Utilizing Mole-Rat Activity for Archaeological Survey:

A Case Study and a Proposal

Yair Sapir and Avraham Faust

Many studies have attempted to identify invisible archaeological sites, mainly in areas covered with dense vegetation, where remains cannot be easily identified by the naked eye (Kintigh 1988; Krakker et al. 1983; Lightfoot 1989; Nance and Ball 1986, 1989; Scheele 1990; Shott 1985, 1989). In the Middle East, the vegetation is usually sparser, and it is often assumed that visibility is not a problem (as noted, for example, by Ur 2010:40). Thus, even tiny prehistoric sites can be identified in at least some seasons (cf. Marder et al. 2011), and typical habitation sites of "historical periods," which are our interest here, are presumed to be easily identifiable (although Field and Banning 1998 and Hitchings et al. 2013 showed that this assumption is not always correct). The common survey method

ABSTRACT

Identifying previously unknown sites is a fundamental goal of the archaeological inquiry. In this article, after reporting the results of our work at Tel 'Eton (Israel), we propose a new method that can increase the effectiveness of surveys. As part of a study of site formation processes, molehills (mole-rat back-dirt hills) were systematically sifted at Tel 'Eton and its surroundings. It was apparent that the number and size of sherds in molehills on the mound greatly exceeded those found in its surroundings. The incidental identification of many sherds in molehills northwest of the mound, therefore, led us to suspect that this area was settled. This was tested by transecting the area. The finds, along with discoveries in the *wadis* cutting the plain, support this suggestion and allowed us to detect the lower city's boundary. An examination of the site's environments, moreover, enabled us to identify additional anomalies, like the co-occurrence of concentrations of sherds, red-soiled molehills, and slags, which might indicate an extra-mural workshop. Consequently, we suggest that a systematic examination of rodents' back-dirt mounds can be an effective method—faster, cheaper, and more efficient than pedestrian surveys or shovel tests—of discovering unknown sites even in regions with good visibility.

Identificar los sitios previamente desconocidos es un objetivo fundamental de la investigación arqueológica. Eneste artículo, después de informar de los resultados de nuestro trabajo en Tel 'Eton (Israel), proponemos un nuevo método que puede aumentar la eficacia de los peritajes. Como parte de un estudio de los procesos de formación de sitio, unas toperas (montículos formados por la rata topo con la tierra extraída) fueron sistemáticamente tamizadas en Tel 'Eton y sus alrededores. Aparentemente el número y tamaño de fragmentos de ceramica en las toperas sobre el montículo superaba al de los de alrededor. La identificación incidental un gran numero de fragmentos en toperas al noroeste del montículo, nos llevó a sospechar que esta zona también fue habitada. Esto fue probado transectando la zona. Los hallazgos, junto con descubrimientos en los *wadies* que cortan la llanura, apoyan esta sugerencia, y nos permitió detectar los límites de la ciudad inferior. Un examen del entorno del sitio, además, nos permitió identificar anomalías adicionales, como la coocurrencia de las concentraciones de fragmentos, montículos de tierra rojiza y escorias, lo que podría la presencia de taller extramural. En consecuencia, se sugiere que un examen sistemático de los montículos de desechos de roedores puede ser un método efectivo—más rápido, más barato y más eficiente que los peritajes pedestres o pruebas de pala - de descubrir sitios desconocidos, incluso en regiones con buena visibilidad.

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includes pedestrian survey, with varied levels of intensity (e.g., Adams 1972; Dagan 2000; Finkelstein et al. 1997; MacDonald 2004:6–7; Miller 1991; Ofer 1993; Zertal 1992–2005). Other field methods (excluding remote sensing)[1] of discovering sites, and especially methods to study the subsurface that are common in other parts of the world, have not received much scholarly attention.[2] In cases where "advanced" methods of site discovery are applied, modifications are made in order to make it suitable for the local conditions. For example, while shovel testing was originally developed in North America as a means to identify sites in low-visibility areas, it was adopted in Israel in a completely different manner as a method to improve the dating of already known sites and to advance the understanding of the occupation history of the various parts of the sites (following Portugali 1982; e.g., Leibner 2009; for comprehensive discussion, see Faust and Katz 2012).[3]

This paper evolved from a more comprehensive study of site formation processes in Tel 'Eton, in which we studied the effect of bioturbation on the movement of archaeological artifacts, mainly of sherds, on the mound itself and surrounding area. For that purpose, we examined hundreds of molehills that were piled up on the surface in various areas on the *tell* (mound) and on the hills surrounding it. Unintentionally, the results led us to develop a method for utilizing bioturbation activity, which is basically no more than a disturbance to the archaeological record, to enhance the quality of surveys even in areas of seemingly high visibility and to reveal features that are buried below the surface and are not identified in common pedestrian survey methods. Consequently, in this article, we would like to offer a simple and quick method that can improve the quality of archaeological survey and its accuracy, not only in regions where low visibility poses a problem, but also in areas where the problem is regarded as relatively minor. The procedure suggested below can be applied, with appropriate modifications of course, to most regions of the world where bioturbation caused by rodents is frequent.

BACKGROUND

Tel 'Eton is a large archaeological site (ca. 6.6 ha) in the southeastern *Shephelah* (lowland), Israel. The site is located some 11 km southeast of Tel Lachish, on the southern bank of the Nahal Adoraim streambed (Figure 1). The mound was briefly excavated in 1977 by the Lachish expedition (Ayalon 1985; Zimhoni 1985) and is currently being excavated by an expedition from Bar-Ilan University. The results (Faust 2009, 2011, 2014; Faust et al. 2014; Faust and Katz 2015) indicate that the site was settled already

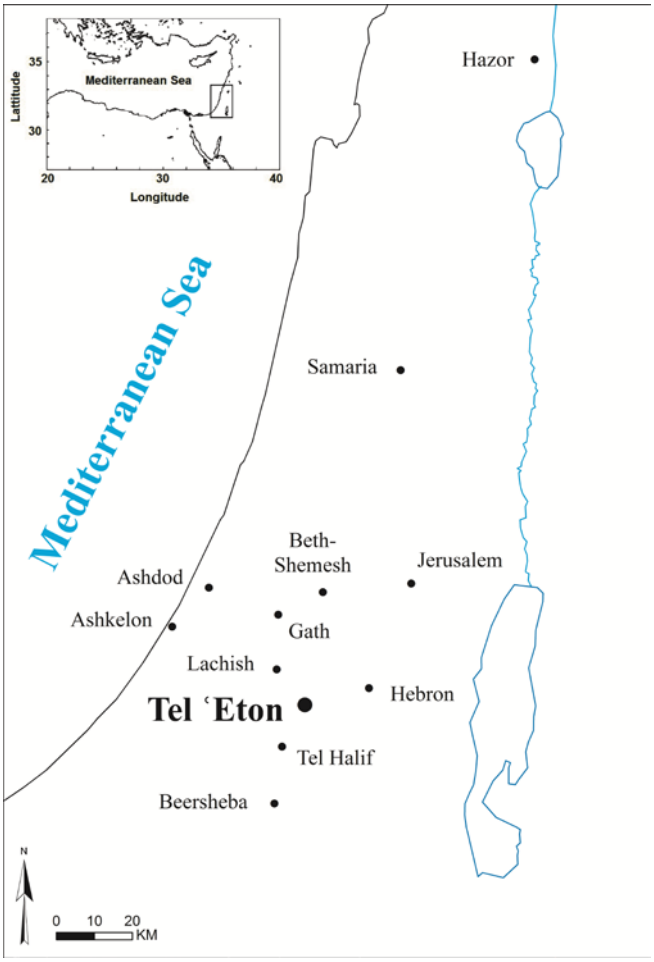


FIGURE 1. Location map of Tel 'Eton and environs. Inset map shows the site's location in relation to the Mediterranean Sea.

during the Early Bronze Age (third millennium B.C.). After a settlement gap in the late third millennium B.C. (Intermediate Bronze Age) and perhaps even during the first half of the second millennium B.C. (Middle Bronze Age), a town was established on the mound in the Late Bronze Age. This Canaanite town apparently shrunk in size during the Iron Age I (late second millennium B.C.), but was later expanded again, and it eventually became a central town in the kingdom of Judah. This town was devastated in the late eighth century B.C., probably during the campaign of Sennacherib, the Assyrian king, in 701 B.C. (see also Katz and Faust 2012). Despite some short-lived attempts at resettlement, the mound was abandoned until the fourth century B.C., when a fort and a village were built on the *tell*. Those existed until the third century B.C., when the mound was finally abandoned (see also Faust et al. 2015).

As part of a comprehensive research study of site formation processes in Tel 'Eton and its surroundings (Sapir, Avraham, and Faust 2016; Sapir, Pariente, Sapir, Katz, and Faust 2016), we tried to reconstruct the way in which the current surface of the site (and archaeological *tells* in general) were created, and how sherds and other artifacts that originate in archaeological layers deep below the current surface find their way to the topsoil. For

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TABLE 1. Summary of the Results of Molehill Sifting.

		Sherds per Molehill		Average Sherds Size[a]	
	Sample Size (n)	μ	s	μ	s
Mound	80	9.2	4.8	2.7	1.0
Surrounding (Units A-D)	98	3.2	2.9	2.3	1.0
Unit E[b]	25	9.1	5.7	2.3	1.0

[a]Dimensions in cm (only artifacts larger than 5 mm were collected).

[b]The numbers of sherds in this unit are significantly ($t = 5.07$, $df = 27.37$; $p < .001$) higher than in the other units (A–D) outside the Mound, and are very close to the numbers on the Mound itself ($p = .96$). However, the size of the sherds in Unit E is significantly ($t = -6.09$; $df = 406.80$; $p < .001$) smaller than the size of the sherds found on the mound and is very similar to that of units A–D ($p = .51$). Therefore, we treated Unit E separately.

this purpose, and in order to get a better understanding of the mechanisms that cause upward movement of artifacts (mainly sherds) to the surface, some experiments and tests were conducted, including systematic examinations of molehills.

Some research has addressed bioturbation processes in archaeological settings (for example, Balek 2002; Blackham 2000; Bubel 2002; Erlandson 1984; Wood and Johnson 1978), but only rarely has the subject been utilized for traditional archaeological field purposes, e.g., for defining sites or for dating (for an exception, see Johnston [2002]; see also Banning [2002:73]). The assemblages unearthed in rodents' back-dirt hills have been occasionally mentioned in studies, but usually not systematically or in conjunction with the finds of digs or surveys (e.g., Becker and Roulette 2008; Boula 2009; Burger 2002; Gause and Gerike 1997; Ludwig 2013; Minor 2005; Nicholson 2011; Robbins-Wade 2003; UC Berkeley Physical & Environmental Planning Capital Projects 2013). In the Near East, Kaplan (1958:151) reported the finding of ashy material and high concentration of small artifacts in molehills. Bruder (1982) studied the vertical movement of flints within molehills and cracks, and Więckowski et al. (2013) combined the finds in porcupine back-dirt hills with those of a dig to delineate the boundaries of a cemetery.

In the research area, the blind mole-rat (*Spalax ehrenbergi*) seems to be the most dominant rodent among those that can directly move relatively large artifacts, and it was therefore the focus of this study. The mole-rat is a rodent that lives and forages in underground burrow systems (Heth 1989; Nevo 1961; Zuri and Terkel 1996). The ecology and the burrowing patterns of the mole-rat are adjusted to the climatic conditions and are affected by the soil properties (e.g., grain-size distribution, bulk density) and fertility in terms of roots biomass. Its population density is about 2.5–7.7 individuals per 1000 m^2 (Heth 1989), and its main burrowing activity is carried out during the winter (November to April), when the soil is wet. Most of the tunnels are horizontal, at depths of 10–40 cm below the surface (Heth 1989; Zuri and Terkel 1996), and are used for foraging purposes. During the spring (April to early June), the mole-rat burrows deeper tunnels, up to a depth of 150 cm, for other purposes such as nesting (nest depth varies greatly, and in some cases nests might be located above ground level). During the summer the burrowing activity almost stops, most of the feeding tunnels are abandoned, and a new tunnel system will be burrowed in the following winter (Heth 1989; Heth et al. 1989; Nevo 1961; Zuri and Terkel 1996). The back-dirt material from the burrowing is usually taken upwards in short vertical tunnels and creates small piles on the surface around the opening of the tunnel; the feeding tunnels create smaller hills compared to deeper burrowing activities. The material (soil and artifacts) that ends up in each back-dirt mound can arrive from an average horizontal distance of $\mu = 1.3–3.1$ m within the subsurface (depending on the conditions; Heth 1989; Zuri and Terkel 1996). The size of the small artifacts that are moved to those piles and left in the activity zone is limited by the diameter of the tunnel, ca. 7 cm (Bruder 1982; Heth 1989).

During the 2014 excavation season at Tel 'Eton, we examined a total of 229 molehills on the mound and in its surroundings. The molehills were selected during pedestrian survey in an attempt to arrive at a uniform coverage of each examined unit (described below), and not all molehills were examined. We sampled only back-dirt hills of feeding tunnels (and not the larger nesting back-dirt piles), and all samples were therefore of a similar volume (more below). All material associated with each molehill was sifted through a 5-mm mesh. Although other types of finds, for example glass, were collected, only pottery sherds were numerous enough to allow any quantitative analysis. Every sampled molehill location was recorded by GPS, and the data were processed in a Geographic Information System (GIS), utilizing ESRI ArcMap. Later on, in the laboratory, the sherds (larger than 5 mm) were counted and measured for their largest axis with a millimeter ruler.

Initially, we examined 80 molehills on the southern/upper part of the mound. Subsequently, as part of the effort to understand the formation of the environment of Tel 'Eton, and following the assumption that some of the surrounding soil is of an anthropogenic source and was partly taken from the mound (Dagan 2014:91; Faust 2011:222; Faust and Katz 2012:179–180), we decided to perform the same examination in the mound's environment (see Figure 2 for unit locations).

Some interesting patterns emerged from the results. On the mound, not a single molehill sampled was found devoid of sherds. The average number of sherds in a molehill was $\mu = 9.2$, and the average size was $\mu = 2.7$ cm (Table 1).[4] The mound's environment was divided, and five units (A–E) were studied separately. As was expected, the mound and its environment represent significantly different groups, both in the number ($t = 9.71$; $df = 124.75$; $p < .001$) and the size of the sherds ($t = 7.88$; $df = 749.98$; $p < .001$), with but one exception—Unit E (Table 1), which will be discussed later. In Units A–D the average number of sherds per molehill was $\mu = 3.2$, and the average size of the

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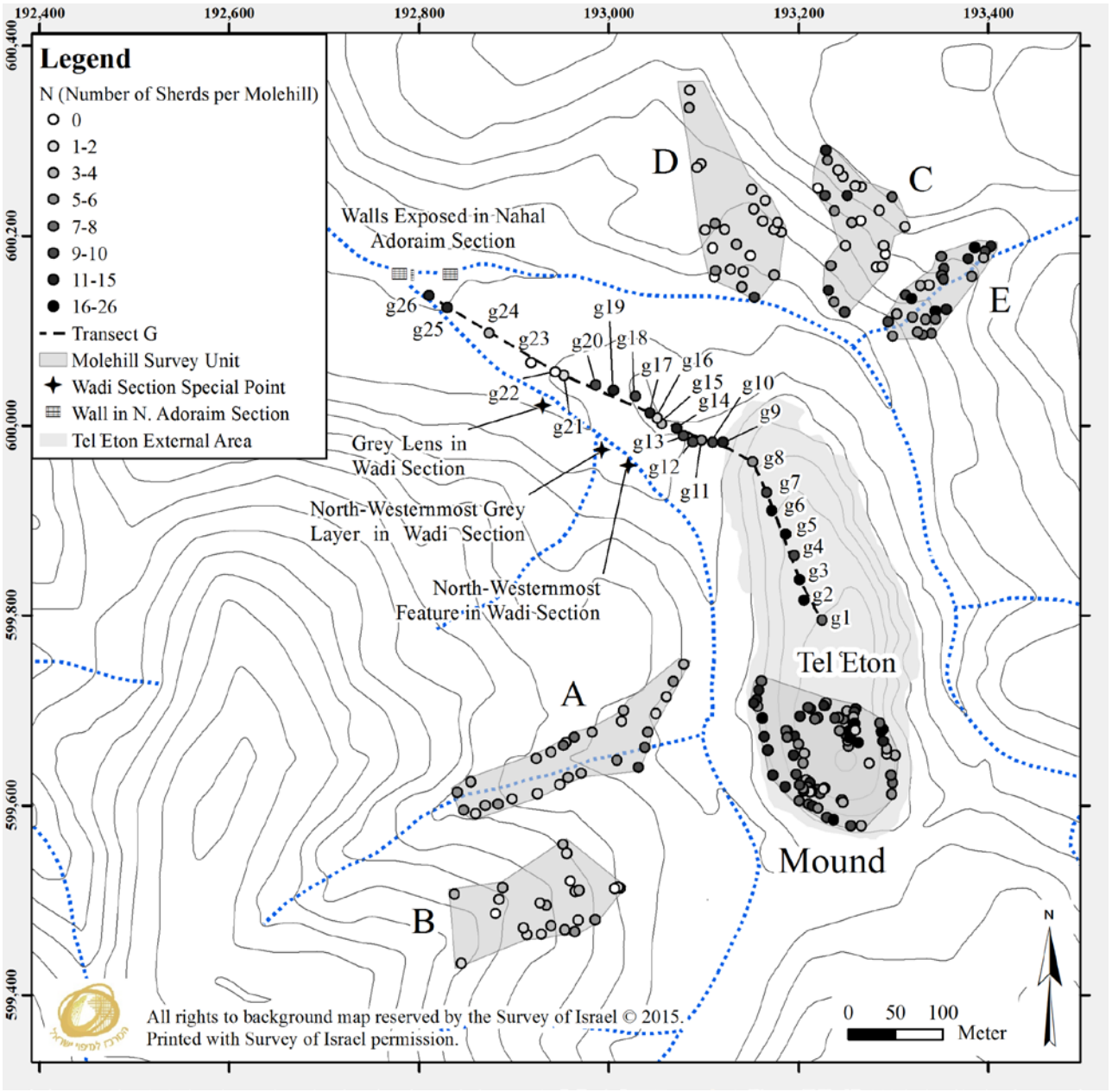


FIGURE 2. Sampling map (survey units and points). Mound: Area sampled on the southern/upper part of the mound (n = 80 molehills; 1.7 ha); (a) valley to the west of the mound (n = 27; 1.2 ha); (b) hill slope to the southwest of the mound (n = 23; 1.3 ha); (c) hill slope to the northeast of the mound (n = 24; 1.0 ha); (d) valley to the north of the mound (n = 24; 1.4 ha); (e) valley to the northeast of the mound (n = 25; .6 ha); Transect G (g1–g26): on the northern slopes of the mound and the plain to its northwest (dashed line). The coordinates are according to Israel Transverse Mercator (ITM), commonly referred to as the New Israel Grid. All rights to background map reserved by the Survey of Israel © 2015. Printed with permission from the Survey of Israel.

sherds was μ = 2.3 cm (some of the molehills in these areas were even devoid of any finds whatsoever). Whether an average of μ = 3.2 sherds per pile is high when compared to an area that is farther away from human settlements will be discussed elsewhere. However, the above-mentioned results clearly show that there is a significant distinction between the mound and its surroundings as far as the number of sherds and their size are concerned.

MOLEHILLS AND THE LOWER CITY

During the 2014 excavation season, we re-measured the area of the *tell* and, for that purpose, we encircled the mound, walking along the border between the sharp slopes of the mound and the plain around it with a hand-held GPS. Subsequent to the above-mentioned survey of molehills, we were naturally attracted to these small hills, and although we did not examine

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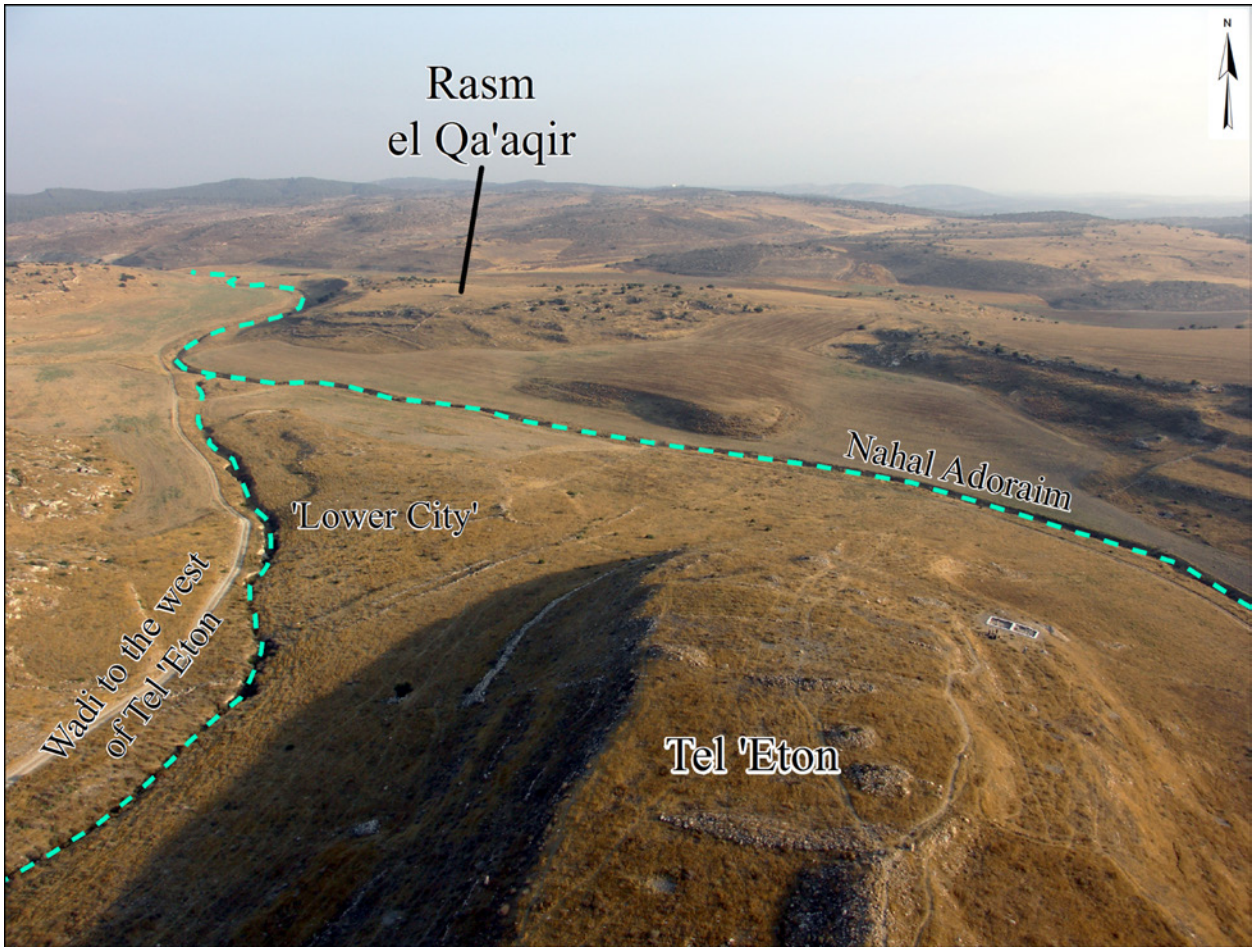


FIGURE 3. Aerial photograph of Tel 'Eton (its northern part) and its surroundings, looking north in summer 2006. Photographed by SkyView Photography Ltd.

them systematically, we identified a relatively high concentration of sherds in one area, even without sifting the soil. No archaeological remains had been reported in this intensively surveyed area before (see Dagan 2006), although it is located immediately to the northwest of the mound, in a triangular plain, bounded by Nahal Adoraim and the *wadi* (streambed) to the west of the site (see Figures 2 and 3). The location of the randomly identified concentration of sherds negates the possibility that the sherds could have arrived from the mound by natural processes like erosion (Rosen 1986), leading us to speculate that this area may have been settled—perhaps as a lower city of the mound. Since the study of the molehills triggered this speculation, and since we already knew that at least in some cases we can differentiate between the site and its surroundings on the basis of the number and size of sherds unearthed in those piles, we decided to implement this method systematically in an attempt to learn about the reality of this area. For this, we transected the area from the top of the mound, through the slopes and the above-mentioned plain, to the *wadis* meeting point farther north (Transect G, samples g1–g26 in Figure 2).

The results (Figures 2 and 4; Table 2) reveal a very clear pattern, even without applying any statistical analysis: Samples g1–g9, which are located within the northern slope of the mound, had very high concentration of sherds (μ =14.1), even when compared to the samples taken from the top of the Mound (μ = 9.2, see Table 1).[5] Samples g10–g20, taken from outside the mound, exhibit a decrease in the number of sherds (μ = 8.9), yet this concentration is still similar (given the small sample size) to the values of the mound samples. Samples g21–g24 are four consecutive samples with very low values (0–4 sherds), which are clearly distinct from samples g10–g20 (Mann-Whitney test, Z = 2.64; $p < .01$). This is followed by samples g25–g26, which, again, exhibit a high concentration of sherds (n = 13–15). The high concentrations of sherds that were found in samples g10–g20 seem to support our suggestion that this area was settled, and that there was some kind of a lower city there. The sharp decrease in samples g21–g24 seems to indicate the boundary of the settled area; the sharp increase in samples g25–g26 probably relates to another settlement and will be discussed below.

As a result of our new interest in the plain to the northwest of the site, and in tandem with the above-mentioned transect, we inspected the *wadi* that bounds the estimated lower-city area from the west. The floods of winter 2013–2014 exposed various features such as walls, floors and pottery vessels in the *wadi* banks (Figures 5 and 6). Also uncovered, on top of the well-distinguished natural brown soil, were continuous layers that,

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TABLE 2. Results from Sifting the Molehills of Transect G.

Sample	Sherds per Molehill	Average Sherds Size[a]
g1	8	2.0
g2	21	2.5
g3	16	2.2
g4	10	3.1
g5	19	2.6
g6	23	2.9
g7	9	2.5
g8	6	2.9
g9	15	2.6
g10	9	2.1
g11	6	1.9
g12	10	1.9
g13	10	2.4
g14	11	2.3
g15	4	2.4
g16	2	1.6
g17	12	1.6
g18	10	2.0
g19	14	2.3
g20	10	2.1
g21	2	1.9
g22	0	-
g23	0	-
g24	4	1.9
g25	13	2.1
g26	15	4.1

[a]Dimensions in cm (only artifacts larger than 5 mm were collected).

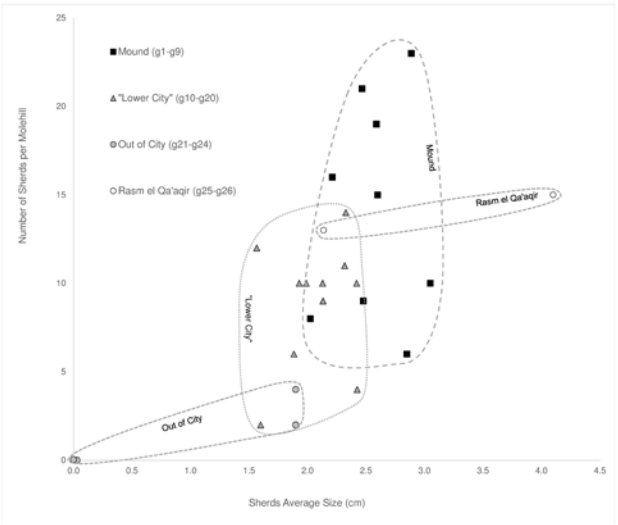


FIGURE 4. Scatter plot showing the average size and number of the pottery sherds that were sifted from the molehills of Transect G, divided into subgroups. For the location of Transect G and the various molehills, see Figure 2. For the data, see Table 2 and discussion in the text.

given their gray color (Sapir, Pariente, Sapir, Katz, and Faust 2016), appear to be anthropogenic. It is interesting to note that the zone in which the number of sherds was very low (samples g21–g24) appears to be topographically beyond the farthermost features that are seen in the *wadi* section (Figure 2). These observations also support the existence of a lower city (as well as its approximate border).

The increase in the number of sherds in samples g25–g26, following the "sterile" zone of samples g21–g24, can be explained by the existence of Rasm el Qa'aqir to the north of Nahal Adoraim (see Dagan 2006:Site 729). Dagan's survey locates the site on the hill itself, whereas we found (in addition to the pottery) exposed wall remains in the northern section of the streambed, near its meeting with the *wadi* to the west of the *tell* (Figures 2 and 7). The finds imply that the current streambed is not the original one. It can be assumed that the original course was slightly more to the southeast, near the relatively sterile zone, and that the location of samples g21–g24 was northwest of the lower city's boundary. If so, the course apparently changed at a later stage, either artificially or naturally, and the new route cut through the extant walls of Rasm el Qa'aqir. The full reconstruction of this scenario is outside the scope of this paper, but it appears that all lines of evidence point to the existence of a lower city below Tel 'Eton and enable us to partially delineate its boundaries. Since rims were few and small, we could not use them for dating, but given that Rasm el Qa'aqir was settled until the Early Islamic period (i.e., much later than the mound) we examined the assemblages unearthed in the Transect G molehills for "late" (Byzantine or early Islamic) ribbed body sherds. Although more such sherds were found in molehills g25–g26 than in the other molehills, the difference was insignificant (perhaps due to the small sample size).

SURVEY IN UNIT E

As already hinted above, high concentrations of pottery sherds were found in Unit E, located northeast of the mound (Figure 2; Table 1). The numbers of sherds in this Unit are significantly (t = 5.07, df = 27.37; $p < .001$) higher than in the other units (A–D) outside the mound, and are very close to the numbers on the mound itself (see Table 1). However, the size of the sherds in Unit E is significantly (t = -6.09; df = 406.80; $p < .001$) smaller than the size of the sherds found on the mound and is very similar to that of the sherds found in Units A–D (see Table 1). Unit E, therefore, is a sort of intermediate zone, whose concentration of sherds is similar to that of the *tell*, but whose sherd size is similar to that of the surrounding units.

In addition, slags were found in some of the molehills in the lower (southwestern) part of Unit E—samples e21, e28, e31 (Figures 8 and 9). Such slags were not found elsewhere, and

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FIGURE 5. Walls remains exposed in the north-westernmost point in the *wadi* section to the west of Tel 'Eton. The picture was taken to northeast. Scale bar units are 20 cm. Photograph courtesy of Yaacov Sapir.



FIGURE 6. Walls and floors remains exposed in the *wadi* section to the west of Tel 'Eton. The northern slope of Tel 'Eton can be seen at the top-right corner. The picture was taken to northeast. Scale bar units are 20 cm. Photograph courtesy of Yaacov Sapir.

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FIGURE 7. Wall remains in the north bank of Nahal Adoraim streambed, near its meeting with the western *wadi*. Note also the monolith lying in the streambed. The picture was taken to north. Scale bar units are 20 cm. Photograph courtesy of Yaacov Sapir.



Figure 8. Slags discovered from sifting in Unit E.

this concentration is not likely to be a coincidence. Moreover, in samples e21, e28, e29 (Figure 9), also taken from the lower part of Unit E, the earth in molehills was redder than the rest of the Unit E area; this color difference could be seen clearly in piles that were not rain-washed. The color range of these samples was Munsell 7.5YR4-5/4-6, while the other piles were in the color range of 10YR4-6/3-4 (Figure 10). Soil reddening might occur following heating at high temperature, starting from ca. 250°C (Cornell and Schwertman 2003:460; Gualtieri and Venturelli 1999; Pomies et al. 1998; Torrent and Barrón 2003).[6] We tend to attribute these finds to a possible workshop, whose extent can be roughly estimated by the redder soil and the slags.

Such small-sized finds would be very difficult to find through a regular survey method, but when examining the molehills, they immediately caught the eye. At any event, this finding indicates intensive activity in this area, which might explain the large number of sherds found in Unit E. The higher sherd density, the presence of slags, and the few redder soiled molehills all suggest that this Unit greatly differed from the other Units.

Our work in Unit E, however, brought up a possible drawback of the molehill sifting method. Since the mole-rat burrowing preferences are affected by parameters such as large rocks, soil texture, agricultural activity, and soil fertility (Bocek 1986; Golley et al. 1975; Heth 1989; Kimchi and Terkel 2003; Schlitter et al. 2008), there are areas in which mole-rat burrowing activity is less extensive than in others. When the activity is completely halted, the method suggested below cannot be used. We note that there was a cultivated field in the upper part of the valley (northeast of sample e1) in which no molehills were found—this part of the valley was not, therefore, sampled. The issue is briefly addressed below in the "Drawbacks and Improvements" section.

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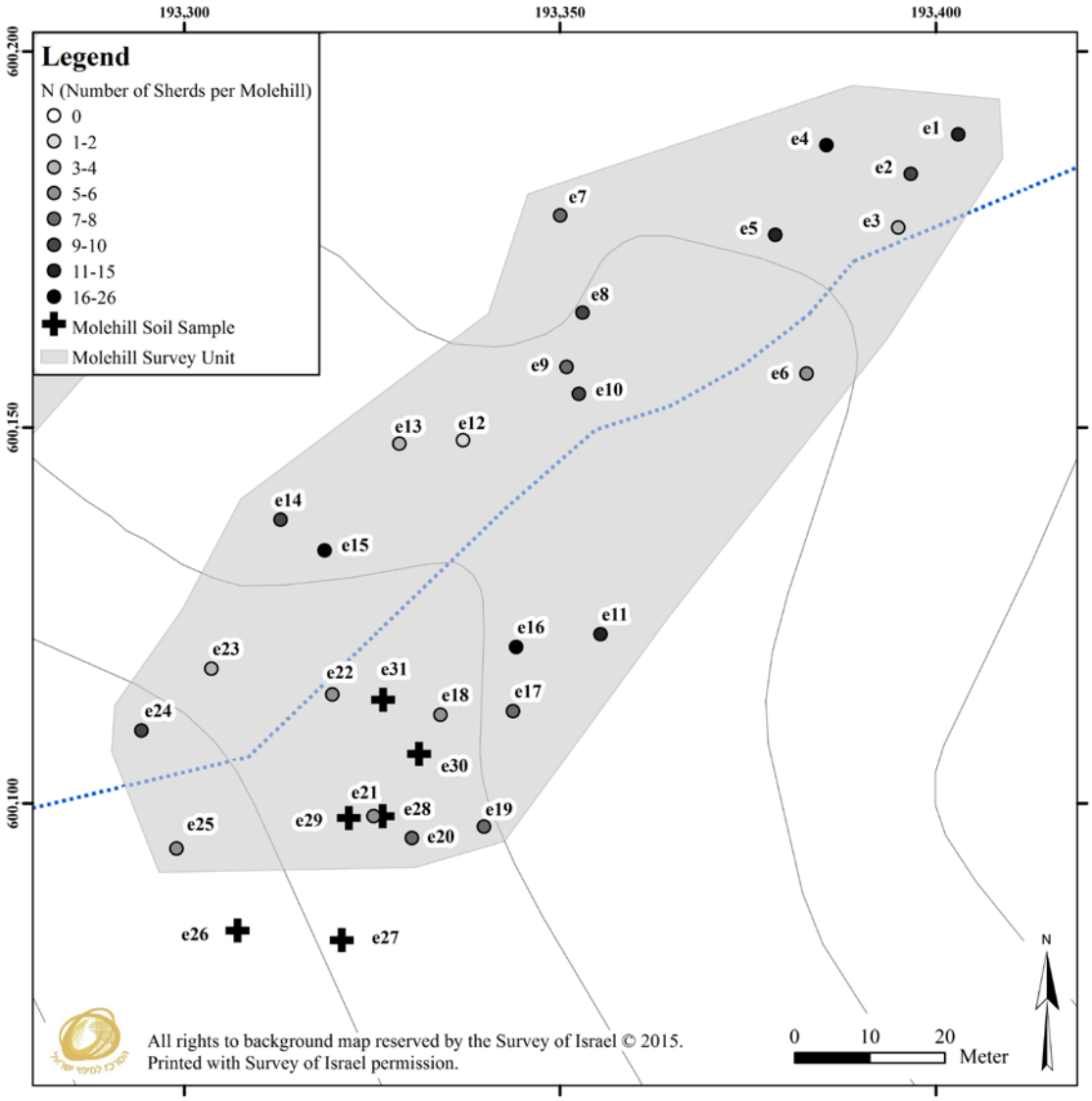


FIGURE 9. Unit E, with location of samples. Molehills e26–e31 were taken following the initial discovery of the differences in color, for the purpose of soil analysis; no sherd count was carried out there. The coordinates are according to Israel Transverse Mercator. All rights to background map reserved by the Survey of Israel © 2015. Printed with permission from Survey of Israel.

A NOTE ON THE SIZE OF THE SHERDS

Before we discuss the possible implications of the present study, we would like to comment on one pattern that stood out in the above discussion and that we believe is indicative of the post-depositional processes the region went through.

The results show that, statistically, the sizes of the sherds on the mound are significantly larger than their sizes in the surrounding Units—on the *tell*, the average size is $\mu = 2.7$ cm, whereas in Units A–D the average size is $\mu = 2.3$ cm, and this is also the average in Unit E (Table 1). The findings of Transect G (Figures 2 and 4; Table 2) show a similar pattern, where the samples that are included in the mound area (g1–g9) give an average size of $\mu = 2.6$ cm, and the samples from the lower-city area have an average size of $\mu = 2.1$ cm. It seems that there are two groups—on the mound, the average sherds size is around $\mu = 2.6$–2.7 cm, whereas outside the mound the average size is $\mu = 2.1$–2.3 cm. This might imply that the two groups went through different processes. One possible explanation for this difference might be that the surroundings of the mound went through more intensive tillage that continuously broke and wore down the sherds in the topsoil. The *tell* went through tillage too, but this is true only in part of its terraces (Faust and Katz 2012). Moreover, the tillage on the mound is assumed to be of a lesser intensity because it is much harder to bring heavy tillage equipment to the top of the mound than to the low valleys in the surroundings. Therefore, and despite the above-mentioned reservations, we tend to relate the difference in the sizes of sherds to the intensity of agricultural activities.

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DISCUSSION: MOLE-RATS AND SURVEYS

In the Middle East in general, and in Israel in particular, the accepted survey method is pedestrian survey, either selective, intensive, or a combination of both (e.g., Finkelstein et al. 1997; MacDonald 2004:6–7; Miller 1991; Ofer 1993; Ur 2010; Zertal 1992–2005). The general assumption (as observed for example by Ur [2010:40]), even if implicit, is that the visibility is good and there are no difficulties in identifying habitation sites, at least during some seasons (for exceptions, see Field and Banning [1998]; Hitchings et al. [2013]).[7] This paradigm is so dominant that when the shovel testing method, originally designated to identify sites in low-visibility areas (Kintigh 1988; Krakker et al. 1983; Lightfoot 1989; Nance and Ball 1986, 1989; Scheele 1990; Shott 1985, 1989), was introduced, it was usually used not for its original purpose (for exceptions, see Banning 1996; Field and Banning 1998) but for improving the dating and getting better resolution of the history of different parts of known sites (following Portugali 1982; e.g., Leibner 2009; for comprehensive discussion, see Faust and Katz 2012). However, the findings of this research show that even in regions with high visibility, a method for identifying buried sites that are not discovered in a pedestrian survey might be useful, and it seems that despite its limitations (see more below), there are advantages to using the molehill sifting method for identifying sites and their borders.

The main burrowing activity of the mole-rat, the feeding tunneling, creates a mixture of soil and small artifacts in the back-dirt hills. These soil components and artifacts are limited in their size due to the diameter of the tunnels, ca. 7 cm for the mole-rat. The burrowing is mainly horizontal, and the material reaches the surface from a tunnel segment located between two adjacent piles in average distances of μ = 1.3–3.1 m, and from depths of 10–40 cm (Heth 1989; Zuri and Terkel 1996).[8]

Notably, the mixing and random properties that are inherent in the activity of fossorial mammals such as the mole-rat can at least partially solve the difficulties in achieving representative samples. The assemblages created by the burrowing activities of rodents were rarely studied in the Near East as part of an archaeological inquiry (Blackham 2000; Bruder 1982; Więckowski et al. 2013) and never as part of a method to identify sites or even to identify the boundaries of the studied sites (cf., Nicholson 2011; Więckowski et al. 2013). Moreover, although it is used more often in other regions, this is not usually done as part of a systematic survey method but only in addition to a pedestrian survey in low-visibility areas (e.g., Becker and Roulette 2008; Boula 2009; Burger 2002; Gause and Gerike 1997; Ludwig 2013; Minor 2005; Robbins-Wade 2003; UC Berkeley Physical & Environmental Planning Capital Projects 2013).

A systematic examination of the finds in molehills, however, is a quick survey method: in our study a single surveyor covered each survey unit in the mound's surroundings (each with approximately 25 samples) in about four to five hours; on the mound, where more samples were taken, it took a single surveyor about 15 hours to cover the entire area (80 samples). Later, in the laboratory, the counting and measuring of the sherds from the various units (with the exception of the mound) took another hour at most per unit. Shovel tests, which might be regarded as a similar source of information on the subsurface, are far more time consuming.[9] Thus, meticulous shovel testing was carried out in 2006 in Tel 'Eton (Faust and Katz 2012), and 39 1-x-1-m squares were dug to a 20 cm depth. The fieldwork took 10 days, eight hours gross (about seven hours net), a day. The survey group consisted of a crew of two people working six days, and four people working four days. The time dedicated to this quite small number of test squares was quite long. To make the comparison of the fieldwork more explicit, while a single surveyor can examine (and sift) about 25 molehills covering a topographical unit of some 0.6–1.4 ha (see details in Figure 2) in four to five hours, this is the approximate length of time that it will take a team of two (!) surveyors to excavate and sift only two 1-x-1-m squares. To summarize a different way, as far as person field days are concerned, molehills covering an entire topographical unit can be surveyed in the same time that it takes to excavate one shovel testing square. This exemplifies the advantages of sifting the molehills, which produces much more comprehensive data in much less time and with far less effort.

Drawbacks and Improvements

One possible drawback of the method is that its usefulness is affected by the aforementioned preferences and subsequent burrowing patterns of the mole-rat in various environments. For example, on the basis of previous studies, we expect the mole-rat to be more active in soils with higher food availability and lower clay fractions (Heth 1989) and less active in agricultural soils (Golley et al. 1975; Schlitter et al. 2008). However, it is possible that working during a different season (e.g., after the winter and before the fields tillage) would provide data for cultivated areas too (our survey was conducted in the summer, after the harvest). One should be familiar with these preferences and deal with them, but it is important to note that they do not disrupt random sampling in areas in which the mole-rat is active. Moreover, the preferences of the mole-rat might sometimes be useful for extracting more information about the survey unit, such as the soil properties, buried large rocks, etc. Thus, it is likely that areas with large buried buildings and rocks will hinder the activity of mole-rats, and if an area without molehills can be identified within an area where cultural deposits are frequent (based on the molehills in the surrounding area, and perhaps other lines of evidence) one may suspect that perhaps a large building (a palace with a podium, a pyramid, etc.) is buried there (cf. Johnston 2002, and below).

In addition, we should note that the small number of typologically datable rims uncovered during this project does not allow chronological discussion, and in this respect the proposed method cannot replace the common pedestrian survey, and more samples will be required for this purpose. We think it is important to note, however, that even 1-x-1-m shovel tests do not supply sufficient data for dating, although, due to their higher volume of earth, they do provide more information (e.g., sherds) than molehills (Faust and Katz 2012). Still, the molehill sifting method can identify loci of human activities, and once those are identified, other methods can be used to date them.

Notably, we did not systematically measure the volume of the molehills as part of our protocol (more below). It must be stressed, however, that the volume of molehills cannot account for the different finds in the site and its surroundings because

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FIGURE 10. Molehills in hue of 10YR (encircled in the lower part) and in redder hue of 7.5YR (encircled right next to the figure in the upper part).

differences were observed not only in the number of sherds (which can be affected by the volume of the molehills), but also in their average size (which is not affected by the volume). At any event, we subsequently examined the volume of 22 molehills on the mound and 22 in Unit B, and while there was a difference in the average volume of molehills (μ = 2.8 liter, s = 1.2 on the mound, and μ = 2.2 liter, s = 1.1 in Unit B) it was far too small to account for the high difference in the number of sherds uncovered in each area (and, as mentioned, it cannot account for the difference in their size).

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Additional drawbacks relate to the shallowness of the mole-rat feeding tunnels and to their diameter, which limit the finds to ca. 7 cm. While one should be aware of these limitations, they do not influence our ability to use molehills to identify sites or other loci of human activity. We also have a few recommendations for improving future work. One may study additional types of finds, not systematically addressed in this paper, like flints and bones. Additionally, and although it did not prove crucial in this case (above), we suggest that the volume of each molehill be examined and recorded (alternatively, one may collect only a standardized volume from each molehill). Naturally, not only can other types of burrowing animals be studied, but future research can also examine different types of activities of mole-rats, e.g., their deeper nesting back-dirt piles, which were not studied here. Thus, in the future, we hope to carry out a much broader study in order to examine the limitations of the methods, to improve data collection, and to create a more standardized protocol.

SUMMARY AND CONCLUSIONS

While originally an offshoot of a larger attempt to understand archaeological formation processes at Tel 'Eton, in which molehills were sifted systematically in order to understand how sherds were moved to the topsoil, this study not only presents the results of our fieldwork, but is also an explicit call for the systematic use of rodent back-dirt hills as part of the archaeological inquiry.

The understanding that the identification of sherds in molehills can be used to distinguish between the site and the surrounding areas led us to identify a lower city below the *tell*. The molehills that were examined in Transect G, from the top of the mound to the *wadi* junction to its northwest, showed that the intensity of sherds is very high on the *tell* slopes, and although it decreases in the plain to its northwest (where the lower city seems to have been located) its level there is similar to its level at the top of the mound. Moving farther to the northwest, the number of sherds declines dramatically in the very same area where the boundary of the lower city is supposed to be, according to the finds in the nearby *wadi* section. This drastic decline occurs where we suspect the original route of Nahal Adoraim marked the boundary of the lower city. Moving farther northwest along this transect, the number of sherds increased again, probably because we reached the settlement of Rasm el Qa'aqir, which existed to the north of the lower city. Not only did the transect enable us to identify the existence of the lower city and its boundaries (which, in retrospect, were confirmed by an examination of the above-mentioned section created in the *wadi*), but in this case it enabled us to identify the change in the route of the Nahal Adoraim streambed. Beyond the identification of the lower city, the study of the molehills allowed us to identify additional phenomena, such as special finds that are not usually identified in surveys, and changes in the color of the soil, which might indicate the existence of an extra-mural industry.

Recapitulating the relative advantages and disadvantages of the methods discussed, it is clear that a pedestrian survey is the cheapest and fastest method to cover large areas. This method, however, misses sites (and even large sites) not only in areas of low visibility, but also in regions where identifying sites is not considered to be a problem. Shovel tests were developed as a strategy to overcome the limitations of pedestrian surveys and to identify sites in areas of low visibility. The method suggested here, of examining molehills, shares the shovel test's virtue of enabling scholars to reach the subsurface and to identify remains of extant human activities not visible to the naked eye, but it has a major advantage over shovel tests in terms of time and speed. This new method allows scholars to cover much larger areas and to study their subsurface in a fast and cheap manner.

We therefore suggest that sifting molehills and examining the finds therein (number of finds, as well as their type, size, date, etc.) can be systematically used as an easy and quick survey method for discovering unknown sites and features. We stress that the same method can be applied, throughout the world, to the back-dirt of other rodents in which artifacts may be found (e.g., prairie-dog, armadillo, gopher, porcupine, and rabbit; Bubel 2002; Wood and Johnson 1978; updated distribution maps and burrowing patterns of various rodents are presented at the International Union for Conservation of Nature Red List 2015). The rodent back-dirt sifting method has the advantages of shovel tests, like reaching the subsurface and preventing data bias due to parameters such as the pottery characteristics that might distort the results of pedestrian surveys (e.g. Faust and Katz 2012:174). It is therefore suitable for exploring sites under low-visibility conditions, but does not suffer from the main drawback of shovel testing—the long time that such a method consumes for planning and sampling. An additional advantage relates to the large number of molehills studied over relatively large areas, which by far exceeds the possible number of shovel tests. This makes it an excellent method for studying the boundaries of sites and for identifying special features within and outside of sites—for example, special finds, such as the slags discussed above, or a negative pattern created by the lack of molehills, which might sometimes be indicative of a different type of remains. While more extensive work is needed to examine various aspects of this method and to develop a sound protocol, we would like to suggest that examining the back-dirt of burrowing animals should become an integral part of any intensive survey that aims to identify not only "sites" but also additional loci of human activity, including what may be defined as places of low-intensity activity. Apparently, we can allow the rodents do some of our work.

POSTSCRIPT

After the completion of this article, during the tenth season of excavations at Tel 'Eton in the summer of 2015, we excavated one square in the area of the suspected lower city. The excavations revealed substantial cultural remains, including parts of a well-preserved building, with a few phases (dated to the late Iron Age), along with diverse accumulations and surfaces within the structure and without it. We did not reach bedrock, of course, and we do not know how deep the archaeological deposits are, but the finds clearly validate the suggestion (initially based on the finds in the molehills) that there was a significant human occupation in the flat area to the northwest of the mound.

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Data Availability Statement

The physical and digital data reported in this paper are currently stored at the Tel 'Eton archaeological laboratory (building 508/5) at Bar-Ilan University, Ramat Gan, Israel. To access the material, please contact Avraham Faust via email (avraham.faust@biu.ac.il) or phone (972–3-635-2113).

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NOTES

1. In some instances, remote sensing methods are used to identify sites in the Middle East (e.g., Ur 2010, 2013; Casana 2014, and references), but in this article we concentrate on field methods of studying the subsurface. Remote sensing can be used in conjunction with the method suggested below and advances our ability to identify archaeological sites (see also Chase et al. 2014, for the significance of LiDAR data in areas with limited visibility).
2. Survey methods were addressed at length, especially regarding the eastern Mediterranean (see, e.g., various papers in Francovich and Patterson 2000; Pasquinucci and Trement 2000; Alcock and Cherry 2004), where many methods and techniques, including onsite and offsite surface collection, remote sensing, and even comparisons of survey assemblages and the results of excavations, were scrutinized. Still, these studies hardly employed shovel testing or other systematic means of collecting artifacts from the subsurface.
3. Visibility was addressed in details in the study of the eastern Mediterranean (e.g., Bintliff et al. 1999, 2000; Davis 2004; Mee and Cavanagh 2000; Schon 2000), but these works are not directly related to the problems addressed here.
4. When the data from the molehills in Transect G (Table 2, and below) that were inside the mound area and were examined at a later stage are added to the calculation, the average number of sherds slightly increases to $\mu = 9.7$ sherds (the average size remains unchanged, $\mu = 2.7$ cm).
5. If this concentration is not a random result caused by the size of the sample, it might be explained by gravitational processes (e.g., artifacts movement as a result of erosion and trampling) that moved sherds from the top of the mound to its lower parts. It is, therefore, not surprising that, despite this difference, the sizes of the sherds in the two areas (head of the mound and its northern slope) are very similar (more below). The difference might also be a result of the nature of the mole-rat activity in the slopes (assuming larger distances between openings, and hence slightly larger molehills, with somewhat more finds), but the issue exceeds the scope of this paper.
6. Using Fourier transform infrared spectroscopy (FTIR) analysis, after Berna et al. (2007), we did not find heating signals in these molehills, but one should bear in mind that this signal does not exist in material that was heated to temperatures of below 400°C and, furthermore, the signal might be blurred as a consequence of bioturbation and other mechanisms.
7. The identification of prehistoric sites—up to about 7,000 years ago—is more complex and is not discussed here.
8. We must note that the horizontal burrowing does not significantly blur the boundaries of "sites" (cf., Banning 2002:54; Erlandson 1984:789; Nicholson 2011; it can also be compared to long-term tillage effects, e.g., Banning 2002:73; Dunnel 1990). This is because the tunnels between every two molehills are quite short, and hence artifacts are not directly moved across large distances. In addition, where the cultural deposits are located in a different topographical or land-cover units (e.g., separation by deep *wadi*, bedrock outcrops, large buried rocks, or stone walls), mole-rat activity across the boundary is limited to start with, hence limiting the blurring of the boundaries. At any event, the mere existence of well-defined boundaries, as can be seen in the data presented in this article where different units were easily identified and demarcated (Figure 2; Table 1), clearly shows that the activity does not blur them enough to be indiscernible.
9. In theory, one might suggest that the comparison between the molehills and the shovel test pits is not appropriate, since the latter are more voluminous and hence supply more information. Still, while a 1-x-1-m square is too small to supply sufficient sherds for good dating (Faust and Katz 2012), it is far too large for our purpose of identifying human activity), and the extra volume of the shovel tests does not give them any advantage over the molehills, which, despite their more limited volume, supply enough data in order to identify human activity.

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AUTHOR INFORMATION

Yair Sapir ■ The Institute of Archaeology, The Martin (Szusz) Department of Land of Israel Studies and Archaeology, Bar-Ilan University, Ramat Gan 5290002, Israel (yairsap@gmail.com)

Avraham Faust ■ The Institute of Archaeology, The Martin (Szusz) department of Land of Israel Studies and Archaeology, Bar-Ilan University, Ramat Gan 5290002, Israel (avraham.faust@biu.ac.il)

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