Reconstruction of spatial organization in abandoned Maasai settlements: implications for site structure in the Pastoral Neolithic of East Africa

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Abstract

The analysis of spatial organization in archaeological sites is important for the interpretation of economic and social issues. In East Africa, the appearance of mobile herders, adoption of pastoralism by some hunter–gatherers, and spread of competing pastoral groups, create a complex archaeological record and interpretive problems associated with the beginnings of food production. Spatial analyses could contribute to their resolution, but are difficult because most sites lack macroscopic features. We present a geo-ethnoarchaeological study of abandoned pastoral Maasai settlements that allows us to evaluate the “archaeological visibility” of ephemeral features such as hearths, trash pits, gates, houses and fences. Micromorphology, mineralogy and phytolith analyses show that features containing ash have the highest visibility. Livestock enclosures, a feature studied by us previously, can also be identified based on this suite of techniques. Large livestock gates have poor visibility but may be recognized. Small gates, fences and house floors could not be detected using the methods applied here. Identifying livestock enclosures, trash pits and cooking hearths based on this approach, and houses based on post-hole positions, will contribute to a better understanding of the spread of food production in Africa. Our findings will also contribute to studies of pastoralists in other regions of the world.

Keywords: Maasai pastoralists; Ethnoarchaeology; Mineralogy; Micromorphology; Phytoliths; Geoarchaeology; Site structure

1. Introduction

The spatial organization of human settlements often reflects sociopolitical, economic, and belief systems, as well as social relations among families [17,22,29,32–34,44,60]. Interpretation of past societies from spatial data has been best developed for agricultural societies living in permanent village or urban settings with considerable investment in architecture [34,36,41]. Recognition and interpretation of ephemeral spatial features characteristic of highly mobile hunter–gatherer or pastoral societies has posed a major challenge for archaeologists. This is largely because mobility constrains the use of building material and the accumulation of material culture, and sites do not often preserve well [5,15,22,23,49,50,63].

Studies of one of the fundamental societal changes in the Holocene in Africa—the beginnings of food production—have not benefited from detailed spatial data because, unlike other regions of the world, settled villages are rare among late hunter–gatherer and early food producing societies. In Africa animals rather than plants were the earliest domesticates (cattle, donkeys), and mobile herders the earliest food producers. This resulted in a different trajectory of intensification and societal change than in other regions, and a distinctive material record (for details see [38]). In keeping with this pattern, in East Africa, mobile hunter–gatherer and pastoral groups predominated during the initial period...
of adoption of food production (termed the Pastoral Neolithic, ca. 5000–1300 BP). A complex mosaic of mobile hunter–gatherer and pastoral societies remains in the region to this day.

The lack of sites with recognizable architecture has constrained interpretation of the spread of food production in East Africa. A basic understanding of socio-economic differentiation and change in East Africa during the adoption of food production has been obtained from many lines of evidence, especially lithics, ceramics, and fauna. Still poorly understood, however, are the nature of interactions between hunter–gatherers and early pastoralists, variations in the organization of competing pastoral societies, and household level analyses of gender-based or specialized activities and social relations [24,46,56]. These issues are fundamental to understanding the process of spread of food production in the region and many of them could be addressed with additional spatial data on late Holocene settlements. To understand social relations and economic activities within residential settlements for example, archaeologists need to be able to differentiate domestic household space, public space, and areas of livestock holding within domestic settlements. In order to achieve this, information on the size and layout of houses, spatial relations among houses, house-enclosure relations, and the size of settlements in relation to the number of domestic units is essential [25,40].

In recent years, micromorphological and geochemical approaches have contributed to the detection of activity areas in archaeological sites, allowing identification of ephemeral or poorly preserved hearths, trash accumulations and livestock enclosures (e.g., [9,13,14,16,26,37,39,43,55]). These studies have been carried out however, primarily in European and Eastern Mediterranean environmental contexts and are thus particularly relevant to soil types, plants, and climates, characteristic of these regions. In order to carry out geoarchaeological studies in Africa, these factors (i.e., soils, plants, climate) need to be characterized locally. Archaeologists have not however, employed geoarchaeological approaches to spatial studies widely in Africa. To date, spatial research in East Africa has focused on location of settlements on the landscape, and examining activity areas within sites based on artifact type and density [8,51]. East African sites of the Pastoral Neolithic period commonly lack macroscopic features. Hearths are rare. Post-holes have been recognized from a few sites such as Narosura [48]. The only hut floor so far excavated is from the Elmenteitan site of Ngamuriak [52]. Therefore micromorphological and geochemical research to enhance the detection of ephemeral features in East African sites is necessary in order to understand the broad layout of hunter–gatherer and early pastoral sites.

In this paper, we discuss geoarchaeological approaches to reconstruction of spatial organization of East African pastoral sites, based on geo-ethnoarchaeological research on abandoned Maasai settlements. Fieldwork was conducted in southern Kenya, near Rombo town, among the Kísongo Maasai (Fig. 1a). We present a study of the microstructure, mineralogy, and phytolith contents of house floors, cooking hearths, gates, fences, and trash pits, sampled from four abandoned pastoral Maasai settlements. Using this method, we characterize and evaluate the potential for “archaeological visibility” of these features.

In the following section, we present background ethnographic and ethnoarchaeological data on East African Maasai pastoralists, focusing on the structure of settlements in relation to the social activities that take place in and around them.

1.1. Maasai: ethnographic background

The Maasai are Nilotic speaking pastoralists. Their society is relatively egalitarian with a clan based social organization and an age set system. It is however, sometimes termed a gerontocracy with more power going to elders and to men [12,20,21,42,57–59]. Adult men are in charge of management of herds, family labor, and care of livestock. Until recently, warrior age sets were responsible for defense of livestock and settlements. Herding is primarily carried out by boys and young men. Women are responsible for the household. They milk livestock, open gates in the morning to let the family herds out for grazing, collect firewood and water, build and maintain houses, clean, cook, sew, and care for children.

Most features of Maasai settlements are determined by their focus on livestock [62]. Domestic settlements, enkang in Maa or bona in Swahili, are the primary settlements used throughout the year by Maasai families. Several other more temporary settlement types exist (e.g., seasonal cattle camps, warrior encampments and meat-feasting sites). Several polygamous extended families (3–12 households, 10–50 people) live together in domestic settlements in order to share labor for herding and to protect the herds [4,28,30]. Although animals are herded together, each household is economically independent. The size of domestic settlements varies greatly, depending upon how many families are living there and the size of their herds. Cattle holdings may range between 20 and 350 head per family [4,6,30]. Mbæ reports a range of settlement size between 20 and 80 m. Family settlements last between a few and 20 years, with an average of 4 years [62].

The spatial organization of domestic settlements follows set rules which reflect social organization, including polygamy, kinship, and seniority [40] (see also [29] for the Luo). In a typical settlement, houses are arranged in a roughly circular pattern around a central cattle enclosure. The entire settlement is ringed with a
thorn fence in order to protect livestock from predators. The central enclosure is surrounded by smaller livestock enclosures for calves, sheep and goats [3,40] (see for example Fig. 2a). Kinship and seniority is indicated by the position of houses relative to gates. Each adult male has his own gate in the perimeter fence, and the house of his first wife is built to the right of this. Houses of subsequent wives are placed on either side of the gate [40,42,58]. Houses, averaging 6×3 by 1.5 m are occupied by a woman, her children, and young livestock; they are made of a mixture of ash, cattle dung, and mud over a wooden frame [3,40]. Within houses spatial activities are centered around the cooking hearth where food preparation, distribution, and consumption occur. Women sweep their hearths daily and dispose off ashes in secondary refuse. Separate daytime activity areas for men and women are common. The men’s area is usually under a shade tree within 15 m of the settlement [40]. This is the place where men discuss herd management and politics, rest, play games, and manufacture or repair tools. The only features in this area are a hearth and possibly a stake windbreak [40]. The women’s area is close to the household gate, where they may go to prepare food and make ornaments. Children also play in this area.

2. Materials and methods

2.1. Fieldwork

Fieldwork was initiated in the 1990s by one of us (K.R.) who focused on collection of ethnographic data from Maasai settlements in southern Kenya [53,54]. Geoarchaeologically oriented fieldwork was conducted by R.S.-G. in May 1999 and January 2001. One inhabited and four abandoned bomas were sketch mapped using compass and tape, and sediments were sampled inside and outside the abandoned bomas. Ole Koringo, a long time collaborator of K.R. located abandoned bomas and features within them, and estimated dates of boma abandonment, based on his life history in the area. In order to study the taphonomy of features we asked Ole Koringo to locate bomas of varying ages. We were able to sample four abandoned bomas: abandoned approximately one year before sampling (termed AB1), 20 years before sampling (termed AB20), 30 years before sampling (termed AB30), and one abandoned 40 years before sampling (termed AB40) (Fig. 1b). Bomas in the study area were typically occupied for some 10–15 years.

Fig. 1. (a) Map of Kenya showing the Rombo area near Mt. Kilimanjaro, where fieldwork was conducted. (b) Topographic map of the study area showing the location of the inhabited boma (IB) and the four abandoned bomas (AB1 to AB40). Elevation contours are in feet.
Sampling locations within bomas included houses (inside and outside), cooking hearths, gates, fences and trash pits. The central cattle enclosure and one or more caprine enclosures had been previously sampled (reported in [55]) (Fig. 2b). Information regarding the formation and placement of these features was collected through conversations with Ole Koringo and his son, Ole Parmitoro. Several samples of regional sediment were collected outside each boma. These samples served as controls to which all analyses of feature sediments were compared (Fig. 2b).

Each feature was sampled through excavation of $1 \times 1$ m test pit. These were excavated to a depth of about 20 cm below the contact between the feature and regional sediments. Ole Koringo and R.S.-G. located gates visually in the inhabited boma and in AB1, and based on Ole Koringo’s memory for the older abandoned bomas. R.S.-G. sampled fences only in the inhabited boma and in AB1, where she could clearly observe their woody remnants. Ole Koringo located houses in the older abandoned bomas by finding their hearthstones. Women normally use three local basalt boulders as hearthstones on which they balance metal cooking pots. Hearthstones are rarely removed from abandoned bomas. Hearths were sampled directly between such hearthstones, and living floors were sampled about 0.5 m away from the hearthstones. Sediments outside the houses, but still within boma perimeters, were sampled 3–4 m away from hearthstones. Ole Parmitoro located one trash pit 3–4 m away from the main cattle gate of AB1. Test pits for the collection of regional sediment samples were dug to approximately 30 cm below surface. Thickness of stratigraphic units (distinguished primarily by color) within test pits was measured. Loose sediment samples (at least 5 g each) from different layers were collected in plastic bags. Care was taken to sample the central portion of such layers in order to avoid contamination by over and underlying layers. In cases where no stratigraphy was observed, samples were taken in 5 or 10 cm intervals from top to bottom of the test pits. All loose samples were used for both mineralogical and phytolith analyses. Block sediment samples were collected from all feature types and regional sediments, and were tightly wrapped with paper and masking tape. Plant samples were taken from extant fences and included the trees Acacia mellifera (Eiti in Maa, used for internal fencing and as fuel) and Acacia tortilis (Entepesi in Maa, used for external fencing). These were ashed (550 °C/4 h) and analyzed for phytoliths and mineralogy.

2.2. Laboratory techniques

Micromorphological, mineralogical and phytolith analyses were performed using methods and instrumentation described in Shahack-Gross et al. [55]. These
include a polarizing light microscope (Nikon Labophot2-pol), Fourier Transform Infrared (FTIR) spectroscopy (MIDAC Corp., Costa Mesa, CA, USA), X-Ray powder Diffraction (XRD) (Rigaku Corp., Japan), Energy Dispersive X-ray spectrometry (EDS) (Jeol 6400 Scanning Electron Microscope with an EDS Link, Oxford Instruments), and quantitative phytolith analyses based on methods developed by Albert et al. [1]. Phytolith morphologies follow from various studies, including Albert et al. [1], Mulholland and Rapp [45] and Albert and Weiner [2]. Micromorphological descriptions follow Bullock et al. [10] and Courty et al. [13].

3. Results

3.1. Field observations

3.1.1. Regional sediments (i.e., control samples)
Analyses of all features were compared to those of the regional sediments. The regional sediments in the study area were brown or red clays. No stratigraphy was usually observed at the depths dug in this study (Fig. 3a). The observed gross structure of regional sediments is blocky and coloration is uniform along the profile.

3.1.2. Settlements
Sketches of the inhabited boma and four abandoned bomas are shown in Fig. 2. The structure and features in the most recently abandoned boma, AB1, were fairly well preserved. The settlement’s perimeter was clearly visible, as were the perimeters of enclosures and houses (Fig. 4a). Less than 20 years after abandonment, older bomas were completely degraded at the time of sampling. No aboveground features, except for occasional hearthstones, remained (Fig. 4c).

3.1.3. Houses
Built by women from a wooden frame and covered by plaster, prepared from a mixture of dung and ash, traditional Maasai houses are oval. The plaster mixture is about 80% by volume cattle dung and 20% by volume ash. The wooden frame is made from dense and compact wood, and known by the Maasai to be less subject than others to the depredations of termites. This includes wood from the following trees: Acacia tortilis, Eseki (a sacred tree, not identified), and A. tortilis. Inside the houses there are storage and sleeping areas, and a central cooking hearth.

The process of disintegration of houses starts with the disarticulation of the dung and ash plaster from the walls and roof, followed by the collapse of the roof (Fig. 4b). Walls come down last. This was observed in AB1 in May 1999 and in January 2001. The cooking hearthstones are the only visible objects left after houses have been abandoned and degraded.

3.1.4. Living floors
Stratigraphic units were not visible in profiles opened inside houses (Fig. 3b). The only exception is an upper finely laminated thin layer (1 cm) in the AB1 location. This layer appeared in all test pits opened in and around the AB1 location. As a result, we attributed it to a flooding event that we were told triggered the abandonment of this settlement in December 1998. Profiles outside houses, in general, also did not have macroscopically visible stratigraphy (Fig. 3c).

3.1.5. Hearths
Wood is the only source of fuel for the cooking hearth. Species that do not produce a lot of smoke are selected, commonly A. mellifera. During the early stages of lighting a fire, some grasses are also used. Dung is never burned as fuel. Dung may be burned inside a house, however, if a pest (i.e., a snake or scorpion) has entered, because the smoke is very strong. Metal pots are used for cooking and balanced on three local basalt boulder hearthstones. Profiles of recently used hearths from AB1 show a white-gray layer of wood ash, about 10 cm thick (Fig. 3d). Usually, the ash layers overlay a red-burned soil layer of 1–2 cm thickness. Below, the sediment did not seem to be heat affected. Charcoal particles were often observed. In AB20, AB30, and AB40, profiles between hearthstones always revealed a grayish ash layer, and sometimes a red-burned layer. Pieces of charcoal were always present. The ash layers were usually thin, averaging about 5 cm (Fig. 3e).

3.1.6. Trash pits
A trash pit (about 1×1 m) that is still in use was observed near the inhabited boma. Trash was of household origin, mostly composed of ash from the cooking hearth. Bones from meals were also thrown into the trash after they had been crushed by humans (and later, dogs) for the extraction of marrow. Other items thrown into the trash pit include broken calabashes and old clothing. According to Lekatoo Ole Parmitoro, trash pits are left open and covered by grass only before the trash is about to be burned. The trash is burned every month or two, or earlier if it is rotten or smelly. Every woman living in the boma has her own trash pit that she uses as long as she lives in the boma.

One trash pit was sampled in the AB1 location. The profile of this feature is relatively deep (ca. 40 cm) and complex (Fig. 3f). The profile was covered by some 6 cm of local sediment that was deposited on top of the pit during the 1998 flood. The uppermost anthropogenic
layer was a thin (1 cm) black layer that overlaid a 13 cm thick pale orange layer that contained gray ashy nodules. This pale orange layer overlaid a black layer (19 cm thick) that contained a dark orange lens with several gray ashy nodules. The black layer overlaid the regional sediment. No bones were observed in the open profile.

3.1.7. Gates

Maasai settlements in the study area have two types of gates, wide ones used by both people and livestock, and narrow ones used primarily by people. Test pits opened in both types of gates and several meters away from gates did not show well-defined stratigraphy, and in fact resemble profiles of control regional sediments.

Fig. 3. Photographs of sediment profiles in open test pits. (a) Regional sediment in the vicinity of AB1. (b) Sediment inside a house in the AB20 location. (c) Sediment outside the same house as in (b). Note the similarity between the sediments shown in (a), (b), and (c). (d) A hearth profile in the AB1 location. Note an upper light layer of ash, overlying a red-burned regional sediment. (e) A hearth profile in the AB30 location. Note a very thin light layer of ash overlying a red-burned regional sediment. (f) Sediments in the trash pit at the AB1 location. Note larger size and complexity of this profile relative to those of the cooking hearths. The upper dark layer is probably a humus horizon that formed after the inundation of this locality in 1998. The upper light layer is light orange colored, overlying a black colored layer that contains light and dark orange colored ash lenses. The black layer is in direct contact with the regional sediment below. Arrows indicate the contacts between burned features and underlying regional sediments. Scale bar: 10 cm.

Fig. 4. Features observed at abandoned bomas. (a) AB1 in May 1999. Note the elevated dung heaps (1, 2) of caprine enclosures, intact house (4), and fences (5). (b) AB1 in January 2001, view similar to that in (a). Note the caprine dung heaps (1, 2), the flat dung floor of the cattle central enclosure (3), house (4), same as in (a), but the roof has collapsed, and the absence of enclosure fences, now demarcated by grass growth (5). Field of view in (a) and (b) is approximately 20 m. (c) View of AB30. Note the absence of above ground features except for three basalt hearthstones (indicated by arrow).
3.1.8. Fences

Fences are made from thorny tree branches. The branches of *A. mellifera* have relatively small thorns and are thus used for internal fencing (i.e., small stock enclosures and around houses), while the branches of *A. tortilis* have large thorns, thus it is used for the defensive external fence surrounding the whole settlement. In January 2001, all the fences in AB1 had decayed, i.e., in less than 2 years after abandonment (Fig. 4b). Old wooden fences, exposed for many years to the forces of nature, are not re-used because they are no longer strong. People prefer to cut fresh trees for building a new boma. Because the decay of the wood is above ground, no test pits were opened at these locations.

In summary, field observations in opened test pits show that living floor and gate profiles are similar to those of regional sediments. This indicates that such features, as well as fenced areas, will be difficult to recognize visually in archaeological sites in East Africa. On the other hand, features containing ash (i.e., hearths and trash accumulations) may be recognized visually based on color differences. Note, however, that ash accumulations, as observed in the taphonomic sequence of cooking hearths in this study, tend to thin with time. This observation indicates that ash accumulations may also be difficult to recognize visually in archaeological sites in East Africa.

3.2. Micromorphology

In this section we describe the micromorphology of regional sediments and ash that was obtained experimentally from *Acacia* trees used by people living in the study area (Table 1). These descriptions serve for comparison with the micromorphology of boma features. The micromorphology of house floors and gate areas is similar to that of regional sediments and is thus not elaborated on in this section.

3.2.1. Regional sediments

Five embedded blocks were prepared from regional sediments (Fig. 5a). All five are similar, composed of a clay-rich groundmass that contains randomly distributed grains of basalt and basalt-derived minerals (i.e., feldspars and pyroxenes), and occasional pedogenic carbonate nodules. The concentration of the grains and nodules is, on average, 10–20%. The clay-rich groundmass shows no preferred orientation (i.e., an undifferentiated birefringence, or, b-fabric), probably indicating little pedogenic activity. The microstructure is complex, including poorly developed angular blocky, granular, and crumbly structures. Evidence for bioturbation includes earthworm granules (sensu [11]), possible earthworm casts, and an overall granular appearance.

3.2.2. Experimental wood ashing

The ashes of the wood and bark of *A. mellifera* and *A. tortilis* were embedded on microscope slides. They are composed of pseudomorphs of calcite after Ca-oxalate crystals. Some rhombohedral crystals are arranged in linear arrays (Fig. 5b).

3.2.3. Hearths

Block samples collected from hearths show characteristic features of wood ash. The ash is composed of rhombic calcite crystals, some present in the form of linear arrays similar to those observed in ashed *A. mellifera* and *A. tortilis* (Fig. 5c). Pieces of charcoal are always present, and in recent ashes from AB1 some woody tissues that are only partially burned still contain Ca-oxalate druses and crystals embedded in them. The ashy layer also contains lumps of red-burned regional sediment. The burned regional sediments do not differ micromorphologically from unburned regional sediments.

Blocks of hearths from AB20 and AB40 show that the calcitic wood ash and charcoal fragments are mixed with local regional sediments, but the layer of ash can be observed clearly (Fig. 5d). One block of ash from AB1 was taken from a house with a collapsed roof. Here, a thin layer (about 0.5 cm) of vegetal debris from the roof accumulated on top of the ash. The ash itself was heavily stained with organic compounds and appears to be in the process of dissolution. On top of the vegetal layer, a thin layer (0.2 cm) of regional sediment had already accumulated by 2001 (Fig. 5e, g).

3.2.4. Trash pit

One block obtained from the trash pit found outside the perimeter of AB1 shows a mixture of ash and sediment. Certain areas appear to be completely charred, some contain vegetal matter that is either not burned or partially burned. Many areas are organically stained. The microstructure is relatively massive, but more porous in the charred areas. Vertical, water-draining channels occur in the thick charred layer. The upper ashy layer (orange colored) contains phosphatic nodules and a few bone fragments that appear to be burned (Fig. 5f). The intermediate ashy layer (gray colored) seems to be composed of well-preserved wood ash, based on the occurrence of linear arrays of calcite pseudomorphs after Ca-oxalate crystals. It also contains a few bone fragments that appear to be burned. The lower layer is composed primarily of charred vegetal matter.

In summary, only ash-containing features could be differentiated from regional sediments based on micromorphological criteria. However, calcitic ash seems to be dissolved by organic solutions, and probably also rainfall, in a matter of a few years. This contributes to the thinning.
Table 1
Micromorphological descriptions of sampled sediments (refer to text for terminology)

<table>
<thead>
<tr>
<th>Context (Sample nos.)</th>
<th>Microstructure</th>
<th>Related distribution</th>
<th>Fine fraction</th>
<th>Notes</th>
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<tbody>
<tr>
<td><strong>Regional sediments</strong>&lt;sup&gt;b&lt;/sup&gt;</td>
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<tr>
<td>Representative (KEN-19, 31, 133, 181, 225)</td>
<td>Mostly granular and crumb with compound packing voids. Also poorly developed angular blocky structure. Other voids are vughs, chambers and channels.</td>
<td>Open to closed porphyric.</td>
<td>Light to dark brown clay with undifferentiated b-fabric.</td>
<td>Coarse fraction includes 20 µm to 4 mm grains of basalt, feldspars and pyroxene, poorly sorted and angular. Occasional pedogenic carbonate nodules (up to 200 µm), earthworm granules and possible earthworm casts (up to 300 µm). Crack and laminated microstructure at top of samples 31 and 181 due to flooding event, together with crystallitic b-fabric (carbonate probably originates from within boma sediments).</td>
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<td><strong>Living floor profiles</strong></td>
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<tr>
<td>AB1 (KEN-150, 168)</td>
<td>Same as regional sediments.</td>
<td>Same as regional sediments.</td>
<td>Same as regional sediments.</td>
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<tr>
<td>AB20 (KEN-121, 122)</td>
<td>Same as regional sediments.</td>
<td>Same as regional sediments.</td>
<td>Same as regional sediments.</td>
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<tr>
<td><strong>Hearths</strong></td>
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<td>AB1 (KEN-143, 160, 161)</td>
<td>Upper (1 cm): Vegetal matter. Spongy structure. Middle (~10 cm): Ash. Angular to sub-angular blocky structures. In certain areas vesicular structure due to dissolution. Mostly planar voids and vughs, few channels and chambers.</td>
<td>Open porphyric.</td>
<td>White, gray and yellowish calcite. Crystallitic b-fabric.</td>
<td>Probably from collapse of house roof and/or walls. Organic staining especially in upper parts. Calcite crystals are rhombohedral, up to 15 µm. Coarse fraction contains granules of burned regional sediment (0.1–5 mm) and angular pieces of charcoal (0.01–15 mm). Possible phosphatic nodules. Few small areas contain spherulites. Upper parts may also include charcoal fragments.</td>
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<td></td>
<td>Middle (7 cm): (a) Three cm of regional sediment mixed with enclosure sediment (probably cattle), granular structure.</td>
<td>Porphyric.</td>
<td>Light to dark brown clay in granules of regional sediments, and light brown clay mixed with opaline phytoliths in granules of organic-poor cattle enclosure sediments. Crystallitic b-fabric.</td>
<td>This layer may be interpreted as originating from the collapse of the house roof and/or walls, covering the hearth. Contains a few phosphatic nodules. Enclosure sediments show faint “undulating” structure and contain relatively many carbonatic minerals. These may be attributed to degraded Ca-oxalates that were originally from the ash that was mixed with the dung to plaster the house roof and walls.</td>
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of ash profiles, probably together with compaction of these sediments. Therefore, small ashy features such as cooking hearths may be difficult to recognize in archaeological sites in East Africa (and probably elsewhere), while ashy trash accumulations are more likely to preserve and be recognized visually in archaeological sites.

3.3. Mineralogical characterization of bulk samples

Table 2 shows the minerals present in regional sediments, experimentally ashed trees and boma features. Regional sediments in the study area are largely composed of clay minerals (for a more detailed characterization see [55]). The FTIR spectra of sediments collected from house floors resemble those of regional sediments (Fig. 6a). The FTIR spectra of ashes collected from hearths at the AB1 location are composed of calcite (Fig. 6b). Fresh ash of *A. mellifera* and *A. tortilis*, experimentally burned in the laboratory, is composed mainly of calcite, some ammonium sulfate and traces ofapatite (spectrum not shown here), from either the wood or the bark of the trees. In this context, the absence of

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<tbody>
<tr>
<td>(b) Four cm of ash and charcoal mixed with regional sediment, vesicular microstructure.</td>
<td>Porphyric.</td>
<td>Gray to brown calcite mixed with clay. Crystallitic b-fabric.</td>
<td>This layer represents the hearth. The ash is still calcitic and the vesicular structure implies that it is in a process of dissolution. A few phosphatic nodules occur.</td>
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<td>Lower: Regional sediment, sub-angular blocky structure.</td>
<td>Closed porphyric.</td>
<td>Same as regional sediments.</td>
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<td>Trash pit AB1 (KEN-193)</td>
<td>Upper (1 cm): Black layer containing a mixture of organic matter, regional sediment, calcite and spherulites. Granular microstructure.</td>
<td>Porphyric.</td>
<td>Yellow, brown and black organic matter and clay. Crystallitic b-fabric.</td>
<td>This layer probably represents the lower part of the flood-deposited material, mostly originating from anthropogenic sediments from AB1.</td>
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<td>Middle a (5 cm): Dark orange layer containing vegetal matter, charcoal, regional sediment, calcitic ash, possible enclosure sediments and phosphatic nodules. Granular to massive microstructures, compound packing voids.</td>
<td>Porphyric.</td>
<td>Gray, yellow, orange and brown, calcite, organic matter and clay. Undifferentiated and crystallitic b-fabrics.</td>
<td>This layer seems to represent burned material with its ash partially dissolved, and formation of phosphatic nodules.</td>
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<td>Middle b (4 cm): Pale orange layer containing material as in the layer above it, but with relatively more ash. Massive to granular structure, compound packing voids.</td>
<td>Porphyric.</td>
<td>Gray to brown calcite and clay, crystallitic b-fabric.</td>
<td>This layer seems to represent better preserved ash, some of it still contains linear arrays of calcite pseudomorphs after Ca-oxalate rhombs. This layer contains a few burned and unburned bone fragments (0.05–0.9 mm). The lower part of the layer contains vertical, water draining, channels.</td>
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<tr>
<td>Lower: Black layer containing charred and partially charred vegetal matter with small amounts of calcitic ash. Spongy structure, simple packing voids.</td>
<td>Chitonic.</td>
<td>Brown to black organic matter, undifferentiated and crystallitic b-fabrics.</td>
<td>This layer seems to represent a burning event with low oxygen availability, thus forming charcoal. The internal organization of this layer is disturbed due to water infiltration from the layer above it. There are a few calcium oxalate druses.</td>
<td></td>
</tr>
</tbody>
</table>

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*a* The relationship between the coarse and fine units. Porphyric: large units occur in a dense groundmass of smaller units; monic: presence of units of one size group; chitonic: coarse units surrounded by smaller units [10].

*b* Previously reported in Shahack-Gross et al. [55].
traces of apatite in the hearth ash is puzzling. The absence of ammonium sulfate in hearth ash is explained by its high solubility in water. Upon dissolution of fresh hearth ash in 1 N HCl, its insoluble remains have an FTIR spectrum characterized by a broad absorption centered around 1050 cm$^{-1}$ (Fig. 6c). Such a spectrum was also obtained from the acid insoluble fraction (AIF) of the experimentally ashed tree barks, but almost nothing remained of the experimentally ashed wood. An orange-colored layer from the trash pit in the AB1 location has an FTIR spectrum similar to that of the AIF of hearth ash (Fig. 6d, cf. Fig. 6c). The material present in the AIF of the hearth ash (Fig. 6c) is probably burned regional sediment, with its clay component undergoing a crystallographic transformation due to pyrolisation. This interpretation is supported by the orange color of the sediment from the trash pit (Fig. 6d).

In summary, just as in the field and micromorphological observations, the only really indicative mineralogical signals in bulk samples are from ash-containing features.

3.4. Quantitative phytolith analyses

Phytoliths in the study area can preserve for at least thousands of years [55]. Phytolith concentrations from regional sediments and boma features are shown in Fig. 7. Concentrations are presented as millions of phytoliths per 1 g of total sediment. Concentrations in regional sediments, sediments from living floors, hearths, gates, and around gates are all similar. A significant difference in phytolith concentrations exists only for the trash pit sediments, with average concentrations higher than 10 million phytoliths in 1 g of sediment. For comparison, the phytolith concentrations from enclosure sediments range between 1 and 55 million phytoliths in 1 g of sediment, averaging more than 10 million phytoliths in 1 g of sediment [55].
Exceptionally high phytolith concentrations are found in one sample of regional sediment. This sample is from AB30 where the boma perimeter was not observed, thus this sample may actually represent a livestock enclosure sediment or a livestock gate. Sediments from presumed house floors in AB20 and AB30 have phytolith concentrations similar to those of regional sediments, except for two samples taken from the upper 5 cm of these profiles. In addition, two sediments sampled outside houses have relatively high phytolith concentrations that may be due to the presence of dung around the houses. Two hearths sampled in AB20 also had phytolith concentrations significantly higher than in regional sediments. In addition, two gate samples had relatively higher concentrations of phytoliths than regional sediments. These are from the wide gate of AB1 that served for the passage of livestock.

Phytolith concentrations in acacia tree bark, as represented in the ashing experiment are very low. Thus identifying the presence of wooden fences based on phytoliths is not feasible. Overall, it appears that phytolith concentrations in the range of 0 to 4 millions in 1 g of sediment characterize regional sediments and most of the boma features. Higher phytolith concentrations represent anthropogenic addition of material rich in phytoliths. Small amounts of additional grassy material result in concentrations in the range of 4–8 million phytoliths in 1 g of sediment, while addition of large amounts as in the trash pit and livestock enclosures result in much higher concentrations of phytoliths.

Analyses of phytoliths with characteristic morphologies were performed on samples of hearth ash, cattle enclosure sediments, caprine (i.e., sheep and goats) enclosure sediments and regional sediments. The phytolith

### Table 2

<table>
<thead>
<tr>
<th>Category</th>
<th>Sub-category</th>
<th>Major components</th>
<th>Minor components</th>
<th>Average weight % of AIF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Regional sediments&lt;sup&gt;a&lt;/sup&gt;</td>
<td></td>
<td>Clay (kaolinite).</td>
<td>Vermiculite, plagioclase, olivine, iron oxides, sodium nitrate, possible carbonates, opal, unidentified peaks at 1010, 754 and 746–748 cm&lt;sup&gt;-1&lt;/sup&gt;.</td>
<td>89.3±5.87 (n = 15)</td>
</tr>
<tr>
<td>Cattle enclosure sediments&lt;sup&gt;a&lt;/sup&gt;</td>
<td>Organic-rich</td>
<td>Clay, organic matter.</td>
<td>Monohydrocalcite.</td>
<td>67.1±21.55 (n = 3)</td>
</tr>
<tr>
<td></td>
<td>Organic-poor</td>
<td>Clay, opal.</td>
<td>Monohydrocalcite, organic matter.</td>
<td>82.8±9.81 (n = 16)</td>
</tr>
<tr>
<td>Caprine enclosure sediments&lt;sup&gt;a&lt;/sup&gt;</td>
<td>Organic-rich</td>
<td>Clay, monohydrocalcite, ammonium sulfate, organic matter.</td>
<td>Mg-rich calcite, unidentified peaks at 1155, 754 and 615 cm&lt;sup&gt;-1&lt;/sup&gt;.</td>
<td>55.6±16.92 (n = 5)</td>
</tr>
<tr>
<td></td>
<td>Organic-poor</td>
<td>Clay, monohydrocalcite, opal, Mg-rich calcite.</td>
<td>Organic matter, possible Ca-oxalate, unidentified peaks at 879, 688 and 574 cm&lt;sup&gt;-1&lt;/sup&gt;.</td>
<td>71.3±15.34 (n = 11)</td>
</tr>
<tr>
<td>Regional sediments overlain by enclosure sediments&lt;sup&gt;a&lt;/sup&gt;</td>
<td></td>
<td>Clay.</td>
<td>Carbonate, opal, sodium nitrate, unidentified peaks at 688 and 754 cm&lt;sup&gt;-1&lt;/sup&gt;.</td>
<td>87.0±6.36 (n = 14)</td>
</tr>
<tr>
<td>Living floors</td>
<td></td>
<td>Clay.</td>
<td>Sodium nitrate, unidentified peak at 688 cm&lt;sup&gt;-1&lt;/sup&gt;.</td>
<td>91.4±3.92 (n = 12)</td>
</tr>
<tr>
<td>Hearths</td>
<td>Recent ash (AB1)</td>
<td>Calcite.</td>
<td>Possible clay.</td>
<td>16.0±1.60 (n = 5)</td>
</tr>
<tr>
<td></td>
<td>Old ash (AB20, AB30, AB40)</td>
<td>Clay, calcite.</td>
<td>Unidentified peak at 688 cm&lt;sup&gt;-1&lt;/sup&gt;.</td>
<td>80.9±4.42 (n = 4)</td>
</tr>
<tr>
<td>Experimental wood ashing (Acacia mellifera and Acacia tortilis)</td>
<td>Wood</td>
<td>Calcite.</td>
<td>Ammonium sulfate in A. tortilis only.</td>
<td>0.7±0.91 (n = 2)</td>
</tr>
<tr>
<td></td>
<td>Bark</td>
<td>Calcite.</td>
<td>Possible clay, ammonium sulfate in A. tortilis only.</td>
<td>3.4±3.56 (n = 2)</td>
</tr>
<tr>
<td>Trash pit</td>
<td>Burned regional sediment</td>
<td></td>
<td>Opal, possible phosphate minerals, sodium nitrate.</td>
<td>72.5±3.41 (n = 5)</td>
</tr>
<tr>
<td>Gates</td>
<td></td>
<td>Clay.</td>
<td>Unidentified peaks at 688 and 749 cm&lt;sup&gt;-1&lt;/sup&gt;.</td>
<td>88.0±6.69 (n = 18)</td>
</tr>
</tbody>
</table>

<sup>a</sup> Previously reported in Shahack-Gross et al. [55].
assemblages are quite similar to one another, with no consistent differences that can be used as indicators of specific anthropogenic features (Fig. 8).

4. Discussion

The results of this study are relevant to understanding site taphonomy, to feature recognition and spatial analyses of structures of mobile hunter–gatherer and pastoral settlements, and to design of excavation strategies. The study shows that a range of features from open-air Maasai settlements, hearths, trash pits and livestock gates, can be differentiated from sediments outside settlements (regional sediments), using a suite of techniques that characterize the micromorphology, mineralogy and phytoliths of the anthropogenic sediments. Table 3 summarizes the indicators that can be used to identify each feature (for more details on livestock enclosures see [55]). Hearths and trash pits can be identified micromorphologically, mineralogically, and based on their phytolith concentrations. Livestock gates may be identified based on their phytolith contents alone. Techniques employed in this study did not however, allow identification of living floors and fences. These findings are especially significant for archaeologists seeking to identify spatial patterning in mobile settlements because they are counterintuitive. Houses and fences are by far the broadest and most visible features of present day pastoral settlements, but could not be identified. Smaller scale features such as hearths, trash pits and livestock gates could be identified. Fortunately these identifiable features are spatially significant. In recent years, ethnoarchaeological studies have shown that hearths and trash piles are key to the recognition of broad spatial patterning and more relevant to the social organization of settlements than previously realized (e.g., [15,18,35,40,47]). Gates are also key to understanding the spatial layout and social structure (number of households, kinship and seniority) of African settlements [29,40]. There is also much variation among contemporary pastoral ethnic groups in the spatial layout of such features, and spatial analyses may contribute to differentiating among Neolithic pastoral groups. In addition, such spatial data will allow the hypothesis that hunter–gatherers adopting food production in East Africa lived in settlements that varied spatially from pastoral norms to be tested.

Below we discuss factors underlying the identification of the most prominent features that could be identified in Maasai settlements, namely hearths and trash pits. Both features are composed of wood ash, characterized by the mineral calcite. The source of the calcite is the combustion of Ca-oxalate monohydrate (whewellite, CaC2O4\(\cdot\)H2O) crystals that are commonly found in wood [19,31,61]. Our experimental wood ashing shows that well-preserved ash is characterized by the presence of linear arrays of calcite pseudomorphs after Ca-oxalate crystals. This accords with Gourlay and Grime’s [27] histological study of African acacia species, where they show that rhombic Ca-oxalate crystals are arranged inside the woody tissue in long chains. This study also shows that combustion of A. mellifera is similar to that of coal, which may explain the Maasai preference for this tree species as fuel. Gourlay and Grime’s [27] histological study of African acacia species, where they show that rhombic Ca-oxalate crystals are arranged inside the woody tissue in long chains. This study also shows that combustion of A. mellifera is similar to that of coal, which may explain the Maasai preference for this tree species as fuel. Gourlay and Grime’s [27] point out as well that the presence of Ca-oxalates in acacia trees makes them less palatable to termites, which supports the Maasai explanation for their preference of certain trees for building materials. This suggests that there are reasons for choices of fuel and building materials to have been similar in the region in the past, and for the likelihood of detection of present features to be relevant to the past.

Dissolution of calcitic ash in one hearth in the AB1 location was also observed. In this case the hearth was
covered by roof-fall (i.e., organic matter). The decomposition of organic matter involves the formation of organic acids which may be the agents dissolving the calcitic ash. It is important to note that even if the ash dissolves, its insoluble component of burned regional sediment remains. The latter can be distinguished from unburned regional sediment by infrared spectroscopy, and may serve as an indicator of hearth or trash...
accumulations. Taken together, our evidence suggests that hearths and trash pits may be identified mineralogically either by the presence of calcite in cases of good preservation, or presence of burned regional sediment in cases of poor preservation. This contrasts with the findings of previous studies of the insoluble remains of wood ash in the Mediterranean region which suggested identification based on the presence of wood phytoliths and siliceous aggregates (e.g., [1]). Wood phytoliths were not diagnostic and siliceous aggregates not found in our study. This highlights the importance of studying the visibility of features in different regions of the world.

Following this discussion of site taphonomy and feature recognition, the important question is how likely are these indicators to survive into the archaeological record? These degraded features of Maasai pastoral sites (hearth, trash pits and livestock gates) can be identified based on a suite of indicators that persist up to 40 years after site abandonment. It is highly likely that they will persist in archaeological sites. Conditions that are especially conducive to this are the following. Thick features such as enclosure and trash pit sediments preserve well micromorphologically at depths where they are protected from fragmentation by root action and bioturbation. Indicative minerals should similarly preserve for long periods of time as long as the conditions in the sediment correspond to their stability fields. Opal (phytoliths), for example, is stable in the pH range between 5 and 9 [31], and the mineral dahlilite is stable above pH 7 [7]. Considering the alkaline nature of East African soils, opal phytoliths and authigenic dahlilite are likely to persist for long periods of time. Therefore, we do not think that phytolith concentrations will change much over long periods of time, especially in the deeper parts of features, away from mechanical mixing through root action and bioturbation. We conclude that archaeologists can identify livestock enclosures, trash accumulations and hearths in East African Pastoral Neolithic sites using the combination of the lines of evidence presented here.

Having discussed identifiable features, it is also important to examine the reasons for the lack of visibility of houses and fences in our study. No compacted features in living floors of houses were detected microscopically in this study (see also [26]). This may relate to loading associated with the human frame, as compaction was observed microscopically in regional sediments that underlie livestock enclosures [55]. This indicates that the soil type found in the study area may form compacted surfaces only under very heavy loads (i.e., cattle vs. human: ~200 kg vs. ~60–70 kg). Thus, in order to locate living floors, or house perimeters, in East African sites, the traditional post-hole feature is more useful than compacted features. Wooden fences were not identified in this study mainly because the two Acacia species used in our study area do not produce distinctive phytoliths and could be used as indicators for such features.

Our findings are also significant for future excavation strategies. This study shows that the size and placement of identifiable features may hamper their detection during excavation. Cooking hearths have a small area and are thin. We advocate therefore that slight color changes in excavated profiles/areas, and especially in thin (1–2 cm) layers or lenses should be recorded and possibly analyzed, as these may represent poorly preserved hearths. In addition trash pits in the study area are located outside the site’s perimeter, and as a result excavations of pastoral and hunter–gatherer sites should extend beyond the site’s perimeter (this is also necessary for obtaining regional sediments as controls). Finally the current practice of focusing on small excavated areas in large sites minimizes the chance of encountering more than one feature (for example, a whole excavation may be placed in one large livestock enclosure). As a result we suggest that future excavations focus on horizontal rather than vertical aspects of sites. Once a general understanding of site-structure has been achieved, certain areas may be dedicated for vertical excavation. In summary, in order to start looking for patterns in internal arrangement of Holocene sites in East Africa, it is necessary to conduct excavations on a scale that will locate as many features as possible and allow redundancy in spatial patterning to emerge.

5. Conclusion

This geo-ethnoarchaeological study of abandoned pastoral Maasai settlements provides the first evaluation of the “archaeological visibility” of ephemeral features such as hearths, trash pits, gates, houses and fences in African contexts. Micromorphology, mineralogy and phytolith analyses show that features containing ash have the highest visibility and allow clear identification of trash pits and cooking hearths on mobile pastoral settlements. Large livestock gates may also be recognized. Interestingly the most visible features of pastoral settlements today, fences, house floors and small gates
could not be detected using the methods applied here. These findings regarding identification of hearths, trash pits and livestock gates complement and significantly extend previous geoarchaeological identification of livestock enclosures in Africa, and studies of the remains of wood ash in other regions [1,55]. They also have important implications for the design of future research on African pastoral sites.

Taken together micromorphological, mineralogical and phytoliths analyses, combined with identification of hearths based on stone features, house floors based on post-holes, and lithic, ceramic and faunal analyses, will enable archaeologists to reconstruct relationships among features within mobile sites. These data may be used to address issues of socio-economic identity of sites, the nature of interactions between hunter–gatherers and early food producers, variation in the organization of competing pastoral societies, and household level analyses of gender-based or specialized activities during the period of advent of food production into East Africa. This approach will also be useful in addressing the interpretation of pastoral, and other ephemeral sites associated with mobile people in other regions of the world.

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References


