Quaternary International 417 (2016) 82–93

Contents lists available at ScienceDirect

Quaternary International

journal homepage: www.elsevier.com/locate/quaint

From site formation processes to human behaviour: Towards a constructive approach to depict palimpsests in Roca dels Bous

Jorge Martínez-Moreno [a,*], Rafael Mora Torcal [a], Miquel Roy Sunyer [a], Alfonso Benito-Calvo [b]

[a] Centre d'Estudis del Patrimoni arqueològic de la Prehistoria (CEPAP-UAB), Universitat Autonoma de Barcelona, 08193 Bellaterra, Spain
[b] Centro Nacional de Investigación sobre la Evolución Humana (CENIEH), Paseo Sierra de Atapuerca, 3, 09002 Burgos, Spain

ARTICLE INFO

Article history:
Available online 21 October 2015

Keywords:
Palimpsest
Site formation processes
High-tech fieldwork
Archeological level
Association
Superposition

ABSTRACT

Study of the archaeological record underpins characterization of human behaviour in the past. However, site formation processes modify archaeological deposits affecting identification of activities and/or contexts which provide information on those behaviours. Such phenomena form palimpsests in which associations between artefacts and behaviour are not always clear.

Roca dels Bous is a multi-layered Mousterian rock shelter where we apply a series of high-tech approaches. Design of a digital environment is connected with assessment of the influence of site formation processes on archaeological levels. We present examples of this application which represent a significant improvement in the quality of information recovered during fieldwork.

Integration of these technologies enables development of a constructive approach to fieldwork which does not concentrate exclusively on the recovery and recording of artefacts during excavation with a view to their future 'reconstruction' through post-excavation techniques. Alternatively we propose to intervene directly with the archaeological record in parallel with its excavation. The application of new technologies integrates spatial and contextual information obtained during fieldwork with which to create hypotheses that will be verified or rejected according to data obtained in excavation. The continual interaction between data and hypotheses makes it possible to detect errors in interpretation of the archaeological record which would be difficult to recognise when applying post-excavation techniques where, at times, associated contextual evidence is lost.

This approach reminds us of the difficulty in defining concepts such as 'spatial/temporal association' or 'archaeological level', which are basic to discussion in Archaeology. Finally, we think this constructive approach to fieldwork enables us to address the study of palimpsests, a key concept in the interpretation of the archaeological record.

1. Introduction: from frozen images to site formation processes

Palimpsest is a polysemic and multiscalar concept affecting the archaeological record on several levels (Bailey, 1983, 2007). This perspective implies that the notion of palimpsest is present all phases connected with interpretation of the archaeological record, from artefact recovery – understood as anything resulting from human activity (Clarke, 1978) – to justification of final inferences; thus, it concerns theory, method and data. The palimpsest is an intrinsic property of the archaeological record formed by spatial/temporal associations between lithic remains, bones and less commonly hearths, which are the raw material characterizing past human lifestyles (Gregg et al., 1991).

The metaphor of the "Pompeian premise" was central in the main Processual discussion of the static or dynamic nature of the archaeological record (Schiffer, 1972, 1976; Binford, 1981, 1983). This controversy is now outdated and palimpsest is considered as an inherent attribute integrated in the interpretation of the archaeological record (Holdoway and Wandsnider (ed), 2008 and references therein; Bailey and Galadinou, 2009; Kuhn and Clark, 2015). Although study of palimpsests leads to inferences on activities and behaviour, problems of interpretation persist as there are no agreed protocols with which to address the topic (Villa, 1977, 2004; Malinsky-Buller et al., 2011).

* Corresponding author.
E-mail address: jorge.martinez@uab.cat (J. Martínez-Moreno).

http://dx.doi.org/10.1016/j.quaint.2015.09.038

Although any artefact elicits implications for the notion of dynamics, there are differences on the relevance of those inferences. Bordes (1975) warned of excesses in interpretation of an assemblage of remains without understanding the context in which they appear. High resolution sites, key to identifying processes and behaviour, illustrate this conflict (Dibble et al., 1997; Pettit, 1997; Vaquero, 2012). Technical and spatial information provided by the refitting of a core and its associated tools represent a series of actions which occur in a minute fraction of time. Defined as the “15 minutes of fame” syndrome (Hallos, 2005), this paradox is not easy to identify in most archaeological deposits, as they rarely record these moments in time. We suspect that such limited visibility is the result of events which happened in an imprecise time period representing tens or hundreds of years. In such a scenario, is it possible to find indicators which provide information on the notion of dynamics? In part, this question reflects the expectations of each discipline. In Palaeobiology a temporal resolution in the order of 10^2 to 10^4 years defines these components as ‘synchronous’ (Beherensmeyer, 1982). However, it may be relevant to ask whether such a time scale is adequate for the reconstruction of past group behaviour. Although these intervals do not evoke specific situations, such as those described in high resolution sites, they provide information on the organization of systems designed to give continuity to a way of life. In consequence, palimpsests are key to detecting this organization.

In the Processual debate cited above, Binford considered the archaeological record to be static, its dynamics recoverable only through observations of the present-day world which generate analogous records. Uniformitarianism is a powerful tool in developing hypotheses, such as the toss/drop zones illustrating how current dynamics lead to behaviour which should be sought in the archaeological record (Binford, 1983). The distribution of residuals around hearths is an idea explored through a wide spectrum of approaches, from a direct use (‘naïve uniformitarianism’) (Isaac, 1983) to more sophisticated approaches (Stapert, 1990; Henry, 2012). Nevertheless, such an approach is incomplete. The archaeological record is not a frozen image of the past. The present informs us about situations which occurred in the past, but it does not necessarily explain the past. Indeed, this is the classic problem of equifinality: reliable analogous phenomena are not explanations of processes which occurred in the past (Gifford, 1981; Holdaway and Wandsnider (ed), 2008).

In our opinion, the structure of the archaeological record is related to the concept of Taphonomy, understood as the transit from the biosphere to the lithosphere (Efremov, 1940; Lawrence, 1971; Behrensmeyer et al., 2000). Taphonomy combines modifications which are biostratinomic (produced on the surface) and fossil diagenetic (related to burial) along with those produced during recovery and study. Artefacts are dynamic as these modifications affect all indicators of human activity and the spatial/temporal relationships among their constituents. Indeed, actualistic studies allow detection and description of such alterations (Gifford, 1981; Schiffer, 1987; Gregg et al., 1991). The notion of taphonomic transformation calls for caution when making direct inferences, and warns of the need for greater rigour in discussion of data in order to justify its interpretation. From this perspective, hypotheses and methods used in recovery are interacting spheres when analysing the impact of formation processes on the archaeological record, prior to inferring behaviour.

This means that field data, hypotheses and methods involved in recovery often must be updated. In a textbook par excellence such as Archaeology (Renfrew and Bahn, 1991), fieldwork is little more than collateral routines, as the significance of many examples presented cannot be separated from the way in which archaeological were recovered. The design of how to mediate static archaeology is the foundation on which to recover its dynamic. In this article we advocate what we call a “constructive” approach or proactive action in parallel with the development of fieldwork, in which basic information – sometimes intuition – arising during excavation, if not assessed at that time run the risk of not being incorporated into its interpretation. Our proposal describes research developed over recent years in several rockshelters in Northeastern Iberian Peninsula, illustrated here in Roca dels Bous, which cannot be considered a high resolution site. This constraint has forced the development of a series of theoretical, methodological and technical principles to address the study of palimpsests. The problems we see at this site, which we suspect are common, motivated us to develop a proposal affecting object recovery, decision-making which determine its future analysis and interpretation.

Our aim in this constructive approach is not the ‘reconstruction’ of archaeological levels; we elect to build them in parallel with their excavation. We emphasize constant interaction between data acquisition and interpretation, in which fieldwork plays an active role in the definition of these analytic units. It works from hypotheses which are generated and then compared with information obtained in excavation. In this system, implementation of new technologies is essential in assessing inferences which often force reorganization of the excavation. No less important is that application of the same methodological principles for 15 years minimizes biases derived from alternative methods, a factor whose incidence is difficult to assess but possibly important (Dibble et al., 2005, 2009; McPherron et al., 2005).

2. Fieldwork architectural design: from coordinate capture to digital management

If we accept that the archaeological record is dynamic, then our approach to fieldwork should be dynamic. Today, new technologies make it possible to provide real-time information on the evolution of the excavation (Craig and Aldenderfer, 2003). Microcomputing has had a profound technical impact on the management of fieldwork data, even in adverse conditions (McPherron and Dibble, 2003). In parallel, since the 1990s we have seen a growing bibliography associated with the use of Geographic Information Systems (GIS) in Archaeology (among others Allen et al., 1990; Conolly and Lake, 2006; Owens et al., 2014). As a result, microcomputing and the associated digital environment are among the tools used in many current fieldwork projects.

These tools are incorporated in all excavation routines from spatial data capture, through preliminary description and marking to its storage in the form of field inventories. Several interconnected gadgets involved in these tasks are embedded in fieldwork. Although high-tech applications are not an end in themselves, they improve the excavation facilitating tasks, reducing errors which accumulate during information recovery, and advising of complex factors which affect later interpretation of the archaeological record (Fig. 1). Many projects have developed in similar digital environments (Dibble and McPherron, 1998; Canals et al., 2008) which will likely become more widespread in facilitating the recovery, storage and reliability of information obtained in fieldwork.

2.1. Not enough bites: towards a big database environment

The system is structured around a database as a support for the storage and exploitation of information recovered during fieldwork. It coordinates individual spatial, contextual and artefact attributes of the currently more than 200,000 items, whose management required the development of specific software. Design of this programme – called ArqueoUAB – began 30 years

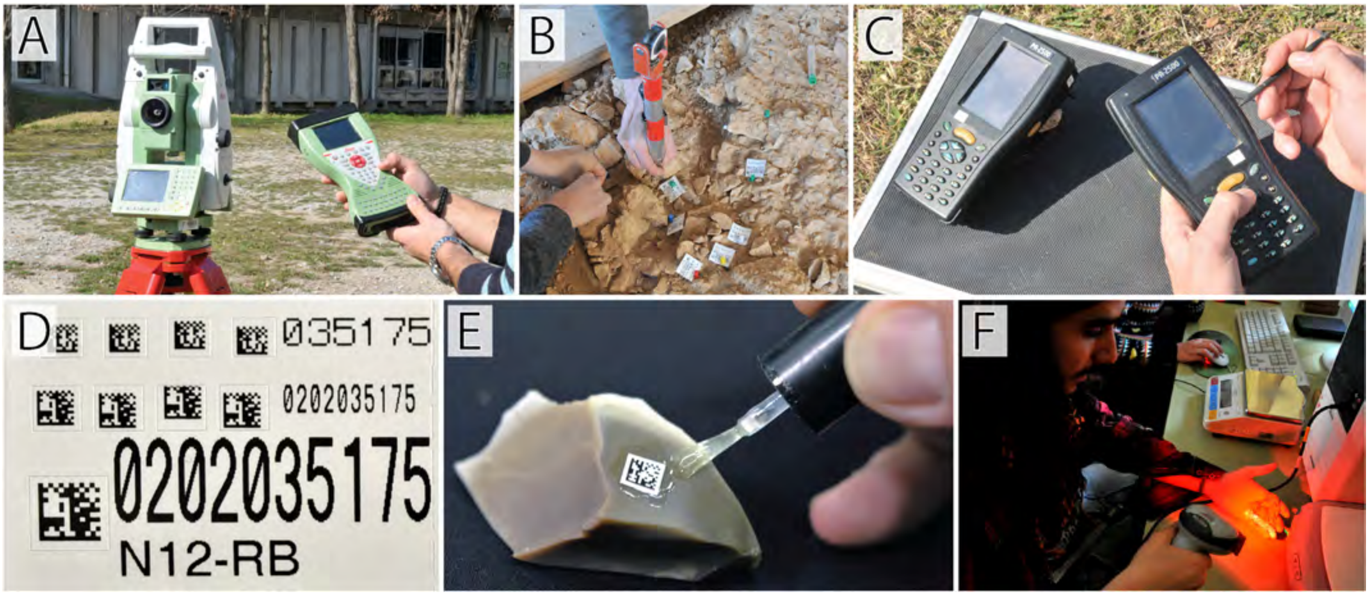

Fig. 1. Technological components used in fieldwork. A) Theodolite laser which works with a remote control. B) Prism to record the three-dimensional position of artefacts which are given an identification DM-code label. C) Personal Digital Assistant used as a notebook. D) Different-sized DM-codes used in coordinate identification. E) Direct positioning of a DM-code on an artefact. F) Reading code with a laser reader connected to a PC.

ago in Fortran and GwBasic, programme languages now obsolete (Lucas et al., 1986; Mora, 1988). Currently the software programme is in Visual Basic 6 and the relational database is in MySQL (2014), which allows adequate management of a volume of information of ongoing projects.

ArqueoUAB is a software programme for data management (input, editing and query) which greatly facilitates later work with GIS programmes. It manages georeferenced information, facilitating later graphic representation, and through queries enables the acquisition of counts, statistical data and all types of inventories (Mora et al., 2014). This flexible application has supported projects in caves, shelters and large open-air sites, among them Roca dels Bous. While it is not the aim of this article to describe the relational architecture of the database, we emphasize its coordination with other tools embedded in fieldwork: total station, personal digital assistant and DM-codes.

2.2. Capture of three-dimensional data

'Modern' excavation techniques are based on the need to position the archaeological record on the horizontal and vertical plane on the principle of Cartesian coordinates, a tradition which developed in the 1950s (Laplace and Méroc, 1954). This system aims at retrieving the three dimensional position of an artefact from terrestrial/aerial grids which demarcate 1 m^2 surfaces, and combines that with depth taken from a level -0- obtained with an optical level. Likewise, it proposed excavating by 10 cm-thick artificial levels, criteria which could be modified according to the excavator's needs.

Nowadays, optical levels and grids have been replaced by the total station (Parcerisas and Mora, 1995). The specifications of this topographic machine, whose use is increasingly common, has been explained in other articles (Dibble, 1987; Rick, 1996; Dibble and McPherron, 1998; McPherron, 2005), so we will focus on describing its use in our project. Currently we use a Leica TPS1200 robotic total station with remote control which improves data capture (Leica TPS, 2014). From two georeferenced points, the device generates a virtual three-dimensional space which includes the excavation area, turning the site into an integrated space and from Cartesian coordinates -X Y Z-re-establishes the position of any element with millimetre accuracy (Fig. 1).

The basic unit of information is the three-dimensional position of elements recovered, which are encoded with different types of alphanumerical strings. A first type corresponds to discreet coordinates of artefacts which are assigned to an archaeological level. Furthermore, a series of points outline natural or anthropic shapes corresponding to 'lines' and "polygons" of GIS software. Lines are continuous strings of coordinates which allow graphic representations to be edited as georeferenced topographic and stratigraphic sequences. Polygons are series of points which define the shapes and edges of natural (blocks) or anthropic (hearths or pits) elements, and which are stored as individual strings. The total station has a memory unit that stores geospatial data identifiers which are downloaded to the computer through a USB interface at the end of the session.

2.3. Digital alternatives to tedious tasks: artefact description and labelling in the field

Once the coordinates of a point have been captured, the total station generates an alphanumeric identifier composed of a contextual indicator (level name or shape) and a numerical sequence. In the coordinates, each alphanumeric string designates discrete artefacts which are assigned Data Matrix (DM) labels and their attributes are taken in the field with a personal digital assistant (PDA) (Fig. 1).

PDAs are notebooks with hierarchical dictionaries identical to those programmed into the database. Each coordinate is defined by a string of attributes: contextual (orientation, slope), quantitative (length, width, thickness) and qualitative (for bones, identification of specific anatomical level; for lithics, raw material and category). This description is stored in the PDA and at the end of the session is transferred to the microcomputer. Each coordinated piece is placed in an individual bag with its corresponding alphanumeric identifier (DM-code). ArqueoUAB identifies and combines spatial data obtained through the total station with the attributes of each piece and the database is updated daily. The digital inventory allows us to query specific artefacts and generate files for graphic representation.

Each coordinate has an identifying label, and once cleaned and dried, it is usually marked manually. Several factors make this a thankless task (blank surface difficult to write on, quality of individual writing) producing errors that can lead to the loss of contextual information of the artefact. One way of overcoming such a problem is to use digital slides such as bar codes (Dibble et al., 2007). We propose that DM-codes produce several improvements in the labelling of museum and fieldwork collections. First is size and currently we use codes between 2.5 × 2.5 or 5 × 5 mm capable of storing 6–10 digits, sufficient to identify individual artefacts. These codes adhere directly to the piece facilitating its handling and limiting labelling errors. Even if the code is damaged, it can be recovered if it conserves 30% of the printed surface. The code is read with a laser-reader connected to a computer, linking it with the stored record in ArqueoUAB software (Martínez-Moreno et al., 2011; Roda et al., 2014) (Fig. 1).

2.4. Visualscapes: from visual representation to interpretative applications

ArqueoUAB centralizes information received from fieldwork devices and the transfer of information enables a continuous update of data during excavation. As a georeferenced database, it links spatial position with attributes defining each coordinate. Data taken in the field with PDA are checked and, if needed, rectified. This series of interrelated tables allow all kinds of enquiries, turning ArqueoUAB into a powerful analytical tool (Mora et al., 2014).

ArqueoUAB generates customized tables from which bidimensional graphics are created (plans and sections) (Mora, 1988; Mora et al., 2001). These files contain artefact coordinates and volume defined by the perimeter and thickness of hearths and large blocks, and can also be combined with stratigraphic unit strings. When edited with GIS software, files produce plots which analyse associations between coordinates and shapes, leading to spatial and temporal inferences. The combinations of Cartesian X–Y coordinates generate distributions on the horizontal plan; meanwhile X–Z coordinates plot vertical dispersion on the E–W axis, and Y–Z in the N–S direction of the virtual site grid. Although usually spatial associates are inferred from distributions on the horizontal plane, cross-sections should be included in plans to enable visualization of the geometry of the archaeological record (Koetje, 1991; Pallarés, 1999; McPherron et al., 2005; Martínez-Moreno et al., 2004, 2010) (Fig. 2). Application of GIS in field work facilitates more widespread use of this representation (Galoti et al., 2012; Sañudo et al., 2012; Machado et al., 2013; Vaquero et al., 2015).

A common problem is that cross-sections parallel to the N–S or E–W axes of the grid do not always provide information on the organization of materials, as it is necessary to combine several sagittal and longitudinal cross sections to be representative. An alternative is oblique plots which combine X/Y–Z coordinates to visualize the dynamic of the archaeological level and analyse virtual spatial associations between concentrations which cannot be connected by orthogonal cross-sections (Roy, under revision). Such visualscapes (Llobera, 2003) allow identification of morphologies which are not always easily defined, and are of heuristic value in helping make decisions on problems arising during excavation. It is not a simulation in the sense of a reconstruction of the excavation based on information provided by the database (Koetje, 1991). We do not propose a recreation without the support of contextual information; we propose to structure inferences from data and controlled hypotheses based on database/excavation interaction. In this approach, the information provided by excavation is key.

2.5. New technologies, different objectives: 3D models of restoration

Differences between concepts of reconstruction and construction can be assessed through the application of digital technologies used in fieldwork to generate three-dimensional models: 3D scanning and photogrammetry. Although results are similar, there are significant differences in their application in fieldwork. 3D scanning was successfully used in the restoration of architectural structures and documentation of rock art or artefacts. Recently they have aided fieldwork recording of some Mousterian sites providing graphic documentation of extraordinary quality. However, its use involves difficulties related to learning how to handle it, time invested in data-processing, or logistical problems involved when setting it up which affect development of the excavation. This device seems to be better adapted for use at the end of the field season (McPherron et al., 2009). Photogrammetry, however, only requires a standard digital camera and total station; photos are processed in a computer with PhotoScan software and resulting models are integrated in a GIS environment (De Reu et al., 2013). While 3D geometric resolution is lower, results are obtained quickly. Trials undertaken at Roca dels Bous confirm its easy integration into fieldwork (Fig. 3).

These technologies define different relationships with fieldwork. Because of technical requirements, recovery from the 3D Scanner is better suited to post-excavation and although these high quality results enable research of the record, they do not allow for immediate application of inferences, so we consider them to be essentially 'illustrative' in nature. Photogrammetry generates models in parallel with fieldwork and is also illustrative in character, but the information it provides is channelled into inferences which can be assessed during excavation. Although these devices are not mutually exclusive and it is advisable to combine both methods, the flexibility of photogrammetry resembles a constructive focus on the immediate transfer of information and continues to validate or modify fieldwork strategy. At the same time, it allows space/time relationships to be actively and positively established, which affects the type of information generated during the excavation.

These technologies indicate the need to assess their pros and cons when it comes to applying them in excavation. Although such high quality recording systems encourage interaction between hypothesis and data, they do not have the same significance when developing a constructive approach such as that proposed here. Examples from Roca dels Bous can be used to analyse the implications of this constructive approach.

3. A not very promising site: dynamics at the Mousterian site of Roca dels Bous

The Mousterian site of Roca dels Bous (Southeastern Prepyrenees, Iberian Peninsula) is a slope deposit located by a large limestone wall which was recently used to shelter livestock (Fig. 4). Systematic excavation began in 2001 and currently the excavation area covers a surface of 100 m^2 in which several archaeological levels have been identified: R3, N10, N12, N14 and S9. In this article we focus on N10 and N12 (Martínez-Moreno et al., 2004, 2010). Two questions arise from this description: Why excavate such a large surface?, and no less important: What is an "archaeological level"? These questions affect methods of excavation applied and research of the site.

Excavating on a large scale might suggest an interest in undertaking a palaeo-ethnographic excavation, aimed at identifying large

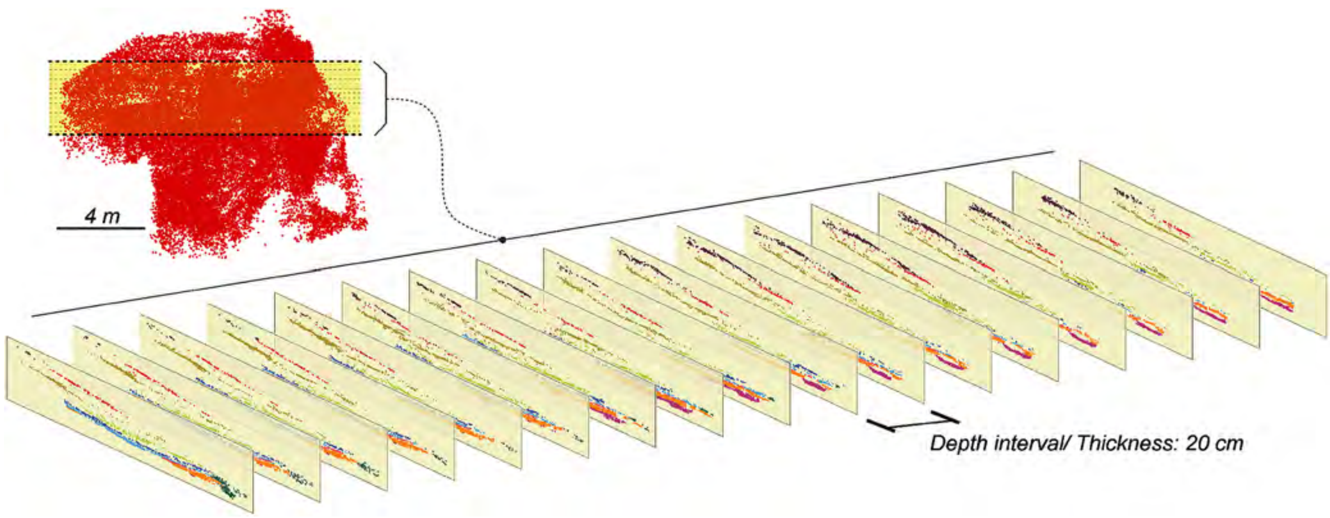

Fig. 2. Tomographic approach generated from ArqueoUAB. This software automatically creates files with X–Z or Y–Z coordinates every 20 cm that can be edited graphically with ArcGIS. These successions of visualscapes benable dissection of the vertical evolution (E–W direction) along 15 linear meters of a multilayered archaeological deposit (yellow area) (Roy, under review). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

Fig. 3. 3D model produced through digital photogrammetry allowing detection of several relevant details. The first is a series of medium-sized rocks (5–10 cm) on which N12 developed, identified by a hearth apparently 3 m long, corresponding to several stratified combustion structures. The shape of the thermally altered surfaces indicates they were set up on a slope (see Fig. 5 and 6).

spaces where activities took place and are interpreted as activity zones, such as described in the classic Pincevent site (Leroi-Gourhan and Brézillon, 1966). While this principle directly or indirectly governs large scale excavation in some Middle Palaeolithic open-air and rock shelter sites (Roebroeks, 1988; Carbonell (ed), 2012), it is difficult in Roca dels Bous because of the impact of formation processes. In this deposit, debris cones converge that feed the accretion of vertical sediments such as sands and chaotic clasts which fluctuate between centimetre-sized fragments and big rocks generated by weathering of the rock-shelter wall. Carbonate precipitation cemented the sediment forming a matrix of chaotic volumes with poor archaeological visibility (Martínez-Moreno et al., 2004; Benito Calvo et al., 2009) (Figs. 3 and 5).

Faced with these limitations, the abundance of bones, lithic artefacts and presence of hearths throughout the excavated surface, led us to question what attributes define an archaeological level. This consideration shows how difficult it is to interpret a relatively common phenomenon such as the presence of combustion structures in similar contextual positions, and provokes questions such as: Do they form part of the same occupation? Were they in use at the same time? Do they correspond to different times? No less relevant is how to associate artefacts with combustion structures. Roca dels Bous has theoretical and methodological implications for the interpretation of palimpsests with a spatial resolution in which patterns of management of space around hearths are suggested (Fig. 5).

3.1. What is an “archaeological level”?

Traditionally an archaeological level is equated to sedimentary changes in a stratigraphic sequence; geological terms such as bed, couche or layer are used as synonyms. Such use is

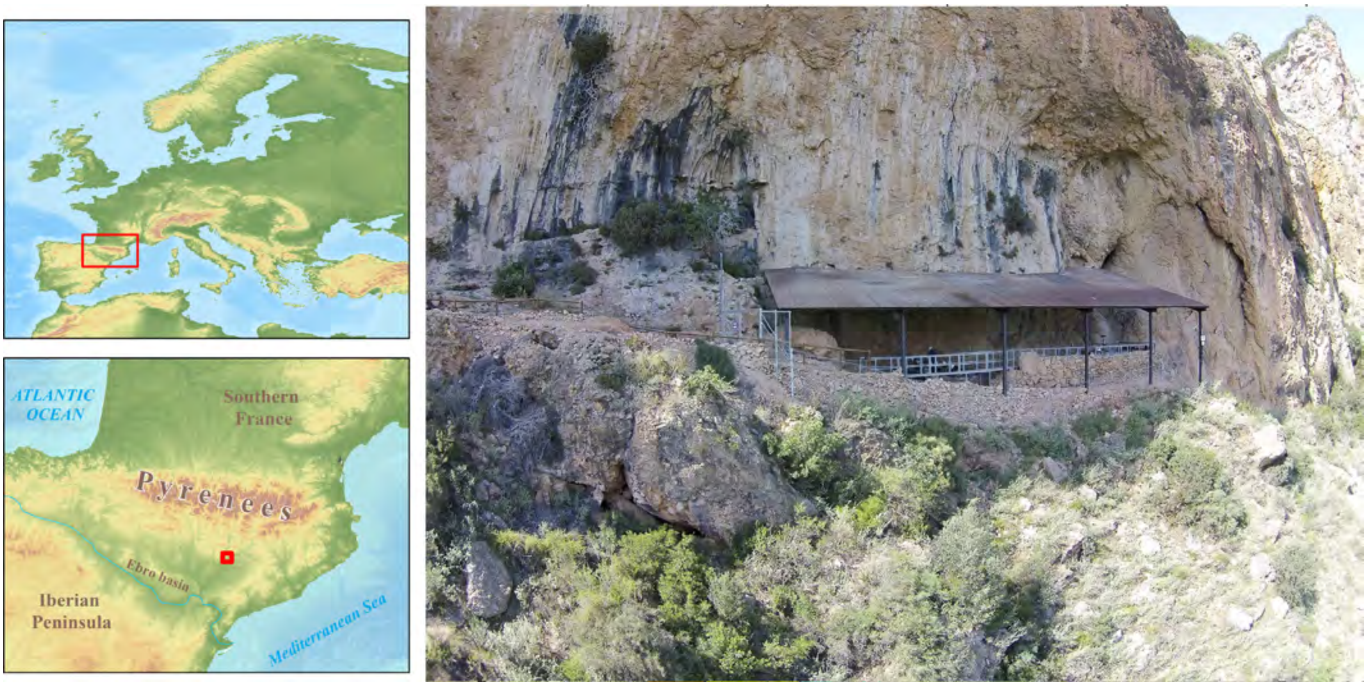

Fig. 4. Location of Roca dels Bous in the Northeast Iberian Peninsula. The excavated zone in the photo corresponds to the part of the deposit artificially flattened in order to build a wall which served as a pen until recently.

Fig. 5. General view showing the convex shape created by the sedimentary structure on which N12 sits (compare with Fig. 3). 3 hearths (a, b, c) are evident in the lower right corner which we attribute to another archaeological level – N14 – overlying N12 as seen by the orange sterile sedimentary complex. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

confusing as these terms define geological levels which can contain several archaeological levels, or the same archaeological level which may develop through several geological layers (Villa, 1977; Villa and Courtin, 1983). At present it has been replaced by "context": an entity which includes attributes such as the sedimentary matrix in which artefacts are contained, its vertical and horizontal position within this physical medium and spatial association with other artefacts in the same sedimentary level (Renfrew and Bahn, 1991). This notion of sedimentary structure with artefacts associated in space and time refers to two principles defined by Lyell (1833): association and superposition. Consideration of these associated components assumes a temporal relationship between them; superposition implies that they are anterior or posterior.

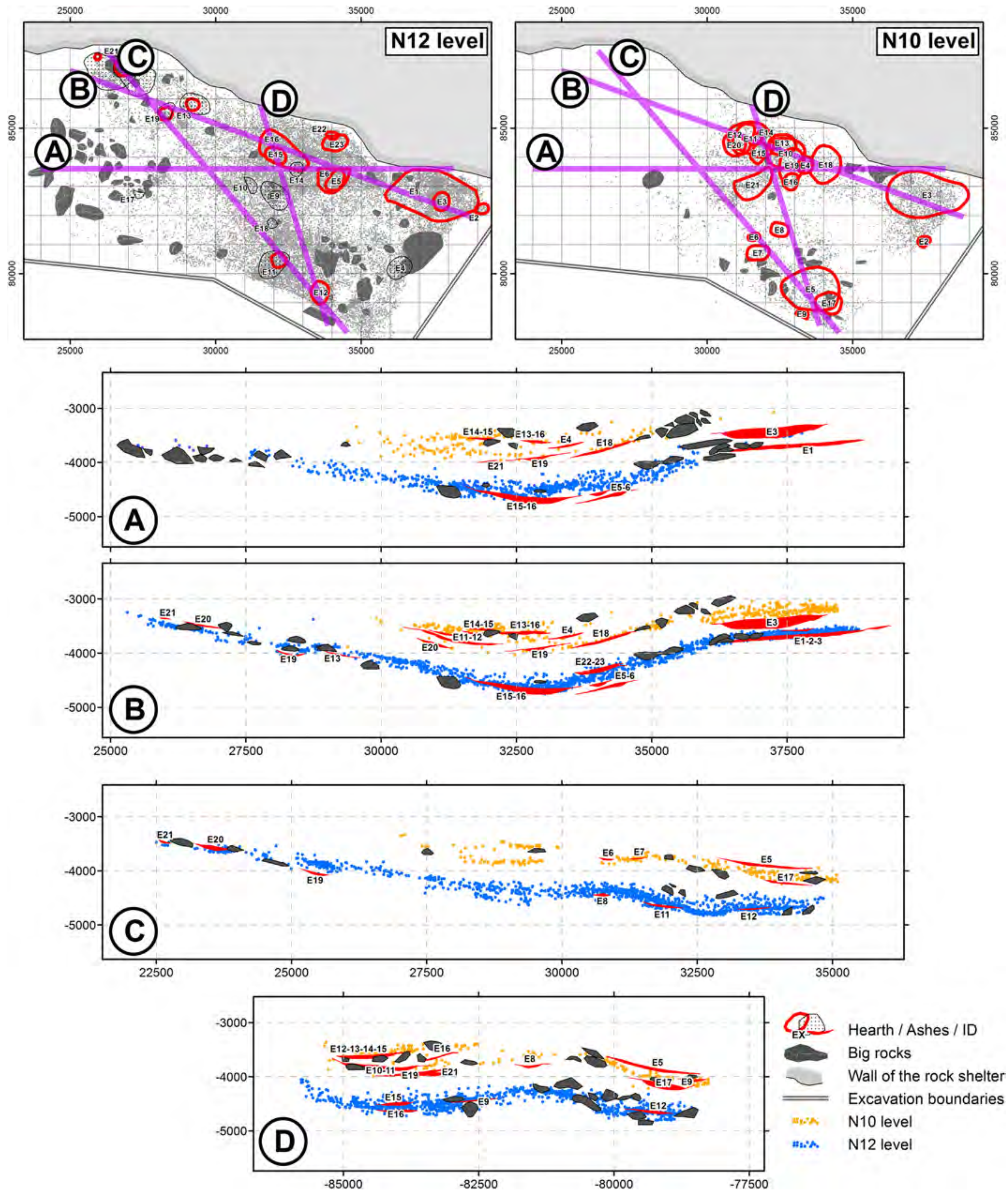

Fig. 6. Visualscapes characterizing N10 and N12 that exemplify notions of association and superposition. The upper part shows the horizontal distribution of coordinates, hearths and blocks in N10 and N12 (see legend on the lower right corner), vertical (A) and oblique (B, C and D) plots in 20 cm-thick rectangles. The projections illustrate how these levels are structured following natural slope relief, usually with a vertical dispersion between 5 and 10 cm, and how their vertical distribution varies according to each plot, providing indications of the temporal relationship between artefacts, hearths and fallen rocks. The following comments relate to these graphics: A) E–W cross-section in which N10 and N12 are longitudinally superimposed over a distance of 14 m. A sterile layer between the two archaeological levels shows no indication of percolation that might suggest a mixing of materials between the two contexts. The superposition of hearths in N10 and N12 can be seen in coordinates X = 32,500–35,000. B) Oblique cross-section similar to A oriented parallel to the rock shelter wall to observe the westward continuation of N12. By rotating the projection angle, one can see the successive placement of hearths which overlap and

Such concepts are key to the organization of fieldwork and were systematically applied throughout the excavation. Because of poor archaeological visibility, information from contextual indicators took precedence over excavation of horizontal surfaces and artificial levels. Artefacts were systematically coordinated and integrated within sedimentary particles (Gifford, 1981; Bertran et al., 2012) assuming that such point clusters define volumes containing artefacts which are spatially and temporally associated. These clusters with evidence of human activity form scatters in the horizontal and vertical scale, as opposed to zones in which these indicators disappear. Such coordinate geometry defines the limits and extent from roof to base of what we call ‘archaeological level”.

As coordinates can be rapidly taken with a total station, all stone tool categories, regardless of size (including micro-debitage), were plotted. Also plotted were bone remains, mostly fragments unidentifiable on a specific and anatomical level due to aggressive syn/post-depositional processes such as rock falls or sedimentary compression. The aim was to take the largest number of coordinates possible in order to retrieve their spatial and contextual position. With the aid of infographic representation it was possible to analyse the floor and vertical development of these artefact associations integrating the perimeter and volume of hearths and rocks greater than 15 cm (Fig. 6).

Topographic information derived from combining the position of coordinates, blocks and hearths, identifies occupations located on slopes, and not on flat surfaces. The first 5°–10° in the N–S sense is usually in a slope deposit connected to a wall. Of more interest are the two opposing E–W and W–E slopes, which are not very steep and which converge in the central zone of the excavation forming a natural concave depression. This arrangement implies that vertical accretion is the result of lateral sediment deposition forming two cones located at the ends of the rock shelter, and which have now disappeared (Benito-Calvo et al., 2009).

These formation processes structure a space composed of volumes of different shapes and dimensions which may relate to rhythms of sedimentation which are not necessarily homogenous. Depending on the distance of the lateral cones, sub-horizontal platforms were produced which are connected and form a depression of 15 m^2. These dynamic volumes are unclear and their excavation by artificial flat-horizons does not seem to be an appropriate technique; it is better to follow natural slopes indicated by the grouping of coordinates and fabric of artefacts, blocks and hearths (Lenoble and Bertran, 2004; McPherron, 2005), as was systematically put into practise in N10 and N12 (Benito-Calvo et al., 2009). The slope of the hearths and the stable levels on which blocks rest provide clues with which to identify the geometry of those levels. Restoration of the deposit morphology cannot be understood without the constant interaction between excavation data in the form of three-dimensional coordinates and infographic representations, which often oblige one to rethink fieldwork strategy in order to establish coherence between excavated surfaces and excavation data.

Interpretation of the archaeological record is based on concepts of association and superposition, as from the moment an artefact is assigned to a level, it is assumed that it shares the same context with other components. This idea, examined and verified through refitting, has been key in reconstructions undertaken in high resolution sites mentioned earlier. In Roca dels Bous, cross-sections identified a 30 cm-thick sterile layer separating N10 and N12, whose vertical development extends more than 8 lineal metres. Its horizontal and vertical distribution indicates a lack of lateral continuity towards the E and W due to recent remodelling of the rock shelter as an animal pen (Fig. 4). Nevertheless, the geometry indicates that these assemblages were generated at different times and may rule out vertical migrations which imply mixing of artefacts. These visualscapes justify the validity of the principle of superposition in defining artefacts assumed to be associated (Fig. 6).

The vertical dispersion of N10 and N12 levels is not excessive, confirming the perception that many excavated areas were quickly depleted. As average level thickness is 5 cm in N10 and 10 cm in N12, although it reaches 20–25 cm in some zones, levels can be considered as relatively discrete. However, it is not possible to propose a palaeoethnographic interpretation of these surfaces at Roca dels Bous; on the contrary, they display the complex interaction between natural processes and accumulations resulting from human activities. In this sense, it has been suggested that the so-called “structures d'accueil” (reception structures) outlined by the arrangement of hearths and blocks could indicate management of space (Rigaud and Geneste, 1988; Kolen, 1999). With coordinates of artefacts, hearths and rocks one can assess with millimetre precision these associations and infer the validity of concepts of association/superposition within a level. Cross-sections with the altimetric position of large stones, hearths and their relationship with coordinates clearly demonstrate that they are associated with the top, centre and base of hearths; in blocks they appear in similar positions (before, during and after collapse) (Fig. 6). As seen below, an important indicator of diachrony is the superposition of hearths observed within N10 and N12.

3.2. *Same space/same time?: the meaning of spatial/temporal association*

N10 and N12 are the result of two distinct but interrelated phenomena: they are formed by an indeterminate number of events which occur in an imprecise time scale. This phenomenon was identified in N10 during excavation of an area in which 10 overlapping hearths were located in an 8 m^2 depression next to the wall (Martínez-Moreno et al., 2004). The slope of the excavated hearths and dispersal of coordinates identified a 20 cm-deep, parabolic shape. Plot geometry indicated a level of limited vertical dispersal, which towards the E was interspersed with artefacts and hearths forming a fan-shaped geometry representing the silting up of this depression (Fig. 7). Some hearths appeared in similar contextual positions so that it was difficult to determine whether they operated at the same time or corresponded to different events, that is, if they were “synchronous” or “diachronic”. In N10 which can be considered a living floor (Villa, 1977, 2004; Malinsky-Buller et al., 2011), a succession of occupations is recorded within a few metres that are the same shape as the relief formed at the intersection of the two lateral debris cones. This example reminds us of a property, not evident in the archaeological record, that we call fusion/fission processes and is demonstrated visually in the fill of the natural depression (Fig. 7). In this case, it is not clear that burial of these surfaces was a homogenous and continuous process. On the contrary, differences are indicated in sedimentation rhythms within the deposit causing slower burial in some zones with apparently associated artefacts; meanwhile, rapid vertical accretion in other zones – as indicated by the overlapping of hearths –

explain the sedimentary fill of the depression in N10. The accumulation in E3 (between X = 36,000–38,000) is interesting as it does not appear to be associated with the rest of N10. C) Oblique cross-section shows variations in level morphology depending on the graphic generated. In this case, the way in which N10 and N12 conform to the slope from the side cone E can be identified. The superposition of artefacts is visible in N10 (X = 27,500–30,000) by the outline of coordinates separated by a block. The concave shape of the depression whose edge E is demarcated by hearths from roof to floor is between X = 32,500–35,000. D) Oblique cross-section identifying the N10 and N12 projection towards the cave exterior and which allows identification of the stratification of different hearths, indicating the existence of different temporal events.

suggests temporal diachrony (Martínez-Moreno et al., 2004, 2010; Mora et al., 2008).

It is not easy to distinguish and assign specific artefacts to a precise time as that represented by a hearth; consequently such levels cannot be interpreted as unique events. The relationship between blocks and artefacts or the altimetric position of hearths indicates that these accumulations record periods of formation which are difficult to assess, and remind us that it is wrong to infer spatial associations without taking vertical dispersion into account. This principle implies that making associations between artefacts or artefacts and hearths is a hypothesis which has to be proven. It also implies that when interpreting site organization, distribution on the horizontal scale is secondary to information provided by vertical distribution. Even in levels with low vertical dispersal, 'synchronous' spatial associations are not necessarily related to a temporal scale.

Together, these observations indicate that the principle of superposition is a multi-scalar concept. On the one hand it describes recurring visits to the site in which artefacts associated with subsistence are transported, made and abandoned. The idea of contextual associated defines N10 and N12 as distinct phases, separated by a period without human activity on a temporal scale that is difficult to specify. In these two events, differences can be seen in the management of raw materials, knapping systems and tool form which we link to distinct use of the landscape or settlement pattern. These inferences provide information on organizational changes within Neanderthal behaviour (Martínez-Moreno et al., 2004, 2010). At the same time, the notion of superposition defines N10 and N12 as an accumulation of events in which shaped artefacts were made and abandoned during specific situations related to subsistence over an indeterminate time scale. While knapping, tool repair and carcass processing around Roca dels Bous hearths are activities which were identified during the excavation and confirmed by study of the artefacts (de la Torre et al., 2012), nevertheless, these are not pristine places, and do not illustrate precise activities, but record a mix of different temporal events. This fuzzy scenario invokes the notion of palimpsest.

4. Discussion: beyond the "15 minutes of fame" syndrome

David Clark (1973) defined Archaeology as the discipline with the theory and practice for recovery of unobservable hominid behaviour patterns from indirect traces in bad samples. Such a perspective implies that archaeological 'reconstruction' is not easy when identifying behaviour from an elusive archaeological record. This article has explored the analytical potential of the concept of construction in parallel with excavation to test the validity of units of analysis as an 'archaeological level'; the concept is not new, but essential when organizing research. The examples presented here confirm that palimpsests are a common phenomenon and that formation processes and reuse of the same space over an indefinite time scale makes it difficult to identify specific events.

Ascription of artefacts to an 'archaeological level' is not an arbitrary decision; it involves establishing space/time relationships which also separate other artefacts with different contextual relationships. In regard to criteria for inclusion or segregation, decisions taken in the field affect future research on contexts and artefacts. In this article we explore a perspective which considers coordinates of artefacts, hearths and fallen rocks as sedimentary particles in order to assess the notion of space/time association (Gifford, 1981; Bertran et al., 2012). This perspective is reductionist as techniques such as soil micromorphology and refitting generate inferences on the idea of contextual integrity which merit attention.

Soil micromorphology identifies syn/post-depositional processes that are not clear but which affect the sedimentary matrix and form of the archaeological record (Courty et al., 1989). It is also used to study the formation of combustion structures considered as short temporal events which may be associated with concrete activities. This technique leads to a better understanding of site formation processes and identification of the space/time integrity of contexts. It also identifies reuse of hearths which is not easy to establish with artefacts, as has been seen in several Mousterian sites in the Iberian Peninsula such as Abric Romaní or Salt (Vallverdu and Courty, 2012; Mallol et al., 2013), and which was identified during the excavation of some of the Roca dels Bous hearths (Martínez-Moreno et al., 2004).

Analysis of artefacts also provides information on space/time associations. Refitting has been undertaken with lithics, bones and hearth rocks (Hofman and Enloe (ed), 1992 and references therein) converting them into the 'smoking gun' in establishing synchronic associations. However, not all refitting provides the same type of information regarding the notion of temporal resolution (Bordes, 1980; Cahen, 1980). Refitting of tools between levels facilitates study of stratigraphic sequences and identification of syn/post-depositional processes (Villa, 1982; Bordes, 2003). In a similar vein, artefact recycling or fragmentation of knapping sequences indicate that on occasion refitting reveals management of artefacts at different times. These behaviours are widely dispersed in space and time (Barkai et al. (ed), 2015 and references therein) indicating the significant potential of refitting in the analysis of palimpsests (de la Torre et al., 2012).

If palimpsest is an intrinsic attribute of the archaeological record, the idea of synchrony is a difficult proposal to assess. Space/time associations based on criteria such as spatial contiguity, should be considered as a hypothesis and not an organizing principle. This proposition affects the application of spatial analysis from the horizontal distribution of artefacts. These techniques, widely used since the 1970s (among others Hodder and Orton, 1976; Kintigh and Ammerman, 1982; Hietala (ed) 1984 and references therein), have evolved into geo-statistical testing currently integrated in GIS software (Llobera, 2003; Lloyd and Atkinson, 2004). It is not our concern here to review techniques of spatial analysis on which much has been written. Such techniques, coming from locational analysis developed in Geography and Ecology (Clarke, 1978; Roper, 1979), display the spatial dimension of a phenomenon in which the time variable is not easily integrated.

The N10 and N12 accumulations prove reuse of the rock shelter over a long time scale, although not necessarily for prolonged periods, but periods of time difficult to assess. This idea is incompatible with a perspective considering an organized space to be 'synchronic', and resulting from a single event. Assessing relationships between artefacts in order to infer or reject the notion of space/time association, produces a fuzzy scenario in which it is not easy to identify concrete activities. Although there are indicators of synchrony, and associations can be made between artefacts, or between artefacts and discrete events such as hearths, these occur in a limited number of cases. Such observations remind us that relationships between artefacts considered to be associated and to define units of analysis as an archaeological level should be considered as a hypothesis to be confirmed, without ruling out that they may have internal diachrony.

Archaeological level, association and superposition are concepts that are part of the core of our discipline, and despite their antiquity have substantial heuristic potential. We propose an update emphasizing vertical dispersion as a key attribute in assessing space/time associations seen on the horizontal plane. Prioritizing information provided by the vertical over the horizontal scale affects the notion of space/time association as indicated by the plots

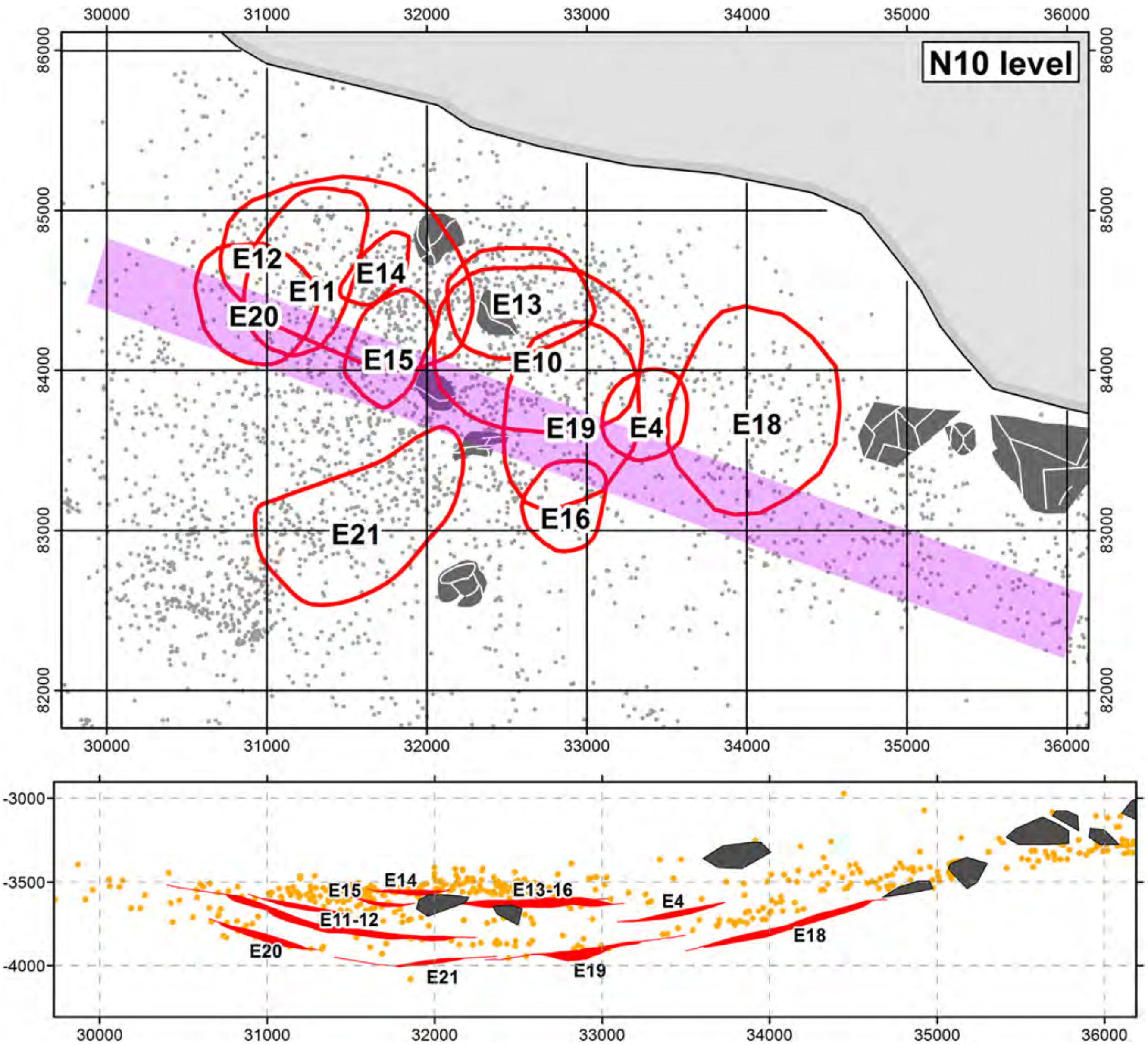

Fig. 7. Accumulation of stratified hearths in N10. This oblique cross-section is similar to plot B in Fig. 6 projecting 40 cm. Interaction between hearths and the convex depression can be seen and the position of coordinates show the impact of fusion/fission processes on this zone. Coordinates also show that association between artefacts and hearths is not clearly established.

discussed in this article (Fig. 6 and 7), and warns of the need not to accept such associations as foregone conclusions or the result of geo-statistical tests. They are a hypothesis which must be tested to define more precisely what is understood by archaeological level.

This approach does not provide a definitive solution, but overcomes errors arising from a direct reading of artefacts recovered from deposits with limited temporal solution. It also warns us that interpretation is the sum of transformations which are connected, from the discard of an artefact thousands of years ago to its analysis. From this perspective, the archaeological record is the result of interaction between behaviours of people in the past, syn/post-depositional processes and decisions that we put into practise in their recovery and interpretation. It is not easy to determine these biases as many factors are involved in which decisions taken in the present are important. Such a holistic perspective confirms the palimpsest as a multiscalar, polysemic concept (Bailey, 1983, 2007), and reminds us that the archaeological record is a dynamic entity constructed in the present, a long way from those frozen images rescued from the past.

5. Conclusion: towards a constructive approach to fieldwork

In this paper we suggest dealing with the study of palimpsests from a methodological approach while treating empirical aspects marginally. This problem affects all periods and it is symptomatic that it has been discussed in Middle Palaeolithic sites which have archaeological levels with accumulations of artefacts and hearths (among others Vaquero, 2012; Sañudo et al., 2012; Marrero et al., 2011 Machado et al., 2013; Mallol et al., 2013). As such, it may provoke interest in studying problems related with the temporal resolution of those sites.

The notion of palimpsests in Roca dels Bous definitely affects interpretation of the archaeological record and hinders confirmation of precise associations between artefacts and behaviour.

However, it can explain repeated occupations in a space with discarded tools and food waste, where fire brings together tasks and social interaction of groups. That is, it allows inferences to be made assessing behaviour associated with management of space and the use of fire, key to the identification of "modern" behaviour previous to *Homo sapiens*. This proposal has evolutionary inferences with implications affecting Neanderthal social organization and cognition (Binford, 1983). While we will not expand on this particular discussion here, we think that such an interesting observation lacks rigorous discussion of the archaeological evidence. The archaeological indicators presented here question the idea that limited ability regarding the management of fire or organization of activities around hearths. Precise documentation of archaeological contexts can explain normal use of fire and its integration with Neanderthal subsistence and social life.

In discussions concerning complex ideas such as behaviour or evolutionary trends, fieldwork is key to documenting and explaining these inferences. Use of high-tech devices enable management of an enormous amount of information as it is being generated by fieldwork and limit errors which occur during recovery and recording. The digital environment implies a qualitative improvement and represents a breakthrough in fieldwork, since increasing technology fosters synergies in generating and monitoring hypotheses during the excavation. Consequently, a constructive strategy may involve qualitative change in the organization of fieldwork in view of future use of the data.

This is not incompatible with using post-excavation analytical techniques to reveal evidence not identified during excavation. Geo-statistical, soil micromorphology and refitting are techniques whose results can be used to assess associations, and allow a more precise definition of what we understand by archaeological level. It is crucial to consider this as a constructive form of analysis which guides future excavation activity. From the moment it is used in parallel with excavation, it integrates contextual information that is not always recorded or is difficult to identify through geo-statistical testing. This parallel structure means qualitative improvement over post-excavation 'reconstruction' in the definition of space/time relationships which make up an archaeological level.

Having information on the evolution of fieldwork in (almost) real time identifies the accumulation of errors which are difficult to remove in post-excavation approaches. New technologies make it feasible to consider artefacts not just as coordinates whose contextual framework is defined *a posteriori*. Our constructive approach does not resolve limitations inherent in the study of palimpsests, but it helps us address the discussion on implications arising from the archaeological record and advances reconstruction of past behaviour.

Acknowledgements

This article is the result of several presentations in workshops: *On shelter's ledge*: *histories, theories and methods of rockshelter research,* UISPP Lisbon, 2005; *Human evolution, a long trip without end: the application of data recovery, data management and computer analysis in Palaeolithic sites*, CAA, Granada 2010; and *Advances in Archaeological Palimpsest Dissection*, UISPP Burgos, 2014. We thank Carolina Mallol and Cristo Hernández of the University of Laguna, organizers of this symposium for their kind invitation to participate in this volume. We thank constructive feedback provided by the editor and reviewers of the submitted manuscript. Roca dels Bous fieldwork is part of the project "Human settlement during the Upper Pleistocene and Holocene in the South-eastern Pyrenees" (HAR2013-42338) and the 2014SGR-0084 research group. Fieldwork has been supported by the Serveí d'Arquelogía í Paleontología-Generalítat de Catalunya.

References

Allen, K., Green, S., Zubrow, E.B. (Eds.), 1990. Interpreting Space: GIS and Archaeology. Taylor and Francis, London.
Bailey, G., 1983. Concepts of time in Quaternary prehistory. Annual Review of Anthropology 12, 165–192.
Bailey, G., 2007. Time perspectives, palimpsests and the archaeology of time. Journal of Anthropological Archaeology 26, 198–223.
Bailey, G., Galanidou, N., 2009. Caves, palimpsests and dwelling spaces: examples from the Upper Palaeolithic of south-east Europe. World Archaeology 41, 215–241.
The origins of recycling: a Paleolithic perspective. In: Barkai, R., Lemorini, C., Vaquero, M. (Eds.), Quaternary International 361.
Beherensmeyer, A.K., 1982. Time resolution in fluvial vertebrate assemblages. Paleobiology 8, 211–227.
Behrensmeyer, A.K., Kidwell, S., Gastaldo, R., 2000. Taphonomy and Paleobiology. Paleobiology 26 (sp4), 103–147.
Benito-Calvo, A., Martínez-Moreno, J., Jorda, J., de la Torre, I., Mora, R., 2009. Sedimentological and archaeological fabrics in Palaeolithic levels of the south-eastern Pyrenees: Cova Gran and Roca dels Bous Sites (Lleida, Spain). Journal of Archaeological Science 36, 2566–2577.
Bertran, P., Lenoble, A., Todisco, D., Desrosiers, P., Sørensen, M., 2012. Particle size distribution of lithic assemblages and taphonomy of Palaeolithic sites. Journal of Archaoelogical Science 39, 3148–3166.
Binford, L.R., 1981. Behavioral archaeology and the "Pompeii premise". Journal of Anthropological Research 37, 195–208.
Binford, L.R., 1983. In Pursuit of the Past: Decoding the Archaeological Record. Thames and Hudson, London.
Bordes, F., 1975. Sur la notion de sol d'habitat en préhistoire paléolithique. Bulletin de la Société préhistorique française 72, 139–144.
Bordes, F., 1980. Savez-vous remonter les cailloux à la mode de chez nous? Bulletin de la Societé Préhistorique Français 77, 232–234.
Bordes, J.-G., 2003. Lithic taphonomy of the Chàtelperronian/Aurignacian interstratifications in Roc de Combe and Le Piage (Lot, France). In: Zilhão, d'Errico (Eds.), The Chronology of the Aurignacian and the Transitional Technocomplexes, Trabalhos de Arqueologia n° 33, pp. 223–244.
Cahen, D., 1980. Question de contemporanéité: l'apport des remontages. Bulletin de la Societé Préhistorique Française 77, 230–232.
Canals, A., Rodríguez, J., Sánchez, R., 2008. The 3COORsystem for data recording in archaeology. Journal of Anthropological Sciences 86, 133–141.
High resolution archaeology and neanderthal behavior. In: Carbonell, E. (Ed.), 2012. Time and Space in Level J of Abric Romaní (Capellades, Spain), Vertebrate Paleobiology and Paleoanthropology – Springer. Springer.
Clarke, D., 1973. The loss of the innocence. Antiquity 47, 6–18.
Clarke, D., 1978. Arqueología Analítica, 2on ed [1984]. Bellaterra.
Conolly, J., Lake, M., 2006. Geographical Information Systems in Archaeology. Cambridge University Press, Cambridge.
Courty, M.-A., Goldberg, P., Macphail, R.I., 1989. Soils and Micromorphology in Archaeology. Cambridge University Press, Cambridge.
Craig, N., Aldenderfer, M., 2003. Preliminary stages in development of a real-time digital data recording system for archaeological excavation using ArcView GIS 3.1. Journal of GIS in Archaeology 1, 13–22.
de la Torre, I., Martínez-Moreno, J., Mora, R., 2012. When bones are not enough: lithic refits and occupation dynamics in the Middle Palaeolithic. Level 10 of Roca dels Bous (Catalonia, Spain). In: Seetah, K., Gravina, B. (Eds.), Bones for Tools–Tools for Bones: the Interplay between Objects and Objectives. McDonald Institute for Archaeological Research, Cambridge, pp. 13–23.
De Reu, J., Plets, G., Verhoeven, G., De Smedt, P., Bats, M., Cherretté, B., De Maeyer, W., Deconynck, J., Herremans, D., Laloo, P., Van Meirvenne, M., De Clercq, M., 2013. Towards a three-dimensional cost-effective registration of archaeological heritage. Journal of Archaeological Science 40, 1108–1121.
Dibble, H., 1987. Measurement of artefact provenience with an electronic theodolite. Journal of Field Archaeology 14, 249–254.
Dibble, H., McPherron, S., 1998. On the computerization of archaeological projects. Journal of Field Archaeology 15, 431–440.
Dibble, H., Chase, P., McPherron, S., Tuffreau, A., 1997. Testing the reality of a "living floor" with archaeological data. American Antiquity 62, 629–651.
Dibble, H., Raczek, T., McPherron, D., 2005. Excavator bias at the site of Pech de l'Azé IV (France). Journal of Field Archaeology 30, 317–328.
Dibble, H., Marean, C., McPherron, S., 2007. On the use of barcodes in excavation projects with examples from Mossel Bay (South Africa) and Roc de Marsal (France). SAA Archaeological Record 7, 33–38.
Dibble, H., McPherron, S., Sandgathe, D., Goldberg, P., Turq, A., Lenoir, M., 2009. Context, curation, and bias: an evaluation of the Middle Paleolithic collections of Combe-Grenal (France). Journal of Archaeological Science 36, 2540–2550.
Efremov, I., 1940. Taphonomy: new branch of Paleontology. Pan-American Geology 74, 81–93.
Gallotti, R., Lembo, G., Peretto, C., 2012. Mapping three-dimensional density patterns for analyzing artefact (re)distribution trends in Palaeolithic Sites. Advances in Anthropology 2, 39–48.
Gifford, D., 1981. Taphonomy and palaeoecology: a critical review of archaeology's sister discipline. In: Schiffer, M. (Ed.), Advances in Archaeological Method and Theory 4Academic Press, pp. 77–101.
Gregg, S., Kintigh, K., Whallon, R., 1991. Linking ethnoarchaeological interpretation and archaeologicl data: the sensitivity of spatial analytical methods to

postdeposicional disturbance. In: Kroll, E.M., Price, D. (Eds.), The Interpretation of Archaeological Spatial Patterning. Interdisciplinary Contributions to Archaeology. Plenum Press, pp. 149–196.
Hallos, J., 2005. "15 minutes of fame": Exploring the temporal dimension of Middle Pleistocene lithic technology. Journal of Human Evolution 49, 155–179.
Henry, D., 2012. The palimpsest problem, hearth pattern analysis, and Middle Paleolithic site structure. Quaternary International 247, 246–266.
Hietala, H. (Ed.), 1984. Intrasite Spatial Analysis in Archaeology. Cambridge Univ. Press.
Hodder, I., Orton, C., 1976. Spatial Analysis in Archaeology. Univ. Press, Oxford.
Hofman, J., Enloe, J., 1992. Piecing Together the Past: Applications of Refitting Studies in Archaeology. In: British Archaeological Reports International Series 578.
Holdaway, S., Wandsnider, L., 2008. Time in Archaeology: Time Perspectivism Revisited. University of Utah Press.
Isaac, G., 1983. Bones in contention: competing explanations for the juxtaposition of Early Pleistocene artifacts and faunal remains. In: Clutton-Brock, J., Grigson, C. (Eds.), Animals and Archaeology. Hunters and Their Prey, British Archaeological Reports International Series 163, pp. 3–20.
Kintigh, K., Ammerman, A., 1982. Heuristic approaches to spatial analysis. American Antiquity 47, 31–63.
Koetje, T., 1991. Simulated archaeological levels and the analysis of Le Flageolet II, The Dordogne, France. Journal Field Archaeology 18, 187–198.
Kolen, J., 1999. Hominids without homes: on the nature of Middle Palaeolithic settlement in Europe. In: Roebroeks, W., Gamble, C. (Eds.), The Middle Palaeolithic Occupation of Europe. University of Leiden, pp. 139–175.
Kuhn, S., Clark, A., 2015. Artifact densities and assemblage formation: evidence from Tabun cave. Journal of Anthropological Archaeology 38, 8–16.
Laplace, G., Méroc, L., 1954. Application des coordonnées cartésiennes à la fouille d'un gisement. Bulletin de la Société Préhistorique Française, pp. 58–66.
Lawrence, D., 1971. The nature and structure of Palaeocology. Journal of Paleontology 45, 593–607.
Leica TPS1200, 2014. Electronic Document. http://www.leica-geosystems.es/downloads123/zz/tps/tps1200/Leica_TPS1200 (accessed 20.12.14.).
Lenoble, A., Bertran, P., 2004. Fabric of Paleolithic levels: methods and implications for site formation processes. Journal of Archaeological Science 31, 457–469.
Leroi-Gourhan, A., Brézillon, N., 1966. L'habitation magdalénienne n° 1 de Pincevent près Monterau (Seine-et-Marne) Gallia Préhistoire 9, pp. 263–385.
Llobera, M., 2003. Extending GIS-based visual analysis: the concept of visualscapes. International Journal of Geographical Information Science 17, 25–48.
Lloyd, C., Atkinson, P., 2004. Archaeology and geostatistics. Journal of Archaeological Science 31, 151–165.
Lucas, J.M., Mora, R., Miret, J., 1986. Utilización del ordenador en el análisis microespacial. In: Burillo (Ed.), Arqueología Espacial 7, pp. 147–168. Teruel.
Lyell, C., 1833. Principles of Geology, Being an Attempt to Explain the Former Changes of the Earth's Surface, by Reference to Causes Now in Operation. John Murray, London.
Machado, J., Hernández, C., Mallol, C., Galván, B., 2013. Lithic production, site formation and Middle Palaeolithic palimpsest analysis: in search of human occupation episodes at Abric del Pastor Stratigraphic Unit IV (Alicante, Spain). Journal of Archaeological Science 40, 2254–2273.
Malinsky-Buller, A., Hovers, E., Marder, O., 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, 89–101.
Mallol, C., Hernández, C., Cabanes, D., Sistiaga, A., Machado, J., Rodríguez, A., Pérez, L., Galván, B., 2013. The black layer of Middle Palaeolithic combustion structures. Interpretation and archaeostratigraphic implications. Journal of Archaeological Science 40, 2515–2537.
Marrero, E., Hernández, C.M., Galván, B., 2011. El análisis espacial en el estudio de las secuencias de facies arqueosedimentarias. Criterios para identificar eventos de ocupación en yacimientos del Paleolítico Medio: El Salt y el Abric del Pastor (Alcoy, Alicante, España). Recerques del Museu d'Alcoi 20, 7–32.
Martínez-Moreno, J., Mora, R., de la Torre, I., 2004. Methodological approach for understanding middle palaeolithic settlement dynamics at la Roca dels Bous (la Noguera, Catalunya, Northeast Spain). In: Conard, N. (Ed.), Settlement Dynamics of the Middle Palaeolithic and Middle Stone Age II. Kerns Verlag, Tubingen, pp. 393–413.
Martínez-Moreno, J., de la Torre, I., Mora, R., Casanova, J., 2010. Technical variability and changes in the pattern of settlement at Roca dels bous (southeastern Pre-Pyrenees, Spain). In: Conard, N. (Ed.), Settlement Dynamics of the Middle Palaeolithic and Middle Stone Age III. Kerns Verlag, Tubingen, pp. 485–508.
Martínez-Moreno, J., González Marcén, P., Mora, R., 2011. Data matrix (DM) codes: a technological process for the management of the archaeological record. Journal of Cultural Heritage 12, 134–139.
McPherron, S., 2005. Artifact orientations and site formation processes from total station proveniences. Journal of Archaeological Science 32, 1003–1014.
McPherron, S., Dibble, H., 2003. Using computers in adverse field conditions. SAA Archaeological Record 3, 28–32.
McPherron, S., Dibble, H., Goldberg, P., 2005. Zeitschrift fur Geoarchaeology 20, 243–262.
McPherron, S., Gernat, T., Hublin, J.J., 2009. Structured light scanning for high-resolution documentation of in situ archaeological finds. Journal of Archaeological Science 36, 19–24.
Mora, R., 1988. El Paleolitico medio en Catalunya (unpublished Ph.D). Universitat Barcelona.
Mora, R., Parcerisas, J., Martinez-Moreno, J., 2001. Computer-based recording systems of Pleistocene deposits with large mammals. In: The World of Elephants/La Terra degli Elefanti. Proceedings of the First International Congress, pp. 219–224. Rome.
Mora, R., Martinez-Moreno, J., Casanova, J., 2008. Abordando la noción de "variabilidad musteriense" en Roca dels Bous (Prepirineo suroriental, Lleida). Trabajos de Prehistoria 65 (2), 13–28.
Mora, R., Martínez-Moreno, J., Roda Gilabert, X., Roy Sunyer, M., Vega Bolívar, S., 2014. Métodos de excavación: del trabajo de campo a la interpretación arqueológica. Treballs d'Arqueologia 14, 7–20.
MySQL, 2014. Electronic Document. http://dev.mysql.com/ (accessed 20.12.14.).
Owens, J., Sandes, A., Stephenson, B., Dixon, D., Zajanc, C., 2014. A Geographic Information Systems (GIS): Training Manual for Historians and Historical Social Scientists. www.geographicallyintegratedhistory.com.
Pallarés, M., 1999. Teoria i mètode sobre l'anàlisis espacial en Arqueologia. La gestió de l'espai social a l'interior de l'assentament de Font del Ros (Berga, Barcelona) (unpublished Ph.D). Universitat Autònoma Barcelona.
Parcerisas, J., Mora, R., 1995. La estación total inteligente y sus aplicaciones en el trabajo arqueológico. In: Valdés, L.A., Pujuana, I. (Eds.), Aplicaciones Informáticas en Arqueología: Teorías y Sistemas, pp. 409–417. Bilbao.
Pettitt, P., 1997. High resolution neanderthals? Interpreting Palaeolithic intrasite spatial data. World Archaeology 28, 208–224.
Renfrew, C., Bahn, P., 1991. Archaeology. Theories, Methods and Practices, first ed. Thames and Hudson, London.
Rick, J.W., 1996. Total stations in archaeology. Bulletin Society for American Archaeology 14, 24–27.
Rigaud, J.P., Geneste, J.-M., 1988. L'utilisation de l'espace dans la Grotte Vaufrey. In: Rigaud (Ed.), La grotte Vaufrey à Cénac-Saint-Julien (Dordogne), XIX Mémoire de la Societe Prehistorique Française, pp. 593–611.
Roda Gilabert, X., Samper Carro, S., Mora, R., González Marcén, P., Martínez-Moreno, J., 2014. La aplicación de los códigos Data Matrix (DM) en el registro y la catalogación arqueológica. Treballs d'Arqueologia 14, 95–107.
Roebroeks, W., 1988. From Find Scatters to Early Hominid Behaviour a Study of Middle Palaeolithic Riverside Settlements at Maastricht-belvédère (The Netherlands). In: Analecta Praehistorica Leidensia 21.
Roper, D., 1979. The method and theory of site catchment analysis: a review. In: Schiffer, M.B. (Ed.), Advances in Archaeological Method and Theory 2Academic Press, New York, pp. 119–140.
Roy, M. under revision. Deconstructing archaeological palimpsests: Applicability of automated GIS algorithms. 43rd Computer Applications and Quantitative Methods in Archaeology-Keep the revolution going Conference, Siena.
Sañudo, P., Vallverdú, J., Canals, A., 2012. Spatial patterns in Level J. In: Carbonell, E. (Ed.), High Resolution Archaeology and Neanderthal Behavior, Vertebrate Paleobiology and Paleoanthropology – Springer, pp. 47–76.
Schiffer, M.B., 1972. Archaeological context and systemic context. American Antiquity 37, 156–165.
Schiffer, M.B., 1976. Behavioral Archaeology. Academic Press, New York.
Schiffer, M.B., 1987. Formation Processes of the Archaeological Record. Univ. New Mexico Press, Alburquerque.
Stapert, D., 1990. Middle Palaeolithic dwellings: fact or fiction? Some applications of the ring and sector method. Palaeohistoria 31, 1–19.
Vallverdu, J., Courty, M.A., 2012. Microestratigraphic analysis of level J deposits: a dual paleoenvironmental-paleoethnographic contribution to Paleolithic archaeology at the Abric Romani. In: Carbonell, E. (Ed.), High Resolution Archaeology and Neanderthal Behavior, Vertebrate Paleobiology and Paleoanthropology – Springer, pp. 77–133.
Vaquero, M., 2012. Neanderthal Behavior and temporal resolution of Archeological assemblages. In: Carbonell, E. (Ed.), High Resolution Archaeology and Neanderthal Behavior, Vertebrate Paleobiology and Paleoanthropology – Springer. Springer, pp. 1–16.
Villa, P., 1977. Sols et niveaux d'habitat du paléolithique inférieur en Europe et au Proche Orient. Quaternaria 19, 107–134.
Villa, P., 1982. Conjoinable pieces and site formation processes. American Antiquity 47, 276–290.
Villa, P., 2004. Taphonomy and stratigraphy in European Prehistory. Before Farming 1, 1–20.
Villa, P., Courtin, J., 1983. The interpretation of stratified sites. A view from underground. Journal of Archaeological Science 10, 267–281.