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Signs of soil fertigation in the desert: A pigeon tower structure near Byzantine Shivta, Israel

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ABSTRACT

This article explores a means used by Byzantine agriculturists in the Negev in southern Israel to achieve sustainable soil improvement: pigeon manure. We found high concentrations of manure in ancient pigeon towers strewn across the Byzantine agricultural landscape, characterized by the widespread construction of terraces and dams to manage runoff and floodwater. We show that nitrogen (N), phosphate (P) and organic matter (OM), reliable and recognized indices of soil characterization used by both practical agriculturists and archaeologists, are associated with such towers. The distribution patterns of these indicators have shown congruent and significant perturbations north of the pigeon tower at Shivta. Comparisons with other ancient Levantine installations of this type suggest that the perturbations we identified are associated with a single, above-ground opening that did not survive the destruction of the tower. The door facilitated the controlled, periodical extraction of accumulated manure from inside the tower. This study supports the suggested importance of pigeon manure, evidently used to ameliorate local desert soils, and stresses the usefulness of chemical tests, traditional quantifiers of agricultural soil quality, and anthropogenic interference in identifying pigeon towers and clarifying archaeological problems in a desert environment.

1. Introduction

Agriculture in the Negev desert during the Byzantine period (4th–7th centuries CE) demonstrates the existence of professionally designed, complex agricultural systems that altered local landscapes and which involved the widespread construction of terraces and dams to control runoff and floodwater. Such farming practices during the Byzantine period have been revealed during numerous archaeological surveys conducted in the Negev desert in southern Israel (see: Kedar, 1957; Evenari et al., 1982; Haiman, 2012; Avni et al., 2012; Ashkenazi et al., 2012 and references therein). However, little is known on how soil fertility was maintained by farming communities in the Negev. A physical study aiming to date past anthropogenic influences on Negev soils (Avni et al., 2012) did not search for traces of soil amelioration. Similarly, a small-scale study of soil fertility in the Negev used conventional soil chemistry parameters, but mentioned no evidence for past attempts at manuring those soils by adding essential nutrients, e.g., nitrogen (Ward et al., 2001). In an attempt to address this problem, we studied a Byzantine pigeon tower, an isolated structure used for husbanding pigeons near Shivta, a large, ancient village in the Israel's southern Negev. Initially, we will describe some relevant aspects of the environment in which it was constructed and functioned. This will be followed by the methods used to identify pigeon towers as such, and a brief description of the role and importance of these structures.

Arable soils in the Negev, including those around Shivta, are poor in organic material and essential nutrients, notably nitrogen (Singer, 2007). In the Negev, as in most deserts throughout the world, water availability is the prime limiting factor for plant growth, while the presence of nitrogen is probably the second (Vitousek and Howarth, 1991; Sher et al., 2013). Ancient systems for the acquisition and management of water to enable agriculture in the Negev have been studied to a significant extent (e.g., Evenari et al., 1982; Bruins, 2012). However, only a few studies have reported signs of attempts to ameliorate Negev soils in ancient times

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(e.g., Bruins, 1986: 81,103; van Asperen et al., 2014; Shahack-Goss et al., 2014).

Manuring of cultivated soils to retain their fertility is an ancient, well known, universal, practice. Studies of past manuring, mostly in Europe, have shown that manuring Mediterranean agricultural soils with mammal dung was probably practiced as early as Middle-Late Neolithic Greece (Vaiglova et al., 2014). By the 1st century BCE, Roman writers discussed manuring (Fenton, 1981), indicating that this practice had become widespread in Roman agronomic practices.

Manure production in Byzantine Sagalassos (in modern Turkey) exemplifies its importance for a Levantine site contemperaneous with Shivta and within the same empire ruled from Constantinople (Baeten et al., 2012). Contemporary indigenous Bedouin from Egypt's Sinai peninsula, related to semi-nomadic populations in the Negev, have been documented as habitually using goat manure to fertilize traditional gardens (Perevolotsky, 1981). Visible traces of dung, mainly spherulites derived from excrement, have been found in Negev soils associated with various archaeological sites, possibly indicating the intentional manipulation of dung (Shahack-Gross, 2011; Shahack-Goss et al., 2014 and references therein). However, such finds in themselves do not necessarily reflect intentional manuring.

Investigation of Roman and Byzantine (4th–7th century CE) Negev farmsteads displaying evidence of herding have yielded inconclusive information on the presence of manure and the possible attempt to ameliorate soil (Evenari et al., 1982; Rosen, 1987; van Asperen et al., 2014). This ambiguity regarding fertilization of Negev soils, in conjunction with the discovery of evidence for local pigeon husbanding, has led to examinations of whether pigeon manure might have been systematically gathered and stored by the local population. Such practices, characteristic of a valuable commodity, might indicate its use in increasing the fertility of local fields (see also: Hirschfeld and Tepper, 2006; Tepper, 2007).

The efficacy of pigeon manure as a fertilizer is superior, from the point of view of the nitrogen it supplies, to that of mammals. Mammals excrete nitrogen as urine, a diluted solution of urea. Being a liquid, urine is difficult to collect, handle, and store, and the nitrogen in it is rapidly depleted by associated enzymes and microorganisms. Birds, on the other hand, excrete nitrogen as uric acid, a solid and relatively stable compound, easily handled, stored, and utilized. As with mammal dung, mentioned above, the use of pigeon manure for soil amelioration is also referred to by Roman writers from the 1st century BCE (Fenton, 1981).

Nowadays, pigeon manure is used as a fertilizer in some traditional Levantine agricultures, especially in small-scale intensive gardening (Husselman, 1953; Amirkhani et al., 2010; Ibrahim and Eleiwa, 2008). This suggests a similar role for Levantine pigeons in earlier times. The pigeon towers discovered in the Negev, and specifically in the area of Shivta (Fig. 1–2), may have served as a source of fertilizer for the local fields. Pigeon husbandry in the ancient southern Levant is presently identified mainly by architectural remains, including constructed pigeon towers and quarried subterranean installations. Some of these remains are well preserved, while others are barely recognizable ruins.

Many pigeon towers are dated to the Roman-Byzantine periods (1st–7th centuries CE; e.g., Zissu, 1995; Hirschfeld and Tepper, 2006; Tepper and Bar-Oz, 2016), and several have been found in the arid zones of the Negev desert (Fig. 1; Table 1). Pigeon towers are generally located at a distance from the inhabited area, close to the cultivable land. Their prevalence attests to the valuable economic role played by pigeons during those times, as the possible source of manure, meat, entertainment, and cultic needs. However, identifying a ruined ancient pigeon tower often relies on architectural considerations along with visible macro remains like bones and egg shells. When such remains are absent, a secure identification of a pigeon tower is currently impossible.

Studies of the effects of birds on their environment have shown that ornithogenic soils contain high amounts of phosphate (P) and organic matter (OM) (Bolter, 2011). OM and P content have been recognized as indicators of anthropogenic interference in archaeological sites (Homburg et al., 2005; Goldberg and Macphail, 2006: 344; Aderley et al., 2008). In the search for additional aids to identify pigeon towers, it has been suggested that the chemical analysis of soil associated with securely identified pigeon towers be examined in order to provide a characteristic profile with which other, less securely identified, sites could be compared.

For that purpose we focused on a securely identified pigeon tower situated near the UNESCO world Heritage site of Shivta in the Negev desert (Fig. 2). Shivta and the ancient farmlands around it have been explored since the latter half of the 19th century (See: Palmer, 1871; Segal, 1983; Hirschfeld, 2003 and references therein). The site contains remnants of 170 houses and three churches from the Byzantine period, dated to the 4th–7th centuries CE.

The ancient agricultural lands associated with Shivta include fields and dams in the Lavan Valley basin (over 197 km^2; see Kedar, 1957). They are accompanied by sophisticated systems for collecting and distributing runoff water indicative of advanced agricultural practices. Four pigeon towers have been identified within this vicinity until now, all less than one km from the settlement site, and three of them are dated to the Byzantine period (see Table 1). Like many of the pigeon towers of that period, these four were built as free standing structures, rectangular or circular in plan with an estimated height of c. 6–9 m, and containing hundreds of pigeonholes for the birds to nest (see: Netzer, 1991: 370–373, 637; Zissu, 1995; Foerster, 1995: 219–223; Hirschfeld and Tepper, 2006 and references therein).

Previous field studies of ancient Shivta have revealed extensive agricultural development in its vicinity (see: Kedar, 1957; Evenari et al., 1982; Hirschfeld and Tepper, 2006). This has led to speculation that the inhabitants utilized animal manure, particularly pigeon dung, to correct the inherent shortage of nitrogen in the local soil (Tepper, 2007). For the present study, one of Shivta's four pigeon towers was selected for further investigation (Fig. 3). This selection was based on the tower's relatively good state preservation and thus its potential for serving as a particularly informative model for verifying the connection between visible pigeon remains (e.g., bones, broken egg shells and manure) and local soil chemistry. It was reasoned that demonstrating a connection by means of such a well preserved and securely identified pigeon tower, could facilitate the identification of pigeon husbandry in other, less well preserved, sites. Furthermore, establishing a positive correlation between the presence of this tower and changes in the chemistry of the soils surrounding it could help our understanding of the role of pigeon towers and the manure they yielded for ancient agricultural systems in general.

2. Material and methods

The pigeon tower studied here was excavated in 2004 and proved to be the best preserved of the four installations in the immediate vicinity of Shivta (Hirschfeld and Tepper, 2006, Fig. 2: PT No. 1; Figs. 3–6). The circular plan structure was built on bedrock and is preserved to a maximum height of 1.2 m above ground level. Its bottom was constructed as a space to store manure by sealing the floor and the inner face of the lower walls with mortar. At its base the external diameter of the structure is 5.2 m and the wall thickness is about 85 cm. The internal space (3.5 m in diameter) is divided by a Y-shaped wall into three rooms (Fig. 4). Four rows of

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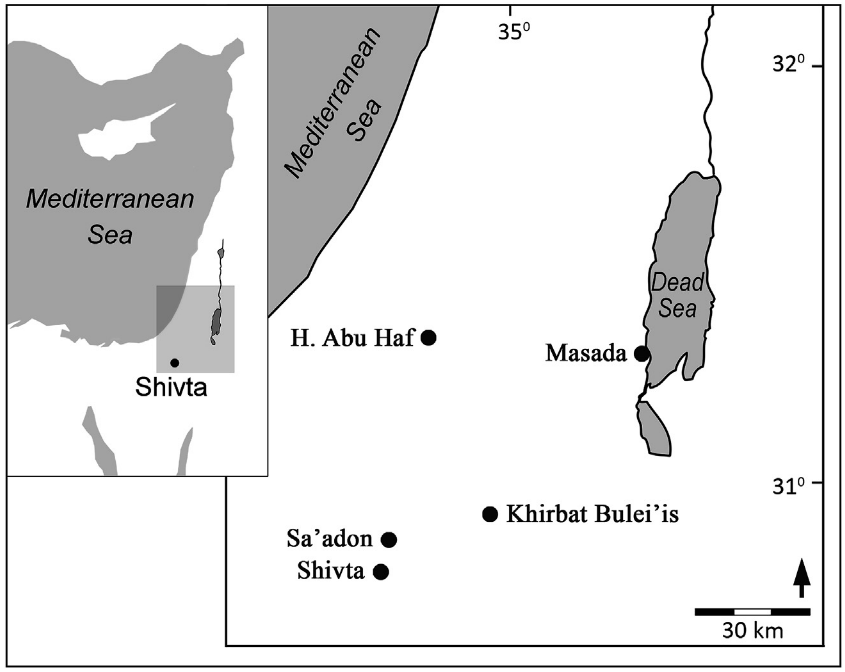

Fig. 1. Location map: Pigeon towers in the Negev, Israel (see Table 1).

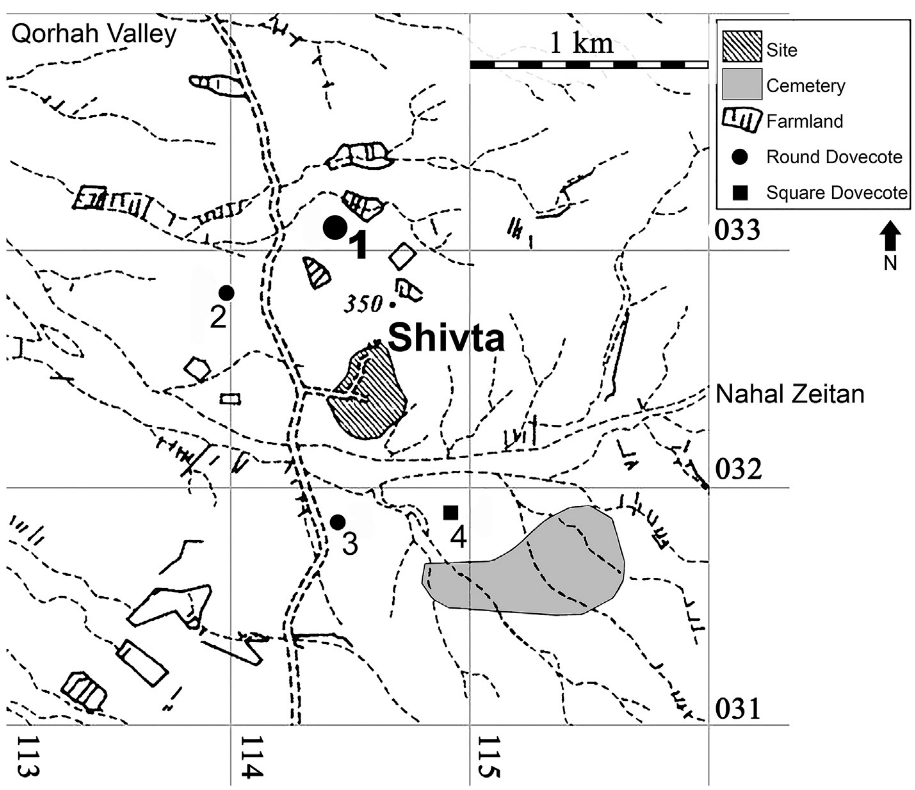

Fig. 2. The four pigeon towers in the vicinity of Shivta, including the one studied here (No. 1).

triangular nesting compartments, constructed of sun-dried mud-bricks and small stones, were preserved along the interior walls up to a height of 1.15 m above the dirt floor. On top of this floor, a layer of detritus c. 30–40 cm in depth was identified (L-814, section A-A', in Fig. 4; see Hirschfeld and Tepper, 2006). This waste layer contained pigeon bones, broken pigeon eggs, pigeon dung (Fig. 5A–D), organic material containing nesting material and seeds (Ramsay et al., 2016). The condition of the bones and the preservation state of biological finds (e.g., undamaged branches, complete manure pellets, fully preserved seeds and pigeon bones) displayed no water damage, demonstrating that no water, which might have damaged the material or washed it away, penetrated the structure.

Table 1
Structural variations in pigeon towers in the Negev Desert.

Site	PT Type	Period/date	References
Abu Haf	Round	Early Roman	Zissu 1995
Masada	Round	Early Roman	Netzer 1991; Foerster 1995
Masada	Rectangular	Early Roman	Netzer 1991; Foerster 1995
Masada	Rectangular	Early Roman	Netzer 1991; Foerster 1995
Bulei'is	Round	Byzantine	Peretz and Shaul 2011
Sa'adon	Round	Byzantine	Tepper and Bar-Oz 2016
Sa'adon	Rectangular	Byzantine	Tepper and Bar-Oz 2016
Shivta	Round	Byzantine	Hirschfeld and Tepper 2006: Building 6; See Fig. 2 No. 1
Shivta	Round	Byzantine (?)	Hirschfeld and Tepper 2006 Building 1; See Fig. 2 No. 2
Shivta	Round	Byzantine	Hirschfeld and Tepper 2006 Building 2: See Fig. 2 no. 3
Shivta	Rectangular	Roman	Hirschfeld and Tepper 2006 Building 4: See Fig. 2: No. 4

Fig. 3. Shivta: Pigeon Tower No. 1 before excavation, facing south.

Sometime during antiquity, the pigeon tower suddenly collapsed inward, as we inferred from the numerous pigeon bones, ostensibly from birds killed during the collapse, found inside. The fallen ashlars overlaying the pigeon living floor and layer of detritus, together with accumulated wind-blown sediment and the arid environment, formed a sealing layer. The abundant biological material encased beneath this sealing laying and the floor of the structure was thereby protected from environmental and human disturbances until our excavation.

A single radiocarbon dating, conducted on pigeon dung from the living floor of the tower (Locus 817), yielded a date of 550 CAL CE (Beta Analytics Sample # 92,415; Ramsay et al., 2016: Table 1). This dating correlates extremely well with the analysis of pottery found in association with the pigeon tower (i.e., 6th century CE; for more details see Hirschfeld and Tepper, 2006: 97–104).

Soil sampling points, considered to offer the greatest potential based on earlier findings, had previously been selected heuristically (Hirschfeld and Tepper, 2006; Ramsay and Tepper, 2010). One sampling point was inside the pigeon tower, just above the floor exposed by the excavation (Fig. 6; see No. 9). Eight additional sampling points were chosen outside the tower, along straight lines extending south, west, north, and east from its walls (Fig. 7). Along each line two such points were sampled about 5–10 cm below the surface, one 5 m and the other 10 m distant from the walls of the pigeon tower. Background samples were taken from arid soil c. 50 m away from the tower. We estimated that the upper surface of the soil outside the building prior to its destruction conformed with the bottom level of the fallen ashlars which were strewn along the ground adjacent to the collapsed tower. If so, the upper surface of this ancient soil was just a few cm below the contemporary surface. Soil samples, about 500 g each, were collected using a trowel that was wiped clean before each such sampling, and then packed in new paper bags, stapled, and marked.

The samples were analyzed by a commercial soil testing laboratory, certified by the Israeli Laboratory Certifying Authority. In preparation for the chemical analysis, uniform weight soil samples were dessicated in a drying cabinet at 65–70° C, and were then ground and passed through a 2 mm sieve.

2.1. Analysis

The three chemical entities analyzed – phosphorous (P), nitrogen (N), and organic matter (OM) – are routinely used by practicing commercial farmers to evaluate soil fertility. In addition, phosphorous is commonly used by archaeologists to quantify anthropogenic interference (Nielsen and Kristiansen, 2014). The phosphorous levels of our soil samples were estimated colorimetrically using a process involving hot acid hydrolyzing, followed by cooling, developing an ammonium molybdate complex color, and estimating absorbency at 880 nm (SM 4500 P E). This spectrophotometric reaction is commonly used for soil analysis in archaeological contexts using the standard extraction methods. Matrix interference and variation in extraction methods preclude quantitative comparisons of P content in different archaeological soils (Holliday, 2007). However, in our study we were interested in the *relative* quantity of P from different sampling points rather than obtaining absolute values. Comparing the current samples with other soils was beyond the scope of this study. Furthermore, the detailed method chosen was one specifically designed for manured soils (Hedley et al., 1982; step 5; Sharpley et al., 2004).

Nitrogen (N) was analyzed by the Kjeldahl method which is suitable for analyzing reduced quantities of N in organic polymeric systems, but is less efficient for analyzing oxidized forms like nitrates and nitrites. In the Negev soils, specifically, it has been reported that significant quantities of nitrogen remain for relatively lengthy periods of time in plant litter, which is slow to decompose (Zaady et al., 1996). A previous study of Negev soil also used the Kjeldahl method to estimate the quantities of N in that soil (Russow et al., 2005).

Ammonia, also detectable by the Kjeldahl method, tends to be oxidized or volatilize in the high pH of Negev soils (Zaady, 2005; Sher et al., 2013). During the formation processes of the site under consideration here, in the covered, sealed, and generally reduced environment of the bottom of the destroyed pigeon tower, N is not likely to have been oxidized to nitrite or nitrate. However, some desert soils actively accumulate these oxidized forms (Zaady,

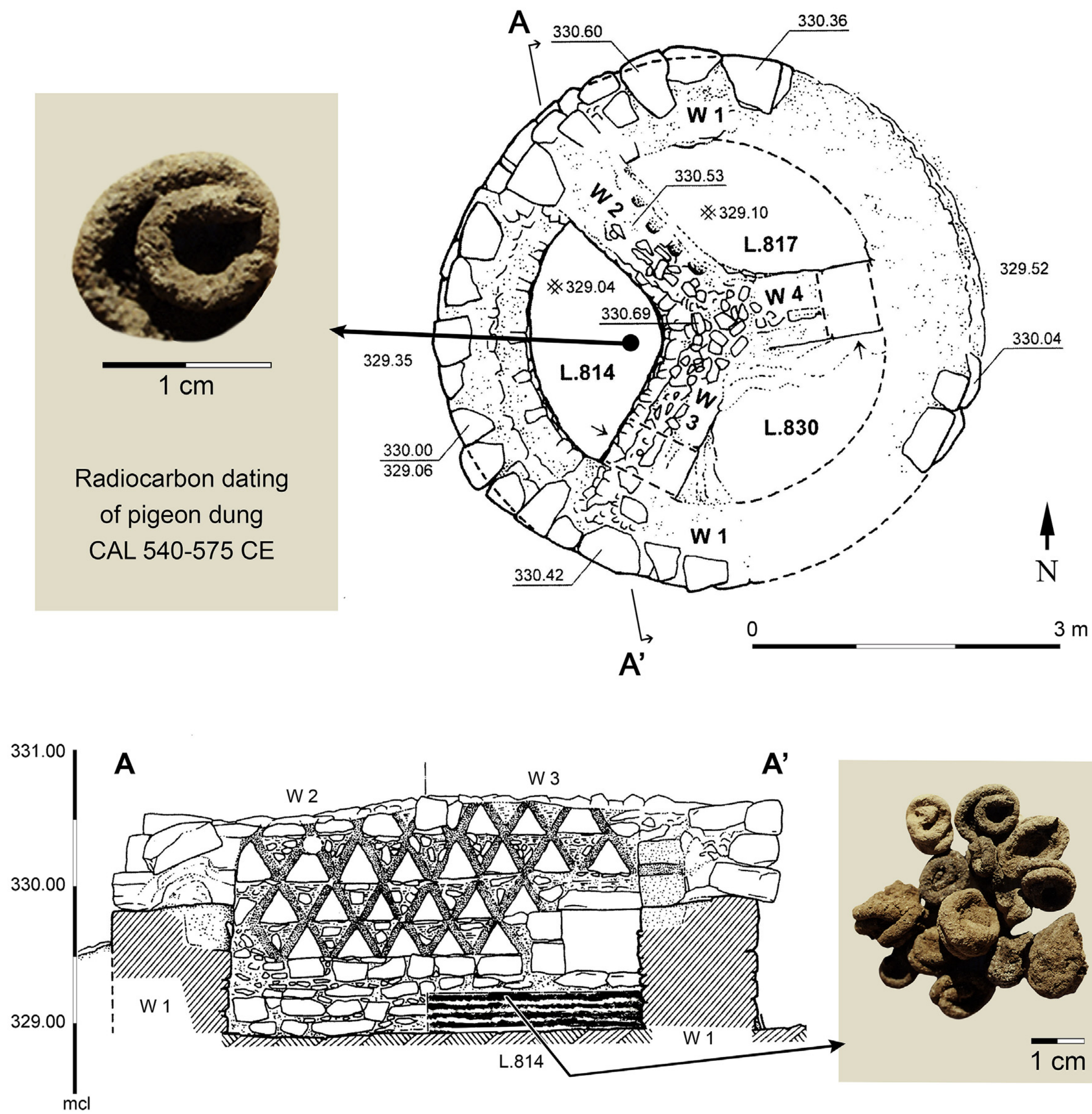

Fig. 4. Plan and sections of Pigeon Tower No. 1, including the layer of detritus (L-814) at section AA.

2005; Sher et al., 2013). If such oxidized forms did in fact accumulate *outside* the pigeon tower, we reasoned that they were probably unconnected to past anthropogenic activities, and we have therefore attempted to minimize their effect in the preset study.

Organic matter (OM) was estimated using the Walkely-Black method (Schumacher, 2002). This method determines the concentration of organic C, a major OM component, and uses an accepted factor to derive the OM content, reporting it as such. This method has a lower coefficient of variation than the often used, fast and less tedious combustion methods (e.g., Macphail et al., 2004; Milek and Roberts, 2013). A previous study of Negev soils also used the Walkely-Black method with satisfactory results, comparable to the ones reported here (Ward et al., 2001).

In order to establish a baseline against which to judge the levels of these chemical entities, we sampled 13 points from a nearby terrain, about 50–75 m distant from the pigeon tower, and not likely to have been affected by it. We used a nonparametric bootstrap technique with 10,000 replications in order to estimate the mean and 95% confidence interval for these 13 points, henceforth referred to as the background level. Any measurement in the pigeon tower samples that was above or below the confidence interval was considered significantly higher or lower, respectively, than the background level.

The analytical approach we use here has been previously applied and established across a variety of soils and climates and in various contexts, including modern, commercial and traditional family farming (e.g., Aderley et al., 2008). In particular, this approach has been used successfully to assay soil fertility and identify anthropogenic interferences in archaeological soils (Homburg et al., 2005; Goldberg and Macphail, 2006: 344). As will be shown and discussed below, this approach has proven useful here as well, in our search for pigeon chemical fingerprints in an archaeological site.

3. Results and discussion

The pigeon tower examined here was a focus of biological activity. The levels of P, N, and OM inside it were found to be significantly and substantially higher than those in the soil of the tower's

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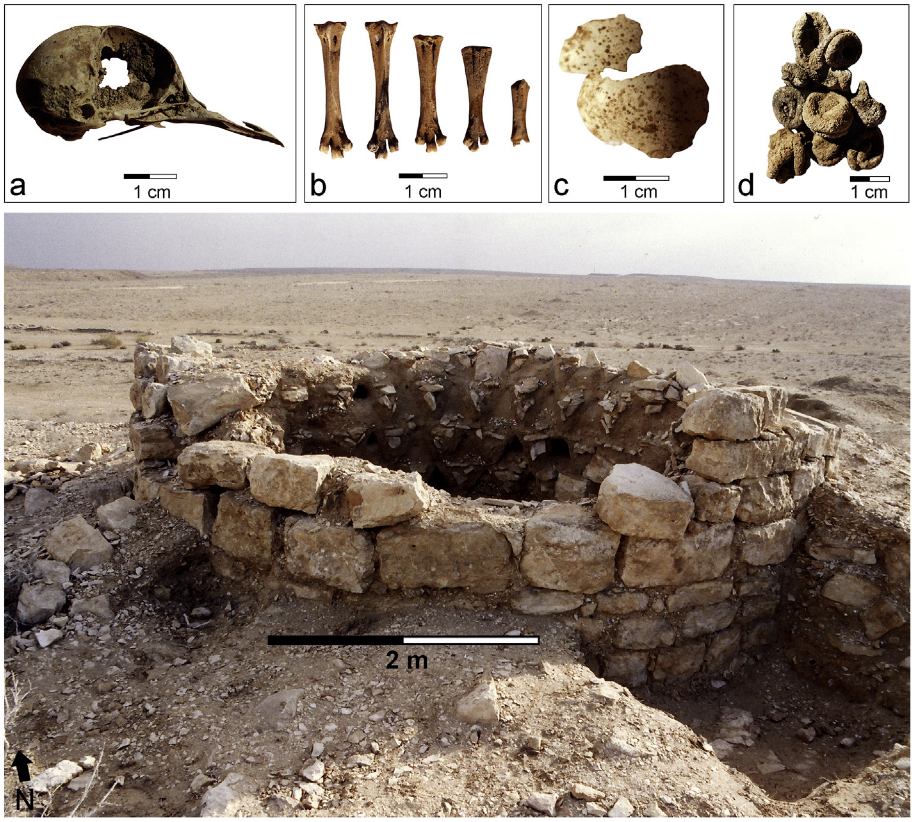

Fig. 5. Shivta: Pigeon Tower No. 1 following excavation, facing east. The finds from the layer of detritus (L-814) include: A. Pigeon skull; B. Pigeon bones; C. Pigeon egg shells; D. Pigeon dung.

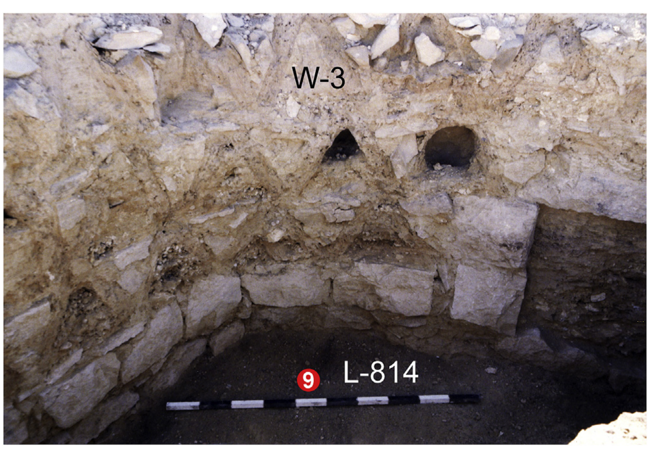

Fig. 6. Shivta: Pigeon Tower No. 1, location of sample No. 9 (L-814) on top of the layer of detritus.

immediate surroundings, as well as those of the background. The average content of OM in the immediate surrounding of the tower was found to be 0.5%, ranging from 0.38% to 0.68% (Table 2; Fig. 7). The average content of OM for the background samples is 0.3%, and most of the pigeon tower samples contain significantly more OM than that. The levels of P and N outside the tower are mostly the same or lower than the background levels, except on the north side, where they are significantly higher. For all the sampling points there is a clear association between OM and N, and between P and N (Fig. 8). A closer look at this association reveals that the sampling points closer to the pigeon tower (assigned odd numbers in Figs. 7 and 8) are highly correlated – they are arranged tightly along the regression line – while the more distant ones (assigned even numbers) are not correlated at all.

The low levels of N and P in the soil around the pigeon tower (i.e., low relative to the levels measured in northern Israel) are similar to the N and P levels in the soils of the site area and in the Negev soils in general (Ravikovitch, 1981:439–433). However, traces of the past can be discerned in the organization of the N and P concentrations around the pigeon tower (Fig. 7).

The high concentration of P and N inside the pigeon tower and their congruent patterns with OM along the northern transect support their interpretation as indicators of purposefully organized biological activity. Thus, it appears that, in some of the chosen sampling points, environmental disturbances could not mask the influence of the pigeon tower even more than a thousand years after its destruction. Superimposing the soil chemical analysis onto an architectural plan of the pigeon tower (Fig. 7; Table 2) shows a spike in concentration pointing north. The concentration of these three elements is higher closer to the tower, and progressively decreases with distance.

Previous archaeological studies of soil chemistry have demonstrated that variations in P concentrations at archaeological sites are often positively associated with variations in the anthropogenic activity in the soil of that site (Holliday, 2007). Often a relative increase of P in a given area is specifically associated with refuse handling (Roose and Nolan, 2012). High P concentration has also been associated with archaeological structures identified as doors, corridors, and pathways (Vizcaino and Canabate, 1999). The consistent patterns of P, N, and OM, in the aforementioned northern spike, outside the pigeon tower, suggest a non-random diffusion away from the structure, possibly associated with the passing of

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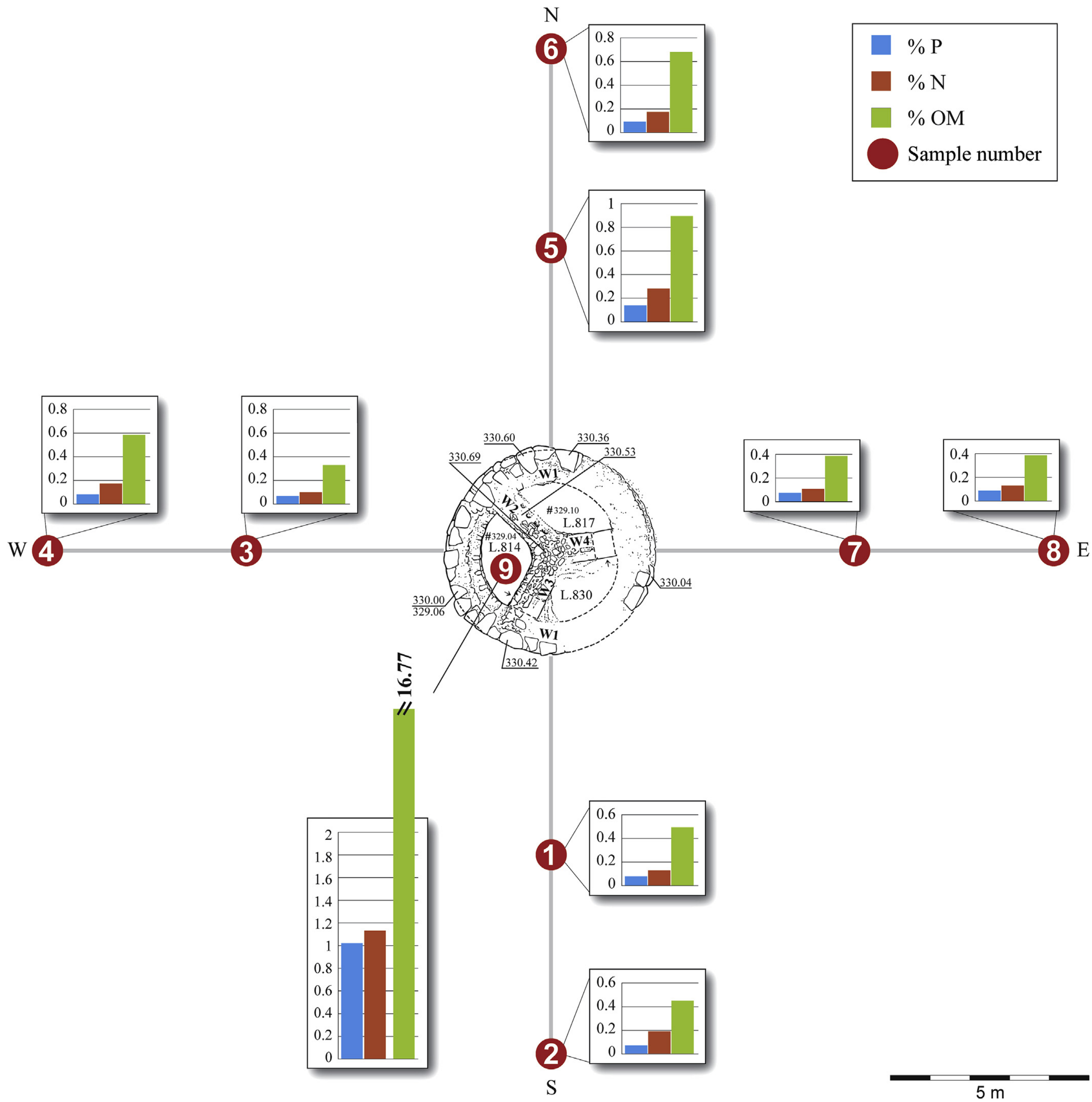

Fig. 7. The sampling scheme and the distribution of nitrogen (N), phosphorus (P), and organic material (OM) in and around PT No. 1.

pigeon manure through an opening. That activity was apparently concentrated in the northern, shaded side of the structure, which would have sheltered the workers from the sun when they performed the cumbersome work of extracting the manure.

When examining the fallen ashlar, a worked stone bearing a short inscription "ΔOPON" ("gift" in Greek; Hirschfeld and Tepper, 2006: 97, Fig. 14) was discovered and we assumed that it was used as a lintel. However, no signs of a built *in situ* threshold, that might indicate the existence of a door or some other ground-level opening of the pigeon tower has been found. A possible solution to this enigma, which may further enhance our understanding of the architecture of this tower and how it functioned, can be gleaned from other archaeological excavations in the region, and from ancient written sources. At times, a single door above the ground was a common feature of Egyptian dovecots in Karantis, Egypt, dated, like Shivta, to the Roman and Byzantine periods (Husselman, 1953). "The only entrance to this dovecote was a door at the southern end, nearly 3 m above ground level. No stairs led to the door." In such cases, access to the entrance was probably via a ladder. In a second case, "a small opening at the base of the dovecote tower was closed by a wooden door, which remained in its original position … The size of the opening and its location make it probable that it was used for the removal of the manure from the bottom of the dovecote," (Husselman, 1953: 89).

Table 2
Levels of chemical entities found in soil and background samples for Pigeon Tower No. 1.

Sample	Distance (m)	Direction	Phosphorus (P,%)	Nitrogen (N,%)	Organic Matter (OM, %)
Background	>50	–	0.081 (0.075,0.086)	0.242 (0.208,0.275)	0.35 (0.298,0.408)
PT1	5	South	0.081 (0.506)	0.13 (<0.0001)	**0.5 (<0.0001)**
PT2	10	South	0.06 (<0.0001)	0.18 (<0.0001)	**0.44 (0.001)**
PT3	5	West	0.051 (<0.0001)	0.09 (<0.0001)	0.32 (0.146)
PT4	10	West	0.07 (<0.0001)	0.17 (<0.0001)	**0.58 (<0.0001)**
PT5	5	North	**0.147 (<0.0001)**	**0.29 (0.002)**	**0.9 (<0.0001)**
PT6	10	North	0.086 (0.034)	0.17 (<0.0001)	**0.68 (<0.0001)**
PT7	5	East	0.066 (<0.0001)	0.1 (<0.0001)	0.38 (0.142)
PT8	10	East	**0.093 (<0.0001)**	0.13 (<0.0001)	0.39 (0.081)
PT9	0	Center	**1.104 (<0.0001)**	**1.67 (<0.0001)**	**16.77 (<0.0001)**

Pigeon tower samples are numbered as in Figs. 4 and 6 and the distance is measured from the pigeon tower outer wall. Values significantly higher than the background level are in bold. Estimates for pigeon tower samples are given by their p-value in parentheses. Background estimates are given with their confidence intervals in parentheses.

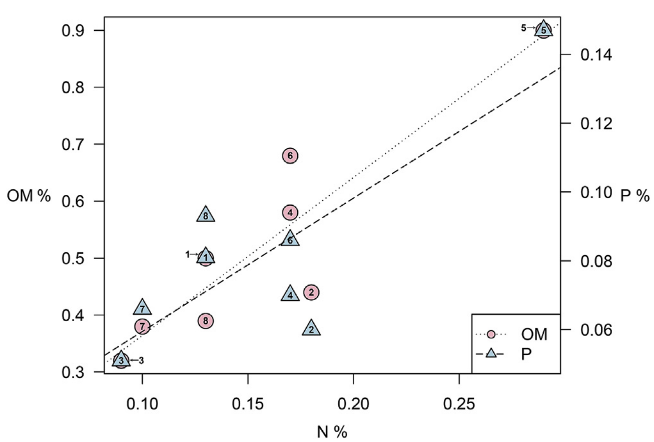

Fig. 8. The association between organic material (OM) and nitrogen (N) and between phosphorus (P) and nitrogen (N), around pigeon Tower No. 1. The solid line represents the regression line. Samples are numbered as in Fig. 7.

A literary description of a Roman pigeon tower by Varro (Marcus Terentius Varro, 116–27 BCE) specifies "one narrow door" and special, partially-blocked windows (Varro Rerum Rusticarum III para 266). An observation in Jewish-Mishnaic sources dated to about 180–220 CE may imply that pigeon tower openings were indeed approached by a ladder, and were thus above ground: "A ladder must be kept away from a dovecote four cubits so that a weasel should not be able to spring" (Mishna, Bava Batra 2:5 n.d., translated by eMishna.com). Such a ladder is also common in modern structures housing pigeons (Zissu, 1995: Figs. 8, 9, 10). Tightly controlled, limited access seems to have been a typical feature in late, pre-modern Persian dovecotes as well: "The towers are entered once a year for the collection of manure. A small door (occasionally there are two) usually at the ground level are sealed," (Amirkhani et al., 2010: 47). Thus, a reasonable solution to the aforementioned enigma — a door, but no doorway or threshold — is that the Shivta pigeon tower we studied here also had an above-ground opening on the north side that was accessed by a ladder.

4. Conclusions

Soils associated with a ruined Roman-Byzantine pigeon tower in the Negev desert, near Byzantine Shivta, retained quantifiable traces of phosphorous (P), nitrogen (N) and organic matter (OM). All were analyzed using standard methods and analytical processes to examine agricultural soil fertility. It seems that OM and N can be used, in addition to P, to look for anthropogenic and ornithogenic soils in such deserts, and that a positive association exists between the three entities. These entities reflect past activities associated with husbanded pigeons, mainly manure accumulation and its removal.

The distribution of these entities suggests the existence of a single opening, most probably accessed by ladder. Such an opening was not discerned architecturally in the present case, but was rather inferred based on ethnographic and archaeological evidence from other sites, as well as from descriptions in relevant ancient literature. Thus, the distribution patterns of these chemical entities, combined with an analysis of the architectural remains, improves our understanding of the architecture and function of the pigeon tower.

The pigeon tower presented here is but one of numerous such Roman and Byzantine structures in the Negev, Israel, which have been tentatively identified using the criteria available at the time of their study. Archaeological pigeon towers in the Negev are topographically and architecturally heterogeneous, and their state of preservation varies greatly. Therefore, a positive identification of an archaeological site as the location of pigeon husbandry cannot be based solely on architectural considerations. A collaborative, multidisciplinary approach must be taken in order to substantiate such assumptions. The findings of this study may facilitate the identification of other ruined structures as sites of ancient pigeon husbandry, and stimulate the search for additional indicators of the past presence of pigeons at sites under archaeological scrutiny.

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