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The influence of raw material qualities in the lithic technology of Gran Dolina (Units TD6 and TD10) and Galería (Sierra de Atapuerca, Burgos, Spain): A view from experimental archeology

L'influence des qualités des matières premières dans l'industrie lithique de Gran Dolina (couches TD6 et TD10) et Galería (Sierra de Atapuerca, Burgos, Espagne) : une étude d'archéologie expérimentale

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ABSTRACT

This paper analyses the qualities of the raw materials used in two Palaeolithic sites (Gran Dolina and Galería) of the Sierra de Atapuerca (Burgos, Spain) during the Lower and Middle Pleistocene, and their influence in the development of knapping. These sites offer a chronological sequence that allows us to study the evolution of lithic technology at a local scale during 1.2 Ma. Combining technological analysis and experimental archaeology has proven to be an excellent tool for the understanding and the interpretation of the qualities of raw materials and their relation with the development of the gestures, methods and techniques.

RÉSUMÉ

Cet article analyse les qualités des matières premières employées dans deux gisements (Gran Dolina et Galería) de la Sierra de Atapuerca (Burgos, Espagne) pendant le Pléistocène inférieur et moyen, et son influence sur le processus de la taille. Ces sites archéologiques ont une séquence chronologique qui nous permet d'étudier l'évolution de la technologie lithique à une échelle locale pendant 1,2 Ma. La combinaison d'analyses techniques des

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assemblages lithiques avec l'archéologie expérimentale constitue une excellente méthode d'étude pour comprendre et pour interpréter les qualités des matières premières et leur relation avec le développement des gestes, méthodes et techniques.

1. Introduction

The Sierra de Atapuerca sites, located 15 km east of the city of Burgos (Spain) (Fig. 1), cover a time spanning between about 1.22 Ma to 0.01 Ma. This chronological sequence allows us to study different cultural horizons belonging to the Pleistocene and Holocene. The hominins that occupied this environment during the Early and Middle Pleistocene developed technological strategies that can be ascribed to Mode 1, Mode 2, the transition between Modes 2 and 3, and Mode 3 (Ollé et al., 2013; Terradillos-Bernal and Díez-Fernández-Lomana, 2012) (Table 1).

One of the reasons for a human presence throughout this long chronological period is the existence in this environment of a wide variety and a large number of lithic raw materials (mainly Neogene chert).

An extensive range of analyses have been conducted on the lithic artefacts recovered from the Sierra de Atapuerca (Carbonell et al., 1999, 2001; López-Ortega et al., 2011; Ollé et al., 2013; Rodríguez, 2004; Terradillos-Bernal and Rodríguez, 2012). We have complemented these analyses with the development of a complex program of experimental knapping that analyses the influence of the qualities of the raw materials in the technological behaviour.

In this paper we study the Gran Dolina (Units TD6 and TD10) and Galería assemblages, dating to the Early (TD6) and Middle Pleistocene (TD10, and Galería), from this perspective (Table 1, Fig. 1).

The development of complex programs of experimental knapping has been successful for the analyses of different variables such as: raw materials, techniques, knappers, and technological modes (Baena and Cuartero, 2006; Brenet, 2013; Perles, 1991; Terradillos-Bernal and Alonso-Alcalde, 2011, *inter alia*).

2. Objectives

The analyses of raw material of these levels have specific aims, which must be met through the development of the experimental program. The aim of this paper is to answer questions such as:

- Among a large range of raw materials in this environment, which are the basic characteristics of the raw materials used?
- How did they influence in the different processes of knapping?
- What were the bases of the selection of each raw material?
- Is it possible to observe a selection and/or a differential use of raw materials depending on the technological mode that was developed, the functionality of the site, or the methods of knapping used?
- What are the advantages of using chert over other raw materials?
- Was there a cultural tradition related to the use of Cretaceous chert?
- Why was Cretaceous chert mainly selected to produce flake instruments?
- What are the advantages of using this raw material?

3. Materials

3.1. Gran Dolina

Gran Dolina is a cave filled with 18 m of sediment in which 11 lithostratigraphical units have been identified (TD1 to TD11, from bottom to top).

3.1.1. Gran Dolina TD6

Unit TD6 (Table 1) has a maximum thickness of 2.40 m and is constituted essentially of calcareous conglomerates, pebbles and limestone gravel within a matrix composed of sand and clay (Pérez-González et al., 2001). TD6 lies 1 m below the Matuyama–Brunhes limit (located at the top of layer TD7) (Parés and Pérez-González, 1999), and has been dated by a combination of ESR and palaeomagnetic techniques to between 780 and 857 ka (Falguères et al., 1999), and by thermoluminescence to > 960 ± 120 ka (Berger et al., 2008). A new palaeomagnetic study indicates a minimum age of 936 ka for the archaeo-paleontological record of TD6 (Parés et al., 2013). TD6 stands out for the presence of human remains classified as *Homo antecessor* (Carbonell et al., 1995) with evidence of cannibalism (Carbonell et al., 2010; Fernández-Jalvo et al., 1996).

This study involved analysis of a sample of 570 pieces from sublevels TD6-1 and 2 (excavations carried out between 1994 and 1996 and between 2003 and 2006). To date the total number of pieces recovered at TD6 is 999 (Table 3). The lithic industry of TD6 has been classified as Mode 1, though it displays certain features which point to developments at the oldest Early Pleistocene sites in southern Europe, such as raw material management (particularly the preferential use of Cretaceous chert for instruments made with flakes) and the use of varied, more complex knapping strategies (Carbonell and Rodríguez, 2006; Carbonell et al., 1999; Ollé et al., 2013).

Raw material management is characterised by the use of mostly Neogene chert. The secondary raw materials at the site are Cretaceous chert, limestone, quartzite, quartz and sandstone. All these raw materials are local and appear within a maximum distance of five kilometres (Fig. 2, Table 2).

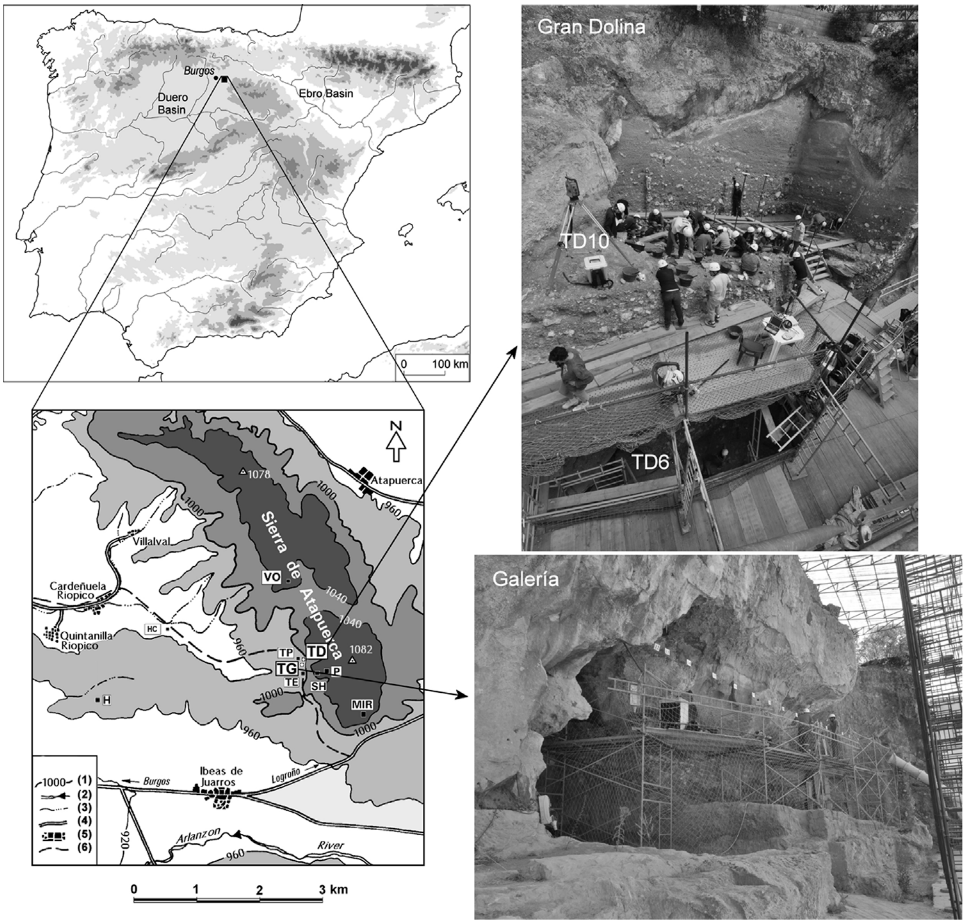

Fig. 1. Location of the studied sites.

Fig. 1. Localisation des gisements étudiés.

Instruments made from pebbles (0.1%) are scarce, while those made from medium-sized thick flakes are more plentiful. A high percentage of hammerstones and manuports (12.5%) have been recovered. The knapping strategies documented in Unit TD6 are characterised by the use of orthogonal angles. This orthogonal knapping could have been conditioned by the morphology of the Palaeozoic materials (quartzite and sandstone) that are on the Arlanzón T4 terrace, which is the nearest to Gran Dolina (Fig. 3-1). A unique feature in TD6 is the presence of large Neogene chert cores (up to 26 cm in length) with a lack of intensive reduction (Fig. 3-6). The hominins of TD6 produced 23.4 flakes per kilogram from chert and an average of 18 flakes from other materials. Among the retouched flakes there is a significant presence of denticulates, convex dihedrals (scrapers), and concave dihedrals (notches).

3.1.2. *Gran Dolina TD10*

Unit TD10 (Table 1) is divided into four lithostratigraphic subunits (TD10.4 to TD10.1, from bottom to the top), with a maximum thickness of 2.50 m. At the time when TD10 was formed the entrance to the cave was in the form of a large rock shelter caused by the collapse of the roof. ESR combined with uranium-series dating give ages of 337 ± 29 ka for the upper part of TD10-1; 379 ± 57 ka at the bottom of TD10-1 and 418 ± 63 ka in the upper part of TD10-2 (Falguères et al., 1999). Thermoluminescence dating has given ages of between 244 ± 26 ka for TD10-2 and 430 ± 59 ka for TD10-3 (Berger et al., 2008).

For this study we analysed a sample of the lithic repertoires of TD10-1 (914 pieces) and TD10-2 (1853 pieces). Up to now a total of 31,680 artefacts have been found in TD10-1 and TD10-2, although 9366 were indeterminable due to preservation problems (Table 3). The lithic industry of the upper levels of TD10 (TD10-1 and TD10-2) has been classified as transitional between Modes 2 and 3 (Ollé et al., 2013). This lithic industry is characterised by a rational, intensive management of the best-quality raw materials, and a tendency towards standardisation of small pieces. The most commonly used raw material is Neogene chert (Table 2). The use of chert increases in TD10-2, reaching as much as 95.7% of the total. TD10 produced 170 flakes per kilogram from chert and an average of 38 flakes from other materials.

In TD10, the *chaîne opératoire* is fragmented, because part of the knapping was done away from the site. Flake production processes are characterized by the low percentage of cores and their introduction to the site at

Table 1
Archaeological levels from Atapuerca sites studied in this work.
Tableau 1
Ensembles archéologiques des gisements d'Atapuerca étudiés dans ce travail.

Site/level	Karstic morphology	Dating (ka)		Studied sample	Technology
Gran Dolina TD10-1a	Rockshelter	337 ± 29 ESR/Series U (Falguères et al., 2001)		471	Transition Mode 2–Mode 3
Gran Dolina TD10-1b	Rockshelter	379 ± 57 ESR/Series U (Falguères et al., 2001)		481	Transition Mode 2–Mode 3
Gran Dolina TD10-2	Cave	244 ± 26 TL (Berger et al., 2008) 418 ± 63 ESR/Series U (Falguères et al., 2001)		1853	Transition Mode 2–Mode 3
Gran Dolina TD10-3	Cave	430 ± 59 TL (Berger et al., 2008)		–	Mode 2
Gran Dolina TD6	Cave	780–857 ESR/paleomagnetic (Falguères et al., 1999) > 936 paleomagnetic (Parés et al., 2013) > 960 ± 120 TL/IRSL (Berger et al., 2008)		570	Mode 1
Galeria GIII, series 1	Cave	256 ± 23 TL/IRSL (Berger et al., 2008)	200–300 ESR-US (Falguères et al., 2013)	151	Transition Mode 2–Mode 3
Galeria GIII, series 2	Cave	466 ± 39 TL (Berger et al., 2008)		152	Transition Mode 2–Mode 3
Galeria GII, series 3	Cave			229	Mode 2
Galeria GII, series 4	Cave	422 ± 55 TL (Berger et al., 2008)	350–450 ESR-US (Falguères et al., 2013)	203	Mode 2
Galeria GII, series 5	Cave	503 ± 95 TL (Berger et al., 2008)		285	Mode 2

TL: thermoluminescence; IRSL: infrared stimulated luminescence; U: uranium; ESR: electron spin resonance.

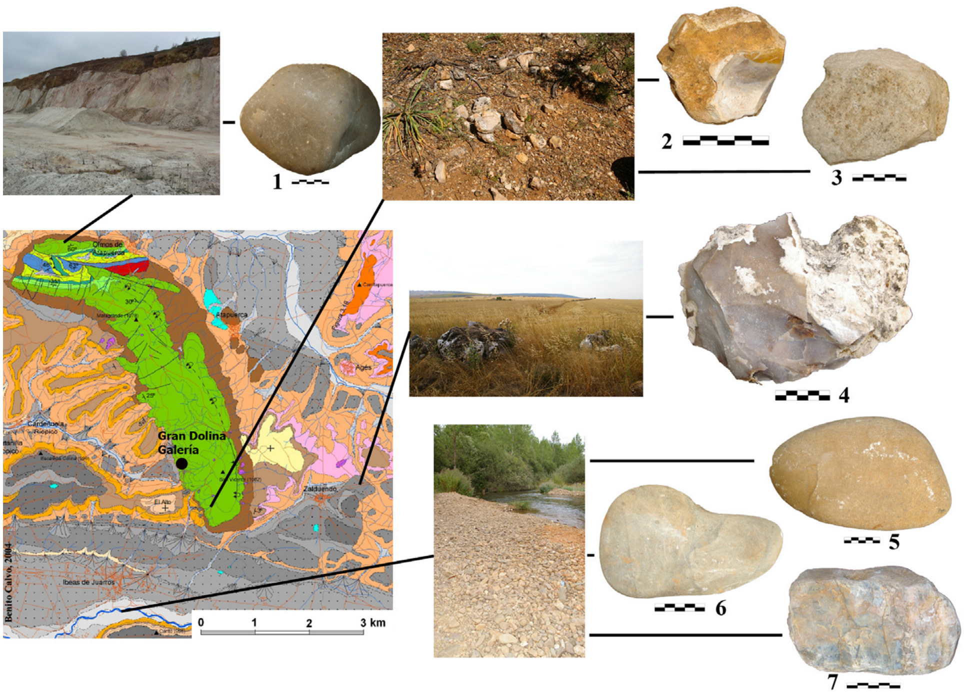

Fig. 2. (Colour online). Origin of the raw materials used in the experimental program. 1: Utrillas Quartzite; 2: Cretaceous chert; 3: limestone; 4: Neogene chert; 5: sandstone; 6: quartzite from the Arlanzón river; 7: quartz.
Fig. 2. (Couleur en ligne). Origine des matières premières employées dans le programme expérimental. 1 : Quartzite du faciès « Utrillas » ; 2 : silex crétacé ; 3 : calcaire ; 4 : silex néogène ; 5 : grès ; 6 : quartzite de la rivière Arlanzón ; 7 : quartz.

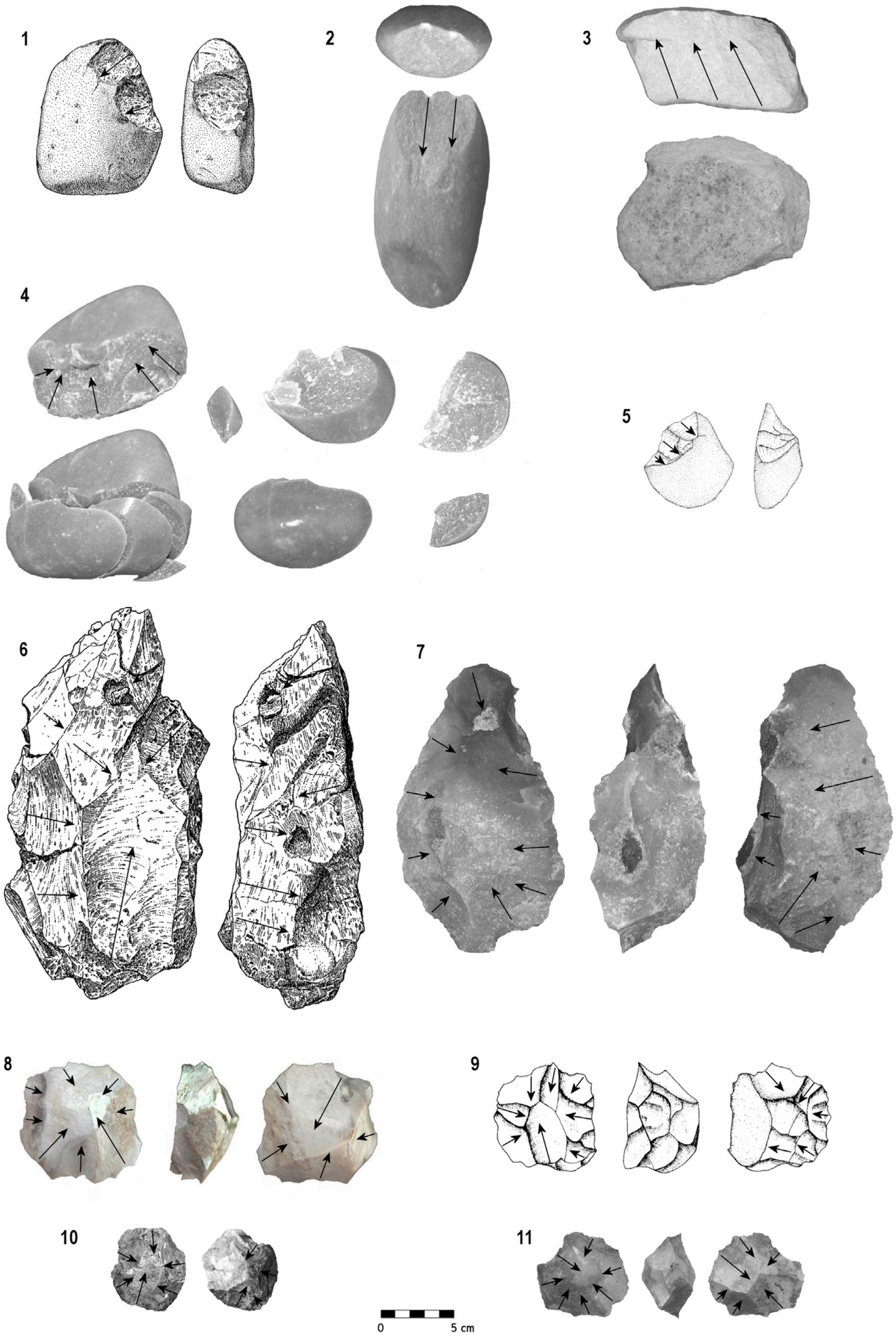

Fig. 3. Experimental and archaeological lithic industry from Atapuerca sites I. 1: Limestone pebble instrument from TD6; 2: experimental limestone pebble instrument; 3: experimental sandstone pebble instrument; 4: experimental Utrillas quartzite pebble instrument and flakes; 5: limestone pebble instrument form TD10; 6: core on Neogene chert from TD6; 7: experimental core made with Neogene chert; 8: experimental Levallois Neogene chert core; 9: Levallois Neogene chert core from TD10; 10: discoidal core from Galería (Cretaceous chert); 11: experimental discoidal core on Cretaceous chert.

Fig. 3. Industrie lithique expérimentale et archéologique des gisements d'Atapuerca I. 1 : Outil lithique sur galet en calcaire de TD6 ; 2 : outil lithique expérimental sur galet de calcaire ; 3 : outil lithique expérimental sur galet de grès ; 4 : outil lithique expérimental sur galet de quartzite d'Utrillas ; 5 : outil lithique sur galet de grès de TD10 ; 6 : nucléus de silex néogène de TD6 ; 7 : nucléus expérimental en silex néogène ; 8 : nucléus expérimental Levallois en silex néogène ; 9 : nucléus Levallois en silex néogène de TD10 ; 10 : nucléus discoïde en silex crétacé de Galería ; 11 : nucléus expérimental discoïde en silex crétacé.

Table 2
Raw materials of the lithic assemblages of Gran Dolina and Galería.
Tableau 2
Matières premières lithiques des ensembles archéologiques de Gran Dolina et Galería.

Levels	Neogene chert	Cretaceous chert	Indeterminable. chert	Quartzite	Sandstone	Quartz	Limestone	Other	Total
TD6	391 *(39.1%)*	98 *(9.8%)*	0	248 *(24.8%)*	90 *(9.0%)*	77 *(7.7%)*	95 *(9.5%)*	0	999
GII	647 *(64.0%)*	54 *(5.3%)*	0	172 *(17.0%)*	80 *(7.9%)*	18 *(1.8%)*	37 *(3.7%)*	3 *(0.3%)*	1011
GIII	450 *(56.5%)*	24 *(3.0%)*	0	180 *(22.6%)*	95 *(11.9%)*	15 *(1.9%)*	24 *(3.0%)*	9 *(1.1%)*	797
TD10-2	7457 *(76.1%)*	1671 *(17.1%)*	243 *(2.5%)*	176 *(1.8%)*	164 *(1.7%)*	51 *(0.5%)*	18 *(0.2%)*	16 *(0.2%)*	9796
TD10-1	11,206 *(51.2%)*	1453 *(6.6%)*	766 *(3.5%)*	3768 *(17.2%)*	3905 *(17.8%)*	708 *(3.2%)*	57 *(0.3%)*	21 *(0.1%)*	21,884

intermediate knapping phases. The Levallois and Discoid methods were developed almost exclusively on chert (Fig. 3-9). The Discoid knapping method stands out among other operative processes used at the site. The Levallois method has been documented but in small numbers and a variety of forms (Ollé et al., 2013; Terradillos-Bernal and Rodríguez, 2012).

Few instruments made from limestone, quartzite or sandstone pebbles have been recovered in TD10-1 and TD10-2, and all were made with low to medium quality materials (Fig. 3-5). Denticulated dihedrals and convex continuous dihedrals (scrapers) predominate (Fig. 4-8–10 and 12).

3.2. *Galería*

Galería is made of three different deposits: the Tres Simas Boca Norte (TN), Galería (TG) and Covacha de los Zarpazos (TZ). Archaeopalaeontological material has been recovered from two of the six lithostratigraphic units (GII and GIII), and five lithic series have been distinguished within these units (Table 1). This site functioned mainly as a natural trap due to the existence of a vertical shaft located in TN (Díez and Rosell, 1998). Datings have given an age of 256 ± 23 ka (TL and IRSL) for Unit GIIIb (lithic series I), 466 ± 39 ka (TL) for Unit GIIIa (lithic series II), and 503 ± 95 ka (TL) for Unit GIIa (lithic series V) (Berger et al., 2008). According to Falguères et al. (2013) the ESR ages of GIII and GIIb units (series I–III) range between 200 and 300 ka, whereas for GIIa (series IV and V) the ESR-US ages range between 350 and 450 ka.

This study involved analysis of a sample of 1011 pieces (total No. 1808) (Table 3). The lithic series of Galería have been assigned to Mode 2 (Ollé et al., 2013), although, two of the most modern series (I and II, from Unit GIII) may belong to a transitional phase between Modes 2 and 3 (Terradillos-Bernal and Díez-Fernández-Lomana, 2012). Neogene chert is the most widely used material, but in a much lower proportion than the documented in TD6 and TD10. Another difference among Galería, TD6 and TD10 is the high presence of hammerstones and manuports in Galería (27.2% of the determinable pieces in Unit GIII), primarily of quartzite. Quartzite and sandstone were introduced mainly as natural bases, shaped tools, and flakes.

Qualitatively, the Levallois and Discoid methods stand out. Both of them were developed on chert (Fig. 3-10). A considerable difference has been found in the proportion of flakes in the most ancient levels of Galería (54.5%) and the most recent (35.5%). Galería produced 37 flakes per kilogram from chert and an average of 9.6 flakes from other raw materials.

At this site, the larger, heavier flakes were selected, along with the best raw materials to make tools. Trihedrals, handaxes, and cleavers are rare (Fig. 4-1). Among smaller instruments, denticulated dihedrals and simple convex dihedrals (scrapers) predominate (Fig. 4-13).

Table 3
Technological categories of the lithic assemblages of Gran Dolina and Galería.
Tableau 3
Catégories technologiques des ensembles lithiques de Gran Dolina et Galería.

Levels	Hammerstones/ manuports	Pebble/block cores	Flake cores	Pebble tools	Flake tools	Whole flakes	Broken flakes	Fragments	Total determinable	Indeterminable	Total
TD6	93 *(12.5%)*	52 *(7.0%)*	5 *(0.7%)*	1 *(0.1%)*	61 *(8.2%)*	297 *(40.0%)*	174 *(23.4%)*	60 *(8.1%)*	743 *(74.4%)*	256 *(25.6%)*	999
GII	100 *(14.5%)*	10 *(1.4%)*	8 *(1.2%)*	18 *(2.6%)*	166 *(24.1%)*	234 *(33.9%)*	142 *(20.6%)*	12 *(1.7%)*	690 *(68.2%)*	321 *(31.8%)*	1011
GIII	151 *(27.2%)*	4 *(0.7%)*	24 *(4.3%)*	11 *(2.0%)*	143 *(25.8%)*	140 *(25.2%)*	57 *(10.3%)*	25 *(4.5%)*	555 *(69.6%)*	242 *(30.4%)*	797
TD10-2	32 *(0.5%)*	29 *(0.5%)*	30 *(0.5%)*	1 *(0.01%)*	322 *(5.3%)*	3656 *(59.9%)*	1684 *(27.6%)*	348 *(5.7%)*	6102 *(62.3%)*	3694 *(37.7%)*	9796
TD10-1	177 *(1.1%)*	109 *(0.7%)*	92 *(0.6%)*	17 *(0.1%)*	719 *(4.4%)*	8637 *(53.3%)*	5184 *(32.0%)*	1277 *(7.9%)*	16,212 *(74.1%)*	5,672 *(25.9%)*	21,884

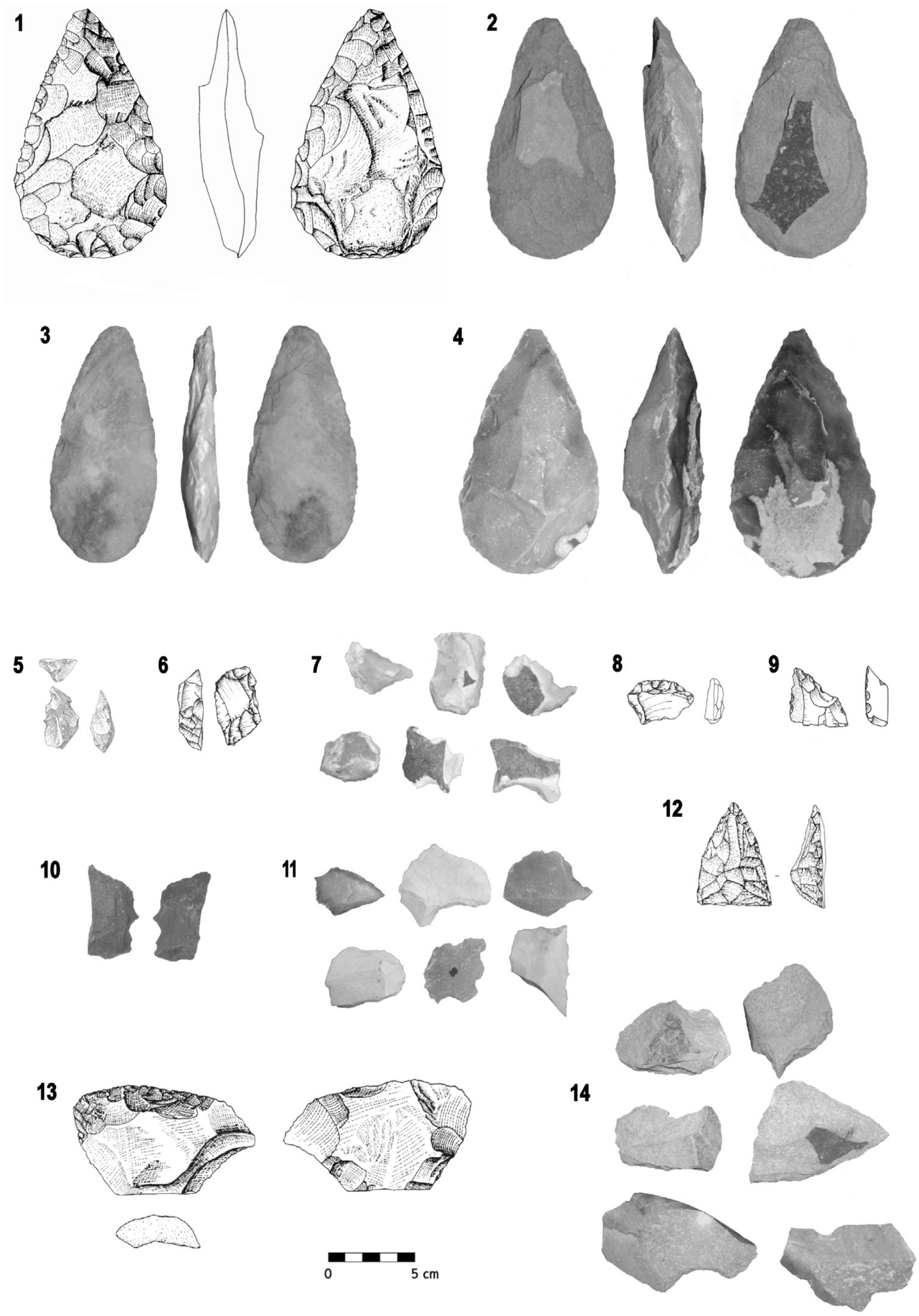

Fig. 4. Experimental and archaeological lithic industry from Atapuerca sites II: 1: Quartzite handaxe from Galería; 2: experimental quartzite handaxe; 3: experimental Neogene chert handaxe (hard and soft hammer); 4: experimental Neogene chert handaxe (hard hammer); 5: denticulate from TD6 (Cretaceous chert); 6 and 8: convex dihedrals from TD10 (Cetaceous chert); 7: experimental instruments made with Cetaceous chert; 9: denticulate from TD10 (Neogene chert); 10: denticulate from TD10 (quartzite from the Arlanzón river); 11: experimental instruments made with Neogene chert; 12: point from TD10 (Utrillas quartzite); 13: convex dihedral (side scraper) from Galería (quartzite from the Arlanzón river); 14: experimental instruments made with quartzite from the Arlanzón river.

Fig. 4. Industrie lithique expérimentale et archéologique des gisements d'Atapuerca I I. 1 : Biface en quartzite de Galería ; 2 : biface en quartzite expérimental ; 3 : biface en silex néogène expérimental (percuteur en pierre et percuteur tendre) ; 4 : biface en silex néogène expérimental (percuteur en pierre) ; 5 : denticulé en silex crétacé de TD6 ; 6 et 8 : dièdre convexe en silex crétacé de TD10 ; 7 : outils lithiques expérimentaux en silex crétacé ; 9 : denticulé en silex néogène de TD10 ; 10 : denticulé en quartzite de la rivière Arlanzón de TD10 ; 11 : outils lithiques expérimentaux en silex néogène ; 12 : pointe en quartzite d'Utrillas de TD10 ; 13 : dièdre convexe de Galería en quartzite de la rivière Arlanzón ; 14 : outils lithiques expérimentaux en quartzite de la rivière Arlanzón.

4. Methods

The experimental analysis allows us to better understand some features of the lithic technology used by the hominins in the past, such as:

- the characteristics of the fracture of the raw materials;
- the influence of blank morphology in the knapping;
- the adjustment of the knapping processes to the raw material quality, that is, the technical problems the hominins had to face, and the possibilities that they had to be able to correct them, for example changing their technique or adapting their knapping methods to the raw material constraints.

First, we developed an extensive survey of the environment of the Sierra de Atapuerca, in order to locate the supply sources of the lithic raw material used in the archaeological sites.

The experimental program consisted of 92 individualized experiments (45 focused on flake production and 47 on tool shaping) using seven raw materials (Neogene and Cretaceous chert, Limestone, Utrillas facies quartzite, and Arlanzón river sandstone, quartzite, and quartz).

Ten knappers with very diverse theoretical and practical knowledge took part in the experiments (Tables 4 and 5). This allowed us to differentiate the technical variables determined by the knowledge and the physical conditions of the knappers with the variables determined by the raw materials (Terradillos-Bernal and Alonso-Alcalde, 2011).

The experimental program was made up of two complementary levels:

- general qualities of raw materials: we conducted general experiments with the raw materials used in Gran Dolina and Galería to study the fracture standards of these materials. We analysed seven primary types of rocks: Neogene chert, Cretaceous chert (chert is divided in these two petrologic groups), Quartzite from the Arlanzón river, Utrillas Quartzite, Sandstone, Quartz and limestone (Tables 2, 4 and 5, Fig. 2). We analysed their physical-mechanical properties to infer the initial technical problems that the hominins at these sites faced and the ways in which they may have dealt with those problems;
- relation of the raw material qualities with the knapping methods and techniques: one of the main phases of this experimental knapping program consisted of the replication of the techniques, and shaping and exploitation methods identified in the archaeological assemblages. We analysed their response to the different methods and techniques used and whether the techniques they used had to be adapted to the raw materials chosen.

Our study of technological processes (archaeological and experimental) was based on the stage in which the objects were produced during the knapping sequence. The objects were classified into structural categories (hammerstones and manuports, cores, retouched instruments, and flakes). We analysed some common characteristics across all structural categories, such as raw material, morphology, weight, size and production methods/techniques, as well as particular features such as obliquity, reduction intensity, and edge delineation. We also analysed the morphology of the cutting edges (Carbonell et al., 1982; Terradillos-Bernal and Rodríguez, 2012).

5. Results of the experimental program

5.1. *Characteristics and qualities of raw materials*

5.1.1. *Neogene chert*

The Neogene chert belongs to the Late Miocene (Pineda, 1997), and it is found in the form of large blocks that outcropped following the erosion of the Astaracian marls and marly limestone in which they were contained (Ollé et al., 2013).

Neogene chert is highly heterogeneous in its reaction to knapping (Table 6, Fig. 2-4). The heterogeneity consists of two main areas: the interior, which features little crystallization and contains geodes; and the exterior (between 1 and 10 cm), which features a very thin, homogeneously crystallized grain. The outside material is not excessively hard, whereas the interior requires greater knapping intensity due to the lack of the transmission of force. The relative softness of this material means it can be knapped with small hammers.

5.1.2. *Cretaceous chert*

Cretaceous chert belongs to the Turonian-Lower Santonian (Pineda, 1997). This is a fossiliferous chert with a microcrystalline wackestone structure (Ollé et al., 2013).

Cretaceous chert has a medium to high suitability for knapping but this is limited by its small size, polyhedral and thick morphology, and the presence of some irregularities and fissures (Table 6, Fig. 2-2). It is a material that requires the use of low-middle force at the initial stages of knapping and middle-intense force during the advanced reduction phases, especially if the angles are abrupt. Proportionally large hammers and narrow percussion platforms have to be used to prevent overshots.

5.1.3. *Utrillas facies quartzite*

Utrillas quartzite is a Cretaceous material (Albian). The tenacious rocks (compact quartzarenite), or the very tenacious (metaquartzite, orthoquartzite) have been generically labelled quartzite (Ollé et al., 2013; Pineda, 1997).

Utrillas facies quartzite (Table 6) is a very abundant material and has good qualities for knapping (Fig. 2-1). Its advantages are that it is easy to control the products obtained, it results in a limited number of accidents and it produces regular and very hard edges, but its spherical morphology, its hardness and the fissures present in approximately 70% of the pieces are its primary disadvantages. Its morphology requires the use of large, dense hammers and sharp strikes by the knapper, especially during the phases in which the size is reduced and percussion angles increase.

Table 4
Primary features in the experimentations with different knappers.
Tableau 4
Caractéristiques principales des expérimentations avec différents tailleurs.

Knappers	Experience and knowledge			Experiment development			
	Practice	Theoretical	Experience with chert	Methods and techniques	Support	Accidents	Flakes production
1	Medium	High	No	Bif. Ce Alt.	Air	Platform fractures	Medium
2	Medium	High	No	Bif. Ce Alt.	Air	Hinged flakes, platform fractures	High
3	Null	Null	No	Internal percussion	Ground	Fractures	Low
4	High	High	Yes	Levallois	Air	Hinged flakes	Medium
5	High	High	Yes	Uni Ce massive	Air	Plunging flakes	High
6	Low	Medium	Yes	Bif. Or Alt.	Air	Platform fractures	Low
7	High	High	Yes	Bif. Ce Alt./Trif. marginal	Ground	Hinged flakes, platform fractures	High
8	Very high	High	Yes	Bif. Ce/Levallois	Air	No	High
9	Very high	High	Yes	Levallois/Discoid	Leg/Air	*Siret* fractures and hinged flakes	High
10	Medium	Low	Yes	Bif. Or Alt.	Leg	*Siret* fractures and hinged flakes	Medium

Trif.: trifacial; Bif.: bifacial; Uni: unifacial; Ce: centripetal; Alt.: alternating; Or: orthogonal.

5.1.4. Arlanzón river quartzite

The Arlanzón River provides Palaeozoic materials, from La Demanda ridge (quartzite, sandstone and quartz). Among the different varieties of quartzite from the Arlanzón river terraces (Table 6, Fig. 2-6), we analysed the ones with the best qualities for knapping. This raw material represents 3% of the pebbles (according to the analysis of a sample of 800 pebbles) in the Arlanzón river terrace area. They are large, irregular pebbles with an average length of 10 cm. The grain is thin, the structure is homogeneous and they tend to lack fissures or fractures. The experimental analyses have allowed us to know that their suitability for knapping is only ordinary because the cortex impedes the correct transmission of force, resulting in short, quadrangular products.

5.1.5. Arlanzón river sandstone

Sandstone represents 21% of the pebbles in the different terraces of the River Arlanzón (Table 6, Fig. 2-5). These are medium-sized to large pebbles with an average length of 9.1 cm and tend to be flat. Our experiments show that sandstone is a soft material with a homogeneous structure and thin to medium-sized grain. It features a considerable number of frontal fissures that determine the knapping processes and cause numerous fractures. The reduction of this material normally requires the use of a wide platform, which generates massive products. The flakes resulting from this raw material are very irregular, have sinuous edges, little cutting capacity and are very fragile. This is a very suitable material for the production of large, forceful, flat tools.

5.1.6. Arlanzón river quartz

Quartz represents 13% of the pebbles in the terraces of the River Arlanzón (Table 6, Fig. 2-7). These pebbles are small and thick with a thin to medium-sized grain and have some irregularities and fissures that cross the three base axes. The fissures cause fractured, hinged flakes (many of them with Siret fractures), which have limited potential for use.

5.1.7. Limestone

Limestone was procured from the karst, from the Cretaceous substratum of the Sierra de Atapuerca (Ollé et al., 2013). Limestone is the most abundant and the geographically closest raw material in the Sierra de Atapuerca (Table 6, Fig. 2-3). It appears in thick and irregular blocks distributed both inside and outside the caves. Its properties make it a poor material for knapping and it is highly heterogeneous.

5.2. The influence of raw materials on the knapping techniques and methods

5.2.1. Exploitation: the production of flakes (débitage)

We carried out eight experiments using the Discoid method (well represented in Middle Pleistocene assemblages). When it is used on Neogene chert the Discoid method allows a large number of flakes with homogeneous morphologies to be extracted using wide percussion platforms and limited force. In the final stages of exploitation, principally with quartzite and Cretaceous chert, more accidents occur with this method, most commonly fractures (often Siret fractures) and hinged flakes (Fig. 3-8 and 11).

The Levallois method was used in 15 experiments in its different variants, in three of them combined with the

Table 5
List of knapping experiments.
Tableau 5
Liste des expérimentations de taille.

No. Experiment	Knapper	Raw material	Methods	Knapping objective
1	1	Neogene chert	Alternating centripetal unifacial	E
2	2	Neogene chert	Alternating centripetal unifacial	E
3	3	Neogene chert	Improvisation	E
4	4	Neogene chert	Levallois	E
5	5	Neogene chert	Massive centripetal unifacial	E
6	6	Neogene chert	Massive bifacial orthogonal	E
7	7	Neogene chert	Alternating centripetal unifacial/Trifacial	E
8	8	Neogene chert	Centripetal bifacial/levallois	E
9	9	Neogene chert	Levallois/Discoid	E
10	10	Neogene chert	Massive centripetal bifacial	E
11	5	Neogene chert	Centripetal bifacial/discoid//levallois	E
12	5	Neogene chert	Centripetal bifacial. large size	E
13	5	Neogene chert	Centripetal bifacial. large size	E
14	5	Neogene chert	Discoid	E
15	5	Neogene chert	Discoid	E
16	5	Neogene chert	Recurrent levallois	E
17	5	Neogene chert	Recurrent levallois	E
18	5	Neogene chert	Bipolar knapping on anvil	E
19	5	Neogene chert	Bipolar knapping on anvil	E
20	5	Neogene chert	Bipolar knapping on anvil	E
21	5	Neogene chert	Bifacial handaxe	C
22	5	Neogene chert	Bifacial handaxe	C
23	5	Neogene chert	Bifacial handaxe	C
24	5	Neogene chert	Bifacial handaxe	C
25	5	Neogene chert	Bifacial handaxe	C
26	5	Neogene chert	Bifacial handaxe	C
27	5	Neogene chert	Cleaver	C
28	5	Neogene chert	Cleaver	C
29	5	Neogene chert	Cleaver	C
30	5	Neogene chert	Convex dihedral	C
31	5	Neogene chert	Denticulate dihedral	C
32	5	Neogene chert	Concave dihedral	C
33	5	Neogene chert	Straight dihedral	C
34	5	Neogene chert	Trihedral with bilateral dihedrals	C
35	5	Neogene chert	Punch dihedral	C
36	5	Cretaceous chert	Discoid/Recurrent and linear levallois	E
37	5	Cretaceous chert	Discoid	E
38	5	Cretaceous chert	Discoid	E
39	5	Cretaceous chert	Recurrent levallois	E
40	5	Cretaceous chert	Recurrent levallois	E
41	5	Cretaceous chert	Recurrent levallois	E
42	5	Cretaceous chert	Convex dihedral	C
43	5	Cretaceous chert	Denticulate dihedral	C
44	5	Cretaceous chert	Concave dihedral	C
45	5	Cretaceous chert	Straight dihedral	C
46	5	Cretaceous chert	Punch dihedral	C
47	5	Quartzite (Utrillas)	Discoid	E
48	5	Quartzite (Utrillas)	Discoid	E
49	5	Quartzite (Utrillas)	Discoid	E
50	5	Quartzite (Utrillas)	Preferential levallois	E
51	5	Quartzite (Utrillas)	Recurrent levallois	E
52	5	Quartzite (Utrillas)	Massive longitudinal unipolar unifacial	E
53	5	Quartzite (Utrillas)	Point/Convex dihedral	E
54	5	Quartize (Arlanzón)	Recurrent levallois	E
55	5	Quartize (Arlanzón)	Recurrent levallois	E
56	5	Quartize (Arlanzón)	Recurrent levallois	C
57	5	Quartize (Arlanzón)	Massive centripetal unifacial	E
58	5	Quartize (Arlanzón)	Large trihedral	E
59	5	Quartize (Arlanzón)	Cleaver	E
60	5	Quartize (Arlanzón)	Cleaver	E
61	5	Quartize (Arlanzón)	Bifacial handaxe	C
62	5	Quartize (Arlanzón)	Bifacial handaxe	C
63	5	Quartize (Arlanzón)	Bifacial handaxe	C
64	5	Quartize (Arlanzón)	Convex dihedral	C
65	5	Quartize (Arlanzón)	Denticulate dihedral	C

Table 5 (*Continued*)

No. Experiment	Knapper	Raw material	Methods	Knapping objective
66	5	Quartize (Arlanzón)	Concave dihedral	C
67	5	Quartize (Arlanzón)	Straight dihedral	C
68	5	Quartize (Arlanzón)	Trihedral with bilateral dihedrals	C
69	5	Quartize (Arlanzón)	Punch dihedral	C
70	5	Sandstone	Massive longitudinal unipolar unifacial	C
71	5	Sandstone	Massive longitudinal unipolar unifacial	C
72	5	Sandstone	Cleaver	C
73	5	Sandstone	Cleaver	E
74	5	Sandstone	Bifacial handaxe	E
75	5	Sandstone	Bifacial handaxe	C
76	5	Sandstone	Bifacial handaxe	C
77	5	Sandstone	Bifacial handaxe	C
78	5	Sandstone	Convex dihedral	C
79	5	Sandstone	Denticulate dihedral	C
80	5	Sandstone	Concave dihedral	C
81	5	Sandstone	Straight dihedral	C
82	5	Sandstone	Trihedral with bilateral dihedrals	C
83	5	Sandstone	Punch dihedral	C
84	5	Quartz	Bipolar knapping on anvil	C
85	5	Quartz	Bipolar knapping on anvil	C
86	5	Quartz	Bipolar knapping on anvil	C
87	5	Quartz	Alternating centripetal unifacial	E
88	5	Quartz	Massive longitudinal unipolar unifacial	E
89	5	Limestone	Massive longitudinal bipolar unifacial	E
90	5	Limestone	Alternating centripetal unifacial	E
91	5	Limestone	Longitudinal unipolar unifacial	C
92	5	Limestone	Longitudinal unipolar unifacial	C

Quartzite (Arlanzón): quartzite from the Arlanzón river; quartzite (Utrillas): quartzite from the "Utrillas" facies; knapping objective. E: exploitation (production of flakes); C: shaping of tools.

Discoid method. This combination is rare in the archaeological assemblages studied, but has a great qualitative value. The Levallois method is considerably efficient (high/middle) when it is used on Neogene chert (six experiments) and is even more efficient when combined with the Discoid method. On Neogene chert, the best results with Levallois method were obtained from thick flake blanks. On Cretaceous chert (four experiments), the Levallois method seems to be a relatively inefficient strategy due to two basic reasons: the limited size of the blanks, which makes prehension difficult, and the presence of at least one fissure. The products that typically tend to be related to this method were not generated (Fig. 3-8).

When we used Utrillas quartzite (two experiments) the Levallois method was perfectly adapted to the homogeneous qualities of the material. The quartzite from the River Arlanzón (three experiments) yielded numerous hinged flakes and the initial morphometry of the blanks was worse suited to the Levallois method.

We conducted nine experiments using the unifacial/bifacial massive unipolar method or using the centripetal method (Fig. 3-2–4). In experiments with Neogene chert we were able to select large, very thick bases with wide, non-cortical initial platforms. This allowed us to obtain large, thick flakes from the first reduction phase, almost with a predetermined morphology if the edges and angles were well controlled. This is a very opportunistic and quick method, suitable for use with large fragments of Neogene chert.

Six experiments were carried out with bipolar knapping on anvil on Neogene chert ($n = 3$) and quartz ($n = 3$). None of the experiments improved upon the results produced with other techniques and methods.

5.2.2. Shaping

In Gran Dolina TD6 and TD10 instruments made on pebbles are scarce and all were made of low to medium quality materials like limestone or quartzite of scanty quality because they are short cycle tools, which only need a heavy weight. We verified experimentally that the making of pebble tools is very simple, affecting only a small proportion of the edge and closely connected to the use of weight as an active factor.

We verified that the selection of the initial raw materials for the configuration of handaxes and cleavers (documented in Galería) gave priority to morphology over quality, having selected flat sandstone pebbles and big Neogene chert flakes.

In the case of small flake instruments the production is characterized by its simplicity and speed (between 10 seconds and 2 minutes) (Fig. 4-7, 11, and 14). Neogene chert yields the largest formats and the sharpest edges. Cretaceous chert presents more regular and resistant edges, but requires a greater investment of force (Table 6). The small size of Cretaceous chert pieces does not allow numerous reactivation phases to be carried out. Retouch is easy on the quartzite and sandstone of the Arlanzón terraces, although the resulting flake edges are duller and less regular. The rectification of knapping accidents is more complex with these materials.

6. Discussion

6.1. Raw materials selection

Comparing archaeological and experimental artefacts in Cretaceous chert demonstrates how early hominins had to

Table 6
Primary features of the raw materials used at Gran Dolina and Galería.
Tableau 6
Caractéristiques principales des matières premières utilisées à Gran Dolina et à Galería.

	Geological origin	Spatial origin	Abundance	Size	Homogeneity	Grain	Resistance to fracture	Quality for knapping	Quality of the cutting edge
Neogene chert	Late Miocene	1.5–3 km. Erosion plains	High	Very large	Medium	Micro	Low	Medium/high	High
Cretaceous chert	Turonian–Lower Santonian	1.5–2 km. Erosion plains	Low	Small	High	Micro	Medium	Medium/high	High
Utrillas quartzite	Utrillas facies/Cretaceous	4 km. Fluvial paleochannel	High	Large	High	Fine	Medium/high	Medium/high	High
Arlanzón Quartzite	Palaeozoic	< 0.5 km. Fluvial terraces and colluviums	High	Large	Medium	Fine/medium	Medium	Medium	Medium
Quartz	Palaeozoic	< 0.5 km. Fluvial terraces and colluviums	Medium	Medium	Low	Fine/medium	Medium	Low	Low
Sandstone	Palaeozoic	< 0.5 km. Fluvial terraces and colluviums	High	Large	Medium	Fine/medium	Low/medium	Medium	Low
Limestone	Cretaceous	0 km. Caves	Very high	All formats	Medium	Micro/fine	Low	Low	Medium/low

overcome considerable difficulties in order to adapt their knapping techniques to this raw material. The hominins at the sites studied did not make the most of their efforts to become profitable, through controlled and complex knapping, the effort expended to obtain these nodules.

The products generated in the experiments with Neogene chert are larger (average 50.2 mm) than those documented in the archaeological record of TD6 (36 mm), Galería (36.7 mm) or TD10 (23 mm). This confirms that the hominins at Atapuerca intensively used the materials that were transported to the site for exploitation, even though the source of those materials was not far. The production of small flakes (primarily in sublevel TD10-2) is related to the maximum use of the blocks of chert. Furthermore, more functional products used in activities that require precision were generated in the same way.

Neogene chert not only offers the possibility of obtaining longer cutting edges, but it is also an abundant material with little resistance to fracture available in large blocks. The reduction of these blocks allowed large flakes to be extracted that were subsequently transported to the site and used as cores. On the other hand, Utrillas quartzite seems to allow for the development of complex knapping methods (Levallois and Discoid) and its raw edges are very sharp, regular and resistant. Nevertheless, its use is very limited. We observed through some experiments that the main difficulty of these blanks is their spherical morphology and the problem of extracting the *entame*.

From the technological analysis we determined that there was a considerable increase in the use of chert documented in TD10 compared to TD6. Experimentally, we found that in TD10 one of the objectives was to obtain natural cutting edges on small objects. We were able to determine a direct relationship between the length of useful cutting edge, the quality of the raw materials and the knapping methods employed.

We documented little resistance to conchoidal fracture on Neogene chert blanks. This is consistent with the fact that the assemblages with higher proportions of this chert contain a lower proportion of hammers.

6.2. Methods and knapping strategies

6.2.1. Exploitation: the production of flakes (débitage)

The flake production documented in Unit TD6 of Gran Dolina consists of a small but very significant assemblage of quartzite cores and large chert cores. Through experimentation, we verified that the sphericity of the pebbles found in terrace T4 of the River Arlanzón (the terrace nearest to the site) influenced the development of massive, orthogonal knapping products. Palaeozoic materials from terrace T4 of the River Arlanzón were used in TD6 because of its proximity to the site but these hominins had little ability and/or interest to modify the initial formats. The experiments with quartzite, quartz and sandstone from the Arlanzón River present the most fissures and the most spherical shapes, which results in knapping with very abrupt angles (Fig. 3-3 and 4). In general, it seems that the hominins at these sites did not place much importance on the initial selection of the stones or on the modification of the initial blanks.

In TD6 the hominins abandoned the exploitation of large blocks of Neogene chert in the most optimal phase for the extraction of flakes. Our experimental knapping shows that these cores were abandoned after an initial series of cleaning removals (Fig. 3-6–7). In light of this fact, two complementary hypotheses can be put forward:

- these cores were part of a reserve of raw materials;
- for some reason that we do not know yet, the hominins left Gran Dolina before they had planned to and did not take these blocks with them due to their weight, and because they could easily be replaced in the surroundings.

In the development of the Levallois and Discoid methods the initial format (thick and trapezoidal) of most of the blocks of chert is very important. In Middle Pleistocene assemblages the Discoid method was the most suitable for the raw materials used in the production of small flakes. Its use in association with the Levallois method results in more fluid knapping during the last phases of reduction.

In the experimental program an average of 22 flakes were obtained per kilogram from chert (with a maximum of 82 and a minimum of 9) and 17 from Palaeozoic materials (quartzite, sandstone and quartz), with a maximum of 38 and a minimum of 10. It can be seen that the production from Palaeozoic materials is more homogeneous (because it offers fewer possibilities). If we compare it with the archaeological record, we note that TD6 yielded 23.4 products per kilogram of chert, Galería 37 and TD10 170; whereas in TD6, other raw materials generated 18 flakes per kilogram in Galería 9.6 and in TD10 38.

A considerable difference was found in the proportion of flakes between the most ancient levels of Galería and the most modern. Why is there such a big difference in the proportion of flakes in these levels? There are two possible explanations for these differences:

- there is a progression in the increase in the size of the flakes, so there is an inversely proportional relationship between the size of the flakes and the quantity of flakes;
- in the most modern levels the *chaînes opératoires* are more incomplete and fragmented, because less knapping activity has been documented in those units.

6.2.2. The shaping of tools

The experimental program on quartzite and limestone verified that early hominins collected blanks that enabled them to quickly produce heavy, blunt instruments through a very short knapping process. So, in TD6 fractured cores and cores with noticeable knapping accidents were used as well as fractured hammerstones, fragments and limestone pebbles. In TD6 and TD10, medium quality raw materials were selected to shape instruments from pebbles.

Galería contains a significant presence of large handaxes and cleavers (Fig. 4-1). In order to produce these flat and large tool flakes the hominins selected flat pebbles intensifying the acquisition of sandstone (21% among pebble instruments and 9.1% among tool flakes). We verified through diverse experiments that sandstone is a raw

Table 7
Percentage of Cretaceous chert in the archaeological assemblages.
Tableau 7
Pourcentage de silex crétacé dans les ensembles archéologiques.

Levels	Percentage of Cretaceous chert		
	In the entire assemblage	Among the Flakes	Among Flake tools
TD6	9.8	13.8	27.9
GII	5.3	8.0	10.2
GIII	3.0	5.6	7.7
TD10-2	17.1	27.1	39.4
TD10-1	6.6	8.8	15.6

material that offers a scanty resistance and allows the fluid application of the knapping with a soft hammer. The production of these instruments made us stricter in selecting the blanks: they had to be flat, of scanty resistance to the fracture and without fissures. In the experiments in which we did not use soft hammers we generated thick and asymmetric large cutting tools, with a triangular thick sagittal cross-section. Instruments made with the soft hammer technique are flatter and more symmetrical (from the sagittal edge), there are more hinged removals (but less marked), and extractions are narrow, very flat and rectangular. This technique has proven to be effective only with Neogene chert and sandstone, due to the initial morphology of the blanks and their reduced resistance to fracture. The great energy investment that we have used in the experiments and that past hominins used in the production of these instruments must have been related to the planning of activities, which would imply the use of multi-functional instruments.

The flake instruments in the archaeological record generally show evidence of expeditious shaping. The retouched flakes made of Cretaceous chert have regular and durable cutting edges. Little striking intensity was needed to retouch the Neogene chert flakes, as we corroborated in our experimental program. The hominins at these sites knew how to correctly assess the qualities of Cretaceous chert to produce small instruments, although they did not attain a great degree of control in knapping this raw material. Therefore, the proportion of the use of this stone is higher among flakes and small implements (primarily in TD10-2 and TD6) (Table 7).

6.3. *The role of activities on the raw material and technical choices*

Clearly, the type of occupation influenced the selection of raw materials and technical strategies implemented. Unit TD6 contains intense hominin occupations (Ollé et al., 2013). In this archaeological ensemble a complex carcass processing has been reconstructed, together with the evidence of cultural cannibalism (Carbonell et al., 2010; Saladié et al., 2011). The TD6 lithic assemblage shows the use of a wide range of raw materials for the implementation of diverse activities. In this sense, we have documented a high proportion of flakes produced with a great variety of raw materials. This fact owes to the presence of the flakes obtained in the production of short cycle pebble tools, and flakes from quartzite, sandstone and limestone cores due to the proximity of the sources. There are also chert flakes (principally Neogene) for activities that need a great cut capacity.

In the shaping of flake tools the hominins of TD6 preferentially selected the Cretaceous chert because this material obtains a regular and durable cutting edge. Thus we can relate the notable percentage of flake tools (especially on Cretaceous chert) to the development of non-cut activities. There are also expedient instruments (pebble tools) with a very simple knapping that affects only a small proportion of the edge, closely connected to the use of weight as an active factor. In the short cycle pebble tools, hammerstones and manuports, the hominins of TD6 chose closer and more abundant, poorer quality limestones and quartzite from the T4 of the Arlanzón river.

The lithic assemblages of Units TD10.2 and TD10.1 show differences, which reflect diverse subsistence strategies. The large amount of faunal and lithic remains throughout the thick stratigraphic sequence, concentrated in well-defined layers, must reflect several episodes of visits to the cave organised most likely as a base camp, where several activities would have been carried out (Ollé et al., 2013). In TD10 the knapping of chert (almost in an exclusive way) to produce flakes is due to the importance of cut activities in a primary access to biomass. Chert is more productive than quartzite and quartz, because it requires narrower platforms of percussion, repairing knapping accidents is easier with chert, and this raw material yields a greater number of small flakes. The Levallois and Discoid methods are most effective for the production of medium and small flakes. For shaping flakes the TD10 hominins almost only used chert (principally Neogene) because little striking force is needed to retouch.

The utilization of Cretaceous chert to make small flake tools is due to the quality of the retouched cutting edges. However, the effort invested in the location and exploitation of this raw material is not worth the result, because the Neogene chert, much more abundant and accessible, can generate good cutting edges. In this sense, the constant and repeated use of Cretaceous chert throughout the Pleistocene might correspond to a cultural tradition. For this reason, we confirmed that in TD6 (27.9%) as well as in some sublevels of TD10 (TD10-2 = 39.4%), Cretaceous chert was preferentially selected for the production of small instruments (Table 7).

The evidence of human occupations in Galería reflects short-term activities related to the role of this cave as a natural trap (Díez and Rosell, 1998). The Galería lithic assemblage is composed of large shaped tools such as handaxes and cleavers, and well-shaped small tools (side scrapers, points, denticulates, notches, etc.). Production processes were seldom performed at Galería, as many of the implements were produced before entering the cave, but when present they reflect standardisation (Ollé et al., 2013). Only in Galería have we identified long cycle pebble tools, in which the hominins gave priority to the initial big and flat format of the pebbles (sandstone) and to a limited resistance of the fracture that would allow them to apply hard and soft percussion (chert and sandstone). In Galería, the robustness of the artefacts has more importance (e.g., the higher relative proportion of Palaeozoic materials) than in the lithic assemblages of TD6 and TD10. In this site the introduction of large and flat blanks of sandstone and Neogene chert to make handaxes is due to the developed forceful activities, but in this case they needed tools with more regular and sharp edges.

In Galería, the Cretaceous chert has a scanty presence because the hominins generated instruments of larger size, and the initial formats of this material do not work for this (Table 7).

7. Conclusions

The development of an extensive experimental program applied to the study of the lithic technology of Gran Dolina and Galería has allowed us to draw some general conclusions, and has provided answers to some of the specific questions raised by the technological studies.

The hominins that occupied this environment during the Early and Middle Pleistocene developed their technological strategies in a similar environment, with similar resources, and with the same raw materials (same qualities, format, availability...). Nevertheless, the hominins selected a different proportion of raw materials. These choices influenced the knapping activities. In this way, there are similarities in the technological record of Gran Dolina and Galería due to utilization of the same raw materials, but there is also a significant variability related to the differences in the proportions of raw materials used in the lithic assemblages.

The variations in the representation of each raw material in the *chaîne opératoire* of the archaeological ensembles are determined by the knapping objectives, which are related to the kind of activity that took place.

The development of a program of experimental knapping allows us to confirm that the selection of raw material depended on the technological modes and the activities developed. Mode 1 of TD6 emphasizes the selection of Palaeozoic materials with thick formats on which an orthogonal knapping is applied, although we can see an important difference with the rest of the Lower Pleistocene European sites of Mode 1, like the preferential selection of the Cretaceous chert to make small tools. In Mode 2 of Galería the selection of large and flat blanks of sandstone and Neogene chert for the production of handaxes stands out. Finally, in the transitional assemblages (Mode 2–Mode 3) of TD10-1 and TD10-2 the selection of Neogene chert predominates, which allowed a knapping intensification and the production of a great proportion of flakes with more cutting edge.

The reasons for the selection of each raw material are:

- the quartzite of scanty quality and thick formats because of its proximity;
- the sandstone of flat format due to its adequacy to produce handaxes and its scanty resistance of fracture;
- the Neogene chert due to its abundance, proximity, scanty resistance of fracture and thick formats that adjust to the development of the Levallois and Discoid methods.

As to the Cretaceous chert, this raw material generates the best and most resistant cutting edges, and the use of this chert is related to an inherited cultural tradition.

In summary, the development of a complex program of experimental knapping organized on the basis of questions raised in certain archaeological assemblages has allowed us to complement the technological analyses of the lithic industry of Gran Dolina and Galería sites.

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