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# Geochemical records of palaeoenvironmental controls on peat forming processes in the Mfabeni peatland, Kwazulu Natal, South Africa since the Late Pleistocene

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ABSTRACT

The Mfabeni peatland is the only known sub-tropical coastal fen that transcends the Last Glacial Maximum (LGM). This ca. 10 m thick peat sequence provides a continuous sedimentation record spanning from the late Pleistocene to present (basal age c. 47 kcal yr BP). We investigated the paleaeoenvironmental controls on peat formation and organic matter source input at the Mfabeni fen by: 1) exploring geochemical records (mass accumulation rate, total organic carbon, carbon accumulation rate, $\delta^{13}C$, $\delta^{15}N$ and C/N ratio) to delineate primary production, organic matter source input, preservation and diagenetic processes, and 2) employ these geochemical signatures to reconstruct the palaeoenvironmental conditions and prevailing climate that drove carbon accumulation in the peatland. We established that the Mfabeni peat sediments have undergone minimal diagenetic alteration. The peat sequence was divided into 5 linear sedimentation rate (LSR) stages indicating distinct changes in climate and hydrological conditions: *LSR stage 1* (c. 47 to c. 32.2 kcal yr BP): predominantly cool and wet climate with C4 plant assemblages, interrupted by two short warming events. *LSR stage 2* (c. 32.2 to c. 27.6 kcal yr BP): dry and windy climate followed by a brief warm and wet period with increased C4 sedge swamp vegetation. *LSR stage 3* (c. 27.6 to c. 20.3 kcal yr BP): initial cool and wet period with prevailing C4 sedge plant assemblage until c. 23 kcal yr BP; then an abrupt change to dry and cool glacial conditions and steady increases in C3 grasses. *LSR stage 4* (c. 20.3 to c. 10.4 kcal yr BP): continuation of cool and dry conditions and strong C3 grassland signature until c. 15 kcal yr BP, after which precipitation increases. *LSR stage 5* (c. 10.4 kcal yr BP to present): characterised by extreme fluctuations between pervasive wet and warm to cool interglacial conditions with intermittent abrupt millennial-scale cooling/drying events and oscillations between C3 and C4 plant assemblages. In this study we reconstructed a high-resolution record of local hydrology, bulk plant assemblage and inferred climate since the Late Pleistocene, which suggest an anti-phase link between Southern African and the Northern Hemisphere, most notably during Heinrich (5 to 2) and Younger Dryas events.



## 1. Introduction

Peatlands play a pivotal role in the global carbon (C) cycle, serving as a direct link between the short-term (atmosphere, biosphere and hydrosphere) and long-term (geosphere) carbon reservoirs. Under sequestering conditions, peatlands serve as sinks for atmospheric $CO_2$, important sources of $CH_4$ and exporters of fluvial dissolved and particulate organic carbon to down-stream ecosystems (Worrall et al., 2003). The balance between ecosystem productivity and respiration, controlled primarily by precipitation, temperature, water table fluctuation and local topography, determines if a peatland acts as a C sink or source.

Contemporary global peatland C stocks have been estimated to be in excess of 450 Petagrams (1 Pg $= 10^{15}$ g), equivalent to 75% of $CO_2$ stored in the atmosphere at any given time (Strack, 2008). The vast majority (~90%) of peatlands are found in the Northern Hemisphere temperate and boreal regions, with tropical and sub-tropical peatlands constituting the balance (Immirzi et al., 1992; Page et al., 2011). However, because of their relatively higher carbon accumulation rate (CAR; Chimner and Ewel, 2005; Strack, 2008), tropical peatlands are estimated to represent up to a quarter of the potential global peatland C stock (Strack, 2008; Page et al., 2011), and they are at a greater risk of degradation and overexploitation due to their proximity to populated areas and climate change (Rieley et al., 1996). Currently, there is limited scientific understanding of the processes that regulate C cycling and accumulation in tropical peatlands (Chimner and Ewel, 2005), and how changing climate and increasing anthropogenic pressures will affect low latitude peatland systems and their ability to sequester C.

Southern Africa is situated at the interface of tropical and temperate climate systems. The region is influenced by the largest asymmetrical

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cross-continental tropical convection (Stokes et al., 1997) as a consequence of seasonal fluctuations in the Inter Tropical Convergence Zone (ITCZ), and large temperature gradients between the warm Agulhas and cold Benguela oceanic currents (Preston-Whyte and Tyson, 1998; Tyson and Preston-Whyte, 2000). Due to the topography and semi-arid climate of Southern Africa, archives are not commonly preserved, and few continuous palaeoenvironment records exist (Chase and Meadows, 2007), despite strong evidence of climate variability from Antarctic ice cores and low latitude African hydrological investigations (Bard et al., 1997; Blunier et al., 1998; Gasse, 2000; Stocker, 2000; Stenni et al., 2001). A few detailed limnology studies have been undertaken in regional lakes (Meadows et al., 1996; Meadows and Baxter, 1999; Partridge, 2002; Kristen et al., 2010), but due to the fact that most of southern Africa is water scarce, freshwater lakes are uncommon. Speleothem archives from South African caves have yielded high-resolution climate records (Talma and Vogel, 1992; Lee-Thorp et al., 2001; Holmgren et al., 2003; Holzkämper et al., 2009), but these records either do not span the Last Glacial Maximum (LGM) or are incomplete with at least one or more hiatuses of between 2.5 and 10 kyr. Several palynology studies have been undertaken in regional coastal peatlands (Finch and Hill, 2008; Neumann et al., 2008, 2010; Walther and Neumann, 2011; Valsecchi et al., 2013) however, with the exception of the Mfabeni peatland study (Finch and Hill, 2008) the palynology records are limited to the deglacial and Holocene periods. To our knowledge, the only geochemical palaeoclimatic study undertaken on the sub-tropical Braamhoek peatland in the austral summer rainfall region of South Africa is by Norström et al. (2009). This inland wetland is located on the Eastern escarpment at 1700 m a.s.l. and lies over 290 km from the nearest coastline with a palaeorecord extending only as far back as c. 16 kcal yr BP.

The lack of high-resolution terrestrial palaeoclimate records on the African sub-continent continues to hinder the understanding of past climate forcing factors and their environmental impacts (Chase and Meadows, 2007; Gasse et al., 2008). Additional high resolution multi-proxy and multi-archive studies are therefore needed to elucidate past climate fluctuations and modelling of the ensuing environmental responses to these changes in the future. In this context, organic matter (OM) rich peat deposits are ideally suited for palaeoenvironmental studies as they are well preserved archives that are subject to mainly autochthonous depositional regimes that are largely regulated by climate (Strack, 2008). The aim of this research is to investigate climatic and environmental conditions that have prevailed in the southern African region since the Late Pleistocene. Our objective is to reconstruct the palaeoenvironmental controls on past C accumulation and OM source input at the sub-tropical coastal Mfabeni fen by: 1) delineating primary production, OM source input, OM preservation and diagenetic processes which affected the formation of these peat deposits, and 2) using multiple geochemical proxy signatures such as, mass accumulation rate (MAR), total organic carbon (TOC), carbon accumulation rate (CAR), $\delta^{13}C$, $\delta^{15}N$ and C/N, to reconstruct the palaeoenvironmental conditions and prevailing climate in the peatland over the last c. 47 kcal yr BP.

## 2. Methods

### 2.1. Site description

St Lucia is one of the largest estuarine systems on the African continent (Vrdoljak and Hart, 2007). It falls within the UNESCO World Heritage iSimangaliso Wetland Park, situated on the northern shores of Kwazulu-Natal province, South Africa (Fig. 1). Lake St Lucia, the dominant north–south aligned water body, has an extent of 350 $km^2$ and an average depth of only 90 cm. At its northern end, the lake is fed by four regional rivers with a combined catchment of approximately 6085 $km^2$, namely the uMkhuze, Nyalazi, Mzinene and Hluhluwe rivers. To the south, a narrow 22 km long waterway sporadically links the lake to the Indian Ocean, and to the east the lake is fed with fresh water by the large Maputuland unconfined aquifer (Kelbe et al., 1995; Taylor et al., 2006a).

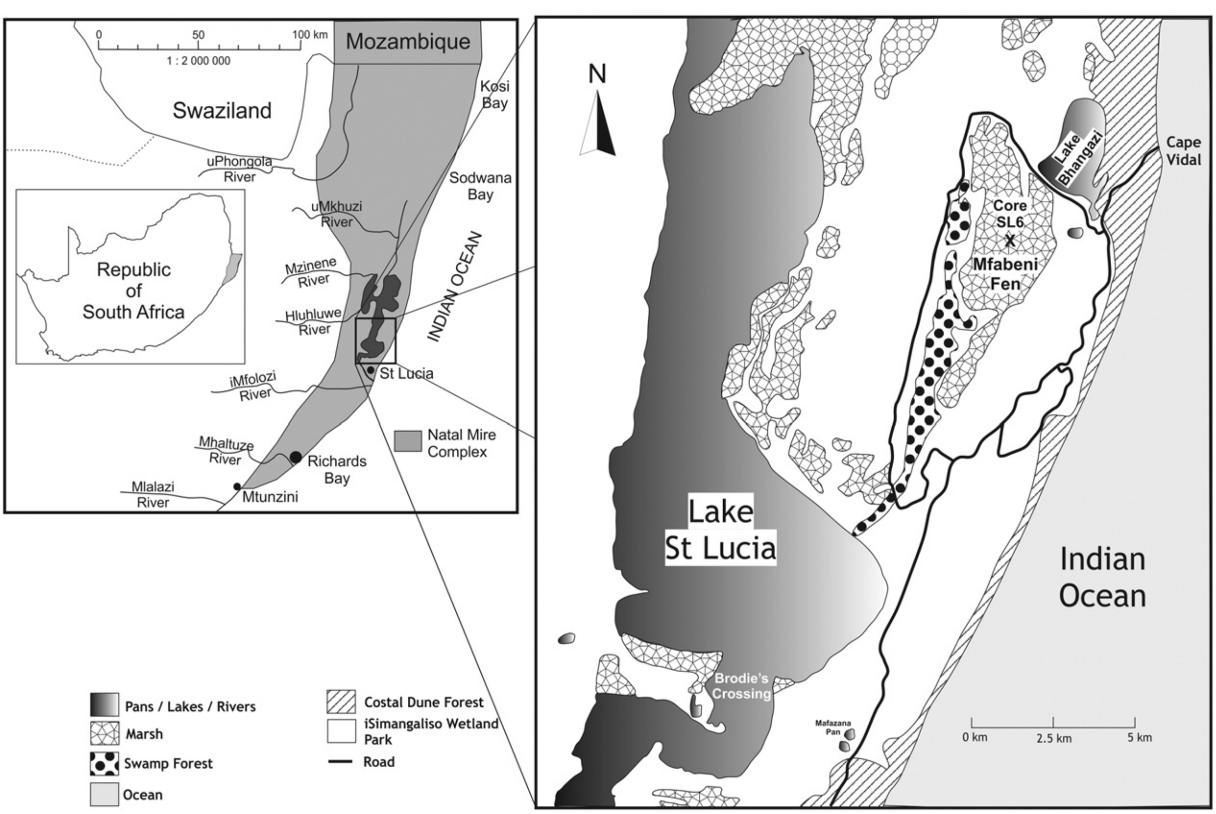


**Fig. 1.** Mfabeni Peatland, iSimangaliso Wetland Park, St Lucia, northern KwaZulu Natal, South Africa with major habitat groups and dominant water bodies represented.