Beyond maps: Patterns of formation processes at the Middle Pleistocene open-air site of Marathousa 1, Megalopolis Basin, Greece

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Abstract

Recent excavations at the Middle Pleistocene open-air site of Marathousa 1 have unearthed in one of the two investigated areas (Area A) a partial skeleton of a single individual of *Elephas (Palaeoloxodon) antiquus* and other faunal remains in spatial and stratigraphic association with lithic artefacts. In Area B, a much higher number of lithic artefacts was collected, spatially and stratigraphically associated with other faunal remains. The two areas are stratigraphically correlated, the main fossiliferous layers representing an *en mass* depositional process in a lake margin context. Evidence of butchering (cut-marks) has been identified on two bones of the elephant skeleton, as well on other mammal bones from Area B. However, due to the secondary deposition of the main find-bearing units, it is of primary importance to evaluate the degree and reliability of the spatial association of the lithic artefacts with the faunal remains. Indeed, spatial association does not necessarily imply causation, since natural syn- and post-depositional processes may equally produce spatial association. Assessing the degree and extent of post-depositional reworking processes is crucial to fully comprehend the archaeological record, and therefore to reliably interpret past human behaviours. The present study uses a comprehensive set of spatial statistics in order to disentangle the depositional processes behind the distribution of the archaeological and palaeontological record at Marathousa 1. Preliminary results of our analyses suggest minor reworking and substantial spatial association of the lithic and faunal assemblages, supporting the current interpretation of Marathousa 1 as a butchering site.

Keywords: Spatial analysis, Site formation processes, Vertical distribution, Fabric analysis, Point pattern analysis, Middle Pleistocene

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1. Introduction

Archaeological site formation processes, intensively studied since the early 1970s (Isaac, 1967; Schiffer, 1972, 1983, 1987; Shackley, 1978; Wood and Johnson, 1978; Schick, 1984, 1986, 1987; Petraglia and Nash, 1987; Petraglia and Potts, 1994, among others) , “still insufficiently taken in consideration” (Texier, 2000) at the beginning of the 21st century, are nowadays fully acknowledged in the archaeological practice (Villa, 2004; Bailey, 2007; Brantingham et al., 2007; Malinsky-Buller et al., 2011; Vaquero et al., 2012; Bargalló et al., 2016, among others). Drawing inferences about past human behaviours from scatters of archaeological remains must account for syn- and post-depositional contextual processes.

Several methods are currently applied in order to qualify and quantify the type and degree of reworking of archaeological assemblages. Within the framework of a geoarchaeological and taphonomic approach, spatial statistics offer meaningful contributions in unravelling site formation and modification processes from spatial patterns. However, while the spatio-temporal dimension is an ineluctable inherent property of any biotic or abiotic process, spatial statistics are still insufficiently applied.

Distribution maps are cornerstones of the archaeological documentation process and are primary analytic tools. However, their visual interpretation is prone to subjectivity and is not reproducible (Bevan et al., 2013). Since the early 1970’s (see Hodder and Orton (1976); Orton (1982) and references therein), the traditional, intuitive, ‘eyeballing’ method of spotting spatial patterns has been abandoned in favour of more objective approaches, extensively borrowed from other fields. Nevertheless, quantitative methods, while still percolating in the archaeological sciences from neighbouring disciplines, are not extensively used. Moreover, only a relatively small number of studies have explicitly applied spatial point pattern analysis or geostatistics to the study of site formation and modification processes (Lenoble et al. (2008); Domínguez-Rodrigo et al. (2014b,a, 2017); Carrer (2015); Giusti and Arzarello (2016); Organista et al. (2017) - but see Hivernel and Hodder (1984) for an earlier work on the subject).

The goal of a taphonomic approach to spatial analysis is to move beyond distribution maps by applying a comprehensive set of multiscale and multivariate spatial statistics in order to reliably construct inferences from spatial patterns. An exhaustive spatial analytic approach to archaeological inference, combined with a taphonomic perspective, is essential for evaluating the depositional processes and integrity of the archaeological assemblage, and consequently for a reliable interpretation of past human behaviours.

The present study uses a comprehensive set of spatial statistics (fabric, vertical distribution and point pattern analyses) in order to disentangle the depositional processes behind the spatial distribution of the archaeological and palaeontological record recovered during excavation at the Middle Pleistocene open-air site of Marathousa 1, Megalopolis, Greece (Panagopoulou et al., 2015; Harvati et al., 2016).

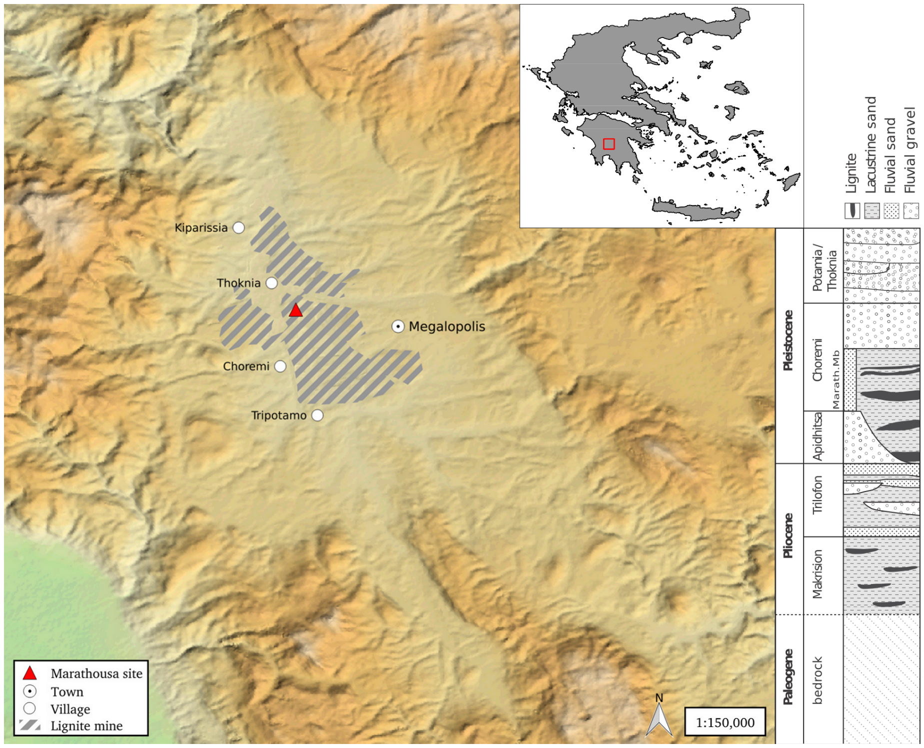

Figure 1: Geographical location of the Marathousa 1 site in the Megalopolis basin and stratigraphic column, modified after van Vugt et al. (2000).

1.1. *Marathousa 1*

The site (Fig. 1), discovered in 2013 at the edge of an active lignite quarry (Thompson et al., this issue), is located between two lignite seams in the Pleistocene deposits of the Megalopolis basin, Marathousa Member of the Choremi Formation (van Vugt et al., 2000). The regular alternation of lacustrine clay, silt and sand beds with lignite seams has been interpreted having cyclic glacial (or stadial) and interglacial (or interstadial) origin (Nickel et al., 1996). The half-graben configuration of the basin, with major subsidence along the NW-SE trending normal faults along the eastern margin, resulted in the gentle dip of the lake bottom at the opposite, western, margin of the lake, enabling the formation of swamps and the accumulation of organic material for prolonged periods of time (van Vugt et al., 2000).

Two excavation areas have been investigated since 2013: Area A, where several skeletal elements of a single individual of *Elephas (Palaeoloxodon) antiquus* have been unearthed, together with a number of lithic artefacts (Konidaris et al., this issue; Tourloukis et al., this issue); and Area B, located 60 m to the South along the exposed section, where the lithic assemblage is richer and occurs in association with a faunal assemblage composed of isolated elephant bones, cervids and carnivores among others (Fig. **??**). Evidence of butchering (cut-marks) have been identified on two of the ele-

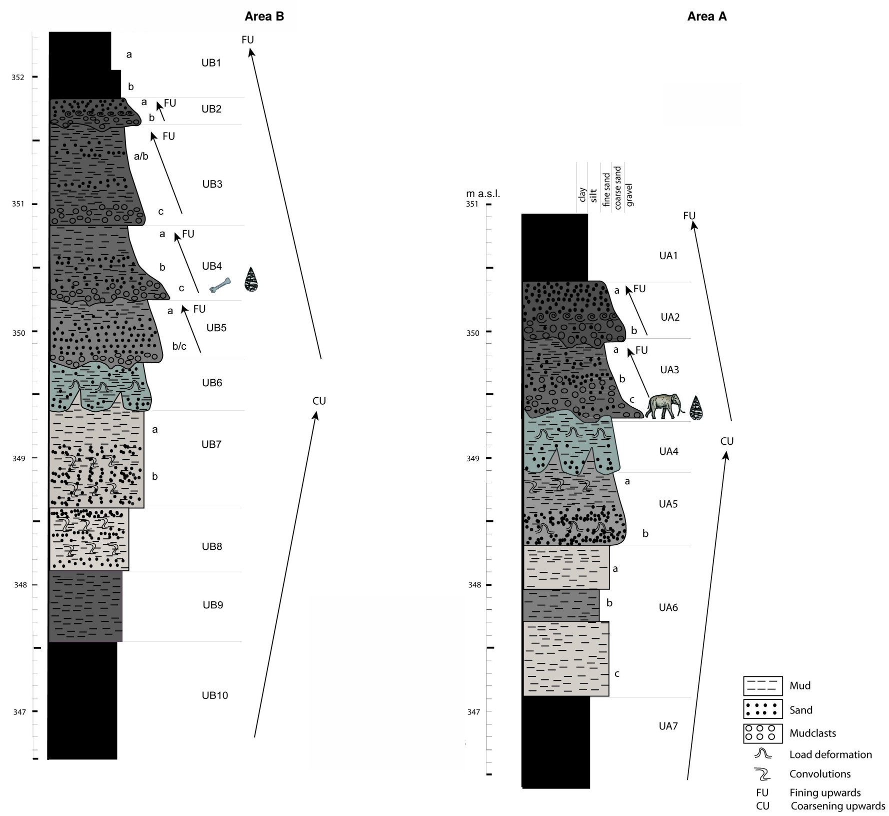

Figure 2: Stratigraphic setting of the Marathousa 1 site, modified after Karkanas et al. (this issue).

phant bones from Area A, as well on elephant and other mammal bones from Area B (Konidaris et al., this issue).

The sedimentary sequence of the site (Fig. 2) includes lacustrine and fluvio-lacustrine clastic deposits between lignite seams II (UA7-UB10) and III (UA1-UB1) (Karkanas et al., Tourloukis et al., this issue). A major hiatus (UA3/4, UB5/6), attributed to exposure and erosion of a lake shore mudflat, divides the sequence in two parts. The lower part is characterized by high rate subaqueous sedimentation of bedded sands and silts; while the upper one is characterized by a series of erosional bounded depositional units, attributed to subaerial organic- and carbonate-rich mudflows and hyperconcentrated flows (Karkanas et al., this issue).

The erosional contacts UA3c/4 and UB4c/5a separate the two main find-bearing units in both areas. In Area A, the elephant remains lie at the contact of UA3c/4 and are covered by UA3c (Fig. 3a); while in Area B, most of the remains were collected from unit UB4c (Fig. 3b). Units UA3c and UB4c (organic-rich, intraclast-rich silty sands) resemble diluite mudflows, showing a chaotic structure of rip-up clasts from

Figure 3: Photograph (2017) of the left femur of the *Elephas (Palaeoloxodon) antiquus*, lying at the contact of UA3c/4 and covered by UA3c (a). South profile (2015) of the excavation Area B, exposing the UB4c/5a erosional contact (b).

the underlying unit, small-to-large wood fragments, and rare rock clasts. In Area B, a relatively low number of remains was also found in massive organic-rich silty sands (UB5a), which locally overlay channalized sands (UB5b/c), probably not preserved in Area A (Karkanas et al., this issue).

The flow event described above (units UA3c and UB4c), and specifically the erosional contacts between the fossiliferous horizons in the two areas (UA3c/4 and UB4c/5a), provide the essential background for the analysis and interpretation of the spatial distributions at Marathousa 1.

The secondary depositional nature of the main find horizons raises the question of how reliable is the spatial association between the lithic artefacts and the partial skeleton of a single *Elephas (Palaeoloxodon) antiquus* individual and other faunal remains. Since spatial association does not necessarily imply causation, and consequently synchrony (**??**), the answer has important consequences for the interpretation of the site in the broader context of the Middle Pleistocene human-proboscidean interactions. We aim to tackle this question and disentangle the formation processes acting at Marathousa 1 on the basis of spatial patterns through a three-prong spatial analytic approach:

1. by analysing, in a frame of references, the orientation patterns of remains from relevant stratigraphic units;
2. by quantifying and comparing their relative vertical distributions;
3. by identifying spatial trends in either the assemblage intensities and the associa-

tions between classes of remains.

For both areas, the working hypothesis is that the flow event, represented by units UA3c and UB4c, eroded and scoured the exposed surface (where the elephant was lying), thereby entraining clastic material (including probably artefacts) and re-depositing this material at a close distance. Two contrasting models are tested. The autochthonous model (Domínguez-Rodrigo et al., 2012, sensu) states that the post-depositional UA3c-UB4c flow reworked *on site* the assemblage and altered the original, pristine *in situ* deposition. This model implies the loss of any primary spatial relations between remains, but minor transport from the primary depositional *loci* and re-deposition (**?**, sensu). On the other hand, the allochthonous model (Domínguez-Rodrigo et al., 2012, sensu) implies significant transport from the original *loci* and re-elaboration (**?**, sensu). According to this model, the spurious spatial association between the lithic artefacts and faunal remains does not support any behavioural interpretation.

2. Material and methods

Since 2013, systematic investigation of the Marathousa 1 site has been carried out by a joint team from the Ephoreia of Palaeoanthropology-Speleology (Greek Ministry of Culture) and the University of Tübingen. A grid system of 1 square meter units was set up, oriented -14 degrees off the magnetic North, and including the two areas of investigation. The excavation of the deposit proceeded in 50x50 cm sub-squares in Area B and 1x1 m squares in Area A, and spits of 5 to 10 cm thickness, respectively. Systematic water-screening of sediments was carried out on-site using 1 mm sieves in order to guarantee recovery of the small-size fraction (e.g., micro-artefacts, small mammal remains, fish, molluscs and small fragments of organic and inorganic material). The three-dimensional coordinates of finds (i.e., all the lithic artefacts, teeth and diagnostic bones; bones and organic material with a-axis $\geq$ 20 mm), collected spits of sediment, samples and geological features (e.g., erosional contacts and mud cracks) were recorded with a Total Station. Dense clouds of surface points of the Elephant skeletal elements were acquired using both a Total Station and a close-range photogrammetric technique.

The dimensions (length, width and thickness) of registered finds were measured on-site with millimetre rules. Orientation (dip and strike) of elongated particles (i.e., faunal remains, large wood fragments and lithic artefacts) was recorded since 2013 with a 30 degree accuracy, using a clock-like system (the strike was measured, relatively to the grid North, in twelve clockwise intervals). In 2015, the use of a compass and inclinometer with an accuracy of 1 degree was introduced in Area B to gradually replace the former method.

The widespread use of a compass and inclinometer to record orientation data (Voorhies, 1966; Bertran and Texier, 1995; Bertran et al., 1997; Lenoble and Bertran, 2004; **?**; Eren et al., 2010; Benito-Calvo et al., 2011; Domínguez-Rodrigo et al., 2012; Domínguez-Rodrigo and García-Pérez, 2013; Domínguez-Rodrigo et al., 2014c; Cobo-Sánchez et al., 2014; Organista et al., 2017, among others) was favoured over the alternative use of a total station (**??**McPherron, 2005; **?**; Bernatchez, 2010, among others), mostly due to the time-restricted conditions of the rescue excavation conducted at Marathousa 1.

Measurements of the strike (azimuth) and dip of eleongated finds were taken along the symmetrical longitudinal a-axis (SLA) of bones (Domínguez-Rodrigo and García-Pérez, 2013), lithic artefacts (Bertran and Texier, 1995) and organic material, using the lowest endpoint of the axis as an indicator of the vector direction.

Other major axes have been alternatively used with the recent application of GIS techniques to retrieve orientation data from secondary source (i.e., excavation photographs, drawings or maps) (Boschian and Saccà, 2010; Benito-Calvo and de la Torre, 2011; de la Torre and Benito-Calvo, 2013; Walter and Trauth, 2013; García-Moreno et al., 2016; Sánchez-Romero et al., 2016). However, the experimental works of Domínguez-Rodrigo and García-Pérez (2013) and Domínguez-Rodrigo et al. (2014c) showed that the SLA, defined as the major axis which symmetrically divide the bone, is more accurate in determining the preferential orientation of anisotropic assemblages. This a-axis is commonly used in taphonomic studies (**???**Domínguez-Rodrigo et al., 2012, 2014a; **?**, among others) and not explicitly define, but commonly refer to it as the clast/artefact long or major axis, in studies which employ a sedimentological approach to archaeological fabric (Bertran and Texier, 1995; Bertran et al., 1997; Lenoble and Bertran, 2004; Benito-Calvo et al., 2009, among others).

The present study focuses on the excavated stratigraphic units in which most of the archaeological and palaeontological remains were recovered in both excavation areas, namely in UA3c and UA4 in Area A, and UB4c and UB5a in Area B. From the total, subset samples of material were used for each specific spatial analysis. For the fabric analysis we included material collected until 2016. For the vertical distribution and point pattern analyses, the region of investigation was limited to the squares excavated from 2013 until 2015, 25 and 29 square meters respectively in each area.

The analyses were performed in R statistical software (R Core Team, 2016). In order to make this research reproducible (Marwick, 2017; Marwick et al., 2017), a repository containing a compendium of data, source code and text is open licensed and available at the DOI: 10.5281/zenodo.822273

2.1. Fabric analysis

The study of the clast fabric (i.e., the orientation pattern of elongated sedimentary particles, including bones and artefacts), first addressed by Voorhies (1966); Isaac (1967); Bar-Yosef and Tchernov (1972); Schick (1986), more recently led to a noteworthy development of methods and propagation of applications in Palaeolithic site formation studies (Bertran and Texier, 1995; Bertran et al., 1997; Lenoble and Bertran, 2004; Lenoble et al., 2008; McPherron, 2005; Benito-Calvo et al., 2009, 2011; Benito-Calvo and de la Torre, 2011; Bernatchez, 2010; Boschian and Saccà, 2010; Domínguez-Rodrigo et al., 2012; Domínguez-Rodrigo and García-Pérez, 2013; Domínguez-Rodrigo et al., 2014c; de la Torre and Benito-Calvo, 2013; Walter and Trauth, 2013; García-Moreno et al., 2016; Sánchez-Romero et al., 2016, among others).

Fabric analysis can provide valuable insight into site formation and taphonomic processes, allowing to discriminate between orientation patterns (isotropic, linear or planar) associated with different sedimentary processes. Nevertheless, grey zones exist

Table 1: List of sampled observations for the fabric analysis.

Sample	n	Type		
		Fauna	Wood	Lithic
UA3c	49	23	25	1
UA4	38	8	30	-
E. (P.) antiquus	63			
UB4c (clock)	86	68	4	14
UB4c (compass)	65	47	10	8

between depositional processes, so that an unequivocal discrimination based only on fabric observations is often not possible, and other taphonomic criteria must also be considered (Lenoble and Bertran, 2004).

As part of our three-prong spatial analytic approach, we conducted comparative fabric analysis with the aim to investigate the dynamics of the depositional processes at Marathousa 1.

At the margin of a lacustrine environment, relatively close to the surrounding relief, a combination of high- and low-energy processes can be expected. According to the depositional context of the site (Karkanas et al., this issue),

Since fabric strength has been found to be positively correlated with the shape and size of the clast, for the fabric analysis we subset samples of remains with length $\geq$ 2 cm and elongation index (the ratio length/width) $I_e \geq 1.6$ (Lenoble and Bertran, 2004). The samples are listed in Table 1 and include mostly wood fragments and faunal remains from the four stratigraphic units under investigation. No distinction of skeletal elements was made, both due to the high fragmentation rate of faunal remains in Area B, and because recent experiments showed a similar orientation pattern for different bone shapes (Domínguez-Rodrigo et al., 2012; Domínguez-Rodrigo and García-Pérez, 2013).

The sample of bones belonging to the individual of *Elephas (P.) antiquus* from Area A was analysed separately and included the humerus, ulna, femur and tibia; the atlas, axis and 16 complete vertebrae or vertebral fragments; 29 complete ribs or rib fragments; 2 calcanea; 4 metatarsals/metacarpals; the pyramidal; the trapezoid and the pelvis. The sample from UB5a was too small (only 7 observations) and was therefore excluded. The sample from the UB4c unit was divided in two sub-samples considered separately: those recorded using the clock method and those recorded using the compass method. All the sampled observations are representative of the whole study area.

In order to asses the reliability of the orientation data recorded using the clock method, the non-parametric Watson's two-sample test was conducted on a subset of data from Area B, unit UB4c (n = 38) recorded using both the compass and clock method. The test failed to reject the null hypothesis that two samples (clock- and compass-based measurements) belong to the same parent population ($U^2 = 0.1097$, $p-value > 0.10$). The Woodcock and Benn diagrams showed little difference between the two distributions (see SI).

Rose diagrams and uniformity tests, such as Rayleigh, Kuiper, Watson and Rao tests (Jammalamadaka et al., 2001), were used to visualise and evaluate circular isotropy in the sample distribution. The Rayleigh test is used to assess the significance of the sample mean resultant length ($\bar{R}$), assuming that the distribution is unimodal and not bi- or plurimodal. The $\bar{R}$ ranges from 0 to 1: values close to 1 indicate that the data are closely clustered around the mean direction; when the data are evenly spread $\bar{R}$ has a value close to 0. Kuiper, Watson and Rao are omnibus tests used to detect multimodal departures from circular uniformity. The test results are evaluated against critical values: a result higher than the critical value rejects with confidence the null hypothesis of isotropy.

Randomness testing of three-dimensional data was conducted with the Woodcock S_1/S_3 test (Woodcock and Naylor, 1983). Considering both the dip (plunge) and strike (bearing) of the oriented items, this method, based on three ordered eigenvalues (S_1, S_2, S_3), is able to discriminate the shape and strength of the distributions. The shape parameter $K = \frac{ln(S_1/S_2)}{ln(S_2/S_3)}$ ranges from zero (uni-axial girdles) to infinite (uni-axial clusters). The parameter $C = ln(S_1/S_3)$ expresses the strength of the preferential orientation, and its significance is evaluated against critical values from simulated random samples of different sizes. A perfect random uniform distribution would have $C = 0$ and $K = 1$.

The Benn (Benn, 1994) diagram adds to the Woodcock test an isotropy ($IS = S_3/S_1$) and an elongation ($ES = 1 - (S_2/S_1)$) index. Like the former method, it is able to differentiate between linear (cluster), planar (girdle) or isotropic distributions. There are no published raw data from actualistic studies on depositional processes affecting the orientation of bones and artefacts deposited on lacustrine floodplains (but see Morton (2004) and Cobo-Sánchez et al. (2014) as pioneer studies on this subject). However, we included in the Benn diagram references to published results from observation of fabrics in modern subaereal slope deposits, i.e., debris flow, runoff and solifluction (Bertran et al., 1997; Lenoble and Bertran, 2004).

2.2. Vertical distribution

The vertical distribution of materials has been long investigated with the aim of identifying cultural levels, by visually interpreting cross-sectional plots. However, recent advances in GIS techniques allow to inspect at higher resolution the three-dimensional distributions of archaeological remains (**?**Anderson and Burke, 2008, among others).

In analysing the vertical dispersion of material at Marathousa 1, we provisionally assume that a general concentration of unsorted lithic artefacts and faunal remains in the proximity of the erosional surfaces would support an autochthonous origin of the assemblages; whereas a homogeneous vertical distribution of remains from the UA3c and UB4c units would suggest an allochthonous origin, significant transport and subsequent redeposition of the material. Indeed, massive process, such as mudflows or hyperconcentrated flows, have high erosional power and rather chaotic structure, which would result in homogeneous dispersion of embedded clasts throughout the sequence. However, graded bedding could result in such fluid depositional environments, associated with a decrease in transport energy ().

In order to estimate the degree of vertical dispersion while controlling for the size of the archaeological material, dimensional classes were set up following typological criteria. Lithic artefacts were classified as debris/chips when smaller than a cutoff