Geophysical Research Abstracts
Vol. 12, EGU2010-5029, 2010
EGU General Assembly 2010

Geometrical and physical properties of the 1982-84 deformation source at Campi Flegrei - Italy

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Deformation of the ground surface in volcanic areas is generally recognized as a reliable indicator of unrest, possibly resulting from the intrusion of fresh magma within the shallow rock layers. The intrusion process is usually represented by a deformation source such as an ellipsoidal pressurized cavity, embedded within a homogeneous and elastic half-space. Similar source models allow inferring the depth, the location and the (incremental) volume of the intrusion, which are very important parameters for volcanic risk implications. However, assuming a homogeneous and elastic rheology and, assigning a priori the shape and the mechanism of the source (within a very restricted "library" of available solutions) may bias considerably the inference of source parameters. In complete generality, any point source deformation, including overpressure sources, may be described in terms of a suitable moment tensor, while the assumption of an overpressure source strongly restricts the variety of allowable moment tensors. In particular, by assuming a pressurized cavity, we rule out the possibility that either shear failure may precede magma emplacement (seismically induced intrusion) or may accompany it (mixed tensile and shear mode fracture). Another possibility is that a pre-existent weakness plane may be chosen by the ascending magma (fracture toughness heterogeneity). We perform joint inversion of levelling and EDM data (part of latter are unpublished), collected during the 1982-84 unrest at Campi Flegrei caldera: a 43% misfit reduction is obtained for a general moment source if the elastic heterogeneities computed from seismic tomography are accouted for. The inferred source is at 5.2 km depth but cannot be interpreted as a simple pressurized cavity. Moreover, if mass conservation is accounted for, magma emplaced within a shallow source must come from a (generally deeper) reservoir, which is usually assumed to be deep enough to be simply neglected. At Campi Flegrei, seismic tomography indicates that the "deep" magma source is rather shallow (at 7-8 km depth), so that its presence should be included in any thorough attempt to source modeling. Taking into account a deflating source at 7.5 km depth (represented either as a horizontal sill or as an isotropic cavity) and an inflating moment source, the fit of both levelling and EDM data improves further (misfit reduction 80%), but still the best fitting moment source (at 5.5 km depth) falls outside the range of pressurized ellipsoidal cavities. The shallow moment source may be decomposed in a tensile and a shear dislocation. No clue is obtained that the shear and the tensile mechanisms should be located in different positions. Our favourite interpretation is in terms of a crack opening in mixed tensile and shear mode, as would be provided by fluid magma unwelding pre-stressed solid rock. Although this decomposition of the source is not unique, the proposed solution is physically motivated by the minimum overpressure requirement. An important implication of this new interpretation is that the magma emplaced in the shallow moment source during the 1982-84 unrest was not added to already resident magma at the same position.