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Steam-driven explosions at Solfatara volcano, Campi Flegrei: new insights from an experimental approach

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The Solfatara crater is a highly active hydrothermal site located in the central part of the Campi Flegrei Caldera (south-central Italy). Campi Flegrei is one of most active calderas in the world, characterized by intense unrest episodes involving massive ground deformation, high seismicity and continuous gas emissions from the Solfatara crater. These episodes are thought to be driven by the complex interaction between a deep magmatic source and a shallow hydrothermal system [Orsi et al., 1999]. The most recent unrest episode started in 2006, exhibiting an increase in the degassing activity, especially in the Pisciarelli field (SE of Solfatara crater). In such an active magmato-hydrothermal system steam-driven explosive eruptions (phreatic or hydrothermal) are a likely potential hazard - one that is difficult to predict in terms of timing and magnitude.

Here we present an experimental approach based on a rapid decompression experiments to investigate the different scenarios likely for steam explosions in the Solfatara area. The experimental setup produces fragmentation precipitated by the release of Argon gas overpressure and assisted by water-to-steam flashing within the connected pore space of the tested samples. We have investigated varying P-T conditions and varying gas-to-liquid ratios.

The experimental conditions used in this case study mimic those of a mixing zone present at the base of the hydrothermal system below Solfatara at a depth between 1000 and 1500 m (15-25 MPa) and temperatures from 270°C to 300°C [Caliro et al., 2007]. Neapolitan Yellow Tuff is used as sample material for the study as it is the stratigraphic unit expected at this depth in this region [Orsi et al. 1996].

Sensors monitor temperature and pressure evolution during the experiments, enabling the determination of the speed of fragmentation. A high-speed camera (10000 fps) is used to measure the ejection velocities of the gas–particle mixtures. The fragments generated are recovered and changes in grain-size distribution yield fragmentation efficiency. Further, both different degrees of water saturation and tempered samples have been used in order to investigate strength reduction due to both water-weakening effects and zeolite dissolution.

The mechanical energies released by the explosions have been compared with the fragmentation speeds revealing significant differences between dry, partially- and fully-saturated conditions. Generally, higher fragmentation efficiency and kinetic energy of ejected clasts were observed with water saturation. These effects are enhanced especially in the case of zeolite-depleted samples.

Our results indicate that the energy conversion is different for gas versus steam-driven fragmentation. Indeed the energy released by the steam expansion is highly efficient in the fragmentation process whereas the work done by gas expansion in combination with steam is mostly converted into the kinetic energy and transferred to the particles.