The development of stgMaDDS – the Magma Dynamics Demonstration Suite on StGermain

A collective explorative development effort between CIG & AuScope Simulation & Modelling through VPAC

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The aim of stgMaDDS was to implement the CIG Magma Migration working group's series of benchmark models [1], "the MAgma Dynamics Demonstration Suite" to assess the feasibility of building these into an existing computational framework StGermain currently used for GALE. These models were specifically designed to highlight and benchmark the fundamental numerical and software challenges in developing the next generation of magma migration codes. In particular, to explore the computational issues in developing tightly coupled multi-physics fluid/solid solvers for FEM models at the mid-ocean ridge scale.

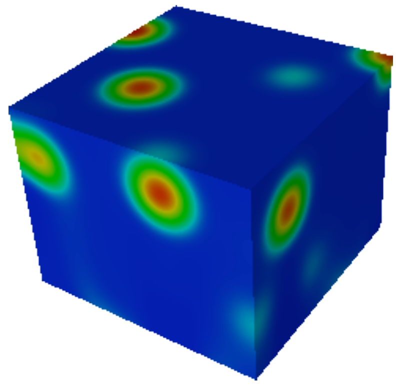

Figure 1 - From benchmark 4: A collection of 3-D solitary porosity waves

The effort began with discussions about Stokes and multi-scale and multi-physics solvers between Marc Spiegelman and Steve Quenette at CMG2006 in Israel. At that time CIG and VPAC were developing GALE based on Underworld through the StGermain approach and framework. This approach enables a 'building blocks' view of the complex numerical and physical problem. At the Magma Migration working group meeting at Columbia University a piece-wise approach was decided based on incrementally solving the steps of the benchmark models.

The processes are modelled via a coupling of Stokes flow for the solid phase and Darcy's law for the flow of the melt through this deforming permeable material. The porosity field is dynamic and evolves in time in response to sold advection, compaction and expansion of the solid phase driven by fluid pressure and the degree of melting. The rate of asthenospheric melting is currently described via a simple productivity function proportional to the rate of decompression which may be modified with negligible affect on the rest of the code. More complex thermodynamic coupling, requires a larger multi-physics framework.

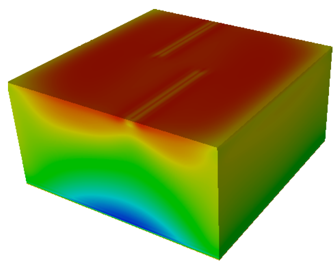

Figure 2 - From benchmark 5: A fully coupled isoviscous McKenzie system

Development

VPAC appointed Dave Lee under the direction of Spiegelman, Luke Hodkinson and Steve to develop the software. Subsequently Dave May become involved as an early test case for his block matrix extensions to PETSc. Spiegelman invested some time to reformulate the benchmarks to better suit numerical models.

The benchmark codes are available, with commentary at http://www.geodynamics.org/cig/workinggroups/magma/workarea/benchmark. The activity has been highly beneficial to all parties involved. In particular, once implemented and correctness was proven, the emphasis has shifted to the development of adequate pre-conditioners. Marc has subsequently pursued methods and environment to explore pre-conditioner development. VPAC has subsequently begun developing a PDE level to its high level language, enabling much of the MaDDS problem to be described without having to write C or StGermain object code.

1. 'An Introduction and Tutorial to the "McKenzie Equations" for magma migration', Marc Spiegelman, Richard Katz and Gideon Simpson - http://www.geodynamics.org/cig/workinggroups/magma/workarea/benchmark/McKenzieIntroBenchmarks.pdf