Pollen analysis of Iron Age cow dung in Southern Africa

Article *in* Vegetation History and Archaeobotany · January 2000

DOI: 10.1007/BF01294638

4 authors, including:

José Carrión
University of Murcia

Louis Scott
University of the Free State

Veget Hist Archaeobot (2000) 9:239–249

Vegetation History and Archaeobotany

Pollen analysis of Iron Age cow dung in southern Africa

José S. Carrión[1], Louis Scott[2], Tom Huffman[3] and Cobus Dreyer[4]

[1] Departamento de Biología Vegetal, Universidad de Murcia, E-30100 Espinardo, Murcia, Spain
[2] Department of Botany and Genetics, University of the Orange Free State, Bloemfontein 9300, South Africa
[3] Department of Archaeology, University of the Witwatersrand, Johannesburg, Wits 2150 South Africa
[4] National Museum, Bloemfontein 9300, South Africa

Received October 27, 1999 / Accepted May 16, 2000

Abstract. Thick accumulations of consolidated cow dung occur in ancient *kraals* (byres or corrals) in the bushveld and highveld areas of Zimbabwe, Botswana, and South Africa dating from the last 2000 years. They originated from long-term cattle herding by Iron Age people. The "vitrified" or baked dung deposits are thought to be a product of the burning of cow dung as fuel, either for domestic purposes or for iron smelting. In order to establish the palaeoecological potential of this material, 36 samples of cow dung from archaeological sites within the present-day savanna and grassland biomes were analyzed for pollen and other microfossils. Of the samples, 29 contained pollen together with other microfossils that support a faecal origin of the material such as sordariaceous ascospores, *Thecaphora, Gelasinospora*, and *Chaetomium,* and eggs of the intestinal parasite *Trichuris*. Similar microfossils were also found in recent fresh cow dung from the same study areas. The presence of pollen grains and spores in most of the Iron Age samples lead to the assumption that they survived the burning because fire temperatures were not high enough to destroy them. Pollen in these cow dung pieces is apparently sealed and can be preserved under open-air conditions at sites under which pollen in other deposits like soils, will decay away. Good pollen preservation and palynomorph diversity were found with mainly Poaceae, and secondly Chenopodiaceae and Cyperaceae as the most important pollen types, while trees and shrubs indicating savanna are rare. In the case of the samples that came from the subtropical savanna biome the latter result is unexpected and suggests that the cattle were kept in more open vegetation than the woody environments of today. Recent cow dung samples reflect the composition of present-day vegetation by showing considerably higher proportions of tree pollen than the fossil assemblages.

Key words: Palynology – Cow dung – Holocene – Iron Age – Southern Africa

Correspondence to: José S. Carrión (email: carrion@um.es)

Introduction

For several decades, archaeologists have attributed a diversity of solid slag-like materials associated with Iron Age finds in southern Africa to metal smelting slag (Dart 1931), while uncertainty prevailed about their origin. At present, however, there seems to be consensus that the silicon-rich material is the product of the burning of cow dung, a traditional fuel of African people (Dreyer 1997). Although it is possible that the slag-like finds may have formed during iron smelting, most were not formed during this process. Stanley (1934) analyzed the chemical and physical properties of some material and concluded that it could not be metal smelting slag. Friede et al. (1982) suggested that these finds should not be attributed to smelting unless they were found in the context of furnaces. EDX (energy dispersive X-ray) analysis of dung material from Winburg, Doornpoort in the Free State, indicated a high silicon content but no sign of smelted metal. The material had probably been derived from organic materials and consisted mainly of silica residues of phytoliths in Iron Age cow dung. Although in some cases they came from ancient *kraals*, deposits were probably produced in a special way, that is, as far as we know, not practised on a large scale by traditional communities any more.

The first Iron Age settlements south of the river Limpopo in southern Africa arrived before 400 A.D. from north of this river, where their presence was reported several hundred years earlier (Vogel 1995). The Iron Age settlement pattern seems to have been influenced by fluctuating climate cycles as defined by Tyson and Lindesay (1992), and Huffman (1996). Wet, warm periods show an increase in Iron Age activity while cool dry phases like the Little Ice Age (A.D. 1675-1780) show a lack of settlement (Table 1). With our aim of finding more direct evidence of environmental change during Iron Age times in southern Africa, this paper investigates the palaeoecological potential for pollen analysis of burnt or "vitrified" cow dung from different phases listed in Table 1. To find pollen in dry open-air sites in the corrosive environment of soils is virtually impossible, but burnt or vitrified cow dung pieces can apparently seal their contents from the

Table 1. Climatic fluctuations in southern Africa over the last 2000 years according to Tyson and Lyndesay (1992) that serve as basis for comparisons with Iron Age settlement patterns (Huffman 1996, Vogel 1996)

Age A.D.	calibrated	Climate
1790-1810	1790 - 1810	warm/wet
1675-1780	1675 - 1780	cool
1500-1675	1425 - 1675	warm/wet
1300-1500	1290 - 1425	cool/dry
900 -1300	900 - 1290	warm/wet
600 - 900	no data	cool
250 - 600	500 - 700	warm/wet
100 - 200	no data	cool

elements and microbial action, preserving the pollen. We were unable to find previous reports on the palynology of fossil or fresh cattle dung, but that of several other big mammals are available (Martin et al 1961; Iberall 1972; Davis et al 1984).

Material and methods

The studied Iron Age dung samples are derived from two study areas. Study Area 1 in the south represents a relatively small geographical area of the highveld, and Study Area 2, a vast region to the north (Fig. 1). The areas differ markedly, with Study Area 1 at Doornpoort near Winburg, in the grassland biome (major regional ecological community) experiencing severe frost in winter, and Study Area 2 surrounding the river Limpopo in the savanna biome, which has a more subtropical climate. The samples varied in appearance, some being of a typical hard type with cavities that are presumably the result of bubble formation in a molten state (Fig. 2). Others are more solid in appearance and may have experienced lower temperatures in their formation (Fig. 2). None of them were found in the context of smelting furnaces.

Several, but not all of the samples have been found in association with archaeological levels that have previously been radiocarbon dated (Table 2). The dung itself has not been dated since its organic content is low as result of loss of organic matter on ignition. Apparently only the most resistant pieces like microscopic charcoal and pollen survived. Available data from Study Area 1 suggest that the samples are associated with occupation between A.D. 1660 and 1810 (Dreyer 1992) and those from Study Area 2 range between ca. A.D. 350 and 1900 (Table 2).

For control and in order to establish possible bias of cow dung pollen assemblages as a result of dietary preferences of cattle, a set of modern cow dung samples composed of up to 9 sub-samples were collected from comparable areas (Table 3).

Thirty-six fossil samples of Iron Age dung weighing 4-12.1g were processed following conventional methods in palynology using HCl, HF, KOH and mineral separation with a heavy liquid ($ZnCl_2$). After removing the outside layers, samples were washed in acid and rinsed vigorously in water to clean out cavities as a precaution against recent pollen contamination. A known number of exotic palynomorphs was added to samples in order to estimate the pollen concentrations of samples.

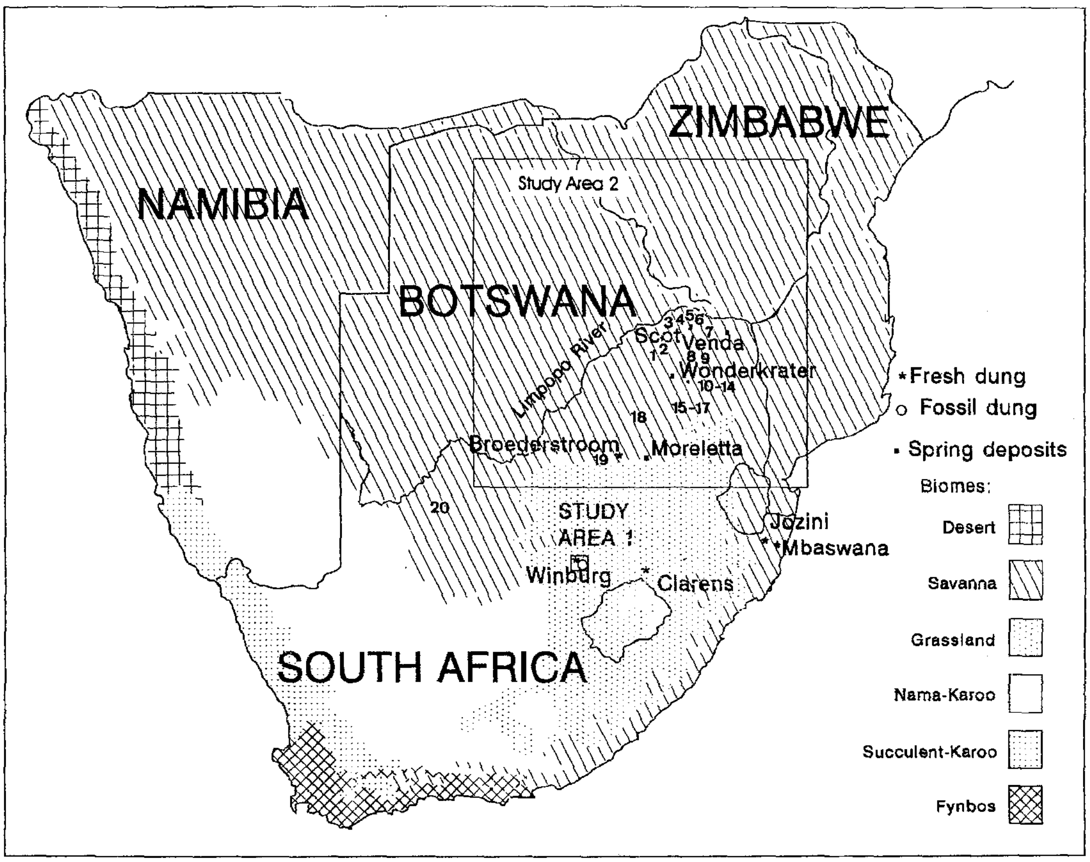

Fig 1. Locality of the study areas. **1** Woolandale, Woolandale Mound-II; **2** Montevideo; **3** Little Muck; **4** K2; **5** Shroda; **6** Skutwater; **7** Evelyn; **8** Matshaba; **9** Dzata; **10** Tshitheme; **11** Mabvoho; **12** Manavehela; **13** Malla; **14** Tavhatshena; **15** Bambo; **16** Ficus; **17** Pont Drift; **18** Nylsvley; **19** Broederstroom; **20** Dithakong

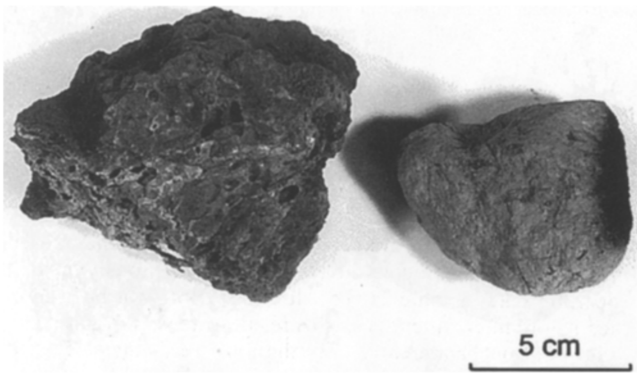

Fig. 2. Left Vitreous "slag-like" cow dung with bubble cavities which probably formed at a relatively high temperature; **Right** Dung that probably baked at a lower temperature

Twenty-nine samples contained pollen and other microfossils (Fig. 3) but only 19 were rich enough to be included in the pollen diagrams. After discarding three unproductive recent surface samples of cow dung from the Lake Sibaya area, we investigated six modern dung samples from different areas (Fig. 1). Sub-samples weighing 3.3-5.1 g and from the innermost parts of the dung, were processed with KOH and acetolysis, and underwent mineral separation.

All slides were mounted in glycerine jelly and stained with safranine. Identifications of pollen were performed using the reference collection of the Palynological Laboratory at the University of the Orange Free State. The other palynomorph types correspond to the descriptions by van Geel et al. (1981, 1983, 1989), and Carrión and van Geel (1999c) (Fig. 3) except for the Form A (Jarzen and Elsik 1986). The nomenclature of plant taxa follows Arnold and de Wet (1993).

Results

Pollen percentage diagrams were drawn using the TILIA-GRAPH program (Grimm 1987), representing fossil dung from the two study areas are shown in Figs. 4-7 and the modern dung samples in Figs. 8-9. Pollen concentration values are shown in Table 2 (Iron Age) and Table 3 (modern).

Table 2. Iron Age cow dung samples, chronological setting, pollen concentration, pollen sum (including non-pollen palynomorphs), and indeterminable types. * hard dung type with cavities (Fig. 2); + samples included in pollen diagrams (Figs. 4-7)

Sample	Site	Age A.D.	Pollen concentration (grains/gm)	Pollen sum	Indet %
Study Area 1					
2015 * +	Doornpoort	1660-1810	169,283	1007	2
2018 * +	Doornpoort	1660-1810	130,456	639	3.3
2019 +	Doornpoort	1660-1810	21,680	196	2
2021 * +	Doornpoort	1660-1810	6712	171	3
2022 * +	Doornpoort	1660-1810	617	193	3
2027 +	Doornpoort	1660-1810	21,230	509	5.5
2028 +	Doornpoort	1660-1810	37,825	238	3.4
Study Area 2					
2032 *	Mabvoho	Late 19th century	10,242	40	0
2042	Malla	1800-1900	2523	7	0
2043 +	Mahavehela	1750-1850	48,554	517	6.2
2038 +	Matshaba	1750-1850	2276,426	4820	0.8
2037 *	Little Muck	1700-1800	1214	48	0
2047 +	Dzata	1690-1740	128,757	704	1.6
2046 +	Tshitheme	1600-1700	679,028	593	8.6
9638 +	Bambo	1600-1700	Not available	1993	1.1
2049 +	Dithakong	ca. 1600	51,476	215	3.3
2031 +	Nylsvlei	1500-1600	755,990	1181	2.6
2039	Evelyn	1400-1500	22,981	30	0
2033	Tavhatshena	1300-1500	4695	53	0
2029 +	Tavhatshena	1300-1400	387,773	746	4.8
2030 +	Montevideo	1300-1400	111,678	630	4.3
2054	Ficus	1300-1400	1225	37	0
2034	Skutwater	1250-1300	1435	74	0
2035 +	Woolandale	1250-1300	281,971	830	2.6
2036 *	Woolandale Mound II	1250-1300	844	83	0
2053	K2	1000-1220	4555	56	0
2044 +	Schrodar	900-1000	416,929	490	13.5
2050	Pont Drift	900-100	3765	53	8.7
2052 +	Broederstroom	350-550	1075	336	1

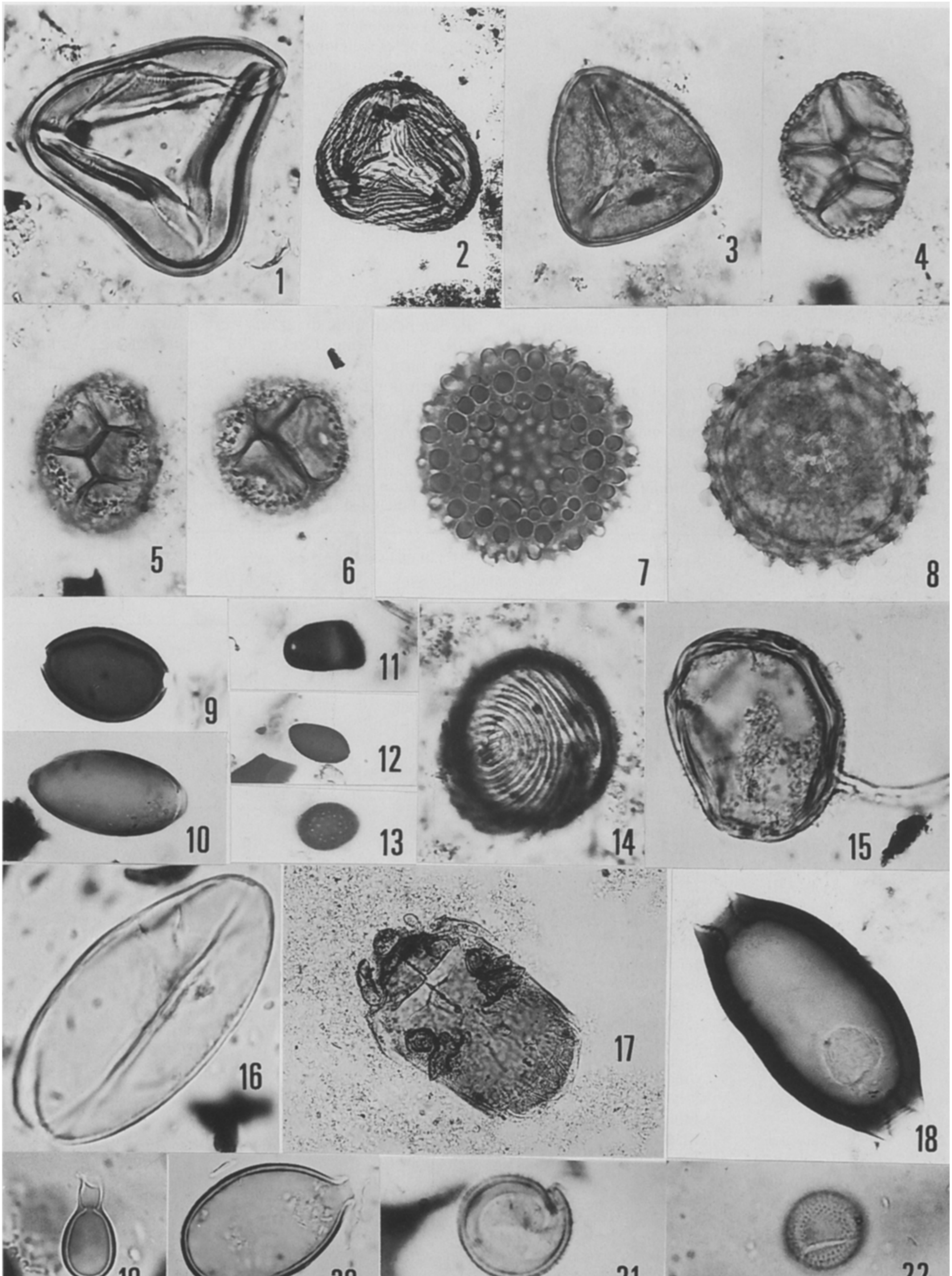
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22

Table 3. Modern cow dung samples, pollen concentration, pollen sum (including non-pollen palynomorphs), indeterminable types, and surrounding present-day vegetation according to Low and Rebelo (1996)

Sample No.	Site (Fig. 1)	Pollen conc. (grains/gm)	Sum	Indet %	Biome	Vegetation type
3521	Winburg	138,451	340	0.3	grassland	moist cool highveld grassland
3522	Clarens	127,474	360	7.2	grassland	wet cold highveld grassland
3520	Broederstroom	254,573	341	4.4	savanna-grassland	transition between rocky highveld grassland and mixed bushveld
3515	Mbaswana	53,254	321	7.2	savanna	Natal lowveld bushveld
3516	Jozini	5376	250	16.4	savanna	transition between Natal lowveld bushveld and sweet lowveld bushveld
3517-9	Lake Sibaya	almost barren			savanna-forest	sand forest

Iron Age cow dung

In Study Area 1 near Winburg, Free State, South Africa (Figs. 4-7), pollen spectra were dominated by Poaceae, and secondly by Chenopodiaceae, with noticeable amounts of Asteraceae and Cyperaceae in several samples. Only a little tree pollen was represented (for example *Podocarpus, Rhus,* Sapotaceae, *Rhamnus* and *Tarchonanthus*) and they show percentages below 2% while there was quite a diversity of herb pollen (such as *Ruschia*, Acanthaceae, *Stoebe* and *Crassula*). Together with the pollen types, several additional microfossils were also found in all the samples except 2028, of which the most important was Glomaceae. The additional forms included fern and moss spores, Sordariaceae ascospores, other fungal spores such as *Thecaphora*, *Gelasinospora*, *Chaetomium, Tilletia,* and Types 204 and 123, algal zygospores such as *Spirogyra, Zygnema* and *Debarya*, *Pseudoschizaea* cysts, and microfossils of animal origin such as *Trichuris* and *Acari* remains. Pollen concentrations varied greatly from 617 to 169,283 grains/g (Table 2). Except in the cases of samples 2015 and 2018, pollen concentration and pollen sums were generally higher in the samples which did not show cavities. Values of indeterminable palynomorph types were not high (2-5.5%).

Pollen spectra from Study Area 2 (Figs. 6-7) showed a consistent dominance of Poaceae and abundance of Cyperaceae, with occasional high values of Chenopodiaceae, but Asteraceae percentages were lower than from Study Area 1. Tree pollen (*Acacia*, Celastraceae, Oleaceae, *Rhamnus*) was correspondingly scarce, while the diversity of herbaceous pollen and non-pollen groups was noteworthy. Pollen concentrations were also very variable, ranging from 844 to more than 2 million grains per gram (Table 2). Samples showing cavities (2032, 2037, 2036), showed lower pollen concentrations than in the former group of samples, possibly owing to pollen destruction in a higher temperature of dung burning. Indeterminable types did not exceed 9%, except in sample 2044 (13.5%). Glomaceae and Sordariaceae were the main non-pollen palynomorphs, while other types such as Type 179 (animal origin) and *Pellaea* spores occasionally reached amounts above 2%. It must be noted that, despite the different geographical origin of the samples, the microfossil assemblages of Study Area 2 were very similar to those of Study Area 1.

Modern cow dung

Pollen assemblages from fresh cow dung samples were in good agreement with the composition of the present-day vegetation in the surroundings of the sampling sites including the representation of modern exotic pollen of *Eucalyptus*, Cupressaceae and *Pinus* (Figs. 8-9, Table 3). The sample from Winburg matched surface soil samples from the moist cool highveld grassland in the central Free State (Cooremans 1989) being dominated by grasses with minor appearances of *Rhus*, *Maytenus* and Chenopodiaceae pollen. A surface sample from a densely wooded slope at Clarens gave a high local tree pollen count, higher than that of the surrounding grassland (Scott 1989). The most prominent shrubs and trees (*Leucosidea sericea, Euclea undulata, Myrsine africana, Buddleja salviifolia, Clutia pulchella, Maytenus heterophylla*), smaller shrubs (*Erica* sp.) and climbers (*Clematis oweniae*), were represented in the pollen spectra. There is a strong similarity between this pollen spectrum and those obtained from hyrax dung middens at the vicinity (Scott and Vogel 1992; Carrión et al. 1999a).

The sample from Broederstroom covers a transitional area in Gauteng between rocky highveld grassland and mixed bushveld. Since the site is shaped by hills, a fire-maintained grass vegetation is dominant, but there is a great diversity of trees and shrubs such as *Combretum apiculatum, C. molle, Acacia caffra, Grewia occidentalis, Protea caffra, Maytenus heterophylla, Rhus leptodictya,*

←

Fig. 3. Light microscope micrographs of non-pollen palynomorphs in Iron Age cow dung from southern Africa. **1** *Pellaea* x701; **2** *Mohria* x520; **3** Pteridophyta triletes x1750; **4-6** *Thecaphora* x1750; **7-8** Form-A x1750; **9** Type 204 x1750; **10-12** Sordariaceae x1750; **13** *Gelasinospora* x1750; **14** *Pseudoschizaea* x 1750; **15** *Glomus* x 1750; **16** *Spirogyra* x701; **17** Acari x701; **18** *Trichuris* x701; **19** *Rivularia* x1750; **20** Type 179 x520; **21-22** Type 128 x1750

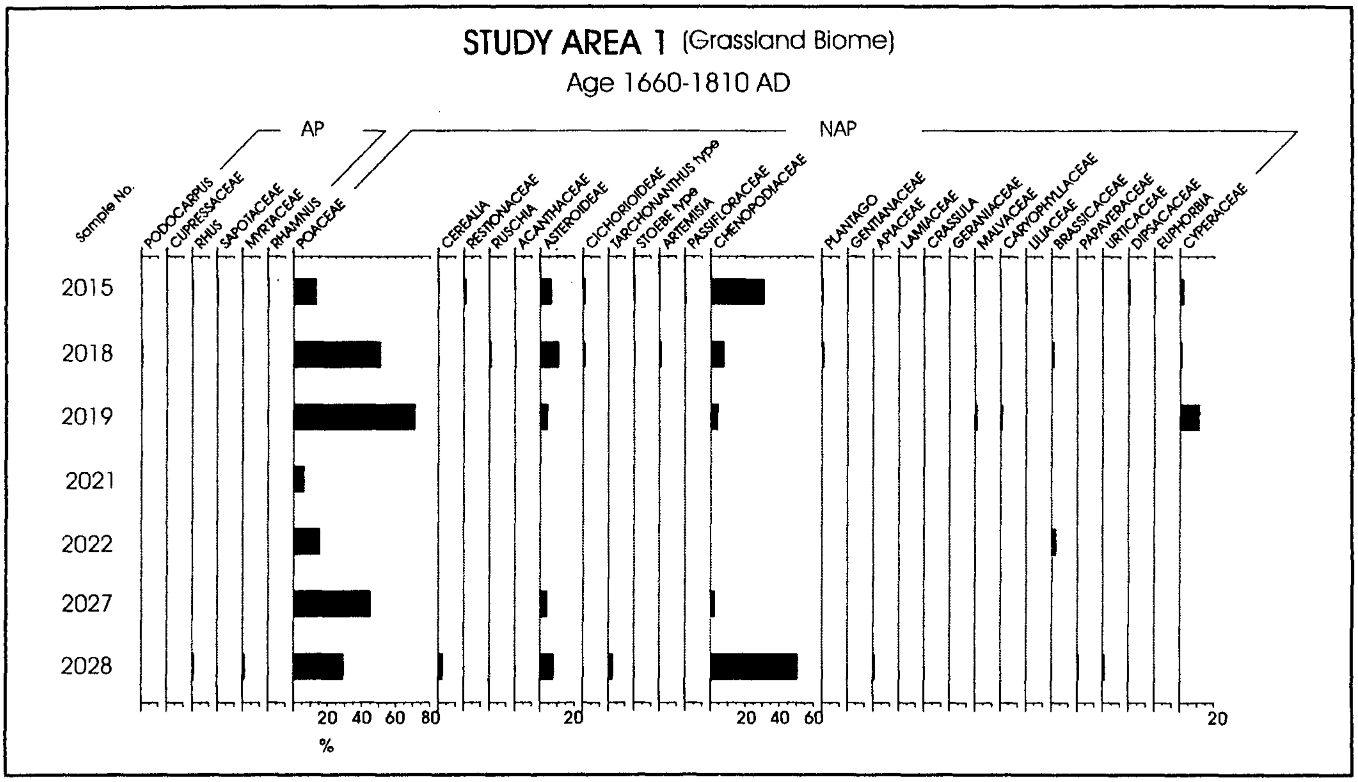

Fig. 4. Pollen percentages in fossil cow dung samples from Study Area 1

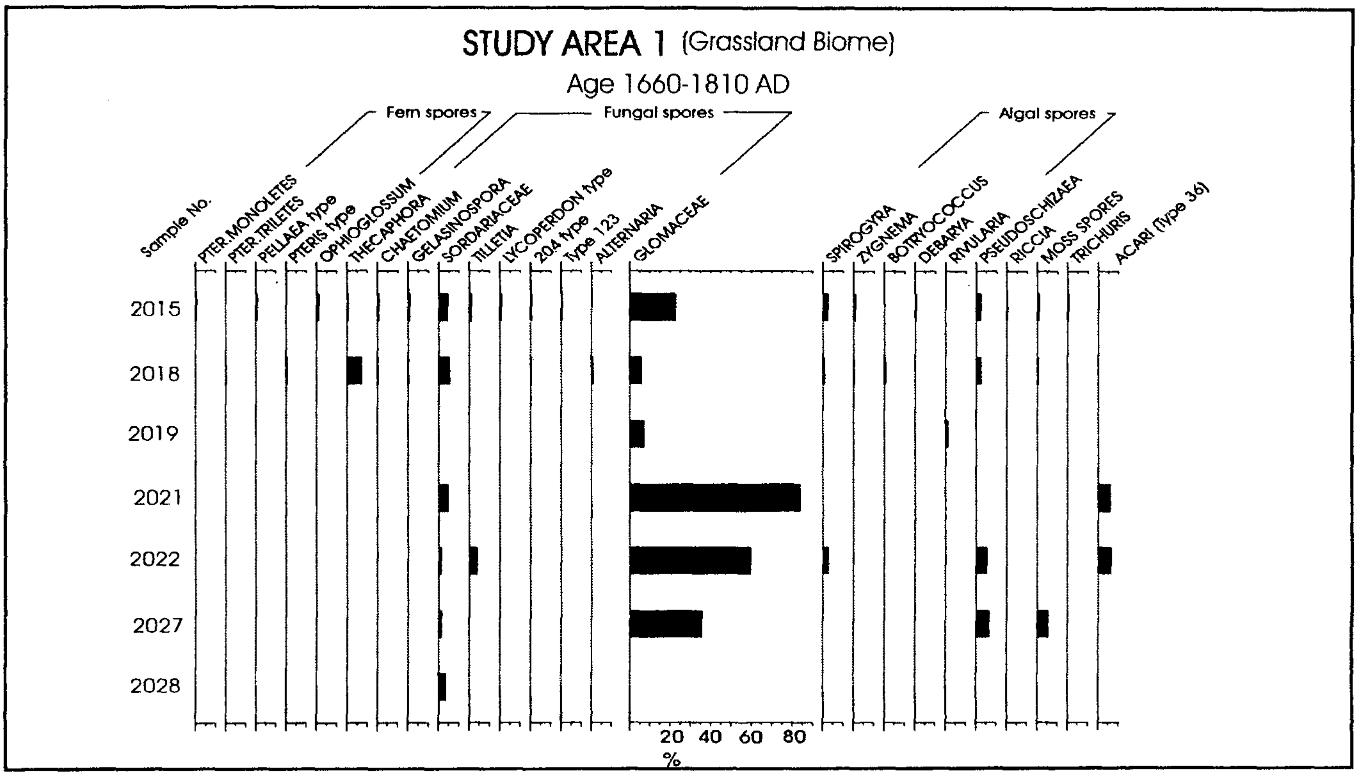

Fig. 5. Spores and other palynomorph percentages in fossil cow dung samples from Study Area 1

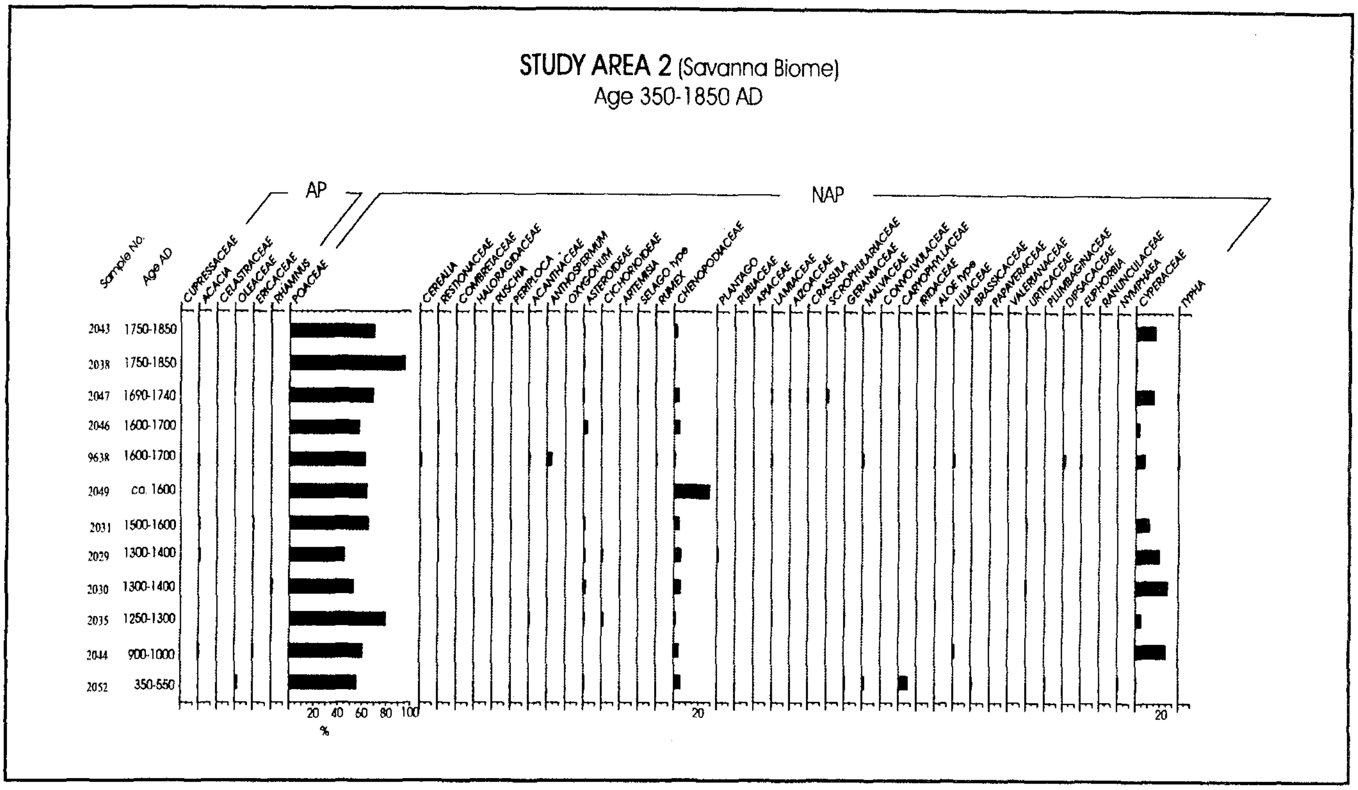

Fig. 6. Pollen percentages in fossil cow dung samples from Study Area 2

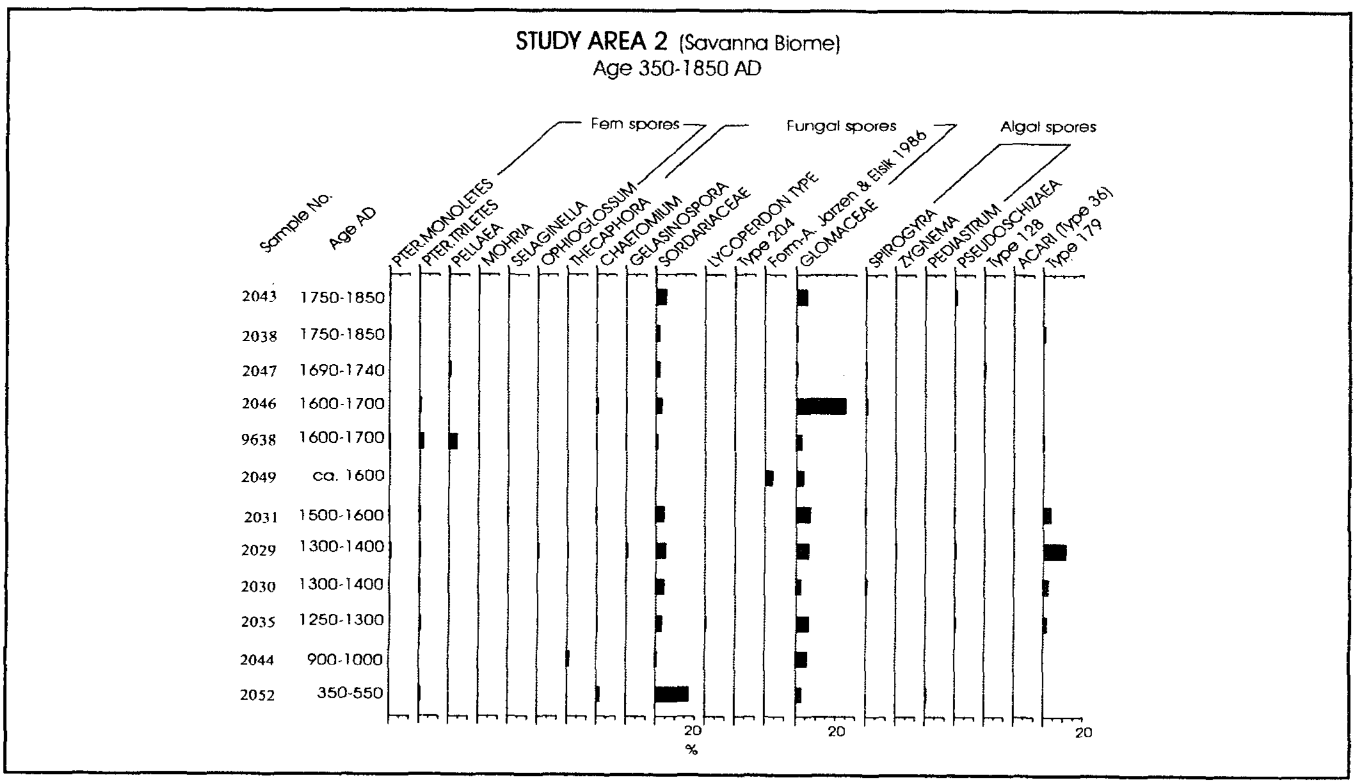

Fig 7. Spores and other palynomorph percentages in fossil cow dung samples from Study Area 2

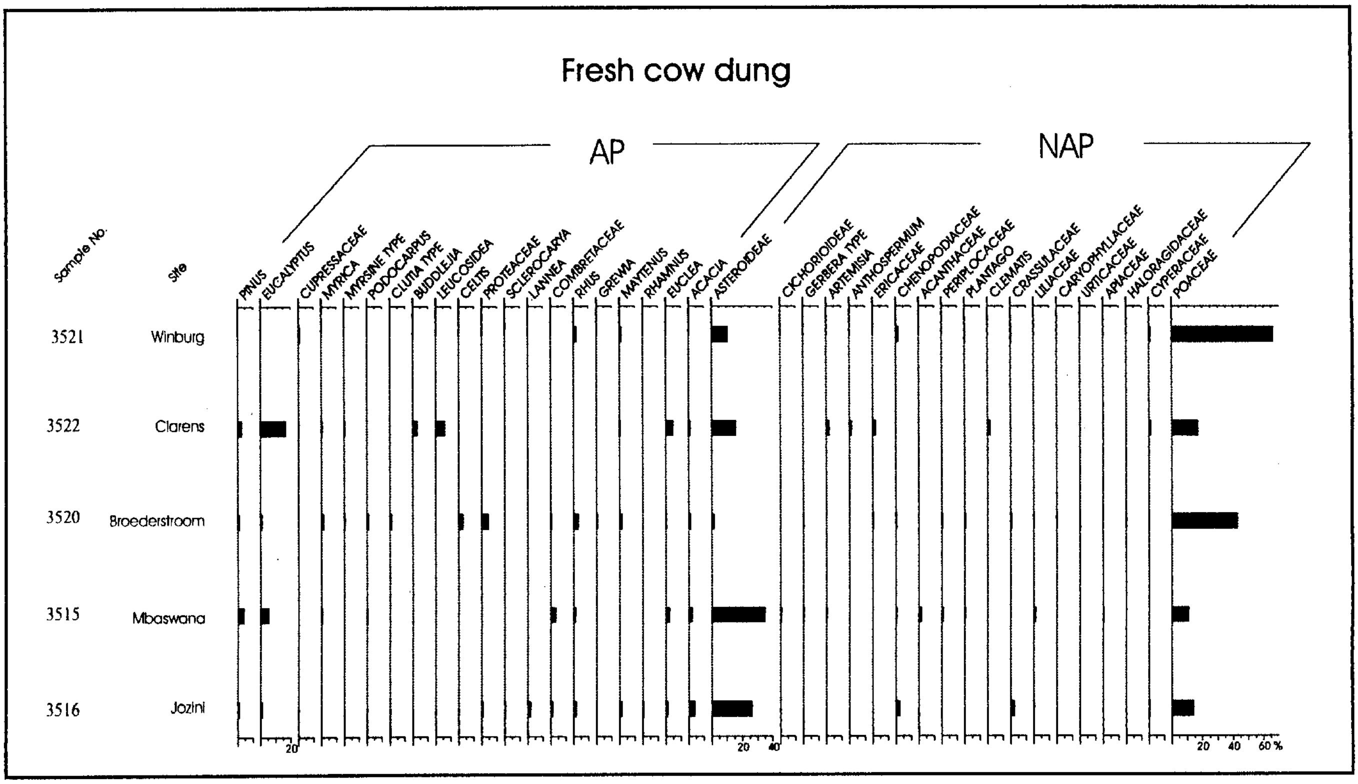

Fig. 8. Pollen percentages in modern cow dung samples

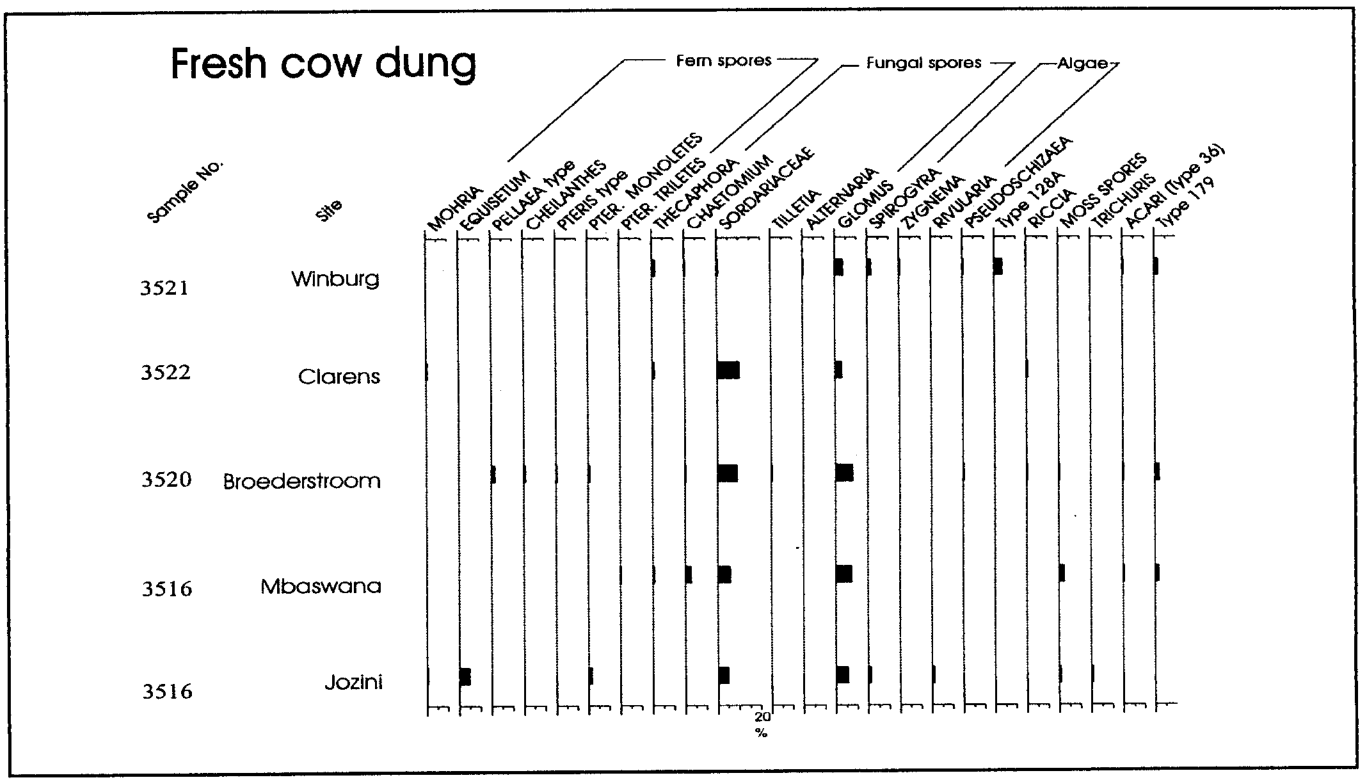

Fig. 9. Percentage diagram showing spores and other palynomorphs in modern cow dung samples

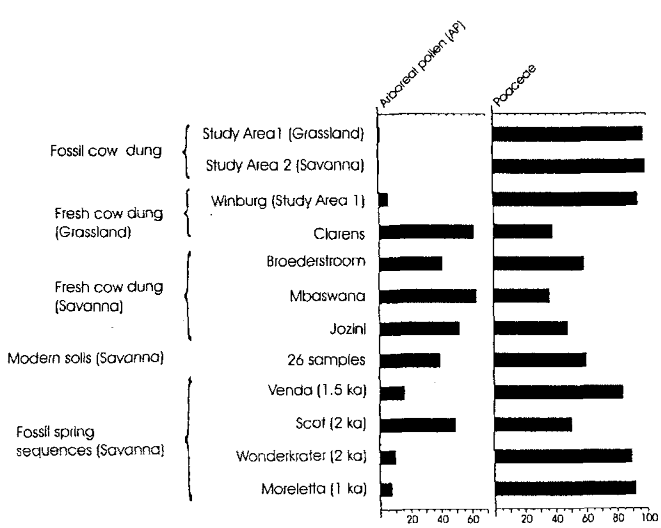

Fig. 10. Tree to grass percentage ratios for Iron Age and modern cow dung samples from Study Areas 1 and 2, compared with the average composition in 26 modern surface samples (Scott 1982b) and averages from fossil spring sites over the last 2000 years (2 ka) from Study Area 2: Tate Venda (Scott 1987), Scot (Scott 1982c), Wonderkrater (Scott 1982b) and Moreletta River (Scott 1984) (Fig. 1)

R. magalismontana, *Euclea crispa*, and *Celtis africana* (Low and Rebelo 1996). All of these genera were represented in the pollen spectra in proportions comparable to their occurrence in the vegetation. In addition, this sample was similar to surface pollen spectra from the wider area (Scott 1982a).

The samples from Mbaswana and Jozini fall into the savanna biome within the Natal lowveld bushveld, which is characterized by a mix of scrub and savanna with a dense herbaceous layer (Low and Rebelo 1996). Among the most prominent trees are *Acacia tortilis*, *A. karroo*, *A. nigrescens*, *Combretum apiculatum*, *Euclea schimperi*, *Sclerocarya birrea*, *Maytenus heterophylla*, and *Lannea stuhlmannii*. As for the previous samples, there was a good agreement between vegetation and modern cow dung pollen spectra, although the high proportions of Asteraceae were unexpected.

Total pollen concentrations in the fresh samples did not exceed values found in the most productive Iron Age dung, which varied between 5376 and 254,576 grains/g. This is attributed to a loss of volume of burned dung. Percentages of indeterminable types did not exceed 8% except for the sample 3516 (16.4%), which showed high amounts of Asteraceae. A preparation consisting of three sub-samples from the surroundings of sand forest on the coast at Lake Sibaya, northeastern Kwazulu-Natal, was poor in pollen and was therefore not analyzed. The low pollen contents in preparations could either be attributed to over-representation of other organic material or to quick exine decomposition under the damp coastal conditions.

In the cases of Mbaswana and Jozini, high Asteraceae pollen may reflect over-grazing in the grass communities of the sand bushveld as winter season over-representation, or differential exine preservation. However, we observed that insects were active in most fresh dung specimens and therefore insects may have increased Asteraceae pollen in these as well as in fossil specimens. Other pollen types may also have been incorporated into the dung through biotic transport therefore contributing to a greater diversity of pollen types including insect-pollinated taxa (Carrión et al. 1999b). Apart from pollen, all the samples analyzed contained other palynomorphs, especially Sordariaceae ascospores, and *Glomus* chlamydospores. There were other fungal spores such as *Gelasinospora*, *Thecaphora*, *Chaetomium*, and *Trichuris*, algal spores such as *Spirogyra*, *Zygnema* and *Rivularia*, fern and bryophyte spores, and microfossils of uncertain biological origin such as Types 128A and *Pseudoschizaea* (Fig. 3), in minor proportions.

Discussion

An important question is whether pollen from the area grazed by cattle survived the burning of dung or if it represents the local *kraal* spectra that were trapped in slag immediately after the burning. If the former is true, it is remarkable that pollen survived the burning of cow dung under high temperatures. It may be explained that if the temperatures were not too high, melting of "slag" was probably good for preservation because after solidification it ensured that pollen was sealed off from oxygen. Those samples that apparently formed under lower temperatures (Fig. 2), showed the highest pollen concentrations, supporting this view.

By comparing pollen analytical results of fossil material with modern samples we can see a strong similarity in the non-pollen palynomorph facies, suggesting that we are indeed dealing with burnt dung. In fact, Sordariaceae and *Trichuris* are good indicators of dung while *Gelasinospora*, *Chaetomium*, and Type 204 are very common in dung apart from other organic debris (van Geel et al. 1981, 1983, 1989). In addition, the grass parasites *Tilletia* and *Thecaphora*, and the humus decomposers *Lycoper-*

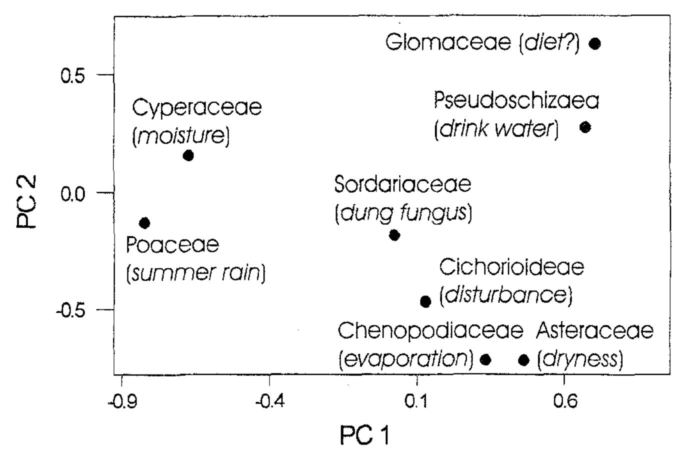

Fig. 11. First and 2nd principal component values of a single data matrix of the most prominent pollen and microfossil types of both study areas as illustrated in Figs. 4-7. Possible environmental indications or origin of these palynomorphs are suggested in italics

don, Type 123, and Form A, suggest the primary origin is vegetable matter. Water input, either through diet or post-depositionally, is suggested by a number of aquatic or semi-aquatic palynomorphs such as *Nymphaea*, Zygnemataceae, *Botryococcus, Rivularia, Pseudoschizaea*, Type 128, Type 179, together with moss and fern spores. All of these spore types could also have been transported to dung through ingestion by cattle of stagnant, shallow, or open water.

As expected, the pollen spectra suggest that the environments from the two areas differ, with the Doornpoort site containing slightly less grass and Cyperaceae but more Chenopodiaceae. The Chenopodiaceae especially at Doornpoort may not strictly be indicating dryness and strong evaporation, as is usually the case with this family, but the presence of a disturbance weed, *moroho* (*Chenopodium album*) that is often used as food by traditional Africans.

In comparison with modern pollen spectra from the subtropical woodland area in the north (Scott 1982a), those of the Iron Age cow dung contained a remarkably low concentration of arboreal pollen (AP) for the area. Although modern bush encroachment as result of farming practices makes the modern vegetation unnaturally dense, the contrast between Iron Age dung samples and the modern spectra from both dung and soils is striking (Fig. 10). During the last two thousand years, the vegetation in the wider savanna region was apparently slightly more open than at present. This is suggested by pollen in spring and lake sediments (Fig. 10) from Scot (Scott 1982b), Tate Vondo (Scott 1987) and Wonderkrater, (Scott 1982a), the Pretoria Saltpan (Scott 1999) and Moreletta spruit (Scott 1984). The Iron Age cow dung samples from the woodland area, however, seem to indicate a much more open environment than these fossil spectra, possibly pointing to a vegetation mosaic with open veld near *kraals* and woody vegetation in the distance. The scarcity of tree pollen may be attributed to either human impact or climatic conditions. It can be expected that pollen composition in the dung is likely to reflect moisture conditions rather than mild temperature fluctuations of the late Holocene. Therefore high grass proportions in dung are probably due to good rainfall. Scott and Vogel (1992) suggested that during the wet periods or seasons, grass pollen frequency obscures tree pollen in hyrax dung. Warm, wet climates (like those that are thought to facilitate more intense settlement of Iron Age people (Huffman 1996), however, should produce both abundant tree and grass pollen and this is not the case in the fossil material, suggesting that climate was not the reason for sparse tree cover. Cool, dry conditions may result in relatively more tree pollen as long as these conditions do not involve frost that will prevent the flowering of trees. No doubt the grassy diet of cattle might also have played a role in obscuring the relative percentage of savanna pollen in their dung but the pollen analysis of fresh cow dung suggests that the bias in favour of Poaceae pollen by diet is not significant.

It is known that tree and shrub pollen increases in certain wooded areas in South Africa as result of bush encroachment due to over-grazing, (Scott 1987, Scott and Vogel 1992). We assume that encroachment was not intense during Iron Age times despite possible intense grazing in certain areas. The immediate surroundings of Iron Age settlements were probably open due to firewood clearance. Similar situations can be seen in modern examples from Botswana (Huffman 1996). Preliminary pollen analysis of soils from Silver Leaves, one of the earliest Iron Age sites in the eastern escarpment region (Scott and Klapwijk, unpublished data) supports the idea that *kraals* were treeless. It is possible that the herders confined cattle to open grassy areas that surrounded their *kraals* to keep them out of danger, but it is difficult to envisage that they permanently stayed in the close vicinity of the *kraals* without occasionally wandering into the distant surroundings.

The explanation for high grass pollen can however be more complex, for example that the activities resulting in slag formation occurred during the moist full summer season every year when grasses were in the peak of flowering and tree pollen production was relatively low.

When we view the fossil cow dung pollen from Study Area 2 as a chronological sequence (Figs. 6-7), no significant change in environment seems to occur over time (compared with Table 1), except that tree pollen disappeared in the younger samples (Fig. 6) suggesting the gradual removal of trees over time. The fossil spring sequences in areas that were less affected by human activity showed greater change in pollen composition that are apparently related to climate change (Scott, 1982a,c, 1984, 1987, 1999). It is therefore possible that cattle grazing and firewood clearance created an apparently uniform environment at places near Iron Age settlements, of which the pollen spectra were not markedly affected by climate change. Principal components analysis of all the Iron Age dung samples from both study areas, however, suggests that pollen composition was influenced to some degree by moisture change whether seasonal or long-term. In the first principal component (PC 1), moisture indicators such as Poaceae and Cyperaceae are contrasted against dryness indicators such as Asteraceae and Chenopodiaceae (Fig. 11).

Conclusions

Pollen concentration in fossil cow dung from Iron Age sites in southern Africa is often acceptable enough to reflect environmental conditions under which it formed. The open environments we see could be the *kraals* or wider surroundings of *kraals* that were cleared for firewood. The fossil pollen spectra from springs suggest that the areas at greater distances from *kraals* were well covered with trees although the vegetation must have been slightly more open than today. Therefore Iron Age people apparently did have a marked impact on the vegetation by creating open environments in areas where they farmed cattle.

Although the potential of cow dung for palaeoenvironmental reconstruction can presently only be demonstrated in the African context, similar deposits may eventually be discovered in other regions like India or Spain where the culture of cattle breeding has been well established for many centuries. However, more taphonomic control of the forming processes should be gained for this material to be fully useful in palaeoenvironmental studies. Experiments aimed at producing vitrified dung from fresh cow dung should be useful in explaining the origin and microfossil contents of the studied material. Stable carbon isotope composition could further be valuable to determine the relative proportion of C4 grass or other plants in the diet of the cattle.

Acknowledgements. Karl W. Butzer suggested this study but several years earlier Jannie Loubser provided the first sample from Bambo to Louis Scott. Frederick Scott and Makisang Nyakale helped with laboratory processing, and F. Gázquez and M.T. Escudero with artwork. We thank George Theron for permission to sample material on Doornpoort. J.S. Carrión thanks the Spanish CICYT CLI-97-0445-C02-01 project, and the DGICYT (PR95-209), Fundación Séneca (Comunidad Autónoma de Murcia), and Universidad de Murcia for granting stays in the University of the Orange Free State during 1996, 1997, and 1999.

References

Arnold JPH, Wet BC De (1993) Plants of southern Africa: names and distribution. Memoirs of the Botanical Survey of South Africa 62. National Botanical Institute, Pretoria

Carrión JS, Scott L, Vogel J (1999a) Twentieth century changes in montane vegetation in the eastern Free State, South Africa, derived from palynology of hyrax dung middens. J Quat Sci 14: 1-16

Carrión JS, Munuera M, Navarro C, Burjachs F, Dupré M, Walker MJC (1999b) Palaeoecological potential of pollen records in caves: the case of Mediterranean Spain. Quat Sci Rev 18: 67-78

Carrión JS, van Geel B (1999c) Fine-resolution Upper Weichselian and Holocene palynological record from Navarrés (Valencia, Spain) and a discussion about factors of Mediterranean forest succession. Rev Palaeobot Palynol 106: 209-236

Cooremans B (1989) Pollen production in central southern Africa. Pollen Spores 31 (1-2): 61-78

Dart RA (1931) The ancient iron smelting cavern at Mumbwa. Proc R Soc South Africa 19: 379

Davis OK, Agenbroad L, Martin PS, Mead JI (1984) The Pleistocene dung blanket of Bechan Cave, Utah. Special Publication Carnegie Museum of Natural History 8: 267-282

Dreyer JJB (1992) The Iron Age archaeology of Doornpoort, Winburg, Orange Free State. Navorsinge van die Nasionale Museum Bloemfontein 8: 261-390

Dreyer JJB (1997) Slag from Late Iron Age sites: Metal-working or cow dung? Research by the Cultural History Museum (Pretoria) 6: 94-103

Friede HM, Hejja AA, Koursaris A (1982) Archaeo-metallurgical studies of iron smelting slags from prehistoric sites in southern Africa. J South African Institute of Mining and Metallurgy 82: 38-50

Geel B van, Bohncke SJP, Dee H (1981) A palaeoecological study of an Upper Late Glacial and Holocene sequence from "De Borchert", The Netherlands. Rev Palaeobot Palynol 31: 367-448

Geel B van, Hallewas DP, Pals JP (1983) A Late Holocene deposit under The Westfriese Zeedijk near Eukhuizen (Prov. of Noord-Holland, The Netherlands): palaeoecological and archaeological aspects. Rev Palaeobot Palynol 38: 269-335

Geel B van, Coope GR, Hammen T van der (1989) Palaeoecology and stratigraphy of the Lateglacial type section at Usselo (The Netherlands). Rev Palaeobot Palynol 60: 25-129

Grimm EC (1987) Coniss: a Fortran 77 program for stratigraphically constrained cluster analysis by the method of incremental sum of squares. Computers and Geosciences 13: 13-35

Huffman TN (1996) Archaeological evidence for climatic change during the last 2000 years in southern Africa. Quat Int 33: 55-60

Iberall ER (1972) Paleoecological studies from fecal pellets: Stanton's Cave, Grand Canyon, Arizona. Unpub. Master's thesis, University of Arizona

Jarzen DM, Elsik WC (1986) Fungal palynomorphs recovered from recent river deposits, Luangwa Valley, Zambia. Palynology 10: 35-60

Martin PS, Sabels BE, Shutler D Jr. (1961) Rampart Cave coprolite and ecology of the Shasta ground sloth. American J Sci 259: 102-127

Low AB, Rebelo A (1996) Vegetation of South Africa, Lesotho and Swaziland. Department of Environmental Affairs and Tourism, Pretoria

Scott L (1982a) A 5000-year old pollen record from spring deposits in the bushveld at the north of the Soutpansberg, South Africa. Palaeoecol Africa 14: 45-55

Scott L (1982b) A Late Quaternary pollen record from the Transvaal bushveld, South Africa. Quat Res 17: 339-370

Scott L (1982c) Pollen analyses of Late Cainozoic deposits in the Transvaal, South Africa, and their bearing on palaeoclimates. Palaeoecol Africa 15: 101-107

Scott L (1984) Reconstruction of Late Quaternary palaeoenvironments in the Transvaal Region, South Africa, based on palynological evidence. In: Vogel JC (ed) Late Cainozoic paleoclimates in the southern Hemisphere. Balkema, Rotterdam, pp 317-327

Scott L (1987) Late Quaternary forest history in Venda, southern Africa. Rev Palaeobot Palynol 53: 1-10

Scott L (1989) Late Quaternary vegetation history and climatic change in the eastern Orange Free State, South Africa. South African J Bot 55: 107-116

Scott L (1999) Vegetation history and climate in the Savanna biome South Africa since 190,000 ka: a comparison of pollen data from the Tswaing Crater (the Pretoria Saltpan) and Wonderkrater. Quat Int 57/58: 215-223

Scott L, Vogel J (1992) Short-term changes of climate and vegetation revealed by pollen analysis of hyrax dung in South Africa. Rev Palaeobot Palynol 74: 283-291

Stanley GH (1934) On a specimen of supposed slag from the Mumbwa Cave. South African J Sci 31: 505-508

Tyson PD, Lindesay JA (1992) The climate of the last 2000 years in southern Africa. Holocene 2: 271-278

Vogel JC (1995) The temporal distribution of radiocarbon dates for the Iron Age in southern Africa. South African Archaeol Bull 50: 106-109