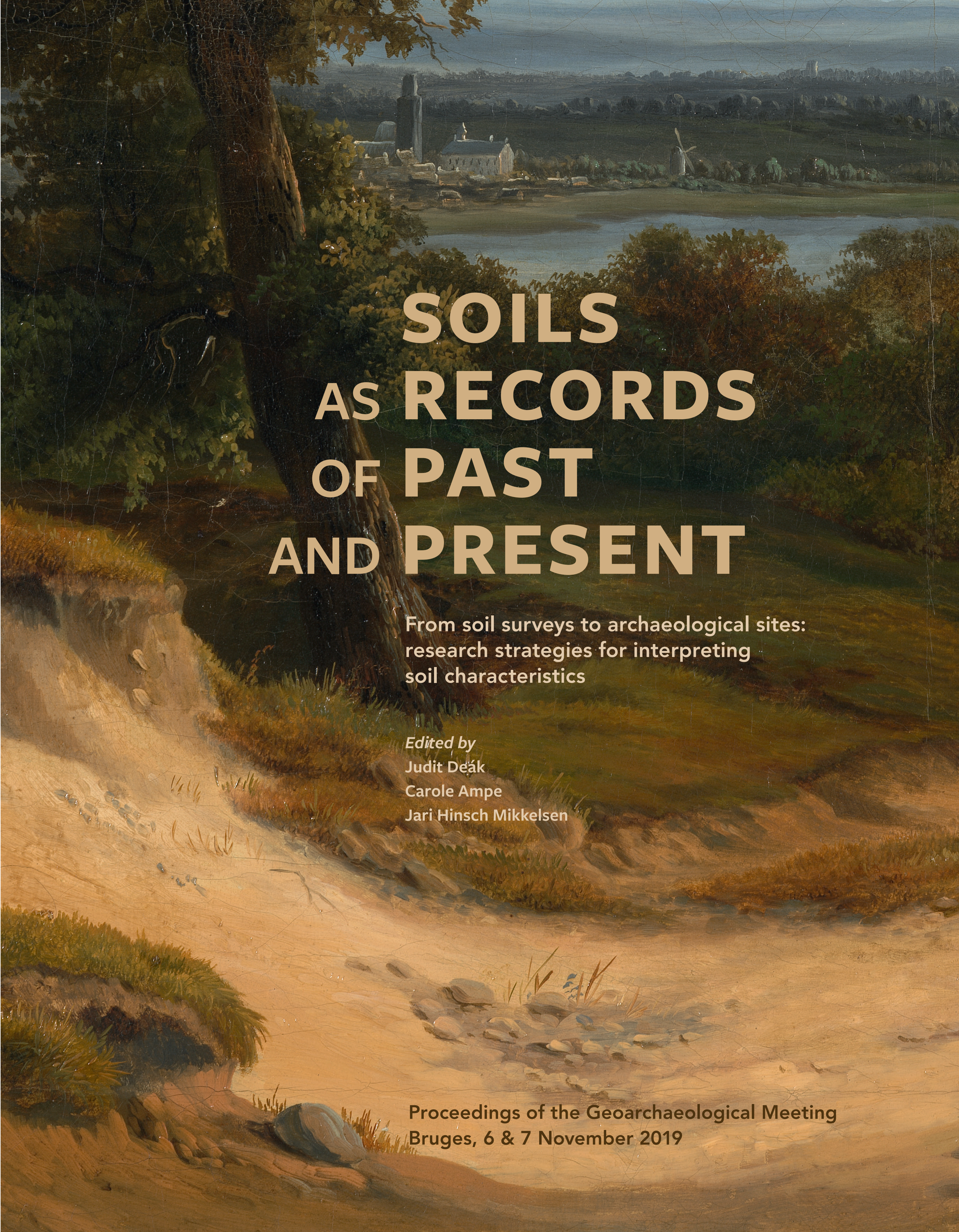

SOILS AS RECORDS OF PAST AND PRESENT

From soil surveys to archaeological sites: research strategies for interpreting soil characteristics

Edited by
Judit Deák
Carole Ampe
Jari Hinsch Mikkelsen

Proceedings of the Geoarchaeological Meeting
Bruges, 6 & 7 November 2019

This book is published on the occasion of the Geoarchaeological Meeting:

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TABLE OF CONTENT

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5. Present and future use of soil data

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Cover, p. 6
Landscape with cows near Oudenaarde (detail),
Jean Baptiste Daveloose

Soil collages p. 16, 87, 173, 261, 297

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THE BYRE'S TALE

Farming nutrient-poor cover sands at the edge of the Roman Empire (NW-Belgium)

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ABSTRACT
Prior to the construction of a high-speed railway track (TGV) between Antwerp (Belgium) and the Dutch border, archaeological and geoarchaeological research was conducted at several archaeological sites. All are situated in the northern Campine, a region characterised by quartz-rich, nutrient-poor cover sands. On the site of Brecht-Zoegweg, two well preserved deepened byres ('*potstallen*') were uncovered in Roman stable-houses. Stables with sunken floors are commonly recorded on Roman-period farms in the sandy part of northern Belgium. Following medieval to sub-recent parallels in the area, they are considered to be features serving agricultural fertilising purposes through the intentional accumulation of dung and the creation of manure by mixing with added organic matter (sods or 'plaggen'). This archaeopedological research investigates several questions concerning the origin and the infill process of these remarkable features. Field observations, analytical and micromorphological data point to a gradual succession of events leading to a byre with a sunken floor, rather than an intentional digging out of the floor concomitant with the house construction and a post-occupational filling or levelling. It is furthermore suggested that plaggen fertilisation could indeed have been applied, at least in some of the phases of the byre use.

KEYWORDS
byre, *potstal*, cover sands, Gallo-Roman period, northern Belgium, soil micromorphology, archaeopedology

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1. The Roman byre on the cover sands

Late prehistoric and Roman period farm construction in the Northwest European plain was essentially characterised by the dominance of the so-called stable house: a timber-framed construction in which humans lived together with their animals under the same roof, with the stabling part generally taking up one third of the total floor surface, often over the total width of the house. Several studies have pointed to the importance of this *Hauslandschaft* for the socio-economic and cultural understanding of these early farming societies living on the poorer, sandy soils (Haarnagel, 1979; Zimmermann, 1999; Roymans, 1996, and De Clercq, 2012). It appears that the household, the house, and cattle were closely intertwined elements in rural society, even on an ideological level (Roymans, 1999; Roymans and Gerritsen, 2002). Notwithstanding the swift introduction of various new aspects of farming techniques, these century-old local housebuilding traditions continued to be applied during the Roman period. In fact, in the middle Roman period (ca. 70-270 AD) and, more specifically, on the cover sands of NW-Belgium and SW-Netherlands, the tradition was even intensified (De Clercq, 2011). Probably following economic pressure on the acid, gradually depleting sandy soils (Groenman-Van Waateringhe, 1983), timber farmhouse architecture was modified, giving way to the construction of larger stable-houses from the 2nd century to the late 3rd century AD and onwards. This increase in surface, however, was not related to the space covered for human housing, but to the area used for (cattle) stabling (byre) and storing (attic) purposes (De Clercq, 2011: 245). More importantly, the concept of the stable itself seems to also have been altered. Whereas before the floor levels for human and animal parts were equal, after ca. 150 AD the stabling areas became deepened.

Morphological identical stabling features with a sunken floor called ‘potstal’ are common to the north of Belgium and other rather poor areas more to the northeast from the middle ages up until quite recent periods (Lindemans, 1952, 349; Spek, 2004).

The term *potstal* (byre) (Domhof, 1953; Zimmerman, 1999) in itself is not precisely defined. It is a Dutch word that refers to a stable with a floor lower than the rest of the farmhouse and where animals were kept overnight and/or during winter (Mücher et al., 1990). The concept in itself occurs in various regions, periods, and cultures throughout the NW-European cover sand plains. Importantly, the presence of a byre is usually linked to an agricultural management system, carried out to improve soil fertility in oligotrophic sandy heathlands. Turf sods, or plaggen, are collected from the outfield areas (heather, forest, marshy areas) and spread out at the bottom of the byre where they function as an absorbent bedding and become mixed with urine and excrements of the stabled animals, hence increasing the sheer volume of organic matter (manure) to be spread on the arable infields as a fertiliser. By penning the animals in deepened stables, not only can the direct access and safety to them be better controlled, but also the spatial concentration of their excrements and therefore, even enhanced in volume. Furthermore, a sunken byre filled with manure provides good insulation against frost, which came in through the floor more than through the walls and roof (Zimmermann, 1999). This is similar to a soil management technique known from India, where potassium and nitrogen rich soil from underneath the stable is dug out and is used to fertilise fields (Chiel, 2012, 19).

While the occurrence of a field management system using a sunken floor, byres, is suggested for the Roman period in the Campine region, based on the morphological similarities with more recent parallels, it has never been demonstrated from an analytical point of view (Leenders, 2003).

This study investigates for the first time archaeopedologicaly, if such a similar management system could have been applied in the Roman period and if the deepened stabling parts are indeed related to such a system. The investigation approach presented here completes already existing research methods used to unravel parts of buildings, dwellings, etc. Perhaps the best-known example is the application of phosphate analysis. Well planned, thoughtful and focused research during the excavation often gives clear insight into whether a certain structure was used as a stable. The approach developed in northern France can serve as an example (Broes et al., 2012). It is also clear that this approach is complementary to the one presented here.

2. The Roman stable-houses at Brecht-Zoegweg

During the preliminary field investigations preceding the construction of the railroad track between Antwerp and the Dutch border, it became clear that at four locations further archaeological excavations were necessary to document the Iron Age, Roman and Medieval settlements present underneath the future track. The excavations were conducted on behalf of the Belgian Railroads and co-ordinated by the Province of Antwerp (Delaruelle et al., 2004). At three of the sites, Ekeren-Het Laar, Brecht-Hanenpad, and Brecht-Zoegweg plaggen soils were present widespread (De Coninck, 1958, 1959a, 1959b, 1960a, 1960b). On these three sites (Figure 1) thorough archeopedological research was carried out (Mikkelsen et al., 2002a, 2002b, 2002c,

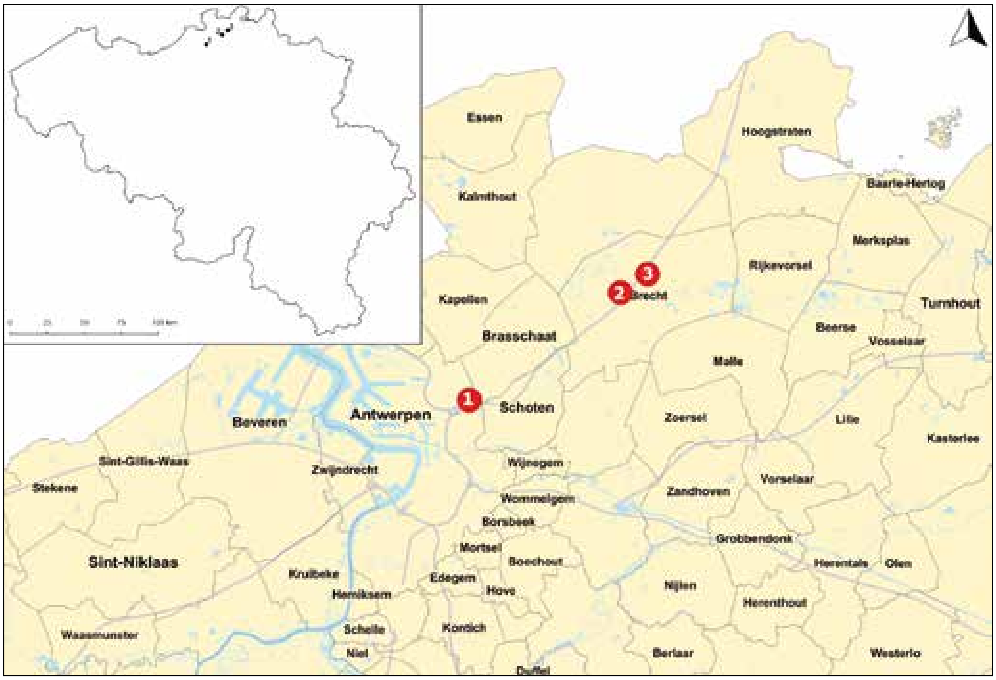

Figure 1. Map northern Belgium with the location of the three archaeological excavations:
1. Ekeren-Het Laar
2. Brecht-Zoegweg
3. Brecht-Hanenpad

2002d). Together, the sites form an almost continuous rural settlement landscape from the early Iron Age onwards.

One site, Brecht-Zoegweg, is particularly interesting due to the presence of stables with a sunken floor. At this site, the first settlements in the form of a few isolated buildings could be dated to the middle Iron Age (475/450-250 BC). From the early Roman period, a farming community settled and occupied the site until the last quarter of the 3rd century. Traces from the early (402-900 AD) and high medieval period (900-1200 AD) were excavated as well (Bungeneers et al., 2004).

At the site, 17 main buildings could be identified (Delaruelle et al., 2004). In six of these stable-houses, all belonging to the later occupation phases, a dark greyish-brown soil infilling was delineated. These humus-rich deposits were observed in the north-eastern part of the houses and covered the full width of 4-8 m. They are characterised by a 60-80 cm deep sunken floor covered by a thick fill of largely homogeneous, humus-rich greyish-brown earth. The humus-rich soil corresponds to the farmsteads' stable and would as such be called a *'potstal'* or a byre.

The two best preserved byres were selected for more detailed archaeopedological studies (Mikkelsen et al., 2002d). The large farmstead (S14) is approximately 28.5 m long and 7.5 m wide (Figure 2; Figure 3). The stable may be up to 18 m long and includes two large postholes. Based on ceramic finds, the building was dated to 175-225 AD. The slightly smaller byre S47 is 27 m long and 6 m wide and is ceramic-dated to 80/90-150 AD (Figure 2).

Figure 2. Excavation plan of the large byre S14 (above) and the slightly smaller byre S47 (below). © Heritage Service, Province of Antwerp.

Figure 3. View on byre S14 from the Brecht-Zoegweg excavation. Notice the thick humiferous horizons. A small brook running into the Weerijsbeek is located about 50 m to the right of the structure.

3. The present day soilscape

At the central part of the site Brecht-Zoegweg, the soils are composed of light sandy loam and are characterised by humus-iron B-horizons with a gley horizon starting between 80-120 cm depth and a clayey substrate starting at less than 125 cm depth. Secondary loamy sandy plaggen soils are present with a moderate dry to moderate wet drainage class (De Coninck, 1959a, 1959b). During the archaeological excavation, it was noted that the plaggen soils were heavily influenced by levelling and deep ploughing. Particularly on the original higher landscape positions, significant parts of the archaeological record were destroyed through deep ploughing.

The region is composed of flat to gentle sloping interfluvia, alternating with very gentle valley slopes and meandering rivers and tributaries. With the intensification of agriculture and the introduction of a plaggen infield-outfield management, the landscape was partly levelled and organic-rich soil material was brought onto the fields as fertiliser. This offered some protection to the archaeologically interesting layers that occur today, buried below two to four plough layers of up to 80 cm cumulative thickness. Considering that the original A and E/B horizons are locally preserved, the soil surface was raised before the first ploughing. The introduction of the plaggen infield-outfield management in general has been suggested from the 6th to the 8th century AD and onwards (Von Fastabend and von Raupach, 1962; Von Mückenhausen et al., 1968).

Due to a relatively high groundwater table, widespread oxido-reduction is observed as rusty mottles and concretions. In the deeper structures excavated, such as the water wells, the Campine Clay and peat layers could be observed, possibly belonging to the late Pleistocene Formation of St.-Lenaarts (De Ploey, 1961, 57).

4. Methodology

During the fieldwork, lateral and vertical soil variability and the presence or absence of special soil characteristics were recorded. Field sketches were made of the profiles, indicating horizons, positions of sampling, and special characteristics. The site, archaeological structures, and soil profiles were described and sampled according to the Handbook for Comprehensive and Adequate Field Soil Data Bases (Langohr, 1994) and the Guidelines for Soil Profile Description (FAO, 2006). More specific archaeo-pedological field checklists were used when needed (Fechner et al., 2004).

In the laboratory, texture was determined by Robinson pipette (<50 μm) after dry sieving (>50 μm) and the destruction of organic matter. Bulk density is the calculated average weight of 4-7 samples of each 100 cm^3, dried for 24 hours at 105 °C. pH: is the water/soil ratio of 1/1. For organic matter we used the method of wet combustion, applying potassium dichromate and H_2SO_4. Total Nitrogen: according to the Kjeldahl method of wet oxidation, using sulphuric acid and K_2SO_4. Extractable basic cations: Na, Mg, Ca and K were measured with an atomic absorption spectrophotometer. Cation Exchange Capacity (CEC): by adding ammonium acetate and using spectrocolometry. Citrate-bicarbonate-dithionite (CBD) extractable Fe and Al were obtained following the method of Mehra and Jackson (1960). Organic, inorganic, and total phosphor were analysed by adding H_2SO_4 and subsequently ammoniummolybdate and ascorbic acid, thereby measuring the blue colour in an unburned (inorganic P) and a burned (total P) sample (Mikkelsen et al., 1996).

Special undisturbed samples were impregnated with polystyrene resin (Stoops, 2003). Soil thin sections, 30 µm thick, were studied under the petrographic microscope, and descriptions followed the international guidelines of Stoops (2003). Detailed micromorphological descriptions were effectuated, though only the elements useful for the discussion are highlighted. A more systematic presentation of this micromorphology data is the object of a paper to be published in a subsequent research phase.

5. Physical and chemical aspects of the byre sediments

5.1. Byre S14, profile P1

Byre S14 was divided into 17 squares, each measuring 2 m by 3.5 to 4 m. This provided approximately 75 m of vertical soil profiles that were all examined. A detailed sampling strategy for laboratory analyses and a micromorphological study were performed on three soil transects.

Profile S14-P1 is a 2 m wide soil transect studied centrally in the byre (Figure 4). The particle size distribution divides the soil horizons (H) into three units: H1-2, H3-7, and H8 (Table 1), suggesting a difference in deposition. The organic carbon content is stable throughout H1-6, with a peak in the dark brownish H7. The nitrogen-carbon rate increases with depth, possibly because the deeper horizons are more liable to nitrogen leaching if reducing conditions prevail at the base for some time every year; the organic matter content remains stable throughout. Very low values of dithionite extractable iron suggest that

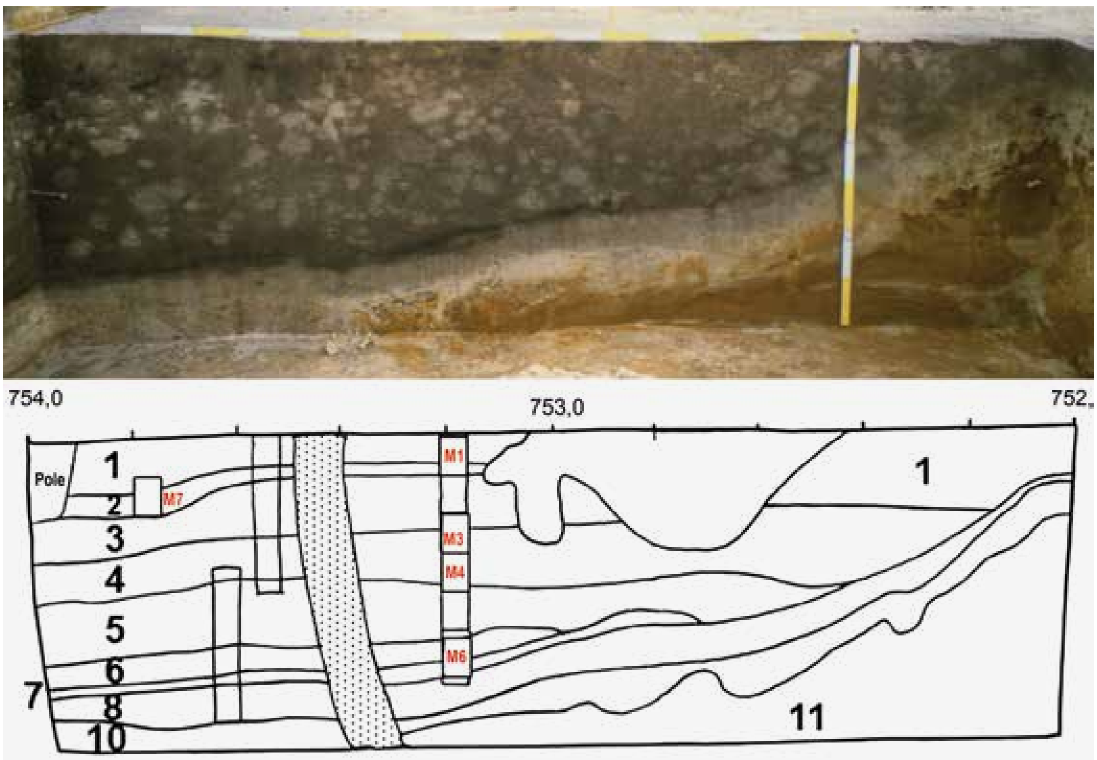

Figure 4. Photo and sketch of profile S14-P1. In the deepest part of the byre, the thin black layer (H7) was interpreted in the field as a wooden floor. The sketch indicates the horizons (black numbers), the micromorphology samples (red numbers), and the sampling zone for laboratory analyses (dotted).

Table 1. Analytical data for byre S14, profiles P1, P2 and P4a

Profile	Horizon	Depth	Particle size (μm, %)[a]								Org.	Total	C/N[b]
			<2	2-20	20-50	50-100	100-200	200-500	500-1000	1000-2000	C.	N.	
		(cm)									(%)	(%)	(%)
S14-P1	1	0-4	4.5	7.1	7.9	14.5	33.7	30.9	1.1	0.3	0,43	0,035	12
	2	5-8	4,8	8,0	8,0	14,3	36,0	27,9	0,9	0,1	0,62	0,043	14
	3	12-17	5,8	4,6	13,4	19,1	36,0	20,3	0,8	0,0	0,29	0,021	14
	4	20-26	5,9	5,6	11,9	17,2	37,9	20,5	0,8	0,2	0,55	0,033	17
	5	28-34	5,9	6,1	12,4	19,3	35,2	19,8	0,8	0,5	0,56	0,036	16
	6	38-43	6,1	4,7	11,5	18,0	38,5	20,0	1,0	0,2	0,54	0,032	
	7	44-47	6,6	6,2	11,7	18,1	35,4	20,9	0,9	0,2	1,24	0,074	17
	8	49-54	3,6	4,7	9,2	16,5	40,9	23,6	1,3	0,2	0,24	0,012	20
S14-P2	1	1-8	5,2	5,4	11,8	19,1	35,6	22,0	0,8	0,1	0,39	0,030	13
	3	10-17	4,2	3,9	10,8	17,5	40,5	22,2	0,9	0,0	0,25	0,015	16
	5	40-47	7,2	6,5	13,0	19,3	34,3	18,7	0,8	0,2	0,72	0,044	16
	Pole-1	36-44	4,7	3,4	8,4	15,5	39,0	27,1	1,5	0,4	0,17	0,015	12
	Pole-2	48-56	4,7	3,2	3,5	11,0	34,8	40,6	1,8	0,4	0,09	0,009	10
	Pole-3	64-72	7,3	4,3	12,3	18,3	36,4	20,5	0,8	0,1	0,16	0,017	9
	11	81-89	6,7	0,4	0,1	19,6	55,4	17,1	0,5	0,2			
	10	32-39	9,2	5,2	4,3	22,1	42,5	16,7	0,0	0,0	0,06	0,012	5
S14-P4a	SS										5,27	0,082	64
	3b	0-10	6,9	6,2	12,6	20,2	34,1	19,2	0,8	0,0	0,43	0,029	15
	4b	10-17	7,3	6,4	11,4	18,6	33,2	18,8	2,3	2,0	0,58	0,027	22
	25	17-26	5,2	4,8	11,1	18,2	34,0	24,9	1,5	0,3	0,23	0,015	16
	8	26-32	3,1	2,5	4,4	9,7	32,9	44,3	2,9	0,2	0,07	0,006	11

Profile	Horizon	Exch. basic cations				CEC/	BS[c]	Dith. Cit.	P_2O_5			pH	Thin
		Ca^{++}	Mg^{++}	K^+	Na^+	soil		Fe_2O_3	Organic	Inorganic	Total	H_2O	section
		cmol(+)/kg soil by NH_4OAc					(%)	(%)		(%)		(1:1)	no.
S14-P1	1	0,6	0,08	0,083	0,016	2,8	28	0,07	0,002	0,064	0,065	6,0	M1, M7
	2							0,07	0,017	0,045	0,062	5,9	M1, M7
	3	0,9	0,16	0,130	0,021	2,6	47	0,02	0,028	0,014	0,041	6,0	M3
	4							0,03	0,039	0,032	0,071	5,8	M3, M4
	5	0,7	0,12	0,146	0,026	3,4	29	0,03	0,005	0,048	0,053	5,6	M4
	6							0,04	0,003	0,017	0,020	5,6	M6
	7							0,06	0,021	0,014	0,034	5,5	M6
	8	0,6	0,10	0,098	0,018	2,2	37	0,03	0,001	0,009	0,010	5,5	M6
S14-P2	1							0,03				5,9	
	3							<0,02				5,9	
	5							0,02				5,0	
	Pole-1							0,11				5,4	M9
	Pole-2							0,28				5,0	
	Pole-3							0,04				4,7	M11
	11							0,28				5,5	
	10							0,04	0,005	0,068	0,011	4,8	
S14-P4a	SS							1,93	0,010	0,842	0,852	5,9	M28
	3b	0,5	0,09	0,261	0,069	3,4	27	0,07	0,023	0,045	0,069	5,1	
	4b	1,0	0,16	0,270	0,025	5,6	26	0,41	0,020	0,141	0,161	5,3	M29
	25	0,8	0,12	0,155	0,011	2,9	37	0,07	0,013	0,062	0,075	5,9	
	8							0,03	0,009	0,005	0,014	6,2	

[a] % of fine earth fraction [b] Ratio carbon-nitrogen [c] Base saturation

iron has been leached out of the soil, possibly related to a fluctuating water table, although it cannot be excluded that the accumulated earth was poor in iron. The lowest level of phosphorus is found in H6-8 and the highest in H4. Despite the observed peaks, the concentrations of phosphorus are, in general, remarkably low.

5.2. BYRE S14, PROFILE P2

Profile S14-P2, 2.5 m long, is situated perpendicular to S14-P1. It offers insight into the sedimentary characteristics from one of the central postholes towards the northern house wall (Figure 5).

The three humiferous horizons (1, 2, 3, Fig. 5) have a uniform texture, but show little similarities with the texture of the posthole (sandy texture) and the parent material (sand to loamy sand). Their loamy sand texture is comparable with the humiferous horizons of the previous profile. This suggests that the earth material had a similar source, different from what is found in the immediate vicinity of the byre. The content of iron oxides is very low in the humiferous horizons, slightly higher in the upper part of the posthole and in a part of the parent material.

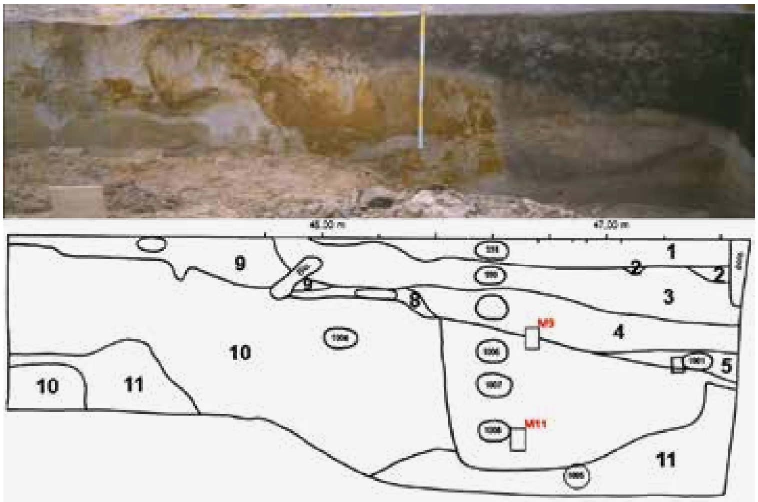

Figure 5. Photo of profile S14-P2, with the dark greyish brown humiferous horizons on top (H1-4) covering the central posthole (PH). The sketch indicates the horizons (black larger numbers), the samples for laboratory analyses (smaller black numbers in circles), and the micromorphology samples (red numbers).

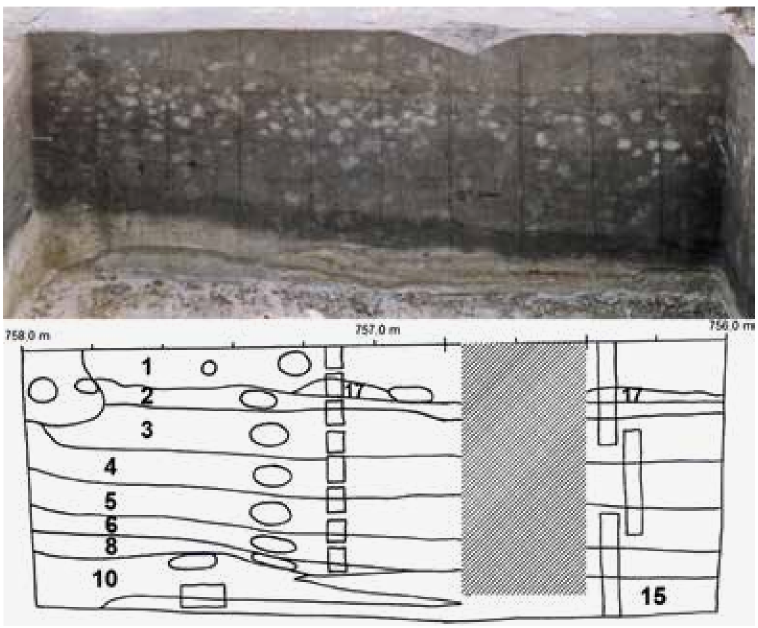

Figure 6. Photo and sketch of S14-P3. The sketch indicates the horizons (black numbers) and the zone where samples were taken for determining the bulk density (hatched).

5.3. BYRE S14, PROFILE P3

For profile S14-P3, bulk density measurements provides an insight into the soil density in function of the depth. A relatively higher density in H6 (62-67cm) may reflect a more intense phase of trampling in the byre (Figure 6 and 7). A rather high bulk density, just below the humiferous horizon (H15), cannot be explained entirely by the higher clay content. Trampling, with reduction of the original soil porosity (Rentzel et al., 2017) before the stable was enriched with soil clods, could explain the denser structure.

5.4. BYRE S14, PROFILE P4A

Profile S14-P4a, 3.5 m long, is located towards the south-western limit of the byre (Figure 8). At this location, the humiferous horizons merely reach 30 cm thickness and are characterised by a peculiarly high concentration of charcoal and pinkish-reddish soil material. The horizons H3b, H4b and H25 have a similar texture (loamy sand), while H8 is significantly different, with less clay, silt and fine sand, and considerably more medium sand. The fraction coarser than 2 mm is composed of iron concretions, charcoal, and burned soil aggregates. One sample, collected explicitly in the central part of the remains of a possible fire pit, contained a high amount of organic carbon, iron oxides, and extremely high concentrations of phosphorus (0.85 % P_2O_5). This suggests that bones have been burned.

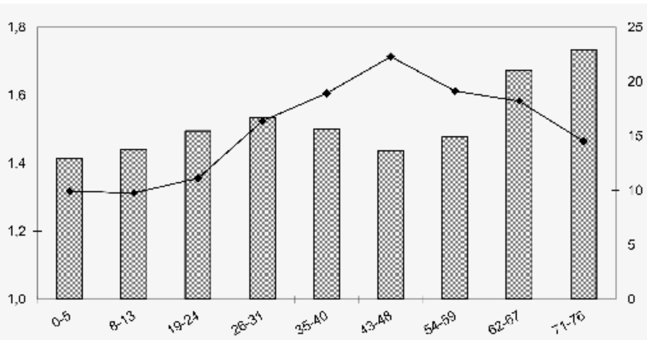

Figure 7. Bulk density (black line) and actual water content (dashed line) for profile S14-P3. Left: bulk density in g/cc, right: % water. Below: depth in cm.

5.5. BYRE S47, PROFILE P2A

This reference profile of the smaller byre S47-P2a is 4 m long and 57 cm deep (Figure 9). The profile is built up of, more or less, horizontal horizons that disappear towards the walls of the building. Interesting are the whitish sandy spots in H4 and H5. They are remains of individual soil clods. Based on bulk density measurements, it seems the soil is most compacted at a depth between 23-32 cm (Figure 10). Possibly, this is due to trampling by animals, or it is a buried living floor (Rentzel et al., 2017). The texture of H1-5 (humiferous horizons) is very different from that of H10-11 (parent material). The distribution of organic matter is relatively homogeneous, suggesting a good mixing of the upper humiferous horizons, which again, may be the result of animal trampling. Very high C/N (Table 2: H5) ratios at the bottom of the byre, where very little or no mixing has occurred, provide arguments for a vegetation of sods from a heathland or a coniferous forest. Organic matter accumulation as a result of *in situ* vegetation development cannot be invoked as no evidence of meso or macrofauna was found in the horizontal sections made during the fieldwork.

The C/N ratio together with the physical and chemical parameters of S47-P2a suggest an interesting interpretation concerning the field observed morphology of the soil horizons. It seems that the deeper part of the byre was filled with soil fragments from various soil horizons. This filling was sufficiently thick so that the deeper part of

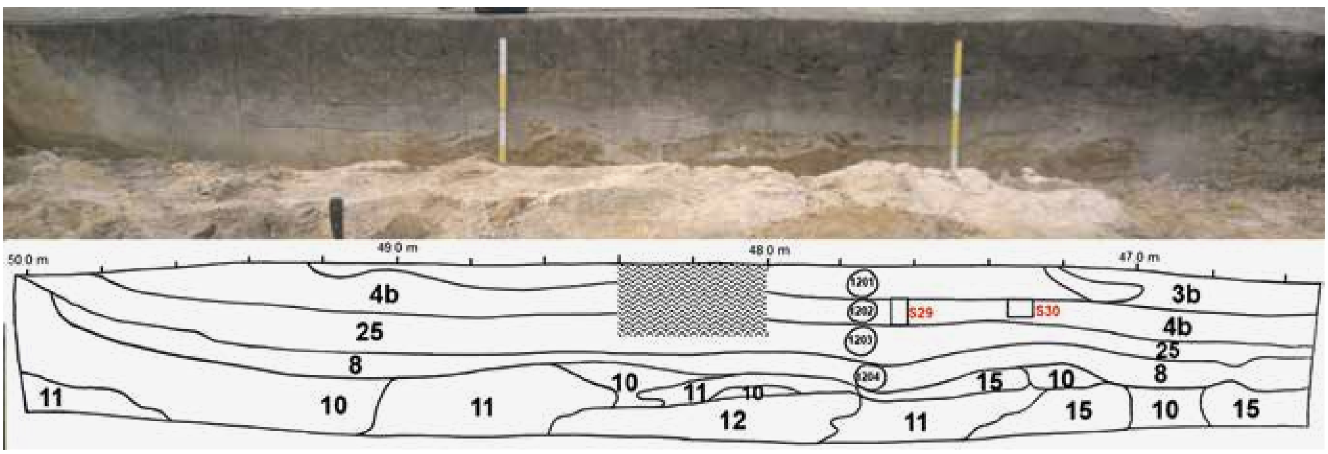

Figure 8. Photo and sketch of profile S14-P4a. The sketch indicates: the horizons (black larger numbers), the samples for laboratory analyses (smaller black numbers in circles), the two micromorphology samples (red numbers), and the special samples for analyses of the fraction coarser than 2 mm (dashed surface).

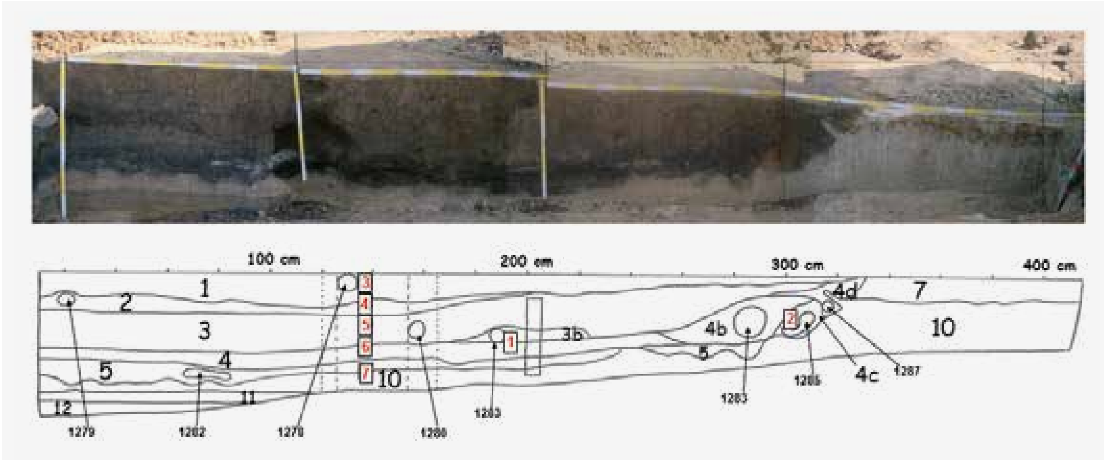

Figure 9. Photo and sketch of profile S47-P2a. The sketch indicates the horizons (black larger numbers), the sampling for laboratory analyses (smaller black numbers associated to circles), and the micromorphology samples (red numbers).

the byre was never homogenised. Here, we still find remnants of the original material of Podzol horizons like the Bs, Bh, and even E-horizon material. The high C/N ratio in the deeper part of the byre also indicates a soil that would typically form under heathland (Rove et al., 2006). In the upper horizon, the mixing was much better. Here, no fragments of the original soil are visible and the C/N ratio is much lower.

H5 is not part of the humiferous horizons, but is part of the parent material, enriched by accumulation of organic material. It is possible that a certain degree of anthropic mixing occurred when the byre was emptied. Then, a first layer of material was added (H4) and shortly afterward, possibly in different phases, H3 was accumulated. This occurred while the animals had ample time to accumulate 0.5 % phosphorus. Towards the surface, H1 and H2 contain significantly lower concentrations of phosphorus. This could be related to a younger phase of the building, but with a different use than cattle housing.

5.6. BYRE S47, PROFILE P3B

The posthole in S47-P3b (H6) cuts through H3 (Figure 11), indicating that this and the underlying horizons are older than the posthole and that the posthole is older than H1 and H2. Whether this means that the byre has gone through at least two life cycles remains an open question. This seems quite possible when we look at the phosphorus concentrations in function of depth (S47- P2a, P2b, P3b) (Table 2). In all vertical sequences, H1 and H2 contain considerably less phosphorus than H3 and H4. This seems to imply that the original byre starts from H3 and downwards. Later, the building was reconstructed (posthole 81/462) and humus-rich material accumulated inside again (H1-2). This time, however, it may not have functioned as a byre. In any case,

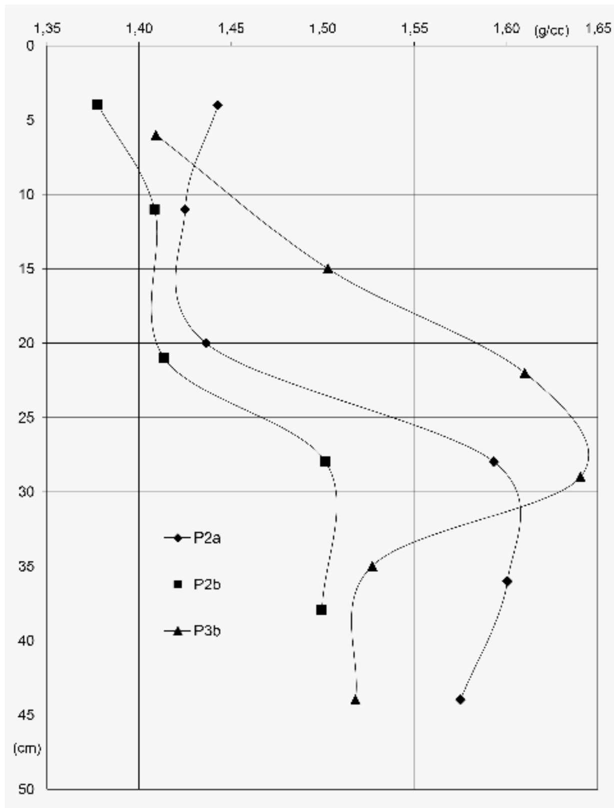

Figure 10. The bulk density in function of depth for byre S47, profiles P2a, P2b, and P3b.

Table 2. Analytical data for byre S47, profile P2a

Profile	Horizon	Depth	Particle size (µm, %)[a]								Org. C.	Total N.	C/N[b]
		(cm)	<2	2-20	20-50	50-100	100-200	200-500	500-1000	1000-2000	(%)	(%)	(%)
P2a	SS										0,50		
	1	0-10	5,8	7,4	13,7	19,2	36,1	16,7	1,0	0,1	0,45	0,038	12
	2	10-16	7,0	12,2	14,0	19,3	33,7	12,9	0,6	0,3	0,44	0,035	13
	3	16-30	4,2	9,6	13,2	20,0	34,7	16,5	1,3	0,5	0,52	0,035	15
	3b	20-26	18,9	14,5	8,9	16,5	21,6	8,9	5,7	5,0	0,31	0,039	8
	4	30-36	3,0	7,9	13,2	20,7	38,5	16,0	0,6	0,1	0,70	0,035	20
	5	36-40/45	2,6	4,7	6,7	14,6	55,7	15,4	0,3	0,0	0,55	0,015	37
	4b	9/22-25	3,7	7,9	12,2	19,0	39,6	16,2	1,1	0,3	0,99		
	4c	13-19	5,2	6,3	11,8	16,4	43,6	15,4	0,9	0,4	0,43		
	4e	18-23	2,7	2,5	2,7	8,6	72,3	10,6	0,4	0,2	0,33		
	4d	7-13	4,6	5,1	9,3	15,9	49,4	14,6	1,0	0,1	0,43		
	10	40/45-47	0,7	0,1	0,1	2,9	77,4	18,4	0,2	0,2			
	11	47-52	0,8	0,1	0,1	1,9	78,7	13,1	3,9	1,4			

Profile	Horizon	Exch. basic cations				CEC/	BS[c]	Dith. Cit.	P_2O_5			pH	Thin
		Ca^{++}	Mg^{++}	K^{+}	Na^{+}	soil		Fe_2O_3	Organic	Inorganic	Total	H_2O	section
		cmol(+)/kg soil by NH_4OAc					(%)	(%)		(%)		(1:1)	no.
P2a	SS							0,05				5,9	
	1	0,6	0,09	0,26	0,02	3,3	29,2	0,12	0,058	0,027	0,085	5,7	M3, M4
	2	1,5	0,24	0,25	0,10	4,5	46,4	0,18	0,023	0,140	0,163	5,9	M4
	3	1,5	0,20	0,18	0,02	4,7	40,5	0,23	0,033	0,511	0,544	5,9	M5
	3b	9,9	1,80	0,36	0,11	15,3	79,5	1,38	0,022	0,133	0,155	5,9	M1
	4	2,2	0,23	0,11	0,02	4,5	56,7	0,14	0,013	0,047	0,060	6,1	M1, M5-6
	5	2,6	0,27	0,06	0,01	4,5	65,4	0,12	0,011	0,060	0,071	6,1	M7
	4b								0,024	0,236	0,260	5,8	M2
	4c							0,10	0,012	0,116	0,128	5,6	M2
	4e							0,29	0,003	0,230	0,233	5,6	
	4d								0,005	0,084	0,089	5,5	
	10												M7
	11												

[a] % of fine earth fraction [b] Ratio carbon-nitrogen [c] Base saturation

no clear phosphorus peak was measured. A change from cattle to sheep breeding does not explain for the decrease in phosphorus. In cattle dung, the average concentration of phosphorus (P_2O_5) is 2.9 kg per ton of manure and for sheep and goats the concentration is 3.5 kg per ton, which is very similar (Vlaamse Landmaatschappij, 2016, Table p. 7). It should be noted that the measurements are based on present day cattle and sheep breeding, where cattle are kept inside year-round and sheep are usually not.

5.7. BYRE S47, THE SLOPING BYRE FLOOR

Sunken byres frequently occur with flat bases, but locally deepened areas within the byre, (shallow) pits and sloping levels, also occur (Laloo et al., 2008). S47-P3b shows a slightly sloping byre base, where the thickness of the humiferous horizons is reduced over several meters. In S47-P2a, the outer profile boundary shows a more average degree of steepness. This can be interpreted in various ways. While the boundaries of the stable to the exterior walls of the house are fixed, those inside the building may have varied from time to time. It is quite possible that the byre was larger during the years when the herd was more extensive, and vice versa. As a result of such a flexible boundary between the inside space dedicated to the byre versus the living space, a less steep slope developed. Another suggestion is that the deeper part was used for large cattle, and the shallower part - approximately from the posthole in P3b and towards the boundary of this profile - for smaller animals, such as goats and sheep. A last

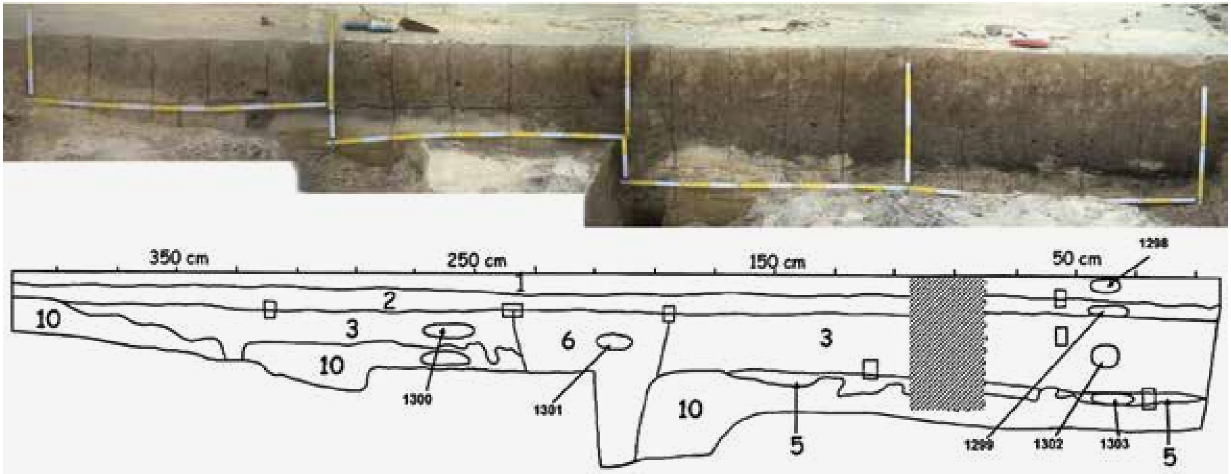

Figure 11. Photo and sketch of byre S47 profile P3b. The sketch indicates the horizons (bigger black numbers), the samples for laboratory analyses (smaller black numbers), and where samples were taken for bulk density (hatched zone).

interpretation, adopted by the authors of this paper, is that the sunken floor of the byre is the result of the regular recovering of manure whereby small quantities of bottom sand of the byre were removed to leave a clean floor. By this process, a gradually deepened section of the house is created. Close to the walls of the building, where less manure can accumulate and where the soil is less intensively trampled, less soil material was removed. The result is a shallower floor towards the byre walls versus the more intensively used central part of the house. Similar observations were made during the excavation at Gent-Kluizendok (Laloo et al., 2008).

Table 3. Phosphorus data for byre S47, profiles P2b, P3b and posthole 82/462

Profile	Horizon		Depth	P_2O_5		
				Organic	Inorganic	Total
	no.	symbol	(cm)		(%)	
P2b	1		1-7	0,030	0,118	0,148
	3		13-19	0,029	0,582	0,610
	4		26-33	0,008	0,320	0,328
	5		35-40	0,016	0,219	0,235
	7	C2	4-9	0,003	0,123	0,126
	10	C1	22-28	0,001	0,000	0,001
P3b	1		1-7	0,037	0,106	0,142
	2		12-18	0,028	0,095	0,124
	3	left	14-22	0,018	0,410	0,428
	3	right	23-30	0,020	0,202	0,222
	5		40-43	0,010	0,899	0,909
81/462	6	upper	20-25	0,018	0,254	0,271
	6	central	42-52	0,004	0,134	0,138
	6	lower	66-76	0,012	0,062	0,074
	10	below	90-100	0,004	0,039	0,042

6. Soil micromorphology of the byre sediments

6.1. BYRE S14, PROFILE P1

The soil material consists mainly of quartz sand. In addition, sub-rounded to rounded, un-weathered to slightly weathered glauconite grains are also present. In the deeper horizons, the glauconite is more weathered. This indicates a possible 'profile inversion' whereby the current deepest soil material originates at least partly from surface horizons that have undergone stronger weathering.

Many angular to sub-angular flint fragments are observed, ranging from 0.2 to 0.5 mm, with a few up to a few mm in size. It is practically impossible to distinguish between debris of flint artefacts and artefact production (chips) and natural flint (Angelucci, 2017).

Opale phytoliths occur in all horizons, except H6 and H7. They do not seem to have been burned. This is a typical characteristic of grasses such as cereals and other plants with high silicate content. The floor of a stable can be characterised by a thick layer of large phytoliths (Courty et al., 1989, 115-125; Vrydaghs et al., 2017), which are part of the manure and urine when the organic material is digested by oxidation.

Sclerotia (remains of certain fungi, Chet et al., 1969) occur in most horizons of the byre. They are all fragmented, indicating that the soil has moved and became disturbed, possibly when the sods were cut on the heathland and transferred to the byre. It may also be the result of trampling in the byre.

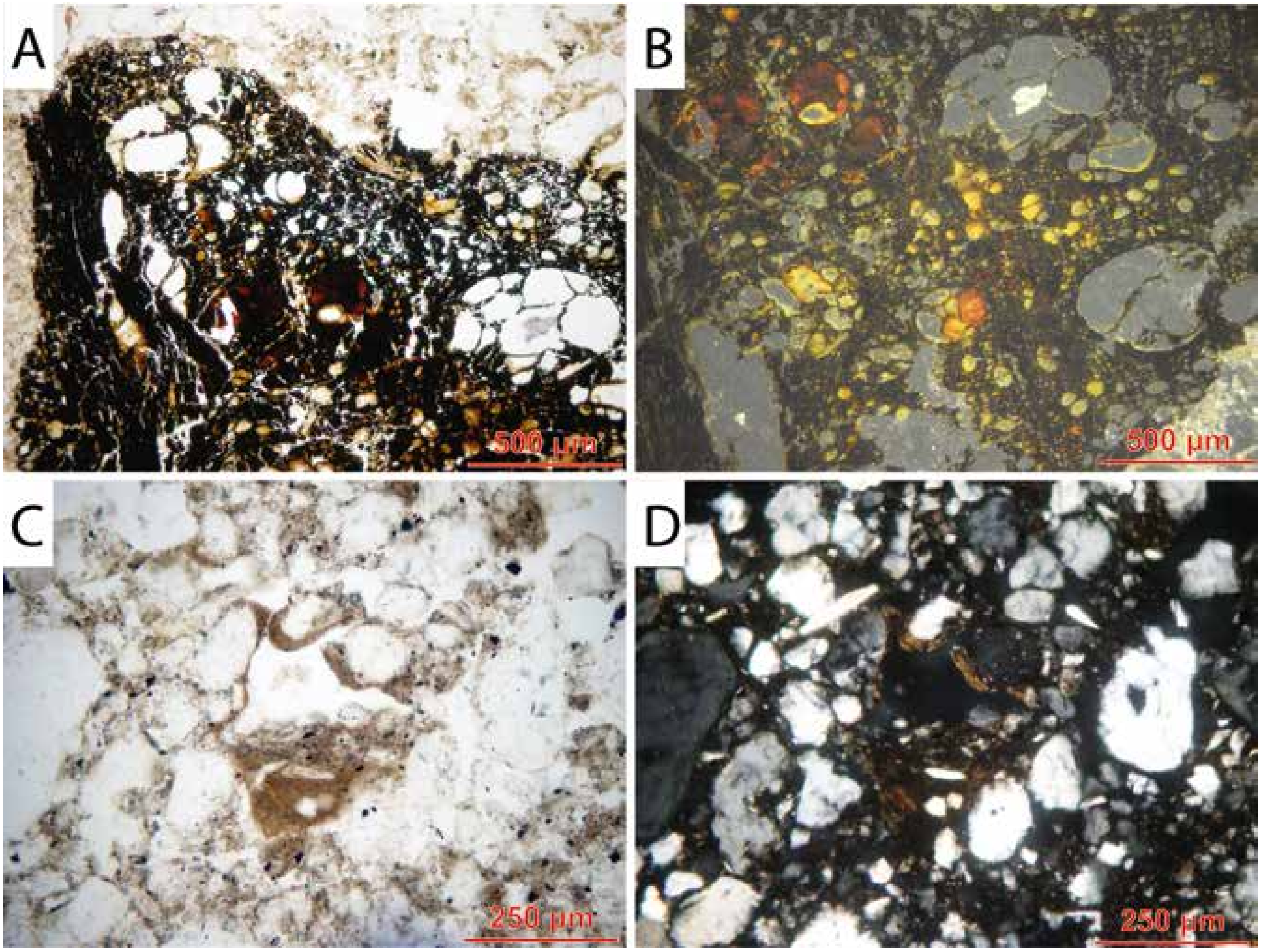

Figure 12. Soil micromorphological photos from byre S47, profile P2a. **A**: Charcoal filled with iron-rich limpid clay (H1, 0-7 cm; PPL + OIL). **B**: Same pedofeatures as photo A (XPL+OIL). **C**: Present-day incomplete dusty clay and silty coating with sandy top coating. (H1-2, 9-16 cm. PPL). **D**: Same pedofeatures as photo C (XPL). Silty parts slightly birefringent. PPL: plane polarized light. XPL: crossed polarizers. OIL: oblique incident light.

Charcoal is observed throughout the humiferous horizons, except in H3 and H7. The absence of charcoal in H7 is interesting. Already during the field research, the origin of this horizon was questioned, as it occurs as a thin black line in the soil sequence. Charcoal was found in the thin sections both above and below H7, but not in the horizon itself. It is suggested that H7 could be the remnant of a wooden floor. If this is the case, the planks have not been burned. However, there are no micromorphological pedofeatures that confirm or reject the theory of the wooden floor. The charcoal is scattered over several horizons and does not occur in large concentrations. It occurs usually in the shape of small pieces of less than one mm. This distribution pattern can suggest three hypotheses. Firstly, the stable burned down. This is unlikely given the size and distribution of the charcoal throughout the soil. Secondly, the charcoal was already present in the field, due to the deliberate or accidental burning of the vegetation. This would imply that this vegetation would have consisted largely of shrubs and trees, since heather and grasses produce mainly ashes and only small amounts of charcoal when burned. In acidic soils, ash weathers relatively quickly, unlike charcoal (Courty et al., 1989, 113; Canti, 2017; Canti and Brochier, 2017). The third, and the most likely, explanation is that the charcoal was added regularly to the byre, as for example after cleaning the fireplace used for cooking. This waste was probably thrown between the animals, that, with time, would mixed it with the humiferous material. At the site Brecht-Ringlaan, located 3.5 km to the northeast of Brecht-Zoegweg, several byres were excavated (Bracke et al., 2015). One byre was studied more in detail, including sieving bulk samples of the byre fill. This revealed a large fraction of micro waste. Dumping the household waste in the byre was given as an explanation

(Van Quaethem, 2016). Indeed charcoal, just like bark, has a very high C/N ratio so when it is added to a nitrogen-rich environment, it will immediately adsorb nitrogen and potential smells.

Dusty coatings are observed in all studied profile horizons except H1. Such dusty coatings are often associated with agricultural activities because of the presence of bare soil with increased water infiltration. However, it is known that the presence of dusty coatings alone is insufficient to conclude that the soil has undergone agriculture (Macphail et al., 1990; Deák et al., 2017). The observed coatings often are not only very dusty, but also contain loam and even visible grains of sand (Figure 12: photo C and D). The development of such coarse coatings requires a soil environment characterised by a strong sudden infiltration of liquid. One of which is indeed inside a byre, where the soil is unprotected by vegetation and the animals urinate regularly. This can result in a relatively concentrated amount of liquid that infiltrates and penetrates the soil in a short period. Horizontal dusty crusts (Figure 13: photo G) are described for H3-4 (common), H4 (few), H6 (very few) and H8 (even fewer). As they are often associated with open spaces and as they are still in their original horizontal deposition, it indicates that the soil didn't become mixed after the development of these pedofeatures. The described crusts are an indication of a vegetation-free sedimentation environment, where the soil builds up in horizontal layers that always fossilise and protect the underlying crusts. Crusts can form on the soil surface through splash if little or no vegetation grows on it, but as soon as the soil is tilled, they become fragmented and lose their orientation.

In H2, H4, H7, and H8 cross-layered clayey pedorelicts were observed. It is assumed that this originates from the deeper geological layers, possibly the Campine Clay. Clay was used for many household purposes: for walls, floors, and kitchen equipment. The fragments were not burned, so they are not ceramic fragments. In H2 and H3-4 ceramic fragments were observed under the microscope.

6.2. BYRE S14, PROFILE P2

In the upper part of this profile, sampled at the edge of the posthole and H4, glauconite, flint, phytoliths, charcoal, dusty coatings, dusty crusts, iron, and clayey pedorelicts were observed. The discussion and interpretations made for S14-P1 also apply to these thin sections. In addition to the pedofeatures already mentioned (glauconite, sclerotia, charcoal fragments, few dusty clay coatings), a flint fragment that may have been cracked by fire and many thin limpid clay coatings were described in the thin section from the deeper part of the posthole. The limpid clay coatings are in situ.

6.3. BYRE S14, PROFILE P4

One thin section was sampled in H4b. It is very heterogeneous and polygenetic. Dusty clay coatings can be associated with cattle trampling. The frequent concretions cemented with iron-rich clay clearly do not originate from the soils of the surrounding area. Some concretions may contain iron phosphate, but this was not analysed further. Embedded in the larger charcoal fragments are secondary iron and dusty coatings (Figure 12: photo A and B). In the soil's fine material, clay phosphate coatings occur (Figure 13: photo H). Both types of coating indicate that the soil has undergone a period of highly active iron phosphate and clay migration. This was probably due to an increase in pH when ash and charcoal were added to the soil. Furthermore, there are many pedorelicts. Some have been burned, others not, but they all consist of the same clayey soil material. These may be the remains of a clay floor or walls that were burnt down.

6.4. BYRE S47, PROFILE P2A

Mineralogically, the soil material consists mainly of unweathered quartz, sub-angular and never rounded. Glauconite is also very common, slightly weathered to weathered. In H3 the glauconite is weathered with a reddish-brown colour, but some grains are also un-weathered. In situ weathering of glauconite seems excluded. Probably, the glauconite has its origin in the variety of soil materials that have been mixed in the byre.

Opal phytoliths occur in H1-5 and H7-8. In H1-2 the concentration is high. Such phytoliths are common in 'grasses'. These may have ended up in the byre with the soil material or as hay used as winter fodder.

Flint occurs in H3-8. It is typically angular in shape, but semi-rounded fragments were also observed. The very large (up to 2.5 mm diameter) fragments are interesting. These fall completely outside the textural pattern of the soil. The most logical explanation is that the flint was among the materials that were brought into the byre by man, possible from material brought from the nearby brook valley.

Charcoal occurs in all horizons, except in H8. It is generally larger than that observed in the larger byre (S14), although the large fragments are often broken. Considering the variation in size and the in situ breaking of the larger fragments, it seems most plausible that the charcoal here is originating from the cleaning of a fireplace. One piece of charcoal (Figure 13: photo A and B), with a size of 2.4 mm, is interesting as it is filled with limpid clay. Such a process takes place in a very stable environment, such as a soil under a forest cover. In a byre, clay and humus migration resulting in dusty coatings would be more likely. This fragment is, therefore, a pedorelict that was brought into the byre.

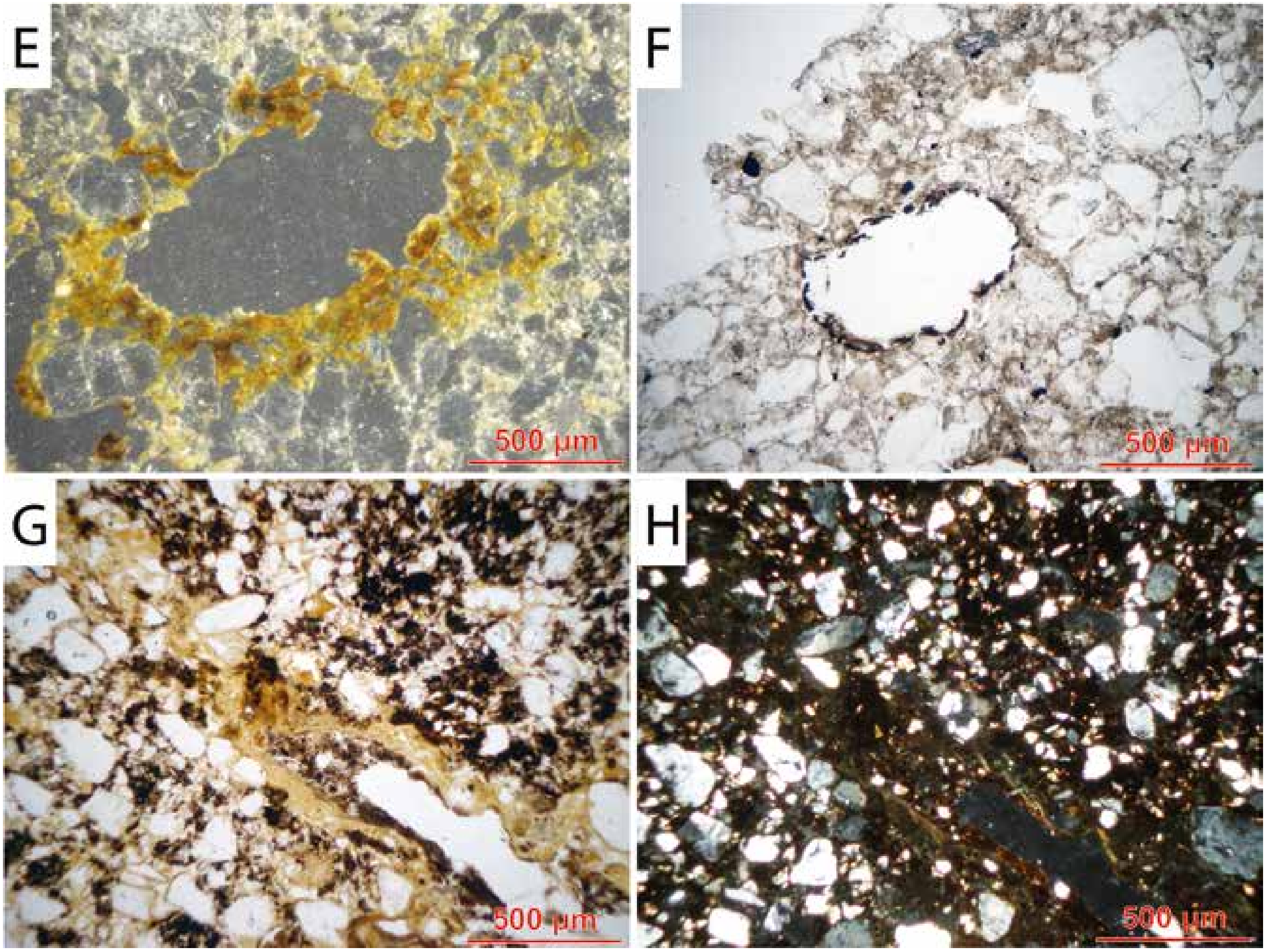

Figure 13. Soil micromorphological photos from byre S47 profile P2a. **E**: Iron stains around the open space indicate an environment with oxido-reduction. In addition, the iron is mobilised from the matrix and deposited around the open spaces where oxygen is available, indicating a strongly reduced environment of the "gley" type (cf. marsh soils). (H1-2, 9-16 cm: XPL+OIL). **F**: Broken, non-birefringent coating of organic material in open space, (H1-2, 9-16 cm; PPL). **G**: Phosphorous-rich clay coating. No birefringence. (H3-4, 26-33 cm; PPL). **H**: Same clay coating as for photo G (XPL).

Sclerotia occur in H1, H3, H4, H6, and H7. They are fragmented, indicating a certain degree of transport and/or trampling.

One pedorelict, 7 mm in size, was observed in H1; this pedorelict has a fine texture, suggesting that it stems from the geological substrate. That such a large fragment has been preserved indicates that H1 was not bioturbated by trampling of cattle and has not been homogenised by any other process since this relic was introduced into the byre sediment. This is an additional argument for interpreting H1 as a levelling layer after the demolition of the building.

Dusty coatings are particularly common in H3, but also occur in several other horizons. They have various forms such as typical coatings, crescentic coatings, capping in macropores, and dusty coatings. They indicate that the soil has been subject to rapid infiltration/percolation of liquids mixed with loose soil on an exposed surface. Some coatings contain coarse loam and sand particles (Figure 12: photos C and D), which is exceptional. A byre floor on which urine is released by the cattle could produce such coatings.

The crescentic shapes of some coatings indicate that they are still in situ. As the macropores are still open, it suggests that they are related to the deeper part of the byre which was no longer trampled by the animals.

The dusty coatings probably developed during the period when the byre material accumulated. It is assumed that those that were found deepest, migrated first. When new sods were added, the depth of the dusty coatings gradually shifted upwards.

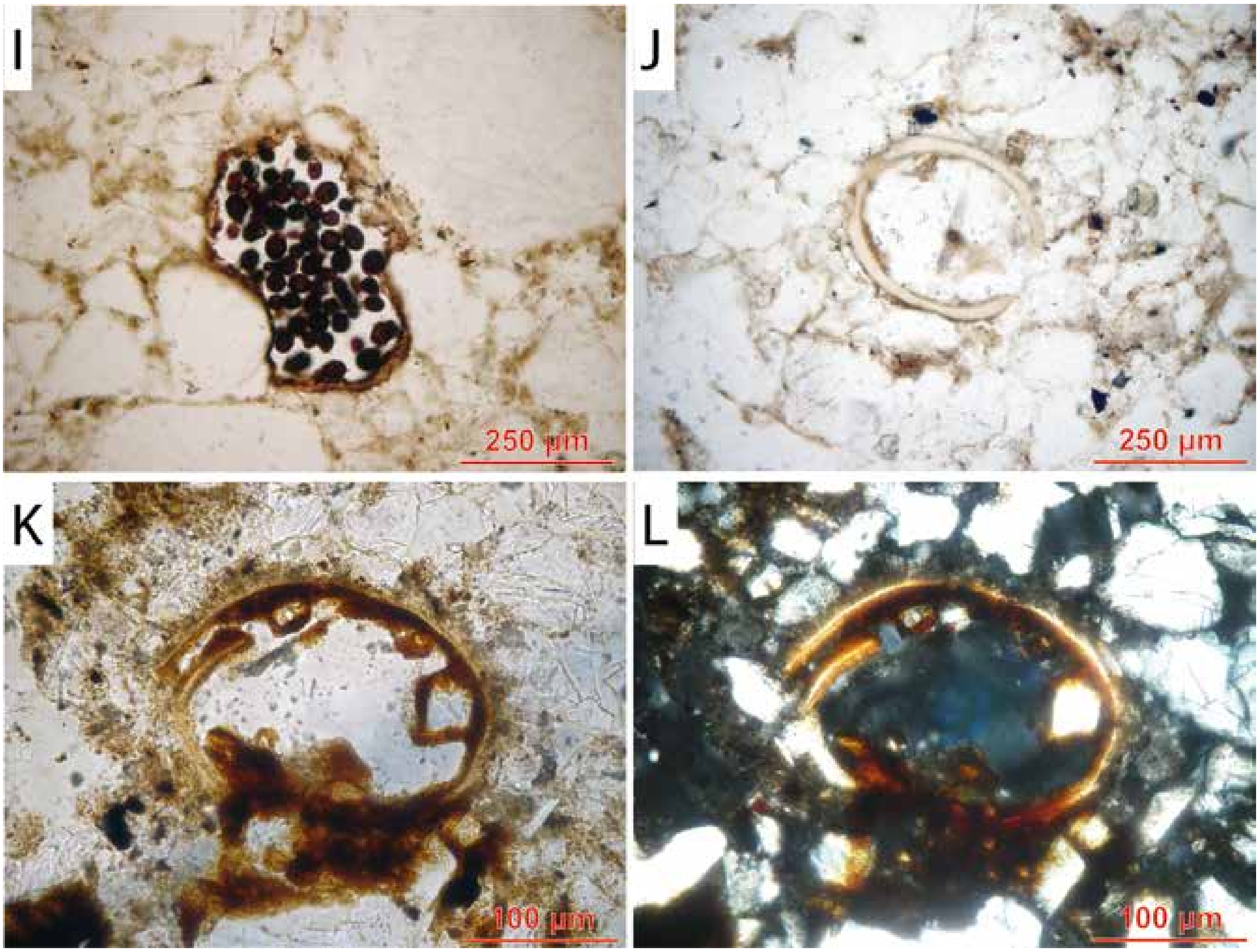

Figure 14. Soil micromorphological photos from byre S14 profile P1. **I**: Organic tissue with spores and iron stains. (PPL). **J**: A well-preserved bright ring, which is a spore form of vesicular arbuscular mycorrhizae. (lower part of H2; PPL). **K**: Bright ring (impregnated by iron and filled with grains of clay and fine sand size. (lower part of H2; PPL). **L**: same bright ring as photo C (XPL).

Broken coatings were described in several thin sections (Figure 13: photo F). They contain an important amount of amorphous organic material, but in some cases, they are also of the dusty type.

In the thin sections of H1, 2, 3 and 6, iron and manganese accumulations are observed. They occur as hypocoatings or as soft concretions (Figure 13: photo E). This type of soil characteristic is related to oxido-reduction, probably in the form of a high groundwater table or when the soil is within range of the capillary ascent of the groundwater table during the wetter periods of the year. In H6, two types were described: one type consists of orange-light-brown concretions, interpreted as probably being brought into the byre with the soil clods. Another soil characteristic are the dark blackish red pedofeatures. This type (Figure 13: photo G) forms under rather strong reducing conditions of the gley type (cf. marshy soils). This may well correspond to the period when cattle were penned in the byre, producing large amounts of manure and urine, creating an environment with high bacterial activity. In such conditions, the soil may, at least temporarily, have been oxygen depleted.

Yellowish isotropic coatings are observed in the last two horizons (H3 and H7) (Figure 13: photo H). They are an additional indication of intensive accumulation of manure. This corresponds well with the high phosphorus content in H3, and to a lesser extent in H7.

6.5. THE BRIGHT RINGS

Several circular rings were observed in the thin sections. They are not damaged or deformed, are almost perfectly circular, and are all birefringent. These pedofeatures are

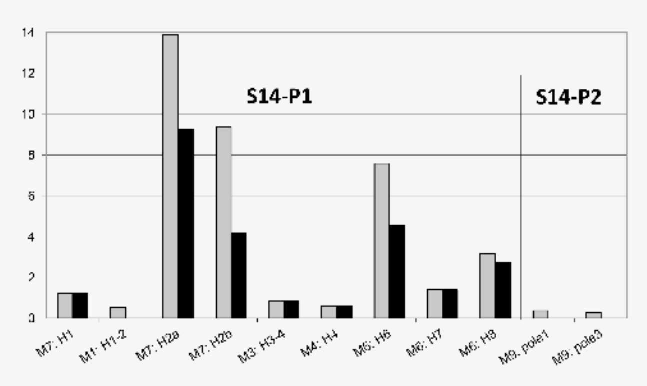

Figure 15. Number of bright rings per thin sections (counted for surfaces of 10 cm²). Data from byre S14, profile P1 and P2. Grey bars: total number; black bars: complete rings.

extensively discussed by Romans and Robertson (1983). These scholars interpret these as remnants of fungal tissues (moulds) that are associated with cattle and/or sheep excrements. In addition, this study reveals that in soils buried for more than 900 years, these features are birefringent.

These bright rings are frequently found in the thin sections of byre S14, but with a somewhat uneven distribution pattern. No rings were observed in byre S47. The total quantity observed, either as fully preserved rings or as fragmented or collapsed rings, was counted (Figure 15). Firstly, and probably most essential, is the fact that these rings are completely absent in profile S14-P4a and S14-P4b, both of which are a part of what is the heterogeneous part in the byre. Secondly, only two fragments of bright rings were found in the posthole of profile S14-P5, and none in the horizon just above the posthole (H4). Thirdly, the rings were frequently observed in profile S14-P1.

It is important to distinguish between complete bright rings and fragmented rings. It can be assumed that the complete rings are in situ. When the rings occur fragmented, they may have been transported over a short distance. It should be noted, however, that most of the samples consisted of more than 50% of complete rings, and none of them consisted of less than 25 %. The rings that were not fragmented, but appeared collapsed, were included in the fragmented rings, although this could have happened in situ. It should also be mentioned that fragments that were observed close to each other and that came from the same ring, were counted only once. The rings were never found in clusters but were scattered throughout the respective horizons. There were some small differences between the rings. For example, some were a bit darker brown, while most had a beige colour. The dimensions could also vary a little and were typically around 150-200 µm. Most fragments (partly) retained their round shape (Figure 14: photo I, J and K). One exception is the fragment from the deepest part of the posthole in profile S14-P2. In this case, it is doubtful whether it is part of a bright ring. Evidently, the calculated density per surface of the thin section (Figure 15) is too small to have any statistical value concerning the involved horizons, but it provides a good idea of the concentrations throughout the byre horizons. For example, they are nearly absent in the posthole and just above it, and the greatest concentrations occur in H2, and to a lesser extent in H6 and H8.

According to the above presented data, the following interpretations can be made:

- The bright rings possibly accumulated in the byres more than 900 year ago, thus indicating this particular stabling practice during the 12th century or earlier; this is in good agreement with the chronological setting established by the archaeologists.
- Most of the rings are still in situ, either as well-preserved rings or as in situ collapsed ones. This indicates that these deposits represent the original byre material and that trampling or any other kind of deep disturbance can be excluded.
- Their presence indicates that the house was used for sheep and/or cattle stabling.
- The higher concentrations of bright rings observed in P1H2 and P1H6-8 of byre S14 indicate that the byre was used more intensively for cattle, at least for two periods. It is also possible that during these two periods the animals stayed longer in the byre before new earth was added. This would provide more time for the accumulation of the rings.

7. Discussion

During the fieldwork on the site of Brecht-Zoegweg, special attention was paid to the two best-preserved byres: S47 and the much larger S14. These two archaeological structures were immediately identified as excellent cases for further detailed archaeopedological research.

Both features are characterised by a deeply incised floor which, according to soil surface reconstruction based on the soil maps, may have been between 70 and 120 cm below the original soil surface of the site. The byre is at its deepest in the central part and gently slopes towards the outer walls. Black horizontal bands are observed in the central part of both byres. They are probably the remains of a wooden floor that was used to prevent the cattle from sinking too deeply into the ground. This process of puddling can become a problem if the level of the deep byre floor comes within range of the fluctuating water table.

There are strong indications that at least part of the humus-rich soil in byre S14 represents the material that accumulated when the stable-house was in active use. An argument for this hypothesis is the presence of bright organic rings in the larger byre. These are produced by moulds that occur in places where cattle excrements occur. The brightness of the rings indicates that they have reached an age of at least 900 years. The heterogeneous soil material observed around profile S14-P4a however, does not show any indication for the presence of cattle, but contains numerous fragments of charcoal and fire structures, including clay-rich elements. Most probably, the charcoal and burned soil came into the byre as household waste. Undoubtedly, the byre fill would show seasonal differences. In the summer, the input of household waste upon manure would increase. In the winter, when the cattle would stay in the byre, manure would dominate the fill.

In the smaller byre S47, the very high concentration of phosphorus in multiple horizons matches the history as a byre with long periods of cattle raising. The upper horizons contain considerably less phosphorus, but cover the central post hole. It seems that they are of a more recent date and hence post-date the actual use of the stable-house and its byre.

The high content of phosphorus in certain horizons indicates that these were at the surface of the byre for longer periods, allowing more phosphorus to accumulate.

The earth that was brought into the byre most likely came from a forest or heathland, as suggested by the relatively high C/N ratio, still present today in the deeper horizons of both byres. In comparison with the surrounding soil, the byre material is enriched with organic carbon, nitrogen, alkaline cations, and phosphorus. In addition, the pH was increased, but this may be due to recent agricultural practices.

In byre S14, we find indications that iron and phosphorus were largely leached out after the burial of the occupation surface. This byre is close to the local brook, in a lower and wetter landscape position than byre S47, which may explain the leaching. During longer periods of reduction conditions, the Fe in iron-phosphate bonds is reduced from Fe^{3+} to Fe^{2+}. This makes phosphorus much more mobile (Brady and Weil, 1999, 560-561). On the other hand, iron and phosphorus have been conserved in the somewhat drier byre S47.

Several characteristics of the humiferous fill of the byres can be related to post-occupational processes and point to the discarding of the structures. Concerning the difference in phosphorus content between the two byres, it could be argued that the function of the two stables was different. The small byre, relatively rich in phosphorus, would have been a byre, and the large one, with little phosphorus, would have had a different function. A more likely explanation is that the large byre, was constructed in a lower landscape position and therefore more liable to a fluctuating groundwater table with associated reduction processes and leaching of iron phosphate compounds.

After the sites were abandoned, it seems that the large wooden central posts were recovered, and the site was levelled to a certain extent with soil from the surroundings. It is not excluded that the site continued to be used as agricultural land. The heterogeneous filling in the upper horizons of the southwestern part of S14 can be related to the utilisation, after its abandonment, as a waste pit. A similar interpretation was proposed for a byre in Scotland (Guttmann et al., 2003, 18).

A remarkable feature of the humiferous horizons are the numerous lighter coloured patches, most of them with a sub-rounded contour. This is related to a post-occupation process of organic matter consumption by microbiological activity, a process accelerated in recent decades since the high increase of nitrogen-rich substances (mainly nitrate). The input can come from both the direct application of fertiliser and by air-born input.

While the use of the byres for stabling cattle could be demonstrated, from the data of this study it cannot be concluded with certainty that farmers were already using plaggen farming techniques in this region during the Roman period. The archaeopedological characteristics of the byres however, point to a complex use-sequence exemplified by three successive management phases.

The first phase starts with a byre bottom that is at the same level as the rest of the sandy farm floor. It is not clear if sods or plaggen were applied in this phase. However, each time when collecting the manure, some earth of the byre floor was scraped away. As a result, the byre bottom became gradually deeper. This process was less intensive near the wall of the byre because of a building stability risk and was more pronounced towards the centre. Possibly, the scraping of the underlying soil was intentionally done, after all the underlying soil was trampled and soaked with nutrients after a season of manure and urine deposition.

In a second phase, the lowest part of the byre floor became so deep that it reached the influence of the groundwater table. This could be related to particularly rainy period(s). The water-saturated soil created a risk for the stability of the building and provided problems of poaching of the cattle. In order to face these difficulties, the floor was raised. Soil clods and pottery fragments were dumped in the deepest positions and the whole layer was covered by a wooden floor. Consequently, this bottom horizon was not disturbed further by cattle trampling.

During the third phase, presumably each time after collecting the manure, some earth, possibly soil clods, were deposited on the byre bottom. This earth became mixed with the manure by the animal trampling. Keeping in mind the problems experienced towards the end of phase 1, care was taken to leave at least some of this earth during the next extraction phase. Consequently, the byre bottom gradually moved up and over the years a characteristic thick, relatively homogeneous humiferous soil sediment accumulated. Whether the extra earth was only spread over the floor after the extraction of the manure or if soil clods were regularly dumped in the byre during the cattle stabling such as in the plaggen type of management, is not sure and can only be checked by studying the Roman period infield plough layers. At the time of this research there is no reliable information about this subject available in the studied region.

The succession of interventions proposed here, and based on two cases, supports the theory that the sunken floors were not excavated during the construction phase of the building. The regular input of earth, probably soil clods, along phase 3, resulted in the thick humiferous horizon that fills the byre. This is the item that received the most attention from the archaeologist and that has been investigated in more detail in this archaeopedological research.

Another interpretation would be that the byres were indeed intentionally dug out in the soil, but only in a shallow way during or soon after the stable house was built. Following intensive use and repetitive emptying of the stables throughout time, the original floor level got scraped away and the stable gradually deepened, taking away evidence of its very first phases of use. In any case, both interpretations demonstrate the byres' complex biography of use and discard, only leaving us with the sediments of the last phases of use and the discard of the structure.

8. Conclusions

The study of two byres, dating back to the Roman period, provided valuable information on the complex life-history of the use and discard of stables with a sunken floor, also known as byres of the *potstal* type. Detailed field observations of 75 m of soil profiles in a grid of two by four m, in combination with physical and chemical laboratory analyses and an extended soil micromorphological study have supplied valuable insights into the life cycle of such byres.

The importance of a combined field strategy to assess these remarkable structures is evident, where the archaeological and archaeopedological investigations are united. In future research of byres from poor sandy cover sands, we recommend the analysis of the byres for phosphorus, carbon and nitrogen (C/N ratio), and to combine this information with a soil micromorphological study. In the ideal case, this research would be expanded with studies of the agricultural infields, where the byre manure was applied. Only then we will be able to fully understand the nutrition cycle of the Gallo-Roman farmers.

Although the study was unable to document that a plaggen infield-outfield farming system was carried out in the region during the Roman period, the study did reveal a system where manure and soil nutrients were carefully collected and, at least to some extent, mixed with soil material.

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