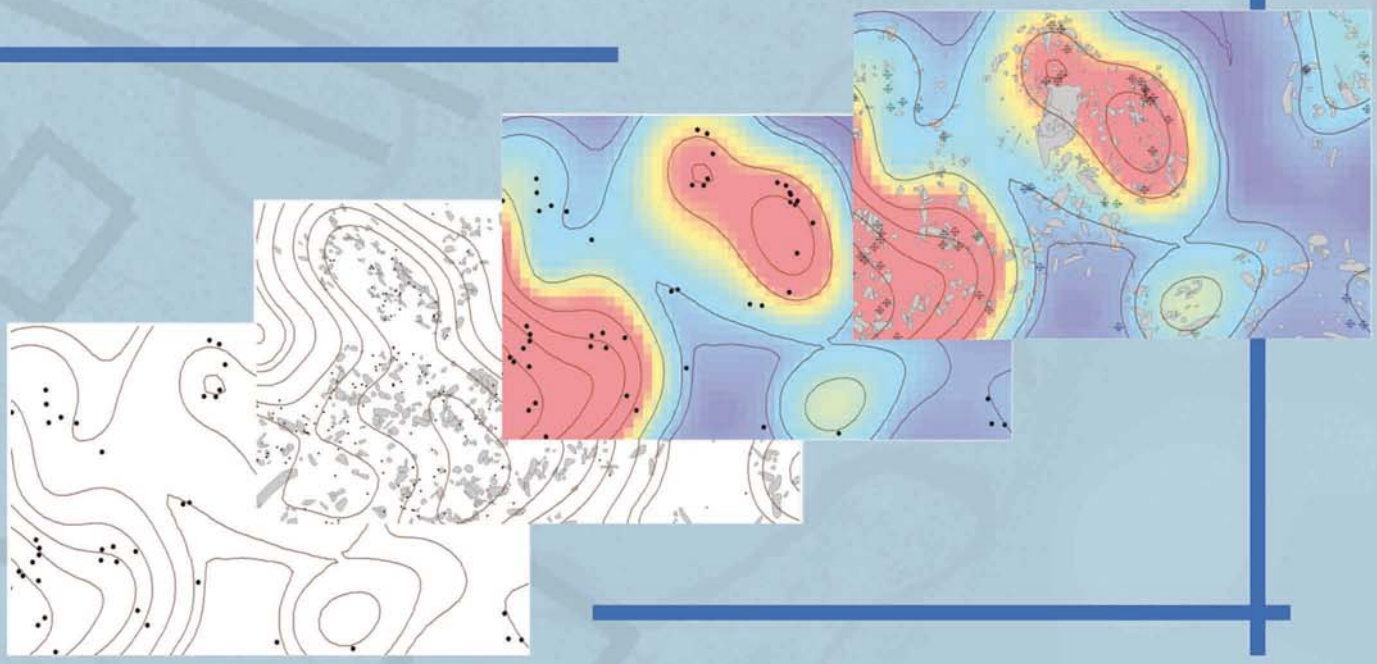
DEBATING SPATIAL ARCHAEOLOGY

Proceedings of the International Workshop on Landscape and Spatial Analysis in Archaeology Santander, June 8th – 9th, 2012



Edited by
Alejandro García, Jesús García,
Alfredo Maximiano, Joseba Ríos-Garaizar

instituto internacional de investigaciones prehistóricas de cantabria
iipc

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Contents.

François Djindjian
Contacts and movements of human groups in the European upper Palaeolithic: The adaptations to climate changes of the resource management strategies inside the territory and the annual cycle 1

Joan Negre • Rocío Gómez
Beyond Prediction. Artificial Neural Networks and Multiscalar Approaches applied to the study of historical dynamics 45

Katia Francesca Achino • Micaela Angle • Juan Anton Barcelò • Federica Micarelli
The pile dwelling of Villaggio delle Macine: an analysis of the spatial differentiation of social activities 55

Michal Birkenfeld • A. Nigel Goring-Morris
Stratigraphy and Spatial Analysis at Pre-Pottery Neolithic B Kfar HaHoresh, Israel: Using GIS Applications in Inter-Site Analyses 65

Ángel D. Bastos • Daniel J. Martín-Arroyo • Mª del Mar Castro • Lázaro G. Lagóstena
Rethinking the Boundaries of *Baetica*: a Historiographical Criticism from Spatial Display 81

Nicolas Antunes • William E. Banks • Francesco D'Errico
Evaluating Viking eco-cultural niche variability between the Medieval Climate Optimum and the Little Ice Age: a feasibility study 95

Amèlia Bargalló • María Gema Chacón • Bruno Gómez de Soler • María Soto
The role of the limestone in the Middle Palaeolithic technological behaviours through the refitting and the spatial patterning analysis: the level O of the Abric Romaní site (Capellades, Barcelona, Spain) 113

Rodrigo Villalobos • Germán Delibes de Castro • Miguel Ángel Moreno • Javier Basconcillos
The megalithic "Golden Crescent". An approach to one space in Northern Burgos (Spain) which hosted the adoption and evolution of megalithism 131

Solène Caux
A new piece within a larger puzzle: characterisation of 'grain de mil' flint from the Charente-Maritime, a central resource for the reconstruction of Palaeolithic territories in south-western France 143

Aleix Eixea • Valentín Villaverde • João Zilhão • Mercè Bergadà • Alfred Sanchis • Juan Vicente Morales • Cristina Real • José Ángel Martínez
Variation in the use of space through time at Abrigo de la Quebrada (Chelva, Valencia): the case of Middle Paleolithic levels IV and VII 153

Jorge de Torres • Marisa Ruiz-Gálvez • Youssef Bokbot • Mercedes Farjas • Pablo de la Presa • José María Señorán
Traditional wisdom and landscape management. A longue durée history of human exploitation of a critical resource. The case of the Oukaïmeden valley (High Atlas, Morocco) 167

Kristen Mann
Social Living: visualizing spatial variability in households at Early Iron Age Zagora on Andros, Greece. 179

Irene Ortíz • Javier Baena • María Gema Chacón
GIS spatial distribution analysis in raw material quarrying sites: the example of El Cañaveral (Madrid, Spain) 199

Vicente Bayarri • Elena Castillo
Geometric characterization and analysis of complex elements through the integration of different Geomatics Techniques. Application to caves 213

Jesús García • Armando Ezquerro
New techniques for artefactual surveying: GIS-GPS methodology for the study of Roman habitational contexts 225

Alejandro García • Miguel Ángel Fano
Palaeolithic sites beyond the archaeological deposits 231

Elisabet López i Garriga
Volumetric study of megalithic constructions of the Eastern Pyrenees 243

Alfredo Maximiano • Alfredo Prieto
Recognition of Prehistoric Canoeists' Passages in the Fuego-Patagonia Region: First steps in a Geo-computing approach to the characterisation of archaeological evidence 251

Paula Ortega
Visibility: a new outlook to the study of Palaeolithic Art. Preliminary research 259

Oriol Vicente • Ann Gómez • Camilo Barcía • Miquel Molist
Study of the spatial variability of Caserna de Sant Pau del Camp (Barcelona): old excavations, new approaches 267

Organization Committee:

Alejandro García Moreno, IIIPC, Universidad de Cantabria. *garcia@rgzm.com*

Jesús García Sánchez, Universidad de Cantabria. *jesus.garciasan@gmail.com*

Alfredo Maximiano Castillejo, IIIPC, Universidad de Cantabria. *maximianoam@uncian.es*

Joseba Ríos Garaizar, CENIEH. *joseba.rios@cenieh.es*

Scientific Committe:

Javier BAENA PREYSLER, Universidad Autónoma de Madrid. *javier.baena@uam.es*

Hans Peter BLANKHOLM, University of Tromso. *hans.petter.blankholm@uit.no*

Enrique CERRILLO CUENCA, IAM-CSIC. *ecerrillo@iam.csic.es*

Mercedes FARJÁS ABADÍA, Universidad Politécnica de Madrid. *m.farjas@upm.es*

Manuel Ramón GONZÁLEZ MORALES, IIIPC, Universidad de Cantabria. *moralesm@unican.es*

Ignasi GRAU MIRA, Universidad de Alicante. *ignacio.grau@ua.es*

Marcos LLOBERA, University of Washington. *mllobera@u.washington.edu*

Gary LOCK, University of Oxford. *gary.lock@arch.ox.ac.uk*

Holley MOYES, University of California Merced. *hmoyes@ucmerced.edu*

Roberto ONTAÑÓN PEREDO, Gobierno de Cantabria. *ontanon_r@gobcantabria.es*

Manuel SANTONJA GÓMEZ, CENIEH. *manuel.santonja@cenieh.es*

Penny SPIKINS, University of York. *penny.spikins@york.ac.uk*

José Manuel VICENT GARCÍA, CCHS-CSIC. *juan.vicent@cchs.csic.es*

David WHEATLEY, University of Southampton. *D.W.Wheatley@soton.ac.uk*

List of participants:

Katia Francesca ACHINO, Universitat Autónoma de Barcelona. *katiafrancesca@libero.it*

Nicolas ANTUNES, Université de Bordeuax 1. *antunes.nicolas@gmail.com*

Camilo BARCÍA GARCÍA, Universitat Autónoma de Barcelona. *camilo.barcia@e-campus.uab.cat*

Amelia BARGALLÓ FERRERONS, Universitat Autónoma de Barcelona. *amelia@prehistoria.urv.cat*

Vicente BAYARRI, GIM Geomatics. *vbayarri@gmail.com*

Manuel BEA MARTÍNEZ, Universidad de Zaragoza. *manumbea@unizar.es*

Jesús BERMEJO TIRADO. *jesusbermejotirado@gmail.com*

Michal BIRKENFELD, Hebrew University of Jerusalem. *michal.birkenfeld@mail.huji.ac.il*

Solene CAUX, Université de Bordeuax 1. *solene.caux@gmail.com*

Enrico CREMA, University College London. *enrico.crema@gmail.com*

María Gema CHACÓN NAVARRO, IPHES. *gchacon@iphes.cat*

Adriana CHAUVÍN GRANDELA. *adriana.chauvin@gmail.com*

Paloma de la PEÑA, Universidad Complutense de Madrid. *palomeke13@yahoo.es*

Jorge DE TORRES RODRÍGUEZ, Universidad Complutense de Madrid. *jorgedetorres@yahoo.es*

Iván DÍAZ. *ivandiazsm@gmail.com*

Marta DÍAZ GUARDAMINO, University of Southampton. *M.M.Diaz-Guardamino-Uribe@soton.ac.uk*

Aleix Eixea, Universidad de Valencia. *alejo.eixea@uv.es*

Ravid EKSHTAIN, Hebrew University of Jerusalem. *ravid.ekshtain@mail.huji.ac.il*

Miguel Ángel FANO MARTÍNEZ, Universidad de La Rioja. *miguel-angel.fano@unirioja.es*

María Cristina FERNÁNDEZ LASO, Universitat Rovira i Virgili. *mcfernandezlaso@gmail.com*

Mae GODER GOLDBERGER, Hebrew University of Jerusalem. *mae.goder@mail.huji.ac.il*

Rocío GÓMEZ. *rocio.in.wonderland@gmail.com*

Iain JOHNSON, University of Sidney. *ian.johnson@sydney.edu.au*

Olaf JOERIS, MONREPOS-Römisch Germanisches Zentralmuseum Mainz. *joeris@rgzm.de*

Melie LE ROY, Université de Bourdeaux. *melie.leroy@u-bordeaux.fr*

Elisabet LÓPEZ I GARRIGA. *garriga1988@gmail.com*

Sandra LÓPEZ VARELA, Universidad Autónoma del Estado de Morelos. *SLVARELA@UAEM.MX*

Kristen MANN, University of Sidney. *kman2025@uni.sydney.edu.au*

Daniel Jesús MARTÍN-ARROYO SÁNCHEZ, Universidad de Cádiz. *daniel.martinarroyo@mail.uca.es*

Monika MICHALOWICZ, University of Lodz. *monimic@tlen.pl*

Miguel MORENO GALLO, Universidad de Burgos. *mamgallo@ubu.es*

Itziar NAVARRO AMEZKETA, Universidad del País Vasco. *itziarnabarro@hotmail.com*

Joan NEGRE, Universitat Autónoma de Barcelona. *negreperez@gmail.com*

Gary NOBLES, University of Groningen. *g.r.nobles@rug.nl*

Javier ORDOÑO DAUBAGNA, Universidad del País Vasco. *javier.ordono@ehu.es*

Paula ORTEGA MARTÍNEZ, Universidad de Salamanca. *ortegap@usal.es*

Irene ORTIZ NIETO-MÁRQUEZ, Universidad Autónoma de Madrid. *irene.ortiz@uam.es*

Cristina REAL MARGALEF, Universidad de Valencia. *cristina.real@uv.es*

Gerard REMOLINS ZAMORA. *menairo@hotmail.com*

Phil RIRIS, University of Southampton. *P.Riris@soton.ac.uk*

Bernardo RONDELLI, IMF-CSIC. *bernardorondelli@yahoo.it*

José María SEÑORAN, INCIPIT-CSIC. *jose_seoran@hotmail.com*

Santiago VALLEJO RODRÍGUEZ. *svallejo_rodriguez@hotmail.com*

Iago VÁZQUEZ. *iagovazquezfernandez@yahoo.es*

Oriol VICENTE CAMPOS, Universitat Autónoma de Barcelona. *oriol.vicente@uab.cat*

Rodrigo VILLALOBOS GARCÍA, Universidad de Valladolid. *rvillalobos@fyl.uva.es*

Mu-Chun WU, University of Oxford. *mu-chun.wu@hertford.ox.ac.uk*

Foreword.

The present volume includes some of the contributions submitted to the *Debating Spatial Archaeology* International Workshop, held in Santander (Spain) in June, 8th-9th, 2012. The main aim of this conference was to provide a debate forum where archaeologists could discuss what *space* means in Archaeology, how it is perceived and interpreted by archaeologists, and why. Keeping in mind the need for a connection between methodology issues, analysis results and interpretations, participants were encouraged not only to analyse spatial variability, but to point out the probable reasons for such variability in terms of social space, as well as to discuss how their spatial analyses could improve the understanding of social and historical dynamics within their case studies.

The study of spatiality is one of the most important issues in Archaeology. Since the very first moments of the discipline, the understanding of spatial relations has been a key factor for interpreting past social dynamics. The importance of spatial analyses has led to the appearance of specific issues within Archaeology, such as Landscape Archaeology, Spatial Statistics, Cognitive Archaeology, etc., all of which can broadly be included within the Spatial Archaeology issue. On the other hand, in recent years there has been great improvement in recording methods and analysis tools, mainly thanks to the generalization of GIS, which has contributed to the development of spatial analyses.

However, these methodological improvements and conceptual developments have not always had an accompanying parallel theoretical dissertation about the real application of spatial analyses to archaeological interpretations; spatial analyses usually focus on geographic data and cartographic outcomes which have to be inserted into a previously defined, fixed framework valid in its own right, instead of really trying to link those results with the proposed interpretations. In these cases, space is automatically assumed to be a fully significant concept, either from an economic or relational perspective, but without a serious discussion of what it really means with relation to each particular case.

In order to address these issues, the conference was divided into three major thematic sessions, every session covering a specific issue of Spatial Archaeology:

- **Beyond archaeological spatial datasets: Old Restrictions and New Opportunities in Archaeological Spatial Information**: Chaired by G. Lock, this session aimed to discuss the epistemological, analytical and interpretative potential of spatial data in archaeological contexts related to current advances (theoretical and methodological) in space technology.

At present, progress in the process of capturing, managing and analyzing spatial data in archaeological contexts has been a real revolution in our discipline. Despite this, we must admit that the technology beyond the capability of formulating and resolving our spatial problems, and under these circumstances, it is not unusual to continue to apply outdated analytical routines and old approaches to these new resources. Therefore we are interested in current theoretical and methodological issues which are applied, successfully, to other spatial problems. In consequence, this session addressed three specific issues regarding the analysis and interpretation of archaeological datasets:

- Management and use of *time component* in the collections of spatial data and, specifically, to contrast the real possibilities of the *space-time cube* in archeology contexts.
- Out of spatiality: Data quality and material analysis, trying to give answers to questions like: What should be the quality in the analysis of the spatial material to generate consistent information with the spatial problem investigated? Would we go beyond the rated entity distributions on a surface?
- The possibility of advances in Heuristic Approach as a way of solving certain archaeological spatial problems, and in particular referred to the Geostatistical Approach, Spatial Simulation Process and Analytical Visualization.

- **The use of space from an evolutionary perspective:** This session was chaired by P. Spikins and focused on the use of landscape and the internal organization of habitats, camps, etc. which constitute a major theme in the studies of human evolution, since they tell us how humans interacted with space and how this relationship changed over time. This session aimed to cover some of the various analytical approaches applied to assess certain landmarks of evolution such as the colonization of new lands; the beginning of land use planning; the changes in dependence on ecological conditions; the manipulation of space; or the adaptation and internal structure of habitats.

  Moreover, this session also aimed to address the need of an integration of these questions in a holistic approach incorporating biology, subsistence strategies or technological provisioning, which could explain important issues about social and economic changes in the past.

- **People beyond the numbers: the anthropological implications of spatial analyses**: The aim of this session, chaired by M. Llobera, was to discuss how human behavior had to be considered and introduced in spatial analyses, by considering the broad spectrum of choices available for any given human being or society, as well as the different ways in which spatial analyses results could be interpreted when considering behavioral variability.

The generalization of GIS, Virtual Reality and agent-based approaches entailed a big improvement in analyses focusing on the relationship between human beings and their space, thanks to the possibility of measuring and quantifying several human experiences such as visibility and perception, movement, communication, etc. On the other hand, the application of predictive models allows building different hypothetical scenarios, which makes possible to explore how changes in specific conditions (environmental, demographic, technological, architectural, etc.) could be related to human behavioral variability.

However, these approaches usually lack a previous, reflexive hypothesis on which factors could have contributed to human group decision-making processes, and consequently on which variables have to be considered when modeling human behavior, the weight of these variables, or their meaning (*e.g.* what a strategic location really means?). On the other hand, results of spatial analyses are often considered as an *end product* of research, without integrating those results into an anthropological and historical dissertation.

In consequence, the aim of this session was not to support inductive approaches to spatial analyses, but to discuss how human behavior had to be integrated in Spatial Archaeology from an anthropological perspective.

Within this customary and social event we host the exhibition of various and heterogeneous research in the form of posters. Authors exposed their work ranging from the Paleolithic to Roman Ages, and despite de Iberian focus of the research we were proud to exhibit some of the preliminary results from a research undertaken in Patagonia. The posters were afterwards presented in the form of a short paper within this volume to help other colleagues to get a print and commented text about such incipient research in some cases.

Thematics included in this poster session involved various statistical and spatial analysis applied to both local and regional perspectives, from single cave or roman farmsteads contexts to wider landscape context as the canoeist passages. But summing up the discussion we are able to found something in common: the need of research to detect and study the variability of archaeological evidence which permit us to discern human behaviour that can be studied through archaeology.The workshop started with an invited talk from Professor F. Djindjian, who went over the history of Spatial Archaeology, offering a background of the evolution of the discipline and its state of the art nowadays. After the three thematic sessions, the conference ended with a roundtable, moderated by J. Baena and which title was **An Open Dissertation: "...And now; what we do with Spatial Archaeology?**, where all issues, questions and conclusions addressed during the workshop were

discussed. According to Baena´s synopsis, the contributions submitted to the conference mainly "*tried to explore human behaviour by dynamically using GIS tools, DB and algorithms to understand individual or collective decision on space and territory*", generally by focusing on some major issues such as how to manage time in space; how archaeologist defined archaeological entities; how archaeological distributions could be predicted, and thus, human behaviour; and how methodologies could improve archaeologists´ abilities to understand spatial patterns, which could provide traces about human behavior or activities.

During this roundtable, a broad range of aspects related with interpretation on Spatial Archaeology were discussed, mainly related with the concept of *time* (and its integration) in archaeological spatial analyses; the definition and conception of *space* within archaeologist; the validity of archaeological categories (*scale, distribution, feature, sample,* etc.), spatial analyses and models (neural networks, predictive modelling, theoretical approaches to human behaviour on space, etc.) when interpreting the spatial behaviour of past societies and individuals; or the real impact of technological trends and computer applications on Spatial Analyses (as Baena set out: "*Are the computing changes produced in the directions of our needs, or are we adapting our needs to the computing changes?*").

Fortunately, consensus on most of these issues was never achieved, which enabled rich and constructive discussions beyond the holding of the conference…

The workshop was held by the University of Cantabria and supported by the Cantabria International Institute for Prehistoric Research (IIIPC), with the collaboration of Cantabria International Campus, the Regional Government of Cantabria, the Altamira National Museum and Research Centre, and the Museum for Prehistory and Archaeology of Cantabria.



Contacts and movements of human groups in the European upper Palaeolithic: The adaptations to climate changes of the resource management strategies inside the territory and the annual cycle

François Djindjian[1]

[1] University of Paris 1 Pantheon Sorbonne & CNRS UMR 7041 Arscan

Francois.Djindjian@univ-paris1.fr

Abstract

The accumulation of data on the activity of Palaeolithic human group networks (source of raw materials, location of sites, seasonal hunting, etc.) allows gradually highlighting strategies for occupation of the territory of which the main parameters are the area of the territory, the food resources management and the seasonality of activities:

- *Local Opportunistic Strategy.*

  The area of the territory is limited (less than 1000 km^2). Mobility is low. Hunting is opportunistic. The habitat is permanent in a rockshelter. After exhaustion of the territory, the group abandoned its habitat and emigrated in another region. Contacts between human groups are limited. This strategy is adopted by the Mousterian groups during the OIS 4 and begins to be abandoned by groups of MP/UP transition industries. It is taken up during the maximum ice age from 21 000 BP at the time of the abandonment of the occupation of the middle Europe by Gravettian groups and their refuge to the Mediterranean regions (see below the seasonal mobility strategy).

- *Extended planned strategy.*

  The area of the territory is large (10 000 to 100 000 km^2). Mobility is high. There is a specialization of the travels and of the site locations: raw material distant sources, specialized hunting, seasonal sites, bivouac, art caves, within a recognized territory where travels are common. Contacts between human groups of the same network are numerous (meeting points) promoting exchanges and standardization of material culture. Camp-sites are seasonal. The food strategy specializes in hunting the herds of large migrant mammals (reindeer, bison) or horses. This strategy marks the success of the organization of the human groups in a network during the upper Palaeolithic period (Aurignacian, Gravettian, Magdalenian).

- *Semi-sedentary strategy*

  The residential camp-sites are occupied eight to ten months in the year. The territory is large (10 000 to 100 000 km^2). The food resource is mainly based on the mammoths through accumulations of bones, of natural or anthropogenic origin, which are found systematically nearby sites, providing food, fuel, building material for the dwellings and raw material for the manufacture of tools and weapons. Technical inventions without future are noted: terracotta figurines, polishing. Art is developed. Food is stored in pits dug in permafrost near the dwellings. This strategy is known in only three short and specific episodes in the history of the

European upper Palaeolithic: Pavlovian (around 27 000 BP in Moravia), Eastern Gravettian (24 000 - 21 000 BP in Central and Eastern Europe), Mezinian (Upper and middle Dnepr basin around 15 000 to 14 000 BP).

- *Seasonal mobility strategy*
  The territory is open to an uninhabited North where the human groups organize summer raids. The residential camps are located in the southern regions during 6 months of the year. Movements are carried out on several hundred kilometers during summer for specialized hunting (reindeer) and for the procurement of good quality flint. The territories of refuge are less extended and partitioned (Solutrean in sub-Cantabrian and sub-Pyrenean regions, Adriatic Epigravettian, Epigravettian of the Black Sea). This strategy corresponds to the short periods of the maximum ice age climate amelioration (Late Solutrean and Late Badegoulian in Western Europe, Sagvarian in Central Europe and Molodovian in Eastern Europe).

- *Restricted Planned strategy*
  The territories are limited (1 000 to 10 000 km^2). The human groups are located in specialized seasonal camp-sites. The diversification of food is pushed to its maximum (opportunistic hunting, specialized hunting of altitude with the conquest of the altitude, fishing, mollusk collecting). The supply of raw material is local in the territory and depends on the quality of outcrops that are found. Art is little developed. This strategy concerns the Epipalaeolithic groups.

Keywords: mobility, resource management, territory, demography, Upper Palaeolithic, Europe.

1. Introduction

The most striking advances in the researches on the upper Palaeolithic of the past twenty years are in the studies raw material procurement (especially of rare raw materials that reveal the most distant travelling) and in the development of zoo-archaeology (when it concerns hunting specialization, seasonality and food resource strategy in the annual cycle). Then the researches on the concepts of territories are coming from naturally. But a systemic approach is needed, integrating the raw material procurement, the seasonal hunting travels and the technical systems to reconstitute the system.

During the Lisbon UISPP Congress in 2006, the commission 4, jointly with the commission 8, had organized the colloquium 16, dedicated on the concepts of hunter-gatherer territory. The colloquium made a state of the art concerning the progress of ideas and the research on this theme in the European upper Palaeolithic. I have then introduced (Djindjian 2009a), the proposal of diversified socio-economic strategies of hunters-gatherer groups in the European upper Palaeolithic which had a deep influence on the change of technical systems and then of material culture.

Five strategies were then defined:

- Local opportunistic strategy,
- Extended planned strategy,
- Semi-sedentary strategy,
- Seasonal mobility strategy,
- Restricted planned strategy.

2. The mobility of the Paleolithic groups

The organization of the mobility of the Palaeolithic groups has been little addressed in the literature, excepted by ethno-archaeological approaches. The publication of reference is obviously Binford (1980), which proposes to distinguish between two extreme attitudes:

- Mobility of settlements ("*residential mobility"*): the groups of hunter-gatherers install their settlements close to food resources. This '*opportunistic*' strategy is implemented by small highly mobile groups (nuclear family) which are not building large residential settlements.
- Mobility of groups ("*logistic mobility*") which is characterized by larger base camps where families are living, and satellite camps where a part of the group travels to procure resources (hunting camps, raw materials outcrops, etc.) or to store them in caches.

Binford thus opposed "*foragers*" characterized by a low mobility of travelling and a high mobility of settlements to "*collectors*" characterized by a high mobility of travelling and a low mobility of settlements. The Binford paper suggested to ethno-archaeologists to analyze territory management strategies of the populations they studied through the model of Binford (for example Fitzhugh & Habu 2002). Some of them have proposed a linear evolution of opportunistic strategies towards the planned strategies, getting back the social stage evolution of N. Marr but inversing the Efimienko conclusions of the matriarchal planned model of the Eastern Gravettian and the familial opportunistic model of the Magdalenian (Efimienko 1953). We had already written in (Djindjian, Kozlowski and Otte 1999: 132) that it was better to search the reasons for a strategy change in adaptations to environmental changes. In the pages that follow, we define several models which will confirm such an influence.

3. The Local Opportunist Strategy

3.1 Definition and characteristics of a local opportunist strategy

The area of the territory is limited (500 to 1000 km2). This territory is corresponding more or less to a maximum day's walk, or about 20 km around the settlement which is a unique and permanent residence, mostly located in a natural rockshelter. As a result, on a limited territory, even well located on animal migration routes, the meat carrying capacity is limited. Hunting is then opportunistic, all edible game being a potential target. This rule does not necessarily involve a general hunting; it must also take advantage of the opportunities of the territory (natural traps, cliffs, gullies) to carry out specialized hunts leaving the remains of kill sites, which are playing a fundamental role in the food resource strategy. But the sampling must be controlled. Because, if animal exhaustion, the human group needs to desert its territory for settling in another place.

Mobility is therefore low on the area of the territory, limited to short circulations for hunting or raw material procurement. The raw material is therefore particularly varied, depending on only accessible outcrops in the territory: either a good flint outcrop is found there and it will happily be exploited; or, there is none, and it must then be necessary to exploit outcrops offering substitution raw materials: quartzite, dolerite, aphanite, quartz, siliceous limestone, rhyolite, jasper, opal, radiolarite, porphyry, etc. The chipped stone industry will then offer a wide variety of raw materials on which the objects have been chipped, and even have a different composition: with good raw material, more artefacts having high quality chipping; with a second choice material, more artefacts with a rudimentary chipping!

Mobility will also play a significant role in the choice of chipping techniques and in the variability of artefact assemblages. Mobility indeed means to travel 'light' over long distances, and therefore to carry handicrafts (blades, Levallois blades) and lightweight and productive nucleus (Acheulean handaxes, Mousterian and Micoquian handaxes, blade and bladelet prismatic cores). In contrast, low mobility does not require such a portability and induces abundance in the settlements of less productive nucleus (flake Levallois cores, discoid cores) and flake industries (Clactonian, Tayacian, Mousterian with scrapers, notches and denticulate, etc.). Contacts between human groups, too, are limited. Indeed, the probability to meet another group in a so limited territory, is low, except, and this is necessary for the survival of human groups, to have meetings in accessible places because the system cannot indeed operate on a completely self-sufficient mode.

The geometric model that represents the best a social structure of this type is the hexagonal network well known by crystallographers and geographers (Figure 1). In this model, the maximum number of possible contacts with neighboring cells is 6, number that decreases if

there are no neighbors, i.e. in the case of non-occupied cells. It should be noted the importance of the vertex of the hexagons, which are the meeting places of the groups of contiguous territories (three groups). Here we find the application of the geographic model of Christaller with the primacy to trading fact that comes here in a primacy to contacts. But we can just as well considering a meeting place which would be the middle of one hexagon side, limited this time to two contiguous cells, and which corresponds to the primacy to transport (or in this case the shortest trip for a meeting).

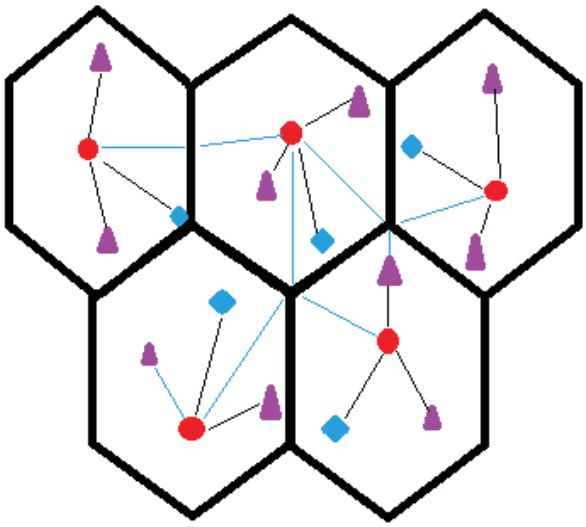


Figure 1: Geometric model of a local opportunist strategy (red round: settlements; purple triangle: kill and hunting sites; blue squares: raw material outcrops).

The reader will observe here that a meeting site for three contiguous territories is the equivalent of a triple surface's territory with four settlements. How then distinguish the two structures, with the only material culture? In a meeting site, the abandoned objects have partial sequences of the flint artefact manufacturing processes in far greater numbers than in the main settlements, the people coming for a short period with tools. Apparently, such a structure has not already been observed, but maybe it has not been sought? A seasonal mechanism can also be integrated within this model without changing in its nature with trips to unoccupied spaces (high valleys, altitudes).

At this stage, three hypotheses may be analyzed:

- H1. A meat carrying capacity of a 500 to 1,000 km^2 area during the ice age period allows feeding, with an annual renewal of the stock, a group of 30 to 35 people.

- H2. The same meat carrying capacity allows feeding, with an annual renewal of the stock, a smaller group until a minimum limit of 8 to 10 individuals. The population density of Holocene hunter-gatherers is known from ethnographic studies and varies between 0.01 h/km^2 for the Inuit to 0.15 h/km^2 for the Hadra of Tanzania (Hassan 1981). On an area of 1000 km^2, a density of 0.01 h/km^2 induces a group of 10 individuals. We will discuss below in Chapter 7 this demographic question in comparison with the extended planned strategy. Note, however, that a territory of 500 to 1000 km^2 is not particularly a small one. The area of the France, if its km^2 were all hospitable, could accommodate only 500 to 1000 of these territories.

- H3. The volume of procurement does not allows a natural renewal of the stock, regardless of the size of the group, and sooner or later, the group is forced to emigrate to a new territory, without human occupation, when the food stock is exhausted or when the energy required to successfully hunt a stock lower or more difficult to capture becomes too exhausting for the group.

In the latter case, the network of the territories must be open or incomplete (Figure 2). The incompleteness of the network is directly related to two critical state variables: the exhaustion time of a territory and its regeneration time. In the case of a one year exhaustion time and a 3 years regeneration time, the incompleteness is then 75%. The example of the French territory and its 550,000 km2 led us in this case to 150 groups or about 5 000 people (for groups of 30 individuals) or 1 500 people (for groups of 10 individuals). The system involves a low occupation, and, as a result, rare contacts between groups, promoting the heterogeneity of handicraft production and limiting the genetic exchange between groups. Is this emigration territory a contiguous territory reserved for the group, equivalent of the crop rotation of the agro-pastoral system? Or is it a distant territory?

In the first case, the group must reserve enough contiguous territories and rotate there regularly. This closed model does not seem credible insofar as it would be hardly possible for a group to protect against other groups wanting settling there, a food space, admittedly loose, but existing and necessary for the survival of the group. In addition, the model drastically limits contacts with other groups. The second case is a very open, sparse network, and each emigration is the occasion of meetings with other groups and the hope of a territory abounding in game. But how to be sure to find it, how to make sufficient provisions for a travel of unknown duration while the very purpose of this emigration is a food scarcity, in summary how to manage the risk? It is precisely because the risk is not under control, that the feasibility of the latter case is unreliable, unless of course, in borderline and critical cases.

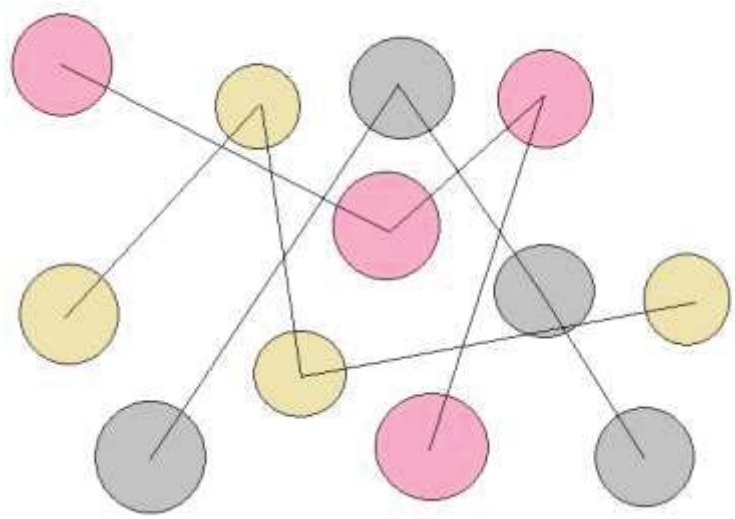


Figure 2: Schematization of a territory change in the local opportunist strategy

This mechanism also works in both ways. A more temperate environment, like the OIS 3 (interpleniglacial Würm), increase the meat carrying capacity favoring the growth of the group, its duplication and migration in this case with the best chance of success. Such a process during the OIS 3, was at the origin of the conquest of the middle and northern Europe involving the polymorphism observed for final Middle Palaeolithic industries and for transition industries.

Better yet, the transition to the Holocene, which diversifies the food potential (fish, sea and river mollusks, plant gathering), and accompanies a quick socialization of hunting inventions (bow, traps), allows to increase both the population density and the sedentarity of the group (see below the restricted planned strategy). In the opposite case of a strong deterioration of climate (such as the OIS4 or the OIS 2 maximum ice age), after the gradual reduction of the group individuals, the disappearing or the regrouping of too small groups, by lowering the population density, initiates a process of gapped network of territories or abandonment of areas which have become inhospitable, resulting in rarer contacts, related to the lack of mobility and greater intergroup distance, and consequently a higher inbreeding.

3.2. Human groups that apply a local opportunist strategy

The Mousterian groups of OIS 4 have adopted a local opportunistic strategy which has been progressively abandoned by the groups at the Upper Palaeolithic-Middle Palaeolithic transition. The change of the cold dry climate of OIS 4 between 75 000 BP and approximately 55 000 BP after the long interglacial OIS 5 (115 000 - 75 000 BP), certainly causes a demographic collapse and a flow to the South of Europe of Neanderthal groups. Although the revision of the chrono-

stratigraphic system is expected in Aquitaine and its integration with the known data of Central and Mediterranean Europe, however it is possible to see trends in the development of lithic industries in their chrono-stratigraphic context:

- At the beginning of the OIS 4, the rapid decline of the Levallois technique,

- Throughout the OIS 4, a very important development of scrapers, as well as notches and denticulates, of which the highly variable ratio appears to be due more to raw material procurement constraints rather than to any technical or cultural tradition.

- At the end of the OIS 4 and at the beginning of the OIS 3, the rapid growth of the Levallois technique, the emergence of bifacial artefacts (Mousterian of Acheulean tradition, Micoquian), the reappearance of the laminar Levallois technique and the development of the knives.

The study of raw materials procurement distances quite systematically highlights a distance less than 20 km, and the choice of various raw materials, linked to their availability in the restricted territory. Archaeozoological studies on the middle Palaeolithic taphocenoses have not yet reached the level of knowledge of those of the upper Palaeolithic, although since 20 years, promising researches have been published. Several kill and butchering sites have been recently studied: La Borde (aurochs), Coudoulous, Wallertheim, Mauran (bison), Patel (reindeer), Solutré (reindeer and horse), which highlight the ability of Mousterian groups to find natural places (traps, cliff foot, narrow passages, etc.) facilitating hunting (Jaubert et al. 1990; Farizy, David and Jaubert 1994; Gaudsinski 1995; Jaubert et al. 2005; Niven et al. 2012).

The existence of these sites instead argues the judicious choice of the territory and the effectiveness of its occupation. Furthermore, the taphocenose of the settlement reveals the diversity of game hunting and fully or partially carried back to the site: Pech de l'Azé 1, level 4 (red deer, reindeer, aurochs, bison, horse, roe deer) and a complementary seasonality: bison in winter, deer in the spring/summer (Rendu et al. 2009); Combe-Grenal levels 17-35 (red deer, reindeer, bison, aurochs, horse, ibex); Saint-Césaire, Mousterian level : (bison, reindeer, horse). Most of the Neanderthals remains are from this period and the accentuation of the morpho-cranial physical traits, compared to the old Neanderthal, seems to confirm a limited genetic exchange to correlate together with an ice age geographic partition, low mobility and the restricted territory previously described.

It is not question to deduce here that the model of the local opportunist strategy would be the general model of all the groups of Neanderthals and middle Palaeolithic industries. It would be particularly interesting to better understand the food resources strategies of the human groups and their industries from the OIS 7 to OIS 5. Thus, the blade production technique, here

associated with a more productive nucleus and portable equipment synonymous of greater mobility, appears well before the Upper Palaeolithic:

- Isotopic stage 7 (250 000 - 200 000 BP) corresponding to an interglacial period. Assemblages see the emergence of the technique Levallois (thus defining the beginning of the Middle Palaeolithic) in flake chipping industry. But the blade production technique is already known (Tabun D in the Levant, Saint-Valéry sur Somme in France).

- Isotopic stage 6 (200 000 - 115 000 BP) corresponding to an ice age period. Assemblages indicate the predominance of Quina (scrapers) technique.

- Isotope stage 5 (115 000 - 75 000 BP) corresponding to an interglacial period. Assemblages indicate the predominance of the Levallois technique. The prismatic blade production technique is present (in France, for example, Riencourt the Bapaume, Seclin, Bettancourt Saint-Ouen, Rocourt, the sites of the Vanne river (Yonne), sites of the Bergerac region, etc.).

- Isotopic stage 4 (75 000 - 55 000 BP) corresponding to an ice age period. Assemblages indicate a predominance of scrapers, notches and denticulates. The Levallois technique decreases gradually at the transition between isotopic stages 5 and 4.

- Isotope stage 3 (55 000 - 28 000 BP) corresponding to an interpleniglacial period. At the beginning of the OIS 3, assemblages see the new development of the Levallois technique, the emergence of bifacial pieces, handaxes and knives, the emergence of the blade Levallois technique and the blade and bladelet prismatic technique : Mousterian of Acheulean tradition in Western Europe; Bohunician (Oliva 1984) in Central Europe and Kremenician (Stepanchuk & Cohen, 2000-01) in Eastern Europe; Micoquian in Central and Eastern Europe, etc., anticipating the rapid emergence of Transition industries during the second part of OIS 3 : Uluzzian in the South of Italy, Castelperronian in Western Europe, Szeletian in Central Europe, Streletian and Gorotsovian in Eastern Europe, Jerzmanowician and Lincombian in Northern Europe, etc. At the same time in the upper Danube basin and then expanding down on the coasts of the Western Mediterranean, the first phase of Aurignacian industry (very early Aurignacian) appears, exactly as another technical solution to the same process of the polymorphic technological diversification of OIS 3. An extremely revealing case of polymorphism of this period of OIS 3 is provided by the lower Rhône basin where around 40 000 BP, a local Middle Palaeolithic industry, the Neronian, is characterized by production of blades and bladelets and the development of microliths on a good quality flint extracted more than 100 km. It is superimposed by a classic final Mousterian followed by a very early Aurignacian (Slimak 2008).

Much later, in the upper Palaeolithic, the flake chipping reappears at the ice age maximum from 21 000 BP, at the time of the abandonment of the middle Europe occupation by the Gravettian groups and their withdrawal to the Mediterranean regions (see below the seasonal mobility strategy), towards industries which succeeded it in Western Europe: the lower Solutrean and the early Badegoulian. The archaic features of the lower Solutrean industry have often noted, involving the hypothesis of an origin of the Solutrean in a very late Mousterian in the lower Rhône Valley (Smith 1966). It is also significant to point out that the Badegoulian, often referred to as the 'ugly' industry of the upper Palaeolithic, just after the beautiful laurel points and shouldered points of the late Solutrean, considered to be the most aesthetic industries of the upper Palaeolithic (Bordes 1968).

This contradiction between on the one hand the lower Solutrean and the other the middle and upper Solutrean (we prefer the terms early Solutrean and late Solutrean as defined in Djindjian, Kozlowski and Otte 1999), is interpreted by the hypothesis formulated by M. Otte of the arrival of the final Aterian in the South of the Spain via the Gibraltar Strait (Otte 2011). In fact, the real reason for these drastic changes in the industries of the maximum ice age is the abandonment of the middle Europe by the Gravettian groups around 21 000 BP. During their flowing back to the South of Europe, the human groups have lost their raw material outcrops and the hunting strategy of specialized herbivores during their migration. They are doomed to regress to a local opportunistic strategy and poor quality raw materials exactly as the Mousterian of the OIS 4, but without losing the long tradition of prismatic core technique (limited to the production of bladelets, which gives an “aurignacoïde” aspect to industries: Proto-Solutrean (ex-Aurignacian V), Badegoulian, Epiaurignacian, Muralovkian (Djindjian 1996). The flake chipping reappears however (flat faced points of the lower Solutrean similar to the Levallois points; “sausage” sliced chipping, transversal burin and “raclettes” of the Badegoulian).

When the climate is changing to a more humid but still very cold episode, such as between 20,000 and 19,000 BP (late Solutrean) or between 18,000 and 16,500 BP (late Badegoulian), the groups adopt a strategy of summer mobility (see below) to move northward in the summer, to exploit once again the good flint outcrops and the migratory herbivores (reindeer) resources. This is the case in Western Europe (late Solutrean, late Badegoulian), in Central Europe (Sagvarian, early Epigravettian) and in Eastern Europe exploring up from the northern coast of the Black Sea, a lake at this time, towards the valleys of the Dniester, the Dnieper and the Don (Molodovian, early Epigravettian). Industries have then abandoned both the substitution raw material and the flake chipping (Djindjian, Kozlowski and Otte 1999; Djindjian et al. 2006).

4. The Extended Planed Strategy

4.1 Definition and characteristics of an extended planned strategy

The area of the territory is wide (30 000 to 100 000 km^2 and more). Mobility is high. The settlements are seasonal. There is a specialization of travels and sites: distant raw material outcrops, specialized hunting, seasonal sites, bivouacs, art caves, within a recognized territory where travels are permanent. Contacts between human groups of a same network are frequent (multiple meeting points rather than an aggregation single-site) promoting exchanges and standardization of material culture. Figure 3 shows the diagram of an extended planned strategy model, the different types of sites, the circulation area of a group and the multiple opportunities of meeting between several groups.

The interpenetration of the circulation areas highlights the properties of this strategy over all others:

- each parcel of territory is shared between several travelling areas of human groups, allowing a greater population density,

- the travelling area of a human group have a much larger area, providing a much better food carrying capacity to the group and optimal population (thirty to thirty-five persons),

- the specialization on hunting herds of migrant herbivores like reindeers (North to South and lower valley to upper valley), or moving on a vast plain like the bison or going down the same paths like the horse, allows procuring abundant food, at different times of the annual cycle and for many human groups, involving meat storage,

- the mobility allows to multiply the meetings and therefore the exchange of information, know-how and individuals (see below), favoring the homogeneity of the material culture and a more rapid adaptation to environmental changes,

- the success of the system allows the population growth that makes possible the creation of a new group from several existing groups, colonizing new territories,

- the recovery of the travelling areas allows the development ad infinitum of peopling uninhabited spaces, and the existence of a same material culture over millions of km^2,

- the territory ends at the boundary of a territory of another network of human groups (and therefore of another culture), or of a territory without sufficient food carrying capacity or at the limit of a natural geographical barrier : coastlines, glaciers, mountains without crossing pass under 600 meters of altitude (Djindjian 1995).

The implementation of an extended planned strategy requires the socialization of several innovations:

- The memory of important events (periods of migration) associated with time management (probably a lunar calendar),

- the memory of places, and therefore the ability of orientation and navigation (probably from rivers and characteristic landmarks in the landscape),

- the marking the territory, human group and individuals, which helps groups to identify themselves as part of the same network, and check that the crossed areas are part of the territory (see below, chapter 9, art).

- Today, for the European Upper Palaeolithic, no modeling of the food resource in the annual cycle has been unfortunately achieved, compared to the models of Keene (1979), Jochim (1976) and Hassan (1981) for the Holocene. The taphocenose gives already first indications on the strong seasonal specialization of the food resource strategy that specializes in hunting the herds of large migrant mammals (reindeer, bison) or horses, which make up almost 90% of the taphocenose of the Palaeolithic settlements of the middle Europe.

The taphocenose of the Magdalenian in Aquitaine is indicative of this specialization. The rockshelters of the valleys of the Dordogne and the Vézère in Perigord and Quercy, often located near a ford on the river, have delivered, from the beginnings of Aurignacian to late Magdalenian, a taphocenose dominated by reindeer. During the Magdalenian period, this dominance varies between 80 and 95% of the present species. This importance of the reindeer is related to a hunting camp-site at the time of the seasonal migration of reindeer from the lower valleys to the upper valleys of the rivers descending from the Massif Central in the plain of Aquitaine. But where were the groups during other times of the year? And what is the reason for the contradiction between the representation of a bison/horse model in Magdalenian parietal art and the quite exclusive taphocenose of the reindeer, at the origin of the famous sentence "reindeer Age" of Prehistorians at the end of the 19th century?

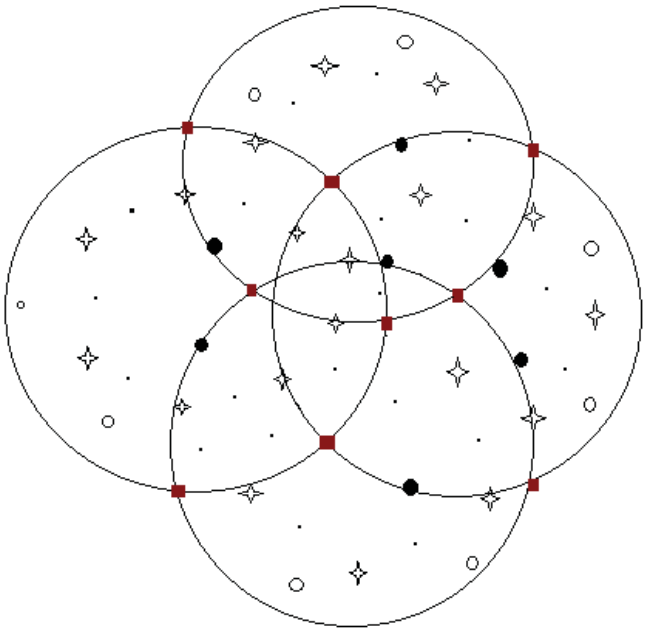


Figure 3: Geometric model of the extended planned strategy (Star: seasonal sites; red squares: hunting camps; black points: raw material outcrops, circles: bivouacs).

It is in the Aquitaine plain, that bison and horses were hunted by Magdalenian groups. Unfortunately, the deposits of rivers descending from the Pyrenees and the Massif Central have buried the upper Palaeolithic settlements (such as those of the Po basin) under more than ten meters of sedimentation. Therefore, these open air sites are not detectable. We have however the trace of this hunt on the edge of the Aquitaine plain. In Gironde, in the Middle Magdalenian of Jaurias, Fongaban, Roc de Marcamps, Moulin Neuf, Chaire à Calvin, the fauna is shared between bison, horse and antelope saïga. The reindeer is present only in small proportion (5-10%). To the South, in the sites of the Landes area, over a hunting territory opened on the Aquitaine plain, in the rockshelters of Duruthy/Dufaure, the fauna reindeer-bison-horse is dominant in the Middle Magdalenian, then an evolution appears, reindeer becomes dominant in the upper Magdalenian, related to the installation of the reindeer in the short valleys of the North of the Pyrenees following the melting of the glaciers, and finally red deer in the Azilian. In the Basque country, Cantabria and Asturias, the red deer is dominant in Riera, Juyo (layer 7) Ekain, Urtiaga, La Paloma (layer 8), Tito Bustillo, El Pendo, Morin (layer 2), with a pourcentage often greater than 80% of the fauna remains. But there is another category of sites, where the ibex is dominant in the same proportions, greater than 80% in Rascano, Erralla V, Bolingkoba III, Ermittia, revealing a specialization of the hunting with season and altitude. On the northern slope of the Pyrenees, a similar situation is known: the ibex is dominant to nearly 80% in the altitude settlements at La Vache, Les Eglises, Bedeilhac and Belvis.

The food procurement strategy in the annual cycle of the Magdalenian groups in the North of the Pyrenees is therefore based on a three-floor procurement system: bison/horse in the plain; reindeer in the valleys; ibex in altitude sites. The model is analogous in Basque country and Cantabria: bison/horse in the plain or coastal zone (as in Altamira), red deer in the settlements of lower valleys and ibex in altitude sites.

In the Middle Europe, on the other hand, it is the reindeer an horse assemblage which is widely dominating in the basins of the Loire, the Saône (Solutré), the Rhine (Gönnersdorf, Andernach), in the Paris Basin (98% of reindeer at Pincevent and Verberie, 91% of horse at Marolles/Grand Canton), in Belgium, in Switzerland (70% of horse, 20% of reindeer in Champréveyres).

At the beginning of the Upper Palaeolithic, the fauna of the OIS 3 was more diversified. For example, in Aquitaine, the aurochs, mégalocéros deer, equus hydruntinus, wild boar, roe deer are present but disappear around 27,000 BP, with the deterioration of the climate of the OIS 2, just after the arrival of the first Gravettian groups, to take refuge in the sub-Cantabrian and sub-Pyrenean Iberian Peninsula. They will return in Aquitaine only from the Bølling. The red deer, until then very present, will persist during the maximum ice age in endemic way. From 27 000 BP, in Middle Europe, the specialization of food resources on bison, horses and reindeer is also a consequence of the OIS 2 environment.

4.2. Human groups that apply an extended planned strategy

The extended planned strategy concretizes the success of the large networking organization of the human groups during the Upper Palaeolithic: Aurignacian and Gravettian from 34 000 to 21 000 BP and Magdalenian from 16 500 to 12 500 BP, which only the inhospitable environment of the glacial maximum has locked. The extent of the territory and the multiplication of the meetings cause the diffusion of knowledge and know-how, homogenizing the material culture, on areas astonishing by their magnitude: the Aurignacian present from West to East from the Atlantic to the Urals and into the Middle East (Caucasus, Levant, Iran), and from South to North, from Gibraltar to Wales. Certainly the Aurignacian homogenization has not been made in one day. It is possible to map this expansion probably from the kernel of the very early Aurignacian of the upper valley of the Danube, towards the South by the Western Alps (Rhone Valley) and the Eastern Alps (Fumane). From 36 000 BP, to the West, it reaches the northern slope of the Pyrenees and the Cantabrian mountains and then around 34,000 BP, it occupies the whole Aquitaine until Charente. To the East, it occupies the Central Europe (Czech Republic, Hungary), reaching Bulgaria (Temnata, Bacho Kiro) then the Romania. Around 31 000 BP, taking advantage of a climate improvement, it colonizes Northern Europe: Belgium, England

(by crossing the Channel on dry land), North of Germany, small Poland and Russia. The success of the Aurignacian system is also the success of the European upper Palaeolithic.

The Gravettian does not present as many differences with the Aurignacian that lithic technology innovations suggest it. After all, the emergence of the backed retouch is the invention of a side handling, whereas the innovation of a tanged point is only an improvement of an axial handling already existing in the Aurignacian. Based on current data, the Gravettian seems appearing around 29 000 BP in Central Europe in the same location as the first Aurignacian. It is spreading to the West by the same paths (Danube, Rhine, Doubs, Saône, Loire to the West and Rhone to the South) and to the East (Pannonia plain). But, unlike the Aurignacian, the Gravettian will undergo the effects of the climate deterioration that soon to 27,000 BP will isolate the Gravettian territories and differentiate it in particular sequences: Western Gravettian; Pavlovian in Central Europe, Eastern Gravettian, Tyrrhenian Gravettian (Noaillian), Adriatic Gravettian, Gravettian of the Dniester, etc. The history of the Gravettian ends around 21 000 BP with the abandonment of the territories of Middle Europe and with the generalized reflux towards the southern Mediterranean (Iberian Solutrean, Adriatic Epigravettian, Provencal and Tyrrhenian Epigravettian, Balkan Epigravettian, Epigravettian of the northern Black Sea).

In the middle Europe, the cold and dry climate conditions and tundra environment are fair back to cold steppes and herbivore migrations only by 16,500 BP. This is the time where the Magdalenian is constituted in a restricted Aquitania-Cantabria territory evolving from the late Badegoulian. Then, the re-colonization of Aquitaine until the Charente occurs. The middle Europe is reached around 15 500 BP by the Loire basin, the access to the Saône basin, and, in a reverse path to the Aurignacian and the Gravettian, the arrival in Central Europe (Rhine, Danube) until small Poland. The Bölling climate improvement will allow the upper Magdalenian to settle on the whole of Europe (Belgium, Germany) and then certainly by a special adaptation to differentiate in the Cresswellian in England and the Hambourgian on the northern coast of Europe (Netherlands, North of Germany, North of the Poland).

4.3. Network, super-network and territory of hunter-gatherer groups

In the case of the Aurignacian, the Gravettian and Magdalenian, the standardization of material culture on a considerable (European) space has implications for inter-group transmissions and communication modes. Indeed, human groups must live in a network and meet frequently to exchange (people, knowledge and know-how) under the risk to differentiate their material culture. The diagram in Figure 3 shows how the strong imbrication of the circulation areas of groups allows both the pooling of seasonal specialized hunting sites and raw material outcrops,

the meeting of the groups on these sites, and the natural expansion of groups in any uninhabited spaces. Such a colonization is done by the multiplication of groups (and therefore in relying on demographic growth) while saving the ability of inter-group meetings. The intergroup transmission (by contact) is done “near to near” without any contact between the two geographically most extreme groups of the same culture (for example between Aquitaine and the Iran or between Wales and Puglia).

At this level of discussion, an important parameter takes place, that of the surface of the circulation area of a group. It is variable because it depends on both the food carrying capacity in the annual cycle, of the raw material resources, of the physical geography (natural barriers, valleys, plains, latitude) of the territory of the group. More the 'carrying capacity' (in the broad sense) is high, more the circulation spaces are tightened and more the density of groups is high.

The Aquitaine-Cantabrian territory is a good example:

- Horse hunting in all zones of low and medium altitude,
- Bison seasonal hunting on the great plain of Aquitania and in its borders (Charente, Basque country and Cantabria), in its seasonal grazing course,
- Reindeer seasonal hunting during the upper valley to lower valley migration time in the rivers that descend from the Massif Central (Dordogne, Vézère, Lot, etc.),
- Reindeer seasonal hunting in the short valleys of the North of the Pyrenees (from 14 000 BP with the melting of the glaciers which are opening the altitudes),
- Red deer seasonal hunting in the valleys of the coastlines of Basque country, Cantabria and Asturias,
- Ibex seasonal hunting in the high altitude of Cantabrian and Pyrenean mountains.

In contrast, the same cultural tradition can be achieved by much larger circulation areas and a lower density of groups. This situation occurs especially in Central and Eastern Europe because of the high latitude and continental climate accentuating the migration mechanisms and of the scarcity of good flint outcrops. So it is probably the case for Gravettian and Magdalenian groups that cross the Carpathians Mountains by the Moravian Gate or the Poprad Gate, and who organize an area of seasonal travel between North (small Poland) and South (Slovakia).

The concept of territory that we have defined as the Culture does not therefore say that the territory has been traversed North to South and from East to West by the same human group. It means that groups that are part of it, share the same material culture and that they identify

themselves at an individual, intra-group and intergroup level by means of expression ('Art') which allow them to recognize each other.

It means that there are also hermetic borders between different Cultures. We know at least two examples. The first example is the border between the Middle Magdalenian groups and those of the Mezinian between 15 000 and 14 000 BP in Poland which resulted in the extermination of a Magdalenian group in the cave of Mascyska. A second example is the progression, blocked by Epigravettian groups, of the middle Magdalenian group colonization to the Languedoc coast (Gaze, Canecaude, Bize) that no geographical barrier prevents progress and which will reach the delta of the Rhône only at the upper Magdalenian, then allowing them to progress towards the North following up the Rhône valley.

The question has then to be considered to introduce the concept of network of networks for very large cultural territories, which the change of zoocenoses (and thus food economy), the variations in latitude and longitude and the natural geographical barriers will naturally differentiate. We know several examples of such a situation.

The first example is that of the middle Magdalenian at the time where, starting from the Charente, it begins the colonization of the Loire basin, crosses the passage between Loire and Saône (by the Dheune and the Bourbince rivers), then goes upstream the Doubs to the Burgundy gate, arrives at the Rhine going upstream to the Constance lake to pass to the upper Danube valley (by the Riss river) and then descends it to arrive into the Pannonia plain. The food economy of these middle Magdalenian groups, revealed by the site taphocenose, is based on reindeer and horse hunting.

During the Bölling, the upper Magdalenian will have colonized the whole territory of the great northern plain: Paris Basin, Belgium, Rhine, Elbe basin, Bohemia. It is thus possible to distinguish two networks in the Middle Magdalenian, the first is the Aquitania-Cantabria network and the second is the middle Europe network, for which the connection is made between the Loire and Charente rivers. Here we find the former proposal for a distinction between the Magdalenian "à navettes" and the "hispanic" Magdalenian (Allain et al. 1985). A differentiation is developing in the material culture of the bone industry (shuttles, Lussac-Angles spears) and in the art production. The Cresswello-Hambourgian represents a higher step of differentiation of lithic industry (abandonment of backed bladelets, development of points).

A second example is that of the Eastern Gravettian (see 5 below) for which we know the sites in Central Europe and Eastern Europe on a surface area of 1 million km^2 (Kostienki to Willendorf and Kraków-Spadzista to Zaraysk). Unfortunately the number of sites is too limited for a precise reconstruction of their system. The question arises here also by the existence of several North-

South traffic networks, contiguous: in Central Europe from Krakow-Spadzista to Moravany and Willendorf; in Eastern Europe from Kostienki to Zaraysk, and with a possible connection between the two networks in Belarus. The parameter of the 30 000 to 100 000 km^2 of territory area therefore corresponds to a flexible concept in the expansion (the Aquitania-Cantabria territory at the lower Magdalenian) or in the regression of territory (Gravettian flowing back at the Protomagdalenian) and in its multiplication (network, super-network).

4.4. Iconocenoses of mobile and cave art for the European Aurignacian, Gravettian and Magdalenian

Studies on the bestiary represented in the Palaeolithic mobile and cave art provide evidence when the problem is processed by correlating the iconocenoses with the zoocenoses at the level of the territory of settlements instead of processing them as once when trying to correlate without success the iconocenoses and the taphocenoses at the level of the site (Djindjian, 2004a, 2004b, 2006, 2009b, 2010).

Concerning the Aurignacian and the Gravettian, which are not differentiated by the bestiary, three iconocenoses are highlighted: a continental iconocenoses (60% of the figurative bestiary is represented by the association of mammoth, rhinoceros, feline and bear), an Atlantic iconocenose (more than 50% of the figurative bestiary is represented by the association horse, bison, aurochs and mammoth) and a Mediterranean iconocenose (association horse and aurochs). The mapping of these iconocenoses highlights two major Aurignacian and Gravettian territories, firstly the Aquitania-Cantabria area and secondly the Danube-Rhine-Saône-Rhône area. The recent revision and expected ageing to the Gravettian but also to the Aurignacian of a part of the Cantabrian and Asturian cave art (with an iconocenose horse, aurochs, deer and doe) does not affect the clear separation of the Atlantic area and the continental area (Figure 4).

Concerning the Middle Magdalenian, several models are highlighted:

- model A: association with a horse and bison dominance,

The A1 model, with a horse and bison dominance, is represented predominantly on the northern slope of the Pyrenees, Basque country and on the Cantabrian coast:

- North Pyrenean caves: Labastide, Tuc d'Audoubert, Enlene, Marsoulas, Mas d'Azil Ganties-Montespan, Portel, Massat, Fontanet, Eglises, La Vache, Niaux, Gazel, Le Portel (camarin),

 Cantabria and Basque country caves : Pindal, Altamira, Ekain, Santimamiñe, Oxocellaya, Etxeberri, Etcheberriko-Karbia,

The model A1 is also represented in all the Magdalenian sculptured friezes known in rockshelters in Roc-aux-Sorciers (Angles sur l'Anglin, Vienne), in Chaire à Calvin (Charentes) and in Cap Blanc and Reverdit (Perigord) (without forgetting the question of the age of the Roc de Sers frieze).

There is also an A2 model variant, with a horse/bison + mammoth/rhinoceros + "tectiform" dominance, present only in four caves in Perigord: Rouffignac, Font de Gaume, Combarelles I/II and Bernifal. This variant is the unique and exceptional case of an iconocenose that is not related to a natural zoocenose.



Figure 4: Iconocenoses of the Aurignacian and the Gravettian in Europe (1: Atlantic; 2: Continental; 3: Mediterranean).

- Model B: association with a horse and reindeer dominance

The B2 model, with a horse/reindeer with mammoth/rhinoceros dominance, is present in the regions of the middle Europe. It is recognized from the mobile art of the settlements of La Marche (Vienne), La Goutte-Roffat (Loire), Arlay and la Colombière (Jura), Gönnersdorf and Andernach (Rhineland) and Pekarna (Moravia). It is dated of the middle and upper Magdalenian.

The B1 model, with a horse and reindeer dominance, is known in the upper valleys of Perigord and Quercy. It is recognized from mobile art in rockshelters (Laugerie-Basse, La Madeleine, Limeuil (Perigord) and Sainte-Eulalie (Quercy)) but also in caves located in the valleys descending from the Massif Central: the La Forêt cave in Tursac (Perigord) and the Pergouset cave (Quercy). These sites are dated to the middle and upper Magdalenian.

Are these areas of bestiaries marking the existence of territories of networks? We argued repeatedly that the A1 and B2 models represented more or less the two Magdalenian networks previously mentioned: the Aquitania-Cantabria A1 network and the middle Europe B2 network (Figure 5). The area of Perigord and Quercy however reveals an interesting complexity: the A1 model is present by sculptured frieze rockshelters, the B1 model by small decorated caves and the mobile art of large settlements while the A2 model intrigues by his multi-model syncretism in four major caves not far from few kilometers near les Eyzies. Is it therefore necessary to add at the territoriality system proposed, the concept of seasonality (by adding to the horse/reindeer B1 model in Perigord/Quercy, one of its equivalent, the horse/deer/doe model of the Cantabria and Asturias) and the concept of meeting point or aggregation area (A2 = A1 + B2 + B1)?



Figure 5: Middle Magdalenian Iconocenoses in Europe (A: bison/horse model; B1: horse/reindeer model in Aquitaine-Cantabria area; B2: reindeer/horse/mammoth/rhino model in the area of Middle Europe).

5. The Semi-sedentary Strategy

5.1. Definition and characteristics of a semi-sedentary strategy

The territory is wide (100 000 km^2). The settlements are occupied at least eight to ten months in the year. The time of occupation is linked to the exceptional circumstances of an economy based primarily on the mammoth.

Close to each settlement, and functionally and stratigraphically linked to it, is located a mammoth bone bed widely exploited by the human group. The origin of such a bone bed is very probably natural: due to a change of humidity of the climate, with snow in late autumn and winter, herds of mammoths cannot feed on the grass of the steppe, and condemn them to starve and be covered with snow at the next storm. These bone beds are found most often in deep ravines of valley slopes, which offer the only protection against the wind and storms but that fill quickly snow. Frozen carcasses are discovered in early spring, melting snow, by human groups that are systematically prospecting to discover it and settle in their immediate vicinity. The frozen carcasses, systematically exploited, then serve as food resources, fuel, materials of construction of the huts and raw material for the manufacture of tools and weapons.

The taphocenose is characteristic of this food resource economy: predominance of the remains of mammoths; importance of the remains of fur-bearing animals, carnivores (wolf, fox, wolverine, bear and feline) and rodents (marmot, hare); presence of herbivores (reindeer, bison, horse and musk-ox). The mammoth is also hunted, like the rhinoceros, but individually and butchered on the place of his death. Alone the remains of herbivores cannot feed the total population of a settlement during the long period of occupation. Therefore, it is the discovery of the herd of frozen mammoths which provides both the ability to install the settlement and the food stock for the whole human group during the season.

How to prepare and conserve this stock of food for the annual needs? Binford (1993) has suggested that the many pits around the huts (and from which have been extracted the loess to fill in the mammoth bones in the construction of the walls), dug up until the permafrost, could be used especially as a natural refrigerator for the meat storage during summer. When the food stock is exhausted, even completed by additional hunting for other herbivores, including mammoths, the settlement is abandoned.

These settlements have then a one year duration of occupation, from early spring, date of their creation to the early spring of the following year, in an annual cycle that will be repeated every time when herds of mammoths are trapped by the humidity of the climate which changes the very cold and very dry ideal climate for the mammoth steppe.

After abandonment of the site, the distribution of the mammoth bone remains is characteristic:

- In the mammoth bone beds, the absolute predominance of ribs, vertebrae, sterna, feet bones (phalanx, metacarpus, metatarsus, carpus, tarsus and sesamoid bone) and hyoid bones, absence of other anatomical parts, and the presence of many small hearths between carcasses, of flint tools for butchering and mammoth bone tools (picks, choppers),

- In the dwelling structures, the absolute predominance of scapulae, pelvis, long bones, skulls, mandibles and tusks of mammoths, extracted from the mammoth bone bed as building materials for the huts. But other bones were recovered on the surface of the ground in the vicinity, including adult male individuals and which are often showing a surface alteration ("weathering") due to a long time exposition at the ground surface. It should also be noted the important presence of tools: tusks of young mammoths (pick), fragments of pelvis and scapulae (choppers) and appointed ribs.

Unfortunately, the systematic use of mammoth fresh bones to supply the hearths does not allow reconstituting the carcasses that have no longer than 15 to 20% of the skeleton bones.

The settlements with mammoth bone dwellings (whatever their architecture, see below) have been occupied over a long time in the annual cycle well confirmed by the seasonality studies (reindeer in the spring, marmot in the summer, fur animals in winter). But we also know settlements without mammoth bone dwellings which are seasonal camp-sites for the raw material procurement (near flint outcrops, fossil shells of the Sarmatian sea deposits and fossil amber sites) and specialized hunting to horse, marmot or another mammal (Figure 6). Several settlements with mammoth bone dwellings are known to have been reoccupied so for a short period: the mammoth bone bed had been filled up by colluviums and were no more visible but bones emerged from collapsed huts revealing the former occupation. The group then installed its dwellings naturally between the collapsed huts and on the location of the fulfilled ravine, recovering on the occasion the mammoth bones coming out of the ground.

Finally, the mammoth bone beds were either fully exploited (when they were discovered during the snow melting and then a settlements was erected in its close proximity), or partially exploited (when they were discovered after the snow melting and that carcasses become unfit for food) for raw material (ivory, bones) and fuel (in this case, few flint tools are found as in Sevsk or Berelekh), or not exploited (because never discovered) like in Jouravka.

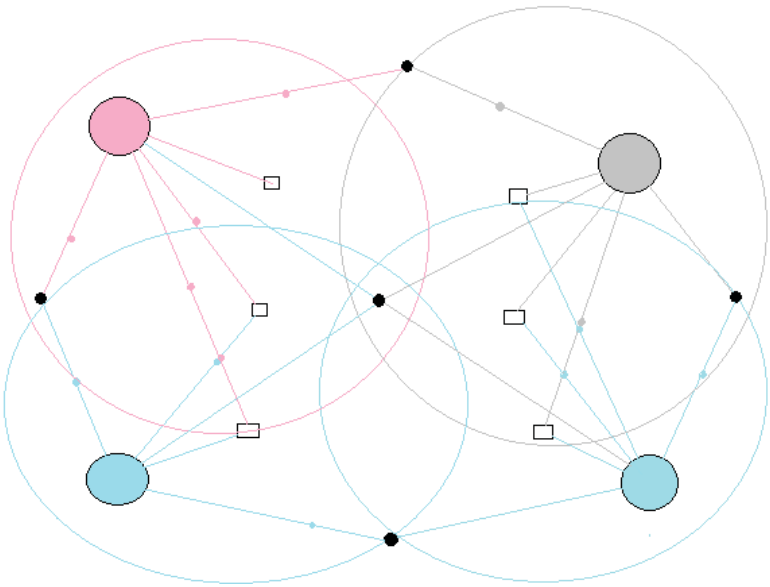


Figure 6: Geometric model of the semi-sedentary strategy (large circles: settlements; rectangles: hunting camps; black points: raw material outcrops).

The longtime of occupation, even if the settlement has been partially or totally left by the group for its seasonal travels inside the territory, is at the origin of technical inventions without future: terra cotta figurines (Pavlovian) and polishing (Kostienki). The discovery of the terracotta technology is the result of a mechanism of serendipity: a fireplace installed upon loess sediment and used during several months cooked the loess. Mobile art (ivory, amber, tooth, soft stone and shell) is particularly developed in the form of sculptures, painting, engraving and objects of adornment. Parietal art, in the form of paintings and engravings on the mammoth bones and by the bone association in the walls of the huts (nesting of the mandibles, alignments of long bones), is also present, proof that it is not the mere fact the caves but settlements also.

5.1. Human groups that apply a semi-sedentary strategy

The semi-sedentary strategy concerns only three specific and short episodes in the history of the European Upper Palaeolithic: Pavlovian (around 27-26 000 BP in Moravia), Eastern Gravettian (24 000 - 21 000 BP in Central and Eastern Europe) and Mezinian (middle and upper Dnieper basin around 15 000 - 14 000 BP).

The Pavlovian (stricto sensu for the occupations of the early Gravettian dated around 27- 26 000 BP) is well known by the open air sites of the Pavlov hill (Dolni Vestonice, Pavlov I and II, Milovice) overlooking a lake and by the site of Predmost in Moravia (Valoch 1996). The lithic industry is closed from the industry of the early Gravettian occupation layers of the site of

Willendorf II (Lower-Austria). The spatial structures left by the bones in Dolní Věstonice (Absolon (1924-1939), Klima (1947-1991), Svoboda), Pavlov (Klima, (1947-1991) and Milovice (Oliva, 1986-91) are still today the subject of discussions concerning their interpretations. At Dolní Věstonice, B. Klima has highlighted two circular dwelling structures, of 6 meters in diameter, delimited by stones, loess embankment and fixing holes, with indoor hearths and external pits. Nearby, a filled ravine provided a mammoth bone bed of 45 meters long and 12 meters wide. At Pavlov, B. Klima discovered eleven similar circular dwelling structures. At Milovice, M. Oliva discovered several circular dwelling structures with central fireplace, defined by circles of large mammoth bones (scapulae, pelvis, long bones and mandibles) collected on the nearby mammoth bone bed of which there is only an over-representation of ribs, vertebrae and foot bones (Klima 1994, 1995; Svoboda 1994; Oliva 2009). No study today was made to try to locate these exceptional sites in a territory of circulation of the Pavlovian groups.

The Eastern Gravettian corresponds to a peopling now well dated between 24 000 and 21 000 BP, marking the end of the presence of the Gravettian in Central and Eastern Europe. The main known sites are located in Central Europe (Krakow-Spadzista in Poland near Kraków); Moravany in Slovakia; Willendorf II in Lower-Austria) and Eastern Europe where they occupy a very large territory including the Don basin (Kostienki, Gagarino, Khotylevo II), the Oka basin (Zaraysk) to the North, the Desna basin (Avdeevo on the Seim, tributary of the Desna in Russia, Puchkari in Ukraine), the Pripiet basin in Belarus (Berdysh and Iurovichi). The flint industry is characterized by the presence of Kostienki points and Kostienki knifes. At Krakow-Spadzista, a mammoth bone bed has been recognized and a part of the dwelling area. On the famous site of Kostienki, near Voronezh on the Don, discovered by I. Poliakov in 1875, and which concentrates together more than 20 Palaeolithic settlements on an area of less than 50 km^2, P. Efimienko, excavated between 1931 and 1935, the site of Kostienki 1 and in the layer 1, he carried out a large open area excavation that reveals a dwelling structure of 36 x 15 m^2 which became characteristic of the Eastern Gravettian dwelling : a central alignment of a dozen of hearths surrounded by an oval alignment of large and small pits (Efimienko 1953, 1958). Efimienko has defined this structure as "a long time sedentary dwelling occupied for several years by mammoth hunters" (Efimienko 1953: 429). In the 1960s, A. Rogatchev and N. Praslov, discovered in Kostienki 1, layer 1, near the dwelling discovered by Efimienko, a second dwelling with a similar structure. The same structure was discovered at Avdeevo excavations by Gvosdover & Grigoriev (Gvosdover 1995). The dwelling structure discovered by Rogatchev in 1937-38, at Kostienki 4 Aleksandrovka is probably similar even though it has been defined differently (Rogatchev 1955). It would be the same at Pouchkari I. The structure type (Kostienki-Avdeevo) is an elongated structure with a central alignment of a dozen of hearths

surrounded by a series of large and small pits forming an oval structure, and which is typical of the Eastern Gravettian between 24 000 - 21 000 BP (Praslov and Rogatchev 1982). A single mammoth bone bed has been found near the Eastern Gravettian settlement of Krakow-Spadzista (Poland).

The Mezinian is a peopling occupying the middle and upper Dnieper basin now well dated after rectification (Iakovleva 2009) in a short period between 15 000 and 14 000 BP (Figure 7).

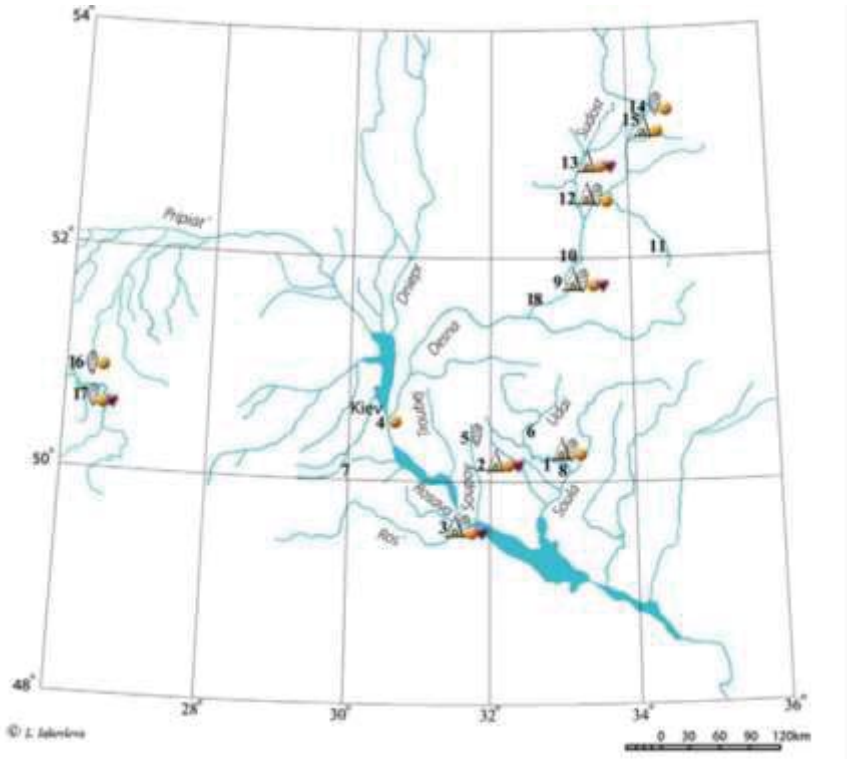
The mammoth bone huts of Gontsy, Dobranichivka, Mezine, Mejiriche and Ioudinovo, the most spectacular of all, were circular or oval, with a diameter of about 4 to 8 meters, with exceptions. They are located at a distance of 10 to 25 meters from each other (up to at least four huts were found in Gontsy, Dobranichivka, Ioudinovo and Mejiriche) and are usually surrounded by a variable number of pits of 1 to 3 meters in diameter, used for the extraction of the loess, as storage and sometimes as dump. One or several hearths are usually located inside the hut, with exceptions. The architecture is characteristic: the foundations are a circle of inserted skulls; the walls are built with large mammoth bones: skulls, scapulae, pelvis, long bones, mandibles which has been modified (holes, sharpening and digging) to bind them together. The selection and geometric arrangement of these bones in the walls identify each hut. These structures are surrounded by working areas and outside hearths dumping areas, animal butchering areas and nearby to large accumulations of mammoth carcasses that have been exploited as construction materials for building huts, as raw material for manufacturing weapons and tools, as a source of fuel for hearths and as a food resource.

In this large plain, without natural rockshelters or caves and rock outcrops, parietal art is expressed fully in the settlements by paintings and engravings on the bones of the walls of the huts and the particularly rich mobile art is manifested especially by female statuettes, decorated tools, objects of adornment (bracelets and diadems in ivory, pendants) and engravings on mammoth tusks.

Except the mammoth bone dwelling settlements, the most famous and sought for hut sites, other short occupation sites without huts are known, specialized in hunting horse (Fastiv) or marmot (Jouravka), near flint outcrops (such as Kanev or Puchkari) revealing long distant travels for flint, amber, Sarmatian fossil shells or shells from the Black Sea shores.

The territory of the Mezinian is centered in the upper basin of the Dnieper and its tributaries (Pripiat, Desna), and limited to the South by the boundary between the tundra/steppe zoocenose of the mammoth, rhinoceros, horse and reindeer and the steppe zoocenose of the horse, bison and saiga antelope, which corresponds to a environmental constant in the landscape of the southern Ukraine and the southern European Russia (tchernoziom area and steppe area). The

elderly used names for the Mezine culture (North of Ukraine), the Mejiriche culture (middle Ukraine) or the Elisseevichi culture (Desna river in Russia) are only local variants of a same cultural and territorial entity, the Mezine culture. The question of an equivalent peopling in the Don basin ('Zamiatnine culture') is argued by the two large huts of Kostienki 11 Anosovka 2, a site unfortunately unique and poorly dated.



Carte des sites dates entre 15 000 bp - 14 000 bp des regions du Dniepr moyen et superieur et du Desna (Ukraine et Russie):
1 - Gontsy, 2 - Dobranichivka, 3 - Mejiriche, 4 - Kiev - Kirilovskaia, 5 - Semenivka, 6 - Jouravka, 7 - Fastiv, 8 - Vilchanka, 9 - Mezine, 10 - Chulatovo, 11 - Sevsk, 12 - Ioudinovo, 13 - Elisseevichi, 14 - Timonovka, 15 - Suponevo, 16 - Gorodok, 17 - Barmaki, 18 - Boujanka.

Figure 7: The territory of the Mezinian in Eastern Europe on the middle and upper Dnieper basin (15 000 - 14 000 BP).

6. The Strategy of Seasonal Mobility

6.1. Definition and characteristics of a seasonal mobility strategy

The territory is open towards an uninhabited area where human groups are seasonally travelling. These areas are typically a northern area, uninhabited and uninhabitable throughout the year.

Such a strategy has to be distinguished from the extended planned strategy where are integrated inside the territory the seasonal spaces, for example altitude hunting camps or specialized hunting camps in specific places related to animal migration times. The demonstration requires a detailed seasonality study to demonstrate that the settlements have been occupied only during the summer.

Peopling is located in the southern regions during a large part of the year. Travels are performed on several hundred kilometers during summer for specialized hunting (usually the reindeer) and for the flint raw material procurement. The withdrawn territories depend on Mediterranean geography: Solutrean in the sub-Cantabrian and sub-Pyrenean areas; early Epigravettian in the Adriatic gulf, Epigravettian of the Balkans area, early Epigravettian of the northern Black Sea and their occupation correspond to a local opportunist strategy. Summer mobility territories correspond to uninhabited areas of middle Europe, once occupied before the glacial maximum. To access it, sometimes requires long paths and passages through practicable passes at the maximum ice age, i.e. an altitude less than 600 meters (Figure 8).

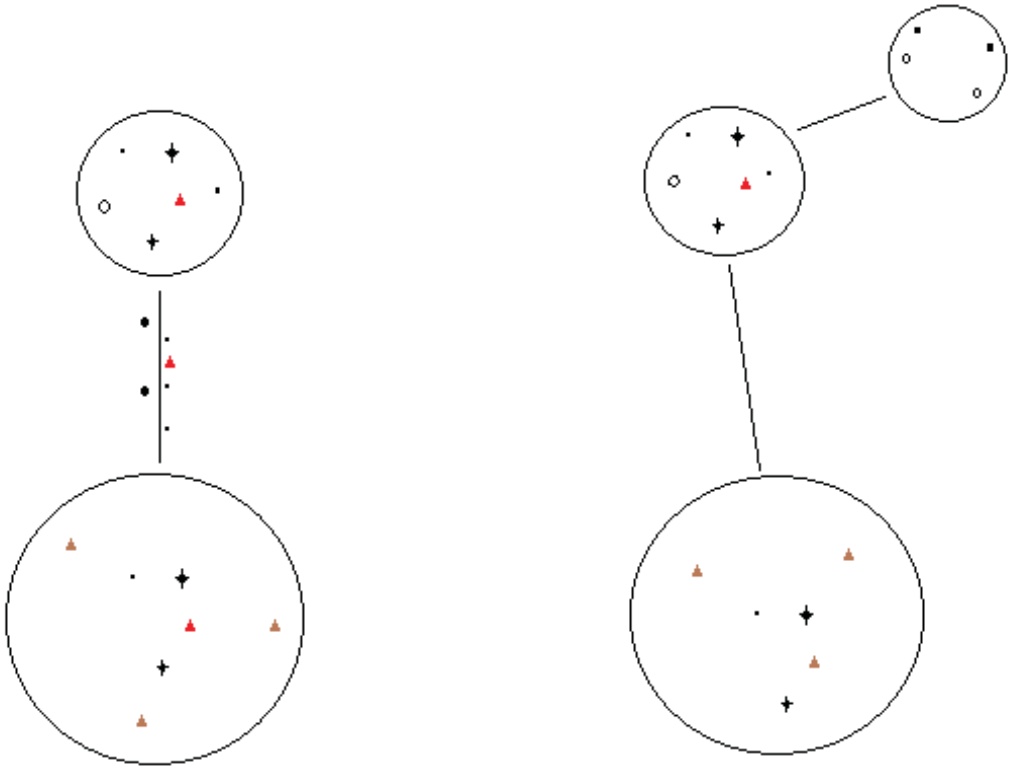


Figure 8: Geometric model of a seasonal mobility strategy.

6.2. Human groups that apply a seasonal mobility strategy

The human groups that apply a strategy of maximum glacial summer mobility are the following (Figure 9):

- Late Solutrean and late Badegoulian in Western Europe,
- Sagvarian in Central Europe,
- Early Epigravettian in the Balkans,
- Molodovian of the Dniester basin and early Epigravettian upon the northern coast of the Black Sea.

This strategy is based on the existence of two climatic episodes dated around 20 000 - 19 000 BP for the first and 18 000 - 16 500 BP for the second. The existence of these episodes, undoubtedly present by fossil soils in the loess sequences of Central and Eastern Europe (Ivanova 1969; Haesarts 1990), has been questioned by Western palynologists, quite rightly moreover, concerning the pollen sequences in caves and rockshelters. In a recent study of correlation of reference sequences in non-anthropogenic contexts (Bosselin and Djindjian 2002), we have shown that these episodes existed, according to climatologists who are specialist of loess sequences and ice cores, but that they were characterized by an increase of humidity without change of temperature in the very cold climate of the glacial maximum, promoting the development of the vegetation cover, and therefore the demography of herbivores and the seasonal come back of human groups.

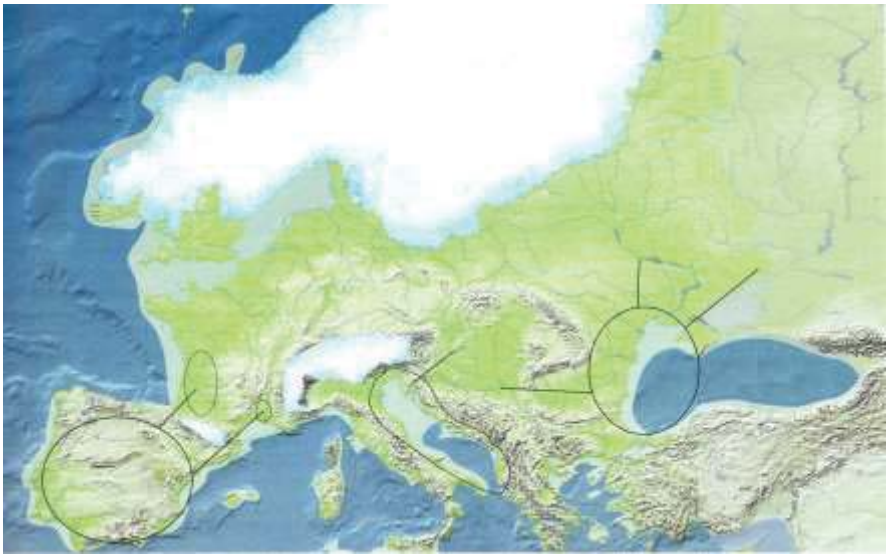


Figure 9: Seasonal mobility strategy: European peopling at glacial maximum.

In Hungary, in the Pannonia plain, the Sagvarian is characterized by open air summer occupation settlements, specialized in reindeer hunting, and present only during these two episodes (Dobosi 2009). These groups come either from the East, installed on the lower Danube basin in Romania and Bulgaria, through the iron gates, or from the South, installed on the shorelines of the Adriatic Gulf, through the Postojna pass in Slovenia.

In Eastern Europe, from 21 000 BP, the human groups of Eastern Gravettian abandon the great plain and took refuge between 21 000 BP and 17,000 BP, on the northern area of the Black Sea, at that time a lake of much smaller size. The identified cultures are an "aurignacoïde" industry (Muralovkian) and an early Epigravettian industry. The taphocenose reveals a very strong horse, bison and saiga dominance with the poor presence of reindeer. At the same time, the early Epigravettian settlements of the Dniester valley and its tributaries (Molodovian sensu stricto), located on the north slope of the Carpathians (Moldova, Ukraine, Romania), including the best studied sites of Molodova V and Cosaoutsy, have a taphocenose-dominated by reindeer and horse. Further to the North, the steppe-tundra area is the field of mammoth, rhinoceros, reindeer, horse and muskox where groups are making summer travelling for hunting reindeer and procuring flint raw material.

Apparently more complex seems to be the Western European situation. Indeed, it is difficult to imagine the Perigord, world center of the prehistory, depopulated at the glacial maximum or occupied only during a season. The new archeozoological studies of Castel (Castel, Chadelle and Geneste 2005) highlight a seasonal end of winter/ spring period for Solutrean sites of Perigord and Charente and during summer, specialized hunting to reindeer in the upper part of the massif central rivers (Dordogne, Vezere, Lot, Aveyron), and in the North: Loire river (Fressignes), Yonne river (Trilobite) until the Saône river (Solutré), and flint extraction in the outcrops of the Loire (Les Maitreaux) or the Seine basin (La Celle Saint-Cyr).

Then, two hypotheses may be discussed:

- The Solutrean groups are present throughout the year in Aquitaine, and made summer travels to the North or at the upper part of the Massif Central rivers for specialized reindeer hunting and for raw material procurement.

- The Solutrean groups are not present year-round in Aquitaine (and similarly in Ardeche). The suggestion by Castel of a presence during winter in northern Europe is not credible at the glacial maximum. Then, a solution more in the South has to be looked for. It was the subject of the paper I have given at a colloquium on the Solutrean, "forty years after Ph. Smith (1966) " which took place in La Claise in 2006 and which is unfortunately not yet published today. In this paper, I proposed the idea of a Solutrean and Badegoulian peopling

spatially distributed during the annual cycle between the Iberian Peninsula (sub-Cantabrian and sub-Pyrenean area), Aquitania and (only during episodes of 'Laugerie' and 'Lascaux') summer circulations toward the North, the upper valleys of the Massif Central and the Cantabrian and Asturian coast (Figure 10).



Figure 10: Trans-Pyrenean circulations at the glacial maximum (Solutrean and Badegoulian).

Several arguments were given of which the following ones:

- A strong Solutrean presence in the South of the Iberian Peninsula (Andalusia, valleys of the Tagus and Douro) with art caves (Estremadura) and open-air rock sites (Foz Coa, Siega Verde and others),

- The occupation of the Meseta by Solutrean groups, travelling from and to the basins of the Duro, the Tagus and Andalusia, marked by numerous art caves (La Griega, Los Casares, La Hoz, El Reno, El Turismo, El Cojo),

- The passage of the Solutrean groups from the Meseta to the Ebro Valley, with the importance of the natural way of the Jalon river (Utrilla 1997),

- The passage of the Solutrean through the passes of the Basque Country between the Ebro Valley and the plain of Aquitaine: Abauntz, Coscobilo, Etxauri (Utrilla 1997),

- The presence of pendants made in wild boar tusks in several Solutrean settlements of Aquitaine (Malpas, Roc de Sers, Le Gabillou, Combe-Saunière, Grotte XVI, etc.),

- Shells of strictly Mediterranean origin discovered in the only late Solutrean layers in Charente, Perigord and Quercy, indicating travels to the Mediterranean shore of the human groups (Languedoc, Spanish Levant but also Andalusia),

- The existence in Aquitania of a Mediterranean iconocenose (horse, aurochs, deer, doe, ibex) in several art caves (Lascaux, Le Gabillou, Le Placard) and rockshelters (Bourdeilles, Badegoule) attributed to the Solutrean/Badegoulian period, as well as in Ardeche (Ebbou, Tête du Lion).

7. The Restricted Planned Strategy

7.1. Definition and characteristics of a restricted planned strategy

The territories have a limited area (1 000 to 10 000 km^2). Human groups are installing specialized settlements. The diversification of food resource is maximum (opportunistic hunting, altitude specialized hunting with the conquest of the mountains, fishing, birds, rodents, mollusk collecting). Raw material procurement is local in the territory and depends on the quality of the outcrops which are found. The art is not developed.

7.2. Human groups that apply a restricted planned strategy

This strategy is the result of a gradual reduction of the extended planned strategy, because of the disappearance of hunted animal species due to both the extinguishment of anthropogenic origin (bison in the plain of Aquitaine ?) and an emigration due to climate change (mammoth to Siberia from 14 000 BP; reindeer to Northern Europe from 13 000 BP). The same climate amelioration sees the arrival in Middle Europe of animal species having taken refuge in the Mediterranean area (aurochs, red deer from Bölling, then wild boar, roe deer from Allerød), but whose ethology is not identical to that of the reindeer, bison and horses. The forest invades the steppe landscape. Human groups must adapt and change their hunting techniques (invention of bow and development of microliths). Moreover, the success of the Magdalenian model in Western and Central Europe had seen in its final phase (upper Magdalenian) an occupation or an almost complete acculturation (Northern Europe, Iberian Peninsula), adapting even to more and more diversified local food strategies, increasing with the success of its system, the population density of groups, and then reducing the circulation spaces. When the climate change at the end of the ice age occurs, Late Epigravettian groups on the Tyrrhenian coast, on the Adriatic Gulf, in the Balkans and even in the Levant are adapting much more easily because this process had started for some of them since the 15 ° or 16 ° millennium BP. For the Magdalenian

groups, this process begins at 13° millennium BP, and is concretized by the azilianization of material culture (Azilian groups and Ferdermesser groups), the groups occupying most often the same sites and the same areas. But gradually, from the Dryas III (Brommian, Swiderian, Ahrensbourgian, etc.) and then from the Preboreal (Mesolithic), a process of differentiation is activated who sees the material cultures differentiate themselves regionally and their territories be reduced gradually, while food resource strategies diversify and specialize. In regions that have a high and diversified food carrying capacity in the annual cycle, these processes lead progressively to sedentarity of groups, a necessary step to move to agriculture in the regions of animal and plant high density and large diversity (fertile Crescent in the Middle East).

8. Demography of hunter-gatherer groups

In the case of a local opportunistic strategy, the size of a group in an area of 1,000 km^2 defines the population density. It is very low in the range of 0.01 h/km^2.

In the case of an extended planned strategy, a pixel of 1 000 km^2 territory belongs to the area of circulation of several groups, variable depending on the size of their travel area and their population density. Let a territory of area T, a random distribution of density d of Mi points marking the virtual centers of the group travelling area, the radius of the circulation area of each group (assumed here circular) Ri and the intergroup average distance Dii'. The number of group circulation spaces covering a random pixel of 1 000 km^2, gives an unbiased estimate of the population density of the extended planned strategy. It is a function of T, Ri and Dii'. More the Ri are high and the Dii' low, more the average density per 1 000 km^2 is high. We will not give the detailed calculations, mathematically too complex here. However, we may develop a simplified model that gives an approached order of magnitude of the relations between these different variables. The simplified model is a uniform distribution of groups of identical size (33 individuals) in a territory of surface T (100,000 km^2), with the same radius R of circulation area and the same intergroup average distance D. It is enough to count the number of travelling circles that intersect any circle and which is constant (because they all play a similar role in a uniform distribution). This number, which measures the relationship between d and R/D, is expressed in a simple way by an arithmetic series of ratio 4n - 3 for n varying 2 by 2 or ratio 2n - 1 for n varying $\sqrt{2}$ by $\sqrt{2}$.

It is then possible to construct the graph of Figure 11, which shows the variation of the R/D ratio with d. For a ratio R/D ranking from 1 (equivalent to the model of the local opportunist strategy) to 10 (large spaces of circulation and low inter-group distance), the density d varies from 0.01 h/km^2 to 0.15 h/km^2. The abacus corresponding to R = 50 km, 100 km, 150 km, 200

km and 400 km were plotted as well as those corresponding to D = 20 km and 40 km. Here we find the orders of magnitude proposed by Hassan (1981). The graph shows that the good functioning of the extended planned strategy lies between a travelling area with a radius of 50 km (or 10 000 km^2) to a radius of 400 kilometers (or 500 000 km^2) with an intergroup average distance of 20 to 50 km. This policy allows a population density of 0.01 h/km^2 to 0.1 h/km^2.

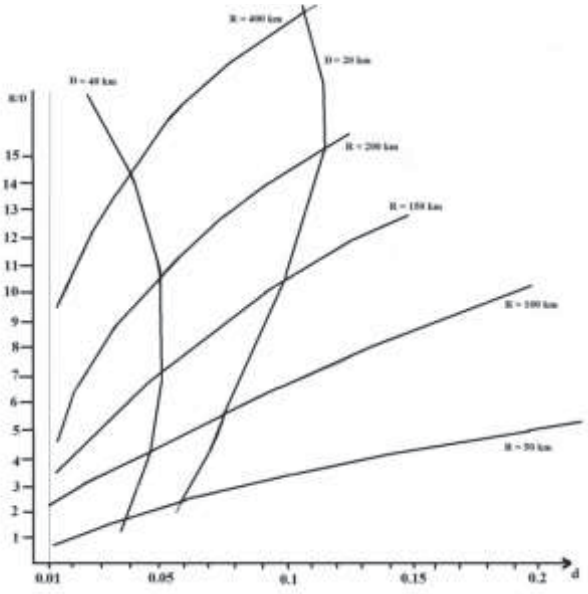


Figure 11: R/D versus d population chart (R: circulation area of the human groups; D: intergroup average distance; d: population density).

It also shows that the continuous passage of a local opportunistic strategy to a planned extended strategy is possible firstly by gradually increasing the circulation space on the same abacus of intra-group distance (for example the 40 km one) then moving on the abacus of travelling radius (for example the 150 km one) to increase the number and therefore the density of groups (if you find hunting species moving or migrating in large group, such as bison and reindeer and if you resolve food planning of the annual cycle, up to the maximum of the carrying capacity).

The reverse process is the same. It is thus possible to propose a population density of Mousterian groups of OIS 4 cutoff to 0,01 h/km^2 in an local opportunistic strategy, then going back gradually in OIS 3 to a density of 0,01 to 0,03 h/km^2, for the final Mousterian and Transition industries continuing a local opportunistic strategy, and then passing to the early Aurignacian, around 34,000 BP, in an extended planned strategy with a population density that can reach and exceed 0,1 h/km^2. The glacial maximum will see a population decline of the groups unable to estimate with currently available data. The process will be reversed with the Magdalenian which will see the Middle Magdalenian in a density of about 0,1 per km^2, which

will continue to grow in the upper Magdalenian and then with the Epipalaeolithic to values greater than 0,1 h/km^2 in a restricted opportunist strategy.

It is difficult to evaluate the demography of the groups following a semi-sedentary strategy because it based still more than the others on the density of the herds of mammoths in the large Eastern and Northern plain. On the basis of a daily diet by individual of 50 kg of herbs, corresponding to a surface of 1000 m^2, a herd of 20 individuals, will graze annually an area of about 7,5 km^2 rounded to 10 km^2. The large Eastern plain occupied during glacial maximum a steppe of 1 000 000 km^2, or 100 000 herds (if they were only to eat), let a density of 0.1 herd/km^2. The model of Redmann (1982), which takes into account rightly the simultaneous biomass of all mammals, concludes at a lower density of 0.402 individuals per km^2 or 0,02 herd/km^2. Considering each human group settled in spring next to a herd of mammoths died during the winter, the density of the groups is equal to the rate of herds that will die during the winter. For example, if this rate ranges from 1% to 5%, the group density ranges from 100 to 500 groups on a territory of 500,000 km^2, with a density of 0.007 to 0.035 h/km^2. The population density of human groups is directly linked to the rate of disappearance of the herds of mammoths in the winter, which is not computable. It is then hardly possible to be more precise. If the rate is high, the demography is high, but the time life of the system is shorter (several hundred years for the Mezinian), due to the rapid disappearance of mammoths in the territory. If the rate is low and allows a demographic renewal, compensating for losses, the lifetime of the system can be long (a few thousand years for the Pavlovian and the Eastern Gravettian) but the demography will be lower.

9. The intergroup social rules in a network of hunter-gatherers groups

The change of scale, from the level of the site and the human group, to that of the territory and the network of groups, requires addressing the question of the existence and meaning of inter-group social rules inside a same network.

It is unfortunately clear that the good old Anglo-Saxon anthropological models are of no assistance here, either because their applications at ten thousand kilometers and ten thousand years is not really possible, or because they define mainly “holdall” organizations (band, tribe, chiefdom) or because they focus on specific mechanisms (and exceptional in the eyes of the anthropologist as gift and gift-back, Kula, potlatch, etc.) of intra-group or intergroup social rules and then losing the integration of these processes in the global system. Aware of this missing, Testart (2005) proposed a more systemic approach to the primary societies to try to define social relationships which include and explain these mechanisms of exception. In the classification of

the societies Testart has defined, the "World 1" type correspond to societies that have no storage of consumption goods, of common use objects or of prestige objects. The upper Palaeolithic hunters-gatherer societies are characteristic of these "World 1" type, or societies without storage. It is worth noting that the tendency of the Prehistorians to imagine "near to near" exchanges in place of direct procurement at long or even medium distances, found its epilogue here: these exchange systems are associated with societies with storage defined as 'World 2' and have no existence in "World 1" societies without storage

As said previously, the proper operation of the system does not need any annual scheduled meeting of all human groups in a single place. On the contrary, meetings (and particular group merging the time of a common task) of several groups in multiple meeting points are much more efficient. During these meetings, it is more useful to communicate knowledge (location of fords, passes, flint or fossil shells outcrops, hunting places, etc.) and technical know-how (flint chipping or bone industry manufacturing, new type of tool, element of projectile or handling, new process of hunting or trapping, etc.) than to exchange objects, because the resources to make it are accessible and opened to everybody.

It is not the same case for individuals. Testart (2005) describes two known systems for marriages that are always made between individuals from two different groups:

- The service for the fiancée or the temporary uxorilocality (for example, Inuit populations), is an example of an open system, requiring the fiancé to settle in the group of its promise and get to its service for some time. After this time, he may return to its birth group with his fiancée.

- The marriage classes (Australian aborigines) is an example of a closed system, which requires also to seek marriage in another group, but with permanent obligations for the son-in-law to his mother-in-law, generating long-term marriage constraints, which Testart called precisely "lifetime obligations".

Thus the intergroup operating engine is the mating necessary for the fertility of the group, for its permanent regeneration, generation after generation. It is also the possibility of the increase of the number of groups in the growing favorable environments, or to the merger of groups in the case of decaying unfavorable environment or in case of dire events that decimated a group. Concerning the Inuit, the fiancé comes with its objects in the group of his fiancée and after that the fiancée comes with its objects in the group of the fiancé. It is therefore not the objects that are exchanged here, but individuals with their objects.

The short-time meeting or merging of groups for special common tasks has to be related with the concept of "macrobands" (Birdsell 1953; Wobst 1974), which have a size of about 500

individuals, i.e. about 20 “microbands” as described by anthropologists for Holocene hunter-gatherer groups. Such a concept has to be related more with the restricted planned strategy which has developed at the Holocene transition and after. During the Pleistocene period, the different existing strategies are confirming the difficulty to apply ethnographic models to real prehistoric cases (Kelly 2007).

10. The function of art in the Early Prehistoric Societies, as a mean of social expression

It came time for prehistoric research to store the words 'Palaeolithic art' and 'Sanctuary' in the gilded cages of historiography. That priest Henri Breuil has found the word "sanctuary" in the emotion of the discovery of series of decorated caves and parietal art, we may accept it. But that his successors who many claim laicism, scientific materialism or Marxism, continue to use the word, or even to use it at every opportunity, each time a mobile art artefact is found in a settlement, that is beyond all scientific understanding!

Prehistoric art is an expression that uses the techniques of sculpture (in the round, high relief, low-relief and cut contour), engraving, painting and casting to represent anthropomorphic, animal or anthropozoomorphic Figures, with a realist, schematic or abstract manner, as well as various geometric Figures inspired by the forms of Nature. This expression is applied to worn objects, tools and weapons; to objects placed inside the dwelling, to the dwelling itself (painted, engraved and carved walls of dwellings in rock shelters or cave entrance from the Aurignacian to the Magdalenian settlements; mammoth bones of huts in the open air settlements). It is also applied in deep caves (parietal art) and on open air rock art.

The mobile art and the parietal art are the components of a single system, the socio-symbolic system of the hunter-gatherers of the European upper Palaeolithic, and it is still surprising to see in the 21st century, researchers considering separately and independently these two expression forms, which are but a single. It is probably for sociological reasons: specialists of cave art studying caves or even regions of caves, museum curators are studying rare collections of mobile art objects and archaeologists are excavating the sites…

This expression, or rather these expressions are so present everywhere, in the settlements, in the burials, worn by an individual from a group, into the bottom of the caves, on a rock, integrated in the landscape and without doubt tattooed on the skin. In palaeolithic society, these expressions have specific functions, application modes and naturally reading rules. It is in that way to go, rather than trying to find an interpretation or a "symbolic meaning" to prehistoric art, which has as much symbolisms as individuals being projected on the expression.

Prehistoric Art appears because the function of this expression becomes useful to the prehistoric society, and not for the reasons of any cognitive evolution. When Art appears around 34,000 BP, in the early Aurignacian, its expression is immediate. It is born because a new system is developing, with a network of human groups travelling in a large space with an extended planned strategy, which creates a territory and defines its boundaries. And the new system requires identifying the actors. Art is a marker of the individual (worn art), of the extended family (mobile and parietal art of the dwelling), of the group (mobile and parietal art of the settlement, characteristic of the group) and of a network of groups (parietal art in deep caves and open air rock sites: iconocenoses, complex signs).

The Art could appear earlier, and by the Neanderthals, for functional reasons (and this would probably be the OIS 5) or do not appear because of the absence of common territory (and this is the case for the OIS 4). The iconocenoses of parietal, rock and mobile art, as we have seen previously for the Aurignacian/Gravettian and Magdalenian, are exhibiting territorial characteristics. The iconocenose represents the zoocenoses met and hunted in the territory of the group network. Expressed on the walls of a cave, it means the place belonging to the territory and then to the group network, which recognizes itself (it is travelling therefore on its territory) or not (it must therefore leave it).

Even more, the topography of the cave is a homothetic reduction of the territory represented by the spatial distribution of mammals. M. Raphaël, A. Laming-Emperaire and A. Leroi-Gourhan had seen it but they have erroneously interpreted it: the large galleries for the great plain; entries and passages for the valleys, diverticula and bottoms for caves with, for each of them, their respectively associated fauna: bison, aurochs, horse for the first; reindeer, red deer for the second, bear, feline and cave animals, including the man who is entered into for the third.

The decorated caves like the rock art areas are not located randomly in the territory: they mark it. And probably not like a church in the center of the village! Rather on the periphery of the territory or on their travelling and access paths, taking advantage of the presence of a karst massif. Reintroduced in the socio-symbolic system of the hunter-gatherer society, Art is no longer reserved for an isolated, secret and demiurge sanctuary, it is integrated in the group day life, in its dwelling and in its essential components, for which it is making sacred the most critical ones: fertility of the group (mostly female and male also sexual expressions) but also fecundity of the hunted animals species, basis of the food resources of the group (Iakovleva 2012) : woman-mammoth (Mezinian), woman-reindeer (Magdalenian of Laugerie-Basse), woman-horse (female representations on the foal incisors of Middle Magdalenian of Angles sur l'Anglin and La Marche), woman-bison (Gravettian of Pech - Merle, Aurignacian of Chauvet).

11. Conclusions

The key for modeling the socio-economic systems of the human groups of middle and upper Palaeolithic of Eurasia is probably in our ability to reconstruct the annual food cycle of human groups in their circulation area. The main food in ice age climate being a meat food, it is from an ethological knowledge and from the reconstitution of zoocenoses that will emerge the knowledge of food resources strategies in the annual cycle and the socio-economic organization of human groups. Then, a wild fauna of low mobility, living in small groups in a small territory, may be associated with small human groups of low mobility, living in a small territory, on a ubiquitous annual cycle, and producing a low mobile and low productive material culture without the need of any 'artistic '.expression. At a high mobility fauna, living in a cold steppe and/or steppe tundra environment, consisting of many herds performing seasonal migration, may be associated with most numerous size groups belonging to a high population density network, travelling on a significant but variable territory depending on available resources, applying an extended planned strategy on a highly specialized annual cycle, manufacturing a mobile and productive industry and marking its individuals, its groups, and its territory by an important 'artistic' expression for which the relationship to the hunted animal is basic. The seasonal mobility strategy appears as a mixed system between the two previous strategies, facilitating the transition from one to the other, according to the climate improvement or deterioration. In this context, the semi-sedentary strategy based on the mammoth economy, represents a remarkable exception, that it anticipates the future by short-lived inventions. Only the Holocene environment, with the stability of the system and the diversification if not the enrichment of food resources, will enable a growth of population density in a planned restricted strategy, which announces in the regions with a high plant and animal diversity, the sedentarity of some groups.

References

Allain, J., R. Desbrosse, J.K. Kozlowski and A. Rigaud. 1985. “Le Magdalénien à navettes”. *Gallia Préhistoire* 28/1: 37-124.

Binford, L.R. 1993. “Bones for stones: considerations of analogues for features found on the Central Russian plain”. *From Kostienki to Clovis. Upper Paleolithic- Paleo-Indian adaptations*. Plenum press. New York and London, 101-124.

Binford, L.R. 1980. “Willow smoke and dog’s tails: Hunter-Gatherer Settlement Systems and Archaeological Site Formation”. *American Antiquity* 45(1): 4-20.

Birdsell, J.B. 1953. "Some environmental and cultural factors influencing the structuring of Australian aboriginal populations". *American Naturalist* 87: 171-207.

Bordes, F. 1968. *Le Paléolithique dans le monde*. Paris: Hachette. L'Univers des Connaissances.

Bosselin, B. and F. Djindjian. 2002. "Un essai de reconstitution du climat entre 40 000 BP et 10 000 BP à partir des séquences polliniques de tourbières et de carottes océaniques et glaciaires à haute résolution". *Archeologia E Calcolatori* 13: 275-300.

Castel, J.C., J.P. Chadelle and J.M. Geneste. 2005. "Nouvelle approche des territoires solutréens du Sud-Ouest de la France". In *Territoires, déplacements, mobilité, échanges pendant la préhistoire. Terres et hommes du Sud*, edited by J. Jaubert and M. Barbaza, 279-294. Éditions du Comité des travaux historiques et scientifiques.

Djindjian, F. 1995. "L'influence des frontières naturelles dans les déplacements des chasseurs cueilleurs au Würm récent". *Prehistoria Alpina* 28 (2): 7-28.

Djindjian, F. 1996. "Les industries aurignacoïdes en Aquitaine entre 25 000 BP et 15 000 BP". In *Preprints du Colloque XI du XII° Congrès UISPP Forli (Italie)*: *The late Aurignacian*, 41-54. Forli: ABACO, Vol. 6.

Djindjian, F. 2004a: "L'Art paléolithique dans son système culturel: essais de corrélation. I. Chronologie, «Styles» et «Cultures»". In *L'Art du Paléolithique supérieur, Colloques n°8.2 & 8.3 du XIV° Congrès International UISPP*, edited by M. Lejeune and A.C Welté, 249-259. Liège Septembre 2001. Liège: ERAUL, 107.

Djindjian, F. 2004b: *L'Art paléolithique dans son système culturel. II. De la variabilité des bestiaires représentés dans l'art pariétal et mobilier paléolithique*. In *Colloque La Spiritualité, Liège décembre 2003*, 127-152. Liège: ERAUL 106.

Djindjian, F. 2009a. "Le concept de territoires pour les chasseurs cueilleurs du Paléolithique supérieur européen". In *Actes du XV° Congrès UISPP, Lisbonne, septembre 2006, Session C16, vol.3: "Le concept de territoires pour les chasseurs cueilleurs du Paléolithique supérieur européen*"; edited by F. Djindjian, J. Kozlowski and N. Bicho, 3-25. BAR, Intern. Series, n°1938. Oxford: Archaeopress.

Djindjian, F. 2009b. "L'art pariétal et l'art mobilier pour l'identification des territoires de peuplement dans le Paléolithique supérieur européen: l'approche par les bestiaries". In *Espaces symboliques dans l'art préhistorique, Actes du XV° Congrès UISPP, Lisbonne, 4-9 septembre 2006, Session C28, vol.40*, edited by F. Djindjian and L. Oosterbeek, 3-20. BAR Intern. Series, n° 1999. Oxford: Archaeopress.

Djindjian, F. 2010. "Territoires aurignaciens en Europe occidentale: faciès industriels et manifestations artistiques".In *Colloque 2-4 Juin 2005: Université de Toulouse-le Mirail: Art rupestre et communications: espaces symboliques et territoires culturels*. *Préhistoire, Art et Sociétés, Revue de la société préhistorique Ariège Pyrénées*, tome LXIII-2008: 17-32.

Djindjian, F., I. Sapozhnikov, V. Stepanchuk and G. Sapozhnikova. 2006: "Upper palaeolithic chronology, cultural facies and economic complexes of the northern black sea area". In *La cuenca mediterranea durante el paleolitico superior 38.000 – 10.000 años. IV° Simposio Cueva de Nerja & Colloque UISPP Commission 8. Nerja (Andalousie), novembre 2004*, edited by J.L. Sanchidrian Torti, A.M. Marquez Alcantara, J.M. Fullola and I Pericot, 46-59. Málaga: Fundacion Cueva de Nerja.

Djindjian, F, J. Kozlowski and M. Otte. 1999. *Le Paléolithique supérieur en Europe*. Paris: Armand Colin.

Efimienko, P.P. 1953. *Les sociétés primitives* (en russe). 3è édition. Kiev.

Efimienko, P.P. 1958. *Kostienki 1* (en russe). Moscou-Leningrad: Nauka.

Dobosi, V. 2009. "Constancy and change in Upper palaeolithic, Hungary". In *Actes du XV° Congrès UISPP, Lisbonne, septembre 2006, Session C16, vol.3*: "*Le concept de territoires pour les chasseurs cueilleurs du Paléolithique supérieur européen*", edited by F. Djindjian, J. Kozlowski and N. Bicho, 123-134. BAR, Intern. Series, n°1938. Oxford: Archaeopress.

Farizy, C., F. David and J. Jaubert. 1994: *Hommes et bisons du Paléolithique moyen à Mauran (Haute-Garonne)*. Paris: CNRS, XXXème supplément à Gallia Préhistoire.

Fitzhugh, B. and J. Habu. 2002. "Beyond foraging and collecting". In *Evolutionary change in Hunter-Gatherer settlement systems*. New-York: Plenum.

Gaudzinski, S. 1995. "Wallertheim Revisited: a re-analysis of the Fauna from the Middle Palaeolithic Site of Wallertheim (Rheinhessen/Germany)". *Journal of Archaeological Science* 22: 51-66.

Gvosdover, M.D. 1995. *Art of the mammoth hunters; the finds from Avdeevo*. Oxford: Oxford Monograph, 49.

Haesarts, P. 1990. "Evolution de l'environnement et du climat au cours de l'Interpléniglaciaire en Basse-Autriche et en Moravie". In *Feuilles de pierre. Les industries à pointes foliacées du Paléolithique supérieur européen*, 523-538. Liège: ERAUL, n°42.

Hassan, F. A. 1981. *Demographic archaeology*. New York Academic Press.

Iakovleva, L. 2009. "L`art mézinien en Europe orientale dans son contexte chronologique, culturel et spirituel". *L`Anthropologie* 113: 691 -752.

Iakovleva, L. 2012. *L'art des origines de l'Ukraine* (en ukrainien). Kiev: Korvinpress.

Ivanova, I. 1969. "Etude géologique des gisements paléolithiques de l'U.R.S.S". *L'Anthropologie* 73: 5-48.

Jaubert, J., M. Lorblanchet, H. Laville, R. Slott-Moller, A. Turq and J.Ph. Brugal. 1990. *Les chasseurs d'Aurochs de La Borde - un site du Paléolithique moyen (Livernon, Lot)*. Paris: MSH, Documents d'Archéologie Française nº 27.

Jaubert, J., B. Kervazo, J.Ph. Burgal, P. Chalard, Ch. Falgueres, M. Jarry, M. Jeannet, C. Lemorini, A. Louchart, F. Maksud, V. Mourre, Y. Quinif and C. Thiebaut. 2005. "Coudoulous I (Tour-de-Faure, Lot), site du Pléistocène moyen en Quercy. Bilan pluridisciplinaire". In *Données récentes sur les modalités de peuplement et sur le cadre chronostratigraphique, géologique et paléogéographique des industries du Paléolithique inférieur et moyen en Europe, Actes du Colloque International de Rennes, 22-25 septembre 2003*, edited by N. Molines, M.H. Moncel and J.L. Monnier, 227-251. BAR International Series, n° 1364.

Jochim, M. A. 1976. *Hunter-gatherer subsistence and settlement: a predictive model*. New York: Academic Press.

Keene, A. S. 1979. "Economic optimization models and the study of hunter-gatherer subsistence settlement systems". I*n Transformations: mathematical approaches to culture change*, edited by C. Renfrew and K. L. Cooke, 369-404. New York: Academic Press.

Kelly R.L. 2007. *The foraging spectrum: diversity in the hunter-gatherer life ways*. New-York: Percheron Press.

Klima, B. 1994. *Pavlov I, Excavations 1952-53*. Liège: ERAUL n°66.

Klima, B. 1995. *Dolni Vestonice II, Ein Mammuthjägerrastplatz und seine Bestattungen*. Liège: ERAUL n°73.

Niven, L., T.E. Steele,W. Rendu, J.B. Mallye, S.P. McPherron, M. Soressi, J. Jaubert, J.J. Hublin. 2012. "Neandertal mobility and large-game hunting: The exploitation of reindeer during the Quina Mousterian at Chez-Pinaud Jonzac (Charente-Maritime, France)". *Journal of Human Evolution* 63: 624-635.

Otte, M. 2011. "Contacts entre Afrique du Nord et Europe durant la Préhistoire". In *Actes du colloque international Préhistoire maghrébine, Tome I, Tamanrasset, 5-7 novembre 2007*, 193-207. CNRPAH.

Oliva, M. 1984. "Le Bohunicien, un nouveau groupe culturel en Moravie. Quelques aspects psychotechniques du développement des industries paléolithiques". *L'Anthropologie* 88(2): 209-220.

Oliva, M. 2009. *Milovice, site of mammoth people below the Pavlov hills*. Anthropos n°27. Brno: Moravske Zemske Museum.

Praslov, N.D. and A.N. Rogatchev (eds.). 1982. *Le Paléolithique de la région de Kostienki-Borschevo sur le Don 1879-1979* (en russe). Leningrad: Nauka.

Redmann, R.E. 1982. "Production and diversity in contemporary grasslands". In *Paleoecology of Beringia*, edited by D.M. Hopkins, J.V. Matthews Jr., C.E. Schweger and S.B. Young, 223-239. New York: Academic Press.

Rendu, W., D. Armand, E. Pubert and M. Soressi. 2009-2010. "Approche taphonomique en cémentochronologie: réexamen du niveau 4 du Pech-de-l'Azé I (Carsac, Dordogne, France)". *Paléo* 21: 223-236.

Rogatchev, A.N. 1955. *Kostienki IV, habitat préhistorique sur le Don* (en russe). MIA, n° 45.

Slimak, L. 2008. "The Neronian and the historical structure of cultural shifts from Middle to Upper Palaeolithic in Mediterranean France". *Journal of Archaeological Science* 35 (8): 2204-2214.

Smith, P. E. L. 1966. *Le Solutréen en France*. Publications de l'Institut de Préhistoire de Bordeaux. Mémoire n°5. Bordeaux: Delmas.

Stepanchuk, V.N. and V.Y. Cohen. 2000-2001. "Middle to Upper Palaeolithic transition in the Eastern Europe". *Préhistoire Européenne* 16-17: 111-132.

Svoboda, J. 1994. *Paléolit Moravy à Sleszka (The Paleolithic of Moravia and Silesia)*. Brno: The Dolni Vestonice Studies, vol. 1.

Testart, A. 2005: *Eléments de classification des sociétés*. Paris: Errance.

Utrilla, P. 1997. "Le couloir de l'Ebre après le pléniglaciaire: influences méditerranéennes et atlantiques". In *Le monde méditerranéen après le pléniglaciaire 18 000 - 12 000 BP, Actes du colloque international de Banyoles 1994*, edited by J.M. Fullola and N. Soler, 431-443. Gérone: Centre d'investigations archéologiques, n°17.

Valoch, K. 1996. *Le paléolithique en Tchéquie et en Slovaquie*. Série Préhistoire d'Europe n°3. Grenoble: Jérôme Millon.

Wobst, H.M. 1974. "Boundary conditions for Palaeolithic social systems: a simulation approach". *American Antiquity* 39(2): 147-178.

Beyond Prediction. Artificial Neural Networks and Multiscalar Approaches applied to the study of historical dynamics

Joan Negre[1]
Rocío Gómez[1]

[1] Universitat Autònoma de Barcelona. Spain

Abstract

Irruption of new technologies in scientific research has contributed to an improvement in results, however they have also been abused, especially in disciplines not used to applying these technologies, such as Archaeology. In this communication we consider the combined use of different tools as a means of analyzing specific historical problems. In the first place, we highlight the use of Artificial Neural Networks as a very effective set of tools in order to generate predictive models of settlement distribution. But we would also like to think about other possibilities this technique offers when willing to expand our samples in order to observe spatial patterns that might be blurred by time and material record destruction. Once these patterns have been separately analyzed, Ripley´s K function becomes one of the most useful tools for their analysis and diachronic comparison, as it presents the divergence with regard to the expected pattern.

Keywords: *Social Complexity, Artificial Neural Networks, Ripley's K Function, Anisotropy*

1. Social complexity

The notion of complexity is initially bound to the inability of understanding and describing the reality we want to study. In many cases, this notion eventually shows up as a synonymous for 'complicated', making that concept one of the observer and not of the observed thing. Just a step further, we find those who claim to understand the problem, which in this case is the society they observe, but they say that it is conditioned by such a number of variables and relations that it is impossible to control and work with it. Thus appear both of the initial versions of complexity that we are going to try to overcome: the subjective vision of reality due to our

inability to describe it, and the objective one, based on the new awareness of multiple connections of the phenomenon which do not allow its study.

The notions of complex and complicated do not have a direct connection, since we can find, for instance, an elaborated n-dimensional chess game which would certainly be very complicated and exceed our intellectual capacities, but nevertheless it could not be considered as complex. One of the necessary characteristics for complexity is just that one of its ability to generate, in a certain reality, emerging elements as well as new connections between those elements. Other features that define it are, for example, some of the basic processes that take place within complex systems such as complication and simplification of its composing parts, either by the widening of new elements which superimpose over the earlier structure, or by the disappearance of some of those elements in favour of others which already existed or were also emergent. In a very simple example, we can understand that de disappearance of the numerous noble powers, characteristic of the feudal period in favour of an absolute monarchical sate power, can be considered a necessary simplification for the emergence of the complex modern society.

When setting out these initial notions of the complexity concept, the higher presence of formal traditional approaches which obviate the reflexive side, inherent in the social analysis, reveals more evident. Those approaches are the ones which describe and abstract a simplified model of reality through different proposals such as the general systems theory or some diffuse logical schemes, usually mixing the method and the aims up. The use of these tools falls on the possibility of being helped to describe reality, as in every model, but in any case the result of its application can be considered an aim, but a tool for our own reflexion. As it happens in the case of statistics applied to our field, these tools become useful for the researcher's arguments, but in any case as demonstrative methods (Abelson 1998, 199). The limitations of an absolutely formal complexity concept use reveal evident when we realize that, in the best of cases, we can only describe the consequences we have observed, leaving apart the elaborated process which defines its causal structure.

Niklas Luhmann is the first one to propose a notion of complexity bound to the need of restricting the wide range of possibilities that appear in a self-organized system which constantly provides new elements and emergent connections (Luhmann 1998: 46-47). Therefore, human social complexity is the greatest exponent of the complexity concept, with distinctive resources and complexity mechanisms which are inseparable of every case of study. With these elements, what we call a human social ecosystem is created. Within it, all the relational and self-organizing features of that society would develop, and we should be able to reconstruct them from the materiality produced by that group in all social fields. In the particular case of social formations, we can find some of the above mentioned characteristics as

complexity defining. That would be the case of the populating between settlements, communications, and production areas, which is able to reproduce, widen or simplify depending on the needs of the social group managing it. The connections made within all the forming elements and its intern self-organizing dynamics define a perfect example of a complex system.

The treatment of some of the elements we have worked with, such as the settlement and organization of space as formalized and integrated data in a scientific explanation, is one of the necessary in favour of a better comprehension of historical phenomena and their complexity. One of the most developed ways with regard to this aspect is the one of the complex systems analysis through the General Systems Theory, although it does not completely fit our needs. One of the elements that we think is to be clarified in that theory, in what matters to its use for historical disciplines, is in particular the one of the possibility that a systemic architecture could be modified and continue being used without some of its systems. This way happens in social formations where, for example, the populating system is based in three contextual subsystems by establishing a strong reductionism: the settlement network, the main production spaces destined to survival and group reproduction, and the communication ways.

Regarding our proposal, the three mentioned elements are related in a symbiotic way and they cannot exist with the lack of any of the others. Evidently, they would not exist without the presence of a social group. Those are the ones which develop, build and maintain them by making of the elements a consequence of specific social actions led to the structuring of a social functional society. The disappearance of any of three elements would mean the breaking of the balance inside of it, which is in constant entropy, and therefore the complete social formation would stop working as such. Changes or modifications in this trinomial are decisions made with a high grade of reflexion and preparation, as in them lie the survival of the group. This reciprocity leads us to set out an adaptive conception of the system to its context, which would reset in order to maintain the explained balance, giving rise to what cybernetic technologies last stages is known as a meta-system.

The meta-systematic approach of society starts from the biological analogy, and it allows us to define complex and organized social formations, mainly defined by their relation with space and the development of certain basic functions such as their preservation, the interrelation between their component systems and the reproduction of that same structure. It is all about an auto-poietic system defined by its organization rather than by a conglomeration of functions (Maturana and Varela, 1994: 107-117). In the light of this last concept, a social formation is defined as auto-poietic by its auto-organizational and auto-reproductive capacity, and thus can exist as it keeps its organization and adapts to the environment where it develops. Then this is about an auto-referential system, in which the same social formation itself is the one that

constructs, upholds and reproduces the elements which it is composed by (Luhmann 1998: 205-208). If we are aware that inside a society a great number of social agents, organizational systems and control structures, all connected among them, take part and that they have their own dynamics and autonomy, we will be able to conceive why do we set out the historical analysis as a fight between the most absolute complexity and our need to understand it.

2. Fuzzy logic and artificial neural networks

One of the elements that help us to define the spatial dimension of our meta-system is the creation of continuous models which represent the probability of an area of containing this complex construct. Also, the tools which, thanks to modern computing have been developed to create these predictive models, have evolved very rapidly over the last decades. Nowadays, one of the most avant-garde procedures regarding work with this kind of data and information is the use of Artificial intelligence (AI), mainly by applying Artificial Neural Networks (ANN), destined to the analysis of complex variable sets, which have led to the birth of an epistemological system named Fuzzy Logic (FL). It appeared in the sixties decade, mainly sustained by the works of Lofti A. Zadeh, a mathematician, engineer and one of the fathers of the Artificial Intelligence and Computing Sciences (Zadeh 1965). Its operational foundations allow us to present new values, inferred from a series of incomplete or ambiguous data (fuzzy data), by working with models, similar to the probabilistic ones, where values vary between 0 and 1. The main difference with probability models lies in the values we obtain when it is applied, being what the FL provides uncertainty while the second one would be more aimed to the research of the expectancy threshold. While one deals with probabilities, the other does it with possibilities.

Another fact is that the ANN are directly connected with the development of Cybernetics and inner information flows inside a system (Wiener 1965), and mainly with the AI and learning and decision taking automation processes (McCarthy 1959). It is about net structures which process a set of data and infer on a result. They emulate operational and logical processes observed for the Biological Neuronal Nets. In this case, the supervised and non-supervised intelligent systems based on ANN have been strongly developed during the last decades in order to improve the learning processes and result reproduction by inference, characteristic of the model creation.

Different techniques and methods of both approaches allow trying to make these domains converge in certain formalizing connectivities which enable us to solve old and new problems under new points of view. These two well-instrumentalized theories working together, are

already visible in different engineering and industrial technology fields, where different intelligent systems, which manage their production means, have come from. Generally, the processes which follow this working pattern are three: the incorporation of information to the system as diffuse values -or learning process -; the execution of resourceful operations such as the integration, comparison, adjustment or repetition, which the *machine* uses to create a new memory from where it generates the results of the ANN; and finally, the response process of the processed information, which will be integrated again as qualitative adjusted data. The union of these three processes is named Neuro-diffuse System, aimed to the construction and operation of intelligent equipment with a wide range of application, which has been enriched by the new advances in this area, such as the evolutive programming or the genetic algorithm (Amozurrutia 2006: 125).

Neuro-diffuse Systems created from the application of ANN are based in a schematic model consisting of three corresponding layers to the three processes that define them: the input layer, the hidden layer and the output layer, and the different interconnections established within their artificial neurons. The input layer would be defined by the different values observed and turned into a diffuse scale from 0 to 1, whereas the hidden layer would work with the calculating nodules in the system which carry out the connection research operations. Finally, the obtained result in the output layer is represented by one or more artificial neurons, or dendrite, which would transform the diffuse outcome of the system into answers or labels previously set by the user, either into the supervised systems, or random in the non-supervised ones. By analogy, the operation of the Neuro-diffuse System would be similar to that of our brain when observing a piece of chocolate cake; we are not really looking at the cake, but from the incomplete data we can observe how one of its pieces is, then our neurons are able to identify it and make the brain part where we store "piece of chocolate" react.

As we have seen, in the field of Social Sciences, and more particularly in the field of historical disciplines, it is strongly constrained by the inherent complexity to the object of study and to the methods that it obliges to develop. Among them, one of the most remarkable and newly incorporated to historical research would be the use of the FL and the ANN, which allow working with the heterogeneous, and often incomplete, data characteristic of the historical research. Some of the most common applications can be found in the world of Archaeology, where we can create this type of AI systems for three main kinds of problems: the search and recognition of taxonomic attributes inside a an archaeological artefact sample; the development of extremely accurate predictive models which allow us to identify the different ways of social settlement of space; and the improvement of the querying systems functionalities, linked to data bases.

In the Neuro-diffuse Systems methodological base, mainly during their learning phase, we find some important answers in the identification of interconnections between settlements and land in a specific period with a high grade of precision (Deravignone and Macchi 2006:130-131). Our interest is not just on the result itself, but in the study of the whole collecting, learning and data treatment process that the ANN managing programs allow us to analyze in a graphical way. From these, we will be able to reach other geospatial analysis functions, as Ripley's K algorithm (Bevan and Conolly 2006), in order to compare the various obtained samples in a diachronic way in different spatial scales. The possibilities which offer the Neuro-diffuse Systems, yet to be consolidated, will enable us to automate certain levels of research over social complexity which reveal themselves unapprochable without computing support. Thanks to the possibilities of the developed tools in this field, now we are able to define with accuracy the spatial limits of a social meta-system. Therefore, the combined application of this knowledge with the different geostatistic functions characteristic of Spatial Analysis, definitely allow us to study the social historical processes with much more definition.

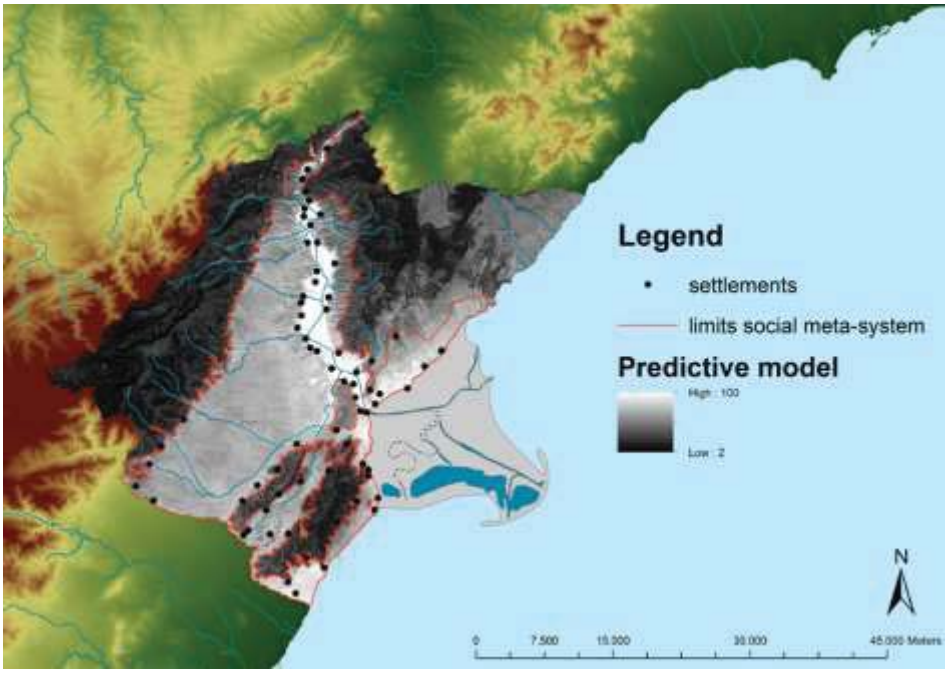


Figure 1: spatial limits of a social meta-system: the medieval Islamic Ṭurṭūša (Tortosa, Catalonia)

3. Multiscalar approaches through Ripley´s function

This multi-distance spatial pattern analysis function has been developed (Ripley 1977) in order to identify aggregation and segregation processes of a net of points in different scales. Taking an arbitrary point in the distribution, this algorithm is defined by an intensity process λ (frequency)

which identifies the average number of individuals in a radius *s* around any of the elements. Therefore, the number of points of a Poisson process in that circle will be $\lambda\pi s^2$, and it would establish the measurement of comparison from which deviation regarding random distribution can be calculated. This divergence is the one measured by the Ripley's K function, which combines frequency and distance to obtain a summary of spatial dependence. That is to say, the centroid dispersion of the entity when the size of the neighbourhood changes, in a distance range established by the number and value of the radii, established at the same time around the point of origin of the analysis (Pélissier i Goreaud 2001:101).

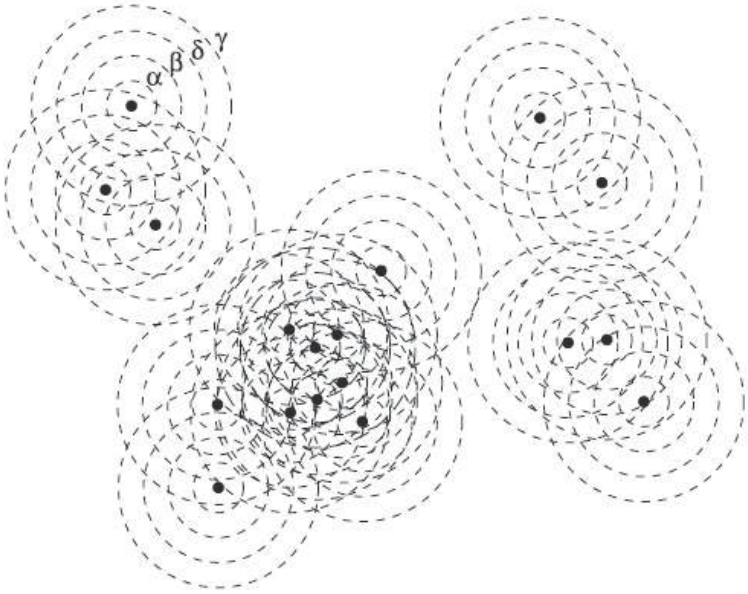


Figure 2: *s* radius circles around every entity in the spatial distribution net (Macchi 2009:240)

When the value returned by this function is higher than expected for a random distribution, the network presents a grouped at this point of analysis scale, while if it would be lower it would be a pattern of uniformity or dispersion. Formally, we can express this function as:

$$\hat{K}(s) = \lambda^{-1} n^{-1} \sum_{i \neq j} I(d_{ij} < s)$$

Figure 3: Ripley's K Function

where d_{ij} is the Euclidean distance between the *i* and *j* points in a data set of *n* points. λ is the average density of points, generally estimated as *n*/*A*, where *A* is the area of the region containing all points.

There are trust tests from the performance of different symmetrical permutations in the test to compare the results with, apart from the possibility to adjust the values according to a variable depending on the sample. In order to study the results of Ripley's K function, it is usual to work over the linearization of this function, which allows diachronic comparison of the different results obtained for every spatial structure in a simple and visual way. As always, the aim of this function is not only the final *K* value, but rather the graphic analysis, the identification of its key points and the argument about its variability.

$$\hat{L}(s) = (\hat{K}(s)/\pi)^{1/2}$$

Figure 4: linearised form of Ripley's K Function

This function allows, apart from comparing different spatial distributions -either settlement, fortification, parish, or any other kind of settlement nets -, the choice, within those mentioned, other possible sub-nets. Nowadays, the GIS programs are, again, the ones which enable us to polish the results of this spatial function by offering the possibility of utilizing the usable spatial polygon of our territory as a reference framework for analysis, as a result of the analysis made from the application of neuronal net systems. The main limitations that we have to overcome now are focused on the framing of these approaches in the Euclidean space plan by avoiding the characteristic anisotropy of geographical realities and social agents which use them. The synthesizing of spatial structure of a settlement distribution net in a lineal-graphical way makes it possible to compare these processes in a diachronic, and therefore, to study the historical dynamics in a much more accurate way.

Some examples of the use of this technique, despite not taking the physical space demarcation that comprises this social system into account yet, can be found in Giancarlo Macchi works about restudying the process of *incastellamento* in Tuscany (Macchi 2009: 241-243), in the study of different social underlying processes that defined the spatial structure of the Kythera island (Bevan and Conolly 2006), or also in the study of the natural factors which have the strongest influence over the settlement distributions in the area of Negev (Israel) with the combined use of this function and Moran's I (Winter-Livneh *et al.* 2010: 293).

4. Conclusions

As we have observed on the previous pages, two are the main concepts which we have tried to deal with in this study. In the first place, the importance of understanding the social complexity that defines all the historical dynamics cannot be analyzed if it is not in a scientific way. The study of elements that form a social meta-system and its inner and outer connections can only be done this way. We present a methodological proposal; we are pretty sure that it is not the only possible one. In second place, despite all the advances we can make regarding the study of these processes in a spatial dimension, the need of a deep reflexion about the study of geographical reality as an Euclidean space is becoming more and more evident. Only by representing our data, either regarding distances, frequencies or density from anisotropic space congruent models which define our geographical reality, we can end up establishing certain correct measurements of the processes that those data define. Thus, only through the measurement of spatial consequences of the historical dynamics we will be able to understand them, and above everything, to compare them, as it is the most powerful tool for historiographical advance.

References

Abelson, R. P. 1998. *La estadística razonada: reglas y principios*. Barcelona: Paidós.

Amozurrutia, J. 2006. Lógica borrosa y redes neuronales artificiales aplicadas a las ciencias sociales. *Estudios sobre las culturas contemporáneas*. 24: 119-167.

Bevan, A. and J. Conolly. 2006. Multis-scalar approaches to settlement pattern analysis. G. Lock and B. Molyneaux (eds.) *Confronting Scale in Archaeology: Issues of Theory and Practice*. New York: Springer. 217-234.

Deravignone, L. and G. Macchi. 2006. Artificial Neural Networks in Archaeology. *Archeologia e Calcolatori*. 17: 121-136.

Luhmann, N. 1998. *Sistemas sociales: lineamientos para una teoría general*. Rubí: Anthropos Editorial.

Macchi, G. 2009. *Spazio e misura. Introduzione ai metodi geografico-quantitativi applicati allo studio dei fenomeni sociali*. Siena: Edizioni dell'Università.

Maturana, H. and F. Varela. 1994. *De máquinas y seres vivos. Autopoiesis: la organización de lo vivo*. Santiago de Chile: Editorial Universitaria.

McCarthy, J. 1959. Programs with Common Sense. *Mechanisation of Thought Processes, Proceedings of the Symposium of the National Physics Laboratory*. London: U.K. Her Majesty's Stationery Office. 77-84.

Pélissier, R. and F. Goreaud. 2001. A practical approach to the study of spatial structure in simple cases of heterogeneous vegetation. *Journal of Vegetation Science*. 12: 99-108.

Ripley, B. 1977. Modelling spatial patterns. *Journal of Royal Statistical Society*. 39: 172-212.

Wiener, N. 1965. *Cybernetics or control and communication in the animal and the machine*. Cabridge: MIT Press.

Winter-Livneh, R., T. Svoray, and I. Gilead. 2010. Settlement patterns, social complexity and agricultural strategis during the Chacolithic period in the Northern Neveg, Israel. *Journal of Archaeological Science*. 37: 284-294.

Zadeh, L. A. 1965. Fuzzy Sets. *Information and Control*. 8: 338-353.

The pile dwelling of Villaggio delle Macine: an analysis of the spatial differentiation of social activities

Katia Francesca Achino[1]
Micaela Angle[2]
Juan Anton Barcelò[3]
Federica Micarelli[4]

[1]PhD student at Universitat Autonoma de Barcelona.
[2]Soprintendenza per i Beni Archeologici del Lazio.
[3]Profesor titular de prehistoria, Universitat Autonoma de Barcelona.
[4] Scuola di Specializzazione, Università di Roma La Sapienza.

Abstract

The Villaggio delle Macine is located in Alban Lake (Castelgandolfo, RM), into which it was still immersed at the moment of discovery, in 1984; after a further lake's waters drop during 2009, two survey campaigns have given start to a study intended to analyze the archaeological artefacts dispersion, distinct for typologies (pottery, game, lithic tools and piles), in attempt to establish if differentiations related to the activities carried out were identifiable, and to identify possible structures or specialized areas. The study has shown the specialized areas presence in pursuance of particular economical and social activities. In this contribution we show the preliminary results of research on two different sectors of site and we introduce some of future perspective, linked with theories of stochastic processes that are the base of geostatistics.

Key words: *pile dwelling, spatial analysis, Villaggio delle Macine*

1. Introduction

The site of Villaggio delle Macine is an exceptional case of pile dwelling for the central Tyrrhenian italian area, dated to Latest Early Bronze age – Early Middle Bronze age (XIX-XVI BC.) for its available datasets and width: it evolved with an almost continuous palisade which covers about one hectare (Chiarucci 1985; 1986-88; 1995). The Villaggio delle Macine is part of a settlement cathegory that in Lazio particularly includes the dwelling sites nearby the Bracciano Lake, the Piediluco basin and the ancient, now drained *Lacus Velinus*'s banks. Most of these submerged villages' discoveries has been accidental and subjected to archaeological surface investigations and artefacts collection; some exceptions are the settlements of Campo di S. Susanna (Rieti) and Vicarello (Bracciano), where excavations were made that led to the identification of pottery fragments, human and animal bones, burnt plants fragments, millstones and grindstones, concotto plasters and palaeosoil samples. Presently, none of these settlements seems to have played such a relevant role as Villaggio delle Macine, except perhaps Campo di S. Susanna's site, which probably had a leading position comparing to remaining sites located

nearby *Lacus Velinus*'s banks; in fact, these latter might have been satellites of the former.

At Villaggio delle Macine many different findings were found, such as piles, *Grotta Nuova facies* ceramics, bronze artefacts (axes and daggers), lithic industry (lithic cores, flakes and *débitage*), bone industry (deer bones worked to obtain axe handles and awls), clay fishing weights and a big number of millstones and grindstones (from which the site's toponym derives) (Angle 2007; Angle *et al*. 2002). The studies about game remains, fruits and seeds discovered in the settlement (Angelini *et al.* 2006; Angle 2007; Carra *et al.* 2007; Zarattini 2001) show that the site had a subsistence economy, based not only on summer-autumn agricultural productions (cereals and leguminous cultivation) but also on collection activities (semi-domestic and wild fruits), hunting (in particular deer and roe), breeding and fishing. The results of study which we present derived from a comparison between two sectors of site: the first one (Sector A), emerged thanks to lake's water drop of 2009, is set nearby the shore, instead the second one stratrigraphically investigated from 2000-01, is in the inner area, about 30 m away (Sector B) (Achino *et al*. 2011).



Figure 1: Exact location of sectors A and B

2. Spatial analysis of artefacts distribution in two sectors of site

We analyzed the archaeological artefacts dispersion, distinct for typologies (pottery, game, lithic tools and piles), in attempt to establish if differentiations related to the activities carried out were identifiable. The study has led to interesting results (Achino *et al*. 2011), showing the specialized areas (micro scale) presence in pursuance of particular activities:

- Sectors devoted to cereals and crops blending and milling

- Waste areas, i.e. sectors where there were ample game remains and a lesser extent of ceramic fragments; the bone finds usually are classifiable in 4 categories of meat yield and the first category, the dominant, is poor in these areas; this certifies the presence of remnants residues of previous activities, such as the butchery, which took place elsewhere, or the preparation and consumption of remaining portions, with the scarp accumulation which constituted the real discharge.

- Sectors for treatment of game remains: it is likely that certain medium-small sized-animal categories could get wholly into the settlement and were partially cooked for deboning.

- Ateliers, i.e. all sectors in which all *cháine operatoire*'s stages of lithic industry were present; such practice is confirmed by lithic cores, core residues/ revitalizations and *débitage* in different sectors with various products depending on the processing stage reached.

- Some pottery classes have been established, on the basis of the possible functionality of the detectable ceramic forms (Recchia 1997a, 1997b; Jhul 1995) and, for the majority of artefacts, which were very fragmented, we have also carried out an analysis of fragments' thickness; the combination of these data allowed us to distinguish 3 categories:

- Ceramics form suitable for consumption (cups, mugs, medium or small-sized bowls; fragments with thickness between 0,1-0,7cm)

- Ceramics form suitable for preservation (big containers like *dolia;* fragments with thickness between 1,1-4cm)

- Ceramics form suitable for cooking (like different pan types; fragments with thickness between 0,8-1cm)

About the ceramics distribution in two sectors, the sector A is the first one for percentage of fragments attributable to every typological forms, instead in the sector B we can notice an average number of fragment which don't exceed 100. For the distribution of predominant forms between the 3 classes, there is a clear gap between two sectors, as in the area A almost only kitchen or tableware forms are present, in particular in west part; in fact, in 2 squares at east there is prevalence of elaborate and consume forms; instead, in the sector B there is a large majority of this latter kind of forms and in just four squares we can see forms used as kitchen/tableware.

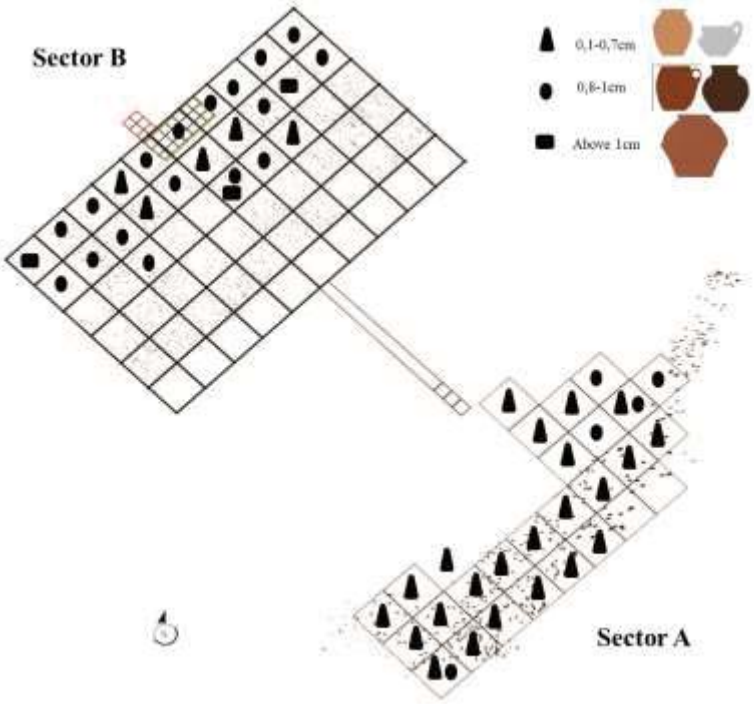


Figure 2: Distribution of pottery categories

However there are also three squares with a fragment's prevalence of forms used to conserve, big dolia. Sectors devoted to cereal and crop blending were identified, in both areas, at east, thanks to presences of hotplates; for the general concotti we could notice a group located at west in the sector A, probably in connection with combustion areas. Instead, the activity of milling is indicated by the presence of millstones that gave the name to the site. This material class was used as a multitasked element, linked to hide and fiber's processing, for flour milling and also to threshing of flax and hemp in Italian pile dwelling. Furthermore the stones were used to hold the fibers and during tanning. They are very common in particular in the sector A even in a big number and expecially nearly water resource (lake), instead in the sector B they are almost absents. Other activity partially made out nearby the water is represented by treatment of particular games' anatomical portions: the concentration of phalanges and metapodials in a limited portion of the sectors for example shows a particular selection directed to the recovery of the skin and made out nearby the water for tanning activities; in the sector B only phalanges were discovered and in particular 7/9 red deer phalanges and one cattle phalanx, instead in the sector A a big number of metapodials.

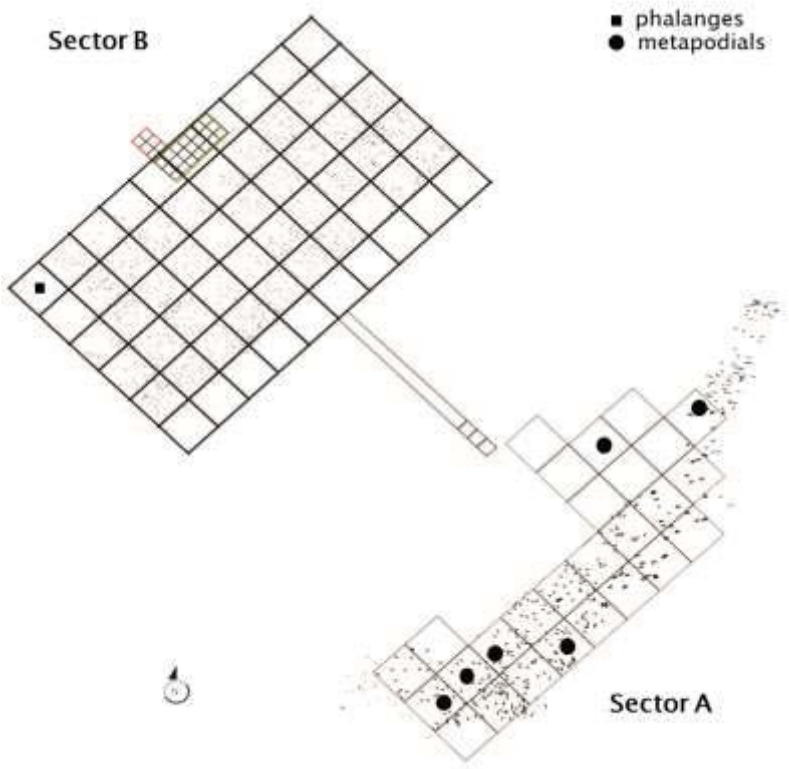


Figure 3: Distribution of metapodials and phalanges

However, to analyze games' remains and understand their different use, according to the study by Cazzella (Bietti Sestieri *et al.* 2002; Cazzella *et al.* 2002; Moscoloni *et al.* 2002), we identify meat yield of the different body portions divided in 4 categories: high, average, little and very little meat yield.

If we have a majority of fragments attributable to little and very little meat yield probably the presence of animal is connected with waste after consume. If instead we have a majority of fragments attributable to the first classes of meat yield probably they made the animals in pieces *in loco* to consume their remains. In the sector A the treatment of faunal remains was present at west, while the dumping activities at east. In sector B, instead, areas of treatment of faunal remains, were predominant, individuated at the side (east and west) of a small central area in which activities of game tipping were present.

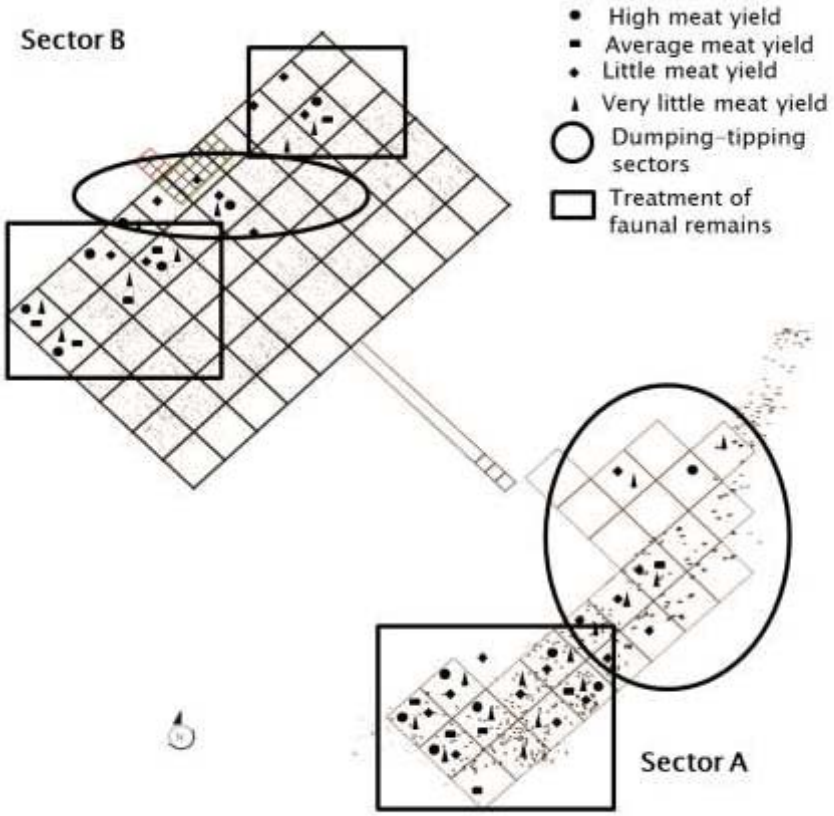


Figure 4: Distribution of game remains

Regarding the presence of lithic tools, areas of lithic ateliers were present only in the Sector A, where remains of all *cháine operatoire*'s stages were identified; instead, on the contrary in the sector B were present only a small amount of debitage.
Finally, there was a good number of spindle whorls and net weights that identify weaving and fishing activities, carried out at the site.

All these data allow us to identify different productive activities related to particular areas of dwelling, linked to site's last phase of life; in the sector B two different dwelling contexts were present: one of them, at east, is characterized by big containers and different kinds of wastes; another one, at west, by traces of game treatment and blending. In the sector A, which could have represented the living-dwelling area, we observe the presence of productive activities linked to water at west, such as leather processing and preliminary phases of weaving; moreover, in this side of sector, some treatment activities were carried out, as processing of faunal remains, lithic *cháine operatoire*, weaving and milling. The east side could be used prevalently as a waste sector, for the presence of faunal remains.

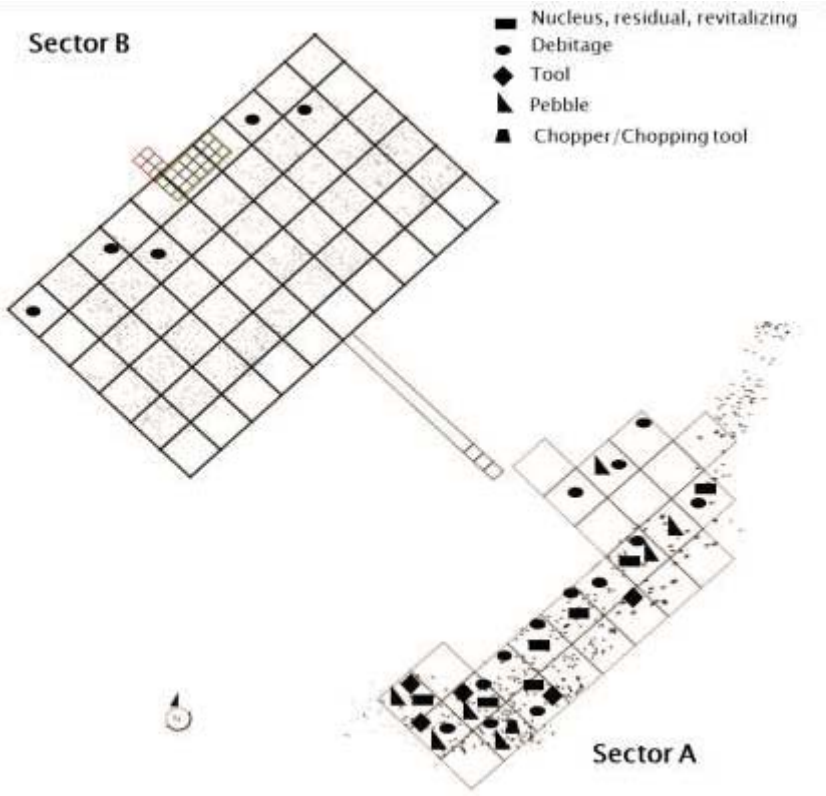


Figure 5: Distribution of lithic tools

3. Future perspective

Thanks to this research, we have studied the last life's phase of site and we have observed the material effects of the depositional and post-depositional processes on social actions, which usually bias the distribution and density of archaeological record. We have obtained some results about different concentration of material linked to different activities in two sectors of site; in the future perspective we want to extend the territorial field investigation with surveys in the nearby areas. These could provide information on different scales: on a semi-micro scale, these may be useful to identify as much as possible accurately the site size, while on a micro scale, they allow us to check spatial limits of the activities' areas. We could also identify their role on the subsistence economy and whether they used to be seasonal or annual activities. This last element would help us to comprehend the modality of site frequentation during the year. In attempt to verify the division and distribution of social activities and any connection between various practices, we will apply the theories of stochastic processes: these are the base of geostatistics, which is a set of statistical methods used to describe spatial relationships among sample data and to apply this analysis to the prediction of spatial and temporal phenomena (Haining 2003; Lloyd and Atkinson 2004). The spatial process that produced the observed frequencies, is composed by a deterministic part and a stochastic variation; we want to apply a

combination of geostatistics and qualitative and statistical models (Barceló 2002; Barceló *et al.* 2008). For example, the multimodal distribution and also probabilistic maps are useful to understand the density probability function of archaeological artefacts associated to each location. Furthermore, we will study the spatial variation of archaeological variables through the measure of spatial correlation or self-correlation; in particular we will use geostatistic methods such as variogram and kriging and, finally, the exponential bi-varied distribution that is useful to show the modalities of occupancy and spatial exploitation. The spatial analysis that we want to carry out must be computerized with the aid of suitable tools such as not only the geostatistics ones but also GIS. The latter allows to reconstruct the relationships between archaeological remains and the spatial distribution of data inside and outside site. In addition, we will work on the main artefacts which characterize the site: the piles; despite the large number of pile heads identified during the field surveys, through superficial collections and in the sectors stratigraphically investigated, a detailed study has not yet been carried out, probably because of the absence of data related to the floor surface and to the pile structures; in fact, there is an additional difficulty in the recognition of exact pile alignments, which are abundant in the territory and probably must be attributed to different building phases of the settlement or restructuring and replacement of some elements in the structures. Nonetheless, between the aims of the research, there is also the attempt to locate hypothetical housing structures: we will try to analyze the frequency and the dispersion of this material class and we will compare it with the dispersion and frequency of the other ones, in order to identify any similarity or specific distribution; this method could eventually help do reconstructive hypotheses about the alignment of piles. Finally, in attempt to study the site on a macro scale, we have to take into account previous studies performed on the site of Villaggio delle Macine, which showed the uniqueness of the settlement (in particular its hypothetical size, the long duration of its frequentation and the significant movements of goods and models from northern Italy and/or regions to the north of Alps); Some scholars (Angle and Guidi 2007) have indicated that this site may have assumed the role of central place; the results obtained thanks to different mechanisms and modalities of analysis, added to comparisons with other big pile dwellings' contexts, will allows us to verify or contradict this main hypothesis.

References

Achino, K. F., M. Angle, and F. Micarelli. 2011. Uomini e laghi. correlazioni spaziali e funzionali dell'ultima fase di vita del Villaggio delle Macine, in *Le palafitte, Atti del Convegno* (in press).

Angle, M. 2007. Comune di Castel Gandolfo. Villaggio delle Macine, in *Repertorio dei siti protostorici del Lazio. Province di Roma, Viterbo e Frosinone*, ed. C. Belardelli. Firenze: All'Insegna del Giglio.

Angle, M. and A. Guidi. 2007. L'antica e media età del Bronzo nel Lazio meridionale, in *Atti della XL Riunione Scientifica*, 147-78. Firenze: "L'Erma" di Bretschneider.

Angle, M., F. Lugli and A. Zarattini. 2002. Lago Albano: il "Villaggio delle Macine", in *Roma Città del Lazio, Catalogo della mostra*, ed. S. Rizzo, 52-56. Roma: De Luca Editori d'Arte.

Angelini, I.; M. Angle, G. Artioli, P. Bellintani, F. Lugli, N. Martinelli, A. Polla, A. Tagliacozzo, and A. Zarattini. 2006. Il Villaggio delle Macine (Castelgandolfo, Roma), in *Lazio e Sabina* 3, ed. G. Ghini, 157-168. Roma: Quasar.

Barcelò, J. A. 2002. Archaeological Thinking: Between Space and Time, in *Archeologia e Calcolatori* No. 13, Ed. Paola Moscati, 237-259. Firenze: All'Insegna del Giglio.

Barceló, J. A. and A. Maximiano. 2008. Some notes regarding distributional analysis of spatial data, in *Layers of Perception. Proceedings of the 35th International Conference on Computer Applications and Quantitative Methods in Archaeology*, ed. A. Posluschny, K. Lambers, I. Herzog 413-7. Bonn: Hablet.

Bietti Sestieri, A.M., A. Cazzella, I. Baroni, Cl. Minniti and G. Recchia. 2002. L'Italia centromeridionale e le isole durante l'età del Bronzo e del Ferro: aspetti metodologici, in *Analisi informatizzata e trattamento delle strutture di abitato di età preistorica e protostorica in Italia*, C. Peretto (a cura di), 321-337, Firenze: Istituto Italiano di Preistoria e Protostoria.

Carra, M., L. Cattani and M. Rizzi. 2007. Sussistenza e paleo ambiente a Villaggio delle Macine (Lago di Albano, Castel Gandolfo, Roma). Studio carpologico, in *Atti della XL Riunione Scientifica*, Strategia di insediamento fra Lazio e Campania in età preistorica e protostorica, 775-786, Firenze: Istituto Italiano di Preistoria e Protostoria.

Cazzella, A., G. Recchia, I. Baroni and Cl. Minniti. 2002. Coppa Nevigata: analisi dell'uso dello spazio in una struttura proto appenninica, in *Analisi informatizzata e trattamento delle strutture di abitato di età preistorica e protostorica in Italia*, C. Peretto (a cura di), 427-443, Firenze: Istituto Italiano di Preistoria e Protostoria.

Chiarucci, V. 1985. Materiali dell'età del bronzo nelle acque del lago Albano, in *Archeologia Laziale* VII, 34-39, Roma: Quasar.

Chiarucci, P. 1986-1988. Il "Villaggio delle Macine" nel Lago Albano, in *Annali Benacensi*, n.9, 407-419, Milano: Assoc. Gruppo Archeologico.

Chiarucci, P. 1995-1996. Il villaggio delle Macine sommerso nelle acque del Lago Albano, in *Bollettino di Archeologia Subacquea* II-III, 176-83, Roma: Ministero per i Beni culturali e ambientali.

Jhul, K. 1995. *The relation between vessel form and vessel function: A methodological study*, Stavanger: Arkeologisk museum i Stavanger.

Lloyd, C. D. and P. M. Atkinson. 2004. Archaeology and geostatistics, in *Journal of Archaeological Science* 31: 151-165; Elsevier.

Moscoloni, M., G. Recchia, I. Baroni and Cl. Minniti. 2002. Coppa Nevigata: analisi funzionale delle strutture subappenniniche dei settori E4 e D5 (Scavi Puglisi-Palmieri in estensione), in *Analisi informatizzata e trattamento delle strutture di abitato di età preistorica e protostorica in Italia*, C. Peretto (a cura di), 443-467, Firenze: Istituto di Preistoria e Protostoria.

Recchia, G. 1997. L'analisi degli aspetti funzionali dei contenitori ceramici: un'ipotesi di percorso applicata all'età del Bronzo dell'Italia Meridionale, in *Origini* XXI: 207-306, Roma: Gangemini Editore Spa.

Recchia, G. 1997. Funzione ed uso della ceramica durante il Bronzo Recente in Italia, in *Atti del Convegno "Il Bronzo recente in Italia"*, Viareggio: M. Baroni.

Zarattini, A. (a cura di) 2001. Il villaggio delle Macine: indagini nel lago di Albano (Castelgandolfo, RM), in *2° Convegno di archeologia subacquea A.I.A.Sub*, 7-9 settembre 2001, Castiglioncello: EdiPuglia.

Stratigraphy and Spatial Analysis at Pre-Pottery Neolithic B Kfar HaHoresh, Israel: Using GIS Applications in Inter-Site Analyses

Michal Birkenfeld[1]

A. Nigel Goring-Morris[1]

[1] Institute of Archaeology, Hebrew University of Jerusalem, Israel.

Abstract

Kfar HaHoresh is a Pre-Pottery Neolithic B mortuary and ritual site located in the lower Galilee, northern Israel. Fifteen seasons of excavation have revealed prolonged and intensive occupation for much of the PPNB (ca. 8750-7,250 calBC). While presenting a unique opportunity for the research of Neolithization processes in the region, such a complex and intricate sequence poses many challenges relating to stratigraphic and spatial analyses.

This paper presents a new methodology aimed at dividing the bulk of the excavated features into stratigraphic analytical units. This methodology, based on GIS applications, emphasizes a three-dimensional approach to the analysis of the spatial distributions of both the architectural remains and the small finds, facilitating subsequent contextual analyses. The preliminary results of the KHH pilot study are presented, highlighting the importance of applying GIS in intra-site contexts.

Keywords: *GIS, intra-site analysis, stratigraphy, Early Neolithic (PPNB), Southern Levant*

1. Introduction

During the last few decades, archaeological research has contributed diverse literature on the use of Geographic Information Systems (GIS). It seems, however, that although GIS is recognized as a useful tool, research has tended to concentrate on larger-scale questions (e.g., landscape archaeology, settlement analysis, cultural resource and heritage management), so that inter-site rather than intra-site studies seem to occupy the major part of the literature of GIS and archaeology. Thus, GIS is applied for conducting Viewshed Analysis (Jones 2006), the study of Visual Space (Llobera 2007), travel-ways, and population dynamics (Whitley and Hicks 2003). In recent years there has been an increase in GIS-based intra-site studies. Most, however, focus on questions of taphonomy and artefact attributes (e.g., Cooper and Qiu 2006; Abe *et al.* 2002). Analyses of intra-site artefact distributions and the study of activity areas, which are of the mainstays of traditional archaeological spatial analyses, are very rare although increasing (e.g.

Alperson-Afil and Goren-Inbar 2010; Apollonio et al. 2012, Kuijt and Goodale, 2009; Spikins et al., 2009; Craig *et al*. 2006; Weiss et al., 2008). This is especially true in Near Eastern Neolithic research, where almost all GIS-based research deals with large-scale processes on regional and multi-regional scales of reference (e.g. Fort *et al* 2012; Ullah 2011).

Previous work has indicated that this dominance of large-scale applications derives both from the developmental origins of GIS as well as from methodological issues related to archaeological excavation and retrieval methods (see Biswell *et al* 1995; Huggett 2000). While we undoubtedly accept the role of historical factors, this paper demonstrates that these issues should not deter us from applying GIS at the intra-site level, as we present a GIS study conducted at the Pre-Pottery Neolithic B (PPNB) site of Kfar HaHoresh. Excavations there have revealed a long and intricate archaeological sequence of occupation. On the one hand, such a sequence raises the relatively rare opportunity of evaluating important processes of change through time. On the other hand, it also poses many challenges relating to stratigraphic and spatial analyses. In the following pages we present a methodological approach aimed at dividing the bulk of the excavated features into stratigraphic analytical units. This methodology, based on GIS applications, emphasizes a three-dimensional approach to the analysis of the spatial distributions of both the architectural remains and the small finds, facilitating subsequent contextual analyses and highlights new possibilities of using GIS in intra-site contexts.

2. The Site of Kfar HaHoresh

The site of Kfar HaHoresh (KHH) is located in the lower Galilee, northern Israel.

Discovered in 1991, 15 seasons of excavations have revealed one of the longest known PPNB sequences in the region, representing >1500years of occupation, ranging from Early, through Middle and Late PPNB (ca. 8750-7,250 calBC). Compared to contemporary sites, KHH is quite small, extending over an area of *ca*. 1.5 acres. It also differs from other sites with regards its topographic setting; while contemporary village sites are usually situated at the edges of large valleys surrounded by adjacent tracts of arable land, KHH is located in the upper reaches of a small, secluded wadi with very little arable land in its vicinity, somewhat isolated from surrounding settlements in Galilee. The main architectural features at the site are lime-plastered surfaces, either free standing or accompanied by long low stone-built walls that delineate the plastered surface on two or three sides.

Other built installations include a wide variety of hearths, constructed ovens, kilns and cists, grave markers and stelae, all set within a backdrop of extensive accumulations of midden

deposits and quantities of fire-cracked stones of varying densities and thickness, representing a wide range of pyrotechnic activities.

The most unique feature of KHH is undoubtedly the large number of human burials, most of which were found associated with the large plaster surfaces. More than 70 burials have been excavated to date, exposing a wide array of mortuary behaviours: burials are varied, and range from primary to secondary and from single to multiple. Both adults and children are represented, and there is an unusual distribution of ages (Eshed *et al* 2008). Several graves show clear signs of re-opening for the addition of extra burials and differential taphonomic processes (Simmons *et al* 2007). Grave goods are quite common, and include chipped and groundstone tools, polished pebbles, beads, different minerals, marine and lacustrine shells, etc. Some of the inhumations show clear associations with animal remains, whether for feasting and as grave goods (Goring-Morris and Horwitz 2007).

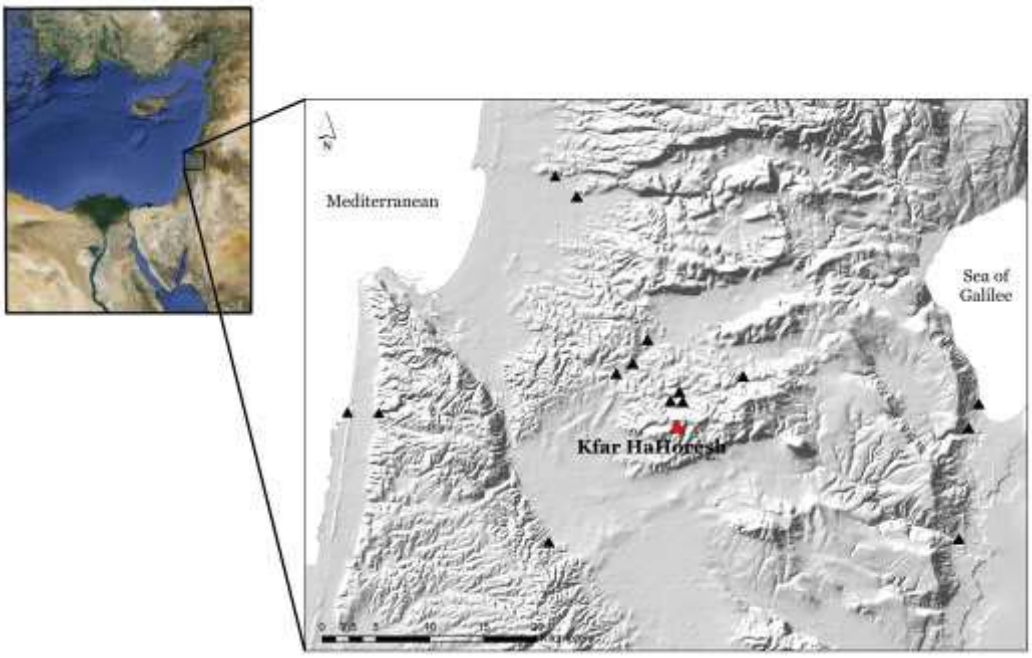


Figure 1: Map of northern Israel, showing the location of Kfar HaHoresh (in red triangle) as well as other PPNB sites (black triangles) in the region.



Figure 2: Kfar HaHoresh during excavation. Note the freestanding plaster surface to the left, and wall-delineated plaster surfaces to the right.

The material culture at KHH is rich and varied, indicating well-developed and extensive regional and extra-regional exchange systems: 'exotic' materials include obsidian from central Anatolia (Delerue 2007); malachite and other minerals originating in Syria, Transjordan and the Dead Sea area, and a variety of marine molluscs from both the Mediterranean and the Red seas (Goring-Morris 2000; Bar-Yosef Mayer 2013; Bar-Yosef Mayer and Porat 2008). Also recovered at the site are figurines of both human and animal depictions, made on stone and on clay, which was widely used at the site, especially for the manufacture of beads, tokens, figurines and ceramics (Biton 2010; Biton *et al* submitted).

The wide range of unusual mortuary installations and practices documented at the site, as well as the varied nature of the material culture remains, their contextual co-associations, alongside the site's unique geographic location, has led to the interpretation of KHH as a cult and mortuary site, serving the populations of nearby settlements in the lowlands (Goring-Morris 2000, Goring-Morris 2005).

Stratigraphic analysis at KHH has proven difficult, due to several factors; first is the issue of uneven, or asymmetrical erosion. Parts of the upper occupation layers were eroded and truncated by current-day topography and recent agricultural activities. Nevertheless, given that the site is situated on a slope, the degree of disturbance was not consistent throughout the area of the site: a bedrock cliff face protected the sediments against erosion from upslope (i.e. the south), while the northern areas suffered much more disturbance. The slope itself poses another

obstacle. Currently, a gentle inclination exists in the main area of excavation, mainly from southwest downwards to the northeast. Although it was established that at the time of the PPNB occupation the slope did exist, the exact inclination of the original surface remained uncertain (Goring-Morris *et al* 1994-5). In contrast, most plaster surfaces and other built features are relatively flat, indicating some sort of levelling or terracing was in use during the occupation (*ibid*). A third factor affecting stratigraphic analysis is the issue of 'spiral' or 'horizontal' stratigraphy; there is evidence that occupation at different periods was more intense in certain areas, while other areas were habitually cleaned and/or levelled. This is compounded by post-depositional processes, mainly the compaction of organic deposits, causing depressions and pits.

These issues of differential erosion, changing slopes and 'horizontal' or 'spiral' stratigraphy, together with the considerable duration of occupation, have rendered stratigraphic analyses at the site difficult and complex. Correlations between the larger, built complexes and other, more ephemeral features and between the built environment and the artefact data sets, often remained inconclusive thus hindering more synthetic or contextual analyses. One of the major aims of the methodology presented below is to facilitate such correlations and consequently enable a deeper, more detailed understating of the KHH occupation.

3. Methodology

A test area was chosen to serve as a pilot study for the presented methodology, thus the data used derives from the West area of the site and comprises 172m^2. The procedure comprises several stages: the stratigraphic analyses and division of the sequence into phases; the digitization, in which all field catalogues and artefact inventories are transformed into digital raw data; and the actual assignment of the finds to the respective stratigraphic phases.

Firstly, all field and laboratory-derived data, including both architectural plans and artefact catalogues were digitized. *AutoCAD* software was used to trace and digitize the field drawings into 3-D polygons. The digitization of the artefact catalogues was more detailed, and required several stages. This is due, in part, to the provenance methodology employed in the field: excavations at KHH are conducted according to loci, using a 1 x 1m grid. Each grid square is further subdivided into four 0.5 x 0.5m sub-squares and excavated in 5cm spits. Most artefacts are recorded accordingly (i.e. by sub-square and spit). However, those items that are considered significant and those deriving from special contexts are registered with full X, Y, Z values. Furthermore, as can be expected in a project spanning some 20 years, technological advancements in archaeological research have both enabled and required modifications to be made in both excavation and recording methods over time. Accordingly, some manipulation

was required in order to create a uniform frame of reference for the artefact assemblages. These manipulations involved assigning random X, Y and Z coordinates within the appropriate square/sub-square and spit to all recovered artefacts. Artefacts that lacked either a grid or spit reference were omitted from the analysis, to avoid any biases. These procedures enabled us to construct uniform and homogenous databases, facilitating consistency in the subsequent analyses (and see Gilead 2002 for a discussion of the statistical significance of such procedures).

Stratigraphic sequencing of all excavated features was then conducted, following Harris (1979a; 1979b), i.e., sequencing was based mainly on the excavator's field observations, while the relationships between the site's architectural features comprise the basis for analysis. The sequence was divided into units, and each locus was assigned to a particular stratigraphic unit.

Once all sequencing was complete and the data was in digital format each artefact could then be assigned to its stratigraphic unit. Using *ArcGIS 9.2*, the bottom 'Z' values of all the loci assigned to a distinct phase were interpolated, thus creating a 3-D surface representing the base of that stratigraphic unit.

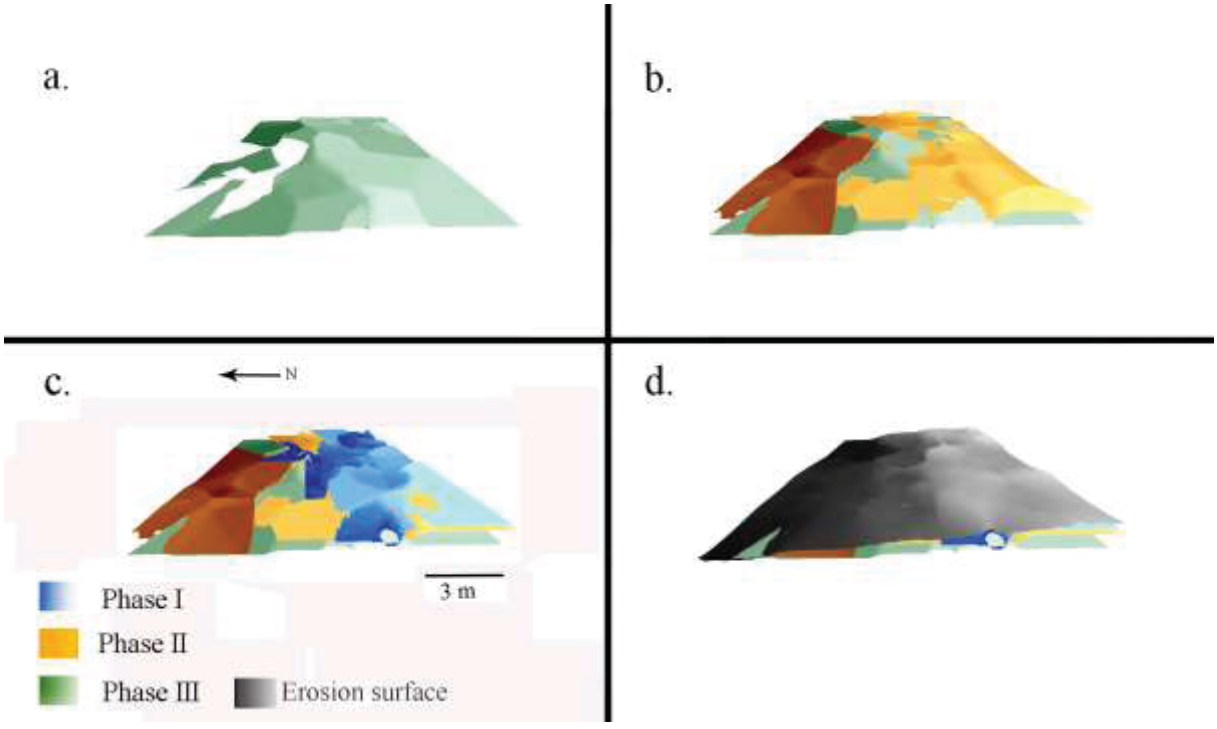


Figure 3: The 'base surfaces' after IDW interpolation and disturbance calculations: a: 'base surface' of unit III; b: combined 'base surfaces' of units II-III; c: combined 'base surfaces' of units I-III; d: combined 'base surfaces' of all three units, with erosion surface cutting through (grey).

The interpolation method used was the inverse distance weighted (IDW) interpolation, which determines cell values using a linearly weighted combination of a set of sample points. The weight is a function of inverse distance. This method was chosen since it enables control of the significance of known points on the interpolated values, based on their distance from the output point. Thus, nearby data will have the most influence, and the surface will have greater resolution (Philip and Watson 1982; Watson and Philip 1985).

The 'base surface' created for each stratigraphic unit represents the *terminus antequem* of that particular unit. The 'base surface' of the subsequent overlying unit is then used as the *terminus postquem* of the first unit. Once all base surfaces are combined and presented together, the areas of overlap between them need to be calculated (Figure 3). These areas of overlap represent locales in which one layer cuts into, and thus disturbs another. This can be caused by events during deposition (for example, a pit dug in one layer that cuts into earlier layers) or post-depositional events (such as post-occupation disturbances, erosion etc.).

Once plotted, each artefact could be allotted a specific stratigraphic assignment in relation to its location between two 'base surfaces'. Once each artefact is assigned to a particular stratigraphic unit, we can then proceed to the analysis of spatial distributions, using the same 'base surfaces' as analytical masks that define and confine the exposed area of each unit. Density maps were produced for each unit, using the Kernel density estimation method.

4. Results

Stratigraphic analysis at KHH has revealed a basic division of the PPNB occupation sequence into three main units: I (latest), II and III (earliest). A fourth, Unit Ø, represents post-occupation colluvium, disturbances, erosion and the plough-zone. Within each unit, several sub-phases can be identified, mainly based on architectural sub-units, i.e. the repair, re-building and reorganization of walls and architectural complexes through time. The above-described methodology has allowed us to obtain a full description of each unit, both in terms of architectural features and artefact assemblages. Thus, a comparison of both was enabled. Since the main subject of the current paper is methodological, we will not attempt a full description of the results, but rather concentrate on the major trends observed and their implications. Furthermore, only the major units will be referred to, as the description of sub-units remains beyond the scope of this paper. As to the results of the artefact spatial analyses, only the results of the lithic assemblage analysis will be described briefly.

4.1. The constructed environment

The earliest unit, **Unit III**, comprises numerous installations, together with two main plaster surfaced complexes (Fig. 4c): One to the west, accompanied by large, stone built walls, and another, free-standing rectangular surface to the east. Several inhumations are associated with this plaster surface, including three secondary inhumations of isolated individuals dug into the plaster. Other inhumations belonging to this unit include four burials, of both adults and children.

The intermediate unit, **Unit II**, represents a shift in the spatial and structural organization of the occupation; a new, large plaster-surfaced structure is built on a previously open area, while a freestanding oval plastered surface replaces the earlier built complex to the west (Fig. 4b). This also incorporates a hearth and monoliths. The burials of this unit are mostly multiple, secondary burials, with but one exception: an articulated female burial whose head was removed, probably prior to burial.

The latest unit at the site, **Unit I**, features the continuation and alteration of the earlier Unit II structure (Fig. 4a), and a new free-standing plastered surface. The two plaster surfaces cover several graves. These are all multiple burials, with up to 17 individuals in a single grave (Eshed et al. 2008). Of note are the burial of a fragmentary modelled skull in a bin, and a multiple secondary burial where the bones were intentionally arranged seemingly as a depiction (Goring-Morris et al. 1998).

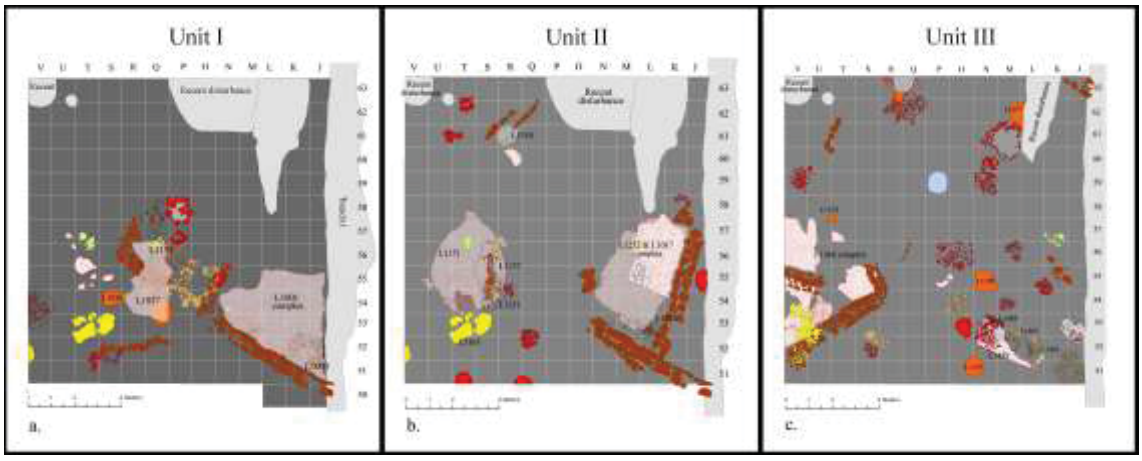


Figure 4: Top plans of the three units, showing various architectural features, plastered surfaces, hearths and graves.

4.2. The flint assemblage

The flint assemblage includes 15,076 items (excluding debris).

		III	II	I	Ø
Primary Element	**N**	1033	738	606	**156**
	%	18.8%	17.6%	13.8%	**16.2%**
Flakes	**N**	1598	1254	1413	**337**
	%	29.2%	30.0%	32.1%	**35.0%**
Blade\lets	**N**	799	723	741	**124**
	%	14.6%	17.3%	16.8%	**12.9%**
Core Trimming Element	**N**	369	221	231	**43**
	%	6.7%	5.3%	5.2%	**4.5%**
Core Tablet	**N**	17	24	12	**3**
	%	0.3%	0.6%	0.3%	**0.3%**
Ridge Blade	**N**	93	55	38	**12**
	%	1.7%	1.3%	0.9%	**1.2%**
Burin spalls	**N**	148	124	105	**13**
	%	2.7%	3.0%	2.4%	**1.4%**
Biface spalls	**N**	2	0	1	**0**
	%	<0.1	0.0%	<0.1	**0.0%**
Chamfered spalls	**N**	31	10	10	**0**
	%	0.6%	0.2%	0.2%	**0.0%**
DBT spalls	**N**	19	7	24	**1**
	%	0.3%	0.2%	0.5%	**0.1%**
Tools	**N**	1137	893	1121	**237**
	%	20.7%	21.3%	25.5%	**24.6%**
Cores	**N**	111	105	80	**29**
	%	2.0%	2.5%	1.8%	**3.0%**

Hammer-stones	**N**	16	5	5	**1**
	%	0.3%	0.1%	0.1%	**0.1%**
Intrusive	**N**	108	24	15	**6**
	%	2.0%	0.6%	0.3%	**0.6%**
TOTAL	**N**	**5481**	**4183**	**4402**	**962**
	%	**100.0%**	**100.0%**	**100.0%**	**100.0%**

Table 1: Flint distribution by type and stratigraphic unit.

Table 1 summarizes the flint counts by type as well as by archaeological unit. Composition-wise, all three assemblages show very similar characteristics, and there seem to be no substantial differences between them. Conversely, if we examine the spatial distributions of the flint artefacts, the three units display quite different patterns.

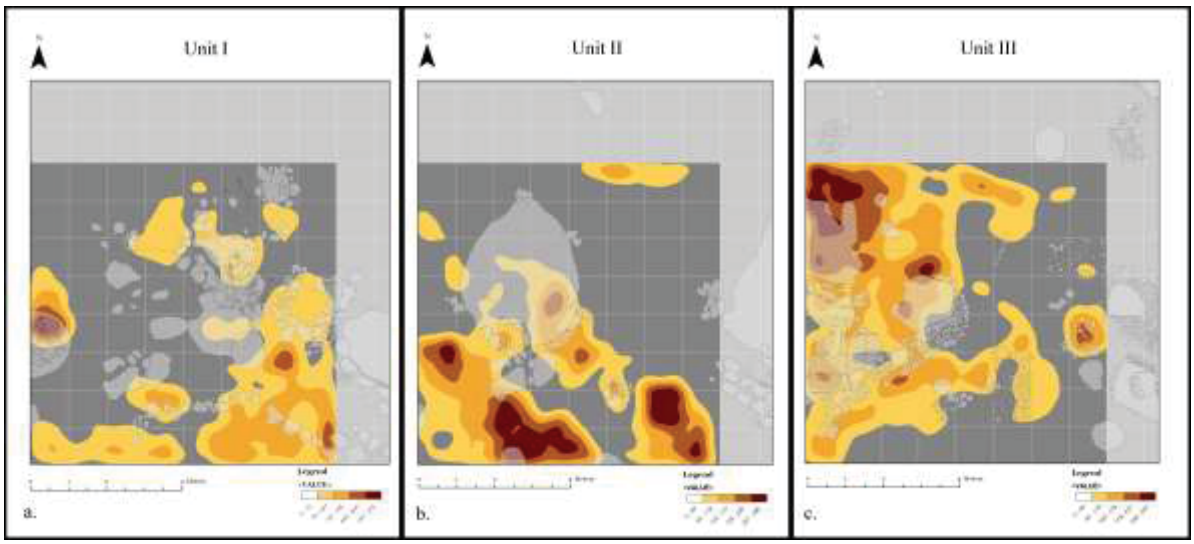


Figure 5: Density maps showing flint debitage distribution within the tested area

In each unit, most of the artefacts are concentrated in the open areas around the main built complexes, and within other installations, such as pits and hearths. In unit III, the association of flint with L1572 pit especially demonstrates this tendency (Figure 5c). In unit II (Figure 5b) there seems to be a concentration of flint in L1157 and L1251 and a secondary concentration associated with L1161 hearth, while in unit I a clear concentration of flint is evident associated with the L1058 hearth (Figure 5a).

5. Discussion and conclusions

The stratigraphic sequence exposed at Kfar HaHoresh is complex, representing the sporadic but recurrent and intensive use of a relatively small area for *ca.*1750 years. The stratigraphic analysis has facilitated the basic division of the PPNB occupation layer into three main units. Once digitized and plotted, these units can be individually analyzed and compared to one another.

Both continuity and breaks were revealed between the three units during analysis. Although most aspects of the material culture examined display clear signs of continuity, we can identify a significant shift, particularly apparent in the transition between Unit III, the earliest unit, and the subsequent Units II-I. This shift is mostly evident in the restructuring and reorganization of the constructed environment: a new massive structure is erected, the orientation of the architecture changed and the weight of the occupation moved eastwards towards the center of the excavated area. At the same time, burial customs became more elaborate and complex, as the multiple, intricate burials of Units II-I replace the single (and perhaps less complex) burials of Unit III.

The methodology employed facilitated the spatial analysis of the flint assemblage in relation to the architectural and other built features at the site. The results demonstrate that knapping debris was concentrated both in the open areas outside the large structures and in and around adjacent installations, such as hearths and pits. The relatively low densities of artefacts within the perimeters of the plaster floors resemble observations from other PPNB occupations such as in Beidha and 'Ain Ghazal (Hardy-Smith & Edwards 2004 and references therein), and raise the likelihood of regular cleaning of the plastered surfaces. Floor maintenance and garbage disposal are considered one of the characteristics of prolonged occupation of a single locale (Schiffer 1972). Even more so with the onset of sedentism, it seems that refuse was habitually collected and systematically disposed of in designated areas.

The results presented are provisional in nature, as the study only focuses on part of the excavated area, and may require future modification. Nonetheless, they emphasise the potential GIS applications have vis-à-vis intra-site analysis. The primary goal of this paper was to present a new methodology, which, through the creation of ‘base surfaces’, enables the analyses of spatial and contextual associations. The creation of these three dimensional units, taking into account the constructed environment and later disturbances, enables us to identify and reconstruct elements of the archaeological depositional processes; it is then possible to recreate the spatial extent or spread of each stratigraphic unit, even when visual identification of relatively featureless areas during excavation was difficult or not possible. Furthermore, it

facilitates correlation of the stratigraphic and spatial data with the artefact datasets. This enables the creation of a truly synthetic approach, enabling more detailed and cognizant spatial and contextual analyses.

The preliminary results of the pilot study described above illustrate and emphasize the importance of three-dimensional spatial analysis at the intra-site level. Previous GIS applications in archaeology have tended to emphasize larger scale inter-site analyses, particularly within the frame of Near Eastern Neolithic research. We believe that the development and refinement of the same GIS capabilities at the intra-site level can and will contribute significantly to much more detailed and holistic comprehension of the highly complex depositional sequences so common in these fields of research.

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References

Abe, Y., C. W. Marean, P. J. Nilssen, Z. Assefa, and E. C. Stone. 2002. "The analysis of cutmarks on archaeofauna: A review and critique of quantification procedures, and a new image-analysis GIS approach." *American Antiquity* no. 67:643–663.

Alperson-Afil, N, and N. Goren-Inbar. 2010. *Ancient flames and controlled use of fire, Acheulian site of Gesher Benot Ya'agov;* New York: Springer.

Apollonio, F. I., M. Gaiani, and B. Benedetti. 2012. "3D reality-based artefact models for the management of archaeological sites using 3D GIS: a framework starting from the case study of the Pompeii Archaeological area." *Journal of Archaeological Science* no. 39 (5):1271-1287.

Biswell, S., L. Cropper, J. Evans, V. Gaffney, and P. Leach. 1995. "GIS and excavation: a cautionary tale from Shepton Mallet, Somerset, England." In *Archaeology and Geographical Information Systems: A European perspective*, edited by G. Lock and Z. Stančič, 269-285. London: Taylor and Francis.

Biton, R. 2010. *The Clay Repertoire from Pre-Pottery Neolithic B Kfar HaHoresh: Not Just the*

Usual Bull, M.A. Thesis, The Hebrew University of Jerusalem.

Biton, R., Y. Goren, and A. N. Goring-Morris. Submitted. "Ceramics in the Levantine Pre-Pottery Neolithic B: Evidence from Kfar HaHoresh." *Journal of Archaeological Science*.

Cooper, J. R., and F. Qiu. 2006. "Expediting and standardizing stone artifact refitting using a computerized suitability model." *Journal of Archaeological Science* no. 33 (7):987-998.

Craig, N., M. Aldenderfer, and H. Moyes. 2006. "Multivariate visualization and analysis of photomapped artifact scatters." *Journal of Archaeological Science* no. 33:1617-1627.

Delerue, S. 2007. *L'Obsidian dans le Processus de Néolithisation du Proche-Orient (12000-6500 av. J.-C. cal)*, Université Bordeaux.

Eshed, V., I. Hershkovitz, and A.N. Goring-Morris. 2008. "A re-evaluation of burial customs in the Pre-Pottery Neolithic B in light of paleodemographic analysis of the human remains from Kfar HaHoresh, Israel." *Paléorient* no. 34:91-103.

Fort, J., T. Pujol, and M. Linden. 2012. "Modeling the Neolithic Transition in the Near East and Europe." *American Antiquity* no. 77 (2):203-219.

Gilead, I. 2002. "Too many notes? Virtual recording of artefacts provenance." In *Virtual archaeology: proceedings of the VAST Euroconference, Arezzo 24-25 November 2000*, edited by F. Niccolucci, 41-44. Oxford: BAR International Series.

Goring-Morris, A.N. 2000. "The quick and the dead: The social context of Aceramic Neolithic mortuary practices as seen from Kfar HaHoresh." In *Life in Neolithic farming communities: Social organization, identity, and differentiation*, edited by I. Kuijt, 103-136. New York: Kluwer Academic\Plenum.

Goring-Morris, A.N. 2005. "Life, death and the emergence of differential status in the Near Eastern Neolithic: Evidence from Kfar HaHoresh, Lower Galilee, Israel." In *Archaeological perspectives on the transmission and transformation of culture in the Eastern Mediterranean*, edited by J. G. D. Clark, 89-105. Oxford: Council for British Research in the Levant and Oxbow Books.

Goring-Morris, A.N., R. Burns, A. Davidzon, V. Eshed, Y. Goren, I. Hershkovitz, S. Kangas, and J. Kelecevic. 1998. "The 1997 season of excavations at the mortuary site of Kfar HaHoresh." *Neo-Lithics* no. 3:1-4.

Goring-Morris, A.N., Y. Goren, L.K. Horwitz, I. Hershkovitz, R. Lieberman, and D. Bar-Yosef. 1994. "The 1992 season of excavations at the Pre-Pottery Neolithic B settlement at Kfar

HaHoresh." *Journal of the Israel Prehistoric Society* no. 26:74-121.

Goring-Morris, A.N., and L.K. Horwitz. 2007. "Funerals and feasts during the Pre-Pottery Neolithic B of the Near East." *Antiquity* no. 81:1-17.

Hardy-Smith, T., and P.C. Edwards. 2004. "The garbage crisis in prehistory: Artefact discard patterns at the Early Natufian site of Wadi Hammeh 27 and the origins of household refuse disposal strategies." *Journal of Anthropological Archaeology* no. 23:253-289.

Harris, E.C. 1979a. *Principles of archaeological stratigraphy*. London: Academic Press.

Harris, E.C. 1979b. "The laws of archaeological stratigraphy." *World Archaeology* no. 11:111-117.

Huggett, J. 2000. "Looking at intra-site GIS." In *CAA 96 Computer applications and quantitative methods in Archaeology*, edited by K. Lockyear, T. J. T. Sly and V. Mihailescu-Birliba, 117-121. Oxford: BAR International Series.

Jones, E.E. 2006. "Using Viewshed analysis to explore settlement choice: a case study of the Onondaga Iroquois." *American Antiquity* no. 71 (3):523-538.

Kuijt, I., and N. Goodale. 2009. "Daily practice and the organization of space at the dawn of agriculture: A case study from the Near East." *American Antiquity* no. 74 (3):403-422.

Llobera, M. 2007. "Reconstructing visual landscapes." *World Archaeology* no. 39 (1):51-69.

Philip, G.M., and D.F Watson. 1982. "A precise method for determining contoured surfaces." *Australian Petroleum Exploration Association Journal* no. 22 (1):205-12.

Schiffer, M.B. 1972. "Archaeological context and systemic context." *American Antiquity* no. 37 (2):156-165.

Simmons, T., L.K. Horwitz, and A.N. Goring-Morris. 2007. "What ceremony else? Taphonomy and the ritual treatment of the dead in the pre-pottery Neolithic B mortuary complex at Kfar HaHoresh, Israel." In *Faces from the past: Diachronic patterns in the biology and health status of human populations from the Eastern Mediterranean. Papers in honour of Patricia Smith*, edited by M. Faerman, L. K. Horwitz, T. Kahana and U. Zilberman, 1-27. Oxford: Archaeopress.

Spikins, P. 2002. "GIS based interpolation applied to distinguishing occupation phases of early prehistoric sites." *journal of Archaeological Science* no. 29:1235-1245.

Ullah, I. I. T. 2011. "A GIS method for assessing the zone of human-environmental impact around archaeological sites: a test case from the Late Neolithic of Wadi Ziglab, Jordan."

Journal of Archaeological Science no. 38 (3):623-632.

Watson, D.F., and G.M. Philip. 1985. "A refinement of Inverse Distance Weighted Interpolation." *Geoprocessing* no. 2:315-327.

Weiss, E., M. E. Kislev, O. Simchoni, D. Nadel, and H. Tschauner. 2008. "Plant-food preparation area on an Upper Paleolithic brush hut floor at Ohalo II, Israel." *Journal of Archaeological Science* no. 35 (8):2400-2414.

Whitley, T.G., and L.M. Hicks. 2003. "A geographic information systems approach to understanding potential prehistoric and historic travel corridors." *Southeastern Archaeology* no. 22 (1):77-91.

Rethinking the Boundaries of *Baetica*: a Historiographical Criticism from Spatial Display

Ángel D. Bastos Zarandieta[1]

Daniel J. Martín-Arroyo Sánchez[1]

Mª del Mar Castro García[1]

Lázaro G. Lagóstena Barrios[1]

[1]HUM-240 – Patrimonio Histórico de Andalucía en la Antigüedad. Área de Historia Antigua. Seminario Agustín de Horozco. University of Cadiz.

Abstract

From a review of the political geography of *Hispania Vlterior Baetica*, we present some methodological principles to propose the geographical demarcation of provincial boundaries. Once the different historical proposals had been mapped, we proposed a buffer as an analysis tool. From the resulting proposal we have developed several study cases relating to the road network, the citizen territories and the provincial *limes*. The combination of various historical sources, the historiography and GIS applications proves its worth in the process of rethinking the provincial boundaries.

Keywords: *Baetica*, *fines*, GIS, historiography, methodology.

1. *Fines Baeticae*: historical issues and objectives.

The construction of the Roman Empire as a political structure entailed the establishment of territorial constituencies – *provinciae* - whose exact definition is still discussed by the historiography. During the conquest of *Hispania*, with a broad front of territorial expansion in the NE-SW diagonal and advancing roughly towards the NW, there was no historical definition of the perception of provincial spaces delimited with appropriate boundaries – *fines*; this became clearer as areas of jurisdictional competence of magistrates appointed by the Roman

Senate as political and military leaders of the conquered territories that were defined (Nicolet, 1978; Roldán, 2001).

A reading of the geographical description of Pliny's *Naturalis Historia* shows the diversity of elements that could be considered and conjugated to delimit a provincial unit: orographic entities, ethnic ensembles (Cruz, 2009), varied symbolic markers, etc. So, to revise the historiographical proposals and to define the boundary of *Baetica* is necessarily a flexible issue, in terms of chronological delimitation and historic perception.

Obtaining the geography of ancient social formations is an aspiration of research that is becoming feasible through the combined development of ICT and GIS. Most of the proposals that are nowadays study references were derived from the limitations of cartographic resources in the past. Today we can review these proposals from an exceptional geographic perception, comparing them with a geographical logic, and also with the use of historically and archaeologically well geo-referenced elements, from literary and epigraphic sources and from the cultural perspective that generated this political and juridisdictional space management.

This is the range and challenge of our research. We have designed a methodology that uses GIS location of urban civic entities bordering the provinces *Baetica*, *Lusitania* and *Tarraconensis* in order to define the buffer in which *fines* should be established.

The ultimate goal of our work is the establishment of a basis for mapping a geography of *Baetica*, beginning with a political geography that reasonably defines the provincial frame and the borders of the *conuenti iuridici*, and the precise location of the urban centres of civic communities. It would be desirable furthermore to make a hypothetical proposal on the territorial reach of the many civic organizations of *Baetica*. But this political geography is a puzzle that requires the correct placement of the pieces, in order to be completely recomposed. The overall objective of our researches about *Baetica* is to achieve quantitative data with spatial projection of available geographical information (surface areas, average altitude, comparative rainfall...), population information (population densities, urban settlement distribution...) and onomastic information (family distribution, community relations); also information about the various natural resources (agricultural, mining, forestry...) and their potential exploitation (crafting, processing, distribution...), and other strategic resources from the perspective of ancient communities (water control, communications, defence…). The importance of the proposed delimitation is that, especially in the context of a reasoned historical hypothesis, it will further the approach to a quantitative history.

2. Historiographical review of Baetican delimitation.

Historiographical Outline

Albertini, E. (1923).	· Based on Pliny descriptions. · *Flumen Anas* as border. · Exceptions on *Metellinum*, *Emerita Augusta* and *Serpa*.
Thouvenot, R. (1940).	· Based on Pliny. · *Flumen Anas* as border. · Exceptions on *Metellinum*, *Emerita Augusta* and *Serpa*. · Increased presence of delimitation by geographical factors. · Mention of the "*provinciae Baeticae Maurorum*" (in the of North Africa).
García Iglesias, L. (1972).	· Focused on the Baetican – Lusitanian border. · *Flumen Anas* **not** as border. · Territories of border cities as delimiters.
Marín, N. and Prieto, A. (1972).	· More attention gived to the indigenous component. · Less specific demarcation. · Pointed out errors in Albertini and Thouvenot.
Alarcão, J. (1988).	· Focused primarily on Western boundary. · *Flumen Anas* not as exact border.
Cortijo Cerezo, M.L. (1993).	· Most detailed, accurated and substantiated research. · Deep historiographical study (from Albertini's to latest researches). · Deep geographical analysis. · Study of the cases of *Baria*, *Lacimurga*, *Metellinum*, *Emerita Augusta*, *Zilil*.
Corrales Aguilar, P. (1997).	· Most based on geographical factors. · Focused on the Eastern boundary. · Lagerly discarded the indigenous component.

Figure 1: Historiographical outline.

The most and best studied territorial limit of all the provinces that formed *Hispania* was that of *Hispania Ulterior Baetica*. Although by the Nineteenth Century, cartographers, geographers and travellers were concerned with showing on the map the possible provincial divisions of Roman *Hispania* (as Sulzer *et al.*, 1893), until the early Twentieth Century we found no academic publications that attempt to capture its delimitation, as well as the various methods to define it.

For the delimitation of these boundaries, researchers have used different criteria. The relevance of these has fluctuated over the years. Thus, we can see how the first authors based their researches on the *chorographia* provided by the classical authors, mainly Pliny and Strabo (Albertini, 1923; Thouvenot, 1940). These works provide not only distances offered by these authors, but also valuable descriptions of landscapes, geographic features, information about the pre-Roman communities and their territorial distribution, etc.

Numerous authors have based their proposals on direct analysis of geographical features such as mountain ranges and rivers of different magnitudes, among other less obvious features. The Roman road network - and related objects - has also been used to characterize the provincial

boundaries. For example, in a critique of the Antonine Itinerary, pathways numbering was used to include them within the same province, (Hurtado, 1964, 102-108). Other authors studied pathways quality to try to establish the point where the responsibility for conservation passed from the hands of one provincial authority to another (Sillières, 1982). It is also stated that Rome based the spatial planning of *Baetica*, at least in the beginning, on pre-Roman divisions. This has led to a deeper study of the archaeological records, especially epigraphic, that could define somehow those old boundaries.

The issue of provincial boundaries of *Baetica* has turned around three points of interest: the river *Anas* as the border limit; the eastern border; and the impact of *Augustus*' land policies. The historiography has widely discussed the use of *flumen Anas* as the province delimiter; some authors have suggested the correspondence between the river and the border (Albertini, 1923; Thouvenot 1940; Alarcão, 1988), others came even to deny this possibility (García Iglesias, 1972). Concerning the delimitation of the eastern border, researchers have mainly focused on the geographical and urban elements (Cortijo, 1993), and have resorted to the indigenous factor to a lesser extent (Marín & Prieto, 1974). Others dismiss this factor, indicating that it could be applied only to the early Romanization period, without affecting the firmer establishment of the borders after *Augustus* (Corrales, 1997). Finally, the inclusion or exclusion of certain municipal *territoria* by *Augustus* and their interaction with the boundary has been readily taken into account in the historiography.

3. Methodological proposal.

The methodology we propose for locating the provincial boundaries is based on applying methods of Geographic Information Technologies to existing historical information. We can clarify the hypothesis and provide new approaches to the historiographical issues. The main proposed processes are:

- Geo-referencing of different historiographical proposals for the Baetican *fines* in a GIS (see Figure 2), delimiting an area of influence that will serve for further spatial analysis, indicating a high probability area for the existence of the ancient boundary. The buffer generated includes, with a double delineation, maximum and minimum extensions of the border on each stretch of the path, defining the frame in which the search for items indicating the existence of provincial boundaries will proceed.

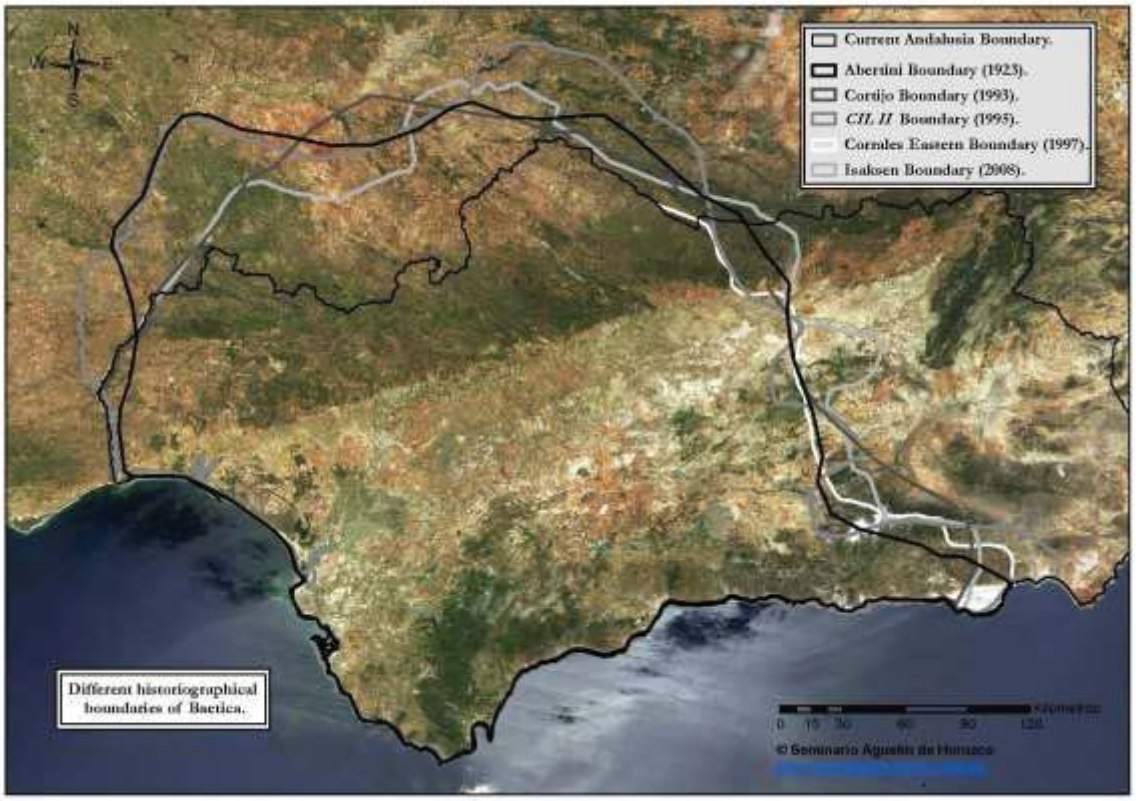


Figure 2: Historiographical proposals for Baetican boundaries.

- Identification and geo-referencing of distinctive elements, boundary markers in Antiquity, within the Baetican territory:

  a. The physical geography, mainly relevant landforms, which define a landmark in the landscape and the hydrography.

  b. The location of civic communities and the interaction of their hypothetical *territoria* among themselves and with provincial boundaries.

  c. The road sources, mainly itinerary information and milestones. These sources provide us with information on the location of unique elements that set limits, whether these were monumental landmarks, *mansiones* or *stationes* located at the intersection of the Roman roads and the hypothetical boundaries.

  d. The monumental landmarks, elements with high significance and uniqueness in the creation of the province.

3.1 Analysis of unique cases.

We present some application examples of the designed methodology for the study of provincial boundaries:

3.1.1. Road landmarks.

The border of *Baetica* served as a starting point for demarcation of *Via Augusta* inside the province. The Arch of *Ianus Augustus, caput uiae* located at the intersection of *Via Augusta*, the river *Baetis* and the provincial border, is known thanks to eleven milestones from different periods that convey different formulas: *a Baete et Iano Augusto*, *ab Iano qui est ad Baetem*, *ab arcu unde incipit Baetica* (*CIL* II 4701, 4703, 4704, 4707-4709, 4711, 4712, 4715-4717, 4721, 4722; Sillières 1981, 255-261).

P. Sillières (1990, 795-798) places this arch on a bridge over the river *Baetis*, near the confluence with river Guadalbullón, from detection on aerial photography and topographic mapping of the remains of *Via Augusta*, the contextualization of the eleven aforementioned milestones and the calculation of the distances provided.

Our review using GIS methodology includes the location of the milestones as mentioned by their discoverers and investigators. In the same way we have geo-referenced *stationes* and *mansiones* from itinerary sources. Subsequently, we created a polyline shape representing *Via Augusta*, outlined from previous studies, and proceeded to search for evidence in the field through remote sensing techniques using orthophotography. We have also taken into account the toponymy relatable to ancient bridges and roads on topographic maps and historical cartography.

The distance provided by one of the geo-referenced milestones (*CIL* 4715) is LXXXII *M(ilia) P(assuum)* towards *Ianus Augustus*. This landmark is located 16 miles from *Corduba* and approximately 2 kilometres from the current village of La Quintana. The aforementioned distance is equal to a total of 121500 meters. For this, we used the polemic equivalence of Radke (1971, col. 1447-1448), the validity of which was tested by Sillières (1990, 60) for *Via Augusta*. The same procedure was applied to the milestone located in the property of Rabanales (*CIL* 4729), which indicates a distance of LXII *milia passuum* towards *Ianus Augustus*, that is 91.5 kilometres. Contrasting this distance in GIS, we obtain a score of 91904 metres. From these calculations we have created a 1000 metre buffer from the *caput viae*, for the purpose of prospecting the land and finding evidence of the monumental arch of *Iano Augustus*.

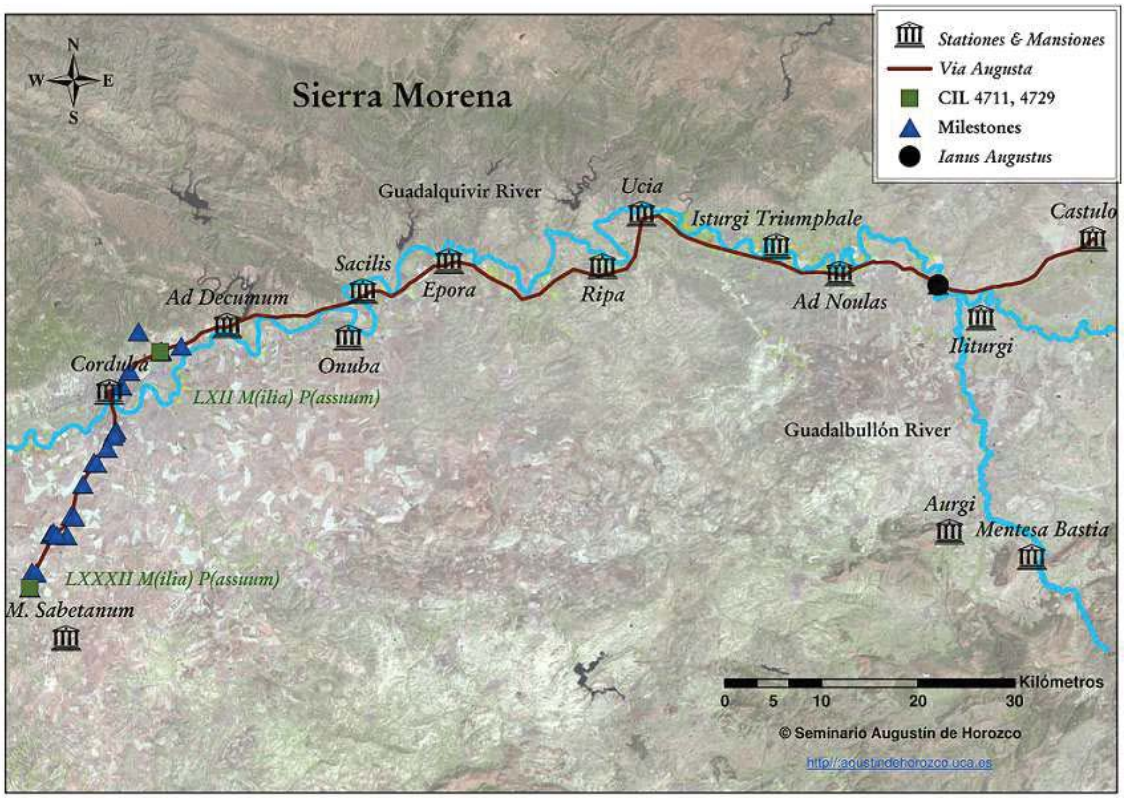


Figure 3: Map of Via Augusta mansions, stations and milestones.

On the western boundary of *Baetica* we observe another case of analysis whose study can be performed using our methodology. This is the case of *Ad Fines*, a *mansio* shown in the itineraries and located on the provincial border. Applying the method of recomposing the road on which it is located, and the conversion and calculation of the distances provided by the sources, we can establish an area of high probability of existence of the border.

3.1.2. Territoria

As we already mentioned, the spatial constitution of *Baetica* had to respond to several factors, recomposition of which leads to the very boundaries of the Roman province. Among these factors *Augustus* encountered the historical rights of pre-existing communities and the needs and commitments acquired with the colonies installed in *Baetica* and its immediate surroundings. At the same time, this colonial settlement was subject to a special process that begins in 45 BC (D.C., XLIII, 39, 4-5), after the Caesarean intervention against Pompeians, and culminated with the second trip of *Augustus* to *Hispania*, between 16 and 13 BC (D.C., LIV, 23, 7), when the province was probably constituted (D.C., LIII, 12, 4).

As we pointed out for the road network, we suggest territorial models of interaction of the colonies with the Baetican boundary (excepting *Baria*):

1. Territories delimiting the Baetican border from the outside: *Acci*.
2. Territories delimiting the Baetican border from the inside: *Tucci*.
3. Territories that exceed the Beatican boundary without affecting it: *Emerita*, *Metellinum* and *Pax Iulia*.
4. Territories which discontinuity affects the Baetican boundary: *Ucubi*.
5. Territories which make the Baetican boundary discontinuous: *Zilil* y *Baria*.

These cases show both different and shared characteristics. The difference between the outer and inner boundary responds to different conditions of the *territoria*, depending on whether it is included in a senatorial province (*Baetica*) or an imperial province (*Citerior Tarraconensis*). The territories could be continuous or discontinuous, establishing territorial 'islands'. These 'islands', single or multiple, could be inside, outside or over the boundaries of the provinces to which the owning cities belonged. Political regulation of this diversity is an issue to consider, but its treatment exceeds the scope of this work. For the hypothetical reconstruction of the territories which form the provincial boundary, we will use a set of strategies adapted to the available documentation.

In the case of *Acci*, a first approximation locates nearby towns according to the mapping offered by Sillières (1990) and, from various regional studies, other archaeological sites. Usually there has been interest shown in the dispersion of epigraphs indicating data such as *origo* or *tribus* as criteria for exclusion or inclusion of a specific territory near the approximate location of the discovery. For *Acci* we take into account the presence of one of the so-called singular *tribus*, the *Pupinia*. However, the scarcity of epigraphs makes their dispersion lack relevance for this study. The agricultural settlements do not allow the creation of a settlement pattern concerning colonization of *Acci*. The geographical analysis of their locations could provide some meaningful information in the future.

For the moment, facing a first cartographic representation of the research, it has been chosen to highlight a number of urban entities, *mansiones* and *thermae*. Surrounding towns are taken as delimiters of the space of *Acci*, with some reservations about its political conditions and more or less eccentric positions within their own territories. *Mansiones* and *thermae* are aggregation points relating to communication routes, and constitute space organizing elements. The road network is an important element in the compression of space, and a fundamental objective for

the advancement of the research. The mining sites are also landmarks, understood from a double geological and archaeological point. They are interesting because traditionally there have been questions regarding the role of mining in the constitution of territories, especially for colonies, and as a hypothetical condition for the exclusion of communities in the creation of the *Baetica* province. The reactivation of mining operations throughout history has often erased ancient traces, so the interpretation of this economic sector requires a special analysis. For that reason we initially chose to include proven Roman mining sites with others potentially exploited by them.

We also used the precise delineation of historical entities specific to the political geography. In the case of *Acci* it is the municipality and the tithe collectors of its diocese between 1750 and 1808 (Lara 2001, 76). In view of the absence of other previous constraints, we used this recent model, appealing to a certain geographic determinism and avoiding anachronisms. However, *Acci* already played a prominent religious role in Pagan and Christian Antiquity, with records of the existence of his bishopric at a late stage (González 2011, 321-327), when its territorial legacy still would not have undergone the medieval border modifications. Ecclesiastical properties and boundaries, beyond its own historical evolution, can syncretize and give continuity to various ancient territorial realities facing the succession of purely political formations.

The resulting image is significant as it suggests that the installation of the c*olonia Iulia Gemella Acci*, far from *Acci Vetus*, set a new power centre that divided a likely domain of *Basti* in the Hoyas de Guadix-Baza. In fact, the domain of the bishopric of *Acci* was restricted in modern times, when the hypothetical historical link with the environment of *Acci Vetus* did not exit, to the geographic unit of the Hoya de Baza and to the strategic corridor de Fiñana.

Limitation of indigenous hegemony and sustainability of the new foundation explain the inclusion of iron deposits in the area of influence of Peñón de Arruta and the surroundings of El Cardal. It also includes silver deposits at Lanteira (Minas del Marquesado). The former ones are attested from archaeology, the last one using toponymy (González 2011, 307). In support of the latter case, we should mention a pedestal dedicated to the goddess Isis (*CILA* IV 122; *CIL* II 3386 (p 952) = *ILS* 4422 = *SIRIS* 00761 = *ILPGr* 63 = *HEp* 5, 1995, 351) which attests to jewellery donation and a significant amount of silver, indirect testimony of the great fortunes that such mining exploitation would have generated.

Taking into account the certainties and uncertainties of the political environment and applying certain logical patterns in the appropriation of space by ancient communities, the Baetican boundary can be recomposed. Meanwhile, the application of techniques such as the historiographical buffer may represent valuable tools for reflection. Applied to the case of *Acci*,

it is observed overlaying the territory of *Acci Vetus*, whose territorial relationship with the colony, provincial affiliation and Baetican boundary effects may be rethought. It would also be interesting to explore the mining potentiality of delimited space by this historiographical buffer, under the criterion of the potential relationship with the colony. Ultimately, the determination of these issues will lead to a better definition of the Baetican boundary in this area.

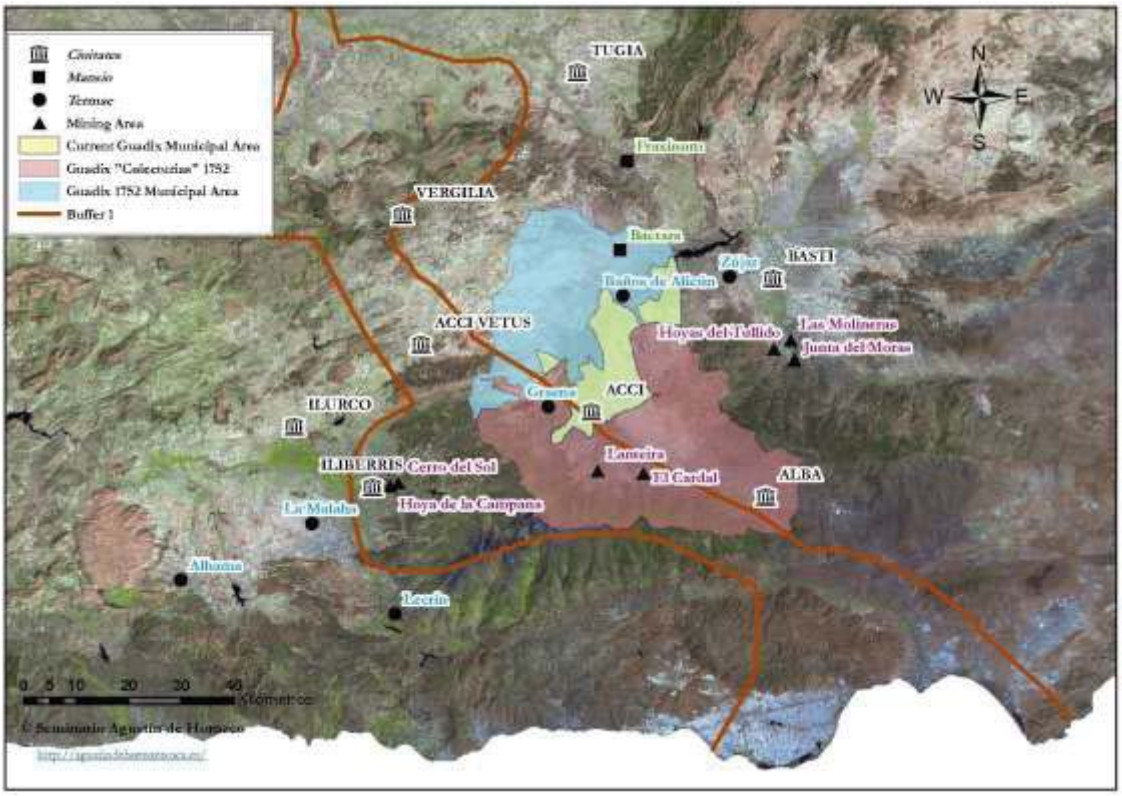


Figure 4: Elements to define the territorium of Acci.

When displaying the buffer and the the path of *flumen Anas* in relation to the most recent proposals about the *territoria* of *Emerita* (Cordero 2010) and *Metellinum* (Haba 1998), there is an evident inaccuracy in the traditional mapping, and potential historic and geographic disputes in the interpretation of provincial boundary. If we take the previous elements, and add the hydrographic network and a set of milestones and civic entities, we obtain a model on which other issues could be raised. First, the so-called '*trifinium* of Hispanic provinces'. We can note the accurate location of certain sites - *Metellinum* and *Lacimurga* - against the multiplicity of proposals given for others - *Contosolia* and *Artigi*. This polarity is also manifested in the assignment of communities to one province or another (Cortijo 1993, 68-71).

Another issue to discuss is the location of the *praefectura* of *Ucubi*. We can note the difficulty of establishing a continuous and consistent distribution of the *territoria* of *Lacimurga* and

Emerita to the environment of Mojón Gordo, especially if we accept the representation of the *territorium* of *Emerita* and the location of *Contosolia* in Casas de Don Pedro, the more likely according to M. L. Cortijo Cerezo (1993, 69). However, we might suppose an extension of the *territorium* of *Lacimurga* between the rivers Guadiana and Gargáligas which border the *territorium* of *Contosolia*, consequently projected to the other side of the Guadiana. Thus, the territory of *Lacimurga* would occupy a southeast quadrant over Mojón Gordo, the *praefectura* of *Ucubi* would take the northeast quadrant and the *territorium* of *Emerita* would spread to the west. Here is another hypothetical framework from which to rethink the layout of Baetican boundary.

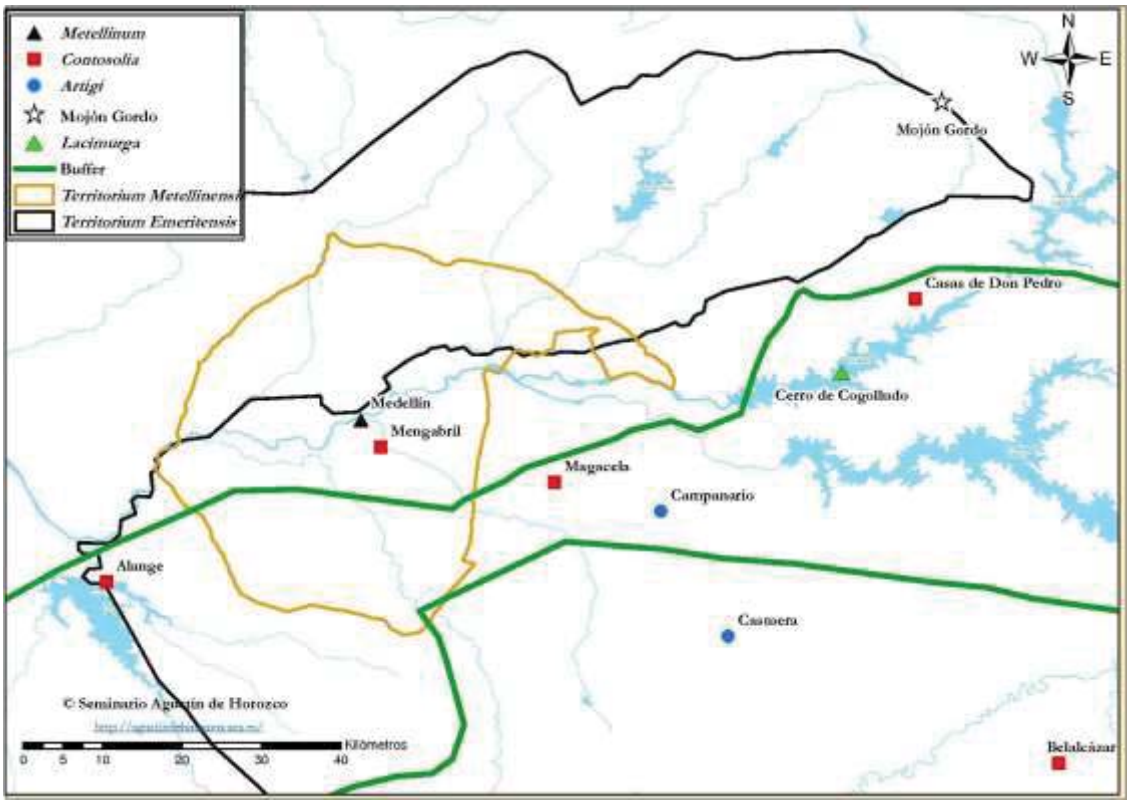


Figure 5: Elements to define the praefectura of Ucubi and trifinium of Hispanic provinces.

4. Conclusions.

The provincial border is the sum of the borders of certain civic communities, a dynamic reality dependent on the imperial policies and the heredities and local ambitions. The challenge of our project requires a rigorous representation and interpretation of the data. The creation of a GIS cartography base will offer a powerful tool for reflection on the Historical Geography.

With this methodology we check the accuracy of the distances provided by epigraphic sources and the suitability of the application of GIS in spatial analysis in studies of Ancient History. So,

with this study we present a methodological approach for the recomposition of the old Roman borders applicable not only to the boundaries of *Hispania Vlterior Baetica*, but also to the whole Roman ambit. A task remaining for further works would be the realization of our own proposal of delimitation of *Baetica*.

References

Albertini, E. 1923. *Les divisions Administratives de l'Espagne romane*. París: De Boccard.

Cordero Ruiz, T. 2010. "Una nueva propuesta sobre los límites del *ager emeritensis* durante el Imperio Romano y la Antigüedad Tardía". *Zephyrus* 65: 149-165.

Corrales Aguilar, P. 1997. "La provincia romana de la *Baetica*: notas para el establecimiento de su límite oriental y su compartimentación conventual". *Baetica: Estudios de arte, geografía e historia* 19: 415-430.

Cortijo Cerezo, M.L. 1993. *La administración territorial de la Bética romana*, Córdoba: Caja de Ahorros de Córdoba.

Cruz Andreotti, G. 2009. "Etnias, fronteras e identidades en la Antigüedad hispana: algunas precisiones metodológicas a partir de las fuentes escritas". *Arqueología Espacial* 27: 63-77.

De Alarcão, J. 1988. *Roman Portugal*, Warminster: Aris & Phillips Ltd.

Dion Cassius. 2004. "Historia romana. Libros XXXVI - XLV". Edited by José María Candau Morón y María Luisa Puertas Castaños. Vol. 326 of Biblioteca Clásica Gredos, edited by Carlos García Gual. Madrid: Editorial Gredos.

Dion Cassius. 2011. "Historia romana. Libros L - LX". Edited by Juan Manuel Cortés Copete. Vol. 395 of *Biblioteca Clásica Gredos*, edited by Carlos García Gual. Madrid: Editorial Gredos.

García Iglesias, L. 1972. "El Guadiana y los límites comunes de Bética y Lusitania". *Hispania Antiqua. Revista de Historia Antigua* 2: 165-178.

González Román, C. 2011. "*Colonia Iulia Gemella Acci* (Guadix, Granada). Colonia de César y Augusto en la Andalucía romana". *Hispania Antigua, Serie Histórica* 6: 297-341.

Haba Quirós, S. 1998. *Medellín Romano. La Colonia Medellinensis y su Territorio*. Badajoz: Diputación de Badajoz.

Hurtado, V. 1964. "Las provincias hispanorromanas y las Vías de Antonino". *El Miliario Extravagante* 5: 102-108.

Lara Ramos, A. 2001. *Iglesia y poder: propiedad y diezmos en la crisis del antiguo régimen. Guadix y su obispado (1750-1808)*. Granada: Biblioteca *Chronica Nova* de Estudios Históricos, Universidad de Granada.

Marín Díaz, N. and A. Prieto Arciniega. 1974. "En torno a un nuevo planteamiento de los límites de la provincia romana de la Bética". *Hispania Antiqua. Revista de Historia Antigua* 4: 77-86.

Nicolet, C. 1978. *Rome et la conquête du monde méditerranéen 264-21 av. J.-C*. Paris: Presses Universitaires de France.

Radke, G. 1971. *Viae publicae romanae*. Stuttgart: Alfred Druckenmuller.

Roldán, J. M. and F. Wulff. 2001. *Citerior y Vlterior: las provincias romanas de Hispania en la era republicana*. Tres Cantos: Istmo.

Silliéres, P. 1981. "A propos d'un nouveau milliaire de la Via Augusta une via militaris en Betique", *Revue d'Ètudes Anciennes* 83: 255-261.

Sillières, P. 1982. "Centuriation et voie romaine au sed de Mérida: contribution à la délimitation de la Bétique et de la Lusitanie". *Mélanges de la Casa de Vélazquez* 18: 437-448.

Sillières, P. 1990. *Les voies de communication de l'Hispanie meridionale*. París: De Boccard.

Thouvenot, R. 1940. *Essai sur la province romaine de la Bétique*. París: De Boccard.

Evaluating Viking eco-cultural niche variability between the Medieval Climate Optimum and the Little Ice Age: a feasibility study

Nicolas Antunes [1,2]

William E. Banks[1,3]

Francesco D'Errico[1,4]

[1] CNRS, UMR 5199–PACEA, Université Bordeaux 1.

[2] Inria Bordeaux Sud-Ouest.

[3] Biodiversity Institute, University of Kansas.

[4] Department of Archaeology, History, Cultural Studies and Religion, University of Bergen.

Abstract

In the northern Atlantic, Norse agricultural and pastoral practices flourished from the 9th to the 13th century, after which Viking occupation of these regions abruptly declined and eventually disappeared towards the beginning of the 15th century. In this study, in order to evaluate the possible role of climatic variability on Viking settlement of these regions, we used the Genetic Algorithm for Rule-Set Prediction (GARP) to reconstruct the Viking eco-cultural niches during the end of the Medieval Warm Period (MWP) and the beginning of the Little Ice Age (LIA).These reconstructions demonstrate that the application of ECNM to this time period and Viking settlement dynamics is both feasible and relevant. Furthermore, preliminary results suggest that climate and environmental change played prominent roles in the abandonment of Greenland by Viking populations and are consistent with available historical accounts. Our results encourage us pursue further analyses with the use of more precise paleoclimatic and archaeological data in order to better understand the role of environmental change in the disappearance of Viking culture from regions of the northern Atlantic.

Keywords*: Norse settlement; Greenland; Eco-cultural niche modeling; Little ice age.*

1. Introduction

Eco-cultural niche modeling (ECNM; Banks *et al.*, 2006; Banks *et al.*, 2008a) is a heuristic approach that has been used to evaluate how prehistoric cultures and their distributions may be affected by abrupt climate, and resulting environmental, change. The objective of this study is to test whether this approach is feasible and relevant for historical populations. ECNM integrates

archaeological, chronological, and environmental datasets, through the use of biocomputational architectures (Peterson *et al.*, 2011), to reconstruct the ecological niche occupied by a past, culturally-cohesive human population. This eco-cultural niche represents the range of environmental conditions within which a given culture can persist without having to immigrate (Banks *et al*., 2008a). To date, ECNM has been used to identify potential human ranges and explore the role of climatic variability on cultural geography and lithic technology during the Last Glacial Maximum (Banks *et al.*, 2009; Banks *et al.*, 2011), as well as to evaluate the role of climate in the disappearance of Neanderthals during the latter stages of Marine Isotope Stage 3 (Banks *et al*., 2008b).

In this feasibility study, we employ ECNM methods to assess the possible impact of climatic variability on the Norse settlement of Greenland. We opt to focus on Viking populations in this sub-arctic region because most authors suggest that the collapse of Viking settlements could be due to climatic change (Dansgaard *et al*., 1975; McGovern, 1991; Stuiver *et al*., 1995; Barlow *et al*., 1997; Kuijpers *et al.*, 1999; Patterson *et al*., 2010; D'Andrea *et al.*, 2011) while others, without systematically excluding climate as a factor, argue that political, economic, and cultural factors were the principal causes (Dugmore *et al.*, 2005, 2012; McGovern, 2007; Massa, 2010).

1.1. Norse settlement

Norse populations populated Iceland around AD 870, and a little over a century later, historical accounts indicate that Erik the Red and his father Thorvald Asvaldsson left Iceland because they had been implicated in a homicide (Gad, 1970; Karlsson 2000). In AD 985, they settled in a land named Greenland which was previously discovered by the explorer Gunnbjörn Ulfsson sometime between AD 876–932 and named Greenland by Erik Thorvaldsson (known as Erik the Red) in order to distinguish it from Iceland, as well as to attract settlers (Massa, 2010). Less than two hundred years later, the population of Greenland had grown to several thousand inhabitants due to climate conditions that favored Viking agricultural and pastoral practices (McGovern, 1991). Viking populations were primarily distributed in two regions: the Eastern Settlement and the Western Settlement (Figure 1). Based on ecclesiastic records, we know that the Western settlement had been abandoned by AD 1350, and the last record that documents a Norse presence Greenland is a letter dated AD 1409, which announces a marriage that took place in AD 1408 (Gad, 1970).

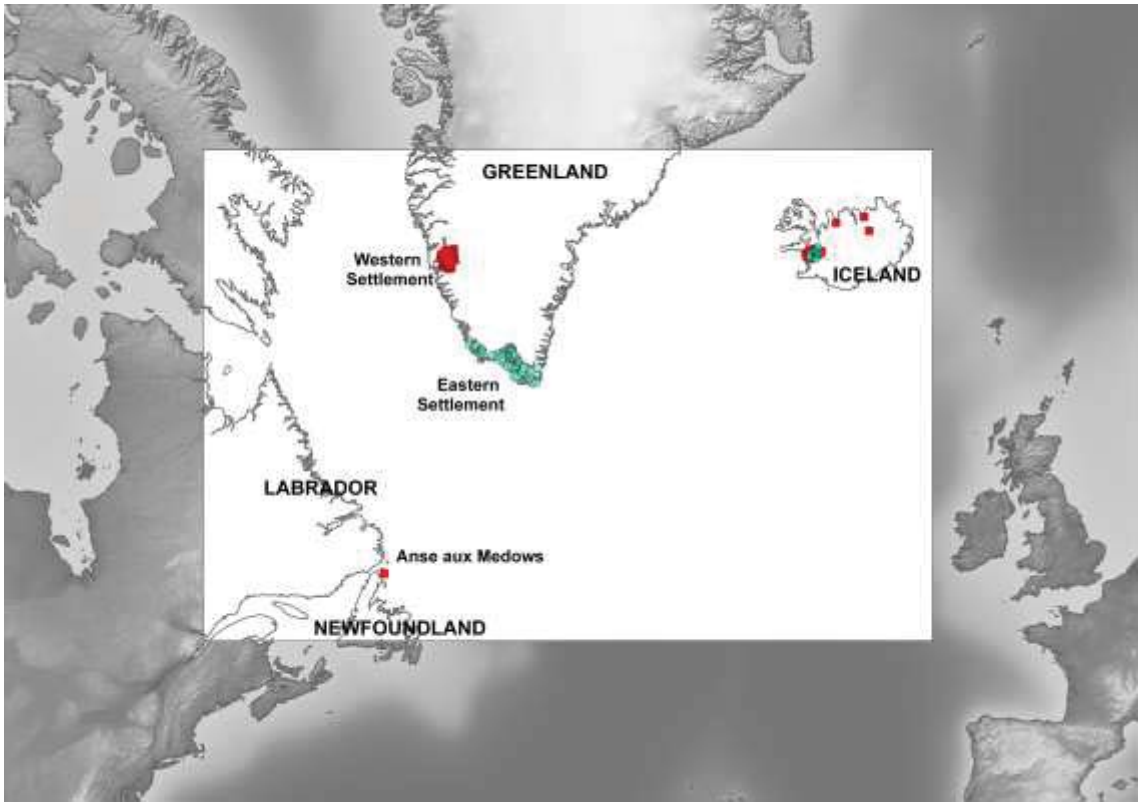


Figure 1: Map of the northern Atlantic showing the locations of the archaeological sites used to reconstruct eco-cultural niches. Both circles and squares represent the "first settlement" while circles alone represent the "second settlement".

1.2. Norse economy

Studies and simulations of farming economies that characterized the Viking era in Iceland suggest that the Norse economy required an adapted land management strategy that was based in part on specific suites of coastal environmental attributes and close economic and social connections between farmsteads (Adderley *et al*, 2008). It is reasonable to assume that the same held true for farmsteads in Greenland (Keller, 1991), and cultural and economic connections between Iceland and Greenland were maintained through trade. Populations in Greenland procured Arctic products such as walrus ivory, polar bear skins, and Arctic falcons, which were exchanged for commodities from Iceland such as iron, salt, timber, honey, and dyes.

Norse subsistence was principally based on livestock including cattle, sheep, goats, pigs and horses (Dugmore *et al*, 2012). While they did cultivate barley, corn spurrey (*Spergula arvensis*) and flax (*Linum usitatissimum*) (Fredskild and Humle 1991, Dugmore *et al.* 2012), most agricultural production focused on fodder used to feed cattle during the winter. These

agricultural practices required special and adapted equipment (closed fields, channel irrigation, manure fertilization, barns) and practices such as forest clearing (Arneborg, 2005; Adderley and Simpson, 2006; Adderley *et al.*, 2008; Buckland *et al*, 2009; Dugomore *et al.*, 2012; Fredskild, 2012). Norse sagas narrate that settlers in Greenland regularly sailed to Newfoundland in order to obtain timber, and a Norse presence in North America is indicated by archaeological materials recovered from the site of the Anse aux Meadows (Wallace, 1991).

During the early stages of their occupation of Greenland, which occurred during the Medieval Warm Period (MWP), Norse populations practiced agriculture and pastoralism while their neighbors, the Inuits, subsisted on sea resources. Isotopic analyses and zooarchaelogical data indicate that, across all five centuries of their Greenland occupation, Norse populations did progressively adopt Inuit subsistence practices to a minor extent (Arneborg *et al.*, 1999, 2012; McGovern *et al.*, 2006). However, as pointed out by several authors, on the whole, Viking populations did not significantly modify their sedentary, production-based lifestyle, and continued as much as possible their 'cultural intransigence' (Barlow *et al.*, 1997); *i.e*., agrarian production combined with livestock grazing.

1.3. Climatic deterioration and social impacts

Numerous climate records indicate that between AD 1350 and AD 1850 the climate deteriorated, and this period is termed the Little Ice Age (LIA). This severe climatic deterioration disturbed the Norse economy (Dansgaard *et al*., 1975; Dugmore *et al*., 2007), adversely affecting agricultural productivity due to dry winds (Lassen *et al*., 2004) and rising sea levels (Mikkelsen *et al*., 2008). These climatic changes also adversely affected trade since sea ice off southeastern Greenland significantly expanded and made shipping between Iceland and Greenland difficult (Kuijpers, *et al.*, 1999). In addition to the lack of hay to feed cattle and a lack of fresh water due to drought, the disruption of maritime trade routes deprived Greenlanders of products such as iron and timber. These colonies were no longer interconnected, thus preventing the maintenance of the Viking lifestyle in an environment not as clement as that of previous centuries. Furthermore, these populations were affected by disease, piracy, and conflicts with Inuits and other neighboring populations that they called "*Skræling"* (*Grœnlendinga saga* and *Eiriks saga rauða*). All of these factors created a situation in which Norse populations were obliged to either modify their subsistence practices or abandon their Greenland settlements.

2. Materials and methods

To estimate Viking eco-cultural niches, we used the Genetic Algorithm for Rule-Set Prediction (GARP; Stockwell and Peters, 1999). For data inputs, GARP requires the geographic coordinates where the target population has been observed as well as raster GIS data layers that summarize the environmental variables that may be involved in constraining its geographic distribution.

2.1. Archaeological data

We obtained the geographic locations of archaeological sites by scanning and rasterizing maps found in the literature (Krogh,1982; Adderley et al. 2008; McGovern et al., 2007) in Visque: a Google Earth application (http://www.nabohome.org/visque/), or in Google Earth research for the Anse aux Meadows.. Archaeological sites are divided into two datasets to match historical accounts of the settlement of Greenland. The first includes all locations (i.e.: Iceland settlement, Eastern and Western Greenland settlements and the Anse aux medows, n = 544) and is used to represent the Norse distribution during the early period of settlement (MWP and initial LIA). The second dataset represents settlement for the LIA and thus excludes sites in regions that are known to have been abandoned at the beginning of that period (i.e.: some Icelandic sites, Western settlement of Greenland and the Anse aux Meadows, n = 447). Site locations are depicted in Figure 1. Two hundred sites were randomly sampled from each dataset in order to produce each eco-cultural niche prediction. The first sample based on all sites is termed "first settlement", and the second based on remaining sites is identified as "second settlement."

2.2. Environmental data

The GIS layers include climatic and topographic data. Climatic data were obtained from a Global Climate Simulation (Jungclaus *et al.*, 2010: http://www.ncdc.noaa.gov/ paleo/metadata/noaa-model-10477.html) and include monthly values for surface solar radiation, surface air temperature at 2 meters above sea level, barometric pressure, and precipitation from AD 800 - 2100. Spatial and temporal computations were processed for each variable. The first step was to increase the spatial resolution for the targeted region (Figure 1), while the second step targeted specific time periods. These operations were performed with the statistical software package R. The spatial treatment was performed using a bilinear method of interpolation, which allows one to obtain a 0.5° resolution from the original 3.5° resolution (*i.e.*, grid cell resolution is refined from 180 km to 26 km on a side). This coarse rounding technique

does not take in account microclimates due to local variations but still provides general climatic trends. These operations allowed us to obtain a total of 16 climatic variables (mean values for the months of April, July, October, as well as an annual mean for each of the four climatic parameters) (Table 1). We also included elevation as an environmental variable (Source: Global Multi-resolution Terrain Elevation, Data 2010 - http://eros.usgs.gov/). In order to make its resolution consistent with the climatic layers, we averaged neighbor squares with the same bilinear interpolation method.

2.3 Eco-cultural niche modeling

With these formatted environmental data layers as input, we used GARP to predict the Norse eco-cultural niche for each settlement described above. The first niche prediction used archaeological sites assigned to the “first settlement” and climatic data of the MWP (AD 985–1200). This period represents the height of the Norse settlement of Greenland. The sites assigned to the "second settlement" and the climatic data for the beginning of LIA (AD 1300–1450) were used to reconstruct an eco-cultural niche corresponding to the period characterized by the abandonment of the Western settlement and ultimately the end of the Viking occupation of Greenland. GARP was set-up to produce 200 predictions (100 max iterations for each), and these were summed to produce the final eco-cultural niche predictions.

In order to evaluate potential changes in the geographic distribution of the Norse niche over time and across period of climatic change, we projected the 11th century, "first settlement" eco-cultural niche prediction onto environmental conditions for each century between AD 800–1600.

2.4. Statistics

To evaluate and compare the MWP and LIA eco-cultural niche predictions, we performed a principal component analysis (PCA) using the library Ade4 of the R software.

3. Results

3.1. Geographic expressions of predicted niches: first and second settlements

The eco-cultural niche predictions performed for the MWP and the LIA are shown in Figure 2. For the first settlement, we note that a high probability of presence is predicted for almost all of Iceland and southwestern Greenland (Figure 2A). One also observes that a high-probability of presence is predicted in a small region of southern Labrador, and a lower probability of presence

is predicted across a larger area to the north. The second settlement's niche (Figure 2B), shows, relative to the first settlement's niche, a geographical contraction and a disappearance of some areas predicted present in Iceland and Greenland during the MWP. These regions that are lost in the LIA prediction are those that included Greenland's Western Settlement and northern Iceland. Similarly, the regions previously predicted present at a low probability level in northern Labrador are not present in the LIA prediction. However, at the same time, there is a geographic expansion of the Norse eco-cultural niche in southern Labrador. Finally, with respect to the Norse LIA niche, the presence of the predicted niche is only in areas that have known archaeological sites. In other words, the geographic expression of this niche prediction corresponds strictly to areas that are known to have been settled.

3.2. Environmental variable correlations: first and second settlements

Principal Component Analyses performed on the environmental variables for the first and second settlements' predicted niches indicate that there are marked differences between the two (Figure 3). The first two components of the PCA of the first settlement's niche (Figure 3A) represent 75.90 % of the total inertia (component 1 = 51.85 %, component 2 = 24.05 %). The first two axes of the PCA of the second settlement's niche (Figure 3B) explain 68.38 % of the total inertia (component 1 = 46.80 %, component 2 = 21.58 %).

Figure 3C and Figure 3D show there to be large differences between absolute inertia values for many variables between the two niche predictions. With respect to the first component, these differences occur for the annual Equivalent Precipitation Temperature (EPTy), Equivalent Precipitation Temperature for the months of July and October (EPTj, EPTo), and mean sea level barometric pressure in July (MSLPj). For the second component, the differences between the two niche predictions exist for elevation (DEM), Surface Solar Radiation during April and July (SSRa, SSRj), Temperature for April and July (T2Ma, T2Mj), Mean Sea Level Pressure (MSLPy, MSLPa, MSLPj, MSLPo), and Equivalent Precipitation Temperature (EPTy, EPTa, EPTj, EPTo). Further, it should be noted when these variables are not opposed, one of both has almost zero inertia. Finally, variables such as Precipitation (EPTa, EPTj, EPTo, EPTy), Surface Solar Radiation (SSRa, SSRj), and Temperature (T2Ma, T2Mj) show a shift to the left in the second settlement's niche, indicating lower mean values (Figure 4). Thus, the second settlement occupied an ecological niche characterized by a dryer annual climate, lower levels of solar radiation, and colder spring and summer months.

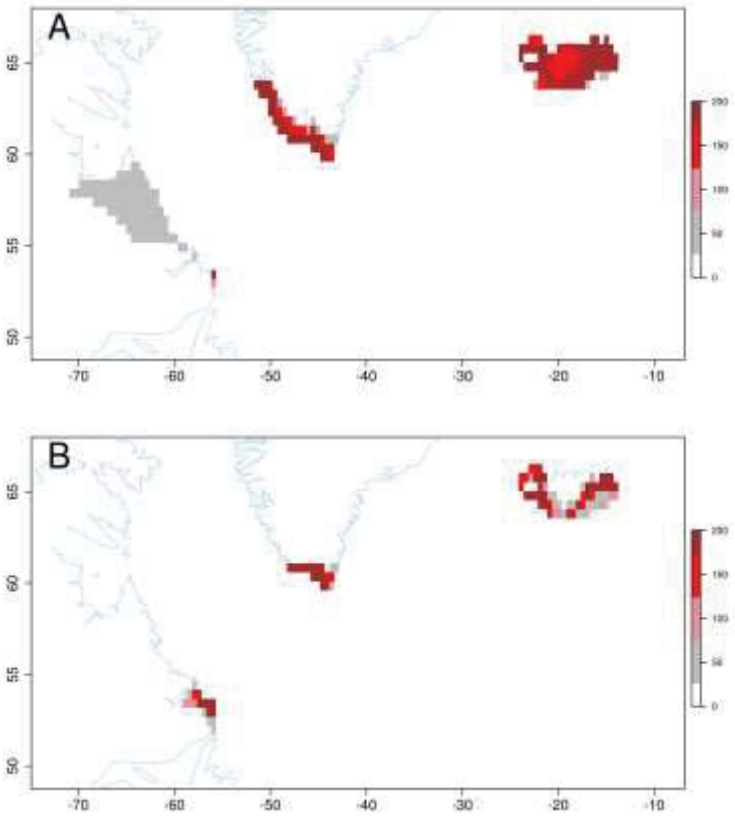


Figure 2: Geographic expressions of the Norse eco-cultural niches predicted for A) the first settlement at the end of the Medieval Warm Period (A.D. 985–1200), and B) the second settlement at the beginning of the Little Ice Age (A.D.1300–1450). These niche reconstructions represent the sum of the 200 produced models and grid square color ranges from grey, to pink, to red, and to brown, or low to high probability: grey = 26–75 models in agreement, pink = 76–125 models in agreement, red = 126-175 models in agreement, and brown = 176-200 models in agreement. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

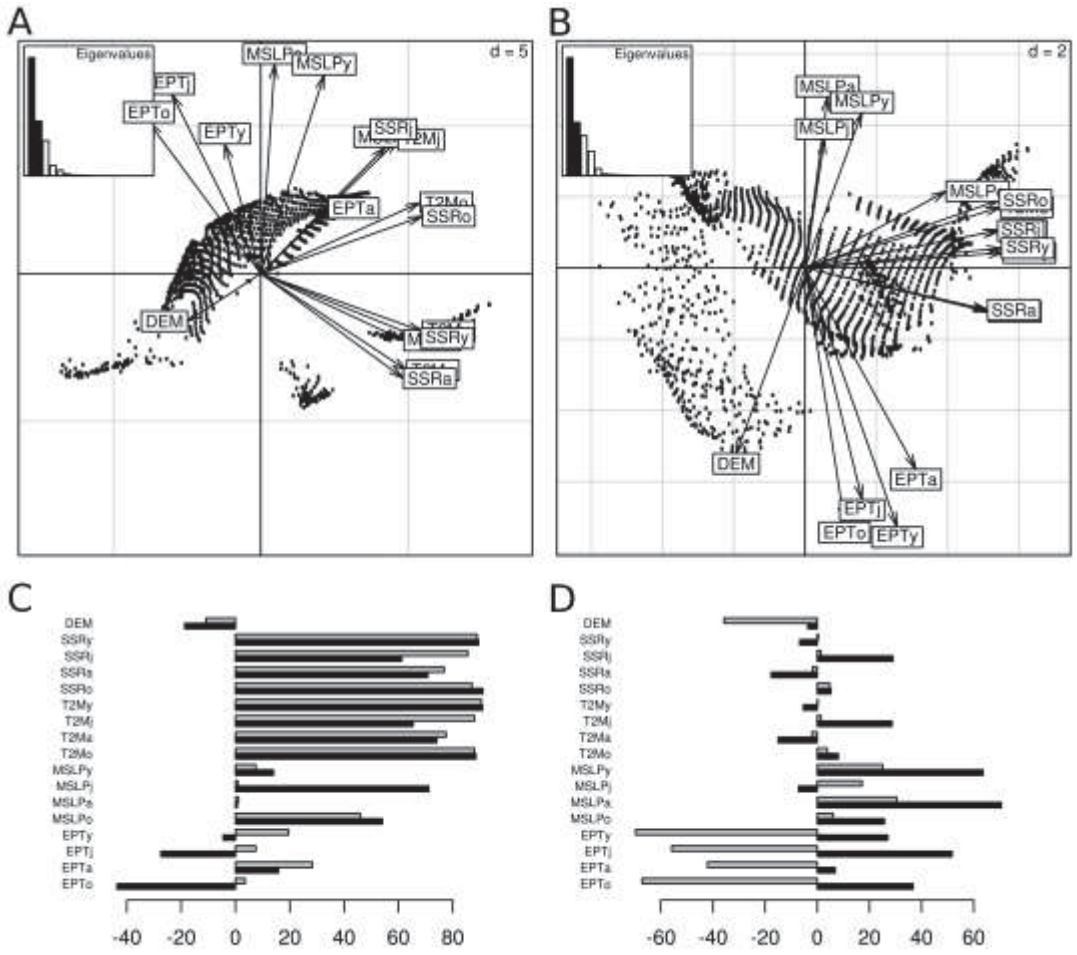


Figure 3: PCA (Principal Component Analysis) of environmental variables of the first and second settlements' predicted eco-cultural niches. Environmental variables are symbolized by arrows, and points depict the predicted presence locations. Black bars represent inertia of the PCA performed on the first settlement's results, while white bars represent depict inertia of the PCA performed on the second settlement's results. (A) Eigen values and factorial map of the first settlement's PCA. (B) Eigen values and factorial map of the second settlement's PCA. (C) Contribution of environmental variables to the first component of each PCA. (D) Contribution of environmental variables to the second component of each PCA. See Table 1 for the list of environmental variables and their abbreviations

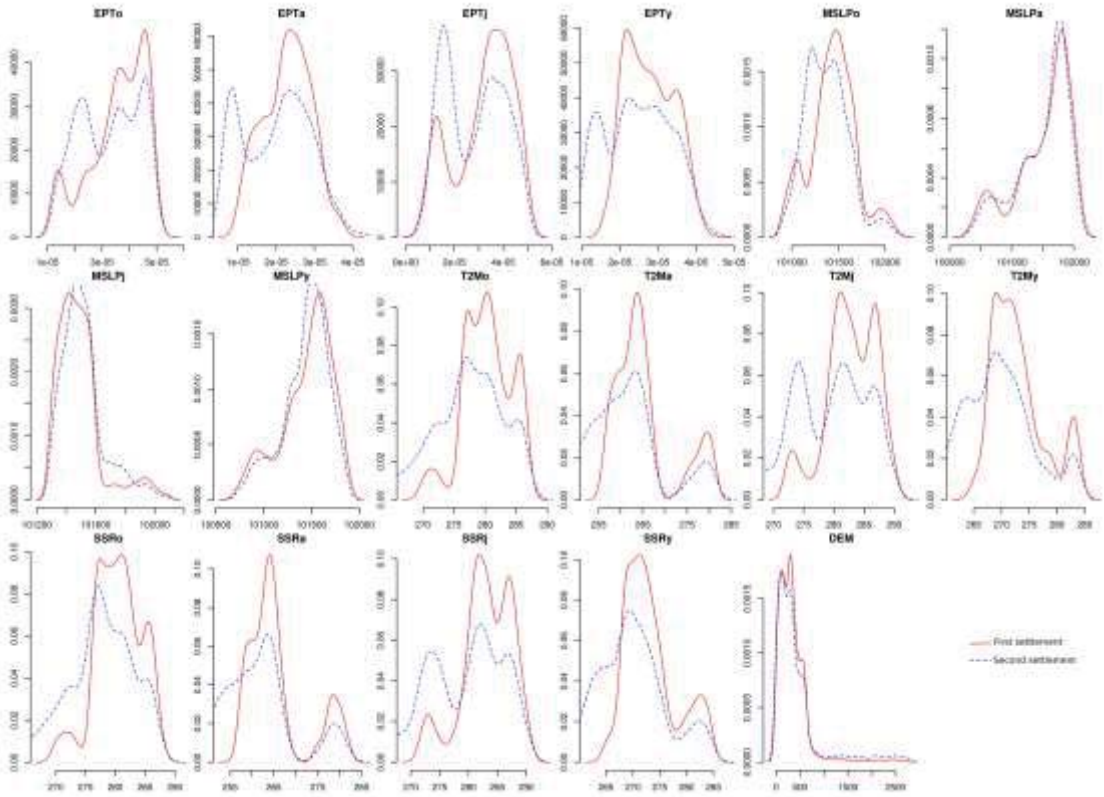


Figure 4: Environmental variable density plots. The density function disperses the mass of the empirical distribution function over a regular grid of at least 512 points. The fast Fourier transform is then used to convolve this approximation with a discrete version of the kernel. Finally, linear approximation is used to evaluate the density at the specified points. See Table 1 for the list of environmental variables and their abbreviations.

3.3. Century-scale variability of the Viking eco-cultural niche

Niche predictions depicted in Figure 5 show the Viking niche predicted for the 11th century (Figure 5C), as well as the projections of this reconstructed niche onto the climatic conditions of other centuries. One notes that the maximum geographic extents of the 11th century prediction and its projections occur during the first four periods (9th–12th centuries). These results correspond closely to the first settlement niche prediction. One also observes that the 10th, 11th and 12th century niche predictions include regions of North America (Northern Labrador / North-Eastern Quebec) but at low levels of probability. On the other hand, the Anse aux Meadows (see location in Figure 1) is never successfully predicted, and only the prediction for the 9th century has a small area, in southeastern Labrador, with a high probability of predicted presence.

The latter four centuries (13th–16th) show a reduction in the geographical area predicted as potentially suitable. There is no longer a presence predicted in North America, and the potential niche in Iceland is relatively small compared to the predictions for the previous centuries (9th-12th). One also observes that in Greenland the geographic extent of the predicted niche decreases. Predictions that have the highest value of presence are located to the south.

4. Discussion

This feasibility study demonstrates that eco-cultural niche modeling methods are effective for evaluating how climatic variability affected the settlement of Greenland by Norse populations, and our results are consistent with available historical accounts (Gad, 1970; Karlsson 2000) and oral histories (*Grœnlendinga saga* and *Eiriks saga rauða*). Furthermore, the Norse niche predictions identify suitable areas for Norse settlement in northeastern North America, and they indicate that climatic variability also affected Norse settlement in Iceland. While there are minor variations in the expression of the Norse niche within each major climatic episode (*i.e*., the Medieval Warm Period and the Little Ice Age), the overall trend shows a contraction of the geographical expression of the ecological conditions occupied by Viking populations. Future work needs to focus on quantifying this reduction and determining whether this contraction represents an actual contraction of the eco-cultural niche, or whether it simply reflects the fact that Viking populations conserved their niche and tracked its shrinking footprint during the climatic deterioration of the LIA.

Such work may also serve to identify the reason behind the slight geographic expansion of the Norse niche during the 15th century, which is an intriguing result considering that it occurs during the period that saw the eventual abandonment of Viking settlements in Greenland. Two hypotheses to explain this pattern could be tested. The first hypothesis postulates that rigorous environmental conditions during the 13th and 14th centuries were sufficient to adversely affect and disrupt local and interregional Viking economies, and when combined with other impacts from disease, piracy, and conflicts with indigenous populations (Dansgaard *et al*., 1975; Keller, 1991; Dugmore *et al.*, 2012), the result was that Viking populations had been adversely impacted by these conditions such that they were unable to respond to a slight period of climatic amelioration. Ultimately, Norse populations were unable to adapt to the LIA and Greenland settlements were abandoned (see Barlow *et al.*, 1997). A second hypothesis is that Viking populations were able to adapt by modifying their agrarian adaptations and adopting subsistence

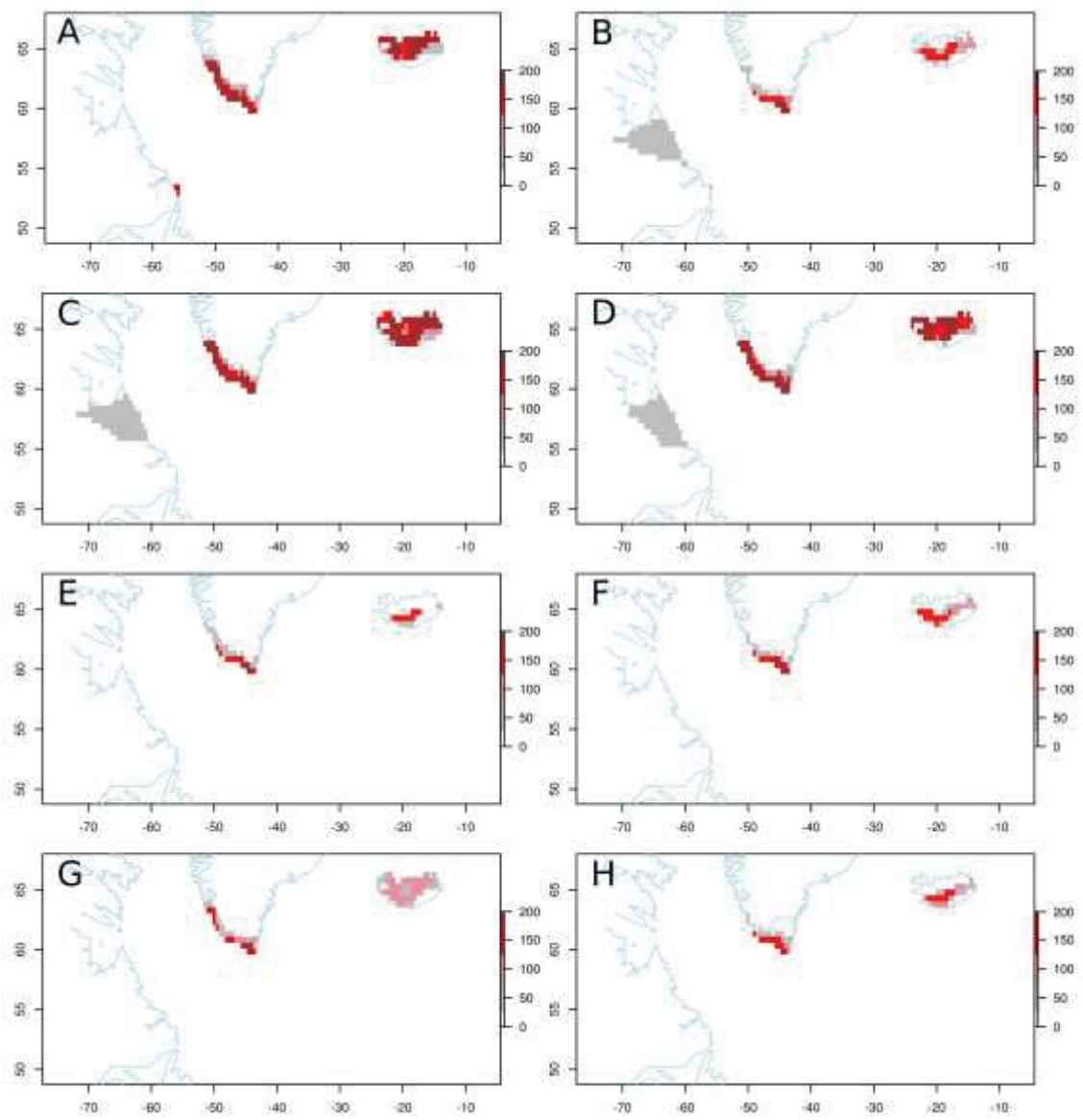


Figure 5: Century-scale variability of the Viking eco-cultural niche. The 11th century Norse eco-cultural niche and its projection onto the climatic conditions of other centuries. (A) projection onto the 9th century, (B) projection onto the 10th century, (C) projection onto the 11th century, (D) projection onto the 12th century, (E) projection onto the 13th century, (F) projection onto the 14th century, (G) projection onto the 15th century, (H) projection in climatic environment for the 16th century. These niche reconstructions represent the sum of the 200 produced models and grid square color ranges from grey, to pink, to red, and to brown, or low to high probability: grey = 26–75 models in agreement, pink = 76–125 models in agreement, red = 126-175 models in agreement, and brown = 176-200 models in agreement. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

methods practiced by indigenous populations, as suggested by Annerborg (2012). Although unlikely, this hypothesis proposes that a Norse presence, albeit reduced, continued in Greenland but became archaeological invisible with respect to its "Viking" signature. One possible way to test this idea is to reconstruct eco-cultural niches based on Iniut archaeological site datasets and compare these results to Norse eco-cultural niche predictions.

Finally, at present, our archaeological and paleoclimatic data have limitations that need to be addressed before future studies may proceed. The attribution of archaeological sites to either the first or second settlement datasets needs to be refined through more detailed analyses of material culture as well as relative and absolute dating techniques. Such work ultimately will allow for more accurate eco-cultural niche predictions. With respect to the climatic data, the data used in this study were simple interpolations of Jungclauss' global climate models. Thus, we would need to apply statistical downscaling techniques to increase the resolution of climatic variables for the targeted time periods. At present, we are collaborating with paleoclimate modelers in order to apply state of the art statistical downscaling techniques (Levasseur *et al.*, 2011) to global simulations that cover the last millennium. With such an approach we can expand the number of climate variables considered, such as relative humidity and wind. Another option, albeit more difficult, is to produce high-resolution paleoclimatic simulations for the MWP and LIA. Once such work has been completed, with these higher-resolution climatic data layers, we will be able to produce more robust eco-cultural niche predictions that better reflect past reality and thereby test the preliminary results obtained with the present study. Moreover, with more precise and robust niche predictions, we will be able to apply statistical methods to identify and evaluate possible niche shifts over time (*e.g.*, partial-ROC methods: Peterson *et al.*, 2008; see Banks *et al.*, 2012 for an archaeological example).

5. Conclusions

The demise of the Norse occupation of Greenland represents one of the few known historical cases in which climate change may have functioned as the prime mover in such cultural (settlement and subsistence) dynamics. Our preliminary results suggest that this is likely the case, but further work incorporating more precise archaeological and paleoclimatic data is necessary to refine and possibly confirm our findings. This additional work will also allow us to better identify and evaluate the environmental factors that played a principal role in the settlement variability documented in the Viking archaeological record. Finally, it may also be possible, albeit difficult, to evaluate the hypothesis that Norse populations adopted more arctic-adapted subsistence practices to the degree that they become archaeologically unrecognizable as Vikings.

Name	Meaning	Unit
EPTo	mean of equivalent precipitation temperature for October	$kg.m^{-2}.s^{-1}$
EPTa	mean of equivalent precipitation temperature for April	$kg.m^{-2}.s^{-1}$
EPTj	mean of equivalent precipitation temperature for July	$kg.m^{-2}.s^{-1}$
EPTy	mean of equivalent precipitation temperature for the year	$kg.m^{-2}.s^{-1}$
MSLPo	mean sea level pressure at the surface for October	Pa
MSLPa	mean sea level pressure at the surface for April	Pa
MSLPj	mean sea level pressure at the surface for July	Pa
MSLPy	mean sea level pressure at the surface for the year	Pa
T2Mo	contains air temperature at 2m for October	K
T2Ma	contains air temperature at 2m for April	K
T2Mj	contains air temperature at 2m for July	K
T2My	contains air temperature at 2m for the year	K
SSRo	surface solar radiation for October	K
SSRa	surface solar radiation for April	K
SSRj	surface solar radiation for July	K
SSRy	surface solar radiation for the year	K
DEM	elevation	m

Table 1: Climatic variables derived from the paleoclimatic simulation and their abbreviations.

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References

Adderley, W. P. and I.A. Simpson. 2006. "Soils and palaeo-climate based evidence for irrigation requirements in Norse Greenland." *Journal of Archaeological Science* 33 (12): 1666 – 1679.

Adderley, W. P., I.A. Simpson and O. Vésteinsson. 2008. "Local-scale adaptations: A modeled assessment of soil, landscape, microclimatic, and management factors in Norse home-field productivities." *Geoarchaeology* 23 (4): 500-527.

Arneborg, J. 2007. "Greenland irrigation systems on a west Nordic background: an overview of the evidence of irrigation systems in Norse Greenland c. 980-1450 AD." *Pamatky Archeol Suppl* 17: 137-145.

Arneborg, J., J. Heinemeier, N. Lynnerup, H.L. Nielsen, N. Rud and A.E. Sveinbjцrnsdóttir. 1999. "Change of Diet of the Greenland Vikings Determined from Stable Carbon Isotope Analysis and 1 4C Dating of Their Bones." *Radiocarbon* 41(2): 157-168.

Arneborg, J., N. Lynnerup, J. Heinemeier, J. Mцhl, N. Rud and A.E. Sveinbjцrnsdóttir. 2012. "Norse Greenland Dietary Economy ca. AD 980-ca. AD 1450: Introduction." *Journal of the North Atlantic* 3: 1-39.

Banks, W.E., F. d'Errico, H.L. Dibble, L. Krishtalka, D. West, D.I. Olszewski, A.T. Peterson, D.G. Anderson, J.C. Gillam, A. Montet-White and others. 2006. "Eco-cultural niche modeling: new tools for reconstructing the geography and ecology of past human populations." *PaleoAnthropology* 4: 68-83.

Banks, W. E., F. d'Errico, A.T. Peterson, M. Vanhaeren, M. Kageyama, P. Sepulchre, G. Ramstein, A. Jost and D. Lunt. 2008a."Human ecological niches and ranges during the LGM in Europe derived from an application of eco-cultural niche modeling." *Journal of Archaeological Science* 35(2): 481–491.

Banks, W. E., F. d'Errico, A.T. Peterson, M. Kageyama, A. Sima and MF. Sánchez-Goñi. 2008b."Neanderthal Extinction by Competitive Exclusion." *PLoS ONE* 3(12): 3972.

Banks, W. E., J. Zilhão, F. d'Errico, M. Kageyama, A. Sima and A. Ronchitelli. 2009. "Investigating links between ecology and bifacial tool types in Western Europe during the Last Glacial Maximum." *Journal of Archaeological Science* 36(12): 2853 - 2867.

Banks, W. E., T. Aubry, F. d'Errico, J. Zilhão, A. Lira-Noriega and A.T. Peterson. 2011. "Eco-cultural niches of the Badegoulian: Unraveling links between cultural adaptation and ecology during the Last Glacial Maximum in France." *Journal of Anthropological Archaeology* 30(3): 359-374.

Banks, W. E., F. d'Errico and J. Zilhão. 2013. "Human-climate interaction during the Early Upper Palaeolithic: testing the hypothesis of an adaptive shift between the Proto-Aurignacian and the Early Aurignacian." *Journal of Human Evolution* 64(1): 39-55.

Barlow, LK., J.P. Sadler, A.E.J. Ogilvie, P.C. Buckland, T. Amorosi, J.H. Ingimundarson, P. Skidmore, A.J. Dugmore and T.H. McGovern. 1997. "Interdisciplinary investigations of the end of the Norse Western Settlement in Greenland." *The Holocene* 7(4): 489-499.

Buckland, P. C., K.J. Edwards, E. Panagiotakopulu and J.E. Schofield. 2009. "Palaeoecological and historical evidence for manuring and irrigation at Garthar (Igaliku), Norse Eastern Settlement, Greenland." *The Holocene* 19: 105-116.

Dansgaard, W., S.J. Johnsen, N. Reeh, N. Gundestrup, H.B. Clausen and C.U.Hammer. 1975 "Climatic changes, Norsemen and modern man." *Nature* 255: 24-28.

Dugmore, A.J., M.J., Church, P.C. Buckland, K.J. Edwards, I., Lawson, T.H. McGovern, E. Panagiotakopulu, I.A. Simpson, P. Skidmore and G. Sveinbjarnardóttir. 2005 "The Norse landnám on the North Atlantic islands: an environmental impact assessment." *Polar Record* 41(1): 21-37.

Dugmore, A.J., C. Keller and T.H. McGovern. 2007. "Norse Greenland settlement: reflections on climate change, trade, and the contrasting fates of human settlements in the North Atlantic islands." *Arctic anthropology* 44(1): 12-36.

Dugmore, A.J., T.H. McGovern, O. Vésteinsson, J. Arneborg, R. Streeter and C. Keller. 2012. "Cultural adaptation, compounding vulnerabilities and conjunctures in Norse Greenland." *Proceedings of the National Academy of Sciences* 109 (10): 3658-3663.

D'Andrea, W.J., Y. Huang, S.C. Fritz and N.J. Anderson. 2011. "Abrupt Holocene climate change as an important factor for human migration in West Greenland." *Proceedings of the National Academy of Sciences* 108 (24): 97-65.

Fredskild, B. and L. Humle. 1991. "Plant remains from the Norse farm Sandnes in the western settlement, Greenland." *Acta Borealia* 8(1): 69-81.

Fredskild, B. 2012. "Erosion and vegetational changes in South Greenland caused by agriculture." *Geografisk Tidsskrift-Danish Journal of Geography* 92: 14-21.

Gad, F.1970. *A History of Greenland, vol. 1: Earliest times to 1700*. London: Hurst and Co. Publishers.

Jungclaus, JH., S.J. Lorenz, C. Timmreck, C.H. Reick, V. Brovkin, K. Six, J. Segschneider, M.A. Giorgetta, T.J. Crowley, J. Pongratz and others. 2010 "Climate and carbon-cycle variability over the last millennium." *Climate of the Past* 6/5: 723-737.

Karlsson, G. 2000. *Iceland's 1100 years: the history of a marginal society*. London: C. Hurst and Co. Publishers.

Keller, C. 1991. "Vikings in the West Atlantic: a model of Norse Greenlandic medieval society." *Acta Archaeologica* 61/1990: 126-141.

Krogh, K.J. 1982. *Eric den Rødes Grønland. København: Nationalmuseets Forlag.* Copenhagen.

Kuijpers, A., N. Abrahamsen, G. Hoffmann, V. Hühnerbach, P. Konradi, H. Kunzendorf, N. Mikkelsen, J. Thiede and W. Weinrebe. 1999. "Climate change and the Viking-age fjord environment of the Eastern Settlement, South Greenland." *Geology of Greenland Survey Bulletin* 183: 61-67.

Lassen, S.J., A. Kuijpers, H. Kunzendorf, G. Hoffmann-Wieck, N. Mikkelsen and P. Konradi. 2004. "Late-Holocene Atlantic bottom-water variability in Igaliku Fjord, south Greenland, reconstructed from foraminifera faunas." *The Holocene* 14(2): 165-171.

Levasseur, G., M. Vrac, D.M. Roche, D. Paillard, A. Martin and J. Vandenberghe. 2011. "Present and LGM permafrost from climate simulations: contribution of statistical downscaling." *Climate of the Past* 7(4): 1225-1246.

Massa, C. 2010. "L'implantation médiévale scandinave de la côte sud-ouest du Groenland comme la limite du modèle agro-pastoral importé d'Europe du nord: Implications paléoenvironnementales." *Sciences Humaines Combinées*.

McGovern, T.H. 1991. "Climate, correlation, and causation in Norse Greenland." *Arctic Anthropology* 28(2): 77-100.

McGovern, T., S. Perdikaris, A. Einarsson and J. Sidell. 2006. "Coastal connections, local fishing, and sustainable egg harvesting: patterns of Viking Age inland wild resource use in Mvatn district, Northern Iceland." *Environmental Archaeology* 11(2): 187-205.

McGovern, T.H., O. Vésteinsson, A. Friðriksson, M. Church, I. Lawson, I.A. Simpson, A. Einarsson, A. Dugmore, G. Cook, S. Perdikaris and others. 2007. "Landscapes of Settlement in Northern Iceland: Historical Ecology of Human Impact and Climate Fluctuation on the Millennial Scale." *American Anthropologist* 109(1): 27-51.

Mikkelsen, N., A. Kuijpers and J. Arneborg. 2008. "The Norse in Greenland and late Holocene sea-level change." *Polar Record* 44(1): 45-50.

Patterson, W.P., K.A. Dietrich, C., Holmden and J.T. Andrews. 2010. "Two millennia of North Atlantic seasonality and implications for Norse colonies." *Proceedings of the National Academy of Sciences* 107(12): 5306-5310.

Peterson, A.T., M. Papes and J. Soberón. 2008. "Rethinking receiver operating characteristic analysis applications in ecological niche modeling." *Ecological Modelling* 213(1): 63-72.

Peterson, A.T., J. Soberon, R.G. Pearson, R.P. Anderson, E., Martinez-Meyer, M Nakamura and M. Araujo. 2011. *Ecological Niches and Geographic Distributions*: Princeton: Univ. Press.

Stockwell, D. 1999. "The GARP modelling system: problems and solutions to automated spatial prediction." *International Journal of Geographical Information Science* 13(2): 143-158.

Stuiver, M., P.M. Grootes and T.F. Braziunas. 1995. "The GISP2 delta 18° climate record of the past 16,500 years and the role of the sun, ocean, and volcanoes." *Quaternary Research* 44(3): 341-354.

Wallace, B.L. 1991. "L'Anse aux Meadows: Gateway to Vinland." *Acta Archaeologica* 61: 166-197.

The role of the limestone in the Middle Palaeolithic technological behaviours through the refitting and the spatial patterning analysis: the level O of the Abric Romaní site (Capellades, Barcelona, Spain)

Amèlia Bargalló [1-2]

María Gema Chacón [1-2-3]

Bruno Gómez de Soler [1-2]

Maria Soto[1-2]

[1] IPHES, Institut Català de Paleoecologia Humana i Evolució Social, C/Escorxador s/n, 43003 Tarragona, Spain

[2] Àrea de Prehistòria, Universitat Rovira i Virgili (URV), Avinguda de Catalunya 35, 43002 Tarragona, Spain

[3] UMR7194 – Département de Préhistoire, Muséum National d'Histoire Naturelle, 1, rue René Panhard, 75013 Paris, France

Abstract

The role of limestone into the Middle Palaeolithic lithic assemblages was considered "minor" and its use normally associated to percussion activities as hammerstones. In this paper we present the data obtained from the studies of: (1) procurement areas, (2) lithic technology and (3) refitting and spatial patterning analysis of the limestone assemblage from level O of the Abric Romaní site. The results obtained have been compared with the rest of archaeological remains of the archaeological level from an interdisciplinary point of view. So, these studies allow to corroborate that limestone role was very important and similar to chert (the mainly raw material used), but not only in the organization of the technological behaviours, but also in the other subsistence activities developed by the Neanderthal groups that occupied the site around 55 ka BP.

Keywords: *Limestone remains, refitting, spatial patterning, Neanderthal, Abric Romaní.*

1. Introduction

The variability of the Middle Paleolithic stone tool assemblages is one of the principal issues in the classic debate about Neanderthal populations, especially because it is one of the main approaches to understanding the behaviour of hominids and obtaining information about social organization and evolutionary changes. Technological studies combined with refitting analysis and spatial patterning of the lithics allows the reconstruction of the technical behaviours of a hominid group from the procurement of the raw material until the discard of the tools. During the Middle Palaeolithic one of the most used lithic raw materials is chert and other type of siliceous rocks due to their good aptitude for knapping (eg. Navazo et al. 2011; Peresani 2012; Thiébaut et al. 2009; Vaquero et al. 2012a). If they were not available at the environment they were replaced or combined with another type of stone (quartz, basalt, limestone, quartzite…) normally collected in local and semi-local areas (eg. Bargalló 2008; De Lombera et al. 2011; Mourre and Thiébaut 2008; Rios-Garaizar 2010).

The limestone, together with others as quartz or quartzite, is one of the so called "minor" raw materials, because: (1) the minor quality and aptitude to knap, (2) the localization of their procurement areas (local) and (3) their main use as hammerstones into the technical knapping processes. Moreover, when these stones were submitted to reduction sequences they were introduced to the site as whole cobbles or pebbles and the knapping methods would be more expedient and with less technical requirements that in the case of siliceous rocks (eg. Discoidal, orthogonal…) (Geneste 1989, 1991a, 1991b; Kuhn 1992, 1995; Otte 1991; Roth and Dibble 1998; Turq 2000). However, these premises do not always reflect the reality of the Middle Palaeolithic lithic assemblages (Agustí et al. 1991; Baena et al. 2005; Bargalló 2008; Chacon 2009, Duran and Soler 2006; Moncel et al. 2007; Mourre and Thiebaut 2008; Colonge and Mourre 2009; Lazuén et al. 2011; Vaquero et al., 2012a, 2012b).

2. Materials

In this paper we present one example about the important role of limestone in the Middle Palaeolithic technological behaviours through the refitting and the spatial patterning analysis at the level O of the Abric Romaní site.

2.1 Abric Romaní

This rockshelter is located near the town of Capellades (Barcelona, Spain) in the travertine cliff called Cinglera del Capelló, at 280 metres above sea level. The strategic geographical and geological position of the site, at the crossroads of different ecosystems (mountainous inland and coastal plain), offered a wide variety of resources to the prehistoric groups (Fig. 1).

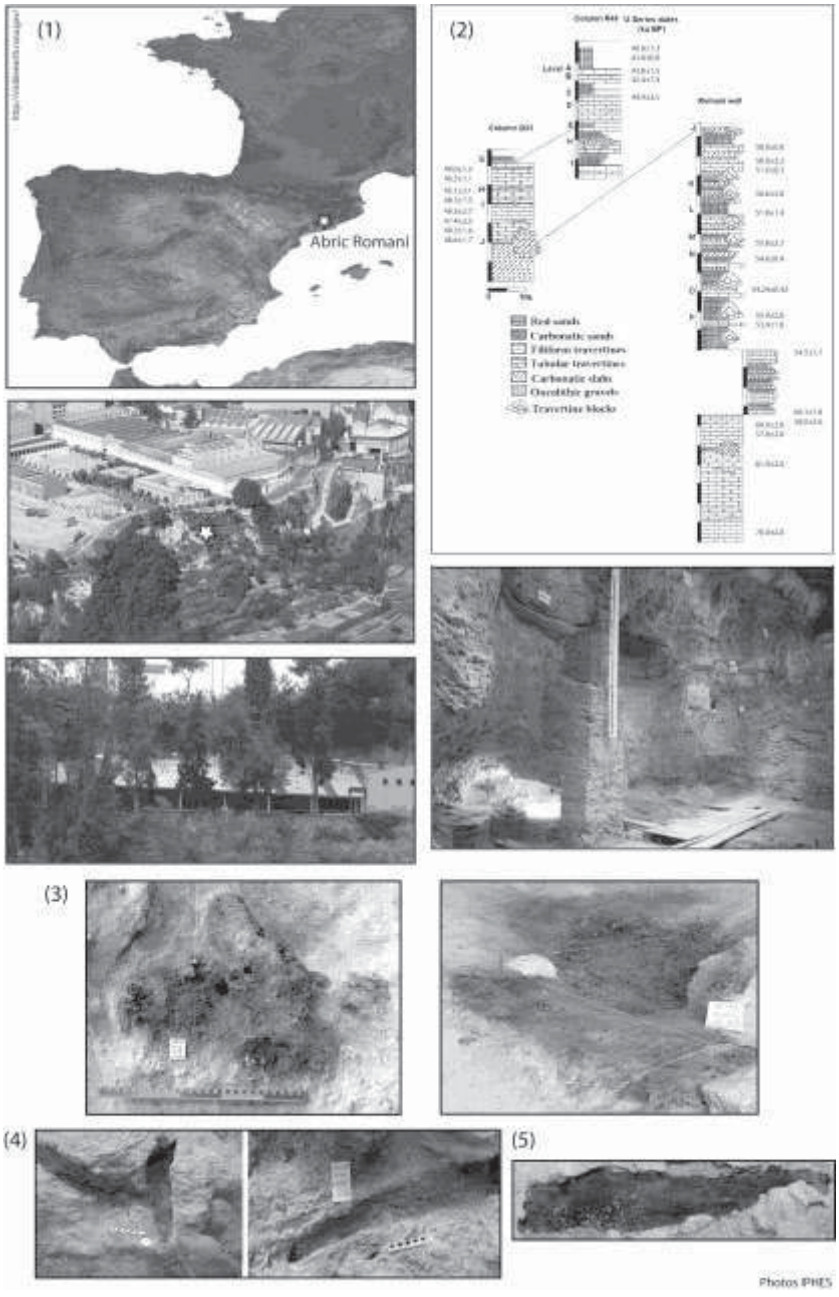


Figure 1: (1) Geographic location of the Abric Romaní site, (2) stratigraphy and dating of the Abric Romaní site (modified from Giralt et Julià, 1996; Bischoff et al., 1988 and 1944; Vallverdú et al. 2012), (3) examples of hearths, (4) examples of negatives of wood remains, (5) examples of positives remains, all from the Abric Romaní site (Photos IPHES)

This site was discovered in 1909 by Amador Romaní and was excavated at different times throughout the 20th century. Current research at the site started in 1983 and is based on the excavations of large surface areas (around 300 m^2) in order to construct a spatial interpretation of the archaeological record.

The 20 m-thick stratigraphy is made up of several sedimentary facies, but tufas are predominant. It has been dated by U-series and radiocarbon between 40 and 70 kyr BP (Bischoff et al., 1988, 1994; Vallverdú et al., 2012). Various different layers have been identified, all belonging to the Middle Palaeolithic except level A, which belongs to the Aurignacian. Fourteen layers (from level B to P) have been excavated until now (Fig. 1). The archaeological levels are thin layers separated by thick and sterile tufa deposits. This is a particularly rapid formation process (the sedimentary rate has been calculated at 0.46 mm/yr − Bischoff et al. 1988), which has produced archaeological levels of high temporal resolution, creating a clear vertical separation of the human occupation horizons (Vaquero 2011). This natural formation processes and the methodology of excavation are particularly favourable for studies on spatial organization. As well, the thermal impacts and combustion structures in these calcareous sediments are well preserved, and a large number of hearths have been identified in all the archaeological layers (Fig 1).

2.2 Level O

The upper section of level O (which focused our study) has been dated around 54.6 ± 2.3 kyr BP (USGS 07-9) (Bischoff et al., 1988; Vallverdú et al., 2012) . Excavated between 2004 and 2011 it has so far provided 38720 remains, with an average of 85.72 remains/m^2. Among these remains there are: lithics (23273), faunal remains (9288), charcoals (4176), wood imprints (109), and combustion structures or hearths (19) (Vallverdú et al., 2012). The current excavation surface reaches 271 m2. In this paper we present the refitting study of the limestone remains recovered at the level O. The materials studied for the refit were recovered from the entire excavated surface (from lines 40 to 62) (Fig 2: A). We aim to provide information about the role of the limestone in the level O of the Abric Romaní.

3. Methods

3.1 Fieldwork. Documentation and record.

As noted previously, the travertine and other sedimentary facies associated with travertine formation form the principal part of the stratigrafic deposit. These processes are characterised by a rapid sedimentary rate. Human occupations were very discontinuous, since the shelter was not habitable during the travertine formation periods (Vaquero, 2008). Archaeological horizons are thin layers separated by thick strata of sterile travertine and they are therefore vertically well delimited. The archaeostratigraphic study has been subdivided the level O into two sublevels (from top to base): Oa and Ob. However, in some areas of the site it has not been possible to differentiate them. For this reason, in these areas the archaeological layer has received the provisional name of "sublevel O". Subsequent transdisciplinary studies will try to clarify the relationships between these areas and the sublevels Oa and Ob.

This level was excavated in the whole surface using a grid of 1 m^2. All materials found were recorded as individual points on a three-dimensional diagram representing the site. All objects were plotted using Cartesian coordinates (X, Y and Z). This method allows us to visualize the three-dimensional space, facilitating the study of activity areas and the possible spatial connections between them. The excavation followed the natural paleorelief, which is guided by sedimentary and archaeological remains. This level shows a spatial distribution in which twelve clusters can be recognised (Fig 2: B). Nine of these domestic areas belong to Oa sublevel and three to Ob sublevel. The archeostratigraphic analysis was done with Golden Surfer Software (Bresnahan et al. 2008).

3.2 Raw Material

Artefacts are first classified according to raw material. Limestones documented in the level O of the Abric Romaní site (Capellades, Barcelona, Spain) have their origin in the outcrops of Prelittoral ranges, in the Palaeogene formations of the Ebro Basin, and in the quaternary deposits of the Anoia fluvial system (Mediona-Riudebitlles river and Carme creek) (Solé Sabarís, 1958-1964; Anandón et al., 1979). Dolomitic limestones and tabulated dolomites are found in Muschelkalk facies of the Prelittoral ranges. Limestones also have been located in the Ebro basin at Orpí formation (Eocene) in primary position, an as part of conglomerates, in secondary position at Pobla de Claramunt formation (Eocene) and Guixera Series (Pliocene) (Fig. 3: A). All these outcrops can be found in an area lower than 10 km, indicating a local

procurement for this raw material (Gómez de Soler, 2007; Gómez de Soler, 2009; Vaquero et al., 2012a; Vaquero et al., 2012b).

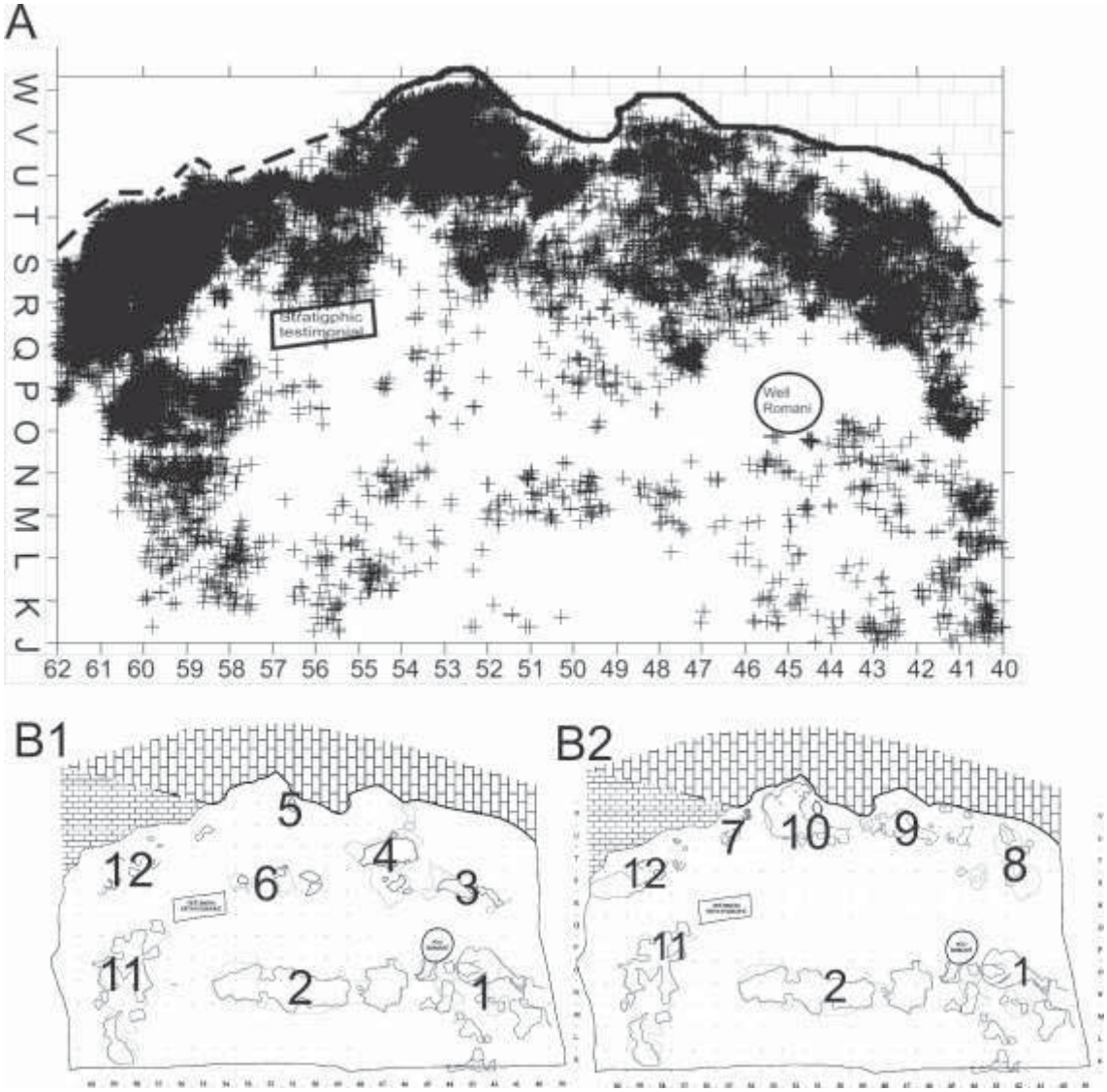


Figure 2: A) Spatial distribution of all the archaeological remains. B) Spatial organization of intra-site activities (B1 Domestic areas at Oa sublevel; B2 Domestic areas at Ob sublevel).

Most cortical surfaces of limestone found in level O indicates its introduction from secondary sources, principally the Anoia River an in a lesser degree the conglomerate formations. Nevertheless some subrounded cobbles have been documented, which is related to a sub-primary origin, suggesting minimum displacement of clasts from outcrops near to the Abric Romaní probably the Muschelkalk facies or the Orpí formation.

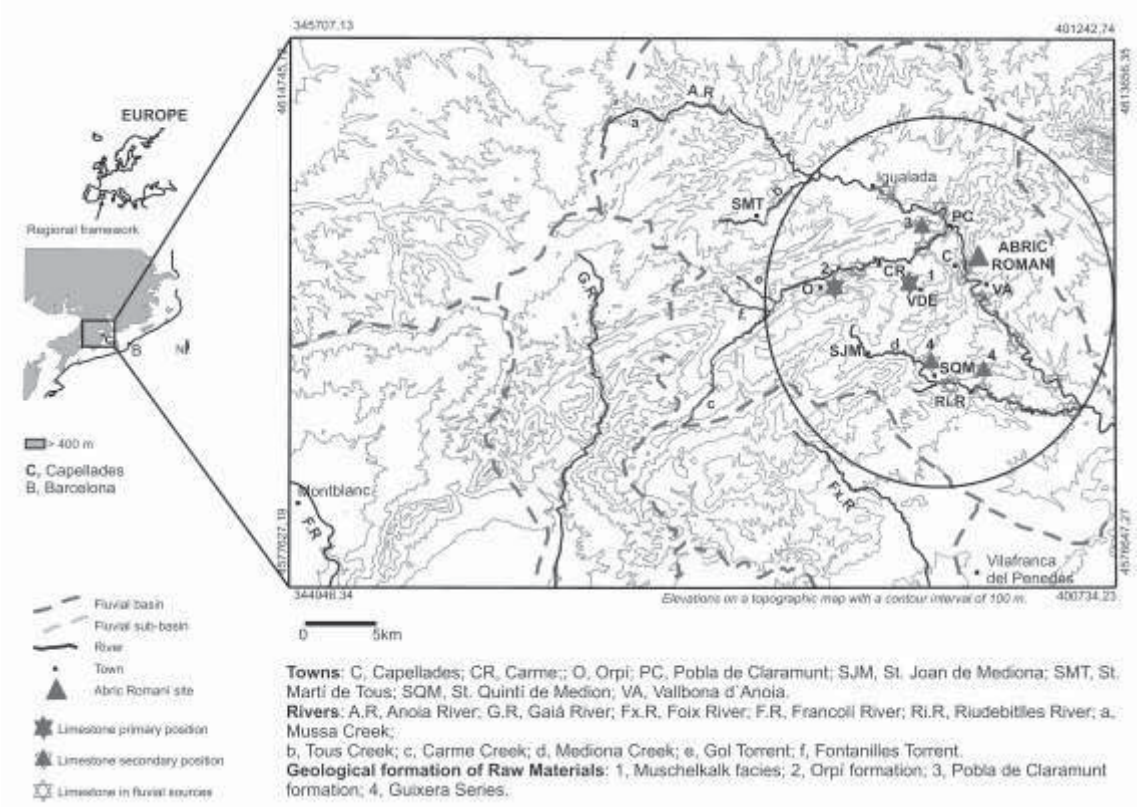


Figure 3: A) Map showing the distribution of the geological formations with limestone resources.

The use of limestone for flake production is associated to its quality and its aptitude for knapping. Mainly two petrological groups have been distinguished. Ones gray to greyish-yellow fine-grained micritic limestone or dolomitic limestone with conchoidal fracture, and the other ones white to greyish-orange medium-grained microsparitic and sparitic with granular fracture. The use of the first group is attested for knapping and percussion activities. Second ones are mainly used as structural elements, for example to delimitate hearths, which is an aspect well documented in the site. In the level O we have documented fourteen types of limestone.

The second classification is performed by Raw Material Units (RMUs) (Roebroeks, 1988; Schäfer, 1990, Odell, 2004). This concept (RMU) incorporates the artefacts produced during the reduction of a single nodule. RMUs are defined according to the macroscopic characteristics of the raw materials including colour, grain, size, texture, inclusions and type of cortex. Although they come from the same nodule, the artefacts forming a RMU do not necessarily correspond to the same technical event, since different episodes can be carried out at different times and places on the artefacts detached from a single nodule. According to the number and type of remains, RMUs have been characterized taking into account two main features: how they were

introduced into the site and what kind of intentional modification was performed on them inside the rock-shelter (Vaquero et al. 2012b).

3.3 Lithic refitting

The first step is based on the identification of individual knapping episodes. Refitting and raw material unit are the best procedures to employ in order to document these technical individual events. Refitting methods have been extensively described in the literature (Cziesla 1990, Hofmen and Enloe, 1992; Morrow 1996; Schurmans and De Bie, 2007). We have used the methods and terminology suggested in Cziesla (1990) and Sisk and Shea (2008). Three kinds of connections have been distinguished: production-sequence, breakage and retouch refits. For production and retouch refits, connection lines have been defined according to the chronological order of detachments, from the first refitted flake to the core or tool (Carbonell, 2012). For the refits of broken artefacts, connection lines have been established taking into account the contacting surface (Carbonell, 2012). Sisk and Shea (2008) point out the importance of the differentiated use of conjoin and refit: 1) Refits are sets of artefacts split from each other by controlled conchoidal fracture (eg. a flake whose ventral side joins to the surface of a core or the dorsal surface of another flake). The refits inform us about technological strategies. 2) Conjoins are fragments of formerly whole artefacts broken by forces other tan conchoidal fracture (eg. natural flaws, bending fractures, fire cracks…).

Considering the methodological and sedimentary framework of the excavation and the problematic of the "minor stone raw materials" during Middle Palaeolithic the aim of this paper is focused in the limestone lithic assemblage from level O at the Abric Romaní site. Recent works about other levels of the site (J and M) allow to aware that the role of limestone were more important for the technological behaviours and the subsistence activities that we observed before (Chacon 2009; Vaquero et al., 2012a, 2012b). We have applied the same methodology to the limestone assemblage of level O: (1) study of the procurement and management areas, (2) study of limestone refitting, (3) analysis of the spatial patterning and lastly (4) comparing and crossing the results of our study with the others anthropic evidences at the site (fauna, hearths and wood remains) to provide information about the role of limestone in the general subsistence activities developed at the site during the occupation of level O. For what type of activities the limestone was used? Does it exist a differential management of limestone comparing with the other stone raw materials used? Which is its place in the frame of the technological knapping processes? Which is its place in the frame of the subsistence activities of the Neanderthals groups that occupied the site?

4. Results

The lithic limestone assemblage of level O is made up of 1212 artefacts. Pieces with less than 2 cm of maximum dimension, complete cobbles and pieces with calcium carbonate concretions (364 in total) have been discarded for refitting analysis. Knapping products from the bulk of the assemblage are mainly flakes (30.06%), fragments (26.42%) and broken flakes and flakes fragments (34.51% together). Cores and retouched artefacts exhibit low percentages, 1.49 and 0.3% respectively.

4.1 RMU

The RMU identified (n=58) correspond to fifty-eight different inputs of lithic resources that were transported to the site. Each RMU was projected to determine its distribution and to check whether any characteristic spatial concentration were present (Fig 4: A). We have differentiated four basic ways in which these resources were introduced as: (1) unworked, (2) tested nodules, (3) partially reduced cores, (4) flakes. The distribution of the fifty-eight RMUs according to these different cathegories indicates that the transport of unworked or tested nodules was one of the strategies. This evidence shows the use of limestone cobbles as hammerstones. The introduction of partially reduced cores is documented for some of the limestone RMUs: several of these units correspond to very short reduction sequences that have provided only few flakes.

4.2 Lithic refitting

Eighty-three connections between two hundred thirty-six pieces have been found, and most of them are knapping sequence refits, such as core-flake or dorsal- ventral joint association. Fifty-one refits and thirty-two conjoins have been identified.

The spatial distribution projections of the connections lines between refits and conjoins points shows a very clear dynamic: it follows the slope of the spatial patterning of the material assemblage (Fig 4: B).

The results of the refitting and spatial pattern study of the limestone from Level O allowed to document the various specific functions depending of its use:

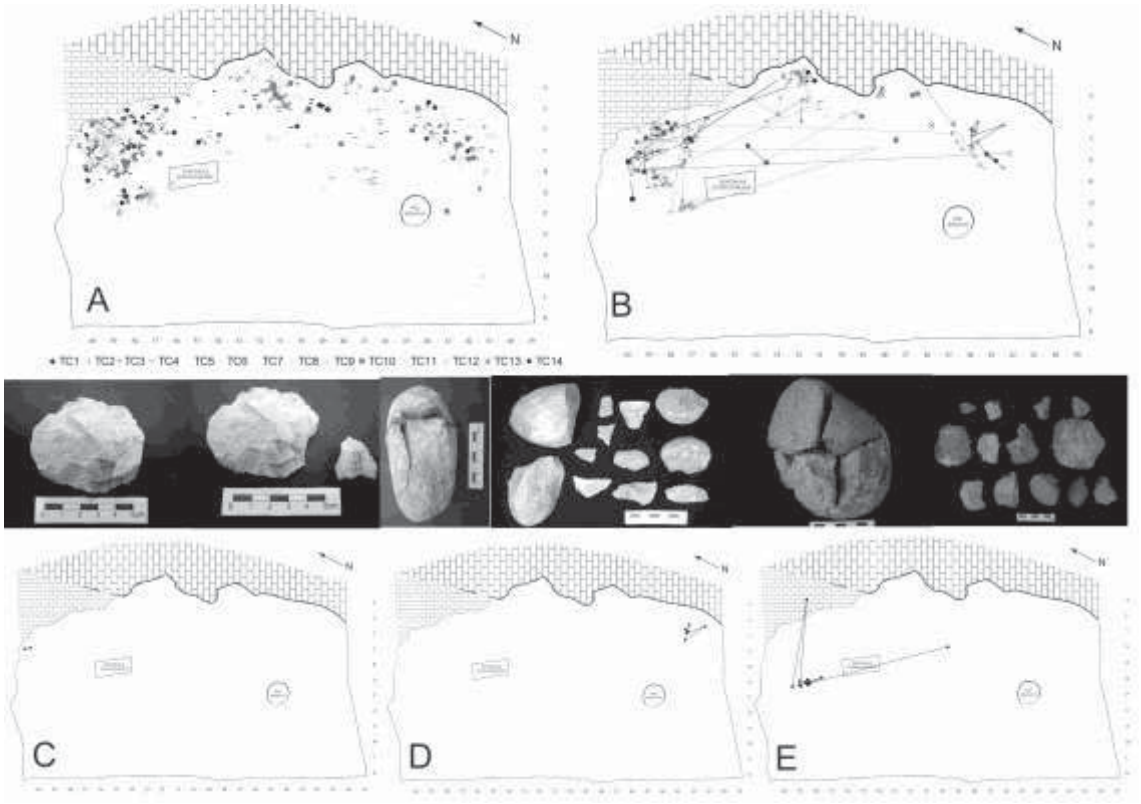


Figure 4: A) Distribution of limestone types. B) Spatial distribution of refitting connection lines. Different types refitting C) Knapping activities. D) Percussion activities and expedient knapping method. E) Thermal fracture.

- ***Limestone knapping assemblage***: We documented limestone lithic remains (cores and knapping products) flaked with similar knapping methods (levallois and discoidal) that were employed on chert (main raw material used in the lithic assemblage). (Fig 4: C)

- ***Limestone used in percussion activities***: Utilisation as hammerstones, either for the development of lithic knapping activities or other activities related to the exploitation of animal carcasses and vegetal resources. (Fig 4: D)

- ***Heated limestone***: On all the surface of level O we identified burned limestone remains. Some of these are located into the hearths and others are scattered all over the settlement area. Sometimes these limestone blocs are used to delimit the hearths (eg. concave or *cuvettes* hearths). Other times they were documented within the hearths as if they had been definitely refused. These last one show specific type of fractures that could be evidence of an utilisation to heat water, make soups (*bouillon gras*), cook meat, etc... (Fig 4: E)

5. Discussion and conclusion

The spatial distribution of the remains shows a similar pattern in all the archaeological levels (Vaquero, 2008; Vaquero 2012b). Limestone remains form levels O are concentrated in discrete clusters formed around hearths. These heart-related accumulations are the principal spatial feature and can be interpreted as house-hold areas. These have been used as a proxy in the recognition of activity areas, along with the spatial distribution of the lithic artefacts and faunal remains. Hearths played a central role in spatial organisation, as most activities were carried out around them. This gives rise to a spatial pattern characterised by well-defined hearth-related accumulations, which have been confirmed by bone and lithic refits (Vaquero and Pastó, 2001; Vaquero et al., 2004, 2007; Rosell et al., 2012). The processing of animal carcasses and bone breakage mainly occurred in the outer zones of the rockshelter, whereas stone knapping was performed in the inner domestic areas. Refit analyses of bones and lithic items have also been used to identify synchronic and diachronic patterns of change in settlement dynamics and in the procurement and management of abiotic (stones) and biotic (fauna, plants) resources and their use at the site (Gabucio et al., 2011; Gabucio et al. 2012; Vaquero et al., 2007, 2012a, b; Vaquero, 2011; Rosell et al., 2012). This dynamic has been also corroborated for the level O. However some of the most important result comes from the directionality of refitting lines in association with the RMUs which they belong (Fig 5). Some connections lines join different accumulations areas. These intercluster refits are very informative about the temporal relationship between the accumulations. As can be observed in Figure 5 A we have some refitting groups. Each of these groups joins two domestic areas (eg. Fig 5 B). The direction of refitting indicates intentional movements performed by Neanderthal groups in the rock-shelter.

Finally, the last point raised in the article was, whether the limestone knapping was similar to flint knapping. From this study we can observed that all the products of the *chaîne operatoire* are represented in this assemblages: cortical products, flake of all sizes, flake fragments, cores and retouched artefacts. If all these items were considered together, distinguishing their different RMUs, we can say that the limestone assemblage of level O come from the entire reduction sequences realised at the site. Nevertheless we can also document in some RMU the transport and introduction to the site of final products (lot of flakes) and the partial development of some reductions sequence. This behaviour could be associated to the provisioning individuals patterns proposed by Kuhn (1992; 1995) and would corresponding to the Neanderthal “tool kits”.

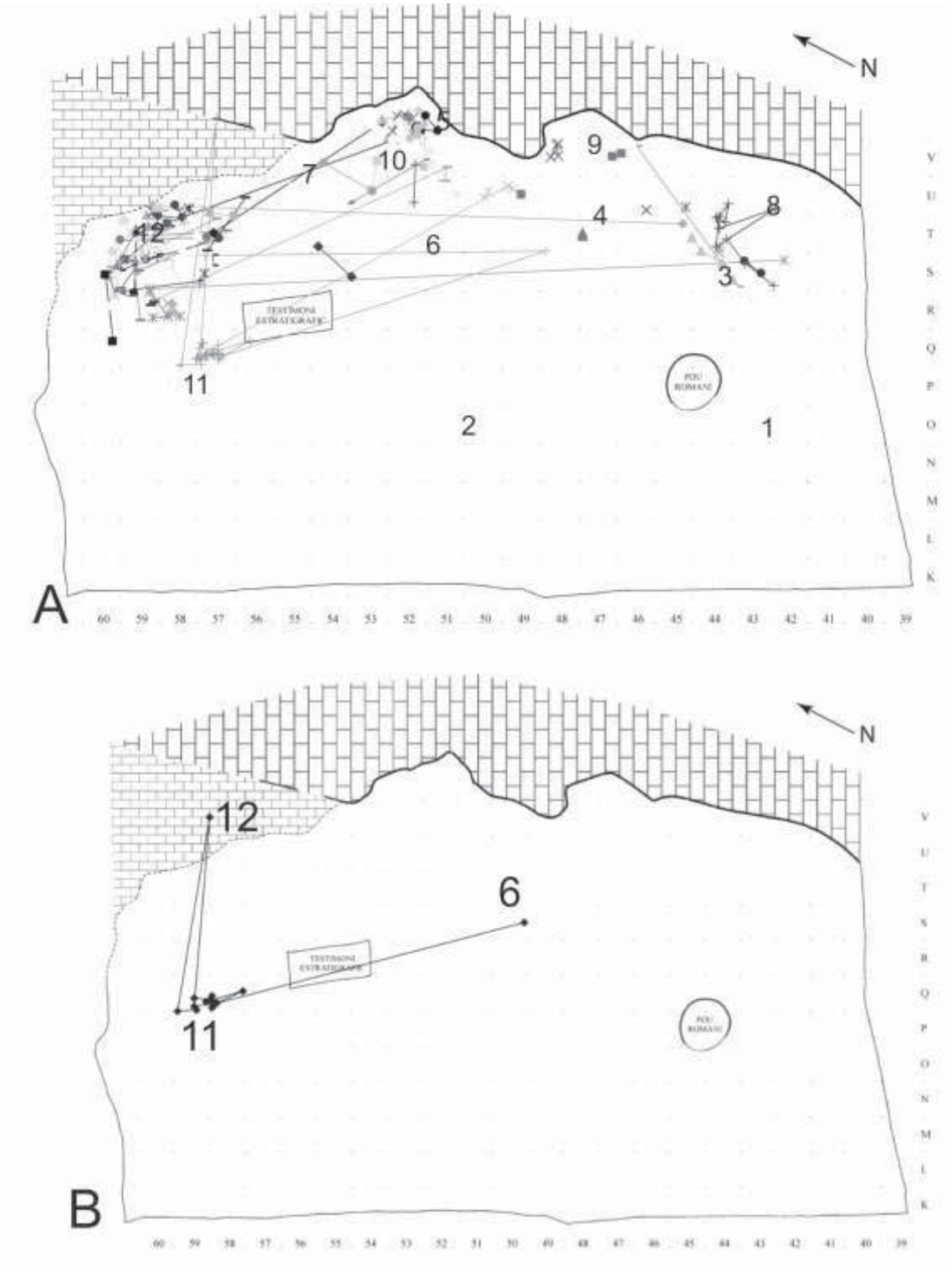


Figure 5: A) Refitting lines in association with domestic areas. B) Refitting of a termical fracture in association with three domestic areas.

Moreover, in level O we identified another type of behaviour related to the abandonment of cores, cobbles and fragments. They did not show any modifications and they were discarded in the beginning of their technical sequence in spite of their very high quality and aptitude for knapping. This could be interpreted as a stockpiling behaviour with the purpose of leaving raw materials for future occupations (provisioning places; Kuhn 1992; 1995). These two types of patterns provide insight into the cognitive planning abilities of Neanderthal groups.

To conclude, the analysis of the limestone remains from Abric Romaní level O shows that their role was very important, not only in the organization of the technological behaviour, but also in the other subsistence activities developed by the Neanderthal groups that occupied the site around 55 ka BP (Gabucio et al. 2011; Gabuccio et al. 2012).

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References

Agustí, B., G. Alcalde, A. Güell, N. Juan-Muns, J.-M. Rueda, and X. Terradas. 1991. "La cova 120, parada de caçadors-recol·lectors del paleolític mitjà." *CYPSELA* 9: 7-20.

Anadón, P., F. Colombo, M. Esteban, M. Marzo, S. Robles, P. Santanach, and L. S. Sugrañes. 1979. "Evolución tecnoestratigráfica de los Catalánides". *Acta Geológica Hispánica* 14: 242-270.

Baena, J., E. Carrión, B. Ruíz, B. Ellwood, C. Sesé, J. Yravedra, J. F. Jordá, P. Uzquiano, R. Velázquez, I. Manzano, A. Sánchez-Marco, and F. Hernández. 2005. "Paleoecología y comportamiento humano durante el Pleistoceno Superior en la comarca de Liébana: La secuencia de la Cueva de El Esquilleu (Occidente de Cantabria, España)." In *Actas de la reunión científica: Neandertales cantábricos. Estado de la cuestión*, edited by R. Montes and J. A. Lasheras, 461-487. Santander: Museo de Altamira.

Bargalló, A. 2008. "*Variability of the levallois and discoid methods at the middle Paleolithic of north-east Catalonia: Puig Marí (Maçanet de la Selva) and Can Planiol (Santa Coloma de Farners)*." *Annali dell'Università degli Studi di Ferrara. Museologia Scientifica e Naturalistica* 2008: 17-20.

Bischoff, J. L., R. Julià, and R. Mora. 1988. "Uranium-series dating of the Mousterian occupation at the Abric Romaní, Spain." *Nature* 332: 68-70.

Bischoff, J. L., K. Ludwig, J. F. García, E. Carbonell, M.l Vaquero, T. W. Stafford, and A. J. T. Jull. 1994. "Dating of the basal Aurignacian sandwich at Abric Romani (Catalonia, Spain) by radiocarbon and Uranium-series." *Journal of Archaeological Science* 21 (4): 541-551.

Bresnaham, T., and K. Dickenson. 2008. *Golden Software, Inc. Surfer 2008*

Carbonell, E. (ed.). 2012. *High Resolution Archaeology and Neanderthal Behavior Time and Space in Level J of Abric Romaní (Capellades, Spain)*. Vertebrate Paleobiology and Paleoanthropology. Dordrecht: Springer.

Chacón, M. G. 2009. *El Paleolítico medio en el suroeste europeo: Abric Romaní (Capellades, Barcelona, España) Payre (Rompón, Ardèche, Francia) y Tournal (Bize, Aude, Francia). Análisis comparativo de los conjuntos líticos y los comportamientos humanos*. Tesis doctoral en cotutela con mención europea, Departament d'Historia i Historia de l'Art, Département de Préhistoire, Universitat Rovira i Virgili, Muséum National d'Histoire Naturelle, Tarragona.

Colonge, D., and V. Mourre. 2009. "Quartzite et quartzites : aspects pétrographiques, économiques et technologiques des matériaux majoritaires du Paléolithique ancien et moyen du Sud-Ouest de la France." In : S. Grimaldi and S. Cura (eds.) : *Technological*

analysis on quartzite exploitation (XVème Congrès de l'UISPP, 4-9 septembre 2006, Lisbonne, 39, session WS 15. 3-12. Oxford: BAR International Series 1998.

Cziesla, E. 1990. "On Refitting of Stone Artefacts." In: E. Cziesla, S. Eickhoff, N. Arts, D. Winter (eds.): *The Big Puzzle*. 9-44. Bonn: Studies in Modern Archaeology.

De Lombera, A., X.-P. Rodríguez, R. Fábregas, and M.-H. Moncel. 2011. "La gestion du quartz au Pléistocène moyen et supérieur. Trois exemples de l'Europe Méridionale." *L'Anthropologie* 115 (2): 294-331.

Duran, J.-P., and N. Soler. 2006. "Variabilité des modalités des débitages et des productions lithiques dans les industries moustériennes de la grotte de l'Arbreda." *Bulletin de la Société Préhistorique Française* 103 (2): 241-262.

Gabucio, M. J., and A. Bargalló. 2011. "Neanderthal subsistence change around 55 kyr." In *Actas das IV Jornadas de Jovens em Investigaçao Arqueológica-JIA 2011*. 2, 193-200. Faro.

Gabucio, M. J., I. Cáceres, and J. Rodell. 2012. "Evaluating post-depositional processes in level O of the Abric Romaní archaeological site." *N. JB. Geol. Paläont. Abh.* 265 (2). 147-163.

Geneste, J.-M. 1989. "Economie des ressources lithiques dans le moustérien du Sud-ouest de la France." In *L'Homme de Neandertal 6, La subsistance*, edited by M. Otte 75-97. Liège: E.R.A.U.L.

Geneste, J.-M. 1991a."L'approvisionnement en matières premières dans les systèmes de production lithique: la dimension spatiale de la technologie." In R. Mora, X. Terradas, A. Parpal, C. Plana (eds.): *Tecnología y cadenas operativas líticas. Reunión Internacional*. 1-35. Bellaterra: Treballs d'Arqueologia I. Universidad Autonóma de Barcelona (U.A.B.).

Geneste, J.-M. 1991b. "Systèmes techniques de production lithique: variation techno-économiques dans les processus de réalisation des outillages paléolithiques." *Techniques et Culture* 17-18: 1-35.

Gómez de Soler, B. 2007. *Áreas de captación y estrategias de aprovisionamiento de rocas silíceas en el nivel L del Abric Romaní (Capellades, Barcelona)*. DEA (Doctorat de Quaternari i Prehistòria), Departament d'Història i Geografia, Àrea de Prehistòria.Universitat Rovira i Virgili, Tarragona.

Gómez de Soler, B. 2009. "Àrees de captació, tecnologia lítica i estratègies d'aprovisionament de roques silícies en el nivell L de l'Abric Romaní (Capellades, Barcelona)." *Quadern de Prehistòria Catalana* 17: 11-55.

Hofman, J. L., and J. G. Enloe. 1992. *Piecing together the Past: applications of refitting studies in Archaeology*. Oxford: BAR Interntional Series 578.

Kuhn, S. L. 1992. "On planning and curated technologies in the Middle Paleolithic." *Journal of Anthropological Research*. 43(3): 185-214.

Kuhn, S. L. 1995. *Mousterian Lithic Technology. An Ecological Perspective*. Princeton University Press.

Lazuén, T., R. Fábregas, A. de Lombera, and X. P. Rodríguez. 2011. "La gestión del utillaje de piedra tallada en el Paleolítico Medio de Galicia. El nivel 3 de Cova Eirós (Triacastela, Lugo)." *Trabajos de Prehistoria* 68(2): 237-258.

Moncel, M.-H., M. G. Chacón, A. Bouteaux, M.-A. Julien, and M. Patou-Mathis. 2007. "Ocupación en abrigo durante el estadio isotópico 5: el nivel D del yacimiento de Payre (Ardèche, Francia). Gestión del territorio y actividades dentro del yacimiento." *Trabajos de Prehistoria* 64(1): 55-76.

Morrow, T. A. 1996. "Bigger is better: comments on Kuhn's formal approach to mobile tool kits." *American Antiquity* 61(3): 581-590.

Mourre, V., and C. Thiébaut. 2008. "L'industrie lithique du Moustérien final de la Grotte du Noisetier (Fréchet-Aure, Hautes-Pyrénées) dans le contexte des Pyrénées centrales françaises." In: R. Mora, J. Martínez, I. de la Torre, J. Casanova (eds.): *Variabilidad técnica del Paleolítico Medio en el sudoeste de Europa*. Barcelona: Treballs d'Arqueología 14.

Navazo, M., R. Alonso-Alcalde, A. Benito-Calvo, J. C. Díez- Lomana, A. Pérez-González, and E. Carbonell. 2011. "Hundidero: mis 4 open air Neanderthal occupations in Sierra de Atapuerca." *Archaeology, Ethnology and Anthropology of Eurasia* 39 (4): 29-41.

Odell, G. H. 2004: *Lithic Analysis*. NewYork: Kluwer Academic. Plenum Publishers.

Otte, M. 1991. "Evolution in the relationships between raw materials and cultural tradition in the European Paleolithic." In *Raw material economies among prehistoric hunter-gatherers,* edited by A. Montet-White, S. Holen, 161-167. Publications in Anthropology, 19. University of Kansas.

Peresani, M. 2012. "Fifty thousand years of flint knapping and tool shaping across the Mousterian and Uluzzian sequence of Fumane cave." *Quaternary International* 247 (0): 125-150.

Rios-Garaizar, J. 2010. "Organización económica de las sociedades neandertales: el caso del Nivel VII de Amalda (Zesto, Gipuzkoa)." *Zephyrus* LXV: 15-37.

Roebroeks, W. 1988. *From find scatters to Early hominid behaviour. A study of Middle Palaeolithic riverside settlements at Maastricht-Belvédère (The Netherlands)*. Leiden: Analecta Praehistorica Leidensia 21.

Rosell, J., R. Blasco, M. C. Fernández-Laso, M. Vaquero, and E. Carbonell. 2012. "Connecting areas: Faunal refits as a diagnostic element to identify synchronicity in the Abric Romaní archaeological assemblages." *Quaternary International* 252 (0): 56-67.

Roth, B. J., and H. L. Dibble. 1998. "Production and Transport of Blanks and Tools at the French Middle Paleolithic Site of Combe-Capelle Bas." *American Antiquity* 63 (1): 47-62.

Schäfer, J. 1990. "Conjoining Artefacts and Consideration of Raw-Material: Their Application at the Middle Palaeolithic Site of the Schweinskopf-Karmelenberg." In: *The Big Puzzle*, edited by E. Cziesla, S. Eickhoff, N. Arts, D. Winter, 83-100. Bonn: Studies in Modern Archaeology.

Schurmans, U. A., and M. De Bie. 2007. *Fitting rocks: lithic refitting examined*. Oxford: BAR International Series 1596.

Sisk, M. L., and J. J. Shea. 2008. "Intrasite spatial variation of the Omo Kibish Middle Stone Age assemblages: Artifact refitting and distribution patterns." *Journal of Human Evolution* 55(3): 486-500.

Solé Sabarís, L. (Dir.). 1958-1964. *Geografia de Catalunya*. 4 vols. Barcelona: Aedos.

Thiébaut, C., L. Meignen, and F. Lévêque. 2009. "Les dernières occupations moustériennes de Saint-Césaire (Charente-Maritime, France): diversité des techniques utilisées et comportements économiques pratiqués." *Bulletin de la Société Préhistorique Française* 106(4): 691-714.

Turq, A. 2000. *Paléolithique inférieur et moyen entre Dordogne et Lot.* Paléo Supplément 2.

Vallverdú, J., S. Alonso, A. Bargalló, R. Bartrolí, G. Campeny, Á. Carrancho, I. Expósito, M. Fontanals, J. Gabucio, B. Gómez, J. M. Prats, P. Sañudo, Á. Solé, J. Vilalta, and E. Carbonell. 2012. "Combustion structures of archaeological level O and mousterian activity areas with use of fire at the Abric Romaní rockshelter (NE Iberian Peninsula)." *Quaternary International* 247 (0): 313-324.

Vaquero, M., and I. Pastó. 2001. "The definition of spatial units in Middle Palaeolithic sites: The hearth-related assemblages." *Journal of Archaeological Science* 28(11): 1209-1220.

Vaquero, M., J. M. Rando, and M. G. Chacón. 2004. "Neanderthal Spatial Behavior ans Social Structure: hearth-related assemblages from the Abric Romaní Middle Palaeolithic Site." In *Settlement Dynamics of the Middle Paleolithic and Middle Stone Age II*, edited by N. J. Conard, 367-392. Tübingen: Kerns Verlag.

Vaquero, M., M. G. Chacón, and J. M. Rando. 2007. "The interpretative potential of lithic refits in a Middle Paleolithic site: the Abric Romaní (Capellades, Spain)." In *Fitting Rocks. Lithic Refitting Examined*, edited by U. A. Schurmans, M. De Bie, 75-89. Oxford: BAR International Series S1596.

Vaquero, M. 2008. "The History of Stones: Behavioural inferences and temporal resolution of an archaeological assemblage from the Middle Palaeolithic." *Journal of Archaeological Science* 35(12): 3178-3185.

Vaquero, M. 2011. "New perspectives on recycling of lithic resources using refitting and spatial data." *Quartär* 58: 113-130.

Vaquero, M., M. G. Chacón, F. Cuartero, M. D. García-Antón, B. Gómez de Soler, and K. Martínez. 2012a. "The lithic assemblage of level J." In High Resolution Archaeology and Neandertal Behavior: Time and Space", E. Carbonell (ed.): *Level J of Abric Romaní (Capellades, Spain)*, 189-311. Dordrecht: Vertebrate Paleobiology and Paleoanthropology Book Series. Springer.

Vaquero, M., M. G. Chacón, M. D.s García-Antón, B. Gómez de Soler, K. Martínez, and F. Cuartero. 2012b. "Time and space in the formation of lithic assemblages: The example of Abric Romaní Level J." *Quaternary International* 247 (0): 162-181.

The megalithic "Golden Crescent". An approach to one space in Northern Burgos (Spain) which hosted the adoption and evolution of megalithism

Rodrigo Villalobos García [1]

Germán Delibes de Castro[1]

Miguel Ángel Moreno Gallo[2]

Javier Basconcillos Arce[3]

[1] Universidad de Valladolid.

[2] Universidad de Burgos

[3] Asociación Geocientífica de Burgos

Abstract

The pan-European phenomenon of the megalithism has in La Lora (Burgos, Spain) one small but astonishing place because of the amount of monuments and the deep archaeological trajectory developed around them. 52 mounds have been discovered here and more than one dozen of these have been completely excavated. In this paper we intend to employ that information to explore some proposals concerning the megalithic phenomenon such as its condition of territorial markers and its relation with the economic resources. For that reason we have elaborated a resources map of the whole area that includes the suitable farming lands, water resources and pathways network. From this information we have analysed the spatial and visual relation between the tombs and the resources taking into account also the chronological dimension. The results could be related with a process of socio-political integration that could have taken place here between c. 4250 and 3000 BC.

Keywords: *Megalithism, Late Neolithic, Economic Resources, Diachronic Evolution, Territorial Appropriation*

1. Introduction

La Lora area is a series of limestone plateaus located in the North-West of Burgos Province, between the Northern Meseta and the Cantabrian region. They are shaped by the valleys and canyons of Ebro, Rudrón and Sedanillo Rivers while their upper platforms reach around 1000 meters above sea level. The oldest references noticing the existence of megalithic monuments in La Lora can be traced back to the middle 20th century (Huidobro 1956). Since then, a considerable number of representative Late Neolithic tombs have been discovered and

excavated (Osaba et al. 1971; Delibes et al. 1982; Rojo 1992; Delibes Rojo and Represa 1993; Moreno 2004, etc.).

This current work is not the very first attempt of analyze La Lora megaliths through a spatial point of view. Two decades ago, M. Rojo related the 11 known Neolithic tombs with their visibility patterns and the economic potential of their surroundings –land, water, and constructive material– (Rojo 1990). Some years after that, M. Moreno looked for the localization criteria of all the megaliths in Burgos Province. He observed that all the optima factors merge in one small horn-shaped area located in the heart of La Lora plateaus, named for that reason as the "Golden Crescent" (Moreno 2004).

Now we restart this kind of approach lead by the recent discovery of new mounds through field-walking surveys and also by the availability of the actual GIS software development. We hope we will be able to understand some aspects of the motivations that drove the Late Neolithic people to build these monuments in their specific locations. Our first step is to relate the 52 nowadays known mounds with the basic economic resources in terms of distance and visual control. The framework of the whole study will be delimited by the 135th sheet of the "Mapa Topográfico Nacional" (MTN), an area of c. 530 km^2 in which centre the Golden Crescent is located.

2. "Terruños, fuentes y trochas". Towards a resources map of La Lora

The productive economic practices spread into the Spanish Northern Meseta in the middle of the sixth millennium cal BC (Rojo et al. 2008). Concerning the Burgos Province, wheat grains coming from levels in where domesticated animals also appeared were dated at the end of the sixth millennium cal BC (Vergès et al. 2008). So, it is highly probable that the people who built La Lora megaliths during the period 4250-3000 cal BC would base its subsistence on farming and herding. One remarkable example of this assumption is that the sediment coming from under the mound of El Moreco passage grave contained cereal pollen, an evidence of the presence of crop fields around it in c. 4000 cal BC (Delibes and Rojo 1997; 2002). It is probable that the neolithic inhabitants of these places organized its activities according to the exploitation of critic resources like as the suitable lands or water sources. Other kind of "resource" considered here is the pathways network: it is valuable at any time, but essential in these moments of land appropriation, when the first supra-communitarian institutions arose as a way of legitimizing and defending territorial rights (Johnson and Earle 2000: 124). Those who controlled land, water and communications gained an advantage against their competing neighbours. At one specific moment of this process the megalithic tombs appeared. Our point of view is that the megalithism were not segregated of other aspects of the every-day life: there are

abundant evidences of the relation between the neolithic peopling and these tombs in the Northern Meseta (Delibes and Zapatero 1996; Delibes et al. 1997; Villalobos in press) and in other surrounding regions –such as Galicia (Gianotti et al. 2011), the Cantabrian Region (Díez Castillo 1995; Yarritu and Gorrotxategui 1995), the Southern Meseta (Bueno et al. 2002: 74), Extremadura (Cerrillo 2006) or Portugal (Senna-Martínez 1996) –, so we interpret the megaliths as land-markers integrated in a system of territorial claiming. For testing this proposal it is essential to build a neolithic-resource map of La Lora (Fig. 1).

2.1 Farm lands.

Although cereal farming was practiced during these times, it must be noted that the neolithic technology would have impeded the exploitation of all the lands that are being ploughed nowadays in La Lora. In the Spanish Northern Meseta the neolithic sites are related with highly productive lands such as the bottom of river valleys, wetlands or endorheic places (Delibes and Fernández 2000; Rubio and Barrio 2003; García 2008; Marcos and Díez 2009), not like as in later moments, during the Copper Age, when animal traction offered the possibility of ploughing harder lands (Delibes 2011). One important issue is to identify the most appropriate lands for farming taking into account the limitations of the neolithic technology.

Two different information sources have been employed. On one side we took the oldest MTN sheet of this area, published in 1933, hoping to find some coincidence between the lands cultivated through preindustrial technology, namely ox-ploughing, and the affordable ones with neolithic technology[1]. On the other hand, different but not incompatible data were offered by the "Mapa de Clases Agrológicas" made by the Spanish Ministry of Agriculture in 1981. Here we found the class IV ("occasional farming land") suitable for our purpose because of its close relation with watercourses and flooding areas. Remember the already mentioned relation between neolithic domestic sites and riverine zones, wetlands or endorheic places.

2.2 Water sources.

The connexion between megaliths and water is remarkable in this space. In the very first place, it is shown by the toponymy: Fuentepecina, Fuenteblanquilla ("Fuente" related to "water source"), Nava Negra ("Nava" related to "swamp"), etc. Also, a quick look to the distribution of megaliths enhances this feeling. They are usually located in the periphery of the plateaus but not at their borders. Instead, they seem in relation with the watercourse heads. In this approach we

[1] The adoption of ploughing, probably used in Central Iberia since the Copper Age, would have introduced substantial differences compared with neolithic farming (Pétrequin et al. 2006), but the lands under exploitation in pre-industrial times are still a good point of reference.

have used the digital topographic data of rivers and streams offered by the Spanish "Instituto Geográfico Nacional" (IGN). In the 83.33 % of the cases the tombs are practically at the same distance from river heads than from rivers, so we have discarded to study the relation with rivers, assuming that this is indeed with the watercourse heads.

2.3 Optima paths.

The domestic mode of production, which in theory ruled the small neolithic communities, states that each cell is self-sufficient. The collective tombs have been usually seen as the familiar tomb of each group. Nevertheless, inter-communitarian relations have been documented in the Northern Meseta during the Late Neolithic (Guerra et al. 2009; Villalobos 2012). Logically, a pathways network connecting the different groups would have existed. Several studies in different contexts have related megalithic monuments, such as dolmens or standing stones, with different kind of routes and it has been also argued that they would have served as waypoints sometimes (e.g. Criado and Villoch 1998; Moreno and Delibes 2007; Murrieta et al. 2011a).

An optima pathways network has been generated with the "pathway" command of IDRISI for inquiring in this issue. The baseline has been the Digital Elevation Model offered by the IGN with a resolution of 5 meters per pixel, modified by adding more cost for simulating the river crossing. As origin and end of the routes each corner and the middle point of each side of the 135th MTN sheet have been used. It seems that the software simulation is acceptable in this particular case because the generated lines match with other information such as wild animal pathways or traditional muleteer routes.

3. Relation between economic resources and monumental tombs

3.1 Tombs and space

As the first step we intend to find out if a relation between the megaliths location and the territorial resources in La Lora did exist. For that purpose, a significance test as proposed in Wheatley and Gillins (2002: 126-7) – also used in the study of megaliths and pathways of southern Iberia in Murrieta et al. (2011b) – seems appropriate. It consists on the partition of the framework in different areas following the value of the euclidean distance between the resources and each pixel. The comparison between the cumulative frequency of the areas surfaces and the number of archaeological cases in each one through a Kolmogorov-Smirnov test should show us if the relation is significant or if it is not. At a significance level of 0.05 (a probability of 95%) the critical value (d) for a sample of 52 cases should be calculated by the following formula:

$$d = 1.36/\sqrt{n} = 1.36/\sqrt{52} = 0.189$$

It means that if the differences between the cumulative frequencies of the surface of "resources" and the number of "mounds" are higher than 0.189 in only one interval, we are supposed to admit that the mounds were built intentionally around these strategic areas. As it can be seen in tables 1 and 2 this situation can be noticed in all the resources tested: watercourse heads (0.345), pathways network (0.192), "occasional" farmlands (0.344) and "1933" farmlands (0.355).

3.2 Analysis by classes. Wide / restricted visibility.

The megalithism is inevitably related with the monumentality because these tombs are the very first human footprints in the landscape. It is usual to find the Late Neolithic monuments in prominent places which offer wide visibility for watch and for being watched. In La Lora this assumption is not entirely correct. After calculating the viewshed of each of the 52 monuments two main categories can be observed: sites with wide visibility (in one or in all directions) and sites with restricted visibility. 33 monuments were ascribed to the class "wide" and 19 to the class "restricted". By applying Tobler's (1993) formula the time taken to reach the different resources from each tomb could be calculated. The combination of the visibility and the time required to reach the resources offers some interesting constants and discontinuities. The mean time taken to reach the "1933" farmlands and watercourse heads do not differ significantly between classes, but the relation with optima paths and "occasional" farmlands shows remarkable results (Table 3). It takes slightly less time to reach the pathways network from the "restricted" that from the "wide", but the difference is stronger concerning the "occasional" farmlands. While from the "wide" class it takes a mean of 6.48 minutes (Std. Dev. = 5.29) for reaching these areas, from the "restricted" it takes only a mean of 2.21 minutes (Std. Dev. = 2.80): the majority of the "restricted" viewshed tombs appear really close to the "occasional" farmlands. Another relevant fact that strengthens this relation is that the 84.21 % of the "restricted" tombs watch the closest areas of this kind of resource, while only the 48.48 % of the "wide" (with a greater viewshed) do it. It is similar as happens concerning the control of pathways: only the 48.48 % of the "wide" tombs watch the closest pathways while the 78.95 % of the "restricted" tombs watch them.

3.3 The Golden Crescent. Two models of tomb, two ways of life?

Through this study we can see how an inversely proportional relationship between viewshed amplitude and access to the basic resources does exist concerning the localisation of La Lora

Late Neolithic tombs. M. Rojo defined two classes of neolithic tombs in La Lora through the analysis of the 11 known sites: i) tombs located in high valleys, without great viewshed but close to fertile lands, and ii) tombs in the top of the plateaus, in open areas but further from productive fields (Rojo 1990). Now we can confirm its original proposal through the analysis of 52 sites. Two main categories seem to exist. The "resource tombs" were built next to farmlands and communication routes, in places that allowed them to watch over those resources but not beyond them. One example is El Moreco, a passage grave who only watches the closest farmlands and pathways, in whose excavation cereal pollen were found under the mound. The other type is the "prominent tombs". They were located distant to farmlands and communication routes, but their great viewshed allowed them to see and be seen from a huge amount of territory, even without taking care of the closest resources. In the case of the "prominent tombs" something must explain the sacrifice of reducing or eliminating the control over of the economic resources for obtaining greater viewshed. Rojo wrote about outside-oriented societies which wanted to show to other people their territorial ownership (Rojo 1990). Here we want to explore not only the desire of be seen, but also the desire of watch and control. From each of the "prominent tombs" a mean of 9.7 other tombs are watched or controlled. But in some cases there are tombs which clearly surpass that mean, such as Las Arnillas, Ciella and El Campo 1. From Las Arnillas other 15 tombs are watched, and from Ciella and El Campo 1 other 19 tombs are watched. In the other hand, Rebolledo is also another "prominent tomb" which only watches other 5 tombs. We want to make a proposal for explaining such variations by introducing a new dimension: the chronology.

4. Diachronic analysis.

About a dozen of the 52 mounds analyzed were excavated two decades ago. They offered a good amount of grave goods and radiocarbonic dates that were used to propose a sequence of use between the late fifth millennium cal BC and the late fourth millennium cal BC (Delibes and Rojo 1997; 2002). Here we want to relate the two classes of tombs identified through the spatial analyse with the chronological dimension for studying their social implications.

The first phase of La Lora megalithism is identified in Rebolledo and Fuentepecina 2, 3 and 4 through some of their grave goods (abundance of archaic types of microliths such as trapezes with concave sides and triangles), and architecture (non-megalithic mounds or simple megalithic chambers without corridor). They are dated around the end of the fifth millennium cal BC. All Fuentepecina sites are "resources tombs", but Rebolledo has a great visual field. Even if Rebolledo has a wide viewshed, it only watches other 5 tombs.

In the second phase, at the beginning of the fourth millennium cal BC, the passage grave model appeared. Now the grave goods are characterized by microliths such as trapezes with straight sides and segments. There were both "resources tombs", such as La Cotorrita, and "prominent tombs" such as Valdemuriel. From this last one other 10 mounds are watched.

Finally, at the end of the fourth millennium cal BC a third phase was identified, characterized by grave goods with the first diamond shape and foliate arrowheads with flat-over retouch. Like in the precedent phases "resources tombs", like Nava Alta, and "prominent tombs", like Ciella and Las Arnillas both appeared. As was noted before, Ciella and Las Arnillas are the neolithic tombs of La Lora that watch the highest quantity of other tombs, 19 and 15 respectively.

As can be seen, there is a sequence during the period c. 4250-3000 cal BC in which both "resources" and "prominent" tombs were built in La Lora (Fig. 2). Concerning the second class, it looks like the desire of controlling other tombs grew over the time. The non megalithic mound of Rebolledo, built in c. 4200 cal BC, only watched at most other 5 tombs. The passage grave of Valdemuriel, built at the beginning of the fourth millennium cal BC, watched other 10 tombs. Finally, the passage graves of Las Arnillas and Ciella, in the late fourth millennium cal BC, watched much more territory and a lot of the other tombs previously built. It seems that a growing symbolic competition took place between the different Late Neolithic communities through more than one millennium in La Lora. The desire of reaching broader viewshed can be related with other aspects such as labour investment and architectonic complexity. These evidences can be explained as expressions of the process of territorial appropriation that took place here since the adoption of the farming and herding. The competition between the different neolithic communities for the scarce resources could have forced them to elaborate more complex social institutions, so they could build bigger monuments with wider projection over the territory.

References

Bueno Ramírez, P., R. Barroso Bermejo, R. Balbín Behrmann, M. Campo Martín, F. Etxeberría Gabilondo, A. González Martín, L. Herrasti Herlogorri, et al. 2002. "Áreas habitacionales y funerarias en el Neolítico de la cuenca interior del Tajo: la provincia de Toledo." *Trabajos de Prehistoria* 59 (2): 65–80.

Cerrillo Cuenca, E. 2006. "Agricultores y ganaderos: paisajes de producción neolíticos de la penillanura extremeña." In *Los Barruecos: Primeros Resultados sobre el Poblamiento Neolítico de la Cuenca Extremeña del Tajo*, edited by E. Cerrillo Cuenca, 137–151. Memorias de Arqueología Extremeña 6. Badajoz: Junta de Extremadura.

Criado Boado, F., and V. Villoch Vázquez. 1998. "La monumentalización del paisaje: Percepción y sentido original en el megalitismo de la sierra de Barbanza (Galicia)." *Trabajos de Prehistoria* 55(1): 63–80.

Delibes de Castro, G. 2011. *El Pan y la Sal. La vida campesina en el Valle Medio del Duero hace cinco mil años*. Valladolid: Real Academia de Bellas Artes de la Purísima Concepción.

Delibes de Castro, G., N. Benet Jordana, R. Pérez Martín, and P. Zapatero Magdaleno. 1997. "De la tumba dolménica como referente territorial, al poblado estable: Notas sobre el hábitat y las formas de vida de las comunidades megalíticas de la Submeseta Norte." In *O neolitico atlántico e as orixes do megalitismo*, edited b. A.A. Rodríguez Casal, 779–808. Santiago de Compostela: universidad de Santiago de Compostela.

Delibes de Castro, G., and J. Fernández Manzano. 2000. "La trayectoria cultural de la Prehistoria Reciente (6400-2500 BP) en la Submeseta Norte: principales hitos de un proceso." In *Actas do 3º Congresso de Arqueología Peninsular. Pré-Historia Recente da Península Ibérica*, 95–112. Porto: Adecap.

Delibes de Castro, G., J. A. Rodríguez Marcos, C. Sanz Mínguez, and J. del Val Recio. 1982. "Dólmenes de Sedano I. El sepulcro de corredor de Ciella." *Noticiario Arqueológico Hispánico* 14: 149–196.

Delibes de Castro, G., M. Rojo Guerra, and J. I. Represa Bermejo. 1993. *Dólmenes de La Lora. Burgos*. Guía Arqueológica. Salamanca: Junta de Castilla y León.

Delibes de Castro, G., and M. Rojo Guerra. 1997. "C14 y Secuencia megalítica en la Lora Burgalesa: Acotaciones a la problemática de las dataciones absolutas referentes a yacimientos dolménicos." In *O neolitico atlántico e as orixes do megalitismo*, edited by A.A. Rodríguez Casal, 391–415. Santiago de Compostela: Universidad de Santiago de Compostela.

Delibes de Castro, G., and M. Rojo Guerra. 2002. "Reflexiones sobre el trasfondo cultural del polimorfismo megalítico en la Lora Burgalesa." *Archivo Español de Arqueología* 75: 21–35.

Delibes de Castro, G., and P. Zapatero Magdaleno. 1996. "De lugar de habitación a sepulcro monumental: Una reflexión sobre la trayectoria del yacimiento Neolítico de La Velilla,

en Osorno (Palencia)." In *I Congrés del Neolític a la Península Ibérica*, 1:337–348. Rubricatum 1. Gavà (Barcelona): Museu de Gavà.

Díez Castillo, A. 1996. "Una cabaña neolítica en los Picos de Europa." In *Actes. I Congrés del Neolític a la península Ibérica*, 1:349–356. Rubricatum 1. Gavà (Barcelona): Museu de Gavà.

García Martínez de Lagrán, I. 2008. "Los humedales y las zonas endorreicas en los modelos de colonización del interior peninsular durante el Neolítico Antiguo: el valle de Ambrona y el valle del Ebro." In *Actas de las I Jornadas de Jóvenes en Investigación Arqueológica: dialogando con la cultura material*, 1:155–162. Madrid: Compañía Española de Reprografía y Servicios.

Gianotti, C., P. Mañana-Borrazás, F. Criado-Boado, and E. López Romero. 2011. "Deconstructing Neolithic Monumental Space: The Montenegro Enclosure in Galicia (Northwest Iberia)." *Cambridge Archaeological Journal* 21(3): 391–406.

Guerra Doce, E., G. Delibes de Castro, P. Zapatero Magdaleno, and R. Villalobos García. 2009. "Primus Inter Pares: estrategias de diferenciación social en los sepulcros megalíticos de la Meseta Norte Española." *BSAA Arqueología* 75: 41–65.

Johnson, A. W., and T. Earle. 2000. *The Evolution of Human Societies. From Foraging Group to Agrarian State*. Second edition. Standford: Standford University Press.

Marcos Sáiz, F.J., and J. Carlos Díez Fernández-Lomana. 2009. "Primeros resultados de la evolución del poblamiento en el entorno de la Sierra de Atapuerca desde el Neolítico a la Edad del Bronce." In *Actas del Congreso Internacional Medio Siglo de Arqueología en el Cantábrico Oriental y su entorno*, edited by Armando Llanos, 777–790. Vitoria: Instituto Alavés de Arqueología.

Moreno Gallo, M. A. 2004. *Megalitismo y geografía. Análisis de los factores de localización espacial de los Dólmenes de la provincia de Burgos*. Studia Archaeologica 93. Salamanca: Universidad de Valladolid.

Moreno Gallo, M. A., and G. Delibes de Castro. 2007. "Dataciones absolutas para un menhir del valle de Valdelucio (Burgos): resultados de un sondeo en el túmulo de "La cuesta del molino"." *Zephyrus* (60): 173–179.

Murrieta Flores, P., L. García Sanjuán, and D. W. Wheatley. 2011a. "Antes de los mapas: navegación y orientación terrestre en la península Ibérica." *Boletín del Instituto Andaluz de Patrimonio Histórico* 77: 85–88.

Murrieta Flores, P., D. W. Wheatley, and L. García Sanjuán. 2011b. "Movilidad y vías de paso en los paisajes prehistóricos: megalitos y vías pecuarias en Almadén de la Plata." In *Tecnologías de la Información Geográfica y Análisis Arqueológico del Territorio*, edited V. Mayoral Herrera y S. Celestino Pérez, 411–423. Anejos del Archivo Español de Arqueología 59. Mérida: Instituto de Arqueología - Mérida.

Huidobro, L. 1954. "Descubrimiento megalítico en Nocedo (Sedano)." *Boletín de la Institución Fernán González* 129: 390–391.

Osaba, B., J. A. Abásolo, J. L. Uribarri, C. Liz, and J.M. Basabe. 1971. "El dolmen de Porquera de Butrón, en la provincia de Burgos." *Noticiario Arqueológico Hispánico* 15: 77–108.

Pétrequin, P., R.M. Arbogast, A.M. Pétrequin, S. Willigen, and M. Bailly. 2006. *Premiers chariots, Premiers araires. La diffusion de la traction animale en Europe pendant les IVe et IIIe millénaires avant notre ère*. CRA Monographies 29. Paris: CNRS Éditions.

Rojo Guerra, M. 1990. "Monumentos megalíticos en la Lora burgalesa: Exégesis del emplazamiento." *Boletín del Seminario de Arte y Arqueología* 56: 53–63.

Rojo Guerra, M. 1992. "El fenómeno megalítico en la Lora burgalesa." Valladolid: Universidad de Valladolid.

Rojo Guerra, M., M. Kunst, R. Garrido Pena, I. García Martínez de Lagrán, and G. Morán Dauchez. 2008. *Paisajes de la Memoria: Asentamientos del Neolítico Antiguo en el Valle de Ambrona (Soria, España)*. Arte y arqueología 23. Valladolid: Universidad de Valladolid.

Rubio de Miguel, I., and J. Barrio Martín. 2003. "Un nuevo yacimiento neolítico al aire libre en la Submeseta Norte: Las Charcas de Fuentepiñel (Segovia)." *Boletín de la Asociación Española de Amigos de la Arqueología* 43: 47–72.

Senna-Martínez, J.C. 1996. "Pastores, recoletores e construtores de megalitos na Plataforma do Mondego no IV e III milenios AC: O sítio de hábitat do Ameal-IV." *Trabalhos de Arqueología da EAM* 3-4: 83–122.

Tobler, W. R. 1993. *Three presentations on geographical analysis and modeling*. Santa Barbara, CA: National Center for Geographic Information and Analysis.

Vergès, J. M., E. Allué, D. E. Angelucci, F. Burjachs, A. Carrancho, A. Cebriá, I. Expósito, M. Fontanals, S. Moral, and M. Vaquero. 2008. "Los niveles neolíticos de la cueva de El Mirador (Sierra de Atapuerca, Burgos): Nuevos datos sobre la implantación y el desarrollo de la economía agropecuaria en la Submeseta Norte." In *IV Congreso del Neolítico Peninsular*, 1:418–427. Alicante: Museo Arqueológico de Alicante.

Villalobos García, R. 2012. "Adornos exóticos en los sepulcros tardoneolíticos de la Submeseta Norte Española. El ejemplo de Las Tuerces como nodo de una red descentralizada de intercambios." In *Actes Xarxes al Neolític*, 265–271. Rubricatum 5. Gavà (Barcelona): Museu de Gavà.

Villalobos García, R. In press. "The megalithic tombs of the Spanish Northern Meseta. Material, political and ideological tie between the Neolithic people and their territory." In *Fonctions, utilisations et représentations de l'espace dans les sépultures monumentales du Néolithique européen*. Aix-en-Provence.

Wheatley, D., and M. Gillins. 2002. *Spatial Technology and Archaeology. The Archaeological Applications of GIS*. Londo: Taylor & Francis.

Yarritu, M. J., and X. Gorrotxategui. 1996. "El poblamiento al aire libre durante el Neolítico y el Calcolítico en el Cantábrico Oriental. Los poblados de Zalama, Ordunte (Valle de Mena, Burgos) e Ilso Betaio (Garape-Artzendariz, Enkarterria, Euskal Herria)." In *Primeros agricultores y ganaderos en el Cantábrico y Alto Ebro*, 199–250. Isturiz 6. San Sebastián: Eusko Ikaskuntza.

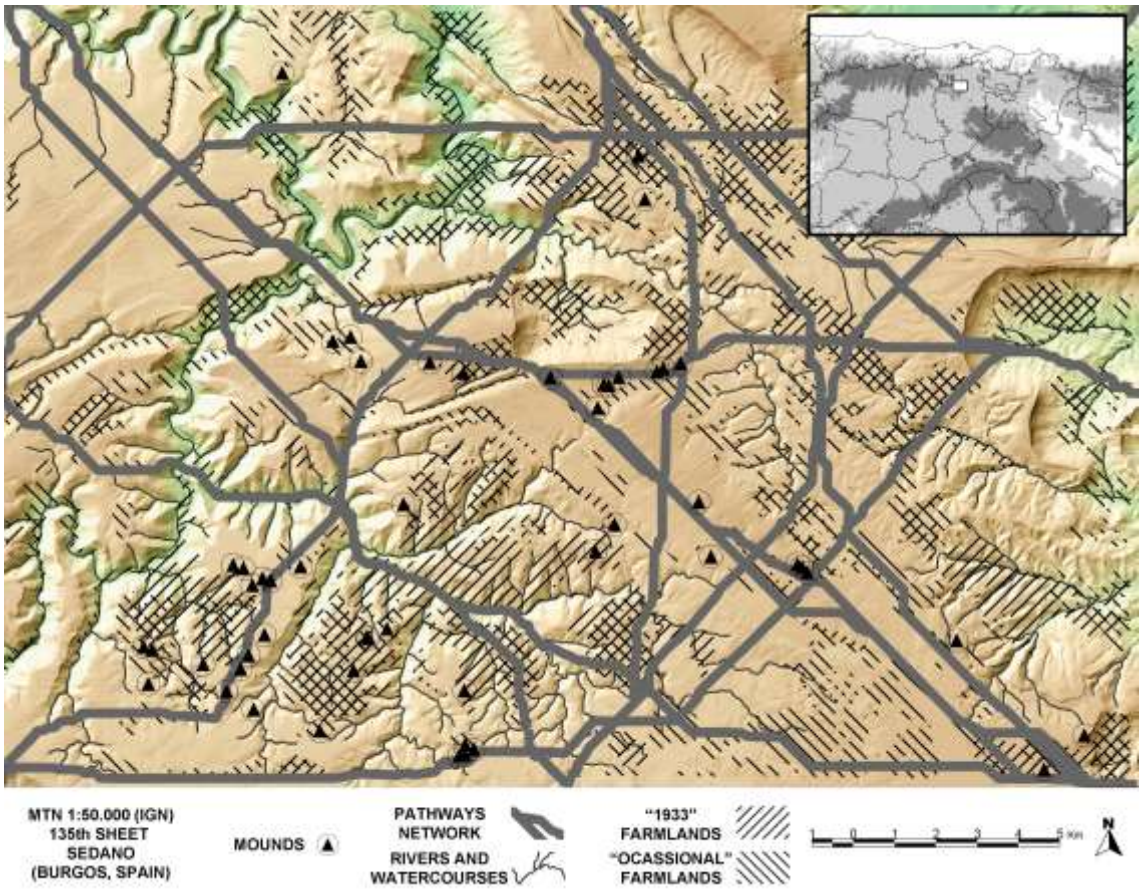


Figure 1: General map. Area localization, archaeological sites and resources.

Background Population (watercourse heads)				Archaeological Cases			dMAX
Area	**Km2**	**Area%**	**Cum%**	**Cases**	**Cases%**	**Cum%**	
1	71.171	0.134	0.134	19	0.365	0.365	0.231
2	133.384	0.251	0.386	19	0.365	0.731	0.345
3	126.419	0.238	0.624	6	0.115	0.846	0.222
4	90.336	0.170	0.794	3	0.058	0.904	0.110
5	58.612	0.111	0.905	2	0.038	0.942	0.037
6	29.354	0.055	0.960	1	0.019	0.962	0.001
7	11.606	0.022	0.982	2	0.038	1.000	0.018
8	3.987	0.008	0.990	0	0.000	1.000	0.010
9	2.488	0.005	0.994	0	0.000	1.000	0.006
10	1.773	0.003	0.998	0	0.000	1.000	0.002
11	0.987	0.002	0.999	0	0.000	1.000	0.001
12	0.284	0.001	1.000	0	0.000	1.000	0.000
Total	530.402	1.000		52	1.000		

Background Population (pathways network)				Archaeological Cases			dMAX
Area	**Km2**	**Area%**	**Cum%**	**Cases**	**Cases%**	**Cum%**	
1	114.141	0.215	0.215	18	0.346	0.346	0.131
2	89.898	0.169	0.385	12	0.231	0.577	0.192
3	70.276	0.132	0.517	1	0.019	0.596	0.079
4	52.661	0.099	0.616	8	0.154	0.750	0.134
5	43.359	0.082	0.698	1	0.019	0.769	0.071
6	36.685	0.069	0.767	6	0.115	0.885	0.117
7	29.883	0.056	0.824	2	0.038	0.923	0.099
8	23.195	0.044	0.867	3	0.058	0.981	0.113
9	17.818	0.034	0.901	1	0.019	1.000	0.099
10	14.125	0.027	0.928	0	0.000	1.000	0.072
11	11.006	0.021	0.948	0	0.000	1.000	0.052
12	8.574	0.016	0.965	0	0.000	1.000	0.035
13	6.890	0.013	0.978	0	0.000	1.000	0.022
14	4.419	0.008	0.986	0	0.000	1.000	0.014
15	2.532	0.005	0.991	0	0.000	1.000	0.009
16	1.773	0.003	0.994	0	0.000	1.000	0.006
17	1.332	0.003	0.997	0	0.000	1.000	0.003
18	1.030	0.002	0.998	0	0.000	1.000	0.002
19	0.586	0.001	1.000	0	0.000	1.000	0.000
20	0.212	0.000	1.000	0	0.000	1.000	0.000
Total	530.394	1.000		52	1.000		

Table 1: Kolmogorov-Smirnov test results of the relation between mounds and watercourse heads and pathways network.

Background Population ("occassional" farmlands)				Archaeological Cases			dMAX
Area	**Km2**	**Area%**	**Cum%**	**Cases**	**Cases%**	**Cum%**	
1	113.213	0.213	0.213	29	0.558	0.558	**0.344**
2	261.766	0.494	0.707	10	0.192	0.750	0.043
3	66.273	0.125	0.832	7	0.135	0.885	0.053
4	36.518	0.069	0.901	4	0.077	0.962	0.061
5	20.354	0.038	0.939	2	0.038	1.000	0.061
6	12.096	0.023	0.962	0	0.000	1.000	0.038
7	8.374	0.016	0.978	0	0.000	1.000	0.022
8	6.144	0.012	0.989	0	0.000	1.000	0.011
9	3.575	0.007	0.996	0	0.000	1.000	0.004
10	1.533	0.003	0.999	0	0.000	1.000	0.001
11	0.482	0.001	1.000	0	0.000	1.000	0.000
12	0.073	0.000	1.000	0	0.000	1.000	0.000
Total	**530.401**	**1.000**		**52**	**1.000**		

Background Population ("1933" farmlands)				Archaeological Cases			dMAX
Area	**Km2**	**Area%**	**Cum%**	**Cases**	**Cases%**	**Cum%**	
1	87.333	0.165	0.165	27	0.519	0.519	**0.355**
2	219.190	0.413	0.578	10	0.192	0.712	0.134
3	65.475	0.123	0.701	2	0.038	0.750	0.049
4	48.842	0.092	0.793	11	0.212	0.962	0.168
5	33.528	0.063	0.857	2	0.038	1.000	0.143
6	25.882	0.049	0.905	0	0.000	1.000	0.095
7	19.477	0.037	0.942	0	0.000	1.000	0.058
8	13.895	0.026	0.968	0	0.000	1.000	0.032
9	8.832	0.017	0.985	0	0.000	1.000	0.015
10	4.982	0.009	0.994	0	0.000	1.000	0.006
11	2.262	0.004	0.999	0	0.000	1.000	0.001
12	0.696	0.001	1.000	0	0.000	1.000	0.000
Total	**530.395**	**1.000**		**54**	**1.000**		

Table 2: Kolmogorov-Smirnov test results of the relation between mounds and "occasional" and "1933" farmlands.

Class		Watercourse heads	Pathways network	"1933" farmlands	"Occasional" farmlands
Wide viewshed (n=33)	Time to reach the resource (mins)	$\overline{x}$ = 8.55	$\overline{x}$ = 12.76	$\overline{x}$ = 5.39	$\overline{x}$ = 6.48
		s = 8.34	s = 13.04	s = 5.21	s = 5.29
	Proportion of tombs that watch over the resource	27.27 %	48.48 %	45.45 %	48.48 %
Restricted viewshed (n=19)	Time to reach the resource (mins)	$\overline{x}$ = 10.79	$\overline{x}$ = 7.95	$\overline{x}$ = 6.84	$\overline{x}$ = 2.21
		s = 6.35	s = 8.57	s = 5.51	s = 2.80
	Proportion of tombs that watch over the resource	42.11 %	78.95 %	63.16 %	84.21 %

Table 3: Results of the relation between the different classes of tombs and their distance to the economic resources.

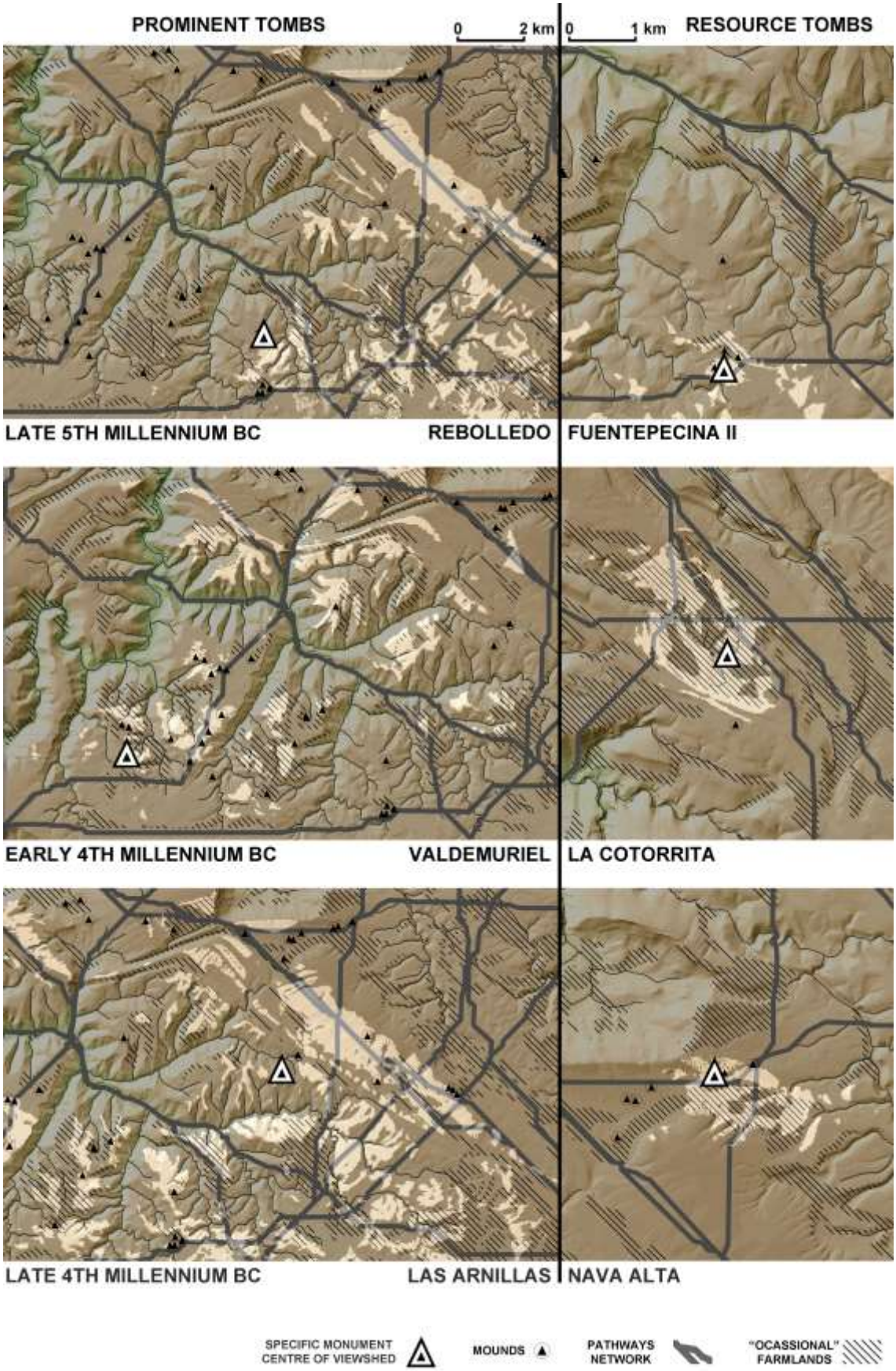


Figure 2: Diachronic evolution of the Late Neolithic tombs of La Lora concerning their viewshed and their relation with the resources.

A new piece within a larger puzzle: characterisation of 'grain de mil' flint from the Charente-Maritime, a central resource for the reconstruction of Palaeolithic territories in south-western France.

Solene Caux[1]

[1] Université Bordeaux 1- PACEA, UMR 5199

Abstract

Despite considerable survey work in the Aquitaine Basin having identified numerous different flint types, certain areas remain under documented with the origin of certain other types of flints still unknown. Originally identified from numerous Middle and Upper Palaeolithic sites across the region, the high-quality 'grain de mil' flint represents a key element for understanding the Palaeolithic occupation of the region. A consideration of the archaeological context of this particular raw material could provide new information concerning the circulation and management of lithic raw materials both within and beyond the Aquitaine Basin. However, we currently lack both a precise characterisation of this flint and an accurate distribution of the outcrops containing it. Furthermore, several authors mention the possibility of similar types of flint existing in the Dordogne. Here we present a geological and petrographic study contributing a new definition of the 'grain de mil' from the Charente-Maritime alongside a more precise understanding of its formation and how it outcrops. These new results seem to exclude a complete correspondence between flints from the Charente-Maritime and Dordogne, thus demonstrating 'grain de mil' flint to represent a raw material specific to the Jonzac anticline.

Keywords: *'grain de mil' flint; lithic raw materials; petrographic study; geological context*

1. Introduction

Investigating relationships between hunter-gatherer groups and the environment is an indispensable means for understanding different prehistoric cultures and the choices which underlie raw material procurement strategies and influence patterns of landscape use. Several studies carried out during the 1980s in the Aquitaine Basin proposed different patterns of raw material procurement and utilisation for the Upper (Demars 1980; Morala 1983) and Middle Palaeolithic occupations of the region (Geneste 1985; Turq 2000). These patterns were primarily based on the diffusion and circulation of well-known flint types such as 'Bergeracois', 'Fumelois', flint from the Chalosse area just to the north of the Pyrenees, Jasper-like materials referred to as 'Jasperoide', etc. (fig. 1). Despite the Aquitaine Basin being one of the best studied regions with numerous examples of different flint types already identified, other sources exploited during both the Middle and Upper Palaeolithic remain poorly documented or neglected with certain areas under-surveyed in terms of available raw materials and their

distribution. The consideration of additional raw materials, such as the 'grain de mil' flint, will undoubtedly shed new light on previously developed models of lithic resource management during prehistory.

Initially documented from an archaeological context in the Pyrenees during the 1980s (Simonnet 1982, 1985), it was not until much later that the first geological deposits containing 'grain de mil' flint were discovered near Jonzac in the Charente-Maritime (Simonnet et al. 2007), thus complementing available information for the northwestern part of the Aquitaine Basin. In the meantime, 'grain de mil' flint was recognised in assemblages from more than twenty Middle and Upper Palaeolithic sites located across the entire Aquitaine Basin (Simonnet 1985, 1999) (Fig. 1). Following these initial publications, 'grain de mil' flint appeared as a highly specific flint recognisable in archaeological record. While these initial studies provided valuable information, no precise definition of the 'grain de mil' flint yet exists, nor has any large-scale geological survey been carried out with the aim of documenting the extension of the geological outcrops containing it. This paper aims to resume what we already know about this flint type and to present the first results of a geological and petrographic study concerning its characterisation and genesis.

2. From its initial documentation to current questions

'Grain de mil' flint was mentioned for the first time in 1982 by R. Simonnet and owes its name to the small 'millet seed' shaped inclusions (Simonnet 1982) which appear when the material is altered (Simonnet 1985, 1999). B. Peybernès (*in* Simonnet 1985) subsequently concluded that they were a mix of bryozoan fragments and small benthic foraminifera, ultimately leading him to suggest that it formed in Cretaceous or Danian limestone. R. Simonnet successfully identified 'grain de mil' flint in several Upper Palaeolithic collections from the south of the Aquitaine Basin and emphasised its role as a '*grand traceur'*. In other words, the reoccurrence of this very high-quality flint in archeological contexts could help elucidate choices concerning the management and procurement of particular raw materials and the territories exploited by the different prehistoric groups (Simonnet 1999). At the same time, A. Morala also identified this particular flint in archeological collections from the northern Aquitaine Basin, although he referred to it as 'microbréchique' based on the presence of numerous small inclusions (Delluc et al. 1988; Morala 1992; Morala, Lenoir, and Turq 2005).

More recently, two sites in the Charente-Maritime, the Middle Palaeolithic site of Chez-Pinaud (Jonzac) and the Gravettian site of Saint-Julien (Bois), yielded evidence for knapping areas with surveys identifying the local raw material employed to be 'grain de mil' (Bordes 2002; Simonnet et al. 2007). This material was described as a translucent, blond to dark flint, presenting numerous, small petrographic 'ghosts' of bryozoans that could be found in outcrops

containing a fair number of high-quality blocks measuring several dozen centimetres. While the altered bioclasts give the flint its particular aspect when found in archaeological contexts, these geological outcrops and the presence of flints portraying different degrees of alteration demonstrate a continuity from the translucent examples to altered specimens with the particular 'grain de mil' aspect. However, while some authors have suggested that similar flint can be found in the Dordogne (Morala et al. 2005), in order for this to hypothesis be verified further survey work and petrographic analyses of flint from both the Charente-Maritime and Dordogne are necessary. With this being the case, a precise definition of 'grain de mil' from the Charente-Maritime is required not only to distinguish it from comparable flint from the Dordogne, but also to map the distribution of pertinent outcrops.

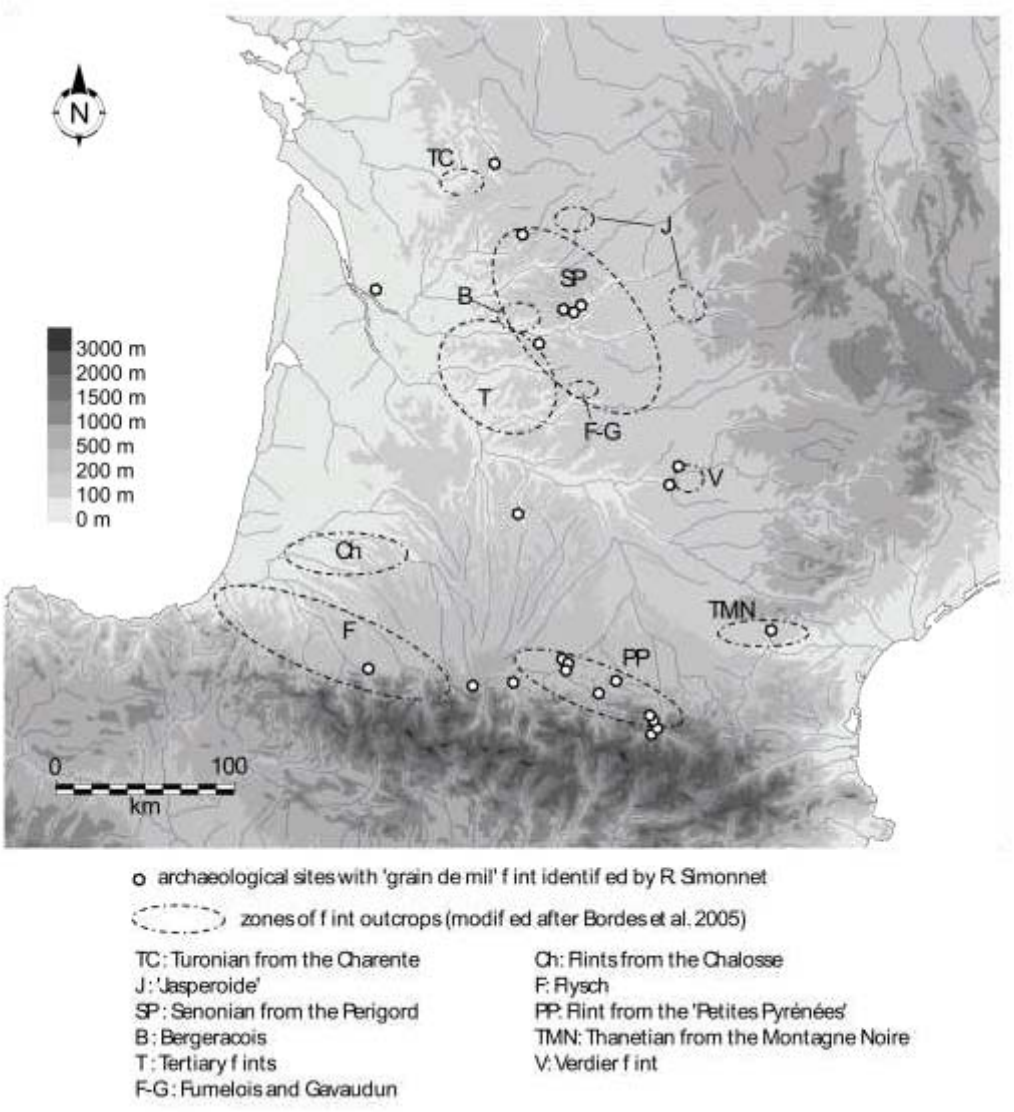


Figure 1: Zones of flint outcrops for main flint types know from the Aquitaine Basin and archaeological sites.

3. Methodology

New geological samples of 'grain de mil' flint from deposits documented by R. Simonnet near Jonzac, Ozillac and Bois (Simonnet 2007) have recently been collected in order to more clearly understand the geological context of these outcrops as well as the formation of this flint. Furthermore, these new samples permit the different degrees of alteration to be compared between non-altered geological flint and archeological specimens. These samples were observed using low to middle magnification (x 30) and provide data for a new description based on several different geological criteria: texture (Dunham 1962) and the size, morphoscopy (degree of roundness and sphericity) and nature of the grains.

4. Geological context of the outcrops

The three locations cited by R. Simonnet correspond to two different geological contexts (fig. 2). Near Jonzac and Ozillac, 'grain de mil' flint is found weathered in decayed Coniacian or Santonian layers, whereas near Bois it derives from Eocene sands. This latter formation is actually a mix of reworked Cretaceous and Tertiary deposits. Based on the regions geomorphology, these three sites sit atop the southwestern limb of the Jonzac anticline (Platel 1976) (fig. 2). The erosion of the fold followed its partial infilling by Eocene sands helps explain the age of the formation and, above all, the manner in which the flint outcrops. Situated primarily in Coniacian or Santonian layers, it can be found in residual deposits as the limestone erodes and, in the case of Bois, can become more or less integrated within the Eocene sands.

5. Petrographic description of 'grain de mil' flint

Present as blocks or slabs of considerable size, this material presents few technological constraints in terms of reduction methods (fig. 3). The thickness of cortex varies from several millimetres to a few centimetres and its composition mirrors that of the silicified zone, presenting the same types of inclusions in congruous quantities and sizes. The limit between these two areas is highly discontinuous, forming a sort of lace. The material has a wackestone to packstone-like texture (based on Dunham's (1962) classification for carbonated rocks) and is composed of between 40 to 80 % grains portraying a high degree of roundness and sphericity. Although grain sizes are mostly between 500 and 1000 μm, bigger elements in the form of large bryozoans fragments are also present. The overall impression is that of a significant selection in terms of grain size (fig. 3). While most are pellets (approximately 60 %), bioclasts, mainly in the form of fragmented bryozoans followed by infrequent benthic foraminifera such as *Miliolidae*, are also present alongside the rare *Textularia* (fig. 4).

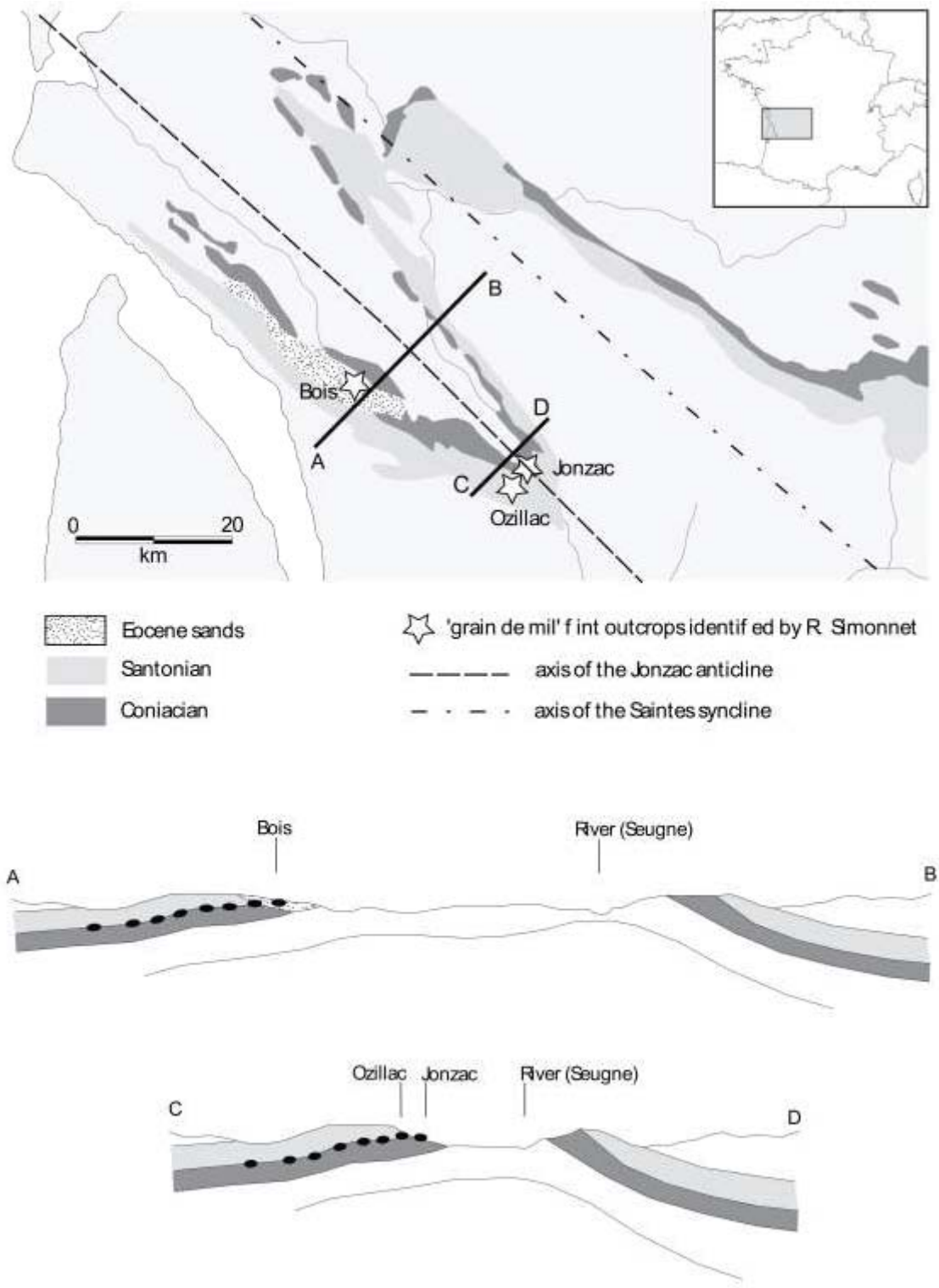


Figure 2: Geomorphological context of the region around the Jonzac anticline. Map and geological section modified after Platel 1976.

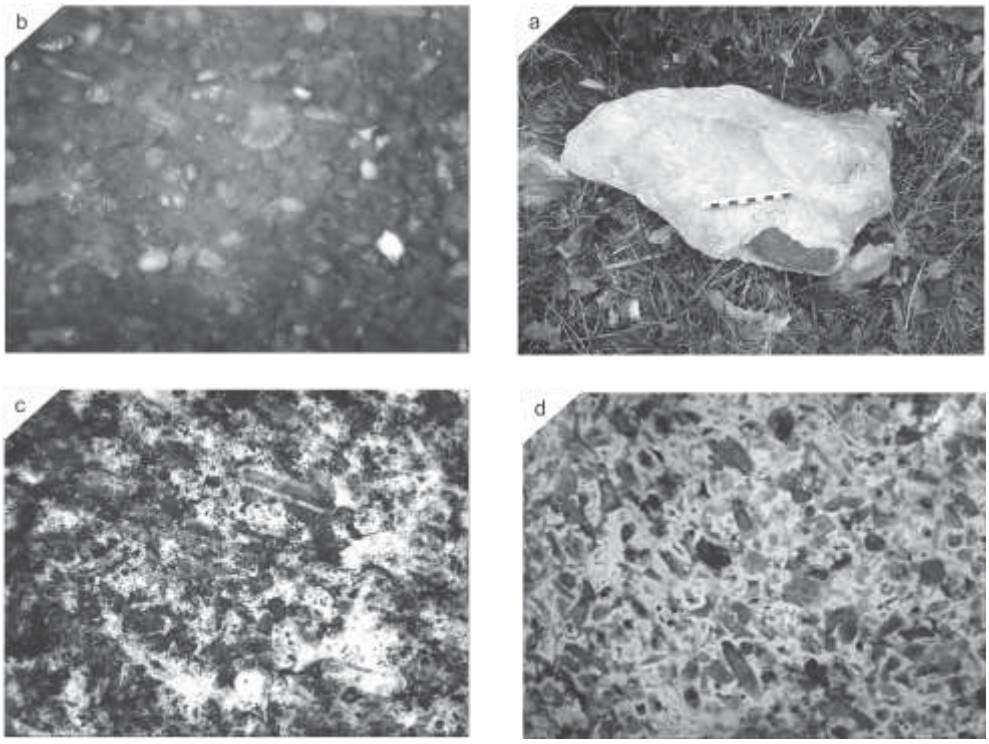


Figure 3: 'Grain de mil' flint: block measuring several dozen centimeters (a) with a wackestone-like to packstone-like texture visible on non-altered (b), slightly altered (c) and very altered (d) examples. The very altered specimen displays the typical 'grain de mil' aspect of this flint type when found in archaeological contexts. Photos S. Caux 2012. Photos b, c and d at 10 x magnification.

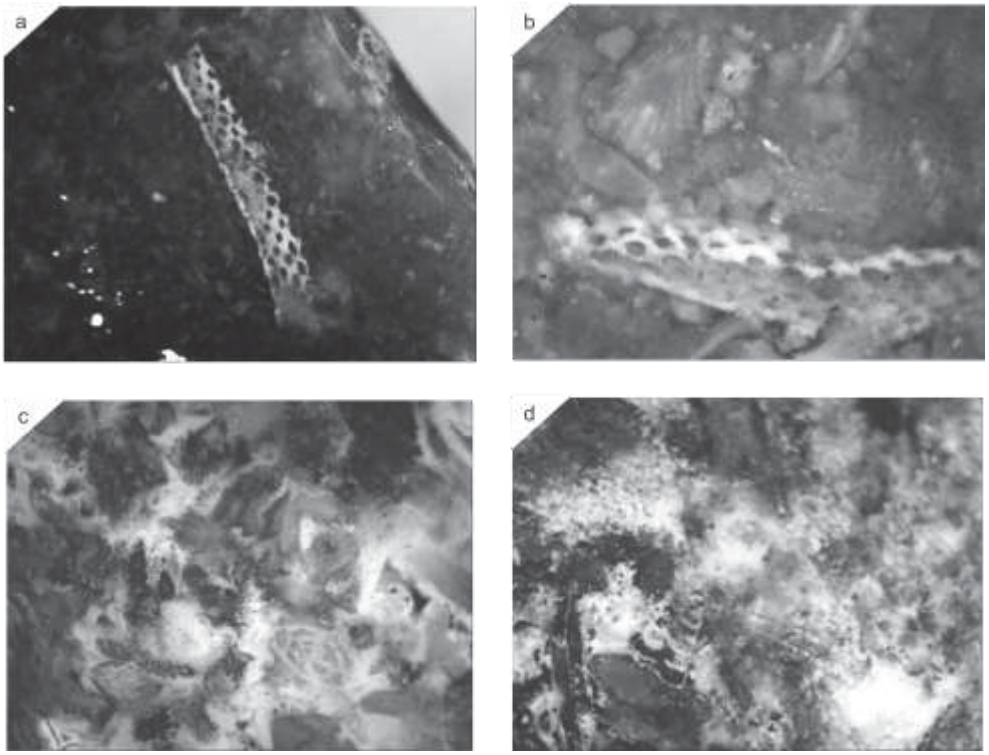


Figure 4: Micropaleontological content of 'grain de mil' flint: Bryozoans (a and b), Miliolidae (c) and Textulariida (d). Photos S. Caux 2012. Magnification a: x 10; b: x 20; c and d: x 30.

These observations, coupled with an examination of the cortical surfaces, demonstrate this flint to present characteristics identical to its host limestone. Secondly, based on the grain size-selection, degree of roundness and sphericity, the flint and by extension, its host-rock, seem to have formed in a middle to high energy environment, namely a littoral facies of a platform-slope system or a barrier facies of a platform-barrier system, a probability confirmed by the presence of bryozoans. However, the occurrence of benthic foraminifera and the lack of detrital quartz grains seem to exclude the hypothesis of a facies forming in direct proximity to the shoreline and tend to favour a barrier-facies characterised by a middle to high energy, open-water environment (fig. 5).

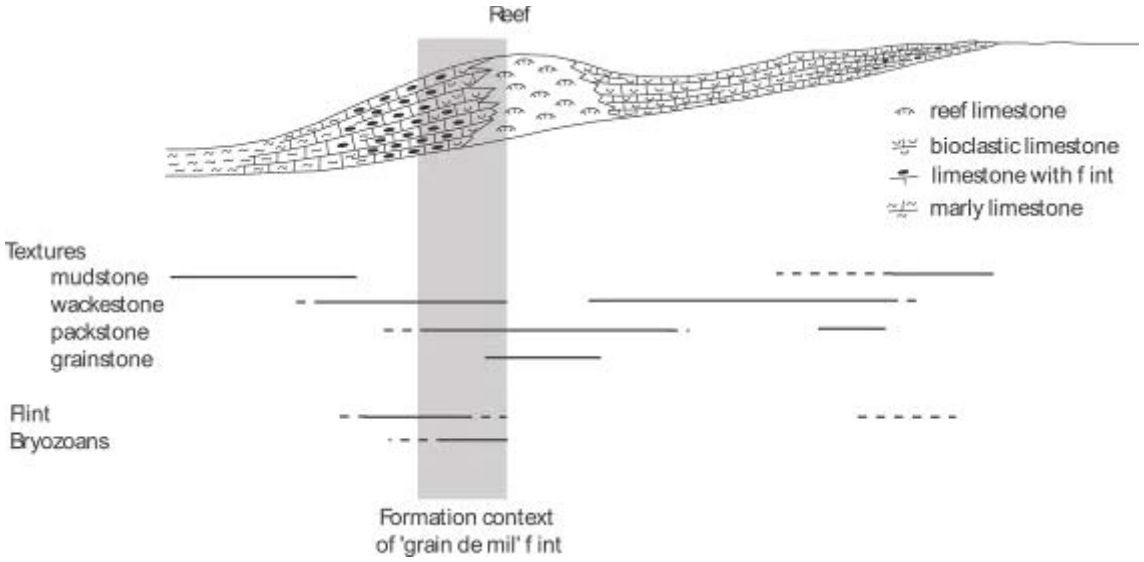


Figure 5: Flint formation in platform-barrier context (modified after Seronie-Vivien 1987).

6. Discussion

These new observations concerning the geological context of the ‘grain de mil’ flint indicates that it ought to be attributed to Coniaco-Santonian layers with its geological characteristics portraying a platform-barrier formation context. However, J-P. Platel (1976) described the Coniacian and Santonian deposits of the region as forming the first two steps of the Coniaco-Maestrichtian megasequence with the Coniacian layers dominated by continental deposits and the Santonian characterised by marly limestone with cherts. In fact, while neither the Coniacian nor the Santonian layers, as described by J-P. Platel, could correspond to the host-limestone for the 'grain de mil' flint described above, his regional scale observations of these layers are interesting. Based on the different outcrops located on either side of the Jonzac anticline, it appears that all the relevant outcrops have been eroded from the uppermost layer of the fold, leading Platel to suggest a platform-slope system model. However, the ‘grain de mil’ flint clearly demonstrates a local platform-barrier system with the Jonzac anticline being substantial

enough to modify the energy of the depositional environment from at least the beginning of the transgression (Coniacian, and perhaps Santonian). Therefore, even if the northern Aquitaine Basin was generally a platform-slope, the fold at Jonzac formed a local platform-barrier system. This observation is significant, not only for the geological history of the Aquitaine Basin, but more particularly for determining the origins of the ‘grain de mil’. This very local formation context is so specific that it seems to exclude the possibility of geological outcrops containing ‘grain de mil’ flint extending beyond the anticline and hence outside the Charente-Maritime. This hypothesis however requires further confirmation by new surveys in both the Charente and Dordogne along the Jonzac anticline and Saintes syncline as well as neighbouring regions; despite the fact that Dordogne flint should not present the same texture or grains of similar size, nature and morphoscopy.

7. Conclusion

Here we have proposed the first description of ‘grain de mil’ flint from the southwestern side of the Jonzac anticline based on a geological and petrographic characterisation complemented by images at low and middle magnifications. Based on new observations concerning the geomorphological context of the Jonzac fold, it seems that the anticline formed a local barrier in the northern Aquitaine platform and that the formation of the 'grand de mil' flint and its characteristic elements result from this very specific formation context. These results require further support from a larger study including surveys along the northeast side of the Jonzac anticline and extending across the Saintes syncline in order to more clearly map the actual area of the ‘grain de mil’ outcrops and its possible variability. Nonetheless, this new description of the ‘grain de mil’ flint from Jonzac represents a solid comparative base for identifying this flint in the archaeological record and complements what we already know about lithic raw materials in the Aquitaine Basin. The integration of this new information from the north-western part of the basin will provide further detail to existing models of both Middle and Upper Palaeolithic raw material economies across the basin and further afield.

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References

Bordes, J.G. 2002. *Les interstratifications Châtelperronien / Aurignacien du Roc-de-Combe et du Piage (Lot, France). Analyse taphonomique des industries lithiques ; implications archéologiques*. Thèse de doctorat, Université Bordeaux 1, Bordeaux.

Delluc, B, G. Delluc, A. Morala, and H. Plisson. 1988. Quelques objets de la grotte de Saint-Front de Domme (Dordogne). *Bulletin de la Société Historique et Archéologique du Périgord* CXV: 11-23.

Demars, P.Y. 1980. *Les matières premières siliceuses utilisées au Paléolithique supérieur dans le Bassin de Brive.* Thèse de doctorat, Université Bordeaux 1, Bordeaux.

Dunham, R. 1962. Classification of carbonate rocks according to depositional texture. *America Association of Petroleum Geologist* 1: 108-121.

Geneste, J.M. 1985. *Analyse lithique d'industries moustériennes du Périgord : une approche technologique du comportement des groupes humains au Paléolithique moyen*. Thèse de doctorat, Université Bordeaux 1, Bordeaux.

Morala, A. 1983. A propos des matières premières en Haut-Agenais. *Bulletin de la Société Préhistorique Française* 80(6) : 169.

Morala, A. 1992. Un site magdalénien supérieur de plein air en Bergeracois : Usine Henry, Creysse (Dordogne). In *Le peuplement magdalénien: paléogéographie physique et humaine,* edited by J.Ph. Rigaud, H. Laville and B. Vandermeersch, 235-246. Paris: Éditions du Comité des Travaux Historiques et Scientifiques.

Morala, A., M. Lenoir, and A. Turq. 2005. Production et utilisation de supports normalisés lamino-laminaires dans la chaîne opératoire des grattoirs Caminade du site du Pigeonnier à Gensac (Gironde, France). In *Production lamellaires attribuées à l'Aurignacien : Chaînes opératoires et perspectives technoculturelles*, *XIV congrès de l'UISPP*, edited by F. Le Brun-Ricalens, J.G. Bordes and F. Bon. Luxembourg: Musée National d'Histoire et d'Art du Luxembourg.

Platel, J.P. 1976. *Carte géologique de Jonzac. 1/50000*. Edited by BRGM.

Simonnet, R. 1982. Grandes lames de silex dans le Paléolithique supérieur des Pyrénées centrales. Essai sur des documents marginaux. *Préhistoire Ariègeoise - Bulletin de la Société Préhistorique de l'Ariège* 37: 61-106.

Simonnet, R. 1985. Le silex du Magdalénien de la Grotte des Eglises dans le Bassin de Tarascon sur Ariège. *Société Préhistorique de l'Ariège* XXXX: 71-97.

Simonnet, R. 1999. De la géologie à la Préhistoire : le silex des Prépyrénées, résultats et réflexions sur les perspectives et les limites de l'étude des matières premières lithiques. *Paléo* 11: 71-88.

Simonnet, R, J.G. Bordes, J. Primault, and F. Bon. 2007. Le silex "Grains de Mil". Localisation des gîtes. In *Frontières naturelles et frontières culturelles dans les Pyrénées préhistoriques*, A*ctes de la table ronde internationale de Tarascon-sur-Ariège, mars 2004*, edited by.N. Cazals, J.E. González Urquijo and X. Terradas Batlle, 101-102. Santander: Instituto Internacional de Investigaciones Prehistóricas de Cantabria.

Turq, A. 2000. Le Paléolithique inférieur et moyen entre Dordogne et Lot. *Paléo* 2.

Variation in the use of space through time at Abrigo de la Quebrada (Chelva, Valencia): the case of Middle Paleolithic levels IV and VII

Aleix Eixea[1]

Valentín Villaverde[1]

João Zilhão[2]

Mercè Bergadà[3]

Alfred Sanchis[4]

Juan Vicente Morales[1]

Cristina Real[1]

José Ángel Martínez[1]

[1] Departament de Prehistòria i Arqueologia, Universitat de València.

[2] ICREA - Departament de Prehistòria, Història Antiga i Arqueologia. Universitat de Barcelona.

[3] Departament de Prehistòria, Història Antiga i Arqueologia. Universitat de Barcelona

[4] Museu de Prehistòria de València. Servei d'Investigació Prehistòrica (SIP). Diputació de València.

Abstract

This paper compares levels IV and VII of Abrigo de la Quebrada (Chelva, Valencia). Firstly, the levels are described. Then, by means of the analysis of the distribution of elements related to lithic reduction methods, faunal remains, and combustion features, similarities and differences in the management of space are discussed. Level IV is a cumulative palimpsest where find densities are high and discriminating between successive episodes of occupation is fraught with serious difficulties. In level VII, carnivore bones and carnivore marks on herbivore remains suggest periodic human abandonment of the site, lithic and bone remains are less abundant, and they are for the most part associated with combustion remains located in the middle of a stratigraphic unit that is significantly thicker. Ongoing taphonomic and geoarcheological work aims at elucidating the role played in the explanation of these differences by changing patterns of sediment accumulation versus changing patterns of human and carnivore use of the site.

Keywords: *Microspace, Diachrony, Middle Paleolithic, Valencian Country, Iberian Peninsula.*

1. Introduction

The Abrigo de la Quebrada is located near Chelva (Los Serranos, Valencia), 65 km NW of the city of Valencia (Fig. 1).

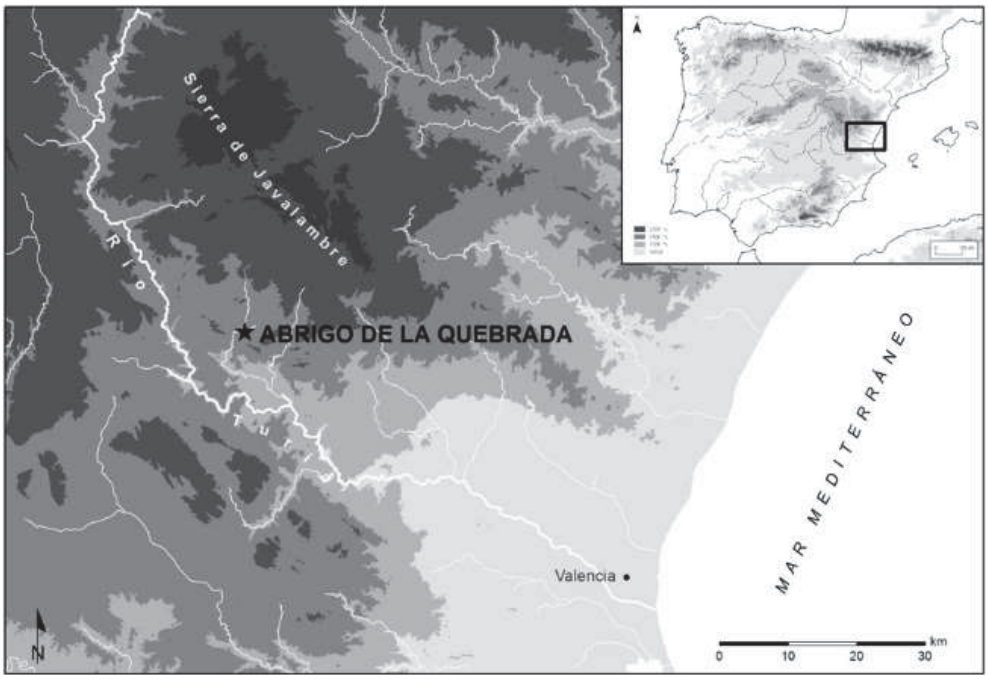


Figure 1. Geographical location of the site.

The site is located on the left side of the Rambla de Ahillas canyon and corresponds to a sheltered, quite even horizontal platform 38 m long and 2 to 9 m wide that slopes slightly from North to South. Given its position (NW-facing, and at the bottom of a narrow, steep gorge), direct exposure to sunlight is limited. The Rambla de Ahillas opens onto a wide plain known as Plano de Arquela, which, combined with the characteristics of the canyon—which terminates in a dead end, forming a sort of natural trap—clearly hint at the reasons underpinning human use of the shelter.

The extant stratigraphy of the Abrigo de la Quebrada consists of eight units spanning a thickness of about 4 m. The base of the sequence has not yet been reached. Level I, at the top, is disturbed as a result of the use of the shelter for penning. Human occupation is recorded in levels II to V, VII, and VIII, all of which contain Middle Paleolithic stone tool assemblages. Anthropogenic inputs are especially significant in units III, IV and V. The pattern of occupation reflected in the lithic and faunal remains found in levels VII and VIII is distinct (Eixea *et al.*,

2011-2012). In this paper, we elaborate on this distinction through a comparison between levels IV and VII.

2. Methodology

The reliability of spatial analysis at Abrigo de la Quebrada is warranted by the high density of finds, the high percentage of ones that were three-dimensionally plotted, and the good control over the provenience of those that were not.

The excavation was carried out in one square meter grid units. As a rule, lithics longer than 2 cm and bone fragments longer than 3 cm were three-dimensionally plotted using a total station. However, some smaller, yet identifiable finds (flake fragments, broken retouched pieces, epiphysis, tooth fragments, microfauna, etc.) were also positioned during the excavation. In order to achieve greater control over the spatial scatter of non-plotted and sieve finds, each square meter was subdivided into sixteen 25x25 cm subunits (Fig. 2.)



Figure 2. Overall view of the site.

The deposits were excavated in 5 cm artificial spits; when necessary, their thickness was adjusted to account for and respect natural stratigraphic boundaries. Sediments from each 1/16 m² subunit of the grid were sieved separately; the corresponding finds, mostly lithic and bone splinters, were also stored separately in order to be counted and added to the site database in the laboratory. Due to the lack of water at the site, dry rather than wet sieving, with a double mesh of 4 and 2 mm, was used. In order to measure the features, both their perimeter and top and bottom elevations were recorded. With the data gathered from the excavation, we generated a GIS system with x-y-z data for both finds and features (stones, hearths, large areas of stained sediment).

The find scatters were represented as density maps, the readability of which, when density is high, is better than that of scatterplots. Density maps are generated from point data by defining a search radius for each output raster cell. The radius determines point search distance or the output values around the points. Density can be calculated by simple functions or by Kernel functions. Here, we used Kernel functions because they yield a smoother output. Using a web of frequencies, finds that were not plotted during excavation (splinters, small fragments, etc.) could also be three-dimensionally positioned, making it possible to include in distribution maps all of the excavation finds. We also produced frequency maps, generated by counting finds per both square meter units and 1/16 m² subunits.

During excavation, each exposed *decapage* surface was recorded via orthophotographically corrected digital panoramic photography, whereby all the features can be seen at the same scale, free of error and deformations. The first step is the production of a panoramic image of the excavated surface from a series of photographs taken from a particular point of the site. Once corrected by means of georeferencing, such images can then be edited to add elements recorded by drawing (e.g., the outlines of stones, burrows, hearths or ash stains).

The size of excavated areas in each level is different, which must be borne in mind in the comparisons, as this factor limits their reach. The data for level IV come from the 21 m^2 excavated in the 2009 field season, while the data obtained for level VII come from the 8 m^2 excavated in 2011 and 2012; where level IV is concerned, the analyzed area represents over 40% of the total surface of the shelter, while a much smaller percentage is involved in the level VII analyses. Moreover, (a) the data for level IV correspond to only a part (albeit a substantial one) of the total sedimentary unit (the spit in direct contact with underlying level V, whose analysis is still pending, has not been considered), while the data for level VII come from the total thickness of the deposit (although, for the faunal remains, only 4 m^2, or half of the area excavated in this level, have been included); (b) volume-wise, the level IV finds come from 3.15

m^3 of excavated sediment, and those from level VII from 1.92 m^3. Despite these limitations, the data suffice to establish the existence of distinct site occupation patterns.

3. Stratigraphy and Dating

Level IV is 13-18 cm-thick and made up of a clayish lime matrix containing medium and fine brown sand (7.5YR 5/3) and 1-4 cm limestone pebbles of sub-angular morphology whose size tends to increase toward the top. The boundary with overlying level III is diffuse. Quartz, feldspar and calcite are the main minerals. The microstructure is generally massive, but cavitary and granular in places. Anthropic components are important, as manifested in the extensive combustion features. Regarding post-depositional processes, $CaCO_3$ deposits of micritic type and coating of bone remains are significant; the latter provokes fragmentation. Biological activity causes porosity, microstructure modification and the incorporation of fecal pellets. Finally, there are carbonate accumulations around detritus material, especially in combustion areas. The accumulation of sediments results from the low intensity action of rain water combined with minor cryoclastic processes, the latter having become more intense towards the upper part of the level. After the period of human occupation, carbonated water percolation suffused the base and formed a carbonated crust in some sections, indicating a rapid crystallization process. The biological activity indicates stability and a slow sedimentation rate (Eixea *et al.*, 2011-2012).

The abundance of combustion features documented in this level—ten *in situ* hearths with different degrees of preservation—bears witness to the importance of the human occupation. Hearths are small, simple and shallow, with round or elongated shapes. They present no previous preparation of the space; their perimeter is not marked by blocks, and they are just a few centimeters deep, with no prior excavation of a *cuvette*. Several large black, ashy and orangey stains, which result from the burning of the sediment and the dispersing of the ash, have also been identified. The hearth-induced rubefaction shows that the poor preservation of charcoal and ash is caused by post-depositional alteration processes relating to a repetitive use of the site and/or a low sedimentation rate, both of which foster a prolonged exposition of combustion features to weathering and trampling agents.

Level V is 13-20 cm-thick. Its lower boundary is erosive but the lower boundary is diffuse. It features a dark (7,5 YR 5/2) sandy silt matrix and contains subangular limestone clasts 1-5 cm-long, increasing in abundance towards the base. Anthropogenic inputs are significant.

Level VI is subdivided in two. Sublevel VIa consists of angular limestone blocks in a sandy matrix (7,5 YR 6/4) and is 10-18 cm-thick across most of the excavated area, reaching 70 cm in the J-3 profile, where it coarsens upwardly. Sublevel VIb is 90-100 cm-thick on average and consists of sands (7,5 YR 6/6) that, towards the base, present laminations of finer material and, upward, contain scattered cobbles and $CaCO_3$ nodules. Its geometry is tabular.

Level VII is 25-80 cm-thick. It mostly consists of autochthonous detrtitical material. The upper part includes roof-fall blocks as well as cobbles and small slabs with slight traces of carbonatation. The matrix is a reddish (7.5 YR 6/4) sandy clay. It features a wedge-like geometry. Half-way through its thickness, a few hearths have been documented in the eastern third of the excavated surface.

For level IV, we have an AMS date obtained on a sample of *Pinus pinaster* charcoal recovered within a combustion feature excavated in spit 7. The sample was ABA-pretreated and yielded an age of 43,930±750 BP (Beta-244002). Another date from the same level obtained on an ABOx-pretreated sample of *Pinus nigra* yielded an age >50.8 ka BP (OxA-24855). Level VII remains undated.

4. Assemblage Composition

A quick comparison of the two levels of concern here shows significant differences in their respective occupation patterns. The density index for the lithics, very high in level IV (28.3), is of only 0.43 in level VII. The same applies to the bone remains, whose density index is 239.1 in level IV and only 20.1 in level VII. This latter difference is drastically reduced, however, if we consider the density index for identifiable bone, which is 2.8 in level IV and 1.2 in level VII. This is significant because it shows that fragmentation processes are less intense in level VII. Explanations for this can be sought in a pattern of less intensive occupation of the site in level VII, where the anthropic component would represent shorter occupations, or in that the contribution of carnivores to the faunal assemblage represents the activity of species other than the hyena, ones that break the bones of the animals consumed to a much lesser extent.

In level IV, the high level of post-depositional fragmentation, which we relate to the action of both heat and trampling, explains why no more than 1.18% of the bone remains are identifiable to species (in level VII, the corresponding percentage is 13.47). Bone breakage in level VII is also high (88% of the faunal remains, teeth excluded, are broken), but the fragments are bigger and, therefore, more amenable to taxonomic identification (Table 1).

Level	m^3	Total lithics	Density of lithics	Total bone	Density of bone	Identified bone	Density of identified bone
IV	3.15	8915	28.3	75296	239.1	892	2.8
VII	1.92	83	0.43	3866	20.1	238	1.2

Table 1. Number of finds and find densities in levels IV and VII.

In level VII, remains of Leporidae are present but, because of the calcium carbonate coating of bone surfaces, few carnivore and/or human processing and consumption marks could be identified. Another important difference between the two levels is that in level VII thermally altered bones are very scarce, a mere 1.4%, in marked contrast with level IV, where thermal alteration affects 60.67% of the bone remains for an area of the same size as that considered in the level VII analyses.

Concerning the lithics (Table 2), the two levels differ in assemblage composition, raw-material selection and technological preference. In level VII, the percentage of chippage and other debris is 57.1, markedly lower than in level IV (87.9); the percentage of retouched pieces is, however, similar in both levels. In level VII, edge-sharpened blanks of considerable size and thickness, infrequent in level IV, have been documented (Villaverde *et al.*, 2012). The differences between the two levels in the size and relative abundance of chippage and debris are not easy to explain. It is possible that the area studied in level VII was more structured than the area studied in level IV, or that the former coincides with a knapping spot. The less intensive post-depositional thermal fragmentation apparent in level IV is likely to be one of the main causes of the scarcity of chippage in this level.

Whether the blanks of those level VII retouched pieces that were intensively sharpened and resharpened were originally flaked prior to or during the occupation of the site cannot be established at present. Importation of ready-made blanks or of finished tools would be consistent with the notion that the level documents short occupations separated by long periods of abandonment, but testing this hypothesis requires further investigation. Where local raw-materials are concerned, it is in any case clear that the level VII lithic assemblages feature complete *chaînes opératoires*, ones whereby procurement ranged widely and the duration of cutting edges was short (Villaverde *et al.*, 2012).

LITHICS CATEGORIES	LEVEL IV	LEVEL VII
Flakes and flake fragments	856 (9.60%)	34 (40.5%)
Laminar flakes and fragments from laminar flakes	28 (0.31%)	0
Thermal fragments	159 (1.79)	0
Cores	28 (0.31%)	1 (1.2%)
Blades and bladelets	5 (0.06%)	0
Chippage and debris	7839 (87.93)	48 (57.1%)
TOTAL	8915	83

Table 2. Lithics counts for levels IV and VII.

In level VII, flint is by far the preferred raw material, accounting for 94.4% of the assemblage. Raw-materials are more diverse in level IV, where quartzite and limestone are 39.8% (Table 3). These differences are suggestive of two different systems of raw-material procurement, with that represented in level VII being less interested in the local rocks, abundant in the site surroundings (Eixea *et al.*, 2011).

RAW-MATERIALS	Flint	Quartzite	Limestone	Quartz	TOTAL
LEVEL IV	655 (60.0%)	244 (22.4%)	190 (17.4%)	2 (0.2%)	1091
LEVEL VII	34 (94.4%)	0	2 (5.6%)	0	36

Table 3. Raw-materials used in levels IV and VII.

Finally, Levallois reduction methods are clearly less important in level VII, where they always are of the recurrent modality, than in level IV (Table 4).

REDUCTION METHOD	Discoidal	Centripetal Recurrent Levallois	Preferential Levallois	Unipolar Recurrent Levallois	Bipolar Recurrent Levallois	Laminar	Kombewa	Indet.	TOTAL
LEVEL IV	306 (54%)	197 (34.8%)	54 (9.5%)	1 (0.2%)	5 (0.9%)	1 (0.2%)	2 (0.4%)	525	1091
LEVEL VII	19 (67.9%)	9 (32.1%)	0	0	0	0	0	5	33

Table 4. Reduction methods used in levels IV and VII.

To these differences in lithic assemblage composition we must add those concerning the faunal remains. It is possible that such differences reflect changes through time in the configuration of the site and its inhabitable space, in climate, and/or in environmental parameters (where the latter are concerned, this could be so especially in the case of the Testudinidae remains recovered in level IV). Moreover, difficulties in the observation of the cortical surfaces of bones prevent us from assessing the role of humans in the accumulation of the remains of Leporidae; in the former, both non-humans (leporids bones from level VII) (pits, bite-marks, scrapes and digested bones) and human (percussion fractures) alterations have been observed. Where medium and large size animals are concerned, the two faunal assemblages are rather similar in species composition, with Bovidae prevailing and both Equidae and Cervidae being represented. The Canidae remains from level VII are of special interest because they point to the possibility of a carnivore use of the shelter during periods of human abandonment (Table 5).

TAXA	Lepo.	Birds	Bovidae	Equidae	Canidae	Cervidae	Testu.	Rhino.	TOTAL
LEVEL IV	100 (11.2%)	0	289 (32.4%)	193 (21.6%)	0	147 (16.5%)	163 (18.3%)	0	892
LEVEL VII	190 (83.2%)	12 (5.3%)	10 (4.4%)	7 (3.1%)	5 (2.2)	2 (0.9%)	0	2 (0.9%)	228

Table 5. Animal taxa identified in levels IV and VII.

5. Spatial Analysis

Given the intra-level connections, both horizontal and vertical, revealed by stone tool refits (Table 6), the spatial analysis of level IV was carried out for the stratigraphic unit as a whole, subsuming the different spits into which it was subdivided at the time of excavation (Eixea *et al.*, 2011-2012). The analysis revealed a typical cumulative palimpsest structure, with abundant superimposed hearths mostly located in the central and western parts of the excavated area. The hearths provided the focus for the spatial organization of activities, namely stone tool knapping and the processing and consumption of prey (Fig. 3). Despite the high density of finds, the pattern of hearth superimposition is suggestive of a repetitive use of the shelter for the same kinds of hunting tasks focused on the acquisition of Bovidae, Equidae and Cervidae (as well as, where small prey are concerned, tortoise).

The level VII deposits are thicker, but, as in other Middle Paleolithic sites in the region, find density is much lower (Villaverde, 2001). Bearing in mind the smaller size of the excavated area, it is clear that, here, hearths were not being continuously altered and dismantled, as opposed to the pattern observed in level IV and all other levels above. The morphology of the hearths, however, is the same: they are simple, shallow (forming 2-3 cm-deep basins), small (30-35 cm in diameter) and elongated, with rubefaction affecting 0.5-1 cm of the underlying deposits. This suggests that they are likely to have been short duration hearths with no continuous maintenance and reconditioning processes. Their emplacement is also identical to that observed in level IV. This is probably a consequence of the spatial restrictions imposed by the dimensions of the shelter and the area protected by its overhang.

Additional data confirm the structural distinction between levels IV and VII. For instance, level VII is thicker and, although the hearths therein were all located in the middle of the level, finds have a more complex vertical distribution and are present throughout the entire sedimentary body (even if its upper third is rather poor in lithic and bone remains, especially those of medium and large animals); the finds relating to human occupation were for the most part recovered in the lower third of the level, at elevations largely coinciding with the presence of hearths. The refitting lines for the two lowermost spits suggest that we may have here a palimpsest where different occupation events are subsumed. Confirmation of this hypothesis requires additional work, namely where refitting is concerned.

The area of level VII with a particularly high density of finds in squares E-3 and E-4 coincides, horizontally and vertically, with the excavated hearths. It remains possible, however, that the stone tools and faunal remains recovered at higher elevations within the level may correspond to low density scatters in the periphery of hearths located elsewhere, outside the small-sized area of this level that has so far been excavated.

In level VII times, local carnivores alternated with humans in the use of the shelter, as shown by the carnivore marks observed on some of the level's faunal remains. It is also possible that the smaller degree of bone breakage and the larger size of the fragments reflect an important role for carnivores in the accumulation of those remains. Alternatively, this difference between the two levels may be due to taphonomic factors, e.g., less trampling due either to the shorter duration of the human occupations and the longer intervals separating each, or to the prevalence of higher sedimentation rates.

Line	Level	Spit	Raw Material	Composition and Elevation bellow Z	Type	Distance	Length
1	IV	6	Quartzite	Flakes (a:1428/ b:1466/ c:1478)	Exploitation	Horizontal	Short (<0.5 m)
2	IV	7	Quartzite	Flakes (a:1407/ b:1394/ c:1420)	Exploitation	Horizontal	Short (<0.5 m)
3	IV	6	Quartzite	Flakes (a:1258/ b:1146)	Exploitation	Horizontal	Medium (0.5 a 2.10 m)
4	IV	6 & 7	Limestone	Edge and flakes (a:1182/ b:1185/ c:1159/ d:1146/ e:1232/ f:1157)	Exploitation	Vertical	Medium (0.5 a 2.10 m)
5	IV	6 & 7	Limestone	Core and flakes (a:1423/ b:1396/ c:1357/ d:1340/ e:1273)	Exploitation	Vertical	Long (2.10 a 4 m)
6	IV	7	Limestone	Flakes (a:1340/ b:1424)	Exploitation	Horizontal	Long (2.10 a 4 m)
7	IV	7	Limestone	Core and flakes (a:1242/ b:1106/ c:1348/ d:1123)	Exploitation	Horizontal	Long (2.10 a 4 m)
8	IV	7	Limestone	Core and flakes (a:1357/ b:1423/ c:1484)	Exploitation	Horizontal	Long (2.10 a 4 m)
9	IV	6 & 7	Limestone	Core and flakes (a:1454/ b:1455/ c:1337)	Exploitation	Vertical	Long (2.10 a 4 m)
10	VII	47	Flint	Flake and flake fragment (a:3321/ b:3329)	Fracture	Horizontal	Short (<0.5 m)
11	VII	47 & 48	Flint	Flake and flake fragment (a:3315/ b:3393)	Fracture	Vertical	Medium (0.5 a 2.10 m)
12	VII	48	Flint	Flake and flake fragment (a:3581/ b:3532)	Fracture	Horizontal	Medium (0.5 a 2.10 m)
13	VII	47 & 48	Flint	Core and flakes (a:3275/ b:3308/ c:3326/ d:3328/ e:3403)	Fracture	Vertical	Medium (0.5 a 2.10 m)

Table 6. Refitting lines for levels IV and VII.

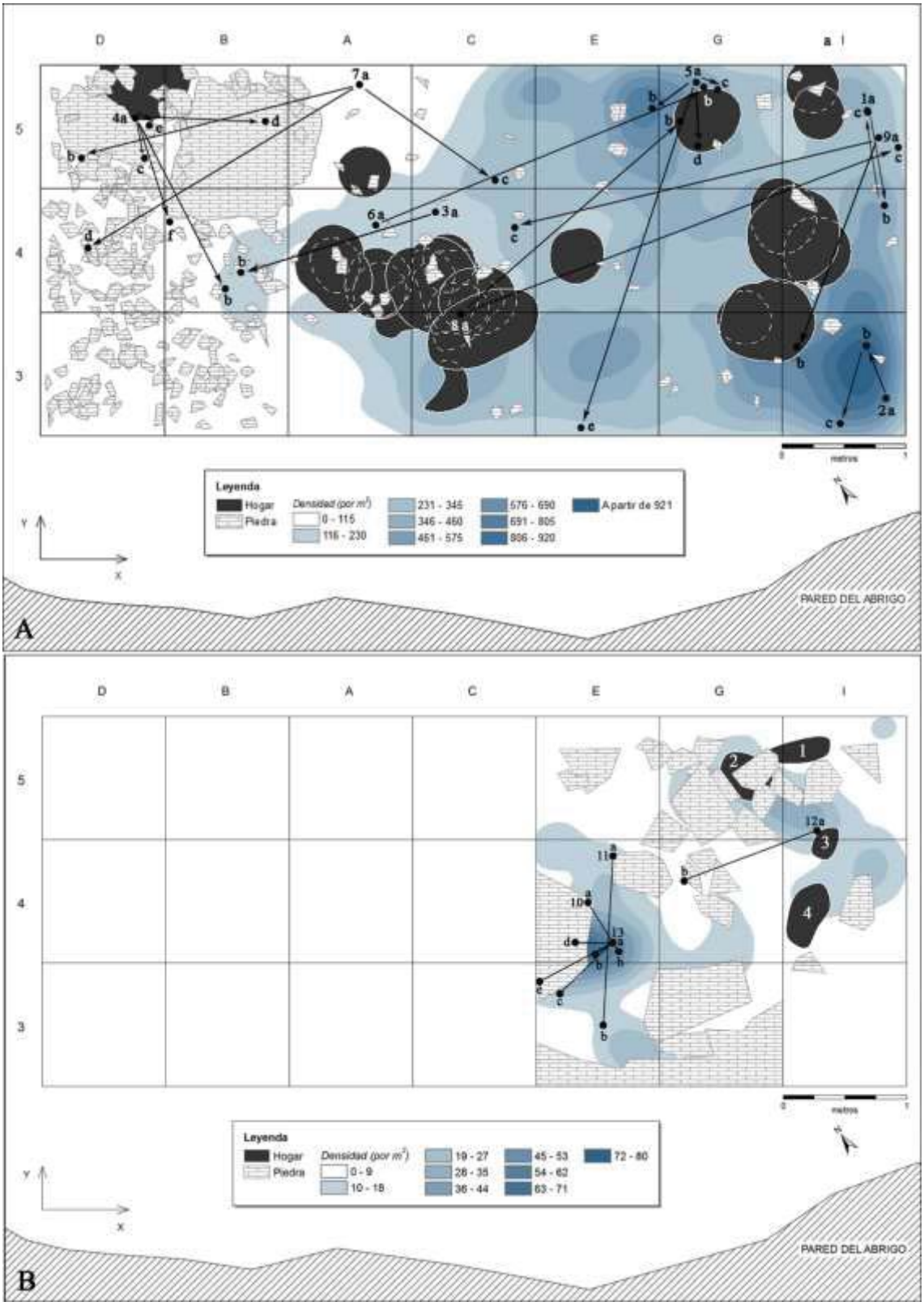


Figure 3. Combustion areas and refitting lines for levels IV (A) and VII (B) plotted over lithics density maps for each level.

6. Conclusion

As they are separated by sterile level VI, the two levels dealt with in this paper, IV and VII, must correspond to two different periods of occupation. The distributions of their respective archeological contents show a clear difference in the density of finds. Level IV has a typical palimpsest structure characterized by the abundance of combustion features, knapping debris and bone fragments. The analysis of the distribution of the least common elements yields a repetitive pattern of occupation characterized by high density scatters around the hearths. In level VII, the density of finds is much lower and the spatial structure is, therefore, better defined. Combustion areas, however, are restricted to the middle and lower spits of the level, opening up the possibility that the lower density find scatters in the upper spits of this level relate to hearths located elsewhere at the site. The role played by natural and anthropogenic factors in the generation of these differences is the subject of ongoing research.

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References

Eixea, A., V. Villaverde and J. Zilhão. 2011."Aproximación al aprovisionamiento de materias primas líticas en el yacimiento del Paleolítico medio del Abrigo de la Quebrada (Chelva, Valencia)." *Trabajos de Prehistoria* 68: 65-78.

Eixea, A., V. Villaverde, J. Zilhão, A. Sanchis, J.V. Morales, C. Real and M. Bergadá. 2011-2012. "El nivel IV del Abrigo de la Quebrada (Chelva, Valencia). Análisis

microespacial y valoración del uso del espacio en los yacimientos del Paleolítico medio valenciano." *Mainaké* XXXIII: 131-162.

Villaverde, V. 2001. *De Neandertales a Cromañones: el inicio del poblamiento humano en las tierras valencianas.* Valencia: Universitat de València: Servei de Publicacions.

Villaverde, V., A. Eixea, J. Rios and J. Zilhão. 2012. "Importancia y valoración de la producción microlevallois en los niveles II y II del Abrigo de la Quebrada (Chelva, Valencia)." *Zephyrus* LXX: 13-32.

Traditional wisdom and landscape management. A longue durée history of human exploitation of a critical resource. The case of the Oukaïmeden valley (High Atlas, Morocco)*

Jorge de Torres [1]

Marisa Ruiz-Gálvez [1]

Youssef Bokbot [2]

Mercedes Farjas [3]

Pablo de la Presa [3]

José María Señoran [4]

[1] Universidad Complutense de Madrid.

[2] Institut des Sciences de l'Archéologie et du Patrimoine du Maroc.

[3] Universidad Politécnica de Madrid

[4] CSIC-Incipit

Abstract

Since 2009, a research project is being carried on at the Oukaïmeden valley (High Atlas, Morocco), aiming at understanding the way humans have used and marked the landscape. One of the main challenges to do so, has been organizing and ascribing chronologically the impressive documentation of rock art depictions of the area. To achieve this goal, a correspondence analysis has been applied in a first step of analysis to weapons engravings, the most abundant depiction. Four different groups have been identified linked to the chronological evolution of this kind of depictions from prehistoric to medieval times. Most important of all, this ordering has a spatial expression with different distributions depending on the chronological period, and also different distribution patterns in Prehistoric or Protohistoric/ Medieval periods. These preliminary results open a way not only to integrate rock art within the rest of ARPA research trends, but to establish a well dated, archaeologically contextualized typology of Saharan rock art later periods.

Keywords: *Rock art, correspondence analysis, spatial archaeology, High Atlas, Oukaïmeden*

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Patrimoine du Maroc and the Complutense University (Madrid) and the coordination of Dr. Youssef Bokbot.

1. Introduction

Oukaïmeden is a typical alpine-like valley, set at 2630 m above sea level at the core of the Morocco's High Atlas. Records from the 16th century onwards refer to its seasonal profit as summer pasturage by herders coming from villages settled at mid altitude both in the Rerhaya valley to the West and the Ourika valley to the East. Both of them claim exclusive rights to the grazing lands of the valley derived from their descent of a mythical ancestor called Sidi Fars, the one who went first to Oukaïmeden and tamed the Nature. Because the valley is a critical resource, periods of both, exploitation and prohibition are well scheduled, remembered and transmitted through legends and stories (Mahdi 1999).

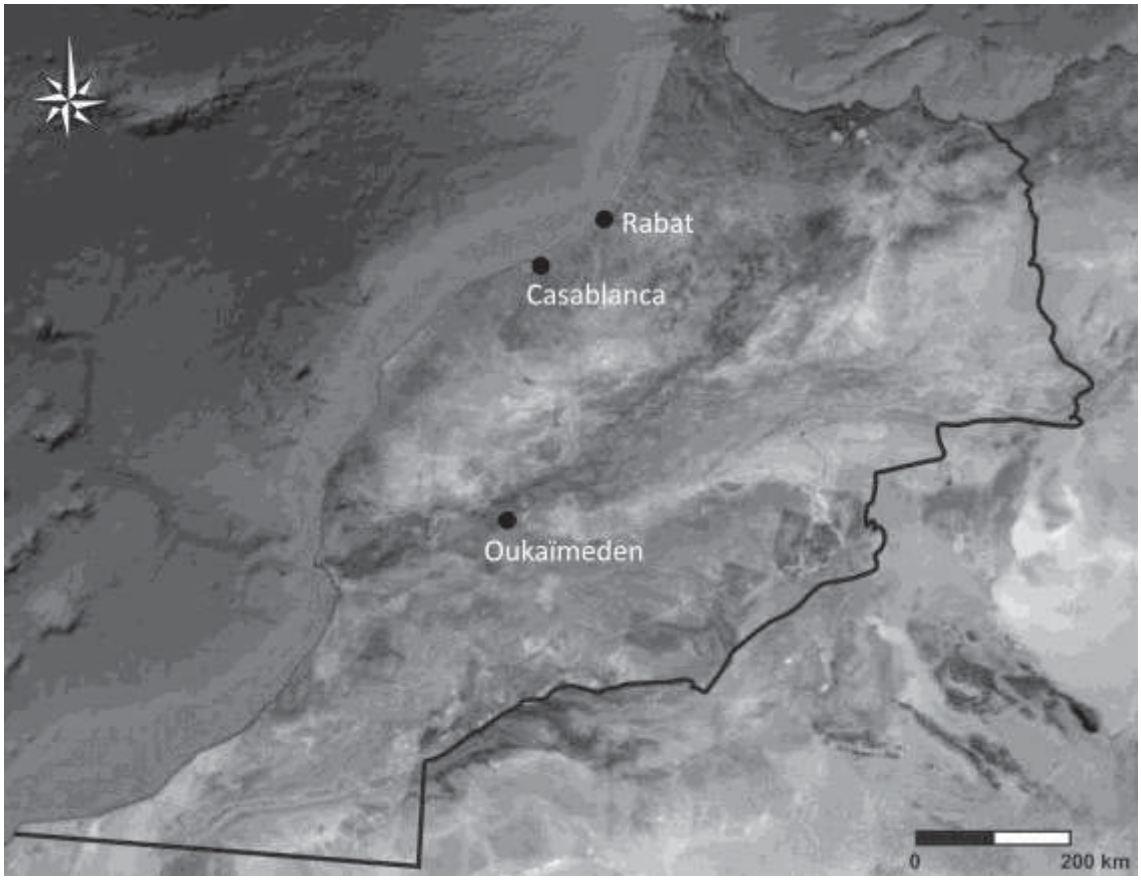


Figure 1: Oukaïmeden valley. After Google Earth, adapted.

The French colonial authorities built in the forties the first road connecting Oukaïmeden with Marrakesh to facilitate access to the colonial army and pacify the Berber tribes of the valley. Some years later, the French built also a ski resort and some chalets. To do this, they moved the

main azib, that is, the summer village of the Rerhaya transhumant herders, and created the first ever permanent village, based on touristic resources of skiing and trekking. In the late forties, during the French colony the first finding of rock art took place, followed shortly after by a systematic analysis by Malhome (1959, 1961). Later findings by Rodrigue (1999) and by the Moroccan team of the Rock Art heritage service (El Graoui et al. 2008, Salih et al. 1998) have shown the richness, importance and variety of the High Atlas rock art.

Despite more than half a century of sporadic research, the prehistory of this area of high mountains remains largely unknown. This is due to the fact that the main interest was focused on rock art representations. The distinctiveness of the vast majority of this work, failed to open new orientations of research needed to advancing scientific knowledge. To try filling these gaps, we are launching since 2008 the research program: "*Art, landscape and settlement at the High Atlas*.", initiated as part of the Moroccan-Spanish cooperation between the Complutense University of Madrid, the Spanish Government and the National Institute of Sciences of the Archaeology and Heritage of Morocco. This project has set out a global study of Oukaïmeden archaeological and ethnographic features in order of understanding the way humans perceived, used and marked the landscape. It has included not only a systematic rock art recording but also the excavation of six archaeological sites, the more systematic and wider set of 14C datings in the High Atlas to the present date, a wide paleoenvironmental sampling and an extensive etnhnographic record of Rerhaya and Ourika herders' traditions (Bokbot et al. 2008, Ruiz-Gálvez et al. 2009, 2010).

Although the project is still in progress, according to radiocarbon dating human presence in the valley started at Late Neolithic (second half of the 4th Millennium BC), while other 14C samples and archaeological items evidence Copper and Bronze Age human settlement in the valley. The most recent sample connected to an archaeological context is dated to 1010-1210 cal AD cal 2σ. Landscape reconstruction through pollen analysis (Ruiz et al. 2010) indicate a rather open landscape with bushes and trees underrepresented. On the contrary, the so called nitrophilous taxa, ruderal plants and mowing grasses stand out. Trophic conditions changed gradually due to population pressure on a fragile environment and climatic conditions seem to be similar to the present day. All the wet areas tested were dated in a historical period according to 14C dates. Based on these data we hypothesized that Oukaïmeden valley, as other marginal areas, was exploited at a late time, not before the mid fourth Millennium BC. The first human presence on the area was related probably with changes on the monsoon regime affecting North Africa, resulting in drier and more contrasted weather conditions and Southwards in the development of the Sahara desert.

2. Unraveling Oukaïmeden rock art trends

One of the main challenges Oukaïmeden project faces is the chronological ascription of much of its archaeological remains. Most of the barrows have been previously plundered, and the wedging conditions of this alpine-like environment have seriously affected other kind of archaeological sites, as shelters. As to rock art, its dating has always been a problem not only in Oukaïmeden but also in all Atlas region. Although some progress has been made (Searight 2004, Searight and Hourbette 1992) in the systematization and development of accurate chronologies, the advances strongly rely on stylistic analyses, and the absence of significant archaeological record linked to the depictions together with the dearth of 14C samples set (Daugas et al. 1998), has prevented a better knowledge of rock art and limits the ability to connect art with the different phases of human occupation on these areas. In our case, dating the rock art becomes even worse, due to the scarcity of rock art overlapping, their almost nonexistent association to archaeological sites and the high proportion of geometric symbols whose chronological adscription is unclear. Finally, the length of Oukaïmeden occupation entails a wide variety of styles, engraving techniques and motifs which make difficult to establish a logical order within the whole depictions set.

The chronological indeterminacy of most rock art depictions have made GIS analysis complicated, doing that most of the analytical tools - catchment and viewshed analysis, shortest path, etc. - almost useless for understanding the human landscape dynamics. Thus, understanding rock art display throughout the valley became a paramount objective within the ARPA project, even if it was a methodologically complicated issue. To unravel rock art chronological patterns, as a previous step for getting knowledge on the human mapping the landscape throughout the time, we have tried to develop a strategy to identify relationships among different kinds of symbols, with the aim at looking for some kind of internal ordering. To achieve this objective we have used the Correspondence Analysis statistical tool, a quantitative, multivariate method which groups variables and units according to the strength of their relationship and represents them in a two axis diagram. The nearer the variables and units are represented, the stronger the relationship and the other way around. This kind of analysis has a strong tradition in archaeological research, especially because it deals with qualitative information which is a very common data set available in Archaeology (Shennan 1992; Jensen and Nielsen 1997). If data are represented in a parabola it indicates a seriate distribution, which often - but not always - has a chronological meaning. The program used has been WinBASP, a free download statistical package developed by Bonn University which can be found at http://www.uni-koeln.de/~al001/.

Correspondence analysis has been first tested on weapon depictions due to their abundance within the whole set (almost 34% of total depictions), and their typological variability (kinds of weapons, handles and blades) which provided a data base with 342 units and 29 variables. Weapons were also chosen due to the chronological implications of some types, especially halberds related to Bronze Age (Chenorkian 1988; Souville 1986, 1991, Searight 2004) and some daggers or scimitars clearly linked to protohistoric or even medieval periods (Salih 2007). The results of the statistical analysis, although preliminary, have been highly significant depicting a clear parabola-like shape which indicates an internal ordering in the sequence as we can see at figure 2 (only variables have been represented to facilitate the graphic understanding). This sequence seems to have a chronological meaning, as halberds - dated at Bronze Age by their resemblance with archaeological findings of such weapons both in Iberia and in Northern Africa (Schuhmacher 2002) - are represented in the middle while swords and daggers (clearly related to later periods) are placed to the left. This situation is coherent with the information we have through engraving overlapping, where this kind of weapons are always on the top. So, our correspondence analysis seems to show a chronological evolution of four groups of four symbols related with weapons. Maces and hammers seem to be the oldest weapons depictions, while swords, daggers and scimitars, some kind of handles, as double appendix ones seem to be more recent. Of course, what the correspondence analysis shows is just a statistical trend, and so the groups detected express the moment when a given variable is more characteristic, but it doesn't mean some examples of this variable can be found before or after the main concentration happens - as is logical.

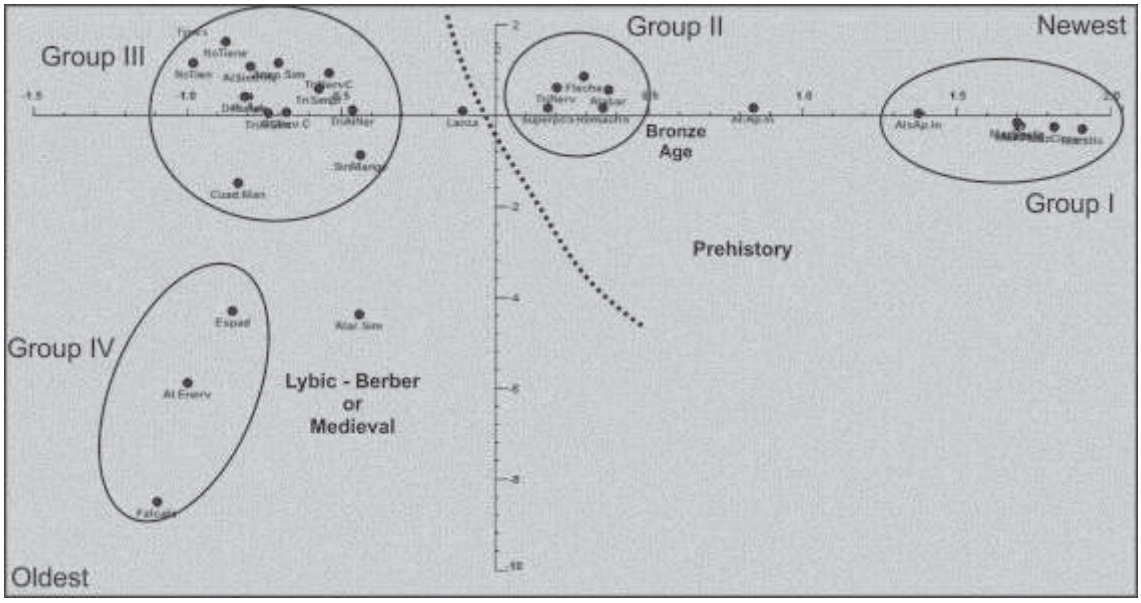


Figure 2: Correspondence analysis distribution and interpretation. Only variables have been represented in order to make the graphic comprehensible.

Although the results are highly provisional and there are still inaccuracies about the exact dating of each symbol or group, it seems clear that at least two groups can be defined as prehistoric - maces/ hammers and halberds - while the two younger (swords, daggers and scimitars) seem to belong to protohistoric or even medieval times. The principal trouble for chronological adscription to the Lybic-berber period derives from its long chronological period, which ranges from the 5th century BC to the Muslim conquest. The chronological ordering of weapons is our first clue to organize the rock carvings in the valley, through associations within other symbols carved on the same panels, and so the results of the correspondence analysis are highly significant not only for understanding rock art dynamics at Oukaïmeden, but very specially for establishing a clear, well dated pattern in Atlas rock art.

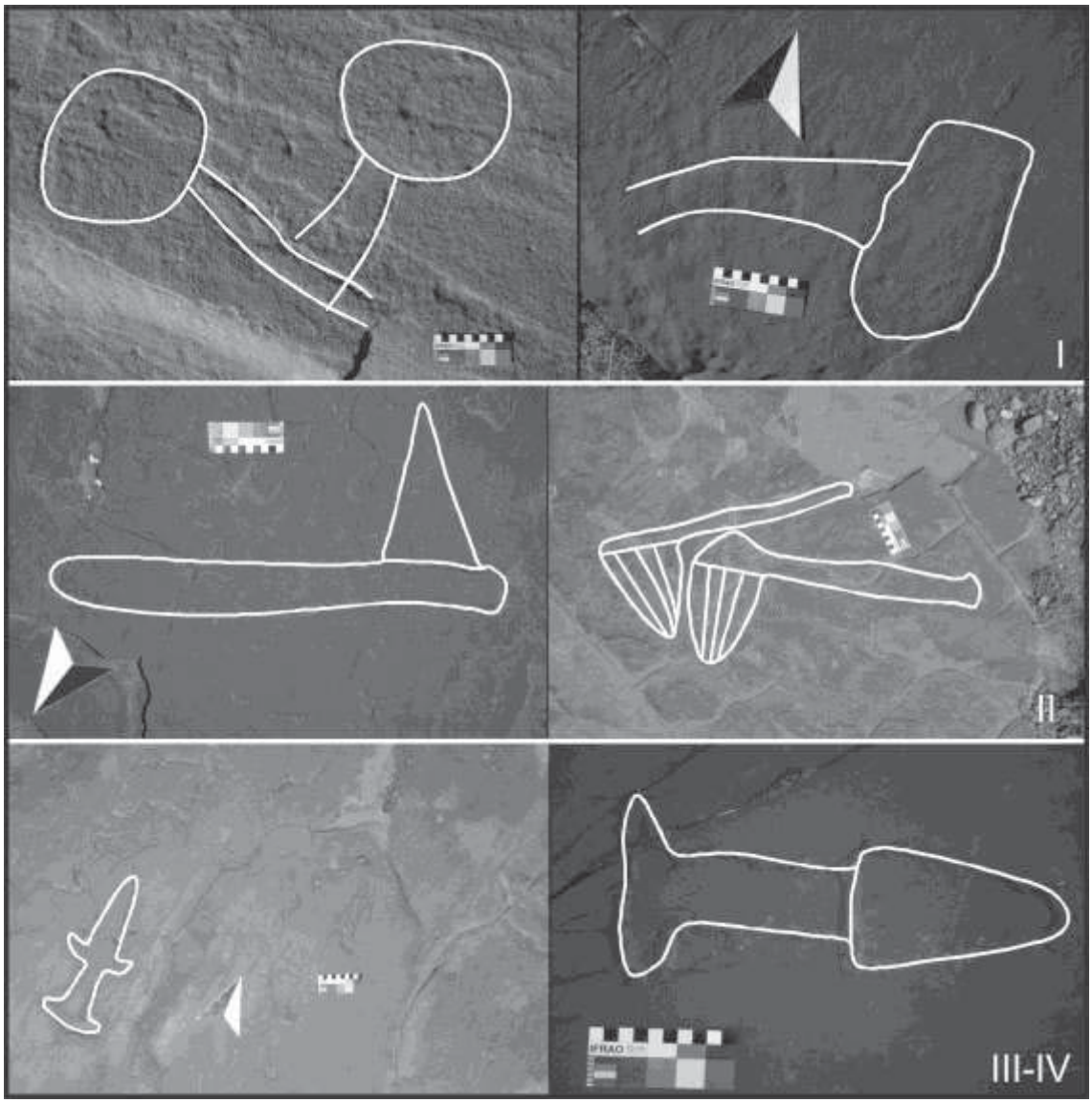


Figure 3: Weapon groups detected through Correspondence Analysis. I Maces (Prehistoric), II Halberds (Prehistoric, probably Bronze Age) III-IV Daggers (Protohistoric or Medieval). Engravings have been highlighted to improve their visualization.

3. Correspondence analysis spatial implications

Relevant as they are, the correspondence analysis results get their full meaning when represented throughout the valley. If the rock art stations are displayed according to the groups detected in figure 2, they seem to have a correlation in spatial patterns, showing different distributions all along the valley. Groups 1 and 2, which were defined as prehistoric, show a similar territorial distribution with two main areas placed on both sides of the valley, and a small amount of depictions in the middle. Third and fourth groups, on the other hand, show a more systematic distribution which covers the full valley. In these periods, new areas related to small streams are used for the weapons depictions. These small areas are associated to grazing areas smaller than the ones related to the main river. Thus that situation could point to a new scheme where the pressure over resources was higher than previously. As most of the weapons depicted in Oukaïmeden belong to groups 3 and 4 it seems that the more intensive distribution of rock art along the valley could be linked to a higher strain over resources and a higher tension among human groups.

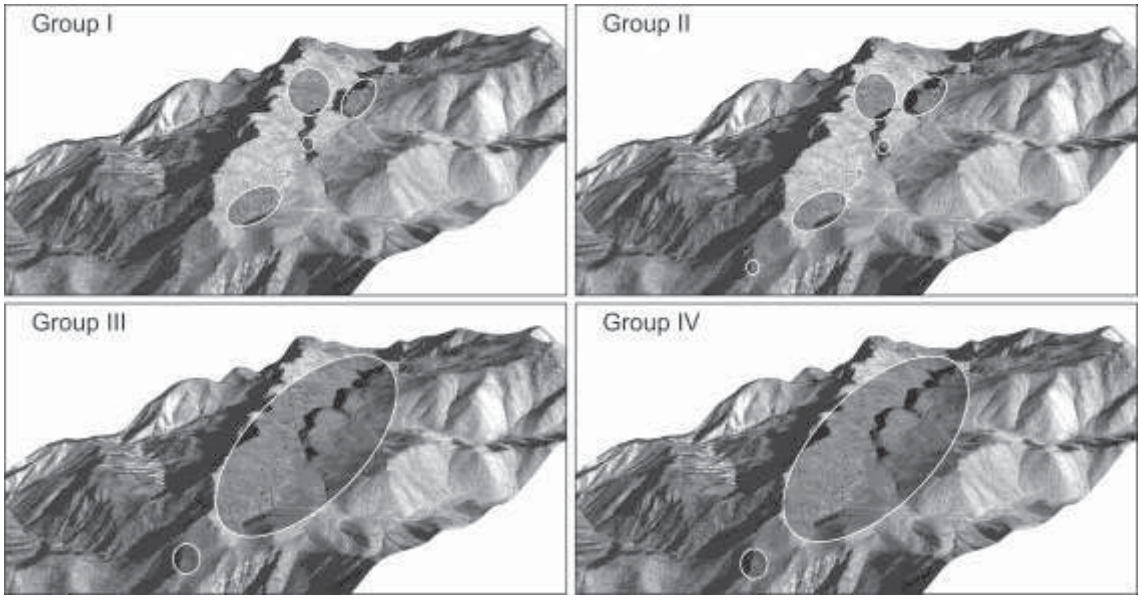


Figure 4: Distribution of engravings corresponding to the four groups detected in the correspondence analysis. Groups I-II are Prehistoric (pattern 1), while III-IV are Protohistoric or Medieval (pattern 2).

As we have said, the main spatial difference between patterns 1 (Prehistoric) and 2 (Protohistoric or Medieval times) comes from the occupation of marginal areas, especially in the north bank of the valley. This difference opens a way to integrate other kind of symbols into our analysis, as depictions placed in this area should hypothetically correspond to Lybic - Berber or Medieval periods. Although this hypothesis needs still to be fully tested, it seems to work with

some of the symbols, as circles with complex decorations which are often interpreted as shields and are usually ascribed to Lybic - Berber chronology in areas nearby. This kind of depictions appear thorough the valley, but also in marginal areas apparently settled during Protohistoric and Historic periods. At least in this case, the hypothesis is coherent with the results of the correspondence analysis.

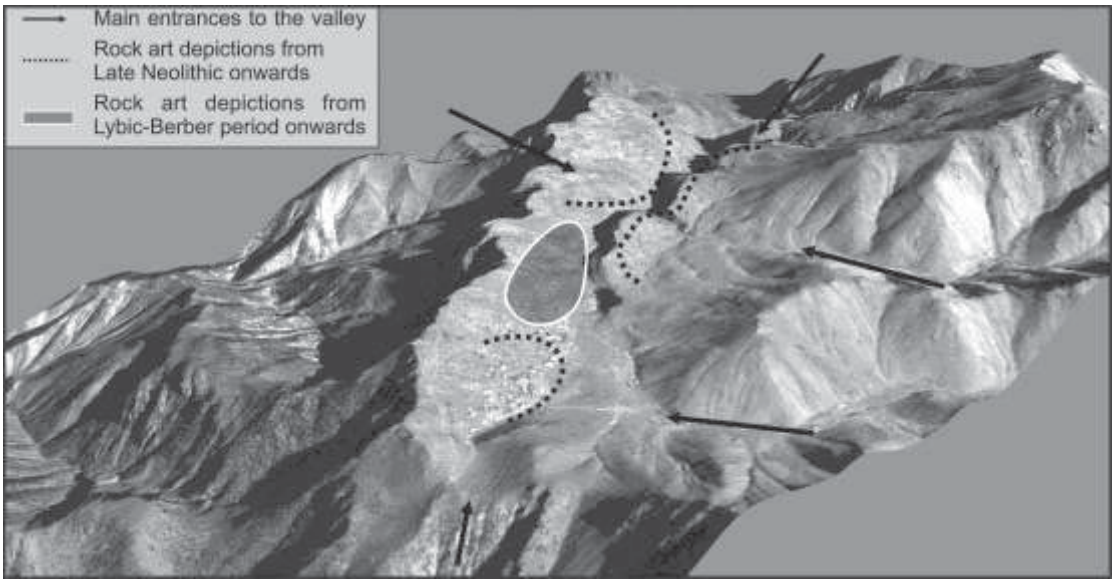


Figure 5: Chronological and spatial interpretation of rock art weapon depictions throughout Oukaïmeden valley.

3. Final remarks

The combination of correspondence analysis statistical tools and GIS data sets has allowed a preliminary sketch of how weapon depictions were displayed through time and space. Although simpler than other, quantitative statistic techniques, correspondence analysis has proved to be quite efficient in order to organize data, to give them a meaning and to help us to present further hypothesis about rock art chronology. Moreover, it has unraveled a logic spatial pattern for understanding rock art throughout the whole period of human exploitation of the valley. This spatial distribution will also have a retroactive effect, as the better we know the patterns of spatial distribution, the more we can define the four groups statistically detected, including other symbols along with weapons. Once this preliminary but essential work has been done, all GIS potential will be used to analyze settlement and rock art patterns throughout the valley.

The final result of this work could have two significant implications. First it could help us to understand the dynamics of the human use of the Oukaïmeden valley through time, valuating the relationship between rock art, barrows or other archaeological sites and the internal

expressions of landscape organization throughout the valley. Secondly, if our hypothesis were correct, the conjunction of Oukaïmeden rock art analysis, digging results and 14C samples would help us to improve substantially our knowledge of the Atlas art chronology, especially in its later periods.

However, the final aim of ARPA project is not only to find the evolution trough time and space of rock art depictions, but to rebuild the whole history of Oukaïmeden trough integration of archaeological excavations, landscape archaeology paleoenvironmental and ethnoarchaeological data. In that context, rock art can only be seem as an important but partial reflection of the complex physic and symbolic world that humans have been building and modifying at Oukaïmeden from Prehistory to the present day. Pollen and archaeological data agree in pointing to a seasonal use of summer pasturage - a critical resource - at the valley from the Later Prehistory to the present day. The way of exploitation has probably changed little, just in degree of intensity, ever since and that is what thanks to the correspondence analysis together with the GIS tool we are aiming at understanding.

Unfortunately, that beautiful landscape and a traditional way of life, well adapted to the environment are in danger of disappearing under the threat of turning the valley of Oukaïmeden into a tourist resort of all year round sun and snow, which will transform the environment negatively, will end with the supply of water to the villages scattered throughout the valley and will destroy what thousands of generations had wisely built.

References

Bokbot, Y., A. Lemjidi, H. Collado, D. J.J., B. Samaniego, E. Galán and R.G. M. 2008. "Arte rupestre, paisaje y poblamiento en el Alto Atlas. Primera campaña en el valle de Oukaïmeden." *Informes y Trabajos del IPCE* 3: 173-179.

Chenorkian, R. 1988. *Les armes métalliques dans l'Art protohistorique de l'Occident Méditerranéen.* París: CNRS.

Daugas, J. P., J. P. Raynal, A. El Idrissi, M. Ousmoi, J. Fain, D. Miallier, M. Montret, S. Sanzelle, T. Pilleyre, S. Occhietti and E. J. Rhodes. 1998. Synthèse radionométrique concernant la sequence Néolithique au Maroc, in *Actes du 3e Congrès international 14C et Archéologie* París, 349-353.

El Graoui, M., M. Alifriqui, H. Junger, A. Nalud and S. Searight, 2008. "Recherches d'indices chronologiques sur le passage des graveurs de rochers de l'Oukaïmeden (Haut Altas, Maroc)." *Sahara* 119: 105-108.

Jensen, C. K. and K. H. Nielsen. 1997. "Burial data and correspondance analysis, in *Burial and society. The chronological and social analysis of archaeological data*." edited by C. K. Jensen and K. H. Nielsen, 29-62. Aarhus: Aarhus University Press.

Mahdi, M.1999. *Pasteurs de l'Atlas. Production Pastoral, Droit et Ritual,* Casablanca: Fondation Adenauer.

Malhomme, J. 1959. *Corpus des gravures rupestres du Grand Atlas (1ère partie),* Rabat.

Malhomme, J. 1961. *Corpus des gravures rupestres du Grand Atlas (2ère partie),* Rabat.

Rodrigue, A. 1999. *L'art rupestre du Haut Atlas marocain,* Paris: L'Harmattan.

Ruiz-Gálvez, M., C. Nieto, J. d. Torres, Y. Bokbot, A. Oujaa, E. Galán, H. Collado, M. el Graoui, M. Farjas, P. d. l. Presa, J. M. Señoran, J. J. Durán, B. Ruiz, M. J. Gil and A. Rubinos, 2009." Informe de la campaña 2009 en el Agdal de Oukaïmeden, (Alto Atlas, Marruecos)." *Informes y Trabajos* 5: 222-243.

Ruiz-Gálvez, M., J. d. Torres, Y. Bokbot, E. Galán, H. Collado, A. Lemjidi, M. Farjas, P. d. l. Presa, J. M. Señoran, A. Rubinos, B. Ruiz, M. J. Gíl, D. Duque and P. d. l. Peña, 2010. Avance del estudio del poblamiento del valle de Oukaïmeden (Alto Atlas, Marruecos), y su relación con el arte prehistórico. Campaña de 2010. *Informes y Trabajos* 7: 258-268.

Ruiz, B., M. Ruiz-Gálvez, M. J. Gil, Y. Bokbot, H. Collado, C. Nieto, G. E., J. d. Torres, M. el Graoui, A. Lemjidi, J. J. Durán, A. Rubinos, J. M. Señoran, M. Farjas and P. d. l. Presa. 2010. "Primeros datos polínicos procedentes del río Irini (Oukaïmeden, Alto Atlas, Marruecos): Aproximación al paisaje vegetal." *Polen* 20: 41-60.

Salih, A. 2007. Sous Zone 1. Maroc/Sahara Atlantique Marocain-Mauritain, in *ICOMOS World Heritage Convention in Rock Art. Sahara-North Africa. www.icomos.org/studies/rockart-Sahara-North Africa.*

Salih, A., A. Oujaa, R. Heckendorf, M. Nami, M. El Graoui, A. Lemjidi and H. Zohal. 1998. "L'aire rupestre de l'Oukaïmeden, Haut Atlas, Maroc: Occupation humaine et économie pastorale." *AVA Beiträge* 18: 253-295.

Schuhmacher, T. X. 2002. "Some remarks on the origin and chronology of halberds in Europe." *Oxford Journal of Archaeology* 21(3): 263-288.

Searight, S. 2004. *The Prehistoric Rock Art of Morocco. A study of its extension, environment and meaning*. Oxford: Archaeopress. BAR International Series 1310.

Searight, S. and D. Hourbette. 1992. *Gravures rupestres du Haut Atlas,* Casablanca: Belvisi.

Shennan, S. 1992. *Arqueología cuantitativa,* Barcelona: Crítica.

Souville, G. 1986. "Témoignages sur l'âge du bronze au Maghreb occidental." *Comptes-rendus des séances de l'Académie des Inscriptions et Belles-Lettres* 130 (1): 97-114.

Souville, G. 1991. "Essai d'interprétation des gravures rupestres du Haut Atlas marocain." *Comptes-rendus des séances de l'Académie des Inscriptions et Belles-Lettres* 135(4): 767-782.

Social Living: visualizing spatial variability in households at Early Iron Age Zagora on Andros, Greece.

Kristen Mann [1]

[1] University of Sydney.

Abstract

This paper explores reading variability in household spatial use from settlement material, alongside issues associated with investigating human behaviour through legacy data. Houses are the *loci* for concentrated, continual and changing activities, and consequently hold valuable insights into the social organisation of ancient settlements. It is argued that behavioural variability is more than an anomaly to be accounted for in household spatial analyses: rather, it constitutes a valuable line of investigation into settlement socio-economic organisation. The fundamental importance of visualising data spatially is also addressed, particularly the ability to visualise issues of data reliability inherent to legacy data, and the consequences this has for interpreting behavioural variability when analysing household archaeological evidence. These issues are explored using material from the Early Iron Age (EIA) site of Zagora on Andros, where, in a preliminary study, it is argued that flexibility and difference in household behaviour were integral aspects of spatial arrangements.

Keywords: *household archaeology, access analysis, behaviour, Heurist, Zagora*

1. Introduction

As described by Stella Souvatzi, households comprise a "great intensity of social relations, practices, choices and decisions" (Souvatzi 2008, 2). As such, they offer a remarkable opportunity to investigate human behaviour and social meaning within a single context. Due to increased recognition of this potential, household archaeology has been gaining traction in recent years (Flannery 1976; Giddens 1984; Beaudry 1989; Allison 1999; Nevett 1999; Hanson 2003; Lang 2005; Ault 2007; Westgate et al. 2007; Souvatzi 2008; Pluckhahn 2010; Yasur-Landau et al. 2011).

This emergent fascination with the human experience and the social meaning of space has its roots in social theory developed within the anthropological and sociological sciences, particularly following the work of Pierre Bourdieu (Berger and Luckman 1966; Bourdieu 1977, 72-95; Baldassare 1978; Rapoport 1982; Lawrence and Low 1990; Blanton 1994; McKie et al. 1999; Schiffer 2000; Tickamyer 2000; Renfrew 2004). Increasing numbers of archaeological studies are incorporating social theory into discussion of ancient households, their composition, life-cycles, social functioning, and the various forces that influence behaviour (Wilk and Rathje

1982; Hendon 1996; Antonaccio 2000; Whittle 2003; Hodder 2005, 2006; Souvatzi 2008; Foxhall and Neher 2011).

If we are to avoid prescriptive or rigidly functionalist inferences regarding household behaviour and its material correlates, it is imperative that we create flexible interpretive frameworks that incorporate diverse theoretical perspectives (c.f. Hillier and Hanson 1984, 53; Schiffer 2000; Souvatzi 2008). Predictive models of household spatial use, while useful in structuring research, often fail to account for diversity and difference in behaviour. The following discussion explores this in relation to applying convex spatial analysis (access analysis) to household data, and to examining the social aspects of household behaviour. Emphasis is placed on the importance of visualizing household data, and data reliability issues, when attempting to place people and social interactions within the material record.

1.1 Scope

This study is part of ongoing doctoral research into EIA households at Zagora on Andros that intensively examines household living spaces and activity patterning with a view to assessing social organisation at the settlement. Central to this research into the spatiality of households is the need to elucidate how spatial variation across the site was connected to household behaviour. This study forms part of a collaborative web-based research project enabling a diversity of specialists to test current theoretical models at a depth and efficiency impossible for one scholar alone (McCallum et al. 2011).

Access analysis is employed as a preliminary method for establishing parameters of potential action and identifying values and behavioural possibilities within households (Hillier and Hanson 1984, 143-155; Cutting 2006; Fisher 2009). This analysis builds on the work of scholars such as Cutting, who emphasise both the limitations of quantitative methods of access analysis and its benefits as a "visually rich tool to think with" (Cutting 2003, 2). The study then explores how a spatially-integrated database, such as Heurist, can help visually contextualise the diverse factors that constrain our ability to recognise and account for behavioural variability in the material record.

1.2 Zagora

Excavated in the 1960s and 1970s, the 6.7ha site of Zagora is located on the west coast of Andros in the Cycladic Archipelago in the western Aegean Sea (Cambitoglou et al. 1971; 1981; 1988). The site is situated on a promontory surrounded by cliffs, with land access controlled by

a fortification wall (Fig.1). Despite its much discussed isolation (e.g. Gates 2011, 197), Zagora had ready access to fertile land and trade (McLoughlin 2000; 2011, 876).

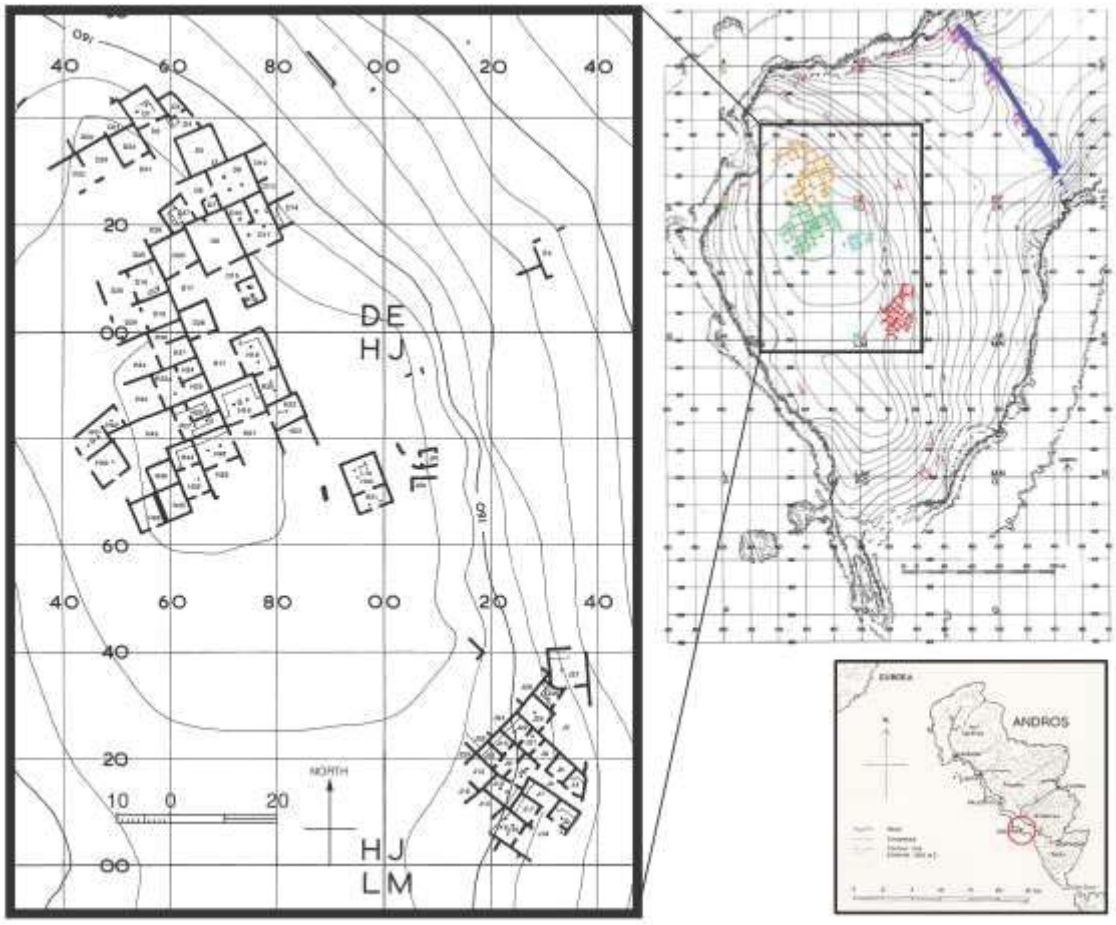


Figure 1: Plan and location of Zagora on Andros. Andros. (J.J. Coulton © AAIA Archives).

Only ten-percent of the site has been excavated, revealing domestic units undisturbed by subsequent occupation in Areas D, H, J, B, E and F (Fig.1). The architecture was agglomerative in construction, with rectangular buildings of schist and marble slabs, resulting in well-defined spaces (Cambitoglou et al. 1988, 147-61). The early phases were characterized by simple one or two room arrangements (as in Fig.2C). Within a generation, existing units were adapted or new rooms added, creating more extensive and complex spatial arrangements (Cambitoglou et al. 1988, 150-54).

The material indicates a desire for extensive storage and preference for access to at least one internal open space (McLoughlin 2011, 869). The prevalence of shared walls and the agglutinative, organic, growth of each neighbourhood indicate some degree of ongoing spatial negotiation between households.

Although the early excavations predate the development of crucial modern field techniques (such as flotation and micro-stratigraphic analysis), the excavations were thoroughly recorded and demonstrate a detailed treatment of domestic finds and architecture commendable for its time (Cambitoglou et al. 1971, 52-61; Cambitoglou et al. 1988, 79-106). However, the excavation and recording techniques originally employed impinge on the questions we can ask of the site and our ability to effectively employ quantitative spatial analyses to do so.

The material discussed comes from the final phase of six household compounds (Table 1) identified on the basis of access[2]. Each compound demonstrates difference in spatial arrangements, or processes that affect data variability, and is under further investigation regarding household behaviour, life-cycles and activity patterns in relation to spatial change

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1.3 Heurist

Heurist is a MySQL based database, with a highly fixable structure that allows records to be linked via relationships and visualised in a variety of ways, particularly spatially (c.f. McCallum Forthcoming). Thanks to its use in wider visual arts based projects, it is also particularly effective at handling multimedia files in relation to interpretive datasets. Heurist has proven a powerful tool for managing, visualising and interpreting the record of the original Zagora excavation data.

The Zagora implementation of Heurist has developed a horizon record (Fig.4a) to group excavation units (originally delineated by arbitrary divisions) into depositional contexts. Each horizon is related to structural features and to other horizon layers, and allocated a spatial footprint to relate it directly to planned features. This allows the spatial information, including the distribution of material by class or assemblage, to be visually displayed alongside the descriptive data for each record. Relative artefact dates then allow for a comparison of sequential phases and spatial changes.

[2] This includes liminal convex spaces (as in Fig2C) that appear to mediate access from the carrier, forming part of the domestic spatial system. Such areas have been identified on the suggestion of spatial articulation on a minimum of three sides by either walls or the angle of wall lines). It should be noted that H34-H35 (or at least H34) was not in use during the final-phase (the entrance to H34 was blocked c.750-730BC, the final phase modifications occurred c.720-700BC). It has been included as it demonstrates many of the non-behavioural factors that affect data variability. Ambiguity also remains as to whether the J3 compound constitutes a complete spatial system or multiple systems accessed via the same corridor space. Until this is better understood, these units are treated here as one system due to the control of J3 over access.

Compound	Est. Floor Area	Indoor Unit	Open Unit	Bench	Hearth	Bin	Column Base
D6-D7-D8- D27	109m²	3	1 (26%)	2	-	-	6
J3-J4-J5-J6-J8-J9-J10-J11-J12-J21-J22	143m²	9	2 (18%)	7	1	-	5
J7- J24- J26-J27	159m²	3	1 (54%)	5	1	-	2
H19-H21-H22-H28	175m²	3	1 (35%)	4	2	1	6
H26-H27-H42-H43-H47	188m²	3	2 (58%)	5	1	-	3
H34-H35-(undesig. porch)	51m²	2	1 (19%)	2	-	-	1

Table 1: Formal properties of the six case-study compounds (according to current extent of excavation).

2. Household behaviour and variability

Although difference and variability in human behaviour can shape settlement organisation and social interactions, they are notoriously difficult to recognise and access archaeologically. Leaving aside issues of material preservation and site taphonomy, the fundamental nature of households can vary across the breadth of humanity, and operate in subtly different ways within different social contexts (Souvatzi 2008, 1-2).

It is the very diversity and "rich variability" of households that render them such a valuable avenue of enquiry for exploring human behaviour: households are best understood as variable and "dynamic social entities", where the use and treatment of space could change continually (Souvatzi 2008, xvii, 7-20). Our approach to investigating household behaviour must be correspondingly dynamic, and flexible enough to account for a broad spectrum of behaviour.

Within household archaeology, there has been much discussion regarding the practical, logical and systematic ways in which people use space (e.g. Kent 1990). However only recently have researchers begun to explore the reflexive relationship between space and behaviour, and the

manifold ways in which people can behave in patterns beyond the 'normal' structures of daily life (Tringham 1991; Ashmore 2002, 102; Souvatzi 2008, 33-35). It is important to take into account the potential for household behaviour to encompass actions that appear "illogical" to modern researchers (c.f. Walker 2002), and not to underestimate the basic human capacity for divergence, difference and spontaneity in terms of actions and choices.

3. Placing people in spatial analysis

It is first necessary to define 'behavioural variability': on what analytical level are we able to explore the diversity of factors that may influence household decision-making processes? Depending on the data available, this may be viewed from the perspective of individual choice and agency, within household units as a whole, or as variation in behaviour between households across a settlement (c.f. Rapoport 1989).

It is important to be aware of the expected scope for variation, diversity and difference in household behaviour. This involves:

- establishing behaviour pertinent to our understanding of household relationships and activity patterning, and the inherent potential for variation;
- identifying how such variation could affect the archaeological record and its interpretation.

While not an exhaustive list, factors that may influence where and when household activities occur include: the physical properties of built spaces; activity requirements (e.g. resources/equipment, light, heat, labour); activity frequency and demand; seasonal change and weather patterns; the concurrence of activities; the cultural division of labour; expected circumstances such as cultural events, or extraneous circumstances such as illness, property damage, or other occurrences outside human control.

At Zagora, the data as currently published renders the household the smallest social unit for meaningful analysis. This study is therefore concerned with the potential for variation in spatial use within individual households, and how differences between these households may reflect varying household strategies or decisions across the site. The immediate goal is not to reconstruct variation in behaviour and spatial use, but to explore how to ensure archaeological inference encompasses the potential for variation within and between households.

3.1 Establishing spatial parameters for household behaviour

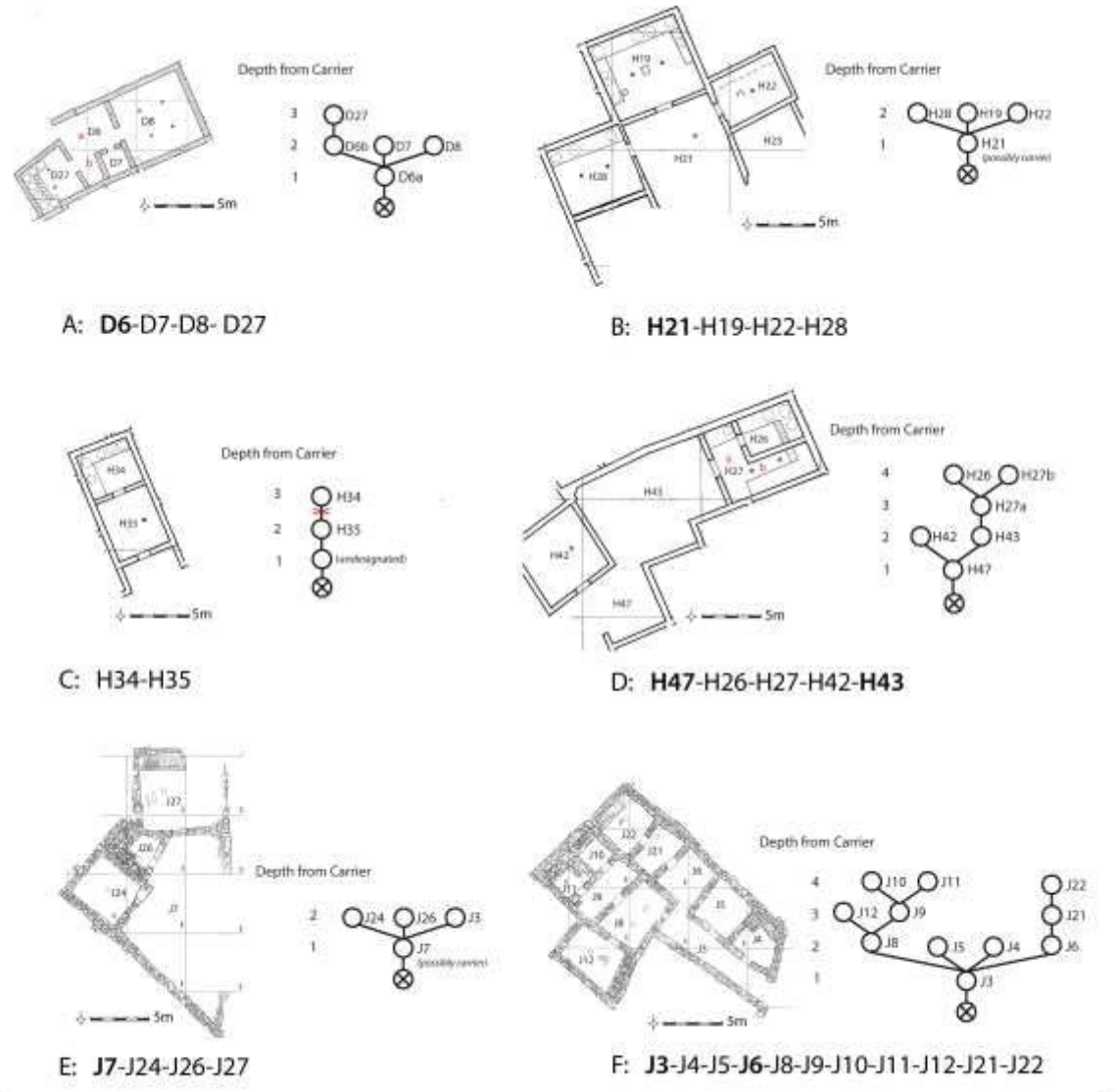
An examination of spatial syntax at Zagora can provide insight into both the behavioural patterning within each compound, and the level of interaction or control between the inhabitants and the larger community (c.f. Hillier and Hanson 1984, 15). The six case studies (Fig.2-3) are used to explore access and communication, with a view to identifying:

- internal spatial patterns and accessibility for each compound;
- any differences that could relate to household behaviour;
- whether there is potential for behaviour to vary between compounds, or within individual compounds, and what significance this may have.

It is inappropriate to apply quantified access analysis to the Zagora legacy data due to issues of preservation, excavation extent and resulting ambiguity in the spatial data (Hillier and Hanson 1984, 97; Cutting 2003, 2006). In particular:

- we currently lack clear information for external spatial use, upper stories or mezzanine levels;
- agricultural disturbance has damaged the southern extent of units H21, H23 and H29, hindering the detection of south-eastern walls for these units;
- there is ambiguity as to whether access to H42 was indeed mediated through H47 or direct from the carrier (the surrounding outside space, as termed by Hillier and Hanson 1984, 148);
- the J3 compound may represent multiple houses (e.g. the units accessed via J8);
- the area west of the¬¬ D6 house has not been excavated, and its spatial relationships may not be fully understood.

Calculating precise numeric spatial properties will create a deceptive impression of accuracy, obscuring data limitations (Cutting 2003, 5). However, a presentation of the justified access graphs for each compound (Fig.2), without accompanying quantitative analysis, has much to contribute to our understanding of potential household behaviour.



Individual household compounds have been identified on the basis of access and include liminal convex spaces (as in Fig. 2C) that mediate access from the carrier. It should be noted that access to H34 was blocked in the final phase, and ambiguity remains as to whether the J3 compound constitutes a complete spatial system or multiple systems accessed via the same corridor space.

Figure 2: Justified access graphs of six household compounds used in the manner of Cutting (2003). (Graphs: author's own; Plans: modification of J.J. Coulton's originals © AAIA Archives).

A preliminary assessment reveals some clear differences. Graphs A, B and E demonstrate patterns of symmetrical accessibility and shallow arrangements, whereas D and F indicate more spatial control with significantly deeper patterns and elements of symmetry at different depths. Graph F in particular stands out, with its multiple points of control over access and movement. Graph C is different again, due to its abandonment prior to the final occupation-phase modification of the other compounds.

A unifying feature of all compounds is that they are consistently non-distributed, with a single open space that controlled access to the carrier. The difference in the degree of access,

integration and spatial movement between these compounds would imply variation in household behaviour across the settlement. This is significant if we are to understand the degree of household autonomy and social differentiation at the site, and contextualise the settlement in relation to broader evidence for EIA social transformations (Fagerström 1988; Thomas and Conant 1999; Dickinson 2006; Gounaris 2007; Mazarakis Ainian 2007; Muhly 2011).

Traditionally, asymmetric access patterns, such as in graphs D and F, are associated with spatial segregation, privacy and functional or social specificity for the deeper units (c.f. Cutting 2003, 4; Mustafa et al. 2010, 159). Indeed, Morris has argued that such concerns stimulated the eighth century spatial changes at Zagora in response to a radical transformation of EIA society across Greece (Morris 1999, 308-309). However, while the symmetrical spaces of compounds A, B and E ensure the privacy of households, they also restrict individual autonomy and lack defined 'intimate' spaces, being more conducive to co-operative activities and multi-tasking (c.f. Robinson 2001; Mustafa et al. 2010, 159).

This analysis remains descriptive, albeit a description that identifies areas for further evaluation. While it is suggestive of patterns of behaviour, further analysis is required if we are to access the people who used these systems.

Room functions remain unclear, and ascribing fixed functions may represent the imposition of modern conceptions of space. However, integrating access patterns with spatial features connected to room use may help illuminate activity patterning (c.f. Fisher 2009, 442-443). Figure 3 incorporates schematic representations of formal hearths, benches and available lighting in relation to the justified access graphs already examined. Immediately such a representation changes the original assessment of these compounds: there are clear similarities in spatial patterns that may reflect household behaviour, despite the differences previously observed.

Significantly:

- The deepest units with the most restricted access to natural light were devoted to storage. While other features, such as hearths, may be present in such spaces, the deepest units universally contain schist benches associated with large storage vessels;

- Such spaces do entail a degree of functional specificity, but only for an activity that involves cumbersome equipment, requires specific conditions (dry and cool), and that in most cases renders such space less practical for other activities.

It is important to note that, with the exception of units H21 and J12, spaces better suited to non-storage activities are consistently defined by relatively large floor areas, shallow access

controlled by a central open space, and a high frequency of symmetry associated with these central spaces. Such spaces represent hubs of movement within each compound, and likely constituted central activity areas in their own right.

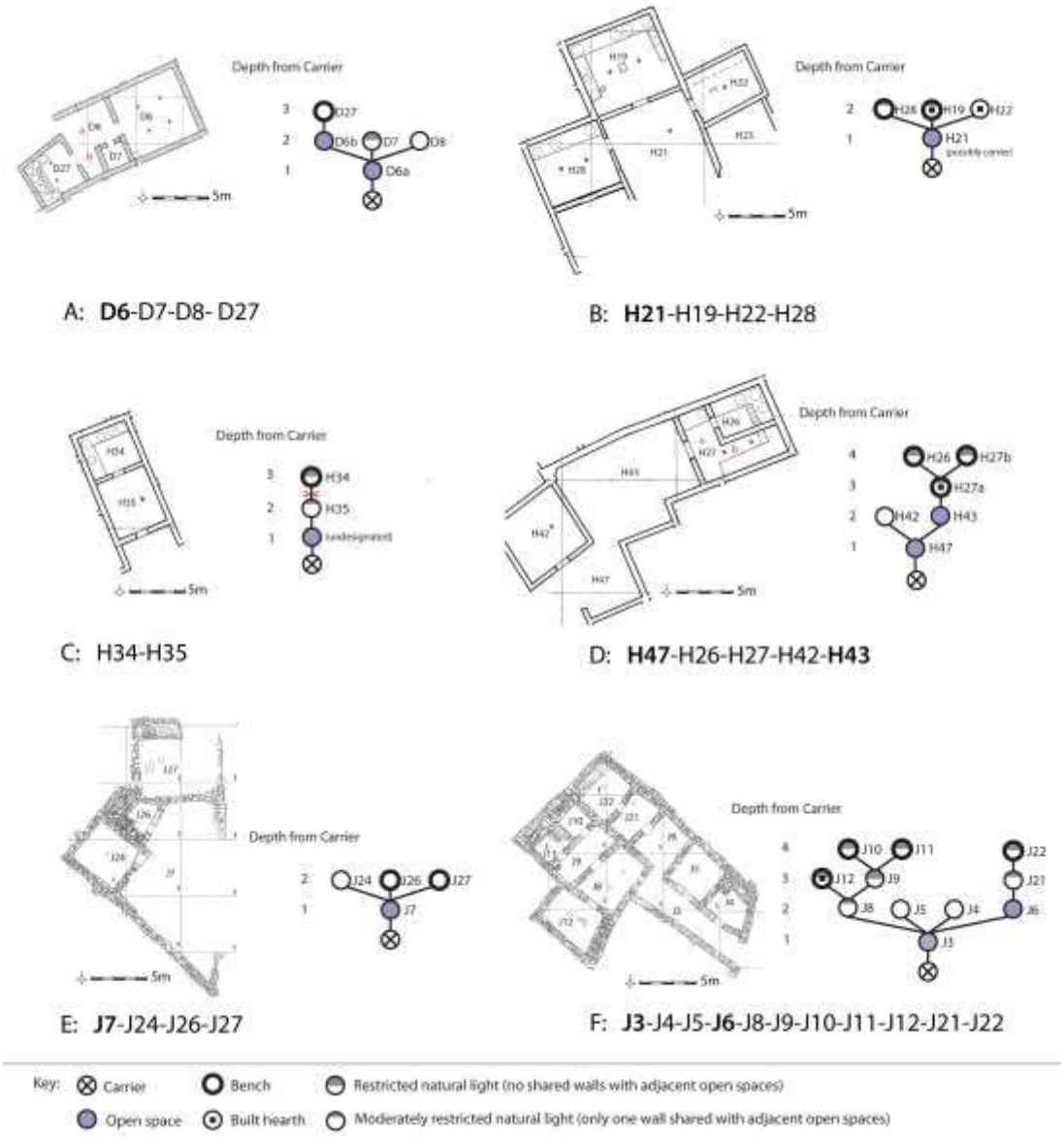


Figure 3: Justified access graphs of six Zagora household compounds in relation to key built features and spatial properties (Graphs: author's own; Plans: modification of J.J. Coulton's originals © AAIA Archives).

With the exception of the J3-compound, it is difficult to detect 'intimate' areas or spatial zones in most Zagora houses (c.f. Robinson 2001). It is unclear whether this is because the permanent stone architecture dominates perceptions of spatial use at Zagora, or because 'intimate' zones and ideas of individual privacy were not integral to household spatial systems. While the size of

most spaces suited to non-storage activity could allow for the creation of temporary or semi-permanent 'intimate' areas, on current evidence the spatial syntax lacks a focus on individual autonomy, and seems instead to emphasise co-operative household activities and decision-making.

Such spatial arrangements enhance flexibility in the patterning of activities and household behaviour, allowing for variation in their location and close connections between multiple activity areas. Although our current understanding of the frequency and patterning of activities undertaken within these spaces is limited, a starting point for further investigation is provided by the patterns identified. These suggest that:

- light and spaciousness (covered or uncovered) were preferred features for activity areas;
- shallow-access spaces and open outdoor areas were central to daily activities and interactions;
- the location and concurrence of activities could be adapted and modified as needed.

Consequentially, the formal properties, stratigraphy, deposits and associated artefacts for the open areas at the heart of access for each compound, and those of the units with direct access to these, warrant further investigation.

Yet some identifiable differences may reflect variation in behaviour between these compounds, particularly regarding hearths. J12 (Fig.3F) and H19 (Fig.3B) represent more spacious units containing both storage benches and hearths; although J12 is a deep unit with controlled access and limited natural light, while H19 (Fig.3B) was shallow with better potential for natural lighting. Unit H42 (Fig.3D) represents a sizeable unit with good access to natural light and no storage benches, however it lacks the formal hearth found in similar spaces elsewhere. Furthermore, no hearth has been identified at all for the D-area compound (Fig.3A). This would suggest that different methods for cooking and heating were employed in these compounds, possibly even different behaviour in social contexts where hearths form the heart of conviviality.

4. Visualising data variability

Recently, as the Zagora data was entered into Heurist, it became evident that some patterns could have resulted from issues of data reliability rather than ancient household behaviour (c.f. McLoughlin Forthcoming). It is vital to account for processes that can create patterns easily misconstrued as reflecting variability in household behaviour. Behavioural archaeologists have

firmly emphasised this point, and developed constructive methodologies for assessing site formation processes (Schiffer 1983; LaMotta and Schiffer 1999; Weiner 2010; Gouma et al. 2011; Malinsky-Buller et al. 2011). However, the value of visual tools can be overlooked in this process. Visualising data reliability highlights such issues, and targets areas of interest that require further examination.

4.1 Publication levels and legacy data

Like many modern projects, current research on Zagora relies on incompletely published legacy data. This is not necessarily problematic, so long as clarity is provided regarding the current level of data available and the original sampling and recording strategies. Traditional excavation publications involving lengthy prose descriptions of stratigraphy and excavation methodologies can obscure our ability to recognise fluctuations in the data related to excavation limits and publication levels. Visualising such data spatially as an integrated part of modern database systems, such as Heurist, is one method for identifying patterns of variability caused by issues pertaining to legacy data and varying publication levels (c.f. McCallum Forthcoming).

Previously published excavation plans gave no intimation of excavation boundaries, with many units, such as J8 (Fig.3F), J27 (Fig.3E) and H42 (Fig.3D) only partially excavated. H42 is significant, as a hearth could exist in the unexcavated area. Previous attempts to compare spatial arrangements across the settlement based solely on the published plans were inevitably limited (Morris 1999; Coucouzeli 2007). The excavated extent of each room and associated deposits are easily visualised in the Heurist database, ensuring that such data patterning is readily accounted for when attempting comparative spatial analyses of households at Zagora.

Many baulks were also left in situ, obscuring spatial features and affecting distribution patterns and assemblage quantification. For the D-house (Fig.4) and unit H35, such baulks cover areas most likely to contain hearths and other features. However this can be added to existing spatial data using Heurist's mapping tool, allowing such information to be accessible during later analyses, ensuring patterns of variability are always balanced against issues of reliability.

At Zagora, the earliest field season used arbitrary excavation divisions, such as spits and 1x1m squares, which broke single deposits into multiple units. Heurist horizon records that group the original excavation units together flag potential reliability issues connected to excavation methodologies, and enable changes in household space caused by changing methodologies to be clearly displayed.

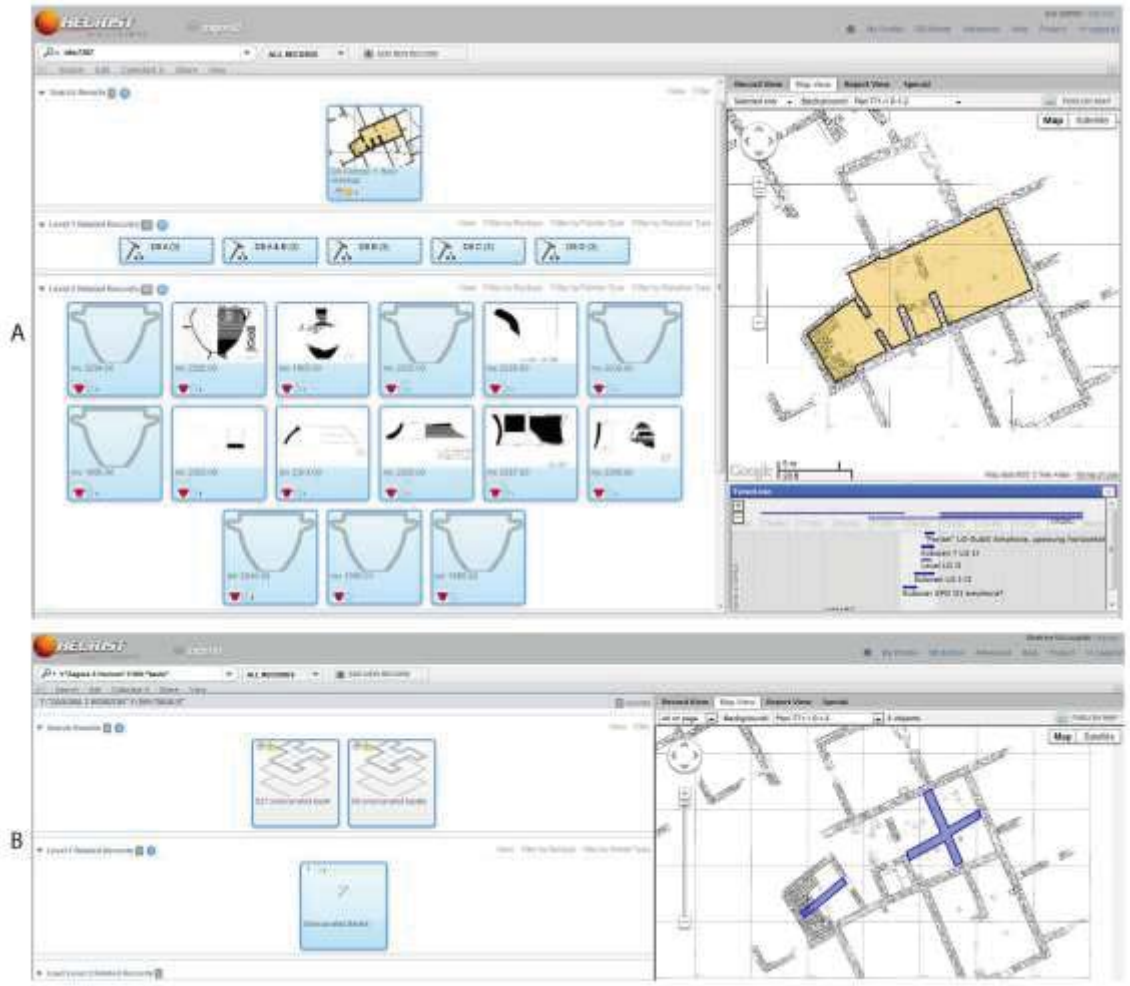


Figure 4: Heurist screenshots showing a) the Horizon 1 record (final floor level) for compound D6-D7-D8-D27 with related data, and b) the unexcavated baulks of D6-D7-D8-D27. (AAIA Archives).

Indeed, a preliminary reassessment of the distribution of coarsewares has altered artefact quantities, distribution and spatial relationships due to the recent development of a methodology for recognising individual vessels from body fragments (Fig.5a, McLoughlin Forthcoming). The ability of Heurist to immediately visualise all related information ensures that subsequent changes to our understanding of spatial use and artefact distribution patterns are traceable.

4.2 Collapse disturbance

Disturbance to floors and occupation material due to processes of abandonment and collapse were expected; however, the extent and variation of this had been underestimated. While collapse-disturbance anomalies are under examination, the presence of data contamination in household deposits is already visible within Heurist through spatial distributions of joining

fragments, relative dating and wear levels recognisable in the record relationships and distributions visualised in the mapping interface.

An example of this is in the household compound H34-H35 (Fig.2C), which was deliberately blocked and abandoned while other households were still active. This difference in behaviour had been flagged for further examination.

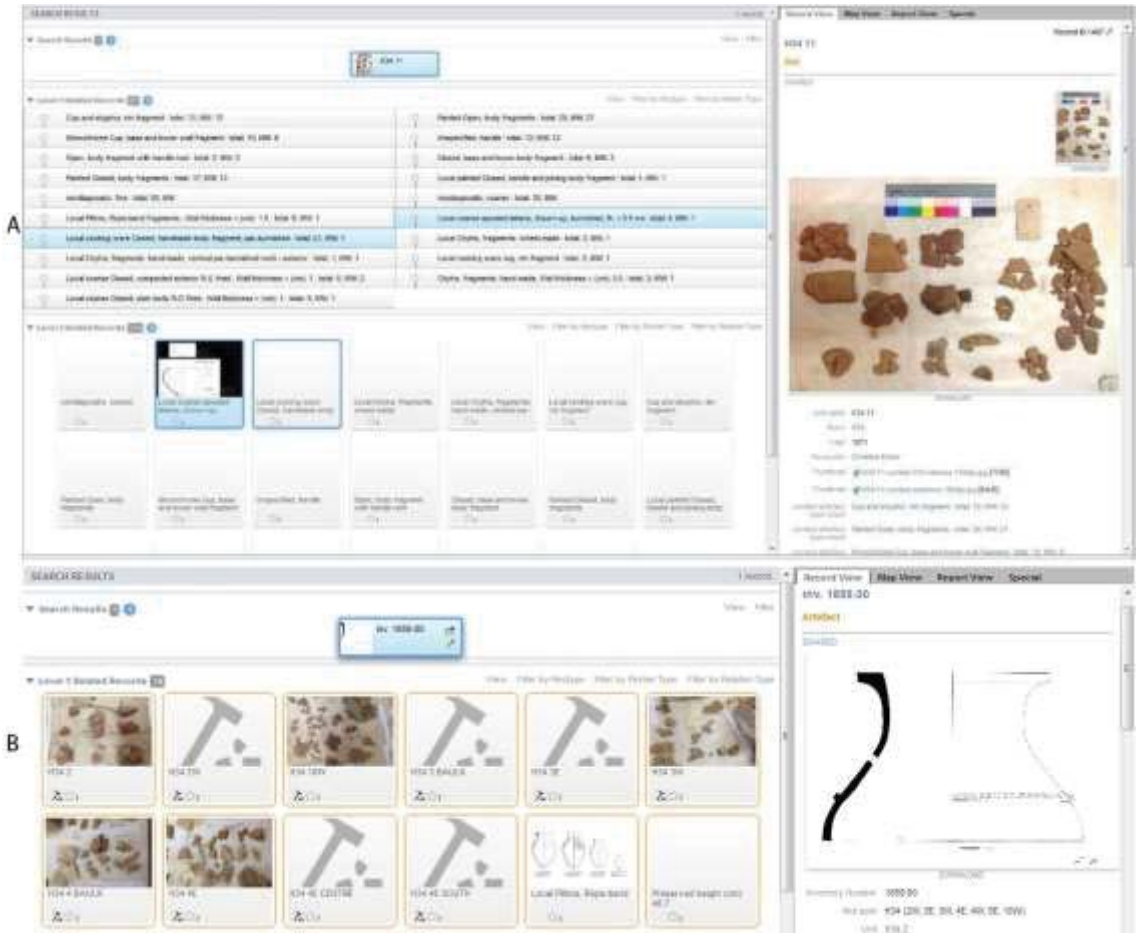


Figure 5: Heurist screenshots showing a) revised artefact counts due to B. McLoughlin's new courseware analysis methodologies, and b) distribution of Inv. 1859 through multiple deposits. (AAIA Archives).

A recent reassessment of the pottery assemblages from the post-abandonment collapse fills and underlying floor deposits suggested extensive disturbance from the bench destruction in H34 (Fig.5b). The large storage vessels appear to have been crushed with explosive force when the wall collapsed, causing parts of the bench to blow out, mixing the bench-fill with the upper surface deposits, and dispersing fragments from vessels left in situ throughout multiple fill deposits (c.f. McLoughlin Forthcoming).

Although these issues are not yet fully understood, it is clear that previous inferences regarding the use of space based on artefact counts and vessel-type distribution are problematic. With the context ceramic data now available in Heurist, such issues can be assessed visually and traced spatially, allowing them to be addressed when contextualising spatial use and distribution patterns.

For future analysis, the access patterns discussed here can be assessed against the distribution patterns of data entered into Heurist and subjected to formal GIS spatial analysis. Meaningful patterns will then be assessed in light of current social theory and insights permitted through the judicious use of anthropological studies and ethnographic observations (such as Bent 1885; Forbes 2007; Gounaris 2011).

5. Addressing behavioural variability: some observations

Spatially integrated databases such as Heurist are invaluable in providing an immediate means of assessing data reliability, and pinpointing variations in artefact distribution patterns and spatial relationships that could reflect variation in household behaviour. Visualising household spatial patterns from within the normal database interface enhances our ability to understand the practicalities of spatial use without needing to reduce behaviour to seemingly logical and predictable patterns. Variability is inherent to human behaviour and relationships, yet it is no easy task to account for behavioural variability in spatial analysis.

Houses and households were, and are, inherently social entities, with underlying codes that structure behaviour in terms of interaction and activities. People work within social structures, but behaviour is not necessarily rigidly defined or limited by these structures. Analytical methodologies must therefore attempt to account for, or at least be flexible enough to allow for, variation and divergences in household behaviour. Often, it will be impossible to give a finite boundary or quantification of such behavioural variables; it is essential to develop approaches that integrate nuanced spatial analysis methods with anthropological theory and ethnographic models.

References

Allison, P. 1999. *The Archaeology of Household Activities*. London: Routledge.

Antonaccio, C. 2000. “Architecture and Behavior: Building Gender into Greek Houses." *The Classical World* 93 (5): 517-533.

Ashmore, W. 2002. “Decisions and Dispositions': Socializing Spatial Archaeology." *American Anthropologist* 104 (4): 1172-1183.

Ault, B. 2007. “Oikos and Oikonomia: Greek Houses, Households and the Domestic Economy." In *Building Communities: House, Settlement and Society in the Aegean and Beyond. Proceedings of a Conference Held at Cardiff University 17-21 April, 2001*, edited by R. Westgate, N. Fisher and J. Whitley, 259-265. London: British School at Athens.

Baldassare, M. 1978. “Human Spatial Behavior." *Annual Review of Sociology* 4: 29-56.

Beaudry, M. 1989. “Household Structures and the Archaeological Record: Examples from New World Historical Sites." In *Households and Communities: Proceedings of the Twenty-First Annual Conference of the Archaeological Association of the University of Calgary*, edited by S. MacEachern, D. Archer and R. Garvin, 84-92. Calgary University of Calgary.

Bent, J. T. 1885. *The Cyclades, or Life among the Insular Greeks*. Charleston: Nabu Press. Original edition, 1885. Reprint, 2010.

Berger, P., and T. Luckman. 1966. *The Social Construction of Reality: A Treatise in the Sociology of Knowledge.* Garden City, New York: Anchor Books.

Blanton, R. 1994. *Houses and Households: A Comparative Study*. New York: Plenum Press.

Bourdieu, P. 1977. *Outline of a Theory of Practice*. Cambridge: Cambridge University Press.

Cambitoglou, A., A. Birchall, J. Coulton, and J. Green. 1988. *Zagora 2: Excavation of a Geometric Town on the Island of Andros. Excavation Season 1969; Study Season 1969-1970*. Athens: Athens Archaeological Society.

Cambitoglou, A., J. Coulton, J. Birmingham, and J. Green. 1971. *Zagora 1: Excavation Season 1967; Study Season 1968-69*. Sydney: Sydney University Press.

Cambitoglou, A., S. Peirce, O. Segal, and J. Papadopoulos. 1981. *Archaeological Museum of Andros: Guide to the Finds from the Excavations of the Geometric Town at Zagora*. Athens: Basil and Goulandris.

Coucouzeli, A. 2007. “From Megaron to Oikos at Zagora." In *Building Communities: House, Settlement and Society in the Aegean and Beyond. Proceedings of a Conference Held at Cardiff University 17-21 April, 2001*, edited by R. Westgate, N. Fisher and J. Whitley, 169-181. London: British School at Athens.

Cutting, M. 2003. “The Use of Spatial Analysis to Study Prehistoric Settlement Architecture." *Oxford Journal of Archaeology* 22 (1): 1-21.

Cutting, M. 2006. “More Than One Way to Study a Building: Approaches to Prehistoric Household and Settlement Space." *Oxford Journal of Archaeology* 25 (3): 225-246.

Dickinson, O. 2006. *The Aegean from Bronze Age to Iron Age: Continuity and Change between the Twelfth and Eighth Centuries B.C.* London and New York: Routledge.

Fagerström, K. 1988. *Greek Iron Age Architecture: Developments through Changing Times*. Göteborg: Paul Åströms Förlag.

Fisher, K. 2009. “Placing Social Interaction: An Integrative Approach to Analyzing Past Built Environments." *Journal of Anthropological Archaeology* 28: 439-457.

Flannery, K. 1976. *The Early Mesoamerican Village*. New York: Academic Press.

Forbes, H. 2007. *Meaning and Identity in a Greek Landscape: An Archaeological Ethnography*. New York: Cambridge University Press.

Foxhall, L., and G. Neher. 2011. "Gender and the City before Modernity: Introduction." *Gender and History*, 23 (3), 491-509.

Gates, C. 2011. *Ancient Cities: The Archaeology of Urban Life in the Ancient Near East and Egypt, Greece and Rome*. London: Routledge.

Giddens, A. 1984. *The Contitution of Society. Outline of a Theory of Structuration*. Cambridge: Polity Press.

Gouma, M., G. van Wijngaarden, and S. Soetens. 2011. "Assessing the Effects of Geomorphological Processes on Archaeological Densities." *Journal of Archaeological Science* 38 (10), 2714-2725.

Gounaris, A. 2007. "Curvilinear Versus Rectangular? A Contribution to the Interpretation of the Evolution in Architectural Forms in Greece During the Protogeometric - Geometric - Archaic Periods Based on a Study of the Constructions at Oropos." In *Oropos and Euboea in the Early Iron Age. Acts of an International Round Table, University of Thessaly. June 18-20, 2004*, edited by A. Mazarakis Ainian, 77-122. Volos: University of Thessaly Press.

Gounaris, A. 2011. "Pastoral Structures: The Encounter of Early Iron Age Archaeology with Ethnography in Mainland Greece." In *The "Dark Ages" Revisited. Acts of an International Symposium in Memory of William D.E. Coulson, 14-15 June 2007*, edited by A Mazarakis Ainian, 247-266. Volos: University of Thessaly Press.

Hanson, J. 2003. *Decoding Homes and Houses*. Cambridge: Cambridge University Press.

Hendon, J. 1996. "Archaeological Approaches to the Organization of Domestic Labor: Household Practice and Domestic Relations." *Annual Review of Anthropology* 25, 45-61.

Hillier, B., and J. Hanson. 1984. *The Social Logic of Space*. Cambridge: Cambridge University Press.

Hodder, I. 2005. *Çatalhöyük Perspectives: Reports from the 1995-99 Seasons*. Cambridge/London: McDonald Institute for Archaeological Research/ British Institute at Ankara.

Hodder, I. 2006. *The Leopard's Tale. Revealing the Mysteries of Çatalhöyük*. London: Thames and Hudson.

Kent, S. 1990. *Domestic Architecture and the Use of Space: An Interdisciplinary Cross-Cultural Study*. Cambridge: Cambridge University Press.

LaMotta, V., and M. Schiffer. 1999. "Formation Processes of House Floor Assemblages." In *The Archaeology of Household Activities*, edited by P. Allison, 19-29. London: Routledge.

Lang, F. 2005. "Structural Change in Archaic Greek Housing." *In Ancient Greek Houses and Households. Chronological, Regional, and Social Diversity*, edited by B. Ault and L. Nevett, 12-35. Philadelphia: University of Pennsylvania Press.

Lawrence, D., and S. Low. 1990. “The Built Environment and Spatial Form." *Annual Review of Anthropology* 19: 453-505.

Malinsky-Buller, A., E. Hovers, and O. Marder. 2011. “Making Time: ‘Living Floors’, ‘Palimpsests’ and Site Formation Processes – a Perspective from the Open-Air Lower Paleolithic Site of Revadim Quarry, Israel." *Journal of Anthropological Archaeology* 30 (2): 89-101.

Mazarakis Ainian, A. 2007. “Architecture and Social Structure in Early Iron Age Greece." In *Building Communities: House, Settlement and Society in the Aegean and Beyond. Proceedings of a Conference Held at Cardiff University 17-21 April, 2001*, edited by R. Westgate, N. Fisher and J. Whitley, 157-168. London: British School at Athens.

McCallum, M. *Forthcoming*. “Zagora and Its Heurist Database: The Architectural Perspective." In *Zagora in Context Settlements and Intercommunal Links in the Geometric Period (900-700 B.C.). Proceedings of a Conference Held at the Athens Archaeological Society, 20-22 May, 2012*, edited by J-P. Descœudres and S. Paspalas. Sydney: Meditarch.

McCallum, M., B. McLoughlin, and W. Mullen. 2011. *Zagora*. Australian Archaeological Institute at Athens. Available from http://www.aaia.chass.usyd.edu.au/Zagora/Zagora/Zagora_3.html.

McKie, L., S. Bowlby, and S. Gregory. 1999. “Connecting Gender, Power and the Household." In *Gender, Power and the Household*, edited by L. McKie, S. Bowlby and S. Gregory, 3-21. London: Macmillan Press.

McLoughlin, B. 2000. *Searching for the Potter's Intention: The Pithos Makers of Zagora*. M.A. Dissertation, University of Sydney.

McLoughlin, B. 2011. “The Pithos Makers at Zagora: Ceramic Technology and Function in an Agricultural Settlement Context." In *The “Dark Ages” Revisited. Acts of an International Symposium in Memory of William D.E. Coulson, 14-15 June 2007*, edited by A Mazarakis Ainian, 869-884. Volos: University of Thessaly Press.

McLoughlin, B. *forthcoming*. “Kitchen equipment at Zagora: Visual tools for identifying vessel types prior to comparative distribution analyses of household coarseware." In *Zagora in Context Settlements and Intercommunal Links in the Geometric Period (900-700 B.C.). Proceedings of a Conference Held at the Athens Archaeological Society, 20-22 May, 2012*, edited by J-P. Descœudres and S. Paspalas. Sydney: Meditarch.

Morris, I. 1999. “Archaeology and Gender Ideologies in Early Archaic Greece." *Transactions of the American Philological Association* 129: 305-317.

Muhly, J. 2011. “Archaic and Classical Greece Would Not Have Been the Same without the Dark Ages." In *The “Dark Ages” Revisited. Acts of an International Symposium in Memory of William D.E. Coulson, 14-15 June 2007,* edited by A Mazarakis Ainian, 45-54. Volos: University of Thessaly Press.

Mustafa, F., A. Hassan, and S. Baper. 2010. “Using Space Syntax Analysis in Detecting Privacy: A Comparative Study of Traditional and Modern House Layouts in Erbil City, Iraq." *Asian Social Science* 6 (8): 157-166.

Nevett, L. 1999. *House and Society in the Ancient Greek World*. Cambridge: Cambridge University Press.

Pluckhahn, T. J. 2010. "Household Archaeology in the Southeastern United States: History, Trends, and Challenges." *Journal of Archaeological Research* 18 (4): 331-385.

Rapoport, Amos. 1982. *The Meaning of the Built Environment: A Nonverbal Communication Approach*. Beverly Hills: Sage Publications.

Rapoport, Anatol. 1989. *Decision Theory and Decision Behaviour: Normative and Descriptive Approaches*. Dordrecht; Boston: Kluwer Academic Publishers.

Renfrew, C. 2004. "Towards a Theory of Material Engagement." *In Rethinking Materiality: The Engagement of Mind with the Material World*, edited by E. DeMarrais, C. Gosden and C. Renfrew, 23-31. Cambridge: McDonald Institute for Archaeological Research.

Robinson, J. 2001. "Institutional Space, Domestic Space, and Power Relations: Revisiting Territoriality with Space Syntax." *Paper read at 3rd International Space Syntax Symposium, May 7-11 2001*, at Atlanta, Georgia Institute of Technology.

Schiffer, M. 1983. "Toward the Identification of Formation Processes." *American Antiquity* 48 (4): 675-706.

Schiffer, M. 2000. "Social Theory in Archaeology: Building Bridges." *In Social Theory in Archaeology*, edited by M. Schiffer, 1-13. Salt Lake City: The University of Utah Press.

Souvatzi, S. 2008. *A Social Archaeology of Households in Neolithic Greece*. Cambridge: Cambridge University Press.

Thomas, C., and C. Conant. 1999. *Citadel to City-State: The Transformation of Greece, 1200-700 B.C.E.* Bloomington: Indiana University.

Tickamyer, A. 2000. "Space Matters! Spatial Inequality in Future Sociology." *Contemporary Sociology* 29 (6): 805-813.

Tringham, R. 1991. "Households with Faces: The Challenge of Gender in Prehistoric Architectural Remains." In *Engendering Archaeology: Women and Prehistory*, edited by J. Gero and Conkey. M., 93-131. Oxford: Blackwell.

Walker, W. 2002. "Stratigraphy and Practical Reason." *American Anthropologist* 104 (1): 159-177.

Weiner, S. 2010. *Microarchaeology: Beyond the Visible Archaeological Record*. New York: Cambridge University Press.

Westgate, R., N. Fisher, and J. Whitley. 2007. *Building Communities: House, Settlement and Society in the Aegean and Beyond. Proceedings of a Conference Held at Cardiff University 17-21 April, 2001*. London: British School at Athens.

Whittle, A. 2003. *An Archaeology of People. Dimensions of Neolithic Life*. London: Routledge.

Wilk, R., and W. Rathje. 1982. "Household Archaeology." *The American Behavioural Scientist* 25 (6): 617-639.

Yasur-Landau, A., J. Ebeling, and L. Mazow. 2011. *Household Archaeology in Ancient Israel and Beyond*. Leiden: Brill.

Gis spatial distribution analysis in raw material quarrying sites: the example of El Cañaveral (Madrid, Spain)

Irene Ortiz Nieto-Márquez [1]

Javier Baena Preysler [1]

Mª Gema Chacón[2, 3]

[1] FPU-MECD. Dep. de Prehistoria y Arqueología. Universidad Autónoma de Madrid.

[2] Institut Catalá de Paleoecologia Humana I evolució Social. Universitat Rovira i Virgili

[3] Dep. De Prehistoria. Museo Nacional de Historia Natural de París.

Abstract

Nowadays spatial archaeology is based mainly on georeferencing methods and computing programs that supply us a lot of information and innovations .We can use it to investigate, among other aspects, on behavioural patterns as well as geomorphological processes. This research shows the utilities of lithic refitting and the use of GIS applications to explain spatial distribution of artifacts, stratigraphic integrity and lithic technology in an open air site used as raw material quarrying site during the Middle Palaeolithic in Madrid, Spain.

Keywords: *Middle Paleolithic, open air quarrying site, refits, GIS, spatial analysis.*

1. Introduction

The archaeological context of the central region of the Iberian Peninsula is full of archaeological remains, particularly in terrace contexts, discovered from the beginning of the XIXth century. From prehistoric times to historical phases, the Lower and Middle Paleolithic occupation of the area has left plenty of sites and remains with different depositional conditions. El Cañaveral archaeological site (Madrid, Spain) is an open air raw material quarrying site, occupied during the Middle Palaeolithic period. The geological context of the site is the tertiary basin of Madrid, part of a bigger morpho-structural unit called Tajo's basin (Baena Preysler et al. 2011).

This site was discovered thanks to some investigation projects supported by the Consejería de Cultura of the region of Madrid. Later excavations conducted by Arquex SL, archaeological company and the UAM research team, determinate different aspects of the site formation and the human occupation (Baena Preysler et al. 2008).

2. Geology

Geologically, the sites located along the M-45 highway have a similar context. Geomorphologically, they are situated on a platform that defines the watershed between the Manzanares and Jarama rivers, where there are a lot of flint blanks on the surface, and occasionally flint outcrops. The unusual abundance of these rocks explains the presence of a high density of archaeological testimonies linked to supply/catchment patterns of raw materials (Baena Preysler et al. 2008).

The preservation of several archaeological sites in this area have been produced by the different sedimentary agents, including eolian and colluvian processes, happened during Quaternary times. These low energy deposits covered and buried the anthropological activities protecting them from other external erosive agents in combination with the creation of lower range topographies generated by the collapse of deep Miocene plaster deposits (Pérez-González and Miguez 1975; Goy, Pérez-González, and Zazo 1989). The numerical dating series obtained by OSL in all areas have registered the activities of human groups along the OIS 3 and latter (Baena Preysler et al. 2008).

3. Archaeological site

Thanks to the discovery of a large number of lithic industries associated with raw material blanks, it was decided to start an open excavation in different areas. One of the main excavations was Área 3. This area totalled 164 m2 and its sequence included at least one clay layer containing large assemblages of lithic industry represented by a great number of cores flakes and hammer stones (Baena Preysler et al. 2011).

The distribution of the lithic material alternates between concentrations with predominantly horizontal layouts and sets of raw materials located along vertical slopes, probably resulting from the soil processes that took place later. As well as this, here the coluvionar deposits were the principal source of raw material and the basis over which the well-preserved traces of knapping activity were superimposed. New coluvionar-eolic episodes affected in a different way the distribution of various knapping areas with the partial deplacements of some pieces and the intrusion of someboulder materials (Baena Preysler et al. 2011).

During the excavation the distribution of oval or circular concentrations of fresh material was recovered, corresponding to particular *debitage* areas as well as hearth remains indicating a temporary occupation of this area.

4. Objectives

In such a kind of archaeological sites, several questions can be answer. First of all the necessity to discriminate different knapping areas in the whole excavation area, and to determinate if this place is a palimpsest as a result of a continuous occupation place, or discrete layers happened. Another objective was to discover the postdepositional agents that could affect the original lithic distribution both in x and y axis and also in z values. The spatial dimensions of refits could offer basic elements in the interpretation of site formation processes.

5. Methodology

A spatial analysis of remains was built up using ArcGIS 9.7. Georeferencing data of the lithic pieces were used to get the distribution map of the area, where we could see three different levels, II, II-III and III., the most important concentrations were selected with raster application, and using the inventory of the excavation, the selected pieces for the research were determined (Fig. 1).

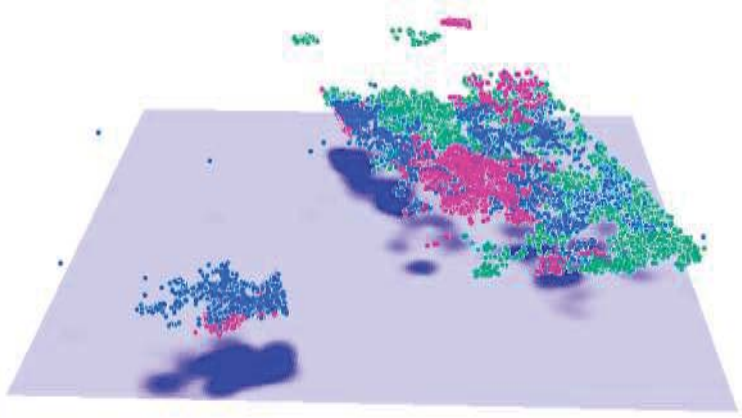


Figure 1: Área 3. Cañaveral. Lithic industry levels.

The aggregates of each level were selected, and in that way 712 pieces were studied from level II, 1208 pieces from level II-III and 2113 pieces from level III, being a total of 4033 pieces.

While we were trying to find refits, a database of all the pieces was made using the Atribute Analysis System describing the raw material, alterations as patinas, thermal alteration, and bouldering. It was documented as well, the cortical index and some knapping accidents. Then

the category of the piece as a flake, blade, core, fragments and retouched objects was established.

During the process of refitting, a new distinction was made, based in the cause of the rupture. There are different types of refits like the ones caused by core reduction sequence that provides great information about operative chains and technology. The second type of refits consists of fragmented artefacts; they could be caused by fractures during the knapping process or during postdepositional processes (Peacock 1991; Jennings 2011). The third type comes from secondary modification of artefacts. This one provided us valuable information about recycling/*ramification*. (Bourguignon, Faivre, and Turq 2004) The last type of refits is based on thermal alterations (J. Dorta Pérez et al. 2010; Frank 2006).

It is important to observe the refits dispersion, both its horizontal dynamic and its vertical one. In the horizontal field it is possible to discover the relations between aggregates, if they are contemporary or not, and in the vertical field it is possible to answer stratigraphic ascriptions between others (Hofman 1992; Cattin 2002; Olive and Pigeot 2006; Almeida 1995).

6. Results

Having done the attribute analysis it was possible to observe some differences between levels. The percentages of flakes in level II and level II-III is more or less the same, while in level III the percentage of flakes drops on behalf of fragments (Fig. 2).

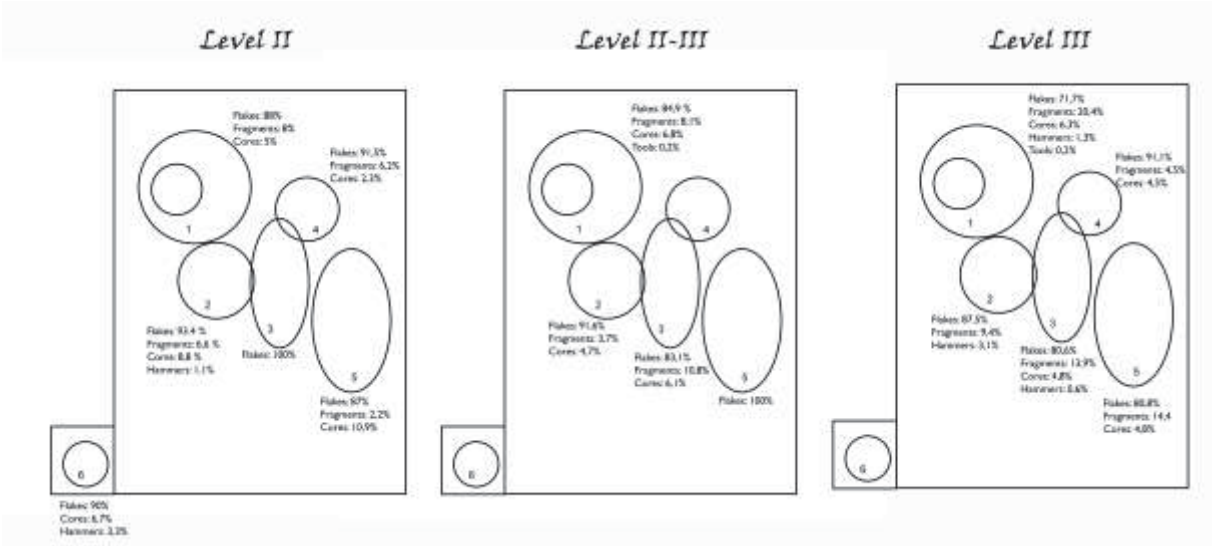


Figure 2: Attribute Analysis Percentage per levels.

Lithic element shapes are also important since the shape of the lithic element is very important, because big nodules provide raw material to knap. On level III there were documented 49 big lithic blanks, the majority were cortical flakes and non cortical flakes. On level II-III there were documented 17 big cortical flakes and finally on level II were only 9 big blanks.

Likewise, some external alteration that affected the lithic was documented. The dispersal or distribution of boulder pieces indicates possible drag lines due to those alterations. The main tendency of the distribution is from NW to SE as if they had been move, maybe by a small stream, particularly on level III. Carbonated pieces were documented as well, and the majority of pieces that have this alteration come from level III (80%), so it involves the presence of water on this level. The presence of this small water stream can be proved by the refits distribution.

There were found 73 groups of reffited pieces, adding up a total of 218 lithic elements.

On **level II** most of the refitted pieces come from core reduction sequences, while there is small presence of natural fractures. The most important group of refits of this level is one composed by11 lithic elements (Fig. 3).

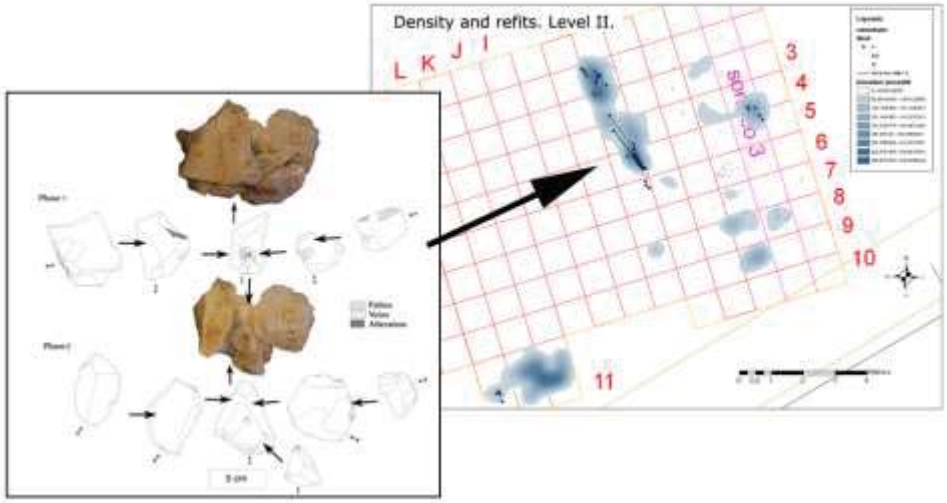


Figure 3: Level II, join lines refits and an example.

As it is possible to see in the map, the majority of the refits are inside the places with high density of material. As well, the lines that join the pieces have a general direction, following NW-SE.

The refitting distances are also important to discriminate natural and human processes (Table 1). We can see in the table there are 17 joins from core reduction sequence that are in a distance

less than 0.3 meters, being only 2 between 1 and 2 meters. In addition, vertical distribution of refits, indicate, that is a very homogeneous level although some pieces show variations.

Refits	Mean Distance (cm)			
	Level II	**Level II-III**	**Level III**	**Between Levels**
Core Reduc. Seq.	29,4	19,1	61	164
Trampling		13	16	19,3
Natural Frac.	130		4	
Current Frac.			169,5	
Internal Fissure				
Thermal Alteration	12,5	5	34,7	22
TOTAL	**31,9**	**18,5**	**56,3**	**81,7**

Table 1: Refits mean distance on Level II, Level II-III, Level III and between levels.

On Figure 3 there is an example of a refit, found on level II. It is a complex of 11 levallois flakes, with unipolar knapping whose aim was the obtaining of levallois points.

On **level II-III** there were found 23 groups of refits, being a total of 71 pieces. The most important type comes again from core reduction sequences represented by 17 groups, followed by thermal alteration with 2 groups. The horizontal distribution of this level is totally different to the other one. Here the majority appear very concentrated, in areas with high density of pieces, although small join lines follow the same direction: NW-SE (Fig. 4).

The distance between them is very homogeneous, because most of them are in a range between 0 and 30 cm of distance. In relation to vertical distribution the level is very homogeneous, defining a clear occupational leve (Table 1).

On level II-III we find one of the biggest refits in Área3. It belongs to a Centripetal Levallois core with different knapping phases, composed of 15 flakes and the core. The maximum distance of these flakes is 21 cm between each other.

Also on level II-III there were found several refits, including 10 flakes in a cortical core. It is also possible to identify different knapping phases and changes in directions. It is a bipolar core with some “preferred” flakes.

The maximum distance between these pieces reached 29 cm, and the lines follow a NW-SE direction

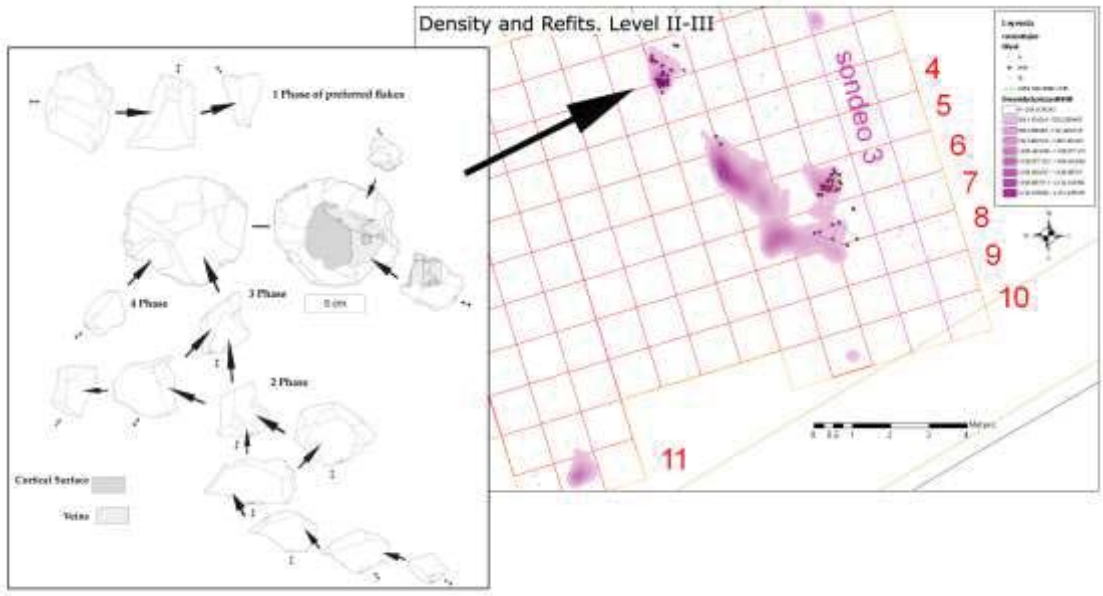


Figure 4: Level II-III, join lines refits and an example of a Levallois core refit.

On **level III** there were found 35 groups of refitted pieces, with a total amount of 89 elements. On this third level the categories of refits shows many differences. Now the most representative category is represented by thermal alteration type (10 groups), followed by core reduction sequence items (8) and trampling elements (7) (Fig. 5). There is at least a single case of every category. Horizontal distribution indicates that that most of the pieces come from places with high density of materials, and between different clusters with higher distances between them (Table 1).

The join lines are still in the same direction, but larger in this case. There are as well some lines that join refits with W-E direction. The distance is clearly higher than in the other two levels. We can find core reduction sequences joins from less than 5 cm to more than 3.5 meters.

Vertical distribution, now, changes a little bit. The distance between them in a vertical scale is higher than on level II and II-III. This shows that there was more movement on the surface on this level than on the other two.

On Figure 5 there is an example of refits found on level III. The appearance and conservation of the pieces is different, caused by water streaming; examples are boulder pieces and the presence of water patinas. None of these pieces is an entire flake; all of them are flake fragments and *"siret"* fractures.

The information we get from **refits between levels** (Fig. 6) is very important to develop an interesting interpretation of the archaeological site, relating strata, making coetaneous

aggregates, in horizontal but also in vertical field. It can also show us some postdepositional processes, as small streams.

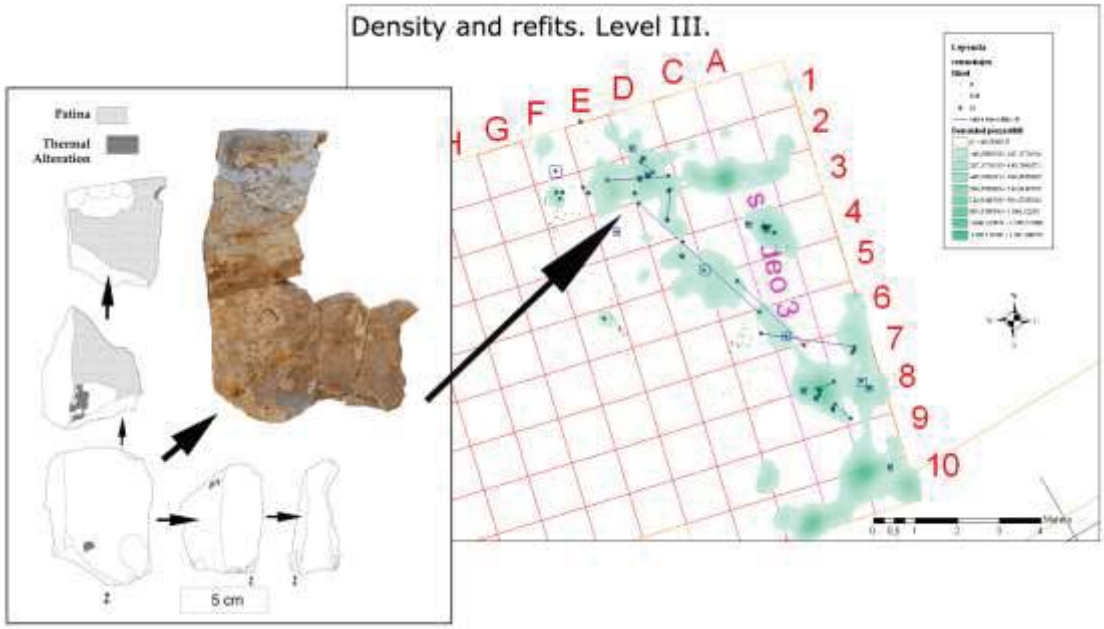


Figure 5: Level III join lines refits and an example.

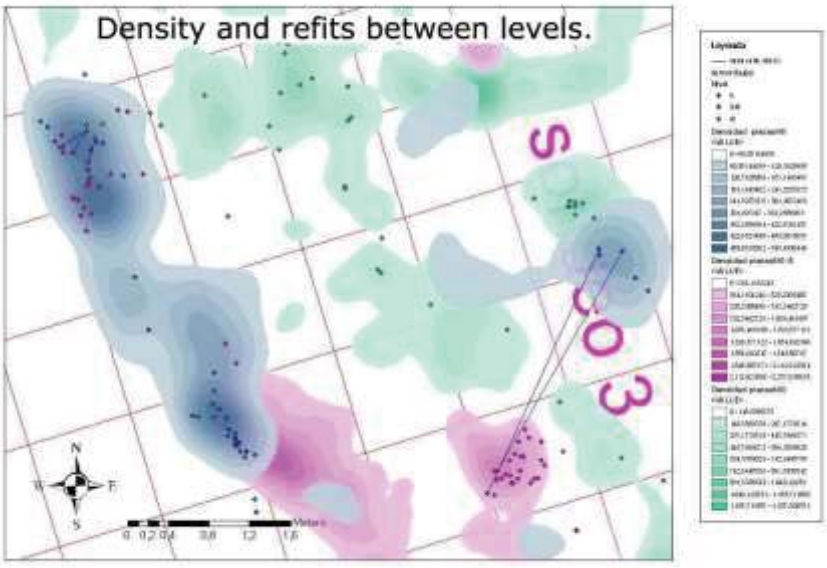


Figure 6: Refits between different levels.

There were 5 refits groups found between different levels. Three of them relate level II and level II-III, one relates level II and III and another one relates level II-III with III. The total number or refitted pieces is 12. The more abundant types are trampling and core reduction sequences, followed by thermal alterations.

These refits are as well inside the places with high lithic density, but the most important data is the direction of the join lines, being totally opposite from the last three levels (Table 1). Refits between levels have NE-SW line directions while refits inside the same level have NW-SE line direction.

Regarding distance between joined pieces, we could appreciate the larger lines belonging to core reduction sequences (2-5 meters), while the rest of the joins by trampling or thermal alteration are separated by less than 30 cm.

On vertical scale, the distances are also longer, because these refits join different levels.

There is a refit composed by a Levallois core over a cortical flake from level II-III, and two flakes from level II. The distance between the flakes was 5 cm but the distance between the core and flakes was 2.51 meters.

The last refit comes from a broken flake due to trampling action. There are 3 flake fragments, a proximal, a mesial and a distal fragment. Distal and proximal fragments belong to level II-III and mesial fragment belongs to level II. The distance between fragments was 24-29 cm.

7. Interpretations

As it possible so see on Table 2, there are a lot of interesting spatial data that could analyze according to their level correspondence.

First of all, there is information about the main characteristics of lithic pieces, like size and its technological category. On level II and II-III the percentage of flakes is higher than fragments, but on level III this proportion changes, to a similar proportion of categories. Also on level III the number of big size pieces is higher than in others, with lower rates on level II-III and II.

This could be explained for functional reasons. The site was used mainly as a quarrying site. First phases of exploitation took place on level III, where the big nodules and cores were discovered and started, and big fragments and flakes were produced (Terradas 2000). As different occupations passed by the place, the number of big pieces decreases and flakes increase in percentage. This circumstance generated the formation of a huge palimpsest of lithic

material in big extensions of this area. There is a reuse of big pieces and flakes and a transformation of them to cores and artefacts (Mangado 2006).

	Level II	Level II-III	Level III
Flakes and Fragments %	More % of Flakes than fragments.		Same % of Flakes and fragments
Big pieces	9 pieces	17 pieces	49 pieces
Cortex Index	Same cortex index. Between 50 and 27%		
Carbonates	low-middle	low-middle	high
Refits Join lines	Shorts. NW-SE	Concentrated	Longs. NW-SE
Refits types	Core reduction sequence		Fractures, Thermal alteration
Refits between levels	Core reduction sequence: NE-SW		Thermal alteration, trampling
Level distributions	Grouped		Random
Density direction	Density following NW-SE direction		

Table 2: Interpretation data.

The dominance of water patina indicates the presence of this element as an erosive agent. Carbonates appear where there is water, like a small stream, in the area. Pieces that have the highest percentage of carbonates belong to level III, according to the presence of water, as refits and join lines prove.

Linking or joining lines show a NW-SE orientation trend, even more on level III. The joins from this level are very long distanced and always follow the same direction. Although, in the other two upper levels, lines were much more concentrated they are also in the same direction.

Using the information provided by refits, it is documented that on level II and II-III the highest percentage come only from core reduction sequences refits, while in level III apart from this, there is also trampling, thermal alterations and natural ones. On Level III pieces were affected by higher movement in comparison with the other two levels, in which more external alterations than in the upper levels happened.

However, some refits between levels were found, a fact that can help us in human actions understanding. On these refits there are two groups that have very long join lines in totally opposite directions, SE-NW. It is not possible that this movement was caused by a geological process, because it crossed the supposed water stream, and refits were caused by core reduction processes. The third refit was caused by trampling, breaking the stone in three pieces (Bordes 2002).

8. Conclusions

With this information we can conclude that El Cañaveral is a raw material quarrying site, in which first phases of the operative chain took place, maybe to transport shaped configurated cores for their exploitation, or directly to transport retouched objects and predetermined final products.

It was possible to link two levels, II and II-III because they share more or less the same techno typological characteristics, confirmed by the presence of refits between them.

Level III suffered the action of a small water stream or water sheet that crossed the whole archaeological site with NW-SE direction. Pieces in this level were transported by the water action as is confirmed by the observed refits and the analysis of external alterations.

On level II and II-III we could document some small and concentrated knapping areas, with very fresh edges in pieces and a high degree of refitting elements. In the excavation period a hearth was discover as well, related to a high number of lithic material. It is still under study, but we already have found some refits that show an intense knapping activity in the area in relation to a more "curated" structure.

References

Almeida, F. 1995. "O Método Das Remontagens Líticas: Enquadramento Teórico e Aplicacoes." *Trabalhos De Arqueologia Da EAM* 3: 1–40.

Baena Preysler, J., S. Bárez, A. Pérez-González, M. Roca, A. Lázaro, R. Márquez, and I. Rus. 2011. "Searchers and Miners: First Signs of Flint Exploitation in Madrid's Region." In *Proceedings of the 2nd International Conference of the UISPP Commission on Flint Miningin Pre- and Protohistoric Times (Madrid, 14-17 October 2009)*, ed. Marta Capote, Susana Consuegra, Pedro Díaz del Río, and Xavier Terradas, 203–220. Madrid: BAR International Series 2260.

Baena Preysler, J., S. Bárez, A. Pérez-González, A. Lázaro, A. Nebot, M. Roca, and T. Pérez. 2008. "El Yacimiento Paleolítico Cañaveral (Coslada-Madrid). La Captación De Recursos Líticos Durante El Musteriense Peninsular." *Arqueoweb. Revista Sobre Arqueología En Internet* 9 (2): 1–32.

Bordes, J.G. 2002. "Les Interstratifications Châtelperronien / Aurignacien Du Roc-de-Combe Et Du Piage (Lot, France). Analyse Taphonomique Des Industries Lithiques ; Implications Archéologiques." L'Universite Bordeaux I.

Bourguignon, Laurence, Jean-Philippe Faivre, and Alain Turq. 2004. "Ramification Des Chaînes Opératoires : Une Spécificité Du Moustérien ?" *Paléo* 16: 37–48.

Cattin, M.I. 2002. "El Remuntatge De Les Restes Lithiques: Organitzacio Interna Dels Assentaments i Lligams Entre Jaciments." *Cota Zero* 17: 79–80.

Frank, A. D. 2006. "El Daño Térmico En Artefactos Líticos : Estudios Experimentales." In *Entre Pasados y Presentes II. Estudios Contemporáneos En Ciencias Antrópológicas*, ed. Tirso Bourlot, Damián Bozzuto, Carolina Crespo, Ana Carolina Hecht, and Nora Kuperszmit, 35–48. Buenos Aires, Argentina.

Goy, J.L., A. Pérez-González, and C. Zazo. 1989. "Cartografía Geológica Del Cuaternario, Geomorfología y Memoria Correspondiente De La Hoja a E. 1: 50.000 De Madrid (559)". Madrid: IGME.

Hofman, JL. 1992. "Putting the Pieces Together: An Introduction to Refitting." *BAR International Series*. http://courses.washington.edu/archyaec/archy483/Readings/hofman92.pdf.

J. Dorta Pérez, Ricardo, C. M. Hernández Gómez, F.J. Molina Hernández, and B. Galván Santos. 2010. "La Alteración Térmica En Los Sílex De Los Valles Alcoyanos (Alicante, España). Una Aproximación Desde La Arqueología Experimental En Contextos Del Paleolítico Medio : El Salt." *Recerques Del Museu d'Alcoi* 19: 33–64.

Jennings, T. A. 2011. "Experimental Production of Bending and Radial Flake Fractures and Implications for Lithic Technologies." *Journal of Archaeological Science* 38 (12) (December): 3644–3651. doi:10.1016/j.jas.2011.08.035. http://linkinghub.elsevier.com/retrieve/pii/S0305440311003141.

Mangado, J. 2006. "El aprovisionamiento en materias primas líticas: hacia una caracterización paleocultural de los comportamientos paleoeconómicos." *Trabajos De Prehistoria*. 63 (2): 79–91.

Olive, M, and N. Pigeot. 2006. "Réflexions Sur Le Temps d ' Un Séjour à Étiolles (Essonne)." *Bulletin De La Société Préhistorique Française* 103 (4): 673–682.

Peacock, E. 1991. "Distinguishing Between Artifacts and Geofacts: A Test Case from Eastern England." *Journal of Field Archaeology.* 18 (3): 345–361.

Pérez-González, A., and F. Miguez. 1975. "Cartografía Del Cuaternario y Memoria De La Hoja Geológica a E. 1:50.000 De Getafe. Nº 582." Madrid: IGME.

Terradas, X. 2000. "Los contextos de producción lítica y las primas minerales en sociedades cazadoras-recolectoras prehistóricas." In *Primer Simposio Sobre La Minería y La Metalúrgia Antigua En El SW Europeo, Serós*, 51–60.

Geometric characterization and analysis of complex elements through the integration of different Geomatics Techniques. Application to caves

Vicente Bayarri Cayón[1]

Elena Castillo López[2]

[1] GIM Geomatics S.L.

[2]Área de Ingeniería Cartográfica, Geodesia y Fotogrametría, E.T.S.I. Caminos, Canales y Puertos, Universidad de Cantabria.

Abstract

The importance given to geomatics within speleology, is that any study after the discovery of a cavity needs a plane on which to rely. Hence the survey is one of the first tasks that are performed. Traditionally, topography was aimed at the final drawing of a plant, a longitudinal profile and some sections. The integration of traditional geomatics tools such as GNSS and total stations with more recent ones such as 3D laser scanners, allows a fast and accurate registration process in order to obtain a comprehensive documentation that covers everything from floor plans, elevation, longitudinal and transverse sections, dimensional analysis and calculation of heights of galleries or caps and to virtual reality systems. This article describes the necessary tasks in both the capture and treatment of the data to generate highly accurate metric documentation and details of such complex and unique places such are caves and cavities.

Keywords: *Cartography, Caves, GNSS, photogrammetry, 3D laser scanner, 3D modelling algorithms*

1. Introduction

Having an accurate map base of a cavity in both 2D and 3D, is important when dumping the captured information, interrelate parameters and conduct effective management of it, although it may become essential when developing and testing predictive models based on knowledge.

In caves, every day more studies are conducted:

- Hydrochemical studies: Systematic studies of the physical and chemical characteristics of the water, is one of the methods for monitoring the evolution of the karst. It contains information as pH, water temperature, conductivity, total dissolved solids, dissolved CO2 and dissolved O2.

- Water Microbiology.

- Climate Study: The presence of people inside the cavities can generate different types of thermal, chemical and biological pollution. The number of people who remain some time daily in the cave is a major source of heat generation and CO2 supply to the confined atmosphere. Therefore, the definition of a threshold equilibrium must be a common practice in environmental management of any tourist cavity, allowing to establish an optimal regime of visits. This is fundamental for the karst heritage conservation.

- Fauna Studies.

- Geotechnical studies.

Multiple parameters are measured, and many of them are highly correlated. Having a sufficiently precise mapping helps in the application of predictive models of behavior or responses. In addition, information created can also be used for the dissemination of the cave and its complex.

2. Background

The importance traditionally given to the topography within speleology, is that any study following the discovery of a cavity requires a plane on which to base it. Hence the survey is one of the first tasks to be performed, and also constitutes the fundamental support to dump all subsequent studies.

At present there are different levels of precision as to topography relates cave. A representation of the physical environment is useful when it meets the purpose for which it was created. As in the mapping process, there is a range of accuracy values depending upon the instruments used:

1. Memory scheme, without scale, supported by descriptions.

2. Drawing at a guess, performed without measure instruments, with approximate scale.

3. Rudimentary plane drawn with data provided by a small compass graduated and rope or tape with divisions in meters.

4. Prism compass and tape.

5. Calibrated prismatic compass and clinometer and non deformable measuring tape.

6. Compass, inclinometer and tape, but with tripod.

7. Measurements with traditional tachometer.

8. Measurements with reflectorless topographic total station.

9. 3D Laser Scanner measurements.

Traditionally, topography was intended to obtain a plant plane or map, and at most cross sections and longitudinal profiles. The present article describes the methodology adopted to accurate geometrically characterize caves, estimating the error and to extract large amounts of spatial information to be introduced into the prediction models of behavior.

3. Methodology

This article shows the methodology used in the characterization of different caves of the Cantabrian Coast. The purpose of surveying was different in each case.

3.1 Choice of Terrestrial Reference System

To carry out a proper recording of information of the cave, in a homogeneous system, it is necessary to clearly identify the terrestrial reference system and projection, nowadays it is recommended to submit the documentation in the global reference system ETRS89 materialized by the National Geodetic Network using space techniques (REGENTE), as recommended by the Royal Decree 1071/2007 of 27 July (BOE. 207 Wednesday August 29, 2007).

3.2. Characterization of the protection environment

The task was carried out in different phases:

A) Creating the network of bases:

After choosing the reference system, a network of reference points is determined inside the environment protection area. The observation method used was differential observations both by static and real-time kinematic (RTK) from reference stations.

B) Geodetic surveying.

From the reference points we proceed to the measuring of mountain at the agreed scale (usually 1:2000).

For this purpose a combined method integrating GNSS-GPS in RTK mode and Topographic Total Stations was used.

3.3. Creation of the primary traverse

The primary traverse is observed; it is a go & back closed traverse which is later adjusted and compensated in each cave. The bases are generally materialized by steel nails.

The coordinate system used is the same as that used in the topographical environment.

3.4. Digitization of the caves

A panoramic 3D laser scanner phase measurement is utilized for the purpose. It provides an accuracy of 2 mm at 25 m, which allows us to obtain documents that meet the metric tolerances required.

In this phase, the following phases have been covered:

1. Position and rotation of the instrument
2. Spatial coordinates: value XYZ
3. Intensity: reflectance value of the material

The georeferencing is performed by using materialized previous topographic bases.

3.5. Preprocessing information: Clean and registration

In this step the field information is filtered and merged in a single model:

1. Cleanliness: It is removed any information that is not desired (noise), either manually or automatically.
2. Record: The position and rotation of the instrument for each scan is calculated in a specific coordinate system. This can be done through references that act as checkpoints.

3. Optimizing model: creating a homogeneous model. The model is structured and divided into parts for ease of handling and understanding.

The result is a point cloud, processed, free of noise, in the same reference system. Subsequently generalizes the information captured by reducing information in order to be possible to load into memory all the scans of both caves.

3.6. Information processing: Information extraction model.

A) Ground Plane

It is obtained by drawing directly from the point cloud. The map shows the outline of the cavities, the overpasses and underpasses, existing paths and stairs inside and other items relating to the urbanization of the rooms as points of light. It also contains the primary traverse axis used to observe the framework. All data is arranged in layers.

B) Longitudinal sections

The longitudinal section reflects in guitar diagram form details such as ceiling height, height from floor level of the room, partial distance, distance to the origin, etc.

Having continuous information of the full cave, permits that the longitudinal section may be drawn at any point, unlike with the traditional measurement methods.

C) Cross sections

They are created and dimensioned throughout the cave where there is a significant section change or in zones of special interest.

Since it is available a high volumetric density of information in the same reference system, it is possible to draw a large number of cross sections, and precisely know distance between galleries, even in case that these elapse in parallel. With other methods it would be very laborious to achieve.



Figure 1: Detail of flat floor of the cavity.

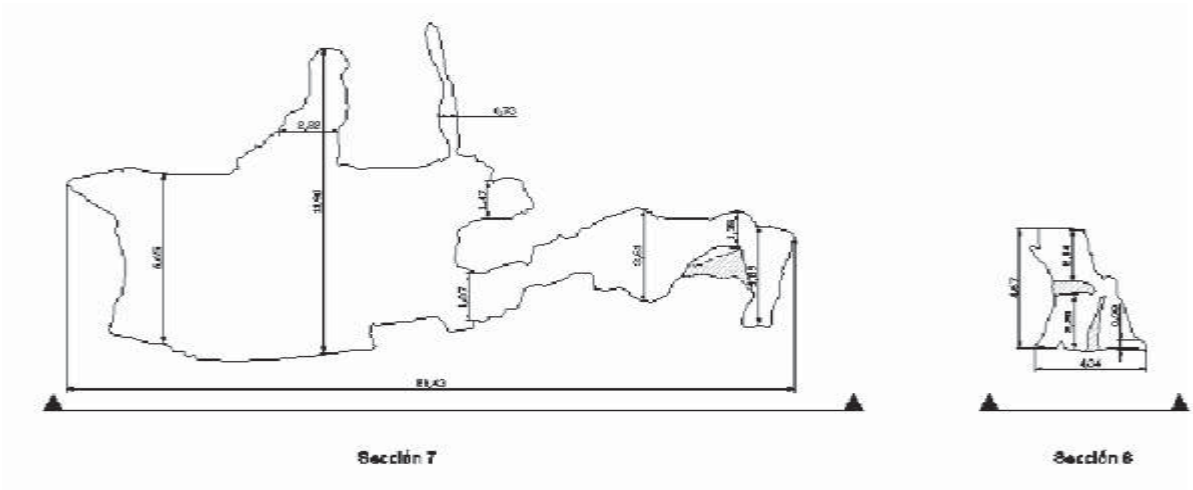


Figure 2: Cross sections detail.

D) Documentation galleries heights

It creates a series of maps with the heights of the galleries. These maps typically have a resolution of 5 to 20 cm.

E) Thickness of the roof.

It creates a series of maps with the thickness of the roof (distance between roof and surface) galleries. These maps usually have a resolution between 5 and 20 cm. From the viewpoint of computational geometry is the distance for the same pair of XY coordinates, between the surface elevation and the roof of the cave.

F) Contour level documentation

It can also be created a series of maps with contour equidistance around 50 cm for the whole cave. For details with microtopography requirements, equidistance can reach 1 cm.

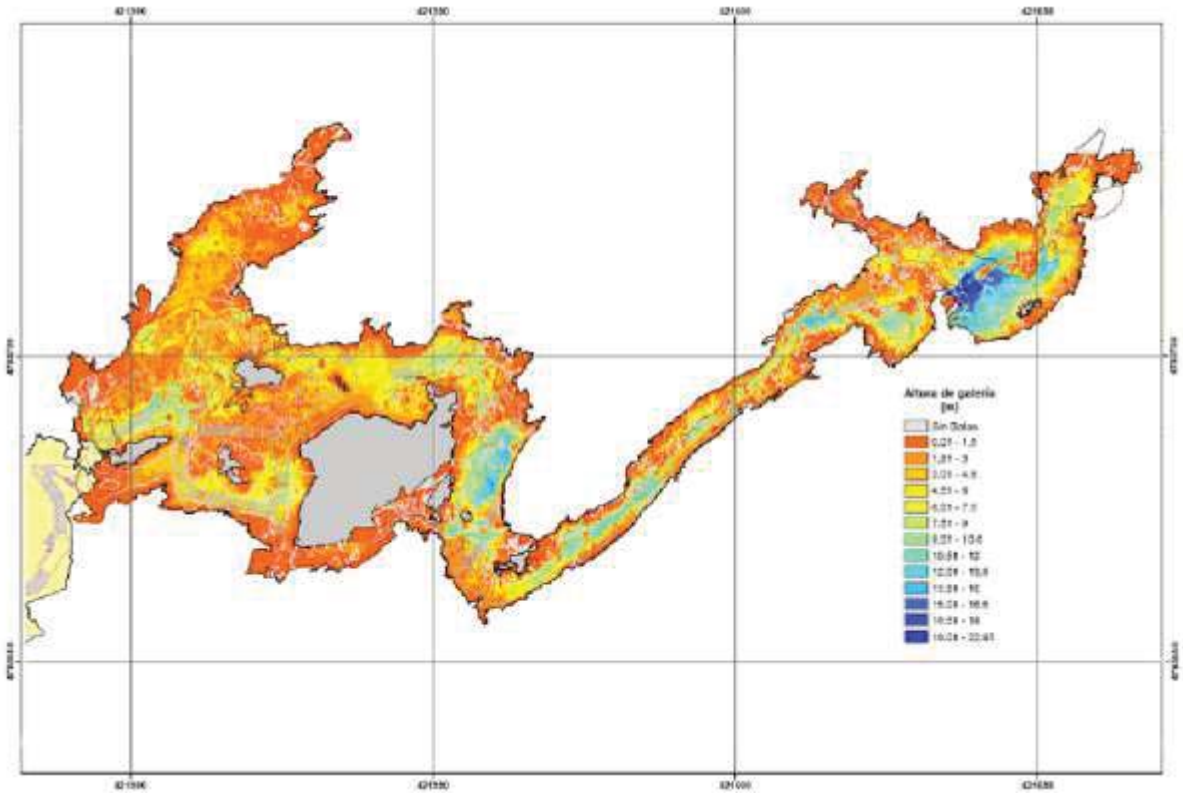


Figure 3: Detail of height galleries.

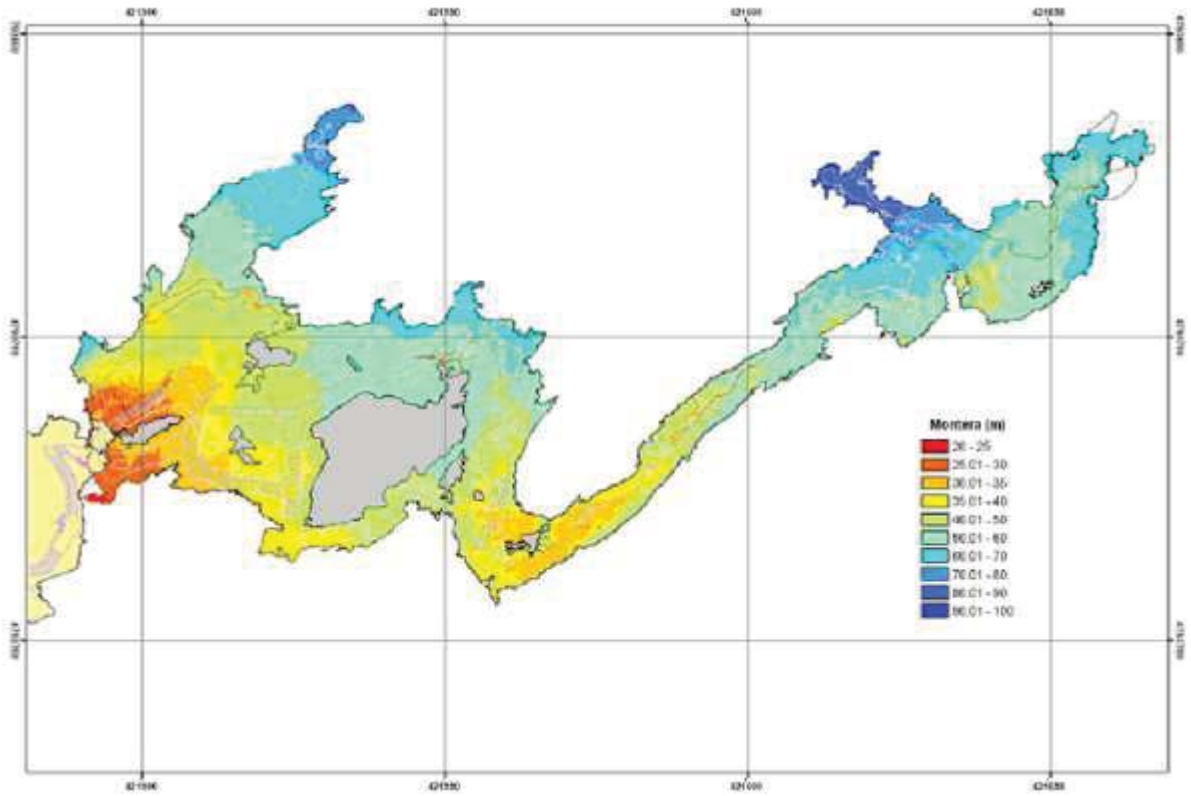


Figure 4: Thickness of the roof.

G) Generation of virtual models.

be used in virtual reality systems. Broadly the steps are as follows:

- Transformation models or points recorded by scanner to manipulable geometry.
- Construction of the 3D model.
  - Continuous Polygonal modeling.
  - Applying color with photorealistic textures.
  - Calculation of the realistic lighting model, that should be viable in real time.
- Development of the script of the application.
- Programming of the Virtual Reality aplication, that has to be real-time interactive.
  - Development of a script of the application.
  - Development of interfaces of the application.

- Visual representation by "High Level Shading Language" (HLSL) to obtain a realistic representation.

- Development and inclusion of multimedia elements to facilitate distribution of content from existing information

H) Generation of physical models

From point cloud data,

Sometimes an exact replica of the cave is needed. Point cloud data constitute the raw material to create it. The 3D model is 3D printed in parts, this pieces are mounted to constitute the basic support that later is decorated.



Figure 5: Generation of virtual models

4. Results

In view of the work it can be concluded that:

- It is possible to carry out a rapid, accurate and reliable measurement of complex elements such as caves or cavities;

- The information can be used to derive maps such as floor plans, contour levels, longitudinal and cross sections or three-dimensional analysis and calculation of heights or thickness of the roof by model comparison.

- The laser scanner, due to the operational readiness in field, the accuracy of data, the possibilities of representation and safety can be considered as an optimal tool for heritage.

- The combination of traditional methods such as polygonal geomatics surveying and GNSS (Global Navigation Satellite System) as with other modern 3D Laser Scanner allows documenting caves in a rigorous and safe way for the heritage.

- This information, can be used as a basis for managers to support their decisions and perform different simulations of predictive behavior processes within a knowledge based system.

- A novel departure cartographic documentation is the creation of virtual models, allowing the tourist exploitation of those resources, and avoiding damage by overuse. In short it is a solution that can achieve a balance between conservation and dissemination.

5. Conclusions

Looking ahead presents many challenges:

- Computational improvements: The study of systems of algorithms to accelerate the adaptation processes of initial data to create geometric data with topological structure.

- More efficient management: Create a Cave information management system, which can be used in decision-making about the same. A dynamic system, with thematic information that allows a real time monitoring.

- Scientific research: intercorrelation of more parameters in complex models that integrate information such as hydrochemistry, water microbiology, climatic, geotechnical and fauna.

- Promoting tourism: higher definition virtual tours. It will be possible to remove a smaller amount of data acquired in the initial phase, and get higher definition models.

References

Barrera, S., A. Otaola, and V. Bayarri. 2008. "Explotación turística no intrusiva de la Cueva de Santimamiñe (Vizcaya) mediante realidad virtual." Paper presented at the II Congreso español sobre cuevas turísticas, Cuevatur 2008. 16-18 octubre de 2008.

Fortea-Pérez, F. J. 1993. *La protección y conservación del arte rupestre paleolítico*. Columbres: Servicio de Publicaciones del Principado de Asturias.

Juberthie, C. 1995. "Cave of Altamira and Paleolithic Cave Art of Northern Spain." *Underground habitats and their protection. Council of Europe Publishing. UNESCO*. http://whc.unesco.org/en/list/310.

New techniques for artefactual surveying: GIS-GPS methodology for the study of Roman habitational contexts

Jesús García-Sanchez[1]

Armando Ezquerro Cordón[2]

[1]Departamento de Ciencias Históricas, Universidad de Cantabria.

[2]Departamente de Prehistoria, Hª Antigua yArqueología, Universidad de Salamanca

Abstract

This paper introduces a hand-held GPS methodology for recording intra-site archaeological datasets. The suggested procedure can be used as a first approach to site definition and in addition as a basis for traditional surveys with systematic sampling and grabbing. The GPS-GIS assisted methodology helps record, manage and analyze clouds of points rather than grid information. To conclude, we present two case studies of several Roman sites in north-central Spain.

Keywords: *GPS, GIS, Field survey, Methodology, Roman Archaeology*.

1. Introduction

The continuous improvement of geopositioning techniques and the increasing availability of multiple outcomes of geographical datasets have made its mark on our current understanding of archaeological records. There are currently big concerns about the application of GIS in archaeology, without remembering that such techniques have been applied to archaeological research since the early 1990s. Now that the tools of this technique are widely available to archaeologists, it is time to explore its inherent capabilities, in order to develop new methodologies, rather than the simple mechanization of tasks that was constantly found in archaeological publications before the "revelation" of GIS.

Those fieldwork techniques which led us to achieve a great understanding of our remote past over previous decades have been updated, thanks to a synergy with information technology; our focus here will be on field surveying. Nevertheless, the rebirth of many of these "old methodologies" are not aimed at neglecting previous applications, but to reinforce them through the introduction of new capabilities of data recording, and managing and displaying surface archaeological datasets.

The pattern distribution of survey collection has been traditionally analysed within units of different shapes and sizes, even developing interesting quantitative approaches (Millet 1991). The inherent spatiality of artefacts has been neglected for several methodological reasons: firstly the huge amounts of pottery in surface scatters and secondly, the scarcity of adequate measuring techniques to deal with such scatters. Sometimes sampling strategies were successfully developed to carry out grabs and artefact collections over sites, resulting in appropriate datasets but in loss of information and the need for interpolations in order to generalize the understanding of regional or micro-regional contexts (Banning 2002).

In the Iberian research context, the inherent spatiality of single artefacts was tackled in the survey of several micro-regions in Extremadura using GPS techniques (Mayoral, Cerrillo Cuenca, and Celestino 2009). That experience was used in regional contexts, while specific places with density peaks over the "background noise" were studied by sampling techniques. Our proposal was inspired by their work, with the aim of achieving a complete record of ancient sites by the geolocation of every sherd or building material within a feasible site context.

2. Code Per Material (CPM) methodology

By developing a hand-held GPS methodology we want to study the spatiality of artefact distributions in site-oriented surveys. GPS allows the user to select different kinds of symbols for displaying different features: we are using it to record scatters in a continuous-path survey. This technique is suitable for recording smooth density surfaces with high detail (including EGNOS correction). These artefact densities can be easily integrated into specific GIS software for the purpose of comparison with other techniques, such as aerial photography or geophysics (Gillings 1996). Furthermore the spatial attributes of large datasets lead us to develop geostatistical analysis, such as Nearest Neighbour, Local Indicators of Spatial Association (Anselin 1995), or Getis-Ord's Hot Spot Analysis (Getis and Ord 1992).

That methodology has been dubbed Code Per Material or CPM, due to the creation of a code-list to represent different kinds of artefacts, from building materials to table and coarse wares. That code-list is open and some new codes can be incorporated during the survey; common-sense communication between surveyors is the only requirement. The resulting cloud point has to be split by the attribute field represented by the kind of artefact. Then we are able to work separately with each layer of information and to compare the presence or absence of different categories of artefacts which might indicate variability in the use of both house spaces or dwelling activities in the surroundings of sites.

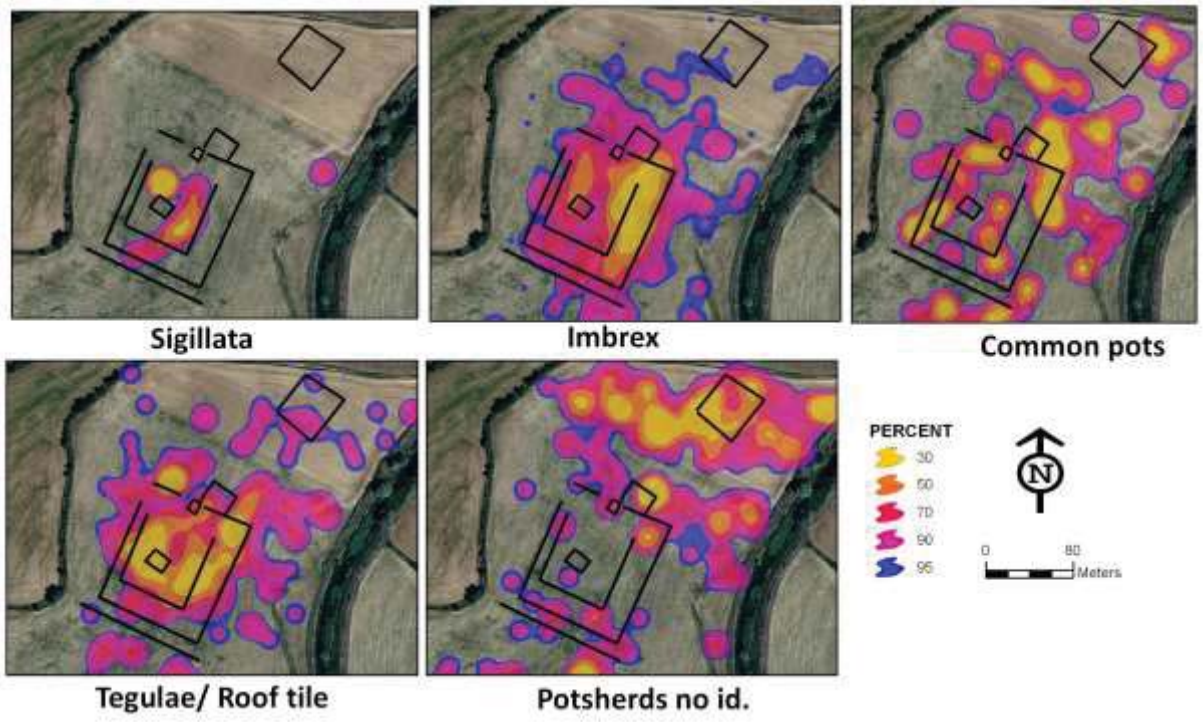


Figure 1: Application of CPM methodology, from general point cloud to single categories densities in Tisosa, Burgos.

2.1 CPM in action: Cardenas River and Sasamón (Burgos)

We present two cases of application of CPM in Roman sites. In this historical context several kinds of artefact, mainly pottery, can be feasibly detected and easily classifiable in the field. Firstly, the Cardenas River survey (La Rioja, Spain) offers some Late Roman villas whose various spatial patterns present differences of both use and occupation in the transitional period to Early Medieval Times.

Moreover, the application of CPM methodology has allowed us to differentiate concentrations of material associated with codes, such as *tegulae*, brick, Late Sigillata, thereby revealing sites with a higher density of construction material, sites with areas of lesser and greater amounts of ceramic material, etc. This enables us to understand the relationship between these sites and the environment (Ezquerro 2011). This CPM methodology has proved to be useful for quick reconnaissance of several sites, some of them with large areas of site-haloes, and has served as a basis for detailed sampling over the main areas. This second survey stage opted for a survey of 1% of the site core, creating a 10 by 10 grid, sampled by means of a 1 sq. metre within each of these grids.



Figure 2: Point cloud over a large Late Roman site in Prados (Cardenas valley).

Secondly, an off-site survey (García-Sánchez and Cisneros 2013) in the surroundings of Sasamón (Burgos, Spain) led to the detection of a large Early Roman building. We named it "Tisosa" after the enormous concentration of building materials, especially Roman roof tiles (tejas). During the autumn of 2011 the proposed methodology was applied in the context of several fields or estates around the expected site-core. CPM has produced information about the core area of this building, and differential patterns of pottery distribution for evaluating human behaviour (C-transforms) and environmental development (N-transforms) in the formation of archaeological record.

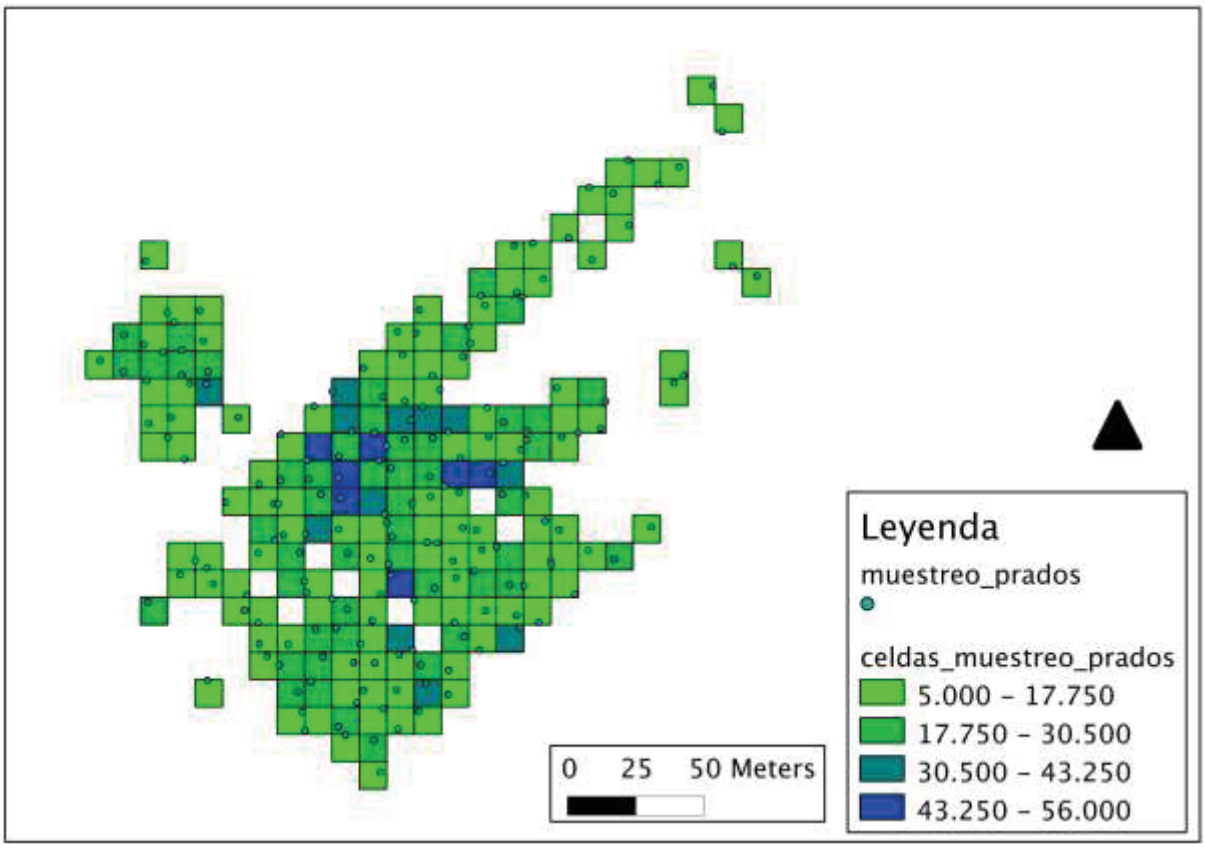


Figure 3: Random sample after CPM in Cardenas valley.

3. Conclusions

As usual, with new methodological proposals, some problems have occurred. During the application of CPM, we faced important issues that have to be discussed carefully. First of all the CPM methodology is based on a continuous-path of where surveyors have to cover the complete area of the site and its closer periphery, sometimes called the site-halo. Each crew member has different knowledge about material culture and some categories are difficult to detect, i.e. early *sigillata* and late *sigillata* are difficult categories for quick recognition by beginners, and that is why traditional surveys make artefact collections for further lab study. Other categories are easier to identify, such as building materials, plain roof tiles or curved tiles. The simpler the codes, the easier it is to commit identification mistakes.

However, there is a critical point of code simplification, below which datasets start to represent nothing but densities, without any further information about the site core, functionality of spaces, chronology and so on. A very large codification of artefacts could be suitable for surveyors with advance knowledge of material culture, but even in these cases we accept that a proper artefactual study must be carried out by traditional approaches. In this sense, the site of Tisosa has been re-surveyed in order to create such an on-site record, and to compare it with the previous results of the

CPM. Eventually, thanks to the detailed spatial information of every sherd this information can be compared to that obtained from grids in statistical terms, e.g. with means analysis, with Student's t test or a non-parametric Wilcoxon test for univariate category comparisons (i.e. tegula densities located in different surveys over a single site) or multivariate analysis for group comparisons.

References

Anselin, L. 1995. "Local Indicators of Spatial Association—LISA." *Geographical Analysis* 27 (2): 93–115.

Banning, E.B. 2002. *Archaeological Survey*. Manuals in Archaeology Method, Theory and Technique. Nueva York: Kluwer Academic.

Ezquerro Cordón, A. 2011. "Desde la Antigüedad Tardía hasta la Alta Edad Media Una propuesta metodológica." In *Actas de las II Jornadas de Jóvenes en Investigación Arqueológica (Madrid, 6, 7 y 8 de mayo de 2009). JIA 2009, Tomo II.*, edited by OrJIA, 439–445. Zaragoza: Portico.

García Sánchez, J., and M. Cisneros Cunchillos. 2013. "An off-site approach to Late Iron Age and Roman landscapes in the Northern Plateau, Spain." *European Journal of Archaeology* 16(2): 289-313.

Getis, A. and J. K Ord. 1992. "The Analysis of Spatial Association by Use of Distance Statistics". *Geographical Analysis* 24 (3): 189–206.

Gillings, M. 1996. "The Utility of the GIS Approach in the Collection, Management, Storage and Analysis of Surface Survey Data". In *The future of Surface Artefact Survey in Europe*, edited by John. Bintliff, Martin. Kuna, and Natalie Venclová, 105–120. Sheffield: Sheffield Academic Press.

Mayoral Herrera, V., E. Cerrillo Cuenca, and S. Celestino. 2009. "Métodos de prospección arqueológica intensiva en el marco de un proyecto regional: el caso de la comarca de La Serena (Badajoz)." *Trabajos de Prehistoria* 66 (1): 7–25.

Millet, M. 1991. "Pottery: populations or supply patterns? The Ager Tarraconensis approach." In *Roman Landscape. Archaeological Survey in the Mediterranean Region*, 18–26. Archaeological Monographs of the British School at Rome 2. London: British School at Rome.

Palaeolithic sites beyond the archaeological deposits

Alejandro García Moreno [1]

Miguel Ángel Fano Martínez [2]

[1] Cantabria International Institute for Prehistoric Research, University of Cantabria. Spain.

[2] Departamento de Ciencias Humanas, Universidad de La Rioja. Spain.

Abstract

Research on Palaeolithic foraging societies has tended to focus on the archaeological deposits formed by the everyday activity of the groups being studied. In contrast, the location and characteristics of the sites containing those deposits have hardly been studied systematically through the application of particular methodologies. However, these sites, whatever activity might have been carried out in them, are also part of the archaeological record, since they were chosen by the hunter groups, and this choice cannot be ignored. In this sense, a particular methodology can be applied to study site locational characteristics and obtain relevant information about the groups' settlement patterns, while an anthropological interpretation of the results will enable an understanding of hunter-gatherer society dynamics. In this paper, we show the possibilities of the application of this kind of approach, focusing on a concrete region, the Nalón river basin (Northern Iberia).

Keywords: *site location preferences, GIS, Late Palaeolithic, Cantabrian Spain, settlement patterns*

1. Introduction

Traditionally, the study of Palaeolithic societies has been based on the analysis of the archaeological deposits, i.e. of their *material culture*. However, if we consider the material culture of past societies in a wider sense, according to which "*material culture was often not a direct reflection of human behaviour; rather it was a transformation of that behaviour"* (Hodder and Hutson 1986: 2), it is clear that such studies cannot be restricted to their material remains (in a general sense) but should also include any aspect reflecting the processes of decision-taking within the Palaeolithic societies, as well as their economic and social organisation.

Hence, the places where the archaeological deposits are found (the sites themselves) form part of the material culture left by Palaeolithic communities, as they were "selected" as a place for occupation in a conscious decision, based on a series of preferences, in order to satisfy certain

needs. Therefore, this act of selecting means that the sites are another aspect of the archaeological record, as they reflect human behaviour.

The study of the reasons that caused a group of Palaeolithic hunters to choose a certain site as a dwelling place, and the determination of the needs which this choice aimed to satisfy, require the use of a specific methodology, designed *ad hoc*, adapted to the particular nature of this type of record. The methodology should be focused on the *locational characteristics* of the sites being studied; a series of factors that are capable of defining their living conditions and their position within the environment and in relation with other sites.

For this purpose, Geographical Information Systems are advantageous, as they enable the quantitative analysis of a series of factors that might influence the process of selecting a site to be occupied (García Moreno 2013). In this way, the locational characteristics of the different sites can be defined objectively so that models reflecting the role played by different sites in their regional context can be established, taking into account other social realities obtained through the study of the archaeological record *sensu stricto* (activities carried out, seasonality of the occupations, etc) (García Moreno and Fano 2011).

2. Justification

Several factors may condition the choice of any given site (Eriksen 1997; Duchadeau-Kervazo 1986), as this choice is the result of a complex process of decision-making aimed at satisfying the group's needs, which, as explained below, are not always connected with their subsistence. In fact, the choice of a certain place might be affected by much more subtle factors, such as the significance or symbolism of elements in the landscape (Tilley 1994), and it always depends on the available options.

Therefore, the availability of natural shelters, like caves and rock-shelters, will favour the choice of such sites for settlements, which is indeed the case on the coast of Northern Spain (González Morales 1997). In other regions, the absence of shelters of that kind will result in dwelling structures being built (Desbrosse and Kozlowski 1994). However, the simple existence of caves does not guarantee that they will be suitable shelters, as that depends on their habitability conditions, which are determined by such factors as their size, internal climate (Márquez Romero and Morales Melero 1986; Ramil Rego 1989-1990), or insolation at their entrances and in their surroundings (García Moreno 2008; Fano 1998), among others.

However, apart from their natural availability and habitability, the choice of a site is normally associated with the exploitation of the environment and resource catchment, supposing that

forager societies tend to locate their settlements in "strategic" places; emplacements allowing them easy access to certain resources, both prey and abiotic goods. Examples are rivers, lakes and fords, where herds of ungulates congregate (Dolukhanov 1997; Julien 1989). Hence, the identification of sites that were highly specialised in capturing certain resources led to the term *"logistic* site" being coined, contrasting with "residential sites", where a much wider range of activities would have been carried out (Binford 1980).

In other models, the access to resources was not considered a determining factor in the choice of a site; this is the case of M. Conkey's aggregation sites (Conkey 1980), where the key seems to be the possibility of congregating a large number of people, and P. Utrilla's base camps (Utrilla Miranda 1994), prioritising characteristics like size, habitability conditions, proximity to sources of water, location, etc. Other authors vindicate symbolic factors, connected with the role sites might play in the perception of the environment and the social construction of prehistoric landscapes (Diggs, Brunswig, and Lambert 2012; González Morales 1997; García Moreno *in press*).

Therefore, the analysis of the elements intervening in the choice of a certain place for a Palaeolithic occupation should be approached from a double perspective: regional and dialectic.

Firstly, it becomes especially important to accept the need for a regional approach as a long-term research strategy for the study of Palaeolithic societies. If the understanding of a Palaeolithic site includes a good knowledge of its local and regional context, as the nomadic nature of these societies seems to require, it is clearly necessary to incorporate precise information about the places where archaeological deposits exist. In this way, our hypotheses about the role played by the different sites within their social context acquire greater robustness.

Secondly, the choice of a place for occupation makes it an integral part of the landscape, as it plays a specific role in the subsistence and social organisation of the human groups. Consequently, settlements are not static and passive places used for shelter and capturing resources, but become *landmarks*, destinations to be reached and where certain economic and social actions are performed. There is therefore a dialectic relationship between the territory (the context of habitability conditions and container of available resources) and the site (which participates in the construction of a social landscape through its own symbolic significance, as a geographical and social landmark) (Butzer 1982).

3. Methodology

The systematic analysis of the characteristics and location of archaeological sites requires the application of a specific methodology allowing an objective comparison between different sites, in the framework of a regional approach as described above.

The methodology applied in this study is based on the definition of a series of indicators that describe the position of each site and the area where they are situated objectively and quantitatively. These indicators can be divided into *Parameters,* which are obtained by direct observation and measurements in the field, and *Variables,* which require the use of a Geographical Information System to be modelled and quantified (García Moreno 2013).

However, site location analysis is only able to assess the factors that might have influenced the choice of the sites; understanding the role played by each site within its regional context and the relationships between different sites requires the integration of data obtained in the location analysis with the information from other archaeological studies (Fig. 1).

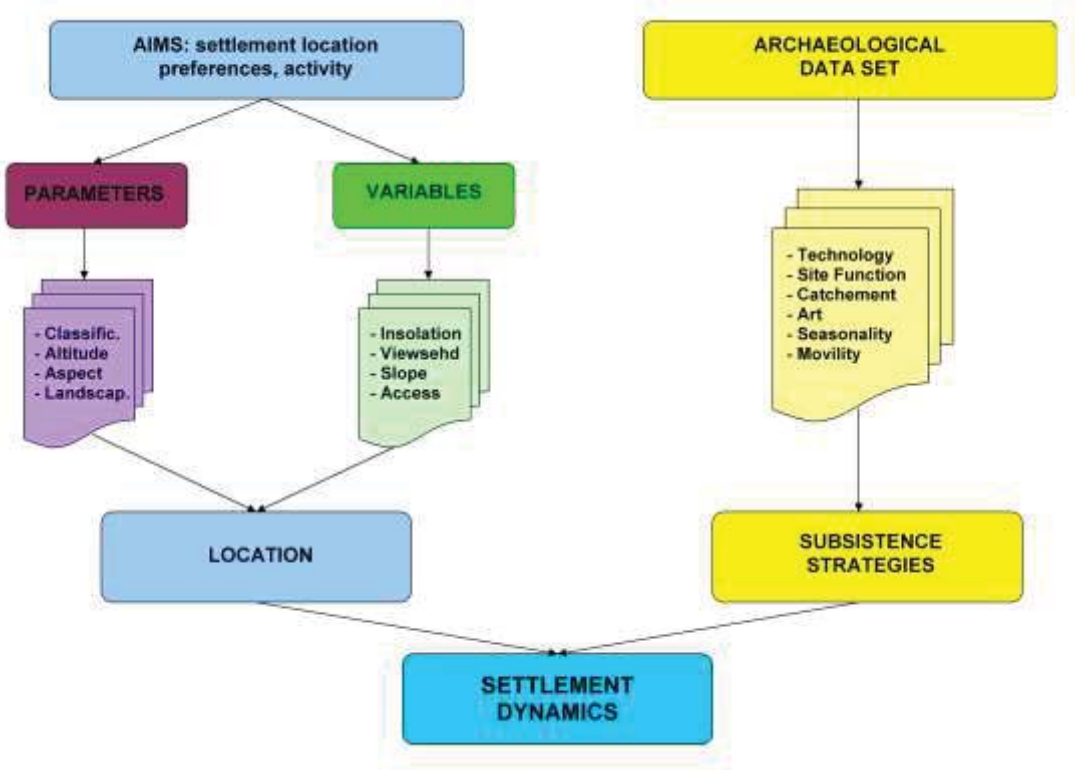


Figure 1: The understanding of Paleolithic settlement patterns requires the integration of site location analyses and archaeological data, as well as the adoption of regional perspective.

4. A case study: the Late Palaeolithic of the Nalón river basin (Asturias, North of Spain)

The Nalón River Basin is an important area in Upper Palaeolithic studies in Northern Spain because of a research project initiated in the 1980s which involved the excavation of several caves and rock-shelters with thick occupation levels belonging to different periods (Fortea 1981). The best documented period in the Nalón river basin is the late Magdalenian, represented by occupation levels at seven sites and evidence of rock art in an eighth, Peña Candamo cave (Fig. 2). This cave was decorated at different times, from the Early Upper Palaeolithic to the Late Magdalenian (Moure 1981; Corchón et al. 2011). The other sites with late Magdalenian levels included in this study are the rock-shelter of La Viña (Fortea 1992), the caves of Las Caldas (Corchón 2007; Corchón *et al.* 2005), Oscura de Ania (Adán et al. 2002), and Sofoxó (Corchón and Hoyos 1972-73; González Sainz 1989), the rock-shelter of Entrefoces (González Morales 1992; González Sainz 1989), and the caves of La Lluera I (Rodríguez Asensio 1990), and La Paloma (Hoyos et al. 1980; González Sainz 1989).

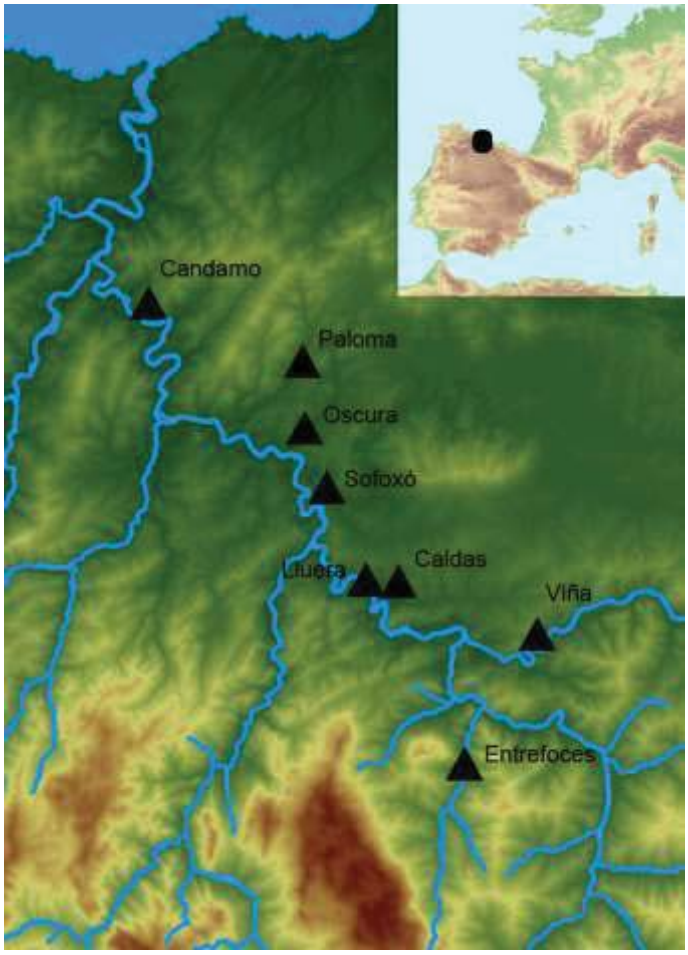


Figure 2: Nalón river basin archaeological sites studied.

The location analysis of this group of sites with the methodology described above succeeded in determining their locational characteristics and the preferences of Magdalenian hunter-gatherer groups shown in their choices of sites. The existence of two very different types of locations could be demonstrated.

First, two sites characterised by their dominant position were identified: La Viña and Candamo (Fig. 3a-b). These are the only sites located midway up the hillsides, which means they enjoy large viewsheds over the surrounding area, together with significant visual presence (*sensu* Garcia Moreno *in press*). At the same time, together with La Lluera, they are the only sites located in the main Nalón river valley. Within the river basin, they are located at the two ends of the group of sites, as they are the first (Candamo) and the last (La Viña) encountered when moving up-valley. Finally, together with Entrefoces, they are the only sites with no other sites within the two-hour isochrone (Fig. 4).

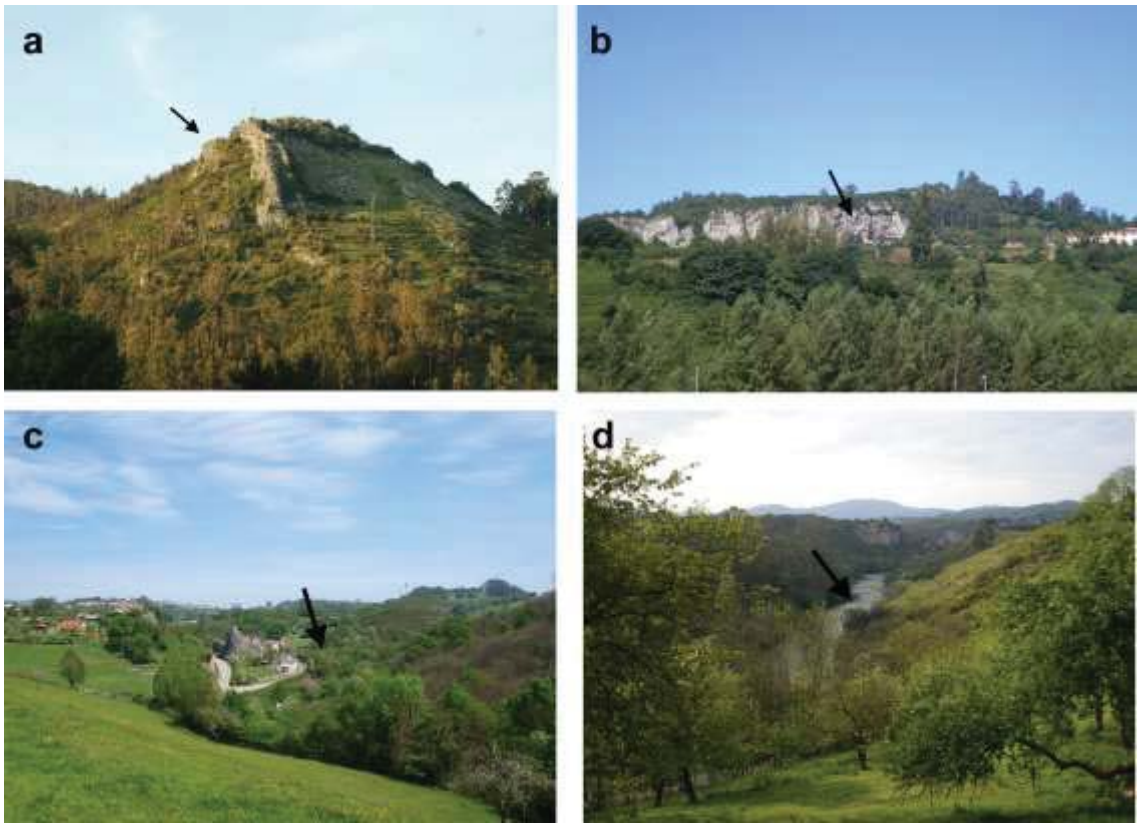


Figure 3: Different sites location along the Nalón river basin: a) Peña de Candamo; b) La Viña; c) Las Caldas; d) Sofoxó.

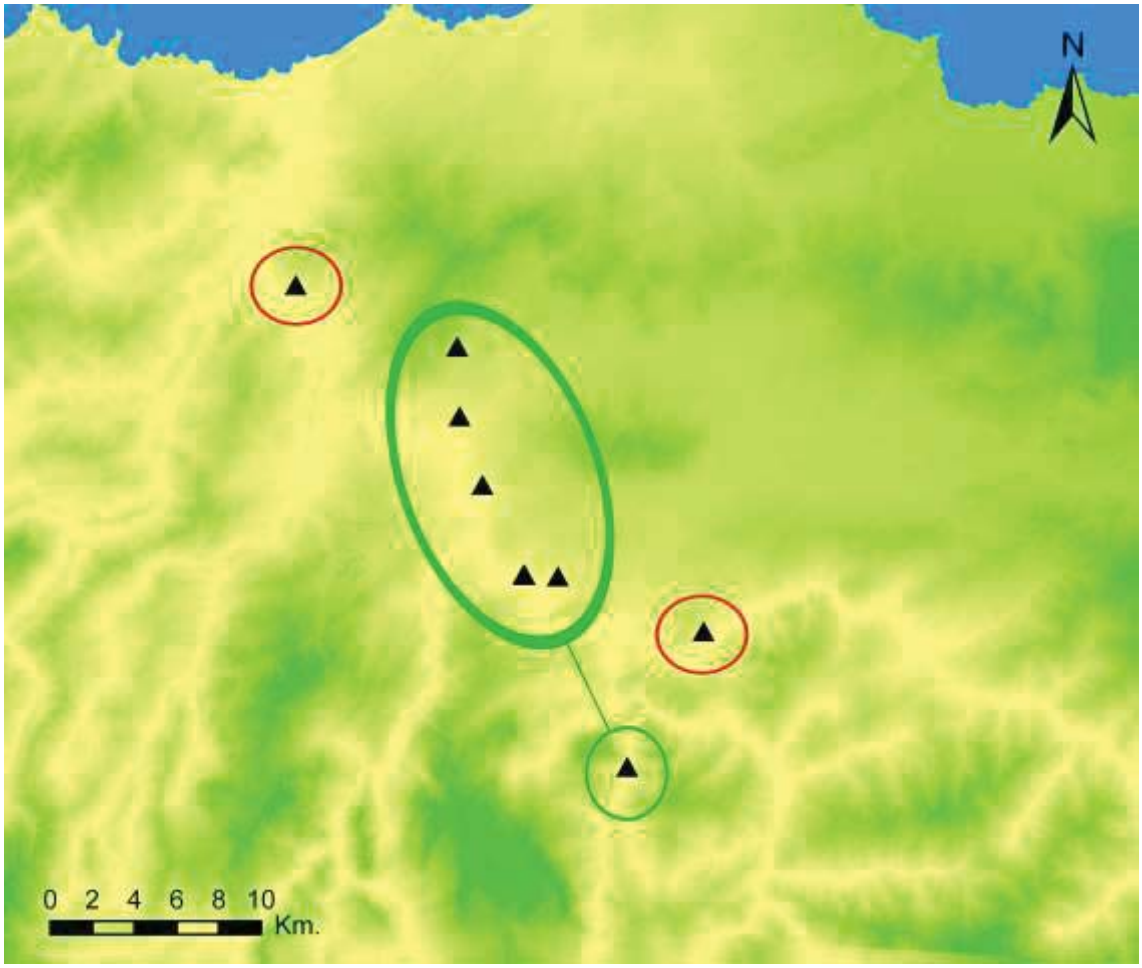


Figure 4: Cumulative Cost Model of movement and diagram of land use pattern for the Nalón river basin. Yellow colors represent the areas with the less cumulated cost, while green represent areas with the higher cost of movement. The green circle represents the sites located on valley/bottoms as well as the network of inter-related sites, while red circles represent the two mid-slope located, exclusive sites.

In contrast, the other sites are located in the valley bottoms, less than ten metres above the lowest point in their surrounding areas, in some cases practically at the level of the modern water-course (Fig. 3c-d). This position means that most of them possess low visibility, apart from those found in open areas, such as the cave of Las Caldas. Except for La Lluera, as mentioned above, all these sites are located in side valleys, tributaries of the Nalón river. However, they are all related with each other, as isochrone calculations reveal that every site is within two hours' distance on foot of at least one other site. Entrefoces rock-shelter, situated in the first foothills of the Cantabrian Mountains is the only exception to this.

5. People beyond the archaeological deposits

In short, the late Magdalenian sites being studied exhibit significant similarities and differences regarding their location. Six of them are situated in relatively similar locations: valley bottoms, with a very low relative altitude allowing more direct access to their surrounding areas and in general with limited visibility from the sites. However, this varies depending on the characteristics of the surroundings of the sites. The other two sites, Peña Candamo and La Viña, are situated in a very different position. They are located on hillsides, in prominent positions within the landscape, with viewsheds that are in general much larger than those of the sites in the valley bottom. At the same time, they appear to be *exclusive* sites, as no other sites are found within two hours' walking time from them. These similarities and differences must have been significant in connection with the role played by each site in its social context.

All this indicates the great interest, within the proposed kind of regional approach, of this type of data for a more anthropological reading of the Magdalenian record. In addition, the evolution in population patterns over time could be linked with the changes identified in economic practices (García Moreno 2013). In this way, the site distribution in the Nalón basin in the late Magdalenian, with a predominance of spatially interconnected sites in the bottoms of side valleys, might respond to an interest in exploiting the territory more directly, in step with the economic diversification that occurred in this period (Terradas Batlle, González Urquijo and Ibáñez Estévez 2007).

6. Acknowledgements

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References

Adán, G., E. García, and J. M. Quesada. 2002. "La industria ósea magdaleniense de Cueva Oscura de Ania (Las Regueras, Asturias). Estudio tecnotipológico y cronoestratigrafía." *Trabajos de Prehistoria* 59 (2): 43-63.

Binford, L. R. 1980. "Willow smoke and dogs' tails: Hunter-gatherer settlement systems and archaeological site formation." *American Antiquity* 45 (1): 4-20.

Butzer, K. W. 1982. *Arqueología. Una ecología del hombre*. Cambridge: Cambridge University Press.

Conkey, M. W. 1980. "The identification of Prehistoric Aggregation Sites: the case of Altamira." *Current Anthropology* 21 (5): 609-630.

Corchón Rodríguez, M. S. 2007. "Investigaciones en la cueva de Las Caldas (Priorio, Oviedo). V. Los niveles del Magdaleniense superior." *Excavaciones Arqueológicas en Asturias 1999-2002* 5: 47-61.

Corchón Rodríguez, M. S., and M. Hoyos. 1972-73. "La cueva de Sofoxó (Las Regueras, Asturias)." *Zephyrus* XXIII-XXIV: 39-102.

Corchón Rodríguez, M.S, A. Mateos, E. Álvarez, J. Martínez, and O. Rivero. 2005. "El final del Magdaleniense medio y la transición al superior en el valle medio del Nalón (Asturias, España)." In *O Paleolítico. Actas do IV Congresso de Arquelogia Peninsular*, edited by N. Bicho, 77-107. Faro: Universidade do Algarve.

Corchón Rodríguez, M.S, D. Garate, D. González, A. L. Muñoz, J. Gómez and J. Sabas. 2011. "Nouveaux regards sur la grotte de La Peña (San Román de Candamo, Asturies)." *L'Anthropologie* 113 (4): 384-424.

Desbrosse, R., and J. Kozlowski. 1994. *Les habitats prehistoriques. Des Australopithèques aux premiers agriculteurs., Documents Préhistoriques*. Cracovia: Université Jagellon.

Diggs, D. M., R. Brunswig, and S. Jo Lambert. 2012. Viewshed Analysis of Native American Sacred Landscapes. In *2011 ESRI User Conference Proceedings*: ESRI. Online: http://proceedings.esri.com/library/userconf../proc11/papers/3027_59.pdf.

Dolukhanov, P. 1997. "Cave versus Open-Air settlement in the European Upper Paleolithic." In *The Human use of caves*, edited by C. Bonsall and C. Tolan-Smith, 9-13. Oxford: Archaeopress.

Duchadeau-Kervazo, C. 1986. "Les sites paléolithiques du bassin de la Dronne (nord de l'Aquitaine). Observations sur les modes et emplacements." *Bulletin de la Société Préhistorique Française* 83 (2): 56-64.

Eriksen, B. V. 1997. "Settlement patterns, cave sites and locational decisions in Late Pleistocene Central Europe." In *The Human use of caves*, edited by Clive Bonsall and Christopher Tolan-Smith, 38-49. Oxford: Archaeopress.

Fano Martínez, M. A. 1998. "La insolación como factor condicionante en la elección de los espacios destinados al hábitat: propuesta metodológica y primeros resultados para el Mesolítico del Cantábrico occidental." *Arqueología Espacial* 19-20: 121-134.

Fortea Pérez, J. 1981. "Investigaciones en la cuenca media del Nalón, Asturias (España). Noticia y primeros resultados." *Zephyrus*, 32-33: 5-16.

Fortea Pérez, J. 1992. "Abrigo de La Viña. Informe de las campañas 1987 a 1990." *Excavaciones Arqueológicas en Asturias 1987-1990*, 2: 19-28.

García Moreno, A. 2008. "Insolación y Hábitat paleolítico en el Valle del Asón (Cantabria, España). Análisis de la influencia de la insolación en los modelos de ocupación paleolíticos." *Cuaternario y Geomorfología* 22 (3-4): 93-105.

García Moreno, A. 2013. "GIS-based methodology for Palaeolithic site location preferences analysis. A case study from Late Palaeolithic Cantabria (Northern Iberian Peninsula)." *Journal of Archaeological Science* 40 (1): 217-226.

García Moreno, A. *in press*. "To see or to be seen, is that the question? An evaluation of Paleolithic sites' visual presence and their role in social organization." *Journal of Anthropological Archaeology*.

García Moreno, A., and M. A. Fano. 2011. "Los sitios paleolíticos en su paisaje: la cueva de El Horno en el contexto de la cuenca del Asón (Cantabria)." *Zephyrus* LXVII: 15-26.

González Morales, M. R. 1992. "Excavaciones en el abrigo de Entrefoces. Campaña de 1987 y 1989." *Excavaciones Arqueológicas en Asturias 1987-90*, 2: 49-52.

González Morales, M. R. 1997. "Changes in the use of caves in Cantabrian Spain during the Stone Age." In *The Human use of caves*, edited by Clive Bonsall and Christopher Tolan-Smith, 63-69. Oxford: Archaeopress.

González Sainz, C. 1989. *El Magdaleniense superior-final de la región cantábrica*. Santander: Ed. Tantín.

Hodder, I., and S. Hutson. 1986. *Reading the past. Current approaches to interpretation in Archaeology*. Cambridge: Cambridge University Press.

Hoyos, M., M. I. Martínez, T. Chapa, P. Castaños and F. B. Sanchiz. 1980. *La Cueva de La Paloma, Soto de las Regueras (Asturias)*. Madrid: Ministerio de Cultura.

Julien, M. 1989. Activités saisonniers et deplacements des Magdaleniens dans le Bassin Parisien. In *Le Magdalenien en Europe. Actes du Colloque de Mayence 1987*, edited by Jean-Philiphe Rigaud, 177-192. Mayence: Université de Liège.

Márquez Romero, J. E., and A. Morales Melero. 1986. "La habitabilidad de las cuevas: análisis morfológico." *Arqueología Espacial* 7: 169-181.

Moure Romanillo, A. 1981. "Algunas consideraciones sobre el mundo de los grabados de San Román de Candamo (Asturias)." In *Altamira Symposium*, edited by Martín Almagro Basch, 339-352. Madrid: Ministerio de Cultura, Dirección General de Bellas Artes, Archivos y Bibliotecas.

Ramil Rego, E. 1989-1990. "Habitabilidad cavernícola: elección de asentamientos." *Brigantium* 6: 191-197.

Rodríguez Asensio, J. A. 1990. "Excavaciones arqueológicas realizadas en la cueva de La Lluera (San Juan de Priorio - Oviedo)." *Excavaciones Arqueológicas en Asturias 1983-1986*, 1: 5-17.

Terradas Batlle, X., J. E. González Urquijo, and J. J. Ibáñez Estévez. 2007. "Los territorios durante el paso al Holoceno en los dos extremos del Pirineo." In *Frontières naturelles et frontières culturelles dans les Pyrénées préhistoriques. / Fronteras naturales y fronteras culturales en los Pirineos prehistóricos. Actas de la reunión celebrada en Tarascon-sur-Ariège en marzo de 2004*, edited by Nathalie Cazals, Jesús E. González Urquijo and Xavier Terradas Batlle, 183-203. Santander: Universidad de Cantabria.

Tilley, C. 1994. *A phenomenology of landscape*. Oxford/Providence: Berg Publishers.

Utrilla Miranda, P. 1994. "Campamentos-base, cazaderos y santuarios. Algunos ejemplos del paleolítico peninsular." In *Homenaje al Dr. Joaquín González Echegaray*, edited by Jose Antonio Lasheras, 97-113. Madrid: Ministerio de Cultura.

Volumetric study of megalithic constructions of the Eastern Pyrenees

Elisabet López i Garriga[1]

[1]ARCHAEOM.Prehistory Department.UniversitatAutònoma de Barcelona.

Abstract

The use of geographic information system (GIS) in the study of the investment work and the socioeconomic structure of the communities who erected the megalithic constructions in the Eastern Pyrenees has an elaborate process on obtaining data and the subsequent mathematical, statistical and GIS treatment of it. The aim is to achieve the social knowledge of the communities that occupied the north-eastern region of the Iberian Peninsula in the Chalcolithic period.

Keywords: *GIS, megalithic constructions, volumetry, geography relations, investment work*.

1. Introduction

The megalithic constructions from a spatial perspective are analysed. This spatial perspective linked to the investment work employed in building these constructions give knowledge of the socioeconomically structure of the communities that built them. The study is made by GIS methodology, which is linked to mathematical calculations in order to obtain the volume of built spaces and it is followed by a statistical treatment of data. In this context, using GIS methodology, the current study examines the link between the investment of work and the specific site of each of the megalithic constructions.

2. Geographic Information System

The geographic information systems (GIS), in general terms, are the tools that allow users to create consults, analyse spatial information, edit data in maps and present the results. An advantage is that these systems can relate information from different sources. For this reason, and recalling that the megalithic constructions have spatial dimension, the use of these systems in this study is the best way to do it. Prior to the creation of a GIS map, a key parameter is used: the internal volume of the megalithic structure and the volume of the mound structure of each of the megalithic constructions, calculated from developed mathematical formulas. The cases of study to perform the mathematical calculations are 26 megalithic constructions of the Pyrenees

in the north-eastern Iberian Peninsula.Obtained the mathematical results,it proceedsto the relationship between these data and spatial data in order to determine the investment work.

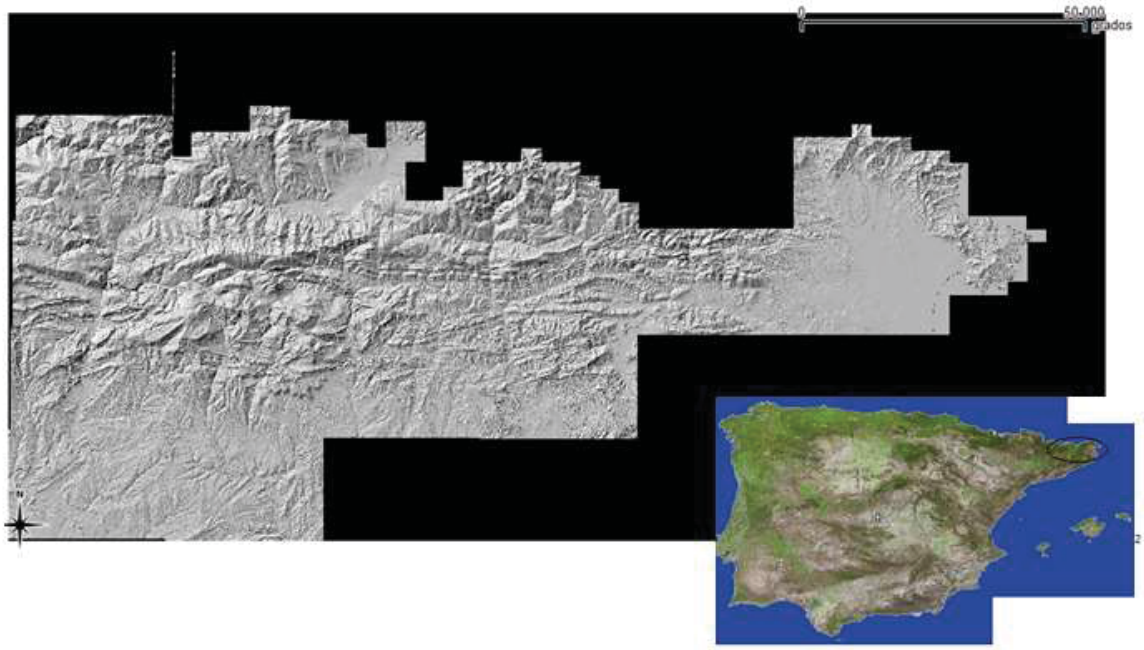


Figure 1: Map of the Eastern Pyrenees and its situation.

Geographic distribution maps using GIS technology are the most visually elements to show the location of all cases of study. The location of the megalithic constructions in space is completely conditioned by the orography, hydrography and climate. The use of the geographic information systems let us observe the relationship between the megalithic constructions and these aspects. In this respect, the control view that certain megalithic constructions represents is shown (e.gVinyesMortes I), or conversely, the willingness of the communities that built it to hide amid the forests without visibility or valleys, where the control exercised is minimal (e.g. Covadel Camp de la Marunya).In this sense, there is a tendency, which must be deeply revised, contradictory to the historiography raised around the megalithic research in Catalonia, which deal with the concealment of certain megalithic constructions but not all. These constructions are located in places completely hidden in forests and mountains that are accessed only through small paths and hidden valleys where visual inspection is minimal and the dominant effect of these structures disappear. This pattern is more visible in constructions situated inland west of the Pyrenees.

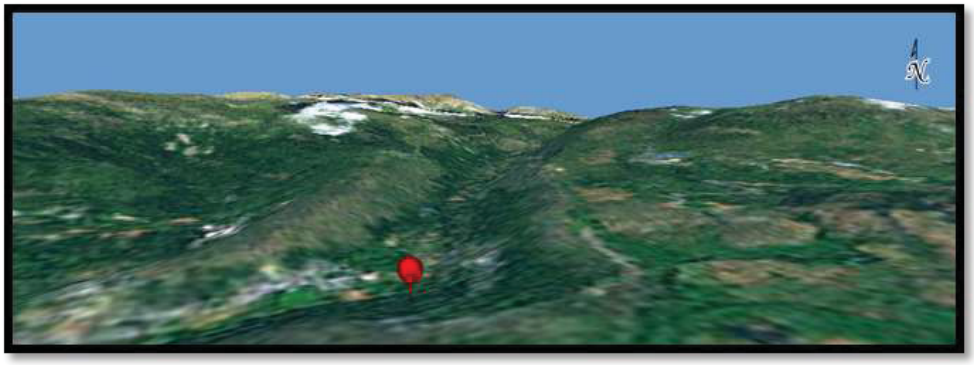


Figure 2: Concealment of certain megalithic constructions (e.g. Covadel Camp de la Marunya, Brangoly).

However, the desire to have a great visual control, to be a territorial marker and the dominance of megalithic construction is still present in many buildings of the Catalan region, specifically on the eastern Pyrenees region corresponding to the Alt Empordà.



Figure 3: Dominance and territorial marker of certain megalithic constructions(e.g. VinyesMortes I, Pau).

Overall, the various analyses and studies made with the GIS system, allow the knowledge of the socioeconomic structure of the communities that built megalithic constructions. It also allows the establishment of a different pattern of construction depending on the area of the Eastern Pyrenees elaborated through the study of the investment work applied to the construction of these megalithic constructions.

3. Volume Calculation of the built structures

The internal morphology of megalithic structures does not usually follow the same pattern of construction. It is true that there are megalithic structures which can be assimilated to a precise geometric shape such as a cube or a rectangular prism(e.g. Lo Pou (Eina), Cist: 1.6 x 1.3 x 1.1). In such cases the mathematical formula applied to calculate the volume is the basic formula of this forms. However, in most cases, the chamber or the corridor (understood as separate entities while carrying out the calculation) may suffer different morphological deformities. The most common are widening or decreasing width in accordance with moving inside the chamber or the corridor (e.g. Cova del Camp de la Marunya (Brangolí), Simple chamber: 2.8 x 1.4-1.62 x 1.85), or the rising or sinking of the roof slab, which is caused by different heights of the side and rear slabs (e.g. La Plagne (Vicdessos), Simple Chamber: 1.4 x 0.9 x 2.2-1.2). In relation to the mound structure we observe that the variability in morphology is also present. The variables from these calculations are the central height of the mound structure and the radius or the two main axes. In the case where the information comes in the first format height and radius is assumed that the mound is circular, so the geometric shape matches with a sphere, carrying out the corresponding mathematical formula to obtain the volume (e.g. CamíVell de les Cases (Pinell de Solsonès), Cist: 5 Ø x 1). However, working with the height and the two main axis, the mound structure is compared to the shape of an ellipse, using the formula for calculating the volume of the geometric shape (e.g. PuigRodó (Roses), Cist: 18.5 x 15.5 x 1). It should be noted that on the calculation of the mound structure, the volume occupied by the megalithic structuremust be subtracted. All the mathematical formulas and their geometric representations are shown in figure 4.

Once performed the GIS study using the volumetric variable as the main parameter, the results are counteracted to verify them using a statistical method and the subsequent data analysis in relation to geography. In this sense,the statistical analysis is essential in order to establish the existence of significant relationships from the perspective of both volumes of the chambers and corridors and mound structures, as these features are chosen to carry out the construction in relation to geographic location. The methodology is based on a statistical study applying a distance matrix followed by a hierarchical cluster analysis (Moore, 2004). The function of the distance matrix is to measure the similarity between the units of analysis and the function of the hierarchical cluster analysis is to establish clusters where all cases have similar properties. In this study, the megalithic constructions are grouped according to the inner volume of the chamber and the corridor and the volume of the mound structure. The results of these analyses are presented as a dendrogram.

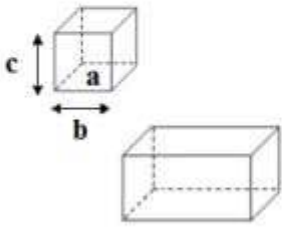
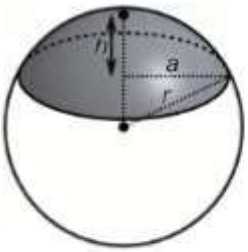
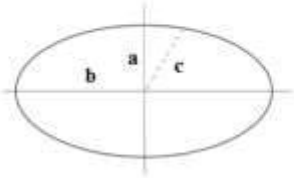
Type	Geometrical Shape	Formula	Variables
Chamber and corridor: exact geometric shape		$V = a * b * c$	a: length b: width c: height
Chamber and corridor: variation in width		*Base Area* = $(B + b) / 2 * h$ $V = (B + b) / 2 * h * H$	B: maximum width b: minimum width H: minimum height h: room length
Chamber and corridor: variation in height		$V = ½ * base\ area * H' + base\ area * H$	H': maximum height minus minimum height H: minimum height
Mound structure: radius		$V = [(\pi * h) / 6] * (3a^2 + h^2)$	a: radius h: height
Mound structure: small axis and big axis		$V = (2 * \pi * a * b * c) / 3$	a: small axis b: big axis c: height

Figure 4: Mathematical formulas and geometrical shape representation.

4. First Results

The first results obtained from the study of megalithic constructions in the Eastern Pyrenees in relation to its geographical location, from the GIS study, are as follows:

- **Boundaries:** well-defined boundariesabout the type of megalithic constructions: single chamber and cists are present throughout; while the presence of the *sepulcres de corredor*is exclusively to the coast.

- **Altimetry:** depending on the geographical relief the altimetry situation of the megalithic constructions is very different. Constructions situated in the eastern Pyrenees are located in very high altimetry in relation at the maximum altimetry of the zone avoiding flat areas. However, the buildings from the inland tend to be placed in a very low altimetry in relation to the maximum altimetry, especially in small valleys.

- **Control and Visual Dominance:** the altimetry conditions are the reason why the coastal constructions have a wide visibility playing a very important visual control and becoming a highly strategic point. On the other hand, a large number of megalithic constructions from the inland are in places where the control and domination is minimal; this suggests the desire of concealment of these buildings.

- **Orography and Supplying Areas:** have an important role in the investment of workemployed in the lifting of megalithic constructions. The conditions of the coastal Pyrenees and the interior Pyrenees are very different. For this reason, there is much distance between the two geographical areas.

- **Hydrographic Network:** coastal constructions show a spatial distribution unlinked from the rivers, possibly due to the presence of the Mediterranean Sea and the mouth of many rivers in relatively close distances. In opposition many inland constructions are located in close proximity to rivers and streams. In the case of *Alt Urgell*is really apparent that the constructions follow the Segre River.

- **Investment Work:** is a topic to work in depth. Despite observing different investments of work in relation to the geographical relief and supplying areas, we should take into account the dimensions of the constructions, which tend to be larger on the coast and have more number of slabs; while the tendency inland is based on smaller buildings with a smaller

number of slabs. It is interesting to observe how the mound structure volume varies in relation to the megalithic structure that contains it. It is observed that large*sepulcres de corredor* are covered with a much reduced volume of mounds, as opposed to small megalithic structures inside the Pyrenees, which consist of large mound structures.

5. Forecast of Work

Once established a methodology that provides reliable results the forecast work lies in the treatment of all data using geographic information systems to develop a GIS that encompasses all the information collected from the different techniques used and show the expected results. Therefore, we must continue developing further research using a great number of important cases of study in order to get solid information. Parallel we have to treat aspects such as an exact calculation of the investment of work, the relationship between the megalithic constructions and the communities who built it and create knowledge about their socio-economic structure. Finally treat other aspects such as the geology of the territory and the geological morphology of the slabs used to be able to locate potential areas of supply.

6. Conclusion

Concerning the conclusions, the application of GIS system linked to the study of the communities who occupied the Eastern Pyrenees during the Chalcolithic period and erected the megalithic constructionsapproached from the point of view of investment work is an study in development so interesting to analyse and develop in depth, especially in an area that has not carried out any investigation of this nature.

The inclusion of the volumetric calculation of built spaces in the megalithic constructions is a completely new parameter, which has an important role in calculating the investment work; along with geological and geographical features of the Eastern Pyrenees. It is a line of research that, together with the use of geographic information systems can provide information on relevant archaeological topics, economic and social, geographical and geological.

References

García Sanjuán, L., S. Metcalfe-Wood, T. Rivera Jiménez, and D. W.Wheatley. 2006. "Análisis de pautas de visibilidad en la distribución de monumentos megalíticos de Sierra Morena

occidental." In *La aplicación de los SIG en la Arqueología del Paisaje,* edited by Ignacio Grau Mira, 181-200. Alicante: Universidad de Alicante.

Montufo, A. M., J.A. Alfonso, J. A. Cámara, F. Molina, Fernando, and L. Spanedda. 2011. "Relaciones visuales entre los yacimientos arqueológicos prehistóricos de las Peñas de los Gitanos (Montefrío, Granada). Estrategias de ocultación, control del espacio productivo y límites." *Antiquitas* 23: 73-85.

Moore, D. S. 2004. *Estadística aplicada básica*. Barcelona: Antoni Bosch.

Wheatly, D. W, L. García Sanjuán, P. Murrieta Flores, and J. Márquez Pérez. 2010. "Approaching the landscape dimension of the megalithic phenomenon in Southern Spain." *Oxford Journal of Archaeology* 29(4): 387-405.

White, D. and S. B. Barber. 2012. "Geospatial modelling of pedestrian transportation networks: a case study from Precolumbian Oaxaca, Mexico." *Journal of Archaeological Science* 39: 2684- 2696.

Recognition of Prehistoric Canoeists' Passages in the Fuego-Patagonia Region: First steps in a Geo-computing approach to the characterisation of archaeological evidence

Alfredo Maximiano Castillejo [1]

Alfredo Prieto Iglesias [2]

[1]Posdoctoral Researcher at *Juan de la Cierva* Programe. IIIPC.University of Cantabria.Spain. JPI Santander Universidades.

[2]Researcher in Centro Universitario Puerto Natales. University of Magallanes. Chile. Programa de Doctorado Universidad Autónoma de Barcelona. España.

Abstract

The main object is identified and establishes an approximation in terms of the main characteristics of a peculiar archaeological event: *Canoeists Passages*. The influence of these *entities* may be a significant component in the spatial organization of landscape mobility among canoeist groups (*Kaweskar* and *Yamana* people) and other hunter-gatherers (*Selknam*) on Isla Grande de Tierra del Fuego (Chile).

We are starting a research line (funded by *Santander Universidades*) related with geo-computational improvements in spatial description and numerical classification of landscape to develop predictive models about potential geographicalpassages(different typesof routes usedfromthe Holoceneto the mid-nineteenth century) that may have been used by hunter-gatherers in their movements around the landscape.

In the most logical assumption about the presence of these *passages*, they must be understand as a expedient solution as routes which enabled the structuring of a particular landscape (extensive area with islands, islets, fjords and substantial tracts of land) for these social groups.The access provided by these *passages* for different collectives (whose livelihoods were developedaround theexploitationof coastal resources andcoastal shippingin canoes) represented complex exchange networks connected with access to raw materials and the exogenousexchange of individuals, information and prestige goods.

Keywords: *Canoeists*; *Spatial prediction*; *Access*; *Mobility*

1. Introduction

This project is based on the application of geo-computing tools (implementation of location prediction models) to detect, describe and compare possible geographical passages (different kinds of routes in use from the early Holocene to the mid-nineteenth century) that might have been used by hunter-gatherer groups in the Fuego-Patagonia region of Chile.

The geographical and ecological particularities of this southern region, combined with its landscape evolution dynamics, are environmental factors that conditioned and continue to condition social dynamics in the area. With these parameters, the heuristic value of a passage would be more that a route to shorten the considerable distances involved in coastal navigation or to avoid certain geographic obstacles (e.g. the foot of a glacier, powerful water currents, etc). These entities, as well as be an expedient solution for transport routes, enabled the palaeo-landscape to be structured, facilitating inter-grupal and inter-ethnic interaction (access to exogenous raw materials, exchange of individuals and prestige goods, spread of ideas and knowledge, and so on). It is very likely that they would have played a significant role in communication and exchange networks amongst these social collectives, whose way of life was focused on the exploitation of littoral resources through "constant transhumance" by coastal navigation.

Therefore, the prediction of locations and the comparison of possible passages will be able to establish vital new information about the mobility of these collectives, impacting on aspects of the perception and visibility of certain archaeological evidence that might be related to the passages, such as the presence or absence of habitat sites, burial places, or the concentration of artistic evidence like paintings and petroglyphs.

In addition, another of the possible applications of this project would be the development of probable analogies with certain issues in European Prehistory (in connection with Palaeolithic and Mesolithic groups on the Atlantic façade, particularly due to environmental and geographic similarities with Scandinavia) related to mobility studies, with similar parameters to the casuistic studied in the Fuego-Patagonia regions (coastal societies). The aim is not a comparative ethnographic study by the mere transfer of components from one region to another, but to investigate new formulae enabling certain archaeological problems to be enunciated and solved, based on the experience acquired with the canoeists' passages in Fuego-Patagonia.

2. What were the reasons and purposes of the Canoeists' Passages?

The historiography of Fuego-Patagonia socials groups is dominated by the idea of low thresholds of penetration by these "coastal" societies towards inland areas, and they are solely associated with interaction constrained to the coastal fringe and short visits inland. As a result of the empirical evidence found in the last ten years, this concept should be reappraised, as the increase of archaeological sites recorded inland has questioned this traditional view.

Such a situation provides an opportunity for this project, as through the parameterisation of a series of environmental and social variables, together with the spatial prediction of passages and

mobility modelling depending on the presence or absence of these entities, new interpretations can be made about movements made inland, in relation with the territoriality of these groups which, until now, have been associated with an essentially coastal model of spatial management.

The main epistemological consideration implying the presence of a passage is based on the notion of expedient communication/connection between inhabited regions in prehistory (ethnic groups known as: Kaweskar, Selknam and Yamanas). If these passages did not exist, the interaction between these groups would probably have more difficult due to a series of hindrances:

a) Geographic accessibility, which in some places is very difficult;

b) Long distances, if journeys had to be made around the coastline;

c) Preservation of knowledge about how the territory was perceived and managed by the agents who travelled around it, which made possible the recognition and use of passages in particular circumstances.

Passages are only possible when a number of barriers exist in addition to a series of motivations for connections between members of the same collective or between different collectives. Under these conditions, an amalgam of natural components and social factors can be defined; these enable interaction through different solutions, of which passages are one of the possible options. The main disadvantage for the detection of these possible passages is their low archaeological visibility due to several factors, like the holistic definition of what constitutes a passage and the presence of elements hampering their detection (environmental and social conditions such as dense vegetation cover and the low visibility of structures and archaeological artefacts). These circumstances form suitable conditions for the application of new methodologies to a problem that cannot be solved with traditional techniques and approaches (Lock and Molyneaux, 2006). For this reason, location prediction is postulated as the best possible heuristic, and this has become a consolidated line of work within Archaeology of the Landscape in the last fifteen years (Fry, 2004; Mehrer and Wescott, 2006; Verhagen and Whitley, 2012).

3. Location prediction as a heuristic way to detect canoeists' passages.

The discovery and historical recording of canoeists' passages across isthmuses has long been known in the case of canoeists in the far south of America (Coppinger, 1883; Hyades and Deniker, 1889; Maldonado, 1907; among others). Chroniclers, sailors and explorers gave information about them from the eighteenth century onwards. Thanks to these sources and

archaeological research, several examples of this kind of site have been located. Few archaeological sites near the passages have been dated. In one case, a deposit near a passage between Seno ContralmiranteMartínez and Ocean Bay has been dated to about 3600 BP. This is an upper date, and the passage may have existed in the place before the time of the determination (Prieto, 2007).

In these circumstances, the archaeological problem is centred on the detection and characterisation of canoeists' passages in a particular area between the western entrance of the Strait of Magellan, Carlos III Island and CapitánAracena Island.

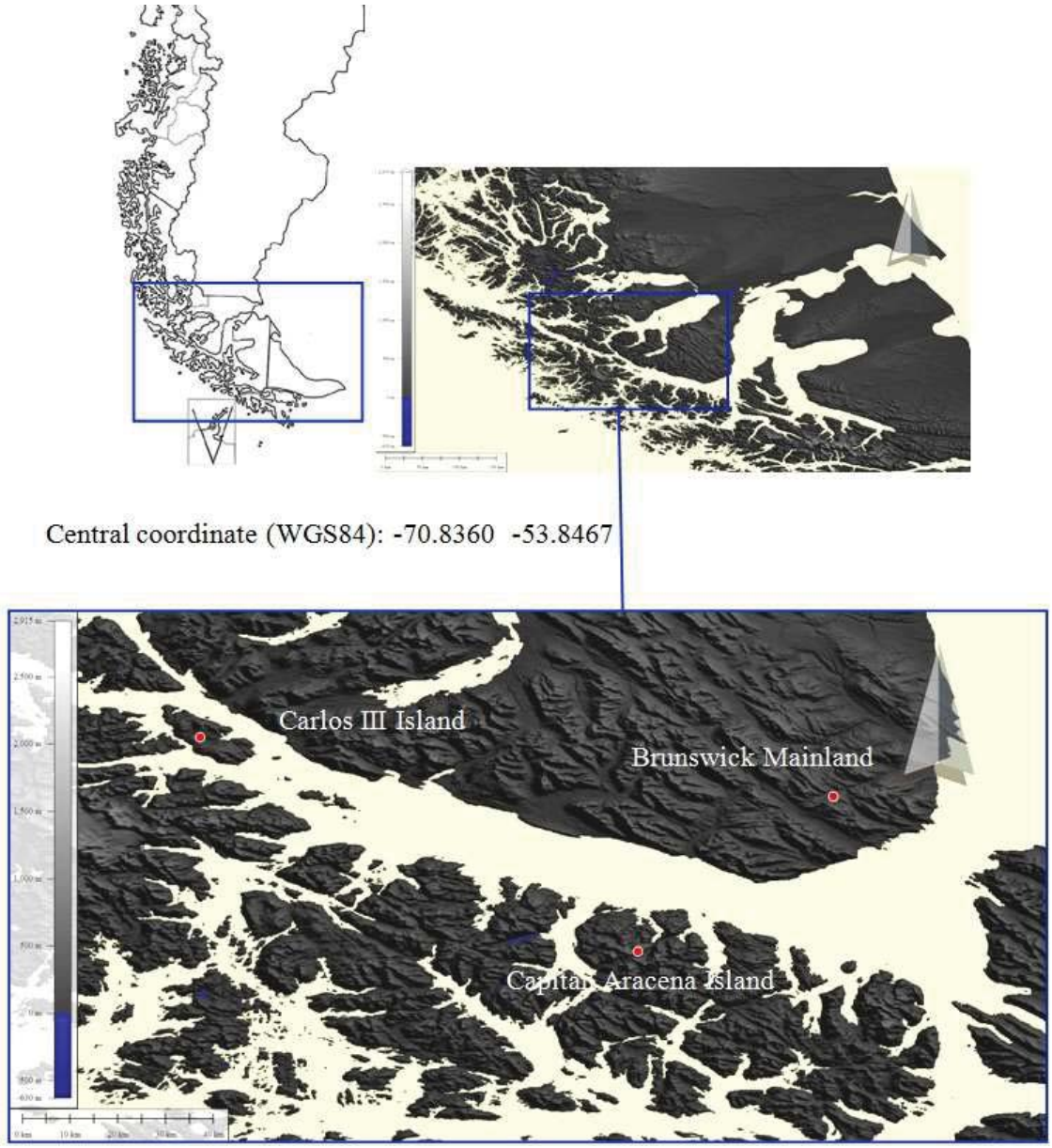


Figure 1: Location of the study area.

This region is characterised by low visibility of potential archaeological remains (dense vegetation cover) and complex topography with mountain chains and river valleys which could be used for the expedient connection between areas which otherwise would involve a long journey if this was done by coastal navigation.

Although the recognition of possible passages is the main objective of this project, what is the definition of a canoeists' passage? Does it depend on a mere criteria of distance depending on whether the journey from *A* to *B* is made by a long coastal voyage or along a valley a few kilometres long that connects with the other side of an isthmus? May it be that the presence of archaeological sites (burials, open-air sites, caves, or places with evidence of rock art) at the ends of the hypothetical passage or on the route are the most important characteristics of such an entity? May some kinds of ethnographic information, such as the sightings of canoeists in inaccessible areas, validate the use of possible routes to reach these remote places (Pallo, 2011).

The fact is that it is not easy to recognise a canoeists' passage, as there is no acknowledged canon for them, and there is no diagnostic materiality that can be attributed to them. For example, can the location of several prehistoric burials along a river corridor be associated with the use of this valley as a passage? To be able to recognise canoeists' passages by location prediction, a series of premises are needed: i) a passage is a "place of attraction", it is an optimal convergence of social, geographic and ecological variables where the social agents could carry out a varied group of actions connected with travel; ii) the possibility of a superimposition of uses of these areas over time should be borne in mind. At a certain time the place may have been used as a passage and *a posteriori* (due to *x* circumstances) this function may have changed; which leads on to the premise iii) that probably some passages were or were not operative at different times due to changing organisation of the territory and/or particular social strategies.

Through the systematic classification of the landscape, together with the characterisation based on a set of variables corresponding to what might constitute a canoeists' passage (among others, accessibility in terms of the land relief, fluctuations in shoreline levels, marine currents, distance to be covered, presence of ice, presence of sites – like dwellings, cemeteries, stone-quarries and hunting-grounds, and even ancestral fears), a list of cases can be drawn up, with statistical significance, which can be compared through fieldwork to corroborate the presence or absence of possible passages in certain places. A reference will be established with a model created *ex profeso* based on a known canoeists' passage (Lapataia Valley, lat-54.732 S; lon-68.878 W, in

Prieto et al. 2000) where environmental, geomorphologic, geographic, topographic and anthropic variables will be characterised.

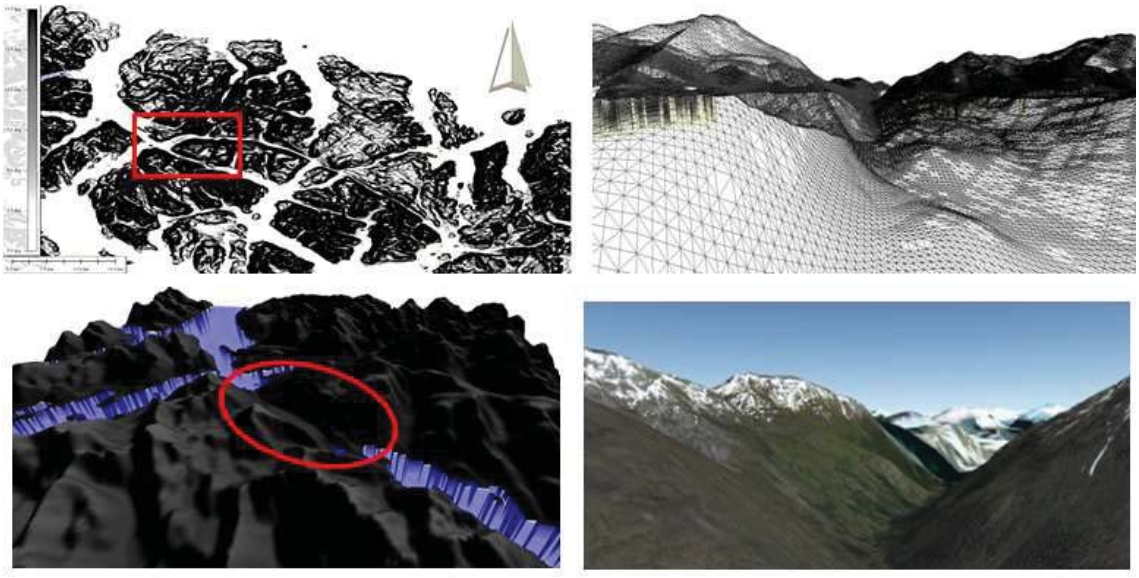


Figure 2: Up left, slope analysis of possible canoeist passage (rectangle in red). DEM of potentialpassage (circle in red) connected with the flat valley bottom and accessibility from the passage itself.

Other variables to be included with these will be based on archaeological data (Laming-Emperaire, 1972; Johnson, 1976; Curry, 1991), ethnographic information (Emperaire, 1963; Legoupil, 1989), and certain biomechanical optima (such as weight transportable by agent types and tolerable maxima depending on slope angle). All these will be used to establish the components of the spatial location prediction model, in which the interaction of a set of variables (basically geological, geographic, climatic, ethnographic and archaeological) will determine a more or less significant location according to the "ideal" passage type.

3. Expected outcomes

After comparing the results obtained in the analytical series and prediction models in the field, a proxy could be determined about the characteristics that define a canoeists' passage. This approach could be transferred to other potential areas of study, both in Fuego-Patagonia and in other parts of the world. In addition, the detection of passages will enable an approach to the mobility of (pre)historic groups in the area. Different scenarios could be established in which

simulations can be developed for mobility within a given area, depending on the presence or absence of passages.

Secondly, it is believed that the detection of possible passages will lead to the location of new archaeological sites (dwellings, expressions of prehistoric art, procurement areas for raw materials, and so on). These new sites will be integrated in a geo-database, enabling an efficient and coherent management of the catalogued (and potentially cataloguable) heritage in Fuego-Patagonia. Finally, selective criteria will be determined for sites, according to which those that are suitable for archaeological research are chosen, taking into account factors of risk, archaeological potential and research needs.

References

Chevallay, D. 1999. *Una ruta terrestre entre el seno Almirantazgo y el canal Beagle: indicio de intercambios entre las etnias fueguinas* (inedit).

Coppinger, R.W. 1883. *The cruise of the Alert W*. London: Swan Sonnenschein and Co.

Curry, P. 1991. "Distribución de sitios e implicaciones para la movilidad de los canoeros en el canal Messier." *Ans. Inst. Pat. Ser. Cs. Hs*. 20: 145-154.

Emperaire, J. 1963. *Los nómades del mar*. Santiago de Chile: Ediciones de la Universidad de Chile.

Hyades, P., and J. Deniker. 1889. *MisssionScientifique du Cap Horn 1882-83*. Paris: Gauthier-Villars.

Fry, G. L. A., B. Skar, G. Jerpåsen, V. Bakkestuen, and L. Erikstad. 2004. "Locating archaeological sites in the landscape: a hierarchical approach based on landscape indicators." *Landscape and Urban Planning* 67 (1-4):97-107.

Johnson, L. L. 1976. "Una prospección arqueológica en Magallanes" *Ans. Inst. Pat.* Vol. 7: 87-94.

Laming-Emperaire, A. 1972. "Los sitios arqueológicos de los archipiélagos de Patagonia Occidental."*Ans. Inst. Pat*. 3: 87-96.

Legoupil, D. 1989. *Ethno-archeologiedans les archipels de Patagonie: les nómadesmarins de Punta Baja.* Paris: Recherche sur les civilizations edit. Memoir 84.

Lock, G., and T.G. Molyneaux (eds.) 2006. *Confronting Scale in Archaeology: Issues of Theory and Practice*. New York: Springer.

Maldonado, R. 1907. Exploración del seno Skyring por la cañonera Magallanesy el escampavía Huemul." *Anuario Hidrográfico de la Marina de Chile* 26: 353-544.

Mehrer, M. W., and K. Wescott (eds.) 2006. *GIS and Archaeological Site Location Modeling.* Boca Raton: Taylor & Francis.

Pallo, M. C. 2011. "Condicionamiento de la dinámica ambiental en las decisiones humanas sobre asentamiento y circulación a lo largo del Estrecho de magallanes durante el Holoceno Tardío." *Magallania* 39 (2): 177-192.

Prieto, A., D. Chevallay, and D. Ovando. 2000. "Los pasos de indios en Patagonia Austral." Desde el país de los gigantes. Perspectivas arqueológicas en Patagonia. IV Jornadas de arqueología de la Patagonia. Río Gallegos, Universidad Nacional de la Patagonia Austral.

Prieto, A. 2007. Los pasos de indios en Patagonia Austral. Anexo Arqueología, etnografía e historia Parque Tierra del Fuego. Estudio, Diagnostico, Diseño y Gestión Parque Regional Tierra del Fuego. Memoria de Proyecto.

Verhagen, P., and T.G. Whitley. 2012. "Integrating Archaeological Theory and Predictive Modeling: a Live Report from the Scene." *Journal of Archaeological Method and Theory* 19: 49–100.

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Visibility: a new outlook to the study of Palaeolithic Art. Preliminary research

Paula Ortega Martínez[1]

[1] Dpto. de Prehistoria, Historia Antigua y Arqueología. Universidad de Salamanca.

Abstract

Beyond the stylistic value, the Paleolithic art is a part of the archaeological record that provides huge information about human groups, as a reflection of values and concepts of these societies, and it must be analyzed as such. The significance of showing or hiding the motifs will be grasped as a relevant characterizing factor.

The aim of this paper is to assess the potential that Spatial Archaeology brings to the study of this archaeological record by means of Visual Prominence Analysis. The main target is evaluating the viability of the analyzed tools in closed spaces, and thereafter, to apply the visibility tools on the parietal art record, exploring the advantages and limitations of these spatial analysis enabled. The final goal is to find out if the desire of projection of these motifs was a relevant factor for Paleolithic societies.

Keywords: *Paleolithic Art, Visibility, Visual Prominence, Methodology*

1. Introduction

The study of prehistoric art has been discussed since the beginning of 19th century. However, the becoming of historiography has made that many studies revolved around aesthetics or typology limiting our knowledge of this archaeological record to the field of styling. In the last decades of 20th century studies have been focused on operational chains, the chemical composition of the pigments, or the morphotypes and their distribution over the territory. Nevertheless, there is not much knowledge about the intentionality of art, due to the fact that there are many variables involved in this field. The factors directly related to the choice of a specific location, technique or morphotype are still unknown.

2. Art as a social product

If we understand art as a one more piece of material culture, we can not ignore that this is a product of a social being. The author, as an element of the society, reflected in its development - besides the particularities of their own skills and expertise in the translation of an idea- a kind of pre-establish concepts in the social group to which belongs. Therefore it is understood that the Paleolithic art reflects in its construction certain cultural processes of the society.

The possibility of determining the desire to show or hide, inherent in the archaeological record, would provide it a core of meaning as a part of the concept of space in these societies. The will of visibility must not be understood from current paradigms based on individual psychology, but in the cultural context of the group (Criado 1993). Thus that will, in this case of the graphs in Paleolithic cave, could determine not only the location of the graphs on the walls of the cavity, but also the represented morphotype and the chosen type of stroke. The existence of a direct relationship between the visibility of the graphic items and a particular technique, morphology, or motive, would lead us to the suggestion that there was a tangible willingness.

The concept of visibility refers to a sensorial access between certain items, whether anthropic or natural, enclosed in a given environment. This concept is not related with a particular chronology (Wheatley and Gillings 2000, 3). However, in the field of archeology, the concepts of visibility and inter-visibility have been associated consistently with historical concepts of territoriality, defense, and acquisition of resources and location of sites.

The first systematic attempts to explore the visual characteristics, dated from the 70s and 80s, with the development of the New Archaeology, closely interwoven with the first spatial studies by Clarke, Hodder and Orton (Clarke 1977, 9). However, the New Archaeology did not have formal means to analyze in a systematic way the visibility of the different archaeological sites. (*cf*. Renfrew 1979).

It was not until the arrival to the social archaeology in the 90's when the perception began to be understood as a human quality rooted in the cultural traditions of each society. That approach provided by Tilley to stand out the special importance of human movement through the environment (Tilley 1994, 73). Proper visual studies are published in the literature between the years 95-96. From then until now, visibility studies have evolved both, methodologically and conceptually, led by researchers such as Wheatley, Gillings, and Garcia Sanjuan.

3. Objectives and Methodology

The aim of this paper is to assess the potential that spatial archeology brings to the study of that type of archaeological record, using the visual prominence analysis in closed scenes like a cavity, through a methodological test, in order to recognize if the will of projection of these graphic motives was an important factor for Paleolithic societies.

Therefore a methodological implementation is proposed based on the notions of visual prominence to relate the most visual prominence graphs and archaeological concepts such as morphotype, technique or chronology.

The study designed in this paper examines the computation of the visual relevance showed by graphs in the cave from the concept of cumulative viewshed analyzed on the TIN of the cavity. That is, an analysis that joins in the same raster the viewshed rasters taken from different observant points placed randomly in the cave space. The result is just one raster map in which each cell has assigned a value ranging from 0, corresponding to the cell that is not visible from the total observer points (Wheatley 1995, 173). On this way you can set a range of ranking the degree of visibility-hiding of the items, thus avoiding the binary analysis of visible-invisible.

In order to confirm the results obtained, it is desirable to repeat this analysis varying the observant points to flee from the conditioner that the location of these points could have on the final analysis.

In this case, the topography of the cavity has been obtained by terrestrial laser scanning. The result is a grid of points with great accuracy. However, this approach presents two problems processing the data through the basic software used in GIS.

On one hand the large number of points that this tool involves due to the high accuracy can not be process by the GIS software, hence it has been purged.

On the other hand triangulation algorithm used by GIS tools can give also problems. These applications tend to triangulate the vertices with a two-dimensional trend causing the triangulation of the points of ceiling and floor, and creating a straight wall that bear into the loss of irregularities of the own cave wall. In the example given this issue is fixed triangulating units individually and then fusing it, thus many shades of the topography of the cavity could be kept (Fig 1). As there are software programs that allow a triangulation of a cavity, we can not confirm the existence of any software that allows at the same time this triangulation and the development of spatial analysis of visibility (TIDOP personal communication).

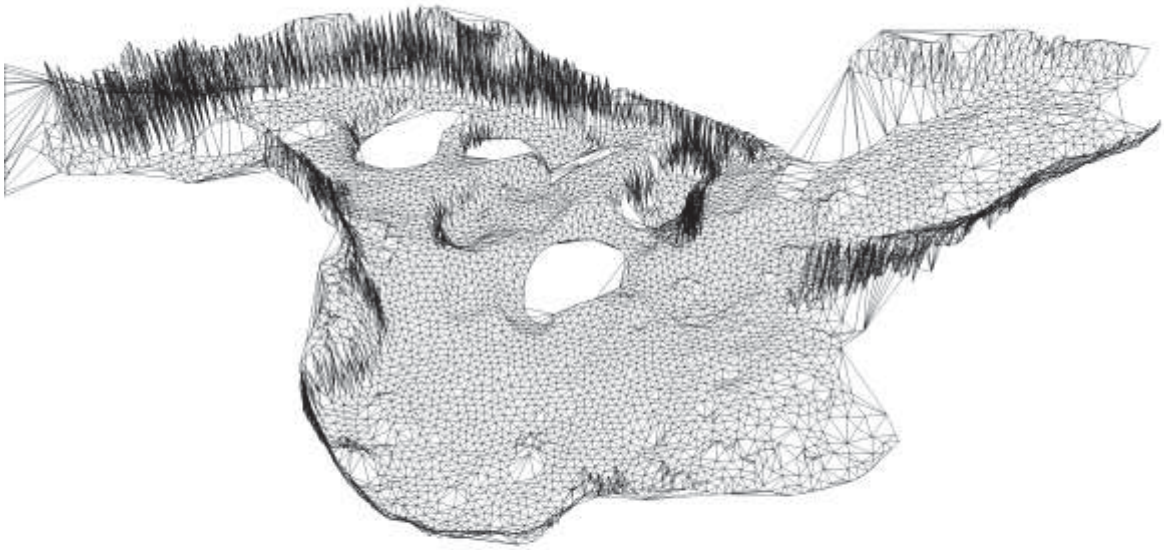


Figure 1: Three-dimensional representation of the topography of the 9th sector of La Griega (Pedraza, Segovia).Triangulation of grid points obtained by the terrestrial laser scanner.

The edge effect problem is the deformation in the subsequent analysis and the interpretation of the cause "when the distribution of continuous monuments outside the study area, the cumulative viewshed map may be considerably underestimated, since the number of lines to the sites limit the transfer of study does not consider these movements bordering the study area" (Conolly and Lake 2009). This is not a problem in these studies inasmuch as the study area is well limited by the very formation of the cavity.

There are many external factors involved in this sensory relationship between the observer and the observed environment. The GIS basic software applications have standard parameters for their calculations that do not attend the archaeological needs. Therefore it is necessary to adapt these analyses to each archaeological study. In our case: the visual impact, the height of the observer, or the dimension of the viewing area.

4. Methodological problems

4.1 Visual impact:

One of the problematic factors that condition this analysis is that conventional visibility analyses adopted to landscape scale are bidimensional. However the raised analysis needs here a three-dimensional application. Therefore we have tried to establish a range of vertical visual incidence (Fig 2). This is the cause why we have established three angles of visibility: 0°, -45° and +45°, considering this range the best suited to the available space in the gap of the cavity. (Zamora 2006).

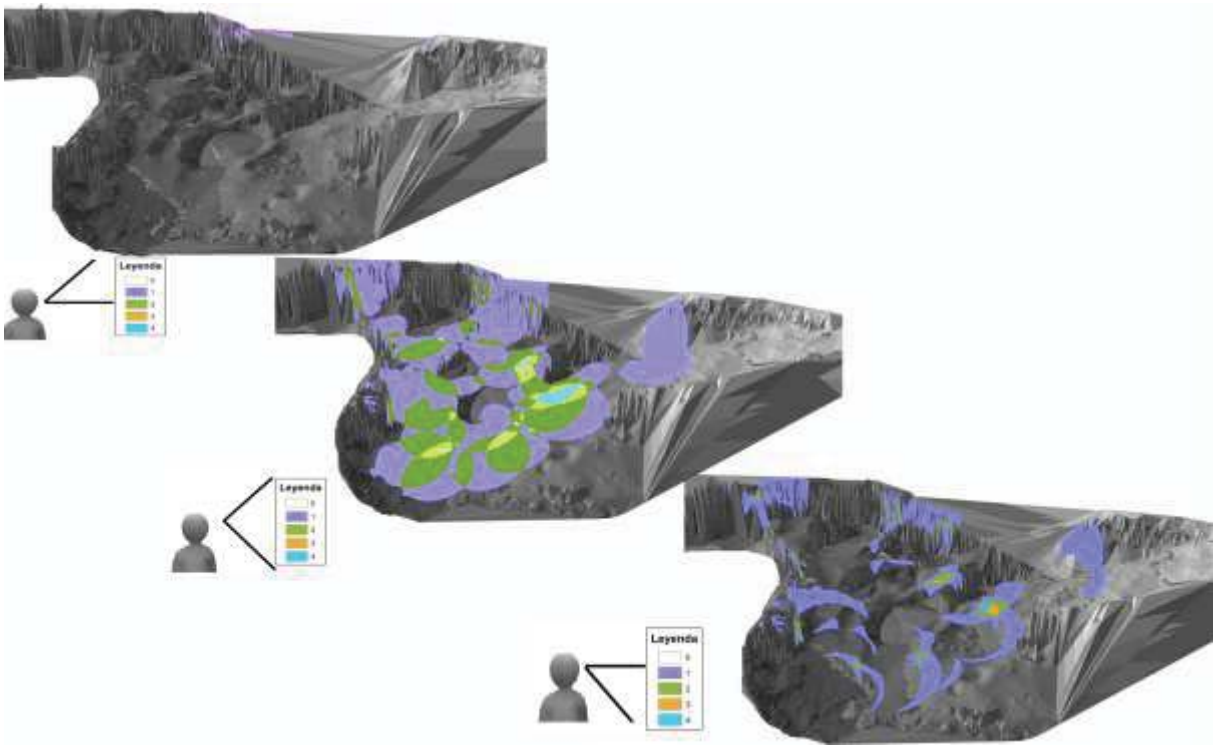


Figure 2: Three-dimensionalrepresentation of the visibility analysisaccording to the incidence angle.

4.2 Lighting:

In the Paleolithic period there were limited resources for artificial lighting which restricts the range of available viewshed.

Three models of artificial light are documented in Paleolithic ages (*cf.* Baune, 1987a, 1987b): hand lamps (lamps with great mobility made with fiber and a deposit of animal fats); torches (a rod of wood or bone with plant fiber placed at one side); the "foyers" or static hearth.

We have few certainties about the attitude of Paleolithic man in the cavities. The latest archaeological researches in caves, like Nerja, have revealed accumulations of coal interpreted like a heaths next to large panels and access and transit areas (Medina et al 2012). However, no records that could reveal the existence of a systematization of this practice have been found in any other cavities. In the absence of information on location general patterns of these static lighting sources, we decided to limit the study to the minimum visibility documented (hand lamp). The assumption of the existence of any other form of lighting (static lighting, the presence of more than one individual carrying other handlamp) would distort the study by preconceptions.

Thus, this project is based on visibility available to a person who carries a mobile light source. So the viewshed was limited with a radius of about 2 m above the point of light. The limiting distance corresponds to the experimental studies based on the brightness of these hand lamps and the capacity of the human eye to perceive elements in low-light scenarios developed by S.A. Baune.

Following these studies can be emphasized that:

- The light range of the hand lamp is between 0.8-0.9 to 0.2-0.3 lux in a diameter of 50 cm.

- The light given off vertically is constant between 0 º and 90º

- The luminance at a distance of two meters is similar to a vision with artificial lighting or mesopic vision.

5. Case study: The IX sector of La Griega

The chosen stage for this project is the sector 9 of the cave La Griega (Pedraza, Segovia). This cavity, where 90 figurative representations and 29 identifiable signs attributed to an Upper Paleolithic Horizon have been documented - show parallel samples with parietal and furniture art of final Solutrean and Late Magdalenian-, is an ideal setting for the analysis of visual prominence and cumulative viewshed, since it is a cave formed by different cave rooms and narrow passages having an unfavourable development to be transited easily (Corchón 1997).

The IX sector is a space consisted of a very irregular ceilinged room, as while in the center the room is about 5m high and on the sides the height decreases until 1 m between ceiling and floor. This sector presents five Paleolithic motives, all of them located along the left wall, because the right wall descends from the ceiling directly attached horizontally to the ground, without notice any clear area of wall.

Thus the motives 1 and 2 are incomplete contours of horses overlapped. The 4th motive is an outlined cervical-dorsal of a horse. Following, the 5th motive is a complete horse (66 x 40 cm), with traces of filling inside, and a deer prótomo placed over the hindquarters of the horse, opposed and inversely oriented. Under the 5th motive, there are a recorded and incomplete outline mustelid (Gloton: Gulo Gulo) or ursid (Ursus sp.), a sign and a possible cervical-dorsal profile of horse (6).

All paleolithic motives present a similar visual predominance (Fig. 3). Even though, all of them are emplaced through the same left wall of the room and on a similar distance to the ground.

The small degree of visual prominence may be conditioned by the applied methodology. Then the large amplitude of the room makes these prints visible from any point within a radius of two meters from the paleolithic motives. That limitation could be depending not by emplacement graphic but because of the pattern of lighting that we are using in this study. It could be that the lighting was not enough to display the motives.

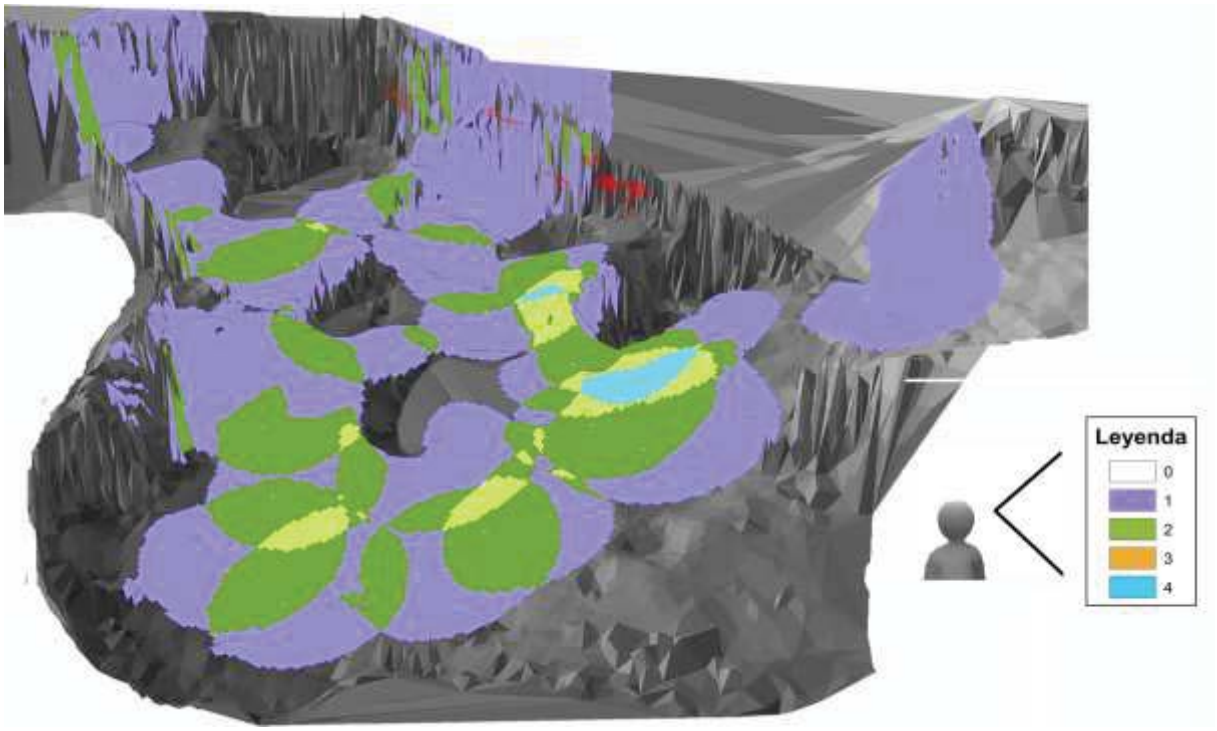


Figure 3: Three-dimensional representation of the visual prominence of Paleolithic art in the sector IX of La Griega.

6. Preliminary conclusions

The application of the above described methodology in the case of the IX sector of the La Griega cave has allowed the experiment and the detection of various unresolved issues in research. In any case, the problems described have no prevented to the achievement of the preliminary outcome of great interest. This methodology is emerging as a very useful tool in the study of a relevant factor in the choice of the stand and the location of Paleolithic art, and it must be polished and profiled. In the future we look forwards to apply and develop this

methodology in other scenes, as well as other sectors of the cavity, in order to establish comparative patterns.

References

Beaune, S. A. de. 1987a. *Les lampes et godets au Paléolithique*. Paris: Éditions du Centre National de la Recherche Scientifique.

Beaune, S. A. de. 1987b. "Palaeolithic Lamps and Their Specialization: A Hypothesis." *Current Anthropology* 28 (4): 569-577.

Clarke, D L. 1977. "Spatial Information in Archaeology." In *Spatial Archaeology*, edited by D.L. Clarke, 1-32. London: Academic Press.

Conolly, J. and M. Lake. 2009. *Sistemas de información geográfica aplicados a la arqueología*. Barcelona: Bellaterra Arqueologia.

Corchón, M. S. 1997. *La cueva de La Griega, Pedraza, (Segovia).* Valladolid: Memorias. Junta de Castilla y León. Conserjería de Educación y Cultura.

Criado Boado, F. 1993. "Visibilidad e interpretación del registro arqueológico." *Trabajos de Prehistoria* 50: 39-56.

Fraser, D. 1983. *Land and Society in Neolithic Orkney* (British Archaeological Reports, Series 117). Oxford: Archaeopress.

Hodder, I. y C. Orton 1976. *Spatial Analysis in Archaeology.* Cambridge: Cambridge University Press.

Llobera, M. 2003. "Extending GIS-based visual analysis: the concept of visualscapes." *International Journal Geographical Information Science* 17(1): 25-48.

Medina M. A., A. Cristo, A. Romero and J. L. Sanchidrián. 2012. "Otro punto de luz. Iluminación estática los "santuarios" paleolíticos: el ejemplo de la Cueva de Nerja (Málaga, España)". In *L'art pléistocène dans le monde / Pleistocene art of the world / Arte pleistoceno en el mundo*, Actes du Congrès IFRAO, Tarascon-sur- Ariège, septembre 2010, Symposium « Art pléistocène en Europe », 105-121. Préhistoire, Art et Sociétés, Bulletin de la Société Préhistorique Ariège-Pyrénées.

Renfrew, C. 1979. *Investigations in Orkney*. London: The Society of Antriquaires of London. Thames and Hudson.

Tilley, C. 1994. *A Phenomenology of Landscape*. Oxford: Berg.

Wheatley, D. 1995. "Cumulative viewshed analysis: a Gis-based method for investigating intervisibility and its archaeological application." In *Archaeology and Geographic Information Systems. A European Perspective*, edited by Gary Lock and Zoran Stancic, 171-186. London: Taylor & Francis.

Wheatley, D. and M. Gillings. 2000. "Vision, Perception and GIS: developing enriched approaches to the study of archaeological visibility." In *Beyond the Map: Archaeological and Spatial Technologies,* edited by Gary Lock, 1-27. Amsterdam: IOS Press.

Zamora, M. 2006. "Visibilidad y SIG en Arqueología: mucho más que ceros y unos." In *La Aplicación de los SIG en la Arqueología del Paisaje*, edited by Ignacio Grau, 42-54. Alicante: Universidad de Alicante.

Study of the spatial variability of Caserna de Sant Pau del Camp (Barcelona): old excavations, new approaches

Oriol Vicente[1]

Ann Gòmez [1]

Camilo Barcía[1]

Miquel Molist[1]

[1]SAPPO Research Group- Department of Prehistory. UAB.

Abstract

The site of Sant Pau del Camp barracks (Barcelona) is an open air prehistoric settlement, which has been occupied for more than two thousand years –from the early stages of the Neolithic up to the Late Bronze age. This study was carried out in the Early Neolithic occupations, particularly in the *Postcardial* horizon (c.4600-4000 BC). Fireplaces, pits and burials were found during the excavation, probably related to the use of this space as an habitat and also as a necropolis. The singularity of the site lies both in the reiteration of the place of occupation during such a long period of time and in the few examples of similar sites for these chronologies at the NE of the Iberian Peninsula.

Given the characteristics of the archaeological intervention –an emergency excavation with a highly segmented registration system-, the analysis has focused on the digitization and geo referencing of archaeological items as well as in the particular and interdisciplinary study of the remains. During the study we used relational databases and Geographic Information Systems for the analytical visualization of topological features found in the archaeological record (materials, structures, etc.). A visual approach has also been used on the analysis of distribution of the archaeological material. The paper attempts to adapt a methodology in order to analyze spatial data that come from old excavations and that have certain limited characteristics. We present the exposition of both the problem and the heuristic approach used in the analysis of spatial variability of the archaeological deposit.

Keywords: *Neolithic, Analytical Visualization, empirical application, pottery*

1. Introduction

From 1988 to 1992 several excavations around the Monastery of Sant Pau del Camp in Barcelona were made. The discovery of prehistoric remains in this area was new and the site became one of the most important sites of the 90's in Catalonia. In the place occupied by the Barracks of the Guardia Civil (the Spanish police force), located in 92 Sant Pau Street, is where the most important

intervention took place thanks to financial and human resources expended and the results we obtained. The excavation was carried out in a total area of about 2800 m^2, 730 m^2 of which were excavated. Directed by R. Farré and coordinated by the Archaeological Service of the city, the results are available in several publications (Granados et al. 1993; Laorden et al. 1993; Molist et al. 2008).

The stratigraphy of the site was defined as a sequence of five geological and archaeological levels due to its successive occupation and subsequent abandonment. Archaeological remains from Level II were attributed to two chronological periods. The upper level was linked to the late Bronze Age, and below it we found a wide range of structures dating to the Ancient Bronze Age. The fourth level, which had a variable thickness up to 60 cm, was darker, made of silt and clay and showed a high degree of organic components. We found the archaeological structures from the Early Neolithic in this level. Three radiocarbon dating were also obtained at this level: one human rest from burial 18 (ref. UBAR 263 = 5.160±130BP) and two faunal remains from pits 1 and 2 (Beta 236174 = 6.290±50BP and Beta 236175 = 6.250±40BP, respectively). A 2σ calibration for each one provided the following dates: 4.250-3.700 cal. BC for the tomb, and 5.360-5.210 and 5.310-5.200 cal BC for pits 1 and 2 respectively (Molist et al. 2008).

During the excavation, we found it difficult to document the cultural soils –significant groups of structures. It was also difficult to differentiate the archaeological levels due to the stratigraphic complexity of the area (post depositional complex processes like water flow) and to the working conditions of the archaeological rescue intervention. We present in this paper the data recovery process from old excavations, its management, and processing and analysis in order to study the spatial use of the site during the Early Neolithic.

2. Methodology

The site was excavated using a grid of $1m^2$ and some artificial layers 10cm thick. Archaeological structures and valuable features were drawn, as well as the position of the archaeological remains. Unfortunately, much of this documentation has been lost.

The project designed to study the archaeological remains started in 2008 and was coordinated by the SAPPO Research Group (Seminar on the Near East Prehistoric Archaeology, Prehistory Department, Autonomous University of Barcelona). The project provided a review of all documentation available and highlighted the need to explore the spatial variability of the site. This meant a significant approach to the knowledge of spatial-temporal continuity of the remains resulting from social actions and natural processes (Barceló et al. 2005; Vicente 2005).

Several specialists examined the material recovered during the excavation and stored it in the warehouse of the Barcelona City History Museum (MUHBA). The most important remains were the lithic ones (13.400), followed by the archaeofaunal pieces (2.200) and ottery remains (1.900), among others. In spite of the loss of some spatial information (x, y, z), we could reconstruct the location of the materials in the general grid and its position in the artificial layer where they appeared. After measuring their frequencies, their grouping and dispersion we analyzed the spatial variability of the area.

Thanks to some drawings and pictures recovered from the documents of the excavation we could digitize the archaeological contexts by vectorizing its shape, size, orientation and spatial position. The most significant structures were a set of 24 burials that showed a high degree of contemporaneity among them –which was indicated by the homogeneity of the materials found, such as the lack of overlaps. During the excavation of these structures it was impossible to document their real depth. Moreover, 30 combustion structures were found, and most of them were hearths and firepits of simple morphologies. A high percentage were filled with medium sized fire-cracked rocks and combustion testimonies such as charcoal, ashes, and so forth. The last group was a set of 9 pits, which due to their dimensions and morphologies could be classified as structures for storage and subsequently used as places for rubbish.

The georeferenciation of topological features from the archaeological contexts enabled us to relate it to the archaeological material found during the excavation, and then analyze their spatial relationships. Relational databases were created and linked to a Geographic Information System in order to carry out this process. Thanks to this method it was possible to select the type of material and some other archaeological features, such as archaeological structures, and then make visual distributions and projections. It was also possible to analyse the stratigraphic position of the material and structures altogether. Manifold System SIG Software and MS Access were the software used. Eventually, a visual analysis with Rockworks software was created using the volumetric characteristics of the structures and their location in the Euclidean space (x, y, z).

3. Results

The distribution of the archaeological finds analysed after a projection of the sections enabled us to determine paleoslope indicators, material concentrations and its relation to the archaeological structures (Fig.1 and Fig. 2). In a first approach we analyzed the variability in the distribution of the ceramic materials, both in horizontal and vertical positions. We selected those objects for its content in chronological markers, which provided a view to their relative chronology. The ceramic assemblage had a high level of fragmentation but showed uneven erosion patterns. We could therefore conclude

that was the reason why there existed insignificant displacement of the material and no strong taphonomic events.

Vertical differentiation was defined by relationships between pottery markers and the features of each structure (in terms of archaeological context). Distance relations, both horizontal and vertical, helped us to discard possible synchronies on nearby structures. There is a clear example in Section X-Y: hearths were found at the same level as the buried bodies (bottom of a non-delimited pit) and no more than 1.5 meters in between, which indicates occupational levels at different depths.

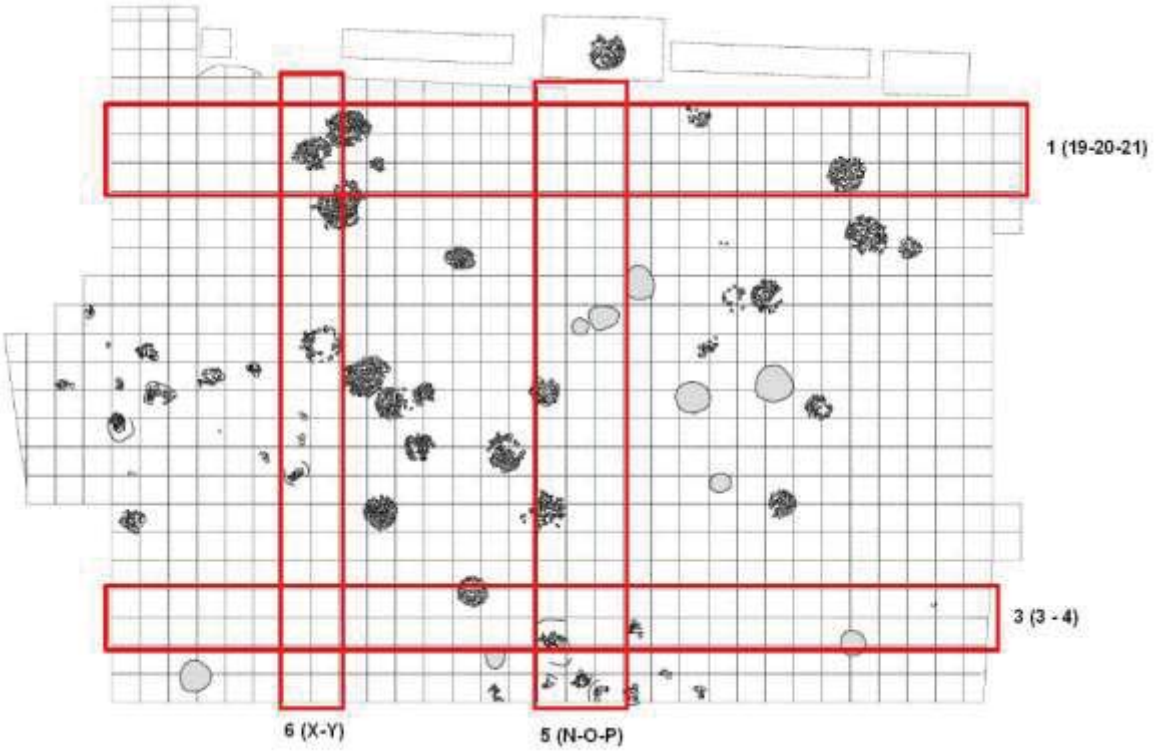


Figure 1: Map of the site with sampling sections marked (Manifold System).

In this respect, three different occupation levels were defined. The ancient one belonging to the Early Neolithic Era was characterized by the presence of impressed pottery inside the pits with *cardium* motifs and plastic applications (*Cardial* and *Epicardial* sets) (Gómez et al. 2008; Molist et al. 2009). We could justify that as a result of a long term occupation in the site, probably as a habitat.

The second one was a first *postcardial* level mainly represented with medium-sized pottery recipients –which had been opened or recently closed with a globular type– and small medium-sized open bowls (Fig 3). Their surfaces were buff-coloured, roughly smoothed and the great majority of the decorations corresponded to plastic motifs, mainly represented by bowed and straight cord type in a single or

multiple types. A significant part of this pottery was related to the set of hearths and firepits as a result of a habitat occupation level.

Eventually, we documented a third level characterized by burials with *postcardial* pottery as a grave goods inside. Unfortunately, we were not able to recognize the existence of an occupation soil related to those burials, probably due to its preservation. It is important to remark that burials had strongly mixed up the lower levels of the site. In that moment we identified the use of the site as a necropolis.

After differentiating the three occupation stages in the site, we tried to identify which layers belonged to the first *postcardial* phase (the second level abovementioned). The purpose was to sample the material found around the structures of combustion, and then separate the artificial layers belonging to the first *postcardial* era from those belonging to former and subsequent stages. In some cases, the material was separated as a consequence of the discontinuity in its discovery; in others, the material was altogether, which lead to a diachronic accumulation that complicated its differentiation. Bearing in mind the registration status of the excavation we had to assume other research limitations. After a visual analysis of this archaeological level we could identify it as a temporal palimpsest (Binford 1981; Bailey 2007). Thus, a continuous accumulation of archaeological materials as a result of many deposition processes in the same place created such a palimpsest level.

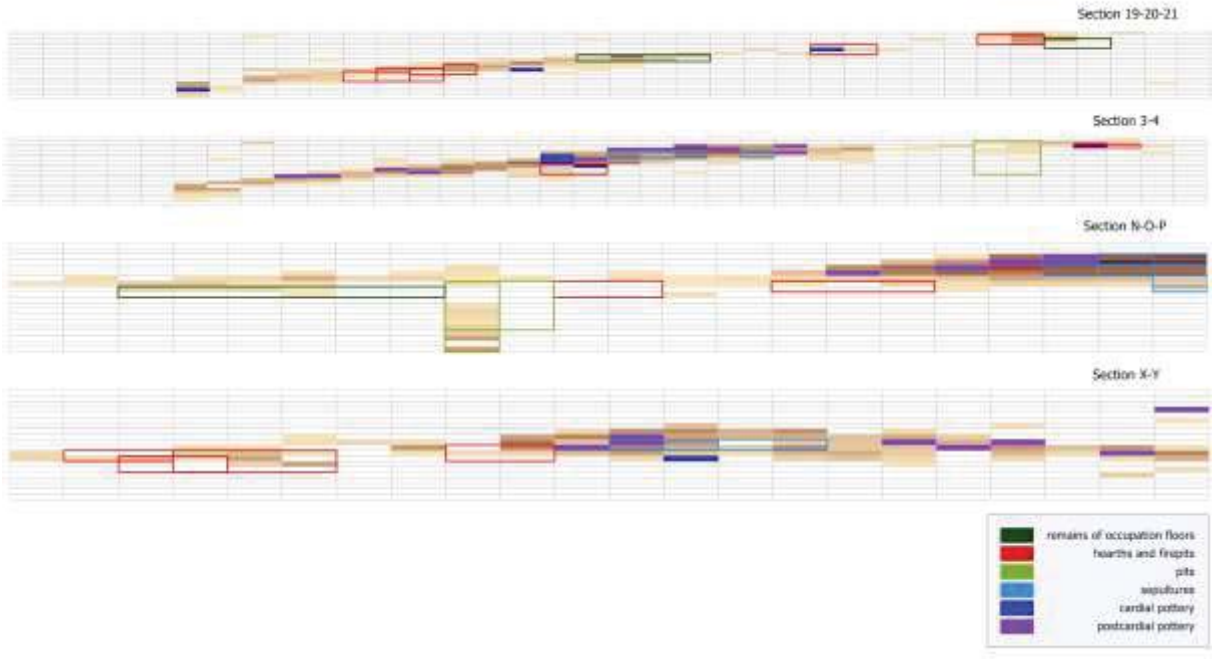


Figure 2: Graphic reconstruction of the sections. (Manifold System).

Although we seriously took into consideration the lack of data on the formation of the site, (i.e., micromorphological analysis on soil formation processes) (Djindjian 1999; Texier 2000), we tried to study how a dynamic accumulation of the materials in medium and long term (both natural and social accumulations) can show internal coherence.

Plotting all identified *postcardial* sherds on a transversal map of the site we observed a significant concentration in the SE squares. Materials found there were divided into two spatial and separated groups –two clear profundity means and medians in each histogram with a decreasing presence around them. The tendency was accumulated in three layers for each group: 17 to 19 in the south-east group and 14 to 16 in the east one (the latter had another tendency on the 12th layer, associated with the latest *postcardial* period). Besides, many of the elements were classified as structures with clear relative chronology. Pits and burials provided *cardial* and *postcardial* markers respectively, and hearths and remains from the occupation floors were dated by nearby pottery or other dated structures (Fig. 4).

The final result comes from a comparison between the different structures and the square frequencies of their adjacent areas (two squares maximum). The layers were also chosen by visually comparing all relative frequencies in several sections. We could prove, once more, that those layers could not be the same because of the slope of the site. Assuming that it would be possible to differentiate elements through natural discontinuities or significant concentrations, a graphic representation of their frequencies in vertical gave us a visual orientation. Pottery concentrations were detected on adjacent squares and layers of dated structures, and the same on tendencies in SE and E groups mentioned before. Those tendencies had a parallel similarity on visual representations. Several areas and layers were delimited this way, containing a representative sample. The subsequent summation and plotting of the squares and isolines (traced in each one by a centroid point located at 50cm from the side) provided, in both cases, a visual and generic approach for the pottery spatial pattern in this site (Fig.5) (Maximiano 2007).

4. Conclusions:

This paper introduces a spatial analysis of the site in Sant Pau del Camp barracks. We took advantage of ICT possibilities, which was very useful for its interpretation. Despite apparent constraints in the registration status of the site and its taphonomic characteristics (impact of old and recent occupations), the archaeological register of Sant Pau del Camp barracks still kept its structural integrity. Therefore, a spatial interpretation became possible both in diachronic and synchronic perspectives.

Our first approach provides a new perspective: the incorporation of the spatial dimension as an analytical variable. In this respect, our next purposes will be focused on analyzing and comparing the results (pottery) with other materials such as malacofauna (Lloveras et al. 2011). In future, we will

probably consider the use of geostatistical techniques in order to go further in inferences about the human use of the space.

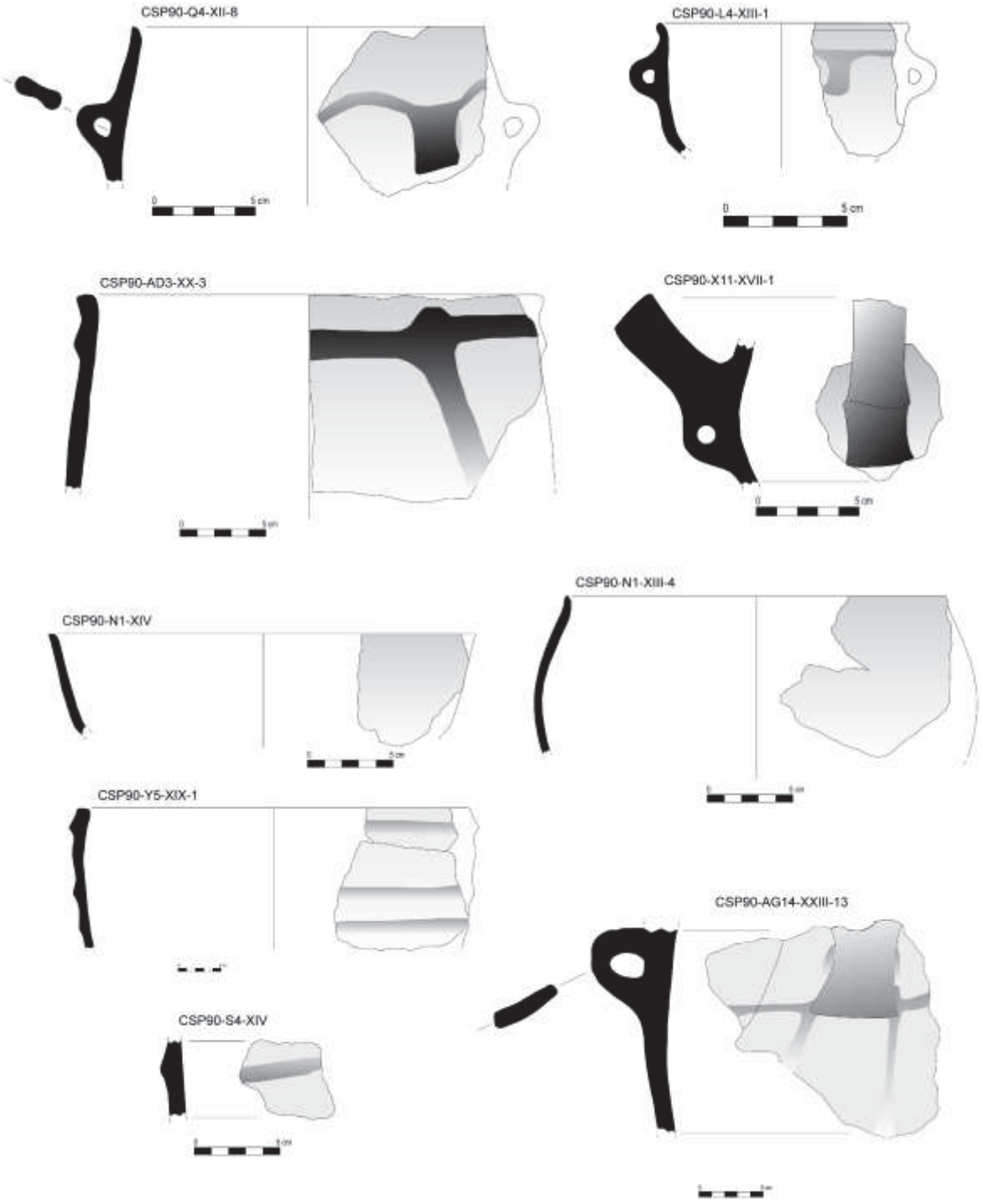


Figure 3: Postcardial pottery decoration used as a chronological marker.

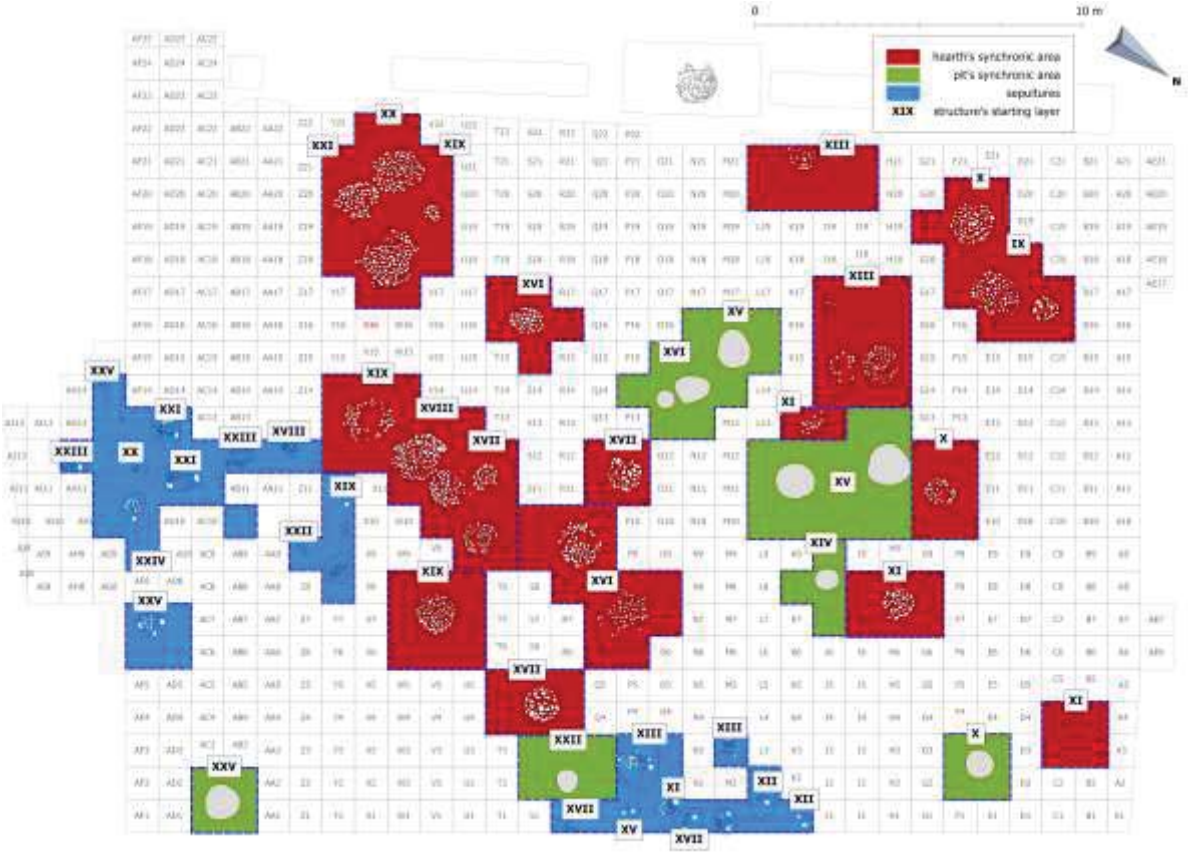


Figure 4: Map of the main site with different types of structures and their respective synchronic area of influence.

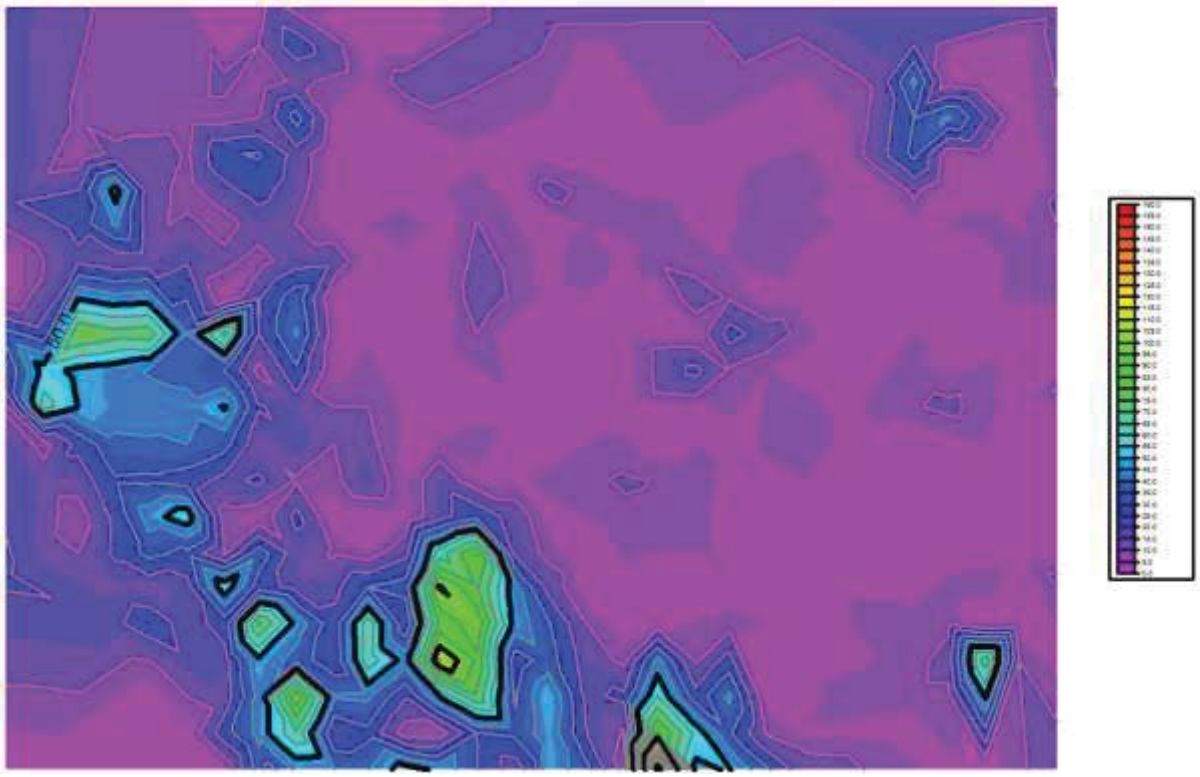


Figure 5: Isolines graphic representation of pottery frequencies traced by centroid points (RockWorks).

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References

Bailey G. 2007. "Time perspectives, palimpsests and the archaeology of time." *Journal of Anthropological Archaeology* 26 (2007): 198-223.

Barceló J. A. A. Maximiano and O. Vicente. 2006. "La Multidimensionalidad del Espacio Arqueológico: Teoría, Matemáticas, Visualización." In *La Aplicación de los SIG en la Arqueología del paisaje*, edited by Ignacio Grau, 29-40. Alicante: Publicaciones de la Universidad de Alicante.

Binford L. 1981. "Behavioral Archaeology and the 'Pompeii Premise.". *Journal of Anthropological Research* 37: 195-208.

Djindjian F. 1999. "L'analyse spatiale de l'habitat; un état de l'art." *Archeologia e Calcolatori* 10: 17-32.

Gómez A. E. Guerrero, X. Clop, and J. Bosch. 2008. "Estudi de la cerámica neolítica del jaciment de la Caserna de Sant Pau." *Quarhis, Quaderns d'Arqueologia i Història de la Ciutat de Barcelona època II* 4: 25-35.

Granados O. F. Puig, and R. Farré. 1993. "La intervenció arqueològica a Sant Pau del Camp: un nou Jaciment prehistòric al Pla de Barcelona.". In *Tribuna d'Arqueologia 1991-1992*. Barcelona: Generalitat de Catalunya. Dept. de Cultura, 1993): 27-32 .

Laorden V. J. L. Prada, F.J.M. Monseñe, and Serra J. 1993. "L'estudi geològic del solar de la Caserna de Sant Pau". In *Tribuna d'Arqueologia 1991-1992*. Barcelona: Generalitat de Catalunya. Dept. de Cultura.

Lloveras L. O. Vicente, M. Molist, J. Nadal, S. Riera, and A. Estrada. 2011. "Interpretación tafonómica de la malacofauna marina en el yacimiento neolítico de la Caserna de Sant Pau (Barcelona)." Paper presented at II Reunión Científica de Arqueomalacología de la Península, Barcelona, May 19-20 mayo, 2011).

Maximiano, A. 2007. "Teoría geoestadística aplicada al análisis de la variabilidad espacial arqueológica intrasite". PhD diss., Department of Prehistory. Universitat Autónoma de Barcelona.

Molist M. Vicente O. and Farré, R. 2008. "El jaciment de la Caserna de Sant Pau del Camp: aproximació a la caracterització d'un assentament del neolític antic." *Quarhis, Quaderns d'Arqueologia i Història de la Ciutat de Barcelona època II* 4: 14-123.

Molist M. Bosch J. Clop X. Gómez A. and Guerrero, E. 2009. "Des vases cardiales dans la ville de Barcelone: Apports du site de la Caserna de Sant Pau del Camp sur le néolithique ancien de la Catalogne". In *De méditerranée et ailleurs. Mélanges offerts à Jean Guilaine*, edited by VV.AA., 547-555. Toulouse: Archives d'Écologie Préhistorique.

Texier, J. P. 2000. "A propos des processus de formation des sites préhistoriques." *Paléo* 12: 379-386.

Vicente, O. 2005. "La aplicación de las nuevas tecnologías de visión computacional en el registro y la modelización de yacimientos arqueológicos." (Diss., Department of Prehistory. Universitat Autónoma de Barcelona.