Chapter 7

Micromorphological Aspects of Site Formation at Keatley Creek

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Introduction

The aim of the research described in this chapter is to clarify the nature of the deposits and soil materials of Keatley Creek—e.g., their composition and texture—and to attempt to better resolve the field identification and characterization of floors, roofs, rim spoil, and other soil materials using the technique of micromorphology. Integrating this information at a higher level, we also wanted to elucidate the nature of site formation processes. The ability to reliably identify floor deposits during field excavations was essential for being able to detect artifact patterning across the floors which could reveal aspects of social and economic organizations in the housepits at Keatley Creek.

Field observations of deposits (e.g., color, texture, structure, and consistence) are a useful means to describe sediments and to make tentative inferences about relevant depositional and post-depositional processes, including geogenic, pedogenic, and anthropogenic processes. However, the use of simple field data alone limits our ability to fully interpret the stratigraphic record. One strategy employed to supplement field observations subjects the samples to a variety of laboratory analyses. These analyses—which employ bulk samples—generally include grain-size and chemical analyses, such as pH, calcium carbonate, organic matter, cation exchange capacity, and soluble and exchangeable ions (see Vol. I, Chap. 6 and Vol. II, Chap. 6).

One of the limiting aspects of the usefulness of interpreting both the field and laboratory data is the typically complex nature (e.g., composition, texture and fabric) of soils and sediments associated with archaeological sites. What, for example, is the significance of a grain-size analysis of a "grey," "ashy" dump deposit, commonly found in archaeological sites, such as the ones studied here? The results generated by a grain-size analysis in such a case do not discriminate between the mineral (e.g., quartz sand, silt, etc.; calcareous ash crystals; phytoliths; bone) and non-mineral components (charcoal, or disseminated organic matter), and one would simply observe a poorly sorted sediment. In other words, bulk samples do not provide the resolution necessary to unravel the complex depositional and post-depositional sequences associated with archaeological sediments (Courty et al. 1989). Thus, grain-size analyses, for example, often do not discriminate between silt or clay that has been translocated through a profile from an overlying surface (translocation), from silt or clay that was deposited as coarser, sand size aggregates composed of these fine materials. This inability is due to the procedures associated with grain size analysis, which attempts to break down the sample into its individual components. In addition, many analyses using bulk samples are limited in their ability to discern a succession of pedological, geological, or anthropogenic events that have been superimposed

Table 1. Keatley Creek: Location and Brief Description of Micromorphology Samples

Sample No.	House Pit	Location	Strat. Unit	Depth[1]	Description
KC-86-7	1	All	2	6–20 bs	Black stony layer; fewer roots than at surface. Laterally greyer and more ashy/less humic.
KC-86-26A	6	B		5–10 bs	Dark brown humic loam (roof) and upper half of lighter colored occupation level.
KC-87-15	7	S rim		12–20 bs; ~15 bd	Slightly compact, grey brown massive, gritty powdery silty sand with angular burnt stones 'floating' in matrix. Some rootlets; some $CaCO_3$ spots on a few stones. Generally sub-horizontal and truncates underlying silty rim spoil. Charcoal throughout.
KC-88-2	104	S end			Gritty black/dark brown silts resting sharply on very hard, sterile stony light brown (calcareous?) silt. Calcareous till could explain preservation of ash.
KC-88-3	104	Pit			Dry, powdery, gritty dark brown/black silt with reddish mottles. Burrowed or dumped hearth material.
KC-88-8	plaza (119)			50 bs	Interbedded light and dark ashy beds with roots and charcoal and perhaps thin ashy stringers in the middle. Laterally some rubefied areas.
KC-88-9	plaza (119)			65 bs	Interbedded light and dark ashy beds. Generally massive but some 1 cm thick layers; at base is compact, very fine silts; laterally insect and cicada burrows.
KC-88-10	plaza (119)			90 bs	Interbedded light and dark ashy beds, riddled with small [1–5 mm] root or insect burrows. Dark, organic-rich layers undulate and laterally thicken and thin.
KC-88-11	plaza (119)			145 bs	From contact between basal massive silts and underlying dark reddish brown stony silty ash. Contact not sharp and punctuated by cicada burrows.
KC-88-12	7			70 bd	Roof (dark grey brown stony/gravely silt) overlying slightly finer and lighter brown fine gravely silt (floor?). Burnt wood (charcoal) and reddening at contact.
KC-88-15	105	Sq. B	Stratum III		Stratum III plus roof fall above it (II). Living floor marked by think scatter of fish bones, partially articulated; sample parted along this floor. To N, more clearly bedded; to S, no evidence for living floor. Sediment grey brown stony sandy silt.
KC-88-16up	105	Sq. A			Living floor and reddened horizon beneath it. Upper part: light medium grey silts with abundant bone; lower part: living floor represented by grey/white sand with bone just above it.
KC-88-17	105	Sq. A		15 bs	Whitish grey occupation zone with underlying material partially reddened. White/grey unit overlies black floor and is locally truncated. White/grey overlain by roof deposits.
KC-88-19	EHPE 12	pit			Dark grey ash dump overlying fire reddened earth from roasting pit (EHPE 12) next to 105. Top of organic matter (grey) resting on jumbled, slightly granular charcoal-rich silts. Bottom part is reddened gritty silts on stony till.
KC-88-20	105	Sq. C: E wall		228 bd	In general, compact gravely clayey silt. Dark grey brown from center of pit fill. Darker at top, and gets lighter with depth. Laterally, large angular stones. Compact due to inclusion of clayey till.
KC-88-21	105	Sq. C		12 bd	~88-15, encompassing roof (Stratum II), floor (III) w/ fish bones, and dark band 3 cm thick below it. Below black band is hard compact grey tan (= reworked till?).
KC-88-22	7	Sq. I			Alternating diffuse and continuous bands of lighter till like sediment and darker organic rich cultural material.
KC-88-24	7	S rim			Below contact between organic rim spoil and burnt loessial deposits at base. Generally fine sandy silts with some grit and stones scattered throughout. Upper part characterized by 5–7 cm thick charcoal rich medium brown silts with stones.

[1] bs = below surface; bd = below datum

upon the same material or substrate. For example, a calcium carbonate analysis may represent both primary (depositional) and secondary (pedogenic) carbonate; a dark layer within a Holocene archaeological site context may represent a soil horizon, an occupation layer, or both.

A technique that is proving increasingly valuable for avoiding many of the above-mentioned limitations is that of micromorphology, the study of undisturbed soils, sediments and other archaeological materials (e.g., ceramics, bricks, mortars) at a microscope scale. Samples are marked in the field so as to retain their original vertical and horizontal orientation. The use of undisturbed, oriented samples conserves the original components and their geometrical relationships, and permits direct observation of composition (mineral and organic), texture (size and sorting), and fabric (the geometric relationships among the constituents) of the intact sample. Within an individual thin section it is therefore possible to observe micro-stratigraphic sequences which reflect temporal changes in depositional and post-depositional processes (Courty et al. 1989).

During the seasons of 1986, 1987, and 1988, samples for micromorphological analysis were collected from a variety of contexts at the Keatley Creek site. These contexts included roof and floor deposits, hearths and ash layers, rim spoil, pit fills, and horizontally bedded water-laid sediments from the "plaza"-like area (HP 119). In 1986, samples from different housepits and stratigraphic units were collected. During the 1987 season, samples were taken mostly from HP 7, where emphasis was placed on studying deposits from the rim, floor, and inter-housepit areas. In 1988, samples were collected from the "plaza"-like area, as well as various housepits (HP's 7, 104, and 119).

Samples were collected in the field as undisturbed blocks, roughly 15 × 7 × 7 cm in size. These blocks were imbedded in polyester resin from which 14 × 7 cm thin sections were prepared (courtesy of the Institut National Agronomique, Grignon, France) following the procedures of Guilloré (Courty et al. 1989). The thin sections were examined with a microfiche viewer and a petrographic microscope under plane polarized (PPL), cross-polarized light (XPL), and oblique incident light (OIL) at magnifications ranging from ~20×–200×. Observations were noted using the descriptive terminology of Bullock et al. (1985) and Courty et al. 1989; definitions of micromorphological terms can be found in Jongerius and Rutherford (1979). The samples used in this study and their locations are presented in Table 1.

Micromorphological Observations

Rim Deposits

A number of samples from rim deposits were collected from HP 7 (Table 1). These are described and discussed below.

Sample **KC-87-15** (Figs. 1 and 2) is a typical rim example. This sample is composed of poorly sorted rock fragments and some pieces of charcoal (1–10 mm in diameter) within a coarse, non-calcareous silt/fine sandy matrix. The latter consists predominantly of rock fragments and finely divided charcoal mixed with clay and undifferentiated organic matter; the charcoal is generally angular, with a shredded appearance. Phytoliths are quite abundant within the organo-mineralic fine fraction.

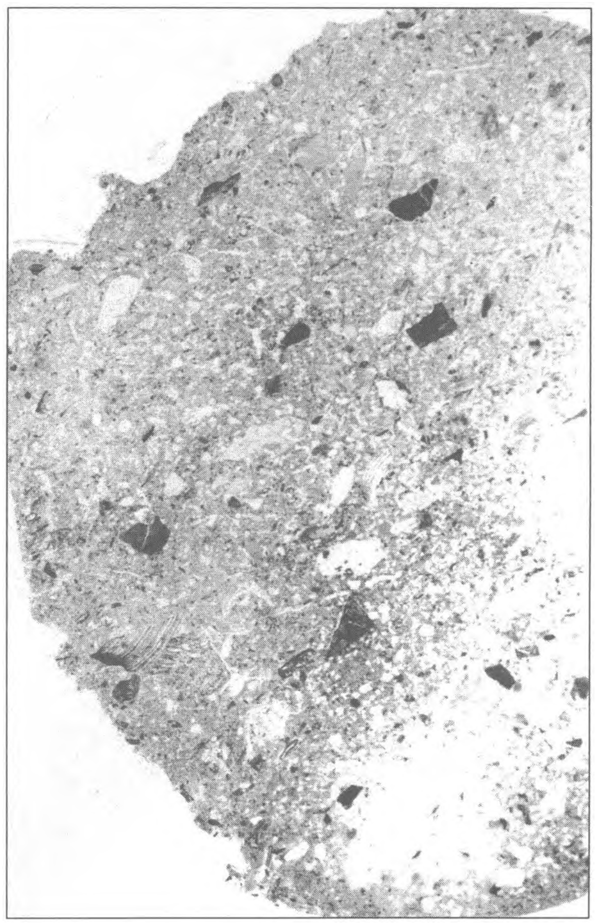

Figure 1. Sample KC-87-15. This macrophotograph of rim spoil shows the poorly sorted and rocky nature of the deposit. Note also the abundance of charcoal. Length of frame = ca. 9 cm.

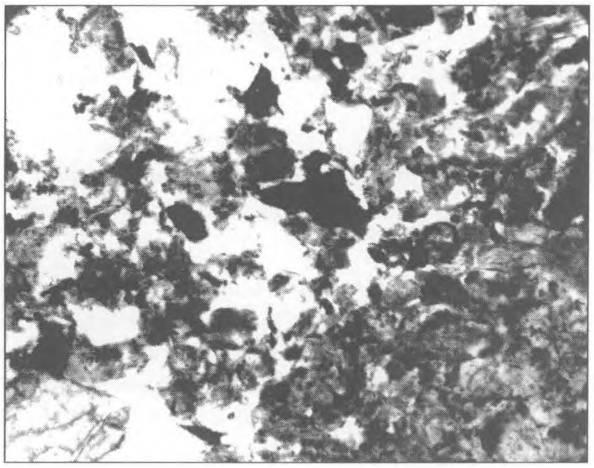

Figure 2. Sample KC-87-15. Illustrated in this photomicrographic detail of Figure 1 are fine grained organic matter and charcoal, as well as numerous phytoliths all well integrated in the matrix. Plane polarized light (PPL); Length of frame = ca. 350 µm.

The fine, shredded nature of the charcoal within the fine fraction and the overall abundance of charcoal and organic matter is strongly reminiscent of a decalcified ash deposit. The presence of phytoliths as well as charcoal indicates that both wood and grasses were burned, although the latter may have decayed in place. The fine grained nature of the sediments suggests the possibility of their representing the finer sweepings of a hearth which would be relatively impoverished in coarser stones. The fine coatings around the coarser rock fragments suggest dumping. The absence in these deposits of any calcareous ash rhombs (Wattez and Courty, 1987) is probably due to post-depositional dissolution of the calcite, since calcite is not stable in these slightly acid soils (Valentine and Lavkulich, 1978).

Elsewhere, e.g., in the proximity of sample **KC-88-22** (Fig. 3), exposed rim sediments consist of alternating diffuse bands of lighter, till-like material and darker, organic-rich cultural material; a pink, fire reddened zone occurs in the middle of this sample and a large cicada burrow was observed at the base.

In thin section, the reddened layers or zones situated within the grey till appear to have been the result of in situ heating because of a visible color gradient of red to tan with depth. On the other hand, rubefied fragments are relatively abundant elsewhere in the sample, but they occur mixed with non-rubefied grains, thereby indicating that these are mixed deposits and that heating of the fragments occurred elsewhere.

The upper part of the sample, closer to the modern surface is more clay-like and contains finely comminuted charcoal, as well as some bone fragments. Phytoliths occur within the darker, charcoal-rich units.

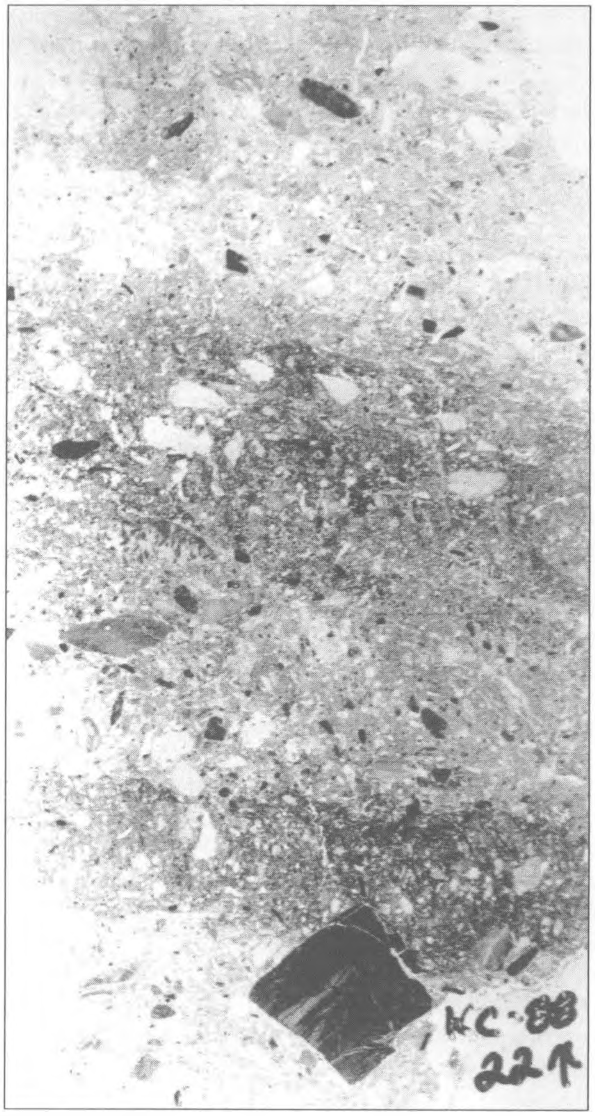

Figure 3. Sample KC-88-22. Macroview of rim spoil showing variegated bands of lighter silts and darker, organic rich silts. The circular features are cicada burrows whose sharp boundaries are clearly evident here. PPL; length of sample = ca. 11 cm.

A final example of rim deposits, sample **KC-88-24** (Fig. 4), comes from below the contact between the organic-rich rim spoil and the burnt loessial deposits at the base. Overall, the sample consists of fine sandy silts with some grit and stones scattered throughout. The upper part is characterized by 5–7 cm thick charcoal-rich medium brown silts with stones and marbling of charcoal in a tan silty matrix that gets lighter with depth. Below this the silts are more massive and lack bedding.

In thin section, the *lower part* consists of compact, moderately sorted silt with millimeter size stony fragments; charcoal is relatively rare in comparison to the upper parts. Phytolith and coprolite fragments are

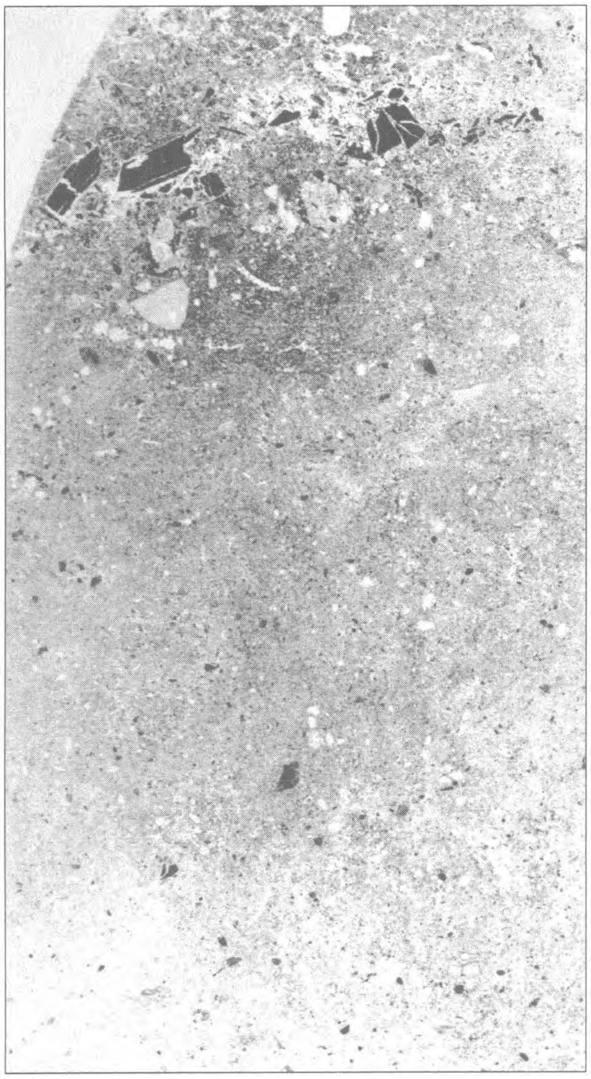

Figure 4. Sample KC-88-24. Illustrated here are charcoal-rich rim deposits in the upper part overlying burnt loessial deposits in the lower part of the photograph. PPL; length of sample = ca. 11 cm.

moderately abundant. Many grains are coated with well sorted tan silt.

The *middle part* contains noticeably more charcoal and exhibits domains where the matrix is more loosely packed and with irregular micro-layering (banded-like fabric probably produced by freeze-thaw processes [Brewer, 1976; van Vliet-Lanoe, 1985]). Phytoliths are more prominent.

Finally, the *upper portion* contains considerably more charcoal, and some of the charcoal is over 10 mm in size. Banded-fabric is locally prominent. Although the material looks reddened (oxidized) by heating, there is no evidence to indicate in situ burning, as for example, the presence of a fire-reddened substrate.

The poor sorting of the sample and the coatings around the coarser grains suggest that this is not an aeolian deposit but one that has been rolled or reworked by gravity. The charcoal-rich middle and upper parts reflect anthropogenic additions to originally sterile sediments, but whether these additions were produced by dumping or colluvial reworking is not certain. The banded fabric is likely a relatively recent phenomenon tied to freeze/thaw activity in the soil.

Discussion of Rim Deposits

The rim deposits from HP 7, particularly those from the base, are not composed strictly of sterile material. Rather, they appear to be a mixture of mostly sterile, poorly sorted silts and stony silts with no cultural debris that are locally mixed with charcoal-rich sediment of cultural origin that have been likely dumped in place. Evidence for intermittent in situ burning activity on the rim is also present, but recognition of criteria for undisturbed fabrics is made difficult by extensive local burrowing by cicadas (as is the case for much of the Keatley Creek deposits; see below). The presence of pedogenically produced banded-fabrics has also resulted in a loss of resolution of information that might have been present in the original depositional fabrics. As mentioned above, although the rim samples are relatively rich in charcoal of various sizes, no traces of calcareous ash were found, likely a result of post-depositional dissolution of calcite.

In sum, the sediments from the rim of HP 7 appear to have accumulated as the combined result of dumped sterile till and charcoal- and phytolith-rich ash deposits, upon which occasional fires were made. Both types of deposits were later reworked by cicadas and their burrowing activity. Moreover, it is possible that the high till content is associated with cleaning in the central part of the structure, or is related to construction and cleaning near the East wall; the proximity to the East wall favors the latter possibility.

Plaza Fills

Several samples from the "plaza"-like area overlying HP 119 were collected during the 1988 season (Table 1). The 2.5 m section studied consisted of buried roof material at the base overlain by massive silts and thin, alternating beds of tan silts and darker powdery silts, with some reworking of reddish layers. Since many of the samples from the plaza area are similar, only a few are described below.

Sample **KC-88-8** (42–55 cm below surface) is relatively rich in organic matter and charcoal, and contains many sand size aggregates of silt that appear to be the result of bedding disrupted by biological activity, such as (horizontal) passage features that contain more loosely packed, lighter material and irregular lighter and darker domains, probably produced by the burrowing of cicadas or other insects. The entire sample displays horizontal, feather-like cracks resembling banded fabrics that are produced by alternate freezing and thawing (see above).

Sample **KC-88-9** (58–75 cm below surface) consists of interbedded light and dark silts, with a number of insect and cicada burrows. In thin section, the silts are overall moderately sorted, homogeneous, with horizontal layering, and contain notably less charcoal than in the overlying samples. Traces of sand size bone and charcoal fragments were observed as well as some burrowing; however, most of the biological disturbance occurs as a vertical system of voids produced by roots.

Sample **KC-88-10** (85–90 cm below surface) (Fig. 5) exhibits interbedded light and dark ashy beds (~1–2 cm thick) that are riddled with small root and insect burrows. Dark, organic-rich layers undulate and laterally thicken and thin. In thin section, the contacts of these broadly diffuse bands of lighter and darker gray, tan, and reddish brown are clear, but blurred by biological activity, mostly root and insect burrows.

Evident at lower magnifications in different strata within the thin section are a number of features:

- generally coarse shreds of organic matter/charcoal, elongated to chunky in shape, with sub-horizontal bedding.
- coarse organic matter mixed with rounded clay papules/rip-up aggregates derived from underlying clayey silts. Aggregates are generally subangular and many look sub-articulated, as if they were broken in place and not transported. In certain layers, parts seem to have been penetrated by insect burrows ("fingers") filled with loosely aggregated material, locally with a bow-like structure.
- One layer contains a band of moderately well-sorted clay that becomes increasingly rich in fine organic matter derived from an underlying unit, possibly representing individual slaking events. Clasts of clay are clearly broken and rounded, suggesting transport or at least breakage in place.

Lithological variability between layers is also quite evident at higher magnifications: The uppermost gray ashy unit in this sample (85–90 cm below surface) is marked by a relative abundance of phytoliths associated with charcoal shreds and modern roots. In coarser silt units, there is a greater abundance of organic matter as well as phytoliths. It is not possible to determine whether the phytoliths result from natural decay of grasses deposited in place or are directly associated with burning activity, and both processes are likely in this context. And, in one of the clayey units, many of the angular clay clasts have different birefringence-fabrics (b-fabrics), indicating that the particles are derived from elsewhere and not broken apart in situ. Locally, the clay aggregates are clearly welded together.

Sample **KC-88-11** (145 below surface) comes from the distinct contact between basal massive silts and underlying dark reddish brown stony silt. Both units are riddled with circular to elliptical tubules 2–15 mm in diameter displaying bow-like fabrics that are produced by burrowing activity of cicadas. The number of these tubules decrease toward the base of the brown, which also becomes stonier at the base. The matrix in the lower unit is dense and quite rich in finely comminuted organic matter. It contains some bone. Its overall stoniness and densely compacted organic-rich

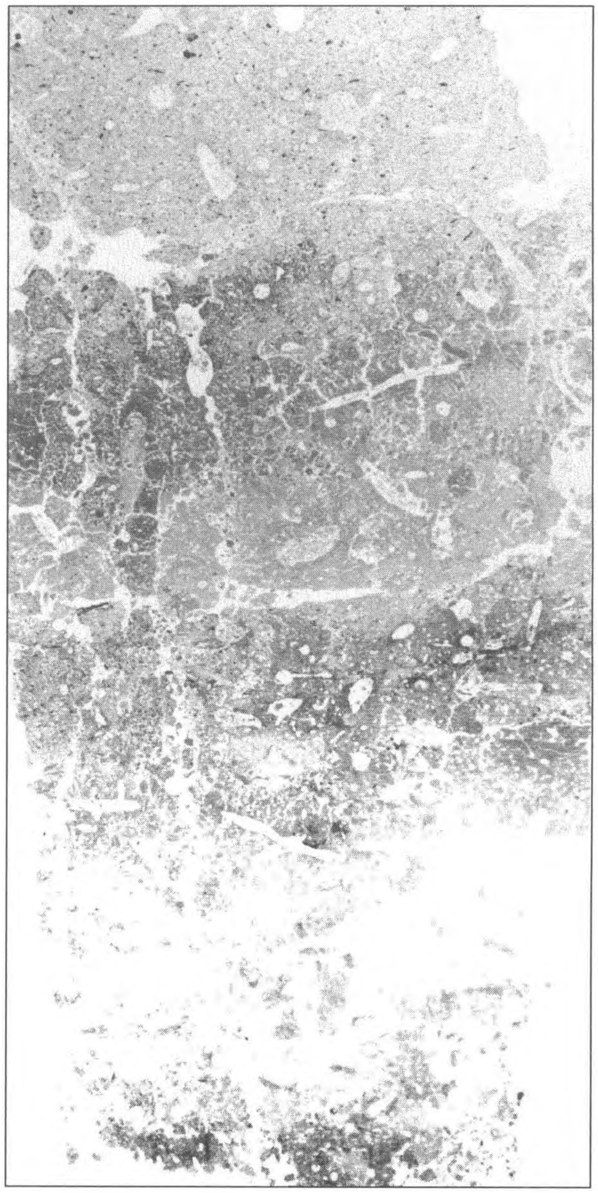

Figure 5. Sample KC-88-10. The "plaza" deposits shown here are interbedded light and dark ashy and clayey sediments that are punctuated by numerous root and insect burrows. PPL; length of sample = ca. 12 cm.

matrix is quite reminiscent of roof collapse observed from excavated structures (see below).

Discussion of the "Plaza"-like Section

Both field and microscopic observations show that the material exposed in the plaza section has some anthropogenic material (charcoal, organic matter) that has been reworked by running water. The presence of redistributed clay curls and rip-up clasts indicate multiple episodes of reworking in which clay settled in water, and after drying, became modified and deformed by desiccation or possibly trampling, and then was picked up by water again during the next runoff event. The very base of the profile contains organic-rich material that is similar to roof collapse observed from in situ housepits and suggests that some roof deposits are buried beneath the "plaza" fill. As has been observed in most of the Keatley Creek samples, evidence of burrowing activity of cicadas and other insects, as well as by roots is quite strong.

Pit Fills

A few samples were examined from interior pits in HP's 104 and 105. The sediments from the pit in the center of HP 104 (sample **KC-88-3**; Fig. 6), for example, are composed of dry, powdery, gritty dark brown/black silt that exhibits a broad reddish band in the middle, and in the field was thought to have been burrowed or to represent dumped hearth material.

In thin section, many of the grains, particularly those rich in clay, are reddened, presumably as a result of having been heated. Furthermore, there are numerous loose pockets of mm-sized charcoal, and bone fragments are relatively common at the base. Modern roots occur at the top of the sample, which exhibits a loose, granular structure and much more sand-size charcoal. Finally, there are numerous cappings of coarse silt over coarser (~1 cm) rock grains.

The sediment within this pit would appear to have an origin similar to the sediments from the south end of the excavation trench (sample **KC-88-2**), which would seem to represent an accumulation of anthropogenic deposits that were dumped upon a sterile, stony silty substrate. In this case, the sediments contain fire-reddened debris that is intermixed with non-heated material. These occurrences indicate that the fire-reddening did not occur in situ, but was inherited from elsewhere.

Sample **KC-88-20** from HP 105 comes from the top, just underneath the fire-reddened part of Stratum VI and within the lighter colored, stony grey silt of Stratum VII. In general, the deposit consists of compact, gravelly clayey silt that is dark grey-brown in the center of the pit fill, but becomes darker at the top and lighter with depth.

In thin section the sediment overall is quite coarse and as in the field, becomes darker towards top. The fine fraction is composed of a mixture of fine sand and silt intermixed with finely comminuted, silt size charcoal; phytoliths are relatively abundant in the fine fraction. Much of the sediment is disturbed by numerous cicada burrows that have homogenized a great deal of the deposit, and several periods of burrowing occurred, as indicated by superposed lighter and darker burrows. Areas that appear to be non-burrowed are characterized by looser material.

Although this sediment is associated with the pit and is rich in charcoal, it exhibits only very few bone pieces. This paucity of bone indicates that the fill might not be associated strictly with cooking of meat as was suggested in the field. The abundance of charcoal, on the other hand, and the coarseness of the sample are reminiscent of deposits associated with roof collapse (see below). The noticeably darker color in the upper part of the sample would support the addition of

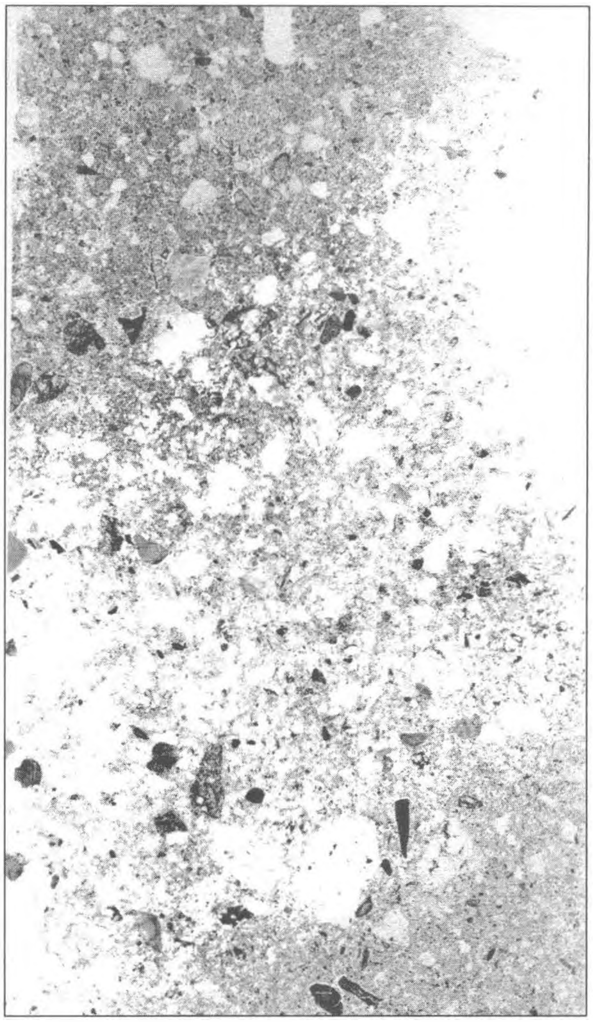

Figure 6. Sample KC-88-3. Macro view of pit fill from the center of HP 104 showing an overall loose mixture of charcoal, silt and rock fragments. PPL; length of sample = ça. 10 cm.

charcoal-rich, roof collapse material. In any case, the sediments are not uniform from top to bottom which in itself might suggest two depositional phases.

Finally, sample **KC-88-19** (Figs. 7 and 8) was collected from a roasting pit (EHPE 12) adjacent to HP 105. The fill consisted of a dark grey ash overlying fire-reddened, gritty silts and stony till. In the field, the deposit gave the impression of being dumped, reddened material.

In thin section, this sample displays an overall uniform, fluffy texture, consisting of finely comminuted pieces of sand-size lithoclasts and reddish loessial aggregates, grains of charcoal, organic matter, bones and a relatively high proportion of phosphatic carnivore coprolites; these range in size from ~0.5–10 mm. The base is redder and is apparently due to an increase in ferruginous grains and loessial aggregates, many of which seem rubefied because of heating; several grains also display thin (20 µm) clay coatings that also enhance the reddish color. Notable in this sample is the striking abundance of charcoal and phytoliths. Some isotropic volcanic glass fragments were also observed, but their small size (sand) would suggest an aeolian origin and not a cultural one, such as obsidian micro-debitage.

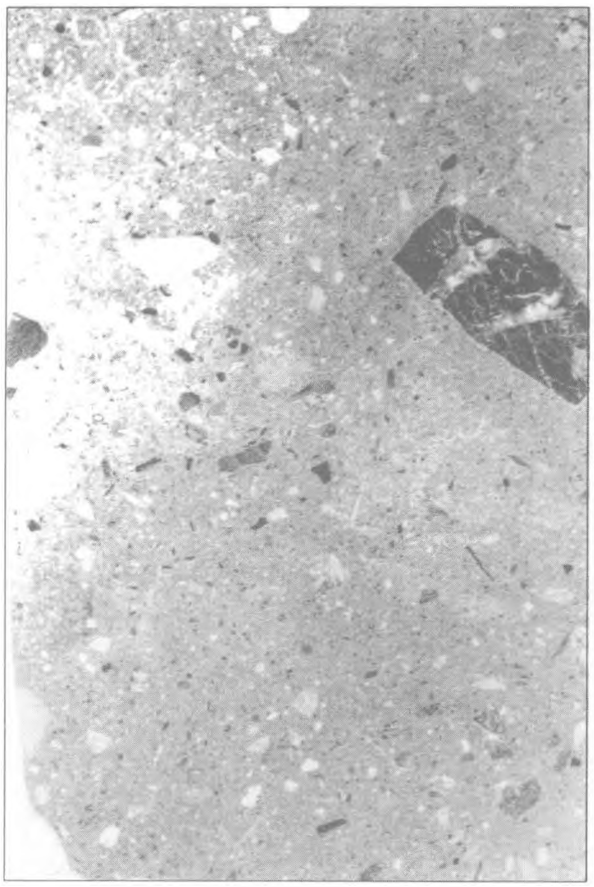

Figure 7. Sample KC-88-19. The sediments illustrated in this macrophotograph from a roasting pit are generally fine grained, uniform and have a fluffy texture. Numerous rock fragments and charcoal pieces are also visible. PPL; length of sample = ca. 8 cm.

In all, the sample appears to represent a charcoal-rich deposit that was dumped in place. In situ burning did not take place as indicated by the aggregated nature of the grains and lack of layering or organization of the charcoal. In light of the abundance of charcoal it is interesting to note the lack of calcareous ash. It is presumed that any traces of original calcite have been leached, as is the case for most sediments in this area.

Discussion of Pit Fill Sediments

The sediments from the pit fills studied here tend to be enriched in charcoal and phytoliths, and also contain traces of bones and some carnivore coprolites, as in the case of sample **KC-88-19**. No indications of in situ burning were evident, as suggested by the lack of any fire-reddened substrates. Rather, grains appear rubefied by having been heated elsewhere and dumped in place. The absence of calcareous ash is likely explained by the fact that soils in this area are slightly acidic and not amenable to the preservation of calcite.

Roof Deposits

Many samples were collected from what appeared to be roof deposits in the field. Due to limitations of space, only some of these deposits will be described and illustrated here.

Micromorphological examination of sample **KC-86-7** from HP 1 yields results similar to field observations. The sediment is generally loosely packed, consisting

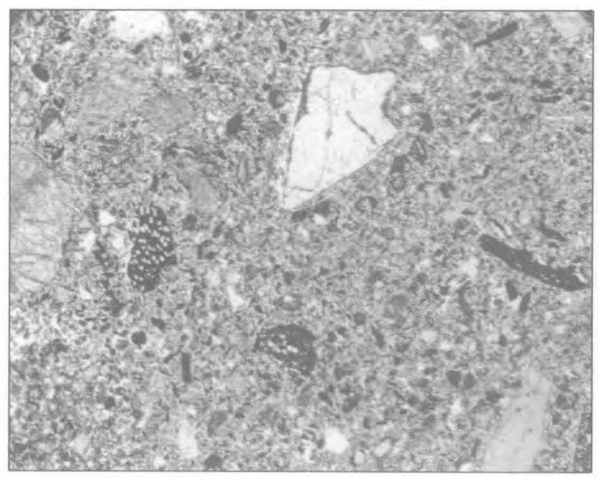

Figure 8. Sample KC-88-19. Detail of Figure 7, showing the abundance of larger and finer size pieces of charcoal. A small, sand size fragment of coprolite is situated in the center-right part of the photograph, just below the large clear grain. PPL; length of sample = ca. 3.5 mm.

of assorted mm and cm size rock fragments within a finer grained matrix. The latter is a well sorted, intimately mixed combination of silt size (~40 mm) angular mineral matter (principally quartz) and undifferentiated organic matter, including charcoal; traces of phytoliths occur, whereas large (mm size) pieces of charcoal are not abundant. In addition, two rounded, yellow sand size coprolites are presumably from carnivores that produce coprolites of similar character; a few angular bone fragments were also noted. Finally, much of the sample is pierced with modern roots that have produced large vughs (irregular voids) and channels.

This homogeneous sample shows an abundance of charcoal. The good integration, sorting and rounding of the mineral and organic (charcoal) grains within the finer matrix, however, points to reworking of these materials by biological activity including the action of insects, rootlets or possibly people, the last perhaps by trampling.

Sample **KC-86-26a** (Fig. 9) from HP 6 traverses roof fall (Stratum III) and deposits constituting part of the underlying occupation (Stratum IV). Three distinct zones could be discerned in thin section, the lower of which includes part of the occupation level.

Figure 9. Sample KC-86-26a. This sample reveals loosely packed rock fragments at the top, overlying a similar layer but which is richer in charcoal, which in turn overlies a slightly finer grained, denser material; the latter representing cicada burrows. PPL; length of sample = ca. 8.5 cm.

1) The *upper part* is characterized by loosely to moderately packed mm size mineral grains mixed with finer sized fragments of charcoal and organic matter; phytoliths are relatively abundant. Locally, where these elements are compacted in cicada burrows, the relative proportion of charcoal increases.
2) The *middle part* is similar to the above but displays a marked increase in coarse pieces of charcoal and contains a few large fragments of bone.
3) The *lower part* resembles the upper but tends to contain less charcoal. Significantly, however, it has distinct areas of very dense fabrics, again due to cicada burrowing. At the very lowest part of the sample, where the microstructure is more open and granular (as at the top), some of the rock grains are coated with poorly oriented, fine silt and clay, presumably due to rolling of these grains.

As appears to be typical of roof samples, the upper part is relatively loose and rich in charcoal, whereas the lower part is commonly denser and exhibits a greater degree of burrowing. Consequently, any extant occupation surfaces have been modified by this biological activity. The occurrence of a few bone fragments might support the presence of an original occupation horizon, although these bones are so scarce that it is difficult to make far-ranging conclusions based on these sparse numbers. In sum, this sample appears to be roof material (zone a) overlying a possible living floor (zone b) that has been partially reworked by biological activity; zone c is essentially sterile material disturbed by bioturbation.

Sample **KC-88-12** (Figs. 10 and 11) from HP 7 in the field was described as dark grey brown stony/gravelly silt (roof) overlying slightly finer and lighter brown fine gravelly silt (floor). At the contact is a fragment of burnt wood (charcoal) with reddening just beneath it.

Thin section observation reveals that the upper part is composed of mm-sized rock fragments in a fine sandy silt matrix. Included within the finer fraction are quartz and rock fragments, large (mm-sized) charcoal pieces as well as finely comminuted charcoal, some bone, and carnivore and herbivore coprolites. The latter consist of rounded, yellow to reddish-brown sand size aggregates with numerous phytoliths, quartz inclusions, and what appears to be volcanic glass or possibly obsidian. In the lower part, the matrix is generally lighter colored and contains less charcoal; it is also aggregated and shows numerous burrows. The latter seems to be responsible for the disarticulation of several pieces of charcoal that have been broken in place and moved a few mm.

In sum, this sample consists of the remains of burned cultural deposits (roof sediments) that have been extensively reworked by burrowing activity of cicadas and rest upon less charcoal-rich silts. The large charcoal pieces could likely be derived from burned wooden beams.

Discussion of Roof Deposits

Although only a few examples of roof deposits were illustrated here, they are overall quite similar, and are typified by a relative abundance of rock fragments and coarse and fine pieces of charcoal that are typically well worked together into the matrix by cicada burrowing. Also quite striking in thin section is the abundance of phytoliths, which seem to be mostly from grasses, although it should be noted that wood phytoliths are generally more difficult to recognize and consequently may be in greater abundance. The presence of grass phytoliths in roof deposits could reflect a number of different factors. It might indicate that either sod or grass thatching was used on the roof, possibly for insulation. When the roof eventually burned, both wood charcoal from beams as well as grass sod/ thatching would be combusted, leaving behind a mixture of charcoal and phytoliths. Alternatively, the phytoliths could represent discarded grass bedding on roofs or possible chinking material.

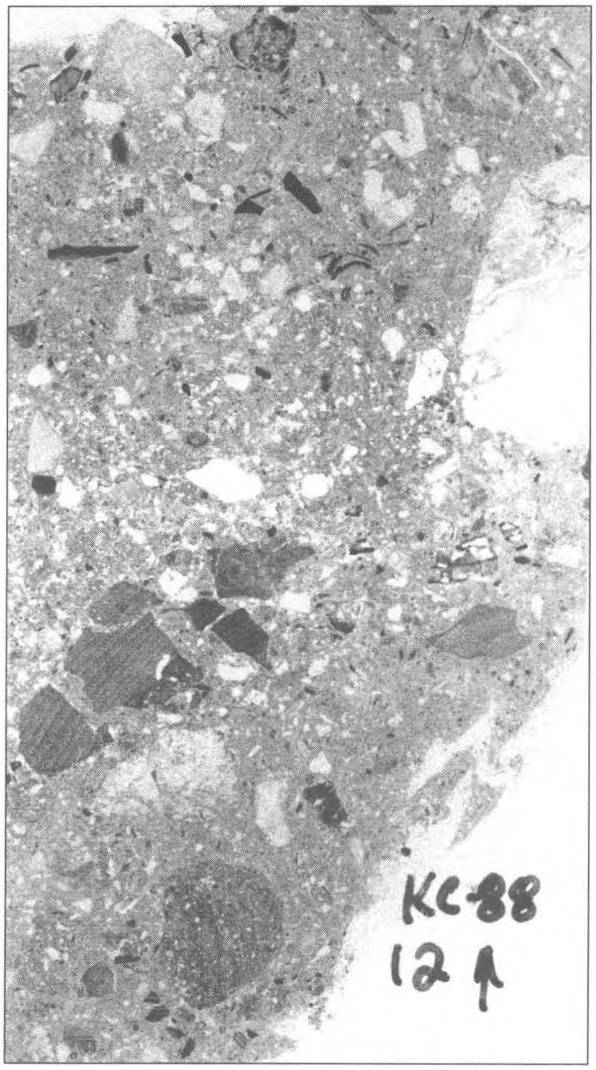

Figure 10. Sample KC-88-12. Macrophotograph of roof deposit overlying somewhat finer grained and lighter colored fine gravelly silt of a floor. Note the charcoal dispersed throughout. PPL; length of sample = ca. 9.5 cm.

Also included in the roof sediments are less abundant remains associated with human activity. These include fragments of bone and occasional pieces of yellow and reddish brown carnivore coprolite, possibly dog. The presence of these items in trace amounts could be explained by the occasional gnawing of bone by a dog, sitting close to the roof. The fact that most of the roof deposits analyzed here are not rich in these items suggests that the roofs were not places of accumulation of fine grained cultural-waste material dumped from somewhere else, such as the house interior. Fire-cracked rock, however, was observed in the field to be a common element in roof deposits. Based on the analyses of rim deposits (see above), it is more likely that rims might have been a preferred locus of accumulation of fine grained cultural waste materials.

Floors

As shown in Table 1, many samples include parts of what were ascribed in the field to floors. Limitations of space preclude a detailed presentation of all the samples, and here we will provide only an eclectic view of the floors; those of the most striking samples. Among the localities which in the field had the clearest examples of intact floors is HP 105.

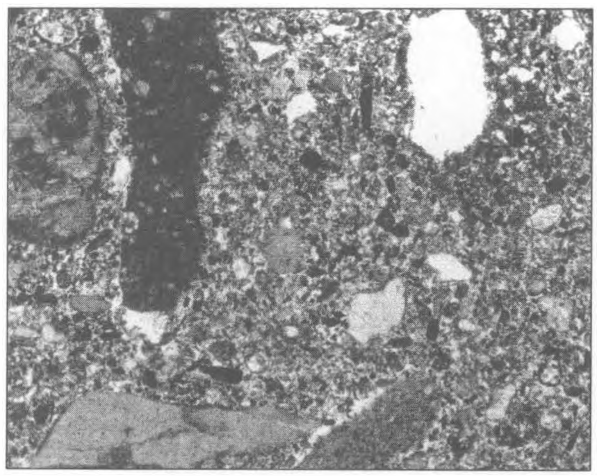

Figure 11. Sample KC-88-12. Detail of upper part of Figure 10 showing finely comminuted charcoal dispersed within the rocky silty matrix. A yellowish carnivore coprolite fragment is visible in the center right of the photograph. PPL; length of sample = ca. 1.7 mm.

Several samples were collected from pronounced living floors excavated in HP 105. In the field the floor of HP 105 was identifiable as a relatively flat surface that was covered with a distinct, ~1–2 mm thick layer of salmon bones. Upon excavation sediments above and below the floor separated easily at the contact.

In sample **KC-88-15** (Figs. 12, 13, and 14), which includes the occupation layer (Stratum III) plus the roof fall above it (Stratum II), the living floor (lf. on Fig. 12) was distinguished in the field by a thin scatter of partially articulated fish bones. The sedimentary matrix is comprised of grey brown stony sandy silt, which in the north of the housepit displays more distinct bedding, with diffuse layers of tan gritty sand.

In thin section the contact between the upper stony, charcoal-rich stratum and the lower is clear. The *upper part* is silty and charcoal rich, with finely comminuted charcoal in a loose matrix that likely is produced by burrowing activity of cicadas. In addition, this upper part of the matrix contains a greater number of aggregates than the lower half. Some phytoliths were observed and in greater quantities than in the lower unit.

The *lower part* is locally reddened, and laminations are exhibited near the top where the matrix has been separated along horizontal cracks. These elongated voids appear to be associated with vegetation (fir needles) that have since partially decayed; they also locally resemble "banded fabric" described above. Just at the contact between the upper and lower parts, some of the matrix is visible as a locally denser band, about 2 mm thick. Although this band is discontinuous across the slide, it does correspond to the level containing salmon bones, and suggests that its dense nature may result from compaction by trampling or other human activity.

Elsewhere, the lower stratum is locally burrowed, and the burrow fillings are compact and rich in organic matter. Micromorphologically, it is not clear why the lower part was slightly redder than the upper part as was observed in the field.

Sample **KC-88-16** also comes from the living floor in Square A. In the field two distinct layers were observed: an *upper* part consists of light medium grey silts with abundant bone, and a living floor (with microfauna) represented by grey/white sand with bone just above it. This upper zone overlies a dark, 1 cm thick more organic layer that rests upon the *lower* part, consisting of a fine reddened horizon that seems disturbed by rodents and insects; a large bone rests just above the floor.

In thin section, the deposit is quite homogeneous, although the lower third is poorer in charcoal. The upper part is characterized by cm thick diffuse zones that are richer and poorer in charcoal; these appear to be alternating sterile and cultural sediments that have been mixed by either burrowing or trampling. A relative abundance of sand size bone fragments and traces of coprolites were observed in this upper part, but these did not appear to be confined to a distinct horizon as would be expected from field observations. Some phytoliths were also observed. The cm thick dark layer is richer in charcoal fragments and could represent the remains of an earlier roof deposit. The lower, reddened part of the sample was not particularly evident in thin section, although it was more compact, slightly clayier and richer in finely divided charcoal. Several cicada burrows occurred throughout the sample.

In sum, the lighter part could be associated with the dumping of sterile till on the floor which was later mixed with more charcoal-rich material. Moreover, this sample, although relatively rich in bone and charcoal, did not reveal any suggestions of the presence of a distinct surface, as was the case for the compacted layer in **KC-88-15**. This observation was somewhat surprising, in light of the proximity of the two samples and their similar nature in the field. This sample was considerably more burrowed, however, which may explain its lack of vertical differentiation. The origin of the more reddish zone at the base is problematic. It is clearly more compact, clayey and richer in organic matter than the overlying deposits, but these materials do not appear to have been heated. This area in the thin section when viewed macroscopically is roughly circular, with a diameter of about 2–3 cm, suggesting that this could represent a rodent burrow. Otherwise, its origin is not clear.

Sample **KC-88-17** (Figs. 15 and 16) was taken 1 m to the north of KC-88-16, where a whitish grey occupation zone (i.e., floor) overlies black floor deposits that rest upon slightly reddened silts. Dark roof deposits cap the entire sequence.

The generally clear lithological variation seen in the field is poorly expressed in thin section, and the abundance of cicada burrows may explain this. Instead, there is considerable local variability of lithology and fabrics, although the upper part is clearly richer in charcoal than the lower one, as shown by a diffuse layer of dispersed charcoal in the upper quarter of the slide. A banded fabric is visible, especially near the top of the sample. Some silty coatings on larger (~1 cm) size rock fragments also occur. Finally, some (fire?) reddening was observed on the grains and silty matrix, and the presence of two calcined bones certainly indicates intensive heating, although no evidence for in situ burning was visible. The red color does not appear to be due to ochre mixed in with the matrix. In any case, the reddened silts observed in the field are

Figure 12. Sample KC-88-15. Macroview of rocky roof deposits overlying a 2 mm thick occupation band just below the horizontal crack near the center of the photograph. In the field, numerous salmon bones were scattered on this surface. The lower part of the slide shows numerous horizontal, elongated cracks that are associated with voids created by the decay of fir needles. PPL; length of sample = ca. 11 cm.

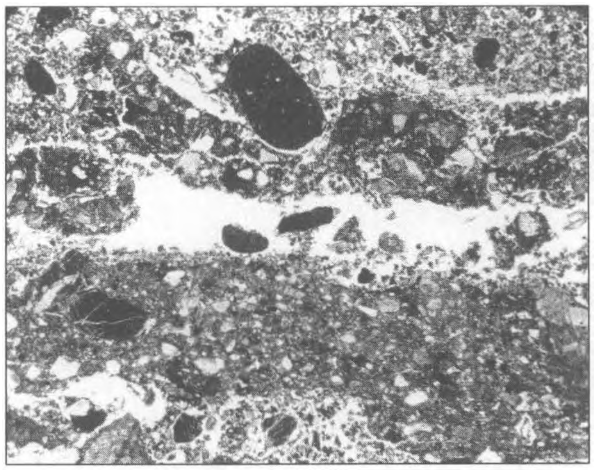

Figure 13. Sample KC-88-15. Detail of Figure 12 showing dense (compacted?) nature of the occupation layer in the lower part of the photograph. PPL; length of sample = ca. 3.5 mm.

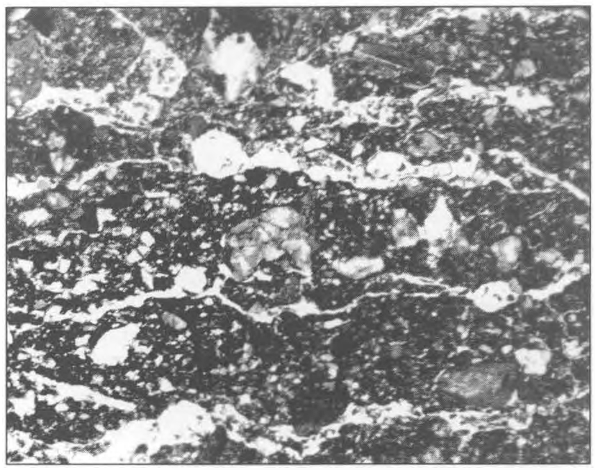

Figure 14. Sample KC-88-15. Detail of lower part of Figure 12. Note the horizontal joint planes and sand size coprolite fragment in the upper left-hand part of the photograph. PPL; length of sample = ca. 3.5 mm.

likely associated with fire-reddening of culturally-enriched (bone, charcoal) silty parent material. Because it exhibits extensive burrows, it is not possible to determine whether it was burned in place.

Sample **KC-88-21** (Square C) is similar to KC-88-15 in the field, encompassing roof (Stratum II) and floor (III) deposits, with fish bones and a dark band 3 cm thick below it. These deposits, in turn, overlie a hard compact grey tan silt (reworked till?).

In thin section, the *upper part* (roof) has a fluffy, aggregated structure, with some coarser charcoal and bone fragments but relatively little charcoal in the matrix. There is a diffuse concentration of bone at the base of this part and at the top of the middle unit. At the bottom of this zone the floor with salmon bones, clearly expressed in the field, is not evident in thin section, and bones are found scattered throughout the slide.

The *middle part* (floor) is darker and richer in fine grained charcoal, which is locally compacted, probably by cicada burrowing. Bone is present and remnants of some calcareous ash occur in this part of the sample. The ash is associated with shreds of organic matter, charcoal and phytoliths. It is interesting that ash does not appear in the lower parts of the sample, although there are abundant phytoliths and charcoal there as well. Some remnants of more compacted areas, similar to that found in **KC-88-15**, can be observed at the base of this part of the slide, although they have been locally disturbed by burrowing.

The *lower part* (till) of the slide displays several burrows and a dense fabric, similar to one that has been produced by cicadas. Some of these burrows are filled

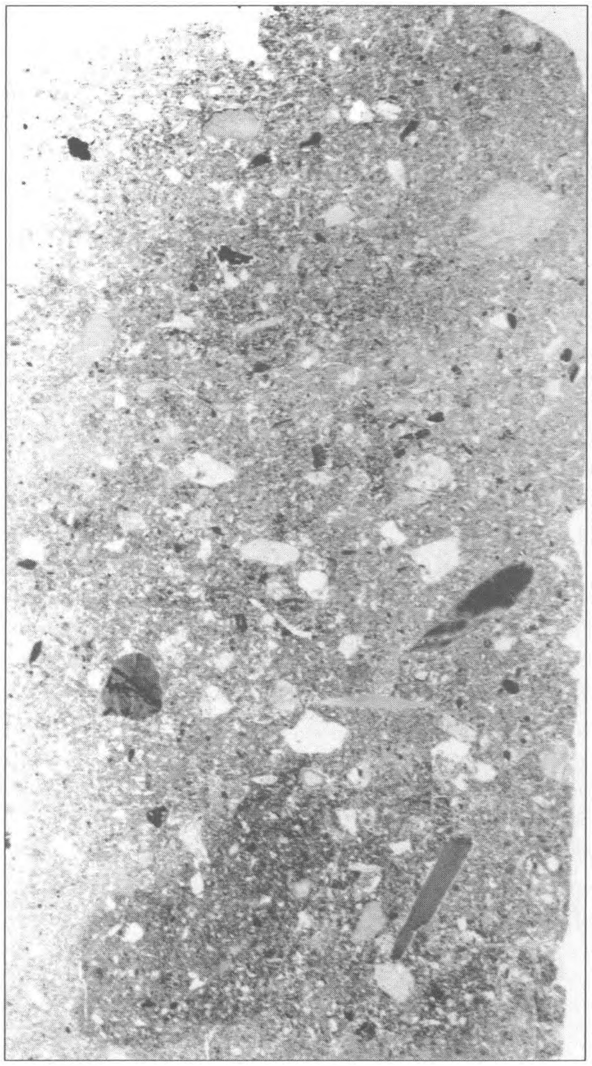

Figure 15. Sample KC-88-17. Macro view of an area identified in the field as a whitish grey occupation zone overlying black floor deposits. This differentiation is not evident here, possibly due to extensive burrowing by cicadas as shown in the lower and central part of this photograph. PPL; length of sample = ca. 10 cm.

with reddened, burnt material, although evidence for in situ burning is absent.

In all, the sample appears to represent charcoal-rich roof deposits overlying ashy deposits (mostly decalcified, although some calcareous ash does remain) that both rest upon slightly rubefied sediment. Extensive burrowing by cicadas has occurred, although it appears that a slightly compacted, probable occupation layer at the interface between the middle and lower portions of the deposits has survived. The reasons for reddish color of the basal part of the section are not clear, but the color could represent the remains of an originally fire-reddened substrate that has since become altered by biological activity.

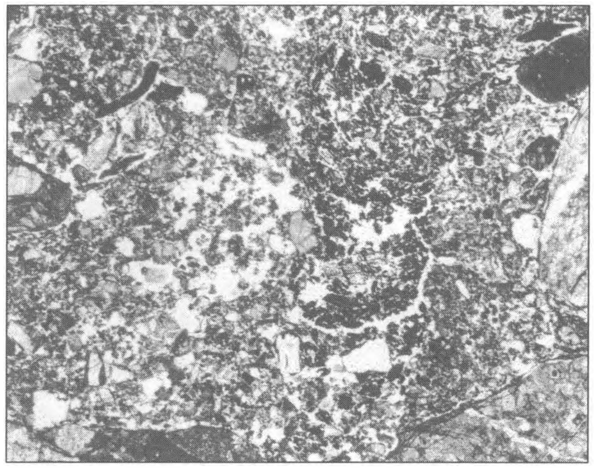

Figure 16. Sample KC-88-17. Detail of middle part of Figure 15 showing a "finger-like" arrangement of charcoal (cicada burrow) within a lighter, more mineral-rich matrix. Note the open nature of the sediment left of the burrow, also caused by burrowing. PPL; length of sample = ca. 3.5 mm.

Discussion of Floor Samples

Overall, the micromorphological expression of the living floors that appeared so evident in the field is not strong in thin section. In sample **KC-88-15** the presence of a living floor was indicated by the breaking of the sample at the layer containing the salmon bone concentration, and the fine, horizontal crack structure, apparently related to vegetation (perhaps matting?) that has since decayed. In sample **KC-88-16**, however, the correspondence between field and thin section sample was less clear, and bone was dispersed throughout the entire upper two-thirds of the slide. The reasons for this lack of correspondence are not apparent, although there is evidence for bioturbation (e.g., cicada burrows). In any case, these samples show that with careful examination thin, laminar compacted zones in thin section can be recognized and ascribed to former occupation surfaces. As noted here, however, often these zones can be locally altered or obliterated by biological activity, thus making their identification difficult or impossible.

Concluding Comments

If we consider the samples as a whole, there are no major differences in composition or texture, and large variations in the proportions of mineral *vs.* organic fractions exist in both the coarse and fine size fractions. Stratigraphic units that were interpreted or ascribed in the field as representing collapsed roof deposits tended to be relatively rich in charcoal, particularly large (cm sized) fragments, but also in finely divided charred vegetal remains. Roof deposits also seem to be richer in remains of the original calcareous ash.

On the other hand, deposits associated with floors or occupation surfaces are overall richer in finer mineral matter, which in the field produces the slightly lighter color of these layers, as for example in sample **KC-88-15.** "Occupation deposits" also did not seem to possess any features that would be associated with anthropogenic activity, such as increases in the amount of bone, ash, burned stones, or very finely divided charcoal. Many micromorphological features, however, may have been destroyed by pedogenetic processes, such as leaching of ash and biological activity. The latter is well expressed in many samples in the form of cicada burrows.

Phytoliths could be observed in most samples, including the supposedly "sterile" rim spoil. In this case, they are probably associated with extensive burning of wood and grasses in the area and their study should complement other palaeobotanical analyses. The relative abundance of phytoliths in roof samples could indicate that either the roofs were loci for organic dumps or that they were covered with grassy sod (see above).

It is hoped that this paper has demonstrated the usefulness of micromorphology in studying anthropogenic deposits, particularly those from Keatley Creek. Here the technique was applied to deposits associated with housepits and included, rims, roofs, floors, reworked sheetflow deposits (the "plaza"), and pit fills. In the case of rim spoil, for example, micromorphological analysis revealed that basal levels of these deposits are less "sterile" than apparent in the field, indicating not only that anthropogenic activities took place prior to their accumulation, but also that they might be associated with house cleaning during occupation. Similarly, micromorphological analysis of pit fills revealed no evidence of in situ burning activity; reddened sediments had been heated elsewhere and dumped in place.

Furthermore, micromorphology has proven very useful in identifying and addressing a wide range of issues that would not have been evident in the field. The identification of phytoliths such as in rims and roofs pointed to probable human discards in areas that such activities would not have been readily assumed. Dumped ash deposits might suggest maintenance of household space. The technique is also successful at isolating a number of post-depositional processes that can significantly affect the interpretation of archaeological date and site formation. These include extensive burrowing by cicadas, which not only obliterate the stratigraphy, but can result in displacement of artifacts. Secondary dissolution of carbonates as seen in thin section, can efface the presence of ashes (essentially composed of calcium carbonate) and result in not only a reduction in volume of the sediment but also elimination of evidence of cultural activity (e.g., in situ burning, or re-mobilization of ashes, such as dumping). Finally, micromorphological analysis of the "plaza" fills shows them to be composed of materials that are ultimately of cultural origin but have been reworked by sheet flow. Thus, the presence of the buried pre-existing housepits that occur at the base of the "plaza" profiles has been obliterated by this deposition. Such reworking also suggests that these eroded cultural materials likely come from other housepits situated upslope that have been eroded. Again, such information reflects upon the integrity of the archaeological record at Keatley Creek.

Finally, although the examples presented here are eclectic in nature, additional, nuanced observations could have further illustrated the value of the technique. It is hoped that this study will encourage subsequent efforts to examine and understand anthropogenic deposits from other housepit sites that are common in the western part of North America.

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