Check for updates

RESEARCH ARTICLE

Magnetic mineralogy of the Baringo core (HSPDP-BTB13-1A, Kenya) shows astronomical forcing with implications for retrieving meaningful paleointensity

[version 1; peer review: 2 approved, 1 approved with reservations]

Mark J. SIER[1,2], Bianca R. Spiering[1], Mark J. Dekkers[1], Frits J. Hilgen[1]

[1]Earth Sciences, Utrecht University Faculty of Geosciences, Utrecht, Utrecht, 3584CB, The Netherlands
[2]Centro Nacional de Investigacion sobre la Evolucion Humana, Burgos, Castile and León, Spain

v1 **First published:** 04 Jul 2025, **5**:177
https://doi.org/10.12688/openreseurope.20266.1
Latest published: 04 Jul 2025, **5**:177
https://doi.org/10.12688/openreseurope.20266.1

Abstract

This study evaluates the potential of the BTB13 sedimentary core from the Baringo Basin, Kenya, to contribute to relative paleointensity (RPI) records and improve geochronological correlations across Eastern Africa. The core, spanning ~3.3-2.6 Ma, is part of the Hominin Sites Paleolakes Drilling Project (HSPDP) and has a robust age model based on magnetostratigraphy and 40Ar/39Ar dating. High-resolution rock magnetic analyses, including NRM/ARM ratios and pseudo-Thellier RPI methods, were applied to test the suitability of the core for RPI reconstruction. Results indicate that the magnetic signal is dominated by environmental rather than geomagnetic influences, with large amplitude NRM/ARM variations failing standard selection criteria for RPI. Spectral analysis reveals strong periodicities at ~22, ~40, ~50, and ~400 kyr, aligning with orbital parameters and suggesting that the magnetic signal is climatically driven, likely linked to lake level changes paced by precession and obliquity cycles. While unsuitable for RPI-based correlations, the BTB13 core preserves a valuable astrochronological signal that can support regional correlation and paleoenvironmental reconstruction in the context of hominin evolution.

Keywords

Chemeron Formation, East African Rift, Relative Paleo Intensity, Pliocene, Pleistocene

Open Peer Review

Approval Status ✓ ✓ ?

	1	2	3
version 1 04 Jul 2025	✓ view	✓ view	? view

1. **Tesfaye Kidane**, Wayne State University, Detroit, USA
2. **Julie Carlut**, Université Paris Cité, Institut de Physique du Globe de Paris, Paris, France
3. **Tilo von Dobeneck**, University of Bremen, Bremen, Germany

Any reports and responses or comments on the article can be found at the end of the article.

This article is included in the Horizon Europe gateway.

This article is included in the Marie-Sklodowska-Curie Actions (MSCA) gateway.

Corresponding author: Mark J. SIER (marksier@gmail.com)

Author roles: SIER MJ: Conceptualization, Data Curation, Formal Analysis, Funding Acquisition, Investigation, Project Administration, Visualization, Writing – Original Draft Preparation, Writing – Review & Editing; **Spiering BR**: Formal Analysis, Investigation, Methodology, Visualization, Writing – Original Draft Preparation, Writing – Review & Editing; **Dekkers MJ**: Methodology, Writing – Review & Editing; **Hilgen FJ**: Formal Analysis, Investigation, Methodology, Writing – Original Draft Preparation, Writing – Review & Editing

Competing interests: No competing interests were disclosed.

Grant information: This project has received funding from the European Union's Horizon Europe research and innovation programme under grant agreement No 101109142.

Copyright: © 2025 SIER MJ *et al*. This is an open access article distributed under the terms of the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

How to cite this article: SIER MJ, Spiering BR, Dekkers MJ and Hilgen FJ. **Magnetic mineralogy of the Baringo core (HSPDP-BTB13-1A, Kenya) shows astronomical forcing with implications for retrieving meaningful paleointensity [version 1; peer review: 2 approved, 1 approved with reservations]** Open Research Europe 2025, **5**:177 https://doi.org/10.12688/openreseurope.20266.1

First published: 04 Jul 2025, **5**:177 https://doi.org/10.12688/openreseurope.20266.1

Introduction

Relative paleointensity (RPI) is a tool used to constrain the age of sedimentary sequences younger than 4 Ma (Channell *et al.*, 2018; Valet *et al.*, 2020; Valet *et al.*, 2005a), based on correlating short- and long-term fluctuations in the intensity of the Earth´s magnetic field (e.g., Sint2000; Valet *et al.*, 2005b). Intensity changes in the Earth´s magnetic field occur at much higher frequencies than reversals of the Earth´s magnetic field. Like the Earth's magnetic reversal record, the RPI record is irregular, unique in time, and the main trend is largely global, meaning that different regions reveal a similar pattern of high and low intensities for the same period of time (e.g. Channell *et al.*, 2018; Tauxe, 1993). Therefore, the RPI from different localities can be compared and potentially correlated if the records are of similar age and of sufficient duration. The integration of RPI with other geochronological techniques, such as radioisotopic dating and magnetostratigraphy, allows for robust age models.

The Hominin Sites Paleolakes Drilling Project (HSPDP) is an international multidisciplinary effort that aims to understand how landscape and climate change shaped the evolution of the hominin lineage (http://hspdp.asu.edu/). Five key (paleo) lake areas were selected for HSPDP in Kenya end Ethiopia: Chew Bahir, Magadi, West Turkana, Northern Awash, and Baringo Tugen Hills Barsemoi (BTB13; Figure 1). Sediment cores were drilled at the selected sites that represent crucial areas for tracking human evolution in Eastern Africa. Evidently, age control is critical in such studies as it constitutes the basis for most of the major hypotheses in palaeoanthropology and archaeology. For the BTB13 sedimentary core from Kenya (Figure 1) a high-resolution age model was published in 2021 based on dated tephras and magnetostratigraphy (Deino *et al.*, 2021; Sier *et al.*, 2021). The geochronological well-constrained BTB13 core in principle can be used to generate an RPI record for future detailed time-stratigraphic correlations to other HSPDP cores, like the Northern Awash cores from the Afar region in Ethiopia, which are geochronologically poorly constrained, but overlap in age with the BTB13 core. Moreover, RPI data of the BTB13 core may contribute to the global RPI record, which remains inadequately documented for the age range represented by the BTB13 core. With this in mind, we measured rock magnetic properties of the BTB13 core. However, to achieve the objectives we first should test whether the samples are suited for RPI reconstruction by determining the origin of the paleomagnetic signal.

Regional and geological setting

The BTB13 drill site (latitude 0.5546°N, longitude 35.9375°E) is located in the Baringo Basin/Tugen Hills, part of the Central Kenya Rift Valley. The drill site is located east of the Saimo Fault, west of Lake Baringo, and just north of the Barsemoi River (Figure 1). The basin contains the most complete Late Neogene sequence of the East African Rift with a duration of 16 Myr (Behrensmeyer *et al.*, 2002; Chapman & Brook, 1978; Deino *et al.*, 2002; Hill, 2002) and a thickness of ~3 km (Gilbert *et al.*, 2010). The strata have been divided into a number of formations and contain fluvio-lacustrine sediments that alternate with layers of trachyte, phonolite and basalts. The Pliocene/Pleistocene Chemeron Formation, the target of the BTB13 core, was first formally described by McCall *et al.* (1967) and ranges in age from 5.3 to 1.6 Ma (Deino *et al.*, 2006). The Chemeron Formation consists of lacustrine and subaerial sedimentary strata and some siliceous tuffs. It is exposed in the eastern foothills of a westward tilted horst block within the basin. A total of 228 meter of core was recovered (Campisano *et al.*, 2017) and the cored strata are correlated to dated outcrops ranging from ~2.6 to 3.3 Ma (Cohen *et al.*, 2016; Deino *et al.*, 2021). The core is primarily composed of clastic deposits, which include a range of materials from muddy fine-grained

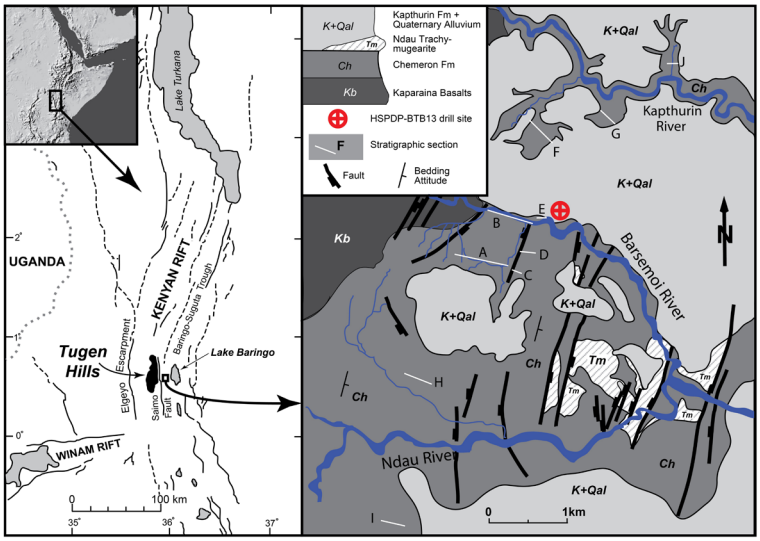


Figure 1. Map of the Baringo area with geological setting, top left insert shows topographic map of East Africa. Location of BTB13 site (latitude 0.5546N, longitude 35.9375E). Stratigraphy of this figure is described in detail in Deino *et al.*, 2006 and Kingston *et al.*, 2007. Figure adapted from Deino *et al.*, 2006.

sandstones to pebble conglomerates. These are interspersed with clayey and diatomaceous lacustrine deposits. The core can be divided into four main lithologic intervals (Westover *et al*., 2021):

1. **Basal Interval:** This section, ranging from approximately 228 mbs (meters below surface) to 201 mbs, is primarily composed of conglomerates and mudstones.

2. **Finer-Grained Clastic Interval:** Extending from around 201 mbs to 107 mbs, this interval is dominated by fine-grained clastic deposits with occasional deep lacustrine layers.

3. **Conglomerate-Rich Interval:** From approximately 107 mbss to 78 mbs, this section is characterized by a high concentration of conglomerates.

4. **Upper Lacustrine Interval:** This interval, spanning from 78 mbs to the top of the core at 5 mbs (with the first 5 meters not recovered), consists of diatomaceous and clayey deep lacustrine sediments interbedded with fine-grained clastics.

The Upper Lacustrine Interval contains five cyclic deep-lake diatomites that are correlated to Diatomite 5 to Diatomite 1 from youngest to oldest in outcrop strata (Deino *et al*., 2006; Kingston *et al*., 2007).

Materials and methods

The BTB13 core was drilled in May-June 2013 (for drilling details see Cohen *et al*., 2016). After drilling, the BTB13 core was transported by airfreight to the National Lacustrine Core Facility (LacCore) at the University of Minnesota (Minneapolis, MN, USA) for comprehensive scanning, processing, description, and subsampling. Detailed analyses of physical properties of cores from all sites were conducted using a Multi-Sensor Core Logger - Standard (MSCL-S, for natural gamma radiation) and a MSCL-XYZ sensor (split core for high-resolution magnetic susceptibility) at intervals ranging from 0.5 to 4 cm. Gamma radiation values of 1 gm/cc (grams per cubic centimeter) and smaller were excluded from interpretation. Values of 1 gm/cc are consistent with water and values < 1 are deemed artifacts for example caused by scanning gaps. Visual core descriptions were also carried out (see Cohen *et al*., 2016 for more details). The paleomagnetic samples used in this study and our previous work (Sier *et al*., 2021) were collected directly after the splitting of the core at the facility.

A total of 543 levels were sampled for a total of 567 paleomagnetic samples at regular intervals throughout the core, with an average spatial resolution of around 0.41 m. Some levels were sampled twice with small unoriented samples collected for rock magnetic experiments. The stratigraphic position of the samples was measured with < 0.5 cm precision. Several methods were used to collect samples. The majority were extracted using a drill press equipped with a water-cooled diamond-coated 2.5 cm diameter bit. Soft levels were sampled by gently pushing custom-made quartz or perspex containers, with standard paleomagnetic sampling dimensions (25 mm diameter, 22 mm length), into the sediment. Levels that were too fragile for drilling but not soft enough for insertion of the quartz cups or perspex containers were carefully carved out in blocks of 2×2 cm. All lithologies encountered in the core were sampled; intervals where the core was distorted as a result of the drilling were avoided, these were mainly situated at the start of core segments. After sampling, the samples were wrapped in laboratory-grade airtight cellophane and stored at temperatures below 5° C.

For our pilot RPI study we performed stepwise progressive static 3-axis Alternating Field (AF) demagnetization of the NRM up to a maximum of 100 mT, in 16 steps using the integrated AF demagnetizer of the DC-SQUID magnetometer at the Centro Nacional de Investigacion sobre la Evolucion Humana (CENIEH) in Burgos (Spain). After each step the remaining NRM was measured with a 2G DC-SQUID magnetometer. NRM intensities were typically several orders of magnitude higher than the instrument sensitivity (~3×10^{-12} Am^2). During the demagnetization process, the specimens were kept in a shielded environment. Stepwise. Anhysteretic Remanent Magnetisation (30 μT steady field) (ARM) acquisition was performed with the same equipment as mentioned above using the same 16 steps. For the pilot data set on 40 randomly selected samples so-called Pseudothellier analysis (Tauxe *et al*., 1995) was performed using the Paleointensity.org open source, online tool for analyzing paleointensity data (Béguin *et al*., 2020). Interpretation was done using the automatic interpretation option on specimen level where only samples that pass the set of selection criteria are considered. These selection criteria are:

$n\geq5$, $f\geq0.35$, $\beta\leq0.1$, $k^{\rightarrow\prime}$ abs$\leq$ 0.164, R^2corr ≥0.995, $MAD_{Free} \leq 5$ $|k^{\rightarrow\prime}|\leq0.2$ $f_{Resid}<0.15$, $\alpha \leq 5$, DANG ≤ 4, $k^{\rightarrow\prime}{}_{AA}$ abs$\leq$ 0.2, $k^{\rightarrow\prime}{}_{DD}$ abs$\leq$ 0.2, $R^2_{corr\ AA} \geq 0.995$, $R^2_{corr\ DD} \geq 0.995$, $f_{Resid} \leq 0.15$ (Béguin *et al*., 2020; Paterson *et al*., 2016). A second automatic interpretation was done with the AF steps up to 15 mT omitted, as our previous work indicated an overprint in these samples up to 15 mT (Sier *et al*., 2021). The remaining samples were measured using the methods above with the exception of the ARM only being measured at 25, 30, and 35 mT. As a result, the data cannot be used for pseudo Thellier RPI but it can be used as a proxy for Magnetic Mineral Content (NRM/ARM) and shows distinct regularity leading us to investigate whether this variability is related to astronomical climate forcing.

Age model

The age model used is in our study is a Bayesian stratigraphic age model based on four identified paleomagnetic reversals in the core (Sier *et al*., 2021), $^{40}Ar/^{39}Ar$ dating (Deino *et al*., 2021), and $^{40}Ar/^{39}Ar$ age calibration of related outcrop diatomaceous units (Deino *et al*., 2006; Kingston *et al*., 2007). $^{40}Ar/^{39}Ar$ dating was done on 12 tephras from the core and 4 tephras in outcrop that were geochemically correlated to the core. The age model of the BTB13 core has not been astronomically tuned, however, the diatomaceous units near the top of the core have been previously linked to precession cycles (Deino *et al*., 2006; Kingston *et al*., 2007). Uncertainties of the age model

vary throughout the core, with the lowest uncertainties in the upper part that contains most geochronological tie points (see figure 6 of Deino *et al.*, 2021).

Spectral analysis

Spectral analysis of the NRM/ARM data was performed with the open source software package Acycle (Li *et al.*, 2019). The data were analyzed in the time domain using the age model of Deino *et al.* (2021). The data were stratigraphically sorted, interpolated to a uniform sample spacing equal to the median sample distance (~0.34 m and ~1 kyr), and demeaned so that it varies around a mean of zero. Subsequently, periodicity was evaluated by applying the multitaper method with default settings (i.e., three 2π prolate tapers with no zero-padding) (Thomson, 1982). Confidence levels were acquired based on the classic first-order autoregressive (AR1) Red Noise model (Gilman *et al.*, 1963; Husson, 2014). Bandpass filtering was applied using the Gauss algorithm (Kodama & Hinnov, 2015) to isolate specific frequency bands.

Results

Relative paleointensity and magnetic mineral concentration

The pilot study of RPI using pseudo-Thellier (see SI, Data availability) shows that only around 50 % of the samples pass the default auto selection criteria of Paleointensity.org (see Béguin *et al.*, 2020; Paterson *et al.*, 2014, for details) and only 1 sample passes when AF demagnetization steps up to 15 mT are deleted. In Figure 2 the BTB13 record of NRM/ARM at 30 mT (487 samples) has been plotted against age together with lithology, gamma density records (GD) and magnetic susceptibility (MS). The BTB13 NRM/ARM data varies several orders of magnitude: maximum values are around 250 times larger than the minimum values with well-defined peaks (Figure 2). Some of these peaks, but not all, correspond with the diatom levels described in the core (Figure 2), which in turn correspond to minima in the GD and MS. The NRM/ARM peaks are highest between ~2.57 and ~2.7 Ma, where the five diatomites occur, and ~2.93 and 3.05 Ma.

Cyclostratigraphy and time series analysis

In the time domain (~3.29–2.56 Ma), high spectral power occurs in three frequency bands centered on periods of ~22 kyr for the NRM/ARM, GD, and MS records, ~40 kyr for the GD and MS records, and ~50 kyr and ~400 kyr for NRM/ARM (Figure 3 A-C). The 40 kyr cyclicity is particularly strong (>>95% confidence level) in the MS data. The 22 kyr cyclicity is mainly developed 2.57-2.73 Ma interval of the BTB13 core, with a stronger expression in the GD and MS data (Figure 3 D-F). The ~22 kyr variability is consistent

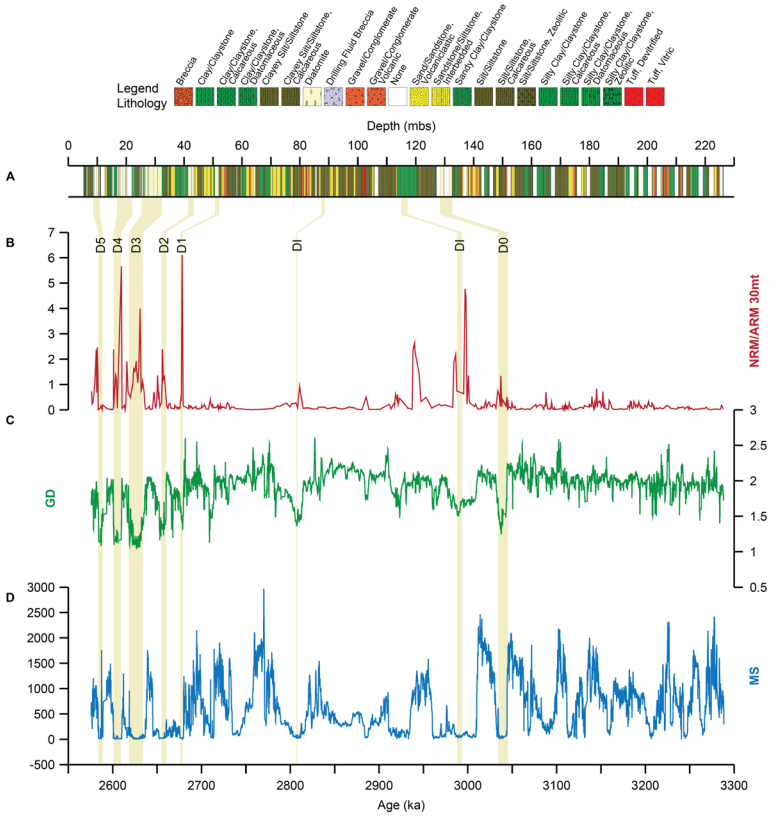


Figure 2. Overview of the BTB13 core data. Lithological log of the BTB13 core (**A**), NRM/ARM 30 mT NRM/ARM (red; **B**), Gamma Density (GD; green; g/cm^3; **C**), and magnetic susceptibility (MS; blue; 10^{-5}; **D**). The position of the diatomites (D0-D5) and diatomite intervals (DIs) is indicated by the beige vertical bars.

between the three datasets in the 2.57-2.73 Ma interval (Figure 4): the NRM/ARM maxima concur with the GD and MS minima and with the diatomites.

The ~50 kyr variability in the NRM/ARM data is roughly consistent with the ~40 kyr variability of the GD and MS datasets (Figure 5a–c), while the ~40 kyr variability in the GD and MS datasets is consistent with one another (Figure 5b, c). The filtered ~40 kyr cyclicity in the MS and GD data follows the obliquity solution (La2004) well (Figure 5D). The ~400 kyr cyclicity in the NRM/ARM and GD data follows the long eccentricity cycle, with the exception that the filter maximum in the middle part of the core occurs slightly later than the long eccentricity maximum (Figure 5D).

Discussion and conclusions

Do the RPI/NRM/ARM data reflect relative paleo-intensity?

Our pilot study using the pseudo-Thellier method demonstrates that the RPI data of the Baringo core are not suitable for reconstructing relative paleo-intensity (see SI for data). Only half of the 40 pilot samples meet the selection criteria of paleointensity.org, and when steps up to 15 mT are excluded—previously identified as the maximum AF step for low-coercivity overprint (Sier *et al.*, 2021) —only one sample qualifies. Another factor is that the depth profile of the 30 mT NRM/ARM data reveals intensity peaks significantly exceeding the range of values for a reliable RPI record. Intensity variations should be limited to a factor of 2–3 (Tauxe, 1993), with some suggesting that a 25% variation is more appropriate (Selkin & Tauxe, 2000).

Previous studies identified Ti-rich titanomagnetite as the dominant remanence carrier (Deino *et al.*, 2006), a finding later confirmed through rock magnetic analyses (Sier *et al.*, 2021). The remanence carrier predominantly falls within the single-domain (SD) range or, in some cases, near the superparamagnetic (SP) domain (Sier *et al.*, 2021). Although these boundary conditions are generally favorable for RPI studies (Tauxe, 1993), the excessive variations in intensity and lack of samples passing the minimum selection criteria prevent the use of either the pseudo-Thellier or classic NRM/ARM RPI methods. Thus interpretation of the data in terms of RPI is ungrounded. The observed regularity and link to diatomites 1–5 already provide valuable clues about this origin, as they suggest that the variability is cyclic and related to astronomical climate forcing with which we will continue the discussion.

Cyclicity

The "RPI", GD, and MS records display significant cyclicity with periods that are close to those of the main astronomical cycles

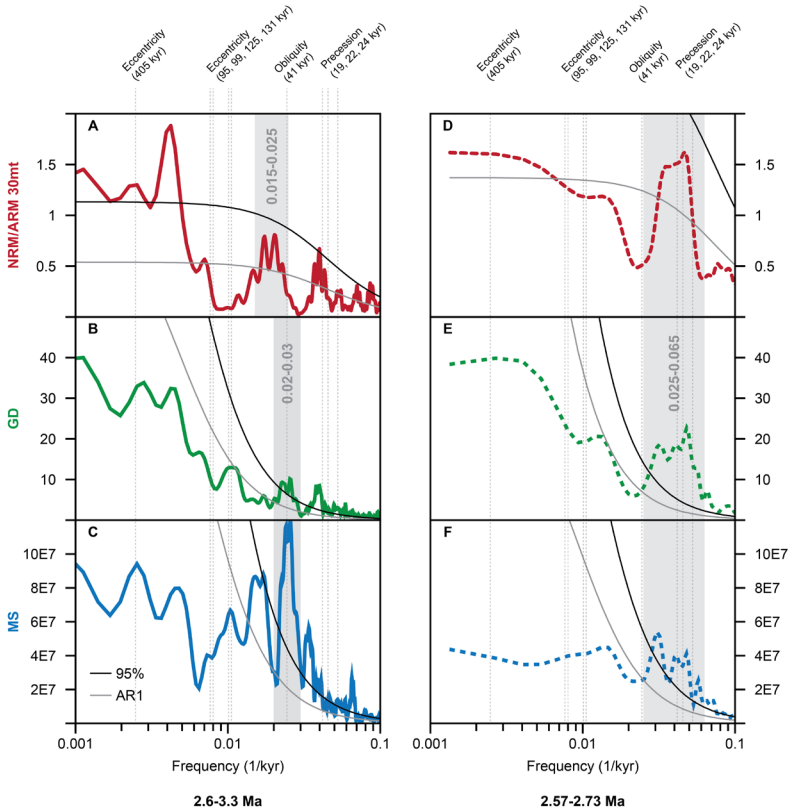


Figure 3. Spectral analysis of the BTB13 core data in the time domain for the 2.6–3.3 Ma (0–230 mbs) interval (solid lines; **A**-**C**) and the 2.57–2.73 Ma (0–75 mbs) interval (dashed lines; **D**-**F**). NRM/ARM in red, GD in green, and MS in blue. A log scale is used for the x (frequency) axis, and a linear scale is used for the y (power) axis. Grey and black solid lines indicate the AR1 model and 95% confidence level, respectively. The gray bars indicate important frequency bands centered around 0.02 1/kyr (50 kyr),0.025 1/kyr (40 kyr), and 0.045 1/kyr (22 kyr). The black dotted vertical lines indicate the main astronomical frequencies of eccentricity, obliquity, and precession.

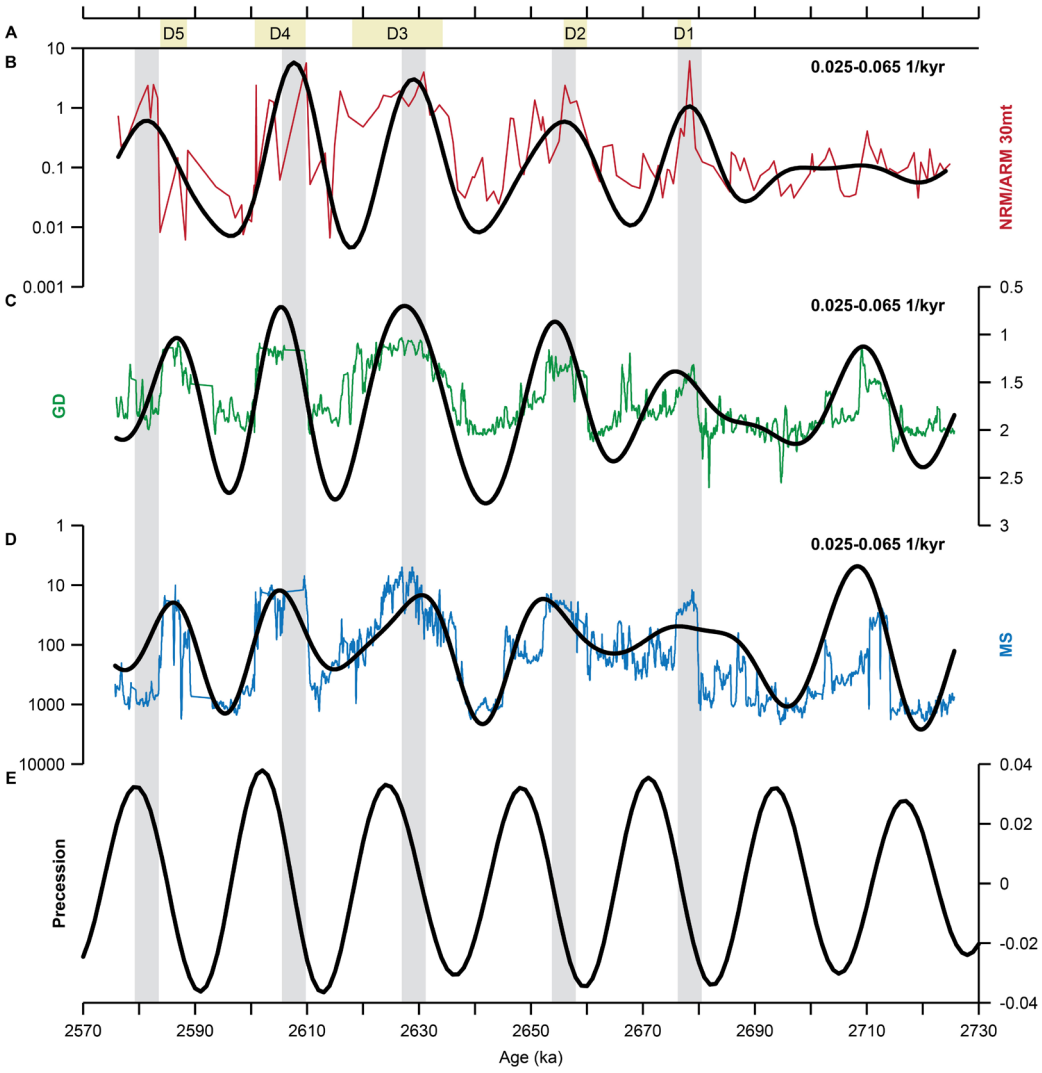


Figure 4. Bandpass filtering of the BTB13 core data for the 2.57–2.73 Ma (0–75 mbs) interval. NRM/ARM in red (**B**), GD in green (**C**), and MS in blue (**D**). The filtered ~22 kyr cyclicity is shown in black (bandpass filter width of 0.025–0.065 1/kyr). Note that NRM/ARM and MS are plotted on a log scale, and MS and GD values are plotted reversed. The positions of the diatomites (D1-D5) are indicated by the beige bars at the top (**A**). Grey vertical bars indicate major NRM/ARM filter maxima. The bandpass filters are compared to the La2004 precession solution (Laskar *et al.*, 2004; **E**).

(Figure 3). Variations occur with periods of ~22 kyr (in particular in the top of the core between 2.73 and 2.57 Ma) and ~40 kyr, suggesting that these cyclic variations are related to climatic precession and obliquity (Figure 4 and Figure 5). There is a strong obliquity signal, but weaker expression of precession, in the pre-2.7 Ma part of the record, which has also been noted by Mitsunaga *et al*. (2023). However, in the top part of the core there is a dominance of precession. Here, diatomites are intercalated at a precession pacing and associated with NRM/ARM maxima and GD and MS minima (Figure 2). It has been shown that these diatomites, and therefore GD and MS minima and RPI maxima, represent deep lake conditions (Deino *et al*., 2006). Deino *et al*. (2006) also related the diatomites to precession, and more specifically to monsoonal intensification during boreal summer insolation maxima (i.e., precession minima), suggesting that the main driver of the observed lake level changes was the North African monsoon. This configuration results in maximum amounts of rainfall over the Sahara and Sahel and would result in increased river runoff towards the BTB13 site and subsequent deepening of the lake. Indeed, modelling studies performed by Bosmans *et al*. (2015) indicated a large increase in rainfall on the northern hemisphere African continent, including eastern Africa, during precession minima. The ~22 kyr variability in the data also neatly follows the precession cycle in the La2004 solution, with NRM/ARM filter maxima occurring at similar positions in a precession cycle (Figure 4d). It is remarkable that this inferred phase relation is largely consistent with the phasing of the filtered 22-kyr cyclicity in the proxy records in the top part of the core relative to climatic precession. Although this could be a coincidence considering the uncertainties in the age

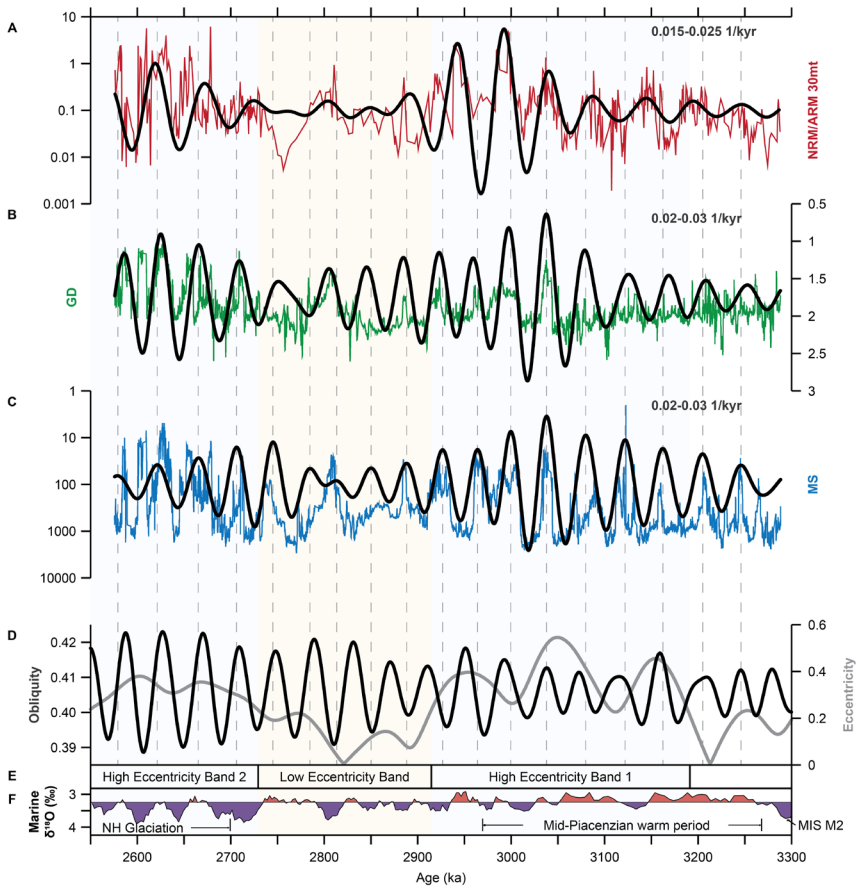


Figure 5. Bandpass filtering of the BTB13 core data for the 2.6–3.3 Ma (0–230 mbs) interval. NRM/ARM in red (**A**), GD in green (**B**), and MS in blue (**C**). The filtered ~50 and ~40 kyr cyclicities are shown in black (bandpass filter widths of 0.015–0.025 and 0.02–0.03 1/kyr, respectively). Note that NRM/ARM and MS are plotted on a log scale, and MS and GD values are plotted reversed. Grey vertical dashed lines indicate MS filter minima of the ~40 kyr cyclicity. The bandpass filters are compared to the La2004 obliquity and eccentricity solutions (Laskar *et al.*, 2004; **D**). Intervals of high and low eccentricity are indicated (**E**). LR04 marine benthic $\delta^{18}O$ stack (Lisiecki & Raymo, 2005) is shown as a proxy for global ice volume (**F**).

model, it is worth mentioning that the Ar/Ar astronomically-tuned ages, which generally have small uncertainties, have been used to construct the age model. The Ar/Ar sanidine ages have been calculated relative to the astronomically calibrated age of 28.201 ± 0.046 Ma of Kuiper *et al.* (2008) for the Fish Canyon sanidine or to sanidine phenocrysts from the Alder Creek Rhyolite of California with an astronomical calibrated age of 1.1848 ± 0.0006 Ma (Niespolo *et al.*, 2017). In addition, astronomical ages of magnetic reversal boundaries have been used to construct the age model.

Evidently, the NRM/ARM record is strongly influenced by an astronomically-paced climatic signal, implying that it does not reflect variations in Earth's magnetic field and thus cannot be used for correlations to other cores using relative paleo-intensity as a tool. However, the astronomical cyclicity in the RPI/NRM/ARM, GD and MS records provides alternative opportunities for correlating the Baringo core to other African lake records with poor age control, like the Northern Awash cores. In addition, these records can potentially be used to construct an astrochronological framework based on tuning the recorded cyclicity in the records to astronomical target curves (e.g., Hilgen *et al.*, 2022; Joordens *et al.*, 2011). For future work on RPI/NRM/ARM records from sedimentary records we believe that, regardless of the quality of RPI/NRM/ARM records, it is important to include spectral analyses as an quality indicator as it provides a straightforward method for identifying cyclicity, which should be absent in high-quality RPI records.

Correlation to other regional continental cores

Like the diatomites, large NRM/ARM peaks only occur during 405 kyr eccentricity maxima, referred to as high eccentricity intervals (Figure 5E). The NRM/ARM peaks between 2.7 and 2.58 Ma are centered at a 405 kyr eccentricity maximum (see Figure 5), while the NRM/ARM peaks between 3.2 and 2.92 Ma occur slightly after an eccentricity maximum. This delay resulted in a periodicity of ~360 kyr, which is somewhat shorter than the 405 kyr period of the long eccentricity cycle. All diatomites correspond to NRM/ARM peaks in our record, but not all of the measured NRM/ARM peaks are associated with a diatomite (Figure 2). This suggests that the NRM/ARM peaks are not an expression of the diatomite formation, but that both the

diatomite formation and the NRM/ARM peaks are an expression of the same driving force. This is important for the correlation between the Northern Awash and Baringo cores. Although no diatomites have been identified in the Awash cores, it is possible that future study of the rock magnetic data will show a similar pattern as in the Baringo core, allowing for the identification of intervals of high and low eccentricity on the long 405-kyr eccentricity scale (Figure 5E). If so, this NRM/ARM, GD, and MS data could still help with building a geochronological model for the Northern Awash cores.

For future research on RPI records derived from sedimentary sequences, we recommend incorporating spectral analyses regardless of the perceived quality of the records. Spectral analysis offers a straightforward method for detecting cyclicity, which should be absent in high-quality RPI records according to most workers. Additionally, NRM/ARM records hold potential for chronological applications, particularly if they can be reliably correlated with astronomical cycles.

Ethics and consent

Ethical approval and consent were not required.

Data availability

The project contains the following underlying data published on figshare.com:

BTB pilot set NRM/ARM data: https://doi.org/10.6084/m9.figshare.28904759.v1

Paleonintensity.org export data: https://doi.org/10.6084/m9.figshare.28906790.v1

BTB NRM/ARM data: https://doi.org/10.6084/m9.figshare.28905680.v1

Data are available under the terms of the Creative Commons Attribution 4.0 International license (CC-BY 4.0).

Acknowledgements

The authors would like to thank the HSPDP team, particularly Andy Cohen. Isabel Hernando Alonso for her assistance during the laboratory work and measurements of the data used in this manuscript.

This research was funded with a Marie Skłodowska-Curie Actions grant to M.J. Sier (Project 101109142, ABCCycle). M.J. Sier is also funded by Social Sciences and Humanities Research Council of Canada (SSHRC) Partnership grant no 895-2024-1005. HSPDP Drilling was funded by International Continental Drilling Program (ICDP) and NSF (Grants EAR-1123942, BCS-1241859 and EAR-1338553). B.R. Spiering is funded by the Dutch Research Council (NWO; grant number OCENW. M.21.031, awarded to F.J. Hilgen).

References

Béguin A, Paterson GA, Biggin AJ, *et al.*: **Paleointensity.org: an online, open source, application for the interpretation of paleointensity data.** *Geochem Geophys Geosyst.* 2020; **21**(5): e2019GC008791.
Publisher Full Text

Behrensmeyer AK, Deino AL, Hill A, *et al.*: **Geology and geochronology of the middle Miocene Kipsaramon site complex, Muruyur Beds, Tugen Hills, Kenya.** *J Hum Evol.* 2002; **42**(1–2): 11–38.
PubMed Abstract | **Publisher Full Text**

Bosmans JHC, Hilgen FJ, Tuenter E, *et al.*: **Obliquity forcing of low-latitude climate.** *Clim Past.* 2015; **11**(10): 1335–1346.
Publisher Full Text

Campisano CJ, Cohen AS, Arrowsmith RJ, *et al.*: **The hominin sites and paleolakes drilling project: high-resolution paleoclimate records from the east african rift system and their implications for understanding the environmental context of hominin evolution.** *PaleoAnthropology.* 2017; 1–43.
Reference Source

Channell JET, Hodell DA, Crowhurst SJ, *et al.*: **Relative Paleointensity (RPI) in the latest Pleistocene (10–45 ka) and implications for deglacial atmospheric radiocarbon.** *Quat Sci Rev.* 2018; **191**: 57–72.
Publisher Full Text

Chapman GR, Brook M: **Chronostratigraphy of the Baringo Basin, Kenya.** In: Bishop, W.W. (Ed.), *Geological Background to Fossil Man.* Scottish Academic Press, Edinburgh, 1978; **6**: 207–223.
Publisher Full Text

Cohen A, Campisano C, Arrowsmith R, *et al.*: **The hominin sites and paleolakes drilling project: inferring the environmental context of human evolution from eastern African rift lake deposits.** *Sci Drill.* 2016; **21**: 1–16.
Publisher Full Text

Deino AL, Kingston JD, Glen JM, *et al.*: **Precessional forcing of lacustrine sedimentation in the late Cenozoic Chemeron Basin, Central Kenya Rift, and calibration of the Gauss/Matuyama boundary.** *Earth Planet Sci Lett.* 2006; **247**(1–2): 41–60.
Publisher Full Text

Deino AL, Sier MJ, Garello DI, *et al.*: **Chronostratigraphy of the Baringo-Tugen Hills-Barsemoi (HSPDP-BTB13-1A) core – ^{40}Ar/^{39}Ar dating, magnetostratigraphy, tephrostratigraphy, sequence stratigraphy and Bayesian age modeling.** *Palaeogeogr Palaeoclimatol Palaeoecol.* 2021; **570**: 109519.
Publisher Full Text

Deino AL, Tauxe L, Monaghan M, *et al.*: **^{40}Ar/^{39}Ar geochronology and paleomagnetic stratigraphy of the Lukeino and lower Chemeron Formations at Tabarin and Kapcheberek, Tugen Hills, Kenya.** *J Hum Evol.* 2002; **42**(1–2): 117–140.
PubMed Abstract | **Publisher Full Text**

Gilbert CC, Goble ED, Hill A: **Miocene cercopithecoidea from the Tugen Hills, Kenya.** *J Hum Evol.* 2010; **59**(5): 465–483.
PubMed Abstract | **Publisher Full Text**

Gilman DL, Fuglister FJ, Mitchell JM: **On the power spectrum of "Red Noise".** *J Atmos Sci.* 1963; **20**(2): 182–184.
Publisher Full Text

Hilgen SL, Hilgen FJ, Adhityatama S, *et al.*: **Towards an astronomical age model for the Lower to Middle Pleistocene hominin-bearing succession of the Sangiran Dome area on Java, Indonesia.** *Quat Sci Rev.* 2022; **297**: 107788.
Publisher Full Text

Hill A: **Paleoanthropological research in the Tugen Hills, Kenya.** *J Hum Evol.* 2002; **42**(1–2): 1–10.
PubMed Abstract | **Publisher Full Text**

Husson D: **MathWorks File Exchange: RedNoise_ConfidenceLevels**. 2014.
Reference Source

Joordens JCA, Vonhof HB, Feibel CS, *et al.*: **An astronomically-tuned climate framework for hominins in the Turkana Basin.** *Earth Planet Sci Lett.* 2011; **307**(1–2): 1–8.
Publisher Full Text

Kingston JD, Deino AL, Edgar RK, *et al.*: **Astronomically forced climate change in the Kenyan Rift Valley 2.7–2.55 Ma: implications for the evolution of early hominin ecosystems.** *J Hum Evol.* 2007; **53**(5): 487–503.
PubMed Abstract | **Publisher Full Text**

Kodama KP, Hinnov LA: **Rock magnetic cyclostratigraphy**. 2015.
Publisher Full Text

Kuiper KF, Deino A, Hilgen FJ, *et al.*: **Synchronizing rock clocks of Earth history.** *Science.* 2008; **320**(5875): 500–4.
PubMed Abstract | **Publisher Full Text**

Laskar J, Robutel P, Joutel F, *et al.*: **A long term numerical solution for the insolation quantities of the Earth.** *Astron Astrophys.* 2004; **428**(1): 261–285.
Publisher Full Text

Li M, Hinnov L, Kump L: ***Acycle*: time-series analysis software for paleoclimate research and education.** *Comput Geosci.* 2019; **127**: 12–22.
Publisher Full Text

Lisiecki LE, Raymo ME: **A Pliocene-Pleistocene stack of 57 globally distributed benthic $\delta^{18}O$ records.** *Paleoceanography.* 2005; **20**(1).
Publisher Full Text

McCall GJH, Baker BH, Walsh J: **Late Tertiary and Quaternary sediments of the Kenya Rift Valley.** In: Bishop, W.W., Clark, J.D. (Eds.), *Background to Evolution in Africa.* Chicago University, Chicago, 1967; 191–220.

Mitsunaga BA, Lupien RL, Ouertani S, *et al.*: **High-Latitude, Indian Ocean, and Orbital Influences on Eastern African Hydroclimate across the Plio-Pleistocene Boundary.** *Paleoceanogr Paleoclimatol.* 2023; **38**(12): e2023PA004671.
Publisher Full Text

Niespolo EM, Rutte D, Deino AL, *et al.*: **Intercalibration and age of the Alder Creek sanidine $^{40}Ar/^{39}Ar$ standard.** *Quat Geochronol.* 2017; **39**: 205–213.
Publisher Full Text

Paterson GA, Heslop D, Pan Y: **The pseudo-Thellier palaeointensity method: new calibration and uncertainty estimates.** *Geophys J Int.* 2016; **207**(3): 1596–1608.
Publisher Full Text

Paterson GA, Tauxe L, Biggin AJ, *et al.*: **On improving the selection of Thellier-type paleointensity data.** *Geochem Geophys Geosyst.* 2014; **15**(4): 1180–1192.
Publisher Full Text

Selkin PA, Tauxe L: **Long-term variations in palaeointensity.** *Philos Trans R Soc London Ser A Math Phys Eng Sci.* 2000; **358**: 1065–1088.
Publisher Full Text

Sier MJ, Dupont-Nivet G, Langereis C, *et al.*: **Magnetostratigraphy of the Hominin Sites and Paleolakes Drilling Project (HSPDP) Baringo-Tugen Hills-Barsemoi core (Kenya).** *Palaeogeogr Palaeoclimatol Palaeoecol.* 2021; **570**: 110190.
Publisher Full Text

Tauxe L: **Sedimentary records of relative paleointensity of the geomagnetic field: theory and practice.** *Rev Geophys.* 1993; **31**(3): 319–354.
Publisher Full Text

Tauxe L, Pick T, Kok YS: **Relative paleointensity in sediments: a Pseudo-Thellier Approach.** *Geophys Res Lett.* 1995; **22**(21): 2885–2888.
Publisher Full Text

Thomson DJ: **Spectrum estimation and harmonic analysis.** *Proc IEEE.* 1982; **70**(9): 1055–1096.
Publisher Full Text

Valet JP, Meynadier L, Guyodo Y: **Geomagnetic dipole strength and reversal rate over the past two million years.** *Nature.* 2005a; **435**(7043): 802–805.
PubMed Abstract | **Publisher Full Text**

Valet JP, Meynadier L, Guyodo Y: **Geomagnetic dipole strength and reversal rate over the past two million years.** *Nature.* 2005b; **435**(7043): 802–5.
PubMed Abstract | **Publisher Full Text**

Valet JP, Thevarasan A, Bassinot F, *et al.*: **Two records of relative paleointensity for the past 4 Myr.** *Front Earth Sci.* 2020; **8**.
Publisher Full Text

Westover KS, Stone JR, Yost CL, *et al.*: **Diatom paleolimnology of late Pliocene Baringo Basin (Kenya) paleolakes.** *Palaeogeogr Palaeoclimatol Palaeoecol.* 2021; **570**: 109382.
Publisher Full Text

Open Peer Review

Current Peer Review Status: ✔ ✔ ?

Version 1

Reviewer Report 09 January 2026

https://doi.org/10.21956/openreseurope.21927.r64543

© **2026 von Dobeneck T.** This is an open access peer review report distributed under the terms of the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

?

Tilo von Dobeneck
University of Bremen, Bremen, Germany

Tilo von Dobeneck
University of Bremen, Faculty of Geosciences and MARUM Research Center, Germany

Open review of the Open Research Europe research article “Magnetic mineralogy of the Baringo core (HSPDP-BTB13-1A, Kenya) shows astronomical forcing with implications for retrieving meaningful paleointensity” by M.J. Sier, B.R. Spiering, M.J. Dekkers & F.J. Hilgen

Following up on the available open-access review by Tesfaye Kidane (2025), I also see the interest of this third in a series of chronostratigraphic papers on Baringo-Tugen Hills-Barsemoi core BTB13-1A, starting with 40Ar/39Ar and magnetostratigraphic dating by Deino et al. (2021), supported by a more detailed presentation and rock-magnetic backup of the paleomagnetic results by Sier et al. (2021), and now expanded to cyclostratigraphy and RPI methodology by Sier et al. (2025). Despite the large petrological and sedimentological inhomogeneity of the sediment core, the time series analysis of physical property logs of magnetic susceptibility (MS) and gamma density (GD) – and to some surprise – even of the supposedly chaotic NRM/ARM “RPI” signal, carry significant spectral energy in the obliquity and eccentricity band. This unexpected fact (but less the initial aim for the laborious RPI analysis to correlate NRM/ARM to RPI stacks) merits to present, filter and interpret all three paleorecords in this third paper and to investigate the astronomical forcing of NRM/ARM, MS and GD alongside.

The paper makes various general and partly ambivalent statements on the nature and applicability of the “Relative Paleointensity” (RPI) method, which could be more differentiated for better precision. In the starting Introduction sentence, RPI is being introduced as a “tool used to constrain the age of sedimentary sequences younger than 4 Ma, based on correlating short- and long-term fluctuations in the intensity of the Earth´s magnetic field”. The RPI method has no principal (physical) age limitations such as for example the radiocarbon method. However, for sedimentological and technical reasons, it is indeed difficult to identify and continuously core and u channel sample (Valet et al. 2020) older marine sediments with reliable preservation of paleofield intensity. To my knowledge, the longest continuous RPI record at present is that of

Pacific IODP Site U1335 (Yamazaki & Yamamoto, 2018), which goes back to 8 Ma. Satisfactory RPI recording qualities of some abyssal cores (e.g. Wang et al. 2021) signalize, that it may be possible in future to extend the reach of RPI stacks further back in time with dedicated coring, but certainly never anywhere like the Geomagnetic Polarity timescale.

Which matters more to me, is the paper's problematic equalization of RPI (1) as “tool” (line 1, paragraph 1) for chronostratigraphic correlation (assuming its validity!), (2) as a paleomagnetic ratio parameter (NRM/ARM), and (3) as reconstruction of “fluctuations in the intensity of the Earth’s magnetic field”. We may agree that in the ideal case of homogenous sediments with stable accumulation conditions, constant texture and uniform, unaltered fine-grained magnetic carriers, RPI does provide a credible proxy record of millennial-scale geomagnetic field intensity changes.

In the more common case of heterogeneous sediments deposited under changing environmental and sedimentological conditions (such as HSPDP-BTB13-1A), geomagnetic field intensity changes are just one (and as it seems here, a minor one) of several factors controlling the ARM-normalized NRM intensity record. Calling the BTB13 NRM/ARM record a “RPI record” sounds therefore euphemistic. The authors’ initial goal (Abstract lines 9-10) of “testing the suitability of the core for RPI reconstruction” is a test, that was bound to fail given the rather noisy NRM inclination and declination data and diverting rock magnetic characteristics presented by Sier et al. (2021). It appears more reasonable to depart from the goal of analyzing the characteristics and possible expression of the NRM/ARM ratio in a complex continental (lacustrine/eolian) sedimentary sequence (which most of the paper actually does) than to aim for a valid, continent-wide applicable RPI reconstruction.

The authors try to resolve this controversy on page 8 by introducing the term “RPI/NRM/ARM”, which I consider as unfortunate, since the first dash symbolizes “and/or” while the second simply means “:”; this terminology is both mathematically and formally confusing. The article title also reads somewhat too euphemistic, since “… with implications for retrieving meaningful paleointensity” (foreseeably) translates more realistically into “…. and causes failure of the RPI method”. I admit that a “trial-and-error” approach occasionally beats applicability rules of chronostratigraphic methods, but alone the lithostratigraphic description of the core casts enormous doubt on the promise of obtaining a RPI record in sensu stricto: interbedded “muddy fine-grained sandstones to pebble conglomerates”, tephras and diatomites, with soft layers, that could be sampled with perspex push-cubes, and hard layers needing diamond-bit drilling; a greater sediment hetereogeneity is hardly imaginable!

Proposing RPI as a potential chronostratigraphic “tool” to refine a (in my impression) very noisy and quite poorly defined directional paleomagnetic record through correlation to RPI stacks appears to me as overoptimistic and misleading approach. This sends a wrong signal to the paleochronology community, who then approaches us paleomagnetists to “kindly RPI-date” all their otherwise “undatable” non-fossiliferous clastic sediment cores. In agreement with the first reviewer, I suggest to reformulate this first article version giving priority to the investigation of orbital cyclicity of rock magnetic records, including the question, which lithological attributes and driving environmental factors control NRM/ARM.

In the first place (this should be more clearly stated!), NRM/ARM measures the grain-level magnetization times the degree of joint spatial magnetic orientation (or randomization) of fine magnetic particles within the sedimentary matrix – which may or may not reflect paleofield

intensity. Studies by Franke et al. (2004) and Hofmann & Fabian (2007, 2009) have statistically quantified the impact of magnetic grain-size, clay mineralogy, carbonate and diatom content, alteration and other sedimentary factors of NRM/ARM and demonstrated, that “RPI” records usually carry a relevant environmental overprint.

Given that the bandpass-filtered signals of the high-resolution MS and GD records largely agree and positively correlate with equally filtered, but interpolated, low-resolution NRM/ARM-derived “RPI” signal indeed implies, that the two-orders-of-magnitude variations of MS entail a proportional, also two-orders-of-magnitude (and therefore definitely not geodynamo-like) variability of NRM/ARM. It would be interesting to see here as well the bandpass-filtered signals and frequency spectra of the separate NRM and ARM records to elucidate, which of the two parameters carries more of an orbital signature (probably ARM), which it inherits to the NRM/ARM ratio parameter. If both NRM and ARM were equally affected by Milancovic cycles, the climatic influence should cancel out in their ratio. It may be useful to also have a correlation matrix of log(MS), GD, log(ARM), log (NRM), log(NRM/ARM), ARM/IRM (or log(ARM/IRM), if normally distributed) together with respective eccentricity, obliquity and precession or insolation target curves. Cross-and phase spectral analyses could eventually deliver orbital characteristics of interesting parameter correlations.

A minor flaw is the use of two different density units, where “gm/cc” is used twice in the text and “g/cm^3” in the Figure 2 legend - only the latter is a valid SI unit. In terms of style and language, figure quality and statistical methodology, the manuscript fulfills modern indexing standards. The article layout would however greatly profit from allowing Figures 1, 2, 3 and 5 to occupy as much lateral space as Figure 4, which only commands over sufficiently large (amongst others, font) size; for the readability of detailed illustrations, particularly in paper printouts, size definitely matters!

References

1. Franke C, Hofmann D, Dobeneck T: Does lithology influence relative paleointensity records? a statistical analysis on South Atlantic pelagic sediments. *Physics of the Earth and Planetary Interiors*. 2004; **147** (2-3): 285-296 Publisher Full Text
2. Hofmann D, Fabian K: Rock magnetic properties and relative paleointensity stack for the last 300 ka based on a stratigraphic network from the subtropical and subantarctic South Atlantic. *Earth and Planetary Science Letters*. 2007; **260** (1-2): 297-312 Publisher Full Text
3. Hofmann D, Fabian K: Correcting relative paleointensity records for variations in sediment composition: Results from a South Atlantic stratigraphic network. *Earth and Planetary Science Letters*. 2009; **284** (1-2): 34-43 Publisher Full Text
4. Wang W, von Dobeneck T, Frederichs T, Zhang Y, et al.: Dating North Pacific Abyssal Sediments by Geomagnetic Paleointensity: Implications of Magnetization Carriers, Plio-Pleistocene Climate Change, and Benthic Redox Conditions. *Frontiers in Earth Science*. 2021; **9**. Publisher Full Text
5. Yamazaki T, Yamamoto Y: Relative Paleointensity and Inclination Anomaly Over the Last 8 Myr Obtained From the Integrated Ocean Drilling Program Site U1335 Sediments in the Eastern Equatorial Pacific. *Journal of Geophysical Research: Solid Earth*. 2018; **123** (9): 7305-7320 Publisher Full Text

Is the work clearly and accurately presented and does it cite the current literature?

Partly

Is the study design appropriate and does the work have academic merit?
Partly

Are sufficient details of methods and analysis provided to allow replication by others?
Yes

If applicable, is the statistical analysis and its interpretation appropriate?
Partly

Are all the source data underlying the results available to ensure full reproducibility?
Yes

Are the conclusions drawn adequately supported by the results?
Partly

Competing Interests: No competing interests were disclosed.

Reviewer Expertise: Environmental and Rock Magnetism, Magnetostratigraphy, Sediment Physical Properties, Paleoceanography, Geostatistics

I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard, however I have significant reservations, as outlined above.

Reviewer Report 31 December 2025

https://doi.org/10.21956/openreseurope.21927.r64548

© 2025 Carlut J. This is an open access peer review report distributed under the terms of the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

Julie Carlut
Université Paris Cité, Institut de Physique du Globe de Paris, Paris, France

The topic of this study is very interesting. The astronomical cyclicity identified in the NRM/ARM, Gamma Density (GD), and especially in magnetic susceptibility suggests that this core could potentially be used to constrain other African lake records that suffer from poor age control. This is particularly valuable given that the BTB13 core spans a time interval overlapping with key hominin-bearing horizons in the region.

Several aspects would benefit from deeper discussion. One point is that the authors do not fully embrace the production of a magnetic mineralogy study. This is likely because the initial objective: reconstructing relative paleointensity variations and establishing a robust age model, was difficult to achieve. Nevertheless, the dataset presented contains interesting and potentially valuable magnetic results. A related difficulty is that the study ends up being highly dependent on an age

model that is itself incomplete, since constraining age models was a goal of the work. This circularity can give the overall impression of a somewhat fragile framework, which could be alleviated by a more explicit (an additional figure?) presentation of the age model based on the 4 reversals and twelve 40Ar/39Ar ages and its uncertainties/limitations.

Minor points
In the Introduction, the first paragraph would be better placed at the end of the section and shortened. Indeed, this paper is not truly a relative paleointensity (RPI) study in the classical sense, but rather a study emphasizing variations in magnetic properties more broadly.
In the Geological Setting section, it is clear that the sedimentary sequence is highly heterogeneous, including lithologies that are particularly unfavorable (e.g., conglomerates). It is well known that paleointensity studies are generally discouraged in heterogeneous sections (see, for example, Tauxe et al., 1993), and therefore disappointing results were to some extent predictable. In this respect, I do not fully agree with the authors' statement referring to "favorable magnetic carriers," as the strong lithological heterogeneity is not sufficiently acknowledged. Ultimately the cyclostratigraphic signal identified here could be already expressed in the lithology itself, something that the Gamma Density proxy partly captures.
The Material and method section contains details that are not really relevant (as "the core was transported by airfreight...")
In the Age Model section, it would be beneficial to introduce upfront the elements that are currently discussed later (page 8). Given how critical the age model is to the entire study, it clearly requires clarification from the beginning. Regarding the spectral analyses, the interpolation of the data to obtain a uniform 1 kyr sampling is a potentially critical step. It is important to ensure that this procedure does not, in any way, condition or bias the results of the spectral analysis. The ~400 kyr cycle appears rather unconvincing to me: the signal is weak and the number of observed cycles is limited.
Ultimately, magnetic susceptibility stands out as the parameter carrying the most robust and interesting signal. But I regret that only NRM/ARM data are presented. Including more classical rock magnetic proxies, such as grain-size indicators (e.g., ARM/K), would strengthen the interpretations.
The zoomed-in analysis over the 2.73–2.56 Ma interval is quite interesting. The correlation between diatomite and precession minima is moderate (three cases out of five), but once again uncertainties in the age model may explain this imperfect correspondence. Phase offsets are observed between maxima in NRM/ARM (and magnetic susceptibility) and the precession signal. The signal appears rich and complex; understanding the origin of these phase relationships would likely be extremely informative. Finally, Figure 5 is particularly interesting and could benefit from a more thorough discussion.

Overall, the authors convincingly demonstrate the presence of a useful astrochronological signal revealed by magnetic parameters in the studied section. The age model it is based on should be more explicitly shown. A figure showing ARM alone and/or ARM/K might be a valuable addition too.

Is the work clearly and accurately presented and does it cite the current literature?
Yes

Is the study design appropriate and does the work have academic merit?

Yes

Are sufficient details of methods and analysis provided to allow replication by others?
Yes

If applicable, is the statistical analysis and its interpretation appropriate?
Yes

Are all the source data underlying the results available to ensure full reproducibility?
Yes

Are the conclusions drawn adequately supported by the results?
Yes

Competing Interests: No competing interests were disclosed.

Reviewer Expertise: Rock magnetism, paleomagnetism

I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard.

Reviewer Report 28 August 2025

https://doi.org/10.21956/openreseurope.21927.r56802

© 2025 Kidane T. This is an open access peer review report distributed under the terms of the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

Tesfaye Kidane
Wayne State University, Detroit, Michigan, USA

Review of the Open Europe paper by SIER et al. (Mark J. SIER, Bianca R. Spiering, Mark J. Dekkers, Frits J. Hilgen)

The paper entitled "**Magnetic Mineralogy of the Baringo core (HSPDP-BTB13-1A, Kenya) shows astronomical forcing with implications for retrieving meaningful paleointensity" by Sier et al**, attempts evaluating the potential of the BTB13 sedimentary core from the Baringo Basin, Kenya, to contribute towards the relative paleointensity (RPI) records and improve regional stratigraphic and geochronologic correlation at the scale of East African region.

General comments

The time window (~3.3–2.6Ma), the BTB13-1A sedimentary core covers, overlaps with the ages of various well known hominid-bearing horizons at many localities in the region, including the Baringo in south, and Omo-Turkana, Chew Bahir basins in the North, and potentially further north in Afar depression, hence age constraints on the Baringo core is of great scientific interest.

Although the original objectives of the authors to contribute to the Relative Paleointensity (RPI) couldn't be achieved, due to the non-suitability of the studied cores, which are claimed to be dominated by environmental influences, the authors disclosed that the BTB13-1A core preserved a strong astrochronological signal, which can be used as another important correlative tool. The astrochronological records of the BTB13 core, which they identified, could potentially be used as a tool for regional correlation and paleoenvironmental reconstruction related to Hominin evolution of the region, including the Omo-Turkana Basin, and further North in the Afar Depression. As a result, the authors have done a good job of identifying and describing the astrochronological signal of the core.

Specific comments
I would avoid the theoretical aspects of the manuscript in spectral analyses and band filtering and focus on the character of the sedimentary core analyses.

1. The introduction needs to be shortened, as it mainly focuses on previous studies on RPI and how that could be used for regional correlations. Because the authors have now tested and known the non-suitability of the core for RPI reconstruction, they rather focus on their main positive contribution, spectral analyses, and astrochronological signal.
2. Could the authors say more about the paradox of having titanomagnetite with single domain (SD) grain sizes as predominant remanence carriers from previous studies (Deino et al., 2006, Deino et al., 2021), and their report of a lack of samples that pass the minimum selection criteria for use of pseudo-Thellier or classic NRM/ARM for RPI analysis.
3. What material characteristics of sediment and sedimentation rate are responsible for elevating NRM/ARM values? Somewhere, it would be helpful to add an explanation of how astrological forcings/fluctuations would result in a material deposition that is characterized by magnetic mineral concentration and grain sizes (rock-magnetic data), with a high NRM/ARM ratio, and low susceptibility.
4. Are there oxygen isotope stratigraphy studies or similar high-quality paleoclimatic and paleoenvironmental studies on the BTB13-1A core to compare with the astrochronological fluctuation reported?
5. A typo in Page 3, paragraph 2, line 5 (at the end of the line, change "end" to and).
6. When referring to previous magnetostratigraphy work in the region, there are more works to be cited in the neighboring basins to the North – Omo-Turkana basin, such as Kidane et al. 2007, Kidane et al. 2014, and the online stratigraphy chart of Turkana basin (https://www.turkanastratigraphy.org/strat-chart/main-strat-chart). This is particularly valid if the authors plan to use the tool in other HSPDP sites, which are either structurally linked basins (such as Chew Bahir), or further north of Omo-Turkana.
7. Page 8, last paragraph and last statement going into page 9, 1st paragraph, states that NRM/ARM peaks are not an expression of the diatomite formation, but both were an expression of the same driving force. If so, why would one need diatomite in the Northern Awash cores to identify these astrochronological signals?

The manuscript is well-written, and the authors include some of the leading authorities in paleomagnetism studies focusing on astronomical calibrations. I recommend indexing of the manuscript with minor revisions.

References
1. DEINO A, KINGSTON J, GLEN J, EDGAR R, et al.: Precessional forcing of lacustrine sedimentation

in the late Cenozoic Chemeron Basin, Central Kenya Rift, and calibration of the Gauss/Matuyama boundary. *Earth and Planetary Science Letters*. 2006; **247** (1-2): 41-60 Publisher Full Text
2. Deino A, Sier M, Garello D, Keller C, et al.: Chronostratigraphy of the Baringo-Tugen Hills-Barsemoi (HSPDP-BTB13-1A) core – 40Ar/39Ar dating, magnetostratigraphy, tephrostratigraphy, sequence stratigraphy and Bayesian age modeling. *Palaeogeography, Palaeoclimatology, Palaeoecology*. 2021; **570**. Publisher Full Text
3. KIDANE T, OTOFUJI Y, BROWN F, TAKEMOTO K, et al.: Two normal paleomagnetic polarity intervals in the lower Matuyama Chron recorded in the Shungura Formation (Omo Valley, Southwest Ethiopia). *Earth and Planetary Science Letters*. 2007; **262** (1-2): 240-256 Publisher Full Text
4. Kidane T, Brown F, Kidney C: Magnetostratigraphy of the Fossil-Rich Shungura Formation, southwest Ethiopia. *Journal of African Earth Sciences*. 2014; **97**: 207-223 Publisher Full Text

Is the work clearly and accurately presented and does it cite the current literature?
Partly

Is the study design appropriate and does the work have academic merit?
Yes

Are sufficient details of methods and analysis provided to allow replication by others?
Partly

If applicable, is the statistical analysis and its interpretation appropriate?
Not applicable

Are all the source data underlying the results available to ensure full reproducibility?
Partly

Are the conclusions drawn adequately supported by the results?
Yes

Competing Interests: No competing interests were disclosed.

Reviewer Expertise: Structural Geology, tectonics, and paleomagnetism

I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard.