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Geomagnetic field intensity in South America over the 500 years: New archeointensity results from South Brazil

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1. Introduction

Tracing the field in the past at the centennial and millennial timescale (i.e., the archeomagnetic timescale) is important in improving geomagnetic field models. The distribution of archeomagnetic data across the globe is very inhomogeneous with almost all data coming from the northern hemisphere, particularly from Europe and Asia (Brown et al., 2015). Yet, the southern hemisphere is the one presenting the highest variability for the past millennia (Constable et al., 2016) and, it is also the region comprising the South Atlantic Anomaly (SAA). The SAA is characterized by the lowest total field intensity and it is presently located in Southern Brazil (e.g., Hartmann and Pacca, 2009; Finlay et al., 2010; Terra Nova et al., 2017). Some studies suggest that SAA is a persistent field feature in South Atlantic for periods longer than historical times (Tarduno et al., 2015; Shah et al., 2016), but the beginning of the influence of strong non-dipole fields at the centennial-scale evolution in South Atlantic region, could give important information about the recurrence of SAA at longer timescales (Trindade et al., in press).

Figure 1: Location map and archeological examples.

We present six new high-quality archeointensity data from Pelotas city (Fig. 1a), South Brazil, dated between 1790 and 1943 CE. These data together with the previously reported in South America, allow us to discuss about the effects of rapid field variations in the region, and the eventual role of regional non-dipolar components on the geomagnetic field observed over South American in the past five centuries.

Archeological sampling

112 architectural brick fragments from 8 buildings (2 farmhouses, 6 historical buildings) from the Pelotas city (Fig.1b, 1d). Their dating is mainly ensured by historical constraints and complemented by archeological evidences, yielding age uncertainties of less than 21 years. The sampling was carried out in the basement of the buildings to make sure that the chosen bricks are associated to the initial phase of construction (Fig. 1c, 1e).

2. Results

2.1 Rock magnetism

Brick fragments possess a magnetic mineralogy suitable for intensity experiments, in particular reversible low-field susceptibility curves during heating and cooling (Fig. 2).

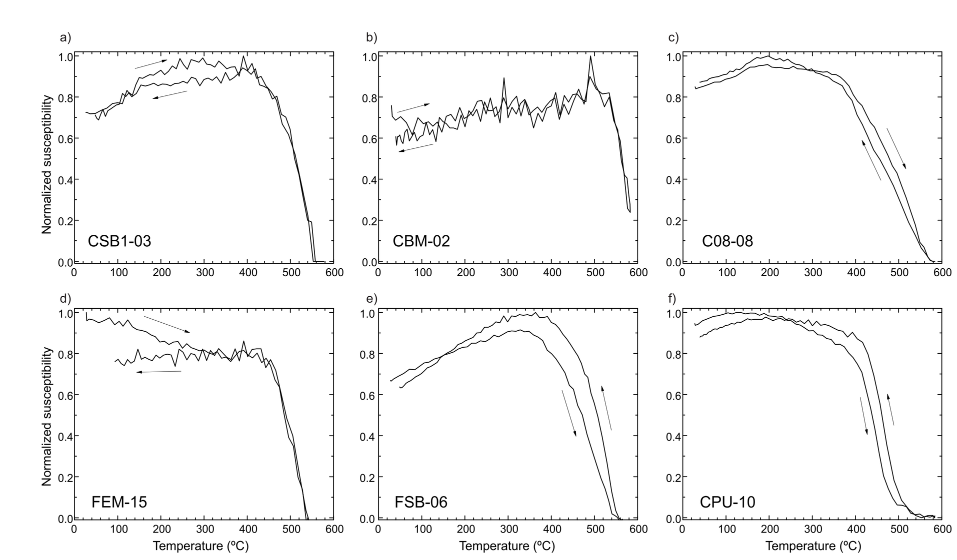

Figure 2: Examples of thermomagnetic curves.

The IRM curves, hysteresis loops and FORC diagrams suggest that the main magnetic carriers are dominated by low-coercivity magnetic phase (magnetite) and the mixture with hematite in varying proportions among fragments, from low to high contribution of hematite (Fig. 3).

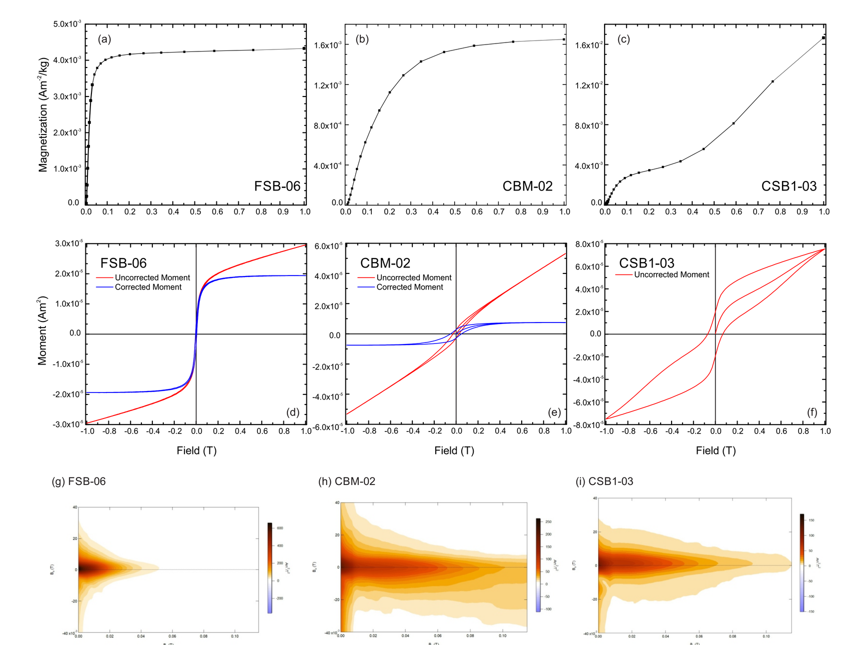

Figure 3: Examples of IRM curves, hysteresis loops and FORC diagrams.

2.2 TT-ZI results

Method: Thellier and Thellier (1959), modified by Coe (1967). **Accounted:** pTRM checks, pTRM tail-checks, TRM anisotropy (ATRM) and cooling rate (CR) corrections.

Strict selection criteria: applied to only retain the most reliable results (Fig. 4); e.g., a ~5% coherence test was considered between intensity values obtained from 2 specimens from a same fragment.

ATRM: ~81% present a weak ATRM degree with values varying from 1.0 to 1.15. Very good consistency observed at the fragment and site levels after ATRM correction (Fig. 5a).

CR: TRM overestimate varies from ~1% to ~20%, but most fragments present values around 9%, after a slow cooling time of 25 h (Fig. 5b).

Success rate (~72%): 26 fragments (52 specimens) from 6 sites.

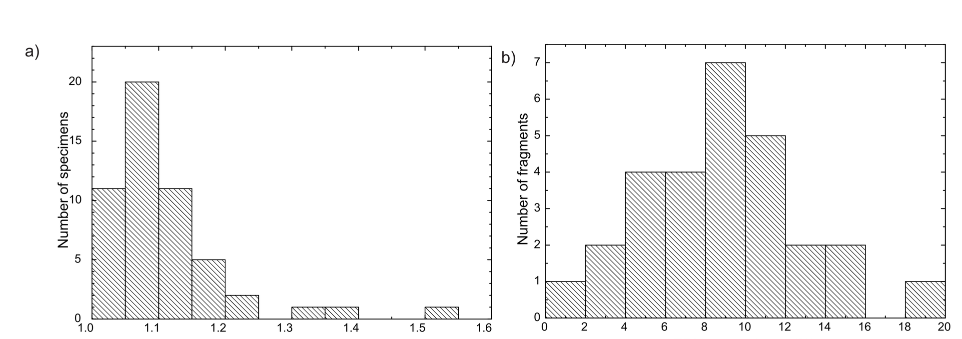

Figure 5: (a) TRM anisotropy degrees, (b) TRM overestimates (slow cooling time of ~25 h).

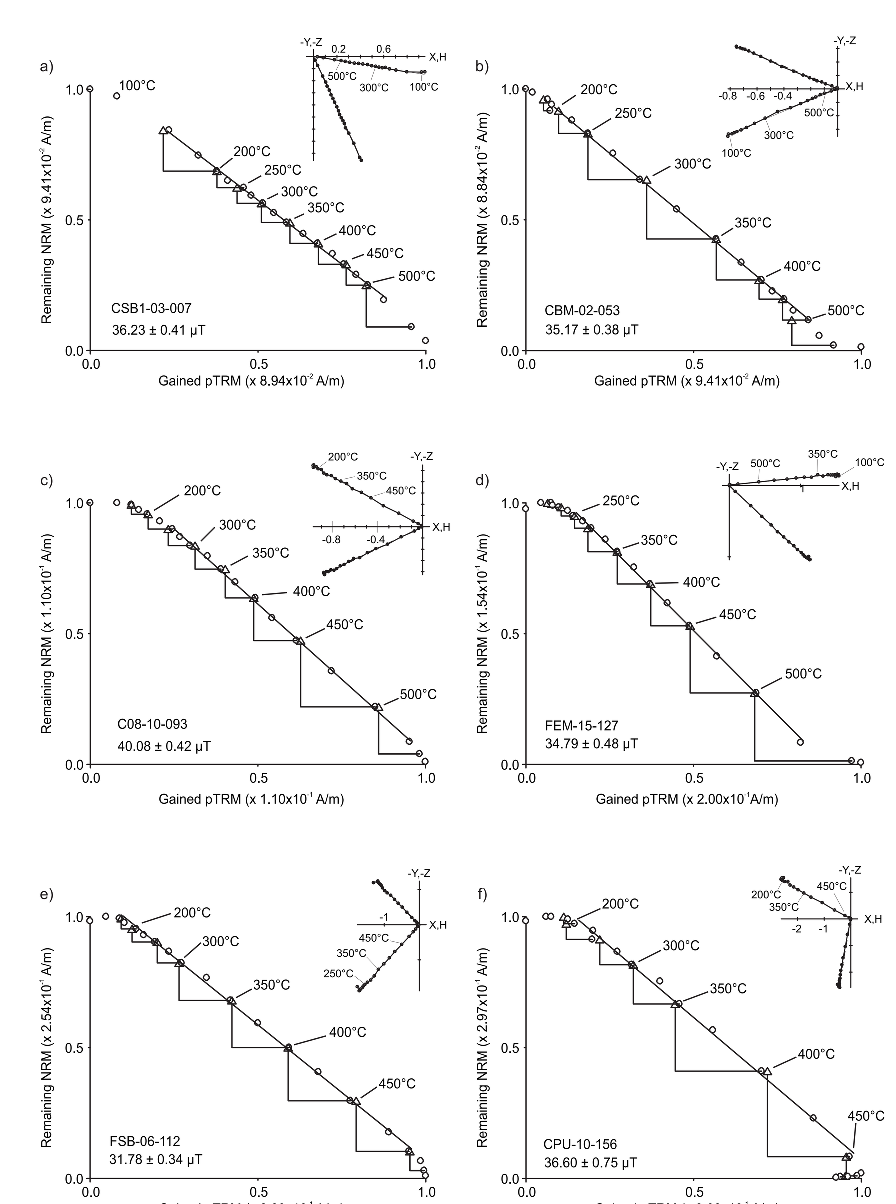

Figure 4: Examples of TT-ZI results.

3. Discussion

Site-mean intensity values vary from 36.4 μT to 27.8 μT (Fig. 6a). The raw dataset for South America includes 67 intensity data between 1500-2000 CE. Most of these data do not comply to minimum quality criteria. After selecting data (Poletti et al., 2016), were retained 38 intensity means from NE, SE and S Brazil, Argentina and Chile (Fig. 6a).

A **qualitative analysis** by reducing the magnetic intensity data for the same latitude (using ADM), show a common decreasing trend, which reflects the continuous decay of the geomagnetic axial dipole on a millennial scale (Poletti et al., 2018). However, they have small differences between them, suggesting that there is a significant non-dipole contribution acting in the region (Fig. 6b).

A **quantitative evaluation** was performed by subtracting the estimated archeointensity from the intensity at the same latitude computed from the recalibrated g10 proposed by Poletti et al. (2018) (Fig. 7).

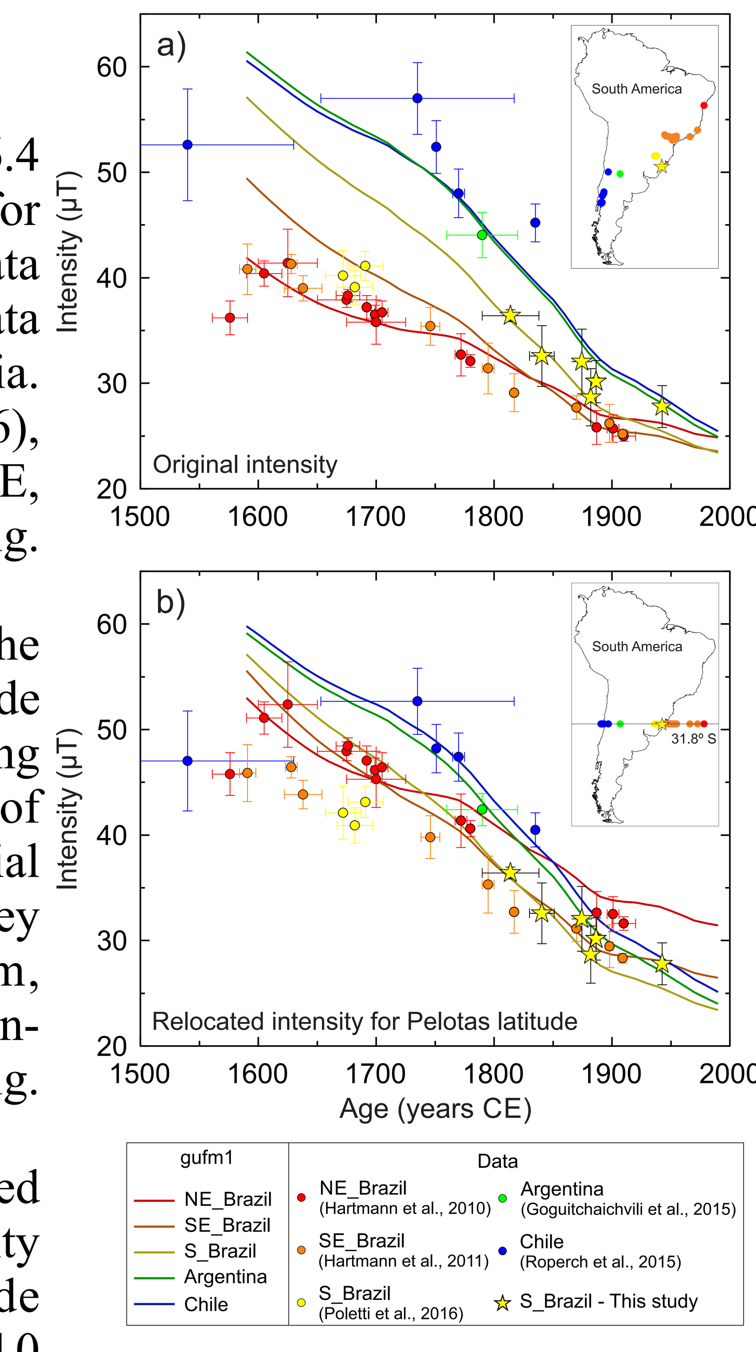

Figure 6: Archeointensity compilation for South America.

Our analysis suggest that the influence of the SAA is present since 1800 CE, and has probably started as early as 1700 CE in the continent. New archeointensity data in Brazil, Paraguay and Argentina would help in better constraining the evolution of the SAA through time.

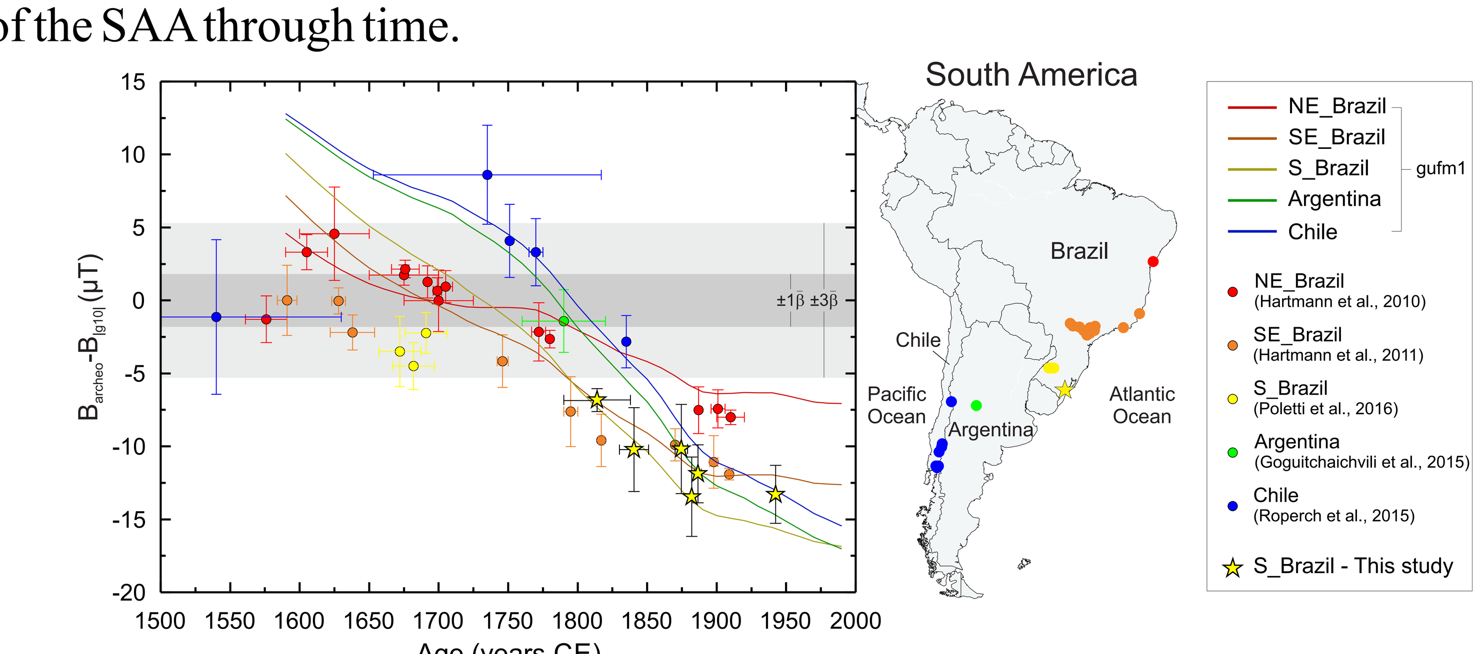

Figure 7: Non-dipolar contributions to geomagnetic field intensity.

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