Journal of Arid Environments 74 (2010) 786–793

Contents lists available at ScienceDirect

Journal of Arid Environments

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

Holocene palaeoenvironments of the Cederberg and Swartruggens mountains, Western Cape, South Africa: Pollen and stable isotope evidence from hyrax dung middens

M.E. Meadows [a,*], B.M. Chase [a,c], M. Seliane [a,b]

[a] Department of Environmental & Geographical Science, University of Cape Town, Rondebosch 7701, South Africa
[b] Macgregor Museum, Kimberley, South Africa
[c] Oxford University Centre for the Environment, University of Oxford, Oxford, UK

ARTICLE INFO

Article history:
Received 29 April 2008
Received in revised form
20 April 2009
Accepted 28 April 2009
Available online 24 October 2009

Keywords:
Fynbos
Hyrax midden
Palynology
Southern Hemisphere
Stable isotope analysis
Vegetation history
Winter rainfall zone

ABSTRACT

The use of pollen analysis of herbivore middens in arid and semi-arid areas has facilitated palaeoenvironmental reconstruction and interpretation in places where this may otherwise be impossible due to the absence of organic sediments. This paper presents evidence based on pollen analysis and stable isotope data of hyrax (*Procavia capensis*) dung middens in the reconstruction and interpretation of the Holocene vegetation history of the Cederberg and Swartruggens mountains. Hyrax middens from upland sites in the Cape Fold Mountains, specifically at Katbakkies Pass (KB) in the Swartruggens and Truitjes Kraal (TK) in the Cederberg, are used to reconstruct past vegetation and palaeoenvironments. Radiocarbon dating of a 20 cm sample at Katbakkies confirms a late Holocene sequence, with sedimentation commencing around 3700 cal yr BP and terminating within the last 600 years. At Truitjes Kraal, a smaller (11 cm) section appears to represent much of the Holocene, with accumulation spanning the period from around 9500 to 1300 cal yr BP. Stable isotope and pollen analyses concur in indicating only relatively subtle changes in vegetation conditions over the Holocene, a conclusion that is compared with and supported by other palaeoecological evidence from the region.

1. Introduction

In respect of Quaternary palaeoenvironmental evidence, there is hemispheric inequity in the distribution of published material and, more so in the arid and semi-arid regions of the southern hemisphere, there remains a marked paucity of information about the environmental dynamics of this time period. In southern Africa, the Quaternary palaeoenvironmental archive is inconsistent both spatially and temporally, and the picture for the winter rainfall zone (WRZ), although beginning to reveal some consistent patterns, remains inadequately resolved (cf. Chase and Meadows, 2007). Southern Africa in general, and the WRZ in particular, is significant from the perspectives of global biodiversity (Myers et al., 2000) and climate systems (Chase and Meadows, 2007), so the lack of evidence for the longer-term dynamics of environmental change in terms of understanding both contemporary and future climate variations warrants closer attention. Traditional palaeoecological methods involving the identification of wetlands with suitably organic sequences rich in pollen, while they have been applied successfully in the region (e.g. Meadows and Sugden, 1991; Carr et al., 2006), are not well suited to the high energy fluvial environments that prevail in a region characterised by high relief, marked rainfall gradients, extreme climate seasonality and strong erosional forces.

Alternative sources of palaeoecological evidence have been successfully applied to the problem of developing a more robust understanding of the complex spatio-temporal changes that have characterised the late Quaternary of southern Africa. Faecal material has proved to be a fruitful source of palaeoenvironmental evidence if it accumulates over time and is suitably preserved (Davis, 2006). The analysis of hyrax (*Procavia* spp.) dung for pollen has already proved to be a very effective tool in arid and semi-arid parts of the Mediterranean-climate region of southern Africa (Scott and Bousman, 1990; Scott and Woodborne, 2007a,b). These 'middens', as they are known, are formed from consolidated faecal material and urine and may contain, in addition to the excreted material itself, inorganic sediment, hair, macro- and micro-plant remains derived both autochthonously and allochthonously. Pollen grains may be preserved, often in very significant concentrations, within the indurated material and is an obvious source of

* Corresponding author. Tel.: +27 21 650 2873; fax: +27 21 650 3456.
E-mail address: michael.meadows@uct.ac.za (M.E. Meadows).

0140-1963/$ – see front matter © 2009 Published by Elsevier Ltd.
doi:10.1016/j.jaridenv.2009.04.020

palaeoenvironmental information over the period of sedimentation (e.g. Gil-Romera et al., 2006, 2007; Scott, 1990, 1994; Scott and Woodborne, 2007a,b).

The Cape Fold Belt mountains (Compton, 2004) of the WRZ have proved a valuable source of midden material. This paper reports on a study of two midden sites in the range of mountains known broadly as the Cederberg. The study is predicated on the basis of the following objectives:

(a) The determination of changing vegetation composition through pollen analysis of hyrax middens.
(b) The reconstruction of late Quaternary environments of the area through stable carbon and nitrogen isotopes as indicators of water availability.
(c) Interpretation of the observed vegetation changes in terms of palaeoenvironmental conditions prevailing over the period of sedimentation, including climatic, fire regime and human disturbance indicators based on the above analyses.
(d) Placing the palaeoenvironmental reconstruction into the broader regional framework through comparison with other related studies.

2. Regional and local setting

The mountains of the southwestern Cape WRZ are dominated by the Cape Fold Belt represented by sedimentary Ordovician sandstones and shales uplifted and contorted during the break-up of Gondwanaland (Compton, 2004). The result is rugged topography characterised by a complex series of elevated ridges and troughs occurring over large areas (Fig. 1). Geomorphological complexity underlies a high degree of spatial and temporal variability in rainfall. Dominated by winter frontal systems, mean annual precipitation varies according to elevation and distance from the coast, exceeding 700 mm around the higher peaks that rise above 2000 m and falling well below 250 mm at Matjies River towards the east (Schulze, 1997). Vegetation is represented by a number of forms of Mountain Fynbos (Taylor, 1996) and characteristically dominated by shrubs of the Ericaceae, Proteaceae and Asteraceae, while Restionaceae are prominent especially on deeper sandy soils. The transition to Succulent Karoo occurs at the arid end of the moisture spectrum, although the boundary appears to have strong geological control as more nutrient rich substrates (e.g. Bokkeveld shales) are associated with a high proportion of succulents (Mucina and Rutherford, 2006) Mountain Renosterveld, dominated by *Elytropappus rhinocerotis*, is more abundant to the south.

The middens under consideration are located a) in the Katbakkies Pass area of the Swartruggens Mountains (representing the southeastern part of the Cederberg) and at Truitjes Kraal (central Cederberg (Fig. 1).

2.1. Katbakkies Pass (KB)

The Katbakkies Pass (19.5610° E; 32.8969° S) lies some 70 km north-east of the town of Ceres at approximately 1190 m amsl. Mean annual precipitation is estimated at around 350 mm (interpolated from data in Schulze, 1997). There are two large middens located either side of the road itself and situated within Table Mountain Group sandstone about 30–40 m above the pass. The middens vary in thickness from 5 to 20 cm and their vertical development appears to be limited by the overhang as, in each case, there is approximately 15 cm from the midden top and the roof of the overhang, perhaps representing the minimum height to fit an adult hyrax. Each midden has a horizontal extent of some 1–3 m. Vegetation in the vicinity is typically a mosaic of renosterveld and mountain fynbos shrubland characterised by *Elytropappus rhinocerotis*, with grasses more common in areas less heavily grazed. Restionaceae elements appear to be more abundant at higher and more exposed parts of the pass than at lower elevations. The Riet River flows approximately 2.5 km northwest of the site in a valley bottom that is relatively densely vegetated and dominated by Cyperaceae, Restionaceae and Poaceae species.

2.2. Truitjes Kraal (TK)

This site (19.3112° E; 32.5123° S) lies some 60 km southeast of the town of Clanwilliam in the central Cederberg (Fig. 1). One of the many small rocky Table Mountain Group sandstone promontories (*kopjies*) is home to several middens at an elevation of approximately 890 m. Mean annual precipitation is estimated at around 250 mm (interpolated from data in Schulze, 1997). The middens were extracted in their entirety from an overhang some 5 m up a 25–30 m north-facing rock face. The Driehoek River flows about 1.25 km north of the site. The TK middens are located within a few kilometres of the relatively sharp transition between the Fynbos and Succulent Karoo Biomes in what is described as restioland with a low shrub understorey and intermittent overstorey of taller shrubs. The *kopjies* themselves maintain taller shrubs and small trees including *Rhus undulata*. Dwarf succulent shrubs belonging to the Crassulaceae and Mesembryanthemaceae families also form part of the vegetation in the vicinity of the site, especially to the east where the Bokkeveld shales outcrop. The narrowly endemic Clanwilliam cedar, *Widdringtonia cedarbergensis*, occurs sporadically at higher elevations, although the nearest populations are several kilometres from this site.

3. Methods

Middens were extracted by cutting away substantial segments using an angle grinder. Material was sub-sampled in the laboratory for pollen and stable isotope analyses in an attempt to maintain stratigraphic consistency of the entire midden. Careful scrutiny of midden structure is necessary to allow this principle to hold as the constitution and construction of hyrax latrines is not fully understood; nevertheless the method adopted has the distinct advantage of requiring significantly fewer radiocarbon age determinations on which to base the chronology. Midden accumulations have pollen from direct dietary input (autochthonous) pollen, togeter with and that derived from aeolian transport and that brought in on the animal fur or feet (allochthonous). The sampled midden material consisted mainly, if not entirely, of hyraceum and faecal pellets. Using a 6 mm steel drill, subsamples were taken at approximately 5 mm intervals along a vertical transect perpendicular to the stratigraphy. Radiocarbon age determinations were conducted by conventional means at the QUADRU laboratory in Pretoria. Due to severe cost limitations, only three samples for the Katbakkies and two for Truitjes Kraal were dated.

Standard pollen concentration methods were used according to laboratory methods suggested in Faegri and Iversen (1989) using potassium hydroxide to dissolve humic acids, acetolysis for cellulose digestion and hydrofluoric acid to remove fine siliceous particulates. Sample weights were recorded and *Lycopodium* spores added as markers to facilitate absolute counting at ×400 or ×630 magnification. Isotope ratios of bulk midden samples were measured on a Thermo-Finnigan Delta-Plus XP isotope ratio mass spectrometer. Samples were combusted at 1020 °C and the carbon and nitrogen converted into CO_2 and N_2 in a Thermo Flash EA 1112 elemental analyser. Gases were introduced into the mass spectrometer in a stream of helium, via a Conflo interface. The standard deviation of repeated determinations of homogeneous material was less than 0.2‰ for both carbon and