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3D image of Brittle/Ductile transition in active volcanic area and its implication on seismicity: The Campi Flegrei caldera case study

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The thermo-rheology of the rocks is a crucial aspect to understand the mechanical behavior of the crust in young and tectonically active area. As a consequence, several studies have been performed since last decades in order to understand the role of thermic state in the evolution of volcanic environments. In this context, we analyze the upper crust rheology of the Campi Flegrei active caldera (Southern Italy). Our target is the evaluation of the 3D geometry of the Brittle-Ductile transition beneath the resurgent caldera, by integrating the available geological, geochemical, and geophysical data. We first performed a numerical thermal model by using the a priori geological and geophysical information; than we employ the retrieved isothermal distribution to image the rheological stratification of the shallow crust beneath caldera. In particular, considering both the thermal proprieties and the mechanical heterogeneities of the upper crust, we performed, in a Finite Element environment, a 3D conductive time dependent thermal model through an numerical of solution of the Fourier equation. The dataset consist in temperature measurements recorded in several deep wells. More specifically, the geothermal gradients were measured in seven deep geothermal boreholes, located in three main distinct areas: Mofete, Licola, and San Vito. In addition, we take into account also the heat flow density map at the caldera surface calculated by considering the thermal measurements carried out in 30 shallow water wells. We estimate the isothermal distribution of the crust calibrating two model parameters: the heat production [W], associated to the magma injection episodes in the last 60 kyears within the magma chamber and the heat flow coefficient [W/m2*K] at the external surface. In particular, the optimization procedure has been performed using an exhaustive grid search, to minimize the differences between model and experimental measurements. The achieved results allowed us to determine the rheological stratification of the crust beneath caldera. The best-fit model suggested that the uprising of a ductile layer, which connects the upper mantle to the volcanic feeding system, could have determined the stress condition that controls the distribution and magnitude of seismicity. Indeed, the computed 3D imaging of Brittle/Ductile transition agreed well with the distribution of earthquake hypocenters in the considered area. The location of the Benioff strain release, of the energy and of the number of earthquakes point out clearly that most of the seismicity occurs above 3500-4000 [m] depth, where the transition zone is individuated. Finally, our analysis revealed that the distribution of the Brittle/Ductile transition has also important implication in constraining the potential seismogenic volume. The inferred depth of 4000 [m] (for ε= 10-8 [s-1]), implies that a fault spanning the whole caldera (about 8000 [m]) with a stress drop of 4 [bar] would result in an event with magnitude 5.1. However, because of its highly fractured structure, such a long seismic rupture is unrealistic for CF caldera, at least in pre-eruptive conditions. In this scenario, a more realistic fault sizes (i.e. 4000x4000 [m2]) suggest as magnitude of pre-eruptive earthquakes at CF caldera lower than 5.