Special Issue: The Apidima Legacy Collections: New Analyses and Interpretations

Apidima Cave at the Last Glacial Maximum: The Lithic Legacy Collection of Cave D (Peloponnese, Greece)

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ABSTRACT
The Apidima cave complex, located on the western coast of the Mani peninsula (Peloponnese, Greece), is a karstic system comprising five caves (A–E). Four of these were investigated by the Museum of Anthropology, University of Athens, during excavations carried out in the 1970s and 1980s, yielding important Paleolithic and paleoanthropological findings that have contributed significantly to discussions of human presence in southeastern Europe. Among these collections is a lithic assemblage from Cave D that has remained unpublished until now. This study presents the first comprehensive description and technological analysis of this material. The analyzed assemblage comprises 678 artifacts, including cores, flakes, bladelets, retouched tools, and a limited amount of chips and debris. Attribute-based and reduction sequence analyses were applied to identify flaking methods, blank production strategies, and retouching techniques. About half of the artifacts were produced on local flint, either grey or black, followed by radiolarite, with andesite, hematite, and other raw materials occurring only sporadically. Reduction sequences indicate that bladelets were the primary objectives of debitage production, although flakes were also produced throughout the reduction process. Both direct percussion and bipolar-on-anvil techniques were used, with some blanks reflecting shifts between these two methods. Unidirectional frontal platform and orthogonal plane cores were reduced using both techniques, whereas semi-tournant cores were exclusively exploited by direct percussion for bladelet production. The retouched tool assemblage is dominated by specimens with abrupt backing, with backed bladelets being the most common tool type, followed by backed points. Together with recent radiometric evidence, the technological characteristics of the Cave D assemblage fit within the heterogeneous (Epi)Gravettian record of the Balkans during the Last Glacial Maximum, consistent with an attribution to the Early Epigravettian. These results provide new data on the Upper Paleolithic of Greece and contribute to discussions of technological variability and human occupation in southeastern Europe during the Late Pleistocene.

INTRODUCTION

SITE BACKGROUND

The Apidima cave complex, located on the western side of the Mani Peninsula in southern Greece, consists of five karstic depressions (A–E) formed into a steep coastal cliff of Middle Triassic-Upper Eocene limestone (Figure 1). Investigations at the site, led by Prof. Theodoros Pitsios, were conducted from 1978 to 1986 in four of the five caves by the Museum of Anthropology (Medical School of the National and Kapodistrian University of Athens). Test pits and limited excavations resulted in the recovery of abundant faunal remains, lithic artifacts, and paleoanthropological material attributed to the Middle (Bartsiokas et al. 2017; Harvati et al. 2019; 2026a [this issue]; Roditi et al. 2026 [this issue]) and Late Pleistocene (Darlas 1995; Harvati et al. 2021; Karakostis et al. 2026 [this issue]; Lax 1995; Lombardo et al. 2026 [this issue]; Mompheratou and Pitsios 1995; Naumann et al. 2026 [this issue]; Tsoukala 1999). The present analysis is the first study on the knapped lithics recovered by the Pitsios team from Cave D.

Located at 24 meters above sea level, Cave D is the highest in elevation of all the Apidima cavities (see Figure 1). Limited contextual information is available for the materials from this legacy collection. Pitsios (1985) and Lax (1995) briefly describe the stratigraphic sequence uncovered in Cave D as follows, from top to bottom:

- DI: culturally sterile layer; bones found in this layer appear fresh and recent in age;
- DII: 2–3cm thick layer of natural salt, locally solid or brecciated;
- DIII: located immediately beneath the salt deposit, this sediment is rich in cultural remains and marine molluscs; bones from this layer appear fossilized.

All excavated sediments were dry sieved using a double layered screen with mesh sizes of 2.5mm and 19mm (Lax 1995; Pitsios 1985), however it is unclear if systematic recovery of micro-artifacts took place. To date, the lithic assemblage from Cave D remains unpublished, with only a brief report providing a preliminary technological assessment of selected artifacts to identify possible *in situ* debitage (Kourtessi-Philippakis 2007).

Preliminary observations of raw material use indicate that black and brown flint, as well as jasper, were preferentially selected for the production of elongated blanks, whereas andesite, quartz, and limestone were primarily exploited for flake production (Kourtessi-Philippakis 2007). The present study identified potential raw material outcrops within the western Mani region. Lenses of black flint have been documented within the Pantokrator limestones of the Ionian Plattenkalk Zone (IGME 1980), which, according to Chiotis (2007), have been significantly affected by metamorphism and tectonic activity. Flint outcrops occur across an extensive stretch of the western coastline of the Mani Peninsula, extending as far north as Verga, approximately 60km from Apidima (Chiotis 2007). Additional occurrences have been reported in the Viros Gorge near Kardamyli (Garefalakis et al. 2018; Tourloukis et al. 2016) and in the Trachila area further south (Karkazi et al. 2024).

Recent radiocarbon dates obtained from shell fragments of the edible topshell (*Phorcus* sp.) recovered during the Pitsios excavation place the Cave D legacy assemblages between 22.7–17.1 ka cal BP (Harvati et al. 2026b [this issue]).

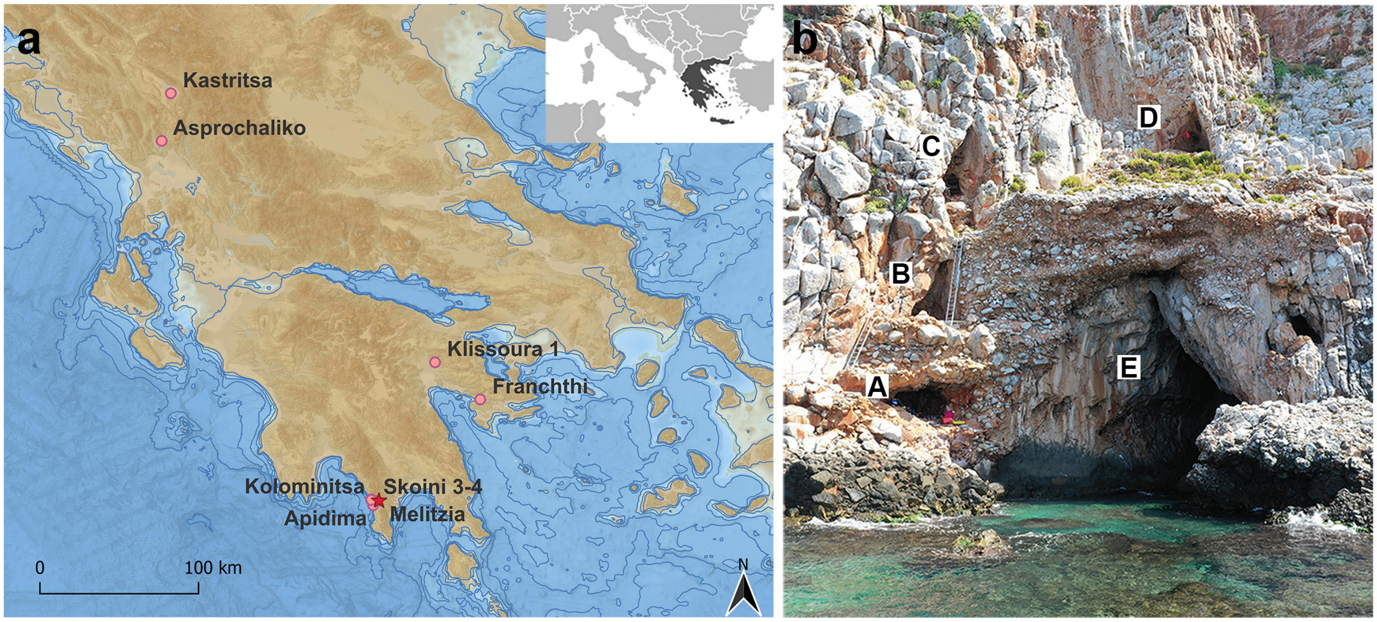

Figure 1. a) Geographic location of Apidima and other late Paleolithic sites mentioned in the text. The map shows the paleogeographic reconstruction of Greece, considering the mean sea level –120m below the current sea level, circa 20,000 BP. The map was generated using QGIS 3.36.3 (https://www.qgis.org/). Source of the Digital Elevation Model and Bathymetry: EMODNED (https://emodnet.ec.europa.eu/geoviewer/). b) The Apidima Cave Complex, showing caves A to E.

MATERIALS AND METHODS

The legacy collections of Apidima are stored at the Museum of Anthropology (School of Medicine, National and Kapodistrian University of Athens).

The observations on the stratigraphy made by Pitsios (1985) suggest that the Cave D lithics were recovered directly below the salt layer in stratum DIII. Although some contextual information (such as elevation and excavation unit) is retained on the find tags, there are no other data available with regard to the stratigraphic units from which the finds derive. Due to the lack of such information, therefore, in our study, we considered the lithics as belonging to a single assemblage.

Technological analysis of the assemblage combined attribute analysis (Andrefsky 1998; Odell 2004; Tostevin 2013) with reduction sequence analysis (Boëda et al. 1990; Geneste 1991; Inizan et al. 1995; Shott 2003) to document and examine a wide range of discrete and metric attributes (Table 1).The variables selected for this study (Table 2) include the lithotypes and their subtypes, along with the shape and possible procurement origin (either primary or secondary), when cortex was evident, the presence and type of patina, and evidence of burning. Raw material classification was conducted macroscopically using a triplet lens (10×, 16×). All specimens were assigned to technological categories (core, flake, blade, bladelet, spall, chunk, chip, debris) (see Table 2).

For each debitage product, the following attributes were recorded: extent and position of cortex, cross-sectional shape, longitudinal profile of the ventral face, orientation of dorsal scars, distal, butt, and bulb characteristics, and production technique.

For each core, raw material volume, number of exploited faces, presence or absence of surface hierarchization, type and preparation of the striking platform, scar direction, stage of exploitation, target product, and volumetric concept were recorded (see Table 2). Core classification follows schematic models based on these attributes, particularly the number (1–4) and spatial arrangement (adjacent or opposed) of exploited faces, together with platform configuration and removal directionality. The following categories are distinguished: PP (parallel planes) cores, including PP1F (single exploited face), PP2ADF and PP2OF (two adjacent or opposed faces, respectively), and PP3F and PP4F (three or four faces), PO (orthogonal planes) cores, defined by two or more orthogonal planes, and semi-circumferential platform cores, characterized by partial rotational development of the reduction surface (narrow, wide, or semi-tournant configurations) (Conard et al. 2004; Falcucci and Peresani 2018; Rossini et al. 2022; Sánchez-Martínez et al. 2022). For each retouched specimen, the location, mode, and extent of the retouch were recorded (Inizan et al. 1995).

To conduct data management, analysis, charting, and basic statistics, the R environment, specifically leveraging various packages such as "ggplot2," "scales," and "Tidyverse" within RStudio Version 1.4.1106 (Lê et al. 2008; Wickham et al. 2019) and IBM SPSS Statistics 31 were utilized. Given that the sample was not normally distributed according to the Shapiro-Wilk and Kolmogorov-Smirnov tests, non-parametric tests (Mann-Whitney and Kruskal-Wallis) were performed.

TABLE 1. DESCRIPTIONS OF VARIABLES RECORDED DURING THE TECHNOLOGICAL ANALYSIS.

Technological analysis	
Identification number	Running ID
Excavation details	Date, box number, old ID (if present)
Raw material	Flint, radiolarite, hematite, andesite, quartz, limestone, chalcedony, indeterminate
Raw material subtype	Black, grainy black, grey (flint), brown, green, red (radiolarite)
Alteration	Fire, patina, indeterminate, no
Degree of integrity	Integer, distal, lateral, mesial, mesio-distal, proximal, proximal-mesial, composite fragment
Metrical attributes	For each debitage blank >100mm²: Length, width, thickness (along the technological axis or considering the longest dimension as length)
Technological categories	Core, flake (length/width ratio ranging from 0 to 1.9), blade (length/width ratio exceeding 2) bladelet (referring to blades with a width ≤12 mm) (Inizan et al. 1992), backed flake, spall (an elongated element detached from a lateral ridge of a flake-core), chunk (a fragmented or unorientable piece), chips (flakes and fragments of flakes with an area smaller than 100 mm²), debris (unorientable pieces with an area smaller than 100mm²)
Production technique	Direct, bipolar, indeterminable, direct-bipolar (for blanks detached by bipolar percussion that display dorsal direct percussion characteristics), bipolar-direct (for blanks detached by direct percussion that display dorsal bipolar percussion characteristics)
For each debitage blank >100mm²	
Cortex coverage	In percentage
Cortex position	Proximal, lateral, lateral back, mesial, distal, transversal, semi-total, total
Raw material form	Slab (flat, tabular piece with planar cortex from bedded raw material), pebble, fragment (angular piece with dull secondary patina from block fragmentation; not water-rounded)

TABLE 1. DESCRIPTIONS OF VARIABLES RECORDED DURING THE TECHNOLOGICAL ANALYSIS (continued).

For each debitage blank >100mm²	
Cross-section shape	Trapezoidal, rectangular, triangular, semi-circular, linear, irregular
Longitudinal profile of the ventral face	Straight, concave, convex, twisted, wavy
Orientation of dorsal scars (including the detached piece)	Unidirectional, bidirectional, perpendicular (for removals on the same debitage surface), orthogonal (for removals on different and orthogonal debitage surfaces), convergent, centripetal
Butt characteristics	Linear, punctiform, plain, broken, cortical, dihedral, faceted, shattered, retouched
Bulb characteristics	Diffuse, pronounced, negative, retouched, absent
Termination	Feathered, hinged, broken, plunging (removal reaching the distal end of the core without significant overpass; non-feather -abrupt or step-like-termination), overshot (removal extending beyond the distal margin, removing part of the distal surface), shattered, retouched
Management blank type	(Full) production, completely cortical flake, semi-cortical flake, naturally backed blade, naturally backed flake, technical blade, technical bladelet (elongated core management removal used to reprepare surfaces or modify debitage direction), technical flake (core management flake used to reprepare surfaces (e.g., after hinged removals) or change debitage direction), crested blade, crested bladelet, crest bilateral, semi-crested, sus crete, tablet
Eraillure scar	Yes, no, esquillament
For each core	
Metrical attributes	Length, width, thickness. Cores are technologically oriented, with the distal end serving as the primary striking platform and the most utilized face, typically exhibiting the latest removals and being designated as the main core face. Measurements were taken in accordance with this orientation whenever feasible; otherwise, the longest dimension was conventionally considered as the length.

TABLE 1. DESCRIPTIONS OF VARIABLES RECORDED DURING THE TECHNOLOGICAL ANALYSIS (continued).

For each core	
Volumetry of the block	Flat parallelepiped, polygonal, triangular prism, trapeze prism, pyramidal, prismatic, irregular
Core blank	Blade, core, flake, fragment, indeterminate, pebble, plaquette, tool
Number of exploited faces	Numerical
Axis	Numerical
Axis type	Long, short, equivalent
Hierarchy of surfaces	Yes, no
Platform preparation	One removal, several removals, no preparation
Direction of the scars	Unidirectional, bidirectional, perpendicular, convergent, centripetal
Target of debitage	Flakes, blades, bladelets, blade-bladelets, flakes-bladelets
Core management	Lateral, distal, no
Exploitation state	Tested, initial, medium, exhausted
Volumetric concept	PP1F, PP2ADF, PP2OF, PP3F, PP4F, PO, STR
General configuration	Semi-tournant, narrow, wide, tranche
For each retouched specimen	
Position, extent, and description	Angle (Abrupt, semi-abrupt, low); extent (Marginal, deep); delineation (Rectilinear, convex, concave, denticulate); position (Direct, inverse, alternate, bipolar)

TABLE 2. ASSEMBLAGE COMPOSITION.

Techno Category	direct	bipolar	combined dir/bip	indeterminate	N	%
core	**15**	**30**	**8**		**53**	**8.3**
blade	**5**	**4**		**2**	**11**	**1.7**
production	3	4		2	9	**1.4**
semi-crested blade	1				1	**0.2**
technical blade	1				1	**0.2**
bladelet	**32**	**25**		**1**	**58**	**9.1**
crested bladelet	2				2	**0.3**
naturally crested bladelet	1				1	**0.2**
production	24	22		1	47	**7.3**
semi-cortical bladelet	1	1			2	**0.3**
semi-crested bladelet	2	1			3	**0.5**
technical bladelet	2				2	**0.3**
indeterminate		1			1	**0.2**
flake	**170**	**98**	**2**	**23**	**293**	**45.8**
cortical flake	7	3		2	12	**1.9**
first flake	2	1			3	**0.5**
production	134	88	1	17	240	**37.5**
semi-cortical flake	5	5		3	13	**2.0**
tablette	2				2	**0.3**
technical flake	19		1		20	**3.1**
indeterminate	1	1		1	3	**0.5**
spall	**2**	**4**			**6**	**0.9**
tool	**43**	**7**		**3**	**53**	**8.3**
production	34	5		2	41	**6.4**
semi-cortical flake	1	2			3	**0.5**
semi-crested bladelet	1				1	**0.2**
technical blade	1				1	**0.2**
technical flake	2				2	**0.3**
indeterminate	4			1	5	**0.8**
chip	**64**	**4**		**1**	**69**	**10.8**
chunk	**27**	**18**		**31**	**76**	**11.9**
debris	**17**			**1**	**18**	**2.8**
hammerstone					**2**	**0.3**
anvil					**1**	**0.2**
Total	**375**	**191**	**12**	**62**	**640**	**100.0**

TABLE 3. RAW MATERIAL TYPE FREQUENCIES.

Raw materials	N	%
flint	345	**50.9**
radiolarite	220	**32.4**
hematite	38	**5.6**
andesite	22	**3.3**
quartz	7	**1.0**
limestone	5	**0.7**
chalcedony	1	**0.2**
indeterminate	40	**5.9**
Total	**678**	**100.0**

TABLE 4. CORES - PERCUSSON TECHNIQUES.

Cores - percussion technique	N	%
bipolar	30	**56.6**
combined	8	**15.1**
direct	15	**28.3**
Total	**53**	**100.0**

RESULTS

ASSEMBLAGE COMPOSITION

The Apidima Cave D assemblage consists of 678 specimens, including 38 hematite pieces that require further analysis and are excluded from the present technological study but are presented in the raw material frequencies (Table 3). Debitage blanks are the most prevalent categories (flakes 45.8%; bladelets 9.1%; blades 1.7%) (see Table 2). Cores constitute 8.3% of the assemblage. Notably, two hammerstones and a possible anvil have also been identified (see Table 2).

The assemblage is overall in fresh condition, while 14.4% exhibit traces of burning, and patinated pieces are rare (<3% of the total). More than half of the assemblage (58.2%) comprises fragmented pieces.

RAW MATERIAL SELECTION

The natural blocks of raw materials selected for flaking varied in shape and size. A wide range of morphologies is observed, including pebbles, slabs, and nodules. Approximately 16% of the assemblage has cortex, most of which indicates the use of pebbles (70.1%), followed by slabs (16.9%) and fragments (13%). Overall, we defined eight lithotypes: flint, radiolarite, hematite, quartz, andesite, limestone, chalcedony, and indeterminate (see Table 3). Among these, we distinguished the characteristics of each subtype:

- Flint: Varieties are matte black, shiny black, grainy black, vitreous white/grey, semi-translucent grey, greyish green, and green. Black and grey flints are both brittle and easy to knap regardless of size, while grey flints are typically more siliceous with fewer cleavage plane fractures.
- Radiolarite: dusky to weak red to dark reddish brown to brown, green and yellow varieties are less frequent. From homogeneous with no cleavages to numerous cleavage fractures and veins of various densities, sizes, and colors.
- Quartz: Milky white and quartz crystal.
- Andesite (also called *krokeatis*): Opaque green varieties, from fine-grained with phenocrysts to coarse-grained subtypes without phenocrysts.

Flint is the most widely used raw material at Apidima Cave D (see Table 3), followed by radiolarite, andesite, and, to a lesser extent, quartz, chalcedony, and limestone. Noteworthy is the presence of hematite, accounting for 5.6%. The indeterminate pieces are either burned or too patinated to designate a raw material type.

REDUCTION STRATEGIES

A technological analysis was performed on the cores and debitage products to obtain detailed insights into reduction sequences, the management of core reduction, the objectives of debitage, and the flaking techniques.

Based on the data collected from the technological and morphometrical analyses of the cores (n=53), two main concepts of debitage were identified—integrated volumetric and additive bipolar on anvil (*sensu* Boëda 2013). Eight cores bear evidence of both bipolar and direct percussion, thereby attesting to the switch between these two main volumetric concepts (Table 4).

The cores are predominantly unidirectional frontal platform cores (PP) (Table 5), with the use of one (PP1F n=12; 22.6%) or two adjacent (PP2FAD n=11; 20.8%) or op-

TABLE 5. VOLUMETRIC CONCEPTS OF DEBITAGE.*

Cores - concept of debitage	N	%
PP1F	12	**22.6**
PP2FAd	11	**20.8**
PP2FO	2	**3.8**
PP3F	15	**28.2**
PP4F	1	**1.9**
Indeterminate	1	**1.9**
STR	7	**13.2**
POS	3	**5.7**
STR+PP1F	1	**1.9**
Total	**53**	**100.0**

*PP = parallel planes; PO = orthogonal planes; 1F–4F = number of exploited faces; ADF = adjacent faces; OF = opposed faces.

posite faces (PP2FO n=2; 3.8%) and are exploited using both direct and bipolar percussion techniques (Figure 2). Cores with three (n=15; 28.3%) and four (n=1; 1.9%) exploited faces (PP3F and PP4F) were produced exclusively using bipolar percussion. In one case, a second platform opposite to the first one was opened and exploited with a few hinged removals (see Figure 2.3). Semi-tournant cores (n=7; 13.2%) were exclusively exploited by direct percussion (see Table 5, see Figure 2). Five of the cores were only tested, and three were discarded at an early stage of exploitation.

According to the organization of the last visible scars, 61.5% of the cores can be classified as bladelet-flake cores, 15.4% bladelet cores, 3.8% blade-bladelet cores, and 19.2% flake cores. Cores for producing flakes are either tested blanks or completely exhausted blanks, not supporting a separate sequence for flake production.

Completely cortical flakes (n=15; 2.4%) and semi-cortical flakes (n=12; 2%) are present in the assemblage, albeit in low quantities (see Table 2). In contrast, fully cortical blades and bladelets are absent. The presence of a few crested and semi-crested elongated blanks indicates efforts to shape the core in preparation for systematic blank production. Core maintenance products, particularly flakes (n=20; 3.1%), are also attested. Additionally, two core tablets, used to rejuvenate the striking platform, are present (see Table 2).

There is limited evidence for the use of bipolar percussion from the initial stages of core reduction. However, some fully cortical blanks exhibit morphological features consistent with this technique, such as flat ventral faces, shattered butts, and pronounced ripple marks. Despite this, the overall characteristics of the cores and associated by-products suggest that bipolar percussion was primarily additive (*sensu* Boeda 2013), used when direct percussion could no longer be effectively applied. Interestingly, two cores attest to the switch from the use of bipolar to direct percussion, and several bipolar cores display negative scars indicative of earlier exploitation through direct percussion (see Figure 2). In some cases (n=12), flakes produced by direct percussion were subsequently used as blanks for bipolar reduction, and in one example (see Figure 2.9), a blade fragment was tested using bipolar percussion.

Bipolar percussion appears to have been used especially to exploit radiolarite (Figure 3). A similar preference for bipolar percussion in the reduction of this raw material has been observed in the Protoaurignacian assemblage of Apidima Cave C (Lombardo et al. 2026 [this issue]). This choice may be linked to the dimensions of the initial blanks or to the qualitative properties of radiolarite, which is rich in natural cleavage planes; bipolar percussion offers an effective means of overcoming these structural weaknesses, while at the same time minimizing flaking errors (Delpiano et al. 2024; Tallavaara et al. 2010). The scatterplots showing the width and thickness of complete cores (see Figure 3) demonstrate a clear trend of progressive reduction in the dimensions of cores exploited by direct percussion compared to those reduced by bipolar percussion.

DEBITAGE TECHNICAL FEATURES

Rectilinear profiles dominate the blade (63.6%), bladelet (86.2%), and flake (83.6%) samples (Table 6). Twisted specimens (5.2% of the bladelet sample) were likely obtained mostly for maintenance, from the periphery of the core's flaking surface. The cross sections are mainly triangular (45.5% for blades, 50% for bladelets, and 34.5% for flakes). The prevalence of triangular cross-sections suggests that a single central ridge was often used as a knapping guide, although a natural lateral ridge or cleavage plane was occasionally used for this purpose as well. Trapeze cross sections are also common among bladelets (24.1%) and blades (27.3%). Unidirectional dorsal scars predominate (27.3% for blades, 51.7% for bladelets, and 44.4% for flakes), followed by bidirectional scars (36.4% for blades, 24.1% for bladelets, and 24.6% for flakes). Orthogonal and perpendicular removals occur sporadically, mostly related to core management operations, and bidirectional scars generally result from bipolar percussion. However, in some cases such bidirectional scars attest to the use of an opposed platform of debitage in direct percussion cores, either linked to the operation of maintenance or to a series of unidirectional reductions.

Distal terminations are mostly plunging (28.6%) or feathered (25%) among bladelets, and feathered terminations are common among blades (33.3%) and flakes (46.9%). Although overshot and plunging are typically the result of striking errors, in some cases, they represent intentional management products for maintaining the core morphology. Butts are predominantly punctiform (35.7%) and linear (21.4%) for bladelets, and predominantly flat (44.6%) for flakes.

The overall morphological and technological analysis of both complete and fragmentary blanks indicates that 45.5% of blades and 55.2% of bladelets are produced by direct percussion, while 36.4% of blades and 43.1% of bladelets were produced by bipolar percussion. A summary of metric attributes of complete blades and bladelets, categorized by percussion technique, is presented in Table 7. No statistically significant differences are observed in the length, width, or thickness of bladelets produced by direct and bipolar percussion (length, p=0.746; width, p=0.123; thickness, p=0.173).

Despite the absence of statistically significant differences in univariate metric comparisons, the bivariate relationship between length and width demonstrates clear morphological tendencies associated with each percussion technique. Bladelets produced by bipolar percussion tend to be proportionally broader and shorter, whereas those obtained by direct percussion are more elongated and more slender. The greater ranges of sizes for bladelets are seen for black flint when direct percussion is employed, and for red radiolarite for bipolar percussion (Figure 4). In fact, radiolarite is the most frequent raw material among bipolar bladelets, mirroring patterns observed in the associated cores and suggesting a preferential use of bipolar

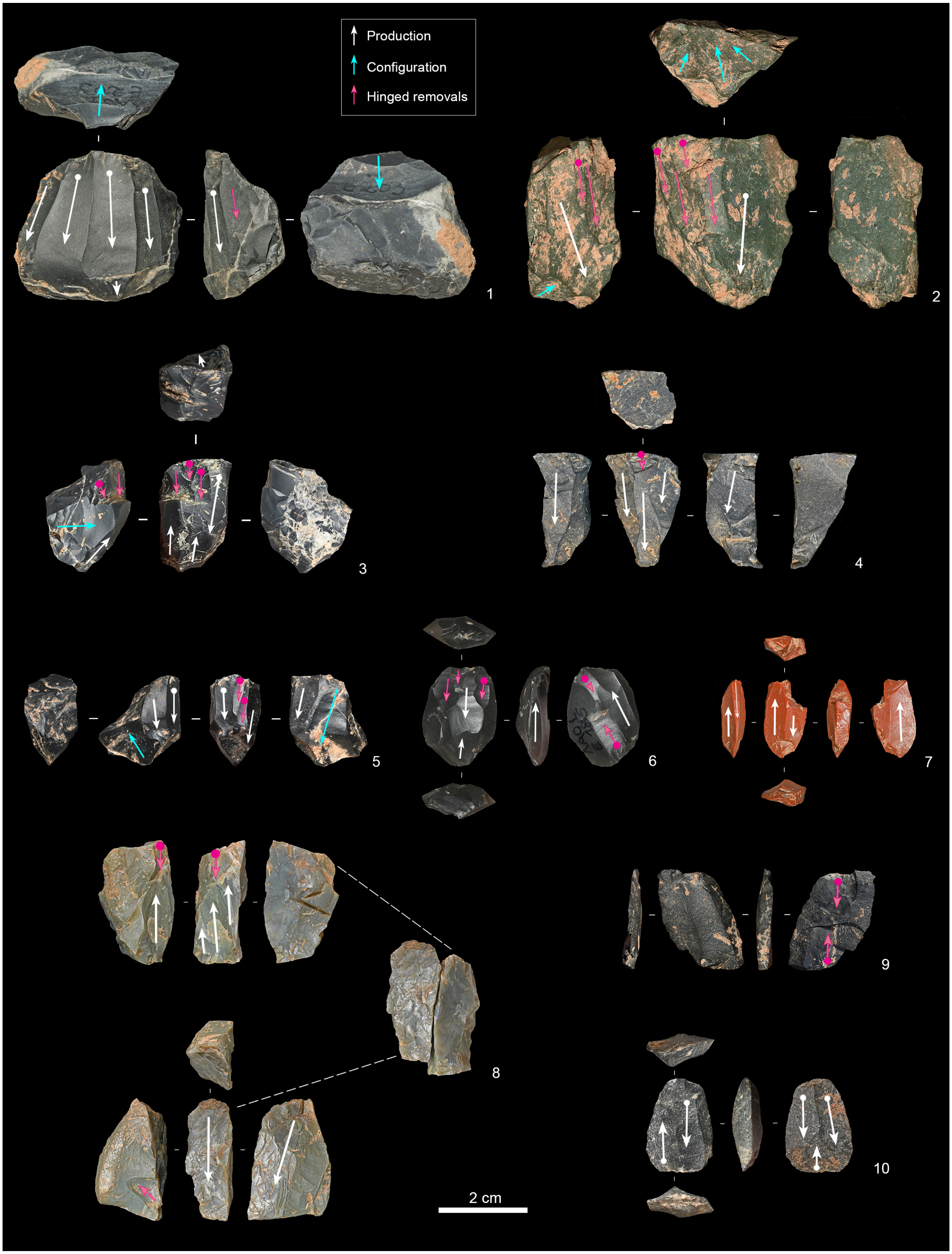

Figure 2. Cores. Semi-tournant cores (1, 2, 4, 5), unifacial parallel planes core with double platform (3), parallel planes bipolar cores with two adjacent faces exploited (6, 10), parallel planes bipolar cores with three faces exploited (7), blade fragment tested by bipolar percussion (9), refit of a semi-tournant core split by subsequent bipolar percussion (8). Black flint (1, 3–6, 9, 10); andesite (2); red radiolarite (7); grey flint (8).

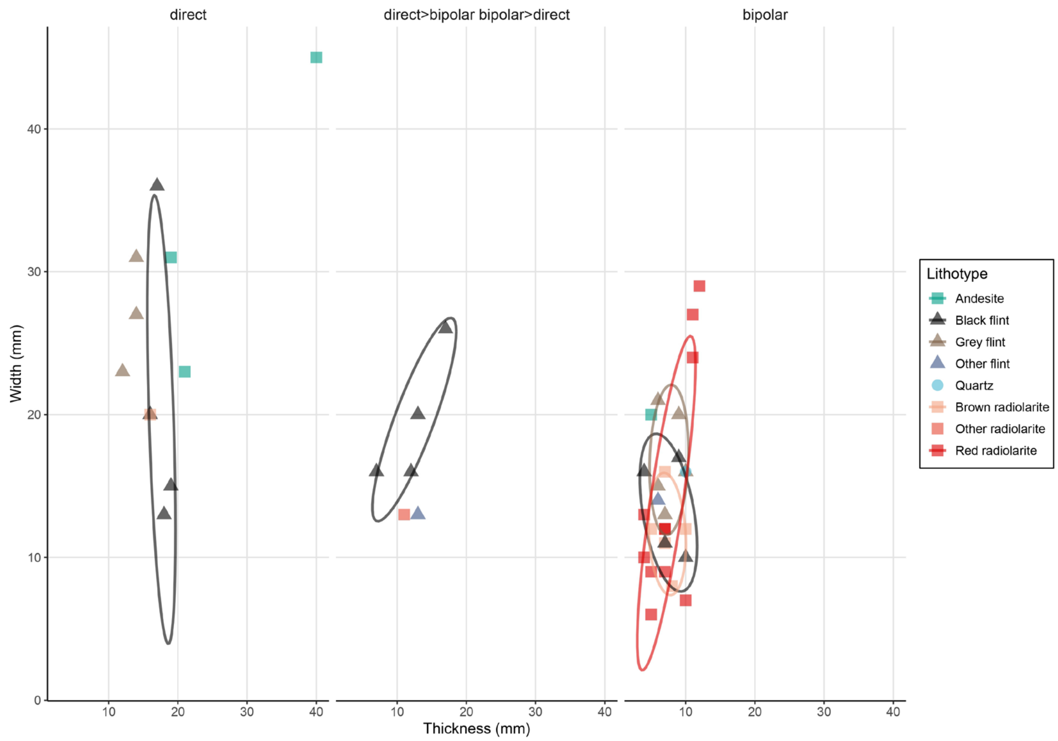

Figure 3. Cores. Scatterplots showing the width and thickness (mm) of complete cores obtained using direct and bipolar percussion, by raw material. The central plot displays cores attesting to the switch between two debitage techniques (both direct-to-bipolar and bipolar-to-direct). The ellipses represent 68% confidence regions for each raw material group.

percussion for this raw material, especially at the later or final stages of the reduction sequence.

A comparable pattern is observed in the flake component (Figure 5). Direct percussion flakes show greater dimensional variability, including longer and wider specimens, while bipolar flakes cluster within a narrower range and tend toward shorter and wider morphologies, with just a few outliers.

RETOUCHED TOOLS

The classification of tool types reveals marked variability, with a clear preference for backed implements (Table 8; Figure 6). Overall, 67.9% of the tools display backed retouch.

Nearly all retouched bladelets are made on full-production debitage blanks (i.e., products of bladelet reduction strategies). The blanks chosen for retouch were produced mostly by direct percussion; however, four backed pieces (i.e., flakes), one backed bladelet, and one steep-backed point were made on blanks derived from bipolar percussion.

Backed bladelets constitute the dominant category (n=11; 20.8%); specimens with marginal backed retouch are also present (n=4; 7.5%). Two atypical shouldered bladelets (characterized by an irregular proximal notch, most likely resulting from regularization) are attested. In some cases, the backing is irregular, with indentations indicating the absence of abrasion intended to regularize the back (Fasser et al. 2019). Backed points are attested (n=6; 11.3%) and often display complementary marginal retouch to shape the tip. In one case, the backed retouch produces an irregular outline, resulting in a blunted-shouldered morphology (see Figure 6.6).

The category of side scrapers is diverse, with technical pieces, flakes, blades, and bladelets used as blanks. Among the end scrapers, a small unguiform specimen manufactured on a semi-cortical flake is present (see Figure 6.17). Blanks produced by direct percussion dominate, with only two side scrapers and one end scraper made on blanks derived from bipolar percussion. Overall, flint is the predominant raw material among tools (58.6%), used for both backed implements and common tools. Grey flint is slightly preferred over black for armatures. Radiolarite (29.3%) is mostly used for the production of armatures and sporadically for common tools.

DISCUSSION

APIDIMA CAVE D LITHIC INDUSTRY

The legacy assemblage of Apidima Cave D is not particularly rich, comprising only 678 artifacts. Small blanks (i.e., chips and debris) are extremely rare, possibly due to collection methods. It is likely that the excavation methodology and sieving strategy affected the recovery of small pieces and the collection of artifacts made of certain raw material types, such as quartz. Despite this uncertainty, due to the lack of excavation documentation, the assemblage compo-

TABLE 6. MORPHOLOGICAL AND TECHNOLOGICAL ATTRIBUTES OF BLADES, BLADELETS, AND FLAKES (for butt and flake terminations, only complete specimens were included).

	blade	%	bladelet	%	flake	%
Curvature profile						
concave	1	**9.1**	3	**5.2**	12	**4.1**
convex					12	**4.1**
rectilinear	7	**63.6**	50	**86.2**	245	**83.6**
twisted	1	**9.1**	3	**5.2**	9	**3.1**
wavy	2	**18.2**	2	**3.4**	15	**5.1**
Cross section						
semi-circular			1	**1.7**	6	**2.0**
irregular			1	**1.7**	15	**5.1**
linear			1	**1.7**	24	**8.2**
rectangular trapezoidal	3	**27.3**	7	**12.1**	46	**15.7**
rectangular triangular			5	**8.6**	43	**14.7**
trapeze	3	**27.3**	14	**24.1**	58	**19.8**
triangular	5	**45.5**	29	**50.0**	101	**34.5**
Dorsal removal						
bidirectional	4	**36.4**	14	**24.1**	72	**24.6**
convergent			1	**1.7**	3	**1.0**
indeterminate					2	**0.7**
natural					17	**5.8**
orthogonal	2	**18.2**	6	**10.3**	30	**10.2**
perpendicular	1	**9.1**	1	**1.7**	18	**6.1**
unidirectional	3	**27.3**	30	**51.7**	130	**44.4**
ventral-bidirectional	1	**9.1**	2	**3.4**	7	**2.4**
ventral-unidirectional			4	**6.9**	14	**4.8**
Butt						
broken					3	**2.3**
cortical			1	**3.6**	6	**4.6**
diffuse					1	**0.8**
dihedral			1	**3.6**	4	**3.1**
flat	1	**16.7**	5	**17.9**	58	**44.6**
linear	1	**16.7**	6	**21.4**	15	**11.5**
negative			1	**3.6**		
no			1	**3.6**	3	**2.3**
punctiform	2	**33.3**	10	**35.7**	11	**8.5**
prepared					4	**3.1**
shattered	2	**33.3**	3	**10.7**	25	**19.2**
Flake termination						
broken	1	**16.7**	5	**17.9**	10	**7.7**
feather	2	**33.3**	7	**25.0**	61	**46.9**
hinged	1	**16.7**	4	**14.3**	17	**13.1**
overshoot					1	**0.8**
plunging	2	**33.3**	8	**28.6**	24	**18.5**
smashed			4	**14.3**	17	**13.1**

TABLE 7. SUMMARY OF METRIC ATTRIBUTES OF BLADES AND BLADELETS (mm).*

Technological class				L	W	T
blade	bipolar	N		**4**	**4**	**4**
		Std. Error of Mean		2.658	1.109	1.683
		Std. Deviation		5.315	2.217	3.367
		Percentiles	25	30.00	13.25	5.00
			50	33.00	14.00	5.50
			75	39.75	17.00	10.50
	direct	N		**1**	**5**	**5**
		Std. Error of Mean			0.400	0.837
		Std. Deviation			0.894	1.871
		Percentiles	25	32.00	13.00	3.50
			50	32.00	13.00	4.00
			75	32.00	14.50	7.00
bladelet	bipolar	N		**20**	**25**	**25**
		Std. Error of Mean		1.106	0.404	0.380
		Std. Deviation		4.946	2.021	1.900
		Percentiles	25	18.00	6.50	4.00
			50	22.50	8.00	5.00
			75	25.75	10.00	6.00
	direct	N		**10**	**32**	**32**
		Std. Error of Mean		1.727	0.352	0.452
		Std. Deviation		5.461	1.992	2.556
		Percentiles	25	18.50	8.00	3.00
			50	23.00	9.00	4.00
			75	29.00	10.00	6.00

*Only complete and almost complete blanks were considered for length, while the fragmented specimens were considered for width and thickness.

sition and preservation condition indicate a chrono-culturally coherent industry, which provides important insights into the use of the cave and its chronology.

The industry is characterized by a high frequency of fresh edges and limited patina, suggesting minimum syn- or post-depositional mechanical or chemical surface modifications. Evidence of thermal alterations, indicative of burning, is consistent with observations in the faunal remains, which point to the possible presence of combustion features or hearth remains (Lax 1995; Lombardo et al. 2025; Roditi et al. in preparation).

Raw material procurement at Apidima Cave D focused on local, semi-local, and non-local available resources ('local' raw materials are considered available at <12km from the site, semi-local <20km from the site, and non-local >20km from the site). Flint represents the most intensively exploited local raw material, followed by radiolarite (also referred to as jasper), while andesite, hematite, and other raw materials occur only sporadically. The preferential use of flint confirms patterns observed at Apidima Cave C (Lombardo et al. 2026 [this issue]) and at other Paleolithic sites of the western Mani peninsula (Darlas and Psathi 2016; Garefalakis et al. 2018; Karkazi et al. 2024; Tourloukis et al. 2016), also called chert by Litsios (2024) and Karkazi et al. (2024). Particularly noteworthy is the presence of hematite in the Cave D assemblage, accounting for 5.6%. According to Darlas and Psathi (2008), hematite was also identified in all Upper Paleolithic layers at Kolominitsa Cave and was possibly used as ochre. Nevertheless, dedicated studies are necessary to determine whether the hematite identified

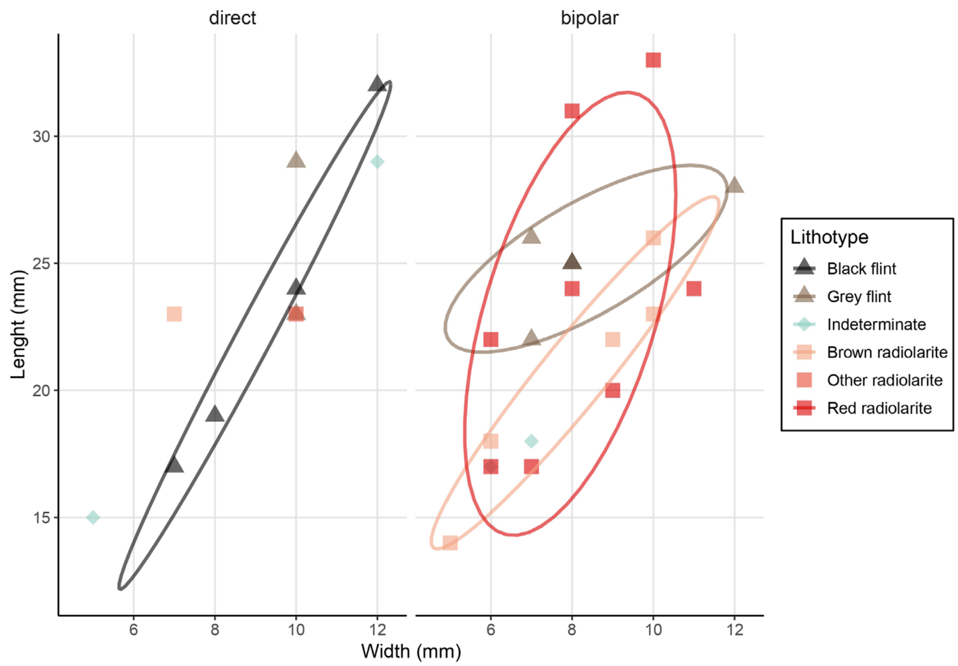

Figure 4. Scatterplot showing the length and width (in mm) of bladelets obtained from direct and bipolar percussion, shown by raw material. The ellipses represent 68% confidence regions for each raw material group.

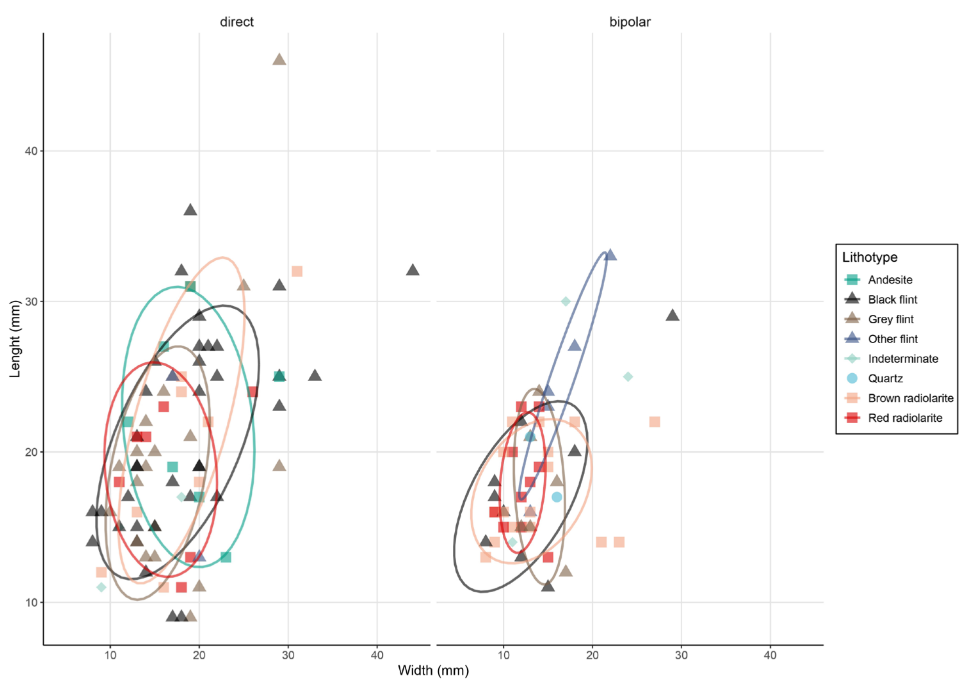

Figure 5. Scatterplot showing the length and width (in mm) of flakes obtained from direct and bipolar percussion, designated by raw material. The ellipses represent 68% confidence regions for each raw material group.

TABLE 8. GENERAL OVERVIEW OF THE TOOL TYPE CATEGOIRES.

Tool type	N	%
marginal backed bladelet	4	7.5
backed blade	1	1.9
backed bladelet	11	20.8
backed piece	6	11.3
backed point	6	11.3
truncated backed point	1	1.9
atypical shouldered backed bladelet	2	3.8
backed fragment	5	9.4
short end-scraper	3	5.7
side scraper	7	13.2
bec	1	1.9
denticulate (+ burin)	2	3.8
geometric	1	1.9
retouched fragment	3	5.7
Total	**53**	**100.0**

in the Apidima Cave D assemblage was intentionally procured and used as ochre.

Reduction sequence analysis indicates that bladelets were the primary objectives of production. Bladelets generally exhibit straight profiles, but are sometimes slightly twisted. Both direct percussion and bipolar-on-anvil techniques were employed in the knapping process, with several blanks indicating shifts between the two methods. Unidirectional frontal platform cores and orthogonal plane cores were exploited using both techniques, whereas semi-tournant cores were reduced exclusively by direct percussion for bladelet production. Bipolar percussion on anvil was applied as a flexible and adaptive strategy, particularly in the reduction of radiolarite, allowing knappers to overcome flaking accidents related to raw material quality and dimensions. The generally small size of the available blocks of high-quality raw materials may partly explain the intensive exploitation of lower-quality materials such as radiolarite. In this context, bipolar percussion appears to have been employed to maximize the productive potential of these more constrained blanks. The technique was also applied to more homogeneous flint blanks, likely in order to maximize productivity and extend the reduction sequence of small-sized cores. Bipolar percussion was mainly used to produce flakes and, more rarely, elongated products, often from cores that were no longer suitable for further reduction by direct percussion. The assistive role of bipolar percussion relative to direct percussion is also evident in core dimensions and exploitation stages, with a clear pattern of progressive volume reduction from cores reduced by direct percussion to those exploited by bipolar percussion.

The debitage assemblage includes several technical pieces for managing lateral and distal core convexities. The sporadic presence of natural surfaces (e.g., cortex) on by-products and cores suggests that most of the initial stages of reduction likely occurred off-site, with cores being prepared and/or partially tested prior to on-site exploitation. On the other hand, the percentage of debitage with cortex (16%), points to on-site blank reduction. Retouched tools demonstrate a clear preference for abrupt retouch, accounting for more than 67% of retouched specimens. Tools made on flint bladelets represent the most abundant category. Backed bladelets and backed points are well represented, including specimens with invasive retouch, and bladelets with angular backs are also attested.

Overall, the technological and typological characteristics of the Cave D lithics fit well within the spectrum of variability characterizing the Late Gravettian/Early Epigravettian. The predominance of backed implements suggests a strong emphasis on hunting-related activities, while evidence for a broad-spectrum subsistence strategy derives primarily from the associated faunal assemblage, which includes small, fast-moving taxa, such as birds and hares, as well as coastal resource exploitation (Lombardo et al. 2025; Roditi et al. in preparation). These practices, although occasionally documented also in earlier Upper Paleolithic phases, peaked during the Epigravettian in the Peloponnese (Starkovich and Ntinou 2017). A Late Gravettian/Early

Figure 6. Tools: backed bladelet (1, 8, 11), backed points (2–4, 6–7, 10), marginal backed bladelets (5, 9), backed blade (15), denticulate and burin (14), side scrapers (12–13), end scrapers (16–17). Black flint (1–3, 10–14, 17); grey flint (6, 7, 9); brown radiolarite (4); red radiolarite (8, 15, 16); other flint (5).

Epigravettian attribution is further supported by the new radiocarbon dates, which fall within a range of ca. 22.7 and 17.1 ka cal BP (Harvati et al. 2026 [this issue]), corresponding to the end of the peak of the Last Glacial ice sheet expansion and the beginnings of glacial retreat (e.g., Hughes and Gibbard 2014).

APIDIMA D IN THE FRAMEWORK OF THE LAST GLACIAL MAXIMUM IN GREECE AND THE BALKANS

The attribution of the Apidima Cave D assemblage must be considered within the broader and increasingly critical reassessment of the Gravettian as a cultural and technological unit. As Reynolds (2021) emphasized, any conceptualization of the Gravettian as a discrete culture, population, or even technocomplex is epistemologically more problematic than usually acknowledged. In terms of lithic techno-typology, Gravettian assemblages in Europe are commonly defined by the systematic production of backed lithic artifacts, including Gravette points, backed bladelets, and, more rarely, shouldered points (Reynolds 2021). However, no single Gravettian technocomplex or unified technological system exists, as lithic production strategies exhibit an exceptionally wide range of technical solutions (Pesesse 2017).

In the Balkans and the Eastern Mediterranean, attempts to define coherent Gravettian trends—often referred to as "Gravettoid" or "Mediterranean Gravettian"—have repeatedly highlighted the difficulty of isolating consistent technological or typological markers (Adam 1989, 2007; Kozlowski 1999; Litsios 2024; Tourloukis and Harvati 2018; Vukosavlević 2023). Archaeological sites in Greece and adjacent regions are overall scarce in the timeframe of the Last Glacial Maximum and have yielded low-density assemblages, raising the important question of whether this pattern reflects a sparse human occupation across the landscape or rather an incomplete picture of land use due to gaps in archaeological research (Kuhn et al. 2026; Perlès 1999). Furthermore, these low-density deposits often lack diagnostic elements altogether (Plavšić and Popović 2019; Stiner et al. 2022). In such contexts, and particularly in the absence of robust absolute dating, assigning specific cultural designations remains challenging (Alex et al. 2019; Anghelinu et al. 2012; Litsios 2024; Mihailovic 2014; Mihailovic and Mihailovic 2007). Mihailovic (2014) stresses the difficulty of distinguishing between the Late Gravettian and the Early Epigravettian, as lithic assemblages are not clearly differentiated in techno-typological terms. Consequently, some studies appear to rely exclusively on chronological markers. According to Ruiz-Redondo et al. (2022) the Gravettian in the Adriatic basin starts between 35,340 and 33,595 cal BP and ends between 26,390 and 24,230 cal BP, while the Early Epigravettian starts around 26,475–25,330 cal BP and ends at ca. 18,165–17,105 cal BP, followed by the Late Epigravettian. If this chronological framework is extended to include the Balkans, Early Epigravettian sites in the area are primarily characterized by blade and bladelet production from unidirectional or bidirectional parallel-plane cores, intended for the manufacture of composite tools (Kuhn et al. 2026; Vukosavlević 2023). Consistent with the evidence from Apidima D, the use of bipolar percussion is also attested, particularly when core dimensions become too small to continue with direct percussion (Vukosavlević 2023). Among the tool types, backed bladelets, microgravettes, and endscrapers dominate, whereas burins are sporadic. Segments and shouldered points are usually absent, with the exception of a single shouldered specimen from Vrbička Cave (Vukosavlević 2023).

The subdivision "Early Epigravettian" as a distinct cultural phase is generally not used in the Greek literature. However, a recent synthesis on the Gravettian industry from Oitylo Bay provides a comparison for the Apidima Cave D assemblage (Litsios 2024). When discussing trends in diagnostic tool types, it should be noted that the assemblages from Tripsana and Skoini 4 are particularly small, whereas the assemblage from Melitzia is richer, largely due to the high proportion of debris, which accounts for 77.2% of the total assemblage. At present, we cannot assess whether this is related to low artifact density, to collection strategies, or the extent of excavated area (see Litsios 2024); therefore, any inferences proposed here should be considered with caution.

In Tripsana Trench A (28,060±250 uncal BP; 33,034–31,504 cal BP, 95% probability), allochthonous brown and reddish cherts (with chert referring to both radiolarite and flint) dominate the assemblage, although quartz, hematite, and andesite (i.e., *krokeatis*) are also attested. Cores are scarce (n=5); among them, specimens with two opposed platforms occur, but unidirectional cores prevail, and the bipolar technique is attested. The tool assemblage includes end scrapers, backed bladelets, and microgravettes (four retouched pieces in total; Litsios 2024). In contrast, Trench B is dominated by semi-local dark grey and black chert. Double-platform cores are more frequent than in Trench A, though they remain scarce. Backed bladelets and backed pieces constitute the most common tools out of five retouched pieces in total (Litsios 2024). Nevertheless, this scanty evidence should be viewed with caution; the geological layer that was dated is poor in artifacts and lacks diagnostic pieces, whereas the scarce archaeological material with Gravettian affinities derives from 0.70–1.20m higher in elevation than the dated layer; hence, the attribution to the Gravettian is essentially based on typological comparisons with Skoini 4 and Melitzia (Litsios 2024: 5, 6).

Similarly, the assemblage from Skoini 4 (spit 6: 26,240±200 uncal BP; 31,210–30,540 cal BP, 95% probability) is dominated by semi-local dark grey and black chert, with reddish-brown chert, quartz, and andesite occurring less frequently (Litsios 2024: 7). Cores are limited in number and are mostly unidirectional, with single platforms for bladelet production, or orthogonal and discoidal for flake production. A single broken Gravettian point is attested, alongside microgravettes and other backed bladelets.

At Melitzia, three "occupational phases" have been identified (Litsios 2024: 8). Phase I (28,050±130 uncal BP; 32,843–31,621 cal BP, 95% probability) yielded very limited and poorly diagnostic material. In Phase II (25,280±130 uncal BP; 29,891–29,232 cal BP, 95.5% probability), highly exploited cores, including rare multi-sided and burin-like cores for microbladelet production, occur alongside points and backed bladelets. In Phase III, blade and bladelet production derives from single-platform cores, and the toolkit is dominated by pointed tools, bilaterally retouched blades, and backed points. Backed bladelets are less frequent.

Based on these assemblage properties, the aforementioned sites from Oitylo Bay have been interpreted as specialized, short-term hunting stations Litsios 2024: 9). Melitzia stands in contrast to the other sites with a larger and more diverse assemblage of lithics, including large-sized blades and pointed backed bladelets, whereas the assemblages from Tripsana and Skoini 4 align more closely with the evidence from Apidima D, particularly in the preferences for smaller implements such as backed bladelets, backed points, and microgravettes. Given the number of cores and technical blanks present in the Apidima D legacy collection, when compared with the sites from the Oitylo Bay, it appears likely that occupation intensity and on-site knapping activities at Apidima D were possibly higher.

Very low artifact densities are also documented at Franchthi Cave in the Argolid. In Phase II (22,330±127 uncal BP; 21,480±350 uncal BP: Perlès 1999; 27,046–26,334 cal BP; 26,773–24,989 cal BP, 95.4% probability, Curve Intcal20: Reimer et al. 2020), backed bladelets predominate and display either a single obtuse backing—similar to some specimens from Apidima D—or double backing and pointed morphologies. In Lithic Phase III, pointed backed bladelets shift from double- to single-backed types. Overall, in both phases, the assemblage is strongly imbalanced towards the production of backed implements (80% of the total; Perlès 1999)—a pattern that is also observed in the Apidima Cave D toolkit (67.9%). A contrasting pattern is evident in Lithic Phase IV (Epigravettian), where backed implements decrease to 45%, accompanied by the appearance of specific tool types, such as numerous La Mouillah points and the introduction of the microburin technique.

A "Gravettoid" level has also been identified within the long stratigraphic sequence of Klissoura Cave 1. The industry of layer III' (23,000±540 uncal BP; 31,460±210 uncal BP: Kuhn 2010; 28,435–26,092; 36,229–35,374 cal BP 95.4% probability, Curve Intcal20: Reimer et al. 2020) is characterized by three reduction systems—single- and double-platform cores for flake production, well-managed cores with postero-lateral crests for blade production, and platform cores exploited from a wide surface toward the narrower side for bladelet production (Kaczanowska et al. 2010). As observed at Apidima, bipolar percussion appears to have been widely employed. As noted by Kaczanowska et al. (2010: 174), "a special feature of some flat cores for bladelets was that in the final phase they were reduced by means of splintered technique, however, still producing bladelet scars." The tool assemblage includes simple backed bladelets with straight or slightly concave backs; notably, two small arched backed pieces are also attested, as at Apidima D.

Comparable patterns are observed in Asprochaliko Layer 10 in northwestern Greece (26,100±900 uncal BP: Adam 1989; 32,829–28609 cal BP, 95.4% probability, Curve Intcal20: Reimer et al. 2020). The lithic industry is dominated by backed bladelets, mostly unilaterally backed. Blade production is not attested, while flake cores dominate and exhibit minimal preparation or maintenance (Adam 1989, 2007).

At Kastritsa, Stratum 5 is likewise dominated by flake blanks, although blade production is attested, and blades and bladelets occur in roughly equal proportions (Adam 2007). The toolkit is primarily composed of backed bladelets, sometimes bilaterally backed with opposed or inverse retouch, whereas shouldered pieces and points are rare. Stratum 3 reflects a technological shift, with an increase in cores and the adoption of two independent striking platforms on opposed axes. In this layer, blades are preferred over flakes for tool manufacture, although tools on bladelets remain dominant. Notably, the microburin technique is attested (Adam 2007).

A different technological pattern is displayed by the lithic assemblage from Apidima Cave C, attributed to the Protoaurignacian (Lombardo et al. 2026 [this issue]). The assemblage is characterized by the use of volumetric unidirectional parallel-plane cores (with semi-circumferential or unifacial delineation) for the production of elongated blanks, primarily bladelets but also flakes. Both direct freehand and bipolar percussion were flexibly employed, with bipolar percussion often used once cores were no longer suitable for exploitation by direct percussion. Carinated cores are sporadic and marginally backed bladelets (mostly with direct, but occasionally inverse or alternating retouch) represent the dominant tool category, in line with Protoaurignacian variability (Lombardo et al. 2026 [this issue]). Similar to Cave D, flint represents the predominant raw material in Cave C (55.1% Cave C; 50.9% Cave D), followed by radiolarite (29.6% Cave C; 32.4% Cave D). Quartz, however, was more extensively exploited in Cave C (10.1%), whereas its use is extremely marginal in Cave D (1%). The increased use of radiolarite and the limited exploitation of quartz in Cave D may reflect differences in raw material procurement strategies between Protoaurignacian and Late Gravettian/Early Epigravettian groups, but may also be related to paleoenvironmental changes, including sea-level fluctuations during the Last Glacial Maximum, which could have altered the accessibility of raw material sources (Lambeck 1996).

The new U-series date obtained from sample APU5 in Cave C yielded an age of 34.5±4.8 ka (Harvati et al. 2026 [this issue]). As the sample derives from a travertine crust interpreted as capping the original sedimentary sequence, the deposits excavated by Pitsios must predate the minimum age of this range (ca. 29 ka). This chronological framework is consistent with the Protoaurignacian attribution of the Cave C lithic assemblage (Lombardo et al. 2026 [this issue]). Moreover, the reconstruction of the cave sequence suggests that, by this time, Cave C was already largely filled by sediments and sealed by the travertine crust, considerably reducing the available habitable space. This may explain the apparent absence of occupation during the Last Glacial Maximum, when Cave D was used between ca. 22.7 and 17.1 ka cal BP.

Against this background and considering its technological and typological similarities with Franchthi Phase II, Klissoura III', and Kastritsa Stratum 5, the Apidima Cave D industry falls within the spectrum of regional Mediterranean Gravettian variability. The new dating obtained from marine shell fragments reportedly associated with the lithic industry (Pitsios 1985) places the assemblage between ca. 22.7 to 17.1 ka cal BP (Harvati et al. 2026 [this issue]), a period that corresponds to an occupational hiatus at Franchthi and Klissoura (Perlès 2016; Starkovich et al. 2018). This chronological range overlaps with the time span generally attributed to the Early Epigravettian in the Balkans. Accordingly, while the technological characteristics align with the broader Gravettian tradition (and probably with its later manifestations), the available chronological evidence supports attributing Apidima D to the Early Epigravettian within the Balkan framework. These results, therefore, situate Apidima D within the heterogeneous and regionally variable techno-cultural landscape of the late Last Glacial Maximum in the Balkans, while simultaneously underscoring the absence of a single homogeneous technological model and the challenges inherent in applying rigid cultural labels when comparing assemblages from different regions.

CONCLUSIONS

This study presents the first comprehensive technological analysis of the lithic assemblage from Apidima Cave D excavated by T. Pitsios and the Museum of Anthropology in the 1980s. Although the assemblage is affected by the limitations typical of legacy collections, particularly the lack of excavation documentation and, therefore, potential biases related to recovery strategies, it preserves sufficiently coherent technological patterns to support a robust interpretation.

When integrated with preliminary faunal analyses and the new radiometric framework, the lithic evidence situates the Cave D assemblage within the heterogeneous Late Gravettian/Early Epigravettian record of the Balkans during the Last Glacial Maximim. The structure of the reduction systems and the composition of the toolkit fall within the documented range of Mediterranean Gravettian variability, while the available chronological data place the assemblage in the later segment of this trajectory, consistent with an Early Epigravettian attribution within the Balkan framework. These findings reinforce current views that emphasize technological diversity rather than a single, unified Gravettian model for Greece and the wider Balkan region and highlight the limitations of rigid cultural classifications when comparing assemblages across regions.

Additionally, our study highlights the importance of reanalyzing legacy collections to refine regional chronologies and technological frameworks, particularly when approached through integrated and comparative methodologies. Apidima Cave D adds new data to the still fragmentary but steadily expanding Upper Paleolithic record of Greece and contributes to ongoing discussions of technological variability and human occupation dynamics in southeastern Europe during the Late Pleistocene.

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DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available on request from the corresponding author.

DECLARATION OF COMPETING INTEREST

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

AUTHOR CONTRIBUTIONS

S.L.: Conceptualization, data curation, formal analysis, investigation, methodology, visualization, writing – original draft **N.T.**: Data curation, methodology, writing – review & editing; **E.R.**: writing – original draft, review & editing; **K.H.**: Conceptualization, project administration, funding acquisition, supervision, validation, writing – review & editing; **V.T.**: Conceptualization, project administration, supervision, validation, writing – review & editing; **V.G.G.**: Resources, writing – review & editing; **K.E.**: Resources, writing – review & editing.

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