



# Flint Type Analysis at Late Acheulian Jaljulia (Israel), and Implications for the Origins of Prepared Core Technologies

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Prepared Core Technologies, often considered a hallmark of the Middle Paleolithic Mousterian, have recently been observed, to some extent, in many late Lower Paleolithic Acheulian sites. This may indicate a Lower Paleolithic origin of the Levallois method, although the circumstances leading to its emergence, spread and assimilation are still debated. We aim at contributing towards this intriguing issue by studying patterns of flint procurement and exploitation at Late Acheulian Jaljulia (Israel; ~500–300 kya). We classified artifacts into flint types, using four samples: a general sample, bifaces, “regular” cores with one/two striking platforms, and prepared cores, divided into proto-Levallois, prepared (general) and discoid cores. A geologic survey located potential flint sources, and a petrographic analysis was used to assign flint types to sources. Our results show that while local Turonian flint of the Bi’na Formation dominates the general sample, selectivity in using specific flint types was observed, including among local materials. While brecciated flint types are especially common among handaxes and discoid cores, among proto-Levallois and prepared cores (general), fine-textured homogenous flint types are more common, suggesting that such flint types are better-suited when improved control over the end-product was desired. Based on our results, and following previous suggestions, we support the hypothesis that prepared core technologies in the Levant did not originate from one single technological trajectory. We support the idea that the production of predetermined blanks was based on knowledge gathered from several technological trajectories, including mainly biface shaping and the production of flakes from regular cores. This novel method was most likely transmitted time and again between individuals, gradually adjusting it to produce improved end-products. We see these conclusions as additional support for the view of prepared core technologies at the Late Acheulian as a demonstration of cumulative culture, and the existence of high-fidelity social learning mechanisms in practice already during the late Lower Paleolithic of the Levant.

**Keywords:** flint types, cumulative culture, Jaljulia, Late Acheulian, handaxes, Levantine Lower Paleolithic, prepared core technologies

## INTRODUCTION

The Acheulian cultural complex is the main cultural entity associated with the Lower Paleolithic of the Levant, dated to between 1.5 and 0.4 mya, and usually attributed to *Homo erectus* (sensu lato) (Bar-Yosef and Belmaker, 2011). Acheulian lithic assemblages are usually characterized by the production of flakes and flake-tools, accompanied, in variable proportions, by the manufacture of bifaces, known as handaxes, or Large Cutting Tools (e.g., Bar-Yosef et al., 1993; Lycett and Gowlett, 2008; Sharon, 2008, 2009, 2010; Barkai, 2009; Machin, 2009). These are considered the hallmark of the Acheulian cultural complex in the Levant.

The Acheulian is commonly referred to as a stagnant culture, with relatively few behavioral and technological changes in comparison to later periods (Bar-Yosef, 1994, 2006). However, while persistence of traditional ways does appear to be the rule during the Acheulian, especially concerning the production of handaxes, this may reflect the suitability of Acheulian technologies to Lower Paleolithic lifeways and adaptation (Finkel and Barkai, 2018), rather than being a limiting factor (Hopkinson et al., 2013). Moreover, significant transformations in human behaviour (such as the use of fire, the occupation of new landscapes, big-game hunting, etc.), in addition to a wide range of lithic technologies (e.g., systematic lithic recycling, the use of soft hammers), have been identified throughout the Acheulian and particularly towards the end of the Lower Paleolithic period (e.g., Nowell and White, 2010; Hopkinson et al., 2013). In recent years, the application of prepared core technologies (PCTs) aimed at the production of predetermined blanks has been demonstrated in several Acheulian contexts (e.g., Santonja and Villa, 2006; Nowell and White, 2010; Picin et al., 2013; Terradillos-Bernal, 2013; Adler et al., 2014; Garcia, 2015; Hérisson et al., 2016; Shimelmitz et al., 2016; Zaidner and Weinstein-Evron, 2016; Goren-Inbar et al., 2018; Michalec et al., 2021; Rosenberg-Yefet et al., 2021; Shipton, 2022). It is often suggested that the invention and assimilation of PCTs, seen by some as the precursors of the Levallois method, reflect a significant shift in cognitive and technological capabilities of Paleolithic populations (Ambrose, 2001; Stout, 2010; Wynn and Coolidge, 2010; Eren and Lycett, 2012; Cole, 2015; Muller et al., 2017).

In this paper, we explore patterns of flint procurement and exploitation at the Late Acheulian site of Jaljulia (Israel), with a special focus on the bifaces and PCT-related artifacts found at the site. We aim at shedding light on the considerations which influenced flint type selection in Jaljulia, and on the circumstances leading to the emergence and adoption of PCTs during the Levantine Acheulian, and their link to the concept of cumulative culture, in light of the work by Rosenberg-Yefet et al. (2021). For this purpose, we visually classified flint artifacts from Jaljulia into flint types, using four separate samples: a general sample, including artifacts from various typo-technological categories; a sample of bifaces; a sample of “regular” cores (with one or two striking platforms), and a sample of PCT-related artifacts. In addition, we performed a geologic survey, aimed at identifying potential flint sources in the vicinity of the

site, and a petrographic analysis of flint thin sections, aimed at identifying the geologic origin, and the potential sources, of the flint used at the site.

## THE MAIN TECHNOLOGICAL TRAJECTORIES OF THE ACHEULIAN

Generally, the Acheulian cultural complex is characterized by three major flake production technologies: the manufacture of large (over 10 cm long) flakes from giant cores for the production of bifaces; small to medium-sized flakes produced from a variety of cores; and small flakes, usually produced from “parent” flakes, often by means of lithic recycling (Lycett and Gowlett, 2008; Machin, 2009; Tryon and Potts, 2011; Agam et al., 2015; Shimelmitz, 2015; Agam and Barkai, 2018; Goren-Inbar et al., 2018; for an alternative view see; Bourguignon et al., 2004). These different core technologies demonstrate a wide variability, and often a wide range of executed activities (Rosenberg-Yefet et al., 2021, 2022). They also differ in their degree of predetermination and planning, as some demonstrate modified, prepared platforms and surfaces, while others do not. Medium-sized and small flakes are further used for the manufacture of various flake tools, used for a variety of tasks, including animal butchering, (e.g., Marinelli et al., 2021), scraping activities (e.g., Marinelli et al., 2019), and plant and tuber processing (e.g., Venditti et al., 2019b).

Handaxes, the hallmark of the Acheulian, are bifacially knapped and shaped artifacts, with a continuous cutting edge running along their contour, and a bi-convex section (Lycett, 2008; Sharon, 2009). They appear repeatedly throughout the entire Old World, starting from 1.8 mya, and until ca. 200,000 years ago in the Levant, with the emergence of the Levantine Middle Paleolithic Mousterian, and even later in Europe. Some scholars suggest that there is a trend in the size and degree of refinement of handaxes through time, with later handaxes being smaller and less refined (e.g., Jelinek, 1977; Matskevich et al., 2001; Zaidner et al., 2006). These suggestions, however, are still under debate. A recent morpho-technological study found this chrono-cultural division to be valid (Herzlinger et al., 2021a), but with Middle Acheulian bifaces to be of better craftsmanship than some of the Late Acheulian assemblages. Key (2019) has proposed, based on 2D and 3D analyses, that while the shape of Acheulian handaxes tends to be diverse and variable, their form is strongly dictated by the volume of the material used. Herzlinger et al. (2021b), however, argue, based on an analysis of Large Cutting Tools from early Acheulian ‘Ubeidiya, that while the final form of these artifacts was strongly affected by the morphological properties of the selected material, the initial choice to use this specific nodule/blank represents a purposeful selection. According to Herzlinger et al. (2021b), this reflects the advanced planning capacities of this early Acheulian population.

While the function(s) of handaxes is still under debate, Wynn and Gowlett (2018) describe the form of handaxes as being “over-determined”, meaning that Acheulian knappers invested more effort in the shaping of these artifacts than was needed for their functionality. This implies that there were factors beyond

functionality affecting the production of handaxes. Several studies have further stressed the possible non-utilitarian aspects of Acheulian bifaces, suggesting a more complex set of considerations in the manufacture of these artifacts (e.g., Kohn and Mithen, 1999; Carbonell and Mosquera, 2006; Shipton and White, 2020).

Another noteworthy component of Acheulian technologies is chopping tools. These artifacts are found in the archaeological record as early as 2.6 mya in Africa, and until 500–300 kya in Asia and the Levant (e.g., Toth, 1985; Barsky et al., 2015; Doronichev, 2016; Villa et al., 2016; Venditti et al., 2021). According to Leakey (1971), a chopper is a core-tool with an edge flaked on one or two intersected faces. While its identification as a core or a core tool is still under debate, a recent use-wear study has supported the classification of chopping tools as tools, used mainly for the chopping of hard and medium materials, most likely bones, probably oriented towards marrow extraction (Venditti et al., 2021).

Stone spheroids and polyhedrons are also well-known from Oldowan and Acheulian sites throughout the Old World (e.g., Bar-Yosef and Goren-Inbar, 1993; Mora and De la Torre, 2005; Sharon et al., 2010). Based on the finds from Olduvai Gorge, Leakey defined polyhedrons as “. . . angular tools with three or more working edges, usually intersecting” and spheroids as “. . . stone balls, smoothly rounded over the whole exterior. Faceted specimens in which the projecting ridges remain or have been only partly removed are more numerous. . .”. Still, the definition of these objects remains debated, with some viewing them as hunting tools (e.g., Isaac, 1987), exhausted cores (e.g., Sahnouni et al., 1997), hammerstones (e.g., Willoughby, 1985), or battering tools (e.g., Yustos et al., 2015). Assaf et al. (2020) suggested that such stone balls from Middle Pleistocene Qesem Cave (Israel) were used for the extraction of marrow, further contributing to the interpretation of these artifacts as tools rather than cores. It was further suggested that these stone balls tend to be made of limestone, as it provided better control over the knapping process (Assaf and Preysler, 2022).

## Prepared Core Technologies in the Acheulian

Prepared core technologies (PCT) of the Levantine Acheulian include proto-Levallois cores, prepared cores (general), and discoid cores (and for more details see Rosenberg-Yefet et al., 2022). PCT are unique blank production methods aimed at producing flakes or blades with a predetermined shape and size. It is said to provide greater control over the size and shape of the final item, compared to regular core technologies, through a meticulous preparation of the core in a series of removals which form the necessary core convexities and dictate the properties of the desired end products (Boëda et al., 1990; Boëda, 1995; Schlanger, 1996; Chazan, 1997; Eren and Lycett, 2012). Some suggest that it minimizes lithic waste while maximizing the end-product cutting edge (Brantingham and Khun, 2001). It has been identified in Middle Paleolithic sites in Africa, Europe and Asia, usually in contexts associated with *Homo heidelbergensis*, *Homo neanderthalensis*, *Denisovans* and *Homo*

*sapiens* (e.g., Eren and Lycett, 2012; Adler et al., 2014; Hublin et al., 2017; Akhilesh et al., 2018; Hu et al., 2019; Xia et al., 2020).

Levallois cores are typically characterized by two asymmetrical platforms, separated by a plane of intersection. The lower platform is relatively thick, and serves as the striking platform. The upper platform is slightly curved and serves as the production surface. Levallois cores can produce one flake, known as linear cores/preferential cores, or a series of flakes, termed recurrent cores. These cores are divided, based on the direction of the flaking, into unidirectional, bidirectional and centripetal (Inizan et al., 1999; Shea, 2013:84–93, and for more information see; Rosenberg-Yefet et al., 2021).

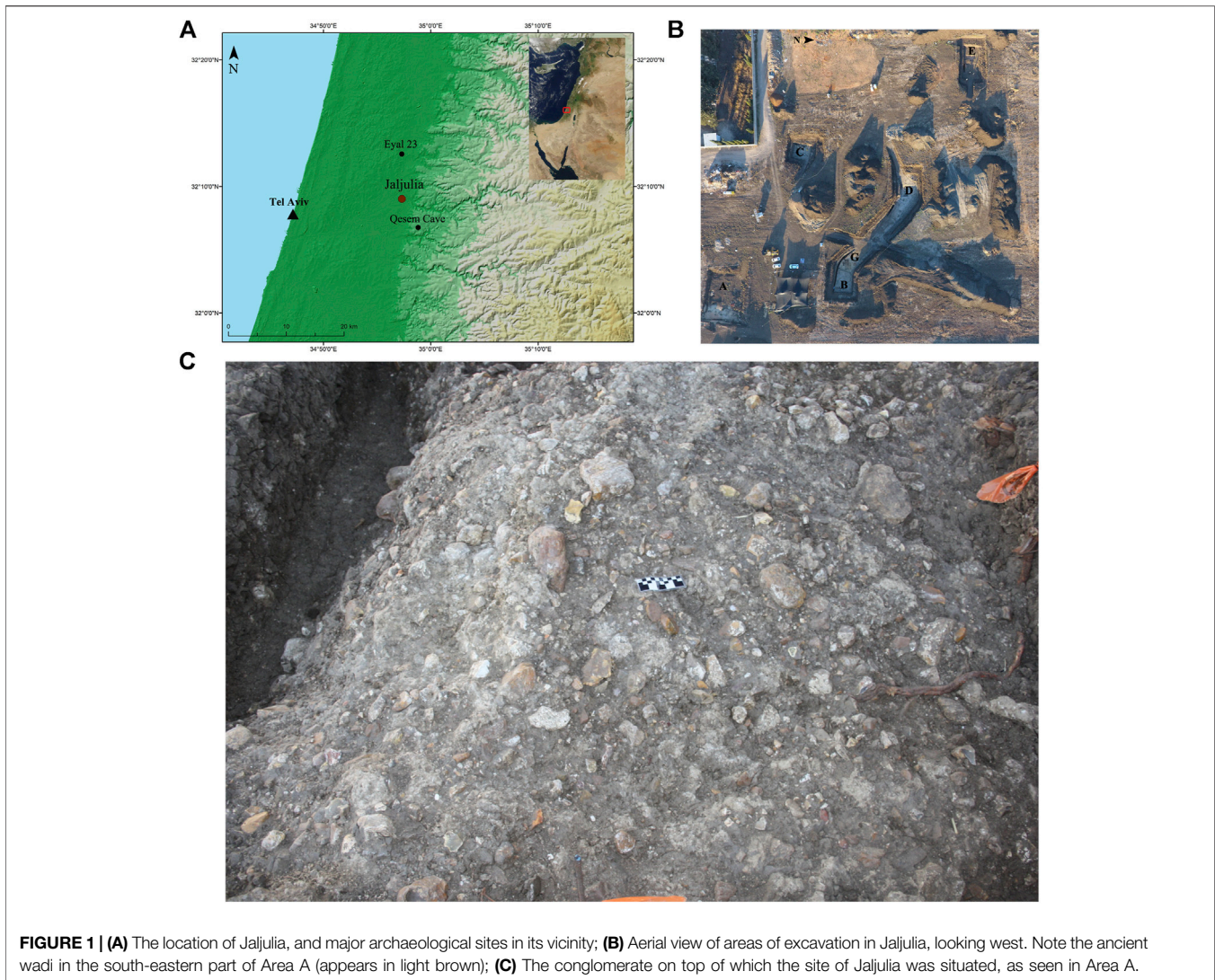
While it was thought in the past that the Levallois method emerged for the first time starting with the Middle Paleolithic Mousterian, several recent studies have securely demonstrated that PCTs, some of which bear similarities with Levallois, had already appeared during the Acheulian (e.g., Chazan 2000; Tryon et al., 2005; de la Torre, 2010; Goren-Inbar, 2011; Moncel et al., 2011; Picin et al., 2013; Adler et al., 2014; Shimelmitz et al., 2016; Zaidner and Weinstein-Evron, 2016; Goren-Inbar et al., 2018; Rosenberg-Yefet et al., 2021). This suggests that the origins of the Levallois method might have been rooted in the Acheulian (Rosenberg-Yefet et al., 2021). Yet the circumstances leading to the emergence of the Levallois methods remain debated.

The recycling of handaxes as “prepared cores” for the detachment of preferential flakes (Tuffreau, 1995; DeBono and Goren-Inbar, 2001; White and Ashton, 2003; Shimelmitz, 2015), has led to proposals linking Acheulian handaxes and the emergence of PCTs, setting the stage for the more fully fledged Levallois method (Rosenberg-Yefet et al., 2021). It has therefore been suggested that Acheulian flint knappers identified the potential in the volumetric structure of handaxes and took advantage of the convexities which characterize handaxes as a “shortcut” in the reduction sequence, allowing the manufacture of predetermined blanks with only a few preparation stages (Rosenberg-Yefet et al., 2021).

In the case of Jaljulia, the term “prepared cores” was used by Rosenberg-Yefet et al. (2021) to describe three groups of cores: proto-Levallois cores, prepared cores (general), and discoid cores. The definition of proto-Levallois cores used here follows Picin (2018), who suggested that for “*hierarchized unidirectional or proto-Levallois cores . . . The core’s volume is divided into two hierarchical surfaces, one a dedicated surface of striking platforms and the other a dedicated flaking surface. The striking platforms are roughly prepared and shaped by the removal of an invasive flake that creates a flat surface in five examples. However, the line of intersection of the striking platforms and the flaking surfaces is not perpendicular to the flaking axis of the predetermined blanks but instead to secant-producing flake platforms with obtuse angles. The lateral and distal convexities are roughly configured by flakes detached parallel or secant to the direction of the flaking production . . .*”

## THE SITE OF JALJULIA

Jaljulia is a Late Acheulian site, located just outside the town of Jaljulia, Israel, in the southern Sharon, on the eastern margins of

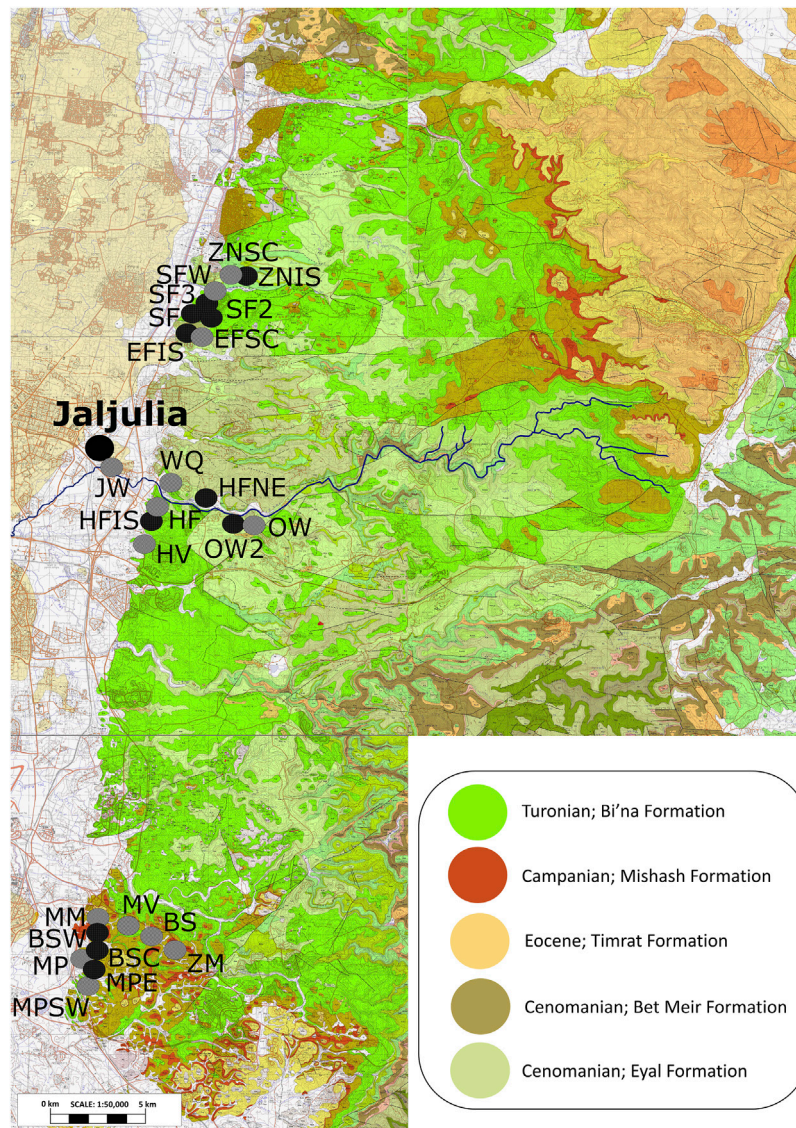


the coastal plain, about 18 km east of the present coastline (Shemer, 2019; **Figure 1A**). It is situated about 6 km south of the late Acheulian site of Eyal 23 and approximately 6 km northwest of the Acheulo-Yabrudian site of Qesem Cave (Ronen and Winter 1997; Gopher et al., 2005). Two seasons of excavation, conducted in 2017 by the Israel Antiquities Authority and in collaboration with the Department of Archaeology at Tel-Aviv University, revealed rich archaeological layers, containing abundant flint artifacts, along with a few isolated animal bones, yielded exclusively from Area D. The archaeological deposits, found at depths varying between 2 and 5 m below the modern surface, are estimated to be spread over an area of at least 1 ha, in what was a dynamic fluvial depositional environment (Shemer, 2019). Water activity was identified throughout the geological sections, implying a transition between a slowly flowing fluvial environment and a standing water body (Shemer et al., 2018).

The environment surrounding the site offered a favourable locality for the activity of early hominins, as indicated by the vast

distribution of archaeological deposits, which are currently considered to be the result of several separate occupations, possibly over a long period of time (Shemer, 2019). Six areas, labelled A through G (excluding F), covering an area of approximately 80 m<sup>2</sup>, were excavated at the site (**Figure 1B**). In Area G multiple horizons were revealed.

A typo-technological analysis of the lithic assemblages is currently underway, with preliminary results indicating that these assemblages are composed mainly of flakes and flake tools, with a notable component of handaxes, in addition to the clear presence of prepared cores. While the archaeological material presents some evidence of weathering, most of the excavated material is well-preserved (Shemer, 2019). The characteristics of the lithic assemblages have led to the preliminary assignment of Jaljulia to the Late Acheulian; chronometric dates are still pending but this indicates an expected time range between 500 and 300 kyr. (Shemer et al., Accepted). A paper providing a detailed presentation of the site's chronology and stratigraphy is soon to be published (Shemer et al., 2022).



**FIGURE 2 |** The geologic setting of Jaljulia, and the potential geologic flint sources located (Table 4). Primary sources are marked by dark circles; secondary sources are marked by light grey circles. Note Wadi Qanah and its tributaries, marked by a dark blue line, running from east to west.

A use wear analysis of the Jaljulia bifaces has demonstrated the processing of hard materials, most likely animal remains, mainly using percussive activities (Zupancich et al., 2021). Prepared cores demonstrate the application of both proto-Levallois production and Discoid production (Rosenberg-Yefet et al., 2021, 2022). Rosenberg-Yefet et al. (2021) argue that Jaljulia PCT-related artifacts reflect an investment of effort in artifact production, pre-planning of the knapping process, and a well-established body of knowledge concerning their manufacture. Rosenberg-Yefet et al. (2022) further argue that the well-established appearance of prepared cores in Jaljulia, as well as in Late Acheulian Revadim, testifies for the emergence of concepts associated with the Levallois method.

## THE GEOLOGIC SETTING

Jaljulia is located within a Turonian (Upper Cretaceous) terrain, known to contain many exposures of flint-bearing limestone of the Bi'na Formation (Hildebrand-Mittlefehldt, N. 2011; Figure 2). The site was deposited immediately above an ancient conglomerate (Figure 1C), a remnant of the floodplain of the nearby Wadi Qanah, which flowed from the east (Shemer, 2019). In Area A of the site, an ancient streambed was uncovered, representing most likely an old channel of Wadi Qanah (Figure 1B). Jaljulia sits 100 m north of the current channel of the wadi, which flows from south of Mount Gerizim, through the Sharon Plain, just south of Jaljulia, and westwards to the Mediterranean (Figure 2). Both the ancient and the current wadi channels are rich in flint nodules of various shapes and

**TABLE 1** | The breakdown of the general sample used in this study.

Category	Area B	Area D	Total
Shaped Items	78	87	165
Flakes	50	32	82
Cortical Flakes	18	29	47
Cores <sup>a</sup>	24	31	55
Core Trimming Elements (CTEs)	10	6	16
Cores-on-Flakes and their products	13	16	29
Blades	1	—	1
Cortical Blades	2	2	4
Shaped items Spalls	8	—	8
<b>Total Number of Artifacts</b>	<b>204</b>	<b>203</b>	<b>407</b>

<sup>a</sup>Including 1 platform, 2 platform and >2 platform cores, blade cores, core fragments, and tested cores.

sizes, originating from various geologic sources. The flint nodules available within the site's conglomerate and in Wadi Qanah were most likely a major source of the lithic materials used by Jaljulia's inhabitants (Shemer, 2019).

The eastern section of Wadi Qanah, ~25–30 km east of Jaljulia, is located near several flint-bearing outcrops of various geologic formations, including Eocene limestone of the Timrat Formation (of the Avedat Group), and Cenomanian (Upper Cretaceous) limestone of the Beit Meir Formation (Judea Group) (Sneh and Shaliv, 2012; **Figure 2**). Additionally, outcrops of Campanian (Upper Cretaceous) flint of the Mishash Formation (Mount Scopus Group) are known to exist about 25–30 km east of Jaljulia (Sneh and Shaliv, 2012).

## MATERIALS AND METHODS

### Materials

Two assemblages from Jaljulia, from Areas B and D, were sampled and analyzed, based on the proportions of each typo-technological category within each assemblage, and were visually classified into flint types ( $n = 407$ ; **Table 1**). These two assemblages are analyzed here both individually, as two separate assemblages, and as an integrated sample. This is aimed at evaluating spatial and possible chronological differences and similarities between the different human occupations at the site. It is also used to reflect broader phenomena of flint selection and preferences during the Late Acheulian of the Levant, as well as to establish a link between the used flint types and the possible origins of Prepared Core Technologies in the late stages of the Levantine Acheulian as a whole. A detailed typo-technological analysis of these lithic assemblages will be published separately. To randomize the selection of these samples, bags of archaeological material were organized in a row, and every third bag was picked. Each selected bag was fully analyzed, until we reached a sample size of at least 200 artifacts from each assemblage (completing the analysis of the last bag), using the same criteria used in Wilson et al. (2016) and Agam (2020), based on the parameters described in detail below. The term “the general sample” appearing throughout this paper refers to this sample. Please note that while the lithic assemblages include chips, chunks and broken flakes, our sample excluded these items as we focus here on *débitage* categories only.

**TABLE 2** | The PCTs sample from Area B.

Category	Type of Blank			
	Cores	CTE	Flakes	Total
Discoid	26	—	14	40
Proto-Levallois	37	20	5	62
Prepared cores (general)	7	39	64	110
<b>Total Number of Artifacts</b>	<b>70</b>	<b>59</b>	<b>83</b>	<b>212</b>

Separate samples included all PCT-related artifacts found in the lithic assemblage of Area B in Jaljulia, and which were available for analysis at the time of data collection ( $n = 212$ ; **Table 2**), and a sample of 60 bifaces (30 from Area B and 30 from Area D). For the biface sample, all bifaces were analyzed, with no selectivity, until we reached 30 bifaces from each assemblage. The PCT-related artifacts in Jaljulia include cores, Core Trimming Elements (CTEs) and products, and are divided into three sub-types: Proto-Levallois, prepared cores (general), and discoid cores. The artifacts analyzed here follow this division. It should be stressed that PCT-related artifacts were also found in the lithic assemblage of Area D in notable proportions. However, at the time of the analysis presented here, these artifacts were not yet available for analysis. Therefore, PCT-related artifacts from Area D are not included in this current study and will be discussed elsewhere. The PCT-related artifacts from Area B are compared to the bifaces sample, the general sample, and to “regular” cores from Areas B and D with one and two striking platforms ( $n = 43$ ). The ‘regular’ cores sample is taken from the general sample, and forms the entire component of one and two platform cores within the general sample.

### Methods

The archaeological artifacts analyzed here were classified into flint types, based on their visual traits, and weighed. The flint types were labeled alphabetically by order of identification. For each flint type, at least one specimen was selected and set aside to be used in comparing and assigning subsequent pieces to flint types. Flint types were classified based on macroscopic traits, such as colour, texture, size and shape of the original nodule (if detectable), degree of homogeneity (based on size of any disturbances, divided into homogeneous, moderately homogenous and heterogenous), degree of translucency (divided into translucent, moderately translucent and opaque), traits of cortex and any visible fossils. The different flint types were then grouped based on shared traits, such as similar texture, similar patterns (e.g., stripes, spots, etc.), the presence of breccia, and more.

Different flint types are defined here by the presence of distinctive morphological and visual features. The visible traits of flint are defined as those visible to the human eye, either with or without magnification (Luedtke, 1992: 59). The differences in colour, texture, fossil presence and other visual characteristics are in many cases the expression of different geologic origins (Malyk-Selivanova et al., 1998; Milne et al., 2009; Allan and Bolton, 2017). Furthermore, texture, shape and structure may influence the quality and degree of flakeability of a flint piece (Bustillo et al.,

2009), and thus its attractiveness and the likelihood of it being chosen for knapping by prehistoric people.

Potential geologic sources were located, surveyed and sampled, following the geologic maps of the region. The survey started with the local Turonian sources, and went as far as up to a distance of ~20 km south of the site (Ilani, 1985; Yechieli, 2008; Hildebrand-Mittlefehldt, 2011). Flint samples were collected from these potential sources. Campanian flint samples of the Mishash Formation, collected from the Ben Shemen Forest, located some 21 km south of Jaljulia, were also used for comparisons.

As mentioned above, some non-Turonian potential flint sources are known to exist 25–30 km to the east of Jaljulia, along the trajectory of Wadi Qana. These sources, however, were not surveyed during this study because of modern geopolitical circumstances. Therefore, we have no information about the abundance of these sources, nor their extent, nature and variety, and therefore cannot include them in this study. It is also possible that the construction of roads and buildings has removed some of the flint sources which existed in the area during prehistory. Consequently, we cannot know the exact number and extent of potential sources which were available to the Jaljulia hominins. These limitations should be kept in mind in our discussion. However, while we could not fully map all potential sources around Jaljulia, the distribution of the sources which we did locate, along with the fact that the site is located immediately next to and directly above rich flint sources, may provide useful insights concerning lithic-related human behaviours at Jaljulia.

Finally, nine standard petrographic thin sections were produced and studied to better understand the geologic origin of the brecciated flint types found at the site. These include three thin sections of samples from Turonian sources; three thin sections of samples from Campanian sources, and three thin sections of archaeological samples from Jaljulia. The thin sections were manufactured in the Thin Section Shop at the Department of Earth Sciences, University of New Brunswick, Fredericton, N.B., Canada. Each thin section was described in terms of the minerals present, the grain size, micro-fossils, degree of homogeneity, and texture. The thin sections were analyzed by optical microscopy in both plane-polarized and cross-polarized light, using a ZEISS Axio Scope.A1 Polarized Light Microscope in the Prehistory lab at Tel-Aviv University, Israel, and a Leitz Wetzlar monocular polarising petrographic microscope in the Geology lab at the Saint John campus of the University of New Brunswick, Canada.

All the data presented in this paper were tested using a Chi Square Test, to evaluate whether any of the results are statistically significant. This was performed using Excel software. Only statistically significant results ( $p < 0.05$ ) are mentioned here.

## RESULTS

### Flint Types and Groups of Flint Types

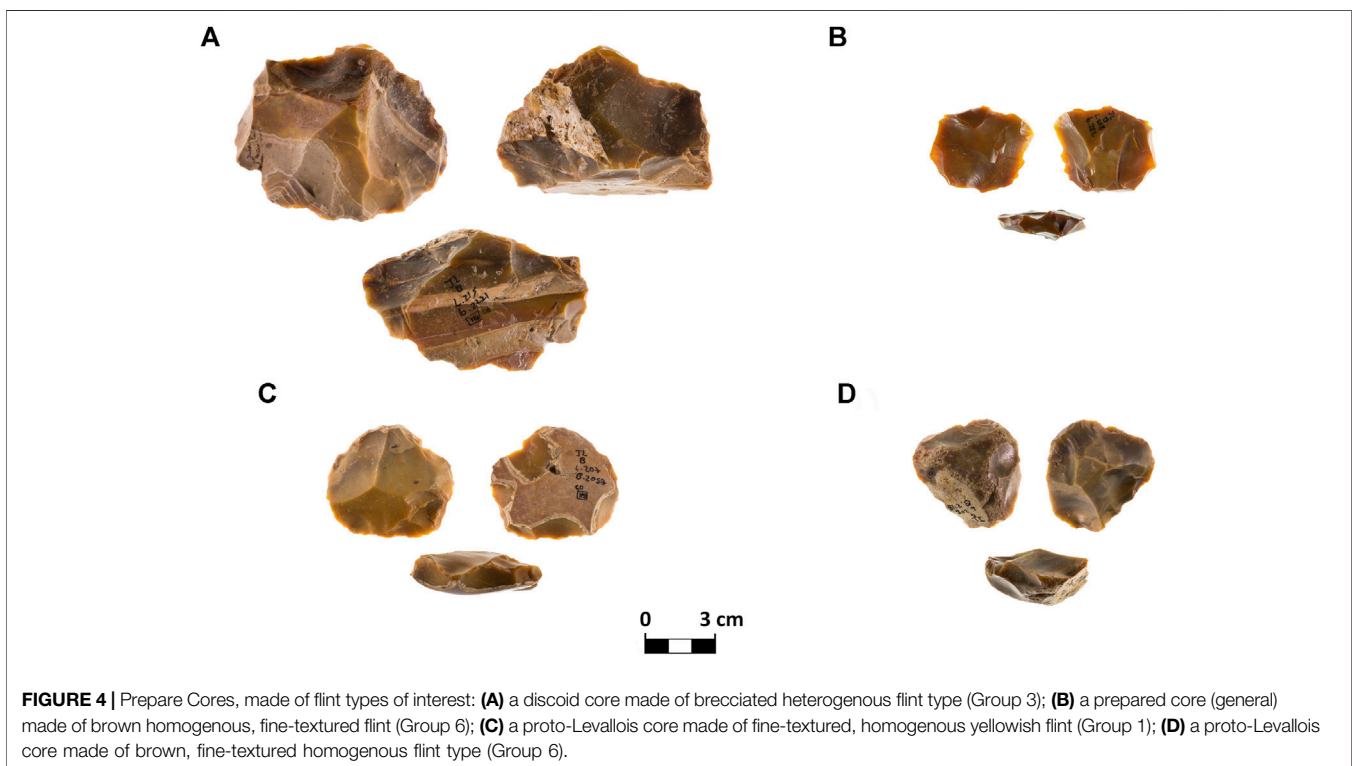
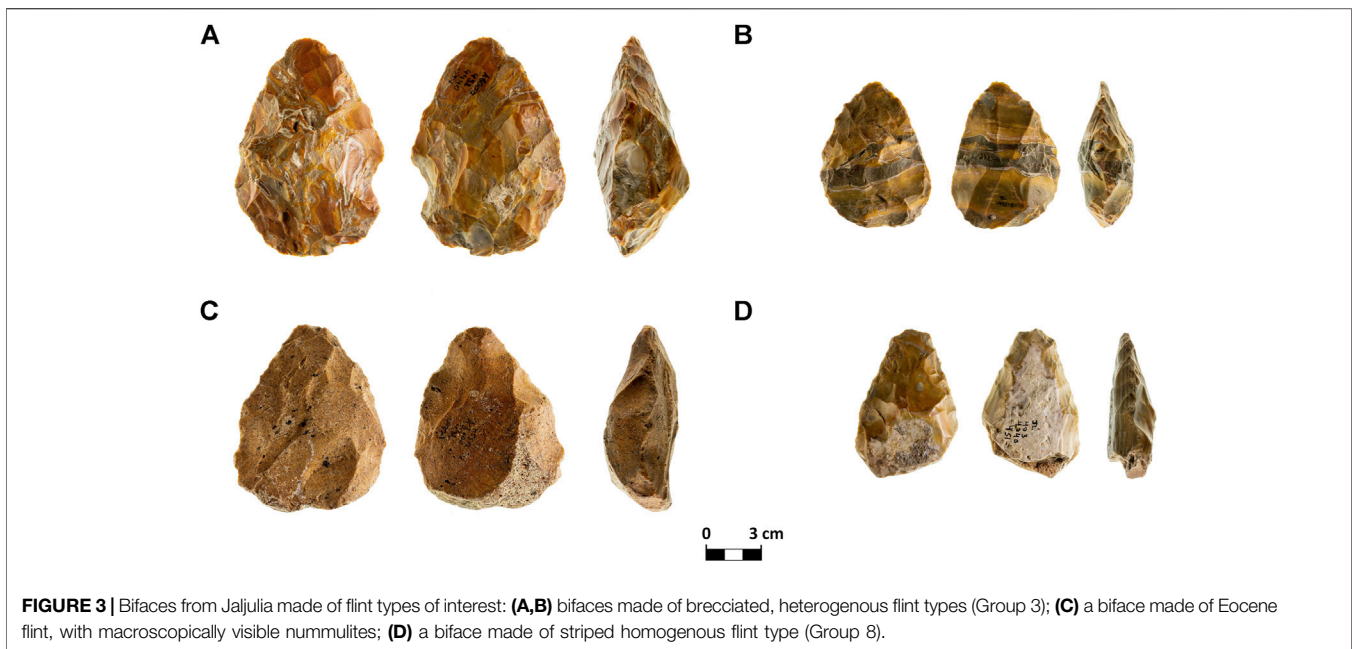
In total, 35 different flint types were described within the Jaljulia sample (**Supplementary Table S1**), and clustered into 10 groups

(**Figures 3, 4; Table 3**). The most common is Group 3, a group of brecciated flint types, followed by Group 1, a group of fine-textured, homogenous yellowish flint types, and Group 6, brown fine-textured homogenous flint types. It should be stressed that most artifacts from Jaljulia are covered by patina, and therefore do not necessarily reflect the original colours of the flint types used.

Almost a half of the general sample is of heterogenous flint (46.7%; **Figure 5A**). Another third is homogenous. The majority of analyzed artifacts (63.4%) are fine-textured (**Figure 5B**). This pattern consistently repeats itself among the different typotechnological categories.

An interesting pattern was observed among the Cores-on-Flakes (COFs; see Agam and Barkai, 2018). While most analyzed flint pieces are fine-textured (63.4%), the proportion of fine-textured flint types among the COFs is greater still (72.2%;  $n = 13$ ). This difference was found to be statistically significant ( $X^2 = 7.59$ ,  $df = 1$ ,  $p < 0.05$ ). This suggests that fine-textured flint types were preferred for the production of small flakes by means of lithic recycling, possibly because of the extremely sharp edges they tend to form (Venditti et al., 2019a). On the other hand, blanks produced from COFs present lower proportions of fine-textured flint types (54.5%;  $n = 6$ ). This may suggest that the desired small flakes produced from COFs were moved to other locations, either within the site, or, alternatively, out of it, while the cores and less desired flakes remained. We hope to be able to test this hypothesis by applying use-wear analysis to these samples in the future. Previous studies have shown that the production of small flakes by means of lithic recycling was an integral trajectory of flake production during the Late Acheulian of the Levant (Agam et al., 2015; Agam and Barkai, 2018). Use-wear and residue analyses of such small flakes from the Late Acheulian site of Revadim indicated their possible role in specific butchery practices that necessitate precision and accuracy (Venditti et al., 2019b, but see; Bilbao et al., 2019). This unique pattern of flint exploitation further stresses the special place of small flakes in the lives of Levantine Acheulian groups.

When comparing Assemblages B and D, a clear consistency in patterns of exploitation can be seen. Both assemblages, for instance, are dominated by fine-textured, homogenous flint types (55.1 and 53.6%, respectively). The proportions of brecciated flint types are also similar (36.3 and 37.8%, respectively). The resemblance in the patterns observed in both assemblages implies a consistency in flint exploitation and selection throughout space, and possibly time, as implied by the chronological differences between the two areas (and for more on the chronology of Areas B and D see Shemer et al., 2022). This may testify to the existence of knowledge transmission procedures among group members concerning the availability of specific flint types in specific locations, as well as concerning the suitability of specific flint types for the production of specific blanks. Preliminary (unpublished) chronometric investigations suggest that area D was inhabited around 500 kyr while area B is much younger, most probably around 330 kyr (Shemer et al., 2022). If these dates are confirmed, this might indicate long-term use of the paleolandscape and long-lasting technological traditions practiced at the site of Jaljulia.



### PCT-Related Artifacts, Cores and Bifaces

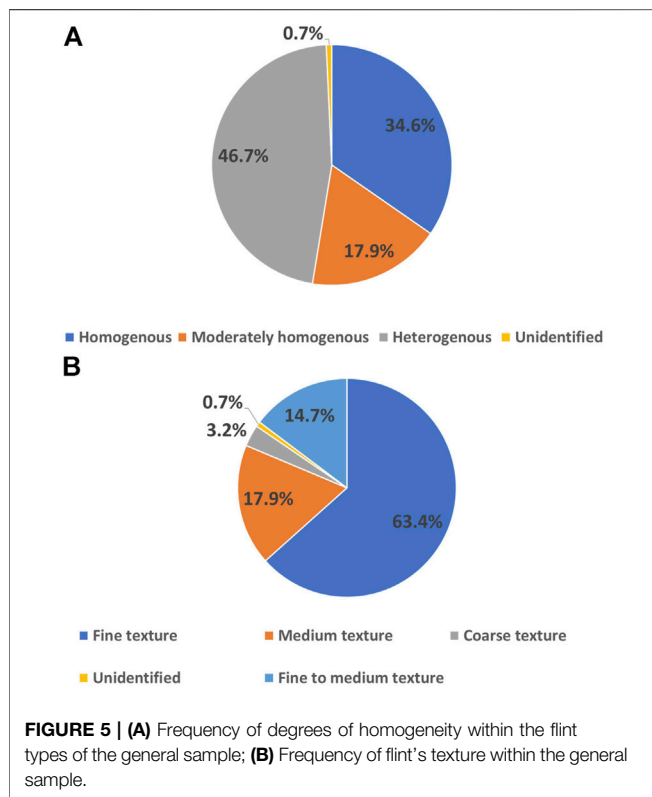
Here we compare the results of the general sample to those of the bifaces, the PCT-related artifacts and the sample of the ‘regular’ cores (cores with one or two platforms). Note that the sample of prepared cores (general) includes only seven cores (Table 2), so these results should be treated cautiously.

“Regular” cores are the heaviest among the different core categories (with an average of 90.9 g; median: 71.0 g;  $n = 43$ ), followed by discolored cores (89.8 g on average; median: 65.5 g;  $n = 26$ ). Proto-Levallois cores are lighter still (74.0 g in average; median: 45.0 g;  $n = 37$ ), while prepared cores (general) are significantly lighter (23.0 g on average; median: 22.0 g;  $n = 7$ ).



**TABLE 3 |** List of the Jaljulia groups of flint types, the flint types included, their descriptions, and their frequency in the sample.

Group	Description	Flint Types Included	Qty.	%
3	Brecciated flint types	C, N, Q, R	127	31.2
1	Fine-textured, homogenous yellowish flint types	A, D, F, G, V, W, AA, AD	110	27.0
6	Brown fine-textured homogenous flint types	K, U, AB, AC	58	14.3
8	Striped fine-textured, homogenous flint types	O, S, X	27	6.6
5	Fine-textured, homogenous brown flint types with minor inclusions	H, M, Z	26	6.4
4	Fine-textured, homogenous, possibly burnt reddish flint types	E, I, J, Y	21	5.2
7	Fine-textured, homogenous spotted flint types	L, AE, AF, AJ	18	4.4
2	Coarse-textured, yellow to orange opaque homogenous flint types	B	13	3.2
9	Coarse-textured, homogenous, brown flint types, possibly with fossils	P, AG, AH, AI	3	0.7
Too weathered to be identifiable to any source	—	—	3	0.7
10	White homogenous, fine-textured, opaque flint types	T	1	0.2
<b>Total Number of Artifacts</b>			<b>407</b>	<b>100.0%</b>



Flint type C, a grey-green to orange-patinated heterogenous opaque brecciated flint type, is the most common flint type in the general sample and among the bifaces, discoid cores and proto-Levallois cores (Figure 6A). It is, however, significantly more common among the bifaces, while being completely absent among the prepared cores (general). The difference observed between the bifaces and the general sample was found to be statistically significant ( $X^2 = 21.00$ ,  $df = 1$ ,  $p < 0.05$ ).

The second most common flint type in the general sample is Type G, a light brown to orange semi-translucent fine-textured flint, with grey-yellow opaque spots (11.1%;  $n = 45$ ). Its percentage among the “regular” cores is similar (11.6%). Its percentage among the small sample of prepared cores

(general), however, is dramatically higher (4 out of 7; 57.1%;  $X^2 = 12.99$ ,  $df = 1$ ,  $p < 0.05$ ), while it is notably less common among the bifaces and discoid cores.

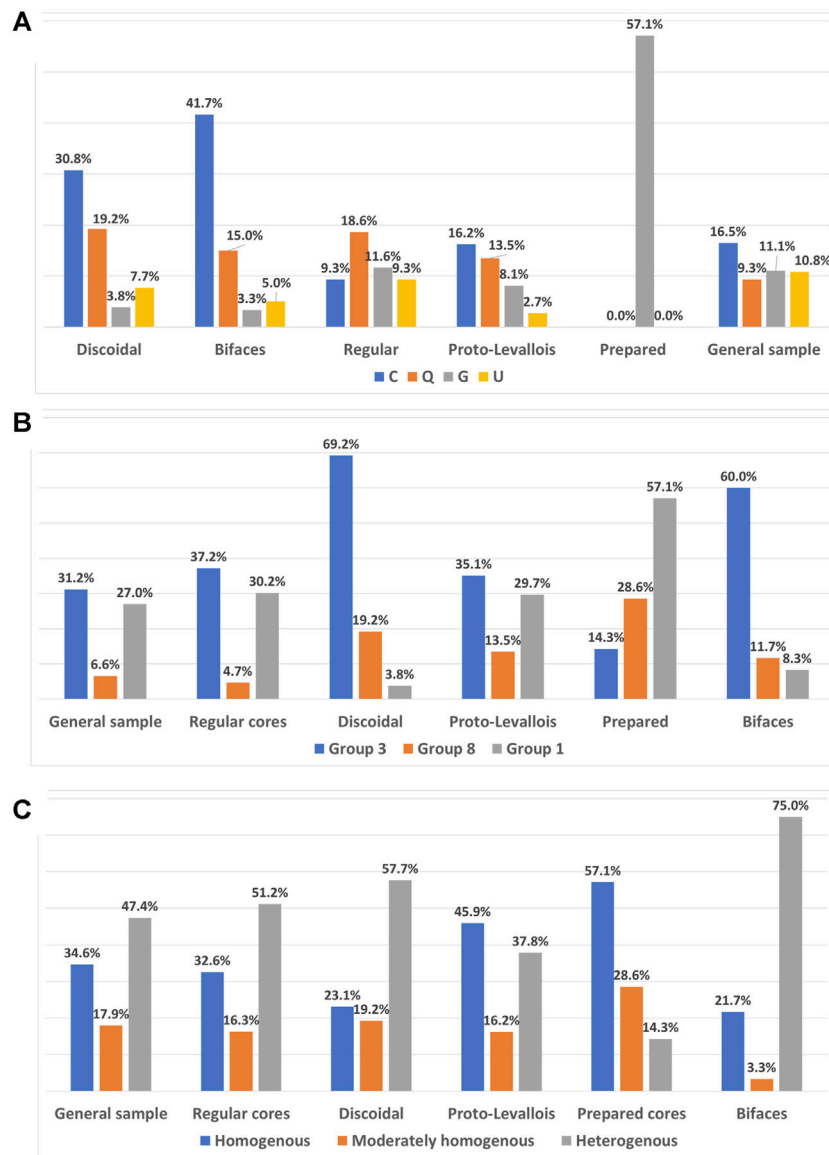
The proportions of Flint Type U, a dark brown fine-textured translucent brecciated flint type, are also of note. While it is relatively frequent in the general sample, the ‘regular’ cores and the discoid cores, its proportions are lower among the bifaces and the proto-Levallois cores, and it is completely absent from the prepared cores (general).

Group 3, a group of brecciated flint types, is the most common group in the general sample (31.2%; Figure 6B). It is, however, significantly more common among the bifaces (60.0%;  $n = 36$ ;  $X^2 = 19.08$ ,  $df = 1$ ,  $p < 0.05$ ). A link between the production of bifaces and the exploitation of brecciated flint types was suggested in the past (Agam et al., 2020). This may be due to the tendency of brecciated flint types to appear in large packages, making them more suitable for biface production. Another possibility is that brecciated flint types lead to more durable tools. This suggestion, however, is yet to be demonstrated.

High proportions of Group 3 were also observed among discoid cores (69.2%;  $n = 18$ ;  $X^2 = 15.87$ ,  $df = 1$ ,  $p < 0.05$ ; Figure 6B). The proto-Levallois cores and “regular” cores, on the other hand, present similar, lower proportions of Group 3 (Figure 6B). These proportions are in accordance with those in the general sample. Among the products of the discoid cores, however, the proportions of Group 3 are notably lower (28.6%;  $n = 4$ ) than among the discoid cores, possibly suggesting that some of these are not easy to recognize, or that these products were transported elsewhere.

Group 8, a group of striped fine-textured, homogenous flint types, probably of local Turonian origin, is more frequent among the discoid, proto-Levallois and prepared cores (general) than among the “regular” cores and the general sample (Figure 6B). Its proportions are also somewhat higher among the bifaces, compared to the general sample and the regular cores. These proportions, however, are significantly lower than those of the brecciated flint types.

Group 1, a group of fine-textured, homogenous yellowish flint types, is also interesting. Its frequency is high in the general sample, as well as among prepared cores (general), proto-Levallois cores and “regular” cores, while being notably lower among bifaces and discoid cores.



**FIGURE 6 | (A)** The frequency of major flint types in the general sample, the bifaces and the four core groups: discoid, Levallois, prepared (general) and “regular” cores. Note that not all flint types are included in this chart, resulting in a sum lower than 100% for each category; **(B)** The proportions of Groups 3, 8 and 1 in the different analyzed categories; **(C)** The proportions of artifacts with different degrees of homogeneity by groups.

Artifacts with patina differences (i.e., with post-patination removals) constitute 25.1% of the general sample ( $n = 102$ ). Such artifacts are significantly less common among the bifaces (1.7%;  $n = 1$ ;  $X^2 = 16.65$ ,  $df = 1$ ,  $p < 0.05$ ), discoid cores (3.8%;  $n = 1$ ;  $X^2 = 6.07$ ,  $df = 1$ ,  $p < 0.05$ ), proto-Levallois cores (13.5%;  $n = 5$ ) and prepared cores (general) (14.3%;  $n = 1$ ), implying that both bifaces and PCT-related categories were more frequently manufactured from fresh blanks rather than “old” recycled blanks (but see Rosenberg-Yefet et al., 2021).

Homogenous flint types are more common among prepared cores (general) (57.1%;  $n = 4$ ) and proto-Levallois cores (45.9%;  $n = 17$ ) than in the other categories (**Figure 6C**).

This may imply that while heterogenous flint types were often used for the manufacture of proto-Levallois cores (as implied by the notable presence of brecciated flint types), homogenous flint types were found to be better suitable for PCT production. This is further supported by the frequency of homogenous flint types among the proto-Levallois flakes (60.0%;  $n = 3$ ) and the flakes produced from discoid cores (71.4%;  $n = 10$ ;  $X^2 = 7.96$ ,  $df = 1$ ,  $p < 0.05$ ). It is possible that the success rate of flake production from such cores was higher when using homogenous flint types. Among the bifaces, on the other hand, heterogenous flint types are significantly more frequent (75.0%;  $n = 45$ ;  $X^2 = 15.92$ ,  $df = 1$ ,  $p < 0.05$ ; see explanation above).

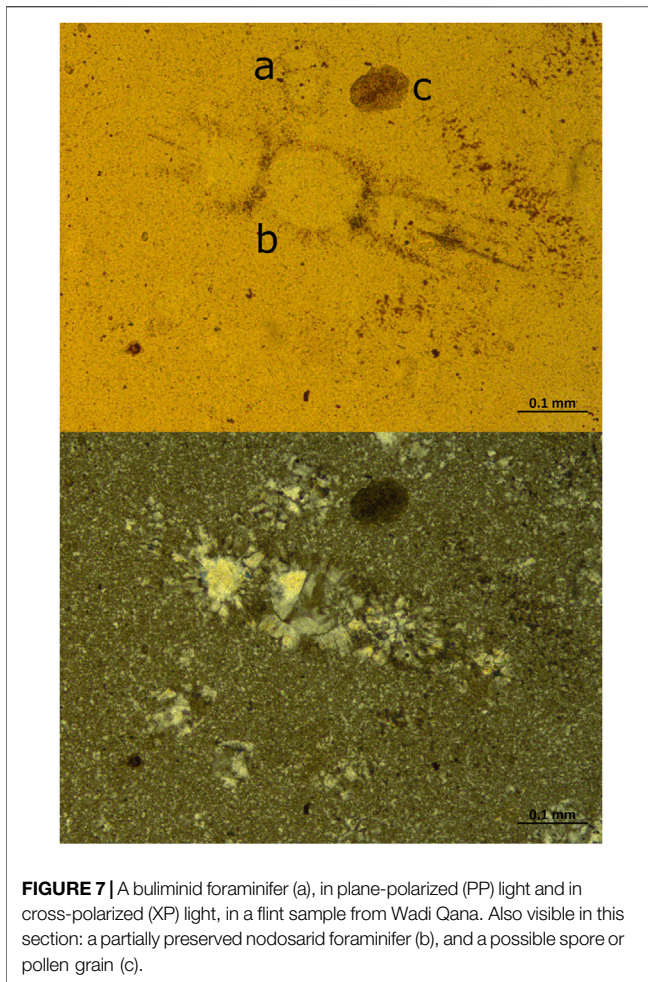
**TABLE 4** | A full list of the identified potential flint sources.

	Name	ID	Coordinates	Age	Formation	Distance from Jaljulia (in km)	<i>In Situ</i> /Secondary
1	Jaljulia Wadi	JW	32° 8'58.96"N, 34°57'42.79"E	Turonian? Campanian? Cenomanian?	?	—	Secondary
2	Wadi Qana	WQ	32° 8'52.49"N, 34°58'4.78"E	Turonian, Campanian?	Bi'na? Mishash? Others?	0.68	Secondary
3	Horashim Forest <i>In situ</i>	HFIS	32° 8'28.58"N, 34°58'18.38"E	Turonian	Bi'na	1.40	Primary
4	Horashim Forest	HF	32° 8'30.27"N, 34°58'23.54"E	Turonian	Bi'na	1.45	Secondary
5	Horashim Village	HV	32° 8'14.56"N, 34°58'7.00"E	Turonian	Bi'na	1.59	Secondary
6	Horashim Forest North-East	HFNE	32° 8'31.91"N, 34°59'9.86"E	Turonian	Bi'na	2.52	Primary
7	Oranit West #2	OW2	32° 8'4.31"N, 34°59'6.64"E	Turonian	Bi'na	2.86	Primary
8	Oranit West	OW	32° 7'59.81"N, 34°59'8.82"E	Turonian	Bi'na	2.97	Secondary
9	Eyal Forest <i>In Situ</i>	EFIS	32°12'41.57"N, 34°59'1.80"E	Upper Cenomanian - Turonian	Eyal	7.15	Primary
10	Eyal Forest Surface Collection	EFSC	32°12'41.57"N, 34°59'1.80"E	Upper Cenomanian - Turonian	Eyal	7.23	Secondary
11	Sapir Forest	SF	32°13'12.18"N, 34°59'6.59"E	Cenomanian or Turonian	Sakhnin/Bi'na	8.15	Primary
12	Sapir Forest Wadi	SFW	32°13'13.78"N, 34°59'10.20"E	Cenomanian or Turonian	Sakhnin/Bi'na	8.18	Secondary
13	Sapir Forest 2	SF2	32°13'11.98"N, 34°59'9.19"E	Cenomanian or Turonian	Sakhnin/Bi'na	8.23	Primary
14	Sapir Forest 3	SF3	32°13'14.37"N, 34°59'9.54"E	Cenomanian or Turonian	Sakhnin/Bi'na	8.31	Primary
15	Zur Natan <i>In Situ</i>	ZNIS	32°14'24.34"N, 35° 0'42.64"E	Cenomanian	Sakhnin	11.03	Primary
16	Zur Natan Surface Collection	ZNSC	32°14'25.27"N, 35° 0'43.11"E	Cenomanian	Sakhnin	11.04	Secondary
17	Mexican Monument	MM	31°57'6.57"N, 34°56'26.50"E	Campanian	Mishash	22.08	Secondary
18	Modiin Viewpoint—Mitzpe Modiin	MV	31°56'57.52"N, 34°57'24.09"E	Campanian	Mishash	22.25	Secondary
19	Ben Shemen	BS	31°56'42.06"N, 34°58'9.07"E	Campanian (Upper Cretaceous)	Mishash	22.53	Secondary
20	Ben-Shemen West	BSW	31°56'48.19"N, 34°56'17.15"E	Campanian	Mishash	22.68	Primary
21	Ben-Shemen Center	BSC	31°56'43.39"N, 34°56'16.67"E	Campanian	Mishash	22.84	Primary + Secondary
22	The Monkeys Park	MP	31°56'38.31"N, 34°55'59.94"E	Cretaceous (Campanian?)	Mishash?	23.03	Secondary
23	Monkeys Park East	MPE	31°56'35.70"N, 34°56'8.76"E	Campanian	Mishash	23.07	Primary + Secondary
24	Monkeys Park South-West	MPSW	31°56'25.59"N, 34°55'48.15"E	Campanian	Mishash	23.47	Secondary
25	Zaglembie Martyrs (Memorial)	ZM	31°56'14.53"N, 34°59'1.06"E	Campanian (Upper Cretaceous) and/ or Santonian (Upper Cretaceous)	Mishash and/or Menuha Formation	23.70	Secondary

## The Potential Geologic Sources of the Jaljulia Flint Types

In total, 25 potential flint sources were found in the area surrounding Jaljulia (Table 4; Figure 2). These include Turonian sources of the Bi'na Formation, located in the immediate vicinity of the site and up to 3 km away; Cenomanian sources of the Eyal and Sakhnin Formations,

located some 7–8 km north of Jaljulia; and Campanian sources of the Mishash Formation, located 22–24 km south of the site. **Supplementary Table S1** presents the association between the Jaljulia flint types and the potential flint sources, based on macroscopic and petrographic similarities, and their assignment to geologic origins; **Supplementary Table S2** presents the general sample and flint types and their assignment to geologic origins.



**FIGURE 7** | A buliminid foraminifer (a), in plane-polarized (PP) light and in cross-polarized (XP) light, in a flint sample from Wadi Qana. Also visible in this section: a partially preserved nodosarid foraminifer (b), and a possible spore or pollen grain (c).

The site of Jaljulia is located 100 m north of the current course of Wadi Qanah, with a possible old channel of the river found in Area A at the site. Additionally, the archaeological layers of Jaljulia were deposited directly above a rich conglomerate containing plenty of flint nodules suitable for knapping (Shemer, 2019; **Figure 1C**). Therefore, it is not surprising that flint types available in the river channel were often used by the site's inhabitants. Furthermore, it is likely that these local rich secondary sources of flint deposits played a part in the decision to settle at the location in the first place and to keep coming back to this preferable locale over significant time periods (Agam, 2020).

Brecciated flint types, which were often used at the site, especially for the production of bifaces and discoid cores, are often considered to be characteristic of the Campanian Mishash Formation (Kolodny, 1969), implying a non-local origin. However, Kolodny et al. (2005) suggest that the cracking, fragmentation and tearing involved in the formation of a brecciated texture are integral parts of the maturation of siliceous sediment into flint. If so, brecciated flint types might be associated with more than the Campanian Mishash Formation, and such a provenance identification should be treated cautiously.

The Campanian Mishash Formation sources closest to Jaljulia are located ~22 km south of the site, in the Ben-Shemen Forest. Additional Campanian Mishash sources are located some 30 km east to the site, in the Shekhem region (Sneh and Shaliv 2012). This would, theoretically, imply that such flint types could have been procured only from distant sources. However, as stated above, the eastern sections of Wadi Qana run by potential flint sources of the Campanian Mishash Formation. The wadi therefore could have potentially contained flint eroded from these eastern sources. In fact, a buliminid foraminifer, a fossil associated with Campanian Mishash flint (**Figure 7**), was observed in a thin section of a sample from the segment of Wadi Qana running through Horashim Forest (~1 km east of Jaljulia). Brecciated flint types were also observed within the ancient wadi found in Area A and in the current bed of Wadi Qana. Future work will attempt to determine whether these breccias are indeed Mishash or of some other origin, but the possibility remains that Campanian flint might have been procured locally from the channel bed and used extensively by the Jaljulia hominins.

As we can assume that the availability of flint at the paleo-landscape was one of the considerations encouraging hominins to settle there to begin with, it makes sense that most of the flint (but not necessarily all of it), would have come from the immediate vicinity of the site. Indeed, a preliminary classification of the Jaljulia flint types to their potential geologic origins, based on macroscopic and petrographic data, shows that all analyzed groups are dominated by locally available flint (**Table 5**), either from a Turonian origin, or from another, more distant source, which was secondarily deposited near Jaljulia. Interestingly, the proportions of such locally available flint are more accentuated among the bifaces (81.7%;  $n = 49$ ), PCTs artifacts (82.3%;  $n = 51$ ) and discoid cores (85.0%;  $n = 34$ ), compared to the general sample and the prepared cores (general). While other types are present in lower proportions, the presence of some Campanian flint types which were not observed in local sources, as well as Cenomanian and Eocene flint types, is of note, indicating the transportation of flint from non-Turonian sources, either by streams, or by human agency. The closest Cenomanian sources (Eyal Formation) are located ~8 km north of Jaljulia. The closest Eocene sources, of the Timrat Formation, are located some 30 km east of Jaljulia. However, similarly to the Campanian eastern sources, these are located along the trajectory of Wadi Qana. Therefore, flint eroded from these sources could have been carried westwards by the river and closer to the site. On the other hand, as no Eocene flint was observed either in the current channel of the river, nor in the old channel found in Area A, we cannot rule out a scenario of the occasional long-distance procurement and transportation of these Eocene flint pieces to the site. Campanian flint types are more frequent in the general sample and the prepared cores (general) than among the other samples. Eocene flint, identified by the presence of macroscopically visible nummulites, is more common among the bifaces than in other categories (**Figure 3C**).

**TABLE 5** | Potential geologic origins of the three Jaljulia samples. The Levallois, discoid and prepared core (general) groups include their products and CTEs.

Potential Geologic Origin	General Sample		Bifaces		Proto-Levallois		Discoid		Prepared (General)	
	Qty.	%	n.	%	n.	%	n.	%	n.	%
Turonian/locally available	272	66.8	49	81.7	51	82.3	34	85.0	80	72.7
Campanian	80	19.7	3	5.0	2	3.2	2	5.0	18	16.4
undetermined	41	10.1	3	5.0	6	9.7	1	2.5	7	6.4
Cenomanian	11	2.7	—	0.0	2	3.2	1	2.5	—	0.0
Eocene	3	0.7	5	8.3	1	1.6	2	5.0	5	4.5
<b>Total Number of Artifacts per Group</b>	<b>407</b>	<b>100.0%</b>	<b>60</b>	<b>100%</b>	<b>62</b>	<b>100%</b>	<b>40</b>	<b>100%</b>	<b>110</b>	<b>100%</b>

## DISCUSSION

### Selectivity in Flint Use

The presence of an old stream-bed in the south-eastern part of the site, as well as evidence for water activity throughout the geological sections of the site (Shemer et al., 2018, Accepted), suggest a landscape favourable for recurrent human occupations, as it was most probably rich in fresh water, vegetation, prey animals (which were attracted to the fresh water and plants), and rocks suitable for the production of stone tools (in stream deposits and near-by geological outcrops). This, in turn, led Late Acheulian humans to repeatedly visit the paleolandscape, as indicated by the wide-spread archaeological localities, which are assumed to be the result of repeated separate occupations over significant time periods throughout the late Lower Paleolithic period (Shemer, 2019; Shemer et al., 2022). The dominance of local flint types observed within the site's lithic assemblages should not, therefore, come as a surprise. Indeed, local lithic materials usually dominate Paleolithic assemblages (e.g., Ekshtain et al., 2017; Groucutt et al., 2017; McHenry and de la Torre, 2018; Agam, 2020).

While some argue that the dominance of local materials in archaeological lithic assemblages suggests that lithic materials were procured as a by-product during the performance of other subsistence activities (e.g., Binford, 1979; Kuhn, 1995; Ekshtain and Tryon, 2019; Shimelmitz et al., 2020), such a pattern may also imply that the high availability of desired lithic materials around a given locality, and their suitability for the manufacture of specific tools and blanks, played a main role in the original decision to repeatedly perform human activities at this location. Furthermore, locally available flint could have been procured by multiple short-distance task-specific ventures, so direct procurement of such materials is also a likely strategy (Agam, 2020, 2021). It is therefore our contention that the abundance of flint in Jaljulia and its surroundings, and its suitability for the production of the various stone tools used by the Jaljulia inhabitants, played a role in the decision to settle and resettle at the place. Clearly, other subsistence resources, such as water, edible plants and animal prey, abundantly available at the locale, further enhanced its attractiveness.

Moreover, the analyzed samples demonstrate some extent of selectivity in flint allocation towards specific knapping trajectories. Some flint types are more frequently applied in

the manufacture of distinct artifact categories than in others. Fine-textured, homogenous flint types, for example, were preferred for the production of cores and Cores-on-Flakes. Brecciated flint types, on the other hand, were especially dominant among the bifaces and discoid cores. This also should not come as a surprise, given that selectivity in stone types use has been repeatedly demonstrated in Levantine Lower Paleolithic contexts (e.g., Bar-Yosef and Goren-Inbar, 1993; Saragusti and Goren-Inbar, 2001; Wilson et al., 2016; Agam, 2020; Assaf and Preysler, 2022), as well as in older contexts in Arica (e.g., Braun et al., 2008a,b; Goldman-Neuman and Hovers, 2012; Reeves et al., 2021). Such selectivity could have been influenced by a wide range of considerations, including mechanical factors, size preferences, and efficiency-related aspects (e.g., availability, accessibility, abundance, endurance etc.). However, considerations extending beyond cost-benefit could also be accounted for, such as cultural, cosmological and/or aesthetic aspects (see discussion in Agam, 2020). The ethnographic record further demonstrates the existence of additional non-utilitarian considerations in the selection of specific stone-types for distinct production trajectories (e.g., Gould and Saggars, 1985; McBryde, 1986; Brumm, 2010; Arthur, 2018; Reimer, 2018), stressing the complexity in straight-forwardly inferring lithic-related decision-making during prehistory. Such considerations have been suggested to be relevant in Paleolithic contexts as well (e.g., Moncel et al., 2012; Radović et al., 2016; Assaf, 2018; Efrati et al., 2019; Assaf and Romagnoli, 2021; Efrati, 2021; Peresani et al., 2021). The inhabitants of Jaljulia might also have had preferences related to specific visual attributes of the flint types and/or meaning attached to such things as the place of origin of the flint, giving it some significance in their relationships with the landscape around them.

The consistency observed in stone-type use and selectivity between the assemblages of Areas B and D implies similar considerations in flint procurement and use throughout space and time. This pattern becomes even more significant if human activities at the two areas were indeed as distant in time as the chronometric results suggest. This may suggest that knowledge was transmitted and shared between individuals, and possibly between groups, concerning the distribution of flint around the site, as well as concerning the suitability of specific flint types for the production of specific tools and blanks. Further studies of the other localities at the site may imply whether similar

considerations in flint selectivity and use were actually practiced throughout the extensive paleo-landscape and the long record of human activity at the locale, which was supposedly spread over hundreds of thousands of years. Even if mostly practical considerations guided flint selectivity at the site, the persistence of such behavioral traits for such an extended duration may stand as another demonstration of the successful mode of adaptation practiced during Acheulian times, notably manifested previously in the continuous application of technological and economic strategies throughout the Lower Paleolithic (e.g., Rabinovich and Biton, 2011; Sharon et al., 2011; Finkel and Barkai, 2018).

The results presented above therefore indicate a profound familiarity of early humans with the geologic resources surrounding them, and understanding of the significance of the different traits of the flint available (either morphological, mechanical, visual, or any combination of the three). Moreover, it shows that attention and effort were put into the acquisition of specific lithic materials for the production of specific tools and blanks. This further implies that the idea that the use of local lithic materials reflects a lack of preference, as well as the integration of lithic procurement into other subsistence activities, should be re-considered.

## Possible Implications for the Emergence of Prepared Core Technologies

While the first emergence and adoption of PCTs and the technological and conceptual roots of the Levallois production seem to be found in the Acheulian, the technological origins of the Levallois production are still disputed. It has been suggested, for example, that earlier core technologies served as a basis for its emergence (Tryon et al., 2005; Sharon, 2009; Johnson and McBrearty 2012; Adler et al., 2014). These proposals support a scenario of convergence rather than “a single origin” hypothesis (Adler et al., 2014). Others, on the other hand, view Acheulian handaxes and cleavers as the basis for the emergence of the Levallois production. There are, for example, cases of handaxes with later preferential flake scars, taking advantage of the convexities of the handaxes, implying a conceptual and technological links between handaxes and Levallois technologies (DeBono and Goren-Inbar, 2001; Marder et al., 2006; Goren-Inbar, 2011; Shimelmitz, 2015; Rosenberg-Yefet and Barkai, 2019). Rolland (1995) proposed that the skill involved in the production of handaxes may have led to the discovery of the Levallois production. Tryon et al. (2005) suggested that the Levallois production was developed from previous Acheulian lithic traditions, namely large blanks used for the manufacture of handaxes and cleavers. While some have suggested a scenario of an unintentional discovery of the Levallois production through the manufacture of bifaces (Rolland, 1995; Shipton et al., 2013), the presence of preparation scars on bifaces with preferential removals before the removal of the predetermined flakes testifies for intentional actions rather than knapping mistakes (Rosenberg-Yefet et al., 2021).

In the case of Jaljulia, Rosenberg-Yefet et al. (2021) demonstrated that handaxes from the site (and from the Late

Acheulian site Revadim) were repeatedly recycled for the production of preferential flakes. Following this, it was proposed that the two technological trajectories are conceptually linked, possibly demonstrating the existence of cumulative culture, or “the Ratcheting Effect”, first defined by Tomasello (1999). This means that high-fidelity social learning mechanisms (i.e., involving teaching and/or imitation) were used to establish beneficial improvements in existing technologies, leading to the formation of new complex technological innovations that could not be invented by a single individual.

The results presented above show that there are similarities between the flint types and groups of flint types used for the production of bifaces and discoid cores, implying a possible shared set of properties applied in the selection of flint types for the manufacture of the two trajectories. Especially interesting are the high proportions of brecciated flint types in both groups, possibly related to the large packages they tend to be found in, and/or to the possible durability of the artifacts produced from such nodules (Agam et al., 2020). On the other hand, the frequencies of these brecciated flint types and groups of flint types among the Proto-Levallois cores and prepared cores (general) do not exceed those observed in the general sample. Rather, homogenous flint types were found to be more common among these two groups. Homogenous flint types are also more frequent among Cores-on-Flakes. It is therefore possible that homogenous lithic materials are a better fit in cases in which a greater degree of control over the end-product is desired, as well as the need to produce sharper edges (Agam and Barkai, 2018). Interestingly, it has been demonstrated that in both Acheulian and MSA African sites Levallois artifacts tend to be made of fine-grained raw materials (Tryon et al., 2005), further underlining the significance of the mechanical properties of the lithic material used for Levallois production.

Thus, it seems that there are technological and conceptual links in flint selectivity and use between PCTs and both flake and biface technologies at Jaljulia. We therefore support the idea of Rosenberg-Yefet et al. (2021), suggesting that it would be more appropriate to speak in terms of multiple technological origins of the Levallois production in the Acheulian, rather than a single origin. As part of the concept of cumulative culture, technological knowledge could have been accumulated through time from various Acheulian lithic trajectories, and combined to create a novel, innovative technological trajectory. The benefit gained from using a circumferential bifacial ridge could have been ‘borrowed’ from the biface production technology, while the technological adjustment of using homogenous, fine-textured lithic materials when looking for a greater control over shape and size could have been ‘borrowed’ from flake production technologies, including “regular” cores and Cores-on-Flakes.

The proposed process suggests the existence of knowledge transmission mechanisms, either ones reflecting high fidelity social learning (involving teaching and/or imitation), or, alternatively, low fidelity social learning, such as stimulus enhancement or local enhancement (Tennie et al., 2016). While both options are valid, we view the former as the more likely. The Proto-Levallois products observed in Jaljulia demonstrate a multi-staged technological procedure, which

demands a high degree of understanding, planning depth and technological know-how (Rosenberg-Yefet et al., 2021). Furthermore, the knowledge transmission suggested above concerning the distribution of suitable flint sources and the suitability of specific flint types or specific tasks also require high-fidelity social learning. Therefore, and as it has already been proposed that Acheulian populations transmitted knowledge and technological know-how using verbal communication (Goren-Inbar, 2011), it is our contention that high fidelity social learning mechanisms were involved in the application of PCTs observed at Jaljulia.

Finally, the Proto-Levallois artifacts has demonstrated a gradual process of development at the end of the Lower Paleolithic of Africa, Europe, the Levant and the Caucasus, towards a sort of proto-Levallois technology (Rosenberg-Yefet et al., 2021, and see references therein). This further accentuates the accumulation of technological innovations, and may be considered to be a demonstration of the Ratcheting Effect of cumulative culture.

## CONCLUSION

This study evaluates patterns of flint procurement and exploitation during the Late Acheulian of the Levant, at the site of Jaljulia. It further compares these patterns between four groups of samples: a general sample, consisting of all typo-technological categories, a sample of bifaces, a sample of “regular” cores, and PCT-related artifacts, including proto-Levallois cores, prepared cores (general) and discoid cores. Our results show that locally available flint types were commonly used at the site, suggesting that their high availability played a role in the decision to locate at the site, in addition to other resources, which further increased the attractiveness of the local paleolandscape. Still, while local flint types were commonly used, a clear selectivity in flint type exploitation was observed, showing that specific flint types were preferred for the production of specific blanks, due to morphological, mechanical or visual considerations, or any combination of these factors.

Our results suggest that PCTs and specifically the Proto-Levallois production procedure did not originate from one single technological trajectory. Rather, it probably incorporated knowledge that was acquired in a long process from several technological trajectories, including biface production, “regular” cores, and Cores-on-Flakes. From each such trajectory, the traits suited for the relevant needs were “burrowed”, taking into account technological traits of known technologies, as well as the suitability of specific flint types for the production of the desired blanks. The knowledge gathered was used to develop a novel, innovative technological trajectory, which was directed towards the manufacture of blanks of

predetermined size and shape. This novel technology was most likely transmitted time and again between individuals, gradually adjusting it to produce improved end-products. These improvements included, most likely, the use of circumferential, bifacially shaped ridges, and the more pronounced exploitation of fine-textured, homogenous flint types, all for a better control over the shape and size of the end-product. We see these conclusions as additional support for our view of the Proto-Levallois production of the Late Acheulian as a demonstration of cumulative culture, and the existence of high-fidelity social learning mechanisms already during Lower Paleolithic times.

## DATA AVAILABILITY STATEMENT

The raw data supporting the conclusion of this article will be made available by the authors, without undue reservation.

## AUTHOR CONTRIBUTIONS

AA is the lead author, with major contributions from TR-Y, LW, MS, and RB. AA, TR-Y, and RB designed the study; AA performed the data analysis and wrote the paper; TR-Y conducted the typo-technological analysis; AA and LW performed the geologic surveys and the petrographic analysis; MS excavated the site of Jaljulia; AA, LW, and RB edited the manuscript; all authors commented on and contributed to the manuscript.

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## SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: <https://www.frontiersin.org/articles/10.3389/feart.2022.858032/full#supplementary-material>

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