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# NUMERICAL COMPUTATION OF DEFORMATION FIELD IN VOLCANIC AREAS

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## Abstract

Surface deformations are important factors for the determination of volcanic hazard. Analytical models cannot take into account all the complexity of a volcanic structure, as the presence of an edifice, of heterogeneities in the country rock, possible asymmetry of the structure, and of the source of pressure. Numerical models are necessary to investigate the importance of these factors in determining the expected values of surface displacements and the shape of the deformation field. Using 3D finite element elastic models we computed surface deformations in response to overpressure generated in reservoirs of different shape and depth having in mind account the major complex volcanic features of Mt. Vesuvius (Italy). Comparison of the results with those of analytical and axis-symmetric numerical models reveals that the complexity of the 3D structure of the volcano have an influence both on the values of the displacements and on the shape of the deformation field that cannot be retrieved with simple models.

## 1. Introduction

Surface deformations in volcanic areas are important indicators of changes in the equilibrium conditions of the structures and their correct interpretation can be a valid aid in risk evaluation. In this context it is sited the research we are performing through numerical modelling on volcanic structure. All the major volcanological and structural features, as well the non uniform response of the country rocks due to rock heterogeneities, and the presence of fractures or fluids have to be taken into account and the relative role and interrelation of the various parameters studied to render plausible and reliable the models.
The actual volcanic structure on which the attention is focused here is Mt. Vesuvius (Italy), a now quiescent volcano, continuously monitored because of its potential hazard. Results obtained by us on this subject have been presented in previous works (Russo & Giberti, 1997, 2002, 2003), but it has to be pointed out that the details of the investigated structure often do not affect in a stringent way the results, so that they can be considered sufficiently general to be applied in other cases (see also Trasatti and al., 2003 and references therein).

## 2. Model and results

In this presentations we shortly summarize some results concerning the deformation pattern obtained by means of a particular 3D model. It is assumed, that the volcano is essentially characterized both by a vertical

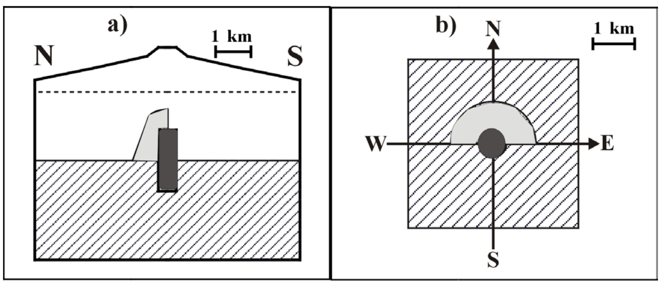


Fig.1. Schematic models

layered structure. i.e. the carbonate basement at 2 km below sea level and the less rigid edifice over it, and by a major lateral asymmetric heterogeneous zone overlaying the carbonate basement. These assumptions are made on the basis of data on the volcano sub superficial structure obtained from various geophysical investigations (references in the above mentioned articles). A schematic view of the vertical NS section (left) and of a horizontal section at depth (right) of one of the model we have studied is shown in Fig. 1 The darker cylindrical zone represents the source of pressure, the grey and hatched zones represent the asymmetric structure and the basement, respectively. An important parameter in controlling the surface deformation is the contrast in Young Modulus between the less rigid zone (white in Fig. 1) and the other two structures, whereas less important was found the effect due to the contrast between them. The results shown in Fig. 2 refer to same Poisson modulus for all the media, a Young modulus of 40 GPa assigned to the basement and to the rigid structure, a contrast of 4 with the less rigid medium and a uniform overpressure of 10 MPa acting on the reservoir's wall.

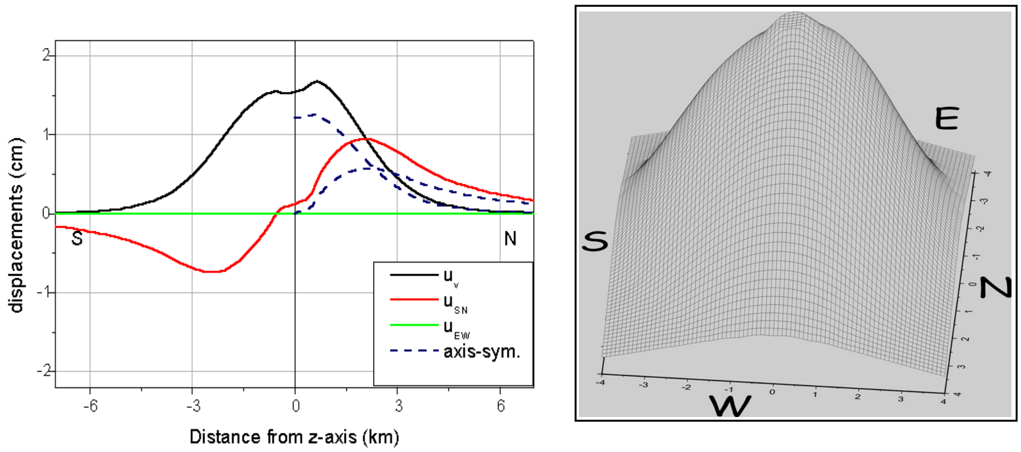


Figure 2. Surface displacements.

The asymmetry in the country rocks is reflected in the asymmetry of the surface displacements (3D normalized view in Fig. 2, at right ), but quite unexpected is the pattern. In fact, the maxima of the vertical and horizontal displacements are attained on the northern part of the edifice, which lays on the asymmetric more rigid and so less deformable structure. The southern part is characterized by radial deformation field which has a smaller maximum, but broader extended with respect to the northern part. The zero of the radial it is shifted in the southern direction (see Fig. 3 at right, that shows the radial displacements field on the on a area which approximately cover the part of the edifice from 500 m above sea level up to the top, i.e. the upper part of the cone).

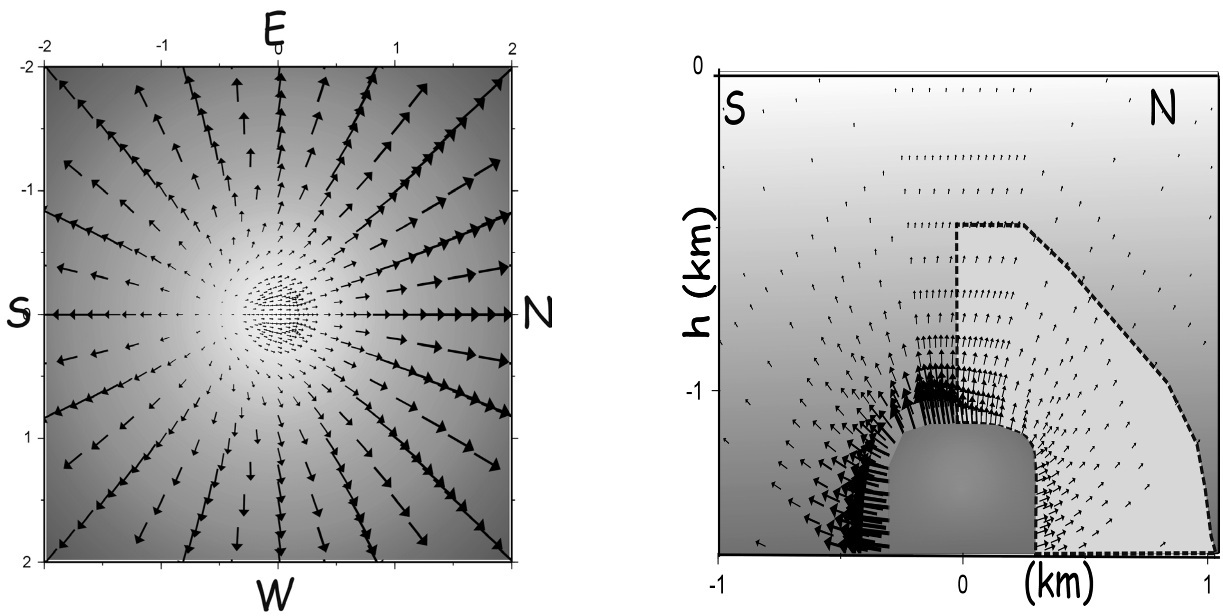


Figure 3: Radial displacements on the top of the edifice (left) and displacements at depth on a vertical NS section (right). See text for more comments.

In Fig.3, at right, the vectorial sum of the vertical and radial displacements at depth on a vertical N-S section are shown. It appears that the presence of the rigid body essentially determines a sort of focalization of displacements both upwards and northwards. Moreover, whereas the directions of the displacements vectors determined by the elastic asymmetry remain unaltered up to the surface, the differences in displacements values, evident near the source, rapidly decrease.

## 3. Conclusions

Numerical models, if a sufficient knowledge of the substructure in a volcano is known, can provide new insight on the expected deformation pattern that cannot be achieved through analytical models, and in particular can help in distinguish features that can be very useful in hazard evaluation. Here it is shown that a larger deformation in a place do not necessarily correspond to inflation of source in that place, nor to looser materials in that zone, and that the deformation pattern could be the result of complex interactions in a heterogeneous medium. The surface displacements that would be observed according to our model are small, but measurable, given the present precision and sensibility of measuring techniques. These results, have, in any case, to be considered as lower bounds: the elastic assumption, in fact, can be inappropriate for the very shallow part of the volcano due to presence of incoherent material, detachment zones and so on. These features would probably enhance displacements and asymmetries. Finally, it has to be noted that almost all the deformation field is concentrated in the upper part of the cone, so that our model would imply that this part of the volcanic structure deserves the major attention in deploying a measuring network for hazard evaluation purpose.

## References


Russo, G., G. Giberti and G. Sartoris (1997). Numerical modeling of surface deformation and mechanical stability of Vesuvius volcano, Italy. *Journal of Geophysical Research*, 102, 24,785-24,800.

Russo, G. and G. Giberti (2000). Mechanical stability of Mt. Vesuvius volcano: effects of asymmetries on the stress field. *Survey on Geophysics*, 21, 407-421.

Russo, G. and G. Giberti (2003). Numerical modeling of surface deformations of Mt. Vesuvius volcano (Italy)in presence of asymmetric heterogeneities. *Journal of Volcanology and Geothermal,* in press.

Trasatti, E. C. Giunchi and M. Bonafede (2003). Effects of topography and rheological layering on ground deformation in volcanic regions. *Journal of Volcanology and Geothermal,* 122, 89-110.