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Micro-Earthquakes Induce Fumarole CO_2 Emissions as Tracers of Subsurface Magmatic Activity: A Case Study from the Tatun Volcano Group, Taiwan

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Monitoring volcanic hazards is crucial, especially in densely populated regions, where early detection is vital for risk mitigation. This requires a multidisciplinary approach, integrating geochemical and geophysical methods. Carbon dioxide (CO_2) emissions are key indicators of subsurface activity, with variations in their concentration and isotopic composition offering valuable insights into volcanic processes. Moreover, CO_2 emissions are intrinsically linked to subsurface seismic activity, as seismic events generate fractures in the rock, creating pathways for the release of deep-seated CO_2. Therefore, combining seismic and geochemical monitoring is essential for a comprehensive understanding of volcanic hazards.

The Tatun Volcano Group (TVG) in Taiwan, located near the densely populated Taipei metropolitan area, is currently dormant. However, several studies have confirmed the presence of a magma body beneath TVG, highlighting the potential for future eruptions and underscoring the need for continuous monitoring. Between 2019 and 2022, we monitored CO_2 concentrations and isotopic compositions ($\delta^{13}C$ and $\delta^{18}O$) to investigate the sources and transport mechanisms of CO_2 emissions at TVG. Our results identify three primary CO_2 sources: magma-derived CO_2, organic matter, and carbonate. A three-component mixing model suggests persistent contributions from magma (~40%), while fluctuations in CO_2 levels were primarily driven by variations in organic matter oxidation (0-30%) and carbonate dissolution or decomposition (30-70%). Organic matter oxidation contributed intermittently to CO_2 emissions, likely due to thermal oxidation. Carbonate-derived CO_2 followed two distinct pathways: (1) a consistent contribution (~30–40%) from carbonate dissolution by acidic hydrothermal fluids, and (2) episodic increases in carbonate-derived CO_2 (up to 70%) linked to thermal decomposition, coinciding with increased gamma-ray radiation due to enhanced rock fracturing induced by the high magnitude earthquakes. Concurrent increases in ion concentrations suggest intensified hydrothermal interactions with newly exposed rock surfaces. Overall, our study indicates that while no new magmatic activity was detected, the persistent presence of mantle-derived CO_2 confirms the existence of a magmatic body beneath TVG, emphasizing the need for continuous monitoring to assess its potential for future volcanic activity.