



For Our World Without Sound: the Opportunistic Debitage in the Italian Context—a Methodological Evaluation of the Lithic Assemblages of Pirro Nord, Cà Belvedere di Montepoggiolo, Ciota Ciara Cave and Riparo Tagliente

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Abstract

The informative potential taken on by lithic artefacts has increased over the years. They gradually grew into proxies to detect the most relevant features of human material culture, including cognitive abilities to realise stone tools or, in other words, to track down the delineation of behavioural complexity. Consequently, notions like predetermination, standardisation (morphologically likewise) and hierarchisation have been intensely used in lithic technology as markers of such complexity, leading to ruling out contexts lacking any trace of these traits. Within the present state of the art, the use of the terms expedient and opportunism has characterised, in a negative way, the dichotomy between complex and simple within prehistoric contexts. Even if a requalification of expedient technologies has been recently observed, opportunistic behaviours still connote the complete absence of planning and complexity (even in terms of the mental scheme) within lithic industries. This background often prevented a consideration as relevant, from a technological and methodological perspective, these assemblages, primarily when Lower Palaeolithic contexts were addressed. With the definition and use of the term opportunisticdebitage, this work questions the possible methodological implications of assemblages known as complexity- and planning-free and that can be found throughout different chronological and cultural phases.

Keywords Lithic technology · Palaeolithic · Lower Pleistocene · Middle Pleistocene · Core technology

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Introduction

The topic of complexity in lithic technology, its identification and delineation through the analysis of lithic assemblages goes a long way back in the history of Palaeolithic archaeology, and plays a distinctive role in our understanding of human behavioural evolution (Baena et al., 2010; Binford, 1977; Carbonell et al., 2016; Davis & Ashton, 2019; Gaucherel, 2020; Meignen et al., 2009; Moncel & Ashton, 2018; Ollé et al., 2013; Shea, 2013; Stout, 2011; Vaesen & Houkes, 2017). Because of this, lithic artefacts took on a tremendous informative potential over time, growing into proxies to detect the most prominent aspects concerning the material culture of prehistoric people. This includes the cognitive abilities employed to make stone tools which are important markers of the so-called behavioural complexity (Davis & Ashton, 2019; Garcia et al., 2013; Nelson, 1991; Stout, 2011). Several authors recently argued whether an actual overestimation of the fundamental importance of lithic technology for prehistoric people was taking place in Palaeolithic research (Sillitoe & Hardy, 2003). In this context, ancient knappers were devoting most of their time and energy to the manufacture of stone tools, hence, the involved mental processes were supposedly driven by well-defined concepts reflected into structured, standardised procedures. In this logic, as stated in the work of Vaquero and Romagnoli (2018, p. 337), this tendency “allowed some researchers to maximise the use of the predetermination concept in the interpretation of lithic technologies”, resulting in a gradual loss of interest for the contexts lacking any degree of predetermination. In other words, the potential existence of complexity, which in lithic technology often goes hand-in-hand with notions such as standardisation and hierarchisation, was deemed to be rather unlikely or disregarded at all.

It is in this scenario that the concept of expedient technology (Binford, 1973, 1977, 1979), defined in terms of technological investment (i.e. time and energy), has been used from then on to characterize unstructured and chaotic behaviours in contrast with the notion mentioned above of formal complexity (i.e. curated technology). Even though this might be an oversimplification, the dichotomy between high- and low-cost technical behaviours has been steadily present, whether implicit or not, in archaeological research and highly debated ever since its definition to postulate the presence of complex thinking (Romagnoli et al., 2018; Vaquero & Romagnoli, 2018).

As a sign of that, over the years, the notion of expediency has been declining and explored under many aspects concerning lithic technology, expanding its original theoretical boundaries. In one case, Nelson (1991) stated that expedient behaviours presented a degree of planning consisting of scheduled and predictable activities. This allowed him to introduce the distinction between expedient and opportunistic technologies, defining the latter as technical behaviours in response to immediate, unanticipated conditions, hence lacking any degree of planning. Even if a resemblance might be possible at the archaeological level (as pointed out by Nelson, 1991), since both models are inclined to take advantage of time and space, minimising the technical efforts to realise stone tools, the distinction persisted.

Within the present state of the art, the framework of expedient technologies has been significantly reconsidered as an attitude, applied to lithic industries as a whole, in which concepts as complexity might still coexist, albeit with an apparent lack of time, energy and predetermination invested for their realisation (Daffara et al., 2021; de Lomberra-Hermida et al., 2016; Mathias et al., 2020; Moncel et al., 2015, 2021; Romagnoli et al., 2018; Vaquero & Romagnoli, 2018). On the other hand, opportunistic behaviours remained as notions designating the complete absence of complexity and planning in lithic assemblages (Antoine et al., 2016, 2019; Bermúdez de Castro et al., 2013; Gallotti & Peretto, 2015; Nicoud et al., 2016; Santagata et al., 2017). Currently, this background is often prevented from considering this kind of industry from a technological and methodological perspective, eventually leading yet to another dichotomy between complexity and opportunism. This is particularly relevant for Lower Palaeolithic industries where pattern recognition might be more challenging due to the absence of structure and standardisation (morphologically likewise). However, it is also a rich chronological phase where the development of behavioural complexity is thought to arise in many aspects.

This paper aims not to entirely erase the concept of simplicity from the analysis of technical behaviours but to question the possible methodological implications of assemblages known as complexity- and planning-free. This purpose will be pursued by defining and using the term opportunistic debitage, building on Arzarello's (2003) work containing an initial reassessment of such behaviours.

The mentioned work aims to address a problematic matter regarding the analysis of lithic productions during the Middle Palaeolithic, which did not fall into the methodological paradigm of Levallois-discoïd-laminar. Those kinds of industries, even if attested to by a significant number of artefacts, were often not considered as relevant within archaeological contexts, being either defined as a by-product of more complex reduction sequences or even disregarded at all.

In this case, Arzarello selected the Mousterian sequence of Riparo Tagliente as a testing ground. Starting from the structure of SSSA (Ashton et al., 1992; Forestier, 1993), Arzarello developed the concept of opportunistic debitage which comprise the algorithm and the fundamentals of SSSA (regarding morphology and volume conception) but unlike the latter, it implies the presence of a mental scheme and capacity of abstraction which Forestier did not consider as a requirement for the SSSA: "L'approche du tailleur clactonien n'est pas une approche qui engendre une stratégie issue d'un schéma mental nécessitant, comme dans le Levallois des facultés d'abstraction très développées" (Forestier, 1993, p. 59). Moreover, Arzarello also provided evidence that the SSSA scheme was not the only option in these productions. Still, it would include a much wider variability implying other knapping strategies (for example, centripetal) related to specific morphologies. The opportunistic debitage was then applied to older contexts in more recently published works to describe industries presenting similar patterns (Arnaud et al., 2017; Arzarello et al., 2013, 2016; Daffara et al., 2021; Niang & Ndiaye, 2016).

Concerning its definition, the opportunistic debitage has been initially described as "a flaking method oriented to raw materials' massive exploitation not implying a core, or any surface, preparation. The striking platforms and knapping surfaces are created as far as the flaking activity continues. [...] The opportunistic debitage includes an

infinite range of variants coming from the same common operative scheme.” (Arzarello, 2003, p. 6). The term opportunism was not applied with a negative connotation but referred to its original semantic definition: “a behaviour in which someone adapts his actions to each context to gain from it the most advantage” (The Oxford English Dictionary OED). This method shows strong adaptability to local raw material morphology and its physical characteristics, and it is oriented towards morphologically non-standardised flake production mainly achieved through short reduction sequences. The subordination to morphological criteria comes from a standard predetermined mental scheme producing highly flexible and variable operative knapping schemes (unipolar, orthogonal, bipolar and centripetal). These are constantly influenced by, and adjusted to, raw material volume as far as the flaking activity is carried on. The aim is the production of functional flakes deriving from a mental scheme easily replicable through technical gestures. Therefore, preparation of the surfaces is never required. The operative schemes’ variability depends on the available natural morphologies and the cores’ volume. In any case, the opportunistic debitage implies a surface’s hierarchisation (Boëda, 1994) or subordination of the morphologies to specific technical criteria (Boëda, 1993; Bourguignon, 1997).

In the end, a contextualization had to be made regarding the branched/ramified productions (Bourguignon et al., 2004; Mathias & Bourguignon, 2020; Mathias et al., 2020; Romagnoli et al., 2018) and their role within the opportunistic debitage. Being considered highly dependent on the flaking method used for the primary production (Bourguignon et al., 2004) and standing as a specific behavioural aspect of the human groups related to techno-economic issues (Mathias & Bourguignon, 2020), they may represent one of the several technical responses or adaptation through which a flaking method is achieved (Romagnoli et al., 2018).

The earliest evidence of the opportunistic debitage is related to the first European peopling by *Homo* sp. during the Lower Pleistocene starting from 1.6 Ma and gradually increasing around 1 Ma (Arzarello et al., 2016; Cheheb et al., 2019; Despriée et al., 2010, 2018; Moncel, 2010; Ollé et al., 2013). The lithic industry was obtained in all these sites by exploiting local raw materials of different qualities (such as flint, limestone, sandstone, quartzite and basalt) and morphologies (nodules, cobbles, pebbles, etc.). The reduction sequences attested to are mainly short and finalised to non-standardised flake production presenting at least one cutting edge achieved through multiple types of debitage (unipolar, orthogonal, bipolar, and centripetal), arbitrarily chosen depending on (or according to) the raw material’s morphology and quality. Tools (usually denticulate and scrapers) are rarely found (Arzarello et al., 2016; Despriée et al., 2010), and unretouched flakes are predominant. Direct percussion by hard hammer is the most commonly used technique, but bipolar-on-anvil is also recognised (de Lombera-Hermida et al., 2016). Since a significant heterogeneity of the reduction sequences and raw materials employed is highlighted, the scientific community does not always agree on associating the concepts of *opportunism* (Arzarello, 2003) and *method* (Boëda, 1994) to describe the lithic complexes belonging to these sites. This brought to the identification of multiple technical behaviours, still without considering the presence of a possible common methodological *substratum* for these chronological phases, which has only recently started to be considered and regarded as “opportunistic” (Agam et al., 2015; Moncel et al., 2019; Moncel,

Ashton, et al., 2020; Moncel, Despriée, et al., 2020; Peretto et al., 2016; Santagata et al., 2017; Vaquero & Romagnoli, 2018).

During the Middle Pleistocene, simultaneously, along with an increase of archaeological evidence, a persistence of the opportunistic debitage can be attested throughout Europe. These assemblages are often associated with the first bifacial complexes (Barsky et al., 2013; Bourguignon et al., 2016; García-Medrano et al., 2015; Martínez & Garcia Garriga, 2016; Moncel et al., 2013, 2014, 2018; Preece & Parfitt, 2012; Santagata, 2016) or to small-medium flake ones (Aureli et al., 2016; Despriée et al., 2010; Gallotti & Peretto, 2015; Grimaldi et al., 2020; Muttillio et al., 2021; Ollé et al., 2013; Parfitt et al., 2008; Preece & Parfitt, 2012; Rocca et al., 2016), although terminological and methodological issues endure. The reduction sequences always comprise strong flexibility and versatility, translating in a constant adaptation to the raw material's morphology and optimisation of flake production. Further implications concerning the increasing complexity highlighted in core technology management for this period (especially regarding the length of the reduction sequences and surface's centripetal conception) are now the centre of an important debate regarding the genesis of more predetermined methods (Moncel Arzarello, & Peretto, 2016; Moncel et al., 2014; Moncel, Ashton, et al., 2020; Ollé et al., 2013; Rossoni-Notter et al., 2016). We suggest that the opportunistic debitage could be the starting point for this process, carrying within itself a tremendous methodological and cultural potential.

Therefore, the first evidence of Levallois production (Moncel, Ashton, et al., 2020) and its earliest diffusion during MIS 12 and MIS 9 (Moncel et al., 2016; Pereira et al., 2016; Rocca, 2016) determined a shift in the flakes complex's methodological analysis at the expense of the opportunistic debitage from this chronological phase onwards. Because of this, the contextualisation of the opportunistic method within the cultural traditions of the Middle and Upper Palaeolithic resulted in being nearly absent, with few cases being excluded (Arzarello, 2003; Daffara, 2017; Santagata et al., 2017).

Materials and Methods

The Italian peninsula provides significant archaeological evidence to contextualise the origin and the evolution of the opportunistic debitage during the Lower, Middle and Upper Pleistocene. For this reason, a selection of four sites (Pirro Nord, Cà Belvedere di Montepoggiolo, Ciota Ciara Cave and Riparo Tagliente; Fig. 1), from different chronological and environmental contexts, was made to better underline this phenomenon through the technological analysis of the lithic assemblages.

Pirro Nord (Foggia, Apulia, Italy) is in an active limestone quarry at the north-western margin of the Gargano promontory. It is part of a karstic complex developed at the top of the Mesozoic limestone formation, part of the "Apricena horst" (Pavia et al., 2012). In the sedimentary fillings of the Pirro 13 fissure (P13), lithic evidence was found alongside Late Villafranchian vertebrate fossils of the Pirro Nord Faunal Unit (Gliozzi et al., 1997). The origin of the deposit is the result of several massive processes (such as debris flow), which gradually chaotically fill



Fig. 1 Map showing the location and photos of the sites analysed in this work: 1, Pirro Nord; 2, Cà Belvedere di Montepoggiolo; 3, Ciota Ciara cave; 4, Riparo Tagliente

the fissure from the top, determining the transportation of artefacts and faunal remains (Giusti & Arzarello, 2016). The age of the site, estimated using biochronological data, falls between 1.6 and 1.3 Ma (Cheheb et al., 2019; López-García et al., 2015).

Cà Belvedere di Montepoggiolo is in northeast Italy near the town of Forlì. The geological succession of the area originated from the Plio-Pleistocene marine deposits “argille-grigio-blu” (grey-blue clay), later covered by the “sabbie gialle” (yellow sands) and subsequently eroded by marine regression (Ricci Lucchi et al., 1982). The yellow sands are not present in the site, and a pebble beach in a fluvial sand matrix was instead found, containing lithic assemblage in primary position (Peretto et al., 1998). The chronological range of the context has been set to 0.85 Ma (shortly after the cooling of MIS22), correlating the latest paleomagnetic analysis with the biochronological data from the surrounding area since no faunal remains were found (Muttoni et al., 2011).

Ciota Ciara cave is on the west slope of Monte Fenera’s karst (899 m a. s. l.) at the entrance of the Sesia valley (Vercelli, Piedmont, Italy). It is a still active karstic cave whose archaeological interest has been the object of systematic

excavations during the '60s, the '90s and again from 2009 onwards (Busa et al., 2005; Daffara et al., 2019; Fedele, 1966). During previous investigations, a long sequence at the cave entrance was unearthed, and four main stratigraphical units were found, each one attesting a phase of human occupation (Angelucci et al., 2019). The archaeological record is abundant, comprising faunal remains, lithic industry, and anthropical evidence (hearths and human remains; Arzarello et al., 2014). According to the chronological data gathered, the Ciota Ciara cave's human use may have occurred during the second half of the Middle Pleistocene (Angelucci et al., 2019; Berto et al., 2016; Cavicchi, 2018; Vietti, 2016).

Riparo Tagliente is a rock shelter situated on the west slope of Valpantena, one of the central valley bottoms of Monti Lessini (Verona, Veneto, Italy). Systematically investigated since 1967, a complex stratigraphy was unearthed attesting two distinct phases of human occupation: the lower one referred to MIS 4–3 with Mousterian and Aurignacian assemblages and the upper one dated to the Late Glacial with Late Epigravettian evidence. A rich faunal record alongside human remains was brought to light (Arnaud et al., 2016; Fontana et al., 2002; Thun Hohenstein & Peretto, 2005). The age of the Mousterian sequence (the one studied in this paper) is estimated to be between 60 and 40 ka based on sedimentological analysis associated with the faunal assemblages (Bartolomei et al., 1982).

The technological analysis was performed to reconstruct exclusively opportunistic assemblages' knapping sequences and core reduction strategies. The aim was to identify the objectives of production, the operative schemes applied to obtain such products and, at the same time, to evaluate how morphology affected those aspects. Therefore, technical criteria are required (Boëda, 2013; Inizan et al., 1995).

For the flakes, several attributes were considered. The knapping technique was identified by analysing the butt and the ventral face (impact point, ripples, hackles). The scars and the presence/position of cortex were analysed to define the knapping method and the different reduction sequences employed. The incidence of debordant and plunging flakes and their morphology were used to identify any possible "intended product" together with the presence and position of the cutting edge (Van Gijn, 1989). Moreover, for each core, a diacritical scheme was realised to recognise and interpret the final steps of core reduction. The dimensional analyses were performed on complete pieces. The technical dimensions of the items were measured according to the minimal rectangle or "box method" (Laplace, 1977). No size categories were created, thus a distinction based on flake length was not required.

For all sites, a sample of lithic artefacts was considered with the aim of being, at the same time, the most representative (concerning raw material exploited and products) but also unintentionally selected regarding the opportunistic debitage (Tables 1 and 2). Cores, flakes (length ≥ 10 mm), and tools from the most abundant levels concerning the opportunistic method were analysed and studied. Overall, the technical behaviours identified through the analysis of cores were divided into (I) unifacial and (II) multifacial, depending on the number of knapping surfaces exploited, (III) cores on flake and (IV) split fractures cores. The terms unipolar, centripetal, orthogonal, and bipolar, applied to core descriptions, indicate how each knapping surface was knapped according to scar removal direction (Inizan et al., 1995).

Table 1 Sites, number of pieces and raw materials of the lithic assemblages analysed. In the case of Pirro Nord, the whole stratigraphic sequence has been considered since it is the result of a gravitative accumulation rather than a proper archaeological stratification due to distinct human occupations

| Sites and levels | Total pieces | Studied pieces | Cores | Flakes | Raw material |
|-------------------------------|---------------------|-------------------|-------|--------|--------------|
| Pirro Nord | 340 | 108 | 19 | 89 | Flint |
| Cà Belvedere di Montepoggiolo | 1319 (76 refitting) | 83 (23 refitting) | 14 | 69 | Flint |
| Level 101 | | | 1 | 7 | |
| Level 102 | | | 2 | 15 | |
| Level 103 | | | 6 | 25 | |
| Level 104 | | | 2 | 10 | |
| Level 105 | | | 1 | 4 | |
| Level 107 | | | 1 | 2 | |
| Level 108 | | | - | 2 | |
| Level 109 | | | 1 | - | |
| Level 111 | | | - | 3 | |
| Level 113 | | | - | 1 | |
| Ciota Ciara cave | 7046 (5017 quartz) | 112 | 8 | 104 | Quartz |
| Level 14 | 3983 (3119 quartz) | | 8 | 104 | |
| Riparo Tagliente | 36.812 | 112 | 11 | 101 | Flint |
| Level 39 | 31 | | - | 7 | |
| Level 41 | 30 | | - | 2 | |
| Level 42 | 1397 | | 7 | 36 | |
| Level 42 alfa | 380 | | - | 14 | |
| Level 44 | 672 | | - | 12 | |
| Level 45 | 160 | | - | 7 | |
| Level 48 | 87 | | 1 | 3 | |
| Level 49 | 187 | | 1 | 13 | |
| Level 50 | 861 | | 1 | 1 | |
| Level 51 | 356 | | - | 5 | |
| Level 52 | 409 | | 1 | 1 | |

The supplementary data for the archaeological collection are available at this link: <https://zenodo.org/record/4228014>.

An experimental collection for each site was obtained from the most abundant raw material in every context (Table 3). Pirro Nord and Cà Belvedere di Montepoggiolo were conceived together since the raw material morphology exploited in both is very similar (i.e. small pebbles). Since the experimentation focused exclusively on opportunistic debitage, its purposes revolved around two main aspects to evaluate its stability and versatility as a method: (a) the volumetric evolution of each block from its initial morphology to its gradual modifications as the knapping activity was carried on and (b) the identification of the leading strategies and aspects influencing any operative schemes. To accomplish these tasks, the creation of the *knapping-event* concept, similar to the one of *algorithm* defined by Forestier (1993), was

Table 2 Knapping goals of the experimental protocol

| Experimental protocol | |
|--------------------------|--|
| Objectives of production | a) Maximized flake-production b) Flake production achieved through a single technical behaviour (i.e. centripetal) c) Flake production with predetermined functional and/or dimensional criteria (i.e. flake presenting a cutting edge of at least 40 mm) |
| Knapping-event change | 1) Absence of knapping criteria 2) Choice of a new striking platform and/or knapping surfaces on arbitrary base (such as “better convexities available”) 3) Raw material quality 4) Dimensional issues 5) Impossibility to achieve the objective of production 6) Core management (such as technical flakes) 7) Knapping errors and/or accidents |

Table 3 Raw materials, the number of blocks collected and flakes obtained during the experimentation

| Site | No. of blocks collected | No. of flakes obtained | Raw material | Weight (kg) |
|--|-------------------------|------------------------|--------------|-------------|
| Pirro Nord/Cà Belvedere di Montepoggiolo | 10 | 302 | Flint | 2.960 |
| Ciota Ciara cave | 10 | 204 | Quartz | 4.220 |
| Riparo Tagliente | 10 | 412 | Flint | 7.430 |

| Knapping Events | | | |
|-----------------|-------------------|------------------|-----------------|
| Sequence | Striking Platform | Knapping Surface | Flakes Obtained |
| 1st | 1 | a | 3 |
| 2nd | a | 1 | 3 |
| 3rd | 2 | b | 2 |
| 4th | a | b | 3 |

Operative scheme: 1a - a1 - 2b - ab

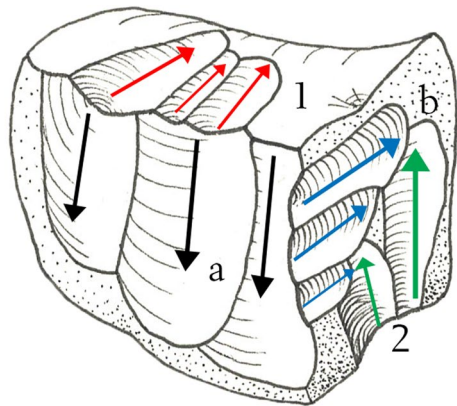


Fig. 2 Experimental protocol: example of an experimental core with its relative operative scheme. The arrows' colours are related to their respective knapping event. Each arrow indicates a removal and its direction. Drawings by M. Cecchetti

necessary (Fig. 2). The *knapping event* can be defined as “the choice of one striking platform and its related knapping surface from which the core will be knapped. The switch or the change of one, or both surfaces previously involved determines the end of that *knapping event* eventually allowing a new one to begin with”. Each new striking platform was marked with consecutive numbers while the knapping surface with successive letters. The striking platform was always written before the knapping surface so that in case the chosen striking platform was formerly a knapping surface (or vice versa), the letters and the numbers were switched rather than using new ones. Once the core was discarded, an operative scheme was obtained by indicating the sequence of each *knapping event* in chronological order (Fig. 2).

Moreover, before starting each experimental sequence, specific knapping goals were established to verify if they could have led to different choices regarding core management or if they required specific knapping patterns (Table 3). The selection of goals was set according to the initial morphology and volume of the blocks, always considering the original archaeological context. To keep track of this process, any time a *knapping-event* switch was performed or the core was discarded, the causes were written down based on the knapper’s indication (Table 3). The aim was to highlight and quantify the main factors affecting the flaking process by comparing each block’s operative scheme with the resulting outcomes. Following the flaking process all along, some questions were addressed. Which are the main aspects influencing the volumetric evolution of the blocks? Are they identifiable? How much does the morphology affect the objectives of production? Is there a concrete subordination to raw material morphology? And, if so, is there any pattern distinguishable in the knapping activity?

The study of the experimental collection took place using the same technical criteria applied for the technological analysis of the archaeological material focusing on the direction of scars, incidence of debordant and plunging flakes and flake functionality (Van Gijn, 1989). The supplementary data for the experimental collection are available at this link: <https://zenodo.org/record/4228014>.

In the end, it was highlighted once again how the experimental knapping activity was applied as a constant analogy to get as close as possible (aware of being far from the absolute certainty) to the identification of a predominant operative scheme (i.e. method) by its application through several technical behaviours.

The Opportunistic Debitage of Pirro Nord and Cà Belvedere di Montepoggiolo

The raw materials employed in the sites mentioned above were locally selected from secondary deposits. The morphology and volume differed within each context, profoundly affecting the reduction sequences. In Pirro Nord, small and medium-sized pebbles (~ 30–80 mm), primarily round and oval, were exploited and collected within the range of the site, in riverbeds or slope deposits. The recognised flint types, coming from the Gargano Cretaceous succession, are of good quality. In Montepoggiolo,

the procurement strategies recall the Pirro Nord ones qualitatively and morphologically. Pebbles and cobbles are slightly longer and oval (~30–100 mm).

Each opportunistic assemblage was oriented towards non-standardised flake production, presenting at least one cutting edge at times opposite to a backed margin (cortical or flat) (Figs. 6 and 7). The technical behaviours applied in each site are deeply related to the locally available morphologies, resulting in different knapping strategies. The presence of natural convexities on the selected blocks is one of the most relevant and frequently attested features. This allows the production of functional flakes without implying core preparation or a decortication phase.

Production

In Pirro Nord and Cà Belvedere di Montepoggiolo, similar morphologies provided an identical technological response, repetitive and deeply assimilated into the method. In both sites, the production was oriented towards roughly quadrangular flakes, which sometimes could be elongated depending on the initial morphology and volume of the core, especially for Montepoggiolo (Figs. 5, 6, and 7). The flakes were obtained through unipolar, orthogonal, bipolar, and centripetal flaking (Fig. 11; Table 4). The dimensional data available for Pirro Nord, both from the archaeological and the experimental collection highlights how the cobbles were originally mainly spherical, rarely larger than 60 mm (Fig. 5). Concerning Montepoggiolo, mostly large oval pebbles were knapped, resulting in longer flakes (Fig. 5). All in

Table 4 Typology of cores analysed in the archaeological (A.) and experimental (E.) record

| Types of core | Pirro Nord | | Cà Belvedere di Montepoggiolo | Ciota Ciara cave | | Riparo Tagliente | |
|----------------------|------------|----|-------------------------------|------------------|----|------------------|----|
| | A | E | | A | E | A | E |
| Unifacial cores | | | | | | | |
| Unipolar | 5 | 2 | 5 | 3 | 5 | 1 | |
| Centripetal | 1 | 2 | 2 | | | 1 | 1 |
| Bipolar | | 1 | | | | | |
| Orthogonal | 2 | 2 | 1 | | | | |
| Multifacial cores | | | | | | | |
| Unipolar | 3 | 4 | 3 | 3 | 8 | 3 | 7 |
| Unipolar–bipolar | | | | | 2 | 1 | |
| Unipolar–orthogonal | 1 | 1 | 1 | 2 | | 2 | 2 |
| Centripetal | 1 | | | | | | |
| Centripetal–unipolar | | 1 | 1 | | | 2 | |
| Orthogonal | | | 1 | | | 1 | |
| Bipolar | 2 | | | | | | |
| Split fracture cores | 1 | | | | | | |
| Cores on flake | 3 | | | | | | |
| Total | 19 | 13 | 14 | 8 | 15 | 11 | 10 |

all, two main reduction strategies were identified: a unidirectional-multifacial flake-production applied on larger volumes and centripetal exploitation of the surfaces on smaller and more rounded cobbles. Given the original dimensions of the raw material and since the adaption to morphology was constant throughout the whole knapping process, the reduction sequences were short and arbitrarily applied on the same core (Table 5).

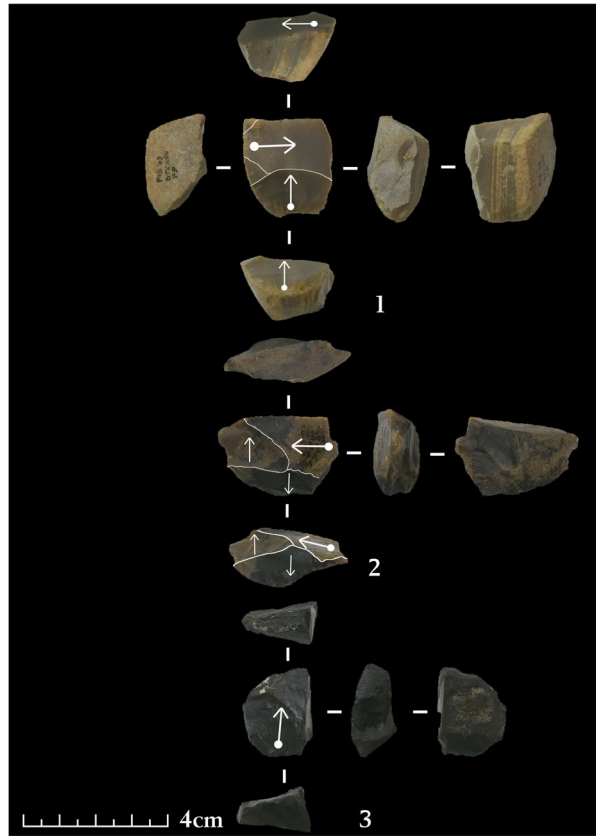
The unipolar production began with the opening of a flat striking platform decaping one of the extremities of the pebbles or exploiting present suitable convexities (Fig. 4, n°1). Parallel unipolar removals gradually decorticated the knapping surfaces. Therefore, knapping surfaces were orthogonally generated, often by negatives of previous removals. The same scheme is observable on striking platforms. The production was carried on until suitable convexities existed. Usually, 3–4 flakes were extracted from each core, but when bigger pebbles were present, such as in Montepoggiolo, a succession of three or four-generation from the same striking platform is attested (Figs. 3 and 4, n°2). Overall, flake production was achieved while maintaining appropriate convexities. The use of lateral debordant flakes, both for the creation of backed margins and as nervure guides, is the technical expedient more frequently adopted (Fig. 10).

A centripetal conception of the surfaces was applied in the second case mentioned above. A single knapping surface was exploited in different directions (usually orthogonal or bipolar, more rarely centripetal *sensu stricto*) through a peripheral striking platform (Fig. 3, n°1; Fig. 4, n°1). This strategy was applied on the rounder cobbles, especially the smallest ones, usually opened by the bipolar on anvil technique. In doing so, larger knapping surfaces were made

Table 5 Pirro Nord 13. Analysis of the experimental cores. N° S. P. indicates the final number of striking platforms on the abandoned cores. N° K. S. indicates the final number of knapping surfaces on the abandoned cores

| Site | Core ID | Knapping-events sequence | Type of core | N° S. P. | N° K. S. | N° Flakes |
|------------|---------|--------------------------|------------------------------------|----------|----------|-----------|
| Pirro Nord | n1 | 1a-ab-bc-2c-cd-dc | Multifacial (centripetal–unipolar) | 6 | 5 | 31 |
| | n2 | 1a-2a-3a-ab | Multifacial (unipolar) | 2 | 2 | 34 |
| | n3 | 1a-ab-bc-cb | Unifacial (unipolar) | 1 | 1 | 42 |
| | n4a | 1a-a1 | Unifacial (orthogonal) | 2 | 2 | 20 |
| | n4b | 1a-a1 | Unifacial (centripetal) | 2 | 2 | 36 |
| | n5a | 1a | Unifacial (centripetal) | 1 | 1 | 11 |
| | n5b | 1a | Unifacial (unipolar) | 1 | 1 | 14 |
| | n6 | 1a-a1-1b-b1 | Multifacial (unipolar–orthogonal) | 3 | 3 | 25 |
| | n8 | 1a | Unifacial (orthogonal) | 2 | 1 | 13 |
| | n10 | 1a-a1 | Unifacial (unipolar) | 2 | 2 | 10 |
| | n7 | 1a-ab-2(ab)-a1 | Multifacial (unipolar) | 3 | 3 | 21 |
| | n9a | 1a-a1 | Unifacial (bipolar) | 1 | 1 | 16 |
| | n9b | 1a-ab-bc | Multifacial (unipolar) | 3 | 3 | 25 |

Fig. 3 Pirro Nord, archaeological: 1, orthogonal core; 2, multifacial orthogonal core on flake; 3, unipolar core



available, and it was also the best way to enhance the cobble's volume. Therefore, it is the most efficient behaviour testified in Pirro Nord (Fig. 3; Table 4). The striking platforms were mainly natural, although in Montepoggiolo flat ones are attested by several refits. The latter was realised through one or more orthogonal removals to the knapping surface to prepare a peripheral striking platform (Fig. 4). During the reduction sequence, each removal would often create new convexities (lateral and or distal) and nervures that allowed the debitage to run around the block until suitable technical criteria existed. As aforementioned, also, in this case, the presence of debordant flakes is quite relevant with the aim of maintaining good angles and convexities and to obtain backed flakes (opposite to a cutting edge) (Fig. 6, n° 4, 6, 11, 12; Fig. 7, n° 4, 8, 10; Fig. 10).

The raw material's morphology dictates the best strategy to employ among the two. Nonetheless, both behaviours can be recognised on the same core. The constant adaptation to morphology is the scheme behind the process for accomplishing the production's goals.

Fig. 4 Cà Belvedere di Montepoggiolo, archaeological: 1, orthogonal multifacial core on small pebble; 2, unipolar core on a large pebble

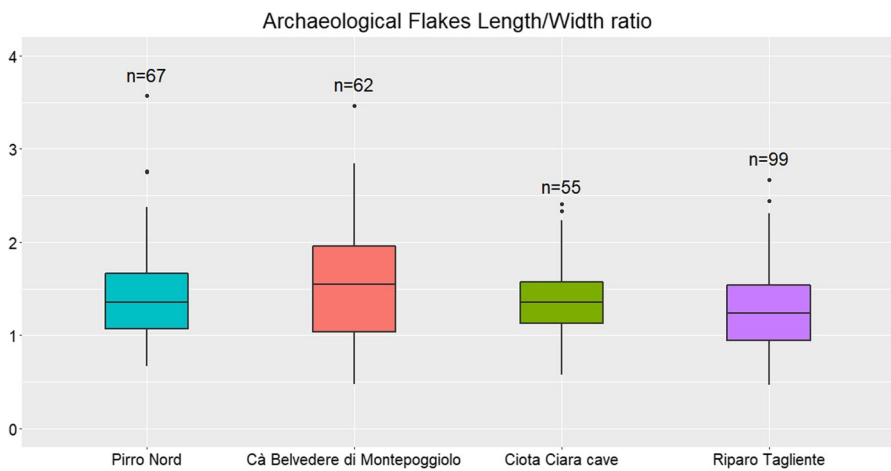
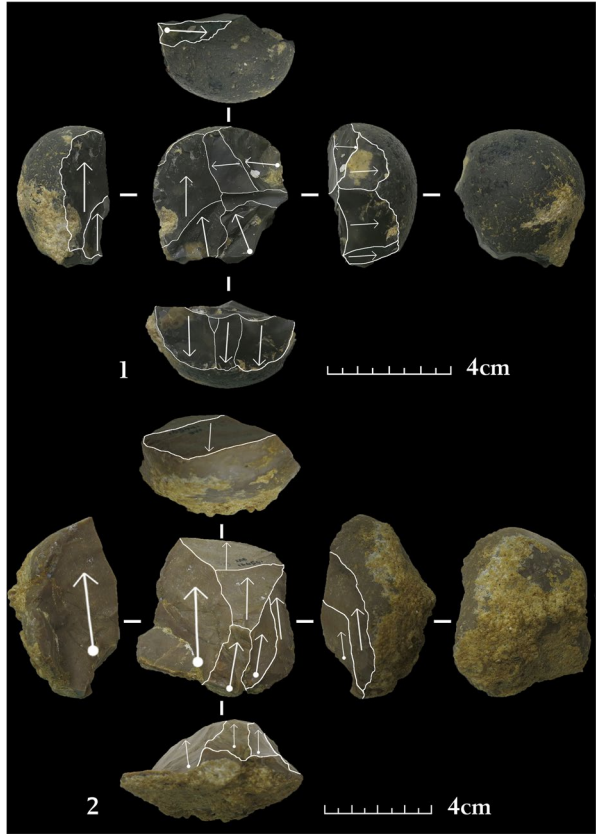


Fig. 5 Dimensional variability of archaeological flakes; yaxis: length/width ratio; xaxis: archaeological site

Fig. 6 Pirro Nord, archaeological: 1–4, flakes with unipolar scars; 5–7, flakes with orthogonal scars; 8–10, flakes with centripetal scars; 11–12, flakes with bipolar scars; 13, cortical flake



Flakes' Analysis

Pirro Nord and Cà Belvedere di Montepoggiolo's flakes share common features. Quadrangular non-standardised shapes are widely attested, slightly longer than larger and with at least one cutting edge, usually on the lateral margin (Figs. 5, 6, and 7). The length of Pirro Nord's flakes ranges between 40 and 15 mm. The average length is 27 mm. Width ranges from 30 to 10 mm, with an average of 20.2 mm. Thickness varies between 16 and 3 mm, and the average value is 8.4 mm. Regarding Cà Belvedere di Montepoggiolo's flakes are longer than Pirro Nord's. Length ranges between 78 and 11 mm; however, for 77% of the pieces, it goes from 19 to 51 mm. The average length is 37.3 mm. Width reaches a maximum value of 51 and a minimum of 12 mm with an average of 26 mm. However, for 87% of flakes, the width spans from 12 to 36 mm. Concerning thickness, it varies from 28 to 2 mm with an average value of 9.3 mm.

The dimensional range of the flakes, with or without cortex, is relatively homogenous, confirming the shortness of the reduction sequences (Fig. 8). The cortical flakes, less attested, are related either to the bipolar technique or to the

Fig. 7 Cà Belvedere di Montepoggiolo, archaeological: 1–7, flakes with unipolar scars; 8–10, flakes with orthogonal scars; 11–12, flakes with centripetal scars; 13–14, cortical flakes



opening of new knapping surfaces. The frequency of functional flakes (with at least one cutting edge) is constant within each employed reduction sequence, indicating that the adaptation to the morphology led to efficient production. Moreover, the presence of backed lateral margins (mainly cortical) opposite to cutting edges can be interpreted as a researched feature for better grasping and, as already mentioned, a technical expedient as well (Figs. 6, 7, and 10). Several refits from Cà Belvedere di Montepoggiolo highlight this strategy as an efficient way to maintain technical criteria alongside flake production. In this case, convergent flakes could be obtained through a removal on the lateral edge of the knapping surface, thus preparing a nervure guide (Fig. 7, n° 4, 5, 6).

The Experimental Collection

The experimental collection of Pirro Nord provided a significant number of debordant flakes, both from unipolar and centripetal cores (Figs. 9 and 10; Table 6). These products were constant in each *knapping event*, showing specific core exploitation behaviours but often being characterised by a lateral cutting edge opposite to a

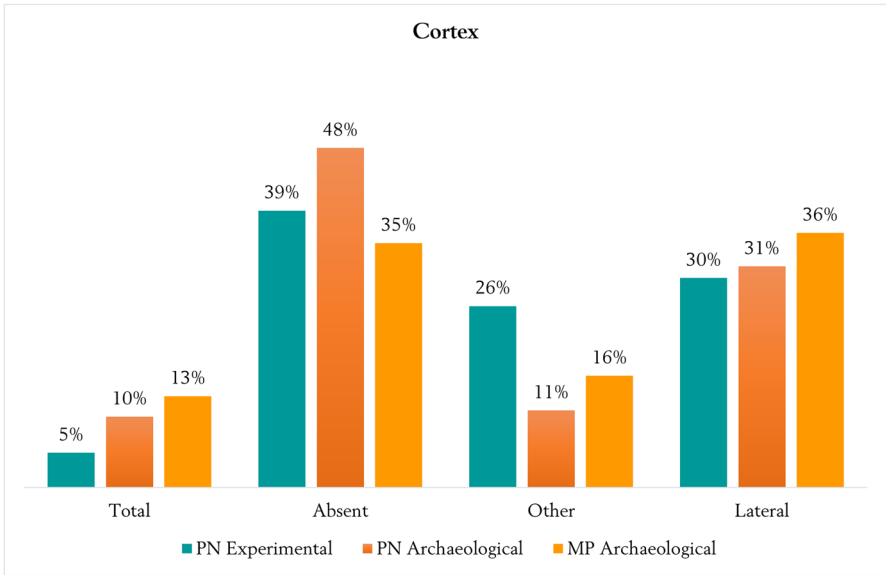


Fig. 8 Pirro Nord and Cà Belvedere di Montepoggiolo. The presence and position of cortex on archaeological and experimental flakes from Pirro Nord (PN) and archaeological flakes from Cà Belvedere di Montepoggiolo (MP)

Fig. 9 Pirro Nord, experimental: 1–7, flakes with unipolar scars; 8–11 flakes with orthogonal scars; 12, flake with centripetal scars; 13, flake with bipolar scars



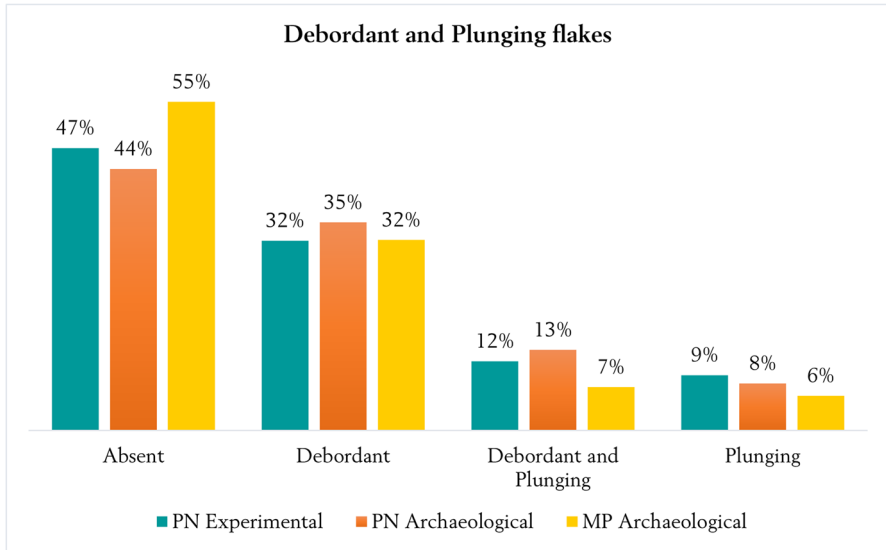


Fig. 10 Pirro Nord and Cà Belvedere di Montepoggiolo. Distribution of debordant and plunging flakes on archaeological and experimental collections from Pirro Nord (PN) and archaeological flakes from Cà Belvedere di Montepoggiolo (MP)

backed margin (Fig. 9, n°1, 3, 4, 9). In unipolar productions, their function was the knapping surface's management, achieved by lowering the core's lateral edges while also creating a nervure guide for the subsequent removals. This way each following flake sets up a lateral convexity and a nervure guide for its consecutive removal, making it possible to quickly obtain sustainable flake-lengths and cutting edges without cortex. In the centripetal sequences, cordal-like removals (Fig. 9, n° 9) were often performed to maintain good convexities, but since the debitage was conducted through a peripheral striking platform, lateral and distal convexities were often, unintentionally, created (Fig. 9, n° 10, 11). This allowed the knapper to effectively run around the block and choose the best surface to control the flake's morphology and functional features. This pattern is evident, especially in the case of smaller cores (Figs. 11 and 12). Therefore, orthogonal removals were performed alternating two distinct directions from the striking platform (Fig. 12, n°3). The experimental collection also yielded many déjeté points, corresponding to 23% of all flakes. The frequency of two orthogonal margins (the lateral and the distal one), forming a tip, often adjacent to a natural backed edge, turned out to be very high in centripetal exploitation (36% of all déjeté points; Fig. 9, n° 8, 10–12). However, these flakes were not morphologically predetermined, as seen in the archaeological record (Arzarello et al., 2016; Potì, 2012). These proved to be rather an unintentional outcome of centripetal reduction sequences, which likely produced quadrangular flakes (i.e. with orthogonal margins) (Fig. 9, n° 8, 10, 11).

The analysis of the experimental production from Pirro Nord displayed a greater affinity between the centripetal reduction sequences and the archaeological collection (Table 5). The ratio between unipolar removals and orthogonal + bipolar ones is

Table 6 Ciota Ciara cave. Analysis of the experimental cores. N° S. P. indicates the final number of striking platforms on the abandoned cores. N° K. S. indicated the final number of knapping surfaces on the abandoned cores

| Site | Core ID | Knapping-events sequence | Type of core | N° S. P. | N° K. S. | N° Flakes |
|------------------|---------|--------------------------|--------------------------------|----------|----------|-----------|
| Ciota Ciara cave | CC1N | 1a-a1-1b-b1 | Multifacial (unipolar-bipolar) | 3 | 4 | 41 |
| | CCN9-1 | 1a-ab-1c | Multifacial (unipolar) | 2 | 3 | 3 |
| | CC3N | 1a-a1-1b-b1 | Multifacial (unipolar-bipolar) | 3 | 3 | 14 |
| | CCN10 | 1a-a1 | Multifacial (unipolar) | 2 | 2 | 4 |
| | CCN5 | 1a-a1-1a1 | Multifacial (unipolar) | 2 | 2 | 23 |
| | CCN9 | 1a-ab-ba | Multifacial (unipolar) | 2 | 2 | 23 |
| | CCN7 | 1a-ab-1a1-a1-1a2 | Multifacial (unipolar) | 2 | 2 | 27 |
| | CCN4b | 1a-ab | Multifacial (unipolar) | 2 | 2 | 10 |
| | CCN4a | 1a-a1 | Multifacial (unipolar) | 2 | 2 | 9 |
| | CCN8 | 1a-21-1aII | Multifacial (unipolar) | 1 | 1 | 11 |
| | CCN6 | 1a | Unifacial (unipolar) | 1 | 1 | 18 |
| | CC2Nb | 1a | Unifacial (unipolar) | 1 | 1 | 3 |
| | CC2Na | 1a | Unifacial (unipolar) | 1 | 1 | 5 |
| | CC2N | 1a-21 | Unifacial (unipolar) | 1 | 1 | 2 |
| | CCN4b1 | 1a | Unifacial (unipolar) | 1 | 1 | 5 |

closer when selecting only centripetal reduction sequences. This is also emphasised by a more significant similarity of the flakes thus obtained (Fig. 6, n° 6–9; Fig. 9, n° 7, 8, 10–12). Hence, the centripetal exploitation of the surfaces was more efficient and quantitatively import when experimenting on smaller volumes and rounder morphologies.

By observing the refitting of the experimental sequences, it appears that, as already stressed, a centripetal conception of the surfaces quickly leads to better control of the flake's morphology. As a result, this may gradually generate greater *awareness* in the knapper's mind during the flaking activity leading to hierarchised reduction sequences and, eventually, obtaining morphologically predetermined products. The presence of déjeté points in Pirro Nord's archaeological record (Fig. 6, n° 8) and convergent flakes from the Cà Belvedere di Montepoggiolo (Fig. 7, n° 4, 5) may be an example of this. Short reduction sequences intensively and constantly applied on many pebbles could lead to a standardised technical behaviour, modulated on the continually changing morphology, potentially generating predetermined

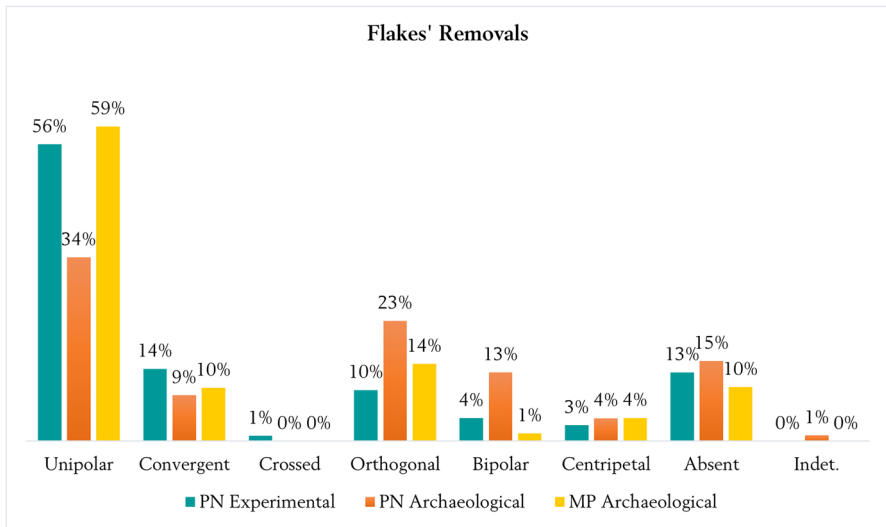


Fig. 11 Pirro Nord and Cà Belvedere di Montepoggiolo. Presence and position of removals on archaeological and experimental flakes from Pirro Nord (PN) and archaeological flakes from Cà Belvedere di Montepoggiolo (MP)

products. In conclusion, similar morphologies can correspond to identical methodological responses (Arzarello et al., 2016).

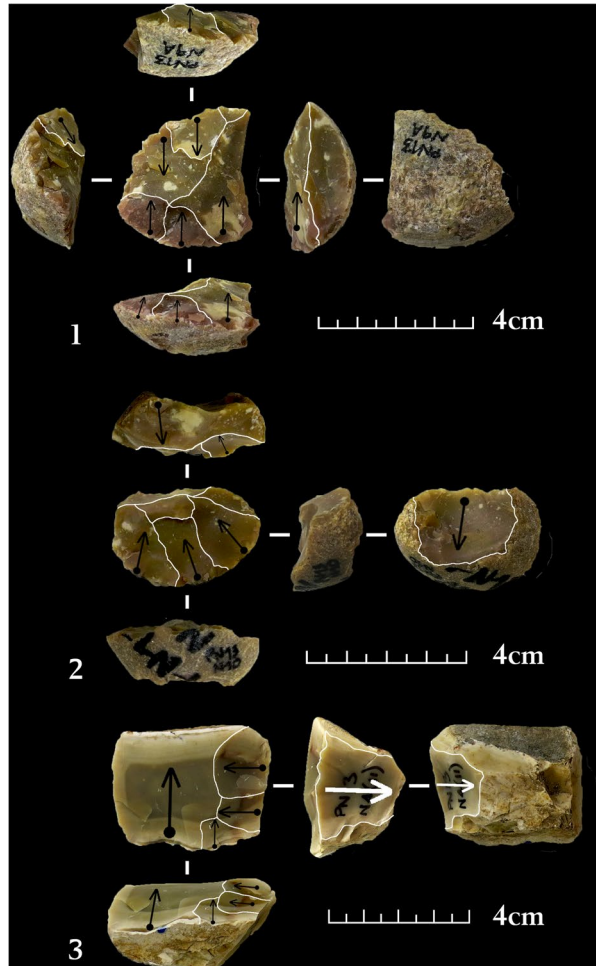
The Opportunistic Debitage of Ciota Ciara Cave and Riparo Tagliente

In terms of raw material selection, the same pattern can be highlighted for the opportunistic assemblages of Ciota Ciara cave and Riparo Tagliente. In the Ciota Ciara cave, vein quartz is the most exploited raw material for opportunistic reduction sequences and other knapping methods (Daffara, 2017). Blocks and nodules of different morphologies and dimensions (40–100 mm) were locally collected along riverbeds and slope deposits (Daffara et al., 2019). Since vein quartz's texture is mainly coarse, implying shorter reduction sequences, more significant importance was given to the presence of suitable natural convexities rather than to the dimensional issues. The same procurement strategies are seen in Riparo Tagliente, where many large flint blocks and nodules of excellent quality were available. As in the previous context, Levallois and discoid productions were made on the same raw material, alongside the laminar method.

Ciota Ciara Cave—Production

In the Ciota Ciara cave, flake production started straight from the block's natural convexities, or arrows, without foreseeing any core preparation or surface management. The production, then, proceeded mainly through unipolar removals, eventually

Fig. 12 Pirro Nord, experimental: 1, bipolar core on small pebble open by split fracture; 2, unipolar multifacial core on small pebble open by split fracture; 3, orthogonal multifacial core



including new knapping surfaces or just switching them (Fig. 13; Table 5). Orthogonal and bipolar removals are less attested to (Fig. 13). The use of the same knapping surface and striking platform until the core's exhaustion was relatively common (Table 4). The produced flakes were quadrangular in shape, yet morphologically non-standardised and with at least a cutting edge on the lateral margin (Fig. 16). According to the raw material features, a high rate of flaking accidents and irregular surfaces on the cores are frequent (Daffara, 2017). Therefore, the creation and management of suitable convexities and nervure-guides were related to the initial morphology of the blocks. Reduction sequence length was proportioned to the initial volume of the block but above all to its *morphological flaking-predisposition*. With this expression, we want to indicate the presence of natural suitable angle and convexities as the guiding line for the block's selection and during the knapping activity. The experimental collection confirmed this, which provided a wide

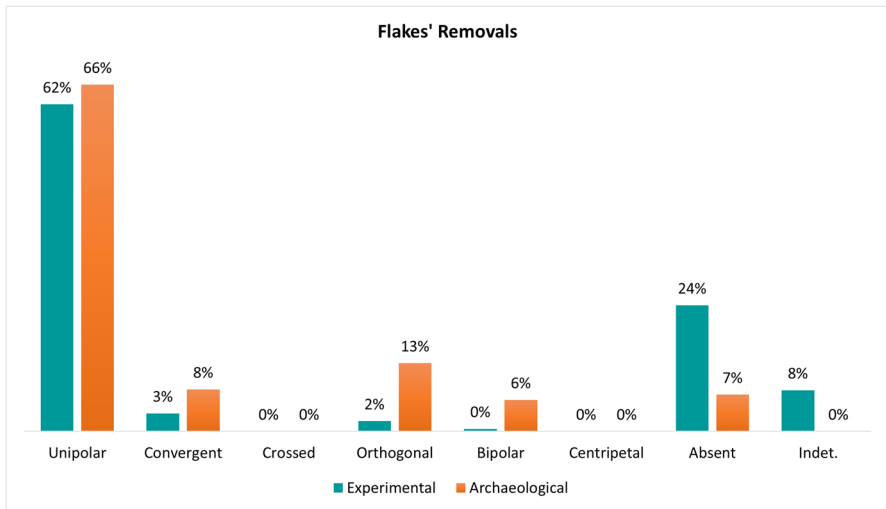


Fig. 13 Ciota Ciara cave. Presence and position of removals on archaeological and experimental flakes

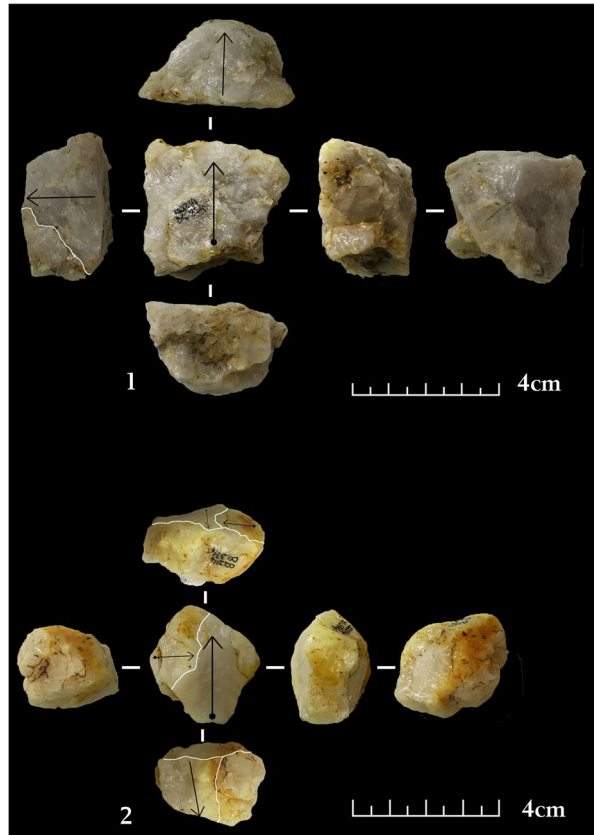
sample of exhausted cores of different morphologies and dimensions. Their analysis emphasises the absence of a specific tendency in choosing one or more striking platforms and knapping surfaces to exploit (Table 6). The objectives of production were instead modulated considering the pre-existing convexities.

No difference was made between natural or flat striking platforms since vein quartz's cortex did not affect the flaking activity. The likelihood of exploiting one knapping surface until the abandonment of the core was relatively high, also considering the high percentage of natural butts. This may also prove that the production phase starts directly on the natural surfaces (Tables 4 and 6).

Ciota Ciara Cave—Flakes

Ciota Ciara's flakes are roughly quadrangular and slightly longer than larger (Fig. 5). Lengths range between 70 and 14 mm with an average of 33.5 mm. Widths span from 12 to 66 mm; however, 82% of flake widths range from 12 to 32 mm. The average width is 25.5. Regarding thickness, it goes from 4 to 24 mm with an average value of 12.5 mm. The flakes show a lateral cutting edge frequently opposite a backed margin (Fig. 16, n° 1, 3, 5, 6; Fig. 18). The presence of guiding arrises is usually related to a single unipolar removal or, more rarely, by a portion of the cortex (Fig. 16, n° 1, 3, 5, 8). Generally, most flakes display only one negative, suggesting that knapping surfaces were not that large, being exploited through few removals until the exhaustion of the natural convexities. In this way, natural edges were used as a technical expedient to achieve functional flake production and create nervure guides. Therefore, the frequency of debordant flakes is quite high (Fig. 18). Orthogonal and bipolar flaking resulted in being sporadically employed (Fig. 13). However, the cores and flakes attesting to these strategies (Fig. 14, n° 2) are not different from the record, fitting well in

Fig. 14 Ciota Ciara cave, archaeological: 1, unipolar multifacial core; 2, orthogonal multifacial core



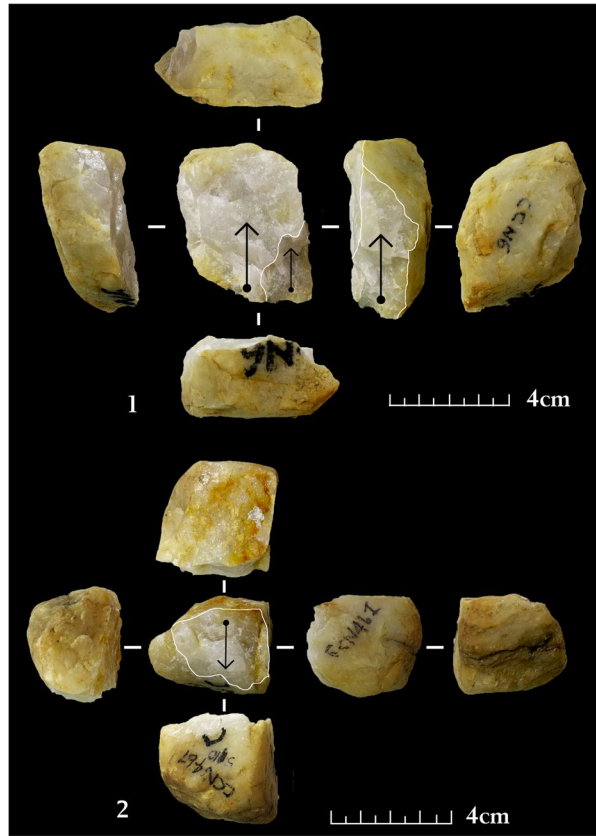
the same operative scheme of subordination and adaptation to the morphology that comprises the whole opportunistic production of the Ciota Ciara cave. Supporting this, the experimental reduction sequences occasionally presented knapping surfaces exploited from several directions, but this was not matched by the flake removal analysis, which shows the same trend as the archaeological cases (Tables 5 and 7; Figs. 13, 15, 16, and 17). On an experimental basis, the functionality rate of the flakes proved to be higher on the smallest and thinnest ones. This, however, is not validated by the archaeological sample, attesting, on the other hand, to a homogeneous distribution of functional flakes within the dimensional range. Therefore, in accomplishing the production goals, it was constant along the entire reduction process, without the need for specific morpho-dimensional criteria.

Once again, the high adaptability towards morphologies and volumes of blocks and cores emerges as the central distinguishable aspect of the opportunistic assemblages. The presence of Levallois and discoid productions within the context proves, on one side, that the exploitation of raw materials qualitatively regarded as inferior does not invalidate the possibility of using more complex

Table 7 Riparo Tagliente. Analysis of the experimental cores. N° S. P. indicates the final number of striking platforms on the abandoned cores. N° K. S. indicated the final number of knapping surfaces on the abandoned cores

| Site | Core ID | Knapping-events sequence | Type of core | N° S. P. | N° K. S. | N° Flakes |
|------------------|---------|--------------------------|-----------------------------------|----------|----------|-----------|
| Riparo Tagliente | RT1N | 1a-a1-1b-a1I-1c | Multifacial (unipolar) | 3 | 3 | 44 |
| | RT2N | 1a-ab-bc-ed | Multifacial (unipolar-orthogonal) | 3 | 3 | 41 |
| | RT3N | 1a-a1-1b-1c | Multifacial (unipolar) | 3 | 3 | 49 |
| | RT5N | 1a-a1-1a1-a1I-1aII | Multifacial (unipolar-orthogonal) | 4 | 5 | 40 |
| | RT6N | 1a-a1 | Multifacial (unipolar) | 2 | 2 | 20 |
| | RT7N | 1a-ab-1b-a1-1a1 | Multifacial (unipolar) | 2 | 2 | 43 |
| | RT8N | 1a-a1-1b-b1 | Multifacial (unipolar) | 2 | 2 | 18 |
| | RT9N | 1a-ab | Multifacial (unipolar) | 2 | 2 | 25 |
| | RT10N | 1a | Unifacial (centripetal) | 1 | 1 | 54 |
| | RT11N | 1a-ab-ac-ba-ab1-bal-abII | Multifacial (unipolar) | 3 | 3 | 78 |

Fig. 15 Ciota Ciara cave, experimental: 1, unipolar multifacial core; 2, unipolar core



flaking methods; On the other hand, it underlines how opportunistic debitage persists during the Middle Palaeolithic as an efficient and independent method (if compared to Levallois and discoid) replicated through several operative knapping schemes (i.e. unipolar, orthogonal, centripetal, bipolar) for the manufacturing of functional products (Figs. 18 and 19).

Riparo Tagliente

Concerning Riparo Tagliente's opportunistic assemblage, the aim was always flake-production achieved through a constant adaptation to the morphological criteria. Since larger, higher-quality blocks were available (nodules and fluvial cobbles), the reduction sequences were longer and more complex (Table 4; Fig. 23). These aspects enhanced the possibility of exploiting more surfaces simultaneously or individually through multifacial removals (unipolar, orthogonal, bipolar, and centripetal s.s.) until the complete depletion of the existent convexities. This determined, eventually, the abandonment of large dimension cores still presenting suitable surfaces for exploitation (Fig. 23). The great abundance of such an excellent raw material

Fig. 16 Ciota Ciara cave, archaeological: 1–9, flakes with unipolar scars; 10, flake with orthogonal scars; 11, flake with bipolar scars



within the site might explain this behaviour (Arzarello, 2003). Of course, the presence of small massively exploited cores also suggests that the production was quantitatively remarking despite anything else.

Again, the initial morphology dictated how the production goals were achieved. This was resolved in a dual case scenario to produce non-standardised quadrangular flakes, slightly elongated with at least one cutting edge (Figs. 5 and 24). In the first case, unipolar-multifacial debitage was set up while a centripetal one occurred in the latter. According to the evolving morphologies, these two strategies were not separately employed but constantly linked and rotated on the same core. The length of these flakes ranges between 20 and 70 mm, with 91% of them ranging from 20 to 50 mm. The average length is 36 mm. Concerning width, it spans from 12 to 65 mm, but 86% is included in a 17–42 mm range. The average width is 30.2 mm. Thickness varies from 4 to 19 mm with an average of 8.6 mm.

Riparo Tagliente—Production

The unipolar production was carried on larger nodules or particularly elongated ones, where the longitudinal axis was often employed as the knapping surface. In

Fig. 17 Ciota Ciara cave, experimental: 1–2, cortical flakes; 3–10, flakes with unipolar scars; 11, flake with orthogonal scars

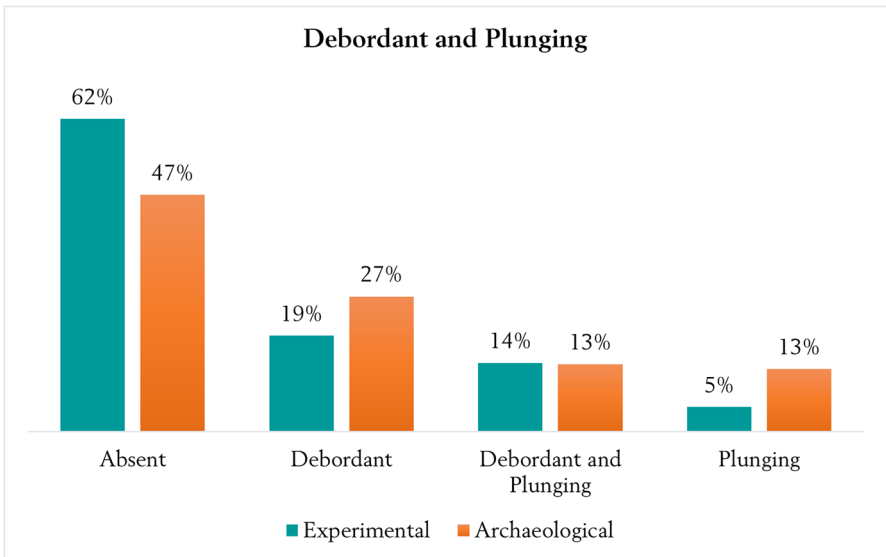
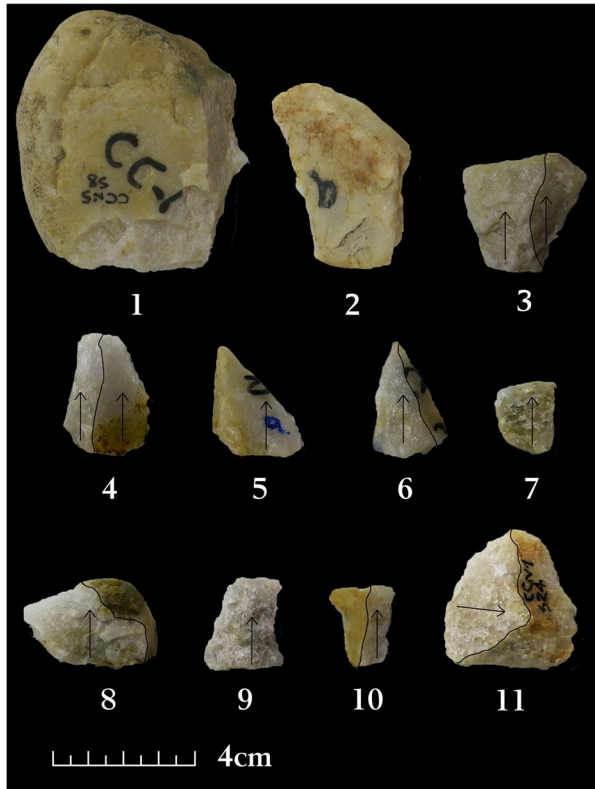


Fig. 18 Ciota Ciara cave. Distribution of debordant and plunging flakes on archaeological and experimental collections

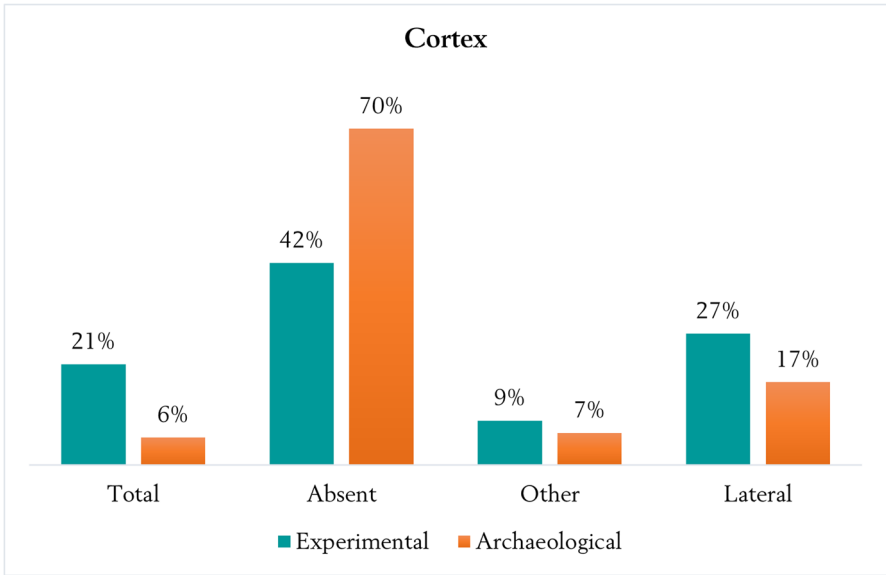


Fig. 19 Ciota Ciara cave. Presence and position of cortex on archaeological and experimental flakes

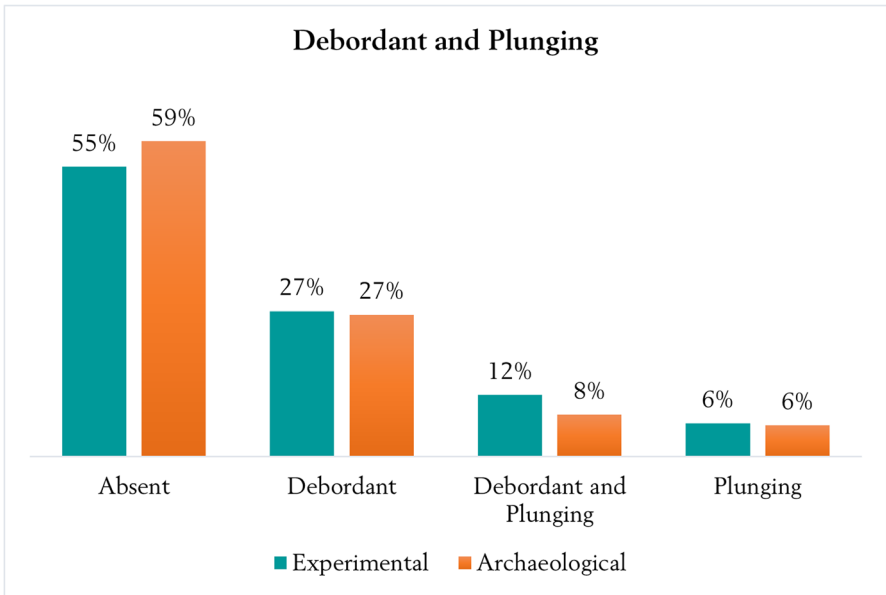


Fig. 20 Riparo Tagliente. Distribution of debordant and plunging flakes on archaeological and experimental collections

this case, the presence of suitable natural convexities was one of the requirements for opening the flaking activity. Most of the nodules presented exposed surfaces due to natural fractures that could speed up the extraction process (Fig. 21). Otherwise, a single cortical flake was needed to prepare the knapping surface. Concerning striking platforms, the same pattern can be attested. The opening of a flat one was necessary when an already existing one was lacking in the initial morphology of the blocks. Elongated laminar-like flakes were thus obtained, more frequently presenting a debordant edge on the lateral margin rather than on the distal one (Fig. 20, 24 n° 1). The cutting edge often corresponded to the scar left by previous removals. The aim was to gradually enlarge the knapping surface, removing the cortex and thus involve the other core's faces. The formation of nervure-guides happened simultaneously to the flake's extraction, being equally exploited as natural edges. These aspects were functional to the flake's length, optimising the knapping surface's productivity in both a quantitative and qualitative way. As stressed above, this strategy resulted, eventually, in semi-tournant behaviours involving, initially, natural edges by progressively exploiting ones created during the production, recalling the laminar conception. As the core's volume decreased, multidirectional flaking could be initiated (Table 5; Figs. 22 and 23). Therefore, switching between the striking platforms and knapping surfaces was rather frequent and functional to preserve the technical criteria. That is why orthogonal and bipolar debitage was likely to happen, both leading to a centripetal conception of knapping surfaces: the same extraction's surface was more frequently knapped as the core's volume decreased. At this stage, the flakes were gradually smaller and quadrangular in shape, bearing no cortex at all. An

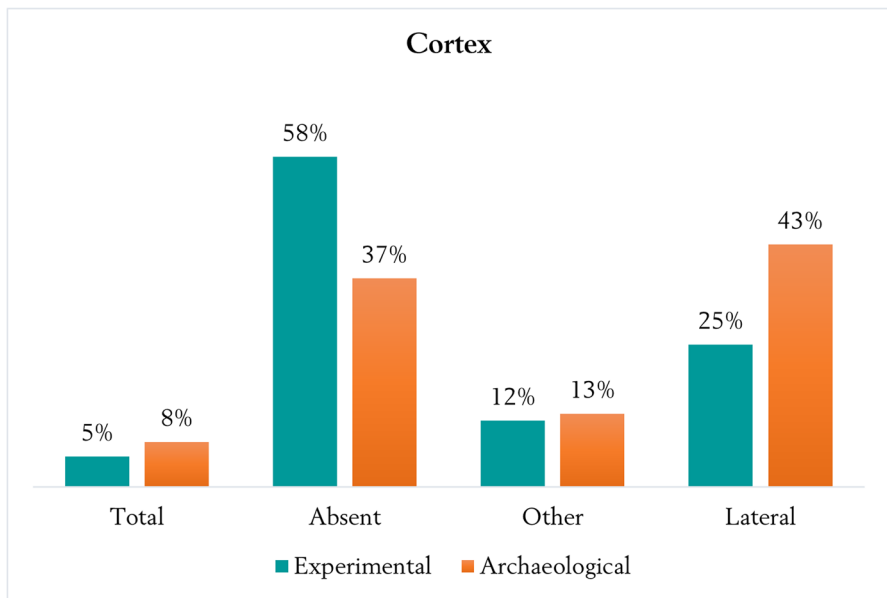


Fig. 21 Riparo Tagliente. Presence and position of cortex on archaeological and experimental flakes

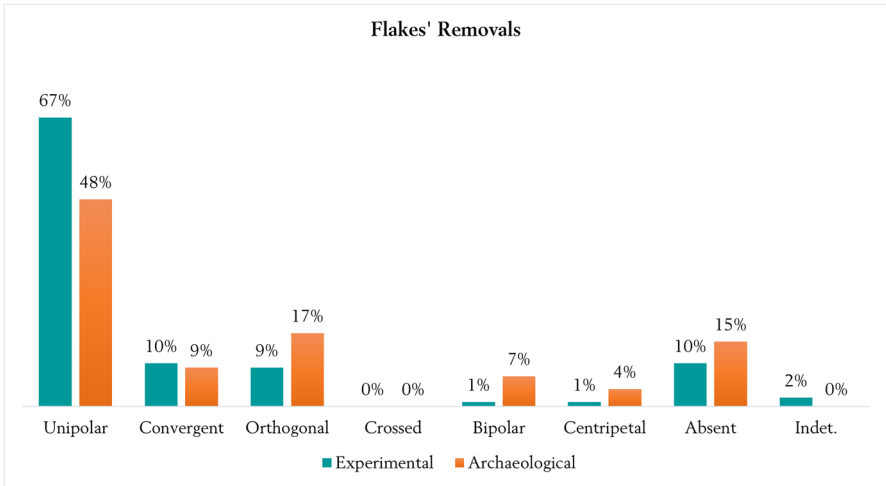
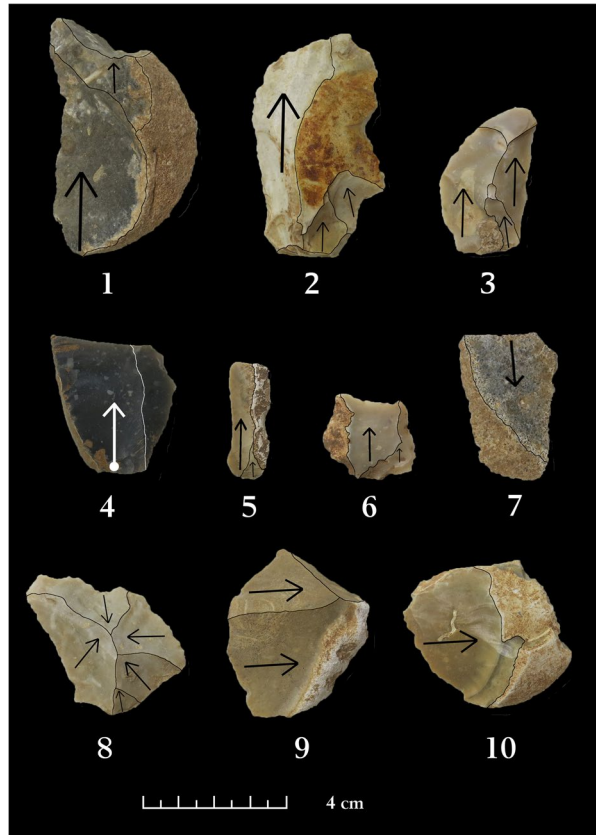


Fig. 22 Riparo Tagliente. Presence and position of removals on archaeological and experimental flakes

Fig. 23 Riparo Tagliente, archaeological: 1, multifacial unipolar core; 2, centripetal core



Fig. 24 Riparo Tagliente, archaeological: 1–6, flakes with unipolar scars; 7, flake with bipolar scars; 8, flake with centripetal scars; 9–10, flakes with orthogonal scars



increased number of cutting edges on the distal margins can be observed. This pattern was then repeated until the core was no further exploitable.

When large fluvial pebbles were collected and flattened, and rounder surfaces were available, centripetal flaking was possible to start the production. In this way, a preexisting peripheral striking platform was available (although the extraction of a cortical flake may have been required to initiate the debitage), resulting in optimising the raw material's economy (Fig. 23, n°2). The production focused on parallel removals, which gradually involved the entire surface, allowing better control over the flake's morpho-technical criteria, granted by easier management of the convexities and guiding arrises. In this case, orthogonal debitage could be highlighted in the early stages of the unipolar production as an expedient to create distal and lateral convexities (Fig. 24, n° 8, 9, 10). Together with the unipolar nervure-guides, these guaranteed that each removal would cover the entire knapping surface length, determining an elongated and regular cutting edge on the flakes. As previously stated, centripetal debitage (mainly orthogonal and bipolar) might have occurred during the final phases of the unipolar cores to deal with the

unlikelihood of exploiting a surface from one direction. Alternated removals were thus more efficient and productively rewarding.

In conclusion, the strategies employed at Riparo Tagliente proved to be efficient in producing flakes presenting at least one cutting edge. The flakes' functionality rate appeared constant within each core, despite the technical behaviours employed to obtain them. Even with a gradual decrease in flake length, the same pattern can be attested, confirming, overall, a well-organised production. Both on the archaeological record and the experimental one, a global increase of the cutting edges per flake (especially on the distal margins) was observed simultaneously to a lowering of the whole length and a drop of the debordant edge frequency. However, this was seemingly not a relevant production goal but still confirms the reliability of the reduction processes even on the final stages of core exploitation. The experimental collection also provided many *déjeté* points, primarily through centripetal debitage. Nevertheless, they resulted in being an unintentional outcome of the flaking processes, mainly due to the convexities management and the possibility of obtaining quadrangular flakes rather than a dedicated flaking scheme.

Riparo Tagliente—Experimental Collection

The analysis of the experimental reduction sequences matched the archaeological ones (Table 7; Fig. 26). Both massively exhausted cores, and ones of more oversized dimensions, still presenting a suitable volume to exploit, were present. Multiple *flaking events* involving all block surfaces or single ones carried on until the core's abandonment. Switching between the striking platforms and knapping surfaces was frequent, significantly as the core dimensions decreased (Table 7). As a matter of fact, on the same core, centripetal debitage often developed into a unidirectional one, or vice versa, leading to short reduction sequences. In this case, it was the experimental work's merit to verify and validate how the morphologies could dictate how the objectives of productions were achieved, generating a vast number of diversified operative schemes still originated from the same mental scheme. Along this line, from a methodological perspective and given the definition of method used for this work "Le mot méthode revoit uniquement à l'étape de production: liaison entre la représentation abstraite de l'objectif et sa concrétisation. ... il s'agit de l'ensemble des démarches raisonnées –schéma opératoire– suivi pour réaliser les objectifs fixés (The word method refers only to the production stage: the link between the abstract expression of the objective and its concretisation. ... it is the set of reasoned steps-operative scheme-followed to achieve the set objectives)" (Boëda, 1994, p. 35), there is no such difference in the several operative schemes (i.e. unipolar, centripetal or multidirectional debitage) used to achieve flake production since their purpose (i.e. mental scheme, method) remains the same. It is the opportunistic method that differentiates itself in multiple types of debitage according to the raw material morphology and quality.

The presence of more complex flaking methods within the Mousterian sequence of Riparo Tagliente imply either surface' hierarchisation (Levallois) or a strong subordination of the raw material's morphology to specific technical criteria (such as

discoïd and laminar), certainly played an influencing role in how the opportunistic sequences were achieved resulting in greater flaking-technical awareness. As a sign of this, several experimental cores showed a greater affinity with discoïd reduction (Fig. 26, n° 1) sequences and laminar ones. In the first case, the centripetal debitage was addressed regarding the convexity management and the use of cordal-like removals. In the latter, experimental cores presenting an elongated morphology together with a low width were exploited through semi-tournant removals, often implying the presence of a central nervure-guide (like a crest; Fig. 25, n° 3, 5).

For these reasons, one can assume, in a broader chronological perspective, that it was indeed the great versatility of the opportunistic debitage to represent, as seen in its earliest evidence (such as in Pirro Nord and C a Belvedere di Montepoggiolo), the groundwork for the rise of such highly specialised and predetermined flaking methods. This might suggest that starting from a deep subordination to morphological criteria to achieve an efficient functional flake production (which is the basic aim of any flaking activity), a greater technical awareness may arise, leading to a possible subordination of the morphology itself to the technical criteria. This aspect may, thus, represent the starting point for Levallois and discoïd methods. That being

Fig. 25 Riparo Tagliente, experimental: 1–2, flakes with orthogonal scars; 3–10, flakes with unipolar scars; 11, flakes with centripetal scars

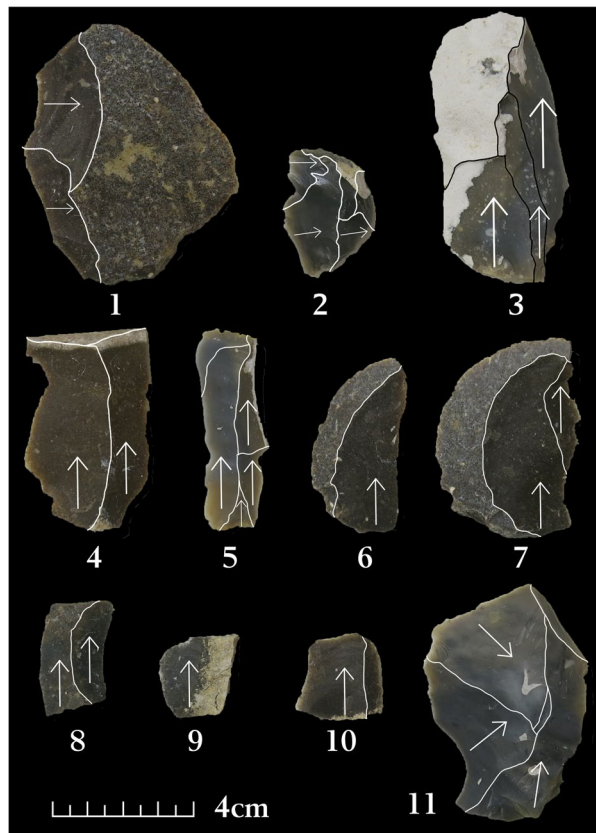
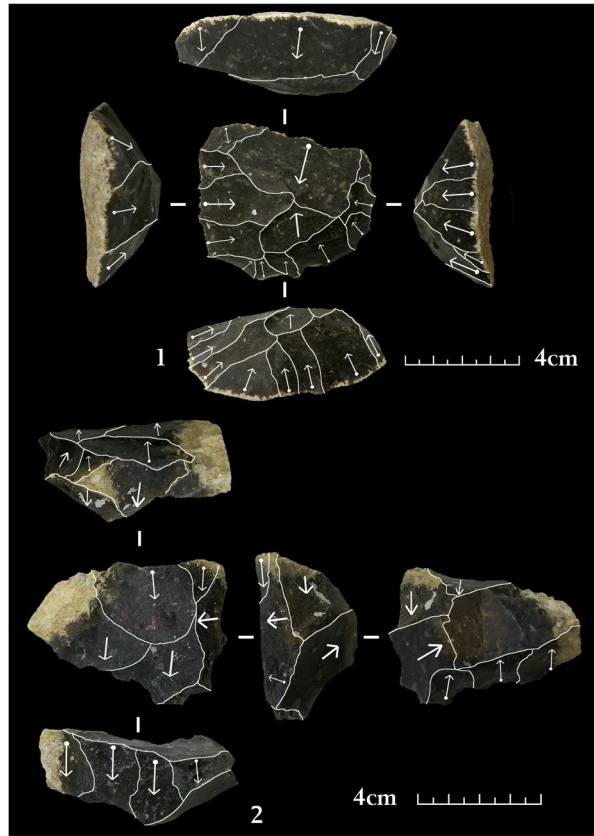


Fig. 26 Riparo Tagliente, experimental: 1, centripetal core; 2, multifacial core



said, their success from the Middle Palaeolithic onward did not prevent opportunistic debitage from persisting during the whole Pleistocene (Fig. 26).

Conclusions

Within the present state of the art, a great debate concerning the methodological attribution of Lower Palaeolithic contexts is taking place. This same debate persists in more recent chronological phases when an attempt to evaluate industries that fall outside the classic Levallois/discoïd/laminar paradigm is performed. The quest for complexity within lithic assemblages is strictly related to this matter, being a critical factor and leitmotif of lithic technology. In this perspective, the distinction between complexity and simplicity developed into several dichotomies in archaeological research (i.e. curation/expediency, expediency/opportunism, etc.). Simultaneously, in lithic technology, notions such as predetermination and hierarchisation became the mirror image of these dichotomies, often embodying the boundary among simple and complex in prehistoric contexts. Nonetheless, while this distinction may be

more vague for more recent cultural phases, for older ones, where the definition of culture itself seems to be fainter, it is inversely much more pronounced.

Currently, the term opportunism represents the other side of this boundary. It is used to imply a lack of planning in the realisation of stone tools (which, on the other hand, is what define expedient behaviours) and, in a broader sense, also to imply the total absence of complexity/mental scheme. Thus, the use of the term opportunism in this work is aimed to re-contextualise the capability of adaptation of prehistoric people in a “positive” way, where by positive it is meant the plausible presence of a methodological substratum (hinting to the existence of complexity?) within these productions and not merely to point out a technical behaviour enabled in response to specific circumstances without any degree of planning.

Moreover, concepts such as expediency, curation, and opportunism are often declined according to the description of technical behaviours that already fall into methodological categories. In this sense, they explain tendencies about the information gathered from the technological analysis of a specific assemblage. For instance, Levallois, discoid and laminar reduction sequences can be conceived and conducted in an expedient/opportunistic way when interpreting these industries in light of raw materials exploited, type of site, vegetation, climate, etc. Or, in other words, when an attempt to understand and define human behaviour in terms of a complexity degree is carried out. Being that the case, the use of these terms does not invalidate the significance of such industries from a methodological perspective.

When dealing with Lower Palaeolithic contexts, on the other hand, it is much harder to analyse patterns and debate the possible existence of flaking methods. Consequently, technical behaviours are frequently labelled as opportunistic and expedient to point out some potential tendencies but often to exclude the notion of complexity. In this scenario, terms like expedient and opportunism are inclined to assume a much more negative connotation because of the very absence of a methodological substratum beneath those technical behaviours.

On top of this, the definition of expediency refers to a behaviour/attitude characterised by a strong capacity of adaptation in response to external variants (i.e. environment, climate, availability of primary resources such as food, water, the raw material to produce stone tools, etc.) paired with an excellent technical skill (the knapper’s expertise) enabling the planning of efficient strategies by prehistoric people. Minimising the technological behaviours of the hominins of the Lower Palaeolithic as practical and mechanical responses (even if planned) to external inputs also means not implying that a methodological background in the lithic productions of these chronological phases could ever exist at any given moment. By doing so, we would assume the absence of “structured expertise” in these lithic assemblages simply because it is not perceivable and it is regarded as a predictable behaviour enabled by adaptability mechanisms under critical conditions (expedient).

By using the terms *opportunistic debitage*, hence defining a flaking method, we want to stress how the incredible versatility and variability implied in these kinds of activities comes from a steady and precise mental scheme (developed at a certain point during times obviously) in which, for example, the possibility of choosing in which manner a specific volume will be knapped is a part itself of the methodological process.

Therefore, the proposal of this work is trying to identify how the earliest European lithic productions, which indeed developed as quick and efficient responses to a hostile and changing environment, gradually changed into systematic and steady productions (even if still strongly subordinated to the surrounding environment) comprising a solid methodological substratum, or in other words, as the concept of flaking method arose. The lack of planning that is assumed under the “opportunistic responses” is what often prevented considering these kinds of productions as methodologically relevant in the past. On the other hand, given that such industries might persist over time through different chrono-cultural phases, it allows a better comparison and contextualisation regarding their methodological relevance. The history of study in lithic technology provides several examples of how the definition of some flaking methods (i.e. Levallois, discoid, among others) underwent several changes and modifications during the years since they included a much wider variability and flexibility than initially expected (Peresani, 2003).

To summarise, the delineation of opportunistic debitage interests a wide chronological frame being characterised all the way through by a strong adaptation and subordination to the morphology and quality of the raw materials locally available, as observed in all the contexts where it was identified. It is defined as “a method oriented to raw materials’ massive exploitation not implying a core, or any surface, preparation. The striking platforms and knapping surfaces are created as far as the flaking activity is carried on. [...] The opportunistic debitage includes an infinite range of variants from the same common operative scheme” (Arzarello, 2003, p. 6). Its flexibility allows the modulation into different technical behaviours, constantly aiming to extract functional products in a highly efficient manner. The easy replicability of the operative scheme through the technical gesture, together with an optimisation of the block’s volume, is the methodological *substratum* behind the mental process.

This methodological and cultural substratum can be viewed as the starting point for more complex flaking methods for the oldest contexts. As seen in the Pirro Nord and Cà Belvedere di Montepoggiolo’s contexts, a centripetal approach was intensively applied on the surfaces because of its efficient production of functional flakes on rounder and smaller morphologies (i.e. pebbles and cobbles; Fig. 28). The exploitation of a peripheral striking platform running around a single knapping surface translates into a gradual and better control of the flake’s morphology and the core’s management. Supporting this hypothesis is the occurrence, in both assemblages, of functional flakes often presenting more than one cutting edge, a backed margin, and a tip associated with centripetal flaking (orthogonal, bipolar and centripetal removals).

It can be argued that these features may be the unintentional outcome of a solid adaptation to specific morphologies (as seen in the experimental centripetal cores). Nonetheless, when systematically and constantly applied, they might eventually standardise the technical gestures, which generate greater awareness during the flaking activity. This being the case, technical expedients can become systemised choices assimilated within a steady mental scheme, thus expanding the possible methodological responses of opportunistic debitage.

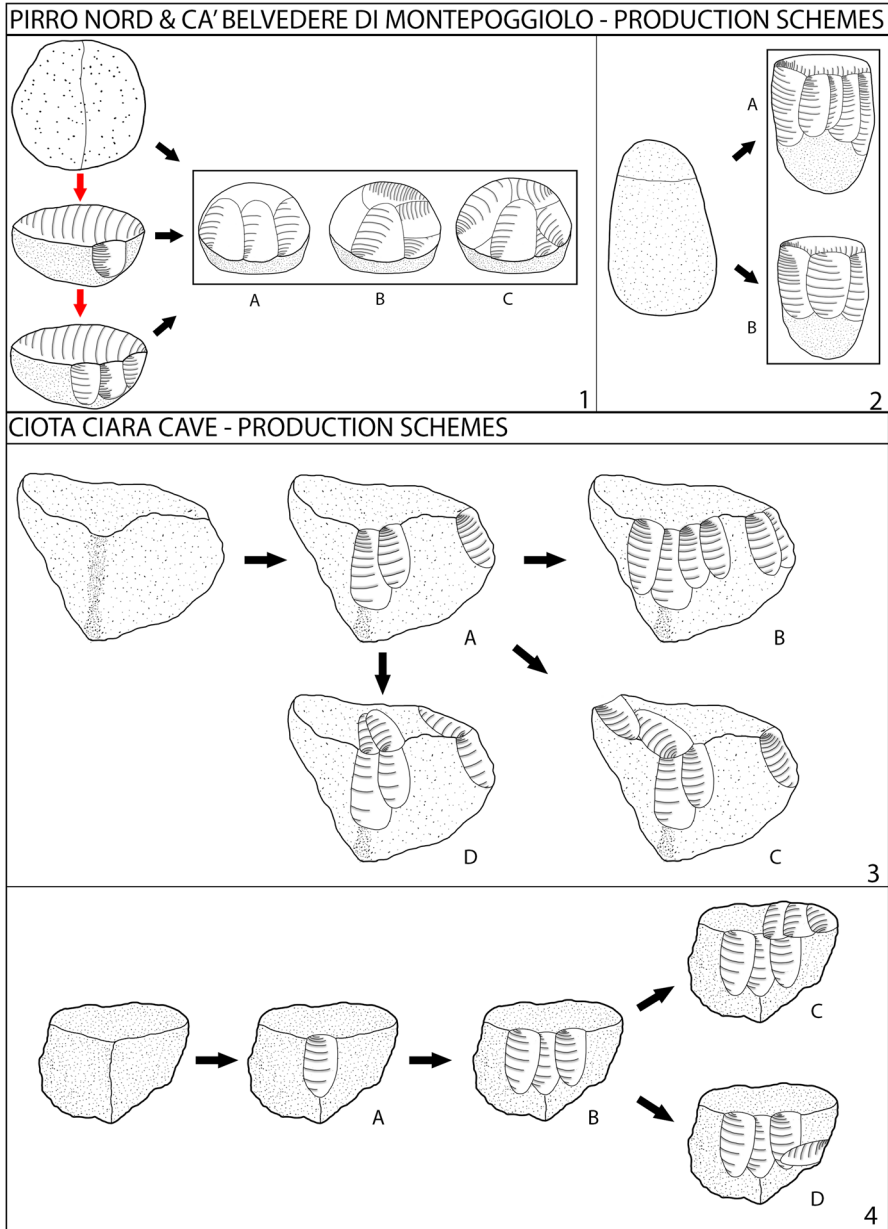


Fig. 27 Pirro Nord and Cà Belvedere di Montepoggiolo production schemes: 1, rounder cobble (A: unipolar production; B orthogonal production; C: centripetal production); 2, oval and elongated pebble (A: unipolar production; B: convergent flake production). Ciota Ciara production schemes: 3, larger blocks and nodules (A: unipolar production on natural arises; B: unipolar production; C: multifacial bipolar/unipolar production; D: multifacial unipolar production); 4, smaller blocks and nodules (A: initialisation on natural arises; B: unipolar production; C: multifacial unipolar production; D: orthogonal production)

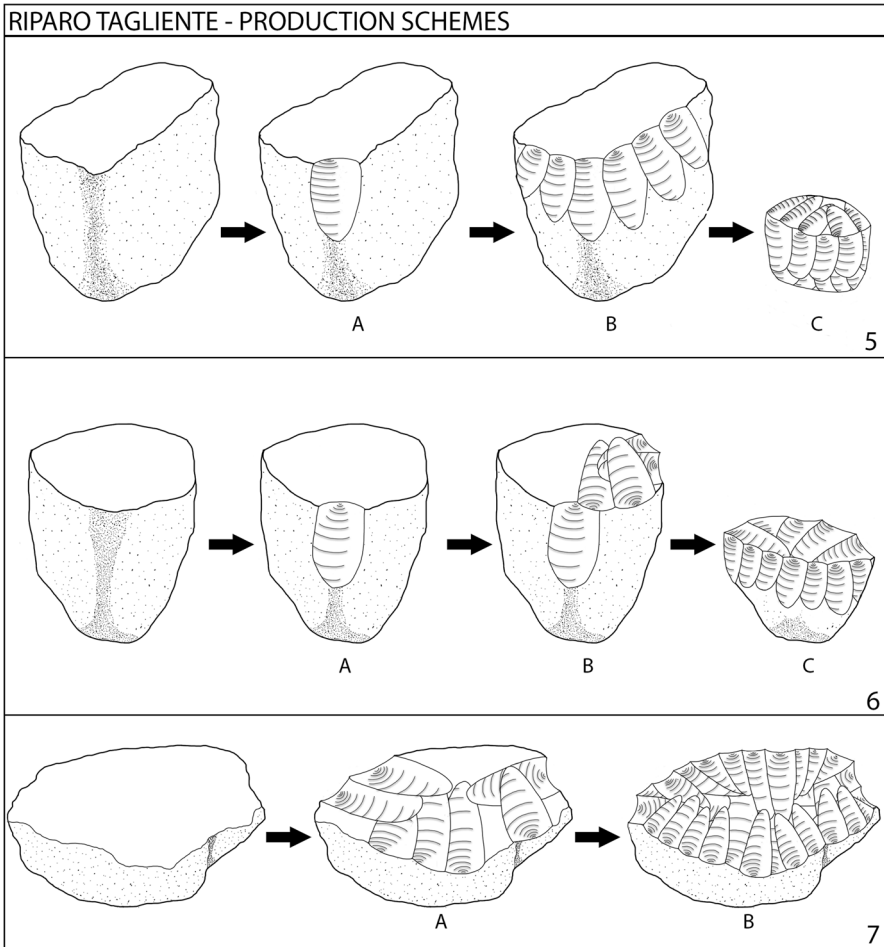


Fig. 28 Riparo Tagliente production schemes: 5, large nodules with longitudinal axis as knapping surface (A: opening of the knapping surface on a natural arris; B: unipolar-semi-tournant production; C: multifacial production); 6, quadrangular and large nodules (A: opening of the striking platform on natural arris; B: orthogonal production; C: multifacial production); 7, flat and rounder blocks and cobbles (A: initialisation of the centripetal production with orthogonal flaking; B: centripetal production)

Following this argument, when broader chronological and geographical ranges are considered, the process of subordination to morphological criteria can be gradually reversed, and the morphology itself becomes subordinated to the technical criteria for the production of predetermined products. Levallois and discoid methods, both profoundly related to the centripetal concept as well as the bifacial shaping, are based on the idea of altering a pre-existing morphology into a fixed shape. Therefore, technical criteria such as the surface hierarchisation, the need for precise lateral and distal convexities (and their preparation), and the creation

of peripheral striking platforms may be viewed as the outcomes of this process, becoming one of the possible, abovementioned, methodological responses.

On the other hand, opportunistic debitage persists as a reliable and independent flaking method for more recent periods such as the Middle Palaeolithic. In these cases, it often coexists with Levallois, discoid and laminar productions, standing as one of the possible behavioural variables of the human groups. It is still identifiable on an archaeological basis through its technical features, even if subjected to different chronological, environmental, and cultural aspects (the latter hardly perceived within the analysis of any lithic industry).

Summing up the results highlighted for Ciota Ciara cave and Riparo Tagliente (Figs. 27 and 28):

- 1) The former underlines how, despite qualitatively inferior raw materials, several technical strategies were efficiently employed to obtain a steady functional flake production. In this case, the adaptation to the available morphologies becomes obvious: a frequent and almost exclusively use of natural arrises along the entire flaking activity is highly witnessed, not only for opportunistic production but also for Levallois discoid.
- 2) In the latter, it can be seen how opportunistic debitage, despite Levallois, discoid and laminar productions, is still the most employed method along the Mousterian sequence. Here it is differentiated into multiple technical behaviours according to the morphologies naturally available (or to their gradual change), sometimes showing similarities with the volumetric conception of other methods but still methodologically distinguishable.

In conclusion, the term “opportunism” is not merely applying flaking criteria and technical skills, completely disentangled from any mental scheme. As observed in this work, what defines a flaking method is its flexibility and potential to be efficiently adopted throughout different chronological and cultural phases, constantly referring to a specific mental scheme. Therefore, the opportunistic debitage may be considered the “link between the abstract representation of the object and its realisation” (Boëda, 1994, p. 35) since it connects a series of technical behaviours and gestures for its realisation (Tixier et al., 1980) not only in a synchronic perspective but mainly in a diachronic one. However, it must be underlined that, as a flaking method, it will always just be a partial aspect of a human group’s material culture, useful for identifying and interpreting specific behaviours yet far from being its unique component.

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Declarations

Conflict of Interest The authors declare no competing interests.

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