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# First 3D multi-frequency reflection seismic investigation of the architecture and magmatic-hydrothermal system at a partly submerged caldera system (Campi Flegrei caldera)

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The Campi Flegrei caldera (CFc) – situated in southern Italy at the border of the densely populated city of Naples – represents one of the world's highest volcanic risk areas as proven by its history of catastrophic eruptions, caldera resurgence, as well as recent volcanic unrest. In particular, the causes of unrest remain strongly debated and may either be attributed to hydrothermalism, magmatism or a combination of both, in each case with different implications for the hazard and risk assessment.

Here, we present the first 3D multi-frequency, multichannel reflection seismic dataset from a (partly) submerged caldera, the CFc. This integrated dataset consists of (1) high-frequency data (up to 1000 Hz) imaging the uppermost 250 m of the caldera's subsurface in high resolution (1 m horizontal, ~2 m vertical), and (2) low-frequency data (10-200 Hz) providing an outstanding signal penetration of up to 2 km subsurface depth. Based on this multi-frequency approach, the caldera's architecture as well as the shallow manifestation of hydrothermalism and magmatism and their deeper-seated roots could be investigated.

We identified a deep-seated, arcuate fracture zone located along the southern portion of the CFc, which likely formed coevally to one of the main caldera-forming events namely, the Campanian Ignimbrite (CI) eruption at 39 ka. This fractured area depicts the southernmost extent of the CFc system. It is associated with the presence of intrusions and submarine vents and, thus, may be regarded as a weak, permeable caldera segment, favouring magma ascent. In the same area, local low-frequency seismoacoustic indications (incoherent, high-amplitude patches) for the presence of a hydrothermal reservoir were found at ~1.5 s TWT (~1.3 km). Also, the high-frequency data revealed shallow (<40 m) anomalous patches (high-amplitude, reversed phase reflection) along the fault zone interpreted as fluids. Therefore, we hypothesize that these fluids originate from a hydrothermal reservoir at ~1.3 km depths, migrating along the highly permeable fault zone to shallower levels. Hence, this fault zone seemingly has a strong control on the ascent of both fluids and magma, thereby depicting a key location for the interconnectivity between the surface and the deep magmatic-hydrothermal system. Thus, they may also play an important role during the recent unrest episodes, for instance by acting as pressure release conduits. Moreover, the shallow fluids cover an area four times larger than the main onshore degassing site around the Solfatara crater, indicating that the marine portion of the CFc plays a substantial role for hydrothermal activity and for the overall degassing budget.

Overall, our findings update the hypothesis of an extension of the hydrothermal system into the offshore sector of the CFc. Furthermore, the fracture zone is seemingly prone to the rise of magma and, thus, may represent a favourable site for future eruptions, which in return has crucial implications for the hazard and risk assessment. Moreover, our study demonstrated the effectiveness of 3D seismic data in providing reliable constraints on the structural framework and magmatic-hydrothermal processes in (partly) submerged volcanic settings.