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

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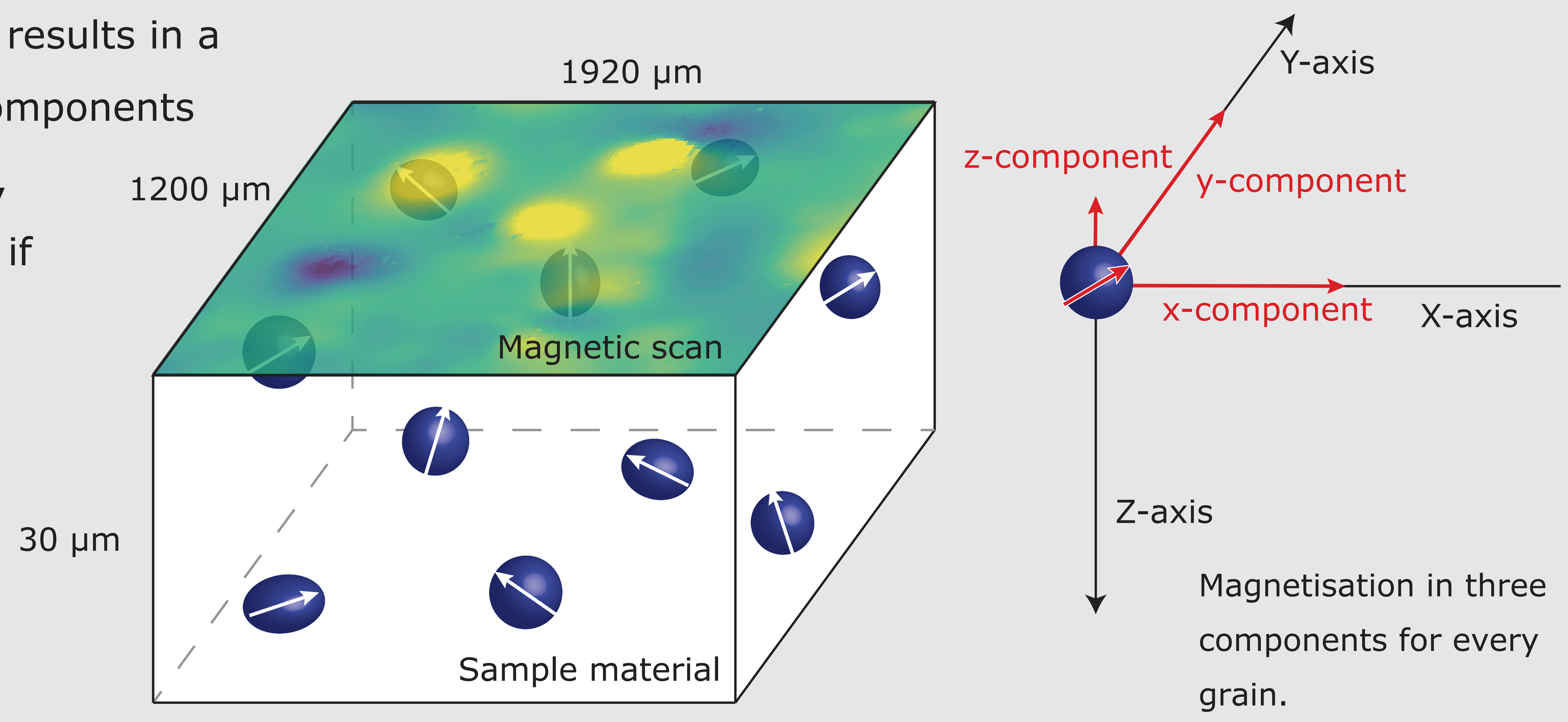
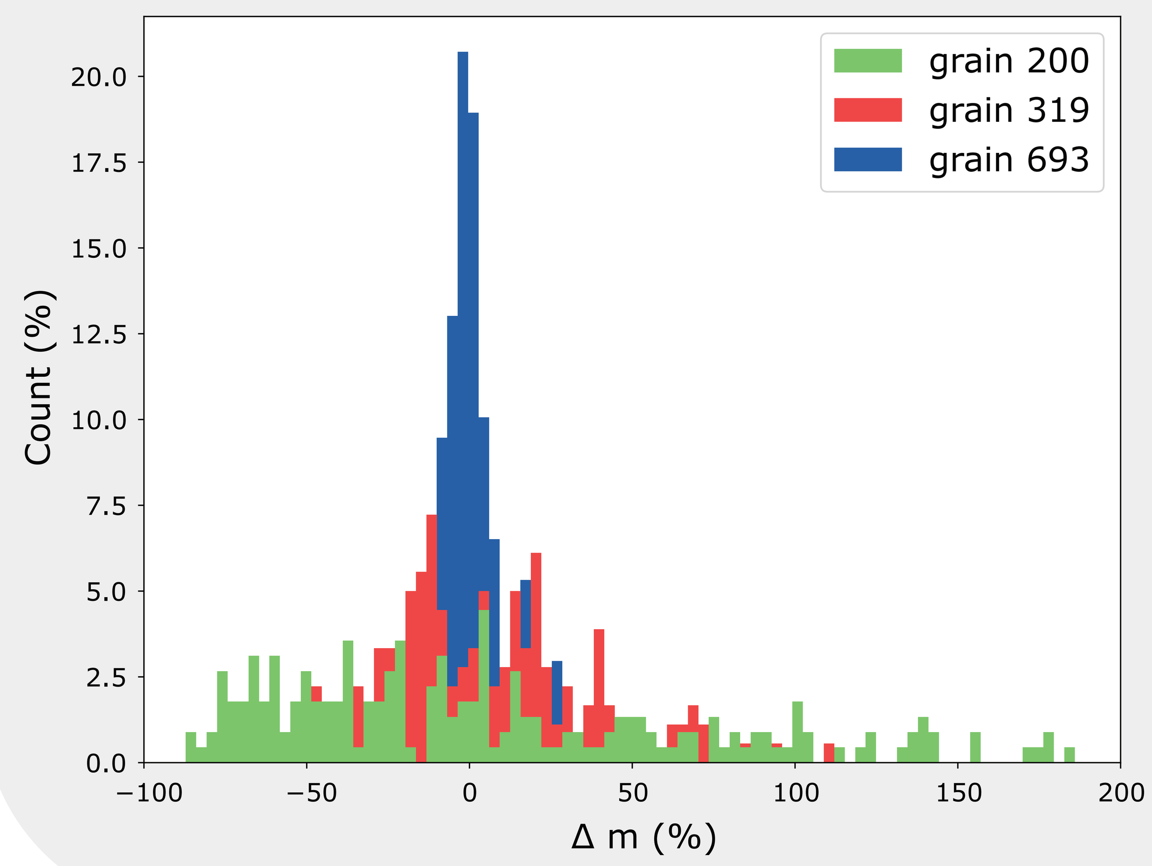
Purpose

Paleomagnetic analysis of rocks often produces irregular results. Some samples behave well in directional experiments, others behave well in intensity experiments, some produce varying results across methods, others do not produce any results. What current methods have in common is that they rely on bulk measurements, producing one result for millions of magnetic grains. Here we present a new method for magnetic analysis, which results in a magnetisation in three components for every individual grain, enabling an investigation if the erratic behavior in classic paleomagnetic experiments stems from the varying magnetic behavior of individual grains.



Intensity results per grain

Each grain has a determined magnetisation in three components for every subarea that it is present in. The figure below shows the percentual difference between the median magnetisation (intensity) for a grains and the individual results for that grain. Results of three typical grains are shown, ranging from a very narrow distribution (grain 693) to a very wide distribution (grain 200).

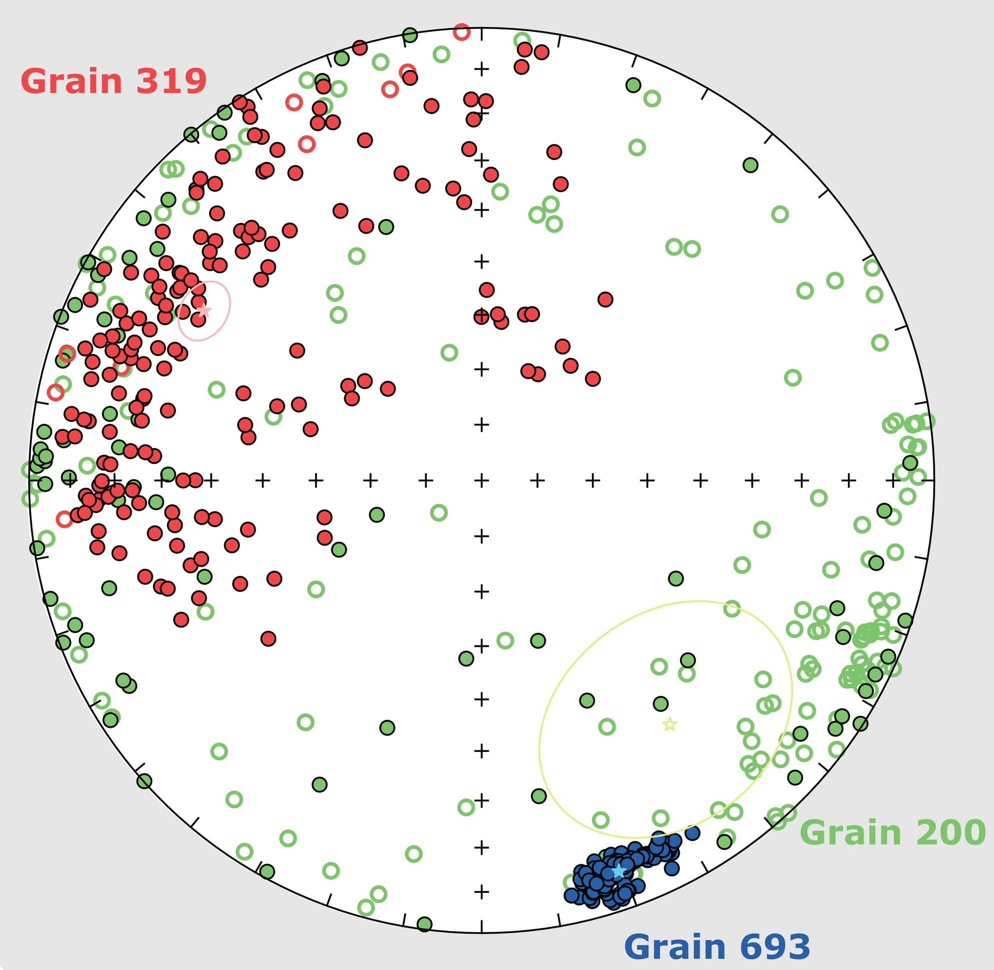


Overview

First, a magnetic surface scan of the sample is made using a QDM. Second, a MicroCT scan is made of the sample material, resulting in the shapes and locations of 1646 iron-oxide grains. Then, the magnetisation in three components is repeatedly determined for every grain. The results are grouped per grain and analysed. The analysis of the same three grains are pictured top-right, middle and bottom-left. Finally the results for all grains are analysed (bottom-right).

Directional results per grain

The individual directional results of three typical grains with various degrees of scatter: from very scattered (grain 200) to very concentrated (grain 693).

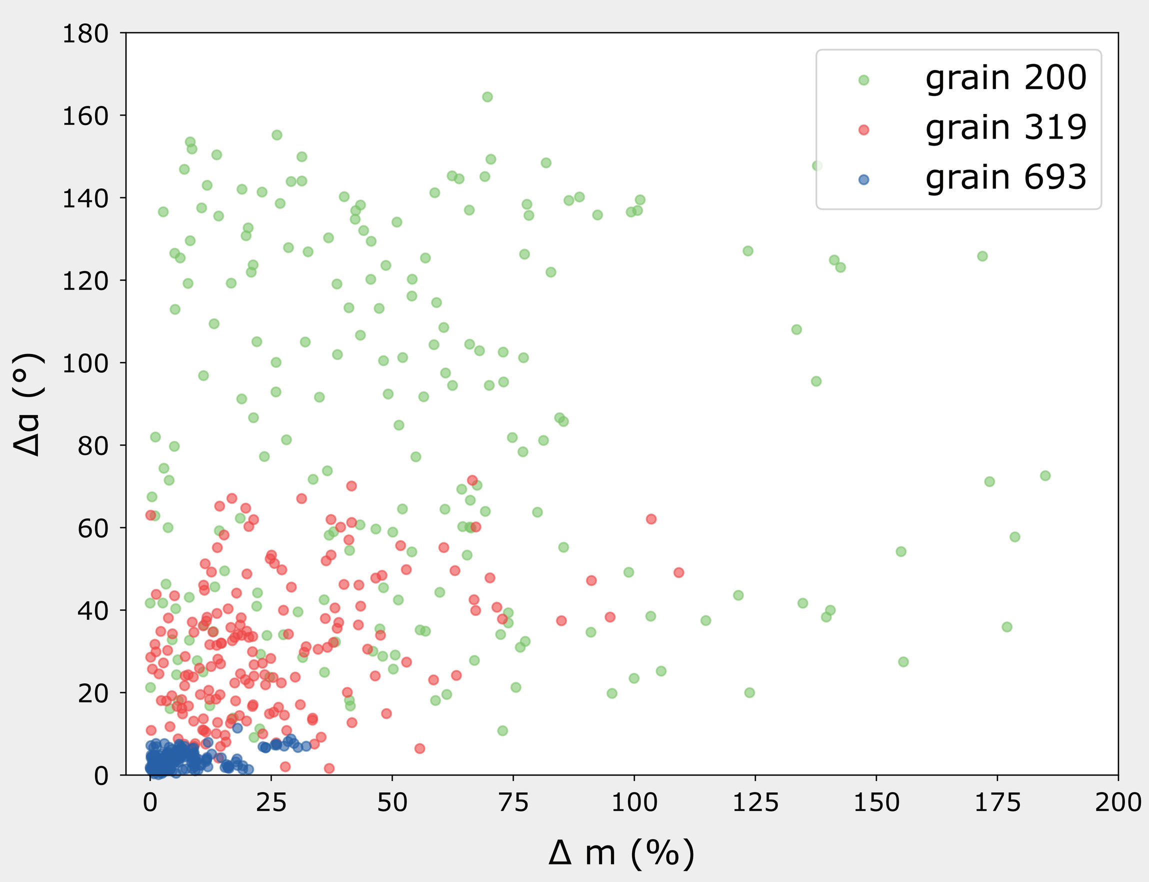


Conclusions & Outlook

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. After that we will work on developing the method for oriented samples and optimizing the workflow for sister samples. Using micromagnetic tomography to analyse magnetic behavior at grain level is a step in understanding how magnetizations are stored in individual grains that was not previously possible.

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. Δα = 150°), while Δm is close to zero and vice versa (upper-left corner vs bottom-right corner).



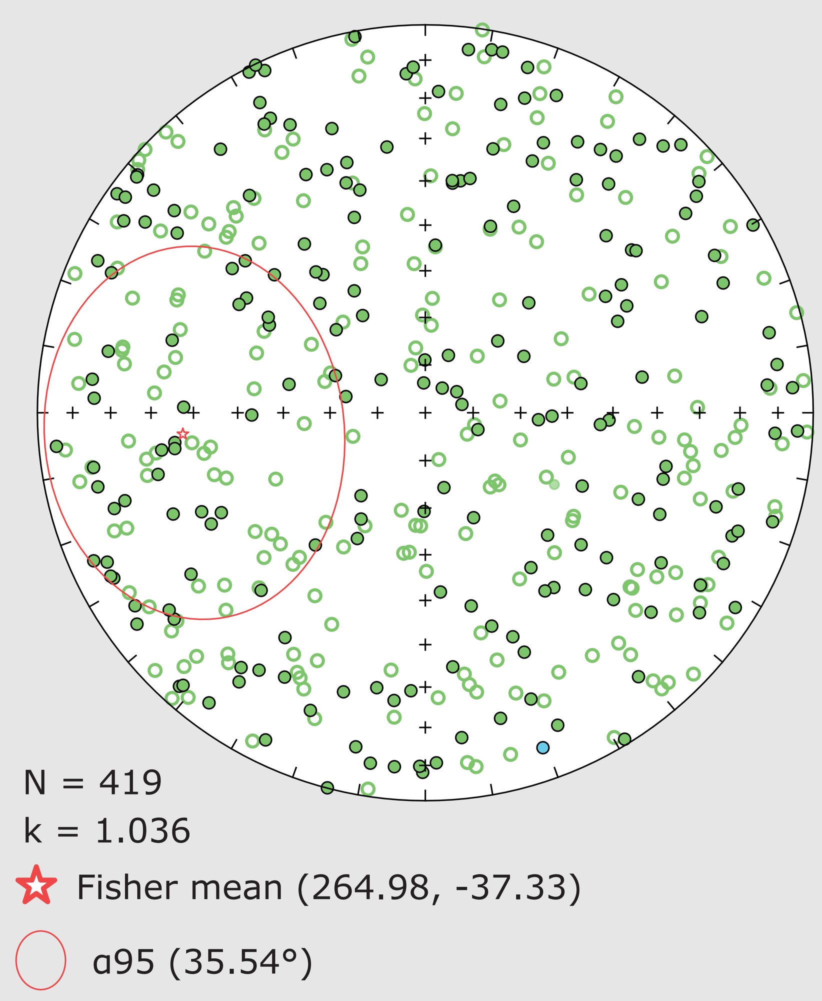
Grain properties

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

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

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

Directional results of all grains



Each grain has a mean direction and from those mean directions we can determine the mean direction of the sample. From the precision parameter (k) and the confidence interval (α95) we can deduce how many grains we need to interpret for a statistically meaningful result. Thus we have taken the step from results from sister specimens to results from sister grains.

Reference

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. (in press).

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