Soil Micromorphology and its contribution to the interpretation of archaeological sites

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The soils and the sediments of archaeological sites provide a context for the artefacts. They are a resource for essential information about stratigraphy, site formation processes and possible natural or artificial disturbances. The microscopic study of thin sections from soils makes it possible to describe and measure components, features and fabrics in undisturbed soils, which cannot be seen by the naked eye. The method provides an important insight into many problems of, for example, soil development, diagenesis, weathering, and soil/plant interactions, and can be used for palaeoenvironmental reconstructions. The use of micromorphology is increasing in a number of disciplines, particularly in soil science, quaternary geology, and palaeoecology. It was not until the 1970s that the micromorphological analysis of soil thin sections was developed for general application in archaeological investigations. Today, soil micromorphology has become one of the established scientific techniques like analysis of macrofossils, charcoal, pollen, and bulk chemical, biological, and physical analysis. Soil micromorphology is an essential part of a recently started project at the Museum of Archaeology, Stavanger, in collaboration with the Department of Soil and Water Sciences at the Agricultural University of Norway at Ås. The project will combine different geoarchaeological methods to obtain new information about prehistoric agriculture, and prehistoric use of the landscape at Jæren, southwestern Norway. The combination of the different geoarchaeological methods is especially expected to throw new light on methodological problems related to pollen analysis in mineral soils.

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Introduction

Soils are important resources of information in scientific investigations of both natural and cultural history, and often they are the only ones. This is the reason why it has become increasingly important for archaeologists to use different soil analytical methods, such as, for example, analysis of pollen and macrofossils and chemical analysis. The use of thin sections made from undisturbed and impregnated soil blocks, allows contextual analysis of taphonomy (e.g. pollen destruction) and depositional relationships between sediments, artefacts and bio-archaeological remains (Matthews et al. 1997:281).

The study of soil micromorphology in archaeological contexts is widely used in Europe. There is an International Archaeological Soil Micromorphology Working Group, which is coordinated by Richard I. Macphail, University College London.

In a collaboration project between the Museum of Archaeology, Stavanger, and the Agricultural University of Norway, Department of Soil and Water Sciences, soil micromorphological analysis will be used in combination with other geoarchaeological methods, to throw light on the processes that formed the cultural landscape of Jæren, southwestern Norway, in prehistoric times.

W.L. Kubiena was the first to study soils in an undisturbed state as a new research area in pedology. In his book «Micropedology» from 1938, and in later publications, he presented a new method for establishing the genetic history of soils and how to classify them.

Micromorphology is the branch of soil science that is concerned with the description, interpretation and, to an increasing extent, the measurement of components, features and fabrics in undisturbed soils at a microscopic level. The method provides information that cannot be obtained by chemical, physical or other methods.

Soil micromorphology is based on the same principles as petrography. Samples for soil micromorphology have to be collected with care and normally with the help of metal boxes («Kubiena-boxes»). This is important in order to ensure that the various components – sand, silt, clay and organic material and the pores in between – stay undisturbed (Courty et al. 1989).

Soil micromorphology includes the examination of clods or aggregates of undisturbed soil material with optical microscopes and more high-powered equipment such as scanning electron microscopes, but is usually restricted to the study of thin sections using polarising or petrographic microscopes (Kemp 1985).

It is essential to establish an intimate connection between the description in the field and the description of the thin section. The magnification of a pocket lens as a connecting link in the analysis is very useful and nearly indispensable. The final identification and interpretation is based upon the entire data set. The samples taken in the field as monoliths, with the help of the Kubiena-boxes, have to be air dried to rid the soil of water because of its deleterious reaction with the resin. In the laboratory, the drying of the soil has to be completed with the help of acetone. The soil blocks have to be impregnated with resin under vacuum conditions and then left for at least two months to allow full impregnation by capillarity (Murphy 1986).

Finally, microscopic thin sections have to be cut from the sample and mounted on glass plates. It is possible to carry out the drying and impregnation processes in one's own laboratory, but more common to have the whole process done by a professional laboratory.

Chemical, physical and mineralogical analyses require representative, homogenised soil samples and the results will therefore be mean average data. This is not the case in micromorphology, which allows the interpretation of exceptional features, which frequently have a clear genetic meaning (Stoops 1998). The normal size of a thin section is 6 x 7.5 cm. The thickness of a thin section should not be more than 20-30 mm to fit on a polarising microscope. Different types of light are used for analysis: plane polarised light (PPL), cross-polarised light (XPL) and oblique incident light (OIL). A further possibility is the use of ultra-violet light (UV). The systematic description of the thin sections follows a universal standard, published as a «Handbook for soil thin section description» by Bullock et al. 1985. The technique of description and interpretation is to a high degree based upon data from pedogenic studies and from agricultural experiments.

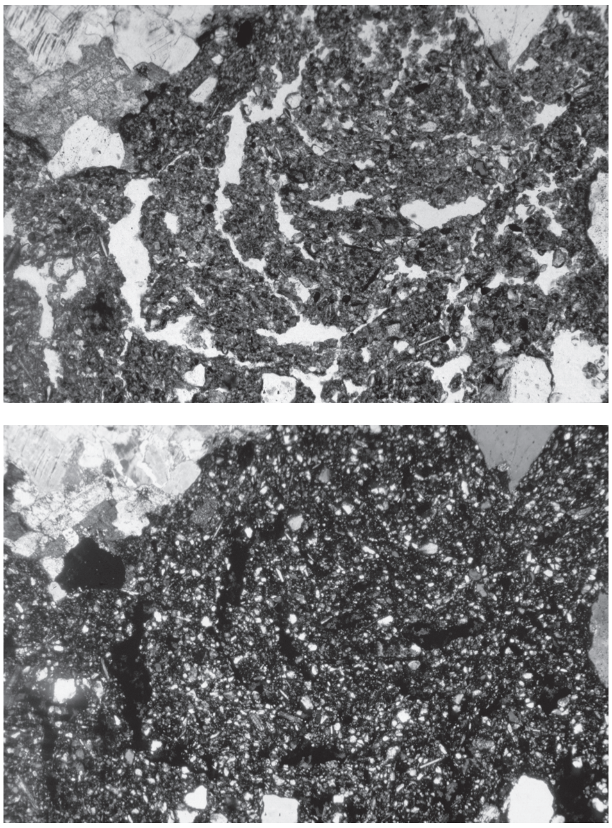
The study of soils and sediments related to archaeological investigations

Originally, soil micromorphology was used to study modern soils. Two important directions of research have evolved. The first one is the investigation of palaeosols in order to study the development of regional landscapes and climatic changes. The other direction is the study of Holocene palaeosols focusing on both local and regional interpretations of human influence on pedogenesis (Macphail & Goldberg 1995).

Roman & Robertson (1983) were among the first to identify historic tilled fields using soil micromorphology. Later, the method was used to trace ancient agriculture by scientists like Macphail et al. (1990). Langohr (1990) was able to map the soil types that were dominant in Belgium in the Neolithic. He could confirm that the Neolithic people preferred to use loessic soils.

Soil micromorphology can support other types of analysis in the reconstruction of prehistoric cultural activities (deforestation, pasturing, clearance, tilling, abandonment and regeneration of natural vegetation). On Neolithic sites in the Dutch coastal provinces, Exaltus & Miedema (1994) were able to identify individual archaeological layers and to reconstruct the processes of their formation.

Micromorphological analysis is today the most reliable method for identifying and understanding the processes



a

b

Fig. 1. Biopore presumably of an earthworm (1a: PPL, x 40; 1b: XPL, x 40), part of a thin section from a buried soil (stagno podzol with iron pan) under a Bronze Age clearance cairn at Chysauster, Penzance, Cornwall, Great Britain (Richard I. Macphail 1996). Photo: B.M. Sageidet.

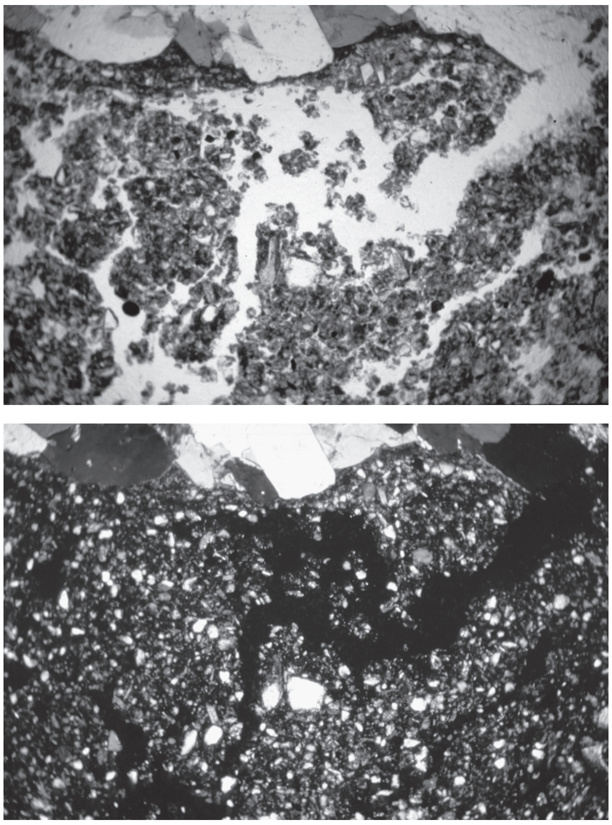


Fig. 2. Black excrements in pore (2a: PPL, x 40; 2b: XPL, x 40), part of a thin section from a buried soil (stagno podzol with iron pan) under a Bronze Age clearance cairn at Chysauster, Penzance, Cornwall Great Britain (Richard I. Macphail 1996). Photo: B.M. Sageidet.

involved in soil formation. Both processes produced by nature as well as those induced by human impact are included.

Buried soils (palaeosols) can contribute to Quaternary studies through their use as stratigraphic marker horizons as well as by providing information on Quaternary environments. As to the latter, it is necessary to assume that the pedological features resulting from past pedogenic processes are similar to those produced by the same processes today. It is also necessary to assume that some soil features and processes are uniquely associated with specific environments. On the basis of these assumptions, certain buried horizons can give indications on climatic, vegetational, topographical and hydrological conditions (Birkeland 1984).

Investigations of prehistoric/historic soils should always include estimates of the degree of conservation. Soil micromorphology is probably most suitable for such an estimation (Macphail et al. 1990). Mixing by the soil fauna, for example, is easy to record (see Fig. 1a and 1b). Excrement in the soil (see Fig. 2a and 2b) may reveal previous inhabitants (organisms) and their environments.

A mobilisation or mixing by tilling may be indicated when fragments of the iron pan are found in a horizon above the natural iron pan (Figs. 3a and 3b).

Micromorphological investigations from the Maiden Castle hillfort, Dorset, England (Macphail, in Sharples 1991) provided details of the past environment and the agricultural economy of the original inhabitants. A non-calcareous brown earth in the mid-Holocene was altered by Neolithic and later Bronze Age activities, specifically woodland clearance and cultivation. The disturbances led to soil disruption, breaking up and exposing of fragile subsoils as well as down-profile soil movements. Chalk, from a lower soil layer at this locality, is easy to recognise in a thin section (Figs. 4a and 4b). A textural feature, dusty clay material as capping along a pore, is shown by Figure 5a and 5b.

A careful study of one or more thin sections, seen in connection with all the other information available from the site in question, is essential to any interpretation. It may be difficult to distinguish between anthropogenic and natural effects on the soil, especially if the anthropogenic effects are indirect, i.e. if they induce or accelerate the natural ones.

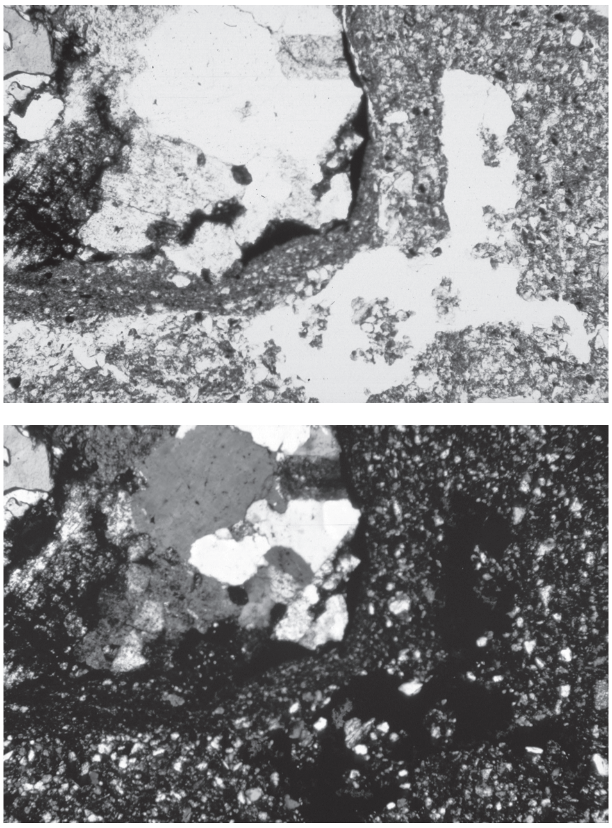


Fig. 3. Crust from the iron pan on a mineral in the Bh-horizon (3a: PPL, x 40; 3b: XPL, x 40), part of a thin section from a buried soil (stagno podzol with iron pan) under a Bronze Age clearance cairn at Chysauster, Penzance, Cornwall, Great Britain (Richard I. Macphail 1996). Photo: B.M. Sageidet.

4a

4b

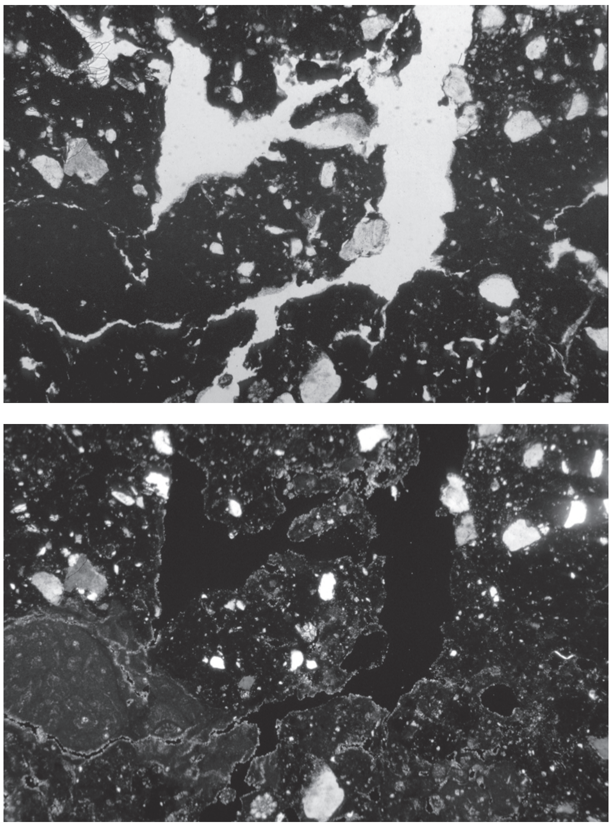


Fig. 4. Chalk, central in the lower part of the slice (4a: PPL, x 25; 4b: XPL, x 25), part of a thin section from a BC-horizon at Maiden Castle, Dorset, Great Britain (Macphail in Sharples 1991). Photo: B.M. Sageidet.

5a

5b

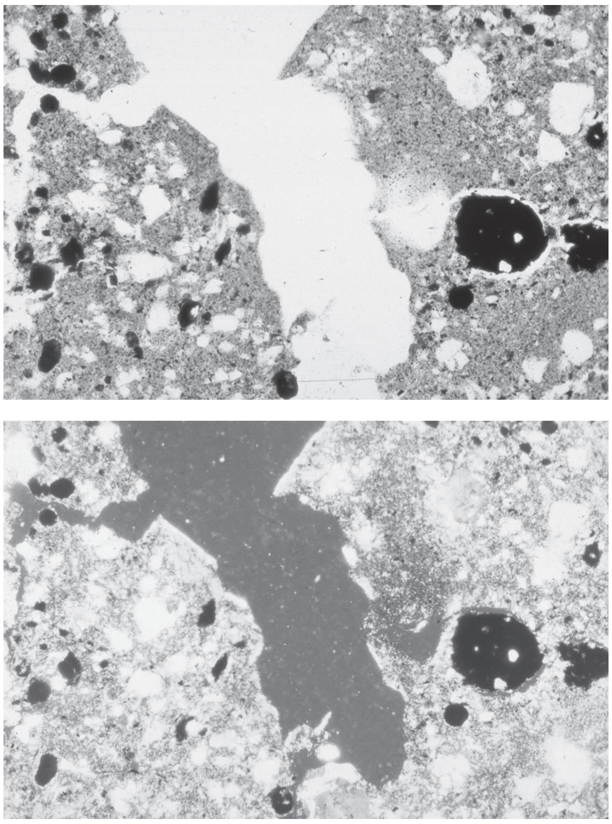


Fig.5. Textural feature: dusty clay material as capping along a pore canal (5a: PPL, x 100; 5b: XPL, x 100), part of a thin section from a site at Maiden Castle, Dorset, Great Britain (Macphail in Sharples 1991). Photo: B.M. Sageidet.

Combination of geoarchaeological methods

The collaboration project between the Museum of Archaeology, Stavanger, Norway and the Agricultural University of Norway, Institute of Soil and Water Sciences will provide new knowledge about agriculture and landscape use at Orstad, Jæren, southwestern Norway, in prehistoric times. The project will combine soil micromorphology and other geoarchaeological methods, including charcoal analysis, soil physical analysis and pollen analysis to achieve an ”indicator package” (c.f. Kenward & Hall 1997). The investigations will reveal the processes that formed the cultural landscape in prehistoric times, and the traces of them in soil profiles.

By combining the various methods the project is expected to throw new light on the methodological problems associated with pollen analysis in mineral soils. The classic method of pollen analysis was originally defined for sediments from bogs, mires and lakes (Fægri & Iversen 1989). The application of the method in mineral soils includes several complex taphonomical problems. In the same way as peat stratigraphy is essential to classic pollen analysis, pedology and soil micromorphology are needed for pollen analysis in mineral soils. The localisation of pollen grains in relation to structural elements in soils by micromorphology can supply a connecting link between pollen and those processes in mineral soils, which are responsible for possible movements in a profile.

Application and development of the soil micromorphological method

Soil micromorphological data should always be part of an interdisciplinary framework. In this way, data from different methods such as charcoal analysis, macrofossil analysis or pollen analysis, can control and complement each other. Especially in modern regions with strong urbanization and many different factors complicating any interpretations, great caution is acquired (Gebhard 1995:26).

The development and application of soil micromorphological techniques in archaeological science has formed a major research growth area in the last decade (Barham & Macphail 1995). A recent development has concentrated on different techniques to quantify and characterise details in soil thin sections. One of them is ”image analysis”. Image analysis is not a standardised method but a quantitative micromorphological examination of attributes in a soil profile, e.g. pore structures, with the help of image analysis systems following mathematical-morphological principles (Bryant & Davidson 1996:816, Serra 1982, Horgan 1998). The method can speed up and improve the statistical reliability of soil thin section interpretations.

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