Density measurement

Meaning

Density measurements are extremely important because they provide a first order indication of textural homogeneity, or heterogeneity, of the magma at the fragmentation level (e.g. Shea et al. 2011; 2012). Furthermore, the derived density distributions are used as filters to select a few clasts, representative of the low, modal and high density values, from each subpopulation observed (e.g. Gurioli et al. 2008). Selected clasts are then used for textural quantification.

Requirements

However, the assumption that the samples represent quenched magma at the fragmentation level has three requirements. First, magma has to be quenched immediately after fragmentation to avoid post-fragmentation expansion that will change the clast vesicularity (Thomas et al. 1994; Gardner et al. 1996; Tait et al. 1998). Second, because juvenile clast density varies with size, only clasts from a restricted size fraction must to be used. Third, the sample has to be representative of the explosion, or unit, in terms of:

- time (i.e. we need to sample narrow stratigraphic intervals in which clasts can be assumed to represent those parts of the magma that were fragmenting at a particular time);
- space (i.e. we need to select more than one section for each event);
- particle size (i.e. if an explosion is bomb, lapilli or ash dominated, the sampling methodology has to be appropriately selected);
- composition (i.e. if the juvenile fraction is heterogeneous, the sample has to reflect this heterogeneity).

Obeying these rules is fundamental if are to translate textural information from erupted clasts back to the properties of the magma in the conduit.

Methodology

Prior to performing density measurements, collected samples are cleaned and dried at T>100 °C for 24 h. For pumice or scoria samples, a subset of clasts is usually ranked by decreasing size and numbered from 1–100 (Figure 1). For other specimens, especially large ones, the rock is cut into halves, one half being kept for scanner imaging and the other serving for density measurements and microscopic imaging. Within the half serving for density, several subsamples corresponding to distinct textural units are carefully removed (Figure 1). If the sample is homogeneous to begin with, no further subdivision is required, provided that its size is large enough for weighing in the laboratory.

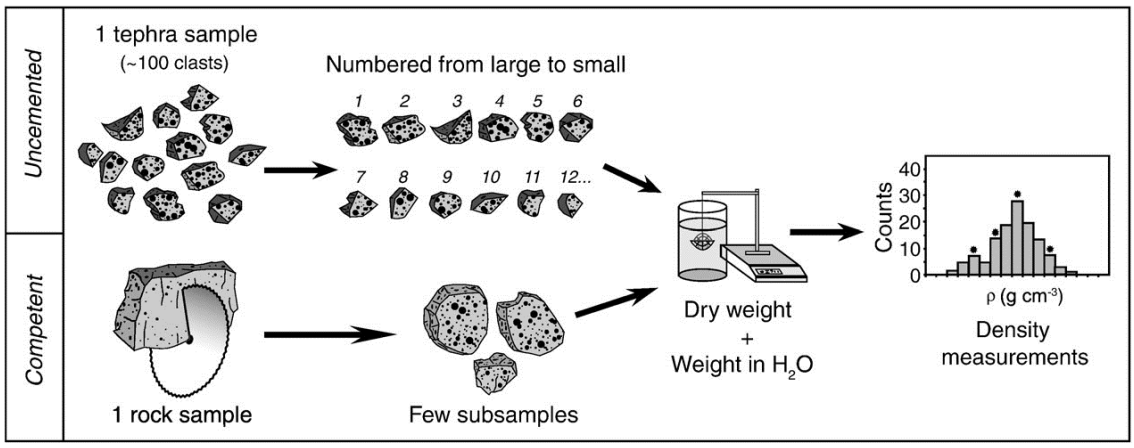


Figure 1 Illustrative cartoon of sampling procedure and density measurements.(modified from Shea et al. 2010)

Wrapping method

The density measurement methods described here are derived from Houghton and Wilson (1989). Clasts or sample subsets are weighed in air (mass ω_{AIR} in g), and either individually wrapped into polyethylene film (of wet weight ω_{WATER}^{film}), or made impermeable using water-proofing spray. They are then weighed once more immersed within water (ω_{WATER}). Specific gravity, and thereby density is expressed as:

$$\rho_{Bulk} = \frac{\omega_{AIR}}{\omega_{AIR} - \left(\omega_{WATER} - \omega_{WATER}^{film}\right)_{[]}}$$

For buoyant particles, e.g., pumice, the clasts are forced down using a ballast of known wet weight and volume. Finally, the dense rock equivalent (DRE) density of the magma is used to obtain porosity (φ) or vesicularity ($\varphi \times 100$):

$$\varphi = \frac{\rho_{DRE} - \rho_{BULK}}{\rho_{DRE}}$$

This technique is rapid and yields large arrays of data. For pumice and scoria sample datasets, density is plotted on a histogram to choose only a few clasts that represent the different end members from the entire distribution (Figure 1). In this manner, 3 to 8 clasts are typically chosen to represent low (1 to 2 clasts), modal (1 to 4 clasts) and high (1 to 2 clasts) vesicularities. For larger samples from lava flows, domes and bombs, tephra clasts showing substantial internal variability, density/vesicularity measurements are done on the subsamples prepared for each textural zone. The chosen clasts/subsamples are made into thin sections with, in the case of pumice or reticulite, impregnation with resin to avoid breakage of thin glass walls.

Natural waterproofing method

For bombs, I am currently developing two methodologies. Method 1 is the "natural waterproofing" approach (Gurioli et al. 2013). Extensive tests showed that decimetric size bombs collected at Stromboli acquired a "natural waterproofing" from their quenched margins, and thus could be weighed in water without waterproofing (Figure 2). This represents a new easy, precise and fast strategy. Method 2 is the "portioning" approach. Because some bombs collected at Stromboli have proved to be highly heterogeneous, density measurements are also completed on small, but representative, pieces of the whole sample.

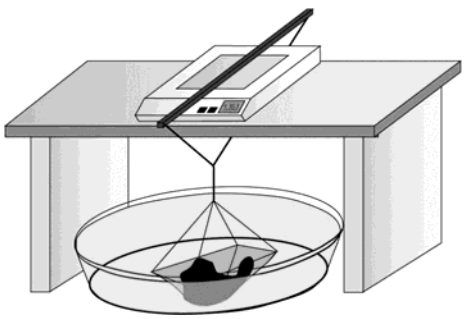


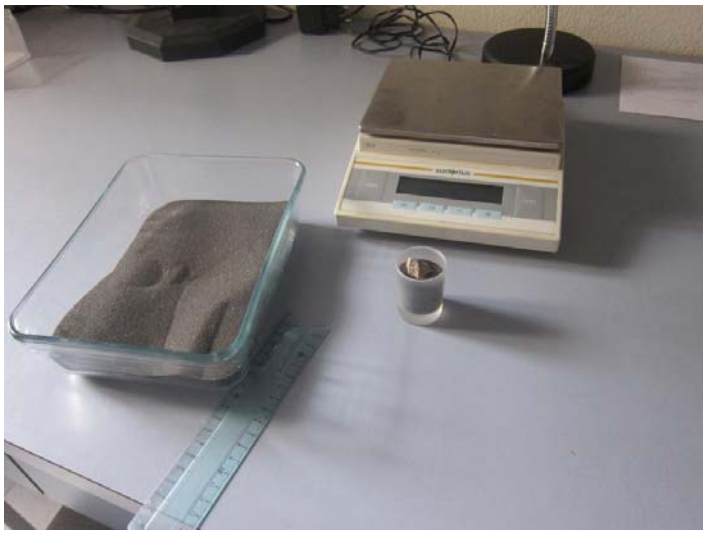
Figure 2 The new designed system used to weight big bombs. The balance is placed on a table and on that a strong wand that has two strings linked to a basket able to contain big clasts. Under the basket is placed a big basin full of water

Glass beads method

This method (Nakamura et al, 2008; Silva, 2008) allow us to calculated the density as well as the volume of an object of irregular size. The material for the measurements consist of

- glass beads with diameter of hundreds of microns (600-800 microns),
- 300+ml Beaker,
- Small measuring recipient of known volume
- standard with a precisely known volume (here a metallic cylinder with a volume measured by the He-Pycnometry).
- Metallic ruler

The density of the beads and the recipients need to be measured every day that we start new measurements.



1. Place the standard in the measuring recipient on the scales ensuring the scale have been prepared for analysis (see Sample Mass).
2. Tare (Zero) the scales
3. Remove the recipient from the scales
4. Remove the standard from the recipient and put to one side.
5. Fill slowly the recipient to about 1/3 volume with the glass beads doing a circular movement
6. Tap the recipient 20 times repeatedly
7. Introduce the standard gently in the beads and fill almost completely (leave 5 mm gap at the top
8. Tap the recipient 30 times
9. Fill the total volume of the recipient
10. Scrape off any excess using a ruler (ensure the same method is repeated for each measurement)
11. Place the recipient (containing the standard/sample and glass beads) on the scale. The displayed mass represents the mass of the glass beads (mb).
12. Repeat x10 (at the commencement of each day's analysis and incrementally throughout the day).
13. Calculate the density of the glass beads (see below)

$$\rho_b = m_b / v_b = mean_{mb} / (v_r - v_s)$$

where $mean_{mb}$ is the mean ot the mass of the glass beads, v_r is the volume of the recipient and v_s the volume of the standard

Once the density of the bead is known, follow the previous steps replacing the standard by the samples. At step (8) we measure the mass of the beads used and we can derive the volume of the beads with:

$$v_b = m_b / \rho_b$$

The volume of the clast is then determined using $v_{clast} = v_r - v_b$

Step 4: Density of the Solid
Step 1: Crush several samples using a mill.
Step 2: Place the sample holder on the scales ensuring the scales have been prepared for analysis (see Sample Mass).
Step 3: Tare (Zero) the scales.
Step 4: Place your milled sample into the sample holder. Record the mass.
Step 5: Place a lid onto the sample holder (the lid for the $10cm^3$ sample holder should be with the standards).
Step 6: Carefully place the sample holder into the fill chamber. From this point, follow the procedure detailed in Step 2.
Note: The lid volume will increase the volume of your result. This should be taken into account when recording the density of the solid. If ignored, lower densities will be calculated and negative isolated vesicularities may result.

Precisions: reproducibility to within 0.01-0.03 gcm^{-3} (see also Barker et al 2012)
Accuracy: accurate to within 0.03 gcm^{-3}