Proposal: Development of a CIG Magma Dynamics Demonstration Suite

Introduction & Rationale: Magma dynamics is an essential process linking observable geochemistry to geodynamics and a fundamental feature of plate boundaries. It should be a crucial component of models of mid-ocean ridges and subduction zones; however, it is seldom included in existing geodynamics models due to the lack of readily available software that includes consistent coupled solid and fluid flow. The goal of the August 18-19, 2006, CIG sponsored Magma Migration workshop was to review the current state of magma dynamics theory and computation and to suggest mechanisms to begin incorporating magma dynamics into existing CIG efforts in solid-state mantle and lithospheric deformation. The workshop identified a well-understood formalism for magma transport in ductile mantle systems (e.g., McKenzie, 1984) as a tractable starting point for a variety of theories for melt transport in the ductile mantle. Here we propose a one-year demonstration project to test the feasibility of integrating magma dynamics into existing CIG software frameworks and provide the first publicly available codes for coupled magma/mantle dynamics. This project is proposed as a direct partnership between the Magma Dynamics working group[1] led by Marc Spiegelman at Columbia University and the Victorian Partnership for Advanced Computing (VPAC) to jointly develop a benchmark suite and documented open source codes on behalf of CIG.

Development Road-map & Strategy: The basic formulation for magma dynamics, as well as a concrete set of benchmark problems culminating in 2- and 3D mid-ocean ridge models, is laid out in a set of notes developed as an outcome of the CIG Magma dynamics workshop[2]. In particular, this document lays out a systematic sequence of benchmark problems including

- Tests for accurate dynamic pressures in existing solid deformation codes (CitCom/Gale/StGermain, VPAC)
- High accuracy code verification suites for time-dependent magma migration (1,2 & 3D solitary wave solvers, Spiegelman)
- Experimentally validated codes for melt-localization due to mantle-shear (Katz et al., 2006)
- 2- and 3D mid-ocean ridge spreading center models with adiabatic melting.

Many of these problems already have an existing parallel code base from either VPAC or Spiegelman's group (developed using PETSc). While most of the existing magma dynamics codes were developed as "research codes" (e.g., they are not well documented

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[1] The Magma Dynamics working group currently includes Marc Spiegelman (Columbia University), Ritske Huismann (Bergen University), Garrett Ito (U. of Hawaii), Richard Katz (Cambridge University), Boris Kaus (ETH Zurich), Laurent Montési (WHOI) and Benjamin Phillips (Los Alamos National Laboratory). The working group is open and invites active participants.

[2] http://geodynamics.org/cig/workinggroups/magma/workarea/benchmark/McKenzieIntroBenchmarks.pdf

or designed for reuse), they provide workable, understood algorithms and results for the full range of benchmark problems. The purpose of this proposal is to re-engineer these algorithms using modern software engineering and existing frameworks into a publicly available, well-documented demonstration software suite for solving magma dynamics problems culminating in 2- and 3D models of mid-ocean ridges with forced adiabatic melting. In this first project, we will focus primarily on the equations for mass and momentum conservation with simplified melting parameterizations. We do not propose to develop a highly generic "reactive flow with full thermodynamics" code – that is beyond the efficient and reusable capabilities of known solvers. Nevertheless, we will build a series of useful and efficacious solvers based on known codes and capabilities, with a long-term goal of integration, based on feedback from the user community from the solvers developed in this proposal.

The specific proposal is for VPAC to supply 0.75 FTE's to implement a suite of well-designed and supported open-source-codes, based on existing algorithms for magma dynamics and existing frameworks and libraries including St. Germain and PETSc. The professional software engineers at VPAC will do the primary code development. The Magma dynamics working group will provide scientific, algorithmic and theoretical expertise in both magma dynamics and solid deformation along with working codes for specific benchmarks. The working group will also provide a dedicated set of users to test these codes and provide a forum for community feedback. As usual, all codes developed during this project will be available through the CIG software repository. While there are clearly identifiable technical issues involved in developing these multi-physics codes, a dedicated partnership between specialists in magma dynamics, solid deformation with complex rheologies (e.g., Gale) and computational science should rapidly determine the feasibility of further code development, while providing high-quality user-friendly software to the community.

Proposal and Requested Resources: This project would be incorporated into the existing VPAC subcontract to CIG and support .75 FTE. As StGermain is the underlying framework for Gale, this partnership should also allow for the eventual integration of crustal and lithospheric fluid flow into CIG. This proposal also requests travel funds for several face-to-face meetings in NYC, Melbourne, and/or Pasadena for intensive software and algorithmic design sessions between developers and members of the working group with specific expertise. Most correspondence and development, however, should occur electronically through e-mail, conference calls (e.g., Skype) and the CIG software repository. The general road map for development follows from the Magma Dynamics Benchmark document with a rough time-line of one year to the implementation of a useable 3D code for time-dependent magma-migration at mid-ocean ridges.