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## Use and re-use: Re-knapped flakes from the Mode 1 site of Fuente Nueva 3 (Orce, Andalucía, Spain)

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### ABSTRACT

The presence of some flaked flakes at the Mode 1 site of Fuente Nueva 3 (1.2 Ma) poses the problem of the use and re-use of flakes as cores for obtaining smaller cutting tools. The industry is characterized by small flint flakes and cores, as well as by numerous limestone heavy-duty tools. Both of the raw materials were collected from local alluvial and colluvial sources. The assemblage presents a significant dimensional dichotomy with, on the one hand, large-sized limestone percussion tools and, on the other hand, small-sized flint debitage. Flint plates, blocks or nodules were obtained from local secondary deposits. There are very few flint cores and the average flake size is only 3 cm. Some of the flakes display opposite ventral surfaces indicating that they were obtained from larger flakes used as cores. In addition, a few intensively exploited flint cores conserve convex surfaces corresponding to their original flake matrices. No appreciably large-sized flint flakes have so far been found at the site suggesting that some phases of the knapping sequences were carried out further away. However, a few flakes could have been expediently re-knapped *in situ*. What can this behavioural choice tell us about early hominin behaviour at Fuente Nueva 3? The re-use of flint flakes as makeshift cores implies a two-step operative scheme involving the choice of a suitable blank that was further reduced on-site. This raises questions about raw material transport during the earliest periods of European Mode 1.

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### 1. Introduction

Core-flake industries attributed to the Oldowan or (heretofore) Mode 1 (Leakey, 1971; Clark, 1970), are currently documented throughout the Old World for a cumulative period of nearly 2 Ma (Barsky, 2009). The assemblages are mirrors to understanding earliest hominin technological capacities and, while the behaviours they reflect are generally elusive, it is likely that their nature was simple and closely related to survival-linked activities. Earliest assemblages contain few retouched items and their lack of typological variability (Isaac, 1984, 1986; de la Torre and Mora, 2005) distances them from the notion of recycling which we may define as: *a process aimed at transforming brute materials or waste into potentially new products destined for future use*. In the context of lithic analysis, the concepts of *reduction*, *re-use* and *recycling* have been more broadly explored for the diversified toolkits of the

Middle and Upper Paleolithic. Questions related to this were notably treated regarding Middle Paleolithic assemblages; especially with regards to re-sharpening (Dibble, 1984; Dibble and Rolland, 1992). The finds raised doubts about the validity of the influential typological models previously proposed by some authors (Bordes, 1953). From the Lower through into the Upper Paleolithic, reduction, re-use and recycling of stone is commonly associated with activities related to population mobility and raw material economy (Féblot-Augustin, 1997; Thacker, 2001; Miller and Barton, 2008). In any case, understanding the beginnings and evolution of these basic economic concepts has largely reposed up to now upon the retouched tool component of Paleolithic assemblages. Given that retouched tools are, by definition, considered to be absent or very rare in Mode 1 (Oldowan) assemblages (Hovers, 2012), what, if anything can be said about reduction, re-use and recycling in the earliest toolkits known to humankind? Even if such notions are not usually associated with Mode 1, many of the toolkits do occasionally display evidence for re-use or multifunctionality of flakes, heavy-duty tools and/or cores. This paper explores how the lithic economic considerations attached to the notion of recycling could have emerged by providing some examples from the Mode 1 site of Fuente Nueva 3 (Orce, Spain).

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The oldest stone tool assemblages are documented in Africa, in the Busidima Formation of the Ethiopian Awash Valley from 2.6 Ma (Kada Gona EG 10 and EG 12 and Ounda Gona OGS 6 and OGS 7 (Semaw et al., 1997, 2003, 2009; Semaw, 2000, 2005; Stout et al., 2010; Campisano, 2012). From around 2.3 Ma to 1.9 Ma, increasingly numerous occurrences situated along the East African Rift valley and in south Africa, bear witness to the beginnings of a long tradition of stone tool manufacture and use that was to become so emblematic of the genesis of humanity. For early hominins, the making of stone tools represents a bifurcation from natural (animal) selection processes which rely upon biological adaptations for surmounting environmental pressures. Developing this new skill thus opened up pathways to innovative survival strategies. Other earliest sites include: AL 666 and AL 894, Hadar, Ethiopia (Kimbel et al., 1996, 1997; Hovers et al., 2002; Hovers, 2003; Goldman-Neuman and Hovers, 2009); Omo 57, 123, 71, Omo Basin, Ethiopia (Chavaillon, 1970, 1976; Merrick et al., 1973; Merrick, 1976; Howell et al., 1987; Feibel et al., 1989; de la Torre, 2004); Fwjj20, East Turkana Basin, Kenya, (Braun et al., 2010); Fejej FJ-1, Omo-Turkana Basin, Ethiopia (Echassoux et al., 2004; Lumley and Beyene, 2004; Barsky et al., 2006, 2011; Chapon et al., 2011); Lokalalei 2C, West Turkana, Kenya (Kibunjia, 1994; Roche et al., 1999; Delagnes and Roche, 2005) and Kanjera South, southwestern Kenya (Behrensmeier et al., 1995; Plummer et al., 1999, 2001; Plummer, 2004; Bishop et al., 2006; Braun et al., 2009). The industries from these sites include cores and flakes, as well as non or slightly modified pebbles, cobbles or blocks. While there is some evidence of micro use-wear (for example at Koobi Fora and Kanjera, Keeley and Toth, 1981; Gibbons, 2009), few flakes from such early sites bear stigmata of intentional, secondary modification (re-knapped or retouched flakes). The lack of truly standardized morphologies and an overall dominance of notched types are both contributing factors to the somewhat nebulous frontier separating intentionally manufactured tools from flakes that were knapped in the aim of producing smaller flakes (Barsky et al., 2013).

Interpretations of these and other Mode 1 industries provide evidence that: 1) hominins made discriminate selection of raw materials even though rocks were generally collected near or on-site and 2) flake production methods were surprisingly systematic and relatively sophisticated (Semaw et al., 1997; Stout et al., 2005). This has led some authors to propose that there was an earlier phase wherein hominins used stones without intentionally modifying them (Panger et al., 2002; Carbonell et al., 2009). Through accidental breakage and opportunistic testing, hominins could have inadvertently discovered advantages in using sharp stone cutting edges to obtain or process resources (Fig. 1, n° 1). This could have led them to select intentional stone reduction as an adaptively viable behaviour. This initializing phase, referred to as *Mode 0* or *Homogeneity* (Carbonell et al., 2009) therefore constitutes the emergence of stone tool technology and its elemental

techno-functional relationship may be illustrated as such (Fig. 1, n° 2).

From around 1.8 Ma–1.6 Ma, ever more numerous African sites bear witness to a series of diachronic, yet analogous and revolutionary changes, wherein toolkits come to include elements reflective of increasingly more complex *chaînes opératoires* foregoing the emergence of the Acheulian in Africa from around 1.75 Ma (Kenya, Kokiselei 4, Texier et al., 2006; Lepre et al., 2011; Ethiopia, Konso Gardula, Asfaw et al., 1992; Beyene et al., 2013). Key sites document the overall tendencies described below, which should be perceived as interrelated (Olduvai Gorge, Melka Kunturé, Omo, Peninj, Leakey, 1971; de la Torre and Mora, 2005; de la Torre et al., 2003):

- 1) Technological innovation and the invention of hierarchical knapping strategies = formal product predetermination.
- 2) Standardization through the systematic reproduction of specific morphologies = the innovation of heavy and light-duty tool types.
- 3) Higher mobility and petro-typological specificity = wide-ranging hominins exploring raw material suitability in accordance with the newly emerging tool types.

Each of the above techno-functional achievements was likely to have been selected if it offered long-term economic (energy-saving) advantages, regardless of the correspondingly costly learning, transitive phase it entailed for its achievement. We illustrate these (Pre-Mode 2) techno-behavioural acquisitions as follows (Fig. 2):

The use of stone was intensified with the advent of intentional reduction and the evolutionary potential latent within each newly produced morpho-type was tested and developed. The capacity to transform lithic raw materials into effective cutting edges through acquired technique was learned and transmitted, thus increasing its complexity with each generation (Tomasello, 1999). Economic concerns accompanied the need to effectively produce small cutting tools and so flakes presenting natural ventral convexities served as makeshift cores with increasing regularity. Each emerging morpho-type enlarged typological variability which, at first, was based on the heavy-duty/light-duty tool dichotomy. The appreciation of raw material variability also grew in pace with

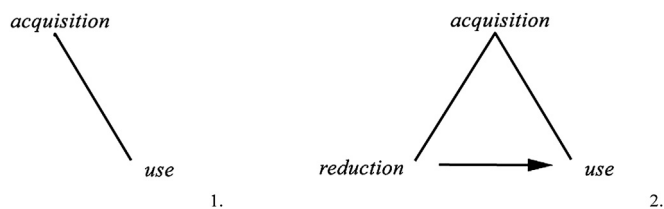


Fig. 1. (1.) Schema of a hypothetical phase wherein stones were acquired and used without intentional modification (>3 Ma in Africa); (2.) Schema of the first intentional lithic reduction methods developed to obtain useable products (2.6–1.9 Ma in Africa). Note that in both cases the acquisition of raw materials was local.

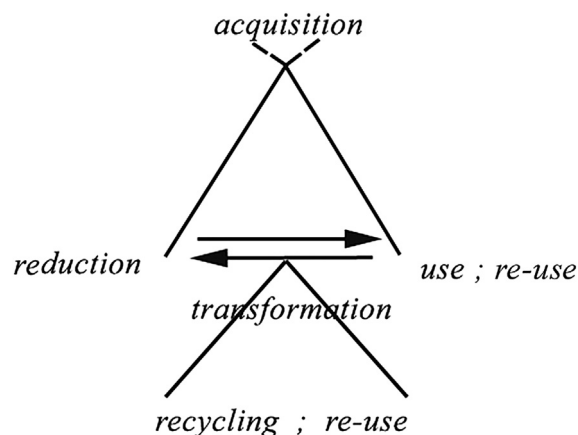


Fig. 2. Schema illustrating the relationships between the different phases of the reduction, re-use and recycling process (1.8 Ma–1.6 Ma in Africa). Materials were used directly or reduced into products which were themselves used or transformed. This cycle may have been repeated (re-use). Transformation is therefore the key element precluding both re-use and recycling. Note that raw material acquisition begins to diversify to include a wider range of materials in response to the techno-functional requirements dictated by newly created morpho-types.

developing petro-functional needs. Looking beyond Africa, an analogous model may be transposed to fit the situation of the earliest Western European toolkits in general; and Fuente Nueva 3 in particular. A handful of Western European Mode 1 sites have yielded a numerically significant lithic sample including secondarily modified flakes characterized by denticulate morphologies such as notches, beaked tools and Tayac points (Barsky et al., 2013). We test the validity of this hypothesis by examining the flint products (flakes and cores) from Fuente Nueva 3, keeping in mind this specific perspective. Because the notion of recycling is so closely linked to product transformation for re-use, we more specifically examine questions related to the innovation of light-duty tools- (absent at Fuente Nueva 3, Toro-Moyano et al., 2010a, 2010b) – from this unique viewpoint. Data for comparison on a broader scale is provided by some other Western European Mode 1 sites, situated mainly around the Mediterranean basin (Fig. 3).

## 2. The Fuente Nueva 3 site and its stone industries

Along with Barranco León, Fuente Nueva 3 (heretofore BL and FN3) is a Lower Pleistocene archaeological site situated in the Guadix-Baza basin in Orce, southern Spain (Toro-Moyano et al., 2010a, 2010b). During the time of the occupation of these two sites, the basin was occupied by the saline lake Baza (Anadón et al., 1994; Anadón and Gabàs, 2009) which existed within an endorheic system from the Upper Miocene to until around 0.2 Ma, at which time its waters were drained by the changing course of the Guadalquivir river and its affluents. Today, the basin preserves a succession of alluvial (Guadix) and colluvial deposits (Baza: lacustrine clays, silts and sands with evaporitic limestone crusting) reaching up to 100 m thick and covering a timescale ranging from the Upper Miocene to the Upper Pleistocene. Over the last half century, numerous fossiliferous and archeological localities have been documented from this unique accumulation of layered, calcareo-evaporitic deposits. Since their discovery, the BL and FN3 sites

have yielded spectacular faunal and lithic assemblages registered within a precise stratigraphical and archeo-chronological context. Ongoing excavations and research at these two important Lower Pleistocene sites have confirmed that the stone industries are in close association with the faunal remains and they continue to yield interesting results concerning the behaviour and lifestyle of the first inhabitants of Europe (Toro-Moyano et al., 2003, 2009, 2010a, 2010b, 2011; Espigares et al., 2012).

The age of the FN3 site has been evaluated using relative and absolute dating methods: by calibrating micro and macro vertebrate biochronology with magnetostratigraphical data (Agusti et al., 1987, 1996, 2007, 2010; Martínez Navarro et al., 1997, 2003, 2010; Oms et al., 1999, 2000a, 2000b; Agusti and Madurell, 2003; Blain, 2003; Scott et al., 2007) and by applying combined U-series/ESR dating to quartz grains and tooth enamel (Duval et al., 2011a, 2012a, 2012b). Consequently, the site's stratigraphical sequence (Fig. 4) is correlated to the Matuyama Chron, between the Olduvai and Jaramillo subchrons (1.78–1.48 Ma 1.07–0.98 Ma, Gradstein et al., 2005). More precisely, an age close to 1.4 Ma is accepted for the site of BL (Toro-Moyano et al., 2013), while the derived features of *Allophaiomys lavocati* at the FN3 site suggest that it is slightly younger: around 1.2 Ma (Agustí and Madurell, 2003). Recently, an infant hominin milk tooth- presently the oldest hominin remain in Europe- has been recovered from BL (Toro-Moyano et al., 2013). These two sites continue to provide some of the most complete and well documented evidence of the first hominins in Western Europe (Fig. 3).

The faunal assemblage at FN3 comprises abundant carnivore remains: *Ursus sp.*, *Canis mosbachensis*, *Lycaon lycaonoides*, *Vulpes cf. praeglacialis*, *Pachycrocuta brevirostris*, *Felidae indet.*, *Lynx sp.*, *Meles sp.*, *Pannonictis cf. nestii*, *Mustelidae indet.*, and large herbivores: *Mammuthus meridionalis*, *Stephanorhinus hundsheimensis*, *Equus altidens*, *Hippopotamus antiquus*, *Bison sp.*, *Ammotragus europaeus*, *Hermitragus cf. albus*, *Praemegaceros cf. verticornis*, *Metacervoceros rhenanus*. The microfauna includes: *Erinacena indet.*, *Crociodura sp.*,



**Fig. 3.** Map showing the location of Fuente Nueva 3 in Orce (Southern Spain) and other Western Eurasian Mode 1 sites. ● Sites with a numerically significant lithic sample including secondarily modified flakes. 1. Dmanisi (1.8 Ma, Georgia, Gabunia et al., 2000, 2002; Lumley et al., 2002; Vekua et al., 2002; Lordkipanidze et al., 2007); 2. Bizat Ruhama (1.6–1.2 Ma, Zaidner, 2013; Zaidner et al., 2010); 3. Korolevo level VII (0.95 Ma, Ukraine, Koulakovska et al., 2010); 4. Kozarnika Cave (1.6–1.4 Ma, Bulgaria, Sirakov et al., 2010); 5. le Vallonnet (1.07–0.984 Ma, France, Lumley et al., 1988); 6. Pont-de-Lavaud in the Loire river basin (>1 Ma, France, Despriée et al., 2006); 7. Bois-de-Riquet at Lézignan-la-Cèbe (1.57 Ma, France, Crochet et al., 2009); 8. Arce, Colle Marino, Fontana Liri (>0.78 Ma, Italy, Biddittu, 1984; Cauche et al., 2004); 9. Ca' Belvedere di Montepoggiolo (1 Ma, Italy, Peretto et al., 1998; Gagnepain et al., 1992; Yokoyama et al., 1992; Falguères, 2003); 10. Pirro Nord (1.6–1.3 Ma, Italy, Arzarello et al., 2007); 11. Atapuerca, Gran Dolina, level TD6 (>0.8 Ma, Spain, Carbonell et al., 1995; Parés and Pérez-González, 1999; Falguères et al., 1999, 2001; Berger et al., 2008) and Atapuerca, Sima de l'Elefante, level TE9 (1.2 Ma, Spain, Rosas et al., 2001; Carbonell et al., 2008; Parés et al., 2006); 12. Vallparadis (1.2–0.6 Ma, Spain, Madurell-Malapeira et al., 2010; Martínez et al., 2010; Duval et al., 2011b); 13. Barranco León and Fuente Nueva 3 at Orce (1.4 and 1.2 Ma, Spain, Agusti et al., 1987, 1996; Agusti and Madurell, 2003; Duval et al., 2011a, 2012; Martínez Navarro et al., 1997, 2003; Oms et al., 1999, 2000a, 2000b; Toro-Moyano et al., 2003, 2010a, 2010b, 2011); 14. Happisburgh 3 (0.95–0.7, England, Parfitt et al., 2010).

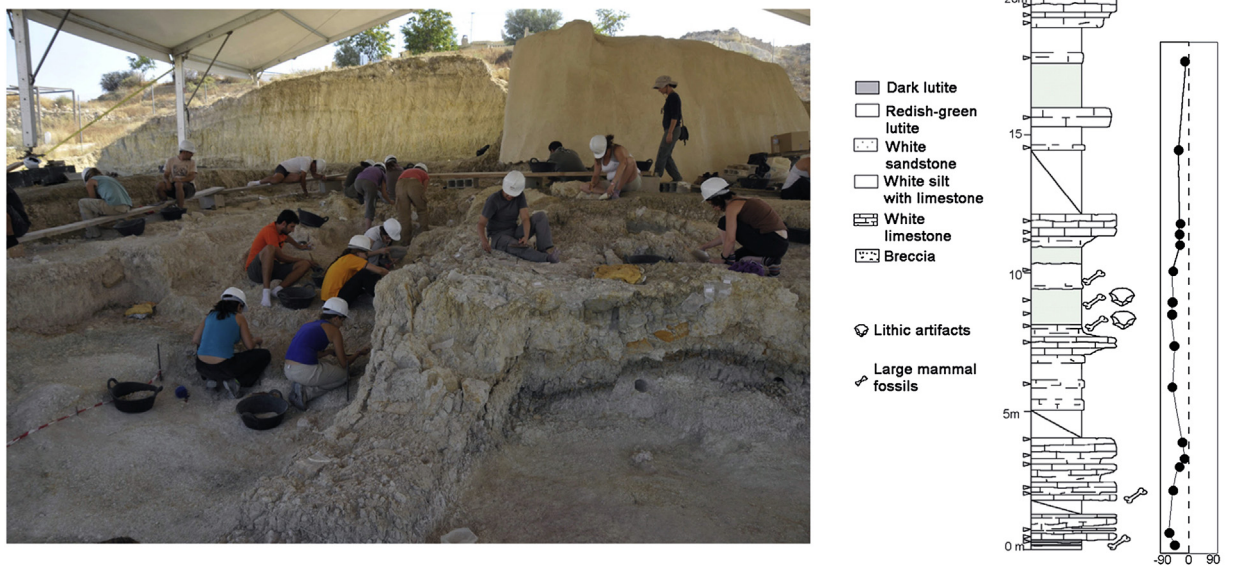


Fig. 4. (left) General view of excavations in 2013 at Fuente Nueva 3 (Orce, Spain) (Photo Jordi Mestre, IPHES) and (right) schematic stratigraphical log of the Fuente Nueva 3 site (after Oms et al., 2000b).

*Sorex minutus*, *Sorex sp.*, *Galemys sp.*, *Asoriculus gibberodon*, *Allophaiomys aff. lavocati*, *Allophaiomys sp.*, *Mimomys savini*, *Castillomys crusafonti*, *Apodemus aff. mystacinus*, *Hystrix sp.*, (Martínez-Navarro et al., 2010 and references therein).

Paleontological remains were first reported from BL in 1983. In 1994, the discovery of some flint artifacts prompted the first excavations at this site a year later. In 1991, some flint tools were also found at FN3 by a local resident. The following year, more flint artifacts were found at the site in sediment that had been mechanically removed during the installation of a telephone pole. Sieving of the sediment yielded more lithics and large mammal fossils, giving rise to the first soundings in 1994 and then to systematic excavations in 1995. The initial findings concerning the lithics were published in pace with ongoing discoveries (Gibert et al., 1992; Tixier et al., 1996; Turq et al., 1996; Martínez Navarro et al., 1997). Around the same time, the first results from the Lower Pleistocene site of Dmanisi were made known to the world; with hominin fossils (*Homo georgicus*) stone tools and fauna attesting to a human presence outside of Africa (Republic of Georgia) as early as 1.81 Ma (Gabunia et al., 2000, 2002; Lumley et al., 2002; Vekua et al., 2002; Lordkipanidze et al., 2007). These discoveries further fueled the already heated debate between supporters of a “short chronology” hypothesis upholding that Western Europe was not successfully colonized until around 0.5 Ma (Roebroeks and Van Kolfschoten, 1995) and proponents of the so-called ‘Old Europe’ claiming that hominins had colonized at a much earlier date; at least around 1 Ma (Lumley, 1971; Lumley et al., 1988; Bosinski, 1992; Rolland, 1992; Aguirre, 2000).). In the 1990s, the discovery of *Homo antecessor* (Bermúdez de Castro et al., 1997) with stone tools and butchered faunal remains in the Aurora Stratum of the Sierra de Atapuerca’s Gran Dolina site- in a precise chrono-stratigraphical position clearly older than the Matuyama-Bruhnes paleomagnetic event- buttressed growing evidence in favour of an early colonization of Western Europe (Carbonell et al., 1995, 1995, 1999, 1999; Falguères et al., 1999; Parés and Pérez-González, 1999). Throughout the next decade, discoveries and intensified research in France, Italy, Spain and even England followed suit (Fig. 3), establishing that hominin groups were successfully implanted in much of the Mediterranean

basin by at least 1.2 Ma. Today, evidence from BL and FN3 continues to provide exceptionally rich lithic and faunal samples for this little known period of early human ancestry. Ongoing research examining different aspects of the lithics from an interdisciplinary standpoint contribute to better understanding the technological and cognitive capacities of the hominins present at these and other Western European Mode 1 sites (Toro-Moyano et al., 2003, 2009, 2010a, 2010b, 2011; Barsky et al., 2010).

### 2.1. Materials and methods: the stone industries from Fuente Nueva 3

The FN3 toolkit clearly belongs to a Mode 1 type techno-complex (Table 1). All of the artifacts were knapped from local flint and limestone of varying quality (Toro-Moyano et al., 2010a, 2010b, 2011). The majority of the limestone artefacts are voluminous, summarily knapped or roughly shaped objects. Many present traces of percussion testifying to their use as heavy-duty tools, perhaps for breaking bones and certainly also for bipolar and direct hammer knapping (percussors, anvils). While most of the limestone is ascribed to the category of “macro” tools, the assemblage also includes cores, flakes and fragments (Table 1). The lightly rolled and more or less altered cortical surfaces of the limestone pebbles and cobbles contribute to difficulties in deciphering removal negatives and other percussion-related stigmata. A considerably high percentage of the FN3 “macro” limestone ( $L > 5$  cm) displays traces of percussion (= 43% of the non-modified limestone and 61% of the worked limestone, Barsky et al., in progress). Traces of percussion include: stigmata, cupula, accidental removal negatives and/or crush marks. Irregular retouch is often observed on removal negative or fracture crests. Impact points evidencing bipolar fracture on an anvil are recognizable on many broken cobbles. Quantitative data buttressed by experimental work is, at present, yielding interesting results about the percussive activities going on at the Orce sites (Barsky et al., in progress). The limestone was apparently also used for flake production and documented recurrent core technologies include unidirectional-unifacial, orthogonal and multiplatform (polyhedral). A few of the cores display short knapping episodes

organized around a relatively acute and sinuous edge, suggesting the beginnings of bifacial technologies. Both direct hammer and bipolar on an anvil methods were used to knap limestone and sometimes both methods are detected on the same piece. Because of the sedimentary situation of the site, all of the limestone artifacts have, up to now, been attributed to manuports (Toro-Moyano et al., 2010a, 2010b).

**Table 1**  
Limestone and flint tools from Fuente Nueva 3 included in this study.

|                       | Tool type                      | FN3        |
|-----------------------|--------------------------------|------------|
| Limestone             | Limestone non modified macro   | 189        |
|                       | Limestone knapped              | 98         |
|                       | Limestone flakes and fragments | 180        |
|                       | <b>Total limestone</b>         | <b>467</b> |
| Flint                 | Flint non modified macro       | 3          |
|                       | Flint knapped                  | 14         |
|                       | Flint flakes and fragments     | 374        |
|                       | <b>Total flint</b>             | <b>391</b> |
| <b>Total industry</b> |                                | <b>858</b> |

The flint assemblage shows a very different profile, most remarkably by its mean small dimensions (most of the flakes are only 2–4 cm long). Cores are scarce and much of the knapping was apparently carried out using bipolar on an anvil reduction strategies. By carrying out knapping experiments, this method was found to leave clearly identifiable stigma on the cores while the resulting flakes only rarely displayed prognostic traces (bullet-like morphologies or opposite impact points on ventral surfaces). We conclude that, although the aforementioned flake morphologies are present in the assemblage, exact quantification of the number of flakes produced by bipolar on an anvil knapping would be erroneous. Suffice it to say that experimental bipolar on an anvil knapping of Orce flint allowed us to reproduce identical flakes and cores as those present in our archeological samples. The use of a recurrent, peripheral knapping gesture on flint cores placed in the centre or on the edge of a limestone anvil is in fact an extremely efficient way to obtain numerous sharp-edged flakes from small, cube-shaped cores. It is to be noted that some of the large, flat limestone artifacts show the same kinds of stigma and breakage patterns as those typically observed on our experimental anvils.

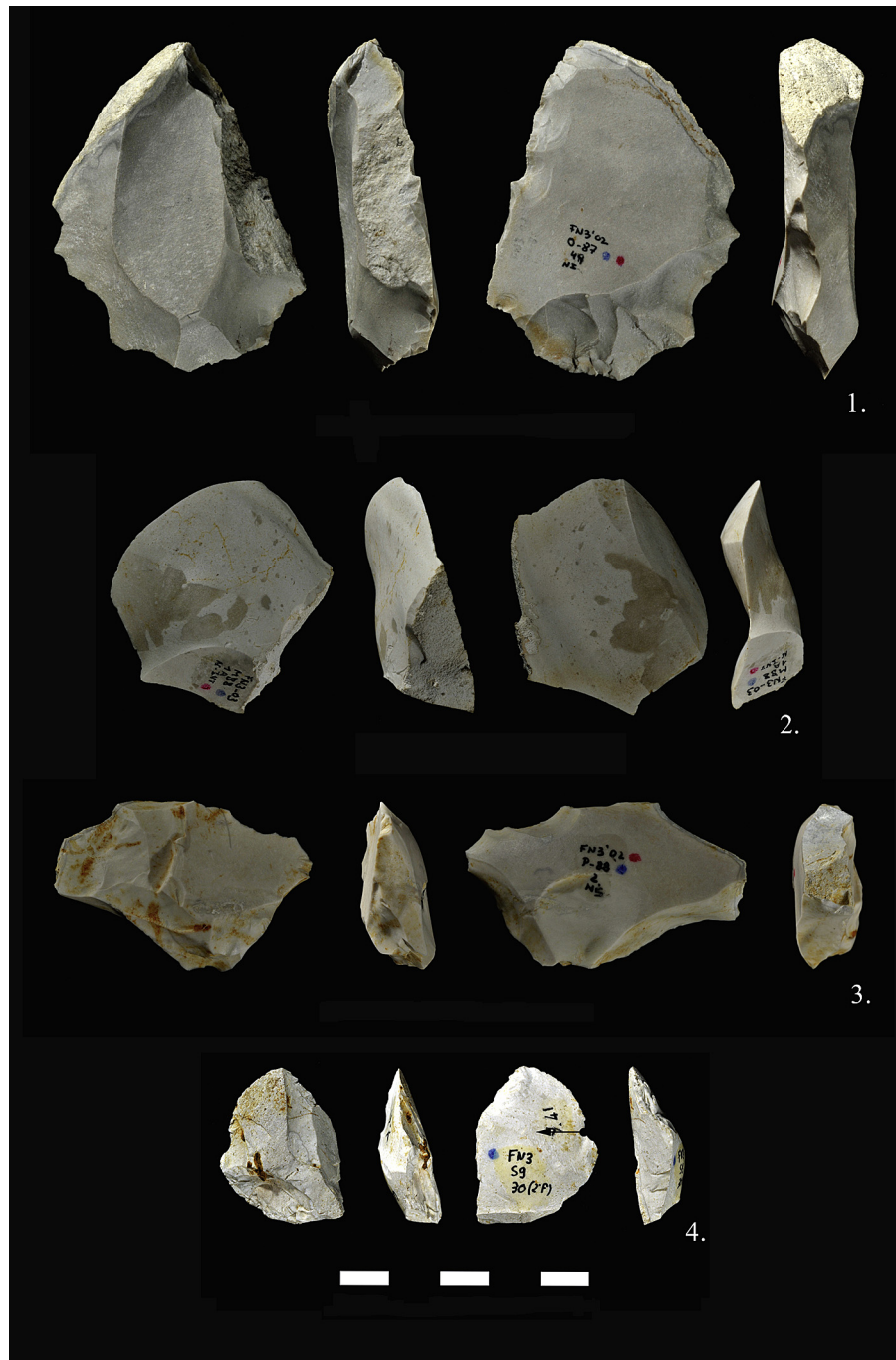
While none of the flakes or fragments are clearly retouched into tool “types” such as notches, scrapers or denticulates (Barsky et al., 2010; Toro-Moyano et al., 2010a, 2010b, 2011), there is evidence of ‘secondary flake knapping’ (Zaidner, 2013). This activity is thought to be linked to bipolar on an anvil production of tiny flakes from small-sized cores. The presence of intentionally retouched tools is considered to be a trademark characterizing the shift from Mode 1 towards Mode 2 (Acheulian). In the latter technological phase shaping and standardization come to represent important cognitive advances. Intentionally retouched tools are absent or extremely rare in the earliest stone industries across the globe. When they are present, they generally display irregular, denticulate morphologies which are at the root of divergent interpretations (de la Torre and Mora, 2005; Hovers, 2012; Barsky et al., 2013). A higher frequency of intentionally retouched tools is one of the main factors defining Mode 2, alongside: an enlarged area for raw material collection, large flake production, shaped cutting tools (picks, handaxes, cleavers), systematic bifacial discoid flake production and the increased standardization of heavy-duty tools. The absence of these features at FN3 therefore underlines the archaic nature of the assemblage. All of these techno-typological traits most certainly reflect behavioural changes that motivated and facilitated more complex social organization. It is likely that time gained by the perfection of a more efficient toolkit would have allowed

hominins to increase the range of their activities (Barsky et al., 2013).

### 3. A second life: evidence of flake ‘re-use’

Keeping this problematic in mind, we have re-examined the flint material from FN3. In the interest of the *reduction, re-use, recycling* process discussed above, we propose specific morpho-technical criteria in order to identify whether any of the industries from Orce might translate one or more of these processes and, if so, to what end (technical constraint, raw material economy, energy saving). These include: flakes with double ventral surfaces and/or posterior removal negatives (Figs. 5–7). Overall, evidence for the ‘re-use’ of flakes is scarce at FN3 but there are a few, intentionally re-knapped flakes and also some flakes showing double ventral surfaces attesting to their origin from larger flakes. This (occasional) use of flakes as cores adds another link in operational schemes recorded at this site. The pieces illustrated and described below constitute some of the clearest examples of flaked-flakes and of flakes obtained from other flakes. Flint types correspond to codes listed in Toro-Moyano et al., (2010a, 2010b).

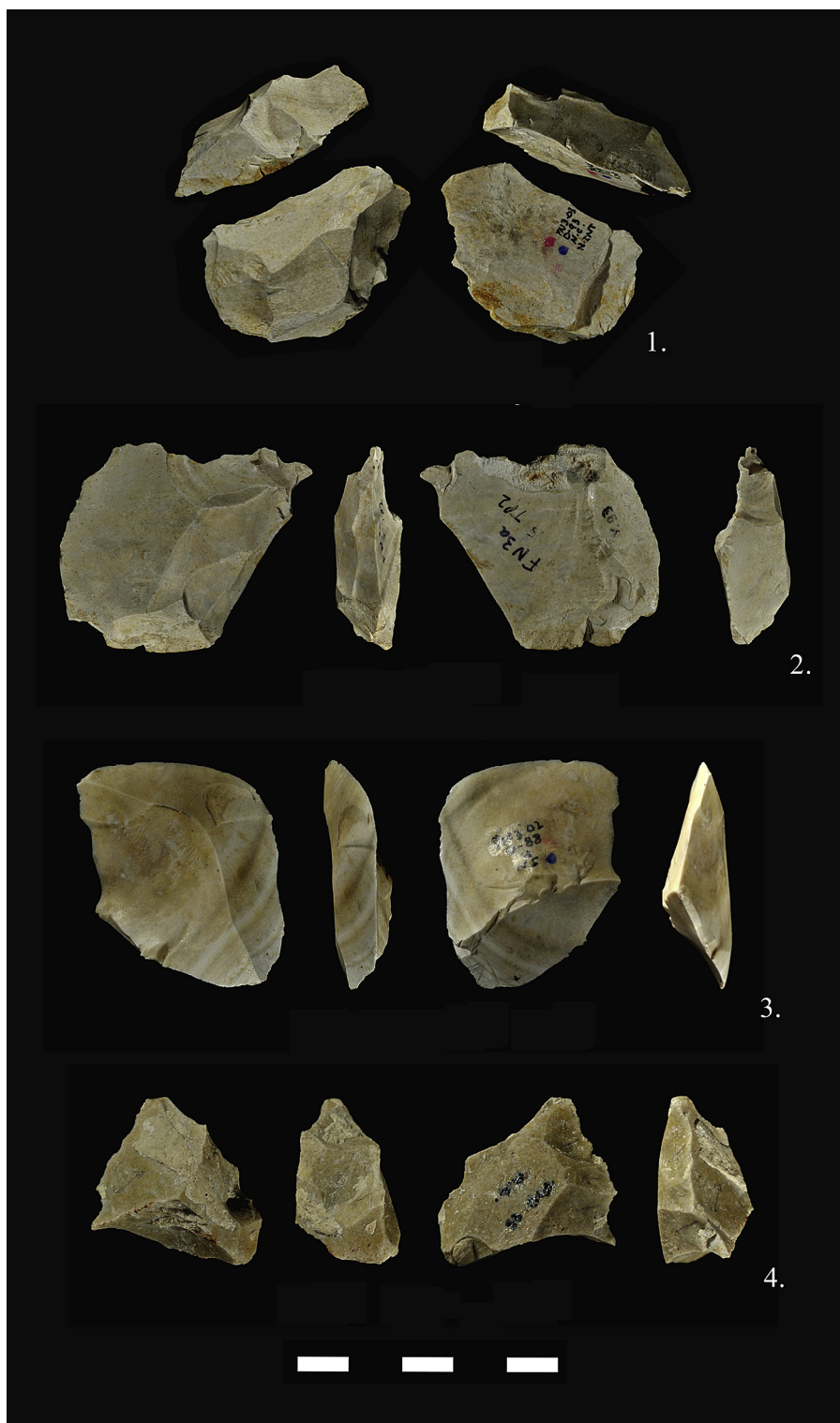
- (Fig. 5, n° 1) Large-sized, thick flake with a cortical distal plane. The flake is slightly altered and has a homogeneous, grey patina. Its ventral convexity (bulb) has been eliminated by at least four unidirectional removals (mean length = 20 mm). A final extraction was effectuated on the dorsal surface of the flake-core’s proximal angle (20 × 22 mm). Its platform was the surface of a previous removal negative and part of the convex ventral surface. This surface was a suitable matrice for obtaining at least five small-sized flakes. Apart from its use as a core, parts of the flake’s thinned edge display flat, irregular retouch and crushing, suggesting that it also served as a tool. Isolated areas of denticulate retouch are also present on the lateral edges of the flake-core.
- (Fig. 5, n° 2) Desilicified flake with covering white patina and a broken lateral edge. The flake, clearly displaying two ventral surfaces with orthogonally oriented striking directions, was obtained from another, distally *outrépassé* flake.
- (Fig. 5, n° 3) Short, thick and distally hinged flake with a homogenous beige patina. The dorsal surface has several removal negatives translating a relatively long knapping sequence with at least three directional changes. The left lateral bord is the plane surface of the original core. The left distal cortical plane served as a platform for two small removals preceding the flake’s extraction (length = 20 mm). The right lateral edge displays an intentional fracture (with impact point) perpendicular to the main knapping plane that was effectuated after the flake’s extraction. The convex ventral surface (bulb) may have served to obtain another flake (20 × 22 × mm), although this negative could be a knapping parasite. Finally, the right distal cutting edge shows a few, irregular, denticulate inverse retouch (mean length = 8 mm).
- (Fig. 5, n° 4) Slightly altered flake with distal cortex and covering white patina. Previous removals are bipolar (n = 2). The platform is smooth and slightly convex. An inverse removal from the lateral edge (22 × 16 mm) thinned the flake’s distal extremity. The resulting cutting edge shows crush marks, as does a portion of the opposing lateral edge.
- (Fig. 6, n° 1) Short, thick, trapezoidal flake with striated beige patina. This non-cortical flake truncated the summital portion of a small, polyhedron-shaped core. It presents a smooth, inclined platform and multidirectional removal negatives on a thick lateral bord as well as on the dorsal surface. A flat, inverse removal was effectuated on the ventral surface from the left



**Fig. 5.** Flint flakes from Fuente Nueva 3 displaying traces of secondary transformation and/or re-use. 1.- FN3'02.087.Nivel inferior.n° 49 (flint type SFN3, 72 × 50 × 14 mm); 2.- FN3'03.M88.Nivel inferior.n° 1 (flint type SFN3, 44 × 42 × 15 mm); 3.- FN3'02.P88.Nivel superior. n° 2 (flint type SFN3, 37 × 58 × 16 mm); 4.- FN3.S9.30.2P.Y41 (flint type SFN1, 29 × 23 × 9 mm). (Photos Jordi Mestre, IPHES).

lateral edge (9 × 20 mm). The impact point is clearly visible, as are tiny crush marks on both surfaces of the cutting edge.

- (Fig. 6, n° 2) Broken flake with a beige patina and residual cortex on the striking platform and proximal bord. An inclined fracture on the distal edge reveals partial desilicification. Previous negatives (at least 5) translate a series of recurrent orthogonal removals prior the flake's extraction. The pointed distal extremity displays irregular retouch. A large, invasive removal originating from the distal extremity occupies the entire length of the flake's ventral surface (53 mm).
- (Fig. 6, n° 3) Flake knapped from fine quality flint with a striated, beige-white patina. It has a wide, open angled platform and two previous, longitudinal removal negatives occupy about half of the distal surface. The remaining surface indicates the ventral face of a larger flake (oriented transversally to the present one).
- (Fig. 6, n° 4) Slightly patinated flake in fine quality, greenish-brown colored flint. The dorsal surface shows that at least two opposite transversal removal negatives were effectuated prior to its extraction. Three small denticulated removals (or retouch) with a mean length of 10 mm originate from the partial ventral



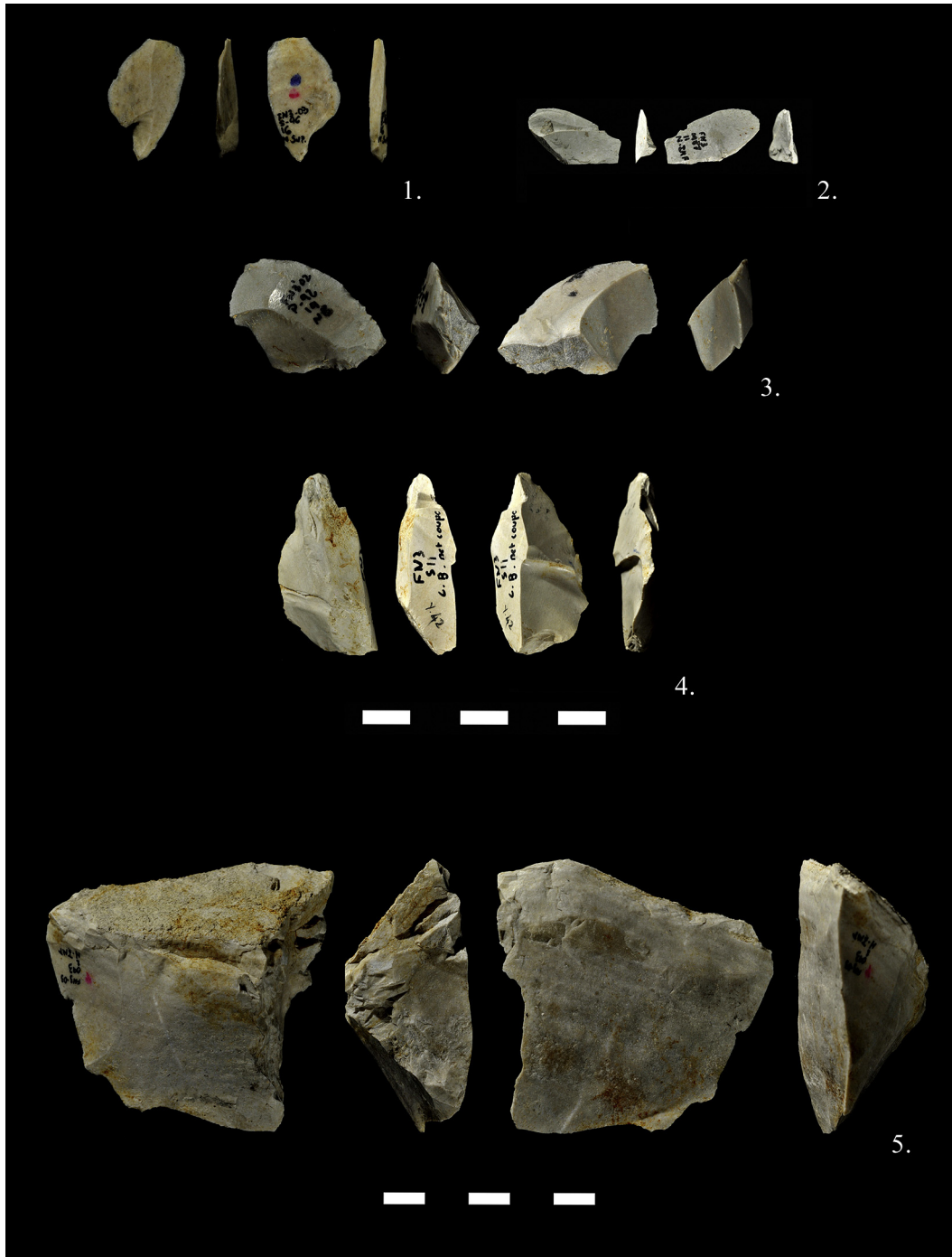
**Fig. 6.** Flint flakes from Fuente Nueva 3 displaying traces of secondary transformation and/or re-use. n° 1 – FN3.093.Nivel intermedio.n° 50254 (flint type SFN3, 31 × 39 × 14 mm); 2.- FN3a.TP2.Y93 (flint type SFN1, 53 × 40 × 13 mm); 3.- FN3'02.O88. n° 4 (flint type SNF3, 44 × 37 × 14 mm); 4.- FN3'95.n° 50314 (flint type SFN4, 32 × 33 × 18 mm). (Photos Jordi Mestre, IPHES).

surface. The series is truncated by an abrupt removal that was made from the dorsal surface, perhaps using an anvil.

- (Fig. 7, n° 1) Tiny flake with a beige patina. The striking platform is barely visible and there is a partial, longitudinal (Siret) fracture. About half of the dorsal surface is occupied by a single, longitudinally oriented removal negative, while the remaining

surface shows the ventral convexity of the transversely oriented flake-core.

- (Fig. 7, n° 2) Small-sized, white patinated flake with a dihedral striking platform and a single longitudinally oriented removal negative. The distal portion of the flake displays the partial remnant of the original flake-core's ventral surface.



**Fig. 7.** Flint flakes from Fuente Nueva 3 displaying traces of secondary transformation and/or re-use. n° 1.- FN3'03.S96.Nivel superior.n° 16 (flint type SFN2, 23 × 13 × 3 mm); 2.- FN3'03.M87. Nivel inferior. n° 11 (flint type SFN1, 11 × 21 × 2 mm); 3.- FN3'02.P92.Nivel superior.n° 19 (flint type SFN3, 23 × 28 × 7 mm); 4.- FN3.S11.CB.Y42 (flint type SFN3, 37 × 18 × 10 mm); 5.- FN3'03.O93.Nivel inferior.n° 1 (flint type SFN3; 60 × 63 × 29 mm). (Photos Jordi Mestre, IPHES).

- (Fig. 7, n° 3) Patinated grey flake with a Siret fracture and a cortical striking platform. A single previous removal negative departing from the same platform is visible on the distal surface which is occupied mainly by the remaining ventral convexity of the original flake-core which was oriented transversally.
- (Fig. 7, n° 4) Partially desilicified flake fragment with a white patina and some cortical residu on its distal portion. Previous removal negatives ( $n = 2$ ) are oriented orthogonally but the flake is partial and lecture is difficult. Likewise, the ventral surface displays a removal negative that could be contemporary

- with the flake's extraction (parasite) but that may have been effectuated secondarily; crush marks are present on the striking area. In any case, the fracture (lateral, longitudinal) is posterior. There is a single, marginal retouch on the edge opposite to the fracture.
- (Fig. 7, n° 5) Large flake on grey-colored, striated plate flint. The striking platform is nul (cortical surface) and the flake may have been obtained by bipolar on an anvil method. The distal surface shows two, relatively large, longitudinally oriented removal negatives. The flake was truncated perpendicularly on one



lateral bord whose surfaces present opposite, removal-type impacts as well as crush marks.

#### 4. Discussion and conclusions: re-use and recycling of stone refuse within the context of the European Mode 1

The concept of recycling is generally linked to economic concerns and the ways in which human technology may be best adapted towards minimal expenditure- in both energy and raw materials. Looking at first technologies, it is interesting to situate the first indications of concerns that led humans to discover ways to avoid waste and thus maximize the fruits of their efforts. The emergence of such concerns for economy is noteworthy since it occasioned changes in early human behaviour: most notably in the longer sequencing of technological chains. However, this additional link in *chaînes opératoires* may be closer to the notion of re-use than to that of recycling even though, in the case of flake re-knapping, there is transformation of the original matrix. We propose that during Mode 1, the occasional transformation and 're-use' of knapping waste reflects a behaviour which, in the face of expediency, was to find its way into the praxis of human culture at an early stage of its development.

The earliest toolkits in Africa and Eurasia are palpable reflections of the human choice to use-reduce stone into sharp-edged products using non-randomized and socially transmitted knapping methods. While the products themselves are not standardized, the means for their production were in fact dictated by basic flake extraction mechanics and were thus limited to only a few basic technological notions. They are flake-core industries without significant typological categories- apart from the macro (core)/micro (flake or fragment) dichotomy. However, they do occasionally contain elements revelatory of additional gestural links in chains of production where simply knapped products were secondarily transformed to create new morphologies. One of the clearest manifestations for this kind of behaviour is the secondary use of flakes with the aim of producing more flakes or shaping tools. In the earliest toolkits there is a fine, interpretative line separating the ways in which we may define such "flaked flakes": as cores or as retouched tools (Barsky et al., 2013; Zaidner, 2013). Earliest African assemblages contain few such items: as in the Ethiopian sites of Kada Gona EG-10, EG-12 and Ounda Gona OGS-7 (2.6 Ma, Semaw, 2000; Semaw et al., 1997, 2010) and AL666 and AL894 (2.3 Ma, Kimbel et al., 1996; Goldman-Neuman and Hovers, 2009). Also in Ethiopia, Omo 71 has yielded an industrial complex including only cores and non-modified flakes (2.34 Ma, Howell et al., 1987; de la Torre, 2004). The industries from Lokalelei 1 and Lokalelei 2C, in Kenya, likewise include few retouched flakes (2.4–2.3 Ma, Kibunjia, 1994; Roche et al., 1999; Delagnes and Roche, 2005). At Lokalelei 2C, some of these: ...are cores recycled for use as tools after debitage was completed (Delagnes and Roche, 2005). These authors distinguish retouch from debitage by techno-morphological considerations such as the size and disposition of the scars, as well as their position (at the end) of the gestural sequencing of the manufacture process. Further economic features are documented at Lokalelei 2C, including the transport of partially reduced cores to the site and the "recycling" of larger-sized chunks and flakes for use as cores (Delagnes and Roche, 2005).

At the above mentioned African sites, economy seems to be related to obtaining a relatively high number of flakes per-core without the need for intermediary phases involving surface preparation, by applying formal and qualitative selective strategies in the first links of the operative chain, i.e. the selection of supports. Before around 1.8–1.5 Ma in Africa, the intentional shaping of flakes and fragments by retouch does not seem to acquire the numerical and formal significance as it does in later sites, for example at Melka

Kunturé Garba IV (1.5 Ma, Chavaillon and Piperno, 1975; Piperno and Bulgarelli-Piperno, 1975; Gallotti, 2013) and Gadeb (1.5 Ma, Clark and Kurashina, 1976, 1979; de la Torre, 2011) in Ethiopia, or at the eponymous Olduvai Gorge sites in Tanzania (Bed I, 1.8 Ma, Leakey, 1971; de la Torre and Mora, 2005). During this "pre-Mode 2" phase of hominin technological development, the elements required for defining appropriate typological classifications remain blurred in most cases and discussions aiming to determine the real significance of this transformed- re-used or recycled- material are far from resolved. However, the incremental intensification and standardization of these secondarily modified products gives way diachronically to truly retouched tool types; finally effacing the problematic frontier between knapping and shaping.

Evidence from the oldest European occurrences indicates a great antiquity for the emergence of the notion of re-use after transformation as a first step in economising lithic products (higher productivity to avoid waste in both energy and raw materials). At Dmanisi, for example, retouched flakes are extremely rare and typically lack standardization (Lumley et al., 2005; Mgeladze et al., 2011). The proportion of notch or denticulate morphologies is pronounced and there are also some cases of invasive removals on ventral flake surfaces. These characteristics are shared by most of the other Western European Mode 1 sites having yielded numerically significant lithic samples: Barranco León and Fuente Nueva 3 (Toro-Moyano et al., 2010a, 2010b), Montepoggiolo (Peretto et al., 1998), Atapuerca level TD6 (Carbonell et al., 1999, 2001; Ollé et al., 2011), Pont-de-Lavaud (Despriée et al., 2006, 2009), le Vallonnet (Lumley et al., 1988), Korolevo levels VI, VII (Koulakovska et al., 2010). Cores from these sites are generally knapped from cobbles carefully selected for their petrographical qualities but also for their formal attributes which allow for flakes to be easily extracted from natural, non-prepared surfaces. Physical constraints were overcome when necessary through intentional cobble breakage and fragments were used either directly or as cores for further flake production.

Our examination of secondarily modified flint flakes at the Mode 1 site of FN3 reveals that the concept of transformation is a key feature contributing to the emergence of the notion of recycling in the early Western European toolkits. At FN3, the overall scarcity of flint cores suggests that some of the knapping took place off-site (Toro-Moyano et al., 2010a, 2010b). Meanwhile, the presence of some re-flaked flakes shows that at least some of these products were transformed into cores and probably re-used on-site. That flint was introduced to the site not only as brute chunks but also as readily knapped flakes entails interesting connotations about hominin planning and foresight for raw material transport, and for the use and re-use of blanks at FN3. It should be remembered that the FN3 site probably represents only one of several points in time and space scattered around the paleo-lake Baza which was certainly a privileged location for hominins as it was for other species of carnivores and herbivores. Hominins used the raw materials immediately available to them to cut meat off carcasses in competition with the other large carnivores present in the area. While limestone was the most abundant material directly available to them, it was clearly preferred for percussive activities. In the meantime, the comparatively sharper cutting edges provided by flint were certainly favoured for meat cutting activities (requiring small-sized, sharp-edged flakes). Since the flint was not so readily available in the environment around the lake (secondary sources: detrital) then it is possible that hominins carried flakes with them which were occasionally re-knapped to produce more of the needed small, sharp-edged tools.

Evidence for the occasional re-knapping of flakes indicative of advanced productive efficiency is broadly linked to an incremental consciousness of the management of relationships

between the different phases of the emerging reduction, re-use and recycling process. The sites discussed in this paper precede the advent of Mode 2 wherein hierarchical core management, large flake production and the intentional shaping and standardization of both small and large tools became widespread. These activities involved an ever widening range of complex processes of product transformation, re-use- and recycling. The development of more effective techno-economic practices leads us to reflect upon the former concept: recycling, and the ways in which this behaviour may be identified in early Paleolithic operative schemes. While the examples from FN3 and other Mode 1 sites show that flakes were only occasionally transformed, this behaviour indicates that, in the face of expediency, hominins were capable of adapting available lithic resources to immediate needs. At FN3, however, it has not been possible to determine whether or not the re-knapped items had been discarded prior to their re-use and, if so, for how long. This time-factor, evident at some Middle Paleolithic sites, is considered by some authors to be essential to identifying truly 'recycled' objects (Vaquero et al., 2012). In some cases, double patina, refitting and/or the re-knapping of previously burnt artifacts provide precious indices of such a time interval separating phases of discard transformation and re-use. Over time, intensification of such processes as shaping and standardization had repercussions on artefact curation and land-use patterns, resulting in the exploitation of a larger variety of raw materials to best respond to the needs of newly created morphotypes. Greater hominin mobility of is one of the hallmarks of Mode 2 achievement that may be connected in some ways to this specifically human behavioural trait of transformation and re-use in the interest of economic concerns (Féblot-Augustin, 1997).

In Western European Mode 2 lithic assemblages, distances in excess of 100 km are recorded to have been covered by hominins seeking out fine quality lithic materials (Despriée et al., 2010). This capacity to cover large distances is coincident with greater technological variability, suggesting that innovated toolkits gave hominins greater freedom to occupy territories even if they were distant from the fine quality raw material sources needed for elaborating the more complex tool types. Fine quality exogenous materials brought from distant sources were generally thoroughly reduced, and not all elements relating to different reduction events are necessarily found on-site (Barsky and de Lumley, 2010). Throughout Mode 2 and especially into Mode 3, widening landscape use appears intimately linked to the segmentation of operative schemes in relation to typological variability and the ensuing enlargement of petrographical diversity (Féblot-Augustin, 1997). Concepts connecting raw material quality and availability to the intensity of retouch (notably Quina) are useful for understanding the "ramification" or complex life-cycle of the standardized toolkits of the Middle Paleolithic and also for defining the role of recycling (Jelinek, 1976; Dibble, 1984; Geneste, 1991; Dibble and Rolland, 1992; Bourguignon et al., 2004; Turq et al., 2013). We consider the capacity demonstrated by the occasional re-use of flint flakes in the Mode 1 site of FN3 to be an example for the early existence of a potential or latent behaviour that was to develop synchronously with multiple changes in technology and tool function following the advent of Mode 2.

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