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A new strategy for estimating eruptive parameters

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Volume determination of tephra deposits is necessary for the assessment of the magnitude, dynamics and hazards of explosive volcanoes. Several methods have been proposed during the last forty years that include integrations of various thinning relationships and the inversion of field observations using analytical and computational models. Regardless of their strong dependence on tephra-deposit exposure and distribution of isomass/isopach contours, empirical integrations of deposit-thinning trends still represent the most widely adopted strategy due to their practical and fast application. The most recent methods involve the best-fitting of thinning data using various exponential segments or a power-law curve on semi-log plots of thickness (or mass/area) versus square root of isopach area. The exponential method is mainly sensitive to the number and the choice of straight segments, whereas the power-law method can better reproduce the natural thinning of tephra deposits but is strongly sensitive to the proximal and distal extremes of integration. We analyze a large dataset of tephra deposits and propose a new empirical method for the determination of tephra-deposit volumes that is based on the integration of the Weibull function. The new method shows a better agreement with observed data reconciling the debate on the use of the exponential versus power-law method. In fact, the Weibull best-fitting only depends on three free parameters (lambda, theta and n), can well reproduce the gradual thinning of tephra deposits and does not depend on the choice of arbitrary segments or of arbitrary extremes of integration. Nonetheless, due to the typical large uncertainties investigated in our study (mainly due to availability of data, compilation of isopach maps and discrepancies from empirical best fits), volume and magnitude of explosive eruptions cannot be considered as absolute values regardless of the technique used. It is important that various empirical and analytical methods are applied in order to assess such an uncertainty.

Previous studies have shown how tephra deposits also retain important information on the height and dynamics of eruptive columns. We show how values of the largest lithics versus square root of isopleth areas can also be well fitted with a Weibull function and how plume height correlates strongly with corresponding Weibull parameters. Weibull parameters derived for both the thinning of tephra deposits and the decrease of lithic diameter with distance from vent can then be combined to classify the style of volcanic eruptions. However, accounting for the uncertainty in the derivation of eruptive parameters (e.g., plume height and volume of tephra deposits) is crucial to any classification of eruption style. As an example, considering a minimum uncertainty of 20% for the determination of plume height, a new eruption classification scheme is presented, which is based on a plot of selected Weibull parameters. Overall, the Weibull fitting represents a stable, versatile and reliable strategy for the estimation of both the volume of tephra deposits and the height of volcanic plumes and for the classification of eruption style.