A late Quaternary pollen sequence from Mfabeni Peatland, South Africa: Reconstructing forest history in Maputaland

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ARTICLE INFO

ABSTRACT

This paper documents a continuous ~44,000-yr pollen record derived from the Mfabeni Peatland on the Maputaland Coastal Plain. A detailed fossil pollen analysis indicates the existence of extensive *Podocarpus*-abundant coastal forests before ~33,000 cal yr BP. The onset of wetter local conditions after this time is inferred from forest retreat and the development of swampy conditions. Conditions during the last glacial maximum (~21,000 cal yr BP) are inferred to have been colder and drier than the present, as evidenced by forest retreat and replacement of swampy reed/sedge communities by dry grassland. Forest growth and expansion during the Holocene Altithermal (~8000–6000 cal yr BP) indicates warm, relatively moist conditions. Previous records from Maputaland have suggested a northward migration of *Podocarpus* forest during the late Holocene. However, we interpret a mid-Holocene decline in *Podocarpus* at Mfabeni as evidence of deforestation. Forest clearance during the mid-Holocene is supported by the appearance of *Morella serrata*, suggesting a shift towards more open grassland/savanna, possibly due to burning. These signals of human impact are coupled with an increase in *Acacia*, indicative of the development of secondary forest and hence disturbance.

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Introduction

Historically, southern African palynological investigations have been disadvantaged by a lack of polliniferous deposits, owing to poor pollen preservation within the region's Quaternary-age deposits (Scott, 1984). Moreover, long records spanning the late glacial and Holocene time periods tend to be discontinuous and 'derived from widely different proxy types that are difficult to compare' (Scott et al., 2008, pg. 198). While suitable sites for pollen analysis are often rare as a consequence of the aridity of the country (Scott, 1984), rich polliniferous deposits occur in the peatlands surrounding coastal lakes in northern KwaZulu-Natal (Scott and Vogel, 2000). Approximately 270 peatlands have been identified within the Maputaland Coastal Plain (Grundling and Mazus, 1998), yet very little is known about the palynology of the area (Scott and Vogel, 2000). These rheotrophic reed–sedge peat-forming wetlands, which form part of the Natal Mire Complex (NMC; Smuts, 1992), are widely recognised for their ecological and conservation importance (Turner and Plater, 2004). Deposits north of Lake St. Lucia are of Holocene age, while those south of the lake are of late Pleistocene age (Grundling, 2002). The older deposits have suffered weathering, resulting in poor pollen preservation; however, those deposits associated with young estuar-ine lakes, such as Lake St. Lucia, do demonstrate potential for palynological analysis (Scott and Vogel, 2000).

The Mfabeni Peatland, situated on the eastern shores of Lake St. Lucia, contains relatively old sediments dating back to 43,100 ^{14}C yr BP at a depth of 9.93 m (Grundling et al., 1998). Although a limited number of studies have been carried out within this peatland, these have focussed on peat accumulation rates (Grundling, 1996; Thamm et al., 1996) and peatland stratigraphy (Grundling et al., 2000), rather than vegetational or climatic reconstruction. Grundling et al. (2000) have used palynology to carry out a preliminary investigation of the vegetation history of Mfabeni; however, no detailed palaeoenviron-mental reconstructions have been undertaken to date. In the southern African context, where suitable sites for palynological in-vestigations are limited, the Maputaland peat deposits, and Mfabeni in particular, represent a valuable opportunity for palaeoenviron-mental research.

Environmental setting

The Maputaland Coastal Plain, which parallels the North Coast of KwaZulu-Natal into Mozambique, hosts the most well-developed peat deposits in southern Africa (Grundling et al., 2000). The Mfabeni Peatland (28°8.92'S, 32°31.12'E; Fig. 1) is situated in the Eastern Shores Nature Reserve at a mean height of approximately 11 m above sea level (Grundling et al., 2000). The area has a mean annual precipita-tion of 1000 mm, 60% of which falls between November and March as
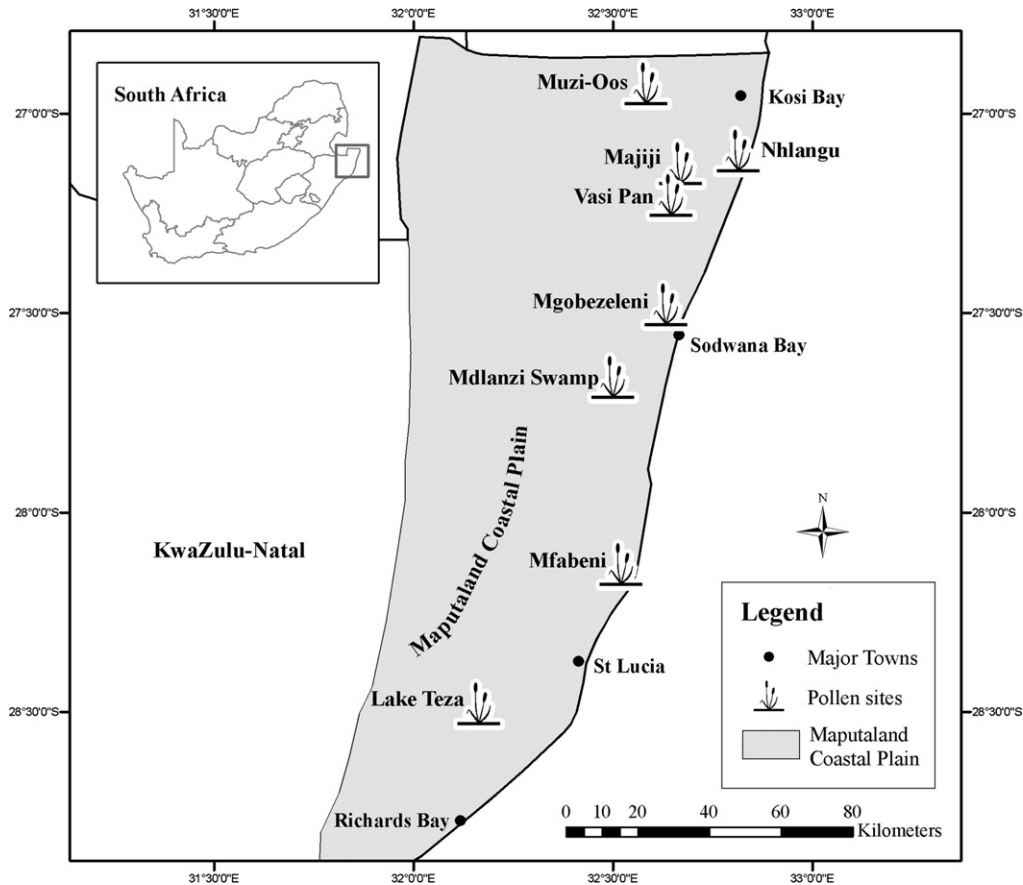
Figure 1. Map of the Maputaland Coastal Plain, along the north coast of KwaZulu-Natal, indicating the position of pollen sites mentioned in the text.

summer rainfall (Grundling et al., 2000). The area experiences hot, wet summers and cool dry winters with a mean annual temperature of approximately 21–23 °C (Turner and Plater, 2004). Groundwater flow into the peatland is derived predominantly from perched aquifers within the neighbouring coastal sand dunes (Grundling et al., 2000). There are no streams flowing into the peatland, keeping the influx of allochthonous material to a favourable minimum.

The Eastern Shores Nature Reserve, which surrounds the peatland, contains a diversity of habitats, including dune forest, grassland, and a mosaic of wetlands and swamp forest (Taylor, 1991; Fig. 2). The vegetation of Eastern Shores has been classified as Coastal Bushveld/ Grassland and Coastal Forest and Thornveld (Acocks Veld Type No. 1) by Low and Rebelo (1996) and Acocks (1988), respectively. More recently, Mucina and Rutherford (2006) classified the Eastern Shores as a mosaic of Maputaland Wooded Grassland, Maputaland Coastal belt and sub-

tropical freshwater wetlands surrounded by Northern Coastal Forests (FOz7). In a detailed botanical study of the Mfabeni Peatland, Venter (2003) developed a physiognomic classification comprising the following units: grass and sedge peatlands, moss peatland and swamp forest. Within these categories the following species dominate: *Andropogon appendiculatus*, *Barringtonia racemosa*, *Bridelia micrantha*, *Cladium mariscus*, *Cyperus* spp., *Eleocharis dulcis*, *Ficus trichopoda*, *Fimbristylis bivalves*, *Ludwigia octovalvis*, *Nephrolepis biserrata*, *Restio zuluensis*, *Rhynchospora* spp., *Scleria poiformis*, *Sphagnum truncatum*, *Stenocleana tenuifolia*, *Syzigium cordatum*, *Typha capensis* and *Xyris natalensis*.

Human impact

The coastal plain area of northern KwaZulu-Natal was widely settled by slash-and-burn type agriculturalists in the early (ca. AD
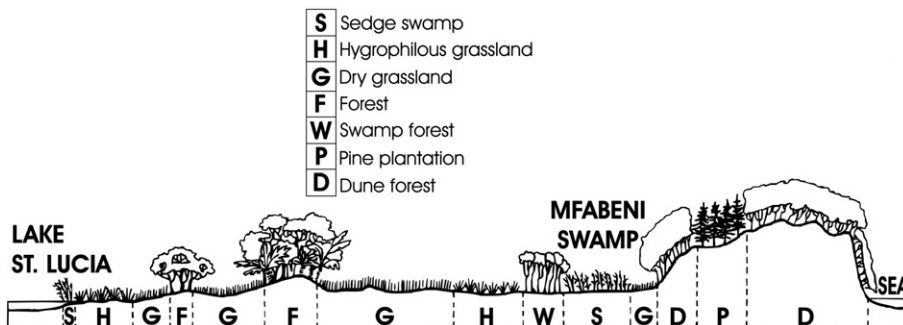

Figure 2. Transect from the coast to the shore of Lake St. Lucia, showing the plant communities of the Eastern Shores area (after Taylor 1991).

Table 1
List of palynomorphs identified for the Mfabeni Peatland with associated indicator values derived from Scott (1999a)

Arboreal (R, T)	Indicator values (Scott 1999a)
Anacardiaceae undiff.	Savanna; relatively warm conditions, wide range of moisture conditions
Apocynaceae undiff.	
Celastraceae undiff.	
Combretaceae: Combretum	
Cyanthaceae undiff.	
Ericaceae undiff.	Cool subhumid conditions, relatively even seasonal moisture distribution
Erythroxylaceae undiff.	
Euporbiaceae undiff.	Microphyllous or plains; relatively warm conditions, wide range of moisture conditions
Fabaceae undiff.	Savanna; relatively warm conditions, wide range of moisture conditions
Flacourtiaceae undiff.	Woodland; subhumid conditions
Mimosaceae: Acacia	Savanna; relatively warm conditions, wide range of moisture conditions
Moraceae: Ficus	
Myricaceae: Morella serrata	Forest edge; subhumid conditions
Myrtaceae undiff.	
Podocarpaceae: Podocarpus	Forest; relatively moist conditions
Proteaceae: Protea	Upland or mesic savanna; wide range of temperatures; subhumid conditions
Rosaceae undiff.	Cool subhumid conditions, relatively even seasonal moisture distribution
Rubiaceae: Psydrax*	
Rubiaceae undiff.	
Herbs (R, T)	
Asteraceae undiff.	Shrubland; relatively even seasonal moisture distribution
Caryophyllaceae undiff.	
Chenopodiaceae undiff.	Halophytes; dry conditions or local evaporation, salinity or disturbance under strong seasonality in climate
Geraniaceae undiff.	
Liliaceae undiff.	
Polygalaceae undiff.*	
Fagaceae-like undiff.*	
Thymeleaceae undiff.	Cool subhumid conditions, relatively even seasonal moisture distribution
Locally dominant (T)	
Cyperaceae undiff.	Semi-aquatics; local swamp, shallow water or damp soil
Haloragidaceae undiff.	
Iridaceae undiff.	
Poaceae undiff.	Grassland or savanna; generally indicative of summer rainfall
Monoletes undiff.	Forest edge; subhumid conditions
Triletes undiff.	Forest edge; subhumid conditions
Undetermined	

R = regional pollen sum; T = total pollen sum; * denotes rare taxon.

250–1000) and late (ca. AD 1000–1840) Iron Age; according to Hall (1981) and Hoffmann (1997), forested and wetland systems of the region underwent considerable transformation as a result of Iron Age agricultural practices. In particular, this included the felling and burning of trees to increase grazing potential and to provide fuel for domestic use and smelting of iron. The landscape or burning indicator fragmentation caused by forest clearance could have accelerated sedimentation and the expansion of coastal reed swamps, which form the present-day large wetland systems of the region (Hoffmann, 1997).

Methodology

A 920-cm sediment core was extracted from the Mfabeni peat deposit in 50-cm segments using a Russian peat corer. The core was subsampled at fixed intervals to extract samples for pollen analysis and radiocarbon dating. Subsampling interval for pollen analysis was determined by initial intervals of 10 cm and then higher resolution

samples at 5-cm intervals where necessary. Subsamples were chemically processed using standard palynological methods of HCl, NaOH and HF digestion (Faegri and Iverson, 1989) and mounted using a tertiary butyl alcohol (TBA)–glycerol suspension. Identification and counts of pollen grains were achieved using fixed traverses across the slide at 400× magnification. A total of 114 samples were counted, with at least 500 pollen grains and spores counted per sample. Taxonomic resolution was limited to the family level for most taxa by the lack of available reference material. A digital reference collection of 350 species was assembled using existing slides from the Drakensberg Mountains (Hill, 1992), pollen slides created from local flowering species at the Mfabeni site and targeted specimens from the Natal Herbarium. Thirty-four palynomorphs were identified and grouped as arboreal (trees and shrubs), herbaceous or locally dominant (aquatic) taxa (Table 1). Regional and total pollen diagrams were plotted using TGView 2.02 (Grimm, 2004). The Constrained Incremental Sum of Squares (CONISS) cluster technique within TGView 2.02 was used to define boundaries between the most distinguishable pollen zones (Grimm, 1987).

Peat subsamples from six suitable basal and intermediate layers bracketing stratigraphic layers (e.g., sand lenses) were dated using radiometric and AMS radiocarbon techniques by the Quaternary Dating Research Unit, CSIR, Pretoria (QUADRU). The samples were calibrated using the radiocarbon calibration program (CALP 1.02) for Southern Hemisphere measurements provided by QUADRU. An age model was developed using a linear regression of calibrated finite dates (reported as 1-sigma age ranges) and approximate ages of pollen zones were interpolated accordingly. To facilitate comparison with other records, we chose to present both radiocarbon (^{14}C yr BP) and calibrated ages (cal yr BP) in the Results and Discussion.

Results

Age model and zonation

The age model developed places the Mfabeni peat core within the time frame of the past ~44,000 cal yr BP (~41,000 ^{14}C yr BP), covering the terminal Pleistocene and Holocene and, importantly, extending through the last glacial maximum (LGM) (Fig. 3; Table 2). The two infinite dates at the base of the core could not be included in the development of the age model. These infinite dates do not contradict the age model but place the basal sediments at an age greater than 46,950 ^{14}C yr BP. CONISS zonation yielded four pollen zones, viz., MF-1, MF-2, MF-3 and MF-4, with MF-2 divided into subzones MF-2a and MF-2b.
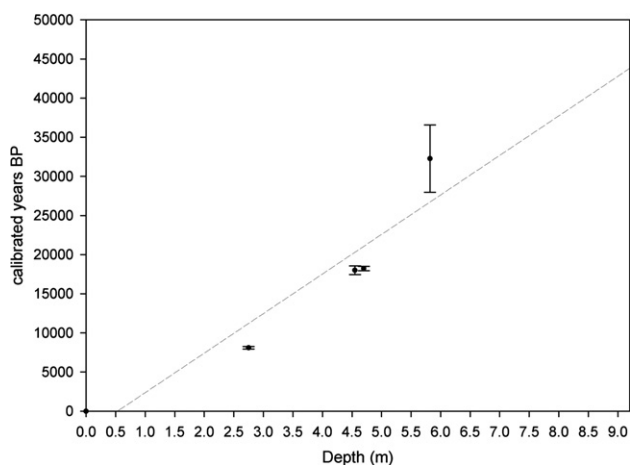
Figure 3. Age model for the Mfabeni Profile based on linear regression of calibrated finite dates (error bars represent 1-sigma age ranges).

Table 2
Radiocarbon results for the Mfabeni Peatland, indicating calibrated and uncalibrated ages

Sample	Lab codes	Depth (m)	^{14}C yr BP	(1σ) cal age ranges
Mfabeni Swamp R1	Pta-9427	2.75	9580±70	8183–8027
Mfabeni Swamp R2	Pta-9425	4.55	17,050±240	18,276–17,724
Mfabeni Swamp R3	Pta-9435	4.70	17,250±120	18,368–18,092
Mfabeni Swamp R4	Pta-9433	5.82	30,850±580	34,422–30,124
Mfabeni Swamp R5	Pta-9434	6.40	>44,750	–
Mfabeni Swamp R6	Pta-9426	7.80	>46,950	–

Calibrated ages are reported as 1-sigma age ranges BP.

Pollen analysis

Pollen data are described according to pollen zones and summarised in Table 3 (Fig. 4). Percentage abundances for regional taxa are quoted using the maximum percentage value (i.e., quoted taxon frequencies can exceed 100%) of the regional sum reached within the relevant zone (Table 3). For local taxa this is calculated using the total pollen sum (Fig. 5).

Discussion

Using the age model developed, pollen zones can be approximately translated into the following time periods: pre-glacial (MF-1; ~44,000–33,000 cal yr BP; ~41,000–31,000 ^{14}C yr BP), late glacial (MF-2a; ~33,000–17,500 cal yr BP; ~31,000–16,000 ^{14}C yr BP), Pleistocene/Holocene transition (MF-2b; 17,500–11,000 cal yr BP; ~16,000–10,000 ^{14}C yr BP), early Holocene (MF-3; 11,000–5000 cal yr BP; ~10,000–4000 ^{14}C yr BP) and late Holocene (MF-4; ~5000 cal yr BP-present; ~4000 ^{14}C yr BP-present). Results are compared with other studies from Mfabeni and Maputaland, in addition to the broader context of palaeoenvironmental research in southern Africa. Palaeoenvironmental inferences are based on the pollen record, using generalised indicator taxa (Scott, 1999a; Table 1) and differentiating between local and regional pollen signals.

Pre-glacial (MF-1)

The base of the pollen record shows relatively high arboreal pollen frequencies, dominated by *Podocarpus*, Anacardiaceae and Celastraceae, indicating the regional presence of *Podocarpus*-abundant forests during this period. These data indicate that the climate

was relatively cool and wet. Wet conditions at Mfabeni are supported by similar conditions recorded at Tswaing Crater at ~43,500 ^{14}C yr BP (Scott, 1999a) in the Transvaalian Ecozone (Deacon and Lancaster, 1988). The local signal is dominated by Poaceae and, to a lesser extent, Cyperaceae indicating open grasslands surrounding the site.

Late glacial (MF-2a)

Podocarpus declines from ~40–80% during the previous period to ~20% during most of the late glacial period. This is accompanied by a decrease in other arboreal taxa, suggesting forest retreat. These results are supported by Grundling et al. (1998), who recorded forest retreat after ~33,000 ^{14}C yr BP with the development of grassland vegetation in the region. Initially this period records a progressive increase in Cyperaceae, indicating sedge dominated, swampy vegetation occupying the site. Dominant Cyperaceae, coupled with the appearance of aquatic Haloragidaceae in the record, suggests a shift towards wetter local conditions and the presence of an open body of water.

This is followed by an abrupt change in the relative composition of Poaceae and Cyperaceae at ~24,000 cal yr BP (~23,000 ^{14}C yr BP). Poaceae become dominant while Cyperaceae begin a steady decline indicating local drying. Herbaceous taxa, particularly Asteraceae, record high frequencies supporting the existence of grasslands in the area, indicative of drier local conditions. This shift towards drier conditions at Mfabeni probably reflects an early onset of the LGM. This is feasible since Mfabeni falls within a coastal zone, and the moderating effect of the ocean may have resulted in a gradual drying trend rather than a sudden very dry event. These dry conditions are widely recorded from other LGM records within the savanna biome (Botha et al., 1992; Partridge, 1997; Scott et al., 2003), and Eeley et al. (1999) note that these hypothermal periods often result in a reduction in forest extent. Although Grundling et al. (1998) infer wetter conditions at Mfabeni for the LGM, we attribute this to a weak chronology characterised by age reversals.

Transition (MF-2b)

This period records a continuation of the trends described for the late glacial. Cyperaceae frequencies continue to decrease while Poaceae remain dominant. *Podocarpus* and other arboreal taxa remain at low frequencies.

Table 3
Summary table indicating pollen zone characteristics

Pollen zone	Depth (cm)	Arboreal taxa	Herbaceous taxa	Local taxa
MF-1	920–710	*Podocarpus* (77%), Celastraceae (51%), Anacardiaceae (36%), Apocynaceae (17%), Ericaceae (12%), Fabaceae (11%), Euphorbiaceae (10%), *Combretum* (5%)	Asteraceae (36%), Liliaceae (22%), Thymeleaceae (8%)	Poaceae (71%), Cyperaceae (50%), pteridophyta (42%), Iridaceae (6%)
MF-2a	710–400	*Podocarpus* (67%), *Ficus* (50%), Celastraceae (31%), Cyanthaceae (25%), Anacardiaceae (21%), Euphorbiaceae (17%), Ericaceae (13%), Apocynaceae (9%), *Protea* (5%)	Asteraceae (67%), Liliaceae (58%), Chenopodiaceae (25%), Caryophyllaceae (13%), Polygalaceae (5%)	Poaceae (75%), Cyperaceae (50%), pteridophyta (13%), Iridaceae (7%), Haloragidaceae (1%)
MF-2b	400–265	*Podocarpus* (30%), Celastraceae (29%), Flacourtiaceae (24%), Fabaceae (19%), Myrtaceae (17%), *Acacia* (13%), *Ficus* (11%), Anacardiaceae (9%), Apocynaceae (9%), Ericaceae (9%), Rubiaceae (9%), Euphorbiaceae (8%), Rosaceae (8%), *Combretum* (6%)	Asteraceae (38%), Liliaceae (18%), Chenopodiaceae (13%), Geraniaceae (9%), Caryophyllaceae (6%), Polygalaceae (5%)	Poaceae (73%), Cyperaceae (27%), pteridophyta (13%), Iridaceae (8%)
MF-3	265–135	*Podocarpus* (72%), Celastraceae (42%), Anacardiaceae (16%), Flacourtiaceae (14%), Apocynaceae (7%), Rubiaceae (7%)	Chenopodiaceae (37%), Liliaceae (29%), Asteraceae (16%)	Poaceae (64%), pteridophyta (64%), Cyperaceae (30%), Iridaceae (17%)
MF-4	135–0	Cyanthaceae (67%), *Podocarpus* (36%), Anacardiaceae (33%), *Acacia* (32%), Ericaceae (30%), *Ficus* (30%), *Morella serrata* (27%), Myrtaceae (22%), Erythroxylaceae (19%), Flacourtiaceae (17%), Celastraceae (14%), Apocynaceae (13%), Rosaceae (8%), Rubiaceae (8%), Euphorbiaceae (5%), Fabaceae (5%)	Chenopodiaceae (52%), Asteraceae (50%), Thymeleaceae (5%)	Poaceae (73%), Cyperaceae (45%), Iridaceae (36%), a discrete increase/ spike in pteridophyta (83%)

Maximum percentage abundance reached within each zone is quoted in parentheses for each taxon.
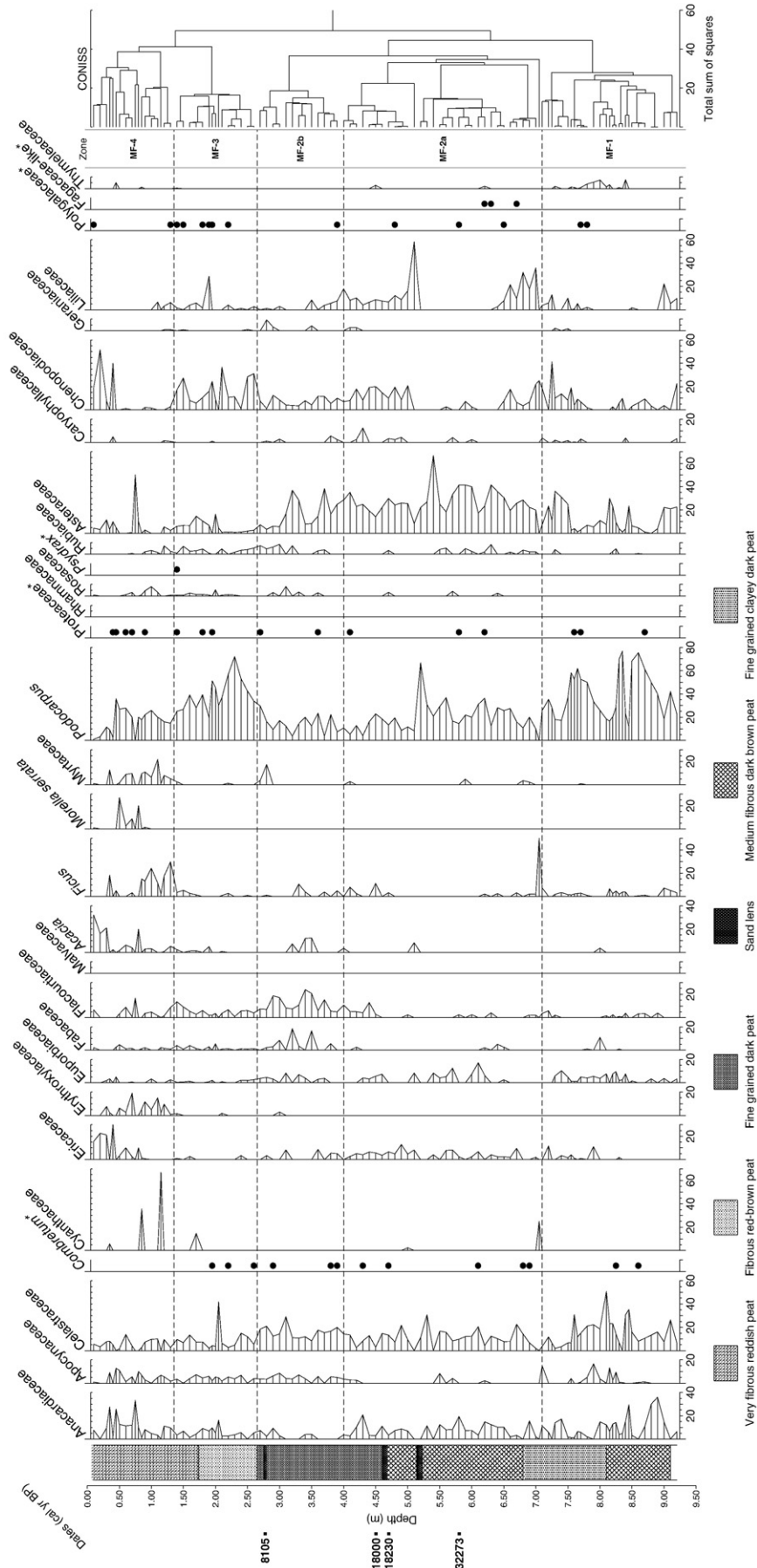
Figure 4. Regional pollen diagram for the Mfabeni Peatland, based on relative pollen frequency, indicating CONISS dendrogram and associated pollen zones. *Rare taxa are presented as presence/absence graphs. Stratigraphy derived from Grundling et al. (2000).
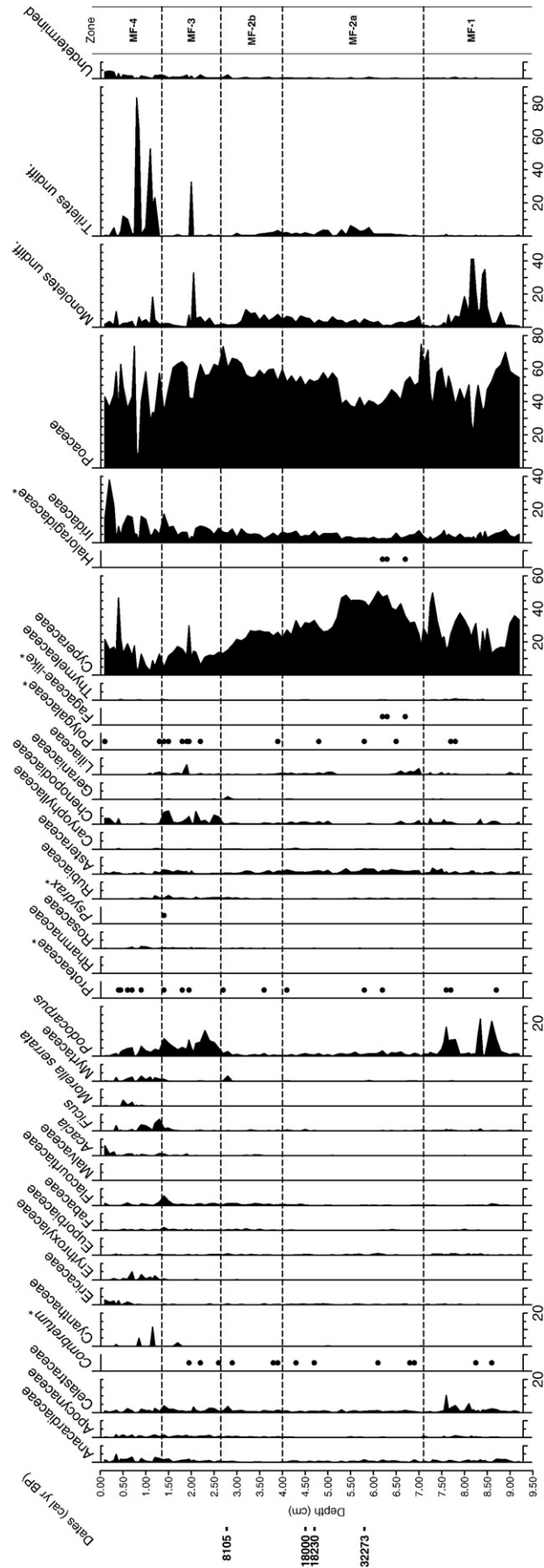
Figure 5. Total pollen diagram for the Mfabeni Peatland, including locally dominant/aquatic taxa. Pollen zones are derived from Figure 3. *Rare taxa are presented as presence/absence graphs.

Early Holocene (MF-3)

An expansion in *Podocarpus*-abundant forests is indicated for the early Holocene, as evidenced by a rapid increase in *Podocarpus* frequencies of ~60%. This is supported by the presence of a diversity of arboreal taxa including Anacardiaceae, Apocynaceae, Celastraceae, Fabaceae, Flacourtiaceae, Rosaceae and Rubiaceae. Similarly, an increase in arboreal taxa is recorded by Grundling et al. (1998) after ~11,570 ^{14}C yr BP.

Evidence for the establishment of *Podocarpus* forest stands in the neighbouring Free State province after ~13,000 ^{14}C yr BP (Scott, 1989) supports indications of moist, cool climate at Mfabeni towards the Pleistocene/Holocene boundary. Deacon and Lancaster (1988) note a fairly rapid amelioration of climatic conditions following the LGM. This was followed by a general increase in temperature reaching up to ~3 °C warmer than present-day, representing Holocene Altithermal (~7000 ^{14}C yr BP; Deacon and Lancaster, 1988). Furthermore, Partridge (1997) deduced conditions considerably wetter than the present for the entire eastern region of South Africa during this epoch. While KwaZulu-Natal suffered considerably colder and drier conditions during the LGM, the warm and wet Holocene Altithermal was highly conducive to forest growth and expansion (Deacon and Lancaster, 1988; Eeley et al., 1999). After the initial expansion in arboreal pollen frequencies, *Podocarpus* records a steady decrease in abundance. Poaceae and Cyperaceae remain at high frequencies, indicating the maintenance of local grasslands.

Late Holocene (M-4)

Arboreal pollen diversity reaches a maximum during the late Holocene, with taxa such as *Acacia*, Cyanthaceae, *Ficus*, *Morella serrata*, Myrtaceae, *Protea* and Rosaceae recording their highest percentages. In contrast to this, *Podocarpus* continues a steady decline during this period, which may be attributed to selective harvesting, general deforestation or burning. The appearance of *M. serrata* and *Acacia* in the record could be indicative of the development of more open vegetation or secondary forest due to disturbance or fire. West (1999) proposes that Iron Age habitation of the region may have helped in the regeneration of the KwaZulu-Natal forests with *Acacia* secondary forest/scrub representing a successional stage induced by anthropogenic impact, although he does not provide unequivocal evidence to prove this hypothesis. While agricultural and exotic pollen taxa are apparently absent from the record, deforestation provides a good indicator of human impacts on the vegetation as early as ~5000 cal yr BP (~4000 ^{14}C yr BP). Regional deforestation is further supported after the mid-Holocene by indications of forest retreat farther north at Nhlangu (Mazus, 1996) and at Lake Teza (Scott and Steenkamp, 1996).

A spike in trilete spores at ~2500 cal yr BP (~2000 ^{14}C yr BP; 80 cm), dominating the pollen spectrum at this depth, probably reflects selective preservation as a result of adverse climate. The onset of adverse climatic conditions at this time is similarly recorded at Wonderkrater and Tswaing in the savanna biome, with evidence for very low temperatures and dry conditions at ~3000 ^{14}C yr BP (Scott, 1990; Scott et al., 2003).

The presence of arboreal pollen taxa including Rosaceae, Anacardiaceae and *Acacia* indicates the establishment of more open savanna/woodland vegetation, similar to that which currently occupies the Mfabeni surrounds. The development of savanna vegetation during the late Holocene, coupled with a decrease in aquatics, reflects a drying trend. These results are supported by the Tswaing (Scott, 1999b) and Wonderkrater (Scott et al., 2003) records, which indicate cool, dry conditions during this period.

Forest history

Forest species composition, in particular with regards the importance of *Podocarpus*, is difficult to assess within the pollen record and requires careful consideration in terms of the production and dispersal qualities of this taxon. *Podocarpus* pollen grains are very well dispersed, often leading to over-representation in the pollen record (Coetzee, 1967; Hamilton, 1972; Scott et al., 1992). Coetzee (1967) recommends that a presence of 10–20% indicates close proximity of this taxon, while frequencies greater than 20% indicate the presence of *Podocarpus* forest. Following this recommendation, the Mfabeni record indicates *Podocarpus* forest before ~33,000 cal yr BP (~31,000 ^{14}C yr BP) and throughout the early and mid-Holocene. According to Eeley et al. (1999), Afromontane forests persisted in the region prior to the LGM while Indian Ocean coastal forest belt expanded along the Mozambique coastline after ~8000 ^{14}C yr BP (MacDevette et al., 1989; Lawes, 1990). While the similar species composition of these forest types prevents their being distinguished at the taxonomic resolution yielded by pollen datasets, they can be differentiated according to the temporal disjunctions in forest presence indicated in the Mfabeni record. A more robust method, using plant functional groupings to recognise distinct 'signatures' for each forest type, may facilitate their differentiation in the future.

Forest composition inferred from Holocene spectra indicates the dominance of other arboreal pollen types over *Podocarpus* pollen, as compared with *Podocarpus* dominated forests in the Pleistocene. This trend may suggest a shift towards swamp forest vegetation during the Holocene, with *Podocarpus* composing a lesser proportion of this forest type. This is concordant with the results of Mazus (2000), who recorded a northward migration of *Podocarpus* forests along the Maputaland Coastal Plain during the Holocene, using pollen data from sites at Muzi-Oos, Mgobezeleni, Majiji, Muzi-Oos, Nhlangu and Vasi Pan within the Natal Mire Complex (Smuts, 1992). The current distribution of *Podocarpus*, along the Maputaland coast, is mainly restricted to the Kosi Bay swamp forests, although it is found farther south at very low frequencies (<1% of the vegetation composition; Scott et al., 1992). Given the recent nature of the recorded decline in *Podocarpus*, we interpret this trend as a likely signal of human activity, particularly forest clearance. Deforestation and anthropogenic burning could account for the decreasing *Podocarpus* pollen frequencies, and for the development of more open woodland/secondary forest. These inferences are supported by the appearance of high levels of the or burning indicator/or burning indicators *Acacia* and *M. serrata* in the record.

The late Quaternary at Mfabeni was characterised by successional changes from grassland to savanna to *Podocarpus* forests, as a result of cyclical changes in regional moisture conditions. The moderated nature of cooling and drying trends experienced during the LGM can probably be attributed to the proximity of the site to the ocean. Major environmental indications through the Mfabeni record are well supported by evidence from previous studies within the savanna biome and southern Africa.

Inferred forest history at Mfabeni has been compared with predicted distributions of indigenous forest in KwaZulu-Natal, based on regional temperature indications for southern Africa (Eeley et al., 1999). Predictions were made using a BIOCLIM-type modelling approach, which explored the impact of palaeoclimatic change on forest distribution during the most extreme recent climatic events, namely the LGM and the Holocene Altithermal. Predictions for the LGM concur with the Mfabeni pollen record, which indicates contracted forest refugia as a result of significantly colder, drier conditions (Eeley et al., 1999). Predictions for the Holocene Altithermal (~8000–6000 ^{14}C yr BP) further support the Mfabeni pollen record by indicating forest growth and expansion as a result of warmer, wetter conditions (Eeley et al., 1999). As predicted distributions were made on a bioclimatic basis and relied on regional indications of climatic conditions as derived from previous palaeoclimatic research, they provide a good indication of forest distribution patterns during these time periods. Thus, strong agreement between these predictions and the Mfabeni pollen record, which are derived

from markedly different data sources, provides strong support for this vegetation reconstruction.

Conclusion

Podocarpus forests are recorded at the commencement of the record suggesting moist, cool conditions. After ~33,000 cal yr BP (~31,000 ^{14}C yr BP), warm, wet local conditions are indicated, with the retreat of forests and expansion of swampy, Cyperaceae-dominated vegetation. Cool, dry conditions are recorded after ~24,000 cal yr BP (~23,000 ^{14}C yr BP), with a shift from Cyperaceae to Poaceae-dominated vegetation. This change is likely to reflect an early onset of the LGM, with a steady shift towards cooler, drier conditions at the close of the Pleistocene.

A succession from grassland to *Podocarpus* forest is indicated around the early Holocene, reflecting moist, cool conditions. During the mid-Holocene a steady shift towards drier conditions is recorded, with the expansion of grassland/savanna elements and establishment of swamp forest vegetation. Indications of deforestation and burning are evidenced by a decline in *Podocarpus* and increases in *Acacia* and *M. serrata*, respectively.

The Mfabeni record falls within a largely understudied part of southern Africa, thus extending our knowledge of palaeoenvironments in the subregion. In addition, the Mfabeni palaeoreconstruction constitutes a continuous record, covering a relatively long time span of ~44,000 yr, thus making a significant contribution towards our limited knowledge of the *Podocarpus* forest history of Maputaland. High levels of pollen preservation within the Mfabeni record, together with relatively old sediments here, suggest potential for future palynological studies in the abundant peatlands of the Maputaland Coastal Plain. Such records enable us to identify baseline conditions and record long-term temporal perspectives within these wetlands (Turner and Plater, 2004) against which contemporary human activity and impact upon these fragile systems can be measured. Further pollen analytical studies, covering a 'much closer grid of sites', are urgently required for successful modelling of environmental change in southern Africa (Scott, 2000, p. 349). Moreover, extension of palaeoenvironmental research to poorly studied areas is necessary if we are to develop a more precise understanding of past climatic changes in the sub region. This research has provided a continuous palaeoenvironmental record for the past ~44,000 yr at the Mfabeni Peatland, thereby furthering palaeoenvironmental research in Maputaland, and making a significant contribution to our understanding of the late Quaternary in the southern African subregion.

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