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Numerical simulations of the dynamics of shallow magma chamber replenishment.

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The evolution of shallow magma chambers is often described as occurring through the arrival of discrete subsequent pulses of volatile-rich magma from deeper regions below the volcano. In several cases, including the Mount St. Helens eruptions in the eighties, the 1991 Pinatubo eruption, the 4100 BP Agnano Monte Spina eruption at Campi Flegrei, and many others, the arrival of deep magma has been found to have shortly preceded and probably triggered the occurrence of an eruption. Here we simulate the dynamics of shallow magma chamber replenishment, with reference to conditions selected as being representative of the Campi Flegrei system. The finite element fluid dynamic code GALES, appositely developed during last years, solves the fundamental transient 2D mass, momentum and energy equations for compressible to incompressible multicomponent homogeneous magma carrying an H_2O+CO_2 gas phase in thermodynamic equilibrium with the silicate melt. The system conditions have been defined in the frame of a large project consortium including scientists from different disciplines, experts on Campi Flegrei. A 3 km deep elliptical chamber with axes some hundreds of meters long hosts phonolitic magma, and is replenished at chamber base by trachytic magma which rises through a several km long dyke. Chamber orientation and dyke width have been varied in different simulations, as well as the volatile content of the two magma types. An initial overpressure is assigned at dyke base. The numerical results show that complex dynamic patterns of volatile-rich buoyant plume generation and development originate from the simulated system conditions. After 5 – 30 minutes, depending on the specific conditions, magma convection and mixing has deeply modified the compositional and dynamic state of magma in the chamber,

with complex velocity patterns and single or multiple vortexes forcing magma to flow up and down in the chamber. Part of the dense magma initially resident in the chamber can be recycled inside the feeding conduit, largely depending on its width. All the simulations show that once a rising plume develops, buoyancy largely dominates over pressure forces, and the time-scale of plume rise and evolution becomes similarly short in all cases. Further gas exsolution in the rising plume translates into an additional contribution to magma chamber pressure, and the final chamber overpressure is 2 – 5 times larger than that applied at dyke base.