



Incised stone artefacts from the Levantine Middle Palaeolithic and human behavioural complexity

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Abstract

In recent years, archaeological research has demonstrated the presence of abstract non-utilitarian behaviour amongst palaeolithic hominins, fuelling discussions concerning the origin and implications of such complex behaviours. A key component in these discussions is the aesthetic and symbolic character of intentionally incised artefacts. In this study, we emphasize the geometry of the incisions as clues to intentionality. Using 3D surface analysis, we characterised incisions found on a Levallois core from Manot cave, and on a flake and retouched blade from Amud cave. In addition, we applied the same methodology to the previously published engraved Levallois core from Qafzeh and the plaquette from Quneitra. The incisions on the Manot, Qafzeh and Quneitra artefacts show similar geometric characteristics. Notably in each of these cases, the incisions form patterns that align with the artefact's surface topography and shape. In contrast, the incisions on the Amud artefacts are shallower, with no clear orientation or patterning. The methodology applied thus creates a comparative context for MP incised items, reinforcing the interpretation of the Manot, Qafzeh and Quneitra artefacts as deliberate engravings, whereas the marks on the items from Amud are consistent with their functional use as abraders. While the Qafzeh, Quneitra and Manot items are isolated initiatives in their chronological and geographic contexts, the shared traits of the intentional engravings underscore their predetermined nature.

Keywords Middle Palaeolithic · Engraved artefacts · 3D surface analysis · Manot cave · Qafzeh · Quneitra, Amud, human behaviour

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Introduction

Modification of material, as evident in the archaeological record, is an expression of cultural evolutionary processes (Ambrose 2001). To shape the material into a predetermined outcome entails planning and execution of the act. These behavioural practices, formed and developed through cultural evolution, granted hominins an advantage in coping with changing environments, furthering processes of human adaptation and fostering social interactions (Boyd and Richerson 1995; Enquist et al. 2008; d'Errico et al. 2009; d'Errico and Colagè 2018; Galway-Witham et al. 2019; Malafouris 2021). Behavioural complexity, as defined by Langley et al. (2008), emphasizes intent, the ability to plan and realise innovative and creative outcomes before their execution. The employment of technological systems, the implementation of subsistence practices, and the use of symbolic interpersonal communication are the main manifestations of complex behaviour practices inferred from the archaeological record (Wobst 1997; Lemonnier 1992; Robb 1998; Kelly et al. 2021; Hovers and Belfer-Cohen 2023).

The presence of portable non-utilitarian artefacts in archaeological assemblages is considered as a proxy for human behavioural complexity (Hovers et al. 2003; d’Errico et al. 2005; Zilhao et al. 2010; Henshilwood and d’Errico 2011; Rodríguez-Vidal et al. 2014; Hoffmann et al. 2018a; Li et al. 2019). Among portable artefacts used as proxies of symbolic behaviour, we find: (1) sea shells collected and used for ornamentation (d’Errico et al. 2005; Bouzouggar et al. 2007; Bar-Yosef Mayer et al. 2009, 2020), (2) use of ochre as colourant (Hovers et al. 2003; Bar-Yosef Mayer et al. 2009; Henshilwood et al. 2011, 2018; Rosso et al. 2016; Hoffmann et al. 2018b), and (3) engraved artefacts made on stone, bone, ostrich egg shells and ochre (Hovers et al. 1997; Texier et al. 2010; d’Errico et al. 2012; Joordens et al. 2015; Majkić et al. 2017, 2018a; Henshilwood et al. 2018; Leder et al. 2021; Prévost et al. 2021).

An important contribution to the success of *H. sapiens* is the instrumental use of social organisation and symbolic systems for social interaction (McBrearty and Brooks 2000; Henshilwood and Marean 2003; Wilkins 2010; Henshilwood and d’Errico 2011; Tylén et al. 2020). Yet, the contribution of extinct hominins should not be overlooked (Langley et al. 2008; Zilhao et al. 2010; Peresani et al. 2014; Roman-dini et al. 2014; Villa and Roebroeks 2014; Hoffmann et al. 2018a; Zilhão 2019; Frayer et al. 2020). Behavioural complexity is not unique to *H. sapiens*, and hominin possession of cognitive abilities (e.g., self-awareness, creativity, imagination, innovation and social interaction) is exhibited early in the archaeological record (Goren-Inbar 1986; Mithen 2003; Hovers 2012; Hodgson 2015; Galway-Witham et al. 2019; Wadley 2021). Some of the earliest expressions of hominin variable cognitive abilities include: (1) lithic technology and systematic knapping already evident in the Oldowan (Langley et al. 2008; Hovers 2012), (2) the use of symmetry as depicted in Acheulian handaxes, often considered the earliest expression of aesthetics (Mithen 2003; Hodgson 2015; Flanders and Key 2023), (3) formulating figurative imagery as expressed in the Lower Palaeolithic figurine from Berekhat Ram (Bednarik 1992), seen as one of the earliest tri-dimensional representations, and (4) engraved figurative images (Goren-Inbar 1986; d’Errico and Nowell 2000; Hovers and Belfer-Cohen 2023).

Symbols are composed of two parts: the sign, which is visible, and the idea it conveys which is not visible to the viewer (Facchini 2000; Langley et al. 2008; Culley and Davidson 2021). Engraved marks (e.g. intentional incisions) on artefacts likely signify the intent of the engraver to form a line or a set of lines with a clear orientation and distribution pattern. In some cases, these incisions address major morphological and technological features of the artefact (Malafouris 2021). To infer that engraved marks are symbols and represent symbolic behaviour, they must depict some level of standardisation, imply sign indexing and show repeated use of signs (Culley and Davidson 2021; Hovers and Belfer-Cohen 2023).

However, not all incisions and patterns have an embedded symbolic meaning. In some cases, incisions on artefacts can result from specific tasks such as cut marks on bones resulting from butchery, incisions and grooves on ochre also result from pigment powder production (Hovers et al. 2003; Rosso et al. 2016), or striations on stone slabs and lithic artefacts result from their use as cutting boards or abraders (Peresani et al. 2014). When incisions display a distinct pattern and cannot be linked to a specific functional task, they are regarded as the result of non-utilitarian practices (Marshack 1976; Moncel et al. 2012). Some researchers advocate that early geometric engravings likely reflect “proto-aesthetic” behaviour, where intentionality and repetitive arrangement of the incisions might not necessarily reflect a symbolic purpose but rather a creation of a visual and regular pattern (Hodgson 2000, 2003), see (Mellet et al. 2019 for a contrasting perspective).

Few incised stone artefacts have been reported from the Eurasian and Levantine Middle Palaeolithic record. Researchers are divided in their opinions regarding the origin of the incisions found on these items. Some argue that they are the result of post-depositional processes or utilitarian use of the artefacts (Peresani et al. 2014), while others view them as evidence of intentionally non-utilitarian engraving (Bednarik 1992; d’Errico and Villa 1997). Artefacts with incisions regarded as non-utilitarian engraving are few and come mostly from sites younger than 120 ka (see Majkić et al. 2018a for a complete inventory and corresponding references). Intentionally modified non-utilitarian bone artefacts, although scarce, are also known from Middle Palaeolithic contexts (Shaham et al. 2019; Leder et al. 2021; Prévost et al. 2021).

In this paper, we present the analysis of an engraved Levallois centripetal core from Manot cave (Marder et al. 2018), and two previously unpublished incised cortical artefacts from Amud cave dated to ca. 68 and ca. 55 ka. The analysis focuses on the anthropic nature of the incisions. The location, distribution, and micro geometry of the incisions are evaluated and characterised. In addition, two other engraved Levantine Middle Palaeolithic lithic artefacts are revisited and studied for comparative context: the engraved core from Qafzeh dated to 100 ka, and the engraved plaque from Quneitra dated to 54 ka (Goren-Inbar 1990; Hovers et al. 1997).

Archaeological sites and Middle Palaeolithic incised stone artefacts from the Levant included in this study

Manot cave

Manot Cave is located in the western Upper Galilee (Fig. 1), Israel, at an elevation of 220 m above sea level (Frumkin et al. 2021). Excavations at the cave exposed several Upper Palaeolithic occupation layers including Ahmarian (46–42

ka calBP), Aurignacian (37.5–35.0 ka calBP) and Atlitian (34.5–33.1 ka) industries in various excavation areas (Marder et al. 2018; Abulafia et al. 2021; Barzilai et al. 2016, 2021; Alex et al. 2017; Berna et al. 2021; Shemer et al. 2024). Middle Palaeolithic and Levallois artefacts were found within the Upper Palaeolithic contexts in all the excavated areas. In Area E of the excavation, the Levallois flakes found within the Levantine Aurignacian assemblages

bear a double patina, indicating they were recycled by the Levantine Aurignacian knappers (Shemer et al. 2024). Recycling of Levallois artefacts mostly into scrapers is a known phenomenon at Levantine Aurignacian sites (Belfer-Cohen and Bar-Yosef 2015; Abulafia et al. 2021; Marder et al. 2021a).

The majority of the Middle Palaeolithic artefacts originate from areas C and D (Marder et al. 2018), where a systematic

a



b

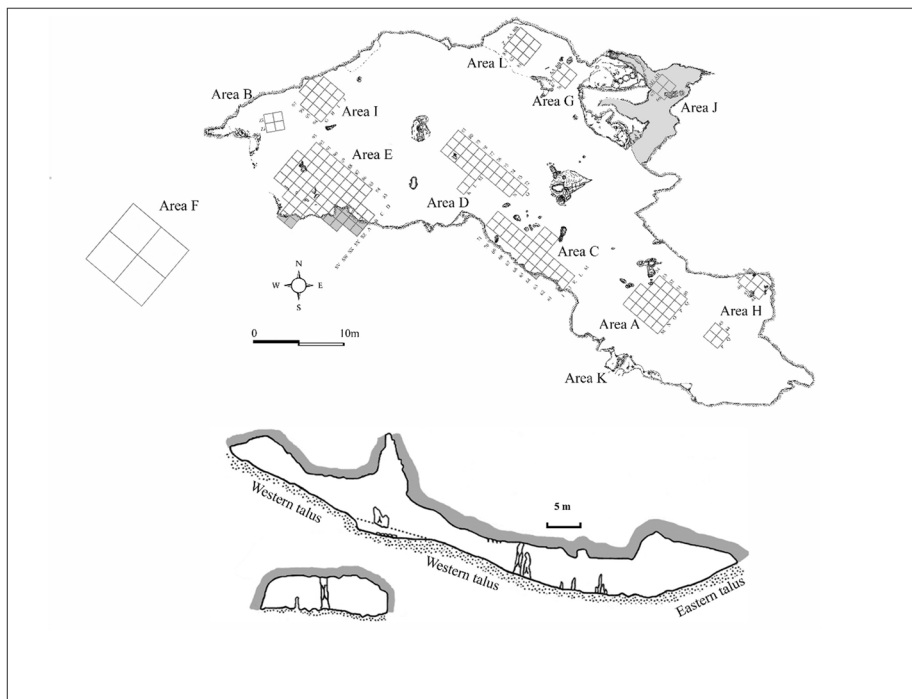


Fig. 1 **a** Location of the archaeological sites mentioned in the text, **b** Manot, map of the excavated areas

collection and study of Levallois artefacts was conducted. In this area there is a stratigraphically evident increase in their percentage, reaching 6% of the assemblage in the lowermost Unit 8. In this area, Levallois artefacts were fresh and mostly non-patinated, consisting of cores, Levallois flakes, and points as well as a retouched Levallois blade. Techno-typological observations correlate these artefacts with other mid-late Middle Palaeolithic assemblages in the Levant (see Marder et al. 2021b for further discussion). The minimum date of a human calvarium (54.7 ± 5.5 ka) coupled with the lithic finds suggest the cave was occupied during the Middle Palaeolithic, although intact occupation levels have not been reached (Hershkovitz et al. 2015; Marder et al. 2018). Among the Levallois artefacts retrieved from area C was a centripetally prepared Levallois core with engraved incisions on its cortical preparation surface (Figs. 2 and 3) (first reported by Marder et al. 2018).

Amud cave

Amud cave is located 5 km northwest of the Sea of Galilee (Fig. 1) on the western margins of the Rift Valley at an elevation of 110 below sea level (Hovers et al. 1995). The site was first excavated in 1961, followed by a season in 1964 and then again between 1991 and 1994 (Suzuki and Takai 1970; Hovers et al. 1995). Three Middle Palaeolithic sub-units (B1, B2 and B4) were identified. Sub-units B1 and B2 yielded similar ages of ~55 ka, whereas an age of ~68 ka was obtained for Unit B4 (Hovers et al. 1995; Valladas et al. 1999; Rink et al. 2001). MP hominin remains were found exclusively along the northern cave wall (Rak et al. 1994; Hovers et al. 1995; 2000; Pearson et al. 2020). Among these findings were intentional burials of an adult (Amud I), an infant (Amud 7) and possibly of another adult (Amud 9), identified as Neanderthals (Hovers et al. 1995; Pearson et al. 2020; Suzuki and Takai 1970). Amud 7 was found with a red deer maxilla placed on its pelvis (Rak et al. 1994; Hovers et al. 2000). Differential use of space within the cave is also suggested by the disparate composition of the lithic assemblage within the excavated areas (Alpers-Afil and Hovers 2005; Hovers et al. 2011). The lithic assemblages are characterised by the dominance of the Levallois unidirectional convergent recurrent flaking mode accompanied by the use of the centripetal Levallois recurrent mode (Hovers 1998, 2004, 2007). The incised cortical blade originated from Area A, sub-unit B1 (Fig. 4) and the incised flake is from Area B, sub-unit B4 (Fig. 5).

Quneitra

Quneitra is a Middle Palaeolithic open-air site located in the northern Golan heights (Fig. 1) and dated to 54 ka (Ziaei et al. 1990). Three excavation seasons between 1983 and 1985 resulted in the identification of four major stratigraphic units, with an archaeological layer in unit C

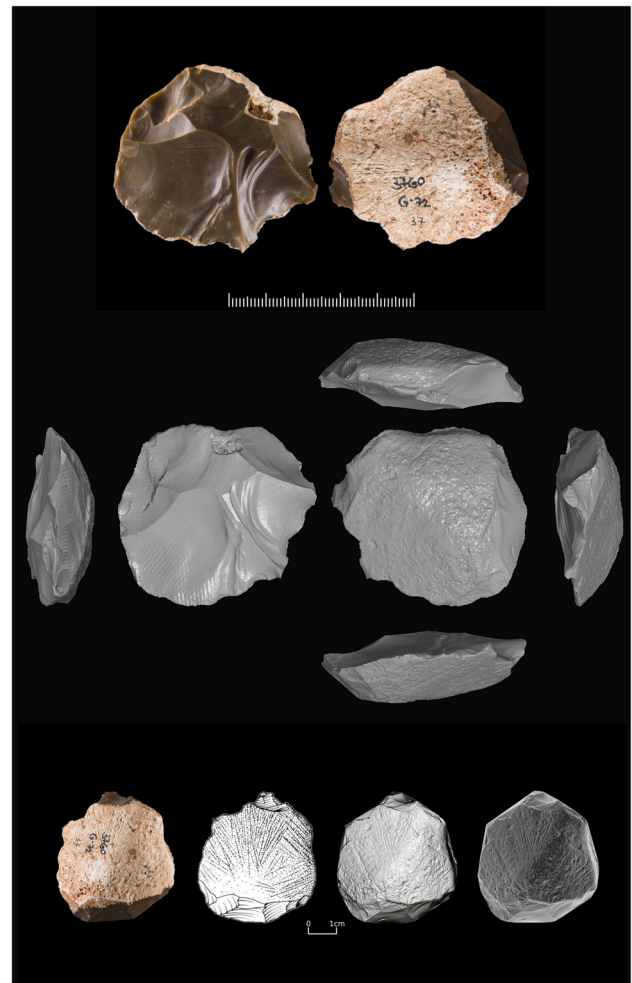


Fig. 2 The engraved cortical Levallois core of Manot. High-resolution photograph and 3D model (photo by E. Ostrovsky and drawing by M. Smelansky, 3-D models by E. Paixão and L. Schunk)

(Goren-Inbar 1990). The archaeological horizon is characterised by a single occupation level composed of stone artefacts (both from basalt and flint), animal bones, and manuports (Goren-Inbar 1990). Two artefacts with similar arc-shaped incisions, a flint plaquette (Goren-Inbar 1990; Marshack 1996) and a fragment of an aurochs' left femur shaft, were found some 2 m apart (Rabinovich 1990; Shaham et al. 2019). The incisions on the bone were initially considered to be non-anthropogenic, either the consequence of natural site formation processes or the result of carnivore gnawing/clawing (Rabinovich 1990). Later this bone was re-studied by Shaham et al. (2019), who interpreted the circular marks as intentional man-made engravings (Fig. 5).

Qafzeh

Qafzeh Cave is located in the Central Lower Galilee some 35 km from today's Mediterranean Sea shoreline

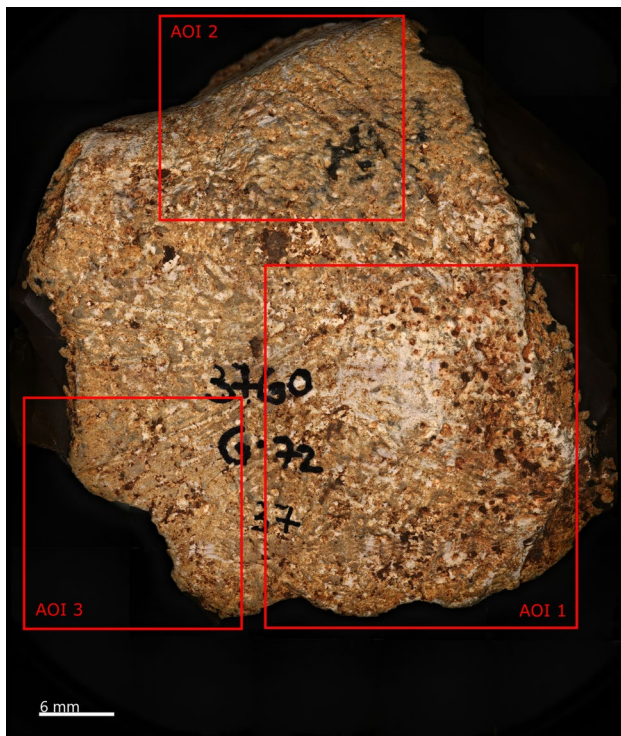


Fig. 3 High-resolution closeup photo of the cortical artefact of Manot showing the different areas of interest where the engraved incisions are located

(Fig. 1). The site was first excavated between 1933 and 1935 by Neuville and Stekelis who focused on the inner chamber and identified 13 layers. Of these, three were attributed to the Upper Palaeolithic (C-E), and the lower seven (F-L) to the Middle Palaeolithic (Vandermeersch 1981). Between 1965 and 1979 excavations were resumed by Vandermeersch, who was later joined by Bar-Yosef. Vandermeersch and Bar-Yosef identified 15 layers in the inner chamber, with both Upper Palaeolithic and Middle Palaeolithic assemblages, and a sequence of 24 layers on the terrace (I-XXIV) all of which contained Middle Palaeolithic assemblages (Vandermeersch 1981; Hovers 2009). Skeletal remains of anatomically modern humans, some of which represent intentional burials, were found within the terrace layers XXIV-XVII and were dated to ~100 ka (Vandermeersch 1969, 1981; Bar-Yosef et al. 1986; Schwarcz et al. 1988; Valladas et al. 1988; Tillier 1990; Belfer-Cohen and Hovers 1992; Vandermeersch and Bar-Yosef 2019). In addition to the burials, layers XXVI-XVII provided an assemblage of ochre pieces and marine shells (Hovers et al. 2003; Bar-Yosef Mayer et al. 2009). Among the lithic artefacts recovered from layer XVII was a fragment of an engraved Levallois core. This core was found close to the burial Qafzeh 8 (Belfer-Cohen and Hovers 1992; Hovers et al. 1997, 2003) (Fig. 5).



Fig. 4 Photo of Amud 1, the retouched blade, note the Incisions on the cortex

Methods

The methods used follow a multi-scale approach to identify and characterise the incisions on the artefacts under discussion. Initial analysis followed the commonly used procedures for the study of this type of artefact, which include (1) macro and microscopic inspection and documentation of natural and anthropogenic modifications on the artefacts' surface, (2) identification of areas of interest, using high-quality images, and (3) based on these images, the incisions found in each area of interest were traced and schematic reconstruction was formulated (d'Errico and Villa 1997; d'Errico and Nowell 2000; d'Errico et al. 2001; Peresani et al. 2014; Majkić et al. 2018b; Brumm et al. 2020). Additionally, due to the small dimensions of the incisions, we employed a non-invasive analytical three-dimensional examination of the artefacts' surface by scanning to generate 3D mapping points (Bello and Galway-Witham 2019; Nerudová and Lepcio 2022). We also conducted a surface texture analysis, which included sampling areas of interest and incisions, and geometry data

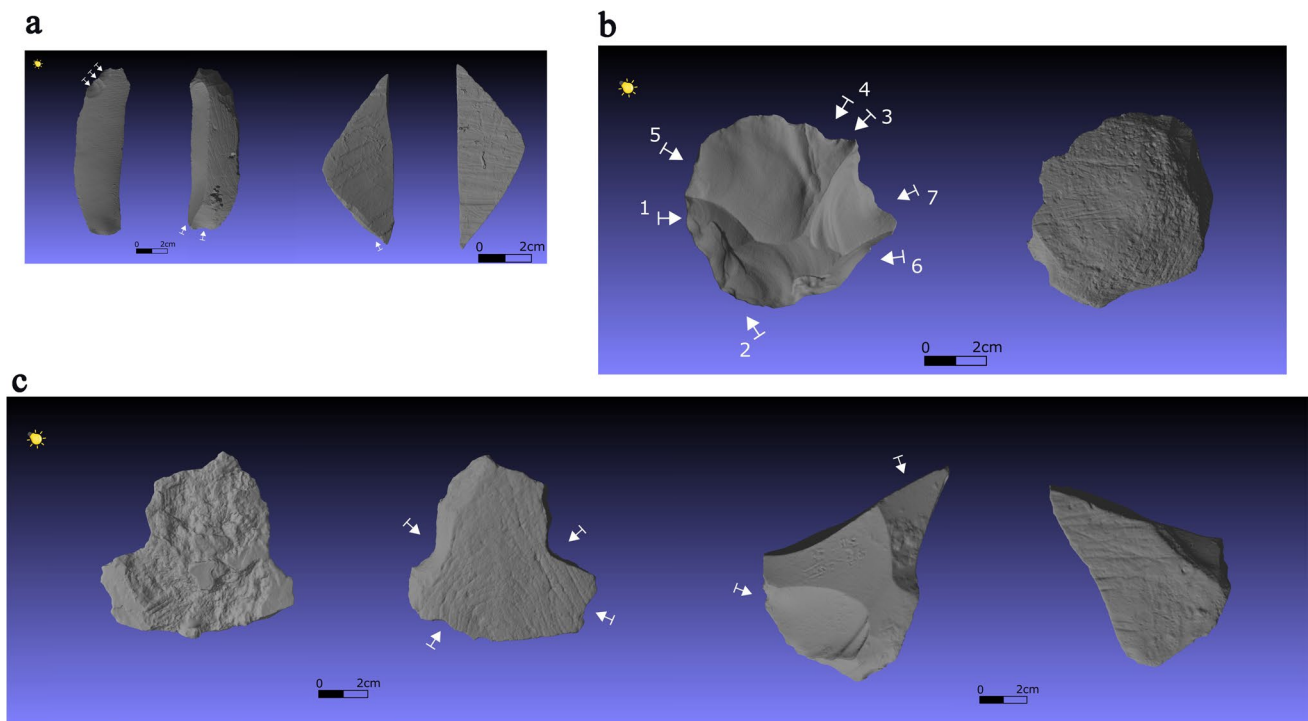


Fig. 5 3D models of the artefacts (arrows show the orientation of the dorsal face scar(s) on each artefact) **a** Illustration of the engraved artefacts of Amud (hereafter Amud 1 and Amud 2, from left to right),

b Illustration of the engraved artefacts of Manot, **c** Illustration of the engraved artefacts of Quneitra (to the left) and Qafzeh (to the right)

acquisition on the profiles of each incision. Similar studies have shown that high-resolution 3D scanning techniques provide more accurate and reliable data than 3D reconstructions based on image stacking techniques.

2D optical microscopy

High-resolution macroscopic (low magnification) images were done using a digital camera (Nikon DSLR camera, model D610 with a Nikon AF-S VR Micro-Nikkor 105 mm f/2.8G IF-ED objective) and a 3D digital automated microscope ZEISS Smartzoom 5 (equipped with a PlanApo 1.6×/0.1 objective, and an integrated segmented LED ring light). During the microscope analysis, all pictures were obtained employing the dedicated software ZEISS Zen Core, using the image Extended Depth of Focus (EDF) stacking module to generate in-focus and sharper images. After the acquisition and when needed, digital images (including overviews, areas of interest, and particular macro features) were edited using GIMP (free open-source image editor, available at <https://www.gimp.org/>, v.2.10.18). Vectorised schematic drawings of the tools' engravings and the combination of different pictures in a single frame were processed using the software Inkscape (free and open-source vector graphics editor, available at <https://inkscape.org/>, v.0.92.4).

3D point cloud acquisition (3D scanning)

For the core from Manot, and Amud artefacts, 3D point clouds were built and generated from a 3D optical scanner AICON SmartScan (field of view of up to 150 mm, 33 µm point to point distance). For the Qafzeh core and Quneitra plaquette, a portable HP 3D Structured Light Scanner Pro S3 was used (DAVID SLS-3, with a 0.06 mm resolution and a field of view up to 120 mm), as these artefacts could not be transported to the laboratory. The generated 3D point clouds enabled 3D reconstructions of the artefacts using MeshLab (an open-source system for processing and editing 3D triangular meshes, available at <http://www.meshlab.net/>, v.2020.03). Metric and morphometric data on the artefacts were acquired with digital callipers and analysis of the 3D mesh models. All 3D models were aligned, and the point clouds were exported as .csv files.

Surface microtopography visual analysis and sampling

For the identification of all features found on the artefacts' surfaces, digital elevation models (i.e., 3D or 2.5D representation models of a surface texture, Digital Elevation Model, DEM) were computed using QGIS (Open-Source Geographic Information System, available at

<https://www.qgis.org/>, v.3.10.5). Here, the 3D surface topographies (points cloud) were used to generate interpolated DEM raster files (using the triangulated irregular network model). The DEM of the artefact was used for visual inspection and identification of surface patches that show higher complexity, lower and higher penetration depth, as well as location and orientation of the incisions across the entire surface. Associated incisions (e.g., based on location and orientation on the surface of the artefacts, mutual distribution, and starting point of the engraving) were schematically grouped into designated Areas of Interest (AOI) (Fig. 6). The designated AOI on the artefacts were identified by using two main Surface Terrain analysis algorithms: (1) slope, which calculates the slope angle based on rate changes of the surface in horizontal and vertical directions from the centre of each cell, and (2) hillshade, that highlights the relief of a given surface based on its slope and aspect complexity. These were generated using the integrated SAGA - System for Automated Geoscientific Analyses packages (see Supplementary Information ESM_1 for a detailed workflow).

Morphometric analysis of the incisions' microgeometry

The morphometric analysis of each incision's micro geometry for surface and profile analysis was done using the software ConfoMap (version ST 8.2.10044, imaging and analysis software for Zeiss Microscopes). Two different templates were used to acquire, import, and analyse data (see online resources files ESM_2 and ESM_3 for workflow and template details). Template 1 (see Online resource file ESM_2 as an example) loads the 2.5-point mesh (.csv file format) of each artefact's incised surface, from which Areas of Interest (AOI) are selected and extracted individually. In the same template, from each AOI, incisions were identified and those with retrievable 3D data were (Fig. 7). After the extraction of all incisions' surface areas, Template 2 (see Online resource file ESM_3 as an example), loads the incision's surfaces and performs the morphometric and geometric analysis. For each incision, we sampled a minimum of three cut sections/profiles. These were positioned and

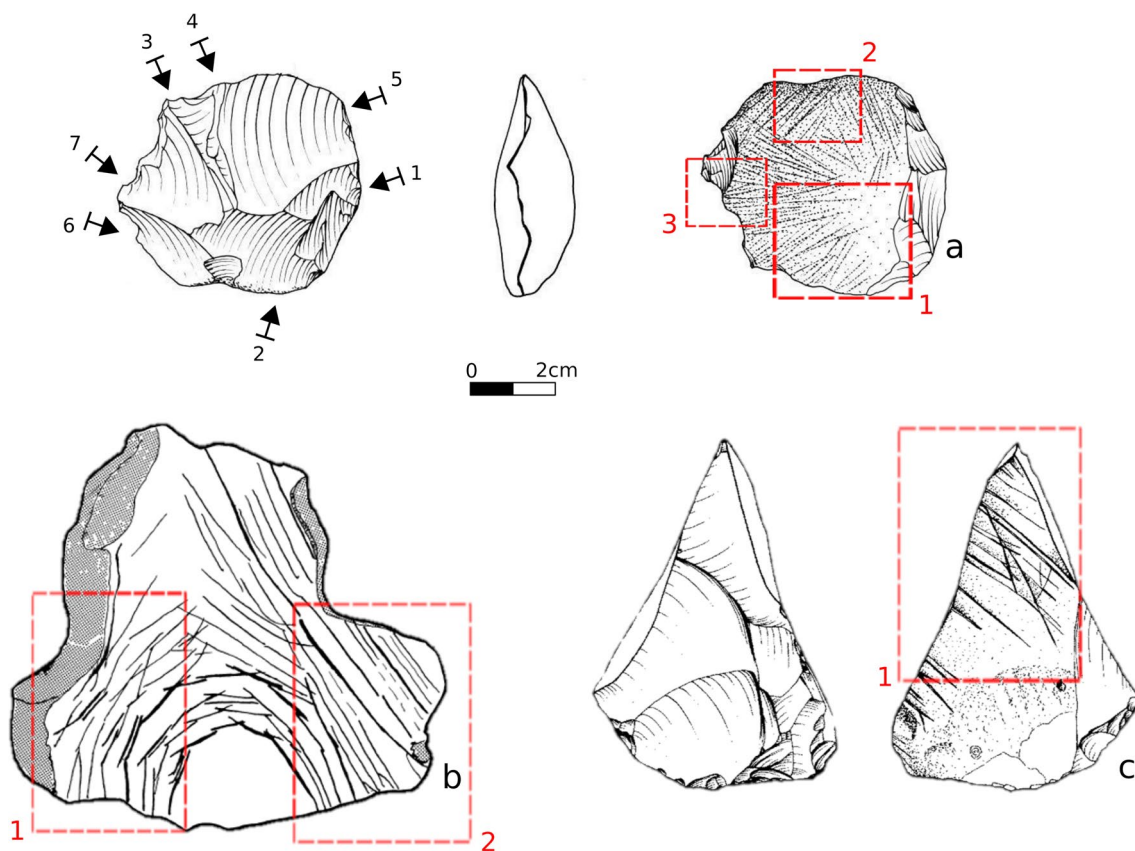


Fig. 6 Schematic drawing of the artefacts of Manot, Quneitra and Qafzeh (same scale) that illustrates the respective Areas of Interest (red dashed lines); **a** Core from Manot drawn by M. Smelansk,

b Plaque from Quneitra adapted from Marshack (1996), **c** the core from Qafzeh adapted from Hovers et al. (1997) drawn by J. Moskovich

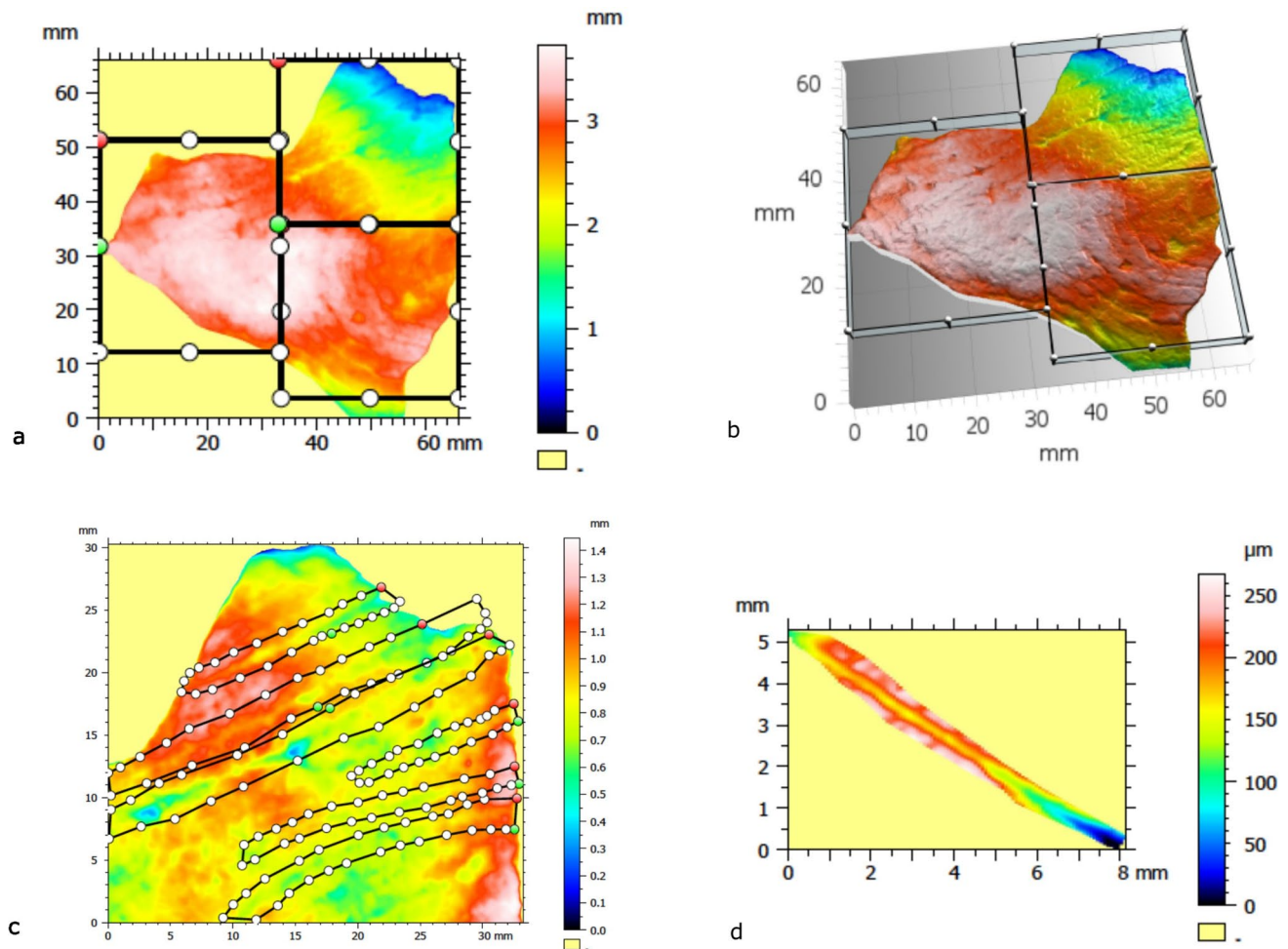


Fig. 7 Schematic illustration of the analysis workflow using Template 1 to select and extract areas of interest and incisions' surface areas for geometry analysis. **a** Selected areas of interest, **b** 3D repre-

sentation of the areas of interest, **c** select and trace incisions, and **d** extract incisions individually

extracted along the longitudinal axis of the incision surface (Fig. 8). On each of the 3 profiles the following four morphometric major features were measured: *distance between the edges of the incision*, *area of the cut* (calculated based on the distance between the edges and morphology of the incision cut section), *maximum depth* (distance between the top of the incisions and its depth), and finally the *opening angle of the incision*. All measurements were combined and extracted in a single .csv file, individually identified by incision numbering, area of interest and artefact. The entire dataset was used for descriptive and inferential statistics for comparison within and between artefacts.

Data processing and analysis

Descriptive statistics were calculated for the measured variables to describe the overall geometry of each incision and for comparison within and between artefacts. Kruskal-Wallis One-Way

ANOVA test was used to compare artefacts with additional Bonferroni corrected Wilcoxon's post hoc tests applied to detect the source of significant variation. All data analysis and plotting were processed with the R open-source software (Online resource file *ESM_4*). A research compendium, using the *rrtools* package by Marwick et al. (2018), including detailed info on used packages and software versions, raw and processed data is available here: <https://doi.org/10.5281/zenodo.6322858>, under the MIT license, data under CC-0, and figures under CC-BY (see further details in Marwick 2017).

Results

The core from Manot

The core was made from a dark brownish-green flint, Munsell colour 10YR 3/2 (Munsell 1975) (Fig. 3) and was

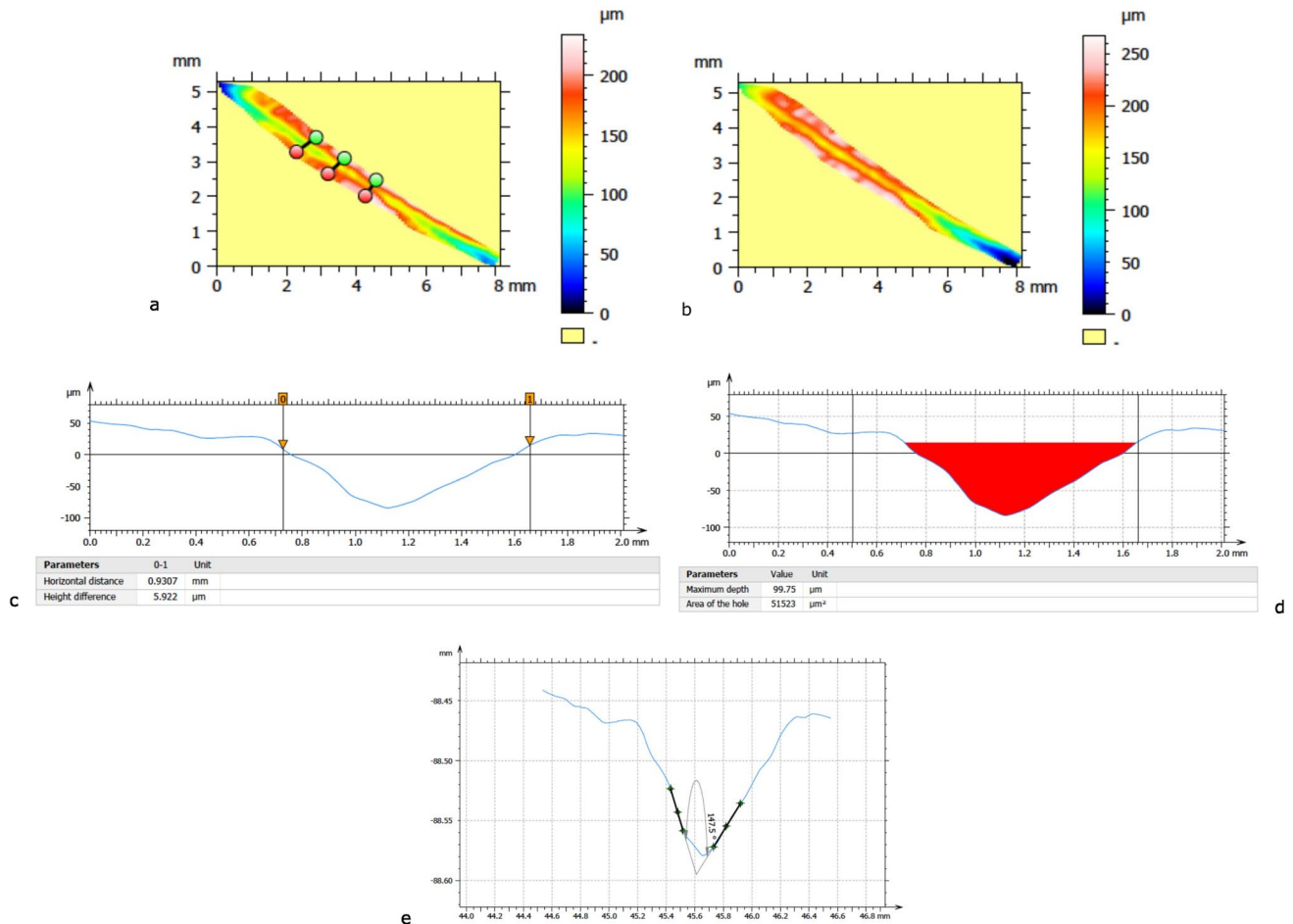


Fig. 8 Schematic illustration of the analysis workflow using Template 2 to import and analyse the geometric features of each incision. **a** import incision surface, **b** select and extract 3 sections/profiles, and

measure **c** horizontal distance, **d** area of the cut and maximum depth, and **e** section angle

worked in its final stage using the Levallois flaking concept. The core's dimensions ($53 \times 47 \times 17$ mm) are within the range of other Levallois cores found at Manot Cave and other Middle Palaeolithic sites in the region such as Amud, Qafzeh, Ein Qashish and Kebara (Hovers 2009; Malinsky-Buller et al. 2014; Marder et al. 2018; Meignen 2019). The core has one dominant striking platform, with the cortex covering most of the preparation surface. The flaking surface displays a centripetal recurrent mode of flaking. Flakes were removed during several sequential and independent stages, initial knapping removed at least four flakes from the striking platform and the right side of the core (Fig. 6: removals 1–4). At this stage, several small flakes may also have been removed from the striking platform. Subsequently, a relatively large, hinged flake (Fig. 6: removal 5) was removed from the core's striking platform, truncating previous removals. Before the core's discard, an additional small striking platform was prepared on the distal edge from which two hinged flakes were knapped (Fig. 6: removals 6–7).

The cortex-covered preparation surface has a slight convex-shaped aspect. Significant degradation of the cortex is seen on the higher topographic surface point nearly centrally located, and on one of the ridges. This is illustrated by a white colouration in contrast to the natural brown colour of the remaining cortical areas. It is not clear whether this smoothing was intentionally inflicted or is a result of some abrasive post-depositional processes. Nevertheless, if post-depositional processes are the cause, these did not significantly affect the rest of the core's preparation surface, as there is no overlap between this patch and the engraved incisions.

The core's cortical surface is marked by parallel and convergent incisions. The group of lines is composed of 64 incisions which radiate in a fan-shape from the centre (where the abraded patch is located) to the core edges (Figs. 5, 6 and 9a). While detaching the final two flakes from the core, some of the incisions were truncated, suggesting that they were made before the final round of flaking. Combined with the

Fig. 9 The Manot core schematic illustrations for left. The location of the engraved incisions identified during the 3D model and GIS inspection. The different colours mark, **a** non-cortical flaking scars, **b** cortical flaking scars, **c** deepest incisions. Narrow lines represent shallow incisions, right. Engraved incisions are superimposed on the map of the ventral surface, showing the deviation of the striation from flake orientations on this surface

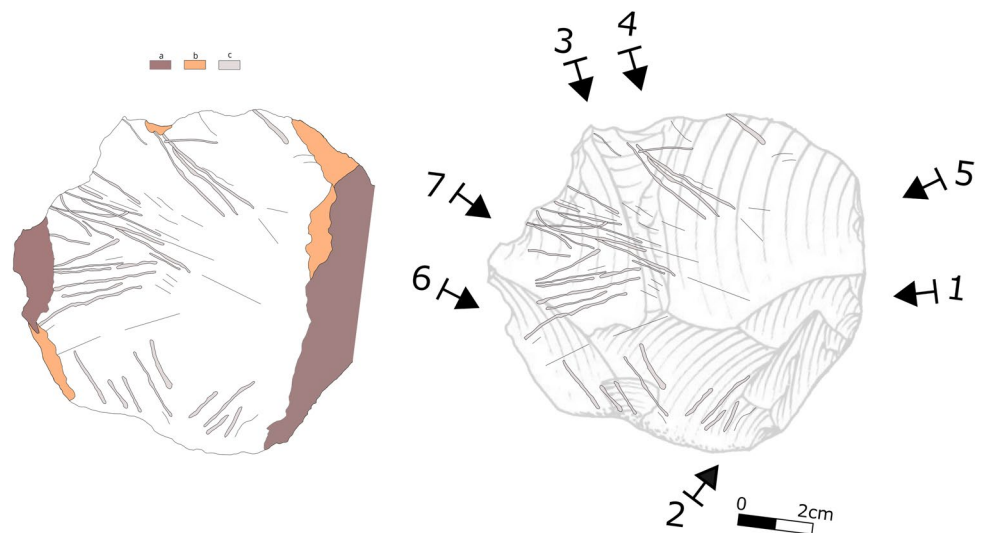


Table 1 General inventory of the number of analysed incisions, organised by site/artefact and area of interest

Site/Artefact	AOI 1	AOI 2	AOI 3	Total
Amud 1	21	10	6	37
Amud 2	11	8	6	25
Manot	3	4	14	21
Quneitra	7	3	18	28
Qafzeh	6	3	0	9

lack of double patination, this indicates that the incisions do not result from post-Middle Palaeolithic recycling activities.

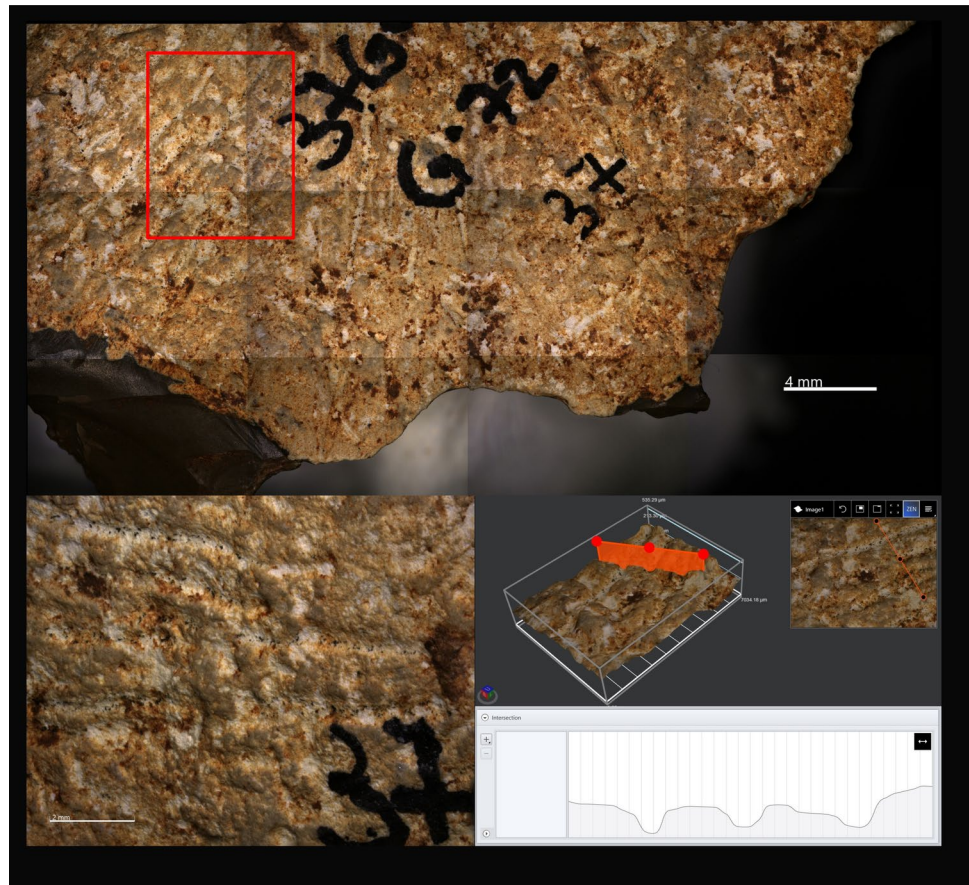
Visual macroscopic examination and GIS Surface Terrain analysis, slope and hillshade, indicate that the incisions are concentrated in three main Areas of Interest (AOI 1, AOI 2 and AOI 3, and see the online resource file ESM_5 for more details) (Table 1). From a total of 64 visually identified incisions 3D reliable data could be retrieved from 21 (four incisions from AOI 1, three from AOI 2 and 14 from AOI 3). This corresponds to 63 measured features including 3 sections/profiles per incision, measured perpendicularly to the long axis of the incision. Four geometric parameters were measured on every section/profile: (1) the distance between the ‘shoulders’ (lateral edges) of the incision, (2) the area of the cut, (3) the opening angle of the incision, and (4) the maximum depth. Figures 10 and 11 plot and summarise the acquired data on each parameter organised by area of interest. (Supplement resource file 5 highlights the unique areas in each AOI). Tables 2 3,4 and 5 present data including all the incisions from all three Areas of Interest.

In terms of the distance between edges, all three AOI on the Manot core show similar data distributions with mean values of 826 μm for OAI 1, 848 μm for OAI 2, and 811 μm

for OAI 3. A similar homogeneous pattern was also found in the measured area of the cut and maximum depth for every incision. For the cut area, mean values are 25,592, 20,100 and 29,378 μm^2 , for OAI 1, 2 and 3 respectively. The mean angle is also similar between the AOI, with 150°, 151 and 148° for OAI 1, 2 and 3 respectively. As for the maximum depth of Incisions, AOI 1 and 3 show a mean of 62.4 and 64.8 μm , while incisions from AOI 2 show a mean value of 52.3 μm , indicating comparatively fewer deep incisions.

AOI 1 has the largest number of incisions and based on visual inspection and digital tracing reconstruction, shows the most uniform distribution (Table 1; Fig. 6). A few shallow striations that barely cut through the cortex are evident in both AOI 1 and 2 (marked as black lines in Fig. 6 and shown in the Fig. 11 boxplot distribution). These striations show a similar orientation and align with the innermost deeper incisions. While most of the incisions are parallel to one another, a few overlaps occur, three in OAI 1 and one in OAI 2, (Figs. 6 and 9a). The fact that the deeper incisions do not overlap is evident from reconstructing the sequence of engravings (Fig. 9a). In AOI 1 and 2, the incisions are oriented and converge towards the centre of the core, while in AOI 3 the point of convergence seems to be the edge and does not reach the cortical surface edge. The three AOI identified on the Manot core do not spatially overlap nor do they cover the complete surface (Figs. 4, 6 and 9a). The open space between the AOI and the similarities between the geometric features measured for the incisions make it impossible to deduce the temporal relation between the areas. Although it may seem that each of the AOI was engraved independently, the relationship between the three areas suggests they relate to one another and result from careful planning and intent. The notion of intent and premeditated planning stems from the convergent orientation of

Fig. 10 Close-up high-resolution macroscopic photo of the Area of Interest 1, showing an engraved area with parallel incisions



the incisions, their consistent parallel arrangement as well as the formation of a visible radiating pattern from the highest point on the surface (Figs. 6 and 9a).

An additional variable that may be used to infer intent is the correlation between the directionality of incisions on the cortical face (i.e., preparation surface) and the scar pattern on the flaking surface (Fig. 9b). To evaluate this correlation the incisions from the preparation surface were superimposed on the flaking surface. Our interpretation, although perhaps speculative, is that a perceived association is seen between the high number of incisions in AOI 1 and AOI 3 and the scars of the last two hinged flakes removed. Flake removals, noted as flake scars 1 and 5, show no evident link with any of the incisions. These flakes were removed from the core's main striking platform and mirrored the highest point on the cortical surface. As noted before, this high point, on the one hand, shows significant degradation of the cortex, and on the other hand, seems to be the focal point towards which most of the incisions converge. The possibility that the observed association between the incisions and the flake removals is not coincidental should not be overlooked.

The artefacts from Amud

Two flint artefacts bearing striations from Amud cave were analysed using the methodology employed in the analysis of the Manot item: an incised cortical blade originated from Area A, sub-unit B1 (Figs. 4 and 5) and an incised flake from Area B sub-unit B4 (Fig. 5). The first artefact (Fig. 4: Amud 1) is a complete retouched cortical blade ($85 \times 24 \times 9$ mm). The cortex covers almost 80% of the dorsal surface with a single scar on the left side. The non-cortical edge is unmodified, while bifacial retouch is evident adjacent to the tip and fine retouch along the right side on the dorsal face. No signs of use-wear were identified in association with the retouch and the fragmentation of the tip. This piece shows numerous incisions over the cortical dorsal surface (a total of 37 were analysed), with diverse orientations (see Fig. 4 for a detailed closeup). Many of the incisions align with the artefact's flaking axis and depict a range of depths. The retouch seems to cut several of the incisions indicating the tool was in use or intentionally modified after the cortex was incised. The second artefact (Fig. 5 - Amud 2) is a fragmented cortical flake ($49 \times 17 \times 16$ mm) with incisions

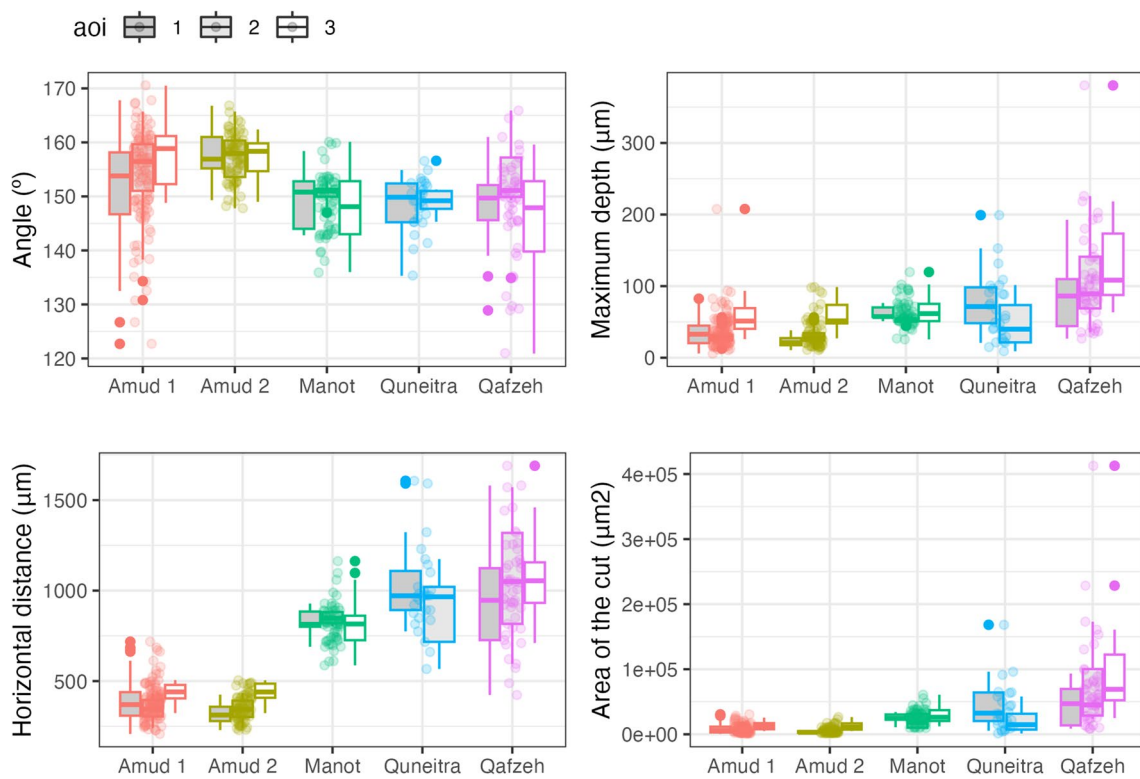


Fig. 11 Boxplot for visualising distance, depth, area and angle data organised by site/artefact and Area of Interest (AOI)

Table 2 Summary statistics for the distance (in µm) of the incision’s profiles organised by site/artefact. (count, maximum, minimum, mean, standard deviation, median)

Site/Artefact	Count	Max	Min	Mean	Sd	Median
Amud 1	111	718	207.9	385.31	100.87	370
Amud 2	73	504.5	229.1	351.57	71.29	348.8
Manot	54	1162.8	587.1	820.31	107.52	822.6
Quneitra	48	1690	423.3	1017.28	281.19	1008.5
Qafzeh	27	1607	416.9	992.86	240.53	970.4

Table 3 Summary statistics for the area of the cut (in µm²) of the incision’s profiles organised by site/artefact. (count, maximum, minimum, mean, standard deviation, median)

Site/Artefact	Count	Max	Min	Mean	Sd	Median
Amud 1	111	30,636	549	8166.31	6210.35	5774
Amud 2	73	26,552	1388	6322.91	5067.44	5114
Manot	54	60,785	9471	27070.26	10875.79	25,896
Quneitra	48	412,713	8746	72488.75	68398.86	56,725
Qafzeh	27	168,305	1378	37903.37	36998.51	26,389

Table 4 Summary statistics for the maximum depth (in µm) of the incision’s profiles organised by site/artefact. (count, maximum, minimum, mean, standard deviation, median)

Site/Artefact	Count	Max	Min	Mean	Sd	Median
Amud 1	111	207.7	5.867	38.04	24.46	31.89
Amud 2	73	98.7	10.6	32.92	20.31	28.01
Manot	54	119.7	25.54	62.06	18.21	57.02
Quneitra	48	380.4	26.68	108.14	64.59	92.96
Qafzeh	27	199.2	9.05	68.57	45.55	59.07

Table 5 Summary statistics for the angle (in degrees °) of the incision’s profiles organised by site/artefact. (count, maximum, minimum, mean, standard deviation, median)

Site/Artefact	Count	Max	Min	Mean	Sd	Median
Amud 1	111	170.5	122.7	153.41	8.75	154.9
Amud 2	73	166.8	147.8	157.40	4.23	157.9
Manot	54	160.1	136.0	148.91	5.32	150.2
Quneitra	48	165.9	120.9	148.08	9.46	150.05
Qafzeh	27	156.6	135.3	148.62	4.81	149.2

evident on the cortex, of which a total of 25 were analysed. The incisions have a parallel orientation mostly overlapping and occasionally intersecting each other and show a perpendicular and oblique directionality relative to the flaking axis of the artefact.

The two artefacts are similar to each other (p -values > 0.05 for pair comparison for each feature, see SOM4 for more details). Both artefacts show low values for the horizontal distance (width) of the incisions. Distance values from the different AOIs on Amud 1 have mean values ranging between 343 and 430 μm , and Amud 2 with a range of values between 318 and 435 μm (Table 2). The incisions on both are shallow and range for Amud 1 from 29.5 to 62.1 μm and on Amud 2 between 22.7 and 59.5 μm (Table 4).

Comparison with the artefacts from Qafzeh and Quneitra

The repetitive engraving and pattern formed by the incisions on the cortical face of the Manot core suggest intent. In contrast, the incisions on the cortical artefacts from Amud are shallower and portray multiple orientations possibly representing a by-product of utilitarian purposes. In an attempt to see if the differences noted between the incisions on the Manot and Amud items are also visible on the artefacts from Quneitra and Qafzeh, the same methodology was used to characterise the incisions of the latter two (Figs. 5 and 6). Tables 2, 3, 4 and 5 describe and summarise the measurements on all artefacts for each of the geometric features (Distance between profiles, area between profiles, depth of incision and angle of profiles). Boxplots in Figs. 11 and 12 statistically describe and illustrate the distribution of the data for each parameter organised by site.

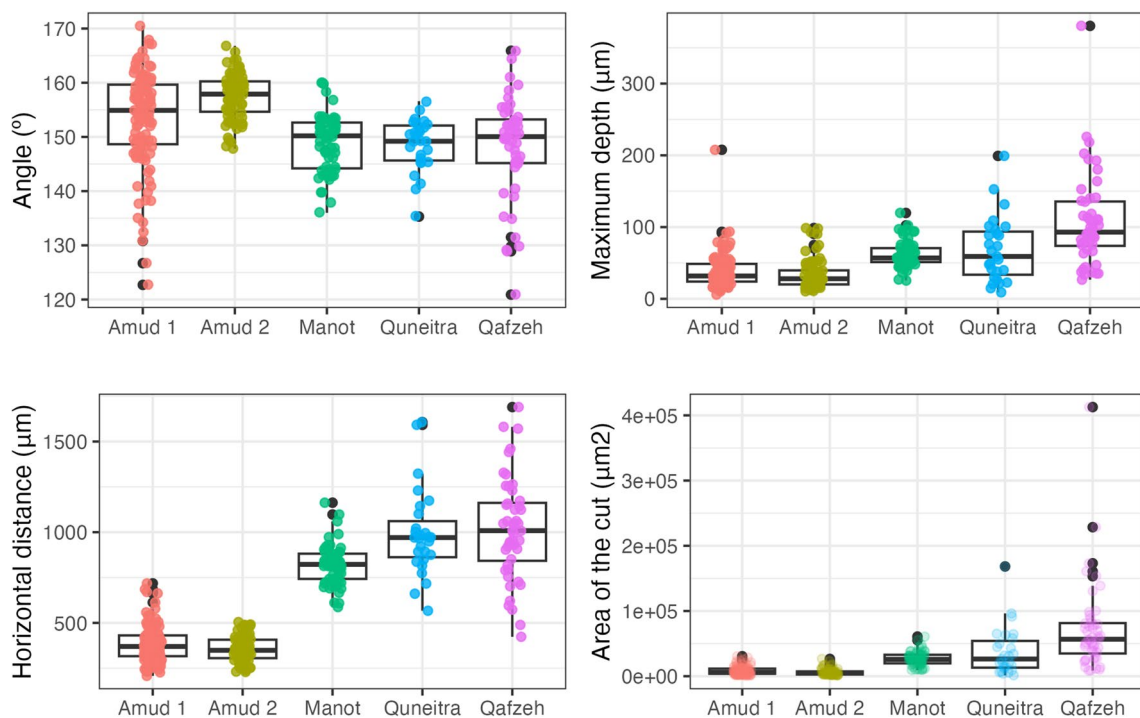


Fig. 12 Boxplot of distance, depth, area and angle data (AOI are aggregated) organised site/artefact

The engraved piece from Qafzeh ($62 \times 40 \times 16$ mm), as the Manot core, is a centripetal recurrent Levallois core with incisions on the preparation face (Hovers et al. 1997). The cortical surface of the Qafzeh core has 27 incisions (our study examined the micro geometry of 9 incisions), mostly parallel to one another, with minimal overlap between them (Hovers et al. 1997). The similarity between the two cores is also evident in the organisation and distribution of the incisions which formed spatially separated groups of parallel incisions. The incisions on both cores do not cut through the cortex and only minimally overlap. On both cores the incisions have been interrupted by flakes removed from the ventral core surface indicating that the incisions were engraved during core exploitation (Hovers et al. 1997). In comparison with the Manot item, the fragmented state of the Qafzeh core suggests no association between the scar pattern and incision directionality. Turning to the micro geometry of the analysed incisions, here too similarities are detected. The ANOVA analysis shows high *p-values* for the depth (*p-value* = 0.919), area of the cut (*p-value* = 0.484) and angle measurements (*p-value* = 0.99), suggesting similar technological traits between the incisions on both cores. Similar to the AOI on the Manot core, the angle values of the incision profiles of the Qafzeh core are homogeneously distributed within and between the two engraved AOI. The measured angles range between 135° and 150° , with mean values of 148° and 150° for both AOIs (Fig. 12). However, considering the distance (*p-value* < 0.05), some difference is observed (Table 2). Nevertheless, the visual distribution of the data, represented by a boxplot (Fig. 12), shows that the angle values from Manot are within the range of values measured on the artefact from Qafzeh, although the latter presents higher variability. Hence, when the mean values are compared, similar patterns are observed. For example, the distance between incision edges on the Qafzeh core ranges from 567 to 1607 μm , and for the Manot core they range from 587 to 1163 μm .

The piece from Quneitra is different from the engraved cores as it is a modified cortical flint plaquette, measuring $68 \times 72 \times 8$ mm (Goren-Inbar 1990; Marshack 1996; Shaham et al. 2019). The plaquette is retouched along two edges and engraved on the smooth cortical face. The incisions form a pattern composed of a set of four nested semicircles carefully incised along the lower and upper sections of the plaquette, and a set of parallel lines (Fig. 5). Two inner arcs may have been more lightly incised at a later stage (Marshack 1996; Shaham et al. 2019). Although lacking ventral flake removals, the retouch along the edge cuts several of the incisions. The incisions on the plaquette differ from those on the two cores both in the distinct arc pattern they form and in the repeated superimposition of incisions (Fig. 5). At the same time, the longitudinal and parallel incisions on the

right side of the piece seem to resemble the engraved patterns observed on the Manot and Qafzeh cores.

To facilitate comparison with the incision angles between the Quneitra plaquette, the two cores and the artefacts from Amud, the engraved incisions were grouped into two AOI: arched incisions (AOI 1) and longitudinal engravings (AOI 2). This enabled the orientation and alignment of the plaquette 3D model with those of the cores, ensuring the accuracy of the incision analysis. The data from the Quneitra plaquette, similar to the Qafzeh core, significantly overlaps with the measurements retrieved from the Manot core. The angle range of the profiles on the plaquette (Table 5) is between 135 and 157, and mean values of 148 and 150 are comparable (*p-value* = 0.97). The same is evident for the distance between edges, the area of the cut and the depth of the incision (Tables 2, 3 and 4). The data collected for the different geometric features of the incisions show similar results for the artefacts from Manot, Qafzeh and Quneitra (*p-values* > 0.05 for pair comparison on the different features, see supplementary resource file ESM_4 for details). These observations align with our initial inspection, based on the visual distribution, location, and orientation of the incisions.

Combining the visual examination and quantitative surface analysis of the incisions' geometric features, the results show the presence of two distinct groups. One group is formed by the two artefacts from Amud and the other with the three artefacts from Manot, Quneitra and Qafzeh. The two artefacts from Amud show similarities with one another. The incisions on both artefacts show no clear or distinct patterning, have a mixed orientation and distribution and show a high degree of overlap. On the other three items, the incisions portray a similar parallel and organised distribution and there is no overlap between the different engraved areas on each of the artefacts. In the case of Manot and Quneitra artefacts, the incisions form a clear geometric pattern. As for the Qafzeh core, the parallel incisions seem to form a pattern, but as the core is broken this is hard to substantiate. Differences between the two groups are also supported by the statistical analysis of the collected data (Figs. 11 and 12). High *p-values* show no significant difference between distance (width), depth, area of the cut and angles of the incisions on the artefacts from Manot, Quneitra and Qafzeh. The same observation is found when both artefacts from Amud are compared. The pairwise comparison between all artefacts shows a clear difference between the two groups (Tables 2, 3 and 4; Figs. 11 and 12). When comparing the horizontal distance (width) of the incisions, a *p-value* < 0.05 separates between the artefacts of Amud and the 3 pieces from Manot, Quneitra and Qafzeh. Of particular interest is the difference in incision depth, the Amud incisions being overall shallower and with a smaller cut breadth.

Discussion

Key areas of research for understanding the intricate behaviour of past societies involve studying aesthetics, creativity, and symbolic representations found in their cultural artefacts and material remains. One archaeological manifestation of creativity and abstract thought is the intentional formation of patterns on artefacts by engraving a series of incisions (Henshilwood et al. 2018; Hodgson 2021; Tylén et al. 2020). Nevertheless, it is always assumed rather than demonstrated that the incisions (and any patterns they form) are the result of intent and predetermination, and demonstrating such intent remains challenging (Hodgson 2019; Mellet et al. 2019; Brumm et al. 2020). In this study, we employed a multi-proxy analytical approach to critically evaluate the characteristics of the incisions on lithic artefacts from the Levantine Middle Palaeolithic. The results of our study allow us to separate analytically and quantitatively the incisions on the Amud artefacts from those on the cores from Manot and Qafzeh and the Quneitra plaque.

The incisions' geometry, location, and spatial organisation on the Levallois core from Manot Cave exclude the possibility that they result from post-depositional mechanisms. Other lithic artefacts found in the same context also lack evidence of post-depositional weathering (Marder et al. 2018). Additionally, the minimal alteration noted on the highest point of the engraved core's cortical surface does not affect the lower planes where the incisions are located. Analytical results show four main interesting aspects: (1) the location of the incisions is concentrated in three distinct main areas of interest; (2) these areas show similar patterning concerning the cross-section angle, parallel distribution and convergent orientation of the incisions; (3) in AOI 1 and 2 the incisions are cut by dorsal flake removals, showing that these were engraved before flaking, and (4) when superimposed, a possible association is indicated between the location of incisions on the preparation surface (dorsal) and the flake scars on the flaking surface of the core (ventral).

Experimental data (d'Errico and Nowell 2000; Hayes et al. 2020) suggest that the incision section/profile is shaped by the tool used. Non-retouched flint artefacts are likely to form a sharp profile with a V-shaped base, while incisions created with a retouched flint artefact have an asymmetric profile. The use of a pointed flint tool results in morphological variability along the incision, and incisions made with bone or wood tools tend to be shallow with a U-shaped profile (d'Errico and Nowell 2000; Hayes et al. 2020). Based on the similarities between the distance (width), area of the cut and depth of the incisions on the three artefacts from Manot, Qafzeh and Quneitra it is reasonable to argue that the incisions were produced by sharp-edged non-retouched tools (likely stone tools) by applying a single stroke per incision.

In contrast, while the incisions on the Amud artefacts are anthropic, but intentionality of their engraving cannot be supported unequivocally. The incisions on the Amud artefacts were formed differently from the Manot, Qafzeh and Quneitra, and may be the result of cutting that occurred on the artefacts or of their use as abraders, leaving marks in the cortex (Peresani et al. 2014). As the retouch on the Amud blade (Fig. 4) occurred after the incisions, it could be that the latter were applied prior to the removal and shaping of the blade. This suggestion is supported by the lack of use-wear marks on the artefact. The detailed study shows that the engraved incisions likely resulted from two different activities performed on the artefacts' cortical surface: (1) cutting on the tools' surface, resulting in linear incisions mainly found on uniform surfaces, and (2) abrading with the tools' surface, which resulted in sub-parallel incisions caused either by abrasion of other flint nodules/cores (to clear the flaking platform), edge scarring (for cleaning the edge before retouch), or edge abrasion to improve hafting strength. These artefacts resemble other archaeological items that have been defined as abraders and whose use is associated with knapping (possibly for the preparation of the striking platform ridge). Such incised lithic cortical artefacts are known from the Italian Middle Palaeolithic record, from Grotta de Fumane, Riparo Tagliente and Grotta Maggiore San Bernardino (Leonardi 1981; Sarti et al. 2004; Peresani et al. 2014). These artefacts do not seem to display a distinct pattern formed by the incisions, there is no evident orientation to the incisions, and they overlap in many cases. Peresani and colleagues (2014) advocate a utilitarian origin of the incisions rather than a symbolic one. Additionally, a study of the incisions on a Middle Palaeolithic cortical flake from Champlost, France, also suggests that the different linear incisions are likely related to the abrasion or regularization of the flake edge (Lhomme and Normand 1993).

The artefacts from Manot and Qafzeh are Levallois cores shaped by centripetal recurrent flaking before their discard. On both cores, the incisions are linear, do not overlap and are cut by flakes removed after the incisions were made. The incisions on the two cores represent a repeated action of engraving that occurred before the final stage of removing flakes from the core. In the case of the Manot core, the incisions form a radiating fan of lines oriented towards the slightly smoothed high point on the preparation surface. The uniqueness of these engraved cores, and the patterns formed by the incisions suggest they are the outcome of intent and creativity. This type of manifestation can be interpreted as an act of deliberate intent to incise and form a pattern while knapping (and see Fogarty et al. 2015; Malafouris 2021). The context within which the Qafzeh core was found supports its interpretation as an exhibit of symbolic behaviour (Hovers et al. 2003; Hovers and Belfer-Cohen 2023). The

engraved core was found in layer XVII adjacent to the burial of Homo 8 and large ochre lumps (Hovers et al. 2003), a combination that is missing from all other stratigraphic contexts in the cave. The engraved core from Manot, on the other hand, is an isolated occurrence and originates from a mixed archaeological context (Marder et al. 2018), thus preventing us from placing it within a cultural symbolic system.

Contrary to the cores from Manot and Qafzeh, the plaquette from Quneitra does not seem to have an evident utilitarian aspect. The plaquette was intentionally shaped, and the incisions seem to relate to the plaquette outline (Shaham et al. 2019). The figurative patterns show a semi-circular design, markedly different from the organised groups of longitudinal incisions found on the Manot and Qafzeh cores. A concentric pattern of incisions similar to those on the Quneitra plaquette was also found on an aurochs' left femur shaft from the same site (Shaham et al. 2019). The composition formed by the incisions was suggested to represent a type of depictive, schematic abstraction which complies with the Gestalt principles of perception (Marshack 1996; Shaham et al. 2019). In this sense, the Quneitra plaquette represents an intentional creative engagement of the engraver with the flint plaquette (cf. Malafouris 2021).

Engraving of abstract patterns during the Middle Palaeolithic and Middle Stone Age (MSA) in Eurasia and Africa was not limited to stone artefacts. Incisions and notches engraved for non-utilitarian purposes were also made on bone, cave walls, ostrich eggshells and ochre. The consistent, yet typically isolated appearance of non-utilitarian engraved objects in the Middle Palaeolithic and MSA record, especially within the later part of the period, suggests either a gradual development or isolated occurrences (independent cultural innovations) of complex human behaviour (Hovers et al. 2003; Henshilwood et al. 2009; Texier et al. 2010; Rodríguez-Vidal et al. 2014; Majkić et al. 2017, 2018b; Assefa et al. 2018; Shaham et al. 2019; Prévost et al. 2021).

This study offers an additional perspective on the character of engraved stone items produced by Palaeolithic hominins and raises further questions regarding their significance. The analytical tools employed to study the geometric characteristics of incisions have shown that the incisions on the Manot and Qafzeh cores and the Quneitra plaquette were intentional and non-utilitarian, while the incisions on the Amud artefacts, albeit anthropogenic, most probably resulted from a utilitarian action such as abrading or scraping. In the case of the Amud blade, further reduction and modification of the tool occurred after the incisions were inflicted. The intentionality of the incisions and patterns formed on the Manot and Qafzeh cores and the Quneitra plaquette is supported by our analysis. These early engravings reflect, minimally, the creation of a visual pattern (Kelly 2019). This said, the identification of these isolated finds in

the Levantine Middle Palaeolithic record testify to occurrences of hominin engagement in forming visual patterns.

Conclusion

In this study, we analysed 5 engraved artefacts from the Levantine Middle Palaeolithic: two engraved Levallois cores from Manot and Qafzeh caves, an engraved plaquette from Quneitra, as well as a flake and cortical blade from Amud cave. When comparing the location and micro geometry of the incisions on the five pieces, similarities are noticeable between the artefacts from Manot, Quneitra and Qafzeh, and a clear distinction from the artefacts from Amud.

The Manot, Qafzeh and Quneitra items show general homogeneity of the characteristics of incisions, albeit with different patterns. As demonstrated in experimental studies (d'Errico and Nowell 2000; Hayes et al. 2020) this would seem to imply that the same type of sharp-edged tool was used to form the incisions on all three artefacts. The incisions on the two Levallois cores were created during the course of the knapping process. The patterns assembled, most notably on the Manot core and Quneitra plaquette, indicate intent, and possibly creativity as the engraving was non-utilitarian. On the other hand, both artefacts from Amud, although engraved on the cortical surface, show varied orientations and distribution of the incisions. The latter is marked by a higher angle, shorter width (distance), is shallow and has a small area when compared to the other three artefacts studied. Based on these data combined with the visual examination, our interpretation is that these artefacts had a utilitarian character and likely were used as abraders.

In our study, we have demonstrated that combining microscopic observations with the analysis of incision patterning and geometric characteristics enables the differentiation between intentionally incised patterns and incisions resulting as by-products of other uses of the artefact. As presented here, the incisions' patterns and geometric features distinguish the Amud artefacts from the other three. These new findings contribute to the discussion relating to the different characters (utilitarian and non-utilitarian) of engraved stone artefacts during the Palaeolithic and provide analytical tools for differentiating the nature of the marks, contributing to a nuanced interpretation of the significance of such items. The repetitive dynamic implementation of incisions on Levallois cores and a plaquette signify the engagement of their makers in actions governed by considerations other than subsistence and sustainability and suggest the presence of creativity, supporting arguments for non-utilitarian, social roles of such items.

Supplementary Information The online version contains supplementary material available at <https://doi.org/10.1007/s12520-024-02111-4>.

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Data availability All data acquisition settings, processing and analysis during the current study are included in this article and its Supplementary Information files, or available on Zenodo (for the R data analysis).

Declarations

Competing interests The authors declare no competing interests.

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