PorousM3, a Finite Element 2-D and 3-D Porous Flow Modeling Code Being Developed to Model Carbon Sequestration

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We present a 2D and 3D MATLAB based finite element code, PorousM3, that models multi-phase fluid flow in a porous medium. PorousM3 solves for a Darcy pressure field using a multi-grid preconditioned conjugate gradient solver. The code is fully parallelized and can run four million degrees of freedom on an 8 gigabyte node. Testing shows that it scales linearly to at least sixteen nodes. Models are constructed using 6-node quadratic triangles or 10-node quadratic tetrahedral elements for pressure. We use unstructured meshes at interfaces with rapidly changing permeability to increase accuracy. This lets us model fault systems, pinch-outs and stratigraphic interfaces by creating areas of very high resolution and specifying permeabilities in those regions. Fluids and their associated temperatures are advected by calculating velocities from the pressure field and temperatures also are diffused in each time step based on the thermal conductivity at each node. We handle multiple fluid phases by tracking each phase's properties at each node and creating chemical rules for interactions between phases. We are applying our code to the strata around the AES Cayuga power station in Lansing, New York as part of a NYSERDA feasibility project on the potential for carbon capture and sequestration in the area. Our models are based on seismic data provided by Anschutz Exploration Corporation and estimated rock properties from well logs. The results are preliminary and show the need for greater constraints on the physical parameters of the target strata and a high degree of variability in flow depending on how regional jointing is modeled.