The Soil Micromorphologist as Team Player
A Multianalytical Approach to the Study of European Microstratigraphy

RICHARD I. MACPHAIL and JILL CRUISE

1. Introduction

Soil micromorphology is one of the major subdisciplines within soil science, with subcommission status in the International Society of Soil Science since 1978. It held its initial working-meeting in London in 1981, where Goldberg (1983) made the first review of the application of soil micromorphology to archaeology. First developed by Kubiena (1938) as a way of studying undisturbed soil in thin sections, soil micromorphology now encompasses a range of ultramicroscopic techniques such as scanning electron microscopy (SEM) that is often linked to

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and talent, has led in recent years to a growing acceptance of the need for closer integration and collaboration. This is certainly the view of soil scientists actively involved in the Archaeological Soil Micromorphology Working Group, an ad hoc group meeting biannually in Europe (Arpin et al., 1998; see http://www.gre.ac.uk/~at05/micro/soilmain/introl.html).

For their own scientific peace of mind, the present authors have adopted procedures that approach the ideal of multianalytical approaches. Thus, the chief microchemical instrumental analyses (e.g., qualitative energy dispersive X-ray analysis or Energy Dispersive X-ray Analysis (EDXRA) and microprobe; e.g., Courty et al., 1989).

In Europe, “geoarchaeologist” is broad umbrella term under which are grouped a range of specialists. Many are geographers, pedologists, and Quaternary scientists, who on occasion take on an implied geoarchaeological role when studying sites associated with human activity (e.g., Kemp, 1985; Preece, 1992; Preece et al., 1995). They also commonly combine geophysical techniques, such as magnetic susceptibility, with standard soil and sediment methodologies, especially when studying wetland sites, although many archaeological soils are studied in this way (Crowther and Barker, 1995; Oldfield et al., 1985; Taylor et al., 1994). Whereas some are soil micromorphologists, others emphasize the analysis of particle size, tephra, phosphate, river gravels, and the X-ray analysis of sediments (see Barham and Macphail, 1995). Geoarchaeologists are grouped with other environmental archaeologists who study microfossils (e.g., pollen, diatoms, nematode eggs), macrofossils (e.g., seeds/grains, charcoal, mollusks, bones, teeth), isotopes, and human remains, and some notable integrated studies have been published (Dockrill et al., 1994; Maggi, 1997; Matthews and Postgate, 1994). Very broadly speaking, soil micromorphologists, like their soil chemist counterparts, are likely to be asked to focus on the on-site and anthropogenic component of a study. Site geologists and geomorphologists, if present, are more likely to take responsibility for the macro geomorphological setting and the off-site studies. For example, paleosols and colluvia may be identified as macrogeological units, but the soil micromorphologist may confirm these identifications and recognize anthropogenic activities that modified or produced these units. This is not to say that soil micromorphologists cannot also act as competent geomorphologists/geologists, and vice versa. Many workers have been trained in all these fields. As stated as follows, the soil micromorphologist works from the field scale to the macroscale, and his/her interpretations may well be of relevance to broad models that reconstruct past landscapes and periods (Crowther et al., 1996; Macphail, 1992; Whittle et al., 1993).

Multidisciplinary environmental studies of archaeological sites that contain a soil science component have been carried out for many years in Europe (Cremaschi, 1985; Dimbleby, 1992; Dockrill et al., 1994; Evans, 1972; Iversen, 1964; Macphail, 1987; Tables 13 and 14, 1994). Such investigations, which involved palynological and land mollusk studies, have contributed enormously to our understanding of past soils, their associated environment, and land use. The specific application of soil micromorphology to European archaeological sites spans the period from the 1950s up to the present day (Castelletti and Cremaschi, 1996; Cornwall, 1958). Nevertheless, one of the constraints that emerged since the late 1950s is a frequent lack of coordination of both sampling and analyses among the various specialists working on a single site or project. For example, when the various specialists sample different parts of the site, conflicting interpretations may result that may be impossible to resolve. This situation is further exacerbated when workers are sampling and analyzing at different scales. Increased dissatisfaction with this situation, which ultimately is a waste of energy and time, has led in recent years to a growing acceptance of the need for closer integration and collaboration. This is certainly the view of soil scientists actively involved in the Archaeological Soil Micromorphology Working Group, an ad hoc group meeting biannually in Europe (Arpin et al., 1998; see http://www.gre.ac.uk/~at05/micro/soilmain/introl.html).

For their own scientific peace of mind, the present authors have adopted procedures that approach the ideal of multianalytical approaches. Thus, the chief aim of this chapter is to illustrate ways in which the soil micromorphologist may more effectively work within a multidisciplinary approach to microstratigraphic studies.

Consensus interpretations will always be more convincing than interpretations based on one discipline working in isolation. Soil micromorphology employed thin sections is in the middle of a scale of stratigraphical studies that involve fieldwork at one end and scanning electron microscopy at the other (e.g., Courty et al., 1989; Macphail, 1998; Macphail et al. 1998a). Soil micromorphology itself is multifaceted, that organic matter, mineral components, pedological activity, and sedimentary processes, for example, can all be identified (Bal, 1982; Bullock et al., 1985; Courty et al., 1989). This technique also lends itself to being integrated with other disciplines, as detailed as follows. Bulk physical and chemical, macro-, and microfossil data can be linked directly with the undisturbed microstratigraphy evident in thin sections. Schematic and numerical/semiquantitative data presentations from combined disciplines is seen as a way of integrating more specialists in the process of creating consensus interpretations.

2. Methods

2.1. Getting the Sampling Right

It is all very good having ambitions to combine post-excavation data in a multidisciplinary way, but this can only work if correct and thoughtful sampling, subsampling, and sample preparation are carried out in the first instance. For example, if soil monoliths are impregnated they cannot be subsampled afterward for soil chemistry. If only large bulk samples are taken, these cannot be used for pollen analysis. Also, if the pollen column is distant from the soil micromorphology samples, data correlation is less certain.

In the field, good results come from combining Kubiena boxes (8 x 7 cm) and square section plastic drainpipe cut into convenient lengths (e.g., 10-20-40 cm) for undisturbed monolith sampling. These are taken exactly alongside plastic bag samples of the archaeological units and layers within them (20-50-200-1,000 cm). Needless to say, all the archaeological contexts of interest must be sampled, with adequate coverage of the vertical stratigraphy, alongside lateral controls, according to the needs of the site study. At this time there must also be good communication with the site's director/area supervisor/environmental manager, in order that archaeological sampling for artifacts and biofacts is
and/or bone analysis can all become crucial elements during the post-excavation phase.

Examination of monoliths in the laboratory allows a second and more relaxed chance to examine the stratigraphy. Monolith cores can be first subsampled for pollen and small chemical samples before being impregnated for thin section analysis. As emphasized throughout this chapter all investigators should regard all techniques as equal approaches. In some situations, the early findings from pollen analysis, for example, may allow better targeting of specific parts of a core for chemical and soil micromorphological studies.

2.2. Multidisciplinary-Analytical Approach

2.2.1. Chemistry and Palynology

The chemical and palynological methods employed are already well established in the literature (Clark, 1990; Engelmark and Linderholm, 1996; Moore et al., 1991). Within the text we cite proportions of organic and inorganic phosphate as extracted by 2% citric acid, before and after ignition at 550°C, and refer to "P ratios." Several studies demonstrated empirically that soils with P ratios of < 1.0 contain inorganic phosphate in the form of neofomed apatite, bone, vivianite, poorly crystallized forms of phosphate and mineralized coprolites, whereas soils with P ratios > 1.0 have been manured and/or contain organic herbivore dung (Engelmark and Linderholm, 1996; Macphail et al., in press).

2.2.2. Choosing Techniques

Different archaeological and pedological questions require a flexibility of approach. For example, at the Romano-British site of Folly Lane, St. Albans (UK), it was necessary that archival information from the Soil Survey of England and Wales should be combined with on-site soil micromorphology, microprobe, and diatom studies in order to investigate the composition and archaeological significance of "turf" mound material (Avery, 1964; Macphail et al., 1998b).

During this first stage of soil micromorphological description and identification, some specific features can be analysed by SEM/EDXRA and/or microprobe (see the following sections). It will be seen that such data retrieval then permits the presentation of soil micromorphological data alongside that from other disciplines, such as chemistry and palynology (cf. Preece et al., 1995, Fig. 6).

2.2.3. Soil Micromorphology

In soil micromorphology, descriptive analysis has produced good results (Bullock et al., 1985) in the identification of (1) microfabric types (absolutely essential), (2) structural and porosity features, (3) natural inclusions (e.g., plant remains such as roots, gravel-size flint, and chalk), (4) anthropogenic inclusions (e.g., charcoal, bone, various coprolites, slag, allochthonous stones), and (5) pedofeatures. The presence of fine charcoal, an abundance of phytoliths, or the presence of diatoms, pollen grains, and fungal spores can all be included within the definition of a microfabric type. Pedofeature studies may include the identification of different types of clay coatings, secondary iron, and manganese nodular impregnations, neofomed vivianite, and different types of soil animal excrements.

2.3. Numerical/Semi-numerical Data Gathering

Since 1992, a combination of description of the previously listed components and features and area counting (as opposed to point counting), has been adopted in about 20 studies. The latter can be extremely accurate, and when tested against image analysis of a counted slide from Overton Experimental Earthwork, as little as a 0 to 5 percent difference was found for each of the 13 vertical 0.5 cm deep transects (Acott et al., 1997; Macphail and Cruise, 1996). As the slide was counted at vertical intervals of 0.5 cm, estimates were based on 0.5 cm squares across the slide. Counting of a slide (7.5 x 5.5 cm) at 0.5 cm intervals, however, takes about 8 working hours, and so it is no light undertaking to carry out this kind of analysis where estimates attain numerical validity. On the other hand, where budget and time constraints are factors in a study, area counting may be carried out at a variety of scales, some of which are considerably less time consuming (see the following text). Estimates of clay coatings in order to identify an argillie horizon (sensu stricto) produced varied results between operators (see also McKeague, 1983; Murphy et al., 1985). This is why Bullock et al. (1985) wisely chose to keep broad groupings in their Frequency and Abundance scales. Additionally, although coarse mineral grains, void space, major microfabric and faunal excrement types can be accurately estimated, small inclusions such as rare fragments of bone can best be recorded on the Abundance scale of Bullock et al. (1985). Point counting at normal intervals (e.g., 1,000 points per standard geological slide) may well miss very small and rare inclusions. That is why in archaeological studies, where microscopic inclusions may be crucial to an interpretation, area estimation/counting is generally preferred.

In fully funded research projects, thin sections can be counted at practical intervals of 0.5 cm. The Wareham Experimental Earthwork study involves image analysis (by Tim Acott, University of Greenwich), which is being employed to count the amount and shape of voids, mineral grains, organic fragments, and the organic matrix, whereas manual counting (Macphail et al., in preparation) is being used for the numerical analysis of faunal droppings and the different types of plant fragments and their distribution. Traditional descriptive soil micromorphology is also being used to check the accuracy of digitized images, which can then be more accurately and more confidently quantified. The combined soil study also involves chemical analysis of samples from 1 to 2 cm spits taken from the same locations (Macphail et al., in preparation).

Since the early 1990s many archaeological deposits were first described, and then counted, so that the stratigraphical distribution of selected materials and features could be more fully appreciated. Reasonable results have been achieved at the 1 cm scale. Here, a thin section (7.5–15.5 cm) takes some 3 to 5 hours to
count. Data may be more rapidly obtained by area counting each archaeological context. These data can be extracted largely from the initial soil micromorphological description and do not require large amounts of extra time. Whenever scale is selected, however, it is essential that the micromorphologist should first examine the slide and gain a general understanding of the soil prior to counting. For example, the soil micromorphologist must be able to differentiate between a natural soil, a washed sediment, and a trampled floor deposit before counting is undertaken. Otherwise counting is a waste of time. Although this basic understanding of the slide may require learned skills and/or advice, it is an absolutely vital step. In fact, numerical data (for its own sake) in soil micromorphology can produce nonsense (Stoops, personal communication, 1997). What is advocated here is the thoughtful gathering of numerical data from thin sections that are already well understood. After counting, slides and counted features can again be analyzed as the understanding of the soil micromorphology deepens. Further benefits arise from the fact that counted data are useful when more than one soil micromorphologist is involved in a single project, because findings can be compared rapidly. Additionally in our experience, during a long-term project, it takes less time to familiarize ourselves with our thin section when we have counts than when we have only long descriptions to read.

2.3.1. Presentation of Soil Micromorphological Data (Courty et al., 1989; Romans and Robertson, 1983; Simpson and Barrett 1996)

In 1994, one of the authors (Macphail) presented a seminar paper to the Archaeological Soil Micromorphology Working Group at Rennes University, France. The object was to demonstrate and discuss the many ways in which soil micromorphological data can be presented and to note the views of the members of the working group. For example, full-page descriptions as per Bullock et al. (1985) were compared with tables summarizing data and their interpretation and schematic diagrams to express numbers of features present (per thin section/horizon). Bullet points were employed in the last example. This simple idea came from a paper by Simpson and Barrett (1996) and has been used by other authors (R. Kemp, Royal Holloway University of London, personal communication 1995; A. Gebhardt, Rennes University, personal communication, 1997). At more recent meetings of the working group (Cambridge, London, and Pisa) some soil micromorphological data were expressed as percentages (e.g., Matthews et al., 1997, Fig. 3a-b), with counted data from experiments illustrated as bar graphs, bullet points (Crowther et al., 1996; Macphail, 1998) and on Frequency and Abundance scales.

Nonsoil micromorphologists may examine data from seed, bone, and palynological studies because these are presented graphically, but soil micromorphological findings have generally been obscured by its presentation either in jargon or as interpretation. The present authors have therefore been endeavoring to make soil micromorphology more user friendly to other scientists. This does not mean, however, that they will fully understand the nitty-gritty of soil micromorphology any more than they would the intricacies of pollen taphonomy and mineralized seed identification, but they can at least see how interpretations are constructed on the logical registration of data as expressed graphically.

The present authors and their colleagues continue to produce soil micromorphological descriptions as the basis on "counted" microfabrics and components. Professor Stoops (University of Gent), although acknowledging the need to summarize data for publication, has also suggested that sufficient data should still be available to enable the reader to judge the scientific merit of the work (Stoops, personal communication, 1997). In papers produced for our peers, this is certainly crucial, but in archaeology we also have to deal with a lay audience. The same must be true for soil micromorphologists reporting to agronomists and to Quaternary scientists. It is therefore up to us to both produce and present data that are both acceptable to our peers and understood by our audience (e.g., archaeologists, paleoenvironmentalists, and field Quaternary scientists).

3. Research Base

Soil micromorphologists working in archaeology need to break new ground because most publications on soil micromorphology have dealt only with natural soils. To achieve this, workers have developed their own specific reference collections, analyzed specific archaeological materials, studied ethnologically interesting sites, and carried out experiments (Courty et al., 1989, 1994; Crownther et al., 1996; Gebhardt, 1992; Goldberg and Whithread, 1993; Wattez and Courty, 1987; Wattez et al., 1990).

In our case, this approach to archaeological soil micromorphology has been supported by two major strategies, as follows:

First, "counting" has been applied to thin-section studies of deposits formed by ethnarchaeological experiments, in order to try and identify key semi-numerical microfabric signatures, that may be of significance in the archaeological record.

A second approach has been to identify from our experience some specific components and microscopic inclusions that regularly occur in archaeological deposits and to analyze examples of these intensively. This is a way to identity the archaeological significance of these, especially when recorded semi-numerically, just as counted pollen or seed types may be given anthropogenic weighting according to, for example, established floras and ecological groupings. Where possible, soil micromorphological findings have been combined with chemical data, macrofossil, and palynological studies of the same horizons and components.

3.1. Experimental Findings

The Ancient (Iron Age) Farm at Butser, Hampshire, U. K. is situated on the chalk of southern England, and is well known in Europe for being a focus of experimental studies in agriculture, arable soils, architectural structures, and their floors (Gebhardt, 1990, 1992; Macphail and Goldberg, 1995; Macphail et
To be consistent with the approach to the study of soils at the Experimental Earthwork at Overton Down (Crowther et al., 1996; Macphail and Cruise, 1996) and at numerous current archaeological sites, it was decided to restudy the floors from the Moel-y-gar House (animal stabling) and the Pimperne House (domestic occupation) at Butser, using counted soil micromorphological data. At the same time, bulk samples were run for chemical and palynological analyses. This approach would then provide an experimental example of multidisciplinary microstratigraphic studies as the preferred approach of the authors. Our work at the Moel-y-gar and Pimperne House floors are examples of soil micromorphology counting and how resulting data can be linked to complementary data from chemistry and palynological studies.

At the Moel-y-gar stable house, three distinct layers were identified (Tables 9.1a and 9.2a): an uppermost cemented crust of layered, long monocotyledonous plant fragments, a “stable soil” of phosphate stained chalk and soil, and a phosphate-contaminated buried subsoil (Macphail and Goldberg, 1995, Fig. 2, Plates 3 and 4). The uppermost layer was further characterized by microprobe and X-ray diffraction analyses to confirm the view that this plant-rich layer that is autofluorescent under ultraviolet light, is cemented by calcium phosphate in the form of hydroxyapatite. Key microstratigraphic features were counted (Tables 9.1a and 9.2a).

At the Pimperne House at Butser, a very different kind of microstratigraphy had developed, with an uppermost trampled/beaten floor layer overlying a buried soil (Tables 9.1b and 9.2b). In addition to the soil microfabric differences, complementary studies found, in comparison with the Moel-y-gar “crust,” a more strongly enhanced magnetic susceptibility, but less organic matter (LOI 18%) and phosphate (2400 ppm P), the last being dominantly in an organic form (P ratio 2.2–3.4). Furthermore, pollen concentrations were considerably lower but contained a far more diverse herbaceous and weed pollen assemblage.

How do these findings compare with archaeological data? At the Italian Neolithic cave of Arene Candide, Liguria, phosphate-stained stabling layers composed of layered and compacted oak twig wood (leaf hay foddering) can be differentiated from sublamina, massive structured mineralogenic domestic floors (Macphail et al., 1997). At the Román London site of 23, Bishopsgate, two counted samples from a red charred floor context were composed of semi-layered plant fragments/cattle dung-like material with total phosphate averaging 9,000 ppm, thus indicating that a likely stable layer had been found (an hypothesis now supported by macrobotanical findings; Macphail et al., in press). Sites ranging from prehistoric to recent from Scotland through Switzerland, Italy, and southern France to north Africa have yielded further comparative examples of floors with covered (roofed) stable and domestic areas having microstratigraphic signatures consistent with the experimental findings from Butser (e.g., Boschian, 1997; Cammas, 1994; Cammas et al., 1996; Davidson et al., 1992; Del Lucchese and Ottomano, 1996; Guélat et al., 1998). At the London Guildhall site two types of Anglo–Danish (1060–1120 A.D.) floors were differentiated on the basis of soil micromorphology, chemistry, and palynology. One floor type has a poorly preserved but diverse pollen assemblage in a heterogeneous mineralogenic (LOI 9%) soil with an enhanced magnetic susceptibility (assumed domestic structure).
### Table 9.1b. Counted Microstratigraphy of Floor and Buried Soil of the Pimperne House 1990 (Sample from Near Oven Location)

| a | B | Al | Al | Al | Al | N1 | N1 | N1 | N1 | N1 | N1 | N1 | S1 | S3 | S6 | S7 | S8 | FF | EX | EX |
|---|---|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 1 | B4 | f | a | f | aa | a | a | a | a | a | a | a | f | a | a | a | a | a |
| 2 | B4 | f | a | f | aaa | a | a | a | a | f | a | a | a | f | a | a | a |
| 3 | B4/B5 | f | a | a | a | a | a | a | a | a | f | f | f | f | f | f | f | f |
| 4 | B5 | a | a | a | a | a | a | a | a | a | f | f | f | f | f | f | f | f |
| 5 | B5 | a | a | a | a | a | a | a | a | a | f | f | f | f | f | f | f | f |
| 6 | B5 | f | a | a | a | a | a | a | a | a | f | f | f | f | f | f | f | f |

Key to Tables 9.1a–9.1b

a = Depth below surface (cm)

B = Microlithic type

B1 = Dominantly organic—very dominant; pale to dark brown speckled and dotted (PPL), isotoe to very low interference color (weak to strong crystalline b-fabric) (XPL), dull brown (OHL) and high auto fluorescence (UVL); dominant amorphous organic; organic matter and tissue fragments, with occasional to abundant calcite crystals, occasional to many phototubes, rare to occasional calcium oxalate dust; rare to very abundant patches of <20 μm size spherules; single-spaced porphyritic; C.F. 70-300 (limit < 10 μm); Coarse mineral—very dominant, well-sorted silicate quartz and very few medium and fine silicate quartzclusions; Brown organic—dominant longitudinal wisps of Fraser cuticles (tissue remains) and frequent mesofungal and parenchyma cells (tissue remnants); much cellulose is poorly birefringent and browned (heavily).

B2 = Dominantly mineral—very dominant; blackish brown (PPL), low to high interference color (weak to strong crystalline b-fabric) (XPL), pale yellow to yellowish brown with frequent black specks (OHL), non-autofluorescent (UVL); abundant amorphous and charred organic matter fragments; rare calcium oxalate dust; <20 μm size spherules and wood ash crystals; single-spaced poryphritic; C.F. 60-110; Coarse mineral—dominant silts, common chalk and flint; few molar shell and biogenic calcite, very few burned soil and argillite (UO) sandy soil inclusions; Coarse organic—few charcoal and very few burned charred tissue fragments and organ remains.

B3 = Dominantly mineral—very dominant; dark reddish brown (PPL), medium; interference colors (weak to strong crystalline b-fabric) (XPL), yellowish orange brown (OHL), non-autofluorescent (UVL); abundant amorphous organic; single-spaced poryphritic; C.F. 50-45; Coarse mineral—dominant silts, common chalk and flint; few molar shell and biogenic calcite; Coarse organic—very few root traces (fragments).

NB: PPL = Plane polarized light; XPL = cross polarized light; OHL = Oblique incident light; UVL = Ultraviolet light.

Major authigenic inclusions

Al1 = Stained chalk (with dark UVL autofluorescence); Al2 = micrite; Al3 = silty micritic, with silified silicate-quartz; Al4 = burned soil (trabulated under OHL); Al5 = soil inclusions (e.g., argillitic subsoil (lay; dash/mixure); Al6 = partially burned pot fragments (> 1 mm); Al7 = coarse charcoal; Al8 = amorphous organic matter; Al9 = ash and fine charred fragments.

Major natural inclusions

Nl1 = chalk; Nl2 = flint; Nl3 = sandy soil; Nl4 = biogenic calcite; Nl5 = molar shell; Nl6 = plant fragments (< 1 mm); Nl7 = roots; Nl8 = root traces/fragments.

Structure

S1 = vitrified; S2 = laminar structure; S3 = amorphous structure; S4 = sponge structure; S5 = subangular blocky structure; S6 = crumb structure; S7 = massive structure; S8 = blocky.

Foliated fabrics

F1 = Horizontal slickensides/clay smear.

Extraneous

Ex1 = organo-mineral excretions (< 300 μm); Ex2 = organo-mineral excretions (< 300 μm); Ex3 = organo-mineral excretions.

Frequency

FF > 75%, very dominant; FF 50-75%, dominant; FF 30-50%, common; FF 15-30%, frequent; FF < 15%, very rare.

Abundance

< 2%, very abundant; 10-20%, abundant; 5-10%, many; 2-5%, occasional; < 2%, rare.
### Table 9.2a. Key Microstratigraphic Features at the Moel-y-gar House

<table>
<thead>
<tr>
<th>Depth and layer</th>
<th>Soil micromorphology</th>
<th>Some complementary studies</th>
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<tr>
<td>1–3 cm (&quot;crust&quot;)</td>
<td>Very dominant partially layered plant fragments &gt; 1 mm in length (grass stems, A16) and abundant amorphous organic matter (humified dung, A18) set in a specific, chiefly autofluorescent (under UV) microfabric (B1) with little evidence of small animal mixing (EX2 and EX3).</td>
<td>Dominant grass stem fragments (W. Caerruthers, personal communication, 1995), high amounts of organic matter (LOI 41%) and inorganic phosphate (6900 ppm P; citric acid P ratio &lt;1.0; 0.5–1.38% elemental P), and unexpectedly high concentration of pollen 822 (grains × 1000) per cm² dominated by grass pollen, compared to only 77 (grains × 1000) per cm² in the subsoil.</td>
</tr>
<tr>
<td>3–9 cm (&quot;stable soil&quot;)</td>
<td>Dominant dark stained chalk clasts (A11) and microfabric type B2, with cracked clast rims and soil ped edges autofluorescent under UV1; dominant subangular blocky structures and burrows within an overall prismatic structure (S3, S5, and S7) (Fig. 14.1).</td>
<td>Organic (LOI 32%) and phosphatic (2849 ppm P; citric acid P ratio &lt;1.0).</td>
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<tr>
<td>9–13 cm (&quot;buried subsoil&quot;)</td>
<td>Only rare anthropogenic inclusion (A1) occur in an unaltered chalk (N1) dominated, increasingly by calcareous soil (B3), with a subangular blocky and spongy structure associated with many very thin to thin organo-mineral excrements (EX2).</td>
<td>Comparatively less organic (25% LOI) and phosphatic (1469 ppm P; citric acid P ratio &gt;1.0).</td>
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### Table 9.2b. Key Microstratigraphic Features at the Pimperne House

<table>
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<th>Depth and layer</th>
<th>Soil micromorphology</th>
<th>Complementary studies</th>
</tr>
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<tbody>
<tr>
<td>1–3 cm (&quot;trampled floor&quot;)</td>
<td>1–3 cm (&quot;trampled floor&quot;): few burned soil fragments (A14), with many coarse charcoal (A17), ash and fine charred materials (A19) and rare amorphous organic matter (dung, A18) fragments, set in a highly heterogeneous mineralogic soil (microfabric type B4) with a dominant (but now cracked) massive structure (S7) (Fig. 14.2).</td>
<td>Moderately humic (LOI 20%) and phosphatic (2430 ppm P; citric acid P ratio &gt;1.0). Highest magnetic susceptibility (47 Si units S1kg10-8, 4.7% MS conversion at 550°C) compared with Moel-y-gar floor (16–27) and surrounding fields (mean 22).</td>
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<tr>
<td>3–6 cm (&quot;buried soil&quot;)</td>
<td>3–6 cm (&quot;buried soil&quot;): only rare to occasional anthropogenic inclusions (A1) in calcareous soil (microfabric type B5) containing many natural inclusions (N1), and featuring first prisms (S3) and increasing amounts of subangular blocky (S5) and crumb (S6) structures, associated with many to abundant organo-mineral excrements (EX1 and EX2).</td>
<td>Similarly humic (LOI 20%) and phosphatic (2310 ppm P; citric acid P ratio &gt;1.0), with magnetic susceptibility at 28 Si units (S1kg10-8).</td>
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</table>
In contrast, other *in situ* floors and floor deposits have well-preserved grass- and cereal-dominated pollen assemblages in highly organic (LOI 30%) and phosphatic (e.g., 6,000 ppm P) deposits characterized by layered plant fragments or probable cattle dung (Cruise and Macphail, in press; Macphail and Cruise, 1995). The latter contexts are interpreted as stable floors and deposits. In order to begin the process of interpreting soils, individual microfeatures need to be characterized.

Some of these are better understood than others. For example, at Overton Down much was made of the apparent transformation of earthworm-worked soils (1–5 mm wide mamillated excrements) into soils featuring 100 to 500 μm thin Enchytraeid-like excrements as a result of changed soil conditions induced by burial (Crowther et al., 1996). The relationship between the excrements of soil fauna and soil conditions is well understood in general (Babel, 1975; Bal, 1982). Equally, the presence of vivianite and related features are seen as indicative of the presence of phosphate, and such features occur in bog ores, occupation deposits, and floors (Landyudt, 1990; Macphail, 1983, 1994). In the following sections, we give two examples of how two important anthropogenic soil components, "dark clay coatings" and "phosphatic nodules," were characterized in order to determine their composition and their implied archaeological significance.

### 3.1.1. Dark Clay Coatings

A feature common to archaeological sites, but which is poorly understood, is dark-reddish brown clay coatings. For many years it was suspected that these were
We tested the hypothesis of a link between these dark clay coatings and animal management at Raunds. First, total phosphate analyses of bulk soil samples revealed an association between these features and phosphate, a simple finding consistent with the literature on phosphate and animal activity (Proudfoot, 1976; Quine, 1995). Moreover, the dark clay coatings are most abundant in layers dominated by concentrations of organic matter and organic phosphate (P ratio 2.3–3.5; Engelnmark and Linderoth, 1996; Macphail et al., in press). The dark reddish colors of the clay coatings already implied that they were humic in character. Finally, the concentration of phosphorus within the dark clay coatings themselves, rather than the soil matrix surrounding them, was confirmed by microprobe studies of numerous examples from two uncovered thin sections. Data from two examples are presented in Table 9.3, with Fig. 9.3 illustrating the mapped presence of P in Sample 9. We can therefore conclude that organic matter and organic P are apparently concentrated in these dark clay coatings.

Dark clay coatings in natural Bt horizons of Alfsols have long been known to contain organic matter and phosphorus, which are related to natural clay translocation with fulvic acid under conifer woodland (e.g., Gray forest soils of Duchandour, 1982, 301; e.g., boreal paleosols of Fedoroff and Goldberg, 1982). Thus any link between dark clay coatings and animal management has to be argued carefully. At Raunds, humic topsoils of Spodosols and acidic Alfsols were present in prehistory, and liquid animal waste passing through these may have mobilized fulvic acid to produce these dark reddish brown clay coatings, which occur alongside other textural features indicative of animal trampling (M. A. Courty, CNRS, Paris, personal communication, 1992). Obviously, this hypothesis of a process active at the microscale is worthy of further testing. But, as fieldwork, bulk chemistry, and soil micromorphology studies have yielded comparable interpretations from nine barrows dating from the Neolithic to the Bronze Age, proxy soil landscapes and their land use can be reconstructed on the scale of kilometers for this part of the Nene river valley. As similar paleosols have been analyzed in the nearby Ouse valley, such findings have implications for regional proxy soil landscape and land-use reconstruction. Past soils of the chalk downs of southern England have already been modeled in this way (Allen 1992; Evans, 1972; Whittle et al., 1993).
3.1.2. Phosphatic Nodules

Three enigmatic materials with specific features under PPL, XPL, OHL, and UVL, were identified in thin sections of an occupation deposit at Poterne (Late Bronze Age, Early Iron Age, Wiltshire; Lawson, 1991). Individual fragments were made into thin sections, with residues being studied under microprobe, through bulk chemistry, and through macroplant remains and pollen analysis. These materials, termed for convenience as "pale nodules" (possible cess-pit nodules), "fused ash" (burned and fused cereal processing waste), and "burned and cemented soil" (often burned, possible stable soil floor deposit), were all autofluorescent under ultraviolet light and contained around 12%, 7%, and 1% P, respectively. Table 9.4 shows an example of how one of these components was defined and then interpreted to become an established microscopic indicator of the presence of domestic cereal processing waste at a site. This description and characterization is a crucial step before such counted components can be given any significance in site reconstruction.

Subsequent to this work, fused ash, cess-pit nodules, and dark clay coatings were found at a number of midden and occupation sites, their semi-quantified presence added to the collage of information available for the interpretation of sites with complicated site formation processes.

4. Discussion

How successful has this fully integrated microstratigraphical approach been? We have already cited our study at Folly Lane where soil micromorphology and microprobe studies were combined with the identification and semi-quantitative analysis of diatoms in thin sections, as one example of a multi-disciplinary investigation of rural Romano-British soils (Macphail et al., 1998b). Such an approach allowed us to go further with our interpretations than would otherwise have been the case if only single or non-integrated techniques had been applied. A consensus understanding of what happens to soils when buried at the Overton Down Experimental Earthwork drew on palynological, microbiological, chemical, soil micromorphological, and archaeological excavation data, and again this led to confident extrapolations when discussing archaeologically buried soils such as at nearby Easton Down (Bell et al., 1996; Crowther et al., 1996; Cruise and Macphail in Whittle et al., 1993). Many other cases have yet to be published, but they can be briefly cited here. As examples, we summarize relevant findings from the Roman site of Colchester House, London, and the Roman to Norman site of Haynes Park, Bedfordshire. At Haynes Park we show how we have graphically...
A number of mechanisms were identified that accelerate weathering of Roman to medieval urban stratigraphy and the formation of a cumulative anthropogenic termed "dark earth" (Macphail, 1994). One atypical urban land use is the stocking of animals, the trampling and rooting-up of soils that could homogenize earth-based (timber and clay) buildings. At Colchester House, London, the coincidence of organic phosphate in subsoils with counted dark clay coatings (Fig. 9.5) allowed the hypothesis that a phase of animal activity could have contributed to the reworking of clay and timber buildings believed to have been on the site before construction of a stone-founded structure in the third century A.D. (Macphail and Cruise, 1997b).

At Haynes Park, Bedfordshire, a catenary sequence contains wet hollows at the bottom of the slope (Macphail and Cruise, 1997a). Fieldwork, excavation, and macrofossil studies suggested that the Roman to Norman deposits were likely the result of dominant arable activity, as indicated by the presence of a Roman corn dryer, charred cereal grains, and substantial lynchet. Soil micromorphology was linked to chemical studies of the dry soils, whereas in the wet hollows, pollen cores were first evaluated before sampling for thin sections and chemistry. Although cultivated soils were broadly identified, the preserved presence of dung fragments and anthropogenic inclusions such as chalk, ashes, and igneous rock (granulitic), along with the magnetic susceptibility and phosphate chemistry additionally implied that manuring had taken place. Furthermore, the palynological study indicated inputs of fresh manure in a landscape where animals grazed on herb-rich grasslands, acid heath, and wet valley bottoms. Microscopic crust and pan fragments alongside phytolith and diatom-rich microfabrics that featured amorphous organic inputs (dung) and concentrations vivianite and poorly crystalline iron phosphate (Fig. 9.6), further implied the on-site presence of animals (Fig. 9.8). Drier soils up slope also contained dark clay coatings (Fig. 9.7) and other features of trampling. When reconstructing the site's past land use and proxy vegetation history, it became clear from modern studies of the same soil type at nearby Woburn that a probable mixed farming regime had been practiced at Haynes Park to offset the susceptibility of the soils to erosion (Catt, 1992; Macphail and Cruise, 1997b).

It may be considered that the wetter the site, the better pollen may be preserved, but the less potential there is for soil micromorphology and chemical analysis, and few peat bogs have been studied using our preferred combined approach. Nevertheless, at Bargone, Liguria, Italy, the colluvial peat bog edge of mountain peat bog was studied in this way in 1994 (Cruise et al., 1996). The site had already been cored several times in its center and fully analyzed for pollen in the late 1980s. Here again, the palynological evaluation of the new cores from the trenches excavation of the bog edge guided the multidisciplinary investigation. Layers of interest within the cores were subsampled for chemistry and soil micromorphology, as well as being chosen for radiocarbon dating. Of particular relevance to this chapter is the discovery that changes in vegetation as recorded by palynological analysis are coincident, for example, with different chemistry and soil micromorphological indications of the peat bog drying out or animal trampling or colluviation. We also have archaeological and diatom data to add to the debate. Such a multidisciplinary approach is a great advance on traditional palynological investigations.

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Table 9.3. Mean Values of P in Dark Clay Coatings (Microprobe Line Analysis) and Background Bulk Chemistry at Raunds (see Fig. 14.3)

<table>
<thead>
<tr>
<th>Sample</th>
<th>Context</th>
<th>Total P ppm</th>
<th>PO ppm</th>
<th>Pot ppm citric acid after ignition at 550°C</th>
<th>P ratio</th>
<th>Coating P ppm (probe)</th>
</tr>
</thead>
<tbody>
<tr>
<td>11</td>
<td>buried soil upper</td>
<td>3.8</td>
<td>1410</td>
<td>n.d.</td>
<td>n.d.</td>
<td>570 (17 points)</td>
</tr>
<tr>
<td>9</td>
<td>buried soil lower</td>
<td>3.3</td>
<td>n.d.</td>
<td>130</td>
<td>350</td>
<td>2.6 2380 (9 points)</td>
</tr>
</tbody>
</table>

presented summarized soil micromorphological, chemical, and pollen data to illustrate and support our arguments as reported to the archaeologists working on the site.
Working within a team can have its own complications. For example, while working on the 500,000 year old site of Boxgrove, West Sussex, UK, findings from the widest imaginable environmental team were debated openly (Roberts and Parfitt, 1999; Roberts et al., 1997; Stringer et al., 1998). Soil sediments with cold formation signatures were associated with cold faunas, and marls contained pond-living mollusks and alluvial deposits had amphibian and fish faunas. On the other hand, Unit 4c, which had all the micromorphological hallmarks of a sediment, was the focus of human activity and full of mammal bone remains and was considered to be a land surface. The described soil microfabrics, including that from several thin sections through “chipping floors,” initially led to an interpretation of Unit 4c as a sediment. It was only after repeated study that some small residual pedological features were identified, and this together with reference to analogues from drowned coastal sites in the UK and ripened polders in Holland allowed the overturning of the original strictly sedimentary hypothesis. Thus, Unit 4c could safely be identified as a bona fide ripened soil (Macphail, 1996). This was not a compromise interpretation to meet the other specialists halfway, but a soil micromorphological contribution from an equal. Counting of soil micromorphological features for its own sake will not yield interpretations, and at Boxgrove because of postburial transformation, less than 5% of the microfabrics contained clues to Unit 4c’s pedological history. There is therefore always the danger that the counting of “identifiable” features, components, and the like may become a mechanical substitute for accurate, thoughtful analysis of a thin section and its interpretation.

5. Conclusions

1. Soil micromorphology can produce extremely accurate semi-quantitative data that is most convincing to non-specialist soil micromorphologists when expressed graphically.
2. Experimental soils when characterized through counted soil micromorphology have specific signatures that are replicated in the archaeological record.
3. The specific analysis of individual microscopic components and pedofeatures that are counted can lead to the identification of features of archaeological significance.
4. The multidisciplinary approach has shown that specific microstratigraphies can have coincident and related chemical and fossil signatures that immensely aid the task of arriving at convincing interpretations of archaeological sites.

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References


