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Isolating Magnetic Moments from Individual Grains in an Assemblage – Upscaling Towards Analyzing Natural Samples

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A b s t r a c t

Methods to derive paleodirections or paleointensities from rocks currently rely on measurements of bulk samples (typically ~10 cc). The process of recording and storing magnetizations as function of temperature, however, differs for grains of various sizes and chemical compositions. Most rocks, by their mere nature, consist of assemblages of grains varying in size, shape, and chemistry. Unraveling the behavior of individual grains is a holy grail in fundamental rock magnetism.

Recently, we showed that it is possible to obtain plausible magnetic moments for individual grains in a synthetic sample by a micromagnetic tomography (MMT) technique. We use a least-squares inversion to obtain these magnetic moments based on the physical locations and dimensions of the grains obtained from a MicroCT scanner and a magnetic flux density map of the surface of the sample. The magnetic flux density map was acquired using a Scanning SQUID Magnetometry (SSM) set-up at the University of Twente, the sample and the sensor are both submerged in liquid Helium (at 4 K) while measuring. Furthermore, the sample used for this proof of concept was optimized for success: it had a low dispersion of the grains, and the grains were large enough so they were easily detected by the MicroCT scanner. To make our MicroCT assisted Micromagnetic tomography technique applicable to real lavas, it is necessary to acquire the magnetic flux density maps at room temperature,

and to be able to handle much higher dispersions of magnetic markers in natural lavas compared to our synthetic sample.

To analyze the magnetic flux at the surface of the sample at room temperature, we used the Magnetic Tunneling Junction (MTJ) scanner at the University of Cambridge. As this machine is less sensitive than the SSM used before, we analyzed our synthetic sample in an IRM state. We were able to recover the pulsed field direction from a limited number of grains reliably. The MTJ, however, is not capable of scanning with small step sizes that would yield enough data to reliably invert for the much higher number of magnetic markers per volume in a natural sample. Moreover, natural lavas are much more complex than the synthetic sample analyzed so far: the grains differ more in composition and size, and many small (submicron) magnetic markers may be present that go undetected by the MicroCT scanner. To scan at room temperature and attain the necessary step size we turned to the Quantum Diamond Magnetometer (QDM) at Harvard University. We scanned a natural volcanic sample from the 1907-flow at Hawaii in two different states; an untreated state, and after a 25 mT AF demagnetization step. In our contribution we will present the results obtained with the QDM scanner and elaborate on the potential of the MicroCT assisted Micromagnetic Tomography technique applied to natural samples. Moreover, we will compare the SSM, MTJ and QDM methods in terms of work flow and quality of the results.