

1 Introduction

The climatic extremes of recent years have heightened our awareness of climatic variability and the potential effects of climatic change. Recent studies show that the 1997/98 El Nino year was one of the most extreme years on record, probably only surpassed by the climatic events occurring during the year of 1998 [*Meteorological Office, 1998*]. [*Mann et al., 1998*] show in a careful study of several paleo temperature proxies that three of the last eight years had the highest mean northern hemisphere temperatures for at least the last 600 years. Climate models predict even further temperature increases, as high as 3°C, over the next 100 years, which would drastically alter precipitation and vegetation patterns.

However, it should be pointed out that such models offer only a simplified view of the Earth's climate, biased by the ideas of the people who designed the model. Climate models also do a rather poor job in modeling regional effects and the impacts on vegetation or agriculture. In addition, all models have difficulties explaining the mechanisms that cause naturally driven climate change such as glacial-interglacial cycles, short term climate fluctuations (shorter than the Milankovitch band) [*Broecker, 1997*], the transitions between climatic extremes [*Taylor et al., 1993*], or the mechanisms of global scale climatic shifts [*Behl and Kennett, 1996*]. To answer such questions it is necessary to provide good field records of climatic change. They have to be of high spatial and temporal resolution and should be more or less evenly distributed in order to investigate possible phase lags between the various climatic signals. Such an experimental data set is necessary to resolve the relationships and underlying causes of climatic change, and to test the validity of today's climate models.

Meteorological records are highly accurate but only cover the last few centuries. Dendrochronology and ice core data can push our climatic knowledge back by some 1000 years, but become increasingly spotty as one goes farther back in time. Prior to the last few thousand years our only climatic information comes from geological sources. Oceanic climate is fairly well represented in this record, due to the large number of fairly well dated cores that cover most of the ocean basins. Based on oxygen isotope variations measured

from calcitic shells, diatom and foram assemblages and sedimentary information we have a good idea of how sea surface temperatures, global ice volume and the strength of some ocean currents have changed over the last few million years. Continental climate is known to a far lesser extent because very few geological archives are available that accurately record climate variations for more than 10,000 years. The Chinese loess-paleosol sequence is probably the longest, followed by the Devil's Hole, Nevada [e.g. *Winograd et al.*, 1992; *Winograd et al.*, 1998] and other speleothem records. Ice cores from Greenland, Antarctica and other smaller icecaps can also yield high resolution information, but in general, our knowledge about continental paleoclimate variations is spotty and does not extend very far back in time.

Lacustrine sediments have long been used for paleoclimate reconstruction. Lakes are relatively abundant and have the potential of providing continuous records of climatic change. Lake sediments contain a variety of paleoclimate indicators. Ostracods can yield important isotopic information that can be translated, among others, into temperature or precipitation changes. Their species assemblage can be diagnostic of certain lacustrine environments [e.g. *Neale*, 1988]. Pollen and plant-macrofossil assemblages can also be used for the reconstruction of paleoenvironments, temperatures or precipitation [e.g. *Bartlein et al.*, 1986; *Overpeck et al.*, 1985]. Mineralogical and sedimentological analyses can yield valuable information about changes in lake chemistry, lake status or productivity, which can all be climate-related. All these methods are powerful tools for paleoclimate reconstruction, but they rarely yield unambiguous results when applied on their own. Multiproxy analyses that combine several techniques are most likely to yield robust and reliable paleoclimate reconstructions.

Rock magnetic, or sediment-magnetic techniques represent an additional tool for paleoclimate reconstruction. They have been used successfully for a variety of paleoclimatic problems. For a review see [*Reynolds and King*, 1995] or section 2.1. The magnetic properties of sediments mainly depend on geological processes such as erosion and weathering, or limnological parameters such as lake status and water chemistry. All of these can be climate-influenced and change the mineralogy, particle-size distribution and

abundance of magnetic minerals in the sediment. Most magnetic grains are too small and occur in concentrations too low to be observed directly, e.g. by optical microscopy, but can be characterized indirectly by measurements of magnetic properties as outlined in chapter 2.

Rock magnetic techniques have several advantages. Most measurements are fast, cheap, highly sensitive, non-destructive and are performed on bulk-samples. This allows for a large number of samples to be processed in a relatively short time and the possibility to construct paleoclimatic records with high spatial or temporal resolutions. Most of the samples can later be used for destructive investigations such as isotope analyses or palynology. Compared to other techniques for paleoclimate reconstruction, Rock magnetic variations depend on a different set of processes. They are likely to record a different aspect of climatic change and can contribute to a more robust climatic interpretation of the sediment record. However, all Rock magnetic techniques are ambiguous and it requires a set of magnetic measurements to characterize the magnetic minerals in a sample. Furthermore, magnetic properties do not constitute a paleoclimatic proxy per se. An often site-specific or regional, model is needed that links Rock magnetic change to paleoclimatic variations. Once such a model is found and verified magnetic variations of lake sediments offer a fast and economical tool to construct high resolution models of paleoclimatic change.

This thesis reports the results from Rock magnetic studies performed on three kettle lakes and one soil profile in Illinois and Minnesota. It is part of a multi-disciplinary study to reconstruct paleoclimatic variations in the Midwestern United States for the last 130 ka. After an introduction to Rock magnetic techniques (chapter 2) I present an overview of the geological setting of the Illinois sites (chapter 3). The magnetic properties of the source material for Pittsburg Basin and Catfish Pond and the effects of pedogenic enhancement are discussed in chapter 4. After describing the magnetic properties of Pittsburg Basin (chapter 5) and Catfish Pond (chapter 6) sediment I present a synthesis of all the available paleoclimatic data and an interpretation in terms of paleoclimatic change (chapter 7). Chapter 8 presents additional Rock magnetic data from Kirchner Marsh, a

small kettle lake in Minnesota. Kirchner Marsh has records a similar climatic history but is much younger in age. The similar sediment-magnetic responses in all three sites allow for the construction of a simple model that links the evolution of small lakes and certain climatic and vegetational changes to variations in sediment-magnetic properties. This model is introduced in chapter 9. The last chapter presents concluding remarks and a proposes a list of magnetic measurements that are useful in characterizing sediment samples for paleoclimate analyses.

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