Quaternary International xxx (2017) 1–11

Contents lists available at ScienceDirect

Quaternary International

journal homepage: www.elsevier.com/locate/quaint

A 5000-yr record of Afromontane vegetation dynamics from the Drakensberg Escarpment, South Africa

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A R T I C L E I N F O

Article history:
Received 9 November 2016
Received in revised form
11 July 2017
Accepted 7 August 2017
Available online xxx

Keywords:
Holocene
Pollen
Vegetation history
Afromontane
Grassland
Forest

A B S T R A C T

Afromontane environments are sensitive to climatic and environmental change as a consequence of their inherent altitudinal and latitudinal gradients. Palaeoecological investigations have been used in these areas to track ecosystem response to climatic and anthropogenic drivers, and have gained prominence in recent years in the context of the need to understand faunal and floral response to future climate uncertainty. This paper focusses on long-term vegetation history in the Drakensberg Escarpment of South Africa, an area with a long history of human habitation, that is internationally recognised for its conservation importance. Ecologists have hypothesised that human-induced burning during the late Quaternary may have been responsible for the expansion of Afromontane grasslands at the expense of forests, which currently exist as refugial patches within fire-protected valleys. Here we test this argument using empirical palaeoecological evidence derived from a subalpine wetland in the Cathedral Peak area of the Drakensberg Escarpment. An age model derived from eight AMS radiocarbon ages, and supported by a pollen time-marker, is used to provide chronological control. Fossil pollen, and carbon and nitrogen isotope analyses, are combined to reconstruct past vegetation dynamics. Results indicate a lack of major compositional vegetation change over the past 5000 years, suggesting long-term vegetation and climatic stability throughout the record. The pollen data show that grasslands have dominated the region, while forests expanded during the late Holocene, thereby refuting the notion of recent forest reduction in the Drakensberg.

1. Introduction

Mountain ecosystems are sensitive to climatic perturbations as a consequence of their topographic diversity, and are likely to be the first places to respond to environmental change (Gosling and Bunting, 2008; Gottfried et al., 2012). The responsive nature of montane ecosystems suggests that they could provide ideal locations for palaeoenvironmental studies, serving as natural laboratories for environmental change research. Palaeoenvironmental studies such as pollen-based vegetation and climate reconstructions provide benchmark understanding of natural variability and help predict species' and ecosystem responses to climate change. Despite a plethora of research into past environmental change in tropical African mountains, there remains a lack of research from the southern extension of the Afromontane archipelago (*sensu* White, 1983). Detailed palaeoecological records are restricted to the Cederberg (Meadows and Sugden, 1990, 1991a, b; Quick et al., 2011; Scott, 1994; Valsecchi et al., 2013), eastern Lesotho Highlands (Fitchett et al., 2016, 2017), Drakensberg (Neumann et al., 2014; Norström et al., 2009, 2014), Winterberg (Meadows and Meadows, 1988; Meadows et al., 1987) and Soutpansberg (Scott, 1982a, 1987). These records provide a spatially and temporally incomplete picture of past vegetation distribution, and vegetation response to climatic variability in the regional context (Hopley et al., 2007; Smith et al., 2002). Additional Holocene palaeoenvironmental records from montane regions of southern Africa are required to provide a more robust understanding of climate-human-ecosystem dynamics across the subregion.

The Drakensberg Escarpment of South Africa has been noted for palaeoecological potential (Deacon and Lancaster, 1988; van Zinderen Bakker, 1955), and has drawn recent research interest in this field (Neumann et al., 2014; Norström et al., 2009, 2014). These

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http://dx.doi.org/10.1016/j.quaint.2017.08.019
1040-6182/

mountains host a number of well-developed peat deposits within isolated wetlands and are characterised by steep environmental gradients with the resulting vegetation belts being sensitive to climatic changes (e.g. Carbutt and Edwards, 2015; Coetzee, 1964; Roberts et al., 2013). The earliest study by van Zinderen Bakker (1955) had no chronology and a low pollen diversity, but illustrated high palynological potential. Hill (1992) established the groundwork for pollen-based research in the KwaZulu-Natal Drakensberg by seasonally monitoring contemporary pollen rain from 13 vegetation types over a two year period. This research was able to confirm the assumption that fossil pollen spectra provide a robust indication of vegetation communities in the KwaZulu-Natal Drakensberg. Regional palynological studies include those at Elim (Scott, 1989), Braamhoek (Norström et al., 2009, 2014) and Mahwaqa Mountain (Neumann et al., 2014) in South Africa, and in the eastern Lesotho Highlands (Fitchett et al., 2016, 2017), providing a long-term palaeoenvironmental context. The Mahwaqa record from the Drakensberg foothills suggests cooler conditions at 18,000–13,500 cal yr BP, with an increase in Ericaceae and *Restio*-type taxa, and a decrease in charred particles. From 13,500 until 8500 cal yr BP, a warming phase is inferred, with the suggestion of increased wetness. The mid-Holocene at Mahwaqa was characterised by warm and dry conditions reaching a minimum in moisture availability at 6800 cal yr BP. Dry conditions prevailed at Braamhoek in the Mpumalanga Drakensberg during the mid to late Holocene (Norström et al., 2009). These drier conditions continued into the late Holocene as evidenced at Mahwaqa between 4600 and 3500 cal yr BP. During this period, *Pentzia*-type Asteraceae, *Ophioglossum* spores and *Euphorbia* increase. During the same period, a reduction in aquatics and swamp plants occurred, supporting the continued dry conditions. Sedge pollen increased after 3500 cal yr BP suggesting more humid conditions, which extended into the colonial period at Mahwaqa and Braamhoek (Neumann et al., 2014; Norström et al., 2014). The high altitude eastern Lesotho Highland sites of Fitchett et al. (2016, 2017), who advocate a multi-proxy approach and present, with sedimentary properties, fossil pollen and diatoms, show a not too dissimilar chronology. In the late Pleistocene these records suggest a wet period from c. 16,450 to 14,440 cal yr BP, with a short drier period lasting approximately 450 years from c. 16,350 to 15,870 cal yr BP. From c. 14,440 until 8650 cal yr BP drier conditions are inferred, shifting to warmer drier conditions from c. 8560 until 7450 cal yr BP for the Sekhokong Range record. The Sekhokong and Mafadi wetland sites both show a complex cold/wet to warm/drier shift. These two geographically close sites are not always in synchronicity; however, both sites witness a cold/wet period from c. 5500 to 1200, with drying thereafter until the present.

In addition to natural drivers of change on the landscape, the Drakensberg are characterised by a long history of human habitation, popularly evidenced by extensive rock art. Understanding the role of human occupation and other ecosystem drivers, particularly in light of future climatic shifts, is a key step to appropriately managing this important watershed, and preserving its cultural and ecotourism value. Despite a wealth of archaeological evidence from the Drakensberg and Maloti Mountains, there are limited palaeoecological data available (Fitchett et al., 2016, 2017; Grab et al., 2005; Plug, 1997; Roberts et al., 2013; van Zinderen Bakker and Werger, 1974). The extent to which Afromontane vegetation was shaped by human inhabitants, in the Drakensberg and elsewhere, has been the subject of some debate (e.g. Meadows and Linder, 1993) and requires investigation by palaeoecological means. In particular, there remains some controversy regarding the nature of past grassland and forest dynamics, and the role of past burning in shaping current vegetation patterns. This paper presents a 5000-yr pollen-based palaeoenvironmental reconstruction from the Catchment VI wetland at Cathedral Peak Research Station in the eastern Drakensberg Escarpment (Fig. 1) that has been interpreted with the aid of radiocarbon dating, a chronostratigraphic marker, and stable carbon and nitrogen isotope analysis. Palaeoecological and archaeological evidence from the Drakensberg and adjacent Maloti Mountains of Lesotho are combined, documenting Holocene vegetation change response to climatic fluctuations and human activity.

2. Environmental setting

2.1. Geology and climate

The geology of the Drakensberg is dominated by the Karoo Supergroup and can be broadly defined as the 'High Berg' and 'Little Berg'. The High Berg mainly consists of double rampart Drakensberg Group Basalts, while the Little Berg is characterised by the Clarens Formation sandstones, and Elliot Formation mudstones and sandstones (Johnson et al., 1996; Killick, 1963; Uken, 1999). The High Berg comprises of summits, plateaus, cliffs, buttresses, deep valleys and high spurs; while the Little Berg is characterised by high altitude grassy slopes with steep-sided river valleys and rocky gorges (Killick, 1963). The morphology of the river valleys are due to the long-term incision (>30 ka) into the highly erodible basalts and sandstones from fast-flowing rivers (Grenfell et al., 2008). Glaciation has been inferred for localized regions of the Drakensberg during the Last Glacial Maximum (LGM) (Mills et al., 2012).

Soils consist predominantly of acidic lithosols derived from the basalt, and are either colluvial or residual in origin (Killick, 1963). The dominant soil-types found at the sample site (Catchment VI, Cathedral Peak) include Champagne, Inanda, Kranskop, Magwa and Nomanci (Kuenene et al., 2011).

The climate of the Drakensberg is strongly influenced by topography, resulting in a high variability in temperature, precipitation, wind, frost, humidity and evaporation. Temperature is a key parameter influencing the high-altitude Drakensberg and Lesotho climate, whereas in the majority of southern Africa, precipitation variability drives the regional climate (Parker et al., 2011; Roberts et al., 2013). Furthermore, north-facing slopes are warmer than south-facing slopes.

Rainfall collected from the Cathedral Peak Meteorological Station between 1950 and 1996 indicates an annual average of 1300 mm, 50% of which falls during the summer months (Department of Water and Sanitation, 2014) and can be attributed to subtropical anticyclones resulting in thunderstorm activity. Strong seasonal variations in climate exist in the Drakensberg. Monthly mean minimum temperatures range between 3.0 °C in July and 12.3 °C in February, while mean maximum temperatures range between 19.7 °C in June and 30.8 °C in November (Everson et al., 2009) with a long-term annual average of 13.8 °C (Everson and Everson, 2016).

2.2. Contemporary vegetation and fire management

The uKhahlamba-Drakensberg Park conservation area was declared a UNESCO World Heritage site in the year 2000 on account of its exceptional biological and cultural diversity (Ezemvelo KZN Wildlife, 2012). The biodiversity of the Drakensberg can be attributed to a combination of climatic conditions, topographical features (Carbutt and Edwards, 2004) and the fire events in the region. The Drakensberg, including the Drakensberg Alpine Centre (DAC) of Floristic Endemism (Van Wyk and Smith, 2001), is typified by high-levels of species richness and endemism (Carbutt and Edwards, 2004, 2006). The moist eastern escarpment has often been cited as a biological corridor and/or refugium for moist, temperate and