Journal of Archaeological Science 38 (2011) 3652–3661

Contents lists available at SciVerse ScienceDirect

Journal of Archaeological Science

journal homepage: http://www.elsevier.com/locate/jas

Trampling experiments at Cova Gran de Santa Linya, Pre-Pyrenees, Spain: their relevance for archaeological fabrics of the Upper–Middle Paleolithic assemblages

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A R T I C L E I N F O

Article history:
Received 6 July 2011
Received in revised form
26 August 2011
Accepted 27 August 2011

Keywords:
Archaeological fabrics
Experimentation
Site formation processes
Cova Gran
Middle and Early Upper Palaeolithic

A B S T R A C T

The study of fabrics, that is, the analysis of the orientation and slope of archaeological and sedimentary materials associated with the Middle Palaeolithic/Upper Palaeolithic (MP/UP) transition at Cova Gran shows substantial differences. Archaeological assemblages are characterised by greater isotropy in the fabrics than the sedimentary levels within which they are located, indicating that these differences may be generated by anthropic processes. One of the anthropogenic processes associated with horizontal and vertical displacement of archaeological artefacts is trampling and circulation caused by later occupations. In order to evaluate the effect of movement on materials, we undertook experiments simulating geological and archaeological conditions at Cova Gran. The results show that human trampling does not cause major isotropy in fabrics, but arranges archaeological assemblages towards planar or linear materials according to surface geometry. We were not able to replicate the fabric pattern of materials from the archaeological levels of Cova Gran, suggesting that they must be associated with the activities of human occupation at each level.

1. Introduction

Determination of the degree of modification of the archaeological record is key to understanding post-depositional and site formation processes. Such processes modify spatial patterns generated by anthropic activities and create arbitrary associations (Butzer, 1982; Schiffer, 1983, 1987). Therefore, an understanding of these dynamics is fundamental in order to interpret the integrity of anthropic occupations (Villa, 2004; Bailey, 2007). At Cova Gran de Santa Linya (Pre-Pyrenees, Iberian Peninsula), this matter is particularly relevant in establishing the degree of homogeneity and contextual resolution. The latter constitutes the basic attributes when addressing the concept of techno-typological change in the Middle/Upper Palaeolithic transition levels (Martínez-Moreno et al., 2010, submitted for publication; Mora et al., 2011).

Analysis of fabrics in archaeology, that is, analysis of the slope and orientation of archaeological elements, has proven to be a useful method in interpreting the formation of archaeological assemblages (Lenoble and Bertran, 2004; McPherron, 2005; Benito-Calvo et al., 2009; Benito-Calvo and de la Torre, 2011). For many years this technique has been applied in sedimentology (Mills, 1983; Benn, 1994; Bertran et al., 1997; Benn and Ringrose, 2001), based on the application of statistical methods to orientation and slope data. In this manner, one can analyse the presence of preferential directions and their relationship with syn/post-depositional geometry, or the possible action of dynamic forces. A widely used technique is the analysis of the fabric shape, which is closely related to formation processes. This technique is calculated from three eigenvectors derived from orientation and slope data (Woodcock, 1977; Woodcock and Naylor, 1983; Vollmer, 1989; Benn, 1994).

At Cova Gran, fabric analysis was applied separately to archaeological artefacts and sedimentary clasts, producing patterns that enabled the differentiation of human activity from geological processes at the same level. In this way, fabrics from archaeological levels showed a pattern that was more isotropic and less affected by terrain slope than its sedimentary corresponding layer (Benito-Calvo et al., 2009).

We suspect that a potential activity that might cause such major isotropy in fabric is trampling over exposed or semi-exposed materials, which could cause the displacement of archaeological accumulations by later occupations. Trampling is a cause of post-depositional alteration, particularly in rock shelters and caves that have been reoccupied frequently (Hughes and Lampert, 1977).

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doi:10.1016/j.jas.2011.08.036

Since Stockton's pioneering study (1973), various attempts have been made to determine the incidence of trampling on the archaeological record, from ethnoarchaeology (Gifford and Behrensmeyer, 1977) to experimental archaeology (Courtin and Villa, 1982; Villa and Courtin, 1983; Gifford-Gonzalez et al., 1985; Nielsen, 1991; see Eren et al., 2010 for additional references). These trampling experiments concentrated on the analysis of variables such as horizontal and vertical displacement of objects resulting from anthropic or animal activity, and alterations produced on the surface of lithic and bone objects. Intense trampling action can generate vertical displacement producing mixing, and also patterns in the horizontal position of materials. Such patterns identify types of circulation in the settlement (traffic zones and marginal zones), showing that large and medium sized objects tend to be displaced towards marginal zones while small objects remain in the traffic zone (Theunissen et al., 1998; Nielsen, 1991).

Nevertheless, the effect of trampling on the fabric of archaeological assemblages, that is variation in orientation and slope of archaeological pieces, is an important question which has received little attention until now. In order to evaluate this effect, in the present study we undertook experiments based on the sedimentary conditions of Cova Gran. We created two experimental areas, with physical substrates similar to the sedimentary levels of Cova Gran, in which we deposited experimental accumulations. These assemblages were placed in the zones and measured before and after being subjected to human trampling processes. We analysed the effect on fabric shape and compared it with the excavated levels of Cova Gran.

2. Cova Gran site

Cova Gran de Santa Linya (318541, 4643877, Zone 31, ETRS89) is situated in the outer marginal sierras of the southern slopes of the Eastern Pre-Pyrenees, close to their junction with the Tertiary Ebro Depression, in the province of Lleida (Catalunya, Spain) (Fig. 1). The Cova Gran site consists of a south-facing rock shelter covering an area of 92 m × 83 m which developed on the concave side of an incised meander at the bottom of the Sant Miquel ravine. The bedrock of the rock shelter consists of limestones of the Bona Formation (Late Cretaceous).

2.1. Geoarchaeological sequence

Excavations at the Cova Gran site which began in 2004 and are still ongoing have been conducted in three areas: Ramp, Transition and Platform Sectors (Figs. 1 and 2), where a sedimentary infill

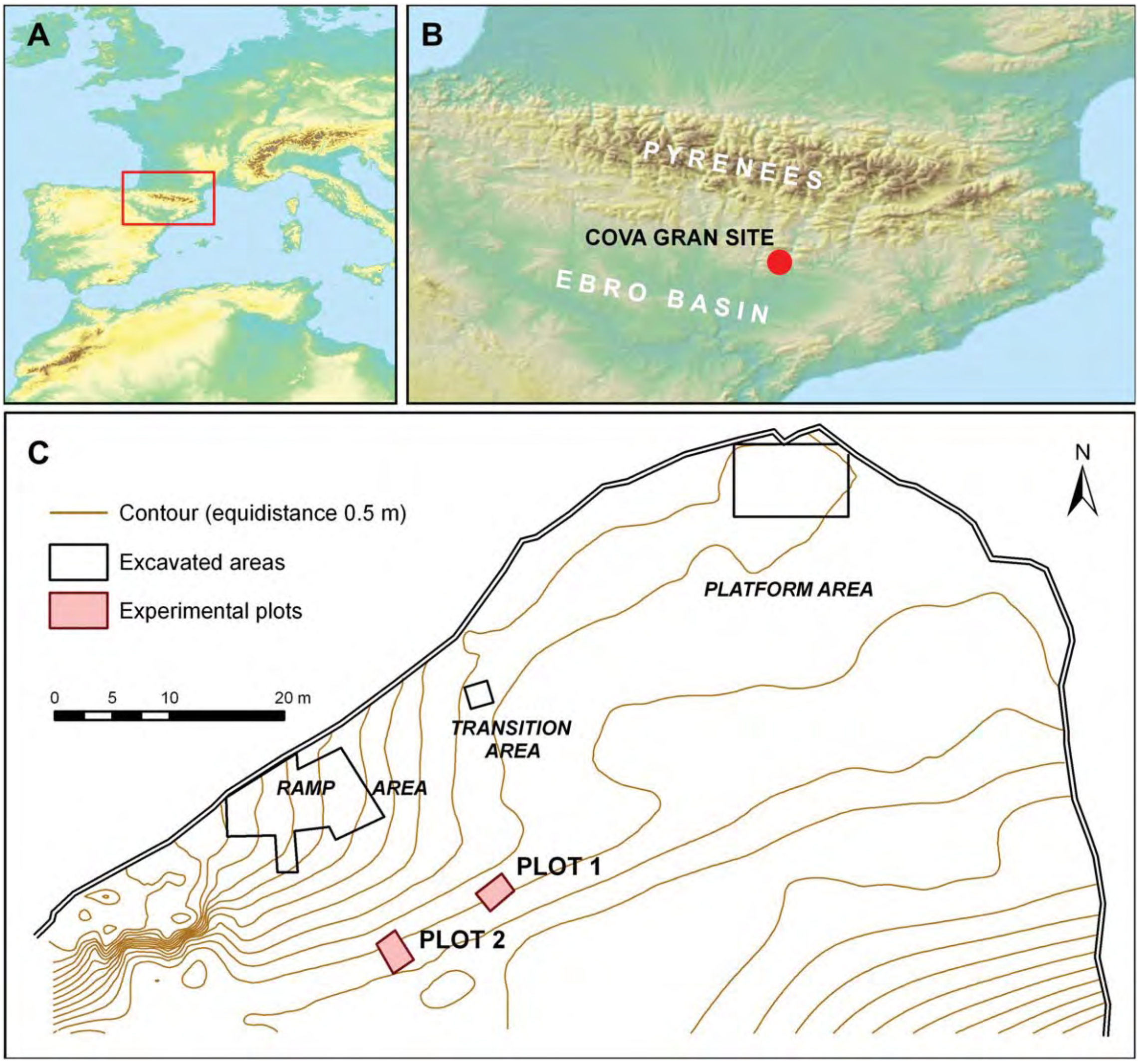

Fig. 1. Location of the Cova Gran site and position of the experimental areas.

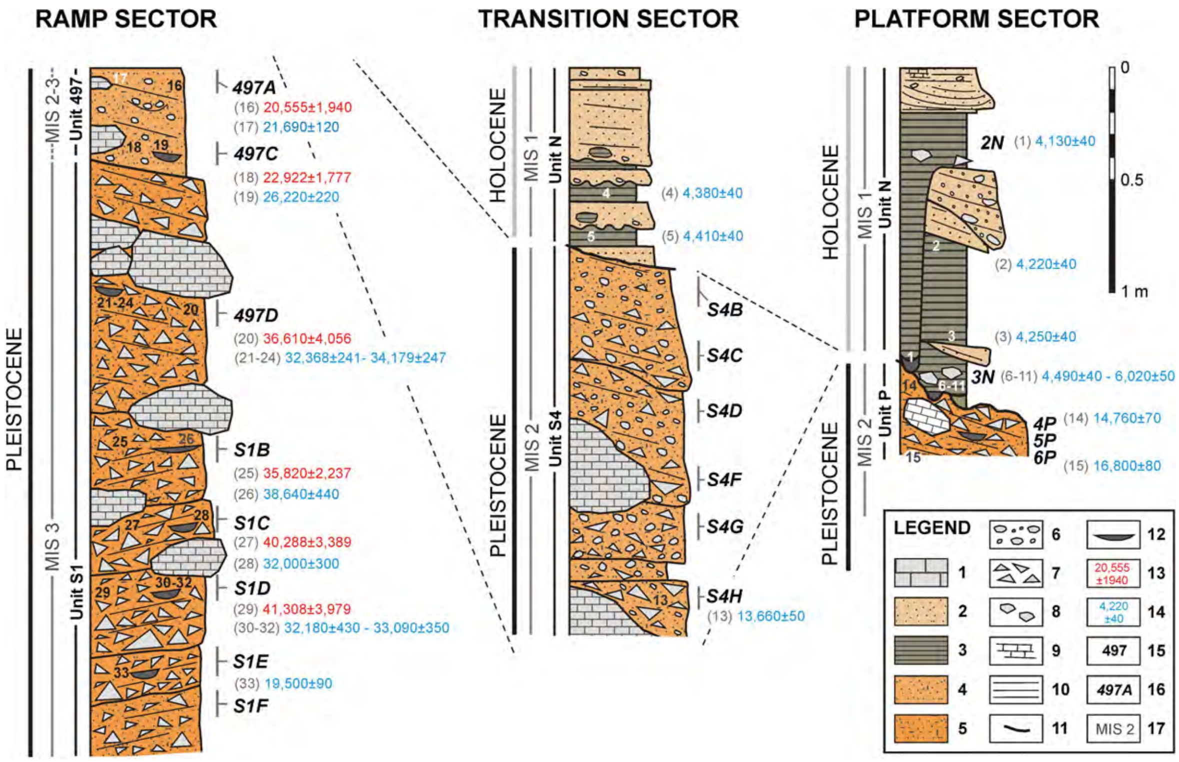

Fig. 2. Stratigraphic, archaeological and chronological sequence of the Cova Gran site. Legend: 1: Limestone blocks; 2: Sands; 3: Fumiers; 4: Clays and sands; 5: Sands, clays and silts; 6: Rounded and subrounded clasts; 7: Angular and subangular clasts; 8: Archaeological block; 9: Carbonation; 10: Bedding; 11: Discontinuity; 12: Hearth; 13: TL data; 14: 14^{C} AMS data; 15: Stratigraphic unit; 16: Archaeological level; 17: MIS (see Mora et al., 2011 for details).

containing Pleistocene and Holocene levels was identified. The oldest deposits, recording the MP/UP transition, are located in the Ramp sector (Figs. 1 and 2). Two stratigraphic units have been identified in this area: the basal unit, or S1, and the overlying unit, or 497 (Mora et al., 2011). The S1 unit consists of autochthonous rock fall deposits (Fig. 2) composed of poorly classified, angular and very angular clasts (gravel size). The limited matrix consists of silty/clayey sands, with calcite and dolomite-like minerals predominating (Benito-Calvo et al., 2009). The basal beds, excavated in the eastern zone of the Ramp, form a depositional slope W–SW, which gradually smoothens. In the upper stretches, located in the western zone of the Ramp, the beds slope E-NE. This setting indicates two areas of sediment origin.

Five Middle Palaeolithic occupations (S1F, S1E, S1D, S1C and S1B) and one Early Upper Palaeolithic (EUP) site (497D) were excavated (Martínez-Moreno et al., 2010) within the S1 unit. The archaeological levels of the Middle Palaeolithic are 10 cm-15 cm thick and contain a high density of flint and metamorphic artefacts, including hammerstones, abundant microdebitage, flakes, cores and retouched tools. Fauna include *Stephanorhinus* sp., *Bos* sp., *Equus caballus*, *Equus cfr. hydruntinus*, *Cervus elaphus*, *Capra pirenaica* and *Oryctolagus cuniculus*, among which diaphyses with fresh fractures have been identified, suggesting that they were brought to the site, processed and consumed by humans. The Upper Palaeolithic 497D level is characterised by the presence of elongated and rectilinear blades, bladelets and flakes (Martínez-Moreno et al., submitted for publication).

The sedimentary unit 497 consists of autochthonous materials which have been washed downslope. It is characterised by fine and very fine, rounded and subrounded gravel containing an abundant matrix of lutitic sands, in which calcite and quartz minerals are equally prevalent (Mora et al., 2011). This unit

Table 1
Eigenvector data and fabric indices of the sedimentary and archaeological materials described in the Cova Gran levels (Benito-Calvo et al., 2009). Eigenvalues and eigenvectors calculated for the sample: Eigenvector *V1*; Eigenvector *V2*; Eigenvector *V3*; *A*: Azimuth; *D*: Dip angle; Eigenvalue *S1*; Eigenvalue *S2*; Eigenvalue *S3*. Fabric indices: Woodcock Index (1977); *C*: Fabric Strength; *I*: Isotropy Index; *E*: Elongation Index; *C**: Cluster Index; *G*: Girdle Index; *U*: Uniform Index.

Eigenvectors																
	Level	*N*	Eigenvectors									Fabric indices				
			V1			*V2*			*V3*							
			A	*D*	S1	*A*	*D*	*S2*	*A*	*D*	*S3*	*K*	*C*	*I*	*E*	*C**
A) Clasts	497A	81	31.6	10.9	0.49	299.1	12.3	0.40	162.0	73.4	0.11	0.14	1.51	0.22	0.17	0.08
	497C	67	101.0	0.3	0.51	11.0	10.8	0.44	192.3	79.3	0.05	0.07	2.40	0.09	0.14	0.07
	S1B	131	259.7	5.0	0.50	350.7	10.3	0.43	144.3	78.6	0.08	0.09	1.86	0.16	0.14	0.07
B) Artefacts	497C	97	75.0	0.8	0.51	344.9	11.9	0.38	168.6	78.1	0.11	0.24	1.51	0.22	0.25	0.13
	497D	90	275.3	9.5	0.45	8.6	19.2	0.40	160.3	68.4	0.15	0.12	1.06	0.35	0.11	0.05
	S1B	122	42.2	7.1	0.44	310.5	13.3	0.41	159.6	74.9	0.16	0.07	1.02	0.36	0.06	0.03
	S1C	77	56.7	2.9	0.49	326.5	2.7	0.41	193.0	86.0	0.10	0.14	1.58	0.21	0.18	0.08

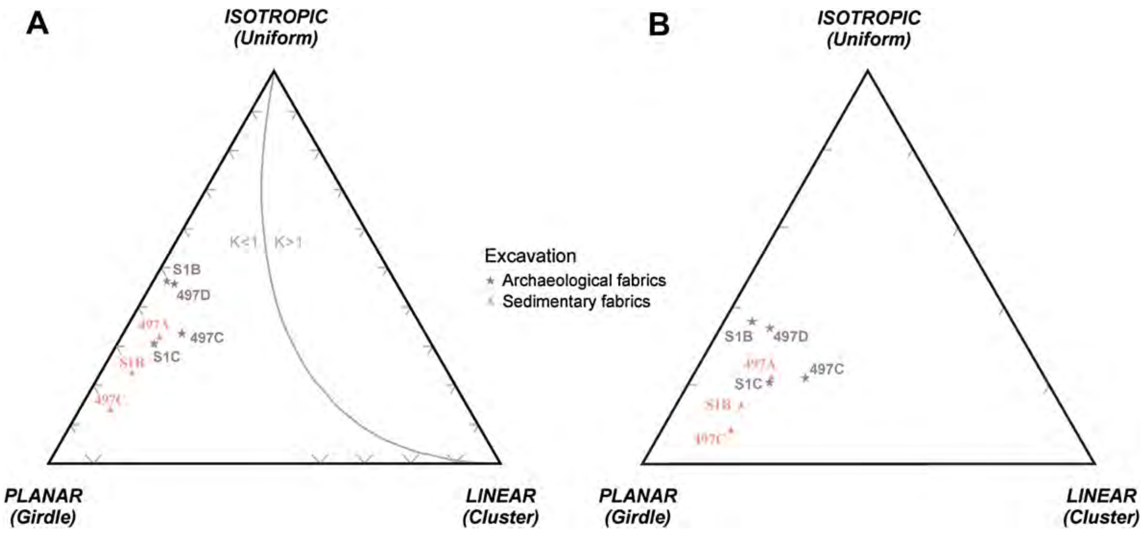

Fig. 3. Fabric ternary diagram showing the sedimentary fabrics and archaeological materials described in the Cova Gran site.

slopes 12° towards N70°E. Archaeological occupations in the 497 unit are found in levels 497C and 497A. Artefacts in level 497C are similar to those found in level 497D, while in 497A the primary knapping objective was bladelet production. Flint, of local origin, is essentially the only raw material used. No bone tools were recovered from EUP levels, although *Stephanorhinus* sp., *E. caballus*, *C. elaphus* and *Capra pyrenaica* were identified in the faunal assemblage. In the EUP levels marine shell ornaments were recovered, including an important assemblage from level 497D which included 25 complete and 12 broken *Nassarius pygmaea*, and 1 *Antalis* sp.

Other Pleistocene units composed of runoff and rock fall deposits were identified in the Transition and Platform zones (Figs. 1 and 2). These deposits contain Upper Palaeolithic units attributed to the Magdalenian techno-complex. A Holocene sequence was observed resting on these units. This sequence is composed of a succession of human occupations (fumier-like deposits), interspersed with tractive events represented by sand and fine gravel levels. Numerous domestic structures (hearths and pits), associated with human occupations during the Neolithic, were discovered (Mora et al., 2011) (Fig. 2).

2.2. *Sedimentological and archaeological fabrics*

The comparative study of sedimentary and archaeological fabrics in various levels of Cova Gran de Santa Linya (Middle Paleolithic and Early Upper Palaeolithic) revealed a differentiation in patterning. Fabric results indicate that sedimentary beds 497A, 497C and S1B were formed mainly by gravitational processes with low depositional angles, characterised by planar fabric morphology and low isotropy (Table 1), and clasts with no preferential orientation (Benito-Calvo et al., 2009). This data indicates the absence of post-depositional movements or flows during sedimentation which would have orientated clasts in a linear direction. In these beds, orientation of the dominant eigenvector tends to align according to the syndepositional slope (Benn, 1994).

Artefact materials in levels 497C, 497D, S1B and S1C display intrinsic characteristics which differentiate them from sedimentological fabrics and could be associated with human activity. Firstly, the surface topography displays no unequivocal arrangement of archaeological pieces. In some cases, artefacts are oriented according to slope, such as in level 497C where the dip orientation of the strata (N70°E) is similar to that of the dominant eigenvector V1 (Table 1). However, in other cases, orientation does not coincide with depositional slopes as seen in level S1B where the bed dips towards the west, while the dominant eigenvector of the archaeological materials shows an azimuth of 42.2° (Benito-Calvo et al., 2009).

Furthermore, artefacts in the Cova Gran levels tend to show a greater dispersion in orientation and a larger dip than clasts, which implies greater isotropy in artefacts than the sedimentary clasts of the beds in which they are found (Fig. 3, Table 1). This factor suggests that archaeological materials were subjected to a process which was distinct from sedimentary fabrics, possibly due to anthropogenic processes. Trampling is one of the most frequently cited activities causing disturbance in archaeological assemblages (Stockton, 1973; Gifford and Behrensmeyer, 1977; Hughes and Lampert, 1977; Courtin and Villa, 1982; Villa and Courtin, 1983; Gifford-Gonzalez et al., 1985; Nielsen, 1991; Theunissen et al., 1998; Eren et al., 2010). In order to monitor the impact of this process and establish whether trampling had influenced the Cova Gran archaeological assemblages, we conducted experiments to determine the effects of anthropic trampling on archaeological materials.

Table 2
Materials used in the experimental Plots 1 and 2.

	Core	Retouched	Flake	Blade	Flake fragment	Blade fragment	Chunk	Bone	Total
Plot 1									
Absolute frequency	3	6	18	15	16	7	5	40	110
Relative frequency	3	5	16	14	15	6	5	36	100
Plot 2									
Absolute frequency	1	5	17	21	10	10	6	40	110
Relative frequency	1	5	15	19	9	9	5	36	100

Fig. 4. Detail of experimental Plot 1 showing the distribution of items.

3. Methodology

Experimentation is based on the creation of two experimental plots which simulate characteristics of the excavated occupations in Cova Gran, in order to study variations in slope and orientation of archaeological assemblages subjected to trampling. This procedure should facilitate comparison with the Cova Gran archaeological assemblages and identify formation processes.

3.1. *Preparation of the experimental plots*

Flint artefacts (flakes, blades, broken pieces) and faunal fragments of various sizes were placed in the experimental plots (Table 2). Seventy lithic artefacts and forty bones identified by Data Matrix codes (Martínez-Moreno et al., 2011), were used in each area and the lithics were positioned on dorsal or ventral faces in equal numbers. We recorded the size according to the morphological axis of each piece and weighed the objects. Each stage of the experimental programme was documented photographically (Fig. 4).

The experimental zones (3 m × 2 m) were placed at the exterior of Cova Gran, on a path that leads to the sieving area. This traffic zone is utilised constantly each day during the six-week excavation period by a group of 30 people with rubber-soled footwear. Before the experiment began, both areas were excavated (0 cm–10 cm) generating planar surfaces with a 4° slope in Plot 1 (Fig. 5), and 9° in Plot 2 (Fig. 6). The floor of each zone was prepared with various angular clasts of different sizes in a clayey/sandy matrix from the Cova Gran excavation zones, in an attempt to simulate the sedimentary characteristics of Zone R at Cova Gran.

The archaeological materials were then deposited by throwing them randomly onto the surface from a height of 1 m. Those pieces which fell with the Data Matrix (DM) code facing downwards were turned so that all codes faced upwards. Subsequently, coordinates of each piece were recorded with a total station, as were the slope and orientation using a clinometer and compass respectively.

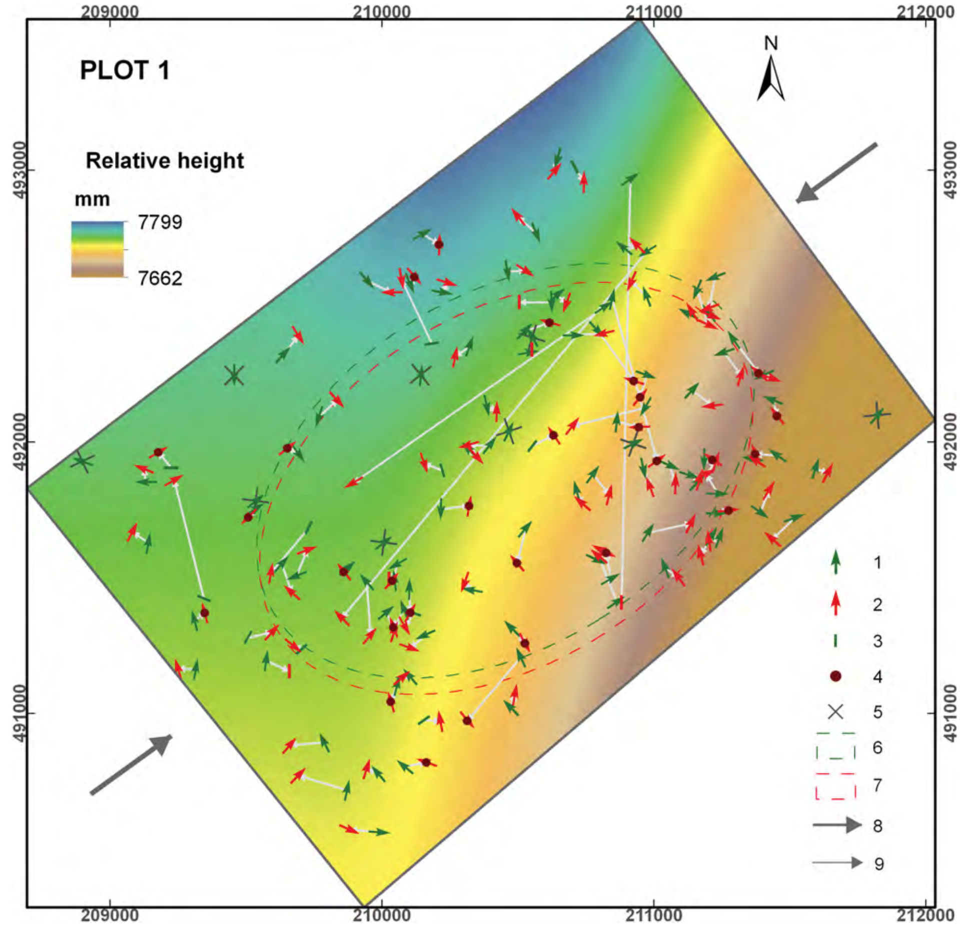

Fig. 5. Characteristics of experimental Plot 1 showing the distribution of items before and after trampling. Legend: 1: Dip direction of items before trampling; 2: Dip direction of items after trampling; 3: Direction of horizontal items; 4: Overturned pieces; 5: Missing pieces; 6: Fragmented items; 7: Directional distribution of the assemblage before trampling; 8: Directional distribution of the assemblage after trampling; 9: Trampling direction; 10: Horizontal displacement of items.

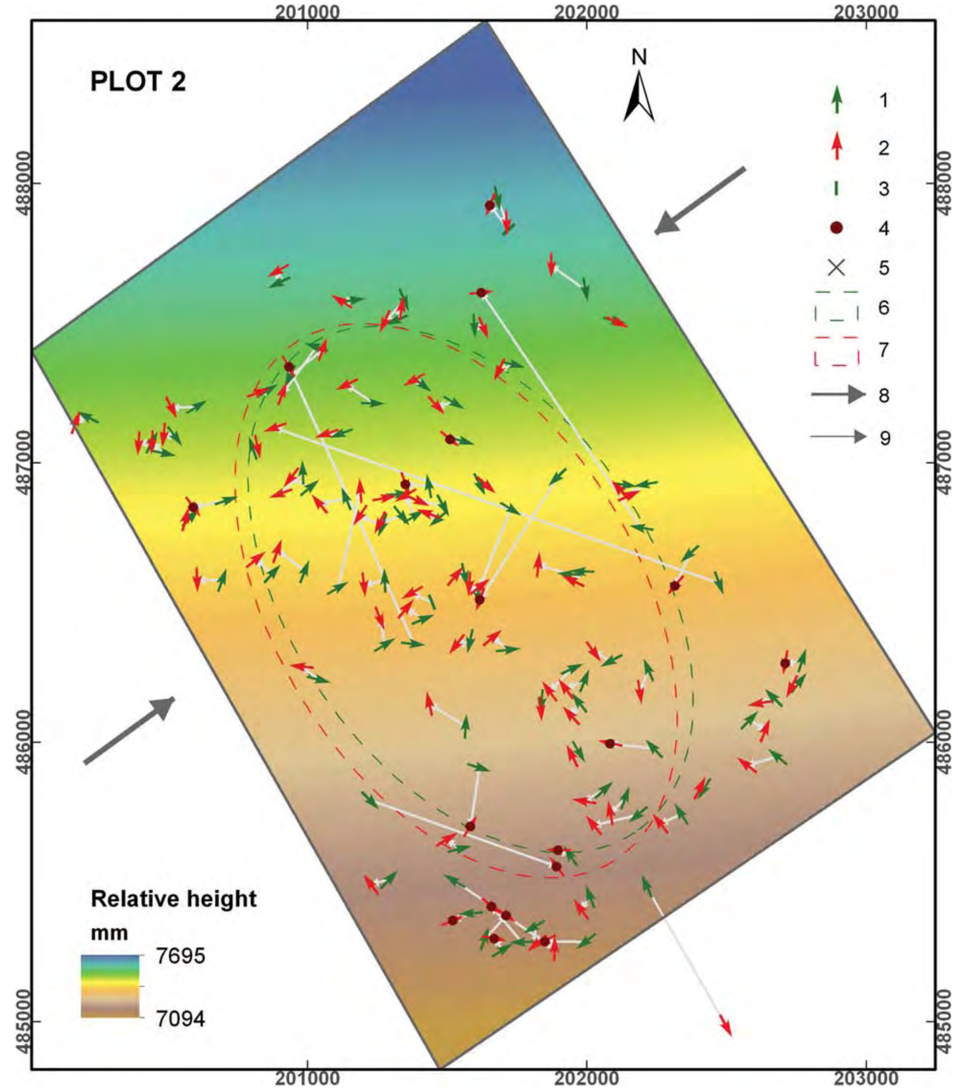

Fig. 6. Characteristics of experimental Plot 2 showing the distribution of items before and after trampling. See legend in Fig. 4.

Finally, the archaeological assemblage was covered with a sterile layer, 2 cm–5cm thick, in a manner similar to the levels of Cova Gran.

3.2. Excavation of the experimental plots

After six weeks of trampling, both areas were excavated following the same methodology used at Cova Gran, coordinating each recovered piece, noting the orientation and final slope, recording the DM code and whether it was on the upper or lower surface of the piece after trampling. This information generated a database which was used to analyse distribution patterns (Figs. 5 and 6) and materials.

3.3. Fabric analysis

Fabric analysis focused on the study of the azimuth and dip angle of the major axis of the items (A-axis). The final result of the fabric of the A-axis depends largely on the size and shape of the clasts. It is considered that the preferential orientation is better reflected in clasts of more than 2 cm, and with elongation values greater than 1.6 cm (Drake, 1974; Kjaer and Krüger, 1998; Bertran and Lenoble, 2002). In this way, we used only the data of items displaying these characteristics of shape and size. The available measurements, *n*, were always higher than 50.

Measurements were represented in rose diagrams and in stereographic projections. The Eigenvector Method was used in the analysis of fabric shape (Vollmer, 1989; Benn, 1994; Benn and Ringrose, 2001; Lenoble and Bertran, 2004; McPherron, 2005; Benito-Calvo et al., 2009). Eigenvectors are calculated for 3 × 3 orientation matrices, from the sums of cross products of the direction cosines of each individual orientation vector. This method simplifies measurements in a tensor of orientation, which defines fabric shape and comprises three eigenvectors (*V1*, *V2* and *V3*) orthogonal with each other. The dominant orientation is represented by vector *V1* which, with vector *V2* form the preferred plane of the fabric, while *V3* is normal to this plane. The degree of population clustering in relation to the eigenvectors is reflected by their modules (or eigenvalues), which are expressed in their normalised values: *S1*, *S2* and *S3*. The relationships of eigenvalues enable differentiation between isotropic ($S1 \approx S2 \approx S3$), planar ($S1 \approx S2 >> S3$), and linear ($S1 >> S2 \approx S3$) fabrics. In the isotropic

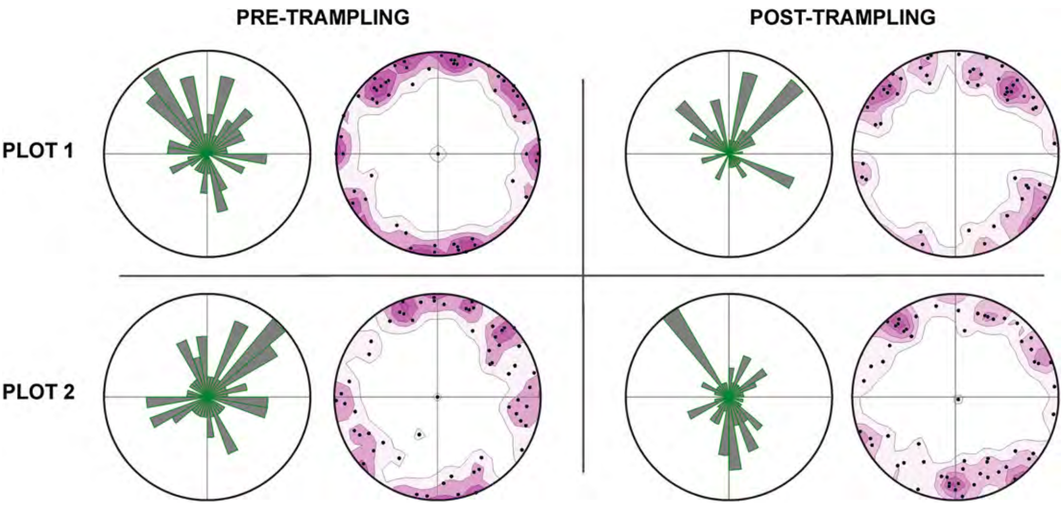

Fig. 7. Angular histograms and stereographic projection of the azimuth and dip of items.

fabrics the items are characterised by a random distribution of the two variables: slope and orientation. In planar fabrics, one variable (for example orientation) has a random distribution, and the other variable (for example slope) has similar values. Lastly, in the linear fabrics the items are orientated in the same direction and have very similar slopes.

Various indices have been proposed using eigenvectors. Woodcock (1977) defines *eigenvalue ratios* $r_1 = \ln(S1/S2)$ and $r_2 = \ln(S2/S3)$, which are projected in a biaxial and orthogonal diagram, where the index $K = r_1/r_2$ represents the bisector which delimits planar ($0 < K < 1$) from linear ($1 < K < \infty$) fabrics. Using this method, Woodcock and Naylor (1983) also establish fabric strength, defined as $C = \ln(S1/S3)$. The greater the C parameter, the further values are from the diagram's point of origin, corresponding to the location of isotropic fabrics. Another representation used to project sedimentary fabrics was proposed by Benn (1994), who defined isotropy ($I = S3/S1$) and elongation ($E = 1-(S2/S1)$ indices. Both indices are projected in a Sneed and Folk ternary diagram, in which continuous variation in fabric shape is reflected, delimited by vertices corresponding to isotropic fabrics, planar *girdles* and linear *clusters*. In our study, we used a fabric ternary diagram and the indices available in SpheriStat software (Version 3), based on Vollmer's Method (Vollmer, 1989). This method provides girdle ($G = 2(S2-S3)/n$), cluster ($C = (S1-S2)/n$) and uniform indices ($U = 3(S3)/n$), which amount to 1 and define the vertices of the ternary diagram. Angular histograms and statistics of item displacement were also calculated using SpheriStat 3. Horizontal displacements of items and directional distribution of the assemblages were calculated using ArcGIS 10.

4. Results

4.1. Pre-trampling fabrics

Plot 1 (Fig. 5) is characterised by a general slope of 4°. Object distribution is planar without a clear dominant orientation (Fig. 7); most pieces were located in the northern hemisphere, with concentrations in a NW direction. In the ternary diagram, the pre-trampling fabric is located very close to the planar apex (girdle), which has high girdle index values (0.74) in relation to cluster and uniform indices (Table 3).

In Plot 2 (with a slope of 9°, Fig. 6), distributions observed in rose diagrams and in the stereographic projection indicate a planar model with no dominant preferential orientation (Fig. 7), but with significant concentrations in a NE direction.

Nevertheless, the eigenvector method and ternary diagram have established differences with Plot 1 fabrics. In the case of Plot 2, although there is a dominant tendency towards girdle distributions, cluster and uniform index values display a notable increase. This difference may be caused by the greater slope of Plot 2, although fabric orientation indicated by the azimuth of the dominant V_1 (41°) does not coincide with the S direction of the slope (Fig. 6).

4.2. Post-trampling fabrics

Following the trampling process in Plot 1, nine pieces could not be located, while 28 pieces had been overturned from their original position. In general, pieces had been displaced at an average length of 13.6 cm; only 3% had been moved more than 1 m (Fig. 5). Vector

Table 3
Eigenvector data and fabric indices of Plots 1 and 2 assemblages before and after trampling.

	Pre-trampling							Post-trampling						
	Eigenvectors				Indices			Eigenvectors				Indices		
	Vector	Trend	Plunge	Value		Value	St.Dev.	Vector	Trend	Plunge	Value		Value	St.Dev.
Plot 1	1	353	3	31.788	Uniform	0.140	0.036	1	341	3	30.282	Uniform	0.078	0.032
	2	263	2	25.416	Girdle	0.754	0.034	2	71	7	24.254	Girdle	0.814	0.030
	3	137	87	2.795	Cluster	0.106	0.013	3	225	83	1.464	Cluster	0.108	0.011
Plot 2	1	41	3	32.651	Uniform	0.182	0.031	1	173	3	36.111	Uniform	0.161	0.031
	2	131	2	24.655	Girdle	0.687	0.030	2	264	1	21.620	Girdle	0.602	0.029
	3	269	87	3.694	Cluster	0.131	0.012	3	19	87	3.270	Cluster	0.238	0.011

Table 4
Mean vector characteristics of item displacements in Plots 1 and 2 after trampling.

	Unweighted				Weighted (vector length)			
	Vector		Module R	Spherical	Vector		Module R	Spherical
	Azimuth (°)	Dip (°)	%	Variance	Azimuth (°)	Dip (°)	%	Variance
Plot 1	151.5	20.0	17.9	0.82	200.9	4.2	39.8	0.60
Plot 2	267.7	−5.2	51.9	0.44	279.7	−0.4	40.7	0.56

orientation, weighted according to length, shows a clear concentration at about 200° (Fig. 9) which coincides with the azimuth of the average vector parallel to the direction of trampling (Table 4, Fig. 5). This orientation is controlled by the three vectors with displacements >1 m. In contrast, the orientation of unweighted vectors shows a random distribution in a SE direction (Fig. 9), as indicated by the azimuth of 151.9° of the average vector (Table 4). This direction coincides with the slope of the terrain (Fig. 5).

With regards to the orientation and slope of the pieces, the stereographic projection and rose diagrams show a distribution with no preferential direction. Many pieces are distributed along the NW-SE axis, parallel to the slope of the terrain, although greater concentrations are located in a NE direction, perpendicular to the slope (Fig. 7). Nevertheless, orientation of the dominant V1 eigenvector is located at 341° (NW), contrary to the slope of the surface. The orientation of V1 is similar to the orientation of the pieces prior to trampling, although the number of pieces has increased in the NE direction. Calculation of the eigenvalues and their projection in the ternary diagram show that the fabric is placed near the planar apex (Fig. 8), increasing the girdle index towards values of 0.814 (Table 3).

In Plot 2, 18 pieces have been overturned (Fig. 6), other 18 pieces were broken, and 15 pieces could not be found. The average displacement of pieces is estimated at a length of about 14.1 cm, with 3.2% having moved >1 m. Direction of displaced pieces, according to length, show an important concentration in WNE directions (Fig. 9), indicated by an azimuth of 279.7° for the average vector of displacement (Table 4). Orientation of unweighted displacements is similar, with most displacements oriented in an NW direction (267.7°), and with values of the R% module higher than in Plot 1, indicating greater concentration of vectors in one direction. These NW orientations are perpendicular to the direction of slope in Plot 2 and tangential to the direction of trampling (Fig. 6).

Object orientation displayed in the angular histogram and the stereographic projection shows a significant increase in a NW orientation, as well as an important concentration of pieces in the opposite orientation (SE) and S (Fig. 7). Minor concentrations can also be observed perpendicular to the NW-SE axis, oriented in the NE and SW directions. In the ternary diagram, the post-trampling materials of Plot 2 are significantly displaced along linear positions (Cluster Index 0.238, Table 3) mainly to the detriment of planar distribution, which decreases to girdle indices of 0.602 (Fig. 8, Table 3).

5. Discussion

The experiments show that the general displacement of pieces due to trampling is similar in both zones, characterised by average lengths of 13.6 cm–14.1 cm, with only 3% exceeding a length of 1 m. Nevertheless, the direction of object displacement generated distinct patterns in each area (Figs. 5, 6 and 9), associated with differences in slope, orientation and direction of trampling. The general direction of object displacements in Plot 1 spreads out widely around a SE orientation, which coincides with the slope of the ground. In contrast, larger displacements show S, SW and WSW orientations which seem to be associated with the direction of trampling (NE–SW axis).

Nevertheless, the general direction of object displacement in Plot 2 (E) tends to be perpendicular to the slope of the ground and oblique to the direction of trampling (Fig. 6). In this plot, large displacements opposite to the direction of the slope, are evident. These patterns suggest that on moderately sloping ground, such as

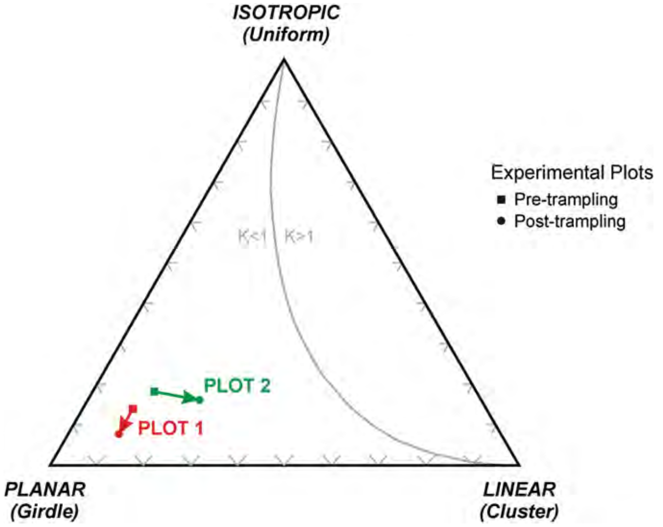

Fig. 8. Fabric ternary diagram showing assemblage distribution of Plots 1 and 2 before and after trampling.

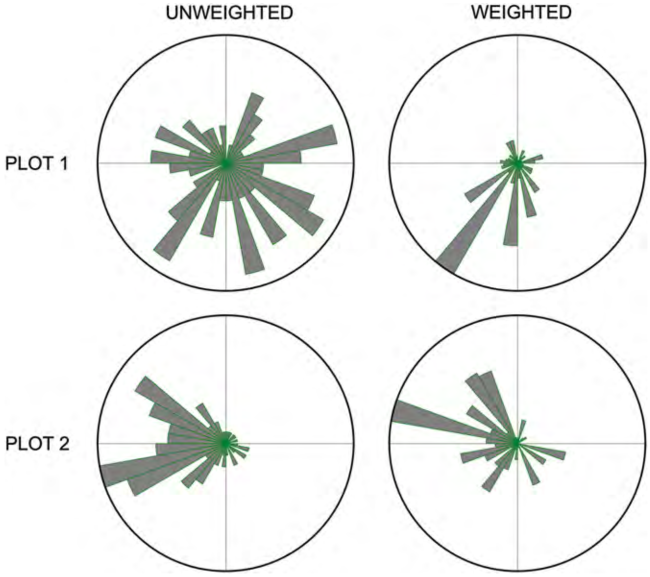

Fig. 9. Angular histograms of item displacement in Plots 1 and 2 after trampling.

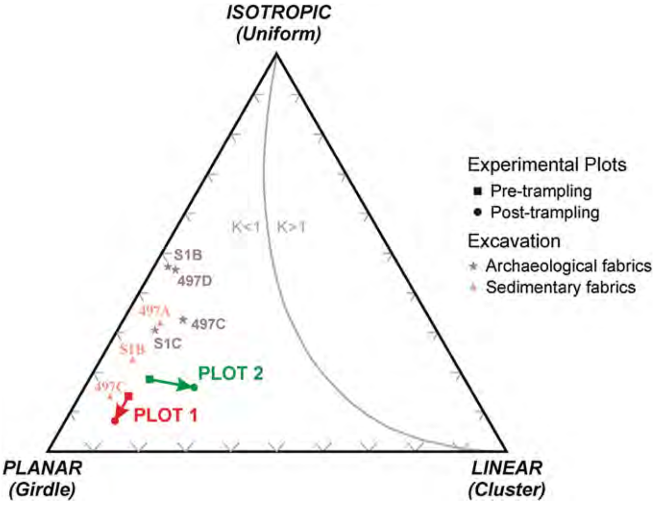

Fig. 10. Ternary diagram comparing fabrics simulated in experimental zones with fabrics associated with the archaeological and sedimentary levels excavated at the Cova Gran site.

the one considered here, the pattern of object displacement may be influenced by the slope, although the latter is not a determining factor, since random trampling can generate different patterns.

Arrangement of objects prior to trampling is likewise slightly influenced by the slope of the terrain. In both areas, pieces thrown on the surface initially show different orientations unrelated to the slope of the ground (Bertran et al., 2006). Nevertheless, in Plot 2, where the slope is more pronounced, fabrics display greater isotropy and linearity than in Plot 1, where, prior to trampling, fabrics' shape tends to be more planar. Subsequently, the trampling process causes a reworking of orientation and inclination of pieces which does not increase isotropy; on the contrary, it tends to generate more ordered patterns which we can relate to soil compaction and ground slope.

In Plot 1, with an average slope of 4°, position of objects tended to be more planar, while on the greater slope of Plot 2, objects tended to form more linear arrangements (Fig. 8). The compression of pieces against a hard substrate composed of large material clasts, caused a decrease in roughness and a levelling of pieces, reducing the original slope of the assemblage and therefore its isotropy.

There are also changes in the orientation of pieces towards less random patterning. In Plot 1, pieces are especially grouped perpendicular to the slope, or parallel to the axis of the slope (Figs. 5 and 7), although they maintain the characteristics of their original arrangement, with the dominant vector V_1 opposite the slope orientation (341°, Table 3). Most objects in Plot 2 are located in the NW, SE and S directions (Fig. 7). SE and S directions coincide with the terrain slope and the azimuth of the dominant vector V_1. This change in orientations from 41° (pre-trampling) to 173° (post-trampling, Table 3) coincides with the terrain slope (Fig. 6). Nevertheless, we note that many pieces are oriented within the axis of the slope, but in the opposite direction (NW). This reorganisation of pieces around the NW-SE axis results in the assemblage as a whole evolving towards more linear forms (Fig. 8). To a lesser extent, some pieces are aligned towards the NE or SW directions which define an axis perpendicular to the slope (Fig. 7).

However, none of the simulations match the pattern of archaeological materials derived from the excavated levels at Cova Gran (Fig. 10). Although all fabrics examined here could be associated with planar forms, pre-trampling fabrics in both experimental areas demonstrate a much lower degree of isotropy than those in the archaeological levels. Comparison can only be made with some fabrics found within the clasts of the sedimentary levels of Cova Gran. This difference is accentuated in post-trampling materials, in which trampling itself decreased the material isotropy forming smoother or more linear morphologies. These differences indicate that trampling does not explain the greater isotropy of the archaeological materials.

In the same way, the results of this experimental programme could suggest that the Cova Gran archaeological materials were not systematically submitted to trampling processes by successive occupations since they maintain a high degree of isotropy. This could indicate that sterile layers separating archaeological levels sealed and preserved discrete archaeological assemblages. Although such layers form palimpsests generated by different events, they have a resolution which allow us to consider the implications mentioned above. The latter are associated with the idea of techno-typological changes, crucial to the debate related to the Middle to Upper Palaeolithic transition.

6. Conclusion

Simulation of trampling processes in two experimental zones has enabled us to analyse some of the effects on archaeological materials, thus increasing our knowledge of how these processes can influence hard clastic substrates. The latter include contexts which have been little studied to date. Previous studies considering less compacted sediments (that is Stockton, 1973; Villa and Courtin, 1983; Gifford-Gonzalez et al., 1985; Nielsen, 1991; Eren et al., 2010) have identified important displacements on the horizontal and vertical scales, without studying the effect on the fabric shape in archaeological assemblages. According to the results of the present experiments, trampling on hard substrates does not cause greater isotropy in the orientation and slope of archaeological objects. On the contrary, trampling causes compaction of the excavation surface which leads to a greater ordering in the orientation and slope of the pieces. The objects tend to be more horizontally positioned, and arranged according to more planar fabric shapes when the slope is low, whereas a more linear fabric shape is obtained when the slope is higher.

Even so, slope influence is not always effective. Before trampling, the original fabrics were little affected by slope, and after trampling, displacement and arrangement of pieces were found to be opposite or oblique to the general slope of the surface in which they settled. This fact seems to be due to the general direction of trampling or specific trampling events which caused widespread displacement.

Although we have not been able to reproduce the fabric shape of the archaeological levels of Cova Gran, the decrease in the degree of isotropy due to trampling processes may indicate that those archaeological materials of Cova Gran in which a degree of isotropy is notable, did not undergo intense trampling. Such evidence suggests that the archaeological materials were not exposed at the surface for a long time, but were vertically and horizontally sealed by clastic sediments. Discreet archaeological levels were thus separated by sterile sediment, where the vertical dispersion of artefacts is quite limited (Martínez-Moreno et al., 2010).

Acknowledgements

Since 2004 the fieldwork project in Cova Gran has been supported by the Servei d'Arqueologia i Paleontologia-Generalitat de Catalunya and the Institut d'Estudis Ilerdencs-Diputació de Lleida. Cova Gran is part of the project *Human Settlement during the Upper Pleistocene and Holocene in the South-Eastern Pyrenees* funded by the Spanish Ministry of Science and Innovation (HAR2010-15002). This is a contribution to the Grup Cultura Material i Comportament

Huma of the Universitat Autònoma de Barcelona (2009SGR-0729). Rafael Mora is grateful to the Icrea Institution for its support.

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