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THREE-DIMENSIONAL CODA WAVE ATTENUATION TOMOGRAPHY OF A VOLCANO: A CASE OF 1982–84 SEISMIC UNREST AT CAMPI FLEGREI CALDERA, SOUTHERN ITALY

Waheed Gbenga AKANDE
Ph.D. Student in Geosciences, University of Aberdeen, Aberdeen, United Kingdom,
Federal University of Technology, Minna, Nigeria
waheed.akande@abdn.ac.uk
Luca DE SIENA
Associate Professor of Geophysics, University of Aberdeen, Aberdeen, United Kingdom,
Institute of Earth Sciences, Johannes Gutenberg University Mainz, Mainz, Germany
ldesiena@uni-mainz.de
Quan GAN
Lecturer in Geosciences, University of Aberdeen, Aberdeen, United Kingdom
gan.quan@abdn.ac.uk

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Active volcanic settings are characterized by ground deformations and seismic unrests which could result in low-magnitude seismicity or a major quake. Campi Flegrei caldera (southern Italy) is a typical example of an active volcano affected by repeated deformation and seismic unrests, which have been monitored with an extensive monitoring network. The late-arriving waves recorded by seismograms, the seismic coda waves, are an invaluable tool to image volcanic structures if combined with standard direct-wave images. The aim of this work is to take advantage of the incoherent coda wave-packets recorded during the seismic unrest of 1982-84 at the caldera to generate 3D coda-wave attenuation models to give insights into the dynamics of the caldera. We adopted 3D coda-attenuation kernels and method developed by Del Pezzo *et al.* (2018) to study our dataset from Wisconsin University's three-component seismic stations to image caldera structures at multiple frequencies during unrest. This technique relies on the solution of Paasschens' equations (Paasschen, 1997; Del Pezzo *et al.*, 2018) in the framework of radiative transfer theory. We apply the technique to model source-station Q_C^{-1} by fitting 15 s of the shear-wave smoothed envelope after 11.5 s from the origin time with a decreasing exponential and filtering in four frequency bands with central frequencies of 3, 6, 12 and 18 Hz. We use the linearized version of the standard exponential relationship between coda envelope decrease and Q_C^{-1} previously employed by Calvet and Margerin (2013). We then fitted the energy versus time data with a line, and we only kept Q_c values when the R^2 fit was higher than 0.7 in the inversion.

The results map coda attenuation in the 3D space without need of pre-existent velocity models. The resolution and stability of the inversion solutions were examined by changing the damping parameters and outputting the corresponding images, inverting for different node spacings and performing checkerboard tests. The resulting attenuation coefficient, an inverse of quality factor (Q_c), obtained from the mixed-determined inversion solution with Matlab©-based codes, along with other geological and structural information, was employed to generate attenuation maps in interpretational software, Voxler©.

The results give an optimum resolution between depths of 1 km and 3 km in the centre of the model, between Pozzuoli town (P) and Solfatara crater (S). The results are reliable, especially at 3 Hz frequency, where coda-based methods had so far failed to provide stable results, due to both longer coda durations and broader kernel illumination. High-attenuation anomalies are obtained below Solfatara and Monte Nuovo (**S** and **M** in Figure 1-a, and bodies **1** and **5** in Figures 1-b and 1-c), marking areas either saturated with water or enriched in molten rocks, feeding the respective fumarole fields. The flattening and horizontal elongation of these anomalies below 2 km depth is a manifestation of the blocking and spreading around of the rising hot magmatic fluids below a previously-inferred low-attenuation caprock, body **3** in Figure 1-b and 1-

c, (Vanorio and Kanitpanyacharoen, 2015; Calò and Tramelli, 2018). However, our results show that this caprock is not laterally uniform, likely due to the ancient remnants of erupted structure, and this heterogeneity explains the difference in the current feeding mechanisms of both Solfatara and Monte Nuovo in relation to the resolved high-attenuation anomalies. The study also resolved a SW-to-NE-trending low-attenuation and high-velocity anomaly which deeps down to *ca.* 3 km under Pozzuoli (body **4** in Figures 1-b and 1-c). We infer that the high seismicity in the region is a consequence of the stress sustained by the caprock from a 4-km-deep feeding deformation source (Amoruso *et al.*, 2014). Above this source, high coda attenuation corresponds to high Vp/Vs ratios and high direct-wave attenuation. The characteristics of the region are likely due to the accumulation of magmatic fluids fed by a deeper magmatic source.

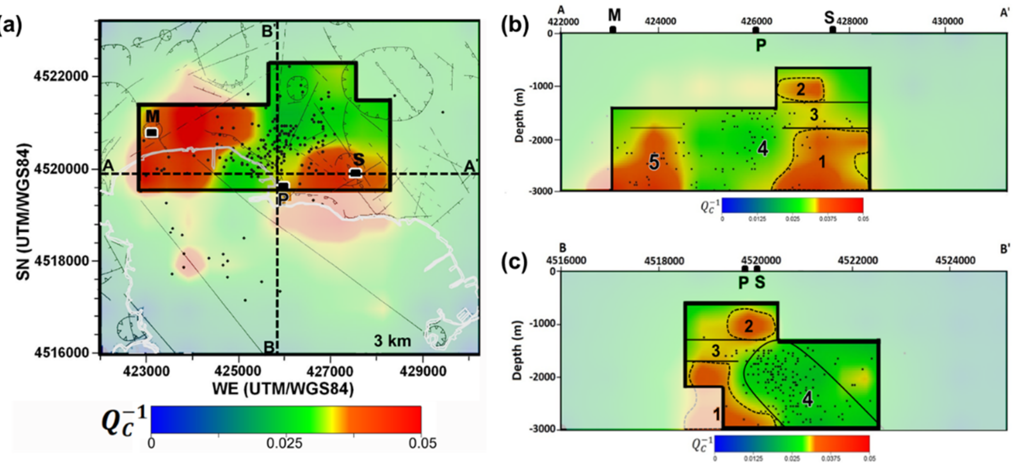

Figure 1. 3D coda attenuation maps generated for the 1983-1984 seismic unrests at Campi Flegrei caldera - (a) The model is shown after inserting the attenuation coefficients from Matlab© in the Voxler© interpretational software, and integrated with plot of topography, structural elements such as faults and geophysical information (black solid circles which represent the January-April, 1984 seismic events), all superimposed on the tomogram. The thick black polygons indicate the area where our results have better resolution, and hence discussed. Figures 1-b and 1-c are the models shown for the dashed line A-A' and B-B' sections in Figure 1-a, respectively.

REFERENCES

Amoruso, A., Crescentini, L., Sabbetta, I., De Martino, P., Obrizzo, F., and Tammaro, U. (2014). Clues to the cause of the 2011-2013 Campi Flegrei caldera unrest, Italy, from continuous GPS data. *Geophysical Research Letters*, *41*, 3081-3088.

Calò, M. and Tramelli, A. (2018). Anatomy of the Campi Flegrei caldera using Enhanced Seismic Tomography Models. *Scientific Reports*, *8*(16254), 1-12.

Calvet, M. and Margerin, L. (2013). Lapse-Time Dependence of Coda Q: Anisotropic Multiple-Scattering Models and Application to Pyrenees. *Bulletin of the Seismological Society of America*, *103*(3), 1993-2010.

Del Pezzo, E., De La Torre, A., Bianco, F., Ibanez, J., Gabrielli, S., and De Siena, L. (2018). Numerically Calculated 3-D Space-Weighting Functions to Image Crustal Volcanic Structures Using Diffuse Coda Waves. *Geosciences, 8*(5), 175-187.

Paasschens, J. (1997). Solution of the time-dependent Boltzmann equation. *Physical Review E, 56*, 1135-1141.

Vanorio, T. and Kanitpanyacharoen, W. (2015). Rock physics of fibrous rocks akin to Roman concrete explains uplifts at Campi Flegrei Caldera. *Science*, *349*(6248), 617-621.