Gas monitoring at volcanic fields outside Naples exposes multiple sources of carbon dioxide emissions

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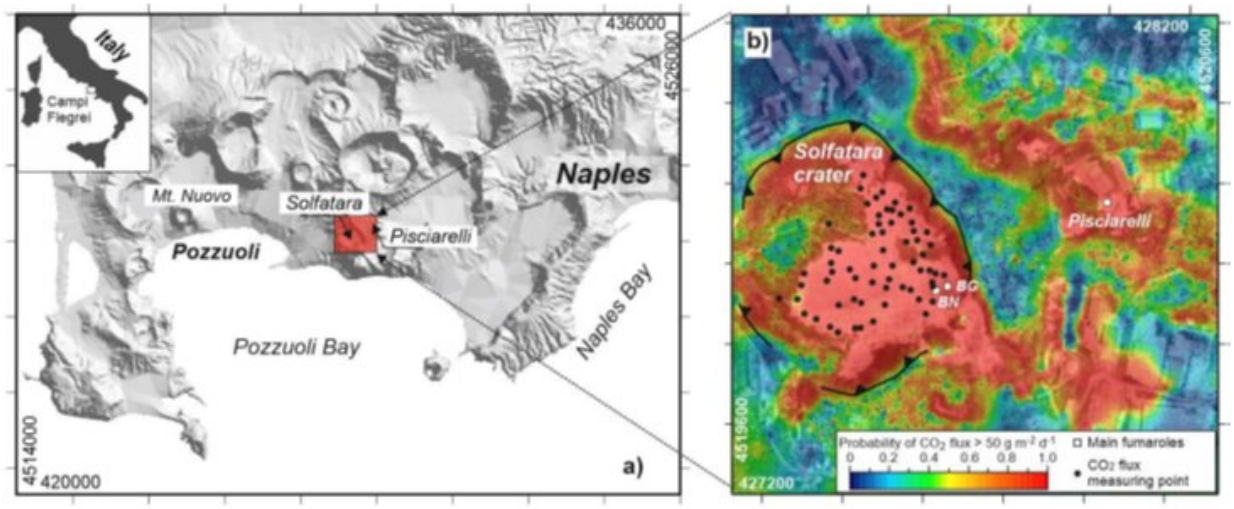

Map of the Phlegraean volcanic fields (left), with details of carbon dioxide emissions from Solfatara crater (right). Source: G. Buono et al., 2023. Credit: Source: G. Buono et al., 2023.

The Phlegraean volcanic fields just west of Naples, Italy, are among the top eight emitters of volcanic carbon dioxide in the world. Since 2005, the Solfatara crater—one of many circular depressions in the landscape left by a long history of eruptions—has been emitting increased volumes of gas.

Today it emits 4,000-5,000 tons of carbon dioxide each day, equivalent to the emissions from burning approximately 500,000 gallons of gasoline. In a new paper published ahead of print in *Geology*, researchers estimate that as much as 20%–40% of the current carbon dioxide emissions are from the dissolution of calcite in the rocks, while 60%–80% is from underground magma.

"Estimating the source of the carbon dioxide is important to properly reconstruct what is happening in the magmatic system and the hydrothermal system," says Gianmarco Buono, a volcanologist at Italian National Institute of Geophysics and Volcanology and lead author of the study. "Our aim is to provide a tool to better discriminate the contribution of magmatic and non-magmatic carbon dioxide that can also be applied to other systems."

When magma moves toward Earth's surface, the decreasing pressure on the magma results in degassing—the release of gases that were previously trapped inside the magma—including water vapor, carbon dioxide, and sulfur dioxide. Scientists monitor volcanoes for unrest and possible eruptions using a variety of observations—detecting earthquakes and tremors related to magma movement, taking detailed measurements of ground deformation, and assessing the types and volumes of gases released at the surface from fumaroles, which are openings in the earth that emit steam and other gases.

Eruptions are often preceded by increased fluxes of gas, but that does not mean that every increase in gas emissions will be followed by an eruption. It is also possible for carbon dioxide to come from sources besides magma. Interaction between hot underground fluids and host rocks can also release carbon dioxide.

Fumaroles at Solfatara crater. Source: Lucia Pappalardo (INGV). Credit: Source: Lucia Pappalardo (Italian National Institute of Geophysics and Volcanology).

The Italian National Institute of Geophysics and Volcanology has been monitoring gas emissions from Solfatara crater since 1983, providing a long record of the changes in volume and composition of the gases released there. By comparing ratios of nitrogen, helium, and carbon dioxide in the emissions, researchers had previously established that the gases were coming from deep sources of magma.

"We focused mainly on geochemical variation, especially for carbon dioxide, helium, and nitrogen, because they are non-reactive species. They contain information about what is happening in the magma," explains Buono.

But when the region started experiencing increased unrest in 2005, the data began to deviate from the chemical fingerprints of the magmas, a trend that continued to increase over time alongside rising temperatures

in the shallow hydrothermal system. The unrest continued, and in 2012 the alert level was raised from green to yellow, indicating that there is heightened activity but not an imminent threat of eruption.

In addition to small earthquakes and higher gas emissions, the region also experienced deformation of the ground surface. Circulation of hot fluids underground could explain the rising temperatures, ground deformation, and increased gas emissions—interaction of hot acidic fluids with calcite in the rocks also releases carbon dioxide.

Drill cores of the rocks from previous studies reveal that calcite in the rocks has similar composition to the gas emissions. The researchers estimate that 20%–40% of the carbon dioxide at the Solfatara crater site was from removal of the calcite in the host rock.

The Phlegraean Fields have hosted volcanic activity since first erupting approximately 40,000 years ago, with the most recent eruption in 1538. There have been several unrest phases since the 1950s. The current research is part of a strategic project by the Italian National Institute of Geophysics and Volcanology, LOVE-CF: Linking surface Observables to sub-Volcanic plumbing-system: a multidisciplinary approach for Eruption forecasting at Campi Flegrei caldera (Italy).

More information: Gianmarco Buono et al, Discriminating carbon dioxide sources during volcanic unrest: The case of Campi Flegrei caldera (Italy), *Geology* (2023). DOI: 10.1130/G50624.1

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