Delamination of Sub-Crustal Lithosphere

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Abstract

Introduction:
Lithospheric delamination beneath the western U.S. is believed to be the driving mechanism responsible for the evolution of magmatic and topographic features observed at the surface in the western U.S.. This process requires hot asthenosphere to be in contact with the underside of cold sub-crustal lithosphere and believed to be initiated by the Yellowstone hot spot plume that due to North American plate motion was previously beneath eastern Oregon and responsible for the Columbia River flood basalt eruptions, and now is under the Yellowstone Caldera. This hotspot plume provides the heat needed for buoyancy for uplift of the Colorado Plateau and among other features is responsible for the uplift needed for the Colorado River to carve out the Grand Canyon. This project aims to understand the nature of lithospheric foundering mechanisms and controlling parameters through finite element simulations of these processes and their evolution with time with the goal of better understanding how the delamination process formed western U.S. topography and produced the observed magmatic events through geologic time.

Use of COMSOL Multiphysics® software:
The weakening role of magma emplacement will be investigated as a delamination genesis. Where the weakening effect of magma (melt) bodies is inferred, based on the calculations for its generation and emplacement (from a related project), it will be simulated by incorporating small domains that have prescribed melt-like properties. The appearance or disappearance of finite magma bodies in our models will be accomplished by adding a threshold temperature/pressure/composition condition term to our viscosity parameterization (rule) in our flow equations. This will be used to mimic both melting and freezing effects on viscosity (i.e., when pressure/temperature/composition conditions are met for melting, viscosity decreases rapidly, and when they are not right for melt conditions the viscosity is not changed and is governed by our viscosity rule devoid of melt). We also include a term for latent heat of melting or freezing, in a similar fashion, to the energy balance equations when these melt conditions are met. These rule-based customized parameterizations are easily implemented in COMSOL, are fully coupled between the flow, conservation of mass and momentum, and energy balance equations.

Results:
Recent results by Vincent (2011) using COMSOL to develop an isothermal non-Newtonian two-

phase crystal suspension (thixotropic rheology) flow model illustrates the ability of COMSOL to handle complex nonlinear fluids with high density contrasts. In that simulation, plaster is injected into water to avoid numerical instabilities from the high-density contrast between plaster and air. The plaster injection simulation shows the plaster move in a plug-like manner into the upper collection chamber as the plaster (lava) dome grows. These behaviors, and the presence of a more intense shear front along the periphery of the dome, demonstrate COMSOL's ability to handle complex nonlinear fluids and high-density contrasts that we will employ in our delamination project described here.

Conclusion:
We will show preliminary results of our work at the 2014 COMSOL conference in Boston.

Reference

Paul Vincent, Prokop Zevada, Numerical and analogue models of lava dome dynamics, COMSOL Annual Conference, Boston, MA, October, 2011.