Micromorphological study of Early Neolithic (LBK) soil features in the Netherlands

D.J. Huisman, F. Brounen, E. Lohof, R. Machiels, J. de Moor, B.J.H. van Os, P. van de Velde, E. Rensink, I.M. van Wijk

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Abstract

We made a detailed study of post holes, pits and ditches from Early Neolithic Linear Pottery Culture (LBK) settlement sites and enclosures using soil micromorphological techniques.

An ample presence of carbonized remains in postholes at the Elsloo Riviusstraat settlement site showed that the three buildings investigated were erected when the settlement already existed. The aggregate structure of the fill demonstrated that the posts were extracted; they did not burn or decay *in situ*. Large pits next to the buildings were used as watering hole and eventually as a rubbish pit. Both pits were adapted for a different use by putting a level of low-temperature heated clay/loam on top of the first fill.

Ditches of enclosures at Beek-Kelmond and Beek-Kerkeveld had a complex history of infilling. Next to sediments deposited in stagnant water, stacked slaking crusts represented deposition of clay eroded by surface run-off during wet spells and subsequent drying out of the resulting puddles. Aggregate-dominated fills represent phases of anthropogenic dumping of soil material. Proximity of the ditches to settlements or refuse dumps was indicated by the amounts of carbonized material in the soil mass. Horizons with intensive bioturbation indicate phases of low sediment supply, plant growth and soil formation. At Beek-Kerkeveld different parts of the enclosure have remarkably different sequences of layers. Non-natural sequences and anthropogenic layers indicate human activities in the area at least up till the time when the ditch had been filled entirely. Filling-up was probably quick and may have been completed within one generation.

Keywords: Loess, postholes, *Langsgruben. Sohlgraben, Spitsgraben*, aggregate structure, heating, rubification, charcoal, abandonment, slaking crusts, clay illuviation

1. Introduction

The spread of agriculture in Central and Western Europe is commonly associated with the Linear Pottery Culture (LBK; e.g. Bakels 2009). The introduction of highly organized LBK sedentary settlements with the full Neolithic package of crops, domesticated animals, pottery and polished stone adzes seems to be abrupt in these areas. Research into how these settlements functioned and evolved into local activities is hampered because intact soils or original surfaces rarely have been preserved. This is due to the fact that the occurrence of LBK settlements in Western and Central Europe is almost exclusively restricted to loess soils. Because of the suitability and popularity of loess for agriculture in later periods, evidence for Neolithic tillage is lost. Moreover, the susceptibility of loess to soil erosion has led to severe erosion in the area since the Early Neolithic (e.g. De Moor & Verstraeten 2008; Fisher – Zujkov 2000, Kadereith *et al.* 2010). Furthermore, soil forming processes (mainly decalcification) play an important role in the conservation of sites. Of the Dutch LBK settlements – mostly restricted to the Graetheide and the Caberg plateau in the southern part of the Province of Limburg (fig. 1) – usually not much more is left than (parts of) soil features, inorganic artefacts and charred bone and plant remains. Bone, antler and even teeth are virtually absent. LBK sites in calcareous soils, e.g. in France and Southern Germany, do contain bone.

Despite the taphonomical problems with LBK sites on loess soils in the Netherlands, the remaining traces still offer possibilities to study settlement development and local activities. In this study, soil micromorphology was used to investigate different types of soil features. The origin or formation of these features was still unclear during the excavation and probably reflect natural or human induced soil disturbances and processes on LBK settlements.

The research was carried out on samples from three LBK sites near the villages of Elsloo and Beek, in the province of Limburg (Southern Netherlands, fig. 1). At one site (Elsloo-Riviusstraat), post holes and pits were sampled to study local activities and site development. At two other sites (Beek-Kerkeveld and Beek-Kelmond), ditches that probably formed part of an enclosure were studied in order to investigate formation processes - including identifying phases of consecutive digging and infilling sequences - and the human factor in these processes.

In this study, anthropogenic soil features are regarded as immovable traces of humanly induced disturbances and include post holes, pits, ditches, etc. As such, they can be regarded as non-portable artefacts (Huisman & Deeben 2009). The sampled features can provide various kinds of information on settlement development and human activities. Post holes that are part of a house plan are formed when a construction is being built. The post hole enclosing the post pipe is filled during placement of the post, the post pipe is filled after the structure has disappeared. As a result, part of the fill (the post hole) reflects local conditions during the construction of the building, whereas the other part (the post pipe) forms a reflection of the conditions after the structure has gone or is dismantled.

Pits may be dug for a single purpose and get filled in immediately after. However, they may also have experienced multiple phases of use, discard, re-use and accidental or on purpose filling. All such phases may be reflected in its fill. The fill of pits can be expected to originate locally and therefore form a reflection of site conditions. Ditches are more likely to have been open and in use for longer periods of time – depending on their use. Because of their location, shape and function, they have a greater chance of getting filled in through natural sedimentation processes, whereas the fill is likely to reflect conditions and changes therein on larger scales than pits or post holes.

Soil micromorphology was used to study the soil features in detail. Soil micromorphology is a technique that uses undisturbed soil samples which are impregnated with resin and subsequently sawn, ground and polished to 30 micron thickness. This allows the samples to be studied by means of microscopes with transmitted light (usually plane polarized light; 'PPL'). For the identification of minerals and specific features additional optical techniques are used. Most common is the use of crossed polarizers (crossed polarized light; 'XPL') and oblique incident light ('OIL'). Soil micromorphology was originally developed as a technique for the study of soil genesis, but in the last decades it is being applied more and more in geoarchaeology and archaeology proper (Courty *et al.* 1989).

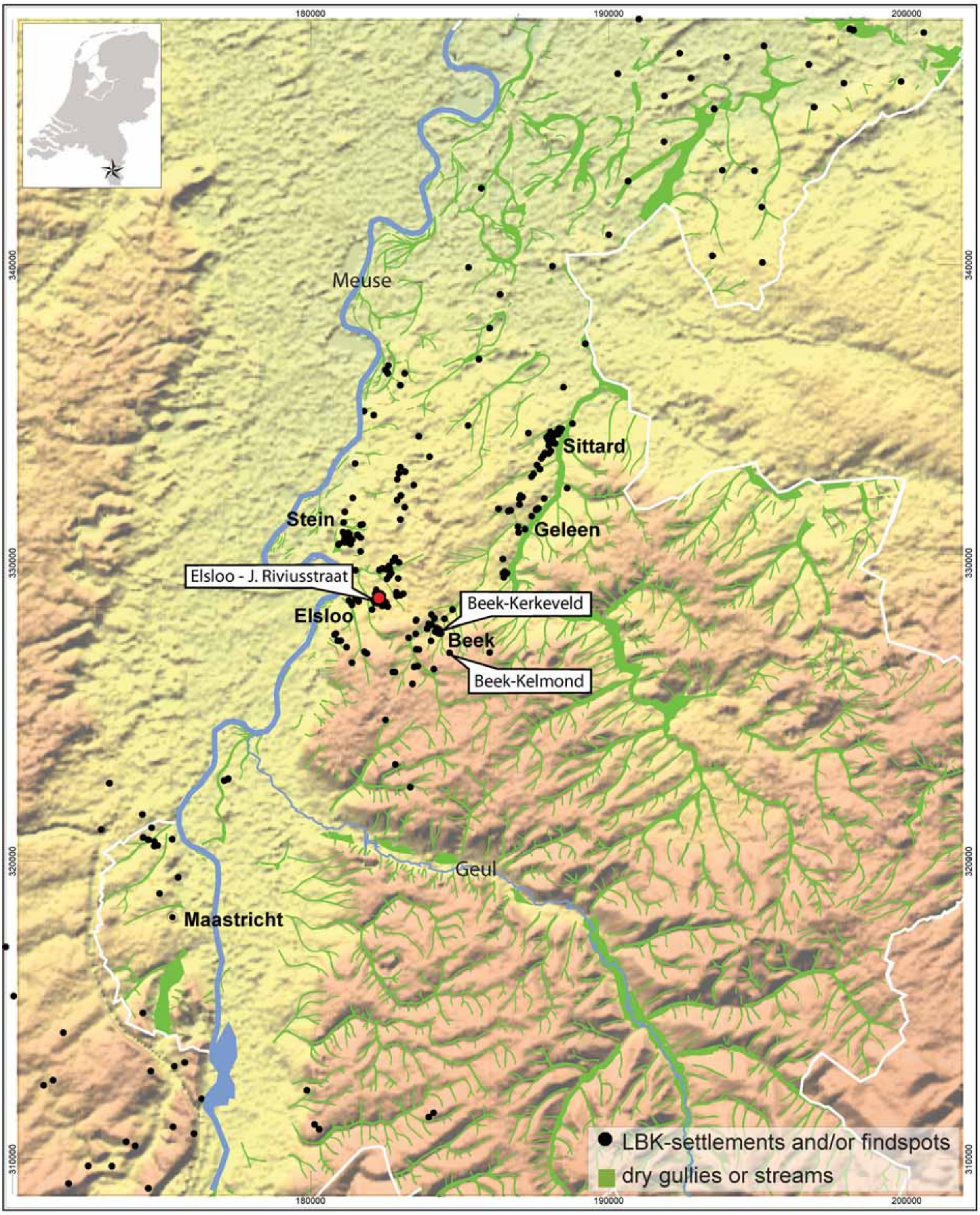


Figure 1. Research area. Dots: the locations of known LBK findspots – including settlements - in the SE Netherlands. The three research locations (Elsloo-Riviusstraat, Beek-Kerkeveld and Beek-Kelmond) are indicated.

However, only a few micromorphological studies that deal with anthropogenic features like postholes, pits or ditches concerning LBK sites in the central European loess area have been published. Of these studies, for example Kooistra (2000), MacPhail (2010) and Huisman *et al.* (2012) deal directly with an archaeological interpretation of the micromorphological observations, whereas e.g. Slager and van de Wetering (1977) focus primarily on specific soil processes instead of archaeological site interpretation proper.

With this study we will demonstrate that using soil micromorphological techniques, archaeological traces and soil phenomena on LBK sites that have suffered severe erosion in the past, still can reveal a lot of information and insight on the development and functioning of these sites.

A

B

C

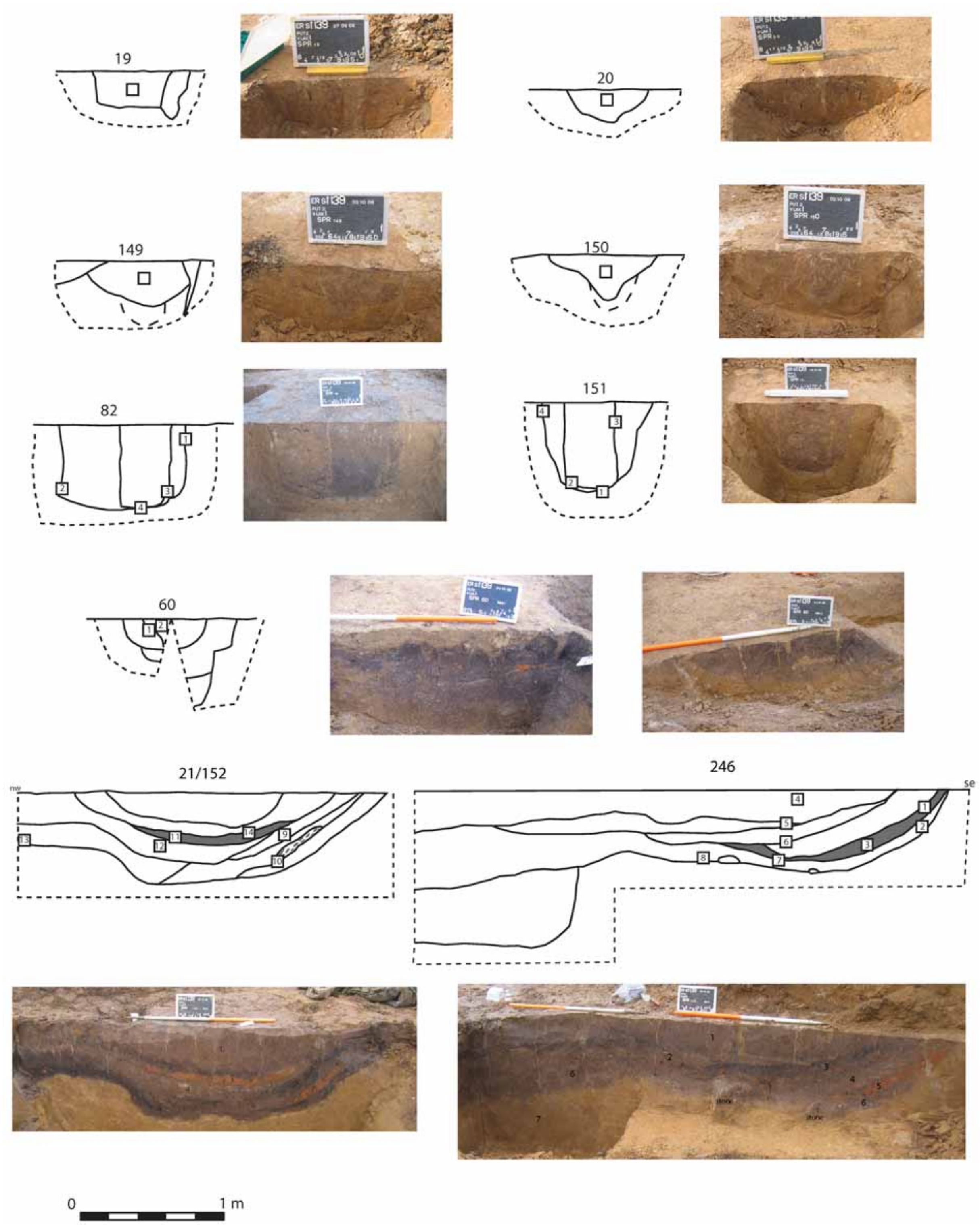


Figure 2. Site map and sample positions of the Elsloo Riviusstraat site. A: Overall plan of the site, as revealed by several excavations in the last c. 60 years. The area of the 2006 excavation is outlined in red. B: Partial plan of the 2006 excavation, showing (in red) the sampled features. C: Photographs and cross sections with sample positions of all sampled features. The grey horizons in the drawings of the langsgruben features (246 and 21/152) indicate rubified material.

2. Site description

2.1 Elsloo-Riviusstraat

Elsoo-Riviusstraat (fig 2A) is a large settlement (estimated > 200 dwellings) which has been inhabited from Modderman phase 1b until the end of the Dutch LBK, phase 2d. Parts of the settlement and its neighbouring cemetery have been excavated between 1958 and 1963 (Modderman 1970). A small-scale developer-funded excavation in the settlement area in 2006 yielded several house plans and associated pits (Porreij 2009; see fig. 2A for the settlement plan and location of the 2006 excavation). The house plans consisted of post holes of various sizes, with clear distinctions between post holes and post pipes. The pits (German: *Langsgruben*) showed layered fills that included bands rich in charcoal or in baked loam.

For this site, two issues will be addressed. The first is the issue of settlement development and abandonment of buildings. As the Elsloo-Riviusstraat settlement consists of many buildings, one question is whether buildings were built on pristine locations, as opposed to locations that already had been influenced by human activities. A second question is whether buildings were abandoned and left to decay, or whether they were broken down and the posts extracted after use. These issues are addressed using samples that were taken from selected post holes during the 2006 excavation (see fig. 2B for sampled features and 2C for cross sections and sample positions).

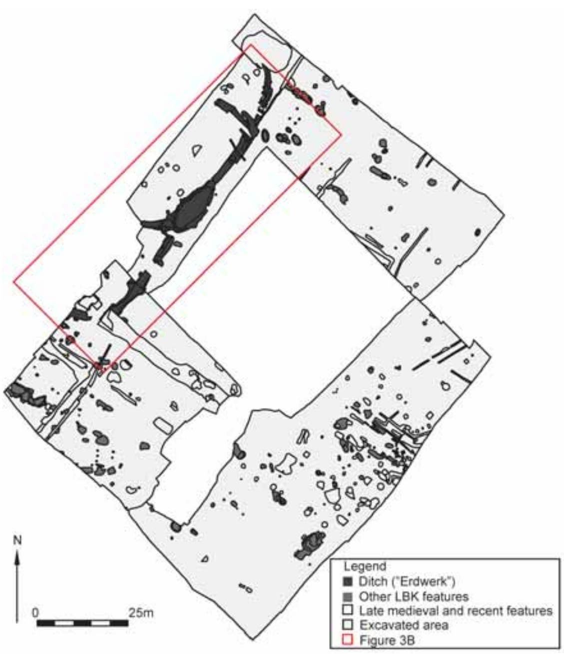
The second issue focuses on the formation processes and use of two large elongated pits (*Langsgruben*) adjacent to an exceptionally heavily founded construction. These pits show a clear layering, with recognizable horizons that are rich in charcoal and/or reddish (heated) loam. It is generally assumed that the pits were formed primarily as loam extraction pits. It is unclear, however, if they had other functions after that and whether the different fill horizons are related to different human activities and site use. In 2009 the site was revisited to sample these pits (see also Huisman et al 2012) specifically to answer these questions.

All samples at Elsloo-Riviusstraat were taken directly from the soil profiles using 8 x 8 cm carton boxes.

2.2 Beek-Kerkeveld

The Beek-Kerkeveld site is situated on the margin of a presumed (based on a scatter of amateur LBK finds) > 2.4 ha settlement site, – which at present is overbuilt by houses. The site was excavated in 2007 (Lohof &Wyns 2009; see fig. 3A for excavation plan). It is situated on a 4% slope leading towards the narrow valley of the Keutelbeek brook. The excavation yielded a series of pits of various sizes and a few dozens of post holes, but the site is severely eroded. One or two clusters of holes seem to form the scanty relic of a house plan, but this interpretation is debated. On the transition of the slope to the valley floor large pits, that at a later stage were connected, form part of an enclosure (German: *Erdwerk*) with two side-branches (Van de Velde, Lohof & Wyns 2009). Macroscopically, several phases were distinguished in the fill of this feature. The oldest recognizable phase is formed by a very narrow, in cross-section V-shaped (German: *Spitzgraben*) discontinuous ditch – or rather a row of oblong pits. Later through the upper reaches of these puts a shallower ditch was dug, with a rounded U-shped cross-section (German: *Sohlgraben*) resulting in a pretzel-like groundplan (fig. 3B). Its fill is heterogeneous, including very finely laminated horizons and horizons with charred material. The slope was, based on the dating of the pottery, in use in phases 1c – 2d. The enclosure can be dated in phase 2d, based on some sherds. An undamaged millstone with its runner, both

A



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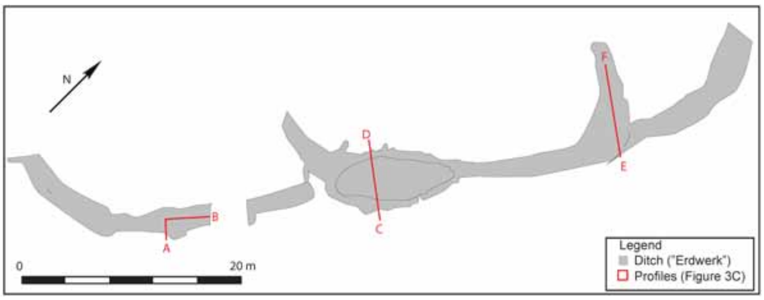

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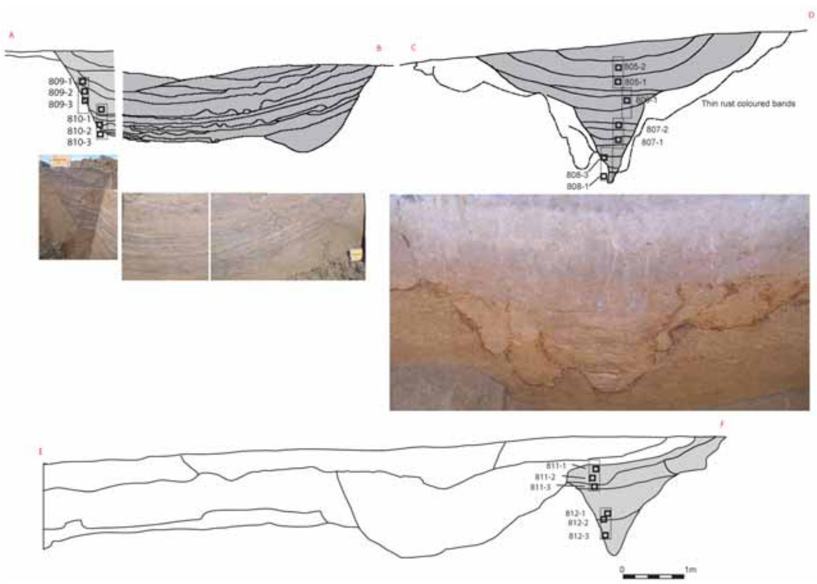


Figure 3. Site map and sample positions of Beek- Kerkeveld. A: Site map and of the whole site. B: Plan of the ditch feature. Sampled cross sections are indicated in red. C: Photographs and cross sections with sample positions. Monoliths are indicated with dashed lines and micromorphological samples are indicated with solid lines.

covered in hematite, was probably deposited on purpose at the bottom of the oblong pits of the first phase.

The Beek-Kerkeveld enclosure can be compared to similar features at several other LBK sites (Van de Velde, Lohof & Wyns 2009) .The Herxheim enclosure for example shows several consecutive phases of digging out and filling in, combined with depositions pottery and human bones (Zeeb-Lanz et al 1997; Schmidt 2004). The sequence of formation, use and abandonment of such enclosures and their relation to human practices remain unclear, however. At Beek-Kerkeveld, the sampling and micromorphological research was meant primarily to elucidate the formation, use and infill history of the enclosure.

Three transects across the enclosure were sampled (see fig. 3B for their position and fig. 3C for the cross sections and sample positions). Those of the central and western profiles are from fills of the first phase (*Spitzgraben*) that are cut off by the fill of the second – rejuvenation – phase (*Sohlgraben*). The eastern profile is not affected by rejuvenation, so here only samples were available from the first (*Spitzgraben*) phase. Sampling was done by hammering or pushing metal boxes of 15 x 50 x 15 cm ('monoliths') into the profiles. After extraction they were brought to the laboratory, where subsamples were taken using 8 x 8 cm carton boxes. In fig. 3C, the monoliths are identified with dashed lines and the sample boxes with solid lines.

2.3 Beek-Kelmond

At Beek-Kelmond, test-trenches were dug on a ploughed field where surface finds by an amateur archaeologist indicated the presence of an LBK settlement (Brounen & Rensink 2007; see fig. 4A for site and trench layout). In these trenches pits and rows of post holes were found and interpreted as remnants of house plans belonging to a partly eroded LBK settlement. In one of the trenches, short stretches of two presumed ditches were observed (see fig. 4B): one with a rounded cross-section (*Sohlgraben*, like the second phase in Beek-Kerkeveld) and an adjoining counterpart with a V-shaped cross-section (*Spitzgraben*). The *Sohlgraben* was filled with layers of grey mottled reworked loess (see fig. 4C). However, since the feature was only encountered in one of the trenches, it is not absolutely certain that the features are from enclosure ditches. If so, they may very well be discontinuous.

Here too, the main question is to elucidate the formation, use and infill history of the presumed enclosure ditch.

Only samples from the *Sohlgraben* were available: During fieldwork a 15 x 50 cm 'monolith' was pushed into the soil profile. It was extracted and brought to the laboratory, where again subsamples were taken using 8 x 8 cm carton boxes (see fig. 4C for sample positions; monolith in broken lines, sample boxes in solid ones).

3. Materials and methods

Samples from the three sites were sent to laboratories for thin section preparation, i.e. impregnation with resin, sawing, lapping and polishing to a thickness of ca. 30 micron. The thin sections from the 2006 Riviusstraat campaign and those from Kerkeveld were prepared by Maja Kooistra and staff of KMS in Bennekom (the Netherlands). Sections from Kelmond were prepared by Julie Boreham at EarthSlides in Cambridge (UK) and those from the 2009 Riviusstraat campaign by George MacLeod at the Thin section & Micromorphology lab in the School of Biological and Environmental Sciences at the University of Stirling (UK).

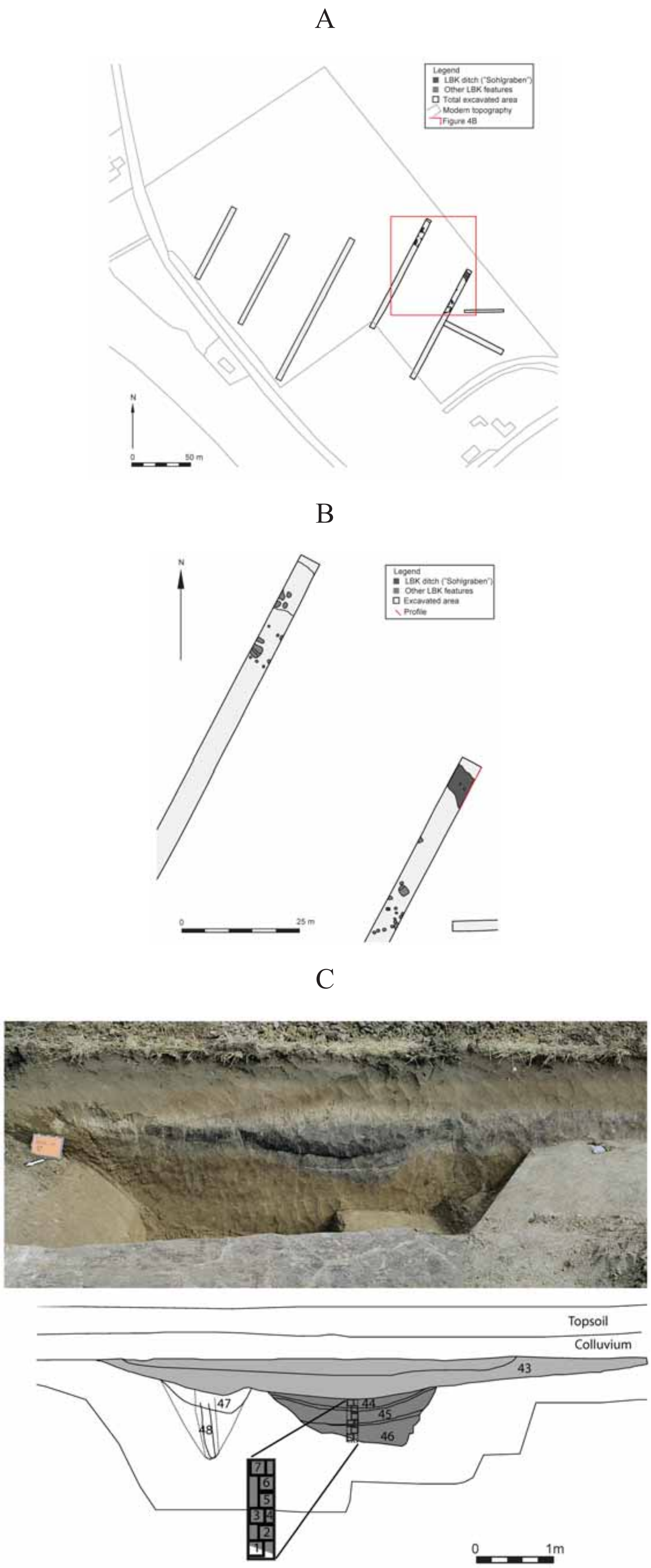


Figure 4. Site map and sample positions of Beek-Kelmond. A: Site map, indicating the excavated area and features. B: Detailed map with the ditch feature and the position of the sampled profile. C: Cross section and sample positions. In order to show the interrelation of the samples – which are very close together - a magnification of the monolith is given.

All sections were studied in the micromorphological laboratory of the Cultural Heritage Agency in Amersfoort, using a Wild 420 Macroscope and Zeiss Axioskop 40 polarizing microscope, both fitted with Zeiss MRc 5 digital cameras. Scans of the thin sections were made using a slide-scanner.

4. Results

Table 1 gives an overview of the micromorphological observations. Scans of characteristic thin sections and photographs of relevant features are given in figs 5-8. The observations for each site are described below.

Location	*Feature*	*Sample*	*Unit*	*General properties*				*Pedofeatures*					*Anthropogenic*			*General remarks*
				Main colour	*Mottling or secondary colour*	*Main structure*	*Subsidiary structure*	*Slaking crust(s) in situ*	*Clay coatings*	*Clay eluviation*	*Iron precipitation*	*Biopores*	*Charcoal*	*Bone*	*Heated loam, ceramics*	
Elsoo Riviusstraat	246	1		R	-	SA B		-	+	-	-	+	-	-	-	
Elsoo Riviusstraat	246	2		Br	-	SA B		-	+	-	+	+	(+)	-	-	
Elsoo Riviusstraat	246	3		Br	-	Po		-	+	-	-	++	(+)	-	+	
Elsoo Riviusstraat	246	4		L Br	D Br; R Br	SA B		-	+	-	-	++	(+)	-	-	
Elsoo Riviusstraat	246	5		Br	D Br	SA B		-	+	-	-	++	++	-	+	
Elsoo Riviusstraat	246	6		L Br	L Br	Po		-	+	-	-	++	+	-	+	
Elsoo Riviusstraat	246	7		Br	-	Po	SA B	-	++	-	-	++	+	+	+	
Elsoo Riviusstraat	246	8		L Br	-	Po		-	(+)	-	(+)	++	-	-	-	
Elsoo Riviusstraat	21/152	9		Gr Br	-	M		-	+	-	-	++	++	+	-	
Elsoo Riviusstraat	21/152	10		Gr Br	-	Po	SA B	-	+(+)	-	-	++	+++	+	+	
Elsoo Riviusstraat	21/152	11		R	R	Aggre WS		-	(+)	-	-	(+)	(+)	-	-	
Elsoo Riviusstraat	21/152	12		L Br	L Br	Aggr SS	Aggr WS	-	+	-	-	(+)	(+)	-	-	
Elsoo Riviusstraat	21/152	13		D Br	-	Po	Aggr WS	-	+	-	-	++	++	+	-	
Elsoo Riviusstraat	21/152	14		R	R	Aggre WS		-	(+)	-	-	(+)	(+)	-	-	
Elsoo Riviusstraat	19			L Br	Gr Br	M	Aggr MS	-	++	+	+	++	(+)	-	-	
Elsoo Riviusstraat	20			L Br	Gr	M		-	(+)	-	(+)	+	(+)	-	-	
Elsoo Riviusstraat	60	1		D Br	-	M		-	++	-	-	++	+++	-	+	
Elsoo Riviusstraat	60	2		L Br	-	M	Aggr VWS	-	+	-	-	+	+	-	+	
Elsoo Riviusstraat	82	1	I (upper part)	Gr Br	-	M	Aggr VWS	-	+	+	-	+	+	-	-	
Elsoo Riviusstraat	82	1	II (lower part)	L Br	-	M		-	(+)	-	-	+	-	-	-	
Elsoo Riviusstraat	82	2	I (right side)	L Br	-	M		-	+	-	-	+	-	-	-	
Elsoo Riviusstraat	82	2	II (left side)	Gr Br	Gr Br	M Po	Aggr VWS	-	+	+	-	+	+	-	-	
Elsoo Riviusstraat	82	3		Gr Br	Gr Br	M		-	++	-	(+)	+	+	-	-	
Elsoo Riviusstraat	82	4	I (upper part)	Gr	-	Aggre WS		-	++	-	+	+	+	-	-	
Elsoo Riviusstraat	82	4	II (lower part)	L Br	-	M		-	-	-	+	(+)	(+)	-	-	
Elsoo Riviusstraat	149			L Br	-	M Pl		-	+	-	+	(+)	(+)	-	-	
Elsoo Riviusstraat	150			L Br	Gr	M		-	+	+	(+)	+	(+)	-	-	
Elsoo Riviusstraat	151	1		Gr	R	M	L L	-	(+)	-	+	(+)	-	-	-	
Elsoo Riviusstraat	151	2	I (Upper left part)	Gr Br	-	M Po	Aggr VWS	-	++	-	-	++	(+)	-	-	
Elsoo Riviusstraat	151	2	II (Rest)	L Br	-	L		-	+(+)	-	(+)	+	-	-	-	
Elsoo Riviusstraat	151	3	I (Left part)	L Br	-	M		-	++	-	-	+	-	-	-	
Elsoo Riviusstraat	151	3	II (Right part)	L Br	-	SA B		-	+	+	-	+	(+)	-	-	
Elsoo Riviusstraat	151	4	I (Left part)	L Br	-	M		-	+	-	++	+	-	-	-	
Elsoo Riviusstraat	151	4	II (Right part)	L Br	-	M		-	-	-	(+)	+	-	-	-	
					-			-							-	

Location	*Feature*	*Sample*	*Unit*	*General properties*				*Pedofeatures*					*Anthropogenic*			*General remarks*
				Main colour	*Mottling or secondary colour*	*Main structure*	*Subsidiary structure*	*Slaking crust(s) in situ*	*Clay coatings*	*Clay eluviation*	*Iron precipitation*	*Biopores*	*Charcoal*	*Bone*	*Heated loam, ceramics*	
Beek Kerkeveld		805-1		L Br	Gr	M		-	(+)	-	+	+	-	-	-	
Beek Kerkeveld		805-2		Gr	-	M Po		-	(+)	-	-	++	-	-	-	
Beek Kerkeveld		806-1		Br	-	M Po		+	+	-	+	+	(+)	-	+	
Beek Kerkeveld		807-1		Br	-	M		+	(+)	-	+	+	-	-	-	
Beek Kerkeveld		807-2		Br	-	M		-	(+)	-	++	+	-	-	-	
Beek Kerkeveld		808-1		L Br	Gr Br	M	Aggr VWS	-	-	-	+	+(+)	-	-	-	
Beek Kerkeveld		808-3	I (top right half)	L Br	-	M		+	(+)	-	+	+(+)	-	-	-	Bad quality slide
Beek Kerkeveld		808-3	II (lower left half)	L Br	Gr Br	M	Aggr VWS	-	(+)	-	+(+)	+	-	-	-	
Beek Kerkeveld		809-1		L Br	Gr	M		-	+	+	-	+	+	-	+	
Beek Kerkeveld		809-2		L Br	Gr	Aggr WMS	SA B	+	+	+	-	+	+	-	-	
Beek Kerkeveld		809-3	I (top left 2/3)	Gr	-	Aggr VWS		+	(+)	-	(+)	+	+	-	+	
Beek Kerkeveld		809-3	II (lower right 1/3)	L Br	Gr Br	M	Aggr VWS	-	(+)	-	+	(+)	-	-	-	
Beek Kerkeveld		810-1	I (Upper half)	R Br	Gr Br	M	L Aggr VWS	-	-	-	-	+	+	-	+	
Beek Kerkeveld		810-1	II (Lower half)	L Gr	D Br	L		+	-	-	+	(+)	+	-	-	
Beek Kerkeveld		810-2	I (Upper right half)	L Br	Gr Br	M	L	-	(+)	-	+(+)	+	-	-	-	
Beek Kerkeveld		810-2	II (Lower left half)	L Br	Gr Br	M	Aggr VWS	-	(+)	-	++	+	-	-	-	
Beek Kerkeveld		810-3		L Br	Gr Br	M	Aggr VWS	+	(+)	-	+	+	-	-	-	
Beek Kerkeveld		811-1		Gr Br	Gr Br	M		-	(+)	-	-	+(+)	++	-	+	Incorrectly numbered as 813-1
Beek Kerkeveld		811-2		L Gr	D Br	M		+	(+)	-	-	+(+)	++	-	+	Incorrectly numbered as 813-2
Beek Kerkeveld		811-3		L Br	Gr Br	M	L L	-	-	-	-	+(+)	(+)	-	-	Incorrectly numbered as 813-3
Beek Kerkeveld		812-1	I (Upper 3/4)	L Br	-	L		+	(+)	-	-	+(+)	(+)	-	-	
Beek Kerkeveld		812-1	II (Lower 1/4)	Br	-	M		-	(+)	-	-	+(+)	(+)	-	-	
Beek Kerkeveld		812-2	I (Top half)	Br	-	L		+	-	-	-	(+)	(+)	-	-	Centre slide too thin
Beek Kerkeveld		812-2	II (Lower half)	Br	Br	M		+	-	-	-	+	(+)	-	-	
Beek Kerkeveld		812-3		L Br	Gr Br	SA B	M	-	-	-	-	+	(+)	-	-	
								-							-	
Beek Kelmond	46	39-1	Unit I (top 2/3)	L Br	Gr Br	M	L	-	(+)	-	+	(+)	-	-	-	
Beek Kelmond	46	39-1	Unit II (lower 1/3)	Gr Br	Gr Br	M		-	(+)	-	-	(+)	+	-	-	
Beek Kelmond	46	39-2		Gr	Gr	M Po		-	(+)	-	(+)	++	-	-	-	
Beek Kelmond	45/46	39-3	Unit I (top 1/2)	Gr	Gr Br	M Po		+	(+)	-	(+)	++	(+)	-	-	= 39-4 Unit I
Beek Kelmond	45/46	39-3	Unit II (lower 1/2)	Gr	-	SA B	L L	-	-	+	(+)	+	(+)	-	-	= 39-4 Unit II
Beek Kelmond	45/46	39-4	Unit I (top 1/2)	Gr	Gr Br	M Po		+	(+)	-	(+)	++	(+)	-	-	= 39-3 Unit I
Beek Kelmond	45/46	39-4	Unit II (lower 1/2)	Gr	-	M Po	Aggr MS	-	-	+	(+)	+	(+)	-	-	= 39-3 Unit II
Beek Kelmond	45	39-5		Gr	-	M Po		+	(+)	-	(+)	++	-	-	-	
Beek Kelmond	44/45	39-6		L Gr	D Gr	M	L L	-	+	-	+	++	+(+)	-	+	
Beek Kelmond	44	39-7		Gr	Gr	M	L L	-	(+)	-	++	+	+	-	+	

Table 1. Micromorphological observations.

Colour codes		*Structure codes*		*Codes for:*		*Codes for:*	
L Gr	Light grey	Aggr SS	Aggregate, strongly separated	Slaking crust(s) in situ		Clay coatings	
Gr	Grey	Aggr MS	Aggregate, moderately separated	Clay eluviation		Iron precipitation	
D Gr	Dark grey	Aggr WMS	Aggregate, weakly to moderately	Bone		Biopores	
Gr Br	Grey-brown	Aggr WS	Aggregate, weakly separated	Heated loam, ceramics		Charcoal	
L Br	Light brown	Aggr VWS	Aggregate, very weakly separated				
L Y Br	Light yellow-brown	L	Layered	-	Absent	-	Absent
Br	Brown	L L	Locally layered	+	Present	(+)	Rare
D Br	Dark brown	L Aggr VWS	Weakly developed layering.			+	Common
			Very weakly separated aggregate				
R Br	Reddish brown	M	Massive			+(+)	Common to abundant
R	Reddish	M L	Massive, layered			++	Abundant
		M Pl	Massive to platy			+++	Very abundant
		M Po	Massive to porous				
		Po	Porous				
		SA B	Subangular blocky				

Legend to Table 1

4.1 Elsloo-Riviusstraat

The post hole thin sections typically show a soil mass that consists of loam aggregates embedded in loam that is richer in carbonized materials. It is noteworthy that the fills of the post holes and the post pipes are very similar; the boundary between the two, although well visible in the field, is hardly recognizable in the thin section. Examples of this can be seen in figures 5A and B. Fissures ('planar voids') show considerable amounts of thick limpid, layered reddish clay coatings, which sporadically include thin layers with silt grains. They are evidence for extensive downward transport of clay and sometimes silt within the profile after the formation of the fill. Some of the features contain iron oxide precipitates. In several of the large post holes (including 82 and 151) blue-grey domains surrounded by rust-coloured spots indicate that locally reducing conditions could still exist. In one sample (151-4) a rust-coloured spot was found to contain the imprints or remnants of a mass of fungal hyphae (fig. 5P,Q). This occurrence, however, does not coincide with the location of rust stains that were macroscopically visible during fieldwork.

The fill of the pits shows a sequence of layers with different characteristics:

(1) The lower horizons show some traces of sedimentary layering (e.g. fig. 5C). Several non-burnt bone fragments were observed (fig. 5D,E), which is remarkable, as preservation conditions for bone are far from good in the decalcified, well-drained soils of the area.

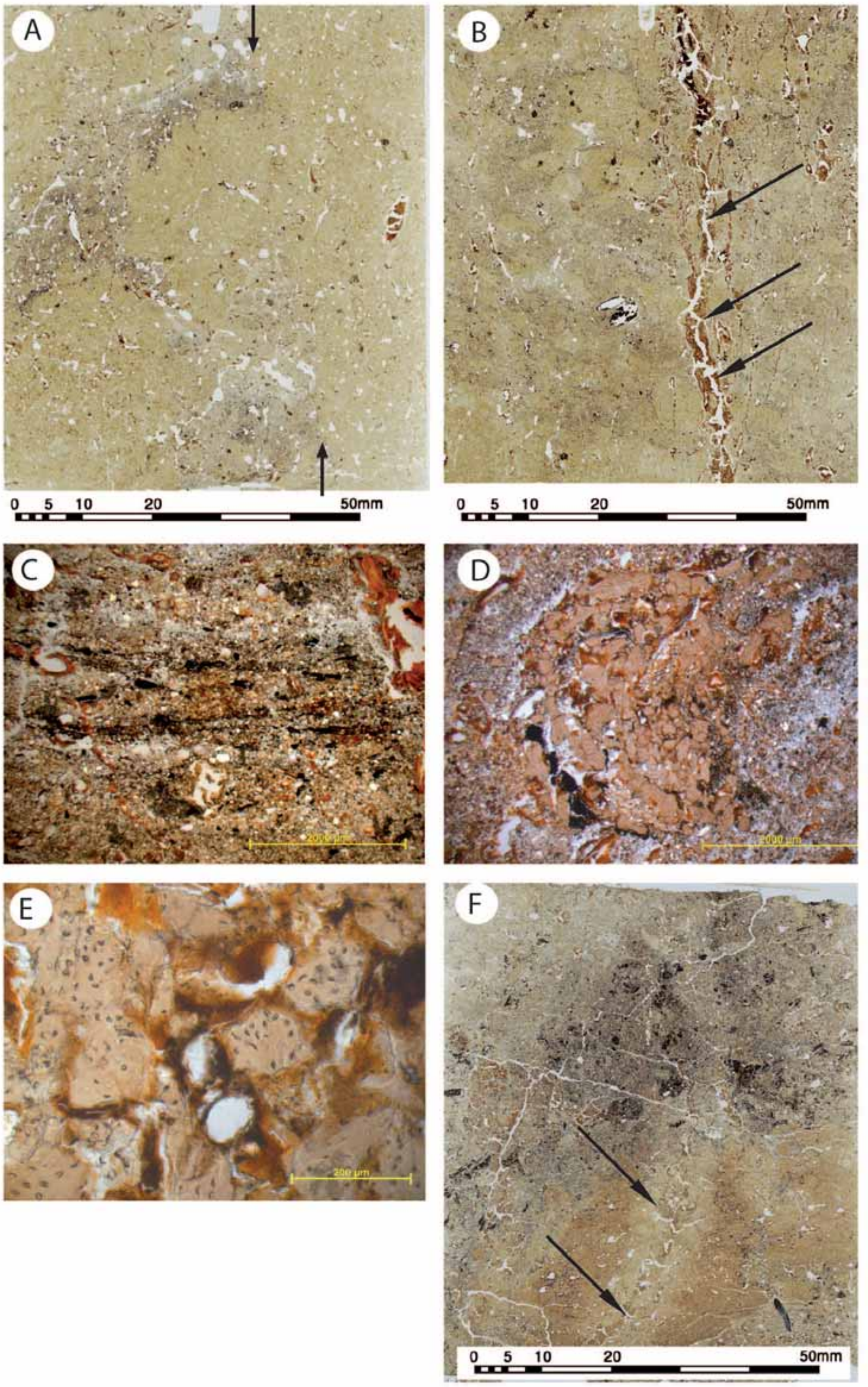
(2) The overlying horizons have a groundmass that consists of rounded aggregates.

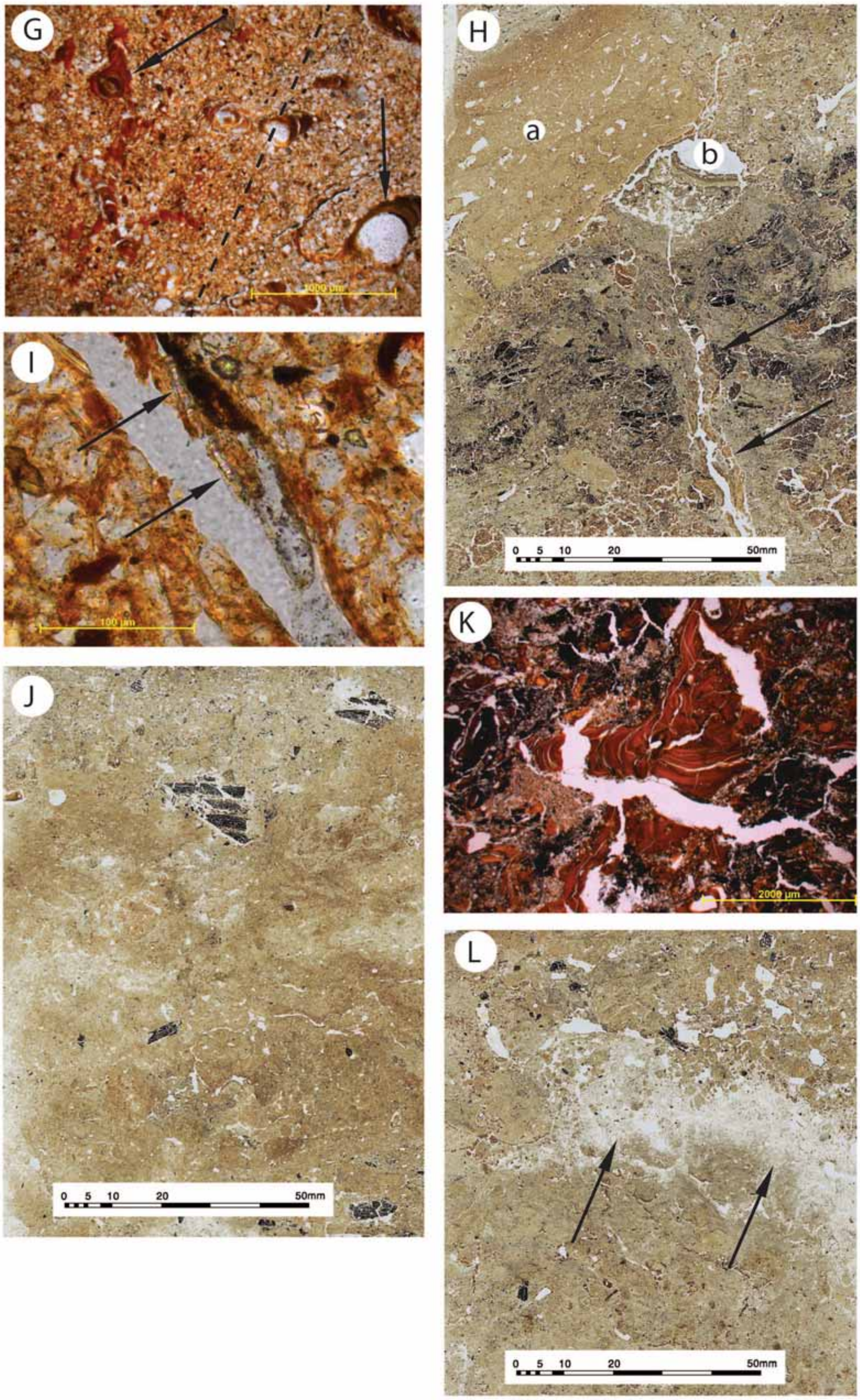
(3) The black layers visible during field work contain large amounts of carbonized material, mostly charcoal. The ubiquitous crescent-shaped fills of wormholes contain mostly fine fragments of carbonized remains. In the non-bioturbated groundmass, however, large charcoal fragments are still present. They often contain clay-filled cavities that are probably related to ash-induced charcoal disintegration (see Huisman et al 2012*)*.

(4) The reddish layers in the pits consist of bits of clay or loam that are coloured probably as a result of heating ('rubification'). These fragments occur in three distinct types: some consist of rubified material that has a structure similar to that of the surrounding soils, including pores, clay coatings, etc. (fig. 5F,G). Others consist of silty clay, similar in composition to the surrounding soil, but with elongated pores. In several of these pores, plant-derived biogenic silica with identifiable plant cell morphology (phytoliths) can be recognized (fig. 5H,I). These fragments sometimes show a gradient from light and pale to darker and more intense red. The third type consists of massive layers of clayey material that are composed of more or less

rounded, relatively small aggregates (fig. 5J). In all cases the boundaries between aggregates or layers and the surrounding soil material is sharp and clear.

The groundmass in the pits contains massive amounts of clay coatings similar to the ones in the post holes, but more frequent and often thicker (e.g. fig. 5H,K). Also some lighter coloured areas occur, consisting of slightly coarser material. As a result they have a bleached or leached-out appearance. They are larger and more common in pits, but can also be found in some of the post holes. These areas are often irregular in shape, with finger-like vertical channel lobes that extend downwards (fig. 5L,M,N,O). See also Huisman *et al.* 2012.

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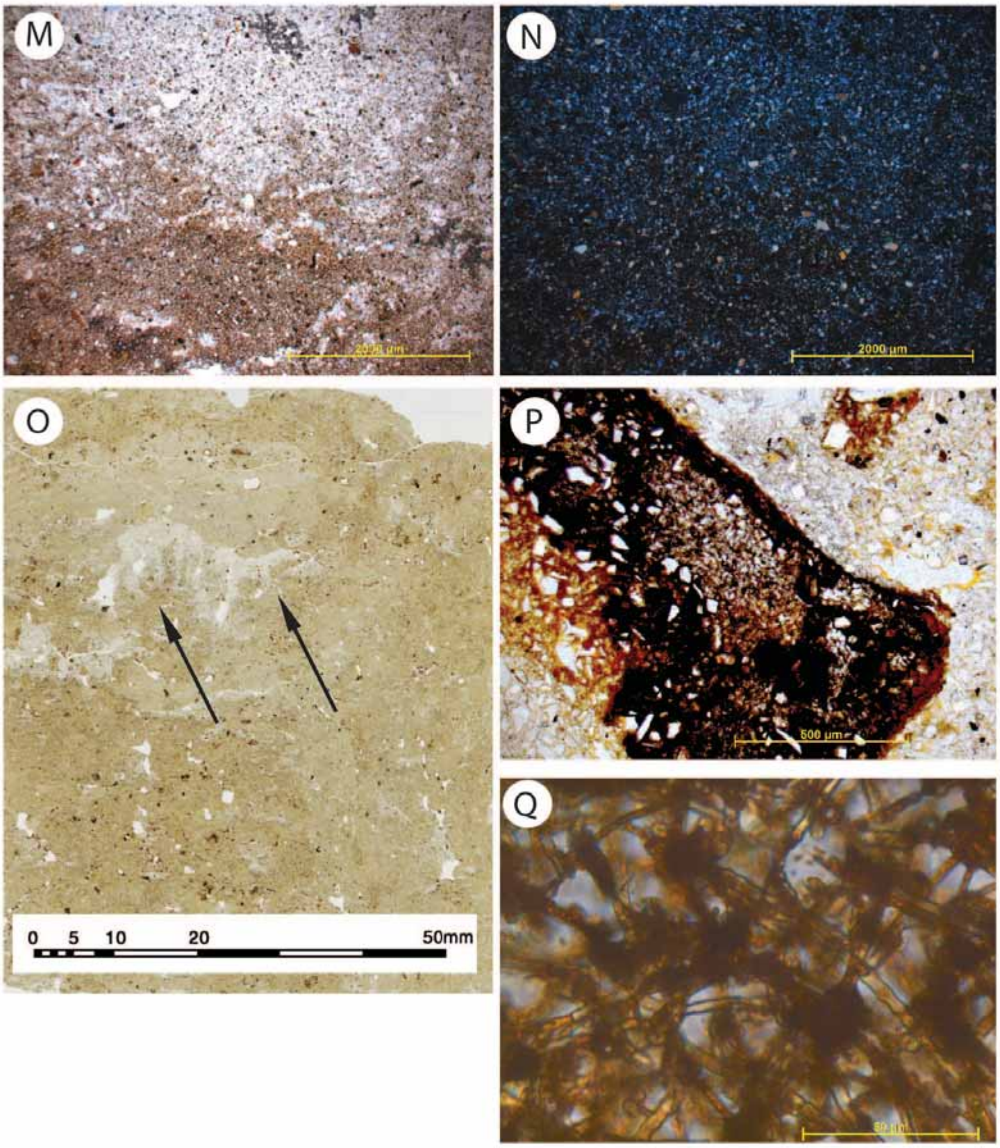

Figure 5. Micromorphological phenomena from Elsloo-Riviusstraat. Scans (A,B,F) were made using slide scanners. Microscope images (C, D,E, J,L,O) are with plain polarized light (PPL), except when indicated differently (XPL = crossed polarizers).
A Scan of thin section 82 - 2, covering the boundary between the post hole fill and the surrounding undisturbed soil (boundary indicated by arrows). The left side of the thin section is the filled-in post hole, containing rounded to subrounded light brown aggregates, embedded in greyish loam that is rich in fine-grained charred organic materials. The right side is the undisturbed loess.
B Scan of thin section 82 – 3, covering the boundary between the pit fill and the post pipe fill. Both areas show aggregates in a way similar to the ones in figure 5A. The vertical system of fissures that separates the pit fill and the post hole fill contains thick clay coatings, which is evidence for extensive clay transport within the profile.
C Sedimentary layering of silt and charred organic remains in lower horizons of pit 21/152, sample 10.
D Bone fragment, ingested and excreted by a worm or other soil fauna in crescent-shaped infillings in a burrow. Pit 246, sample 7.
E Detail of 5D. Bone fragments with recognizable microstructure (Haversian channels; greyish spots). The fragments and pores show coatings of clay and iron oxides.
F Scan of pit 246, sample 5. A large subrounded aggregate of rubified material can be seen in the lower half of the thin section. This aggregate shows biopores and commonly rubified (see fig. 5G) clay coatings on cavity walls. The aggregate is penetrated by a complex of vertical fissures and pores, containing very thick non-rubified clay coatings (arrows). The groundmass directly surrounding this complex has a lighter colour, indicating that some of the iron has been leached.

G Rubified clay coating in aggregate of pit 246, sample 1. The dashed line indicates the transition zone between non-heated (right) and heated (left; slightly more red) material. Clay coatings occur on both sides of the dashed line, but are more reddish due to heating (rubified) to the left.
H Scan of pit 21/152, sample 10. A large, ca. 3 cm thick subangular blocky aggregate of rubified material in the upper left part of the sample (a) shows a colour gradient, with more intense red colours towards the top. Elongated pores in this fragment contain recognizable phytoliths (see fig. 5I). Underneath the aggregate a partially infilled cavity is visible of a burrowing animal (b). Beneath that is a charcoal-rich horizon that is strongly affected by worm activity, fragmenting the charcoal fragments. Massive amounts of illuviated clay are visible in this horizon, beneath it and in the complex of fissures (planar voids) that runs through them from the burrow downwards (arrows).
I Detail of fragment of rubified material in figure 5F, showing an elongated pore with recognizable phytoliths (arrows).
J Scan of pit 21/152, sample 11. Most of the sample consists of a massive horizon that is composed of aggregates of rubified material. Colour differences between the aggregates themselves and with the underlying loam make it likely that the aggregates were heated first and then deposited to form the reddish layer.
K Thick multi-layered reddish clay coating in pit 246, sample 3.
L Scan of pit 21/152, sample 12. A horizontal band in the upper part of the sample (arrows) consists of very light-coloured material with a leached – out appearance, probably due to eluviation of fines.
M Microscope image of the boundary between the light-coloured area and the underlying strata of figure 5 L. There is less fine material in the light-coloured part.
N As figure 5M; XPL. There is no difference in the distribution of the coarser material (white spots are silt-sized quartz grains) between the light-coloured area and the normal groundmass.
O Scan of a sample from post hole 150. The area with the leached-out appearance in the upper part of the sample (arrows) shows vertical finger-like shapes.
P Iron oxide precipitate containing remains of fungal hyphae (post hole 151, sample 4)
Q Detail of Figure 5P showing a concentration of fungal hyphae.

4.2 Beek-Kerkeveld

In the samples from the fill of the Beek-Kerkeveld enclosure - six from the *Sohlgraben* and 13 from the *Spitzgraben* - three different types of groundmass can be distinguished. Discriminating them is sometimes difficult, because some samples have been strongly bioturbated. The three types are:

(1) Groundmass with recognizable thin sedimentary layers (samples 808-3; 810-1,2,3; 811-3; 812-1). These are characterized by well-sorted layering, but lack clear fining or coarsening upwards sequences. This probably results from differences in water flow velocity during deposition in running water (fig. 6A).

(2) Groundmass consisting of a series of stacked fining-upward sequences, each of them ending in a crust (samples 807-1; 809-3; 810-1; 812-2,3). These massive layered silty and clayey crusts (known as 'slaking crusts') commonly result from the disintegration of aggregates under the impact of rain. They easily form on top of sparsely vegetated soils with low clay contents and can often be seen in drying puddles (Pagliai & Stoops 2010). Their occurrence is frequently associated with surface erosion. Due to shrinkage and cracking during drying out these layers become discontinuous (fig. 6B).

(3) Groundmass consisting of rounded to subrounded aggregates of loam (805-1; 806-1; 807-2; 809-1,2; 811-1,2,3; 812-3), comparable to the groundmass in many of the samples from post holes and pits taken at the Elsloo-Riviusstraat site (e.g. fig. 6C). Commonly these samples contain charred remains (usually wood charcoal but sometimes also charred remnants of non-woody plants) and on occasion fragments of ceramics or baked loam.

The degree of bioturbation varies between the samples. Evidence for faunal activity are crescent-shape infilled wormholes, open biopores and – in some cases – elaborate patterns of

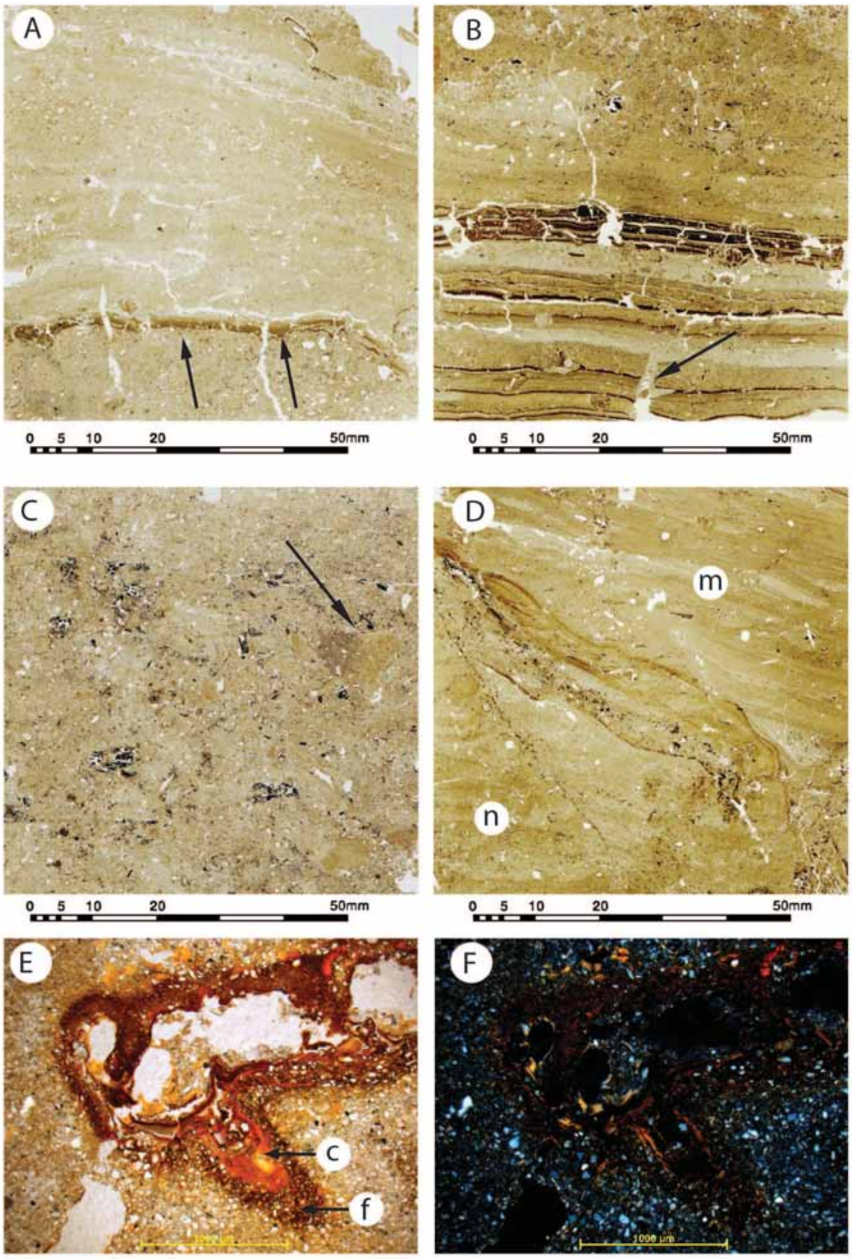

Figure 6. Micromorphological phenomena from Beek-Kerkeveld
A Scan of sample 812-1. Sedimentary layering is visible in the upper ca. 2/3 of the sample. The lower boundary of this unit (arrows) is a slaking crust.
B Scan of sample 810-1. The lower ca. ½ of the sample consists of a series of stacked slaking crusts. The lowermost 3 crusts show a shrinkage fissure (arrow) that has been filled with coarser material from the overlying thin layer.
C Scan of sample 813-2. The massive groundmass consists of aggregates and contains anthropogenic materials, including charred organic particles and small fragments of ceramics and baked loam. One of the ceramic fragments (arrow) is plant-tempered and baking has led to a reduced core and an oxidized exterior surface.
D Scan of sample 810-2. The natural loess deposits in the lower left corner (n) show some degree of grain-size separation and horizontal wavy layering. The boundary with the moat-fill is sharp. The latter (m) shows sedimentary layering, but the characteristics of the groundmass are hard to see due to iron oxide precipitation in the fill and surrounding area, on the boundary between the two units.
E Pore with iron oxide hypocoating (f) and clay coating (c). The clay coating covers the iron hypocoating, which indicates that the iron precipitation predates the formation of clay coatings.
F As E; XPL

cavities that may represent ants nests. The samples with slaking crusts seem least affected by bioturbation, although a few filled in worm tunnels are present in some of them. Sample 805-2 is severely bioturbated and as a result it is impossible to determine whether it started out as a layered, an aggregated or another type of groundmass.

In several samples the transition from ditch fill to surrounding loess sediment is present. These boundaries are without exception sharp and straight. Natural loess deposits typically show some grain-size sorting and wavy horizontal layering (e.g. fig. 6D). The grain-size sorting is caused by variations in wind speed during aeolian deposition, whereas the morphology of the layering is attributed to frost action (Kemp 1999, Van Vliet-Lanoë 2010). It is puzzling, however, that macroscopically these patterns are oriented more or less parallel to the edge of the ditch, i.e. curved, not parallel to the land surface. This may indicate that the ditch was made - at least in places - on the location of an already existing Late Glacial dry valley or depression.

Independent of the types of infill, many samples contain precipitated iron oxides. Precipitation occurs in bands (e.g. fig. 6D) and sometimes in the form of nodules. Where iron oxide precipitates and clay coatings occur together, the clay always envelopes the iron oxides, not the other way round (see fig. 6E,F for an example). This indicates that the iron precipitates were formed prior to the clay coatings.

The sequences in the western and the central profiles are similar: the lowermost horizons are characterized by a layered groundmass overlain by stacked slaking crusts. The top of the fill has an aggregate-dominated groundmass. The east profile, however, shows a different sequence: here the lowermost horizons have an aggregate-structure, immediately overlain by a sequence with slaking crusts. On top of that a stack of layered sediments is found, also with some slaking crust fragments in the top. The very top layers again have an aggregate-dominated groundmass.

4.3 Beek- Kelmond

The samples from Beek-Kelmond represent only a part of the total soil profile of the *Sohlgraben's* fill (see fig. 7 for a composite figure in which scans from all the thin sections are shown in their stratigraphical position). This whole section is light grey in colour. With increasing depth the amount of iron oxide precipitation in pores etc. increases. Within the sample sequence three horizons can be identified:

The top samples (39-7 and 39-6) contain considerable amounts of charred plant remains and some charcoal. They show evidence of intense bioturbation. Probably the whole soil mass has been mixed by the action of burrowing soil fauna, as a result no original depositional (sedimentary) structures have been preserved. In the lowermost sample precipitates of fan-like goethite (FeOOH) seem to form pseudomorphs after some other, possibly organic structures (fig. 8 A-D).

The middle samples (39-5 to 39-3) contain hardly any anthropogenic materials, apart from a few charcoal fragments. In sample 39-5 two thin slaking crusts are partly disturbed by burrowing soil fauna; in fact the whole soil mass still shows substantial bioturbation. Samples 39-4 and 39-3 show a series of thin to very thick irregular slaking crusts surrounded by strongly bioturbated material. In both samples very light layers with a leached or bleached appearance can be seen, similar to the ones found in some of the pits from Elsloo-Riviusstraat (see above).

The bottom samples (39-1 and 39-2) contain very few or no anthropogenic materials except for an increase in carbonized plant remains in the lowermost sample. They are heavily bioturbated, ecept for the lowermost part of the section, where the natural horizontal sedimentary layering has been preserved.

Figure 7. Combined scans of all thin sections from the Beek-Kelmond site; see also figure 2C.

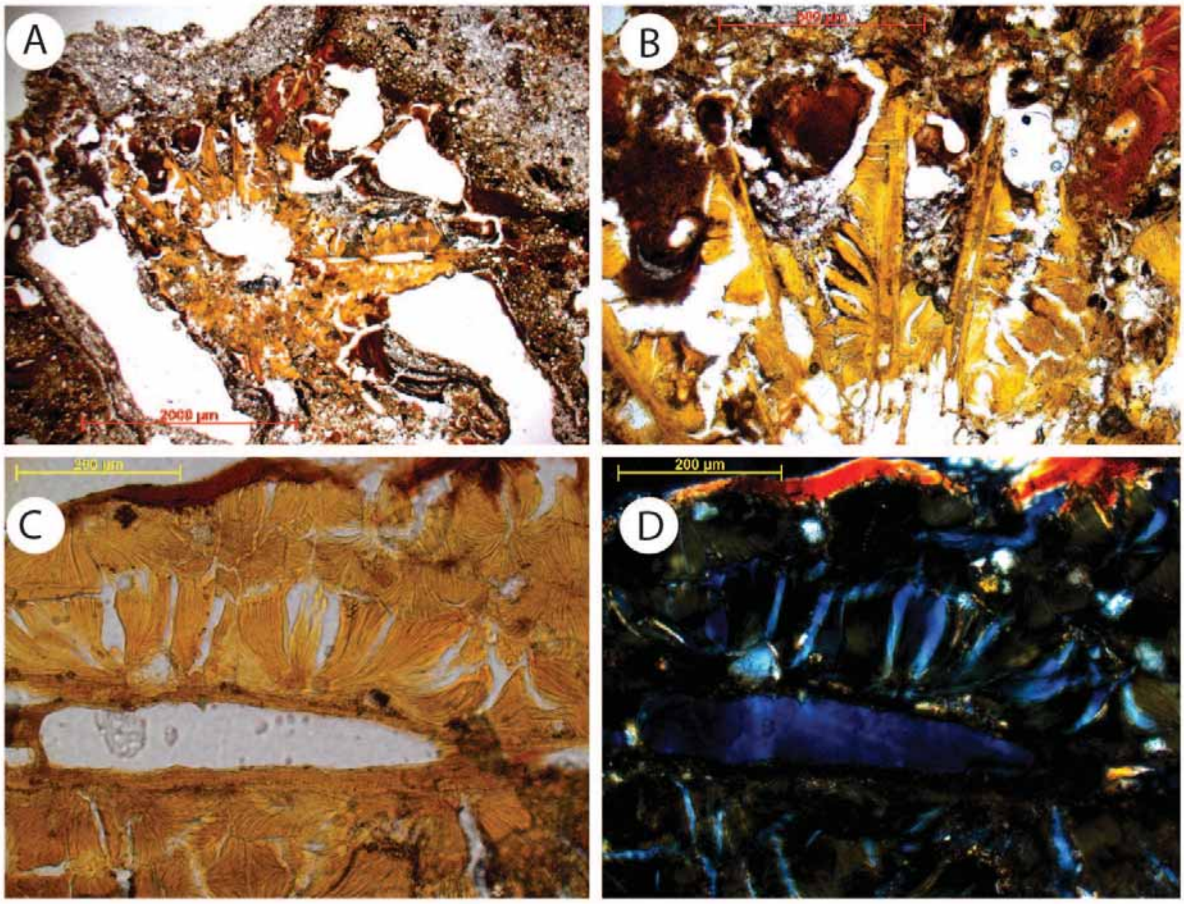

Figure 8. Iron precipitate from Beek-Kelmond, sample 39-7
A Star-shaped composite yellowish iron precipitation - probably goethite - in pore. Possibly pseudomorphs after organic material. Sample 39-7
B Detail of 8A, showing a combination of linear elements and fan-shaped minerals forming feather-like structures. The reddish material is an iron-rich clay coating.
C Finer detail of 8A showing the fan-like structure of the minerals.
D As 8C, XPL, showing that the precipitation of the iron minerals was followed by the formation of a clay coating.

5. Discussion

5.1 Post holes and pits (Elsloo-Riviusstraat)

In Elsloo-Riviusstraat the groundmass of the post holes shows distinctive characteristics of anthropogenically displaced soils. Soil material that is removed and redeposited by human action typically consists of rounded to subrounded aggregates ('clods') of various sizes. Soil material that probably originated from the topsoil of the immediate surroundings of the location is mixed with these clods, as well as waste material (like litter, charred material, heated loam, etc.).

The presence of considerable amounts of ceramic fragments, baked loam and carbonized remains in the first fill of the post hole – i.e. the fill that was formed when the post was placed - is an indication that the location was already in use as a settlement before the building was constructed. It is very unlikely that carbonized material and pottery fragments are present in high quantities on pristine settlement locations (Huisman and Deeben 2009).

The post pipe shows a very similar infilling as the post hole, i.e an aggregate structure with anthropogenic refuse mixed in the soil mass. This indicates that the immediate surroundings of the houses did not change much with respect to the soil conditions and waste material present on the site. The aggregate-fill of the post pipes also indicates that the investigated posts of the buildings were extracted, and that the resulting holes were actively filled in. This not only concerns the large central posts (features 82 and 151, see figs 2A and B), but also the smaller ones. Evidence for other ways of destruction or abandonment of the buildings is lacking: burning would have produced *in situ* heated loam and articulated charcoal. Infilling of holes by natural processes (after decay of the wood or after extraction) would have produced sedimentary layering and/or intense bioturbation. Collapse of the holes after extraction would have left traces that were macroscopically visible. This indicates that after the use, the buildings were dismantled, posts extracted and the resulting cavities actively filled in. The extracted wood may have been re-used elsewhere. The dismantling of the building must have taken place when the settlement was still in use, or very shortly after abandonment. Since the location was not used for a construction, this may indicate that dismantling was followed by a use for which decaying building remains or remaining open holes were not wanted or needed, one could speculate about gardening or keeping domesticated animals. Whatever the reason, it is clear that former house sites were cleaned up, and not left to decay.

The fill of the elongated pits (*Langsgruben*) bears testimony to a completely different formation. The lower reaches – with layered sediment deposits without slaking crusts – were probably formed by underwater deposition. The grain-size sorting rules out stagnant water, but points to water that was perturbed in some way- possibly by trampling in the immediate vicinity. The material may have originated from erosion of the pit sides or from soil and possibly waste material that fell or was dumped into the pit. This first infilling phase of the pit also contains some non-burnt bone fragments. They are small and may originate from degradation and fragmentation of larger bones. The pit fill is not consistent with typical burial fills, which would have an aggregate structure. It is therefore most likely that refuse bone material ended up in the pit by accident. The lack of slaking crusts or fragments of such crusts suggest that these layers were permanently waterlogged and did not dry out. Since this is unlikely because of the generally high permeability of loess deposits, it is more likely that slaking-crusts that must have formed during dry spells were removed later. The lack of slaking crusts therefore suggests that the pit was rejuvenated at some moment prior to the formation of the overlying horizons.

The overlying horizons in the same pit - representing a second phase – seem to have been dumped rather than deposited. This is indicated by the fact that the soil mass is built up from aggregates and by the lack of layering that would be typical for natural sedimentation. The sequence of charcoal-rich dark layers followed by layers of reddish 'baked loam' is common in many pit fills from LBK settlements. The variation in the baked loam fragments makes it likely that each type was produced or has formed under different circumstances:

– The fragments containing recognizable soil characteristics probably originate from below a fire or oven. Their thickness may indicate that the fire was prolonged and hot. So it might have been rather an oven than a simple (cooking) fire.
– The presence of phytoliths in several baked loam fragments is an indication for tempering of the clay or loam with plant material and probably represent a mixture that was needed for a specific purpose. Adding vegetable temper is typically done to enhance the structural capacity of loam or clay by increasing the cohesion and preventing too much shrinkage on drying out. The fragments may have been part of the above-ground structure of an oven or represent pottery sherds and waste from pottery making. Alternatively they could be daub fragments from a burnt building or pieces that became heated after the demolition of a house.

– The third type (clay without temper) was either collected off site (for example for the production of ceramics) or made from a strongly modified local material (i.e. after removal of a particular fraction), as it contains much less silt than the soil on site. In addition, the aggregates appear to be more rounded than the rather angular fragments mentioned above. Together with colour differences between the aggregates and sharp boundaries, this suggests that the material was not heated *in situ*. The way in which the aggregates have been compressed demonstrates that it still was somewhat plastic when deposited in the pit. Apparently it was heated enough to cause red discolouration, but not to the extent that transformations would make it hard and brittle. Moreover, the macroscopic appearance of this layer, with a consistent composition and a more or less uniform thickness and massive structure, suggests that the material was distributed evenly on the floor of the pit. Later the pit was partly filled with more or less clean soil material, as a result of which the baked material compacted. Dumping the red matter without an additional purpose would not have produced a relatively thin continuous homogeneous layer with a more or less uniform thickness and low porosity. Overall, it seems that this layer was made to prepare the pit for a new use in which a compact, more or less flat non-sticky floor surface was needed.
– The charcoal in the dark horizons shows evidence of two types of degradation: breakdown by worms ingesting and excreting fragments, and disintegration. The latter is caused by temporary alkaline and potassium-rich conditions due to ashes having been deposited in the same pit along with the charcoal and soil material (Slager & van de Wetering 1977, Huisman *et al.* 2012).

The overall sequence of events for a Elsloo-Riviusstraat house can be summarized as follows:

Phase 1

Start, expansion and use of the settlement.

Phase 2

Construction of a new building on the site, necessitating the digging of post holes and loam pits. The fill of the post holes incorporates (carbonized) refuse from the surroundings.

Phase 3

Use of the building and adjacent pits. The pits are dug for loam extraction. Subsequently they are used for activities (maybe material processing) that result in underwater deposition of sediments, during which trampling of the bottom layer occurred. Probably some rejuvenation occurred as well. Eventually, in stages, the pits are filled with refuse, including layers of charcoal and ashes and fragments of heated loam. Ashes disappear quickly, but not before causing the disintegration of charcoal and intense clay translocation. Especially wood-ashes are very rich in soluble potassium compounds. Dissolved potassium destabilizes the benzene-like charcoal compounds that then disintegrate (Braadbaart & Poole 2008; Braadbaart *et al.* 2009; Huisman *et al.* 2012). One of the filling phases represents the dumping of a floor-like layer using low-temperature heated loam or clay. The last phases of use of these pits may postdate phase 4.

Phase 4

Destruction of the building. The posts are extracted and the holes are actively filled. The fill of the post pipes incorporates (carbonized) refuse from the surroundings.

Phase 5

Abandonment of the site. Worm activity causes destruction of some of the charcoal in the features. In the 1950s, the site is overbuild and the topsoil is lost due to the construction of houses. Parts of the LBK settlement that were situated below the gardens show evidence of increased biological activity, including ants nests.

5.2 Ditch fills (Beek-Kelmond and Beek-Kerkeveld)

5.2.1 General interpretation

Several types of groundmass have been identified as part of the fill of the ditches. Each type probably represents a different way in which the soil material entered the ditch and deposition took place (see also Stäuble 1997):

The slaking crusts represent periods during which material was washed into the depression and ended up in puddles or very shallow water that finally dried up. Each of these phases may have been as short as one rain event followed by a dry spell. Note that such deposits were absent in the *Langsgruben* in Elsloo-Riviusstraat that were described above.

The concentrated fine soil particles that are typical for slaking crusts are absent in the layered fills. The layering and the subtle variations in grain size nevertheless suggest that the deposits were formed by natural sedimentary processes. It is plausible that they represent continuous series of deposits that were formed under water, without drying out phases in between. This also implies that there was enough water movement to allow some degree of grain-size sorting. It is unlikely that sediment was transported into the ditches by active watercourses like brooks or streams. If e.g. flooding during wet spells had occurred, coarser material (like sand and gravel) would have been present. It is also unlikely that the material was dumped into the ditch, as this would have produced aggregates embedded in the sediment. Presumably soil material from the immediate (upslope) surroundings (including spoil heaps and ramparts) and/or banks of the ditch eroded and washed in, mainly during rainfall events when surface runoff of water took place towards the lower-lying parts of the terrain, which includes the ditches. The deposits that have an aggregate structure are comparable to some of the pit fills from Elsloo Riviusstraat described above and were most probably formed by the dumping of soil material.

5.2.2 Beek-Kerkeveld

As mentioned above, the sequences at Beek-Kerkeveld in the western and the central profiles differ from the eastern profile. In the western and central profile a layered groundmass is overlain by stacks of slaking crusts, followed by an aggregate dominated groundmass. This upper layer probably belongs to a rejuvenation phase. In the eastern profile, however, the lowermost fill has an aggregate structure. It is covered by a sequence with slaking crusts, followed by a stack of layered sediments. The very top layers again consist of a groundmass of aggregates.

The stratigraphical and micromorphological differences in the fills of the eastern profile on the one hand and the western and central profiles on the other reflect disparities in the genesis and use of these parts of the ditch system. The eastern profile only represents the early (*Spitzgraben*) phase that was not affected by rejuvenation, i.e. re-excavation and adaptation of the cross-section. This rejuvenation, present in the central and western profiles, did not affect the lower layers in the eastern profile – although the top layers may have originated from soil material that was displaced when the second phase (*Sohlgraben*) was dug. Therefore, the differences in the lower layers suggest that different parts of the earthwork system have had a different fill-in history. The excavation showed that the first phase of the earthwork consisted of a series of elongated pits that were not connected. This may explain the observed differences in the fills at various locations.

In the <u>western and central profiles</u> the sequence of events can be summarized as follows:
<u>Phase 1:</u>
Digging of a series of narrow elongated non-connected pits with steep sides. Possibly there is the also construction of an earthen rampart, but no trace of it was found.

Phase 2:
The pits are periodically filled with water, e.g. as a result of rainfall. Sediment is deposited on the bottom.
Phase 3:
The pits are dry and probably non-vegetated. Rain events cause the formation of puddles or temporary filling of the pits with water, but they dry up in between. Some biological activity occurs. Absence of anthropogenic refuse makes it unlikely that the dumping zone of a settlement was very close by, but a distance of a few dozen meters or local relief (e.g. a rampart) may have been enough to prevent anthropogenic material from being deposited here.
Phase 4:
Humans fill in the ditch with soil material.
Phase 5:
Rejuvenation of the earthwork. A shallower and broader continuous ditch is dug. Possibly an earthen rampart was constructed, but if so, no traces remain.
Phase 6:
Infilling of the second ditch with soil material. Probably partly by humans, but local erosion and redeposition may also have played a role. Biological activity occurs and is locally intense. This indicates that organic remains were incorporated in the fill. The levels with indications of biological activity may be interpreted as paleosols with limited impact of soil forming processes. Scarcity of anthropogenic refuse makes it unlikely that the dumpzone of a settlement was close by.
In the eastern profile the sequence is as follows:
Phase 1:
Digging of narrow elongated pits with steep sides. The construction of earthen rampart, is possible,but if so, no traces remain. This phase presumably coincides with phase 1 of the western and central profiles.
Phase 2:
After the deposition of millstone and runner, the deepest part of the pit is filled in with soil material, probably by humans. Absence of anthropogenic refuse makes it unlikely that the dumpzone of a settlement was close by. Some wet/dry cycles cause the formation of slaking crusts. Biological activity.
Phase 3:
The pits are filled with water. Sediment is deposited on the bottom (possibly similar to phase 2 of western/central profiles). In latest stage some evidence for drying up of the water.
Phase 4:
The depression is used as dump site and becomes filled up with soil material and refuse. The refuse includes charred remains, ceramic fragments and fragments of baked loam, and may originate from the dumpzone of a settlement close by. Strong biological activity.
Phase 5:
This part of the ditch is not affected by the rejuvenation of the earthwork system.

5.2.3 Beek-Kelmond

At Beek-Kelmond only the lower layers of the *Sohlgraben* could be sampled. As a result only the first phase of the ditch was analyzed. From this, the following sequence can be derived:
Phase 1
Digging of the feature. Possibly there is the also construction of a rampart, but if so, no traces remain.
Phase 2
The ditch is used as a dump for refuse, including charcoal, charred plant remains and fragments of ceramics or baked loam. It is likely that organic remains were dumped as well: the

iron-oxide pseudomorphs shown in fig. 8 may represent imprints of decayed fragments of plant tissue. The strong bioturbation is another indication. It is likely that the anthropogenic material originated from the nearby settlement. Parts of house plans were identified during the excavation at some 20 m distance from the feature.

Phase 3

The ditch collects rainwater and local sediment, resulting in the formation of several slaking crusts. Indications for biological activity make it likely that the location was overgrown at the time, though sparsely. Local material washes in, but may also have been dumped in low amounts. Anthropogenic refuse indicates the presence of a settlement in the immediate vicinity.

Phase 4

The depression is filled in with soil material, possibly by humans, but since strong bioturbation has severely disturbed the morphology of the groundmass this is uncertain.

The rest of the infill was not investigated, but based on macroscopical observations the top presumably consists of material with large amounts of settlement refuse, including charred material, baked loam and ceramic fragments.

5.2.4 Timing of the phases

The various types of infill of the ditch features could easily have been formed in a relatively short period of time: slaking crusts may each represent a single rainfall event, whereas waste dumping and active filling in is virtually instantaneous. Given the limited amount of material deposited in each slaking crust, it is likely that the sedimentation in wet periods occurred fast too. The only evidence for soil forming processes that are contemporary with the sequences described above, is traces of bioturbation. Such traces of biological activity (floral and faunal cavities and tunnels) can easily have formed within a few decades. The evidence for rapid sedimentation and the lack of more intense soil formation indicate that the ditches for the most part were filled in very quickly, likely even within a single generation after their construction.

6. Conclusions

Micromorphological investigation of anthropogenic features was successfully used to study the history and human activities in parts of three LBK (Linear Pottery Culture or *Bandkeramik*) sites in the southern Netherlands. Focus was on post holes from house plans, the function and history of Langsgruben and the sequence of events in construction of earth works.

The study of post holes in Elsloo-Riviusstraat showed that the particular buildings under investigation were erected when the settlement already existed. Large pits next to the buildings had a complex multi-phase history of infilling. After being dug, probably to extract loam, the pits were used for some purpose that resulted in underwater deposition of sediment. After a probable rejuvenation phase, they were adapted for a different use by placing a level of low-temperature heated clay/loam on top of the first fill. These results suggest that the large pits next to buildings were used for different, specific purposes and adapted for their use. They should be regarded as relicts that played a role in the household and technological activities associated with the adjacent house plan. After use, the buildings were dismantled, posts were extracted and the resulting cavities were actively filled in. The fact that former house sites were cleaned up and not left to decay may indicate continued use of the location in the still existing settlement.

Ditches at Beek-Kelmond and Beek-Kerkeveld also had a complex history of infilling. Based on the character of deposition and on the content of the deposited material, several phases could be discerned. They include periods of stagnant water, repeated drying out and wetting phases and anthropogenic dumping of soil material. The distance to settlement–related refuse dumps varied. Horizons with intensive bioturbation probably represent phases of low sediment supply, resulting in plant growth and soil-formation. It is remarkable that different sections through an enclosure ditch like the one at Beek-Kerkeveld can yield considerable differences in the sequence of phases. It is most likely that the filling-up of the ditches took little time, maybe only one generation.

The processes identified are either direct human activities or relatively localized (natural) processes. Extrapolation to larger geomorphological (landscape processes) is hampered by the very localized activities on and specific properties of settlement sites.

For future excavations of LBK settlement sites in loess areas (where severe soil erosion has often resulted in the - partly - destruction of traces), systematic micromorphological sampling of the typical pits (*Langsgruben*) next to buildings can reveal new insights on their formation and use. An interesting line of investigation could be to test whether pits belonging to one house may have been used for different purposes. For the investigation of enclosures, micromorphological studies can be instrumental in determining phasing in their construction and use.

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D.J. Huisman
Cultural Heritage Agency, Amersfoort (h.huisman@cultureelerfgoed.nl)
Leiden University, Faculty of Archaeology

F. Brounen, B.J.H. van Os, E.Rensink
Cultural Heritage Agency, Amersfoort

J. de Moor
EARTH Integrated Archaeology, Amersfoort

E. Lohof
ArcheoBegeleiding, Amsterdam

R. Machiels
ADC Archeoprojecten, Amersfoort

P. van de Velde
Leiden University, Faculty of Archaeology

I. M. van Wijk
ARCHOL B.V., Leiden

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