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ORIGINAL PAPER

Brief interviews with hideous stone: a glimpse into the butchery site of Isernia La Pineta — a combined technological and use-wear approach on the lithic tools to evaluate the function of a Lower Palaeolithic context

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Abstract

The onset of the Middle Pleistocene (780 ka) in the European continent is associated with significant environmental variations (Middle Pleistocene Revolution), innovative behavioural strategies (bifacial productions, land-use patterns, raw material management) and a global increase in the archaeological evidence from 600 ka onward. Whether these changes are related to the rise of the Acheulean, the informative potential carried by these contexts is currently being explored through multidisciplinary approaches, allowing us to infer the role of these sites and the type of activities conducted. From this perspective, the Italian peninsula is a hot spot to compare the different technical behaviours and strategies human groups employ, given its crucial geographic location and solid archaeological record, both culturally and functionally speaking (the presence of sites with and without bifaces and core-and-flake assemblages). The site of Isernia La Pineta (590 ka), offering a rich lithic and faunal record, is an excellent case to join together the lithic technological study (i.e. "cultural" and technical tradition) with the functional analysis (i.e. activities conducted and exploited materials). Here, we present the result of the combined approach of these two disciplines on flint assemblages from layers t.3a and t.3coll. The new data will be discussed within the chrono-cultural framework of the Middle Pleistocene Revolution, linking the degree of complexity of the lithic production of Isernia with its function as a butchery site.

Keywords Isernia La Pineta · Lower Palaeolithic · Middle Pleistocene Revolution · Use-wear analysis · Lithic technology

Introduction

Comprehending the degree of connection between human occupation and environmental conditions at the boundary between the Lower and the Middle Pleistocene has become a crucial and highly addressed topic to understand the European peopling — its modalities and the development of behavioural innovations that might have facilitated the facing of harsh climatic conditions by the hominids — during the Lower Palaeolithic (Hosfield and Cole 2018; Moncel et al. 2018b; Key and Ashton 2022; Zanazzi et al. 2022). Several recent works highlighted that during this chronological framework, major climatic variations occurred and played a fundamental role in the pattern of human colonisation — even though, in some cases, the "lack of hominin occupation without any climatic-based reasons" (Moncel et al. 2018b, p. 78) has been observed — while the archaeological data itself provided evidence for significant anatomical, behavioural and possibly cultural changes confirming the relevance from different aspects of this chronological phase (Moncel et al. 2018c; 2021; García-Medrano et al. 2019; Rineau et al. 2022). Additionally, the final stages of the Lower Pleistocene and the first half of the Middle Pleistocene represent a prolonged phase of environmental, cultural and evolutionary "turmoil" characterised by considerable diversity, ultimately culminating in the transition to Middle Palaeolithic (400–350 ka/MIS 11) during which a solid demographic expansion and regionalisation of the

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cultural aspects will be gradually taking place all over Europe (Moncel et al. 2016; 2020c; Davis and Ashton 2019).

The transition between the Lower and Middle Pleistocene on the European continent is often referred to as Middle Pleistocene Revolution. Its beginning has been universally set to 780 ka with the beginning of the Middle Pleistocene, but it is considered to cover a significantly larger period based on climatic and environmental data (1.2 – 0.45 Ma; Manzi et al. 2011; Moncel et al. 2018b; Muttoni et al. 2018). The Middle Pleistocene Revolution is associated with an abrupt change in the climatic and environmental conditions affecting the faunal assemblages and most likely triggering fluxes of human groups and significant behavioural changes (Manzi 2004; Muttoni et al. 2010; 2018; Manzi et al. 2011; Abbate and Sagri 2012; Moncel et al. 2018b). The change of periodicity in the alternation of glacial/interglacial phases from 41 to 100 ka marked important geomorphic changes and vegetational turnovers all over Europe (Paillard 1998). A global extension of grassland habitats was documented. The increased periodicity resulted in a sharper alternation of close and more open environments corresponding, on a larger scale, to a clearer gap between glacial and interglacial events (Moncel et al. 2018b). According to the available data, this has seemingly enhanced corridors' opening/closing, favouring the diffusion of new faunal species and human groups from Africa and Asia with evidence of anthropic occupation even at higher latitudes (Northern France, England; Parfitt et al. 2010; Preece and Parfitt 2012; Antoine et al. 2019; Moncel et al. 2020a). At the same time, these climatic changes equally affected the continuity of human frequentation, creating a distinct scenario between Northern and Southern Europe. The former was intermittently occupied primarily during favourable climatic phases — as witnessed by the sites of Happisburgh 3, Pakefield, La Noira and Moulin Quignon, which show an abrupt abandonment at the onset of glacial stage 16 — while the latter was more continuously occupied over time due to less-impacting climatic variations (for example, at the site of Notarchirico during MIS 16), depicting an "ebb and flow" model for European peopling (Parfitt et al. 2010; Dennell et al. 2011).

The emergence of bifacial and LCTs industries, new land-use patterns and raw material management and a global increase in the degree of complexity of the lithic productions, even in contexts without bifacial tools (i.e., core and flakes assemblages, such as Pakefield, Atapuerca Gran Dolina TD6, and Isernia La Pineta; Parfitt et al. 2010; Ollé et al. 2013; Gallotti and Peretto 2015; Davis et al. 2021), are among the innovations documented during this important chronological transition (Moncel et al. 2015; Schreve et al. 2015; Moncel and Ashton 2018). The appearance of handaxes in Europe is commonly associated with the Acheulean cultural complex, which should mark a moment of significant cultural and technical renovation related to the arrival of new human species (*Homo heidelbergensis*, *Homo antecessor*) from the African and Asian continents (Manzi 2004; Moncel et al. 2018a). The recent findings of La Noira, Moulin Quignon and Notarchirico show an abrupt and homogeneous emergence of bifacial tools during the interglacial 17 (700 ka), supporting the hypothesis of the arrival of new human groups over the European continent during this time frame. On the other hand, the bifaces recently discovered at La Boella (1.0–0.9 Ma) may question the chronological validity of this model. The most recent works considered them a local evolution rather than an external introduction (Vallverdú et al. 2014; Mosquera et al. 2016), even though, given the proximity of La Boella to the Gibraltar corridor, an earlier arrival of human groups could not be entirely ruled out.

Following this line of thought, this recent increase of data observed all over Europe (Fig. 1) allowed scholars to keep fuelling the debate regarding the timing of the appearance of biface production, its spreading and diversity across Southern, Western and Northern Europe, not to mention its possible connections with pre-existing European human groups (Vallverdú et al. 2014; Schreve et al. 2015; Moncel and Ashton 2018; Moncel et al. 2021). The same concept of what the Acheulean world should include and mean is now being questioned, as pointed out in a recent work: "The term "Acheulean", rather than one uniform cultural tradition, is more appropriate for describing the puzzle of assemblages and strategies recorded in western Europe" (Moncel and Ashton 2018). This is leading to a global shift from the classic paradigm *Bifacial = Acheulean*, also witnessed in the African and Asian continents (Sharon et al. 2011), where the contextualisation of the Acheulean is not strictly based on the presence/absence of bifacial artefacts. Though this recent growth of discoveries, the sporadicity of the archaeological evidence (both chronologically and geographically) still prevents the scientific community from getting a homogeneous framework, and several hypotheses have been suggested to explain the arrival of the Acheulean in the European region (Martínez and Garcia Garriga 2016; Moncel 2017; Moncel et al. 2018c). Within the present state of the art, a dual case scenario is usually assumed concerning either a local origin suggesting evolution from previous occupations (Mode 1, core-and-flake traditions) or an allochthonous introduction (whether episodical or continuous) of new populations alongside the diffusion of new technical traditions (Manzi 2004; Moncel et al. 2015; Voinchet et al. 2015).

With these hypotheses being equally valid and currently debated, it is generally accepted that a cognitive shift occurred during this period, but what are the most valuable and available tools for us to recognise it? The chance of identifying, in terms of material culture, the presence of behavioural changes or being able to discern between

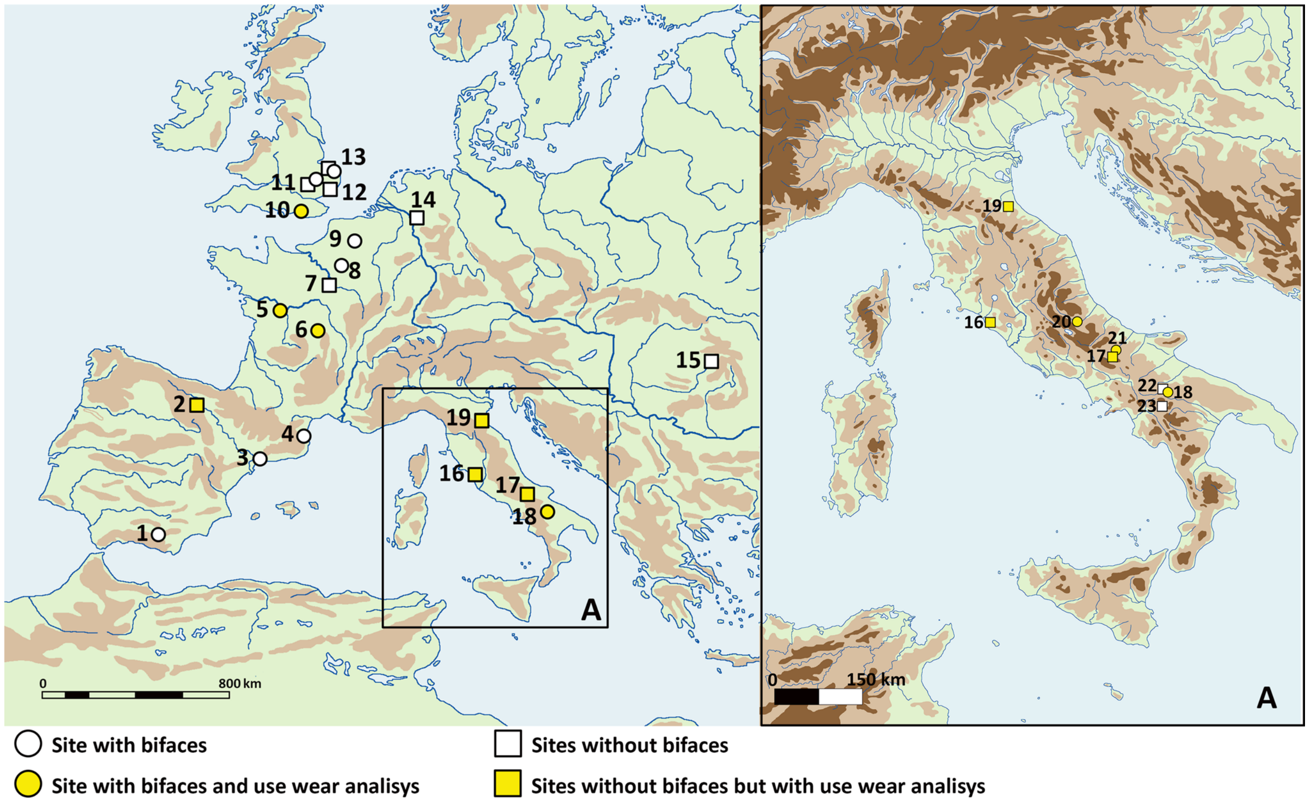


Fig. 1 Map showing Lower Palaeolithic sites mentioned in the text: 1, Cueva Negra; 2, Atapuerca TD6, TD10/Galerìa; 3, Barranc de la Boella; 4, Caune de l'Arago; 5, La Grande Vallée; 6, La Noira; 7, Pradayrol; 8, Moulin Quignon; 9, Cagny la Garenne; 10, Boxgrove; 11, High Lodge, Maidscross Hill; 12, Pakefield; 13, Happisburgh 1, Happisburgh 3; 14, Rhine Basin; 15, Korolevo; 16, Ficoncella; 17, Isernia La Pineta; 18, Notarchirico; 19, Cà Belvedere di Montepoggiolo; 20, Valle Giumentina; 21, Guado San Nicola; 22, Loreto; 23, Atella. A Map of Italy showing major Lower Palaeolithic sites during the first half of the Middle Pleistocene

what is a sign of complexity and what is not are all challenging topics that need to be scientifically addressed and investigated.

From this perspective, the European archaeological background during the Middle Pleistocene Revolution proved to be highly diversified yet quantitatively and geographically fragmented. If we consider the lithic assemblages of this period, for instance, they are characterised by multiple types of debitage (SSDA/opportunistic, centripetal, discoid), which are often not associated with bifacial industries and therefore excluded from the Acheulean revolution (Barsky et al. 2013; Gallotti and Peretto 2015; Aureli et al. 2016; Moncel et al. 2018c). Nonetheless, the documented increase in the centripetal and discoid reduction sequences — even from a complexity point of view — the frequency of retouched flakes and the ability to realise large-sized tools are now considered possible material evidence for the alleged arrival of new populations or the development of new traditions in Western Europe (Roberts 1993; Parfitt et al. 2005; 2010; Carbonell et al. 2010; Guadelli 2012; Ollé et al. 2013; Rossoni-Notter et al. 2016; Moncel and Ashton 2018; Mosquera et al. 2018; Fiedler et al. 2019).

On top of that, recent works highlighted how the concepts of behavioural innovation and cultural change could and should be explored in other areas, such as the analysis of the activities conducted on the different sites, the subsistence strategies pattern or the land-use management (Hardy et al. 2018; Zanazzi et al. 2022; Zohar et al. 2022). These proved to be all valuable proxies to the archaeological investigation, and their integrated approach enabled a higher resolution and a more accurate reconstruction of the Lower Palaeolithic contexts in many cases.

During the Lower/Middle Pleistocene transition, the Italian is a crucial spot for tracking down human dispersal across the European continent, witnessing a solid increase in the archaeological evidence from this chronological phase (Muttillo et al. 2021). It shows a consistent range of contexts spanning from the end of marine isotope stage 17 onwards (Fig. 1A; Pereira et al. 2018), offering one of the earliest traces of the Acheulean cultural complex (approximately 680 ka, in the level G of Notarchirico; Moncel et al. 2020d), providing at the same time contexts without bifaces (Isernia La Pineta, Ficoncella, Loreto and Atella; Gallotti and Peretto 2015; Abruzzese et al. 2016; Aureli et al. 2016) and eventually including the transition to the Middle Palaeolithic with one of the earliest evidence of Levallois technology (Pereira et al. 2016; Guado San Nicola; Arnaud et al. 2017; Moncel et al. 2020b). Additionally, the site of Montepoggiolo also attests to an earlier frequentation of the Italian peninsula during the final stages of the Lower Pleistocene (MIS 21; Falguères 2003).

As previously mentioned, the climatic and environmental data available for the Italian peninsula during this chronological time frame (Bertini 2003; Moncel et al. 2018b; Zanazzi et al. 2022) depicts it as a "shelter" zone during severe climatic crises making it an ideal territory for human occupation during glacial phases and for prolonged periods (as witnessed by the stratigraphic sequence of Notarchirico). Moreover, its role as the possible starting area for the recolonisation of the northern portions of Europe, together with its proximity to Sub-Saharan Africa, makes up for the Italian peninsula's crucial role within the European peopling during the Middle Pleistocene Revolution (Moncel et al. 2020d).

So far, the archaeological record features various technical responses in the lithic assemblages analysed. This includes the realisation of large-sized implements (LCTs, different types of handaxes, pebble tools etc.), a miniaturisation of the debitage products with a high rate of retouched flakes and elaborated and flexible core technologies realised through multiple types of debitage exploiting different qualities (different types of chert, limestone) and morphologies of raw materials (slabs, pebbles, nodules). The additional presence of human remains from the sites of Notarchirico (Belli et al. 1991; Pereira et al. 2015) and Isernia La Pineta (Peretto et al. 2015), attributed to *Homo heidelbergensis* contributed to enriching our vision of this region as a hot spot to explore the diffusion's pattern of new human groups over Europe, not to mention the implications concerning the modalities of the arrival/development of the Acheulean cultural complex in this continent. Thus, tracking innovations and persistent strategies among these contexts through analysing their lithic assemblages could be a valuable way to comprehend the hominin behaviour better and gain more insights into the Lower Palaeolithic.

The site of Isernia La Pineta perfectly fits into this chronological and cultural framework, recording a prolonged phase of human occupation, approximately 600 ka, during the MIS 15 interglacial and witnessing a long tradition of multidisciplinary studies (Longo 1994; Sozzi et al. 1994; Peretto 1996; Coltorti et al. 2005; Rufo et al. 2009; Vergès and Ollé, 2011; Pereira et al. 2015; Peretto et al. 2015; Lugli et al. 2017; Zanazzi et al. 2022). Its lithic assemblage belongs to the small debitage complexes (cores and flakes technology), showing the absence of LCT and bifacial tools and therefore being excluded from the classical Acheulean archetype (Gallotti and Peretto 2015; Muttillo et al. 2021). Nevertheless, complex mental templates can be highlighted in the centripetal and discoid reduction sequences alongside a massive presence of retouched flakes (Gallotti and Peretto 2015). Isernia La Pineta is also close to the site of Notarchirico (695–610 ka; Fig. 1), which was occupied during both warm and cold phases (MIS 17–16) and showed the earliest arrival of bifacial industries into this region (Moncel et al. 2020d). The lithic collection of Notarchirico has yielded handaxes, LCT, pebble tools, cores, flakes and retouched tools (Moncel et al. 2019; Santagata et al. 2020). They are all produced on local raw material, using different kinds of flint and limestone and employing different knapping strategies (i.e. centripetal, SSDA/opportunistic debitage etc.).

Furthermore, the number of open-air sites in Western Europe increased during Middle Pleistocene (Fig. 1), becoming the primary source of information for studying human behaviour through a multidisciplinary approach (Hardy et al. 2018; Pineda et al. 2020; Marinelli et al. 2021). This can raise important questions regarding the complexity and affinity of these two sites and the timing and spreading of possible behavioural innovations regardless of the presence of bifacial/LCT industries. Assessing the strategies adopted by the hominins to access carcasses and meats (scavenging/hunting; primary access or not), types of occupation (prolonged or short-term), spatial use of the area and frequentation over time represent some crucial questions that might help improve the knowledge over the role of this sites and the associated lithic industry. In light of these questions, interpreting the lithic assemblage of Isernia will take on a more specific meaning, not only concerning the chrono-cultural context (Acheulean or not, the complexity of reduction sequences etc.) but also the functional aspect of the sites attesting butchering activities.

The combined approach of lithic technology and use-wear analysis proved to be rewarding for several Lower Palaeolithic contexts (Mitchell J. C., 1998; Peretto et al. 1998; Ollé et al. 2013; Aureli et al. 2016; Hardy et al. 2018; Venditti et al. 2019). This will allow us to address the issues mentioned above and, at the same time, pursue the recent works' tradition of contextualisation of the site of Isernia La Pineta within the "Middle Pleistocene Revolution", the Acheulean paradigm and the peopling of the Italian continent during the final stages of Lower Palaeolithic (Gallotti and Peretto 2015; Moncel et al. 2018c; 2020d). Therefore, this work aims to provide new data on the unpublished materials from layers t.3a and t.3coll of Sector I combining the technological study and the use-wear analysis of the lithic industry realised on flint. The limestone industry is also the object of ongoing research by the same team, whose preliminary results will be presented.

Isernia La Pineta

The site of Isernia La Pineta is within the fluvial basin of the Upper Volturno Valley, a few kilometres outside the town of Isernia (Molise, Italy; Fig. 2). It is an extensive open-air site located at an elevation of 457 m a.s.l. and systematically excavated since 1979 by one of the authors (C. P.; Coltorti 1983; Peretto 1996; 1999). The present area of excavation comprehends Sector I (250 square meters; Fig. 2) and Sector II (90 square meters).

The site lies inside the main fluvial-lacustrine filling of the “Le Piane basin”, representing the highest and, at the same time, the oldest Pleistocene sedimentological unit described in this area. The deposits, composed of a series of fluvial terraces, comprehend a sequence of fluvial, lacustrine and volcanic sediments in which lies the archaeological deposit (Coltorti et al. 2005; Peretto et al. 2015).

The stratigraphy of Isernia La Pineta from the base to the top consists of five sedimentary units (Fig. 2; Coltorti 1983; Peretto et al. 2015): Unit 5 with clayey lacustrine sediments alternated to thin levels of gravels and debris; Unit 4 is characterised by travertines deposited by the freshwater river and, on its top, by a primary pyroclastic flow, named Unit 4 T; Unit 3 is a palustrine deposit with sand and thin layers of gravels and is subdivided into three sedimentary sub-Units (U3A, U3E, U3F); Unit 2 is composed of sands and gravels as well; Unit 1 is a colluvium sequence with sand gravels attesting a pyroclastic fall and weathered by a paleosol at the top. The archaeological layers were identified in the sub-Units 3F (t.3c, t.3b, t.3a) and 3E (3coll, 3 s 1–5, 3 s 6–9) with the layers t.3c, t.3a, and 3coll being the richest in lithic and faunal remains (Fig. 2).

Single sanidine crystals were dated through the 40Ar/39Ar laser fusion method. The crystals were selected from the tephra layer U4T (585 ± 1 ka), and the fluvial units 3coll (586 ± 2 ka), 3s10 (583 ± 3 ka) and 3s6-9 (587 ± 2 ka), right above the archaeosurface t.3a (Fig. 2). The site’s age has been recently set to approximately 583 ka, i.e. to the end

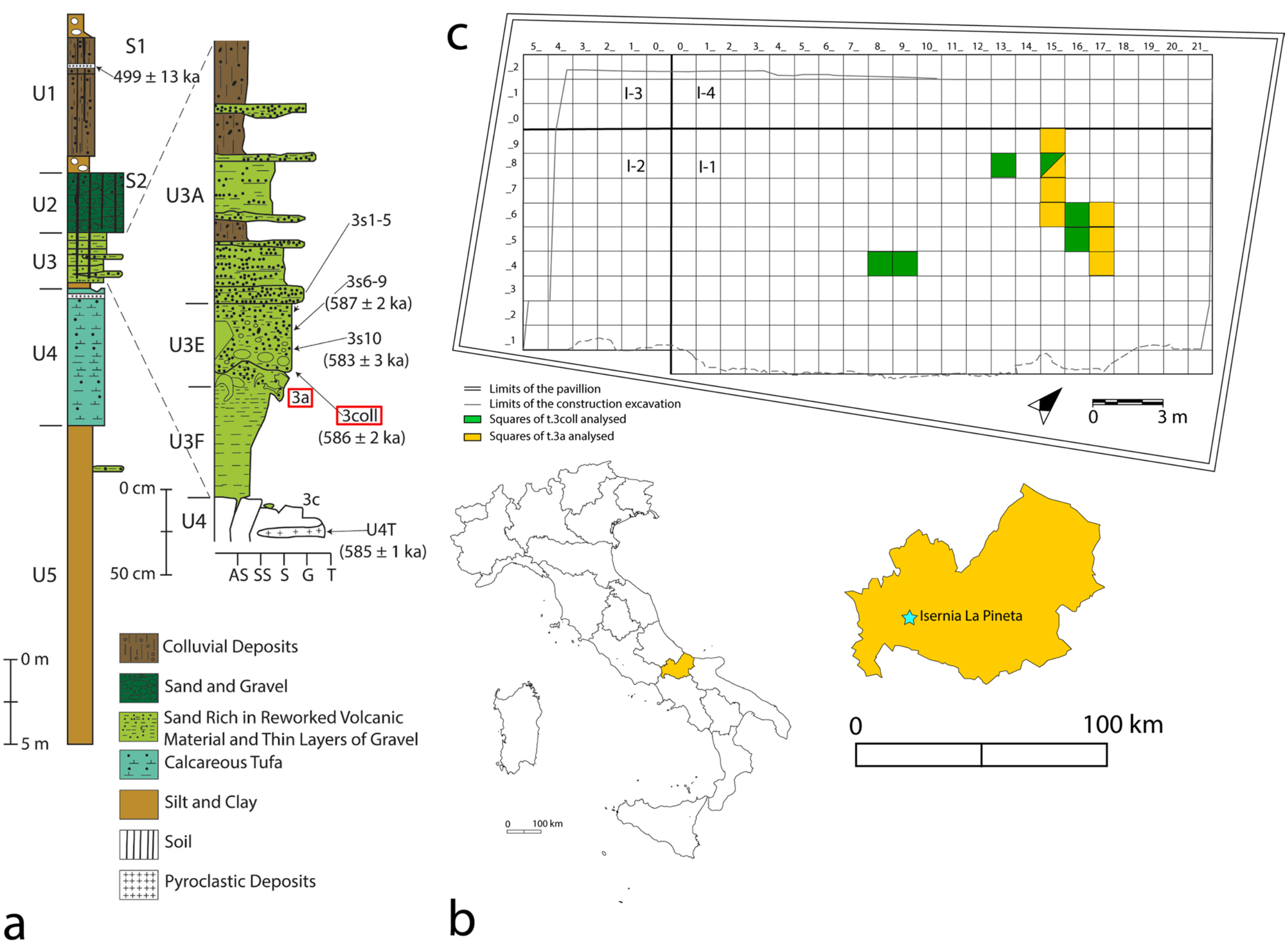


Fig. 2 **a** Stratigraphic sequence of Isernia La Pineta with the indication of the analysed layers (modified from Zanazzi et al. 2022). **b** Location of the site. **c** Excavation area of Sector I with the indication of the analysed squares (modified from Gallotti and Peretto 2015).

of interglacial 15 (MIS 15), according to new 40Ar/39Ar measurements (Peretto et al. 2015).

The faunal assemblage of Isernia La Pineta (Middle Galerian), dominated by large herbivores, suggests an open arboreal steppe environment with the fluctuating presence of ephemeral watercourse and pond (Coltorti et al. 2005). According to the available data, the climate was arider and colder than the present. The abundant faunal remains are associated with numerous lithic tools knapped in situ, exploiting local raw materials to obtain small-sized flakes (flint and limestone) and hammers (Rufo et al. 2009; limestone; Gallotti and Peretto 2015). The hominins' intensive exploitation of the herbivores' carcasses is confirmed by cut marks and intentional fresh bone fractures, pointing to systematic butchering activities over a wide area (Peretto 1996; Pineda et al. 2020). Moreover, in 2014 a human deciduous tooth (*Homo cf. heidelbergensis*) was found within layer 3coll (U3E) (Peretto et al. 2015).

The lithic industry is realised on flint and limestone, with the latter (varicoloured jaspers; Sozzi et al. 1994) being the most exploited raw material (Rufo et al. 2009; Gallotti and Peretto 2015; Rivera Peréz, 2016). The primary deposit is about 5 km from the site where the flint occurs in slabs and lenses inside the Cretaceous limestones. It was locally collected alongside the Carpino river, within the excavation area, under sub-cubic/rectangular slabs (60–100 mm) and exhibited a fine-grained texture and quality. Fracture planes are relatively common within these layers due to the intense tectonic activity recorded in this region. Moreover, given its collection alongside secondary deposits, flint underwent further tectonic breakages (along with the existing fractures) and chemical alterations during the alluvial transport.

Overall, the use of different knapping strategies for flint's reduction sequences (unipolar, centripetal, discoid etc.), some of them applied regardless of the slab shape and volume, alongside the systematic use of retouch, allowed the scientific community to reconsider Isernia La Pineta in the network of those sites witnessing a rise in complexity following the "Middle Pleistocene Revolution" (Gallotti and Peretto 2015; Moncel et al. 2018c).

The lithic industry on flint is oriented to producing morphologically non-standardised flakes of small and medium dimensions (Peretto 1999; Gallotti and Peretto 2015). Even though initially described as unstructured and opportunistic, with a negative connotation (Peretto 1994), a recent review of the lithic assemblage revealed the presence of more complex reduction sequences, suggesting the presence of a high degree of expertise and planning by the hominids (Gallotti and Peretto 2015). Extensive use of freehand percussion and bipolar on anvil technique is reported alongside a massive presence of retouched tools (Peretto 1994; Gallotti and Peretto 2015).

The limestone implements are realised on fluvial pebbles and cobbles available in situ of different morphologies and qualities. The reduction sequences, mainly conducted through unipolar-unifacial debitage, are short and aim to obtain medium-sized flakes sporadically retouched (Rufo et al. 2009; Gallotti and Peretto 2015). The bipolar on anvil technique and freehand percussion are equally attested for this raw material. The collection also identified a few chopper cores, large denticulates (Anconetani et al. 1992) and heavy-duty tool morphotypes (Barsky et al. 2018).

Material and method

The archaeological layers 3a and 3coll

This work focuses on the flint lithic material recovered from the archaeological layers t.3a and 3coll. All the coordinated flint lithic industry (> 1 cm) from layers t.3a and t.3coll of Sector I-1 was initially examined. Then six squares from the level t.3coll (84, 94, 138, 158, 166, 167) and seven squares from the level t.3a (156, 157, 158, 159, 174, 175, 176) were randomly selected and studied (Fig. 2; Table 1). The number of squares was decided to reach a reasonable number of lithic pieces statistically significant. The material from layer t.3coll comes from the 2001–2011 fieldwork, while the one from t.3a comes from the 2016–2017 fieldwork.

Both layers were extensively excavated in Sector I with t.3a in Sector II. All the material studied in this work comes from Sector I since it was more extensively excavated and better preserved. Layer t.3a is at the bottom of sub-unit 3F. It is composed of a high concentration of flint and limestone artefacts and faunal remains lying on the sand and gravel of Unit 3 and the travertines of Unit 4 (Fig. 2; Coltorti et al. 2005). The layer t.3coll (sub-unit 3E) directly lies above t.3a. It is a pyroclastic layer (debris-flow) of reworked and well-sorted elements with a thickness between 30 and 100 cm (Fig. 2). Large sanidine and pyroxene crystals occurred within this layer and were used for the new datations. Numerous lithic and faunal remains were also recovered from this unit (Peretto 1994).

Table 1 The total number of flint pieces from squares 84, 94, 138, 158, 166, and 167 for layer t.3coll and from squares 156, 157, 158, 159, 174, 175, and 176 for layer t.3a (first column) and the ones selected for use-wear analysis

Layer	Flint lithic pieces from selected squares	Selected for use-wear	Flake	Retouched flakes
t.3a	142	25	14	11
t.3coll	817	141	90	51
Total	959	166	104	62

In parallel with the detailed analysis of the siliceous material, the limestone implements from layer t.3coll are being studied and will be the object of a dedicated publication. This ongoing work will focus on unpublished material (up to 2016 fieldwork), integrating the previous work on 304 limestone pieces (Rufo et al. 2009).

Technological analysis

The t.3a and t.3coll lithic assemblages were analysed following the technological approach proposed by Inizan (1999) and Boëda (2013). The concept of *chaîne opératoire* (Leroi-Gourhan 1965; Haudricourt 2018) was applied to conceive all the phases of the flaking activity as a single process, from the raw material selection through the flake's obtainment to their abandonment. Cores were analysed to identify the technical behaviours, the volume management, the techniques used and their ascription to specific flaking methods. The relationship between the knapping surfaces was thus noted alongside their quantity and the direction of flaking employed. The presence/absence of striking platform preparation and the value angle between the knapping surface and its striking platform were also described. These latter aspects were fundamental to the interpretation of the centripetal reduction sequences for:

1) Identifying a possible hierarchisation of the surfaces
2) Assessing flaking's direction (parallel or secant) and how much it was influenced by the natural morphology of the blocks or was instead a researched feature implying the selection of specific morphologies/preparation of the surfaces

For the numbering of knapping surfaces, the terms unifacial (one single flaking surface), bifacial (two adjacent or opposite flaking surfaces) and multifacial (more than two flaking surfaces) were used (Gallotti and Peretto 2015). The terms unipolar, convergent, crossed, orthogonal, bipolar and centripetal refer to the organisation of the scars on the knapping surfaces and the dorsal face of the flakes.

For the flakes' analysis, several other attributes were considered besides the presence and position of the cortex and the butt's shape. For example, data regarding the incidence of *débordant* and plunging margin and whether this could reveal the existence of other knapping surfaces (core's edge), the position, delineation and location of retouch were recorded (Bordes 2000). The angle between the ventral face and the butt was also measured. By using the term *débordant*, we indicate the presence of a back (whether it could be natural or characterised by removals, i.e. core's edge) on the lateral face of an oriented flake. In contrast, the term plunging describes the presence of a back on the distal portion of the flake.

A total of 959 flint lithic artefacts were analysed in this work, 817 from layer t.3coll and 142 from layer t.3a, including cores, flakes, retouched tools and undetermined fragments (Table 2). The high number of undetermined pieces is due to numerous crossed and parallel fractures within the raw material (Gallotti and Peretto 2015) and the use of bipolar on-an-anvil techniques (Vergès and Ollé, 2011). These factors seemingly caused flaking incidence/unintentional breakages to be relatively common during the knapping activity.

Use-wear analysis

The flint lithic industry for the use-wear analysis was selected following two criteria: the presence of at least one useful edge (i.e. edge with an angle between 80° and 60° regardless of its length; chosen according to the criteria developed by Terradillos-Bernal and Rodríguez-Álvarez 2017) and surface preservation (the absence of marked PDSMs, i.e. post-depositional surface modifications; Levi Sala 1986). The sample comprises 166 debitage products (flakes and tools) from stratigraphic units (SU from now on) 3a (25) and 3coll (141); cores and debris were excluded.

The study began with the preliminary evaluation of the state of preservation on the selected samples to identify the different PDMS (post-depositional alterations) that affected the flint lithic industry. After this stage, each artefact was carefully washed with warm water and soap (pH 6) and then furtherly washed for 3 min in demineralised water (75%) and alcohol (25%) using an ultrasonic tank and then left to dry.

The present use-wear study combined the low-power approach (Odell and Cowan 1986) with the high-power

Table 2 Composition of the analysed lithic assemblage from the selected squares from layers t.3a and t.3coll

Categories	Layer t.3a		Layer t.3coll		Total	
	Number	%	Number	%	Number	%
Cores	7	4.9	62	7.5	69	7.2
Unretouched flakes	33	23.2	330	40.5	363	37.9
Retouched flakes	18	12.7	111	13.6	129	13.4
Undetermined fragments	84	59.2	314	38.4	398	41.5
Total	142	-	817	-	959	-

approach (Keeley 1980). The low-power approach provides information about the potential activities (e.g. cutting, scraping, piercing etc.) and identifies the hardness of the worked materials. The worked materials are then grouped into categories: soft (e.g. animal soft tissue, herbaceous plants and some tubers), medium (e.g. fresh wood and hide) and hard (e.g. bone, horn, antler, dry wood and stone). There are some materials with intermediate hardness or resistance, such as soft/medium materials (e.g. fresh hide, wet softwood) or medium/hard materials (e.g. softwood, wet antler; Semenov 1964; Tringham et al. 1974; Odell 1981; Lemorini et al. 2006; 2014). Some works (Moss 1983; Beyries 1987; Ziggiotti 2011; Berruti and Daffara 2014; Burbidge et al. 2014; Lemorini et al. 2014; Van Gijn 2014; Wilkins et al. 2015; Cruz et al. 2015; Berruti and Arzarello 2020; Berruti et al. 2020b; Daffara et al. 2021) show that the combined use of these two approaches is more effective and productive. The high-power approach studies micro-edge rounding, polishes, abrasions and striations. This study provides a more detailed understanding of the activities carried out with the lithic artefacts and supports the diagnosis of the processed materials (Keeley 1980; Ziggioti 2005; Lemorini et al. 2006; 2014; Rots 2010; Van Gijn 2014). The use-wear analysis was conducted using different microscopes: a stereoscopic microscope Seben Incognita III with magnification from 20× to 80×, a Leica EZ4 HD stereoscopic microscope with magnification from ×8 to ×40, a Microscope Camera Dinolight Am413T (for the low power approach analysis) and a metallographic microscope Optika B 600 Met supplied with oculars 10× and five objectives PLAN IOS MET (5–10-20–50-100×) (for the high-power approach analysis).

A detailed study of lithic taphonomy was completed (Burroni et al. 2002; Mazzucco et al. 2013). Based on their origin, post-depositional alterations can be divided into mechanical and chemical alterations. Several of the mechanical post-depositional alterations (PDMS) (cracks, edge crumbling, fractures and rounding of edges and ridges) are visible to the naked eye and can be analysed in detail with the help of the stereomicroscope (Levi Sala 1986; Burroni et al. 2002; Eren et al. 2011a; Mazzucco et al. 2013; Asryan et al. 2014; Lemorini et al. 2014; Asryan 2015). The bright spots (Moss 1983; Levi Sala 1986; Mazzucco et al. 2015) and the polished surfaces' study (Moss 1983; Burroni et al. 2002; Mazzucco et al. 2013) were carried out through the metallographic microscope. The chemical modifications include various degrees of patination (Van Gijn 1990b; Burroni et al. 2002; Glauberman and Thorson, 2012; Mazzucco et al. 2013; Asryan et al. 2014; Asryan 2015), primarily visible in the naked eye, but also some polished areas on the lithic surfaces better discernible at greater magnification with the stereomicroscope (Burroni et al. 2002).

Each artefact was analysed first through the low-magnification methodology and subsequently with the high-magnification methodology. First, recorded in an Access database, the post-depositional alterations, the position and the type of traces of use identified were recorded. The position of the traces identified on the surface of the findings was documented using the diagram created by Van Gijn (1989) and modified by the authors (Fig. S8).

The use-wear analysis and the taphonomic analysis were conducted using different microscopes: a stereoscopic microscope Seben Incognita III with magnification from 20× to 80×, a Leica EZ4 HD stereoscopic microscope with magnification from ×8 to ×40, a Microscope Camera Dinolight Am413T (for the low power approach analysis) and a metallographic microscope Optika B 600 Met supplied with oculars 10× and five objectives PLAN IOS MET (5–10-20–50-100×) (for the high-power approach analysis).

A reference collection with flint flakes was created to better identify the traces of use on the artefacts. The collection was created by one of the authors during the use-wear study of the archaeological site of Guado San Nicola (located a few km from the site of Isernia; Berruti et al. 2020b) in which the raw materials used for stone tools are the same attested at Isernia la Pineta (Peretto et al. 2014). Several specific activities were then completed on different materials (skinning, filleting, woodworking etc.) with the experimental lithic tools to link the use-wear features to tool motions and the processed materials (Table S1). Unretouched flakes issued from the S.S.D.A. method through the hard hammer percussion technique were also used during the experimental work. For each of them, the time of use, the direction of the gesture and the material worked were recorded. Adobe Photoshop CS6 Portable (© Adobe) software was used for image processing since it allows a single image to be built up from several photos taken, focussing on different sample heights.

Result

The technological analysis

Layer t3.coll — cores

At Isernia La Pineta, flint slabs exhibit a sub-cubic/rectangular morphology ranging between 80 and 30 mm. They show tiny portions, or complete absence, of cortex due to their massive natural breakages. Larger blocks often present a thick cortex layer alongside raw material scarcity, making them quantitatively inefficient for flaking. Fractures (visible or not) strongly affected the reduction sequences starting from the slabs' collection.

Cores were classified according to the number of knapping surfaces and their removals (Table 3). The main category is the one with a single extraction surface exploited,

Table 3 Categories of analysed cores coming from the sampled squares from layers t.3a and t.3coll

Categories	t.3a				t.3coll			
	Support				Support			
	Slab	Flake	Pebble	Total	Slab	Flake	Pebble	Total
Unifacial								
Unipolar	2	2	-	4	19	6	1	26
Orthogonal	-	-	-	-	2	1	-	3
Convergent	-	-	-	-	1	-	-	1
Bipolar	-	-	-	-	-	1	-	1
Bifacial								
Unipolar	-	2	-	2	10	2	-	11
Orthogonal	1	-	-	1	2	-	-	2
Centripetal	-	-	-	-	2	-	-	2
Bipolar	-	-	-	-	1	-	-	1
Multifacial								
Unipolar	-	-	-	-	10	-	-	10
Orthogonal	-	-	-	-	2	-	-	2
Bipolar	-	-	-	-	1	-	-	1
Total	3	4	-	7	51	10	1	62

followed by bifacial and multifacial ones (Table 3). The debitage was mainly unipolar, sometimes orthogonal, more rarely, centripetal and bipolar for all categories. The preferred support is slabs, but a conspicuous production using flakes as cores is also attested (Table 3). Slabs measure between 20 and 75 mm, while cores-on-flake are smaller and included within 15 and 50 mm (Table 4). Only one core on a pebble was recorded.

Table 4 Size (mm) of cores' support from the sampled squares from layers t.3a and t.3coll

Layer	t.3coll		t.3a	
Cores' support	Slab ($n=51$)	Flake ($n=10$)	Slab ($n=3$)	Flake ($n=4$)
Length (mm)				
Min	17	21.45	35.9	30.2
Max	74.5	52.75	44.65	50.35
Mean	37.06	31.39	41.42	37.82
St. dev	11.1	8.61	3.92	7.63
Width (mm)				
Min	15.75	17.3	22.4	33.45
Max	58.7	37.05	46.6	41
Mean	29.6	24.91	33.63	37.93
St. dev	10.04	5.81	9.95	3.15
Thickness (mm)				
Min	9.3	12.2	14	19.8
Max	50.1	22.6	30.6	26
Mean	22.95	16.33	22.83	22.9
St. dev	8.33	3.3	6.81	2.53

Cores on slabs show three main categories: (1) large cores with few removals abandoned for their scarcity of raw material or quality ($n=16$; Fig. 3, n°1); (2) small cores, often on slabs' fragments, unifacially exploited for very short reduction sequences (even for a single removal), and still preserving natural surfaces ($n=20$; Fig. 3, n°3; Fig. S1, n°3); (3) cores attesting prolonged flaking, occasionally involving other faces and partially altering the original volume/morphology of the slab ($n=16$; Fig. 3, n. 2; Fig. S1, n°1, 2). Overall, the raw material quality of these cores ranges from poor, for the first category, to average/good for the rest, while the fine-grained flint, attested by several flakes, seems to be nearly absent on the sample selected. The recorded striking platforms on the cores on slabs are mainly natural (33) and flat (17), showing little evidence of preparation. Unifacial cores are primarily associated with natural striking platforms, while bifacial and multifacial cores exhibit a balance between natural and flat. Flat striking platforms are due to cores rotation but might also indicate the research for more suitable knapping angles. Overall, the angle of flaking is attested by a mean value of 78°. The vast majority of the cores still preserve several natural surfaces associated with various portions of the cortex (Fig. 3, n°1, 3).

Cores on flakes are obtained on small flakes (Table 4; Fig. S1, n°4, 5). Just one core on a bigger flake was recorded from this layer. It exhibits a lower quality of the raw material and presents a single removal overlapped by several smaller hinged ones. The reduction sequences show a mean of three removals (Fig. S1, n 4, 5). The cores are knapped unifacially and mainly through unipolar debitage. The ventral face is often the striking platform, while the dorsal face is

Fig. 3 Flint cores from analysed squares from layer t.3coll. 1, bifacial core with unipolar removals; 2, discoidal core; 3, unifacial core with a single removal

the knapping surface. The mean value of the flaking angle is 60°.

Layer t.3a — cores

Seven cores were recorded from layer t.3a, three realised on slabs and four on flake (Table 3; Fig. S2). The debitage is mainly unipolar (Fig. S2, *n*°3), with only one core orthogonally exploited, and is usually conducted on one or two surfaces of the cores. Their size is between 50 and 15 mm for both slabs and cores-on-flakes (Table 4).

Flat striking platforms, attested on two cores on slabs, result from the slabs' opening or the cores' rotation. Larger dimension cores are abandoned at an early stage of flaking due to the quality of the raw material (Fig. 2, *n*. 3), while others of smaller sizes are selected for 1–2 removals (Fig. 3, *n*. 1, 6, 7). The angle of flaking is orthogonal in the core, attesting unipolar debitage, while it measures 70° in the one with orthogonal removals. The absence of cortex is reported for all samples except for one testifying a thin layer in the upper and lower face of the slab.

The four cores-on-flake, all recording unipolar debitage, use the ventral face as the striking platform (with a mean angle of 70°), taking advantage of the convexity on the dorsal face for the production of flakes (Fig. S2, *n*°1, 2). On one of the bifacial cores, the inversion between the knapping surface and the striking platform was performed, while semi-tournant exploitation was recorded on one of the unifacial cores (Fig. S2, *n*°3). Four removals per core were observed except the largest one, an opening flake of a large nodule of poor quality presenting one single removal.

Layer t.3coll — flakes

Unretouched flakes from layer t.3coll are 330, accounting for 40% of the entire layer (Table 2). Their morphology is roughly quadrangular, slightly longer than large (Table 5; Fig. 4). The presence of a backed margin, whether it is *débordant* (31%), plunging (11%), *débordant* and plunging (10%), or on all sides (2%), is quite frequent. An additional knapping surface was recorded on 25% of these backed margins. The incidence of a backed margin opposite to a cutting edge, lateral or distal, was also quite common (Fig. 4, *n*. 2, 3, 7, 11).

The absence of cortex was recorded on 82% of the flakes. Striking platforms mainly exhibit exploitation of natural (40.6%) and flat (37%) surfaces followed by cortical (6%), dihedral (3%), linear (3%), facetted (1%; *n* = 4) and punctiform (1%; *n* = 4). The butts fractured during knapping are relatively low (5%). All striking platforms present a mean angle of 100°, including within a range of 70° and 130°.

Table 5 Size (mm) of unretouched and retouched flakes from selected squares from layers t.3a and t.3coll

Layer	t.3coll		t.3a	
Flakes	Unretouched	Retouched	Unretouched	Retouched
Length (mm)				
Min	10.7	11.55	14.55	14.7
Max	49.35	67.25	46.1	60.8
Mean	23.8	28.79	25.85	31.07
St. dev	7.64	9.21	7.46	13.92
Width (mm)				
Min	5.75	11.2	13.35	20.2
Max	41.95	62.95	40.5	52.45
Mean	20.98	25.34	20.51	28.99
St. dev	6.59	8.84	6.25	9.75
Thickness (mm)				
Min	2.6	4.6	4.85	5
Max	25.2	33.2	17.1	27.8
Mean	9.54	11.66	9.94	13.31
St. dev	3.86	4.83	3.24	6.4

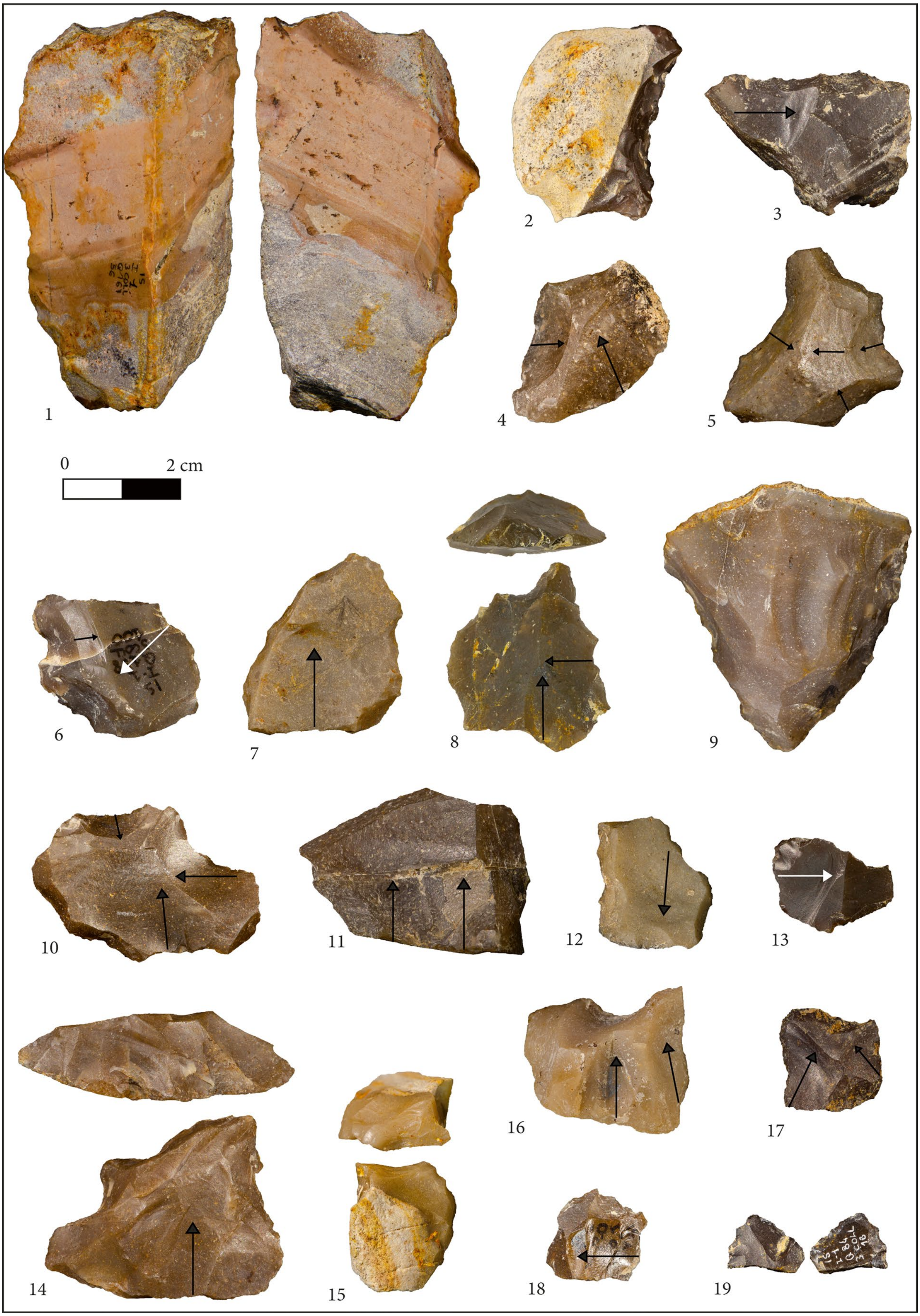
The organisation of the removals display a preferential use of unipolar debitage alternated with an orthogonal one (Fig. 4; *n*° 3, 7, 8, 11, 13, 14, 16, 18). Flakes without negatives on the dorsal face represent the largest group (27%), highlighting the massive usage of natural surfaces throughout the flaking process. They are followed by unipolar (23.3%), orthogonal (18%), convergent (14.6%), bipolar (8%), centripetal (4%) and crossed (4%). The evidence for a Kombewa debitage was found only on 4% (*n* = 13) of all flakes.

Layer t.3coll — retouched flakes

Retouched flakes represent 13.6% of the sample from this layer (Table 2; Fig. 4, *n*°1–3, 6, 8, 9, 12, 14–16, 19). Their dimensional values are more significant than the unretouched pieces (Table 5; Fig. 4, *n*°1). The extension of the retouch is mainly marginal, followed by abrupt and invasive and is usually located on the longest margin of the flakes (the lateral one). However, edge modification of the distal and proximal side is also witnessed within the assemblage (Table 6). The angle of retouch has a mean value of 62° when it is marginal or invasive and 74° when it is abrupt. Tools are retouched on the dorsal face for most cases, even if alternated, and inverse retouches are also attested (Table 6). Concerning tools-typology (Bordes 2000), scrapers are the most common ones (Fig. 4, *n*°1, 3, 9, 12, 19) followed by denticulates (Fig. 4, *n*°2, 6 14) and notches (Table 6; Fig. 4, *n*°8, 16). Then, some composite tools are witnessed, including beaks and points, sometimes combined with scrapers, notches and denticulates (Fig. 4, *n*°8, 15, 16). Scrapers are usually marginally retouched on one side (simple scrapers; Fig. 4, *n*°1, 3) or, more rarely, on two (double and convergent scrapers; Fig. 4, *n*°9, 12). The double-scrapers present a convex delineation of the retouch, usually applied on the lateral and distal margins. The same pattern is witnessed for denticulates, simple and double (Table 6).

Layer t.3a — flakes

From layer t.3a, 33 unretouched flakes were analysed (Table 2; Fig. S3). The dimensional values show quadrangular flakes, slightly longer than larger, comprised between 25 mm in their length and 20 mm in their width (Table 5). The presence of backed margins was recorded on 21 artefacts: 13 *débordant* flakes (Fig. S3, *n*°3, 8) four plungings (Fig. S3, *n*°9), three *débordant* and plunging and one *débordant* on all sides. Only two flakes attested an additional knapping surface on their backed margin (i.e. core's edge). Portions of the cortex were recorded only on seven flakes, usually located on the lateral and distal margins. The analysis of striking platforms shows a preferential use of natural (10) and flat (9) butts, followed by cortical (2) and dihedral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◂**Fig. 4** Flakes and retouched flakes from selected squares from layer t.3coll. 1, Scraper on large flake; 2, denticulate on cortical backed flake; 3, scraper on debordant flake; 4, 5, 10, flakes with centripetal removals; 6, denticulate on flake; 7, debordant flake with unipolar removal; 8, point and notch on a flake with orthogonal removals; 9, convergent scraper with abrupt retouch; 11, debordant flake with unipolar removals; 12, double scraper on flake with bipolar removal; 13, small-sized flake with orthogonal removal; 14, denticulate on flake with unipolar removal; 15, retouched pointed flake; 16, notch and point on flake with unipolar removals; 17, small flake with convergent removals; 18, small flake with orthogonal removal; 19, scraper on small flake

(2). The absence of dihedral, facetted, linear and punctiform ones is reported. Only two fractured butts were found. All striking platforms display a mean angle of 98.5°, including within a range of 86° and 113°. The majority of flakes show either the absence of removals (11; Fig. S3, *n*°1, 6, 8) or unipolar removals (8; Fig. S3, *n*°5), and then orthogonal (4; Fig. S3, *n*°2, 3, 7, 10), convergent (3; Fig. S3, *n*°9), bipolar (2) and crossed (1) removals are almost equally attested within the record, though an absence of centripetal ones was noted. Evidence for Kombewa debitage was reported only on one fragmented piece.

Layer t.3a — retouched flakes

Eighteen retouched flakes were analysed from this layer (Table 2; Fig. S3, *n*°1–4, 6–8). Larger supports have been selected for the retouch, as shown in the dimensional value (Table 5). The retouch is almost exclusively marginal, followed by invasive and abrupt; it is mainly located on the dorsal face and, more rarely, on the ventral (Fig. S3, *n*°1, 6) or both sides (Table 6). Slight preferential use of lateral margin for edge modification was also observed, though the distal part, or even both, are equally retouched. The angle of retouch associated with marginal retouch has a mean value of 61°, while the single abrupt retouch exhibits an edge inclination of 71°. Scrapers (Fig. S3, *n*°1–3, 6) are this layer's most common tool typology, followed by denticulates (Fig. S3, *n*°4, 7, 8) and notches. Scrapers are primarily retouched on one margin, but double and convergent scrapers exist, while notches and denticulates are realised on one side only. Only one composite tool (notch + scraper) is present (Table 5).

Layer t.3coll — limestone

The limestone material from layer t.3coll comprised 748 (Table 7; Fig. S4) pieces and was classified into structural categories (Leakey 1971; Clark and Kleindienst 1974; Chavaillon and Chavaillon 1976; Isaac 1977; Chavaillon 1979; Bordes 2000; Barsky et al. 2015). Most of the collection includes whole non-flaked pebbles and cobbles of different volumes and morphologies, among which 11 percussors were identified (Table 7; Fig. S4, *n*°a). The knapped pieces comprise several morphotypes such as denticulates, heavy-duty scrapers and chopper-like (13%). The ratio between flakes and cores suggests less intensive raw material exploitation than flint. Retouched flakes are rare, consisting of only 6% of all flakes.

Use-wear analysis

Taphonomic analysis result

Most of the selected lithic pieces did not show evident post-depositional alterations, even with the naked eye. Thanks to the microscopic analysis, it was possible to highlight how in some cases, the post-positional tares affected even 90% of the analysed finds (Table 8; Fig. S5). In any case, the selection made in the study's first phase made it possible not to exclude any element from the study.

The taphonomic analysis confirms that the two SU (stratigraphic units) display few differences in the state of preservation (Arzarello and Peretto 2006; Pineda et al. 2020). As noted in the past technological analysis of the lithic industry, the geomorphological analysis and the spatial analysis, the two SU have suffered various post-depositional alteration processes (Arzarello and Peretto 2006; Channarayapatna et al. 2018; Pineda et al. 2020). All 166 flint lithic remains analysed show at least one post-depositional alteration (with various degrees of development; Table 8). The microscopic analysis identifies these alterations: polishing, edge crumbling, deposition of concretion and different patinas (white and Fe–Mn; Fig. S5). Rounding of the surfaces can be attributed to the transport of the lithic industry in the sediment (like a debris flow); edge crumbling can be due to the same phenomenon or to a trampling activity. Although not significantly developed, white patina testifies to alkaline and wet deposition conditions (Dove and Nix 1997; Dove et al. 2008; Glauberman and Thorson 2012). The presence of rare spots of Fe–Mn patina is ascribable to the decomposition of organic materials due to bacteria (Marín-Arroyo et al. 2014). Concretion deposition refers to a deposit of a solid mass, usually composed of inorganic material (also mineral matter). It is typical of sedimentary rocks, especially siliceous ones (Mangado 2004).

Use-wear analysis result

The use-wear analysis of the flint lithic assemblage identified 68 artefacts with traces of use: 8 belonged to SU 3a and 60 to SU 3coll (Fig. 6, 7 S6 and S7). The use-wear analysis of the artefacts belonging to SU 3a allowed identifying eight flakes with wear traces (Table 9). Among them, three artefacts show two zones of use (ZU). In

Table 6 Categories of tools with the position (D = direct, I = inverse) and extension (M = marginal, A = abrupt, I = invasive) of retouch from selected squares from layers t.3a and t.3coll. Values in bold indicate the total number of pieces from layers t.3coll and t.3a

Layer	t.3coll							t.3a							
		Position			Extension				Position			Extension			
Type	n	D	I	D+I	M	A	I	N°	D	I	D+I	M	A	I	Total
Beak	**2**	1	-	1	1	-	1	**-**	-	-	-	-	-	-	**2**
Denticulate simple	**21**	17	4	-	11	5	5	**5**	3	2	-	5	-	-	**26**
Denticulate double	**4**	3	-	1	2	1	1	**-**	-	-	-	-	-	-	**4**
Denticulate and beak	**1**	1	-	-	1	-	-	**-**	-	-	-	-	-	-	**1**
Notch (single)	**14**	12	1	1	-	-	-	**2**	2	-	-	-	-	-	**15**
Notch and point	**1**	-	1	-	1	-	-		-	-	-	-	-	-	**1**
Notch and scraper	**4**	3	-	1	2	2	-	**1**	-	-	1	1	-	-	**5**
Point	**1**	1	-	-	1	-	-	**-**	-	-	-	-	-	-	**1**
Point and scraper	**1**	1	-	-	-	1	-	**-**	-	-	-	-	-	-	**1**
Scraper simple	**48**	31	10	7	34	12	2	**6**	6	-	-	5	1	-	**54**
Scraper double	**10**	5	-	5	4	5	1	**2**	1	-	1	1	-	1	**12**
Scraper convergent	**4**	3	-	1	1	1	2	**2**	2	-	-	1	-	1	**6**
Total	**111**	**78**	**16**	**17**	**58**	**27**	**12**	**18**	**14**	**2**	**2**	**13**	**1**	**2**	**128**

SU 3coll, 63 use-wear traces referable to 60 flakes were found (Table 10). Three of them have two different ZU: two flakes show the same type of traces on both the ZU and one has two different ZU, referable to different types of traces. Of the 68 artefacts with wear traces identified, 31 are retouched (Tables 11 and 12); 4 are from SU 3a (two denticulates and two sidescrapers), and 27 are from SU 3coll (8 denticulates; 16 sidescrapers, two beaks and one notch).

The identification of use-wear traces and their interpretation is based on the experimental activity conducted by Berruti et al., (2020b) and on the description presented by Anderson (1990) (1990), Lemorini et al., (1997, 2006), Hardy (2004), Palmqvist et al., (2005), Claud et al., (2012), Zupancich (2016), Berruti et al., (2020b) and Beyries (2020).

The traces recorded on the Isernia la Pienta flint lithic assemblage can primarily refer to the processing of animal resources. The low-power approach identified a clear predominance of edge removals for processing soft and medium-soft materials. Many traces have been identified linked to a longitudinal action on soft or medium-soft material: small, diagonally oriented edge-removals. During this stage of the analysis have also been recognized traces linked to the longitudinal or transversal action on medium-soft or medium-hard material: big overlapping edge removals with a mixed orientation, diagonal and perpendicular (in many cases associated with edge rounding). During the analysis with the high-power approach, typical polishes of the processes of these materials were identified: hide (edge rounding associated pitted polish), fresh bone (smooth and flat spots of polish), soft animal tissue (lines and band of rough

Table 7 Structural categories of the limestone material from layer t.3coll. *Whole non-flaked pieces are included in the limestone study to determine any (qualitative and morphological) anthropic selective processes (Titton et al. 2018; 2021)

	Categories	Layer t.3coll			
		N	%	*N*	%
Non-modified	*Whole, non-flaked pebbles and cobbles	363	48.5	374	50
	Percussion instrument	11	1.5		
Knapped pieces	Cores	113	15.1	130	17.4
	Retouched cores (denticulate morphology)	7	0.9		
	Loosely configured tools (heavy-duty scraper morphotype)	8	1.1		
	Chopper-like cores	2	0.3		
Flakes	Flakes (unretouched)	115	15.4	122	16.3
	Flake-tools	7	0.9		
Fragments	Broken pebbles and cobbles	3	0.4	122	16.3
	Pebbles and cobble fragments	119	15.9		
Total		748	100	748	100

Table 8 PDMS identified in the lithic industry studied from selected squares from layers t.3coll and t.3a

PDMS	t.3coll ($n=141$)		t.3a ($n=25$)		Total ($n=166$)	
	n	%	*n*	%	*n*	%
Rounding	126	89	24	96	150	90
Edge crumbling	102	72	23	92	125	75
Fe-Ma patina	68	48	14	56	82	49
White patina	19	13	8	32	27	16
Concretion	92	65	15	60	107	64

polish), butchering (usually are a mix of all the other traces individuated) and also indeterminate traces of polish (Fig. 6, 7 S6 and S7).

Tables 9 and 10 show that the identified traces correspond to activities linked to animal carcass processing: butchering, hide, fresh bone and soft animal tissue working. The hardness of the worked materials deduced by the analysis with the low power approach shows a clear predominance of soft and medium-soft materials (Tables 9 and 10).

Discussion

Lithic technology

The site of Isernia is characterised by the exploitation of locally collected rectangular flint slabs ranging between 30 and 80 mm for length/width and 10–35 mm for thickness. These slabs were available within the site as their abundance is reported within the entire archaeological sequence (Peretto 1994; Gallotti and Peretto 2015; Channarayapatna et al. 2018). The massive fractures and the raw material scarcity on larger blocks determined a systematic optimisation of surfaces and volumes during knapping. The rare evidence for fractures and impurities on flakes confirms an efficient raw material selection and reduction processes, while the non-predominant presence of cortex on flakes and cores suggests that hominids selected already broken slabs of small dimensions.

The raw material constraints determined several approaches for flakes' production and cores' management. Direct percussions by hard hammer and bipolar on anvil technique were equally employed (Peretto 1994; Gallotti and Peretto 2015). Even if the latter's identification could be difficult and sometimes produce the same outcome as the former (Jeske and Lurie 1993; Donnart et al. 2009; Bietti et al. 2010; Moyano et al. 2011; Vergès and Ollé, 2011; Eren et al. 2013; Peña, 2015; Shott and Tostevin 2015; Pargeter and Eren 2017; Sánchez-Yustos et al. 2017), these techniques were applied according to raw material morphology and quality. For instance, more cubic slabs without proper convexities could require the bipolar on anvil technique to initialise the flaking activity (Moyano et al. 2011; de Lombera-Hermida et al. 2016). This allowed the check for internal impurities other than producing smaller blocks, eventually knapped through freehand percussion and larger flakes to be retouched later. The bipolar on anvil technique proved to be vastly employed in older sites to overcome the raw materials' quality and volumes and obtain specific products in a controlled way (Barsky 2013; de Lombera-Hermida et al. 2016; Gallotti et al. 2020).

When better convexities existed, direct percussion by a hard hammer was applied right from the start. Given the small dimension of end-products and some cores, both techniques could have been applied on the same core at different stages. In this case, using an anvil might have eased the core handling (Hiscock 2015). The particular hardness (in terms of resistance to fracture) of the raw material of Isernia La Pineta (Crovetto et al. 1994; Peretto 1994; 1999) must also be considered since the requirement for significant strength in the technical gesture could be a requirement have been facilitated by the presence of an anvil. Fractured butts are

Table 9 Use-wear traces on selected squares from layer t.3a lithic industry, grouped by action, method of débitage and worked material. Values in bold indicate the total number of pieces with traces detected for each technique

Material	Bipolar on anvil			Freehand percussion			Tot
	Tran. Act	*Long. Act*	*Mix*	*Tran. Act*	*Long. Act*	*Mix*	
Soft animal tissue					1		1
Butchering				1			1
Soft		2			2		4
Medium soft				1			2
Medium hard				2	1		3
Tot	**0**	**2**	**0**			**0**	10
Tot. for technique	**2**			**8**			

Table 10 Use-wear traces on selected squares from layer t.3coll lithic industry, grouped by action, method of débitage and worked material. Values in bold indicate the total number of pieces with traces for each technique

Material	Bipolar on anvil			Freehand percussion				Tot
	Tran. Act	*Long. Act*	*Mix*	*Tran. Act*	*Long. Act*	*Drill*	*Indet*	
Soft animal tissue		1		1	1			3
Butchering	1			2	4			7
Fresh skin				1		1		2
Fresh Bone				1				1
Soft				2	19			21
Medium soft		1		7	11		1	20
Medium hard				8			1	9
Tot	**1**	**2**	**0**	**23**	**35**	**1**	**2**	63
Tot. for technique	**3**			**60**				

relatively low, though crushing marks on the edge of the platforms, sometimes associated with internal fractures, can be globally observed, pointing to the evidence of repeated impacts. Moreover, the knapping angle (100°) suggests the exploitation of wide and open surfaces. This aspect and the flakes' thickness, often coinciding with the butt's thickness, may confirm the need for inner, possibly stronger, blows to obtain flakes.

Two main strategies were identified (Fig. 5) to manipulate slabs' volumes: (a) the most prominent and flattest surface was knapped through a peripherical striking platform; (b) volumetric exploitation, i.e. semitournant, of the most convex faces from a single striking platform was performed.

In the first case, orthogonal debitage was preferred, possibly leading to a centripetal one (Fig. S1, *n*° 3; Fig. 5). The striking platforms were mainly natural, taking advantage of the natural angles of the slabs without cortex. Opening one or more striking platforms was occasionally required through single removals when the angle between the surfaces was too orthogonal. The direction of flaking was often parallel to the knapping surface, exploiting wide angles (> 100°) and thus obtaining flakes with a constant thickness along their length. The lateral and distal convexities management happened simultaneously with the flaking activity and was usually achieved with orthogonal/bipolar debitage alongside plunging and *débordant* flakes. Reduction sequences were not particularly long, even though the organisation and the number of the removals on flakes suggest the presence of debitage carried on regardless of the slabs' natural shape (Fig. 4, n°5, 10; Fig. S3, n°2).

In the second case, more prominent convexities were favoured on cubic-shaped slabs over flatter surfaces as knapping surfaces (Fig. 5). The debitage was mainly unipolar or convergent, exploiting one slab's face and potentially becoming semitournant (Fig. S1, *n*°2; Fig. S2, *n*°3). The direction of flaking was secant to the knapping surface, given its more pronounced convexity. Consequently, flakes are thicker in the proximal part and thinner in the distal one. The preparation of striking platforms is primarily achieved through single removals, even though natural ones are also frequently used. Usually, only one generation of removals is attested, confirming the deliberate exploitation of natural convexities.

This latter strategy might generate a discoid conception of the volumes (Fig. 3, *n*°2; Fig. S1, *n*°1), already attested in layer t.3c (Gallotti and Peretto 2015) and considered an innovative feature for the Middle Pleistocene transition, as also witnessed in the sites of Notarchirico (Moncel et al. 2020d), Atapuerca (Ollé et al. 2013), Caune de l'Arago (Barsky 2013) and La Noira (Stratum a; Moncel et al. 2020a), simultaneously to the general increase of centripetal productions observed in the sites of Moulin Quignon (Antoine et al. 2019), Atapuerca (Ollé et al. 2013) and Boxgrove (Roberts and Parfitt 1999). The site of Isernia exhibits several technological affinities with the mentioned sites, providing evidence for centripetal and discoid productions, fitting at the same time the "innovations package" supposedly introduced with the Acheulean after MIS 19 but lacking bifacial tools and LCT (Gallotti and Peretto 2015; Moncel and Ashton 2018; Moncel et al. 2018c).

In both layers analysed, unifacial debitage is the most attested strategy. The limited presence of bifacial and multifacial cores is due to the raw material constraints rather than a lack of complexity of the entire assemblage. They either result from single unifacial events occurring at the end of reduction sequences or testify to the opening of striking

Table 11 Zones of use with use-wear traces from selected squares from layer t.3a lithic tools, grouped by action, typology and worked material (four lithic remains four zones of use). Values in bold indicate the total number of retouched pieces with traces

Material	Denticulates		Sidescrapers		Tot
	Tran. act	*Long. act*	*Tran. act*	*Long. act*	
Soft		1			1
Medium soft				1	1
Medium hard	1		1		2
Hard					0
Tot	**1**	**1**	**1**	**1**	4

Table 12 Zones of use with Use-wear traces from selected squares from layer t.3coll lithic tools, grouped by action, typology and worked material (27 lithic artefacts, 30 zones of use). Values in bold indicate the total number of retouched pieces with traces

Material	Denticulates			Sidescrapers		Notches		Beaks		Tot
	Tran. act	*Long. act*	*Mix*	*Tran. act*	*Long. act*	*Long. act*	*Tran. act*	*Long. act*	*Drilling*	
Butchering	1				2	1				4
Hide	1								1	2
Soft animal tissue					1					1
Fresh bone	1									1
Indet pol			1							1
Soft	1	1			1					3
Medium soft	1	3		5	4			1		14
Medium hard				4						4
Tot	**5**	**4**	**1**	**9**	**7**	**1**	**0**	**1**	**1**	30
Tot. for typology	**10**			**17**		**1**		**2**		**30**

platforms to optimise unifacial debitage. The incidence of plunging and *débordant* flakes reveals that knapping surfaces and cores were not remarkably large but still efficiently exploited according to the existing natural arrises to manage the cores' convexities. This might suggest that the need for specific convexities/angles, regardless of the slabs' shape, was seemingly a researched feature within the reduction sequences. These technical expedients proved to be also employed in the coeval Acheulean sites of Moulin Quignon (Antoine et al. 2019) and La Noira (Moncel et al. 2021), especially on centripetal cores.

Besides this, a tendency to exploit cores *expediently* was also identified. Small and, in a minor portion, big cores selected for just one or two removals, even of lower-quality raw material, highlights that the need to produce small functional flakes was the cornerstone of the entire production, as witnessed in other sites associated with animal carcasses exploitation (Mosquera et al. 2015; Aureli et al. 2016; Moncel et al. 2021).

The significant number of recorded core-on-flakes might be a technical expedient to enhance the blocks' volume to obtain small flakes and overcome the presence of cortex and fractures. The removals' dimensions fit the size of the small flakes attested in the rest of the site. However, six cores share some similarities with retouched tools if their size and the presence of functional cutting edges (< 75°) are considered (Fig. S1, *n*°4, 5; Fig. S2, *n*°2). Since we are dealing with a lithic assemblage that produces mainly small flakes, can we correctly distinguish between passive supports (i.e. core) and active ones (i.e. flake/tool)? It is plausible that, given the great flexibility that characterises this lithic industry and its production goals, the boundary between the concept of *debitage* and *façonnage* was subtle and functional to the hominins' necessities. From this point of view, similar behaviours were found at the sites of Ficoncella (Aureli et al. 2016) and Soucy 3 (Lhomme 2007), where a "circularity" of the reduction sequences was reported.

Larger supports were selected for the retouch. The original morphology of flakes was not profoundly altered, even though a substantial modification of the margins was performed to obtain specific shapes (points and scrapers), showing great flexibility and a high level of expertise. Edge modification was applied on all flakes regardless of their characteristics and shapes to get a wide variety of tools, suggesting various functions and usage. Scrapers, denticulates and notches are the most attested tools recalling a pattern seen in other butchery sites of the Middle Pleistocene (Ollé et al. 2013; Aureli et al. 2016; Hérisson et al. 2016; Moncel et al. 2020a; 2020d). However, in Isernia's case, the retouched implementation rate seems much more relevant and comparable with the Acheulean sites of La Noira and Notarchirico, where the presence of points and convergent tools was also reported (Moncel et al. 2020a; 2020d).

Overall, the flint industry of Isernia is characterised by a miniaturisation of the end products and the supports, showing small dimensional values (Fig. 4, *n*°13, 15, 17–19; Fig. S1, *n*°1–5; Fig. S2, *n*°1–3; Fig. S3, *n*°5–10). This is undoubtedly due to the raw material constraints, which the hominins efficiently overcame, highlighting a high level of expertise and producing a sophisticated range of flakes and tools through numerous technical expedients. The Italian peninsula shows an interesting pattern of "miniaturised" lithic production throughout the Middle Pleistocene (Abruzzese et al. 2016; Aureli et al. 2016; Arnaud et al. 2017; Grimaldi et al. 2020; Moncel et al. 2020d). The sites of Notarchirico, Ficoncella, Atella, Guado San Nicola and Fontana Ranuccio all share this feature, especially when flint-realised implements are considered. This pattern may undeniably originate from the available raw materials exploited but also resulted in similar methodological and

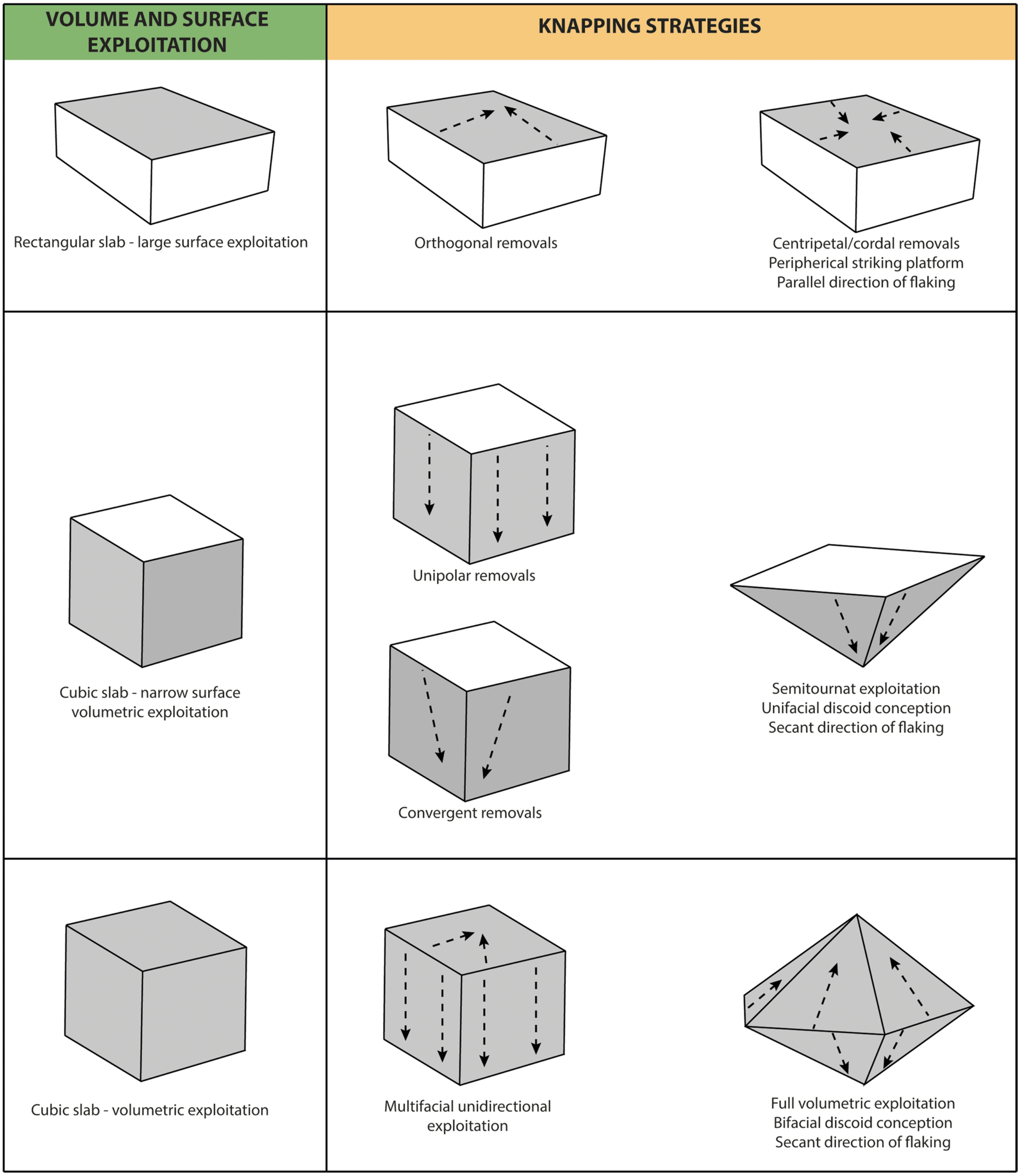


Fig. 5 Diacritic schemes of the knapping strategies documented for layers t.3coll and t.3a at the site of Isernia La Pineta. Drawings and graphic elaboration by M. Carpentieri

technical responses (i.e. the previously mentioned ambivalence between debitage and faconnage, cores-on-flakes, tool-core etc.) that could indicate the possible emergence of a common — possibly cultural? — substratum, as will happen with the Middle Palaeolithic transition (Moncel et al. 2016; 2020c; 2021; Davis and Ashton 2019).

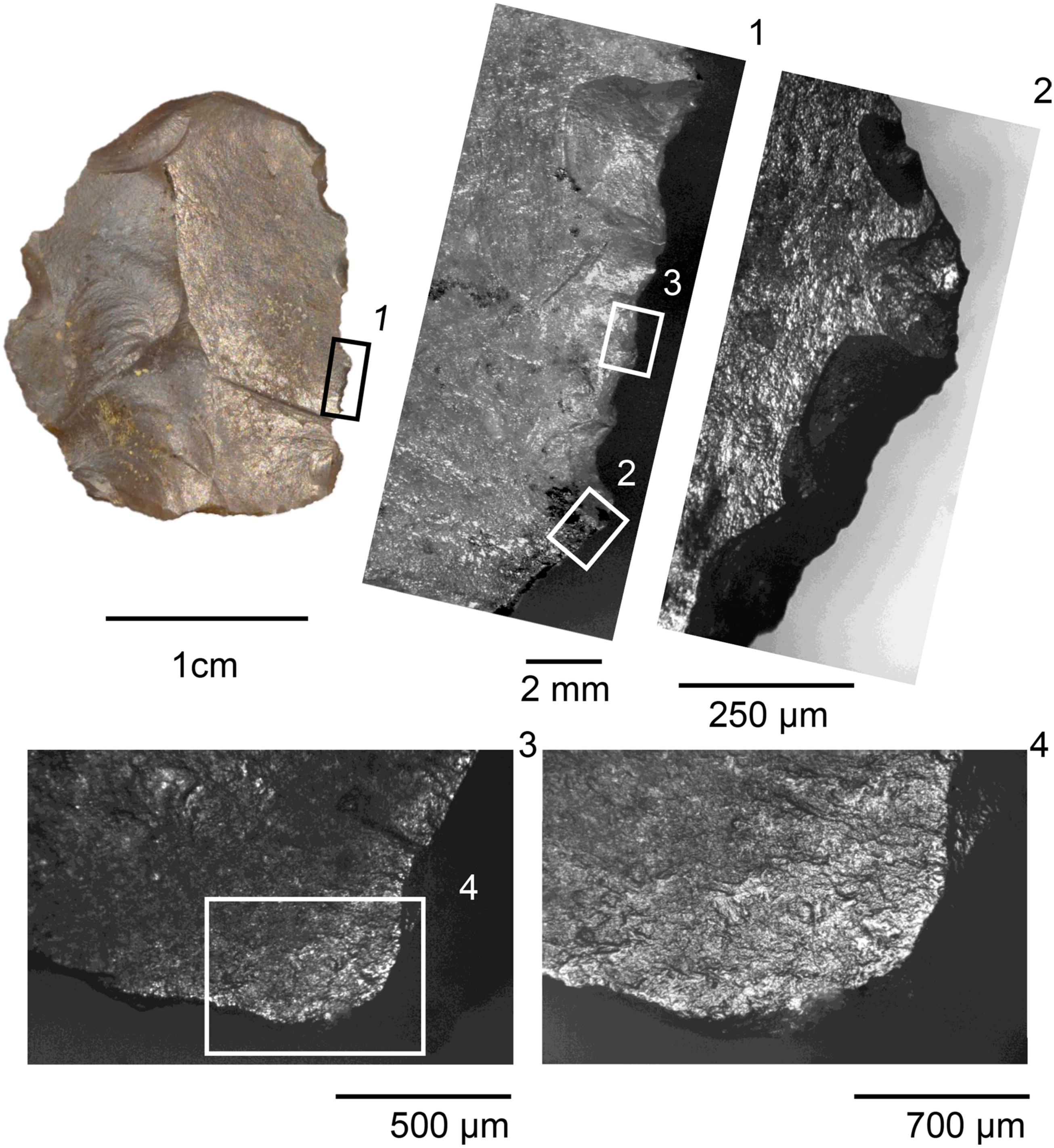
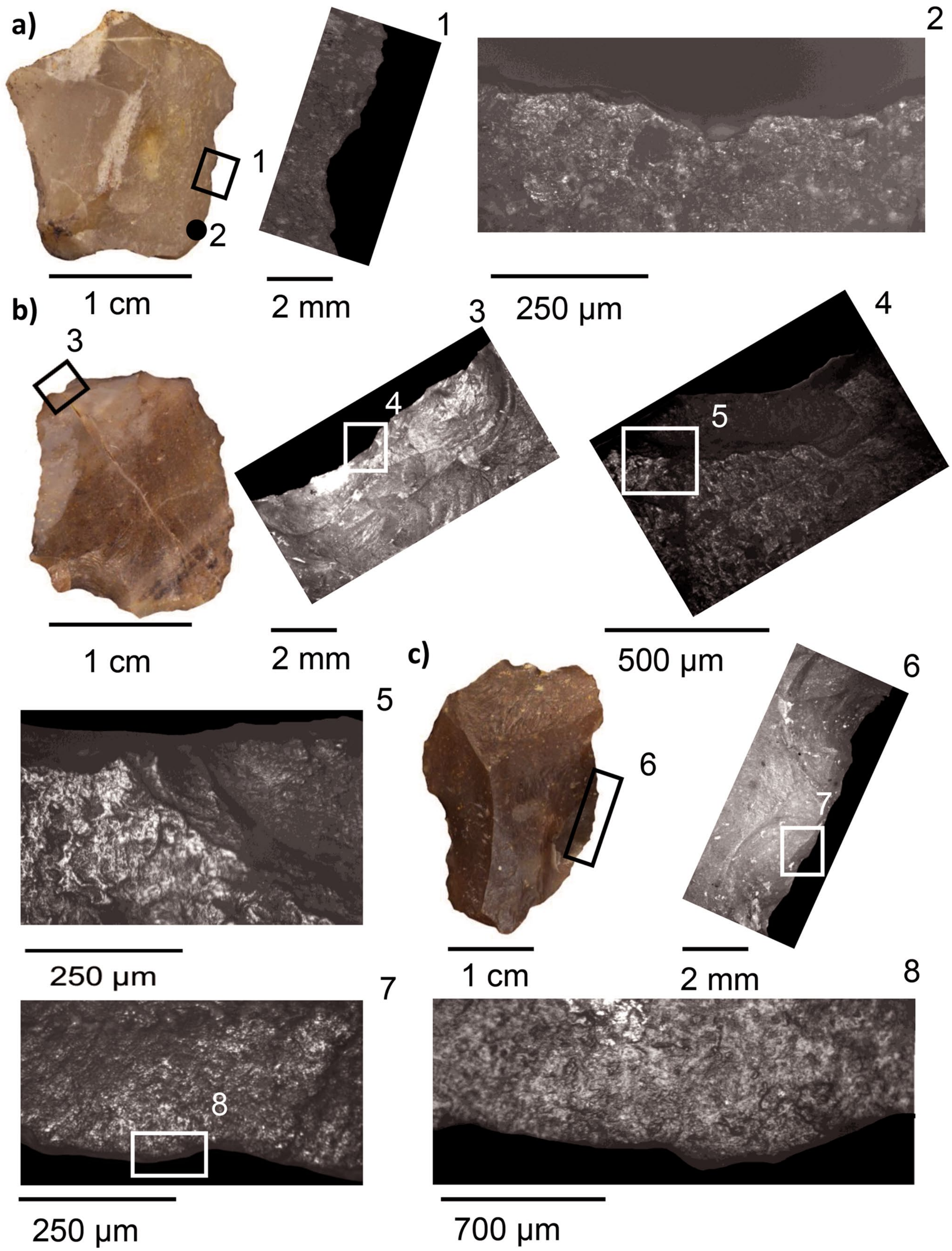


Fig. 6 Use-wear traces on Isernia la Pineta flint flake 157 18 3a with traces interpreted as the result of longitudinal activity on medium soft animal tissue: crescent shape, diagonally oriented edge-removals (1) with a band of rough polish (fleshy tissues) (2, 3 and 4); the identification of use-wear traces and their interpretation is based on the experimental activity conducted by G. L. F. Berruti (2020b) and on the description of use-wear traces presented for example by Anderson (1990), Lemorini et al. (1997; 2006; 2016), Hardy (2004), Palmqvist et al. (2005), Claud et al. (2012), Berruti et al. (2020ab) and Beyries, (2020)

Use-wear analysis and taphonomy

Use-wear studies have already been successful for Lower Pleistocene contexts in Africa: Koobi Fora (1.5 Ma; Keeley and Toth 1981), Kanjera South (2.0 Ma; Lemorini et al. 2014), El-Kherba (1.8 Ma; Sahnouni et al. 2013), Peninj (1.5 Ma; Domínguez-Rodrigo et al. 2001); Asia: Xiaochangliang (1.36 Ma; Chen and Chun 2000) and


a)
1
2
1 cm
2 mm
250 µm
b)
3
4
5
1 cm
2 mm
500 µm
c)
6
7
8
250 µm
1 cm
2 mm
250 µm
700 µm

◂**Fig. 7** Use-wear traces on Isernia la Pineta artefacts from selected squares from layers t.3a and t.3 coll. a Simple scraper 138–198 3coll: (1) use-wear traces interpreted as longitudinal action on fleshy tissues: small, diagonally oriented edge-removals; (2) polish issued from the work of fleshy tissues: part of the polish is characterized by a band of rough polish linked to the edge morphology. b Simple scraper 138–207 3coll: use-wear traces interpreted as transversal action on bone: cracks and latent fractures typical of hard material working (3) with localized areas of smooth and flat polish (4 and 5). c Simple scraper 166–116 use-wear traces interpreted as the result of longitudinal butchering activity: (6) diagonally oriented edge-removals with a (7) band of rough polish (fleshy tissues) and (8) edge rims heavily worn (fresh hide); the identification of use-wear traces and their interpretation is based on the experimental activity conducted by G. L. F. Berruti (2020b) and on the description of use-wear traces presented, for example, by Beyries (2020), Anderson-Gerfaud (1990), Palmqvist (2005), Lemorini (1997; 2006; 2016), Hardy (2004), Claud (2012), Berruti (2020ab) and Zupancich (2016)

Europe: Pirro Nord (1.5–1.3 Ma; Cheheb et al. 2019), El Pino (1.0–0.9 Ma; Domínguez-Solera et al. 2022), Atapuerca Gran Dolina (TD 6, 0.8 Ma; Sala 1998; TD 10, 1.2 Ma; Pedergnana and Ollé, 2020) and Montepoggiolo (0.85 Ma; Peretto et al. 1998). The Middle Pleistocene records increase with use-wear data, such as in the sites of La Noira (700 ka; Hardy et al. 2018), Boxgrove (500 ka; Mitchell 1998), Terra Amata (400 ka; Viallet 2016), Schöningen (300 ka; Rots et al. 2013), Revadim (Agam et al. 2015; Solodenko et al. 2015; Venditti et al. 2019; Marinelli et al. 2021; Zupancich et al. 2021) and Qesem Cave (Lemorini et al. 2006; 2016; 2020). In Italy, use-wear studies comparable with the site of Isernia from a chronological and cultural perspective (Rocca et al. 2016; Muttillo et al. 2021) were realised at Notarchirico (Moncel et al. 2020d; Santagata et al. 2020) and Ficoncella (Aureli et al. 2016), while the works on Guado San Nicola (370–400 ka; Berruti 2017; Berruti et al. 2020b) and Fontana Ranuccio (Marinelli et al. 2019; 2021) belong to MIS 11.

At Isernia La Pineta, post-depositional alterations affected the flint lithic industry to different degrees along the stratigraphic sequence, but they did not prevent the use-wear analysis. The analysis of the post-depositional alterations recorded on lithic artefacts (Eren et al. 2011b; 2011a) can be an essential indicator for the reconstruction of past environmental conditions and site formation processes (Van Gijn 1990a; Mazzucco et al. 2013; Asryan et al. 2014; Chakraborty et al. 2014; Berruti and Arzarello 2020).

The taphonomic analysis shows that the same post-depositional alterations affected the two considered SU with approximately the same intensity (Table 8 and Fig. S5). The degrees of development of the same alterations in the different SU testify that they underwent similar processes. The high percentage (more than 70% of the analysed sample) of lithic artefacts showing smoothing on the surfaces and rounding of edges and ridges can be related to a transport phenomenon, like a debris flow, as also assumed by the previous studies concerning geoarchaeology, taphonomy of the faunal remains and GIS (Peretto 1999; Thun Hohenstein et al. 2009; Gallotti and Peretto 2015; Channarayapatna et al. 2018; Pineda et al. 2020). The taphonomical analysis of the flint lithic industries of the Isernia La Pineta site is the subject of an ongoing study that uses the overlapping method for the taphonomy of the lithic artefacts (Berruti and Arzarello 2020), which aims to relate the different sequences of alterations post depositions found on elements from the various stratigraphic units.

The results of the use-wear analysis on flint flakes through the Low Power approach show that in both the SU (Tables 8 and 9), the flakes were used mainly for cutting (38 on 68) and, to a slightly lesser extent, scraping (28 on 68) soft and medium-soft materials (52 on 68). The high-power approach allowed us to locate diagnostic polish on 14 flint lithic remains correlated to animal carcass processing (Tables 9 and 10) (Fig. 6, 7, S6 and S7). In particular, all the activities associated with carcass processing are attested: cutting of soft animal tissue on four artefacts; cutting, drilling and scraping of fresh hide on two artefacts; and traces of butchering on eight artefacts (mixed traces of working of skin, bone and soft animal tissues) (Fig. 6, 7, S6 and S7). Bone working traces are present on one artefact, exhibiting a scraping action, and are probably linked to the periosteum removal required during marrow extraction (Grayson 1984; Crovetto et al. 1994; Longo 1994). Combining the results of the use-wear analysis (predominant use of the lithic artefacts for the processing of lightly resistant materials) with the palaeontological data is evident that the faunal remains of Isernia la Pineta include animals of various sizes, it is then reasonable to suggest that these tools may have been part of the toolkit used for butchering activities. Furthermore, the presence of cut marks and intentional fractures was highlighted in previous works (Peretto et al. 2004; 2016; Thun Hohenstein et al. 2009; Thun-Hohenstein et al. 2015; Pineda et al. 2020; Zanazzi et al. 2022) and is consistent with the results obtained by the use-wear analysis.

Traces hinting at butchering activities (soft and medium-soft material) are present on 39 lithic artefacts from SU 3coll (Fig. 6, 7, S6 and S7). The exploitation of medium-hard materials is only attested in four pieces (Table 10). From SU 3a, only four elements with these characteristics were found, exhibiting traces linked to the work of soft and medium-soft materials (Table 11). These data are also confirmed by the experimental work made under the supervision of Longo (1994). The results of this work, proving the preferential use and efficiency of small-sized unretouched flakes in butchering activities, fit with the data obtained for other sites of the Middle Pleistocene such as Ficoncella (Aureli et al. 2016), Fontana Ranuccio (Marinelli et al. 2021) and Revadim (Venditti et al. 2019).

Regarding the study of retouched flakes in SU 3a, only four exhibit use-wear traces. Due to this reduced sample, it is impossible to make general considerations (Table 11). On the other hand, in SU 3coll, there are 29 formal tools with wear traces (Table 12). There is a greater incidence of traces linked to transversal work on medium hard and medium soft materials. However, it is impossible to associate a tool with a particular action or a worked material. This data can be related to the results of the experimental work completed in 1993 and with the data obtained by the different studies that assert that in sites of this chronology and with these characteristics, retouching can be associated with the necessity to consolidate the cutting edges or to improve tools' grip (Longo 1994; Aureli et al. 2016; Marinelli et al. 2019; 2021). Both cases can be easily adapted to the need for working with more resistant materials, consequently fitting with the results of our study.

Overall, the use-wear analysis results are consistent with the previous studies conducted by Longo on 1367 lithic artefacts from SU 3a, even if from another sector of the site (Crovetto et al. 1994; Longo 1994) and by Verges on 105 artefacts coming from SU 3a (Sector I) and on 87 elements coming from SU 3a (Vergés, 2002; Vergès and Ollé, 2011). The study conducted by Longo (Crovetto et al. 1994; Longo 1994) highlighted the presence of traces exclusively related to animal carcass processing; on the contrary, the study conducted by Verges (2002, 2011), although identifying more of the 90% of traces as due to butchering activities also found traces linked to the working of vegetal materials. This result might be due to the different areas analysed in these works. In any case, all the studies on the use-wear traces provided similar results proving how the lithic industry of Isernia La Pineta was deeply linked with the exploitation of animal carcasses through the massive production of small-sized flakes and tools, recalling a pattern highlighted by other sites of the first half of the Middle Pleistocene in Europe and the Levant (Longo 1994; Vergés, 2002; Aureli et al. 2016; Hardy et al. 2018; Marinelli et al. 2019; 2021; Venditti et al. 2019).

Recent studies on the identification of use-wear traces on limestone industries granted a better understanding of the function and use of this raw material during the Lower Palaeolithic (Titton 2021; Titton et al. 2021). From this perspective, the ongoing study on the limestone implements of layer t.3coll, presented at a preliminary stage, will allow us to obtain a much higher resolution on the type of activities performed at Isernia La Pineta and the role of this site. The new methodological approach finalised to the analysis of macro-tools with an experimental activity aimed to comprehend the mechanical response of limestone within the reduction sequences (cores exploitation, tool production etc.) and use will be the groundwork to gather possible new behavioural information.

Conclusion

The technological and functional analysis performed on the flint assemblages of layers t.3a and t.3coll provided important information on the function and role of Isernia La Pineta during the first half of the Middle Pleistocene.

Many authors have been questioning the dichotomy between Acheulean and non-Acheulean on the presence of handaxes in the last years based on the recent evidence from Western and Eastern Europe, which shows a wide range of complex technical behaviours (Rocca et al. 2016; Moncel et al. 2018c; Davis and Ashton 2019; Davis et al. 2021). From a technological perspective, the industry of Isernia La Pineta exhibits complex mental templates that allowed some authors to infer its possible relation with the Acheulean complex (Gallotti and Peretto 2015; Muttillo et al. 2021) following the general increase in complexity witnessed during the Middle Pleistocene. The combined approach of lithic technology and use-wear analysis, here as in other sites, proved to be rewarding from a behavioural perspective because it enables the comparison between the degree of complexity of any lithic assemblage (raw material, cores' management, flakes, retouch etc.) with its functional aspects (Mitchell 1998; Aureli et al. 2016; Hardy et al. 2018; Venditti et al. 2019; Moncel et al. 2020d; Marinelli et al. 2021). This would give a more detailed picture of the hominins' subsistence strategies and relative changes/innovations from a "cultural" perspective.

The lithic industry of Isernia La Pineta aimed to produce small-sized flakes and tools realised on local raw material through different debitage attesting to more complex reduction sequences (centripetal and discoid) achieved through various technical expedients. Direct percussion and bipolar on-anvil techniques were employed, accounting for a codified choice from the hominids to overcome the slabs' morphology and quality, reflecting a well-known behaviour observed in other Lower Palaeolithic contexts (de Lombera-Hermida et al. 2016). All the knapping phases were recorded in these layers, confirming that the hominids seemingly selected, used and abandoned the lithic artefacts in the same area.

The use-wear analysis showed that flint artefacts were exclusively used for carcass processing on soft and soft-medium material (meat, fresh hide and animal tissues). Flakes' function was primarily cutting and, to a slightly lesser extent, scraping activities, although all the phases of carcass processing were identified. Minor traces of bone working were also observed and might be related to periosteum removal required during marrow extraction, confirming a butchery-related role of the site (or at least of the flint materials). Different tools were identified from a typological point of view, but no associations were found between specific shapes and worked materials. The efficiency of small unretouched flakes for butchery activities on large herbivores carcasses has been proved in many experimental activities and witnessed in several other Lower Palaeolithic contexts within the Italian peninsula (Boschian and Saccà, 2015; Marinelli et al. 2019; 2021; Rocca et al. 2021).

In conclusion, the analysis of the flint industry of Isernia La Pineta configures the site as specialised in butchering activities on large herbivores' carcasses. Whether these were hunted or scavenged is still a debated topic. The flint lithic assemblage reflects these specific activities by providing many small-sized flakes and tools. This would allow us to compare Isernia with other specialised butchery sites of the first half of the Middle Pleistocene, such as Notarchirico, Ficoncella and Boxgrove, all of them characterised by a massive presence of small-sized artefacts (Roberts and Parfitt 1999; Aureli et al. 2016; Moncel et al. 2020d). The absence, so far, of other kinds of activities conducted at the site, such as the woods and plant processing witnessed at La Noira, Atapuerca, and in some levels of l'Arago, might suggest a different type of occupation and role of these contexts over time (Hardy et al. 2018). Furthermore, the lack of largely shaped tools (i.e. bifaces, LCT) at Isernia seems unrelated to the activities conducted here since, in other sites, such as La Noira, the bifaces were also employed for butchery activities.

The systematic exploitation of local raw materials in all the mentioned sites, often placed in the proximity of watercourses, indicates that the subsistence strategies of the hominins involved a relatively small area of action, whether short- or long-term occupations were performed. The analysis of the isotopes of strontium performed on the human tooth of Isernia seems to confirm this trend (Lugli et al. 2017).

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Declarations

Competing interests The authors declare no competing interests.

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