Intrusive magmatism on terrestrial planets: what can we learn form elastic-plated gravity current models ?

Clément thorey
IPGP
thorey@ipgp.fr

June 9, 2015

Key words: Magmatic intrusions, Elastic-plated gravity current, Thermal processes, Rheology, Temperature-dependent viscosity, Elastic sheet, Laccolith, Sill, Earth, Moon, Low-slope domes, Floor-fractured craters, Elastic-sheet thickness, Crater depression, Gravitational anomalies.

Abstract

When magma is forced to the surface, only a small amount of it actually reaches that level. Most of the magma is intruded into the crust where it solidifies into a wide range of features, from the small scale sills and laccoliths to large scale batholiths (several hundred kilometers in size). On Earth, these magmatic intrusions are often exposed at the surface by later erosion and geophysical sounding can provide information on their presence, morphology and growth even at depth. On terrestrial planets, our only way to probe the importance of intrusive magmatism is to look for surface deformation produced by eventual shallow magmatic intrusions. On the Moon for instance, several morphological structures have been proposed to result from the emplacement of shallow magmatic intrusions such as low-slope domes in the lunar maria or the atypical floor characteristics of floor-fractured craters. However, such observations must be linked to dynamic models of of magma emplacement at depth in order to provide insights into magma physical properties, injection rate, emplacement depth and the intrusion process itself.

In this thesis, we first investigate the relation between the final shape of shallow intermediate-scale magmatic intrusions (sills and laccoliths) and their cooling. We propose a model for the spreading of an elastic-plated gravity current with a temperature-dependent viscosity that accounts for a realistic magma rheology, melt crystallization and heating of the surrounding medium. The mechanisms that drive cooling of the intrusions vary from the Earth to the Moon and the ability of the model to reproduce the final morphologies (aspect ratio) of terrestrial laccoliths and low-slope lunar domes is examined.

On the Moon, emplacement of magmatic intrusions into the crust has also been proposed as a possible mechanism for the formation of floor-fractured craters. We propose a model for an elastic-plated gravity current spreading beneath an elastic overburden of variable thickness. We find that several characteristics of floor-fractured craters are indeed consistent with the emplacement of a large volume of magma beneath their floor. In addition, using the unprecedented resolution of the NASA's Gravity Recovery and Interior Laboratory (GRAIL) mission, in combination with topographic data obtained from the Lunar Orbiter Laser Altimeter (LOLA) instrument, we show that lunar floor-fractured craters present gravitational anomalies consistent with magmatic intrusions intruding a crust characterized by a 12% porosity. The implications in terms of lunar evolution are examined.