Ancient CPU-GPU simulation of evolving fracture networks in a poro-elasto-plastic medium with pressure-dependent permeability

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Fluid flow in the earth is controlled by fracture networks that evolve in response to far field stress, local stress perturbations, and the pressure state of the fluid within them. The se-processes are very important for many geophysical systems, including earthquakes and volcanoes. Modelling the underlying physics is challenging because the time scales involved, from the elastic wave speed of crack growth to pressure diffusion and flow, make the se-problems numerically cumbersome. Our approach to model the se-processes is to couple the elastic-plastic response of the solid porous matrix to a pressure dependent (nonlinear) diffusion model for the fluid flow. Changes in the fluid pressure introduce changes in stresses in the porous media, which may lead to either hydro-facture or shear fracture

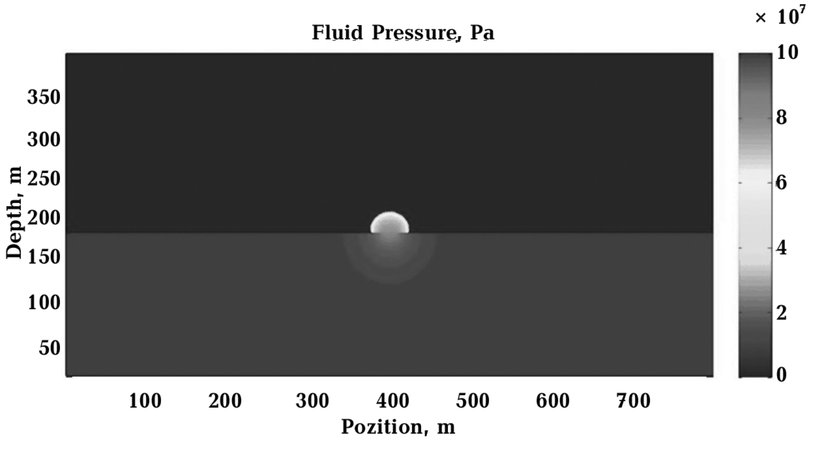

Fig. 1. CPU-GPU Poro-elasticity: 800×400points, grid size of 25 m. One day of simulation. Computation time: 42 min.

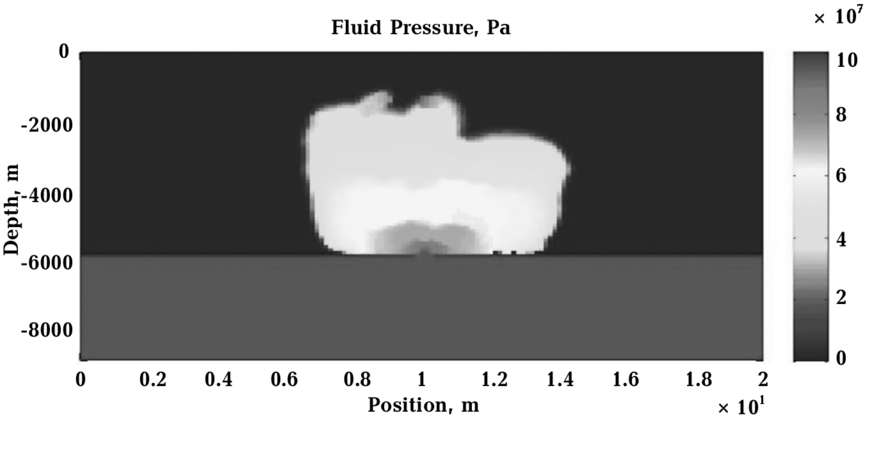

Fig. 2. Poro-elasto-plastic CPU (MATLAB): 150×100 points. Grid size is133 min *X* and 90 min *Y*. One day of simulation. Computation time: about 7 hours.

within the solid. See page forces, forces related by gradients of pore pressure, can also promote delocalized crack formation. Many models of fracture propagation have been developed using finite elements or other numerical methods in order to overcome the high deformation of the grid, however costly re-meshing algorithms are necessary to accurate model the evolving crack. The complete model, nonlinear diffusion and poro-elasto-plasticity, is very computationally expensive. GPU technology allows high resolution modelling and easy implementation of explicit finite difference methods in an efficient way. We have taken advantage of many-cores GPU technology together with CPU and developed a high-resolution fully explicit finite difference model of nonlinear diffusion coupled with the mechanical response of poro-elasto-plastic medium (Fig. 1). In our algorithm, we can model both the propagation of previously de?ned fractures and fracture generation and growth in response to the evolving stress field. Our model includes shear and tensile cracking, which plays a dominant role in the hydraulic properties of the poro-elastic media as well as changes in the rheological properties. High resolution 2D simulations are presented showing the hydro-mechanical evolution of systems driven by high pressure sources at depth, such as some aftershock sequences and with application to volcano-mechanics. Using CPU-GPU approach numerical resolution can be increased to more than three times and computational time is decreased as much as at enth-compared with the CPU alone approach (Fig. 2).

Thermal conductivity of the deep Earth's minerals

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Knowledge of thermal conductivity of the deep Earth's materials is critical for understanding of the Earth's thermal structure, evolution, and dynamics. Here we report on direct measurements of the lattice and radiative thermal conductivity of mantle and core materials under the pressure-temperature (*P-T*) conditions approaching those in the Earth's mantle and core by using optical spectroscopy and pulsed laser techniques in diamond anvil cells (DAC).

We developed and tested a new flash-heating high-pressure technique to measure thermal diffusivity, which involves time-resolved radiometry combined with a pulsed IR laser source [Beck et al., 2007]. The results for MgO, NaCl, and KCl obtained to 32 GPa and 2600 K agree with previous studies at low pressure and high temperature and enable tests of models for the combined pressure-temperature dependence of thermal conductivity. Preliminary results on the thermal conductivity of magnesium silicate perovskite to 125 GPa and 4000 K and [Goncharov et al., 2010] suggest a larger value than what was previously estimated, although the uncertainty is very large. Future accurate experimental measurements of the phonon contribution to the thermal conductivity of lower mantle materials will require a number of carefully crafted experiments under high pressure and temperature conditions to determine the thermal conductivity of all the materials used in the DAC. Measurements of the thermal conductivity of Ar are currently in progress and they will be presented at the meeting.

To determine the thermal conductivity of Fe and its temperature dependence at high pressures we use combined continuous and pulsed laser heating techniques. A thin plate of Fe is positioned in a medium (e.g., Ar), laser heating is applied from one side and the temperature is measured from both sides of the sample radiometrically. The thermal conductivity is determined by fitting the results of finite element calculations to the experimental results. This work is currently in progress.

Another technique of measurements of the thermal conductivity, time-domain thermoreflectance (TDTR), has been recently applied for the DAC studies [Hsieh et al., 2009]. A collaborative study of the thermal conductivity of MgO single crystal (as a benchmark sample) at high pressures with a group of Prof. D. Cahill (University of Illinois) is currently in progress, and the preliminary results will be reported at the meeting.

We will also present optical absorption data for lower mantle minerals to assess the effect of composition (including iron oxidation state), structure, temperture, and iron spin state on radiative heat transfer. The ultimate goal is to determine through these measurements the radiative thermal conduc-