Electrical charging of volcanic ash from Eyjafjallajökull

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1. Introduction

Lightning is commonly produced during volcanic eruptions (Fig 1), and electric fields and charged particles have also been measured in distal plumes a long way from the vent (e.g. Hatakayema, 1958, Harrison et al, 2010).

Fig 1 Lightning produced in the Eyjafjallajokull 2010 eruption (scienceblogs.com)

Established charge generation mechanisms are:
- Fracto-emission – fracturing of magma
- Triboelectric – frictional interactions within the tephra plume
- Enhancement of thundercloud charging mechanisms – dependent on plume height and temperature

Motivation:
- Why do some plumes produce more lightning than others? (Fig 2)
- Why is charge observed in distal plumes?

Eyjafjallajökull 2010 Grímsvötn 2011

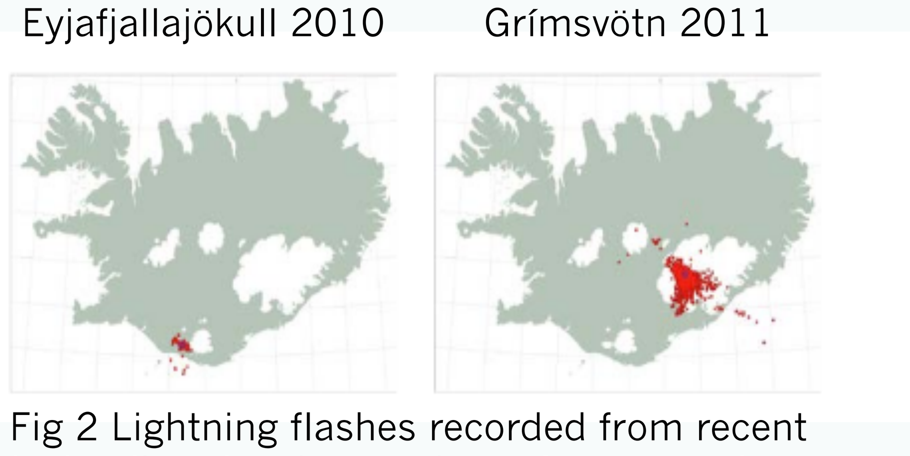

Fig 2 Lightning flashes recorded from recent Icelandic volcanic eruptions (Arason et al, 2013)

We previously found that ash from the 2011 Grımsvötn eruption charged according to the "width" (span) of its size distribution, with wider distributions charging more easily (Houghton et al, 2013). Here we present a similar analysis of ash from the 2010 Eyjafjallajökull eruption.

2. Self-charging measurements

The principle of the measurement is to allow ash samples to fall under gravity, and measure their charge. Small quantities (0.5g) of ash are loaded into grounded delivery tubes and any pre-existing charge is left to decay. The sample is then released, and charge developed by collisional interactions while it falls is collected on a Faraday cup and the voltage V measured with an electrometer. Charge Q is calculated from $Q = CV$ where C is the apparatus capacitance (130pF)

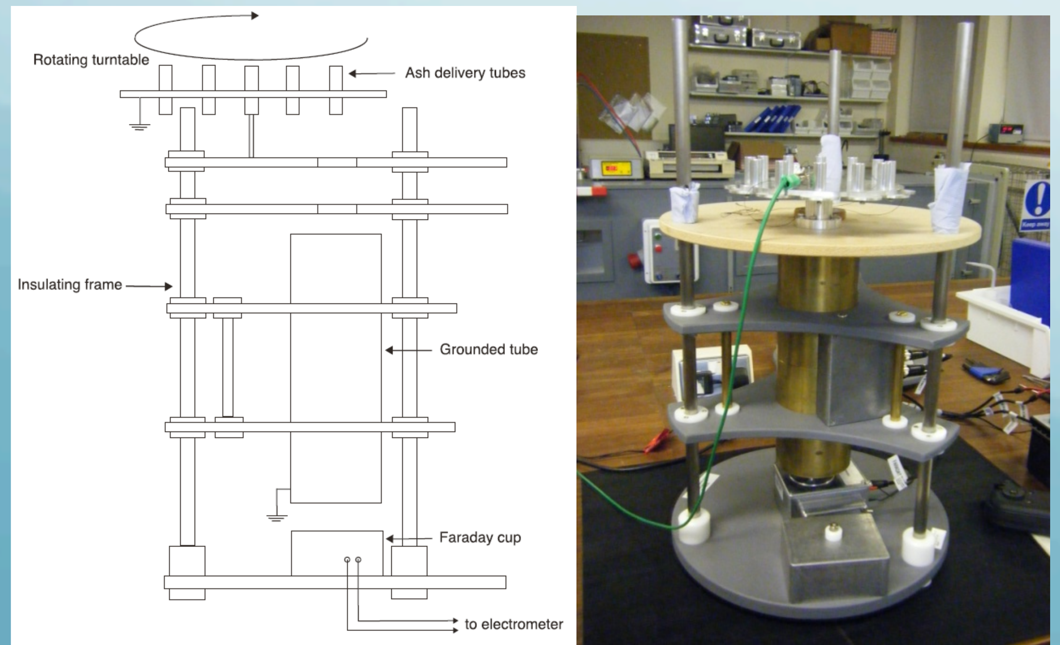

Fig 3 Ash drop apparatus (left) schematic (right) photograph

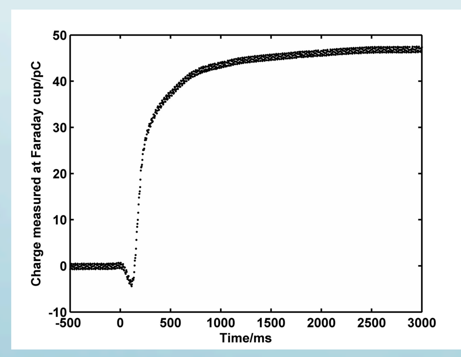

Fig 4 Typical trace measured as an ash sample is collected by the Faraday cup.

3. Samples used

Ash samples were obtained 22km from the crater on 5 May 2010. They were dry sieved (to preserve any electrostatically bound aggregates) and the size distribution of each sieved fraction measured with a Malvern Mastersizer laser diffractometer.

Note that the sieves sort particles by mass, whereas the laser diffractometer responds to volume.

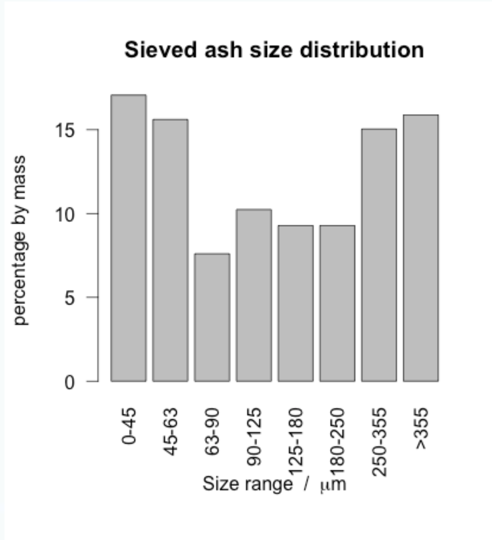

Fig 5 Dry sieved ash fractions

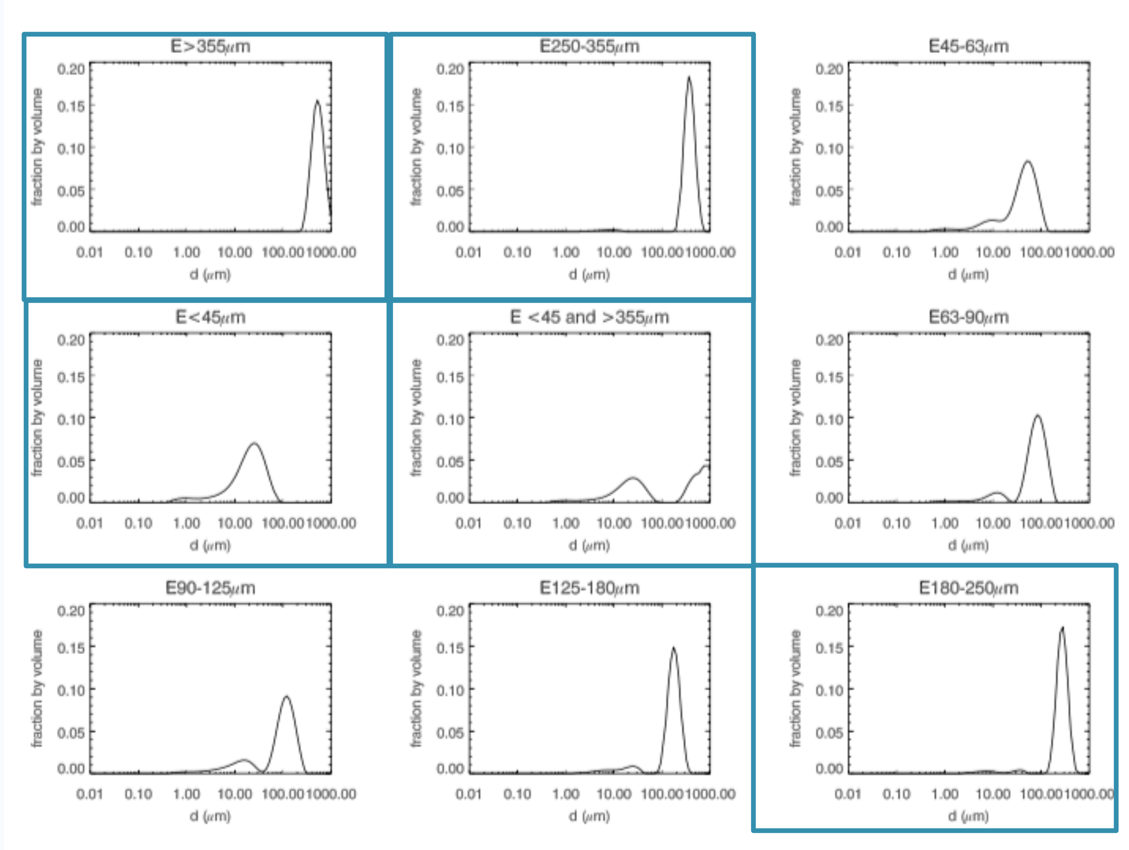

Fig 6 Size distributions of each sieved fraction. The middle plot (E<45 and >355 μ m) is an artificial mixture created by mixing the smallest and largest size fractions. The samples that were tested are in blue boxes.

4A. Results – charging sign and magnitude

Like the Grımsvötn ash, Eyjafjallajökull ash charged more efficiently for samples with a greater span (Fig 7).

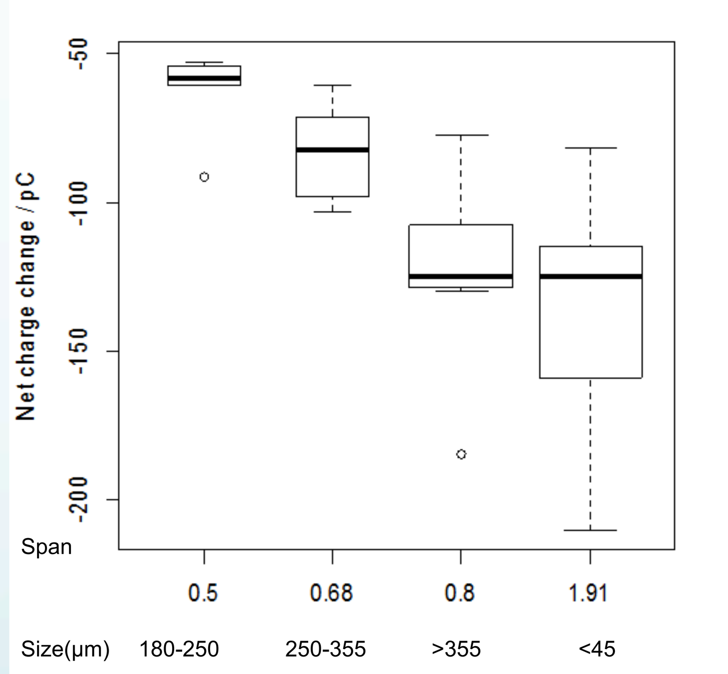

Fig 7 Self-charging of different sieve fractions with span (particle size is also shown)

"Span" is defined as the difference between the 90th and 10th percentiles of particle diameter, normalised by the median diameter (e.g. Houghton et al, 2013)

- The net sign of charging was opposite to the results for Grımsvötn ash reported in Houghton et al (2013) (Fig 8)
- Grımsvötn ash charges more easily than Eyjafjallajökull, even for similar span samples.

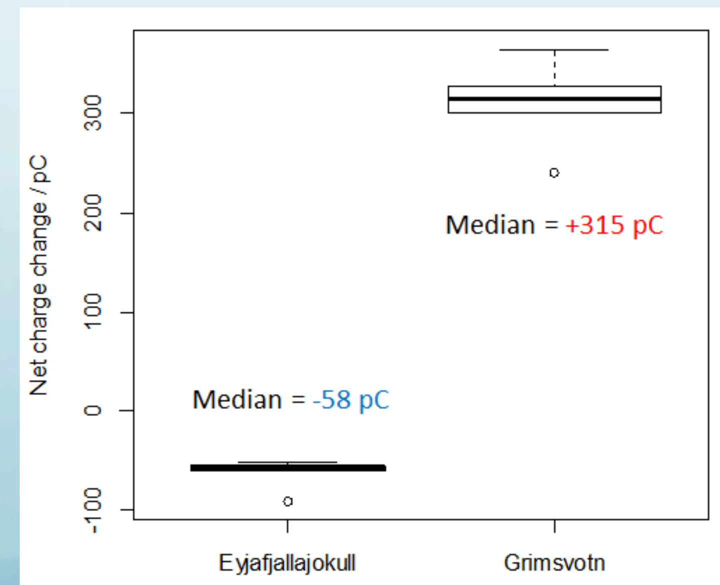

Fig 8 Comparison of charging for 180-250 μ m ash samples from the two Icelandic volcanoes.

4B. Results – role of fine particles

Samples containing the smallest particles (<45 μ m) showed a clear mixture of polarities with negative particles landing first and positive later, unlike any of the other size distributions, Fig 9.

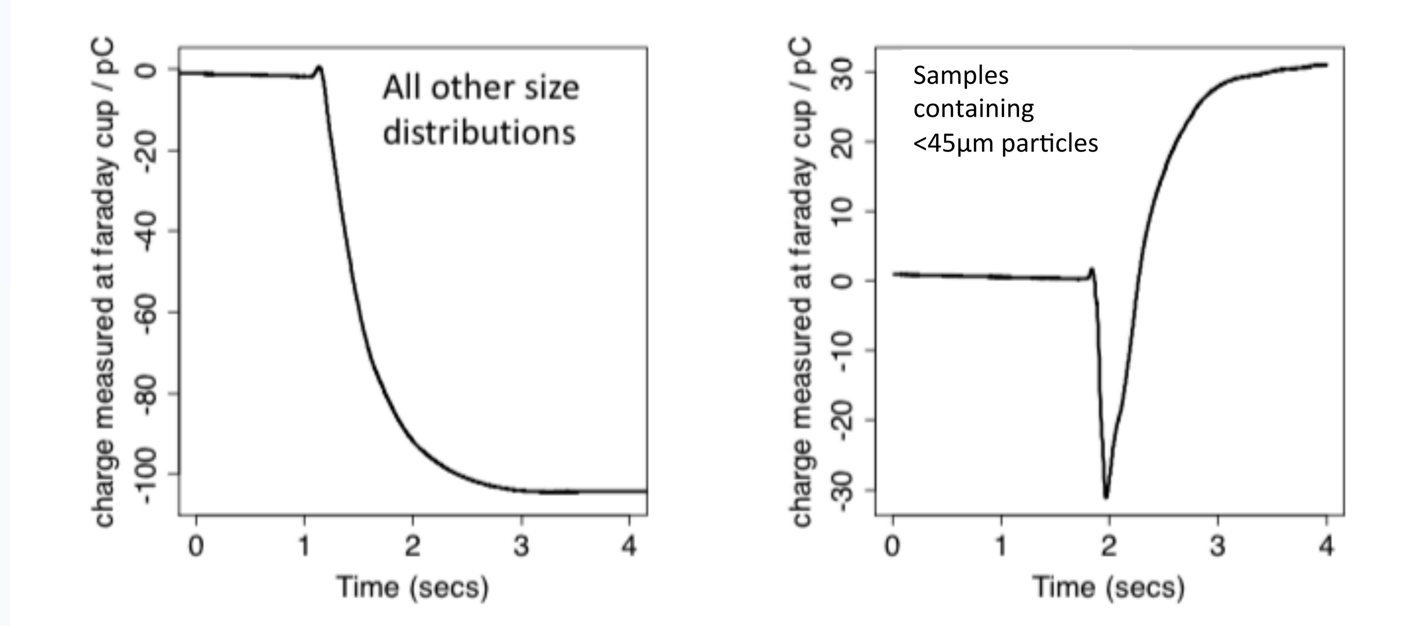

Fig 9 (left) Typical charge measurements for most ash samples (right) for samples including <45 μ m particles

Presence of the smallest particles may enhance bipolar charging, implying that the largest particles (which land first) become negatively charged and the smallest positive. As smaller particles are more numerous, this leads to an overall net positive charge. There is more positive charge if the span is broader.

5. Conclusions

- Eyjafjallajökull ash samples retrieved from 22km away from the vent were tested for triboelectric charging
- Charging of ash samples from both Grımsvötn and Eyjafjallajökull increases with particle span.
- Grımsvötn ash charges more readily than Eyjafjallajökull, indicating other factors are likely to be involved (e.g. compositional differences, known to affect tribo-charging via the work function).

References
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