The source depth of Strombolian explosions: a multiparametric approach and comparison

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The source depth of an individual explosion during Strombolian-style explosive volcanic activity can be defined as the depth of the region within the volcanic conduit where magma fragmentation occurs and the acceleration of pyroclasts by the expanding gas continuum begins. Source depth is thought to exert a first-order control on the final ejection dynamics of the pyroclasts and the ensuing eruptive styles and hazards. As such, different methods to estimate source depth have been developed in the past.

Here, we used three independent methods to estimate the source depth of some Strombolian explosions from Stromboli and Etna volcanoes (Italy). The first method uses the back-tracking of the trajectories of pyroclasts leaving the vent to infer their minimum release depth. It is a purely geometric method relying on the assumption that pyroclasts follow linear trajectories after fragmentation. The second method uses the time delay between the appearance of pyroclasts at the vent and the arrival of acoustic waves at a recording station at a known distance from the vent. This method relies on several assumptions, including (i) the sound velocity inside the conduit, (ii) the co-location of source depth of pyroclasts and acoustic waves, and (iii) a constant velocity of pyroclasts in the conduit, following the initial acceleration. The third method uses the velocity of pyroclasts progressively exiting the vent. This velocity decays following a non-linear trend which is function of the source depth, as illustrated by previous experimental and theoretical studies. As for the second method, also this last one assumes a constant velocity of pyroclasts rising in the conduit.

For the Etna case, the three methods provide consistent results and a shallow (<20 m) source depth of the explosions. For the Stromboli case, the first and third methods provide shallow (around 6 and 15 m, respectively) source depths while the second method provides depths of around 60 m. The incompatibility of such large depths with the first two methods, and given the relative assumptions, we believe that in the Stromboli case the co-location of the particles and acoustic source is probably the least strong assumption. These results suggest that caution should be used in assessing source depth from a single methodology, and that more investigations are required on the source of acoustic signals from the explosions and on the motion (specifically the acceleration and deceleration) of pyroclasts ascending along the conduit.

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