Biomolecular and micromorphological analysis of suspected faecal deposits at Neolithic Çatalhöyük, Turkey

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Suspected coprolites from midden, burial and room fill contexts at Çatalhöyük were analysed by GC/MS and thin section micromorphology. Assessment of sterol biomarkers enabled a distinction between faecal and non-faecal sources for the deposits to be made, with bile acid biomarkers indicating that many of the faecal deposits are human coprolites. The relative lack of ruminant faeces could be due to this material being used as a fuel source. Deposits in burials were observed to contain soil and plant derived sterols rather than their faecal counterparts. Further analysis in thin section enabled identification of associated materials and contents. Diagnostic inclusions such as bone and plant fragments were only present in some of the human coprolites, which were observed to have a very similar morphology to decayed plant remains. This study illustrates the difficulties in distinguishing coprolites in the field and under the microscope, and demonstrates the importance of integrating biogeochemical methods, particularly when such deposits are used as the basis for interpreting human health and diet, and use-of-space in settlements.

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1. Introduction

Çatalhöyük is an early Neolithic site in south-central Anatolia, Turkey, dated between c.7400–6000 BC (Cessford et al., 2005). Discovered by James Mellaart in the late 1950s, the first excavations were carried out between 1961 and 1965 (Mellaart, 1967) and it has become recognised internationally as the largest early settled village in the world, with remarkably well preserved wall paintings and sculptures ( Hodder, 2006). The abundant plant and faunal remains ( Fairbairn et al., 2002; Russell and Martin, 2005) mean it has become a key case study for understanding early settlement architecture, a key feature of the site is the extensive midden deposits located adjacent to buildings, which are commonly reused as packing material ( Shillito et al., 2008).

Faecal deposits are observed to be an abundant component of middens at many near-eastern sites, through micromorphological observations of structure and inclusions such as bone fragments and hackberry pericarps ( Matthews, 2001; Matthews, 2005; Shillito et al., 2009; Matthews, 2010) and the presence of calcareous spherulites in herbivore dung ( Canti, 1999; Shahack-Gross, 2011). The appearance of these deposits can be highly variable, some having a distinct sub-rounded morphology whilst others are present as amorphous organic stains or compressed layers interspersed between layers of ash and charred plants. These deposits have significant potential as indicators of human and animal diet and the large quantity of this material in close proximity to buildings at Çatalhöyük has significant implications for understanding health and use-of-space in the settlement. The accurate identification of faecal material as either human or animal is essential in the correct interpretation of archaeological deposits and to enable further investigation of health and diet in the Neolithic.

Identification of this material in the field is still uncertain, due to similarities in morphology and structure with deposits such as yellow ochre, clays and silts, and uncertainties about whether amorphous organic material may derive from decayed food remains ( Matthews, 2005). For example, mineralized phosphate-rich organic material inside hackberry pericarps has a similar appearance to omnivore coprolites in thin section ( Shillito et al., 2009). Interpretation of yellow deposits in other contexts such as **
graves and room fill is also problematic, where it can be difficult to distinguish possible coprolites in the pelvic region of skeletons and associated with faunal material, from non-faecal deposits.

In thin section, inclusions which distinguish faecal material from other organic deposits, such as spherulites and plant and bone fragments, may not always be present. In cases where plant and bone inclusions are visible, it may be difficult to distinguish between omnivore and ruminant derived deposits solely on the basis of external morphology and contents as human diet can be highly variable. Studies of Clovis period coprolites have debated whether the use of morphology and contents is a reliable species indicator (Goldberg et al., 2009; Rasmussen et al., 2009). Biomolecular analysis of organic residues by GC/MS can be used to identify coprolites with greater certainty and is able to distinguish between omnivore and ruminant material on the basis of sterol content and between omnivore species on the basis of dominant bile acids (Elhmmali et al., 1997; Bull et al., 2002).

The use of sterols and bile acids as biomarkers is possible due to the relative stability of these compounds combined with a specificity for certain species. Soil and gut derived sterols can be distinguished on the basis of their stereochemistry, i.e. 5α-products are the result of microbial reduction external to the gut rather than the 5β-products that are produced in the gastrointestinal tract, with 5β-cholestan-3β-ol (coprostanol) being the predominant biomarker for human faeces; see Bull et al. (1999a, 2002) for a detailed overview of the source and application of faecal biomarkers.

Pilot studies at Çatalhöyük have shown it is possible to recover significant quantities of sterols from samples of this age and to distinguish faecal material from mudbrick controls (Bull et al., 2006). On the basis of previous micromorphology studies and observations during excavations at Çatalhöyük (Matthews et al., 1996; Matthews, 2005) it is hypothesised that distinct orange/yellow deposits in middens, room fill and graves are coprolites. It is further hypothesised that differences in coprolite micromorphology are due to the difference in species. The first hypothesis will be tested through biomolecular analysis of organic residues. The second hypothesis will be tested by comparing organic residue results with the appearance of the deposits in thin section.

Comparisons of the appearance of coprolites from finely stratified midden deposits in thin section will enable identification of the specific depositional context of these remains. This in turn can be used to help understand questions of midden formation processes, and provide the basis for further analysis of human and animal diet and health in the Neolithic. In addition, the comparison between microscopic and organic geochemical analyses will help future identifications of faecal material in thin section.

2. Materials and methods

2.1. Field sampling

Middens were surveyed in each of the three major excavation areas at Çatalhöyük East [Fig. 1(a)] and sections selected to investigate sequences of undisturbed, finely stratified layers, where yellow/orange inclusions, suspected to be faecal deposits, were visible at the macroscale. Examples can be seen in Fig. 1(b) and (d). In addition, material collected as “coprolites” from burials and room fill deposits were selected. Samples for thin section micromorphology were collected by cutting blocks from midden faces and wrapping these with tissue and tape to avoid disturbing the deposits. Orange inclusions suspected to be faecal material were sub-sampled directly from the face of the blocks, to enable direct comparison between biomolecular analysis and thin section micromorphology. In total, seventeen deposits were selected from midden sections, six from room infill and five from burials. Samples and context details are provided in Table 1. Excavation records with context data are available online at www.catalhoyuk.com/database/catal/.

2.2. Biomolecular analysis

Faecal biomarkers were isolated for analysis from suspected coprolites following the methods of Bull et al. (1999b) for sterol...
3. Results

3.1. Biomolecular analysis of organic residues by GC/MS

The abundance of sterols, relative to each other, is shown in Table 2. Typical examples of GC traces showing sterols and bile acids are given in Figs. 2 and 3. The likely origin of the residues is assessed initially using the ratios discussed earlier (Bull et al., 2002) and subsequently through the examination of the bile acids present. The initial study at Çatalhöyük revealed a human origin for four of the seven deposits studied (Bull et al., 2006) with the values of Ratio 2 obtained from the coprolite samples being 0.79 and 0.92, and the midden deposit samples having values of 0.83 and 1.00. These values are well above the threshold value of 0.7 that indicates a likely faecal origin.

In the present study, values returned using Ratio 1 are consistent with sixteen of the twenty-eight deposits being of faecal origin (values of 0.73–0.95) with a further three possibly comprising faeces mixed with another deposit type (values of 0.73–0.86). Of these, nineteen, values returned using Ratio 3 suggest that fifteen are most likely derived from omnivores (values ranging from 0.81 to 0.87) one is possibly of ruminant origin (value of 0.57), and three may be mixed (values around 0.7). Further clarification through analysis of bile acids supports a human origin for the omnivore coprolites and the mixed samples due to the dominant presence of both lithocholic (LC) and deoxycholic acid (DOC). The possible ruminant deposit (4477 s7) contains high quantities of 5β-stigmasterol, 5α-stigmasterol and sitosterol at 0.04, 0.2 and 0.1 μg g⁻¹.

Table 1

<table>
<thead>
<tr>
<th>Area</th>
<th>Sample number</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Middens</td>
<td>4040</td>
<td>25 cm thick, multiple fine layers with mudbrick. Sample collected as coprolite.</td>
</tr>
<tr>
<td></td>
<td>13103</td>
<td>Orange material adjacent to massive aggregate deposits.</td>
</tr>
<tr>
<td></td>
<td>13103</td>
<td>Orange deposit in large ash layer with plant inclusions.</td>
</tr>
<tr>
<td></td>
<td>13103</td>
<td>Thin orange lense associated with fine ash layers.</td>
</tr>
<tr>
<td></td>
<td>13103</td>
<td>Thin orange lense associated with multiple fine layers and brown organics.</td>
</tr>
<tr>
<td>South</td>
<td>1668 U1</td>
<td>Space 115, coprolite.</td>
</tr>
<tr>
<td></td>
<td>2739 b</td>
<td>Space 115. 3 to 4 layers of ash deposits, with interleaved lenses of coprolite and phytoliths.</td>
</tr>
<tr>
<td></td>
<td>12519</td>
<td>Thin orange lense associated with multiple fine layers.</td>
</tr>
<tr>
<td></td>
<td>12519</td>
<td>Thin orange lense associated with multiple fine layers.</td>
</tr>
<tr>
<td></td>
<td>12524</td>
<td>Orange deposit</td>
</tr>
<tr>
<td></td>
<td>12524</td>
<td>Orange deposit under ash.</td>
</tr>
<tr>
<td></td>
<td>12504</td>
<td>Thin orange lense associated with multiple fine layers.</td>
</tr>
<tr>
<td></td>
<td>12504</td>
<td>Thin orange lense associated with multiple fine layers.</td>
</tr>
<tr>
<td></td>
<td>TP 7867</td>
<td>Orange-brown deposit associated with grey ash layers.</td>
</tr>
<tr>
<td></td>
<td>8932 3/13</td>
<td>Yellow deposit associated with ashy grey lenses.</td>
</tr>
<tr>
<td></td>
<td>8932 3/05</td>
<td>Yellow deposit associated with ashy grey lenses.</td>
</tr>
<tr>
<td></td>
<td>8932 3/09</td>
<td>Yellow deposit associated with ashy grey lenses.</td>
</tr>
<tr>
<td>Burials</td>
<td>North 1380</td>
<td>Building 1, Feature 28. Between mandible and sternum.</td>
</tr>
<tr>
<td></td>
<td>1380 x</td>
<td>Building 1, Feature 28, Space 100</td>
</tr>
<tr>
<td></td>
<td>1494</td>
<td>Building 1, Space 71, Feature 40.</td>
</tr>
<tr>
<td></td>
<td>1993</td>
<td>Building 1, Space 71, Feature 29/49, ochre</td>
</tr>
<tr>
<td></td>
<td>1985</td>
<td>Building 1, Space 71, Feature 211.</td>
</tr>
<tr>
<td></td>
<td>Adult and child burial.</td>
<td></td>
</tr>
<tr>
<td>Room fill</td>
<td>South 4477</td>
<td>Building 23, Space 178/179. Mixed with orange and greyish brown clayey silts, with plaster and brick debris.</td>
</tr>
<tr>
<td></td>
<td>2754</td>
<td>Building 2, Space 117, overlying plaster floor.</td>
</tr>
<tr>
<td></td>
<td>2754</td>
<td>Building 2, Space 117, overlying plaster floor.</td>
</tr>
<tr>
<td></td>
<td>2766</td>
<td>Building 2, Space 117, overlying plaster floor.</td>
</tr>
<tr>
<td></td>
<td>2767</td>
<td>Building 2, Space 117, overlying plaster floor.</td>
</tr>
<tr>
<td>North</td>
<td>1360</td>
<td>Building 1, Space 71.</td>
</tr>
<tr>
<td></td>
<td>4040</td>
<td>Orange-brown deposit under room fill</td>
</tr>
</tbody>
</table>

faecal biomarkers and a modified version of the methodology proposed by Elhmmani et al. (1997) for bile acid faecal biomarkers. For the latter method 5% acetic acid in methanol was used as the second eluent for the separation performed using the SPE amino-propyl column.

2.3. GC and GC/MS conditions

GC analyses were performed using a Hewlett-Packard 5890 series II gas chromatograph fitted with a fused silica capillary column (Chrompack CPSil-5 CB, 50 m × 0.32 mm) coated with a 100% dimethylpolysiloxane stationary phase (film thickness 0.12 mm). Derivatized samples were injected (1.0 ml) via an on-column injector as solutions in hexane. He was used as the carrier gas. For the sterol fraction the temperature was held at 40 °C for 1 min, following injection, then programmed (1 min) to 200 °C at a rate of 10 °C min⁻¹ then to 300 °C at a rate of 3 °C min⁻¹ with a final hold-time of 20 min. For the bile acid fraction the oven was held for 1 min at 40 °C following injection, then temperature programmed from 40 to 230 °C at 20 °C min⁻¹, then to 300 °C at 2 °C min⁻¹, and held at that temperature for 20 min. GC/MS analyses were conducted using a ThermoQuest TraceMS instrument equipped with an identical column. In both cases, the temperature programmes employed were the same as used for the corresponding GC analysis. The ion source was maintained at 200 °C and the transfer line at 300 °C. The emission current was set to 150 μA and the electron energy to 70 eV. The analyser was set to scan m/z 50–650 with a duty cycle time of 0.6 s. GC/MS peak assignments were made by comparison with known mass spectra.

In order to identify the likely source of any biomarkers present, three ratios can be calculated:

Ratio 1: Coprostanol/(coprostanol + 5α-cholesterol)
Ratio 2: Coprostanol + epicoprostanol/(coprostanol + epicoprostanol + 5x-cholesterol)
Ratio 3: (Coprostanol + epicoprostanol)/(5β-stigmastanol + 5β-epistigmastanol)

It has been proposed that for Ratio 1, a value greater than 0.7 is a definite indication of faecal pollution (Grimalt et al., 1990). Ratio 2 has been proposed by Bull et al. (2002) to account for diagenetic processes leading to the formation of epicoprostanol. Archaeological values are thus adjusted to take into account the further possible transformation of coprostanol to epicoprostanol. Ratio 3 is used to confirm if the presence of faecal material is from either pig/human (predominantly coprostanol and epicoprostanol), or a ruminant species (predominantly 5β-stigmastanol and 5β-epistigmastanol).

2.4. Thin section preparation and analysis

Resin impregnation was carried out on oven dried blocks using Taab epoxy resin under vacuum, hardened at 70 °C for 12 h. Slides were prepared by successively cutting and grinding the block face to a standard thickness of 30 μ. Micromorphological descriptions were carried out according to standard terminology and by comparisons with previously published and reference material (Matthews et al., 1996; Matthews, 2005; Bullock et al., 1985; Courty et al., 1989).

Table 2. Typical examples of GC traces showing sterols and bile acids.
respectively whilst coprostanol and cholesterol are found at 0.02 and 0.03 mg g⁻¹, respectively.

For the non-faecal samples, three contain no residues (7867, 8864, 1993), with six containing residues from a non-faecal source, indicated by the dominance of cholesterol, sitosterol and 5α-stigmasterol rather than the 5β-stanols formed in the gut. This pattern is observed in three of the burial samples and three of the midden samples and can be interpreted as the remains of decayed organic material. Thin section observation of the midden samples with non-faecal residues indicates that two are anthropogenic clay fragments (12524 s14 and 13103 s24); plant residues are likely to be from the decayed plant material used as temper. This can be seen in thin section by the presence of abundant pseudomorphic voids [Fig. 4(g)], which remain as impressions in the clay after the organic temper has decayed. Conversely, 7867 which is observed in thin section to be a clay deposit with no plant temper contains no residues [Fig. 4(h)]. 12504 s16 contains small quantities of cholesterol, 5β-stigmastanol, sitosterol and 5α-stigmasterol. Although

Table 2

| Midden samples | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | Ratio 1 | Ratio 3 | DOC | LC |
|----------------|---|---|---|---|---|---|---|---|---|----|----|----|-------|-------|-----|----|---|
| 8864 4        | 4 | 4 | 2 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4     | 4     | 4   |    |   |
| 11016 4       | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4     | 4     | 4   |    |   |
| 13103 34      | 34| 34| 34| 34| 34| 34| 34| 34| 34| 34 | 34 | 34 | 34    | 34    | 34  |    |   |
| 13103 21      | 21| 21| 21| 21| 21| 21| 21| 21| 21| 21 | 21 | 21 | 21    | 21    | 21  |    |   |
| 13103 27      | 27| 27| 27| 27| 27| 27| 27| 27| 27| 27 | 27 | 27 | 27    | 27    | 27  |    |   |

![Fig. 2. GC trace for sterols from room fill sample 2574 S4.](image2)

![Fig. 3. GC trace for bile acids from room fill sample 2574 S4.](image3)
this contains a 5β-stanol, the low concentration at 0.01 µg g⁻¹ and the lack of any other 5β-stanols, suggests that it does not have a faecal source and can be considered as a minor background quantity of 5β-stigmastanol.

One deposit which was initially slightly ambiguous is the adult and child burial sample (1985 s5) which exhibited a trace of coprostanol. Further observation of the results indicates this deposit has a noticeably high concentration of cholesterol at 2.6 µg g⁻¹ compared to 0.02 µg g⁻¹ coprostanol, with other residues of 5α-cholesterol (0.06 µg g⁻¹), 5α-campestanol (0.3 µg g⁻¹), sitosterol (1 µg g⁻¹) and 5α-stigmastanol (2.8 µg g⁻¹). The presence of cholesterol has been noted in studies of mummies, but the cholesterol has not been attributed to any specific source (Buckley and Evershed, 2001; Buckley et al., 2004). Cholesterol has also been observed in studies of mummies by Degano and Colombini (2009), where it is interpreted as having derived from human skin. Although cholesterol would be expected to be present in very minor amounts in the remains of decaying plants, there would be a predominant concentration of sitosterol. The origin of the cholesterol in this deposit is therefore likely to be animal derived.

Samples that did not contain faecal sterols were also lacking in LC or DOC, confirming that these do not contain any notable quantities of faeces, whilst the samples with omnivore faecalsterol ratios all contain dominant amounts of LC and DOC acids. This strongly supports the presence of human faecal material in these samples. Sample 1 (4477 s7), observed to contain a possible mix of faecal inputs, contained DOC only, supporting a ruminant origin. 11016 s4 observed to contain possible ruminant faecal material, did not contain detectable traces of bile acids. The lack of any hydroxycholesterol acid excludes a porcine origin for the omnivore coprolites.

3.2. Thin section micromorphology

Twelve deposits analysed for faecal residues were observed in thin section for comparison of the specific context, associations and micromorphological features, summarized in Table 3. The size and morphology of the deposits range from distinct sub-rounded inclusions embedded in an ashy matrix, to amorphous material with a less distinct morphology. A more linear morphology is observed in some deposits due to compression, perhaps from trampling or the weight of overlying deposits.

The colour of the deposits is variable and ranges from a pale yellowish brown to a very intense orange [Fig. 4]. All of the deposits have an amorphous fine fabric, with some containing phosphate nodules, plant voids and embedded bone fragments and phytoliths. None of the samples observed have the linear fibrous structure and high level of plant inclusions associated with animal dung. No faecal spherulites were observed.

Deposits with a distinct morphology (such as 13103 s34) are very well preserved with minimal post-depositional alterations. Deposits with a more amorphous structure appear to be partially disaggregated, likely to be a result of bioturbation. This occurs predominantly in samples from the later Neolithic deposits in the TP Area (8932) which have been subject to greater exposure and where post-depositional processes such as gypsum crystallisation are more frequent.

A number of samples recorded as coprolites in the field do not appear to be organic remains in thin section, supported by the lack of faecal residues. These include clay deposits with mineral inclusions and pseudomorphic voids from decayed plant temper discussed earlier, which demonstrate that these are anthropogenic aggregates such as ceramic production debris (Matthews et al., 1997). Deposit 11016 s4 appears to be orange amorphous organic material in thin section, with microbial staining [Fig. 4(j)]. There are no inclusions to suggest this is a coprolite, and the residues do not support a faecal origin, however it is interesting to note that the appearance is similar to deposit 12519 s7 identified as human faeces. Similarly 12504 s16 with low quantities of non-faecal residues has an amorphous structure with a more yellowish colour and no plant or bone fragment inclusions [Fig. 4(b)].

4. Discussion

Analysis of the results has distinguished deposits as omnivore faeces, deposits containing non-faecal residues, or deposits that do not contain any residues. Samples with corresponding thin sections have enabled comparison between GC/MS results and micromorphology. Results are discussed for each of the three context types investigated, followed by the implications of this for wider
questions at Çatalhöyük and the Near Eastern Neolithic, and other
sites containing such deposits.

4.1. Middens

Sediment samples from middens have been shown previously
to contain high levels of faecal residues (Bull et al., 2006). This
study has integrated thin section micromorphology to the study of
a wider range of deposits, and indicates that faecal residues are
present in coprolite deposits present as distinct inclusions in
middens, which can be observed in situ in thin section. In the
present study, samples from middens were most frequently
identified as human faeces on the basis of sterol and bile acid
distributions, compared to burial and room fill contexts which
were more variable.

However, not all midden deposits analysed were confirmed as
human coprolites. The ratio of C27 to C29 5β-stanols (Ratio 2) in
eighteen samples in one deposit (11016 s4) returned a value of 0.05 suggesting the
presence of ruminant derived faecal material, but further exami-
nation of this data indicated that only 0.002 presence of ruminant derived faecal material, but further exami-

Table 3

<table>
<thead>
<tr>
<th>Area</th>
<th>Sample</th>
<th>Context</th>
<th>Colour in plane polarized light</th>
<th>Structure and inclusions</th>
<th>Post-depositional alterations</th>
<th>Fig. 4 reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>TP</td>
<td>8932/05</td>
<td>Midden</td>
<td>Yellow-brown</td>
<td>Disaggregated/amorphous with bone fragment embedded inclusions.</td>
<td>Modern plant roots, gypsum crystalisation</td>
<td>C</td>
</tr>
<tr>
<td></td>
<td>8932/09</td>
<td>Midden</td>
<td>Yellow-brown</td>
<td>Disaggregated/amorphous.</td>
<td>Modern plant roots, gypsum crystalisation</td>
<td>D</td>
</tr>
<tr>
<td>4040</td>
<td>13103 s27</td>
<td>Midden</td>
<td>Pale orange</td>
<td>Amorphous fine fabric, fibrous, with pseudomorphic voids from decayed plant material.</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>13103 s24</td>
<td>Midden</td>
<td>Reddish brown</td>
<td>Clay fine fabric. Abundant pseudomorphic voids from decayed plant material.</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>13013 s34</td>
<td>Midden</td>
<td>Orange-brown</td>
<td>Amorphous organic deposit with small rounded, embedded mineral inclusions</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>11016</td>
<td>Midden</td>
<td>Orange</td>
<td>Amorphous organic deposit with no inclusions.</td>
<td>Black spots/microbial staining</td>
<td>J</td>
</tr>
<tr>
<td>South</td>
<td>12519 s7</td>
<td>Midden</td>
<td>Orange</td>
<td>Amorphous organic deposit with linear voids, perhaps from decayed plant material.</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>12504 s16</td>
<td>Midden</td>
<td>Yellow</td>
<td>Amorphous organic deposit with microcrystal inclusions.</td>
<td>Occasional microcrystal inclusions.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>3922.10</td>
<td>Room</td>
<td>Yellow</td>
<td>Amorphous fine fabric. Pseudomorphic voids from decayed plant material, and phytoliths</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

North 12519 s7 Midden Orange Amorphous organic deposit with linear voids, perhaps from decayed plant material. Occasional microcrystal inclusions. Possible microbial staining

The burial contexts are particularly interesting. Four of the samples analysed from burials were found to contain no faecal residues, with only one sample hypothesized to be a coprolite from a burial being found to contain faecal residues in this study, and these were found in very low concentrations compared to other contexts. It is likely that these are background levels. A lack of faecal residues in the burial could be due to poor preservation, although this seems unlikely considering the high recovery of faecal residues from other contexts. This lack of faecal residues in the burial deposits therefore refutes the hypothesis that these are faecal deposits, as suggested when the samples were collected in the field. The presence of coprolites in burials analysed in this study is not supported.

Three of the five burial samples did contain non-faecal sterols including cholesterol, campesterol, 5β-stigmastanol, 5α-campes-
tanol and sitosterol. For example sterols observed in 1380 Sx taken from a grave context in the North Area indicate that it is not of faecal origin and the concentrations of sitosterol and 5α-stigmas-
tanol in this sample are relatively high, at 20 and 74.5 μg g⁻¹ respectively, compared to 4.6 μg g⁻¹ cholesterol. 1360 S1, from a yellow deposit between the mandible and sternum, contains sitosterol and 5α-stigmastanol but no cholesterol. Both results suggest a plant origin for these residues.

Asouti et al. (1999) suggest the importance of plants in burials, but also note the lack of charred macrobotanical remains in these contexts which have previously made this hypothesis difficult to
support. Considering the burial context these three samples could be interpreted as decayed plant material deposited in the grave, supporting early suggestions of the deliberate inclusion of plants in graves (Mellaart, 1967) as well as more recent phytolith and botanical studies which have found impressions of reed baskets and caches of hackberry pericarps, for example in the burial beneath Building 6 in the BACH area (Asouti et al., 1999). These results suggest that whilst some of the material identified as coprolites in burials in the field has been accurately identified, it is likely that some of these yellow deposits are related to the death and decay of plants placed in the burials. Further interpretation of this material in burials therefore requires biomolecular analysis for correct identification as either coprolite or decayed plant remains.

The high concentration of cholesterol in the adult and child burial (1985 s5) described earlier also suggests a possibility of animal products as grave goods. The inclusion of animal in human burials at Çatalhöyük is known only rarely through the presence of whole and partial animal skeletal remains (Russell and Düring, 2006; Russell et al., 2009). It is assumed at Çatalhöyük and other Neolithic sites in Anatolia that grave goods in general are often absent due to the lack of physical remains (e.g. Bacvarov, 2006). It is suggested that greater consideration needs to be given to the possibility of grave goods that have decayed, but which may have left chemical and microscopic signatures. Although micromorphology samples were not available for the burials investigated in this study, the combination of the techniques in midden and room fill deposits has demonstrated how this can aid in the interpretation and is planned for future research.

4.3. Room fill

Five of the six room fill samples contained faecal residues, with the sixth sample containing plant sterols only. These deposits are from Building 2, Space 117, excavated in 1997 (samples 2754 S2 and S4, 2766 S5 and 2767 S4). Archive excavation data for this unit debates whether these are yellow ochre or coprolites, with a tentative interpretation being that these represent animal penning during an intermediate phase between house floors and demolition back fill (Reagan, in Farid, 1997). Reagan also notes the presence of large animal bones scattered either over or within the deposit. Faunal records indicate the presence ofdigested bone and mention the possibility of dog faeces based on these inclusions.

However, micromorphological analysis suggests that these were omnivore rather than ruminant coprolites and were unlikely to be penning areas due to the lack of sediment compaction (Matthews, 2005) [Fig. 4(a)]. Biomolecular analysis of these samples presented here indicates that the faeces present was human not animal, confirmed by both sterol and bile acid residues [Figs. 2 and 3] thereby supporting Matthews’ hypothesis that this was a latrine area rather briefly used as a waste dump or toilet area in an abandoned building, prior to being back filled with building demolition debris. The building debris layers reported by Reagan (in Farid, 1997) that overly the coprolitic layer are interspersed with finer deposits of “midden like” ashy and bone material, which would also suggest some cyclical use of this area as midden.

4.4. Implications for the identification of coprolite deposits in the field

The presence of faecal residues, non-faecal residues and a lack of any residues in some deposits can now be used to discuss the implications for identifying coprolites in the field, particularly samples collected from burials and as non-discreet orange deposits (or “stains”) in the field. The recovery of relatively high concentrations of residues from samples observed to be discrete orange deposits in the field and in thin section suggests identification of coprolites from such discrete concretions is more reliable. Some samples identified as coprolites in the field are shown to be mudbrick and clay fragments on the basis of micromorphology and residue analysis. Other coprolites suggested to be dog on the basis of their context and associations in the field, are shown to be human. This illustrates the difficulty in identification of coprolites purely on the basis of visible morphological characteristics and highlights the importance of biomolecular analysis for correct interpretation.

4.5. Identification of coprolitic material from middens in thin section

Analyses of samples from the TP Area (8932 S3, S5, S9 and S13) indicate that these are all human faecal material, confirmed by the presence of faecal sterols and bile acids (S13 is human faeces with other organic material, most likely decayed plants due to the high sitosterol at 0.7 μg g⁻¹ compared to 0.2 μg g⁻¹ cholesterol). Observation of these deposits in thin section shows them to be amorphous organic material with few inclusions that would enable them to be confidently interpreted as coprolites. This illustrates the benefit of organic residue analysis in interpreting the fine organic layers observed in many thin section samples. This also indicates that assignment of amorphous organic material in thin section without a clear structure could be the remains of decayed plant remains rather than faecal material. Caution needs to be taken therefore in assigning organic remains as faecal material, particularly when this assignment is fundamental to the interpretation.

Of four samples from unit 13103 in the 4040 area, three were identified as human faeces on the basis of sterol ratios and the presence of LC and DOC (S21, S27, and S34). All three samples had relatively high concentrations of coprostanol at 19.8, 34.4 and 21.1 μg g⁻¹ respectively. These are seen in thin section to be amorphous organic material, again with few inclusions. 13103 S34 has a value of 0.75 for Ratio 3 which suggests it is faecal material mixed with another organic deposit. Sample 13103 S24 did not contain faecal residues – micromorphology demonstrates that this is a clay fragment containing plant material as temper, as discussed earlier. Although distinguishing between different omnivore species in thin section is difficult, this study confirms that other micromorphological features, such as a lack of trampling, are good indicators to distinguish animal penning areas.

Deposits such as clay and ochre fragments, which may not be clear in the field, are easily distinguishable from faecal material in thin section. However distinguishing between omnivore and non-faecal organic material is more difficult. There is no clear difference between human faecal material which is orange and that which has a yellow-brown colour. Both types are shown to be human on the basis of residues and the reasons for their different appearance is unclear but could be related to preservation or diet.

4.6. Implications of faecal residues for the interpretation of midden formation processes and human activity, and diet

Analysis of midden formation processes, and subsequently human activities, relies on the characterisation of finely stratified deposits, including ash, partially charred plant material, bone fragments and organic remains. The distinction between human and animal waste and between coprolites, and other inclusions, is essential in interpreting activities. In turn the correct identification of coprolites as either human or animal enables the inclusions within the coprolites to be analysed in dietary studies. For example,
preliminary phytolith analysis of deposit 4477 s7, the only deposit in this study which contains ruminant faeces, indicates a dominance of well preserved grass and cereal husks, which can now be linked to animal foddering practices rather than human diet.

The dominance of human faecal material is surprising considering the large amount of animals present at the site, indicated through analysis of faunal remains (Russell and Martin, 2005) and identification of animal pens and faecal spherulites in hearths and middens (Matthews et al., 1996; Matthews, 2005). Only one sample, 4477 s7, is shown to contain faeces from a ruminant species, with the value calculated for Ratio 1 (0.58) suggesting a mixture of faecal material with another deposit (perhaps the undigested plant remains present within the animal faeces).

This could suggest that animal faeces were not being deposited in the middens, perhaps because they were used as fuel, evidence of which is presented in Çatalhöyük middens through the presence of calcareous spherulites in ash deposits and partially charred animal dung (Shillito et al., 2008; Matthews, 2005). A dominance of human faecal residues has been observed in other prehistoric contexts such as the Neolithic/Bronze Age site of Sanday, Orkney, where they are suggested to have been applied to soils as manure. In this study there was also an absence of cattle or sheep manure, with the suggestion being that these were used preferentially as a fuel source (Simpson et al., 1998). However it must also be noted that this could be due to a sampling bias, as ruminant faeces may be more difficult to identify in the field due to poorer contrast with the sediment matrix.

5. Conclusions

Biomolecular analysis of organic residues in orange/yellow deposits from midden, room fill and burial contexts at Çatalhöyük has demonstrated the presence of faecal sterols in some, but not all of the deposits. In deposits identified as faeces, these are interpreted as human on the basis of sterol distributions and bile acids present. Both midden and room fill deposits contain high quantities of human faecal material, whilst yellow deposits in burials are largely plant derived.

Comparison of organic residue results with the appearance of the deposits in thin section has demonstrated that some organic remains which do not contain diagnostic inclusions, such as bone and plant fragments are, in fact, coprolites. However, some organic remains without diagnostic inclusions do not contain faecal residues.

It is also noted that some deposits contain only plant derived sterols. Comparison of the appearance of these in thin section shows the presence of pseudomorphous voids from decayed plant temper and it is suggested that the plant sterols are a result of this plant material. Plant derived sterols are also present in some of the burial samples, refuting the hypothesis that these deposits, found in the pelvis region of skeletons, are coprolites, but supporting the hypothesis of plants being included as grave goods at Çatalhöyük.

The identification of human faecal deposits in close proximity to buildings is interesting from a health and use-of-space perspective. The relative lack of herbivore faecal deposits could be a result of such material being burnt as fuel.

The comparison between microscopic and organic geochemical analyses presented here has implications for future identifications of faecal material in thin section. The results presented here demonstrate that interpretation of decayed organic remains in thin section can be ambiguous and that biomolecular analysis is necessary for the correct interpretation of such remains. However micromorphological analysis can reliably distinguish organic and non-organic deposits which may appear similar at the macro-scale.

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