Simplifying assumptions in volcano modeling: are we missing something crucial?

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Volcanoes are extremely complex natural systems, in which the interplay of different forces and physical processes determines a variety of behaviors that can be hard to interpret. The deep magmatic systems cannot be directly observed, and we must rely on indirect information. The latter typically consists of data from a variety of monitoring techniques, be it geochemical, geohpysical or petrological. Even though technology is making gorgeous improvements in terms of resolution and quality of collected data, it is still not obvious and univocally determined how to interpret them in terms of deep processes. Physical models of volcanic systems try to capture the essence of these processes, even though they are limited by the intrinsic uncertainty of initial and boundary conditions, as well as by the necessary simplifying assumptions that need to be made in order to make the system mathematically manageable. We try to assess the importance of some of the most commonly employed assumptions, and show that results are very sensitive to the choices made.

Results from forward modeling of magmatic processes, such as the arrival of magma from depth into an established, shallower reservoir, show that the patterns of pressure and density variations are complex both in space and time (Longo et al., 2012). Even within a relatively small magma chamber, there are regions undergoing pressurization and others being depressurized, evolving with time. Conversely, the most common models for the inversion of deformation data assume that the source is uniformly pressurized (e.g., Mogi, 1958). Therefore, inversion of synthetic data obtained from forward modeling does not reproduce the actual synthetic sources of deformation: preliminary results show that magma recharge into an already established reservoir does not have any signature in the deformation signal. On the other hand, inversion of gravity anomaly data is able to identify more precisely processes that involve complex space-time variations of density, including replenishment of emplaced reservoirs. It is thus evident how our assumptions can bias the understanding of complex volcanic processes. On the other hand, it is obviously impossible to describe such systems in complete detail: when should we stop approximating? Defining the processes that determine the first-order behavior of a volcanic system is a much needed but extremely hard goal to achieve.