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<td>Authors(s)</td>
<td>Lewis, Helen</td>
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Micromorphological study of ridge-and-furrow remains at Watson’s Lane, Little Thetford, Cambridgeshire

By H. A. Lewis
For the Cambridge Archaeological Unit
March 1999

Introduction

The Watson’s Lane site included part of a relatively well-preserved ridge-and-furrow field from the Medieval and post-Medieval periods (SMR 09873). The ridge-and-furrow area investigated included 12 ridges spaced c. 4 m apart, and standing up to 1 m (Gdaniec and Butler 1994, 6). Trial trenching of the area was carried out by the Cambridge Archaeological Unit in 1995. Trench 10 (see Figure 1) cut across the line of the ridge and furrow system, exposing Ridges 3-10 in section (see Figure 2 - ridges are numbered from north to south). This trench was opened to allow detailed study of the field system, with the ultimate aim being reconstruction of the processes involved in its development. In addition to field description, the system was studied through soil micromorphology as forms part of doctoral research on the characterisation of ancient tillage practices through field and soil micromorphological analyses (Lewis 1998).

Figure 1  Plan showing the excavation layout and location of Trench 10
(from Lucas and Hinman 1998, 2)
Previous studies of ridged fields (e.g. Lerche 1982, 1984a; Parry 1976; Ramskou 1981) suggest that it may be possible to define ridged field typologies based on function and technology. Variation over time seen in the features comprising an individual field may be used as an indicator of changes in the farming system in question as a whole. Very few detailed analyses have, however, been conducted, and there are many unresolved issues. One of the questions of interest for the purposes of this study is whether typical ridge and furrow morphology is related solely to relatively late types of ploughing, or could result from earlier systems (e.g. ard ploughing), or even be created using totally different types of implements (spades) (Lerche 1982, 1984).

Pre-modern tilling with a mouldboard plough was generally carried out in strips. The usual pattern was to start ploughing at the middle of a strip, turning the soil to the right side, and to ‘circle’ around the strips clockwise, turning each slice into the previous furrow. The furrows at the edges of the strips would be left uncovered (‘open furrows’). Lerche (1994) has demonstrated by experiment that once this pattern has been repeated several times a visible ridge is produced along the middle line of the strip, and open furrows occur between the strips. This operation – ‘ploughing together’ - is the basis for creating ridge-and-furrow field structures with a plough (Figure 3). The ridge-and-furrow develops as the soil accumulates in the centre of the strip, being constantly moved from the edges. The furrows become deeper at the same time, and often deepen so much that they extend below the original surface level, and through the topsoil itself into the underlying horizon. One could level out ridge-and-furrow by interchanging ‘ploughing together’ with a pattern known as ‘splitting’, where ploughing starts at the edge of a strip, splitting the ridge and creating two open furrows. This last practice is seen as being mainly used in modern times (since the 19th century AD), when better underground drainage lessened the need for ridges and open furrows (Lerche 1994, 15-20). At Sarup, Denmark (Lerche 1994, 142), the fill of ‘open furrows’ was more clayey (presumably due to crusting, soil creep etc.) and stony (possibly from stone collecting, water erosion in the furrows, or plough action) than the surrounding soil.
The pre-medieval origins of ridge-and-furrow are poorly understood. Whether ridge-and-furrow development is simply the result of mouldboard plough technology and/or came about because of land division and tenure strategies, and how it relates to the beginnings of open-field systems are still open questions. Dating is also a problem. Ridge-and-furrow is normally dated to Medieval times partly on the basis of spatial correspondence between surviving ridged fields and historically-recorded fields, and because earlier (Saxon) settlement patterns do not appear to correspond to ridge-and-furrow systems (Hall 1981; and see Fowler 1981). At Haystack Hill (XXX) however, the association of this type of field structure with a late Iron Age or Romano-British settlement has led the excavator to suggest that either the ridge-and-furrow system also dates to this period, or that the settlement form of ‘scooped hut enclosures’ has a longer and later history than previously thought (Adams 1996, 6). It is, however, also possible that Medieval farmers respected the earlier settlement - for example, the use of prehistoric field boundaries in Medieval field systems has been reported at Caxton, Cambridgeshire (Denison 1998).

The practice of creating ridge-and-furrow is generally associated with broad ridged fields (5-20 m wide ridges) (Parry 1976; Carter et al. 1997, 447) or grooved rig (as broad rig, but without obvious ridges, only widely-spaced furrows) (Dixon 1994; Carter et al. 1997, 447). Case studies of the histories of particular ridge-and-furrow fields and field systems are presented by Hall (1981), Bowen (1963) and Parry (1976), among others.

There has long been discussion over whether certain ridged field forms, particularly narrow ridged (0.5-1.1 m between ridges), were created by ploughs or using spades/shovels. Various forms include cord rig (<1.25 m wide ridges), which may date from at least 5 000 BP in some areas (sites with prehistoric narrow-ridged fields include North Mains, Strathallen (Scotland), Glenree (Ireland) and Kilellan Farm, Islay (Scotland) (Macphail et al. 1990a, 57-64; Caulfield 1978, 137; Chadburn 1987; Carter et al. 1997, 447; Halliday and Reynolds 1984). Ramskou (1981, 101) discusses whether the field remains at Lindholm Høje, Denmark, were created using a spade, mattock or plough. He concludes that the narrow ridged system was made using a plough, based on the evidence of faint plough furrows, harrow marks, hoof marks and human footprints, which could represent a headland, along with the fact that no spade marks were found (see also Lerche 1982; 1994, 148). In addition, narrow-ridged systems have been related to finds of carbonised barley in Scotland, which implies, according to Carter (1993-4, 90) that they were probably created by ploughing, although there is no reason given nor evident as to why barley could not have been grown in a spade-tilled field, or a field tilled with a combination of ard and spade (e.g. as is possibly the case at Kilellan Farm (Halliday et al. 1981, 56)). Spades are known to have been used in ridge creation at least in historic times (Bowen 1963). Ridged fields have also been associated with hoeing in other parts of the world (e.g. in North America - Currie 1994), but this option has not been discussed regarding early European examples.

Recently cord rig has been ascribed to a combination of ard and spade tillage, and the use of some ridge-and-furrow systems for the production of grazing and not cereal crops has been proposed (Carter et al. 1997, 447). However, while ridge-and-furrow systems have been typological classification (e.g. Bowen 1963; Parry 1976), the different morphologies presented by spade-tilled and ploughed narrow ridge systems have not been discussed in any...
detail. Spade tillage might produce substantially different ridge organisation when compared to ploughing, although both overturn a slice. This has yet to be examined in any detail. Traction spades, which also turn to one side, should still create piled soils, but do not necessarily lead to overturned slices (Steensberg 1971-2, 19, 21). Excavations at Kellah Burn (Northumberland) have produced cord rig remains dating to the later Iron Age or Roman period, overlying ard or plough marks (J. Pollard, pers. comm.). The relationship of the marks either to type of implement or to the overlying narrow-ridged system is uncertain, but they do have a similar orientation. This could support the suggestion that they were created by traction tilling and not spade digging.

Finally here, Carter et al. (1997, 455-6) use soil pollen evidence associated with groove-ridged field systems at Lour (Scotland) to suggest that, at this site at least, tillage was carried out in relation to the reseeding of grazing land. They suggest that the importance of cereal crops may be overestimated by assuming that traction tilling features are always related to cereals. This is supported by historical evidence which documents the use of ridge-and-furrow for grass growth and as permanent pasture during post-Medieval times. Such land use is thought to mark a change in practice at the end of the Medieval period (Hall 1981, 26). Rees (1979, 742) also questions the relationship between traction implements and arable farming for grain, suggesting that it is difficult to say that they are not associated with the hay harvest, especially in those later periods with a good deal of evidence suggesting that hay was an important crop.

The Little Thetford study

The aim of this study was to obtain a more detailed description of soil features resulting from ridge-and-furrow systems, with a focus on the identification (if possible) of the type of implement(s) involved in the field’s development, and of changes in the farming regime over time. Unfortunately the weather, and thus soil conditions, were adverse for this type of study during the time of the excavation. Very warm and rainfree conditions persisted for months, and the high clay component of the soil (reflected in its ‘dried cement’ consistency) meant that it was virtually impossible to clean down a section and, once cleaned, to distinguish between soil horizons (contrast was very low). Only a few individual furrows could be positively identified, and microexcavation or detailed field analysis of these proved futile.

A general section was drawn (C. A. U. WAT95 Section No. 3). The soil profile agreed with that recorded previously both by the Cambridge Archaeology Unit (Gdaniec 1994, 1,4) and the Geophysical Surveys of Bradford (1995, Figure 12). Most other parts of the site opened up in the 1995 season also fit the profile description given below (Table 1).

Regarding the ridge-and-furrow system generally, two main phases were identified in the field. The ridges were all less than 2 m high in total (topsoil and B horizon), and mainly less than 4.5 m wide. They ran relatively straight. These characteristics suggest they fall into Bowen’s (1963, 34) narrow rig type, which may date to the late eighteenth and nineteenth centuries (see Parry 1976 for more). An earlier set of ridges (but not furrows) was expressed in the B horizon under the modern topsoil. These ridges were located c. 30-60 cm off-centre from the highest point of the ridges in the topsoil. Gdaniec and Butler (1994, 6) suggest from their earthwork survey that the narrow ridges represented by the later phase may have been later additions to a broader system. In the field, however, it seemed to this author that each later narrow ridge had an earlier, narrow precursor, and there was no evidence for a broader system. It is clear from the thin sections (see below) that the visibility of the underlying system is based in the later development of a clay-enriched B(t) horizon, and need not be explained by a different field morphology per se. A more pertinent question may be why the B horizon boundary developed at the depth at which it occurs within the system in general. Occasional individual furrows seen at this horizon boundary in the field may represent a difference in a particular tilling episode, or might have been ‘open furrows’ (usually for drainage), that later filled in through soil creep (Lerche 1994, 141-2). The latter interpretation would explain their visibility (see below for more).
Table 1 The soil profile from Trench 10, Watson’s Lane, Little Thetford

<table>
<thead>
<tr>
<th>Context Number</th>
<th>Horizon</th>
<th>Thickness</th>
<th>General description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1995</td>
<td>1994</td>
<td></td>
<td></td>
</tr>
<tr>
<td>[200]</td>
<td>[001]</td>
<td></td>
<td></td>
</tr>
<tr>
<td>A-B interface</td>
<td></td>
<td>1-5 cm (intermittent)</td>
<td>As A horizon (above), but with frequent orange flecking. Subangular blocky peds, 2 cm size. Inclusions as above.</td>
</tr>
<tr>
<td>[201]</td>
<td>[002]</td>
<td></td>
<td></td>
</tr>
<tr>
<td>B (old Ap) Bh (U. Bradford)</td>
<td>10-50 cm</td>
<td>Sandy clay loam. Friable when wet, stiffer with depth. Light to mid orange-brown. Massive, possibly columnar in places (peds c 4x10 cm). Occasional fine and larger roots. Rare larger rounded/sub-rounded stones, often with downward bedding in base of layer. Other inclusions as in [200]. Occasional earthworm noted.</td>
<td></td>
</tr>
<tr>
<td>B-C interface</td>
<td></td>
<td>&lt;3-10 cm (intermittent)</td>
<td>(Sandy) clay. Very stiff when wet, solid when dry. Grey. Massive. Gradual boundary with B, sharp and straight with C. Possible furrows.</td>
</tr>
<tr>
<td>[202]</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C (natural)</td>
<td></td>
<td></td>
<td>Varies: 1. pale yellow very stiff clay 2. bluish-grey very stiff clay (Cg) 3. red-orange sand/gravel 4. sandy grey clay (base of Bg? C?)</td>
</tr>
</tbody>
</table>

Only three sets of samples were taken for soil micromorphological analysis (see Table 2). Profile 3 was a background sample through an apparently typical part of the section, and one ‘good’ individual furrow was sampled (Profile 1) from the section. This furrow was found at the topsoil-B horizon boundary in Ridge 10. It was 20 cm wide and 15 cm deep, and had a flattened U-shaped profile. Despite the suggested late date for narrow rig (see above), these characteristics put the furrow into a range typical for Medieval plough furrows (see Lerche 1994, 105-6). Profile 2 came from the base of a furrow exposed in the natural subsoil in the main excavated area. This had a similar shape in section to that described above. Unfortunately, this sample was disturbed in transit, and broke down to the extent that analysis in thin section was deemed to be unproductive. The samples are listed below (Table 2).

At the time further sampling seemed to be futile, given both the hardness of the soil and the difficulty in distinguishing relevant features (and thus of deciding where to sample!). No area on the site was uninvolved in the ridge and furrow system, so it was not possible to take control samples for comparison to the tilled profiles.

Table 2 List of micromorphology samples from Trench 10, Little Thetford

<table>
<thead>
<tr>
<th>Sample/Profile Number</th>
<th>CAU Environmental No.</th>
<th>CAU Context No.</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>WAT 95 PR 1</td>
<td>39</td>
<td>200-201</td>
<td>Individual furrow in Ridge 10</td>
</tr>
<tr>
<td>WAT 95 PR 2</td>
<td>40</td>
<td>201-202</td>
<td>Base of furrow exposed between Ridges 5 and 6</td>
</tr>
<tr>
<td>WAT 95 PR 3/1, 3/2, 3/3</td>
<td>41</td>
<td>200-201</td>
<td>Vertical column through Ridge 6, over ditch feature</td>
</tr>
</tbody>
</table>

The micromorphology samples

The thin sections produced contain only contexts [200] and [201]. The detailed soil micromorphology descriptions are given in the appendix, and are summarised in Table 3 below. Context [200] is a modern Ap horizon (tilled topsoil), and has a more organic nature (organic-stained), as is to be expected from a topsoil.
Underlying [201] has Bt characteristics (accumulation of illuviated clay).

Table 3  Summary of the general soil micromorphological characteristics of WAT 1 and WAT 3† (see Appendix II)

<table>
<thead>
<tr>
<th>Horizon/context</th>
<th>Ap/200</th>
<th>B(t)/201</th>
</tr>
</thead>
<tbody>
<tr>
<td>Characteristic</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Microstructure</td>
<td>Granular and subangular blocky; apedal crack and vugh in peds</td>
<td>Apedal crack and subangular blocky</td>
</tr>
<tr>
<td>Porosity</td>
<td>15-20%: interpedal cracks and channels; intrapedal vughs and cracks</td>
<td>As [201], but mostly intrapedal.</td>
</tr>
<tr>
<td>Mineral components</td>
<td>coarse: fine ratio - 30:70</td>
<td>30:70 - versus [200] - increase in clay (to c. 40%), at expense of silt and very fine sand</td>
</tr>
<tr>
<td>Organic components</td>
<td>&lt;10%; mostly fine to very fine amorphous and structural remains, and ‘punctuations’. Organic staining on most of the fabric.</td>
<td>&lt;10%. As [200], but less organic stained.</td>
</tr>
<tr>
<td>Groundmass</td>
<td>Stipple-speckled with some poro- and granostriation. Reddish-brown (PPL &amp; CPL), moderately birefringent. Clay is light reddish brown (PPL), light orange (CPL), and dusty.</td>
<td>Grano- and porostriated, some stipple-speckled. Reticulate striated with depth. Light yellow-brown (PPL &amp; CPL), dusty-dirty clay, cleaner where granostriated.</td>
</tr>
<tr>
<td>Pedofeatures</td>
<td>Fragments of an iron-stained fabric, as well as of [201] material at horizon boundary zone (particularly in WAT 3, but occasionally in WAT 1). Dusty clay coatings and infills. Amorphous organic staining. Iron and manganese-rich nodules. Rare pottery fragment.</td>
<td>Fragments of [201] material (some as infills in channels, but, especially in WAT 3, some as aggregates). Dusty-dirty clay coatings and infills, some clean coatings in zones. Amorphous organic staining. Sesquioxide (iron)-rich zones.</td>
</tr>
</tbody>
</table>

Both samples present several types of microfeatures that relate to their tillage history. In both profiles analysed there are numerous clay-based textural pedofeatures that are generally held to be indicative of disturbance - dusty to dirty clay infillings and coatings, as well as an overall dusty fine groundmass (e.g. Macphail et al. 1987; Macphail 1986b; 1987a, b & c; Jongerius 1970). The latter is more dominant in the modern topsoil ([200]) than in the lower layer, but only because of the strong presence of granostriated cleaner clay in the Bt horizon ([201]) and because of the more organic (stained) nature of [200], and not because there is a greater amount of dusty clay itself. While dusty clay coatings have been demonstrated to occur under certain conditions with tillage (Jongerius 1983), they have also been found in many disturbed soils under bare surfaces, regardless of whether these have been cultivated or not. For instance, raindrop splash on bare earth where vegetation has been removed by fire, making it susceptible to leaching, has been seen to create such features (Boulbin 1976; Limbrey 1975; Gebhardt 1990, 33; 1993, 334-335; Macphail and Goldberg 1990; Macphail et al. 1990a, 54-55; Mikkelsen and Langohr 1996). In addition, such features have been related to deforestation followed by illuviation (French In press a), and to tree throw disturbance (Macphail 1987d; Macphail et al. 1990a; Macphail and Goldberg 1990; Gebhardt 1993, 336). Characteristics that are possibly more specific to tillage in these samples include void ‘echoes’ of the furrow cut sampled, mixing of [200] and [201] fabrics at the horizon boundary, and the development of a possible agriculturally-like zone at this boundary. These features will be described by profile below.

**WAT 1**

It is unfortunate that it was not possible to sample this furrow so as to include material external to the cut, but certain characteristics of the fill represented in the thin section profile are interesting, especially when compared to WAT 3 characteristics (see below).

This profile, while showing only the fill of the mark, contains both [200] and [201] horizons, with a relatively sharp boundary between them, and only very occasional mixing of the materials at this boundary zone (see Figure 4). The presence of the Bt horizon as a horizon in the furrow fill indicates that the Bt developed after the tilling episode represented by this feature. Given this, it is not surprising that there is little mixing of the horizons seen in the fill, unlike that seen at the horizon boundary in WAT 3 (see below). This lack of mixing may be one reason why this furrow was visible as an individual mark in the field. It is also possible that the furrow fill had a slightly more

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† All percentages are based on visual estimates of area.
organic nature (re. organic staining) than the material outside of the feature, but this was not noted in the field (and similarly strong organic staining was seen in [200] material which was not evidently within a furrow - see WAT 3 below). This individual furrow might represent some kind of 'open' furrow, which did not see frequent repeated tilling.

The development of a horizon boundary within a tillage feature fill, as opposed to around the feature cut, appears to contradict ideas that soil horizon boundaries are often located and created at the base of tillage due to the change from a loose (porous) furrow fill to a dense zone immediately underlying the feature (zone of physical compaction, and often with fines accumulation (panning) adding to the density increase). At other sites, e.g. at Bjerre Site 7, Denmark, certain horizon boundaries follow tillage mark cuts (bases and sides), suggesting that tillage mark boundary zones are important factors in the location of later accumulation zones for translocated material (see Lewis 1998 for more). At Little Thetford, certain accumulation zones do appear to agree with that suggestion (e.g. the fact that the Ap-B(t) horizon boundary follows the general ridge-and-furrow topography, as opposed to being a straight line cutting through ridges. Also see WAT 3 below regarding an accumulation zone of clay possibly marking the base of a tillage zone at this boundary). But the horizon boundary internal to this furrow suggests that individual tillage feature cuts do not necessarily always play an important role in boundary formation. It is unclear what component of the enhanced clay content in the B horizon within the furrow is related to soil creep while the furrow was open, as opposed to later clay movement related to Bt horizon development.

At the base of the fill is a zone of connected planar voids that appear to echo the furrow cut (as represented by the shape of the fill in total) (see Figure 3). Given the amount of clay translocation seen in the sections, it is difficult to imagine how such voids would have remained unfilled with textural pedofeatures (clay and silt infillings) if they had been open since the tilling episode represented by this furrow, and it is likely that they are modern, created during field and/or sample drying. Whether or not these planar voids have become expressed through drying of the sample or were present prior to this, their location and organisation suggests that they represent shear planes (lines of weakness) associated with the furrow cut, in a manner similar to those seen through experimental tillage at the Silsoe soil bin, Bedfordshire, and Lejre Historisk-Arkæologisk Forsøgscenter, Denmark (Lewis 1998). Early tillage mark feature characteristics appear to have a long-term impact on soil characteristics.

Figure 4 WAT 1 furrow characteristics
[Image removed]

There do not appear to be any distinguishing characteristics related to implement type. Given the existence of the ridge-and-furrow system, it can be assumed that a turning implement (plough, spade) was involved in field creation, but there are no clear indicators that this particular furrow was created by such an implement as opposed to a pushing implement (ard), except for the slightly higher organic nature of the fill in relation to the surrounding soil. (Other characteristics of features created by turning implements at other sites include indicators of profile inversion - lenses of upper A horizon materials as basal fills of furrows; lenses of B horizon materials as upper fills of furrows - and cut patterns expressing the presence of a mouldboard – see Lewis 1998.)

WAT 3

The WAT 3 profile cut across the [200]-[201] boundary in a ridge. The horizon boundary zone in this case is diffuse, running over 3 cm between the two main horizons. It consists of mixed fragments of [200] and [201] fabrics. This mixing is probably related to tilling, and is a typical characteristic of furrow fill materials (see Lewis 1998), although no furrow was noted either in the field or upon thin section examination. This fabric mixing, with aggregates of B(t) material pulled up into the lower Ap (and vice versa), indicates that the tilling disturbance seen at this point (c. 35-40 cm deep in the modern profile) occurred after the Bt horizon had developed. Microstratigraphically, then, it appears that the furrow sampled in WAT 1 predates what seemed in the field to be the same phase boundary (Ap-B(t) horizon boundary) in the ridge sampled for WAT 3. The B(t) horizon developed its characteristics at some point between the tillage episodes represented in the two profiles.

The horizon boundary zone, while diffuse, is clearly marked not only by colour (related to clay, organic staining and manganese inclusions), but also by a horizontal lens of clay accumulation. The dusty clay accumulation lens at the base of this mixed boundary (top of the B(t)) has been created by more than just the translocation processes active in producing the many infills and coatings seen throughout the profile. The expression of accumulation as a distinct lens may simply show a strengthening of influence of the underlying developing B(t) in creating a stronger barrier to clay infiltration. On the other hand, the appearance of the lens may be likened to ‘plough pan’ formation. If the mixing seen in the diffuse horizon boundary zone is related to the
Little Thetford ridge-and-furrow

passage of an implement, pulling fragments of the B(t) up into the Ap, and dropping fragments of Ap down into the top of the disturbed B(t), then the clay-rich lens immediately underlying the mixed boundary may represent a base of tillage zone. If this is the case, then clay accumulation in a lens at this point might be related to the barrier created by physical compaction at the base of a ploughzone. In this location, then, unlike in the furrow seen in profile WAT I, the soil horizon boundary depth may represent tillage feature zones as mentioned above.

Summary

While no information regarding implement involved was forthcoming (except for the presence of furrows, which suggests that a traction implement was involved in the creation of this ridge-and-furrow system, and the existence of the ridge-and-furrow itself, showing the use of a turning implement - these together tend to imply the use of a plough), the micromorphological analysis of ridge-and-furrow materials has provided a means of subphasing the features sampled. A zone of clay accumulation was identified and related to compaction (‘plough pan’).

Like the plough marks sampled at Hengistbury Head Site 6 (Dorset) (Lewis 1998), the mark sampled here did not have a basal fines lens (panning lens) in its fill, although clay accumulation was seen at what might be a base of tilling in the other sample from Little Thetford. This is unlike what was seen in ard and spade marks sampled from other sites (ibid). Why these signs of movement and post-depositional accumulation of fine particles at the boundaries of implement marks, which appear to be typical of many tillage implement features, should not be seen in the mouldboard ploughed examples studied is unclear.

Some plough marks (e.g. at Hengistbury Head Site 6 and at Lincent, Belgium – see Lewis 1998) do possess a basal fill, but this is a thicker lens of more organic soil lining the cut at the base and to one side, which presumably marks the turning over of upper A horizon material into the base of each feature, and not a panning lens. This inversion was not seen in the plough mark sampled at Little Thetford, which may support the interpretation of it as a possible ‘open furrow’ in the ridge-and-furrow system.

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Appendix

Field procedures

Recording profiles

A soil profile may be defined as ‘...a two-dimensional representation of a soil...(which) consists of a vertical succession of horizons which, in a simple situation, are genetically related’ (Courty et al. 1989, 10). The profile consists of layers called horizons, which both mark the stages in the development of the soil body, and the zones of interaction between the mineral and organic materials which create soil. The specific types of genetic relationships between and development of horizons in a profile are the basis for soil classification (see, e.g., Duchaufour 1982, Bridges 1978, FAO 1988, re. classification principles and schemes). All profile descriptions here follow the British system, after Avery (1980). General field descriptions for each profile sampled are found under each thin section profile heading below.

Taking samples

Soil blocks (as opposed to peels) were taken for the study. The removal of such blocks entails inserting metal tins into the soil profile face, after having carved out an appropriately-sized soil block. The box with sample is removed using a trowel or spade, is wrapped and taped to ensure its structural integrity, and is labelled (site, sample number and orientation). Sample removal did not vary from the procedures described in the major sources (e.g. Courty et al., 1989, 42-43). Extreme profile dryness was problematic in regard to both visibility and sample taking at Little Thetford. Dryness in a more clayey soil leads to a reduction in contrast, making it difficult to see the features and horizons of the profile, and it also makes it very hard to physically clean back a section and cut out samples.

One sample from Little Thetford was disturbed in such a way as to destroy its structural integrity (see main text). If one were interested more in basic soil components than in structure and organisation, this sample could still be useful. For this study, however, it was deemed ‘beyond redemption’ and disposed of.

Soil samples for thin section are normally taken, and thin sections produced, with a vertical orientation (top of field profile = up on thin section), i.e. soil is not usually recorded in plan in micromorphology. Although some have advocated combining vertical and horizontal aspects (e.g. J. Becze-Deak, pers. comm.), others (e.g. Vogel et al. 1993, 302-303) suggest that vertical sections are best when examining certain structural features, such as channels and cracks. All samples for this work were taken with a vertical orientation.

Laboratory procedures

Producing thin sections

All thin sections were prepared and examined at the McBurney Laboratory, Department of Archaeology, University of Cambridge. The method used generally follows that described by Murphy (1986).

In order to impregnate a sample, it is necessary to remove as much water as possible before introducing the resin mixture, otherwise the resin will not set properly, as it is not miscible with water (Courty et al. 1989, 57; Murphy 1982, 720). Upon arrival at the laboratory, the wrapping around each sample was cut away on the top face, and the samples left to air dry for at least 6 weeks before impregnation with resin.

Where soils are highly organic or clayey it is preferable to remove soil moisture using an acetone replacement technique (such as that of Fitzpatrick and Gudmundsson 1978; Miedema et al. 1974; Murphy 1985), instead of air drying. Acetone replacement has the advantage of replacing the water in the pores without major change to pore space or soil structure. This method was, however, not used in the broader study of which Little Thetford was but one part because most of the soils involved did not have an especially organic- or clay-rich nature, although in retrospect this site might have responded better to a replacement method than to air drying. For this project, air drying was chosen as the least complicated method which was still appropriate for the majority of the soils involved. It was decided that structural changes could be anticipated, and should not necessarily affect the identification of useful tillage indicators - any indicators which could not survive or were created by drying would certainly not be useful for comparison to many archaeological materials.

The effects of air drying on a soil block have been previously described by Kubiena (1938), Courty et al. (1989, 57), and Murphy (1982), among others. There are a number of changes which occur in the drying soil which may influence later interpretation:

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1 The thin sections were produced by J. Boast.
• as a soil begins to dry from the newly exposed surfaces inwards, the soil solution begins to evaporate. This leads to a shrinkage of the solid soil body, and this may be quite profound in a soil which holds a great deal of water or holds its water tightly bound to soil particles (e.g. a soil with a high clay content or a highly organic soil) (C. P. Murphy 1982, 719-720). Air drying may thus produce pore spaces not seen in the original soil, or enlarge existing pore space.

• salts within the soil solution begin to effloresce. In extreme cases, where there are large quantities of salts, this efflorescence leads to surface deposits visible to the naked eye. The effects of evaporation are strongest at the edges of the soil block, which is one reason (the other being potential for disturbance during and after sampling) why sections are cut from the centre of impregnated blocks. If some salts cannot reach the surface, they are deposited within the soil, sometimes resulting in an accumulation (illuvial) zone in the outer parts of the block and a depletion (eluvial) zone in the centre of the block (Kubiena 1938, 48-49).

• oxidation of the organic components of the soil is normally related to oven-drying (Jongerius and Heintzberger 1975), but some degree of oxidation must occur during air-drying as well.

When the samples were dry, they were impregnated using a mixture of crystic polyester resin and acetone analar, with a catalyst of methylmethyketoneperoxide (see Table 4). They were left for up to one hour to capillary rise, and then topped up to the top of the samples. After impregnation, samples were placed in a Qualivac vacuum oven and held at a vacuum of 30 mm mercury for 24 hours. After vacuuming, the samples were left for six or more weeks to cure. All were topped up with the basic resin mixture when needed. Final curing involved heating in an Mido/6/SS/F fan-assisted oven at 70° C for 12 hours.

The production of thin sections entails sawing the hardened block into slices, temporarily mounting these for grinding down to 20-30 μm, then permanently mounting and cover-slipping them. Orientation and sample number are noted at each stage. In this project an M. K. Brick tile-diamond saw and a G. Brot thin laminations multi-plate grinder were used. Hand-finishing was necessary due to problems of uneven glass slides (J. Boast, pers. comm.).

Table 4  Sample preparation for thin section production

<table>
<thead>
<tr>
<th>Sample numbers</th>
<th>Drying time</th>
<th>Impregnation mixture</th>
<th>Vacuum and curing procedure</th>
</tr>
</thead>
<tbody>
<tr>
<td>WAT 95</td>
<td>Airdried at room temperature for &gt;6 weeks</td>
<td>1000 ml crytic resin:12 ml catalyst (MEKP). Topped up with same mixture.</td>
<td>Held at vacuum of 30 mm mercury for 24 hours. Left to cure at room temperature for &gt;6 weeks. Final curing at 70° C for 12 hours</td>
</tr>
</tbody>
</table>

Thin section description

All thin sections were described under plane-polarised (PPL), cross-polarised (CPL) and reflected light (RL) using a Wild Photomakroskop M400 and a Leitz LABORLUX® 12 POL S. The sections were observed at a mesoscopic level (x 1 - by naked eye with transmitted light) for the purpose of linking field observations with thin section units, and at low (x 20- x 200) and high (> x 200) magnifications (after Courty et al. 1989, 70, 72, 75).

All thin sections were described following the guidelines of Bullock et al. (1985) and Fitzpatrick (1993). Other references used include Adams et al. (1984), Brewer (1976) and Courty et al. (1989). The descriptions are presented in a standard micromorphological format below, and discussed in a more accessible way in the text. Further description of criteria used is given below. The blocks and thin sections are stored at the McBurney Laboratory, Department of Archaeology, University of Cambridge.

Photography and image database creation

The life-size thin section picture was colour photocopied direct from the thin section. Micro- and mesoscopic images were photographed under both the Wild Photomakroskop M400 and the Leitz LABORLUX® 12 POL S, using Ektar 100 asa colour slide or print film with a 35 mm magazine and shutterpiece, with attached Wild MPS46 Photoautomat, following the instructions given in the Wild MPS46/52 (Leica Heerbrugg AG 1991) and Wild M400 (Wild Heerbrugg Ltd. 1978) user manuals². An 80A blue filter was placed between the camera a light source to balance for daylight film. Colours are not true.

² And with the advice of Wendy Matthews.
An image database was created as an appendix to the Ph.D. thesis associated with this report (Lewis 1998). This database is an addition to the photocopied prints presented in the text, and was produced as a means of better displaying general fabric and pedofeature description in this visually-based field of study. The procedure for creating this is described at the beginning of the CD. Images from Little Thetford are listed in the table at the beginning of the CD itself. They are not included in this report.

**Thin section interpretation and data presentation**

Many pedologists appear to prefer to describe thin sections using relatively ‘objective’ systems (such as the Bullock *et al.* 1985 method), as opposed to more interpretive terminology. For archaeological applications, the development of a more objective descriptive method is generally lauded, with the previous emphasis on soil genesis being seen as hindering the analysis of archaeological deposits (e.g. Matthews *et al.*. 1997, 282). In this study both the Bullock *et al.*. (1985) and Fitzpatrick (1993) guidelines are used. This may seem a sort of *non sequitur* to some, as the Bullock *et al.*. method is specifically designed to provide description with a minimum of interpretation (apparently working on the principle that ‘...a good description is something permanent, whereas interpretations may be ephemeral’ (Courty *et al.*. 1989, 64)), but Fitzpatrick provides a more interpretive (pedogenetic) terminology.

Regarding the specifics of the thin section descriptions, Table 5 outlines decisions on descriptive criteria made by the author which vary from the standard methods used. In addition to the detailed thin section descriptions, some more detailed field/laboratory notes are included at the beginning of some of the site thin section descriptions presented below.

**Table 5 Additional criteria for the thin section descriptions**

<table>
<thead>
<tr>
<th>Descriptive parameter</th>
<th>Decision</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Texture</strong></td>
<td>Texture is described after Bullock <em>et al.</em> (1985). All grains larger than 2,000 µm are called rock fragments. There is an additional division in some cases between coarse (20-50 µm) and fine (2-20 µm) silt. This limit does not follow any system, and was simply convenient for the features described in this way.</td>
</tr>
<tr>
<td><strong>Coarse/fine limit</strong></td>
<td>A 100 µm limit was used to describe coarse:fine ratios (coarse/very coarse/medium/fine sand = coarse; very fine sand/silt/clay = fine).</td>
</tr>
<tr>
<td><strong>Amorphous organic components</strong></td>
<td>Amorphous organics are not described beyond colour and general size. Organic components in general were not described in great detail for this appendix, which is biased towards structure and textural and fabric pedofeatures.</td>
</tr>
<tr>
<td><strong>Frequency (percentages)</strong></td>
<td>All percentages are visual estimates of proportionate area, often in reference to an abundance chart (Bullock <em>et al.</em>. 1985, 24-25). It was decided not to point count features for this project, and image analysis technology was not available.</td>
</tr>
<tr>
<td><strong>Light sources</strong></td>
<td>Fabrics were described in plane polarised light (PPL), cross polarised light (CPL) and reflected light (RL) only.</td>
</tr>
<tr>
<td><strong>Horizon distinctions</strong></td>
<td>Horizons are named in the descriptions as context numbers given in the field ([204] etc.).</td>
</tr>
<tr>
<td><strong>Horizon names</strong></td>
<td>Ap/bAp - refer to tilled horizons/buried tilled horizons. All other horizon names follow Avery (1980).</td>
</tr>
</tbody>
</table>