Rock magnetism and geomagnetic field strength of the rare Iron Age (300–500 BC) artifacts from Tamilnadu: The first Virtual Axial Dipole Moment determination from India

R. Mohamed Asanulla [a,b,*], T. Radhakrishna [a], R. Venkatachalapathy [b], C. Manoharan [b], G.S. Soumya [a], P. Sutharsan [c]

[a] National Centre for Earth Science Studies, Akkulam 695 011, Trivandrum, India
[b] Department of Physics, Annamalai University, Annamalainagar 608 002, Tamilnadu, India
[c] Department of Physics, Sir Theagaraya College, Chennai 600 021, India

ARTICLE INFO

ABSTRACT

Archaeological artifacts are abundant in India to undertake archaeointensity (AI) research. High quality AI data from this region are essential to improve global geomagnetic field (GGF) model secular variation curve for the past few millennia for its applicability to the Indian region. Rock magnetic and AI investigations are carried out on 15 rare Megalithic/Iron Age (300–500 BC) pottery samples from the Sengalur site, Tamilnadu, India. Rock magnetic results indicate that either SD/PSD type of ferrimagnetic mineral (magnetite/titanomagnetite) is responsible for magnetic remanence. Temperature versus susceptibility experiments for most of the samples yield reversible heating and cooling curves with Curie temperatures of 565–585 °C. AI values are determined by the Thellier–Thellier method as modified by Coe 1967 (Zero-field/In-field method). The AI data of the present study meets the reliability and quality criteria adopted for the AI determinations worldwide. The mean AI of 47.48 $\pm$ 1.72 μT and a mean Virtual Axial Dipole Moment of 11.7 $\pm$ 0.4 $\times$ 10^{22} Am^2 are estimated. This new AI data are in good agreement with the predictions of ARCH3K.1 GGF model for the period of 300–500 BC for India derived from the GEOMAGIA. V$_3$ updated database. Other models incorporating sediment data are not consistent with the actual values of direct determination.

1. Introduction

Estimations of absolute archaeo/palaeo intensity (AI/PI) from India, are very essential because long-term variation of the past earth magnetic field (EMF) components are virtually unknown for the region. Such data have been obtained for many other regions of the globe ([2,7,15,31,43,51]; etc.). The data are frequently used in deep earth investigations for understanding behavior of geodynamo processes and fluid motion in the outer core etc. [7,19,49]. Archaeological samples, volcanic materials and sediments are generally used for this study. However, archaeological pottery samples are most preferred because they provide reliable absolute intensity results although they may not always provide original magnetization direction.

India is a seventh largest country in the world; it has rich historical past and large amount of archaeological artifacts and

thus is a favorable place to obtain a long-term behavior of the past EMF. Although a few studies were conducted, only the recent AI study by Venkatachalapathy et al. [58] meets modern reliability criteria. As a result, reconstructions of regional secular variation over the Indian subcontinent rely on global models based on data from elsewhere. In order to generate global model secular variation curve, a huge amount of AI/PI and directional dataset was compiled ([10,11,16,21,26,32,33,37] ref there in). In recent years, new updated global geomagnetic field models (CALS3K.4; [36]; ARCH3K.1: [35]; CALS10K.1b: [37]) have been generated based on modern AI techniques, better age controls and advanced modeling methods. These models are very useful for global researchers in order to compare and evaluate their results. An effort is made by global modelers to develop global model secular variation curve for India for the past few millennia. High quality archeo/palaeo AI/PI data from India thus becomes important contribution by two folds. The data are useful to reduce regional bias and improve the quality and reliability of global models. The study enables us to develop long-term secular variation curve for India independently by direct determinations. This paper is an attempt towards this
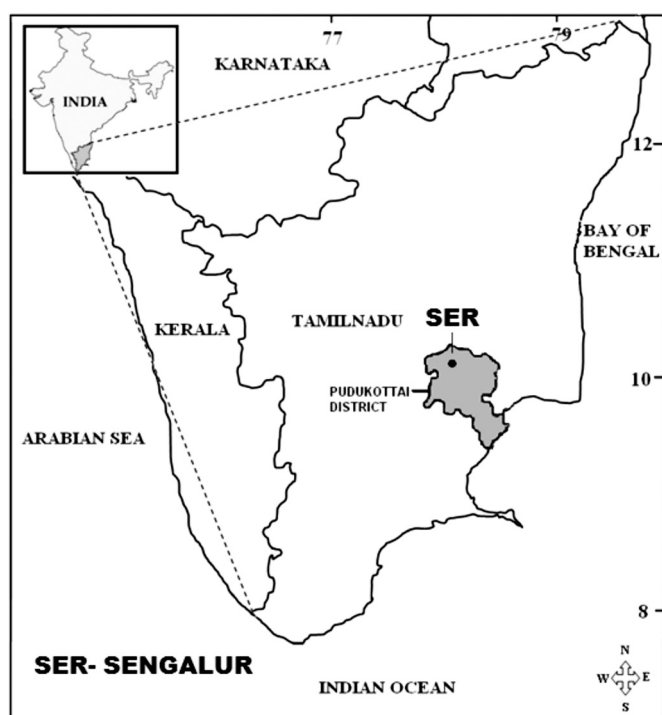
* Corresponding author at: National Centre for Earth Science Studies, Akkulam 695 011, Trivandrum, India.
E-mail address: asanulla84@gmail.com (R. Mohamed Asanulla).

Table 1
Details of Archaeological samples collected in the Sengalur site from Southern India.

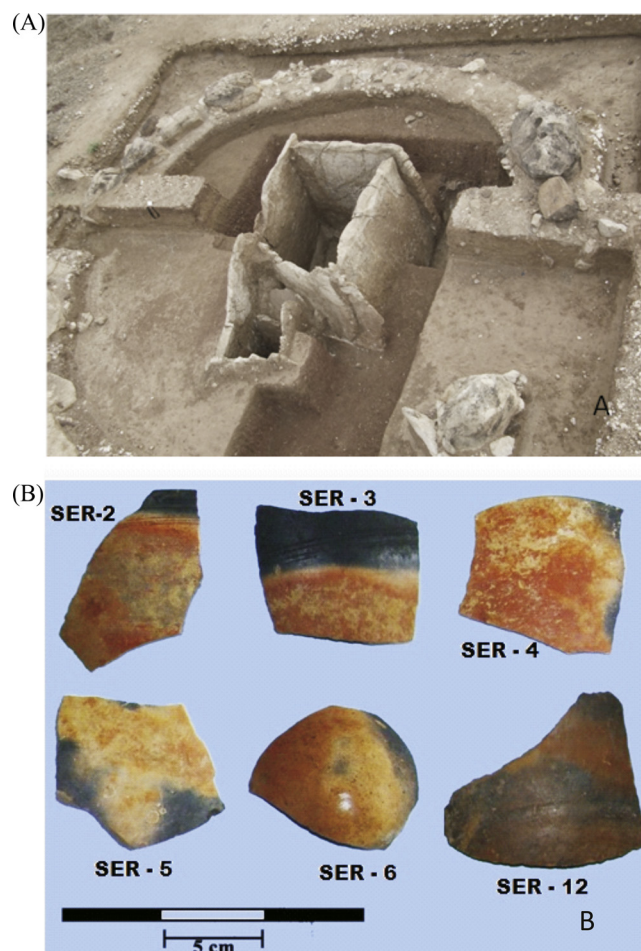| Sengalur sample ID	Collected	Archaeological name of the pottery	Description	Archaeological (Or) historical period	Archaeological age	References
SER-1, 3 and 9		Small pot sherd	Fine black and red ware; out turned rim found at interior	Megalithic or iron age	500–400 BC	
SER-2, 8 and 10		Pot sherd	Black and red ware; out turned rim found at interior	Megalithic or iron age	500–300 BC	
SER- 4 and 5		Fine plate	Black and red ware; out turned rim found at interior	Megalithic or iron age	500–300 BC	
SER-6 and 7	Below two meter depth for the well preserved rectangular megalithic burial structure	Rimless bowl	Polished black and red ware; band style found at exterior	Megalithic or iron age	500–300 BC	[12,22]; [54]
SER-11,12 and 13		Rimless bowl/jar	Polished black and red ware; band style found at exterior	Megalithic or iron age	500–300 BC	
SER-14 and 15		Fine rimless bowl	Polished black and red ware; band style found at exterior	Megalithic or iron age	500–300 BC	

Fig. 1. Location map of the archaeological site Sengalur in Tamilnadu, India.

Fig. 2. (A) Field photograph of rare rectangular Megalithic burial structure excavated in Sengalur, Tamilnadu, and (B) Examples of samples from Sengalur (SER) site. (For interpretation of the references to color in this figure, the reader is referred to the web version of this article.)

objective. We estimated new reliable AI data on rare Iron Age (300–500 BC) pottery sherds from Indian region and compare the results with recently updated global model prediction for India.

2. Material and methods

2.1. Study area and sampling site

Samples for this study come from Tamilnadu, located in the southern part of India (Fig. 1). Tamilnadu is one of the familiar place of ancient civilization, culture, heritage and urbanism from historical and pre historical period. Pudukottai is one of the main districts in Tamilnadu, which has rich historical and pre historical past and is famous for large amount of pottery production in ancient times. In 2009, the Archaeological Survey of India (ASI) sur-

veyed Pudukottai district and identified many megalithic structure in and around Sengalur village (10°40′165′′N; 78°53′634′′E; Fig. 1) situated at 38 km from Pudukottai. The ASI excavated this site in 2010 and identified a rare rectangular shape burial site, unearthed