Methods for the Study of *Intrasite* Spatial Patterning in Palaeolithic sites: A Case Study of Level IV Bolomor Cave (Valencia, Spain)

Pablo SAÑUDO[1] – Antoni CANALS[1] – Josep FERNÁNDEZ PERIS[2] – Manuel VAQUERO[1]

[1]IPHES (Institut Catalá de Paleoecologia Humana i Evolució Social),
Àrea de Prehistòria (Universitat Rovira i Virgili) España
[2]SIP (Servei de Investigació Prehistòrica) Museo de Prehistoria. Diputación de Valencia. España
pablo.sanudo@bolomor.com
antoni.canals@prehistoria.urv.cat
josep.fernandez@bolomor.com
manuel.vaquero@urv.cat

Abstract
Geographical Information Systems and other technological devices have provided a high degree of resolution to archaeological research. The use of GIS in archaeological spatial analysis enables the management of a wide range of archaeological data and helps solve interpretative questions. This paper aims to show the potential for employing GIS on the intrasite analysis of Palaeolithic sites, combined with a set of methods proposed for providing a high temporal resolution of the analyzed record. We also present a case study (Bolomor cave level IV with a Middle Palaeolithic chronology of 128 ky), characterized by the presence of anthropogenic structures and a high density of archaeological items. The application of the proposed methodology to this case study allows the reconstruction of occupation patterns based on the spatial organization in hearth-related assemblages.

Keywords
intrasite spatial analysis, Geographical Information Systems, Palaeolithic, Bolomor Cave, activity areas

1. Introduction

In the past few years the development and evolution of computer systems have significantly improved the analysis, interpretation and perspectives of intrasite spatial studies. These changes, which began with landscape analysis and the application of different statistical calculations, have culminated in more complex analysis with the use of Geographical Information Systems (GIS) and 3D reconstruction. Although relatively recent, the archaeological use of GIS has proven its capability and effectiveness in relating spatial archaeological data with computing and statistic tools, generating a powerful tool for archaeological analysis.

The interest in intrasite spatial analysis took on special significance with New Archaeology's focus on reconstructing past social contexts and behaviour. Its development was accompanied by considerations of ethnographic works and improved documentation of the archaeological record. The exponential expansion of computer systems was a one of the most promising developments.

The necessary aim of this development is the recovery of the most complete archaeological record possible, which is often very complex in Palaeolithic sites in comparison with more recent ones. One of these reasons is the complexity of post-depositional processes acting upon complex sedimentary sequences. Taking the formation processes into consideration is fundamental, and are inherent objectives, in order to obtain a correct interpretation of the spatial model, taking into account the palimpsest effect or approximation to fix the activity events' synchronicity. Without these premises it is impossible to consider the characteristics of human behaviour and human social relationships.

In this way, we outline a method for approaching intrasite spatial analysis and the interpretation of Palaeolithic sites, taking into account the particular formation processes at each site and their relevance to achieve the highest temporal resolution as possible.

2. Methods

The study of intrasite spatial patterning in Palaeolithic sites is based on the reconstruction and analysis of the archaeological record, referring to its three-dimensional position. Archaeological records are plotted bi-dimensionally and tri-dimensionally, both in vertical and horizontal projection to allow the observation of variations in the distribution and characteristics of the items.

The use of GIS makes the management of all this information possible through vector designs and alpha-numeric database combinations. The use of this software allows the identification and analysis of site formation processes, occupation events and spatial occupation patterns. The spatial information management is simplified by controlling databases through queries in SQL protocol (*Standard Query Language*).

The overlap of different occupational events in the same space – palimpsests – is one of the most relevant problems for the application and interpretation of intrasite analysis at Palaeolithic sites. These can often be approached through geoarchaeological analysis, but lithostratigraphic units are sometimes homogeneous, and it is impossible to distinguish different sedimentary episodes. In such cases, archaeostratigraphy allows occupational events to be separated by identifying sterile beds (Canals 1993; Canals *et al*. 2003). Three-dimensional reconstruction of archaeological items and structures leads to a greater degree of realism, which in turn leads to better and more objective interpretative results.

Archaeostratigraphic analysis is based on plotting archaeological elements in cross-sectional profiles. The items are plotted on bi-dimensional profiles from their three-dimensional coordinates, creating archaeological cross-sections with transverse and longitudinal plotting (XZ and YZ). The thickness of this profiles must be as thick as possible, to avoid the effects of slope distortion. The first analytical stage of the archaeostratigraphic study consists of identifying the elements that allow us to characterize existing archaeological assemblages. The profiles are analyzed separately, considering the stratigraphic information they provide. The archaeostratigraphic delimitation of the occupation levels is based on the delimitation of the continuous sterile beds. These levels can be classified according to their accuracy, making an assessment of spatial and temporal relations and of the fidelity of archaeological items (Chenorkian 1988; Canals 1993). This hierarchic classification is based on the width of the sterile beds, the widest and thickest being the most reliable ones. The use of control loops allows the verification of the stratigraphic coherence between transversal and longitudinal profiles, by analysing their intersection zone (Canals 1993). The control of this zone allows the verification of the altimetric and volumetric position of sterile beds in both profiles. Through the control of all control loops (generating a net of crossed profiles) it is possible to obtain a good delimitation of the sterile beds in all its extension.

The statistical and analytical tools GIS provides are interpretatively beneficial, as they add objectivity to the analysis. The statistical methods commonly used in this kind of analysis can be classified in two types: distance methods and square methods. Distance methods are based on the calculation of distances between each element of a distribution, from the X and Y coordinates of each one. The most common methods in this category are Nearest Neighbour analysis, k-means clusters and density maps (Whallon 1974; Kintigh and Ammerman 1982; Simek 1984; Koetje 1987). Square methods analyze a distribution pattern using a grid with continuous squares. These analyses allow for the influence of the random or non-random character of a distribution and define concentration areas, corroborated by other statistics like Chi-square (*X2*) or Kendall's Tau coefficient (Hietala and Stevens 1977). One of the most-used square methods in archaeology is dimensional analysis of variance, developed in ecology (Greig-Smith 1952, 1964) and introduced to archaeology by Whallon (1973). Applied to intrasite study, it allows the frequency calculation in each square of the grid.

Density maps are probably the tool used most often in the statistical analysis of clustered patterns at archaeological sites, as they allow the calculation of the concentration index of any distribution pattern, establishing the percentage of items within an area of a given radius. This calculation allows the number of categories and the radius area in which the calculation is made to be controlled, and the statistical method to apply. The result is a percentage counting of items in the specific area compared to the amount of items in the entire study area, allowing the degree of cultural modification in the designated areas to be determined. In addition to X and Y, density maps can combine a third value (denominated Population Field), which allows, for example, the relations between concentrations and size or degree of burning to be calculated.

Other proximity calculations like buffers, applied on structures or other elements, allow possible activity areas to be related to such archaeological elements as hearths.

3. Applied methods: The case of Bolomor cave level IV

Bolomor Cave is a Middle Pleistocene site located on the Mediterranean coast, in contact with mountain systems from the Valldigna valley (Valencia, Spain). Field work began in 1989, recording a wide litostratigraphy with 17 levels and a chronology between 400–100 ky. The multi-disciplinary analysis of this site has resulted in important contributions regarding lithics, faunal remains, hearths, palaeo-environment and social behaviour (Fumanal 1993; Fernández Peris 2007; Blasco 2006; Sañudo 2007)

Level IV was analyzed using the methodology described above. The archaeological data were recovered during the excavation process, analyzed with an interdisciplinary perspective, and then entered with the planimetric data into a GIS. This combination of archaeological data allows a global management of the analyzed record and the possibility to make all the analyses described above.

The first aspect taken into account was the archaeostratigraphic analysis of the sedimentary deposit. The study area was divided into 8 cross-sectional (bands 2 and 4) and 9 longitudinal sections (bands D, F and H) of 25cm thickness, with a total of 42 control loops (*Fig. 1*). Control loops are the cross points between a longitudinal and a transversal section. We use these points in the archaeostratigraphic study for verifying the accuracy and the veracity of each section.

The seventeen sections studied demonstrate the existence of a continuous sterile bed. This bed displays punctual material intrusions and a variable thickness between three and eight centimetres that agree volumetrically and topographically with the intersection of the corresponding profiles (*Fig. 2*). The topographical position of this bed presents unequal levels, with values between -202cm and -207cm, in the most elevated zone, and -239cm -247cm in the lowest one. This continuous sterile bed divides the homogenous sedimentary package of level IV into two archaeostratigraphic units, CBIV-1 and CBIV-2.

Unit CBIV-1 has an approximated thickness of 13cm and is limited by level III above, and below by the sterile level already mentioned. Unit CBIV-2, with a maximum thickness of 20cm, is limited by the sterile level above and by level V below. Both units display a high temporal resolution of the archaeological record, which contrasts with large diachronic palimpsests. The 3D reconstruction corroborates these observations with the relations between the superimposed hearths and the sterile bed.

After this archaeoestratigraphic characterization, both units were analysed separately, in an effort to define the identifiable spatial and temporal relations, using the methods proposed above. The archaeological record was analyzed with different plots, taking into account the characteristic elements than can contribute the most information to the organization of the spatial patterning.

The archaeostratigraphic unit CBIV-1 has different activity episodes, identified by the high density of small elements. The other activity area contains larger and more diverse archaeological items, and may correspond to a refuse area outside the activity area. The small bones grouped in squares D2, D3 and F3 are associated with a concentration of bone

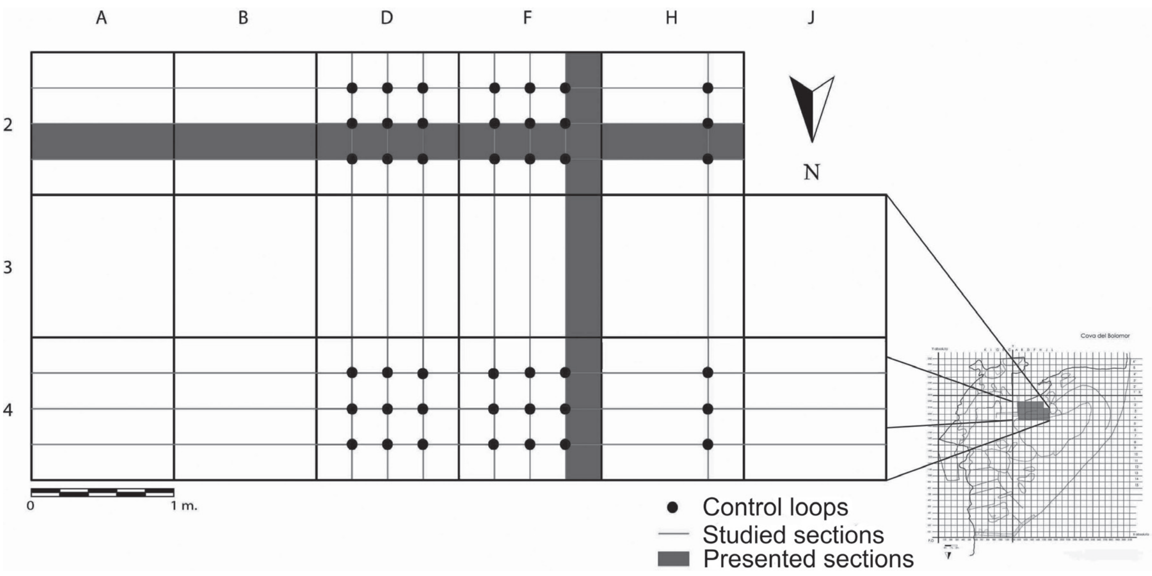

Fig. 1. Sections and control loops for the archaeostratigraphic study.

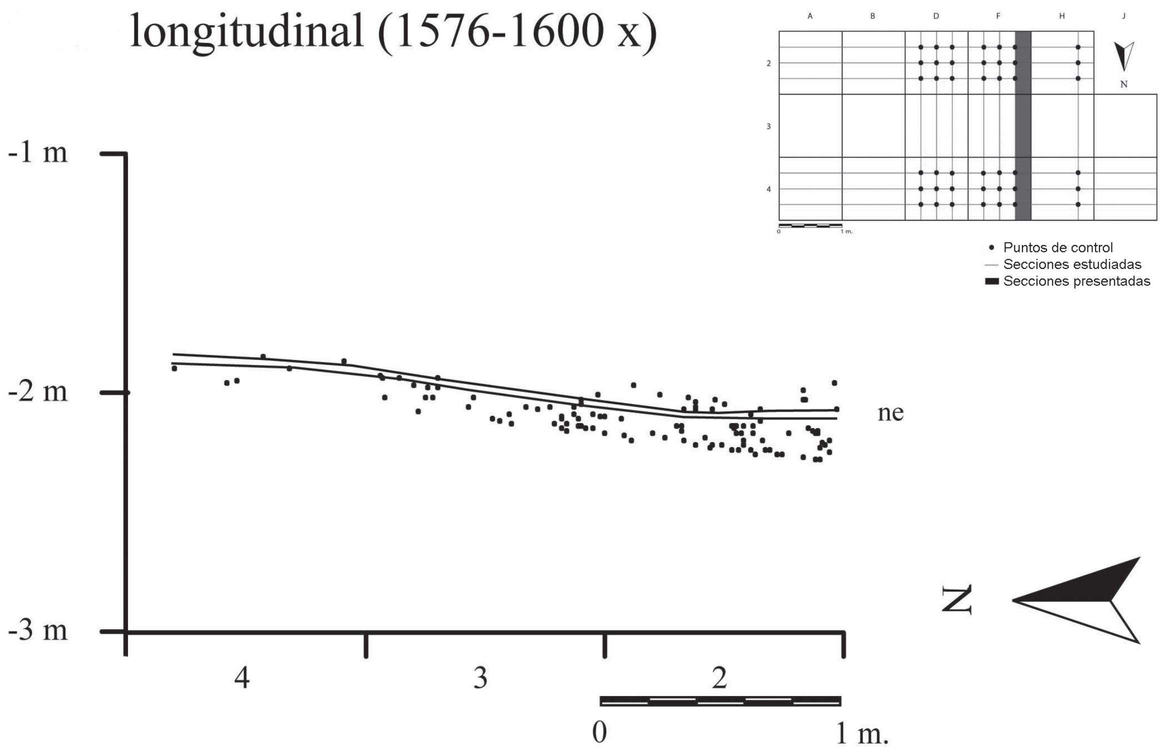

Fig. 2. Level IV longitudinal section with the sterile layer dividing the two archaeostratigraphic units.

impact flakes (*Fig. 3*), which indicates the existence of a fracturation activity episode. The small lithics also appear grouped in primary accumulations that occupy the squares B2, B3, D2, D3 and F2 and a secondary one in H3/H4. The first accumulation is spatially related with the fracturation area, showing a relation between them. The second, formed by small *debris* and flakes, corresponds to a very concrete activity episode; although the absence of refits prevents relations of temporality between them to be established. The existence of exhausted cores around the edges of the accumulation seems to indicate preventive maintenance, these having been rejected outside the activity area after use (Schiffer 1972, 1987; Yellen 1977; Binford 1978).

Unit CBIV-2 presents a different and more heterogeneous pattern, shown by the existence of diverse structural elements that articulate the space: the shelter itself, the hearths, the block accumulations identified and the *structures latentes*. The internal patterning of the studied surface is conditioned for shelter drip-line, creating a differentiation between the protected zone and the external one, as recognised in CBIV-1.

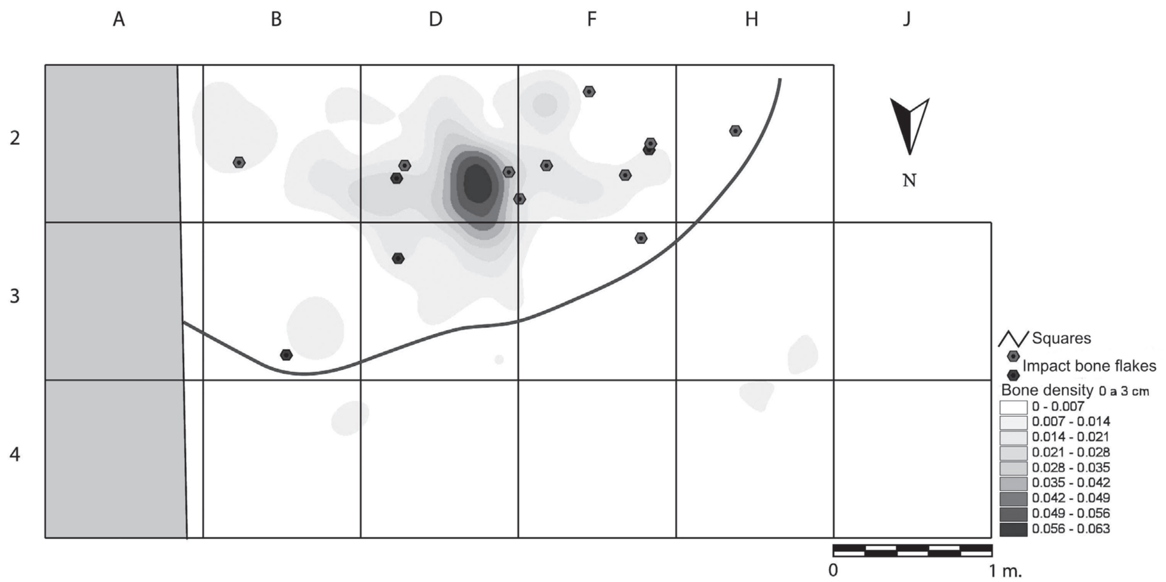

Fig. 3. Elements related to a faunal processing activity in CBIV-1 unit.

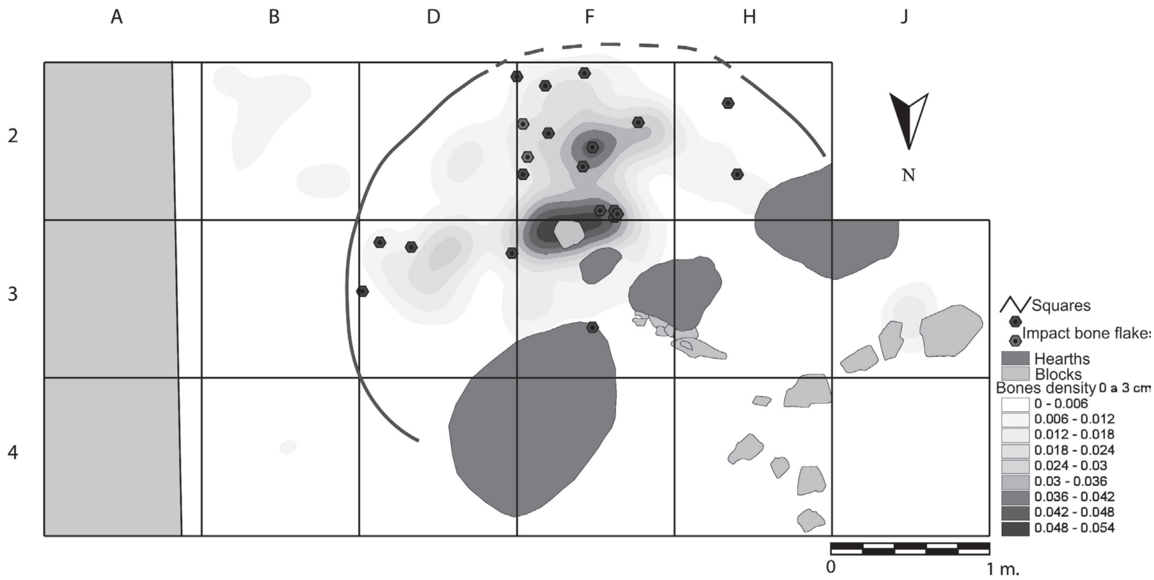

Fig. 4. Faunal processing activity related to the CBIV-2 unit hearths.

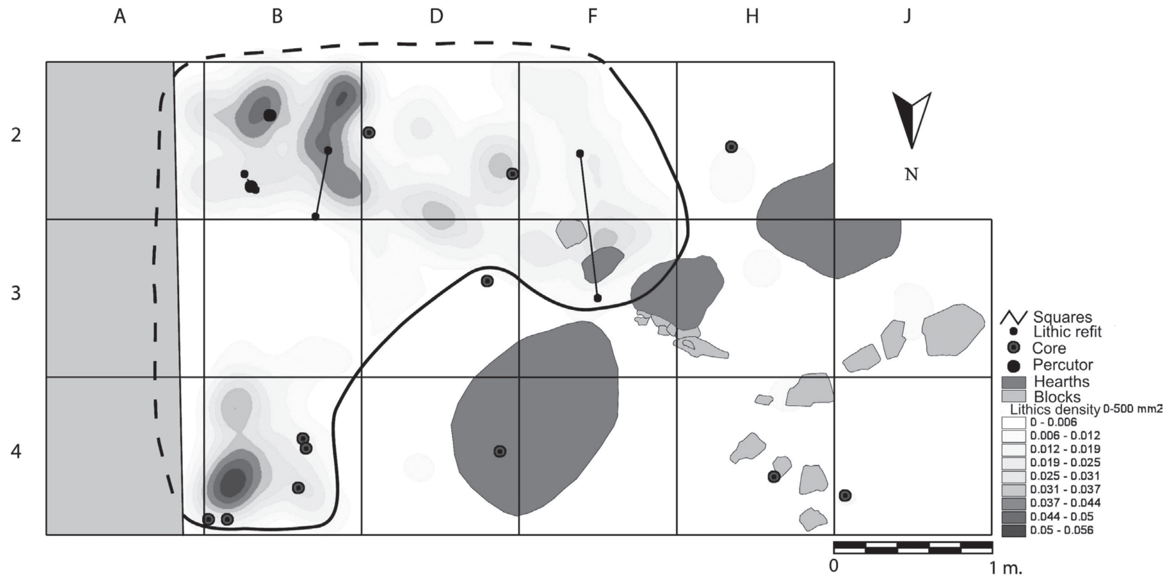

Fig. 5. Lithic production in CBIV-2 unit.

The relation between the hearths disposition and the elements of the shelter determines the organization of the occupation strategies of this unit, in line with the observations of other scholars (Henry *et al.* 2004). The CBIV-2 hearths are aligned under the shelter drip-line and the activity area is related to the internal side. This disposition provides a space with light and heat, free of the smoke produced by the hearths.

The small items indicate a production place, originating in an activity area related to the hearths, which is developed on the internal side of these (Binford 1978; Brooks and Yellen 1987; Stevenson 1991; Vaquero and Pastó 2001). On the external side accumulations of small items are not documented. Characteristics for the record in this zone are the presence of large items and exhausted cores. These elements indicate the development of preventive maintenance activities, rejecting the elements produced or employed in the activity area towards a *toss* zone located in the frontal space (Schiffer 1972, 1987; Yellen 1977; Binford 1978). This disposition of the archaeological materials agrees with a *drop* and *toss* model, corresponding to hearth-related assemblages.

The small bones and impact flakes appear grouped in the squares F2 and F3 (*Fig. 4*), associated with hearth B and the small thermal impact close to this, indicating a faunal processing activity. The small lithics forms a great concentration that occupies the squares B2, B4, D2, D3, F2 and F3 (the emptiness of the B3 square is artificial) (*Fig. 5*). The recovered material presents different reduction and transformation episodes, placed in the area close to the hearths, spatially coincident with the disposition of the processing area.

4. Conclusions

The proposed methodology employed for the analysis of Bolomor Cave Level IV has enabled both the delimitation of the different occupational events and the definition of the activity episodes developed within these. This method provides a high degree of accuracy, making it possible to establish temporal relations within the studied set. The results obtained make it possible to reconstruct the occupational pattern in both units.

CBIV-1 is defined by the high temporal relation of the archaeological record, which is consistent with the definition of a *drop* zone where the anthropogenic activities took place. The distortion caused the superposition of activity episodes is minimal, indicating the high synchronic relationship of the record. This presents a multifunctional area, demonstrated by the superposition of small bones and líthics, where the production and use of líthic tools and the processing and consumption of animal resources developed. This archaeological record presents the characteristics of a domestic area, a place in which most of the daily activities occurred (O'Connell 1987; Yellen 1977; Brooks and Yellen 1987). The identification of these is similar to the observation and analysis in other archaeological deposits (Vaquero and Pastó 2001; Henry *et al.* 2004). In summary, in unit CBIV-1 the domestic areas are the basic spatial unit, establishing the guideline of the *occupation model of the small surface*.

The archaeological accumulation of unit CBIV-2 creates a spatial unit in which a wide set of daily activities took place, like food processing, consumption and tool production. The development of these generates the small elements, deposited *in situ*, which enable activity areas to be identified, in agreement with the definition of *drop* zones (Binford 1978). These activity areas display the characteristics of a domestic area or spatial unit, where most of the daily activities were performed (O'Connell 1987; Yellen 1977). Activities that were developed around hearths, originating as a hearth-related assemblages, are widely documented in ethnographic research (Binford 1978; O'Conell 1987; O'Conell *et al.* 1991; Bartram et al. 1991; Yellen 1977) and have been well documented archaeologically (Vaquero and Pastó 2001; Henry *et al.* 2004).

The interpretation of unit CBIV-2 allows us to suggest a hypothesis about the occupational pattern and the development of the spatial organization strategies. The existence of an important occupation event is demonstrated by at least the hearths and the domestic area associated to them. These elements show the characteristics of the *occupation model of the small surface*; based on the hearth-related assemblages, these were probably influential in the extensive development of the occupation.

References

Bartram, Laurence E., Ellen M. Kroll and Henry T. Bunn (1991). Variability in camp structure and bone refuse patterning at Kua San hunter-gatherer camps. In: Ellen M. Kroll and Theron D. Price (eds.) *The interpretation of archaeological spatial patterning*. New York: Plenum Press, 77–144.

Binford, Lewis R. (1978). Dimensional analysis of behavior and site structure: learning from an Eskimo hunting stand. *American Antiquity* 43(3), 330–361.

Blasco, Ruth (2006). *Estrategias de subsistencia de los homínidos del Nivel XII de la Cova del Bolomor (La Valldigna, Valencia)*. Àrea de Prehistòria. Departament d'Història, Història de l'Art i Geografia. Tarragona, Universitat Rovira i Virgili: 236.

Brooks, Allison S. and John E. Yellen (1987). The preservation of activity areas in the archaeological record: etnoarchaeological and archaeological work in Northwest Ngamiland, Botswana. In: Susan Kent (ed.) *Method and theory for activity area research. An ethnoarchaeological approach*. New York: Columbia University Press, 63–106.

Canals, Antoni (1993). *Methode et techniques archeo-stratigraphiques pour l'etude des gisements archeologiques en sediment homogene: aplication au complexe CIII de la Grotte du Lazaret, Nice (Alpes Maritimes)*. (Informatique appliquée: base de données et visualisation tridimensionnelle d'ensembles archéologiques). Institut de Paleontologie Humaine. Paris: Museum National d'Histoire Naturelle, 124.

Canals, Antoni, Josep Vallverdú and Eudald Carbonell (2003). New archaeo-stratigraphic data for the TD6 level in relation to *Homo*

Antecessor (lower Pleistocene) at the site of Atapuerca, North-central Spain. *Geoarchaeology: An International Journal* 18(5), 481–504.

Fernández Peris, Josep (2007). *La Cova del Bolomor (Tavernes de la Valldigna, Valencia). Las industrias líticas del Pleistoceno medio en el ámbito del Mediterráneo peninsular*. Valencia, Servicio de Investigación Prehistórica, Diputación Provincial de Valencia. Trabajos Varios del SIP, nº 108.

Fumanal, Maria Pilar (1993). El yacimiento premusteriense de la Cova del Bolomor (Tavernes de Valldigna, País Valenciano). Estudio geomorfológico y sedimentoclimático. *Cuad. de Geogr*. 54, 223–248.

Greig-Smith, Peter (1952). "The use of random and contiguous quadrats in the study of the structure of plant communities." *Annals of Botany n.s.* 16, 293–316.

Greig-Smith, Peter (1964). *Quantitative plant ecology*. London: Methuen.

Henry, Donald. O., Harold J. Hietala, Arlene M. Rosen, Yuri E. Demidenko, Vitaliy I. Usik, and Teresa L. Armagan (2004). Human behavioral organization in the middle Paleolithic: Were Neanderthals different? *American Anthropologist* 106(1), 17–31.

Hietala, Harold J. and Dominique E. Stevens (1977). Spatial analysis: multiple procedures in pattern recognition studies. *American Antiquity* 42(4), 539–559.

Kintigh, Keith W. and Albert Ammerman (1982). Heuristic approaches to spatial analysis in archaeology. *American Antiquity* 47(1), 31–63.

Koetje, Todd A. (1987). *Spatial patterns in magdalenian open air sites from the Isle Valley, Southwestern France*. Oxford: B.A.R International Series.

O'Connell, James F. (1987). Alyawara site structure and its archaeological implications. *American Antiquity* 52(1), 74–108.

O'Connell, James F., Kristen Hawkes and Nicholas Blurton Jones (1991). Distribution of refuse-producing activities at Hadza residential base camps: implications for analyses of archaeological site structure. In: Ellen M. Kroll and Theron D. Price (eds.) *The interpretation of archaeological spatial patterning*. New York: Plenum Press, 61–76.

Sañudo Die, Pablo (2007). *Análisis espacial del nivel IV de la Cova del Bolomor. Hogares y áreas domésticas a inicios del Pleistoceno superior Àrea de Prehistòria*. Departament d'Història, Història de l'Art i Geografia. Tarragona: Universitat Rovira i Virgili, 167.

Simek, Jan F. (1984). Integrating pattern and context in spatial archaeology. *Journal of Archaeological Science* 11, 405–420.

Schiffer, Michael B. (1972). Archaeological context and systemic context. *American Antiquity* 37(2), 156–165.

Schiffer, Michael B. (1987). *Formation processes of the archaeological record*. Alburquerque: University of New Mexico Press.

Stevenson, Marc G. (1991). Beyond the formation of hearth-associated artifact assemblages. In: E. M. Kroll and T.D. Price (eds.) *The interpretation of archaeological spatial patterning*. New York: Plenum Press, 269–296.

Vaquero, Manuel and Ignasi Pastó (2001). The definition of spatial units in middle Palaeolithic sites: The heart-related assemblages. *Journal of Archaeological Science* 28, 1209–1220.

Whallon, Robert (1973). Spatial Analysis of Occupation Floors I: Application of Dimensional Analysis of Variance. *American Antiquity* 38(3), 266–278.

Whallon, Robert (1974). Spatial Analysis of Occupation Floors II – Application of Nearest Neighbor Analysis. *American Antiquity* 39(1), 16–34.

Yellen, John E. (1977). *Archaeological Approaches to the Present*. New York: AcademicPress.