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Geomagnetic field strength recorded in Iron Age ceramics from southern Africa

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ABSTRACT

The Earth's dipole magnetic field has decreased in intensity by 5 to 10 percent over the last 150 years. To understand more about the nature of this decline, it is desirable to have a longer record, extending back in time beyond the data available from modern magnetic observatories. Firing of archeologic objects (e.g. ceramics and hut floors) raises temperatures above the Curie temperatures of their constituent magnetic minerals. Paleointensity analyses of fired artefacts-- commonly known as archeomagnetism—can provide longer term geomagnetic records. Such studies are well developed at North Hemisphere sites, but there are no extensive records from the Southern Hemisphere for the millennium prior to the era of observatory recording. There is an extensive record of Iron Age ceramics from southern Africa, with associated burnt structures that has the potential to provide a Southern Hemisphere geomagnetic field record. We discuss our efforts to test the potential of this record using rock magnetic and paleointensity analyses of Iron age test samples. Rock magnetic results to date suggest that Iron age Iron age ceramics contain magnetic minerals of appropriate composition and size to retain a high resolution record of past field intensity. Data from preliminary paleointensity experiments further support this conclusion.

Key words: archeomagnetism, geomagnetism, paleomagnetism, secular variation, paleointensity.

INTRODUCTION

The rapid decay of Earth's dipole magnetic field over the last 150 years, as documented by magnetic observatories, has fuelled speculation that we are heading toward a geomagnetic reversal (Figure 1). The decay may be related to the growth of a patch of reversed field flux in the Southern Hemisphere. The growth of such patches is seen as a precursor to geomagnetic reversals in some numerical simulations of the geodynamo. However, whether we are heading toward a reversal, or if the observed changes are part of normal secular variation represents an on-going debate.

It would be useful to have a longer dipole record to better understand the importance of the dipole decay, and this has motivated renewed interest in archeomagnetism. Some models based on available data predict almost no change in dipole field intensity in the 250 years prior to the start of modern observatory measurements (~1840), and other global field models predict only modest changes on a longer 1000-year time scale (Figure 2).

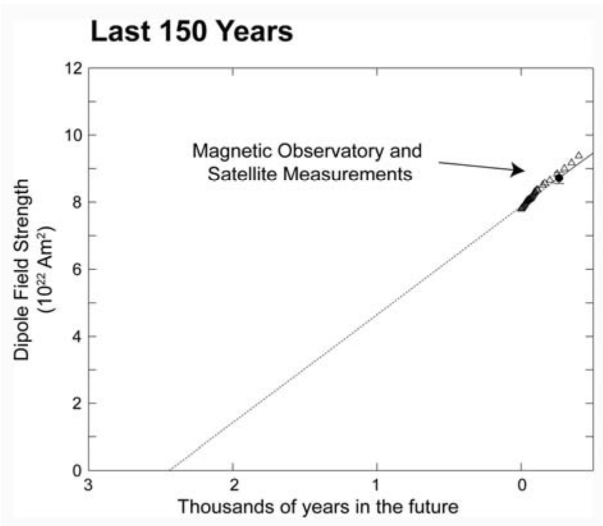

Figure 1. Dipole field intensity from magnetic observatories and satellite measurements with extrapolation into the future, after Tarduno (2009).

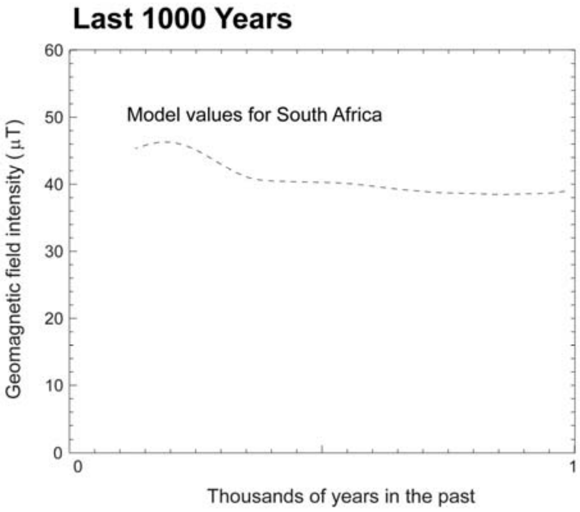

Figure 2. Predicted geomagnetic field intensity for South Africa in the past based on the global field model of Korte and Constable (2005).

However, there are as yet no extensive paleointensity records from the Southern Hemisphere spanning these ages; the “global” geomagnetic intensity models are overwhelmingly dominated by Northern Hemisphere data.

Southern Africa holds a rich history of Iron Age ceramics and burnt structures (Huffmam, 2007) that may be suitable for archeomagnetic analysis and that could provide further insight. Here, we discuss the potential of this record through rock magnetic tests.

METHODS AND RESULTS

The most robust paleointensity determinations rely on a series of paired heatings (the Thellier technique modified by Coe, see Tarduno et al., 2006, and references therein). First, a sample is demagnetised by heating over a discrete temperature range in a magnetically shielded oven, and the natural remanent magnetization (NRM) lost is recorded. Next the sample is reheated over the same temperature range in the presence of an applied field. A partial thermoremanent magnetization (pTRM) is imparted. Because the applied laboratory field is known, the NRM and pTRM data can be used to solve for the ancient field strength.

To accurately record paleointensity, samples should contain magnetic grains having single domain, or single domain like (so-called pseudo-single domain) characteristics. The magnetic mineralogy should also be stable upon laboratory heating. To assess magnetic domain state, magnetic hysteresis data have been collected using an Alternating Gradient Force Magnetometer. To evaluate Curie temperatures of magnetic carriers, and their stability upon laboratory heating, magnetic susceptibility data have been collected using an AGICO KLY-4S Kappabridge with a CS-3 furnace. Susceptibility measurements were made in air and in a controlled Ar atmosphere. Natural remanent magnetizations were demagnetised, and laboratory thermo-remanences imparted, using an ASC TD48 thermal demagnetisation device with field coil. Magnetic remanence measurements were conducted using a 2G DC SQUID magnetometer housed in a magnetically shielded room (ambient field less than 200 nT). All magnetic measurements were made in the paleomagnetic laboratories at the University of Rochester.

Magnetic hysteresis measurements reveal single domain to pseudo-single domain magnetic carriers for Iron Age pottery samples, suggesting they can preserve paleointensity signals. Curie temperatures indicate magnetite-like compositions. Preliminary paleointensity experiments indicate that ceramics have stable magnetization after partial thermal demagnetisation, and progressively acquire laboratory partial-thermorement magnetizations (when fields are applied).

CONCLUSIONS

Iron age ceramics from southern Africa appear to be suitable recorders of past geomagnetic field strength. Measurement of well-dated specimens (underway in a collaborative project between the University of Rochester, University of KwaZulu-Natal and University of the Witswatersrand) should yield a Southern Hemisphere paleointensity record. This record should ultimately provide context useful for understanding the significance of the modern dipole field decay.

ACKNOWLEDGMENTS

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