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Possible mechanisms for uplift and subsidence at collapse calderas

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Ground deformation at collapse calderas very often involves up and down movements at surface. In classical strato-volcanoes, shallow magma inflation is the cause of uplift of the volcano surface, whereas subsidence is ascribed to the deflation of the magma chamber subsequent to the eruption. While such mechanism is generally very clear at these volcanoes, collapse calderas show much more complex behavior, in the sense that several uplift-subsidence sequences may occur without any interposed eruption. Such observation, which has become very clear starting from the 80's, when several calderas worldwide showed such deformation behavior, pushed many researchers to hypothesize alternative models, in which fluids different from magma play a major role in the deformation processes.

This work tries to give physical interpretations to such behavior, by proposing two different kinds of models which can be able, in principle, to reproduce the up and down movements at calderas without eruptions. We show that both a purely magmatic model and a model based on the injection of hot fluids at shallower levels are able to reproduce up and down ground movements at calderas, provided some physical conditions are satisfied. The main factor for discriminating between the two mechanisms is to jointly consider ground deformation and gravity anomaly data. In particular, the implicit symmetry of the governing equations for these two classes of data make in principle easy to discriminate the appropriate mechanism, also in presence of structural complexities not completely known. The time evolution of gravity and ground deformation changes is also a key tool to distinguish if magma or other fluids are involved during unrests. In addition, mechanical considerations about the depth of the main magma chambers as related to the shape of the caldera can be also used as a further constraint. The theoretical considerations enlightened in this work are then applied to model the Campi Flegrei unrest episodes occurred from 1969 to present, indicating that low density/viscosity fluid injection plays an important role.