SPELEOTHEM RECORD OF THE SOUTH ATLANTIC ANOMALY EVOLUTION

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ABSTRACT

Two speleothems from central Brazil were studied in order to recover the geomagnetic field variations during the last ~1500 years in South America. The sampling site (Pau d'Alho cave) is located close to the minimum of the South Atlantic Geomagnetic Anomaly (SAGA), which is one of the main anomalous features of the present-day field and stretches over the South Atlantic Ocean and South America. According to our results, before 1500 CE the speleothem magnetic data follows the geomagnetic model ARCH3k.1, with rapid directional variations (> 0.1 °/yr) between ~860-960 CE and ~1450-1750 CE. This pattern of rapid variations trails similar changes reported for South Africa but with a delay of 224 ± 50 years. We interpret this delay as a result of the westward migration of the SAGA, after its inception into the west coast of Africa. Our interpretation is further reinforced by synthetic models of reversed magnetic flux patches at the core-mantle boundary.

Keywords: Speleothem, Rock magnetism, Paleomagnetism

RESUMEN

Se estudiaron dos espeleotemas del centro de Brasil con el objetivo de recuperar las variaciones del campo geomagnético durante los últimos ~ 1500 años en América del Sur. El sitio de muestreo (cueva Pau d'Alho) se encuentra cerca del mínimo de la Anomalía Geomagnética del Atlántico Sur (SAGA), que es una de las principales características anómalas del campo actual y se extiende sobre el Océano Atlántico Sur y América del Sur. Según nuestros resultados, antes de 1500 CE, los datos magnéticos obtenidos de la espeleotema siguen el modelo geomagnético ARCH3k.1, con variaciones direccionales rápidas (> 0.1°/año) entre ~860-960 CE y ~1450-1750 CE. Este patrón de variaciones rápidas sigue los cambios similares reportados para Sudáfrica pero con un retraso de 224 ± 50 años. Interpretamos este retraso como resultado de la migración hacia el oeste de la SAGA, después de su inicio en la costa oeste de África. Nuestra interpretación se ve reforzada por modelos sintéticos de parches de flujo magnético invertido en el límite núcleo-manto.

Palabras claves: Espeleotemas, Magnetismo de roca, Paleomagnetismo

1. Introduction

The South Atlantic Geomagnetic Anomaly (SAGA) is one of the main anomalies of the present-day field. It encompasses the minimum intensities of the field and spreads over the South Atlantic and the South American continent. Reconstructing the SAGA evolution through time, particularly before the advent of geomagnetic observatories is a dificult task given the scarcity of geomagnetic data in the Southern Hemisphere (Archeomagnetic datasets from Africa and South America correspond, respectively, to only 2.5 % and 2.8 % to the global geomagnetic database).

Speleothems are faithful recorders of the geomagnetic field. Although weakly magnetic, they present several advantages over archeomagnetic and sedimentary archives. They are usually continuous over thousands of years, can be precisely dated by the radiometric ^{230}U-^{234}Th method and the time between remanence acquisition and the radiometric age is negligible. In addition, speleothems are not affected by post-depositional compaction effects.

Here we present the results obtained on two stalagmites from Pau d'Alho cave, which cover the variations of the geomagnetic field (direction and relative intensity) across the past 1500 yrs (Fig. 1). Details of this study were fully reported in Trindade *et al*. (2018).

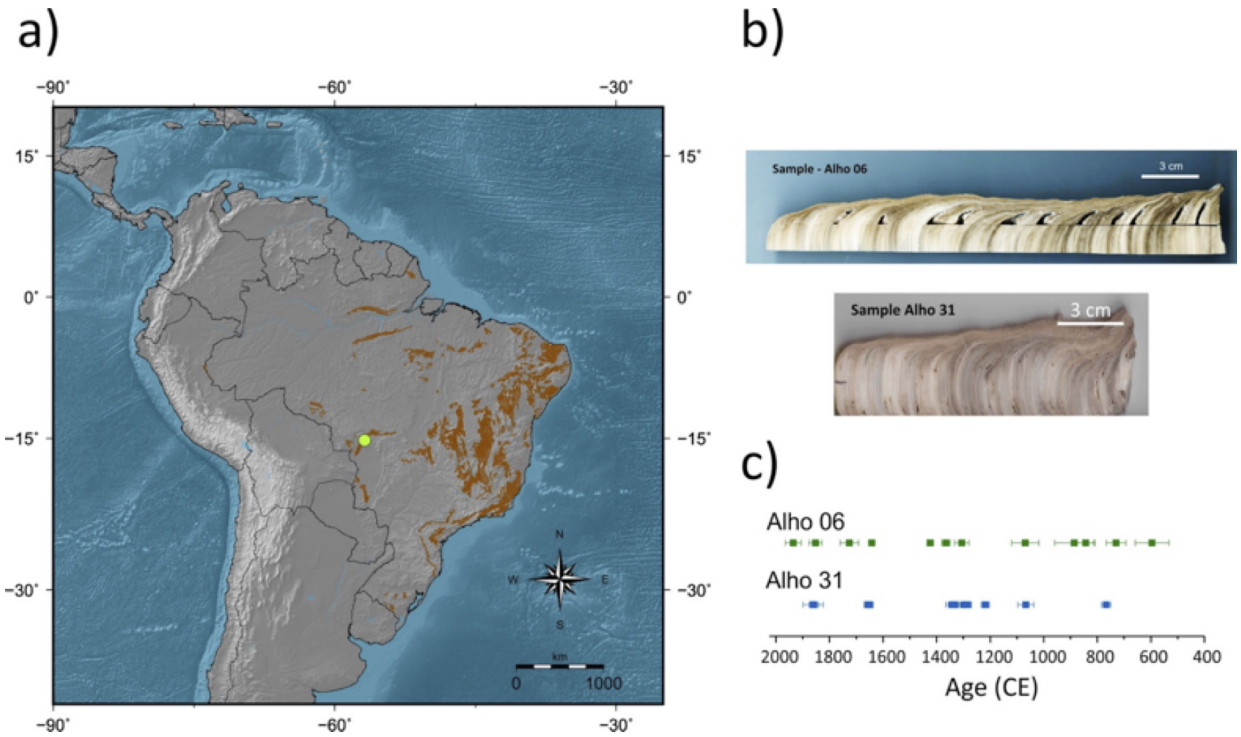

Figure 1 – (a) Location of Pau d'Alho cave in South America, (b) the two sampled stalagmites (ALHO6 and ALHO31), and the corresponding U-Th ages with respective error bars.

2. Methods

Natural remanent magnetization of both stalagmites was measured at the Laboratório de Paleomagnetismo of Universidade de São Paulo (USPmag) using a SQUID magnetometer coupled with an alternating field (AF) demagnetizer (2G Enterprises). A total of 61 specimens (ALHO6: 34 specimens, ALHO31: 27 specimens) were submitted to stepwise alternating field (AF) demagnetization up to 100 mT. Directions were calculated using principal component analysis.

3. Results and conclusions

Vector directions were calculated with an AF field range varying from ~12 mT to 35 mT (Fig. 2). Five specimens out of 61 displayed unstable behavior during demagnetization or maximum angular deviation (MAD)≥ 20°, and were not further considered. ALHO6 record starts at ~540 CE, while ALHO31 records start at ~1100 CE. Taking the entire record, magnetic declinations show two cycles of changing declination, with positive peaks at ~900 CE and ~1700 CE, and a negative peak at ~1200 CE. Declination decreases since ~1700 CE. The magnetic inclination increases from 543 CE until ~1100 CE, followed by a progressive decrease from about -40° to near 0° in recent times.

In addition to the directional data, the relative paleointensity was calculated for all samples with MAD values lower than 20° across the same alternating field used in the vectorial analysis. The straight pseudo-Arai

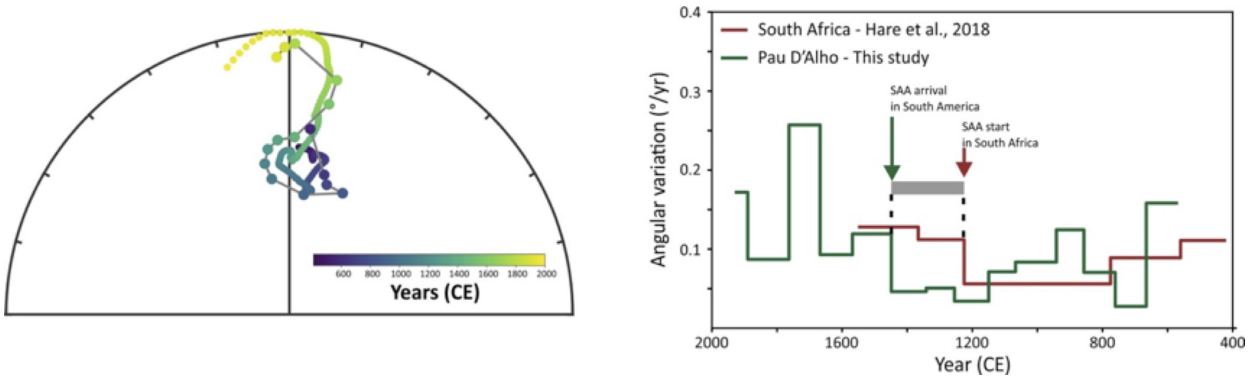

Figure 2 – (Left panel) Evolution of the geomagnetic field for the past ~1500 yrs as recorded by the ALHO6 and ALHO31 stalagmites (datapoints) compared to the ARCH3.1 model (continuous line); (right panel) comparison of angular variation of the geomagnetic field directions in South Africa (red) and South America (green).

plots obtained corroborate the single-domain nature of the magnetic assemblage inferred from hysteresis experiments. The general trend of geomagnetic field evolution for the past millennia is reproduced in the two stalagmites and fit remarkably well the pattern defined by the high quality archeointensity data for South America (Poletti *et al*., 2016), with marked intensity peaks at ~800-1000 CE and ~1400-1700 CE.

The speleothem record matches both in direction and intensity the evolution of the field described by the geomagnetic model ARCH3k.1. A combined curve of paleosecular variation constructed for the two stalagmites (Fig. 2) describes a clockwise loop from ~570 CE to ~1450 CE, followed by a northward departure up to ~1700 CE and then a rapid westward migration until ~1920 CE. Before 1590 CE, the variation observed on the stalagmite record is ~0.10 °/yr until ~1450 CE, with a peak of 0.12 °/yr at ~900 CE. After ~1450 CE, there is a general increase, with marked shifts at ~1500 CE and ~1700 CE.

When compared to the variations in South Africa, both paths increase their angular variation to ~0.13°/yr (Fig. 2) with a time-lag of ~250 yrs. This result is validated by both ARCH3k.1 models in their respective locations for this period. From the period from ~1200 CE to ~600 CE the same trends are observed in both continents, with a decrease in South Africa from 550 CE to ~750 CE and a similar decrease in South America from ~850 CE to ~1150 CE.

These results suggest that the South Atlantic Geomagnetic Anomaly is a recurrent feature, with at least two cycles of generation and westward migration in the past two millenia.

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