Geophysical Research Abstracts
Vol. 18, EGU2016-5030, 2016
EGU General Assembly 2016

Fiber-Reinforced Rocks Akin to Roman Concrete Help Explain Ground Deformation at Campi Flegrei Caldera

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The caldera of Campi Flegrei is one of the active hydrothermal systems of the Mediterranean region experiencing notable unrest episodes in a densely populated area. During the last crisis of 1982-1984, nearly 40,000 people were evacuated for almost two years from the main town of Pozzuoli, the Roman Puteoli, due to the large uplifts ($\sim$2 m over two years) and the persistent seismic activity. The evacuation severely hampered the economy and the social make-up of the community, which included the relocation of schools and commercial shops as well as the harbor being rendered useless for docking. Despite the large uplifts, the release of strain appears delayed. Seismicity begins and reaches a magnitude of 4.0 only upon relatively large uplifts ($\sim$ 70-80 cm) contrary to what is generally observed for calderas exhibiting much lower deformation levels. Over and above the specific mechanism causing the unrest and the lack of identification of a shallow magmatic reservoir (< 4 km) by seismic data, there is a core question of how the subsurface rocks of Campi Flegrei withstand a large strain and have high strength.

We performed a series of direct measurements on deep well cores by combining high-resolution microstructural and mineralogical analyses with the elastic and mechanical properties of well cores from the deep wells drilled in the area right before the unrest of 1982-1984 - San Vito (SV1 and SV2) and Mofete (MF1, MF2, MF5). The rock physics analysis of the well cores provides evidence for the existence of two horizons, above and below the seismogenic area, underlying a natural, coupled process. The basement is a calc-silicate rock housing hydrothermal decarbonation reactions, which provide lime-rich fluids. The caprock above the seismogenic area has a pozzolanic composition and a fibril-rich matrix made of intertwining filaments of ettringite and tobemorite, resulting from lime-pozzolanic reactions.

These findings provide evidence for a natural process reflecting that engineering the mortar of the Roman concrete. The formation of fibrous minerals by intertwining filaments confers shear and tensile strength to the caprock, contributing to its ductility and increased resistance to fracture. The importance of the findings reported in this study lies not only on the fibrous and compositionally nature of the caprock but also on its possible physicochemical deterioration. Given the P-T-XCO_2 conditions regulating the decarbonation reactions, the influx of new fluids into the Campi Flegrei system lowers the temperature of the decarbonation reaction and dilutes the existing CO_2, thus triggering additional CO_2, methane, and steam to form. As these gases rise toward the surface, the natural cement layer halts them, leading to pore pressure increase and subsequent ground deformations.