

Making Dust: The easy way of generating (a lot of) fine ash during tumbling experiments

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1. Introduction

Pyroclastic density currents (PDCs) are gravitationally controlled, volcanic flows. They are composed of a multi-phase mixture of pyroclasts, lithics, and volcanic gas and are some of the most hazardous and destructive volcanic phenomena, accounting for approximately 33 % of fatalities.

During PDC transport and sedimentation, ash is generated through clast-clast interactions involving abrasion, friction, and collision, as well as grain size reduction and clast breakage. Variations in ash production and in grain size distribution (GSD) directly influence the flow dynamics of PDCs.

For a better understanding of clast shape evolution and ash generation efficiency in PDCs, low-energy laboratory tumbling experiments were conducted.

Field: Clasts of different shape in fall (left) and traction carpet deposits (right)



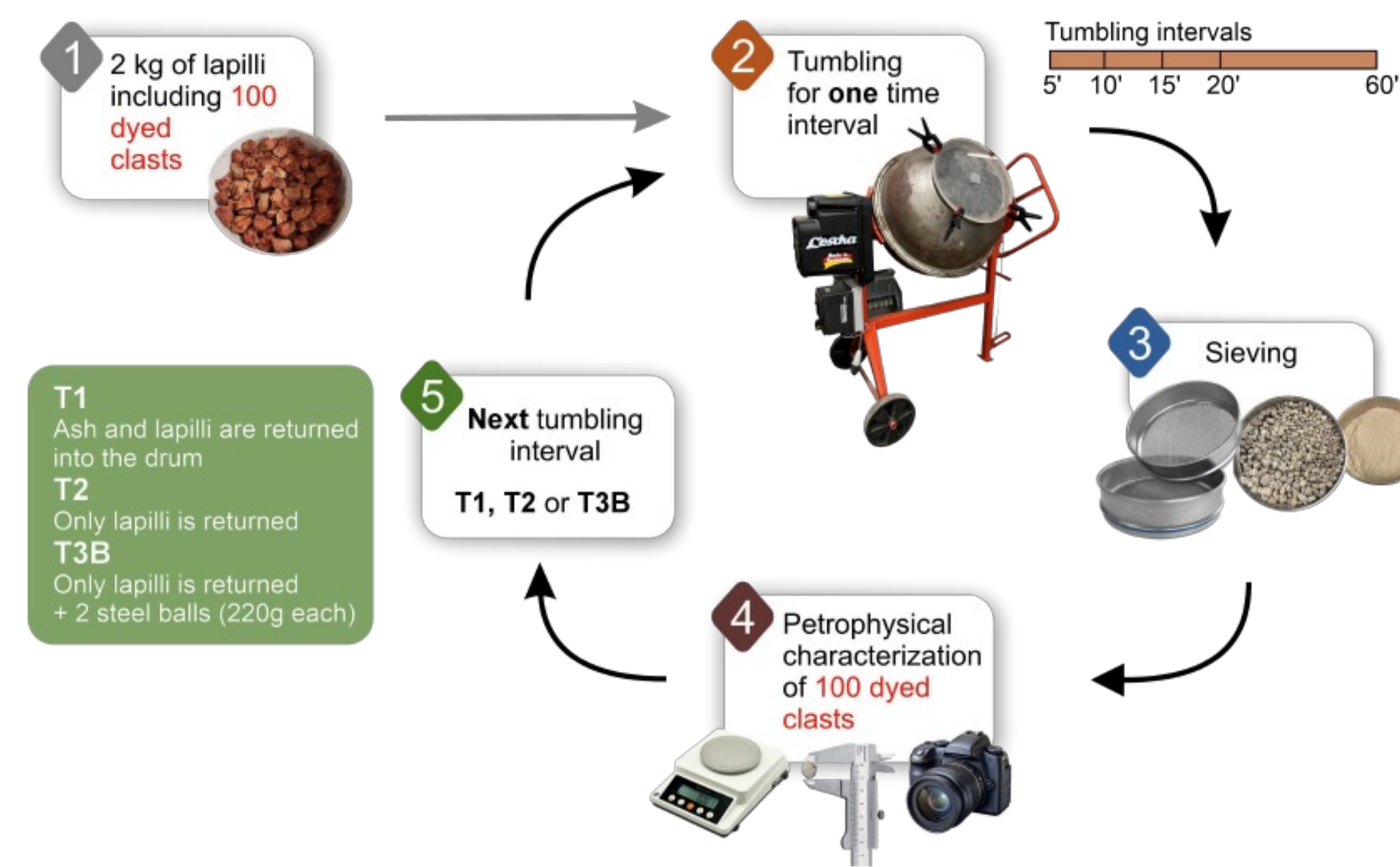
Field appearance of Laacher See eruption deposits near Nickenich, Germany, showing 1) **LEFT** dominantly angular clasts in proximal fall deposits (white clasts = juvenile pumice, dark clasts = lithics) and 2) **RIGHT** intercalated deposits of fall and PDC deposits where a substantial number of pumice lapilli are notably rounded.

2. Laboratory: Experiments and Methods

Two kilograms of angular lapilli pumice from the Middle Laacher See Tephra (MLST) originating from the 12,900 a BP Laacher See. Three different experiments types were designed (T1, T2, T3B).

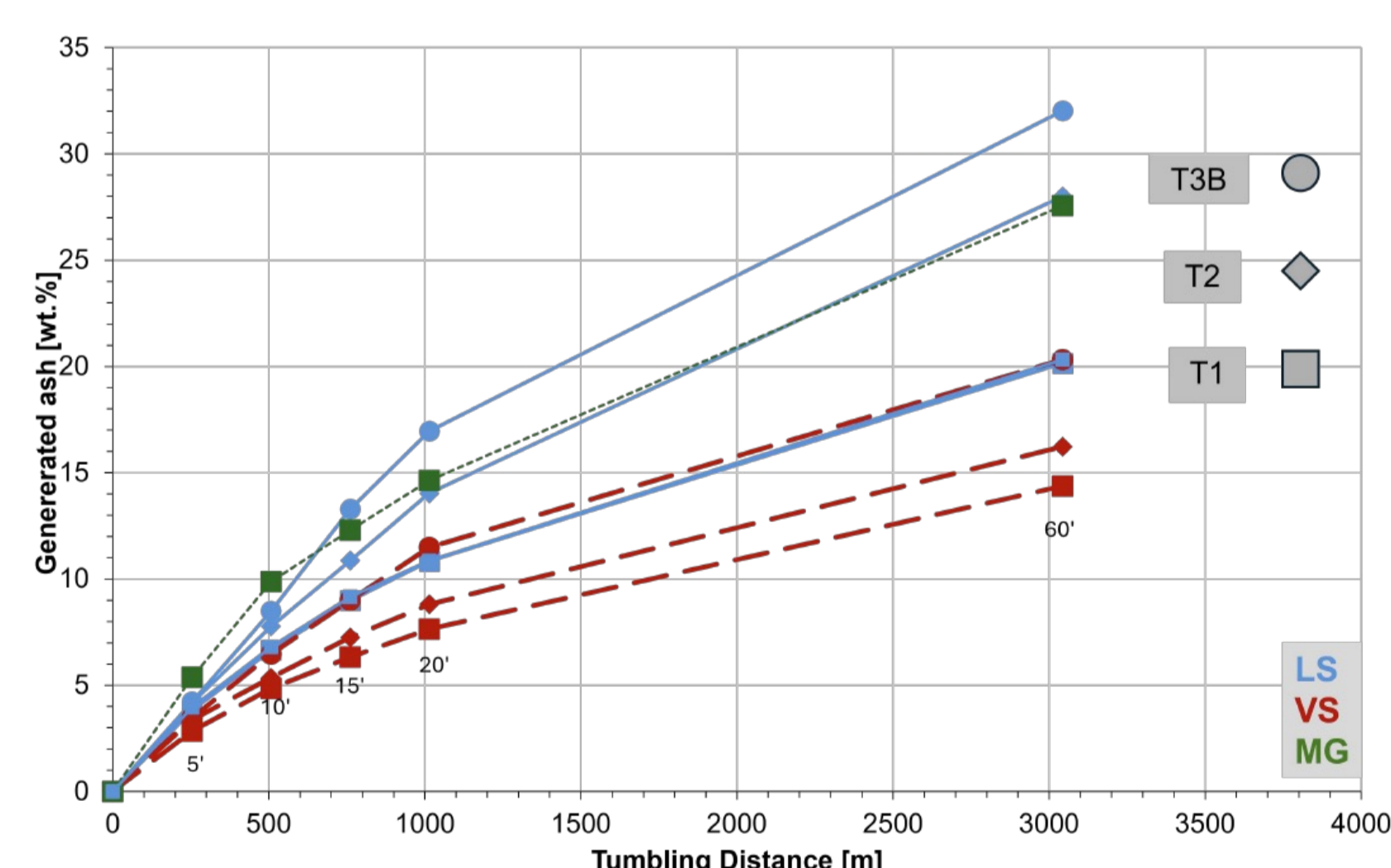
After each time step, the ash was sieved and weighed. The ash was either returned to the drum (T1) for further tumbling or stored separately (T2, T3B).

The ash fraction's GSD was analysed by dry sieving for particles down to 32 µm and by laser diffraction for particles below 32 µm. To compare results from experiments T1, T2, and T3B, laser diffraction data (originally in vol. %) were converted to mass [g] and plotted alongside the dry sieving results as weight percent to get a GSD of the total ash fraction.



Schematic overview of the experimental workflow with experiment types (T1, T2, T3B), sample preparation and sample processing.

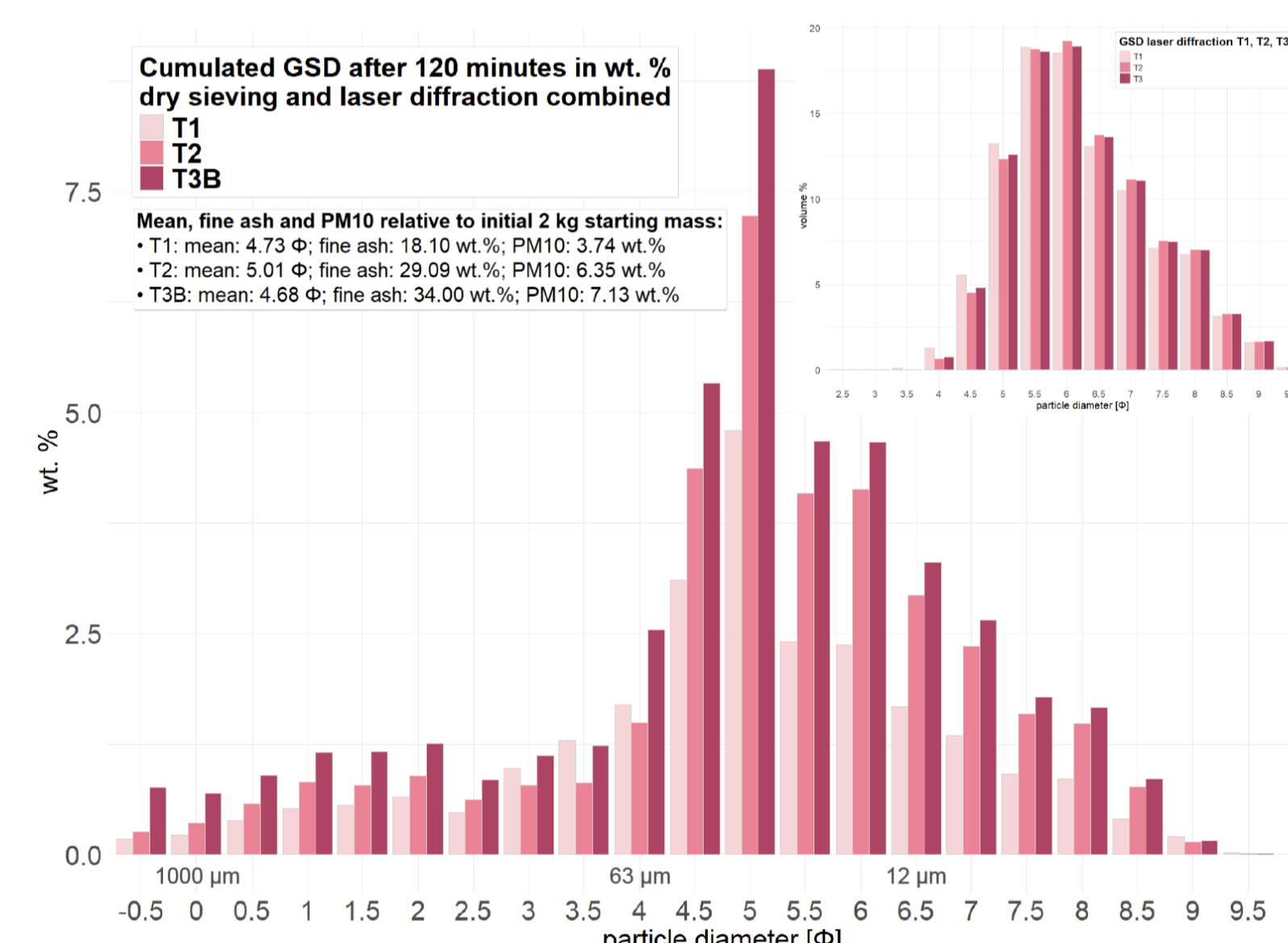
3. Results and Interpretation



Ash production during tumbling experiments, plotted as cumulative ash fraction (weight fraction of the starting mass) against the rotational distance for experiments T1, T2 and T3B (Set A) for Laacher See (LS), Vesuvius (VS) and Meager (MG)

Ash generation:

- Higher for Laacher See than Vesuvius (-> see talk by Figueiredo et al.)
- Positive correlation with collisional energy (ash removed/steel balls)
- All experiments resulted in mean grain sizes within the fine ash range!
 - T2 produced the smallest average particle sizes, with a mean of 5.01 Φ (29.16 µm)
 - T3B produced the largest mean particle sizes, with a mean of 4.68 Φ (39.01 µm).
- considerable proportion of fine ash (< 63 µm) and PM10 (≤ 10 µm) relative to the starting mass of 2 kg
 - • Fine ash: 18 % (T1), 29 % (T2), 34 % (T3B)
 - • PM10: 4 % (T1), 6 % (T2), 7 % (T3B)



Cumulated grain size distribution after 120 minutes for T1, T2, T3B experiments (dry sieving and laser diffraction combined) of experimentally generated ash and laser diffraction.

4. Conclusion

- Laboratory tumbling experiments provide a robust framework to quantitatively map the influence of sample properties, and experiment energy on ash generation and related clast shape change.
- Our experiments produced a notably high proportion of fine ash and PM10, even during short duration and low energy conditions.
- We expect that ash generation and clast shape change (indicator of abrasion) take place more efficiently during "real" PDCs. Continued ash generation will "replenish" the PDC in movement that are continuously deplete in ash by elutriation to the overriding ash cloud.

Associated hazards:

- Increased PDC mobility and accordingly longer runout distances of the PDC, substantially increasing the possible affected areas.
- Respiratory health hazard due to high concentration of PM10 particles.