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A new interpretation of the 1982-84 unrest episode at Campi Flegrei Caldera (Italy) by numerical inversion

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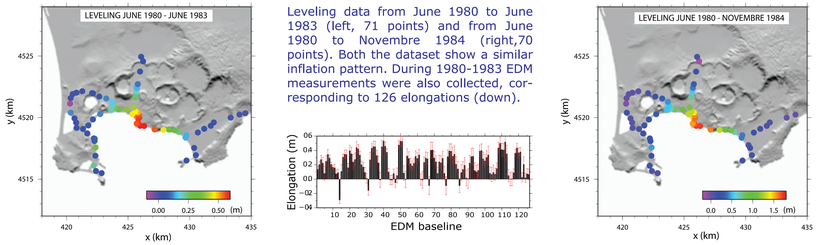
Poster XY 0448

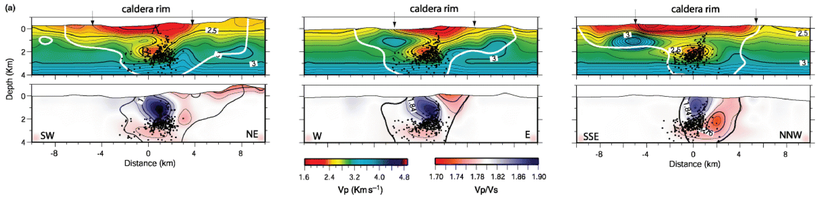
SUMMARY

The 1982-84 unrest episode at Campi Flegrei was characterized by huge deformation (1.8 m uplift) located inside the caldera. We combine simple point source mechanisms (dipoles and double couples) to represent arbitrary sources such as a sphere, an ellipsoid or a sill. The models are realized by Finite Element and the medium is characterized by elastic heterogeneities consistent with seismic tomography. We study the deformation detected by leveling and EDM techniques by coupling the FE forward models with an inversion procedure. The potential point sources are contained in a volume of 4x4x4 km^3 located beneath Pozzuoli, the site of maximum displacement. The best-fitting source is located beneath Pozzuoli at about 5 km b.s.l. and undergoes to horizontal compression and vertical dilatation.

DATA



Leveling data from June 1980 to June 1983 (left, 71 points) and from June 1980 to Novembre 1984 (right,70 points). Both the dataset show a similar inflation pattern. During 1980-1983 EDM measurements were also collected, corresponding to 126 elongations (down).

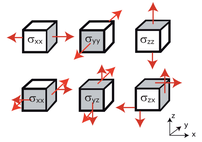


Seismic tomography *(Chiarabba and Moretti, 2006)* evidences a continuous ring of high Vp anomaly defining the caldera rim.The low Vp, low Vp/Vs between 2-4 km is interpreted as a rock volume filled by overpressurized gas.

METHOD

MODEL

The deformation is modelled by a point-source whose intensity is characterized by a stress tensor. Depending on the principal stresses, this kind of source may represent either a sphere, an ellipsoid, a fault, or a sill.



FORWARD PROBLEM

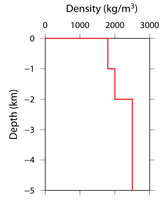
The FE grid is made of 150'000 brick elements. The potential sources are contained in a volume of 10x10x10 elements, spaced by 400 m. 6'000 solutions are computed at leveling and EDM sites, for each element-source (1000) and for each stress component. The resulting surface displacement is the superposition of the 6 elementary sources depicted on the left.

ELASTIC STRUCTURE

We consider 2 different classes of models:

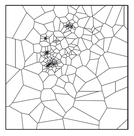
HOF homogeneous medium with rigidity μ = 1 GPa and density ρ = 2500 kg/m^3;

HEF heterogeneous medium with elastic structure computed from the seismic tomography, using the density layering showed in the panel (right).

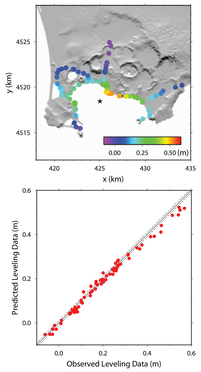


INVERSION

The search in the model space is performed using the neighbourhood algorithm (*Sambridge, 1999*). It retrieves 9 parameters for the inflation: source position (3) and stress components (6). The global search is followed by a bayesian inference of the sampled models.



SYNTHETIC TEST

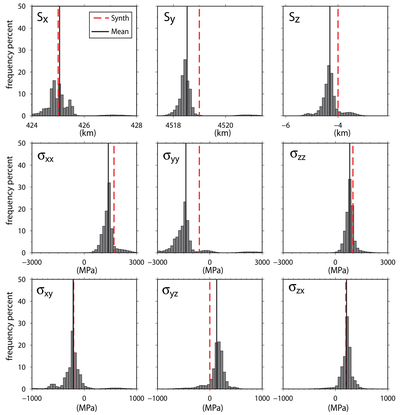


A synthetic test is performed to set up the inversion procedure. The synthetic source is characterized by the following parameters:

Center (425, 4519, -4) km

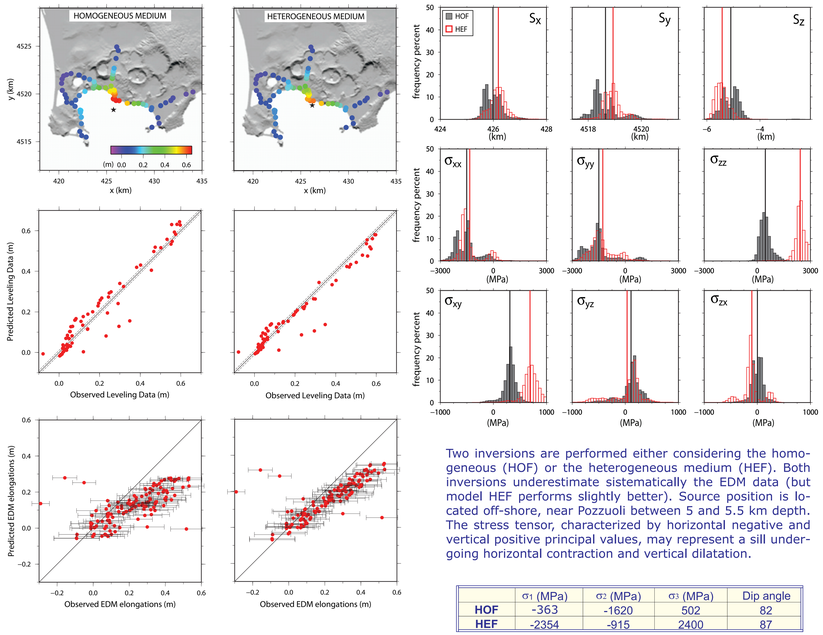
Stress tensor (MPa)

$$\begin{bmatrix} 1700 & -200 & 200 \\ -200 & -600 & 0 \\ 200 & 0 & 1000 \end{bmatrix}$$



A bias between source position Sy and stress component σ_{yy} is present, probably due to the datapoints geometry.

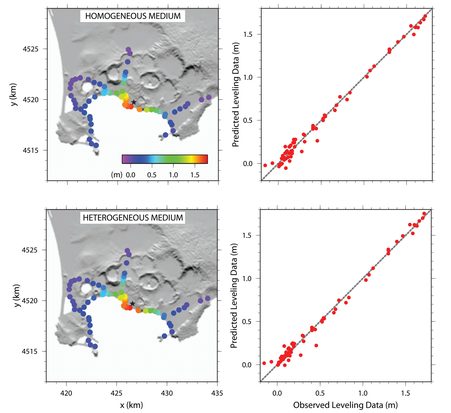
INVERSION OF LEVELING AND EDM DATA (1980-1983)

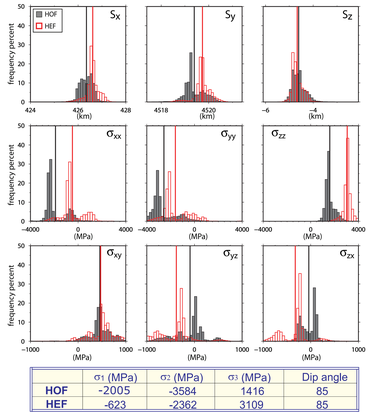


Two inversions are performed either considering the homogeneous (HOF) or the heterogeneous medium (HEF). Both inversions underestimate sistematically the EDM data (but model HEF performs slightly better). Source position is located off-shore, near Pozzuoli between 5 and 5.5 km depth. The stress tensor, characterized by horizontal negative and vertical positive principal values, may represent a sill undergoing horizontal contraction and vertical dilatation.

	σ_1 (MPa)	σ_2 (MPa)	σ_3 (MPa)	Dip angle
HOF	-363	-1620	502	82
HEF	-2354	-915	2400	87

INVERSION OF LEVELING DATA (1980-1984)



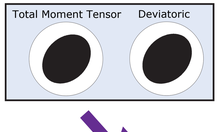


	σ_1 (MPa)	σ_2 (MPa)	σ_3 (MPa)	Dip angle
HOF	-2005	-3584	1416	85
HEF	-623	-2362	3109	85

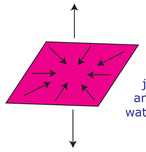
When we consider the leveling data of the whole unrest phase (1.7 m maximum uplift), the source position (for both homogeneous and heterogeneous models) is retrieved onshore, near Pozzuoli at 4.5 km depth. The source shape is slightly different due to the different stress components. However, it can still be interpreted in terms of a sill-like source as in the 1980-83 data inversion.

SOURCE INTERPRETATION

The source mechanism can be interpreted in terms of moment tensor $M_{ij} = V*\sigma_{ij}$ where V is the FE volume and σ_{ij} the stress tensor characterizing the source.

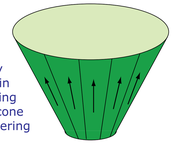


This kind of focal mechanism is usually observed in volcanic areas and explained in terms of sliding along ring faults *(Nettles and Ekstrom, 1998)*.



The sill undergoes rapid injection of magma and superheated water.

Inflation of a deep source may increase stress in the rocks, leading to sliding on cone faults bordering the caldera.



The inverted sources may be interpreted as shear sliding along ring faults bordering the caldera. The central dome is uplifted while the local medium undergoes to horizontal contraction. Very low volume variations are observed: the dome may resurge by buoyancy effects, rather than overpressure variations. This behaviour of the source is compatible with the intrusion of new mass leading to changes in the thermo-mechanical equilibrium but no volume variations.

CONCLUSIONS

- **All the inversions performed show evidence of a deformation source located near Pozzuoli at about 4.5-5 km b.s.l..**
- **The source stress tensors indicate horizontal compression and vertical dilatation (sill-like model) which can be intepreted as shear sliding along ring faults bordering the caldera.**
- **Elastic heterogeneities may influence in modifying the source depth and volume variations.**
- **New inversions are in progress using also gravity data observed at CF. The gravity variations observed at CF should be interpreted as due to the deformation induced in the medium by the sliding mechanism described above, without noticeable variation of the source volume.**