Comparing acoustic emissions and the resultant fractures in Campi Flegrei tuff.

Supervisor: Prof. Dr. Luca De Siena (FB09 – GS);

Co-supervisors outside M3ODEL: Prof. Dr. Virginia Toy (FB09 – GS);

Francesco Cappuccio's broader PhD topic, with the title "*Image analysis of CT datasets, quantification of porosity, and applications to understanding fracturing and permeability of rock masses*" has seen him develop various python scripts for analysis of X-ray Computed Tomography (xCT) scans of fractured rock cores. He will submit his thesis at the University of Otago in New Zealand at the end of September 2020. The computational methods he has developed are novel and of interest to several PIs of M3ODEL, and are already reported in two publications (Cappuccio et al., in press, Verolino et al., 2019), and another currently in preparation (Cappucio et al., in prep.). I request support for Cappuccio to work at Universität Mainz with Prof. De Siena from October 2020, to perform modelling using finite-difference simulation of the wave equation in effective viscoelastic media. These analyses will be included in the manuscript in preparation. The topic is broadly connected with the line of research followed by the PhD candidate Yi Zhang.

Research Background

To explore in 3D the development of fracture-porosity in ignimbrite deposits, which are prevalent around active volcano-geothermal systems, Francesco has employed CT scanning of experimentally-deformed natural samples of Neapolitan yellow tuff collected in an open quarry on the edges of the Quarto Plain area, NW of Naples, Italy. The samples were deformed in a triaxial apparatus at a range of confining and fluid pressures, and strain rates, until failure. The structures that developed during loading were explored in 3D images of the deformed samples acquired using X-ray computed tomography (CT). After loading, the samples experience overall porosity reduction purely due to mechanical compaction, especially those deformed at wet conditions, which experienced greatest loss of small pores (<26 µm) and failed at comparatively low peak stresses. Fractures were also separated from the images, and their true orientations measured. These have similar orientations to faults and fractures previously described from field studies in the same study area. We infer this reflects the influence of a regional anisotropic fabric in the tuff, which influences the development of microfractures more than any imposed regional tectonic stresses. Porosities measured through image analysis have been compared with those measured experimentally, and with equivalent petrophysical parameters recorded in laboratory tests. We also considered how fracture geometries relate to the densities of particles (pumices, lithics, and crystals) that they completely or partially transect. Relative particle densities were inferred from the CT attenuation coefficients of the particles and their internal porosities. Fractures are commonly debonded across the interface of matrix with particles with high attenuation coefficients, which have high densities and/or atomic number. Low-attenuating particles with high intragrain porosity are associated with fractures that penetrate into them, or within which new fractures nucleated and coalesced with larger fracture networks in the sample.

During the internship Cappuccio will first collaboratively examine acoustic emissions recorded during the experimental deformation. With the support of Yi Zhang and Ms Pilar DI Martino Perez from the University of Aberdeen, we expect to prove that *AE are able to show the loci of fracture nucleation within the heterogeneous media, and that this information can be used to relate their nucleation to petrophysical and mineralogical parameters*. **Two requests for**

scholarships to support the visit of for Ms Di Martino Perez (M3ODEL and DAAD), which will coincide with that of Cappuccio, have already been submitted. The evaluation of the DAAD application is expected by the end of this month. With Zhang already in Mainz, we would build a team of three PhD students focused on a specific topic of broad interest for the Institute of Physics and Geosciences.

In the second part of this proposed project, Cappuccio will acquire new pre- and post-deformation CT scans of Neopolitan Yellow Tuff samples. He will also measure the seismic wave propagation speeds and anisotropies in those samples in the Experimental Geophysics Laboratory at Ruhr-Universität Bochum. There, elastic waves generated by ultrasonic transducers are passed through 30-40mm diameter cylindrical samples and captured by 4 x p and 1 x s-wave transducers. It is possible to carry out these experiments under load. Measurement at orthogonal (and perhaps intermediate) orientations through the samples will provide information about their elastic wave anisotropies, and allow micro-tomographic reconstruction of their internal elastic wave structure that can be correlated to the mineralogical and structural information acquired by CT.

After data collection has been finalised, samples that show the best-resolved definition of heterogeneities and highest-quality AE will be selected (Cappuccio, Perez). Then, the team will explore how attenuation of seismic waves relates to / reveals the orientation and shape of defects such as pores (Cappuccio,Zhang, Perez). We will define synthetic media based on CT scans (Cappuccio) using existing python and Matlab scripts, adding random velocity fluctuations depending on the statistical distribution of these anomalies (Zhang – research topic discussed with Prof. Markus Bachmayr) and forward modelling the existing seismic data with a finite difference code (Perez). This is an existing finite-difference forward modelling scheme for the propagation of seismic waves in anisotropic viscoelastic media, which allows to test the effect of the petrological parameters defined by Cappuccio's CT analyses on seismic waveforms. By the interaction with Zhang and Perez, Cappuccio will improve his modelling skills, understanding how the microstructural analyses he does can have an effect on geophysical signals.

Duration: 4 months

Task	Activity	Time frame
1	Map fracture nucleation and propagation from acoustic emissions recorded during experimental deformation of Campi Flegrei tuff and relate these results to fractures analysed in CT scans of the same samples. Include in manuscript and submit it.	6 weeks
2	Acquire new measurements of seismic wave propagation through deformed and undeformed samples of CF tuff at Ruhr Universität Bochum (Prof. Renner's Lab; existing collaboration).	2 weeks

3	Forward modelling of AE waveforms in fully-characterized heterogeneous samples.	10 weeks

References:

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Verolino, A., White, J. D. L., Dürig, T., & Cappuccio, F. (2019). Black Point–Pyroclasts of a Surtseyan eruption show no change during edifice growth to the surface from 100 m water depth. Journal of Volcanology and Geothermal Research, 384, 85-102. https://doi.org/10.1016/j.jvolgeores.2019.07.013