



Environmental reconstruction of a Roman Period settlement site in Uitgeest (The Netherlands), with special reference to coprophilous fungi

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Abstract

A palaeo-environmental reconstruction from the Roman Period settlement site Uitgeest-Dorregeest (northwestern Netherlands) based on samples of old soil horizons derived from sods used for building well walls is presented. The settlement was situated in an open landscape, not far from the coast, about 50 km north of the Roman–German border. The site has revealed archaeological evidence for local prosperity and trade with inhabitants of the Roman Empire. Pollen, other microfossils, fruits, seeds, mosses, mites and beetles indicate that the sods were taken from moist, slightly brackish, grazed meadows. The record of fungal spores points to the presence of dung. The various ascospore types, derived from coprophilous fungi that are generally neglected as palaeo-environmental indicators, have been described, illustrated, and their indicator value discussed.

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1. Introduction

Human impact on past vegetation can be deduced from pollen records, preferably in combination with the study of macroremains. An important anthropogenic environmental change at or near settlement sites is eutrophication resulting from the production of dung by high densities of domesticated herbivores. Also leaf-foraging, grazing, deforestation and crop cultivation could have a considerable impact on the natural landscape. Man and domesticated animals could have been responsible for a range of new habitats, and also the mycoflora of settlement sites and the surrounding arable land, pastures and hay-meadows could have different fungal assemblages relative to undisturbed natural ecosystems.

Pollen slides may contain a wide range of other microfossils, the study of which is a long-term research project of van Geel. Several hundreds of ‘Types’ have been distinguished in various deposits (peat, lacustrine sediments, samples from archaeological sites). Among the microfossils are fungal and algal spores and remains of cyanobacteria ([12], and references therein). Palaeo-ecological studies including the fungal remains show that some fungi represent a new and valuable category of anthropogenic indicators. In the present paper, we emphasise the indicator value of spores produced by Ascomycetes, which occur on the dung of mammals.

2. Site description

From 1980 to 1983 the Dutch State Service for Archaeological Investigations (ROB) carried out large-scale excavations of a Roman Period settlement site near

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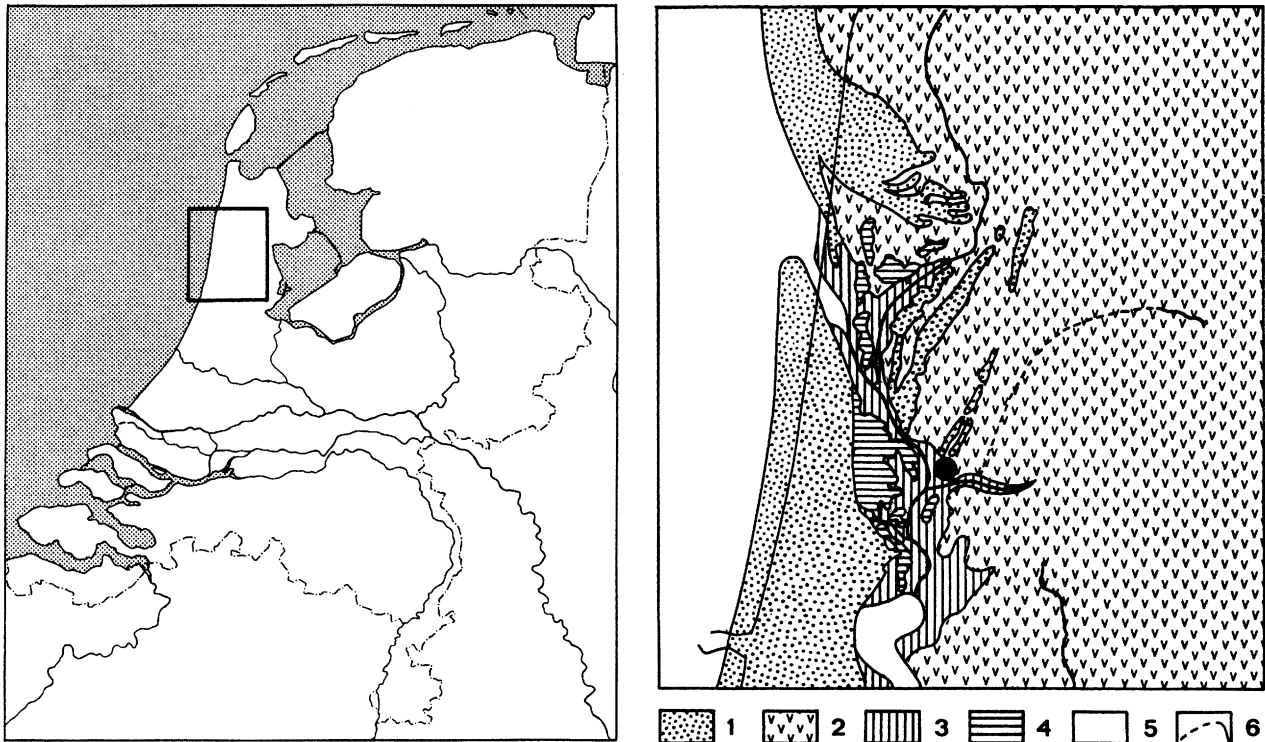


Fig. 1. Map showing the Roman Period settlement site near Uitgeest and its surroundings, scale 1:400,000. Legend: (1) beach barriers and older dunes, (2) peat, (3) marine deposits, clay, (4) marine deposits, sand and loam, (5) open water, and (6) rivulets.

the village of Uitgeest, location Dorregeest, in the province of Noord-Holland, The Netherlands [2,9,41,42]. The landscape development in this area was strongly determined by geological events occurring in the former IJ estuary [38,43]. The Roman Period habitation traces at the excavated site were concentrated on top of a small, relatively dry sandy ridge (Fig. 1). To the east of this ridge there were large raised bogs, and to the west, north and north-east there were relatively low marshes on clayey soils intersected by creeks. During the habitation in the Roman Period these creeks filled up with organic deposits and habitation debris. The lower areas surrounding the settlement must have been quite moist, especially during winter. The settlement features date from the first century BC until the third quarter of the third century AD. House-plans, wells and numerous ditches, probably connected with agriculture or horticulture, were excavated. Rows of small posts bordered the settlement at the west and north-east. These were probably fences to keep the domesticated animals in the pastures and away from the farmyards. At some places in these border areas human footprints and imprints of cattle-hooves were found.

Investigations of the numerous bones and plant remains have given an insight into the food economy; barley, emmer wheat, oats, linseed and horse-bean were cultivated (Buurman, unpublished data). However, there was only little space at the sandy ridge for crop culti-

vation, and cattle breeding was very important, evidenced by the large amounts of slaughter debris and the hoof imprints in the muddy banks. Also bones of horses, sheep, goat, pigs, chicken and dogs were found. The landscape offered a large grazing area for the herbivores. On the estuarine deposits natural grasslands must have developed on the salt marshes. Some samples from the settlement contained numerous remains of plants from salt marshes (Buurman, unpublished data). The archaeological evidence shows the prosperity of the inhabitants. Numerous luxurious and exotic goods, e.g. bronze vessels, ornaments, a *Buxus* wooden pan-flute and seeds of radish (*Raphanus sativus*) [2] were found, which must have been acquired by exchange. The 'treasure' of 1302 silver coins (denarii) points to trade with the inhabitants of the Roman Empire; the northern border being only 10 (until AD 30) to 50 km distant. It is known that especially in the period AD 150–250 there was much contact between the free Germans and the Roman Empire [21]. It is possible that the prosperity of the settlement was the result of trade in products of stock-breeding such as skins and hides, smoked meat, dairy products, wool and living animals.

Wells were concentrated near the houses on the sandy ridge. The linings of these wells were built up from sods (Fig. 2), which in some cases were founded on a wooden cart-wheel. These sods have been collected by cutting the vegetation-covered surface layer of soils in



Fig. 2. Excavated wells showing the sods which were used to build-up the linings of the wells.

the surroundings of the settlement. During the excavation it was observed that the old soil surfaces of the sods were still covered with well-preserved plant remains, the mosses were especially recognisable. Samples of the sods were taken in metal boxes, subsamples from these were taken for the study of microfossils and macroremains. The results of micro and macrofossil analysis of these sod samples are given in the present paper.

3. Material and methods

Sixteen samples of sod-surfaces were prepared for the analysis of microfossils [10]. Only four samples contained sufficient material for a complete analysis (Table 1). The microfossil slides of the other 12 samples were screened for the presence of coprophilous fungi (which were common in most of the samples). For microfossil types not illustrated in Plate 1 reference is made to descriptions and illustrations by van Geel [11], van Geel et al. [14,15,18] and Pals et al. [31]. Ascospores of the *Arnium imitans*-type (Type 262) and *Chaetomium* (Type 7A) were not recorded in the four samples (Table 1), but were of regular occurrence in some of the other samples.

Sixteen subsamples were analysed for macrofossils. The material was boiled for 5 min in a 5% KOH solution and strained through a sieve of $150 \times 150 \mu\text{m}$ mesh. Samples were analysed for fruits, seeds, vegetative plant remains and zoological material. Each subsample had a

volume of ca. 10 cm^3 only, which is very small for the study of macrofossils. Quantitative results per subsample are not relevant and therefore we show total numbers only. In Tables 2 and 3 we present the botanical macrofossil taxa (fruits/seeds and mosses, respectively). Moss remains could not be counted and therefore their presence has been indicated as + or ++. Tables 4 and 5 show the records of beetles (Coleoptera) and mites (Acari).

4. Interpretation

4.1. Botanical micro and macrofossils (Tables 1–3)

The pollen records indicate a treeless landscape (total tree pollen percentages varying between 3.2 and 9.1%). The construction of the wells with sods instead of wood may relate to the scarceness of trees in the surroundings. The presence of Cerealia pollen is not surprising in this anthropogenic context. They do not necessarily point to the presence of arable fields, but may originate from threshing of cereals. The relatively high pollen percentages of Poaceae, Asteraceae liguliflorae, Fabaceae, Lamiaceae and *Plantago lanceolata* point to grazed grasslands, which may have been regularly inundated (algae present in all four subsamples). Among the recorded fungal spores are various taxa indicative of the presence of dung: *Sporormiella*-type, *Podospora*-type, *Cercophora*-type, *Sordaria*-type and *Tripterospora*-type (Plate 1). Egg shells of the intestinal parasite *Trichuris*

Table 1
Pollen and other microfossils of four sod-samples

Sample no.	1	2	3	4
Trees				
<i>Abies</i>	–	+	–	–
<i>Alnus</i>	2.1	2.8	0.7	2.9
<i>Betula</i>	1.1	1.5	0.4	0.5
<i>Carpinus</i>	–	0.9	–	+
<i>Corylus</i>	0.8	0.2	–	–
<i>Fagus</i>	1.3	+	–	0.5
<i>Picea</i>	–	–	–	0.2
<i>Pinus</i>	0.6	1.0	1.9	4.8
<i>Quercus</i>	0.4	0.7	–	0.2
<i>Tilia</i>	–	–	0.2	+
Herbaceous taxa				
Apiaceae	+	0.4	0.2	0.2
<i>Artemisia</i>	–	0.7	0.2	0.2
Asteraceae liguliflorae	7.0	4.8	17.1	10.1
Asteraceae tubuliflorae	1.1	0.9	–	0.5
Brassicaceae	0.6	0.9	1.9	1.2
Caryophyllaceae	+	–	0.7	–
Cerealia (<i>Secale</i> included)	0.8	1.7	0.2	+
Chenopodiaceae	0.6	1.0	1.2	1.4
Cyperaceae	2.3	5.2	48.3	13.2
Ericales	0.4	0.4	–	0.2
Fabaceae	3.8	3.3	0.4	1.7
Lamiaceae	–	9.3	10.9	30.1
<i>Myrica</i>	–	0.2	–	–
<i>Plantago lanceolata</i>	27.2	3.7	–	1.4
<i>Plantago major/medica</i>	0.2	–	–	0.2
Poaceae (excl. Cerealia)	46.7	52.1	13.7	25.1
Poaceae epidermis (charred)	+	+	0.2	+
<i>Polygonum aviculare</i> -type	0.2	–	–	–
<i>Polygonum persicaria</i> -type	+	–	–	–
<i>Potentilla</i> -type	–	3.4	0.4	0.5
Ranunculaceae	1.1	2.0	0.4	3.9
Rosaceae undif.	–	1.0	–	0.2
<i>Rumex acetosa</i> -type	1.5	1.7	–	0.2
<i>Oxyria</i> -type	–	–	–	0.2
cf. <i>Triglochin</i>	–	–	0.4	–
Ferns and mosses				
Monoete psilate	–	–	1.4	0.5
<i>Pteridium</i>	0.4	–	0.4	1.2
<i>Sphagnum</i>	0.2	0.4	0.2	–
Algae and other aquatic taxa				
<i>Botryococcus</i>	–	–	0.4	–
<i>Pediastrum</i>	–	0.4	2.1	0.2
<i>Mougeotia</i> (Type 313F)	–	0.2	0.4	0.7
<i>Spirogyra</i> (Type 130)	–	0.2	–	1.2
<i>Spirogyra</i> (Type 132)	–	0.2	–	–
Type 128A	–	2.4	1.2	6.7
Type 128B	–	1.3	0.9	2.4
Type 367	–	–	0.4	–
<i>Riccia</i> cf. <i>sorocarpa</i> (Type 165)	–	+	–	–
Fungi^a				
Type 55A (<i>Sordaria</i> -type) ^a	1.3	1.7	1.2	1.2
<i>Cercophora</i> -type (Type 112) ^a	–	+	0.7	0.7
<i>Sporormiella</i> -type (Type 113) ^a	0.4	0.9	2.4	0.2
<i>Tripterospora</i> -type (Type 169) ^a	0.4	–	–	0.5
<i>Podospora</i> -type (Type 368) ^a	0.4	1.3	0.7	1.9
<i>Arniun</i> -type (Type 261) ^a	–	–	0.2	2.6
<i>Coniochaeta</i> cf. <i>ligniaria</i> (Type 172) ^a	+	–	0.4	0.2
Type 55B ^a	–	–	7.8	0.5

Table 1 (continued)

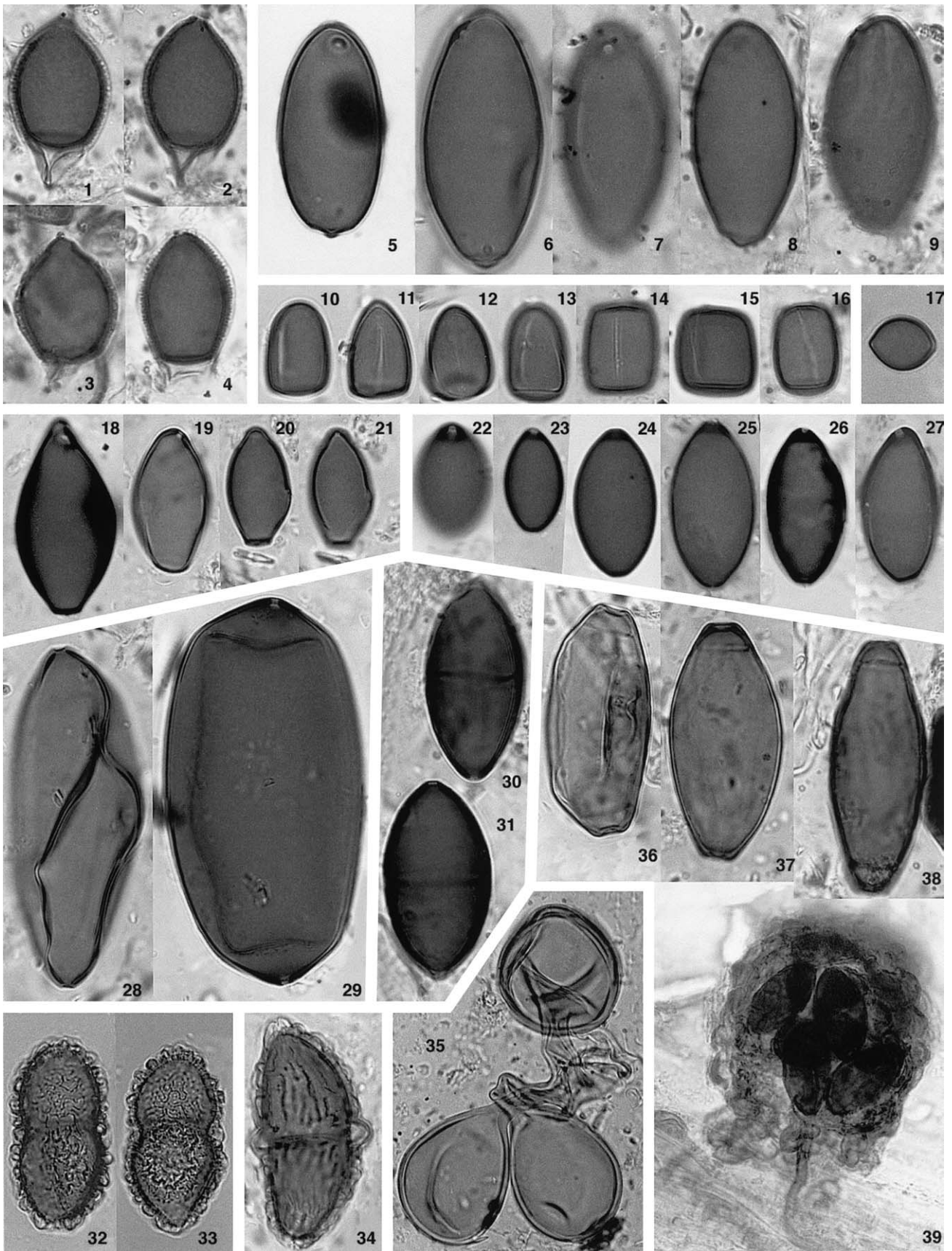
Sample no.	1	2	3	4
Fungi				
<i>Valsaria</i> -type (Type 263)	–	–	+	–
<i>Anthostomella fuegiana</i> (Type 4)	–	0.2	0.2	–
<i>Valsaria variospora</i> -type (Type 140)	–	–	10.9	–
<i>Diporotheca rhizophila</i> (Type 143)	–	+	0.4	0.5
<i>Tilletia sphagni</i> (Type 27)	0.2	–	–	–
<i>Gaeumannomyces</i> (Type 126)	–	0.2	1.6	0.5
<i>Glomus</i> (Type 207)	0.4	+	+	1.4
Microfossils of zoological origin				
Type 119	–	4.1	0.7	13.5
Type 179	–	+	0.2	–
<i>Arcella</i> (Type 352)	+	–	–	–
<i>Trichuris</i> (Type 531)	–	+	–	+

Percentages are based on total pollen per sample (+ means: observed after counting).

^aCoprophilous.

also point to deposition of excrements. More local environmental details can be derived from the record of fruits and seeds. The various taxa indicate damp to wet, mesotrophic to eutrophic meadows and ruderal sites.

In Table 2, the species found have been arranged according to their occurrence in present-day plant communities, according to Schaminée et al. [32–34] and Stortelder et al. [36]. The community *Asteretea tripolii* consists of typical saltmarsh plants. The *Plantaginetea majoris* occurs on heavily trodden places. Within this community, various indicator species of the *Lolio-Potentillion anserinae* alliance are present. This vegetation type is characteristic of transitional areas between wet and dry or salt and fresh water conditions. Grazing is also beneficial for the development of this vegetation where disturbed soils (probably as a consequence of trampling by domesticated herbivores) and some marine influence provide a suitable habitat for pioneers. *Molinio-Arrhenatheretea* vegetation comprises wet, grazed grasslands. The *Galio-Urticetea* occurs on nitrogen-rich soils. *Phragmitetea* vegetation is characterised by reed and other tall plants that border open water. *Parvocaricetea* species occur on damp places depleted in nitrogen. The *Isoeto-Nanojuncetea* community is characterised by pioneer species on poor soils. Species of *Stellarietea mediae* occur on cultivated fields. Additional evidence on the composition of the environment comes from mosses: *Calliergonella cuspidata* is a species of *Carex* fens and damp meadows. *Campyllum polygamum* is a slightly halotolerant species of calcareous coastal habitats, but it also occurs on mineral and organic soils at inland sites. *Drepanocladus aduncus* is a slightly halotolerant species on wet soils, often growing permanently inundated. *Rhytidiadelphus squarrosus* occurs from damp, wet meadows to open



forests, often occurring under anthropogenic influence. In general, the recorded mosses indicate damp to wet sites [37].

4.2. Beetles (Table 4)

Although the KOH treatment heavily affected the insect remains, and the samples were much smaller than regular insect samples, some additional information can be derived from these remains [25–27]. Only remains of adult Coleoptera were identified. *Atracthelophorus* and *Helophorus* (s. str.) species live in water or in wet mud banks [22]. All stages of *Cercyon convexiusculus* and the larvae of *Microcara testacea* live along fresh water edges. *Aphodius* species live predominantly in dung, preferably in droppings, *Anotylus rugosus* is also frequently found in droppings. *Enicmus transversus* feeds on fungi, frequently in decaying plant matter and also in manure. *Hypera venustus* feeds on species of *Anthyllis*, *Lotus*, *Trifolium* and *Vicia* [25]. None of these plant genera are represented as macrofossils, but seeds of Fabaceae are rarely preserved, unless they are carbonised. This weevil is found both at inland sites and salt marshes. In conclusion, the few beetle remains indicate the presence of water sides, dung, fungi and additional plant taxa.

4.3. Mites (Table 5)

The ecological preferences of mite species has been the subject of study by Schelvis. Different ecological groups have been distinguished [35]. The species *Scheloribates laevigatus* (most common in the Uitgeest samples), *Scutovertex sculptus*, *Trichoribates novus* and *Eupelops occultus* are members of an ecological group mainly occurring in damp to wet meadows (freshwater or brackish conditions). *Achipteria coleoptrata* is a species with a broad ecological amplitude, but it generally occurs within damp sites like banks and carrs. *Latilamellobates incisellus* and *Punctoribates hexagonus* point to brackish meadows, the latter species indicative of marine influence as is *Scutovertex pilosetosus*. *Uropoda orbicularis* and representatives of Macrochelidae and Parasitinae are dung indicators. Therefore, the mites indicate damp meadows with a maritime influence and presence of dung.

5. Discussion and conclusions

The pollen record shows that the region around the settlement was largely treeless. Macrofossils give more detail about local conditions at the sites where the sods were taken from. Soil disturbance by trampling, and grazing in salt marshes combined with temporary inundations by brackish water characterised the site. Additional evidence for grazing comes from the fungal spore record, this is dominated by dung-inhabiting taxa. Coprophilous fungi may be host-specific in the choice of their substrate (occurring only on dung of certain mammal species). The indicator value of coprophilous fungi is hardly used in environmental archaeology and with the present publication we would like to attract the attention of the palynologists studying material from archaeological sites. In raised bog deposits (relatively distant from settlement sites) the spores of coprophilous fungi are very rare, even during periods of intense human impact in the areas around these bogs [11], but samples from archaeological sites can be rich in these spores [3,14–16,19,40]. Apparently the dispersal and transport of the fungal spores is less efficient in comparison with tree pollen, probably partly due to the position of fungal fruit bodies near the ground, where wind dispersal is less effective. As a consequence, the records of spores of coprophilous fungi can be used as an indication for the presence of the animals near the sample site. This can be a source of information, especially in case where animal bones are not preserved.

6. Descriptions, illustrations and the indicator value of recorded ascospores

6.1. Type 55A: *Sordaria*-type, ascospores (Plate 1, 22–27)

These ascospores are one-celled, ellipsoidal, brown, 16–31 × 10–17 μm in size, with an apical pore about 1.5 μm wide. Wall around the apical pore is relatively thick and dark. The basal end of the spore is slightly flattened.

Type 55A spores probably were produced by various different species belonging to the (mostly coprophilous) Sordariales. Van Geel et al. [14], Willemsen et al. [40] and Buurman et al. [3] have recorded numerous

Plate 1. Fungal remains from sods used to build wells in the Roman Period settlement Uitgeest-Dorreegeest, The Netherlands. (1–4) Ascospores of *Tripterospora*-type (Type 169; 1000 ×). (1 and 2) High and middle focus of one individual spore, which also shows the remains of a hyaline basal pedicel; (5–9) ascospores of *Podospora*-type (Type 368; 1000 ×), (7 and 8) high and middle focus of one individual spore; (10–16) separate cells of ascospores of *Sporormiella*-type (Type 113; 1000 ×); (17) ascospore of *Chaetomium* (Type 7A; 1000 ×); (18–21) ascospores of *Cercophora*-type (Type 112; 1000 ×); (22–27) ascospores of *Sordaria*-type (Type 55A; 1000 ×); (28 and 29) ascospores of *Arniium*-type (Type 261; 1000 ×); (30 and 31) ascospores of *Arniium imitans*-type (Type 262; 1000 ×); (32 and 33) ascospores of *Valsaria variospora*-type (Type 140; 1000 × in high and middle focus); (34) ascospore of *Valsaria*-type (Type 263; 1000 × in middle and high focus); (35) chlamydospores of *Glomus* cf. *fasciculatum*, still attached by mycelium (Type 207; 500 ×); (36–38) ascospores of *Diporothea rhizophila* (Type 143; 1000 ×); (39) fruit-body with ascospores of *Diporothea rhizophila* (Type 143; 500 ×).

Table 2
Fruits and seeds

	Number	Asteretea tripolii	Plantaginetea majoris	Molinio-Arrhenatheretea	Galio-Urticetea	Parvocaricetea	Isoeto-Nanojuncetea	Phragmitetea	Stellarietea mediae
<i>Centaurium</i> sp.	1	+							
<i>Euphrasia/Odontites</i>	17	+							
<i>Glaux maritima</i>	1	+							
<i>Triglochin maritima</i>	1	+							
<i>Juncus gerardi</i>	135	+	+						
<i>Carex otrubaelvulpina</i>	1		+						
<i>Eleocharis palustris</i>	1		+						
<i>Plantago major</i>	6		+						
<i>Potentilla anserina</i>	6		+						
<i>Triglochin palustris</i>	2		+						
<i>Cerastium</i> sp.	2		+	+					
<i>Leontodon autumnalis</i>	1		+	+					
<i>Poa pratensis/trivialis</i>	1		+	+	+				
<i>Ranunculus acris/repens</i>	2		+	+	+				
<i>Agrostis</i> sp.	1		+	+	+	+	+		
<i>Sagina</i> sp.	2		+				+		
<i>Rhinanthus</i> sp.	4			+					
<i>Cirsium</i> sp.	1			+	+				+
<i>Urtica dioica</i>	5				+				
<i>Juncus articulatus</i> -type	151					+			
<i>Ranunculus flammula</i>	1					+			
<i>Juncus bufonius</i>	168						+		
<i>Scirpus setaceus</i>	7						+		
<i>Juncus effuses</i> -type	1							+	
<i>Scirpus lacustris</i> ssp. <i>tabernaemontani</i>	2							+	
<i>Typha</i> sp.	1							+	
cf. <i>Veronica anagallis-aquatica</i>	1							+	
cf. <i>Setaria</i> sp. chaff-fragment	1								+
<i>Sonchus asper</i>	1								+
<i>Danthonia decumbens</i>	4								
<i>Juncus</i> sp. (indet.)	8								
<i>Poa</i> sp.	1								
Poaceae undif., epidermis fragments	5								
<i>Potentilla</i> sp.	2								

Table 3
Mosses

<i>Calliergonella cuspidata</i>	++
<i>Campylium polygamum</i>	+
<i>Drepanocladus aduncus</i>	++
<i>Rhytidiadelphus squarrosus</i>	++
<i>Sphagnum</i> section <i>Acutifolia</i>	+

Table 4
Coleoptera

<i>Helophorus</i> (<i>Atracthelophorus</i> / <i>Helophorus</i> s.str.) sp.	1
<i>Cercyon convexiusculus</i>	1
<i>Anotylus rugosus</i>	1
Staphylinidae indet.	1
<i>Enicmus transversus</i>	1
<i>Longitarsus</i> sp.	1
<i>Aphodius</i> sp.	1
<i>Microcara testacea</i>	1
<i>Hypera venusta</i>	1
Curculionidae indet.	1

Nomenclature is done following the works of Lohse and Lucht [26] and Lucht [27].

Table 5
Acari

Oribatida:	
<i>Oribatula tibialis</i>	1
<i>Punctoribates hexagonus</i>	1
<i>Scheloribates laevigatus</i>	24
<i>Scheloribates latipes?</i>	1
<i>Scutovertex pilosetosus</i>	2
<i>Scutovertex sculptus</i>	1
<i>Latilamellobates incisellus</i>	1
<i>Trichoribates novus</i>	3
<i>Trichoribates trimaculatus</i>	2
<i>Eupelops occultus</i>	5
<i>Achipteria coleoptrata</i>	16
Oribatida (nymph indet.)	3
Oribatida (adult indet.)	11
Gamasida:	
<i>Uropoda orbicularis</i> (Gamasida; deutonymph)	1
Gamasida/Macrochelidae	1
Gamasida/Parasitinae?	1

Type 55A ascospores, together with spores of other coprophilous taxa, in deposits from settlement sites.

6.2. Type 112: *Cercophora*-type, ascospores (Plate 1, 18–21)

These ascospores are 13–27 (–36) × 6–14 (–18) μm in size, truncated at the basal side and tapering at the apical end. Subapical pore is ca. 0.7 μm in diameter. Ascospores with one septum also occur, and if so, there is no constriction at the septum. The fossil spores may

still have the hyaline appendage at the basal end. According to Lundqvist [29], representatives of the Sordariaceous genus *Cercophora* are coprophilous or occur on decaying wood and herbaceous stems and leaves. Van Geel [11] recognised fossil spores of the *Cercophora*-type for the first time, and Buurman et al. [3] recorded many spores of this type, in combination with other dung indicators, at a Bronze Age site in The Netherlands.

6.3. Type 169: *Tripterospora*-type, ascospores (Plate 1, 1–4)

These ascospores are 19–24 × 13–17 μm in size, ellipsoidal with somewhat eccentrically placed 11.5 μm wide germ pore at the apex, with the truncated base ca. 10 μm in diameter. Some spores still show the remains of ca. 9 μm long hyaline basal pedicel. Type 169 ascospores probably were produced by a coprophilous representative of the Sordariales [29] related to the genus *Tripterospora* (*Zopfiella*, see Ref. [28]).

6.4. Type 386: *Podospora*-type, ascospores (Plate 1, 5–9)

These ascospores are one-celled, ellipsoidal, smooth, brown and 39–48 × 16–23 μm in size, with one protruding pore 2 μm in diameter, directly below the apex. The pore is surrounded by an annulus and the basal end is bluntly conical.

Spores of the *Podospora*-type (coprophilous Sordariales; see Ref. [29]) are of regular occurrence in samples from archaeological sites [3,13,14].

6.5. Type 113: *Sporormiella*-type, separate cells of ascospores (Plate 1, 10–16)

Ascospores of extant *Sporormiella* species are three- to many-septate, smooth and dark brown. The septa are transverse to oblique, every cell showing an elongated germ slit, extending the entire length of the cell. Ascospores easily split up in separate cells, and as a consequence in the fossil state no observations of complete ascospores can be made. Nevertheless, the separate ascospore cells show sufficient features for identification. Species identification of *Sporormiella*-type is not possible because fruit-bodies, asci and complete ascospores are not available. Most *Sporormiella* species are coprophilous [1]. The representatives of the related, coprophilous genus *Sporormia* are without germ slits, but as the descriptions of Ahmed and Cain [1] are based on non-germinated spores, a slit may appear after germination of *Sporormia*-spores, and therefore we cannot exclude that also *Sporormia* is among our fossil spores.

Fossil cells of ascospores are of 14–21 × 11–17 μm in size. There are two types of *Sporormiella*-type cells: (i)

half-ovoid cells (Plate 1, 10–13) which are the terminal cells of ascospores, the flattened part originally forming the connection with the adjacent ascospore cell, and (ii) the central ascospore cells (Plate 1, 14–16) which are more or less cylindrical. All cells show an oblique to diagonal germ slit. Fossil spores of *Sporormiella* were distinguished by Davis et al. [6], Davis and Turner [5] and Davis [4] who concluded that ascospores of these coprophilous fungi can be used as indicators for increased population densities of herbivores. Samples from the N-Siberian site of the Jarkov mammoth (van Geel, unpublished) are rich in spores of the *Sporormiella*-type.

6.6. Type 7A: *Chaetomium* sp., ascospores
(Plate 1, 17)

These ascospores are one-celled, lemon-shaped, somewhat flattened in one plane, light brown and $6\text{--}12 \times 4\text{--}9 \mu\text{m}$ in size. The identification of extant *Chaetomium* species is mainly based on the characteristics of the intact perithecia with their apical tuft of bristles. These features are normally not observed in the fossil state.

Chaetomium species are common, saprophytic cellulose-decomposers occurring on cloth, leather, bones, feathers, decaying herbaceous stems, etc. They are seldom found on dung, except when it is mixed with straw [7,8]. Buurman et al. [3] mentioned high frequencies of *Chaetomium* ascospores as an indication of human impact from a Bronze Age site in The Netherlands.

6.7. Type 143: *Diporothea rhizophila*, ascospores
(Plate 1, 36–38)

These ascospores are biseptate, $47\text{--}52 \times 17\text{--}25 \mu\text{m}$ in size, fusiform, and with both truncate ends having a germ pore $2\text{--}3 \mu\text{m}$ in diameter. The surface is often with dark brown anastomosing ribs (not illustrated here, but see Ref. [17]). Fruit-bodies (see Plate 1, 39) ca. $100 \times 75 \mu\text{m}$, still with ascospores inside, were found in a sandy subsoil sample from one of the sods from Uitgeest. The fruit-bodies were, with their mycelium, in organic connection with unidentifiable rootlets.

Originally the genus *Diporothea* was classified as a representative of the Meliolaceae by Gordon and Shaw [20], but Mibey and Hawksworth [30] introduced the family Diporotheaceae to accommodate the genus *Diporothea*. Gordon and Shaw illustrated *D. rhizophila* and mentioned roots of *Solanum* species as the substrate of the parasitic fungus. In the material from the archaeological site Uitgeest we did not find pollen or seeds of *Solanum*, but *S. nigrum* or *S. dulcamara* would fit with local nitrogen-rich environments.

6.8. Type 207: *Glomus* cf. *fasciculatum*, chlamydospores
(Plate 1, 35)

Chlamydospores of *Glomus* occurred isolated in microfossil samples, but they were also observed—in clusters still attached by mycelium—in macrofossil samples. The spores of *Glomus* are extremely variable in size ($17\text{--}138 \mu\text{m}$). *Glomus* was especially common in Uitgeest samples taken from below the old soil surface, because it is an endomycorrhizal fungus occurring on the roots of a variety of host plants. Chlamydospores observed in lake deposits are indicative of erosion of soils in the catchment of the lake [18].

6.9. Type 140: *Valsaria variospora*-type, ascospores
(Plate 1, 32, 33)

These ascospores are uniseptate and slightly constricted, $28\text{--}40 \times 11\text{--}23 \mu\text{m}$ in size, inclusive of the $1\text{--}2 \mu\text{m}$ thick, undulating epispore, which is attached to the spore wall at regular intervals.

Fossil ascospores of the Type 140 often occur in deposits formed under eutrophic wet conditions [15,39]. The ascomycete *V. variospora*, as described by Hawksworth and Booth [23], has ascospores, which are quite similar to Type 140, as can also be seen in Ref. [24].

6.10. Type 263: *Valsaria*-type, ascospores
(Plate 1, 34)

These ascospores are uniseptate, ca. $42 \times 22 \mu\text{m}$ in size, inclusive of the characteristic velum, which forms longitudinal ribs and an equatorial ring around the septum. Like Type 140, these seem to be ascospores of a (different) member of the genus *Valsaria*.

6.11. Type 261: *Arnium*-type, ascospores
(Plate 1, 28 and 29)

These ascospores are one-celled, ellipsoidal, $52\text{--}86 \times 30\text{--}36 \mu\text{m}$ in size, with ca. $1.5 \mu\text{m}$ wide pore at both ends. The large spores are characteristic, but not with certainty identifiable to any genus. They seem to belong to a member of the Sordariales, most probably to the genus *Arnium*, which is one of the few genera with ascospores with two germ pores [29].

6.12. Type 262: *A. imitans*-type, ascospores
(Plate 1, 30 and 31)

These ascospores are uniseptate (with an indistinct, thin median septum), ellipsoidal, $38\text{--}41 \times 18\text{--}21 \mu\text{m}$ in size, with a ca. $1 \mu\text{m}$ wide, slightly protruding pore at both ends. They seem to belong to a member of the Sordariales, most probably to the genus *Arnium*, which is one of the few genera with ascospores with two germ

pores [29]. The genus has few species with septate ascospores, e.g. *A. imitans*, but the ascospore dimensions are too large.

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