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Lava flow magnetic anomaly mapping with UAVs

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Mapping of magnetic anomalies in volcanic areas is a valuable tool to better understand lava flow geometries and dynamics. The high magnetization of basaltic lava allows us to easily identify buried lava flows, providing constraints on the total volume of old erupted material and the flow geometry, while magnetic mapping of volcanic intrusions in country rock enables us to model feeder dike geometry. The low magnetic signals within recent lava flows can identify areas that are still above the Curie temperature, constraining the dynamic of recent flow, and negative anomalies above old empty lava tubes can allow us to identify these hidden conduits.

Traditionally, magnetic anomaly mapping for small regions is performed by walking through the survey area and for larger regions using crewed aircraft. Walking is often daunting, labor-intensive, and potentially dangerous. On the other hand, crewed aircraft are normally expensive and require a significant logistical organization before the survey. Uncrewed aerial vehicles (UAVs) have the potential to bridge the gap and collect a significant amount of high-resolution data in a relatively short time, possibly in areas not easily accessible. UAVs also provide the opportunity to collect data at multiple altitudes, providing a full gradient of the measured field.

Here we present the results from both old and recent lava flows. Little Cones in Nevada (USA) consists of two visible cones erupted ~0.8Ma in the vicinity of the proposed nuclear repository of Yucca Mountain, Nevada. The lava flows from the two cones are partially buried by alluvium and not visible above ground. Our UAV data collection and data inversion allowed us to map the full extent of the lava flow and estimate the total volume of effused material. Our surveys of Hell's Half Acre (~3000 BCE) lava flow, and Kings' Bowl (~300 BCE) flow in Idaho (USA) are examples of the use of magnetic anomalies to identify lava tubes, feeding dikes, and flow morphology. Our 2022 survey of the 2018 Pacaya (Guatemala) lava flow is an example of a hard-to-access flow in which we can identify the warmer core that has not yet cooled below the Curie temperature. A survey of the 2018 Lower East Rift Zone eruption of Kīlauea in Hawai□i (USA) conducted in 2022 is another example of a negative anomaly possibly associated with areas that are still hot, or lava tubes. In all the surveys we collected a few hundred line kms of data in a few days using two 200 Hz triaxial fluxgate magnetometers mounted on a medium-lift drone. UAV magnetic surveys in volcanic regions are a powerful tool for understanding old and recent volcanic processes.