A non-dipole intensity peak precursor: case study of a mid-Miocene geomagnetic reversal from lava flows of Gran Canaria

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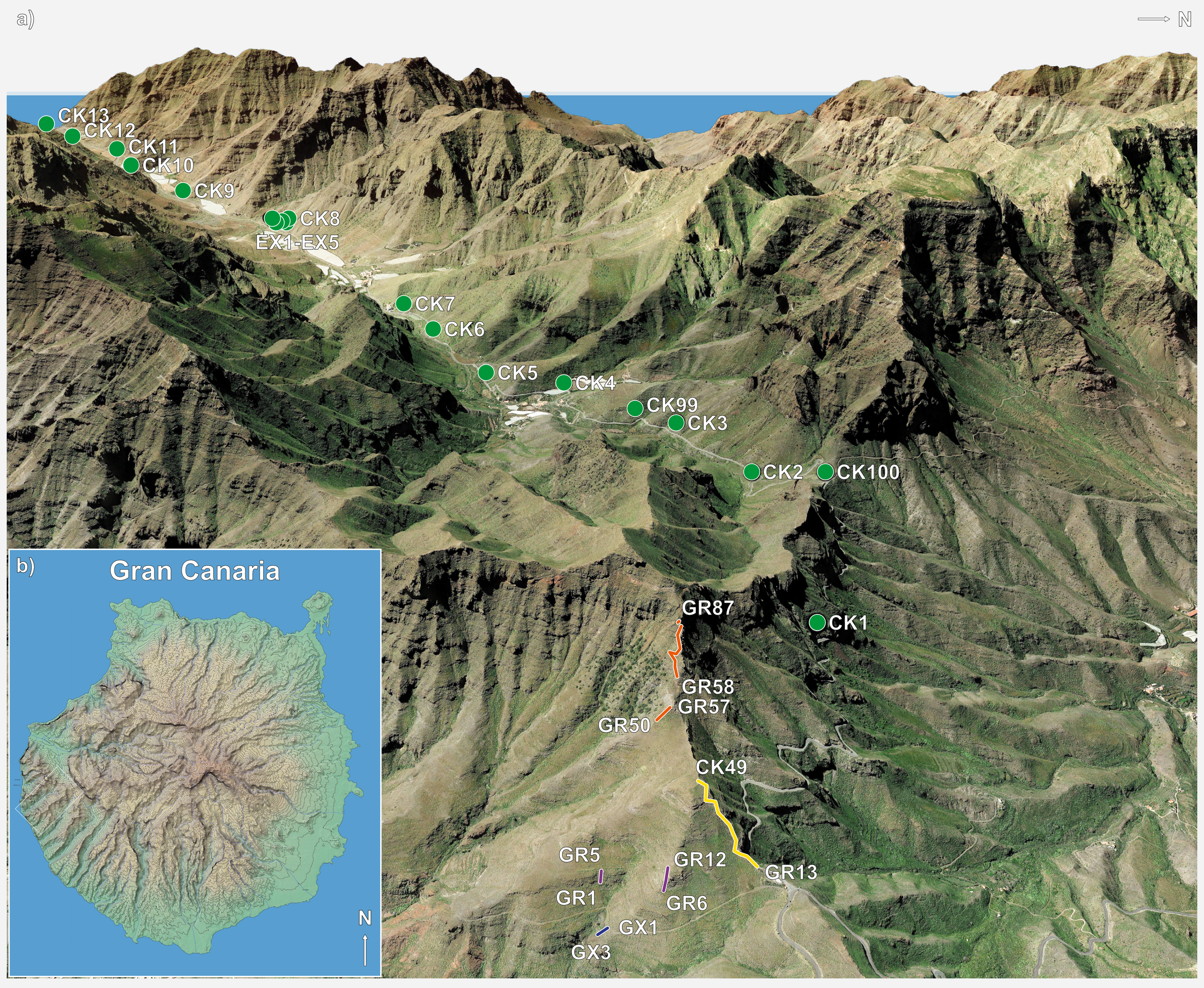
The problem

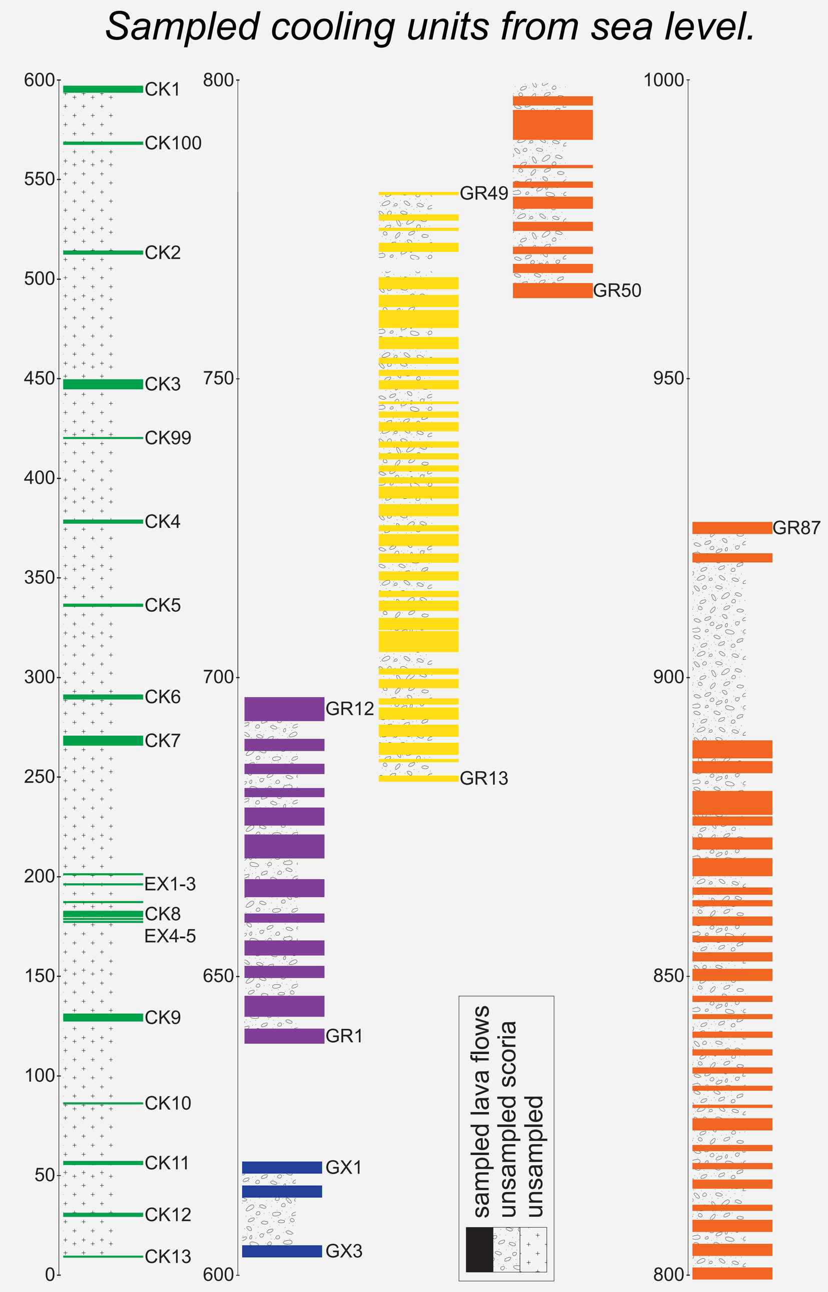
Our Earth's magnetic field reverses its polarity non-periodically. Despite the large number of reversals in the magnetographic record, the geometry of the Earth's magnetic field and the mechanisms driving reversals still remain obscure. One reason is because the more readily available sedimentary records lack temporal resolution for recording the rapid field changes during a reversal. Another reason is because the volcanic data records -that may have the necessary temporal resolution- are dependent on volcanic eruption frequency and much more difficult to find. To further our understanding of magnetic reversals, high quality volcanic records need to be discovered and studied. This is what we have done here by studying a mid-Miocene reversal recorded by lava flows on Gran Canaria.



Sampling and measuring

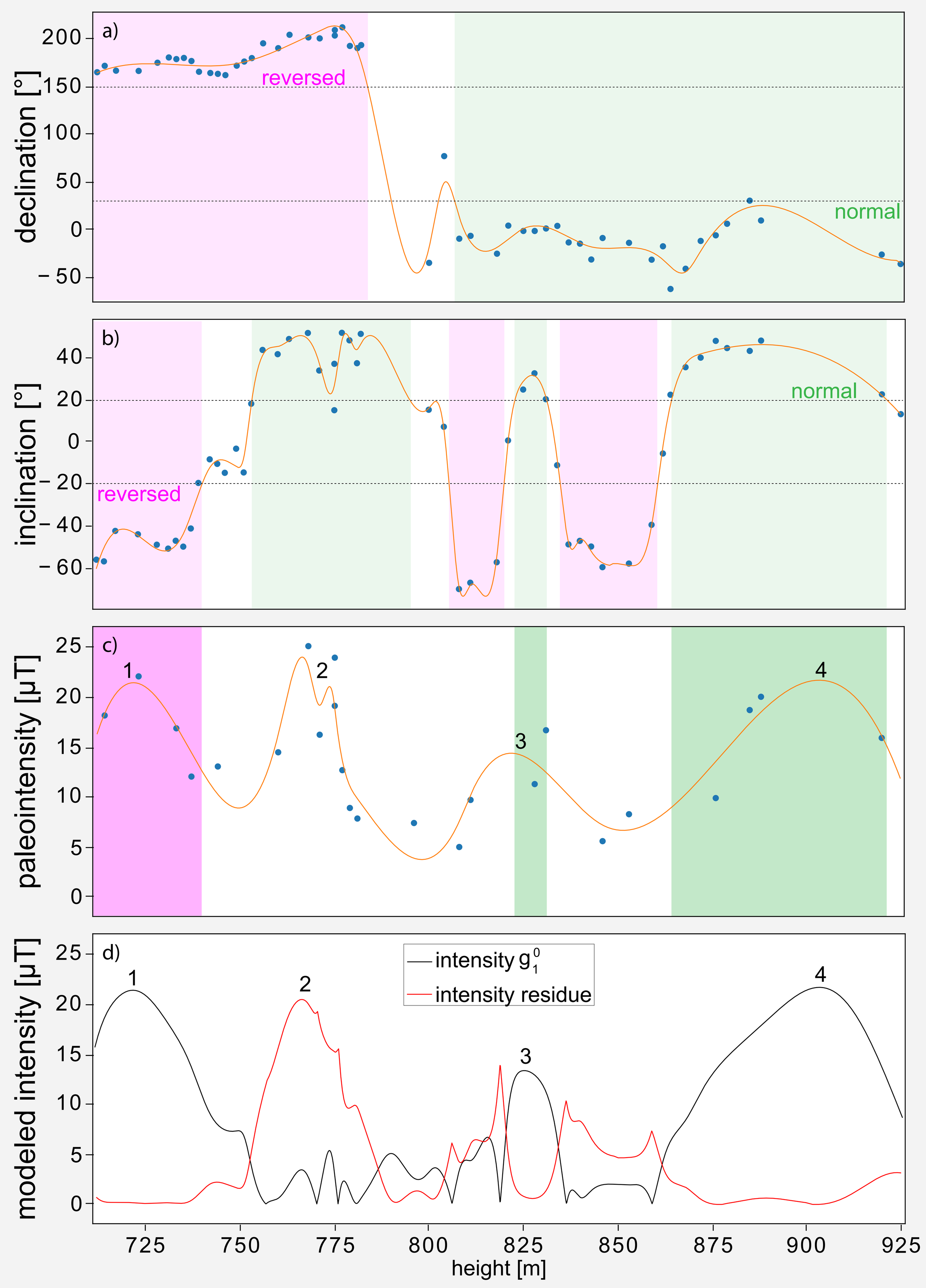
The sampled section on Gran Canaria was deposited by a 2000m high shield volcano (van den Boogaard and Schmincke, 1998) during the short-lasting shield building phase of the island, around 14.5-14.0 Ma (Toll and Carracedo, 2016). This volcano caused a continuous eruption of low viscosity basalts, which led to a thick sequence of lava flows of Hawaiian type fissure eruptions (Toll and Carracedo, 2016). A reversal in this section was previously discovered by Leonhardt et al., (2002). We sampled the section with 110 independent cooling units. The first 600m from sea level was sampled every ~50 altimeters. Between 600-925m every cooling unit was sampled. All cooling units were measured intensively; A rock magnetic analyses for each cooling unit was obtained with a VSM and a susceptibility measurement. Directions for each cooling unit were obtained with both thermal and alternating field demagnetization experiments. Lastly the paleointensity record was measured with an IZZI-Thellier and Pseudo-Thellier experiment.

Sampled cooling units from sea level.

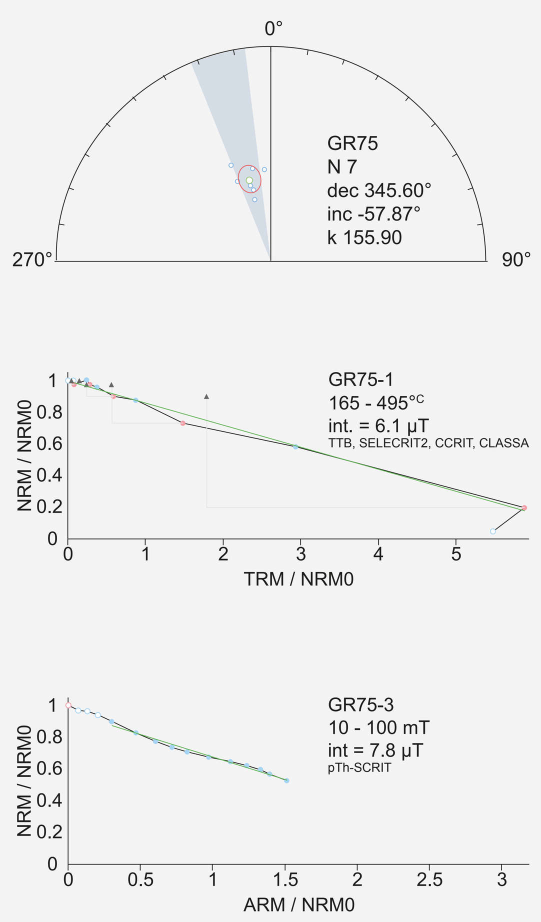


Discussion and Conclusion

To further unravel the non-axial dipole higher order pole contribution we built a simplified spherical harmonic model for the high quality interval of the measured paleomagnetic record. The top three panels on the figure to the right contain the high-quality records (blue dots) with a fitted spline (orange line). The bottom panel contains the resulting total intensity of our simplified spherical harmonic model in which only the axial dipole component, term g^0_1, was fitted (black line). The model shows three clear peaks that coincide with peak 1, 3, and 4 of our paleointensity data. This is expected, because during these peaks both the inclination and the declination show the same polarity. However, the second peak, of 25 μT, cannot be explained by the axial dipole field, because during this peak the declination has a reversed polarity at the same time as the inclination has a normal polarity. It is generally accepted that during a reversal the axial dipole component is weak and therefore the non-dipole components are more dominant, however, it is a new observation that the non-axial dipole and higher order pole contributions can increase in strength to a size that is comparable to the intensity of the axial-dipole field.

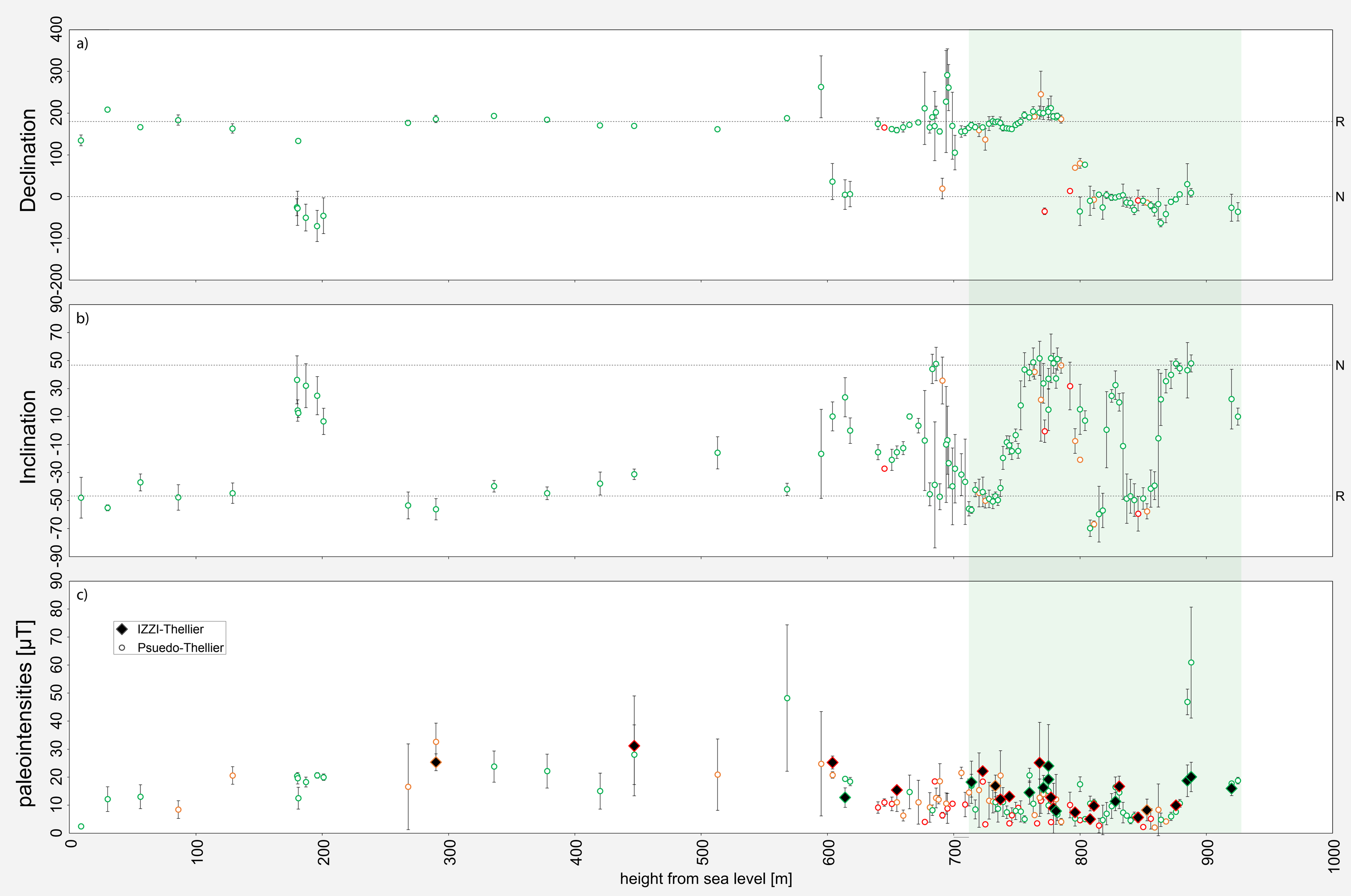


Example: paleodirection of a cooling unit and an IZZI- and pseudo-Thellier measurement.



Results

The figure to the right shows the full paleomagnetic record of our Gran Canaria section. The highest data resolution was obtained in the green shaded area, for both the paleodirection and paleointensity data. The paleodirections in this area contains a declination which reverses once in the time the inclination reverses 5 times. This is a clear indicator of a complex field geometry during the reversal, with contributions of non-axial dipole and higher order pole components. The pulsating field strength in the green shaded area is a striking feature of the paleointensity record. It appears that the field is fluctuating between approximately 5 and 25 μT, which is both seen in the IZZI-Thellier and Pseudo-Thellier paleointensity measurements. Four intensity peaks can be distinguished at 725, 775, 825 and 900m elevation.



green: 5 or more, orange: 2-3, red: 1-2 successful measurements per cooling unit

References

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