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The environmental magnetic record of palaeoenvironmental variations during the past 3100 years: A possible solar influence?

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ABSTRACT

Sediments from Pookot Lake (PK) in southern India have provided a record of local environmental changes and catchment processes during the past 3100 cal. years B.P. Variations in the rock magnetic parameters (χ_{lf}, χ_{fd}, χ_{ARM} and IRM's at different field strengths) of sediments from two AMS ^{14}C-dated cores reflect climate-induced changes in the catchment of Pookot Lake. Assuming that rainfall is most likely the dominant driving mechanism behind the rock magnetic variations of PK sediments, the environmental history of the site has been reconstructed. Rock magnetic parameters exhibit significant variations during the past 3100 years. The palaeoenvironmental history of the Pookot Lake region may be divided into three phases. During the first phase (~3100 to 2500 cal. years B.P.), catchment erosion and detrital influx were high, indicating a strong monsoon. The second phase, which lasted from 2500 to 1000 cal. years B.P., was characterised by low and steady rainfall, resulting in a low and uniform catchment erosion and detrital influx. Phase 2 was interspersed with brief intervals of strong monsoon and characterised by frequent drying up of the lake. During Phase 3 (~1000 cal. years B.P. to the present), catchment erosion was high, indicating a shift to strong monsoonal conditions. It appears that monsoonal rainfall in the region is influenced by solar activity, with periods of high total solar irradiance being characterised by high rainfall and vice versa; it was relatively low during the Little Ice Age and high during the Medieval Warm Period. The magnetic susceptibility (χ_{lf}) data exhibit a number of periodicities which might have a solar origin. The χ_{lf} record exhibits similarities with other continental and marine palaeoclimatic records from the region, indicating that regional trends in the monsoon during the Late Holocene are broadly similar.

1. Introduction

Rock magnetism (or environmental magnetism) deals with the study of the magnetic properties of a wide range of natural materials including soil, sediment, dust and peat (Oldfield, 1999). Rock magnetic measurements have the advantages of being rapid, inexpensive, sensitive and non-destructive (Walden, 1999a). They have successfully been applied to characterise dust particles and atmospheric pollution (Warrier et al., 2014a; Blaha et al., 2008), study heavy metal pollution in soils and sediments (Wang, 2013; Pozza et al., 2004), understand pedogenic processes (Maher et al., 2003; Sandeep et al., 2012), reconstruct palaeoclimatic and palaeoenvironmental conditions (Shankar et al., 2006; Geiss et al., 2003), estimate opaque and heavy mineral contents in beach placers (Shankar et al., 1996), quantify particulate pollution in rivers (Sandeep et al., 2011), unmix sediment sources (Shankar et al., 1994; Yu and Oldfield, 1989), and characterise archaeological samples (Bradak et al., 2009; Mighall et al., 2009). Rock magnetic techniques have also been employed to study lake sediments (Geiss et al., 2003, 2004; Peck et al., 2004; Foster et al., 2008; Shankar et al., 2006; Warrier et al., 2014b), which provide information on the concentration, grain size and mineralogy of magnetic minerals present. This information may be used to determine catchment processes in response to environmental/climatic changes. Hence, past environmental/climatic changes may be reconstructed based on the rock magnetic data for lacustrine sediment cores. In India, most studies on lake sediments are confined to western India, Rajasthan and the Himalaya (Saini et al., 2005; Prasad and Enzel, 2006; Juyal et al., 2009; Kotlia et al., 2000; Krishnamurthy et al., 1986; Kajale and Deotare, 1997; Srivastava et al., 2013). Only a limited number of rock magnetic studies have been carried out on lake sediments of southern India to decipher palaeoenvironmental conditions (Shankar et al., 2006). There are thousands of lakes in southern India, which remain largely unexplored. In this paper, we have investigated sediments from the Pookot Lake (PK), southwestern India using rock magnetic methods to determine catchment-related and environmental processes during the past 3100 years.

Variations in the magnetic properties of lake sediments are dependent upon a variety of processes either outside the lake (pedogenesis

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and erosion in the catchment) or within it (biogenic and authigenic). Ferrimagnetic iron sulphide (greigite) may form in anoxic environments characterised by high organic matter content and rapid sedimentation (Snowball, 1991; Roberts and Turner, 1993; Jelinowska et al., 1997). Its occurrence is usually coupled with dissolution of magnetite (Snowball and Thompson, 1990; Roberts and Turner, 1993; Anderson and Rippey, 1988), which may alter the magnetic signature recorded in sediments. Bacterial and anthropogenic magnetite may also be present in lake sediments. When post-depositional processes, anthropogenic, biogenic/authigenic effects are absent or limited, a simple model of detrital magnetic minerals being derived from a lake catchment may be used to semi-quantify the detrital flux from the catchment, either by runoff or aeolian processes (Dearing et al., 1981; Oldfield, 1991).

The main objectives of this investigation are to explore the (a) palaeoenvironmental changes of the Pookot Lake area during the Late Holocene, (b) presence of any periodicities in the sedimentary magnetic record, (c) influence of total solar irradiance on monsoon, and (d) regional trends in environmental changes by comparing them with other palaeoclimatic records from the region.

2. Materials and methods

2.1. Study area

Pookot Lake (PK) is a closed, natural lake situated at an altitude of 775 m in the *Sahyadri* (the Western Ghat) near Vythiri in Wayanad

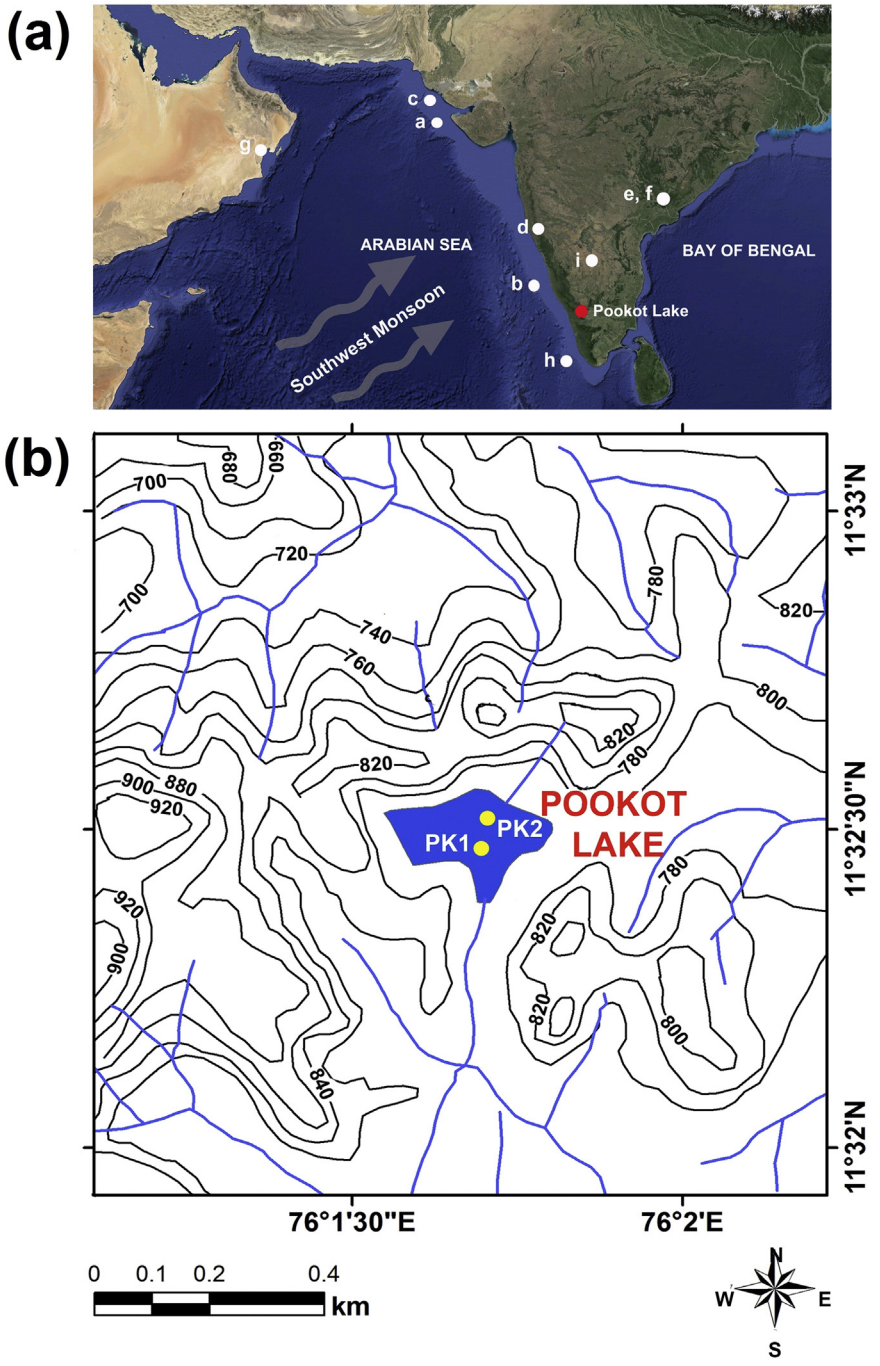

Fig. 1. (a) Satellite imagery showing the location of Pookot Lake in southwestern India and other palaeoarchives that are referred to in the text. (b) Location map showing the topography of the Pookot Lake and its surrounding area. Topographic contours are in metres. The locations of cores PK1 and PK2 are shown.