Modeling the Distribution of Iron-oxides in Basalt by combining FIB-SEM and MicroCT Measurements

How Micromagnetic Tomography deals with Ghosts
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The problem
Micromagnetic Tomography (MMT) infers the magnetic moment per grain through a well-posed inversion[11] by employing magnetometry at the surface of the sample and MicroCT for the position of all relevant grains. However, MicroCT detects iron-oxide particles > 1 micrometer, while the smallest, signal carrying, particles are 40 nm[2]. Therefore, small grains, not sorted, although their magnetic signal is still present. Furthermore, we do not yet know how many of these small (ghost) grains are present in natural Hawaiian basaltic lava, a frequently used sample for MMT studies and development[13,14].

Why should you care?
Paleomagnetism is an important tool for dating rocks, understanding Earth’s magnetic field behavior, and providing constraints for tectonic plate reconstructions. By measuring the signal produced by magnetic minerals (iron-oxides) in a volcanic rock sample, we might learn the direction and intensity of Earth’s magnetic field stored many years ago when the rock solidified. Unfortunately, many iron-oxides incorrectly store the magnetic signal leading to failed experiments. Luckily, with Micromagnetic Tomography we can study the signal of individual iron-oxides and only focus on the good recorders[3-5]. However, there are still some hurdles on the way (see The problem).

Methods
We applied the slice-and-view procedure[17] on a Hawaiian volcanic sample using FIBSEM. We have analyzed a 26 x 10 x 10 µm subdomain with 20 nm pixel size. We extracted 1841 iron-oxides and observed that these particles reside on large mineral interfaces with a surface area of 1.53 * 10^3 mm^2 (see central figure). We also employed MicroCT data on a 60 µm thick slice of Hawaii [30]. We extracted 1646 iron-oxides and 4.00 mm^2 mineral interfaces. To create a grain-size distribution from 20 nm to 10 µm MicroCT and FIBSEM data must be linked; FIBSEM detects grains between 20 nm to 1 µm and MicroCT detects grains larger than 1.5 µm. We decided to link the grains using mineral interface area: we calculated the number of grains per mineral interface area present in FIBSEM. Then, we scaled that number to the mineral interface area visible in MicroCT data to obtain our scaled grain distribution.

Workflow

Results and Discussion

Conclusions & Key points
➢ We employed FIBSEM to obtain iron-oxides in the range 20 nm to 1 µm. These iron-oxides are clustered at large mineral interfaces.
➢ We scaled the number of iron-oxides acquired with FIBSEM and MicroCT to create a grain size distribution for iron-oxides from 20 nm to 10 µm.
➢ With this distribution we can build grain models of basaltic rocks.

References