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Mapping the Past

From sampling sites and landscapes to exploring the 'archaeological continuum'

edited by

Michel Dabas, Stefano Campana and Apostolos Sarris

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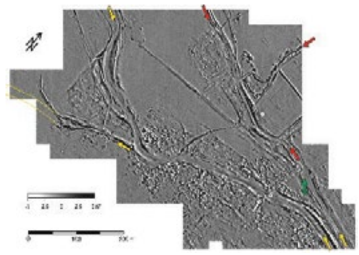

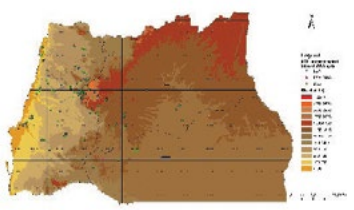

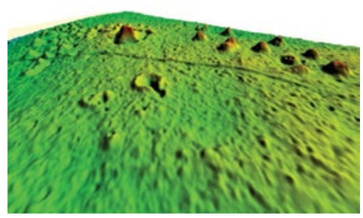

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From sampling sites and landscapes to exploring the 'archaeological continuum'

Proceedings of the XVIII UISPP World Congress
(4-9 June 2018, Paris, France)
Volume 8

Session VIII-1

edited by

Michel Dabas, Stefano Campana
and Apostolos Sarris

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Foreword to the XVIII UISPP Congress Proceedings

UISPP has a long history, originating in 1865 in the International Congress of Prehistoric Anthropology and Archaeology (CIAAP). This organisation ran until 1931 when UISPP was founded in Bern. In 1955, UISPP became a member of the International Council of Philosophy and Human Sciences, a non-governmental organisation within UNESCO.

UISPP has a structure of more than thirty scientific commissions which form a very representative network of worldwide specialists in prehistory and protohistory. The commissions cover all archaeological specialisms: historiography; archaeological methods and theory; material culture by period (Palaeolithic, Neolithic, Bronze Age, Iron Age) and by continents (Europe, Asia, Africa, Pacific, America); palaeoenvironment and palaeoclimatology; archaeology in specific environments (mountain, desert, steppe, tropical); archaeometry; art and culture; technology and economy; biological anthropology; funerary archaeology; archaeology and society.

The UISPP XVIII World Congress of 2018 was hosted in Paris by the University Paris 1 Panthéon-Sorbonne with the strong support of all French institutions related to archaeology. It featured 122 sessions, and over 1800 papers were delivered by scientists from almost 60 countries and from all continents.

The proceedings published in this series, but also in issues of specialised scientific journals, will remain as the most important legacy of the congress.

L'UISPP a une longue histoire, à partir de 1865, avec le Congrès International d'Anthropologie et d'Archéologie Préhistorique (C.I.A.A.P.), jusqu'en 1931, date de la Fondation à Berne de l'UISPP. En 1955, l'UISPP est devenu membre du Conseil International de philosophie et de Sciences humaines, associée à l'UNESCO. L'UISPP repose sur plus de trente commissions scientifiques qui représentent un réseau représentatif des spécialistes mondiaux de la préhistoire et de la protohistoire, couvrant toutes les spécialités de l'archéologie : historiographie, théorie et méthodes de l'archéologie ; Culture matérielle par période (Paléolithique, néolithique, âge du bronze, âge du fer) et par continents (Europe, Asie, Afrique, Pacifique, Amérique), paléoenvironnement et paléoclimatologie ; Archéologie dans des environnements spécifiques (montagne, désert, steppes, zone tropicale), archéométrie ; Art et culture ; Technologie et économie ; anthropologie biologique ; archéologie funéraire ; archéologie et sociétés.

Le XVIII° Congrès mondial de l'UISPP en 2018, accueilli à Paris en France par l'université Paris 1 Panthéon-Sorbonne et avec le soutien de toutes les institutions françaises liées à l'archéologie, comportait 122 sessions, plus de 1800 communications de scientifiques venus de près de 60 pays et de tous les continents.

Les actes du congrès, édités par l'UISPP comme dans des numéros spéciaux de revues scientifiques spécialisées, constitueront un des résultats les plus importants du Congrès.

Marta Azarello

Secretary-General /
Secrétaire général UISPP

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Mapping the Past

From sampling sites and landscapes to exploring the 'archaeological continuum'

General introductory text of the series

The last decade has seen the application of new approaches to landscape archaeology, essentially based on high-precision, high-speed, large-scale geophysical surveys along with the collection and analysis of high-resolution LiDAR data and the integration of multiple data sources based on GIS spatial tools. These approaches have proved their potential effectiveness in rural and formerly urban landscapes, suggesting the possibility of prompting the adoption of new paradigms within landscape studies.

The application of large-scale and multi-source surveys, especially at parts of countries such as Britain, Austria, Belgium, France, Germany, Italy, Norway and Sweden, has eliminated as far as possible gaps in space and time and has radically transformed archaeologists' views about almost every aspect of the past.

A crucial concept shared by all of these major surveys has been the perceived possibility of identifying what might be called the '*archaeological continuum*' within the areas concerned.

This concept can be defined as the summative evidence detected (or detectable) within the area under examination, reducing spatial and chronological gaps as far as possible through the intensive and extensive application of a wide variety of exploratory methods and analytical techniques.

Research work across Europe has already demonstrated that it is now possible to explore the whole landscape of carefully chosen areas and study them as an archaeological *continuum.*

Archaeological interpretations derived from this kind of approach can be expected to reveal differing layers of information belonging to a variety of chronological horizons, each displaying mutual physical (stratigraphic) and conceptual relationships within that horizon.

Introduction to the volume

The session of UISPP 'Mapping the Past' has brought together several contributions reflecting on the need to develop sustainable and reliable approaches aiming to map our landscape heritage. At the same time, these communications have raised new archaeological questions and proposed alternative conservation strategies directly stimulated by the radical ideas inherent in the concept of the 'archaeological continuum' which is depicted by the landscape surveys more clearly than has been possible in the past.

This volume consists of six contributions that cover different aspects of the study of our cultural heritage, not in the form of a discrete set of sites but in the form of a continuum both spatial and temporal. In relation to the origin of the concept of the '*archaeological continuum*', our first author, S. Campana, notes that this new vision makes it possible to get rid of the traditional approach, which is based on punctual sites that translate into a 'point' distribution on a map. The archaeological site is no longer an entity characterized by a defined boundary, itself underpinned by the old assumption that human behavior is partially confined in space. Only research on a smaller scale, that is to say at the level of the landscape (essentially based on landscape blocks), makes it possible to have the necessary perspective. As traditional tools like 'surface collection' became inadequate for this purpose, Campana proposes a new scale of study that is adapted to the archaeological questioning and not vice versa.

Wooded areas, often considered as white areas due to lack of effective prospecting systems, have recently benefited from LiDAR technology (ALS). The micro-reliefs highlighted by the article of M. Szubski allow us to view a continuum of occupation in the pristine forest of Bialowicza (Poland) over a considerable area (1500 km^2). It is actually part of a more comprehensive study of the biodiversity of this environment, which includes the identification of paleo-environmental features and archaeological features since the Iron Age. The challenge is the characterization of a particular type of structures (mounds), which dominates the landscape of the forest. The return to the field is always necessary to distinguish on the function and the chronology of these mounds (funerary versus production). The author shows that these mounds form a specific continuous landscape over time and space and whose morphological study by ALS could make it possible to deduce their function.

The third paper by Daniela de Matos *et al.* illustrates the construction of a cultural landscape over an even longer continuum time (since the Pleistocene) in a particular region of Angola. The continuity of traditional semi-nomadic foraging life has attracted the curiosity of anthropologists and archaeologists who were part of a large-scale geologic survey mission. If the hunters-gatherers have been shaped by the exploitation and adaptation of landforms and geological formations, the comprehension of these societies is mainly possible through the tools provided by archeology and geosciences.

A. Sarris *et al*., describe an investigation in another type of difficult environment, namely the coastal zones. The Lechaion Harbour and Settlement Project in the vicinity of Corinth, Greece aims at studying the settlement through all his time-life. Geophysical data were massively used and proofed successfully to reveal the formation of that particular site, both from natural and anthropogenic causes. Like the previous case study in Angola, geophysical and archaeological approaches, working in tandem, were possible to reveal the interaction between natural hazards and the human habitation of the coastal landscape of Lechaion.

The case-study described by W. de Neef and F. Vermeulen in Italy (Potenza Valley Project) is a long term project that has also used numerous technics to study a temporal gap linked to the proto-historic settlements (and their catchment), which are often hindered by the numerous studies related to Roman and Late Antique times. For this purpose, numerous non-destructive technics were used and helped at filling this time and spatial gap. Practically, several micro-regions, reflecting the site catchment of the settlements, were intensively studied. This paper also addresses the challenge of the use of non-destructive techniques: detection and interpretation of ephemeral traces without ground- truthing and the problem of detectability as a function of landscape formation processes.

The last paper by T. Herbich focuses on three different sites in the Fayum Oasis, Egypt. Non-invasive methods were used resulting in the discovery of a number of buried channels suggesting the importance of water which controlled irrigation in this particular area. Together with the traces of water erosion found, which were interpreted as an explanation for settlement destruction, the paper makes a clear demonstration that landscape changes are directly related to the habitation changes.

In conclusion, the use of new and non-destructive technologies like LiDAR, GPR and other conventional technologies like magnetics, resistivity, aerial, etc. has helped us to fill some of the spatial and time gaps encountered. These new technologies are usable in challenging environments like forests, coastal regions, desert areas and mountainous zones, which have been poorly described in the past. The complexity of data obtained in these specific areas demonstrate in fact a continuity of landscape usage that was not observable with standard tools like field surveying or aerial photos.

We should not forget that this new information lead also to a higher level of complexity in our interpretation of the archaeological data. As a consequence, we need to start focusing also on improving the quality of our interpretation in parallel to the large quantity of data collected. This new information rises an awareness about new preservation processes for our buried cultural heritage, which in turn should reflect in new preservation policies for our landscape.

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Establishing meanings, roles and limits of '*Archaeological Continuum*' paradigms

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'After all, no one lived, worked, and died solely within the confines of his or her own settlement'
(T. W. Gallant 1986)

Abstract

This paper introduces the concept of continuity within the landscapes of the past, discussing the development of ideas about the meaning and mutual relationships of the terms 'site' and 'landscape' within concerted efforts to develop a methodological framework that would enable research to move away from traditional 'site-based' archaeology towards a more genuine focus on a 'landscape' scale of investigation and interpretation. It is argued that what we should be seeking, within the limits of practicality and with as few spatial and chronological gaps as possible, is the capacity to analyse physical, cultural, social and in some cases even political interrelationships in space and time across significant sample areas of intensively studied landscape.

Keywords: continuity, discontinuity, site, landscape, scale of investigation

Résumé

Cet article introduit le concept de la continuité dans les paysages du passé en abordant le développement d'idées sur le sens et les relations mutuelles des termes « site » et « paysage » dans le cadre d'efforts concertés visant à développer un cadre méthodologique permettant aux chercheurs d'abandonner l'archéologie traditionnelle « basée sur les sites » pour se concentrer davantage sur une échelle d'investigation et d'interprétation « proprement du paysag e». Il est soutenu que ce que nous devrions rechercher, dans les limites de la fonctionnalité et avec le moins de lacunes spatiales et chronologiques possibles, est la capacité d'analyser les interrelations physiques, culturelles, sociales et parfois même politiques dans l'espace et dans le temps, à l'aide d'un échantillon significatif zones de paysage étudié de manière intensive.

Mots-clés : continuité, discontinuité, site, paysage, échelle d'investigation

1. Introduction

There is a strong possibility that what we see in past and present distribution maps reflects not so much the original spread of human activity across the landscape as a 'filtered' version strongly affected by data-collection strategies, methodologies and discontinuities in the present-day land-use.

A guiding principle which could help us to offset at least some of these shortcomings could lie in the integration of our basic thinking and practical methodology of the concept of the '*archaeological continuum*'. This would mean revisiting a hypothesis developed in the late 1970s and widely accepted even in Mediterranean archaeology. This questioned the supposition that human behaviour is spatially confined, producing what we might call 'site-based archaeology', and arguing instead that the archaeological record is spatially continuous (Foley 1981a). Accepting this alternative paradigm we should, within the archaeological community, have developed consistent and effective practices that would have enabled the assembly of evidence that closed or at least reduced some of the gaps in the basic data upon which we had been formulating our landscape interpretations up to that point. However, while the concept of continuity continues to play a progressively key role within the development of stratigraphic archaeology, mainly within the practice of archaeological excavation, the concept never established itself to quite the same extent within archaeological investigation and interpretation at the landscape scale.

In this context the term '*archaeological continuum*' could perhaps be seen as another formulation of the deliberately provocative neologism '*emptyscape*' coined by the author to describe the prevalence of 'empty' spaces within current archaeological maps (Campana 2018). The '*emptyscape*' concept, in turn, could find a parallel in Groube's '*black holes*' (1981), representing in many cases not real gaps but simply weaknesses in our ability to detect relevant archaeological evidence in particular areas or for particular periods in the passage of time. Looking at it in another way, both in practical and ideological terms, the '*archaeological continuum*' could be seen as an antonym of '*archaeological emptiness*'.

A misunderstanding may arise here about our determination to achieve comprehensiveness. It is rightly acknowledged that the archaeological record is and always will be incomplete in the sense that so much of what once existed has been placed beyond effective recovery by later human activity or the inevitable degradation of post-depositional processes. The approach that is being advocating here is not aimed at the 'total' recovery of past situations but rather at a ***fair representativeness***, or a reasonable representation, of landscapes created or influenced by the impact of past human activity (economic, social and political) as well by natural environmental transformations over time. The attempt to attain 'fair representativeness' would mean that research designs, methodological frameworks, analytical practices and reporting procedures should be consistent with the objective of gathering as large a range as possible of the 'facts' that are pertinent to the broad archaeological questions currently under discussion. At the same time, we must ***always be aware of what is or might be missing***, which should entail being aware of its presence elsewhere in practice or even just in theory. This would also mean keeping thoroughly up to date with all kinds of evidence actually or theoretically recoverable in our own or other contexts, as well as challenge 'emptiness' by seeking new ways to recognize, record and interpret kinds of evidence that for one reason or another may have remained hidden from us up till now.

However, to illustrate the concept of continuity within landscapes it will be useful in the rest of this paper to discuss the development of concepts about the meaning and mutual relationships of the terms 'site' and 'landscape', in the light of a concerted effort to develop a methodological framework that would enable us to move away from traditional 'site-based' archaeology and towards a genuine 'landscape' scale of investigation and interpretation. What we are seeking, within the limits of practicality and with as few remaining gaps as possible, is the capacity to analyse physical, cultural, social and in some cases even political inter-relationships in space and time across a significant piece of landscape.

2. Sites and landscapes: shifting the paradigm from isolation to interconnection

The concept of 'site' has a long history in archaeology, characterized by repetitive updating of the meaning in response to the arrival of new methods, more advanced technology and of course the intellectual development of the discipline as a whole. Well into the last century the term was mostly associated with standing monuments or partially preserved ruins. Following WWII, the term was expanded to cover underground remains, including the traces of settlements and other features identified through aerial survey and air photography (Bradford 1957). A few years later the meaning was expanded to include scatters or concentrations of cultural material brought to the surface by the inexorable spread of mechanical agriculture (Ward Perkins 1961). When only monuments or standing ruins were involved, the need to define the term 'site' did not really arise. But as soon as the range of evidence was broadened to include surface artefacts and the traces of below-ground features revealed by air photography or ground-based survey, the definition of 'site' became more problematic, hedged around by a number of inherent difficulties. With the appearance of so-called processual archaeology and the idea of a universal methodology, Lewis Binford (1964) extended the implication of 'site' to encompass any trace of human activity, whatever its age or function, defining the 'site' by its formal content and the spatial and associational structure of the populations of cultural items and features that betrayed its presence.

In the 1970s the widespread development of field survey in archaeology and the overall desire for the better definition of concepts and their practical application in this field provided another spur for re-thinking and re-definition of the terms used in archaeological discourse. Several different and sometimes 'competing' schemes were defined – too many and too varied to be discussed in detail here. That said, it is relevant to note that most of definitions still in use share two elements in common: a 'site' is always defined (and delimited if only conceptually) by some kind of ***boundary***; the 'site' also becomes the ***elementary unit*** through which the 'archaeological landscape' is itself defined, commonly seen as equivalent to the 'stratigraphic unit' in the field of archaeological excavation. However, there are significant several differences between 'site' and 'stratigraphic unit' (Manacorda 2007). Indeed, two major peculiarities of the 'stratigraphic unit' are substantial continuity within the archaeological record, and mutual physical relationships between the various units. Both of these characteristics are typically missing in attempts at comparison between 'sites' since the latter usually appear in the archaeological record as systematically isolated physical elements surrounded by impenetrable 'blanks' within which little if any form of interconnection can be traced. That said, as we will see as the discussion unravels, the parallel between archaeological excavation and landscape analysis can help to focus attention on some of the contentious issues involved in the continuing discussion of concepts, definitions and practices within the field of landscape archaeology. For instance, alongside the concept of 'site', the development of wide-ranging archaeological survey work has given rise to the balancing concepts of 'off-site' or 'non-site', perhaps best described and discussed in the first instance by Foley (1981b). In the archaeological literature of the following decades the terms 'off-site' and 'non-site' came into regular use for such things as the artefactual evidence of agricultural cultivation (manuring) or other kinds of human activity that had failed to leave stratified archaeological deposits in the sub-surface soil. But the very concept of 'off-site' calls into question the initial idea that human behaviour is spatially confined to what archaeologists had decided to define as 'sites'. Foley introduced (within the particular circumstances of nomadic societies) a new and ground-breaking concept, the proposition that the archaeological record is, at least originally, ***spatially continuous***. At that time, in the 1980s and onwards, continuity in this sense was described primarily through observed and recorded variabilities within artefact densities detected across the target landscape. On the other hand, an equally important role in establishing the reality of such continuity had already been played, as mentioned above, by well-timed aerial survey work above favourable landscape areas, typified by the exceptional results achieved in parts of southern Italy in the months immediately before and after the end of WWII, revealing virtually uninterrupted evidence of human settlement and landscape exploitation across a vast stretch of space and time (Bradford 1957; Radcliffe 2006).

The concept of continuity also worked well in theoretical terms as a response to the problem of site definition and to inherent subjectivity in the identification and interpretation of surface evidence. Indeed, some scholars shifted the orientation of research away from the 'site' to the artefact or cultural feature (solving site definition issue) in the broader sense as the minimal unit representing past human activity answering intrinsic subjectivity within site definition by emphasising any changes in whatever kind of evidence density (Thomas 1975). The term 'artefact' was at that time being used for the most part to mean material evidence identified by field-walking survey in the form of 'positive' physical features or surface assemblages reflecting past by human activity: vestigial walls or earthworks, building materials, charcoal or industrial waste, potsherds, tiles, tools, weapons, ornaments, coins, glass and so forth. By contrast, 'negative' features concealed beneath the present land surface, such as pits, post holes, boundary or drainage ditches, enclosures, field systems and abandoned communication routes remained more or less invisible to field-walking survey and were thus not included within the definition of 'artefacts'.

However, further developments in the decades either side of the second millennium made artefact-level surveys a required standard by British and UK-influenced archaeologists in the Mediterranean area. Among the main consequences of this attention to artefact-based investigation there was an intensification of survey work that aimed at improving the quality of data recovery, counterbalanced to some extent by a progressive reduction in the size of the area that could realistically be subjected to intensive investigation. In practice, post-depositional processes and variations in ancient and/or present-day land use, along with other factors, can still produce significant inadequacies and risks of bias in the collected information, giving rise to continuing but as yet unresolved criticism about the validity of landscape interpretations based on this kind of survey work. Despite genuine efforts to overcome these semantic and practical difficulties, and to refine the procedures used in the collection and interpretation of 'site', 'off-site' and 'non-site' evidence, these aspects of the archaeological process remain a controversial source of debate and disagreement within the global topic of methodological approaches to landscape archaeology (Terrenato 2004).

The meaning of '***landscape***' in archaeology has changed significantly over time. For long periods it was thought of largely in artistic and aesthetic terms. The close association of the words 'landscape' and 'archaeology' does not have a particularly long history. Initially, the 'landscape' simply represented something larger than the 'site', a framework for conceptualizing observations, speculative inter-relationships or parallels between sites of a particular type, or to suggest or deduce transformations across time: identifying the settlement patterns and material culture of a particular region, and their changes over time, became the main focus of the investigation. Between the 1970s and 1980s 'landscape' become an object of investigation in its own right and 'landscape archaeology', now recognised as such, began to take its present shape. The first linking of the two words as a meaningful whole should perhaps be attributed to the British archaeologists Mick Aston and Trevor Rowley in the mid-1970s (Aston and Rowley 1974) but it was only from the mid to late 1980s that the formulation attained common usage in academic publications (David and Thomas 2008). At that time, the focus was on human impact, people and interactions with their physical surroundings. Among outcomes focusing on the relationship between human beings and the environment there then came about a substantial proliferation and refinement in field practices and statistical methods of analysis, particularly with regard to the distribution of archaeological material and sites across the broader landscape (Hodder and Orton 1976). In such a context Hodder (1978) and others moved towards a more socially-oriented assessment of landscapes based on ideas about the social construction of space, encompassing an interlinked complex of practices, meanings, attitudes and values. This approach involved the consideration of landscapes in all their lived-in dimensions – 'experiential, social, ontological, epistemological, emotional, as place and emplacement concern social identity as much as they concern the economic and environmental aspects of life' (David and Thomas 2008). However, despite the best intentions of reducing or eliminating gaps in the recorded spatial distributions, the overall methodological framework, at least within the Mediterranean area, remained largely 'site-based', defined as a set of physical nodes within a background of largely unexplored open space.

3. The *continuum* of space (and time) in landscape archaeology

Despite several decades of theorising and the general acceptance of 'archaeological continuity', experience on the ground has yet to achieve the final goal – the collection of relevant evidence from beyond the level of 'sites' in order to detect physical relationships between elements (paleo-surfaces, archaeological features, natural remains, etc) that would allow the archaeologist to depict past landscapes as continuous human ecosystem in both space and time. Indeed, even in the best case-studies a major bias was seen to be inherent in the concept of density plots derived from the surface collection of plough-disturbed artefacts. The representation of variable densities across the landscape, rather than as single dots for individual occurrences in a sea of 'emptiness', should in theory have provided a more realistic depiction of landscape continuity. However, density patterns do not in themselves represent any real physical or functional relationship between surface scatters beyond a mathematical interpolation process: the number of artefacts in sherds per hectare (or whatever spatial unit the archaeologist might choose to employ). Given the acknowledged frailties of artefact-collection the chance of establishing *either* continuity *or* genuine spatial relationships between differing density areas came down to purely speculative estimates – sometimes based on no more than a few sherds within any chosen hectare, devoid of any tangible physical relationship.

There are further sources of potential bias or uncertainty in the definition of 'off-site' data. The presence or absence of evidence was intended to be artefact-based (as is often the case within the 'sites' themselves) but associated in the 'off-site' context with activities which leave in the sub-surface soil no archaeological stratification to betray the presence of related anthropic activity. This is in fact a faulty characterisation of the situation. The process of manuring or other agricultural processes *do* sometimes generate stratification, however ephemeral, that would sometimes be detectable through the application of appropriate investigative techniques (Powlesland 2009). Palaeo-soils of this kind might well be bounded by or associated with field system and ditches, whether for demarcation or drainage, or by specific agricultural practices, road systems, water supply and even settlements and productive areas. Deposits of this kind can be identified indirectly by the presence of artefact scatters on the surface but the boundaries and inter-relationships between the activities involved in their creation can rarely be detected through field-walking survey. In this case, theoretical and methodological issues interact with one another. On the one hand there are strong ambiguities in the definition of the 'off-site' evidence but at the same time there are methodological inadequacies that prevent our escape from this kind of uncertainty or apparent 'gap' in the available evidence.

It might be useful here to return for a moment to the parallel with archaeological excavation. Philip Barker, in his magisterial book on 'Techniques of Archaeological Excavation', stresses the importance of stratigraphic excavation over *large areas*, in particular criticising any real reliance of excavation by trial trenching: 'To dig holes, however well recorded, in an ancient site is like cutting pieces out of a hitherto unexamined manuscript, transcribing the fragments, and then destroying them, a practice which would reduce historians to an unbelieving stupor but whose counterpart is accepted by the majority of archaeologists as valid research. A single section, even of a ditch, can be grossly misleading, as anyone who has cut multiple sections will know. [...] Extensive excavations on sites previously trenched [...] have so often shown that the earlier conclusions have been completely misleading, that it is now clear that only total, or near-total, excavation will yield results which are not deceptive' (Barker 1977).

The analogy with current practice in landscape archaeology is very strong. Excavation by trial trenches fits well enough with the concept of 'site-based' landscape archaeology, characterized as it is by the relative isolation of individual 'sites' or bits of 'sites' within a more or less unexplored surrounding landscape. But, for a broader definition of landscape archaeology, trenching of this kind falls far short of the sort of critical mass advocated by Barker ('only total, or near-total, excavation'). Instead, it is liable to uncover just the tips of the proverbial iceberg, concentrating on the partial sampling of individual 'sites' already identified through field-walking survey but unlikely – for want of any realistic means of 'targeting' the operation – to reveal anything useful in the vastly greater area of the intervening spaces. The absence of evidence for physical continuity between the 'sites' excludes the possibility of establishing reliable stratigraphical relationships between them. There may, of course, be apparent chronological synergies based on the mutual presence of distinctive artefacts or well-monitored radiocarbon samples but even in the most favourable circumstances this provides no more than a sort of 'proto-stratigraphic' relationship between the sites involved. Open-area excavation, by contrast, investigates real stratigraphical relationships through an intimate contextual logic that has as its guide and ultimate purpose the recognition and physical interconnection of the archaeological evidences.

4. Towards a new methodological approach

The need for a different set of methodological procedures has been widely acknowledged within the archaeological community (Knapp and Ashmore 1999; David and Thomas 2008) but proposals which offer the real possibility of change in our capacity to detect and record continuity have so far proved elusive, or in some cases illusory. How, indeed, can we escape from this 'blind alley'?

The problem goes back to the first principles. At the very start of the search we need to recognize the complexity of investigating past landscapes, particularly so in the Mediterranean world where climate, soils and land-use place so many obstacles in our way. In doing that, we may be well-advised to set aside any seeming equivalence between field-walking survey and archaeological excavation, the latter acknowledged as the most comprehensive method at our disposal for the direct exploration of evidence from beneath the present-day land surface. Many innovative techniques and investigative methods have been devised to allow us to gather information about individual 'sites' or group of 'sites' but most of them can be applied systematically *only* within the framework of archaeological excavation. A 'landscape', however restricted or extensive in scale, is much more complex, multivariate and diffusely stratified than any individual 'site' but – just like the 'site' – it can be, and *has* to be, defined through observed relationships in four dimensions: three dealing with space (ideally devoid of gaps) and the fourth of course with time. Currently, no single methodology equivalent to that of excavation has yet been devised or become available for the study of 'landscapes' as such. Around the Mediterranean the situation has been complicated by the prominent – one might say over-riding – role that field-walking survey has continued to play in the pursuit of landscape archaeology, acting as a *de facto* – but clearly inadequate – counterpart to the central role occupied by archaeological excavation at 'site' level. This is a major problem which clearly affects and also in some senses derives from the question of definitions. Within any landscape research project based on the identification of relative artefact densities a large amount of the potentially relevant evidence remains undetected because of the widely acknowledged frailties and inherent risks of bias involved in the surface collection technique. A further, and even more debilitating weakness, lies in the technique's incapacity to detect with any clarity a broad range of below-ground features which are necessary to fill otherwise insurmountable ***gaps*** in the basic evidence upon which we base our overall understanding of the landscape (or even, whether in theory or practice, to determine what really constitutes 'site' or 'off-site' features within the broader context of the 'landscape').

There is an urgent need to develop a **new methodological framework**, building on past experience but capable of responding to current and future archaeological questions, re-balancing the currently dominant 'site'-based' approach by defining new scenarios and new **units of analysis** that will facilitate our search for understanding of past landscapes in all their complexity and mutability across the passage of time.

5. A new elementary unit: the 'local' scale

Historians and archaeologists have long recognized the value of 'context', the interrelationship of physical, biological, social, economic and cultural circumstances within a landscape: 'the whole of relationships that gives things mutual attraction, congruence, meaning and value' (Carandini 2017). Despite this, the interpretation-unit of landscape studies in the Mediterranean world has still remained primarily that of the 'site'. Settlements, particularly 'central places', cemeteries, productive structures, temples and churches have long constituted the pivots of landscape studies particularly around the Mediterranean but also in Continental Europe. In reality, of course, rural landscapes do not consist of settlements and 'sites' alone: inseparable elements in the understanding of past landscapes lie in the study of agricultural patterns, the shapes and sizes of enclosed fields or open pastureland, the parcels of land and elements of the local environment that people of one age or another exploited and enjoyed in their daily lives. These little considered and frequently undetected 'landscape elements' offer us invaluable insights into the realities of past societies and their social, economic and political systems (Muir 2000).

In much the same way communication systems, infrastructure elements, ecofacts, geomorphology, hydrology and the distribution an availability of natural resources are often overlooked or only briefly considered despite constituting essential elements in the 'connective tissue' of man-made landscapes (Campana 2009). Moving from site-based archaeology to a genuinely 'landscape' approach means exploring and analysing sample areas of the land-mass as human ecosystems, contextualizing sites, features and environmental evidence so as to envisage a more realistic and nuanced image of the whole (Butzer 1982).

The underpinning and added value of this approach will lie in a quantitative and above all qualitative improvement in our data sources and in the possibility of establishing meaningful relationships between differing types of archaeological evidence. In some instances, physical overlaps or other discernible relationships between features may allow us to apply or extend the stratigraphic approach which is now an integral part of almost all archaeological thinking, including in the final analysis also landscape archaeology. Instead of establishing historical reconstructions by comparing individual 'sites' or groups of 'sites' belonging to differing contexts or even time-frames, this shift from a 'site' to a 'landscape' perspective will provide a more stimulating and fulfilling opportunity to compare differing contexts or situations in the past not as individual sites, features and artefact scatters but as multi-faceted and intelligible human ecosystems.

To achieve this advance in our understanding of landscape in human terms we must define and then implement a suitable scale of investigation and formulate an appropriate methodological framework – or more correctly, perhaps, a *range* of appropriate means of investigation and analysis. Elsewhere I mentioned the need for what we might call the 'local scale', lying somewhere between the scale of large 'regional' areas (the 'macro' scale) and that of spatial foci (the 'site' scale; Campana 2018). This 'local scale' might focus on areas broadly matching the **physical scale at which human societies operate**, within which human eco-cultural systems form and re-form over the time. A predecessor or equivalent of this concept might perhaps be found in the so-called 'catchment area'. It is difficult, or perhaps simply inappropriate, to attempt a definition of size by pinpointing a particular range in terms of hectares, square kilometres or whatever. A more suitable measure might be to propose that within such an area of landscape the scale of mapped and documented detail should be such that any settlement, road system, field pattern, geomorphological element or other significant feature should be capable of depiction by its physical characteristics, notably shape and size, rather than just by dots or symbols. In broad terms, perhaps, the scale of mapping might lie within the range of 1:10,000 to 1:2,000.

The definition and implementation of a new analytical level does not in any way mean abandoning those that have been used as a matter of routine in the past. The 'macro' scale, for large regions, and the 'point' scale (for individual 'sites'), will continue to play a fundamental role in communicating information or responding to questions that can only be answered through investigation at a sufficiently broad or concentrated scale. The questioning, analysis and interpretation of archaeological data are of course heavily dependent on the level of analytical scale. For example, business or trade relations in the manufacture or distribution of ceramics, building materials, luxury goods and the like should generally be studied and then illustrated at the maximum scale, preferably that of the Mediterranean, European and beyond. Other phenomena, including the creation and supply of resources such as metals, stones, clay, wood, etc. may require observation and analysis at the regional or even sub-regional scale. When contemplating a research project, it is essential to establish a clear definition of the archaeological questions that one is aiming to address, and to understand which scale or scales might be appropriate in achieving the desired objectives. The choice is not always straightforward and may be particularly problematic for landscape studies which by their very nature are generally multifaceted and strongly interdisciplinary. Interacting with fields of study such as geology, geomorphology and palynology often means dealing with spatial and temporal scales which are very different from those which are customary within archaeology.

That said, past experience in central and northern Europe has demonstrated over and again that a full-blooded multidisciplinary approach, along with multiple scales of investigation and presentation, is essential if one is to record and explain the complexities of human behaviour, as must be the ultimate aim in landscape research. Besides open-minded and critical thinking, projects of this kind demand the creation of a methodological framework that itself remains permanently open, in a state of continual development so that it can take advantage of whatever established or innovatory technique might (now or in the near future) help to improve our overall understanding of the past.

Currently, alongside the 'traditional' framework of Mediterranean landscape archaeology, which for all the vulnerabilities of field-walking survey is still valid in many respects (Banning 2002), there are several fields of related study – such as remote sensing, geo-archaeology and bio-archaeology – that have enormous potential for widening our understanding if properly integrated within a landscape perspective. To take just a single example, experience of remote sensing techniques has shown quite clearly that a central role in reducing the evidential gaps within and between survey areas can be played – on both arable land and permanent pasture – by high-precision, high-speed, large-scale, continuous geophysical survey (Powlesland 2009; Millett 2016; Gaffney *et al.* 2012; Campana 2018). In wooded areas, so prevalent in Italy and other parts of the Mediterranean, the next transformative development might lie in the collection and analysis of high-resolution LiDAR data, perhaps mainly from lightweight equipment mounted on locally-controlled drones rather than traditional aircraft (Opitz and Cowley 2013; Campana 2017).

Despite the very real differences in climate and ground conditions, it is a striking reality that, wherever large-scale continuous geophysical surveys have been implemented in these countries, the results have totally transformed archaeologists' views about almost every aspect of the past (Powlesland 2009; Neubauer *et al.* 2013; Campana 2018). When integrated with the techniques traditionally used around the Mediterranean, these complementary techniques and their theoretical underpinning, so revolutionary in their impact on landscape studies elsewhere (and partially introduced by the present writer in Central Italy too), will hopefully bring about radical changes in the methodological framework, or frameworks, through which we will be able to confront archaeological and historical questions that have long been crying out for answers (Ch'ng *et al.* 2011).

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Mound landscape continuum. Mapping barrows (and more) in the Białowieża Forest, Poland

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Abstract

The Białowieża Forest is one of the largest forested areas in Poland. In total it occupies nearly 1500 km², of which 42% is placed in Poland and the rest is in Belarus. It is considered as a primeval forest because almost entirely area is protected since the sixteenth century. This unique situation results in very good preservation of archaeological features visible in the terrain relief. Dense woodland was almost inaccessible for standard prospection methods like field survey or aerial archaeology. Technology development of airborne laser scanning (ALS) changed this situation.

Using ALS mapping of the Białowieża Forest provided hundreds of anthropogenic features with preserved own shape. One type of features however dominates figures – almost 90% of all- are mounds. They occur alone, in clusters, in different size and shape. Often one cannot distinguish sepulchral barrows from well preserved traces of modern exploitation of forest resources (production of charcoal, tar kilns, potash production).

Keywords: Białowieża forest, landscape archaeology, als survey, anthropogenic mounds

Résumé

La forêt de Białowieża est l'une des plus grandes zones forestières de Pologne. Au total, elle occupe près de 1500 km², dont 42% en Pologne et le reste en Biélorussie. Elle est considérée comme une forêt vierge parce que la quasi-totalité de sa superficie est protégée depuis le XVIe siècle. Cette situation unique implique une très bonne conservation des éléments archéologiques visibles en relief sur le terrain. Les forêts denses sont presque inaccessibles par les méthodes de prospection standard telle que les enquêtes de terrain ou l'archéologie aérienne. Le développement technologique du balayage laser aéroporté (ALS) a changé cette situation.

La cartographie de la forêt de Białowieża par laser a fourni des centaines de structures anthropiques ayant une forme spécifique bien préservée. Cependant, un type de structure domine : les monticules (90% des structures détectées). Ils apparaissent seuls, en grappes, de tailles et de formes différentes. On a observé tout particulièrement un tumulus ainsi, que des traces bien conservées de l'exploitation moderne des ressources forestières (production de charbon de bois, fours à goudron, production de potasse).

Mots-clés : forêt de Białowieża, archéologie du paysage, prospection lidar, tumulus

1. Introduction

Despite many years of traditional surface surveys, white spots are still visible on the archaeological maps of every country. Most often woodland areas were overlooked by researchers, due to the complexities of field prospection in a forest environment. Until recently, one of the oldest forests in Europe – the Białowieża Forest – was one of such white spots.

The Białowieża Forest complex, which covers 1500 km², belongs to two countries: Poland (635 km²) and Belarus (865 km²). It forms a compact woodland complex, and is considered to be one of the last primaeval forests areas in Europe (Askins, 2014). Due to its exceptional natural values, the entire Białowieża Forest was inscribed in 2014 on the UNESCO World Heritage List. Polish part,

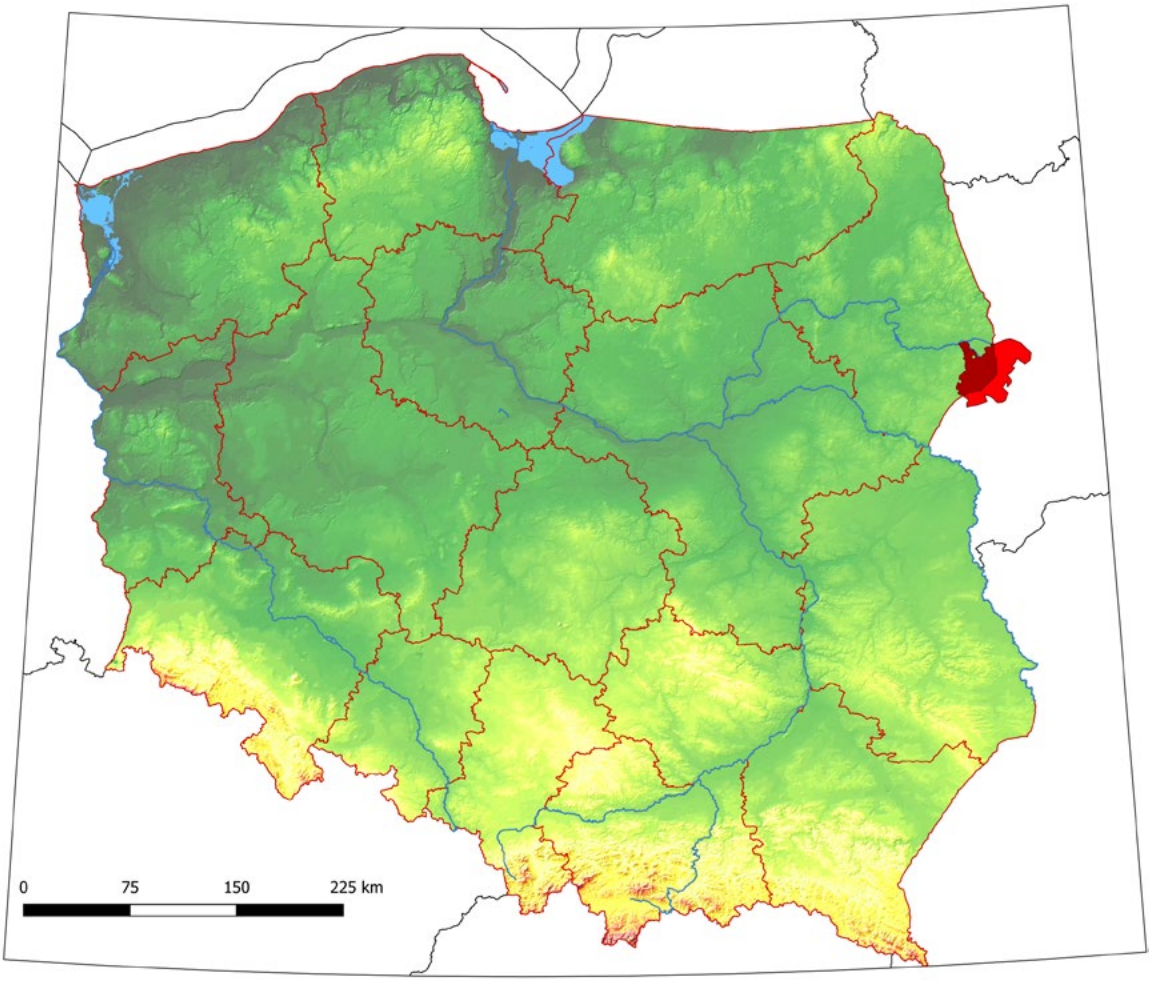

Figure 1: Localization of the Białowieża Primeval Forest in Poland.
Dark red – Polish part; red – Belarus part.

which is discussed in this article, is located in the north-eastern part of the country, within the Bielsk Plain, in the basin of two main rivers the Narew and Bug (Kondracki 2011) (Figure 1).

The unique character of the Białowieża Forest results from its long-term protection, dating back to the 15th century. In that period, the area was used as a royal hunting garden (Samojlik, Rotherham and Jędrzejewska 2013a: 191-193). The Bialowieza Forest has never been exploited for large-scale tree felling, and much of its area has never been subject to extensive modern agriculture (Mitchell and Cole 1998). This resulted in the protection not only of its natural resources but also of the archaeological heritage.

Due to the dense forest cover traditional archaeological research, and in particular field prospection, was significantly hampered. An entirely new view of woodland areas was introduced by the development of airborne laser scanning (ALS, LiDAR) (Crutchley and Crow 2010; Doneus and Briese 2011). Its widespread use in archaeology continually provides us with discoveries and allows to observe the prehistoric forest landscape on a new, broader scale (Mlekuž 2012, 2013).

In the years 2016-2018, the entire Polish part of the Białowieża Forest was surveyed by laser scanning as part of the ISOK project (Maślanka and Wężyk 2015). Subsequently, extensive remote sensing and verification studies were carried out, leading to the full mapping of the archaeological and historical heritage of the Forest (Wawrzeniuk *et al.* 2017). This article presents preliminary results of mound studies and its potential when spatial data is included, research and interpretation of these monument.

2. Previous archaeological research in the Białowieża Forest

The interest in human activity research in the Białowieża Forest goes back to amateur studies in the 19th century (de Ronke 1830; Hedemann 1935). Before World War II, the most significant research in Białowieża was conducted by the German professor A. Götze. From the beginning, the interest of researchers was focused on mounds, interpreted as barrows because they are relatively numerous and easy to identify in the field. In 1918, Götze inventoried 328 earth mounds, 35 of which were excavated (Götze 1929).

In the interwar period, Z. Szmidt carried out small surveys in the Zamczysko sacred site and surface surveys near villages of Rudnia and Krynica in the Dziki Nikor swamp in Belarus (Szmidt 1922). In turn, A. Klein examined two Early Medieval burial mounds in the Lady Forest (Walicka 1958).

After World War II, research in the Forest continued. In 1959, rescue excavations in the Hajduki sacred site took place. Another major study of the mounds was carried out in 1963. When three burial mounds were excavated and dated to the Early Medieval period (Żurowski 1963). Since 1969, research in the Białowieża National Park, an area of strict nature protection, was conducted by the Institute of Material Culture of the Polish Academy of Sciences. This work provided further discoveries of mounds, always identified as barrows and included archaeological excavations (Górska 1973, 1976). It was not until the next century that the Białowieża Forest became the object of subsequent archaeological research. Since 2003 D. Krasnodębski from the Institute of Archaeology and Ethnology of the Polish Academy of Sciences has been an excavating of various areas of the Forest. So far, he has examined a number of a flat sites and burial mounds from the Early Iron Age, the Roman Period and Early Middle Ages (Krasnodębski *et al.* 2005, 2008, 2011; Krasnodębski and Olczak 2006). Significant research was also carried out in 2004-2007 by a team from the Mammal Research Institute of the Polish Academy of Sciences, which included a comprehensive drilling and soil studies of previously unknown mounds were performed. Some of them were interpreted as production mounds, mainly based on the diversity of elements in the soil (Samojlik 2007). Until 2015, about 800 mounds of various types were recorded most of which were interpreted as barrows from the Early Middle Ages.

Along with the emergence of prospecting systems using data from airborne laser scanning, projects using this remote sensing method were launched. In 2016 a project funded by the General Directorate of State Forests in Poland was initiated which studies biodiversity in the Białowieża Forest (Zapłata and Stereńczak 2016) It includes the identification of archaeological features (Krasnodębski and Olczak 2017). In 2017 the Institute of Archaeology of the Cardinal Stefan Wyszyński University, started the project 'Cultural and natural heritage of the Bialowieża Forest' it is assuming an interdisciplinary, comprehensive recognition of the archaeological heritage in the Polish part of the Forest. As part of this project, for the detailed research on various anthropogenic structures, many subprojects were carried out.

3. Land use and landscape changes in Białowieża Primeval Forest

Important information on the use of Białowieża Forest area was provided by palynological research. A number of drillings allowed us to distinguish four main phases of the pollen profiles concerning historical periods and a fifth one concerning contemporary times (Latałowa *et al.* 2015, fig. 17.4).

The first period of increased human activity dates to the early Iron Age, when the areas of the Forest and neighbouring lands were populated by the Hatched Pottery Culture (HPC) communities (Olczak 2009). From the areas of Podlasie, including the Bialowieża Forest, settlement of the Wielbark Culture (Roman Iron Age/Roman Influence Period) usually considered as a groups of migrating Germanic People (Barford, Kobyliński and Krasnodębski 1991), have also been recorded. In this period, the method of forest burning was applied in order to obtain areas for agricultural cultivation as well as grazing of animals. The HPC communities also cut down trees to obtain charcoal, used for iron production.

The second phase, related to the Migration Period and the Early Middle Ages, begins with a settlement hiatus. Forest regeneration accompanied the emigration of the Wielbark culture communities away from the Bialowieza Forest (Zimny, Latałowa and Pędziszewska 2017). The settlement hiatus lasted until the arrival of the Slavs, which is considered to be the beginning of the Early Middle Ages (Barford, Kobyliński and Krasnodębski 1991). The settlement in this period was not intense (Samojlik, Rotherham and Jędrzejewska 2013b). It was probably focused on the insular dry areas of the Forest. These communities left mainly barrow graveyards and a few discovered flat sites (Krasnodębski *et al.* 2005, 2011; Krasnodębski and Olczak 2017).

The next period of Forest settlement begins in the 14th century and lasted until the 16th century. This is the period in which the Białowieża Forest was under royal protection as a hunting forest. At that time, the use of this forest's resources was limited by royal restrictions. Entrance to the forest was defined by the so-called access rights, while the settlement was focused outside its borders (Samojlik and Jędrzejewska 2004). This period is the time of low utilization of forest resources. The largest anthropogenic changes occurred in the Royal Hunting Gardens, located in the central part of the Polish Forest (Samojlik, Rotherham and Jędrzejewska 2013a).

In the period from the 17th to the 18th century the human activity in the Bialowieża Forest increased, which can be well seen in palynological profiles (Latałowa *et al.* 2015; Zimny, Latałowa and Pędziszewska 2017). During this period, the first evidence of utilizing the forest for industrial purposes appear. There are sites where of bog iron ore was collected (Samojlik 2009) as well as potash and charcoal production (Samojlik 2016), in the form of charcoal and tar kilns (Samojlik *et al.* 2013). After the partition in 1795 the lands of Poland were divided between three neighbouring countries: the Prussian Kingdom, Austria under the Habsburg rule and the Russian Empire. Białowieża was connected to the last one, like the rest of North-Eastern Poland. It became an Imperial Forest and the restrictions regarding the use of forest resources were restored. However small settlement centres continued to exist in the entire area of the forest complex.

From the period of World War I to modern times, the Bialowieża Forest has been undergoing its worst and the best periods. On the one hand, it is the period of the largest tree cutting in its history as well as the total extinction of its bison population during the first and the Second World War (Jędrzejewska *et al.* 1997). On the other hand, since 1921, when Poland regained its independence, a national reserve was created in the Forest. Since 1945, the forest belonging to the Białowieża Primeval Forest are managed by the State Forestry Service, and since 1990 a limitation of tree cutting and artificial cultivation has been implemented. In the last 200 years, despite numerous administrative changes, the area of the Forest was constantly covered with dense tree cover, a landscape characterized by the symbiosis between man and nature, which is clearly confirmed by research (see Mikusińska *et al.* 2013; Baker *et al.* 2015). The best proof of this was the inscription of the Białowieża National Park into the UNESO World Heritage List in 1979, which was extended to the territory of the Belarusian Forest in 1992 (Krzyściak-Kosińska, Arnolbik and Antczak 2012). Since 2014, the entire area of the Polish and Belarusian part of the Forest has been inscribed on the UNSECO list.

4. Methods

Thanks to the dissemination of airborne laser scanning as a method of remote sensing of features with preserved anthropogenic form, it became possible to study densely forested areas (Figure 2). During the Białowieża Primeval Forest mounds mapping, a four-step source data analysis method was used. 1 – Reclassification and preparation of DTM; 2 – remote sensing of features with different DTM visualizations; 3 – verification and field documentation of features; 4 – spatial and statistical analysis of acquired sources.

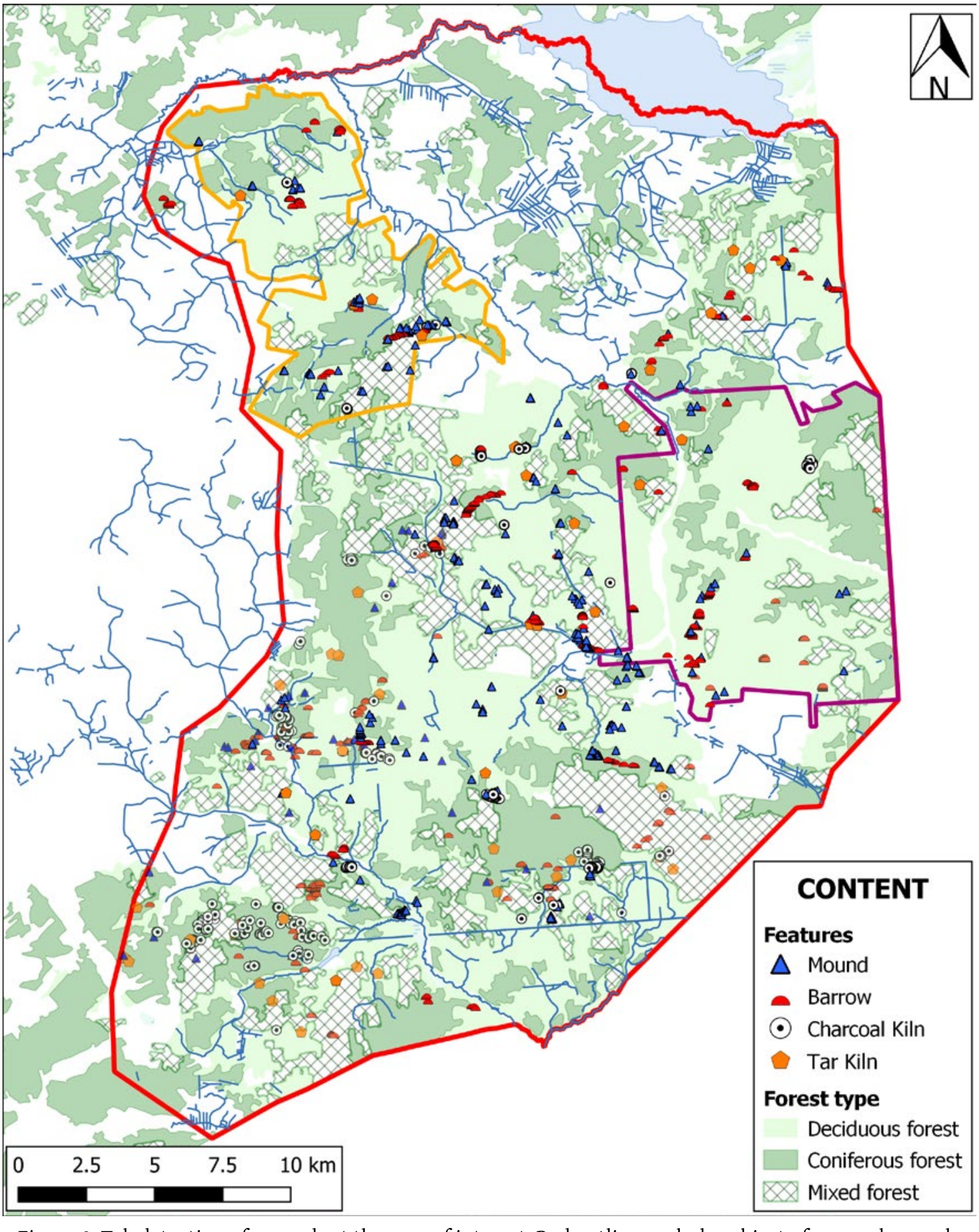

Figure 2. Teledetection of mounds at the area of interest. Red outline – whole subject of research; purple outline – Białowieża Strict Reserve; yellow outline – Ladzka Forest (former Białowieża Forest massive). Semi-transparent point mark features that were detected but have not been yet verified.

Reclassification and preparation of DTM

Data from airborne laser scanning, in the form of a raw point cloud in .las format were obtained from the ISOK program (Wężyk 2015). Parameters of the performed scan are: discrete return data, ≥4 points per m^2, scanning angle ≤ 25°, diameter of the laser beam ≤ 0.5 m, altitude error Z ≤ ± 0.15 m (Kruczyński, Stojek and Cisło-Lesicka 2015). These parameters allow for archaeological prospecting

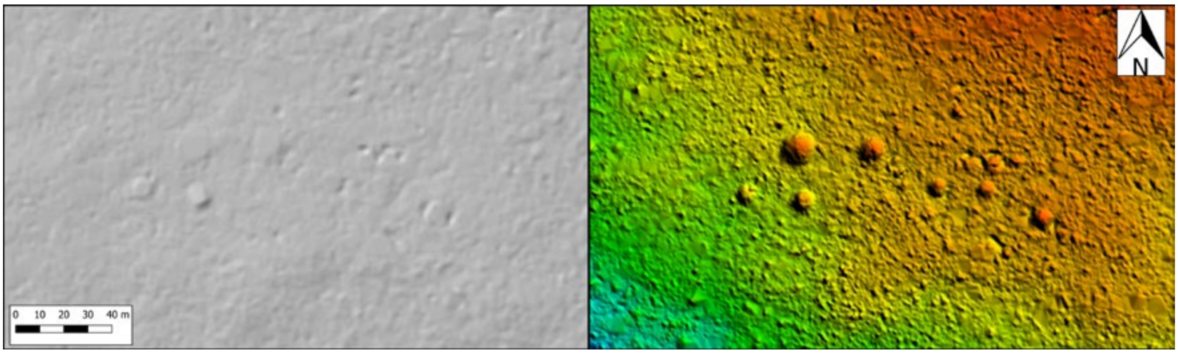

Figure 3. Example of classification method and 'missing' mounds. Left – DTM from classification in ISOK project, right – DTM from re-classified point cloud in LAStools.

(more in Opitz and Cowley 2012), especially after using the appropriate algorithms for point cloud classification (Opitz 2016).

Despite the fact that the purchased data were originally classified, for the needs of archaeology their reclassification was necessary. The filtration of points to obtain exclusively reflections from the ground level was carried out using the LAStools software with the parameters of the non-aggressive 'wilderness' classification. Due to numerous fallen trees in the Bialowieża Forest (which are not exported by forest services, due to the numerous restrictions of nature reserves) with standard classification that minimizes the 'noise', some features such as burial mounds were cut out. Therefore, a low aggressive classification was required in order to preserve all potential anthropogenic features (Figure 3).

Using the blastdem application in the LAStools software, DTM was generated in the form of TIN with pixel size close to 0.5 meter in ASCII format. Next, in GlobalMapper 18 software raster geotiffs were created in PL1992 system (EPSG: 2180) divided into 5 x 7 km rectangles corresponding to the numbering of the Polish Archaeological Record.

Remote sensing of features with different DTM visualizations

Based on the obtained geotiffs, in the RVT[1] application, a number of DTM visualizations profiled for archaeology were generated (Kokajl and Hesse 2016). The hill shade visualization (A: 315, H: 25), Multihillshade (D: 16, H: 25) and Local Dominance (R: 5-15) were considered the most useful for the geomorphology of the Bialowieża Forest area. Especially the latter has proved to be extremely effective in the case of small anthropogenic terrain forms found on flat terrain (Figure 4).

Subsequently the features were mapped with QGIS 2.18/3.4 software, in which raster data were integrated. An editable attribute table was prepared, describing primarily the type of feature, the assumed chronology, the degree of visibility on the DTM and the type of object geometry. In the course of remote sensing, all features of alleged anthropogenic origin were mapped, but also subjected to a thorough analysis based on the researcher's experience (Palmer 2013).

Verification and field documentation of features

All features identified with DTM analysis were verified in the field. This is necessary due to the imperfections of the ALS method as well as the need for their field documentation. Surface surveys were carried out using Garmin portable GPS GLONASS devices. Despite the thick forest cover (Figure 5), the quality of measurements varies between 3-6 meters, which allows to determine the object with a satisfactory accuracy, allowing for the correlation of the DTM

[1] https://iaps.zrc-sazu.si/en/rvt#v

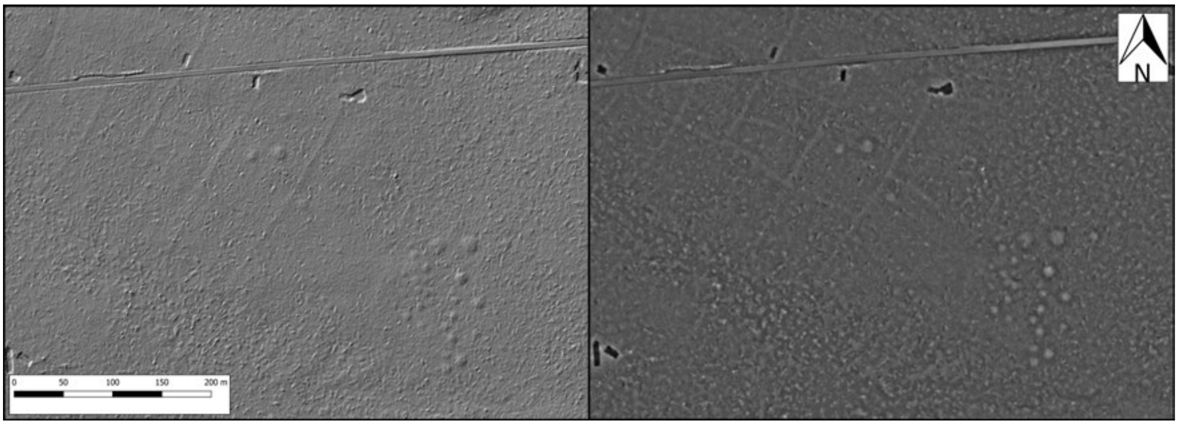

Figure 4. Example of visualization methods in flat area of the Białowieża Forest.
With detailed DTM visualization we can observe small structures like old field boundaries.
Left – hillshade A:315, H:25, right – Local Dominance radius 5:15.

results. Visualizations, along with the location of the features were uploaded directly to the devices, which allowed for a current, precise view of the points location. Thanks to the black and white visualization of Local Dominance, the output files were small, which allowed for the large amounts of data upload.

In the field, for each feature, apart from the GPS measurements, a series of photographs and a description on a special feature card were made (which subsequently is a source for the attribute table). At the end of each research season, all points are integrated in the GIS environment.

Spatial and statistical analysis

Different types of features, distinguished on the basis of their morphology, were classified on the basis of the DTM. Our interest concerns all manifestations of human activity, resulting in the anthropogenic field shapes, from the prehistory to modern times, to modern times. Settlements, numerous prehistoric mounds, modern traces of production, traces of former arable fields, militaria, places of natural resources exploitation etc. were mapped. Thanks to the data integration in the GIS environment, it is possible to locate them accurately and study on the basis of the spatial analyses – settlement analysis, co-occurrence of different types of features or prognosis of them endanger level (Hesse 2013).

Figure 5. In woodland, handheld GPS struggles.
During verification we combine GPS with
imported ALS data and tablets with
maps of teledetected features
(photo by K. Niedziółka).

5. The dominating role of mounds in the landscape of the Białowieża Forest

1848 (this number may change because not all features had been verified in the field) anthropogenic forms were recorded through remote sensing in the area of the Polish part of Białowieża Primeval Forest

Type	No.
Mounds	583*
Barrows	798*
Charcoal Kilns	287*
Tar Kilns	56*
Summary	1724*

Table 1. Number of anthropogenic features recorded in the area of the Polish part of Białowieża Primeval Forest.
* This number may change because not all features had been verified

with the use of the DTM for field verification. As many as 1724* (93.3%) of them are mounds, i.e. variously shaped monuments consisting of an earth embankment manifested in the field (Table 1).

In the area of Białowieża Forest, several types of mounds can be distinguished on the basis of their function. First of all, the mounds can be divided to funerary (burial mounds) and production mounds (related to the forest material processing). Most often, this is related to their chronological position – burial mounds occur from the early Iron Age to the Middle Ages, while the production mounds are dated back primarily to the modern period. Distinct morphological differences between them can be observed:

Barrows:

The burial mounds are numerous and often occur in characteristic clusters. They are always circular mounds, varying from very small (5-8 meters in diameter), to large (over 20 meters in diameter). Based on the spatial layout of the mounds, 5 types of clusters have been distinguished.

I. Single barrow (Figure 6: A)

A round mound, isolated from other similar structures with a 200-meter diameter buffer. Mounds of this type are relatively rare in the Białowieża Forest. They are usually located on small elevations. Until now, none have been excavated.

II. Double barrows (Figure 6: B)

Mounds occurring side by side at a small distance, isolated with a 200 meters diameter buffer from other similar structures. These mounds occur throughout the entire Białowieża Forest. Despite excavations carried out in the 2018 season, their chronology is still unknown.

III. Barrows in a linear layout (Figure 6: C)

Barrows in a characteristic, compact or semi-compact linear arrangement. Mounds create cemetery consisting of 12 to over 20 features of similar geographic orientation. Until now, all excavated sites date to the early Middle Ages (XIII-X AC). (Goetze 1929, Krasnodębski 2006, Rutyna and Szubski 2018).

IV. Barrows in a compact cluster (Figure 6: D)

Mounds in a compact cluster are distinguished on the basis of the distribution of mounds and distances between particular features. They form burial grounds in which the mounds occur in distances smaller than 25 meters from each other (defined by the buffer). So far, mounds of this type have been explored at three sites: Szczekotowo (Götze 1929; Krasnodębski *et al.* 2011), Jelonka (Krasnodębski *et al.* 2011), Puszcza Ladzka (Wawrzeniuk 2017). They have mainly revealed inhumations, dated back to the eleventh to twelfth century AD.

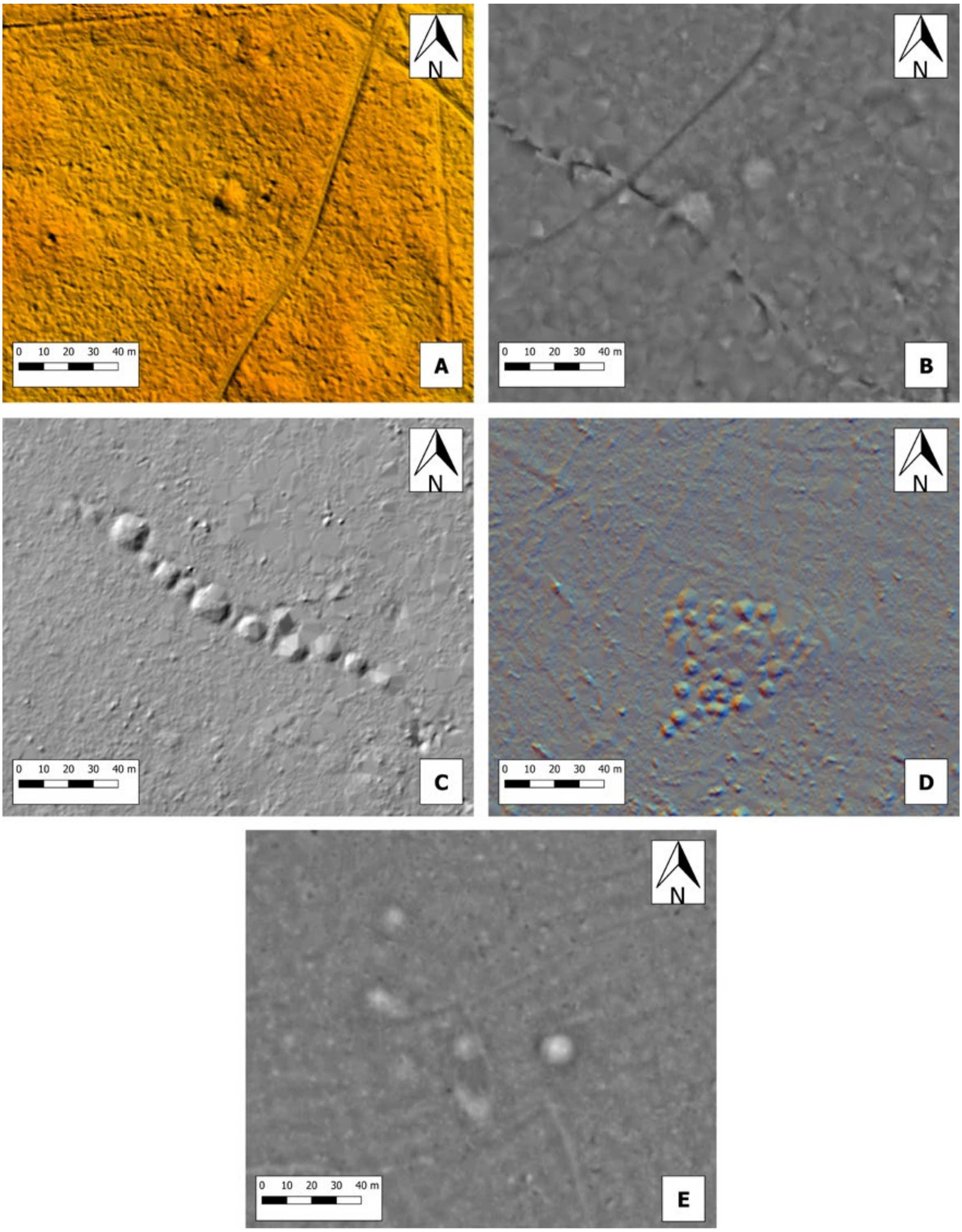

Figure 6. Different types of barrow clusters observed in the Białowieża Forest.
A – single barrow, B – Double barrows, C – Barrows in a linear layout,
D – Barrows in a compact cluster, E – Barrows in the scattered cluster.

V. The burial mounds in scattered cluster (Figure 6: E)

Mounds in scattered cluster are distinguished on the basis of their distribution and distance between particular features. They form burial ground where the mounds are more than 25 meters apart (defined by the buffer). Such cemeteries are commonly found in the Białowieża Forest.

Excavations in recent years reveal that most of them are dated back to the early Iron Age/early Roman Period.

Modern mounds:

Modern mounds mainly consist of field shapes made up of mainly circular or elongated oval earth embankments. They have been identified as a post-production residue related to the exploitation of forest resources. Studies on this type of features occurrence is strongly associated with the development of remote sensing methods, that have revealed hundreds or even thousands of such structures (Ludemann 2012; Hesse 2013; Carrari *et al.* 2017; Schimdt *et al.* 2016). In the Białowieża Forest, modern mounds occur insularly, what resulted from the limited access to the forest from the 15th century. Nevertheless, thanks to the extremely well-preserved terrain relief, very diverse forms occur including:

I. Charcoal kilns

Charcoal kilns are defined as small mounds with circular plan. They are, remnants of the dry wood distillation process. These structures are often very subtle, often virtually invisible in the field. The embankment is made of charcoal fragments, which can be located even on the surface. They occur in clusters of several to several dozen features. There are three main morphological forms identified as charcoal kilns in the Białowieża Forest: features without trenches and with only an embankment (Figure 7: A) (known, for example, from central Poland [Bakuła, Ostrowski and Zapłata 2014]); features with a circular trench or trenches at the base of the embankment (Figure 7: B); features with small openings at the base of the embankment, resembling the 'daisy flower' in plan (Figure 7: C) (known from southern Poland [Rutkiewicz *et al.* 2017]).

II. Large charcoal kilns

A different type of charcoal kilns is represented by very large features consisting of irregular piles, usually arranged in rectangular structures (Figure 8: A). These piles are constructed mainly of a sediment mixed with charcoal fragments. They also have traces of constructions (Samojlik *et al.* 2013). These structures are always located in the immediate vicinity of watercourses. These are probably the remains of large, modern period facilities, operated by a few to a dozen people. Today's field form is an eroded residue of the product collected from the inside, i.e. decks of charcoal.

III. Tar kilns

During the remote sensing, also 56 remnants of tar distillers – structures related to the wood tar production process – were identified. These features, in the form of round constructions, have a circular embankment with a depression in the middle, at one point cut with a trench being a gutter leading to the tar tank (Figure 8: B). Inside the depression, pine resinous logs were laid and covered with a turf, subsequently burned to obtain dripping liquid tar (Czopek 1997). Fragments of charcoal and sometimes clay. often occur on the surfaces of these features Features from the Bialowieża Forest have been dated back to the XVII-XVIII century (Samojlik 2007, p. 101-102). Tar distillers always occur in the direct vicinity of the roads which are visible on DTM.

IV. Chimney-shaped mounds (?)

Very large mounds with depression in the central part, still do not have a clearly defined function and chronology (Figure 8: C). Very high (about 1-2 meters) features with diameters from 25 to 35 meters are probably related to the modern tar production (Krasnodębski and Olczak 2017). 20-40 cm sized rocks often occur inside the cavities. To confirm this hypothesis, however, such structures require more invasive research.

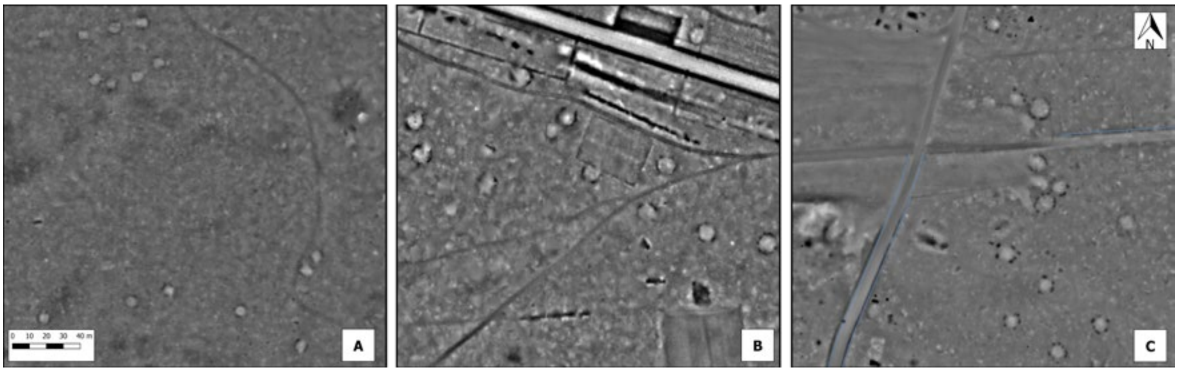

Figure 7. Different types of small charcoal kilns.
A – kiln without trench, B – kiln with trench, C – 'daisy flower' kiln.

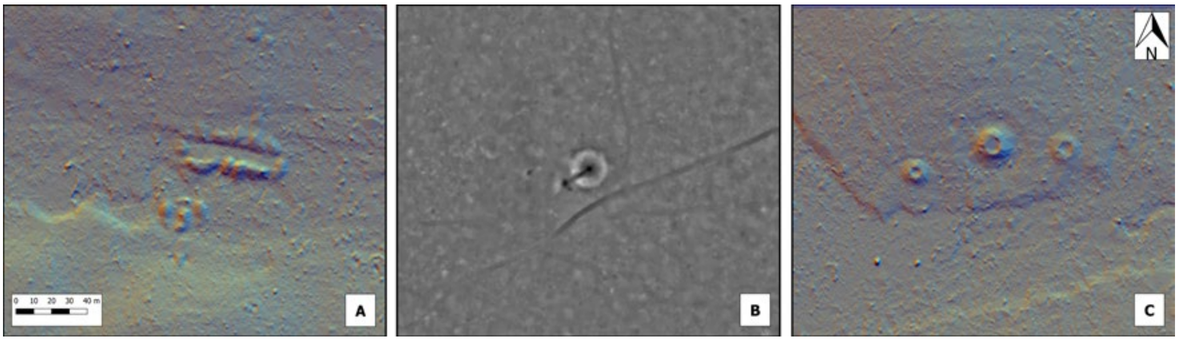

Figure 8. Different types of large modern mounds. A – large charcoal kilns,
B – Tar distiller (tar kiln), C – Chimney-shaped mounds (?) (probably tar kilns).

6. Discussion

Mounds, especially burial mounds have fascinated archaeologists from the beginnings of amateur excavation research because of their distinct landscape form and the mystery of the 'hidden treasure' In the early period of scientific archaeology, funerary sites were mainly a source of knowledge on prehistoric communities, through the discovery of their material culture. In recent years, the view of these ubiquitous features has covered a wider scale of landscape, referred as the 'barrow landscape' (Bourgeois 2013). These studies concern the research of barrows in the modern landscape (de Reu 2012; Bourgeois 2013; Johnson 2017), their natural environment in prehistory (Sudnik-Wójcikowska and Moysiyenko 2008; Fyfe 2012; Doorenbosch 2013), settlement environment (Eckardt *et al.* 2009; Fontijn 2013) or perception by the prehistoric communities (Makarowicz 2010; Lovschal 2013).

In the Białowieża Forest, without any doubt, we can talk about a barrow landscape, although it would be more appropriate to define it as a mound landscape, because mounds have different functions. This function is the subject of a discussion going back to the 1970s. After the first major research of I. Górska in the area of the Białowieża National Park (1973; 1976), Polish literature began to relate them to the intense settlement during the Early Middle Ages and the large number of barrows dated back to this period (Zoll-Adamikowa 1975, 1979). Polemics arguing with this thesis were brought forward during the research conducted by the Mammal Research Institute of the Polish Academy of Sciences. According to the researchers micro-invasive research, revealed – that most of the mounds are modern period structures (Samojlik 2007: fig. 40; Krasnodębski *et al.* 2011, p. 149). However, it should be noted that these results were based on drilling and surface studies, including the dating of charcoal from the mounds surfaces. Although, the fallacy of the thesis that all mounds from the Białowieża Forest are related to the Early Medieval origin is quite clear, the use of airborne laser scanning also undermines the negation of many mounds as barrows. In my opinion, the morphology of embankments is extremely important, which – thanks to ALS – can be studied in detail. Mounds with undamaged circular embankments should be interpreted as barrows. Destruction of the embankment is not related to the construction and functioning of the mound, it can only take place through post-deployment processes. The opposite situation occurs in the case of the production mounds – the embankment is always somewhat damaged. This is due to the fact that the product (charcoal, potash, tar) was collected after production. Moreover, the building material used in construction was wood, which disappears in the combustion process or was removed as a product. Such a mound is destroyed immediately after its use, and the resulting irregular embankments covered with a sediment resulting from natural accumulation. Even in small circular charcoal kilns (Figure 7: A, B, C) a residual embankment can be observed. The interpretation of mounds with a un-damaged embankments as a modern potash kilns, are based on uncertain dates, from the charcoals found on a surface, or small change in the soil chemical structure (Samojlik 2007, p. 91-95; Krasnodębski and Olczak 2017, p. 17) seem to be unconvincing.

Another issue is raised by the intensity of settlement in the Białowieża Forest, which would seem to be in contradiction with its primeval character. Despite the discovery of many anthropogenic features in the Forest, including the probable remains of prehistoric fields (Zapłata and Stereńczak 2016, p. 249; Wawrzeniuk *et al.* p. 196-197) and numerous mounds, it should be stressed that they occur insularly and are closely related to present day dry areas of the forest. Moreover, when settlement considered not as a whole, but in diachronic succession, this largely reveals the episodic nature of settlement activity. This has also been confirmed by palynological research (Latałowa *et al.* 2015). Undoubtedly, the greatest impact on the richly preserved archaeological and historical objects is the fact that human impact on the Białowieża Forest is limited. Areas never subjected to intensive ploughing retain unchanged anthropogenic field shapes. This gives us a unique opportunity to analyse the original spatial layouts of mounds in the natural environment, which can be used as a specific comparative study to reconstruct the landscape on a regional scale (for example based on the prognosis of mounds occurrence, e.g. Carrero-Pazos 2018).

7. Conclusion

Airborne laser scanning has fundamentally changed the picture of woodland archaeology and landscape research. Despite the many known mound sites, this method has provided a wealth of new discoveries, complementing the existing ‘white spots’ in the Białowieża Primeval Forest. The accurate mapping of structures and their spatial analyses however, has proved to be a more important factor. This allows us to recognize patterns that ruled people’s ways of transforming the landscape, especially in the sacred sphere. In the long-term perspective, spatial analyses lead to the creation of catalogues of features and clusters that will enable the non-invasive identification of mounds – in chronological or functional terms.

The unusually favourable preservation conditions of anthropogenic features in the Białowieża Forest has led to an unprecedented abundance of sites. 1724 shapes identified as mounds were mapped, covering structures from prehistoric to modern times. This abundance, however, is not the result of the intensity of settlement, but rather from the lack of destructive agents throughout the forest´s history. Recently the use of modern ploughing methods has been extremely destructive for archaeological sites with preserved anthropogenic field shapes.

Thanks to protection dating back to the fifteenth century, there are places in the Białowieża Forest that with full conviction can be referred to as ‘barrow landscapes’ or even ‘mound landscapes’. From the early Iron Age to the Middle Ages, barrows co-exist with modern production mounds, creating a palimpsest in the modern landscape (Figure 9). Subsequent communities settled in the area had to see and precept existing mounds, which probably became part of their tradition and perception.

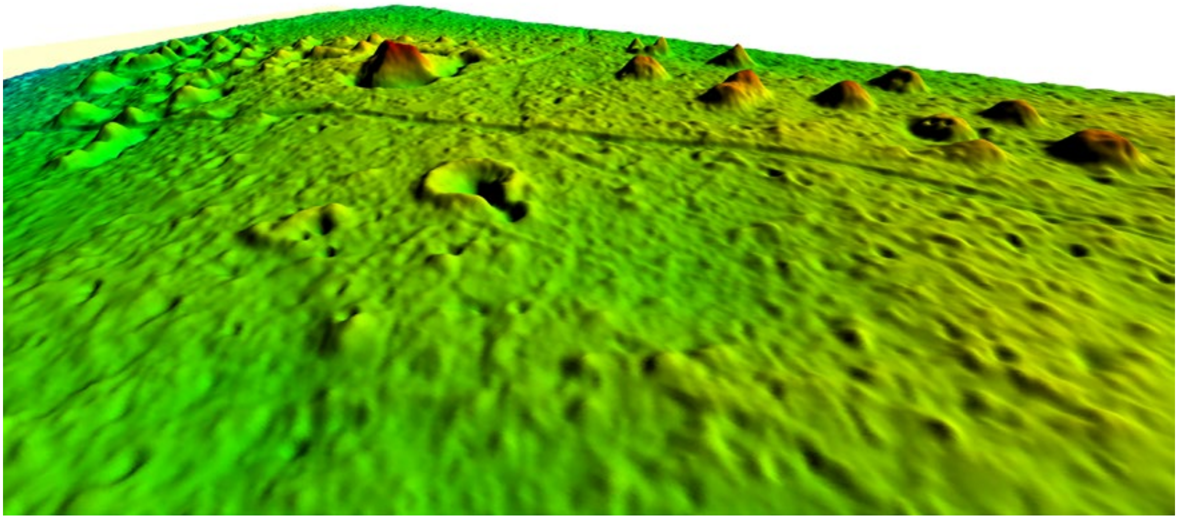

Figure 9. Generated 3D model DTM of unique 'mound landscape' of the Szczekotowo Reserve. Builders of the tar distiller (in front) had to be aware of barrows in their landscape like those who had been using this space before them.

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An integrated approach to the construction of cultural landscapes in Southwest Angola: The case of Huila

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Abstract

The Huíla Province in Southwest Angola yields geomorphological characteristics which favoured preservation of remains of past human societies, namely under transitional conditions of refugia, spanning from the Plio-Pleistocene to the past millennium. The African Archaeology research group at the Earth and Memory Institute (Polytechnic of Tomar/Geosciences Centre of the University of Coimbra) and its partners in Germany and Angola undertake an approach to these territories and cultural landscapes integrating the geosciences in the palaeanthropological research driving this archaeological inquiry.

While in the Kwanza Sul and Namibe provinces, we have conducted research on cultural landscapes dominated by rock art and burial features, in the specific ecological niche of the Leba Formation-Karst System of the Huíla Plateau, we aim to approach Quaternary hunter-gatherer activities and technological innovations that may illustrate dynamic developmental processes towards social stabilization. This region reveals great potential but remains insufficiently studied.

Keywords: geoscience, palaeanthropology, hunder-gatherers, Angola

Résumé

Les caractéristiques géomorphologiques de la Province d'Huíla, dans le Sudouest de l'Angola, ont favorisé la préservation de vestiges de sociétés humaines dans le passé, nottament dans le cadre de conditions de transition ou de réfuge, depuis le Plio-Pleistocène jusqu'au dernier millénaire. Le groupe de recherches en Archéologie Africaine de l'Institut Terre et Mémoire / Polytechnique de Tomar /Centre de Géosciences de l'Université de Coimbra, et leurs partenaires, entreprennent une approche à ces territoires et paysages culturels en intégrant les géosciences avec la recherche anthropologique qui guide les enquêtes archéologiques.

Alors que dans les provinces du Kwanza Sud et du Namibe on a conduit des recherches portant sur les paysages culturels dominés par l'art rupestre et les structures funéraires, dans la niche écologique du système karstique de Huíla, lequel a révélé un grand potentiel encore insuffisamment étudié, on mise sur l'approche aux activités et innovations technologiques des chasseurs-cueilleurs du Quaternaire qui puissent illustrer des processus de développement dynamique vers la stabilisation sociale.

Mots-clés : géoscience, paléoanthropologie, chasseur-cueilleur, Angola

1. Geography and Historical Background

The study region is located in the Province of Huíla in the Southwest of Angola. The province occupies an estimated area of 78,879 km^2, divided into 14 municipalities, with an approximate population of 2.4 million according to the Census of 2014. The majority of the population is concentrated in Lubango, capital of the province and the main urban centre of the region, where many migrants from the North and East of the country found a more peaceful settlement during the civil war.

The population of Huíla today, just like the rest of Angola, is mainly Bantu, with a high percentage of Mumuílas, belonging mostly to five ethno-linguistic groups namely the Nyanheca-Humbi, Umbundo, Nganguela, Quioco and Herero. A sixth group, non-Bantu populations, such as descendants of Bushmen or Khoisan, represent a social minority. However, at the time of the first anthropological inquiry of Southwestern Angola, explorers of the XVIII century reported that both the woodlands of the Central Plateau and the Namib desert were shared between agro-pastoralist Bantu-speaking populations with Late Iron Age technology and numerous groups of Bushman (called Bosquímanos in Angola) that maintained a semi-nomadic foraging and hunting lifeway, as well as cultural and technological production similar to the Late Stone Age (LSA) (Ervedosa, C. 1980; Almeida, A. 1994; Yellen, J. 1990).

In the last 25,000 years, these indigenous populations of hunter-gatherers have been mostly segregated or pushed to what are now the drylands of Southern Africa. Even though paleoanthropological research has emphasized these regions due to the distribution of present-day Khoisan, other aspects of landscape, genetics, ethnolinguistics and material culture indicate that the conventional northern border of the drylands (Kunene/Zambezi rivers) was a much more fluid boundary including transitional biomes of Zambia and Angola (e.g. Mitchel, P. 2017). In this complex geographic and ethnographic history, cut by contemporary political borders, the Huíla Province stands out as a major hotspot for biodiversity and human settlement, preserving an important heritage that will be highlighted in this paper, as a first step in the outline of areas of interest for heritage and cultural landscapes in Angola.

2. Geology and Geomorphology of the Huíla Plateau

The Huíla Plateau at maximum altitudes between 2200 and 1800 m, is subdivided in two main landforms, the Bimbe and Humpata Plateaus. The karstic landscape of Huíla stands on top of this high plain, at the southernmost tip of the Central Plateau of Angola, covering approximately 300 km of stepped and escarped relief from NE-SW, composed of irregular crests of quartzite at north and laterite soils that spread to south, bordering the Namib Desert.

The Southwest of Angola is characterized by a variety of geological units, geomorphological features and peculiarities that have been the object of debate about the names and ages of the outcropped sequence (Mouta, F. 1953; Feio, M. 1964, 1981; do Amaral, I. 1973; Matias, D. 1980; Carvalho, H. 1983, 1984; Carvalho, H. and Alves, P. 1993; Carvalho *et al.* 2000; Pereira, E. *et al.* 2011, 2013; Lopes, F. *et al.* 2016). Here we adopt the same division as M. Marques (1977) and F. Lopes *et al.* (2016) that separate several geomorphological units, three of which concern our research (Figure 1):

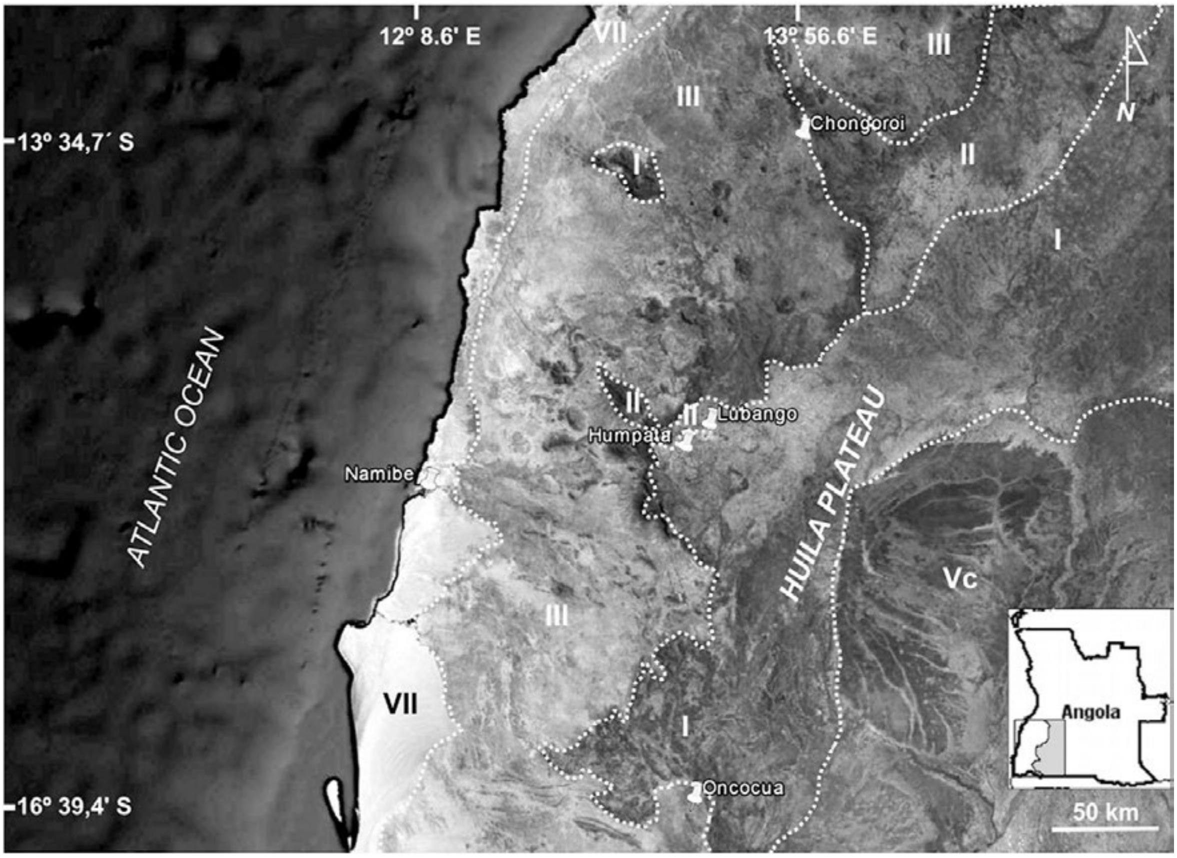

Figure 1. Location of Geological Units of Southwest Angola: I – Ancient Plateau; II – Marginal Mountain Range; III – Transition zone; Vc- Cunene Basin; VII – Coastal Zone/Desert (in Lopes *et al.* 2016).

1. *Unit I*, the Ancient Plateau, which includes the southern half of the plateau edge and is represented by a flattened and tectonically uplifted surface;

2. *Unit II*, the Marginal Mountain Range, which comprises the northern half of the plateau edge and is represented by very sharp reliefs with altitude ranging from 1000 m (Oncocua) to 2300 m (Humpata Plateau);

3. *Unit III*, a Transition zone, extending parallel to the Atlantic Ocean and is represented by a succession of plateaus at different levels in a steep horizon of pinnacles, shafts, sometimes impressive scarps of bare rock. An impressive landscape resulting of the differential erosion of sedimentary units of volcanoclastic, metamorphic and carbonated rocks that rest in non-conformity over a sialic base granite of Pre-Eburnean origins (e.g. Pereira, E. *et al.* 2011).

In the Marginal Mountain Range, the dolomites of Leba-Tchamalindi Formation sit on top of the Chela Group, mainly represented by dolerites and quartzites, which are the main sources of rock fall and accumulation of debris in the foothills of the western edge of the Huíla plateau.

The Leba-Tchamalindi Formation at *c.* 1800-1600 m (e.g. Correia, H. 1976; Pereira, E. *et al.* 2011) is a unique carbonated unit and the most recent in the Paleoproterozoic sequence developing in horizontal and sub-horizontal bedplates, with unique calcified structures of stromatolitic greyish-blue dolomites and intercalations of siltites and cherts.

This biostroma indicates that the limestone formed in conditions of shallow water either in marine coastal conditions or lacustrine of very high salinity (Correia, H. 1976). The geography and geomorphology of the Leba karst seems to indicate that the genesis of the bedrock is related with a paleoshore. Posterior fossilization and karstification of the foliations built up by green-blue algae is connected with regional tectonics and cyclic environmental changes that determined the up-lift and exposure event bringing the formation to the high altitude and beginning of fossilization.

The limestone pavement presents a characteristic relief of flat incised surfaces of exposed bedrock resultant of a corrosive drainage dissolution through acid rain. This specific formation at Leba represents a sedimentary-tectonic cycle post-Chela where strong erosive ablation of the depression of Tchivinguiro allowed to open up valleys in the faults. It is unquestionable that the inferior limit of the formation corresponds to an important lithological discontinuity resultant of change from detritic sedimentation to another essentially chemical. At Northwest of Lubango at some of the highest altitudes of the Plateau (2326 and 2330 m), the Tundavala Gorge is the most famous canyon as a touristic attraction of local and foreigner visitors and classified geological heritage site (Henriques, M. *et al.* 2013; Tavares, M. *et al.* 2015).

This limestone outcrop presents a variety of subterranean morphologies allowing underground water flow that have reveal a complex karstic system of tunnels, caves, sinkholes and rock shelters with preservation of Neogene (Pliocene-Pleistocene) and Holocene horizons of paleontological and archaeological potential in Tchíua, Cangalongue, Ufefa, Malola and Leba (Mouta, F. 1953; Camarate-França, J. 1964a; Vale, F. and Gonçalves, F. 1968; do Amaral, I. 1973).

The dolomites of the Huíla Plateau represent orogenic events and environmental conditions homologous to other areas of Africa. The karstic regions of Southwestern Africa extending south and east include the Karstveld of Northern Namibia where the same geology is found in the Otavi Mountains, Baynes Mountains and Kaokoland, and Aha in Botswana, which are bordered by the Namib and Kalahari deserts at distances of 80 to 180 km.

The dolomite bedrock allows systems of underground water drainage and corrosion favourable for cave formation, sinkholes and springs making this sector of the Great Escarpment of Southern Africa being one of the widest sources of the subcontinent's fresh water as well as hotspot for biodiversity. Due to underground waterflow, soil cover in the highlands is usually thin, except in poljes and valleys, where ephemeral rivers often appear during rainfall season when saturation of bedrock occurs. These ephemeral rivers are locally called 'mulolas' from which the water is drained several hundred miles west and east, sourcing the hydrographic basins of the main rivers Curoca, Caculavar, Cunene and Cubango/Okavango. The specific topography and geomorphology are key to understand the biotic mosaic of Southwestern Africa that favoured flora and fauna endemism in the past.

3. Changes in Climate and Vegetation

Climate proxies for the Pleistocene and Holocene of Africa demonstrate considerable regional climatic variation over the past 500,000 years in this area, which significantly influenced the mosaic of paleolandscapes occupied by the first *Homo* lineages. Terrestrial and marine datasets show rapid changes in global wind patterns; global and regional sea surface temperatures; and the Milankovitch cycles due to Earth orbital variations (Blome, M. *et al.* 2012). These conditions had a major impact on hydrological systems of current drylands (Dupont, L. and Behling, H. 2006; Dupont, L. *et al.* 2008). These studies show cumulative physiographic phenomena that influenced rainfall regimes and continental temperature contributing to environmental change in this sub-region of Africa.

The climatic gradients reflect strong differences between the coastal plains and the inland highlands. The highlands correspond to the strip of the Great Escarpments of crossing Angola and Namibia overlooking the Namib Desert. The Escarpment extends further to Cape Province, in South Africa, represented also in some areas of Zimbabwe, where climate and vegetation show similar characteristics.

Between the Marginal Mountain range and the transition zone there are clear climate differences influenced by global sea surface temperatures and wind currents, such as the Benguela Current and the Angolan Low, which seem to play a major role in precipitation and temperature controls (Munday, C. and Washington, R. 2017) and also contributed to shaping the ecology and the relief (Feio 1981).

To the south and west in the lowlands below around 500 meters of altitude, climate is warm and dry. Strong insolation had a major impact on the quarzitic crest of the plateau and thermoclasty shaped the western edge, forming cracks and accumulations of debris (Lopes, F. *et al.* 2016). In the areas to the east, beyond the urban centre of Lubango, climate alternates between periods of intense rainfall and dryness and is included in the sub-tropical warm regimes.

In the highlands of Huíla, the seasons alternate from periods of monsoon to drought: the rainfall season occurs from October to April and the dry season from May to September. Mean annual precipitation varies from 800-900 mm and mean annual temperatures are of 17°C to 18°C with amplitudes of 5°C. Temperatures may reach maximums of 35-37° during the day (October-January) and minimum temperatures may reach negative -2°C or more at night (June-August) (Cruz, J. 1940). In the interior of the Humpata Plateau, the Depression of Tchivinguiro presents a micro-climate that may be classified as temperate-warm, similar to Mediterranean, with mean annual precipitations of 926 mm. Recent data indicates that rainfall regime in the Huíla Province has declined to cycles of five years, meaning that in each cycle four years are below the previous annual rate (Carvalho, S. *et al.* 2016) causing a climate crisis.

The Huíla Province is characterized by an interface landscape between the desert and the tropical rainforest with patches of sub-montane bush, Afro-alpine vegetation and savanna (Barbosa 1970). The vegetation in the plateau is classified within the «Miombo» woodlands (Figueiredo, E. *et al.* 2009; Chisingui, A. 2018) with endemic species of *Braschystegia*, *Julbernardia* e *Berlinia*, as well as exotic species of *Euphorbia* sp. app. *barnardii* and *Ziziphus abyssinica*, mostly observed in the karstic field.

Climatic change in the Southwest of Angola has been felt more severely during the last decade with recurrent cycles of droughts and floods resulting in high agricultural and livestock losses, as well as destruction of wildlife habitats and extinction of native species (Huntley and Matos 1994, Cain 2017). Direct human impact, like bushfires and deforestation for charcoal and crop fields, represent a cumulative threat to the natural ecology but also to preservation of the local heritage.

4. Palaeontological Investigations of the Leba Dolomites

In Angola, the Leba Formation (approximately 60 m thick) is mainly composed of black-coloured, laminated dolomitic limestones with abundant stromatolites and increasing chert content towards the top (Tavares *et al.* 2015). It is a unique geological outcrop that shows potential for vast research regarding the last 1000 Ma due to specific conditions of fossilization and preservation of organic materials.

The bedrock itself presents diverse stromatolithic structures, i.e., rocky structures made by photosynthetic cyanobacteria, organisms that provide ancient records of first forms of life on earth around 3.6 billions of years ago. In early XX century, the economic interest of mining regions gave the off-set of paleontological research in Sub-Saharan Africa. During geological survey and charting of outcrops and landforms, numerous fossil discoveries were recorded in limestone quarries both in the bedrock and the breccias of dolomitic karstvelds across South Africa, Zimbabwe, Namibia and Angola (Beetz, P. 1933; Dart, R. 1950).

In the karstic landscape of Huila there are several fossiliferous deposits associated with debris of blasting zones of the limestone or next to the kilns, discarded by the production line due to low quality (Klemme 1955). Mostly around the quarries of hydraulic lime, because sinter was excavated for that purpose, vertebrae fauna is abundantly present in the blocks rejected by miners, and which are frequently associated to breccias and karst-fills of caves. In the studied region, this is the case for all the lime quarries observed in the dolomites of Leba-Tchamalindi Formation.

In the Humpata Plateau, there are five main cave systems linked to modern kilns and factories, which operated from the late 1940's to mid-1990's: Leba, Tchivinguiro, Malola, Ufefua, Tchíua and Cangalonge (Figure 2). Due to easier access, these locations were briefly surveyed by the Angola Paleontology Expedition directed by M. Pickford in 1989 and 1990, who relocated the first sites discovered in Tchíua (mistakenly called Leba by Telles Antunes 1965) during the Geological Mapping Mission between 1947 and 1950 (Mouta, M. 1950). The Tchíua quarry yielded several complete skulls and mandibles as well more than 50 postcranial bones of cercopithecid (Pickford *et al.* 1992). These first fossils launched the idea of a contemporaneity with the Plio-Pleistocene primates found at the Cradle of Humankind in South Africa (Dart, R. 1950; Arambourg, C. and Mouta, F. 1952), and thus the possibility of same pre-human species in Angola like the *Australopithecines* or *Homo erectus* (Mouta, F. 1953).

The first specimens became the object of extensive description and analysis by several authors (Telles Antunes, M. 1965; Pickford, M. *et al.* 1994; Jablonski, N. 1995; Delson, E. and Dean, D. 1993; Gilbert *et al.* 2009), but only Pickford and his team developed actual fieldwork in Angola. During his brief exploration, new paleontological sites were discovered in the Cudeje valley and Cangalongue but the breccias were only briefly surveyed.

The main interest in the fossiliferous breccias of the Humpata Plateau, apart from the Cercopithecids, is the abundant microfauna, which yields information concerning the age and palaeoecology of the breccias. These indicate that all the Humpata sites are of late Pliocene to early Pleistocene age. Age estimations of the sequence of breccias indicate Cangalongue may be dated between 1.3 and 1.8 Myr, while Malola may be about the same age as Makapansgat in South Africa (Pickford *et al.* 1994). The faunas collected offer an interesting overlook of endemic vertebrae fauna in the region but their biostratigraphic significance holds important data on cave formation and landscape development in the Pliocene and Pleistocene. It seems that in the areas where sinter was mined more extensively very few fossils of Pliocene age are present. This is the case for the Leba valley, at the northern edge of the limestone formation more affected by erosion, than further south in Cangalonge. The breccias are often coarse with very little material derived from the ancient land surface, and only the early stages of cave systems are preserved such as Leba Cave. In other locations like Malola, Tchíua and Ufefua, the pink breccias are interpreted as exhibiting near surface genesis (Pickford *et al.* 1992). At Tchíua, abundant fauna of bovids and chunks of speleothems are still observed in the pink breccias of the quarry reaching a maximum depth of 3 m in some places. Some lithic pieces are also present in the debris characterized by patinated white surface.

In the hill of Tchivinguiro Spring, locally called Nandimba, fossiliferous pink breccias are observed in the walls of small caves above the spring. In addition, inside the Cave of Tchinviguiro/Nandimba, these breccias are observed in the vertical cracks of the main chamber with blocks of dolomite. Up North where sinter was mined more extensively in the quarries of Leba very few fossils are present today though some references indicate abundant fauna seen in the early stages of mining (Mouta, F. 1953; Mason, R. 1975). The breccias at northern edge of the limestone are often coarse, composed of big blocks of dolomite supported by sinter with very little clastic material. It seems that deflation of ancient land surface occurred and only the lower roots of the cave systems are

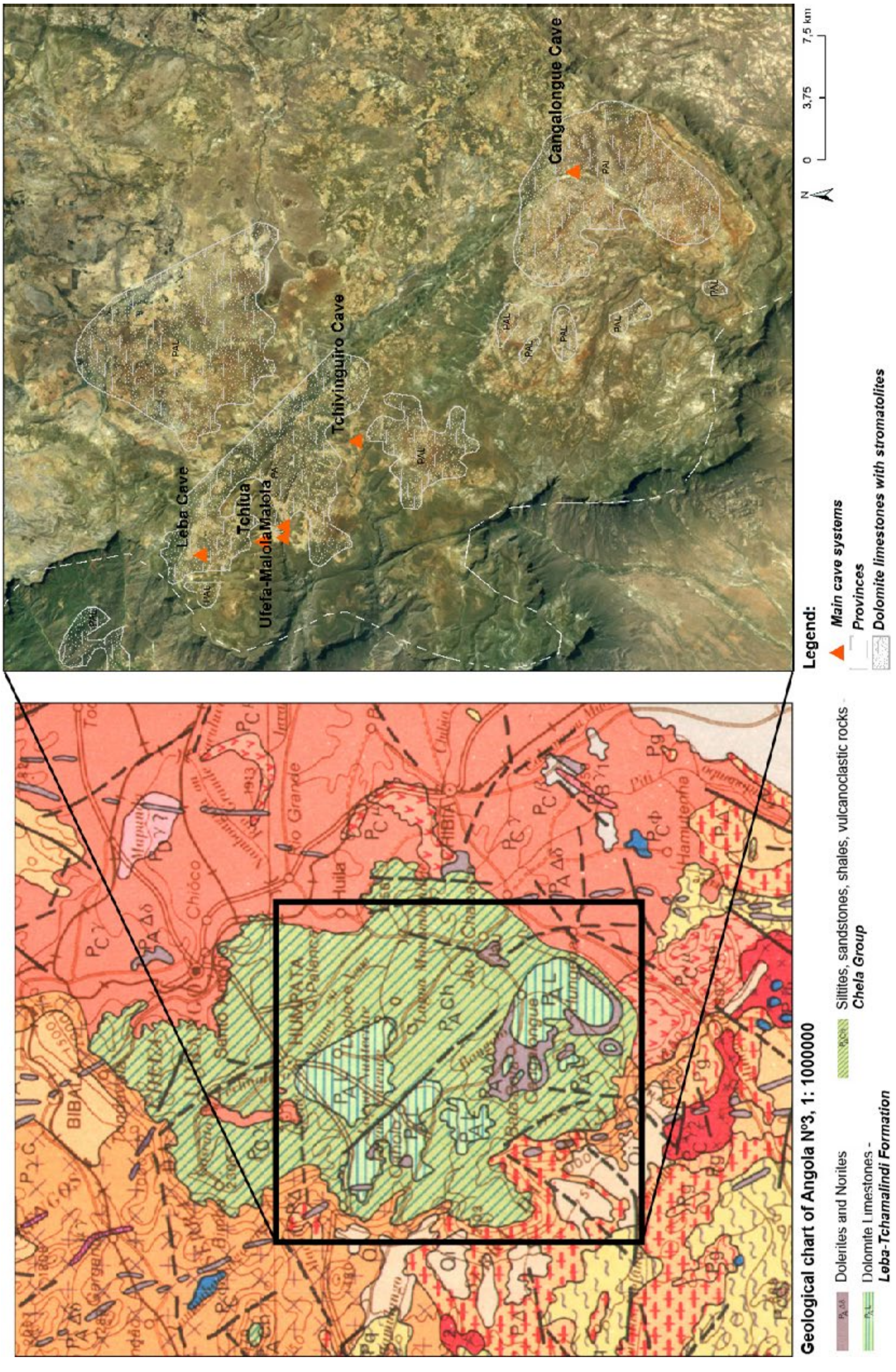

Figure 2. Extract of the geological map (Matias 1980) and location of the cave systems in the Leba Formation dolomites (map by Inês Pinto and D. Matos).

preserved today, which would explain deposition of archaeological materials in the screes of the river shore of Leba.

5. Archaeological Research in Southwest Angola

Stone Age archaeological finds have been known in Huíla Province since the early 1930's following the geological mapping of mining resources by the Geological Mission of Angola (Mouta, F. 1934). The enlargement of railways across the country, following the establishment of colonial farms and industrial explorations, multiplied the number of discoveries in the southwest region. An ever-growing interest in the heritage and history of both ethnic groups and endogenous resources (fauna and flora) triggered a series of Scientific Missions by Portuguese scholars from 1940s to late 1960s. At first, these missions aimed to provide a charted picture of the colony and were focused in geography, geology, soils, anthropology, biology, botany and zoology. During these early missions, researchers frequently bumped upon prehistoric artefacts that reported to an ancient past of African civilizations. In 1947, the discovery of the paleontological remains at Tchíua and Leba (Mouta, F. 1953; Camarate-França, J. 1964a), which likely dated to a presumed Early (ESA) and Middle Stone Age (MSA), stimulated the joint efforts of geologists and anthropologists to survey and excavate archaeological sites that provided a better picture of traditions of indigenous populations and their ancestors. Especially one ethnic group, the Khoi-San, who kept traditional semi-nomadic foraging lifestyle among pastoralists, attracted the curiosity of anthropologists and Africanists. By the mid-XX century, these Bushmen were already rare in Huíla (completely absent today) and the prehistoric remains were perceived to illustrate their traditions and territory prior to the arrival of Bantus from the East (Almeida, A. 1956, 1970).

The Anthropobiological Mission of Angola (1948-1955) was directed by anthropologist António de Almeida and geologist José Camarate-França as co-director. Although archaeology was not a priority in the goals of the survey mission, thousands of sites and prehistoric assemblages were gathered in the same expeditions that intended to perform anthropometric measurements of the people and research on the tribes' health (Poloni, R. 2012; Almeida, A. and Camarate-França, J. 1960; Almeida, A. and Camarate-França, J. 1964). Following this work, the first prehistoric chart of Angola was published by A Almeida and H. Breuil (1965) joining the information gathered both in the South and North of Angola. Later the Mission of Archaeological Studies in Southwest Angola (MEASA) headed by Miguel Ramos from 1966-67 (Ramos, M. 1966-67) relocated and sampled more than a hundred ESA and MSA sites in the provinces of Huíla, Namibe, Cunene and Cuando-Cubango. He directed excavations in two new sites of the Early Stone Age: Campangombe-Santo António and Maconge-Santo António. Though Ramos intended to pursue doctoral studies on this topic under supervision of André-Leroi-Gourhan, his thesis was never concluded and only brief articles offered introductory notes on the collection and not the necessary characterization of lithic industries, behavioural or ecological diversity (Ramos, M. 1970, 1974, 1980, 1982, 1984).

Today, all the assemblages from Southwest Angola are curated by the University of Lisbon in Portugal. The project of GIS mapping of the Archaeology Collection of Angola is an on-going endeavour by Ana Godinho Coelho and Inês Pinto at the National Museum of Natural History and Science in Lisbon with the collaboration of D. Matos. Inventory and description of lithic industries are sided with the revision of coordinates and relocation of the sites in the field. A preliminary map was produced to revise the Early and Middle Stone Age assemblages of the Southwest (Figure 3). These include a total of 201 provenances mainly concentrated between the Namibe and the Huíla Province, indicating that this region is an important area for heritage research of Angola.

The MicroGAP 2018: Preliminary results

In February 2018, a new mission of studies was initiated in Southwest Angola, targeting Leba Cave (Figure 4) in the Leba valley, at the northern edge of the dolomite outcrop of the Humpata Plateau.

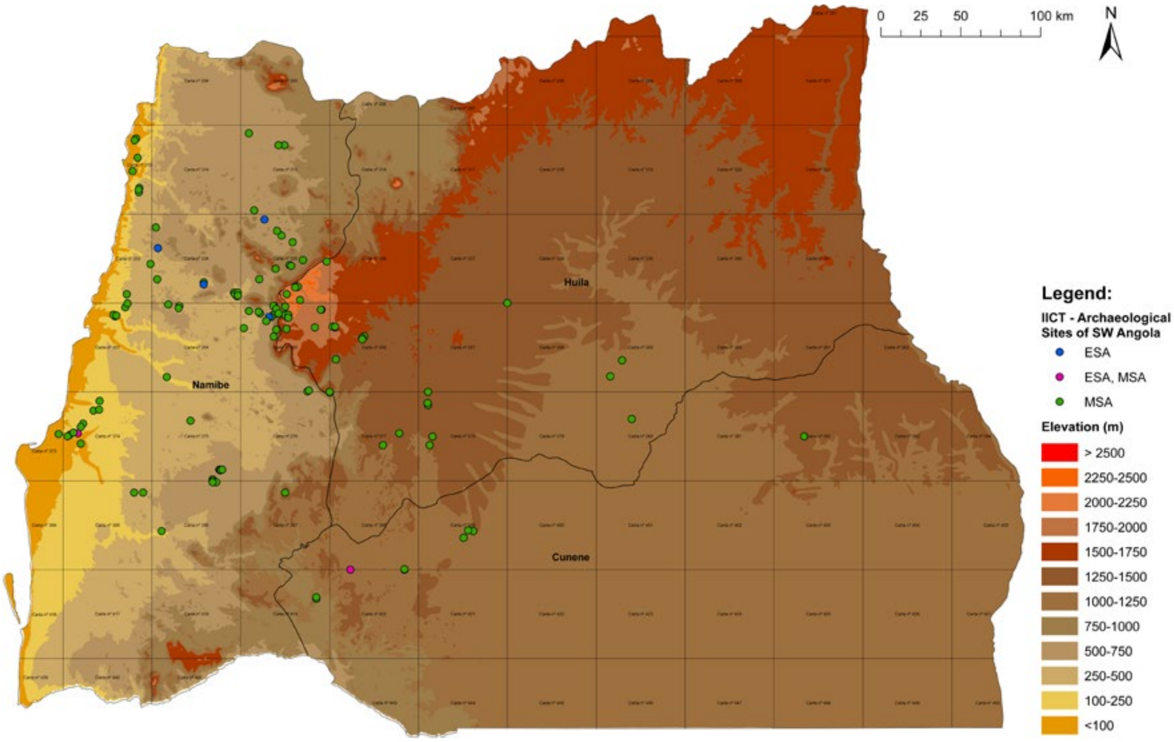

Figure 3. Distribution of ESA and MSA sites in the collection of the IICT from Angola (in Matos *et al.* 2014).

The Mission of Geoarchaeological Studies of Leba Karst (MicroGAP) was a pilot project developed in two campaigns during the year 2018. The initial goal was to investigate the geomorphology and stratigraphy of the Stone Age occupations in Leba Cave and the development of karstic infillings in the Leba basin during the Pleistocene and Holocene.

The word Leba has its origins in the indigenous toponym *eleva*, which means 'hole in the rock' or 'crevice' in the local dialect of Nyanheka (Camarate-França 1964). The diversity of caves known in the area remained in the toponym adopted for the most famous sightseeing point in Angola at the western edge of Serra da Leba and its serpent-like road. However, the name Leba refers to the village at the road marks 146-140, where the ruins of an old farm and factory are visible. A few buildings like the school, the health centre and the chapel are still used by the local community.

Leba Cave (15°05'01.34''S, 13°15'34.61''E) is a cavity with 48 m depth and a maximum width of 6 m, dipping 3 m south. The cave is located next to two kilns for hydraulic lime and the main factory of Fazenda da Leba founded in 1950. The site was discovered during the construction work for the factory and was investigated by F. Mouta in 1947, becoming a target for excavations by the Anthropobiological Mission of Angola in 1950. J. Camarate-França authored the excavation work but his notes were published only after his death (1964). This report describes a six-unit sequence of archaeological horizons with materials of the colonial period and Iron Age followed by Late Stone Age, Middle Stone Age, with Sangoan artifacts at the lower level. The artefacts from this excavation remained unstudied until recently (Matos, D. 2013) but their exact provenance inside the cave was unclear. It is also not clear where a second excavation was performed by Vítor Oliveira Jorge in 1974, though several artefacts, which are preserved in Lubango, Angola, are referenced as Stone Age and Iron Age from Leba Cave. Detailed information of his work appears to have been lost according to the author's references (Jorge, V. 1974, 1975).

In the literature, the Leba Cave is presented as having two chambers, but in fact is one single room, like a tube, with lateral widening cracks filled with sediment. Sequential displacements of the ceiling contributed to a shift in conditions of light and moisture inside the tube and consequently

Figure 4. Entrance of Leba Cave (photo by D. Matos).

in changes of deposition and diagenesis. Nowadays the environment inside the cave is quite dry with few active drips at 30 m from the entrance. No stalagmites are present but the negatives of their previous existence are still there, which may indicate either they were broken intentionally by people or non-intentionally by local tectonics and geogenic phenomena.

Ripple marks under the brim of the cave entrance show that the cavity we access today may correspond to the early stages of the cave system when speleogenesis was stimulated by rather abundant surface water probably forming a waterfall, similar to Namdimba Spring. Tufa lobes found next to the Leba Cave are consistent with such interpretation. Occupation inside the cave definitely happened when the water table became significantly lower and made the cavity accessible.

The fieldwork in 2018 was divided in two phases: the first excavation, that focused essentially in the collection of contextual data for sediment analysis, soil micromorphology and dating inside Leba Cave; the second, survey, intended to locate other points of interest with the support of the local community.

The strategy for testing inside Leba Cave aimed to: 1) perform limited re-excavation of the profiles remaining from old excavations; 2) re-evaluate the stratigraphy and formation processes describing anthropogenic, geogenic and biogenic deposits and features; 3) record the sequence of cultural traits in the Pleistocene and Early Holocene horizons; and 4) start establishing a geo-chronological model for Southwest Angola.

Excavations targeted two areas inside the cave that presented indicators of previous interventions, predictably related to the work of J. Camarate-França in 1950. The sequence and typology of archaeological materials is consistent with this presumption, however these areas also show distinctive depositional environments and diagenetic features, and possibly also different formation histories and chronologies. Protocols for dating were applied in sampling for Optical Stimulated Luminescence (OSL) and Uranium-Thorium series (U-Th). The collection of samples for soil micromorphology and sediment minerology paired with absolute dating promises to unveil the particularities of the geochronological and paleoenvironmental context of anthropogenic occupation in the Leba karstic system.

In order to better understand alteration of the karstic landform and dispersion of archaeology along the Leba basin we conducted a survey of northern edge of the outcrop recording fissures, alluvial fan eposits, breccias or terraces with lithic artefacts in the northern edge of the outcrop in a radius of 10 km. Survey showed that the ancient land surface at the northern edge of the dolomites has been more extensively affected by erosion, where humans have a much recent impact through lime quarrying. Nonetheless physical and chemical processes derived from past climatic conditions seem to play a main role in the evolution of the landscape during the Pleistocene and early Holocene.

At the top of the hill several shafts and chimneys were detected during survey, most of them filled with pink to reddish sediments. Same fissure fillings are exposed by the quarrying and observed in profiles along the edges of the dolomites. We have found abundant lithic materials such as flakes, blades and points in screes and alluvial fan deposits that derive from old caves or fissures altered by weathering and movement of blocks (Figure 5).

This is the case for a new site identified and named Hunters Cave (pt: *Gruta do Caçador*). Close to Leba Cave, around 800 m East at the same altitude, the dolomite ridge hides two adjacent galleries with abundant artefacts homologous to the materials found in Leba Cave. These are the remnants of a bigger cave which has been half destroyed since many lithics and fauna are found in the slope under the rock shelter. In future work we intend to explore the relationship between the alluvium deposits and the karstic-fillings to obtain a more complete picture on the Quaternary paleolandscape in the Leba basin.

6. Conclusions

The research undertaken so far at the Leba complex presents evidence of an unequal but recurrent use of territory and its basic geomorphological characteristics, allowing for insights into human adaptations to contextual, namely environmental, but also anthropic, changes. These would be more familiar to contemporary populations once the relations between Bantu and Khoisan populations are assessed; however, the cross-chronological study required by the various identified sites and stratigraphy enables us to understand the contemporary landscape as fossil evidence of several other stages in past transformations, itself of use for contemporary society awareness.

The ongoing research, allowed for the characterization of occupation layers and related environmental and climatic contexts, being focused on Quaternary hunter-gatherers (MSA and LSA namely). The use and management of basic resources locally available such as fresh water, lithic raw materials, fauna and flora are some of the main features approached at the landscape scale. These demonstrate how the current landscape has been shaped by past natural processes and human-environment interactions.

Moreover, it is not unlikely that earlier Quaternary layers may yield evidence of human occupation, extending the knowledge about earlier humans in Southwestern Africa, itself contributing to conceive a different landscape for the African ESA (where the ‘East Side Story’ model is increasingly challenged).

This will lead to identify main areas of heritage interest, using a methodology that has been previously tested, to conceive cultural landscapes in the Ebo plateau (Kuanza-Sul) or in the Tchitundo-Hulo complex (Namibe). As in these cases, apart from design of conservation strategies (e.g. listing the sites as national heritage), it will be recommended to engage the local inhabitants in the management of the overall landscape and its key sites. For the Leba region a good possible way to ensure this will be through the structuring of a geopark, under UNESCO rules, which will consider together the geomorphological features (such as the Leba Cave) and the geological

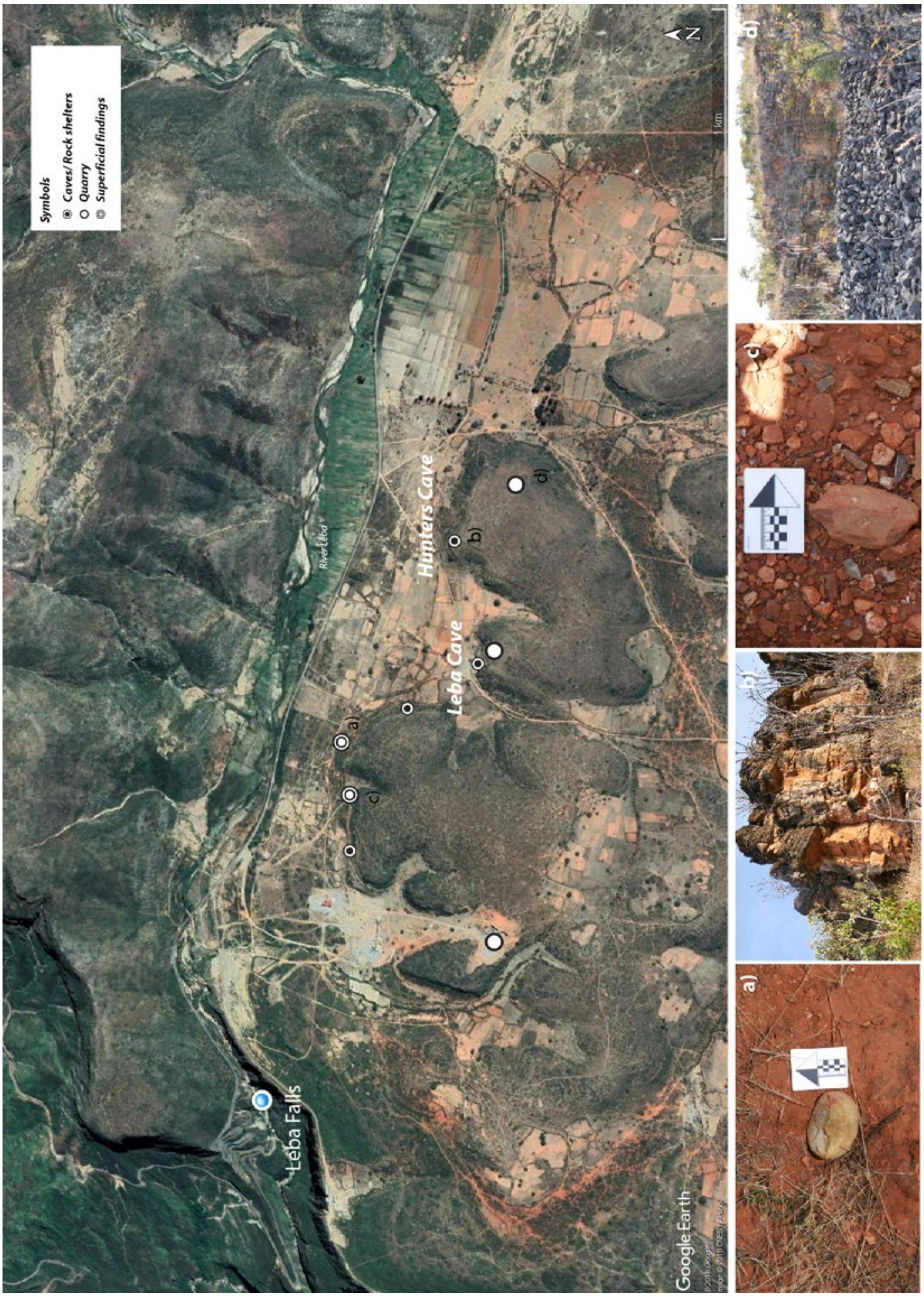

Figure 5. Location of cave sites and archaeology in the Leba Valley, a) and c) Middle Stone Age tools; b) Hunters Cave; d) Leba quarry.

features (such as the Tundavala and Leba geosites; Henriques, M. H. *et al.* 2013; Tavares *et al.* 2015), the biome, and their co-evolution with hominins.

This approach, anchored in the assessment of human resources, techniques and logistics, will also contribute for the generation of territory-based data, for future inter-regional comparative studies. The establishment of a permanent geosciences research base, namely in collaboration with the Mandume ya Ndemufayo University of Lubango, will be a step to undertake, in order to consolidate the already accomplished efforts.

The construction of cultural landscapes of societies of hunter-gatherers should result of an approach to the activities and techniques of those societies, on one hand based on the studies of archaeology and anthropology (that explain their functionality) and on the other hand by the geosciences (that explains their surroundings and conditions of context). It is not our goal to merely map the past but to launch a new inquiry to these landscapes that can be used to further establish scientific research in these fields and develop strategies of heritage management and conservation within the country.

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Geophysical explorations of the classical coastal settlement of Lechaion, Peloponnese (Greece)

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Abstract

The geophysical survey at Lechaion was carried out under the framework of the Lechaion Harbor and Settlement Project (LHSP) that aims to study the settlement and its harbor during its habitation. Lechaion was the western and most important seaport of Corinth due to its proximity to the city.

The geophysical results were mainly correlated to a system of parallel N-S roads crossing the site, verifying a number of features that were originally suggested from various historical, aerial and satellite images. Around the lagoon, features follow the direction of the modern shoreline, suggesting that its shape has not changed significantly since the ancient times. To the north of the central lagoon, an area of more than 100 x 100 m has been clearly differentiated from its surroundings suggesting a region of high deposition. The joint employment and interpretation from diverse satellite and ground based techniques proved their efficiency in reconstructing the cultural dynamics of coastal archaeological sites in Eastern Mediterranean.

Keywords: geophysical prospection, coastal settlement, classical period, Lechaion, Greece

Résumé

Une prospection géophysique a été menée à Lechaion dans le cadre du *Lechaion Harbor and Settlement Project* (LHSP), lequel vise l'étude du site et de son port. Lechaion était le port maritime principal de la ville de Corinthe, située à moins de 3 km à l'est.

Les données géophysiques démontrent l'existence d'un système de rues parallèles orientées nord-sud et confirment les résultats obtenus précédemment à partir de l'étude de photographies aériennes historiques et d'images satellites. Autour du lagon, les anomalies géophysiques suivent l'orientation de la ligne côtière moderne, ce qui suggère que celle-ci n'a pas évolué de manière significative depuis l'Antiquité. Au nord du lagon central, une zone de plus d'un hectare se distingue clairement des environs et semble couvertes par d'importants dépôts. L'étude du site de Lechaion démontre l'efficacité de l'analyse combinée de techniques terrestres, aériennes et satellites pour reconstituer les dynamiques culturelles des sites archéologiques côtiers en Méditerranée orientale.

Mots-clés : prospection géophysique, site côtier, période classique, Lechaion, Grèce

Figure 1. Area coverage from the various geophysical survey techniques during the first two fieldwork campaigns at Lechaion, Peloponnese.

1. Introduction

The first two phases of the geophysical prospection survey at the archaeological site of Lechaion (Figure 1) were carried out in 2016 and 2017 under the framework of the Lechaion Harbor and Settlement Project (LHSP) that aims to the study of the settlement and its harbor from its earliest use during the Mycenaean period and perhaps earlier until its abandonment in the second half of the 6th century CE.

Lechaion was the western and most important seaport of Corinth due to its proximity to the city. Long fortification walls connected the city with the port and the naval dockyard that the Corinthians had formed in the wider area. The foundations of these long walls and especially the western wall have already been revealed in 1892 as part of an excavation campaign. The Corinthians increased the security and port capacity through technical projects on the port. The first infrastructures would seem to have been built during the late Geometric period, to serve first trade with and then colonial expansion into the West. The basilica of Saint Leonidi is hosted in the ancient harbor, which is considered the largest paleochristian church in Greece with dimensions 220 m long and 50 m wide and one of the landmarks in the architecture of churches. Both ports of Lechaion (access to the Corinthian Gulf) and Kenchrai (access to the Saronic Gulf) provided the foundation for the dominance of Corinth during the Classical and Roman periods.

Most of the region was covered by magnetic and GPR techniques, which proved to be the most efficient for the particular geomorphological settings of the coastal settlement. A number of sections of the site were scanned by various methods in order to address specific questions that arose from the geophysical data. This manifold approach has proven to be most effective when question driven geophysical prospection is undertaken during the investigation of an archaeological area (Sarris 2013).

2. Methodology

Magnetic, ERT, EMI, soil resistance and GPR were employed in a complementary manner to record the subsurface information at specific areas of the archaeological site of Lechaion. These geophysical techniques were chosen as the most appropriate for meeting the goals of the project, according to the needs of the research, the geomorphological characteristics of the site, and the expected subsurface archaeological targets – with respect to the detection and mapping of them.

Magnetic survey was carried out using a Sensorik and System technologie (SENSYS) MX Compact Survey System. SENSYS MX is a multi-channel measurement system, equipped with 8 FGM600 gradiometers, navigated via a DGPS using the NMEA 0183 standard. In areas which were difficult to navigate with the extension of the multisensory system, two handheld Bartington vertical magnetic gradient magnetometers (fluxgate gradiometers) were employed. The electromagnetic induction data were collected with a CMD Mini Explorer unit by GF Instruments designed for multi-depth measurements. CMD Mini Explorer is used for the assessment of ground conductivity and of in-phase (susceptibility) using three dipoles centered at distances (0.2 m, 1.71 m, 1.18 m) and a frequency of 30 KHz, thus having a variable effective high/low depth range (0.5/0.25 m, 1.0/1.5 m, 1.8/0.9 m). For GPR data collection, the Noggin Plus-Smart Cart system by Sensors and Software was used with a 250 MHz antenna. For prospecting with GPR, grids were designated to delimit the areas of interest and data were collected in parallel transects along the Y direction. The Syscal Pro resistivity meter connected to the Syscal Switch Pro 96 (Iris Instruments) was used to capture and store the ERT field data. The instrument has the capability to simultaneously drive up to 96 electrodes which are laid out along a transect and which are connected to the resistivity unit through a multiclone cable. Resistance mapping was completed with the Geoscan Research RM85 instrument configured in a Twin probe electrode array.

All the geophysical techniques emphasized the detailed mapping of the investigated areas (0.5 m by 0.1 m sampling for magnetic measurements, 0.025 m along the GPR transects separated at 0.5 m parallel profiles, 1 m inter-electrode spacing for the ERT, 1 m by 1 m for electrical resistance etc.). Magnetic techniques covered the largest section of the site (57,700 sq. meters), followed by the GPR survey (23,500 sq. meters) and the soil resistance mapping (8,000 sq. meters). EMI methods scanned about 6,100 sq. meters and the ERT lines targeted specific sections covering 4,100 sq. meters (Figure 1).

3. Processing of geophysical measurements

Despiking, Grid matching, Line equalization techniques were applied to magnetic, soil resistance and EMI data before using a Kriging algorithm for interpolation. Compression of the original dynamic range of values and the application of derivative filters enhanced the subtle anomalies. Colour and grey scale geophysical maps were produced: Hot colours (reddish colours) in colour maps and light (white) colours in grey scale maps represent high intensity values. Cold colours (bluish colours) in colour maps and dark (black) colours in grey scale maps represent low intensity anomalies. GIS software (ArcGIS v.10.3) was used to rectify the geophysical maps and overlay them on the topographic plan of the site and other satellite or aerial images.

Similar was the processing of the ERT data. Despiking and compression of the dynamic range were applied to each one of the 2D ERT tomographies to remove apparent extremely noisy resistivity measurements. Different 2D resistivity inversion algorithms (Loke and Barker 1996) were used to process the data. The algorithms divide the subsurface in rectangular parameters of constant resistivity that can vary their value independently during the inversion process.

Processing of the GPR data was carried out using EKKO Project 2 by Sensors and Software. Preprocessing included the trace reposition of the individual GPR transects, time zero correction and the application of a Dewow filer. Following this, GPR signals were enhanced through background removal, application of a SEC gain and band pass filtering in the frequency domain. By the time the processing on the radargrams was complete, Hilbert Transform was applied to calculate the instantaneous amplitude and extract depth slices, namely horizontal slices depicting the registered reflectors with increasing depth. Depth values were estimated based on the hyperbola curve fitting method (v~0.9-0.95 m/nsec).

4. Discussion of Results

Despite the high noise levels due to the intense historical and modern exploitation of the land, the magnetic survey that was carried out to the south section of the site indicated that the settlement expanded around the lagoon, which seems to have retain its shape from the ancient times (Figure 2). The structural remains follow the same orientation of the shore line of the lagoon. The structures are mainly orthogonal, having internal divisions and some of them are of monumental dimensions. Magnetic values are more pronounced closer to the lagoon, suggesting a denser occupation in this section, probably of more coastal type of activities. Further to the central east region, 4 almost parallel segments, 5, 9 and 5 m apart correspondingly, starting from the northern one, represent the relics of a large compound, which appears with strong signals in the GPR measurements (Figure 3). Indeed, within the first 50-160 cm below the surface, a three aisled basilica appears. It has a length of more than 31 m (35 m including the apse), which means it is about 1/5-1/6 times the size of the large basilica of Leonidi which lies to the NW. Immediately to the south and east of the basilica high reflectance anomalies dominate the region in contrast to the surrounding region. In consideration of their depth (150-160 cm) and amorphous shapes, they can be interpreted as geological formations. In contrast, the area to the NW of the basilica exhibits more homogeneous and quiet magnetic levels, which may be caused due to depositional processes from the narrow channel immediately to the north. This may be indeed the case, as the particular narrow width section of the lagoon could be exposed in frequent high energy water masses entering the channel of the lagoon from the east. Similar signs of siltation and high salt concentration are shown by the high EMI conductivity measurements to the south of the central south section of the lagoon.

Within the lagoon, the magnetic measurements registered very vague anomalies that are hard to identify as residues of sunken ships or any massive architecture. The only strong candidate is an area of ~28 x 8 m, located at the south end of the lagoon, exhibiting slightly higher values than the rest of the surrounding region. On the other hand, the 7 parallel ERT transects that were executed in the north section of the lagoon produced a 3-layer stratigraphy consisting of: a top 2 m thick conductive layer A (0.2-0.6 Ohm.m), related to fine clay sediments, saturated with saline water; a middle more resistive silty or/and sandy clay layer B (1.0-4.0 Ohm.m) of variable thickness (5 m in the interior of the lagoon, 9 m towards the periphery of the lagoon), most probably due to the slight dipping trend of the bottom Layer C towards NE, which is of intermediate resistivity values (0.6-1.0 Ohm.m) (Figure 4).

To the east of the Leonidi basilica, three long N-S features (A25, A20 and A26) that can be identified with roads are visible in the magnetic data, merging to a common location that can be a crossroad (Figure 5). The largest segment of them (feature A25) extends for about 40 m in a slightly NW-SE direction to turn to the E-W direction (feature A26) at the cross section with the N-S street A20. The signature of the street A21 is clearly defined for about 43 m, before fading away as we move towards the north and at the interface of anomaly A28, which defines the boundary of a region that consists of a very smooth low magnetic background. This region seems to continue further to the east as it registers in a very similar way to the GPR data. Despite the fact that magnetic data cannot directly indicate possible siltation or deposition processes (like EM, GPR or ERT methods), the fact that there is a clearly defined outline of a relatively magnetically ‘quiet’ region indicates

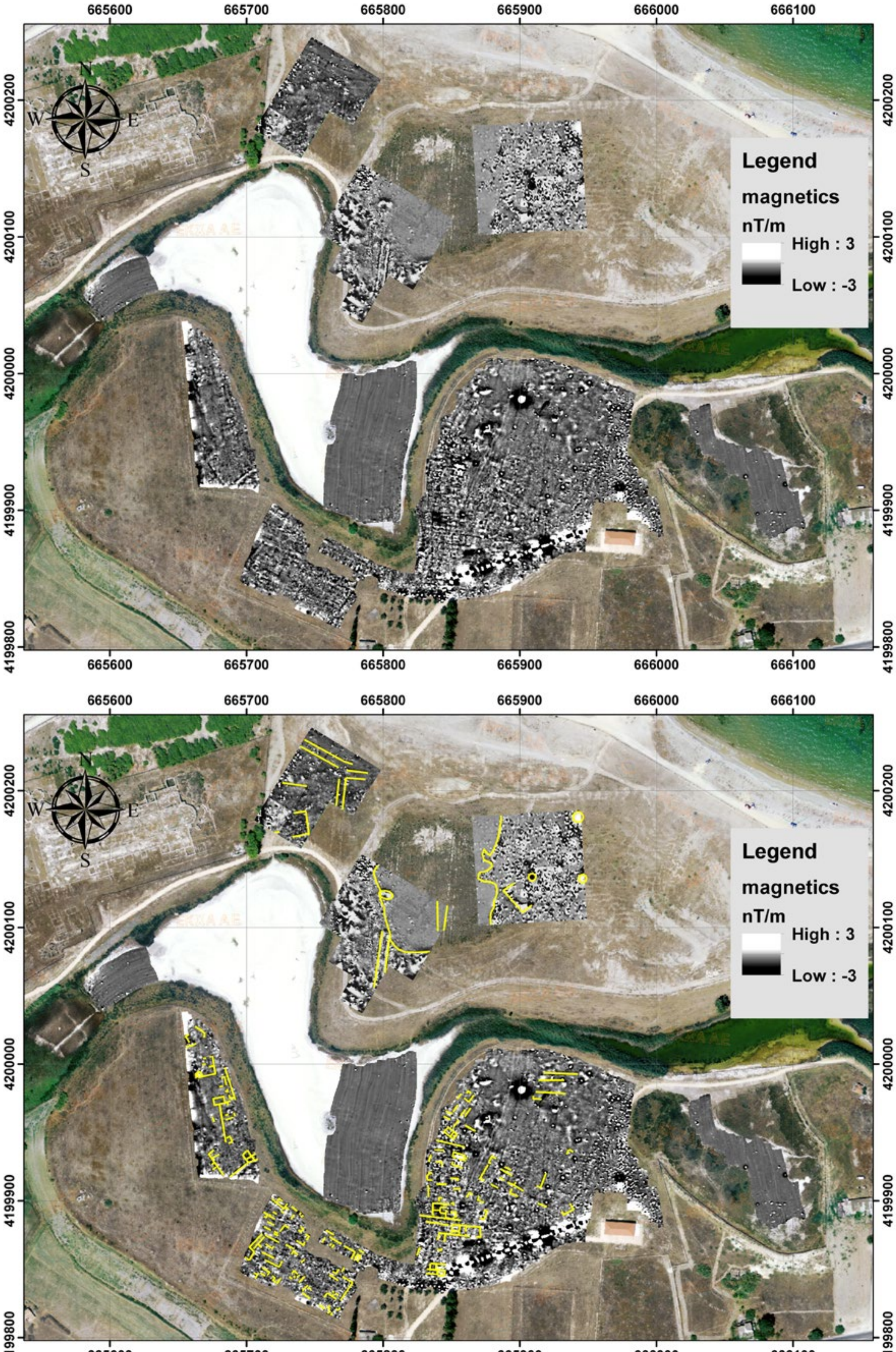

Figure 2. Top: Results of the magnetic survey at the south and north sections of the ancient settlement of Lechaion. Bottom: Diagrammatic interpretation of the results of the magnetic anomalies.

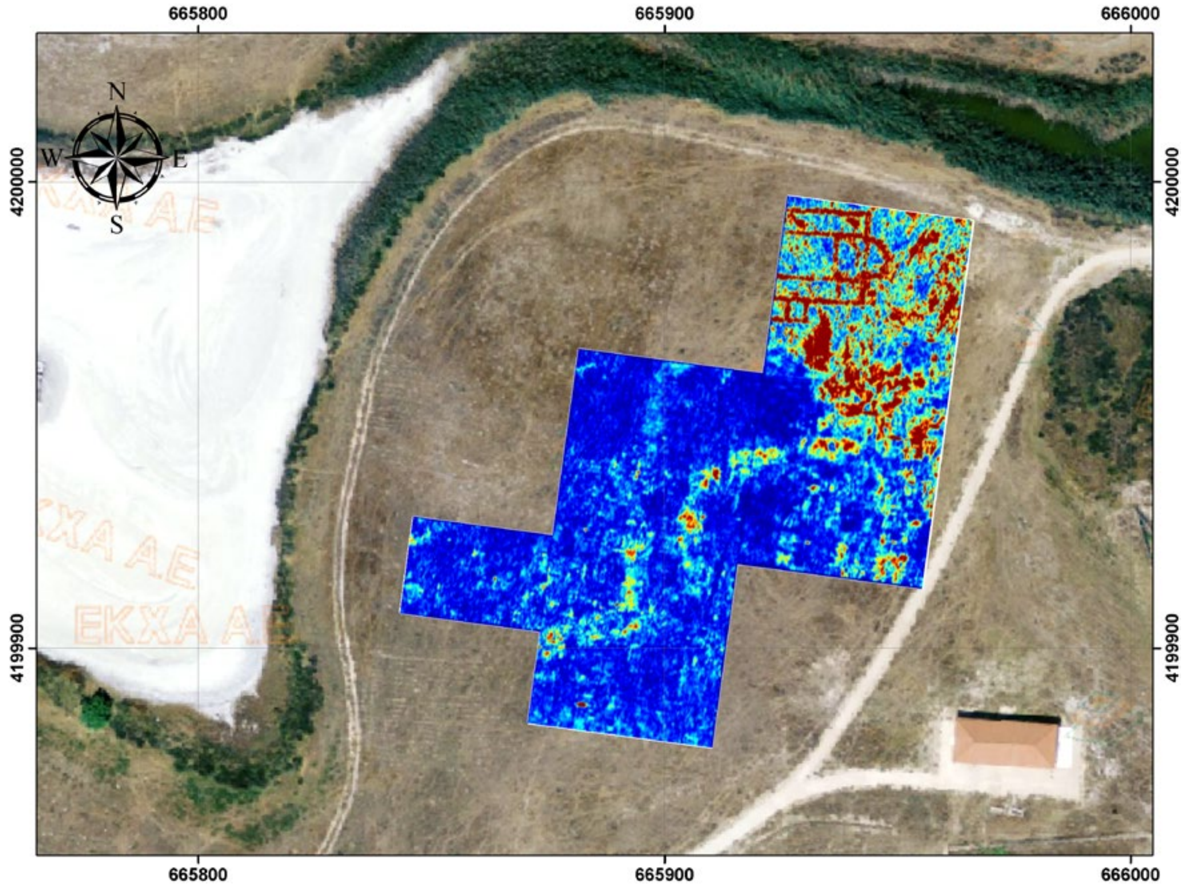

Figure 3. Results of the GPR survey at the SE section of the site of Lechaion.

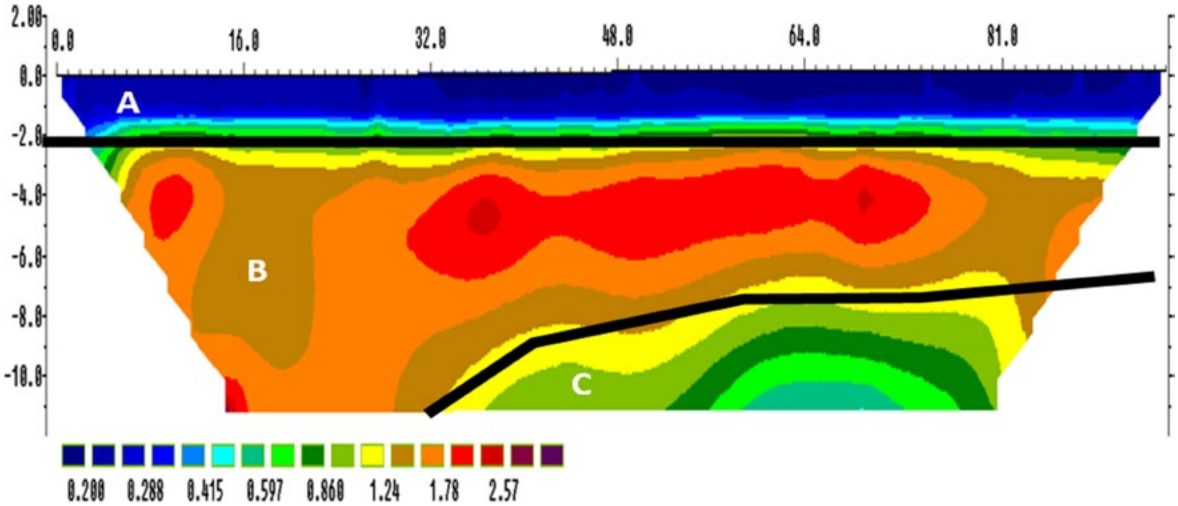

Figure 4. Geological stratigraphy at the northern section of the large lagoon resulting from the ERT survey.

a differentiation from the rest of the area. This is indeed in perfect agreement with the GPR data, which define the same area of high conductivity (and thus absorption of the GPR electromagnetic waves) (Figure 6). The GPR signal becomes saturated below the 60-100 cm depth.

Towards the NE, a number of circular high conductive features (A31, A32, A33, A36 and A37) start appearing at the same depth (50-60 cm) and up to a depth of 120-130 cm (Figure 6). Their radii vary from 7 to 11 m. Further to the NE, the soil resistance values reached the highest readings that have been collected in the site, which should be expected due to the sand that covers this particular

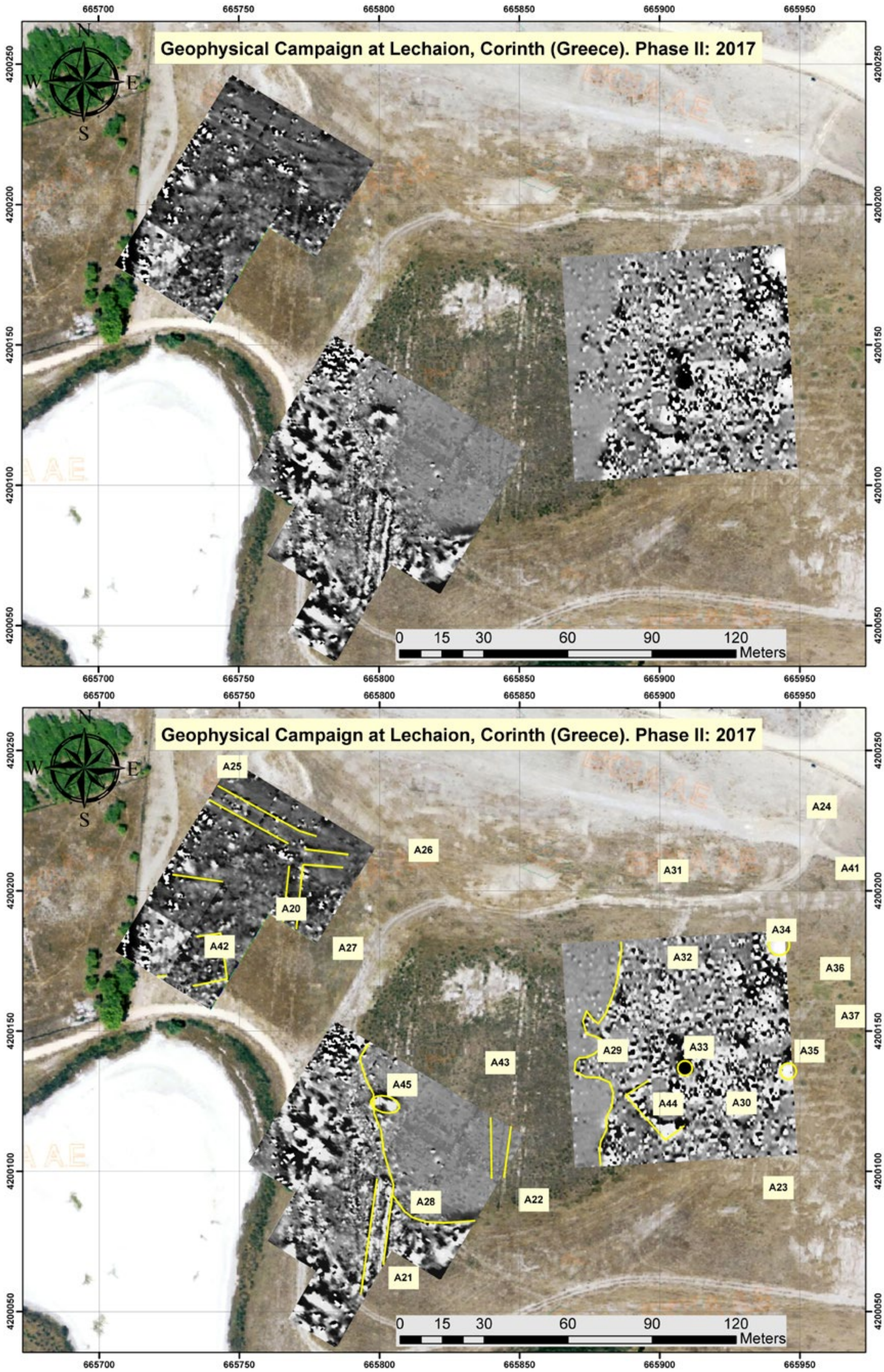

Figure 5. Top: Results of the magnetic survey at the north section of the site of Lechaion. Bottom: Diagrammatic interpretation of the magnetic anomalies identified in the north section of the site.

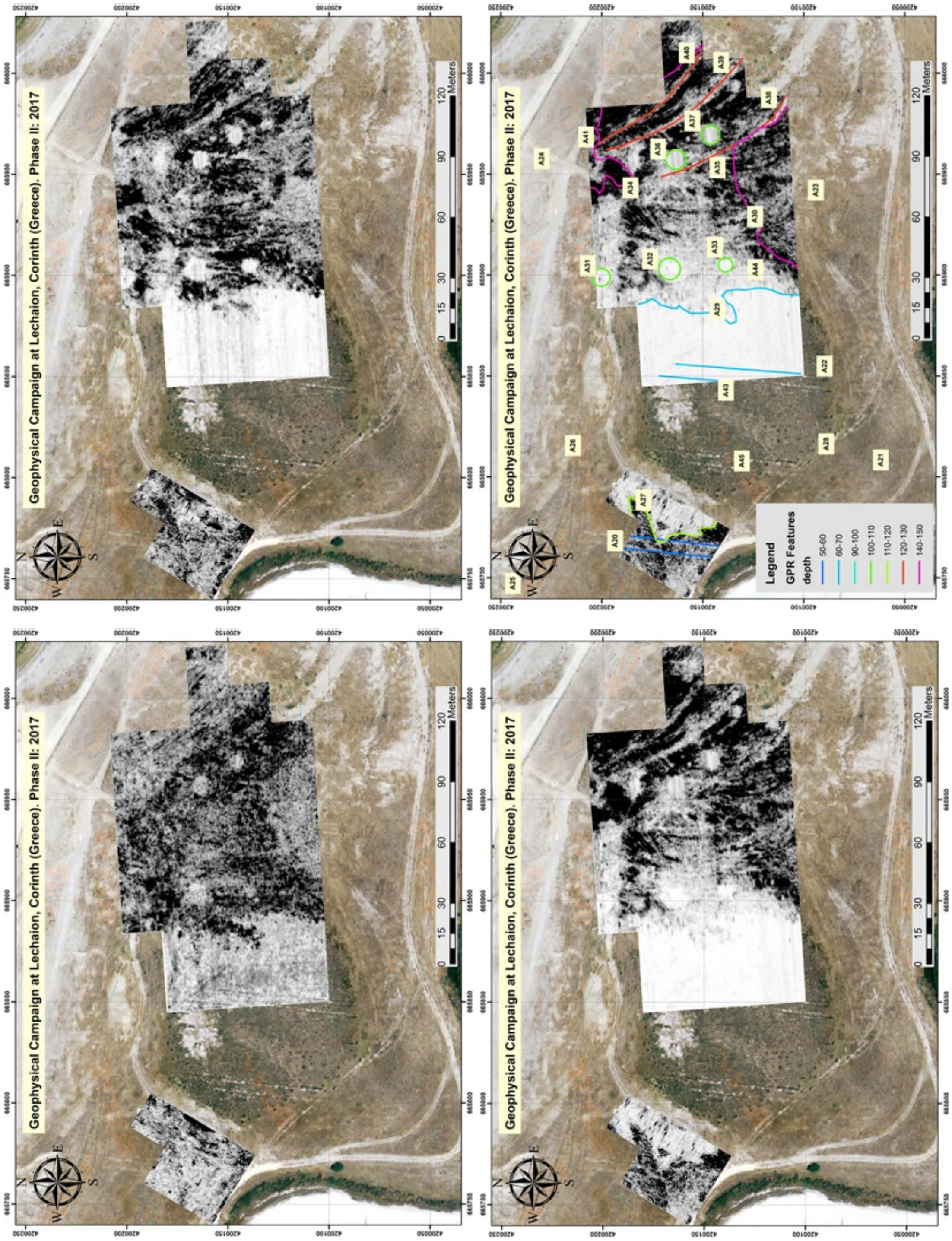

Figure 6. Results of the GPR survey at the NE section of the site. Top left: Depth slice of 70–80 cm; top right: Depth slice of 100–110 cm; bottom left: Depth slice of 140–150 cm; bottom right: Diagrammatic interpretation of the GPR reflectors.

area (indication of sea wave deposition?). This was also confirmed from a couple of ERT lines that were carried out in this particular section and indicated a superficial resistive layer (2 m thick) of more than 60 Ohm.m (sand ?). Interesting enough, this high resistive layer was interrupted when crossing the respective round conductive features shown in the GPR slices. The remaining superficial part of the stratigraphy is characterized by patches of a less resistive material (silty sand?) with resistivity 6-60 Ohm.m, below which there is a relatively uniform conductive layer (0.6-6 Ohm.m) that is attributed to a sedimentary formation saturated with salty water.

In the same area towards the NE, a series of extensive linear concave features (with most intense features A38, A39 and A40), extending parallel to the NW coastline, appear in all depth slices below the 1 m (Figure 6). There is no regularity in the shape or the distance between the particular features and thus it may be possible to constitute traces of depositions from past incoming sea waves that may have modified the coastline in different historical periods.

5. Final remarks

During the two fieldwork campaign seasons, geophysical data started to reveal the formation of the site of Lechaion, both natural and anthropogenic. Having gone through a diachronic habitation, the site exhibits a number of interesting features that can be related to the intense occupation of the site in the ancient times and to the more recent historical activities until the abandonment of the site.

The high density of occupation of the coastal settlement in antiquity has been manifested especially to the south of the lagoon. Fewer structural remains have been located to the north of the lagoon. The geophysical signals (and satellite imagery) support the observations made by Romano (2003, 2006) studying the 1987 balloon imagery taken by Myers (Hemans *et al.* 1987). At least three – four of the seven N-S 30 feet wide roads that Romano identified in the images of Myers were confirmed through the geophysical techniques. The streets are 37m apart and they fit to the plan suggested by Romano. Similarly, an E-W road was identified to the NW section of the surveyed region. However, the traces of the roads are also visible on the current terrain, extending down to the shallow depth layers (~50-60 cm below the surface) and this may suggest that they may be of a later period.

The above hypothesis can be further supported by the large (~100 x 100 m) low magnetic background and high conductivity central area that was identified to the north of the main lagoon, suggesting a region of high deposition, intact from other geological processes. The ERT measurements confirmed that in this particular region, right below the top sandy layer, there is a highly conductive formation saturated with salty water. If this is the case, then this region could have comprised an outer lagoon connected to the NE (or the northern) coastline but, until further studies are conducted, of an unknown date.

The dynamic interaction between the sea and the coastal region and the intrusion of the sea towards the main lagoons is supported by the geophysical data. This is especially evident by a series of extensive linear concave features extending parallel to the NE coastline, which could be attributed to traces of depositions from past incoming sea waves. This can also support the hypothesis made for the 5 shallow circular conductive features found in the particular region, namely that they are anthropogenic constructions used either as fish tanks or for salt production, similar to the facilities found in other Iron Age and Roman period sites (Wooddwiss 1992).

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A view from the hills. Investigating protohistoric phases in the longue durée of the Potenza Valley (Marche, Italy)

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Abstract

We present new research of protohistoric communities in Central-Adriatic Italy through non-invasive prospection of pre-Roman settlements and their catchments. We look beyond the well-known burial record of the indigenous Piceni groups in the present-day region of Marche, instead investigating the much less studied settlement patterns in the Bronze and Iron Age. We seek to place habitations and territorial behavior in the archaeological continuum, in both a diachronic and a spatial context. The diachronic aspect concerns adding time depth to the until now predominantly Roman and Late Antique research themes of the Potenza Valley Survey project (PVS, 2000-2017). The spatial continuum concerns our aim to fill in the blanks in the known protohistoric record through detailed research of habitation zones and productive catchments. We do this using mainly non-invasive prospection techniques. In this paper, we discuss our approach and its challenges, and present preliminary results and considerations of the fieldwork that was carried out at the site of Monte Franco (Pollenza).

Keywords: archaeological prospection, protohistory, micro-regional analysis, Italy

Résumé

Nous présentons une nouvelle recherche sur les communautés protohistoriques en Italie centrale-Adriatique par le biais d'une prospection non invasive de sites d'habitat pré-romains et de leur contexte territorial. Nous nous intéressons au-delà des sites funéraires bien connus des groupes autochtones Picènes dans la région actuelle des Marches et examinons plutôt les schémas d'établissement beaucoup moins étudiés de l'âge du bronze et du fer. Nous cherchons à situer les habitations et les comportements territoriaux dans le continuum archéologique, au sens diachronique et spatial. L'aspect diachronique concerne l'addition de la dimension temps aux thèmes de recherche à prédominance romaine et d'Antiquité tardive du projet Potenza Valley Survey (PVS, 2000-2017). Le continuum spatial concerne notre objectif de combler les lacunes du contexte protohistorique connu grâce à une recherche détaillée des zones d'habitation et des territoires productifs. Nous faisons cela en utilisant principalement des techniques de prospection non invasives. Dans cet article, nous discutons de notre approche et de ses défis, et présentons les résultats préliminaires et les considérations du travail de terrain sur le site d'étude de cas Monte Franco (Pollenza).

Mots-clés : prospection archéologique, protohistoire, analyse micro-régionale, Italie

1. Introduction

This paper presents a new phase in the long-term landscape-archaeological research of Ghent University in the Italian region Marche, focusing on the social organization of protohistoric communities as expressed by their spatial behavior in settlements and their catchments. The current FWO-funded 'Neighbours and Nobles' project aims at a better understanding of the poorly understood settlement record of local Bronze and Iron Age groups in Central-Adriatic Italy through the non-invasive prospection of micro-regions with habitations and their surroundings. The analysis and interpretation of the integrated data from geophysical surveys, fieldwalking surveys, aerial photography and topographical work gives new insights in the daily organization and territorial arrangements of pre-Roman groups; a valuable addition to the well-

Figure 1. View from Monte Pitino across the middle Potenza Valley (Marche, Italy) towards the Monte Franco-Pollenza ridge. Locations mentioned in the text are indicated.

known Iron Age burials of this part of Italy. Moreover, we use prospection data not only as a means to put dots on the map, but rather to analyze the arrangement of space as an expression of social norms. To this end, we have to look beyond the 'site' and instead focus on the wider habitus of these pre-Roman communities. This paper discusses the scientific and environmental background to our ongoing studies, our conceptual points of departure, the challenges to our approach, and first results of fieldwork at one of our case study areas: the Monte Franco near Passo di Treia (Figure 1).

2. The Potenza Valley Project

Since 2000, the landscape-archaeological Potenza Valley Survey (PVS) project of Ghent University investigates changing social complexity in the Adriatic valley of the river Potenza through the analysis of spatial patterns on the surface and in near-surface archaeological records (Vermeulen *et al.* 2017). The PVS has had a strong geo-archaeological focus from the beginning, using a multi-disciplinary toolkit to map, analyze, and understand the occurrence of archaeological traces in various situations. Accordingly, the project was initialized as a cooperation between the Departments of Archaeology and Geography, expressing a strong interest in understanding landscape formation processes in relation to the preservation and detectability of past human occupation traces. Moreover, the project had from its onset a strong methodological interest in developing approaches and techniques for the study of regional archaeological dynamics. This is expressed in the focus on testing and fine-tuning archaeological prospection techniques, including geophysical methods, aerial photography, remote sensing, field walking, and targeted coring.

The PVS surveys were executed at different resolutions: extensive surface surveys to obtain a general overview of land use dynamics through time, and intensive gridded surveys to map local distribution patterns and occupation trends. These surveys were followed by intensive site studies using geophysical techniques and aerial photography, the combination of which has proven very successful in mapping intra-site layouts of Roman-period centers including the abandoned towns of Potentia, Trea, Villa Ricina, and Septempeda. The magnetic gradiometry survey of the multi-period site Montarice near the coastal town of Porto Recanati demonstrated the potential for prospection of pre-Roman traces.

Figure 2. Prospection techniques applied in the 2018 fieldwork. From left to right: geophysical survey (ground penetrating radar), intensive artefact survey, manual augering, aerial photography / micro-topographical survey using drones.

The geo-archaeological approach and methodological interest of the PVS continues in the current Neighbours and Nobles sub-project (Figure 2). This study puts the spotlight on the protohistoric phases in Central Adriatic Italy, which have remained underexposed compared to occupation in the Roman and later periods. We are especially interested in assessing geophysical prospection techniques for the detection and interpretation of Bronze and Iron Age settlement and land use. There are still few (well-published) examples of geophysical surveys on pre-Roman sites in Italy as compared to the historical periods, despite an increase in geophysical prospection surveys in recent years. This may partly have to do with the popularity of ground penetrating radar (GPR) in archaeological prospection in Italy; a method which has proven its merits in the mapping of stone architectural remains such as the Roman cities of Interramna Lirenas and Falerii Novi (Verdonck *et al.* 2018), but which often produces far less eloquent data in non-monumental and ephemeral pre- and protohistoric contexts – and which are then, unfortunately, rarely published. From the outset of the current project, we therefore try to avoid such predispositions by testing several techniques available to us and evaluating their results in relation to soil and archaeological parameters. On the basis of the results of a previous magnetometry survey by Eastern Atlas at the coastal site of Montarice (Vermeulen *et al.* 2017: 55; De Neef and Ullrich in press), we hoped that this technique would be effective elsewhere in the valley.

3. Missing aspects of the archaeological continuum in Central-Adriatic Italy

Central-Adriatic Italy has been studied by several landscape-archaeological research projects, but this has not resulted in a well-balanced archaeological record. Pre-Roman settlement and land use remain underrepresented themes despite a recent revival in studies of the Iron Age *Piceni* populations in which the local heritage authorities take an active role. Although a growing number of pre- and protohistoric sites are being investigated (for instance the current research at Belmonte Piceno by the University of Freiburg (Germany), Monte Croce Guardia (Cardarelli *et al.* 2017), Miralbello, Serra de' Conti, and the recently discovered princely grave at Corinaldo (Boschi 2018)), still little is known about regional settlement patterns and the social dynamics behind them, land use systems and subsistence. This can partly be ascribed to a traditional focus on (rich) Piceni burials, but also on the research questions of regional archaeological projects. These have often been centered on the historical phases: from the surveys of the territories of Roman towns like *Cingulum* (Percossi and Silvestrini 1986), *Cupra Marittima* (Ciarrocchi 1999) and *Asculum* (Conta 1982) in the 1970s, the *Formae Italiae* mapping project around Roman *Trea* (Moscatelli 1988) and the surveys around the Roman towns of *Urbs Salvia*, *Pausulae* and *Cluana* (Vettorazzi 1987; Moscatelli and Vettorazzi 1988) in the 1980s, in the 1990s and early 2000s the systematic surveys in the *ager Pisaurensis* (Campagnoli 1999) and the Pisa University surveys near the Roman town *Firmum* between the rivers Aso and Tenna (Pasquinucci and Menchelli 2004; Menchelli 2012; but see also Ciuccarelli 2012 for a protohistoric study of these surveys), to a predominant focus of the PVS project itself on the historical phases, as its original title was '*The Potenza Valley Survey. From Acculturation to Social Complexity in Antiquity: a regional geo-archaeological and historical approach*' (Boullart 2003).

Nevertheless, all these mapping projects have also recorded pre-Roman surface artefact scatters attesting to the *longue durée* of human presence in Marche. These records paint a picture of predominantly small-scale settlements with a low level of centralization up to the Roman colonization in the third century BC. This dispersed settlement pattern is difficult to associate with the elaborate burial clusters which suggest increasing social complexity and distinct territorial behavior from the Late Bronze Age onwards. We appear to be missing a piece of the puzzle to be able to understand the socio-economic and socio-political structures and cohesion of these communities. We argue that to grasp these issues we have to look at the whole habitus of a community; i.e. to look at the landscape continuum, and that we have to employ additional methods to uncover the whole spectrum of human activity. In the following section we present the environment in which the communities under study moved and what is known about the pre-Roman groups in our focus area, the Potenza Valley.

4. The Potenza Valley and its pre-Roman record

The PVS targeted three transects in the coastal, lower, middle, and sub-Apennine zones of the Potenza basin, which are representative of the landscape and climate zones in this part of Adriatic Italy (Figure 3). The Potenza river is ca. 80 km long and flows from its origin near Monte Pennino (ca. 1600 m) towards the Adriatic coast through an elongated basin of ca. 775 km^2 (Goethals *et al.* 2005). In the upper valley it cuts two limestone / marl anticline ridges, the Umbro-Marchean chain and the Marchean chain, which result in dramatic gorges near Pioraco and San Severino Marche. These two cuts offer passageways into an inland basin known as the Inland Marche Basin or the Matelica-Camerino synclinorum, an undulating landscape zone of colluvial and alluvial deposits and occasionally preserved Middle and Lower Pleistocene river terraces (Taelman *et al.* 2017: 48). The Inner Marche Basin flourished in the Iron Age, especially in the Orientalizing period (7th century BC), as can be seen in the exceptionally rich funerary record of the Piceni center situated on the remnant river terraces at Matelica (Silvestrini and Sabbatini 2008). Matelica is also one of

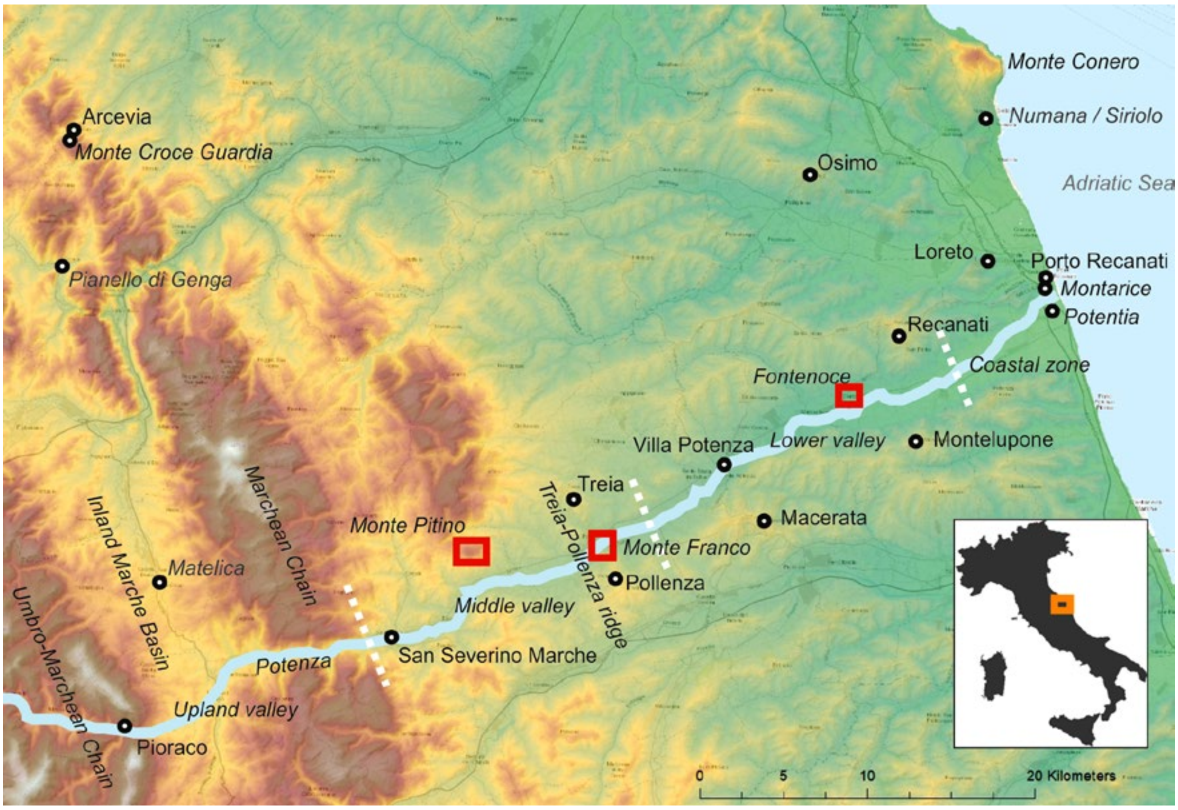

Figure 3. The Potenza valley (Marche, Italy). Areas and sites mentioned in the text are indicated.

the few excavated Piceni settlements in Marche and serves as a point of reference for our work, even if it has only been partially investigated and problems with its chronology are not solved.

The central part of the Potenza valley is characterized by a 10-100 m wide meandering river bed. The landscape is hilly with ridges, often steep slopes and incised secondary valleys. The ridges consist of Miocene-Pliocene pelitic-arenitic deposits (metamorphosed sandstones), sometimes with pronounced outcrops such as the Monte Pitino near San Severino Marche. The Monte Pitino prominently overlooks the middle Potenza Valley and the lower neighboring ridge of Monte Penna, where a well-known Orientalizing Piceni necropolis was discovered in the 1950s. Further Piceni burials were found in the valley bottom, at Ponte di Pitino, indicating that Iron Age activity covered all altitudes in this part of the valley. Locating the settlement(s) associated with the community buried at Monte Penna and understanding the spatial organization of this micro-region are among our current questions. Our working hypothesis is that an associated settlement center may have been situated on top or on the slopes of the Monte Pitino. The summit of Monte Pitino is overbuilt by a Medieval castle but following archival records of rescue excavations in the 1980s and topographic work by the PVS we presume that older (Iron Age and Roman) settlement remains are also present (Vermeulen *et al.* 2009; Vermeulen *et al.* 2017: 70-73; De Neef and Vermeulen 2018).

At Passo di Treia the Potenza cuts through a third ridge, this time a sandstone one running between Pollenza and Treia. The result is a remarkable bottleneck overlooked by the Monte Franco hill (fig. 5). Delia Lollini excavated a Bronze Age site near the top of the hill in the 1950s (unpublished; mentioned in Piangatelli 1970). At the base of the hill, near the river, the Iron Age necropolis of Moie di Pollenza (9th-5th centuries BC) is situated which testifies to the long-term pre-Roman occupation of this zone. On the other side of the river, further funerary traces were found during rescue excavations in the town center of Passo di Treia, while circular features possibly related to Piceni tombs were detected by aerial photography directly opposite the Moie di Pollenza site (Vermeulen *et al.* 2017: 73-78; site 23 in fig. 5). In 2001, the PVS surveys mapped several artefact clusters at the base of the Monte Franco which can be dated to the Iron Age and Roman periods, but the chronological development and spatial link of these occupation traces to the Moie di Pollenza necropolis was not further investigated. This is one of our current research aims; this case study is discussed below.

After the Passo di Treia bottleneck, the Potenza Valley becomes wider, resulting in a braided river system in a flat valley bottom broadening into a coastal plain filled with clastic sediments of up to 40 m thick. The thick sediments and alluvial inundation hinder the detection of ancient human occupation, but occasional surface artefact scatters are indicative of exposed paleo-riverbeds, such as is the case at the diffuse protohistoric artefact scatter and Roman rural settlement near Casa Apis (PVS sites 28 and 121; Percossi *et al.* 2006; Vermeulen *et al.* 2017: 154-155). Evidence for pre-Roman occupation of the valley floor comes from the Chalcolithic burials and settlement at Fontenoce, as well as the recently found Piceni tomb nearby (Finocchi *et al.* 2017). The valley is bordered to the north and south by ridges of pelitic mudstones on which Medieval towns such as Recanati and Potenza Picena are situated, but older settlement remains such as the fortified Iron Age village of Montelupone are also known (pers. comm. Andrea Cardarelli). In the subcoastal zone, the ridges are covered by remnant marine terraces with gravel layers of up to more than 5 m thick, for instance on the flat plateau of Montarice, just outside the coastal town of Porto Recanati. Here, periodical occupation between the Middle Bronze Age to the Middle Ages was established by PVS fieldwalking surveys, while Bronze Age contexts were excavated on its flanks in the 1950s (but never published). Aerial photography and magnetic gradiometry surveys confirm the presence of archaeological features including defensive structures, pits, ditches and probably habitation structures. Just south of Porto Recanati, the Potenza reaches the Adriatic coast. In the coastal zone, alluvial sediments cover ancient beach ridges parallel to the coastline, including the one on which the Roman city Potentia was built. Beyond the beach ridges, loamy and clayey deposits indicate the former presence of coastal lagoons. Apart from the prospections and excavations of Potentia

(Vermeulen *et al.* 2017: 99-111), the archaeology of the coastal zone remains poorly known because it is now densely inhabited.

The previous section presented some keyholes into pre-Roman occupation in the different landscape zones of the Potenza valley. These pieces of the puzzle must now be contextualized and connected by looking at the blank spots on the map around them.

5. Approach and methods

Our research draws on the proposition that space is intrinsic to human activity, and thus that the spatial layout of domestic, settlement, and regional contexts reflects socially and culturally given norms (Hillier and Hanson 1984; Kolb and Snead 1997). Therefore, spatial characteristics of human activity areas can be used to identify societal organization, socio-economic diversification, and socio-political complexity (Benech 2007; Cutting 2006; Pearson and Richards 2003). Spatial patterns are commonly used to this end by archaeologists on landscape and site scale, for instance in analysing burial clusters or regional settlement systems, while functionality of urban areas and large buildings have successfully been investigated through approaches like space syntax (Hillier 2014). In our work, we take a similar approach to an intermediate scale of micro-regions, covering both settlements and their catchments as the arenas of social organization at a daily-life, community scale.

Micro-regional analysis allows us to expand from a traditional settlement-focused approach to a more inclusive coverage of all areas of daily human activity. Settlements do not just consist of huts or houses, but of a wide range of structural parts and activity areas. Their arrangement reflects the internal coherence, interdependence, and communal effort of the people involved. Degrees of social interaction between members of protohistoric communities can be deciphered by looking at the spatial characteristics and arrangements of places in their wider habitat: habitations, public areas, communal structures, the placement of cemeteries, workshops, roads, field boundaries and enclosures, storage facilities, etc. In settlements, characteristics such as site extent, internal plan (structures and infrastructures), differentiation between built and non-built areas, and the presence of specific functional areas (workshops, storage facilities, ritual spaces) can reveal levels of planning and interlinkage. The presence of defensive features such as walls or moats indicates an underlying group identity and inherent distinction from other groups, while their erection requires initiative, planning and organization. The arrangement of the settlement catchment may likewise reveal much about the community's economic and political structure: separate production zones (workshops, kilns), but also waste disposal, graves, roads, and field systems all reflect levels of organization and cultural norms. Furthermore, by taking an interpretive and experimental approach to the estimation of workloads and energy input for the realization of such features, we expect to be able to make statements about community integration and internal organization of such groups.

We perform our spatial research primarily on non-invasive datasets obtained in selected micro-regions. The selection of these areas is based on the results of the PVS project and other research conducted in Marche, from which we have a general but still fragmentary idea of protohistoric location preference. We focus on the Potenza Valley because we know the area and argue that it is representative for most landscape zones in Marche, but we also look beyond the basin if opportunities arise: in 2018 we carried out fieldwork at Monte Croce Guardia near the town of Arcevia, in collaboration with the research team directed by prof. dr. Andrea Cardarelli of La Sapienza University of Rome. Our selection is based on an assessment of potentially preserved archaeological traces in the area, the quality of the legacy data, accessibility and owner consent, suitability for archaeological and geophysical prospection, and the possibilities to link our data with other archaeological studies, as we were able to do at Monte Croce Guardia.

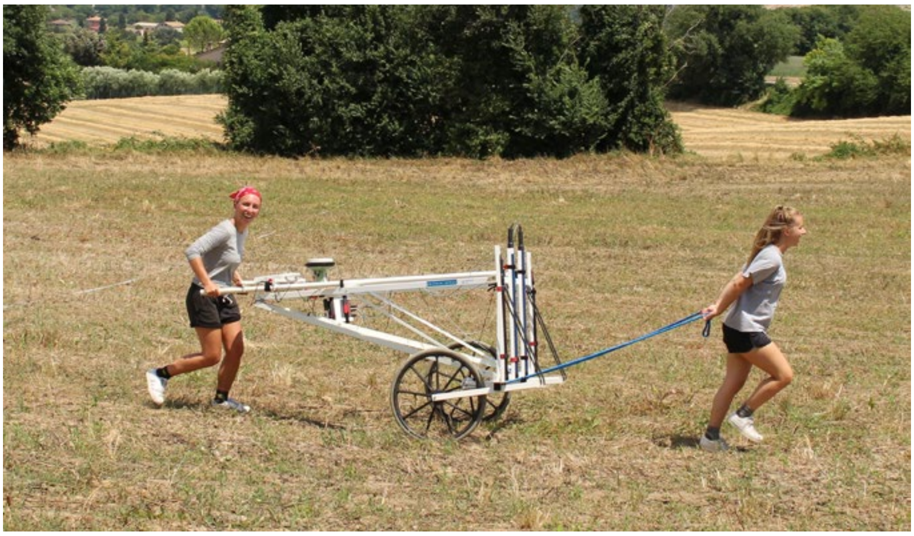

Figure 4. The magnetic gradiometry system LEA-MINI during the 2018 prospection at Monte Franco (Pollenza, Marche).

We apply high-resolution artefact surveys, geophysical prospection techniques, aerial photography, (micro-) topographical and pedological work to get a better understanding of the occupation of selected case study areas. The integrated use of these techniques allows us to detect both artefactual (utensils, structures) and non-artefactual (field borders, empty areas) aspects of past human behaviour. Moreover, they allow us to look beyond the borders of the archaeological 'site' and to study how such human activity foci are situated in wider catchments. Pedestrian surveys are conducted at a high resolution (units of 30x30m, walker interval 5m) to be able to document small-scale artefact scatters. In areas of interest the coverage may be increased or additional 100% coverage samples may be collected (Figure 2, second from left). For geophysical prospection we mainly apply magnetic gradiometry and ground penetrating radar (GPR), but other techniques may be used as well. We use a modular GPR system of a Sensors and Software Spidar network consisting of 15 pulse EKKO PRO 500 MHz antennas, towed by an ATV, allowing the coverage of large open areas (Figure 2, left). Magnetic gradiometry surveys are conducted using a mobile LEA MINI system mounted with four Sensys gradiometer probes at 0.5 m distance (Figure 4). This light and flexible cart allows us to investigate large open areas but also to access more remote locations and sloping terrain, making it especially useful for the prospection of protohistoric remains. Pedological studies are focused on recording local soils and deposition processes affecting the archaeological record and its detectability by non-invasive prospection techniques. Targeted drillings using a manual Edelman screw auger are conducted to characterize features detected in the geophysical surveys and collect soil samples for laboratory analysis and datable materials (Figure 2, second from right). These studies are supported by micro-topographical mapping through drone imaging, conducted in collaboration with Dr Daniele Ferdani of ITABC-CNR (Figure 2, right). At Monte Croce Guardia, we will be able to evaluate our interpretation of geophysical data by an excavation planned in autumn 2019 and study the geophysical properties of the detected features. In the following section, we illustrate our research with the 2018 results of one case study area in the Potenza Valley: the Monte Franco bottleneck.

6. Case study: Monte Franco

The poorly understood settlement record of the Monte Franco area contrasts with past and current scientific interest in the nearby Piceni necropolis of Moie di Pollenza. Nevertheless, excavations of the necropolis revealed traces of Bronze Age and Early Iron Age habitation levels below 7th century BC Piceni burials (Lollini 1963: 322-323; Lollini 1966). Together with the unpublished results of Lollini's trial trenches of Middle / Late Bronze Age contexts on top of the Monte Franco (materials and excavation documentation archived at the Soprintendenza in Ancona), these attest to a long-duration occupation of both the hill and the open areas at its base. This was confirmed by the PVS surveys in 2001 at the eastern foot of the hill where dense concentrations of Iron Age materials were recorded, including *impasto* storage vessels, local *bucchero* pottery, wattle-and-daub fragments, and imported wares such as Southern-Italian geometric and Greek potsherds (Boullart 2003: 175; Vermeulen *et al.* 2017: 73-78; fig. 5). The survey materials are contemporary to some of the tombs in the Moie di Pollenza necropolis. Our interest in this area focuses on understanding the spatial and temporal associations between the different archaeological sites, as well as the spatial organization of the wider area. An interesting aspect in our ongoing investigations here involves Lollini's suggestion, based on the variety of tomb types at Moie di Pollenza, that the Monte Franco area may have been a 'hub' inhabited by different population groups. This hypothesis can be tested by carefully assessing the spatial arrangements of other archaeological evidence.

In 2018, we conducted an intensive artefact re-survey of the arable fields east of Monte Franco. This resulted in a high-resolution surface artefact distribution map in which two discrete artefact concentrations were identified. The first is a predominantly Roman scatter with a large quantity of building and storage material and a remarkably low amount of fine wares, but also protohistoric materials indicating continuation in occupation. This site overlaps with PVS site 77 (Figure 5). The second concentration dates to the Iron Age and consists of a broad range of artefact classes including fine wares, cooking wares, coarse storage wares, and rooftiles and overlaps with the southern part of PVS site 12 (Figure 5). It is located near the south-eastern base of the Monte Franco hill and was tentatively dated to the 6th century BC on the basis of the local *bucchero* and imported red-paint wares. Interestingly, the *bucchero* wares do not occur in the contemporary Moie di Pollenza burial contexts (pers. comm. Benedetta Ficcadenti): there appears to be a clear functional difference between the sites.

The surroundings of the Iron Age artefact scatter were geophysically surveyed using GPR and magnetic gradiometry equipment. The 500 MHz GPR survey executed by Dr Lieven Verdonck (Ghent University) did not result in the detection of apparent anthropogenic features. The clayey soils of the Monte Franco area result in a high attenuation of the radar waves, due to which we only see some near-surface natural features, an effect also seen at other sites in the Potenza Valley. The magnetometry survey was more successful: a range of anthropogenic and natural features were recorded (Figure 6). A series of linear and singular magnetic features were detected in the area of the Iron Age surface scatter, but also outside of it. Targeted manual augerings confirmed their archaeological relevance by exposing anthropogenic layers with charcoal, pottery, and tile fragments; also in features which were initially interpreted as natural phenomena or highly magnetic modern disturbances. Moreover, magnetic susceptibility measurements of soil samples from the cores indicate the depth of the deposits producing the magnetic signal, typically between 80-100 cm.

The magnetic survey of the area is not finished and this discussion is preliminary, but we can already point to spatial arrangements visible in the surface artefact distribution and the associated magnetic features. A semi-rectangular, strongly magnetic feature (feature 1 in Figure 7) is situated within a linear feature following the base of the Monte Franco (feature 2). Coring in this anomaly revealed burnt clay and tiles, indicating its architectural character, which we now interpret as a residential building. Artefact survey of this area is severely hindered by vegetation, due to which we cannot conclude whether this feature is related to surface material contemporary to the Iron Age scatter. Buildings with roof tiles and stone foundations are commonly assumed to be introduced in Picenum in the 6th century, but there are few direct parallels. An additional problem is that absolute dating of such contexts is problematic due to the so-called Hallstatt plateau in the calibration curves of C14-dates between 800-400 BC, but in the future we hope to be able to provide a relative date for this feature based on *in situ* artefacts.

Further north in the same linear feature, there are more magnetic anomalies which were confirmed to be anthropogenic; most notably a reversed-comma shaped feature within the actual surface

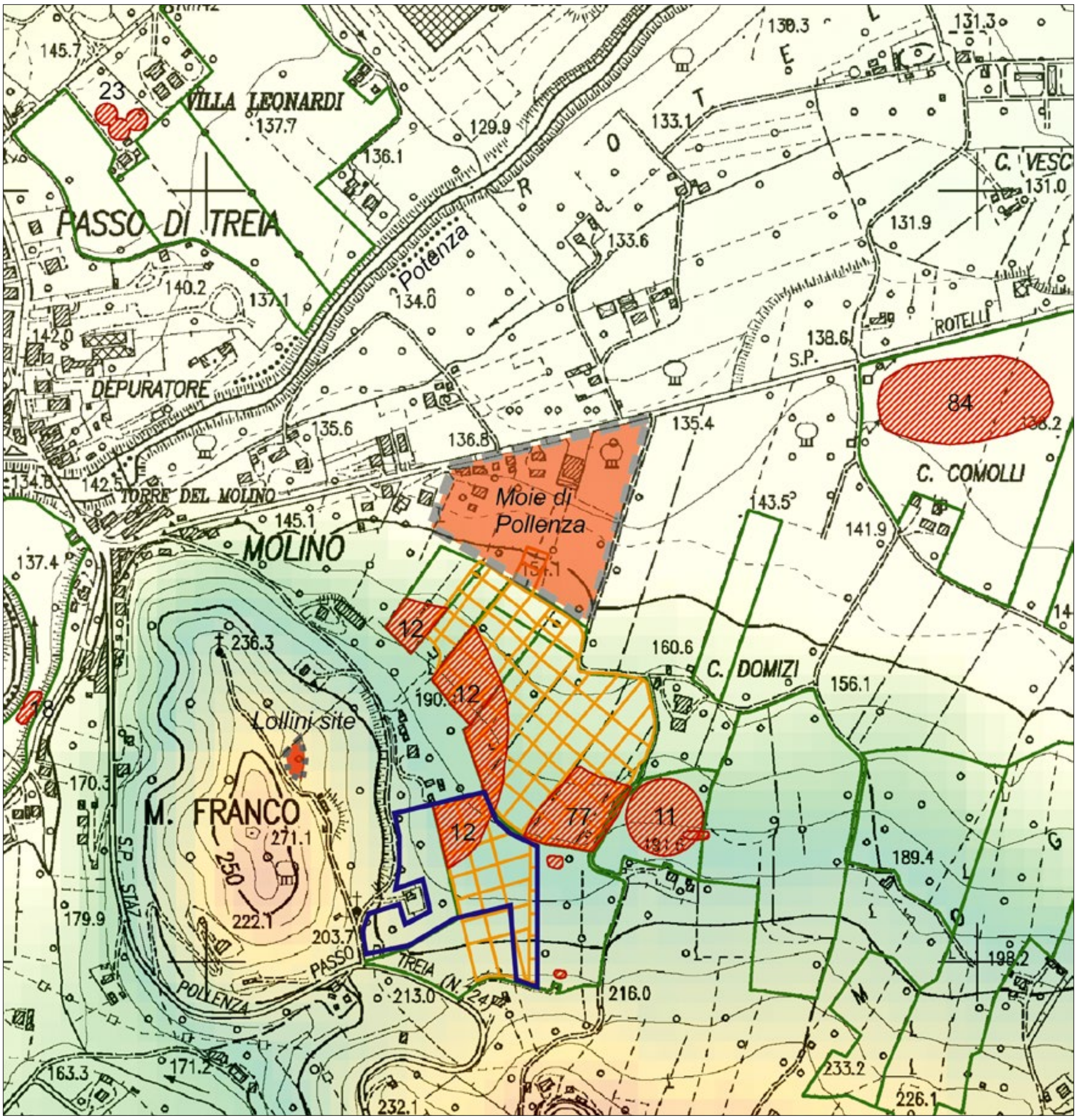

Figure 5. Overview of the Monte Franco area (Pollenza, Marche) on the 1:10.000 IGMI topographical map. The 2001 PVS extensive survey areas are outlined in green; the 2018 survey areas in yellow. Surface sites recorded during the 2001 PVS survey are indicated with labelled hatched red areas. The Moie di Pollenza necropolis and the area of Lollini's 1953 excavations near the summit of Monte Franco are indicated in red with dashed grey outline. The 2018 geophysical survey area is outlined in blue.

scatter (feature 3). Striking is the curvilinear feature in the centre of the investigated area (feature 4) which does not relate to the present-day morphology. It may be interpreted as a terrace or enclosure wall, but further research is needed; an extension of the magnetometry survey and targeted coring in 2019 will hopefully give more insight in the nature of this feature. South of this curvilinear feature are a number of positive magnetic features (cluster 5); the ones targeted by coring are all caused by man-made deposits with highly magnetic properties, including burnt clay and organic soil with charcoal and pottery.

The Monte Franco area shows clear indications of deliberate spatial planning, but we also see changes in land use through time. On the basis of excavation sketches we were able to reconstruct the location of the Middle / Late Bronze Age site excavated by Lollini in the 1950s on top of

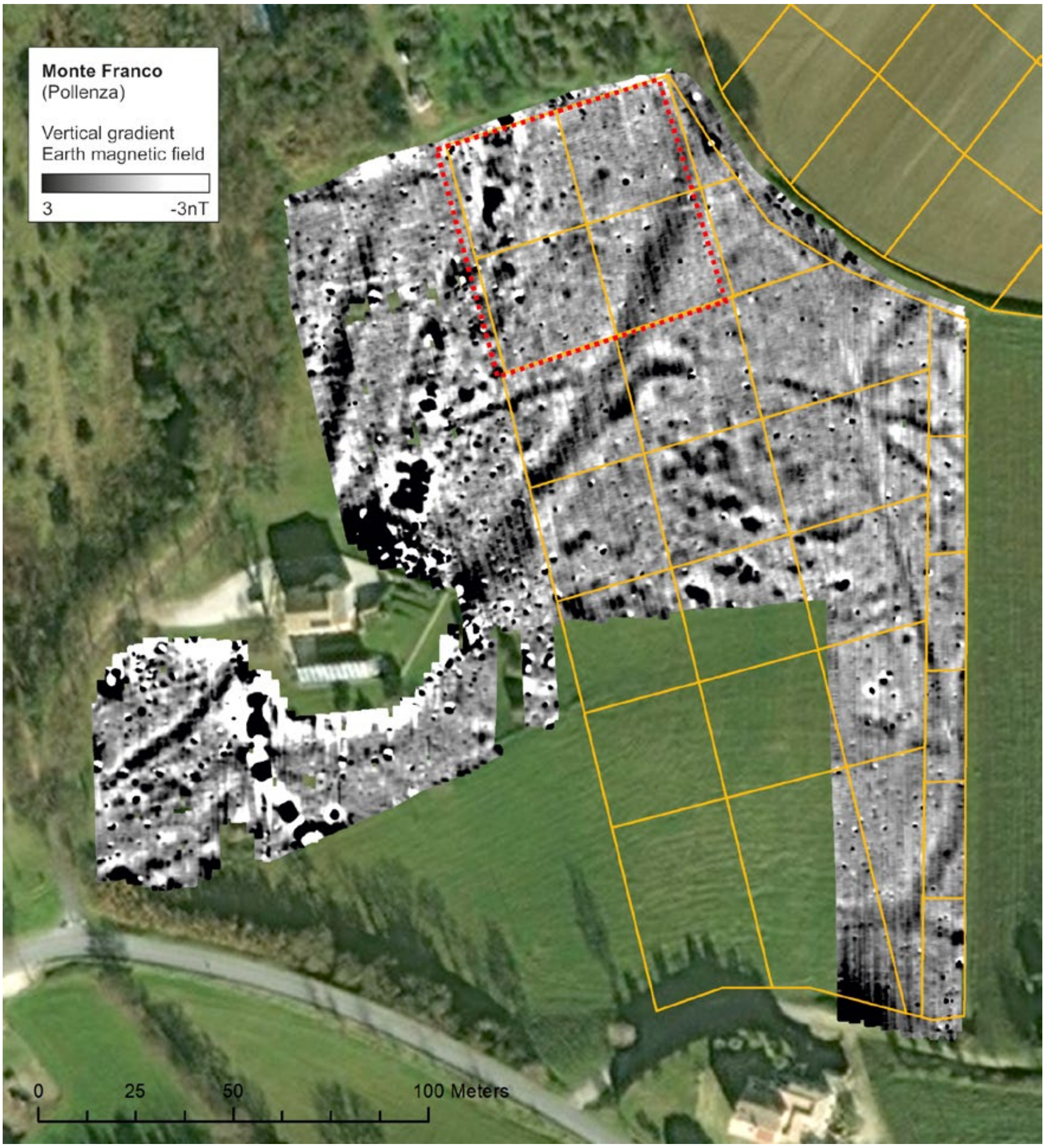

Figure 6. Magnetic gradiometry results of the Monte Franco area. The survey units with the highest protohistoric artefact densities, overlapping with PVS site 12 as shown in Figure 5, are outlined with a red dashed line.

the hill (Figure 5). The Moie di Pollenza necropolis partially overlaps with settlement remains contemporary to the hilltop site (Lollini calls these 'nivelli apenninici', i.e. Middle Bronze Age levels) and with Early Iron Age (9th-8th century BC) habitation contexts. However, in the 6th century BC this zone near the river becomes exclusively funeral. The 6th century BC settlement in the surface artefact data, associated with a series of magnetic features, is situated further upslope and away from the necropolis. There is a diffuse concentration of surface protohistoric material near the necropolis which may be related to the burials, as two impasto spindle whorls (which are often found in grave contexts) suggest: the necropolis may continue further south / upslope than is currently known.

Alternating occupied and 'empty' areas can also be seen in the magnetometry data: the archaeologically relevant features are aligned at the foot of the Monte Franco and border on a

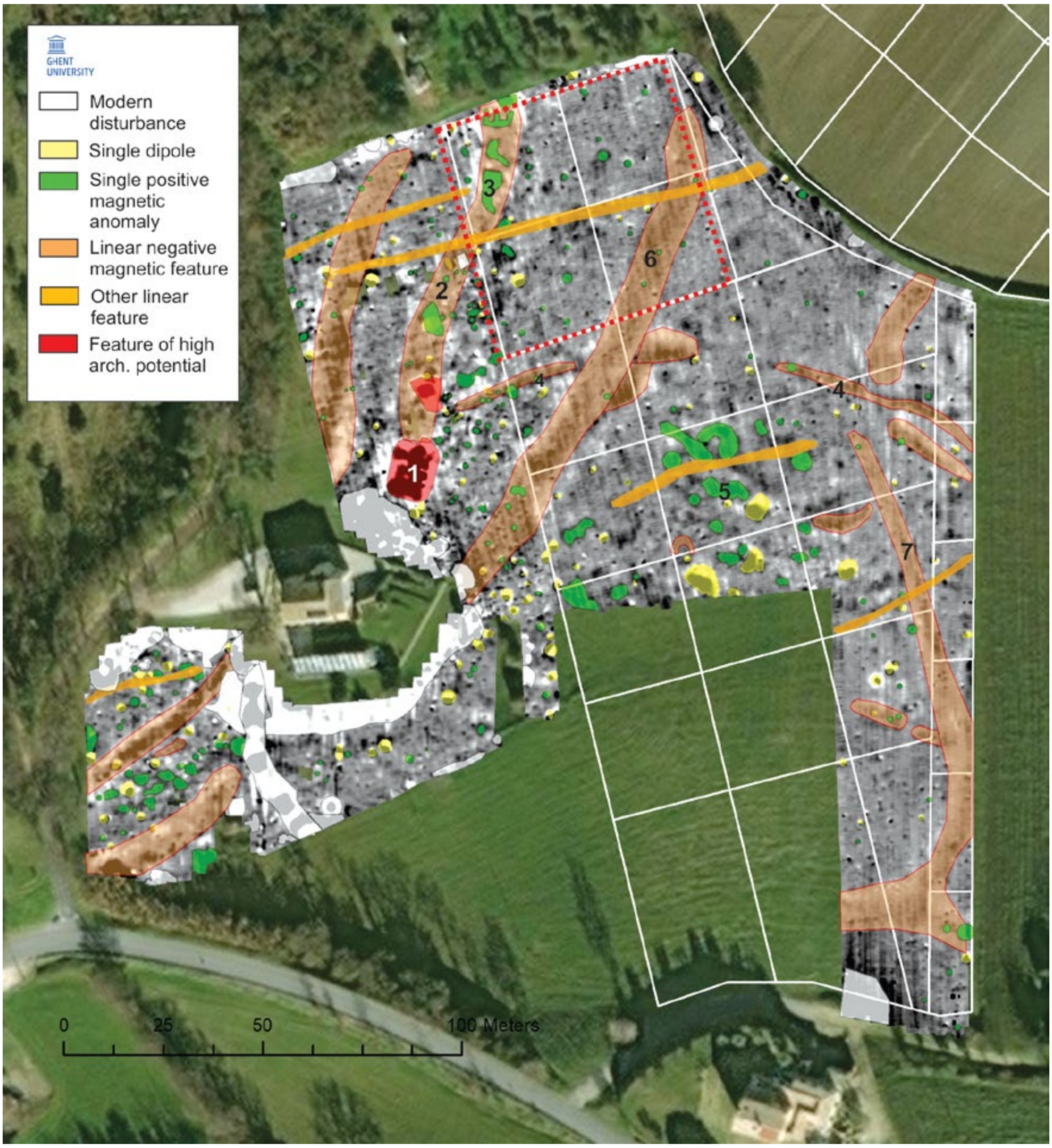

Figure 7. Interpretation of the magnetic gradiometry results of the Monte Franco area. The survey units with the highest protohistoric artefact densities, overlapping with PVS site 12 as shown in Figure 5, are outlined with a red dashed line.

magnetically quiet zone, which reflects conscious choices in how the area was occupied. The strongly magnetic features of cluster 5 are possibly related to production, located in a distinct area which is bounded by a series of linear features (features 4, 6, and 7), and are not associated with (dense) surface material. Although the partial geophysical coverage of this zone does not allow us now to make statements about the nature of the linear features, we see them as expressions of regulated activity areas.

7. Conclusion

In this brief overview we have presented the aims and approach of our current study of protohistoric communities in Central-Adriatic Italy. We focus specifically on spatial and chronological blanks in the archaeological record in this part of the peninsula: Bronze and

Iron Age settlements and their catchments. Our aim is to obtain a better understanding of the socio-political and socio-economic structures of local communities in the centuries leading up to the Roman conquest, by looking at the spatial characteristics of their daily environments. The use of non-invasive prospection techniques is central to our research questions, since they allow us to cover large areas within and beyond settlements, and trace a wide range of human activity. Accordingly, this study has archaeological and methodological implications: we hope to get new insights in a poorly known aspect of protohistoric communities by finetuning our multidisciplinary prospection methodology and using its results for interpretive spatial research. Therefor we use non-invasive prospection data not just for the identification of sites of interest, but also as an interpretive tool.

Evidently, there are a number of challenges to our approach, as we have shown in this paper. First, the detection of ephemeral traces is difficult and their interpretation often impossible without further (invasive) research. Second, the detectability of archaeological traces is complex and requires a good knowledge of local site and landscape formation processes in the assessment of various techniques. As discussed above, the Monte Franco case study is an example of well-preserved Iron Age contexts which are detectable by magnetometry but not by GPR, while the surface artefact distribution overlaps only partially with the subsurface features. Not all subsurface features produce surface artefacts, either because they are beyond the reach of the plough (horizontally or vertically), or because they are associated with artefactless activities – scenarios we have to investigate further in the coming years. In the coming campaigns, we will also test soil resistance methods on this site. Third, the spatial analysis of such areas is hindered by the low chronological resolution of successive occupation phases but also by the general nature of protohistoric traces. These are essentially non-urban environments in which we cannot identify the function of buildings, let alone single rooms, on the basis of their geophysical signature; the majority of traces in our case studies are pits, ditches, and other non-architectural elements. It is difficult to apply quantitative approaches such as space syntax on such data because of our uncertainty of the contemporaneity of single features. Therefore, we take a qualitative approach in which we try to identify different functional and productive areas, the arrangement of public and private space, and signs of regulated land management.

As for now, our research is still underway and we cannot yet present a final case. Yet the here presented preliminary data of Monte Franco, a protohistoric centre in the middle valley of the river Potenza in the Marche, shows the potential of our approach in identifying a wide range of archaeological traces and interpreting their spatial arrangement. In the near future, we hope to add more geophysical datasets to our study of this area in order to understand the organization of this particular micro-region in the valley bottom. Further work at hilltop, slope and mountaintop areas will allow us to get a better grip on the archaeological continuum of the hilly landscape of pre-Roman Picenum.

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Magnetic method in the study of the influence of environmental conditions on settlement activity: case study from Fayum Oasis (Egypt)

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Abstract

The article presents research on three settlements from the Greco-Roman period (304 BC – 395 AD), located in different areas of the Fayum oasis in Egypt: Philoteris, Al-Qarah al-Hamra, and Neiloupolis. Life in these settlements ended as a result of phenomena related to water: either because of its shortage (the cessation of water supply via canals, as in the case of Philoteris, confirmed in written sources), or its excess (the flooding of settlements after the water level rose in Lake Moeris, as in the cases of Al-Qarah al-Hamra and Neiloupolis). These phenomena are clearly visible in the results of geophysical surveys. The malfunction of the water system was probably caused by a cataclysm, which occurred in the first half of the 4th century AD. It caused the destruction of the water reservoir located in the highest, southern part of the oasis, which was responsible for the regulation of the water economy in the area. The date of the cataclysm has been indicated by data obtained during archaeological research (ceramics dating). Additionally, the hypothesis has been confirmed by information provided by Karanis excavation results: the city grew rapidly in the middle of the 4th century AD – probably as a result of the inflow of people from the neighboring settlements, which had been flooded by water.

Keywords: archaeological prospection, environmental studies, landscape archaeology, Greco-Roman period, Fayum oasis, magnetic method

Résumé

Cet article présente des recherches sur trois établissements de la période gréco-romaine (304 av. J.-C. – 395 après J.-C.) situés dans différentes zones de l'oasis de Fayoum en Égypte: Philoteris, Al-Qarah al-Hamra et Neiloupolis. La vie dans ces établissements a pris fin en raison de phénomènes liés à l'eau: soit en raison de sa pénurie (cessation de l'approvisionnement de l'eau par les canaux pour le cas de Philoteris, ce qui a été confirmé par des sources écrites), soit en raison de son excès (inondation par montée du niveau des eaux du lac Moeris dans les cas d'Al-Qarah al-Hamra et de Neiloupolis). Ces phénomènes sont clairement visibles dans les résultats des prospections géophysiques. Le dysfonctionnement du système de gestion des eaux a probablement été provoqué par un cataclysme survenu dans la première moitié du IVe siècle ap. J.-C. Cela a entraîné la destruction du réservoir d'eau situé dans la partie la plus haute et la plus méridionale de l'oasis, responsable de la régulation de l'eau dans cette région. La date du cataclysme a été indiquée grâce aux données issues des recherches archéologiques (datation des céramiques). En outre, cette hypothèse a été confirmée par les informations fournies par les résultats des fouilles de Karanis: la ville a connu une croissance rapide au milieu du IVe siècle après J.-C. – probablement du fait de l'afflux des personnes des villages voisins, inondés par les eaux.

Mots-clés : prospection archéologique, études environnementales, archéologie du paysage, période gréco-romaine, oasis du Fayoum, méthode magnetique

1. The Fayum Oasis

The Fayum Oasis is a depression with an area of about 1700 km^2, lying on the western side of the Nile Valley, with a characteristic shape of a leaf, whose stem connects to the valley. The northern edge of the oasis lies about 50 km south of the southern edge of the Nile Delta (Figure 1). Oases

Figure 1. Satellite image of the Fayum Oasis (Google). 1 – section of the dam forming the el-Mala'a basin; 2 – reconstructed sections of the dam forming the el-Mala'a basin; 3 – partly preserved sections of the dams at the entrance to the Hawara channel; 4 – reconstructed sections of the dam at the entrance to the Hawara channel; 5 – hypothetical extent of el-Mala'a basin. Contour lines 0 and 20 ASL after Hassan 1986: 484, fig. 1; location of dams forming the el-Mala'a basin and near the entrance to the Hawara channel, and the extent of el-Mala'a basin after Garbrecht 1996: figs 4, 5 and 15; location of Wadi el-Nazha after Bagnall and Rathbone 2004: 128, fig. 5.1.1.

of the Western Desert located west of the Nile Valley are irrigated by the Nubian aquifer and the water is only taken from wells. However, in the case of Fayum, the source of water is different: the oasis receives water from the Nile, through its side branch called Bahr Yusuf, which flows into the oasis through the Hawara Channel. The water is distributed through a network of canals, and finally flows into Lake Qarun (ancient Lake Moeris) in the northern part of the oasis, currently covering an area of 233 km^2. Bahr Yusuf flows into the Hawara Channel at 24 m ASL, and the level of the lake surface is currently at – 44 m ASL; the deepest point of depression reaches to the depth of -53 m ASL.

The Fayum Depression was formed during the late Pliocene or the early Pleistocene period, after the Pliocene invasion of the Mediterranean Sea into the Nile Valley. Scientists do not fully understand how the depression was created; the prevailing view is that it was formed by water erosion as a result solution weathering (Sampsell 2003: 92). Throughout the millennia, the depression was filled with water during the annual floods of the Nile; the inflow stopped during low water level in the river, and the level of the formed lake in the depression decreased due to evaporation (1700 mm/year, Garbrecht 1996: 50). Areas temporarily devoid of water turned into swamps. As a result of this process, the surface of the depression was covered by a layer of Nile silt.

2. Human activity in Fayum: from lake and swamp to the granary of Rome

The oldest traces of settlements in Fayum date to the Neolithic period. The location of settlements at altitudes above 15-18 m ASL also determines the level of the lake that filled the depression

(Phillips *et al.* 2016). In the Old Kingdom period, the water reached to around 20 m ASL (Hassan and Tassie 2006). The lake and the Bahr Yusuf canal were used for transporting basalt blocks from the quarries in Widan el-Faras: basalt was used for pavement in many temples in pyramid complexes. Blocks of basalt were moved along a specially constructed stone road to a quay on the shore of the lake, loaded on barges and transported to Giza during the period of high flood (Bloxam and Storemyr 2002). During the Middle Kingdom (app. 2050 – 1760 BC), in particular during the rule of the 12th dynasty (1976 – 1794 BC), the inflow of water to the oasis began to be controlled. Proof for this are the remains of dams found in the location where Bahr Yusuf flows into the Hawara Channel (Garbrecht 1996; Römer 2017) (Figure 1). At that time, the huge potential of Fayum as an area ideal for settlement and agriculture was noticed. To exploit this potential, however, it was necessary to permanently lower the level of the lake by limiting the inflow of water. The level was stabilized at about 10-15 m ASL, which provided area for cultivation on the plateau extending from the entry point of Bahr Yusuf to the oasis (Hassan and Tassie 2006). Settlements were established in the region right afterwards. None of the archaeological sites, which date back to this period, lie below 18 m ASL (the water level was subjected to temporary changes), e.g. Sokonopaiou Nesos and Quta (20 m), Medinet Madi (26 m), Abgig and Biahmu (18 m), cemetery in Tebtunis (26 m), temple and settlement in Qasr el-Saga (31 m) (Römer 2017).

The most significant changes in the Fayum landscape occurred in the beginning of the Ptolemaic period (304-30 BC), and were related to the demographic policy of the first rulers of the dynasty. These rulers urgently needed land for Greeks settling in Egypt. The land was given to, among others, Greek soldiers after completing their service, as well as to important members of administration. The construction of canals for water transport and the creation of reservoirs for excess water was a major endeavor in the Ptolemaic Kingdom. The project's implementation had to already begin in the times of its first ruler, Ptolemy I Soter, because in the oldest written sources about Fayum, after 260 BC, the canals had already been dug, and new settlements had been founded in the north-eastern and western parts of the oasis (Manson 2013). The undertaking was certainly significant, as proven by the names given to settlements established along the canal transporting water in the western part of the oasis, in the area called Themistou Meris. The village Philoteris was named after one of Ptolemy II's sisters, and the other village – Theadelphia – commemorated the divine brotherhood of Ptolemy II and his wife and sister Arsinoe (Bevan 2014: 116). The project tripled the area of agricultural land and Lake Moeris was lowered to a level at which it can be seen today. Thanks to a full control of water distribution, it was possible to regulate its flow all year round. In some years, it even allowed for a second harvest of summer crops, which made these lands exceptionally valuable (which was reflected in high lease fees; Monson 2013: 90-92).

When Rome took over control of Egypt (30 BC), it did not affect the life of the oasis. The Greek language prevailed, and the main goal to achieve was still agricultural production, of strategic importance to the empire. Geological research indicates that the level of the lake changed, which undoubtedly influenced the settlement conditions in its closest neighborhood (Hassan, Tassie 2006). Excavations in the north-western part of the oasis provided evidence for the existence of settlements from the Roman period (30 BC – 395 AD), located slightly higher than the current level of the lake, but which were flooded due to the rising water levels (Barnard *et al.* 2015: 52-54). Written sources confirm that in the 4th century AD, at the end of the Roman rule in Egypt, water shortages began in the higher western part of the oasis, which in turn led to the depopulation of that area and its desertification (Römer 2013). Agriculture entered these areas once more only in the 20th century.

In the next part of the article, we will focus on the results of research of 3 sites, which were affected by either a lack of water or its excess. These are: Medinet Watfa (ancient Philoteris) on the western side of the oasis, and Qaret Rusas (identified as ancient Neiloupolis; Derda 2006: 16-17) and al-Qarah al-Hamra (ancient name is unknown) on the north-eastern side of the oasis (Figure 1). The research at Watfa was part of the Fayum Survey Project, led by Cornelia Römer, currently from DAI in Cairo. The study of the sites on the opposite side of the oasis was conducted as part of the URU Fayum Project, an international and interdisciplinary research program carried out by the University of California, Los Angeles, the University of Groningen (the Netherlands), and the University of Auckland (New Zealand), under a joint direction of Willeke Z. Wendrich, René Cappers and Simon J. Holdaway.

3. Medinat Watfa (Philoteris)

Philoteris was one of a group of villages founded in north-western Fayum, on the south side of the western edge of Lake Moeris, in Themistou Meris. Irrigation was obtained thanks to the construction of a canal transporting water at a length of approx. 60 km. The remains of the canal system in Themistou Meris were already noticed by archaeologists in the early 19th century. The canals, along with the remains of water storage basins, became much more visible when aerial photographs were taken into consideration (Davoli 1998: 329-330). Excavations were carried out only once – at the end of the 19th century but only to find papyri which would establish the ancient name of the settlement (Grenfell *et al.* 1900). The methodological research of the site, began by the Fayum Survey Project, focused in the first stage on a careful surface survey, which aimed to reconstruct the plan of the settlement and its surroundings, and to analyze the surface pottery, which would establish how long it was inhabited. The size of the residential area was determined (430 x 250 m), and buildings with a characteristic plan, such as a temple, baths, residential buildings and warehouses, and a cemetery, were identified (Römer 2003). Both limestone blocks and sun-dried mud-bricks were used as building material, both with a high content of Nile mud (usually with magnetic properties in the range of 2 x 10^{-3}SI to 4 x 10^{-3}SI), as well as bricks made of local silts, with much lower magnetic properties (not more than 0.4 x 10^{-3}SI) (Herbich and Römer 2013). The characteristic feature of the buildings was that both types of bricks were used simultaneously. Pottery analysis determined that the settlement was abandoned in the 4th century AD (Römer 2013).

In the reconstruction of canal and basin networks, surface research was complemented by the analysis of satellite photos, which at the time seemed to present in its entirety the water economy in the village (Figure 2). Researchers identified the canal that brought the water to the settlement,

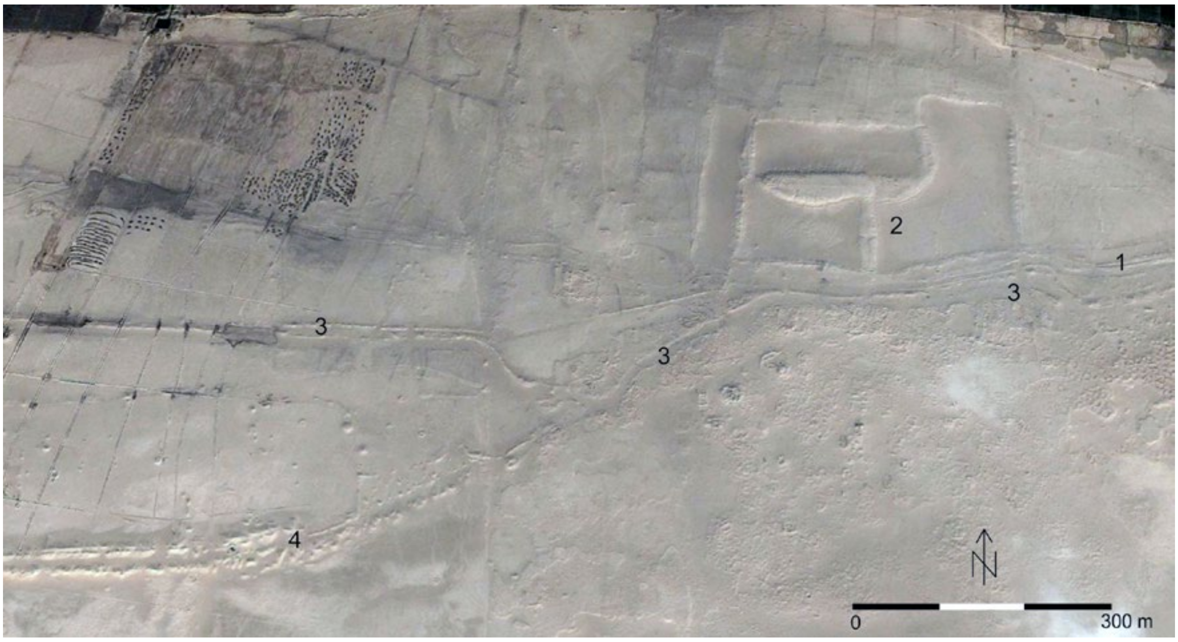

Figure 2. Medinat Watfa (Philoteris). Satellite image of the site (Google). 1 – northern canal supplying water to basins; 2 – basins; 3- canal supplying water to Dionisias; 4 – canal directed towards Dionisias, vanishing in the surface relief halfway between Medinet Watfa and Dionisias.

splitting into two canals on the eastern side of the village. The north canal supplied water storage basins, the southern canal – provided water to the village and continued westward, transporting water to Dionisias, located about 4 km farther.

This wide range of non-invasive methods was in the next stage of the project, in 2011, enriched by magnetic surveys. Measurements were taken with a Geoscan Research FM256 fluxgate gradiometers, and the sampling grid was set at 8 measurements per 1 square meter (every 25 cm along traverses 0.5 apart). During two seasons, an area of 30 ha was examined (Herbich and Römer 2013) (Figure 3). In many places, the magnetic map gave a much more precise image of the buildings than the surface observations. However, the main benefit of the magnetic surveys was the enhancement of knowledge of the water transport system, as the measurements gave a far more accurate picture of the canals, compared to the satellite images and surface observations taken beforehand. We owe the clear image of the canals to the layers of Nile mud, deposited at the bottom and sides of the canals. The canals were carved into bedrock which has a much

Figure 3. Medinat Watfa (Philoteris). Magnetic map superimposed on satellite image (Google).

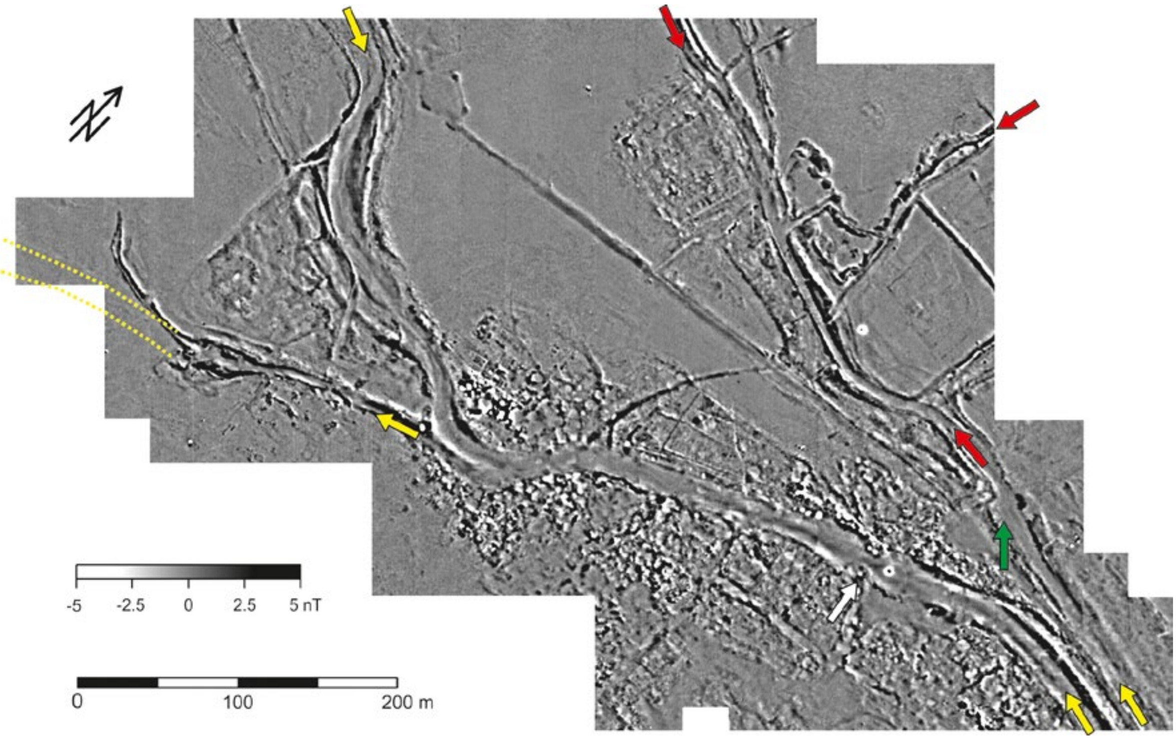

Figure 4. Medinat Watfa (Philoteris). Magnetic map of the western part of the site. Red arrows indicate canals identified by magnetic survey alone, yellow arrows illustrate canals traced on the ground, the green arrow indicate hypothetical small harbor and the white arrow shows hypothetical foundations of a bridge. The yellow dotted lines mark a canal traced on the ground not present on the magnetic map owing to the absence in its bed of alluvial (silt) deposits, indicating that the canal was never used.

lower magnetic susceptibility (below 0.05 x 10^{-3}SI) than Nile mud. The magnetic map showed sections of a canal not visible on the surface, clearly showing where it had been altered in the past. It also allowed to locate bays – probably used for mooring boats. In one location, the image showed certain structures that narrowed the canal – they were interpreted to be pillars of a bridge (Figure 4). The map also provided a surprise, which was a magnetic image of a now buried canal, carved into bedrock to a depth of at least 3 m, running westwards towards Dionisias. The canal is clearly visible on satellite images at a distance of over 2 km, however on the magnetic map it is visible only in the closest vicinity of Philoteris, disappearing at a distance of 150 m from the western border of the settlement (Figure 4). The information that both – the satellite and the magnetic image – provide together, indicate that the canal had been prepared for transporting water. However, the lack of Nile mud (or its presence, but on only its very short section) proves that the canal was either not used at all or used very briefly, not long enough for the layer of silt to deposit on its bottom and sides. Therefore, it is possible to suppose that the settlement stopped being supplied with water (Herbich and Römer 2013).

4. Al-Qarah al-Hamra

The Hamra site, which lies on the north-eastern side of Lake Karanis, was identified during the implementation of a surface research program on the eastern side of the lake. The site lies at a level of -39 m ASL, approximately 1 km inland from the lake's shore. The presence of an archaeological site was indicated by pottery sherds visible on the surface. The site is covered by sand; there are no visible traces of buildings on the surface (Cappers *et al.* 2013: 37) (Figure 5).

Magnetic research carried out in the area of pottery concentration gave a very distinctive image of a small settlement, with a clear orthogonal lay-out (Figure 6). The map clearly shows

Figure 5. Al-Qarah al-Hamra. Surface of the site.

Figure 6. Al-Qarah al-Hamra. Magnetic map.

the southern and western borders of the village. The nature of the anomalies indicates that we are dealing with buildings made out of the sun-dried Nile mud-brick, and linear anomalies with increased values of magnetic field correspond to walls. Streets crossing at right angles are also visible. The clear plan allows to interpret the functions of individual buildings, e.g. a series of anomalies with outer dimensions of 4 x 8 m, visible on the northern side of the street running along the east-west direction, in its western part, correspond to typical Roman shops. Oval anomalies with a diameter of up to 2 m, with large amplitude values, visible in many places, always within the area of the settlement, correspond to kilns or furnaces. Slightly larger anomalies of similar signatures (3-4 m in diameter), on the southern edge of the settlement, may correspond to furnaces for the production of pottery. During excavations carried out by the URU project, two of the oval anomalies have been confirmed to be furnaces, as was the silt material used for buildings (Barnard *et al.* 2015).

Without a shadow of a doubt, the distinctive strip of irregular anomalies, approx. 20 m wide, with large amplitude values, visible on the north-eastern side of the research area, does not correspond to buildings. The intensity of these anomalies decreases towards the north-east. The north-eastern border of the strip is very clear and behind it the area is equally free of any disturbances, as on the southern and western sides of the settlement. The anomalies seem to reflect a process of the settlement's destruction caused by water erosion. The following sequence of events can be deduced. The village lay a short distance away from the lake, on a slope. After the water level rose, it dissolved the above-ground parts of the buildings, and the mud coming from them settled along the shore of the lake. The north-eastern edge of the anomaly strip set a new shoreline after the water level stabilized at a new higher level. Excavations confirmed that the buildings were covered by water for some time. This is evidenced by the partly dissolved mud-brick walls and layers of mud. A layer of calcium carbonate was found on pottery sherds and stone blocks. This layer is formed by algae in shallow alkaline water (Barnard *et al.* 2015: 52).

The settlement was probably founded in the Ptolemaic period. The date of its desertion was determined by pottery analysis: none was found to be older than 4th century (Cappers *et al.* 2013: 37).

5. Qaret Rusas (Neiloupolis)

The site is located at the north-eastern edge of Lake Karun, on a limestone peninsula, 3 m above the surface of the lake, approx. 6 km south-east from al-Qarah al-Hamra. There are no visible signs of a settlement on the sand-covered surface; however, building remains have been uncovered in several places during illegal excavations. In these places the sand is overlying molten mud-brick, which is an indication that the village had once been under water (Figure 7). The fact that the settlement had been under water is confirmed by, similarly to al-Qarah al-Hamra, a thick layer of calcium carbonate visible on the pottery sherds and limestone blocks (Cappers *et al.* 2013: 37). The site has not been methodically excavated but was included in the surface research program conducted by the URU project. As part of these studies, the surface pottery was dated and magnetic tests were carried out.

Magnetic studies showed that the village was founded on an orthogonal plan, with the orientation of buildings following the cardinal directions (Figure 8). The area roughly corresponds to a rectangle with sides 200 (EW) by 160 m. Three linear anomalies are clearly visible on the EW line in the southern part of the settlement, up to approx. 5 m wide, and a few transverse ones up to approx. 3 m wide. These anomalies undoubtedly correspond to streets. Among these anomalies, a number of buildings can be identified, and their internal layouts can be reconstructed. Anomalies characteristic of kilns and furnaces have also been registered. A number of structures appear to be blurred – this probably reflects the blurred contours of buildings damaged by water.

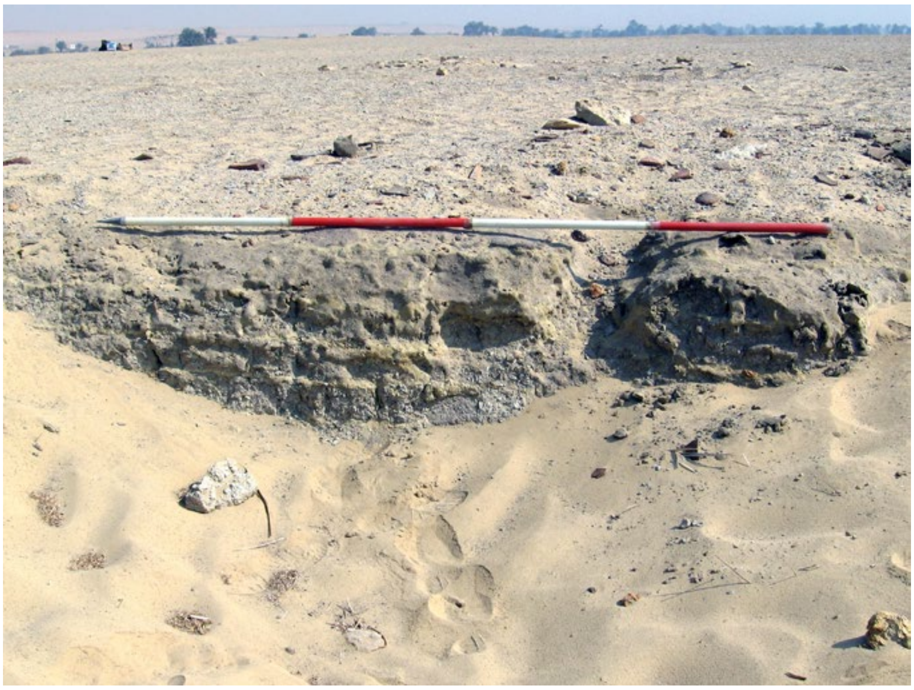

Figure 7. Qaret Rusas (Neiloupolis). Remains of mud-brick architecture with molten upper layer of bricks, uncovered during illegal excavations. Phot. T. Herbich.

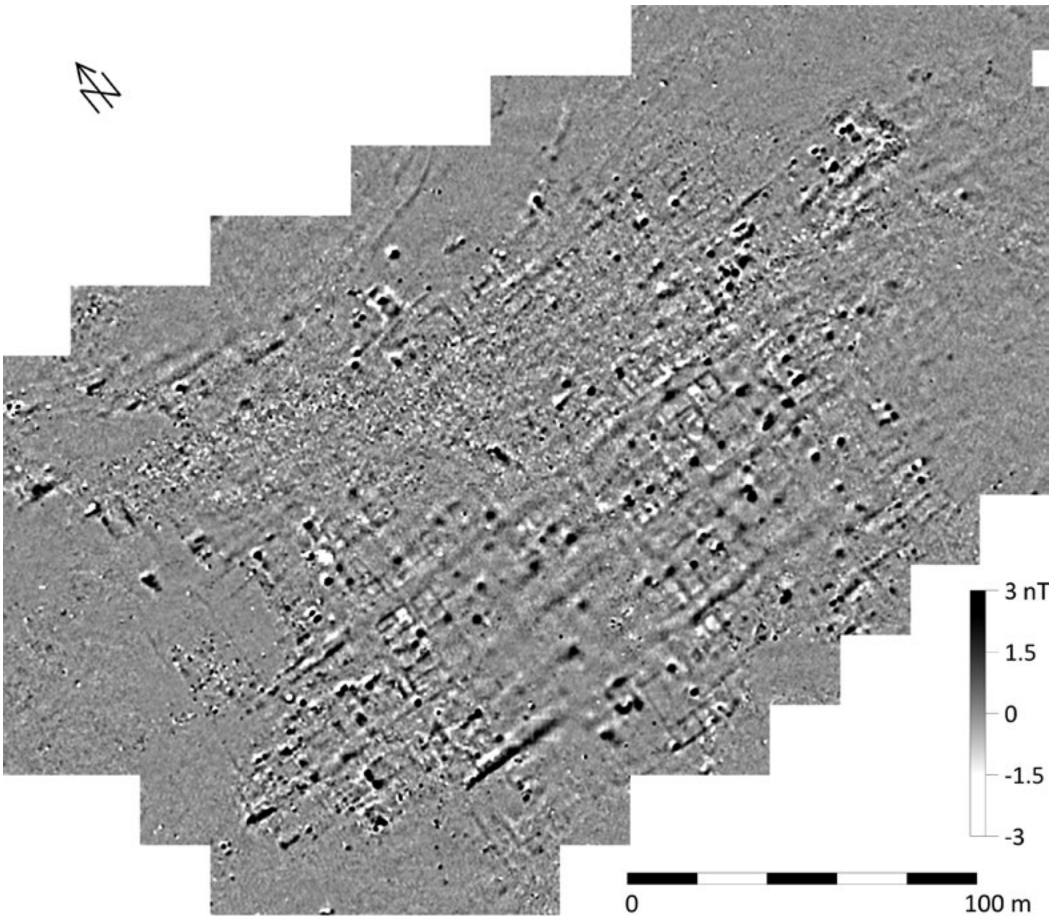

Figure 8. Qaret Rusas (Neiloupolis). Magnetic map.

The village was probably established in early Roman period. No ceramics dating to later than 4th century were found, indicating the time when the settlement was deserted (Cappers *et al.* 2013: 37-8).

6. Reasons for leaving the settlements

The results of geophysical surveys presented in this paper, carried out on sites located 40 km away from each other, supported by the results of archaeological research, prove that a similar process within a similar time-frame occurred. The process was triggered by a lack of water in the elevated south-western side of Lake Moeris, which caused its inhabitants to leave, while the water level at the north-eastern edge of the lake rose, leading to the destruction of the settlements. There are written sources from the area of Themistou Meris, where Philoteris lies, confirming a gradual decrease in water supply and the depopulation which it caused (Römer 2013).

An analysis of ancient sources, and surveys carried out at various times in the southern part of the oasis, allowed to hypothesize about the reasons for the disappearance of the three settlements described in this paper.

From the ancient sources, in particular the information given by Diodorus and Strabo, it can be assumed that in the southern part of the oasis there was an artificial reservoir, supplied with water from the Nile. Its purpose was to control the irrigation of the oasis (Garbrecht 1996: 73-74). Two researchers, Günther Garbrecht and Horst Jaritz, not only determined the exact location of this reservoir in a depression in the area of el-Mala'a in the southern part of the oasis, but also precisely reconstructed the location of a dam, which blocked the water from flowing away from the depression to the north (Garbrecht 1996: 53-55, 57). According to both researchers, the following phases of the reservoir's life span can be distinguished: during the Ptolemaic period, an earth dyke was erected to block the outflow of water. In the second phase, in the early Roman period, a limestone wall reinforced the original dyke. In the third phase, the limestone wall was replaced by a mud-brick wall (Garbrecht, Jaritz 1990, after Römer 2017: 182). The time of construction of the earth dyke during the Ptolemaic period was confirmed by drilling carried out at the beginning of the 20th century (Hassan, Tassie 2006: 38).

Cornelia Römer was the first one to connect the water shortage, which caused the fall of Philoteris, to the reservoir at el-Mala'a. She put forward a hypothesis that the lack of water in Themistou Meris occurred as a result of a cataclysm, which destroyed the proper functioning of the dam creating the reservoir. The devastation of the dam and a probable lack of funds for its reconstruction led firstly to a dysfunction of the water system and then to the disappearance of water in north-western Fayum (Römer 2013).

The loss of control over the maintenance of water in the el-Mala'a reservoir, containing 250-300 millions m^3 of water, with a surface of approx. 114 km^2 (Garbrecht 1996: 54), led to the elevation of water in Lake Moeris, which in turn caused the flooding of settlements located in its immediate neighborhood. This fate met al-Qarah al-Hamra and Qarert Rusas. The water, previously held in the reservoir, flowed into the lake through the Wadi el-Nazha gorge. Fragments of brick reinforcements preserved in the narrow part of the gorge, constructed below the dam, were in Römer's opinion an effort to stop the outflow of water from the reservoir (Römer 2013).

The research conducted by the URU project in Karanis led to some very interesting conclusions. Research of Karanis's suburbs proved that they were established in the 4th century, i.e. during the period when al-Qarah al-Hamra and Qarert Rusas, located in Karanis's vicinity, were flooded. Therefore, it is possible to assume that the sudden expansion of Karanis occurred as a result of an inflow of people to the area from the flooded settlements (Barnard *et al.* 2015).

7. Conclusions

In a somewhat unexpected way, the geophysical research allowed to link the changes in the landscape, which occurred over hundreds of square kilometers, with the processes which took place in the settlements. These processes caused significant changes in the demography of Fayum Oasis: the depopulation of some areas due to a lack of water (as illustrated by research conducted in Philoteris), the destruction of settlements caused by an excess of water in other areas (the case of al-Qarah al-Hamra and Qarert Rusas), and finally, a change in the population and size of existing settlements (Karanis).

The described events were without a doubt a tragedy for the inhabitants of Themistou Meris and the settlements located near Lake Moeris, however, they proved invaluable to the enhancement of knowledge of Egypt in the Ptolemaic-Roman period. Thanks to the desertification of the area and the desertion of the villages in Themistou Meris, and the very low humidity of the land, many written documents have been preserved to our times. Thanks to this, Fayum became a richly documented region for understanding agriculture, local administration, and above all the rural society of Ptolemaic and Roman Egypt (Monson 2013: 91).

Acknowledgement

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EXPLORING THE WORLD'S PREHISTORY

Session VIII-1 of UISPP 2018 in Paris 'Mapping the Past' brought together several contributions reflecting on the need to develop sustainable and reliable approaches to mapping our landscape heritage. The session was guided by the crucial concept termed the 'archaeological continuum'. This concept can be defined as a proactive approach to landscape survey based on the summative evidence detected (or detectable) within the area under examination, reducing spatial and chronological gaps as far as possible through the intensive and extensive application of a wide variety of exploratory methods and analytical techniques. Research work across Europe as well as contributions presented in this session have demonstrated that it is now possible to explore the whole landscape of carefully chosen areas and study them as an archaeological continuum. Archaeological interpretations derived from this kind of approach can be expected to reveal different layers of information belonging to a variety of chronological horizons, each displaying mutual physical (stratigraphic) and conceptual relationships within that horizon. The raising of new archaeological questions and also the development of alternative conservation strategies directly stimulated by the radical ideas inherent in the concept of the 'archaeological continuum' are among the major outcomes of the session.

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