Multi-vent/lobe tephra deposition from the 1256 Al-Madinah eruption, Saudi Arabia

Emily Kawabata[1], Mark S Bebbington[1], Shane J Cronin[1], Rashad Moufti[2], Ting Wang[3]

[1]Massey University, New Zealand, [2]King Abdulaziz University, Saudi Arabia, [3]University of Otago, New Zealand

E-mail: e.kawabata@massey.ac.nz

We demonstrate a method for evaluating properties of complex tephra-producing eruptions in basaltic field environments, using a historic example of a 52 day long multistage eruption. The 1256 Al Madinah eruption in Saudi Arabia produced 6 pyroclastic cones, of which the largest three produced significant scoria fall based on recent fieldwork. Tephra dispersal from this eruption had not been investigated since the written accounts of Al Samhoody (1440 - 1506) and Abdul Haq Dehelvi (1551 - 1642). The recent measurements of tephra fall thickness although almost completely unvegetated, show the influence of 800 years spent in a hyper-arid environment. The outermost and finest grained deposits have been partly eroded or reworked, with primary deposit thickness being minimum values only. For deposits <2-3 cm thick, >95% of the material has been redispersed by wind and annual brief rainfall runoff. Coarser, thicker deposits, however, are extremely well preserved.

Our method for estimating tephra attenuation uses actual tephra thickness measurements, incorporating small random perturbations in particle movements due to wind and clast size. The actual thickness observed at any given point differs from an ideal (model) thickness. This difference is termed the *sampling error* and can be explicitly incorporated in the estimation procedure. Since the thickness is strictly nonnegative, and we expect a larger error for larger measurements, a multiplicative error structure is assumed. Hence our focus is the relative error R=O/E, where O is the observed thickness and E is the expected thickness under the model. We consider the Weibull and gamma distributions, which have different tail behaviours, to describe this inherent variability in the tephra thickness measurements.

While the Weibull distribution was a better description of fresh deposits from the 1973 Heimaey and 1977 Ukinrek Maars eruptions, the robustness of this error distribution for ancient and potentially reworked deposits needs to be investigated. This was done by simulating an error distribution of suitable sample size from each distribution. This sample was thinned probabilistically, with thinner (and hence finer) thickness measurements having greater probability of disappearing; this mimics the change in observed tephra thickness over time. Regardless of whether a Weibull or a gamma distribution was simulated, thinning consistently produced an observed sample consistent with a gamma distribution.

We applied our mixture attenuation model with gamma-distributed sampling error to reconstruct the number of eruptive phases from each of the three explosive vents and estimate their sizes, attenuation rates, wind directions and relative strengths. The best description of the event includes four components (accounting for 83% of the total eruptive volume) on the northern vent, one component (8%) on the central vent and one component (9%) on the southern vent.