Magnetic analysis of individual iron oxide grains; application of Micromagnetic Tomography to a natural sample.

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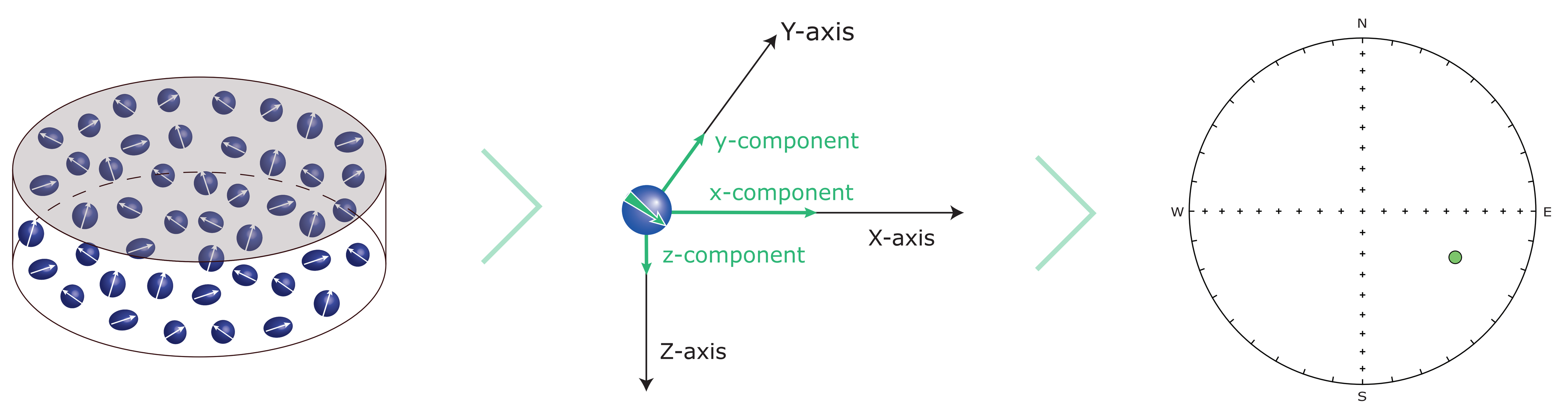
Framework: why a new method for paleomagnetism?

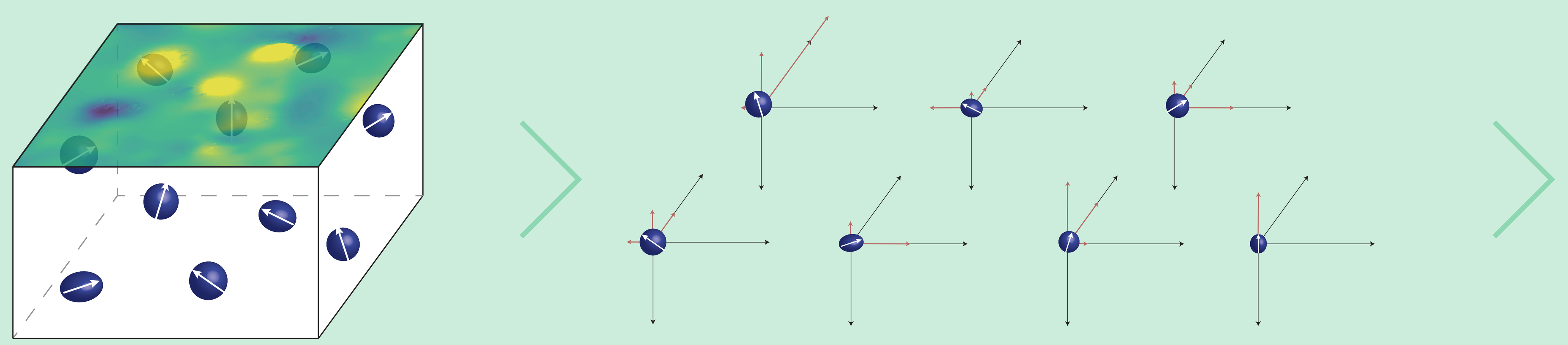
Paleomagnetism studies the behavior of the ancient Earth magnetic Field. **Current paleomagnetic methods** measure bulk samples, resulting in a single solution for millions of grains.



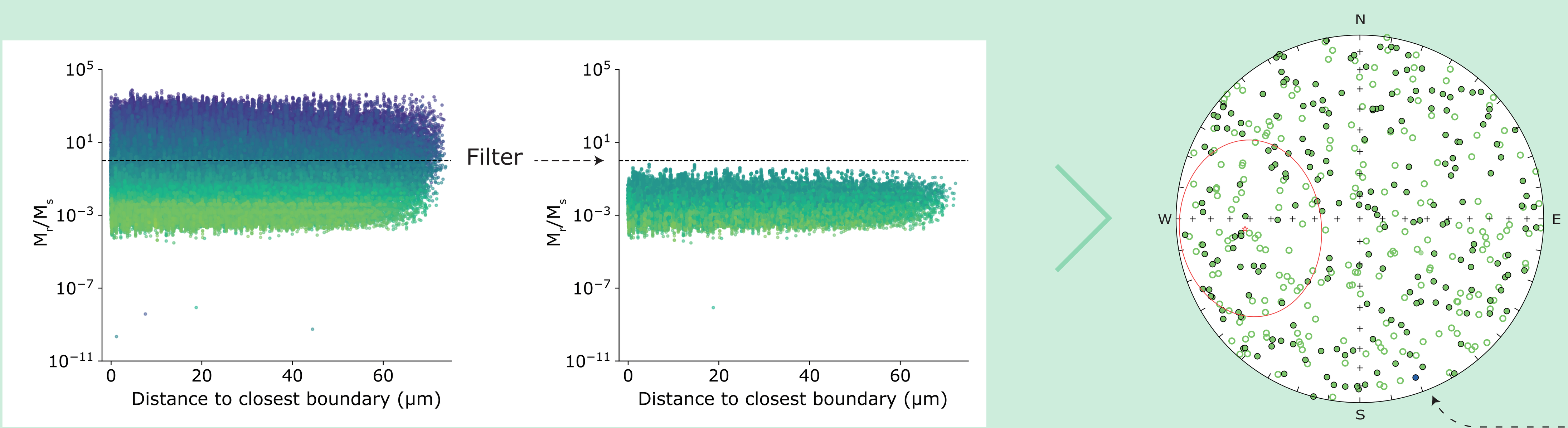
Bulk sample: millions of grains — Single measurement — Single solution

New method: Micromagnetic Tomography

Micromagnetic Tomography measures a microsample under a QDM and in a MicroCT, and then determines the magnetisation for each grain individually. These results can be statistically analysed and filtered leading to a more detailed understanding of the magnetic signal.



Microsample: 1646 grains — Individual results per grain



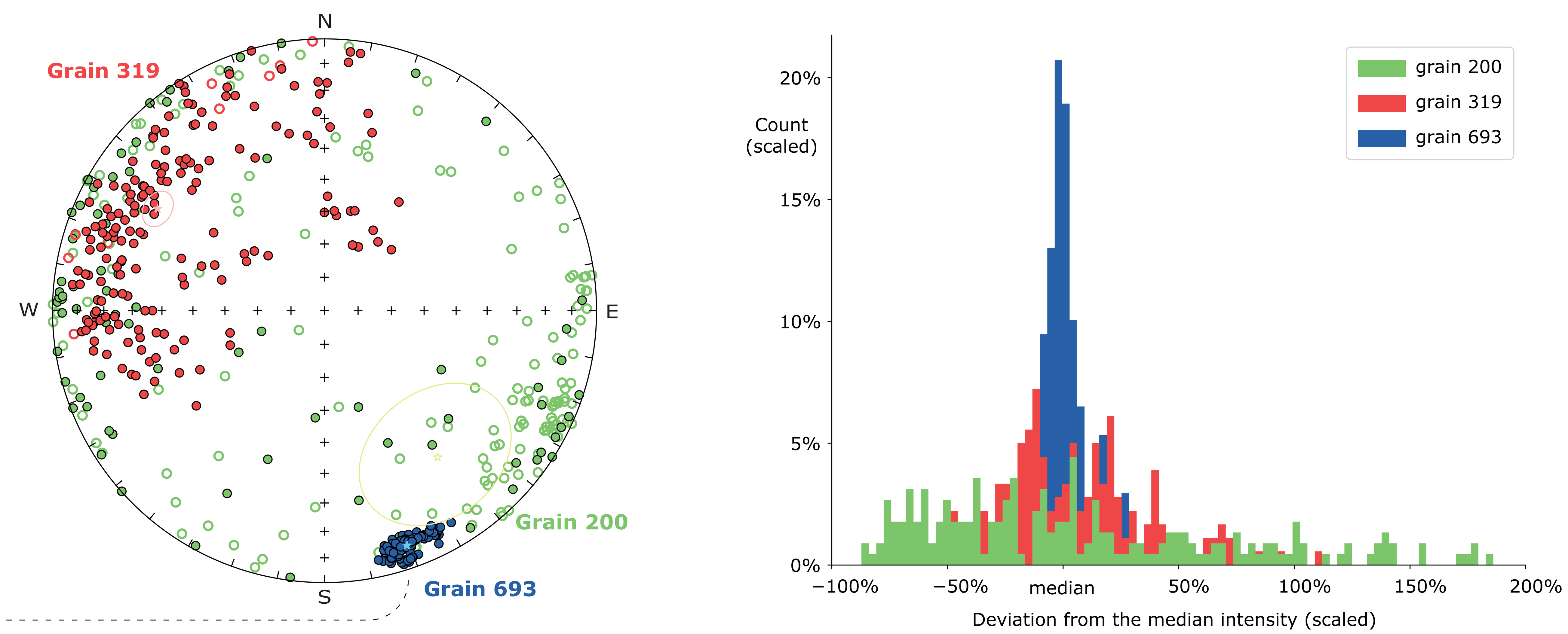
Statistical analysis — Filtered directions

Take home message

We have achieved the first step in performing classic paleomagnetic analysis at grain level. The next step is to perform AF-demagnetisation steps on these microsamples. Using micromagnetic tomography to analyse magnetic behavior at grain level opens up a new level of understanding how magnetizations are stored in individual grains that was not previously possible.

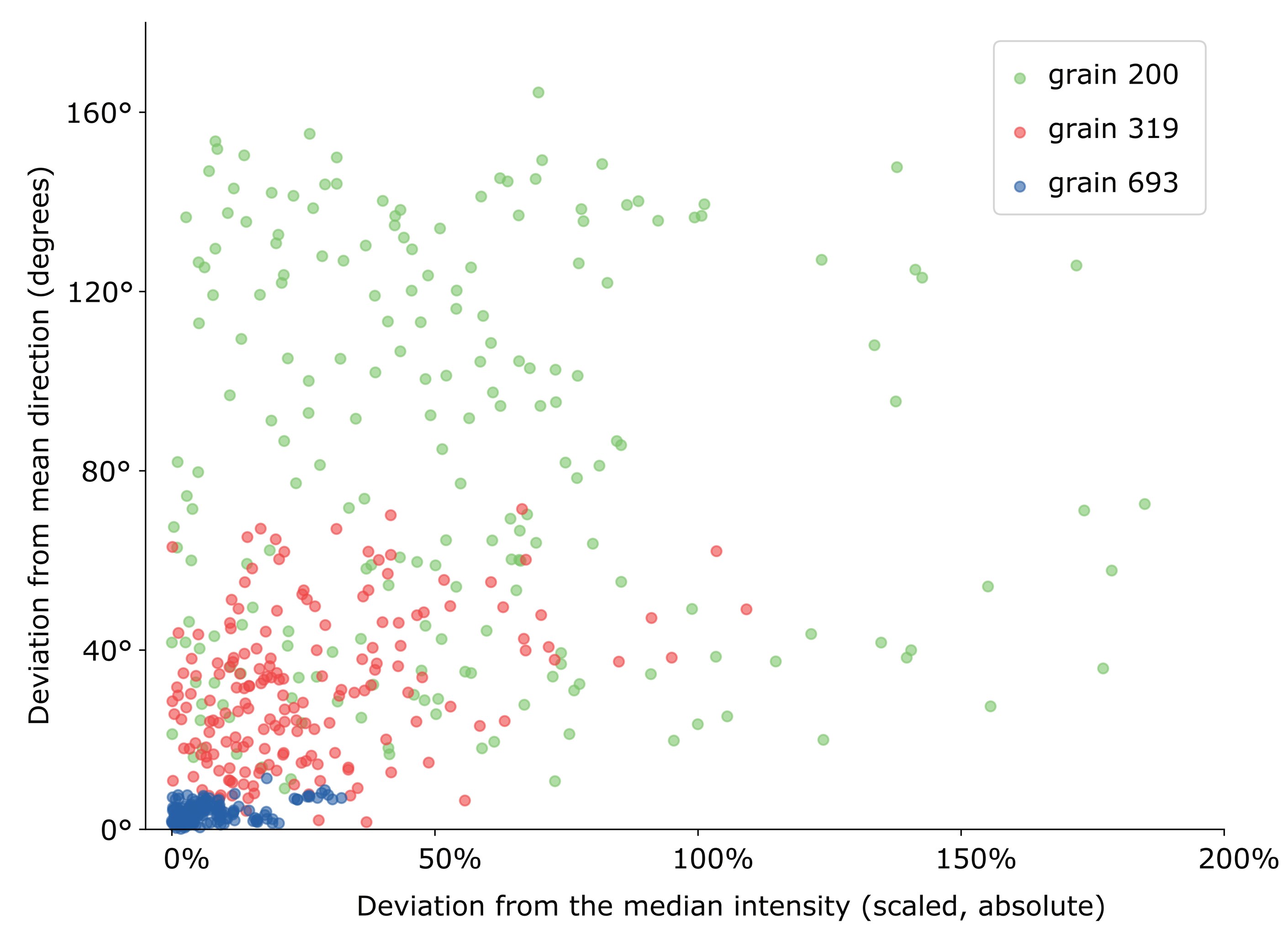
A case study of three grains from a volcanic sample

The microsample contains 1646 individual iron oxide grains. The magnetisation in three components was repeatedly determined for each grain. Grain 200, 319 and 693 show varying degrees of scatter, both in the directional results (equal area projection, left) and in the intensity results (histogram, right).



Direction vs Intensity results

We initially hoped that individual results with a large directional deviation would correspond to the results with a large intensity deviation, as the direction and intensity come from the same initial magnetisation in three components. Below can be seen that this is not the case. Sometimes the directional results have a high deviation (eg. $\Delta\alpha = 150^\circ$), while Δm is close to zero and vice versa (upper-left corner vs bottom-right corner).



Grain properties

Grain 200
Volume = 13.53 μm³
Weighted depth = 34.92 μm
N = 225
k = 1.185
α95 = 21.69°
Median Intensity = 3.92e-9 Am²
SSR = 6.70e-5 μm⁻¹

Grain 319
Volume = 14.15 μm³
Weighted depth = 23.17 μm
N = 180
k = 5.630
α95 = 4.88°
Median Intensity = 1.18e-10 Am²
SSR = 3.79e-4 μm⁻¹

Grain 693
Volume = 3717.32 μm³
Weighted depth = 14.82 μm
N = 169
k = 363.463
α95 = 0.57°
Median Intensity = 7.03e-11 Am²
SSR = 5.95e-2 μm⁻¹

Figures adapted from: **Kosters, M.E.**, de Boer, R. A., Out, F., Cortés-Ortuño, D.I., de Groot, L.V., (2023), Unraveling the Magnetic Signal of Individual Grains in a Hawaiian Lava Using Micromagnetic Tomography. Geochemistry, Geophysics, Geosystems, 24, e2022GC010462.

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