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Non-Linear Spatial Patterning in Cultural Site Formation Processes - The Evidence from Micro-Artefacts in Cores from a Neolithic Tell Site in Greece

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1. Introduction

Micro-artefacts (i.e., cultural particles smaller than 2mm in diameter), due to their abundance and incorporation into the sedimentary matrix of an archaeological deposit, constitute a significant part of the cultural particles present [21]. Micro-artefact analysis is extensively complex due to the different micro-artefact categories that may appear in an archaeological context and also because of the numerous cultural (and non-cultural/natural) formation processes that may have been involved in the creation of characteristics specific to an archaeological context.

Recently, the use of a non-linear method (i.e., spherical-SOFM) on micro-artefact data has shown that the method is able to recognize and to provide a visual representation of micro-artefact patterns prior to performing any statistical analysis on the data, providing a quick view into possible relationships or differences that may occur between temporally, spatially, and culturally different archaeological contexts (i.e., pits and ditches from the Neolithic Tell site at Paliambela (Pieria region-Northern Greece) which unusually comprises an extended settlement component [8].

It was shown that the spherical-SOFM non-linear method revealed patterns among the data that linear methods were unable to classify. Furthermore, the method attempted to overcome the difficulties posed by the friable nature of different micro-artefact classes (for example, unburnt clay, burnt clay, bone, shell, or charcoal). Material characteristics and the process of micro-artefact generation, including the effects of post-depositional processes, were considered as important factors in the search for strong pattern recognition [9]. The analysis has shown that similar classes of micro-artefacts in three analyzed data sets were

characterized by different non-linear associations, further suggesting that these were possibly formed through different cultural formation processes [8].



Figure 1. Map of Greece, showing the location of Paliambela (Source: 'Paliambela excavation' archive).

The use of the spherical-SOFM non-linear method was also able to recognize and to provide a visual representation of micro-artefact patterns in archaeological contexts (i.e., a colluvial deposit from a Hellenistic Theatre in NW Greece) affected *only* by natural formation processes [10, 11].

The implication of the applied non-linear method (i.e., spherical-SOFM) is that it has the 'ability' to demonstrate the dynamics of cultural or natural formation processes in leaving non-linear 'signals' in archaeological contexts being in a '*non equilibrium*' state until the time of recovery. Therefore, the rationality for developing such recognitions in archaeological contexts is to release the dynamics of formation processes since archaeological patterning is arguably (at least for the most part) the result of the interplay between many complex processes, both cultural and non-cultural (natural) [2, 28, 1, 16]. Therefore, this type of recognition is of critical importance also in core-data, since this type of data provide broader spatial information and are more sensitive in both cultural and natural formation processes.

Section 2 briefly describes how the spherical self-organizing map creates a 3D visual or graphical representation of the data. Section 3 presents a summary of previous geoarchaeological work on core-data from the Neolithic Tell site at Paliambela (Pieria region-Northern

Greece) while section 4 and section 5 offer the results of this study and some concluding remarks, respectively.

2. Spherical self-organizing feature map

The Spherical Self-Organizing Feature Map (S-SOFM), introduced by Kohonen [7], maps n -dimensional data into a low-dimensional space. The spherical SOFM [17] the low-dimensional space is a tessellated sphere that is formed by subdividing an icosahedron. Every vertex on this sphere is a strategic location of an n -dimensional vector that represents an ensemble of similar data vectors which are assigned to the vector during the mapping operation. It is therefore necessary to visually enhance variations in the data using the physical attributes of the mapping lattice. The benefit of a spherical lattice in the implementation of the S-SOFM is that the enclosed space can be used to generate a 3D visual representation of some physical aspect of the n -dimensional data.

Conventional implementation of the S-SOFM method have used a 2D lattice as the low-dimensional space, and associations in the data are visualized by means of a terrain map, wherein elevation represents some aspect of the vector(s) at that location [27, 24]. Relative similarity between data vectors mapped into the sphere can be visualized by introducing distortions in the sphere accompanied by changes in the colour. Informative characteristics of the data are reflected as distortions and colour gradations on the surface of the sphere. The formulation of these measures is a non-trivial task and often application dependent. The measures reflect desired data correlations (either linear or non-linear) and must be defined by the researcher who is familiar with the underlying data set. It is this aspect of the S-SOFM that differs from existing literature about the self-organizing feature map. The S-SOFM utilizes the spherical lattice of the S-SOFM space to generate a visual form of the clustered data that is more intuitive and easy to perceive. A visual form of the data is created by scaling the radial distance of the vertices on the sphere in proportion to a measure characterizing some physical aspect of the data. Examples illustrating the various implementations of the spherical SOFM on different data and the use of possible measures to create spherical SOFM graphical representations are discussed in Sangole [17] and Sangole and Knopf [18].

3. Summary of previous work on core-data from the Neolithic Tell site at Paliambela (Pieria region-Northern Greece-Fig.1)

Coring, as a minimally destructive technique, facilitates the definition of subsurface units, provides a clear view of the buried surfaces on which occupations took place [23]. The macroscopic examination of all twelve cores drawn from the subsurface investigation conducted on the tell, revealed three basic stratigraphic units: bedrock, occupation deposits and a top-soil layer. Given, therefore, their relative macrostratigraphic similarity and the rather broad stratigraphic resolution/delineation required from the cores at Paliambela, three cores (out

of 12) were selected for analysis (i.e., nos 1083-84-85, Fig.2). These were judged to provide good site coverage from east to west, and thus offer information regarding the depth and thickness of the cultural deposits on the tell, on a coarse temporal and spatial scale.

The analysis of three cores (out of twelve) defined the stratigraphy of the site on a coarse temporal and spatial scale. The culturally sterile bedrock was identified at ca 2m depth and the initial human occupation probably started on top of the bedrock, because remnants of any overlying palaeosol have not been recognised, suggesting that this might have been stripped or reworked by subsequent human activity.

The analysis of the occupation deposits revealed significant variation, both temporal and spatial, in micro-artefacts (burnt clay, unburnt clay, shell, bone and charcoal) and so, presumably, in human activity on the site. This indicates that the surviving occupation deposits built up sufficiently rapidly and bury and preserve variable concentrations of micro-artefacts. In short, the analysis of the cores revealed that the tell component of the site might have been the product of long term anthropogenic accretion of sediment and artefactual material that created a low mound, with 0.5-2m of *surviving* occupation debris. [8].

4. Non-linear micro-artefact patterning as a general indicator of differences in cultural site formation processes

4.1. Laboratory procedures

The laboratory procedure followed in micro-artefact analysis used two divisions of the phi (ϕ) scale, that is -2.00ϕ and 0ϕ . Contents of the bulk samples were passed through a stack of 4mm (-2.00ϕ) and 1mm (0ϕ) sieves. The material retained in the 1mm sieve created the sub-sample that was processed for micro-artefacts and an optical microscope was used for identifications. Five micro-artefact categories were identified in the deposits from the cores: unburnt clay (e.g., from mudbricks, wattle and daub constructions), burnt clay (i.e., burnt specimens of the previous category), shell (marine shells), bone (animal bone), and charcoal (charred organic particles).

Shell, bone and charcoal were easily distinguished, but the more problematic distinction between unburnt clay and burnt clay was based on the following observations: unburnt clay grains were often very fragile even in this small fraction and were, in most cases, subdiscoidal, ranging in colour from light grey to dark grey; burnt clay fragments were, in most cases, spherical particles of brownish colour, and relatively more solid than the unburnt clay ones.

In the core samples (total number: 120 sediment samples, ca. 1000kg each), the total sub-sample was sorted for micro-artefacts and the total mass for each material class was weighed on an electronic precision balance. Physically sorting the total sub-sample for micro-artefacts, followed by weighing of each category, provides a representative picture of the micro-artefacts present in a sample and is feasible when small sample sizes are involved in analysis, as in the case of the cores.

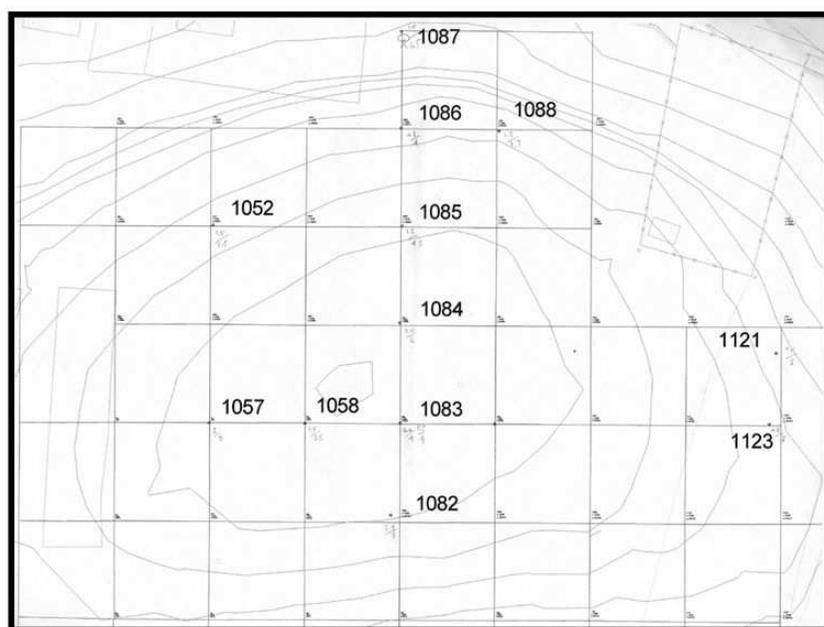


Figure 2. Contour map of the Neolithic tell showing the location of the Cores. Contours at 10m (Source: 'Paliambela excavation' archive).

Micro-artefact density (D) was obtained by using the following equation: $D = m/v$, where m is the weight of each material class, and v is the volume of each sample. This method is rather simple but needs the total sub-sample to be sorted for micro-artefacts and the various material types to be weighed in a high precision electronic balance.

The construction of the S-SOFM graphical representation was based on a database of 120 five-dimensional records, each dimension representing a micro-artefact category. Every row represented the point-counting results. Figure 3 shows the formation of three distinct white regions that correspond to the micro-artefact core-data from the site. A non-linear structure lies within this statistical space which can be distinguished into three separate sub-structures. The spherical-SOFM pattern recognition procedure provides a comprehensive preliminary visual representation of inherent non-linear characteristics in data, serving as the initial step in the analysis of the multidimensional micro-artefact data. In this study three meaningful components were revealed – which appeared to be the determinants for the constitution of the analysed data set. This further suggests that the three groups of contexts (i.e., micro-artefacts from the three cores) from the site were possibly formed through different formation processes.

It is important to mention that the five classes of micro-artefacts set for analysis -i.e., micro-shell, micro-bone, microfragments of charcoal, microfragments of burnt clay, and microfragments of unburnt clay- generate from an interpretatively complicated set of larger artefacts, those made of friable materials -the so called 'size unstable' [22].

The preservation of such materials in an archaeological context indeed, is closely connected not only with the length of deposition but also with the rate and type of weathering [22].

Moreover, micro-artefacts provide different information than do larger artefacts and definitely should not be used simply to reflect 'noise' in larger artefacts [6].

Therefore, the researcher cannot assume that, for example, chronologically distant archaeological contexts will provide similar or different micro-artefact patterning due to the many factors that may account for the observed pattern. The implication is that it enhances attempts for developing interpretations on micro-artefact patterning by providing strong pattern recognition.

The observation of this pattern in cultural indicators such as micro-artefacts should be related at least in part (and arguably for the most part) with differences in the spatial organization of activities carried out in the site and ending up in the deposits. In other words, it should be related with spatial differences in cultural formation processes. That these differences in cultural processes had become so embedded in the sedimentary traces of the deposits arguably reflects *long-term continuity* of distinct patterns of spatial organisation of behaviour.

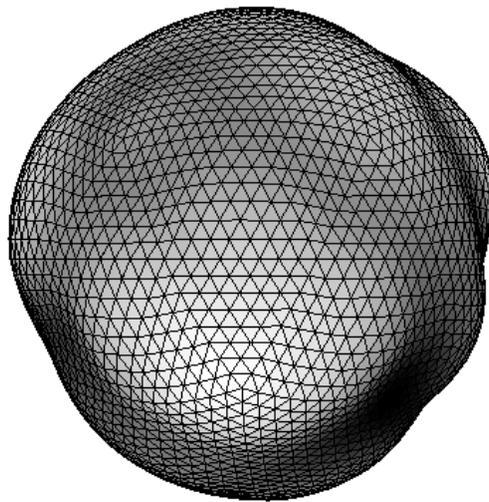


Figure 3. View of the S-SOFM graphical representation showing the formation of three distinct white regions – corresponding to micro-artefact core-data (each for a core).

In this study, the critical prerequisite was rather the depiction of the existence of differences in formation processes (and arguably of cultural formation processes) and of spatial content between different contexts (i.e., cores) from the site, on a broad spatial and temporal scale, than a detailed presentation of the spatial and temporal use of space on the tell settlement or of differences in formation processes between different activity areas across the site.

Despite the natural and cultural agents/processes that have disorganized the site's behavioural contexts, the archaeological sediments from Paliambela still preserve significant non-linear behavioural information. The spatial differences in cultural formation processes

arguably reflect long-term continuity of distinct patterns of spatial organisation of behaviour. The term 'continuity' is conceptualized here as the cultural product of different social systems (Neolithic or later) that inhabited Paliambela. Their cultural outcomes, embedded in and decoded from the archaeological sediments, contributed significantly to the site's formation, transforming it into a cultural product. Therefore, the archaeological sediments of Paliambela, enclose significant cultural information, and this study has demonstrated the potential of the non-linear method to help identify this information.

5. Conclusions: The importance of understanding formation processes in a non-linear world

Since Schiffer's [19] original recognition of the importance of studying and understanding the formation processes of the archaeological record, many authors have pointed out their critical importance [5, 12, 13, 25]. Moreover, it is now widely accepted that variability is introduced into the archaeological record through cultural and non-cultural formation processes which distort systemic patterns as well as creating their own patterns [20].

The unit of analysis appropriate for identifying formation processes is, according to Schiffer [20] the deposit, but "viewing the deposit as a single discrete depositional event or process has its problems, as a single depositional process can give rise to materials in different deposits, and conversely, a single deposit can contain the products of many different depositional processes" [20].

However, despite the recognised importance of cultural and natural processes in the formation of the archaeological record, studies addressing the interpretative potential of micro-artefacts remain relatively limited, although micro-artefacts, due to their abundance and incorporation in an archaeological deposit constitute a significant part of the cultural particles present and may provide information on the cultural and natural formation processes occurring in a deposit [4, 3, 26, 6, 21].

Dunnell and Stein [6] outline some of the important characteristics of micro-artefacts that compel their consideration as archaeological data of the first order. They note, that information content may be different for micro-artefacts than for larger artefacts and they may be most informative about different things (e.g., particle transport and site formation processes). Equally important, processes that generate microscopic artefacts vary depending on material and context [6]. These last two issues, differing information content and differing formation processes within the micro-scale are important reasons for undertaking micro-artefact analysis [6].

Then again, attempting to define cultural and natural formation processes in a site focusing, for example, either in their variability or in the proportional correlation among micro-artefact classes may be misleading because their archaeological significance rests upon understanding the interaction among, the almost, numerous variables within a sequence which would determine their transport potential.

The example offered in this study indicates that similar types of micro-artefacts within different archaeological contexts across the site exhibit significant non-linear information plausibly as a result of different types of formation processes that were assumed to imply, for the most part, differences in cultural formation processes. In any case, stronger interpretation can only be achieved by strong micro-artefact pattern recognition [9, 10] especially in cases of archaeological deposits sensitive to cultural formation processes.

Without underestimating the effects of natural processes or rather 'naively' expecting cultural factors to account for all the extant variability in an archaeological site, it seems that drawing logical connections between geoarchaeological data and past human activities upgrades and enhances cultural interference upon natural factors in a site's formation. The study of micro-artefacts, those cultural particles included into archaeological sediments, although by no means conclusive, can be utilised to identify forms of behaviour enacted within a site, when strong pattern recognition has been achieved [8].

New ways of describing differences in archaeological assemblages could only be effective if we could connect them with past human behaviour in a non static physical environment. The identification of cultural formation processes, spatially and temporally, on the micro-level in a complex site, as Paliambela, indicates that such discrimination is possible through the application of a certain methodology. More importantly, it calls for awareness of the multiplicity of scales at which these cultural processes can be traced. Although not exhaustive, the non linear spherical self organizing feature map method has provided a higher resolution with which to view the archaeological information encoded within archaeological sediments.

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