The lithic assemblage from Pont-de-Lavaud (Indre, France) and the role of the bipolar-on-anvil technique in the Lower and Early Middle Pleistocene technology.

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Abstract: The lithic assemblage of the Pont-de-Lavaud site (Indre, France) shows a technical choice within the Lower Pleistocene European Mode 1 sites, which is defined by the widespread use of the bipolar-on-anvil knapping technique. Although it is traditionally considered an expedient percussion method, in this lithic assemblage a selective technical behavior regarding the reduction methods and raw material is identified. In this respect, different knapping methods are applied in accordance with a combination of the percussion axis and the recurrence of the reduction series. These features are also observed in the archaeological record from other Lower and Middle Pleistocene sites, which are discussed in the text. The role of this knapping technique in the hominin technology is, in our opinion, greater than previously believed. Its implementation cannot be considered as proof of opportunistic or expedient activities. The bipolar-on-anvil technique is applied in different contexts, on different raw materials and as a technical choice or gesture in the reduction sequences. Because of its low technical requirements, it can be considered as a successful technological strategy for overcoming raw material constraints for producing some specific types of pieces. Its ubiquitous presence, both from a diachronic and geographical point of view, is proof of its considerable technical versatility and, hence, of Mode 1 hominin technological flexibility and capabilities.

Key-words: Mode 1 Technology, Lower Pleistocene, lithic technology, Bipolar reduction, quartz, lithic assemblages.

1. Introduction.

The archaeological site of Pont-de-Lavaud is one of the Lower Pleistocene sites located in the Middle Loire River Basin to the north of the Massif Central (France) (Despriée & Gageonnet, 2003; Despriée et al. 2006, 2010). Because of its location on the northern edge of the Massif Central it became one of the first sites providing evidence for human settlement beyond the 45° N latitude outside the circum-Mediterranean area (Despriée et al. 2006). The technological characteristics of the lithic assemblage fall within the European Mode 1 Techno-complex (Mosquera et al. 2013) but show some peculiar features defined by the almost exclusive use of quartz, and the use of bipolar-on-anvil as the main knapping technique (Despriée et al. 2010). Hence, the human occupations of the Pont-de-Lavaud site can be considered as an example of the technological and settlement flexibility of the European late Lower Pleistocene hominins.

This assemblage shows a technical specialization defined by a very high proportion of a specific knapping technique: bipolar-on-anvil reduction. The aim of this paper is to focus on this method in order to describe its use on a specific raw material, quartz. Its implementation could be explained either as an adaptive strategy to environmental and lithological constraints or as a cultural choice. Secondly, the predominance of the bipolar-on-anvil technique in this late Early Pleistocene site raises the question about its role within the hominin technological behaviour of the Mode 1 and Mode 2 techno-complexes, which will be further discussed.

Several authors have approached this technique through experimental programs and ethnographic models in order to characterize the flaking products and their visibility in the archaeological record (Curtoni, 1996; Kobayashi, 1975; Hayden, 1980; Honea, 1965; Johnson, 1978; Prous & Lima, 1990; Shott, 1989, 1999). Even though increasing attention has recently been paid to this technique in the African and Asian context through experimental approaches (Díez et al. 2009, 2011; Mora & de la Torre, 2005; Gurtov & Eren, 2014; Zaidner, 2013; Sánchez et al. 2012), less attention was paid to it in the European record until the last decades (Callahan, 1987; Crovetto et al. 1994a; Donnart et al. 2009; van der Drift, 2012; Driscoll, 2011a; Mourre & Jarry, 2009-2010; de la Peña, 2011; Rankama, 2002; Vergès & Ollé, 2011). On the other hand, few works have dealt with the functionality and socio-economic context of this knapping technique in either prehistoric or actual human communities (Bradbury, 2010; Eren et al. 2013; Goodyear, 1993; Jeske, 1992; Knutsson, 1988; Kuijt & Russell, 1993; Lindgren, 2003; Shott, 1989, 1999).

It has traditionally been considered that the bipolar-on-anvil percussion was an expedient technology that was used as a complement to freehand percussion, and that it was directly linked to raw materials constraints (Bordes, 1947; Breuil, 1954). Nevertheless, as in the case treated here, this premise is not so straightforward and

the bipolar-on-anvil technique is applied on different materials (i.e. Berman et al. 1999; Curtoni, 1996; de la Peña & Vega, 2013; Binford & Quimby, 1963; Peretto et al., 1998) and in different contexts. Traditionally, it has been considered to be a direct response to raw material constraints (Curtoni, 1996; Díez et al. 2011; Prous & Lima, 1990), but other factors must be taken into account such as a selective behavior (Barsky et al. 2011), socio-economic factors such as recycling or toolkit maintenance (Jeske, 1982; Goodyear, 1993; de la Peña & Vega, 2013) and even group mobility (Shott, 1989, Eren et al. 2013). It must therefore also be understood to be one of the earliest technological responses to functional or environmental constraints.

2. The bipolar-on-anvil technique.

The bipolar-on-anvil technique is aimed at obtaining flakes through an elementary operational sequence, which consists of using a hammer to strike a core, which is positioned on a stationary anvil (Crabtree, 1972; van der Drift, 2012; Mourre, 2004; Shott, 1989, Prous & Lima, 1990). The similarity of this knapping technique, in terms of movements, requirements (both cognitive and in terms of grip and skill) and elements with the percussive activities and strength-based use of tools observed in some chimpanzees and capuchin monkeys for processing organic materials (especially nut cracking), place it as one of the earliest knapping techniques used by hominins (Ambrose, 2001; Bril et al. 2012; de Beaune, 2004; Panger et al. 2002; Sanz & Morgan, 2007; Visalberghi et al. 2007; Westergaard, 1995; Whiten et al. 2009: 431; Wynn & McGrew, 1989).

These ape activities are defined by selecting two objects (anvil and hammerstone, usually of mineral origin), transporting either both or only one of them (Boesh & Boesch 1984; Visalberghi et al. 2007, 2009; Spagnoletti et al. 2011), and their interaction with another material, such as nuts, in order to achieve an immediate goal, obtaining the food resource. In some cases, some lithic by-products with suitable cutting edges can be inadvertently produced. These resemble artefacts from the earliest archaeological sites (Mercader et al. 2007; Panger et al. 2002; Westergaard, 1995). These technical and behavioral convergences may point to the origin of the hominin technology. Its similarity, as well as the presumed homogeneity of early hominin technology (Carbonell et al. 2009), may explain the difficulties, or even the impossibility, to identify any links between the apes pounding activities and the first stages of tool technology in the archaeological records (see Panger et al. 2002: 242). The recent discoveries from Lomekwi 3, dated to 3,3 Ma, seem to support this hypothesis (Harmand et al., 2015).

Its simplicity makes it an easy technique to learn and apply. Because of this, it is sometimes cited as a learning activity or, based on ethnographic evidence, as evidence for the division of lithic production tasks by gender (Hayden, 1980; Lindgren, 2003; Sillitoe & Hardy, 2003; Weedman, 2010). The bipolar-on-anvil technique has been

shown to be suitable in various technological and economic contexts in which the main objectives are the production of lithic implements (Shott, 1989, 1999; Hayden, 1980; Prous & Lima, 1990); specific tools (Hayden, 1980; Jones, 1994); or microliths for making composite tools (Eren et al. 2013; de la Peña & Vega 2013; Klaric, 2009; Prous & Lima, 1990).

Because of its specific flaking mechanics, this technique has some advantages in comparison with freehand percussion. The specific initiation and propagation model of the fracture force related to bipolar percussion (Cotterell & Kaminga, 1987) makes it easier to overcome some raw material's internal flaws, which is especially relevant to quartz based assemblages (Bordes, 1947, Breuil, 1954; Prous & Lima, 1990; Díez et al. 2009). This simplicity is, however, limited by the lack of knapping control, which makes it impossible to manufacture predetermined flaking products (Bordes, 1947; Hardaker, 1979; Shott, 1989; Patterson & Sollberg, 1976). Experimental approaches do, nevertheless, show that some foreseeable morphologies, edge angles and blank sizes can be obtained, which in some cases could reflect the knappers' main objectives (Díez et al. 2011; Mourre, 2004; Prous & Lima, 1990).

The absence of format limits on how the core is gripped for knapping, which is indeed defined by the width of the knapper's fingers, is one of these technique's main advantages over freehand percussion. It can be used to reduce small sized pebbles (Berman et al. 1999; Curtoni, 1996; Kuijt & Russell, 1993; Honea, 1965); profiting small flakes as cores for secondary knapping (Zaidner, 2013; Crovetto et al. 1994b); for recycling tools as cores, and for toolkit maintenance (Goodyear, 1993; Jeske, 1992; Amick, 2007; Hiscock, 2003; de la Peña & Vega, 2013). In some cases, the bipolar-on-anvil technique can be performed as a technical gesture within a more complex *chaîne opératoire* in order to create new striking platforms in large pebbles or hard materials (Arzarello & Peretto, 2010; Bosinski & Guicharnaud, 2008), or to break large blocks into smaller fragments which may then be further reduced by freehand percussion (Bracco, 1993; 1998).

This expedient technology thus makes maximum use of the raw materials with only a small investment in terms of technological knowhow (Putt, 2015). This is especially evident in a socioeconomic context of low regional mobility and maximization of local lithic resources (Curtoni, 1996; Eren et al. 2013; Goodyear, 1993; Jeske, 1992; Shott, 1989). The versatility of bipolar-on-anvil percussion is defined by its multiple functional contexts, and technical and cognitive simplicity. These features explain its widespread use throughout space and time. Nevertheless, the identification of this technique in some assemblages may be overlooked in previous analysis due to the great difficulty in identifying artefacts produced using this method (Driscoll, 2011a; Johnson, 1978).

3. The Pont-de-Lavaud site

The Pont-de-Lavaud site is located at Eguzon-Chantôme (Indre) in the Massif Central sector of the Middle Creuse River Valley, at the southern boundary of the Centre Region (Indre, France). In this area, the Creuse river flows north-westwards through the Aigurande Plateau along tectonic accidents that cut through the metamorphic and magmatic units to a depth of around 145m (Figure 1).

Upstream and downstream to the Eguzon dam, many terraces and remnants of fluvial formations are observed at relative altitudes of around +90/+105 m. The ESR ages from this alluvial formation (Sheet I) range from 1.2 to 1.0 Ma (Despriée et al. 2004, 2009; Falguères et al. 2002, Voinchet et al. 2010). About 15 archaeological sites yielding Mode 1 lithic industry were identified in the fluvial remnants. One of these, the prehistoric site of Pont-de-Lavaud, was discovered near the hamlet of Fressignes in 1982. It is located on the westwards tilting slope of the interfluv between the Creuse and a small tributary, la Clavière. It was excavated from 1984 to 1994 (Despriée & Gageonnet 2003; Despriée et al. 2006; 2010).

Figure 1

3.1. Stratigraphy of the Pont-de-Lavaud Site

At Pont-de-Lavaud, the main prehistoric occupations were embedded in the two sedimentary units deposited on the bedrock (from bottom to top): a diamicton and a fluvial formation (Figure 1c).

The first unit, with a surface area of about 100 m², is a diamicton overlaying the micaschist bedrock which was uncovered by the river incision at the beginning of a cold isotopic stage. This coarse unit contains gravels, cobbles and blocks of endogenous rocks that downsloped from the tertiary detrital formation spread over the plateau: granite, gneiss, micaschist, amphibolite and quartz. All these materials are weathered and only quartz cobbles and pebbles are preserved in a clayey and sandy, gravely red-brown matrix which contains much debris from the disintegrating materials. During deposition, the biggest cobbles or boulders of quartz, 15 to 30 cm long, sank due to gravity and are visible at the base of the slope deposits. The top of the diamicton is a thick level of weathered quartz pebbles and cobbles (4 to 8 cm long).

During pleniglacial phase, cryoturbation had disturbed these sediments: periglacial phenomenas, such as clay diapers and stone clusters are observed in sections of the

slope deposit and polygons are visible in the altered micaschist bedrock (Despriée and Gageonnet, 2003; Despriée et al. 2006).

Afterwards, the human occupations took place during an early interglacial period with warm and wet climatic conditions. According to pollen and phytolith analyses, hominins settled down in a closed forested environment, dominated by deciduous trees (*Quercus* and *Castanea*)- This including relict taxa such as *Juglans*, *Carya* and *Pterocarya* that were associated with herbaceous vegetation, mainly composed of temperate Poaceae (Pooideae) (Marquer et al. 2011; Messenger et al. 2011).

Later, the diamicton was covered again by a fluvial formation called the Pont-de-Lavaud/Le Cerisier Formation (Sheet I), composed of beds of coarse sands that overlay the archaeological layer (Figure 1c). The thickness of this fossil fluvial formation reaches up to 15m in the Le Cerisier Terrace; at Pont-de-Lavaud. After a long period of erosion due to the tilting of the Fressignes Compartiment, the residual thickness is of about 1.50 m (Despriée et al. 2004, 2006, 2011). At Pont-de-Lavaud, the ESR ponderate age obtained for the fluvial quartz grains is $1.055 \text{ ka} \pm 55 \text{ ka}$ (Voinchet et al. 2010).

3.2. The archaeological level

In the archaeological layer, two stone pavements of about 25 m^2 each, have been identified and interpreted as hominins arrangements. These structures (Pont-de-Lavaud 1 and 2) were built with large quartz cobbles and weathered vein quartz fragments (10-25 cm long) gathered from the base of the slope deposit. These cobbles are bigger than the other ones present on the surface of the diamicton, which have a mean size of 2-8 cm. In addition to these pavements, which are delimited by large aligned quartz cobbles, some postholes have also been identified, suggesting the existence of an artificial shelter (Despriée & Gageonnet 2003), becoming one of the scarce evidences of habitat arrangement in late Lower Pleistocene sites. The vertical and horizontal distributions of the quartz artifacts, broken quartz cobbles and debris uncovered between the pavement stones and on their limits (wall effect), reinforce this hypothesis (Despriée et al. 2009) (Figure 2). Because of the acidity of the soil, the only paleontological finding recovered was a flat bone fragment ascribed to an equid mandible (Despriée & Gageonnet 2003: 396).

Figure 2

4. Materials and Methods.

4.1. Sampling

The lithic assemblage recovered from Pont-de-Lavaud amounts to about 8000 artifacts made exclusively on quartz pebbles and subangular vein quartz fragments (Despriée et al. 2010), including 4000 broken pebbles. A total of 1321 pieces have been selected as anthropically modified because of the presence of percussion marks and evidence of flaking based on observations from previous experiments (Despriée et al., 2010: 347).

Three different techniques were recognized depending in part on cobbles morphology and size (Despriée et al. 2009): (1) freehand hard hammer percussion, (2) bipolar-on-anvil reduction, and (3) the anvil technique (Crabtree 1972: 9-10; Toth, 1982: 129). The bipolar-on-anvil technique was mainly applied to small and medium sized, ovoid and polyhedral quartz pebbles. The anvil technique was mainly used to knap vein quartz fragments. The core technology used, whatever the mode, was defined by short and simple reduction sequences, consistent with the European Mode 1 techno-complex (Despriée et al. 2009; 2011; Mosquera et al. 2013).

For this study, we have considered the corpus of 1321 artifacts, mostly made on quartz pebbles and cobbles. The pebble assemblage reflects the technological characteristics and technical variability of the Pont-de-Lavaud site (Despriée et al., 2009; 2010) since the same main methods were applied on the pebbles and the vein quartz. In this paper we will focus on the different bipolar-on-anvil methods identified at the site and their suitability to the characteristics of the quartz. Besides, their characteristics (presence of neo-cortical surfaces, low incidence of internal flaws, etc.) allow a more reliable technical reading than the rolled vein fragments and, consequently, provide a better understanding of the reduction and shaping processes.

We must bear in mind the problems inherent to dealing with quartz lithic assemblages (Driscoll, 2011a, 2011b; Tallavaara et al. 2010), which in some cases are difficult to analyze because of the quality of this raw material (fracture patterns). Taking into account the characteristics of quartz, with uneven to conchoidal fracture, and also the peculiarities of the knapping methods used in this assemblage (Hayden, 1980), in some cases it has been difficult to make a proper technical analysis of the implements (Despriée et al. 2010: 348). Besides, some authors attest that some end products obtained by bipolar-on-anvil technique may not greatly differ from those obtained by freehand percussion (Gurtov & Eren, 2014). In order to eliminate this uncertainty and achieve a precise understanding of the *chaînes opératoires* at the site, the technological analysis has only been based on the artifacts with clear percussion marks (de Lombera, 2009). This includes impact points on detached and flaked products, the directions of the removals, and the percussion technique used, and all this provides a proper diacritical and technical reading of the artifacts (Figure 3). The bipolar technique was observed through the identification of one or two opposite impact points and trimming or marginal retouch on the extremity of the split pebbles. The “split fracture” produced pieces with several shattered sides and polygonal section

(e.g. Mourre, 1996; Mourre and Jarry, 2009-2010; Faivre et al., 2010; de Lombera et al., 2011; Garcia et al., 2013; Zaidner, 2013; Gurtov and Eren, 2014) that were reproduced during our own experiments on the same type of quartz. Nevertheless, the predominantly grainy texture of the Pont-de-Lavaud quartz may prevent recognizable knapping stigmas on the artifacts (de Lombera, 2009). Additionally, the slight patina on the archaeological pieces may hide the stigma from macroscopic identification.

4.2. Additional experiments

At Argenton-sur-Creuse we developed another experimental program with local raw materials in order to enlarge the first experimental corpus made during and after the excavations, and to solve some technological questions posed by the bipolar techniques performed on quartz. Twenty-two pebbles of the same size and form were knapped by three medium and highly experienced knappers replicating the morphotypes and processes identified in the archaeological assemblage. The knapping stigma and technical features of the percussive elements and knapping products were recorded. The complete analysis of the experimental sample is still underway but some observations are used in this paper to describe the bipolar methods and its results.

Finally, a natural sample was taken from a segment of one circle of pebbles produced by periglacial processes, located in the upper layer (Despriée & Gageonnet 2003), in order to compare it to the archaeological record, taking into account their dimensions, morphologies and the presence of stigma. For this purpose, a 0.5x0.5 m test pit was made, from which 432 fragments, pebbles and cobbles were recovered. The fluvial blanks represent 65.5% of the sample.

Figure 3

4.3. Categories of selected artifacts

Taking these factors into account, we divided the lithic assemblage (n=1321) into three populations. The first one contains artefacts that display clear percussion stigma (n=264), while the second one (n=242) is composed of morphologically and technically similar artefacts (in terms of striking platforms, removal directions, etc.) but showing only ambiguous stigma (Table 1 and 2), and the third population (n=815) contains products from the *chaines opératoires* identified at the site. This identification is the result of morphometric and morpho-technical analysis, and is based on a study of the previous groups along with the data obtained in the experimental study. We must bear in mind the high fragmentation index of quartz artefacts during reduction sequences, which provides a large quantity of by-products lacking percussion marks, that could therefore be misidentified (Driscoll, 2011b; Tallavaara et al. 2010). In fact, some of the

pieces belonging to each group have been refitted, reinforcing the hypothesis that they were produced by knapping (Figure 4). This problematic is also reported from other Late Lower Pleistocene lithic assemblages, especially those knapped from quartz (i.e. Güleş et al. 2009).

Figure 4

When we compare the composition of these two samples, taking into account the main categories of objects (cores, retouched objects and flaking products), the χ^2 homogeneity test shows that no significant differences exist ($\chi^2=0,746$, $DF=2$, $p=0,689$). As stated before, the current study is based on the technological features of the first population in order to define the main technical features of the lithic assemblage. Thus, all the results and numbers presented here refer to the first population (Table 1).

Although quartz is the only raw material used at the site, artifacts are defined by their morpho-structural varieties in terms of quartz texture and homogeneity in order to identify the raw material supply at the site and the technical strategies used there (Martínez & Llana, 1996; de Lombera, 2009). Grain or crystal size as well as any internal flaws or cleavage planes in the quartz blanks are considered the main factor limiting control of knapping sequences (de Lombera et al., 2011; Mourre, 1996). Quartz artifacts were therefore placed into four Morpho-structural Groups on the basis of the presence/absence of grainy texture and of internal flaws or cleavage planes: NN (no grain, no plane), NY (no grain, plane), YN (grainy, no plane) and YY (grainy, plane). This classification on the basis of quartz formation and mechanical properties makes it possible recognize the technological or economic criteria applied to the selection of artifacts in accordance with the prevalent technical needs of prehistoric communities (de Lombera et al. 2011).

4.4. Lithic Technology Analysis Method

In lithic technology analysis, lithic categories are stated on the basis of freehand percussion on brittle materials such as flint, in which clear conchoidal fractures and impact points makes it possible to identify the different reduction stages based on the dichotomy between “detached products” (flakes) and “flaked products” (cores and retouched tools) (Carbonell et al. 1983). For this reason, the technological study has been based on those attributes established by the Logical Analytical System (LAS) (Carbonell et al. 1983, 1992; Rodríguez, 2004). Nevertheless, such distinctions cannot always be made for bipolar-on-anvil products since some products share features linked to flaked and detached objects, especially during the final stages of reduction. Consequently, several authors have defined these objects to as “*nucleiforms*”, or

“splintered pieces” (Díez et al. 2009; Prous & Lima, 1990; Shott, 1999). In this case, the splintered pieces are considered to be cores.

5. Results. The lithic assemblage.

5.1. Categories

In the Pont-de-Lavaud assemblage all the categories of lithic production are present, but cores are overrepresented in comparison with the knapping products (flakes and fragments) (Population 1, Table 1). Cores and cores on flakes account for 57.25% of the assemblage, while flaking products only amount to 29.77%. This feature could be explained by the bipolar technique, for which the products rate can be lower than other methods. Besides, in some cases, the distinction between bipolar core/product may be ambiguous, since it does not always show the specific features of detached products (Prous & Lima 1990; Shott 1989; 1999). On the other hand, the lower percentage of flaking products may indicate that flakes were transported.

Table 1

Table 2

5.2. Raw materials.

The raw material is exclusively quartz, which has rolled down from thick tertiary fluvial spreading on the plateau. Only one flint element was recorded. The quartz that could be gathered on the surface of the diamicton are pebbles and cobbles linked to the alluvia, ranging in size from 15 mm to up to 20-30 cm long. They show a well-developed fluvial neocortex. The natural pebble sample mean size is 32.5x24.1x15mm (n=283). Only 23.3% of them are more than 40 mm long. The mean size of the knapped pebbles and cobbles is 53.3x46.8x34.6 mm and therefore the larger ones were selected for knapping. The morphology of the pebbles is variable but most are spherical and ovoid with a circular or oval section; many have flat surfaces (56.1%) with suitable natural angles for starting the reduction sequences. Others are polyhedral with flat or curved surfaces; some of them are parallelepiped with quadrangular cross-sections (39.48%). In the control sample ovoid and polyhedral morphologies represent 27.35% and parallelepiped 39.22%.

With respect to the morpho-structural characteristics of the Pont-de-Lavaud quartz lithological variability, it is dominated by the grainy Morphostructural groups (YN, YY, totaling 53% of the sample), specially related to medium and small ovoid pebbles. The

aggregated crystals have plurimillimeter size. On the other hand, the NY Morphostructural group is generally related to the weathered vein quartz fragments. The NN group is scantily represented in the natural sample, but in the archaeological record artefacts with absence of internal flaws or cleavage planes is remarkable (27.1%). Although the overall lithic assemblage reflects the natural occurrences of quartz types and morpho-structural groups at the Pont-de-Lavaud site, the size and morphology of the pebbles and cobbles provide clear evidence of selection.

The fluvial nature of the pebbles and cobbles accounts for the partial elimination of internal flaws. In the vein quartz blocks, however, they are more frequently present, preventing breakage control during knapping. Despite the type of raw material and the presence of some internal flaws, the pebbles are suitable in size, morphology, homogeneity and quality for long and structured knapping reduction sequences, as shown by the presence of a bifacial centripetal core (Figure 8.5). On the other hand, the high tenacity of the pebbles requires the implementation of force to initially break them. Thus, although bipolar reduction has been traditionally considered to be a means of overcoming the raw material's limiting factors, such as the quality and dimensions of pebbles (Bordes, 1947; Crovetto et al. 1994a; Hardaker, 1979), at Pont-de-Lavaud, the raw material's characteristics cannot be considered to be major factor limiting the application of reduction sequences that are more complex than the bipolar percussion.

Although grainy morphostructural groups (YN and YY) are the best-represented quartz varieties, there is no direct relationship between morpho-structural groups and lithic categories (Table 1). A higher incidence of the macrocrystalline groups (NY and NN) is only observed for the configured tools, possibly linked to the higher functionality and efficiency of their cutting edges (de Lombera et al. 2011).

5.3. Percussion and passive elements. Hammerstones and anvils.

Only 4 percussion tools were identified: one hammerstone, two anvils and a passive hammerstone. The hammerstone is a quartz cobble measuring 85x59x52mm. It offers a good manual grip and the arrangement of the battering marks, clustered in the lateral and distal part of the pebble, indicate its function as a freehand hammerstone. It also bears some crushing marks and pits in the proximal edge, indicating a second active zone, also possibly linked to freehand percussion. No percussion marks were identified on the flat and central faces or at the edge of the pebbles, which are considered to be direct indicators of the bipolar-on-anvil technique (Roda et al. 2012; Prous & Lima, 1990).

Large blocks were selected to be used as anvils. One of them is a fragmented rounded pebble measuring 136x127x60mm, while the other is a large angular block of vein quartz measuring 210x150x75mm. They are parallelepipeds; a shape that guarantees

the stability of both the anvil on the ground and the core on the anvil's upper surface. These anvils have clear battering and percussion marks clustered in the centre of their flat upper surfaces (Figure 5).

In these cases, the percussion stigmas identified on the anvils' passive faces consist of clustered Hertzian cones that could be explained either by interactions between the hammerstone and the anvil when blows missed their targets or core-anvil interaction. The light percussion wear could be explained by the fact that the scarce recurrence of the reduction series produces a reduced number of blows per core, so that the damage on the anvil surfaces is minimized, and only small crushing marks are visible in those areas where recurrent blows were made. We must not reject the possibility that microscopic stigmas may be present (Vergès & Ollé, 2011), but the lower magnification approach used for this work does not allow us to identify them. Those features produced when an intensive reduction of core volumes has taken place (Roda et al. 2012; de la Torre et al. 2013) are therefore not very well developed here.

On the lower faces of the anvils –which lay on the ground–, some chipping and crushing is visible on ridges. Although the elasticity of the ground prevented from scars forming (vg. de la Torre et al. 2013), in this case, the stigma are only present in certain segments of the ridges, indicating the punctuated contact points with harder materials on the ground (ie. other pebbles). In some cases, they might be the result of short removals on the lateral faces of the anvil, but in other cases, their technical axes are perpendicular to the anvil's surface, that is, they appear on the upper faces, so that they must be related to another kind of activity and not to a knapping percussive action (i.e. Mora & de la Torre 2005).

Figure 5

Finally, a large block of quartz used as a passive hammerstone was discovered at the site that had been driven vertically into the Pont-de-Lavaud-1 structure. The upper ridge shows heavy battering marks (Despriée et al. 2009: 133). Its upper convex surface prevents from obtaining a suitable stable surface to properly settle the core, thus, discarding its functionality as a bipolar knapping anvil (Despriée et al. 2009; 2010).

We must bear in mind that those objects might have been multifunctional and perhaps also linked to pounding activities on organic materials (Goren-Inbar et al. 2002; Mora & de la Torre, 2005). However, given the features of the knapping products, the characteristics of the stigma identified in the passive percussion elements and the replicate data obtained in our experimentation program, we consider that these items were mainly used in percussive knapping sequences rather than other tasks such as processing organic materials (see also Díez et al. 2009).

5.4. Reduction methods.

Several Knapping methods were identified in the Pont-de-Lavaud lithic assemblage, linked to two different techniques: freehand percussion and bipolar-on-anvil reduction. The anvil technique was not identified in this sample (apart from the anvil previously described).

With respect to freehand percussion elements, three methods have been identified on the cores (unipolar longitudinal, centripetal and orthogonal), linked to unifacial and bifacial strategies and making use of the natural surfaces of the pebbles and cobbles as striking platforms. Cores were initially reduced by a series of parallel removals (Unipolar Longitudinal method, cf. SDDA (Forestier 1993) producing knapping products with cortical striking platforms and natural backs. Some cores present evidence of a few, isolated removals without a structured scheme (7.32%). In these cases, short series of removals were carried out, yielding a mean number of 3.5 negative scars per core. Most of the cores were abandoned during the initial stages of reduction (71%), with most of the cortical surfaces being retained. Large elongated cobbles were preferred to those on which bipolar knapping was applied (Table 3 and Figures 6 and 8). When the reduction sequences continued, bifacial strategies were developed through orthogonal and centripetal methods, alternating the knapping surfaces. In the case of the only centripetal core, bifacial reduction was implemented along the whole perimeter of the core.

Table 3

Figure 6

For bipolar-on-anvil percussion, five different methods were defined on the basis of three major features: (1) the position of the pebbles longest axis with respect to the anvil surface (horizontal or vertical); (2) the morphology of the knapped segment (rectilinear, convex, uni-angular/pointed), and (3) finally, the recurrence of the reduction series and number of blows (impact points identified on flake's dorsal surfaces and cores) (Figure 7).

Figure 7

1) Bipolar-on-anvil recurrent with rectilinear or convex edges (Bipolar A) (n=28).

Quartz cobbles were struck perpendicular to their longest axis (horizontal) with recurrent removals from the same striking platform, which yielded products with rectilinear or convex edges. The thicker cobbles were selected (Table 3) in order to produce longer products. The reduction may have focused on exploiting a single cortical platform through unipolar longitudinal removals and bipolar opposed series. In such cases, the reduction series could affect up to half of the core's periphery (35.7%). Because of the anvil's counterstrike, most of these cores show evidence of opposite removals on their knapping surfaces (96.4%). The cores were abandoned at an advanced stage in the reduction process (after 75% of it) and have more impact points on their edges (mean: 2.15) (Figure 8). Flakes show evidence of cortical striking platforms, lateral cortical residues, and removals from their dorsal surfaces in parallel or opposing directions. In some cases, flake morphologies are similar to those made by freehand percussion but they are often more overstruck and overshoot.

Figure 8

2) Bipolar-on-anvil recurrent with uniangular edges (Bipolar B) (n=12). As in the previous case, quartz cobbles were laid horizontally on the anvil. Reduction sequences were applied to two adjacent segments of the core, usually following the pebble's longitudinal and transversal axes. The reduction series therefore affected nearly half the perimeter of the core (33.3%) and generated the highest number of impact points (mean number ranging from 2.4 to 2.8) (Figure 9). The removals from the knapping surfaces were carried out in opposite directions and at abrupt angles (83.3%). Flaking products are similar to those previously defined.

3) Bipolar-on-anvil with uniangular edges (Bipolar C) (n=13). Quartz pebbles were laid with their longest axis resting on the anvil, but only one blow was applied to fracture them. In this respect, the upper face, struck by the hammerstone, has a single impact point, and the fracture surface has angular morphologies. The lower face (in contact with the anvil) may present one or several impact points depending on topographies of the anvil and the lower face of the core. Usually, when contact between the two was made at a single point, the surface of the core has a split fracture with a fissure connecting both impact points (Figure 9). When the anvil's topography was irregular there may have been several contact surfaces below the fracture plane. Therefore, counterstrikes from the anvil may have produced several impact points and breakage planes, which generated more flakes.

Hence, a single strong blow must have been made in order to fracture the pebbles (split fracture). Fracture processes were therefore uncontrolled and caused multiple breakage planes and pointed morphologies on both cores and flakes. In this case, the strike and counterstrike points were not aligned in the same fracture plane (non-axial

percussion). In some cases, the hammerstone blow may have been ahead of the anvil's counterstrikes, generating pointed morphologies, that is, with a positive angle with respect to the transversal axis (with mean values of 104°). On the other hand, when the anvil's contact points were behind the hammerstone impact point, bi-pointed morphologies could have been obtained (negative angles with mean values of 145°) (Figure 9).

Figure 9

4) Bipolar horizontal rectilinear (Bipolar D) (n=66). Cobbles were also laid horizontally on the anvil and knapped on their longest axis and only one blow was used to break it. The impact and counterstrike points were aligned (axial percussion), so that a flat and rectilinear fracture plane was obtained. A split fracture/fissure might appear along the plane connecting both impact points. In a few cases, these surfaces were used as new striking platforms for removing one or two more products in the transversal axis of the core, which created a pointed end. For this purpose, thinner cobbles were selected (29.7 mm in average). Flakes were thick, and often overstruck and overshoot, with cortical residues on the dorsal faces. Refits show that the knapping sequences were based on reducing the mass of the core, since the blows were applied deep inside the core mass instead of focusing on the edge of the platform, providing thick blanks (Figure 10). There might have been some recurrence of the reduction series, but this is not reflected on the core's knapped perimeter and morphologies or in the number of impact points that remain (1.6).

Figure 10

5) Bipolar-on-anvil axial/vertical (Bipolar E) (n=17). Pebbles were settled on the anvil on their longest axis and knapped parallel to it, creating longitudinal or bipolar opposing removals from both poles of the same flaking surface. On small and medium-sized pebbles (Table 3), two opposing series of removals appear to be a response to the effects of both the hammerstone and the anvil. In some cases, especially on the shortest ones, the pebble was split into two equal parts (*hemilithic*) (Prou & Lima, 1990; Shott, 1989). On the other hand, on large pebbles, when the elastic response of the anvil was not sufficient to start a breakage/fracture plane, only a removal from the hammerstone strike was detached, and the only evidence of a response from the anvil is the presence of battering marks on the lower surface (Mourre, 2004) (Figure 9). In this method, few blows were applied, as the number of impact points visible is low (mean values ranging from 1.1 to 1.6), and 95.7% of the cores show evidence of a unifacial series and an incipient reduction stage. The vertical reduction of pebbles was therefore more expediently applied, and fewer flaked products were obtained per core

than at other archaeological sites where this method has been identified (Mourre, 2004).

Flakes had reduced striking platforms (punctiform and lineal), as the area interacting with the hammerstone and anvil was small. Because few blows were applied to these cores, the dorsal surfaces show a predominance of cortical remains. Bipolar products preserve two opposite impact points on their ventral surfaces, with clear knapping stigma. In some cases, flakes may have punctiform or lineal striking platforms and feather or hinge terminations. They are similar to those products obtained by freehand percussion but presents crushed ridges on the striking platforms.

5.5. *Flakes and products.*

In our population series 1, 77 lithic objects were identified as knapping products (flakes, broken flakes, flake fragments and chunks), representing the 29.77%. As stated before, the difficulties in terms of differentiating between cores and flakes must be kept in mind when dealing with bipolar-on-anvil reduction. On the other hand, given the technical characteristic of the two main “*chaines opératoires*” identified in the site, the features of bipolar flakes may not really differ from flakes obtained by freehand percussion. The reduction sequences were based on the volumetric management of the cores’ surfaces. Recurrence of blows per core was rare, and they were never directed at reduced interaction surfaces (ridges or points). Thus, flakes have thick striking platforms (mean thicknesses of 19 mm). 86.6% of the flakes have a platform surface and only 13.3% have lineal or punctiform platforms. Besides, the non-recurrence of hammerstone blows on the same area prevented the formation of the diagnostic battering and crushed ridges on a flake’s striking platforms.

The mean size of the whole flakes is 35.42x38.38x17.78 mm. They are slightly wider, as reduction methods were based on using the pebble’s shortest axis (thickness) as a flaking surface. The absence of platform preparation and the use of natural surfaces as striking platforms explain the high presence of cortical remains on striking platforms (81.67%) and dorsal surfaces (95%). Ventral faces are rectilinear (50%) or concave (27%), with no clear bulbs of percussion. In some cases, especially on small pebbles knapped vertically, two opposite impact points can be observed at the same fracture plane (Figure 11).

The scarcity of knapping accidents stands out. This may have been due to the knapping techniques used or internal flaws in the quartz, although bipolar-on-anvil reduction is defined by high percentages of hinge or step terminations, as well as a high incidence of broken flakes (FBP) and chunks, specifically in quartz assemblages (Eren et al. 2013; Kuijt et al. 1995). This fact may be related to the idiosyncratic nature of the reduction methods defined before, with low reduction intensity, a low core to product ratio, and the high quality of the quartz pebbles. Interestingly, others experiments have noted

that quartz bipolar-on-anvil knapping produces more diagnostic and complete flakes (Driscoll 2011b; Callahan et al., 1992, in Tallavaara et al., 2010). Although most of the flakes are overstruck and overshoot, 61.1% of the flakes of our corpus have with suitable potential shapes, especially with single (35°-55°: 38.3%) or semi-abrupt (55°-75°: 10%) dihedral cutting edges. Some pointed morphologies were also obtained (3.33%).

Figure 11

5.6. The shaped and retouched tools.

The tools in the sample represent only 9.1% of the assemblage, in which 18 tools were made from pebbles, 4 from flakes, and there are 2 for which the type of blank cannot be recognized. The mean size of the pebble tools is 72.8x62.8x30.9 mm, while in the case of the retouched flakes the mean size is 67x64x21 mm. The shaping was focused on the lateral faces of the pebble with unifacial, direct, marginal, and semi-abrupt removals that provided continuous or denticulated cutting edges. Typologically, the bigger pebble tools are classified as a chopper and a pick (Figure 12). On the other hand, the medium-sized and flat pebbles are classified as notches (n=4), denticulate (n=1) and side-scrapers (n=4).

The retouched flakes are included in the abrupt (n=1), notch (n=1), denticulate (n=1) and sidescraper (n=1) types (Figure 13). With respect to the morpho-structural varieties of quartz and the selection of blanks, the occurrence of the non-grainy groups (NY and NN) is higher than in the other lithic categories, linked to the higher efficiency of their cutting edges (de Lombera et al. 2011) (Table 1).

Figure 12

Figure 13

6. Discussion. The bipolar-on-anvil technique at Pont-de-Lavaud and Pleistocene hominin technology.

6.1. General features of the Pont-de-Lavaud Lithic assemblage.

The technological features of the lithic assemblage of the Pont-de-Lavaud site point to two main, expedient strategies of bipolar and freehand percussion. Several methods for the bipolar-on-anvil technique were observed. They are characterized by a low number of removals per core as well as the limited number of percussion stigmas, whether on active or passive supports. Pebbles were selected, as suggested by their size (40-70 mm) and morphologies (ovoid or polyhedral), and reduced through short

reduction sequences in order to obtain thick end-products with suitable cutting edges. Larger pebbles were managed by longer reduction processes and direct percussion (Table 3). Neither intense reduction through bifacial series, nor rotation of the cores to create new striking surfaces were identified. There was therefore no attempt to exercise volumetric control during knapping sequences. This is directly reflected in the absence of standardization and predetermination of flaking products whatever the methods, although the bipolar reduction does, however, produce foreseeable morphologies (Mourre, 2004; Prous & Lima, 1990).

Core reduction sequences were focused on producing flakes with functional lateral cutting edges rather than blanks for further retouching or shaping purposes (only four retouched flakes were identified in the sample), which points to the immediacy of functional goals. This is a common feature of Eurasian Mode 1-type industries (Mosquera et al. 2013). The under-representation of complete flakes in the assemblage could be explained by the intensity of breakage of the products due to quartz and methods, or by exportation from the site of products with suitable cutting edges and morphologies.

Regarding the relationship between the quartz morphostructural groups and reduction methods, the knapping methods were selected in accordance to the quartz texture. The simplest method (bipolar rectilinear) was applied on those pebbles with marked internal flaws (NY and YY groups, 21.9% and 15.24%, respectively), possibly to avoid knapping accidents or because the results did not permit to continue. Freehand percussion was preferred on pebbles with a grainy texture (YN and YY groups) due to the conchoidal fracture patterns of this kind of texture allowing better knapping control (de Lomberra, 2009; Mourre, 1996) (Figure 14 and Table 1). Thus, we may observe a sort of raw material selection by the morphological and petrographic characteristics and functional properties of the quartz.

Figure 14

The Pont-de-Lavaud lithic assemblage is defined by the exclusive use of quartz and the generalized use of some main expedient knapping techniques and methods. Although complexity does not seem to be a characteristic of the core technology at the site, there are some trends in terms of pebble selection and knapping methods that reinforce the idea that the technological behavior belong to a same concept.

The widespread use of the bipolar-on-anvil technique at Pont-de-Lavaud is quite remarkable within the framework of the European Lower Pleistocene. For example, in some neighboring and contemporaneous sites, such as Lunery, bipolar products are almost absent (Despriée et al. 2010). Although this knapping technique is known at other Lower Pleistocene Eurasian sites, its large role in this lithic assemblage must not

be only considered as an epiphenomenon within the technological behavior of Lower Pleistocene hominins. Besides, despite this apparent technical homogeneity, constrained by the raw material and techniques principally used, the Pont-de-Lavaud lithic assemblage shows wide internal variations that reflect the technological knowledge and flexibility of European Mode 1 populations.

6.2. The Bipolar-on-anvil technique in the African and Asian context.

Other Lower and Early Middle Pleistocene sites have allowed us to outline some aspects of the technical variability of the Mode 1 and Mode 2 populations, as well as the specific role of the bipolar-on-anvil technique in the hominins' technical repertoire as an adaptive strategy. Interestingly, given its similarity with ape's percussive behaviors this technique has been proposed as one of the earliest hominine knapping techniques for the achievement of sharp stone tools (vg. Putt, 2015; Wynn et al. 2011). In fact, the recently published lithic assemblage from Lomekwi 3, dated in 3.3. Ma, is interpreted as the technological stage between the pounding oriented stone tool use and the earliest flaking oriented knapping behavior (Harmand et al. 2015).

The bipolar-on-anvil technique is absent from the Oldowan lithic assemblages dated to 2.4-2.6 Ma (Kada Gona and Lokalelei) (Semaw, 2000; Roche et al. 1999). The reduction sequences in these assemblages show developed technical skillfulness with long and complex operational chains (Delagnes & Roche, 2005), far from the chimpanzees' tool making and the lithic tools from Lomekwi 3 (Harmand et al. 2015; Schick et al. 1999; Toth et al. 1993). Those assemblages would represent an evolved stage in early hominin technology (Carbonell et al. 2009). Thus, if we consider the bipolar-on-anvil technique to be one of the links between early hominin technology and primate strength-based activities, we should expect to find such products at the earliest sites, as Lomekwi 3 proves.

The bipolar reduction has been documented in the Eastern African archaeological records at *circa* 2.3 million years old, such as at AL 666 in Hadar (Ethiopia) and several *loci* from the Member F of the Omo formation (Boisserie et al. 2008; de la Torre, 2004, Goldman & Hovers, 2012) (Table 4). In these cases, bipolar reduction usually played a complementary role in knapping techniques. In other cases, it may have become the main technique applied, such as at Senga 5A (Zaire), where the only available raw materials were small quartz pebbles (Ludwig & Harris, 1998: 90; Hovers, 2003). However, we must be cautious about the possible intrusive character of the lithic assemblage and its direct relation to the Lower Pleistocene faunal record (Harris et al. 1990; Tappen & Harris, 1995).

Bipolar reduction has also been identified in the lithic assemblages of FxJj 3 (Koobi Fora) (Ludwig & Harris 1998), as well as at Member 5 of Sterkfontein (South Africa) (Kuman, 1998), the latter possibly linked to an abundance of quartz close to the site.

In the Upper beds of Olduvai (Bed III and IV) the presence of pitted anvils was firstly related to the production of *outils écaillés* and bipolar knapping (Leakey & Roe, 1994; Jones, 1994). However, according to Mora & de la Torre (2005) the stigmata identified in the pitted anvils and stones recovered from the Lower Beds (Bed I and II) must be considered as by-products of other subsistence activities such as breaking bones, smashing nuts and processing diverse organic elements rather than lithic production activities. Nevertheless, other authors, based on experimental approaches, claim that these objects must be linked to knapping activities that played a relevant role in the lithic assemblages of FLK and BK from Olduvai Bed I and II (Díez et al. 2009, 2011). As this technique is almost only applied to quartz, it is considered as a technical adaptation to the constraints imposed by the uneven quartz fracture pattern and blanks' morphologies and sizes (Díez et al. 2011).

Table 4

Outside Africa, in the Levant, bipolar reduction has been identified at several archaeological sites of the earliest phases of settlement, for instance at Bizat Ruhama (Israel, Zaidner, 2013) (Table 4). In this case, it is related to a maximum use of small flint nodules and to systematic secondary flaking in order to produce small flakes. The pitted anvils from Ubeidiya and Gesher Benot Ya’aqov have been interpreted as evidence of subsistence activities such as cracking nuts (Goren-Inbar et al. 2002) and are not related to lithic production.

In Eastern Asia, evidence of this technique has been detected at several Early and Early Middle Pleistocene sites, where the lithic supply is basically restricted to quartz and poor quality flint or limestone nodules. At the archaeological site of Longgupo (Central China, 2.2 Ma) (Han et al., ip), this technique has been identified on 17% of the recovered artifacts, made on limestone. As they are defined by short reduction sequences (Boëda and Hou, 2011), there are some questions about the anthropic origin of some of the artefacts. At the nearby site of Longgudong, dated at around 2.1-2.4 Ma (Shi et al., 2007), the bipolar reduction played a complementary role of producing small flint implements (Dong, 2006; Hou & Zhao, 2010).

In the Nihewan Basin (Northeast China), several Lower Pleistocene sites have yielded evidence of bipolar reduction, particularly the sites at Xiaoxangliang (1.36 Ma) and Donggutuo (1.1 Ma) (Hou, pers. comm.; Liu et al., 2013) (Figure 15). According to Shen et al. (2010), this technique was probably used to overcome the high incidence of internal flaws in the local flint outcrops. In this sense, the lack of this technique at the Cenjiawan site (1.1 My), only 1,500 m from the aforementioned ones (Shen & Qi, 2004) is explained by the higher quality and finer-grained local chert varieties.

Figure 15

In Locality 1 at Zhoukoudian, the presence of bipolar reduction is observed throughout the whole sequence. It has been interpreted as a strategy to optimize poor quality raw materials, especially quartz (Shen & Qi, 2004), while quartzite and basalt were preferred for making heavy duty tools and percussive items (Figure 15). Nevertheless, a higher degree of selection of supports by their quality is observed through time. Artifacts from the upper levels are made from better quality blanks than for the lower part of the sequence (Leng, 1998), whereas the frequency of bipolar reduction seems to remain constant. At Locality 1, the quality of raw materials must not therefore be considered to be the only factor to explain the presence of the bipolar reduction throughout the whole sequence. At the nearby Locality 15 (155-284 Ky, Shen et al. 2004), the lithic assemblage is also dominated by quartz and evidence for the use of the bipolar reduction is very scarce. According to Gao (2000a), its low frequency at Locality 15 may be linked to a higher degree of skill of hominins using the freehand percussion technique. Here again, cultural or cognitive causes are claimed.

In the Bose Basin (South China) bipolar reduction is generally present at the various sites (Xie & Bodin, 2007), but playing a secondary role, especially in the Mode 2 lithic assemblage from Fengshudao (Zhang et al. 2010). In this region, the raw materials available are medium and large quartzite cobbles, possibly suitable for freehand percussion.

Overall, according to Gao (2000b), the common features of the presence of the bipolar technique in lithic assemblages from Northern China are: 1) a complementary role in most of the lithic assemblages, despite the Zhoukoudian Loc 1 site; 2) the bipolar reduction is mostly applied to quartz; 3) the bipolar products are small; 4) most of these artifacts were not retouched, which indicates that the main aim of the reduction sequences was to obtain suitable blanks. These features are also observed at several Late Middle and Early Upper Pleistocene sites in South and North China, where the bipolar-on-anvil reduction has also been linked to assemblages on quartz or poor quality flint. On these bases, some authors consider this feature as proof of cultural continuity through the Asian Pleistocene (Chen et al. 2010; Derevianko, 2011; Pei et al. 2013).

6.3. The European context.

In Europe, the bipolar-on-anvil technique is present in the earliest European occupations - to which the lithic assemblage from Pont-de-Lavaud must be compared. It has been reported in the Lower Pleistocene records from Monte Poggiolo in Italy (Peretto et al. 1998), Fuente Nueva 3 and Barranco Leon (Orce), TD6 level of Gran Dolina (Atapuerca) and Vallparadís, in Spain (Carbonell et al. 1999; Martínez et al. 2010; Oms et al. 2000, Toro et al. 2011). Interestingly, at the lower levels from Sima del

Elefante (Atapuerca, Spain), dated at 1.22 Ma, the bipolar-on-anvil technique has not been identified (de Lombera et al. 2015). Flint is the main raw material used at these sites and both bipolar-on-anvil and freehand technique are usually present, playing different roles in the lithic production (Table 5). Only at Vallparadís, quartz is the predominant raw material. Another common feature is the dominance of simple *debitage* products such as flakes, cores and rare retouched tools. They therefore fall within the European Mode 1 techno-complex (Mosquera et al. 2013).

At Orce (Southern Spain), the sites of Fuente Nueva 3 and Barranco León are dated between 1.4 to 1.3 Ma (Toro et al. 2011, 2013; Oms et al. 2000). At these sites, differential use of raw materials has been documented. Flint was used for recurrent processes to produce blanks, while limestone blocks were mainly devoted to percussion activities (Barsky et al. 2015). The bipolar-on-anvil technique is predominant among the reduction sequences, and was exclusively used on small and semi-rounded flint nodules with parallelepiped morphologies. These were knapped by recurrent unifacial or bifacial series, sometimes rotating the percussion surfaces and producing cube-shaped cores. It is also noteworthy that the freehand hard-hammer technique was also punctually used (Barsky et al. 2010).

Table 5

At the Monte Poggiolo site (Forlì, Italy), dated to around 1 Ma by paleomagnetism and ESR (Peretto et al. 1998, Falguères, 2003, *contra* Muttoni et al., 2011), the bipolar-on-anvil technique is mostly used in the first stages of the core reduction sequence. The aim was to open and create a percussion platform (split technique) on spherical flint cobbles for freehand percussion (Azzarello & Peretto, 2010). Bipolar reduction (axial method) was punctually used to produce flakes.

The *H. antecessor* occupations at the TD6 level of the Gran Dolina cave (Atapuerca, Spain) have been dated by biostratigraphy, paleomagnetism and ESR to around 0.8-0.9 Ma (Parés et al. 2013; Berger et al. 2008). Although the bipolar-on-anvil technique was not identified in the initial studies of the lithic assemblage (Carbonell et al. 1999), new and updated data show that this technique is punctually present and only applied to quartz, as a complementary technique to freehand percussion (Ollé et al. 2013). At this site, the cores were reduced by orthogonal and not recurrent strategies, providing thick flakes.

The site of Vallparadis (Girona, Spain) has yielded a rich lithic assemblage that is mainly made up of quartz and dated to around 0.9 Ma (Martínez et al. 2010). The bipolar-on-anvil technique was widely used, mainly on small cubic or polyhedral quartz clasts that were easily available close to the site (García, et al. 2013). The axial method was

mainly used, few recurrent, often giving flakes with cortical butts and dorsal backs. Two knapping modes were identified on the number of platforms and rotations of the core. In the final stages, these modes generated polyhedral and cubical core morphologies. It is important to note that retouched tools such as denticulates and notches, becs or pointed tools are well represented, as at the other Lower Pleistocene sites (Barsky et al. 2013; García et al. 2013), although some of them could be considered as pseudo-retouched tools or by-products of the bipolar reduction, as noted at Bizat Ruhama and Isernia (Crovetto et al. 1994b; Zaidner, 2013).

The lithic assemblage from Isernia La Pineta (Italy), dated to around 0.65 Ma (Coltorti et al. 2005), has been widely studied using experimental and techno-typological analyses (Crovetto et al. 1994a; Gallotti & Peretto, 2015). Differential raw material management has been documented: flint slabs and semi-rounded fragments used for flake production processes, while limestone blocks used for percussion and shaping. The bipolar-on-anvil technique was mainly used, but the freehand method was also employed. However, when the latter was used, the main aim was to obtain blank-flakes to be reduced by the non-axial bipolar method. The bipolar-on-anvil technique is frequently documented from the initial stages of the operational sequence (Crovetto et al. 1994a). A combination of the two knapping techniques throughout the different stages of the *chaîne opératoire* has therefore been documented here. The bipolar reduction was applied for systematic secondary flaking in a similar way to what was described for the Lower Pleistocene site of Bizat Ruhama (Zaidner, 2013).

Slightly younger than Isernia, the P levels of the Arago site (Tautavel) in France has been dated to around 0.55 Ma by climatic correlation with the radiometric dates of the basal stalagmitic floor (Falguères et al. 2015). This level is therefore one of the oldest Acheulian sites in Europe. The lithic assemblage is characterized by a wide diversity of rocks, but quartz is the dominant raw material (Barsky & de Lumley, 2010; Barsky, 2013). The mainly used supports are semi-rounded quartz pebbles and large thick flakes with parallelepiped forms. The cores were orthogonally rotated during reduction, yielding cubic and pyramidal morphologies. The freehand hard-hammer technique was also used.

6.4. The role of the bipolar-on-anvil technique in the Lower Pleistocene and the Early Middle Pleistocene.

The archaeological record from the Lower and Early Middle Pleistocene sites show a wide range of bipolar-on-anvil methods. This is firstly reflected by the different roles played by the bipolar technique in the archaeological records. It is also an adaptation to different constraining factors such as the availability of lithic resources, their mechanical properties and the sizes and morphologies of the available supports. We observe large varieties of bipolar knapping methods (axial, non-axial, recurrent, etc.), often chosen to suit the initial forms of the supports and possibly the purposes of the

reduction sequences. The bipolar-on-anvil technique generally plays a complementary role (Table 4 and 5). Freehand percussion is preferred on large pebbles or fine-grained stones (basalt, quartzite, flint...) and for applying more complex and long methods (centripetal, orthogonal, etc.) (Omo, Fejej FJ-1a, Zhoukoudian Loc 1, etc.). Bipolar percussion was principally used for expedient reduction of poor quality materials to produce for instance small flakes (i.e. Barsky, et al. 2013; Shen et al. 2010; de la Torre, 2004). This technique was also applied as a technical option to open striking platforms on large cobbles, as in the case of Monte Poggiolo (Arzarello & Peretto, 2010). This technical behavior implies a selective management of lithic resources, reflecting a high level of knowledge of the mechanical and functional properties of different raw materials for the Early Pleistocene hominins (Braun et al. 2009). When it plays a dominant role, as at the Pont-de-Lavaud site, bipolar strategy is linked to an expedient reduction of local resources (especially quartz and flint or even limestone) defined by the presence of internal flaws (e.g. BK, Isernia, Bizat Ruhama, Xiaoxangliang, Donggutuo) or the small size of pebbles that limits knapping by freehand percussion (Senga 5A, Orce and Vallparadís). In these cases, bipolar reduction becomes a technological option in answer to the constraints imposed by the lithic resources available close to the sites. Freehand percussion is also applied in order to develop more complex operative sequences on some supports. Some random connections between these two knapping techniques can be identified in some cases (Díez et al. 2009). Nevertheless, on the basis of the quality of the raw material, at the Pont-de-Lavaud site, the use of this technique must be understood as a technological choice rather than determinism imposed by the raw material.

Some authors claim that there is a direct relationship between the bipolar-on-anvil technique and quartz-based assemblages (Bordes, 1947; Díez et al. 2011). This raw material would be too difficult to flake. It tends to shatter along cleavage planes, yielding abundant debris or angular chunks (Tallavaara, 2010). Experimental approaches have nevertheless shown that quartz is highly amenable to bipolar knapping, providing greater efficiency in terms of cutting edge length per mass than other raw materials, such as basalt (Gurtov et Eren, 2014). When the two percussion techniques are applied to quartz, no significant differences in edge cutting characteristics and functional capabilities in terms of efficiency are observed (Díez et al. 2011; Jones 1994: 286). On the contrary, the little use of the bipolar reduction at Zhoukoudian Loc 15, linked to a better selection of the quartz in term of quality (Gao, 2000a), as well as the complementary role of this technique in other quartz-based assemblages (Barsky et al. 2011; de la Torre, 2004), seem to refute a straightforward relationship between this knapping technique and quartz. This premise is based on a presumed homogeneity of quartz, but we must take its variations into account (de Lombera et al. 2011; Llana & Villar, 1996, Driscoll, 2011b).

Despite the apparent technical homogeneity of bipolar reduction, there are considerable differences between the methods on the basis of the percussion axis, core rotation and recurrence of removals series (Mourre, 2004; Honea, 1965; Binford & Quimby, 1963). Because of its low technical requirements or because it was not necessary, cores are exploited without prior preparation of the striking platforms or volumes. At Pont-de-Lavaud the choice of method is related to the form and size of the original pebbles. Vertical axial bipolar reduction is the most widely used, because it is the only way to open and work small ovoid pebbles. When thin and small ones are intensively knapped, they yield small rectangular and thin cores, as well as thin flakes with crushed and lineal/punctiform striking platforms. In some cases, opposed striking platforms and percussion waves are preserved with the typical features of the “Bipolar products” (i.e. Shott, 1989). There is no core rotation and a high striking recurrence on the same striking platforms with no breakage control or precise location of the loading point. This kind of product has been identified, for instance, at Nihewan Basin (namely Xiaochangliang) and Orce (Liu et al. 2013; Gao, 2000b; Barsky et al. 2013) (Figure 15).

When quadrangular or tabular morphologies are reduced, they usually produce cubic or polyhedral cores. The axis of core percussion can be either vertical or horizontal. In this case, the impact point is located on the edges and striking platforms rotate, progressively reducing the core mass and yielding orthogonal or polyhedral cores. The ratio of blows per core is lower, and some control of the core volume reduction can be achieved (*controlled bipolar-on-anvil percussion*, Barsky et al. 2011: 212). As the reduction is based at the edges, flakes present thicker striking platforms, similar to free-hand percussion with crushed edges and pits on the surface. Although transversal and radial fractures may occur, flakes may present opposing striking platforms (Díez et al. 2011; García et al. 2013). This method was the most frequently used at the Pont-de-Lavaud site, with volumetric reduction of the cores along their shorter axis (pebble slicing) providing thick flakes with sharp lateral edges.

Finally, non-axial percussion is observed in other archaeological records such as Donggutuo or at Nihewan Basin. The technological axis of the hammerstone/core and the core/anvil contact points are not aligned. The cores have a pyramidal morphology with elongated removals, sometimes laminar (Hou, 2008) yielding long and narrow flakes. This method is also observed in the lithic assemblages from Isernia la Pineta (Italy) and Bizat Ruhama (Israel), but in these cases the flakes are shorter and larger. They are defined by the presence of notches and denticulated pseudo-retouches produced by the anvil (Crovetto et al. 1994a; Zaidner, 2013; Vergès & Ollé, 2011).

We must keep in mind that the uneven description of the bipolar-on-anvil reduction methods in the literature makes it difficult to achieve diachronic, functional or regional comparison. All of them are present in the Lower Pleistocene records. When this percussion technique is predominant, there does not seem to reflect a regional

feature. For instance, in the lithic records of Pont-de-Lavaud and Vallparadís, several methods are identified combining axial, non-axial, vertical and horizontal percussion and yielding a broad variability of products. During the Lower and Middle Pleistocene, this technique was mainly applied to obtain lithic implements with different morphological features. Nevertheless, the change in the settlement dynamics during the Upper Paleolithic reflects new economic behavior. Increase in mobility is parallel to increase in the use of the bipolar-on-anvil percussion, aiming at improving the lithic resources and balancing time and energy costs (Eren et al. 2013: 254). Likely, the bipolar-on-anvil technique was therefore assimilated for recycling tools and toolkit maintenance in the Late Upper Pleistocene and Holocene records (Amick, 2007; Goodyear, 1993; Jeske, 1982, de la Peña and Vega, 2013)

7. Conclusions.

Wide technical variations can be observed in the lithic assemblage from Pont-de-Lavaud. One of these is the bipolar-on-anvil percussion. Five different methods have been described on the basis of: (1) the axis of percussion, (2) the recurrence of the knapping sequence, and (3) the final morphology of the core edge. The combination of these variables provides a wide morphological variety of cores and end-products. The aim of this technique is to produce thick flakes with suitable cutting edges, or/and to exploit some specific raw materials or forms of supports. Few retouched items have been observed. Most of them are denticulates and side scrapers. The raw material available close to the site is defined by the presence of several types of quartz supports (pebbles, eroded vein quartz fragments, etc.). The size and quality of these stones are not a significant impediment to the use of complex reduction sequences, as the presence of some bifacial centripetal cores seems to attest. The Pont-de-Lavaud lithic assemblage is one of the few sites, along with Vallparadís, where a technological choice is observed within the European Late Lower Pleistocene corpus with a large role of the bipolar-on-anvil percussion.

The bipolar-on-anvil technique has been traditionally considered as a poor alternative to freehand percussion, and used as reaction to the limitations of the raw materials. Nevertheless, this premise is not so straightforward, and the bipolar-on-anvil technique is applied in different contexts, on different materials and even as a technical option in some *chaînes opératoires*. Its high role in the lithic assemblage from Pont-de-Lavaud raises questions about the socioeconomic role of this technique in Lower and Early Middle Pleistocene technology, which was, in our opinion, greater than was previously indicated by some authors.

The Lower and Early Middle Pleistocene archaeological contexts provide a mosaic of operational, occupational and functional basis for this knapping technique. Its ubiquitous presence from both a diachronic and geographic point of view is an evidence of its considerable technical flexibility and versatility. Although it is not

generally present in the earliest hominin lithic records, its similarity with the percussion activities of apes could indicate a link between ape and hominin technologies. Bipolar-on-anvil percussion is one of the most widespread techniques in the Prehistoric technological repertoire and, despite its simplicity, it is a successful technical strategy for overcoming raw material and environmental constraints. This type of adaptive and flexible behavior could allow hominins to explore and conquer new territories.

Acknowledgments.

Fieldworks, excavation and geological studies at Pont-de-Lavaud site were supported by French Ministry of Culture (Programme 2: First Palaeolithic Settlements in the fossil fluvial deposits in the Middle Loire Basin). This research was supported by Ministerio de Educación y Ciencia, Dirección General de Cooperación Internacional y Relaciones Institucionales of the Spanish Government Grant (HF2007-0122) and experimentations were supported by the Council of the Region Centre (France). Geochronological and palaeoenvironmental data were obtained thanks to the Department of Prehistory, National Museum of Natural History, Paris, and the National Center of Scientific Research (UMR 7194) Paris. Thanks to Dra. Yamei Hou for allowing us to review the lithic assemblages from the Nihewan Basin sites and Zhoukoudian Localities in the IVPP (Beijing). The data from Chinese sites was obtained thanks to the AGAUR Generalitat de Catalunya CONE-3/2010 program (CONE30007) and co-funded by the Ministerio de Economía y Competitividad (CGL2012-38434-C03-03) and the National Science Foundation of China (No.41272033). A. L.-H. was beneficiary of a predoctoral grant from Fundación Atapuerca. We also thank the two anonymous reviewers for their suggestions and comments that have improved the manuscript.

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Figure captions:

Figure 1: A: Map location of the prehistoric sites in the relation to the Sheet I in the Crozant and Eguzon-Chanrôme area. B: Schematic cross-section in the Massif Central showing the location of Pont-de-Lavaud in the alluvial Sheet I (point). C: Stratigraphy of the site. 0-1: altered micaschist of the floor. 2: diamicton. 3: fluvial deposits. 4: modern soil.

Figure 2: Spatial distribution of the lithic artifacts and their relationship with the dwelling structures Pavement 1 and 2, according to Despriée & Gageonnet (2003). Below, sections of the vertical distribution of the artifacts within the dwelling structure. Note that the artifacts were lying on the stone pavement surface (discontinuous line) (plans by G. Gourcimault).

Figure 3: Photographs of the knapping stigmas and scars. Arrows mark the impact points and directions. 1) Impact point on a core showing proximal and radial fissures, as well as edge battering. 2) Edge battering on a bipolar core. Note the cascade of scars due to recurrent strikes. 3) Herzian cones on the lower surface of the core due to the anvil's response. 4) Impact point, radial and striking platform radial fissures. 5, 6 and 7) Radial and split fissures starting from the impact point. Number 6 is an experimental piece.

Figure 4: Refittings between cores and flakes. 1.) No percussion stigmas have been identified on the flake. 2) Refitting between the core (R0-178) and a flake (R0-160). Note that the flake shows a previous removal scar.

Figure 5. Photography of the anvil and detail of the Herzian cones on the upper surface.

Figure 6: Scatterplot of the technological length and width of the cores against the different methods identified in the lithic assemblage.

Figure 7: Schematic representation of the technical features (a-c) and bipolar knapping methods (d).

Figure 8: Quartz cores from Pont-de-Lavaud knapped following a bipolar-on-anvil recurrent technique, with rectilinear or convex edges (1-4), and freehand bifacial core, with centripal removals (5).

Figure 9: Bipolar-on-anvil quartz cores from Pont-de-Lavaud. 1: recurrent bipolar-on-anvil core with uniangular edges; 2, 3 and 4: Bipolar-on-anvil cores with uniangular edges; 5, 6, 7 and 8: Bipolar-on-anvil cores with axial/vertical removals.

Figure 10: Quartz cores from Pont-de-Lavaud, knapped with a bipolar horizontal rectilinear technique.

Figure 11: Quartz flakes from Pont-de-Lavaud.

Figure 12: Unifacial pebble tools on quartz from Pont-de-Lavaud, 1, 2 and 3: Chopper, 4: unifacial uniangular (pick).

Figure 13: Quartz tools, on flake (1, 3 and 4) and fragment (2), from Pont-de-Lavaud. 1: Abrupt; 2 and 3: denticulate; 4: sidescraper.

Figure 14: Representation of the knapping methods used for their quartz morpho-structural groups.

Figure 15: Flint bipolar cores (1-3) and flakes (4-6) from Xiaoxangliang. Quartz bipolar core (7) and flake (8) from Zhoukoudian. (Photos: A. Ollé/IPHES).

Table 1: Lithic categories and quartz morpho-structural groups at the Pont-de-Lavaud site. Artifacts with obvious knapping stigmas (Population 1).

Table 2: Lithic categories and quartz morpho-structural groups at the Pont-de-Lavaud site. Artifacts with diffused and ambiguous knapping stigmas (Population 2).

Table 3: Number of impact points, technological and morphological measures (in mm) of the cores for the knapping methods identified in the lithic assemblage.

Table 4: Technical features of the bipolar-on-anvil technique as used at the main African and Asian sites mentioned in the text.

Table 5: Technical features of the bipolar-on-anvil technique as used at the main European sites mentioned in the text.

Table-1

	Quartz										Flint %		TOTAL %	
	NN %		NY %		YN %		YY %		Indet %					
Hammerstones and Anvils					2	3,0			2	66,7			4	1,5
Cores	2	33,3	68	60,7	28	42,4	55	72,4					153	58,0
Pebbles tools			10	8,9	5	7,6	3	3,9					18	6,8
Retouched flakes	1	16,7	2	1,8	2	3,0	1	1,3					6	2,3
Broken cores			1	0,9	4	6,1							5	1,9
Entire Flakes	2	33,3	21	18,8	15	22,7	12	15,8					50	18,9
Broken Flakes			3	2,7	7	10,6	1	1,3					11	4,2
Flaking Fragments	1	16,7	6	5,4	3	4,5	4	5,3	1	33,3	1	100	16	6,1
Indet			1	0,9									1	0,4
TOTAL	6	2,3	112	42,4	66	25,0	76	28,8	3	1,1	1	0,4	264	

Table 1

Table-2

	Quartz										TOTAL	
	NN	%	NY	%	YN	%	YY	%	Indet	%		
Cores	1	50	41	66,1	57	54,3	52	74,3	1	33,3	152	62,8
Pebble Tools			1	1,6	6	5,7	2	2,9			9	3,7
Retouched Tools			1	1,6	2	1,9	1	1,4	1	33,3	5	2,1
Entire Flakes	1	50	16	25,8	36	34,3	12	17,1			65	26,9
Bronken Flakes			2	3,2	2	1,9	1	1,4			5	2,1
Flaking Fragments			1	1,6	2	1,9	2	2,9			5	2,1
Indet									1	33,3	1	0,4
TOTAL	2	0,8	62	25,6	105	43,4	70	28,9	3	1,2	242	

Table 2

Table-3

	Bipolar A (n=28)	Bipolar B (n=12)	Bipolar C (n=13)	Bipolar D (n=66)	Bipolar E (n=17)	Free-hand percussion (n=17)
Mean number of Impact points (surface 1)	2,15	2,4	1,25	1,62	1,11	3
Mean number of Impact points (surface 2)	1,94	2,8	1,37	1,14	1,44	0,5
Mean Morph. Length	69,79	67,83	34,59	56,35	46,74	65,12
Mean Morph. Width	52,68	53,75	28,47	45,01	34,63	47,88
Mean Morph. Thickness	35,61	34,08	18,94	29,77	25,37	33,24
Desvest Length	26,04	22,4	8,92	22,59	11,92	26,43
Desvest Width	14,8	16,8	6,48	19,78	13,06	22,94
Desvest Thickness	14,3	15,73	6,04	12,72	11,51	12,89
Maximum and Minimun length	160-25	115-40	51-21	145-25	74-31	136-31

Table 3

Table-4

Sites	Age	Technological Mode	Role of Bipolar Technique	Bipolar Method	Main objective	Raw Material	Blanks quality	Blanks nature and morphology	Blanks size	References
Lomekwi 3 (West Turkana, Kenya)	3,3 Ma	Mode 1	Complementary	Horizontal axial/non axial	Obtain flakes	Basalt, phonolite.	Regular	Cobbles and blocks	Large	Harmand et al., 2015
A.L.666 (Hadar, Ethiopia)	2,36 Ma	Mode 1	Complementary	n/a	Obtain flakes	Quartz (no dominante)	Good	n/a	Small	Goldman-Neuman & Hovers 2012
Omo123, FtJi 1, FtJi 2, FtJi 5 (Omo member F, Ethiopia)	2,33 Ma	Mode 1	Complementary	n/a	Obtain flakes	Chert (quartz?)	Regular-bad	Irregular fragments or fragments of small pebbles	Small	Boisserie et al 2008 De la Torre 2004
Senga 5A (Zaire)	2,3 Ma	Mode 1	Leading	n/a	Obtain flakes	Quartz	n/a	Pebbles	Small	Ludwig & Harris 1998
Longgupo (China)	2,2 Ma	Mode 1	Complementary in general, and leading to obtain flakes	Splitting the pebble in its long axis	Obtain flakes	Limestone (91%), volcanic rock	Regular-bad	Blocks and pebbles	Large-Medium	Boeda & Hou 2011
Sterkfontein Member 5 (South Africa)	2-1.7 Ma	Mode 1	Complementary	n/a	Obtain flakes	Vein Quartz (91%)	n/a	Pebbles, cobbles	Small and large	Kuman 1998
Fejej FJ-1a (Omo, Ethiopia)	1.9 Ma	Mode 1	Complementary	Vertical/horizontal axial/non axial	Obtain flakes	Quartz (91%)	Good (¿)	cubic pebbles	Small	Barksy et al 2011
FxJj 3 (Koobi Fora, Kenya)	ca 1.8 Ma	Mode 1	Complementary	n/a	Obtain flakes	Quartz (no dominante)	n/a	n/a	Small	Ludwig & Harris 1998
FLK North (levels 1-6) (Olduvai, Upper Bed I,	ca 1,8 My	Mode 1	Complementary	Horizontal/vertical axial	Obtain flakes	Quartz (54%)	Regular-bad	Tabular blocks or slabs	Medium-small	Díez-Martín et al 2010,

Tanzania)										2011
Bizat Ruhama (Israel)	1,6 Ma	Mode 1	Leading	Non axial	Obtain flakes	Chert (100%)	Regular-bad	Pebbles	Small	Yeshurun et al 2011 Zaidner 2013
Xiaoxangliang (Nihewan Basin, China)	1,36 Ma	Mode 1	Complementary	Vertical axial	Obtain flakes	Chert, quartzite ç	Regular-bad	“Chunks”	Small	Shen et al 2010
BK (Olduvai, Upper Bed II, Tanzania)	1,2 Ma	Mode 1	Leading	Horizontal/vertical axial	Obtain flakes	Quartz	Regular-bad	Tabular blocks or slabs	Small	Díez-Martín et al 2009, 2011
Donggutuo Layer C (Nihewan Basin, China)	1,1 Ma	Mode 1	Leading	Vertical non axial	Obtain flakes	Quartz (no dominante)	Regular-bad (ç)	“Chunks”	Small	Shen et al 2010
Longgudong (China)	End of the Lower Pleistocene	Mode 1	Complementary	n/a	Obtain flakes	Chert	n/a	n/a	Small	Dong 2006
Dursunlu (Turkey)	780-990 Ka	Mode 1	Complementary	n/a	Obtain flakes	Quartz (95%)	Regular-bad	Clasts	Small	Güleç et al 2009
Zhoukoudian Loc. 1 (China)	780-400 Ka	Mode 1	Leading	Vertical axial	Obtain flakes	Quartz (89% del total)	Not uniform	Cobbles	Small	Leng 1998
Fengshudao (Bose Basin, China)	ca. 803 Ka	Mode 2	Complementary	n/a	Obtain flakes	Quartzite is the most frequent; chert and quartz are very rare	Regular	Cobbles, boulders, and blocks	n/a	Zhang et al 2010
Thomas Quarry hominid Cave (Morroco)	500 -360 Ka	Mode 2	Complementary	axial bipolar technique	Obtain flakes	Quartzite (85,2%)	n/a	Small, flat cobbles and one parallelepipedal cobble	Small	Raynal et al 2010
Liangshan (China)	Middle	Mode 1	Complementary	n/a	Obtain flakes	Quartz (37%) no dominante (volcanic rock	Regular-bad	Pebbles	Small	Leng 1998

	Pleist.					38%)	(ϵ)			
Yarimburgaz (Turkey)	Latter half of Middle Pleist	Mode 1	Complementary	n/a	Obtain flakes	Quartz (17,7% del total)	Regular	Pebbles	Medium-small	Kuhn et al 1996
Kashafrud Basin (Iran)	Middle Pleist.	Mode 1	Complementary	n/a	Obtain flakes	Quartz	Regular	Pebbles	Small	Biglari & Shidrang 2006
Zhoukoudian Loc. 15 (China)	>284-155 Ka	Mode 1/3 ?	Complementary	Vertical axial	Obtain flakes	Quartz (95,2%)	Bad	Cobbles	Small	Gao 2000a

Table-5

Sites	Chronology	Technological Mode	Role of Bipolar Technique	Bipolar Method	Main objective	Raw Material	Blanks quality	Blanks nature and morphology	Blanks size	References
Fuente Nueva Barranco León (Spain)	1.3 to 1.2 Ma	Mode 1	Leading	Horizontal bipolar -axial- (Unifacial/Bifacial ort.)	Obtain flakes	Flint	Regular	Parallelepiped and semirounded fragments	Medium/small	Toro et al., 2011
Pont de Lavaud (France)	1.2 Ma	Mode 1	Leading	Horizontal/vertical bipolar -axial/non axial (Unifacial)	Obtain flakes	Quartz	Regular	Rounded flat cobble	Medium	Despriée et al., 2009; 2010
Vallparadis (Spain)	1 Ma	Mode 1	Leading	Horizontal/vertical bipolar -axial/non axial	Obtain flakes	Quartz	Bad	Clast	Small	García et al., 2013
Monte Poggiolo (Italy)	1 Ma	Mode 1	Complementary	Split /Vertical bipolar -axial- (Unifacial)	Creation of a striking platform	Flint	Good	Ovoid cobble	All sizes	Peretto et al., 1998
Sierra de Atapuerca Gran Dolina TD6 (Spain)	0.9 Ma	Mode 1	Complementary	Horizontal/vertical bipolar -axial- (Unifacial/Bifacial ort.)	Obtain flakes	Quartz	Bad	Cobble	Small	Ollé et al., 2013
Isernia la Pineta (Italy)	0.65 Ma	Mode 1?	Leading	Horizontal bipolar -axial- (Unifacial/Bifacial/Multifacial ort.)	Obtain flakes	Flint	Bad	Slabs and parallelepiped fragments/flakes	Medium/small	Crovetto et al, 1994
La Caune de l’Arago (France)	0.55 Ma	Mode 2	Leading	Horizontal bipolar -axial- (Unifacial/Bifacial/Multifacial ort.)	Obtain flakes	Quartz	Regular/bad	Parallelepiped, semirounded fragments/flakes	Medium/small	Barsky & de Lumley 2010

Figure-1

Figure-2

Figure-3

Figure-4

Figure-5

Figure-6

Figure 6

Figure-7

Figure-8

Figure-9

Figure-10

Figure-11

Figure-12

Figure-13

Figure-14

Figure 14

Figure-15