Paleomagnetic behavior and stability of a very recent lava flow, the 2021 La Palma eruption, Spain

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1. Introduction

Volcanic rocks are used as a source to study the past behavior of the Earth's magnetic field. When volcanic rocks cool in the geomagnetic field, they archive the past direction and intensity. While obtaining paleodirections is relatively easy, obtaining information about the intensity of the Earth's magnetic field is much more difficult. Usually, only 10-20% of the samples used in paleointensity methods are successful. Recent studies propose the remanence in samples is unstable and may change over time. Aging experiments [1] on samples with a given TRM indicate samples may experience "fragile" curvature. In September 2021, the Cumbre Vieja volcano on the island of La Palma, Canary Islands, Spain, erupted. Here, we test whether the intensity recorded by very young samples is accurate, if their remanent magnetization changes over time and whether the presence or absence of a geomagnetic field influences their stored magnetizations.

2. Geological setting and sampling

La Palma is one of the seven islands of the Canary Islands, Spain. At the southern tip of the island, the Cumbre Vieja volcanic ridge is located. The eruption of 2021 lasted 85 days and was the largest eruption in the recorded history of the island [2]. The fieldwork was carried out in November 2021, when the volcano was still active. Therefore, the youngest part of the flow was less than 2 weeks old when sampled. At three sites, LP1, LP2, and LP3 (Figure 1), samples were taken spread out. Between 9-19 standard paleomagnetic cores of 5-10cm in length were drilled at each site and samples were oriented with a magnetic compass. Samples were transported back to Utrecht University in magnetically shielded boxes.
Five batches of the same samples were made:
Batch 1: directions and intensities measured immediately after the fieldwork.
Batch 2+3: intensity samples stored in the Earth's magnetic field for several years (in-field).
Batch 4+5: intensity samples stored out of the Earth's magnetic field for several years (out-field).

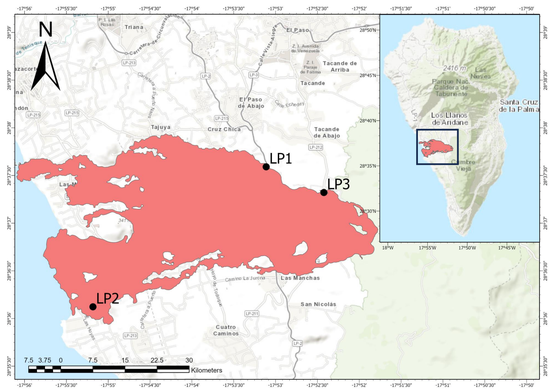


Figure 1| Map of the island of La Palma with in red the area covered by the 2021 flow. LP1, LP2, and LP3 are the locations of the sampling sites in this study

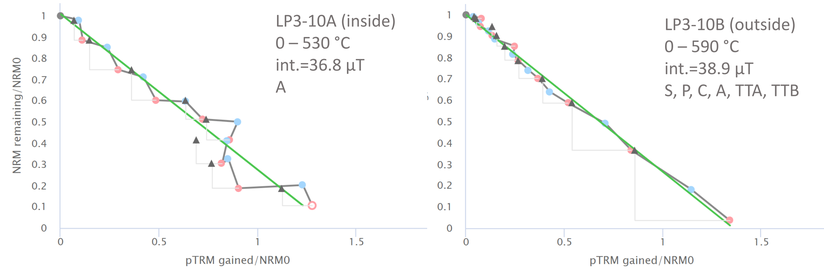


Figure 2| Paleointensity results of two samples from LP3 of batch 1. The green line is the largest interpreted segment. The six selection criteria are: S= SELCRIT, P=PICRIT, C=CCRIT, A=CLASS A, TTA, TTB. The expected intensity on La Palma in October 2021 was 38.7µT

3. Directions batch 1

From batch 1 paleomagnetic directions were obtained with thermal and alternating field(AF) demagnetization experiments. Zijderveld diagrams indicate that LP2 has moved during cooling, only the low temperatures (0-300°C) cluster with LP1 and LP3 and are therefore interpreted. With AF, LP2 lost most of its magnetization at fields under 60mT and the results were too scattered to be reliably interpreted, it is therefore not used for calculating the mean directions. The expected direction on La Palma in October 2021 was -4.9° for declination and 37.1° for inclination. The results from our samples yields a +0.9° difference with the reference declination and -2.2° for inclination.

4. Intensity batch 1

The paleointensity was derived from 72 samples with the IZZI-Thellier technique. Usually, samples for paleointensity experiments are prepared from the inside of cores to limit the amount of possible alteration. Here, we used samples from both the inside (A-samples) and outside (B-samples) of cores. For LP1 and LP3, five volcanic glass samples were included in the measurements.

The main observations are:
1. 65% of the samples from the inner core (A) passed at least one selection criterion but the outer core (B) samples were more successful, with 94% of the samples passing at least one selection criterion (Figure 3B).
2. The least successful was LP2. Although only Arai segments with low MAD-angles were interpreted the intensity was probably affected by the rotation.
3. Of LP2 the B-samples gave more accurate results.
4. The volcanic glass samples were very successful and accurate.

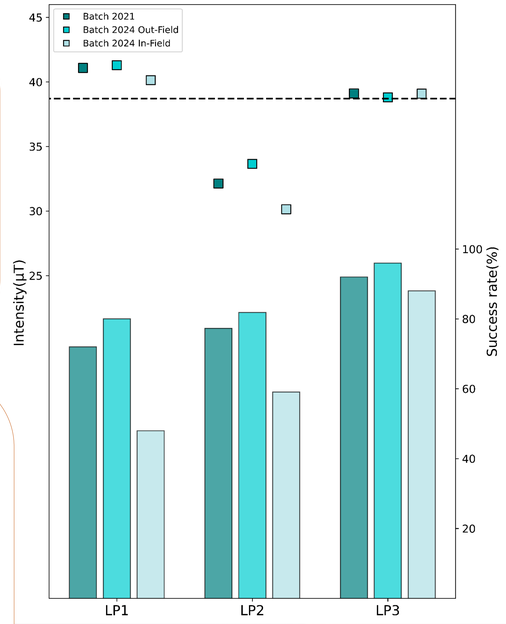
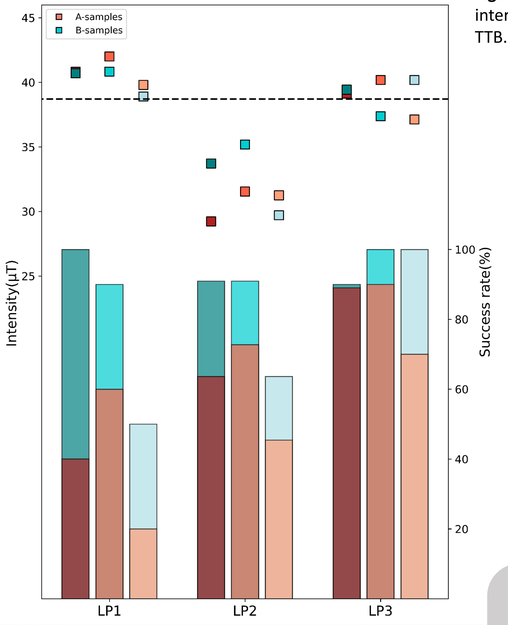


Figure 3A| Results of all accepted interpretations.



3B| Only results from A- and B-samples

5. Intensity batch 2 and 4

Batch 2 (in-field) and batch 4 (out-field) were measured two years after sampling. The main observations are:
1. The out-field samples have the highest success rate, the success rate is lower for the batch stored in-field (Figure 3A).
2. The outside (B) samples are still more successful than the inside (A) samples (Figure 3B), although of the out-field batch more A-samples got accepted than in 2021.
3. There is a >6µT difference between the B-samples of LP2 depending whether they are stored in- or out-field.

→ Outside samples are more successful due to faster cooling rates

Outlook

The samples from batch 3 and 5 will be allowed to age for some extra time and measured later. Additionally, we plan to visit La Palma again to re-sample our sites. Unfortunately, all our sampling sites appear to be covered by a new part of the flow. While LP1 and LP3 might be still accessible, it is unlikely we can visit the exact location of LP2.

References
[1] Tauxe, Lisa, et al. (2021) Understanding nonideal paleointensity recording in igneous rocks: Insights from aging experiments on lava samples and the causes and consequences of "fragile" curvature in Arai plots.
[2] Civico, R., Ricci, et al (2022). High-resolution digital surface model of the 2021 eruption deposit of Cumbre Vieja volcano, La Palma, Spain.

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