Proceedings of the British Academy, 77, 39–59

Soil Micromorphology in Archaeology

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Summary. Soil micromorphology consists of the integrated use of various microscopic techniques for studying the arrangement and the nature of components that form sediments and soils. The power of this analysis in archaeology is to provide key information which can discriminate the sedimentary signatures diagnostic of human-related activities from those resulting from natural phenomena.

Soil micromorphology has became popular in the last decade in archaeology, although the potential of the microscopic approach has been well known for more than fifty years, due to the recent increase in interest in site formation processes. This type of analysis can be used to achieve a detailed environmental reconstruction of human palaeolandscapes or to identify the various kinds of domestic and specialised activities which are involved in the formation of living floors and of anthropogenic structures.

The future progress of soil micromorphology in archaeology requires us to enrich our knowledge of the sedimentary dynamics of cultural processes and to increase the number of well-trained scientists in this new field of investigation. A better integration of the analysis at the microscopic scale with the field perception should help to improve the characterisation of site formation processes whilst the excavation is taking place.

1. Introduction

In archaeology, the study of sediments and soils has been shown to be an essential component of environmental reconstruction which may concern either palaeolandscapes and human impact at a regional scale, or site formation processes ruled by both natural factors and human activities (Butzer

1982; Hassan 1978; Gladfelter 1981; Stein and Farrand 1985). To achieve one or both of these objectives, specialists in sedimentary archaeology have developed various approaches in relation to their academic origin and depending on their laboratory facilities. Scientists with rather different competencies are now facing a particular challenge: to demonstrate the sagacity of their methodological choice and the efficiency of their approach.

In the recent years, soil micromorphologists have striven to meet the challenge by demonstrating that the microscope was an essential tool to analyse ancient soils and site formation processes (Courty *et al.* 1989). The objective of this paper is to analyse the present situation of soil micromorphology in archaeology by considering: (i) how this approach was developed, (ii) how it has enriched our knowledge of archaeological sediments, and (iii) what is the present situation. Although the future of soil micromorphology in archaeology is apparently promising, it may be worthwhile to discuss, in conclusion, how this relatively young method of investigation should progress in order to rapidly achieve its full maturity.

Before entering the debate, it may be useful to outline the method. Soil micromorphology is the study under the optical microscope of thin sections prepared from undisturbed and oriented samples after they have been impregnated by synthetic resin. For an efficient coordination between field observations and microscopic investigations, soil thin sections have to be larger (*ca.* 12 × 7 cm or more) than the standard petrographic ones, but have the same thickness (25 μm). A continuous observation from the field scale down to high magnification, permitted by scanning electron microscopes, allows an exhaustive characterisation (nature, shape, size, frequency, etc.) of elementary components and the study of their arrangement. A high level of significance is given to specific attributes, which are subdivided according to their origin into three well-defined groups:

i) Sedimentary features which are diagnostic of the source of the sediments, the mode of transport and depositional conditions (Figure 1).

ii) Pedological features that give information about the dynamics of each soil-forming process and about the interaction of these processes through time (Figure 2).

iii) Anthropogenic features related to human activities, which can be identified at various scales, such as mineral or organic components of human origin or which may correspond to specific fabrics induced by human transformations (Figure 3). Both human-induced fabrics and anthropogenic components can have been produced intentionally or accidentally.

The high efficiency of this approach is due to the use of standardised optical and crystallographic procedures to observe transparent thin sections

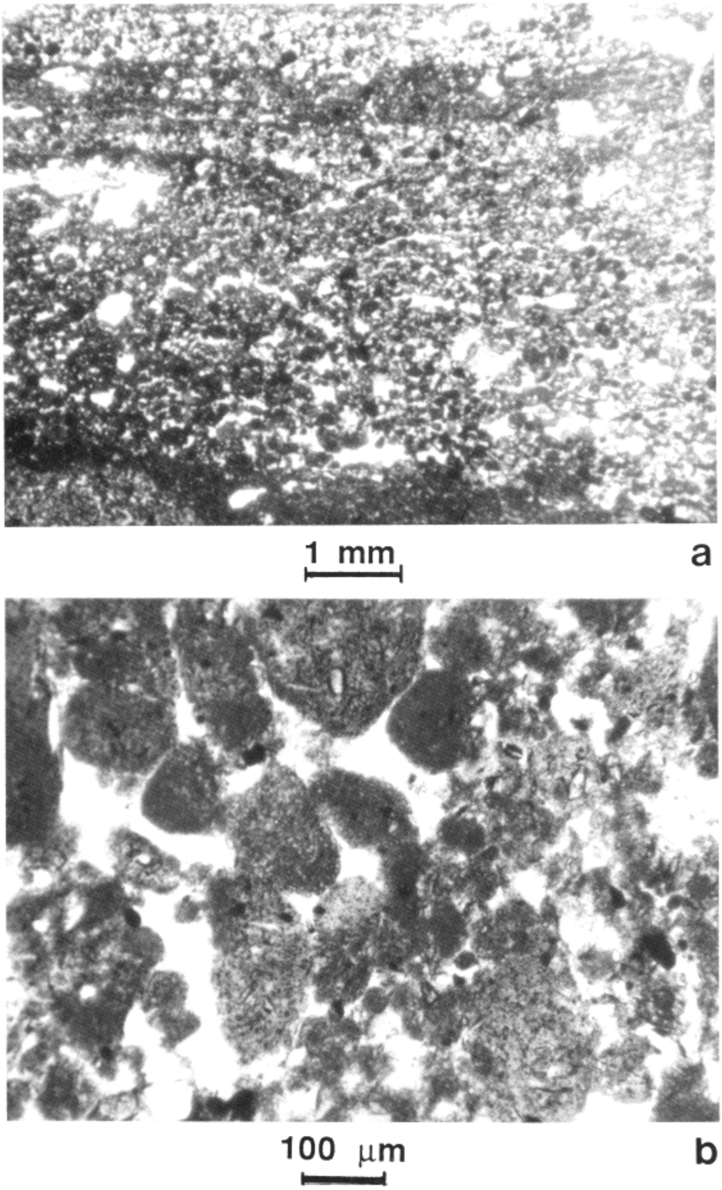


Figure 1. Compound sedimentary features diagnostic of the source of sediments, of the mode of transport and of depositional conditions: (a) the clear micro-layering observed at low magnification indicates repeated episodes of low energy water reworking (run-off) interrupted by phases of desiccation; (b) the well rounded aggregates observed at high magnification relate to air transportation by saltation ("pseudo-sands"); most aggregates consist of dense calcitic fine silt which have been eroded by wind from superficial crusts formed on bare soil surface. Buried soil formed during the late third millennium B.C. in Upper Mesopotamia, Abu Hjeira 2, north-eastern Syria (director M. Lutz).

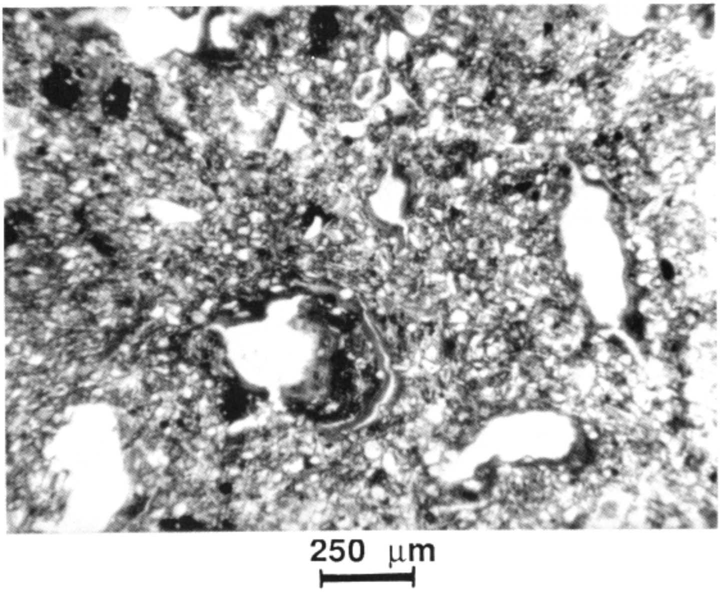


Figure 2. B horizon of an argillic brown earth formed under a forest cover: the diagnostic fabric consists of abundant clay coatings in the channels. The dark colour of the coatings is due to the fine addition to the clay of micro-contrasted particles which indicates that the soil surface was not densely covered by the vegetation. Late Holocene argillic brown earth on loess deposits, Paris Basin.

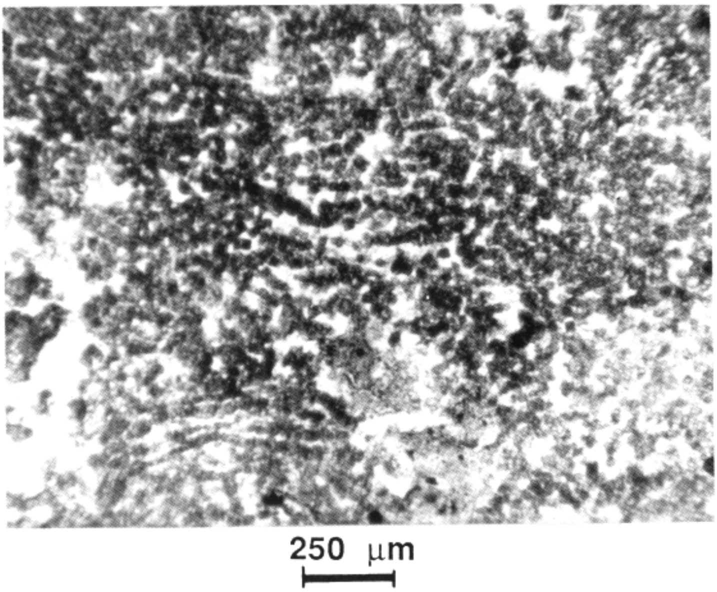


Figure 3. Typical open fabric of a wood ash layer which has not suffered subsequent trampling or alteration by post-depositional processes. The good preservation of the plant pseudomorphs indicates firing around 500°C. Mesolithic ash layer, cave of Abeurador, south-eastern France (director J. Vaquer).

of standard thickness. Moreover, this representation makes easier the perception of spatial relationships between components, fabrics and features which is essential to enable the reconstruction of the sequential evolution of soils and sediments through time.

2. The advancement of soil micromorphology in archaeology

2.1 The academic context

Two decisive periods have marked more than half a century of continuing research in archaeological sedimentology. The first was in the late 1950's when interest in prehistoric sediments increased considerably, especially in Europe (Campy 1982; Farrand 1975; Laville 1976; Miskovsky 1974). Quaternary geologists and prehistorians essentially worked together on the chronostratigraphy of prehistoric sequences, emphasising the palaeoclimatic implications. They gave little consideration to the regional significance of the sedimentary signal recorded at the micro-regional scale of archaeological sites. Field stratigraphical interpretations were supported by analytical data, the validity of which had never been evaluated. Particle size analysis was routinely performed because it is easy to handle both technically and scientifically.

For academic reasons, individuals sharing a common interest in archaeological sediments have rapidly formed a scientific community that has been rather independent of related disciplines in earth sciences (classical sedimentology, geochemistry, pedology, etc.). Consequently, archaeological sedimentology has not fully profited from the technical and scientific progresses accomplished in these various fields. Furthermore, the results achieved in archaeological sedimentology have not been critically evaluated by the larger community of earth science specialists. This situation may explain why soil micromorphology was not introduced at this stage in archaeological sedimentology, although the microscopic approach was entering its golden age in soil science, and was already familiar to soil scientists dealing with archaeological soils (Romans and Robertson 1983).

An important change marked archaeological sedimentology in the late 1970's when Karl Butzer, followed by others, clearly stated that archaeological sediments are singular because they relate to interactive processes ruled by human beings and natural factors (Butzer 1982). Geoarchaeologists suddenly realised that past humans had contributed to the sedimentation process of archaeological sites not only with lithics, bones or plants but with mineral components which may have substantially affected the original sedimentary signal (Stein 1985). This new generation of archaeological sedimentologists has much debated the necessity of a careful examination of sediments to identify the cultural components of the site matrix (Stein 1985). They have, however, never considered the necessity of adapting methods and related techniques to achieve the new goals. Using methods similar to those of their predecessors, they have been mostly able to detect anthropogenic influence on sediments but have not been able to recognise the human activities involved.

At the same time, soil micromorphology was introduced into archaeology by earth scientists who were external to this new trend of archaeological sedimentology. Familiar with the microscopic scale from their basic training at university, they naturally thought the use of thin sections was necessary when facing archaeological sediments and soils. They spontaneously joined the group of soil micromorphologists and have remained highly pragmatic when characterising sedimentary signatures of cultural activities. Evolving rather far from the theoretical debate of archaeology, they however realised that the introduction of the soil micromorphological approach was throwing a new light on contextual archaeology (Fisher and Macphail 1985; Goldberg 1979, 1981; Courty and Fedoroff 1982, 1985).

At the same time, following the lead of André Leroi-Gourhan, French archaeologists have been discussing the dynamics of formation of living floors. They have essentially taken into consideration the spatial distribution of artefacts and their typological and technological characteristics, whereas they have made little use of the sedimentary attributes because the close relationship between the sedimentary matrix and cultural processes was still poorly documented (Audouze 1985; David *et al.* 1973; Rigaud 1979).

2.2 The present situation of soil micromorphology in archaeology

2.2.1 The scientific position

Since its modest beginning in the late 1970's, soil micromorphology has been continually progressing in archaeology, especially in Western Europe where there has been an increasing demand for micromorphological investigations from archaeologists of various origins. Two orientations are now appearing although they share some common interest:

i) An environmental approach in which the micromorphological study of soils and sediments leads to the environmental reconstruction of human palaeolandscapes at a regional or micro-regional scale (site level). Beyond the characterisation of naturally-induced phenomena, the recognition of human influence (through devegetation, cultivation, etc.) on palaeolandscapes is an essential objective of the micromorphological analysis (Courty 1990; Macphail *et al.* 1987, 1990; Romans and Robertson 1983).

ii) A cultural approach which is oriented towards the recognition of human activities analysed in a spatio-temporal perspective. The essential objective is to integrate an accurate knowledge of the sedimentary matrix into the traditional archaeological approach of studying artefacts for a comprehensive functional analysis of a site (Courty *et al.* 1989).

These two approaches are widely accepted although they both face some difficulties.

Many colleagues, either in Quaternary geology or soil science, still deny that the microscopic scale should be an imperative level of perception in landscape analysis. They essentially achieve landscape reconstruction by analysing at the field level, spatial relationships between stratigraphical units of both pedogenic and sedimentary origin. Analytical data and micromorphological observations are used to complete the diagnosis of morphological properties recognised at high levels of organisation (horizon, profile, site regional scale). Their attitude is surprising considering that the efficiency of the microscopic approach for palaeogeographic reconstruction has been largely demonstrated by sedimentologists working with consolidated rocks.

The difficulties in contextual archaeology are different. We face three kinds of reaction:

i) A positive attitude, where results are well accepted but have limited impact because they are not properly integrated into the archaeological construction. This is essentially a problem of dialogue due to important differences in the interpretative systems used in the naturalistic approach and those of social sciences.

ii) Suspicion: total refutation is probably less common now than in the beginning when the identification of anthropogenic deposits based on the use of thin sections was not always accepted by archaeologists. It is however common to meet a certain scepticism and surprise regarding the accuracy of information that can be obtained by soil micromorphology. In this case, archaeologists often require a preliminary study performed without providing the basic contextual data which are essential for a comprehensive interpretation of the thin sections. The real soil micromorphological study will only start if the test was able to give convincing results.

iii) A constructive attitude has recently appeared from archaeologists who have fully evaluated the potential of soil micromorphology. They regard the microscopic study of thin sections as the logical continuation of the excavation because it not only reveals the constitution of the sedimentary matrix but also questions the validity of the field criteria used for the supposedly objective description of facts and for the collection of data during the excavation. They have realised that the micromorphological characteristics of archaeological sediments have to be taken into account when discussing field evidence and that an efficient field strategy requires the understanding of dynamics at different spatial scales from the macro-regionial scale down to the microscopic level. Undoubtedly, in this perspective, soil micromorphology has reached a new plateau that we had not even suspected when we started to work for archaeologists. This situation implies that when dealing with cultural processes the micromorphological approach should be handled by archaeologists themselves because the concepts debated are the ones of archaeology and the objectives are those of contextual archaeology.

2.2.2 Achievements

i) Palaeoenvironmental changes and archaeological implications.

The recognition in thin sections of the successive pedological phases recorded during the historical development of a soil is probably the most diagnostic result that can be used to document past-environmental change (Fedoroff and Goldberg 1982; Kemp 1985; Macphail 1986). Each phase is defined by a group of pedological features which relate to elementary soil-forming processes (e.g., biological activity, translocation of clay, accumulation of secondary carbonates, etc.). Their intrinsic properties and their spatial distribution provide information about the hydric regime of the soil during each phase of development and about the vegetation cover (Fedoroff *et al.* 1990), (Figure 2). The characteristics of the transition between two pedological phases aid in elucidating the dynamics of the transformation and the factors which induced the change (climate, self-degradation of the soil-system, human impact). A sequential chronology can thus be established not only in polycyclic palaeosols formed during a few thousand years, but also in any kind of stratigraphical unit which may be less than a few hundred years old (Figure 4). The results achieved shed new light on stratigraphical sequences which can only be simply interpreted as the succession of accumulation phases, interrupted by periods of soil development. Each unit appears, in most cases, to be the result of a complex imbrication of sedimentary and pedological events which have been more or less simultaneous.

Micromorphological investigations have shown to be highly helpful in discriminating *in situ* soils or palaeosols from pedosediments which are no longer in their primary situation because they have been reworked by sedimentary processes (Goldberg 1987), (Figure 5). The distinction is often difficult in the field because *in situ* palaeosols and sediment derived from palaeosols may present similar morphological properties. Particle size distribution and routine soil analyses can rarely resolve this question. This explains the common errors of chronostratigraphical interpretation which do not use soil micromorphological data (Goldberg 1979).

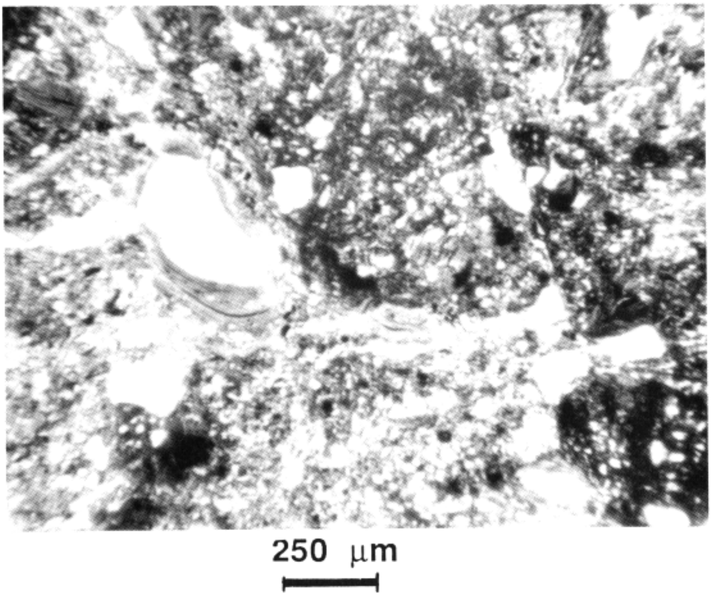


Figure 4. Polycyclic palaeosol developed during the last Interglacial period. The hierarchy of pedological fabrics and features allows recognition of the succession of several phases of soil development under a forest cover interrupted by degration phases of the soil cover (minor colluviation and cryoturbation). Iville palaeosol, Paris Basin.

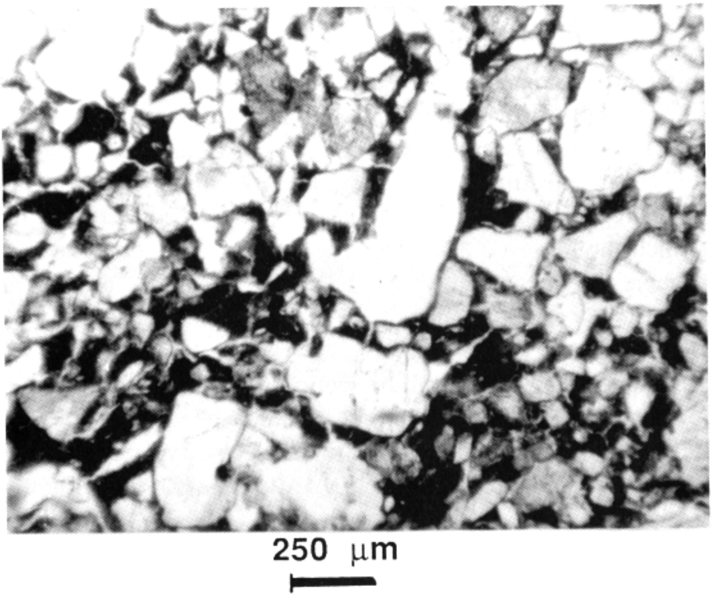


Figure 5. Massive sandy clay unit which results from the colluvial reworking of a palaeosol developed during the last Interglacial period. Pre-existing pedological features have been strongly altered and are not recognisable in the homogeneous dusty clay fine mass. Archaeological unit with Middle Palaeolithic industry, site of Villejuif, Paris Basin (director Ph. Andrieux).

ii) Distinction between natural factors and human influence.

The study in thin section of archaeological sediments from various cultural periods, and collected in diverse geological and climatic locations, has permitted the differentiation of anthropogenic sediments from natural ones (Courty *et al.* 1989). This term implies that human agencies directly influenced the formation of the deposits, either by controlling their accumulation or by inducing transformations of natural sediments. Sediments which are totally related to cultural processes, both in the mode of deposition and in the nature of constituents, are termed anthropogenic. An ash unit is, for example, a typical anthropogenic sediment. The similarities observed in a large variety of cultural settings reveal the nature of the combustible used and the history of the combustion (Wattez 1988), (Figure 2). Living floors are another common type of anthropogenic sediments which are characterised by a specific fabric produced by trampling (Figure 6).

In other cases, human activities are only partly responsible for the formation of the sediments, which may be of natural origin. For example, human influence in most of ancient cultivated soils consists of structural modifications to natural soils, in addition to a minor input of anthropogenic constituents (manure, liming, etc.), except in the case of plaggen soils and garden soils in urban environments which may be totally anthropogenic (Courty *et al.* 1989).

Not all archaeological sediments are anthropogenic in origin. Evidence of human influence, recognised at the microscopic level in the nature of basic components or in their arrangement, is often rare (Figure 7) or even absent (Figure 8). In theses cases, post-depositional processes may have strongly obliterated cultural features (Courty and Fedoroff 1982; Courty *et al.* 1989). It may also suggest that human activities have not affected the sedimentary matrix, which should be confirmed by the study of artefacts. The absence of anthropogenic features may even indicate that artefacts are not in their primary position because the anthropogenic signal has been erased by subsequent reworking.

For example, the study of thin sections has been shown to provide essential information in discriminating human-related units from biogenic accumulations in some cave deposits because the two types of sediments may show similar characteristics in the field (Wattez *et al.* 1990), (Figure 9).

iii) Dynamics of cultural processes.

Thin section study of anthropogenic sediments can aid in the accurate recognition of the different groups of cultural deposits which have been theoretically distinguished by Karl Butzer (1982).

Primary cultural deposits relate to accumulation on the soil surface during the utilisation of an activity area; they may have been altered by

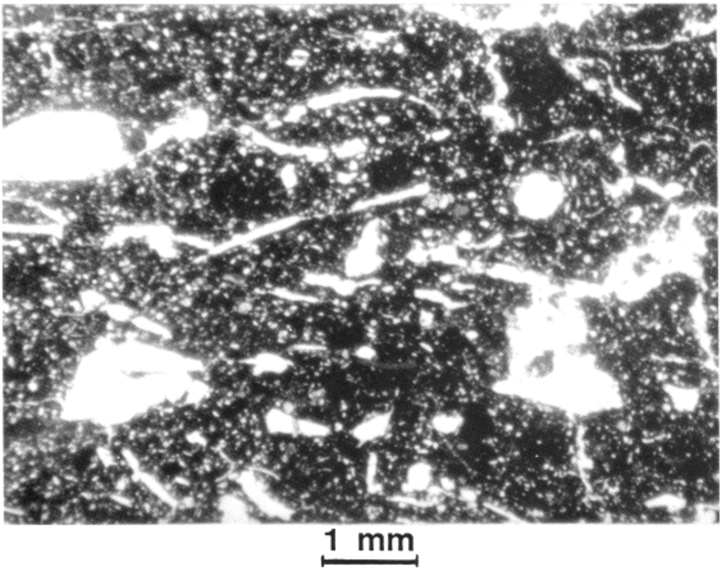


Figure 6. Typical fabric of a living floor induced by repeated trampling and by addition of very fine anthropogenic debris and soil fragments (dark spots). Neolithic Pre-ceramic site of Netiv Hagdud, Jordan Valley (director O. Bar Yosef).

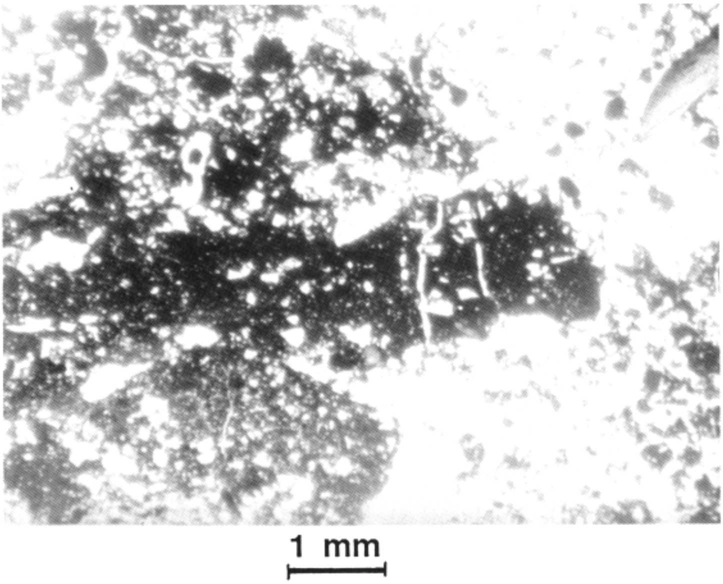
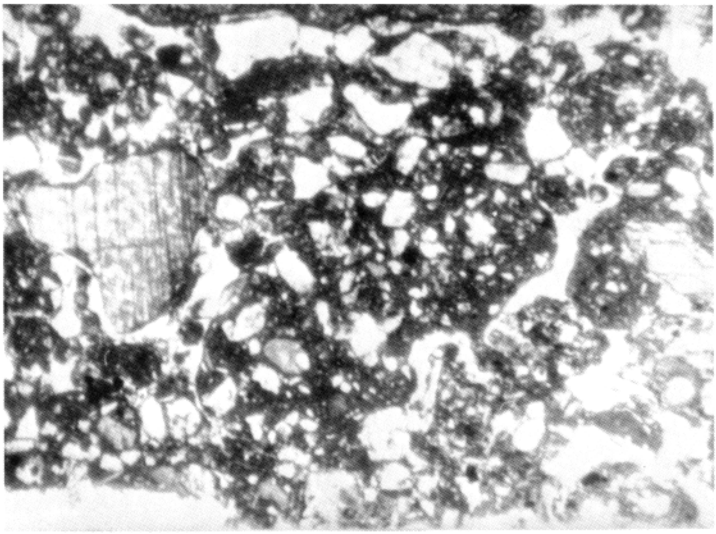
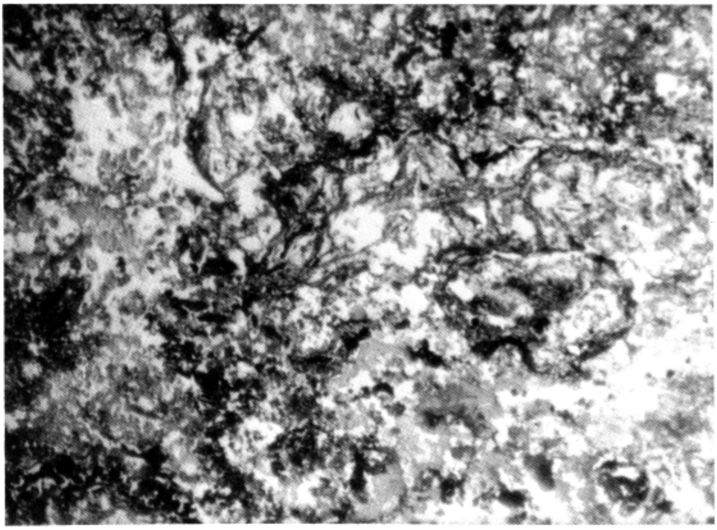


Figure 7. Relict living floor consisting of a trampled sub-surface at the bottom (dense fine layer) and an active layer on the top rich in anthropogenic constituents (ash, bones). The surrounding open sandy matrix has been intensively reworked by biological activity. Late Magdalenian archaeological layer, site of Verberie, Oise valley, Paris Basin (director F. Audouze).



250 µm

Figure 8. Archaeological unit strongly reworked by post-depositional processes which consist of detrital sedimentation, dissolution of carbonates, cryoturbation and biological activity. Anthropogenic constituents are only observed at high magnification in the fine mass (bone fragments); evidence for human-related fabric is not recognisable. Mousterian layer VIII, cave of Vaufrey, south-western France (director J. Ph. Rigaud).



1 mm

Figure 9. Grey ash layer formed by the accumulation of bird excrement which has been burnt, possibly by humans. Mesolithic layer, cave of Fontbreguoua, south France (director J. Courtin).

post-depositional processes. A large number of ash layers are primary cultural deposits (Figure 3), as well as living floors (Figure 6).

Secondary cultural deposits are primary deposits which have suffered important modifications in their original settings, either because they have been displaced (e.g., dumped ashes cleaned from a fire place, Figure 10) or because there was a significant change in the utilisation of the activity area. In the latter case, secondary cultural deposits appear finely mixed with primary cultural ones which relate to the latest phase of human activity.

Tertiary cultural deposits correspond to the cultural disturbances defined by Butzer (1982). They have been totally removed from their original settings because of spatial rearrangement or cleaning (e.g., digging of ditch, dumping; Figure 11) and may have been reutilised for a specific purpose (e.g., terracing).

The distinction among these three groups is essentially based on the study of the spatial relationships of the elementary constituents, rather than their intrinsic characteristics which may not always have been strongly modified through reutilisation and displacement.

At the present stage, we are able to decipher the effects of successive reworking and of subsequent alteration by natural processes. We are certainly limited to the specific identification of a few cultural signals because our reference system is still incomplete. Comparison with features obtained in controlled conditions, from experiment or from ethnoarchaeological studies, has appeared to be essential in evaluating the respective role of all the cultural processes which interact to result in specific sedimentary signals.

2.2.3 The academic situation

Soil micromorphology in archaeology is rapidly gaining maturity although its real progress is modest. Most senior scientists in archaeological sedimentology are not using soil micromorphology and its possibilities are essentially being exploited by young scientists. In addition to technical or financial problems, beginners have to face several difficulties:

i) There are practical problems in the preparation of thin sections because only a few departments of archaeology or environmental archaeology have the basic equipment. In many cases, thin sections have to be made in departments of soil science which cannot always respond rapidly to the increasing demand.

ii) Absence or scarcity of reference materials ("benchmark" thin sections, published catalogues, etc.). Each researcher is more or less trying to build his or her own reference collection which is not only time-consuming but also casts doubt upon the validity of the interpretation achieved. The recently

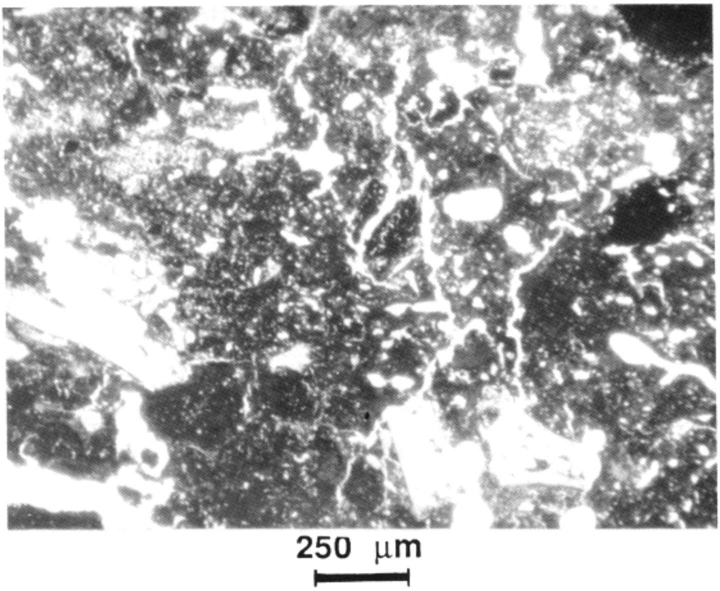


Figure 10. Secondary anthropogenic deposits: dumped ash cleaned from a fire place, finely mixed with domestic refuse (bones) and soil fragments which have been intensively trampled while the soil was water saturated (well-expressed dusty clay coatings in cavities). Mesolithic layer of the shelter of Bavans, eastern France (director G. Aimé).

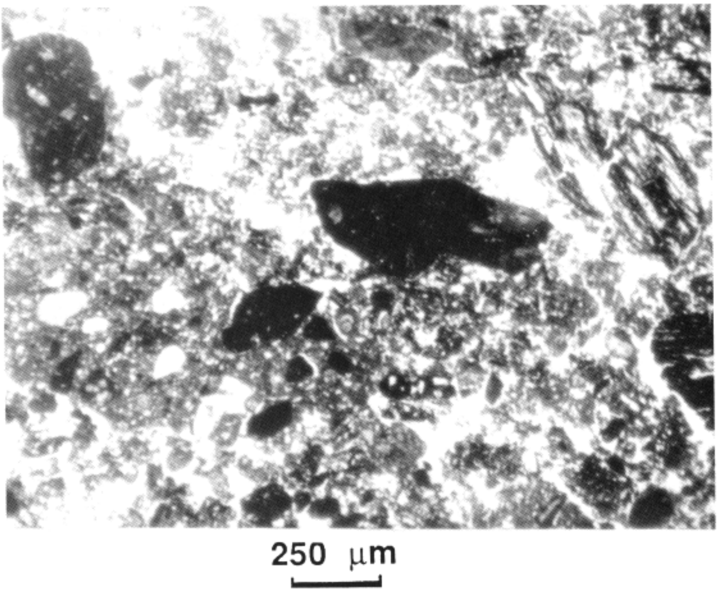


Figure 11. Tertiary cultural deposits: domestic refuse (ash, animal dung) and debris from construction materials (living floors, bricks) dumped in a pit. Neolithic Pre-ceramic site of Netiv Hagdud, Jordan Valley (director O. Bar Yosef). The main difference from Figure 10 is the very open fabric which indicates that the dumped deposits have not suffered any trampling.

published handbook "Soils and Micromorphology in Archaeology" (Courty *et al.* 1989) should partly fill the gap although it cannot be not exhaustive.

iii) Lack of training fully oriented towards the objectives of soil micromorphology in archaeology. This problem is probably more crucial for the few young and audacious archaeologists that are now following this approach.

iv) An important time investment before being able to make comprehensive descriptions of thin sections and to achieve coherent interpretation.

v) Difficulty of corroborative scientific evaluation because of insufficient communication between practitioners, despite a number of international fora.

vi) Necessity to produce results rapidly to answer the demand of archaeologists (e.g., in rescue projects). In these cases, the contribution of soil micromorphology consists mostly of fastidious description, the conclusions being often superficial or obscure to the archaeologist.

These different limitations explain why many young scientists involved in this field make little profit from the information recorded in thin sections and are not using the optimal potential of soil micromorphology in archaeology. This situation may become detrimental to the future of the discipline.

3. Perspectives

Discussing the future of soil micromorphology in archaeology implies that we can effectively solve our present difficulties and that we should decide what are our long term scientific objectives. Predictions are always delicate and may benefit from the lessons of the past. Soil micromorphology has now been used in soil science for nearly half a century and it may be worthwhile to comment upon a few points of its history.

3.1 Lessons from soil micromorphology in soil science

Technical difficulties in the preparation of high quality and large sized thin sections have limited for a long while the development of soil micromorphology in many soil departments, although others had considerably improved the technique more than fifteen years ago. Technical problems cannot thus explain why soil micromorphology is used in soil science in a non-systematic manner when utilisation of routine soil analyses has been standardised for more than 50 years.

Scientific difficulties have been, and still are, probably more limiting because soil scientists often have a basic training in agronomical sciences (especially in France and the USA) which includes only a limited background in geology and generally no knowledge of petrography. Soil micromorphology in soil science is taught in a large number of soil science and earth science departments, but this basic knowledge is apparently insufficient and intensive courses in soil micromorphology have recently been created.

Soil scientists have commonly escaped their knowledge deficiencies in two ways :

i) Those with a sufficient background in petrography have focused on the weathering of mineral constituents and have paid little attention to the overall organisation of soil constituents.

ii) Others have been using only scanning electron microscopes, and related microprobe techniques, without investigating the intermediate levels of organisation between the field and the ultramicroscopic level.

A large number of soil micromorphologists have, however, overcome the inherent difficulties of thin sections and have been able to handle properly a multi-scale approach, both through time and through spatial scales.

For many years, soil micromorphology has been essentially promoted in studies dealing with soil genesis. In this field a few experts have achieved world-wide experience and are considered to possess the key to interpretation. Unfortunately, most of the available textbooks are essentially devoted to the description of thin sections (Bullock *et al.* 1985; Brewer and Sleeman 1988; Fitzpatrick 1984) whereas there is a lack of a general textbook dealing with the interpretation of pedological features recognised at the microscopic scales in modern and ancient soils. Moreover, soil micromorphologists have performed few experiments which could help to corroborate their conclusions (see, for example, Mücher and de Ploey 1990). This explains why they are often accused of working from intuition. On the other hand, in the numerous regional studies of soil-landscapes, soil micromorphology has been commonly used, but only as one of many techniques.

Soil micromorphology has suffered a clear decline in this field since the 1970's because the understanding of soil genesis is not at present a predominant objective of soil science.

In the recent years, soil micromorphology has however largely expanded its field of application to biological, physical and chemical aspects of soils (e.g., structural modification under farming practises, deterioration of the soil ecosystem by man, behaviour of heavy metals in soils, etc.), (see, for example, Bresson and Boiffin 1990; Thompson *et al.* 1990). Because in these cases soil micromorphology is combined with other methods to answer specific questions, the logic of the micromorphological investigation can be more efficiently evidenced. It seems that through this direction, soil micromorphology is progressing successfully in soil science.

3.2 The future of soil micromorphology in archaeology

3.2.1 Scientific objectives

The lessons from soil science suggest that we should not be too ambitious in hoping to obtain the maximum benefit from soil micromorphology in the next few years. Our progress is not only dependent upon technical or financial factors. The most important and the most delicate question is whether we have the conceptual capacities to process the impressive quantity of data already collected and continually increasing. Our immediate objectives should then be:

i) to normalise the collection of data not only at the microscopic level but also in the field which may have important implications on field strategies adopted by archaeologists;

ii) to build reference systems by using standardised, or at least well-defined procedures (especially for experiments) and to publish them rapidly; great care has to be taken in their elaboration in order to avoid invalidating former results although some may have to be revised.

We should be modest in our aims and restrict our interpretation to data that we can identify by using our reference systems. Hypotheses can however be formulated on features of unknown origin by taking other criteria into account, for example the artefactual context.

We should rapidly develop the utilisation of more powerful techniques (SEM, STEM, microprobes, etc.) for the characterisation of constituents which are poorly determined in thin sections: impregnation by fat, blood or urine and other kinds of organic matter, phosphatic residues, etc. We should however be aware that sophisticated techniques are always fascinating and that they can easily divert the research from its primary goals. The petrographic microscope is certainly not self-sufficient but is absolutely necessary to make the link between field observations and any other kind of investigation on specific components of the sedimentary matrix (from grain size to molecular content).

We are also expecting from the progress achieved in image analysis an increase in systematic interpretation. The first attempt to understand structural modifications of soils by human trampling is already promising (Whitbread and Goldberg 1991). Image analysis should provide an efficient way to standardise our observations and to achieve a satisfactory level of quantification.

We are aware that the development of soil micromorphology in archaeology requires a close collaboration with archaeologists. This implies that we first have to facilitate the dialogue by making achievements in soil micromorphology accessible to all archaeologists. An effort has to be made in this direction by using a simple but strictly codified terminology. It is also highly important that all archaeologists accept that we are not providing them with data but that we are combining complementary approaches to meet common objectives.

The objectives of soil micromorphology in archaeology are those of contextual archaeology: to consider human activities through time and through space by analysing spatio-temporal relationships between the sedimentary matrix and its artefactual content. Our short experience has already shown that a large range of human activities has been recorded at the sedimentary level and that the signals of those activities can be deciphered. In the near future, for example when working on hunting sites which have been well preserved, we should be able to identify by their sedimentary signatures : outside fireplaces, cooking zones, eating zones, inner-hut fire places, rest zones, storage zones, passage zones. This ambitious objective faces more practical limitations than scientific problems. We are not going to impregnate the entire site and conduct the excavation under the microscope. Important choices have to be made right in the field which means that the micromorphological study begins with, and is part, of the excavation.

3.2.2 Academic organisation

The entrance of soil micromorphology into archaeology raises the important problem of academic institutions. The practical aspects of the preparation of thin sections can be easily solved until departments in archaeology or environmental archaeology can get their own equipment. The more delicate question is whether there is a scientific environment favourable to micromorphological investigations in archaeology. The full development of soil micromorphology in archaeology, especially when dealing with cultural aspects, requires the complete integration of the method with the archaeological methodology, started in the field, continued in the laboratory and achieved in publications. The inherent difficulties in soil micromorphological research can however handicap beginners, who may not find advisers in this field within departments of archaeology. From our own experience, one cannot hope to gain a solid level of expertise by spending hours with the microscope, even with a good knowledge of the related literature. A constant discussion with colleagues of what is seen under the microscope is absolutely essential to test the objectivity of observations and the logic of interpretation.

4. Conclusions

We can expect environmental change, induced by natural factors or by humans, to have been recorded in sedimentary materials only when the perturbation has been strong enough to modify their singular properties. The recognition in the field of these modifications is essentially limited by the fact that observable properties at this level of organisation are the resultant of complex interactions between elementary components of various sizes (atomic, molecular, nanometre, microscopic, etc.). Observations of thin sections prepared from undisturbed samples provide substantial information about most reactions which have affected the basic constituents of sediments (sand-, silt- and clay-sized mineral particles and organic components). These reactions are characterised by their specific signals which may relate to sedimentary changes, pedological modifications or man-induced transformations. The interpretation of each signal and the recognition of its succession can aid in the elucidation of the historical development of a given pedogenised sediment which may have been influenced by man. The microscopic scale thus allows an accurate perception of the dominant processes which are broadly identified at the field level. This approach is also essential to decipher minor events which have been offset by dominant processes.

For these two reasons, soil micromorphology offers environmental archaeology the opportunity to accurately identify man-induced transformations on ancient landscapes and to reconstruct landscape evolution with a very fine time resolution.

In contextual archaeology, soil micromorphology appears as an innovative approach which has already shed a new light in the recognition of cultural influences on the sediments. The most promising achievements expected concern the functional analysis of archaeological sites which implies that we should rapidly be able to decipher sedimentary signals related to the everyday life of our ancestors.

The singularity of the micromorphological approach requires a well defined system of concepts and methods and specific training. Soil micromorphology should consequently be a full branch of instruction in archaeology with a large diversity of objectives. We have to be cautious that the promotion of this new sub-discipline does not however create a community of scientists who are so specialised that their results will remain inaccessible to others. This pitfall can be avoided by demonstrating how investigations at microscopic scales performed by specialists can change the field perception of any archaeologist.

In conclusion, the successful future of soil micromorphology in archaeology implies not only that the number of practitioners should increase, but also that dialogue with archaeologists should be considerably improved.

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