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Identifying Human Behaviour by using Soil Micromorphology— a geoarchaeological approach

Sayantani Neogi

This paper attempts to discuss the role of soil micromorphology in understanding human behaviour from the past. The soil stratigraphy and detailed micro-morphological studies from archaeological sites and Quaternary landscapes opens the opportunity to investigate a complex subject of study. The soils and paleosols are sources of informations for palaeoecology and human occupations, little exploited because of the complexity of the processes of soil formation. The case study has been taken from an ongoing research project of north-western India, specifically from the Harappan site of Alamgirpur in Uttar Pradesh to explain the nature and role of Geoarchaeology as an interdisciplinary approach.

Keywords: Soil stratigraphy, soil micro-morphology, palaeosols, palaeoecology, geoarchaeology

Introduction

The landscape that surrounds us is essential to our life and activity and thus understanding of its characteristics and processes are important for sustainable development. Formed through long ages by changing climatic conditions, topography and geological materials, the landscape is complex and includes both resources and hazards to our society. Therefore the study of landscape characteristics is important, not only for benefit but also for survival. The landscape also forms an archive in which information on past processes are recorded as landforms and materials. Reading this record correctly might give us understanding of the past responses to changed conditions. Thus it forms the key to understand and also to predict future development. An understanding of landform changes, geomorphic processes, and interactions between humans and the Earth's surface are not mere fads for us. When combined with our traditional concerns and research in human-land interactions, this background becomes particularly relevant to the modern research and education agenda and this is one arena where geoarchaeological researches start playing cards. This interdisciplinary approach can solve out several questions related to human behaviour and adaptations to an environment and for geoarchaeologists, Quaternary epoch becomes an important and interesting period of puzzles to be solved out.

One of the main objectives of this paper is to understand the importance of studying human behaviour by means of soil stratigraphy and micromorphology. Stratigraphic units (Lowe 1997) include: lithostratigraphy (naming of formations for purposes of geological mapping); biostratigraphy (rock layers based upon fossil content); chronostratigraphy (rock layers based upon their numerical ages); magnetostratigraphy (study of rock layers based upon orientation of magnetic particles); Soil stratigraphy (study and mapping of soil layers, modern and ancient); and event stratigraphy (study and correlation of catastrophic events in geological history), etc. In archaeological site formation studies, the knowledge of soil stratigraphy is widely used. This is because there are numerous archaeological sites on the continental sedimentary environments were pedological processes are active. The law of superposition holds true, and this can help date finds from each archaeological context. On the other hand, absolute dates and findings from archaeological sites also serve to date soil forming processes and duration in a particular context. Soil stratigraphy is thereby widely related to soil morphology. It is the area of soil science that deals with the form, structure, and organization of the soil material. Soil morphology is ordinarily observed, described, and studied in the field but can be continued in the laboratory with optical and electron microscopes.

Soil micromorphology is thereby concerned with the description, interpretation, and measurement of soil components and features smaller than what can be readily seen with the naked eye. "Soil micromorphology is a tool to extend macromorphology"(Wilding and Flach 1985). Micromorphological studies add a visual form to the substances determined from other types of analysis (Kubiena 1964).Many micromorphological studies require the use of thin sections and petrographic equipment. Once a thin section is prepared, microscopic observation techniques are used. The microstratigraphic study through micromorphological analysis of the sediments enables the identification of palaeoecology of archaeological sites.

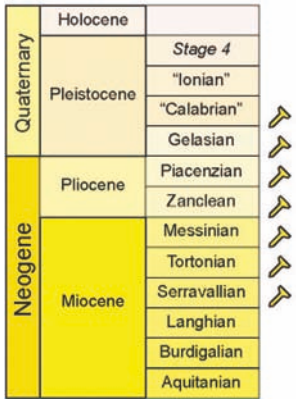

Fig 1. Geological Time Scale

Soil stratigraphical and micromorphological studies are concerned with certain principles involved in the study of Quaternary palaeosols and their application in Quaternary stratigraphy. Quaternary is the most recent period of geologic time, roughly the last 2 million years. When compared to the entire length of earth's history the Quaternary is only an instant. However, it is clearly a very important period of time for understanding current and future environmental change, and it also forms the background for human history and prehistory. With the response to Quaternary environmental change, there have been changes in landscapes beyond the limits of glaciation. These include:

- Changes in vegetation
- The changing hydrology and sedimentology of rivers and lakes
- The expansion and contractions of deserts.
- The loess record of environmental changes.

A Case Study

My current research is to understand the relationship between sites, rivers, floodplains, associated land-use and the nature of on-site activities at a series of selected sites during the Harappan and Painted Grey Ware cultural phases (Table 1) in north-western India. The hypothesis of this study is whether the first settlers were utilising a naturally replenishing floodplain, or a slowly aggrading system from either river or monsoonal effect. The main methods being used for this study are geoarchaeological survey with associated specific site investigations, soil micro morphology and geochemistry. The sites that are and will be analysed includes Alamgirpur in Uttar Pradesh, Sampolia Khera and Bhimwada Jodha in the village of Masudpur (Haryana) and Burj (Haryana) (Fig 3). This doctoral research is one components of the much larger UKIERI funded project of 'Land, Water and Settlement: Environmental constraints and human responses in northwest India between 2000 and 300 BC'.

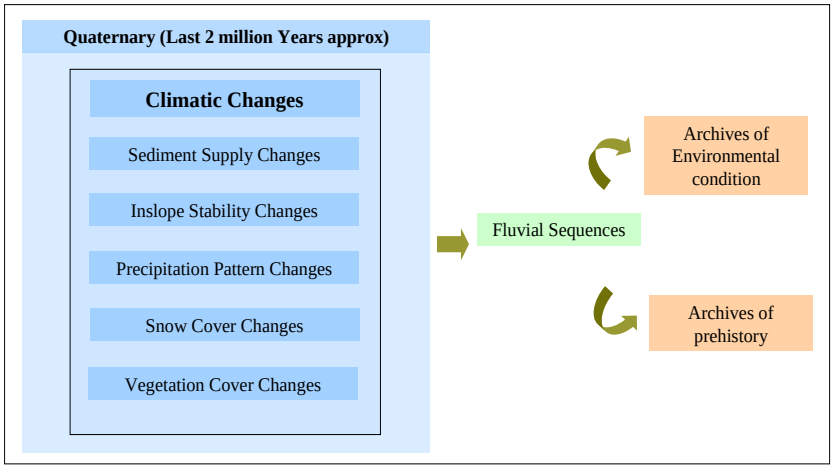

Fig 2. Effect of Climatic Changes on prehistory and environmental conditions

Background

The plains of the modern states of Haryana and western Uttar Pradesh are particularly important for understanding the rise and fall of urban Harappan civilization at it's eastern edge. It is quite well-known that this civilization rose to a great height during that period as revealed by spectacular city planning, making of characteristic pottery, giving shape to different innovative ideas through various forms of art and antiquities as well as local and long distance trade (Agrawal 2007). However, c. 2000 BC the urban civilization apparently started to collapse. There was an increase in the number of settlements towards it's eastern edge, long-distance trade was reduced and there was also a marked reduction in the production of a wide range of special luxury items such as long barrel cylinder beads, and inscribed stamp seals, which were in many ways the hallmarks of urban Harappans (Agrawal 2007). It was not before ca 600 BC that there was again a rise of urban characteristics in north India in the form of city-states.

Archaeologists have tried to understand the reasons for the decline and deurbanisation of the Indus civilization since it was first discovered. Major changes in the environment has often been cited as a critical factor in this decline. M.R Sahni (1956) first proposed the Indus silting concept, and this subsequently received impetus from Raikes (1965, 1967a) and Dales (1965). According to them, devastating tectonic activity might have led to heavy flood and damming of the Indus River resulting in drastic channel avulsion. This could have affected Mohenjo-Daro and adjacent areas. Also, Mackay (1938) stated that the dramatic shift in the course of Indus in its mid-lower course led to the abandonment of Mohenjo-Daro. This idea later received support from Lambrick (1967) and Mughal (1990). However, while Indus flooding could have affected the urban site of Mohenjo-Daro, it doesn't explain the reasons for the decline of the Harappan urbanism in more eastern areas that are not watered by the Indus River.

There has also been speculation that tectonic activity accompanied by the river capture led to the disappearance of the Ghaggar-Hakra river channel (Lambrick 1964, Wilhelmy 1969, Ghose et al 1979, Yashpal et al 1980, S.P Gupta 1996, 2001, Mughal 1997, Posseshl 2002, Valdiya 2002, Lal et al 2003), which used to run almost parallel with the Indus. At some point, the river appears to have been beheaded and the river became dry. Drying up of this river is often associated with the disappearance of the Vedic Saraswati (Oldham 1874, 1893; Stein 1942; Mughal 1997; Ghose et al 1979; Yashpal et al 1980; Valdiya 2002), and is also frequently stated to be the key reason for the abandonment of the sites in Cholistan and Rajasthan (Stein 1942; Mughal 1997; Valdiya 2002; Lal et al 2003), contributing to the downfall of the urban Harappan system.

Geoarchaeological study is an essential tool for investigating what was happening in landscape on the eastern edges of the Harappan civilization during this period. Although data from soil stratigraphy and micromorphology is not directly related to material culture, it can reflect sequences of landscape change and land use management. And because the process of landscape change involves human impact, either negative or positive, soil stratigraphy and micromorphology can contribute invaluable information on the inter-relationship between human activity and landscape change. The need for geoarchaeological studies for better understanding of Harappan civilization has been stated by Schuldenrein (2002), particularly for understanding site formation processes and changes in the nature of man-environment interactions in order to address questions of environmental changes and the human response to such changes.

Eastward shift and climatic change

It has been put forward that there had been a climatic change in this eastern edge of the civilization i.e. in the modern northwestern part of the Indian subcontinent. This involves an increase in aridity, less rainfall and a major shift in river course alignment (Allchin 1995) Possehl (1999c: 19-33) has also discussed the apparent eastward shifting of the culture through time. This in turn raises the question of whether there is any relationship between this eastward shift and climatic change? In terms of baseline data, what is required is to find out the pattern of settlement distribution in this area, target studies of a selection of important sites, and investigate these and their hinterlands through geoarchaeological survey and a programme of environmental sampling. Both on-site and off-site investigations and sampling will form a major part of the geoarchaeological studies, along with other scientific researches. The 'Land, Water and Settlement Project' is trying to work on all these aspects and the contribution of this research will

be addressing the geoarchaeolgical questions. Alamgirpur of western Uttar Pradesh, Sampolia Khera and Bhimwala Jodha of Masudpur and Burj in Haryana are four such sites where systematic excavations has been done after undertaking extensive exploration by the project team.

Sites

The site of Alamgirpur was first excavated by Dr Y.D. Sharma of Archaeological Survey of India (ASI) in May 1958 (IAR 1958-1959: 52) (Plate 1). In May 2008, the site was re-excavated under the direction of R.N Singh from Banaras Hindu University. Alamgirpur has evidence of cultural material from Mature and Late Harappan period, Painted Grey ware culture and some historical evidence (Table 1) also (Singh et al 2008). The LWS project conducted excavations at Sampolia Khera and Bhimwada Jodha near Masudpur in 2009. Both sites have evidence of Early, Mature and Late Harappan period settlement (Singh et al 2009). The study of geoarchaeology from these sites remains particularly important in order to relate the possible climatic and environmental changes (which includes influences of floods, drying up of nearby channels, increasing aridity) from Early to Mature Harappan, from Mature to Late Harappan and from Late Harappan to the subsequent Painted Grey Ware (PGW) culture with the nature of human adaption. It will help unravel questions of site context, the topography of the natural terrain, and landscape modification due to population pressure and resource stress in a particular area (cf. Schuldenrein 2007). It is very important to know the human-ecological dynamics of this region. This includes tracing the alluvial geomorphology of the area and then subsequently linking the influence of geomorphology to the living pattern of the dwellers. If sites had developed on riverine alluvial deposits, then what were the influences of the river on the site formation processes? For example— the site of Alamgirpur is located close to the modern River Hindon whereas no such modern river is now existent close to Masudpur. Nonetheless, recently built canals in this area are said to have been constructed along the courses of former river channels, which is something being investigated by the colleagues in the larger UKIERI project. If the associated geographical changes and their effects on human life and settlement can be traced, then the site formation processes of these two sites will become clearer. These should particularly be able to address the following issues:

- The formation sequence and post-depositional transformations of the early Holocene landscape anad its palaeosols;
- What land-use activities are evident in pre-Harappan and Harappan times? And how do these relate to on-site data for agricultural activities, production and consumption?

Addressing these may throw some light on the question of 'what was happening in this part during the early and mature Harappan times and why there was an eastward shifting in the Harappan culture at about. 2000 BC'? The implications of these site specific studies should help address the broader question of the downfall of the urban Harappan civilization.

The present Hindon River is a tributary of the Yamuna River. To the east of Baghpat, about 40km north of New Delhi, the Hindon is deeply incised through very fine white sand and silt deposits up to a depth of about 4m, set within a 2-3km wide floodplain. The floodplain/valley edges are defined by irregular but linear arrangements of sand dunes (c. 6-8m high), such as around the village of Pura and the protected Harappan site of Alamgirpur. The floodplain floor of the Hindon appears to be comprised of reworked riverine deposits, finely laminated and cross bedded, rather than alluvial deposits. This testifies to high volume/ high velocity floodwater and river avulsion events occurring regularly in the past. A farmer spoken to at Pura said that until about 10 years ago, the fields to either side of the Hindon had flooded every year during the monsoon. An inspection of the eastern side of the Yamuna River floodplain/valley close to Baghpat (c. 30-50km to the north of Delhi) suggested that a similar dune system was present, but has been much disturbed by quarrying. The Yamuna River itself has a very large and broad meander course that is only weakly incised into the floodplain in this area. When the Yamuna was visited on May 21st, close to the site of Isopur Til, there was no water flowing in the river, and cars were crossing the river using sand bars. This suggests that the modern water flow in the Yamuna is often dramatically affected and depleted by the canal systems of Haryana and western UP (Singh et al. 2008).

Inspection of the open eroding sections of the site made it clear that the archaeological deposits (c. 3+m thick) have accumulated on a

possibly truncated palaeosol composed of pale yellowish brown silt over a substrate of yellow silt with abundant calcium carbonate concretions and nodules. Some 200m off-site to the south, a quarry pit revealed at least 4m depth of aeolian sands that overlie white, laminated, fine river sands. This stands in marked contrast to the valley fill profile of the plains adjacent to the Hindon where a pale brown agricultural topsoil some 0.8m thick overlies at least 1.5+m of reddish brown silty clay loam, most probably of alluvial derivation. These land surfaces require further investigation in the future.

The 2008 excavation by BHU primarily aimed to reassess the stratigraphic chronology of the site and to obtain new samples for radiometric dating, as well as samples for plant remains and phytoliths and also to investigate the nature and formation of the occupation deposits and the old land surface using thin section micromorphology. Three trenches were excavated: the YD2 trench, the ZB2 trench and the Section Cutting Trench. However, samples for soil micromorphology were only collected from the YD2 trench and the Section Cutting Trench (Plate 2).

Objectives and methodology

The major objective of this study is to understand the nature of Harappan site development. This involves investigating both constructional and depositional aspects of the archaeological record, and the micro-environmental conditions present during human occupation by means of palaeo-pedology and petrography.

Specifically, our approach involves:

- Using geoarchaeological surveys of the environs of the sites of Alamgirpur (Uttar Pradesh), Masudpur and Burj(Haryana) to detect buried soil and erosion sequences, and using micromorphological analysis to aid in their interpretation.
- Distinguishing between natural sedimentary processes and potentially anthropic sedimentary processes in the formation of archaeological levels.

The identification of soil formation processes aids the reconstruction of the past by indicating the past bioclimatic environmental circumstances. Indeed it is often possible to relate a soil type to a particular ecological niche in the landscape. Soils and their properties are the product of different soil-forming factors (i.e. climate, organisms, relief, parent material and time) (Jenny 1941), the parent material (Harden 1990) and human activities, and together these control the degree of soil development. As soil-forming factors also govern geomorphic processeses, landscape evolution is intimately related to soil development (McFadden and Kneupfer 1990). Therefore, if we classify a palaeosol by means of a particular type of soil forming process and find an actual analogue, we can suggest the type of environment that was associated with a particular archaeological site (Retallack 1994).

The foremost objective is the identification of sedimentary contexts of the archaeological sites. For explaining the micro-environmental conditions, a geoarchaeological approach to the sedimentological record needs to be developed. The major part will be to distinguish between sedimentary processes and anthropic sedimentary processes in the formation of archaeological levels. The palaeoenvironmental analysis and the interpretation of sedimentary record of stratigraphic sequences is to be done. The formation process analysis needs a high knowledge of other disciplines. Geosciences have certain applications in the analytical research of sedimentary of sedimentary record. Thereby, pedosedimentary processes are to be articulated in the analysis of the transport origin and on the post depositional transformation of the sediments to be observed in the thin sections.

This project requires fieldwork and also laboratory work. Extensive fieldwork on the region will provide us with a detailed geomorphological knowledge of the area.

Field observations

Before fieldwork, maps have to be prepared and general geomorphological features have to be sketched based on interpretation of aerial photographs, orthographic aerial images, and available maps from present and previously performed surveys in the areas.

Field records are normally produced in three complementary forms and may be augmented by data from samples collected for further laboratory work. These are:

- Field notes: These are written descriptions of observed features which will also include precise details of location.
- Drawings and photographs: Many features are best described by means of carefully labeled field sketches, supplemented where possible by photographs.

- Graphic logs: These are diagrams of measured vertical sections through sedimentary rock units.

During fieldwork, information has to be recorded at selected locations within sedimentary formations. Careful drawing of the stratigraphic blocks from the section of the excavated trenches is very important. Lithology, texture and sedimentary structures of the sediments can be observed by naked eye and can be noted down for future references.

Laboratory processes

The soil blocks that had been and will be collected from excavated trenches as well as from different off-site surveys had been/will be were impregnated and thin sectioned using the methodology of Murphy (1986), and described using the accepted terminology of Bullock et al. (1985) and Stoops (2003). Few thin sections from Alamgirpur had already been analyzed using polarized light microscopes (Leitz Laborlux 12 POL S microscopes and a Wild Photomakroskop M400) at magnifications from 4 to 400 under plane polarized (PPL), cross-polarized (XPL), reflected (RL), and ultraviolet (UV) light sources.

New Results

The soils and palaeosols are a source of information for relating palaeo landscape context and human occupations. This study will involve the investigation of some soil formation processes of the buried soil horizons of this tropical semi-arid region. Soil micromorphology is a technique well suited for this type of analysis, supplemented by fundamental field descriptions and basic cartography of the geomorphologic units of the area. It can, for example, try to answer whether the pre-site soils were subjected to freshwater flooding and alluviation or not, as well as were they aggrading, disrupted by agriculture, and/ or affected by seasonal aridity or not?

As an example of the work so far done, a very early observation from some of the thin sections from the site of Alamgirpur shows the occurrence of clay illuviation in the pre-ste old land surface. Illuviation is the process of the deposition of colloids, soluble salts, and suspended fine material (silt and clay) particles in a lower soil horizon through the process of eluviation (downward movement) from an upper soil horizon (Federoff 1987, 1997). The phase of illuviation is characterised micromorphologically by the existence of reddish or yellowish clay coatings in the groundmass and pore spaces. They show strong orientations, with micro-laminations only being seen as a result of variations in the iron content which clearly show the successive episodes of accumulation. This may be indicative of successive phases of disturbance of the soil surface prior to site occupation as well as minor additions of possible overbank flood silts and clays. In the site of Alamgirpur, this will help to identify the palaeoenvironment of the area to be humid to sub-humid, perhaps already subject to minor alluvial aggradation. Soil micromorphology also shows the site to be in a braided plain. There are evidences of weathered broken up silt made mudbricks in humified silty-sandy churned up soil matrix along with phytoliths, amorphous organic mineral components, dirty clay coatings and orangish mottles in between suggesting wetting and drying, floods with little insitu occupation (Plates 3&4).

Palaeosols on-site and off-site along with stratigraphic sequence off-site will help to identify the sequence of landscape changes. This will in turn help to investigate the effects of changes on groundwater / soil system and therefore agriculture that could be supported. This could throw some light on whether the effects of sustainability of agricultural system had affected nucleated settlement of Harappans or not.

Conclusions

Changes in the climate and consequent changes in the sea level are reflected in spatial shifts of geomorphic domain, and associated sedimentary packages. The correlation of the terrace sequences of NW Europe, which can provide a framework for the Palaeolithic record is, therefore, of great importance. Palaeoenvironmental data from these archives is also important in understanding human adaptations and migrations during the Pleistocene (Bridgland et al, 2006).

During the last decades, special attention has been paid to the Pleistocene – Holocene (PH) transition and to the mutual interactions between the natural environment and human societies. The time span wrapping the PH limit, the late glacial and early Holocene, records the last major global climate change. The transition from the glacial cold climatic mode to interglacial temperate conditions occurred through complex interactions among marine, terrestrial and atmospheric processes and was

modulated by minor abrupt fluctuations affecting the biotic and abiotic systems. These fluctuations occurred at a moment when almost the entire planet was populated by communities of hunter-gatherers characterized by quite complex social and cultural patterns and a relatively simple economy, with subsistence strategies based on the predation of natural resources. The appearance of agriculture and animal husbandry took place in the Near East after a short time, rapidly spreading to other territories, and leading to one of the major transformations in human socioeconomic, behavioral and cultural systems.

The relationship between natural and cultural factors has long been debated and environmental and cultural changes are often co-related, even if under different perspectives. Multi- and interdisciplinary studies, which allow researchers to gather data from different fields and compare natural and cultural phenomena under an integrated and diachronic point of view, are critical to improve our knowledge on these topics. In this sense, Geoarchaeology is a mean to interrelate the dynamics of the physical environment and that of the human groups. The disciplines of geology and archaeology find a natural interface here, both contributing to, and benefiting from one another. Precisely datable artifacts and contexts provide the geoarchaeologists with abundant chronologic control that is almost unparalleled for any other moment of geologic time. Archaeologists

Table 1 : Rough Chronology of the Early Indian-subcontinental cultures

Cultural Period	Rough Time Period
Early Harappan	c. 3200-2600 B.C.
Mature Harappan	c. 2600-1900 B.C.
Late Harappan	c. 1900-1300 B.C.
Painted Grey Ware	
(PGW)	c. 1300-700 B.C.
Northern Black Polished Ware (NBPW)	c. 700-300 B.C.
Early Historic	c. 300 B.C. onwards

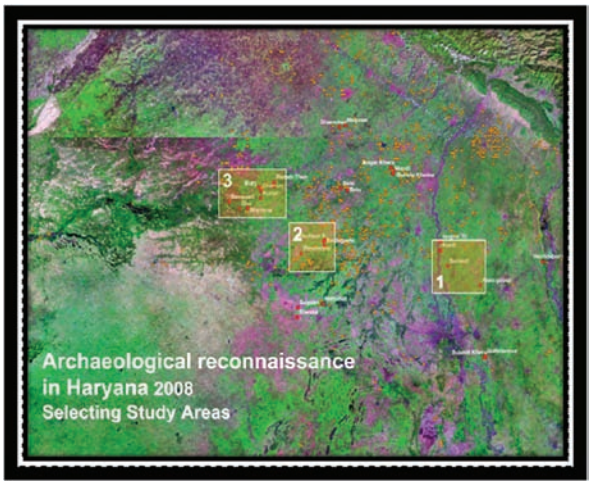

Fig 3: Distribution of Indus sites in Haryana and western UP, with location of study areas; Alamgirpur (Area 1), Masudpur (Area 2) and Burj (Area 3) shown.

Plate 1: The site of Alamgirpur as seen from a distance.

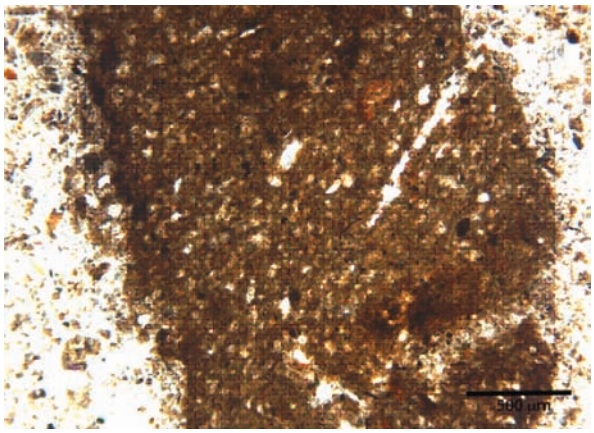

Plate 2: Soil blocks taken from the stratigraphy of S-C Trench, Alamgirpur

Plate 3: Microphotograph of a mud-brick structure.

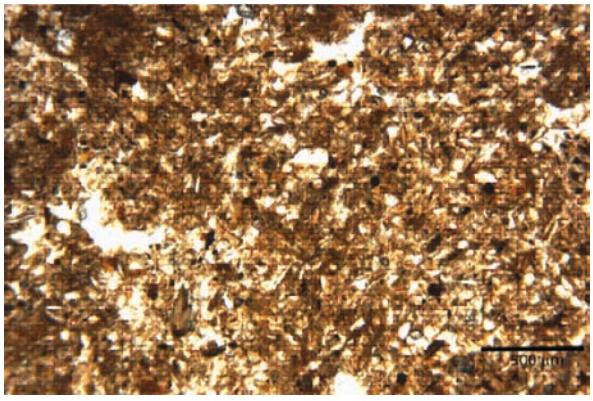

Plate 4: Microphotograph of a soil thin section from Alamgirpur showing orangish iron mottles intermittently suggesting alternate wetting and drying phenomena.

benefit by gaining a broad understanding of the physical environment in which the material remains they study were generated. Indeed, one of the more important realizations of modern archaeology is that the physical environment is dynamic. The resources, topography, and configuration of the landscape noted in a particular location today were no doubt different in the past. Judgements and interpretations about past cultures and civilizations must therefore take these dynamic elements into consideration.

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