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# Glacial–interglacial climatic variations at the Schirmacher Oasis, East Antarctica: The first report from environmental magnetism

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ABSTRACT

We discuss in this paper the first detailed environmental magnetic record of glacial–interglacial climatic variations in the Schirmacher Oasis, East Antarctica. We determined environmental magnetic properties and inter-parametric ratios ($\chi_{lf}$, $\chi_{fd}$ %, $\chi_{ARM}$, SIRM, $\chi_{ARM}$/SIRM, $\chi_{ARM}/\chi_{lf}$, $\chi_{ARM}/\chi_{fd}$, SIRM/$\chi_{lf}$, S-ratio and HIRM) for sediment samples of a core from the Sandy Lake. Accelerator mass spectrometer (AMS) $^{14}C$ dates were obtained on the organic matter from bulk sediment samples. The sediment core spans the past ~42.5 cal. ka B.P. The magnetic minerals are mainly detrital and catchment-derived, as there is no evidence for the presence of authigenic greigite, bacterial magnetite or diagenetic dissolution. The last glacial period is characterized by a high concentration of ferrimagnetic minerals such as titanomagnetite (high values of $\chi_{lf}$, SIRM etc.) and coarse magnetic grain size (low $\chi_{ARM}$/SIRM and $\chi_{ARM}/\chi_{lf}$ values and high S-ratio values). Deglaciation in the Schirmacher Oasis began around 21 cal. ka B.P. as suggested by the low magnetic mineral concentration. The Holocene period is characterized by relatively warm climatic events as seen in the low values of magnetic susceptibility which is primarily contributed by fine-grained titanomagnetite resulting from pedogenesis (high $\chi_{fd}$ % values). Several of the relatively warm and cold events that we deciphered from the environmental magnetic data are correlatable with lake sediments from the Schirmacher Oasis and other ice-free areas in East Antarctica and from ice-core records on the Antarctic Plateau.



## 1. Introduction

Paleoarchives such as marine and lake sediments, ice-cores, tree-rings, corals and speleothems have been successfully used to determine past variations in climate on different time-scales. These archives are abundant in tropical and temperate regions. However, polar regions, especially Antarctica, offer ice cores and marine sediments apart from lake sediments for paleoclimatic reconstruction. Lacustrine sediments are most widely used for paleoclimatic reconstruction as they are ideal repositories of air-borne and especially stream-borne materials (Peck et al., 2004; Foster et al., 2008; Mügler et al., 2010; Warrier et al., 2014a). They bear a strong signal of catchment soils via the inputs of minerogenic and chemical weathering products. They are more sensitive than ocean sediments to climatic and environmental changes because of their smaller size and higher sedimentation rates. Lake sediment records, therefore, allow a finer temporal resolution and a direct comparison with known historical and instrumental climatic records of the surrounding area.

Environmental magnetism (also known as rock magnetism or mineral magnetism) concerns the application of rock magnetic methods to environmental studies. The technique has been successfully used to identify the link between environmental processes and the magnetic minerals present in rocks, soils, sediments etc. Magnetic minerals such as magnetite, maghemite, hematite, goethite and greigite occur as accessory minerals in natural samples and are useful proxies for determining changes in past climate. Being omnipresent in the environment, the aforementioned minerals are produced, transported, and deposited in lacustrine or marine systems. It is well established that the magnetic mineral content of sediments provides a sensitive medium for recording environmental change (Evans and Heller, 2003). For a given climatic regime, magnetic minerals are characterized by a particular concentration, grain size and mineralogy. Any change in climate would then modify one or more of the above-mentioned attributes of magnetic minerals. Lake sediments record this change through temporal and spatial variations in the mineralogy, concentration and grain size of magnetic carriers. Due to the easy, rapid, non-destructive and sensitive

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nature of the measurements, environmental magnetism has found varied applications (Shankar et al., 2006; Sandeep et al., 2010, 2012; Tudryn et al., 2010; Warrier et al., 2011, 2014b). However, in Antarctica only a few detailed studies on paleoenvironmental reconstruction using environmental magnetism are reported (Sagnotti et al., 2001; Bloemendal et al., 2003; Phartiyal et al., 2011; Brachfeld et al., 2013, 2002; Phartiyal, in press).

The continent of Antarctica is bestowed with several ice-free areas such as the Schirmacher Oasis, the Larsemann Hills, the Amery Oasis, the Bunger Hills, the Windmill Islands and the Vestfold Hills. The ice-free areas have plenty of fresh-water lakes that are potential archives of past climatic variations. Although lake sediments in most ice-free regions are well studied (see Verleyen et al., 2011 and Hall, 2009 for review), Schirmacher Oasis is one region from which a limited number of paleoclimate records have been reported (Bera, 2004; Sharma et al., 2007; Phartiyal et al., 2011; Phartiyal, in press). In this study, we have attempted to reconstruct the paleoenvironmental/paleoclimatic changes in the Schirmacher Oasis (hereafter referred to as SO) based on the environmental magnetic properties of a sediment core from the Sandy Lake.

## 2. Study area

Situated in the Queen Maud Land (East Antarctica), the Schirmacher Oasis is a 35 km$^2$ ice-free area and lies between the margins of the continental ice sheet and the ice-shelf (Fig. 1). It consists of several hills of low elevation (~200 m; Srivastava and Khare, 2009) and about 120 lakes which may be classified as epishelf, proglacial and landlocked, depending on their geomorphic evolution (Ravindra, 2001). Sandy Lake (70°45′45.9″S; 11°47′34.7″E) is one of the small, land-locked lakes (Fig. 1c) situated ~2.5 km from the Indian Research Station — *Maitri*. It is a shallow, fresh water lake with a water depth of 1–2 m. It receives water from a few streams in the catchment. The Lake is covered with ice for almost 7–8 months in a year but ice-free for the remaining period. The thickness of the ice cover is 0.5 to 1 m. There is very little vegetation in the catchment in the form of mosses etc. The Lake is surrounded by *roche moutonnées* (erosional forms created by the passage of a glacier on an underlying rock; Benn and Evans, 1998). The terrain is predominantly gneissic with the felsic variety (belonging to the Precambrian age; Sengupta, 1986) constituting >85% of the exposed bed-rocks (Rao, 2000). Other rock types found are alaskite, garnet-biotite gneiss, pyroxene granulites, enderbites, calc-granulites, khondalites, migmatites and streaky gneiss, intruded by basalt, lamprophyre, pegmatite, dolerite and ophiolite rock types (Sengupta, 1986; Bose and Sengupta, 2003). The general weather conditions in the Schirmacher Oasis are harsh with dry and extremely low temperatures and strong winds. The summer season is from November to February when the maximum temperature varies from 0.4 to −2.6 °C and the minimum temperature from −2.7 to −8.8 °C. During winter (March to October), the maximum temperature dips to between −4.5 and −12.9 °C and the minimum temperature plummets to −10.4 to −20.9 °C (Lal, 2006). July and August are the coldest months whereas December and January record the warmest temperatures. The annual average wind speed is 17.5 knots; winds blow mainly from the southeast (Lal, 2006). Precipitation is scanty and is mainly received in the form of snowfall. It is more frequent between April and September.

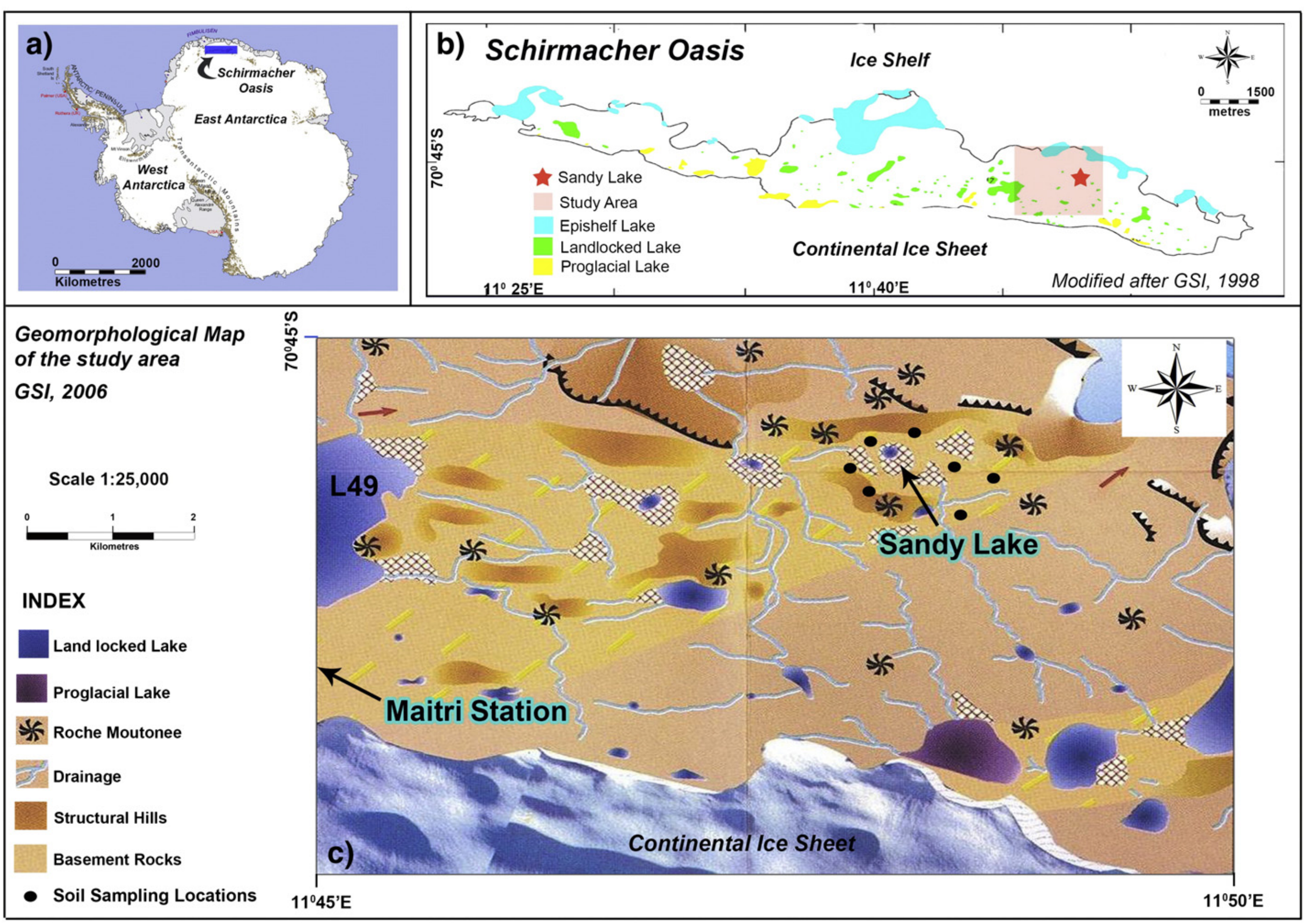


**Fig. 1.** (a) Map of Antarctica showing the location of Schirmacher Oasis; (b) Map of Schirmacher Oasis (modified after Ravindra, 2001) showing the location of Sandy Lake (indicated by a "*"); (c) Geomorphological map of the area around Sandy Lake (modified after Geological Survey of India, 2006); Locations of soil samples are also shown.