Human Palaeontology and Prehistory

Ungulate carcass transport strategies at the Middle Palaeolithic site of Abric Romaní (Capellades, Spain)

Stratégies de transport de carcasses d'ongulé au site Paléolithique moyen de l'Abric Romani (Capellades, Espagne)

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A R T I C L E   I N F O

A B S T R A C T

We evaluated the skeletal profiles from several levels of the Neanderthal site of Abric Romaní, focusing on the methodology proposed by Faith and Gordon (2007): differences in the skeletal distribution of animals in accordance with their size and weight; the statistical correlation between the skeletal profiles and standard food utility index; and the anatomical diversity of size-weight categories. Results indicate an unconstrained transport strategy in all levels and all size-weight categories. However, we also found differences in the skeletal distribution of medium-sized and large animals, which may be due to different transport strategies. These characteristics suggest that the superposition of transport and occupation events could be responsible for our results. In addition, we applied the same analysis to Hadza assemblages, which revealed similar results to those found at Abric Romaní. The most striking feature of the Hadza assemblages examined is the superposition of transport events as a result of successive occupation/deposition events. This suggests that the transport strategies used by Neanderthals at Abric Romaní are also characterized by a high degree of diversity in transport decisions.

R É S U M É

Nous évaluons les profils squelettiques de différents niveaux du site néandertalien de l'Abric Romani, en mettant l'accent sur la méthodologie proposée par Faith et Gordon (2007) : différences de répartition des squelettes d'animaux en accord avec leur taille et leur poids ; corrélation statistique entre les profils squelettiques et l'index d'utilisation de nourriture

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standard ; diversité anatomique des catégories de poids et de tailles. Les résultats indiquent une stratégie de transport non contraint à tous les niveaux et pour toutes les catégories. Sont également trouvées des différences dans la répartition des squelettes d'animaux de moyennes et de grandes tailles, qui peuvent être dues à des différences de stratégie de transport. Ces caractéristiques suggèrent que la superposition d'événements de transport et d'occupation peut être responsable de nos résultats. En outre, nous avons appliqué la même analyse aux assemblages de Hadza, qui révèlent des résultats similaires à ceux de l'Abric Romani. Le trait le plus étonnant des assemblages de Hadza examinés est que la superposition des événements de transport est considérée comme le résultat d'évènements successifs occupation/dépôt. Ceci suggère que les stratégies de transport utilisées par les Néandertaliens à l'Abric Romani sont aussi caractérisées par un haut degré de diversité dans les décisions relatives au transport.

1. Introduction

The transport of animal carcasses to archaeological sites has been studied by means of the reconstruction and analyses of skeletal profiles through skeletal part frequencies, established utility ranks and theoretical transport models. Potential behavioural implications have been drawn through comparisons with ethnoarchaeological works, the exclusive source of information with which to establish analogies in relation to present-day human hunter-gatherer behaviour (e.g. Binford, 1978, 1981, 1984; Bunn and Ezzo, 1993; Bunn et al., 1988; Clerghorn and Marean, 2004; Domínguez-Rodrigo et al., 2009; Lupo, 2001; Marean and Clerghorn, 2003; Monahan, 1998; O'Connell et al., 1988a, 1988b, 1990, 1992).

With regard to the analysis of skeletal profiles, Perkins and Daly (1968) proposed that a high presence of long limb bones and heads versus a low presence of vertebrae and ribs in archaeological sites was evidence of human activities, the result of a differential transport strategy that they called the *schlep effect*. According to this proposal, the human group discarded the postcranial axial skeleton at the kill/butchering site and transported only the limbs and heads to the residential camp. More recent works have suggested that the previously proposed *schlep effect* seemed rather to be the result of an incomplete analysis of the faunal record (Clerghorn and Marean, 2004; Domínguez-Rodrigo, 1999; Marean and Clerghorn, 2003). These authors assert that the study of transport strategies based on the presence or absence of the postcranial axial skeleton can lead to misinterpretations of the archaeological record (Bunn, 1983; Clerghorn and Marean, 2004; Marean and Clerghorn, 2003; O'Connell et al., 1990, 1992). As Marean and Clerghorn (2003) have indicated, a great number of processes could result in a head and limb assemblage because these are elements with high mineral density in some of their portions, and are therefore more resistant to attritional processes. Some of these processes include human activities such as boiling, cleaning labours or fire management (Costamagno and Rigaud, 2014), which have been observed at the Abric Romaní site (Gabucio et al., 2014; Vallverdú et al., 2012). So as these researchers have proposed, the analysis of skeletal profiles and transport strategies should only consider high-survival elements (Clerghorn and Marean, 2004; Marean and Clerghorn, 2003).

One of the objectives of many ethnoarchaeological studies conducted since the 1970s has been to analyse why some specific body parts are transported while others are discarded (e.g. Binford, 1978; Bunn, 1983; O'Connell et al., 1988a, 1988b, 1990, 1992). To this end, food utility indices were created in which skeletal elements are rated based on their marrow content, intra-osseous fat content or the fleshy tissues attached to them (e.g. Binford, 1981; Emerson, 1993; Lyman, 1994; Metcalfe and Jones, 1988; Morin, 2007). Many ethnoarchaeological and methodological studies have focused on analysing and categorizing the economic value of each animal body part (e.g. Bartram, 1993a, 1993b; Bartram and Marean, 1999; Bartram et al., 1991; Binford, 1978; Emerson, 1993; Lyman, 1994; Marean and Frey, 1997; Marlowe, 2010; Metcalfe and Jones, 1988; O'Connell et al., 1988a, 1988b, 1990, 1992).

Based on the value of the anatomical parts transported, Binford (1978) established a theoretical model consisting of three different transport strategies:

- bulk: maximized transport of high and moderate utility elements, discarding low utility elements at the kill/butchering site;
- gourmet: maximized transport of high utility elements, discarding moderate and low utility elements;
- unbiased: body parts are transported relative to their food utility. This makes it possible to draw a correlation between butchering and transport actions in order to define economic variables.

Faith and Gordon (2007) add a strategy to Binford's model;

- unconstrained, in which the animal body parts are transported in relation to their abundance in a complete skeleton.

Thus, large accumulations of faunal remains at archaeological sites should reveal skeletal patterns resulting from transport and/or discard decisions.

Ethnoarchaeological studies have also looked into the behavioural characteristics of present-day foragers in order to determine whether their practices are reflected in Upper and Middle Palaeolithic archaeological sites (Bunn, 1983).

According to these works, transport decisions depend on numerous social, ecological and/or economic factors (e.g. Binford, 1978; Blurton Jones et al., 1989; Hawkes et al., 2001; Lupo, 2001; Monahan, 1998; O'Connell et al., 1992). For example, Monahan (1998) refuted the hypothesis that defined the Hadza as a hunter-gatherer group that transports only heads and limbs, defended previously by Bunn et al. (1988), as well as the hypothesis that defined them as a group that always transports the postcranial axial skeleton, as O'Connell et al. (1990) claimed. Monahan (1998) concluded that archaeological assemblages do not reflect a single transport model, but rather the sum total of different overlapping transport events. This amalgamation makes it difficult to read specific events at archaeological sites, and when they are combined with the participation of other taphonomic agents, it is even more difficult to make inferences about the subsistence strategies of prehistoric hominins (Saladié et al., 2011).

Studies on the prey acquisition and transport decisions of Neanderthal groups suggest that these groups' exploitation of the herbivores in their environment was highly complex, with medium-sized and large ungulates being the most common animal remains recovered at archaeological sites (e.g. Brugal and David, 1993; Costamagno et al., 2006; Daujeard, 2004; Daujeard and Moncel, 2010; Daujeard et al., 2012; Fernández et al., 1998; Gaudzinski and Niven, 2009; Jaubert and Brugal, 1990; Moncel and Daujeard, 2012; Moncel et al., 2004; Patou-Mathis, 2000; Rendu, 2010; Rendu et al., 2012; Romandini et al., 2014; Rosell et al., 2012a, 2012b; Stiner, 1991, 1994, 2002, 2009; Voormolen, 2008). At Mousterian sites, the most common skeletal profiles are characterized by the scarcity of the postcranial axial skeleton and the predominance of the long limb bones and heads (Gaudzinski and Niven, 2009; Romandini et al., 2014; Rosell et al., 2012a, 2012b; Valensi and Psathi, 2004). At some sites, where the faunal remains of medium-sized animals outnumber those of large animals, it has been suggested that the skeletal profile is the result of a differential transport based on animal size-weight (e.g. Gaudzinski and Niven, 2009; Patou-Mathis, 2000; Rendu, 2010; Romandini et al., 2014; Rosell et al., 2012a, 2012b).

Abric Romaní consists of an extensive sequence of levels containing clear material evidence of Neanderthal occupation and activities (e.g. Carbonell, 2002, 2012; Chacón et al., 2007, 2010; Fernández-Laso et al., 2010; Gabucio et al., 2013, 2014; Rosell et al., 2012a, 2012b; Vallverdú et al., 2005; Vallverdú et al., 2012; Vaquero et al., 2001, 2012a, 2012b). The transport sequence starts with access to one or more animal carcasses and ends with the discarding of unused or exhausted animal remains (Binford, 1978). Therefore, the transport of carcasses is one of the steps undertaken during the animal butchering process. However, it is also important to explore the abandonment of some body parts, whether consumed or not, at any of the stages prior to their exhaustion. This is most likely to happen, as indicated by a large number of ethnoarchaeological works (e.g. Binford, 1978, 1981; Bunn and Kroll, 1986, 1988; Bunn et al., 1988; Hawkes et al., 2001; Hayden, 1981; Lupo, 2001; Monahan, 1998; O'Connell et al., 1988a, 1988b, 1990, 1992; Schoville and Otárola-Castillo,

2014; Yellen, 1977), as well as research conducted at archaeological sites (Domínguez-Rodrigo et al., 2009; Gaudzinski and Niven, 2009; Moncel et al., 2004; Niven et al., 2012; Patou-Mathis, 2000; Rendu, 2010; Romandini et al., 2014; Saladié et al., 2011), during the preparation of the carcass for transport from the kill/butchering site.

The transport patterns established by hominins, including modern humans, may be subject to many different variables, including social factors such as group size, or situational aspects such as the size of the animal hunted, among many others (Binford, 1978, 1981; Bunn, 1993; Bunn and Kroll, 1986, 1988; Bunn et al., 1988; Hayden, 1981; Monahan, 1998; Schoville and Otárola-Castillo, 2014). The study of what parts of the animal are brought back to camp can therefore provide insight into those social factors, or at least allow for a tangential approach towards them through inferences made about transport patterns.

In the case of the Abric Romaní Neanderthal site, medium-sized animals (the size of adult deer) are thought to have been transported whole to the central camp, and large animals (horses and aurochs adults-sized) were processed at the kill/butchering site, with only their limbs and heads carried back to camp (Cáceres et al., 1998; Fernández-Laso et al., 2011; Rosell et al., 2012a, 2012b; Saladié and Aïmene, 1998; Vallverdú et al., 2005). Our analysis of the faunal record of Abric Romaní reveals the presence of all parts of the skeleton in all the size-weight categories. For these reasons, the aim of this paper is to review the carcass transport strategies employed by the Neanderthal groups who occupied Abric Romaní and to infer the socioeconomic connotations that the strategies chosen by these hominin groups may have had. Working from this starting point, our objective is to study the skeletal profiles of the different assemblages generated by the Neanderthals at Abric Romaní in accordance with the proposals put forth by Marean et al. (Clerghorn and Marean, 2004; Marean and Clerghorn, 2003; Marean et al., 2004), i.e. analysing only the high-survival elements and relating them to the survival and nutritional value of the body parts and skeletal segments, and with those advanced by Faith and Gordon (2007), i.e. combining the correlations between utility rank indices and the anatomical diversity of the skeletal profiles to evaluate possible decisions in the transport of carcasses by Neanderthal groups. We centre our analyses on the large and medium-sized ungulates, mainly represented by deer, horses and aurochs, because they are the most common animals in the archaeozoological record of Abric Romaní, and previous works focus the discussion of Neanderthals transport strategies on these two size-weight categories.

2. Abric Romaní

The Abric Romaní archaeological site is a rock-shelter located on the northeastern side of the Cinglera del Capelló cliff in the town of Capellades, 45 km northwest of Barcelona, Spain. Its coordinates are 41° 32′ N and 1° 41′ E, its altitude is 280 m asl, and the cliff wall faces north-northeast. Its stratigraphy is made up of 20 m of well-stratified travertine sediments. Rock fragmentation and alluvial and biochemical sedimentary processes

generated boundstones, gravels, calcarenites, and calcilutites interbedded with very fine archaeological levels. U-series and radiocarbon dates put the Abric Romaní chronostratigraphy between 70 and 40 kyr. The sedimentation rate is estimated at around 0.6 m/kyr (Bischoff et al., 1988). Discovered in 1909 by Amador Romaní, the site was excavated at different periods throughout the 20th century. Ongoing excavations started in 1983 under the direction of Dr Eudald Carbonell.

Except for level A, all of the archaeological units in the sequence correspond to the Middle Palaeolithic (Fig. 1). The upper levels of the sequence (A–E) were largely excavated during the previous excavations, and levels E–I were also affected by these digs, although to a lesser extent.

The different levels of Abric Romaní are the result of the accumulation of an unknown number of occupational events. The occupation models that make up the archaeological record can be distinguished as long-term occupation events or short occupation and/or non-residential events (Vallverdú et al., 2005, 2010; Vaquero et al., 2012a). In both models, the hearths were reused, especially in long-term events, which resulted in the preservation of these structures (Vallverdú et al., 2010; Vallverdú et al., 2012). The main characteristic that differentiates these two occupation models in the record is that in the short-term or non-residential events (Table 1), areas where specific activities were performed (conservation areas for animal biomass, knapping areas, butchering areas) can be isolated and differentiated (Vallverdú et al., 2005). Meanwhile, levels characterized by long-term events exhibit overlapping of different areas and places where activities occurred and these cannot be clearly differentiated from one another (Vaquero et al., 2012b).

Therefore, the representation and superposition of occupancy models may involve the mixing of materials corresponding to different types of strategies. This effect is also observed in the lithic assemblage of Abric Romaní (Vaquero, 2008). The predominant structural category is that of flakes. Cores and retouched flakes are not abundant in the assemblages from the different levels (Chacón and Fernández-Laso, 2007; Martínez and Rando, 2000; Vaquero, 2008; Vaquero et al., 2001, 2004). The predominant raw material in the assemblage is flint, compared to other materials such as quartz or limestone. Other raw materials, like slate, sandstone, quartzite and, to a lesser extent, porphyry are also present (Table 1). Most raw materials are found in nearby sheltered environments, such as the terraces of the Anoia River and the Palaeozoic formations of the Capellades strait. Flint, however, is found in various formations located within a radius of about 28 km (Table 1) (Gómez de Soler, 2007; Morant and García-Antón, 2000). Short-duration or non-residential occupation events have been linked to the transport and abandonment of most of the retouched artefacts, notches and denticulates, whereas the exploitation of cores oriented towards the production of small flakes has been associated with long-term occupation events. The grounds for these conclusions lie in the fact that flint is the preferential raw material at the site, and it comes from reservoir outcrops not found in the immediate vicinity. Therefore, the abandonment of retouched elements has been related to less economical

occupations and the exploitation of cores to occupations that tend to maximize resources (Vallverdú et al., 2005; Vaquero et al., 2012a).

Since the 1990s, considerable importance has been placed on the zooarchaeological and taphonomic studies of the faunal remains recovered in the Abric Romaní sequence, many of them part of multidisciplinary research projects (e.g. Aïmene, 1997, 1998; Aïmene et al., 1996; Cáceres, 1998; Cáceres et al., 1998, 2012; Carbonell, 2002; Chacón and Fernández-Laso, 2007; Chacón et al., 2007, 2010; Gabucio et al., 2013, 2014; Rosell et al., 2012a, 2012b; Vallverdú et al., 2005, 2010). Faunal remains are very abundant in all of the levels of the Abric Romaní stratigraphic sequence. A total of 13 different taxa have been identified, although deer (*Cervus elaphus*) and horses (*Equus ferus*) are the most abundant animals (Table 2). Auroch remains (*Bos primigenius*) are also common at the current bottom of the sequence and chamois (*Rupicapra pyrenaica*) in the upper levels. Rhinoceros (*Stephanorhinus sp. hemitoechus*) remains have been documented in several levels, although they are scarce. In level E, a proboscidean femur shaft has been recovered. Although large herbivores predominate in all of the levels, some carnivore remains have also been recovered (Table 2) (Supplementary material).

Combustion structures are also common in all of the levels excavated at Abric Romaní to date. These structures are circular or oval in appearance and are distinct from the travertine substrate. They are characterized by a colour change, by the stratification of rubefied and carbonaceous facies and by sediment compaction.

The hearth areas also contain combustion waste products, such as ashes and coals, along with other remainders of anthropic activity, such as bone and stone remains (Vallverdú, 2002; Vallverdú and Courty, 2012; Vallverdú et al., 2012). Abric Romaní has yielded fossil wood remains recovered as empty cavities in the shape and with the negative mould of the original wood surface. These remains are empty travertine imprints of completely decayed wood (Carbonell, 2002; Castro-Curel and Carbonell, 1995). The wood totally decays leaving only an imprint in the travertine when the water process stops (Castro-Curel and Carbonell, 1995). The study of these imprints has made it possible to distinguish between firewood and worked wood (Allué et al., 2012; Solé et al., 2014).

2.1. Zooarchaelogical and taphonomical data

The data for this study were extracted from Rosell et al. (2012a, 2012b) for level J (Ja and Jb sublevels), Chacón and Fernández-Laso (2007) and Fernández-Laso et al. (2010) for level K, Chacón et al. (2007, 2010) for level L, and our own analysis of the level M assemblage. We only use the remains of the large and medium ungulates. The very large and small ungulates and the carnivore remains are not included because they are poorly represented in the Abric Romaní sequence. However, we use the presence of some bones of very large size to support some of our conclusions. These levels are not affected by the pits of the former excavations and were extensively excavated ($\approx 250\,\text{m}^2$) in the recent archaeological interventions, thereby ensuring an absence of bias in the collection of the faunal remains.
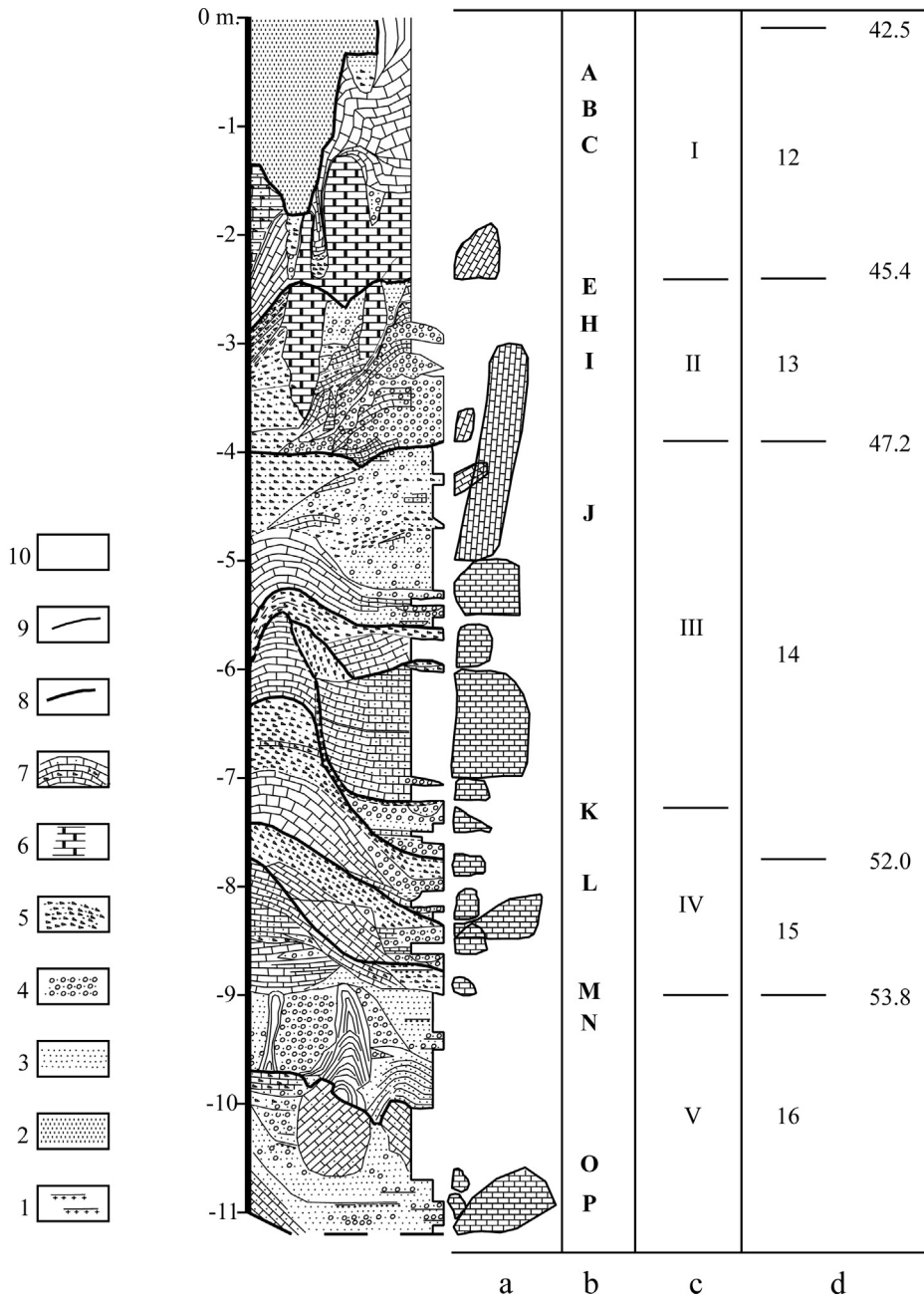
Fig. 1. The lithostratigraphic column of the Abric Romaní Coveta Nord profile (figure elaborated and courtesy by J. Vallverdú et al., 2012). The stratigraphic column contains the temporal position of the archaeological level in accordance with the chronology of the basal boundaries of the Dansgaard–Oeschger events in the GISP2 temporal scale model (Blunier and Brook, 2001). An updated summary of the absolute ages of the Abric Romaní archaeological beds has recently been published (Vaquero et al., 2013). Legend for the lithological column: 1, organomineral grey horizon; 2, red siliciclastic and calcitic silty sand; 3, yellow calcitic sand; 4, yellow tuffaceous-travertine gravel and calcitic sand; 5, platy gravels of crystallitic travertine and calcitic sand and silt; 6, speleothems; 7, cemented sands and travertines; 8, diastem; 9, paraconformity or erosive unconformity; 10, archaeological bed. Legend for the comment columns: a: rock-fall of travertine blocks and megablocks; b: letters of the archaeological beds; c: sedimentary sequences; d: the lower boundary chronology of the Dansgaard–Oeschger events in the temporal scale model of the GISP2 core (Blunier and Brook, 2001).

Fig. 1. Lithostratigraphie du profil de la Coveta nord de l'Abric Romani (Vallverdú et al., 2012). La colonne stratigraphique contient la position temporelle des couches archéologiques en relation avec la chronologie des limites basales des événements avec le modèle temporel de GISP2 Dansgaard–Oeschger (Blunier et Brook, 2001). Un résumé actualisé des couches archéologiques de l'Abric Romani a récemment été publié (Vaquero et al., 2013). Légende pour la colonne lithologique : 1, horizon gris organominéral ; 2, sable limoneux silicoclastique et calcitique rouge ; 3, sable calcitique jaune ; 4, gravier travertineux et sable calcitique jaune ; 5, graviers lamellaires aplatis de travertin cristallin et sable et limon calcitiques ; 6, spéléothème ; 7, sables et travertins cimentés ; 8, diastème ; 9, paraconformités et discordances érosives ; 10, couche archéologique. Légende des commentaires : a : chute de travertins et de mégablocs gravitaires ; b : lettre des couches archéologiques ; c : séquences sédimentaires ; d : chronologie de la limite basale des événements Dansgaard–Oeschger dans le modèle d'échelle temporelle du carottage GISP2 (Blunier et Brook, 2001).

Table 1
Summary by layer, occupation type, lithic, wood used and previously enunciated transport strategies (Bischoff et al., 1988; Burjachs and Julià 1994; Carbonell, 2012; Chacón et al., 2007, 2010; Gómez de Soler, 2007; Rosell et al., 2012a, 2012b; Solé et al., 2014; Vallverdú et al., 2012; Vaquero et al., 2012a, 2012b).

Tableau 1
Résumé par niveaux, type d'occupation, lithique, bois utilisé et stratégies de transport précédemment énoncées (Bischoff et al., 1988 ; Burjachs et Julià 1994 ; Carbonell, 2012 ; Chacón et al., 2007, 2010 ; Gómez de Soler, 2007 ; Rosell et al., 2012a, 2012b ; Solé et al., 2014 ; Vallverdú et al., 2012 ; Vaquero et al., 2012a, 2012b).

Abric Romaní	Model of occupation	Lithic		Charcoals, hearths and wood remains	Ungulate	Mortality profiles	Carcasses Transport Strategies
		Raw Material	Knapping Methods				
Level J	Residential camp: Long-term occupation	Flint (75%) outcrops to 5 km and 25 km Quartz and Limestone (10%) local 5 km	Discoid + centripetal Lithics tools: Denticulates and cores are scarce; small flakes are common	*Pynus sylvestris* (71%) *Pinus uncinata* (3.4%) Hearhts = 60 Combustion and configuration. Preservation of wood is scarce, fuel wood accumulations. Pointed wooden element	*Cervus elaphus Equus ferus Equus hydruntinus Stephanorhinus sp. hemitoechus Bos primigenius Rupicapra pyrenaica* Proboscidea	Ja: Young = 8 Juvenile = 8 Prime Adult = 22 Old = 4 Jb: Young = 3 Juvenile = 3 Prime Adult = 8 Old = 1	Differential transport: Small and Medium animals were transported whole to the site; Large animal were processed on kill site and transport only their high food utility element
Level K	Residential camp: Short-term occupation	Local and semi-local raw materials between 15 and 20 km Flint (47.9%) Limestone (19.2%) Quartz (28%)	Discoid Lithics tools: Denticulates and cores are scarce; small flakes are common	*Pynus sylvestris* (54.51%) *Pinus uncinata* (0.4%) Hearhts = 25 Combustion and configuration. Little accumulation of negative with signs of cremation	*Cervus elaphus Equus ferus Stephanorhinus hemitoechus Bos primigenius*	Young = 2 Juvenile = 2 Prime Adult = 8 Old = 1	Differential transport: Small and Medium animals were transported whole to the site; Large animal were processed on kill site and transport only their high food utility element
Level L	Residential camp: Short-term occupation	Local and semi-local raw materials between 15 and 20 km Flint (83.7%) Limestone (9.9%) Quartz (3.3%)	Discoid Lithics tools: Denticulates and cores are scarce; small flakes arecommon	*Pynus sylvestris* (63.78%) *Pinus uncinata* (2.8%) Hearhts = 23 Combustion and configuration. Four accumulations grouped together to hearths	*Cervus elaphus Equus ferus Bos primigenius*	Young = 2 Juvenile = 2 Prime Adult = 4 Old = 2	Differential transport: Small and Medium animals were transported whole to the site; Large animal were processed on kill site and transport only their high food utility element
Level M	Residential camp: Long-term occupation	Local and semi-local raw materials between 15 and 20 km Flint (80%) Limestone (9.4%) Quartz (5.3%)	Discoid + centripetal Lithics tools: Denticulates, scarpers and cores are scarce; small flakes are very common	*Pinus Sylvestris/nigra* (59%) *Pinus uncinata* (1.5%) Hearhts = 37 Combustion and configuration. Four accumulations grouped together to hearths	*Cervus elaphus Equus ferus Stephanorhinus hemitoechus Bos primigenius*	Young = 3 Juvenile = 2 Prime Adult = 11 Old = 2	Differential transport: Small and Medium animals were transported whole to the site; Large animal were processed on kill site and transport only their high food utility element

Table 2
Faunal taxa identified at Abric Romaní and their location in the sequence by archaeological levels named from top to the base by capital letters.
Tableau 2
Animaux identifiés dans l'ensemble faunistique de l'Abric Romani et leur place dans la séquence par niveaux archéologiques nommés du sommet vers la base (avec lettres majuscules).

	A	B	C	D	E	F	G	H	I	J	K	L	M	N
Ursus sp.		X											X	
Canis lupus		X			X									
Panthera leo spelaea									X					
Panthera pardus				X										
Lynx sp.	X	X			X									
Felis silvestris	X	X											X	
Crocuta crocuta	X	X			X								X	
Proboscidea indet.					X									
Stephanorhinus cf. hemitoechus								X					X	
Equus ferus	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Cervus elaphus	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Bos primigenius					X				X	X	X	X	X	X
Rupicapra pyrenaica	X	X		X	X	X	X	X		X				

Table 3
Distribution of the number of identified specimens (NISP), total minimal number of elements (MNE), MNE of the high and low-survival elements and the minimal number of individuals (MNI) of levels Ja, Jb, K, L and M by size-weight categories. Data for levels Ja and Jb extracted from Rosell et al. (2012a, 2012b); for level K from Chacón and Fernández-Laso (2007) and Fernández-Laso et al. (2010); for level L, Chacón et al. (2007, 2010); authors' analysis for level M data.
Tableau 3
Répartition du nombre de spécimens identifiés (NISP), du nombre minimal total d'éléments (MNE), MNE des éléments de haute et faible survie et du nombre minimum d'individus (INM) des niveaux Ja, Jb, K, L et M par catégories de tailles et de poids. Les données pour les niveaux Ja et Jb sont extraites de Rosell et al. (2012a, 2012b) ; pour le niveau K, de Chacón et Fernández-Laso (2007) et Fernández-Laso et al. (2010) ; pour le niveau L, de Chacón et al. (2007, 2010) ; pour les données de la couche M, de l'analyse de ces auteurs.

Level	Animal size	NISP	Total MNE	High-survival elements MNE	Low-survival elements MNE	MNI
Ja	Large	439	118	113	5	17
	Medium	497	171	123	48	15
Jb	Large	154	42	42	0	6
	Medium	96	52	45	7	3
K	Large	71	22	16	6	4
	Medium	335	69	49	20	9
L	Large	40	15	12	3	6
	Medium	96	37	32	5	5
M	Large	105	44	36	8	10
	Medium	711	104	71	33	7

Level Ja yielded 6738 faunal remains, of which 984 (14.6%) were identified anatomically. The taxonomic diversity of this level is high although ungulate remains predominate. Rosell et al. (2012b) identified *Equus ferus* (NISP = 351), *Cervus elaphus* (NISP = 497), *Bos primigenius* (NISP = 88), *Stephanorhinus hemitoechus* (NISP = 33), *Rupicapra pyrenaica* (NISP = 6), *Ursus sp.* (NISP = 1), *Lynx sp.* (NISP = 1), *Canis lupus* (NISP = 2) and *Vulpes vulpes* (NISP = 1). This taxonomic distribution shows that medium-sized and large animals are the most abundant, while very large and small animals are scarce (Table 3). Level Ja is an anthropogenic accumulation in which the activity and disturbance of carnivores (NR = 61) was extremely rare (Cáceres et al., 2012; Rosell et al., 2012a, 2012b). Lithic remains refits (262 refitting groups) and the overlapping of the hearths indicate that the level was formed in different occupational events, in long- to medium-term occupations with intercalated phases of short or non-residential occupations (Vallverdú et al., 2012; Vaquero et al., 2012a, 2012b).

In level Jb, 1722 faunal remains were recovered, 281 (16.3%) of which were identified anatomically. Rosell et al. (2012b) identified *E. ferus* (NISP = 139), *C. elaphus* (NISP = 96), *B. primigenius* (NISP = 15), *S. hemitoechus*

(NISP = 27) *R. pyrenaica* (NISP = 2), *Lynx sp.* (NISP = 1) and *Crocuta crocuta* (NISP = 1). Level Jb also corresponds to a long-term occupation. From a zooarchaeological perspective, levels Ja and Jb exhibit the same features (Rosell et al., 2012b), but unlike the occupation of Ja, the breadth of the occupation does not cover the entire surface area, but rather is concentrated in the central area of the rock-shelter floor (Carbonell, 2012; Sañudo et al., 2012).

A total of 2564 faunal remains were recovered from level K, 406 (15.8%) of which were identified anatomically (Chacón et al., 2010). The taxa recorded in the assemblage are *C. elaphus* (NISP = 335), *E. ferus* (NISP = 56), and *B. primigenius* (NISP = 15). As in the previous levels, the level K assemblage has been interpreted as anthropogenic in origin, but this unit has yielded more evidence of the secondary activity of carnivores on the faunal remains (NR = 78) (Chacón et al., 2010; Fernández-Laso et al., 2010). Level K is the result of overlapping short-term occupations (Chacón et al., 2010, 2013).

Level L yielded 1002 faunal remains, 136 (13.6%) of which were identified anatomically (Chacón et al., 2010). The taxa identified are *C. elaphus* (NISP = 96), *E. ferus* (NISP = 34) and *B. primigenius* (NISP = 6). Level L is characterized by a low MNI compared to the other levels

Table 4
Number of remains (NR) and corresponding percentage of anthropogenic and carnivore modifications in levels Ja, Jb, K, L and M (Chacón et al., 2007, 2010; Fernández-Laso et al., 2010; Rosell et al., 2012a, 2012b).

Tableau 4
Nombre de restes (NR) et pourcentage correspondant des modifications anthropiques dues aux carnivores dans les couches Ja, Jb, K, L et M (Chacón et al., 2007, 2010 ; Fernández-Laso et al., 2010 ; Rosell et al., 2012a, 2012b).

	Ja		Jb		K		L		M	
	NR	%	NR	%	NR	%	NR	%	NR	%
Cut marks	448	6.6	69	4	105	4.1	67	6.7	292	6.7
Percussion marks	804	11.9	149	8.6	275	10.7	34	3.4	163	3.7
Burned bones	2113	31.3	317	18.4	1301	20.7	513	51.2	1599	36.9
Tooth marks	61	0.9	4	0.2	78	3	8	0.8	13	0.3
Total	6738		1722		2564		1002		4334	

(Supplementary material), which has been related to shorter occupation events or occupations of small groups of Neanderthals. At the same time, there is less dispersion of the remains across the living floor. The lithic and faunal remain refits also suggest that level L is the product of short occupations, as most of the connections were made within the defined accumulation activity areas (Chacón et al., 2007, 2010; Fernández-Laso et al., 2010).

A total of 4334 faunal remains were recovered from level M, 836 of which have been anatomically identified. The taxa represented in this assemblage are *C. elaphus* (NISP = 711), *E. ferus* (NISP = 84), *B. primigenius* (NISP = 31), *Stephanorhinus cf. hemitoechus* (NISP = 2), *Ursus* sp. (NISP = 1) and *C. crocuta* (NISP = 1). The internal distribution of the faunal and lithic record, along with the intentional accumulation of firewood, has led to the suggestion that level M is the product of a reiteration of long-term occupations, showing a similar occupational pattern to level Ja. The abundance of remains as well as their dispersion and the MNI of the different animals (Table 3) seem to corroborate this hypothesis (Chacón et al., 2010, 2013; Fernández-Laso et al., 2011; Solé et al., 2014).

The most abundant modifications produced during the biostratinomic phase (after Capaldo, 1998) are related to the exploitation of nutrients by Neanderthals (Table 4): cut marks (disarticulation, defleshing, evisceration, skinning) and bone breakage are abundant. Modifications caused by carnivores are virtually absent in the assemblages from the four levels analysed here. In levels Ja, Jb, L and M the modifications produced by carnivores affect less than 1% of the assemblage, with the exception of level K, where carnivore modifications affect 3% remains. Nevertheless, the impact of carnivores is still low throughout the assemblage, and occurs only on remains previously abandoned by Neanderthals (Chacón et al., 2010). The absence or scarcity of carnivore-induced modifications as well as the distribution of cut marks, mainly on shaft fragments, along with almost universal anthropogenic bone breakage, support the Neanderthals' primary access to the different animals documented in the various levels (e.g. Aïmene, 1997, 1998; Cáceres, 1998; Cáceres et al., 1998; Carbonell, 2002; Chacón and Fernández-Laso, 2007; Chacón et al., 2007, 2010; Rosell et al., 2012a, 2012b). Burned bones are also very common in the assemblages, possibly resulting from different processes such as food preparation, cleaning of the living floor or specific use as fuel (Cáceres, 2002; Gabucio et al., 2014).

All of the assemblages are characterized by the elevated presence of high-survival elements (skulls, jaws and fragments of shafts of the long bones of the limbs) to the detriment of low-survival elements (ribs, vertebrae, coxa, scapula, phalanges and compact bones) (Chacón and Fernández-Laso, 2007; Chacón et al., 2007, 2010; Fernández-Laso et al., 2010; Rosell et al., 2012a, 2012b; and our own analyses of Level M). It seems clear that during the occupations of Abric Romaní, deer and horses formed an important part of the Neanderthals' diet. Previous studies suggest that these skeletal profiles are associated with the differential transport of prey. Based on this model, deer were transported whole and the axial skeleton of large animals (horses, aurochs and rhinos) were abandoned at the kill/butchering site (Cáceres et al., 1998; Fernández-Laso et al., 2011; Rosell et al., 2012a, 2012b; Vallverdú et al., 2005).

3. Methods

As mentioned earlier, the archaeological remains at the site are the result of different accumulation events. In the case of the faunal remains, each of the different transport events that generated the final archaeological assemblage cannot be isolated (Monahan, 1998; Saladié et al., 2011). For this reason, we have used the total number of ungulate remains for each species/age classes and size-weight categories in each level with the goal of identifying the possible transport strategy that generated the entire assemblage. The minimal number of elements (MNE) and the minimal animal units (MAU) were calculated in all five assemblages considering the bone landmarks in conjunction with a repetition of regions and sides, and the anatomical position (left/right) of the bones, as described by Saladié et al. (2011). As indicated in Faith and Gordon (2007), the MNE was calculated taking into account the shaft fragments in the assemblages. We only considered the high-survival elements and did not use the low-survival elements (Marean and Clerghorn, 2003). This is because the high-survival elements are more resistant to the different attritional processes and more accurately reflect the original abundance of elements resulting from hominin transport/discard decisions. We test the correlations between the %MAU of high-survival elements of large and medium-sized animals and their bone mineral density by portions (Lam et al., 1999; Lyman, 1994), in order to consider the

Table 5
Distribution of taxa present in the Abric Romaní levels by size-weight categories.
Tableau 5
Répartition des taxons de faune présents dans les niveaux de l'Abric Romani par catégories de tailles et de poids.

Size	Weight	Taxa
Very large	> 1000 kg	*Stephanorhinus* cf. *hemitoechus*
Large	300–1000 kg	*Equus ferus* adult
		Bos primigenius adult
Medium	100–300 kg	*Equus ferus* infantile
		Bos primigenius infantile
		Cervus elaphus adult
Small	< 100 kg	*Cervus elaphus* infantile
		Rupicapra pyrenaica adult

possible intervention of destructive taphonomic process as well as for these elements where densities are also variable. To compare the distribution of the elements (MNE) into the size-weight groups (large and medium-sized animals) (Table 5) of each set, we applied a Chi^2 test. The correlation analysis between the %MAU and the Standard Food Utility Index (SFUI) (Metcalfe and Jones, 1988) was calculated by means of Spearman's rank-order correlation coefficient (r_s). In keeping with Faith and Gordon (2007), we used Spearman's r_s because the correlation is dependent on rank-order values and the MAU and SFUI should be treated as ordinal-scale measures. In addition, we tested the MAU with the Unsaturated Marrow Index (UMI) (Morin, 2007), with the purpose of identifying a possible preference in the transport of bones as a function of their marrow and grease content. As with the SFUI, we use Spearman's r_s to test the statistical correlation.

Our assessment of the correlation between MAU and SFUI results takes into account the possibility of type I and type II statistical errors due to the small size of most of the assemblages (Faith and Gordon, 2007). Type I errors are those in which significant correlations are found in an assemblage when no such correlation exists in the population assemblage, and type II errors are those in which no correlation is found in an assemblage despite the presence of a correlation in the population assemblage. Faith and Gordon (2007) noted that type II errors are very common in assemblages with an MNE lower than 100 and resulting from an unconstrained or bulk strategy.

Finally, and again in keeping with the proposals of Faith and Gordon (2007), we applied the Shannon Diversity Index (evenness), where evenness is equal to $E = \Sigma - (Pi \times i \ ln \ P)/ln \ S$. S is the number of types of elements (e.g. MNE of humeri, femora, skulls) and pi is the standardized proportion of specimens of the i-th element. Finally, we compared the Abric Romaní assemblages using information from the faunal assemblages of the Hadza campsites of Mugugu and Tispitibe, published by Lupo (2001). The Hadza are a hunter-gatherer group that has been intensely studied with regard to different social and economic aspects, and especially concerning their animal carcass discard and transport strategies (Bunn, 1993; Bunn et al., 1988, 1991; Monahan, 1998; O'Connell, 1993; O'Connell et al., 1988a, 1988b, 1990). At these two sites, the faunal remains were collected from the surface and subsurface at a depth of 10 cm, the

MNE was calculated using all identified parts (including the diagnostic limb bone shaft), and the assemblages were formed through the overlapping of events/occupations (Lupo, 2001).

4. Results

4.1. Level Ja

The NISP and MNE show that the most abundant elements in all size-weight groups are those belonging to the skull, mandibles and the long bones (Supplementary material). Vertebrae, ribs and coxae are present in all size-weights but almost anecdotally. However, it is worth noting that according the %MAU, they are more common among large size, except for the coxae (Fig. 2). The Chi^2 analysis of the MNE from medium-sized versus large animals [Chi^2 = 66; degrees freedom = 54; P(same) = 0.127] revealed that there is no statistical similarity between the two size groups. The test between bone mineral density and %MAU are not statistically significant [Large size: Spearman's r_s = 0.205; P(same) = 0.464] [Medium size: Spearman's r_s = 0.339; P(same) = 0.216], this indicate that a relation between the conservation and the mineral density cannot be prove (Carbonell, 2012).

For large animals, high-survival elements had an MNE of 113. We found no statistically significant correlations between the %MAU and SFUI (Table 6; Fig. 3). With an MNE of close to 100, the Spearman's r_s of 0.404 falls within the range (95% CI) of bulk (0.275–0.964) and unconstrained (−0.732 to 0.743) transport strategies. The evenness value is 0.937, which places it within the values of a bulk strategy (0.927–0.989) (Table 6). In this case, the lack of a significant correlation between the %MAU and SFUI may be due to a type II error.

In the medium-sized animals set, the MNE of high-survival items is 123. This group did not show a statistically significant correlation between the %MAU and SFUI (Table 6) (Fig. 3). The Spearman's r_s of 0.380, with an MNE of close to 100, falls within the range (95% CI) of bulk and unconstrained transport strategies. The evenness value of 0.972 places it within the values of the bulk and unconstrained strategy (0.961–0.996).

We found statistically significant correlations between the %MAU and UMI for large and medium animals [Large size: Spearman's r_s = 0.711; P(same) = 0.038] [Medium size: Spearman's r_s = 0.677; P(same) = 0.05] (Table 6).

4.2. Level Jb

In the large and medium-sized animal assemblages, the most abundant bones are skulls, mandibles and long bones, according to the NISP and MNE (Supplementary material) (Table 3). The test between bone mineral density and %MAU are not statistically significant [Large size: Spearman's r_s = 0.068; P(same) = 0.810] [Medium size: Spearman's r_s = 0.167; P(same) = 0.553], this indicates that a relation between the conservation and the mineral density cannot be prove (Carbonell, 2012).

According to the %MAU, the cranial and long limb bones dominate among the large and medium-sized animals
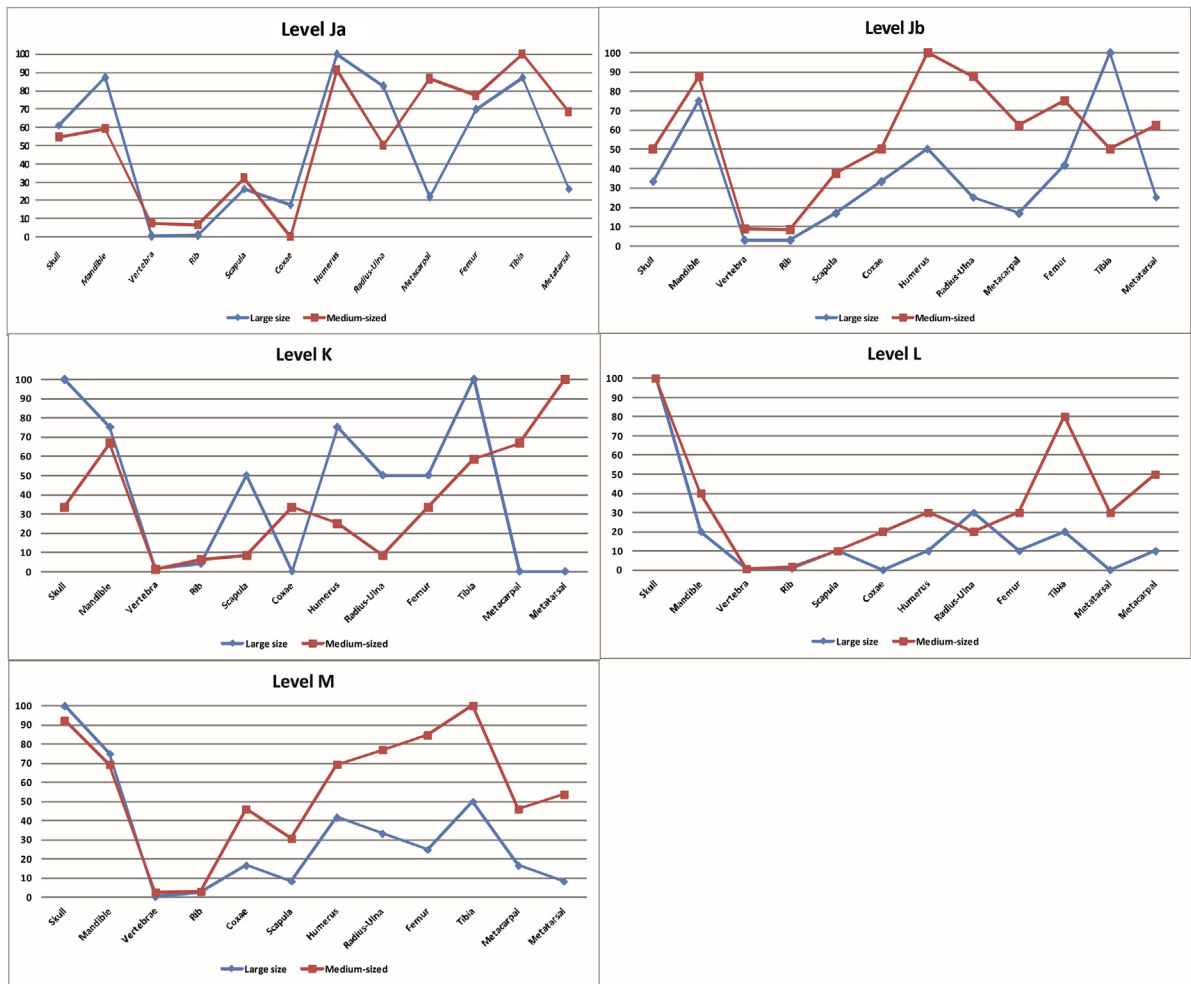
Fig. 2. Distribution of the percentage of minimal animal unit (%MAU) in the main size-weight categories for levels Ja, Jb, K, L and M. Lg: Large size; Ms: Medium size.
Fig. 2. Répartition du pourcentage de l'unité animale minimale (% MAU) dans les principales catégories de tailles et de poids pour les couches Ja, Jb, K, L et M. Lg : grande taille ; Ms : taille moyenne.

(Fig. 2), although they differ in the presence of the fore- and hind-limb elements. The bones of the forelimbs (humeri and radii-ulnae) are the most abundant in the medium-sized animal set, while in the large animals, the tibiae are the most common elements. Humeri and femora are present in similar percentages. A comparison of the skeletal profiles of the large and medium-sized animal remains by means of a Chi² test [Chi² = 10.13; degrees freedom = 11;

Table 6
Evenness values and correlations of the different levels analysed by size-weight categories.
Tableau 6
Valeurs de l'*Evenness* et corrélations entre les différentes couches archéologiques analysées par catégories de poids.

Level/size-weight	MNE	Evenness (E)	%MAU/SFUI		%MAU/UMI	
			Spearman's (r_s)	P	Spearman's (r_s)	P
Ja large	113	0.937	0.404	0.326	0.711	0.003
Ja medium	123	0.972	0.380	0.359	0.677	0.05
Jb large	42	0.907	0.455	0.258	0.854	0.006
Jb medium	45	0.980	−0.169	0.699	0.548	0.13
K large	16	0.978	0.048	0.946	0.579	0.114
K medium	49	0.939	−0.168	0.695	0.753	0.023
L large	12	0.957	−0.368	0.368	0.569	0.13
L medium	32	0.959	0.306	0.460	0.762	0.023
M large	36	0.927	−0.238	0.536	0.726	0.031
M medium	71	0.983	0.407	0.316	0.899	0.002

MNE: minimum number of elements; %MAU: percentage of minimal animal unit; SFUI: standard food utility index; UMI: Unsaturated Marrow Index.
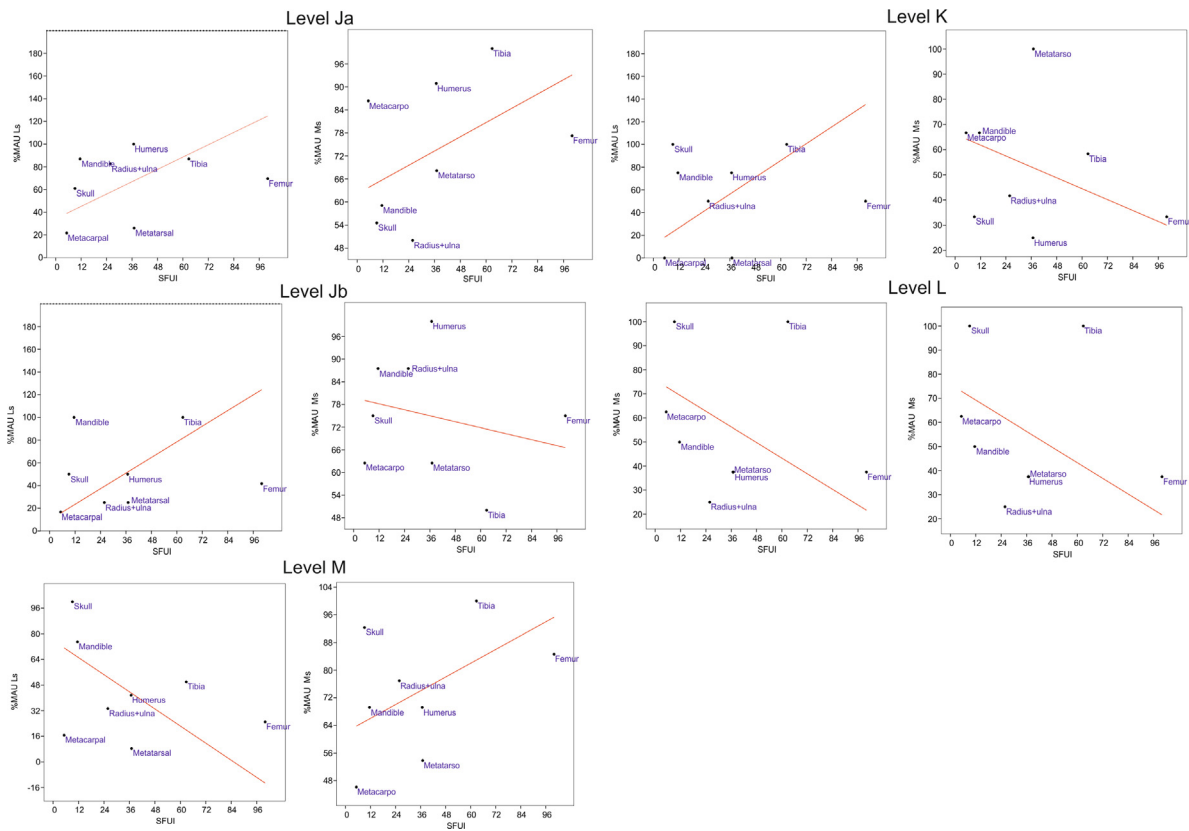
Fig. 3. Linear correlation of percentage of minimal animal unit (%MAU)–standard food utility index (SFUI) for large and medium size in each level.
Fig. 3. Corrélation linéaire de %MAU–SFUI pour la taille grande et moyenne dans chaque couche archéologique. MAU : unité animale minimum ; SFUI : index d'utilité standard de nourriture.

P(same) = 0.518] supports the differing distribution of these two size-weight groups.

An MNE of 42 was found for the high-survival elements of the large animals. No statistically significant correlation was observed between the %MAU and SFUI (Fig. 3); Spearman's r_s of 0.455 is within the range (95% CI) of the bulk and unconstrained strategies obtained by Faith and Gordon (2007) (Table 6). The evenness value of 0.907 falls within the values described for bulk and unbiased strategies (Table 6). As was the case with the elements of the large size-weight assemblage in level Ja, there is a potential type II statistical error for the correlation between the %MAU and SFUI. As indicated by Faith and Gordon (2007), this error type is more common with lower MNE.

The high-survival elements of the medium-sized animal remains have an MNE of 45. No statistically significant correlation was found between the %MAU and SFUI (Fig. 3); Spearman's r_s (−0.169) falls within the range (95% CI) of an unconstrained strategy for an assemblage close to 50 MNE (Table 6). The evenness value of 0.980 is within unconstrained and bulk strategy values.

We found statistically significant correlations between the %MAU and UMI for large animals [Large size: Spearman's r_s = 0.854; P(same) = 0.006] and a not statistically significant correlations for medium animals [Medium size: Spearman's r_s = 0.548; P(same) = 0.13] (Table 6).

4.3. Level K

The most abundant remains in terms of NISP and MNE belong to the medium-sized animal category (Table 3). The %MAU indicates a difference in the distribution among the size groups (Fig. 2). Among the large animals, the most abundant elements are of the bones of the skull and the long bones, especially the tibiae. However, in the set of medium-sized animals, although the mandibles and tibiae are abundant, the metatarsals are the most common elements. The test between bone mineral density and %MAU are not statistically significant [Large size: Spearman's r_s = 0.227; P(same) = 0.415] [Medium size: Spearman's r_s = 0.335; P(same) = 0.193], this indicates that a relation between the conservation and the mineral density cannot be proven (Fernández-Laso et al., 2011). The Chi² test [Chi² = 16.996; degrees of freedom = 11; P(same) = 0.10796] showed that the anatomical distribution of the two size-weight groups is not the same. The MNE of the large animal set is 16. There is no statistically significant correlation between the %MAU and SFUI (Fig. 3). Both Spearman's r_s (0.048) and the evenness value (0.978) placed this group within the ranges (95% CI) of bulk and unconstrained transport strategies (Table 6).

The medium-sized animal assemblage has an MNE of 49. There is no statistically significant correlation between the

%MAU and SFUI (Fig. 3). Spearman's r_s (−0.168) suggests that this set is the result of an unconstrained strategy and the evenness value (0.939) indicates that it is the product of unconstrained or bulk transport strategies (Table 6).

We found no statistically significant correlations between the %MAU and UMI for large animals [Large size: Spearman's r_s = 0.579; P(same) = 0.114] and a high statistically significant correlation for medium animals [Medium size: Spearman's r_s = 0.753; P(same) = 0.023] (Table 6).

4.4. Level L

As in most of the levels, medium-sized animal remains outnumber the remains of large animals (Table 3). According to the %MAU, in both size-weight categories, the most abundant elements are the skulls, while the scarcest elements in the assemblage are vertebrae and ribs (Fig. 2). The appendicular elements, especially the tibiae, are more numerous among the medium-sized animals than among the large animals. The Chi^2 test [Chi^2 = 7.248; degrees freedom = 11; P(same) = 0.778] reveals that there is not similarity in the anatomical representation between medium-sized and large animals. The test between bone mineral density and %MAU are not statistically significant [Large size: Spearman's r_s = 0.04; P(same) = 0.886] [Medium size: Spearman's r_s = 0.297; P(same) = 0.281]; this indicates that a relation between the conservation and the mineral density cannot be proven (Fernández-Laso et al., 2011).

The MNE of the large animals is 12. There is no statistically significant correlation between the %MAU and SFUI (Fig. 3). Spearman's r_s (−0.368) places this group as the result of an unconstrained transport strategy and the evenness value (0.957) puts it within the range (95% CI) of values of the bulk and unconstrained transport strategies (Table 6).

The medium-sized animal set has an MNE of 32. A statistically significant correlation was found between the %MAU and SFUI (Fig. 3). As for the large size-weight group, the Spearman's r_s (0.306) indicates an unconstrained strategy and the evenness value (0.959) suggests a bulk or unconstrained transport strategy (Table 6).

We found no statistically significant correlations between the %MAU and UMI for large animals [Large size: Spearman's r_s = 0.569; P(same) = 0.130] and a high statistically significant correlation for medium animals [Medium size: Spearman's r_s = 0.762; P(same) = 0.024] (Table 6).

4.5. Level M

The anatomical distribution (NISP and MNE) (Supplementary material) shows a predominance of medium-sized animal remains (Table 3). According to the MNE, skulls are the most abundant and the elements of the postcranial axial skeleton are the scarcest in both weight groups. However, the two groups differ in the distribution of the long limb bones because, although a similar trend is found in both groups, the long bones are scarcer (%MAU) in the large animal set (Fig. 2). The test between bone mineral density and %MAU are statistically significant [Large size: Spearman's r_s = 0.436; P(same) = 0.0024] [Medium size:

Spearman's r_s = 0.426; P(same) = 0.003], this indicate a relation between the conservation of bone portions and their mineral density.

The Chi^2 test [Chi^2 = 8.485; degrees of freedom = 11; P(same) = 0.669] supports the difference in distribution in the skeletal profiles of large versus medium-sized animals.

An MNE of 36 was found for the large animals in this level. There is no statistically significant correlation between the %MAU and SFUI (Fig. 3). Spearman's r_s (−0.238) is within the range (95% CI) of an unconstrained transport strategy according to the proposals of Faith and Gordon (2007). The evenness value of 0.927 is within the range of bulk and unconstrained transport strategies (Table 6).

The medium-sized animals have an MNE of 71. There is no statistically significant correlation between the %MAU and SFUI (Fig. 3). Spearman's r_s of 0.407 falls within the range (95% CI) of bulk and unconstrained transport strategies, and the evenness value (0.983), in turn, suggests an unconstrained type strategy (Table 6).

We found statistically significant correlations between the %MAU and UMI for large and medium animals [Large size: Spearman's r_s = 0.726; P(same) = 0.0316] [Medium size: Spearman's r_s = 0.899; P(same) = 0.002] (Table 6).

4.6. Hadza assemblages

In order to compare the transport models of Abric Romaní levels Ja, K, L and M, we examined correlations between the %MAU and SFUI and applied the evenness metric to the faunal assemblages recovered during the excavation of the Tispitibe and Mugugu Hadza camps (Lupo, 2001). In these assemblages the species identified by Lupo (2001) were Impala, Zebra and Alcelaphine. In order to have a sufficiently large sample with which to compare with the results of Faith and Gordon (2007) and ours, we combined the MNE of these three species. The results of these analyses of the faunal assemblages (Table 7) indicate that the assemblages at both camps are the product of an unconstrained transport strategy.

5. Discussion

According to the values of the correlation between the presence/absence of elements and their economic value given by Faith and Gordon (2007), two groups can be distinguished in the levels examined in this paper:

- a group composed of sets where r_s is within the range of 95% CI values obtained by Faith and Gordon (2007) for an unconstrained strategy. This group contains the assemblages of faunal remains from large animals from levels L and M (Fig. 4), and the remains the medium-sized animals of levels Jb, K, L (Fig. 4);
- a group in which r_s falls within the range of 95% CI values for bulk and unconstrained transport strategies. This group includes the large animals of levels Ja, Jb, K and the medium-sized animals of levels Ja and M (Fig. 4).

On the other hand, the evenness value for all of the sets of remains reveals a different distribution, clearly

Table 7

Minimum number of elements (MNE), Evenness, Spearman's rank-order correlation, and transport strategy interpretation for Hadza campsite of Tispitibe and Mugugu, from Lupo (2001).

Tableau 7

Nombre minimum d'éléments (MNE), *Evenness*, corrélation de Spearman, et interprétation de la stratégie de transport à partir des études des campements Hadza de Tispitibe et Mugugu, de Lupo (2001).

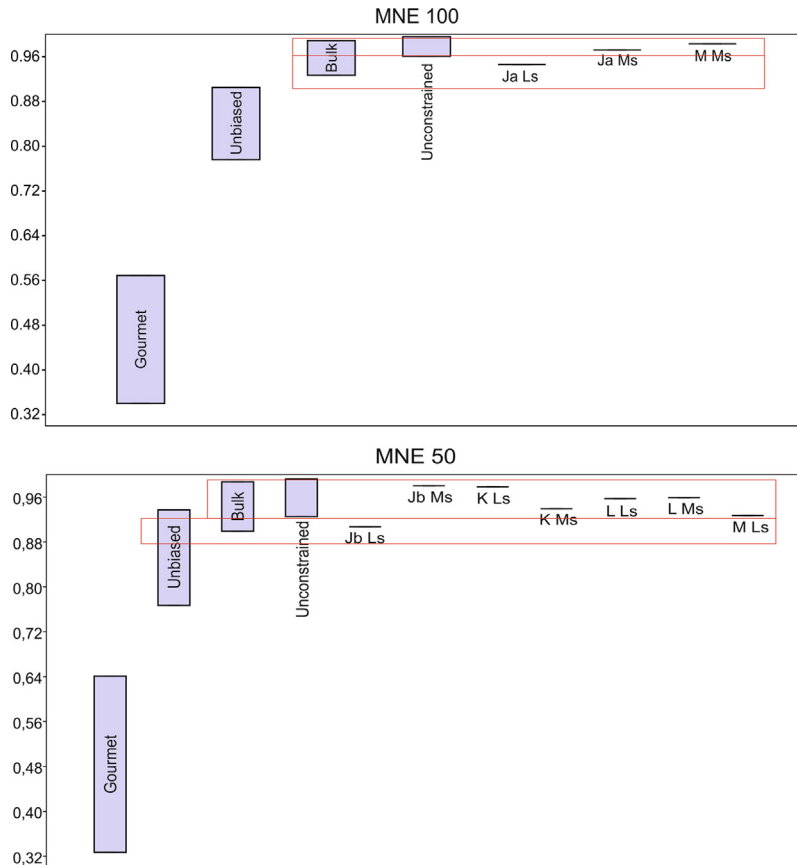|	MNE	Evenness	Correlation		Strategy
			r_s	P	
Tispitibe	40	0.966	−0.163	0.707	Unconstrained
Mugugu	36	0.940	−0.390	0.344	Unconstrained

Fig. 4. Distribution of the Spearman's correlation values between percentage of minimal animal unit (%MAU)–standard food utility index (SFUI) for animals of levels Ja, Jb, K, L and M in relation to the values of 95% CI for the different transport strategies for a sample size of MNE 100 and MNE 50 (Faith and Gordon, 2007). Ls: Large size; Ms: Medium-sized.

Fig. 4. Répartition des valeurs de corrélation de Spearman entre %MAU-SFUI pour les animaux des couches Ja, Jb, K, L et M en relation avec les valeurs de IC95 % afin de distinguer les différentes stratégies de transport pour un échantillon de MNE 100 et MNE 50 (Faith et Gordon, 2007). Ls : taille grande ; Ms : taille moyenne.

corresponding to two transport strategies: the bulk strategy for the large animals of level Ja and the unconstrained strategy for the medium-sized animals of level M (Fig. 5). For the large animals of level Jb, the evenness value is within the values of the bulk and unbiased strategies (Fig. 5). For the large animals of levels K, L and M (Fig. 5) and the medium-sized animals of levels Ja, Jb, K and L (Fig. 5), the evenness values fall within the range of 95% CI values for the bulk and unconstrained strategies.

Based on these results, there are two possible statistical type II errors (in which a statistically significant correlation between the %MAU-SFUI was not observed although the set was formed attending to the maximization of the utility elements transported): in the data for the large animals of levels Ja and Jb. In these cases, due to the size of the MNE, there might not have been a statistically significant correlation between the %MAU and SFUI because the evenness value indicates a bulk strategy for large animals in level Ja and a bulk and unbiased strategy for large animals in level Jb.

Faith and Gordon (2007) indicate that when MNE size decreases, especially for small assemblages (MNE 50), the evenness value of the bulk and unconstrained strategies overlaps. Therefore, at levels where there are no identified
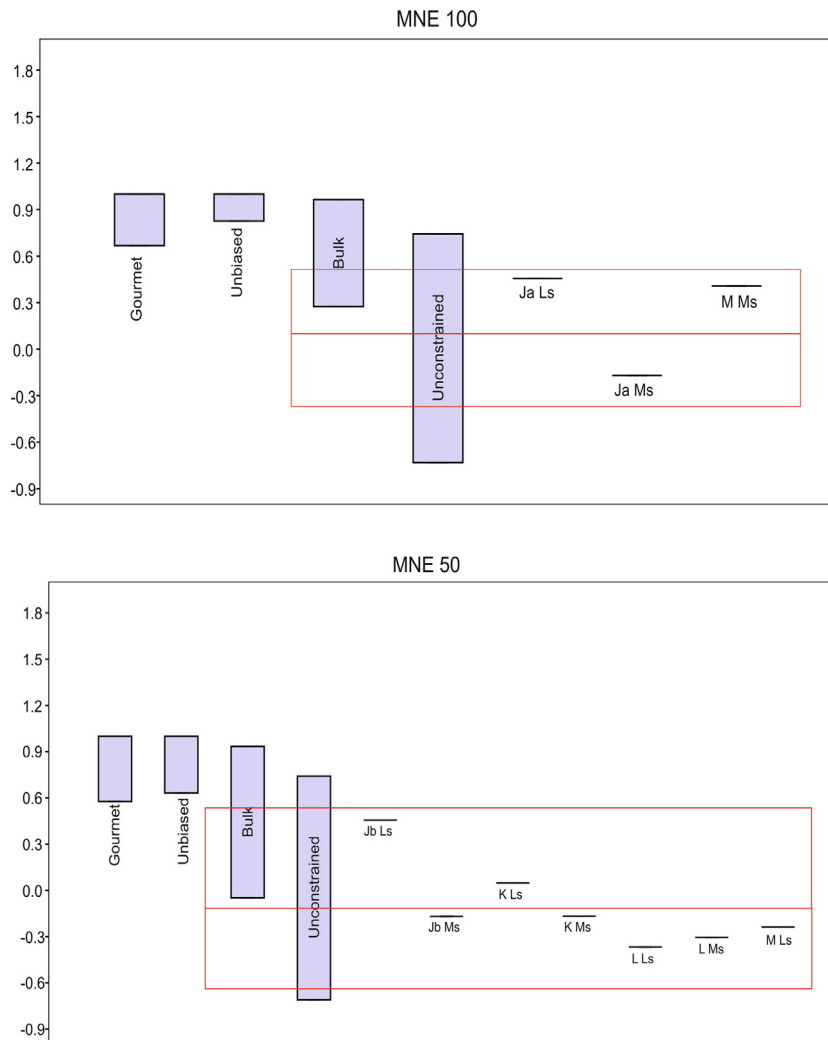
Fig. 5. Distribution of the evenness values for the large animals of levels Ja, Jb, K, L and M in relation to the values of 95% CI for the different transport strategies for a sample size of minimum number of elements (MNE) 100 and MNE 50 (Faith and Gordon, 2007). Ls: Large size; Ms: Medium-sized.
Fig. 5. Répartition des valeurs de l'*Evenness* pour les grands animaux des niveaux Ja, Jb, K, L et M par rapport aux valeurs de IC95 % des différentes stratégies de transport pour des tailles d'échantillonnage de MNE 100 et MNE 50 (Faith et Gordon, 2007). Ls : taille grande ; Ms : taille moyenne.

type II errors, the lack of a significant correlation between the %MAU and SFUI suggests an unconstrained transport strategy. According to these data, the predominant strategy among the Abric Romaní levels analysed here for medium-sized and large animals would be unconstrained. This would suggest that the body parts of the prey were transported from the kill/butchering site to the campsite according to their abundance in a complete skeleton (Faith and Gordon, 2007). In other words, these results suggest the transport of complete carcasses to the shelter, regardless of the size of the animal, meaning similar transport patterns were employed for deer, horses and aurochs. However, comparisons (Chi² test) between the skeletal profiles of the large and medium-sized animals indicate that there are not similarities in the anatomical distributions in all of the levels studied, which points to a possible differential treatment of carcasses based on animal weight.

The analysis between bone mineral density and %MAU indicate two results. On levels Ja, Jb, K and L has not been observed differential conservation based on the mineral content of bones (Lam et al., 1999; Lyman, 1994). In contrast, in level M, we found a high statistically significant correlation between bone mineral density by portions and the %MAU of high-survival elements for large and medium size. This indicates that parts of bones with low mineral density are suffering a taphonomic process that is creating an underrepresentation of these anatomical parts. Taken into account the low alterations by carnivores and the high presence of anthropic activities, among which stand cremation and fire used (Costamagno and Rigaud, 2014; Gabucio et al., 2013, 2014; Vallverdú et al., 2012), this underrepresentation could be a combination between hominin activities.

In previous studies of these levels, some authors suggested the existence of the differential transport of

animals based on size-weight (Chacón et al., 2007, 2010; Fernández-Laso et al., 2010; Rosell et al., 2012a, 2012b). It was argued that large animals (horses and aurochs) would have been processed at the kill/butchering site with the intention of facilitating their transport to the shelter, while body parts, which were energetically not worth carrying were left behind due to their low economic value. In contrast, medium-sized animals (deer) would have been transported intact and completely exploited at the campsite (Carbonell, 2002, 2012; Chacón and Fernández-Laso, 2007; Fernández-Laso et al., 2010, 2011; Rosell, 2001; Rosell et al., 2012a, 2012b; Vallverdú et al., 2005). According to these studies, differential transport decisions were linked to the animal's weight, which is not contrary to our results. However, it was argued that this pattern is visible through a greater or lesser presence of the postcranial axial skeleton. But, having evaluated the anatomical distribution (%MAU) in the size-weight categories of the different levels (Fig. 2), it became clear that the differences proposed due to the presence of the postcranial axial skeleton are not supported. The size-weight categories of all of the levels exhibit a very similar concentration of vertebrae and ribs. In levels K, L and M, the presence of these bones for large and medium-sized animals is virtually identical. In levels Ja and Jb, although there are more vertebrae and ribs among the medium-sized animals, their presence is still scarce and they never exceed 10% of the MAU.

Valensi and Psathi (2004) note that in the Middle Palaeolithic levels of the sites of Lazaret (France), Arma delle Maine (Italy), Madonna dell'Arma (Italy), Caverna delle Fate (Italy), St. Lucia Superiore (Italy) and San Francesco (Italy) the pattern of anatomical distribution is characterized by the abundance of cranial and appendicular elements and by the scarcity of the postcranial axial skeleton, regardless of the size-weight of the animals. They indicate that this pattern suggests a primary access and a transport of complete or nearly complete carcasses into the sites (Valensi and Psathi, 2004). The same anatomical distribution was observed by Moncel et al. (2004) for medium-sized animals at the Grotte de Saint-Marcel. They said that the absence of part of the axial elements, like ribs, could be the result of a differential transport. However, the absence of the epiphyses of long bones also indicates that these under-representations could be result of an intensive treatment of these anatomical parts by boiling or use as fuel. Moncel et al. (2004) hypothesize that the assemblage is the result of differential transport of certain anatomical parts, but the presence, even in very small quantities, of all parts of the skeleton shows that some hunted animals were carried complete to the cave. On the other hand, Romandini et al. (2014) indicate that Grotta di Fumane was used as a habitat where the processing of carcasses was finalized after having been begun at the kill site. They infer that human groups transported to the site selected anatomical parts with high nutritional value. Gaudzinski and Niven (2009) evaluate the open-air site of Salzgitter-Lebenstedt (Germany) specializing in the hunt of *Rangifer tarandus*. It was found that the axial skeleton is always underrepresented in this assemblage, and never exceeds 20% of the MAU. Gaudzinski and Niven (2009) define the presence of long bones as result of economic decisions made by hominins.

Given this distribution, just as we observed in our study of the faunal remains of levels J, K, L and M at Abric Romaní, it seems that the trunk would be the most commonly scarce segment in all cases of transport. However, the absence of vertebrae and ribs, together with other low-survival elements may be due in part to multiple attritional processes (Lyman, 1994; Marean and Spencer, 1991), crushing of axial bones in order to collect the fat with boiling practices, and even intentional cremation during maintenance work on hearths or the cleaning of the living floor (Costamagno and Rigaud, 2014; Gabucio et al., 2014; Thery-Parisot and Costamagno, 2005; Vallverdú et al., 2005; Vallverdú et al., 2012). On the other hand, the absence of bones of the trunk is not universal in these assemblages, so their presence, although scarce, indicates that at some point some carcasses arrived the shelter intact, as for example Saladié et al. (2011) indicate for level TD-6 of Gran Dolina, Domínguez-Rodrigo et al. (2009) for FLK-*Zinjanthropus* 22 site or Moncel et al. (2004) for the Mousterian site of Grotte de Saint-Marcel. Therefore, the sum of attrition generated by Neanderthals and other postdepositional processes has resulted in a high degree of uniformity in the skeletal profiles of the Abric Romaní levels, characterized by the scarcity of the axial skeleton as in many Neanderthal' sites, for example Grotte de Saint-Marcel (Moncel et al., 2004) or Lazaret (Valensi and Psathi, 2004).

In keeping with these proposals, the distribution of high-survival bones has to be studied to determine whether the carcasses were carried to the shelter complete, as suggested by the combination of non-correlations of %MAU and SFUI and the evenness values, relying on the proposals of Faith and Gordon (2007), or if the carcasses of animals of different weight groups were subjected to different transport strategies, as indicated by the comparison of their anatomical distribution using the Chi^2 test. Thus, considering the different frequencies of the %MAU, it becomes clear that the primary differences among the size-weight categories lie in the abundance of the appendicular bones. For example, in levels Jb, L, K and M, although the frequency of large and medium-sized animal skulls is similar, there are fewer long bones of large animals than of medium-sized animals (Fig. 2) (Supplementary material). This would support the hypothesis of reduced transport of the long bones of large animals from the kill/butchering site to the campsite in these levels. In level Ja, there seem to be fewer differences in this regard, particularly in terms of the frequency of the proximal appendicular bones (femora and humeri) and intermediate appendicular bones (radii-ulnae and tibiae). However, the representation of metapodials does seem to have a relationship to size-weight, as those from medium-sized animals are much more abundant than those from large animals, especially in level K (Fig. 2) (Supplementary material).

Based on these observations, it seems that the anatomical representation of the animals documented in Abric Romaní may be related to the sum of different carcass transport patterns, with animal size being one of the determining factors. Some researchers, such as Monahan (1998) and Lupo (2001), have argued that the superposition of different transport strategies makes them less visible and more difficult to relate to concrete

transportation/abandonment decisions. In fact, Lupo (2001) suggests that transport/abandonment decisions are more accurately reflected at a single-event kill/butchering site than in camps where overlapping masks possible differences between one event and another.

It seems that the same superposition would characterize the skeletal profiles of the most abundant animals at Abric Romaní: deer, horses and aurochs. However, the remains of a rhino in level M (one femur diaphysis) may reflect the transport of only a few bones of a carcass.

This variability of different transport models used by Neanderthals is also observed in some hunter-gatherer groups (Binford, 1978, 1981; Bunn, 1993; Bunn and Kroll, 1986, 1988; Bunn et al., 1988; Monahan, 1998; Schoville and Otárola-Castillo, 2014). Therefore, different specific conditions may affect each hunting event differently. The studies conducted by Gifford-Gonzalez (1993) and Monahan (1998) indicate that some of the variables that affect the transport decisions of these groups are the weight of the animals, the number of people involved in the hunt, the number of carriers and the possibility of calling more people to help, the number of hunted animals, the anatomy of the animal itself, the cost of processing and transporting a carcass, competition with other carnivores in the environment, and the distance to the camp. Ethnographic studies of the Hadza indicate that there are even more variables in play, such as the hunger of the hunters and the toolkit they are carrying (Bunn et al., 1988, 1991; Bunn, 1993; Monahan, 1998; O'Connell, 1993; O'Connell et al., 1988a, 1988b, 1990; Oliver, 1993). More recently, Schoville and Otárola-Castillo (2014) asserted that, for the Hadza, the most important factors in deciding which body parts are transported are the number of carriers, the size of the animal and the distance from the camp.

Based on this information, we know that the Hadza use a variety of different transport strategies for all animal size-weights (Bunn, 1993; Bunn et al., 1988, 1991; Lupo, 2001; Monahan, 1998; O'Connell, 1993; O'Connell et al., 1988a, 1988b, 1990). This behaviour results in bone accumulations created by multiple transport events (Lupo, 2001). Hadza in these two camps (Lupo, 2001) and in general (Bunn, 1993; Bunn et al., 1988, 1991; Monahan, 1998; O'Connell, 1993; O'Connell et al., 1988a, 1988b, 1990) employed highly variable transport strategies for the animal carcasses brought back to camp, including the transport of complete carcasses or only a few elements. The result of the analyses of Mugugu and Tispitibe camps indicates an unconstrained transport strategy (Table 7). For this reason, the Hadza can be used to determine how a highly variable animal carcass transport pattern is reflected in the faunal record like a palimpsest result of an unconstrained transport strategy (Table 7).

The presence of most of the parts of the skeleton in all of the analysed sets suggests that the trunks, particularly of medium-sized and large animals, were wholly or partially transported to the shelter at some time. This may be consistent with the transport of complete carcasses and therefore with an unconstrained transport strategy. The result of the analyses between the %MAU and UMI, indicates that there exists a correlation between the transport of bones and their riches in marrow and grease (Morin, 2007), except for the large size of level K and L and medium size of level

Jb, which may be due to a small size of the sample. On the assemblages with high significant statistical correlations could be supported the hypotheses of a preferential transport of bones in function of the marrow riches, that is, long bones. At the same time, differences in the anatomical representation indicate that this model was not the only one used, or not necessarily the most common one used, since the skeletal profiles analysed are different by size-weights.

Carnivory and meat-sharing are central features of current hunter-gatherers, so these behaviours are critical in the evolution of hominin social relations (Stiner, 2009). The stable isotope analyses of the Neanderthal remains of Vindija, Jonzac and Marillac, among others (Fizet et al., 1995; Richards et al., 2000), together with a great number of zooarchaeological researches (Daujeard and Moncel, 2010; Gaudzinski and Niven, 2009; Moncel et al., 2004; Patou-Mathis, 2000; Rendu, 2010; Rendu et al., 2012; Romandini et al., 2014), indicate that Neanderthals' primary food source consisted of large herbivores (Bocherens, 2011; Bocherens et al., 1999; Richards et al., 2000, 2008). According to Hayden (1981), cooperation in hunting and meat-sharing is closely related to the importance of this resource to a particular group. As shown by Stiner (2009) for Qesem cave, Middle Palaeolithic hominins delayed the consumption of their prey long enough to transport the animal carcasses back to camp.

Back at home base, the Neanderthal group must have shared. It is assumed that this circumstance would have been the same in levels Ja, Jb, K, L and M of Abric Romaní. The transport of numerous animal parts necessarily entailed cooperation between different individuals. The number of carriers was possibly variable, and this conditioned the transport strategies chosen. However, although many other factors could have played a key role in these decisions, they unfortunately do not have archaeological visibility.

6. Conclusions

The Neanderthal groups who occupied Abric Romaní during the formation of levels Ja, Jb, K, L and M developed variable transport strategies for medium-sized and large animals. The end could result in transport processes is a mixed skeletal profile, in which some of these strategies have low archaeological visibility. However, certain guidelines can be established. It seems that the postcranial axial skeleton was transported only in a few events and once inside the Abric Romaí was highly sensitive to destruction by taphonomic processes, among those are the produced by the Neanderthals. However, the decision to transport or discard at the kill/butchering site would not have been made in relation to the size-weight difference between large and medium-sized animals. The long bones and the skull bones were commonly transported, but in this case, there are differences in the distribution linked to the size-weight category, so the size of the animal itself would have been a factor of these different anatomical profiles. Therefore, evidence of an unconstrained strategy is possibly an artefact caused by the combination of different types of transport, such as in the levels of Abric Romaní. One of these transport types is the transport of the bones

richest in marrow and grease, as the high statistical correlations of MAU and UMI indicate. These conclusions can be extrapolated to other Middle Palaeolithic assemblages with similar skeletal profiles, in which human activity is the main cause of accumulation and subsequent attritional processes, are scarce. It would be desirable to extend this study with larger samples in order to test our conclusions.

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Appendix A. Supplementary material

Supplementary material associated with this article can be found in the online version available at http://dx.doi.org/10.1016/j.crpv.2015.11.006.

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