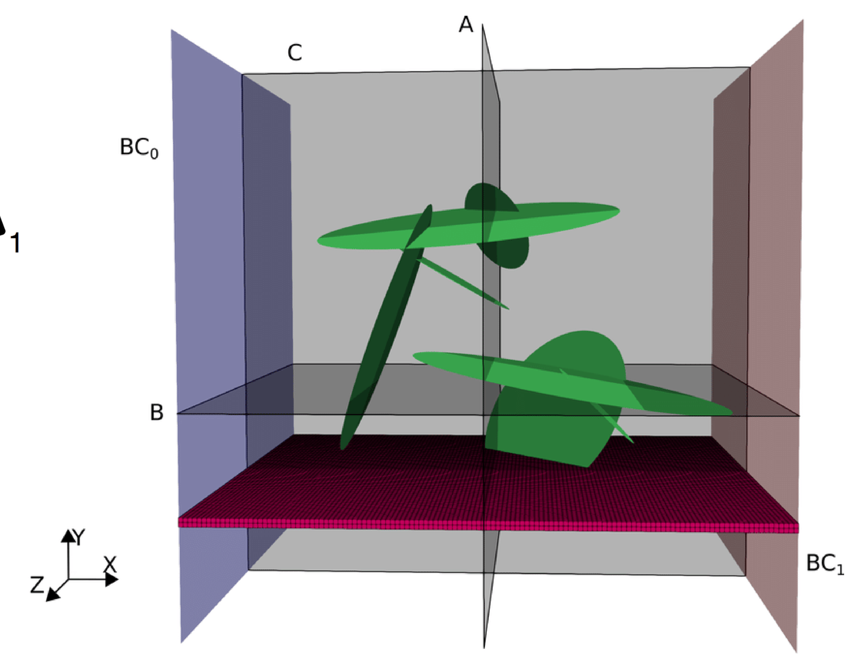
STOMP-GT (GeoThermal) has been developed to simulate coupled flow and transport of air, water, salt, and conservative and reactive species in a non-isothermal environment.

Discrete fracture modeling has been added to the STOMP-GT mode.

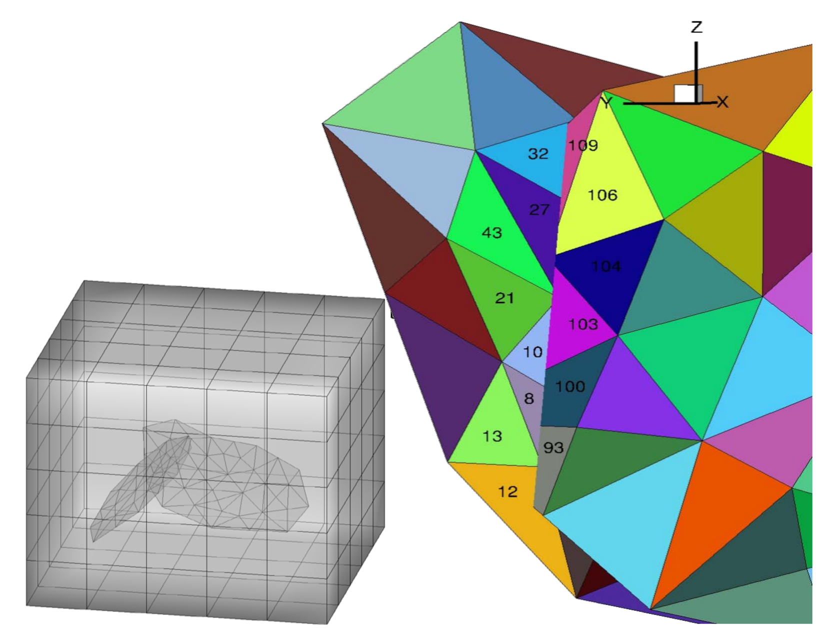
- Fractures are modeled as planar triangles with dynamic apertures.
- Fractures overlay a porous material matrix, discretized into hexahedrons that are used to compute fluid flow through the matrix and geomechanical stress.

Geomechanical stress can be applied to the network which determines the fracture aperture size, and thus the permeability.





Example of embedded fractures and fracture tessellation



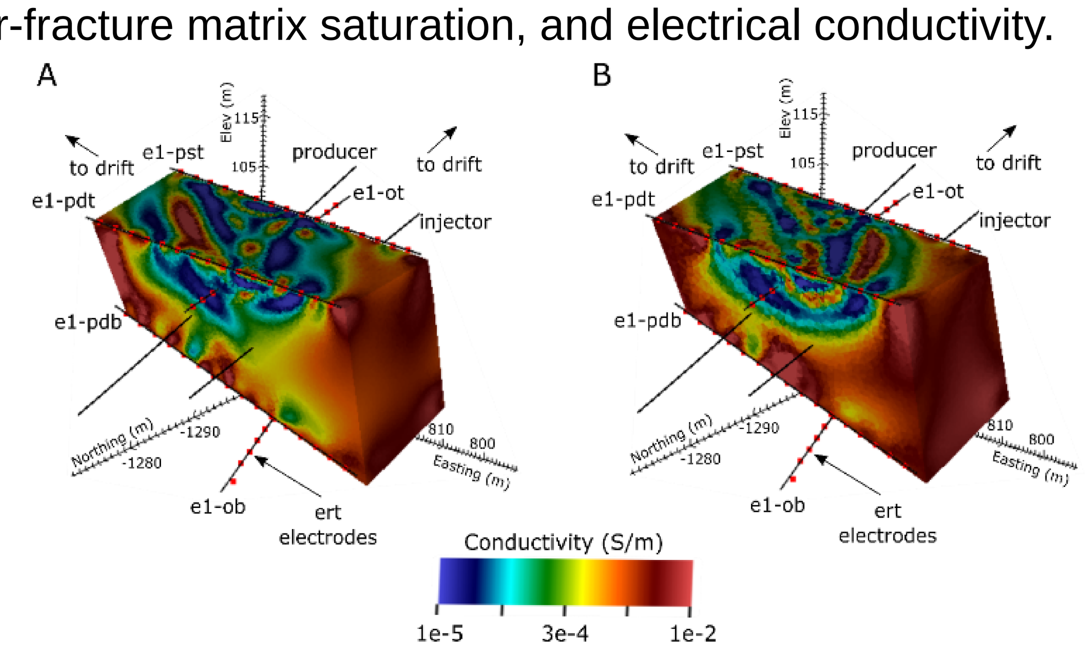
Intersecting fractures require pathway weighting algorithms to determine exchange.

Applications

Introduction of discrete fractures into STOMP-GT has the potential to dramatically improve the fidelity of simulations of real-world scenarios, including injection experiments, geomechanics, and impacts of large "fractures" such as tunnels on transport.

- Injection boreholes
- Sampling boreholes
- Tunnels
- Faults
- Known fracture distribution

STOMP-GT can potentially be coupled with electrical resistivity tomography (ERT). Inverse approach allows ERT to inform STOMP and aid in the calculation of the change in parameters such as fracture aperture, fluid composition, near-fracture matrix saturation, and electrical conductivity.



STOMP-GT coupled with ERT imaging can be used to estimate changes in conductivity..

Abstract

Substantial effort has gone into research on the evolution of UNE signatures within the below and above ground environments as a result of natural, relatively slow transport mechanisms. Dynamics of signature evolution in the subsurface just after UNE detonation (e.g. fractionation of volatile noble gas precursors) have been increasingly demonstrated to have critical influence in determining eventual noble gas signatures exploited by monitoring technologies. Traditionally, subsurface transport modeling using the Subsurface Transport Over Multiple Phases (STOMP) code and other similar simulators have largely treated the early-time UNE environment very simplistically as an ill-defined, high temperature and pressure "energy pill" or have even begun simulations with some generic initial distribution of the radionuclides under the assumption that the early time dynamics took place rapidly and have concluded. In an effort to bridge this gap in UNE signature simulation capability, geomechanical and discrete fracture simulation capabilities have been implemented in STOMP to more directly assess the impact of early time rock damage and high temperature and pressure induced transport on UNE signature evolution. An overview of these implementations along with results of initial scenario simulations and projected future work will be presented.

Conclusions

- The combination of dynamic geomechanical stress response and discrete fractures in transport simulations allows for closer coupling of geologic damage and permeability to be evaluated in early time UNE simulations.
- Past research has indicated the importance that transport in the first few meters has on the eventual fate of material signatures reaching the surface.
- These improvements in STOMP will go a long way towards filling this gap in current end-to-end UNE signature modeling

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